STREAMFLOW TO THE GULF OF MEXICO

By Linda J. Judd

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95–4054

Prepared in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY
GULF OF MEXICO PROGRAM

Austin, Texas
1995

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS

Multiply	By	To obtain
acre	0.4047	square hectometer
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Streamflow to the Gulf of Mexico

By Linda J. Judd

Abstract

Fifty-four major streams discharging directly to the Gulf of Mexico and having drainage areas exceeding 200 square miles were identified in the United States. Forty-four U.S. Geological Survey streamflow-gaging stations along the Gulf of Mexico with at least 40 years of daily streamflow data also were identified. These stations include most of the major streams and comprise 95 percent of the drainage area to the Gulf from the United States.

Daily mean values of continuously monitored streamflow were aggregated, annually and monthly, for selected stations. The mean, minimum, and maximum values were determined for the aggregated data for each station.

Statistical and graphical representations of temporal trends in streamflow are given for stations included in this report. Substantial percentage changes in annual and monthly streamflow between early (before 1963) and late (1963–90) time periods describe long-term temporal trends in streamflow for most of the 44 long-term stations. Graphical representations of long- and short-term temporal trends are presented for total gaged annual mean streamflow for each of 12 segments dividing the Gulf Coast.

Temporal trends in streamflow were related to major factors that affect streamflow: precipitation, land use, withdrawals of surface water, reservoir operations, and other factors. Low- and high-streamflow periods are related to extremes in precipitation; substantial increases in streamflow are associated with urbanization; decreases in streamflow are coincident with increases in withdrawals of surface water; and increases in minimum streamflows and decreases in maximum streamflows are associated with increases in the number of reservoirs. Other factors (springflow, soil composition, and effluent discharges) affect monthly minimum streamflow for some stations.

Seasonal or monthly distributions of streamflow were determined for each of the 44 long-term stations; months with high or low streamflow are presented for each station. Precipitation is the primary factor that affects the distributions of streamflow. Other factors that affect streamflow distributions include land use in urban areas, withdrawals of surface water for irrigation, and reservoir operation.

INTRODUCTION

In response to a growing concern about the declining ecological condition of the Gulf of Mexico, the U.S. Environmental Protection Agency initiated the Gulf of Mexico Program (GMP) in 1991 to develop and implement a plan to protect and manage the marine resources of the Gulf. The GMP consists of several technical committees. This report has been prepared by the U.S. Geological Survey (USGS) in cooperation with the Freshwater Inflow Committee of the GMP.

Protection and management of the marine resources of the Gulf of Mexico are critically linked to freshwater inflow (streamflow) to the Gulf. Many marine species are sensitive to changes in salinity, sediment loads, and other water-quality constituents dependent on streamflow. Diversity of marine life in the Gulf is limited by the sensitivity of species to variations in streamflow (Britton and Morton, 1989, p. 203–204). Because streamflow affects water quality and marine life of the Gulf, a directive of the Freshwater Inflow Committee was to perform a study that would identify data pertinent to streamflow to the Gulf and determine temporal trends and distributions of that streamflow.

Summary of Previous Investigations

The study for the Freshwater Inflow Committee was conducted in four parts. The first part of the study identified available data regarding streamflow to the

Gulf; identified existing regulations affecting streamflow to the Gulf; divided the area contributing streamflow to the Gulf into 12 hydrologic segments based on State boundaries, stream drainage, and major geographic divides between receiving bays and estuaries; and determined historical trends in annual streamflow to the Gulf (Slade, 1992).

The second part of the study consisted of case studies of temporal trends in annual streamflow for each of four basins that discharge to the Gulf: the Nueces and Trinity River Basins in Texas, the Pearl River Basin in Mississippi and Louisiana, and the Apalachicola River Basin in Georgia, Alabama, and Florida. Temporal trends in annual streamflow were determined for many streamflow-gaging stations within each of these basins. For each basin, trends in annual streamflow were compared to trends in annual precipitation, to withdrawals of surface water, and to reservoir development within that basin.

The third part of the study determined temporal trends in monthly streamflow for each of 44 USGS streamflow-gaging stations along the Gulf Coast with at least 40 years of record. These trends were compared to expected changes in streamflow caused by factors that affect streamflow: precipitation, land use, withdrawals of surface water, reservoir operations, and other factors.

The fourth part of the study determined distributions of monthly streamflow for the entire period of record for each of the 44 long-term gaging stations and, as done for the third part of the study, related these distributions to factors that affect streamflow. Distributions were represented by 10th, 25th, 50th, 75th, and 90th percentile values of monthly streamflow for the entire period of record for each of the stations. Boxplots were constructed to graphically represent these percentile values for each station.

Purpose and Scope

The purpose of this report is to summarize the approach and findings of the study performed for the Freshwater Inflow Committee of the GMP. Streamflow data analyzed in this study were obtained from the USGS national data base—National Water Information System (NWIS). The data represent streamflow proximate to the Gulf Coast and streamflow that has been monitored daily for at least 40 years. These data are from streamflow-gaging stations on streams whose drainage areas collectively represent about 95 percent of the total drainage area from the United States to the Gulf.

Regulations Affecting Streamflow to the Gulf

Slade (1992) identified six major agencies that develop or enforce regulations affecting streamflow to the Gulf: the Rio Grande Compact, the Texas Natural Resource Conservation Commission, the Alabama Department of Environmental Management, the Florida Department of Environmental Regulation, the U.S. Army Corps of Engineers, and the International Boundary and Water Commission. The Rio Grande Compact (between Colorado, New Mexico, and Texas) and the International Boundary and Water Commission regulate streamflow in the Rio Grande. The U.S. Army Corps of Engineers regulates the streamflow of the Mississippi and Atchafalaya Rivers.

Other agencies identified by Slade (1992), which probably have only minimal effects on streamflow regulation to the Gulf, are the U.S. Fish and Wildlife Service and (in Texas) the Angelina and Neches River Authority and the Lower Colorado River Authority.

METHODS OF ANALYSES

Statistical and graphical methods of analyses, as defined in this section, were used to represent temporal trends and distributions in streamflow for stations included in this report. Daily mean values of continuously monitored streamflow were aggregated, annually and monthly, for selected stations. Therefore, 1 annual value and 12 monthly values exist for every year of streamflow data for a station. The mean, minimum, and maximum values (streamflow perspectives) were each determined for the aggregated data for each station.

Statistical Method

Annual and monthly streamflow data for the entire period of record for each of the 44 long-term stations were divided into two equal time periods, and the change in mean streamflow between the two periods was calculated. The "early" period of record is that prior to 1963 (water year), and the "late" period of record is from 1963 through 1990 (water year) or the date that the latest data are available. Substantial changes in mean streamflow between the early and late periods were identified for annual and monthly streamflow for each station. The term "substantial" change in streamflow is used in this report to indicate an increase of at least 50 percent or a decrease of at least 20 percent in mean streamflow between the early and late periods. A substantial change in mean streamflow between the two periods is considered to represent a long-term temporal trend in streamflow for a station.

Seasonal or monthly distributions of streamflow were determined for each of the 44 long-term stations for each streamflow perspective. The 2 months with the highest streamflow in the seasonal distribution cycle are indicated with a positive (+) sign and the 2 months with lowest streamflow are indicated with a negative (-) sign.

Graphical Methods

Two graphical methods were used to determine temporal trends. A "best fit" straight-line regression of the data represents a long-term trend that can indicate an increase or decrease in streamflow over the entire period of record for a station. The LOcally WEighted regression and Smoothing Scatterplots (LOWESS) technique, as identified by Cleveland (1979), represents a short-term trend that can indicate an increase or decrease in streamflow for short time segments during the period of record. The graphical long-term trend, therefore, is represented by a straight line and the short-term trend by a curvilinear line. Annual mean streamflow during 1947–86 for the 44 long-term stations was totaled, by segment, for each of the 12 hydrologic segments dividing the Gulf Coast. Graphs of temporal trends of the total gaged annual mean streamflow for each segment were prepared by Slade (1992) and are included in this report.

SUMMARY OF STREAMFLOW DATA

Almost all data concerning the quantity and quality of streamflow to the Gulf of Mexico historically have been collected by the USGS as part of the Federal-State Cooperative and National Stream Quality Accounting Network (NASQAN) Programs.

Quantity

The USGS maintains an extensive data base on streamflow data throughout the United States. Data collection began over 100 years ago, and at present there are about 7,400 streamflow-gaging stations in the United States (Paulson and others, 1991, p. 11). The USGS collects and publishes daily streamflow for these stations in cooperation with Federal, State, and local agencies.

Slade (1992) identified 54 streams that discharge directly to the Gulf of Mexico and have drainage areas exceeding 200 mi^2. USGS stations are located on the lower reaches of each of these streams, therefore the streamflow at these stations comprises most of the freshwater inflow to the Gulf from these streams. The periods of record of daily mean streamflow data for these stations range from 21 to 73 years. Forty-four stations with at least 40 years of record are located near the Gulf Coast (fig. 1). These stations include most of the major streams and comprise 95 percent of the drainage area to the Gulf from the United States. The name, location, period of record, and drainage area for each station is presented in table 1. A unique eight-digit number is assigned by the USGS to each station. In this report, the 44 long-term stations are assigned station sequence numbers, sequentially numbered 1 to 44 from west to east. The USGS station numbers and station sequence numbers for each station are listed in table 1. The station sequence numbers will be referred to as station numbers hereafter in this report.

Quality

The USGS collects and publishes daily and periodic values for water-quality data. Daily values of dissolved solids, suspended sediment, dissolved oxygen, pH, and water temperature exist for many of the stations within 200 mi of the Gulf Coast on the 54 major streams. Daily values of dissolved solids are calculated from measurements of specific conductance. The period of record and number of years of data for the streamflow and water-quality data are presented in table 2. Data for some streams were collected at more than one site. Periodic values for nutrients, bacteria, major and minor ions, organics, and radiochemical analyses are available for many of these streams. Data for most of these water-quality constituents are collected infrequently—typically about four to eight samples per year. However, an assessment of the nutrient data available at stations near the Gulf Coast reveals that a large data base exists for nitrogen and phosphorous measurements (table 3). This table presents analyses available after 1968; data prior to this date are excluded because of changes in laboratory procedures for analyzing nitrogen samples. Nutrient data are available for 40 of the 44 streams with long-term stations near the Gulf Coast and also for 30 of 32 streams with

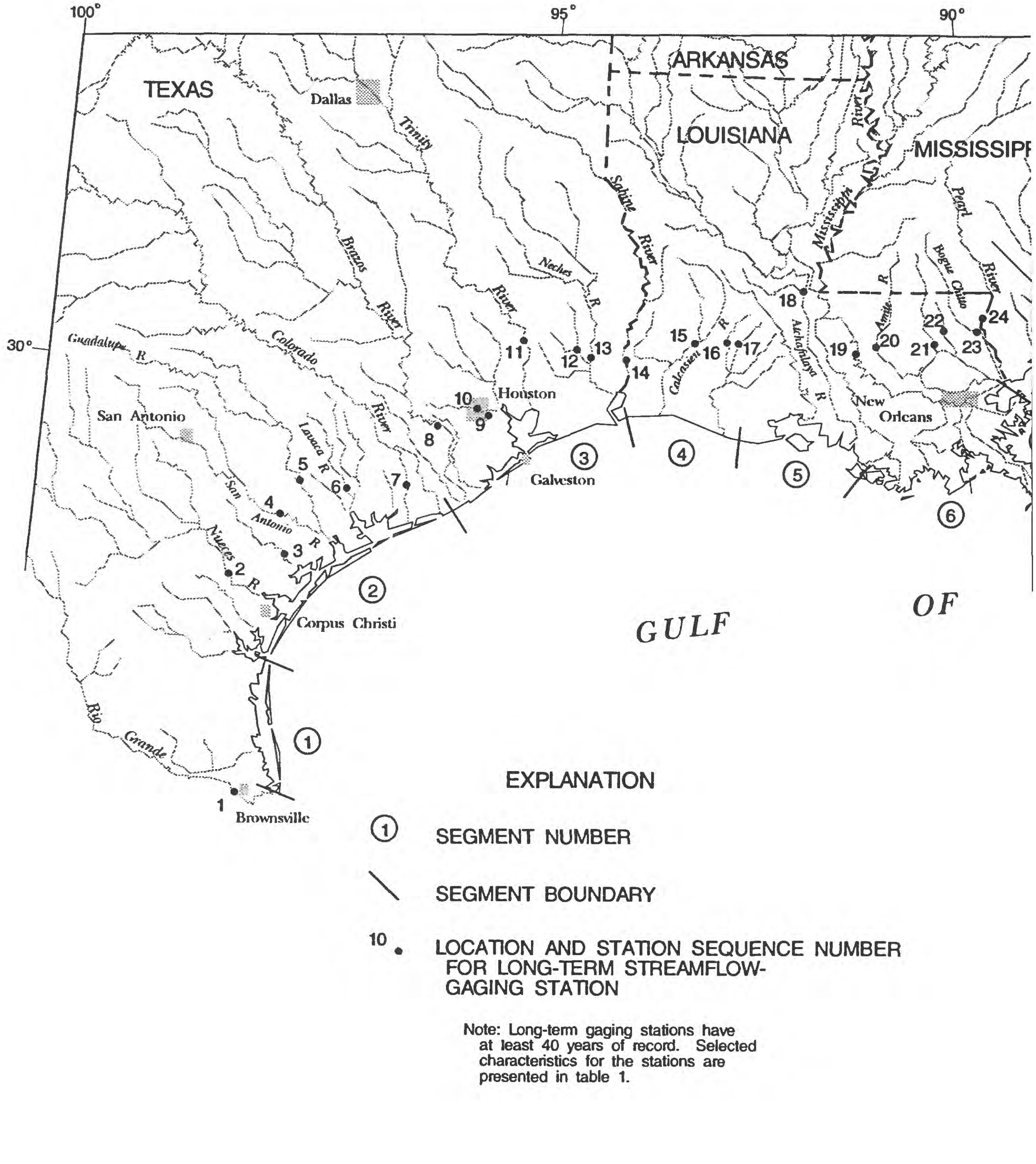
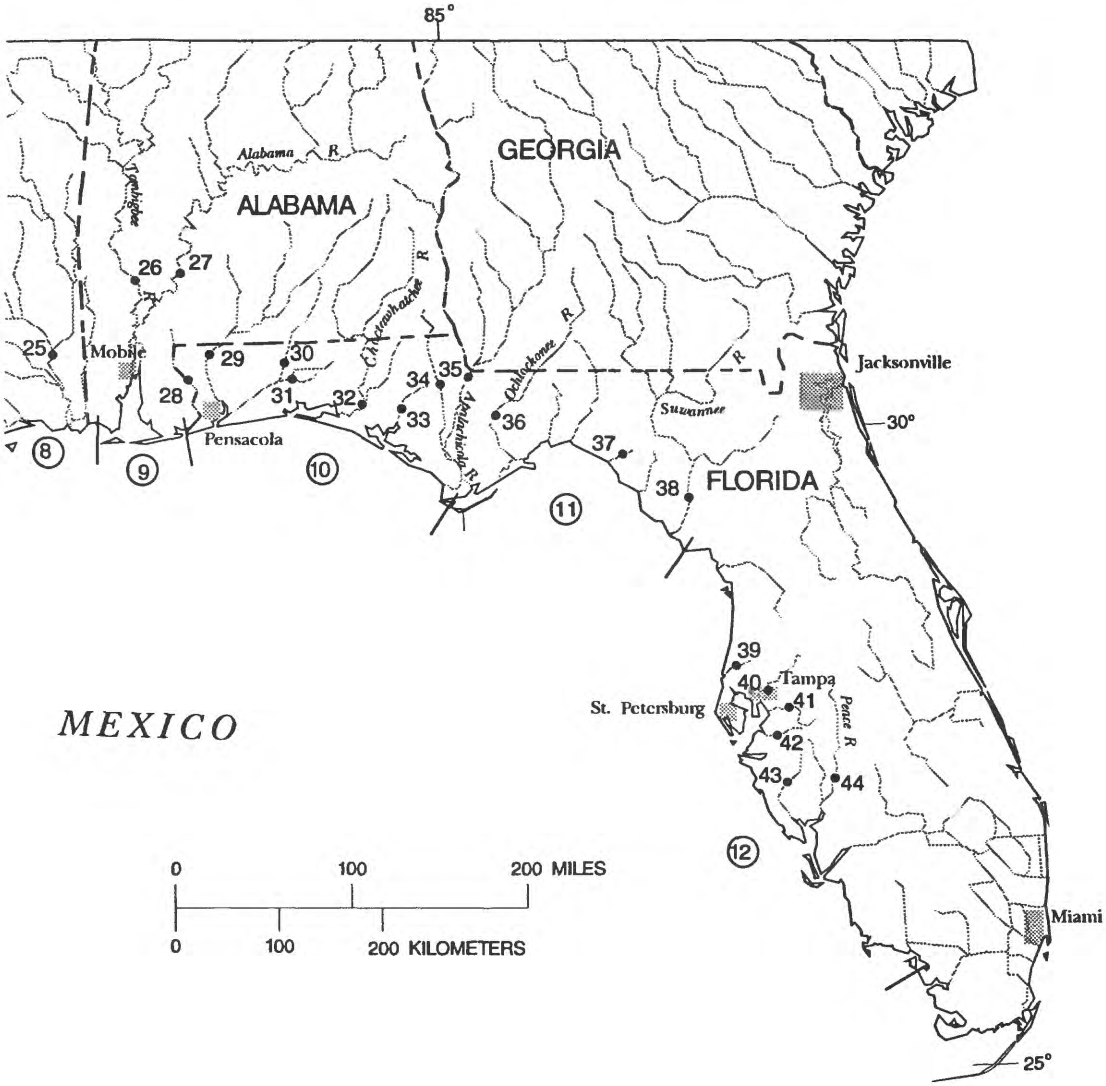


Figure 1. Hydrologic segments, Gulf of Mexico coast, and locations of long-term streamflow-gaging stations on the lower reaches of streams that discharge directly into the Gulf.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Alabama R
Tombigbee
Choctawhatchee R
Apalachicola R
Ochlockonee R
Suwannee R
FLORIDA
Jacksonville
30°
Mobile
Pensacola
St. Petersburg
Tampa
Peace R
Miami
25°
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Table 1. Selected characteristics for long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico

[mi^2, square miles]

Station number	USGS station number	Stream name and location	Latitude	Longitude	Period of record	Years of record	Drainage area (mi^2)
1	08475000	Rio Grande near Brownsville, Tex.	25°52'35"	97°27'15"	1934–92	59	176,333
2	08211000	Nueces River near Mathis, Tex.	28°02'17"	97°51'36"	1940–92	53	16,660
3	08189500	Mission River at Refugio, Tex.	28°17'30"	97°16'44"	1940–92	53	690
4	08188500	San Antonio River at Goliad, Tex.	28°38'58"	97°23'04"	1940–92	53	3,921
5	08176500	Guadalupe River at Victoria, Tex.	28°47'34"	97°00'46"	1934–92	59	5,198
6	08164000	Lavaca River near Edna, Tex.	28°57'35"	96°41'10"	1939–92	54	817
7	08162000	Colorado River at Wharton, Tex.	29°18'32"	96°06'13"	1938–92	55	42,240
8	08114000	Brazos River at Richmond, Tex.	29°34'56"	95°45'27"	1922–92	71	45,007
9	08075000	Brays Bayou at Houston, Tex.	29°41'49"	95°24'43"	1937–92	56	95
10	08074500	Whiteoak Bayou at Houston, Tex.	29°46'30"	95°23'49"	1937–92	56	86
11	08066500	Trinity River at Romayor, Tex.	30°25'30"	94°51'02"	1925–92	68	17,186
12	08041500	Village Creek near Kountze, Tex.	30°23'52"	94°15'48"	1940–92	53	860
13	08041000	Neches River at Evadale, Tex.	30°21'20"	94°05'35"	1921–92	72	7,951
14	08030500	Sabine River near Ruliff, Tex.	30°18'13"	93°44'37"	1924–92	69	9,329
15	08015500	Calcasieu River near Kinder, La.	30°30'10"	92°54'55"	1938–92	55	1,700
16	08012000	Bayou Nezpique near Basile, La.	30°28'50"	92°37'55"	1938–92	55	527
17	08010000	Bayou des Cannes near Eunice, La.	30°29'00"	92°29'25"	1938–92	55	131
18	07381490	Atchafalaya River at Simmesport, La.	30°58'57"	91°47'54"	1934–92	59	87,570
19	07373291	Mississippi River at Tarbert, La.	30°57'40"	91°39'52"	1928–92	65	1,129,810
20	07378500	Amite River near Denham Springs, La.	30°27'50"	90°59'25"	1939–92	54	1,280
21	07375500	Tangipahoa River at Robert, La.	30°30'23"	90°21'42"	1938–92	55	646
22	07375000	Tchefuncta River near Folsom, La.	30°36'57"	90°14'55"	1943–92	50	96
23	02492000	Bogue Chitto near Bush, La.	30°37'45"	89°53'50"	1937–92	56	1,213
24	02489500	Pearl River near Bogalusa, La.	30°47'35"	89°49'15"	1938–92	55	6,573
25	02479000	Pascagoula River at Merrill, Miss.	30°58'40"	88°43'35"	1930–92	63	6,590
26	02469761	Tombigbee River near Coffeeville, Ala.	31°45'30"	88°07'45"	1928–92	65	18,417
27	02429500	Alabama River at Claiborne, Ala.	31°32'48"	87°30'45"	1931–92	62	22,000
28	02376500	Perdido River at Barrinear Park, Fla.	30°41'25"	87°26'25"	1942–92	51	394
29	02375500	Escambia River near Century, Fla.	30°57'54"	87°14'03"	1934–92	59	3,817
30	02368000	Yellow River at Milligan, Fla.	30°45'10"	86°37'45"	1939–92	54	624
31	02369000	Shoal River near Crestview, Fla.	30°41'50"	86°34'15"	1939–92	54	474
32	02366500	Choctawhatchee River near Bruce, Fla.	30°27'03"	85°53'54"	1930–92	63	4,384
33	02359500	Econfina Creek near Bennett, Fla.	30°23'04"	85°33'24"	1935–92	58	122
34	02359000	Chipola River near Altha, Fla.	30°32'02"	85°09'55"	1944–92	49	781
35	02358000	Apalachicola River at Chattahoochee, Fla.	30°42'03"	84°51'33"	1928–92	65	17,200

Table 1. Selected characteristics for long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico—Continued

Station number	USGS station number	Stream name and location	Latitude	Longitude	Period of record	Years of record	Drainage area (mi^2)
36	02330000	Ochlockonee River near Bloxham, Fla.	30°23'10"	84°38'59"	1927–92	66	1,700
37	02324500	Fenholloway River at Foley, Fla.	30°03'55"	83°34'29"	1947–92	46	120
38	02323500	Suwannee River near Wilcox, Fla.	29°35'22"	82°56'12"	1941–92	52	9,640
39	02310000	Anclote River near Elfers, Fla.	28°12'50"	82°40'00"	1947–92	46	72
40	02304500	Hillsborough River near Tampa, Fla.	28°01'25"	82°25'40"	1938–92	55	650
41	02301500	Alafia River at Lithia, Fla.	27°52'19"	82°12'41"	1932–92	61	335
42	02300500	Little Manatee River near Wimauma, Fla.	27°40'15"	82°21'10"	1940–92	53	149
43	02298830	Myakka River near Sarasota, Fla.	27°14'25"	82°18'50"	1937–92	56	229
44	02296750	Peace River at Arcadia, Fla.	27°13'19"	81°52'34"	1932–92	61	1,367

drainage areas larger than 500 mi^2. For the period from 1968 to 1992, 31 of the stations have at least 20 years of available data; and 37 stations have at least 15 years of available data.

Salinity data for sites in bays and estuaries of the Gulf vary in period of record and frequency of measurements; much of the data was collected as part of short-term projects, and less than 2 years of data exist for most sites. About 2,400 sites have been sampled, and more than 1 million measurements of salinity have been made (Slade, 1992).

TEMPORAL TRENDS AND DISTRIBUTIONS OF STREAMFLOW

Temporal Trends

Long-term temporal trends in annual and monthly streamflow are indicated by substantial change in mean streamflow between the early and late periods for most of the 44 long-term stations. Substantial changes in annual and monthly streamflow for each of the 44 long-term stations are presented in tables 4–6.

The long-term trends represented by the substantial changes in monthly streamflow for the 44 long-term stations indicate a regional pattern. This pattern is observed in tables 4–6 where stations are sequentially numbered from west to east (fig. 1). Substantial increases or decreases in streamflow occurred for many months at most of the stations in Texas (stations 1–14). Few substantial changes occurred at stations near the Louisiana, Mississippi, and Alabama Coasts, and the northwest coast of Florida (stations 15–38). However, streamflow at stations located near the coast of west-central Florida (stations 39–44) decreased substantially for many months.

Graphs of long- and short-term temporal trends in total gaged annual mean streamflow for the 12 hydrologic segments are presented in figures 2–13. The graph for each segment represents temporal trends in annual mean streamflow in that segment (fig. 1).

Distributions

Regional similarities in the seasonal or monthly distributions of streamflow are evident for the 44 long-term stations along the Gulf Coast. These similarities are observed by comparing, for nearby stations, months when high or low streamflow occur (fig. 1 and table 7). Months of high or low streamflow are months for which the median streamflow represents the two highest or two lowest monthly values for a particular streamflow perspective and station. Months of high or low streamflow are the same or about the same for the following groups of stations: 3–8; 9–10; 12–17; 18–19; 20–32, 34–36, 38; and 39–44.

FACTORS ASSOCIATED WITH STREAMFLOW

Major factors that affect streamflow include precipitation, land use, withdrawals of surface water, reservoir operations, and other factors. The effects of each

Table 2. Identified major streams that discharge directly to the Gulf of Mexico and periods of record for daily values of streamflow and water quality in the lower reaches of those streams

[mi^2, square miles; (59), number in parentheses indicates years of record available; --, data not collected]

Stream name (State)	Drainage area (mi^2)	Period of record and number of years of daily values data for:					
		Streamflow	Dissolved solids	Suspended sediment	Dissolved oxygen	pH	Water temperature
Rio Grande (Tex.)	176,333	1934–92 (59)	1966–92 (23)	1966–83 (18)	--	--	1967–83 (11)
San Fernando Creek (Tex.)	507	1965–89 (24)	--	--	--	--	--
Nueces River (Tex.)	16,660	1940–92 (53)	1942–91 (50)	1950–51 (2)	--	--	1948–91 (36)
Aransas River (Tex.)	247	1965–92 (28)	--	--	--	--	--
Mission River (Tex.)	690	1940–92 (53)	1962–81 (20)	--	--	--	1961–81 (21)
San Antonio River (Tex.)	3,921	1925–92 (57)	1960–92 (33)	--	--	--	1959–92 (34)
Guadalupe River (Tex.)	5,198	1936–92 (57)	1966–83 (18)	--	--	--	1967–83 (17)
Lavaca River (Tex.)	817	1939–92 (54)	1978–81 (4)	--	--	--	1978–81 (4)
Colorado River (Tex.)	42,240	1939–92 (54)	1945–92 (48)	1957–73 (17)	--	--	1948–92 (40)
San Bernard River (Tex.)	727	1955–92 (38)	1978–81 (4)	--	--	--	1978–81 (4)
Brazos River (Tex.)	45,007	1904–92 (72)	1942–92 (51)	1966–86 (21)	--	--	1951–92 (39)
Buffalo Bayou (Tex.)	317	1964–92 (21)	1979–92 (10)	--	1986–89 (4)	--	1979–89 (7)
Trinity River (Tex.)	17,186	1925–92 (68)	1942–92 (47)	1955–71 (4)	1975–92 (18)	1975–92 (18)	1950–92 (39)
Pine Island Bayou (Tex.)	336	1968–92 (25)	1968–89 (22)	--	--	--	1968–89 (22)
Village Creek (Tex.)	860	1925–92 (55)	1968–70 (3)	--	--	--	1968–70 (3)
Neches River (Tex.)	7,951	1905–92 (73)	1948–92 (45)	--	--	--	1948–92 (34)
Sabine River (Tex.)	9,329	1925–92 (68)	1946–92 (46)	--	1968–75 (8)	1968–75 (8)	1948–92 (38)
Calcasieu River (La.)	1,700	1923–88 (52)	1968–87 (12)	--	1968–77 (5)	1968–77 (5)	1968–87 (12)
Bayou Nezpique (La.)	527	1939–88 (50)	--	--	--	--	--
Vermilion River (La.)	Unknown	1968–88 (21)	1958–82 (20)	--	1971–82 (12)	1976–82 (7)	1949–82 (25)
Atchafalaya River (La.)	87,570	1935–88 (54)	1952–81 (16)	1973–85 (9)	--	--	1953–84 (12)
Mississippi River (La.)	1,129,810	1934–88 (55)	1950–88 (39)	1950–75 (26)	1967–88 (22)	1968–88 (21)	1954–88 (33)
Amite River (La.)	1,280	1939–88 (50)	1968–81 (12)	--	--	--	1968–81 (11)
Tangipahoa River (La.)	646	1939–88 (50)	1963–83 (6)	--	--	--	1963–83 (6)
Bogue Chitto (La.)	1,213	1938–88 (51)	1975–82 (8)	--	--	--	1975–82 (8)
Pearl River (Miss.)	6,573	1939–88 (50)	1963–85 (13)	1967–87 (21)	1975–85 (11)	1975–85 (11)	1963–85 (13)
Wolf River (Miss.)	308	1972–88 (17)	1978–81 (4)	--	--	--	1978–81 (4)
Red Creek (Miss.)	441	1959–88 (30)	1985–86 (2)	--	--	--	1985–86 (2)
Black Creek (Miss.)	701	1972–88 (17)	--	--	--	--	--
Pascagoula River (Miss.)	6,590	1931–88 (58)	1970–81 (12)	--	--	--	1958–81 (13)
Tombigbee River (Ala.)	18,417	1929–88 (60)	1966–88 (21)	--	--	--	1963–88 (26)
Alabama River (Ala.)	22,000	1931–88 (58)	1966–87 (17)	--	--	--	1966–87 (17)
Perdido River (Ala.)	394	1942–88 (47)	1979–81 (3)	--	--	--	1979–81 (3)
Escambia River (Fla.)	3,817	1935–88 (54)	--	--	--	--	--
Big Coldwater (Fla.)	237	1938–88 (49)	--	--	--	--	1960–60 (1)

Table 2. Identified major streams that discharge directly to the Gulf of Mexico and periods of record for daily values of streamflow and water quality in the lower reaches of those streams—Continued

Stream name (State)	Drainage area (mi^2)	Period of record and number of years of daily values data for:					
		Streamflow	Dissolved solids	Suspended sediment	Dissolved oxygen	pH	Water temperature
Blackwater River (Fla.)	205	1951–88 (38)	--	--	--	--	1961–69 (3)
Yellow River (Fla.)	624	1939–88 (50)	1965–72 (8)	--	--	--	1965–72 (8)
Shoal River (Fla.)	474	1939–88 (50)	--	--	--	--	--
Choctawhatchee River (Fla.)	4,384	1930–88 (59)	1964–83 (18)	--	--	--	1965–83 (17)
Chipola River (Fla.)	781	1922–88 (53)	1965–72 (8)	--	--	--	1965–72 (8)
Apalachicola River (Fla.)	17,200	1929–88 (60)	1963–79 (17)	--	1974–79 (6)	1974–78 (5)	1965–79 (14)
Ochlockonee River (Fla.)	1,700	1927–88 (62)	1965–72 (8)	--	--	--	1965–72 (8)
Saint Marks River (Fla.)	535	1957–88 (30)	--	--	--	--	--
Aucilla River (Fla.)	747	1950–88 (39)	1979–81 (3)	--	--	--	1979–81 (3)
Steinhatchee River (Fla.)	350	1951–88 (38)	1979–82 (4)	--	--	--	1979–82 (4)
Suwannee River (Fla.)	9,640	1942–88 (47)	1966–77 (12)	--	--	--	1965–77 (13)
Waccasassa River (Fla.)	480	1964–88 (18)	--	--	--	--	--
Withlacoochee River (Fla.)	2,020	1970–88 (19)	1950–83 (23)	--	--	1950–50 (1)	1950–83 (21)
Hillsborough River (Fla.)	650	1939–88 (50)	1965–82 (11)	--	--	--	1965–82 (11)
Alafia River (Fla.)	335	1933–88 (56)	1958–86 (22)	--	--	1964–70 (5)	1958–86 (21)
Myakka River (Fla.)	229	1937–88 (52)	1963–81 (6)	--	--	--	1963–81 (7)
Horse Creek (Fla.)	218	1951–88 (38)	1965–67 (3)	--	--	--	1965–67 (3)
Peace River (Fla.)	1,367	1932–88 (57)	1962–81 (20)	--	--	1962–70 (7)	1962–81 (20)
Caloosahatchee River (Fla.)	Unknown	1967–88 (22)	1965–82 (17)	--	--	--	1964–83 (20)

of these factors are discussed and related to the streamflow trends and distributions for selected stations—those expected to demonstrate streamflow trends because of the factors.

Precipitation

Precipitation is the primary factor that affects streamflow at most stations. Increased precipitation typically causes increased runoff and subsequent streamflow. For example, Greene and Slade (1995) partially attribute increases in streamflow for the Pearl River to increases in precipitation in that basin. The relation between precipitation and streamflow is dependent partly on soil type, soil moisture, and evapotranspiration.

Short-term temporal trends in streamflow relate to extremes in precipitation (droughts and floods) for many streams discharging to the Gulf of Mexico. Droughts and floods are observed sometimes as decreases or increases in streamflow as indicated by short-term trends. Droughts or floods of long duration generally affect long-term trends.

Droughts in Texas during the 1950's and 1960's are associated with decreases in streamflow at each of the long-term stations in Texas. The effects of these droughts are observed as depressions in the short-term trends in total gaged annual mean streamflow for hydrologic segments 1–3 during the 1950's and 1960's (figs. 2–4). Segments 1–3 encompass the Texas Coast (fig. 1).

Droughts affected northern Florida during 1932–35, 1949–57, and 1967–69 (Paulson and others, 1991, p. 235). Decreases in streamflow are evident during 1949–57 and 1967–69 for short-term trends in total gaged annual mean streamflow for hydrologic segments 10–11 in northern Florida (figs. 1, 11–12).

Table 3. Nutrient data available from 1968 through 1992 for streamflow sites along the Gulf of Mexico coast

[At least 46 years of daily streamflow data are available for each of these stations. --, no record]

USGS station number	Stream name (State)	Period of record	Years of available data	Approximate number of analyses			
				Total nitrogen	Total phosphorous	Dissolved nitrogen	Dissolved phosphorous
08475000	Rio Grande (Tex.)	1968–92	25	100	140	50	100
08210000	Nueces River (Tex.)	1968–92	25	150	180	20	120
08189500	Mission River (Tex.)	1968–92	25	60	130	40	80
08188500	San Antonio River (Tex.)	1968–92	25	150	210	40	110
08176500	Guadalupe River (Tex.)	1968–92	25	90	150	50	90
08164000	Lavaca River (Tex.)	1968–92	25	120	140	50	90
08162000	Colorado River (Tex.)	1968–92	25	150	180	50	110
08114000	Brazos River (Tex.)	1968–92	25	110	150	10	80
08075000	Brays Bayou (Tex.)	1968–92	25	110	170	0	0
08074500	Whiteoak Bayou (Tex.)	1968–92	25	130	190	0	0
08066500	Trinity River (Tex.)	1968–92	25	160	200	50	110
08041500	Village Creek (Tex.)	1968–85	0	0	0	0	0
08041000	Neches River (Tex.)	1968–92	25	100	180	40	110
08030500	Sabine River (Tex.)	1968–92	25	90	160	40	90
08015500	Calcasieu River (La.)	1975–92	19	40	80	20	80
08012000	Bayou Nezpique (La.)	--	0	0	0	0	0
08010000	Bayou des Cannes (La.)	--	0	0	0	0	0
07381495	Atchafalaya River (La.)	1978–92	15	100	140	40	90
07289000	Mississippi River (Miss.)	1973–92	20	90	120	20	80
07378510	Amite River (La.)	1973–85	13	80	100	20	60
07375500	Tangipahoa River (La.)	1972–92	21	20	60	20	60
07375050	Tchefuncta River (La.)	1977–92	16	50	80	20	80
02492000	Bogue Chitto (La.)	1974–92	19	90	140	20	100
02490193	Pearl River (La.)	1975–85	11	60	60	0	0
02479020	Pascagoula River (Miss.)	1971–92	22	110	150	20	100
02469762	Tombigbee River (Ala.)	1971–92	22	90	140	20	90
02429500	Alabama River (Ala.)	1972–91	20	100	160	20	100
02376500	Perdido River (Fla.)	1968–92	25	50	100	20	90
02375500	Escambia River (Fla.)	1972–92	21	90	150	20	100
02368000	Yellow River (Fla.)	1971–92	22	90	140	20	90
02369000	Shoal River (Fla.)	1970–86	0	0	0	0	0
02366500	Choctawhatchee River (Fla.)	1971–92	22	80	120	30	90
02359500	Econfina Creek (Fla.)	1971–86	16	20	40	20	40
02359000	Chipola River (Fla.)	1971–92	22	80	140	20	90
02358000	Apalachicola River (Fla.)	1971–92	22	90	150	40	100

Table 3. Nutrient data available from 1968 through 1992 for streamflow sites along the Gulf of Mexico coast—Continued

USGS station number	Stream name (State)	Period of record	Years of available data	Approximate number of analyses			
				Total nitrogen	Total phosphorous	Dissolved nitrogen	Dissolved phosphorous
02329000	Ochlockonee River (Fla.)	1968–92	25	90	140	20	90
02324500	Fenholloway River (Fla.)	1969–77	9	10	20	0	0
02323500	Suwannee River (Fla.)	1968–88	21	80	100	0	0
02310000	Anclote River (Fla.)	1971–91	21	110	120	0	0
02304000	Hillsborough River (Fla.)	1971–91	21	100	110	0	0
02301500	Alafia River (Fla.)	1971–91	21	100	150	10	80
02300500	Little Manatee River (Fla.)	1971–88	18	60	70	0	0
02298830	Myakka River (Fla.)	1968–91	24	60	90	10	70
02295637	Peace River (Fla.)	1971–91	21	120	140	0	0

Droughts during 1949–82 are associated with decreases in streamflow for the stations on the Anclote, Hillsborough, Alafia, Little Manatee, Myakka, and Peace Rivers in west-central Florida. The large number of drought years in the late period for these river basins is a partial cause of decreased streamflow. Substantial changes in streamflow for most of these stations indicate decreased streamflow (tables 4–6, stations 39–44). The long- and short-term trend in total gaged annual mean streamflow for hydrologic segment 12 in central Florida also indicates decreasing streamflow (figs. 1 and 13).

Recent (1970's to 1980's) floods in the Pearl and Pascagoula River Basins in Louisiana and Mississippi are associated with increases in streamflow in these rivers. The Pearl and Pascagoula Rivers are located in hydrologic segment 8 (fig. 1). The short-term trend for segment 8 indicates increasing streamflow during this period (fig. 9).

Stations that have similar distributions of monthly streamflow typically are located in areas of the United States with similar annual mean precipitation. Streamflow for stations in areas with similar precipitation, but with dissimilar distributions of monthly streamflow, probably is affected by factors other than precipitation.

Land Use

Land use in a watershed affects the land surface and infiltration of precipitation and thus affects the amount of surface runoff and streamflow. Urbanization increases impervious cover in a watershed. The increased impervious cover typically reduces the amount of infiltration and depression storage and therefore increases surface runoff and streamflow. Temporal increases in streamflow in Brays and Whiteoak Bayous is associated with increased urbanization in the watersheds of these bayous in Houston, Texas. Substantial changes in streamflow for these stations indicate increases in annual and monthly streamflow (tables 4–6, stations 9–10).

The variations between monthly distributions of streamflow for Brays and Whiteoak Bayous are similar, as indicated by months of high and low streamflows for these stations (table 7, stations 9–10). The months of high and low streamflow for these stations are different from those of stations with less urbanization.

Withdrawals of Surface Water

Withdrawals of surface water primarily include agricultural, industrial, and municipal use (Carr and others, 1990, p. 28). Water for agricultural use is consumed at rates much greater than for other uses and thus can cause decreased streamflow. Withdrawals, by state, for irrigation in Texas and Florida exceed irrigation withdrawals, by state, in Louisiana, Mississippi, and Alabama (U.S. National Oceanic and Atmospheric Administration, 1985). Many substantial changes in streamflow have been observed for Texas and Florida (stations 1–14, 28–44); but Louisiana, Mississippi, and

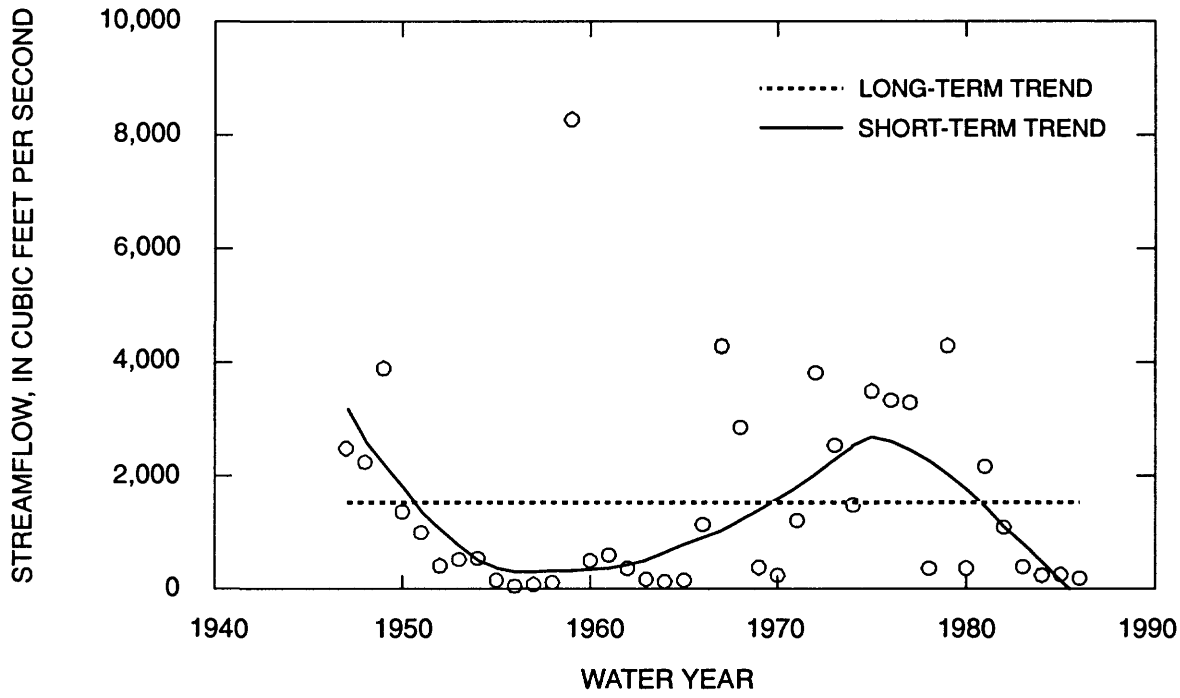

Figure 2. Temporal trends in total gaged annual mean streamflow into hydrologic segment 1, Gulf of Mexico coast (see fig. 1).

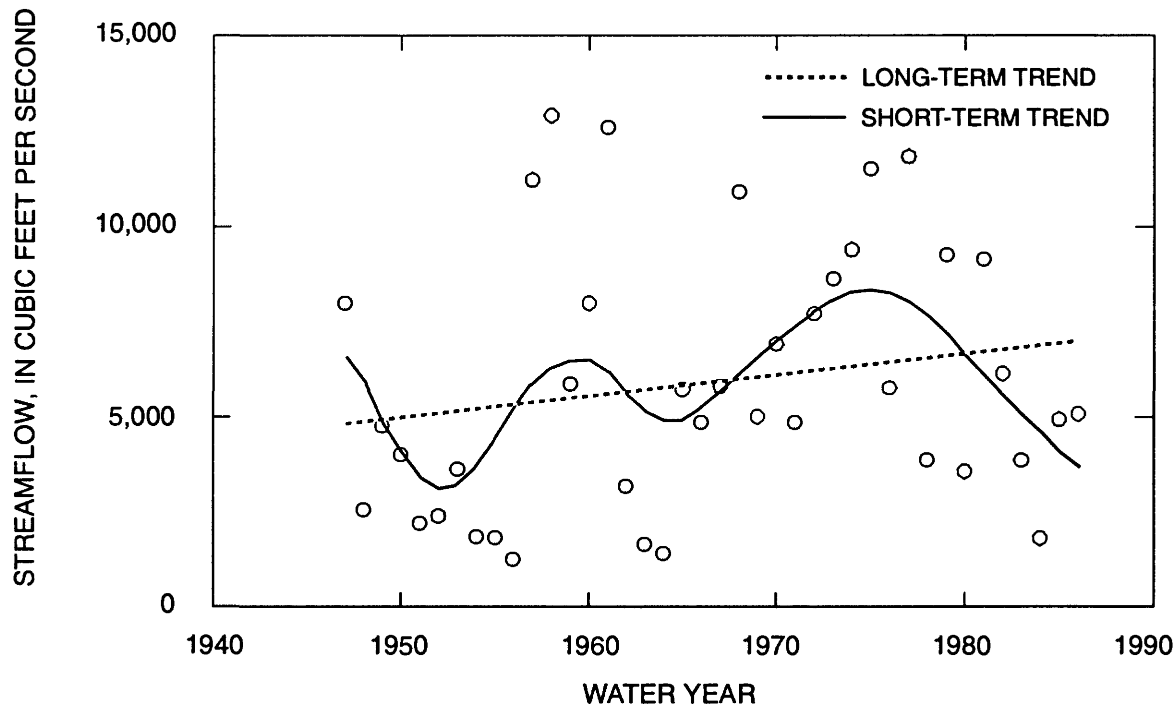

Figure 3. Temporal trends in total gaged annual mean streamflow into hydrologic segment 2, Gulf of Mexico coast (see fig. 1).

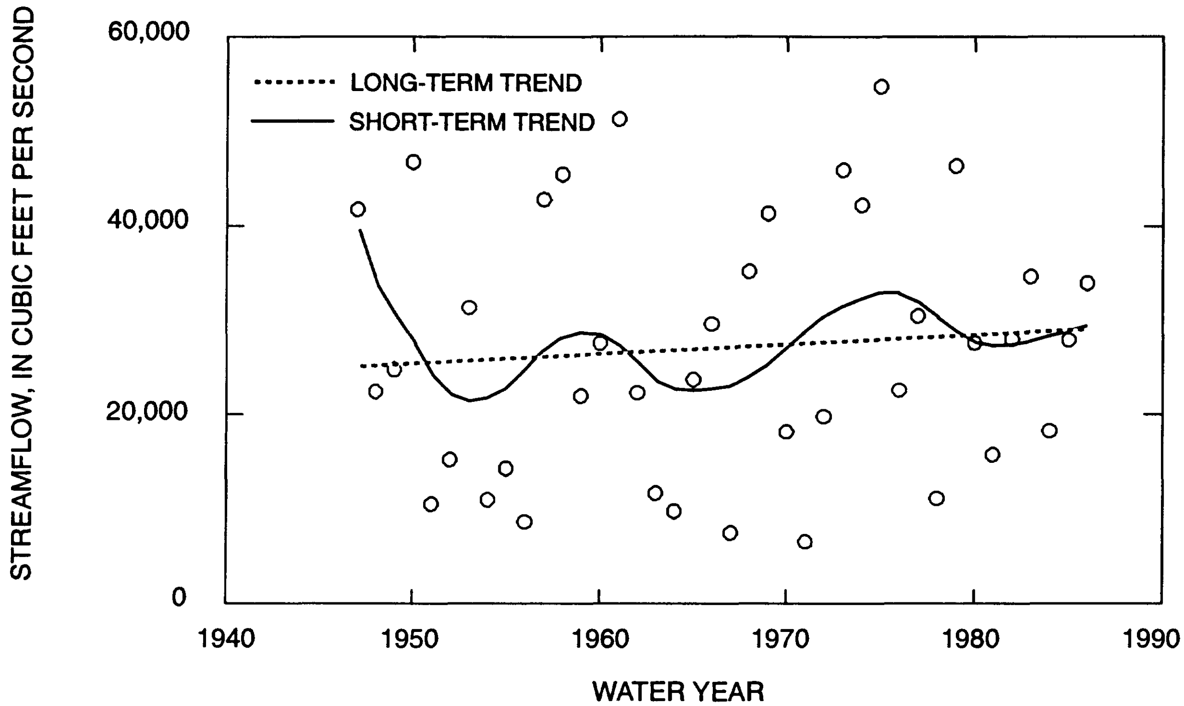

Figure 4. Temporal trends in total gaged annual mean streamflow into hydrologic segment 3, Gulf of Mexico coast (see fig. 1).

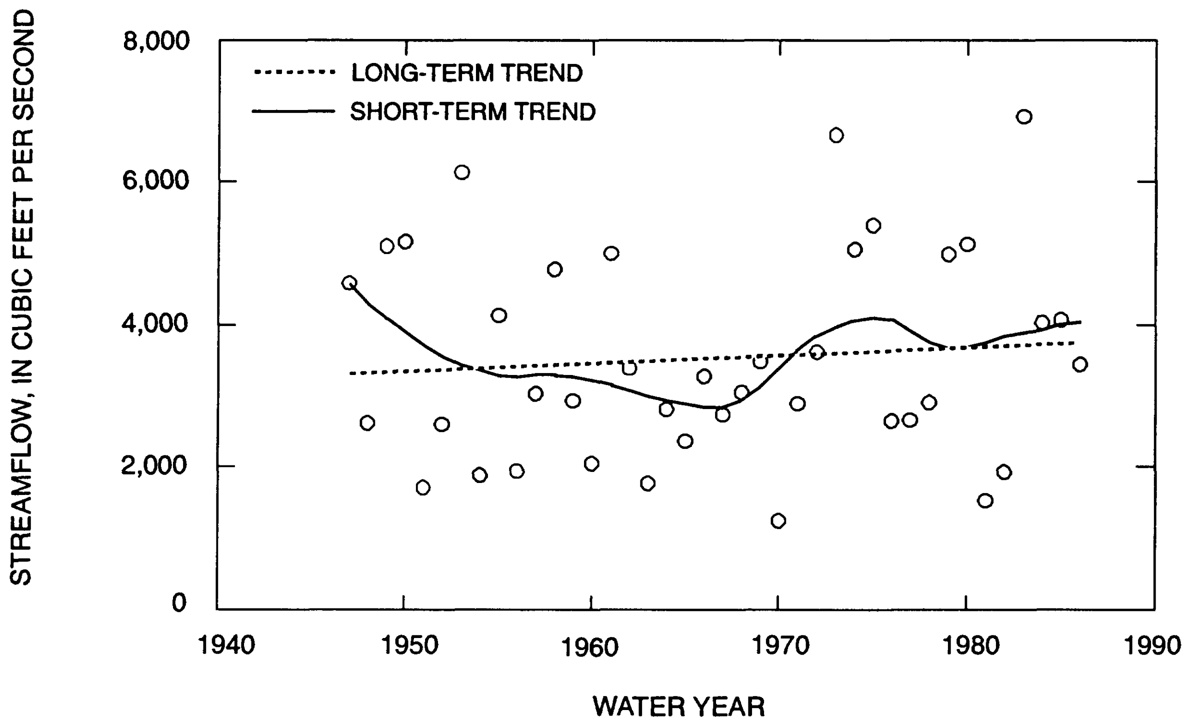

Figure 5. Temporal trends in total gaged annual mean streamflow into hydrologic segment 4, Gulf of Mexico coast (see fig. 1).

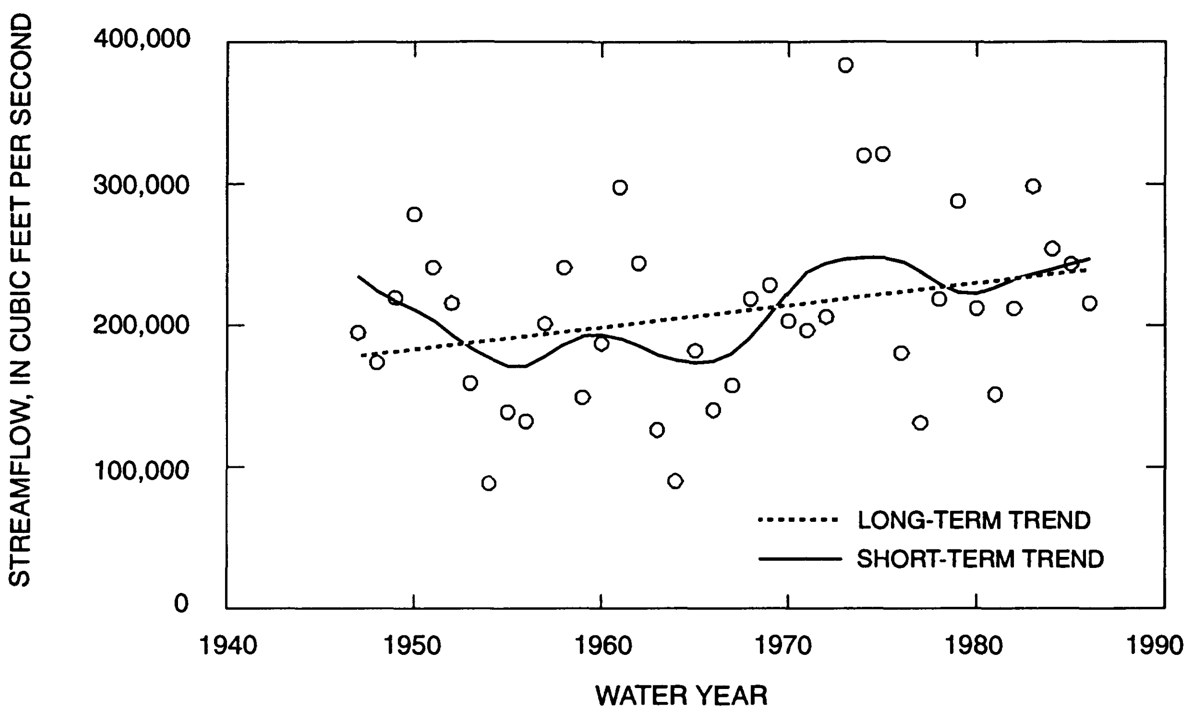

Figure 6. Temporal trends in total gaged annual mean streamflow into hydrologic segment 5, Gulf of Mexico coast (see fig. 1).

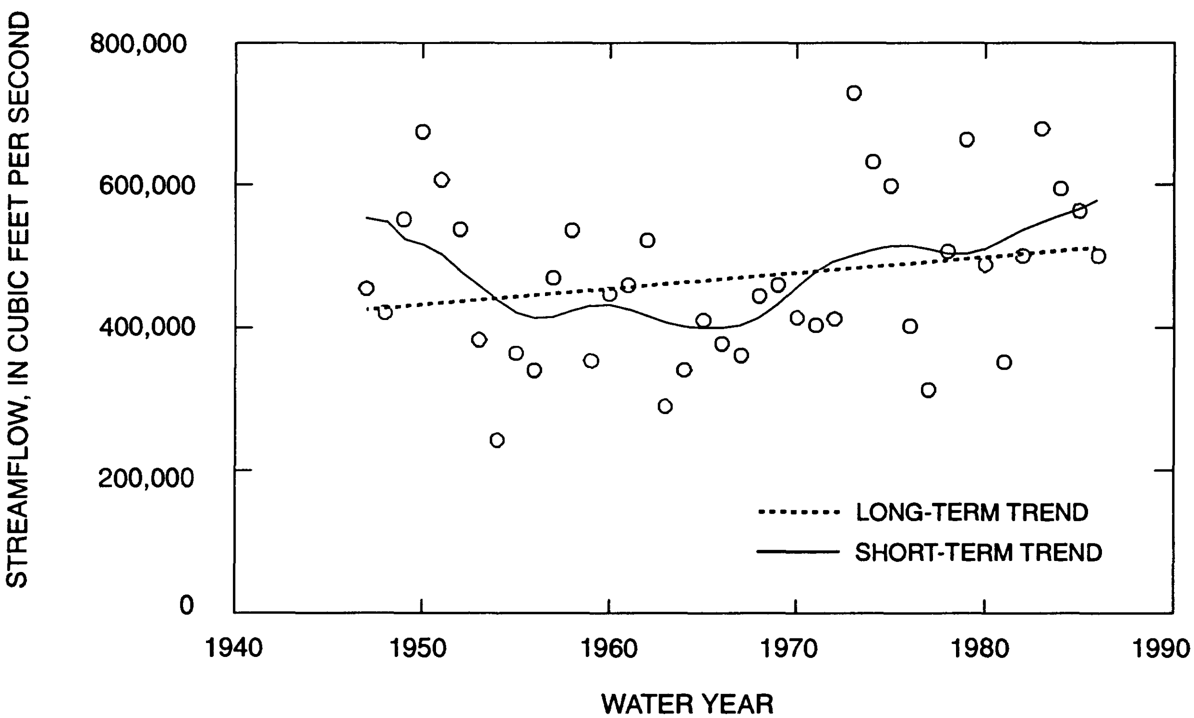

Figure 7. Temporal trends in total gaged annual mean streamflow into hydrologic segment 6, Gulf of Mexico coast (see fig. 1).

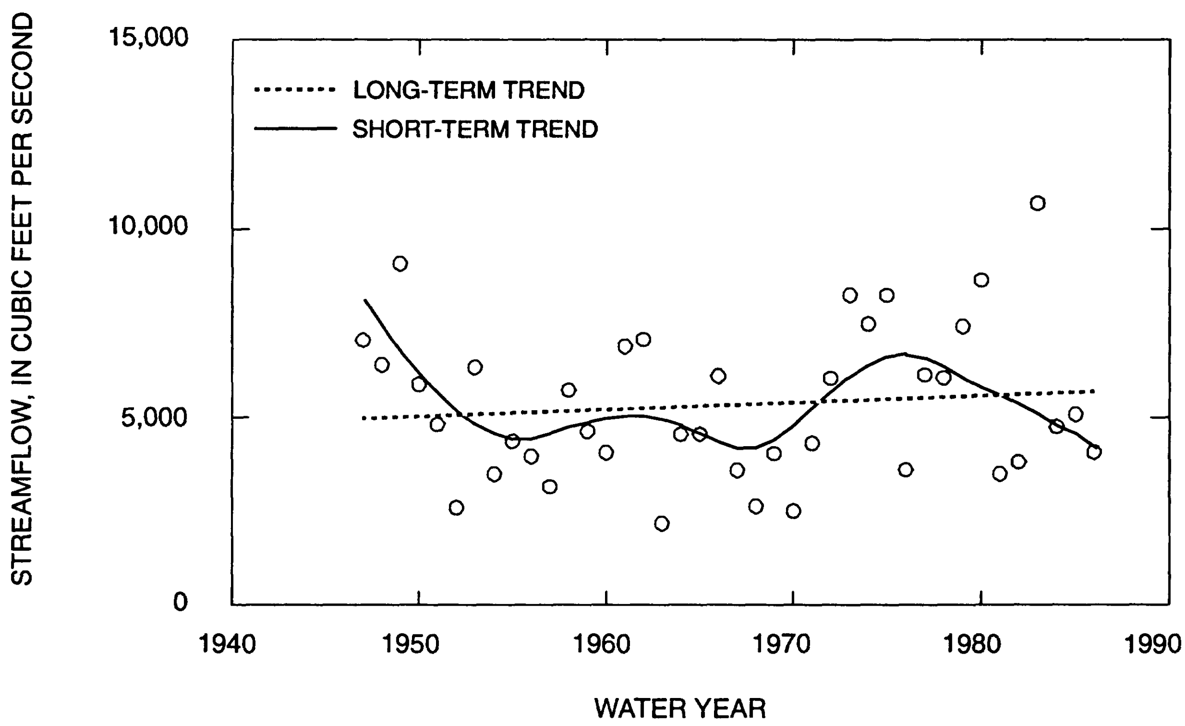

Figure 8. Temporal trends in total gaged annual mean streamflow into hydrologic segment 7, Gulf of Mexico coast (see fig. 1).

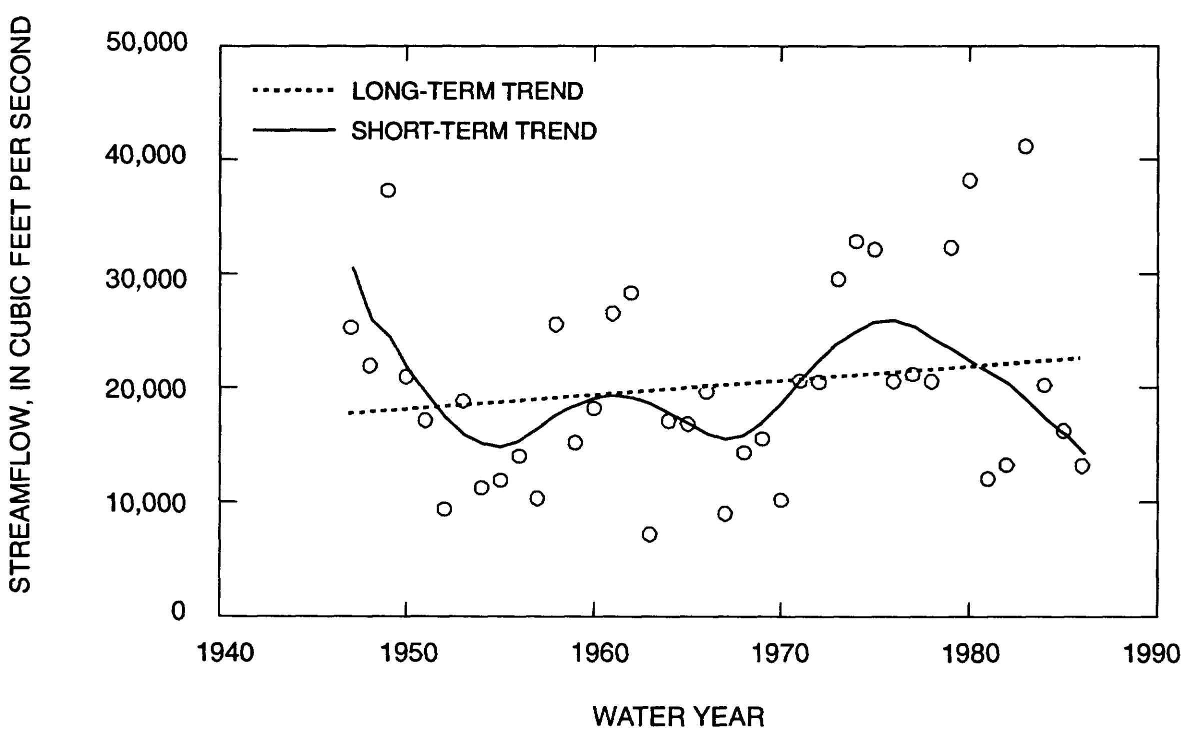

Figure 9. Temporal trends in total gaged annual mean streamflow into hydrologic segment 8, Gulf of Mexico coast (see fig. 1).

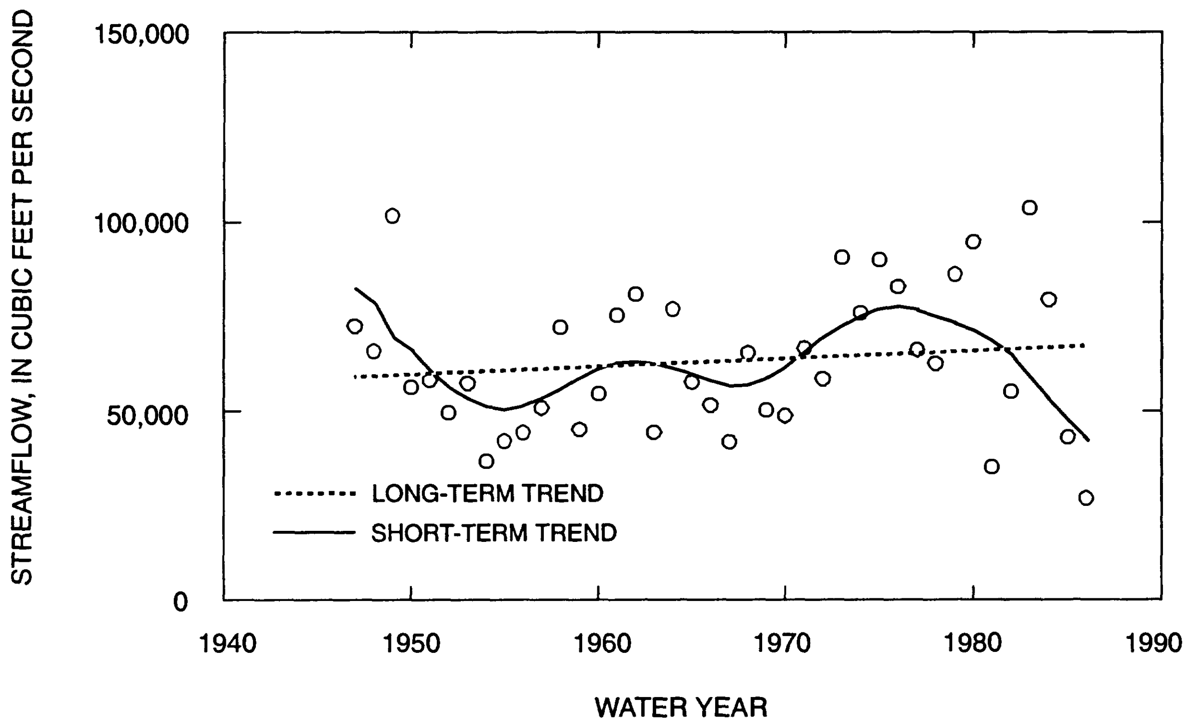

Figure 10. Temporal trends in total gaged annual mean streamflow into hydrologic segment 9, Gulf of Mexico coast (see fig. 1).

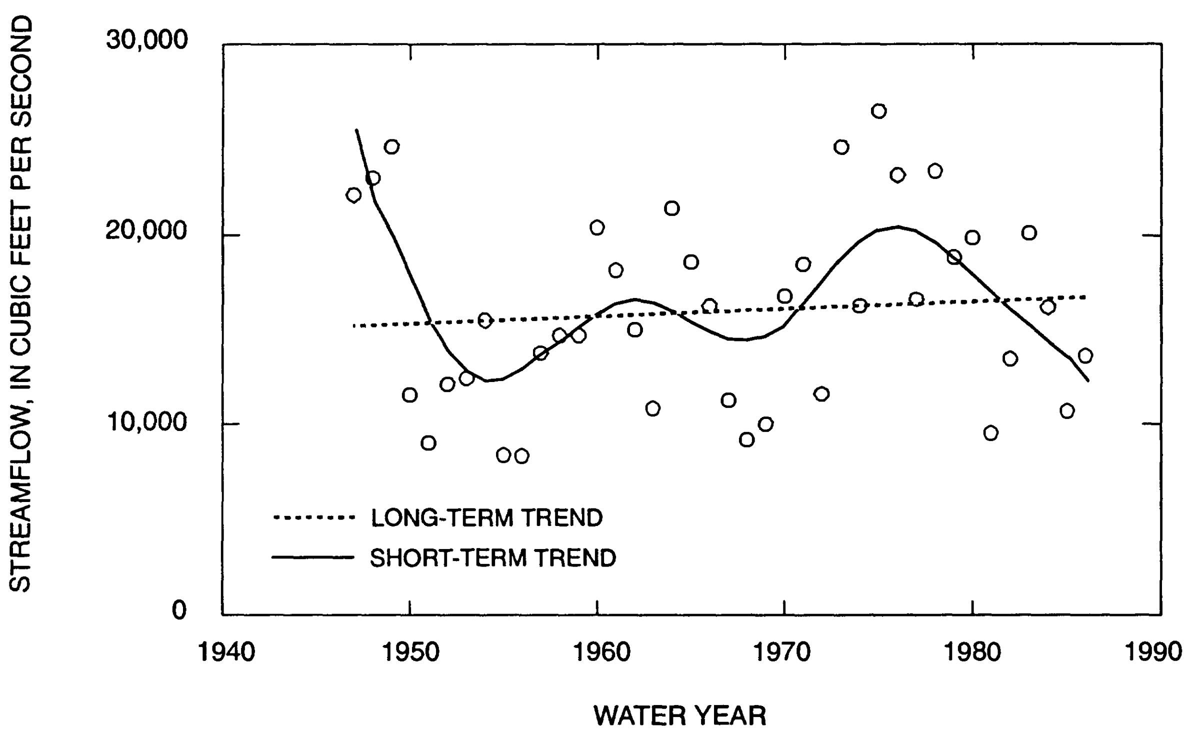

Figure 11. Temporal trends in total gaged annual mean streamflow into hydrologic segment 10, Gulf of Mexico coast (see fig. 1).

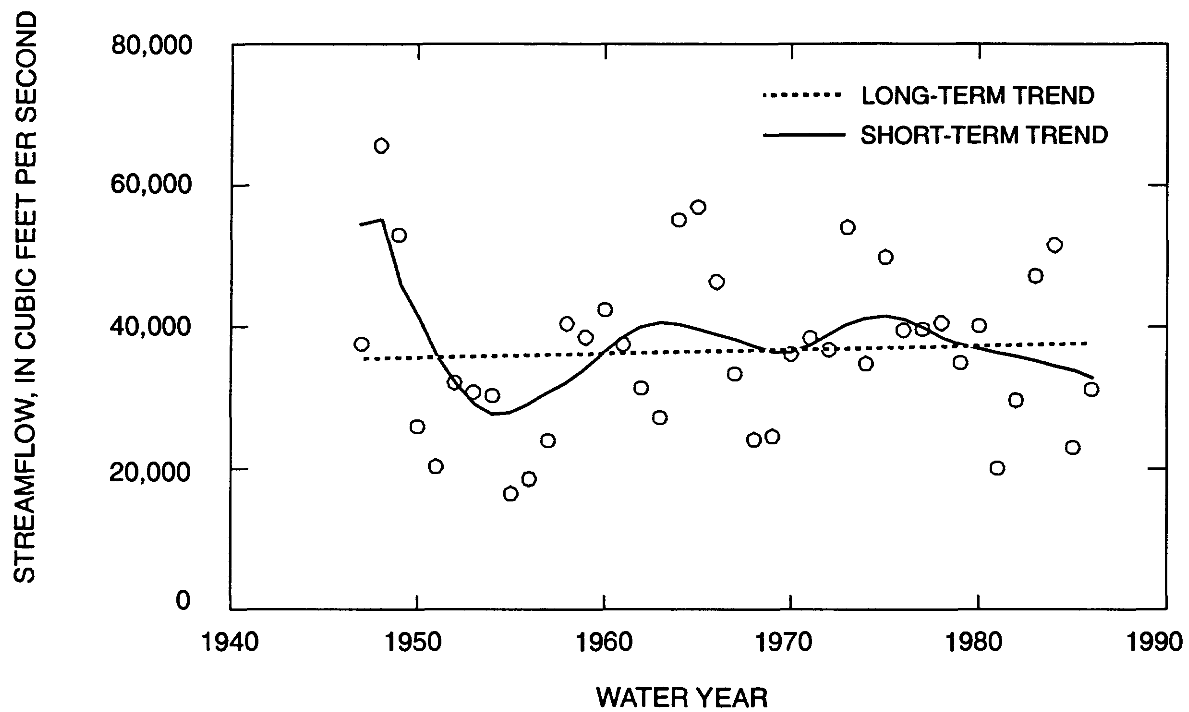

Figure 12. Temporal trends in total gaged annual mean streamflow into hydrologic segment 11, Gulf of Mexico coast (see fig. 1).

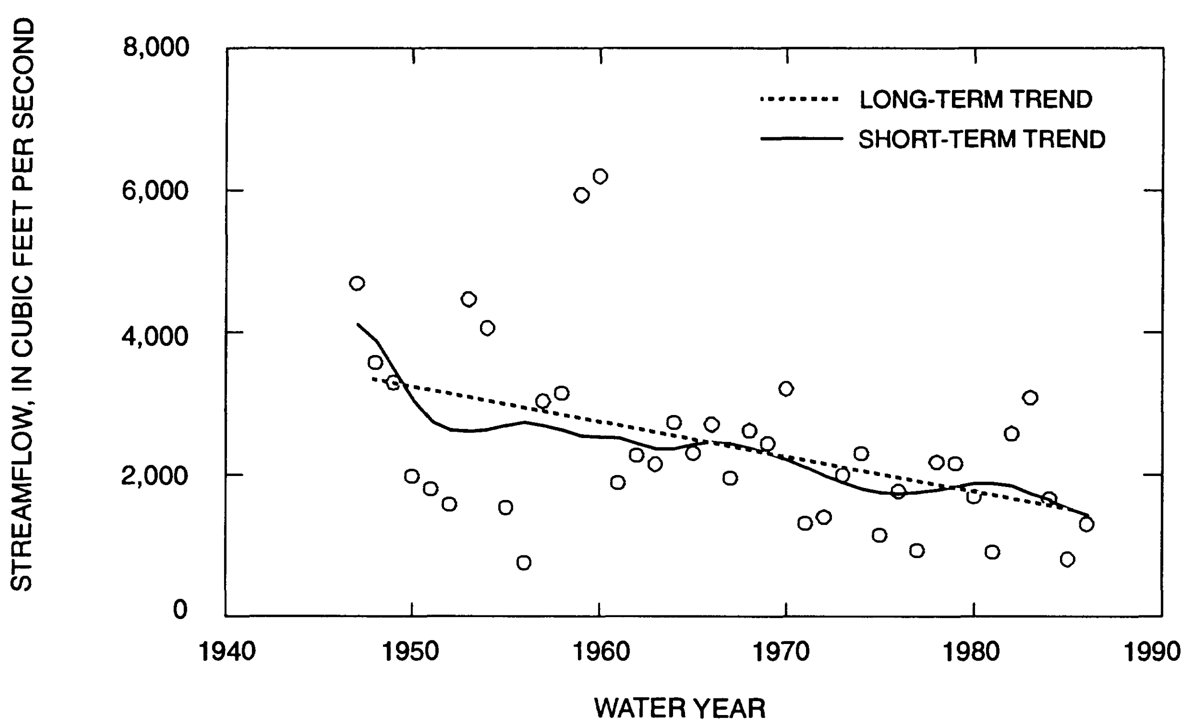

Figure 13. Temporal trends in total-gaged annual-mean streamflow into hydrologic segment 12, Gulf of Mexico coast (see fig. 1).

Table 4. Substantial percent change in mean values between two periods of monthly mean streamflow and annual mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico

[Periods represent record prior to water year 1963 and record from water year 1963 through 1990. D, at least 20-percent decrease in streamflow; --, less than 50-percent increase or 20-percent decrease in streamflow; I, at least 50-percent increase in streamflow]

Station number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1	D	D	D	D	D	D	D	D	D	D	D	D	D
2	--	--	I	--	D	D	D	D	--	D	I	--	--
3	I	I	I	I	--	--	--	I	I	I	--	I	I
4	--	--	I	I	--	I	--	--	I	--	I	--	I
5	--	--	--	--	--	--	--	--	I	--	I	--	--
6	D	D	--	I	--	--	--	I	I	D	D	I	--
7	D	D	D	--	D	--	--	--	--	D	D	--	--
8	D	--	--	D	--	--	--	--	--	--	--	--	--
9	I	--	I	I	I	I	I	I	I	I	I	I	I
10	I	--	--	--	--	I	I	I	I	--	I	I	I
11	--	--	--	D	--	--	--	--	--	--	--	--	--
12	D	D	--	--	--	--	--	--	--	--	--	--	--
13	I	--	D	D	D	D	D	D	--	I	I	I	--
14	--	D	--	D	D	--	--	D	--	--	--	I	--
15	I	--	--	--	--	--	--	D	D	--	D	I	--
16	I	--	I	--	--	--	--	--	--	--	--	--	--
17	I	--	--	--	--	--	I	--	D	--	--	--	--
18	I	I	I	--	--	--	--	--	--	--	--	--	--
19	--	--	I	--	--	--	--	--	--	--	--	--	--
20	I	--	--	--	--	--	I	--	--	--	--	--	--
21	--	D	--	--	--	--	I	--	--	D	--	--	--
22	--	D	--	--	--	--	--	--	--	D	--	--	--
23	--	--	--	--	--	--	--	--	--	D	--	--	--
24	I	--	I	I	--	--	--	--	--	D	--	--	--
25	--	--	--	--	--	--	--	--	--	D	--	--	--
26	I	--	--	--	--	--	--	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	--	--
28	--	--	--	--	--	--	D	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	D	--	--	--
30	--	--	--	--	--	--	--	--	--	D	--	--	--

Table 4. Substantial percent change in mean values between two periods of monthly mean streamflow and annual mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico—Continued

Station number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
31	--	--	--	--	--	--	--	--	--	--	--	--	--
32	--	--	--	--	--	--	--	--	--	--	--	D	--
33	--	--	--	--	--	--	--	--	--	--	--	--	--
34	--	--	--	--	--	--	--	--	--	--	--	--	--
35	--	--	--	--	--	--	--	--	--	--	--	--	--
36	D	--	--	I	I	--	--	--	--	--	--	--	--
37	D	--	--	I	--	--	--	I	--	--	I	--	--
38	--	D	--	--	--	--	--	--	--	--	--	--	--
39	D	D	D	--	--	D	D	--	--	D	D	D	D
40	D	D	D	--	--	D	D	D	D	D	D	D	D
41	D	--	--	--	--	--	--	--	--	D	D	D	D
42	D	--	--	--	--	--	--	--	D	D	D	D	D
43	D	--	--	--	I	--	--	--	--	D	D	D	--
44	D	D	--	--	--	--	D	D	D	D	D	D	D

Alabama (stations 15–27) have had few or no substantial decreases in streamflow (tables 4–6).

Since 1940, surface-water withdrawals have increased for several basins in Texas: nearly twofold for the Rio Grande (withdrawals from the United States), more than eightfold for the Nueces, more than threefold for the Colorado, more than fourfold for the Trinity, and nearly threefold for the Neches (Texas Natural Resources Conservation Commission, written commun., 1991). Increased withdrawals probably contribute to decreased streamflow in these basins.

In Florida, increases in population, tourism, and irrigated acreage have caused increased withdrawals of surface water. Irrigation demands increased because of an increase in agricultural acreage (70,000 acres) from the late 1970's to the late 1980's (Florida Department of Agriculture and Consumer Services, 1986). Large seasonal variations occur in withdrawals for irrigation of citrus crops in central Florida. Typically, relatively less precipitation and more irrigation takes place during spring (March, April, and May) than summer (July, August, and September) (Carr and others, 1990). These monthly variances are evident in the streamflow distributions for the Anclote, Hillsborough, Alafia, Little Manatee, Myakka, and Peace Rivers in west-central Florida; streamflows are low during late spring (May and June) and high during late summer (August and September) for the stations on these rivers (table 7, stations 39–44). Differences in short-term trends in streamflow between spring and summer months exist for the Anclote, Hillsborough, Alafia, and Little Manatee Rivers.

Reservoir Operations

Reservoirs store water for flood control, withdrawals, recreation, and other uses and can account for much water loss caused by evaporation and infiltration. For example, evaporation from the reservoirs on the Nueces River contributes to the reduction in streamflow to the Gulf from the Nueces River. From 1984 through 1990, the filling of and evaporation from Choke Canyon Reservoir on the Nueces River are equivalent to about 24 percent of the annual mean

Table 5. Substantial percent change in mean values between two periods of monthly minimum daily mean streamflow and annual minimum daily mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico

[Periods represent record prior to water year 1963 and record from water year 1963 through 1990. D, at least 20-percent decrease in streamflow; --, less than 50-percent increase or 20-percent decrease in streamflow; I, at least 50-percent increase in streamflow]

Station number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1	D	D	D	D	D	D	D	D	D	D	--	D	D
2	I	I	I	I	I	I	I	D	I	I	I	--	I
3	I	I	I	I	I	I	I	I	I	I	I	I	I
4	I	I	I	I	I	I	I	I	I	I	I	I	I
5	--	--	--	--	--	--	--	--	I	I	I	I	--
6	--	--	--	--	--	--	--	I	I	I	I	--	--
7	D	D	D	D	D	D	--	--	I	--	D	D	D
8	--	--	--	--	--	--	--	--	--	I	I	--	--
9	I	I	I	I	I	I	I	I	I	I	I	I	I
10	I	I	I	I	I	I	I	I	I	I	I	I	I
11	I	I	--	D	D	--	--	--	I	I	I	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	--
13	I	--	--	D	D	--	--	--	I	I	I	I	--
14	--	D	--	D	D	--	D	D	--	--	I	I	--
15	--	--	--	--	--	--	--	--	--	D	--	--	--
16	I	I	--	--	D	I	--	I	I	--	--	D	--
17	--	I	I	I	--	I	I	I	--	--	D	D	--
18	I	I	I	I	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--	--	--	--	--
22	--	--	--	--	--	--	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--	--	--	--	--	--
24	--	--	I	I	--	D	--	--	--	--	--	--	--
25	--	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	D	D	--	--	--	--	--	--
27	--	--	--	--	--	--	D	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 5. Substantial percent change in mean values between two periods of monthly minimum daily mean streamflow and annual minimum daily mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico—Continued

Station number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
31	--	--	--	--	--	--	--	--	--	--	--	--	--
32	--	--	--	--	--	--	--	--	--	--	--	--	--
33	--	--	--	--	--	--	--	--	--	--	--	--	--
34	--	--	--	--	--	--	--	--	--	--	--	--	--
35	--	--	--	--	--	--	--	--	--	--	--	--	--
36	--	--	I	I	I	I	--	I	I	--	D	--	--
37	--	--	I	I	I	--	I	I	I	I	I	I	I
38	--	D	--	--	--	--	--	--	--	--	--	--	--
39	D	D	D	--	--	D	D	D	D	--	D	D	D
40	D	D	D	D	--	D	D	D	D	D	D	D	D
41	--	--	--	--	--	--	--	I	I	--	--	--	--
42	--	--	--	--	I	--	--	I	--	D	--	--	--
43	--	--	--	I	I	I	I	I	I	D	--	D	--
44	D	D	D	--	--	D	D	D	D	D	D	D	D

streamflow to the Gulf from the Nueces River (Greene and Slade, 1995).

The number of major reservoirs in each studied basin from 1910 through 1988 are listed in table 8. Major reservoirs represent those with a normal storage capacity of at least 5,000 acre-ft or a maximum storage capacity of at least 25,000 acre-ft. Major reservoirs are present in 27 of the 44 basins studied, and the number of reservoirs for most of these basins has increased substantially.

Reservoir operations typically result in increases in minimum streamflow and decreases in maximum streamflow (Wolman, 1990). Streamflow trends for stations on the Nueces, Brazos, and Neches Rivers in Texas indicate typical streamflow changes. Substantial increases in monthly minimum streamflow and decreases in monthly maximum streamflow occurred for several months for each of these stations (tables 5–6, stations 2, 8, 13). Greene and Slade (1995) reported that trends in annual streamflow indicate increases in minimum streamflow and decreases in maximum streamflow in the Trinity River in Texas and the Apalachicola River in Florida after construction of reservoirs in those basins. They reported that peak streamflows were reduced as much as 75 percent following reservoir construction in the upper reaches of the Trinity River, and peak streamflows to the Gulf from the Apalachicola River were reduced by 23 percent after the construction of Lake Seminole.

Other Factors

Factors other than precipitation, land use, withdrawals of surface water, and reservoir operations also can affect streamflow. Minimum streamflow can be affected by springflow, soil characteristics, and effluent discharges. For example, springflow partially affects minimum streamflow in the Guadalupe River in Texas; soil characteristics influence minimum streamflows in the Lavaca and Mission Rivers in Texas; and effluent discharges augment minimum streamflow in the San Antonio River in Texas and the Fenholloway River in Florida.

Table 6. Substantial percent change in mean values between two periods of monthly maximum daily mean streamflow and annual maximum daily mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico

[Periods represent record prior to water year 1963 and record from water year 1963 through 1990. D, at least 20-percent decrease in streamflow; --, less than 50-percent increase or 20-percent decrease in streamflow; I, at least 50-percent increase in streamflow]

Station number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1	D	D	D	D	D	D	D	D	D	D	D	D	D
2	--	--	I	I	D	D	D	D	--	D	I	--	--
3	I	I	I	I	D	D	--	I	I	--	D	I	I
4	--	--	--	I	--	--	--	--	I	D	--	I	--
5	D	--	--	--	--	--	--	--	--	D	--	--	--
6	D	D	--	I	--	--	--	--	I	D	D	I	--
7	D	D	--	--	D	--	D	--	--	D	D	--	--
8	D	--	D	D	--	--	--	--	--	D	D	D	--
9	--	--	--	I	--	I	I	I	I	--	I	I	I
10	I	D	--	--	--	I	I	I	I	--	I	I	I
11	--	--	--	--	--	--	--	--	--	--	--	--	--
12	D	D	--	--	--	--	--	--	--	I	D	D	--
13	--	--	D	D	D	D	D	D	D	I	I	--	D
14	--	--	--	--	--	--	--	--	--	--	--	--	--
15	I	--	--	--	--	--	--	D	--	I	D	I	--
16	I	I	--	--	--	--	--	--	--	--	--	I	--
17	I	I	I	--	--	I	I	--	D	--	--	I	--
18	I	I	I	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--
20	I	--	--	--	--	--	I	--	--	--	I	I	--
21	I	D	--	I	--	--	I	--	D	D	--	--	--
22	--	D	--	--	--	--	I	--	--	D	--	--	--
23	I	D	--	--	--	--	I	--	--	D	D	--	--
24	I	--	--	--	--	--	--	--	--	D	--	--	--
25	I	--	--	--	--	--	--	--	--	D	D	--	--
26	I	--	--	--	--	--	--	--	I	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	--	--
28	I	--	--	--	I	--	D	--	--	--	--	D	--
29	--	--	--	--	I	--	--	--	--	--	--	D	--
30	--	I	D	--	--	--	--	--	--	D	--	D	--

Table 6. Substantial percent change in mean values between two periods of monthly maximum daily mean streamflow and annual maximum daily mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico—Continued

Station number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
31	I	--	--	--	I	--	--	--	I	--	--	D	--
32	--	--	--	--	I	--	--	--	--	--	D	D	--
33	--	--	--	--	--	--	--	--	--	--	--	D	--
34	--	--	--	I	I	--	D	--	--	--	--	--	--
35	--	--	--	--	--	--	--	--	--	--	--	--	--
36	--	--	I	I	I	--	--	--	--	--	--	--	--
37	D	D	--	--	--	--	--	I	D	--	I	--	--
38	--	--	--	--	I	--	--	--	--	--	--	--	--
39	D	D	--	--	--	D	D	--	I	D	D	--	D
40	D	D	--	--	--	D	D	D	D	D	D	D	D
41	D	D	--	--	--	D	--	I	D	D	D	D	D
42	D	D	--	--	--	--	--	I	D	D	D	D	D
43	D	D	--	--	--	--	I	--	--	D	D	D	D
44	D	D	--	--	--	--	D	D	D	D	D	D	D

Streamflow diversions also can affect streamflow. For example, the lower reaches of the Mississippi and Atchafalaya Rivers have been regulated since 1977 by the U.S. Army Corps of Engineers. Thirty percent of the total streamflow in both rivers is diverted to the Atchafalaya River through the Old River outflow channel near Simmesport, Louisiana, and 70 percent of the total streamflow is diverted to the Mississippi River (Wolman, 1990, p. 324; Slade, 1992). This diversion results in increases in streamflow in the Atchafalaya River downstream from the diversion. Distributions of monthly streamflow and months of high and low streamflow for stations 18 and 19 are similar (table 7), probably because of this diversion.

CONCLUSIONS

Temporal trends in streamflow for most long-term stations indicate changes in streamflow to the Gulf of Mexico. Precipitation is the principal factor that affects streamflow at most stations, but other factors, including those which are human related, also can have major effects on streamflow. Urbanization, withdrawals of surface water, and the number of reservoirs have increased in the basins for many streams discharging to the Gulf. The effects of these factors on the streamflow varies among streams.

REFERENCES CITED

Britton, J.C., and Morton, Brian, 1989, Shore ecology of the Gulf of Mexico: Austin, University of Texas Press, 387 p.

Carr, J.E., Chase, E.B., Paulson, R.W., and Moody, D.W., 1990, National water summary 1987—Hydrologic events and water supply and use: U.S. Geological Survey Water-Supply Paper 2350, 553 p.

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots: Journal of the American Statistical Association, v. 74, no. 368, p. 829–836.

Florida Department of Agriculture and Consumer Services, 1986, Vegetable summary 1985: Tallahassee, Florida Agricultural Statistics, 68 p.

Greene, K.E., and Slade, R.M., Jr., 1995, Streamflow analysis of the Apalachicola, Pearl, Trinity, and Nueces River Basins, Southeastern United States: U.S. Geological Survey Water-Resources Investigations Report 95–4043, 64 p.

Langbein, W.B., and Iseri, K.T., 1960, General introduction and hydrologic definitions: U.S. Geological Survey Water-Supply Paper 1541–A, 29 p.

Paulson, R.W., Chase, E.B., Roberts, R.S., and Moody, D.W., 1991, National water summary 1988–89—Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, 591 p.

Slade, R.M., Jr., 1992 [1993], Status of the Gulf of Mexico—Preliminary report on inflows from streams: U.S. Environmental Protection Agency, 64 p.

U.S. National Oceanic and Atmospheric Administration, National Ocean Service, 1985, Gulf of Mexico, coastal and ocean zones, strategic assessment: U.S. Department of Commerce, Data atlas, 6 sections [variously paged].

Wolman, M.G., 1990, Surface water hydrology, the geology of North America, v. 0–1: Boulder, The Geological Society of America, 374 p.

Table 7. Months of high and low streamflow for monthly mean, monthly minimum daily mean, and monthly maximum daily mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico

[Months of high (+) or low (-) streamflow are the 2 months for which the median streamflow is highest and the 2 months for which the median streamflow is lowest for a particular streamflow perspective and station. Stations with more than 2 months of high or low streamflow indicated are those that have equal median streamflow for more than 1 month. Stations where symbols are absent represent intermediate streamflow. O N D J F M A M J J A S, October November December January February March April May June July August September; +, high streamflow; –, low streamflow]

Station number	Monthly mean streamflow												Monthly minimum streamflow												Monthly maximum streamflow											
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1	+					–	–					+	+	+					–					–	+			–		–						+
2			–	–				+	+							–	–				+		+				–	–				+	+			
3				–				+	+		–				+			+				–	–					–			–	+		–		+
4								+	+	–	–				+	+	+						–	–			–	–				+	+			
5								+	+		–	–						+		+			–	–				–				+	+		–	
6	–				+			+			–		–				+	+					–	–								+	+	–	–	
7		–						+	+		–		–			–					+	+					–					+	+		–	
8								+	+		–	–	–							+	+		–									+	+		–	–
9				+	+	–		+			–		–				+	+	–		–	–	–		–				+			+		–		
10	–			+	+						–					+	+						–	–	–				+			+			–	
11						+		+			–	–	–				+			+				–	–				+			+			–	
12					+	+					–	–				+	+						–	–					+	+					–	–
13	–				+	+						–	–				+	+						–	–					+	+					–
14	–				+	+						–	–	–			+	+							–				+	+						–
15	–			+		+					–		–			+	+							–	–			+		+						–
16	–	–		+	+								–	–		+	+								–				+	+					–	
17	–		+		+							–	–	–		+							+		–		+		+	+						–
18	–						+	+				–	–					+	+					–	–					+	+					–
19	–						+	+				–	–					+	+					–	–					+	+					–
20	–				+	+						–	–	–			+	+						–	–				+	+					–	–

Table 7. Months of high and low streamflow for monthly mean, monthly minimum daily mean, and monthly maximum daily mean streamflow for 44 long-term streamflow-gaging stations in the lower reaches of streams that discharge directly to the Gulf of Mexico—Continued

Station number	Monthly mean streamflow												Monthly minimum streamflow												Monthly maximum streamflow											
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
21	–	–			+	+							–	–			+	+							–				+	+						–
22	–				+	+						–	–	–		+	+	+				–		–	–				+	+			–			
23	–				+	+						–	–				+	+						–	–					+	+					–
24	–				+	+						–	–				+	+						–	–				+	+						–
25	–				+	+						–	–				+	+						–	–				+	+						–
26	–				+	+						–	–				+	+						–	–				+	+						–
27	–				+	+						–	–				+	+						–	–					+	+					–
28	–	–			+	+							–			+		+			–			–	–	–			+	+						
29	–					+	+					–	–				+	+						–	–					+	+					–
30	–	–			+	+							–				+	+						–	–	–			+	+						
31	–	–			+	+											+	+			–			–	–	–			+	+						
32	–	–			+	+							–	–			+	+						–	–	–			+	+						
33					+	+		–	–									+	+	–	–				–					+		–				+
34	–	–			+	+							–	–			+	+							–	–			+	+						
35	–	–			+	+							–	–			+	+							–	–				+	+					
36	–	–			+	+							–	–			+	+							–	–			+	+						
37		–	–		+						+				–		+	+			–		–			–	–		+						+	
38		–	–			+	+							–	–			+	+							–	–			+	+					
39								–	–		+	+								–	–		+	+								–	–		+	+
40								–	–		+	+								–	–		+	+			–					–			+	+
41							–	–			+	+								–	–		+	+		–						–			+	+
42		–						–			+	+								–	–		+	+			–					–			+	+
43			–					–			+	+								–	–		+	+			–					–			+	+
44			–					–			+	+							–	–			+	+			–					–			+	+

Table 8. Number of major reservoirs in drainage basin of streams that discharge directly to the Gulf of Mexico, 1910–88

[Number of reservoirs at beginning of indicated year. No major reservoirs identified for the excluded streams. Major reservoirs represent those that have a normal storage capacity of at least 5,000 acre-feet or a maximum storage capacity of at least 25,000 acre-feet. --, no major reservoirs]

Station number	Drainage basin	1910	1920	1930	1940	1950	1960	1970	1980	1988
1	Rio Grande	2	10	12	17	18	22	26	30	32
2	Nueces River	--	--	--	--	1	2	2	2	3
4	San Antonio River	--	1	1	1	1	1	3	3	3
5	Guadalupe River	--	--	2	3	3	3	4	4	5
6	Lavaca River	--	--	--	--	--	--	--	1	1
7	Colorado River	2	2	2	6	9	15	21	23	23
8	Brazos River	--	--	5	7	11	21	32	37	41
11	Trinity River	--	2	4	7	7	18	25	27	31
13	Neches River	--	--	--	--	1	4	7	10	10
14	Sabine River	--	--	--	--	1	5	12	13	14
15	Calcasieu River	--	--	--	--	--	--	1	1	1
17	Bayou des Cannes	--	--	--	--	1	1	1	1	1
18	Atchafalaya River	2	4	12	22	33	56	81	103	106
19	Mississippi River	69	125	189	390	483	606	780	925	948
24	Pearl River	--	--	--	--	--	--	1	1	1
25	Pascagoula River	--	--	--	1	1	2	3	5	5
26	Tombigbee River	--	1	1	3	4	9	14	20	26
27	Alabama River	--	1	5	7	8	8	14	20	20
29	Escambia River	--	--	2	2	2	2	2	2	2
32	Choctawhatchee River	--	--	--	1	1	1	1	1	1
33	Econfina Creek	--	--	--	--	--	--	1	1	1
34	Chipola River	--	--	--	--	--	--	1	1	1
35	Apalachicola River	--	1	2	3	3	6	8	11	11
36	Ochlockonee River	--	--	1	1	1	1	1	1	1
40	Hillsborough River	--	--	--	--	1	1	1	1	1
41	Alafia River	--	--	--	--	--	--	--	1	1
42	Little Manatee River	--	--	--	--	--	--	--	1	1

GLOSSARY

Definitions in this glossary are modified primarily from Langbein and Iseri (1960).

Cubic foot per second - A unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of rectangular cross section, 1 foot wide and 1 foot deep, flowing water at a mean velocity of 1 foot per second.

Discharge - The volume of water (or more broadly, volume of fluid plus suspended sediment) that passes a given point within a given period of time.

Drainage area - That area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream upstream from the specified location.

Drought - A period of deficient precipitation or runoff extending over an indefinite number of days, but with no set standard by which to determine the amount of deficiency needed to constitute a drought.

Evapotranspiration - Water withdrawn from a land area by evaporation from water surfaces and moist soil and plant transpiration.

Infiltration - The flow of a fluid into a substance through pores or small openings.

Percentiles - Values that divide the data into 100 equal parts. A 75th percentile value indicates that 75 percent of the data in a group is less than or equal to that value.

Precipitation - The discharge of water, in liquid or solid state, from the atmosphere generally to a land or water surface.

Regulation - Manipulation of the flow of a stream.

Reservoir - A pond, lake, or basin, either natural or human-made, for the storage, regulation, or control of water.

Runoff - That part of precipitation that appears in surface streams. The volume of runoff is equal to precipitation minus infiltration and evaporation.

Salinity - Minerals and organic matter dissolved in water, generally expressed as milligrams per liter (mg/L) of dissolved solids. Concentrations of more than 1,000 mg/L are considered unsuitable for human consumption and 35,000 mg/L are defined as seawater.

Storage - Water impounded in reservoirs.

Normal capacity - Total volume below the normal retention level, including dead storage (volume in a reservoir below the lowest controllable level) but excluding flood control or surcharge storage (storage that results from flashboards increasing the dam height and allowing temporary detention of a volume of flood water above the controllable pool level).

Maximum capacity - Total volume below the maximum obtainable water-surface elevation, including surcharge storage.

Streamflow - The discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course.

Annual maximum daily mean streamflow - The maximum daily mean streamflow value for a specific year.

Annual minimum daily mean streamflow - The minimum daily mean streamflow value for a specific year.

Annual mean streamflow - The arithmetic mean of daily mean streamflow for a specific year.

Daily mean streamflow - The time-weighted mean of instantaneous streamflow (streamflow at a particular instant of time) for a specific day.

Monthly maximum daily mean streamflow - The maximum daily mean streamflow value for a specific month.

Monthly minimum daily mean streamflow - The minimum daily mean streamflow value for a specific month.

Monthly mean streamflow - The arithmetic mean of daily mean streamflow for a specific month.

Streamflow-gaging station - A site on a stream or canal where systematic streamflow data are obtained.

Watershed - Term used to signify drainage basin or catchment area.

Water year - In U.S. Geological Survey publications, the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of 12 months. Thus, the year ended September 30, 1959, is called the "1959 water year."

Withdrawal of surface water - The removal of water diverted from a stream, lake, or reservoir.

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