MEASUREMENT OF 1999 DROUGHT CONDITIONS IN MISSISSIPPI

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INTRODUCTION

Accurate and reliable water-resources data collected during drought conditions are critical to regulatory agencies such as the Mississippi Department of Environmental Quality (MDEQ). Droughts have affected Mississippi during 1940-44, 1951-57, 1962-71, 1980-82, and 1983-88. In late summer and early autumn 1999, many areas of Mississippi experienced near record drought conditions causing concern to many private and public interests. Personnel from the U.S. Geological Survey (USGS), in cooperation with the MDEQ Office of Land and Water Resources (MDEQ-OLWR), measured water levels and streamflows throughout the State of Mississippi during drought conditions in August through October 1999.

Droughts are normal, recurring hydrological events caused by deficiency of precipitation over an extended period of time that can have adverse effects on anthropogenic use of water. Much of the State of Mississippi has continued to experience drought conditions through late winter of 2000. Data on minimum streamflows are an important factor for determining the regulation of flow control structures, effluent, and surface water withdrawals and other water-management decisions during droughts. Data on minimum streamflows become paramount during drought conditions.

This report presents information related to the legal aspects of drought conditions and includes selected data collected at streamgages affected by severe drought conditions in Mississippi during the late summer and early autumn of 1999. Comparisons of 1999 low-flow characteristics at selected streamgages to other period-of-record low-flows at selected gages in the State are also presented.

MISSISSIPPI WATER LAW

According to Mississippi Water Laws (1956), water occurring in any watercourse, lake, or other natural water body of the State was declared to be among the basic resources of this State and subject to appropriation in accordance with the provisions of Section 51-3-3 of the Water Laws of Mississippi, Code of 1972, as amended; and the control, development and use of water for all beneficial purposes shall be in the State, which, in the exercise of its police powers, shall take such measures as shall effectuate full utilization and protection of the water resources of the State. Section 51-3-3 of the Water Laws of Mississippi, Code of 1972, as amended, was approved by the Mississippi Legislature on April 6, 1956. This Section allowed the appropriation of a specified amount of water, at a specific time at a specific place, authorized and allotted by the Board of Water Commissioners of the State of Mississippi (now the MDEQ-OLWR), for beneficial purposes. The State of Mississippi was the first State east of the Mississippi River to enact this type of law.

Under Section 51-3-7 of the Water Laws of Mississippi, Code of 1972, as amended, no right to appropriate or use water subject to appropriation shall be initiated or acquired except upon compliance with the provisions of this chapter, and no person shall take water from a stream, lake or other watercourse without having a valid right to do so.

Subject to the common law or other lawful water rights of others, any person may build and maintain a dam on any stream where the drainage area is fifty (50) acres or less and utilize the impounded water without a permit from the board so long as such action does not affect the established average minimum flow in the stream below the dam.

During the period 1956 to 1985, the Board of Water Commissioners had the authority to permit the appropriation of surface water of any stream only in excess of the established average minimum flow as based on records or other computations by the Board. The established average minimum flow was defined as "the average minimum daily flow occurring during each of the five lowest years in the period of the preceding twenty consecutive years, (5Q20)." The board determined and established the average minimum lake level for a given lake as the 5Q20. The Board had the authority to permit the appropriation of water of any lake only in excess of the established average minimum lake level.

On April 1, 1985, the Water Laws of Mississippi, Code of 1972, was amended. Section 51-3-5 required that no one, who was not specifically exempted by this chapter, should use water without having first obtained a permit to appropriate water for beneficial use. All persons having acquired a right to use surface water prior to April 1, 1985, were entitled to continue such use, provided that such rights were contingent upon filing a notice of claim to such use with the commission on a form promulgated by the Commission of Natural Resources of the State of Mississippi. For the first time, the appropriation of ground water from wells with a surface casing diameter of 6 inches or larger required a permit. A person was required to obtain a permit to use water for domestic purposes.

Under the Water Laws amended in 1985, the established minimum flow was defined as the average streamflow rate over 7 consecutive days that may be expected to be reached as an annual minimum no more frequently than 1 year in 10 (7Q10). The established average minimum lake level for a given lake was also amended to be the 7Q10 lake level.

The Board (MDEQ-OLWR) has the authority to permit the use of water from any surface stream and lake only in excess of the established minimum flow based on records or computations by the Commission. The Board may authorize the permittee to use the established minimum flow and the water below the established minimum lake level for industrial purposes upon written assurance, supported by such data and reporting requirements that the Board deems appropriate, that the water shall be returned to the stream at a point downstream from the place of withdrawal, and will not result in any substantial detriment to property owners affected thereby or to the public interest. No use of water shall be authorized that will impair the effect of stream standards set under the pollution control laws of this State based upon a minimum streamflow.

In 1999, under the above stated provision, when streamflow in the Leaf River decreased to less than the established minimum flow, the Georgia Pacific Paper Mill at New Augusta and the Mississippi Power Company at Hattiesburg were authorized to use the established minimum flow in the Leaf River under the assurance that the water would be returned to the river at basically the same place, volume, and quality.

MISSISSIPPI PRECIPITATION AND STREAMFLOW

Mississippi has an average annual rainfall of about 56 inches annually. This ranges from about 68 inches near the Gulf of Mexico coast to about 50 inches in the northern areas of the State. Annual extremes for the period of record are less than 37 inches in 1889 to more than 83 inches in 1983. About 40 inches (70 percent) of the average 56 inches falls in the winter and early spring. Low streamflows generally occur in the late summer and early autumn. The principal source of moisture for the State is the Gulf of Mexico, although the eastern Pacific Ocean can also bring significant moisture to the State, mostly during the summer and early autumn months. Streamflow generally reflects rainfall in that high streamflows generally occur from late fall to late spring, and low flows generally occur from late summer to early fall. The high variability in precipitation makes characterizing and forecasting climatology in the State an inexact science at best.

DROUGHT CHARACTERIZATION METHODS AND INDICES

There are many empirical methods and indices for characterizing drought. Due to the extreme variability in rainfall for any given year, various drought indices have been developed to describe and document lack of moisture. One of the simplest methods of documenting drought is by computing percent departure from normal precipitation. For streamflow, low-flow duration characteristics are used in many States to describe and document drought in streams. Low flow characteristics for streamflow generally are computed for a selected consecutive-day period for a given recurrence interval or chance of

occurrence. In 1992, Fowler described drought in terms of a departure from normal surface water flows in documenting drought conditions in Indiana. In the last 5 months of a 12-month study Wendland (1990) correlated streamflows with accumulated precipitation. Wendland also found similar response in correlating soil moisture to accumulated precipitation. Since streamflow can be directly correlated with precipitation, drought flows can also be characterized by using a percent departure from normal. There are various drought indices accepted as a means of characterizing drought such, as the Crop Moisture Index, Keetch-Byram Drought Index and the widely accepted Palmer Drought Severity Index, which will be discussed in more detail in the following paragraphs.

Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is a soil moisture algorithm developed by W.C. Palmer (1965) and calibrated for relatively homogenous regions. The PDSI is used by many Federal and State agencies as a trigger for instituting drought relief programs. The PDSI is the first comprehensive drought index developed for the United States. According to Hayes (2000) there are notable limitations to the PDSI:

- The values that initiate, end, and quantify the intensity of a drought were arbitrarily selected from a study of central Iowa and western Kansas and are largely empirical.
- The PDSI is sensitive to the available water content of a given soil.
- Multi-layered soils are simplified.
- Times of concentration for run-off are ignored.
- Potential evapotransporation is approximated by using the Thornwaite method.

Hayes also identifies other limitations to the PDSI. Nevertheless, the PDSI is a widely accepted description of drought conditions in the United States.

7-Day, 10-Year Low Flow Discharge

For anthropogenic use, it is critical to describe conditions that guarantee or prohibit surface-water availability. Surface-water streamflow duration characteristics are important for water-supply

planning, waste-load allocation, storage-facility design, irrigation, wildlife and fish conservation, and recreational uses. In Mississippi, the legal characteristic to define surface-water use has been the 7-day, 10-year low-flow discharge (7Q10). The 7Q10 is defined as the annual minimum average discharge for 7 consecutive days for a 10-year recurrence interval. Because the inverse of recurrence interval is the probability of occurrence, the 7Q10 can be stated as the minimum average discharge for 7 consecutive days that has a 10-percent chance of occurrence. 7Q10 values are used by the MDEQ-OLWR to permit both waste-water effluent discharge into surface-water streams and surface-water withdrawal. In 1990 low-flow characteristics were determined for gages in Mississippi (Telis 1990). There were rivers flowing at rates less than 7Q10 values at many gages in the State during August and September 1999.

STUDY AREA

The USGS currently operates 97 continuous recording streamgages in Mississippi. Seventy of these stream gages were selected for use in this report (fig. 1). Drainage areas ranged from 2.01 to 6,590 square miles. Slopes and lengths upstream of selected streamgages ranged from 1.0 to 38.1 feet per mile, and 2.01 to 185 miles, respectively. Twenty-five selected gages (table 1) provide an abbreviated synoptic view of drought conditions in the State during the 1999 water year.

1999 DROUGHT RESULTS IN MISSISSIPPI

According to a United States Department of Agriculture (USDA) emergency declaration on January 7, 2000, USDA Secretary Dan Glickman declared 81 Mississippi counties in a drought due to insufficient rainfall and extreme heat that occurred from March 1, 1998 until November 18, 1999 (National Drought Mitigation Center 2000).

After a moderately dry 1999 calendar year, many rivers in the State were experiencing record low flows for January and February 2000. According to Plunkett et al (2000), annual mean streamflow was normal (within the 25th and 75th quartile of the long term median discharge for the reference water year period 1961-1990) in most streams in Mississippi during the 1999 water year. Comparisons of monthly mean and annual mean runoff in the 1999 water year with median runoff for the reference water year period 1961-90 were made for three representative USGS streamgages:

Station name and number	1999 runoff (in inches)	Median value 1961-90 (in inches)	Percent of median
Tombigbee River at Stennis Lock and Dam near Columbus, MS	23.03	21.10	109
Pascagoula River at Merrill, MS	13.79	20.64	67
Big Black River near Bovina, MS	19.46	17.67	110

If data within the 25th and 75th quartile of the median flow are considered normal, then streamflow at two of three representative gages in the State was normal for the 1999 water year; however, during August and September 1999, all three gages were below normal (<25th quartile of the median value for the period of record (fig. 2). The Pascagoula River at Merrill, flowed below normal for 7 months in the 1999 water year (December 1998, January, April, May, July, August, and September 1999). Many of the gages in the Pascagoula River Basin flowed below their computed 7Q10 value.

RESULTS AND SUMMARY

Of 70 USGS continuous recording streamgages selected for this report, 16 had at least one daily mean discharge below the published 7Q10 value. Thirteen of the 16 gages had 7 consecutive daily mean discharges below the published 7Q10 indicating that at these gages, low flows occurred for a sustained period (fig. 1, table 1). Of the 16 streamgages that flowed below 7Q10, 5 gages were located in the Tennessee-Tombigbee River Basin, 7 gages were located in the Pascagoula River Basin, 1 gage was located in the coastal river basins, 1 gage was located in the Pearl River Basin, 1 gage was located in the Big Black River Basin, and 1 gage was located in the Tennessee River Basin.

In order to understand the variability in measurement and difficulty in patterning a relation of drought over time, annual mean discharges for 10 selected gages from six river basins throughout the State were plotted as a departure from the period of record mean annual discharge (figs. 3-5). Although there is considerable variability of the data for the six river basins, drought periods are evident in the decades of the 1940's, 1950's, 1960's, and 1980's that are much more severe than what has occurred in the State in the recent years.

Monthly mean discharges for three representative gages at the Tombigbee River at Stennis Lock and Dam near Columbus, the Big Black River near Bovina, and the Pascagoula River at Merrill, were plotted with the 25th and 75th quartiles of the period of record mean monthly median discharges. The Tombigbee River at Stennis Lock and Dam near Columbus, and the Big Black River near Bovina, flowed normal in the 1999 water year except for the months of August and September. The Pascagoula River at Merrill, flowed below the normal range for 7 of the 12 months of the water year. In addition, although data are considerably variable, it is evident from figs. 3-5 that drought conditions in 1999 were relatively mild when compared to conditions in the 1940's through the 1960's, and the 1980's.

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Table 1. Basin and low-flow characteristics for 25 selected streamgages in Mississippi.

[mi^2 square miles, ft/mi, feet per mile, ft ³/s, cubic feet per second; 7Q10, 7-day, 10-year low flow discharge, 7-day low flow discharge, 7Q]

Drainage basin	Station number	Station name	Drainage area (mi^2)	Length (miles)	Slope (ft/mi)	Period of record (years)	Mean annual discharge (ft³/s)	1999 Annual mean discharge (ft³/s)	7Q10 (ft³/s)	Time-sampling error (percent)	1999 Minimum daily discharge (ft³/s)	Period of record minimum daily discharge (ft³/s)	1999 Minimum daily 7Q (ft³/s)	Period of record minimum daily 7Q (ft³/s)	Period of record minimum daily 7Q Date
Tennessee- Tombigbee Waterway	2431000	Tombigbee River near Fulton, MS	612	42.2	3.5	1986-99	685	885	27	10	114	33	128	36	10/01/1984
						1929-99	956	885				12	128	15	09/01/1943
	2436500	Town Creek near Nettleton, MS	620	38.2	6.9	1939-99	990	1060	4.6	13	22	1	23	1.6	10/08/1942
	2438400	Buttahatchie River near Aberdeen, MS	799	63.8	4.1	1966-99	1452	1301	117	7	110	90	112	99	08/28/1988
	2441390	Tombigbee River at Stennis L&D near Columbus, MS	4460	143	1.4	1982-99	7838	7530	228	7	285	120	438	170	10/20/1981
						1900-12, 1929-99	6886	7530							
	2448000	Tombigbee River at Macon, MS	7590	90.5	2.5	1929-99	10600	10832	92	9	749	23	51	25	08/24/1943
Pascagoula River	2470000	Leaf River near Collins, MS	1743	88.7	3	1938-99	3110	3561	72	6	69	65	72	57	08/24/1957
	2472500	Boule Creek near Hattiesburg, MS	304	51	6.5	1938-99	454	300	100	4	107	83	108	84	08/24/1957
	2473500	Tallahala Creek at Laurel, MS	238	56.5	3.2	1938-99	348	151	4.4	12	4.7	1.8	5.3	2	10/26/1963
	2474560	Leaf River near New Augusta, MS	2540	139	2.3	1984-99	3918	2177	497	13	472	472	476	476	09/22/1999
	2475000	Leaf River at McLain, MS	3500	169	1.9	1940	5469	3247	596	6	549	482	553	488	10/20/1963
	2475500	Chunky River near Chunky, MS	369	39.8	5.3	1938-99	502	265	5.2	14	7.5	1.6	8.5	1.8	09/25/1954
	2478500	Chickasawhay River at Leakesville, MS	2690	184	1.6	1938-99	3915	2630	248	9	264	162	268	166	10/25/1963
	2479000	Pascagoula River at Merrill, MS	6590	184	1.9	1931-99	10060	6692	917	8	868	704	878	708	10/20/1963
	2479300	Red Creek at Vestry, MS	441	76.1	2.9	1956-99	679	546	109	9	108	89	109	90	10/18/1963
Wolf River	2481510	Wolf River near Landon, MS	308	60.4	4.9	1971-99	645	274	40	11	30	30	31	31	09/22/1999
Pearl River	2482000	Pearl River at Edinburg, MS	904	76.3	1.3	1928-99	1166	1783	6.4	14	5.6	2.2	7.1	2.3	09/24/1956
	2484000	Yockanookany River near Kosciusko, MS	303	37.1	3.3	1938-99	447	357	5.5	8	7.5	2.3	7.5	2.4	08/19/1943
	2484500	Yockanookany River near Carthage, MS	499	73.9	2.2	1944-99	680	437	9.5	10	14	5.3	14	6.3	09/07/1954
	2486000	Pearl River at Jackson, MS	3170	177	1	1962-99	4513	2748	103	12	187	45	191	63	09/17/1963
						1902-12, 1929-99	4172	2748							
	2488500	Pearl River near Monticello, MS	4990	273	1	1962-99	7226	4441	359	9	447	269	458	274	10/21/1963
						1939-99	6938	4441							
Yazoo River	7268000	Little Tallahatchie River at Etta, MS	526	32	5.3	1938-99	882	647	9.8	13	19	4.1	20	4.3	10/03/1938
	7283000	Skuna River at Bruce, MS	254	31.2	3.6	1948-99	372	454	2.5	13	7	1	7.2	1.1	08/14/1954
Big Black River	7290000	Big Black River near Bovina, MS	2812	216	1.3	1938-99	3808	4028	65	11	155	67	168	67	09/30/1954
Homochitto River	7291000	Homochitto River at Eddiceton, MS	181	32.6	6.2	1969-99	269	198	33	4	37	11	39	13	05/29/1989
	7292500	Homochitto River at Rosetta, MS	787	64.4	5	1952-99	1167	906	152	8	168	129	173	132	09/22/1956

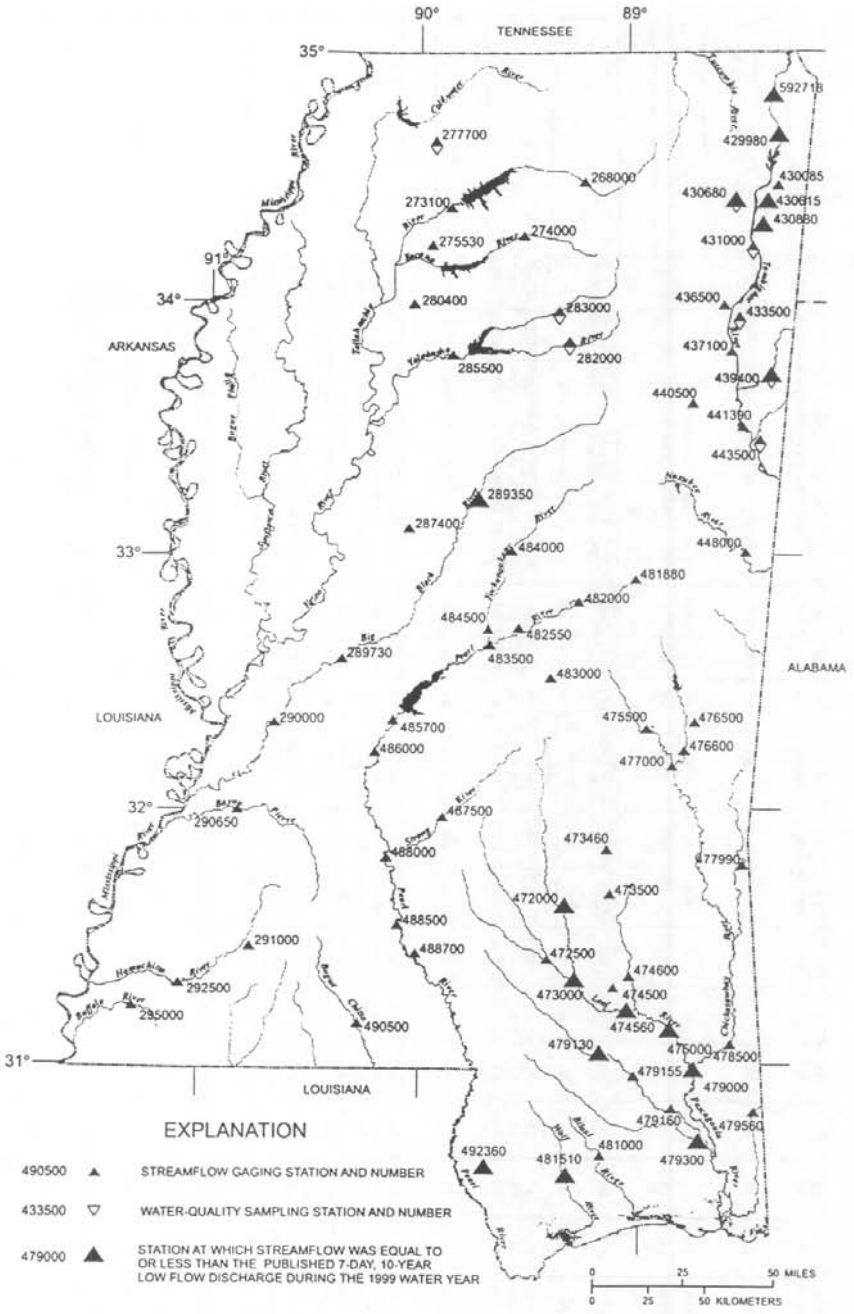

Figure 1.--Seventy selected continuous record streamgages in Mississippi for which low-flow statistics were compared during the 1999 water year.

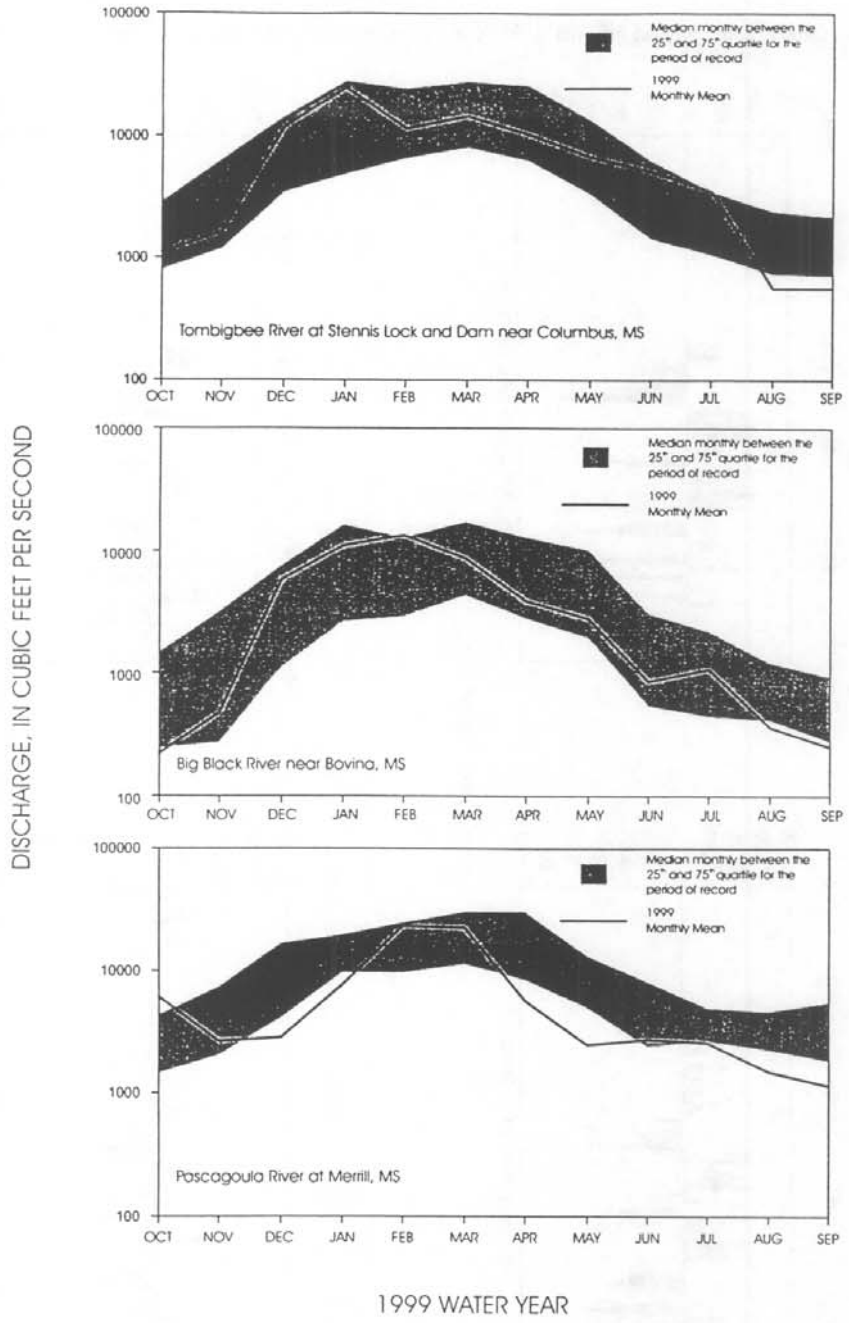

Figure 2.– 1999 monthly mean discharge and range between the 25th and 75th quartile for the period of record median monthly discharge for three representative streamgages in Mississippi.

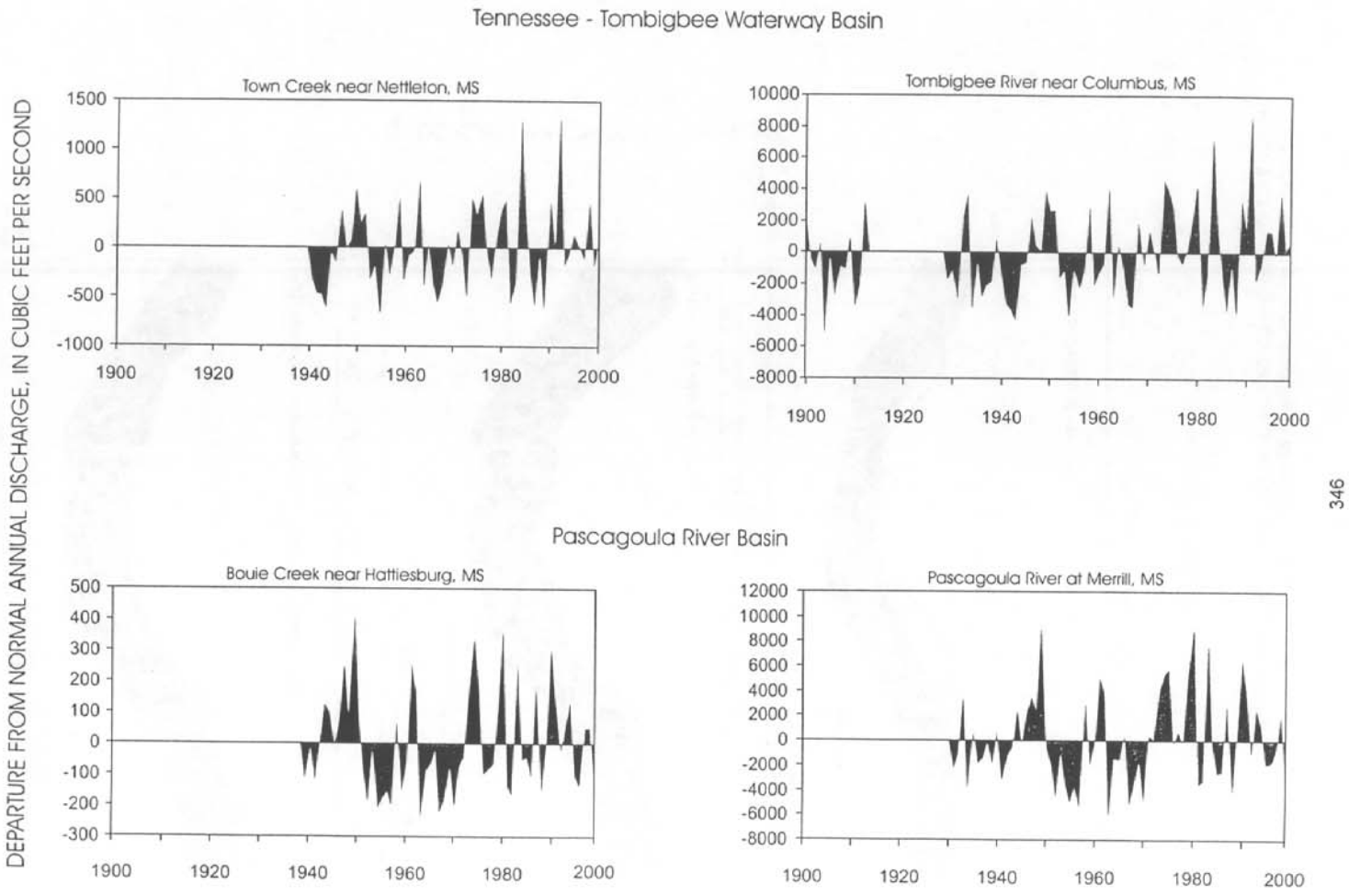

Figure 3. -- Departure from normal annual discharge for four selected streamgages in the Tennessee-Tombigbee Waterway and Pascagoula River Basins in Mississippi.

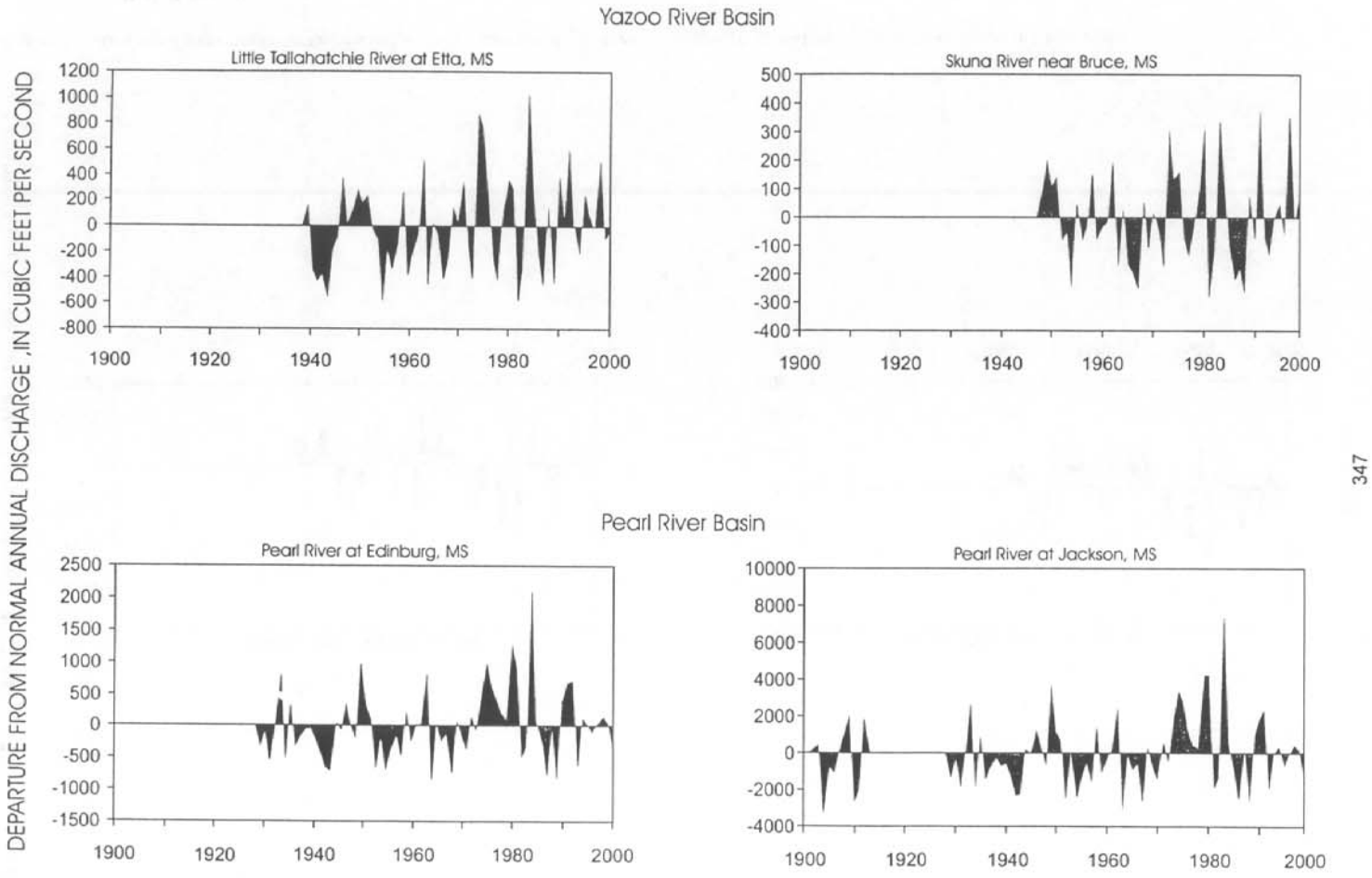

Figure 4. – Departure from normal annuall discharge for four selected streamgages in the Yazoo and Pearl River Basins in Mississippi.

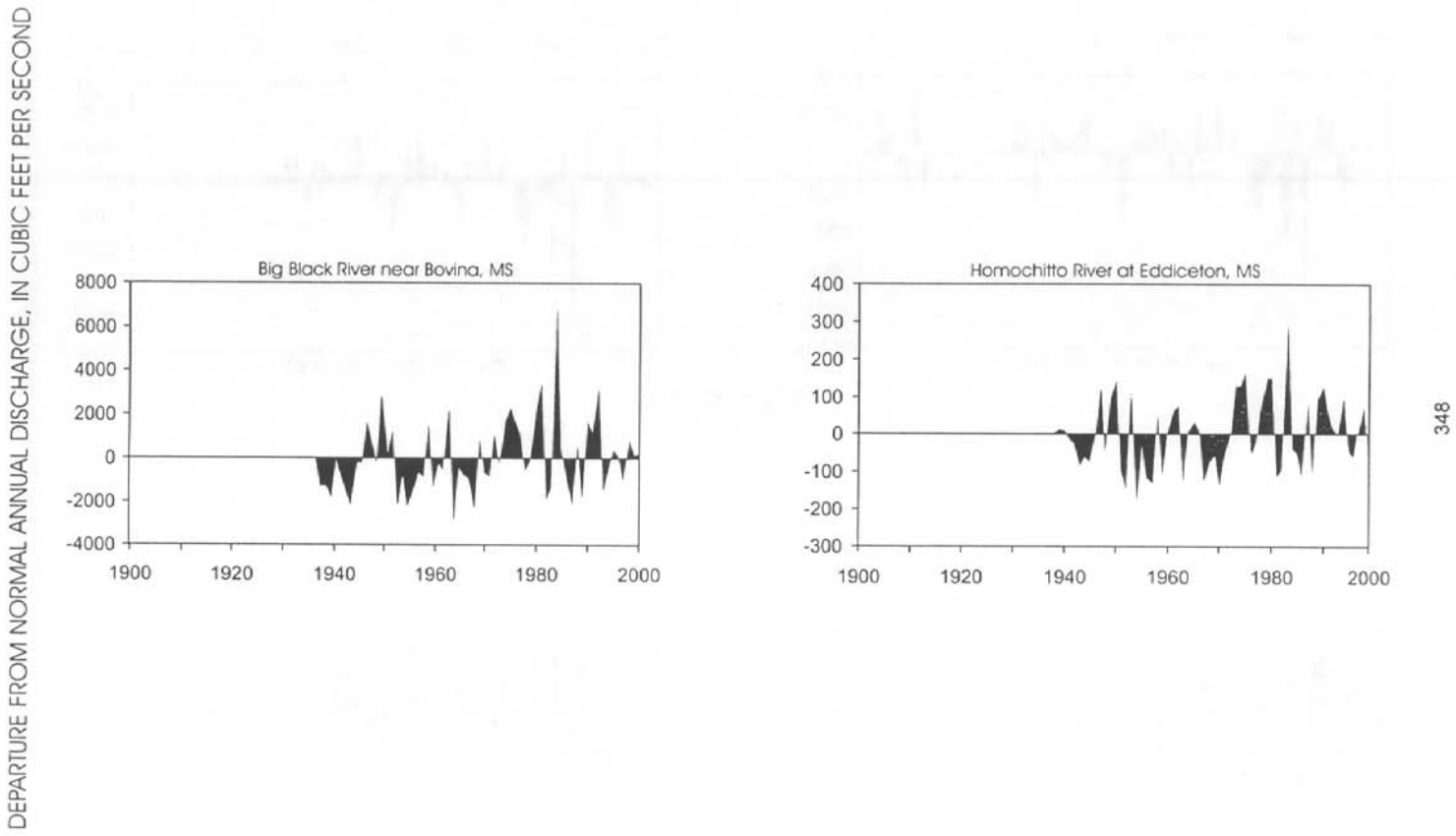

Figure 5. – Departure from normal annual discharge for two selected streamgages in the Big Black and Homochitto River Basins in Mississippi.