THE EFFECT OF THE 1986 DROUGHT ON STREAMFLOW IN SELECTED STREAMS IN MISSISSIPPI

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INTRODUCTION

Mississippi has a history of high accumulations of precipitation during short periods of time, and, as a result, many parts of the state have been subjected to devastating floods. A considerable amount of attention has been centered on flood control and drainage in the past.

In recent years, more emphasis has been placed on the established minimum flow of streams. This minimum flow, known as 7-day Q_{10}, is defined in Mississippi state statues (Section 51-3-3) as "the average flow rate over 7 consecutive days that is expected to be reached as an annual minimum no more frequently than 1 year in 10." Base flow is derived entirely from groundwater released from storage and is governed by the rate at which it finds its way into stream channels. Therefore, the hydrologic characteristics of the geologic formation adjacent to the stream channel have a major influence on the low-flow regime of the stream.

The changing faces of agriculture and industry, along with rapid economic development within certain areas of the state, have resulted in an increased consumption of groundwater to the extent that serious shortages have occurred. In the near future, some industries and municipalities may have to rely on withdrawals from surface water as an alternate source to supplement or, in some cases, replace their existing groundwater supplies. As a result of this increased reliance on surface water, serious shortages may also occur during periods of low streamflow.

The low flow characteristics of a stream govern the availability of useable surface water from that stream. The characteristics that are of particular significance are the magnitude of the low flow, the frequency and duration of low flow conditions, and the quality of water during low flow periods.

PURPOSE AND SCOPE

This paper analyzes the effects of the drought on streamflow by comparing 1986 mean stream discharges with mean stream discharges for the period of record at selected sites. Comparisons have been made of three watersheds in different geologic settings which exhibit distinctively different water-yielding characteristics. The three watersheds are the Bogue Chitto near Tylertown, Town Creek in Tupelo, and the Big Sunflower River at Sunflower.

SEVERITY OF DROUGHT

The State of Mississippi was subjected to a severe drought in 1986, particularly during the months of January through April. During this period, rainfall amounts ranged from 9.5 inches below normal in the Gulf Coast Region to over 15 inches below normal in the East Central Region (Figure 1) (NOAA, 1987). The rainfall for the entire year is shown by selected periods and compared to long-term normal (1951-1980) in Figure 2.

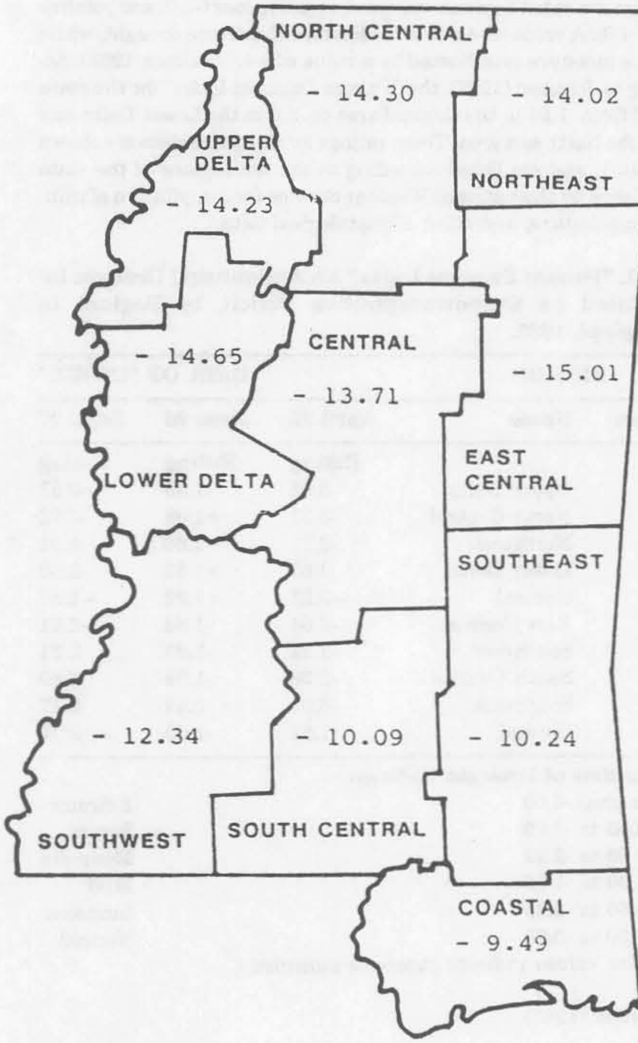

Figure 1. Deviation from Normal Precipitation in Inches by Regions, for Period January through April, 1986, Mississippi. After NOAA (1987)

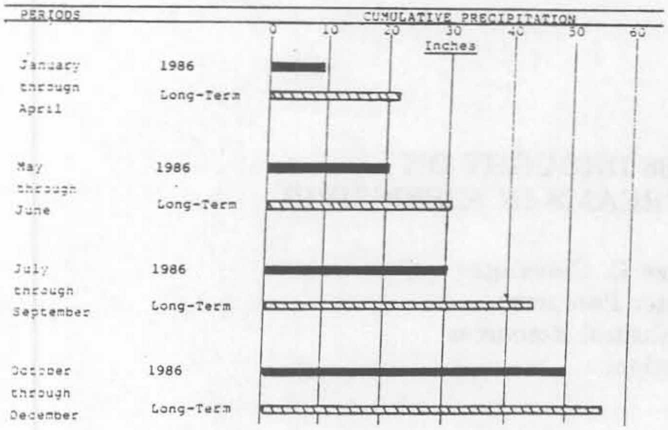

Figure 2. 1986 Cumulative precipitation totals Versus Long-Term Normal (1951-19980) by Selected Periods, State of Mississippi. After NOAA (1987)

The "Palmer Drought Index" is a method by which agricultural droughts are rated between values of negative four (-4.0) and positive four (+4.0). A value of -4.0 is an indication of extreme drought, while extreme moisture is indicated by a value of +4.0 (Palmer, 1968). According to Johnson (1987), the "Palmer Drought Index" for the state ranged from -1.51 in the Coastal area to -3.6 in the Lower Delta and -3.7 in the Northeast area. These ratings for the entire state are shown in Table 1, and are listed according to the ten regions of the state established by the national Weather Service for compilation of rainfall, temperature, and other climatological data.

Table 1. "Palmer Drought Index" An Agricultural Drought Index Based on Evapotranspiration Deficit, by Regions in Mississippi, 1986.

REGION		DATA OF "INDEX"		
Number	Name	April 26	June 28	Sept. 27
		Rating	Rating	Rating
1	Upper Delta	-3.05	-1.99	+0.57
2	North Central	-3.21	+1.08	-2.02
3	Northeast	-3.71	+1.80	-1.91
4	Lower Delta	-3.57	+1.32	-2.58
5	Central	−3.27	+1.22	−1.87
6	East Central	-3.64	-1.93	-2.21
7	Southwest	-3.14	-1.93	-2.21
8	South Central	-2.39	-1.92	2.89
9	Southeast	-3.00	2.69	-2.17
10	Coastal	-1.51	-1.65	-2.74

Definition of Drought Ratings:

(minus) -4.00	Extreme
-3.00 to -3.99	Severe
-2.00 to -2.99	Moderate
-1.00 to -1.99	Mild
-0.50 to -0.99	Incipient
+0.50 to -0.50	Normal

Positive values indicate excessive moisture.

From John (1987)

EFFECT OF THE 1986 DROUGHT ON STREAMFLOW

The two factors which are directly affected by the drought and exert the most influence on streamflow are (1) the surface run-off from the drainage area of a given watershed; and (2) the infiltration of rainfall and storage of this water in the ground. It is this groundwater that is later released through seeps and springs which provides base flow to a stream, and thus, maintains stream flow during dry weather.

The variations in streamflow found in Mississippi's streams are dependent upon the water-yielding characteristics and lithology of the underlying and surrounding geologic units. For example, some areas in the northern part of the state are underlain mostly by clay and chalk of the Selma Group. Most of the rainfall in these areas runs off rapidly causing high peak streamflows and groundwater storage that is insufficient to maintain streamflow during extended rainless periods.

On the other hand, other areas in the state are underlain by sands and gravels such as those found in the Citronelle Formation and Miocene Series. In these areas, surface soils are highly pervious, permitting a large percentage of rainfall to be stored in the ground and later released to streams as base flow. As a result, moderate flows are sustained for longer durations due to higher base flow. Because of the increased amount of rainfall that soaks into the ground, surface run-off is reduced resulting in much lower peak flows.

BOGUE CHITTO NEAR TYLERTOWN, MISSISSIPPI

The Bogue Chitto, a tributary of the Pearl River, has a drainage area of 492 square miles and is located in the Southwest Region of Mississippi. The watershed is wide with relatively flat floodplains which are heavily forested. The natural channel of the Bogue Chitto, composed of sand and gravel, meanders through the floodplain. The upland portion of the drainage area is composed primarily of the highly pervious sands and gravels of the Citronelle Formation. This highly permeable surface allows an estimated 50 percent of rainfall to infiltrate into the ground and become stored. As a result, only about 50 percent of the rainfall becomes surface run-off.

During January through April of 1986, a severe drought condition was experienced in the Southwest Region because of a deficit of 12.34 inches in precipitation (figure 1) (NOAA, 1987). Throughout this period, the mean discharge for the Bogue Chitto was only about 40 percent of the 1945-1985 normal. This low streamflow from January through april is reflected by comparing the 1986 discharge rate of 600 cfs with the normal rate of 1400 cfs for the same four month period.

In June, the effect of the drought was still evident. Streamflow at this time was estimated to be about 50 percent of normal, where it remained through september (USGS, 1986). The 1986 drought was finally broken during October through December when rainfall accumulations were more than 8 inches above normal (NOAA, 1987). This rainfall resulted in the Bogue Chitto having streamflows of 200 percent above normal (USGS, 1986).

TOWN CREEK AT EASON BOULEVARD IN TUPELO, MISSISSIPPI

Town Creek, a tributary of the Tombigbee River, has a drainage area of 233 square miles and is located in the Northeast Region of Mississippi. The floodplains in the watershed are wide and fairly flat. Most of the area has been cleared of trees and is presently under cultivation. The stream channels have been straightened and widened to reduce overbank flooding and to prevent stream meandering. The upland areas are mostly in pasture with some cultivation. Topographic relief in the uplands ranges from moderate to gentle.

Except for the extreme northwestern part of the drainage area, the land surface is underlain by a thick layer of mostly chalk (with some clay) from the Selma Group. The chalk allows little infiltration and storage of water in the subsurface. As a result, almost all rainfall becomes surface run-off with very little left for base flow. This high run-off and low base flow situation is characteristic of this area of the state.

The upper reaches of a few streams in the northwestern part of the watershed extend into sandy areas that contribute small amounts of base flow. The contribution of these streams during extended dry periods is lost primarily to evapotranspiration before it reaches Tupelo.

As a result of 14.02 inch deficit in rainfall accumulation (Figure 1), the Northeast Region was in a severe drought condition during the months of January through April of 1986. In January, several rainfall stations reported all-time record low rainfall amounts for the month (NOAA, 1987).

The 1986 mean discharge of Town Creek for the period of January through April was approximately 30 to 35 cfs which is about 10 percent of normal mean discharge for the same months -during the interval of 1971 to 1985. In May, streamflow was less than 8 cfs for a few days. Mean flow for all of May, however, was about 25cfs which is still less than 10 percent of normal flow for May. During the month of June, surface run-off increased the average flow to approximately 200 cfs and the mean flow became normal for June.

In the period of July to October, 1986, the streamflow of Town Creek decreased to as low as 1 cfs. The mean flow for those four months, however, was 10 to 15 cfs, or 30 percent of normal for the same months (USGS, 1986). Rainfall accumulation in October through December was more than 10 inches above normal (NOAA, 1987) resulting in mean flows of 400 to 500 percent above normal mean flows (USGS, 1986).

BIG SUNFLOWER RIVER AT SUNFLOWER, MISSISSIPPI

The Mississippi Delta is underlain by a unique geologic formation known as the Mississippi River Valley Alluvium. The entire course of the Big Sunflower River has cut its channel into this formation, before draining into the Yazoo River at the southern end of the Delta area.

The drainage area at the gaging station on the Big Sunflower River at Sunflower, Mississippi, is 767 square miles. The basin, which is located in the Upper Delta Region in northwest Mississippi, is flat, well drained and supports intensive agricultural operations. Although most of the land contains row crops, a considerable amount of acreage is also used in rice production. Since the late 1960's and early 1970's, an increasing interest has been shown in aquaculture as well.

Land surface in the Delta consists of heavy clays 10 to 25 feet thick which overlay the Mississippi River Valley Alluvial aquifer (MRVA).

The static water levels in the aquifer were generally 10 to 30 feet below land surface in 1986 (DNR, 1986). The Big Sunflower River frequently floods during the winter and spring months due to heavy rainfall and high surface run-off. Flood stages often persist for long periods of time because of slow drainage in the basin. In most areas, the heavy clays at land surface are so impervious that very little infiltration of rainfall can occur.

The Big Sunflower River, which is deeply incised into the MRVA, had relatively high base flow yields from the aquifer prior to 1981. According to Harvey (1956), the water level in the MRVA at Sunflower was 100 feet above MSL in 1956 (Figure 3). By 1981, the water level in the aquifer was at 97 feet above MSL, a decline of 3 feet in 25 years. The water level had declined an additional 10 feet to 87 feet above MSL by 1986 (DNR, 1986).

As the water level in the aquifer declines, the contribution of base flow yields from the aquifer to the stream also declines. In 1964, the U.S. Geological Survey (USGS) determined the 7-day Q10 flow rate to be 145cfs (Speer et al., 1964). By 1975, the USGS reported the 7-day Q10 flow rate at 100 cfs (Tharpe, 1975). In 1986, mean low-flows were 40 to 60 cfs except for the period of May through August when tailwater from irrigated fields augmented stream flows (Army COE, 1986).

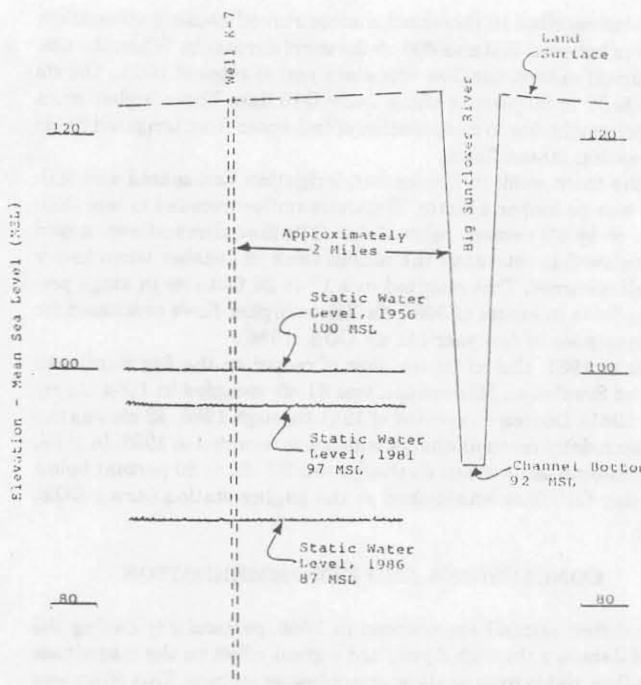

Figure 3. Schematic Diagram of Static Water levels in Mississippi River Valley Aquifer, Big Sunflower River at Sunflower, Mississippi.

The low streamflows experienced in 1986 defy comparison with the normal mean discharge record from 1936 to 1985. Instead, the comparison is made to the established minimum flow, 7-10 Q10 of 100 cfs (Tharpe, 1975). A hydrograph of the 1986 stream flow is depicted in Figure 4.

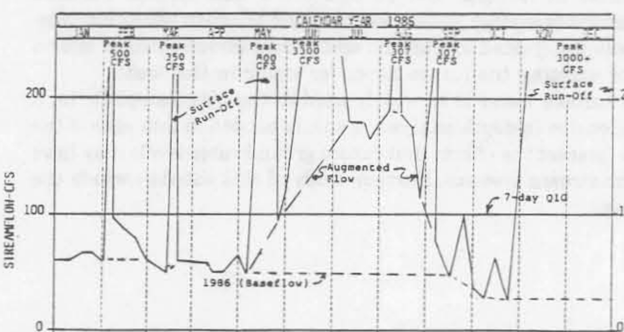

Figure 4. Streamflow in Big Sunflower River at Sunflower, Mississippi, 1986.
After Army COE (1986)

The low-flows of 1986 began on January 1, 1986, with a flow rate of 50 to 60 cfs, some 40 to 50 percent below 7-day Q10 flow (Army COE, 1986). This low-flow was a result of over 3 inches of deficit rainfall in November and December of 1985 (NOAA, 1987). Streamflow remained at 50 to 60 cfs through the month of April (Army COE, 1986) due to a deficit of over 14 inches of rainfall during the first four months.

The period of May through August, 1986 experienced rainfall amounts which were close to normal (NOAA, 1987). These precipitation rates resulted in increased surface run-off causing streamflow to rise to between 700 and 800 cfs for short durations. When the surface run-off ceased, the flow was sustained at rates of 150 to 180 cfs which is 50 to 80 percent above 7-day Q10 flow. These higher rates were primarily due to contribution of tail-water from irrigated fields augmenting streamflows.

By the third week in September, irrigation had ceased and tail-water was no longer a factor. Thus, streamflow receded to less than 40 cfs, or by 60 percent below 7-day Q10 flow. Streamflows stayed at or below this rate until the second week in October when heavy rainfall occurred. This resulted in a 19 to 20 foot rise in stage producing flows in excess of 3000 cfs. These higher flows continued for the remainder of the year (Army COE, 1986).

Prior to 1981, the minimum flow of record on the Big Sunflower River at Sunflower, Mississippi, was 81 cfs recorded in 1954 (Army COE, 1981). During the period of 1981 through 1985, 48 cfs was the minimum daily mean discharge which was recorded in 1985. In 1986, the minimum daily mean discharge was 20 cfs, or 80 percent below the 7-day Q10 flow established at the gaging station (Army COE, 1986).

CONCLUSIONS AND RECOMMENDATION

The deficit rainfall experienced in 1986, particularly during the period January through April, had a great effect on the magnitude of low-flow yields from shallow groundwater storage. This effect was evident in some areas in the fall of 1986 when flows went below the established minimum flow, 7-day Q10. In areas where the geologic formations restrict groundwater movement, it may be a year or more before the full effect is evident.

Knowledge of the low-flow characteristics of streams in Mississippi should be useful in developing potential solutions to water problems in the state. The need for further development of alternate water resources, particularly for consumptive uses, has increased rapidly in recent years. As industrial, agricultural, and municipal uses continue to expand in Mississippi, critical areas are expected to increase in number and become more wide-spread. Planned development of surface water resources and effective water management policies, guided by current and future investigations, offer a basis for meeting the future needs for water in the area.

Since surface water is so widely used in the Mississippi Delta, a comprehensive in-depth analysis is vitally needed in that area of the state to forecast the effects that future groundwater levels may have upon the stream systems. Further study of this should include the following:

(1) The interrelationship between the groundwater recession and the low-flow recessions in streams.
(2) The effects of different surface water environments on the MRVA's yields and recharge.
(3) The effects of deepening or widening of stream channels upon the low-flow regime of streams and upon the groundwater table adjacent to streams.
(4) The effects of floods upon the groundwater table adjacent to streams.

If present trends are allowed to continue, many streams in the Delta may not have sufficient base flow to support fish and other wildlife resources; therefore, alternate means of sustaining flows must be found.

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