MEASUREMENT OF STREAMFLOW IN THE LOWER YAZOO RIVER USING AN ACOUSTIC DOPPLER CURRENT PROFILER, JANUARY-AUGUST 1996

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INTRODUCTION

The Yazoo River in west-central Mississippi drains some of the nation's richest farmland. Sediment and chemical loads from the basin are of great interest to scientists, as well as to the agricultural community because of the loss of topsoil and expensive agricultural chemicals. However, accurate sediment and chemical loads from the Yazoo River are not available because of the complexity in determining discharge from the Yazoo River near its confluence with the Mississippi River at Vicksburg.

Except during periods of extremely low flow, backwater from the Mississippi River at Vicksburg, Miss., affects the stage and discharge of the lower Yazoo River. During medium to high stage on the Mississippi River at Vicksburg, the lower Yazoo River is greatly affected by a wedge of backwater that is forced into the Yazoo River channel. During periods when the Mississippi River is rising rapidly, water may flow in the upstream direction in all or part of the Yazoo River channel below Steel Bayou. This bi-directional flow makes it virtually impossible to measure streamflow in the lower Yazoo River using a conventional current meter. With the development of acoustic doppler current profiler (ADCP) technology, it has become possible to quickly and safely make accurate streamflow measurements in large rivers with complex flow conditions.

Beginning January 1996, weekly streamflow measurements were made by the U.S. Geological Survey (USGS) by using an ADCP on the Yazoo River below Steele Bayou near Long Lake, Miss. This report summarizes the streamflow measurements and the procedures used by the U.S. Geological Survey to make those measurements.

YAZOO RIVER BASIN

The Yazoo River Basin drains the entire Mississippi alluvial plain in Mississippi and is formed by the confluence of the Tallahatchie and Yalobusha Rivers. The Yazoo River flows south from Greeenwood along the eastern edge of the alluvial valley until reaching the Mississippi River at Vicksburg. The 13,400-square mile Yazoo River Basin is divided about equally between upper hill land and the alluvial plain. Four flood-control reservoirs (Arkubutla, Sardis, Enid, and Grenada Lakes) were built between 1940 and 1950 and are located in the northeastern part of the basin. These reservoirs control the discharge from more than 4,400 square miles of drainage area within the Yazoo River Basin, and, combined, the reservoirs provide 3.8 million acre feet of storage at flood pool (U.S. Army Corps of Engineers 1968).

Tributary inflow from the alluvial plain below Yazoo City to the Yazoo River is diverted by a levee along the right bank of the river channel from Yazoo City to the split of the old channel and the Yazoo River Diversion Channel. In the mid 1960s, the U.S. Army Corps of Engineers (COE) constructed a diversion canal that connected Steele Bayou, Deer Creek, Little Sunflower, and Big Sunflower drainage basins. Only two flood-control structures, Steele Bayou and Little Sunflower, control runoff from the four basins. The flood gates at Steele Bayou and Little Sunflower are closed when tailwater elevations (Yazoo River stage) approach the pool elevations at each structure. This prevents extensive alluvial flooding by backwater from the Mississippi River. When the stage in the Yazoo River drops below the pool elevation, the flood-control structures are opened, allowing the tributaries to flow into the Yazoo River.

HISTORICAL BACKGROUND

Prior to 1876, the Mississippi River flowed through the current Centennial Lake, around Desoto Island, and along the current Port of Vicksburg. On April 26, 1876, the Mississippi River cut its current channel through Centennial Cutoff, rendering the city of Vicksburg without river front access. At that time, the mouth of the Yazoo River was located several miles north of Vicksburg. In 1903, the COE constructed the Yazoo River Diversion Canal to reconnect the city of Vicksburg to the Mississippi River (COE 1968; Figure 1).

The present channalized Yazoo River diverges from the Old Channel at river mile 8.1 (Figure 1). At a stage of approximately 74.2 feet above sea level at the Vicksburg COE gage, the Mississippi River flows over its left (east) bank near Paw Paw Bayou and allows backwater to enter the Yazoo River via the Old Channel (H. Noble, COE, oral commun., 1996).

Historic discharge data on the Yazoo River indicates that the average discharge at the COE gage in Greenwood was 10,400 cubic feet per second (ft^3/s) between 1907 and 1980.

During this period, the maximum measured discharge was 72,900 ft^3/s and the minimum measured discharge was 536 ft^3/s. Daily record of stage on the Yazoo River at Redwood dates back to 1911, with miscellaneous discharge measurements beginning in January 1932 (COE 199

STUDY SITE

The study site where stream discharge measurements were made is located within a reach of channel approximately 8.5 miles above the current mouth of the Yazoo River and 1.3 miles downstream from the confluence of Steele Bayou (Figure 2). The study site is located about 1,000 feet upstream from the Old Channel and downstream of the proposed pumping station. This proposed pumping station would be used to pump flood waters trapped behind the levees of Steele Bayou, Deer Creek, Little Sunflower, and Big Sunflower Rivers into the Yazoo River when the Steele Bayou and Little Sunflower flood-control structures are closed.

ACOUSTIC DOPPLER CURRENT PROFILER

An acoustic doppler current profiler (ADCP) measures a vertical profile of water velocities in three dimensions in a number of discrete depth cells (Figure 3).The ADCP also measures its own velocity relative to the bottom of the channel. The velocity of the ADCP is then subtracted from the velocity of the water relative to the ADCP to determine the velocity of the water relative to the earth. Sound waves are reflected mostly by particles of suspended sediment within the water column that move with the water, thus providing an accurate measurement of water direction and velocity (RD Instruments 1995).

The discharge that is computed from a single ADCP measurement contains four distinctive parts (Figure 3): (1) the top 10 percent, which is estimated internally by the ADCP program, (2) the middle, which is directly measured by the ADCP, (3) the bottom, which is estimated internally by the ADCP, and (4) side estimates, which are computed manually after returning from the field. Each measurement performed consisted of three individual transects or river crossings that were combined to compute a mean discharge value (Table 1).

YAZOO RIVER ADCP MEASUREMENTS

Generally, the stage of the Mississippi River at Vicksburg affects the stage and discharge of the lower Yazoo River. Figure 4 shows a plot of stage through the time of the study from both the Mississippi River at Vicksburg and the Yazoo River at Steele Bayou and the discharges measured with an ADCP on the Yazoo River below Steele Bayou.

Between January and August of 1996, USGS personnel made 32 discharge measurements on the Yazoo River below Steele Bayou using an ADCP (Table 2). The ADCP discharge measurements ranged from a maximum of 53,800 ft^3/s on April 26 to a minimum net flow of negative 3754 ft^3/s on May 20. During this time, the stage of the Yazoo River at Steele Bayou ranged from 90.98 feet on May 29 to 60.93 feet on August 30. This range in stage reflects a fluctuation of 30.43 feet. Most of this fluctuation can be attributed to backwater from the Mississippi River.

During the ADCP measurement made on April 26 (53,800 ft^3/s) the stage of the Yazoo River at Steel Bayou was 73.11 feet. At this stage, the lower Yazoo River flows mainly within its own channel and has not yet begun to extend into the floodplain. This large discharge is a combination of flows being released from the flood-control structures at Steele Bayou and Little Sunflower River as well as the discharge from the upper Yazoo River Basin. The stage of the Mississippi River at Vicksburg during this measurement was stable at 70.42 feet.

During May, the stage of the Mississippi River was rising in response to the annual spring runoff. The lower Yazoo River was completely engulfed in backwater from the Mississippi River. The ADCP measurement made on May 6 (4,880 ft^3/s) indicated that flow in the top several feet of the Yazoo River channel was moving downstream, while flow near the bottom of the channel was moving upstream because of the high stage of the Mississippi River. Figure 5 shows one of the transects made during this measurement. This cross section is projected 270 degrees from north and is looking upstream. Positive velocities (downstream flow) are represented by light gray to white shades. Negative velocities (upstream flow) are represented by the dark gray to black shades. During this bidirectional flow, the Yazoo River at Steel Bayou stage was 81.99 feet, and the Mississippi River at Vicksburg stage was 78.02 feet. On May 20, a discharge of negative 3,750 ft^3/s was measured with the ADCP. During this measurement, flows were not as stratified. However, this measurement indicated negative flow to be moving from the right bank side of the Yazoo River channel toward the left bank. This indicates that Mississippi River was moving upstream into the Yazoo River through the Old Channel. The stage of the Mississippi River at Vicksburg was near 87 feet, and the stage of the Yazoo River was 87.82 feet.

Bidirectional flow and other complex flow conditions are virtually undetectable using conventional sounding methods. A conventional current meter can be used to determine depth, velocity at fixed points, and flow direction at the water surface, but cannot determine the variations in flow direction within the water column. The development of acoustic doppler current profilers has made it possible to

measure streamflow with great precision during complex flow conditions.

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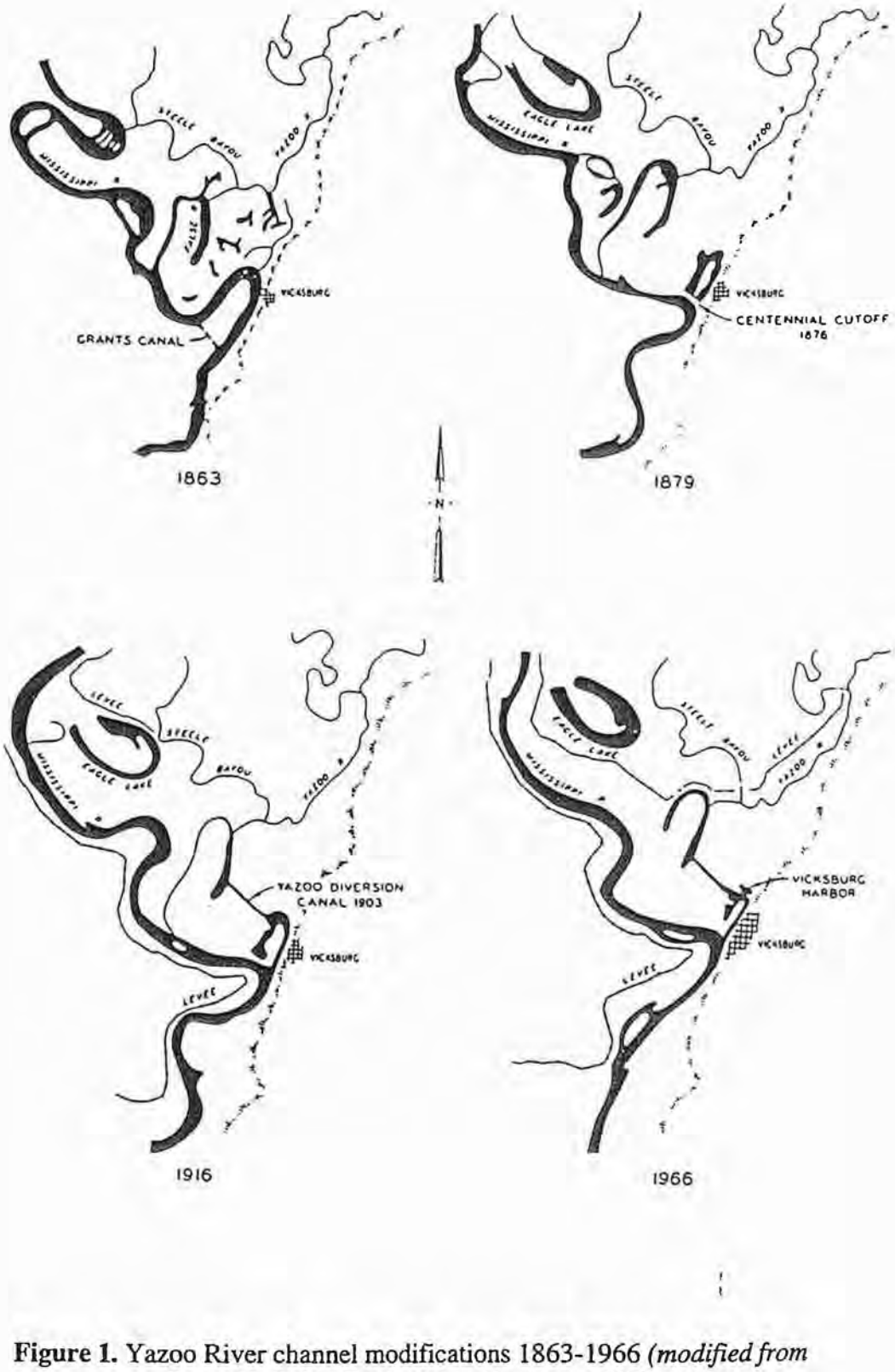
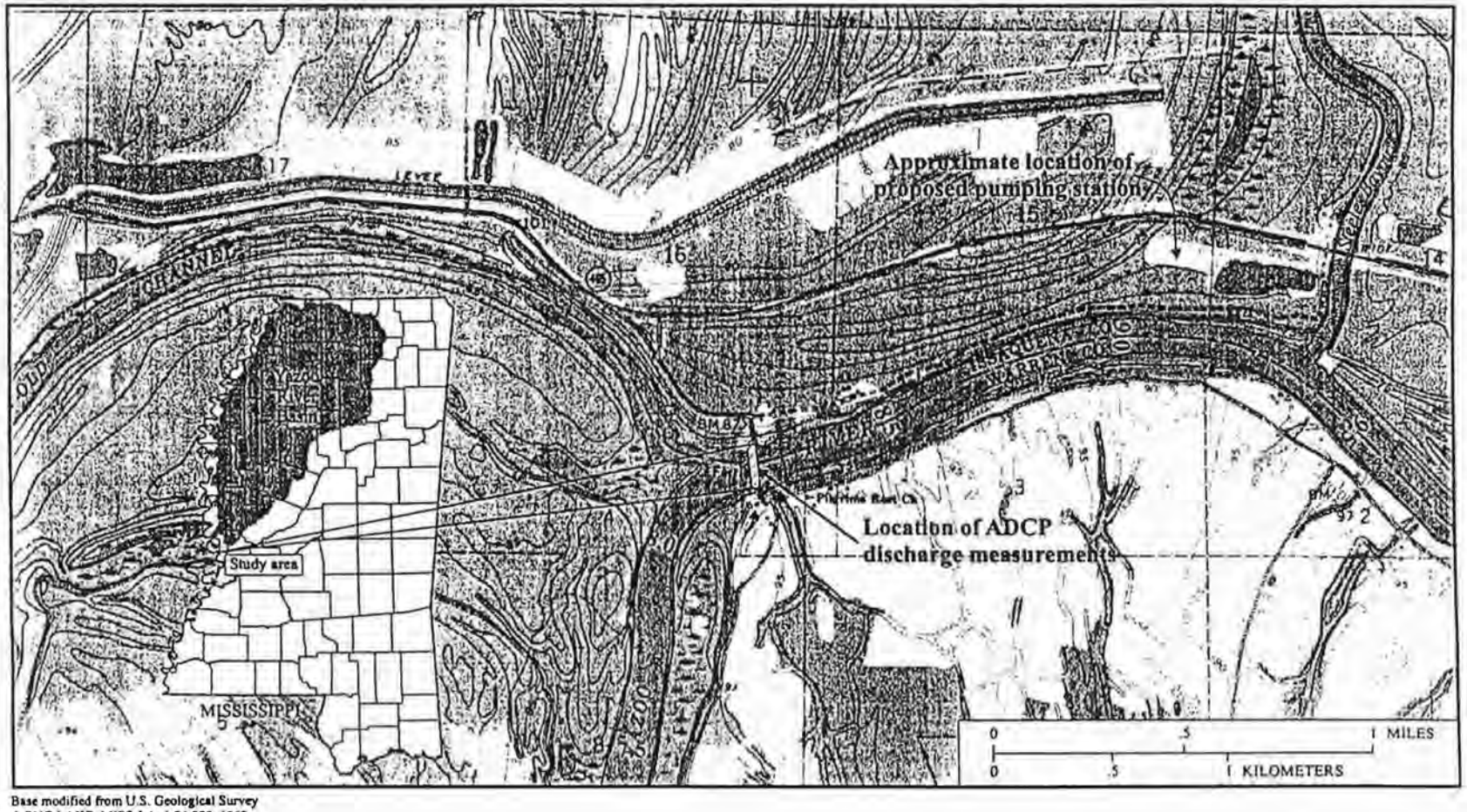


Figure 1. Yazoo River channel modifications 1863-1966 *(modified from Perry H. Rahn, Engineering Geology, 1986).*



Base modified from U.S. Geological Survey
LONG LAKE, MISS-LA. 1:24,000, 1962

Figure 2. Location of study area.

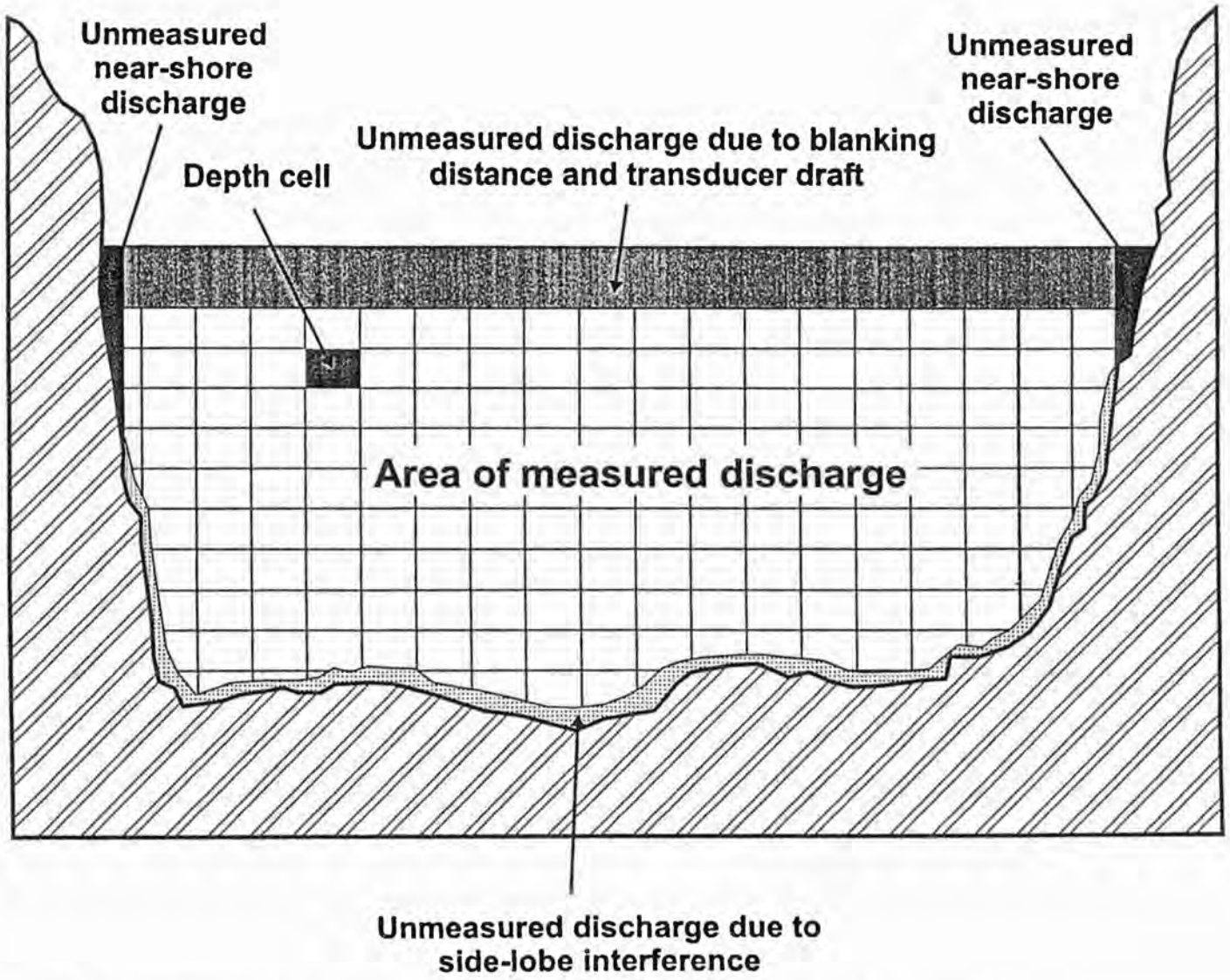


Figure 3. Cross section showing areas of measured and unmeasured discharge.

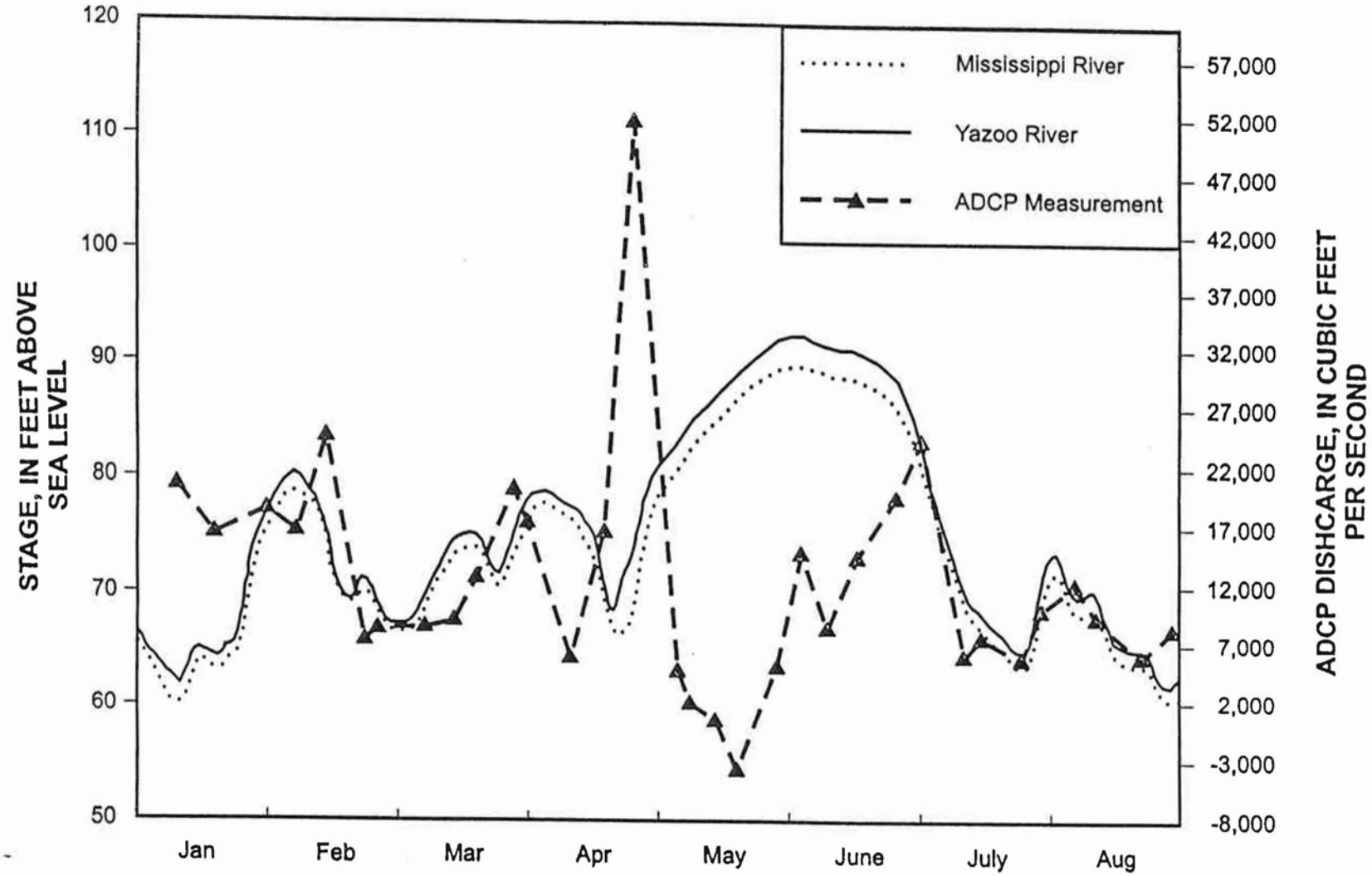


Figure 4. Plot of stage through time of Mississippi and Yazoo Rivers with ADCP measurements of Yazoo River.

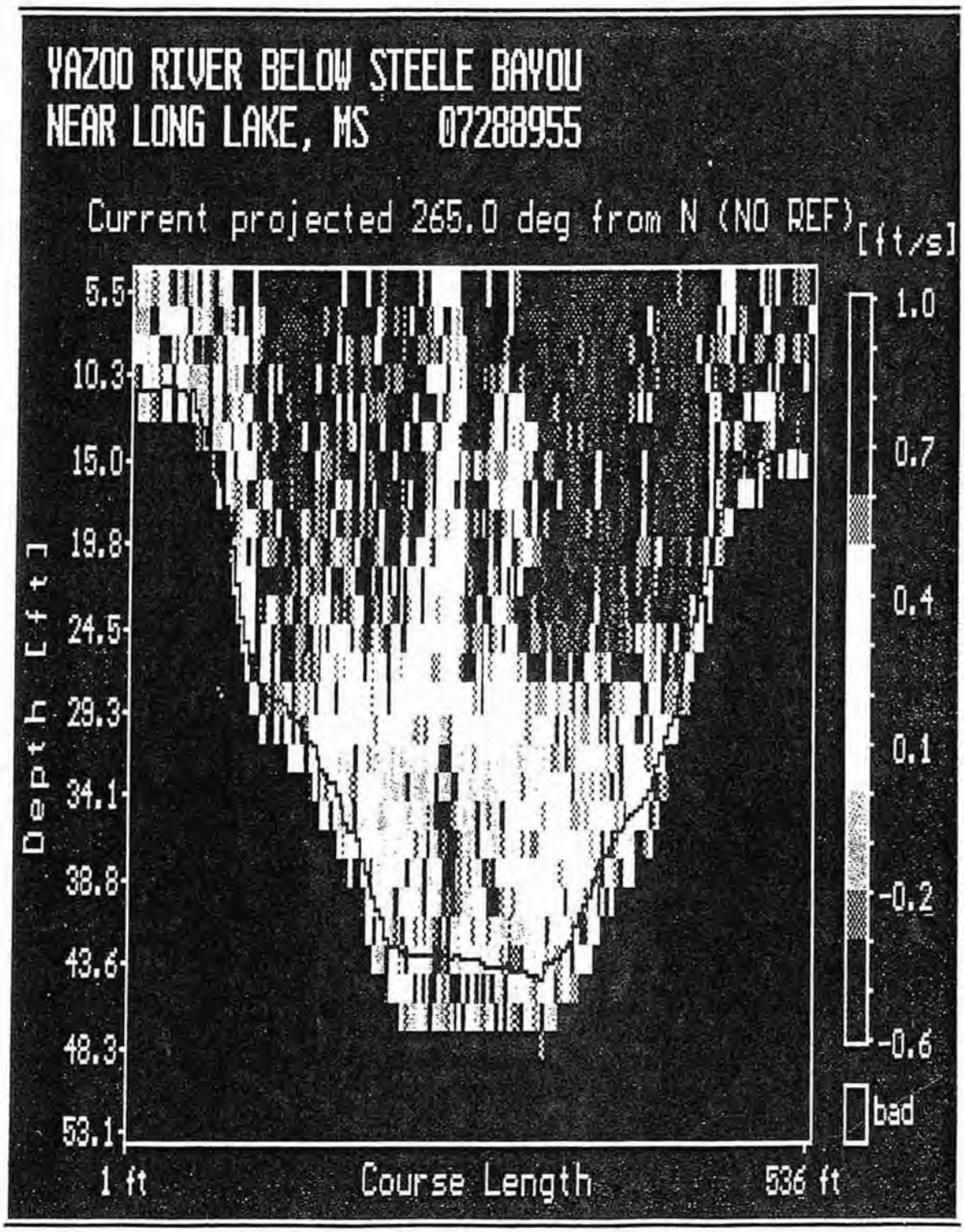


Figure 5. Screen view of doppler program showing bi-directional flow in the Yazoo River.

Table 1. Example of individual transects with incremental discharge for each discharge measurement.
[Distances are in feet; discharges are in cubic feet per second]

Transect number	Distance to L/R bank	Distance to R/L bank	Total distance	Incremental discharges						
				Top	Middle	Bottom	Left	Right	Total	Mean
1	30	100	724	2,854	14,406	1,330	7	52	18,649	
2	100	170	796	2,788	14,535	1,269	48	-204	18,436	18,500
3	150	100	800	2,859	14,234	1,338	70	50	18,551	

Table 2. Discharge measured with Acoustic Doppler Current Profiler on Yazoo River below Steele Bayou near Long Lake, Mississippi.
[ft^3/s, cubic feet per second]

Measurement number	Date	Gage height (feet)	ADCP measured mean discharge (ft^3/s)
1	01/10/96	61.91	20,500
2	01/19/96	64.25	16,500
3	01/31/96	77.12	18,500
4	02/07/96	79.91	16,600
5	02/14/96	75.47	24,600
6	02/23/96	71.12	7,490
7	02/26/96	68.89	8,350
8	03/08/96	69.94	8,600
9	03/15/96	74.67	9,200
10	03/20/96	74.97	12,800
11	03/29/96	75.08	20,300
12	04/01/96	78.15	17,500
13	04/11/96	77.56	5,970
14	04/19/96	70.53	16,700
15	04/26/96	74.11	51,800
16	05/06/96	82.99	4,770
17	05/09/96	84.48	1,910
18	05/15/96	87.06	580
19	05/20/96	88.02	-3,750
20	05/29/96	91.98	5,130
21	06/04/96	92.36	14,800
22	06/10/96	91.36	8,420
23	06/17/96	90.87	14,500
24	06/26/96	88.51	19,600
25	07/12/96	70.06	6,110
26	07/16/96	68.15	7,640
27	07/25/96	64.71	5,800
28	07/30/96	70.93	10,100
29	08/07/96	69.64	12,300
30	08/12/96	68.69	9,410
31	08/23/96	63.88	6,070
32	08/30/96	60.93	8,390