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DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TIME OF TRAVEL OF SELECTED ARKANSAS STREAMS

By T. E. Lamb

Water-Resources Investigations Report 82-4048

Prepared in cooperation with the

ARKANSAS GEOLOGICAL COMMISSION

and

ARKANSAS DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

Little Rock, Arkansas

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply U.S. Customary unit	By	To obtain SI unit
miles (mi)	1.609	kilometers (km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
pounds (lb)	0.4536	kilogram (kg)
gallons (gal)	3.785	liter (L)

TIME OF TRAVEL OF SELECTED ARKANSAS STREAMS

By T. E. Lamb

ABSTRACT

Traveltime of water-soluble materials in streams is important for stream modeling, pollution studies, and estimating arrival time of contaminants to points downstream from spills. Between 1971 and 1981, time-of-travel and dispersion measurements were made in 15 streams in Arkansas. Most of the streams studied were at or near base flow. Graphs are presented for predicting traveltime of solutes in segments of the streams studied. The relationship of time of passage and peak unit concentration to traveltime is presented for two of the streams. Examples of use and application of the data are given.

INTRODUCTION

Rivers and streams are major natural resources of Arkansas. In addition to use for water supply, hydroelectric power, recreation, and navigation these rivers and streams are continually being used to absorb and transport waste substances from the activities of our society. If any harmful substances enter the streams, the speed at which these substances will travel downstream becomes a matter of concern. Flow velocities of streams can vary from very fast during floods to extremely slow during periods of dry weather. Velocities are also affected by channel slope, shape, bed material, and vegetation. For these reasons, it is difficult to make a general estimate of the traveltime of a material being carried downstream in a river.

The purpose of this report is (1) to present the results of time-of-travel and dispersion measurements made on selected streams in Arkansas from 1971 to 1981, and (2) to present a graphical method for quickly predicting traveltime, peak concentration, and duration of an accidentally spilled contaminant for those streams where enough data are available. Tracer studies were conducted on the various streams (fig. 1) for different purposes and vary in levels of completeness. Some studies were made only to determine time of travel, others included dispersion data; some studies were for very short reaches of streams, others are for stream reaches of greater than 100 miles. Data collected on the Arkansas River are presented for the reader's information only. Analysis of these data was attempted, but meaningful traveltimes could not be determined due to rapidly changing river flows during the study.

Results of these studies apply only to materials that are soluble in water. Considerations outside the scope of this study must be made for estimating traveltime of materials that are not soluble in water.

The methods for predicting traveltimes and concentrations given in this report are for use only on the streams measured and within the discharge ranges shown on the graphs.

These studies were made by the U.S. Geological Survey in cooperation with the Arkansas Geological Commission and the Arkansas Department of Pollution Control and Ecology.

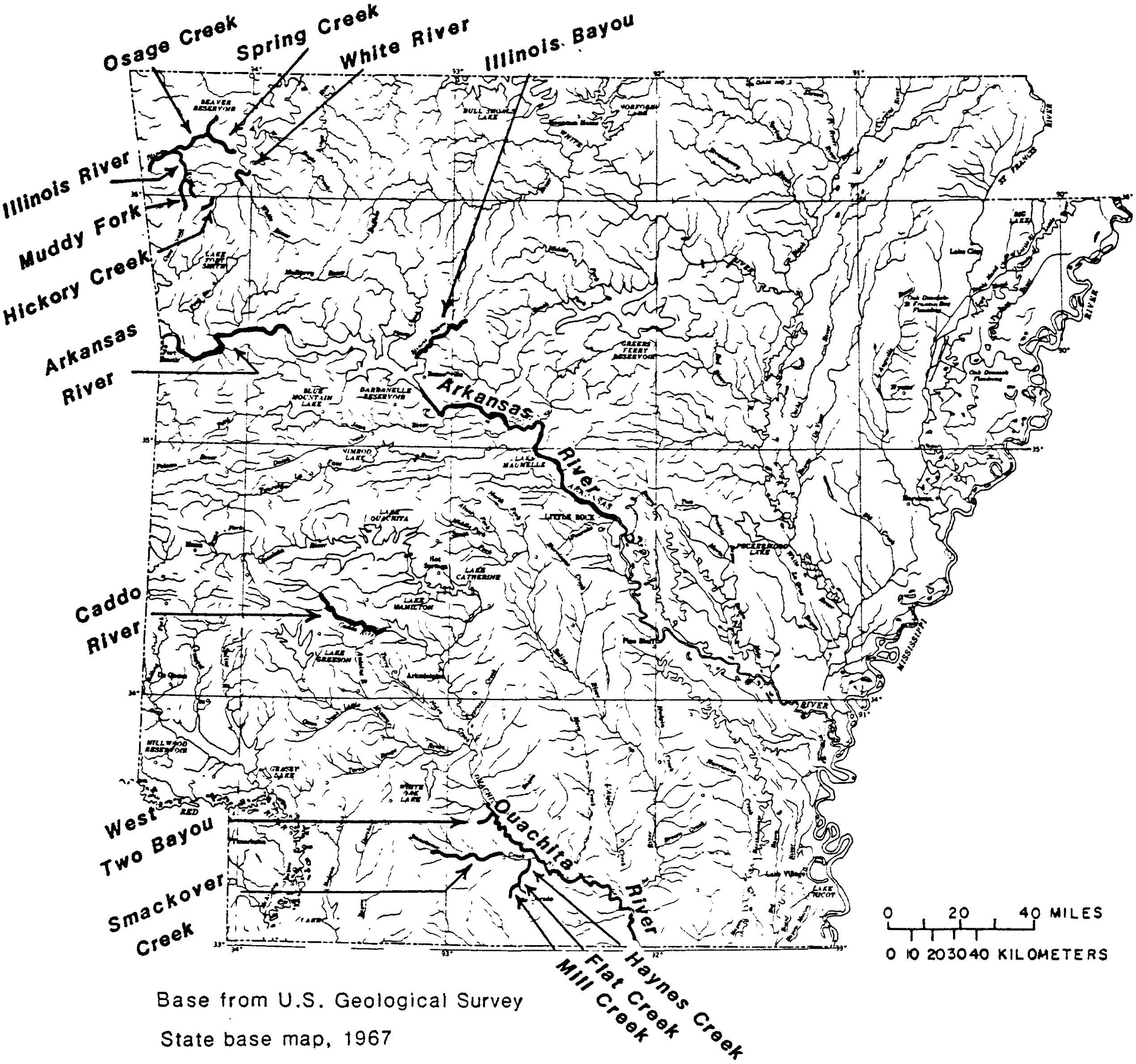


Figure 1.—Location of Arkansas stream segments studied.

Dye-Tracer Theory

Dye injected into a stream acts as a tracer of the water particles in the stream. Measuring the movement of the tracer is a method of measuring the motion of the stream and its dispersion characteristics. Dispersion of the tracer occurs in all three dimensions of the channel. Vertical dispersion normally takes place rapidly in a stream, followed by lateral dispersion at a rate depending on the channel width and flow properties. Longitudinal dispersion continues indefinitely because there are no physical boundaries (Hubbard and others, 1982). Longitudinal dispersion is the dispersion component of primary interest in this report.

Because the tracer particles travel at different rates as they move downstream, a cloud having various concentrations of the tracer forms in the stream. The movement of this cloud past successive points downstream from an instantaneous tracer injection can be represented by time-concentration curves, which are defined by the concentration of the tracer in water samples taken at selected time intervals during the dye-cloud passage, as shown in figure 2. These time-concentration curves are the basis for determining traveltime and dispersion characteristics of a stream for observed flow conditions.

Several points on the curves in Figure 2 are of interest: (1) The traveltime of the initial concentration, or leading edge, of the dye cloud from one sampling site in a stream to another (t_e); (2) the travel time of the peak concentration (t_p); (3) the travel time of the last of the dye cloud, or trailing edge (t_f), defined for this report as the time

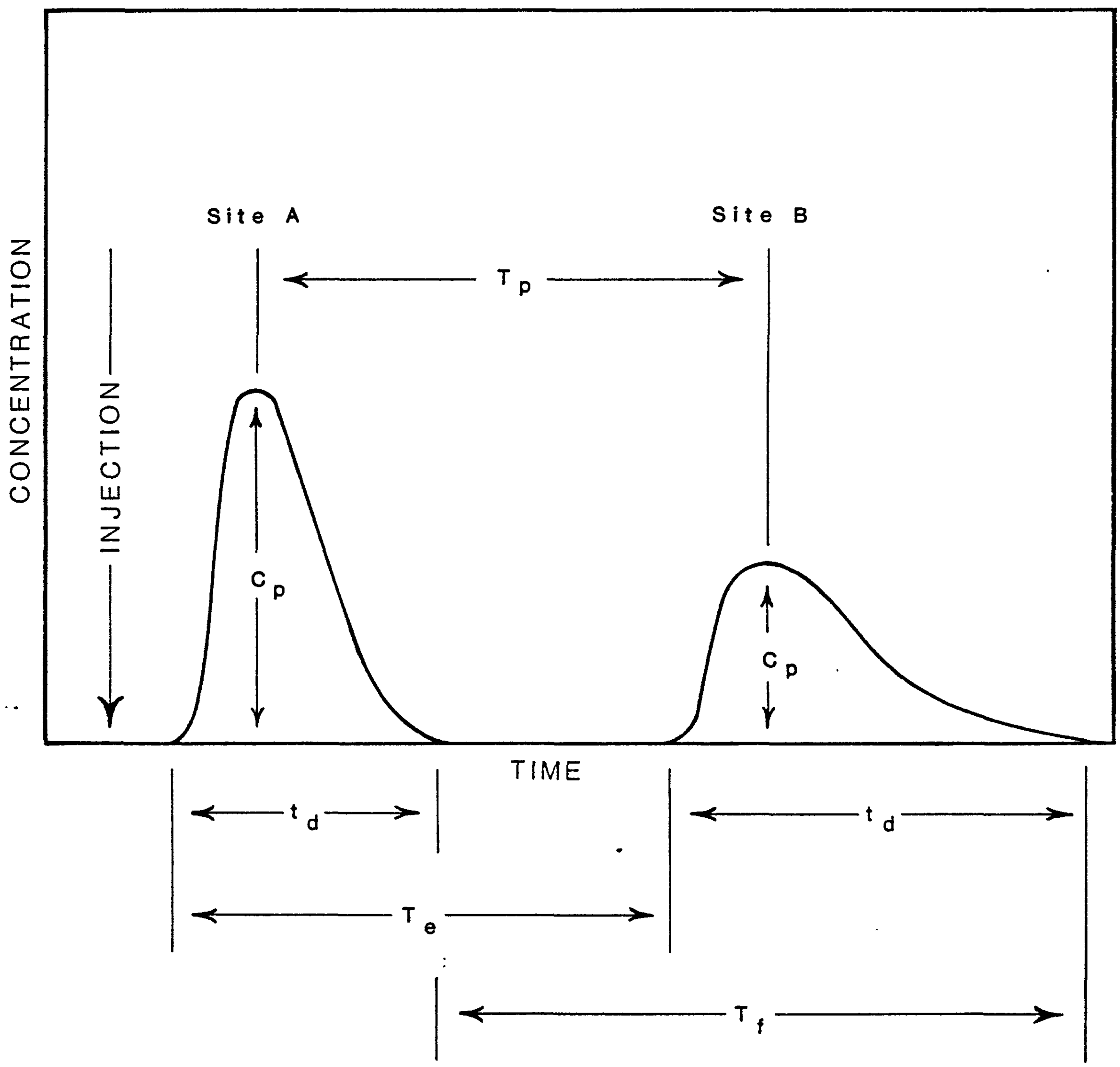


Figure 2.—Definition sketch of time-concentration curves.

when the dye concentration reaches 10 percent of the peak concentration; (4) the time of passage of the dye cloud (t_d); and (5) the magnitude of the peak concentration (c_p). The leading edge represents the movement of the fastest water particles in the stream. The velocity of the peak approximates the average velocity of all the water particles, although the average velocity is actually the velocity of the centroid of the time-concentration curve. The time of occurence of the centroid is, however, usually very close to the time of occurence of peak concentration which is easier to obtain.

As soon as vertical and lateral dispersion of the tracer cloud is complete, the area under the time-concentration curve will be equal at all sampling sites downstream from the injection point for a conservative tracer (one with no losses), if the discharge for the reach is constant. Most tracers, however, are not conservative and tracer losses must be accounted for. The tracer losses can be determined if the entire dye cloud is measured and the discharge is known at each sampling point. The time-concentration curve, adjusted for tracer losses, represents primarily the longitudinal dispersion characteristic for flow conditions in the stream reach. Curves for which t_d is relatively large and on which the slope of the falling limb is rather flat would indicate significant longitudinal dispersion. Conversely, curves for which t_d is relatively small and on which the slope of the falling limb is rather steep would indicate relatively less longitudinal dispersion.

Data-Collection Techniques

For the studies described in this report, rhodamine WT, a fluorescent dye, was used as the tracer. The amount of dye to be injected in any study reach was determined from the discharge, estimated average velocity, and length of that reach. The dye was injected instantaneously at approximately the center of the stream channel. Whenever possible, the dye was injected far enough upstream from the beginning of the stream reach of interest to allow vertical and lateral dispersion of the dye to take place before the dye cloud reached the first sampling site (fig. 3). Where this was not possible because of time or physical constraints, the injection was made as far upstream as practical and the small error in traveltime introduced by incomplete mixing at the first sampling site was ignored.

Sampling sites were located at appropriate intervals downstream, based on access and points of interest, such as water intakes, sewage outfalls, and highway crossings. At each sampling site, water samples were collected at predetermined intervals from before arrival of the dye cloud until the dye concentration in the samples was less than 10 percent of the peak concentration passing the site. The discharge at each sampling site was determined by current-meter measurements or from the stage-discharge relationship at a gaging station.

The samples collected at each site were analyzed using a fluorometer, which is an instrument that measures fluorescence (Wilson, 1968). The amount of fluorescence measured is proportional to the concentration of dye in each water sample. A typical plot of time-concentration curves for sampling sites downstream from a single dye injection is shown in figure 4.

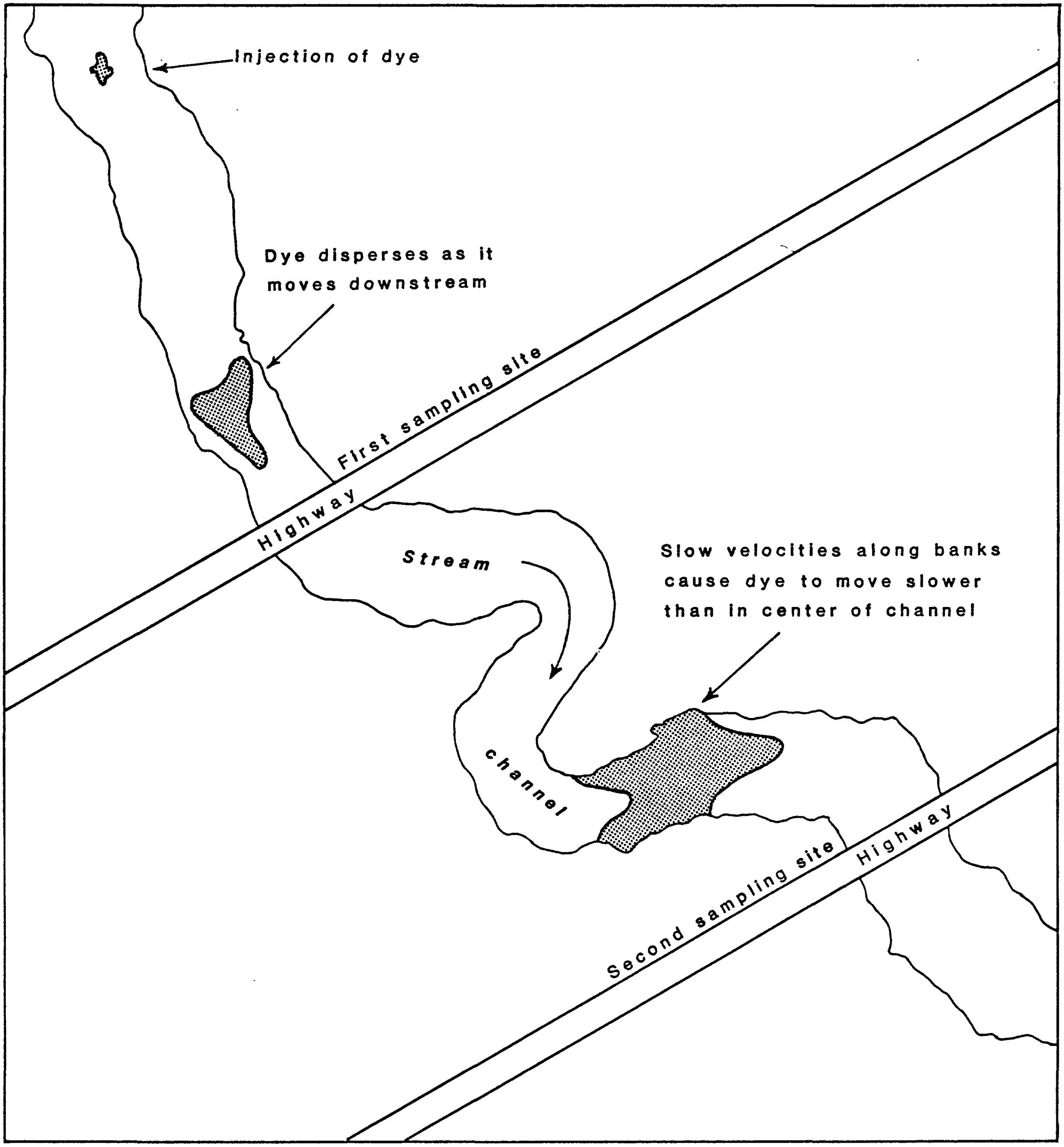


Figure 3.—Downstream dispersion of dye cloud and location of sampling sites.

Analytical Techniques

After analysis of all samples, the dye concentration for each sample was plotted against the time the sample was collected. A curve was then drawn through the points plotted for each site, as shown in figure 4. From these curves, traveltime of the peak concentation and leading edge of the dye cloud, duration (time of passage) of the dye cloud, and percent recovery of the dye injected, were determined for each sampling site.

Duration of the dye cloud is defined as the difference between the arrival time of the first indication of fluorescence above the natural level in the stream and the time the concentration of dye declines to 10 percent of the peak concentration of the dye cloud. Percent recovery (R_p) of the dye injected was computed using the following equation for rhodamine WT:

$$R_p = 1.51 \frac{Q_m A_c}{\forall}, \qquad (1)$$

where

Q_m is the discharge at the point of sampling or the maximum in the intervening reach, in cubic meters per second,

A_c is the mean area of the time-concentration curve, in micrograms per liter-hours, and

$\forall$ is the volume of dye injected, in liters.

The observed dye concentrations C_{obs} , when adjusted for dye losses, can be used to simulate adequately concentrations that would be produced by a conservative tracer (C_{con}). The relationship between the two is as follows:

$$C_{con} = 100 \frac{C_{obs}}{R_p} \qquad (2)$$

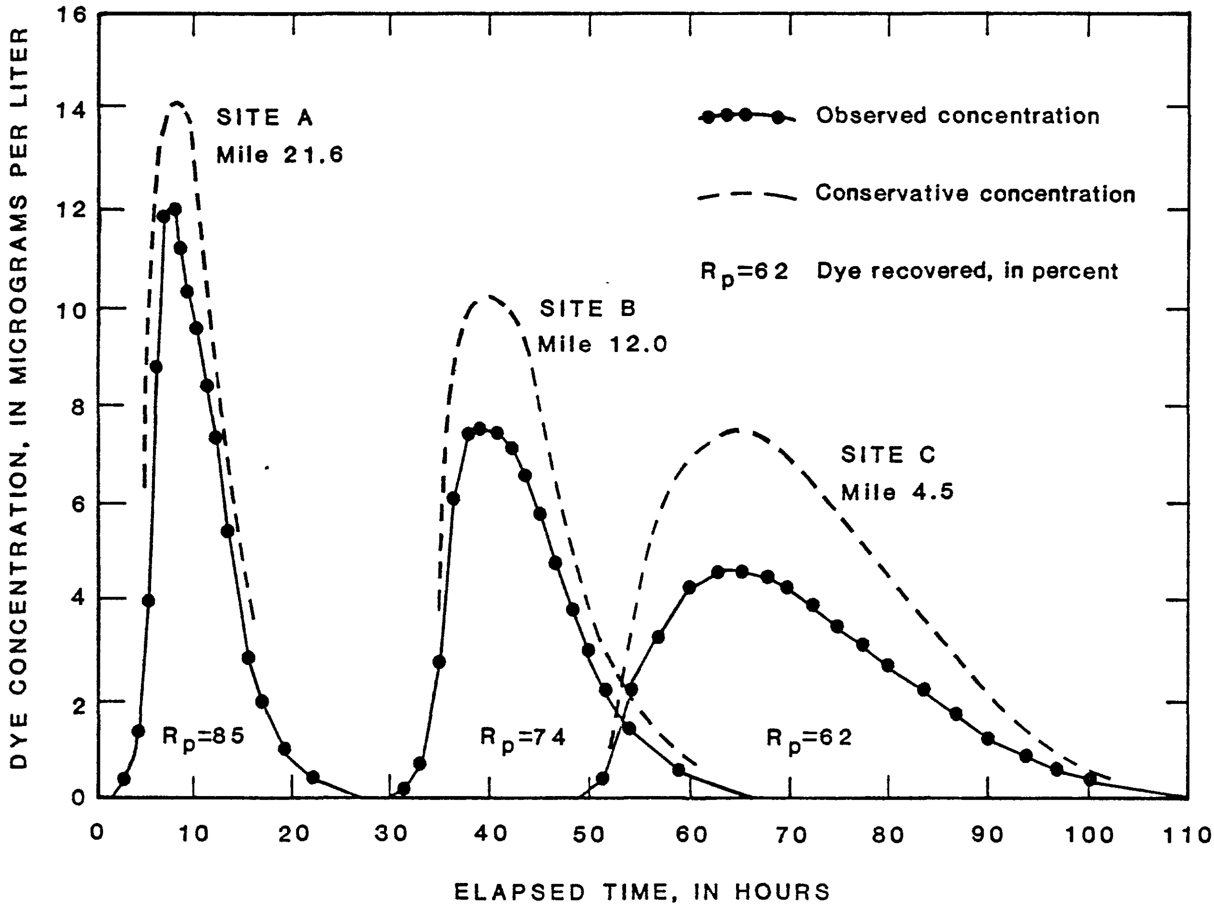


Figure 4.—Relation of observed dye concentration to conservative concentration with time.

The example in figure 4 shows the time-concentration curve plotted for a conservative tracer.

The variation in longitudinal dispersion in a stream can be interpreted by adjusting time-concentration curves for different tests at different flows for the amount of dye injected, losses of dye experienced, and the discharge in the reach. The result of this adjustment after each time interval on each curve is called unit concentration (C_u) and is defined as the concentration (C_{con}) produced in one unit of flow (Q_m) by one unit of weight of a conservative solute (Hubbard and others, 1982). Unit concentrations may be computed by the equation

$$C_u = \frac{C_{con}\ Q_m}{W_d}, \qquad (3)$$

where W_d is the weight of pure dye injected.

For each stream where enough data were collected, unit concentrations of peaks were plotted versus traveltime on log-paper and a curve was drawn through these points. This is called a peak unit-concentration curve. For accidental spills of soluble contaminants in a stream, the extreme peak unit-concentration curve can be used to estimate the maximum concentration of the contaminant to be expected at a point downstream. These curves should be used only for the range of discharges noted on the graphs. Peak unit-concentration curves were drawn for each tracer study done on a stream where enough data were collected at two or more different discharges. An upper envelope curve was then drawn for all these curves on a stream; this is called an extreme peak unit-concentration curve (fig. 9).

Presentation of Data

Traveltime was defined over a range of flows for Caddo River, Illinois Bayou, and Illinois River by making two or more tracer injections on each stream at different flow rates. One traveltime study was made, at or near base flow, for each of twelve other streams or stream segments. Where a gaging station was located within the stream segment studied, the traveltimes for that stream were related to discharge at the gaging station. For stream segments with no gaging station, the applicable discharge (Q) is noted on the traveltime curves for that stream.

Maps showing injection and sampling sites for each stream segment studied are presented in figures 5, 10, 12, 17, 25, 27, 30, 32, 34, and 36. Traveltime data are presented graphically (figs. 6-9, 11, 13-16, 18-20, 21-24, 26, 28, 29, and 31) with the traveltime characteristics of the tracer cloud shown in relation to the distance traveled. Time of passage and extreme peak unit concentration are related to traveltime of the peak concentration, where data were available.

For the Arkansas River, time concentration curves for each sampling site and time-discharge hydrographs for each dam in the river segments studied are shown (figs. 33 and 35). No other interpretation of the data was attempted, as previously explained.

Data collected on Arkansas streams are given in table 1. Some data in Smackover Creek that were not interpreted because of rainfall that occurred while the study was in progress are also included in table 1.

Example of Application

A railroad car derails and accidentally spills 1,000 pounds of a soluble contaminant into the Caddo River near Caddo Gap at river mile 61 (fig. 5). At the Glenwood water treatment plant located at river mile 52.5, the operator needs to know when he can expect the contaminant to arrive at his intake, how long it will take to pass the intake, and what the maximum concentration in micrograms per liter might be. An estimate of these values can be made as follows:

1. Determine the discharge at the highway 70 gage at Glenwood (the Caddo River curves are referenced to this gage.) For this example, assume that the discharge is 60 ft^3/s.

2. To determine the leading edge traveltime of the contaminant cloud, use figure 6, entering at mile 61 (spill site) and mile 52.5 (water intake). The leading edge traveltime is 44 hours (71 minus 27 hours). An estimate of the peak concentration traveltime can be made, using figure 7, and is 50 hours.

3. Time of passage of the contaminant cloud can be determined using figure 8. Enter with 50 hours, the peak concentration traveltime, and read 47 hours using the 60 ft^3/s curve.

4. To determine the maximum possible peak concentration of the contaminant cloud passing the water intake, use figure 9. Enter with 50 hours, the peak concentration traveltime, and read 220 units, the extreme peak unit concentration (C_u). The maximum concentration (C_{max}) can be computed using equation 3:

$$C_{max} = \frac{C_u W_d}{Q_m},$$

where

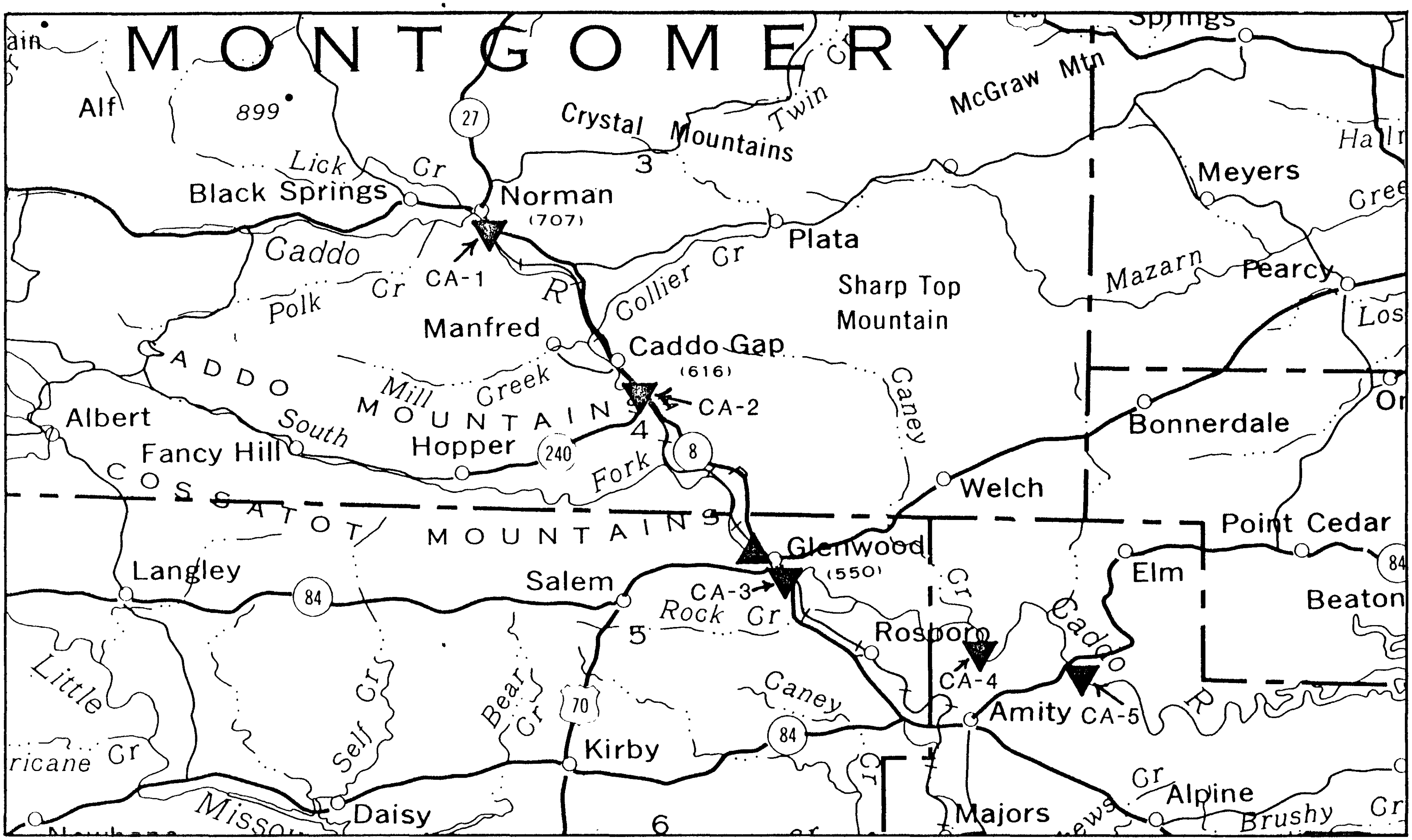
W_d is pounds of soluble contaminant entering the stream, and

Q_m is discharge in cubic feet per second, at point of interest.

For this example, assume that the discharge at the water intake is the same as at the nearby gage (60 ft^3/s). Therefore, the maximum concentration expected is:

$$C_{max} = \frac{220 \times 1{,}000}{60}$$

$$= 3{,}667 \ \mu g/L.$$



Base from U.S. Geological Survey
State base map, 1:250,000

0 5 10 MILES

0 5 10 KILOMETERS

EXPLANATION

▼ CA-1 **Sampling site and number**

▲ **Gaging station**

See table 1 for river miles of sampling sites

Figure 5.—Study reach of the Caddo River.

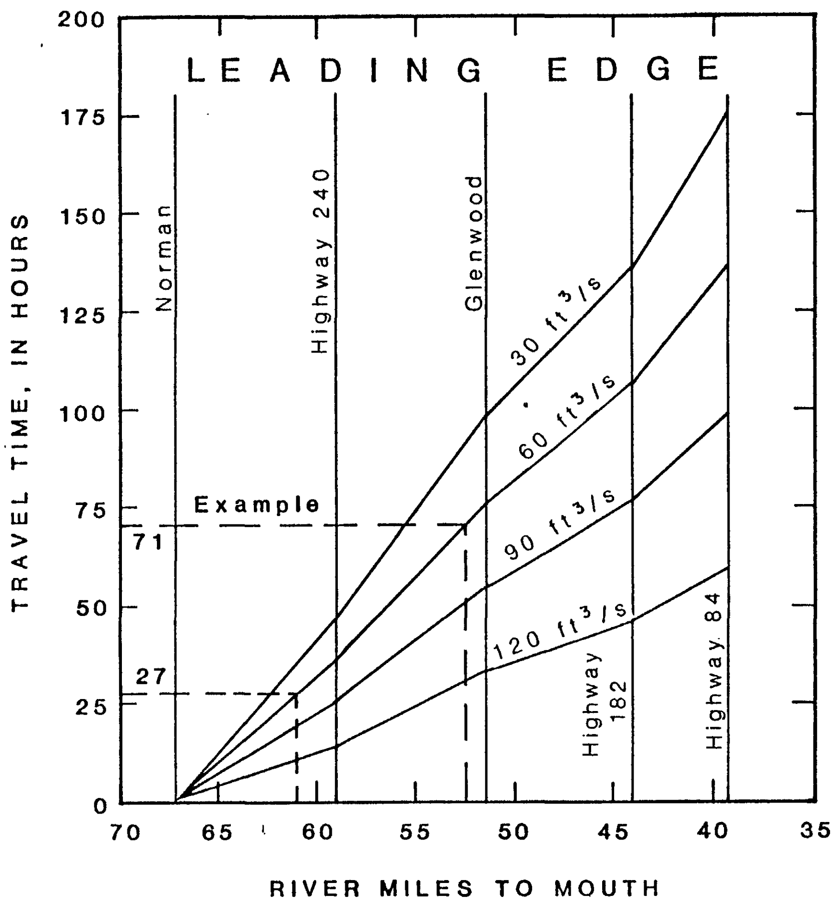


Figure 6.—Travel time of tracer cloud leading edge, Caddo River, for selected discharge at gage on highway 70 at Glenwood.

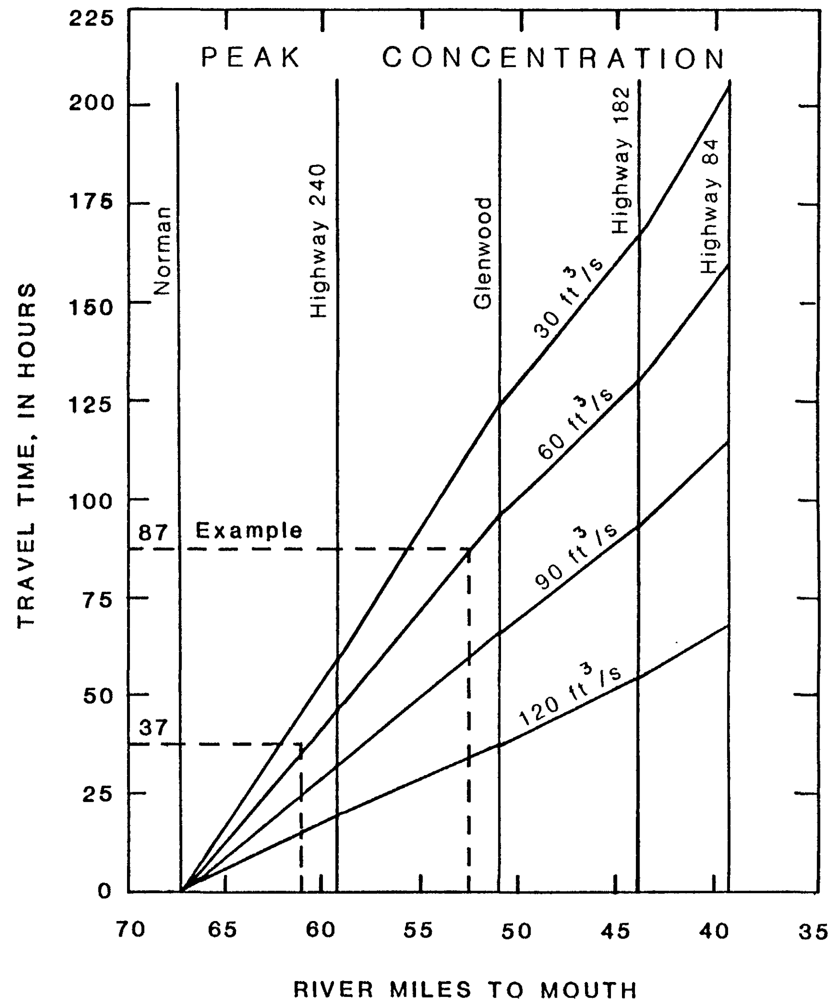


Figure 7.—Traveltime of tracer cloud peak concentration, Caddo River, Arkansas, for selected discharge at the gage on highway 70 at Glenwood.

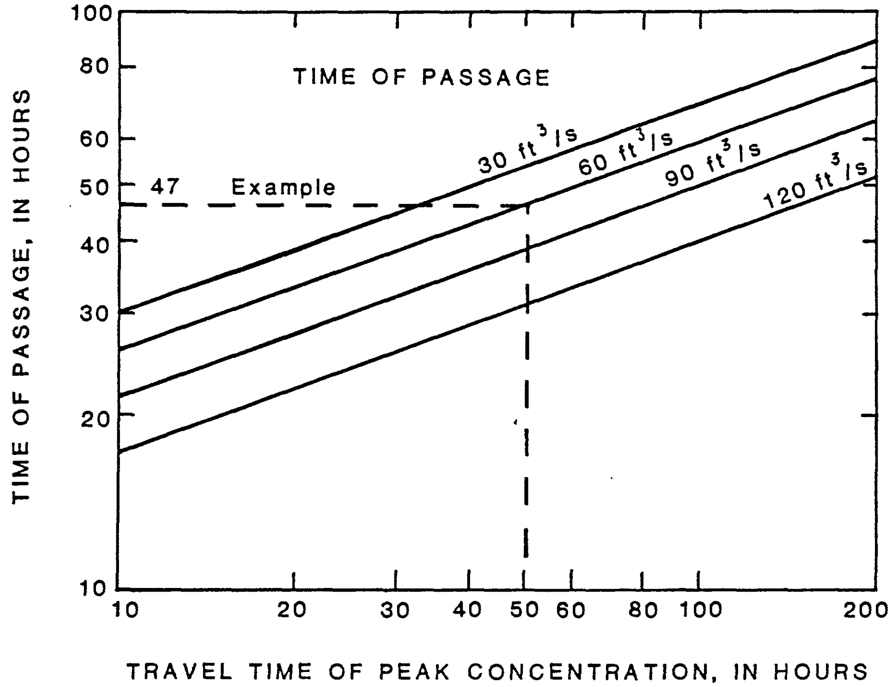


Figure 8.—Time of passage of tracer cloud, Caddo River, Arkansas, for selected discharges at the gage on highway 70 at Glenwood.

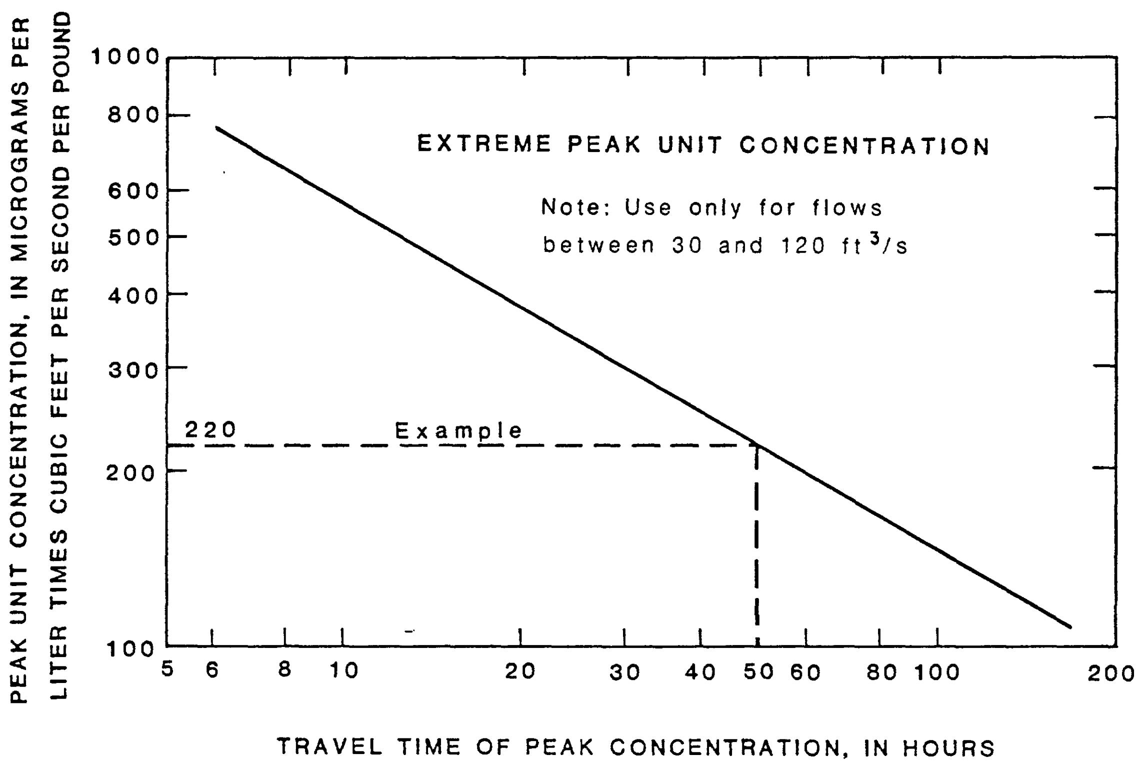


Figure 9.--Extreme peak unit concentration for conservative tracer in Caddo River, between river miles 67.1 and 39.3.

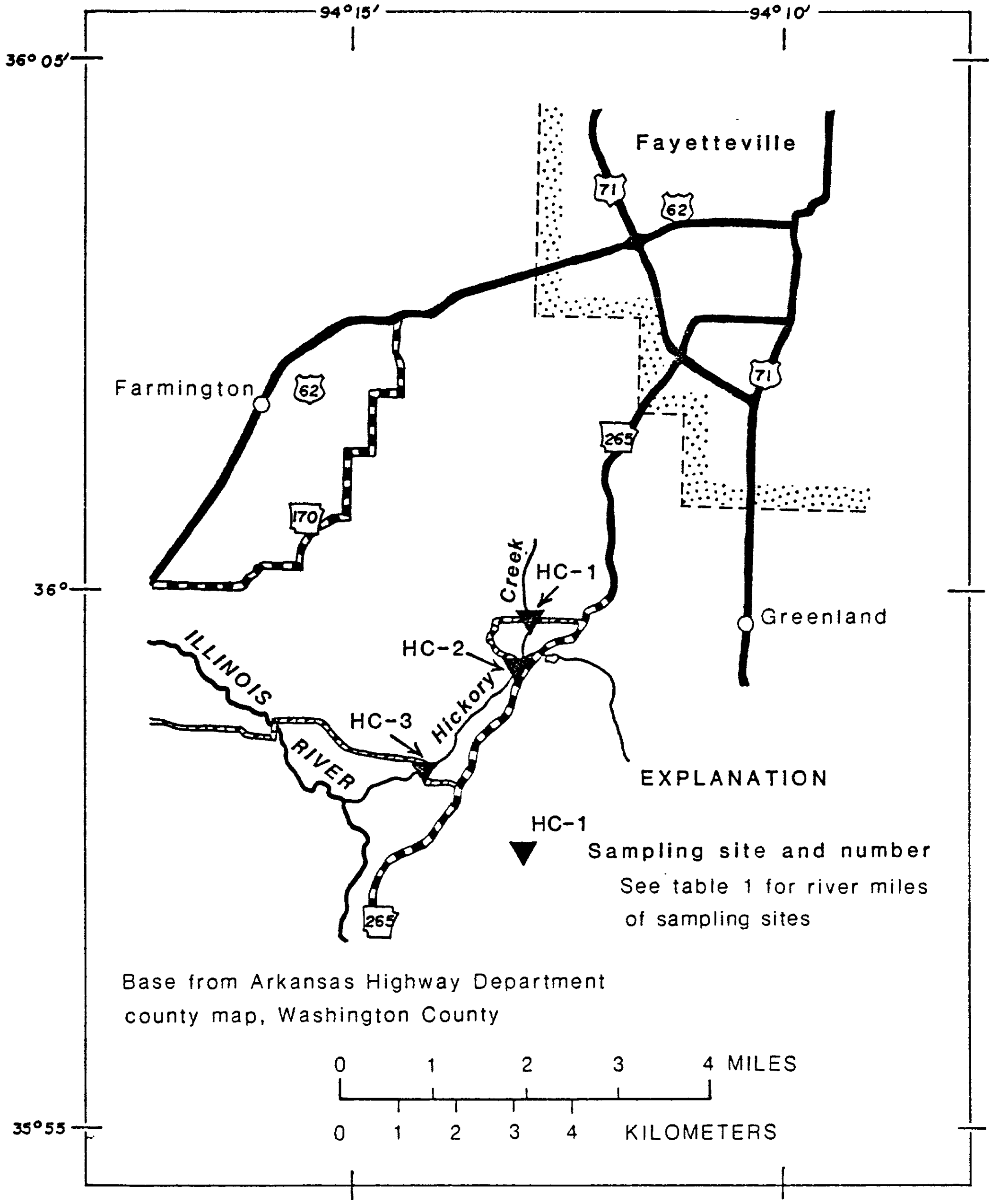


Figure 10.—Hickory Creek stream segment studied.

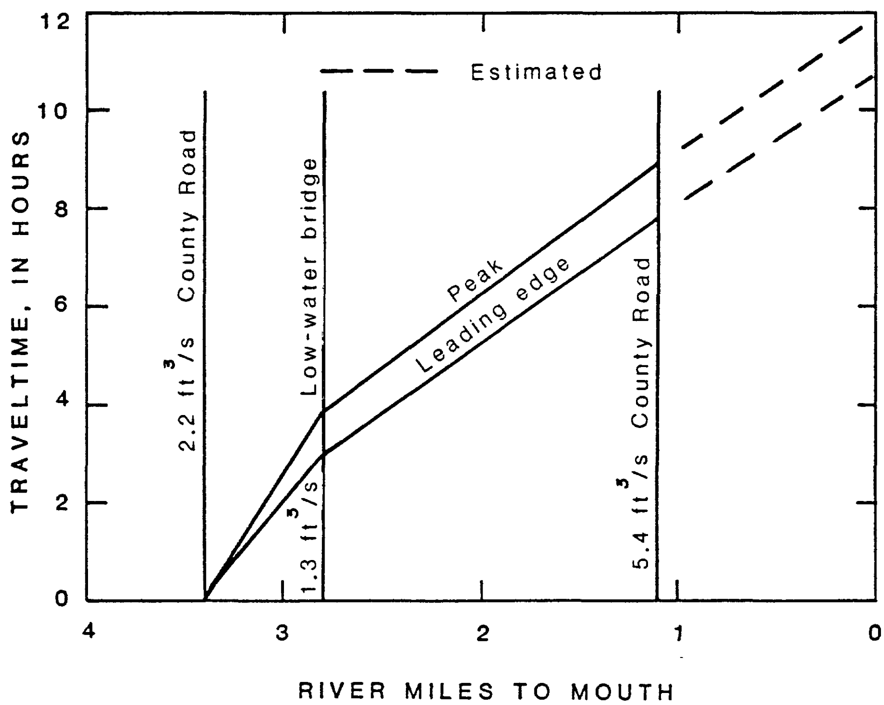


Figure 11.—Traveltime of tracer cloud in Hickory Creek, Arkansas, for discharges noted at each site.

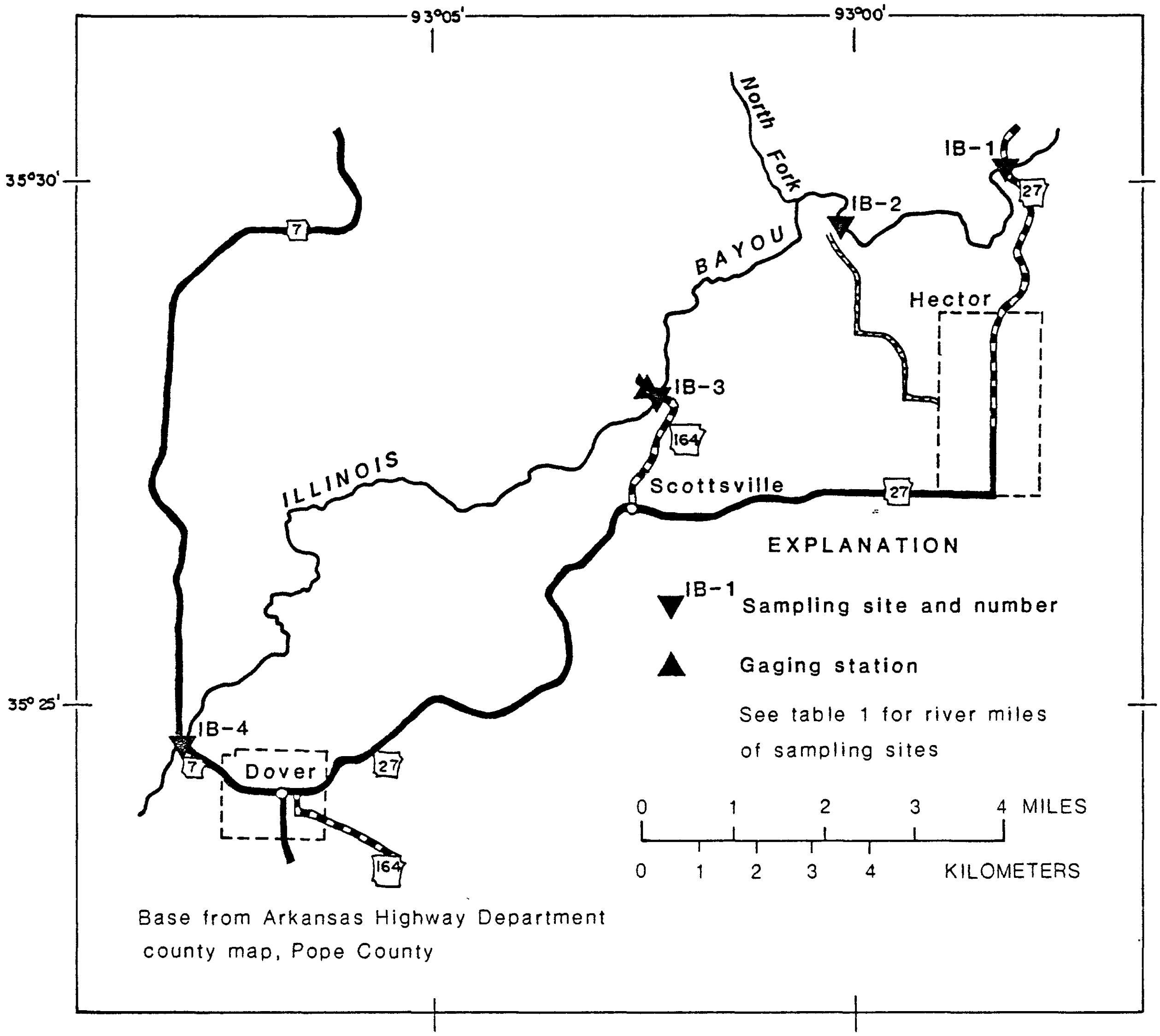


Figure 12.—Illinois Bayou stream segment studied.

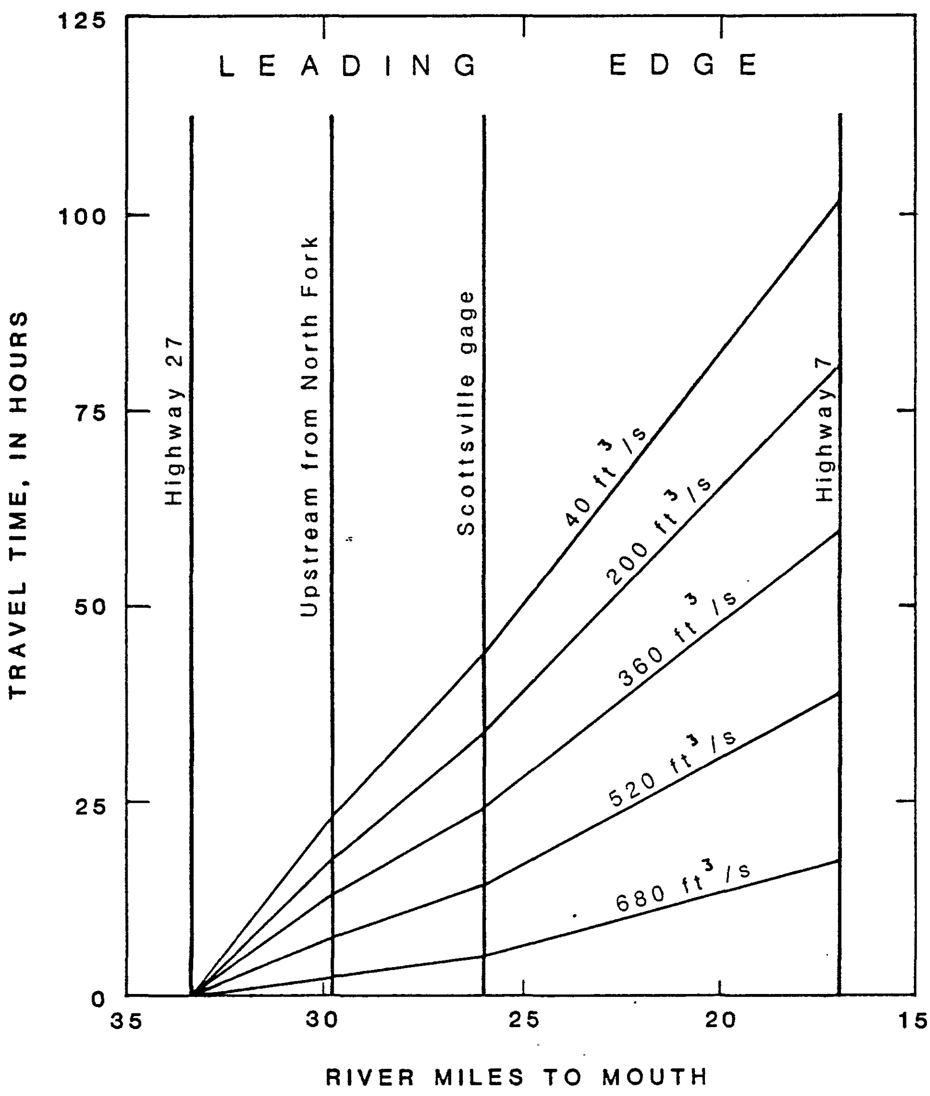


Figure 13.—Traveltime of tracer cloud leading edge, Illinois Bayou, for selected discharges at the gage on highway 164 near Scottsville.

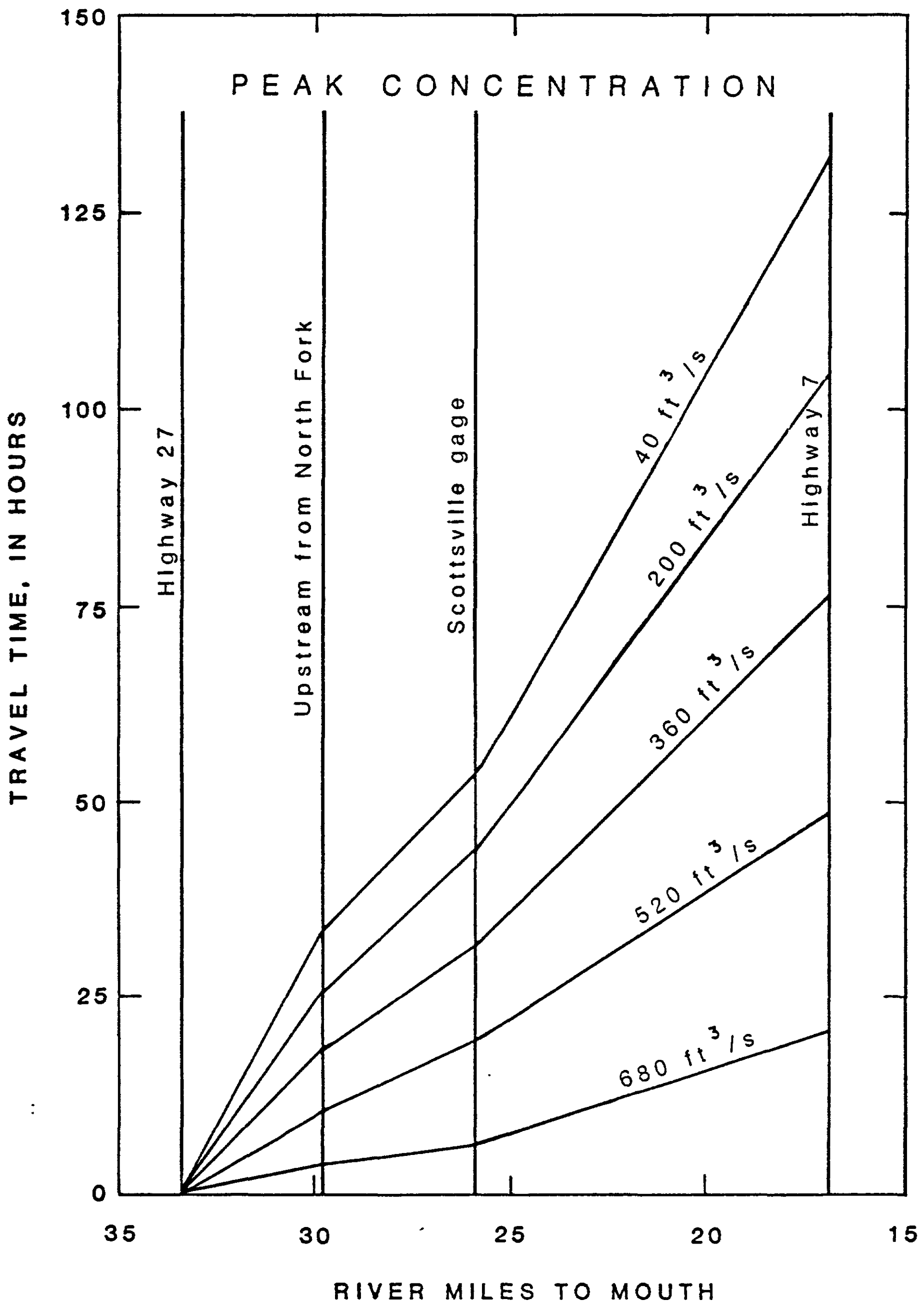


Figure 14.—Peak concentration traveltime of tracer cloud, Illinois Bayou, for selected discharges at the gage on highway 164 near Scottsville.

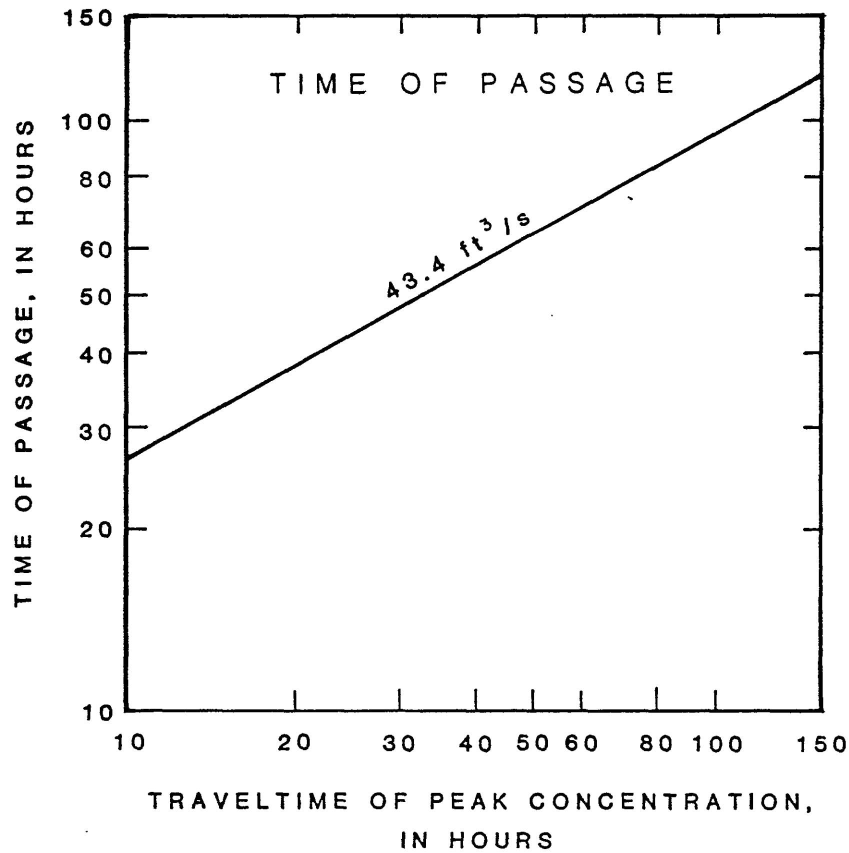


Figure 15.—Time of passage of tracer cloud, Illinois Bayou, for the discharge of 43.4 cubic feet per second at the gage on highway 164 near Scottsville.

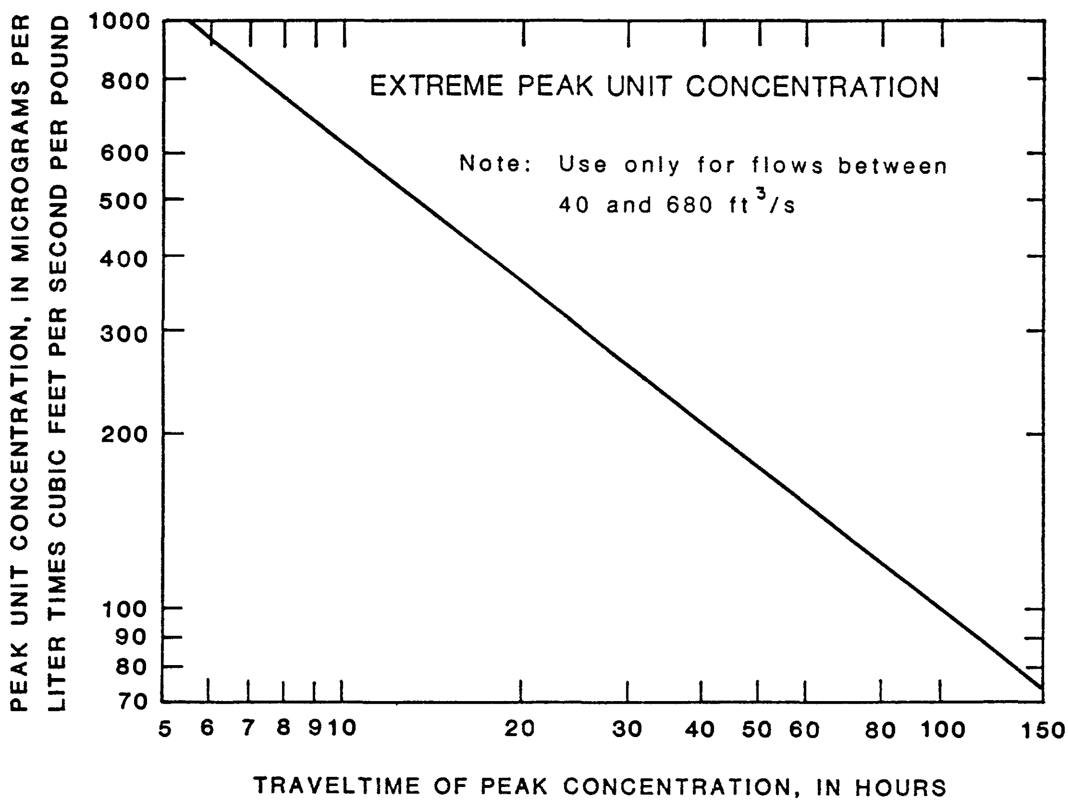


Figure 16.—Extreme peak unit concentration for conservative tracer in Illinois Bayou, between river miles 33.4 and 17.

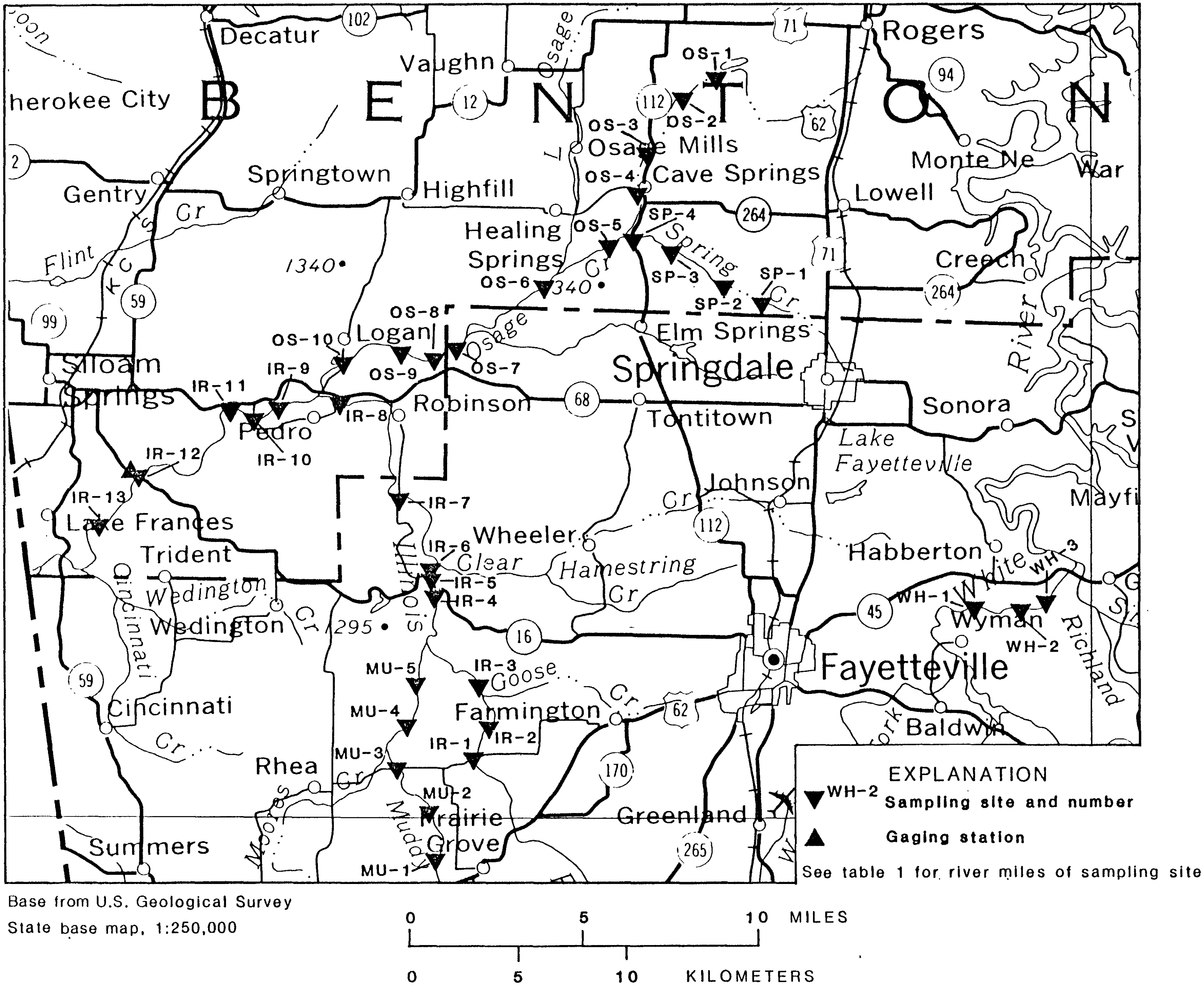


Figure 17.—Illinois River, Osage Creek, Spring Creek, Muddy Fork, and White River stream segments studied.

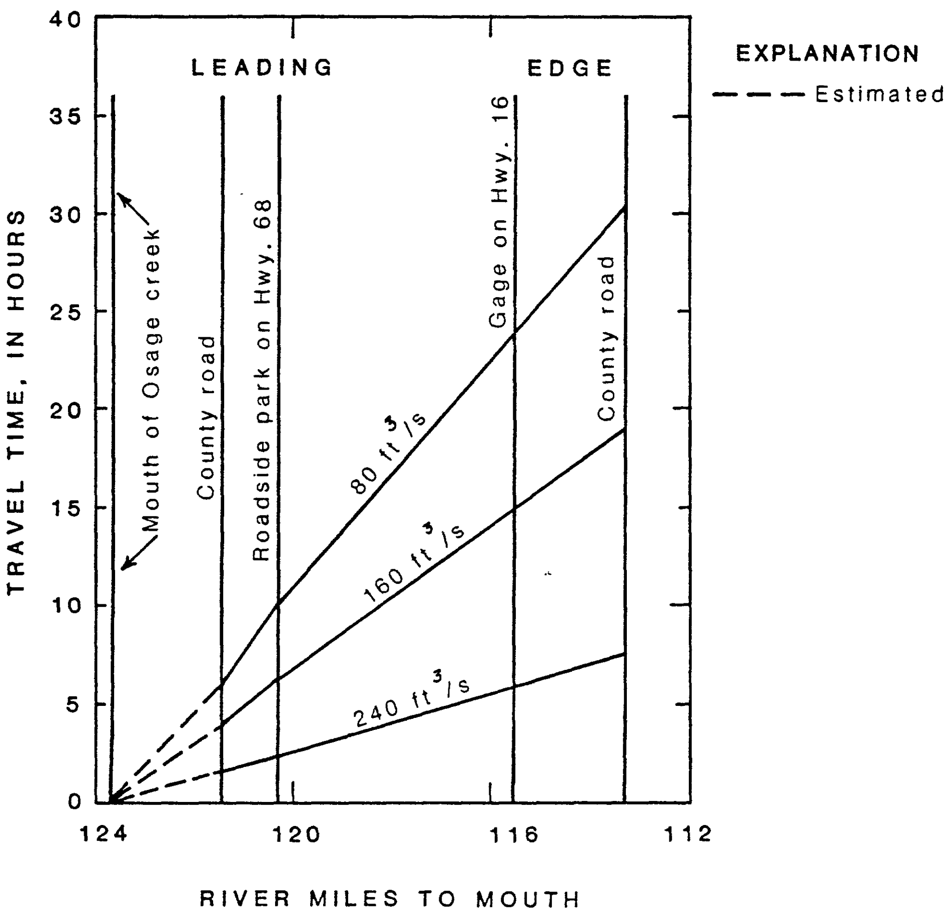


Figure 18.—Traveltime of leading edge of tracer cloud, lower Illinois River, Arkansas, for selected discharges at the gage on highway 16 near Siloam Springs.

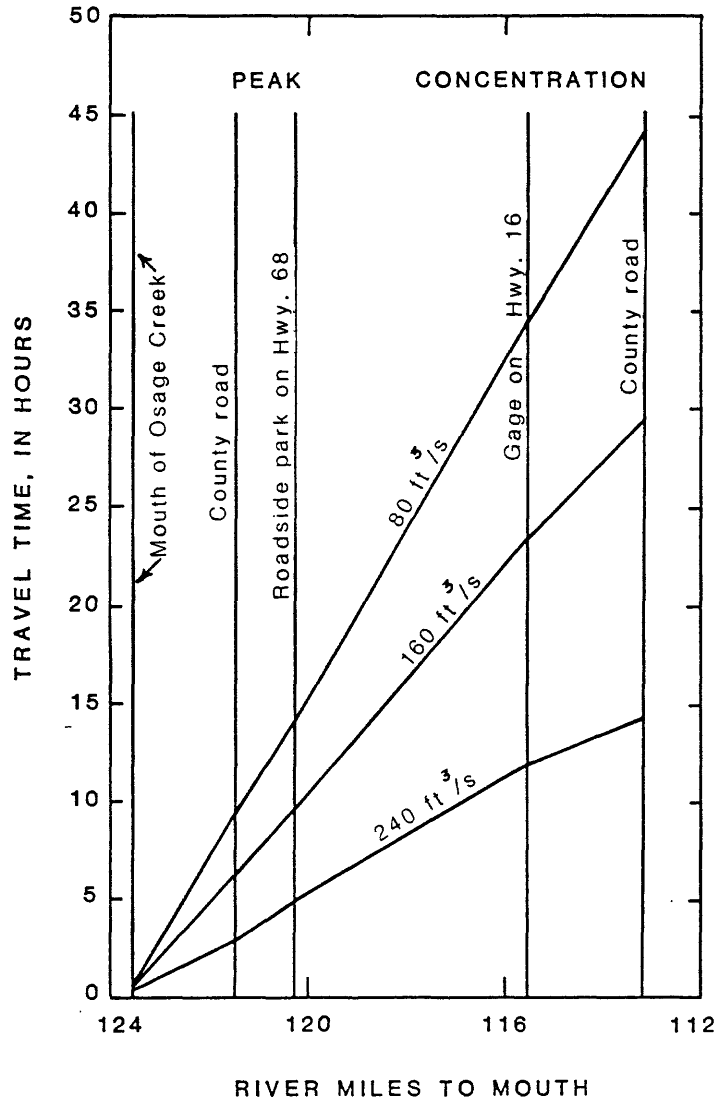


Figure 19.—Traveltime of peak concentration of tracer cloud, lower Illinois River, Arkansas, for selected discharges at the gage on highway 16 near Siloam Springs.

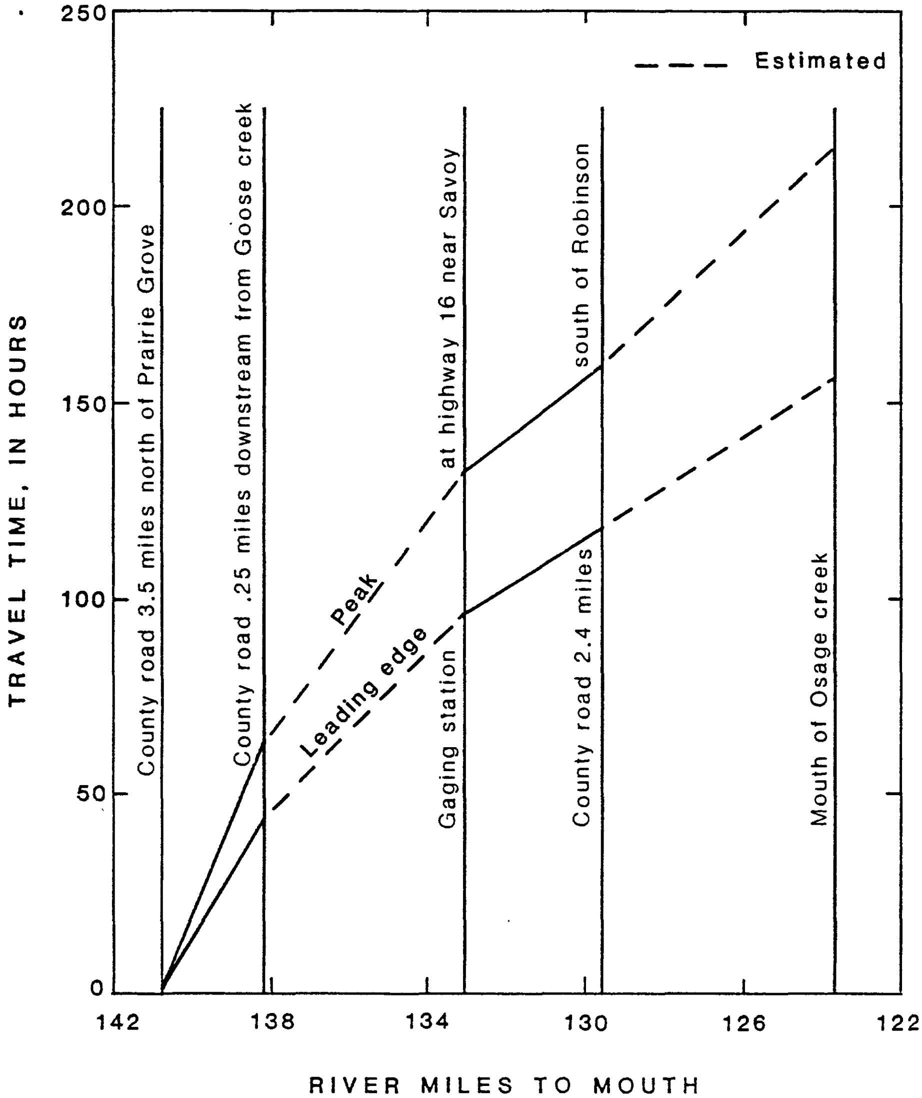


Figure 20.—Traveltime of tracer cloud in upper Illinois River, Arkansas, for a discharge of 10.5 cfs at the gage on highway 16 near Savoy.

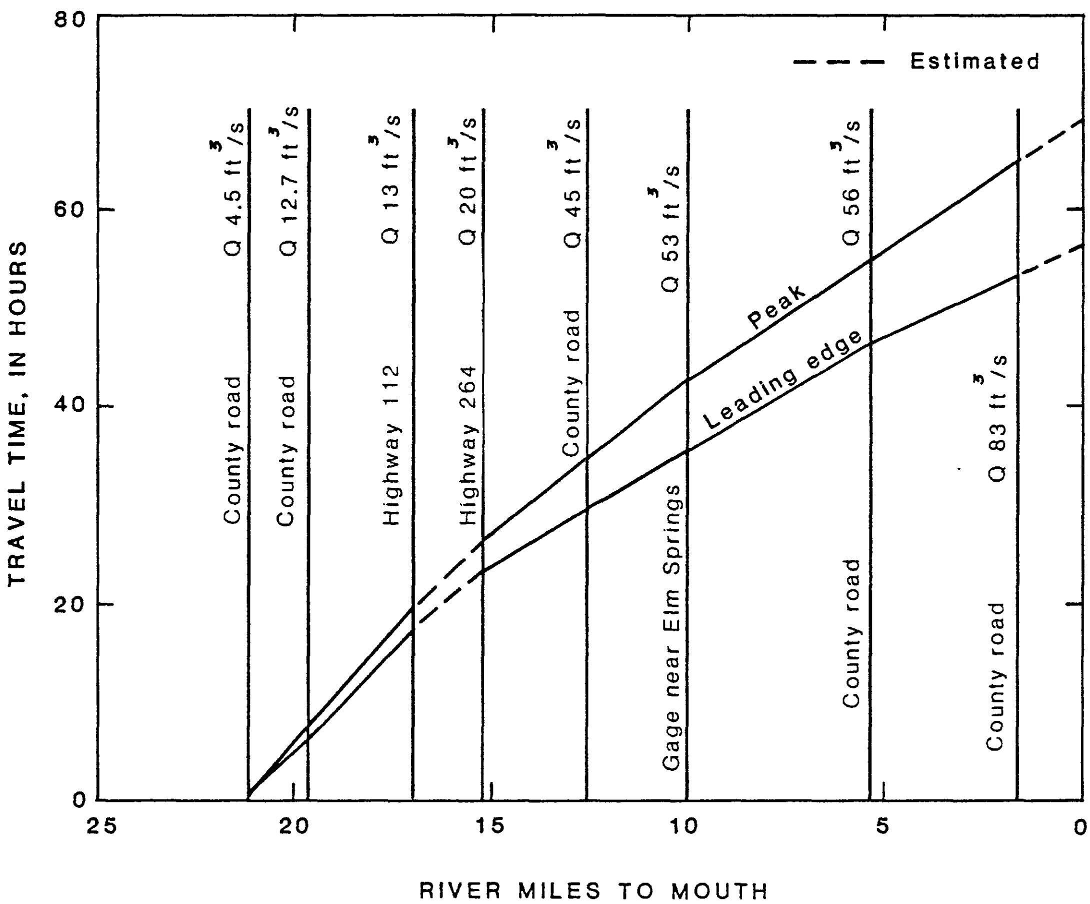


Figure 21.—Traveltime of tracer cloud in Osage Creek, Arkansas, for an average discharge of 56 ft^3/s at the gage near Elm Springs. Discharge at time of sampling at each site is noted above. Instantaneous discharge varied by as much as 20 ft^3/s from daily average flow during time of sampling.

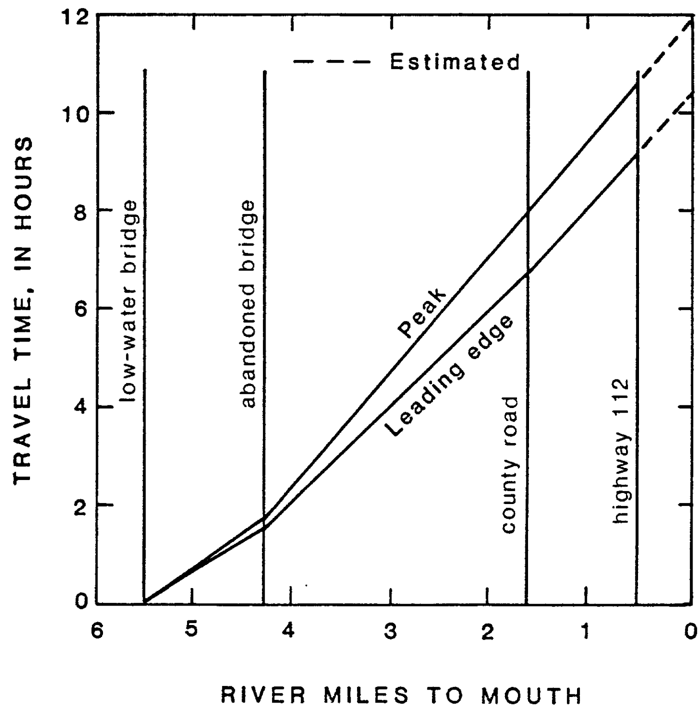


Figure 22.—Traveltime of tracer cloud in Spring Creek, Arkansas for a discharge of 23.8 ft^3/second at highway 112 near Cave Springs.

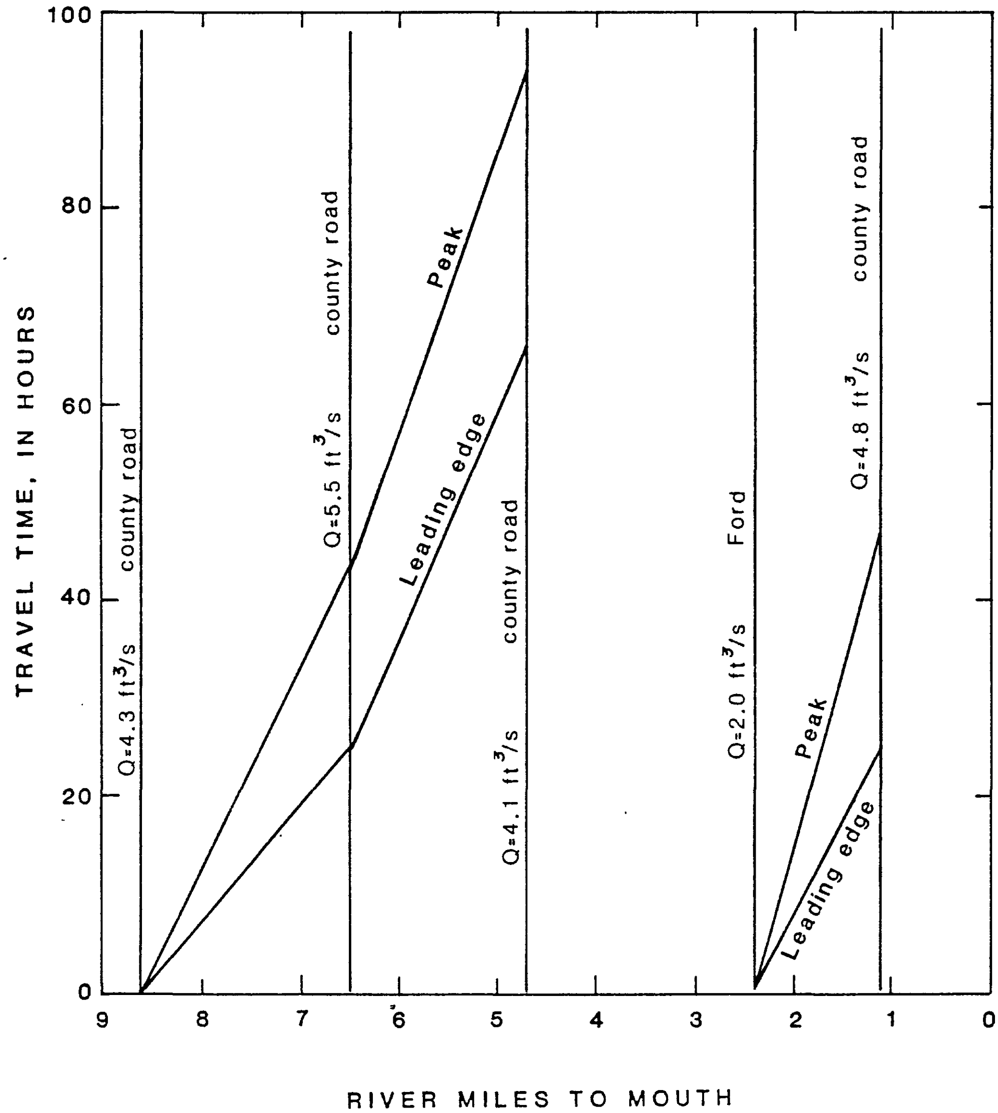


Figure 23.—Traveltime of tracer cloud in Muddy Fork, Arkansas for discharges noted at each site.

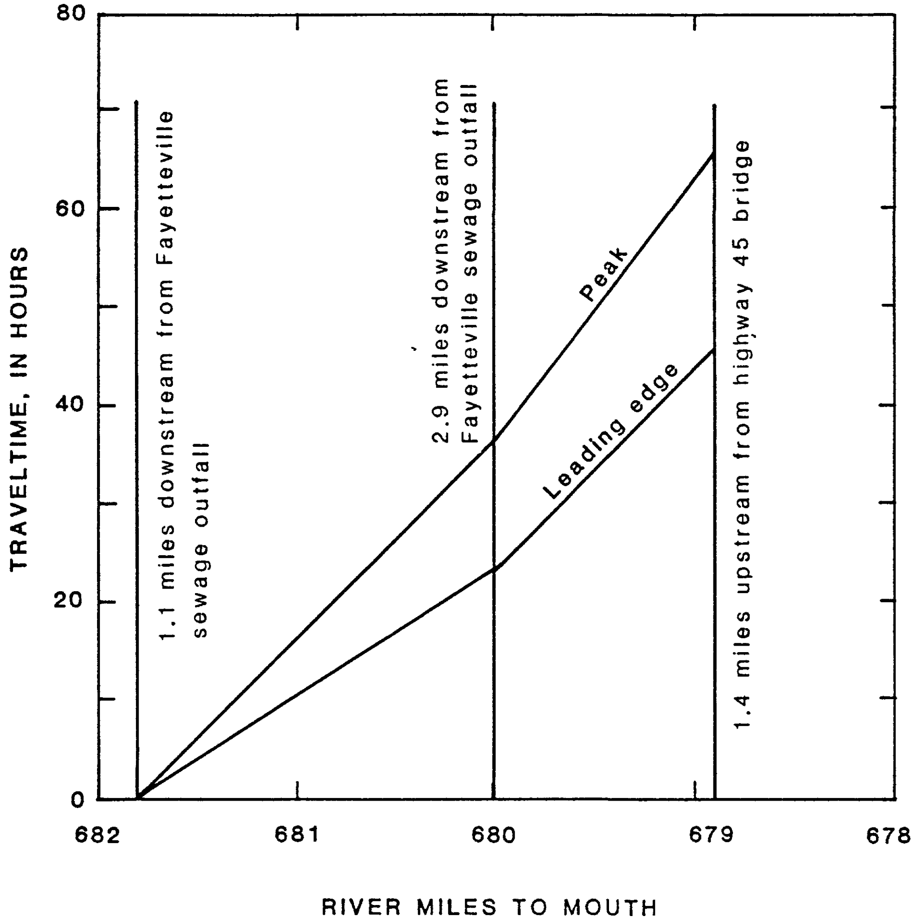


Figure 24.—Traveltime of tracer cloud in White River, Arkansas for typical diel flow of 8 to 15 ft^3/s.

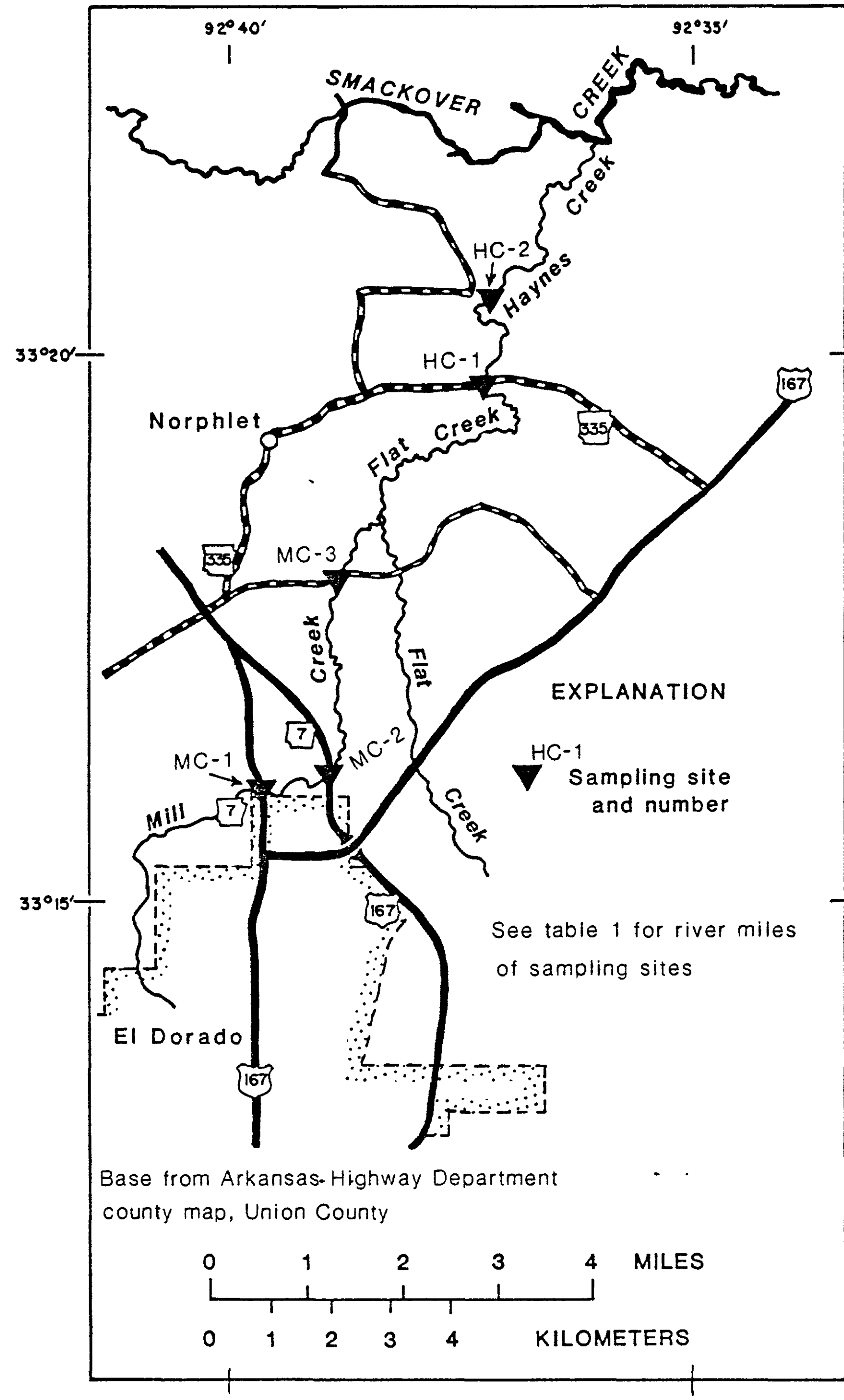


Figure 25.—Mill Creek, Flat Creek, and Haynes Creek stream system studied.

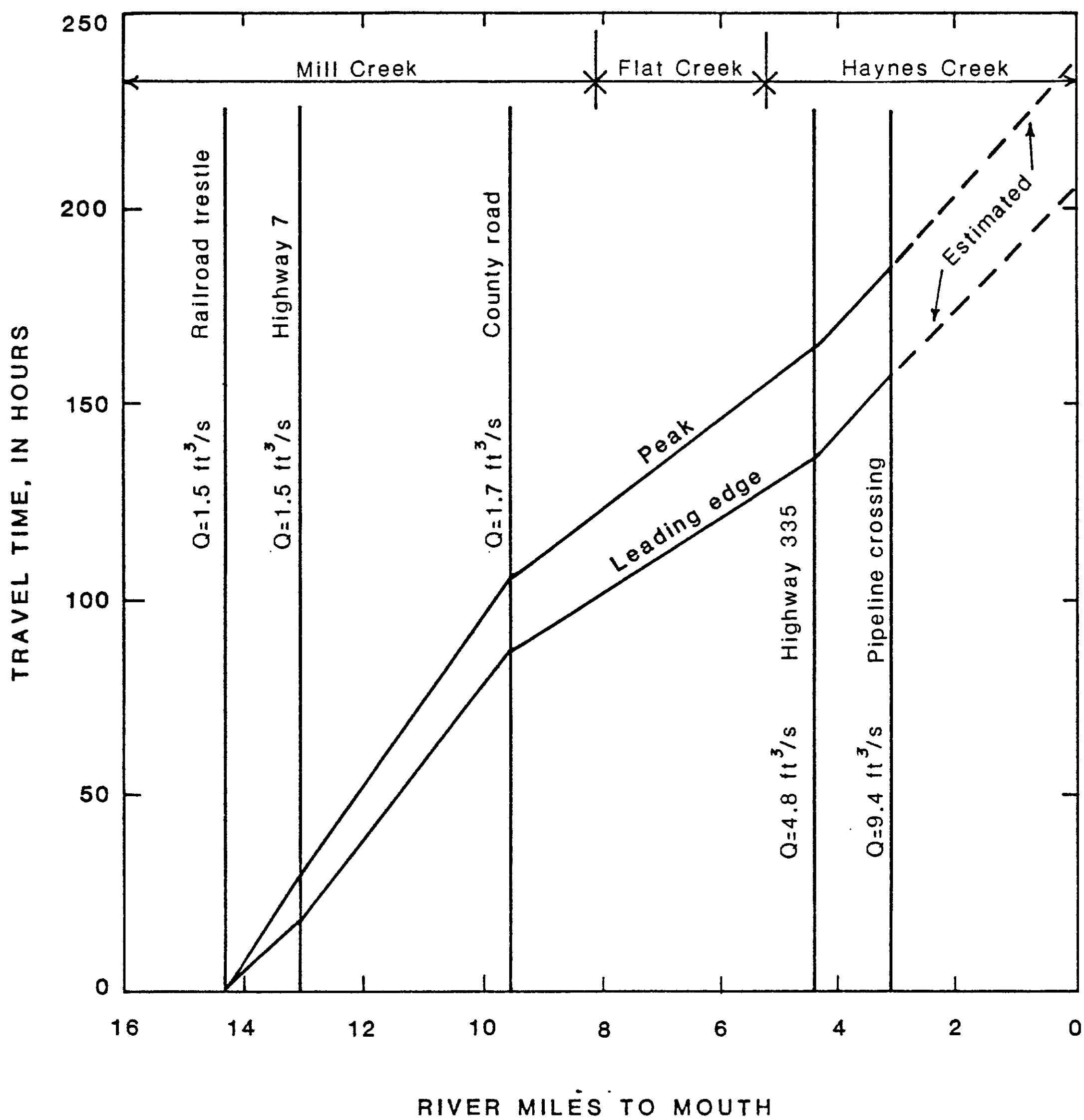
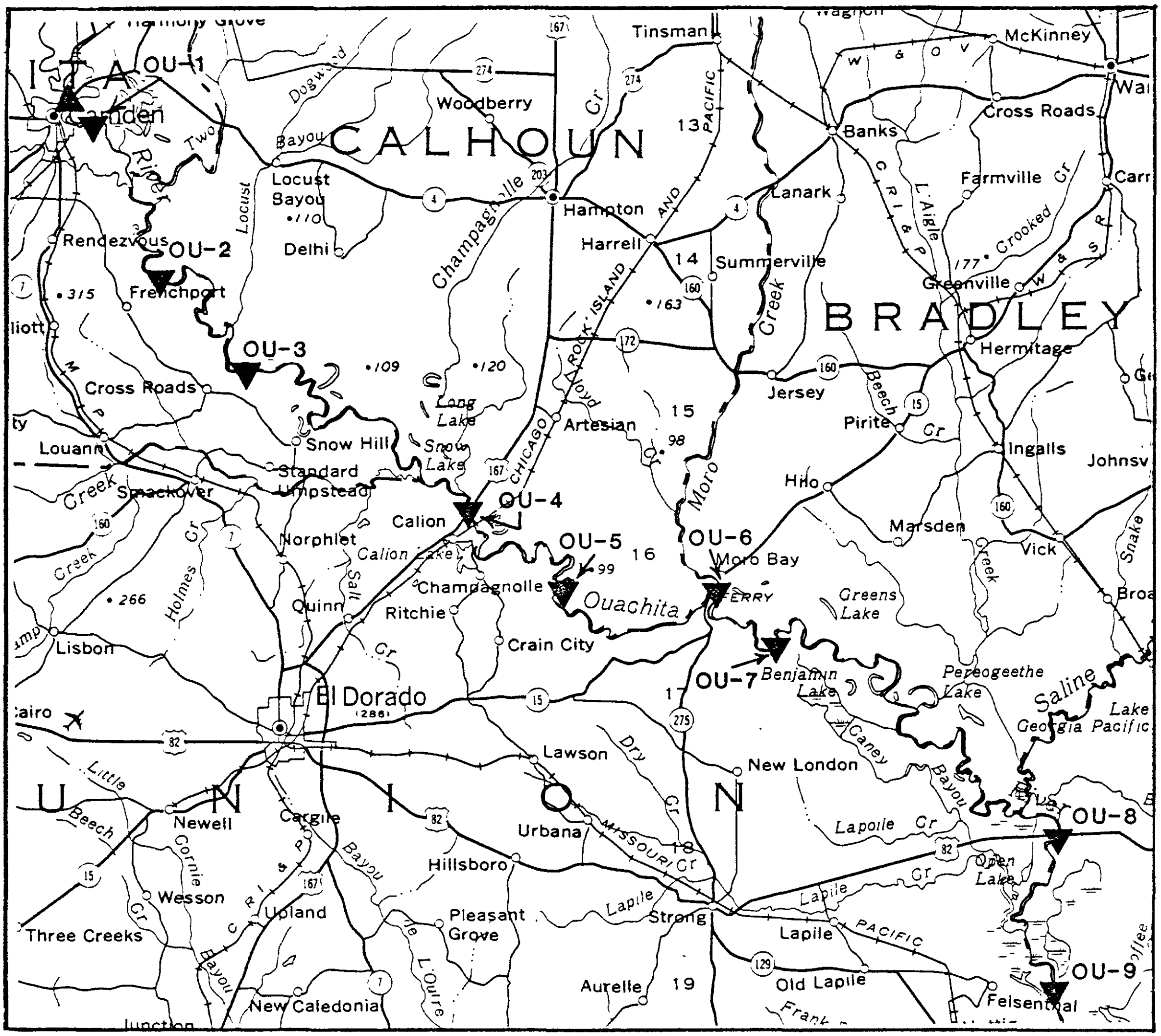


Figure 26.—Traveltime of the tracer cloud in the stream system of Mill Creek, Flat Creek, and Haynes Creek located northeast of El Dorado, Arkansas. Discharge at time of tracer cloud passage is noted at each sampling site.



Base from U.S. Geological Survey
State base map, 1:500,00

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

▼ OU-9 Sampling site and number

▲ Gaging station

See table 1 for river miles of sampling sites

Figure 27.—Ouachita River stream segment studied.

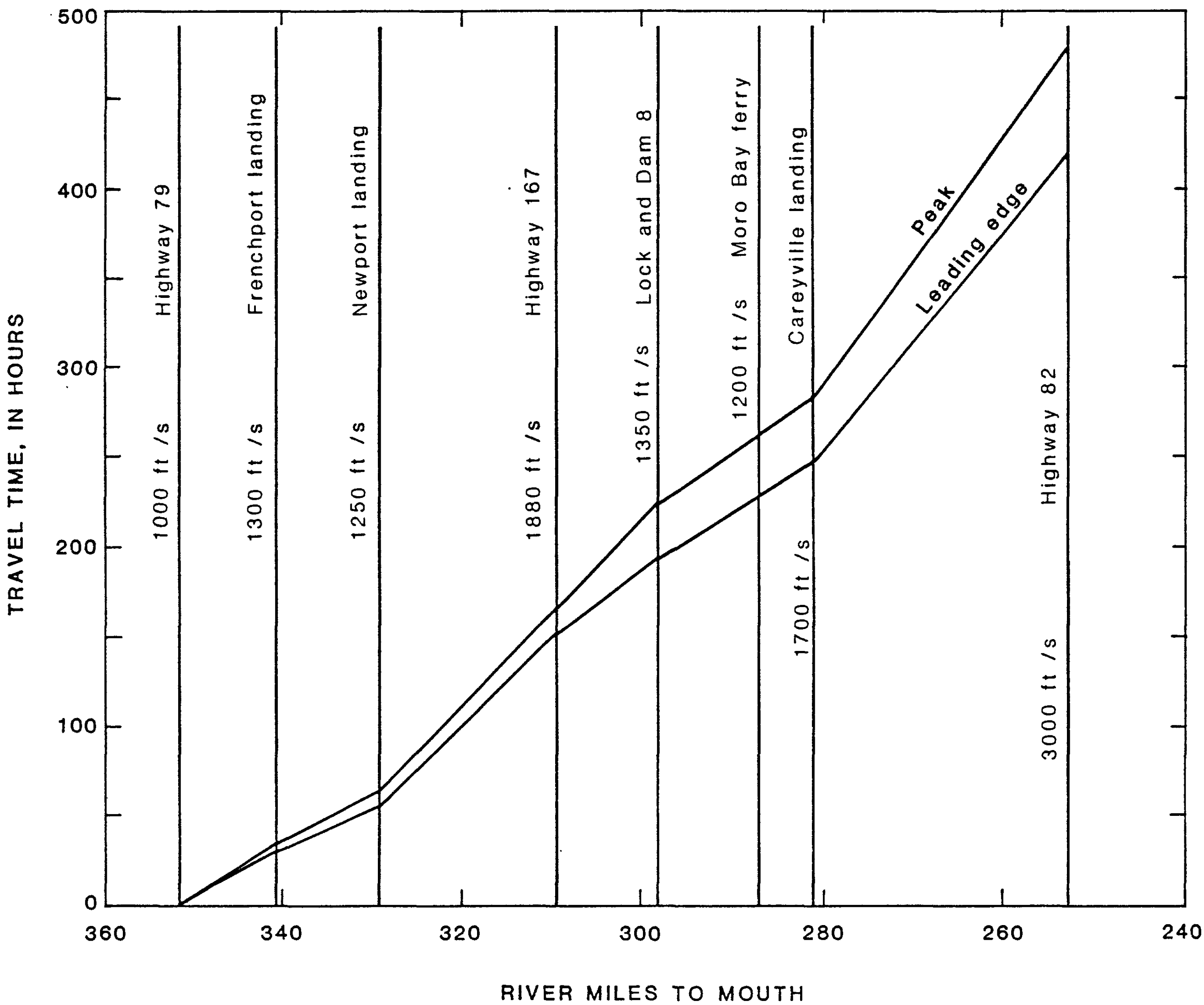


Figure 28.—Traveltime of tracer cloud in Ouachita River, mile 351.1 to 252.9, for normal summertime variable flow of 1000 to 3000 ft^3/s. Flow at time of tracer cloud passage shown for each site.

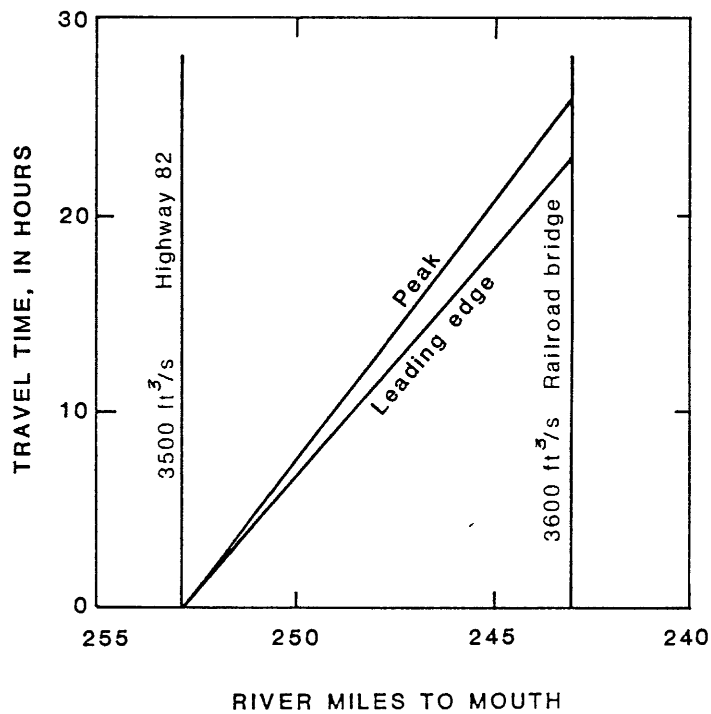


Figure 29.—Traveltime of tracer cloud in Ouachita River, mile 252.9 243.0, for discharges noted at each site.

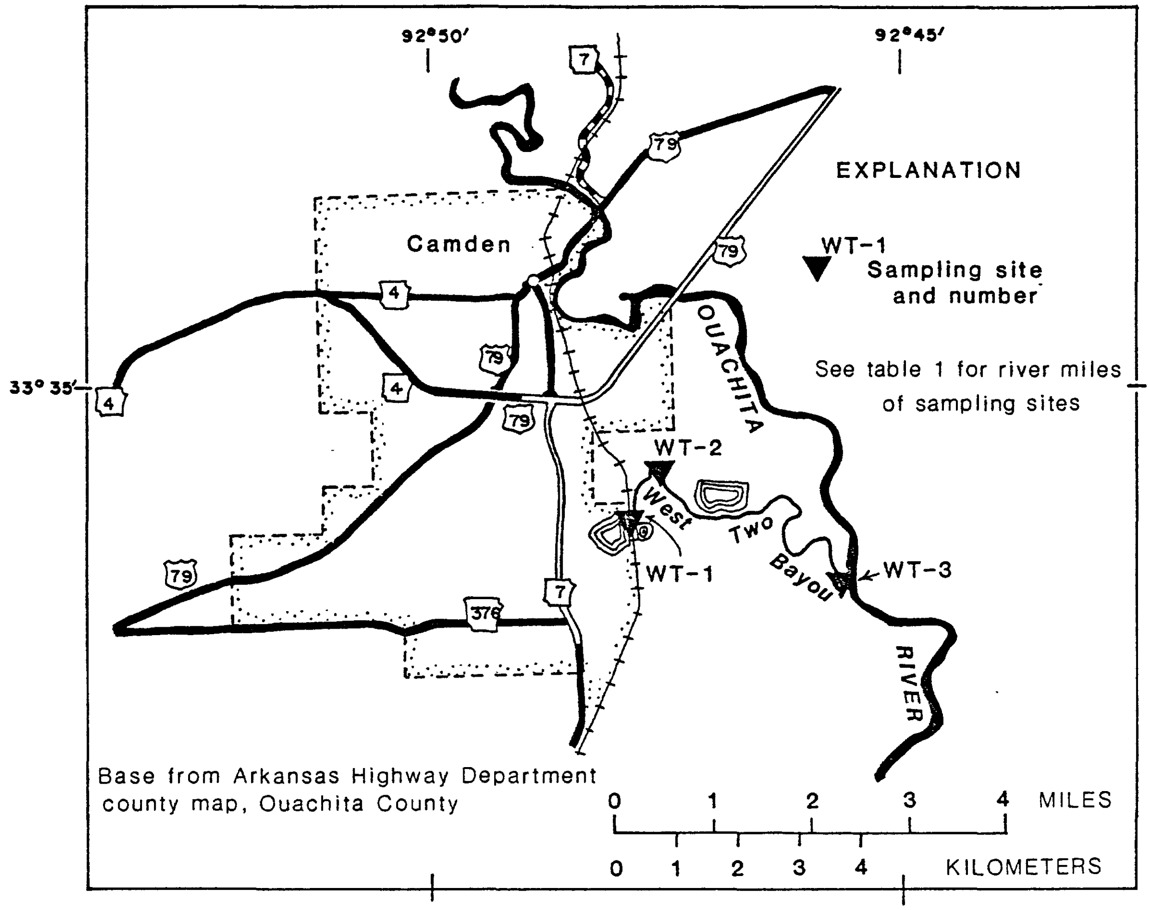


Figure 30.—West Two Bayou stream segment studied.

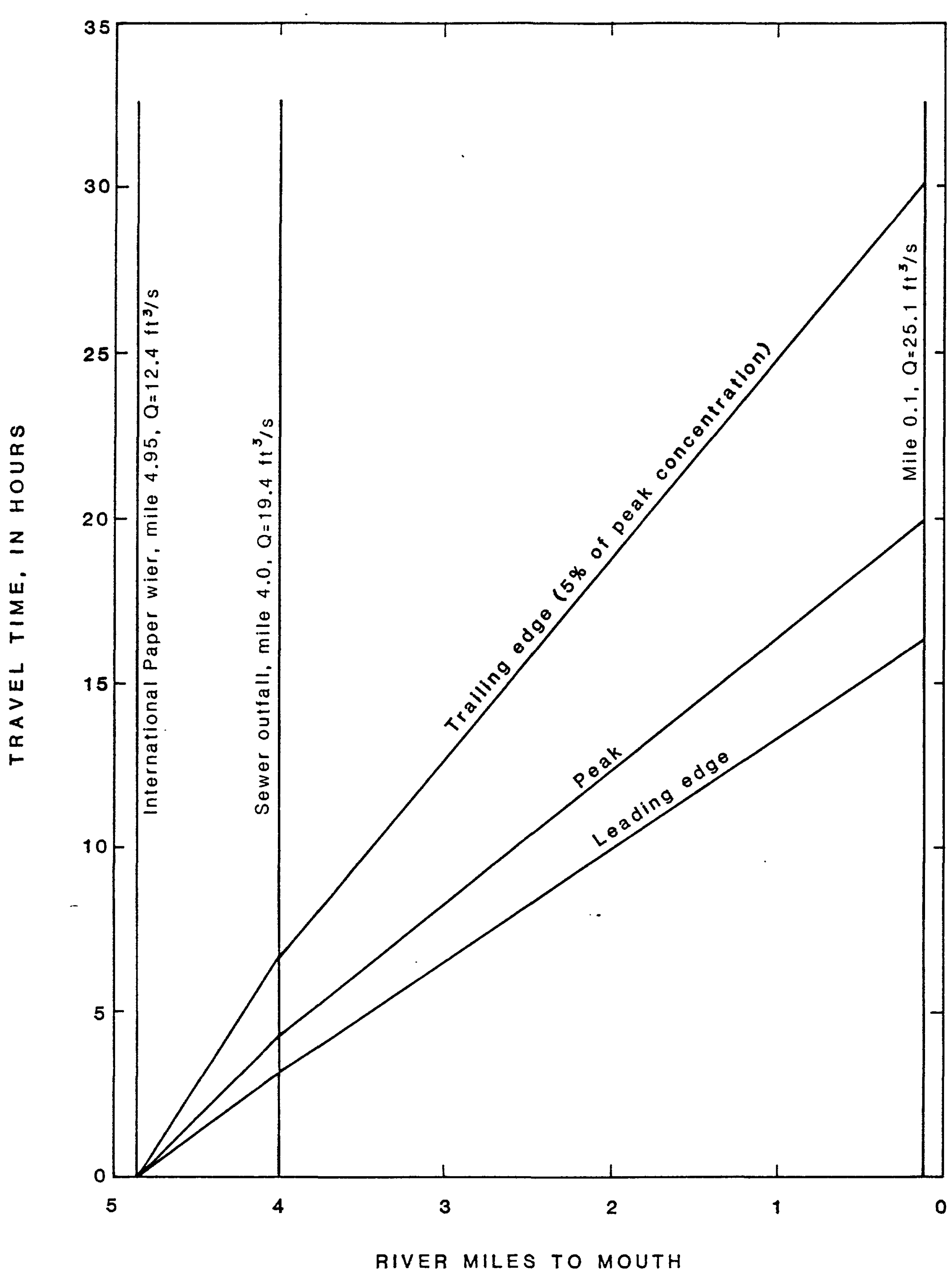
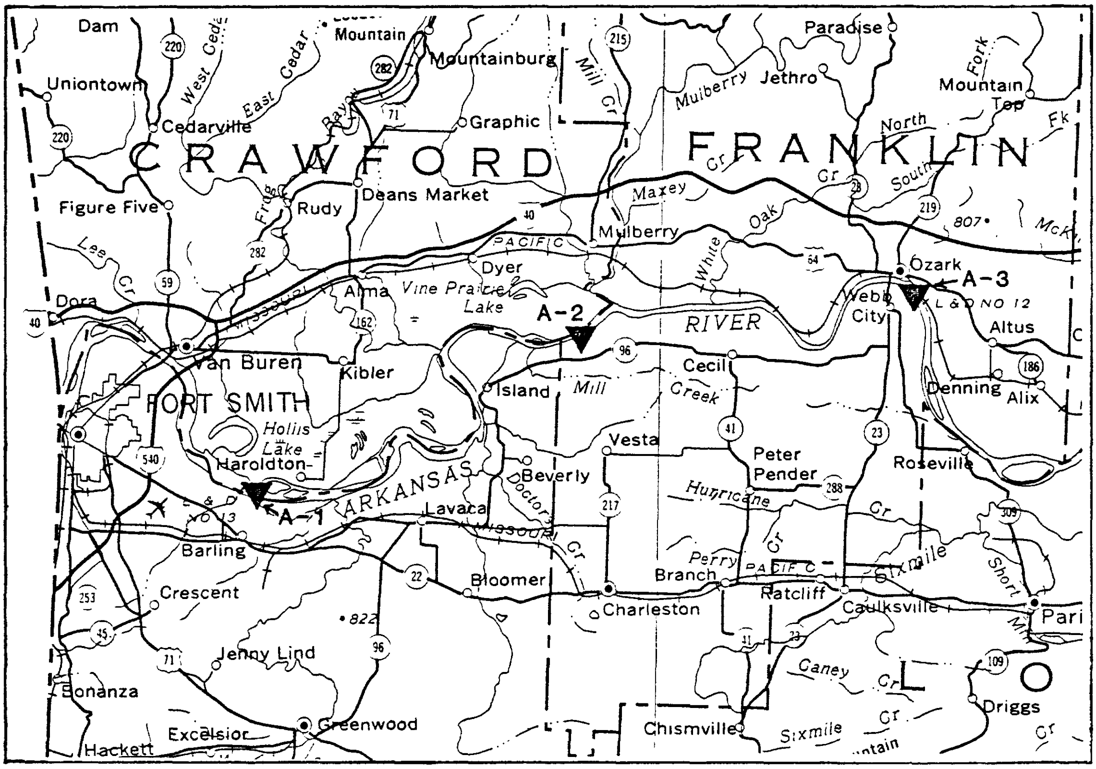


Figure 31.—Traveltime of tracer cloud in West Two Bayou and tributary.



Base from U.S. Geological Survey
State base map, 1:500,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

A-1 ▼ **Sampling site and number**

See table 1 for river miles of sampling sites

Figure 32.—Arkansas River stream segment studied, Dam 13 to Ozark Dam.

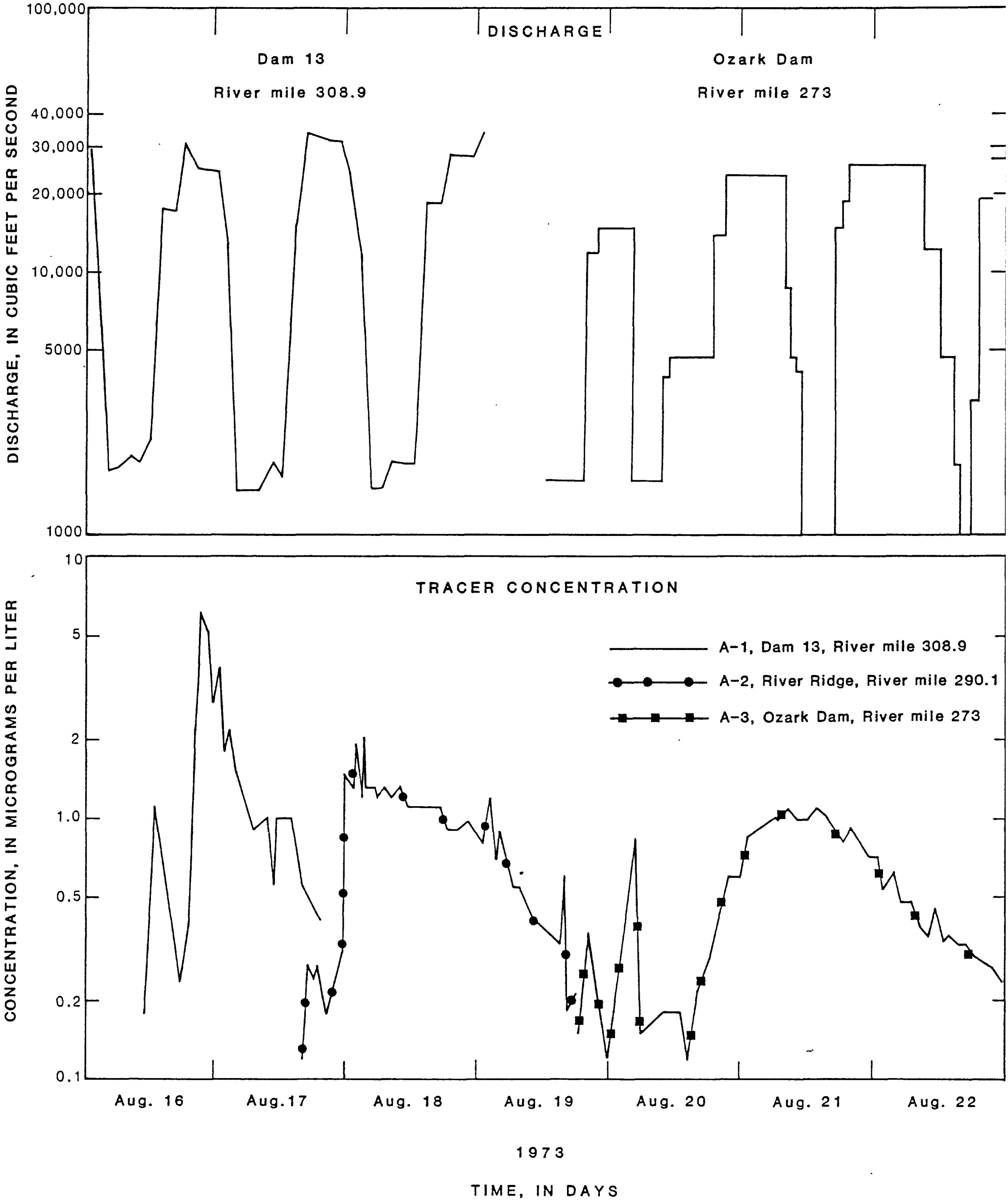
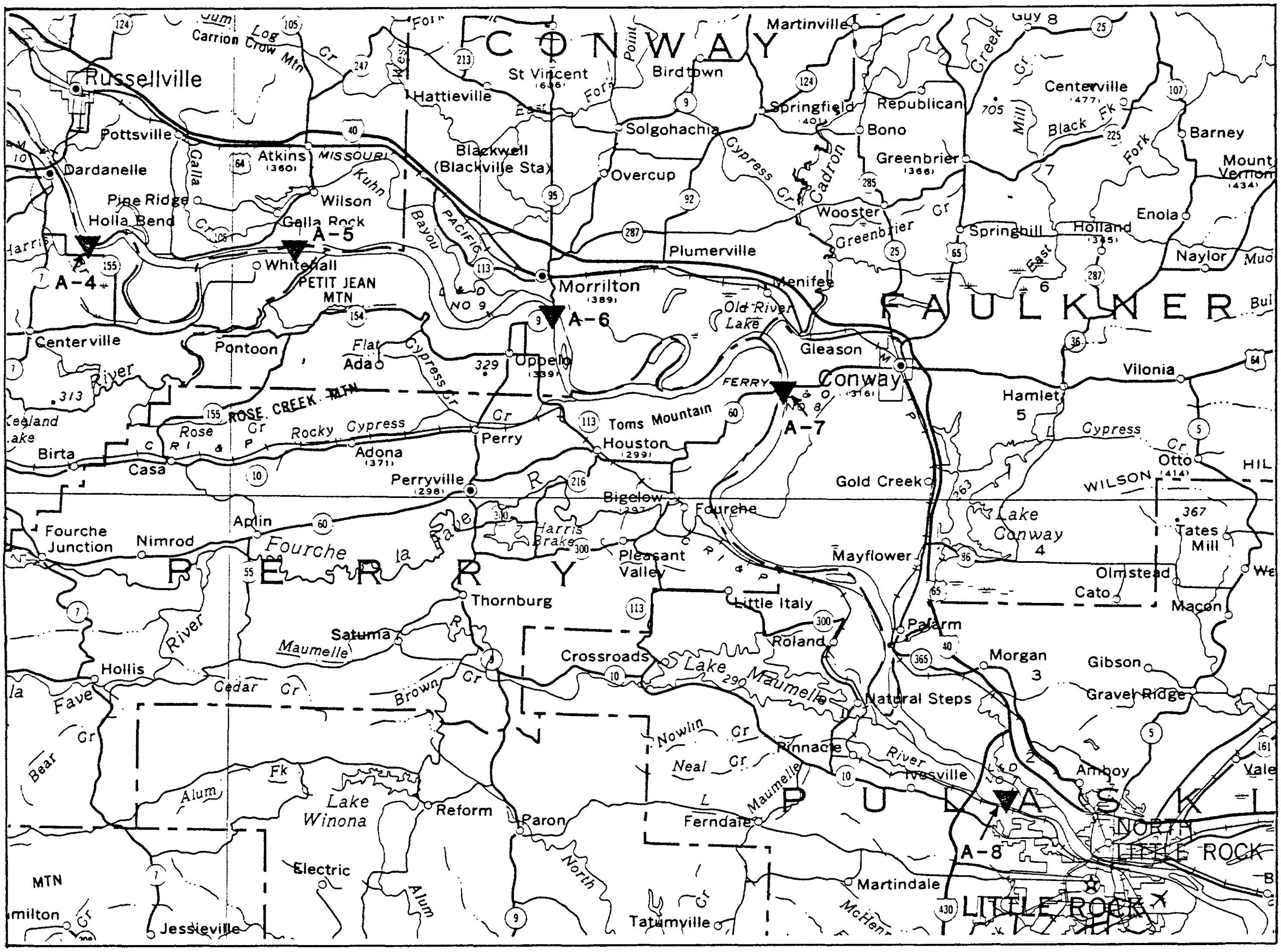


Figure 33.—Tracer time-concentration graphs and discharge hydrographs for the Arkansas River from Dam 13 near Fort Smith to Ozark Dam at Ozark.



Base from U.S. Geological Survey
State base map, 1:500,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

▼ A-4 Sampling site and number

See table 1 for river miles of sampling sites

Figure 34.—Arkansas River stream segment studied, Dardanelle to Murray Dam.

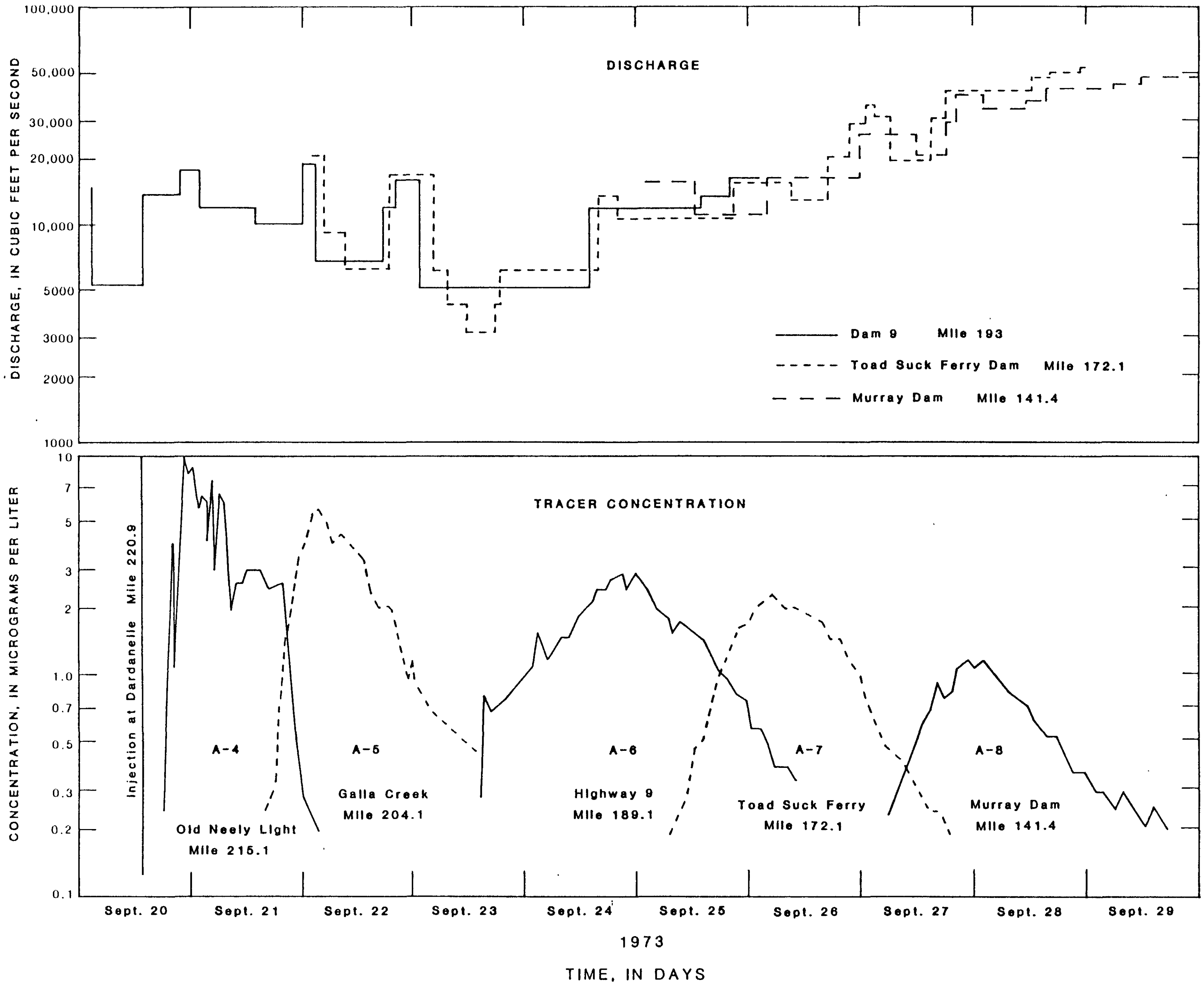
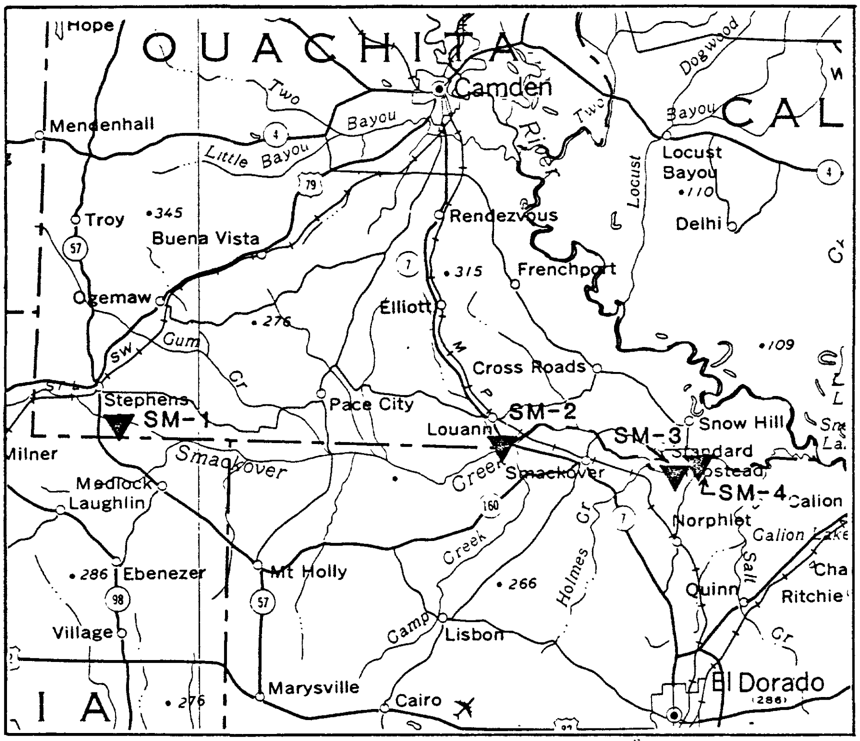


Figure 35.—Tracer time concentration graphs and discharge hydrographs for the Arkansas River from Dardanelle Dam at Dardanelle to Murray Dam at Little Rock.



Base from U.S. Geological Survey
State base map, 1:500,000

0 10 20 MILES

0 10 20 KILOMETERS

EXPLANATION

▼ SM-1 Sampling site and number

See table 1 for river miles of sampling sites

Figure 36.—Smackover Creek stream segment studied.

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Table 1.--Traveltime data collected for streams in Arkansas

Location and Date	Site designation	Dis tance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (µg/L)	Discharge at sampling site (ft^3/s)
CADDO RIVER								
June 14, 1971								
Norman	CA1	67.1	----	----	----	----	----	21.0
Highway 240 near Caddo Gap	CA2	59.1	8.0	45.3	56.0	48.0	1.3	34.3
Low-water bridge at Glenwood	CA3	51.3	15.8	95.0	120	72.0	0.4	34.4
Highway 182 near Amity	CA4	44.1	23.0	132	162	85.0	0.2	39.5
June 12, 1972								
Low-water bridge at Glenwood	CA3	51.3	----	----	----	----	----	33.3
Highway 182 near Amity	CA4	44.1	7.2	42.9	57.0	57.0	1.8	33.8
Highway 84 near Amity	CA5	39.3	12.0	81.2	101	77.0	1.0	37.6
May 21, 1973								
Norman	CA1	67.1	----	----	----	----	----	59.3
Highway 240 near Caddo Gap	CA2	59.1	8.0	17.9	23.5	25.0	2.9	101
Low-water bridge at Glenwood	CA3	51.3	15.8	40.1	46.5	33.2	1.2	110

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site desig- nation	Dis tance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concen- trations (μg/L)	Discharge at sampling site (ft^3/s)
CADDO RIVER--Continued								
May 21, 1973								
Low-water bridge at Glenwood	CA3	51.3	----	----	----	----	----	110
Highway 182 near Amity	CA4	44.1	7.2	15.5	20.6	25.0	2.7	124
Highway 84 near Amity	CA5	39.3	12.0	31.7	37.3	29.8	1.6	136
HICKORY CREEK								
August 3, 1981								
County Road, 2.3 miles west of Greenland	HC1	3.4	----	----	----	----	----	2.2
Low-water bridge	HC2	2.8	0.6	2.9	3.9	----	----	1.3
County Road, 3.8 miles southwest of Greenland	HC3	1.1	2.3	7.9	9.0	----	----	5.4

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (µg/L)	Discharge at sampling site (ft^3/s)
ILLINOIS BAYOU								
May 9, 1977								
Highway 27 near Hector	IB1	33.4	----	----	----	----	----	36.2
Upstream from North Fork	IB2	29.8	3.6	23.1	32.8	52.0	8.0	37.7
Scottsville gage	IB3	26.0	7.4	43.9	56.7	58.4	3.1	43.4
Highway 7 near Dover	IB4	17.0	16.4	103	133	123	1.3	46.0
March 27, 1979								
Highway 27 near Hector	IB1	33.4	----	----	----	----	----	479
Scottsville gage	IB3	26.0	7.4	5.3	6.0	4.7	0.5	680
March 27, 1979								
Scottsville gage	IB3	26.0	----	----	----	----	----	720
Highway 7 near Dover	IB4	17.0	9.0	6.2	7.9	11.1	0.6	774

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (μg/L)	Discharge at sampling site (ft^3/s)
ILLINOIS RIVER								
September 6, 1978								
County Road, 2.4 miles south of Robinson	IR7	129.6	----	----	----	----	----	22.9
County Road, 0.85 miles upstream from Osage Creek	IR8	124.6	5.0	33.1	47.2	40	6.4	23.4
November 27, 1978								
County Road, 2.2 miles downstream from Osage Creek	IR10	121.5	----	----	----	----	----	275
Highway 16, 3.1 miles southeast of Highway 68	IR12	115.5	6.0	3.7	8.4	12.8	5.1	245
County Road, 2.25 miles east of Ark.-Okla. border	IR13	113.3	8.2	5.4	10.4	15.9	3.7	240
July 23, 1979								
County Road, 3.5 miles north of Prairie Grove	IR1	140.7	-----	----	----	----	----	2.0
0.6 miles upstream from Goose Creek	IR2	139.0	1.7	27.0	43.6	40.8	4.9	2.9
County Road, 1/4 mile downstream from Goose Creek	IR3	138.1	2.6	46.8	67.8	53.5	1.7	6.0

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (μg/L)	Discharge at sampling site (ft^3/s)
ILLINOIS RIVER--Continued								
September 21, 1981								
One-half mile upstream from Highway 16 near Savoy	IR4	133.6	----	----	----	----	----	10.6
Highway 16 near Savoy	IR5	133.1	0.5	3.6	4.4	----	----	10.6
0.2 mile downstream from Highway 16 near Savoy	IR6	132.9	0.7	4.8	6.2	----	----	10.6
County Road, 2.4 miles, south of Robinson	IR7	129.6	4.0	26.3	32.6	----	----	----
1.3 miles downstream from Osage Creek	IR9	122.4	----	----	----	----	----	85
County Road, 2.2 miles downstream from Osage Creek	IR10	121.5	0.9	2.2	3.6	----	----	85
Roadside Park, 5.8 miles east of Siloam Springs	IR11	120.3	2.1	5.8	8.0	----	----	84.8
Highway 16, 3.1 miles southeast of Highway 68	IR12	115.5	6.9	19.1	28.5	----	----	92

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site desig-nation	Dis tance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concen-trations (µg/L)	Discharge at sampling site (ft^3/s)
MILL CREEK-FLAT CREEK-HAYNES CREEK								
July 17, 1981								
Railroad trestle, 0.1 mile east of Highway 7 spur in El Dorado	MC1	14.3	----	----	----	----	----	1.5
Highway 7	MC2	13.1	1.2	19.2	30.7	----	13	1.5
County Road, 1 mile southeast of Norphlet	MC3	9.5	4.8	89.9	108	----	4.6	1.7
July 17, 1981								
County Road, 1 mile southeast of Norphlet	MC3	9.5	----	----	----	----	----	1.7
Highway 335	MC1	4.4	5.1	48.3	58.4	----	11	4.8
Pipeline crossing, 0.1 mile east of county road, 1 mile north of Highway 335	MC2	3.1	6.4	69.9	81.6	----	9	9.4

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (μg/L)	Discharge at sampling site (ft^3/s)
MUDDY FORK								
November 27, 1978								
County Road, 1.3 miles northwest of Prairie Grove	MU1	8.6	----	----	----	----	----	4.3
County Road, 1.0 mile west of Viney Grove	MU2	6.5	2.1	25.5	44.8	----	5.5	5.5
County Road, 2.0 miles northwest of Viney Grove	MU3	4.7	3.9	68.2	98.0	----	3.0	4.1
July 23, 1979								
Ford, 2.8 miles northwest of Viney Grove	MU4	2.4	----	----	----	----	----	2.0
County Road, 3.7 miles northwest of Viney Grove	MU5	1.1	1.3	25.6	49.4	----	3.8	4.8

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (µg/L)	Discharge at sampling site (ft^3/s)
OSAGE CREEK								
September 6, 1978								
County Road, 1.3 miles south of Highway 71, 2.3 miles east of Highway 112	OS1	21.1	----	----	----	----	----	4.5
County Road, 1 mile east of Highway 112	OS2	19.6	1.5	5.9	7.0	----	4.9	12.7
Highway 112	OS3	17.0	4.1	17.4	19.6	----	3.0	13.0
County Road, at gage, 3.2 miles northwest of Elm Springs	OS6	10.0	----	----	----	----	----	50
County Road, 2.3 miles northeast of Robinson	OS8	5.4	4.6	10.0	12.2	----	3.4	56
County Road, 0.6 mile south of Logan	OS10	1.6	8.4	17.8	22.6	----	2.9	83

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site desig-nation	Dis tance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concen-trations (µg/L)	Discharge at sampling site (ft^3/s)
				OSAGE CREEK--Continued				
July 24, 1979								
Highway 264 at Cave Springs	OS4	15.2	----	----	----	----	----	20
County Road, 1.9 miles southwest of Cave Springs	OS5	12.6	2.6	6.4	8.4	----	6.0	45
County Road, at gage, 3.2 miles, northwest of Elm Springs	OS6	10.0	5.2	12.6	16.5	----	----	55
September 22, 1981								
Shoal, 0.6 mile upstream from county road	OS7	6.0	----	----	----	----	----	50
County Road, 2.3 miles northeast of Robinson	OS8	5.4	0.6	0.7	1.3	----	----	51
0.8 mile downstream from Wildcat Creek	OS9	4.1	1.9	2.9	4.1	----	----	65
County Road, 0.6 mile south of Logan	OS10	1.6	4.4	8.8	12.1	----	----	69

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (μg/L)	Discharge at sampling site (ft^3/s)
OUACHITA RIVER								
June 16, 1980								
Highway 79 at Camden	OU1	351.1	----	----	----	----	93	1,000
Frenchport Landing	OU2	340.1	11.0	30.2	35.6	13.0	9.0	1,300
Newport Landing	OU3	329.4	21.7	55.8	63.9	17.7	6.6	1,250
July 11, 1980								
Newport Landing	OU3	329.4	----	----	----	----	89	1,100
Highway 167 at Calion	OU4	309.9	19.5	95.5	101	----	2.3	1,880
June 16, 1980								
Highway 167 at Calion	OU4	309.9	----	----	----	----	105	1,500
Lock and Dam 8	OU5	298.5	11.4	41.3	61.2	42.7	1.7	1,350
Moro Bay Ferry (Highway 15)	OU6	287.4	22.5	79.1	99.2	43.4	1.5	1,200

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (µg/L)	Discharge at sampling site (ft^3/s)
OUACHITA RIVER--Continued								
June 17, 1980								
Moro Bay Ferry (Highway 15)	OU6	287.4	----	----	----	----	3.5	2,000
Careyville Landing	OU7	281.6	5.8	19.2	22.9	11.5	1.5	1,700
July 9, 1980								
Careyville Landing	OU7	281.6	----	----	----	----	450	1,800
Highway 82	OU8	252.9	28.7	175	201	----	1.2	3,000
June 16, 1980								
Highway 82	OU8	252.9	----	----	----	----	9.0	3,500
Abandoned Railroad Bridge	OU9	243.0	9.9	23.1	26.5	11.0	3.6	3,600

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (μg/L)	Discharge at sampling site (ft^3/s)
SMACKOVER CREEK								
August 18, 1980								
0.7 mile southwest of Joyce City	SM3	8.6	----	----	----	----	----	1.9
County Road, 0.4 mile south of Joyce City	SM4	8.0	0.6	10.9	18.0	----	----	1.9
July 2, 1981								
County Road, 2.1 miles southeast of Stephens	SM1	48.1	----	----	----	----	----	5
Highway 7 gage near Smackover	SM2	22.0	26.1	94.3	103	----	0.7	[1]45-700
July 2, 1981								
County Road, 2.1 miles southeast of Stephens	SM1	48.1	----	----	----	----	----	1.5
Highway 7 gage near Smackover	SM2	22.0	26.1	162	208	----	2.2	[1]16-107

[1] Rainfall occurred after injection of tracer

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (µg/L)	Discharge at sampling site (ft^3/s)
SPRING CREEK								
September 7, 1978								
Low-water bridge, 0.6 mile downstream from Springdale STP	SP1	0.6	5.5	----	----	----	----	----
Abandoned low-water bridge	SP2	4.3	1.2	1.5	1.7	----	14.5	19.6
County Road, 0.7 miles east of Highway 112	SP3	1.6	3.9	6.7	8.0	----	5.1	21.6
Highway 112, 1.4 miles south of Cave Springs	SP4	0.5	5.0	9.2	10.6	----	3.8	23.8

Table 1.--Traveltime data collected for streams in Arkansas--Continued

Location and Date	Site designation	Distance from mouth (miles)	Distance from first sampling site (miles)	Elapsed time leading edge (hours)	Elapsed time peak (hours)	Time of passage (hours)	Peak Observed Concentrations (µg/L)	Discharge at sampling site (ft^3/s)
				WEST TWO BAYOU				
Abandoned low-water	SP2	4.3	1.2	1.5	1.7	----	14.5	19.6
September 2, 1981								
International Paper Co. wier	WT1	4.9	----	----	----	----	----	12.4
New Sewer Outfall	WT2	4.0	0.9	3.3	4.4	3.5	93	19.4
Near Mouth	WT3	0.1	4.8	16.5	20.1	14.0	10.6	25.1
				WHITE RIVER				
October 6, 1980								
Shoal, 1.1 miles downstream from Fayetteville sewage outfall	WH1	681.8	----	----	----	----	310	8-15
2.9 miles downstream from Fayetteville sewage outfall	WH2	680.0	1.8	23.7	36.6	----	1.5	8-15
1.4 miles upstream from Highway 45 bridge	WH3	678.9	2.9	46.5	66.8	----	0.6	8-15