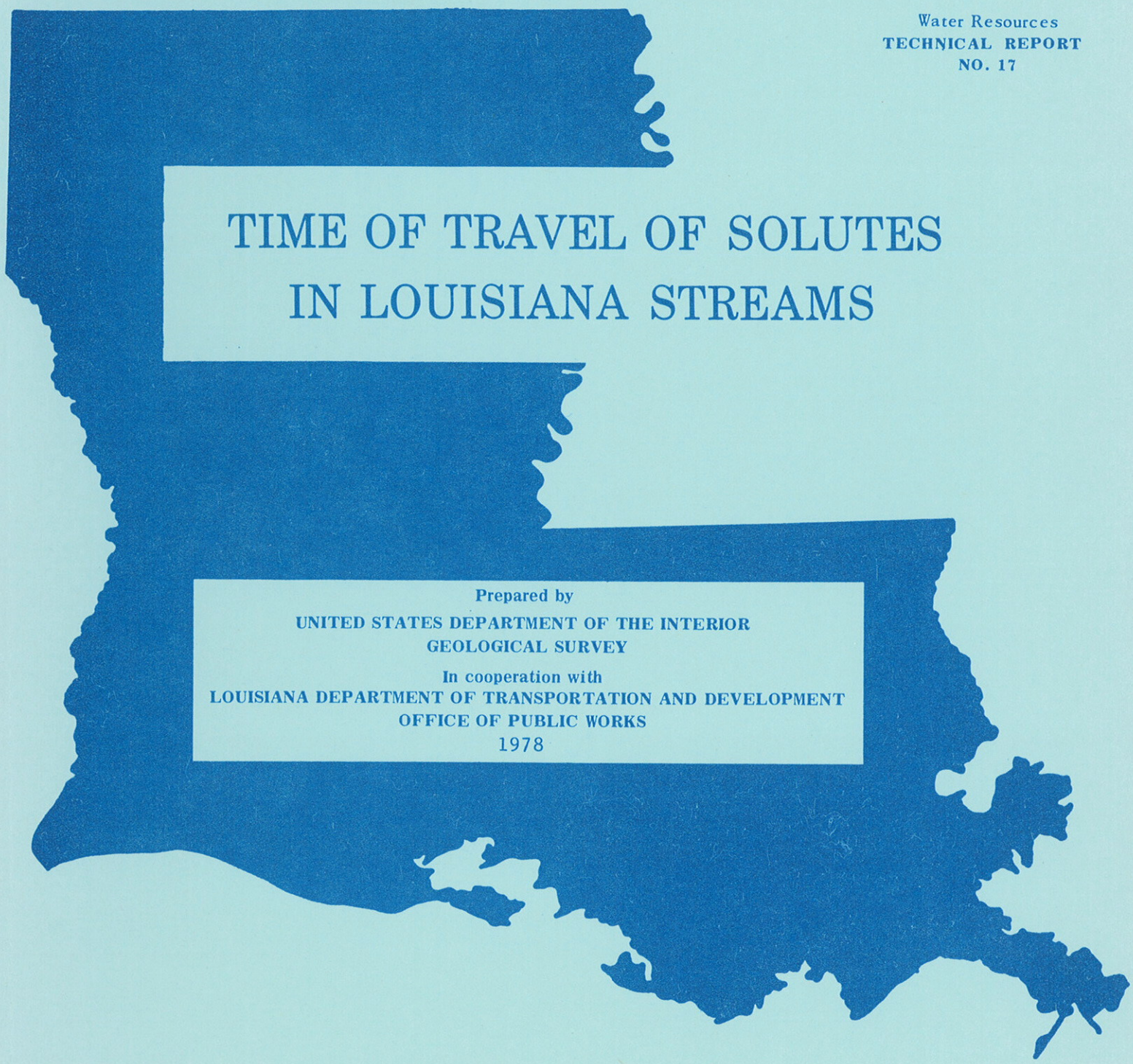
STATE OF LOUISIANA

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

OFFICE OF PUBLIC WORKS

Water Resources
TECHNICAL REPORT
NO. 17

TIME OF TRAVEL OF SOLUTES IN LOUISIANA STREAMS



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By

Anthony J. Calandro
U.S. Geological Survey

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EDWIN W. EDWARDS, Governor

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GEORGE FISCHER, Secretary

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ROY AGUILLARD, Assistant Secretary

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H. WILLIAM MENARD, Director

Louisiana District

A. N. CAMERON, Chief

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FACTORS FOR CONVERTING U.S. CUSTOMARY UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The analyses and compilations in this report were made with U.S. customary units of measurement. To convert U.S. customary units to metric units, the following conversion factors should be used:

Multiply U.S. customary units	By	To obtain metric units
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
	.02832	cubic meter per second (m^3/s)
foot (ft)	.3048	meter (m)
foot per second (ft/s)	.3048	meter per second (m/s)
mile (mi)	1.609	kilometer (km)
pound (lb)	.4536	kilogram (kg)
square mile (mi^2)	2.590	square kilometer (km^2)

TIME OF TRAVEL OF SOLUTES IN LOUISIANA STREAMS

By Anthony J. Calandro

ABSTRACT

Prediction of travel rates of water in streams is important for pollution studies and in the event of accidental spills of contaminants. This report summarizes the traveltime and dispersion of solutes in 18 streams in Louisiana that were measured by injecting a fluorescent water tracer. Nine of the eighteen streams were studied through a range of discharges. The relations of unit concentration and traveltime to discharge in these streams are presented graphically to enable prediction of the traveltimes for contaminants downstream from accidental spills.

In addition, standard multiple-linear regression techniques, relating traveltime and dispersion characteristics to basin parameters, were used to develop equations for estimating traveltimes, dispersion of solutes, and peak concentrations for ungaged streams in Louisiana.

All data collected for water-tracer studies of Louisiana streams are given in this report. Examples of use and application of the data and the predictive equations are also given.

INTRODUCTION

The possibility of accidental spills of contaminants are of concern to those using water from streams. This report provides a means for water managers to predict the time of travel, the maximum concentrations, and the duration of pollutants spilled in streams in Louisiana.

The purpose of this report is (1) to make available the results of the numerous time-of-travel measurements made on streams in Louisiana from 1968 to 1977, (2) to summarize graphically the observations of the rate of longitudinal dispersion for solutes in the streams, and (3) to present a regionalization of the data based on the 18 streams studied so that predictions can be made for the many unmeasured streams in Louisiana.

These studies were made by the U.S. Geological Survey in cooperation with the Louisiana Department of Transportation and Development, Office of Public Works.

The studies were made by injecting a known amount of fluorescent water tracer into the streams at selected sites and at selected flow rates. As the water tracer moved downstream, it was monitored at several points along the stream. Because traveltime varies with discharge, two or more measurements were made for different flow rates within the range expected to be equaled or exceeded 50 to 90 percent of the time.

The results of these studies apply only to pollutants and contaminants that are soluble in water. Additional considerations, outside the scope of this report, must be made for estimating traveltime of materials that are not soluble in water.

Figure 1 is a map of Louisiana showing the reaches along the streams where time-of-travel studies were made.

DATA-COLLECTION TECHNIQUES

A measured amount of fluorescent water tracer was injected in the center of each stream at the upper end of a reach. Traveltime was measured by observing the movement of the water-tracer cloud along the stream course. As fluorescence is related to concentration, a fluorometer was used to define the intensity of the tracer cloud as it moved downstream. Water samples were collected periodically at selected sites downstream during the duration of the cloud. Some samples were collected manually, and others by an automatic sampler located in the center of the stream. The discharge at each sampling site was determined from discharge measurements or from the stage-discharge relationship at a gaging station on the stream.

ANALYTICAL TECHNIQUE

The water samples were first analyzed in the field with a fluorometer to assure that samples were collected during the passage of the entire water-tracer cloud. The final analysis of each water sample was performed under laboratory conditions; the fluorometer was operated at a constant temperature, and all samples were analyzed at the same temperature. The fluorometer was calibrated using a set of standard solutions of known concentration. The standard dye solutions were made by a serial dilution process using distilled water and a sample of the tracer used in the injection. A time-concentration curve was drawn for each sampling site by plotting the concentration for each sample against the actual time when the sample was taken, and a smooth curve was drawn through the points.

PRESENTATION OF DATA

Traveltime was defined over a range of flows for nine streams by making two or more time-of-travel studies on each stream at different flow rates. One traveltime study was made for each of nine other streams. For convenience of the user, the traveltime for these streams was related to discharge at gaging stations rather than the discharge in the reach. In the event of an accidental spill the discharge can be obtained from a stage-discharge relationship for the gaging station, whereas the discharge in the reach would be more difficult to determine.

Traveltime data are presented graphically (figs. 2-10) for a range of discharges, with the traveltime characteristics of the tracer cloud shown in relation to the distance traveled. Traveltime for the leading edge, the peak concentration, and the trailing edge of the water-tracer cloud were taken from the time-concentration curves for each sampling site. All data collected for Louisiana streams are given in table 1.

For comparison of concentration data from two or more studies on the same stream, all observed concentrations were reduced to "unit concentration" using a method developed by F. A. Kilpatrick (written commun., 1970). For practical use, unit concentration is that concentration which would result at a point downstream from the injection of 1 lb of tracer into 1 ft^3/s of streamflow. Peak unit concentration versus traveltime is shown for 14 streams (figs. 2-15).

Time-of-travel curves for the Mississippi River from the Arkansas-Louisiana State line to Head of Passes (fig. 1) have been published in three separate reports (Martens and others, 1974; Calandro, 1976, 1977). The data on which those reports were based are included in this report.

EXAMPLE OF APPLICATION

A tank truck accidentally spills 1,000 lb of a soluble contaminant into the Amite River at Grangeville, located 88 mi above the river mouth. The traveltime and maximum concentration that can be expected near Denham Springs, located 54 mi above the river mouth, can be determined as follows:

1. Determine the discharge at Darlington and at Denham Springs. The U.S. Geological Survey can furnish the discharge from the stage-discharge relation for Darlington and Denham Springs. For this example, assume that the discharges for Darlington and Denham Springs are 235 and 360 ft^3/s, respectively.

2. To determine the peak traveltime: Enter figure 2B with the discharge at Darlington (235 ft^3/s) because the curves in figure 2 are referenced to Darlington. The traveltime from Darlington to Grangeville is 40 hours, and to Denham Springs is 102 hours. Therefore, the traveltime of the peak concentration from spill

at Grangeville to Denham Springs is 62 hours (102 minus 40). Estimates for the leading edge and trailing edge of the contaminate can also be made using figure 2A and 2C, respectively.

3. To determine the maximum concentrations: Unit concentration (C_u) is defined as the concentration, in micrograms per liter, produced in 1 ft^3/s of streamflow due to the injection of 1 lb of contaminant. It may be computed by the equation

$$C_u=\frac{C_{max}Q}{W}$$

where C_{max}=maximum peak concentration, in micrograms per liter;
W=pounds of contaminant injected; and
Q=discharge, in cubic feet per second, at point of interest.

Once this relationship is defined for a stream, peak concentrations at any point and for a range of discharges may be computed by the equation

$$C_{max}=\frac{C_uW}{Q}.$$

From figure 2D, C_u is 315 µg/L (micrograms per liter) for an elapsed time of 62 hours. Therefore, the maximum concentration expected near Denham Springs is 875 µg/L ($C_{max}=\frac{1,000x315}{360}$).

TIME OF TRAVEL, DISPERSION OF SOLUTES, AND PEAK CONCENTRATIONS ON UNGAGED STREAMS

The equations presented in this section can be used to estimate the traveltimes, dispersion of solutes, and peak concentrations in streams in Louisiana for which data are not available. The equations were developed by relating the traveltime and dispersion characteristics to the basin parameters of the streams measured. The equations can be used for all unregulated streams in Louisiana that have drainage areas of less than 2,000 mi^2.

Standard multiple linear-regression techniques were used to determine the relation of basin parameters to the stream characteristics. The regression analysis was made using four independent variables: discharge, length of reach, slope, and drainage area. The order in which these variables entered the step forward regression computation was length, discharge, drainage area, and slope. Regression analysis controls (F-levels) were set to allow entry and retention of all variables. The length-discharge combination produced the greatest reduction in standard error of estimate. Drainage area improved the standard error of estimate enough to be included. Slope did not decrease the standard error of estimate and was not included in the equations.

Equations listed below were developed by the multiple-regression analyses. The standard error of estimate for each equation is also shown.

Equation	Standard error of estimate, in percent
$TL=5.49 \frac{L^{1.028} A^{0.291}}{Q^{0.556}}$	27
$TP=7.01 \frac{L^{0.984} A^{0.0291}}{Q^{0.553}}$	25
$TT=9.38 \frac{L^{0.941} A^{0.287}}{Q^{0.543}}$	27
$C_u=2,480 \frac{Q^{0.530}}{A^{0.503} L^{0.729}}$	39

In the above equations

TL=traveltime of the leading edge, in hours;
TP=traveltime of the peak concentration, in hours;
TT=traveltime of the trailing edge, in hours;
C_u=peak unit concentration, in $\left(\frac{\text{micrograms per liter times cubic feet per second}}{\text{pounds}}\right)$;
L=reach length, in miles;
Q=discharge, in cubic feet per second; and
A=drainage area, in square miles.

The following is an example computation of the traveltime for a theoretical spill in an unmeasured stream. A tank truck accidentally spills 1,000 lb of a soluble contaminant into the Bogue Chitto near Clifton, located 51 mi above the river mouth. The traveltime and maximum concentration that can be expected at Franklinton, located 40 mi above the mouth, can be estimated as follows:

1. Determine the discharge (Q) at Franklinton from a current-meter measurement or from a stage-discharge relationship. (Assume the discharge at Franklinton is 500 ft^3/s).

2. Determine the length of reach (L), in miles, from Geological Survey 15-minute topographic maps. Length of reach (L) is 11 mi (51 minus 40 mi).

3. Determine the drainage area at Franklinton from Sloss (1971) or from Geological Survey topographic maps. In this case the drainage area is 985 mi^2.

4. By substituting these variables in the equations developed by the multiple-regression analyses,

$$\text{Traveltime of the leading edge (TL)} = 5.49\,\frac{(11)^{1.028}(985)^{0.291}}{(500)^{0.556}} = 15 \text{ hours};$$

$$\text{Traveltime of the peak concentration (TP)} = 7.01\,\frac{(11)^{0.984}(985)^{0.291}}{(500)^{0.553}} = 18 \text{ hours};$$

$$\text{Traveltime of the trailing edge (TT)} = 9.38\,\frac{(11)^{0.941}(985)^{0.287}}{(500)^{0.543}} = 22 \text{ hours};$$

and

$$\text{Peak unit concentration } (C_u) = 2{,}480\left[\frac{(500)^{0.530}}{(985)^{0.503}(11)^{0.729}}\right] = 363 \text{ µg/L}.$$

5. Compute the maximum peak concentration at Franklinton:

$$C_{max} = \frac{363 \times 1{,}000}{500} = 726 \text{ µg/L}.$$

The equations for determining the traveltime of the leading edge, peak concentration, and trailing edge and for determining the peak unit concentration have been reduced to graphical form, as shown in figures 16, 17, 18, and 19, respectively. To illustrate the use of the nomographs the preceding example is used. Enter the figures with drainage area (985 mi^2). Draw a straight line to the reach length (11 mi). At the point where this line intercepts the match line, draw a straight line to the discharge (500 ft^3/s) along the bottom line. The traveltime of the leading edge, peak concentration, and trailing edge and the peak unit concentration can be read (in figs. 16, 17, 18, and 19, respectively) where this line intercepts the fourth line from the top. The following results were obtained for this example:

1. From figure 16, TL=15 hours.
2. From figure 17, TP=18 hours.
3. From figure 18, TT=22 hours.
4. From figure 19, C_u=363 µg/L.

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Table 1.–Time-of-travel data collected for streams in Louisiana

Location	Sampling data											Discharge data							
	River mile	Distance (mi)	Elapsed time leading edge (hrs)	Elapsed time peak (hrs)	Velocity leading edge (ft/s)	Velocity peak (ft/s)	Duration (hrs)	Peak observed concentration (µg/L)	Area of time-concentration curve (µg/L-hrs)	Dye detected (percent)	Peak conservative concentration (µg/L)	Unit concentration $\frac{(\mu g/L \times ft^3/s)}{lb}$	Drainage area (mi^2)	Discharge (ft^3/s)	Flow duration (percent)	Mean depth (ft)	Maximum depth (ft)	Mean velocity (ft/s)	Maximum velocity (ft/s)	Channel width (ft)
AMITE RIVER																			
(Injection site, Liberty, Miss.; lat 31°05'55", long 90°43'10"; river mile 121.0; date, 3-30-68; time, 1730)																			
Darlington, La	106.0	25.0	26.5	36.0	1.38	1.02	25.0	2.40	25.4	42.0	5.70	429	580	388	53	1.7	----	2.58	3.26	88.0
(Injection site, Grangeville, La.; lat 30°44'10", long 90°50'30"; river mile 88.2; date, 4-1-68; time, 0800)																			
Magnolia, La	61.5	26.7	26.0	30.0	1.51	1.31	16.8	11.0	91.9	63.0	17.5	531	884	510	--	----	----	----	----	----
Denham Springs, La	53.8	34.4	35.0	41.0	1.26	1.03	16.8	7.40	63.2	51.0	14.6	520	1,280	600	65	2.2	----	1.77	2.48	153
(Injection site, Darlington, La.; lat 30°52'20", long 90°50'40"; river mile 106.0; date, 4-1-68; time, 0900)																			
Grangeville, La	88.2	17.8	23.0	26.5	1.16	.99	19.5	7.20	56.2	65.0	111	568	741	488	--	4.6	----	1.25	2.09	85.0
(Injection site, La. Highway 432 near Felixville, La.; lat 30°56'43", long 90°51'34"; river mile 112.3; date, 10-21-68; time, 0845)																			
Darlington, La	106.0	6.3	11.0	13.9	.84	.66	9.4	40.0	172	82.0	48.8	1,030	580	200	99	1.7	----	1.78	2.50	70.0
Grangeville, La	88.2	24.1	46.6	57.5	.73	.60	34.2	5.10	82.2	51.0	10.0	273	741	260	--	----	----	----	----	----
Magnolia, La	61.5	50.8	92.0	107	.86	.79	52.0	2.36	55.2	41.0	5.80	190	884	315	--	----	----	----	----	----
Denham Springs, La	53.8	58.5	105	124	.59	.48	67.0	1.96	57.0	47.0	4.20	201	1,280	350	96	1.7	----	1.84	2.07	151
ATCHAFALAYA RIVER																			
(Injection site, above Simmesport, La.; lat 31°02'35", long 91°43'25"; river mile -2.0; date, 8-26-75; time, 1100)																			
Simmesport, La	5.0	7.0	3.00	3.33	3.42	3.08	1.5	------	--------	-----	------	-----	137,000		--	----	----	----	----	----
Melville, La	30.0	32.0	15.7	17.0	2.99	2.76	----	------	--------	-----	------	-----	137,000		--	----	----	----	----	----
Krotz Springs, La	42.0	44.0	23.3	26.3	2.77	2.45	10.0	1.86	10.6	-----	------	796	137,000		65	----	----	----	----	----
Whiskey Bay Pilot Channel	74.0	76.0	46.0	53.0	2.42	2.10	19.0	1.15	11.2	-----	------	454	120,000		--	----	----	----	----	----
Myette Point	95.0	97.0	58.0	65.5	2.45	2.17	22.0	1.06	10.8	-----	------	430	129,000		--	----	----	----	----	----
Wax Lake Outlet	-----	-----	74.0	82.0	----	----	23.0	.68	8.90	-----	------	339	44,600		--	----	----	----	----	----
Morgan City, La	118.0	120.0	74.5	89.0	2.36	1.98	26.5	.58	8.81	-----	------	292	107,000		--	----	----	----	----	----
Below Morgan City, La	125.0	127.0	77.0	92.0	2.42	2.02	27.0	.68	6.71	-----	------	331	107,000		--	----	----	----	----	----
BAYOU ANACOCO																			
(Injection site, Rosepine, La.; lat 30°57'10", long 93°21'10"; river mile 23.6; date, 6-15-69; time, 2030)																			
Parish road	16.5	7.1	16.8	20.0	0.62	0.52	7.0	34.2	116	78.0	43.7	1,310	399	71.1	--	1.1	----	1.34	----	80.0
Mile 9.2	9.2	14.4	37.5	43.0	.51	.47	13.2	12.8	81.9	80.0	16.0	696	410	90.7	--	----	----	----	----	----
La. Highway 111	5.1	18.5	47.5	52.7	.60	.62	14.0	9.80	69.1	65.0	15.0	633	425	95.8	--	1.9	----	.77	1.14	65.0
Mouth	.0	23.6	62.5	68.7	.50	.47	15.0	7.80	60.4	56.0	13.9	573	441	115	--	----	----	----	----	----
(Injection site, Rosepine, La.; lat 30°57'10", long 93°21'10"; river mile 23.6; date, 1-10-70; time, 0900)																			
Parish road	16.5	7.1	6.80	7.80	1.53	1.34	2.2	18.0	17.1	71.0	25.4	4,680	399	440	--	----	----	----	----	----
La. Highway 111	5.1	18.5	18.2	20.7	1.47	1.30	4.2	7.40	14.9	69.0	10.7	2,200	425	471	--	3.0	----	1.39	1.90	122
Mouth	.0	23.6	23.2	25.0	1.50	1.74	4.8	6.50	15.3	70.0	9.30	1,880	441	480	--	----	----	----	----	----
(Injection site, Rosepine, La.; lat 30°57'10", long 93°21'10"; river mile 23.6; date, 1-16-70; time, 2200)																			
Parish road	16.5	7.1	8.30	9.30	1.27	1.12	2.5	12.1	14.4	74.0	16.4	3,700	399	260	--	4.7	----	.87	1.35	68.0
La. Highway 111	5.1	18.5	22.4	24.6	1.18	1.09	4.4	7.00	12.6	74.0	9.50	2,460	425	304	--	----	----	----	----	----
At mouth	.0	23.6	27.8	30.5	1.37	1.27	5.5	3.90	10.6	61.0	6.40	1,650	441	315	--	----	----	----	----	----
BAYOU BARTHOLOMEW																			
(Injection site, above Jones, La.; lat 33°00'26", long 91°37'36"; river mile 73.0; date, 6-21-71; time, 0830)																			
Jones, La	71.0	2.0	4.50	5.75	0.65	0.51	4.0	81.0	150	78.0	104	2,390	1,187	165	89	3.8	----	0.50	----	75.0
Green Grove, La	57.0	16.0	52.0	61.5	.43	.37	19.0	14.4	137	76.4	18.9	467	1,286	157	--	----	----	----	----	----
Beekman, La	36.0	37.0	108	123	.55	.50	31.0	6.80	101	82.5	8.20	299	1,645	230	72	2.4	----	1.00	----	96.0
Mouth	.0	73.0	198	216	.58	.49	42.0	3.20	69.1	70.4	4.60	206	1,665	286	--	6.8	----	.34	----	128

BIG CREEK

(Injection site, U.S. Highway 167 near Dry Prong, La.; lat 31°34'12", long 92°31'34"; river mile 25.0; date, 4-10-72; time, 1423)

Dry Prong, La	24.0	1.0	3.50	4.92	0.42	0.30	4.0	125	250	89.2	140	2,220	6	2.50	--	0.5	----	0.49	0.72	10.0
Pollock, La	13.0	12.0	80.2	87.5	.21	.20	21.8	1.36	14.6	43.9	3.10	413	51	21.0	68	1.0	----	.60	----	40.0

(Injection site, pumping plant at Pollock, La.; lat 31°31'40", long 92°23'48"; river mile 13.0; date, 4-11-72; time, 1022)

La. Highway 8 at Fishville, La	7.0	6.0	10.0	11.8	.88	.75	4.0	18.5	37.0	68.8	26.9	2,220	66	32.5	--	1.6	----	1.07	1.29	26.0
Mouth	.0	13.0	42.5	49.0	.32	.28	36.5	1.50	29.1	66.3	2.26	229	77	40.0	--	----	----	----	----	----

CALCASIEU RIVER

(Injection site, Kinder, La.; lat 30°30'42", long 92°52'07"; river mile 96.5; date, 2-18-70; time, 0700)

Kinder, La	90.0	4.5	5.25	5.80	1.26	1.14	2.0	86.0	86.9	100	86.0	4,390	1,700	796	58	2.7	----	1.57	----	188
Hecker, La	66.0	28.5	40.0	45.5	1.01	.89	15.0	5.10	32.7	71.9	7.10	692	2,070	1,130	--	14.0	----	.54	----	149
Lake Charles, La	50.0	44.5	167	181	.14	.13	43.0	.27	12.3	-----	.28	98	2,310	----------	--	----	----	----	----	-----

(Injection site, Glenmora, La.; lat 30°59'54", long 92°40'25"; river mile 149.0; date, 2-18-70; time, 0900)

Oakdale, La	132.0	17.0	37.0	41.0	.67	.61	11.0	7.80	44.5	69.2	11.3	779	610	250	--	----	----	----	----	-----
Oberlin, La	108.6	40.4	78.0	84.5	.84	.79	24.0	2.90	30.9	49.2	5.80	418	753	293	53	1.9	----	1.76	----	94.0
Kinder, La	90.0	59.0	104	112	1.03	.99	25.0	1.40	15.5	58.1	2.40	399	1,700	690	62	2.3	----	1.50	----	190

(Injection site, Glenmora, La.; lat 30°59'54", long 92°40'25"; river mile 149.0; date, 9-27-70; time, 1845)

Oakdale, La	132.0	17.0	59.0	64.2	.42	.39	14.5	15.0	108	65.8	22.8	615	610	85.0	--	----	----	----	----	-----
Oberlin, La	108.6	40.4	117	129	.59	.53	32.0	4.30	58.2	38.2	11.2	328	753	92.0	79	1.7	----	.80	----	67.0
Kinder, La	90.0	59.0	158	170	.67	.67	32.5	1.40	23.0	58.0	2.40	271	1,700	350	87	1.6	----	1.17	----	183

(Injection site, Kinder, La.; lat 30°30'42", long 92°52'07"; river mile 96.5; date, 9-28-70; time, 0845)

Kinder, La	90.0	4.5	7.25	8.50	.91	.76	3.0	42.0	59.0	100	-------	3,160	1,700	750	60	3.9	----	1.06	----	180
Hecker, La	66.0	28.5	44.0	50.0	.80	.85	22.0	5.00	37.8	84.2	5.90	587	2,070	799	--	12.7	----	.39	----	162
Lake Charles, La	50.0	44.5	222	-------	.11	----	----	.28	--------	-----	-------	-----	2,310	----------	--	----	----	----	----	-----

COMITE RIVER

(Injection site, La. Highway 10 near Clinton, La.; lat 30°51'30", long 91°02'20"; river mile 46.3; date, 4-1-68, time, 1100)

Olive Branch, La	33.8	12.5	50.2	55.4	0.37	0.33	12.0	21.6	125	67.0	32.3	768	145	69.0	62	1.4	----	1.41	1.83	36.0
Fred, La	20.7	25.6	56.5	63.5	3.05	2.37	16.5	11.8	87.2	51.0	23.1	601	230	75.0	--	----	----	----	----	-----
Comite Drive, Baton Rouge, La	13.0	33.3	67.5	75.6	1.03	.93	20.1	9.20	79.9	56.0	16.4	511	245	90.0	--	----	----	----	----	-----

(Injection site, Fred, La.; lat 30°38'36", long 91°05'40"; river mile 20.7; date, 4-2-68; time, 0730)

I.C. RR. bridge near Baton Rouge, La	1.5	19.2	24.0	28.0	1.17	1.00	9.5	34.8	154	69.0	50.4	1,000	332	105	--	----	----	----	----	-----

(Injection site, Clinton, La.; lat 30°53'26", long 91°03'16"; river mile 50.5, date, 11-4-68; time, 0700)

La. Highway 10 near Clinton, La	46.3	4.2	20.0	23.7	.31	.26	7.6	204	703	100	204	1,290	87	27.0	--	1.6	----	.83	1.80	20.0
Olive Branch, La	33.8	16.7	80.0	87.2	.31	.29	18.0	31.8	307	59.9	53.1	459	145	32.0	99	.9	----	.94	1.15	38.0
Fred, La	20.7	29.8	103	110	.84	.84	23.0	18.4	196	43.2	42.7	417	230	36.1	--	.7	----	1.25	1.28	65.0
Comite Drive, Baton Rouge, La	13.0	37.5	113	121	1.13	1.03	29.0	13.8	169	41.4	33.4	363	245	40.0	--	.8	----	1.12	----	38.0
I.C. RR. bridge above mouth	1.5	49.0	132	141	.89	.84	36.6	7.20	109	23.4	30.7	293	332	35.1	--	.8	----	.96	1.54	43.0

DUGDEMONA RIVER

(Injection site, U.S. Highway 167 near Winnfield, La.; lat 31°58'30", long 92°39'10"; river mile 45.0; date, 4-27-71; time, 2200)

U.S. Highway 84 near Winnfield, La	38.0	7.0	44.5	52.0	0.23	0.20	17.0	9.70	79.7	64.0	15.2	541	654	56.0	60	2.1	----	0.79	----	34.0
Rochelle, La	12.0	33.0	168	187	.23	.20	40.0	2.90	64.6	52.0	5.60	199	936	56.0	--	----	----	----	----	-----

MISSISSIPPI RIVER

(Injection site, Baton Rouge, La.; lat 39°26'20", long 91°11'56"; river mile 229.2; date, 9-15-65; time, 2030)

Plaquemine, La	208.0	21.2	10.5	12.0	2.96	2.59	6.8	7.50	19.0	63.0	11.9	1,570	1,129,830	240,000	30	----	----	----	----	-----
Sunshine Bridge	167.5	61.7	36.7	41.0	2.27	2.06	13.0	2.40	17.0	56.0	4.30	567	1,129,860	240,000	30	----	----	----	----	-----
Reserve, La	138.2	91.0	55.4	62.5	2.30	2.00	18.0	1.80	14.9	49.0	3.70	462	1,129,880	240,000	30	----	----	----	----	-----
New Orleans, La	102.8	126.4	83.0	91.0	1.88	1.82	22.0	1.30	14.8	49.0	2.65	365	1,129,910	240,000	30	----	----	----	----	-----

(Injection site, Baton Rouge, La.; lat 30°26'20", long 91°11'56"; river mile 229.2; date, 8-11-69; time, 0705)

Sampling site 1	219.0	10.2	3.50	4.17	4.27	3.59	1.5	15.2	--------	-----	------	-----	1,129,810	364,000	50	----	----	----	----	-----
Sampling site 2	215.0	14.2	5.15	6.00	3.56	3.21	2.0	12.7	--------	-----	------	-----	1,129,810	364,000	50	----	----	----	----	-----

Table 1.–Time-of-travel data collected for streams in Louisiana–Continued

Location	Sampling data											Discharge data							
	River mile	Distance (mi)	Elapsed time leading edge (hrs)	Elapsed time peak (hrs)	Velocity leading edge (ft/s)	Velocity peak (ft/s)	Duration (hrs)	Peak observed concentration (µg/L)	Area of time-concentration curve (µg/L-hrs)	Dye detected (percent)	Peak conservative concentration (µg/L)	Unit concentration $\frac{(\mu g/L \times ft^3/s)}{lb}$	Drainage area (mi^2)	Discharge (ft^3/s)	Flow duration (percent)	Mean depth (ft)	Maximum depth (ft)	Mean velocity (ft/s)	Maximum velocity (ft/s)	Channel width (ft)
MISSISSIPPI RIVER--Continued																			
(Injection site, Baton Rouge, La.; lat 30°26'20", long 91°11'56"; river mile 229.2; date, 8-11-69; time, 0705)--Continued																			
Sampling site 3	212.0	17.2	6.70	7.50	2.86	2.93	2.7	4.80	5.88	95.0	5.06	3,600	1,129,820	360,000	50	----	----	----	----	----
Plaquemine, La., ferry	208.0	21.2	8.40	9.40	3.45	3.09	3.8	3.60	5.82	94.0	3.83	2,750	1,129,830	360,000	50	----	----	----	----	----
Donaldsonville, La	167.5	61.7	28.5	32.0	2.96	2.63	10.0	1.05	5.94	88.0	1.20	840	1,129,860	330,000	50	----	----	----	----	----
Reserve, La	138.2	91.2	45.5	51.0	2.54	2.27	15.0	.75	6.24	87.0	.86	535	1,129,880	310,000	50	----	----	----	----	----
New Orleans, La	102.8	126.2	68.0	75.0	2.28	2.14	18.0	.63	6.57	85.5	.74	426	1,129,910	290,000	50	----	----	----	----	----
(Injection site, Baton Rouge, La.; lat 30°25'20", long 91°12'00"; river mile 228.0; date, 4-24-74; time, 0900)																			
Addis, La. (site 1)	224.0	4.0	1.05	1.05	5.57	5.57	.2	135	---------	-----	------	-----	1,129,810	792,000	85	----	----	----	----	----
Landwood, La. (site 2)	219.0	9.0	2.25	2.30	5.86	5.72	.5	13.2	---------	-----	------	-----	1,129,810	792,000	85	----	----	----	----	----
Burtville, La. (site 3)	212.0	16.0	4.00	4.25	5.86	5.52	2.0	8.50	---------	-----	------	-----	1,129,820	792,000	85	----	----	----	----	----
Plaquemine, La., ferry	208.0	20.0	5.00	5.75	5.86	5.20	2.0	4.40	4.27	95.0	4.63	4,580	1,129,830	792,000	85	----	----	----	----	----
Sunshine Bridge	167.8	60.2	16.5	19.5	5.34	4.53	7.0	1.00	4.00	89.0	1.12	1,110	1,129,860	792,000	85	----	----	----	----	----
Reserve, La	138.2	90.0	25.0	28.5	5.27	4.62	8.5	.82	4.13	92.0	.89	864	1,129,880	792,000	85	----	----	----	----	----
New Orleans, La	102.8	125.0	35.5	39.5	5.16	4.64	11.0	.65	3.97	88.0	.76	724	1,129,910	792,000	85	----	----	----	----	----
Belle Chasse, La	76.0	152.0	44.5	48.5	5.00	4.60	11.0	.58	3.86	86.0	.68	663	1,129,930	792,000	85	----	----	----	----	----
Pointe a la Hache, La	49.0	179.0	53.0	58.0	4.95	4.53	15.0	.49	4.02	90.0	.54	537	1,129,940	792,000	85	----	----	----	----	----
(Injection site, Vicksburg, Miss.; lat 31°21'00", long 90°58'50"; river mile 442.0; date, 7-22-75; time, 0900)																			
Vicksburg, Miss	438.0	4.0	1.50	1.50	3.91	3.91	.5	270	---------	-----	------	-----	1,144,400	410,000	42	----	----	----	----	----
Below Vicksburg, Miss	434.0	4.0	2.50	2.75	5.87	4.69	1.5	33.2	---------	-----	------	-----	1,144,400	410,000	42	----	----	----	----	----
At Togo Landing, Miss	418.0	16.0	7.75	9.25	3.35	2.71	4.2	2.20	4.70	87.0	5.40	2,130	1,145,000	410,000	42	----	----	----	----	----
Natchez, Miss	363.0	79.0	26.5	31.0	4.93	4.25	15.5	.53	4.70	90.0	5.20	500	1,149,400	423,000	42	----	----	----	----	----
Old River Control Structure	314.0	128.0	46.0	53.0	3.69	3.27	23.0	.36	4.00	78.0	5.10	400	1,128,700	423,000	42	----	----	----	----	----
(Injection site, Old River Control Structure; lat 31°04'50", long 31°35'00"; river mile 314.0; date, 7-23-75; time 0900)																			
Old River lock	305.0	9.0	3.50	3.75	3.77	3.52	1.5	21.0	---------	-----	------	-----	1,128,700	350,000	45	----	----	----	----	----
Tunica, La	294.0	20.0	8.00	9.00	3.59	3.07	3.0	4.40	---------	-----	------	-----	1,129,000	350,000	45	----	----	----	----	----
St. Francisville, La	266.0	48.0	17.0	19.5	4.56	3.91	8.5	.94	4.20	93.0	4.50	1,150	1,129,400	350,000	45	----	----	----	----	----
Baton Rouge, La	229.0	85.0	33.0	37.0	3.39	3.10	13.0	.59	3.90	89.0	4.40	680	1,129,810	350,000	45	----	----	----	----	----
Plaquemine, La	208.0	106.0	44.0	48.5	2.80	2.68	15.0	.46	3.50	77.0	4.50	590	1,129,830	350,000	45	----	----	----	----	----
(Injection site, below Greenville, Miss.; lat 33°11'20", long 91°05'30"; river mile 522.8; date, 7-29-75; time 1000)																			
Chatham, Miss	517.0	5.8	1.50	1.50	5.67	5.67	.7	140	---------	-----	------	-----	1,130,700	391,000	40	----	----	----	----	----
Cracraft Landing, Miss	511.4	11.4	3.00	3.25	5.48	4.69	3.0	14.4	---------	-----	------	-----	1,130,730	391,000	40	----	----	----	----	----
Arkansas-Louisiana State line	507.0	15.8	4.00	4.67	6.45	4.54	3.0	10.6	---------	-----	------	-----	1,130,740	391,000	40	----	----	----	----	----
Fitler, Miss	476.5	48.3	14.0	15.0	4.77	4.61	12.0	.62	2.90	87.0	.71	938	1,130,750	395,000	40	----	----	----	----	----
Vicksburg, Miss	434.0	88.8	28.5	32.5	4.10	3.39	16.5	.46	3.10	92.0	.50	650	1,144,400	399,000	40	----	----	----	----	----
(Injection site, Belle Chase, La.; lat 29°51'45", long 89°58'35"; river mile 77.0; date, 4-27-76; time, 1100)																			
Greenwood, La	70.0	7.0	3.08	4.05	3.33	2.53	2.2	9.15	---------	-----	------	-----	1,129,930	466,000	60	----	----	----	----	----
Burbridge, La	61.0	16.0	8.25	10.0	2.55	2.22	4.0	3.43	---------	-----	------	-----	1,129,930	466,000	60	----	----	----	----	----
Pointe a la Hache, La	49.0	28.0	14.5	17.0	2.82	2.51	6.5	1.40	4.50	94.3	4.80	1,380	1,129,940	466,000	60	----	----	----	----	----
Pilottown, La	2.0	75.0	43.5	54.5	2.37	1.84	11.0	.87	5.50	-----	------	754	1,129,970	471,000	60	----	----	----	----	----
NEW RIVER																			
(Injection site, near Geismar, La.; lat 30°12'50", long 91°02'15"; river mile 26.1; date, 4-3-74; time, 0900)																			
La. Highway 30 near Geismar, La	24.5	1.6	10.5	13.5	0.22	0.17	9.0	220	955	100	220	-----	----------	4.90	--	----	----	----	----	----
Near Gonzales, La	17.7	8.4	36.5	60.5	.34	.20	41.5	47.5	422	-----	------	-----	----------	3.70	--	----	----	----	----	----
At Gonzales, La	16.4	9.7	126	------	.11	----	----	------	---------	-----	------	-----	----------	----------	--	----	----	----	----	----
At Gonzales, La	16.0	10.1	148	------	.10	----	----	------	---------	-----	------	-----	----------	----------	--	----	----	----	----	----
At Gonzales, La	15.6	10.5	169	------	.09	----	----	------	---------	-----	------	-----	----------	----------	--	----	----	----	----	----
At Gonzales, La	15.3	10.8	194	------	.08	----	----	------	---------	-----	------	-----	----------	----------	--	----	----	----	----	----

At Gonzales, La	15.0	11.1	217	------	.08	----	----	------	--------	-----	------	-----	----------	----------	--	----	----	----	----	-----
At Gonzales, La	14.7	11.4	241	------	.07	----	----	------	--------	-----	------	-----	----------	----------	--	----	----	----	----	-----

OUACHITA RIVER

(Injection site, above lock 6; lat 33°03'12", long 92°06'30"; river mile 185.8; date, 7-7-71; time, 1400)

Fedsenthal, Ark	182.8	3.0	13.0	25.0	0.34	0.18	20.5	2.20	20.0	65.0	3.40	489	10,787	1,450	--	----	----	----	----	-----

(Injection site, above Sterlington, La.; lat 32°46'37", long 92°03'08"; river mile 156.5; date, 7-7-71; time, 1725)

Sterlington, La	151.3	5.2	17.0	23.0	.45	.33	17.0	2.40	21.6	82.8	3.70	492	12,948	1,700	--	----	----	----	----	-----

PEARL RIVER

(Injection site, 7 mi above Bogalusa, La.; lat 30°51'01", long 89°47'18"; river mile 84.8; date, 5-20-70; time, 0845)

Bogalusa, La	77.5	7.3	5.50	6.50	1.95	1.65	3.0	18.8	29.2	90.0	20.9	2,850	6,630	4,100	51	8.5	----	1.62	2.36	292
West at U.S. Highway 11	22.2	62.6	46.5	50.5	1.98	1.84	12.8	2.00	11.7	49.0	4.10	757	8,450	5,380	--	15.1	----	1.18	2.05	301
East at U.S. Highway 11	27.4	57.4	68.8	74.0	1.16	1.09	24.0	1.20	13.8	12.0	10.0	386	140	112	--	9.2	----	.08	.19	146
West at I-10	14.3	70.5	54.8	62.0	1.40	1.01	26.5	1.70	16.9	62.0	2.70	450	8,560	5,380	--	----	----	----	----	-----
Middle at I-10	13.3	71.5	59.5	64.0	1.74	1.64	30.5	1.30	11.6	-----	------	497	---------	---------	--	----	----	----	----	-----

(Injection site, 7 mi above Bogalusa, La.; lat 30°51'01", long 89°47'18"; river mile 84.8; date, 7-21-70; time, 0715)

Bogalusa, La	77.5	7.3	6.50	7.50	1.65	1.43	3.0	15.4	25.0	66.0	23.3	2,730	6,630	2,350	76	4.9	----	1.55	1.86	293
Pools Bluff, La	65.3	19.5	19.0	22.0	1.43	1.23	6.2	6.00	19.1	-----	------	1,390	6,690	2,700	--	----	----	----	----	-----
Stewarts Bluff, La	41.0	43.8	39.5	42.0	1.74	1.78	9.5	3.00	14.7	-----	------	906	8,000	3,500	--	----	----	----	----	-----
West at U.S. Highway 11	22.2	62.6	52.0	60.5	2.20	1.49	21.0	1.30	11.0	35.0	3.70	526	8,450	4,060	--	9.1	----	1.22	1.48	365
West at I-10	14.3	70.5	64.0	72.0	1.60	1.30	16.0	.92	7.70	-----	------	530	8,560	4,000	--	----	----	----	----	-----
East at U.S. Highway 11	27.4	57.4	81.0	85.5	.48	.46	15.3	.34	2.30	10.0	------	657	140	404	--	9.4	----	.29	.50	148
Middle at I-10	13.3	71.5	69.5	76.0	1.35	1.20	23.0	.90	8.70	-----	------	460	---------	---------	--	----	----	----	----	-----

RED RIVER

(Injection site, above Grand Ecore, La.; lat 31°51'00", long 93°05'36"; river mile 187.5; date, 4-7-71; time, 0715)

Grand Ecore, La	184.0	3.5	2.25	2.50	2.23	2.05	1.8	21.0	19.9	74.2	28.3	4,690	64,575	8,310	--	15.8	----	1.02	----	514
Colfax, La	140.5	47.0	29.0	33.5	2.38	2.05	10.2	4.00	19.2	74.8	5.34	924	66,860	8,660	--	----	----	----	----	-----
Alexandria, La	105.0	82.5	54.0	60.0	2.05	1.97	14.8	2.50	17.8	70.4	3.55	623	67,500	8,810	69	----	----	----	----	-----
La. Highway 115 near Moncla, La	67.5	120.0	84.8	92.5	1.79	1.69	20.0	1.50	15.6	61.0	2.46	427	67,625	8,810	--	5.3	----	2.00	----	832

(Injection site, above Shreveport, La.; lat 32°32'52", long 93°45'17"; river mile 283.0; date, 4-14-71; time, 0805)

Shreveport, La	278.0	5.0	3.00	3.67	2.44	1.99	2.8	21.0	30.0	100	------	3,100	60,613	4,930	75	4.3	----	1.68	2.20	687
Lachute, La	249.0	34.0	27.5	32.0	1.73	1.50	13.5	3.20	21.3	78.5	4.10	668	60,654	4,930	--	----	----	----	----	-----
Coushatta, La	219.0	64.0	48.0	52.0	2.15	2.20	15.5	2.50	18.4	83.2	3.00	614	63,362	6,030	74	----	----	----	----	-----
Grand Ecore, La	184.0	99.0	79.0	87.5	1.65	1.45	19.0	1.50	15.9	77.3	1.90	416	64,575	6,530	--	13.0	----	.94	----	530

(Injection site, above Spring Bank Ferry, Ark.; lat 33°08'47", long 93°50'40"; river mile 339.0; date, 4-19-71; time, 0930)

Spring Bank Ferry, Ark	334.5	4.5	2.75	3.00	2.40	2.20	1.2	30.0	16.2	64.0	46.8	8,200	56,903	3,320	--	8.2	----	1.31	----	310
Hoston, La	318.0	21.0	17.0	19.0	1.70	1.51	6.8	5.50	18.0	89.2	6.20	1,350	57,041	4,160	85	5.3	----	1.73	----	450
Shreveport, La	278.0	61.0	52.8	57.5	1.64	1.56	12.8	2.50	15.6	82.8	3.00	713	60,613	4,480	78	3.9	----	1.68	2.20	685

(Injection site, above Shreveport, La.; lat 32°32'52", long 93°45'17"; river mile 283.0; date, 3-13-72; time, 0825)

Shreveport, La	278.0	5.0	4.25	4.75	1.72	1.54	3.2	22.0	34.8	100	------	2,810	60,613	6,620	68	7.2	15.0	1.33	1.80	694
Lachute, La	249.0	34.0	29.0	33.5	1.72	1.48	12.5	4.50	26.7	99.0	4.54	749	60,654	6,620	--	----	----	----	----	-----
Coushatta, La	219.0	64.0	49.0	54.2	2.20	2.12	14.2	2.60	19.1	89.0	2.92	604	63,362	8,300	67	----	----	----	----	-----
Grand Ecore, La	184.0	99.0	78.0	85.2	1.77	1.66	20.5	1.70	16.9	84.4	2.01	446	64,575	8,890	--	12.0	----	1.48	1.89	500

(Injection site, above Spring Bank Ferry, Ark.; lat 33°08'47", long 93°50'40", river mile 339.0, date, 3-13-72; time, 1245)

Spring Bank Ferry, Ark	334.5	4.5	4.25	5.00	1.55	1.38	2.0	12.6	14.4	69.6	18.1	3,290	56,903	4,310	--	6.7	----	1.17	1.88	548
Hoston, La	318.0	21.0	19.2	21.8	1.61	1.44	7.8	4.70	18.1	91.0	5.17	1,150	57,041	4,500	--	----	----	----	----	-----
Shreveport, La	278.0	61.0	52.0	57.5	1.79	1.64	17.5	1.50	13.0	96.3	1.56	513	60,613	6,620	68	7.2	----	1.33	1.80	694

(Injection site, above Grand Ecore, La.; lat 31°52'10", long 93°06'15"; river mile 191.5; date, 6-12-72; time, 1300)

Grand Ecore, La	184.0	7.5	6.33	7.00	1.75	1.57	3.5	26.4	39.8	85.0	31.1	2,950	64,575	3,800	--	8.1	----	1.09	1.44	435
Colfax, La	140.5	51.0	41.0	45.0	1.83	1.67	12.0	5.50	32.6	73.0	7.50	750	66,860	4,000	--	----	----	----	----	-----
Alexandria, La	105.0	86.5	72.5	79.5	1.66	1.51	17.5	2.60	22.9	61.8	4.20	503	67,500	4,800	84	----	----	----	----	-----
La. Highway 115 near Moncla, La	67.5	124.0	114	122	1.32	1.30	20.0	1.75	18.4	60.8	2.90	422	67,625	5,880	--	3.3	----	2.01	2.40	880

SABINE RIVER

(Injection site, Toledo Bend Dam; lat 31°10'21", long 93°33'52"; river mile 156.5; date, 9-9-69; time, 1140)

4.9 mi below Toledo Bend Dam	151.6	4.9	2.00	2.50	3.59	2.88	1.3	10.3	--------	-----	------	5,130	7,400	----------	--	-----	----	----	----	-----

Table 1.–Time-of-travel data collected for streams in Louisiana–Continued

Location	Sampling data											Discharge data							
	River mile	Distance (mi)	Elapsed time leading edge (hrs)	Elapsed time peak (hrs)	Velocity leading edge (ft/s)	Velocity peak (ft/s)	Duration (hrs)	Peak observed concentration (µg/L)	Area of time-concentration curve (µg/L-hrs)	Dye detected (percent)	Peak conservative concentration (µg/L)	Unit concentration $\frac{(\mu g/L \times ft^3/s)}{lb}$	Drainage area (mi^2)	Discharge (ft^3/s)	Flow duration (percent)	Mean depth (ft)	Maximum depth (ft)	Mean velocity (ft/s)	Maximum velocity (ft/s)	Channel width (ft)
SABINE RIVER--Continued																			
(Injection site, Toledo Bend Dam; lat 31°10'21", long 93°33'52"; river mile 156.5; date, 9-9-69; time, 1140)--Continued																			
Burkeville, Tex	145.8	10.7	5.75	6.80	2.27	1.98	2.3	6.60	--------	79.0	8.40	3,690	7,482	4,500	--	7.1	----	2.13	2.84	297
Mouth of Bayou Anacoco	119.5	37.0	24.8	27.2	2.03	1.89	5.5	1.30	--------	-----	------	1,240	7,732	----------	--	----	----	----	----	-----
Bon Wier, Tex	106.9	49.6	34.2	38.0	1.97	1.71	8.8	1.10	--------	43.0	2.60	975	8,229	3,910	--	5.4	----	1.89	2.64	382
(Injection site, Toledo Bend Dam; lat 31°10'21", long 93°33'52"; river mile 156.5; date, 7-28-70; time, 0810)																			
Burkeville, Tex	145.8	10.7	4.30	5.00	3.65	3.14	2.8	5.90	6.80	66.0	8.90	3,850	7,482	13,300	--	----	----	----	----	-----
Mouth of Bayou Anacoco	119.5	37.0	17.5	19.2	2.92	2.72	4.8	2.20	5.00	-----	------	1,950	7,739	----------	--	----	----	----	----	-----
Bon Wier, Tex	106.9	49.6	22.8	25.5	3.49	2.93	6.3	1.60	4.80	44.0	3.60	1,480	8,229	12,000	--	----	----	----	----	-----
Rulif, Tex	53.7	102.8	52.0	59.0	2.67	2.33	28.0	.63	--------	-----	------	-----	9,329	5,480	--	----	----	----	----	-----
(Injection site, Toledo Bend Dam; lat 31°10'21", long 93°33'52"; river mile 156.5; date, 2-4-72; time, 0905)																			
Burkeville, Tex	145.8	10.7	4.83	5.58	3.26	2.82	2.2	13.9	16.7	89.6	15.5	3,690	7,482	11,900	13	----	----	----	----	-----
Bon Wier, Tex	106.9	49.6	24.8	26.8	2.86	2.73	6.0	4.10	11.8	67.2	6.10	1,550	8,229	12,700	19	----	----	----	----	-----
Duetts Eddy, Tex	72.4	86.1	44.2	47.4	2.60	2.45	9.0	1.70	9.60	60.8	2.80	787	9,036	14,100	--	----	----	----	----	-----
Ruliff, Tex	53.7	102.8	55.0	59.8	2.54	2.21	21.5	.92	6.27	41.7	2.20	651	9,329	14,800	20	----	----	----	----	-----
Orange, Tex	26.2	130.3	75.0	94.0	2.01	1.19	61.0	.18	5.92	38.8	.46	135	9,650	15,300	--	----	----	----	----	-----
SPRING CREEK																			
(Injection site, La. Highway 488 near Elmer, La.; lat 31°09'35", long 92°41'30"; river mile 24.5; date, 8-30-77; time, 1215)																			
La. Highway 112 at Elmer, La	22.0	2.5	14.5	20.8	0.25	0.18	11.2	570	2,370	-----	------	1,070	---------	6.80	--	----	----	0.80	----	14.0
Parish road near Melder, La	13.0	11.5	71.0	80.2	.23	.22	24.0	30.5	374	-----	------	372	---------	26.8	--	----	----	.82	----	33.0
U.S. Highway 165 near Glenmora, La	5.0	19.5	96.2	105	.46	.47	29.5	9.40	126	-----	------	331	68	49.0	68	----	----	----	----	-----
Mouth	.5	24.0	111	120	.45	.47	28.0	4.50	62.6	87.0	5.20	319	90	65.0	--	----	----	----	----	-----
TANGIPAHOA RIVER																			
(Injection site, Greenlaw, La.; lat 30°58'48", long 90°27'38"; river mile 73.6; date, 4-24-69; time, 0050)																			
Kentwood, La	68.5	5.1	8.00	9.75	0.94	0.77	4.5	124	259	100	124	2,130	237	204	--	3.6	----	0.75	1.40	76.0
Tangipahoa, La	62.4	11.2	18.5	21.3	.85	.77	7.5	42.5	156	100	42.5	1,210	340	346	--	2.5	----	1.34	2.95	104
Amite, La	47.8	25.8	32.0	35.0	1.59	1.56	10.0	23.0	114	100	23.0	906	494	420	--	2.7	----	1.43	2.71	108
Independence, La	39.2	34.4	41.0	45.0	1.60	1.26	12.0	18.2	96.8	91.0	20.0	835	512	438	--	2.6	----	1.76	2.66	98.0
Natalbany, La	29.5	44.1	51.5	56.8	1.36	1.21	14.0	14.1	91.6	100	14.1	683	522	510	--	4.2	----	.86	1.39	141
Robert, La	22.6	51.0	60.0	66.0	1.19	1.10	16.0	9.60	63.1	85.0	11.3	675	646	630	50	5.8	7.6	.90	1.67	120
Ponchatoula, La	15.2	58.4	71.0	77.0	.99	.99	16.0	8.60	61.4	87.0	9.90	622	702	660	--	10.7	17.2	.31	.84	178
(Injection site, La. Highway 443 near Natalbany, La.; lat 30°34'10", long 90°24'00"; river mile 29.5; date, 5-17-69; time, 0025)																			
Ponchatoula, La	15.2	14.3	14.0	16.0	1.50	1.31	4.5	12.9	29.8	100	29.8	1,880	702	847	--	11.7	----	.42	.72	180
Lee Landing, La	8.6	20.9	26.0	28.8	.81	.76	7.5	6.40	22.3	85.0	7.50	1,260	---------	895	--	6.8	----	1.22	1.68	108
(Injection site, Greenlaw, La.; lat 30°58'48", long 90°27'38"; river mile 73.6; date, 9-15-69; time, 0108)																			
Kentwood, La	68.5	5.1	11.5	13.8	.65	.54	7.5	85.0	306	100	85.0	1,270	237	122	--	1.6	----	1.32	1.70	56.0
Tangipahoa, La	62.4	11.2	25.5	30.0	.64	.55	11.0	41.0	214	94.0	43.6	845	340	164	--	1.4	3.5	1.56	2.65	69.0
Arcola, La	53.0	20.6	35.5	40.2	1.38	1.35	13.0	24.0	--------	-----	------	-----	381	190	--	----	----	----	----	-----
Amite, La	47.8	25.8	41.5	47.0	1.27	1.13	16.0	16.0	130	85.0	18.8	550	494	245	--	1.3	----	1.13	3.33	98.0
Independence, La	39.2	34.4	53.0	59.0	1.10	1.05	17.0	13.0	107	82.0	15.9	540	512	286	--	1.5	----	1.44	1.83	132
Natalbany, La	29.5	44.1	66.0	73.5	1.09	.98	17.5	10.2	90.0	73.0	14.0	503	522	304	--	2.5	----	1.19	1.79	104
Robert, La	22.6	51.0	77.0	83.0	.92	1.21	17.0	8.50	81.0	69.0	12.3	466	646	319	97	2.4	3.5	1.33	2.23	100
Ponchatoula, La	15.2	58.4	89.0	96.5	.90	.80	18.0	7.20	67.0	67.0	10.7	410	702	383	--	11.5	17.4	.22	.62	149

TCHEFUNCTA RIVER

(Injection site, above La. Highway 10 near Wilma, La.; lat 30°49'55", long 90°17'48"; river mile 69.0; date, 5-24-72; time, 1100)

La. Highway 10 near Wilma, La	67.0	2.0	7.50	10.2	0.39	0.29	7.0	122	338	98.2	124	1,600	20	17.0	--	0.6	----	1.55	2.29	16.0
Folsom, La	37.0	32.0	94.5	102	.51	.50	30.5	3.40	44.9	48.6	7.00	327	96	63.0	60	1.9	----	.73	.84	43.0
Covington, La	20.0	49.0	140	190	.55	.52	36.0	1.70	28.6	35.7	4.57	264	145	72.8	--	1.3	----	1.30	1.62	43.0

TICKFAW RIVER

(Injection site, Liverpool, La.; lat 32°55'47", long 90°40'41"; river mile 76.0; date, 3-8-68; time, 1130)

Greensburg, La	67.0	9.0	31.0	34.0	0.43	0.39	9.0	7.40	30.8	36.8	20.1	1,070	136	105	--	----	----	----	----	----

(Injection site, Greensburg, La.; lat 30°48'55", long 90°38'10"; river mile 67.0; date, 3-8-68; time, 1430)

Montpelier, La	54.0	13.0	19.5	22.2	.98	.86	8.2	9.80	38.8	64.0	15.3	1,120	220	154	--	----	----	----	----	----

(Injection site, Montpelier, La.; lat 30°41'10", long 90°38'35"; river mile 54.0; date, 3-9-68; time, 1100)

Holden, La	34.0	20.0	19.0	23.0	1.54	1.28	8.4	10.5	49.1	30.0	35.0	950	247	187	44	3.0	----	.93	2.04	68.0

(Injection site, above Montpelier, La.; lat 30°42'40", long 90°38'05"; river mile 58.0; date, 10-8-68; time, 0945)

La. Highway 16 at Montpelier, La	54.0	4.0	9.10	11.2	.64	.52	4.7	52.0	137	85.0	61.0	1,680	220	72.0	--	1.4	----	1.29	1.50	40.0
Above Starns bridge	44.0	14.0	48.0	54.2	.38	.34	14.6	15.0	112	76.0	19.8	596	235	79.0	--	2.6	----	.48	1.10	63.0
Holden, La	34.0	24.0	78.0	87.0	.49	.45	20.5	10.1	97.7	55.0	18.4	459	247	66.0	99	1.8	----	.84	1.04	44.0
Springville, La	27.0	31.0	98.0	105	.51	.57	23.0	8.60	87.8	78.0	11.0	430	390	103	--	3.4	----	.22	.73	136

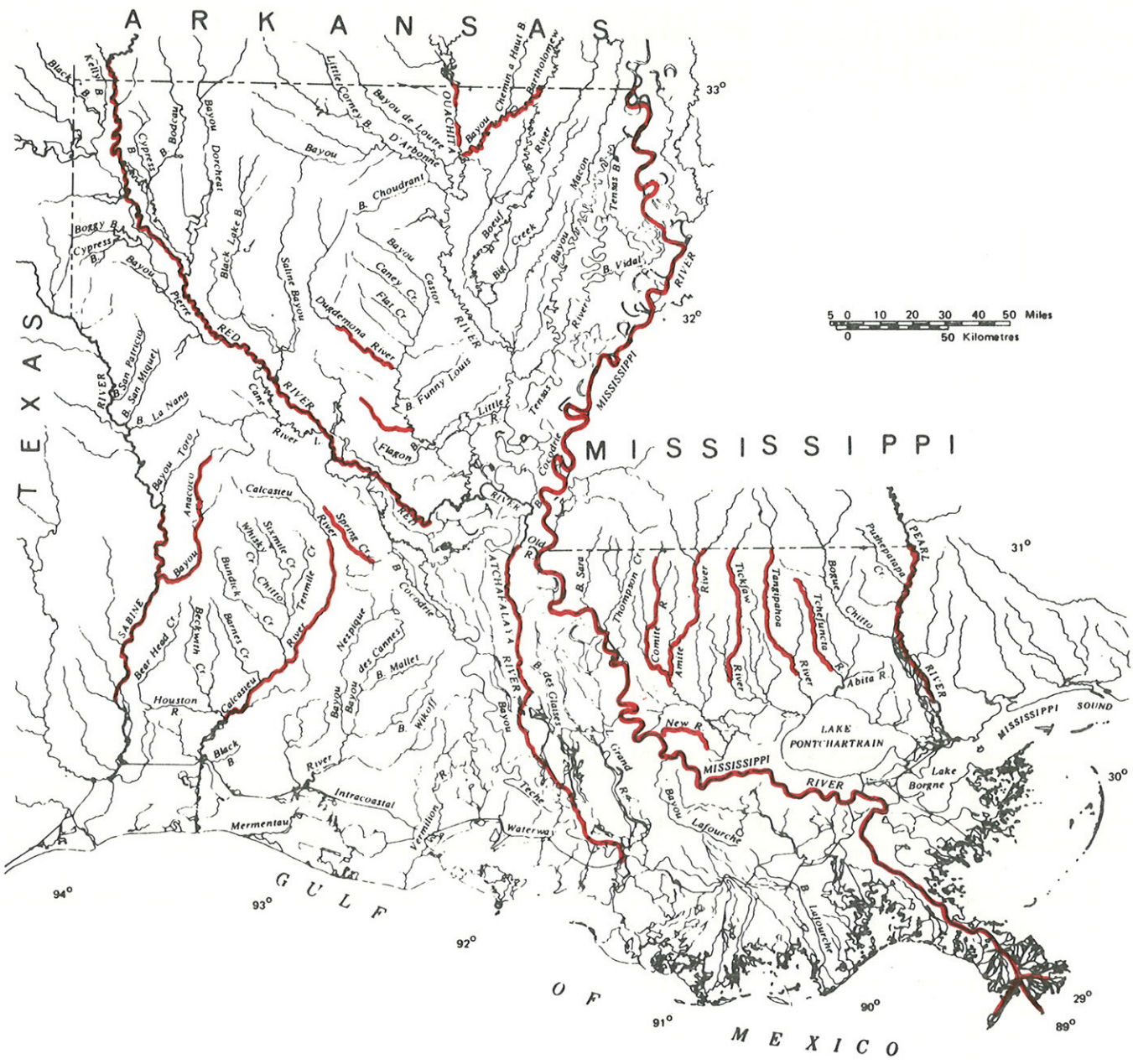


Figure 1.--Location of stream reaches where time-of-travel studies were made.

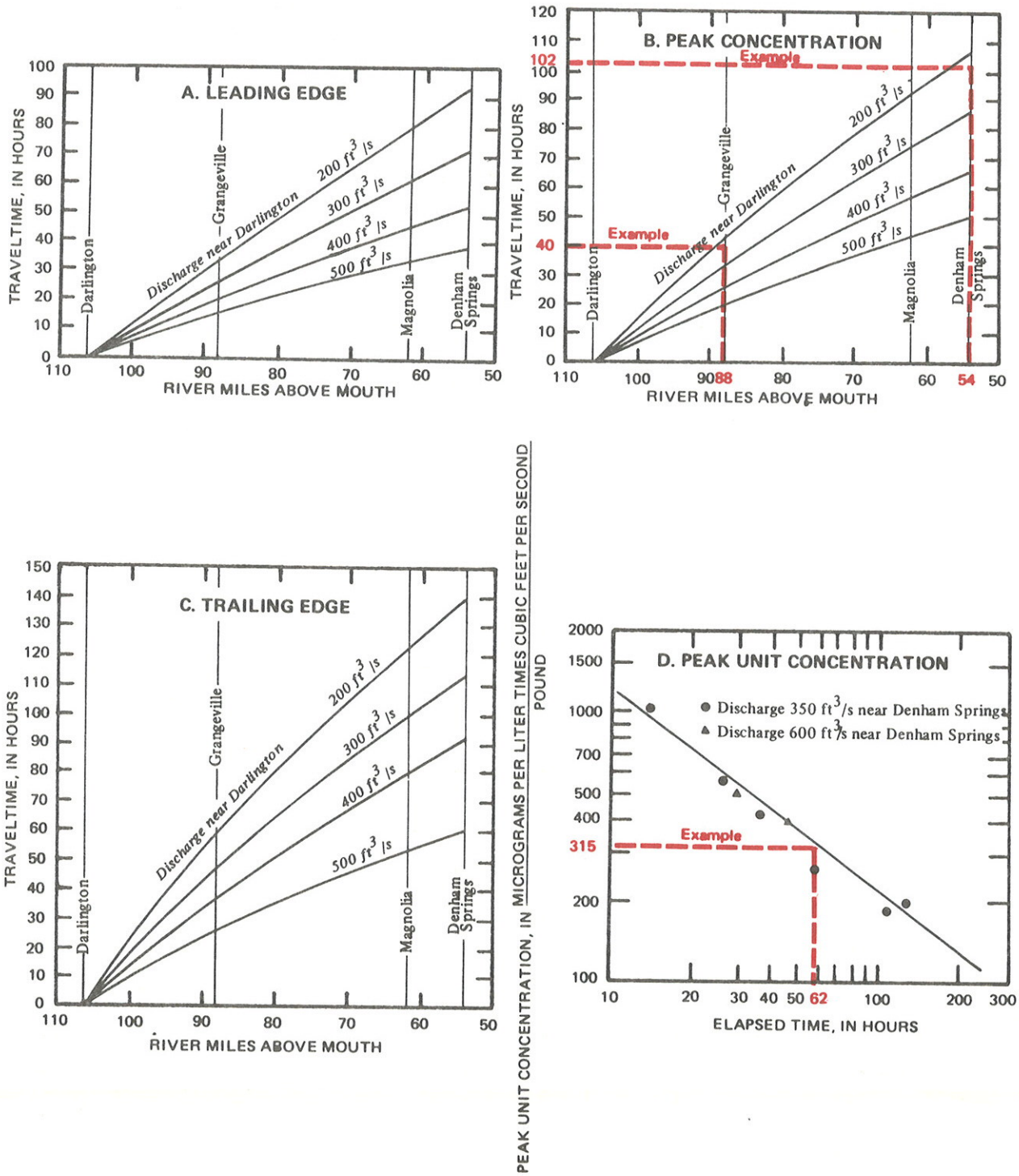


Figure 2.--Curves showing time of travel and peak concentration of tracer cloud, Amite River.

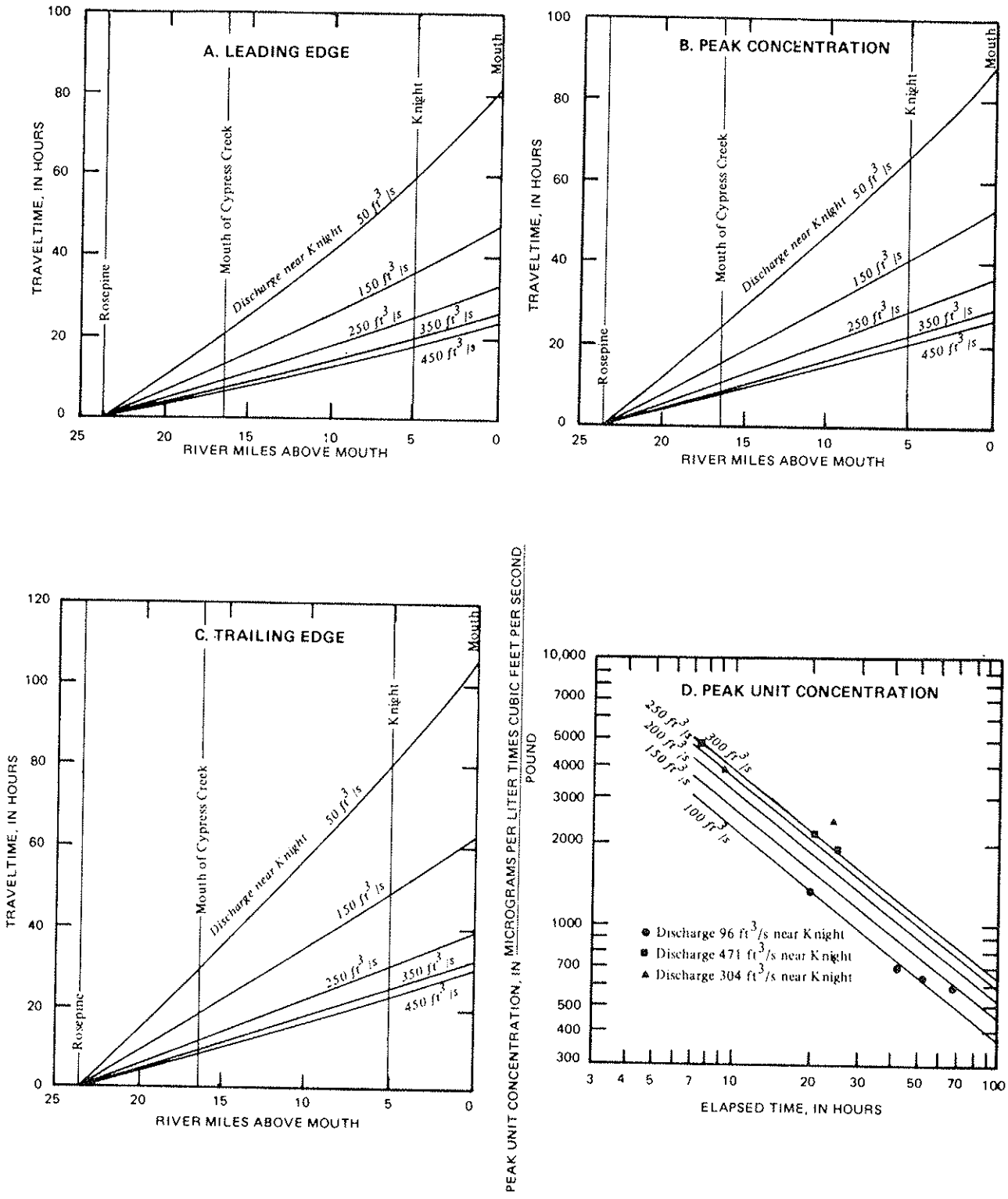


Figure 3.--Curves showing time of travel and peak concentration of tracer cloud, Bayou Anacoco.

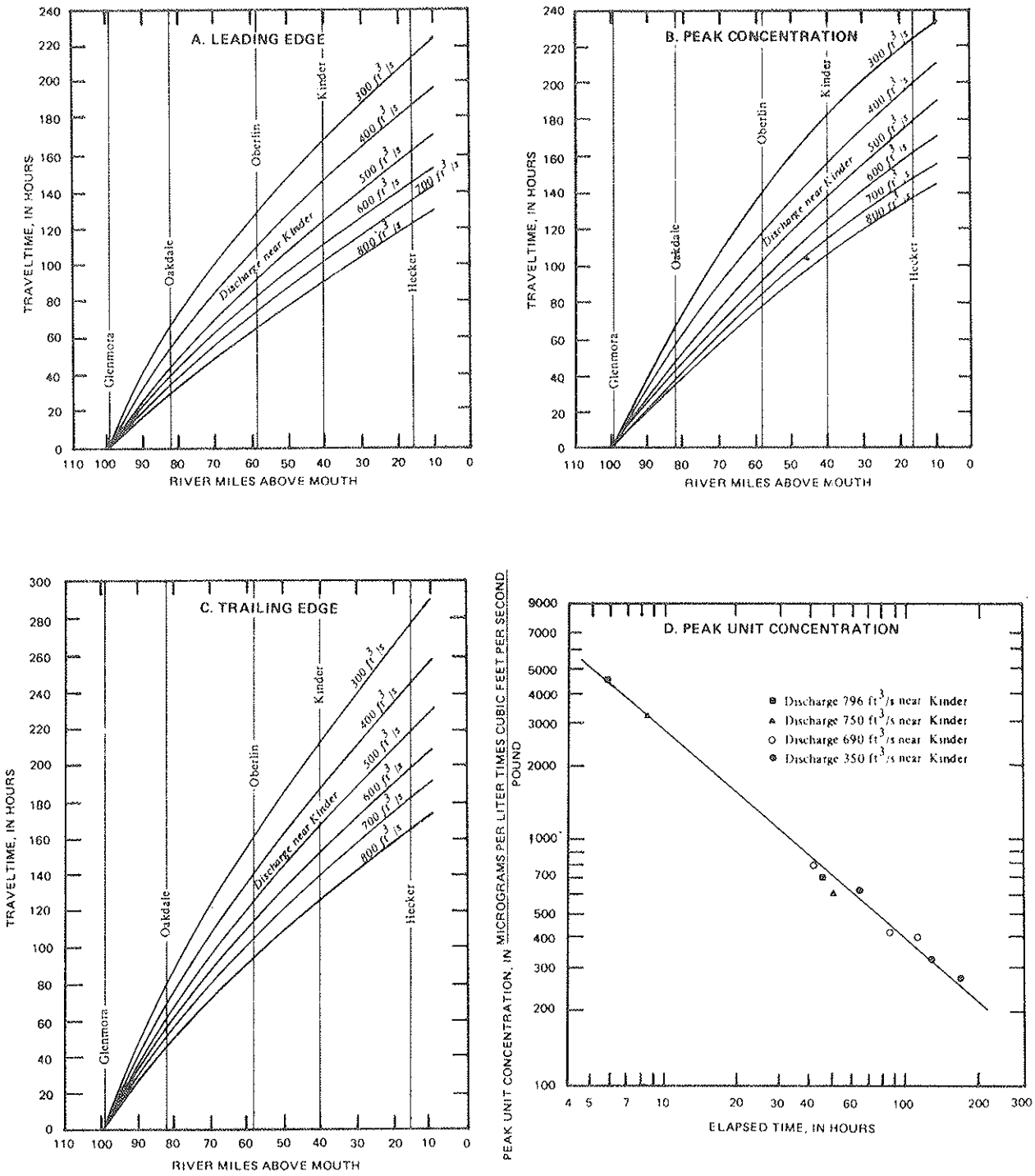


Figure 4.--Curves showing time of travel and peak concentration of tracer cloud, Calcasieu River.

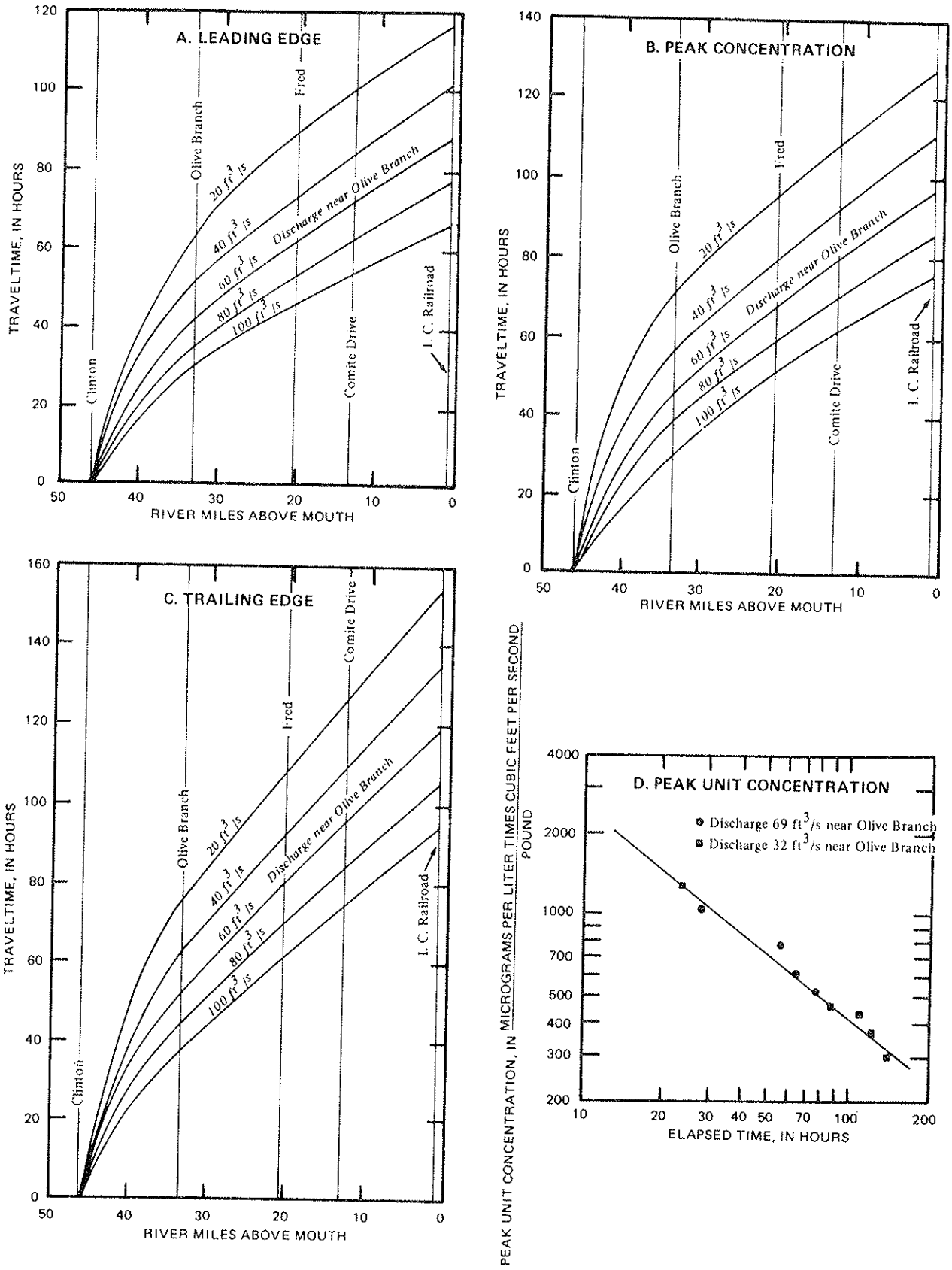


Figure 5.--Curves showing time of travel and peak concentration of tracer cloud, Comite River.

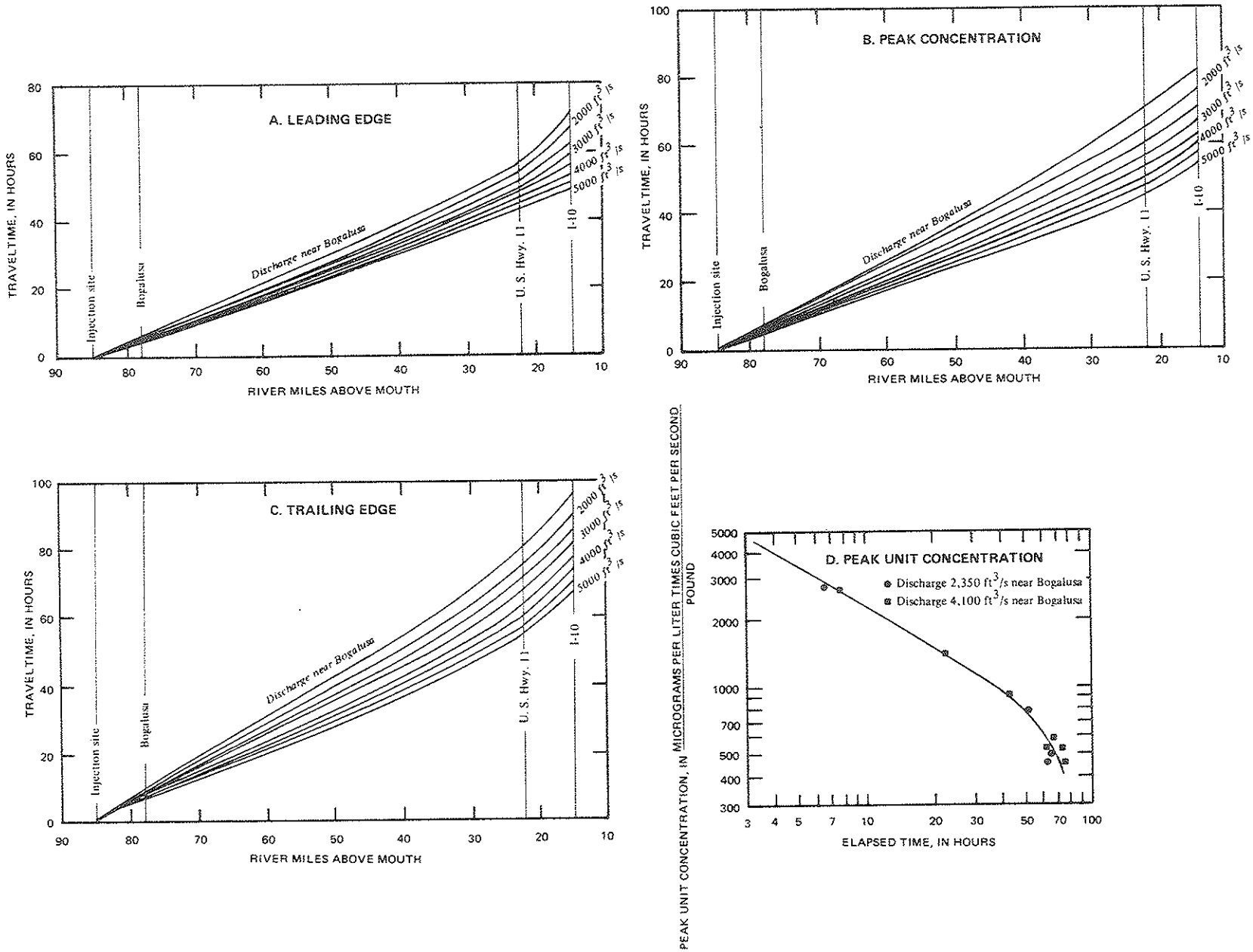
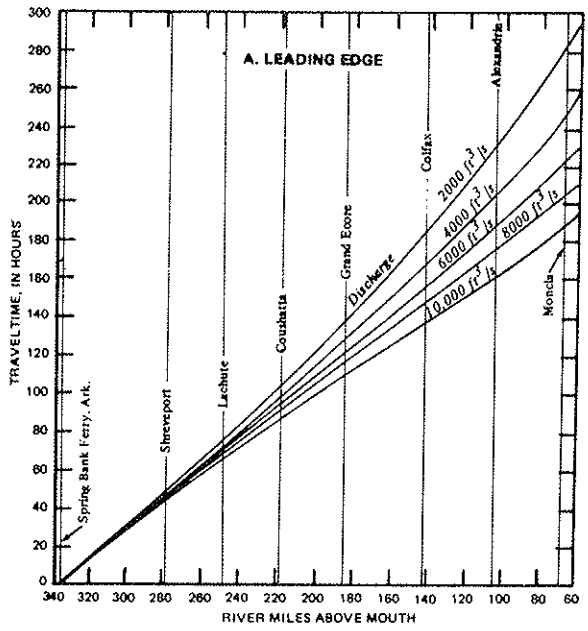
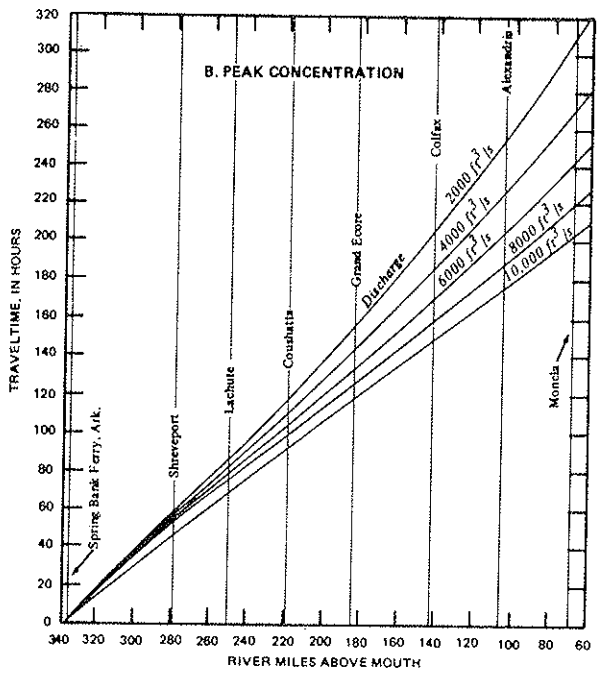
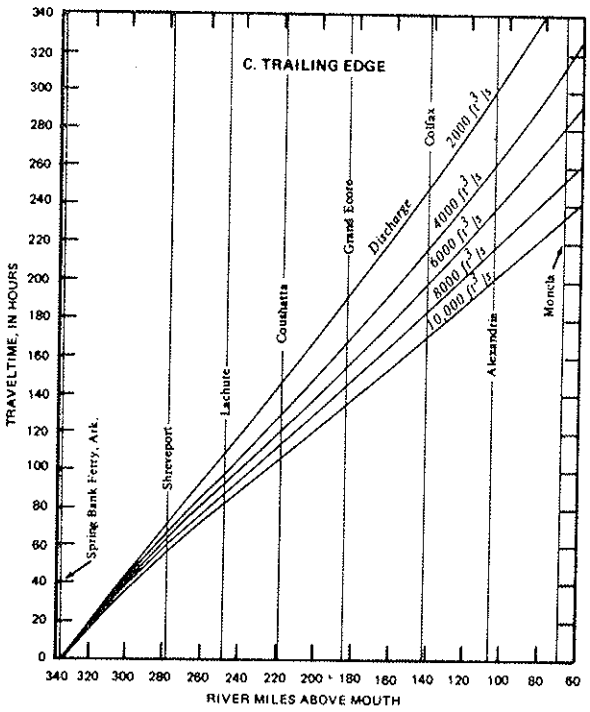


Figure 6.--Curves showing time of travel and peak concentration of tracer cloud, Pearl River.





(Upstream from Grand Ecore, use discharge at Shreveport; downstream from Grand Ecore, use discharge at Alexandria.)



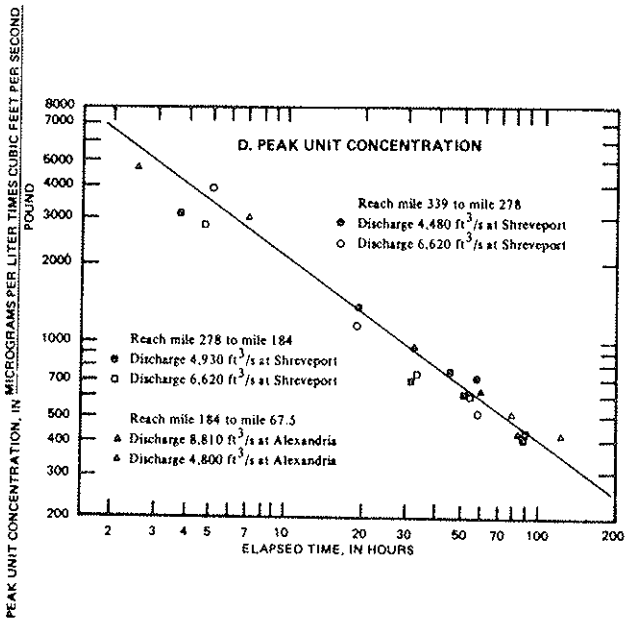


Figure 7.--Curves showing time of travel and peak concentration of tracer cloud, Red River.

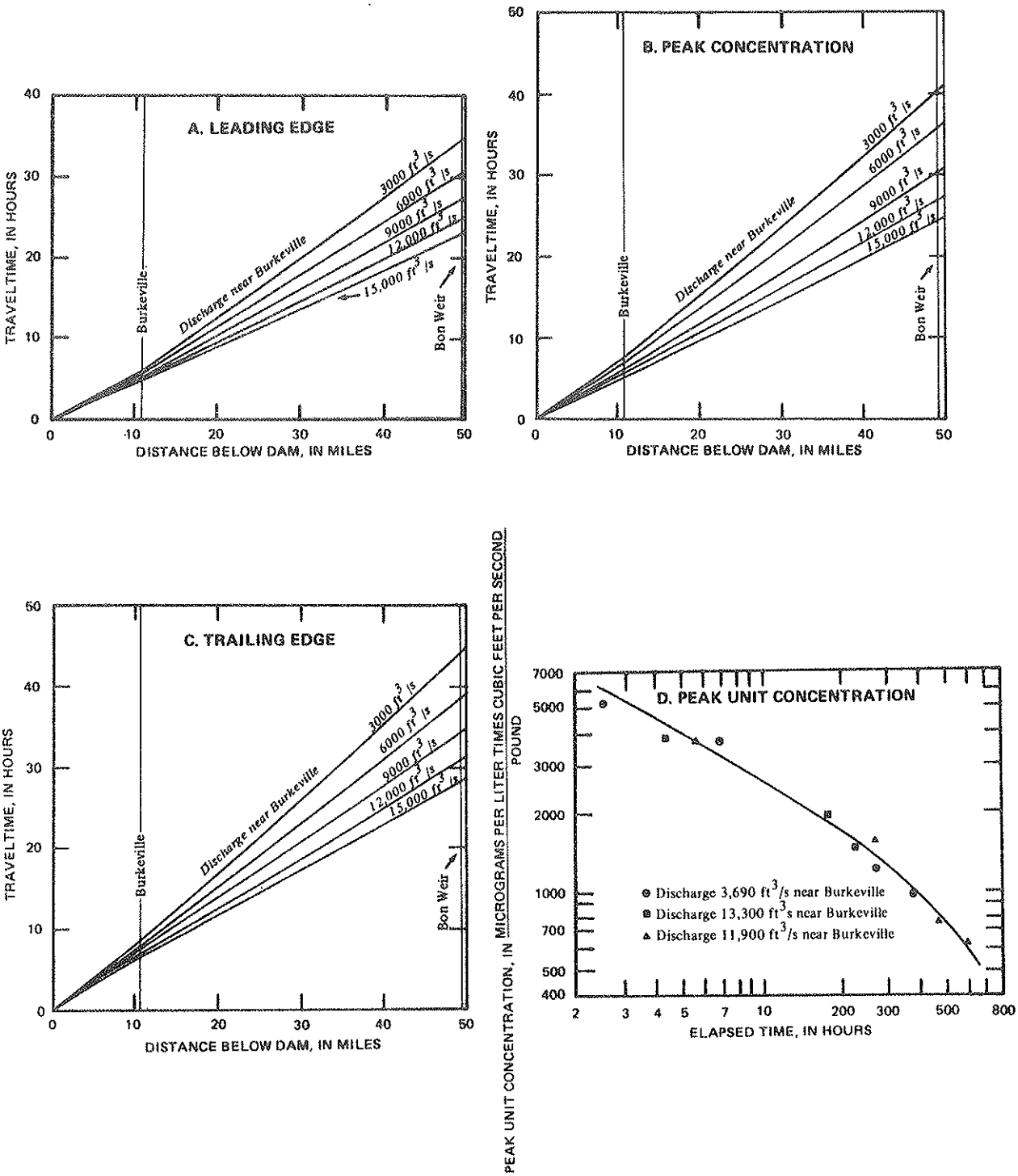


Figure 8.--Curves showing time of travel and peak concentration of tracer cloud, Sabine River.

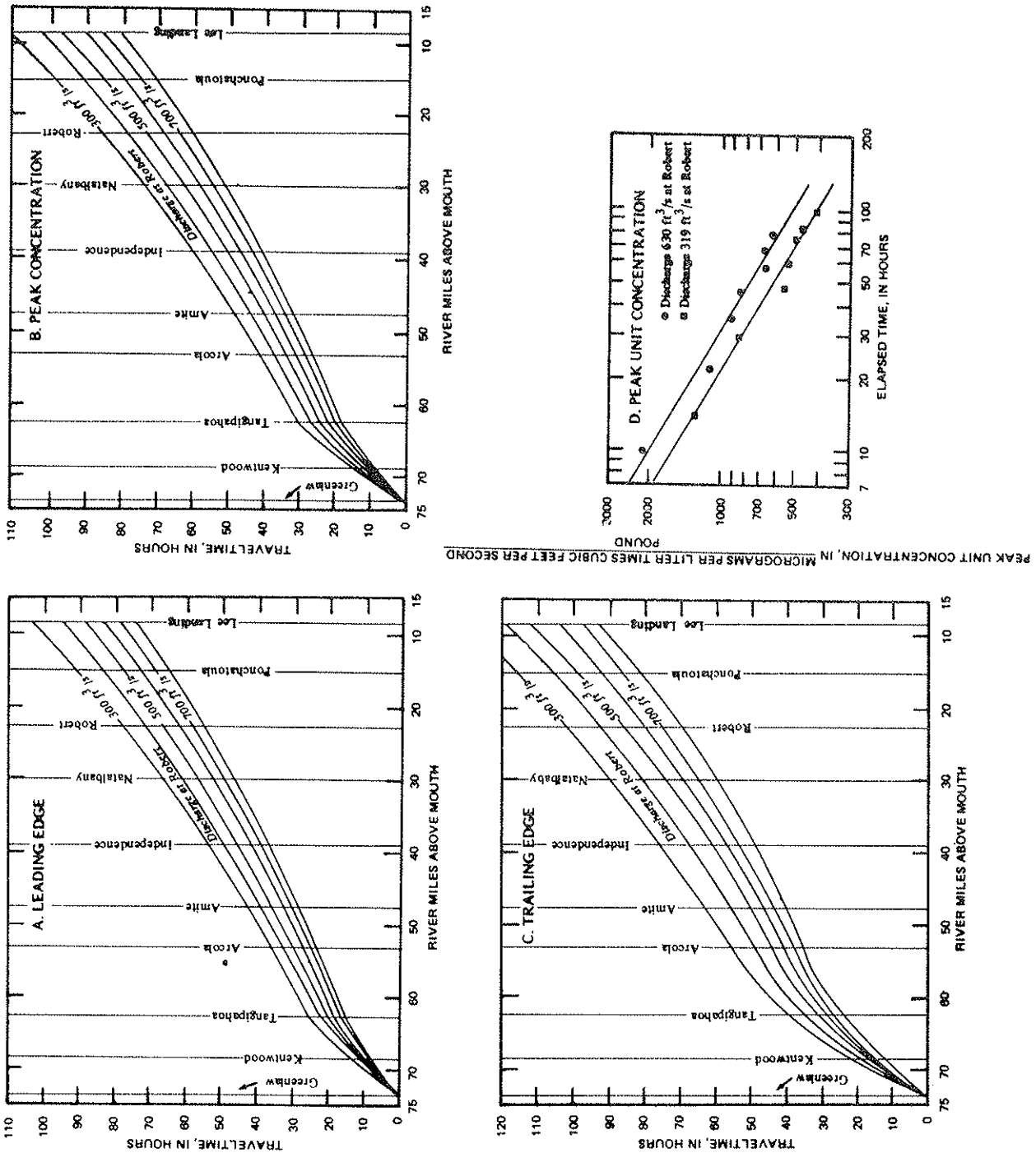


Figure 9.--Curves showing time of travel and peak concentration of tracer cloud, Tangipahoa River.

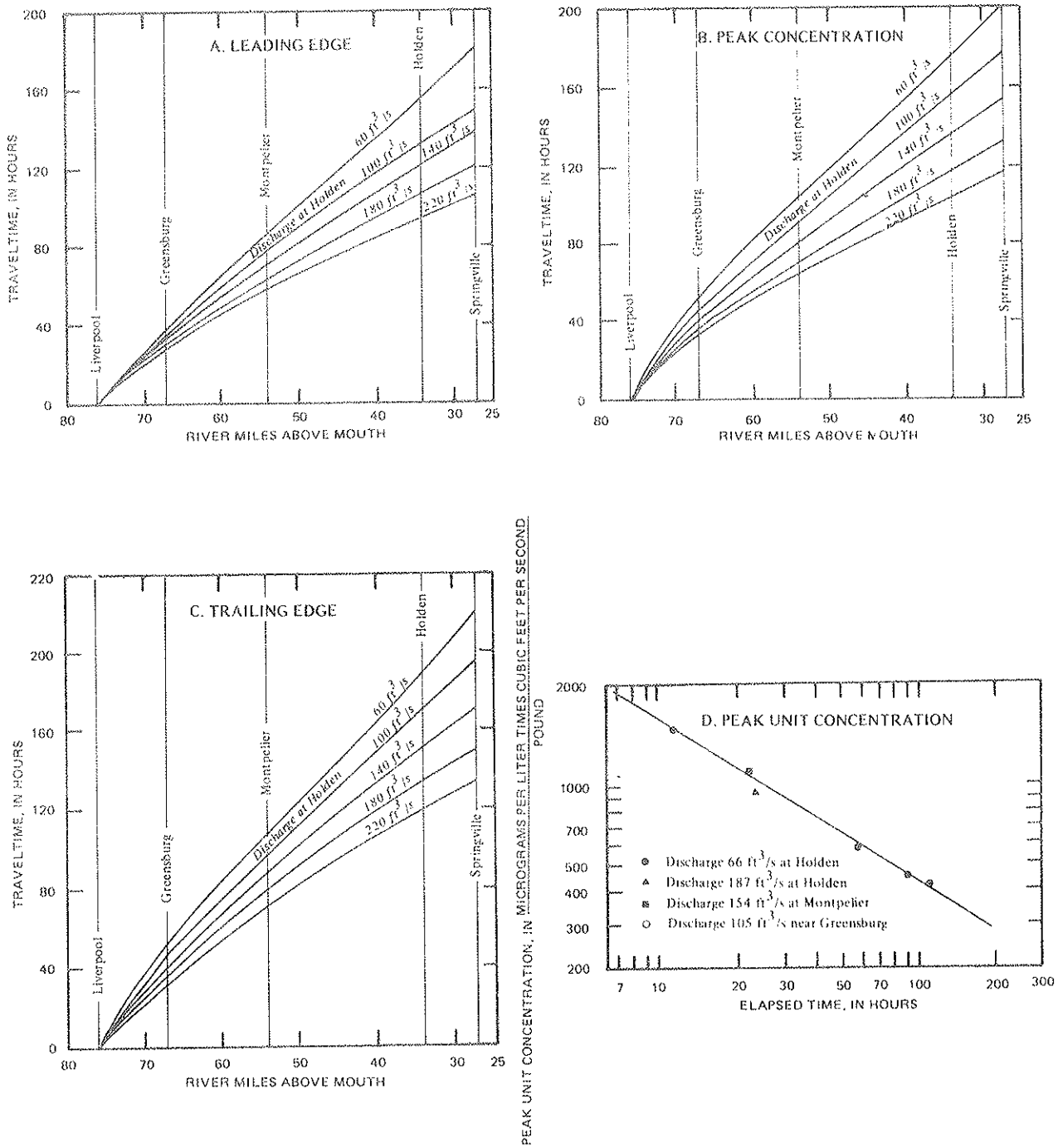


Figure 10.--Curves showing time of travel and peak concentration of tracer cloud, Tickfaw River.

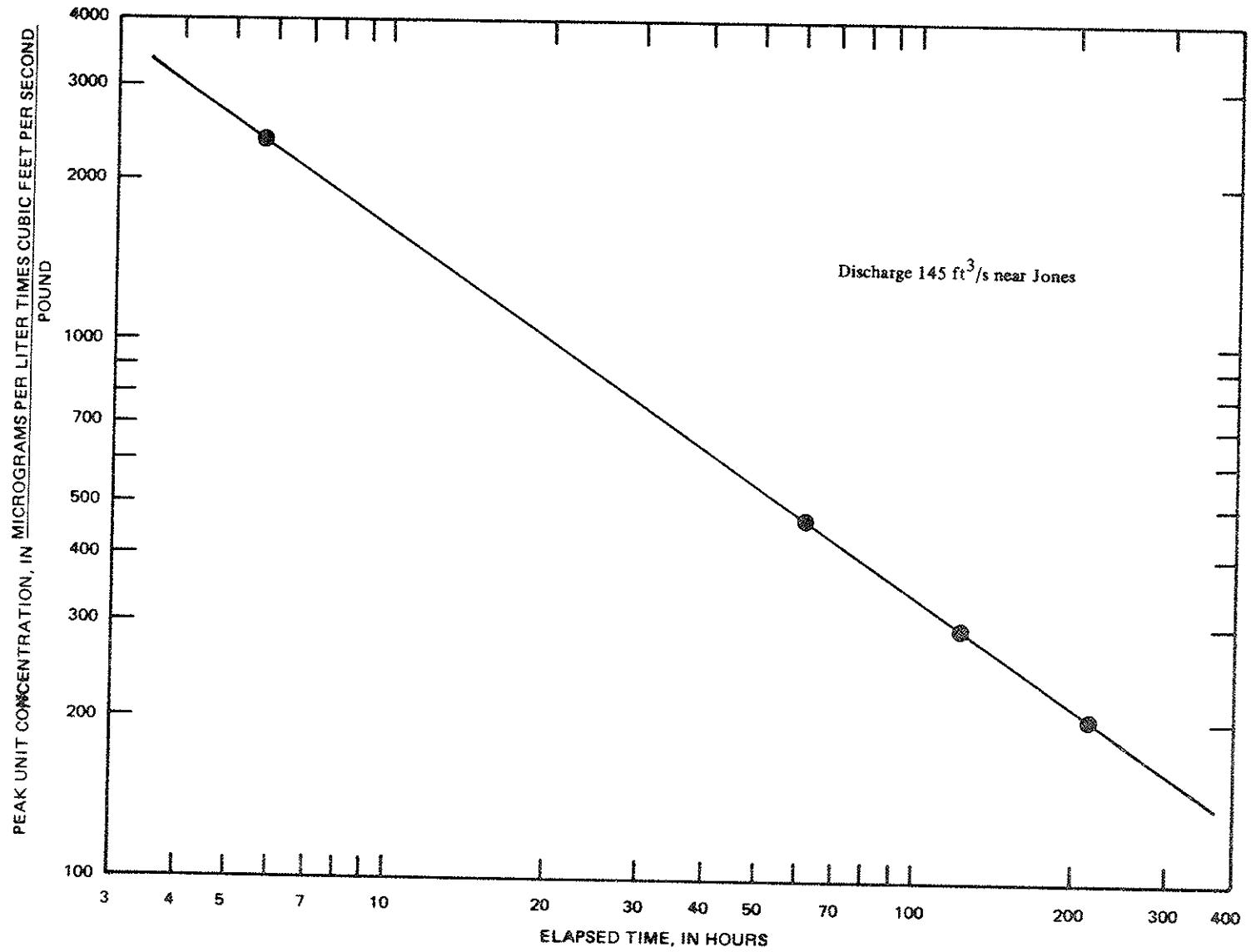


Figure 11.--Peak concentration of tracer cloud, Bayou Bartholomew.

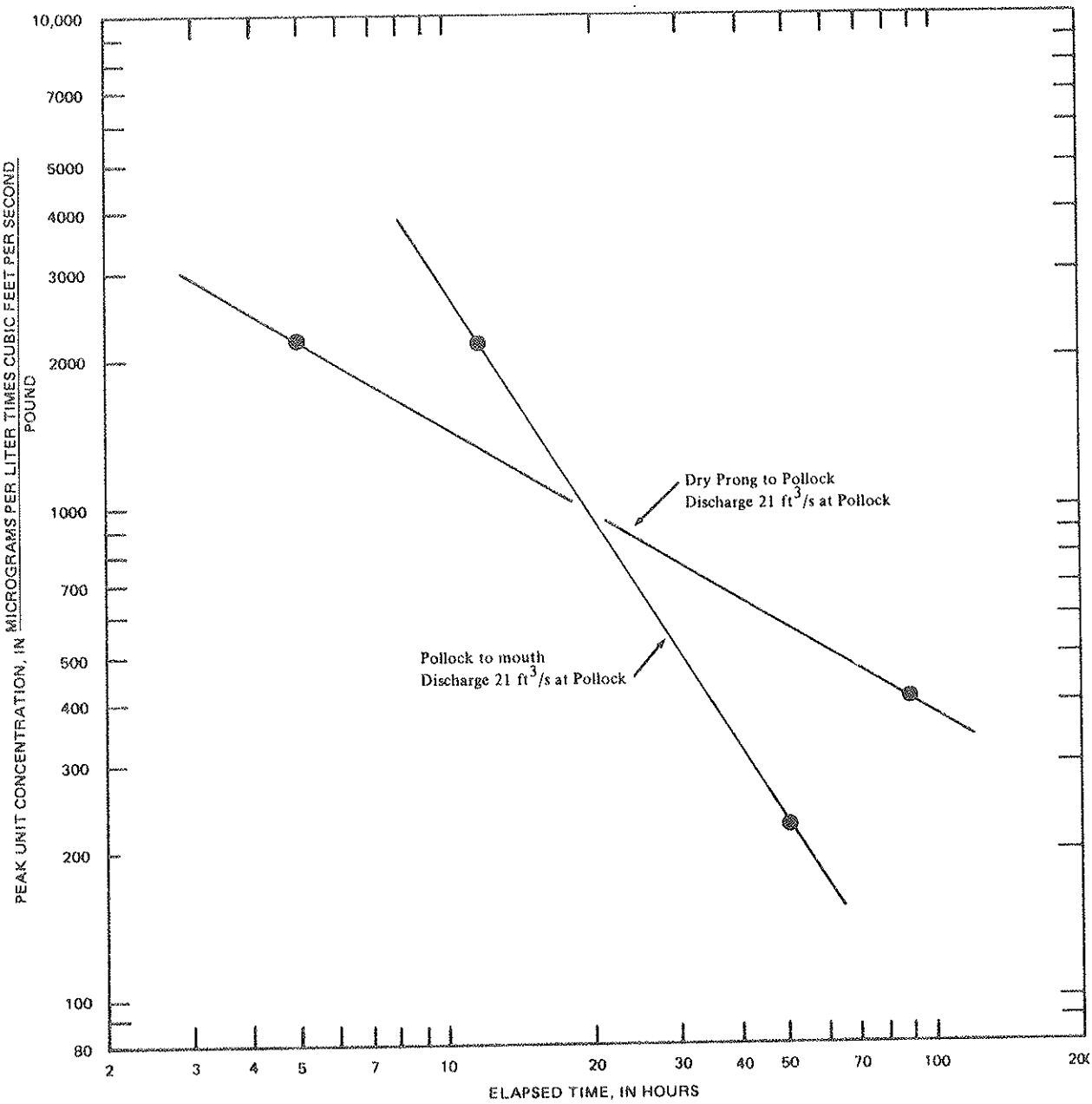


Figure 12.--Peak concentration of tracer cloud, Big Creek.

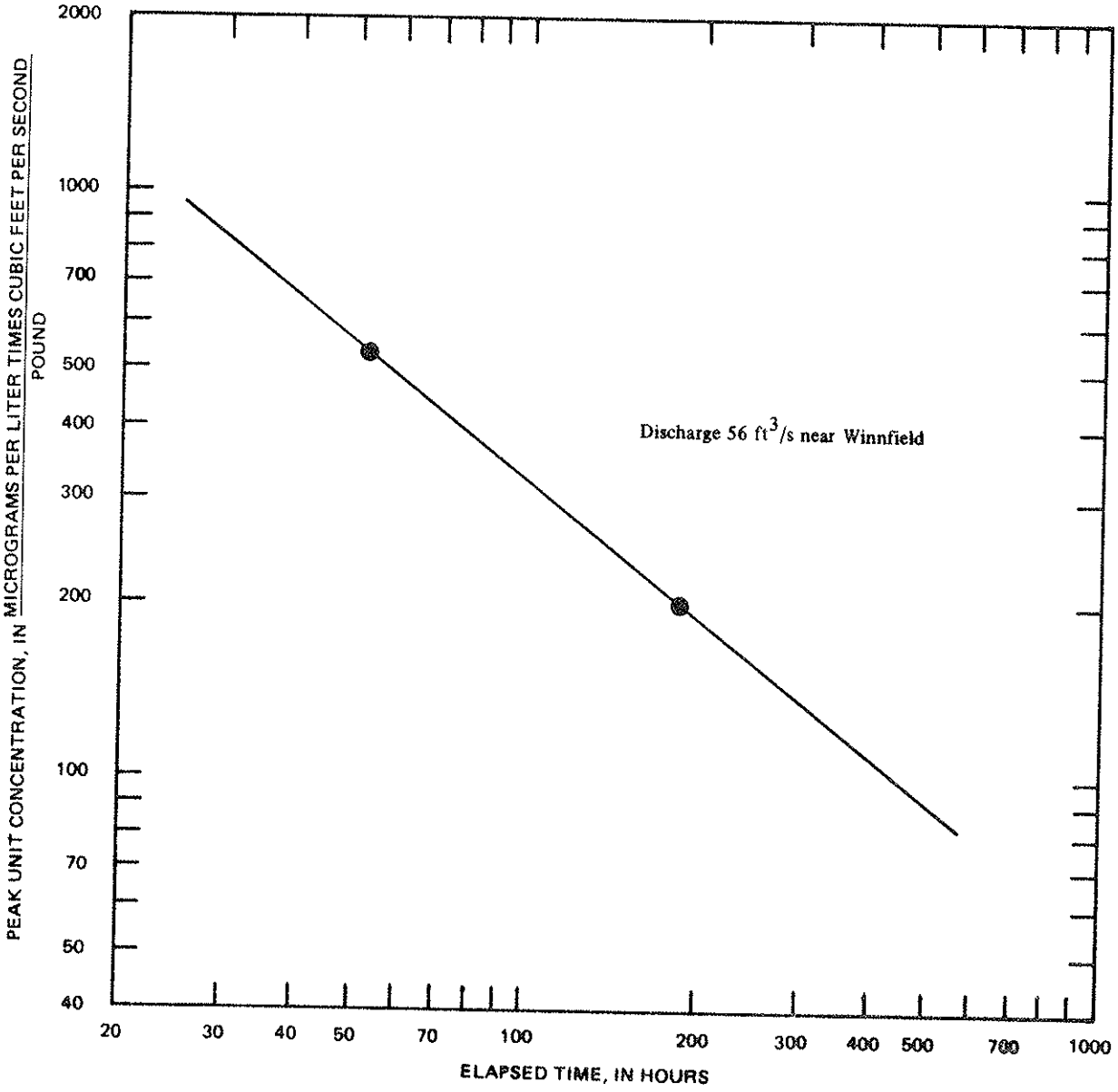
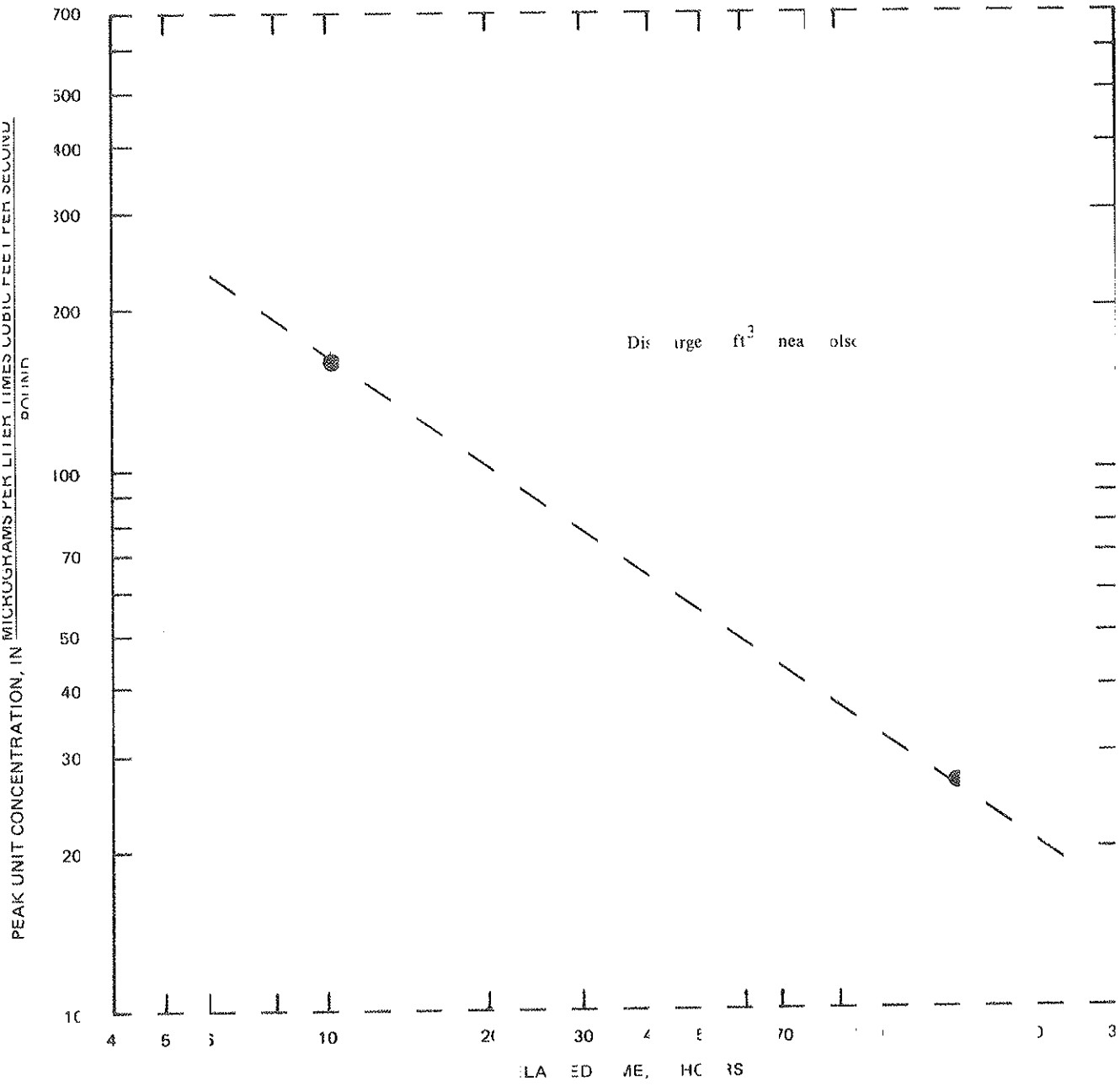


Figure 13.--Peak concentration of tracer cloud, Dugdemona River.



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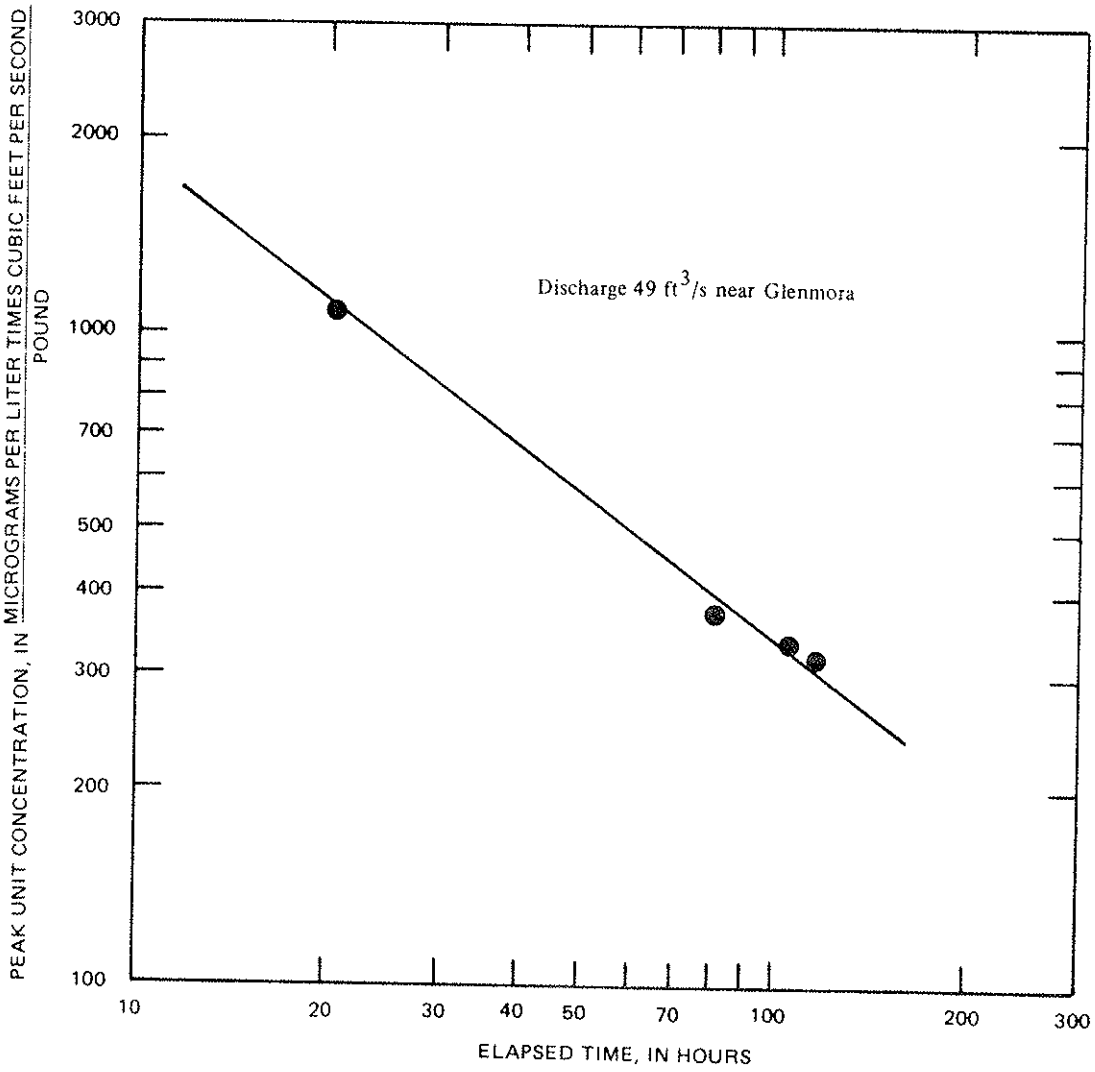

Figure 15.--Peak concentration of tracer cloud, Spring Creek.

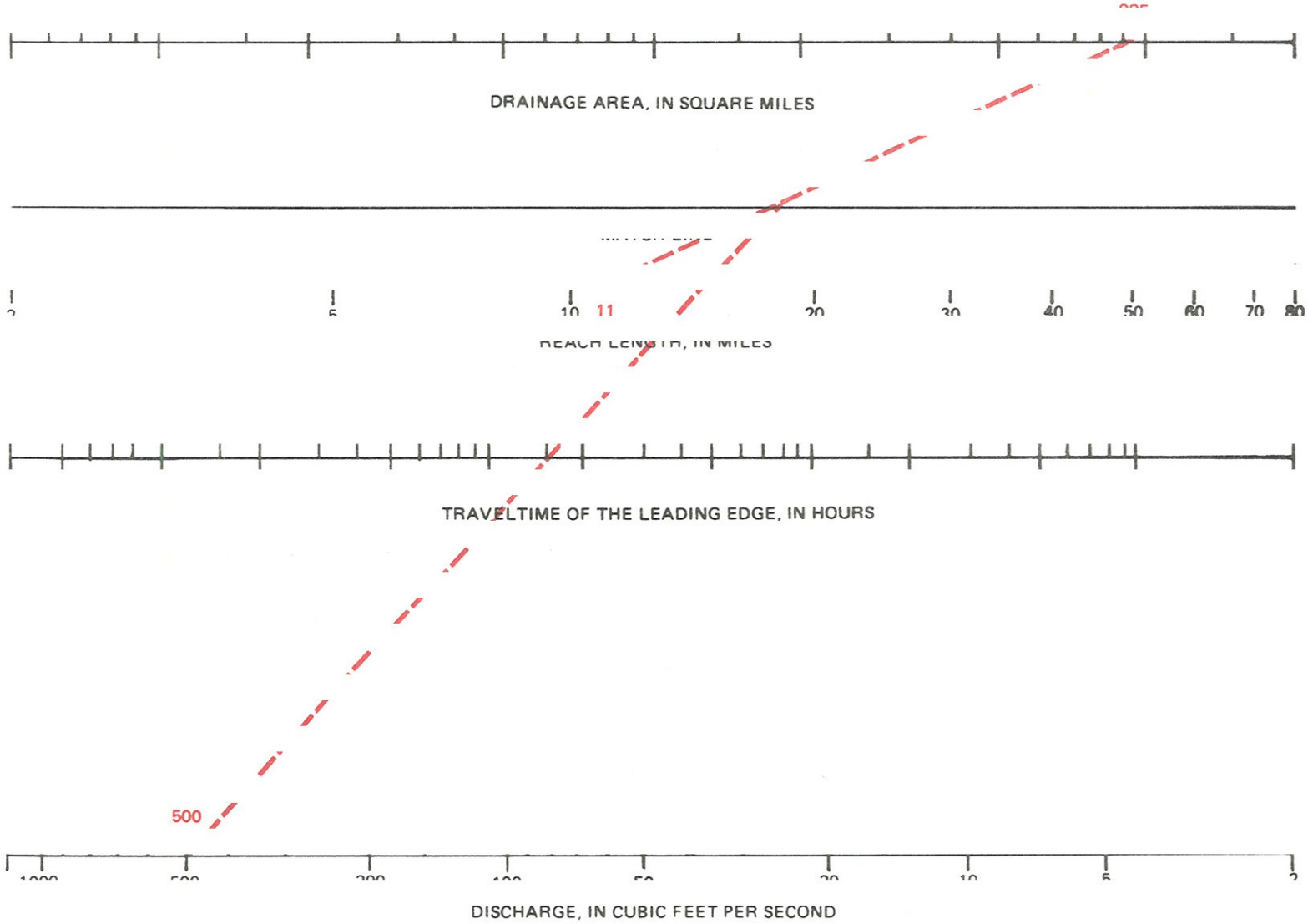

Figure 16.--Relation of traveltime of the leading edge to drainage area, reach length, and

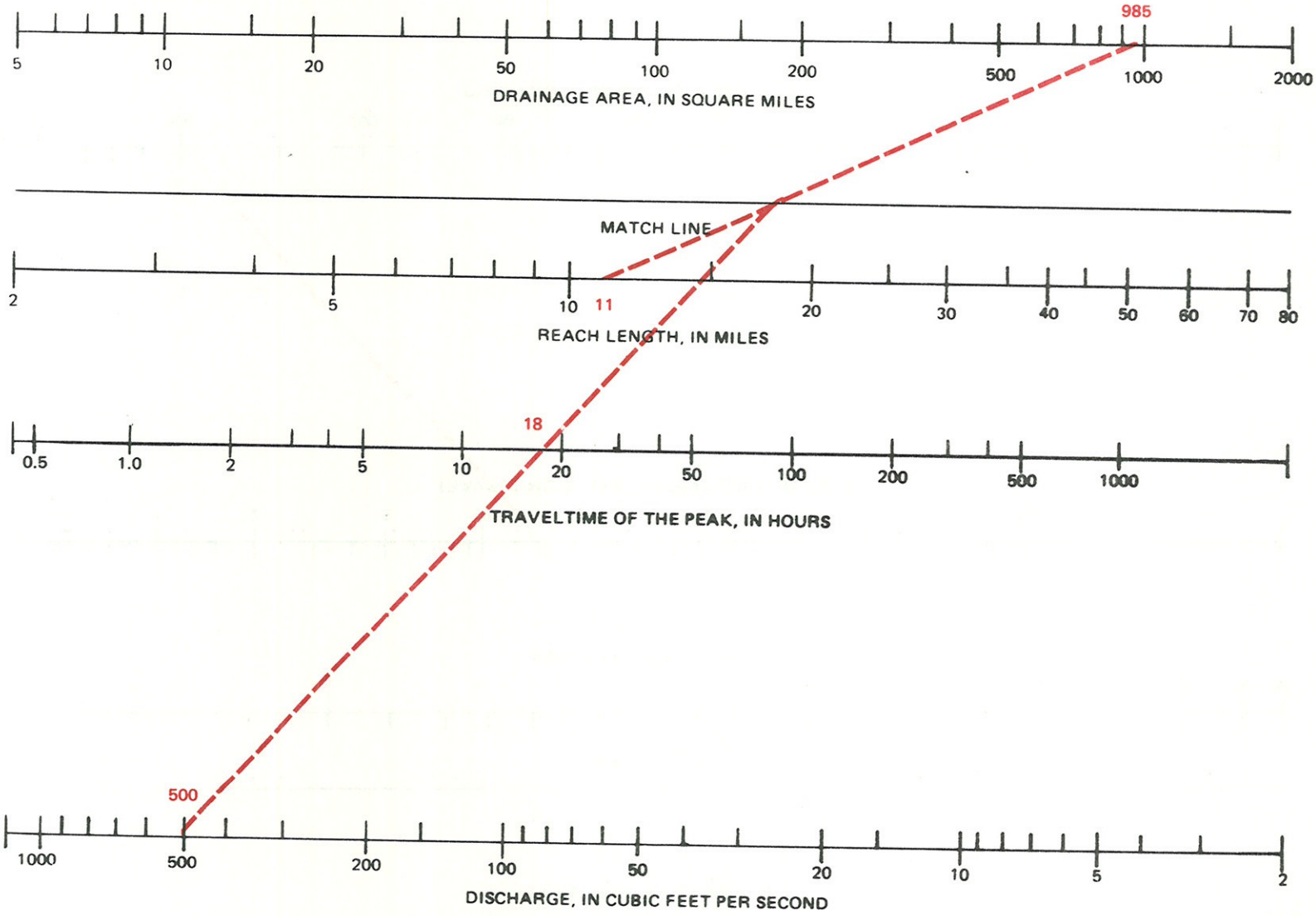

Figure 17.--Relation of traveltime of the peak concentration to drainage area, reach length, and discharge.

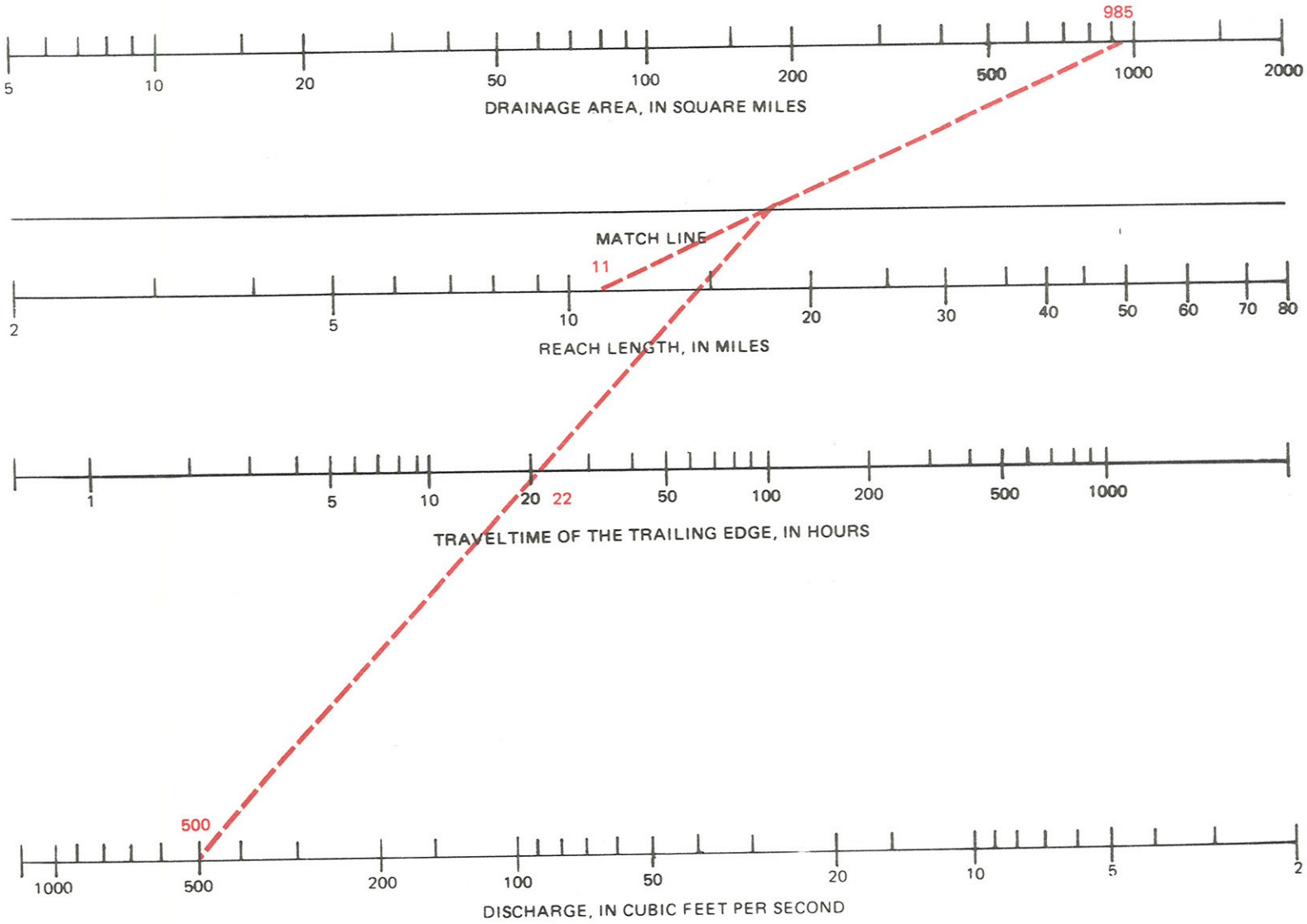

Figure 18.--Relation of traveltime of the trailing edge to drainage area, reach length, and discharge.

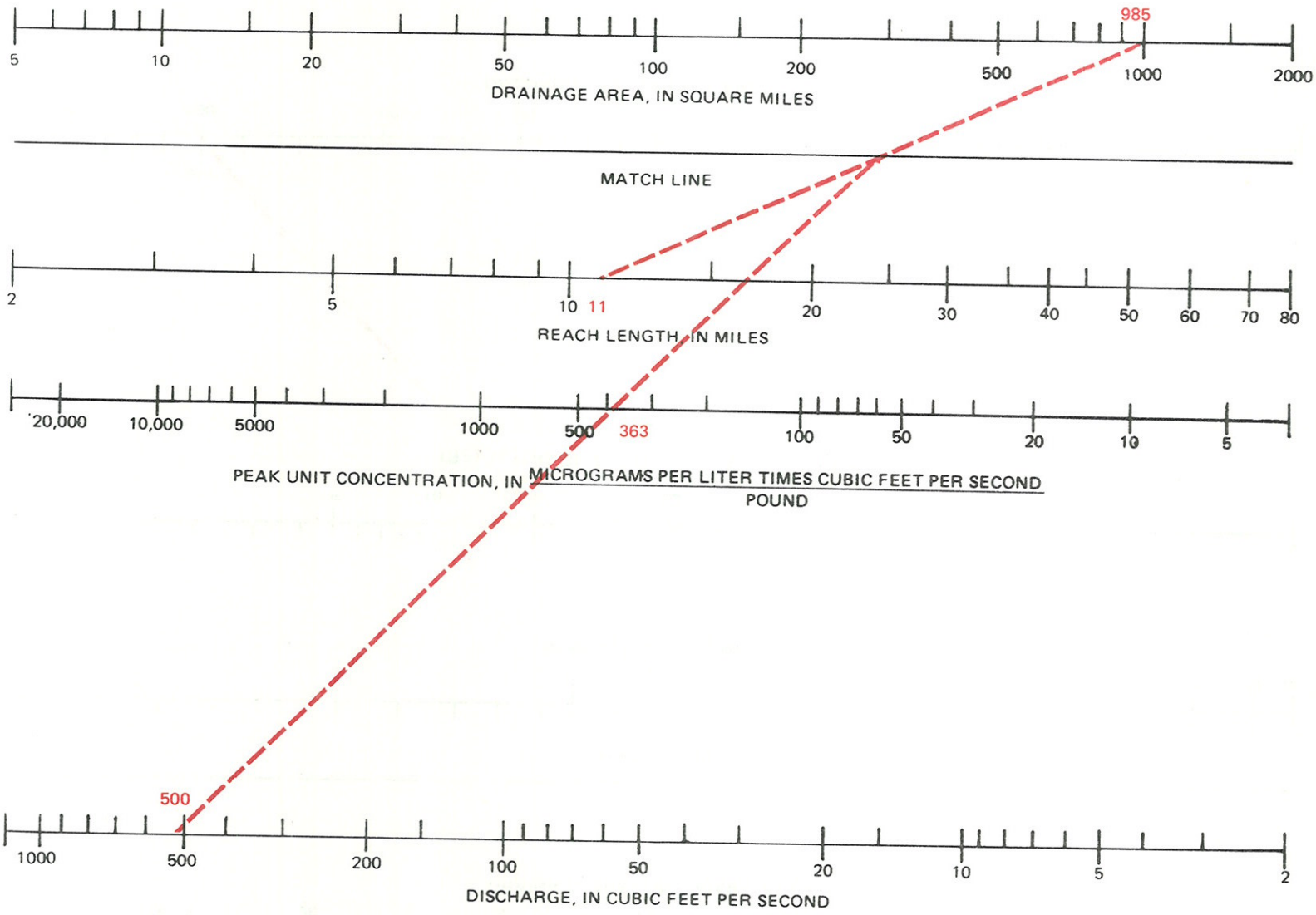

Figure 19.--Relation of peak unit concentration to drainage area, reach length, and discharge.