STATE OF LOUISIANA
DEPARTMENT OF PUBLIC WORKS

Water Resources
TECHNICAL
REPORT NO. 12

TIME OF TRAVEL OF SOLUTES IN MISSISSIPPI RIVER FROM THE ARKANSAS–LOUISIANA STATE LINE TO PLAQUEMINE, LOUISIANA

Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
In cooperation with
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1976

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By

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U.S. Geological Survey

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FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English units	By	To obtain SI units
cubic feet per second (ft^3/s)	28.32	liters per second (l/s)
	.02832	cubic meters per second (m^3/s)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
miles per hour (mi/h)	1.609	kilometers per hour (km/h)
pounds (lb)	.4536	kilograms (kg)

TIME OF TRAVEL OF SOLUTES IN MISSISSIPPI RIVER FROM THE ARKANSAS-LOUISIANA STATE LINE TO PLAQUEMINE, LOUISIANA

By Anthony J. Calandro

ABSTRACT

A water tracer was injected at three locations into the Mississippi River to determine the traveltime, the maximum concentration, the dispersion characteristics, and the duration of a tracer cloud for the reach from the Arkansas-Louisiana State line (mile 507) to Plaquemine, La. (mile 208). The flow in the river at Vicksburg, Miss., was approximately 400,000 cubic feet per second during the study.

Information from this study and from a previous study was used to calibrate a mathematical model developed at the U.S. Geological Survey's Gulf Coast Hydroscience Center. The model was then used to generate time-of-travel curves of the leading edge, the peak, and the trailing edge of the tracer cloud for discharges ranging from 200,000 to 1,500,000 cubic feet per second.

INTRODUCTION

Accidental spills of pollutants are of general concern and could be harmful to water users along the river. Planners and downstream water users should have knowledge of the behavior of dissolved pollutants accidentally spilled into the river.

The purpose of this report is to make available the results of a study of the time of travel of the Mississippi River from the Arkansas-Louisiana State line (mile 507) to Plaquemine, La. (mile 208), and to summarize graphically the observations of the rate of lateral and longitudinal dispersion of solutes at three locations in the reach.

The study was made by the U.S. Geological Survey in cooperation with the Louisiana Department of Public Works.

The study was made in July 1975 when the riverflow was 410,000 ft^3/s at Vicksburg, Miss., and 356,000 ft^3/s at Baton Rouge, La., and was similar to one made on the lower end of the Mississippi River from Baton Rouge to Pointe a la Hache, La. (Martens and others, 1974). A water tracer was injected into the Mississippi River above Vicksburg, Miss., (mile 442) on July 22, 1975; below the Old River control structure (mile 314) on July 23, 1975; and just downstream from Greenville, Miss., (mile 523) on July 29, 1975, to determine the traveltime, the maximum concentrations, the dispersion characteristics, and the duration of the tracer cloud as it moved downstream to Plaquemine, La.

Data collected during this study were used to calibrate a mathematical model developed by McQuivey (in McQuivey and Keefer, 1976a, in press) at the Gulf Coast Hydroscience Center. The model was then used to generate time-of-travel information for discharges ranging from 200,000 to 1,500,000 ft^3/s. A comparison of information generated by the model with observed data from the earlier study on the lower Mississippi showed good agreement.

The results of this study apply only to those solutes whose density and behavior characteristics are similar to those of water. Additional considerations, outside the scope of this report, must be taken when materials that are not soluble in water are accidentally spilled.

TRAVELTIME

Rhodamine WT, a fluorescent tracer, was injected in the center of the channel at each injection site. The tracer was observed in passage at 14 locations over the 315-mile reach to Plaquemine, La. Time-of-travel curves in figures 1, 2, and 3 show the leading edge, the peak, and the trailing edge of the tracer clouds, respectively, as observed and as computed for other flow rates.

Time-location observations made in this study are displayed graphically in red in figures 1, 2, and 3. The curves computed for selected discharges are shown in black on the same figures.

The leading edge is defined as the time the tracer was first detected at the measuring site. (Concentrations were measured to the nearest 0.1 microgram per liter.)

The trailing edge is defined as occurring when the concentration is equal to 10 percent of the peak concentration.

LATERAL DISPERSION

Data for determining lateral dispersion were collected at selected points below each site where the tracer was injected. The water tracer was injected near the midpoint of the river. Curves showing the lateral dispersion at the downstream sites below each injection site are shown in figures 4, 5, and 6.

Lateral dispersion for the injection at mile 523 below Greenville, Miss., are shown for three downstream sites (fig. 4). At mile 517 near Chatham, Miss., the tracer cloud extended from the center of the river to about 400 feet from the left bank with the peak concentration occurring about 900 feet from the left bank. The width of the cloud was about 1,000 feet. At mile 511 near Cracraft Landing, Ark., the cloud was about 1,300 feet wide and had moved to the right bank. The water tracer was not detected within 700 feet of the left bank. At the Arkansas-Louisiana State line (mile 507) the cloud moved to the center of the river. Concentrations were highest near the center with no tracer detected within 100 feet of the right bank.

Lateral dispersion for the injection at mile 442 is shown for three locations downstream (fig. 5). At mile 438 (1.0 mile above Vicksburg Harbor), 4 miles downstream from the injection site, the tracer was not uniformly dispersed as it moved to the right bank. The maximum concentration occurred approximately 400 feet from the right bank, and the cloud was approximately 1,900 feet wide. As the tracer cloud moved to mile 434, the maximum concentrations occurred near the center. At mile 418 the tracer cloud was more evenly dispersed from the right bank to the left bank.

Data for lateral dispersion are shown for two sites below the Old River control structure (fig. 6). At mile 305 near Old River Locks the leading edge and peak concentrations occurred slightly to the right of the center of the river with no tracer detected within 200 feet of the left bank. However, after passage of the peak the trailing edge moved to the left bank. At mile 294 near Tunica, La., the cloud extended from the right bank to approximately 500 feet from the left bank with the peak occurring near the center of the river. The width of the cloud was approximately 3,000 feet.

LONGITUDINAL DISPERSION AND PEAK CONCENTRATION

The location of the leading edge, the peak, and the trailing edge for any elapsed time after a spill or injection in the reach studied can be estimated from the curves in figures 1, 2, and 3. If the discharge rate, time, and place of injection are known, the approximate longitudinal dispersion of a tracer or contaminant cloud passing a point can also be derived from the curves in figures 1, 2, and 3. For example, assume that an accidental spill occurred at Natchez, Miss., (mile 363) and that the longitudinal dispersion at Baton Rouge, La., (mile 229) is needed. The discharge is 800,000 ft^3/s between Natchez, Miss., and the Old River control structure in Louisiana; 200,000 ft^3/s is diverted from the river through the Old River control structure; and the flow between the Old River control structure and Baton Rouge, La., is 600,000 ft^3/s. Using the example in figure 1, the traveltime of the leading edge from Natchez, Miss., (mile 363) to the Old River control structure (mile 314) is 13 hours (54 hours minus 41 hours). The traveltime of the leading edge from the Old River control structure (mile 314) to Baton Rouge, La., (mile 229) is 26 hours (86 hours minus 60 hours). Thus, the traveltime of the leading edge from Natchez, Miss., to Baton Rouge, La., is 39 hours (13 hours plus 26 hours). Similarly, the trailing edge would pass Baton Rouge, La., in 53 hours (see example in fig. 3); hence, the passage time or the longitudinal dispersion is 14 hours. The time of arrival of the peak concentration is 43 hours (fig. 2).

For a given amount of tracer, the greater the river discharge, the less the concentration because of dilution. To allow comparison of concentration data from different tests 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 flow. Peak unit concentrations for the study are shown versus traveltime on the right side of figure 7. Curve A represents conditions between mile 523 and mile 314, and curve B represents conditions between mile 314 and mile 208 (note that the upper parts of the curves merge). Curve B is identical to the curve representing conditions between Baton Rouge and Pointe a la Hache, La. (Martens and others, 1974).

By use of the unit-concentration curves in figure 7, the magnitude of the peak concentration can be determined from the nomograph (fig. 7) where the traveltime, the river discharge, and the weight of the contaminant spilled are known, as demonstrated in the following example.

Assume that 200,000 lb of a soluble conservative contaminant was accidentally spilled at Natchez, Miss. (mile 363). The discharge at Natchez, Miss., is 800,000 ft^3/s, of which 200,000 ft^3/s flows through the Old River control structure. The riverflow at Baton Rouge, La., will be approximately 600,000 ft^3/s (800,000 ft^3/s minus 200,000 ft^3/s). It is desirable to know the traveltime of the peak and the peak concentration of the contaminate at Baton Rouge, La. (mile 229). From figure 2 the traveltime of the peak from Natchez, Miss., (mile 363) to the Old River control structure (mile 314) is 15 hours (62 hours minus 47 hours). The traveltime of the peak from the Old River control structure (mile 314) to Baton Rouge, La., (mile 229) is 28 hours (98 hours minus 70 hours). Thus, the traveltime of the peak from Natchez, Miss., to Baton Rouge, La., is 43 hours (15 hours plus 28 hours). Curve A is used to determine unit concentrations during the first 15 hours, and curve B is used during the next 28 hours. To move from curve A to curve B, enter the nomograph (fig. 7) at 15 hours on curve A and determine the difference from curve A to curve B (5 hours). Enter curve B with 48 hours (43 hours plus 5 hours) and determine a unit concentration of 620. Draw a straight line between a unit concentration of 620 and a weight of 200,000 lb, and mark the intersection of this straight line on the match line. Draw a straight line between the mark on the match line and a discharge of 600,000 ft^3/s, and determine a peak concentration of 210 micrograms per liter at Baton Rouge, La.

The peak concentration can also be determined using the equation

$$\text{Peak concentration} = \frac{\text{unit concentration times weight of contaminant spilled}}{\text{discharge at the sampling site}}.$$

Therefore, from figure 7,

$$\text{Peak concentration} = \frac{620 \times 200{,}000 \text{ lb}}{600{,}000 \text{ ft}^3/\text{s}} = 207 \text{ micrograms per liter.}$$

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