PREPARED BY
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

IN COOPERATION WITH THE
STATE OF LOUISIANA
LOUISIANA DEPARTMENT OF PUBLIC WORKS

LOUISIANA DEPARTMENT OF PUBLIC WORKS
Water Resources
TECHNICAL REPORT NO. 9

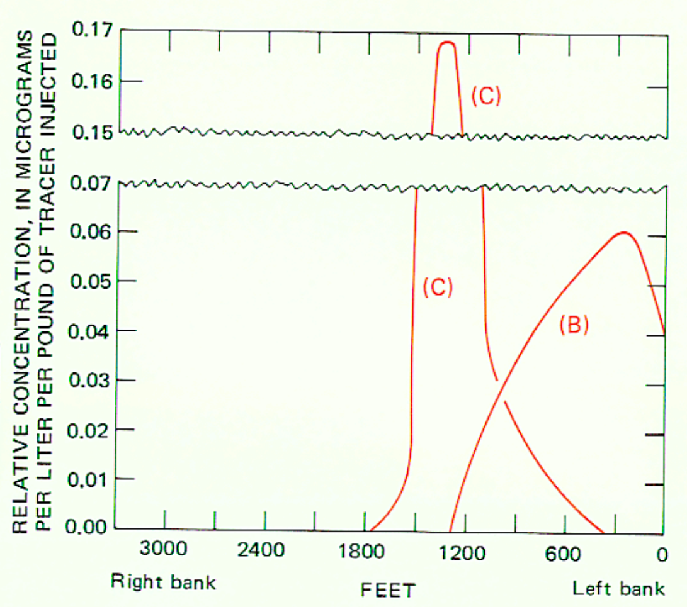


Figure 4.–Relative peak concentration at Addis site (mile 224).

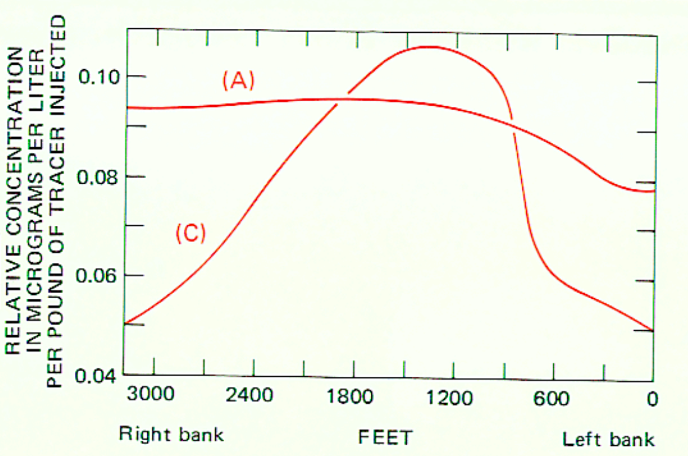


Figure 6.–Relative peak concentration at Burtville site (mile 212).

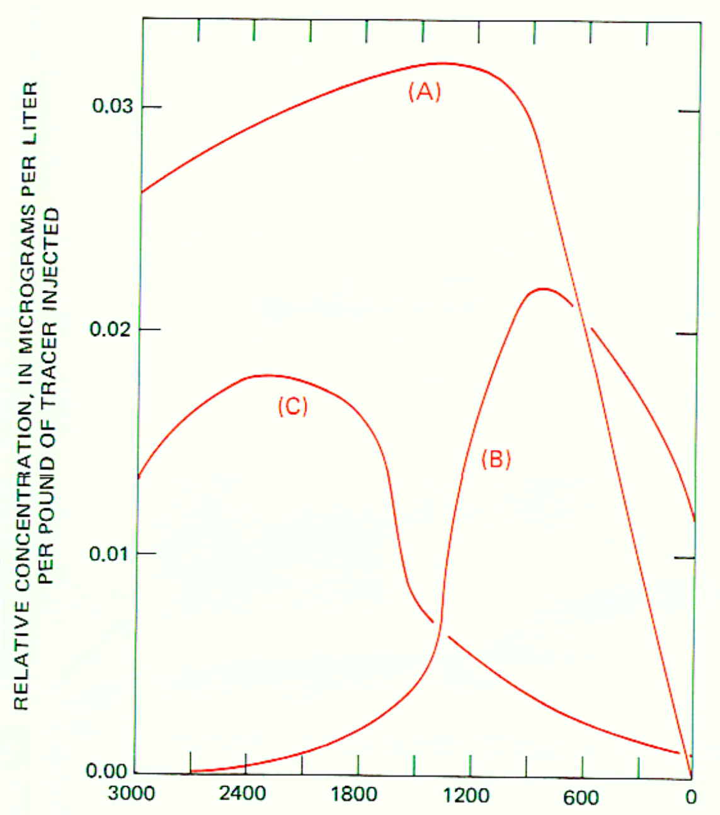


Figure 5.–Relative peak concentration at Longwood site (mile 219).

TIME OF TRAVEL OF SOLUTES IN MISSISSIPPI RIVER FROM BATON ROUGE TO POINTE A LA HACHE, LOUISIANA

INTRODUCTION

At 9 a.m. on April 24, 1974, a water tracer was injected into the Mississippi River at Baton Rouge, La., in order to determine the traveltimes, the maximum concentrations, the dispersion characteristics, and the duration of the tracer cloud as it moved downstream past New Orleans, La. The significance of this study (1974) is that it was made when the Mississippi River at Baton Rouge was approaching flood discharge with a stage of 31 feet and discharge of 800,000 cfs (cubic feet per second). Time-of-travel studies are usually made during periods when streams are at or approaching low flow, for it is at this time that an accidental spill could cause the most harm to water users along the streams. This is an important consideration for water users along the lower Mississippi River as was demonstrated by the studies made by Stewart in 1965 when the flow in the Mississippi River was 240,000 cfs and again by Everett in 1969 when the flow in the river was 364,000 cfs.

Accidental spills on the lower Mississippi River occur most often as a result of navigation accidents; these incidents occur most often during periods of high flow when the river is difficult to navigate. Therefore, it is under these circumstances that planners, environmentalists, and downstream water users need to know the behavior of solutes accidentally spilled into the river.

The Mississippi River between Baton Rouge and the New Orleans metropolitan area is important not only as a navigable stream for oceangoing vessels and barge traffic, but also as a major source of water for many industries and municipalities. In order for these users to properly anticipate the effects of a spill that may affect their utilization of the river water, information on the water speed and on the lateral and longitudinal dispersion of solutes under different flow conditions is required. These factors, as well as vertical dispersion, can be observed by simulating such movement with a water tracer and recording the time the tracer first arrives, peaks, and passes selected downstream sites. Vertical dispersion is usually accomplished quickly, whereas lateral dispersion is not accomplished completely for some distance from the injection point. Longitudinal dispersion continues indefinitely in relation to time and distance; and it is this spread, along with the rate of movement, that provides the most important information.

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.

Time-of-travel studies were made in 1965 (Stewart, 1967) and 1969 (Everett, 1971) to determine the traveltime and dispersion characteristics of water flowing in the Mississippi River. In 1965, a water tracer was injected into the center of the river at Baton Rouge (mile 229) when the discharge was 240,000 cfs and sampled at selected sampling sites downstream as far as New Orleans (Stewart, 1967).

In 1969, in order to obtain a better understanding of the dispersion phenomena—laterally as well as longitudinally—a water tracer was injected near each bank of the river, and two sets of observations at different flow rates were made at selected downstream sites (Everett, 1971). The first set of observations was made between Baton Rouge and New Orleans after the tracer was injected into the river about 1,000 feet from the right bank, which coincides with the point of maximum flow in the channel at about mile 229. The flow at Baton Rouge (mile 229) was 364,000 cfs. The second set of observations was made only between Baton Rouge and Plaquemine when the discharge was 550,000 cfs. At this time the tracer was injected 300 feet from the left bank at about mile 229. These data and their significance were discussed in detail by Everett (1971, p. 44–46).

Everett (1971) assumed a linear relation between traveltime and discharge for points between Baton Rouge and New Orleans to estimate the time of travel for discharge rates other than those observed. One of the objectives of this (1974) study was to determine whether this relation was applicable during periods of higher flow.

The purposes of this report are to determine the time of travel and to summarize graphically the observations of rate of lateral and longitudinal dispersion between Baton Rouge and Pointe a la Hache, La., when the river was near flood discharge. Furthermore, this report correlates these data with those collected in previous studies (Stewart, 1967, and Everett, 1971) when the discharge was in the medium- or low-flow range.

TRAVELTIME

During low and medium flow, discharge of the Mississippi River between Baton Rouge and the Gulf of Mexico is constantly changing as a result of tide effects. This was demonstrated by the discharge measurements made in 1969. The flow at Baton Rouge, when the tracer was injected, was 364,000 cfs, and the flow at New Orleans when the tracer arrived was only 290,000 cfs. Discharge measurements made during this study (1974) indicate a flow of 792,000 cfs at Baton Rouge at the time of tracer injection and 798,000 cfs at Belle Chasse at the time the tracer arrived at that site, thus indicating the dominating effect of high river flow over tidal influences.

Rhodamine WT, a fluorescent tracer, was injected in the center of the channel at Baton Rouge (mile 228) for the (1974) study and was observed in passage at nine locations over the 179-mile reach to Pointe a la Hache, La. Figures 1, 2, and 3 indicate that for higher discharges the relation between traveltime and distance is essentially linear; however, because of tidal influence at lower discharges this relation becomes curvelinear. Thus, the net effect of tides in the lower Mississippi River is to produce a nonlinear traveltime-discharge relation. Nevertheless this most recent test provides a comprehensive evaluation of traveltime versus distance for a complete range in discharges.

Time-location observations made in this and the two previous studies are displayed graphically in red in figures 1, 2, and 3. Extrapolated and interpolated curves computed for selected discharges are shown in solid black lines on the same figures. The dashed black lines (figs. 1, 2, and 3) between New Orleans and Pointe a la Hache have been extended from the computed curves.

LATERAL AND VERTICAL DISPERSION

Lateral mixing in the Mississippi River between Baton Rouge and Plaquemine was studied on two previous occasions when the water tracers were dumped separately near the left and right banks (Everett, 1971). The shape of the lateral dispersion at the first three downstream sites—Addis, Longwood, and Burtville—resulting from these injections is shown on figures 4, 5, and 6.

For this (1974) study the tracer was injected near the midpoint in the river at Baton Rouge (mile 228). At Addis, 4 miles downstream from the injection point, the tracer had dispersed toward both banks and the cloud was approximately 1,400 feet wide. (See curve C on fig. 4.) The water tracer had moved to within 400 feet of the left bank and to within 1,000 feet of the right bank; however, maximum concentrations occurred near the center of the river. No tracer was detected along either bank at this first site. As the tracer moved through the first meander, at Longwood, 9 miles downstream, concentrations were greatest about 500 to 1,000 feet from the right bank. (See curve C on fig. 5.) Although the tracer had spread across the river, concentrations near the left bank were barely detectable. At Burtville, 16 miles downstream, concentrations were again highest near the center of the river. Concentrations near each bank were about half as great as concentrations near the center. (See curve C on fig. 6.)

Vertical dispersion was tested by simultaneously taking samples at the surface and at 50-foot depth at the first three downstream locations. Comparison of the concentrations of these samples shows that vertical mixing was not complete at Addis as surface concentrations were almost double those at the 50-foot depth. However, by the time the tracer had moved to Longwood and Burtville, concentrations at surface and depth were practically the same at each location.

LONGITUDINAL DISPERSION AND PEAK CONCENTRATION

Longitudinal dispersion can be measured in miles occupied by a contaminant or tracer cloud or by the time necessary for the cloud to pass a selected point. Knowledge of the times it takes a contaminant to first arrive and to pass a selected site is useful in developing plans for minimizing the effects of contamination. The time-location position of the leading edge, the peak, and the trailing edge for any elapsed time after a spill or injection of a tracer is shown in figures 1, 2, and 3. These curves can be used to calculate the approximate longitudinal dispersion of a cloud passing a point if the discharge rate and the time and place of injection are known. For example, assume that an accidental spill occurred at mile 190 when the flow was 600,000 cfs and that the longitudinal dispersion at New Orleans was needed. Using the example in figure 1, it is estimated that the leading edge will arrive at New Orleans in 33 hours (45 hours at New Orleans minus 12 hours at mile 190). Similarly, the trailing edge would pass New Orleans in 41 hours (see example on fig. 3); hence, the passage time or the longitudinal dispersion is 8 hours.

In addition to knowing how long a contaminant would be present at a site, it is equally important to know when the peak concentration of the contaminant will arrive and to be able to predict the magnitude of the peak concentration. The time of arrival of the peak concentration can be determined from figure 2 in the same way as was done previously for the leading edge.

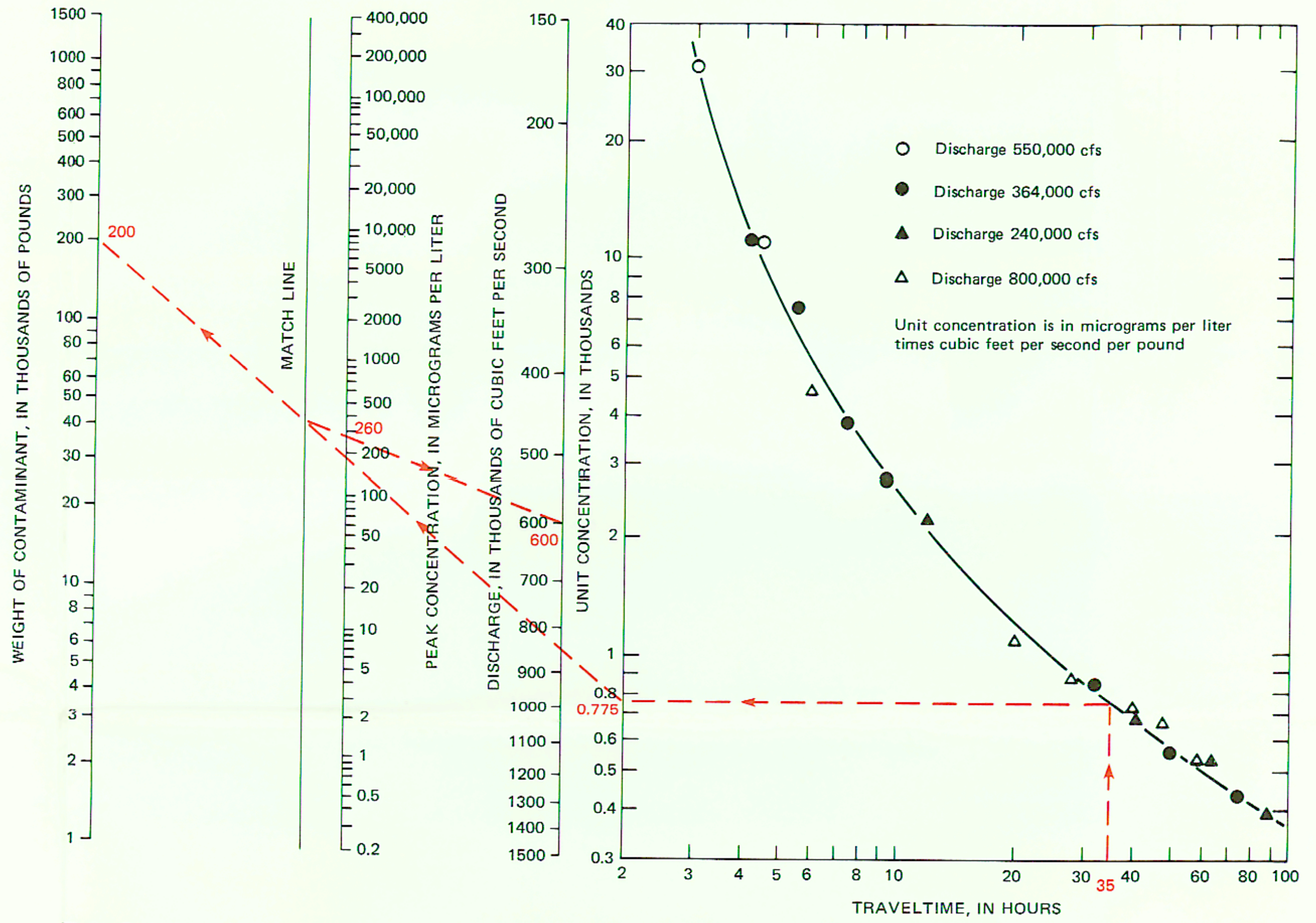


Figure 7.–Nomograph for predicting the peak concentration of a conservative contaminant at downstream sites, by knowing the discharge rate, the elapsed time, and the weight of the contaminant.

Of the four tracer studies that have been made on this part of the Mississippi River, all have been at different discharges and involved the injection of different amounts of tracer. Thus, the concentrations of the tracer clouds as observed at the different downstream locations vary widely. It becomes obvious that, for a given discharge, the greater the amount of tracer injected, the greater the concentrations downstream. Conversely, 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 river, F. A. Kilpatrick (written commun., 1970) developed a method whereby all observed concentrations are reduced to “unit concentrations”. For practical use, unit concentration is that concentration which would result at a downstream point from the injection of 1 pound of tracer into 1 cubic foot per second of flow.

Maximum or peak concentrations are of particular concern; peak unit concentrations for all four tests are shown versus traveltime on the right side of figure 7. It should be noted that despite the great range in discharges these tests cover, the attenuation of peak concentrations conforms to one relationship.

By use of the unit-concentration curve of 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 pounds of a conservative contaminant, one that is completely soluble in water, was accidentally spilled at mile 190 when the river discharge was 600,000 cfs. It is desirable to know the traveltime of the peak and the peak concentration of the contaminant at New Orleans (mile 103). From figure 2 the traveltime of the peak is 35 hours (50 hours minus 15). Enter the nomograph at 35 hours, and determine a unit concentration of 775. Draw a straight line between a unit concentration of 775 and a weight of 200,000 pounds, 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 cfs, and determine a peak concentration of 260 micrograms per liter at New Orleans.

The magnitude of the peak concentration can also be determined using the equation

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

after entering the nomograph (fig. 7) to obtain the unit concentration. Therefore,

$$\text{peak concentration} = \frac{775\times 200{,}000\text{ pounds}}{600{,}000\text{ cfs}} = 258\text{ micrograms per liter.}$$

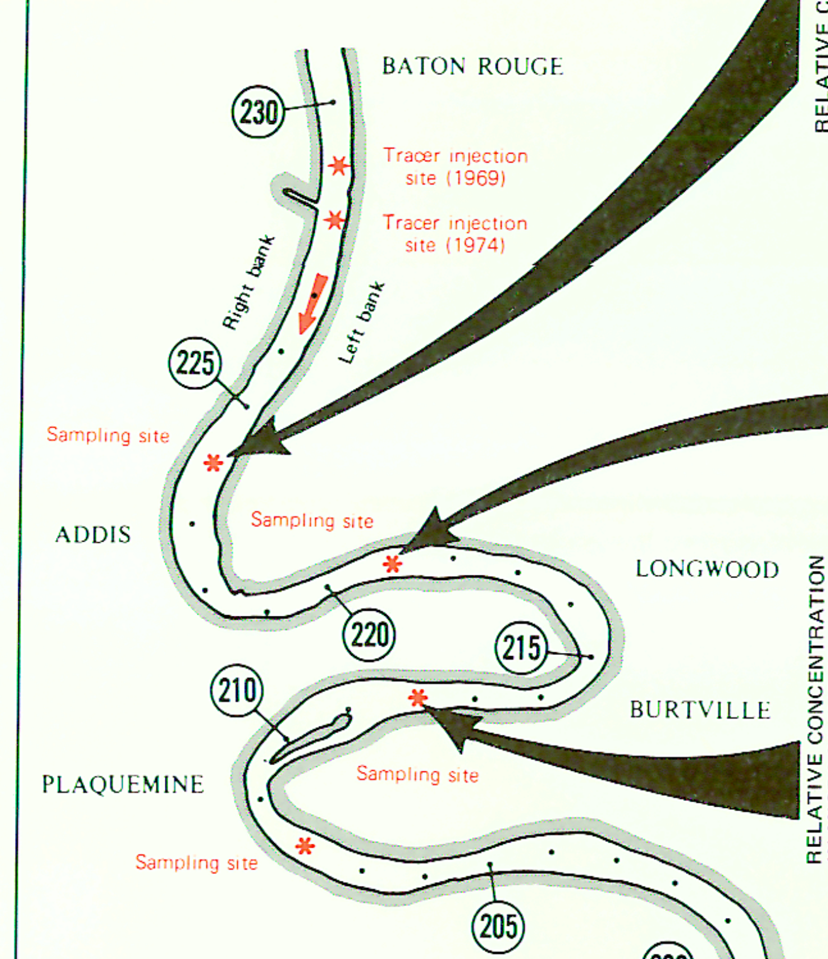
EXPLANATION

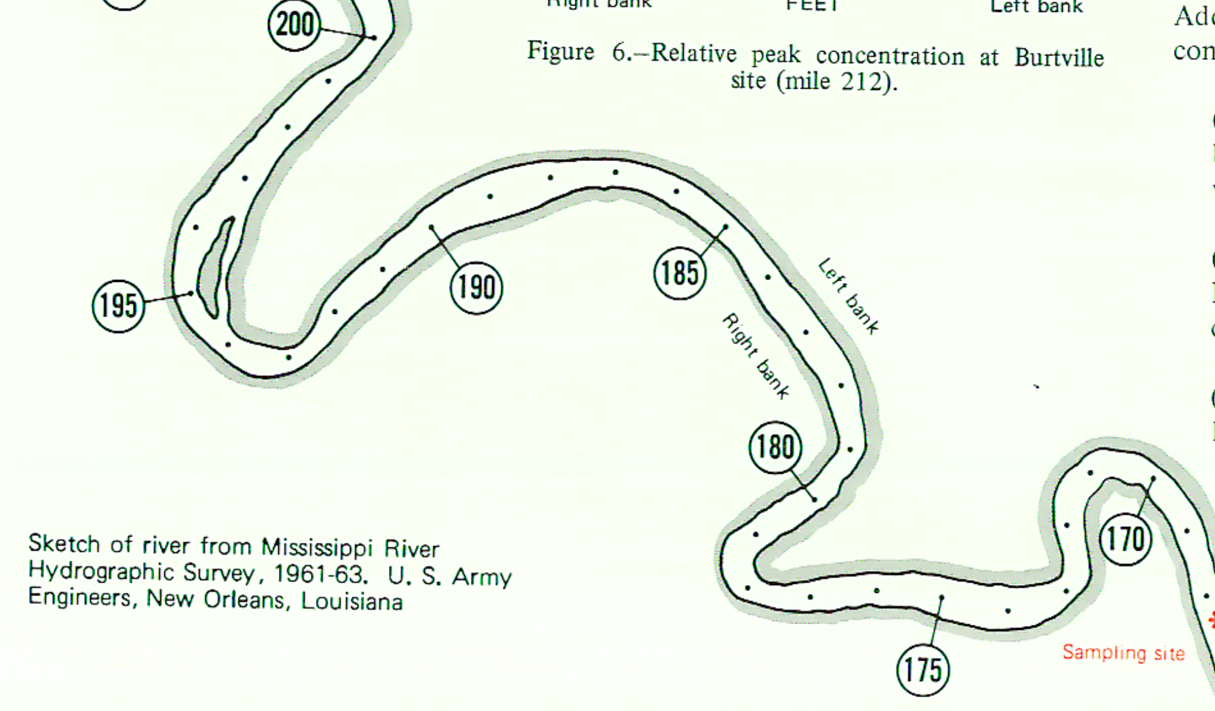
Lateral dispersion (figs. 4, 5, and 6) of peak concentration at Addis, Longwood, and Burtville sites are for the following conditions:

(A) when tracer was injected 1,000 feet from right bank of river at Baton Rouge (mile 229) in 1969, flow was 364,000 cfs;

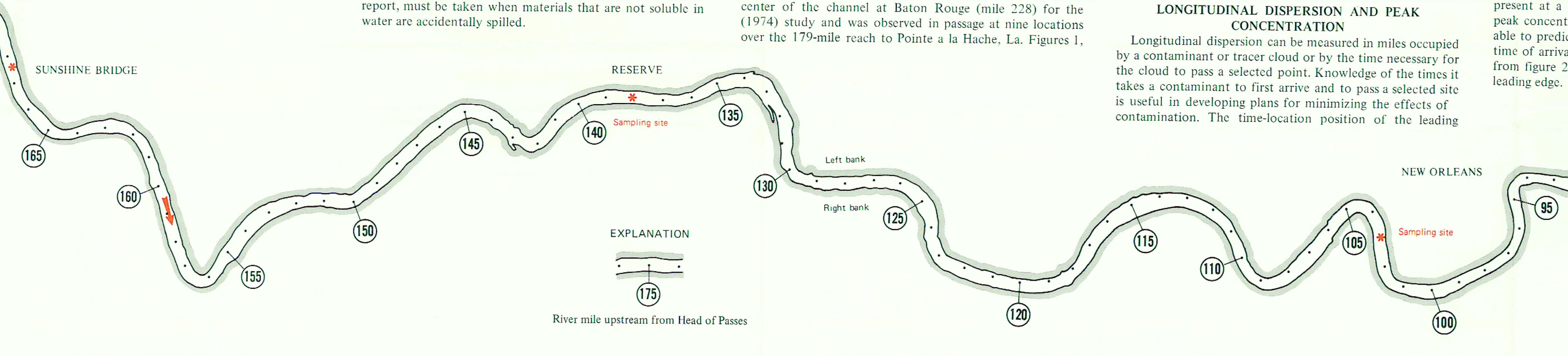
(B) when tracer was injected 300 feet from left bank at Baton Rouge (mile 229) in 1969, flow was 550,000 cfs; and

(C) when tracer was injected in center of river at Baton Rouge (mile 228) in 1974, flow was 800,000 cfs.



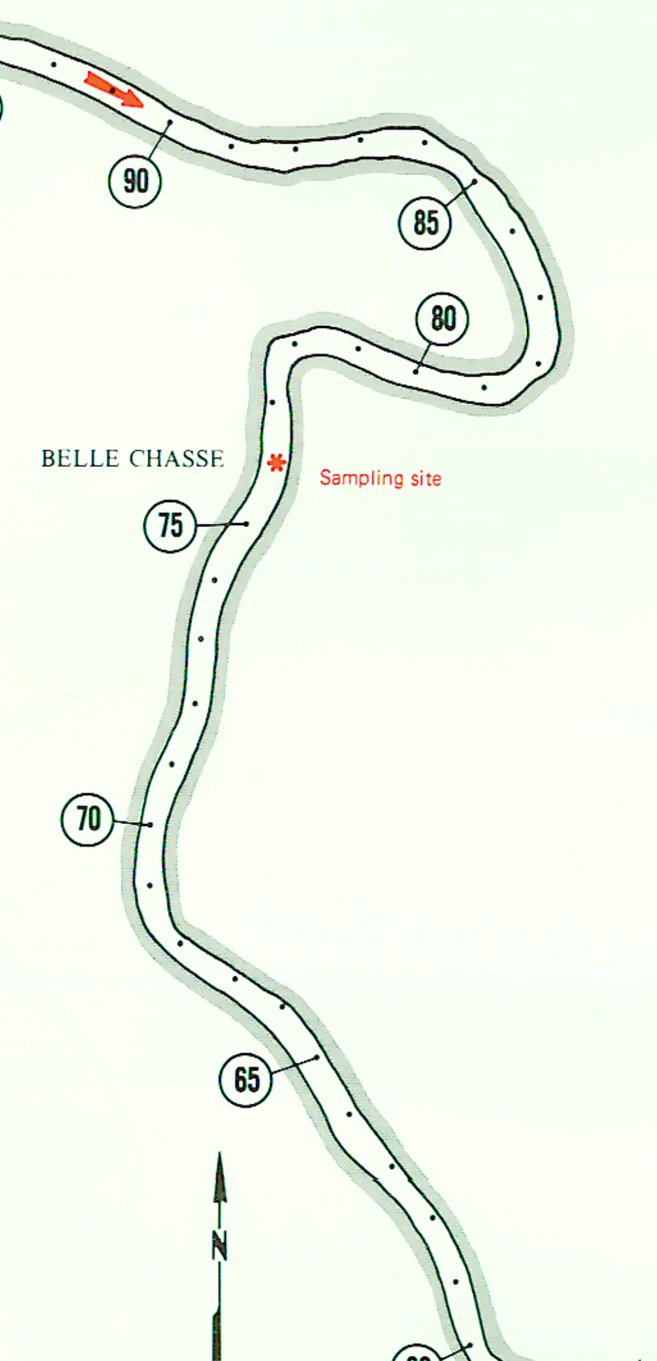


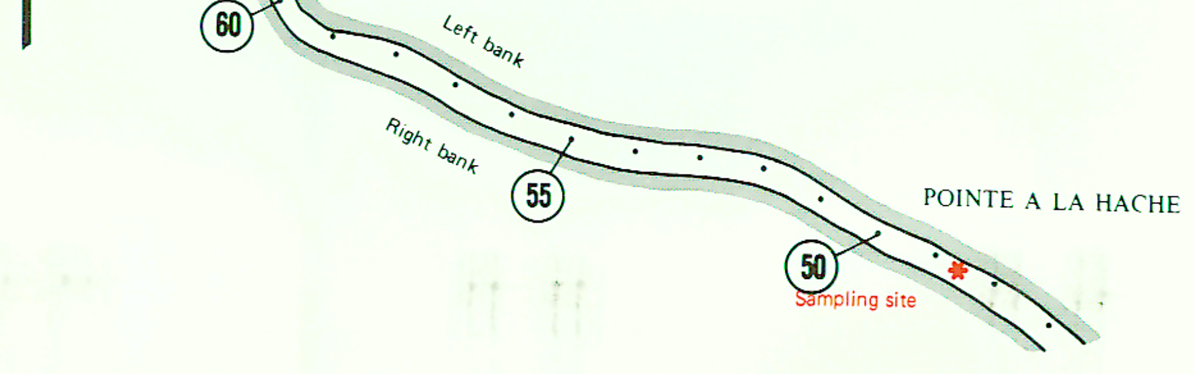
Sketch of river from Mississippi River Hydrographic Survey, 1961-63, U. S. Army Engineers, New Orleans, Louisiana



EXPLANATION

River mile upstream from Head of Passes





Factors for converting English units to Metric units

Multiply English units	*By*	*To obtain Metric units*
Cubic foot per second (cfs)	0.02832	Cubic meter per second
Foot (ft)	0.3048	Meter
Mile	1.609	Kilometer

INDEX MAP OF LOUISIANA

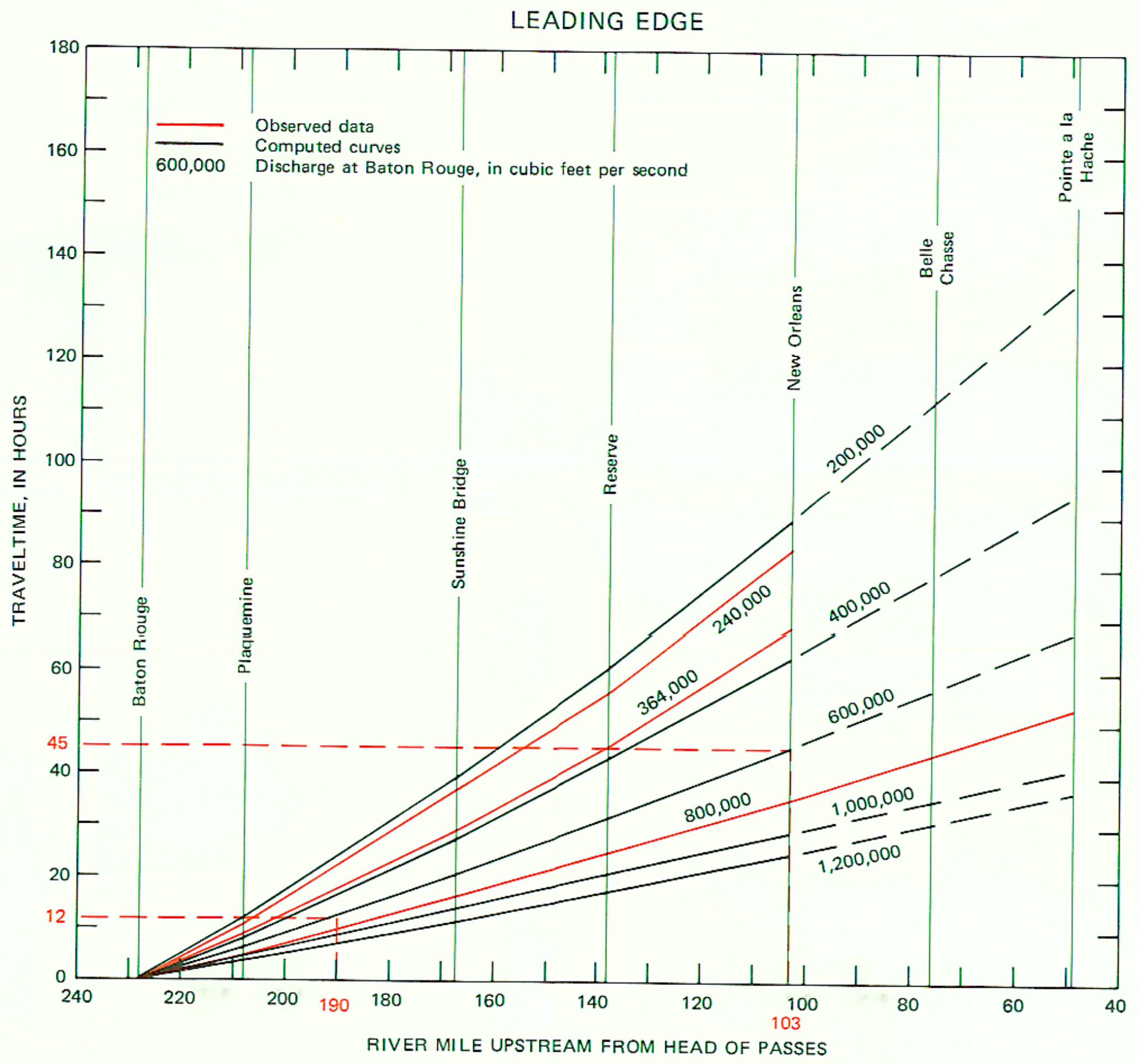


Figure 1.–Curves showing the time of travel of the leading edge of a tracer cloud at downstream locations along the Mississippi River for different discharge rates.

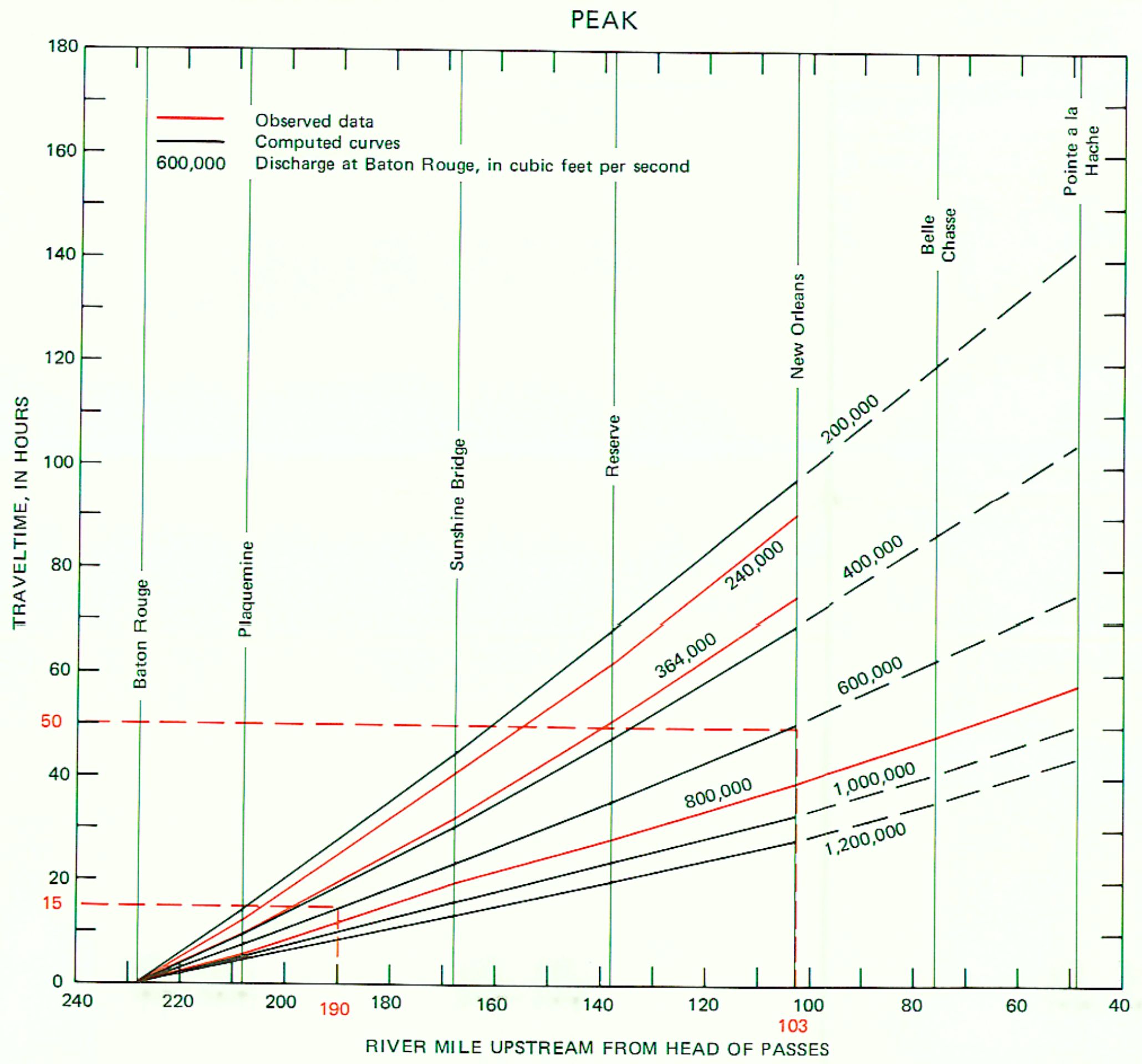


Figure 2.–Curves showing the time of travel of the peak concentration of a tracer cloud at downstream locations along the Mississippi River for different discharge rates.

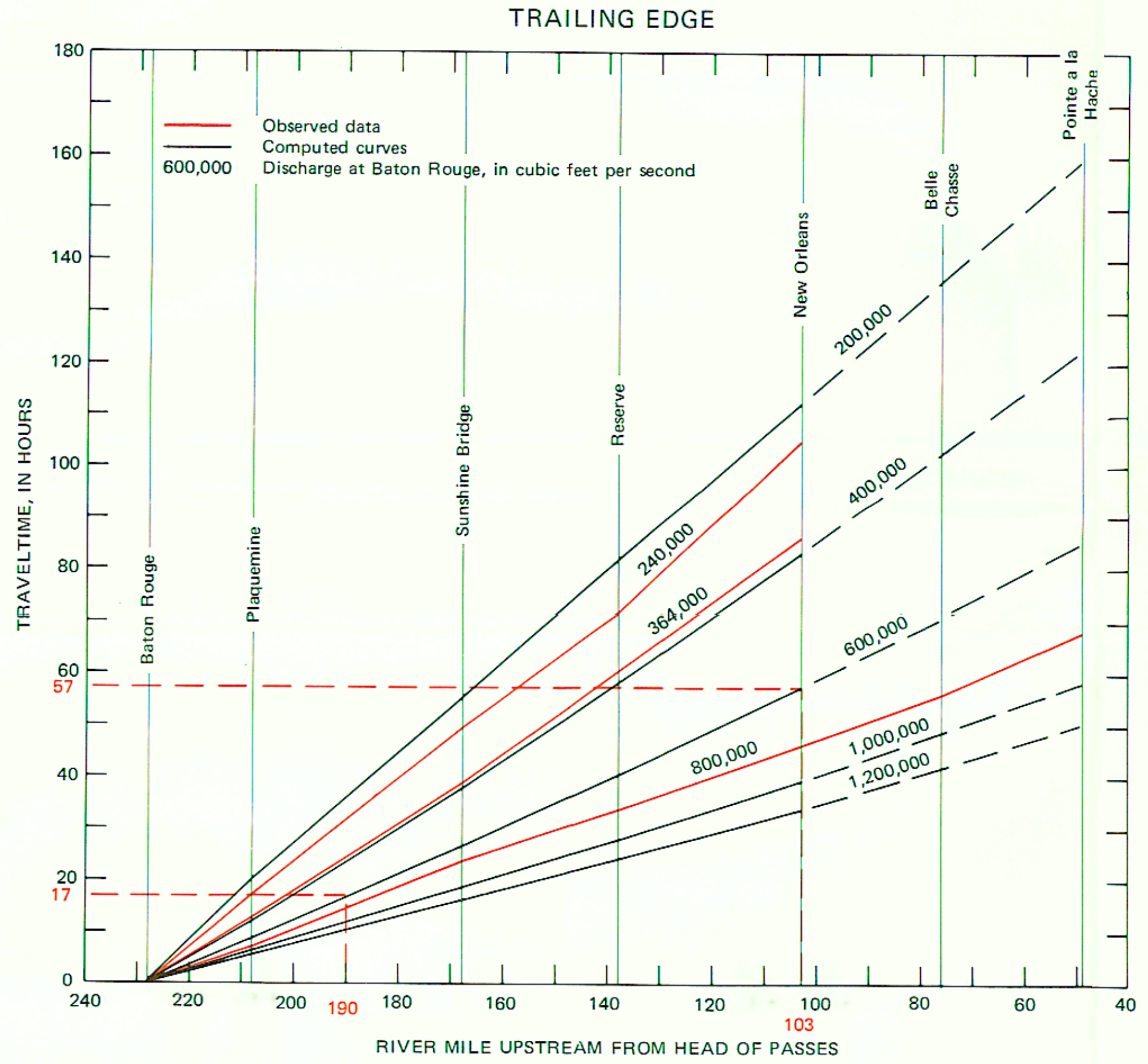


Figure 3.–Curves showing the time of travel of the trailing edge of a tracer cloud at downstream locations along the Mississippi River for different discharge rates.

ACKNOWLEDGMENTS

Special thanks are due the U.S. Coast Guard, U.S. Army Corps of Engineers, New Orleans District, and the Louisiana Department of Public Works for their assistance during the study.

REFERENCES

Everett, D. E., 1971, Hydrologic and quality characteristics of the lower Mississippi River: Louisiana Dept. Public Works Tech. Rept. 5, 48 p.

Stewart, M. R., 1967, Time of travel of solutes in Mississippi River from Baton Rouge to New Orleans, Louisiana: U.S. Geol. Survey Hydrol. Inv. Atlas HA-260.

Time-of-travel study
by
LOUISIANA DISTRICT
WATER RESOURCES DIVISION
U. S. GEOLOGICAL SURVEY

Published by
LOUISIANA DEPARTMENT OF PUBLIC WORKS

TIME OF TRAVEL OF SOLUTES IN MISSISSIPPI RIVER FROM BATON ROUGE TO POINTE A LA HACHE, LOUISIANA

By L. A. Martens and others, U. S. Geological Survey, Baton Rouge, La.
1974