TIME OF TRAVEL OF THE FLINT RIVER, UTAH DAM TO HIGHWAY M-13, MICHIGAN: August 4-8, 1981

By T. Ray Cummings and John B. Miller

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GEOLOGICAL SURVEY

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CONVERSION FACTORS

The inch-pound units used in this report can be converted to the metric system of units as follows:

Multiply inch-pound unit	By	To obtain metric unit
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
feet per second (ft/s)	0.3048	meters per second (m/s)
cubic feet per second (ft^3/s)	28.32	liters per second (L/s)

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ABSTRACT

Tracing of rhodamine WT dye has provided time-of-travel data for waste-load allocation studies of a 42.8-mile reach of the Flint River at low flow. A discharge equaled or exceeded about 90 percent of the time was measured at Grand Traverse Street in Flint before dye injection. Dye was injected at two locations in Flint--at Utah Dam and at Grand Traverse Street. From Utah Dam to Grand Traverse Street, the mean velocity of flow was about 0.1 foot per second; time-of-travel was 35.3 hours. From Grand Traverse Street to Highway M-13, mean velocity was about 0.7 foot per second; time-of-travel was 78.8 hours. Time-of-travel for the reach between Utah Dam and Highway M-13 was thus 114 hours.

INTRODUCTION

At the request of the U.S. Environmental Protection Agency (EPA), the U.S. Geological Survey conducted a time-of-travel study of the Flint River during August 4-8, 1981. The study was designed to support a larger investigation of waste-load allocation, which required data for developing a mathematical model of water quality. The stream reach studied extended from Utah Dam at Flint to Highway M-13 near Fosters (pl. 1), 42.8 miles. Specifically, EPA requested that dye be injected in the river at two locations, and that dye concentrations be measured at two sites downstream to determine time-of-travel[1/]. In support of planned water-quality sampling, discharge measurements of several tributary sites during a 2-week period beginning August 4 were also requested. The purpose of this report is to describe the results of the study and to present the hydrologic data collected.

Samples were collected from bridges at four sites below each injection site. These sites are designated 1T to 4T and 1U to 4U. More than 700 samples were collected. Intervals between sampling ranged from 3 minutes to 1 hour, depending on the time required for passage of a dye cloud. At sites near the dye injection, samples were obtained more frequently and at more than one point in the cross section. A duplicated sample was collected at each sampling point at all sites for laboratory analysis.

1/ Time-of-travel is defined as the elapsed time, in hours, from dye injection to the centroid of the concentration-time curve at a point downstream, or the elapsed time between the centroids of concentration-time curves as the dye-cloud moves downstream.

Analyses of dye concentration were made at a stream site with a Turner Model 111 fluorometer[1/]. Based on results, judgments were made regarding changes in sampling frequency or termination of sampling. Duplicate samples were taken to the laboratory, settled for approximately 24 hours, allowed to come to constant temperature (about 25°C), and analyzed with a Turner Model 10 fluorometer. Results of these laboratory analyses are the basis of interpretations in this report. At sites where more than one point was sampled in the cross-section at the same time, an average concentration for the site was computed. If the difference in concentration between points was great enough and sufficient discharge data were available, an average concentration at the site was determined by weighting according to discharge in the section. Only a single concentration, representing the river at the time of each sampling, is given in table 1.

Method of Investigation

Flow characteristics in the reach of the Flint River between Utah Dam and Grand Traverse Street and in the reach between Grand Traverse Street and Highway M-13 differ signigicantly. Above Grand Traverse Street, the channel is generally deeper and wider due to an inflatable dam a few hundred feet upstream and to Hamilton Dam, about half a mile upstream. Mean velocity was about 0.1 ft/s (feet per second) at the time of the investigation. Downstream from Grand Traverse Street, the velocity of the river was about 0.7 ft/s. Based on these characteristics and the desire to keep dye[2/] concentrations as low as practicable in the river, Grand Traverse Street and Utah Dam were chosen as dye injection sites. Injection at Utah Dam was delayed for 26 hours after injection at Grand Traverse Street to minimize overlapping of dye clouds and to permit study of both reaches within 1 week.

Dye recovery was computed by assuming that each measured concentration represented the concentration during the sampling interval. The amount of dye was calculated using discharge data for the interval; each of these interval amounts were summed and compared to the total amount of dye injected.

Frequent analyses of river water prior to detection of dye indicated a fluorometer reading equivalent to 0.10 µg/L (micrograms per liter) rhodamine WT could be attributed to naturally fluorescent materials in the stream, or to light leakage associated with the fluorometer. Analyses in table 1 have not been corrected by this background amount, although a correction was made when computing dye recovery.

1/ The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

2/ Rhodamine WT was selected for use in the study principally because field tests have demonstrated greater recovery with it than with other dyes. Solutions of rhodamine WT, prepared before the study with water from the Flint River, showed no dye loss after standing 6 days.

FLOW CONDITIONS DURING STUDY

The U.S. Geological Survey operates two gaging stations on the Flint River below Utah Dam. One station, 04148500, Flint River near Flint, is 5.4 miles downstream from Grand Traverse Street. A second station, 04149000, Flint River near Fosters, is at Highway M-13, 40.1 miles downstream from Grand Traverse Street. Hydrographs for these stations during August 4-15 are shown in figure 1.

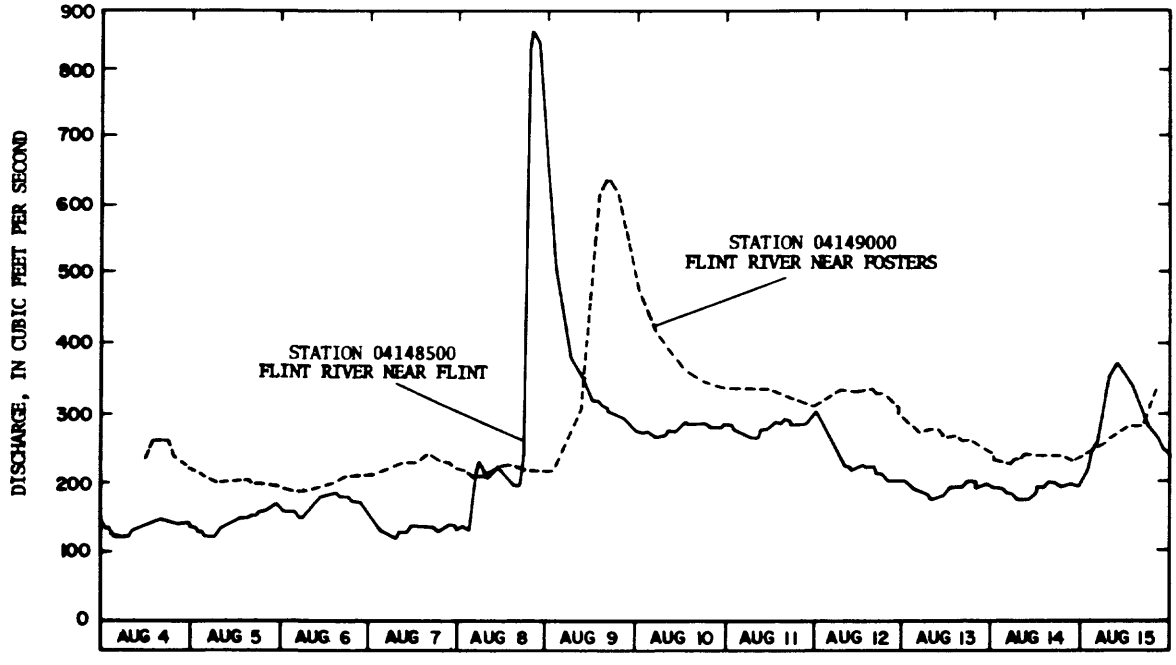

Figure 1. Hydrographs of the Flint River near Flint and near Fosters, August 4-15, 1981.

To provide necessary flow information, additional discharge measurements were made at selected sites (table 2). These data, with discharge records from the gaging stations near Flint and near Fosters and records of waste-treatment plant releases, were used to estimate hydrographs for three sites on the Flint River--at Ballenger Road (site 1T), at Main Street in Flushing (site 2T), and at Highway M-57 (site 3T). These hydrographs are shown in figure 2. Once discharges of the Flint River were adjusted for waste-treatment plant releases, they were transferred to other sites by using time-of-travel data and adjusting each hourly discharge by a coefficient based on the drainage area ratio. Discharge measurements made during the study verify the estimated hydrographs.

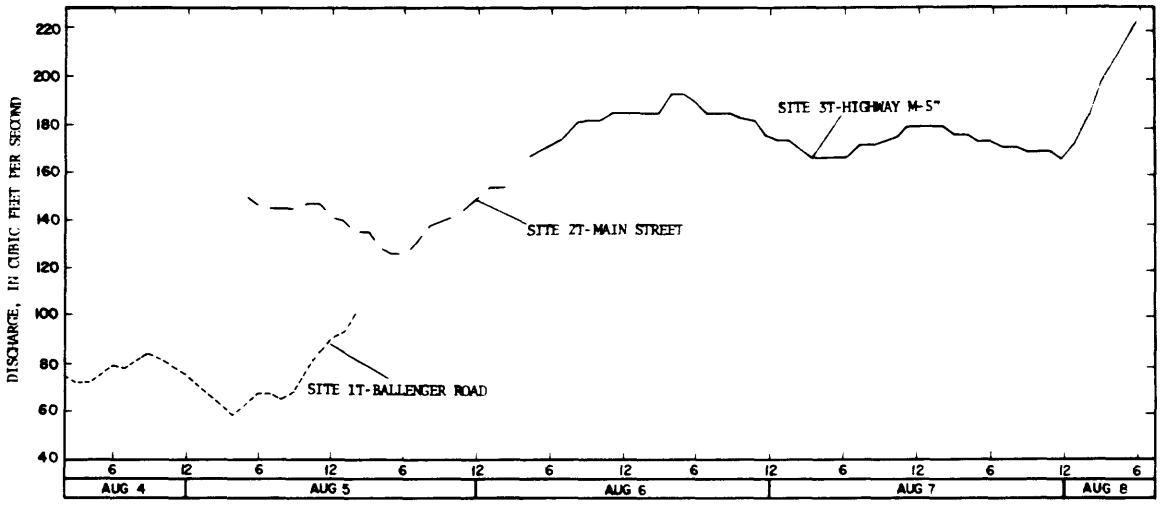

Figure 2. Estimated hydrographs of the Flint River at Ballenger Road, Main Street in Flushing, and Highway M-57, August 4-8, 1981.

Estimates of instantaneous discharge were made for selected tributary sites. These estimates (table 3) were based upon miscellaneous discharge measurements and water-level measurements from a reference point.

Discharge at Grand Traverse Street was 85.7 ft^3/s (cubic feet per second) before the injection of dye on August 4. The discharge of Swartz Creek just prior to injection was 11.1 ft^3/s. If these discharges are added, and compared to flow duration data of the Flint River near Flint, the discharge at Grand Traverse Street at the time of injection is equaled or exceeded about 90 percent of the time (fig. 3). A mean daily discharge as low as 85.7 ft^3/s occurs about once every 1.5 years (fig. 4).

The average monthly discharge near Flint during August is 218 ft^3/s, and thus initial flow conditions were lower than normal when the study began. From August 4 to August 8, average discharge was 178 ft^3/s. A storm on August 8 increased flow to the extent that the average flow during August 4-15 was about 225 ft^3/s. Downstream from Highway M-57, the storm caused dye movement to be more rapid.

DYE INJECTION AND TRACING

Grand Traverse Street to Highway M-13

At Grand Traverse Street, 9.0 liters of rhodamine WT 20 percent solution was injected at 9:55 a.m. on August 4. The amount of dye was computed after considering river distance, mean velocity, and discharge. Dye was poured from a bucket in the center of the river. Dispersion was rapid, and about 600 feet downstream traces of dye had almost reached each bank. The following sections discuss detection and movement of dye at each sampling site.

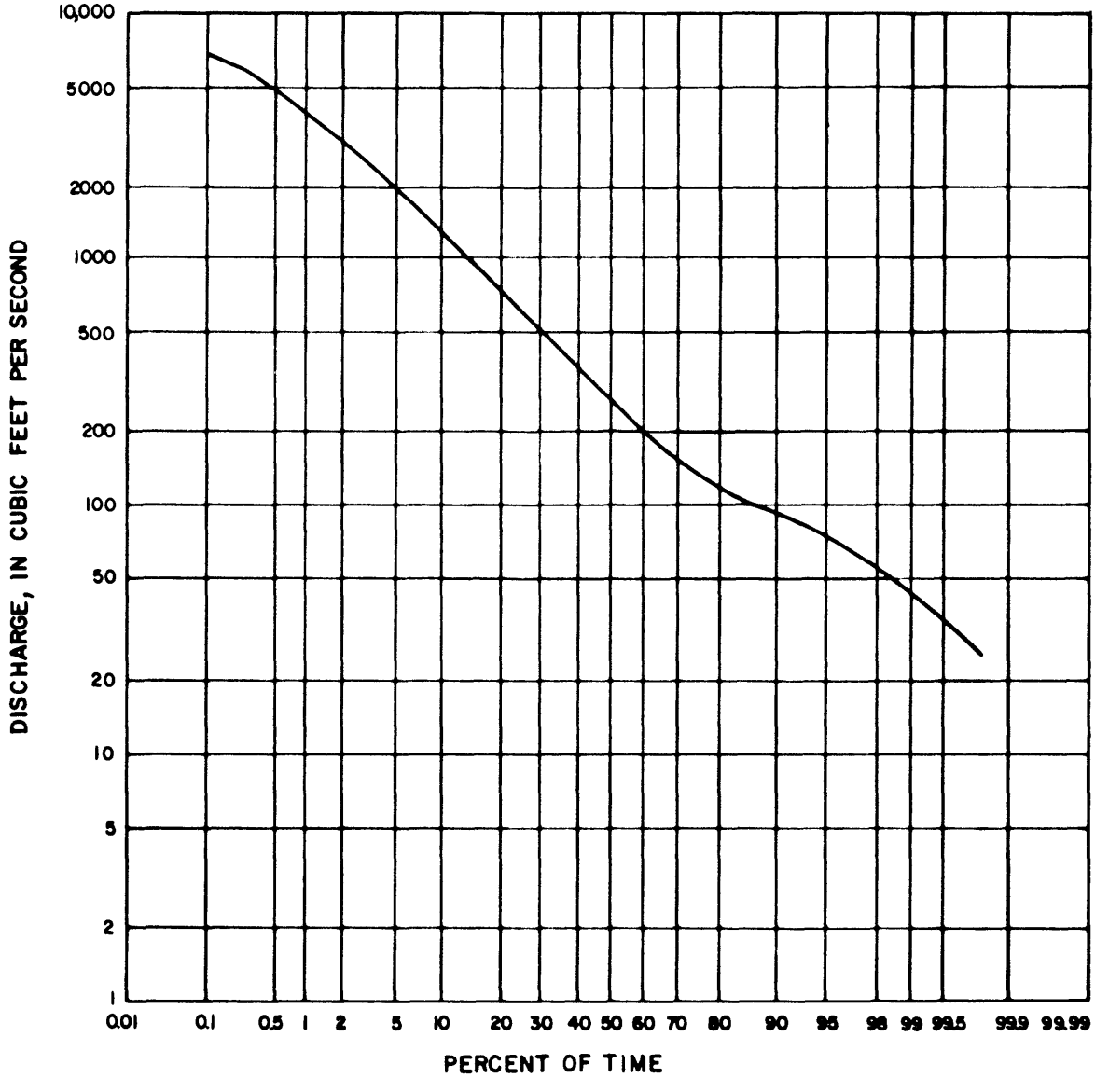

Figure 3. FLow duration of Flint River near Flint, 1934-80.

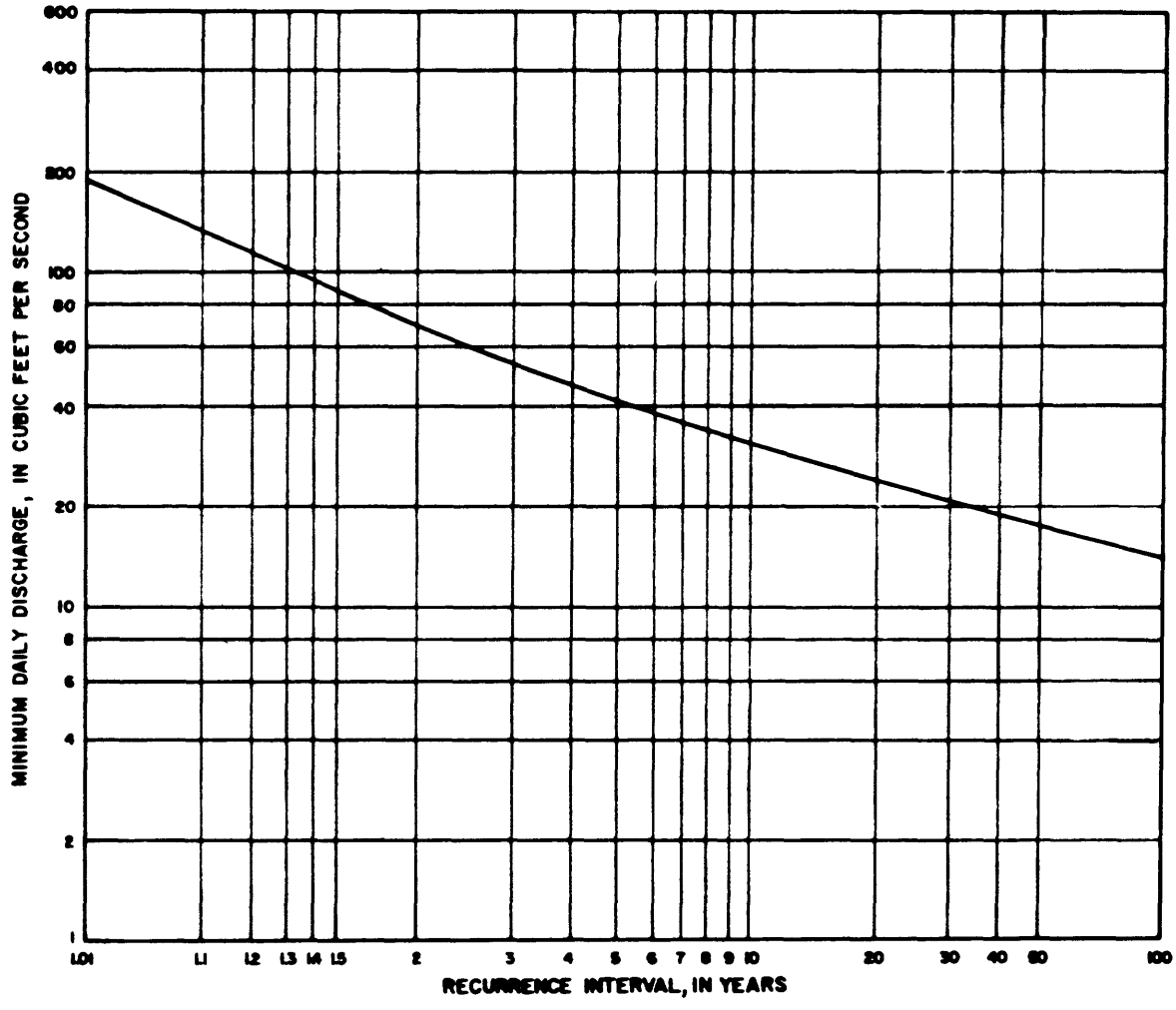

Figure 4. Low-flow frequency of Flint River near Flint, 1934-80.

Site 1T - Ballenger Road, 2.6 miles downstream

The leading edge of the dye cloud was detected at Ballenger Road at 2:40 p.m., 4.7 hours after injection (fig. 5). (Table 4 lists the characteristics

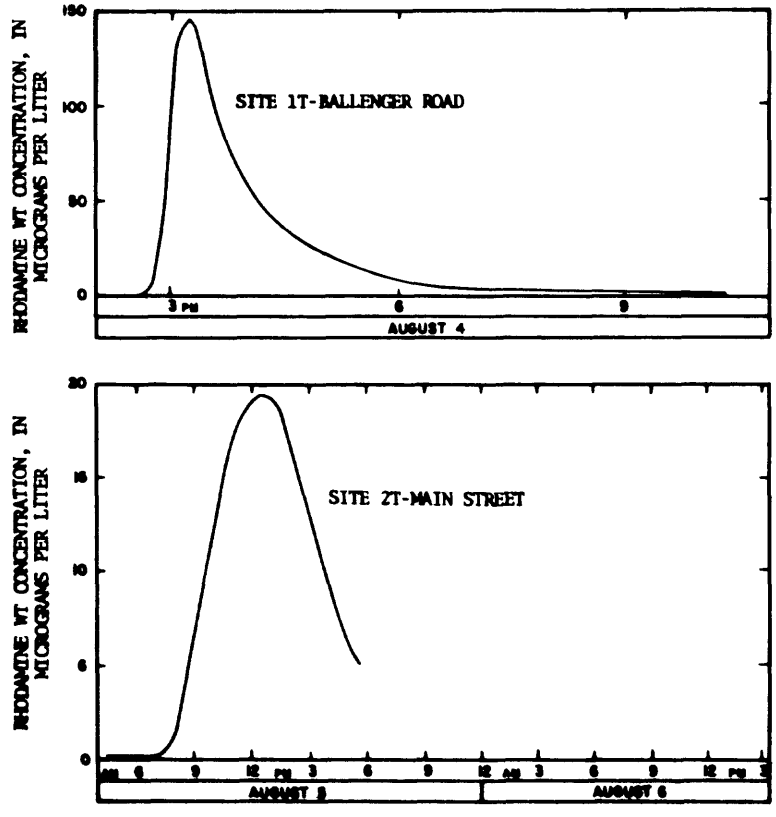

Figure 5. Concentration-time curves for sampling sites at Ballenger Road and at Main Street in Flushing.

of dye clouds at each sampling site.) The peak concentration (146 µg/L) occured 5.2 hours after injection. Samples collected at stream quarter points from the bridge indicated that the dye was not thoroughly mixed, a fact that was also visually apparent. Sampling was continued until 10:20 p.m., when the concentration had decreased to about 1 µg/L.

About 63 percent of the dye was accounted for during the period samples were collected. Recovery was computed using the estimated hydrograph given in figure 2. It is probable, however, that at least 85 percent of the dye injected passed Ballenger Road during passage of the dye cloud. (At Highway M-57, 19.7 miles downstream from Ballenger Road, 83.9 percent of the dye was recovered.) Time-of-travel is estimated to be 5.6 hours from Grand Traverse Street. Time-of-passage[1/] of the dye cloud is estimated to be 12 hours. Dye was also detected at Ballenger Road (0.78 µg/L) at 4:20 p.m. on August 7, but this dye was that injected at Utah Dam on August 5.

1/ Time-of-passage is defined as the time, in hours, between the leading edge and the trailing edge of the dye cloud.

Site 2T - Main Street in Flushing, 11.4 miles downstream

The leading edge of the dye cloud was detected at Main Street in Flushing at 7:00 a.m. on August 5, 21.1 hours after injection (fig. 5). Samples collected at quarter points in the cross section indicated that the dye was not thoroughly mixed in the channel in the early stages of passage. The peak concentration (19.4 µg/L) occurred at 12:18 p.m. on August 5, 26.3 hours after injection. Samples were collected continuously for 11.5 hours, at the end of which time the concentration had decreased to about 5 µg/L. (A subsequent sample collected at 5:00 p.m. on August 7, indicated that dye injected at Utah Dam on August 5 had reached Main Street.) Graphical and regression analyses proved unsuitable for estimating the time-of-passage of the dye cloud because sampling was terminated before recession of the cloud had proceeded far enough. A comparison of data obtained at sites 1T (Ballenger Road) and 3T (Highway M-57), however, suggests that the trailing edge passed Main Street 57 hours after injection, and that the time required for passage was 36 hours.

Time-of-travel can be determined more accurately than other dye-cloud characteristics. Recovery of dye at site 3T suggests that recovery would also have been 84 percent at Main Street, based on the estimated hydrograph shown in figure 2. If so, half of the recoverable dye would have reached Main Street at 2:30 p.m. on August 5. Thus, time-of-travel from the injection site at Grand Traverse Street would be 28.6 hours.

Site 3T - Highway M-57, 22.3 miles downstream

The leading edge of the dye cloud was detected at Highway M-57 at 4:50 a.m. on August 6, 42.9 hours after injection (fig. 6). The peak concentration (12 µg/L) occurred 49.4 hours after injection. Samples were collected continuously for 38 hours until 7:00 p.m. on August 7, when the concentration had decreased to 0.33 µg/L. A single sample was collected 12 hours after continuous sampling was terminated; concentration had decreased to 0.20 µg/L. Graphical extension and regression analysis suggest that dye passage would be complete by 6:30 p.m., August 8, 104 hours after injection. Thus, the time-of-passage of the cloud is estimated to be 61.1 hours. Based on the hydrograph shown in figure 2, dye recovery during this period is estimated to be 83.9 percent. Time-of-travel from injection at Grand Traverse Street to Highway M-57 was 50.5 hours.

Site 4T - Highway M-13, 40.1 miles downstream

The leading edge of the dye cloud was detected at Highway M-13 at 7:30 a.m. on August 7, 69.6 hours after dye injection (fig. 6). The peak concentration (6.25 µg/L) occurred 77.1 hours after injection. Samples were collected for 31 hours, until 2:30 p.m. August 8, when the concentration had fallen to 0.32 µg/L. Both graphical extension of the data and regression analysis suggested that dye passage would be complete by 2:00 p.m. on August 9, 124 hours after dye injection. Thus, the time-of-passage of the cloud is estimated to be 54.5 hours. A more rapid passage of dye at Highway M-13 than at Highway M-57 was likely caused by rain in the lower reaches of the basin. Dye recovery during the 54.5-hour period was 72 percent. Time-of-travel from Grand Traverse Street to Highway M-13 was 78.8 hours.

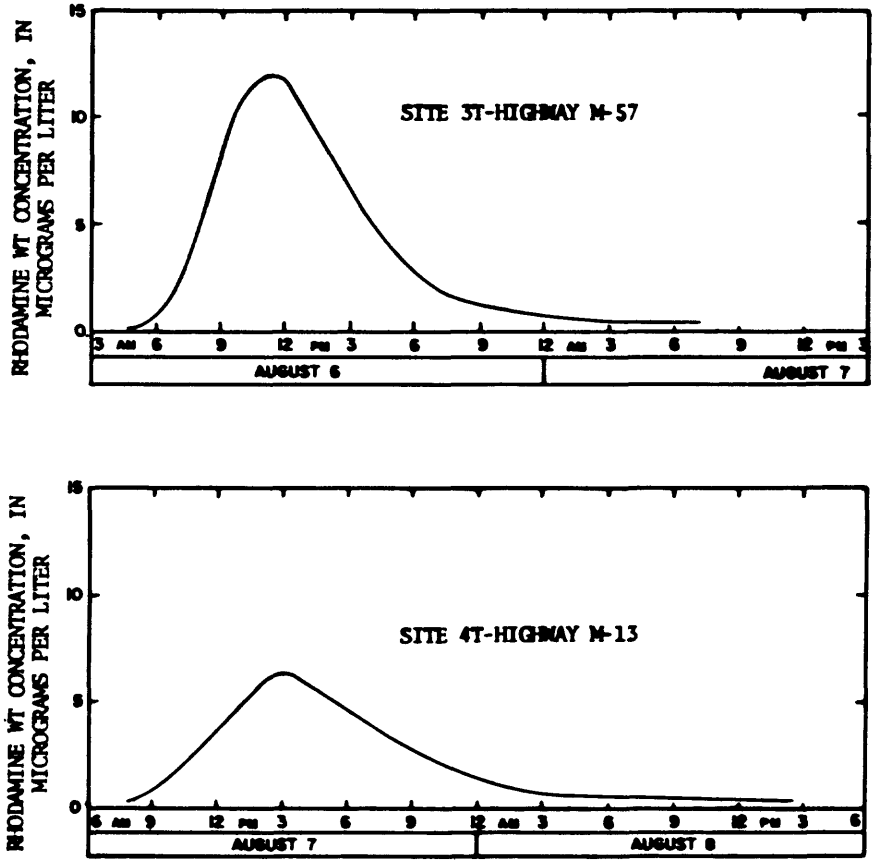

Figure 6. Concentration-time curves for sampling sites at Highway M-57 and Highway M-13.

Dye-cloud movement, Grand Traverse Street to Highway M-13, is summarized in figure 7.

Utah Dam to Grand Traverse Street

At Utah Dam, 1.8 liters of rhodamine WT 20 percent solution was injected at 12:05 p.m. on August 5. The amount of dye injected was based on a discharge of 81.8 ft^3/s measured at Hamilton Avenue, 1.04 miles downstream, immediately before injection. Dye was injected on a line about 74 feet downstream from Utah Dam in the central two-thirds of the river. The following sections discuss detection and movement of dye at each sampling site.

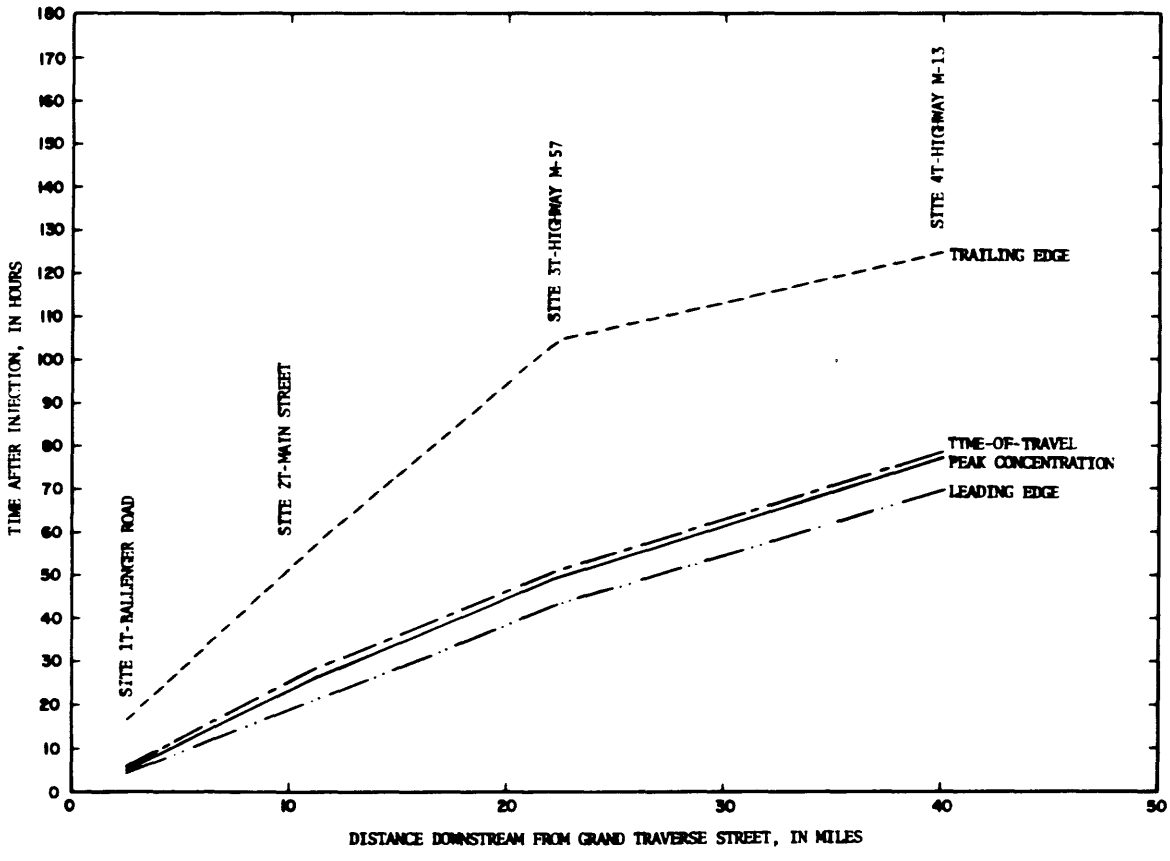

Figure 7. Dye-cloud movement, Grand Traverse Street to Highway M-13.

Site 1U - Leith Street, 0.31 miles downstream

The leading edge of the dye cloud reached Leith Street at 1:21 p.m., 1.3 hours after injection (fig. 8). The dye was not thoroughly mixed in the channel. Samples were collected at quarter points in the cross section at 3- to 5-minute intervals. Because of the low velocity at Leith Street, an accurate measure of discharge was not possible; concentrations given in table 1 were determined by averaging concentrations measured at each sampling point in the stream cross section. The peak concentration (71 µg/L) occurred 1.5 hours after injection. Sampling was terminated at 2:30 p.m., when concentration had decreased to about 8 µg/L.

Although discharge could not be measured at Leith Street, the measurement at Hamilton Avenue indicated that flow at Leith Street was about 82 ft^3/s. Dye recovery, based on this rate, was 68.1 percent by the time sampling was terminated. Had the dye been thoroughly mixed, it may be assumed that at least 86 percent, the amount accounted for at Stevens and Grand Traverse Streets, would also have been accounted for at Leith Street. A computation of time-of-travel, based on an assumed higher recovery at Leith Street, suggests 1.8 hours.

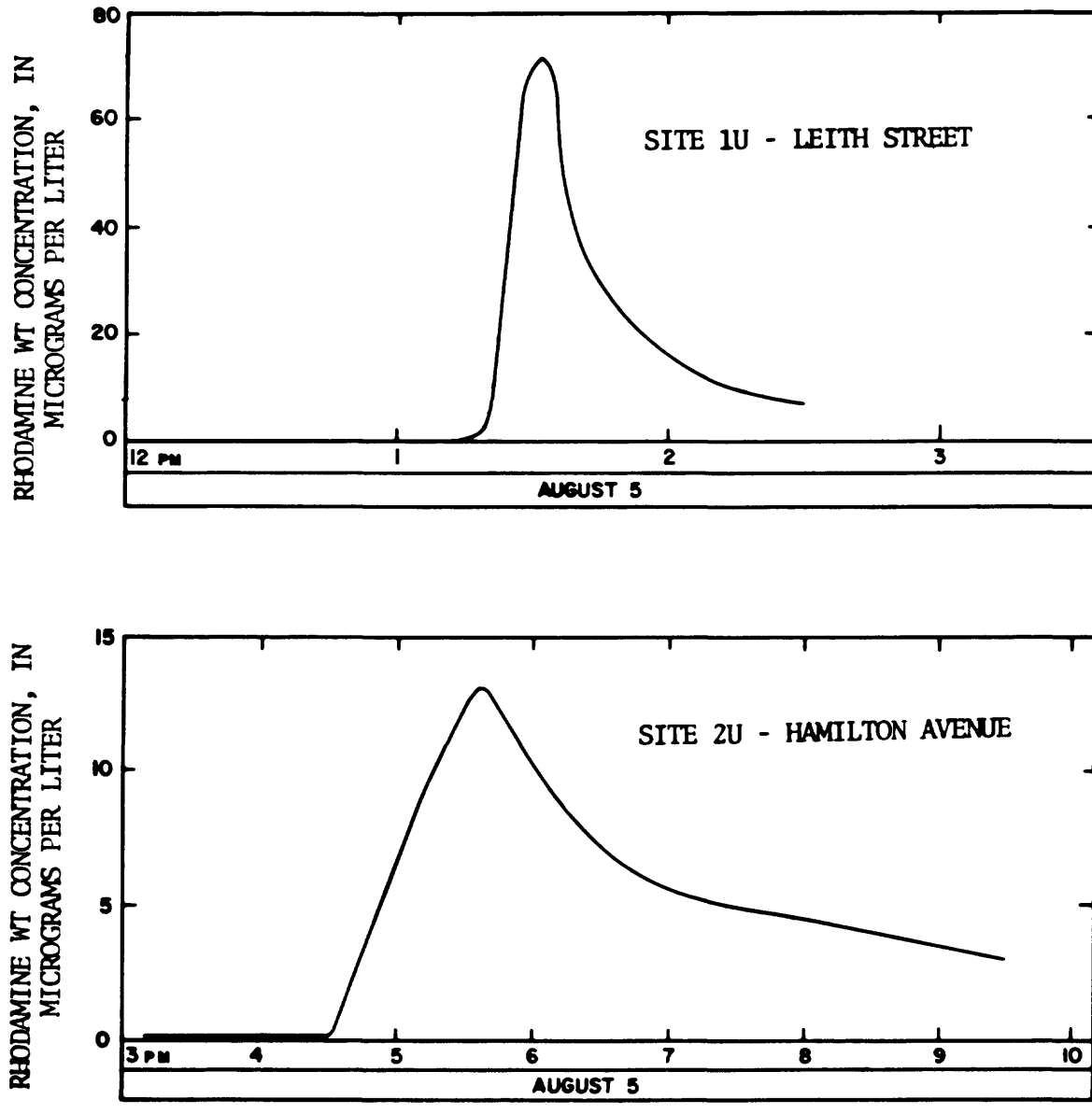

Figure 8. Concentration-time curves for sampling sites at Leith Street and Hamilton Avenue.

Site 2U - Hamilton Avenue, 1.04 miles downstream

The leading edge of the dye cloud reached Hamilton Avenue at 4:45 p.m., 4.7 hours after injection (fig. 8). Samples were collected at two points in the cross section. The discharge measurement made earlier in the day was used to weigh the concentration at each point and thus compute the concentration at the site at the time of sampling. The peak concentration (13 µg/L) occurred 5.5 hours after dye injection at Utah Dam. Sampling was terminated at 9:30 p.m. when the concentration had decreased to 3 µg/L. Recovery of dye at the time sampling ceased, based on a measured discharge of 82 ft^3/s, was 58.2 percent.

Time-of-travel was computed by assuming that at least 86 percent of the dye (the amount recovered at Stevens and Grand Traverse Streets) would have been recovered had sampling continued for a longer time. This assumed higher recovery suggests a time-of-travel from Utah Dam to Hamilton Avenue of 7.0 hours.

Site 3U - Stevens Street, 2.16 miles downstream

The leading edge of the dye cloud reached Stevens Street at 2:00 a.m. August 6, 13.9 hours after injection (fig. 9). Samples were collected at two

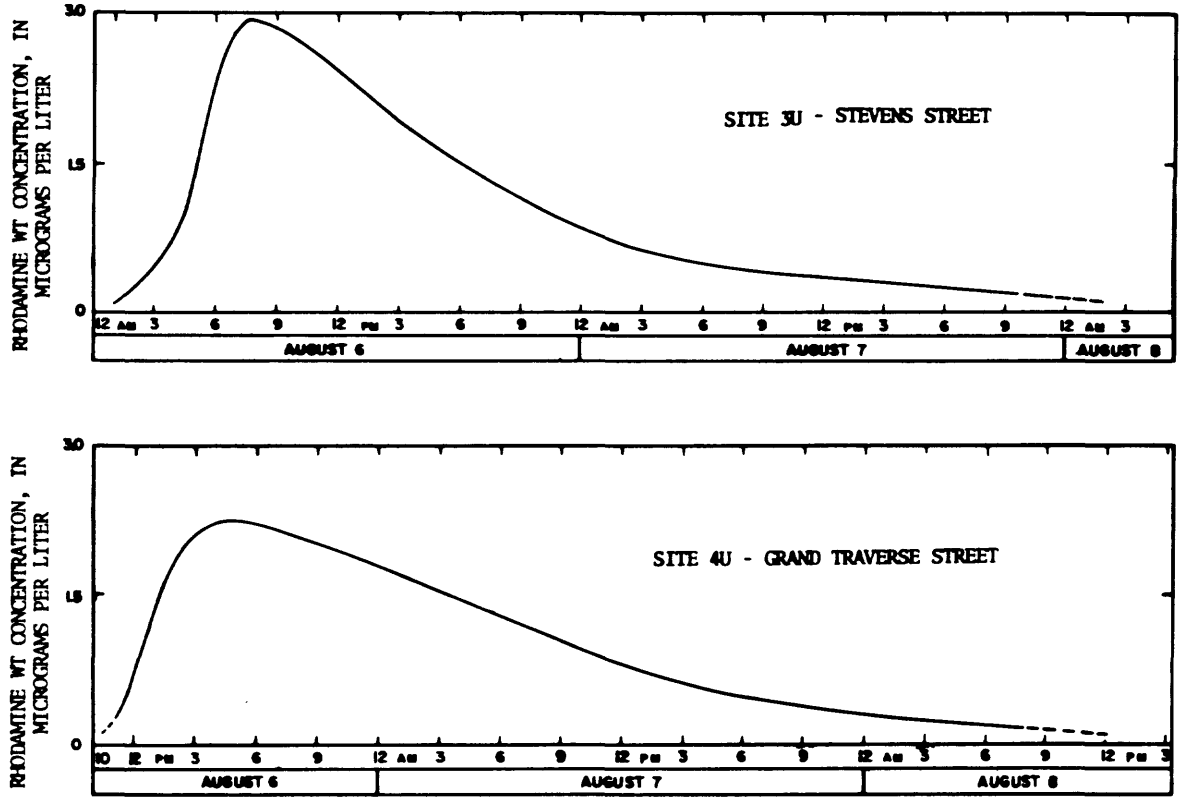

Figure 9. Concentration-time curves for sampling sites at Stevens Street and at Grand Traverse Street.

points in the cross section, each of which probably represented about half the flow. Concentrations given in table 1 are the average of concentrations at each of these points. The peak concentration (2.9 µg/L) occurred 19.2 hours after injection. Sampling was continued until 9:40 p.m. on August 7, at which time concentration had decreased to 0.20 µg/L. Graphical extension of the concentration-time curve suggested that background levels would be reached at 2:00 a.m. on August 8, 61.9 hours after injection. Time-of-passage of the cloud, which is considered well defined, was 48 hours.

Discharge measurements indicate that flow during sampling averaged about 84 ft^3/s. Recovery of dye, based on this flow, was 86.6 percent. Time-of-travel from Utah Dam to Stevens Street was 25 hours.

Site 4U - Grand Traverse Street, 2.73 miles downstream

The leading edge of the dye cloud was detected at Grand Traverse Street at 11:00 a.m. August 6, 22.9 hours after injection (fig. 9). The peak concentration (2.25 µg/L) occurred at 4:30 p.m., 28.4 hours after injection. Sampling was continued until 8:00 a.m. August 8, at which time concentration decreased to 0.20 µg/L. Graphical extension of the concentration-time curve suggests that background level would occur about 12 noon, or 72 hours after injection. Time-of-passage of the cloud, which is considered well defined, was 49.1 hours.

Discharge measurements indicate that the flow during the sampling period was about 85 ft^3/s. Recovery of dye, based on this flow, was 85.8 percent. Time-of-travel from Utah Dam to Grand Traverse Street, is summarized in figure 10.

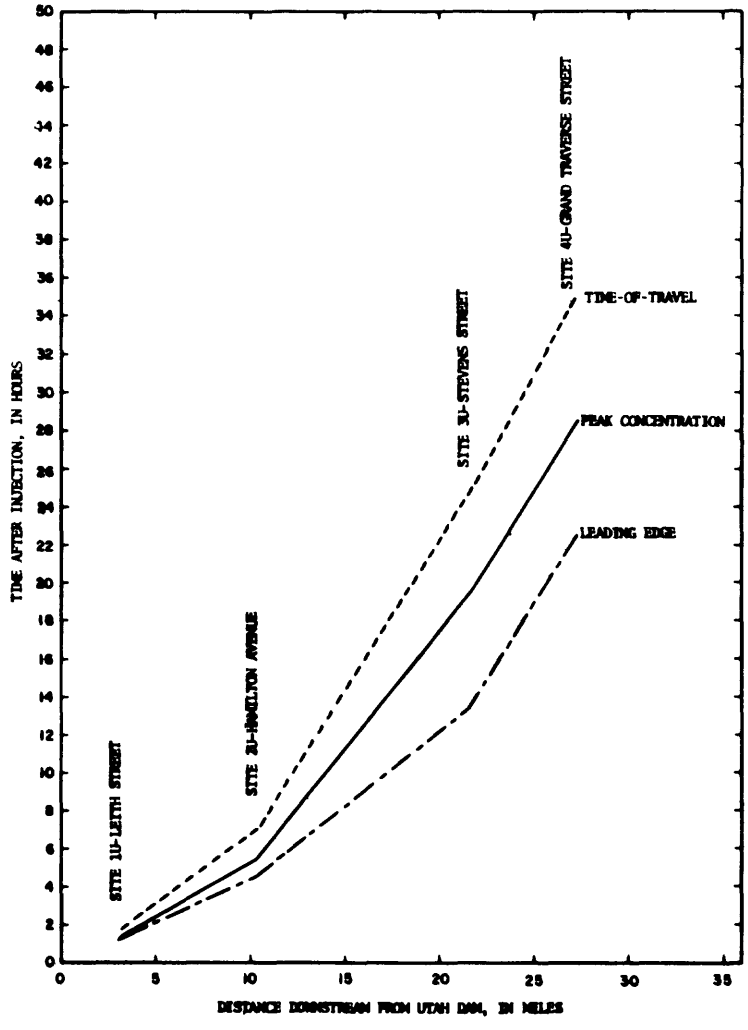

Figure 10. Dye-cloud movement, Utah Dam to Grand Traverse Street.

Time-of-Travel, Utah Dam to Highwy M-13

Figure 11 is a composite of time-of-travel data from both dye injections

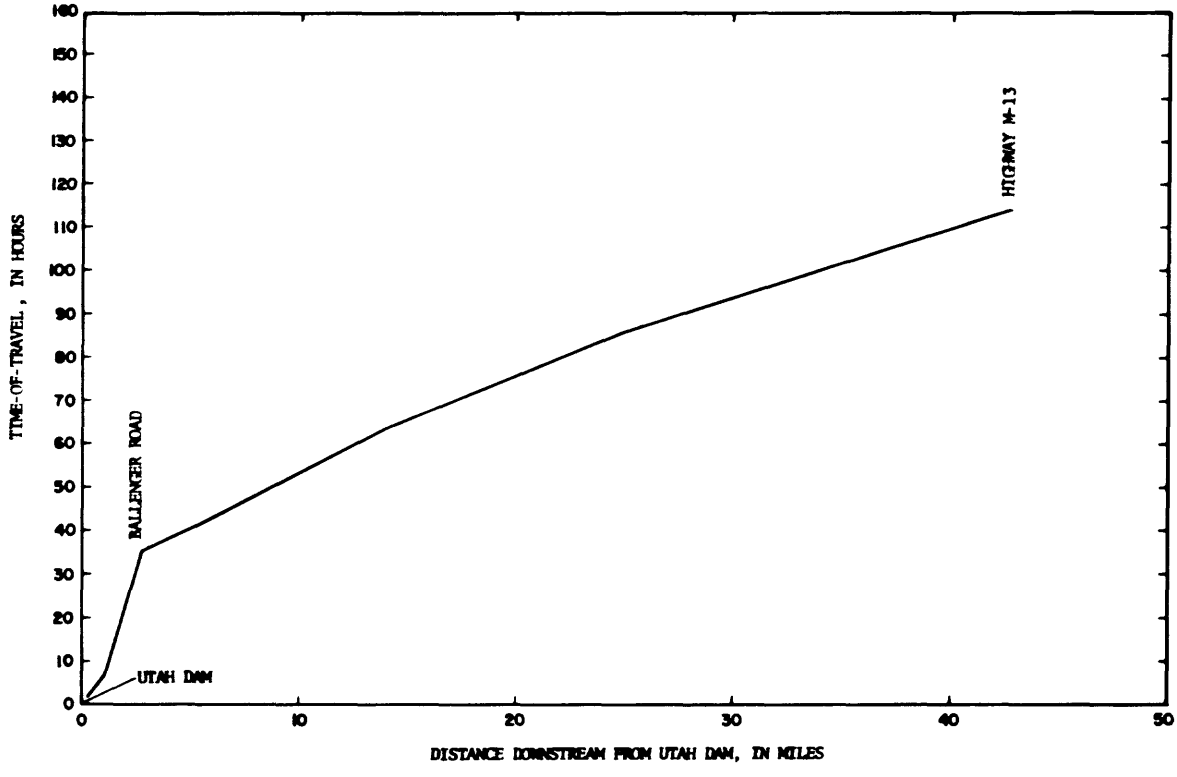

Figure 11. Time-of-travel, Utah Dam to Highway M-13.

in the 42.8-mile reach between Utah Dam and Highway M-13. During the low-flow conditions at the time of this investigation, 114 hours (4 3/4 days) would have been required for dye to move through the reach. Because of the slower velocities in the reach above Grand Traverse Street, about a third of the travel time would occur in the initial 2.73 miles.

SUMMARY

In the 42.8-mile reach from Utah Dam at Flint to Highway M-13 near Fosters, time-of-travel was 114 hours during a low streamflow equaled or exceeded 90 percent of the time. Mean velocity in the initial 2.73 miles between Utah Dam and Grand Traverse Street was about 0.1 ft/s, and time-of-travel was 35.3 hours. From Grand Traverse Street to Highway M-13, mean velocity was about 0.7 ft/s, and time-of-travel was 78.8 hours.

SELECTED REFERENCES

Kilpatrick, F. A., Martens, L. A., and Wilson, J. F., Jr., 1970, Measurement of time of travel and dispersion of dye tracing: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A9, 25 p.

Table 1. Concentrations of rhodamine WT at sampling sites on the Flint River

Site 1T - Ballenger Road

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-4-81	2:23 pm	0.10	8-4-81	3:29 pm	110	8-4-81	4:32 pm	34.8	8-4-81	5:50 pm	10.8
	2:30	.10	Cont.	3:36	95.0	Cont.	4:39	33.5	Cont.	6:00	9.90
	2:40	1.15		3:43	78.8		4:46	30.0		6:10	7.60
	2:47	8.75		3:50	69.5		4:53	26.0		6:30	6.40
	2:54	35.7		3:57	62.7		5:00	23.6		7:00	4.26
	3:01	93.3		4:04	58.7		5:10	19.0		7:30	2.96
	3:08	127		4:11	44.0		5:20	16.5		8:00	1.22
	3:15	146		4:18	39.8		5:30	15.8		10:20	1.08
	3:22	137		4:25	35.3		5.40	12.6	8-7-81	4:20 pm	.78

Site 2T - Main Street in Flushing

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-5-81	6:00 am	0.10	8-5-81	9:30 am	8.89	8-5-81	12:06 pm	19.2	8-5-81	2:42 pm	13.9
	6:30	.10	Cont.	9:42	10.0	Cont.	12:18	19.4	Cont.	2:54	12.9
	7:00	.13		9:54	11.4		12:30	19.0		3:06	12.5
	7:30	.38		10:06	12.6		12:42	18.8		3:18	11.5
	7:42	.55		10:18	14.0		12:54	18.5		3:30	10.5
	7:54	.90		10:30	14.4		1:06	19.0		3:42	10.2
	8:06	1.40		10:42	15.6		1:18	18.9		3:54	9.56
	8:18	1.95		10:54	16.6		1:30	18.5		4:06	9.00
	8:30	2.99		11:06	17.2		1:42	17.6		4:20	8.25
	8:42	3.89		11:18	17.7		1:54	16.5		4:40	7.25
	8:54	4.87		11:30	18.3		2:06	16.0		5:00	6.25
	9:06	6.37		11:42	18.5		2:18	15.5		5:30	5.25
	9:18	7.56		11:54	18.7		2:30	14.6	8-7-81	5:05 pm	.95

Site 3T - Highway M-57

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-6-81	4:50 am	0.15	8-6-81	10:10 am	11.0	8-6-81	3:30 pm	5.50	8-6-81	8:50 pm	1.10
	5:10	.20	Cont.	10:30	11.5	Cont.	3:50	4.75	Cont.	9:10	1.05
	5:30	.30		10:50	12.0		4:10	4.25		9:30	.95
	5:50	.53		11:10	12.0		4:30	4.00		9:50	.93
	6:10	.80		11:30	12.0		4:50	3.50		10:10	.88
	6:30	1.15		11.50	12.0		5:10	3.25		10:30	.85
	6:50	1.73		12:10 pm	11.0		5:30	2.95		11:00	.75
	7:10	2.55		12.30	10.5		5:50	2.70		11:30	.68
	7:30	3.25		12:50	10.0		6:10	2.35		12:00 M	.63
	7:50	4.25		1:10	9.50		6:30	2.20	8-7-81	12:30 am	.58
	8:10	5.25		1:30	9.00		6:50	1.90		1:00	.55
	8:30	6.50		1:50	8.25		7.10	1.75		2:00	.45
	8:50	7.50		2:10	7.75		7:30	1.60		3:00	.43
	9:10	8.75		2:30	7.00		7:50	1.50		5:00	.38
	9:30	10.0		2:50	6.50		8:10	1.35		7:00 pm	.33
	9:50	10.5		3:10	6.00		8:30	1.25	8-8-81	6:32 am	.20

Site 4T - Highway M-13

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-7-81	7:00 am	0.10	8-7-81	2:30 pm	6.00	8-7-81	10:00 pm	2.15	8-8-81	5:30 am	0.62
	7:30	.15	Cont.	3:00	6.25	Cont.	10:30	1.95	Cont.	6:00	.60
	8:00	.20		3:30	6.00		11:00	1.70		6:30	.50
	8:30	.33		4:00	5.75		11:30	1.55		7:00	.48
	9:00	.50		4:30	5.75		12:00 M	1.35		7:30	.45
	9:30	.80		5:00	5.25	8-8-81	12:30 am	1.25		8:00	.42
	10:00	1.10		5:30	5.00		1:00	1.15		8:30	.40
	10:30	1.60		6:00	4.50		1:30	1.05		9:00	.40
	11:00	2.25		6:30	4.25		2:00	.95		9:30	.38
	11:30	2.95		7:00	3.75		2:30	.92		10:00	.38
	12:00 M	3.40		7:30	3.50		3:00	.85		10:30	.35
	12:30 pm	4.00		8:00	3.25		3:30	.82		11:00	.35
	1:00	4.75		8:30	2.95		4:00	.78		2:30 pm	.32
	1:30	5.25		9:00	2.65		4:30	.72			
	2:00	5.75		9:30	2.40		5:00	.68			

Table 1. Concentrations of rhodamine WT at sampling sites on the Flint River--Continued

Site 1U - Leith Street

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-5-81	1:15 pm	0.10	8-5-81	1:33 pm	71.0	8-5-81	1:51 pm	26.8	8-5-81	2:20 pm	8.50
	1:18	.10	Cont.	1:36	54.5	Cont.	1:54	10.7	Cont.	2:25	7.83
	1:21	4.25		1:39	37.7		2:00	12.5		2:30	8.03
	1:24	30.3		1:42	38.8		2:05	21.2	8-7-81	2:15 pm	.15
	1:27	60.0		1:45	24.6		2:10	14.6			
	1:30	70.2		1:48	19.9		2:15	14.3			

Site 2U - Hamilton Avenue

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-5-81	3:10 pm	0.10	8-5-81	5:20 pm	9.56	8-5-81	6:23 pm	8.12	8-5-81	7:26 pm	5.12
	3:40	.10	Cont.	5:27	11.0	Cont.	6:30	7.90	Cont.	7:33	5.13
	4:00	.10		5:34	13.0		6:37	6.12		7:40	5.00
	4:30	.10		5:41	12.0		6:44	5.50		7:47	4.76
	4:45	3.15		5:48	11.7		6:51	5.57		7:54	4.63
	4:52	4.69		5:55	10.2		6:58	5.71		8:01	4.77
	4:59	6.20		6:02	9.76		7:05	5.61		9:30	3.00
	5:06	7.86		6:09	9.48		7:12	5.35	8-7-81	2:30 pm	.18
	5:13	9.34		6:16	8.61		7:19	5.50			

Site 3U - Stevens Street

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-6-81	1:00 am	0.10	8-6-81	5:00 am	1.75	8-6-81	8:35 am	2.78	8-6-81	11:00 pm	0.98
	1:30	.10	Cont.	5:10	1.53	Cont.	8:55	2.83	Cont.	12:00 M	.89
	2:00	.33		5:20	2.08		9:25	2.78	8-7-81	1:00 am	.71
	2:30	.55		5:30	1.63		10:25	2.73		2:00	.65
	2:40	.48		5:40	2.23		10:55	2.68		3:00	.61
	2:50	.48		5:50	1.95		11:25	2.48		4:00	.63
	3:00	.50		6:00	2.00		11:55	2.40		5:00	.51
	3:10	.53		6:10	2.38		12:25 pm	2.35		6:00	.50
	3:20	.52		6:20	2.63		12:55	2.38		7:00	.50
	3:30	.54		6:30	2.60		1:25	2.25		8:00	.43
	3:40	.63		6:40	2.70		1:55	2.03		9:00	.43
	3:50	.68		6:50	2.55		2:25	1.95		10:00	.40
	4:00	.71		7:00	2.58		2:55	1.90		11:00	.40
	4:10	.86		7:15	2.90		3:55	1.83		12:00 N	.38
	4:20	1.00		7:30	2.85		4:55	1.60		1:50 pm	.33
	4:30	.89		7:45	2.73		6:55	1.33		4:07	.28
	4:40	1.11		8:00	2.78		8:55	1.20		8:35	.18
	4:50	1.09		8:15	2.80		10:00	1.05		9:40	.20

Site 4U - Grand Traverse Street

Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)	Date	Time	Rhodamine WT (µg/L)
8-6-81	11:00 am	0.35	8-6-81	4:20 pm	2.25	8-6-81	11:30 pm	1.85	8-7-81	10:00 am	0.98
	12:05 pm	.33	Cont.	4:35	2.25	Cont.	11:45	1.80	Cont.	11:00	.90
	12:40	1.20		4:50	2.20		12:00 M	1.80		12:00 N	.80
	1:50	1.70		5:50	2.15	8-7-81	12:15 am	1.80		2:00 pm	.65
	2:05	1.90		6:50	2.10		12:30	1.75		4:23	.53
	2:20	2.05		7:50	2.00		2:00	1.65		7:10	.45
	2:35	1.90		8:50	1.95		3:00	1.50		8:40	.45
	2:50	2.05		9:15	1.95		4:00	1.45		9:50	.38
	3:05	2.10		9:30	1.95		5:00	1.35		11:00	.35
	3:20	2.10		9:45	2.00		6:00	1.30	8-8-81	8:00 am	.20
	3:35	2.15		10:00	1.90		7:00	1.15			
	3:50	2.15		10:15	1.95		8:00	1.10			
	4:05	2.20		10:30	1.90		9:00	1.00			

Table 2. Miscellaneous discharge measurements at selected sites on the Flint River and tributaries

Stream	Date	Time	Reference point to water surface (ft)	Discharge (ft^3/s)
Flint River at Hamilton Avenue	7-29-81	11:50 am	15.23	149
	8-05-81	11:25 am	15.50	81.8
	8-07-81	3:25 pm	15.49	84.2
Flint River at Harrison Street	7-29-81	10:30 am	18.20	176
Flint River at Grand Traverse Street	8-04-81	9:00 am	26.26	85.7
Flint River at Chevrolet Avenue	7-29-81	9:40 am	24.36	221
Flint River at Ballenger Road	7-29-81	8:50 am	25.79	213
	8-04-81	11:05 am	26.32	85.5
Flint River near Flint (04148500)	8-13-81	3:30 pm	3.24	193
Flint River at Main Street in Flushing	8-04-81	2:15 pm	22.20	139
	8-19-81	12:35 pm	21.82	177
Flint River at M-57 near Montrose	8-05-81	2:40 pm	30.90	148
Flint River near Fosters (04149000)	8-07-81	9:30 pm	2.22	221
	8-13-81	1:05 pm	2.42	270
Swartz Creek at Kearsley Road	8-04-81	9:00 am	22.67	11.1
	8-07-81	5:15 pm	22.74	8.22
	8-08-81	10:15 am	22.47	22.3
	8-10-81	3:30 pm	22.66	11.2
	8-14-81	10:55 am	22.78	6.39
Brent Run at McKinley Road	8-05-81	3:30 pm	16.54	4.52
	8-08-81	11:30 am	16.44	6.39
	8-10-81	12:30 pm	16.44	6.35
	8-14-81	2:30 pm	16.52	4.58
	8-14-81	3:15 pm	16.52	4.87
Pine Run at Morseville Road	8-05-81	4:10 pm	24.82	2.09
	8-08-81	12:20 pm	24.71	2.98
	8-10-81	1:40 pm	24.66	4.17
	8-14-81	4:15 pm	24.81	1.94
Silver Creek at Morseville Road	8-08-81	1:05 pm	18.20	4.34

Table 3. Estimated discharges at water-quality sampling sites on tributaries to the Flint River

Stream	Date	Time	Reference point to water surface (ft)	Discharge (ft^3/s)
Swartz Creek at Kearsley Road	8-04-81	10:15 am	22.68	10.2
	8-05-81	10:30 am	22.69	9.8
	8-06-81	9:55 am	22.35	30.5
	8-07-81	9:50 am	22.72	8.7
	8-08-81	10:10 am	22.49	20.0
	8-09-81	9:40 am	22.45	22.6
	8-12-81	9:50 am	22.70	9.4
Brent Run at McKinley Road	8-04-81	2:20 pm	16.53	4.7
	8-05-81	2:55 pm	16.53	4.7
	8-06-81	1:15 pm	16.52	4.8
	8-07-81	12:15 pm	16.56	4.2
	8-08-81	12:30 pm	16.44	6.4
	8-09-81	12:01 pm	16.25	10.8
	8-10-81	12:40 pm	16.44	6.4
	8-11-81	1:54 pm	16.50	5.2
	8-12-81	12:50 pm	16.50	5.2
Pine Run at Morseville Road	8-08-81	12:05 pm	24.71	3.3
	8-09-81	11:35 pm	24.30	11.7
	8-10-81	12:25 pm	24.70	3.4
	8-12-81	12:30 pm	24.80	2.2

Table 4. Characteristics of dye clouds at sampling sites

Site	Miles downstream from injection site	Elapsed time after dye injection, in hours			Time-of-passage in hours	Time-of-travel in hours	Percent recovery
		Leading edge	Peak concentration	Trailing edge			
1T	2.6	4.8	5.2	17	12.2	5.6	63.2[a/]
2T	11.4	21.1	26.4	57	35.9	28.6	[b/]
3T	22.3	42.9	49.4	104	61.1	50.5	83.9
4T	40.1	69.6	77.1	124	54.4	78.8	72.0
1U	.31	1.3	1.5	[b/]	[b/]	1.8	68.1[a/]
2U	1.04	4.7	5.5	[b/]	[b/]	7.0	58.2[a/]
3U	2.16	13.9	19.2	61.9	48.0	25.0	86.6
4U	2.73	22.9	28.4	72.0	49.1	35.3	86.8

a/ Sampling terminated either prior to complete dye passage or prior to complete mixing of dye.

b/ Satisfactory estimate cannot be made.

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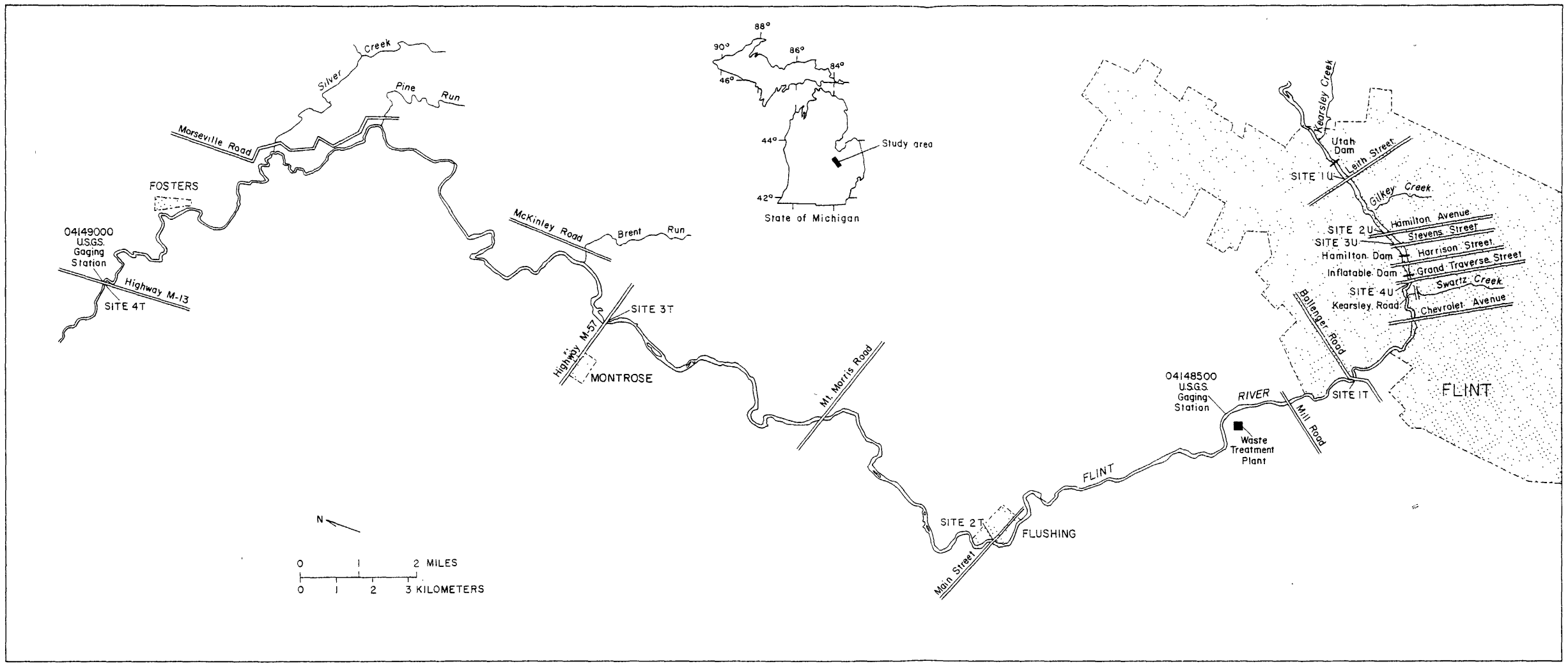

Base from U.S. Geological Survey
1:24,000 quadrangles and city
of Flint map

THE FLINT RIVER