TIME-OF-TRAVEL STUDIES FOR THE LITTLE ANDROSCOGGIN RIVER, MAINE

U.S. GEOLOGICAL SURVEY

Open-File Report 81-640

Prepared in cooperation with the

MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION

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CONTENTS

ILLUSTRATIONS

TABLES

Factors for converting inch-pound to International System Units

To convert from	to	Multiply by
Cubic foot per second (ft^3/s)	Cubic meter per second (m^3/s)	0.02832
Foot (ft)	Meter (m)	0.3048
Foot per second (ft/s)	Meter per second (m/s)	0.3048
Mile (mi)	Kilometer (km)	1.609
Square mile (mi^2)	Square kilometer (km^2)	2.590
Parts per billion (ppb)	Micrograms per liter (ug/l)	1.00

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By William J. Nichols, Jr.[1], Barry M. Reed[2], and Fred W. Greenlaw[3]

ABSTRACT

Time-of-travel studies were conducted at flow durations of 20, 80, and 95 percent on the Little Androscoggin River from South Paris to Auburn, Maine. The river is about 29.3 miles long, and drains an area of about 354 square miles at its mouth.

Traveltimes were determined by tracing the movement of rhodamine WT, a soluble fluorescent dye. The dye was injected into the river at the upstream end of each reach studied and water samples were collected at the downstream end of the study reach and analyzed for dye concentrations.

Time-of-travel data were related to stream discharge to estimate traveltime for a water-soluble contaminant traveling between any two points at any discharge in the low-to-high flow range.

The discharges of the Little Androscoggin River at the time of the study ranged from 40 to 950 cubic feet per second at the Auburn gaging station. Traveltimes from South Paris to Auburn, Maine, ranged from 51 to 648 hours.

[1]Hydrologist, U.S. Geological Survey
[2]Hydrologic Field Assistant, U.S. Geological Survey
[3]Chemist, Maine Department of Environmental Protection

INTRODUCTION

This report presents the results of several individual dye-tracer time-of-travel studies made during 1978 on the Little Androscoggin River. The Little Androscoggin River at Auburn, Maine, drains an area of 354 square miles. The reaches studied extend from South Paris to Oxford, Maine (10.2 mi), from Oxford to Mechanic Falls, Maine (9.1 mi), and from Mechanic Falls to Auburn, Maine (10.0 mi), as shown in figure 1.

Streamflow was measured for each reach for each study and represents discharges that are, on the average, equalled or exceeded 20, 80, and 95 percent of the time, based on the flow duration curve of the Little Androscoggin River near Auburn (fig. 2).

This study was conducted jointly by the Survey (U.S. Geological Survey) and the MDEP (Maine Department of Environmental Protection). The time-of-travel study was conducted by MDEP. The Survey supplied detailed flow data. Data derived in this project are being used to calibrate a waste-load allocation model used by MDEP.

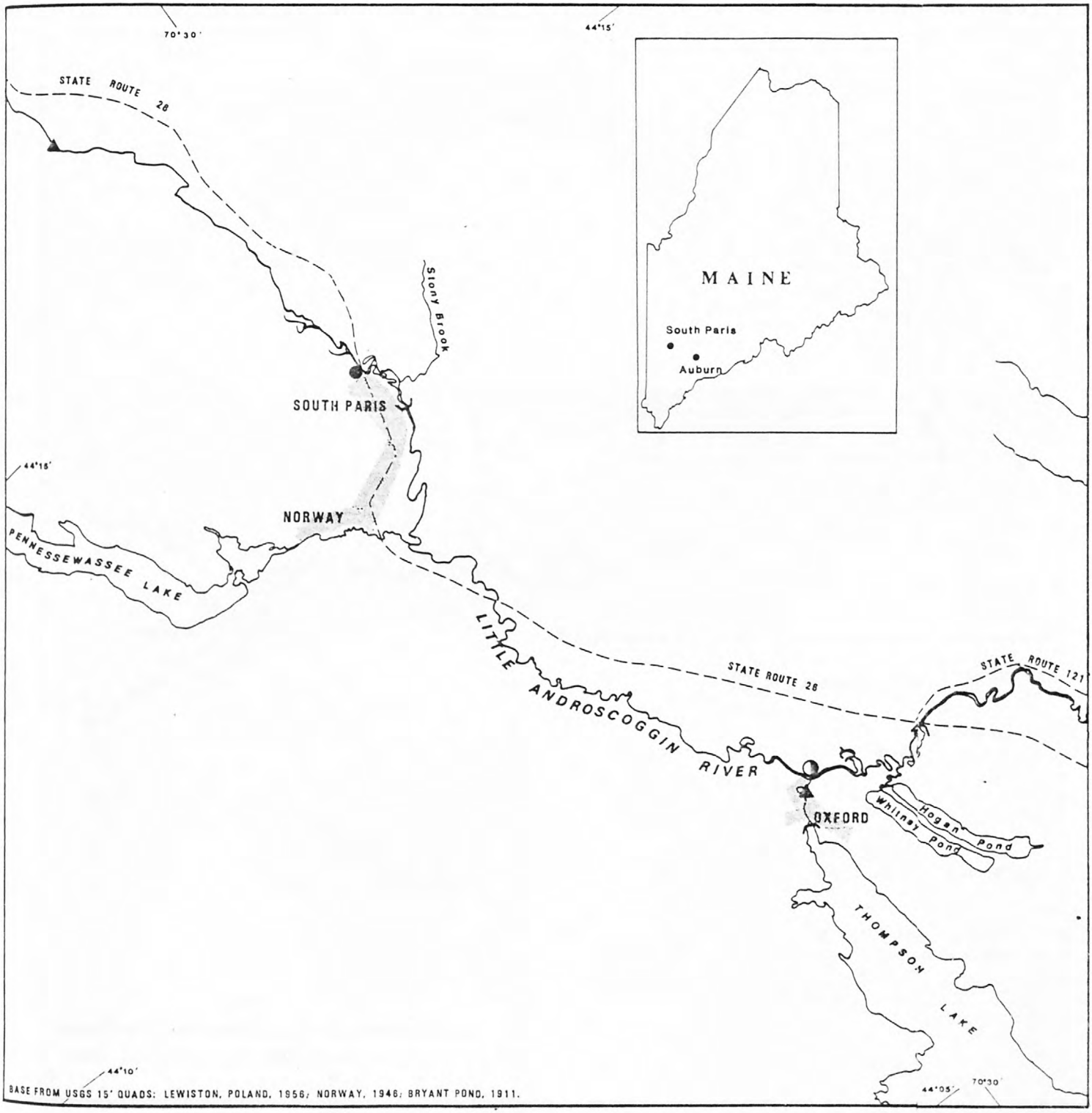
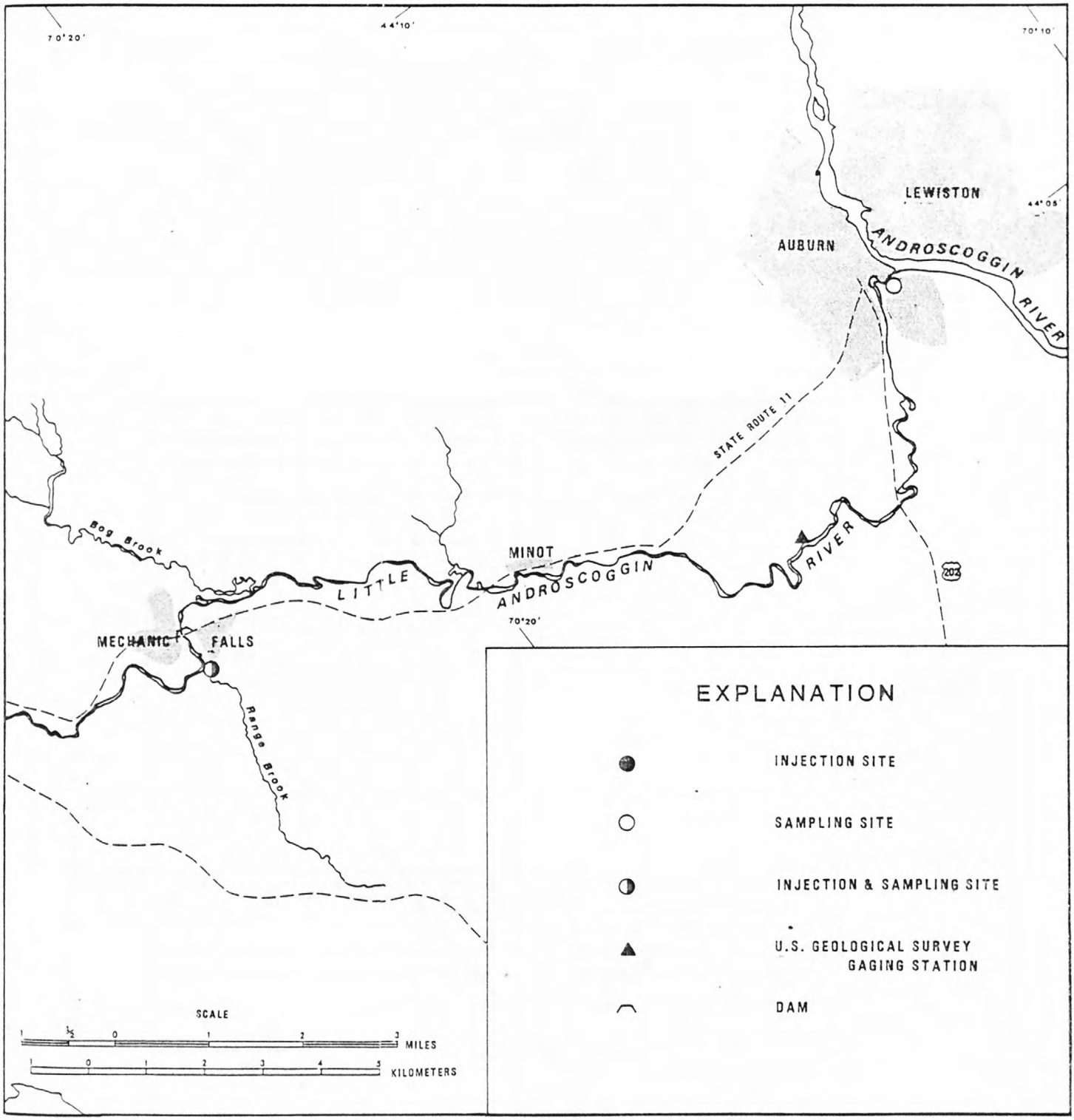


Figure 1. --Location of dye injection and sampling



sites for the reach South Paris to Auburn, Maine.

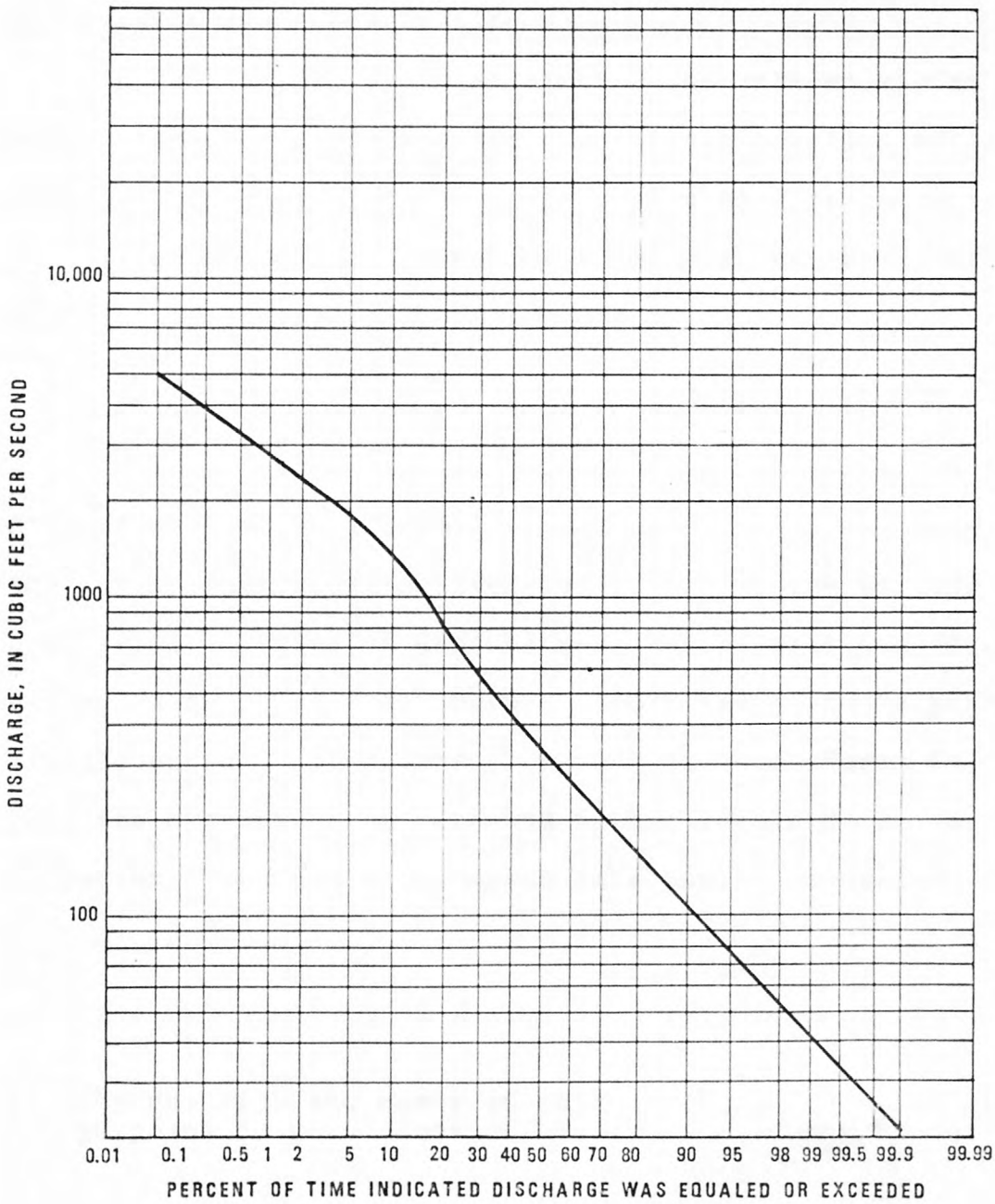


Figure 2. --Duration curve of Little Androscoggin River near Auburn, Maine.

FIELD PROCEDURES

Injection and sampling sites for the time-of-travel studies were located through field and map reconnaissance. The studies were performed on May 23-25, July 11-17, and September 25 to October 11, 1978. Dye was injected into the Little Androscoggin River at South Paris, Oxford, and Mechanic Falls, Maine. Water samples were collected at Oxford, Mechanic Falls, and Auburn for analysis of dye concentration.

In each study, dye was injected instantaneously at one or more points per cross section or by line injection across the entire width of the stream. Water samples were collected by ISCO 1/ point samplers. Periodic grab samples were taken at the midpoint of the river cross section.

RESULTS

Drainage areas are given in table 1 for all sites in the project area where streamflow data are available. Flow rates for the Little Androscoggin River varied during the periods studied because of a series of dams between South Paris and Mechanic Falls, Maine. The reach between South Paris and Mechanic Falls is influenced by four dams. The dam at South Paris is downstream from the dye injection site and is not regulated by any operation. The dam at Thompson Lake outlet is used to maintain

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

the lake level of Thompson Lake. The dam at Welchville is used to maintain lake levels of Hogan and Whitney Ponds, and the fourth dam at Mechanic Falls is used to store water for the local paper mill for use in their paper-making process. These dams affected the flow velocities and traveltimes of the dye cloud between South Paris and Mechanic Falls by altering storage in these reaches.

During the period of the study, refurbishing of the dam at Welchville significantly affected the flow velocities at the Oxford measuring site by storing an abnormal amount of water in the reach. During high flows at Oxford, ~~was~~ water was being ponded. During low flows, intermittent repairs were being made and water passed the measuring site under normal conditons. This resulted in higher velocities at lower flows at Oxford as shown in table 2. The time versus dye concentration curves shown in figures 7-9 were affected by these dams and are a reflection of the storage of water behind the dams. Much longer passage times occurred than would be expected under unregulated flow conditions. Because the regulation of these dams was erratic and data for their operation incomplete, the analysis of this data is limited to the period being studied and should be used cautiously.

Table 1.--Drainage area at key locations

Location of sampling site or gaging station	Drainage area, in square miles
Gaging station on Little Androscoggin River at South Paris (01057000)*	75.8
Little Androscoggin River at South Paris	92.8
Stony Brook at South Paris	14.6
Little Androscoggin River at South Paris (sewage treatment plant)	108
Pennesseewasee Lake Outlet at Norway	30.0
Little Androscoggin River at Oxford	152
Thompson Lake Outlet at Oxford (01058005)*	47.7
Little Androscoggin River at Welchville	216
Little Androscoggin River near Mechanic Falls	229
Range Brook at Mechanic Falls	18.8
Bog Brook at Mechanic Falls	45.3
Gaging station on Little Androscoggin River nr Auburn (01058500)*	328
Little Androscoggin River at Auburn	354

*U.S. Geological Survey gaging station, downstream order number in parentheses.

Plots of dye concentration versus time are presented for each sampling site (figs. 3-5). Time of arrival of the leading edge, centroid (center of mass of the dye cloud), peak concentration, and trailing edge (10 percent of peak concentration) were obtained from the time-concentration curves developed for each sampling section and are summarized in table 2. The curves were extended to those concentrations. The arrival times were related to discharge and are shown in figures 6-8. Dye concentrations were adjusted for background values only.

Figure 6 shows the relation between traveltime of the leading edge, peak concentration, and centroid of the dye cloud versus discharge for the subreach South Paris to Oxford. All discharges are referenced to the U.S. Geological Survey gaging station near Auburn, Maine.

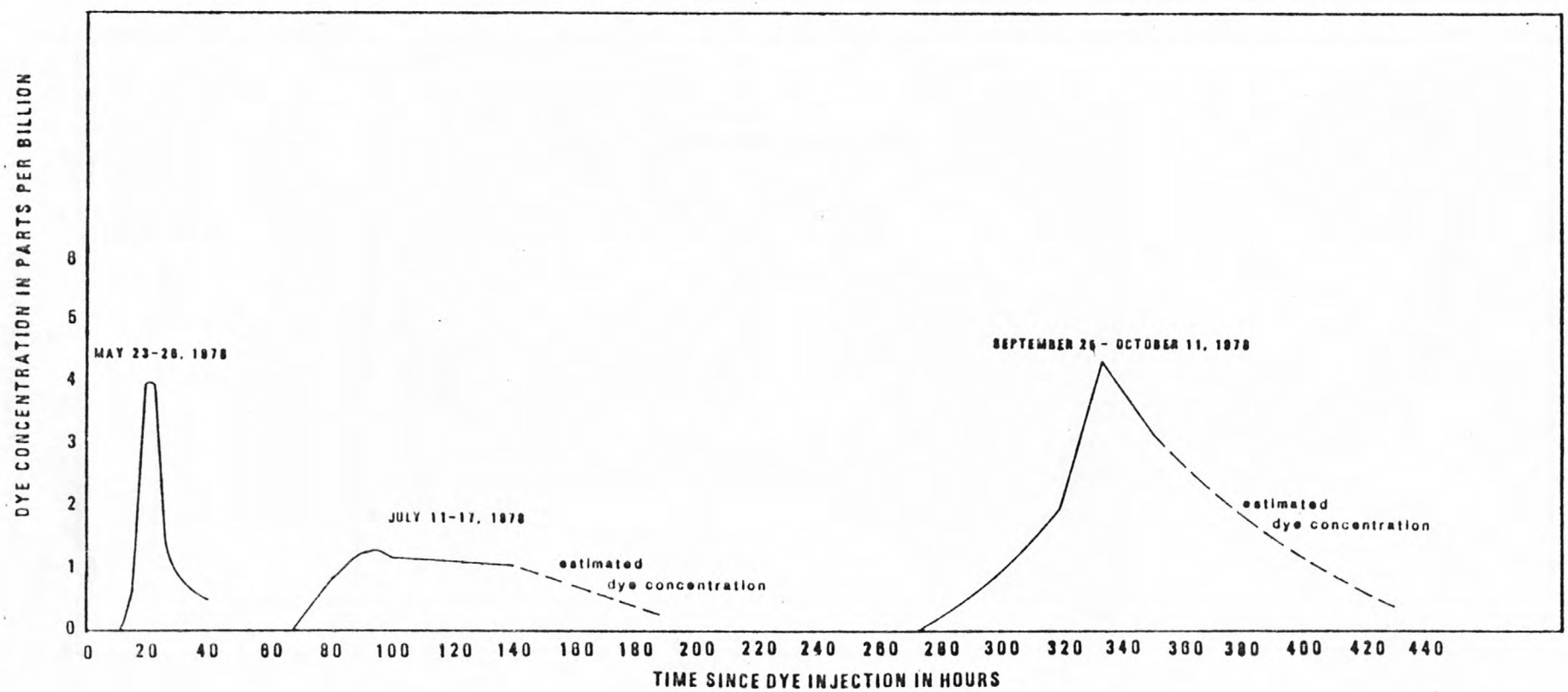


Figure 3. -- Dye concentration versus time at Oxford, Maine
Resulting from a dye injection 10.2 miles upstream at South Paris, Maine.

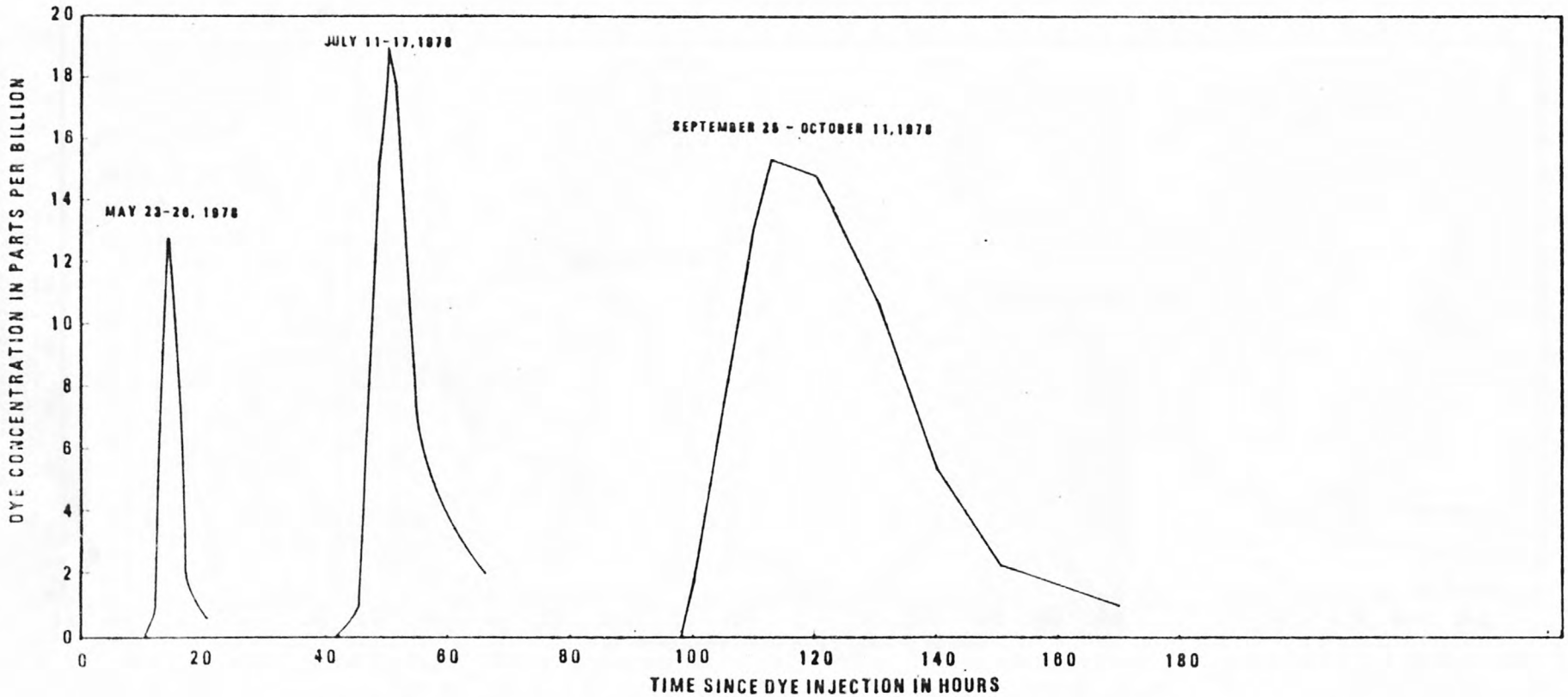


Figure 4. --Dye concentration versus time at Mechanic Falls, Maine Resulting from a dye injection 9.1 miles upstream at Oxford, Maine.

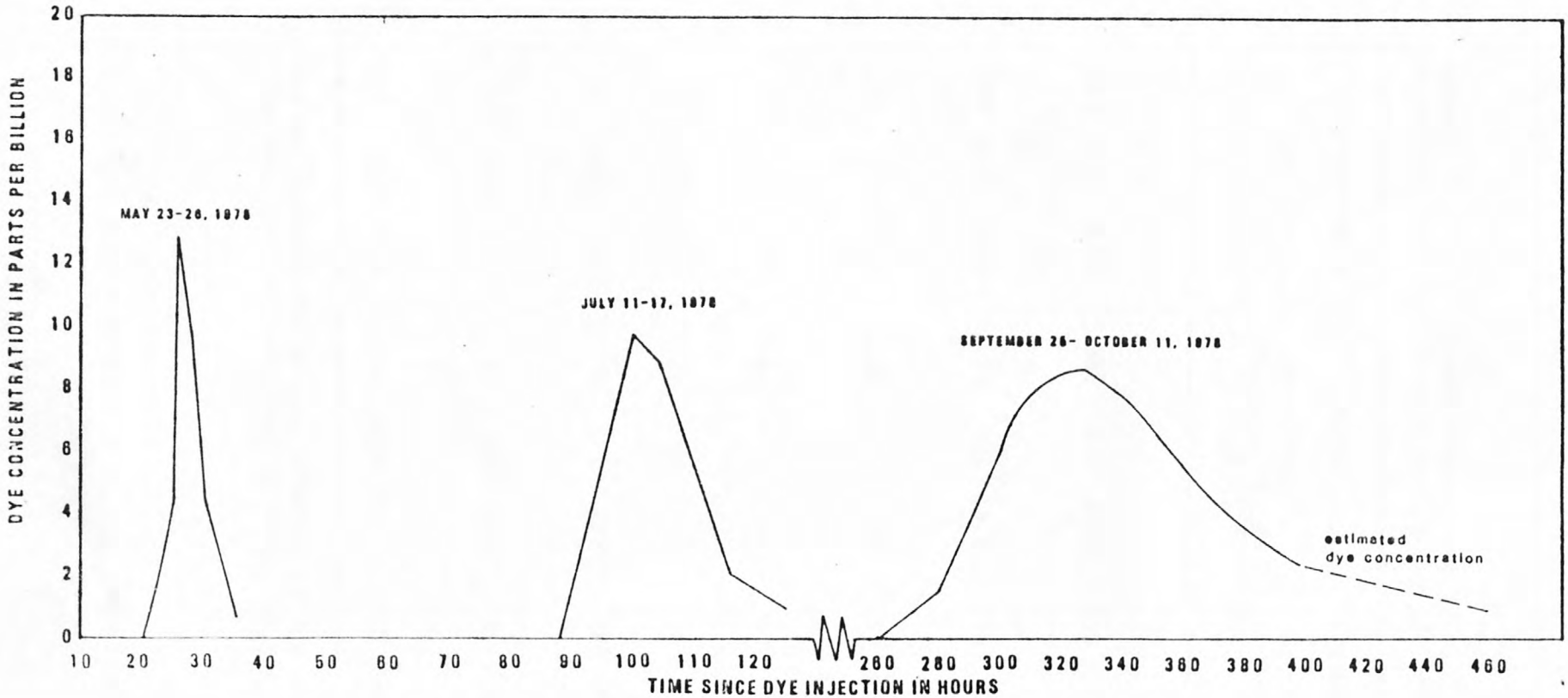


Figure 5. -- Dye concentration versus time at Auburn, Maine
Resulting from a dye injection 10.0 miles upstream at Mechanic Falls, Maine

Table 2.--Summary of time-of-travel results, May 23-25, July 11-17, and September 25 to October 11, 1978

Injection site----	South Paris			Oxford			Mechanic Falls		
Distance to sample site-----	10.2 miles			9.1 miles			10.0 miles		
Sample site-------	Oxford			Mechanic Falls			Auburn		
Date----------	5-23	7-11	9-25	5-23	7-11	9-25	5-23	7-11	9-25
Measured discharge at injection site (ft3/s)	223	23.0	2.40	383	30.8	12.8	653	132	56.0
Measured discharge at sampling site (ft3/s)	383	30.8	12.8	653	132	55.8	953	174	72.1
Mean velocity at sampling site (ft/s)1/	.93	.14	.91	1.35	2.00	1.34	2.53	2.04	.80
Traveltime leading edge (hours)	11	71	276	11	45	98	20	88	270
Peak travel time (hours)	20	96	334	14	50	113	26	101	326
Centroid travel time (hours)	26	120	348	15	53	127	28	105	335
Traveltime trailing edge (hours)	40	196	430	18	67	165	35	125	464
Approximate peak concentration (ppb)	4.0	1.2	4.3	13.0	19.0	15.5	13.0	9.8	8.7

1/ Velocities at Oxford and Mechanic Falls were affected by dam operations at high flows causing velocities to be higher at lower rates of flow.

The time-of-travel of peak concentrations of water-borne contaminants at any point along the reaches studied can be estimated as follows:

1. Obtain the discharge at the USGS gaging station on the Little Androscoggin River near Auburn from the observed gage height-discharge relationship.
2. Divide this discharge by the drainage area of the gaging station to obtain runoff in cubic feet per second per square mile.
3. Multiply the cubic feet per second per square mile obtained by the drainage area at the point of interest to estimate discharge there.
4. Reference the discharge obtained to the same value in figure 6 to obtain estimated time-of-travel of the peak.

Similar curves of traveltime versus discharge for the subreaches Oxford to Mechanic Falls and Mechanic Falls to Auburn are shown in figures 7-8, and can be used in the same manner described above. Figure 9 shows cumulative traveltimes plotted against stream distances. The curves were constructed by summing the traveltimes for the specified discharges between successive sampling sites below South Paris, Maine.

Because of the numerous dams within the study area, a further refinement of the peak traveltimes versus stream distances was compiled in figure 10. Figure 10 shows individual traveltimes versus stream distances for each subreach, with the discharges at injection sites used as the flow reference.

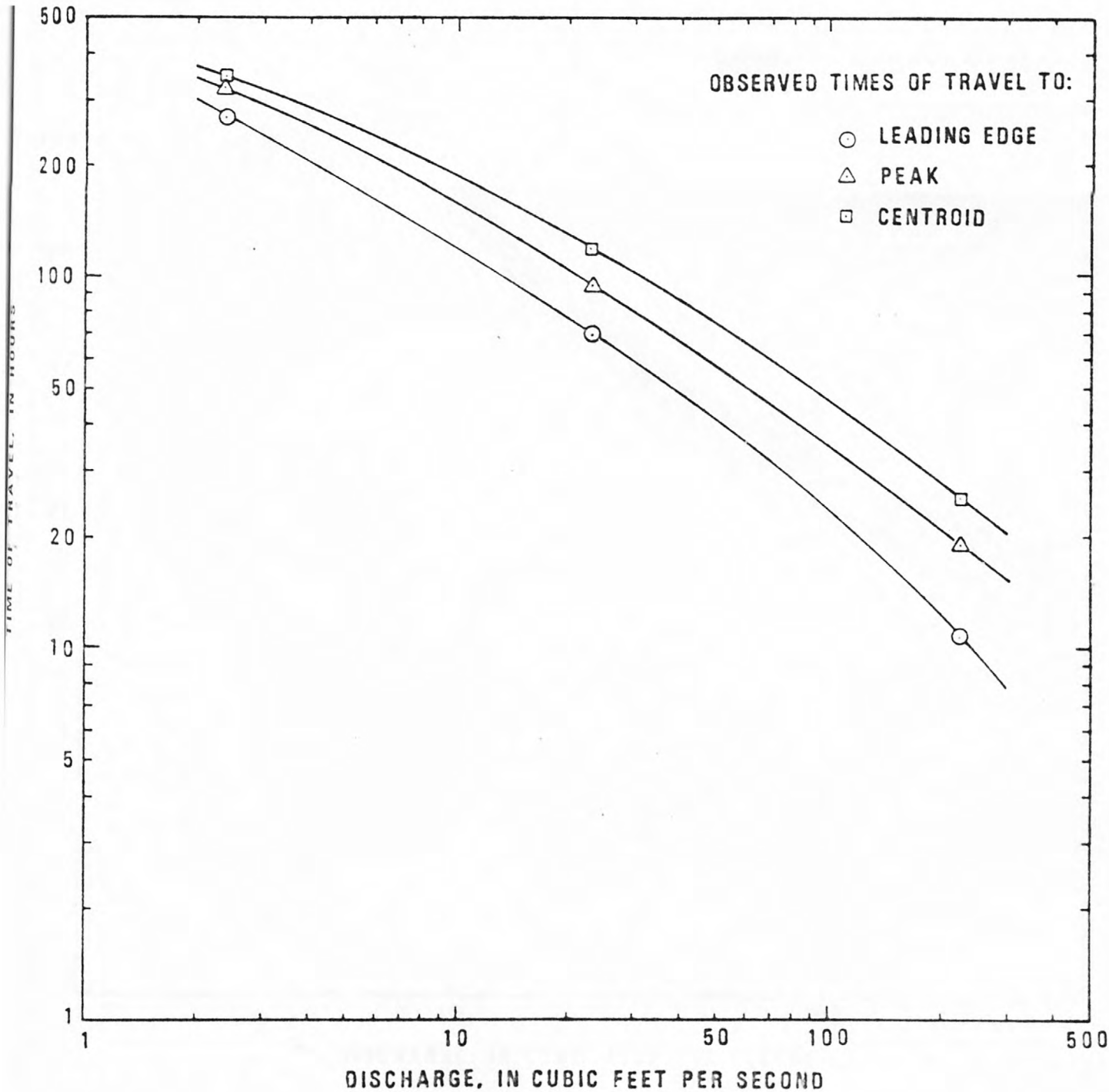


Figure 6. -- Relation of discharge to leading edge, peak, and centroid time of travel from South Paris to Oxford, Maine.

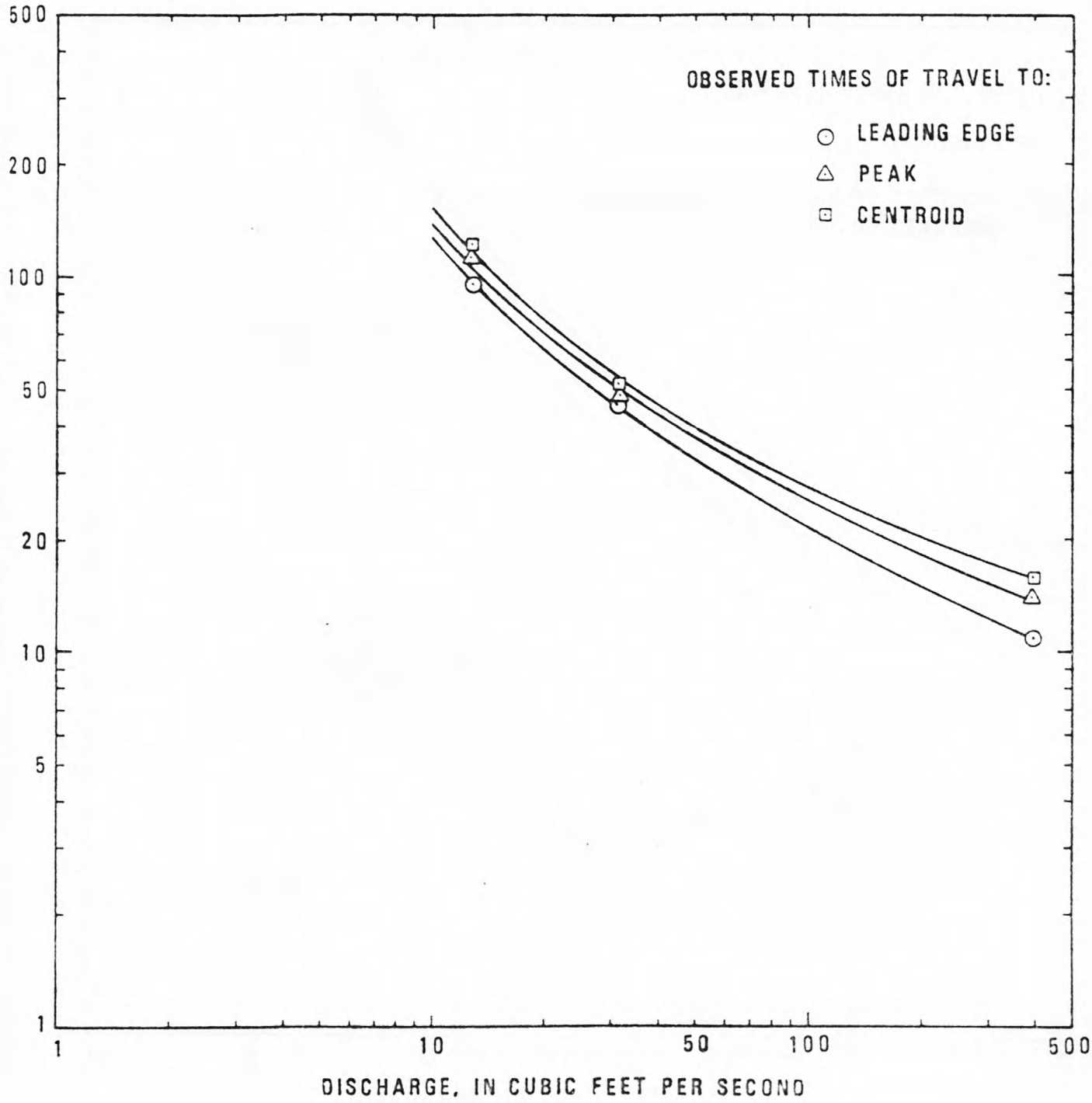


Figure 7. -- Relation of discharge to leading edge, peak, and centroid time of travel from Oxford to Mechanic Falls, Maine.

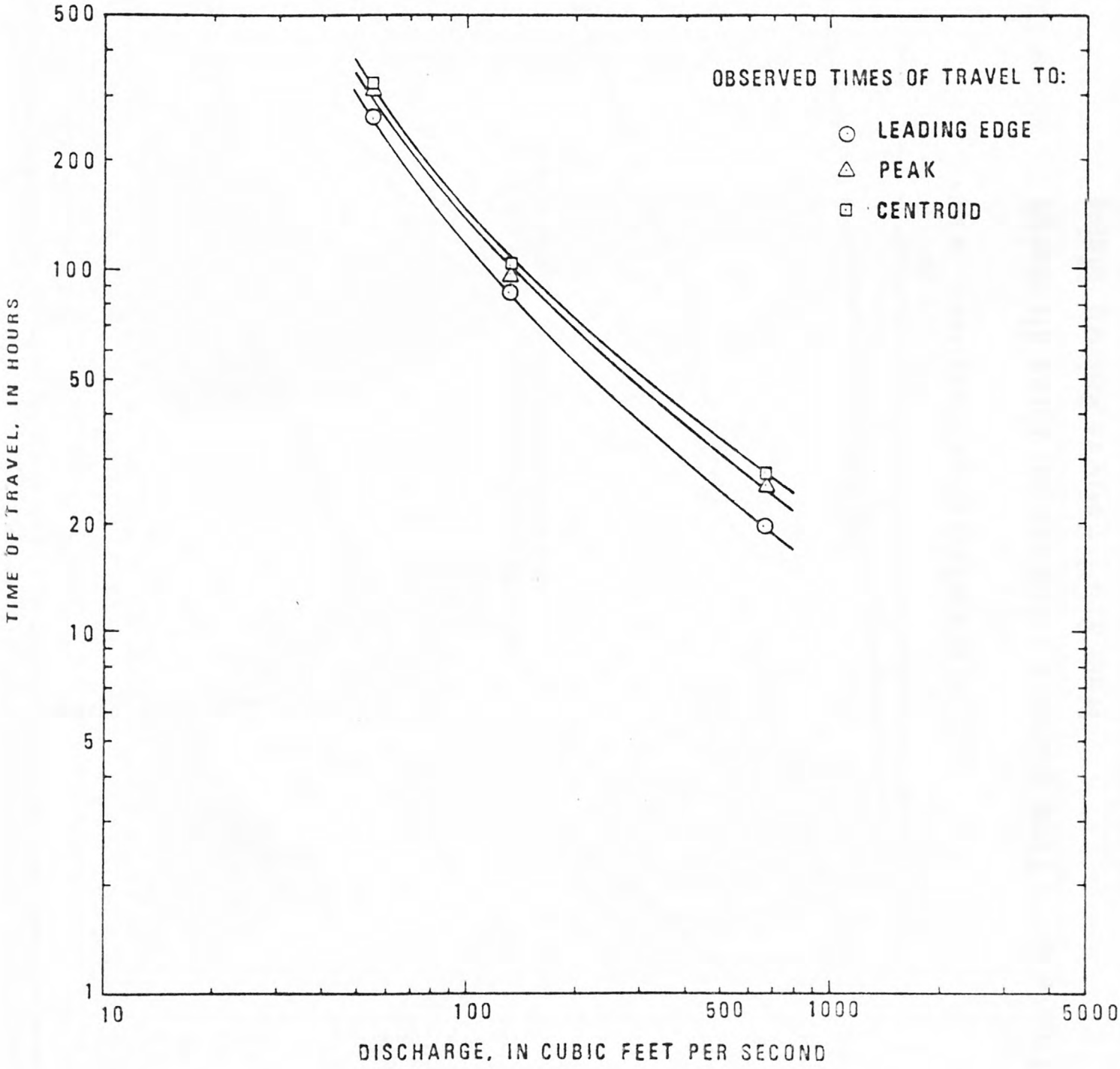


Figure 8.-- Relation of discharge to leading edge, peak, and centroid time of travel from Mechanic Falls to Auburn, Maine.

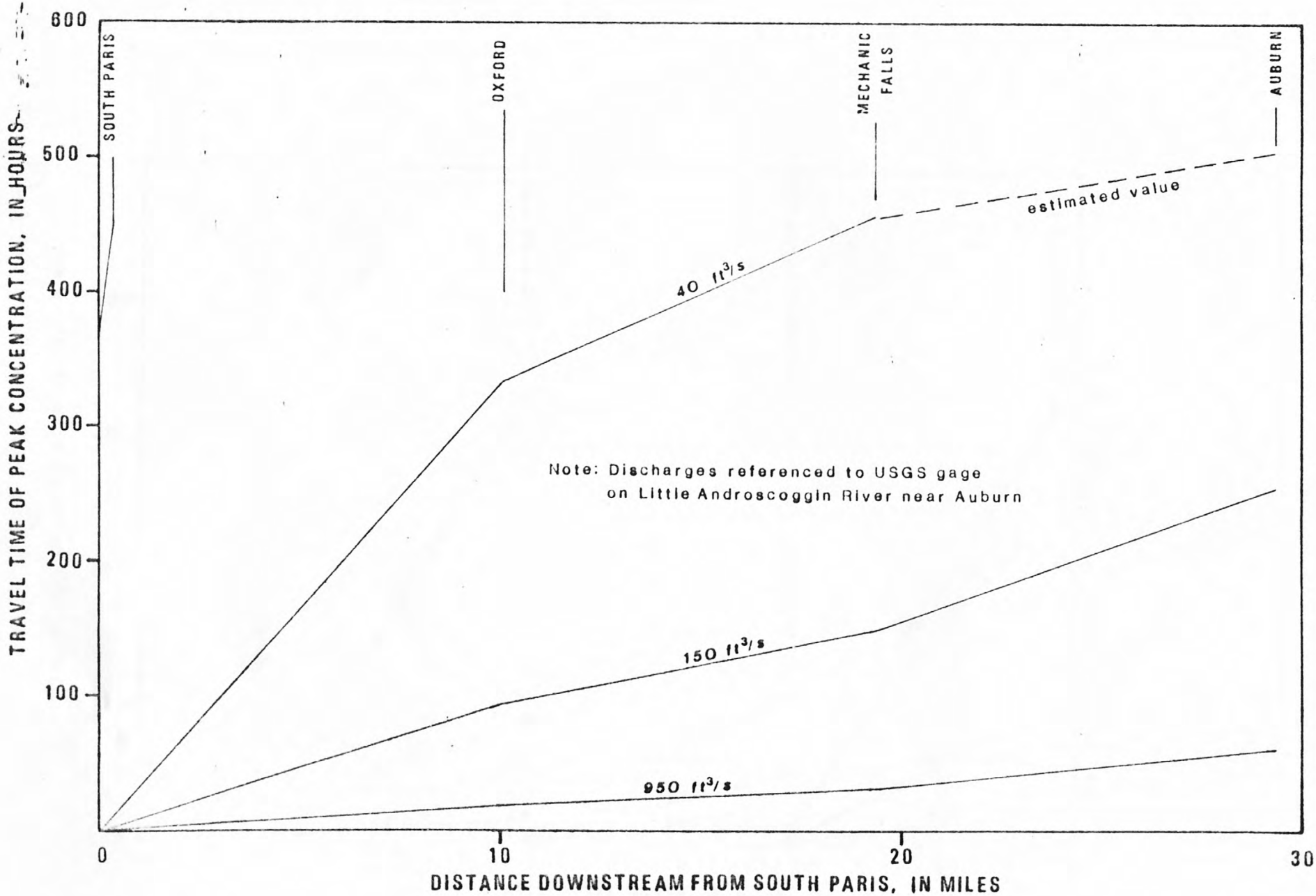


Figure 9.-- Time distance relations for three discharge rates for the reach from South Paris to Auburn, Maine.

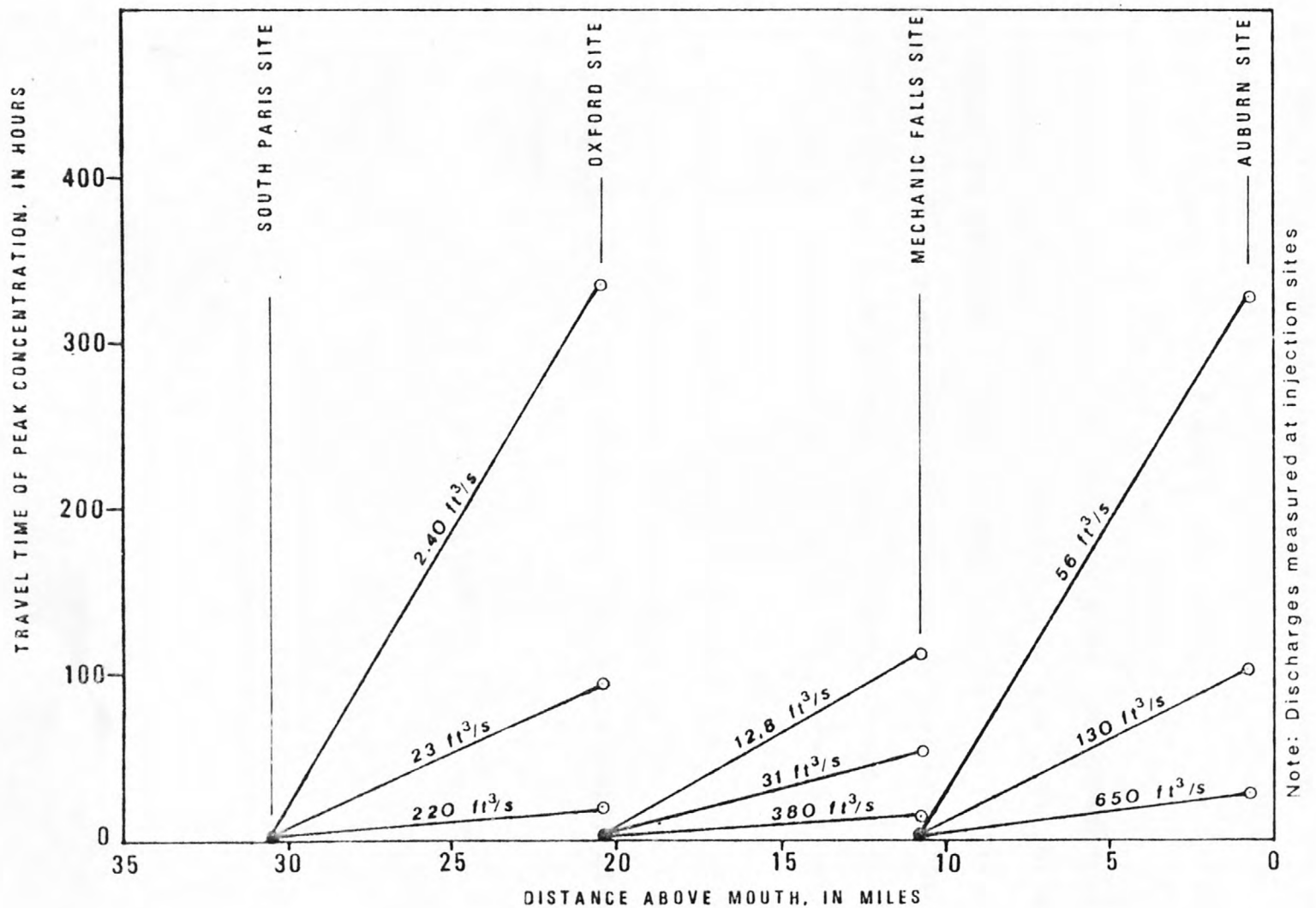


Figure 10. -- Time-distance relations for each of the sub-reaches. South Paris to Auburn, Maine.

CONCLUSIONS

Discharge data for stations operated within the study reaches are available from the U.S. Geological Survey office in Augusta, Maine. The range of discharge at the Little Androscoggin River at Auburn for this study was from 40 to 950 ft^3/s. The applicability of the time-of-travel data is for relatively uniform discharges, therefore use of these data for periods of rapidly changing discharge or where study flows are substantially exceeded should be avoided. Table 2 includes time-of-travel data for instantaneous dye injections. Contaminants that are gradually introduced into a water body have longer passage times than would occur with an instantaneous injection, as used in these studies.

These time-of-travel studies were performed during periods of dam operations and the results are dependent on the dam operations remaining the same. Any alteration can drastically affect river traveltimes.

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