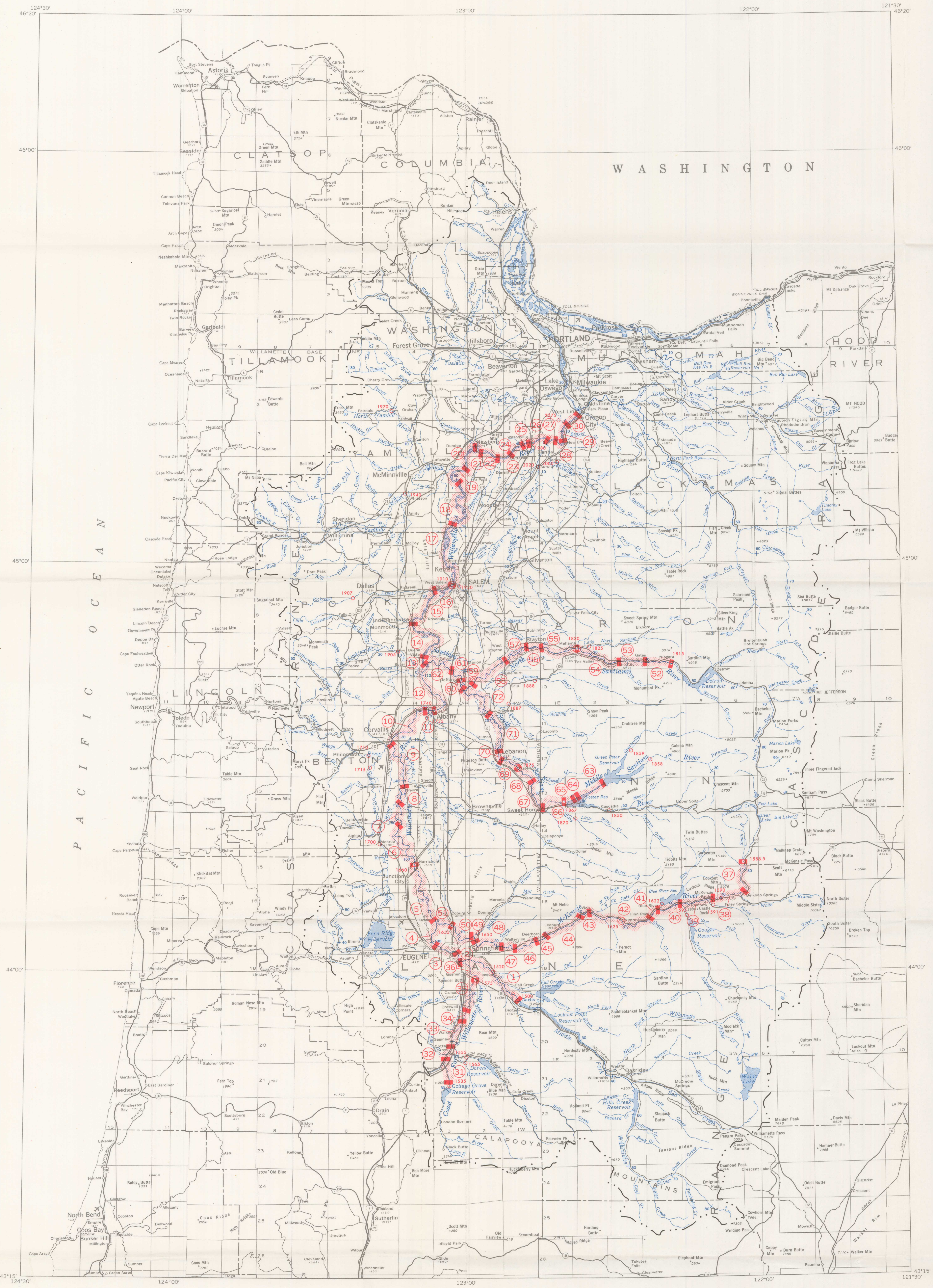
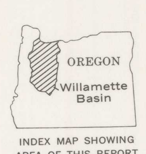


EXPLANATION

Gaging station and number
Index gaging station
Sampling point
Sampling point at gaging station
Sampling point at index gaging station
Subreach number
Basin boundary
Stream mileage
Study reach



INDEX MAP SHOWING AREA OF THIS REPORT

TRAVEL RATES OF WATER FOR SELECTED STREAMS IN THE WILLAMETTE RIVER BASIN, OREGON

This report presents travel rates of water, as defined by dye-tracer studies, for selected streams in the Willamette River basin. The stream reaches studied are shown on the adjoining map.

The data presented are intended to provide information on the travel time of water; however, "travel rate" is used instead of "travel time" to provide a common basis for comparing water movement at various points on the streams. The travel rate of water is the distance that water particles will travel in a unit time.

Travel rates were determined by injecting rhodamine B dye (a fluorescent tracer) into streams and detecting the downstream movement with a fluorometer at selected sampling points. Arrival times of the leading edge and of the peak concentration of the dye were determined at each sampling point. The equipment and methods used were similar to those described by Buchanan (1964).

The studies were made as a Willamette Basin Task Force effort with the overall responsibility delegated to the U.S. Geological Survey. Other agencies that participated either in the collection of field data or in the purchase of materials needed for the studies were as follows: U.S. Corps of Engineers; U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries; U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife; U.S. Public Health Service; Oregon State Fish Commission; Oregon State Game Commission; Oregon State Sanitary Authority; Oregon State University; and Oregon State Water Resources Board.

Travel-Rate Graphs

Dye-tracer studies were made during high, medium, and low flows to define the relation between travel rate and discharge for a series of short subreaches for each of the streams. These relations are presented as graphs which show how the rate varies with the average subreach discharge (figs. 1, 3, 5, 7, and 9). On these travel-rate graphs, separate curves show the rate of travel of the leading edge and of the maximum dye concentration.

The relations between travel rate and discharge generally are well defined, but a few are poorly defined because of channel changes caused by floods between the time of the low- and medium-flow studies. New channels cut by floodwater were shorter or longer than old ones so that travel rates for the two studies could not be compared directly. For example, the main mouth of the McKenzie River during the time of the studies was actually what has been considered to be the alternate mouth (T. 16 S., R. 4 W., sec. 36), at river mile 3.6 (fig. 6). The curve was estimated for the subreach between McKenzie Bridge and South Fork McKenzie River (fig. 5, subreach 39).

In some reaches, artificial channels affected travel rates. At low flows, travel rates are faster through Leaburg canal and Walterville canal than through the McKenzie River channel (fig. 5, subreaches 43, 45-47). As flows increase and more water moves through the natural stream course, travel rates become faster in the river channel than in the canals.

Use of the Travel-Rate Graphs

Travel rate for a subreach is obtained from the graph by entering the discharge figure for the particular subreach and finding the coinciding travel rate from the appropriate curve. For instance, at a discharge of 3,500 cfs (cubic feet per second), the travel rate for the peak concentration is about 2.6 mph (miles per hour) for Middle Fork Willamette River in the reach between Dexter Dam and the mouth of Coast Fork (fig. 1, subreach 1). Travel rate for the leading edge is about 3 mph. Discharge data for use in applying the graphs may be obtained from gaging-station records published in the annual reports of the U.S. Geological Survey. Current discharge data may be obtained from the office of the Water Resources Division, U.S. Geological Survey, Portland, Oreg. Gaging stations on the study streams and near the mouths of tributaries to those streams are shown on the map.

Travel times can be derived for each subreach by dividing the distance along the subreach, shown under each graph, by the travel rate.

Thus, by using the graphs, travel time can be computed for any segment of the stream reaches. For example, the travel time to the Corvallis filtration plant (river mile 133.9) could be computed if a harmful contaminant were accidentally dumped into the Willamette River upstream at river mile 160.0 (just downstream from Harrisburg). To make the computation and determine the arrival time of the contaminant at the Corvallis filtration plant, the stream discharges between the two points must first be determined. If the discharge of the Willamette River was 15,000 cfs above the Long Tom River and 17,000 cfs below, the travel times would be calculated as follows:

Subreach	Discharge (cfs)	A Leading edge travel rate from graphs (mph)	B Distance (miles)	$C=\frac{B}{A}$ Leading edge travel time (hours)
6	15,000	4.1	9.0	2.2
7	15,000	3.6	5.1	1.4
8	17,000	5.0	4.5	0.9
9	17,000	3.6	7.5	2.1
		Total	26.1	6.6

The leading edge of the contaminant should arrive at the filtration plant 6.6 hours after the contaminant is dumped.

Times of travel can be calculated for the peak concentration of a contaminant by using the peak concentration-discharge relation lines and applying the same procedure.

Travel rates determined from the peak-concentration graphs can be used to approximate travel times for stream-temperature prediction and control studies or for biochemical oxygen-demand studies. However, the graphs should be used judiciously because peak concentrations of rhodamine B dye travel slightly faster than the average travel rate of water in a stream (Wilson and Forrest, 1965).

The graphs are not applicable to flood-wave travel because flood waves generally travel much faster than do the water particles.

Typical Travel-Time Graphs

Graphs of travel time in relation to stream distance for selected high, medium, and low flows were plotted for each reach studied (figs. 2, 4, 6, 8, and 10). These travel-time graphs illustrate the use of travel-rate graphs for a range and variability of travel times. Low flow was selected as the minimum scheduled flow to be anticipated after completion of all streamflow-regulation projects (U.S. Army Corps of Engineers, 1951). Medium flow was selected as the average flow of record at gaging stations in the study reaches. High flow was selected as the median 30-day annual high flow and typifies a frequently recurring high flow. The median 30-day annual high flow is defined herein as the median of the annual values of highest mean discharge for 30 consecutive days for the period of record. The 30-day annual high-flow values were prepared by Swift (1966).

In the development of the low-flow and high-flow graphs, monthly discharges of record were chosen that approximated these selected extreme values for one index gaging station (figs. 2, 4, 6, 8, and 10) in each of the reaches studied. Concurrent upstream and downstream flows were obtained for other gaging stations in the reaches.

Flows shown on the graphs apply to the river subreaches in the vicinity of the selected index gaging stations.

Because patterns of flow may be affected by reservoir regulation, travel times can vary from those shown on the graphs, depending on the distribution of flows in the several tributaries.

Summary

Travel rates for high, medium, and low flows were determined by dye-tracer studies for segments of five streams in the Willamette River basin. Relations of travel rate of both the leading edge and the peak dye concentration to discharge were determined and are presented as a series of graphs (figs. 1, 3, 5, 7, and 9). The graphs can be used to determine the travel rate for any subreach for any discharge. Time of travel can be obtained by dividing the length of the subreach by the travel rate. The relations of time of travel to stream distance for selected flows are shown in graphs (figs. 2, 4, 6, 8, and 10) for each of the five stream segments studied. From the graphs, time of travel between any two sites may be quickly determined for the discharges indicated.

References

Buchanan, T. J., 1964, Time of travel of soluble contaminants in streams: Am. Soc. Civil Engineers Proc., v. 90, no. SA 3, p. 1-12.
Swift, C. H., III, 1966, Selected flow characteristics of streams in the Willamette River Basin, Oregon: U.S. Geol. Survey open-file report, 177 p.
U.S. Army Corps of Engineers, 1951, Columbia River and tributaries, Northwestern United States: U.S. 81st Cong., 2d sess., v. V, House Doc. 531, p. 1659-2314.
Wilson, J. F., Jr., and Forrest, W. E., 1965, Potomac River time of travel measurements: Symposium on diffusion in oceans and fresh waters, 1964, at Lamont Geol. Observatory, Palisades, N. Y., Proc., p. 1-18.

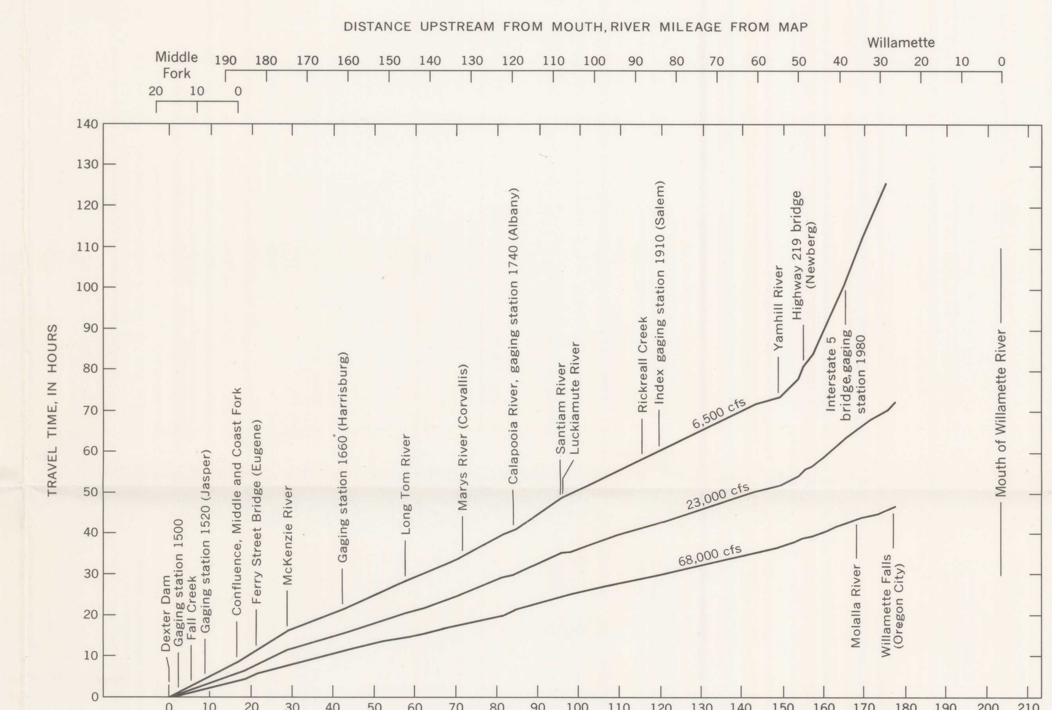


FIGURE 2.—Time of travel of Middle Fork Willamette and Willamette Rivers for selected discharges at index gaging station 1910 (Salem).

FIGURE 1.—Rate of travel for subreach discharge for Middle Fork Willamette and Willamette Rivers.

EXPLANATION
Leading edge of tracer
Peak concentration of tracer
20 Subreach number

TRAVEL RATES OF WATER FOR SELECTED STREAMS IN THE WILLAMETTE RIVER BASIN, OREGON

By
David D. Harris
1968

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W67312