EFFECT OF WATER VELOCITY ON PASSAGE OF SALMONIDS IN A TRANSPORTATION CHANNEL

by

Joseph R. Gauley

September 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

INTRODUCTION

Transportation channels are an integral part of fish passage facilities at many dams. These channels vary somewhat physically, but all have the primary purpose of transporting fish from one point to another. Many of the large dams on the Columbia River--Bonneville, McNary, and The Dalles--have multiple-entrance collection channels which also serve as transportation channels. Some of these dams have, in addition, a single-entrance transportation channel leading to a fishway. The Dalles Dam has both types of channels (Annual fish passage report, North Pacific Division, Corps of Engineers, 1957). These channels make it possible for one fishway to serve two or more collection points.

Water velocity in a transportation channel is important from the standpoint of fish passage as well as water usage. The accepted standard for water velocity in a transportation channel is 2 feet per second (Clay, 1961). Preliminary experiments at the Fisheries-Engineering Research Laboratory indicated that a velocity of less than 2 f.p.s might be satisfactory for passage of salmonids in a transportation channel. If so, present standards might be lowered, resulting in use of less water for fish passage with no loss in passage efficiency.

The objective of this study was to compare fish passage at a lower water velocity (1 f.p.s.) with passage at the present standard of 2 f.p.s.[1/]

EXPERIMENTAL EQUIPMENT

This study was made at the Fisheries-Engineering Research Laboratory, Bonneville Dam. Details of the laboratory have been described by Collins and Elling (1960). The transportation channel was constructed inside the laboratory. This test channel (fig. 1) was 4 feet wide by 91 feet long and was operated at a water depth of 6 feet. The total distance over which fish were timed was about 100 feet, since this included an additional short introductory area extending from a release box to the transportation channel. Water velocity was controlled by regulating the head on a weir between the flow introduction pool and channel (fig. 1). Water elevations (head and tailwater levels) that would give velocities of 1 and 2 f.p.s. were determined before beginning the experiments. Velocities were measured with a cup-type current meter.

1/ Research financed by the U.S. Army Corps of Engineers as part of a broad program of research to provide design criteria for more economical and efficient fish-passage facilities at their projects on the Columbia River.

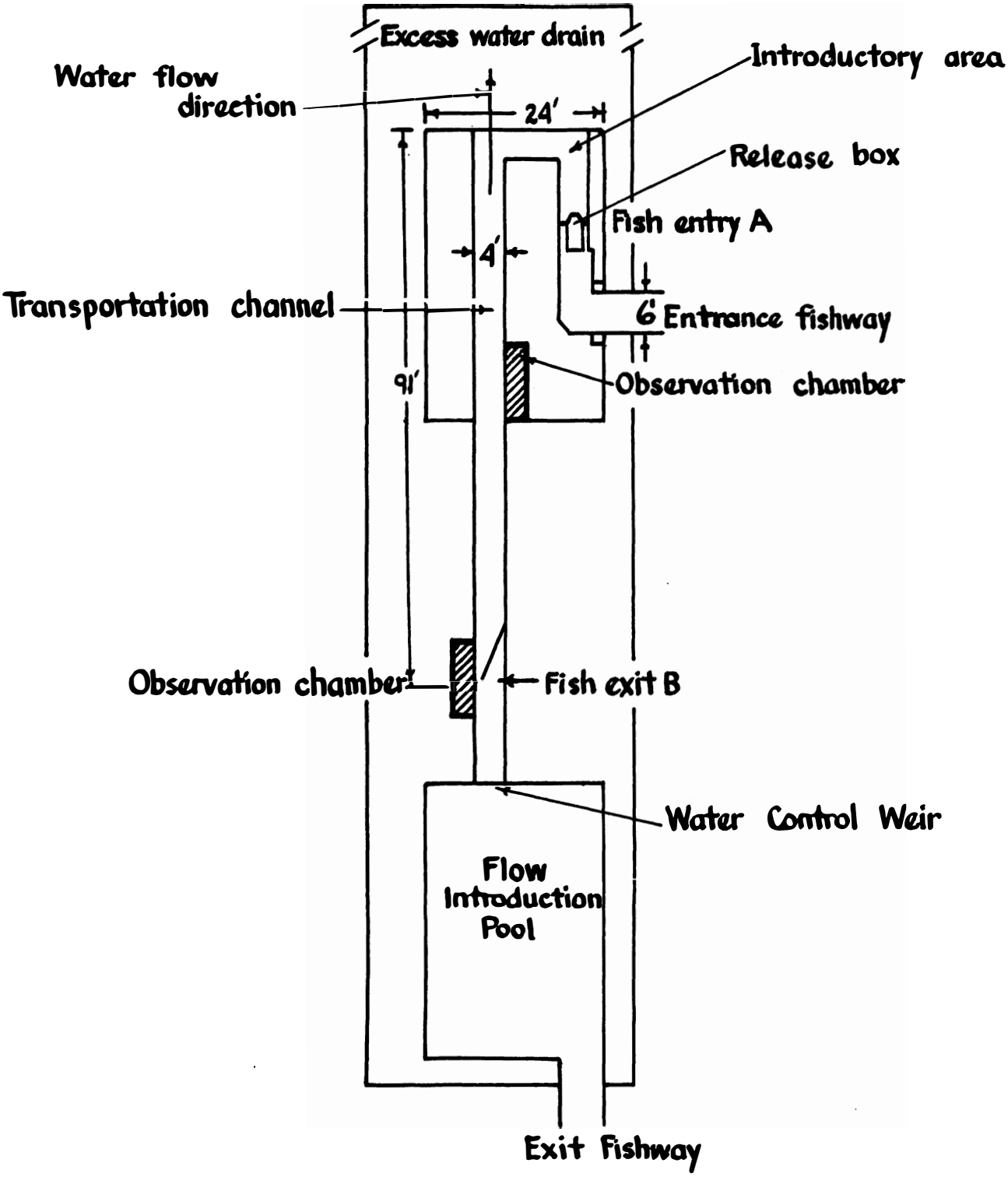

Figure 1.--Diagrammatic plan view of laboratory showing transportation channel, timing zone (A to B), and observation chambers.

The channel was lighted by 1,000-watt mercury vapor lights. These lights were 6 feet apart and suspended 6 feet above the water surface. Light readings at the water surface averaged about 700 foot-candles, which approximates light intensity on a bright cloudy day.

PROCEDURE

Experimental Design

A 2x2 Latin square design was used in these tests. This gave 4 days (2 days at each velocity) of operation for each experiment. Passage times of salmonids in water velocities of 1 and 2 f.p.s. were compared.

Timing and Behavior of Fish

Fish entered a release compartment (fig. 2) where they were identified and released individually into the test area. A time-event recorder was started at this point. The timing zone (A to B, fig. 1) extended from the release box (A) to a submerged observation chamber at the upper end of the channel (B). Fish were directed toward the observation window at the exit point by a deflecting grillwork (fig. 3). This insured accurate observation and timing of the fish under the more turbid water conditions.

Behavior of fish in the channel was observed from two chambers (figs. 1 and 4), one approximately halfway up the channel and the other at the exit point. Frequency of appearance at the observation areas and directional patterns of the fish were recorded.

Analysis of Passage Time and Behavior

Passage time and behavior were examined to determine the effect of water velocity on fish passage. Ninety-five percent confidence intervals about the median (Dixon and Massey, 1957) were applied to test for significance of differences between passage times under the two velocities. Records of the behavior patterns of the various species were inspected for gross differences under the two velocity conditions.

RESULTS

The experiment consisted of four individual tests, each of 4-day duration. Two tests were run with chinook salmon (spring and summer run) and one each with sockeye salmon and steelhead trout.

Chinook

Tests with chinook were run from May 8 to 11 and again from June 12 to 15, 1962. In the trials with spring-run chinook (May 8 to 11), median passage times at water velocities of 1 and 2 f.p.s. were 3.4 and 3.9 minutes, respectively (table 1).

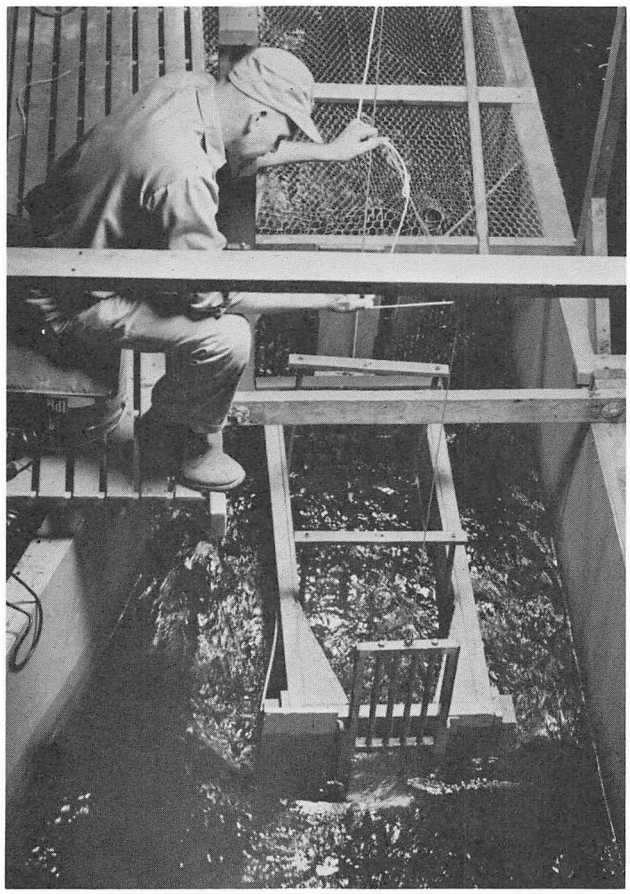

Figure 2.--View of release compartment. Operator has raised the gate (foreground) to allow a fish to enter test area.

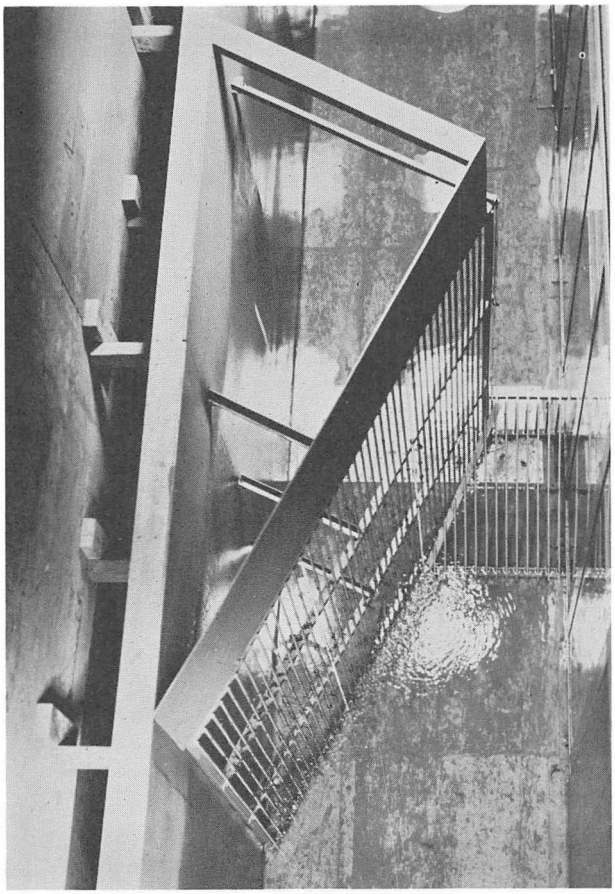

Figure 3.--Exit area showing deflection grilling and plexiglass windows (right) of submerged observation chamber.

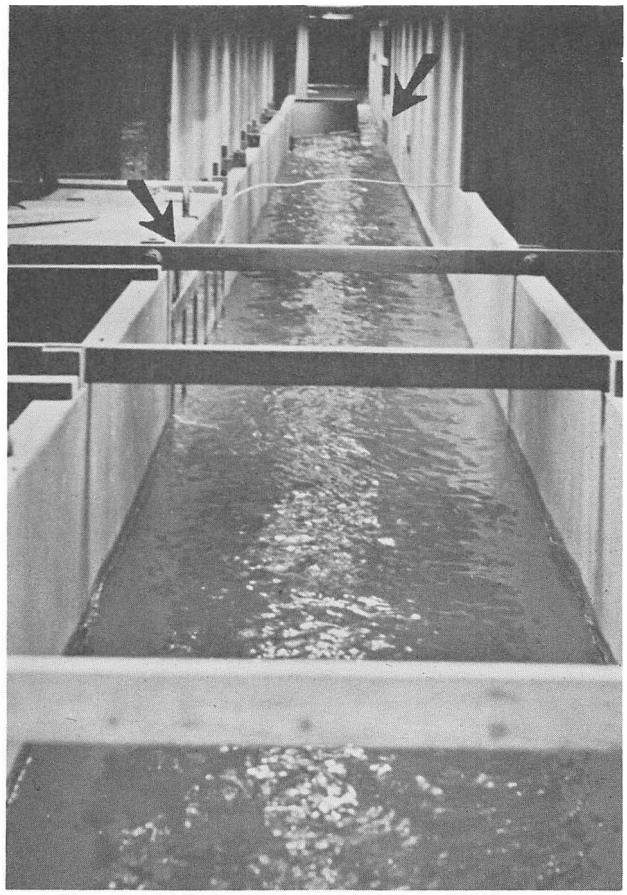

Figure 4.--Looking up transportation channel toward the exit. Arrows indicate observation chambers.

Table 1.--Median and mean passage times of chinook salmon in a transportation channel under water velocities of 1 and 2 f.p.s., May and June 1962.

Test data	Transportation velocity			
	Test 1 (May 8-11)		Test 2 (June 12-15)	
	1 f.p.s.	2 f.p.s.	1 f.p.s	2 f.p.s.
Mean[1/] (minutes)	4.7	4.9	4.8	5.3
Number of fish	37	43	45	75
Median	3.4	3.9	3.1	3.6
Number of fish	37	44	45	75
Lower limit of median[2/]	2.7	3.2	2.5	2.7
Upper limit of median[2/]	5.5	4.5	4.4	4.2

1/ Based only on fish for which complete times are available.

2/ 95 percent confidence intervals about the median.

Passage times in the June test were approximately comparable to those in the earlier test.

Tabular data on confidence intervals about the median are included in table 1. These show the passage times did not differ significantly between velocities or between tests; i.e., all values fell within the assigned confidence intervals. Mean passage times are given for comparative purposes and suggest similar trends.

Observed differences in passage time (fig. 5), i.e., a slightly slower passage under the higher velocity, are in agreement with observations by Weaver (1963), who found that chinook salmon moved progressively slower as velocities increased in the range of 2 to 8 f.p.s.

Examination of the behavior patterns of chinook salmon indicated these were relatively comparable under the two velocity conditions.

Steelhead

Median passage times of steelhead trout (table 2) in water

Table 2.--Median and mean passage times of steelhead trout in transportation velocities of 1 and 2 f.p.s., 1962.

Test data	Transportation velocity	
	1 f.p.s.	2 f.p.s.
	July 30 & Aug. 2	July 31 & Aug. 1
Mean[1/] (minutes).....	9.6	8.1
Number of fish.....	25	18
Median.....	10.6	8.8
Number of fish.....	29	19
Lower limit of median[2/]...	5.4	3.0
Upper limit of median[2/]...	15.0	11.0

1/ Based only on fish for which complete times are available.

2/ 95 percent confidence intervals about the median.

velocities of 1 and 2 f.p.s. were 10.6 and 8.8 minutes, respectively. This difference was not statistically significant. It may be noted that steelhead differed from chinook in that they moved somewhat faster at the higher water velocity (fig. 5). This agrees with the finding of Weaver (1963) that steelhead moved faster as water velocity increased in the range of 2 to 8 f.p.s. Steelhead exhibited only minor behavioral differences under the two velocity conditions. Compared with the other species tested, steelhead obviously spent considerable time in the test channel. The relatively slow passage time may be accounted for by the fact that this species often remains stationary for lengthy periods before moving upstream.

Sockeye

Median passage of sockeye salmon (table 3) did not differ significantly under the two velocity conditions. The sockeye were similar to chinook in that passage time increased as water velocity increased (fig. 5). Observations from the viewing chambers indicated that sockeye were seen more frequently when the water velocity was 2 f.p.s. than when it was 1 f.p.s. This may be accounted for by a higher frequency of to-and-fro swimming activity under the higher water velocity.

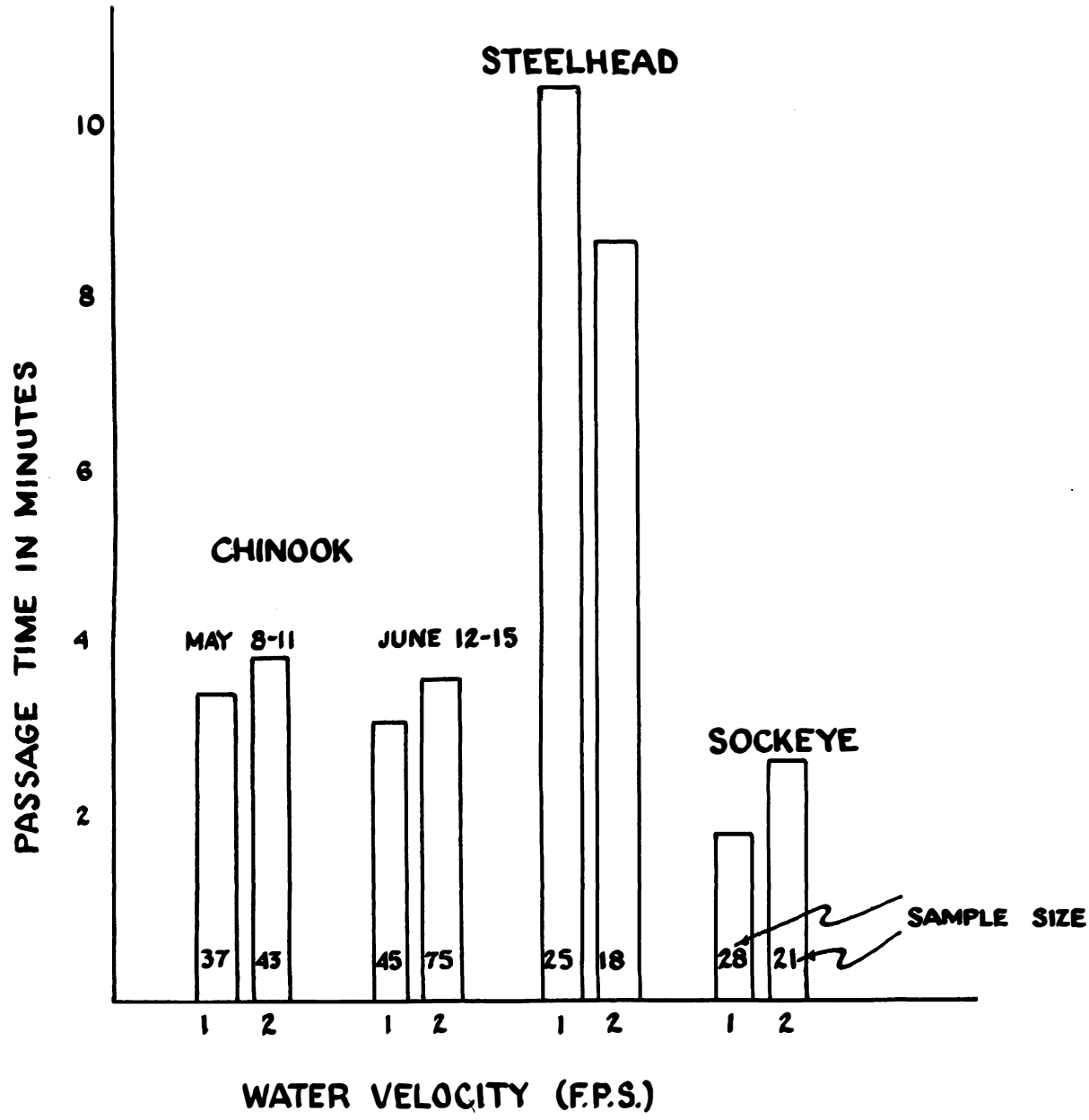

Figure 5.--Median passage times of chinook salmon, sockeye salmon, and steelhead trout in a transportation channel having water velocities of 1 and 2 f.p.s., 1962.

Table 3.--Median and mean passage times of sockeye salmon in transportation velocities 1 and 2 f.p.s., July 1962.

Test data	Transportation velocity	
	1 f.p.s.	2 f.p.s.
	July 10 & 13	July 11 & 12
Mean[1/] (minutes).....	3.1	4.1
Number of fish.....	28	21
Median.....	1.9	2.7
Number of fish.....	28	22
Lower limit of median[2/]....	1.5	2.0
Upper limit of median[2/]....	3.3	5.7

1/ Based only on fish for which complete times are available.

2/ 95 percent confidence intervals about the median.

SUMMARY AND CONCLUSIONS

Passage times and behavior of chinook salmon, sockeye salmon, and steelhead trout in a transportation channel were compared at water velocities of 1 and 2 f.p.s. The channel was 4 feet wide with a water depth of 6 feet. Passage time over a 100-foot distance was used to assess performance under the two velocity conditions.

The experiment consisted of four tests treating individual runs of (1) spring and (2) summer chinook salmon, (3) sockeye salmon, and (4) steelhead trout. Each test was comprised of four trials, two each under velocities of 1 and 2 f.p.s. Numbers tested ranged from 21 to 75 fish at each velocity condition.

Test results were as follows:

1. Median passage times of chinook were about the same at each velocity condition.

2. Steelhead passage times were somewhat slower when the transportation velocity was 1 f.p.s., but the difference was not statistically significant.

3. Median and mean passage times of sockeye were slightly faster in the 1-f.p.s. velocity, but the difference was not statistically significant.

4. Behavior of chinook and steelhead, as viewed from the observation chamber, was about the same under each velocity condition, but sockeye were slightly more active at a velocity of 2 f.p.s.

It is concluded that a velocity of 1 f.p.s. is as suitable as that of 2 f.p.s. for the passage of salmonids in a transportation channel.

LITERATURE CITED

Clay, C. H.
1961. Design of fishways and other fish facilities. The Queen's Printer, Ottawa, Canada, 301 p.

Collins, Gerald B., and Carl H. Elling
1960. Fishway research at the Fisheries-Engineering Research Laboratory. U.S. Fish and Wildlife Service, Circular No. 98, 17 p.

Dixon, Wilfred J., and Frank J. Massey, Jr.
1957. Introduction to statistical analysis. 2d ed. McGraw-Hill Book Co., New York, 488 p.

U.S. Army Corps of Engineers, Portland and Walla Walla Districts.
1957. Annual fish passage report, North Pacific Division; Bonneville, The Dalles, and McNary Dams, 49 p.

Weaver, Charles R.
1963. Influence of water velocity upon orientation and performance of adult migrating salmonids. U.S. Fish and Wildlife Service, Fishery Bulletin, vol. 63, no. 1, p. 97-122.