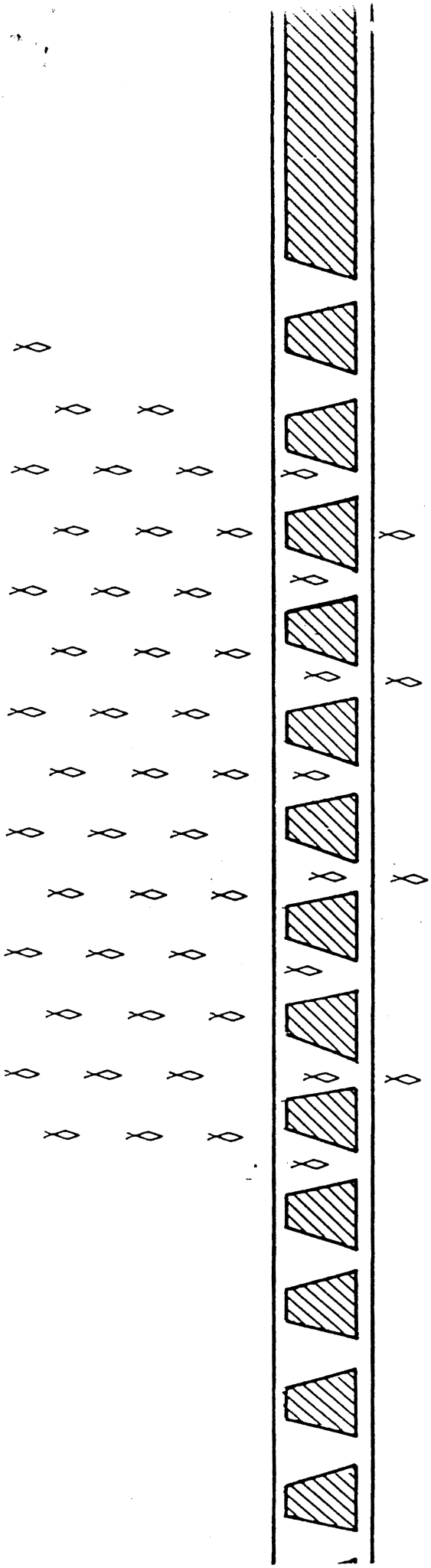

FINAL REPORT

Survival of Coho Salmon Fingerlings Passing Through Operating Turbines With and Without Perforated Bulkheads and of Steelhead Trout Fingerlings Passing Through Spillways With and Without a Flow Deflector

by

Clifford W. Long

Frank J. Ossiander

Thomas E. Ruehle

and

Gene M. Matthews

Report of Research
financed by
U.S. Army Corps of Engineers
(Contract No. DACW68-74-C-0113)

and

Northwest Fisheries Center
National Marine Fisheries Service
Coastal Zone & Estuarine Studies Division
2725 Montlake Boulevard East
Seattle, Washington 98112

February 1975

INTRODUCTION

The spring of 1974 marked the third season of a 3-year study to measure the survival of fingerling salmonids that pass through perforated bulkheads and spillway flow deflectors. These structures were designed by the Corps of Engineers to reduce the high levels of dissolved nitrogen and other gases in the Snake and Columbia rivers caused by the passage of water through standard spillways at low head dams.

The National Marine Fisheries Service (NMFS) in cooperation with the Corps of Engineers, began the studies at Lower Monumental Dam during the spring outmigration of salmon fingerlings in 1972. Results showed that perforated bulkheads installed in skeleton units caused high mortality (50%) to young fall chinook salmon, but flow deflectors with dentates were less harmful (less than 15% mortality). Studies in 1973, conducted with fingerling coho salmon, confirmed that the skeleton units equipped with perforated bulkheads caused high mortalities and showed that coho had a higher survival in passing through a spillway equipped with a plain flow deflector than one having a flow deflector with dentates (Long and Ossiander 1974). Studies reported here measured survival of fingerling coho salmon through operating turbines with and without perforated bulkheads and survival of fingerling steelhead trout through spillways with and without flow deflectors (No dentates)

EXPERIMENTAL DESIGN

Tests to determine survival of coho fingerlings through operating turbines with and without perforated bulkheads were made on April 13,

17, and 21, 1974. Survival of young fish passing through bulkheads operating at 4 different settings were compared with survival of fish passing through a standard turbine operating at 105 or 115% overload. Tests to determine survival of steelhead fingerlings through spillways with and without flow deflectors were made April 27, May 1, and May 5, 1974. For both studies, test fish were released upstream and control fish downstream of the test structure and a percentage of the survivors were recovered from the fingerling collection system at Ice Harbor Dam and by dipnetting the intake gatewells at McNary Dam. Estimates of survival were calculated from the change in ratio of the numbers of test to control fish from the time of release to the time of recovery.

Coho salmon smolts weighing about 20-22/lb were furnished by the Leavenworth Fish Cultural Station; steelhead smolts weighing 8-12/lb were furnished by the Dworshak National Fish Hatchery. Fish were transported by tank truck to the NMFS fish-marking facility at Ice Harbor Dam where they were randomly divided into the number of groups to be released on the next release date and all groups were marked simultaneously by cold-branding. The brand symbol denoted date of release, and the location of the brand on the fish denoted where the fish was released; this provided assurance that even though a brand might be unreadable, its location on the fish would identify the release site. Fish markers were rotated between stations.

After being marked, fish were immediately transferred to tank trucks and transported to Lower Monumental Dam. Each of the groups was placed

in separate holding compartments of tanks supplied with river water pumped from the forebay or the tailrace and forced through spray bars. At the start of a test, fish and water were drained directly from the holding tanks into hoses leading to the designated release location.

Fish were recovered at Ice Harbor Dam from the fingerling collection system which operates 24 hours per day, 7 days per week. In this system, fish enter the intake gatewells and volitionally pass through submerged ports leading to a common flume. Fish were collected at the foot of the flume, anesthetized and examined. After the necessary data were recorded, the fish were placed in a tank until fully recovered and then released into the ice and trash sluiceway for passage to the tailrace to continue their downstream migration. This method satisfied a requirement in statistical procedure that fish recovered at Ice Harbor Dam be carefully handled and returned immediately to the river to become part of the population of experimental fish migrating toward the second recovery site, McNary Dam. At McNary Dam, fish were dipnetted from the gatewells, inspected for marks, and returned to the river to continue their migration.

RELEASE OF FISH

For the turbine studies, turbine (unit) #2 was equipped with perforated bulkheads as shown in Figures 1 and 2 and turbine (unit) #3 served as the standard turbine without bulkheads. Figures 1 and 3 show the position of the releases hoses for test fish for each of the three release days in the respective turbines. Figure 4 shows that the release location of the control groups on the three release days was in the frontroll of the discharge from unit #2.

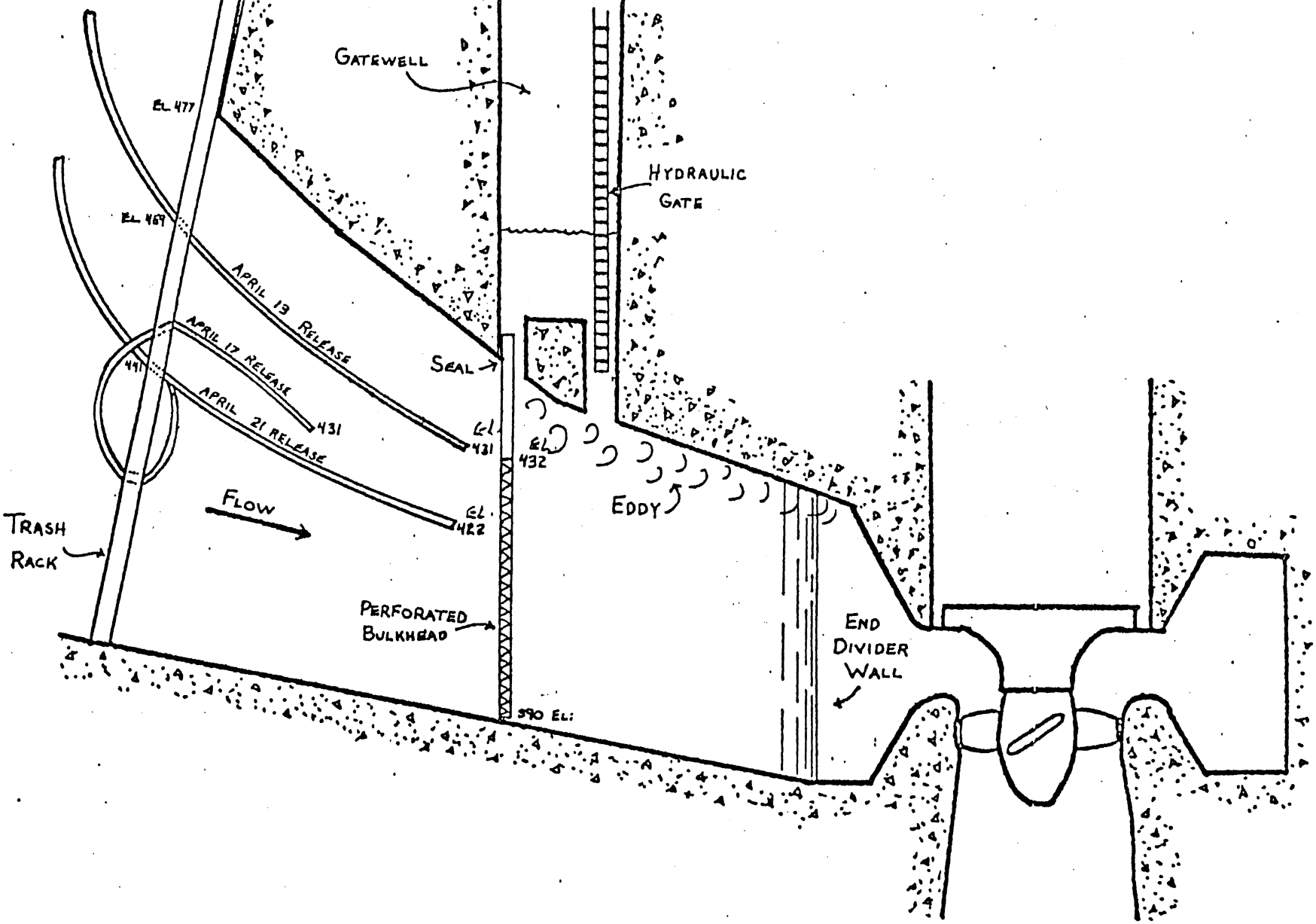

Figure 1.--Cross section of turbine number 2 equipped with perforated bulkheads showing location of fish-release hose for the three release dates. Note position of eddy between the intake ceiling and the upper row of perforations in the bulkhead and the point of termination of the walls that separate the intakes (also see figure 2 for plan view).

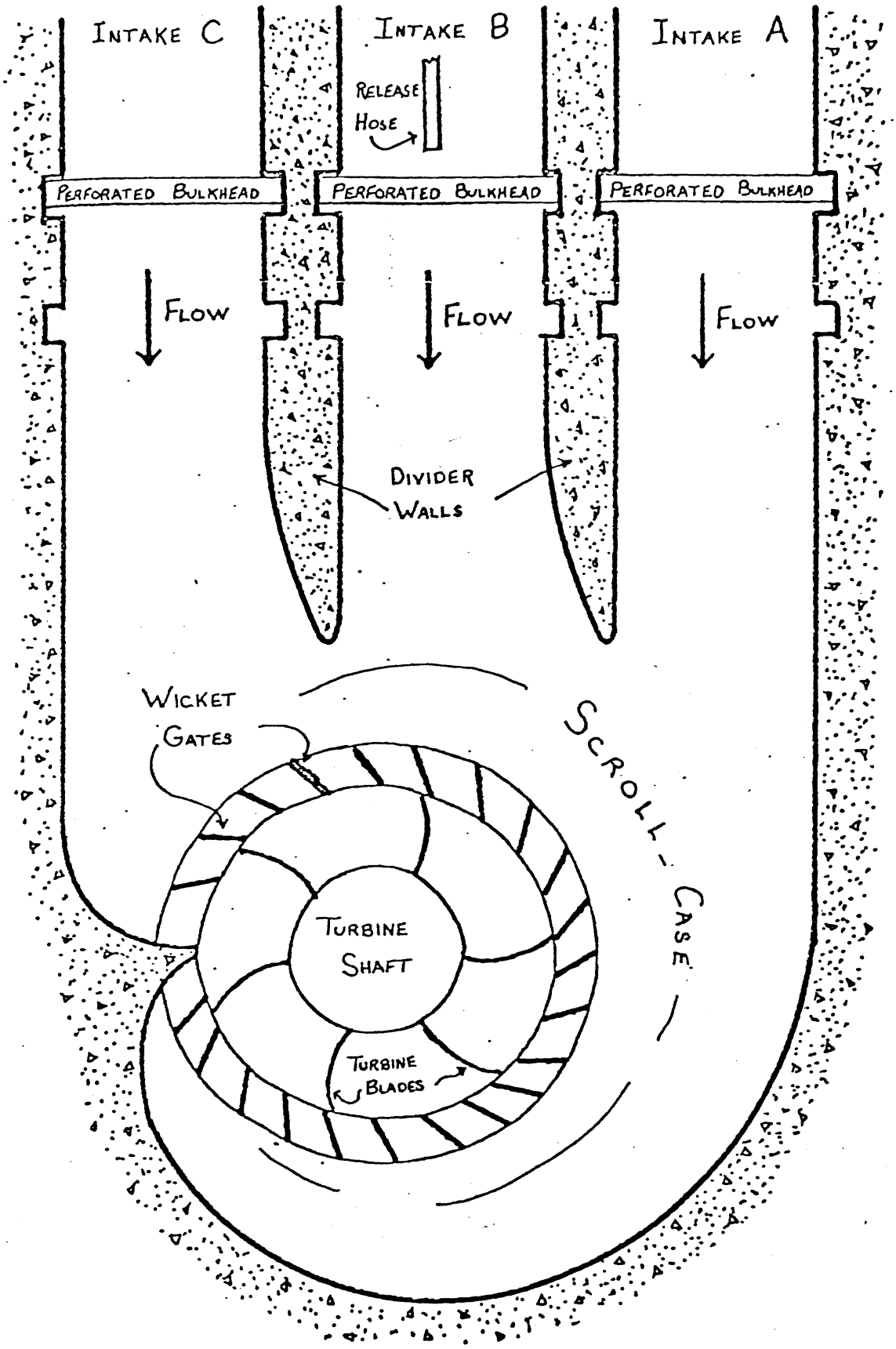

Figure 2.--Plan view of turbine number 2 showing position of fish-release hose, perforated bulkheads, and point of termination of the walls that separate the intakes.

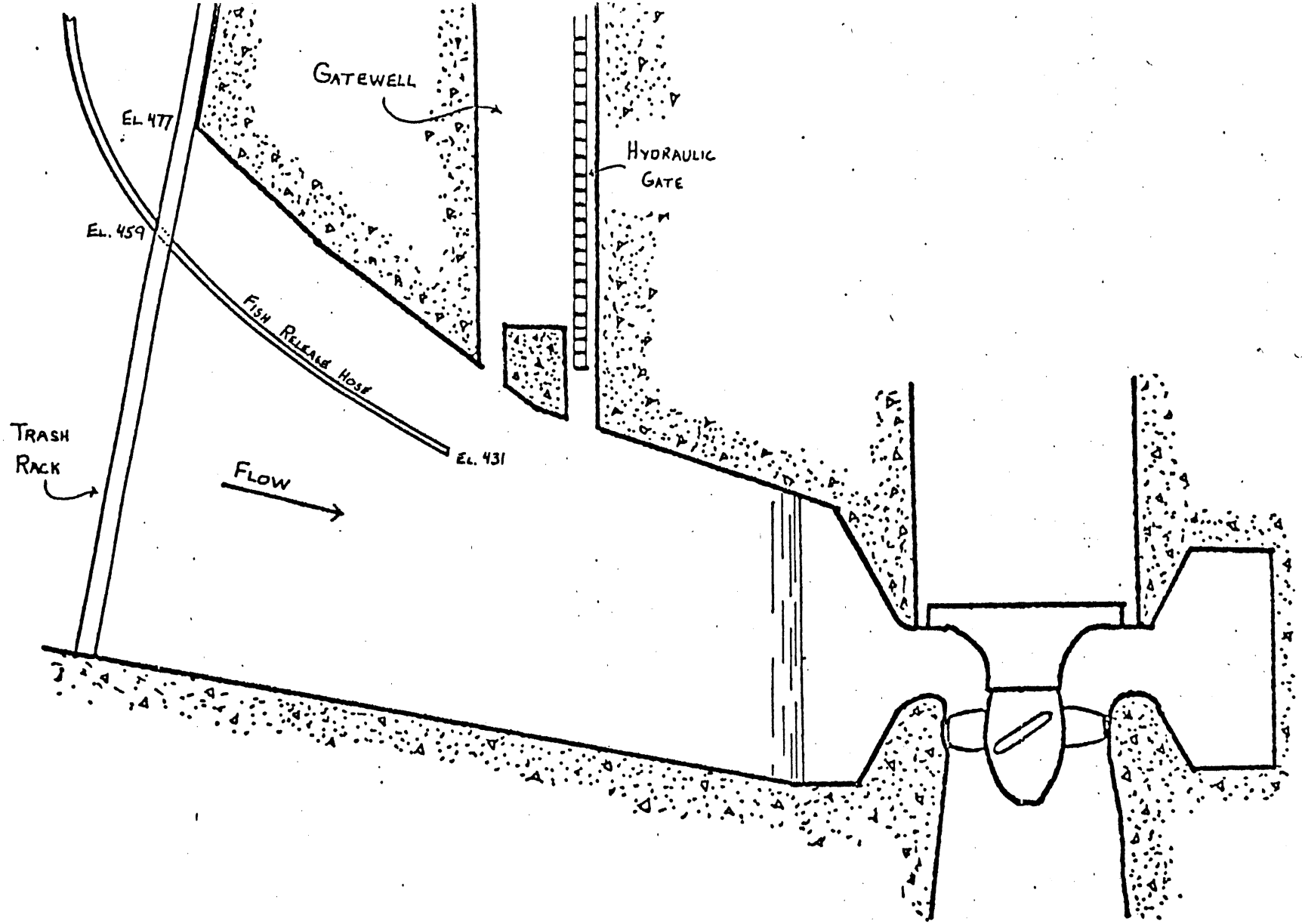

Figure 3.--Cross section of turbine number 3 (which was not equipped with perforated bulkheads) showing location of fish-release hose for the three release dates.

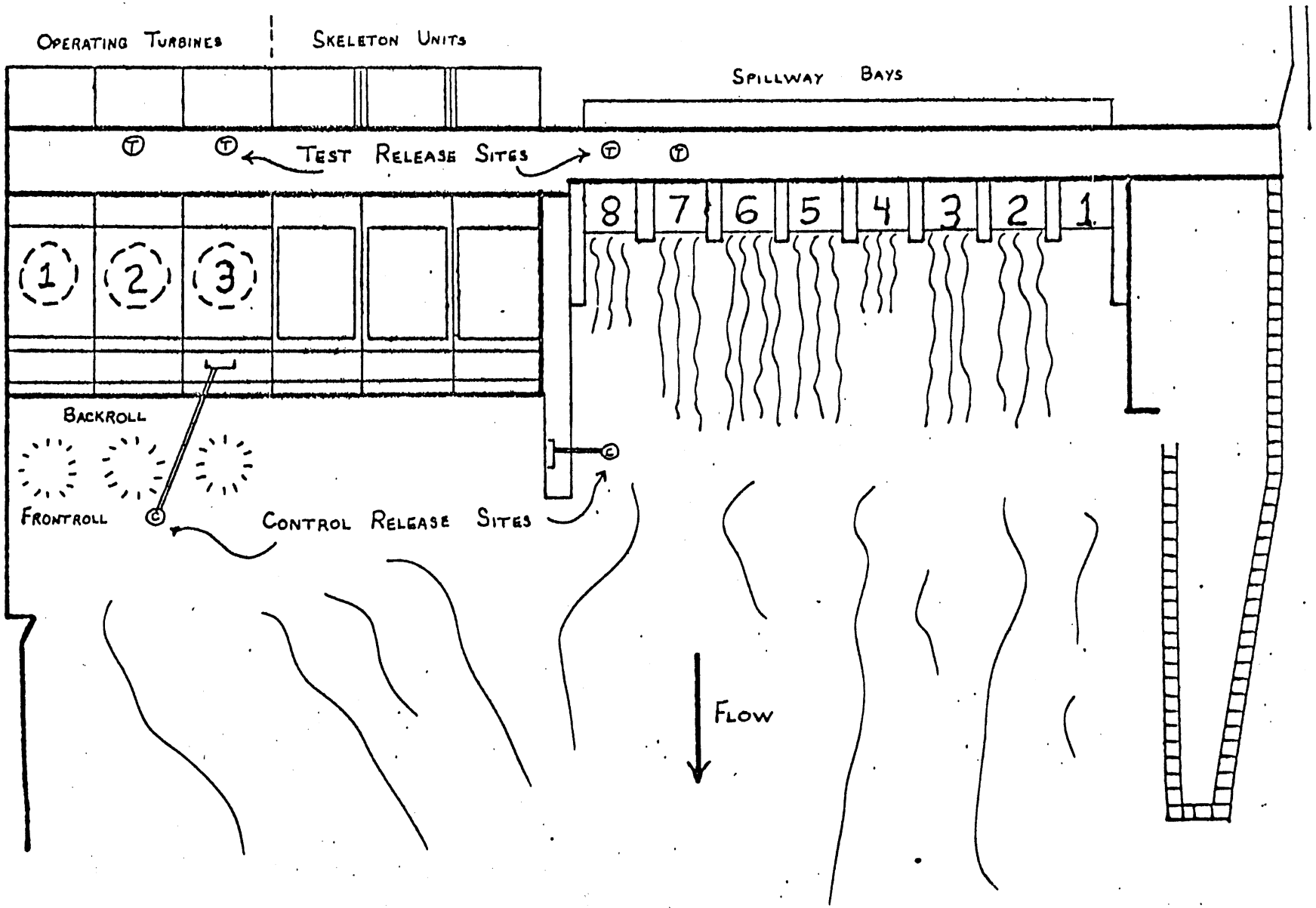

Figure 4.--Plan view of Lower Monumental Dam showing locations where test and control groups of fish were released for both the turbine and spillway studies.

Nine separate groups of coho fingerlings were released on each of three days. One group was released upstream of turbine #3 in intake B while the turbine was operating at either 105% or 115% overload. Four groups were released upstream of the bulkhead in intake B of turbine #2. Each of the 4 groups was released at a discrete combination of wicket gate and blade pitch settings (test 1--66% and 4.6°, test 2--82% and 13.5°, test 3--82% and 4.6°, and test 4--66% and 13.5°). Four groups of control fish were released in the tailrace.

After completing all releases on the first release day (April 13) it was observed that some test fish had entered the gatewells of all three intakes (A, B, and C). There are two possible explanations for this phenomenon. One possibility is that some of the fish released in intake B swam out of intake B into the forebay; some then entered each of the adjacent intakes (A and C) passed through the bulkheads and then up into the corresponding gatewells. Another possibility is that the errant fish passed through the intended bulkhead, entered the eddy lying between the intake ceiling and the uppermost row of perforations in the bulkhead (Figure 1); found their way around the downstream end of the walls separating the B intake from the adjacent A and C intakes (Figure 2); and, following the eddies in each intake, entered the corresponding gatewells. We believe the latter possibility is the most likely because we found about equal numbers of test fish in each of the three gatewells. Had the fish swam out into the forebay before entering the A and C intakes, the numbers of fish found in the A and C gatewells would be fewer than the numbers of fish found in the B gatewell. In any event, as can be seen in Figure 1, the test fish must pass through a perforated bulkhead before they can enter the gatewell because the bulkheads seal against the upstream wall of the gatewells.

We also found that fish from all four test groups were represented in the gatewells. It was apparent that some fish from each of the test groups were delayed between the bulkhead and turbine and therefore did not pass through the turbine at the prescribed turbine setting.

A change in the release location for test fish in turbine #2 was deemed desirable to eliminate this bias. For the second and third release days, we contracted with a commercial diving firm to lower the point of insertion of the release hose through the trash racks so the test fish would pass through the bulkhead at a point well below the eddy and theoretically be less likely to enter the eddy. However, our depth gauge indicated that the hose was at the same depth during the second release as it was for the first release, and we found about the same number of fish in all three intake gatewells. Subsequent inspection of the hose showed that the hose was inserted in the manner shown in Figure 1 (April 17 release) and the actual release was at the same depth as the first release. The commercial firm was contracted again to re-insert the hose at the desired depth (Figure 1) for the third and final release. However, about the same number of fish was found in all three gatewells immediately after the final release was completed.

For the studies of the flow deflector, young steelhead trout were released to pass through spillway 7 (equipped with a flow deflector) and spillway 8 (without a flow deflector). Figure 5 is a cross section of a typical spillway showing where test fish were released and the location of

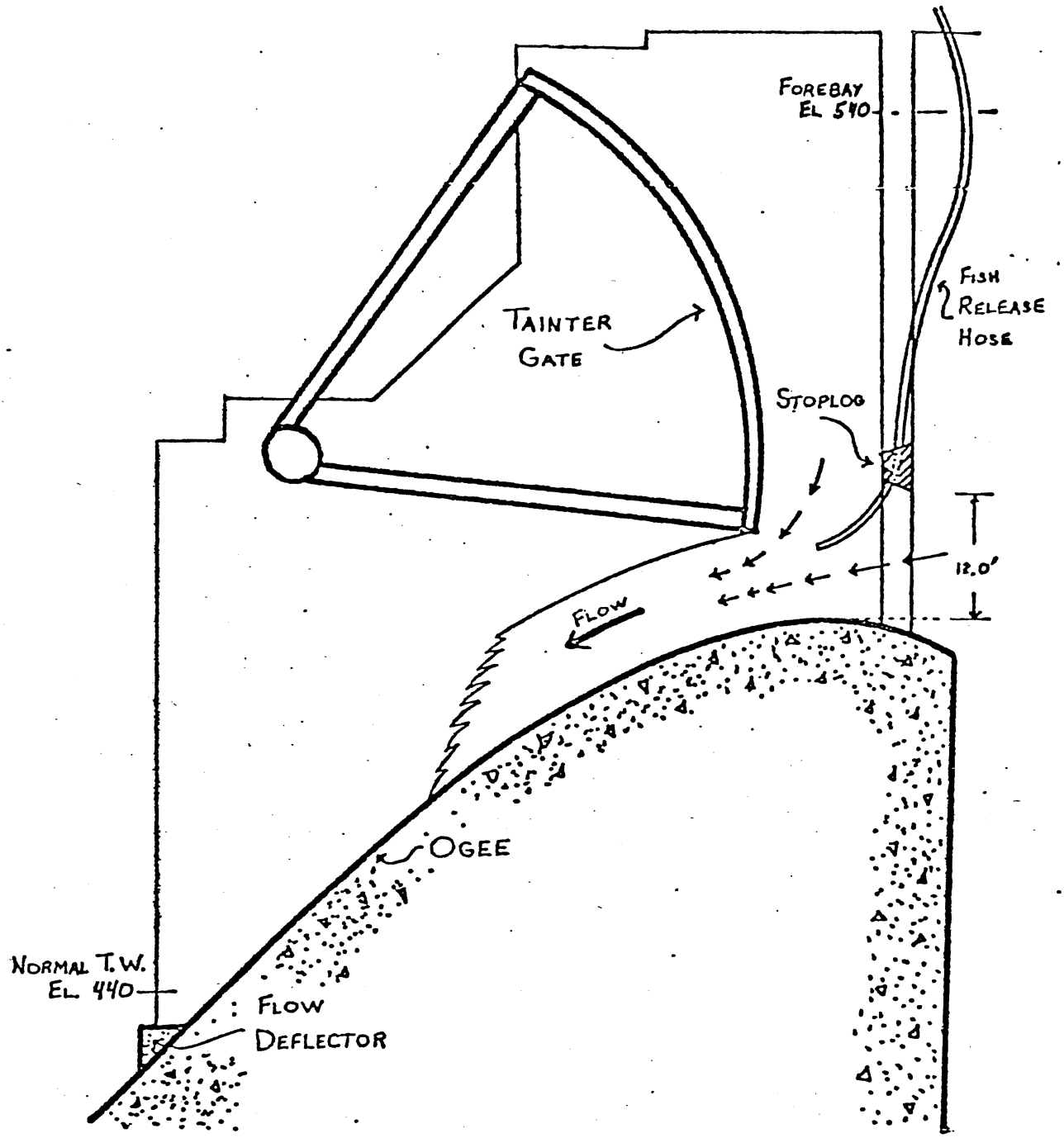

Figure 5.--Cross section of spillway showing location of fish-release hoses in spillways 7 and 8 and position of flow deflector in spillway 7.

the flow deflector on the ogee of spillway 7. The control groups of fish were released downstream of spillway 8 (Figure 4). Three groups of steelhead were employed on each release day, one test group for each of the two spillways and one control group. The two spillways were set to discharge 4800 cfs each during the release.

MORTALITY ESTIMATES

Tables 1 and 2 summarize the release of fish at Lower Monumental Dam and the recovery of survivors at Ice Harbor Dam and McNary Dam. Analysis of these data show that:

(1) all groups of fish were well mixed in time and space upon arrival at Ice Harbor and McNary dams and recovery effort was equivalent within each test;

(2) recoveries of marked fish at the above dams were statistically independent and could be combined;

(3) mortality estimates of test groups were consistent between release dates (tests) and could be combined for further analysis;

(4) mortality estimates for three of the four control groups employed for the turbine studies were consistent between release dates (tests) and could be combined for further analysis. One of the groups had a consistently higher mortality and was not used in the analysis.[1/]

1/ The cause was traced to an unchamfered pipe fitting through which the fish were drained during release. Test releases of fish from this tank and a standard tank into a raceway confirmed the cause of the higher mortality. On this basis, the fourth control group was not used in the analysis.

Table 1. Numbers of juvenile coho salmon released at Lower Monumental Dam and survivors recovered at Ice Harbor Dam and McNary Dam for each of three tests during turbine study.

Release point and test condition	Date and time of day	Number of fish released	Number of fish recovered		
			Ice H. Dam	McNary Dam	Comb.
TEST NUMBER 1	April 13				
Unit #2					
Test condition #1	7:40 pm	28,739	1,014	766	1,780
Test condition #2	8:05 pm	28,856	969	618	1,587
Test condition #3	8:50 pm	28,460	1,006	740	1,746
Test condition #4	9:10 pm	28,558	966	756	1,722
Unit #3					
115% overload		27,961	922	658	1,580
Controls					
#1	7:40 pm	13,724	548	422	970
#2	8:05 pm	14,577	606	460	1,066
#3 1/	8:50 pm	14,551 1/	462 1/	356 1/	818 1/
#4	9:10 pm	14,590	578	428	1,006
Subtotal		200,016	7,071	5,204	12,275
TEST NUMBER 2	April 17				
Unit #2					
Test condition #1	7:10 pm	26,395	1,006	908	1,914
Test condition #2	7:45 pm	23,710	686	650	1,336
Test condition #3	8:20 pm	27,127	1,038	984	2,022
Test condition #4	8:45 pm	27,293	932	812	1,744
Unit #3					
105% overload		27,294	971	880	1,851
Controls					
#1	7:10 pm	14,122	619	506	1,125
#2	7:45 pm	14,121	597	632	1,229
#3 1/	8:20 pm	13,324 1/	443 1/	392 1/	835 1/
#4	8:45 pm	13,665	552	508	1,060
Subtotal		187,051	6,844	6,272	13,116
TEST NUMBER 3	April 21				
Unit #2					
Test condition #1	7:05 pm	31,929	1,198	1,072	2,270
Test condition #2	7:40 pm	31,663	932	856	1,788
Test condition #3	8:15 pm	31,451	1,210	992	2,202
Test condition #4	8:55 pm	30,951	1,162	966	2,128
Unit #3					
115% overload		30,436	1,013	818	1,831
Controls					
#1	7:05 pm	15,100	643	518	1,161
#2	7:40 pm	15,404	698	554	1,252
#3 1/	8:15 pm	14,779 1/	566 1/	364 1/	930 1/
#4	8:55 pm	14,856	651	522	1,173
Subtotal		216,569	8,073	6,662	14,735
TOTAL		603,636	21,988	18,138	40,126

1/ These data not used in final analysis - see footnote, page 7.

Table 2. Numbers of juvenile steelhead trout released at Lower Monumental Dam and survivors recovered at Ice Harbor and McNary Dam for each of three tests during spillway study.

Release location	Date and time of release	Number of fish released	Number of fish recovered		
			Ice H. Dam	McNary Dam	Comb.
TEST NUMBER 1	April 27				
Spillway 7 with flow deflector		29,262	734	746	1,480
Spillway 8 without flow deflector		28,183	536	652	1,188
Control		29,086	810	776	1,586
Subtotal		86,531	2,080	2,174	4,254
TEST NUMBER 2	May 1				
Spillway 7 with flow deflector		31,971	600	764	1,364
Spillway 8 without flow deflector		31,723	382	638	1,020
Control		32,125	759	718	1,477
Subtotal		95,819	1,741	2,120	3,861
TEST NUMBER 3	May 5				
Spillway 7 with flow deflector		29,712	420	636	1,056
Spillway 8 without flow deflector		30,756	231	446	677
Control		30,856	456	520	976
Subtotal		91,324	1,107	1,602	2,709
TOTAL		273,674	4,928	5,896	10,824

Table 3. Mortality of coho fingerlings passing through a standard and a turbine equipped with perforated bulkheads at Lower Monumental Dam based on recovery of test and control fish at Ice Harbor Dam and McNary Dam through June 13, 1974.

Test Condition							Mortality[1]			
							Test release			
Turbine number	Perforated bulkheads	Blade angle	Wicket gate	Water discharge	Water velocity thru bulkhead	Electrical output	1	2	3	Combined tests
		degrees	percent	c.f.s.	f.p.s.	megawatts	percent	percent	percent	percent
2	Present	4.6	66	13,500	46	60	13	11	10	11
	Present	13.5	82	16,500	58	33	23	31	29	28
	Present	4.6	82	14,500	51	63	13	9	11	11
	Present	13.5	66	14,500	51	30	15	22	13	16
3	Absent	on cam	on cam	22,300	NA	155	20	-	24	20
	Absent	on cam	on cam	20,200	NA	142	-	17	-	

1/ The number of combined recoveries are sufficient to assert with 90% confidence that a mortality difference of 10% or greater can be detected at the 0.10 statistical significance level.

Based on the foregoing analysis, the estimated mortality for the turbine study was determined by comparing recoveries from each of the test groups with the combined recoveries of the three control groups. Table 3 lists the estimated survivals by test condition. Fish passing through the standard turbine had a 20 percent mortality. Mortality for the first, third, and fourth test conditions in the turbine equipped with perforated bulkheads was as low or lower than that for the standard turbine. Water velocities through the bulkhead for these tests were 46, 51, and 51 ft/sec. Mortality for the second test condition was significantly higher than that for the standard turbine. Water velocity through the bulkhead for the second test condition was 58 ft/sec.

The delay of some test fish between the bulkhead and the turbine in unit #2 apparently did not significantly affect the data. A statistical analysis of the recapture of the test groups indicated that the rate of recovery and time of maximum recovery of these groups were not significantly different than the recapture of releases through the standard operating turbine. This would indicate that a preponderance of the fish passed through the unit under the designated test condition.

Results of the spillway studies indicate that survival of steelhead is higher through spillways equipped with flow deflectors (2.2 percent mortality) than through standard spillways (27.5 percent mortality).

Sthd

about 97%

CONCLUSIONS

Results of the turbine studies imply that perforated bulkheads can be used in operating turbines without causing a higher mortality than would be experienced by fish passing through a standard turbine operating in the range of 105-115% overload. We strongly suspect that the low survival through unit #2 for the second test condition was due primarily to the relatively high velocity through the bulkhead (58 ft/sec).

The study on mortality of fish passing through a standard spillway in the first study conducted since 1955-56 when Schoeneman, et al (1961) determined that fall chinook passing through the spillways at McNary Dam suffered a 1-3% mortality. Results reported here imply that either the larger steelhead are significantly more susceptible to injury in a standard spillway, or the spillways at Lower Monumental Dam are more harmful than those at McNary Dam. In any event, the addition of flow deflectors to the ogee of existing spillways should result in significantly higher survival of steelhead that pass through spillways.

LITERATURE CITED

Long, Clifford W., and Frank J. Ossiander.
1974. Survival of coho salmon fingerlings passed through a perforated bulkhead in an empty turbine bay and through flow deflectors (with and without dentates) on spillway at Lower Monumental Dam, Snake River April-May 1973. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, Wash., Rep. to U.S. Army Corps of Engineers, Contract No.DACW68-72-C-0101. 20 p. (Processed.)

Schoeneman, Dale E., Richard T. Pressey, and Charles O. Junge, Jr.
1961. Mortalities of downstream migrant salmon at McNary Dam. Trans. Amer. Fish. Soc., 90(1):58-72.