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Development of The Dalles Dam Trash Sluiceway as a Downstream Migrant Bypass System, 1981

ANNUAL PROGRESS REPORT

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ABSTRACT

The ice-trash sluiceway at The Dalles Dam, Columbia River, was evaluated in 1981 as a bypass system for downstream migrating juvenile salmonids. Over 2.6 million salmonids passed through the sluiceway between April 26 and August 8. Passage of yearling salmonids increased approximately 14% for each 1,000 cfs (28 m^3/s) increase in inflow, and the relationship between flow and fish passage was linear between 1200-3600 cfs (34-102 m^3/s). We found no significant difference in fish passage through split or adjacent sluice-gate settings for yearling or subyearling salmonids, but passage for yearlings was significantly greater through three adjacent gates rather than two or four adjacent gates. Sluiceway bypass efficiency was estimated to be 23.8% for yearlings and 31.9% for subyearlings, but was calculated indirectly to be as high as 68.5% and 34.8%, respectively. The fish trap in the sluiceway was found to cause significantly less delayed mortality when operated with an airlift pump than with a fish pump.

INTRODUCTION

Background

Juvenile anadromous salmonids produced in the Columbia River and its tributaries above Bonneville Dam must pass from one to nine dams on their migration to the ocean (Fig. 1). Where there is no downstream migrant protection, fish pass these dams either through the turbines or over the spillway. The proportion of fish using either route varies from year to year with the proportion of water spilled. Studies at main-stem Columbia dams have shown that downstream migrants passing through turbines suffer a much higher mortality than those using spillways (Schoeneman et al. 1961). As more Columbia River hydroelectric and storage projects have been completed in recent years, spilling of excess water has decreased, forcing higher percentages of the juvenile salmonids to pass through the turbines. Consequently, there is an increased need to develop techniques to safely pass juvenile salmonids around dams, thus avoiding mortality to juveniles caused by turbines.

State and federal fisheries agencies have been investigating the following techniques to pass juvenile fish around main-stem dams: (1) Collecting fish at upstream projects and transporting them by truck or barge to the estuary below Bonneville Dam, (2) installing various deflection devices in turbine intakes to guide fish to bypass systems around dams, (3) manipulating flows to spill fish over dams or to pass them quickly through slack water reservoirs before their natural urge to migrate is lost, and (4) operating ice-trash sluiceways as surface skimming bypass systems.

The Oregon Department of Fish and Wildlife (ODFW), with funding from the U.S. Army Corps of Engineers (USACE), has extensively researched the use of The Dalles Dam sluiceway as a juvenile bypass system. The initial study by ODFW in 1977 (Nichols et al. 1978) determined the number and percentage of downstream migrants using the sluiceway under the operating criteria established by Michimoto (1971). Significant numbers of migrants (over 60,000 on peak days) were found to be using the sluiceway during the spring emigration period, but bypass efficiency was estimated at only 40% when the gate openings suggested by Michimoto (1971) were used. Large hourly and daily fluctuations in passage of salmonids through the sluiceway were observed.

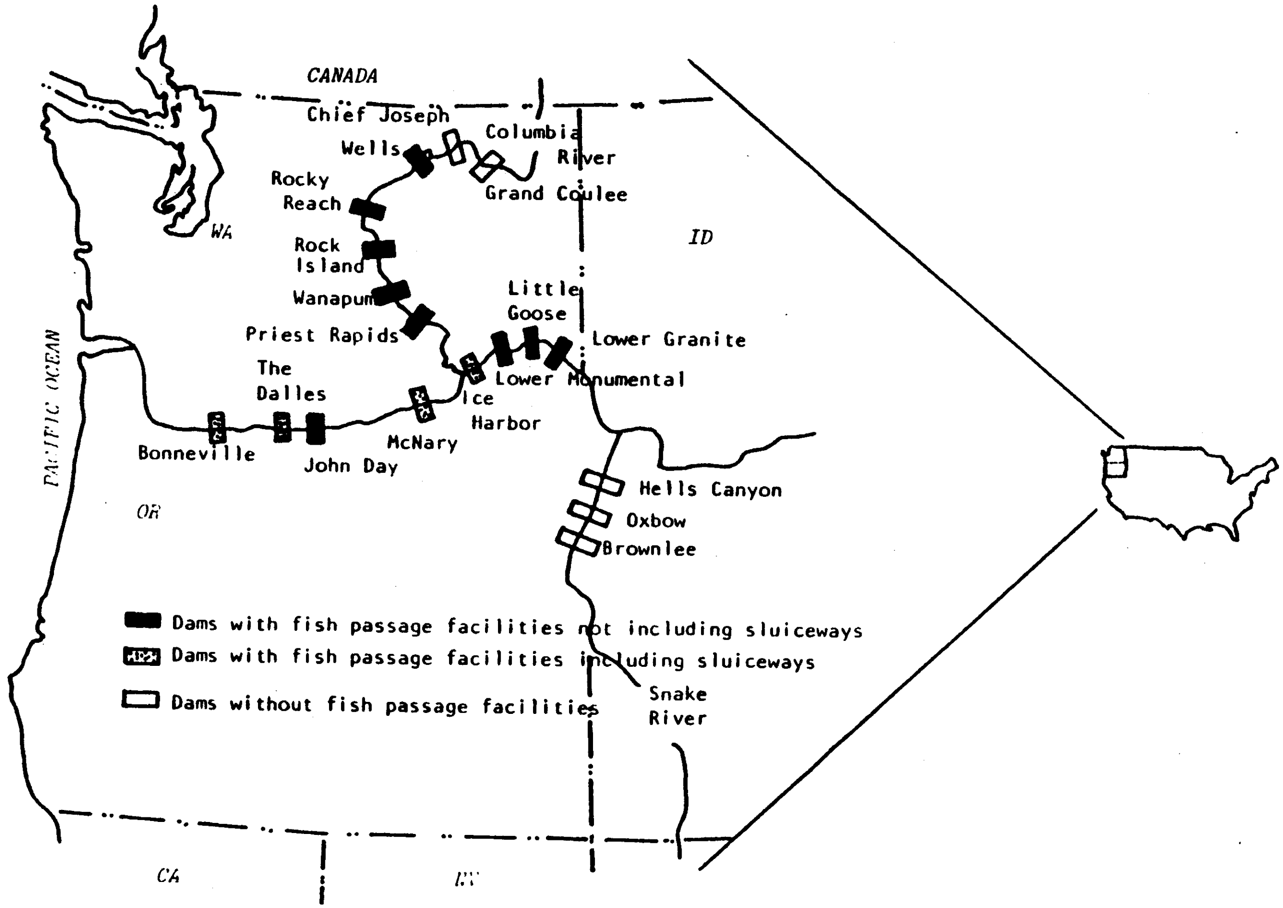

Fig. 1. Locations of dams affecting anadromous fish passage on the main-stem Columbia and Snake rivers.

During 1978, Nichols (1979) studied the effects of various sluice-gate openings on the attraction of juvenile salmonids into the sluiceway. Passage efficiency was greatly increased by opening the proper gates and by increasing flow through the sluiceway from 2,500 cfs (71 m^3/sec) to about 4,000 cfs (113 m^3/sec). The highest passage efficiency was achieved by using the largest surface flow possible through several adjacent gates on the southwest end of the powerhouse (above turbine unit 1). Fish collection efficiency was indirectly estimated at 80%. The sluiceway was operated 24 h/d between April 17 and August 4, and passed an estimated 3.7 million juveniles in 1978.

During 1979, Nichols (1980) determined that sluiceway operation could be reduced from 24 to 16 h/d with no significant reduction to fish passage. Significant numbers of migrant salmonids (1.3 million, primarily subyearling fall chinook) were bypassed through the sluiceway between July 1 and August 17, after the normal season of sluiceway operation. There was also an indication that fish passage through the sluiceway was best with gates open above turbine units 17 and 18 rather than unit 1. It was recommended that the sluiceway be operated into August to protect these later migrating fall chinook. A prototype sampling device, using a stationary trap and fish pump capable of sampling fish without injury from the sluiceway was tested and found to warrant further development.

During 1980, Nichols and Ransom (1981) installed and tested a fish trap and pumping system in the sluiceway capable of capturing fish without injury, which, with refinements, could be used to index migration timing and abundance of juvenile salmonids at The Dalles. The sampler was found to cause minimal descaling to juvenile salmonids.

Developmental studies of sluiceway operating criteria also continued during 1980. The relationship between flow into the sluiceway and bypass efficiency appeared to be linear, although test validity was questionable because a turbine outage caused abnormal flow patterns near the open sluicegates. Subyearling migrants passed through the sluiceway equally well with southwest or northeast gates open. Yearling migrants passed best through open gates on the southwest end of the sluiceway, although a test with hatchery coho indicated gates open on both the southwest and northeast ends may have been more efficient. During 1980, the sluiceway bypassed over 4.4 million juvenile salmonids during their spring and summer migration, as well as over 1,200 subyearling chinook per day in the fall.

Study Objectives for 1981

During 1981, evaluation of The Dalles sluiceway as a juvenile salmonid bypass system and a possible indexing station continued. A USACE funded study was conducted by ODFW with the following objectives:

1. Determine the relationship between surface flow and relative collection efficiency of yearling salmonids into the sluiceway;

2. Determine the optimum sluice-gate openings for attracting maximum numbers of juvenile salmonids into the sluiceway;

A. Determine if attraction of juvenile salmonids into the sluiceway can be improved with split-gate openings;

B. Determine the flow distribution into the southwest end of the sluiceway which attracts the greatest number of juvenile salmonids;

3. Determine the proportion of juvenile salmonids which enter the sluiceway, compared to the total passing The Dalles Dam (bypass efficiency); and

4. Calibrate the fish trap and pump sampler and determine the rate at which it injures juvenile salmonids.

Since spilling of excess water throughout June reduced the limited number of sampling days available, objectives 2A and 2B were not conducted with sub-yearling fish as was originally intended. With approval of Portland District Corps personnel, these objectives were deleted in favor of those of higher priority.

METHODS

Sluiceway and Site Description

The Dalles Dam, located at river mile 192 (309 km), is unique among Columbia River dams in that its powerhouse is situated parallel to river flow (Fig. 2) instead of the typical perpendicular configuration. The sluiceway at The Dalles Dam is a large rectangular channel which extends along the forebay side of the powerhouse, immediately above the turbine intakes (penstocks) and adjacent to the gatewells (Fig. 3). It is 16.5 ft (5.0 m) wide, 49 ft (14.9 m) deep from the underside of the powerhouse deck to the bottom at elevation 134 ft msl (40.8 m), and 2,000 ft (690.6 m) long. The bottom of the sluiceway is level. The sluiceway wall closest to the forebay contains 70 adjustable sluice-gates which can be raised or lower to let water and debris from the forebay enter. There are three sluice-gates for each of the 22 main turbine units, which are numbered from southwest to northeast, and two each for the two fish turbines which provide auxiliary water for the fishways. The three gates above each turbine are also numbered from southwest to northeast. For example, 16_3 denotes the northeastern gate over unit 16, and unit 16 is adjacent and northeast of unit 15.

Sluiceway Operation

Normally the forebay surface is held between elevation 155 and 160 ft (47.2 to 48.8 m). A sill in front of each sluice-gate at elevation 151 ft (46.0 m) limits the elevation to which the top of a gate can be effectively lowered. The option exists for creating submerged flow into the sluiceway by raising the bottom of the sluice-gate above this sill level; however, we used only surface overflow in 1981. Usually only one gate within a group of three mechanized gates (for instance, 1_2 of the three gates over unit 1) was opened if flows less than 2,000 cfs (57 m^3/sec), were desired. To achieve inflow of 2,000-3,000 cfs (57-85 m^3/sec), three gates (i.e., $1_1 1_2 1_3$) were opened. When more than one gate was opened, care was taken to open the gates such that nearly equal amounts of water entered each gate.

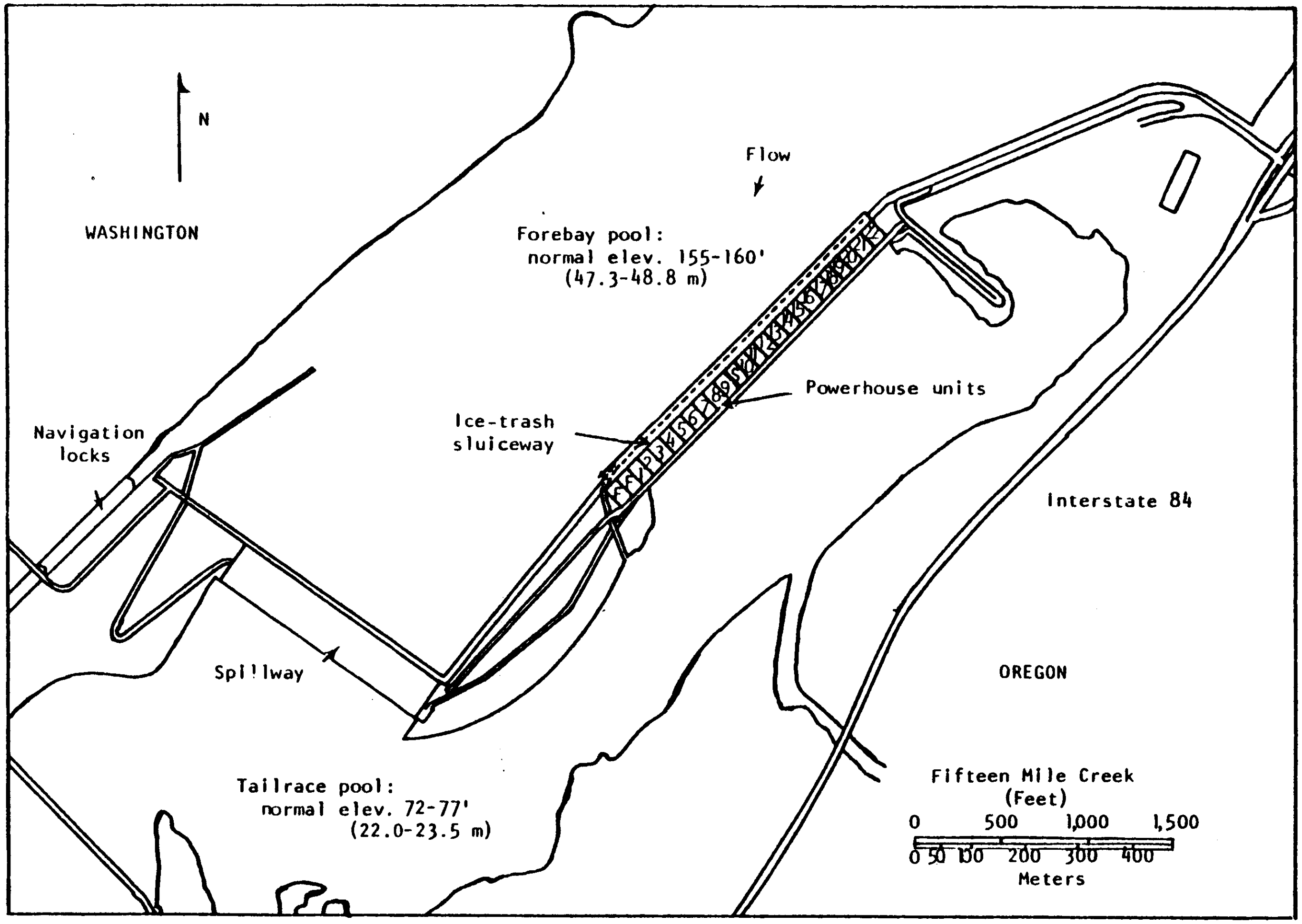

Fig. 2. Plan view of The Dalles Dam, Columbia River.

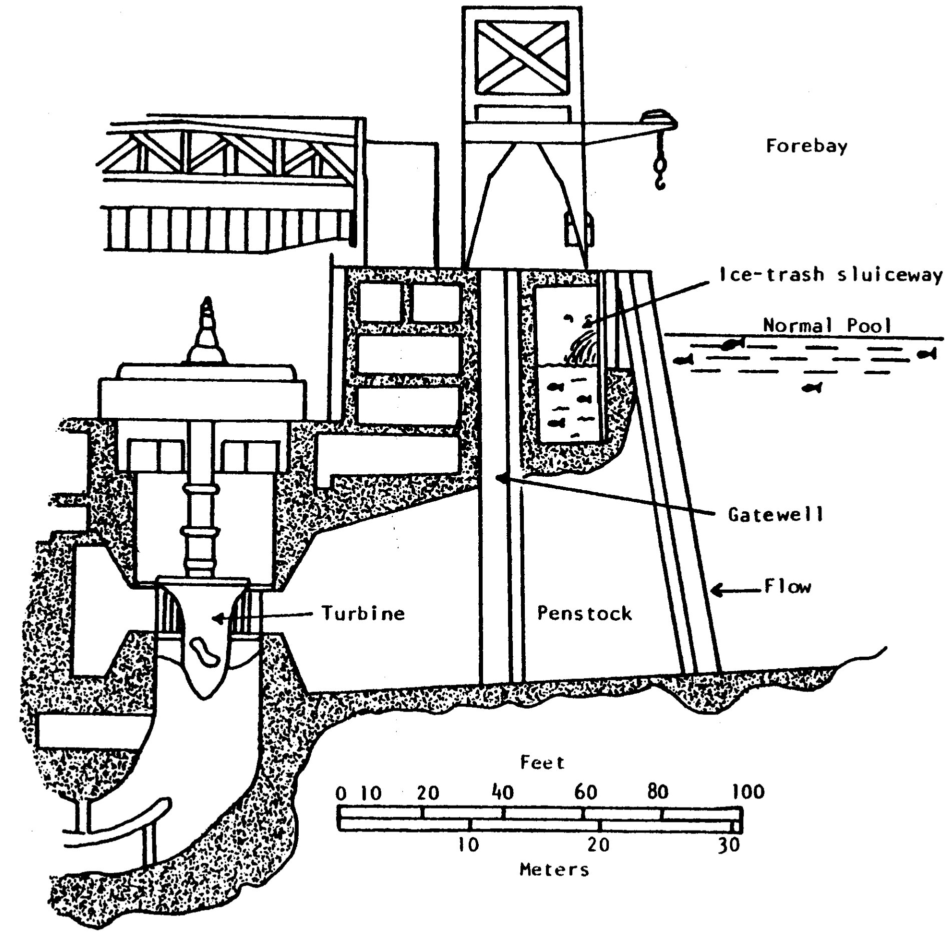

Fig. 3. Cross section of a Columbia River dam with a sluiceway.

We used a gate at the southwest end of the sluiceway to regulate water depth and velocity. This gate, termed the end gate, consists of two leaves which meet at elevation 148 ft (45.1 m) when sealing the sluiceway. Either lowering the bottom gate or raising the upper gate will permit water to flow through the sluiceway. We operated the sluiceway with the end gate fully open in 1981, except for evaluations of the fish trap and pump sampling apparatus. Water enters the sluiceway from the forebay over or under the sluice-gates, flows southwest through the sluiceway channel, plunges over the end gate, and onto a sloping concrete apron, and discharges into the tailrace pool through a raceway at nearly a right angle to the powerhouse.

During the peak of fish passage in the spring, the sluiceway was operated with flows of up to 5,000 cfs (142 m^3/sec) through three of the 70 adjustable sluice-gates. Fish that collected in the bulkhead slots (gatewells) emptied into the sluiceway through seventy 6-in (15.2 cm) orifices which passed a total of 280 cfs (78 m^3/sec). During periods of low fish passage, the sluiceway operated under orifice flow only, or was closed off completely.

Fyke Net Sampling Procedure

A fyke net was used to sample fish using the sluiceway. The net was attached to a metal frame, which was in turn attached to cables anchored on the sluiceway walls. Another cable was attached to the top of the net frame, and to an electric winch on the ceiling over a work platform inside the sluiceway (Fig. 4). This winch was used to raise and lower the net. The net itself (Fig. 5) was 20 ft (6.1 m) long and was equally divided into two sections, the upstream section composed of 1 in (2.5 cm) square nylon mesh and the rear section of 1/4 in (0.6 cm) mesh. The fyke itself was eliminated from the net since velocities fished (10-20 fps [3.0-6.1 m/s]) prevented escapement of fish. The net entrance was 3.5 ft (1.1 m) square, tapering to an 8 in (20.3 cm) cod end.

The numbers of downstream migrants passing through the sluiceway were estimated from net catches, as previously described by Nichols (1979). We generally fished the net for a portion of each hour, and then expanded the catch according to the net sampling efficiency to estimate the numbers of fish passing in 1 h. Actual fishing time was adjusted, based on our expectation of the catch rate, to sample approximately 100 fish per set. This fishing time was allotted to the middle of the hour for which passage was to be estimated. During some tests, we shortened our sampling and estimate periods to 40 min.

Estimates of fish passage during hours or days that were not sampled were interpolated from adjacent estimates. Weekly estimates were made by adding daily totals.

We determined the sampling efficiency of the fyke net at seven combinations of flow and gate settings used in the tests by releasing known numbers of marked fish into the sluiceway and recapturing them with the net. We released 121 groups of 376-613 yearling coho each (61,469 total) at various flows through sluice-gates open on the southwest and occasionally the northeast end of the powerhouse. Fish were released from a hatchery liberation truck through a 6 in (15.2 cm) flexible hose, into a 6 in (15.2 cm) vertical PVC pipe. These pipes were attached to the piernoses at sluice-gates 1_2 and 18_1. Each pipe had

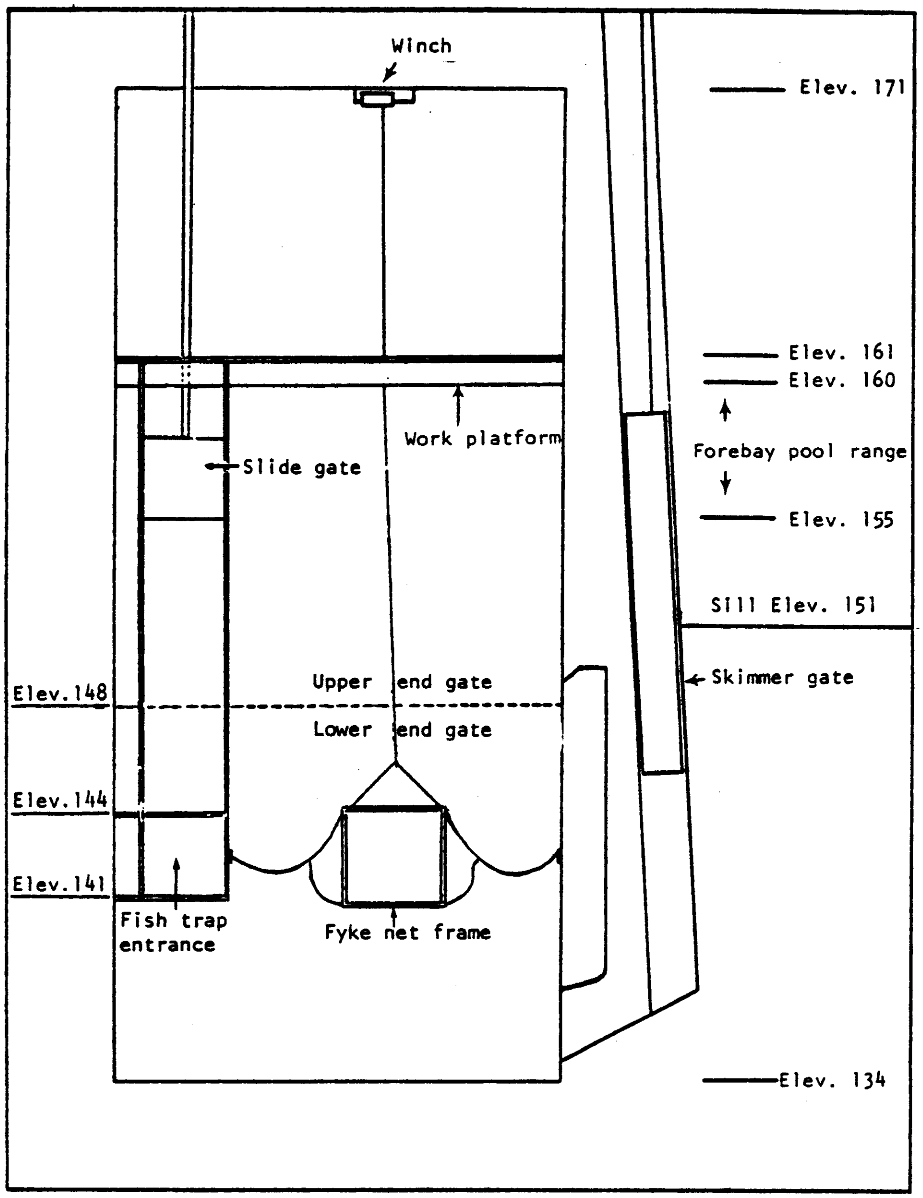

Fig. 4. Cross-sectional view of The Dalles Dam sluiceway showing fyke net and fish trap locations (looking downstream).

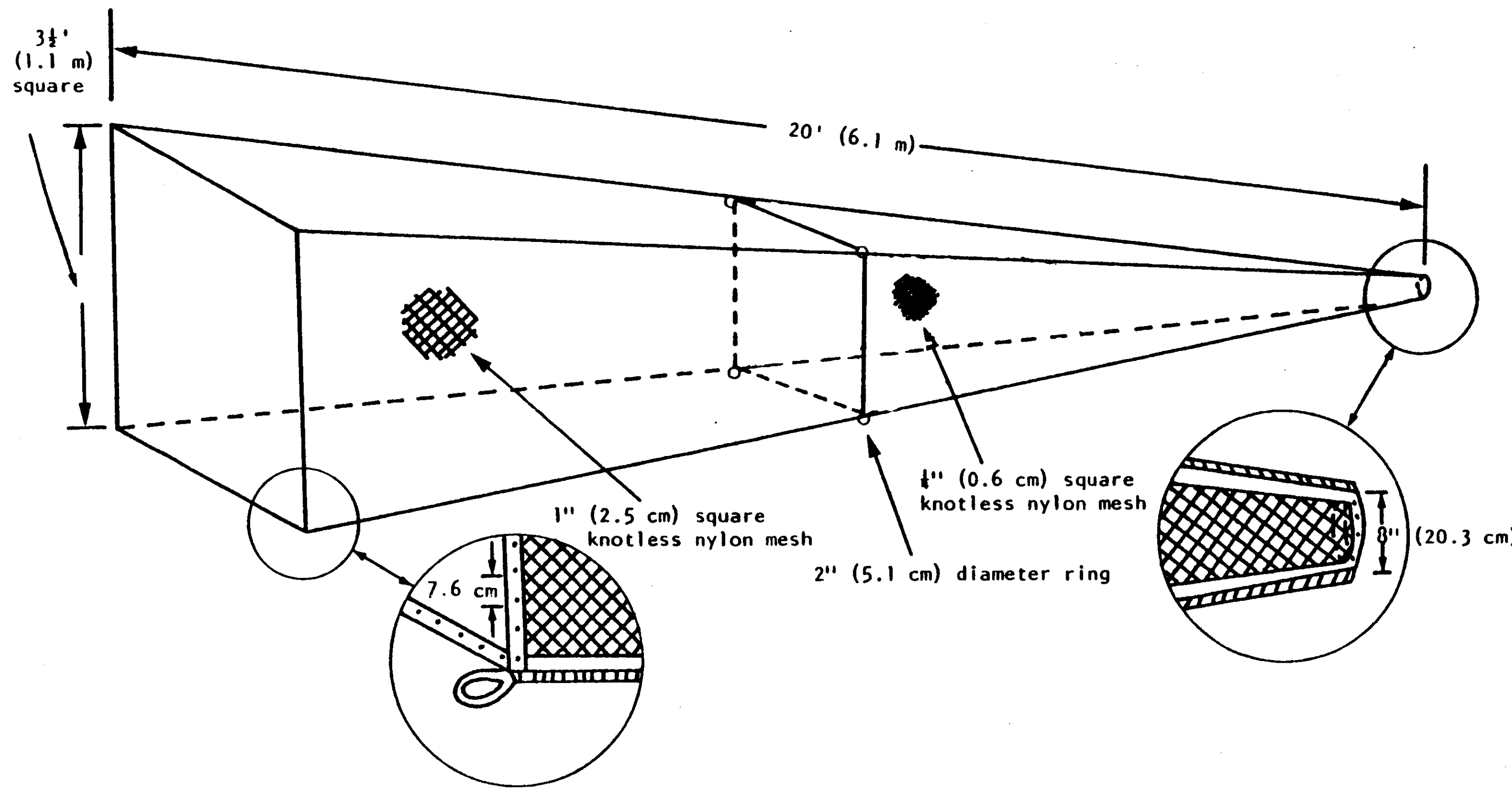

Fig. 5. Schematic diagram of fyke net used to sample juvenile salmonids in The Dalles Dam trash sluiceway.

a 45° elbow attached at the bottom and was adjusted so the released fish entered the water near the middle of the gate, just before entering the sluiceway.

Description of Fish Trap and Pump Sampler

The fish trap and pump sampler was installed in the sluiceway in 1980, and was first evaluated and described by Nichols and Ransom (1981). It was designed to capture fish without injury, and could potentially be used as a permanent indexing device for juvenile out migrants. Prior to the field season in 1981, extensive modifications were made to the trap based on 1980 evaluations. Modifications included the following: (1) lowering the trap to evaluation 142.5 feet (43. 4 m) (2) enlarging the entrance 3 ft x 3 ft (91 cm x 91 cm); (3) lengthening the trap to 68 ft (20.7 m); (4) replacing all sides with stainless steel wedge-wire screen panels of 62% porosity; and (5) replacing the flexible hose at the trap exit with rigid PVC pipe (see Fig. 4 and Fig. 6).

The trap had a 3 ft x 3 ft (91 cm x 91 cm) opening and tapered to a 6 in (15.2 cm) diameter fitting onto which the rigid PVC pipe was attached. The pipe, in turn, ran up to the work platform where it was connected to a centrifugal pump of the type commonly used in salmon hatcheries to move fish. The fish flowed into the trap, were pumped up the hose, flowed out onto a perforated plate where fish and water were separated, and dropped into a holding tank. A trash rack was situated in front of the trap mouth to screen out large debris. When the pump was not in operation a steel slidegate sealed off the trap entrance.

Near the end of the field season, the trap was modified to operate with an airlift pump in lieu of the centrifugal pump. Approximately 360 cfm (8.5 m^3/min) of air at 50 psi was injected into the pipe exiting the trap (Fig. 6). During operation this was approximately 6 ft (1.8 m) below the water surface, and lifted water and fish 11 ft (3.4 m) to the fish separator on the work platform.

Objective 1. Determine the relationship between surface flow and relative collection efficiency of yearling salmonids into the sluiceway.

We monitored passage of juvenile salmonids through the sluiceway with inflows of 1,200, 2,400, and 3,600 cfs (34, 68 and 102 m^3/s) with gates 1_2, $1_2 1_3$ and $1_1 1_2 1_3$ open, respectively. We divided the 16 h daily operation of the sluiceway (6 a.m. to 10 p.m.) into eight 2 h cycles, and tested each of the three flows for 40 min within each cycle. Fish passage was estimated during the last 20 min of each 40 min period, after flow and fish passage had stabilized.

We then expressed fish passage at each flow as a percentage of the total passage within each 2 h cycle. The order in which the three flows were tested within a cycle was systematically randomized.

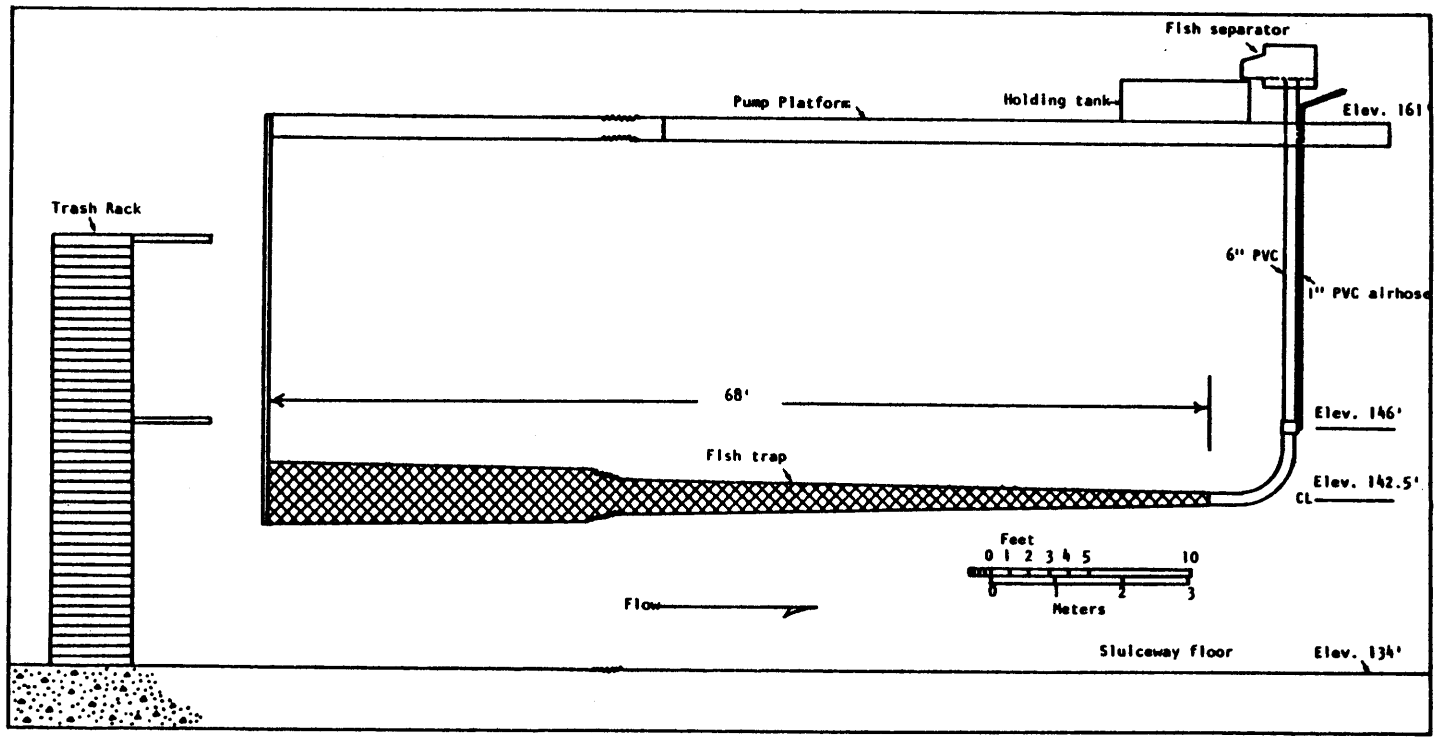

Fig. 6. Side view of the fish trap, pump platform, and trash rack.

Objective 2A. Determine if attraction of juvenile salmonids into the sluiceway can be improved with split-gate openings.

We compared passage of yearling salmonids through the sluiceway with gates $1_1 1_2 1_3$ open to that with $1_1 1_2 18_1 18_2$ open. Total flow for each gate setting was held constant at 3600 cfs (102 m^3/s). We divided the 16 h daily operation (6 a.m. to 10 p.m.) of the sluiceway into two parts in which fish passage was expected to be equal, based on diel sampling. Estimated passage with one set of gate openings during the first period (6 a.m. to noon) was compared to that of the second period (noon to 10 p.m.) with the alternate gate openings. The order in which the gate openings were tested was alternated each day.

Objective 2B. Determine the flow distribution into the southwest end of the sluiceway which attracts the greatest number of juvenile salmonids.

Passage of juvenile salmonids through the sluiceway was compared with two, three and four sluice-gates ($1_1 1_2$, $1_1 1_2 1_3$ and $1_1 1_2 1_3 2_1$, respectively) open while holding the flow constant at 3,000 cfs (102 m^3/s). We divided 16 h daily operation (6 a.m. to 10 p.m.) into eight 2 h cycles, and tested each of the three gate settings for 40 min periods within each cycle. Passage estimates were made during the last 20 min of each period, after flow and passage had stabilized. We then expressed fish passage during each period as a percentage of the total passage during each 2 h cycle. The order in which the three gate settings were tested within a cycle was systematically randomized.

Objective 3. Determine the proportion of juvenile salmonids which enter the sluiceway, compared to the total passing The Dalles Dam (bypass efficiency).

We estimated bypass efficiency by comparing daily catches of juveniles from the gatewells with the sluiceway operational and non-operational on successive days. Bypass efficiency was estimated as one minus the proportionate decrease in gatewell catches when the sluiceway was operating. We dipped all three gatewell slots of units 1-4 and the middle of slots of units 5-9 and 13-16 daily. Sampling from previous years indicated that these gatewells would yield approximately 77% of all gatewell fish. Each slot was dipped until three or fewer fish were caught. The sluiceway was operated at full surface flow averaging approximately 3700 cfs (105 m^3/s) through gates $1_1 1_2 1_3$.

Objective 4. Calibrate the fish trap and pump sampler and determine the rate at which it injures juvenile salmonids.

We were unable to complete calibration of the fish trap and pump sampler because we had difficulty getting the sampler to operate properly. The rigid PVC pipe that replaced the flexible hose exiting the fish trap included a number of 90^o bends and accompanying pipe fittings. Upon testing the modified trap prior to the start of the field season, we discovered that at low test flows and accompanying low water levels, we could not obtain adequate lift to raise water and fish from the trap to our work platform. The reduction in lift was the result of increased drag and vertical distance in the modified system.

There was not time to further modify the trap prior to the start of the experiments. Since we were unable to use the trap for most of the season, we determined sampling efficiency for only the fyke net.

To enable us to determine the condition of fish sampled with the fish trap, we raised the water level in the sluiceway by partially closing the end gate until the fish pump operated satisfactorily. For all tests with the trap, the end gate was raised 8 ft (2.4 m) from the sluiceway bottom, and inflow was 2,800 cfs (79 m^3/s) through gates $1_1 1_2 1_3$. We looked at the descaling rate of "wild" fish captured and the delayed stress mortality of hatchery coho passed through the sampler. To evaluate descaling we examined all fish sampled and estimated percentage descaling individually. We did not know the extent of descaling of "wild" fish prior to their entry into the sluiceway. Originally we had proposed to release groups of fully scaled juveniles directly into the trap at our scheduled test flows. However, these releases were deleted when we were unable to obtain adequate lift with the modified trap.

To estimate delayed stress mortality to fish using the trap, we released hatchery coho into the trap entrance through a flexible hose. These fish were marked, and after recovery were held with a control group with an alternate mark. After 24 h, mortalities in each group were counted.

Both stress mortality and descaling tests were conducted late in the season after the airlift pump had been installed.

RESULTS AND DISCUSSION

Efficiency of Sampling Gear

The sampling efficiency of the fyke net was determined by releasing 13-31 replicate groups of 376-613 yearling coho into the sluiceway for each of the seven combinations of flow and gate settings to be used in accomplishing objectives 1 and 2 (Table 1). We found an inverse, logarithmic relationship between the percentage of fish sampled and flow through sluice-gates open at the southwest end of the sluiceway ($R^2 = 0.90$, $p < 0.01$) (Fig. 7). Since the area the fyke net sampled was constant, the decrease in percentage recaptured as flow increased was due to the increase in cross-sectional area of the water column. These findings compare favorably with those in 1980 (Nichols and Ransom 1981).

Much of the variation in recapture rates can be attributed to the variety of gate settings and flows tested in the sluiceway. One would expect a better fit to the above regression from data for inflows through a single set of sluice-gates. Indeed, this was the case when fyke net efficiency was regressed on inflows of 1,200, 2,400 and 3,600 cfs (34, 68 and 102 m^3/s) through sluice-gates 1_1, $1_2 1_3$ and $1_1 1_2 1_3$, respectively ($R^2 = 0.999$, $p < 0.01$).

With southwest gates open there was a linear relationship between percentage area sampled and percentage of fish recovered ($R^2 = 0.853$, $p < 0.001$) (Fig. 8). Near maximum inflows, the two percentages were very similar, indicating as one would intuitively expect, a thorough mixing of the incoming fish throughout the water column. At lower flows the recapture rate was greater

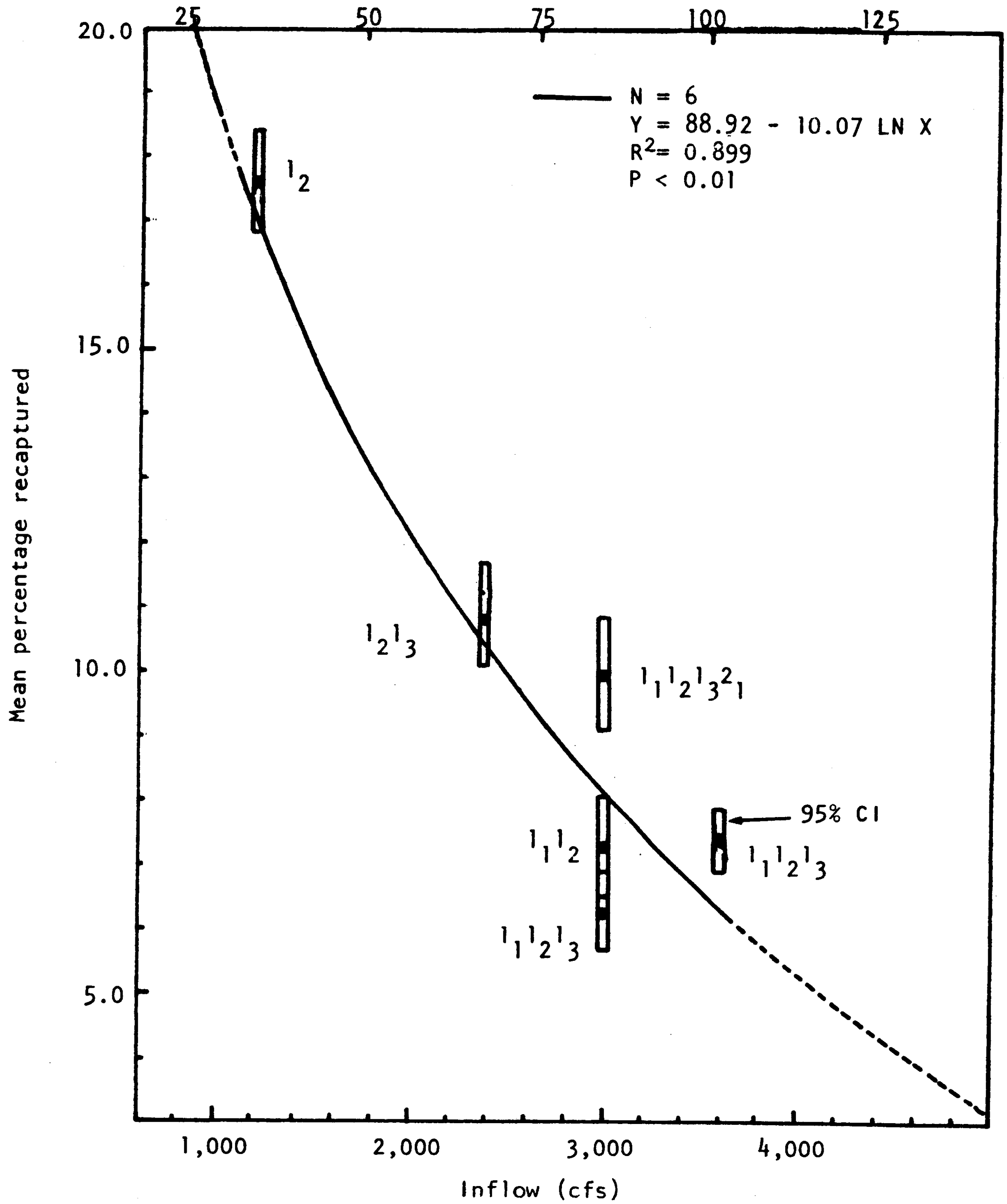

Fig. 7. Relationship of fyke net capture efficiency to sluiceway inflow for yearling coho released in the southwest end of the sluiceway.

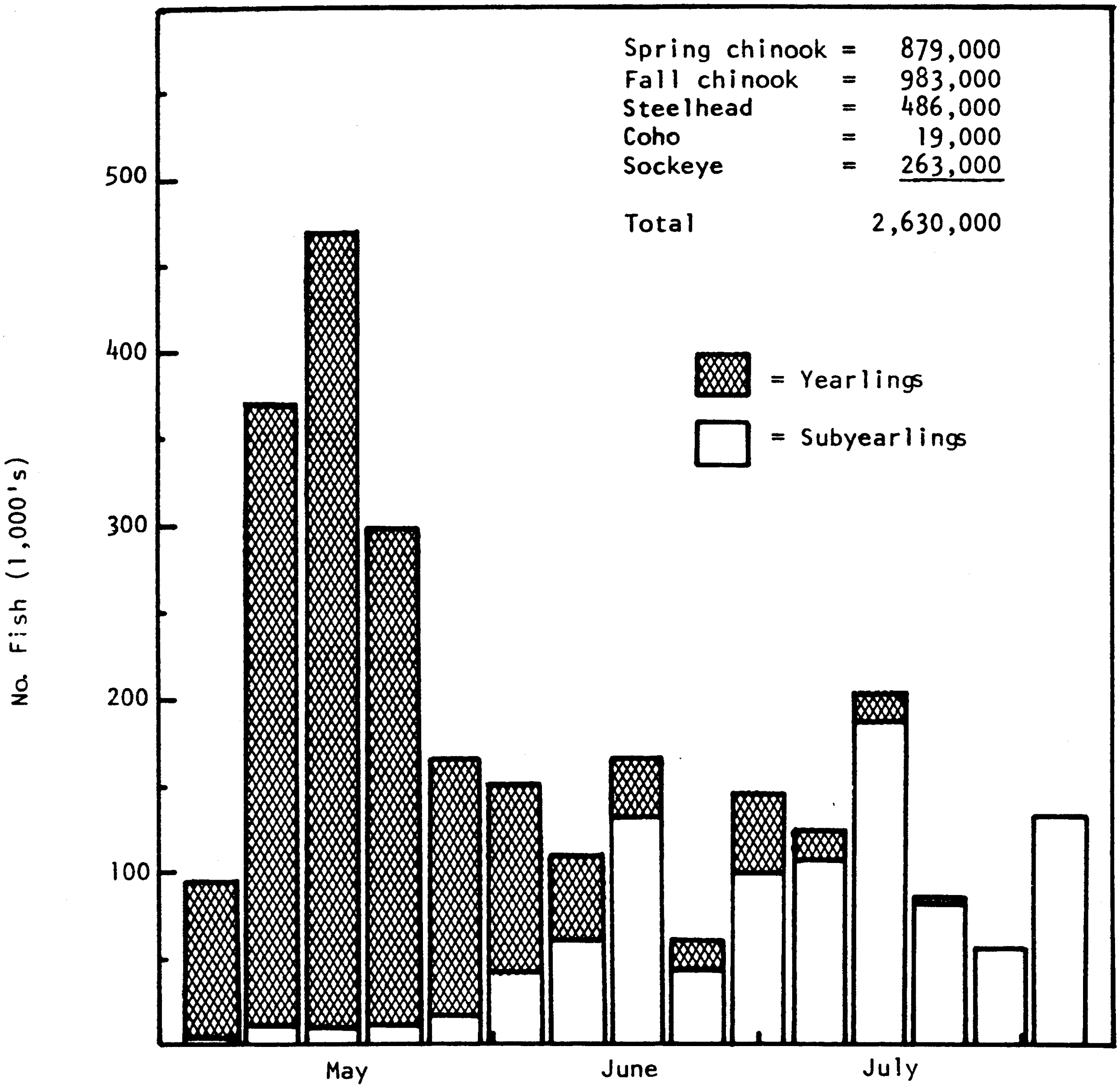

Fig. 8. Estimated weekly passage of juvenile salmonids through The Dalles Dam sluiceway during 1981.

Table 1. Recapture rates in the sluiceway net of yearling coho released into the sluiceway at various flows and gate openings.

Gates open[a]	Inflow cfs (m^3/s)	Total number releases	Range of fish/ release	Mean no. fish/ release	Mean percent recaptured	95% CI	Mean % area sampled
1_2	1,200 (34)	15	508-533	508.5	17.6	± 0.8	10.6
$1_2 1_3$	2,400 (68)	13	500-535	506.9	10.9	± 0.8	7.7
$1_1 1_2$	3,000 (85)	17	430-513	498.4	7.3	± 0.8	6.4
$1_1 1_2 1_3$	3,000 (85)	16	500-511	504.0	6.3	± 0.6	6.2
$1_1 1_2 1_3$	3,600 (102)	31	500-517	503.0	7.4	± 0.5	5.9
$1_1 1_2 1_3 2_1$	3,000 (85)	16	500-554	506.4	10.0	± 0.9	7.6
$1_1 1_2 18_1 18_2$	3,600 (102)	13	376-613	539.9	9.0	± 0.9	5.6

[a] *All releases made through gate* 1_2*, except* $1_1 1_2 18_1 18_2$ *releases which were made through* 18_1*.*

than the percentage area sampled, indicating that the fish concentrated nearer the center of the sluiceway where the fyke net fished (see Fig. 4).

Estimated Fish Pasage through the Sluiceway

Between April 26 and August 8, estimated passage of juvenile salmonids through The Dalles Dam sluiceway was 2.6 million fish (Table 2). Passage of yearling salmonids peaked the second week in May while that of subyearling peaked the second week in July (Fig. 8). The common and scientific names of salmonids sampled are found in Appendix A. Passage of juvenile salmonids through the sluiceway during 1981 was substantially lower than in previous years sampled (1978-1980), the bulk of the reduction being in yearling and subyearling chinook (Table 3). Large numbers of fish probably passed over the spillways in 1981, when an average of 114,300 cfs (3237 m^3/s) was spilled over The Dalles spillway for 36 d between May 7 and July 10 (Fig. 9). Spilling at The Dalles Dam was rare during this period of year in 1978-80. Passage of juvenile salmonids was also lower in 1981 due to closure of the sluiceway for 11 d from June 23 to August 1 during our tests to estimate sluiceway bypass efficiency.

Table 2. Estimated weekly passage of juvenile salmonids through The Dalles Dam sluiceway during 1981.

Date	Yearling chinook	Subyearling chinook	Coho	Sockeye	Steelhead	Total
April 26- May 2	53,700	4,100	--	400	37,600	95,800
03-09	242,400	11,200	--	15,600	103,100	372,300
10-16	277,000	9,400	2,400	66,900	115,900	471,600
17-23	118,400	11,300	2,400	63,900	102,100	298,100
24-30	40,100	16,100	5,900	39,600	62,400	164,100
May 31- June 06	26,800	40,100	3,900	48,700	30,100	149,600
07-13	25,900	59,200	2,000	13,000	9,600	109,700
14-20	9,900	130,000	1,200	5,400	18,300	164,800
21-27	8,800	43,600	500	3,400	4,100	60,400
June 28- July 04	41,400	98,800	1,000	2,900	1,300	145,400
05-11	15,100	105,600	100	1,100	700	122,600
12-18	16,100	186,100	--	1,100	400	203,600
19-25	2,400	81,800	--	400	200	84,800
July 26- August 01	300	54,100	--	300	--	54,700
02-08	100	131,800	--	500	--	132,400
Total	878,400	983,200	19,200	263,100	485,800	2,629,900

Table 3. Passage of juvenile salmonids through the sluiceway from 1978 through 1981.

Year	Sampling period	Estimated fish passage (1,000's) Yearling chinook	Subyearling chinook	Coho	Sockeye	Steel-head	Total	Reference
1981	04/26-08/08	878	983	19	263	486	2,630	Present work
1980	04/12-08/30	1,865	1,773	38	130	612	4,418	Nichols & Ransom 1981
1979	04/08-08/18	1,394	2,017	149	594	455	4,609	Nichols 1980
1978	04/17-06/23 and 07/21-08/04	1,499	568	538	439	623	3,657	Nichols 1979

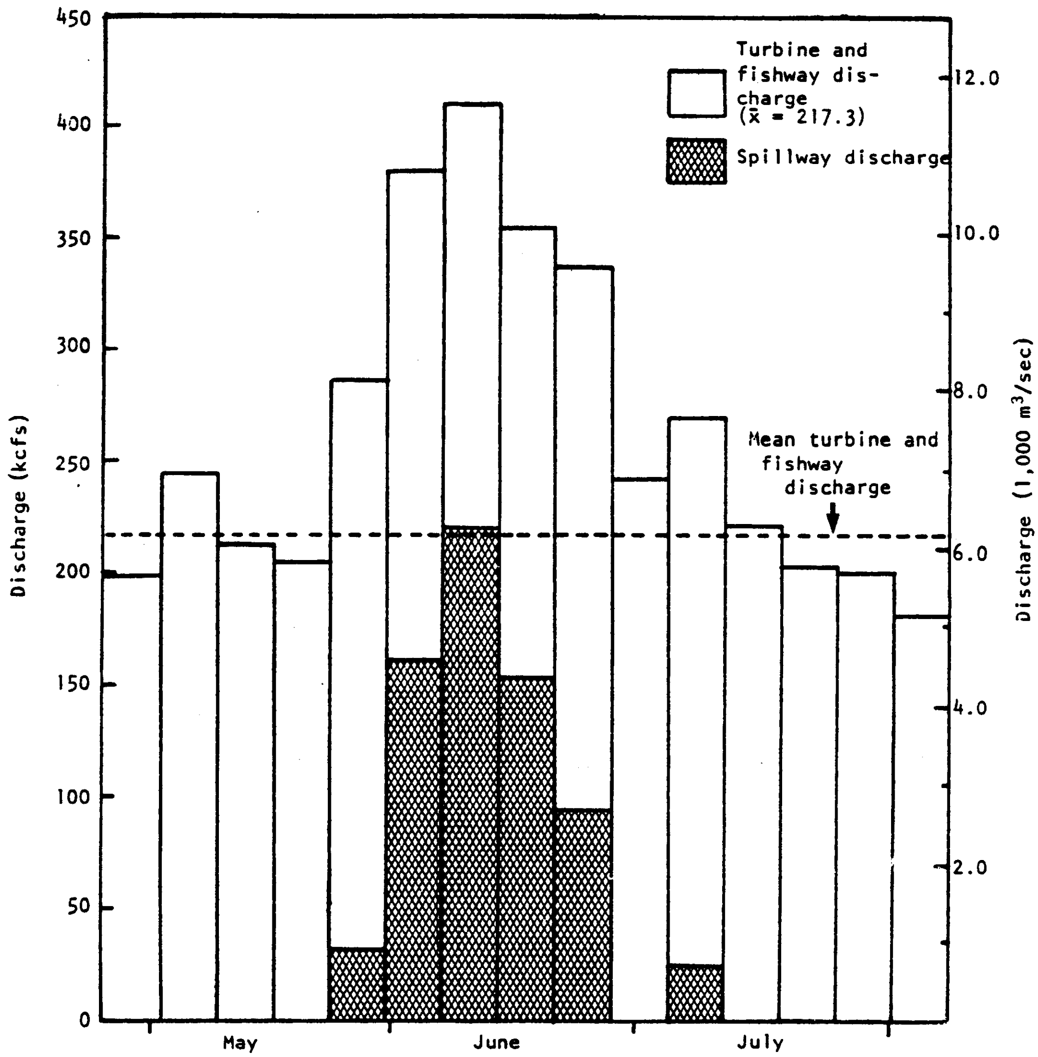

Fig. 9. Weekly average total and spillway discharge at The Dalles Dam during 1981.

Hourly passage of yearling salmonids through the sluiceway with southwest gates open peaked near noon (Fig. 10). This was similar to findings in 1978 (Nichols 1979) and 1980 (Nichols and Ransom 1981). Passage during hours of darkness (10 p.m. to 6 a.m.) has typically been 2-5% of total daily passage. The diel pattern of fish passage with sluice-gates opened at both the southwest and northeast ends (split gates) was similar to that when gates were only open at the southwest end of the sluiceway (Fig. 10).

The diel distribution of subyearling passage was determined in early August. Passage peaked between 1 p.m. and 4 p.m., then dropped sharply, in contrast to 1980 passage which increased from 1 p.m. to a peak between 8 p.m. and 9 p.m. (Nichols and Ransom 1981) (Fig. 11). Less than 5% of subyearlings passed during hours of darkness.

While the hours of peak daily passage have shifted slightly from year to year, the sluiceway has consistently passed few juvenile salmonids at night, typically 2-5% of total daily passage.

Objective 1. Determine the relationship between surface flow and relative collection efficiency of yearling salmonids into the sluiceway.

Fish passage was compared at sluiceway inflows of 1,200, 2,400 and 3,600 cfs (34, 68, and 102 m^3/s) (Table 4). A one-way analysis of variance indicated that the percentage passage (transformed to $\sqrt{\text{arcsin}}$) was significantly higher ($p < 0.001$) at successively higher inflows for all juvenile salmonids combined, as well as for the subgroups of all yearling salmonids (steelhead, yearling chinook, and sockeye). Passage of coho and subyearling chinook followed a different pattern, but this may have been due to the small sample sizes involved. Daily passages are tabulated by group in Appendix B.

We regressed percentage fish passage on sluiceway inflow and found an excellent relationship, when fitted through the origin ($R^2 = 0.996$, $p < 0.05$) (Fig. 12). Passage increased approximately 14% for each 1000 cfs (28 m^3/s) increase in inflow for all species combined. This agrees with results in 1980 when three similar test flows increased passage an average of 18% for each 1,000 cfs (28 m^3/s) (Nichols and Ransom 1981). However, turbine unit 1 was off during that test. While the data fit a straight line best, we know intuitively that the relationship becomes curvilinear since there is a finite number of juveniles available to pass. However, we cannot predict at what flow the increase in percentage fish passage will begin to level off. In fact, this point may well be above the inflow limit of the sluiceway, which is 5,000 cfs (142 m^3/s) at the maximum forebay level of 160 ft (48.8 m).

To illustrate how sluiceway inflow affects bypass efficiency, we developed a scale of approximate sluiceway bypass efficiency (see Fig. 12) based on bypass efficiencies estimated in 1980 under similar gate settings (Nichols and Ransom 1981). The average bypass efficiency and flow for two tests in 1980 were 40.7% at 2650 cfs (75 m^3/s). Since our tests in 1981 indicated there was a direct proportionality between flow and bypass efficiency, we used this proportionality to expand the scale for bypass efficiency in Fig. 12. However, the accuracy of our estimates of bypass efficiency in 1980 was questionable, so the expanded scale for bypass efficiency in Fig. 12 should be used with caution.

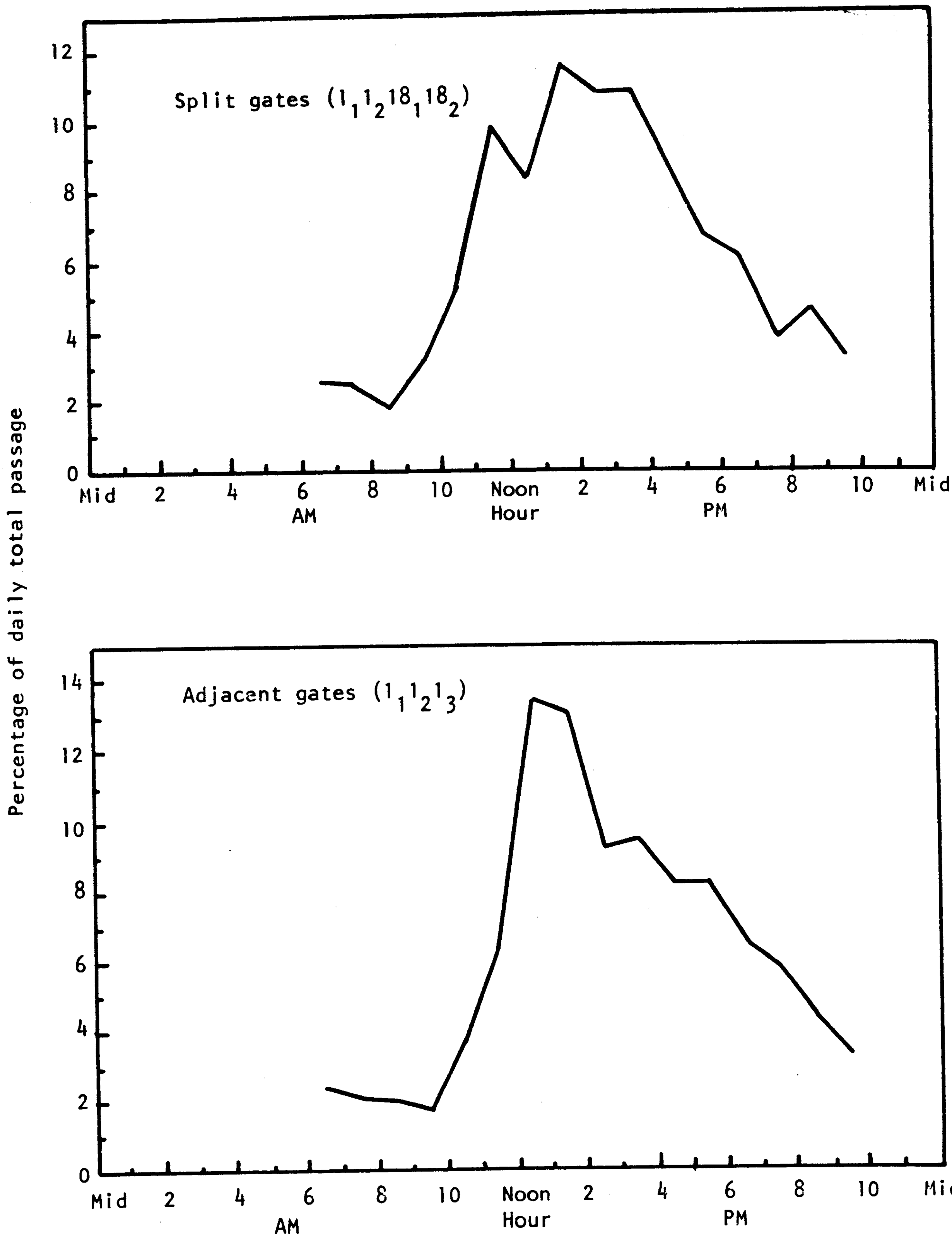

Fig. 10. Hourly passage distributions of yearling salmonids through the sluiceway with 16 h operation May 11-22.

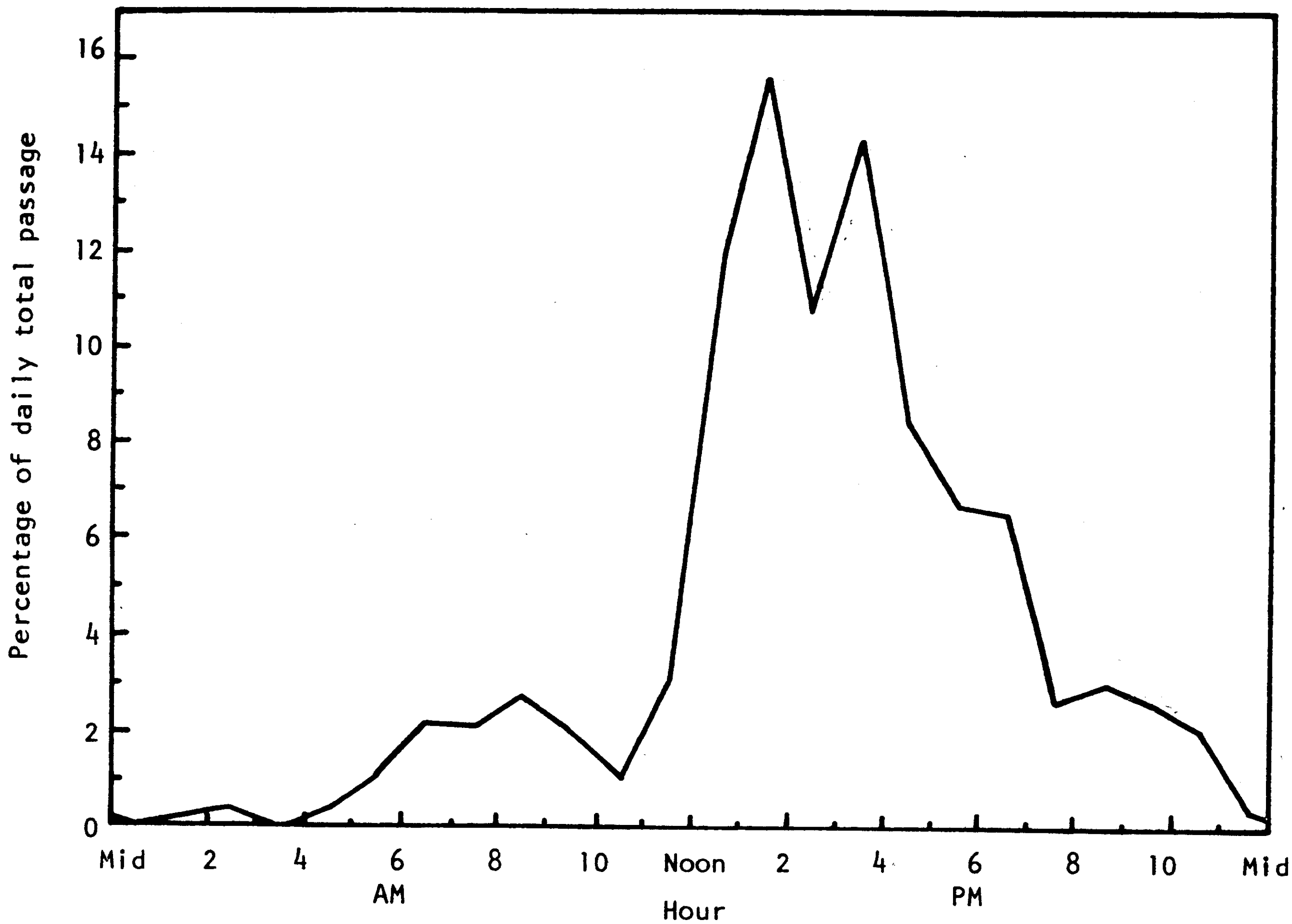

Fig. 11. Diel passage of subyearling salmonids through the sluiceway August 4-6, with sluice gates $1_1 1_2 1_3$ open.

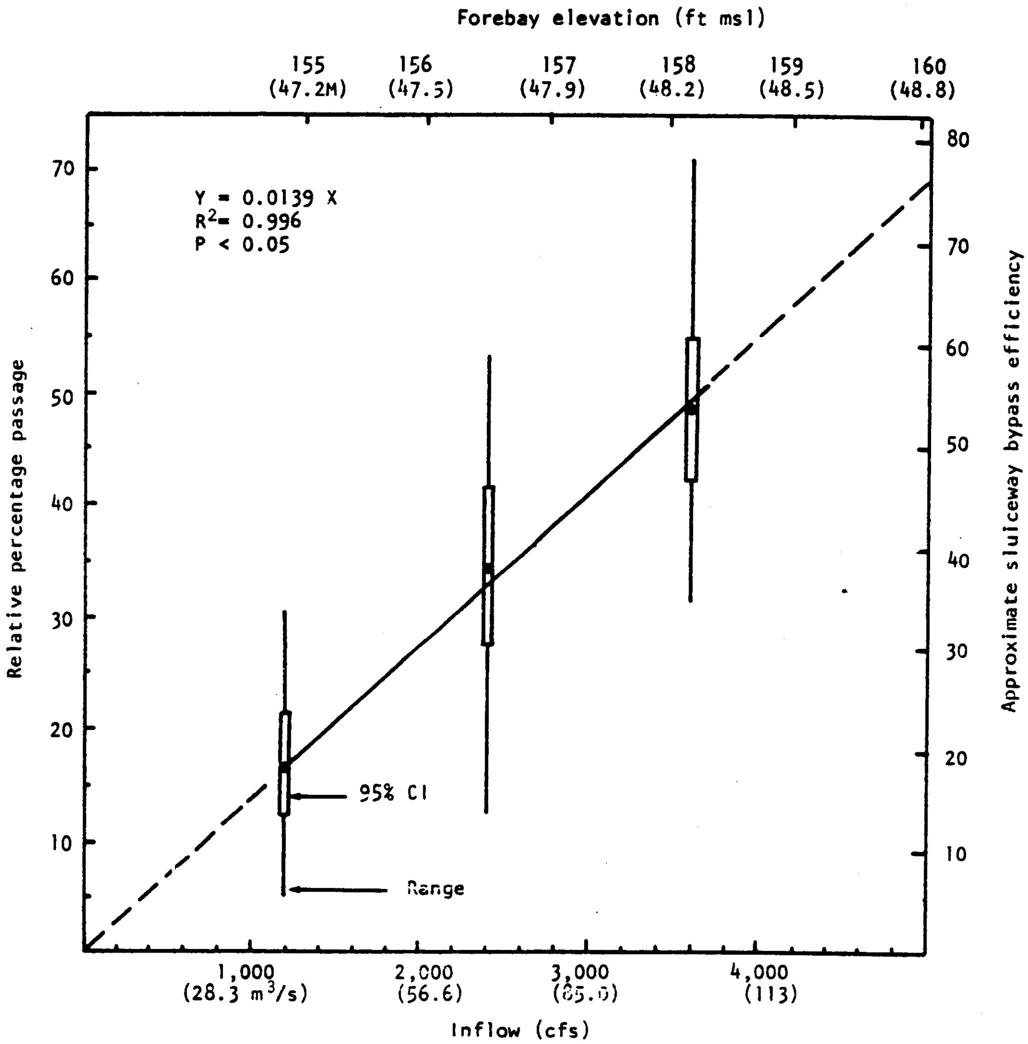

Fig. 12. Relationship of relative percentage passage of juvenile salmonids to sluiceway inflow.

Table 4. Mean percentage of juvenile salmonids passed through the sluiceway at three different inflows tested within 2 h periods.

Group	Mean percentage passage			ANOVA[b]			Multiple range test	
	1,200 cfs[a] (34 m^3/s)	2,400 cfs[a] (68 m^3/s)	3,600 cfs[a] (102 m^3/s)	df within	F	P	Results	P
All species	16.8	34.6	48.7	36	30.50	<0.001	$\bar{x}_{3600} > \bar{x}_{2400} > \bar{x}_{1200}$	<0.01
All yearlings	15.5	34.0	50.5	36	34.55	<0.001	$\bar{x}_{3600} > \bar{x}_{2400} > \bar{x}_{1200}$	<0.01
Steelhead	17.0	36.1	47.0	36	21.37	<0.001	$\bar{x}_{3600} > \bar{x}_{2400} > \bar{x}_{1200}$	<0.01
Yearling chinook	17.8	27.8	54.4	33	20.37	<0.001	$\bar{x}_{3600} > \underline{\bar{x}_{2400} > \bar{x}_{1200}}$[c]	<0.01[d]
Sockeye	9.8	35.9	54.3	33	25.10	<0.001	$\bar{x}_{3600} > \bar{x}_{2400} > \bar{x}_{1200}$	<0.01
Coho[e]	25.2	38.6	36.2	21	0.22	>0.20	--	--
Subyearling[e] chinook	29.7	48.0	22.3	36	4.15	<0.05	$\underline{\bar{x}_{2400} > \bar{x}_{1200}} \underline{> \bar{x}_{3600}}$	<0.01

[a] *1,200 cfs = gate l_2; 2,400 cfs = gates $l_2 l_3$; 3,600 cfs = gates $l_1 l_2 l_3$.*

[b] *Arcsin transformation on percentage passage data.*

[c] *Underscored numbers are not significantly ($P \leq 0.05$) different from each other.*

[d] *For $\bar{x}_{2400} > \bar{x}_{1299}$, $p \simeq 0.06$.*

[e] *Sample sizes small, see appendix Tables B-6 and B-7.*

We feel the magnitude of the bypass efficiency we have projected for a given flow is conservative when compared to indirect estimates of bypass efficiency made in past years (see Objective 3).

This relationship suggests that sluiceway inflow should be maximized during the peak of yearling and subyearling outmigrations (traditionally mid-May and mid-July) to maximize bypass efficiency. Due to the nature of sluiceway hydraulics, maximum inflow can only be achieved by maintaining high forebay levels. An increase in forebay level from 157 to 159 ft msl (47.9 to 48.5m) would increase inflows from 2,800 to 4,200 cfs (99 to 119 m^3/s), respectively (Nichols and Ransom 1981). Figure 14 indicates this would increase relative sluiceway passage by 50%, and increase bypass efficiency from 43% to 65%.

Objective 2A. Determine if the attraction of juvenile salmonids into the sluiceway can be improved with split gate openings.

A two-way analysis of variance showed no significant difference ($p > 0.20$) in fish passage through the sluiceway between adjacent or split gate settings for the following groups: all species combined, all yearlings, four individual yearling species, and subyearling chinook (Table 5). However, a highly significant difference in fish passage between a.m. and p.m. test periods was found ($p < 0.001$). Despite our monitoring of diel passage prior to the test, we apparently divided the day unequally such that an average of 78% of the fish passed during the afternoon period. Regardless, our experiment was designed so that this result did not affect our findings. Estimates of daily fish passage are tabulated by group in Appendix C.

Objective 2B. Determine the flow distribution into the southwest end of the sluiceway which attracts the greatest number of juvenile salmonids.

We compared sluiceway passage with two, three and four gates open while holding total inflow constant at 3000 cfs (85 m^3/s). Percentage passage with each set of gates was then compared with a one-way analysis of variance after an arcsin transformation was applied. Percentage passage through three gates was significantly better ($p < 0.01$) than through two or four gates for all species combined, all yearlings, and steelhead (Table 6). For yearling chinook, the percentage passage through three gates was significantly better than through four gates ($p < 0.025$).

There was no significant difference in passage among the three different settings for sockeye or subyearling chinook, but the numbers passing through the sluiceway (850-4,825 fish daily) were small. With larger samples, we would expect the trend of higher passage through three gates to hold for these groups as well. Estimates of daily fish passage are tabulated by group in Appendix D.

Table 5. Mean daily passage of juvenile salmonids through the sluiceway with adjacent or split gate settings and 3,600 cfs (102 m^3/s) inflow.

	Mean daily passage				ANOVA[a]			
	Adjacent gates[b]		Split gates[c]		Adjac. vs split		AM vs PM	
Group	AM	PM	AM	PM	F	P	F	P
All species	10,369	39,243	12,097	42,791	0.52	>0.20	51.16	<0.001
All yearlings	9,877	38,358	11,717	42,250	0.58	>0.20	50.19	<0.001
Steelhead	2,829	9,270	3,022	12,612	1.55	>0.20	51.45	<0.001
Yearling chinook	4,789	21,363	6,318	23,655	0.54	>0.20	29.31	<0.001
Sockeye	2,230	7,312	2,366	5,715	0.09	>0.20	19.66	<0.001
Coho	30	414	11	269	1.09	>0.20	29.09	<0.001
Subyearling[d] chinook	492	885	381	542	2.11	>0.10	1.33	>0.20

[a] *Square root transformation on data;* $df_{total} = 23$.

[b] *Gates* $1_1 1_2 1_3$ *open.*

[c] *Gates* $1_1 1_2 18_1 18_2$ *open.*

[d] *Variances probably not homogenous.*

Table 6. Percentage daily passage of juvenile salmonids through the sluiceway with 3,000 cfs ($85\ m^3/s$) inflow with two, three or four gates open.

Group	Mean percentage			ANOVA[e]			Multiple range test	
	2 gates[b]	3 gates[c]	4 gates[d]	df_{within}	F	P	Results	p
All species	31.7	39.8	28.5	9	9.85	<0.01	$\bar{x}_3 > \bar{x}_2 > \bar{x}_4$[g]	<0.05
All yearlings	31.7	39.9	28.5	9	9.07	<0.01	$\bar{x}_3 > \bar{x}_2 > \bar{x}_4$	<0.05
Steelhead	30.9	39.7	29.4	9	8.37	<0.01	$\bar{x}_3 > \bar{x}_2 > \bar{x}_4$	<0.05
Yearling chinook	32.5	39.2	28.4	9	6.03	<0.025	$\bar{x}_3 > \bar{x}_2 > \bar{x}_4$	<0.05
Sockeye[f]	30.0	37.3	32.7	9	0.37	>0.20	--	--
Subyearling[f]	30.8	39.9	29.3	9	1.09	>0.20	--	

[a] *No coho were sampled.*

[b] *Gates* $l_1 l_2$ *open.*

[c] *Gates* $l_1 l_2 l_3$ *open.*

[d] *Gates* $l_1 l_2 l_3 2_1$ *open.*

[e] *Arcsin transformation on percentage passage data.*

[f] *Sample sizes were small.*

[g] *Underscored numbers are not significantly* ($P \leq 0.05$) *different from each other.*

Objective 3. Determine the proportion of juvenile salmonids which enter the sluiceway, compared to the total passing The Dalles Dam.

Bypass efficiency, estimated from the change in catches of juvenile salmonids in the gatewells between days when the sluiceway was on and off was estimated to be 23.8% (95% CI ± 49.8%) for yearlings (Table 7). We place low confidence in this estimate since the 95% confidence interval was more than twice the size of our estimate. The poor accuracy of our estimate was due to high variability in our data and to the low number of days available for testing because of extensive spilling in June and July. In addition, we were unable to make the estimate for yearlings until after the majority had migrated during the spring, and thus the estimate may be unrepresentative.

Indirect estimates of bypass efficiency can be made by several methods, principally by comparing estimates of fish passage through the sluiceway with estimates of juvenile passage at John Day Dam. Indirect estimates were 78% in 1978 (Nichols 1979), 85% in 1979 (Nichols 1980), and 67% in 1980 (Nichols and Ransom 1981).

Our comparable indirect estimates of bypass efficiency in 1981 were 68.5% for yearlings and 34.8% for subyearling salmonids. We obtained estimates of daily fish passage at John Day Dam in 1981 (personal communication, Carl Sims, National Marine Fisheries Service, Seattle), and calculated the number which reached The Dalles Dam by assuming that 13% were killed as they passed through the John Day turbines (Raymond and Sims 1980) and that 7% died as they passed through The Dalles pool (approximated from data presented by Raymond 1979) (Table 8). We also assumed that fish passage through spill was proportional to the percentage of the river discharge spilled. We also obtained rough estimates for the number of emigrants exiting the Deschutes River (personal communication, Jeff Ziller, ODFW, Madras). We further assumed that 30% of the emigrants from the Deschutes were lost to mortality or residualism.

The validity of these indirect estimates of bypass efficiency is largely dependent on the accuracy of our estimates of fish passage through the sluiceway. We feel these estimates were highly accurate because we sampled fish passage for 5-7 d/wk for 16 h/d (generally from 6 a.m. to 10 p.m.) when a minimum of 95% of the total daily passage occurred. Additionally, we demonstrated that the sampling efficiency of our fyke net was consistent (see Table 3).

It is important to note that the seasonal estimates of bypass efficiency in this and past years were made when the sluiceway was running for much of the emigration season at less than the optimum adjustment. Various tests were conducted each year which, by design, necessitated operating the sluiceway at lower flows or different sluice-gate settings than we now know to be optimum. Optimum operating conditions throughout the season would have resulted in increased bypass efficiencies.

To determine what factors, other than adjustment of the sluiceway might affect bypass efficiency, we regressed daily bypass efficienices of yearling and subyearling juveniles (based on our indirect estimates) against several variables at The Dalles Dam thought to affect sluiceway passage: spillway discharge (expressed as a percentage of total river flow), turbine discharge, river turbidity, and river temperature. The independent variables were individually regressed untransformed and with exponential, power and logarithmic

Table 7. Bypass efficiency of the sluiceway estimated from changes in the number of juvenile salmonids captured in the gatewells with the sluiceway alternated between on and off.

		Gatewell catch		Proportionate decrease in gatewell catch[a]		Sluiceway efficiency[b]	
Date	Sluiceway operation	Yearlings	Subyearlings	Yearlings	Subyearlings	Yearlings	Subyearlings
June 24	On	36	52				
25	Off	235	99	0.153	0.525	0.847	0.475
29	On	121	103				
30	Off	232	302	0.522	0.341	0.478	0.659
July 01	On	190	336	0.819	1.113	0.181	-0.113
13	On	21	252				
14	Off	86	1,199	0.244	0.210	0.756	0.790
15	On	48	730	0.558	0.609	0.442	0.391
16	Off	169	2,112	0.284	0.346	0.716	0.654
27	On	147	742				
28	Off	111	988	1.324	0.751	-0.324	0.249
29	On	118	1,034	1.063	1.047	-0.063	-0.047
30	Off	49	1,003	2.408	1.031	-1.408	-0.031
31	On	12	840	0.245	0.838	0.744	0.163
Mean						23.8%	31.9%
95% CI						0-73.6%	8.7-55.2%

[a] *Gatewell catch with sluiceway operating divided by gatewell catch with sluiceway off.*
[b] *One minus the proportionate decrease in gatewell catch.*

Table 8. Calculations for the indirect estimate of bypass efficiency for The Dalles Dam sluiceway in 1981.

		Yearlings		Subyearlings
A. Total seasonal estimate to John Day Dam (NMFS)		2,254,121		4,908,277
Minus estimated turbine and reservoir mortality (20%)	- 450,824		- 981,655	
John Day Dam fish arriving at The Dalles Dam		1,803,297		3,926,622
Minus estiamtes during The Dalles Dam sluiceway closure				
1. Prior to April 26	- 67,187		- 61,106	
2. After August 8	0		- 759,584	
3. During efficiency testing (objective 3)	- 11,853		- 679,866	
Minus estimated number passing in spill	- 177,384		- 198,885	
	- 256,425		-1,699,441	
Number of John Day Dam fish available to pass through The Dalles Dam sluiceway		1,546,872		2,227,181
B. Approximate number of Deschutes River juvenile salmonids (wild and hatchery)		905,500		1,200,000
Minus estimates during The Dalles Dam sluiceway closure: 20%	- 181,100		- 240,000	
Minus mortality and residualism: 30%	- 271,650		- 360,000	
	- 452,750		- 600,000	
Approximate number of Deschutes River fish available to pass through The Dalles Dam sluiceway		452,750		600,000
C. Estimate of total number of fish available to pass through The Dalles Dam sluiceway (A+B)		1,999,600		2,827,200
D. Estimated passage through The Dalles Dam sluiceway		1,370,200		983,200
E. Estimated bypass efficiency of The Dalles Dam sluiceway under non-spill conditions (D÷C)		68.5%		34.8%

transformations. No single or multiple regression was statistically significant for either yearlings or subyearlings, virtually all having $R^2 < 0.250$ and $p > 0.50$. These findings should not be viewed as conclusive because of the difficulties in estimating migration times between John Day and The Dalles dams and the periodic influx of juveniles from the Deschutes River.

Objective 4. Calibrate the fish trap and pump sampler and determine the rate at which it injures juvenile salmonids.

We determined the descaling rate and stress mortality of fish sampled with the trap using the fish pump and the airlift. Mean descaling was 4.9% for "wild" juvenile salmonids when the fish pump was used, and 11.0% when the airlift was used (Table 9). However, sample size for the latter was only 10 fish and results should not be viewed as conclusive.

Morality after 24 h was 11.4% when the fish pump was used and 2.3% when the airlift pump was used (Table 10). There was a significant difference in survival between the two methods ($p < 0.025$). Since these tests were conducted late in the season when river temperatures were relatively high (71°F [22°C]), we anticipate that mortality will be even less during the period of peak emigration in the spring when river temperatures are generally 50-60°F (10-15.6°C).

Table 9. Descaling of juvenile salmonids passing through the fish trap sampling apparatus.

	Fish pump				Airlift pump
	July 24	Aug. 13	Aug. 14	Total	Aug. 20-21
Hours operated	2.0	5.0	5.5	12.5	44.0
No. of fish[a] examined	18	22	40	80	10
Range of %[b] descaling	0-15	0-25	0-20	0-25	5-20
Mean %[b] descaling	3.9	4.7	5.5	4.9	11.0
Median %	2.5	2.5	5.0	2.5	10.0

[a] *Virtually all fish were fall chinook.*

[b] *Per fish.*

Table 10. Mortality of yearling coho salmon 24 h after passing through the fish trap sampling apparatus.

	Fish pump	Airlift pump
Date	Aug. 18	Aug. 19
No. of test fish	105	87
No. dead	14	2
Test fish mortality	13.3%	2.3%
No. of control fish	103	82
No. dead	2	0
Control fish mortality	1.9%	0.0
Differential mortality[a]	11.4%	2.3%

[a] *Test mortality less control mortality.*

CONCLUSIONS

1. Over 2.6 million juvenile salmonids passed through the sluiceway between April 26 and August 8, 1981.

2. Yearling passage increased approximately 14% for each 1000 cfs (28 m^3/s) increase in inflow, and the relationship between flow and passage was linear between 1200-3600 cfs (34-102 m^3/s).

3. We found no significant difference in sluiceway passage between split gate or adjacent gate openings for yearlings or subyearlings.

4. For yearlings, sluiceway passage was significantly greater through three adjacent gates rather than through two or four.

5. Sluiceway bypass efficiency was estimated at 23.8% for yearlings and 31.9% for subyearlings from catches in the gatewells on alternate days with the sluiceway on and off. Indirect estimates, based on estimates of fish passing John Day Dam were 68.5% for yearlings and 34.8% for subyearlings.

6. No significant correlation was found between either yearling or subyearling passage through the sluiceway and percentage spill, turbine load, river temperature, or turbidity.

7. With the fish trap, descaling was found to be greater with the airlift than the fish pump, but results were inconclusive since the sample with the airlift pump included only 10 fish. Delayed stress mortality was significantly lower with the airlift than with the fish pump (2.3% vs 11.4%).

RECOMMENDATIONS

1. The sluiceway should be operated with sluice-gates $1_1 1_2 1_3$ fully opened.

2. During periods of peak outmigration, forebay levels should be held as high as possible in order to maximize sluiceway inflow, and thus passage. A minimum forebay level of 159 ft (48.5 m) is recommended for 6 a.m. to 6 p.m. for 2 wk in mid-May and 10 a.m. to 10 p.m. for 2 wk in mid-July, to be adjusted to the time of peak smolt outmigration. For the remainder of the outmigration, the forebay should be held as high as feasible.

3. The airlift alteration to the fish trap-sampler should be further investigated to evaluate sampling efficiency, fish descaling and delayed mortality, preferably near the peak of the smolt outmigration.

4. If the fish trap is to be used for monitoring juvenile salmonid outmigrations, a set of indexing efficiency curves should be developed for independent variables which might affect the proportion of migrants sampled. Such variables could include water spilled, powerhouse loading, river temperature, turbidity, fish size, and fish species.

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APPENDIX A

Common and scientific names of salmonids sampled in the sluiceway at The Dalles Dam.

Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Sockeye salmon	*Oncorhynchus nerka*
Steelhead trout	*Salmo gairdneri*

APPENDIX B

Passage of juvenile salmonids through the sluiceway for three different inflows.

Table B-1. Estimated passage of yearling salmonids through the sluiceway at three different inflows at unit 1.

Date	Time period	Estimated fish passage 1,200 cfs[a] No. (%)	2,400 cfs[a] No. (%)	3,600 cfs[a] No. (%)	Total
5/28	2-4 P	301(23.6)	239(18.8)	733(57.6)	1,273
	4-6 P	340(19.5)	691(39.5)	717(41.0)	1,748
	6-8 P	368(16.2)	987(43.4)	921(40.5)	2,276
	8-10 P	132(3.8)	1,848(53.1)	1,503(43.2)	3,483
5/29	6-8 A	572(19.8)	1,083(37.4)	1,240(42.8)	2,895
	8-10 A	427(16.0)	1,404(52.6)	837(31.4)	2,668
	10 A-noon	569(14.0)	1,326(32.7)	2,163(53.3)	4,058
	noon-2 P	471(9.1)	1,888(36.3)	2,836(54.6)	5,195
	2-4 P	455(19.1)	698(29.3)	1,230(51.6)	2,383
	4-6 P	219(5.0)	1,694(38.5)	2,492(56.6)	4,405
	6-8 P	947(25.1)	821(21.8)	2,004(53.1)	3,772
5/30	6-8 A	162(30.4)	181(34.0)	190(35.6)	533
	8-10 A	240(16.2)	187(12.6)	1,054(71.2)	1,481
Total		5,203	13,047	17,920	36,170
Mean Percentage		16.8%	34.6%	48.6%	

[a] *1,200 cfs = gate 1_2; 2,400 cfs = gates $1_2 1_3$; 3,600 cfs = gates $1_1 1_2 1_3$.*

Table B-2. Estimated passage of yearling salmonids through the sluiceway at three different inflows at unit 1.

Date	Time period	Estimated fish passage 1,200 cfs[a] No. (%)	2,400 cfs[a] No. (%)	3,600 cfs[a] No. (%)	Total period
5/28	2-4 P	284(23.5)	217(18.0)	705(49.9)	1,206
	4-6 P	286(17.8)	607(37.7)	717(41.8)	1,610
	6-8 P	191(10.6)	777(43.0)	837(42.9)	1,805
	8-10 P	76(3.6)	1,015(48.5)	1,002(43.8)	2,093
5/29	6-8 A	521(18.9)	1,057(38.2)	1,182(40.9)	2,760
	8-10 A	427(16.3)	1,357(46.0)	837(34.4)	2,621
	10 A-noon	530(13.4)	1,250(34.3)	2,163(47.8)	3,943
	noon-2 P	451(8.9)	1,787(36.4)	2,836(48.4)	5,074
	2-4 P	442(19.9)	613(31.7)	1,170(46.5)	2,225
	4-6 P	186(4.4)	1,618(38.4)	2,398(49.1)	4,202
	6-8 P	789(22.2)	821(28.7)	1,950(47.8)	3,560
5/30	6-8 A	97(29.0)	129(38.4)	108(34.6)	334
	8-10 A	177(12.9)	145(18.9)	1,054(61.1)	1,376
Total		4,457	11,393	16,959	32,809
Mean Percentage		15.5%	34.0%	50.5%	

[a] *1,200 cfs = gate* 1_2; *2,400 cfs = gates* $1_2 1_3$; *3,600 cfs = gates* $1_1 1_2 1_3$.

Table B-3. Estimated passage of juvenile steelhead through the sluiceway at three different inflows at unit 1.

Date	Time period	Estimated fish passage: 1,200 cfs[a] No. (%)	2,400 cfs[a] No. (%)	3,600 cfs[a] No. (%)	Total
5/28	2-4 P	134(22.8)	87(14.8)	366(62.4)	587
	4-6 P	136(23.2)	251(42.8)	199(34.0)	586
	6-8 P	109(14.0)	420(53.8)	251(32.2)	780
	8-10 P	56(8.1)	326(47.2)	308(44.6)	690
5/29	6-8 A	165(16.8)	413(42.1)	404(41.1)	982
	8-10 A	224(21.0)	562(52.8)	279(26.2)	1,065
	10 A-noon	255(12.8)	834(41.9)	901(45.3)	1,990
	noon-2 P	294(13.1)	708(31.5)	1,245(55.4)	2,247
	2-4 P	147(17.8)	317(38.5)	360(43.7)	824
	4-6 P	88(3.7)	780(32.9)	1,504(63.4)	2,372
	6-8 P	428(25.3)	287(17.0)	975(57.7)	1,690
5/30	6-8 A	97(29.0)	129(38.5)	109(32.5)	335
	8-10 A	88(12.8)	104(15.1)	496(72.1)	688
Total		2,221	5,218	7,397	14,836
Mean Percentage		16.9%	36.1%	47.0%	

[a] *1,200 cfs = gate 1_2; 2,400 cfs = gates $1_2 1_3$; 3,600 cfs = gates $1_1 1_2 1_3$.*

Table B-4. Estimated passage of yearling chinook through the sluiceway at three different inflows at unit 1.

Date	Time period	Estimated fish passage: 1,200 cfs[a] No. (%)	2,400 cfs[a] No. (%)	3,600 cfs[a] No. (%)	Total
5/28	2-4 P	100(27.2)	43(11.7)	225(61.1)	368
	4-6 P	82(18.3)	126(28.2)	239(53.5)	447
	6-8 P	14(4.8)	84(28.7)	195(66.6)	293
	8-10 P	19(6.0)	145(45.6)	154(48.4)	318
5/29	6-8 A	153(18.8)	284(35.0)	375(46.2)	812
	8-10 A	122(14.2)	398(46.2)	341(39.6)	861
	10 A-noon	177(15.7)	227(20.2)	721(64.1)	1,125
	noon-2 P	98(7.5)	371(28.6)	830(63.9)	1,299
	2-4 P	67(14.5)	64(13.9)	330(71.6)	461
	4-6 P	33(6.4)	247(48.0)	235(45.6)	515
	6-8 P	293(60.7)	82(17.0)	108(22.4)	483
5/30	8-10 A	76(19.1)	42(10.6)	279(70.3)	397
Total		1,234	2,113	4,032	7,379
Mean Percentage		17.8%	27.8%	54.4%	

[a] *1,200 cfs = gate 1_2; 2,400 cfs = gates $1_2 1_3$; 3,600 cfs = gates $1_1 1_2 1_3$.*

Table B-5. Estimated passage of juvenile sockeye through the sluiceway at three different inflows at unit 1.

Date	Time period	Estimated fish passage 1,200 cfs[a] No. (%)	2,400 cfs[a] No. (%)	3,600 cfs[a] No. (%)	Total
5/28	2-4 P	17(9.0)	87(46.0)	85(45.0)	189
	4-6 P	41(11.2)	126(34.4)	199(54.4)	366
	6-8 P	55(7.6)	273(38.0)	391(54.4)	719
	8-10 P	0(0)	471(50.4)	463(49.6)	934
5/29	6-8 A	203(21.0)	361(37.3)	404(41.7)	968
	8-10 A	81(11.6)	398(57.2)	217(31.2)	696
	10 A-noon	98(12.4)	152(19.2)	541(68.4)	791
	noon-2 P	59(3.9)	708(46.3)	761(49.8)	1,528
	2-4 P	201(30.4)	190(28.7)	270(40.8)	661
	4-6 P	22(2.1)	419(39.8)	611(58.1)	1,052
	6-8 P	45(4.0)	370(33.1)	704(62.9)	1,119
5/30	8-10 A	13(4.5)	0(0)	279(95.5)	292
Total		835	3,555	4,925	9,315
Mean Percentage		9.8%	35.9%	54.3%	

[a] *1,200 cfs = gate* 1_2; *2,400 cfs = gates* $1_2 1_3$; *3,600 cfs = gates* $1_1 1_2 1_3$.

Table B-6. Estimated passage of juvenile coho through the sluiceway at three different inflows at unit 1.

Date	Time period	Estimated fish passage 1,200 cfs[a] No. (%)	2,400 cfs[a] No. (%)	3,600 cfs[a] No. (%)	Total
5/28	2-4 P	33(54.1)	0(0)	28(45.9)	61
	4-6 P	27(12.7)	105(49.5)	80(37.7)	212
	6-8 P	14(100.0)	0(0)	0(0)	14
	8-10 P	0(0)	72(48.3)	77(51.7)	149
5/29	10 A-noon	0(0)	38(100.0)	0(0)	38
	2-4 P	27(9.7)	42(15.1)	210(75.3)	279
	4-6 P	44(16.8)	171(65.3)	47(17.9)	262
	6-8 P	23(8.6)	82(30.7)	162(60.7)	267
Total		168	510	604	1,282
Mean Percentage		25.2%	38.6%	36.2%	

[a] *1,200 cfs = gate 1_2; 2,400 cfs = gates $1_2 1_3$; 3,600 cfs = gates $1_1 1_2 1_3$.*

Table B-7. Estimated passage of subyearling chinook through the sluiceway at three different inflows at unit 1.

Date	Time period	Estimated fish passage 1,200 cfs[a] No. (%)	2,400 cfs[a] No. (%)	3,600 cfs[a] No. (%)	Total
5/28	2-4 P	17(25.4)	22(32.8)	28(41.8)	67
	4-6 P	54(39.1)	84(60.9)	0(0)	138
	6-8 P	177(37.6)	210(44.6)	84(17.8)	471
	8-10 P	56(4.0)	833(59.9)	501(36.0)	1,390
5/29	6-8 A	51(37.8)	26(19.3)	58(43.0)	135
	8-10 A	0(0)	47(100.0)	0(0)	47
	10 A-noon	39(33.9)	76(66.1)	0(0)	115
	noon-2 P	20(16.5)	101(83.5)	0(0)	121
	2-4 P	13(8.2)	85(53.8)	60(38.0)	158
	4-6 P	33(16.3)	76(37.4)	94(46.3)	203
	6-8 P	158(74.5)	0(0)	54(25.5)	212
5/30	6-8 A	65(32.7)	52(26.1)	82(41.2)	199
	8-10 A	63(60.0)	42(40.0)	0(0)	105
Total		746	1,654	961	3,361
Mean Percentage		29.7%	48.0%	22.3%	

[a] 1,200 cfs = gate 1_2; 2,400 cfs = gates $1_2 1_3$; 3,600 cfs = gates $1_1 1_2 1_3$.

APPENDIX C

Daily passage of juvenile salmonids through the sluiceway for adjacent and split sluice-gate openings.

Table C-1. Estimated passage of all juvenile salmonids through the sluiceway with adjacent and split sluice-gate openings.

	Estimated fish passage				
	Adjacent gates[a]		Split gates[b]		Daily
Date	AM	PM	AM	PM	total
May 11	7,874			36,887	44,761
12		39,549	15,070		54,619
13	21,875			64,956	86,831
14		62,955	17,495		80,450
15	11,402			53,381	64,783
16		46,672	18,158		64,830
18	3,925			31,951	35,876
19		41,711	9,697		51,408
20	6,820			43,414	50,234
21		29,499	6,195		35,694
22	10,319			26,159	36,478
26		15,072	5,968		21,040
Total	62,215	235,458	72,583	256,748	627,004

2-way analysis of variance[c]

Source of variation	Degrees of freedom	Mean square	F	P
Adjacent vs split	1	562.80	0.52	> 0.20
AM vs PM	1	55,771.26	51.16	< 0.001
Error	21	1,090.12	--	--

[a] *Gates* $1_1 1_2 1_3$ *open.*

[b] *Gates* $1_1 1_2 18_1 18_2$ *open.*

[c] *Square root transformation applied to passage estimates.*

Table C-2. Estimated passage of yearling salmonids through the sluiceway with adjacent and split sluice-gate openings.

Date	Estimated fish passage: Adjacent gates[a] AM	Adjacent gates[a] PM	Split gates[b] AM	Split gates[b] PM	Daily total
May 11	7,511			36,887	44,398
12		39,387	14,826		54,213
13	21,565			64,192	85,757
14		61,126	17,215		78,341
15	10,782			53,077	63,859
16		45,984	18,091		64,075
18	3,496			31,005	34,501
19		40,216	9,229		49,445
20	6,236			42,721	48,957
21		29,183	5,788		34,971
22	9,675			25,615	35,290
26		14,252	5,151		19,403
Total	59,265	230,148	70,300	253,497	613,210

2-way analysis of variance[c]

Source of variation	Degrees of freedom	Mean square	F	P
Adjacent vs split	1	654.59	0.58	> 0.20
AM vs PM	1	56,486.99	50.19	< 0.001
Error	21	1,125.35	--	--

[a] *Gates* $1_1 1_2 1_3$ *open.*

[b] *Gates* $1_1 1_2 18_1 18_2$ *open.*

[c] *Square root transformation applied to passage estimates.*

Table C-3. Estimated passage of juvenile steelhead through the sluiceway with adjacent and split sluice-gate openings.

	Estimated fish passage				
	Adjacent gates[a]		Split gates[b]		Daily
Date	AM	PM	AM	PM	total
May 11	1,609			9,062	10,671
12		12,270	4,613		16,883
13	6,719			21,319	28,038
14		11,093	4,209		15,302
15	2,123			9,384	11,507
16		7,413	2,745		10,158
18	1,464			7,217	8,681
19		8,914	2,672		11,586
20	1,947			19,049	20,996
21		10,194	2,262		12,456
22	3,111			9,639	12,750
26		5,734	1,631		7,365
Total	16,973	55,618	18,132	75,670	166,393

2-way analysis of variance[c]

Source of variation	Degrees of freedom	Mean square	F	P
Adjacent vs split	1	454.84	1.55	>0.20
AM vs PM	1	15,069.08	51.45	<0.001
Error	21	292.90	--	--

[a] *Gates* $1_1 1_2 1_3$ *open.*

[b] *Gates* $1_1 1_2 18_1 18_2$ *open.*

[c] *Square root transformation applied to passage estimates.*

Table C-4. Estimated passage of yearling chinook through the sluiceway with adjacent and split sluice-gate openings.

	Estimated fish passage				
	Adjacent gates[a]		Split gates[b]		Daily
Date	AM	PM	AM	PM	total
May 11	4,892			24,104	28,996
12		23,575	9,069		32,644
13	10,663			38,001	48,664
14		43,511	8,907		52,418
15	6,233			34,278	40,511
16		26,139	12,335		38,474
18	1,465			17,726	19,191
19		17,918	3,079		20,997
20	2,598			16,137	18,735
21		12,292	2,726		15,018
22	2,885			11,684	14,569
26		4,742	1,792		6,534
Total	28,736	128,177	37,908	141,930	336,751

2-way analysis of variance[c]

Source of variation	Degrees of freedom	Mean square	F	P
Adjacent vs Split	1	618.03	0.54	>0.20
AM vs PM	1	33,388.72	29.31	<0.001
Error	21	1,139.21	--	--

[a] *Gates* $1_1 1_2 1_3$ *open.*

[b] *Gates* $1_1 1_2 18_1 18_2$ *open.*

[c] *Square root transformation applied to passage estimates.*

Table C-5. Estimated passage of juvenile sockeye through the sluiceway with adjacent and split sluice-gate openings.

	Estimated fish passage				
	Adjacent gates[a]		Split gates[b]		Daily
Date	AM	PM	AM	PM	total
May 11	1,010			3,283	4,293
12		2,833	1,144		3,977
13	4,184			4,472	8,656
14		6,400	4,099		10,499
15	2,427			9,416	11,843
16		12,273	3,011		15,284
18	566			5,893	6,459
19		12,711	3,478		16,189
20	1,602			7,195	8,797
21		6,644	737		7,381
22	3,589			4,028	7,617
26		3,009	1,727		4,736
Total	13,378	43,870	14,196	34,287	105,731

2-way analysis of variance[c]

Source of variation	Degrees of freedom	Mean square	F	P
Adjacent vs Split	1	27.93	0.90	>0.20
AM vs PM	1	6,001.16	19.66	<0.001
Error	21	305.23	--	--

[a] *Gates $1_1 1_2 1_3$ open.*

[b] *Gates $1_1 1_2 18_1 18_2$ open.*

[c] *Square root transformation applied to passage estimates.*

Table C-6. Estimated passage of juvenile coho through the sluiceway with adjacent and split sluice-gate openings.

Date	Estimated fish passage: Adjacent gates[a] AM	Adjacent gates[a] PM	Split gates[b] AM	Split gates[b] PM	Daily total
May 11	0			439	439
12		709	0		709
13	0			399	399
14		123	0		123
15	0			0	0
16		159	0		159
18	0			170	170
19		673	0		673
20	89			341	430
21		53	63		116
22	90			264	354
26		766	0		766
Total	179	2,483	63	1,613	4,338

2-way analysis of variance[c]

Source of variation	Degrees of freedom	Mean square	F	P
Adjacent vs Split	1	46.90	1.09	>0.20
AM vs PM	1	1,247.47	29.09	<0.001
Error	21	42.89	--	--

[a] *Gates $1_1 1_2 1_3$ open.*

[b] *Gates $1_1 1_2 18_1 18_2$ open.*

[c] *Square root transformation applied to passage estimates.*

Table C-7. Estimated passage of subyearling chinook through the sluiceway with adjacent and split sluice-gate openings.

	Estimated fish passage				
	Adjacent gates[a]		Split gates[b]		Daily
Date	AM	PM	AM	PM	total
May 11	363			0	363
12		161	244		405
13	309			764	1,073
14		1,829	280		2,109
15	619			303	922
16		688	67		755
18	429			946	1,375
19		1,495	469		1,964
20	585			694	1,279
21		316	407		723
22	643			543	1,186
26		820	817		1,637
Total	2,948	5,309	2,284	3,250	13,791

2-way analysis of variance[c]

Source of variation	Degrees of freedom	Mean square	F	P
Adjacent vs Split	1	161.05	2.11	>0.10
AM vs PM	1	102.05	1.33	<0.20
Error	21	76.43	--	

a Gates $1_1 1_2 1_3$ open.

b Gates $1_1 1_2 18_1 18_2$ open.

c Square root transformation applied to passage estimates.

APPENDIX D

Daily passage of juvenile salmonids through the sluiceway for inflow through two, three, and four gates.

Table D-1. Estimated passage of all juvenile salmonids through the sluiceway with two, three and four open sluice-gates with 3,000 cfs (85 m^3/s) inflow.

Date	Estimated fish passage Number of gates open[a] 2 No. (%)	3 No. (%)	4 No. (%)	Total
May 5	11,136(33.6)	12,581(37.9)	9,464(28.5)	33,181
6	15,436(34.7)	18,454(41.5)	10,616(23.9)	44,506
7	20,952(39.1)	19,080(35.6)	13,581(25.3)	53,613
8	19,502(26.0)	31,368(41.9)	23,995(32.1)	74,864
Total	67,025(33.3)	81,483(39.2)	57,656(27.5)	206,164

[a] 2 gates = $1_1 1_2$;

3 gates = $1_1 1_2 1_3$;

4 gates = $1_1 1_2 1_3 2_1$.

Table D-2. Estimated passage of all yearling salmonids throught he sluiceway with two, three, and four open sluice-gates with 3,000 cfs (85 m^3/s) inflow.

	Estimated fish passage Number of gates open[a]			
	2	3	4	
Date	No. (%)	No. (%)	No. (%)	Total
May 5	10,971(33.8)	12,328(38.2)	9,032(28.0)	32,331
6	15,186(33.5)	17,653(42.4)	10,496(24.1)	43,335
7	20,455(33.9)	39,140(35.1)	13,470(30.9)	73,065
8	18,786(25.4)	30,472(43.8)	23,350(30.9)	72,608
Total	65,398(31.7)	99,593(39.9)	56,348(28.5)	221,339

a

2 gates = $1_1 1_2$;

3 gates = $1_1 1_2 1_3$;

4 gates = $1_1 1_2 1_3 2_1$.

Table D-3. Estimated passage of juvenile steelhead through the sluiceway with two, three, and four open sluice-gates with 3,000 cfs (85 m^3/s) inflow.

Date	Estimated fish passage Number of gates open[a] 2 No. (%)	 3 No. (%)	 4 No. (%)	Total
May 5	3,923(37.1)	3,741(35.4)	2,912(27.5)	10,576
6	4,657(33.9)	5,920(43.1)	3,174(23.1)	13,751
7	4,977(34.7)	5,386(37.5)	3,986(27.8)	14,349
8	5,236(26.6)	7,245(36.9)	7,177(36.5)	19,658
Total	18,793(33.1)	22,292(38.2)	17,249(28.7)	58,334

a

2 gates = $1_1 1_2$;

3 gates = $1_1 1_2 1_3$;

4 gates = $1_1 1_2 1_3 2_1$.

Table D-4. Estimated passage of yearling chinook through the sluiceway with two, three, and four open sluice-gates with 3,00 cfs (85 m^3/s) inflow.

Date	Estimated fish passage Number of gates open[a] 2 No. (%)	3 No. (%)	4 No. (%)	Total
May 5	6,520(31.3)	8,420(40.5)	5,871(28.2)	20,811
6	10,106(35.9)	11,139(39.6)	6,908(24.5)	28,153
7	14,299(40.5)	12,348(35.0)	8,672(24.6)	35,319
8	12,490(26.0)	21,043(43.7)	14,592(30.3)	48,125
Total	43,415(33.4)	52,950(39.7)	36,043(26.9)	132,408

[a] *2 gates* = $1_1 1_2$;

3 gates = $1_1 1_2 1_3$;

4 gates = $1_1 1_2 1_3 2_1$.

Table D-5. Estimated passage of juvenile sockeye through the sluiceway with two, three, and four open sluice-gates with 3,000 cfs (85 m^3/s) inflow.

Date	Estimated fish passage, Number of gates open[a]: 2 No. (%)	3 No. (%)	4 No. (%)	Total
May 5	528(55.9)	167(17.7)	249(26.4)	944
6	423(29.6)	594(41.5)	414(28.9)	1,431
7	1,179(40.1)	951(32.3)	812(27.6)	2,942
8	1,060(22.0)	2,184(45.3)	1,581(32.8)	4,825
Total	3,190(36.9)	3,896(34.2)	3,056(28.9)	10,142

a

2 gates = $1_1 1_2$;

3 gates = $1_1 1_2 1_3$;

4 gates = $1_1 1_2 1_3 2_1$.

Table D-6. Estimated passage of subyearling chinook through the sluiceway with two, three and four open sluice-gates with 3,000 cfs (85 m^3/s) inflow.

	Estimated fish passage Number of gates open[a]			
	2	3	4	
Date	No. (%)	No. (%)	No. (%)	Total
May 5	165(19.4)	253(29.8)	432(50.8)	850
6	249(21.3)	800(68.4)	120(10.3)	1,169
7	497(49.6)	395(39.4)	111(11.1)	1,003
8	715(31.7)	896(39.7)	645(28.6)	2,256
Total	1,626(30.5)	2,344(44.3)	1,308(25.2)	5,278

a

2 gates = $1_1 1_2$;

3 gates = $1_1 1_2 1_3$;

4 gates = $1_1 1_2 1_3 2_1$.

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