Evaluation of a Bypass System for Juvenile Salmonids at Little Goose Dam

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Introduction

Major dams on the Columbia and Snake Rivers incorporate fish bypass systems to protect fingerling salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri*, during their downstream migration (Bentley and Raymond, 1969; Park and Farr, 1972; Smith and Farr, 1975; Matthews et al., 1977). These systems employ submerged orifices to provide fish with egress from Turbine gatewells where fish either accumulate naturally or are diverted by fish screens in the turbine intakes. The National Marine Fisheries Service, under contract to the U.S. Army Corps of Engineers, has been conducting research on fingerling bypass systems for several years in an attempt to improve efficiency.

In the existing system at Little Goose Dam on the Snake River (Fig. 1), the majority of fingerlings entering the turbine intakes are diverted into gatewell slots by traveling screens. A vertical barrier screen further confines fingerlings to the bulkhead slots of the gatewells (Smith and Farr, 1975). Single 6-inch diameter submerged orifices in the north corner of the upstream walls of each bulkhead slot provide egress from the gatewells but are incapable of adequately passing large numbers of fingerlings from the slots in a timely manner.

In 1978, changes in the generating capacity of Little Goose Dam compounded the inadequacies of the fingerling bypass system From 1971 to 1977, only three generating units were in operation, but in 1978 three more

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ABSTRACT—During the spring of 1978, the National Marine Fisheries Service, under contract to the U.S. Army Corps of Engineers, evaluated a new system for bypassing juvenile chinook salmon, Oncorhynchus tshawytscha, *and steelhead trout,* Salmo gairdneri, *from turbine intakes at Little Goose Dam on the Snake River. The criteria pertaining to orifice size (8-, 10-, or 12-inch diameter); placement (north, south, or both); and lighting (on or off) were examined. Recommendations included: 1) 8- or 10-inch diameter inserts to reduce orifice size (and conserve water) when bypassing chinook salmon and 2) 12-inch diameter lighted orifices in the north and south ends of the upstream walls of the bulkhead slots when bypassing steelhead trout.*

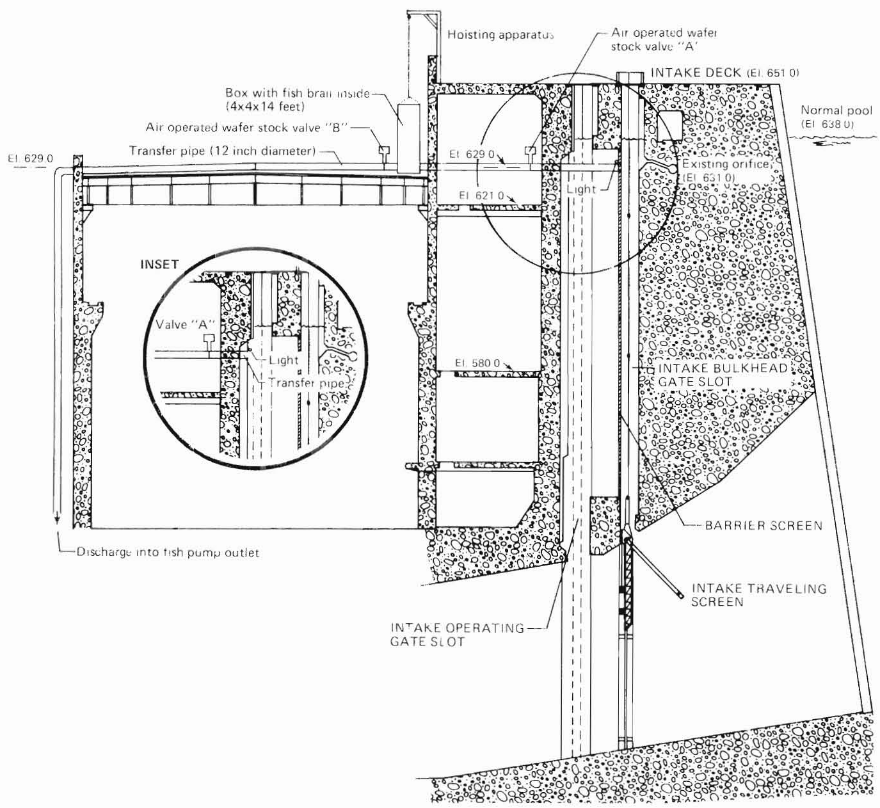

Figure 1.—Experimental orifices and trapping facility as operated in the intake bulkhead gate slot and operating gate slot (see inset) at Little Goose Dam.

units were added. With three additional units in operation, orifice attraction velocities within the bypass system were substantially reduced, resulting in large accumulations of fingerlings in the gatewells. Compounding the problem, excess water (spilled when only three units were operational) is now used for the generation of power through the three additional generating units. Consequently, this makes even more fish available for diversion into gatewells by traveling screens, resulting in an even larger accumulation of fingerlings.

A more recently constructed bypass system at Lower Granite Dam on the Snake River has two 8-inch diameter submerged orifices in each corner of the upstream walls of the bulkhead slot (Matthews et al., 1977). This bypass system passes fish with a high degree of efficiency. Moreover, descaling and injury to fingerlings are less than half of that observed at Little Goose Dam. Consequently, we feel that the bypass system at Little Goose Dam can be improved to pass fish as effectively as the system at Lower Granite Dam.

The purpose of this study is to evaluate criteria for a new bypass system to be installed at Little Goose Dam. Specifically, we evaluated orifice diameter, lighting, and placement in turbine intake gate slots. We conducted tests from 8 April through 3 May 1978, using naturally migrating chinook salmon and steelhead smolts.

Methods and Materials

Figure 1 illustrates the experimental orifices and trapping facility. An improved traveling screen (Matthews et al., 1977) was installed in the turbine intake to guide downstream migrating fingerlings into the test gatewell (1-A). Special efforts were made to maintain standard operating conditions within the turbine; i.e., a uniform turbine generating load of 155 megawatts was maintained, and the traveling screen was operating while all tests were in progress.

Existing orifices were blocked off and the submerged orifices to be tested were located in fingerling transfer pipes near each corner on the downstream wall of the gatewell at an elevation of 629 feet (all elevations are designated as feet above mean sea level). The two 12-inch diameter fingerling transfer pipes were capable of holding 8- or 10-inch diameter orifice inserts at their gatewell entrances. Thus, three orifice pipe sizes were available for testing. Illumination for the orifices was provided by 75-watt swimming pool lights.

Fish were collected at trap-hoppers located outside the powerhouse roof. A fish brail in the traps allowed hoisting of fingerlings to the intake deck for inspection and enumeration. Excess water was eliminated at the holding boxes and carried to the tailrace level by pipe.

Water flow in the trap-hoppers was regulated by two air operated wafer valves (Fig. 1). Water levels in the trap-hoppers were maintained 2 feet lower than the water level in the gatewell. This provided a stable velocity of 12 fps from the orifice entrances through the transfer pipes into the traps. During testing, valve A was operated wide open but was closed for approximately 5 minutes every 2 hours to restrict egress of fish from the gatewell to the traps while fish were brailed to the intake deck. Valve B was adjusted to remove excess water from the traps while maintaining a 2-foot head differential between the gatewell and the traps.

Smolts used in this study were obtained by dipping bulkhead slots other than slot 1-A with a gatewell dip basket (Swan et al., 1979). The fish were transferred to a marking facility where they were anesthetized, marked, and held in stock tanks for 4 hours before being released into the test slot. Chinook salmon were marked by excising a portion of their pectoral or pelvic fins. Steelhead trout were tattooed with colored pigment.

The first test series involved passing fish with the transfer pipes from the bulkhead slot (Fig. 1). The following tests were made using approximately 200 chinook salmon and 200 steelhead trout (three replicates per test): 1) 8-inch diameter north and south orifices operated with lights, 2) 10-inch diameter north and south orifices operated with lights, 3) 10-inch diameter north and south orifices operated without lights, 4) 10-inch diameter north orifice operated with lights, and 5) 12-inch diameter south orifice operated with lights.

To begin a test the bulkhead slot was dipped clean of fish at 1530 hours, and marked fish were introduced via a hose into the center of the bulkhead slot at the 20-foot depth at 1600 hours. During the 24-hour test period each trap was emptied every 2 hours to count marked and naturally entering migrants. Since the vertical barrier screen was intact during these tests, all fish were removed from the bulkhead slot with the gatewell dip basket after each test replicate.

To evaluate the passage efficiency of the orifices, marked fish from the traps plus those marked fish that were recovered in the gatewell at the end of a test were assumed to be the total number of fish available for passage. The pasage efficiency was determined by dividing the number of marked fish removed from the orifice traps by the total number of marked fish available for passage.

Recovery of marked fish was also compared with the recovery of naturally entering (unmarked) migrants. The passage efficiencies of the orifices for the naturally entering fish were calculated in the same manner as used for marked fish.

The second test series involved passing smolts from the operating gate slot when the upper two panels of the vertical barrier screen between the bulkhead and operating slots were removed (Figure 1 inset). The associated transfer pipes were also removed. This test was conducted to determine if fish would voluntarily swim from the bulkhead slot to orifices in the downstream wall of the operating gate slot. The bulkhead slot was darkened during these tests.

Since a portion of the barrier screen was removed, gatewells were not dipped because the operating gate slot was not accessible; therefore, movement of unmarked fish could not be measured. Passage efficiencies were determined by dividing the number of marked fish recovered in the traps by the number introduced. Marked fish data were used to compare results of bulkhead and operating gate slot tests. The same series of tests were scheduled for the operating gate slots that were used for bulkhead slot tests.

On 19 May 1978, directional current readings were made in the three intake bulkhead slots (1-A, 1-B, 1-C) of unit one with a Sevonious-type[1] directional current meter. Readings were taken at an elevation of 629 feet, which corresponds to the depth of the submerged test orifices. Three measurements were made in each slot while the turbine was operated in the standard operating mode. During the measurements the orifices were closed, and measurements were taken near the entrances to the orifices. These measurements were taken to compare water flow characteristics in the A, B, and C slots to determine if current directions at the orifice level might have an effect on fish movement to either side of the gate slot or on fish passage through the orifices.

Results and Discussion

The authors have made no attempt to prejudge an acceptable passage rate for an orifice system. However, during the peak of the downstream migration, over 10,000 fingerlings have been removed from a single gatewell after a 24-hour accumulation. It would appear that a fish passage rate of at least 75 percent of the 24-hour accumulation is necessary if large accumulations of juveniles are to be avoided in gatewells.

Fish Passage Through Orifices Placed in Bulkhead Slot

The results of our tests are summarized in Table 1. The data do not provide clear evidence for an optimum orifice passage arrangement. Some general observations can be made however, that may lead to an optimum arrangement: 1) Two orifices provided the most satisfactory passage efficiencies; 2) lighted orifices definitely increased passage rates for chinook salmon but appeared to be of little value for steelhead trout; 3) both species preferred the north orifice when offered a choice for passage; and 4) relatively high passage rates, from 59 to 63 percent, were achieved for chinook salmon with a single 12-inch diameter orifice (passage rates for steelhead trout through the single 12-inch diameter orifice were lower—23-25 percent).

Throughout the tests steelhead trout showed lower passage rates than did chinook salmon. We speculate that smoltification of chinook salmon may have been more advanced during the test period than of steelhead trout (i.e., tests were run near the peak of the chinook salmon migration, whereas testing was completed prior to the migration peak of steelhead trout). This could account for greater chinook salmon movement through orifices and a subsequently higher recovery rate.

Similar orifice testing conducted at Lower Granite Dam in 1976 showed passage rates for the north orifice to be superior to the south orifice and that in all cases lighted orifices were best[2]. The study showed that the passage efficiency of a single 8-inch diameter lighted north orifice was as efficient as two 6-inch diameter lighted orifices. Studies completed at Bonneville Dam indicated that the passage efficiency for two 8-inch diameter lighted orifices was nearly as good as two 12-inch diameter lighted orifices[3].

Our study indicates that satisfactory passage rates are realized with 8- or 10-inch diameter orifices for chinook salmon, whereas 12-inch diameter orifices would be better for adequate

Table 1.—Passage rate of test (marked) and naturally entering chinook salmon and steelhead through various combinations of 8-, 10-, or 12-inch diameter orifices installed in the downstream side of the bulkhead slot (1-A) at Little Goose Dam.

Species and test condition	Combined number of marked fish released[1]	Passage rate[2] for marked fish (%)			Passage rate[2] for natually entering fish (%)		
		North orifice	South orifice	Both orifices	North orifice	South orifice	Both orifices
Chinook salmon							
North and south 8-inch diameter orifices, lighted	509	39	27	66	61	12	73
North and south 10-inch diameter orifices, lighted	[3]826	37	37	74	47	25	72
North and south 10-inch diameter orifices, dark	626	29	25	54	27	13	40
North 10-inch diameter orifice, lighted	596	38	—	—	62	—	—
South 12-inch diameter orifice, lighted	622	—	59	—	—	63	—
Steelhead							
North and south 8-inch diameter orifices, lighted	575	24	17	41	31	10	41
North and south 10-inch diameter orifices, lighted	[3]694	35	12	46	38	18	56
North and south 10-inch diameter orifices, dark	595	30	16	46	28	23	51
North 10-inch diameter orifice, lighted	471	26	—	—	29	—	—
South 12-inch diameter orifice, lighted	534	—	25	—	—	23	—

[1]Three replicates.
[2]Passage rate equals number of recoveries divided by number released.
[3]Four replicates were used. The turbine was shut down during one test for 2 hours. However, it did not appear to affect recovery rate; therefore, the data were used.

[1]Mention of trade names or commercial products or firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[2]George A. Swan, National Marine Fisheries Service, Big Pasco Industrial Park, Bldg. 900, Pasco, WA 98301, personal commun.

[3]Long, C. W., R. F. Krcma, and T. E. Ruehle. 1977. Development of a system for protecting juvenile salmonids at the second powerhouse at Bonneville Dam. Progress 1976. Final Report of Research to U.S. Army Corps of Engineers, Contract DACW57-76-F-0512. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, Wash. Processed Rep., 15 p.

steelhead trout passage. Because the chinook salmon migration normally precedes the steelhead trout migration at Little Goose Dam, the smaller inserts could be used during the chinook salmon run, and orifice size could be enlarged by the removal of these inserts during the steelhead trout movement. This scheme would allow the conservation of water (i.e., much less water would pass through the 8-inch diameter orifices than through the 12-inch diameter orifices) while maintaining an adequate fish passage rate during the entire salmon and steelhead outmigration. In actual practice, orifices should be drilled through the upstream wall, rather than using the downstream wall as in our test situation.

Fish Passage Through Orifices Placed in Operating Gate Slot

We planned to complete the same experimental design in the operating gate slot that we used for the bulkhead slot, but the tests were terminated after completing the replicated tests with 8-inch diameter north and south lighted orifices. The passage rate through the orifices was only 1 percent for chinook salmon and 4 percent for steelhead trout. It was apparent that the removal of the upper two panels of the barrier screen to allow fingerlings access to the orifices placed in the downstream wall (Figure 1 inset) created an escape route back to the turbine intake. When we dipped the bulkhead slot following the tests, no fish were recovered and very few naturally entering migrants were detected.

Directional Currents in Bulkhead Slot

We have shown that in all the tests where a choice of north or south orifices were offered, both chinook salmon and steelhead trout preferred the north orifice. Our only clue to a reason for this preference was indicated by surface currents observed in the gatewells.

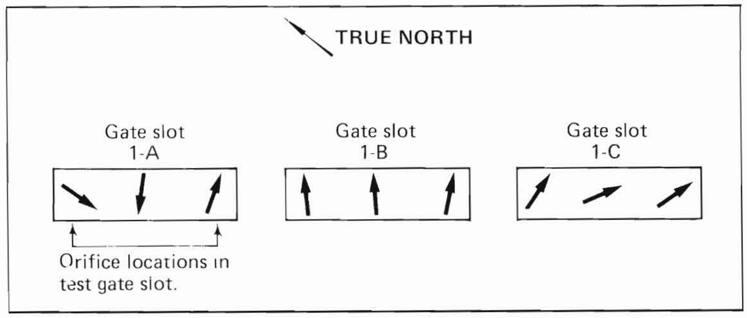

Figure 2.—Directional current readings taken at elevation 629 feet (orifice level) in the intake bulkhead gate slots of unit one at Little Goose Dam.

In the test gatewell (Fig. 2, 1-A), the current at the orifice level was oriented toward the north orifice and away from the south orifice. By contrast, the currents were oriented away from similar orifice locations in gatewells 1-B and 1-C (Fig. 2). If currents are a factor in the selection of the north orifice in 1-A, then a more equal distribution of fish to both orifices could be expected in 1-B and 1-C. However, if the orifices are placed in the upstream wall of the gate slot in a future installation, then most fish may be expected to use the south orifice in the test gatewell (1-A). This rationale presents a strong argument for a placement of two orifices per gatewell for any future orifice system.

Conclusions

Construction of an orifice system in the operating gate slots is not practical. To gain access to the orifices, the upper two panels of the vertical barrier screen must be removed and this creates an escape route for fish back to the turbine intakes.

Current directions may have an effect on fish movement through orifices in gatewells. Because current directions vary in different gatewells, two orifices should be used to realize satisfactory passage.

Lighted orifices increase passage rates for chinook salmon but appear to have little effect on passing steelhead trout.

A complete orifice system at Little Goose Dam requires north and south 12-inch diameter lighted orifices in the downstream walls of the bulkhead slots.

To conserve water while maintaining adequate fish passage, 8- or 10-inch diameter inserts can be used during the chinook salmon migration whereas the 12-inch diameter orifices should be used during steelhead trout movement.

Literature Cited

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