STUDIES TO IMPROVE FISH GUIDING EFFICIENCY OF TRAVELING SCREENS AT LOWER GRANITE DAM

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INTRODUCTION

Migrating salmon and steelhead may travel several hundred miles to and from the ocean in the rivers of the western United States to complete their life cycles. Numerous dams, power plants, and reservoirs located along their routes have caused significant losses of fish. To reduce the losses of juvenile salmonids passing through the power generating turbines, the fish must be screened from the turbine intakes. The most effective method of achieving this has been to employ submersible traveling screens (STS) to guide fish out of the turbine intakes into the gateslots (Figure 1). From the gateslot fish are passed through orifices into a bypass that carries them around the dam into raceways where they can be either released below the dam or transported by barge or truck to safe release areas downstream.

Lower Granite and Little Goose Dams are the upstream collection sites for smolts to be transported from the Snake River. Optimizing collection at these dams is vital to the success of the transportation program.

Indirect estimates of the fish collection efficiencies (FCE) for yearling chinook salmon at Lower Granite Dam with 100% of the flow passing through the powerhouse was only 30% (Sims et al. 1982)--significantly less the the >70% potential collection, assuming that most of the fish guided out of intakes were ultimately collected and that STS guidance efficiency was at least comparable to that measured at McNary and Bonneville Dams (Krcma et al. 1980 and 1982). By contrast, the 60% FCE estimated for steelhead was only slightly under the theoretical potential. If the estimates by Sims are accurate, then the reasons for the low FCEs at Lower Granite Dam need to be determined and rectified.

Possible reasons for the low FCEs at Lower Granite Dam were: 1) powerhouse operations, especially turbine shutdown, during critical periods of

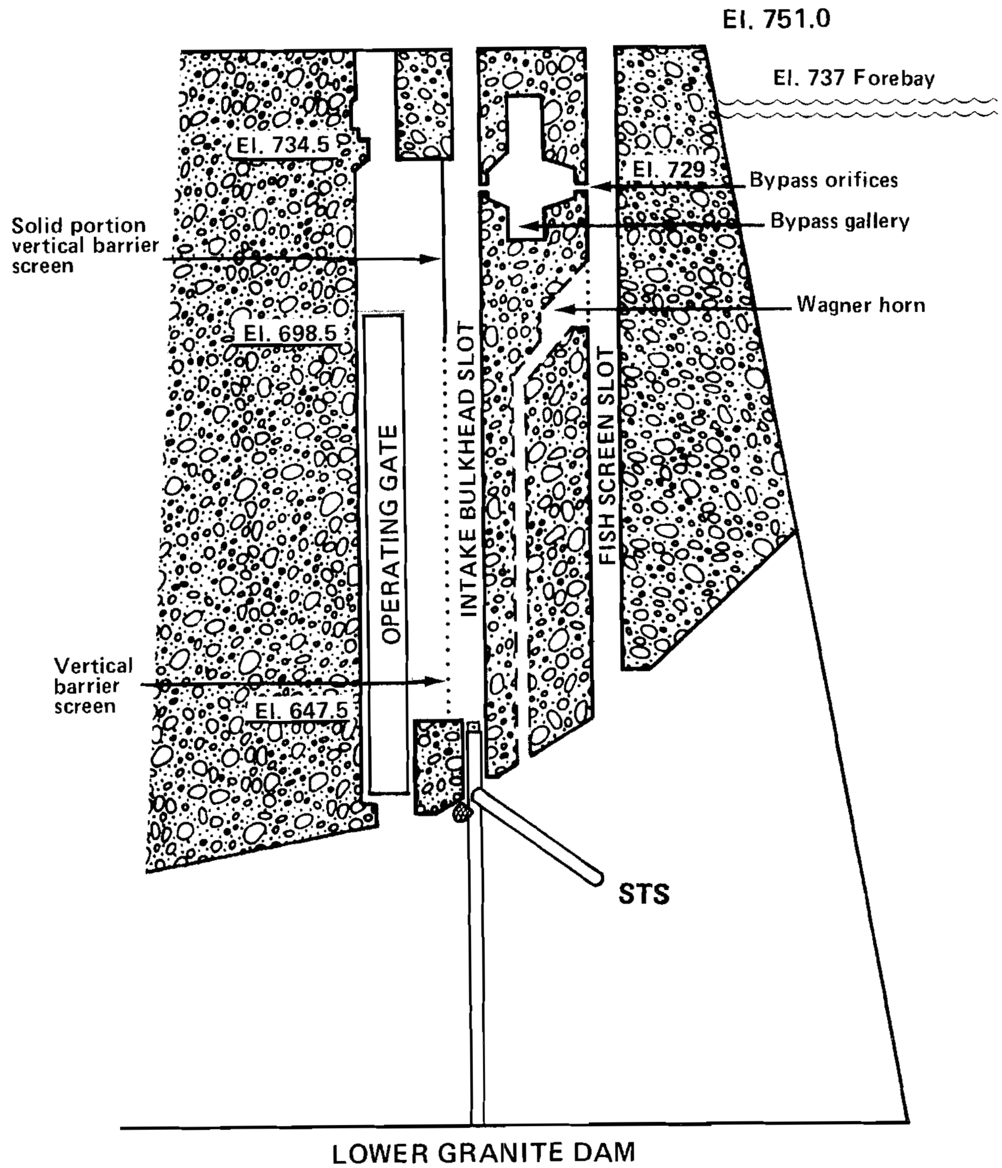

Figure 1.--Typical turbine intake at Lower Granite Dam.

downstream fish movement; 2) fish-guiding efficiencies (FGE) of STSs not being as high as expected; or 3) lower FGE or orifice passage because of vertical barrier screen designs. The objective of the study reported herein was to isolate the cause(s) of the low FCEs at Lower Granite Dam.

METHODS AND MATERIALS

To accomplish the objectives of the study, the National Marine Fisheries Service (NMFS) divided its research into six tasks:

(1) Task 1--Compare FGEs of a standard and modified STS working in conjunction with a standard vertical barrier screen (SVBS) and a balanced flow vertical barrier screen (BFVBS) (Krcma et al. 1982) at various turbine loads.

(2) Task 2--Determine if orifice passage efficiency (OPE) from the gatewell to the collection system could be improved by modifying barrier screen design.

(3) Task 3--Determine if fish were stressed differentially by the two types of barrier screens.

(4) Task 4--Assess whether the flow of water through the two types of barrier screens caused fish impingement problems.

(5) Task 5--Assess whether FCE was affected by unit outage.

(6) Task 6--Determine the vertical distribution of juvenile salmonids entering a turbine intake without an STS in place. [This task was added after NMFS and U.S. Army Corps of Engineers (CofE) personnel made a preliminary analysis of the FGE data].

To ensure sufficient time during the smolt migration to properly complete all the tasks, STS FGE, OPE, and stress tests were conducted simultaneously. Due to fishery agencies concerns about the depressed numbers of spring chinook salmon in the Snake River, Units 4 and 5 were used for testing. Fewer fingerlings pass through these units than through Units 1, 2, and 3, so the research experiment involved less impact on fingerling migration.

Experimental Equipment

The turbine intakes of Lower Granite Dam (Figure 1) are basically identical to those of other hydroelectric dams on the lower Snake and Columbia Rivers with the exception of a special fish screen slot (FSS) constructed upstream from each intake bulkhead slot (BHS). A special fingerling bypass gallery is incorporated into the collection system to receive fingerlings through two submerged 20.3 cm (8-inch) diameter orifices (north and south) from each BHS and FSS. The operating depth of the submerged orifices can vary from 1.2 to 2.3 m (4 to 8 feet) depending on forebay elevations (Matthews et al. 1977).

The following equipment or services were used to conduct the required research:

1) Two STSs, each equipped with a fyke net frame capable of holding a full complement of fyke and gap nets.

2) Two balanced flow vertical barrier screens (BFVBS)--two standard vertical barrier screens (SVBS) were modified by attaching perforated plate with 30% open area to the downstream side of the screened panels.

3) Two portable orifice traps.

4) A special bracket and an underwater television camera.

5) Two gatewell dip nets (Swan et al. 1979).

6) On-deck fish examining facilities.

7) Two mobile cranes.

8) CofE services:

a) Gantry crane service for STS FGE tests.

b) Gantry crane service for modifying the VBS to a BFVBS.

c) Modify one STS. (Remove solid plate in leading end).

Measurements and Procedures

STS Fish Guiding Efficiency

Tests were conducted in Intakes 4A and 4B with two STSs equipped with frames for attaching the fyke nets. The fyke nets included two closure nets attached to the back of the STS and a vertical row of five nets attached to the fyke net frame (Figure 2). Four of these nets were approximately 6.5 ft square and one net was approximately 2.5 x 6.5 ft. The gap net, attached near the top of the STS, captured fingerlings that passed through the space between the top of the STS and the concrete beam that divides the operating gate slot and bulkhead slot.

The procedures for determining FGE were similar to those used in previous experiments of this type. Gatewell dipnet catches provided the number of guided fish; catches from the gap and fyke nets attached to the STS provided numbers of unguided fish.

During FGE tests for evaluating the BFVBS under varying turbine loads, guided fish numbers included only fish from the BHS. However, during the series of FGE tests conducted for the modified STS at the 135 MW load, guided fish included fish from both the BHS and FSS.

FGE was calculated as guided fish divided by the total number of fish passing through the intake during the test period:

$$FGE = \frac{GW}{GW+GN+3(FN)+CN} \times 100$$

GW = gatewell catch (BHS + FSS when applicable)
GN = gapnet catch
FN = fyke net catch
CN = closure net catch

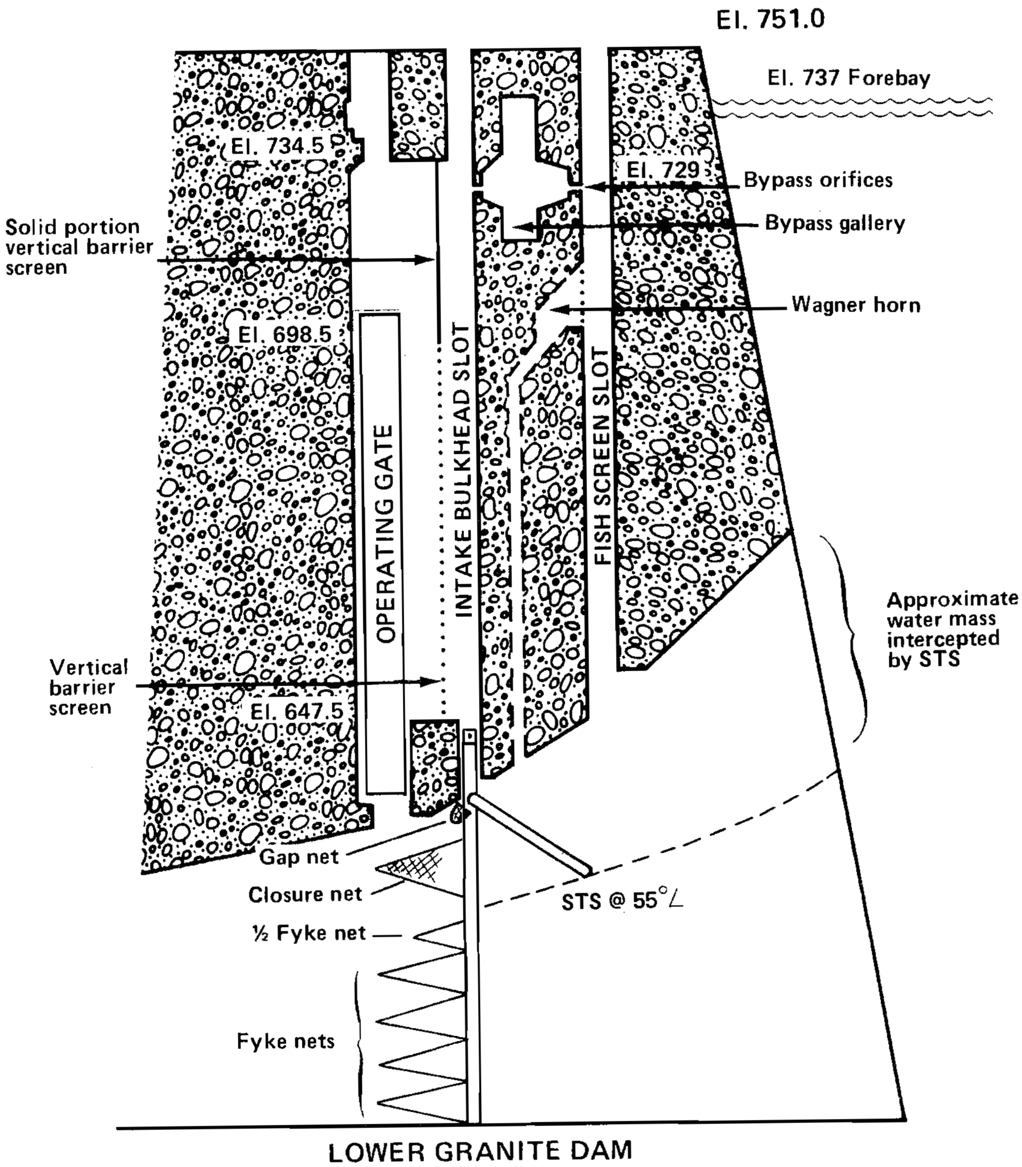

Figure 2.--STS, research nets, and framework used in FGE tests at Lower Granite Dam shown in the testing position in the turbine intake.

To minimize mortality of fish in fyke nets, most STS FGE calculations used estimates of unguided fish derived from a one-third sample of the fingerlings passing below the STS. This was accomplished by trapping fish in a single vertical column of fyke nets that fished the center one-third of the intake not intercepted by the STS. Nets were in place in the remaining area of the intake, but the cod ends of the nets were left open to allow fish to pass on through the intake. The full complement of nets rather than a single row of nets was used to assure an accurate measure of unguided fish. Differential flow conditions due to the absence of nets on either side of the center nets could cause fish to veer off and not be caught. To verify the validity of this estimate, we also conducted some tests that included fyke net catches from the full complement of nets.

The sequence of events for conducting a typical STS FGE test was as follows:

1) Unit 4 was shut down.

2) The STSs with attached fyke net frames were lowered into position in Gatewells 4A and 4B.

3) The bypass orifices in Gatewell 4A and 4B were closed, and the gatewell was dipped to remove all fish present at that time.

4) Unit 4 was returned to service and brought to full load.

5) The number of fish entering the gatewell was monitored by periodic dipnetting.

6) The test was terminated when adequate numbers of fish for statistical needs were collected.

7) The turbine was shut down, and a final cleanout dip was made.

8) The STSs with attached fyke nets and frames were brought to the surface, and the fish were removed from the nets for identification and enumeration

9) The unit was returned to service.

Each test was about 2 to 8 h long depending upon the density of the fish run. The turbine was shut down for about 2 h to install or remove the STS.

Tests were started during the afternoon and terminated about 2100 or 2200 h when adequate numbers of fish had been guided into the gatewell. The number of guided fish removed from the gatewell by dipnetting determined the duration of a test. The experimental design required specific sample sizes and replicates to satisfy specified statistical significance levels for detecting relevant differences of a stated magnitude. This called for three or more replicates with a goal of 200 fish per sample (gatewell catch) for each condition tested. Contingency table procedures using the log-likelihood G-test were used in the statistical analysis (Sokal and Rohlf, 1981). The formulas and procedures used are given in Appendix A.

The number of fish caught and sacrificed in the fyke nets varied depending upon the STS FGE, e.g., if 200 fish were in the gatewell with an FGE of 40%, 300 fish would have passed on through the intake and 100 of these (assuming a one-third sample) would be caught in the fyke nets under each STS per replicate; if FGE was 80%, only 17 fish per replicate would be sacrificed. Therefore, for each STS condition tested the total number of net caught fish would not exceed 600 fish (100 x 2 STSs x 3 replicates = 600) at a 40% FGE and 102 fish at 80% FGE.

If the FGEs during the basic tests were not acceptable (less than 75%), certain additional modifications or operating procedures were to be investigated: (1) if large numbers of fish were being deflected under the screen (determined from closure net data), eliminate a section of solid plate from the lower portion of the STS to increase its porosity or (2) improve FGE by operating the STS at a reduced turbine load.

Orifice Fish Passage Efficiency

OPE tests were conducted at the same time as the STS FGE tests in Gatewells 5A and 5B. Gatewell 5A was equipped with a BFVBS, and Gatewell 5B contained a SVBS for control. Orifice traps were installed in the bypass gallery for the north orifice in each gatewell. The south orifice remained closed during the normal OPE tests. A minimum of three replicates of 24 h duration were conducted with uninterrupted fully loaded (135 MW) unit operation during the test periods. The orifice traps (Figure 3) were attended continuously during each 24-h test. An OPE test was started at 1200 h by cleaning residual fish out of Gatewells 5A and 5B. Dipping the gatewell clean to capture the residual fish after 24 h terminated a test. A 72-h test consisted of the same procedures except that the cleanout dip at the end of the test was made after 72 h of orifice operation. The OPE was measured by comparing the number of residual fish to the total number of fish caught in the orifice trap for each period. Contingency tables utilizing chi-square and/or the "G" statistic were used to analyze the data for significance.

Stress Effects on Fish by Barrier Screens

Descaling of fish was monitored as a measure of fish quality. A fish was considered descaled if it was missing approximately 10% or more of its scales.

In addition, samples of 20 to 30 fish from Gateslots 4A, 4B, 5A, and 5B were transported to the laboratory at the collection facility and subjected to a seawater challenge (Park et al. 1983). These tests were designed to determine if fish were stressed differentially by the different types of barrier screens. All of these tests were coordinated with other NMFS stress studies.

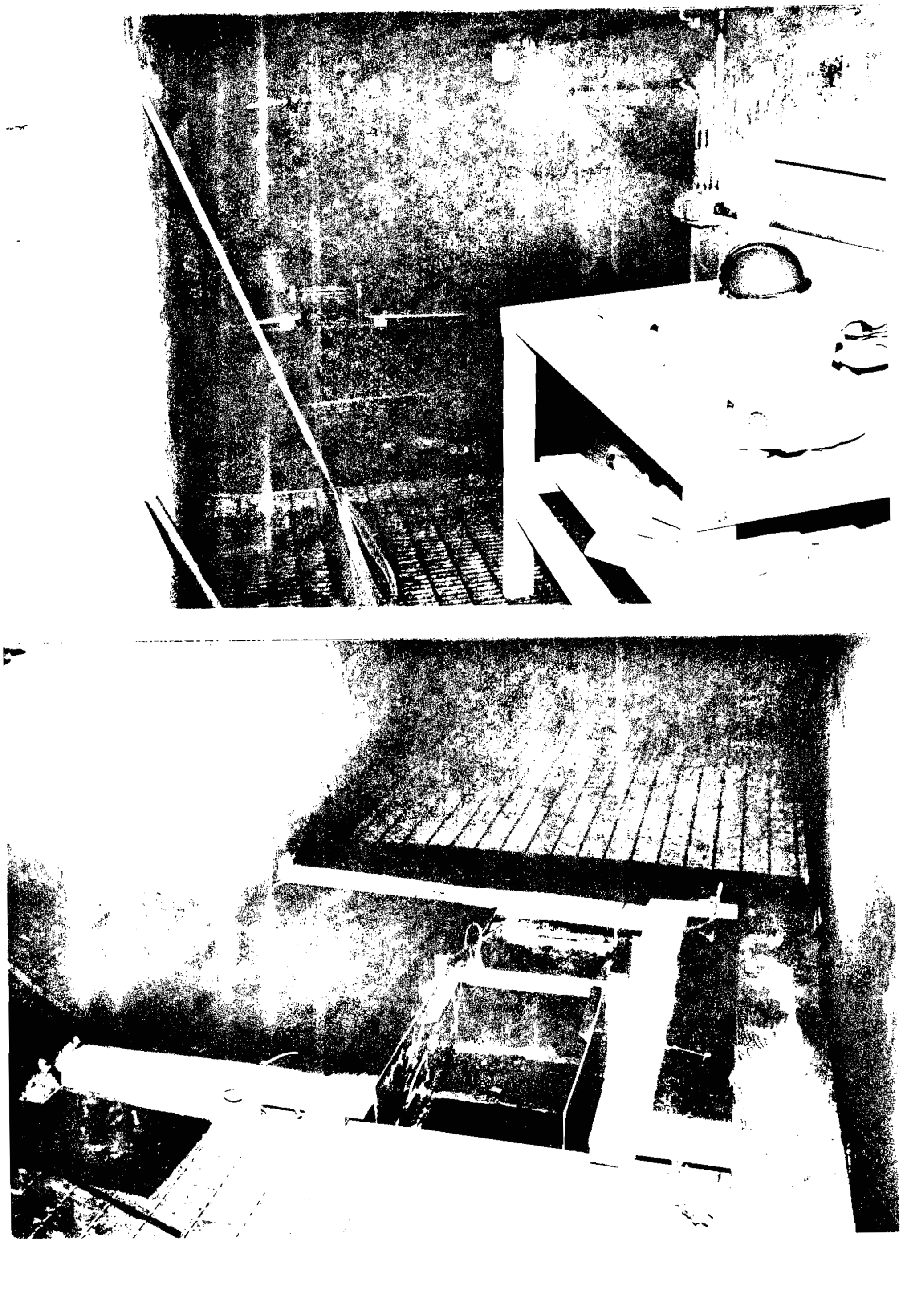

Figure 3.--Orifice traps and a fish examination station were located in the fingerling bypass gallery.

Inspection of VBS for Impinged Fish

An underwater TV camera, mounted on a special bracket, was periodically lowered into the gatewell to scan the SVBS and BFVBS for evidence of impinged fish and debris. These observations were recorded on a video-tape system.

Effects of Unit Outage on Fish Collection Efficiency

These tests were conducted to determine if a significant percentage of the fingerlings in the gatewell swam back out of the gatewells during routine shut down. Two intervals of down time were tested: (1) a short term (about 30 min) and (2) a long term (about 2 h). A group of 100 marked fish were released into the gatewell prior to the shut down. Immediately after the unit was returned to service, recoveries of marked fish were recorded from gatewell dipnet and orifice trap catches. Tests were conducted for both daytime and nighttime conditions, and each test was replicated three times. Statistical analyses of the data were similar to that used for the OPE test.

Vertical Distribution of Fingerlings

Measures of vertical distribution of fingerlings provided the means to determine the proportion of fish that should have been guided by an STS into the gatewell by comparing the fishing depth of the STS with the measured vertical distribution by species entering the turbine intakes. Vertical distribution tests were conducted with the STS removed (Figure 4) using standard procedures established by NMFS in similar testing at other dams.

RESULTS

STS Fish Guiding Efficiency

The FGE for chinook salmon was unacceptable and significantly lower than measured for steelhead ($G=566.43$, $df=1$, $P<0.001$). The average FGEs for all the test conditions combined were 50 and 74% for chinook salmon and steelhead, respectively, (Figure 5) (Appendix B).

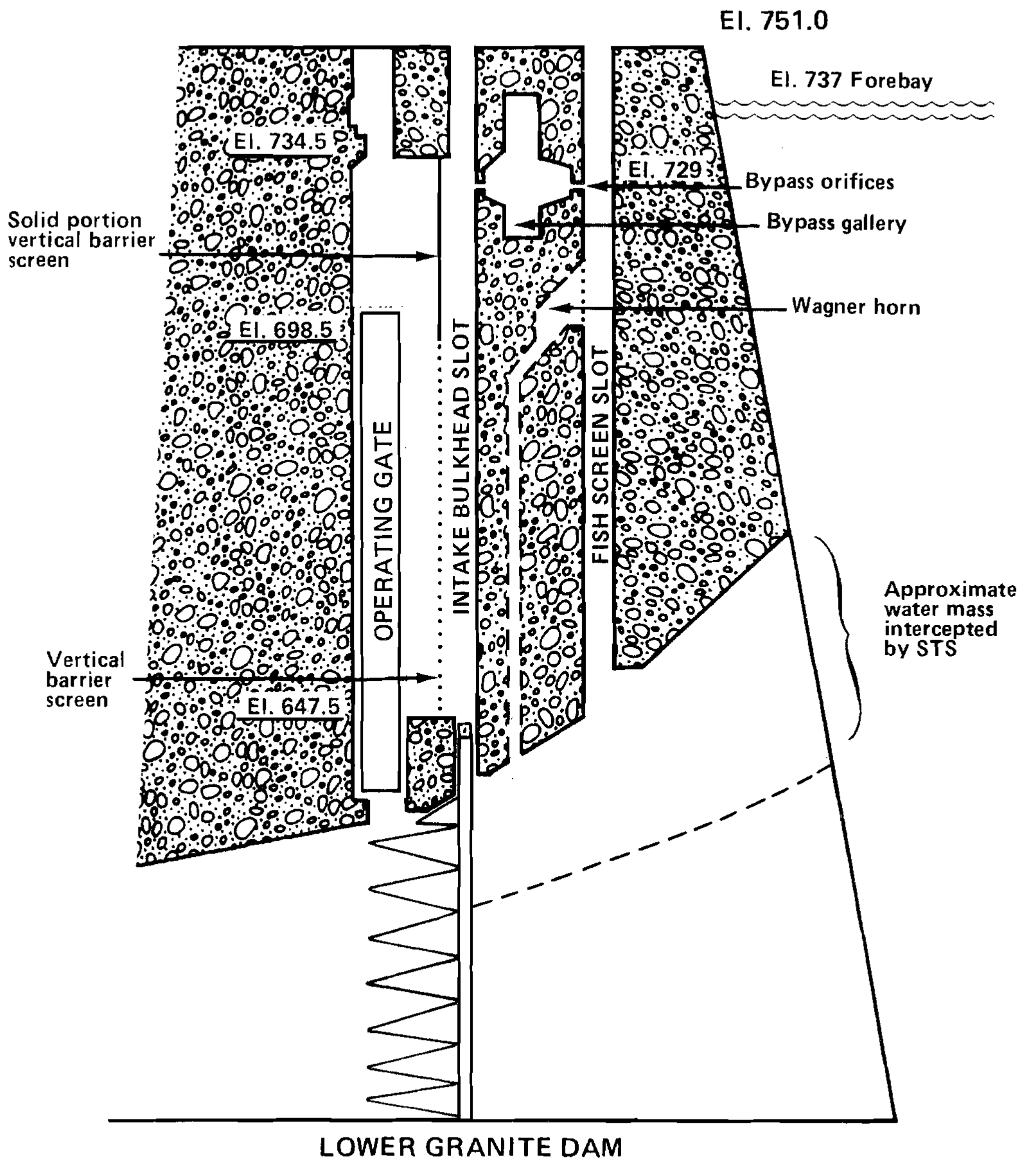

Figure 4.--Fyke net frame and nets are shown in position to study the vertical distribution of juvenile salmonids entering a turbine intake.

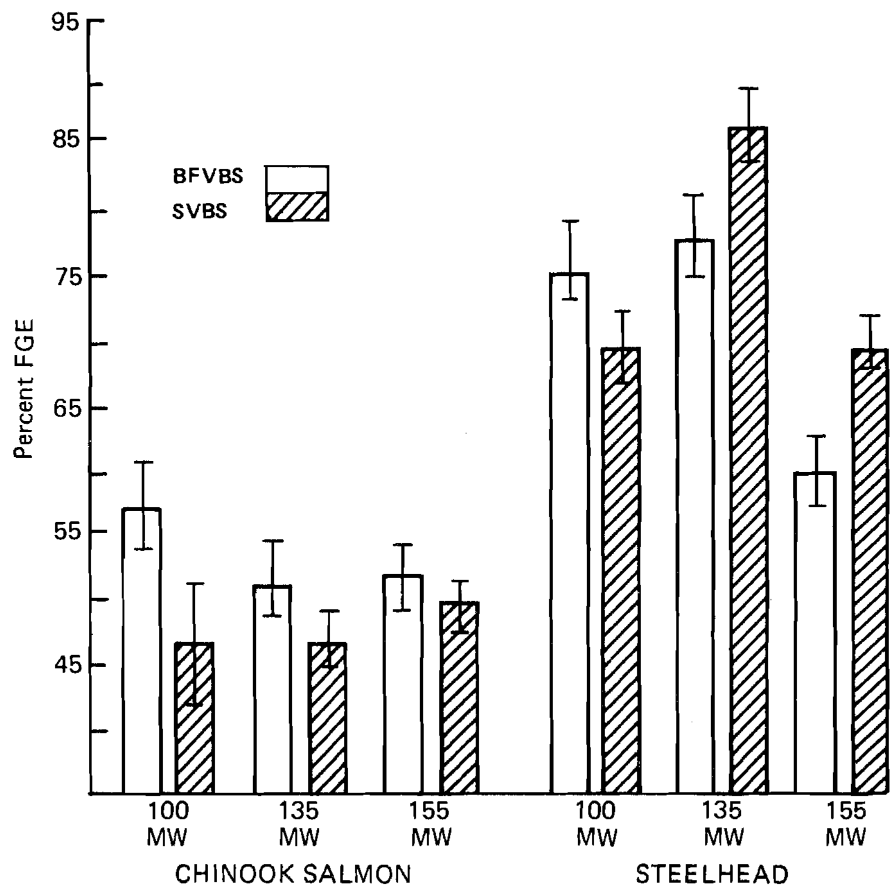

Figure 5.--Percent fish guiding efficiency of the submersible traveling screen operated in a gatewell with a standard vertical barrier screen in comparison with one equipped with a balanced flow vertical barrier screen. The symbol (I——I) represents upper and lower 95% confidence limits (Percent FGE did not include fish from the FSS).

Comparisons of FGE between gatewells containing a SVBS and a BFVBS indicated that the effect of the BFVBS on FGE varied depending on turbine loads. The highest FGE occurred at 100 MW for chinook salmon and at 135 MW for steelhead. A significant increase of 5 to 10% was noted for chinook salmon at 100 MW (G=9.64, df=1, P=0.002) and 135 MW (G=10.00, df=1, P=0.001) loads and no significant difference at the 155 MW load (G=0.88, df=1, P=0.35). Contrary to this, the steelhead FGE with the BFVBS was significantly reduced by about 10% at both the 135 and 155 MW loads [87 vs 78% (G=18.599, df=1, P<0.001) and 70 vs 60% (G=44.32, df=1, P<0.001), respectively]. However, like the chinook salmon, steelhead also showed a significant benefit in FGE with a BFVBS at the 100 MW turbine load [70 vs 76% (G=10.46, df=1, P<0.001.)]

Changing solid plate to perforated plate in the lower portion of the STS significantly improved the FGE for chinook salmon (G=26.76, df=1, P<0.01) but significantly decreased FGE for steelhead (G=215.7, df=1, P<0.001) (Table 1). Even though improved, the FGE for chinook salmon was still unacceptable.

Orifice Passage Efficiency

OPE from the gatewell to the collection system did not show a consistent pattern during VBS tests. Two time periods (24- and 72-h) of gatewell accumulation were tested with a SVBS and BFVBS (Table 2). Of concern is the low OPE for steelhead (16 to 30%). Also confusing was the fact that the lowest OPE occurred for the 72-h test when theoretically tests of this duration should have resulted in the highest OPE. With these data, it was difficult to determine if barrier screen design made a difference. OPE for chinook salmon (57 to 66%) was also less than acceptable for both types of barrier screen conditions.

Table 1.--A comparison of the FGE for chinook salmon and steelhead with the solid plates in the lower part of the STS replaced with perforated plate.

Condition and species	Number guided[1/]	Number unguided	Total	Percent FGE[2/]
Chinook				
With solid plate	964*	867	1,831	53
Without solid plate	606	424	1,030	59
Steelhead				
With solid plate	767*	166	933	82
Without solid plate	3,113	967	4,080	76

1/ Number guided included both BHS and FSS numbers. FSS numbers for tests with solid plates (*) were estimated by using a percentage factor determined from confirmed FSS catches made during tests without solid plates.

2/ Differences in FGE, with and without solid plates, were statistically different with a probability of less than 0.005 for both chinook salmon and steelhead.

Table 2.--Percent orifice passage efficiency of spring chinook salmon and steelhead from gatewells with different barrier screen designs, for 24- and 72-h time periods at Lower Granite Dam - 1982.

	OPE					
	Chinook			Steelhead		
Time period	5A BFVBS (%)	5B SVBS (%)	G-Test	5A BFVBS (%)	5B SVBS (%)	G-Test
24 h	58	57	0.83*	30	24	43.39**
72 h	61	66	55.32**	16	24	402.38**

* Nonsignificant at 0.05 probability level.
** Significant at 0.001 probability level.

Stress Effects on Fish by Barrier Screens

Quality of fish handled remained high throughout both the FGE and OPE tests. No significant difference in fish condition was noted for fish guided into the gatewells equipped with either a BFVBS or SVBS. Descaling remained low for fish in the test gatewells, even for the 72-h test condition.

Further comparison of stress factors for residual fish that were exposed to gatewell conditions with the two barrier screen types for the 72-h tests showed no significant difference when subjected to a seawater challenge.

Inspection of VBS for Impinged Fish

Barrier screens in the test gatewells were inspected by underwater television with the turbine running. The screens appeared clean and very little debris was noted on either type of barrier screen. No impinged fish were observed on either the BFVBS or the SVBS. Fish swimming freely were noted in the vicinity of the screened portion of the barrier screens, but virtually none were observed in the area of the solid panel portion near the top of the barrier screens. The only real difference noted was related to swimming activity of the fish. In the slot with a BFVBS, the fish appeared to be swimming leisurely about, whereas in the slot with an SVBS, more labored swimming was exhibited by fish in their efforts to hold a position in the upwelling current.

Effects of Unit Outage on FCE

The percentages of fish exiting the gatewell during a unit shutdown are shown in Table 3. These data suggest a possible correlation with behavior noted during underwater television observations. The fish in the gatewell with the SVBS appeared to be subjected to prolonged head down swimming into the water flowing up into the gatewell. The head-down orientation may have been the cause of the higher percentage escapement from gatewells containing an SVBS. Further investigation of this behavior and its relation to escapement after unit shutdown is planned for 1983.

Table 3.--Percent of marked fish exiting gatewells following a 30 minute shutdown of the turbine.

	Percent exited		
Species	Unit 4A (BFVBS	Unit 4B (SBVS)	Unit 5B (SVBS)
Chinook	2	24	13
Steelhead	0	12	6

Vertical Distribution of Fingerlings

The results of our vertical distribution tests showed that 76% of the chinook salmon and 92% of the steelhead were located in the water mass that could potentially be intercepted and diverted into the gatewell by the STS (Table 4). This compares with 58 and 76% actually guided into the gatewells by the STS. The lower guidance of chinook salmon may be the result of deflection under the STS.

Table 4.--Distribution of fingerlings that entered a turbine intake during tests with and without an STS.

	Chinook Salmon		Steelhead	
Location	With STS %	Without STS %	With STS %	Without STS %
FSS	3	6	17	30
BHS	53	15	59	25
Intercepted but unguided (gap net catch)	2		2	
Net catch in normal STS operating zone		55		37
Total	58	76	78	92

The vertical distribution tests indicated that chinook salmon appeared to move deeper, which would tend to put a higher percentage of them near the lower end of the STS making them more susceptible to deflection. However, in the case of steelhead, their shallower distribution apparently resulted in a greater potential for being intercepted by the STS with less deflection and consequently a higher FGE.

The ratios of chinook salmon and steelhead that entered the BHS vs FSS during the vertical distribution tests were greatly different than during the STS FGE tests. Significantly larger numbers of steelhead entered the FSS volitionally without an STS than did chinook salmon, and more steelhead entered the FSS than entered the BHS; the opposite occurred when the STS was used. The large numbers of steelhead in the FSS was apparently due to their tendency to concentrate more toward the ceiling as they entered the turbine intakes.

CONCLUSIONS AND RECOMMENDATIONS

1. Improving FGE--FGE for chinook salmon was considerably lower than acceptable (about 50% as opposed to a desirable 70%). Vertical distribution tests indicated that a potential exists for achieving an acceptable level of FGE. To improve FGE at Lower Granite Dam, further efforts are needed to divert and guide more chinook salmon from the turbine intakes. To minimize deflection of the chinook salmon under the screen, one of the most promising possibilities is to increase the flow into the gatewell. Recent hydraulic model studies have shown that increased flow into the gatewells can be accomplished by partially raising the operating gate. In addition, greater STS interception and reduced flow deflection can be achieved by lowering the STS into the intake. This also increases the gatewell throat opening and gap size. The narrow throat and gap openings for screens installed at Lower Granite and Little Goose Dams are considered as potential causes of lower than expected fish guidance. Testing in 1983 will focus on these modifications for improving FGE.

2. Improving OPE--OPE for both chinook salmon and steelhead appeared to be unacceptably low. Based upon earlier studies, a larger diameter orifice is recommended (one 11-inch diameter orifice will pass about the same amount of water as two 8-inch diameter orifices, resulting in a one-orifice-per-gatewell type system). To avoid an OPE bias between a north and south orifice, further studies are needed to develop the ability to control gatewell flows, which should eliminate the bias and enhance OPE. One major possibility (to be tested in 1983) is a further modification of the barrier screen by replacing one of the solid panels of the BFVBS with one that is porous. Recent model studies indicated that this may provide a subtle flow upward toward the vicinity of the orifices and thus may direct more fish to the orifices.

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APPENDIX A

Sample sizes needed to detect differences among test groups

Appendix A.--Sample sizes needed to detect differences among test groups.

The information needed to determine the number of replicates and the sample sizes required per test group are the treatment variability expected, the number of means (or experimental categories) being compared, and the specified precision (i.e., the probability of the type I error, α, and the probability of type II error, β) desired from the statistical test. This information is applied using the following sample size precision formulas:

(1) For obtaining sample sizes in the two group comparison case (Lemeshow et al. 1981):

$$NT=((ZA-ZB)*2)/(2(SP1-SP2)*2).$$

(2) For obtaining confidence intervals and sample sizes for the multinomial, more than two group case (Angers 1974), (Goodman 1965), (Miller 1966):

$$NM=(B)(P_i(1-P_i))/D*2.$$

(3) For obtaining the number of replicates (Steel and Torrie 1960):

$$R>(2(T_1+ T_2)*2)(ST*2)/D*2).$$

Where the following notation is used:

NT	sample size in the two group comparison.
ZA	(1-α)-th percentile of the standard normal distribution.
ZB	β-th percentile of the standard normal distribution.
SP1	is the arcsin transform of the square root of the proportion in the control group
SP2	is the arcsin transform of the square root of the proportion in the test group.
*	indicates exponentiation.
NM	smallest sample size such that the statistical precision levels for the multinomial parameters, P_i are simultaneously satisfied.
B	tabular value for the upper percentile of the chi-squared distribution at the specified statistical precision level with the one degree of freedom.
P_i	expected proportion in each multinomial category.
D	level of difference it is desireable to be able to detect, this can be different for each treatment (or multinomial) category.
R	the number of replicates per treatment.
T_1	t-distribution value associated with type I error.
T_2	t-distribution value associated with type II error; T_2 is the tabulated t for probability 2(1-Q) where Q is the power of the test (1-β) .
ST	estimated experiment-wise error mean square, usually obtained from previous experiments

The degrees of freedom for T_1 and T_2 are the product of (K-1) (R-1) where K is the number of treatment groups, and R the number of replicates. Successive approximations are involved in the calculations for parts (2) and (3) since the number of degrees of freedom associated with tabulated probability distribution values depends on sample size.

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APPENDIX B

Catches of spring chinook salmon and steelhead collected during fish guiding efficiency tests at Lower Granite Dam in spring of 1982

Appendix B.--Catches of spring chinook salmon and steelhead collected during fish guiding efficiency tests at Lower Granite Dam in spring of 1982.

CHINOOK SALMON

Date	Turbine load	BFVBS (4A) BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided & un-guided)	% FGE	SVBS (4B) BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided & un guided)	% FGE
	135 megawatts	SOLID PLATE IN STS							SOLID PLATE IN STS						
4/20		NOT TESTED							484	0	26	597	657	1,141	42
4/21		465	0	14	276	302	767	61	574	0	51	453	516	1,090	53
4/22		245	0	9	65	195	440	56	250	0	11	84	247	497	50
4/23		208	0	15	125	370	578	36	174	0	16	91	268	442	39
	Total	918	0	38	466	867	1,785		1,482	0	104	1,225	1,688	3,170	
	Grand average							51							47
	135 megawatts w/perforated plate - includes FSS catch								PERFORATED PLATE IN STS						
5/4									163	12	6	47	136	311	56
5/5		NOT TESTED							264	13	7	55	161	438	63
5/6									150	4	8	41	127	281	55
	Total								577	29	21	143	424	1,030	
	Grand Average														59 a/
	100 megawatts														
4/26		203	0	1	59	167	370	55	152	0	0	59	168	320	48
4/27		15	0	1	6	19	34	44	11	0	0	7	20	31	35
4/28		65	0	1	9	27	92	71	32	0	0	12	34	66	48
	Total	283	0	3	74	213	496		195	0	0	78	222	417	
	Grand Average							57							47
	155 megawatts														
4/29		318	0	46	84	285	603	53	261	0	23	91	282	543	48
4/30		407	0	42	124	389	796	51	524	0	44	175	528	1,052	50
5/1		22	0	3	8	26	48	46	52	0	1	10	29	81	64
	Total	747	0	91	216	700	1,447		837	0	68	276	839	1,676	
	Grand Average							52							50

STEELHEAD

Date	Turbine load	BFVBS (4A) BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided & un guided)	% FGE	SBVS (4B) BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided & un-guided)	% FGE
	135 megawatts	SOLID PLATE IN STS							SOLID PLATE IN STS						
4/20		NOT TESTED							43	0	2	13	6	49	88
4/21		119	0	0	18	18	137	87	96	0	8	14	22	118	81
4/22		167	0	6	22	70	237	70	157	0	9	4	21	178	88
4/23		309	0	7	25	78	387	80	285	0	3	12	39	324	88
	Total	595	0	13	165	166	761		581	0	22	43	88	669	
	Grand average							78							87
	135 megawatts w/perforated plate - includes FSS catch								PERFORATED PLATE IN STS						
5/4									448	141	13	47	149	738	80
5/5		NOT TESTED							1,044	305	35	133	418	1,767	76
5/6									924	251	25	129	400	1,575	75
	Total								2,416	697	73	309	967	4,080	
	Grand Average														76 a/
	100 megawatts														
4/26		435	0	6	41	124	559	78	367	0	5	45	142	509	72
4/27		237	0	6	15	51	288	82	136	0	3	16	55	191	71
4/28		121	0	3	23	71	192	63	83	0	5	18	58	141	59
	Total	793	0	15	79	246	1,039		586	0	13	79	255	841	
	Grand Average							76							70
	155 megawatts														
4/29		412	0	16	96	287	699	59	329	0	7	65	196	525	63
4/30		505	0	26	140	421	926	55	581	0	27	86	276	857	68
5/1		317	0	18	36	124	441	72	408	0	14	28	97	505	81
	Total	1,234	0	60	272	832	2,066		1,318	0	48	179	569	1,887	
	Grand Average							60							70

a/ Percent FGE for this test condition represents total of fish guided into bulkhead slot (BHS) and fishscreen slot (FSS).