Continuing Studies to Improve and Evaluate Juvenile Salmonid Collection at Lower Granite Dam — 1985

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September 1986

COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

Lower Granite and Little Goose Dams are the two dams where fish are collected for the transportation of smolts from the Snake River (Fig. 1). Acceptable fish collection efficiency at these dams is necessary for program success. The U.S. Army Corps of Engineers (COE) and the National Marine Fisheries Service (NMFS) continue their efforts to improve fish collection at these dams. Submersible traveling screens (STS) that divert smolts from the turbine intakes into gatewells are a vital component of the collection system at these collector dams (Fig. 2). Turbine intakes at Lower Granite Dam are unique because there is a special fish screen slot (FSS) as well as the normal bulkhead slot (BHS) and operating gate slot (OGS) (Matthews et al. 1977). Earlier studies determined that the FSSs were not as efficient as the BHSs for STS operation and, therefore, are no longer used (Park et al. 1976, 1977).

A fish guiding efficiency (FGE) of about 70% was deemed necessary for effective collection based on work conducted at other dams. Tests at McNary and Bonneville Dams (First Powerhouse) determined that the measured FGE approached this theoretical figure (Krcma et al. 1980, 1982).

Studies conducted at Lower Granite Dam over the past 4 years provided valuable information for improving fish collection efficiency at the dam. Baseline data obtained in 1982 revealed that FGE for chinook salmon was only about 50%, considerably below acceptable levels (Swan et al. 1983). Flow patterns from model studies performed in fall 1982 suggested the problem might be fish diverting under the STS. Raising the operating gate in the model increased the flows up the gatewell and reduced the amount of flow deflecting under the STS. Prototype tests of this option were conducted at Lower Granite Dam in 1983. Results showed a positive improvement in FGE (to about 74%) by raising the operating gate 20 feet (Swan et al. 1984).

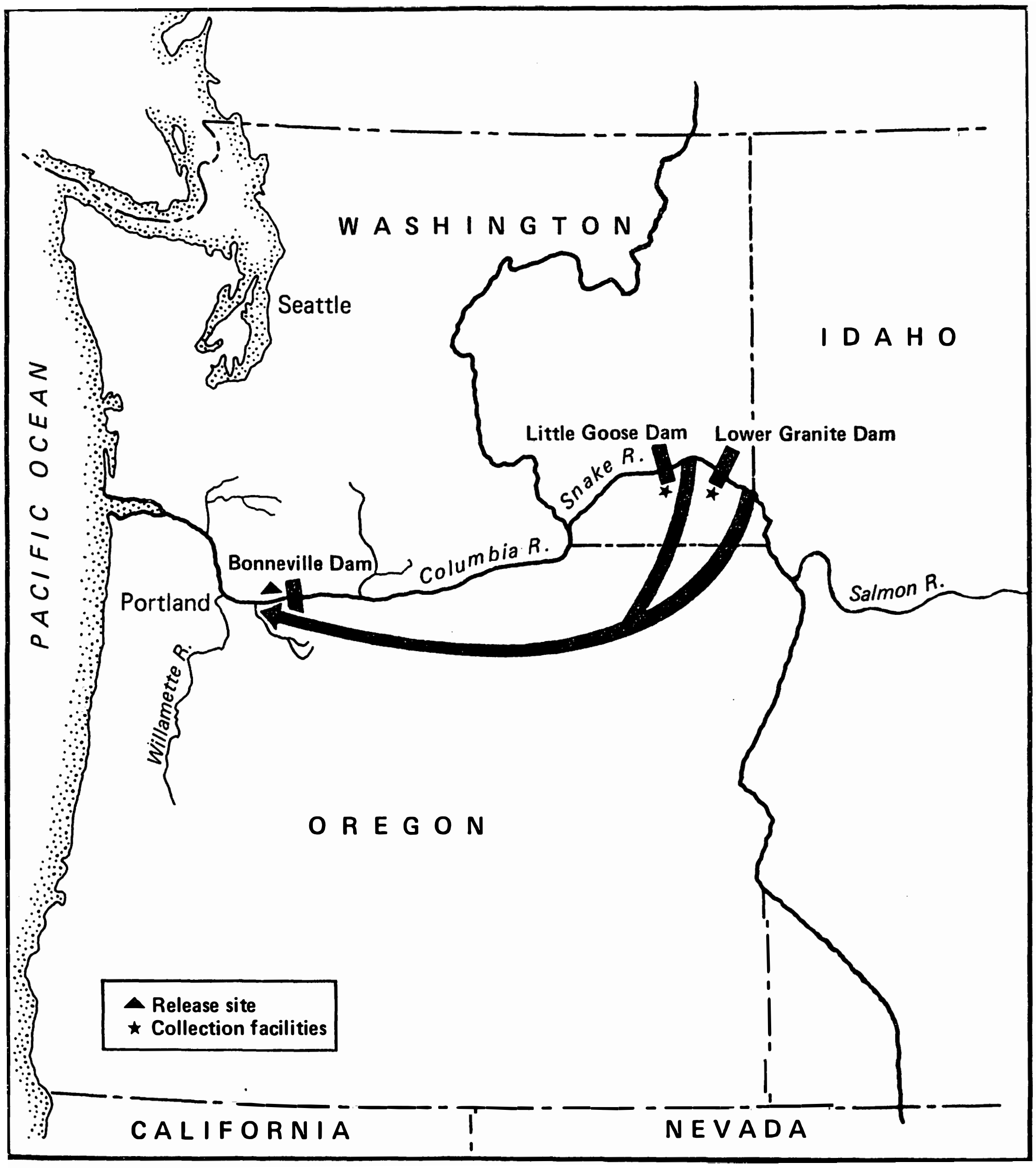

Figure 1.--Locations of fish collection facilities on the Snake River, transportation route, and release site.

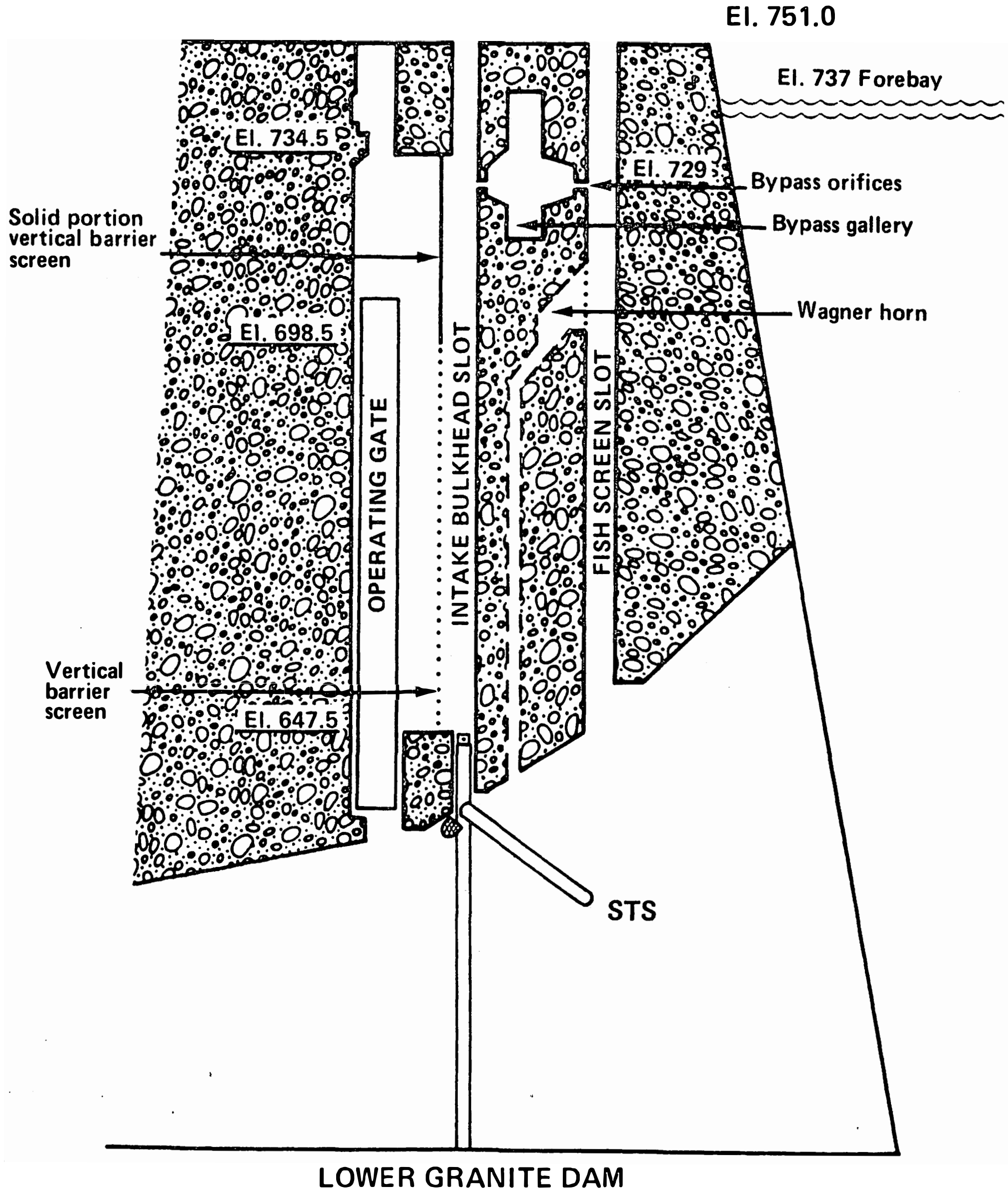

Figure 2.--Typical turbine intake at Lower Granite Dam.

FGE testing in 1984 was designed to determine the benefit of the balanced flow vertical barrier screen (BFVBS) with a raised operating gate. Initial tests produced exceptionally low FGE for chinook salmon--about half that measured in 1983. Attempts to isolate the cause of the decline were inconclusive. There were two differences in test conditions between 1983 and 1984: (1) perforated instead of solid plate on the lower end of the STS and (2) a new trash boom in the forebay (Fig. 3A). The limited testing in 1984 comparing solid with perforated plate showed no appreciable differences. There was no time to isolate differences that might have resulted from the new trash boom. There was speculation, however, that the heavy spill throughout 1984 may have diverted the more surface-oriented fish over the spill, and those entering the power house were the deeper-running, less guidable fish.

Research objectives for 1985 included:

1. Isolating the influence of the trash boom on FGE.

2. Determining if there were significant differences in FGE between a 20- and 62-foot raised operating gate.

3. Measuring vertical distribution to estimate potential FGE and to provide calibration for the hydroacoustics test program conducted simultaneously with the NMFS work.

This report provides analysis of pertinent findings of the research conducted in 1985.

METHODS AND MATERIALS

Experimental Equipment

The following equipment and services were needed to conduct the research:

1. STSs 5 and 15 were equipped with a full complement of fyke and gap nets.

Figure 3(A)

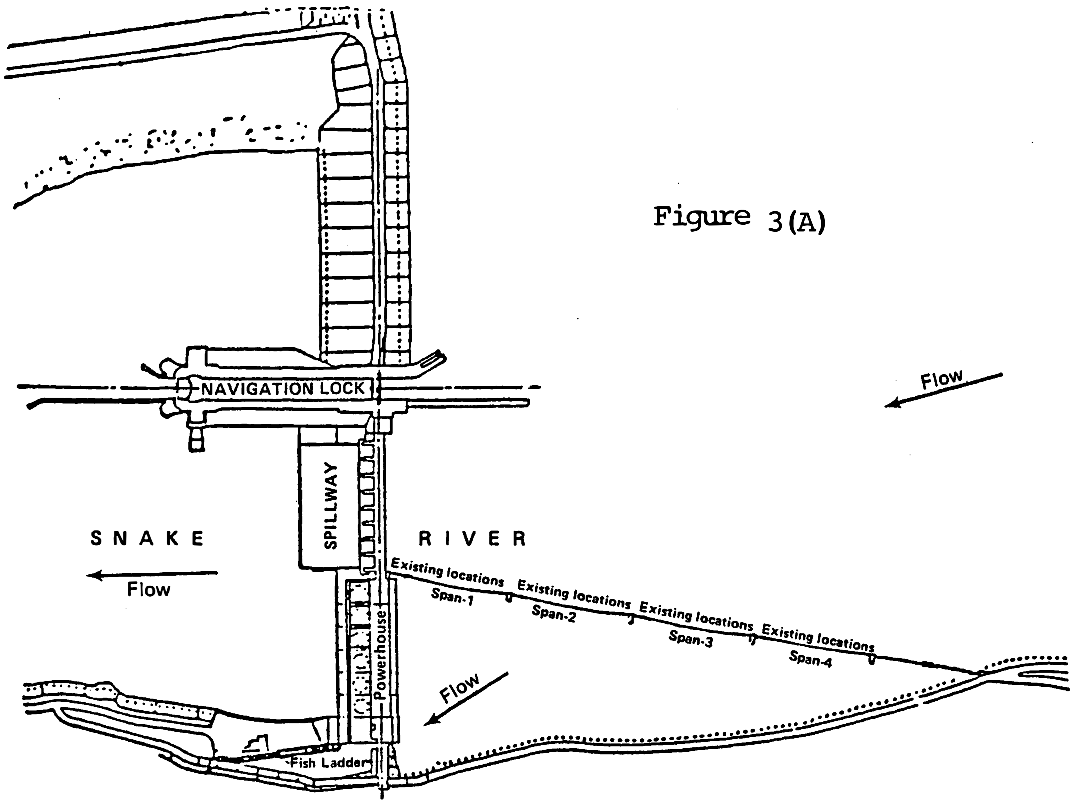

Figure 3(B)

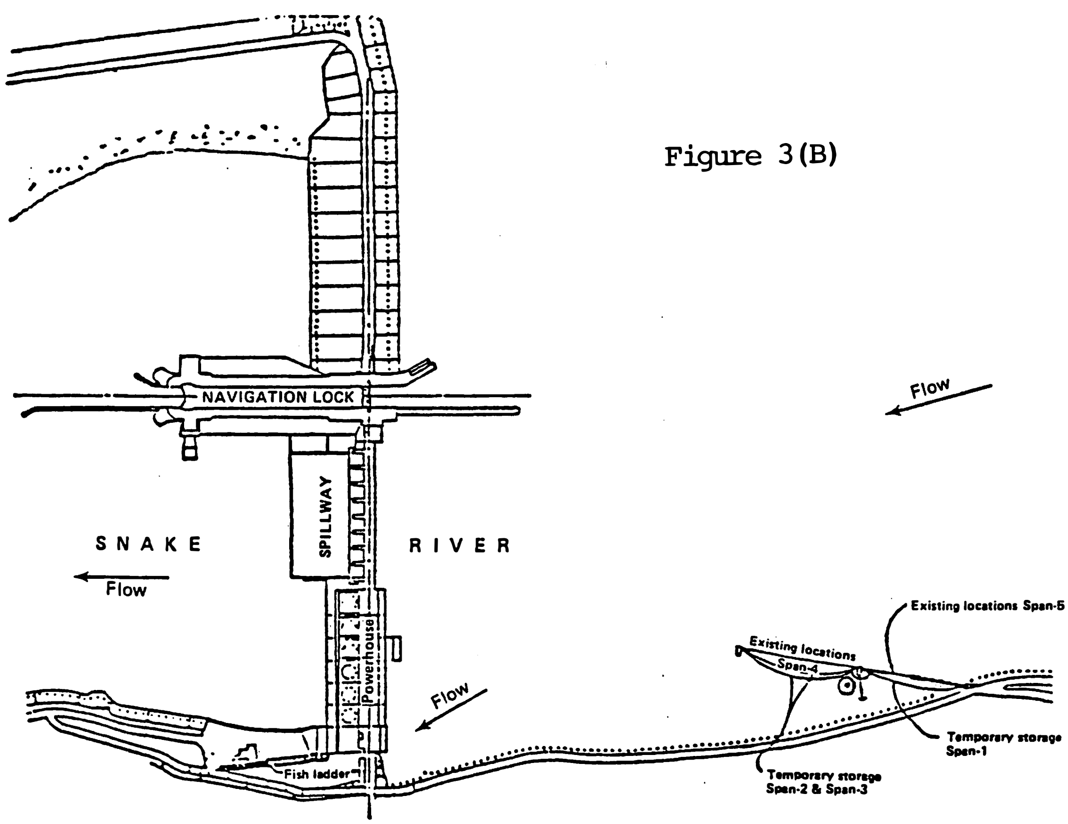

Figure 3.--Plan view of powerhouse, spillway, and other features of Lower Granite Dam - 1985, showing: A. the trash boom in place; and B. the trash boom removed.

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

3. On-deck fish examining facilities.

4. Two mobile cranes.

5. BFVBS in Unit 4A and 4B and a standard vertical barrier screen (SVBS) in Unit 4C. (A BFVBS consists of a SVBS with a 30% porosity plate attached to the downstream side of the screened panels).

6. One vertical distribution net-frame and fyke nets.

7. COE services.

a. Provided gantry crane service for preparation and performance of STS FGE and vertical distribution tests.

b. Provided installation of special plugs to seal off all of the Wagner Horns in Unit 4 to prevent fish entry into the test units.

c. Provided installation of special closure devices in each FSS of Unit 4.

d. Made special provisions for temporarily raising the operating gates in Units 4A and 4B.

e. Provided trash boom disconnecting, removal, and reconnecting services (Figs. 3A and 3B).

f. Provided unit outage required for vertical distribution and FGE tests.

Measurements and Procedures

Testing began in early April when adequate numbers of downstream migrant spring chinook salmon began arriving at Lower Granite Dam. Most tests required simultaneous measures of FGE in Units 4A and 4B and vertical distribution in Unit 4C. Later in the season, to minimize impact on fish, some of the vertical distribution tests were not conducted. Units 4A and 4B were equipped with BFVBS and with modifications that allowed the operating gates to be raised 20 and 62 feet from the standard stored condition. Unit 4C was equipped with a standard vertical barrier screen with no provision for raising the stored operating gate.

STS Fish Guiding Efficiency

Prior to the testing program, closure devices were installed in the FSS of Units 4A, 4B, and 4C to prevent the entry of fish so all the guided fish could be recovered by only having to dip the BHS. Also, a specially designed plug was installed to prevent similar entry in the Wagner Horns of Units 4A, 4B, and 4C.

To obtain numbers of unguided fish in each test, the STSs were equipped with a composite of five rows of nets attached to a net frame suspended below the STS. All of the fish were sampled from the upper three rows of the fyke nets where most of the unguided fish usually passed. A one-third sample was provided in the lower two rows where few fish usually passed (Fig. 4). The uppermost fyke net (one-half fyke net) in each column was approximately 3.5 by 6.5 feet, and the lower nets (full-size fyke nets) were approximately 6.5 feet square. A 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 OGS and BHS. Two closure nets attached to the back of the STS captured fish passing below the STS but over the top of the fyke-net frame.

Turbine Unit 4 was run only when FGE tests were conducted. Test STSs were operated in the standard screen cycling mode (4 min out of every 24 min) to be consistent with operations of the rest of the project STSs. Bypass orifices in Units 4A, 4B, and 4C remained closed throughout the testing season.

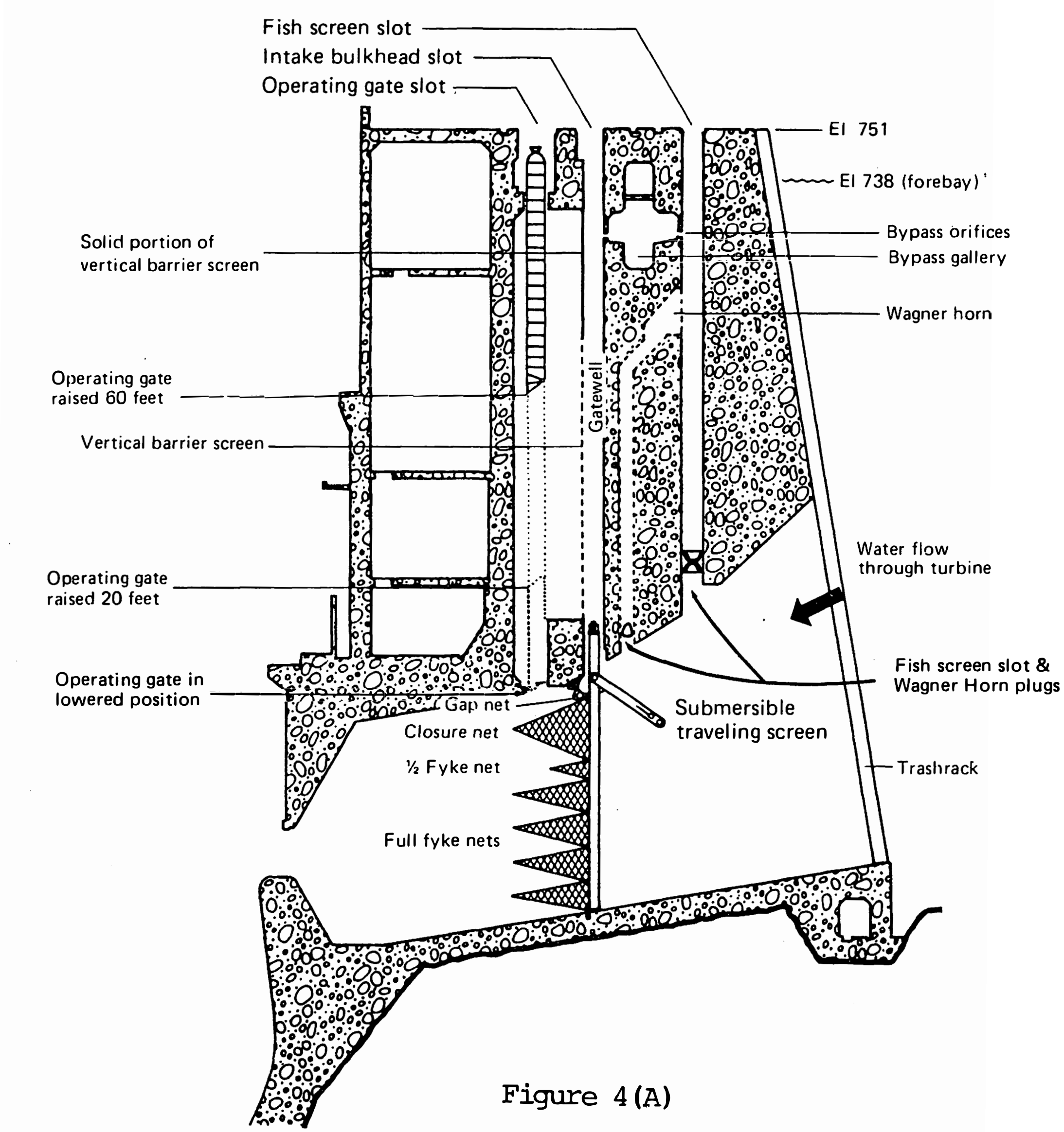

Figure 4(A)

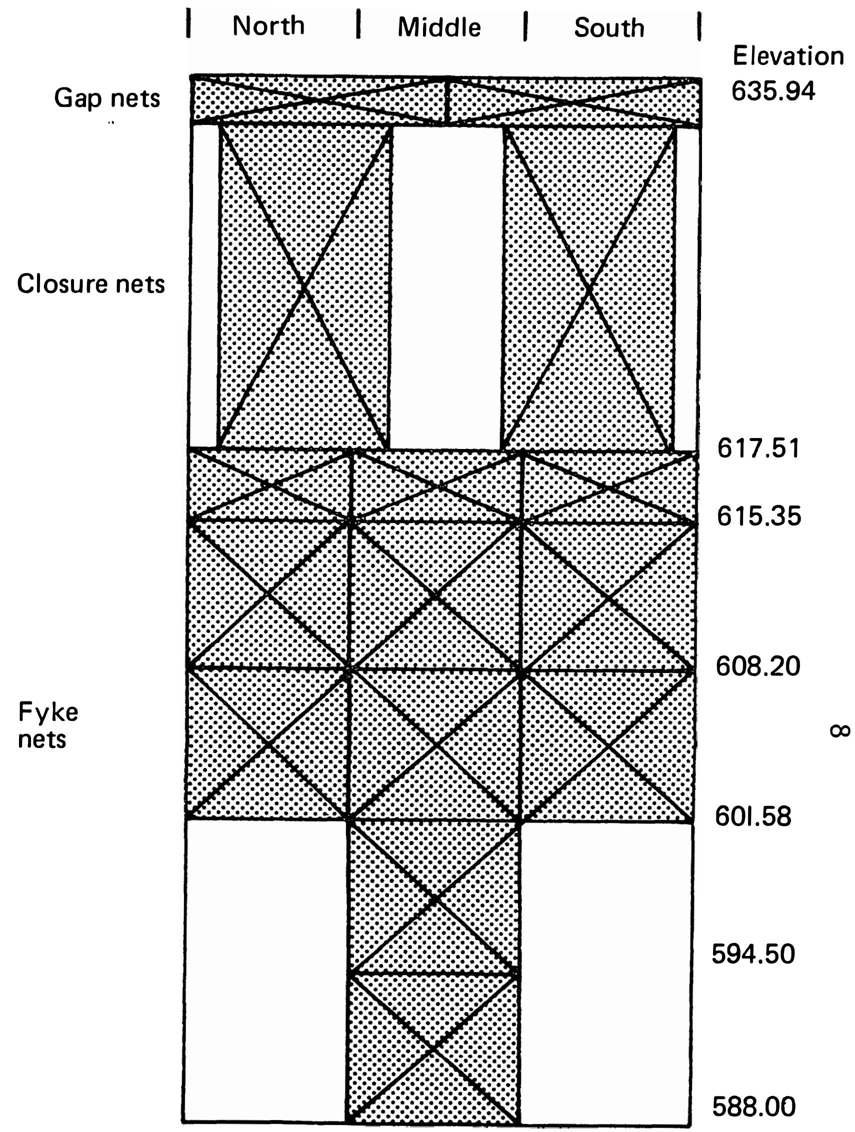

Figure 4(B)

Figure 4.--Cross section of turbine intakes at Lower Granite Dam showing STS, fyke nets, and varying positions of operating gates for FGE testing; a view showing the net layout in 1985 is also shown.

The following sequence of events was typical for conducting an STS FGE test:

1. The STSs in Units 4A and 4B with attached fyke-net frames were lowered into the intake with the gantry crane, and the STSs were extended to the fish guiding angle of 55°.

2. The BHSs were dipped to remove all fish present at that time.

3. The operating gates in Units 4A and 4B were set for the prescribed test condition.

4. The test started as Unit 4 was brought to peak efficiency (135 MW)--the turbine load for all tests conducted in 1985.

5. The numbers of fish entering the BHSs were monitored by periodic dipnetting, and the test was terminated when adequate numbers of fish for statistical needs were collected.

6. The turbine was shut down, and final cleanout dips were made.

7. The operating gates in Units 4A and 4B were returned to their normal or temporary stored position.

8. The STSs were retracted from the 55° angle and brought to the surface. Fish captured in the nets were removed for identification and enumeration.

After the initial test, the following additional steps became routine:

9. The fyke nets were checked for condition, the STSs with attached fyke nets and frames were again lowered into the intake extended to the guiding angle.

10. Just prior to starting the next STS FGE test, the operating gates in Units 4A and 4B were again set at the appropriate respective levels.

11. To begin the next test (about dusk the next evening), Unit 4 was brought on line to peak efficiency and the sequence was repeated.

During a test, the operating gate in one unit was raised 62 feet, and the gate in the other unit was raised 20 feet. The gate levels were reversed during the next replicate series. After sufficient replicates had been conducted to determine if there were significant differences in FGE between the 20- and 62-foot gate conditions, the remainder of the testing compared a standard gate condition to the 62-foot condition.

Seven tests were conducted (Table 1). During Tests 2 and 3, the trash boom was removed ("out"). The trash boom was in place during all other tests. Due to river flow conditions, only two tests were conducted with spill (20 and 40%). The remainder of the tests were performed under a no-spill condition.

NMFS researchers have long suspected that trash (driftwood) buildup in the forebay could affect juvenile salmonid behavior and possibly have some effect on FGE. During Test Series 3, an effort was made to simulate trash buildup in front of Unit 4. With the trash boom out, a COE fish transportation barge and the NMFS research barge were moored abeam of each other along the upstream face of the powerhouse directly over the entrance to the turbine intake of Unit 4. The barges remained in this position during two test replicates (23 and 24 April).

For each test condition, the experimental design required about 500 fish per replicate and a minimum of three replicates to be able to identify a difference of 10% or greater in FGE at an "α" = 0.05 level of significance with a power of test of 1- β" = 0.80. In the repeated trials, the number of replicates was determined using the formulas in Appendix A, as based on FGE

Table 1.--Fish guiding efficiency (FGE) tests and simultaneous vertical distribution (VD) tests were conducted at 135-MW turbine loads with the following conditions in Turbine Unit 4 at Lower Granite Dam in 1985.

Test series no.	Test Condition: FGE tests in Units 4A & 4B[a/] (ft)	Test Condition: Vertical distribution tests in Unit 4C[b/] (ft)	Trash boom	Spill %	No. of replicates: FGE	No. of replicates: VD
1	20 vs 62	0	in	0	5	5
2	20 vs 62	0	out	0	4	4
3	0 vs 62	0	out	0	4	4
4	0 vs 62 (two tests)	0	in	0	4	4
5	0 vs 62	0	in	40	1	1
6	0 vs 62	0	in	0	3	1
7	0 vs 62	0	in	20	3	1

a/ Position of the operating gate (raised 0, 20, or 62 feet). Conditions were reversed alternatively for each replicate.

b/ All tests conducted with the operating gate in the standard stored position.

standard error of 0.0314 obtained from other FGE studies. Contingency table procedures applying the G-test (Sokal and Rohlf 1981) and a balanced cross-over analysis of variance[1/] were used in the statistical analysis.

Each test started between 1800 and 1900 h and was conducted from 1 to 5 h until adequate numbers of guided fish were collected for statistical analysis, as determined by gatewell dipnetting. This would vary depending upon FGE. If FGE was anticipated to be about 60%, then testing would stop after about 300 fish (of the target species) were guided. For 70% FGE, testing would stop when 350 fish were guided. For most tests in 1985, the target number was 300 guided fish.

The procedures for determining FGE were similar to those used in previous experiments of this type (Swan et al. 1983, 1984, 1985). Gatewell dipnet catches provided the number of guided fish; catches from nets attached to the STS provided the estimates of the percentage of unguided fish. Guided fish included fish from the BHS only. FGE was calculated as guided fish divided by the total estimated number of fish passing through the intake during the test period:

$$FGE = \frac{GW}{GW+GN+FN+1.5\,(CN)} \times 100$$

GW = gatewell catch (BHS)
GN = gapnet catch
FN = fyke net catch (multiplied by 3 when fishing only the center one-third of the intake)
CN = closure net; the closure net catch was expanded by 1.5 because the closure nets only fished two-thirds of the area.

[1/] Recommended by Dr. Lyle D. Calvin, Consulting statistician for the COE.

Vertical Distribution Tests

Vertical distribution tests provided the means to determine: (1) how deep chinook salmon and steelhead were traveling in the turbine intake, and if this figure varied through the migration; (2) theoretical FGE (TFGE) based on numbers of fish in the intake that potentially were in the area that could be intercepted by an STS; and (3) an estimate, that could be calibrated with concurrent hydroacoustic tests, of total passage through the intake over several hours.

Tests were conducted in Unit 4C simultaneously with FGE tests in Units 4A and 4B. The operating gate in Unit 4C was in the standard stored position. The top three horizontal rows of the vertical distribution net frame were fully netted in an effort to balance the flows. To minimize fish mortality, only the center vertical column of nets, from ceiling to floor of the turbine intake, had cod ends attached and caught fish (Fig. 5). An analysis by Ossiander[2/] of over 200 replicates of previous FGE and vertical distribution tests at several dams demonstrated that the center row of nets caught about the expected 33% of the total catch. A standard replicate for vertical distribution was conducted in a similar manner and length of time as the FGE tests, i.e., closing the orifice, lowering the net frame, dipnetting the gatewell, etc. At the end of each test, individual net catches were identified and enumerated by species. Vertical distribution was based on an estimate of the total number of fish entering the intake. Since the center column of fyke nets fished one-third of the intake, each net catch was

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2/ Memo 10 March 1986, F. Ossiander to Teri Barila, COE. "Comparisons of center and side net catches from FGE and vertical distribution tests".

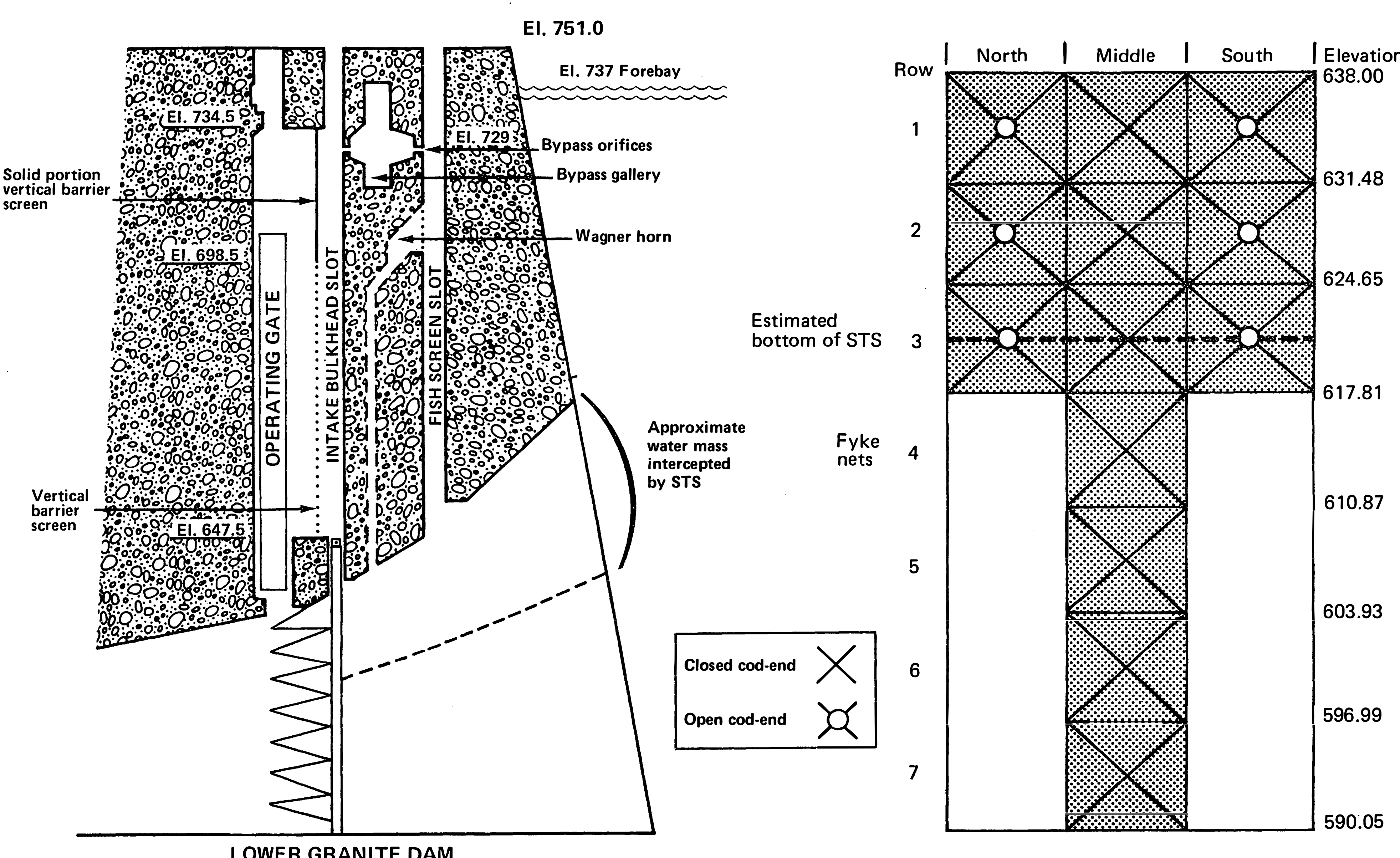

Figure 5(A)

Figure 5(B)

Figure 5.--Fyke net frame and nets at Lower Granite Dam to study the vertical distribution of juvenile salmonids entering a turbine intake; a view showing the layout of fyke nets in 1985 is also shown.

multiplied by a factor of three to estimate the number of fish at that net level. The sum of these estimates plus the gatewell catch provided an estimate of the total number of fish and their distribution when entering the intakes. The percentage of fish for each net level (vertical distribution) was determined by dividing the computed net level catch by the total intake estimate. The (TFGE) estimate was derived by dividing the number of fish caught in the upper two and one-half nets by the total intake estimate. Confidence intervals (CI) for each net catch at the 95% level were defined using the expression:

$$P \pm t_{(1-\alpha/2,\ K-1)}\ S/\sqrt{K}$$

Where: K = number of replicates
S = standard deviation among replicates
α = probability of Type I error.

Fish Quality

Descaling of fish in the BHS was monitored as a measure of fish quality for each FGE and vertical distribution test. Descaling was determined by dividing each side of the fish into five equal areas; if any two areas on a side were 50% or more descaled, the fish was classified as descaled.

RESULTS

STS Fish Guiding Efficiency

A total of seven test series consisting of 25 individual tests were conducted between 11 April and 2 June. The test conducted on 16 April was not used in the statistical analysis of the data, as only one span of the trash boom had been removed at that time. Tables 2 and 3 list the test conditions and the corresponding FGE and TFGE percentages (a numerical listing by species in these tests is shown in Appendix B).

Table 2.--Results of fish guiding efficiency (FGE) and vertical distribution tests on yearling chinook salmon at Lower Granite Dam in 1985.

Test series no.	Dates	No. reps.	Unit 4-C % TFGE[a]	Units 4-A & 4-B % FGE	Units 4-A & 4-B % FGE	Trash boom	Spill (%)
			No raised operating gate	Operating gate raised 20 feet	Operating gate raised 62 feet		
1	11-15 Apr[b]	5	59.6	40.0	40.1	in	0
2	17, 19-21 Apr	4	53.5	35.6	36.6	out	0
				Operating gate raised 0 feet	Operating gate raised 62 feet		
3	22-25 Apr[c]	4	63.2	38.1	42.2	out	0
4	29 Apr-2 May[d]	4	85.2	59.9	70.9	in	0
5	5 May	1	82.6	58.5	50.3	in	40
6	15-17 May[d]	3	75.8 (1 rep)	60.1	72.1	in	0
7	31 May-2 Jun[e]	3	82.3 (1 rep)	55.7	65.3	in	20

[a] Based on results of vertical distribution studies.

[b] The replicate of 16 April was not used in analysis due to partial trash boom configuration.

[c] 23 and 24 April - Barges moored in front of Unit 4 to simulate trash buildup.

[d] Test condition identical in Series 4 and 6. The combined results show that the 71% FGE measured with the operating gate raised 62 feet is significantly higher ($G = 100.21$, $df = 1$, $P < 0.001$) than the 60% FGE measured with the operating gate not raised (standard Lower Granite condition).

[e] Shows a significant benefit ($G = 14.85$), $df = 1$, P 0.001) for raised operating gate but a slightly lower percent than Tests 4 and 6.

Table 3.--Results of fish guiding efficiency (FGE) and vertical distribution tests on steelhead at Lower Granite Dam in 1985.

Test series no.	Dates	No. reps.	Unit 4-C % TFGE[a]	Units 4-A & 4-B % FGE	Units 4-A & 4-B % FGE	Trash boom	Spill (%)
			No raised operating gate	Operating gate raised 20 feet	Operating gate raised 62 feet		
1	11-15 Apr[b]	5	80.9	72.3	67.2	in	0
2	17, 19-21 Apr	4	85.3	72.1	74.1	out	0
				Operating gate raised 0 feet	Operating gate raised 62 feet		
3	22-25 Apr[c]	4	86.3	74.1	73.3	out	0
4	29 Apr-2 May[d]	4	90.7	80.4	84.5	in	0
5	5 May	1	68.6	69.1	68.4	in	40
6	15-17 May[d]	3	89.2 (1 rep)	80.4	85.4	in	0
7	31 May-2 Jun	3	88.8 (1 rep)	82.7	87.2	in	20

a/ Based on results of vertical distribution studies.

b/ The replicate of 16 April was not used in analysis due to partial trash boom configuration.

c/ 23 and 24 April - Barges moored in front of Unit 4 to simulate trash buildup.

d/ Test condition identical in Series 4 and 6.

Initial tests, as in 1984, produced exceptionally low FGE (31 to 40%) for the target species, yearling chinook salmon. Also, as in 1984, FGE improved later in the season and acceptable FGEs (70% or better) were attained about 1 May. In contrast, FGEs for steelhead, as in previous years, generally remained high all season. The lack of change in FGE for steelhead vs increasing FGE over time for yearling chinook salmon in both 1984 and 1985 (Fig. 6) suggests that biological factors (e.g., level of smoltification) rather than mechanical factors may be affecting FGE of yearling chinook salmon.

No significant difference in FGE was measured between the 20-foot vs 62-foot raised gate during a no spill condition with either the boom in (40.0 vs 40.1% FGE) or with the boom out (35.6 vs 36.6% FGE) (Table 2). However, a significant difference was found between the standard stored gate vs 62-foot raised gate (38.1 vs 42.2% FGE) with the trash boom removed and no spill during Test 3 (G^2 = 19.54, df = 1, $P < 0.001$) (Table 4). As the season progressed and FGE improved to 70% or greater, we measured an even greater benefit for the 62-foot raised gate as shown in Tests 4 and 6. The average FGE with the gate raised 62 feet was 71.5% vs 60% with the standard stored gate (G^2 = 100.21, df = 1, $P < 0.001$).

A balanced cross-over analysis of variance was applied to the comparisons at the 20- vs 62-foot and 0- vs 62-foot gate, and the results were:

1. 20- vs 62-foot gates

    Null hypothesis: FGE the same using 20- vs 62-foot heights

    Alternative hypothesis: FGE better with 62-foot height

    $t = -0/7$, 4 df, $P > 0.50$

    We have no evidence for different FGEs with the two heights tested.

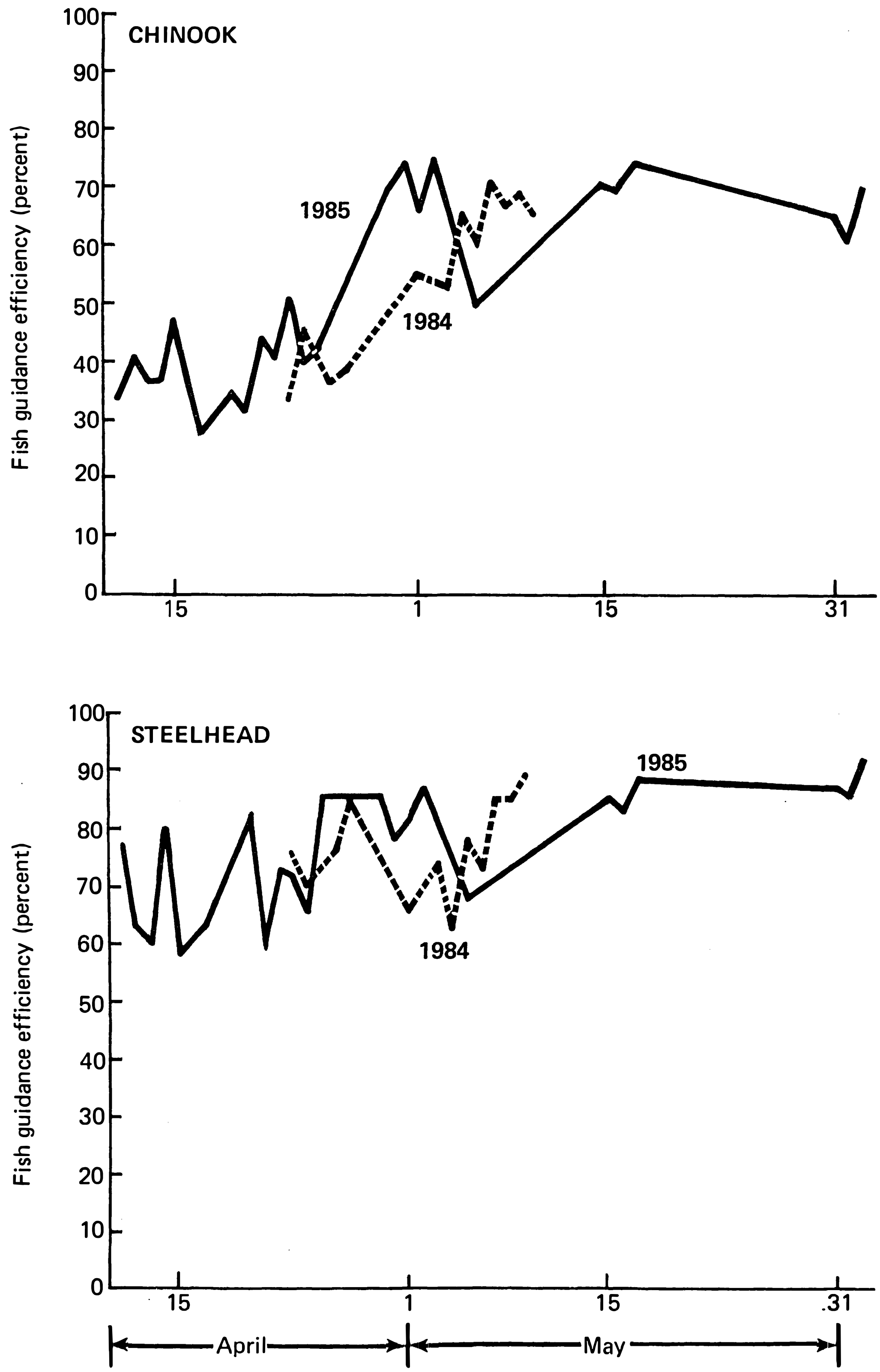

Figure 6.--Comparisons of fish guiding efficiency over time for yearling chinook salmon and steelhead at Lower Granite Dam in 1984 and 1985.

Table 4.--Statistical analysis of Lower Granite Dam FGE tests for yearling chinook salmon, 1985.

For the 11 to 25 April data:

- no significant difference between 20-foot vs 62-foot raised operating gate for the boom in or out. (Tests 1 and 2)

  IN: $G^2 = 0.025$, df = 1, P = 0.86 N.S.

  OUT: $G^2 = 0.001$, df = 1, P = 0.97 N.S.

- significant difference between 0-foot vs 62-foot raised operating gate for the boom OUT. (Test 3)

  $G^2 = 19.54$, df = 1, P < 0.001 *

For the 29 April and later data:

- highly significant difference between standard stored gate vs 62-foot raised gate for the boom in an no spill. (Tests 4 and 6)

  $G^2 = 100.21$, df = 1, P < 0.001 *

  $G^2 = 52.38$, df = 1, P < 0.001

- significant difference between standard stored gate and 62-foot raised gate for the boom in and 20% spill. (Test 7)

  $G^2 - 14.85$, df = 1, P < 0.001 *

- no difference between 0 vs 20% spill with the standard stored gate with the boom in. (Test 6 vs 7)

  $G^2 - 4.43$, df = 1, Padj. 0.017 N.S.

- no difference between 0 vs 20% spill with the 62-foot raised gate with the boom in. (Test 6 vs 7)

  $G^2 = 9.30$, df = 1, Padj. < 0.05 N.S.

- no difference between 0 and 40% spill with the standard stored gate and the boom in. (Test 4 vs 5)

  $G^2 - 0.16$, df = 1, P = 0.69 N.S.

- significant difference between 0 and 40% spill with the 62-foot raised gate and the boom in. (Test 4 vs 5)

  $G^2 - 31.82$, df = 1, Padj. < 0.01 *

2. 0- vs 62-foot gates

Null hypothesis: FGE the same using 0- and 62-foot heights

Alternative hypothesis: FGE better with 62-foot height

$t = 5.4$, 5 df, $P < 0.05$

Conclude that the 62-foot gate gives better FGE.

No futher comparisons were made since conclusions were the same as those derived from use of the G-test.

Constraints were placed on our research schedule by the Fish Passage Center, fisheries agencies, and the Columbia River Inter-Tribal Fish Commission that prevented us from fully testing the influence of the trash boom with and without spill. However, one test at the 40% spill condition was accomplished and served to demonstrate the impact that heavy spill (with the trash boom in place) had on FGE for both chinook salmon and steelhead. For chinook salmon, FGE dropped significantly from 70.9 to 50.3% [Test 4, compared to Test 5 ($G^2 = 31.82$, df = 1, Padj. < 0.01)] with the raised operating gate. There was no difference, though, with the standard stored gate setting. For steelhead, FGE dropped substantially from over 80% (Test 4) to about 69% (Test 5) for both the raised and standard gate setting. The lack of difference at the standard gate setting for chinook salmon cannot be explained.

With 20% spill (Test 7 - 3 replicates), FGEs for chinook salmon were 65.3% (62-foot raised operating gate) and 55.7% (standard gate setting), less than the 72.1 and 60.1%, respectively, in Test 6 (no spill). The difference, however, was not significant. There was no difference in FGE for steelhead between no spill and 20% spill conditions.

There appeared to be no influence on FGE as a result of mooring the barges in front of Unit 4 during Test Series 3. Perhaps the barges did not cover a large enough surface area of the forebay. Also, personnel working on the fish barge during the daytime may have created enough disturbance to discourage fingerlings from concentrating under the barges. In addition, the draft of the barges is about 4 to 6 feet compared to trash floating on the forebay surface.

In 1983, the FSSs in the test units were closed near the intake ceiling. These efforts were not successful, as fish continued to enter the FSSs. An underwater inspection by NMFS scuba divers revealed there were gaps between the Wagner Horn screens and the FSS walls that allowed fish to swim freely to and from the Wagner Horn conduits and the FSSs. In 1984, the FSSs were again closed. In addition, the Wagner Horns were also plugged. These closures failed also, as fish continued to enter the FSSs. In 1985, the COE made special plugs and closures and had them installed by commercial divers. Again, these special plugs and closures were not successful, as a substantial number of fish (primarily steelhead) were found to have entered the FSSs.

Vertical Distribution Tests

The extensive vertical distribution testing at Lower Granite Dam between 11 April and 25 June in 1985 provided the first opportunity to observe the seasonal changes in vertical distribution in the intake as compared to concurrent FGE measures. Testing began earlier in the season than in any previous year. The chinook salmon were much deeper in the intake between 11 and 15 April (Fig. 7) than between 29 April and 2 June (Fig. 8). Figures 9 and 10 show the positive correlation between TFGE and actual FGE as the season progressed. When initial FGE was unacceptably low (about 40%), TFGE estimates

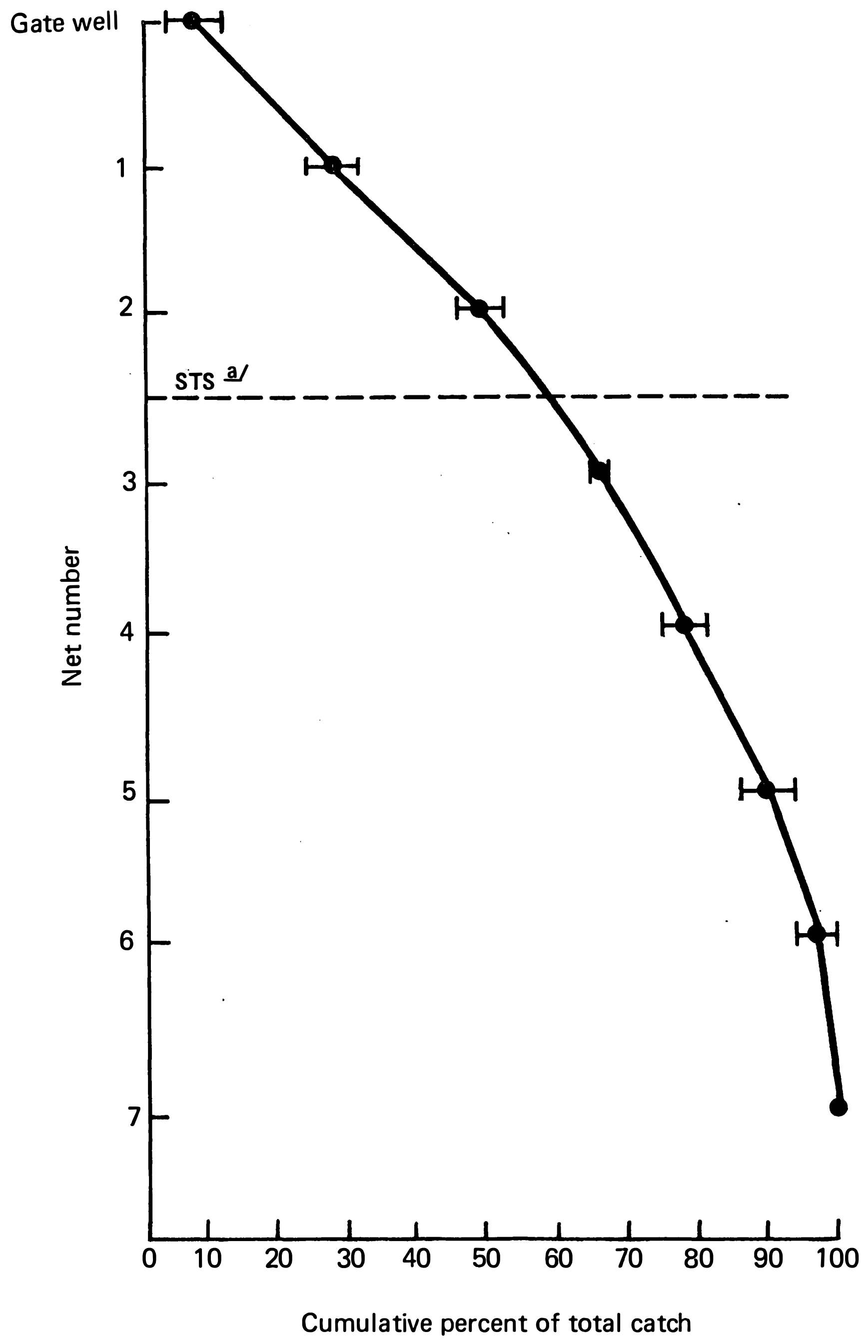

Figure 7.--Vertical distribution curve for early season (11-15 April) tests for yearling chinook salmon at Lower Granite Dam, 1985. The capped lines represent upper and lower 95% confidence limits about the individual points on the curve.

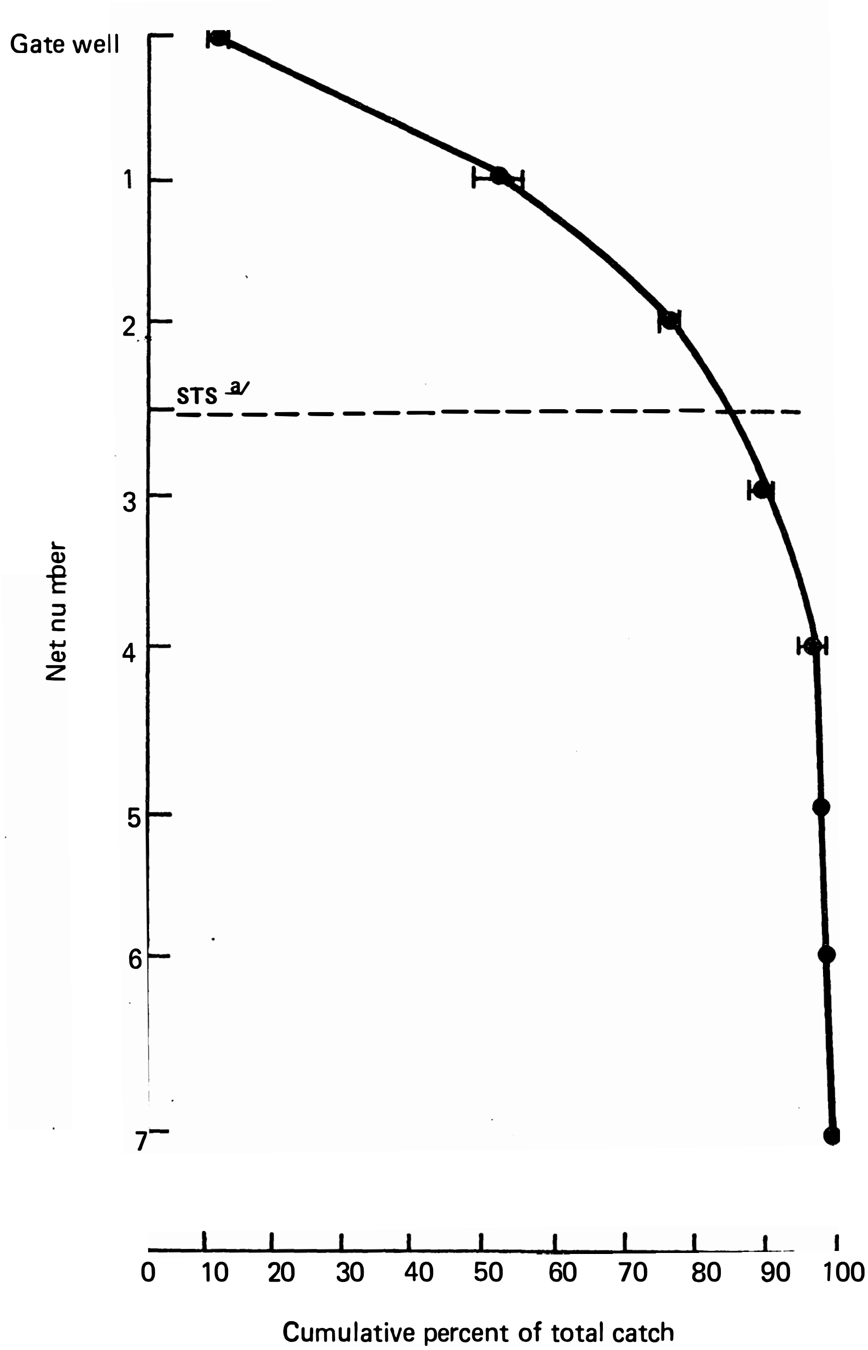

Figure 8.--Vertical distribution curve for late season (29 April through 2 June) testing for yearling chinook salmon at Lower Granite Dam, 1985. The capped lines represent upper and lower 95% confidence limits about the individual points on the curve.

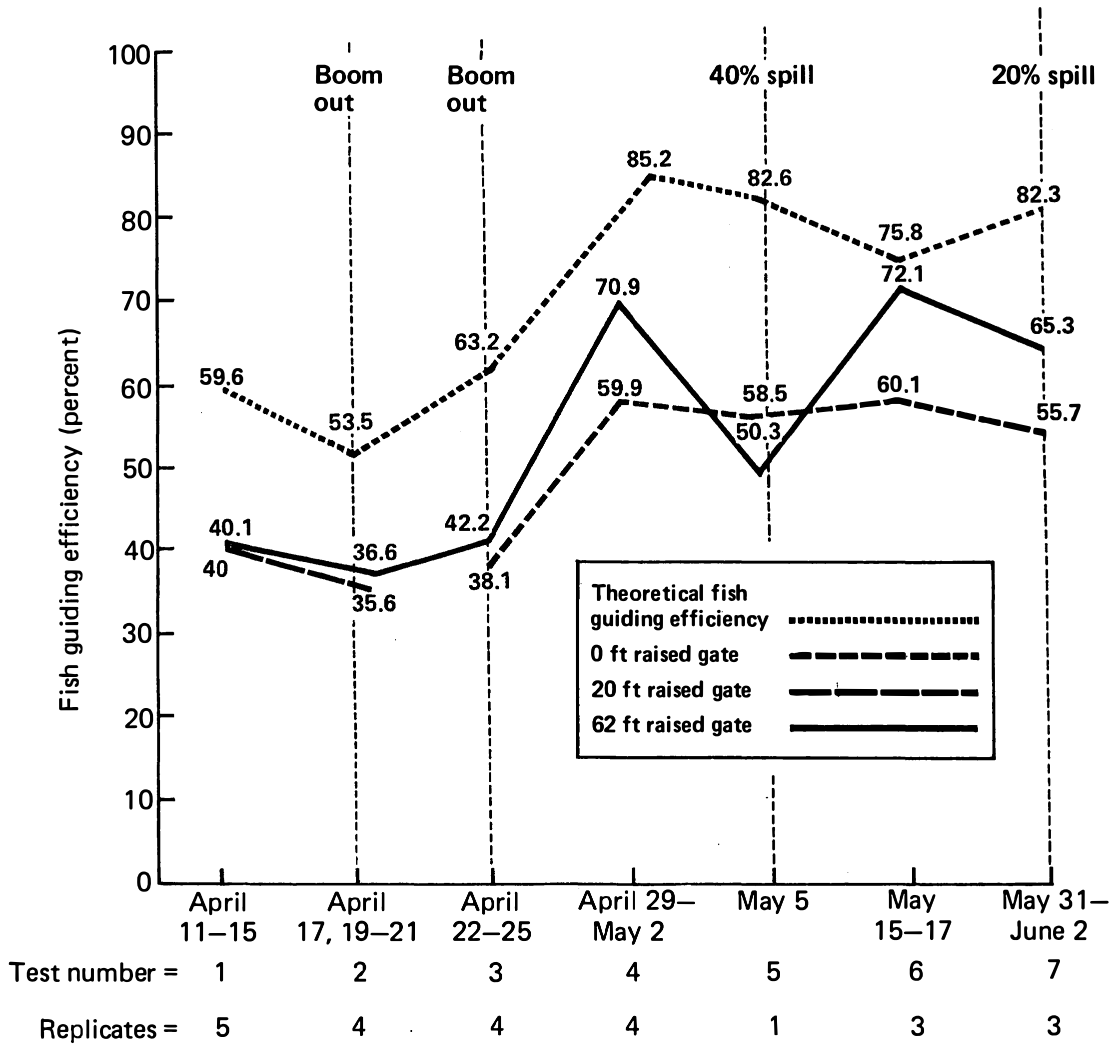

Figure 9.--Comparisons of theoretical fish guiding efficiency and fish guiding efficiency over time for yearling chinook salmon at Lower Granite Dam, 1985, under varying test conditions.

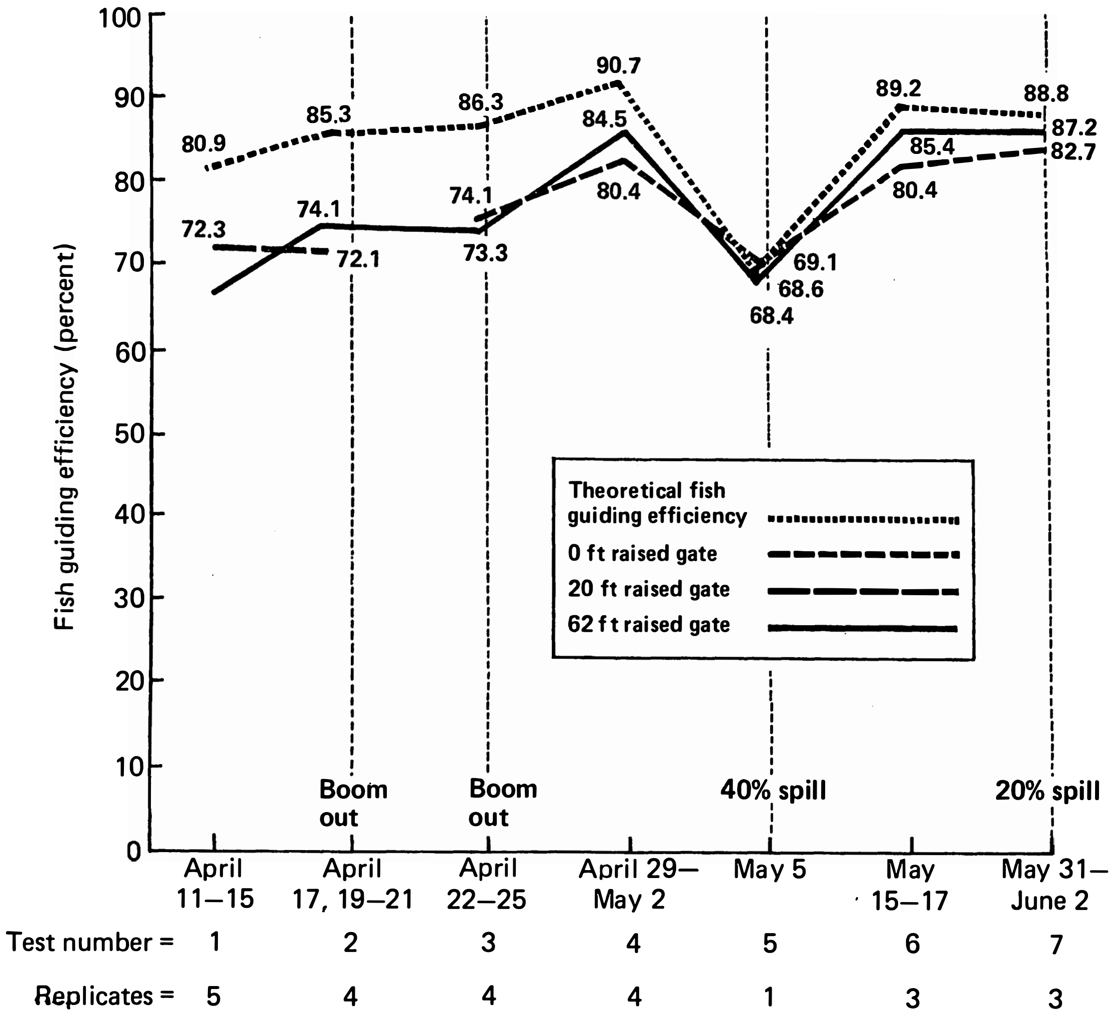

Figure 10.--Comparisons of theoretical fish guiding efficiency and fish guiding efficiency over time for steelhead at Lower Granite Dam, 1985, under varying test conditions.

were also low (less than 60%). Later in the season (29 April and later), when actual FGE reached 71%, TFGE measured about 85%. The range of differences between actual FGE and TFGE for early and late in the testing season was relatively constant.

Fish Quality

Fish condition remained acceptable throughout the season. Descaling was monitored for all test conditions throughout the testing season, and seasonal averages did not exceed 1.4% for chinook salmon or 1.9% for steelhead in any test condition (Table 5).

CONCLUSIONS

1. As in 1984, FGE of yearling chinook salmon increased from about 35 to 40% early in the season to about 70% by 1 May. FGE for steelhead remained high throughout the season. This would suggest that biological factors (e.g., level of smoltification) rather than mechanical factors may be affecting FGE. The 14% difference between TFGE and actual FGE (as at other dams--Bonneville, The Dalles, etc.) probably continued to be deflection of fish under the STS.

2. No significant difference in FGE was found between the 20- vs 62-foot raised operating gate with the trash boom installed or removed.

3. The 62-foot raised operating gate condition provided significantly higher FGE than the standard stored operating gate condition.

4. There was a decline in FGE with 20 and 40% spill with the trash boom in place.

5. There was a good correlation between TFGE and FGE; i.e., the higher the TFGE, the higher the FGE.

Table 5.--Descaling for yearling chinook salmon and steelhead sampled in FGE and vertical distribution testing at Lower Granite Dam, 1985.

Operating gate level (feet)	Fish guiding efficiency tests with balanced flow vertical barrier screen: Unit 4A	Fish guiding efficiency tests with balanced flow vertical barrier screen: Unit 4B	Vertical Distribution with standard vertical barrier screen in Unit 4C
	Chinook salmon (% descaled)		
0	1.1	0.6	1.4
20	0.8	0.1	
62	1.2	0.9	
Grand average	1.1	0.6	
	Steelhead (% descaled)		
0	1.0	1.5	1.5
20	0.8	1.3	
62	1.5	1.9	
Grand average	1.3	1.6	

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APPENDIX A

Sample Sizes Needed for Comparative Trials

In these experiments we are mainly concerned with comparing different treatment groups to determine the best condition. In some cases a comparison is made against a standard value or an estimate of an average value is desired. In the design of these studies, it is necessary to determine the sample sizes required to assure acceptable results.

Typically, the information needed to determine sample sizes and number of replicates required is the experimental error variance, s^2; the size of the effect to be detected, δ ; the number of means being compared, k; and α the and β levels (the probability of a Type I error, α , and the probability of a Type II error, β) desired from the statistical test. It is usual to specify α , β and δ to satisfy research objectives. For the studies considered here we use $\alpha = 0.05$, $\beta = 0.20$ and $\delta = 0.10$. We estimate a value for the standard error, s, based on compilation of data from past fish guidance efficiency (FGE) studies. From these data we obtained a value of 0.0314 for chinook salmon and a value of 0.0272 for steelhead. Limited data from other species show slightly lower standard errors. We have used the value obtained from chinook salmon in our sample size computations.

The data are collected in the form of fish counts and will often be used directly in contingency table analysis. For this analysis, sample size formulas will be used which apply to categorical data. In some tests, the FGE is expressed as a percentage and an average value is also estimated. Standard randomized block procedures apply to these situations.

In these studies we are dealing with research on fish in their natural environment. It is not anticipated that our experiments will contain the uniformity of laboratory studies. When conditions provide the opportunity, we plan additional repeated measurements as assurance against the lack of uniformity in field conditions. These may not be stipulated by a formal experimental design. They have several uses in subsequent data analysis. Replicated measurements should steadily decrease the error associated with the comparisons among treatment groups, and they can also be used to make an assessment of measurement accuracy, e.g., the closeness among comparable measurements (Tsao and Wright 1983). This assessment is especially useful to identify problem areas in the data collection system which may require special investigation. For a more lucid and comprehensive discussion see Cochran and Cox (1957) and Mosteller and Tukey (1977).

In these experiments, we compare experimental units by means of a test of significance. We will be attempting to establish that one procedure is superior or different than another by at least some stated amount. Consequently, the experiments must be large enough to reasonably ensure that if the true difference is equal to or greater than the specified amount, we have a high probability of detecting it, or obtaining a statistically significant result. The procedures used as follows provide an approximation that is adequate for design purposes. The notation for the formulas is given below.

1. Two group comparison case: This case is concerned with determining whether one condition is better than another condition (a one-way comparison), or with determining whether two conditions differ (a two-way comparison). The formula used is:

$$NT = (ZA + ZB)^2 / 2 (\arcsin \sqrt{P} - \arcsin \sqrt{P2})^2.$$

This formula is given by Paulson and Wallis (1947), it is also used by Cochran and Cox (1957), sample size graphs calculated by Feigl (1978) and Lemeshow et al. (1981) showed that it provided the closest approximation to an exact method when the underlying proportions are small. This formula may be expressed in different forms, depending on the definition of ZA and ZB. We follow the form used by Feigl. The formula applies to categorical data.

2. More than two groups or multinomial case: The procedures used for obtaining confidence intervals and sample sizes follow methods given by Angers (1984), Bailey (1980), Goodman (1965), and Miller (1966). The formula used is:

$$NM = [(B)\ (P_i\ (1-P_i)]\ /\ D^2.$$

3. For determining the number of replicates, the procedures follow those given in Steel and Torrie (1960), Cochran and Cox (1957), and Diamond (1981).

The formula used is:

$$R \geq 2\ (T_1 + T_2)^2\ (S^2)\ /\ D^2.$$

This formula is an approximation which depends on how well S^2 estimates the experimental error. Successive approximations must be used since the number of degrees of freedom associated with T_1 and T_2 depends upon R.

The following notation is used in the samples size formulas:

NT - sample size in the two group comparison.

ZA - standardized normal deviate exceeded with probability A. Where A is $1 - \alpha/2$ for the two-sided case and A is $1 - \alpha$ for the one-sided case.

ZB - standardized normal deviate exceeded with probability B. Where B is $1 - \beta$, for the one-sided case. This corresponds to the probability of obtaining a significant result. Note that ZB - -ZB' where B' equals β. Hence, (ZA + ZB) could be written as (ZA - ZB') without altering the value of NT.

P1 - proportion in the control group.

P2 - proportion in the test group.

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 $1-\alpha/k$ statistical precision level with one degree of freedom. Where k is the number of proportions being compared.

P_i - expected proportion in each multinomial category, i = 1, 2, ..., k.

D - level of difference it is desirable 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, α .

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, $1-\beta$.

S_2 - estimated experimental error, this is usually obtained from previous experiments.

The degrees of freedom for T_1 and T_2 are the product (L-1) (R-1), where L 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 assoicated with tabulated probability distribution values depends on sample size.

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APPENDIX B

Catch Data for Fish Guiding Efficiency and Vertical Distribution Tests at Lower Granite Dam, 1984

Appendix Table B1.—Catches of yearling chinook salmon and steelhead during fish guiding efficiency tests conducted at a 135 MW turbine load at Lower Granite Dam in spring of 1985.

				4-A FGE									4-B FGE								
				YEARLING CHINOOK SALMON					STEELHEAD				YEARLING CHINOOK SALMON					STEELHEAD			
Test No.	Date	Trash Boom	% Spill	Gate Position	Gatewell Number	Unguided (Est.)	Total	%	Gatewell Number	Unguided (Est.)	Total	%	Gate Position	Gatewell Number	Unguided (Est.)	Total	%	Gatewell Number	Unguided (Est.)	Total	%
1	4/11	in	0	20 ft	275	569	844	33	67	29	96	70	62 ft	262	506	768	34	58	17	75	77
	4/12	in	0	62 ft	583	845	1428	41	50	30	80	63	20 ft	620	1076	1696	37	45	21	66	68
	4/13	in	0	20 ft	1038	1999	3037	34	85	37	122	70	62 ft	940	1582	2522	37	58	38	96	60
	4/14	in	0	62 ft	448	774	1222	37	52	13	65	80	20 ft	517	710	1227	42	40	11	51	78
	5/15	in	0	20 ft	1192	1114	2306	52	55	14	69	80	62 ft	1062	1216	2278	47	36	26	62	58
	4/16 a/	span 1 removed	0	62 ft	370	671	1041	36	96	34	130	74	62 ft	382	561	943	41	97	26	123	79
2	4/17	out	0	20 ft	106	235	341	31	88	33	121	73	62 ft	89	227	316	28	55	31	86	64
	4/18	No test																			
	4/19	out	0	62 ft	387	734	1121	35	246	83	329	75	20 ft	414	726	1140	36	212	73	285	74
	4/20	out	0	20 ft	314	670	984	32	206	84	290	71	62 ft	324	675	999	32	286	62	348	82
	4/21	out	0	62 ft	536	678	1214	44	100	64	164	61	20 ft	518	715	1233	42	101	40	141	72
3	4/22	out	0	62 ft	933	1326	2259	41	199	74	273	73	0 ft	838	1545	2383	35	169	78	248	68
	4/23 b/	out	0	0 ft	220	340	560	39	315	97	412	76	62 ft	281	273	554	51	200	79	279	72
	4/24 b/	out	0	62 ft	754	1115	1869	40	172	89	261	66	0 ft	719	1073	1792	40	250	69	319	78
	4/25	out	0	0 ft	334	472	806	41	143	62	205	70	62 ft	432	575	1007	43	177	30	207	86
4	4/29	in	0	62 ft	449	189	638	70	219	36	255	86	0 ft	280	168	448	63	181	54	235	77
	4/30	in	0	0 ft	833	608	1441	58	219	75	294	74	62 ft	1030	370	1400	74	217	62	279	78
	5/01	in	0	62 ft	849	432	1281	66	545	121	666	82	0 ft	660	464	1124	59	540	131	671	80
	5/02	in	0	0 ft	346	179	525	66	1037	222	1259	82	62 ft	492	168	660	75	1125	168	1293	87
5	5/05	in	40	62 ft	90	89	179	50	2417	1119	3536	68	0 ft	100	71	171	58	2845	1271	4116	69
6	5/15	in	0	62 ft	321	134	455	71	1374	241	1615	85	0 ft	174	126	300	58	934	240	1174	80
	5/16	in	0	0 ft	357	208	565	63	1126	260	1386	88	62 ft	412	165	577	71	1086	218	1304	83
	5/17	in	0	62 ft	505	179	684	74	1091	146	1237	88	0 ft	365	262	627	58	832	205	1037	80
7	5/31	in	20	62 ft	143	76	219	65	908	139	1047	87	0 ft	116	113	229	51	764	161	925	83
	6/01	in	20	0 ft	194	149	343	57	1110	230	1340	83	62 ft	197	122	319	62	988	165	1153	86
	6/02	in	20	62 ft	171	73	244	70	933	110	1043	89	0 ft	101	65	166	61	604	128	732	83

a/ This replicate not used in analysis due to partial trash boom configuration.

b/ Barges moored in front of Unit 4.

Appendix Table B2.--Catches of yearling chinook salmon during vertical distribution tests in Bulkhead Slot 4-C at Lower Granite Dam, 1985.

	Test 1						Test 2					Test 3					Test 4					Test 5		Test 6		Test 7	
	April																		May							June	
Level[a/]	11	12	13	14	15	CUM %	17	19	20	21	CUM %	22	23[b/]	24[b/]	25	CUM %	29	30	1	2	CUM %	5	%	15	%	2	%
Gatewell	46	412	148	110	212	9	27	147	102	129	8	375	94	370	175	12	76	312	165	169	14	15	7	57	13	46	15
1	171	555	582	396	666	31	93	315	282	345	29	783	171	729	312	36	174	822	513	519	53	102	55	129	42	120	54
2	180	513	594	252	615	51	60	261	219	285	46	690	138	513	234	55	105	504	408	318	79	48	78	120	69	66	75
3	156	432	459	216	396	67	63	243	216	192	61	507	93	399	219	70	72	213	264	120	92	21	87	66	84	45	89
4	129	291	435	180	240	79	51	219	222	258	76	462	69	291	159	82	45	84	114	42	97	15	94	54	96	18	95
5	144	219	336	162	201	89	141	210	216	171	91	399	81	168	126	92	21	36	36	9	99	6	97	12	98	12	99
6	72	108	306	99	159	96	54	87	108	63	97	189	18	81	228	98	12	15	9	6		6	100	0	0	3	100
7	18	72	126	51	81	100	18	42	42	18	100	93	0	36	15	100	3	0	3	0	100	0		9	100	0	
Totals	916	2602	2986	1466	2570		507	1524	1407	1461		3498	664	2587	1468		508	1986	1512	1183		213		447		310	

a/ Levels one through seven refer to the level of the water column fished by the fyke nets used to determine the vertical distribution--Level One being the top net and Level seven the bottom net and the gatewell catch are actual numbers whereas levels one through seven reflect numbers which have been expanded by a factor of three to provide an estimate.

b/ 23 and 24 April - Barges moored in front of Unit 4 to simulate trash buildup.

Appendix Table B3.--Catches of steelhead during vertical distribution tests in Bulkhead Slot 4-C at Lower Granite Dam, 1985.

	Test 1						Test 2					Test 3					Test 4					Test 5		Test 6		Test 7	
	April																		May							June	
Level[a/]	11	12	13	14	15	CUM %	17	19	20	21	CUM %	22	23[b/]	24[b/]	25	CUM %	29	30	1	2	CUM %	5	%	15	%	2	%
Gatewell	27	42	26	28	28	28	22	68	321	61	36	117	103	219	128	31	34	108	305	762	32	1272	17	617	30	106	14
1	27	42	24	27	39	58	24	117	198	60	66	144	147	192	123	64	117	141	300	903	71	2139	45	735	65	351	60
2	12	15	24	9	21	73	15	78	75	39	81	84	81	102	66	82	69	93	129	279	86	1311	62	414	85	171	82
3	15	15	33	9	12	89	9	36	42	15	89	54	33	54	9	90	48	48	51	135	94	1023	75	192	94	93	95
4	9	6	3	0	9	94	27	15	24	24	96	27	21	39	21	96	30	24	42	39	98	720	85	93	98	33	99
5	0	6	0	0	6	96	15	9	9	3	99	15	3	18	0	98	9	6	18	15	99	699	94	24	99	6	100
6	0	0	3	3	6	98	3	3	0	12	100	9	15	3	3		3	3	6	9		381	99	12	100	0	
7	0	3	6	0	3	100	0	0	0	0		0	0	3	0	100	0	0	3	0	100	81	100	0		0	
Totals	90	129	119	76	124		115	326	669	214		450	403	630	350		310	423	854	2142		7626		2087		760	

a/ Levels one through seven refer to the level of the water column fished by the fyke nets used to determine the vertical distribution--Level One being the top net and Level seven the bottom net and the gatewell catch are actual numbers whereas levels one through seven reflect numbers which have been expanded by a factor of three to provide an estimate.

b/ 23 and 24 April - Barges moored in front of Unit 4 to simulate trash buildup.