CZES Coastal Zone and Estuarine Studies

Research to Develop Bar Screens for Guiding Juvenile Salmonids Out of Turbine Intakes at Low Head Dams on the Columbia and Snake Rivers, 1977–79

by

Richard F. Krcma, Winston E. Farr, and Clifford W. Long

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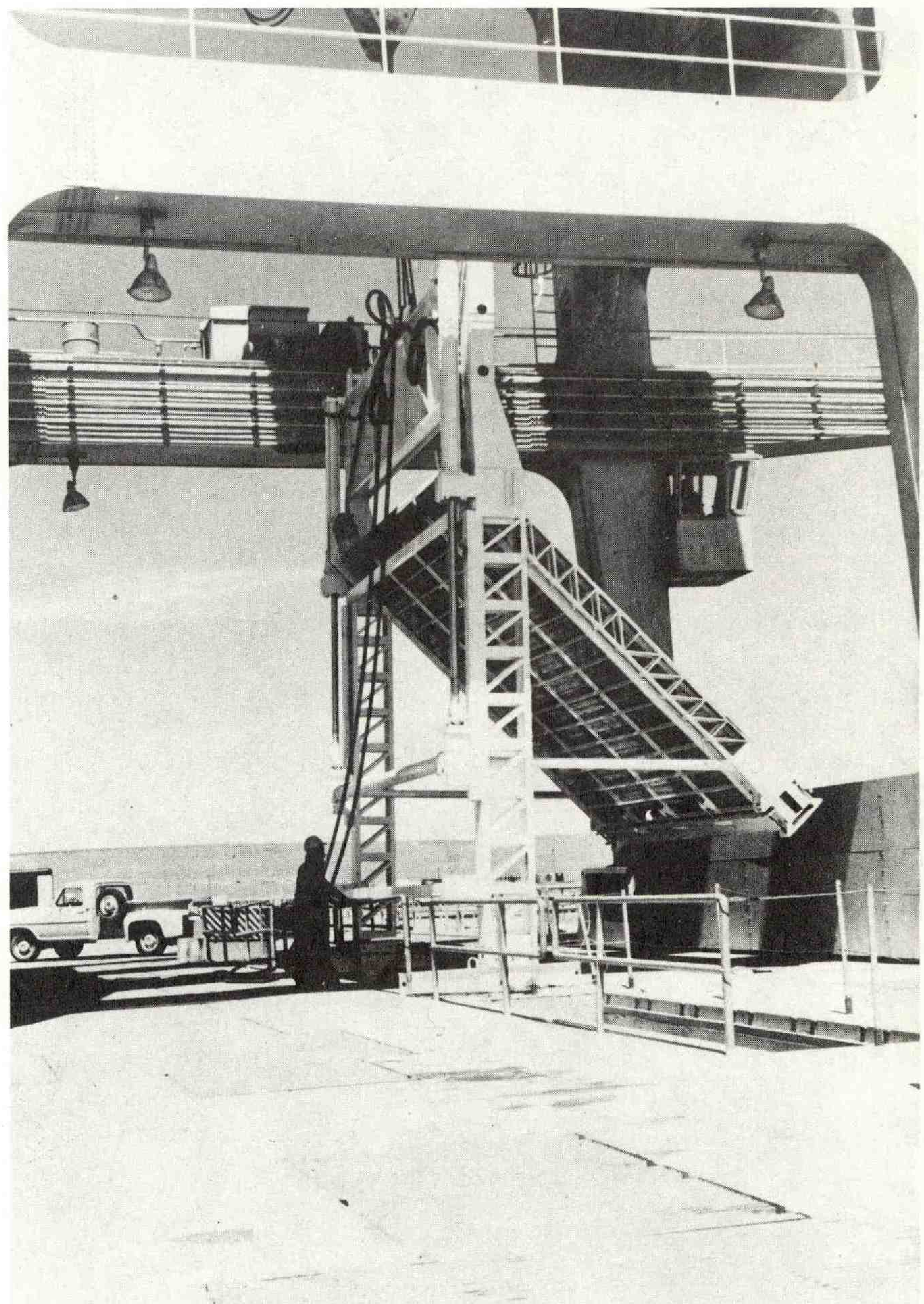
INTRODUCTION

Since 1975, the National Marine Fisheries Service (NMFS), under contract to the U.S. Army Corps of Engineers (CofE), has been conducting research to develop an improved fish protection system for use at Bonneville Dam, McNary Dam, and other CofE dams on the main stem of the Columbia and Snake Rivers. Part of the research objectives called for developing a less expensive (passive) screening system (bar screen) that could be substituted for the submersible traveling screen (STS) presently used to guide fish (mainly Pacific salmon, *Oncorhynchus* spp., and steelhead, *Salmo gairdneri*), out of turbine intakes at hydroelectric dams (Fig. 1) (Long and Krcma 1969; Farr 1974). This is the final report describing research conducted under Corps Contracts No. DACW57-79-F-0163 and DACW57-79-F-0274.

To reduce the losses of oceanbound fingerling salmonids a system for collecting the fish at upstream dams, transporting them around intermediate dams, and releasing them back into the Columbia River at a safe site below Bonneville Dam has been introduced on the Snake and Columbia Rivers (Fig. 2). By bypassing dams, losses due to turbine activity, predation, nitrogen supersaturation, pollution, and delays in passing through large reservoirs are avoided. Screening of the turbine intakes is an important part of the collection system.

The first phase of the study to develop the bar screen was conducted under controlled laboratory conditions. The second phase utilized the findings of the laboratory tests to design prototype screens for testing at dams on the Columbia.

Figure 1. The submersible traveling screen now in general use to guide oceanbound juvenile salmonids out of turbine intakes of dams on Columbia and Snake Rivers.



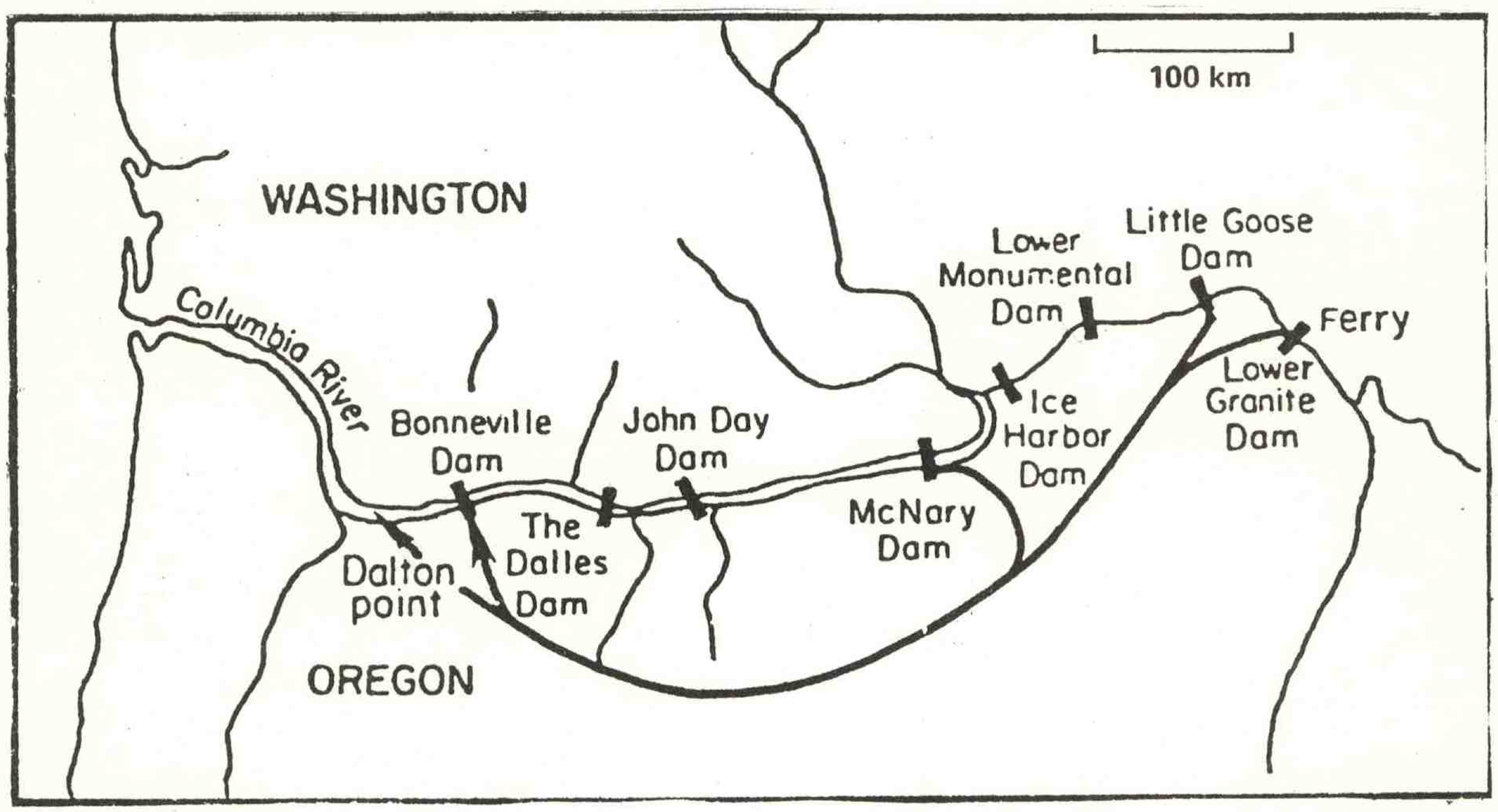


Figure 2.--Transportation routes and release locations for chinook salmon and steelhead collected at Little Goose, Lower Granite, and McNary Dams.

River. Initial prototype studies were conducted at Bonneville Dam in 1977 and 1978. Favorable results led to more extensive testing at McNary Dam in 1978 and 1979.

LABORATORY STUDIES

The laboratory studies were conducted in an oval flume--0.91 m (3.0 feet) wide, 2.1 m (7.0 feet) deep, and 4.88 m (16.0 feet) long (Ruehle et al. 1978). Three 50 hp pumps provided the capability of circulating water through the flume at velocities up to 2.44 m/s (8.0 feet/s).

Various types of screen materials were tested in the flume. They included flat bar screens designed by NMFS; commercially manufactured wedge bar screens of various porosities (hereafter termed Johnson Screen[1]); and a standard screen of crosswoven mesh (similar to that used on the STS). Fish of various lengths were subjected to each type of screen and examined for injuries such as descaling. In addition, tests were conducted with various types of debris to determine the self-cleaning tendencies of each type of screen and how readily each could be cleaned by backflushing or other methods.

From the results of these tests, the flat bar screen and the Johnson screen materials were chosen for testing in the turbine intakes at Bonneville and McNary Dams.

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1 Reference to trade names does not imply endorsement by the National Marine Fish. Service, NOAA.

FIELD STUDIES

The economic and practical feasibility of guiding downstream migrant salmonids out of a hydroelectric turbine intake using a passive fish screening system depends upon a number of factors:

1. The water velocity and guiding angle of the screen must be compatible with the size and swimming capabilities of the fish as computed using vector analysis (Kemeny et al. 1959).

2. The fish should be concentrated near the turbine intake ceiling so only a small amount of the total flow needs to be intercepted with the guiding device to guide a large percentage of the fish (75 to 85%).

3. The debris load in the river should allow a reasonable amount of operating time before the screen requires cleaning.

4. In addition, specific design considerations are necessary so the screening system will not endanger or seriously obstruct the operations of the dam.

Based on the results of the laboratory studies, we believed that fish could be guided safely out of the turbine intakes at both Bonneville and McNary Dams. Vertical distribution curves (Appendix A) established from previous research studies (Long 1968; 1975) indicated that fish-guiding devices that would intercept the upper 3.05 to 4.57 m (10.0 to 15.0 feet) of water at the intake gatewell could guide 80 to 90% of the salmon and steelhead at Bonneville Dam and 75 to 80% of these fish at McNary Dam.

Description of Experimental Equipment

Figure 3 is a transverse section through a turbine intake in a typical hydroelectric dam in the Columbia River. Each turbine has three such intakes. Each of the intakes is constructed with a gatewell that allows a bulkhead gate to be lowered into the intakes so the turbine can be unwatered for maintenance or repair. Fish guiding devices are installed within the intakes via these gatewells. The dimensions of the intakes at the gatewell are about 6.5 m (21.0 feet) wide and 15.5 m (51.0 feet) high.

The water velocities in each of the three intakes of a turbine unit are dissimilar depending upon the design of the turbine. In addition, the intake velocities vary between dams due to the size and shape of the intakes and the hydraulic head on the project. Maximum water velocities in the intakes at Bonneville and McNary Dams are 1.28 m/s (4.2 feet/s), and 1.83 m/s (6.0 feet/s), respectively.

The first bar screen tested was installed in Bonneville Dam by NMFS in 1977. Figure 3 shows the placement of the screen in the intake. The face of the bar screen was constructed of 0.32 cm (1/8 inch) x 2.54 cm (1.0 inch) steel bars placed on edge with a 0.48 cm (3/16 inch) space between them allowing a 60% open area (Fig. 4). The bar screen was slightly narrower than the width of the intake, 6.5 m (21.0 feet) and was 1.5 m (5.0 feet) long. In operation, the face of the bar screen intercepted the upper 1.07 m (3.5 feet) of flow within the intake or only 7.8% of the total area.

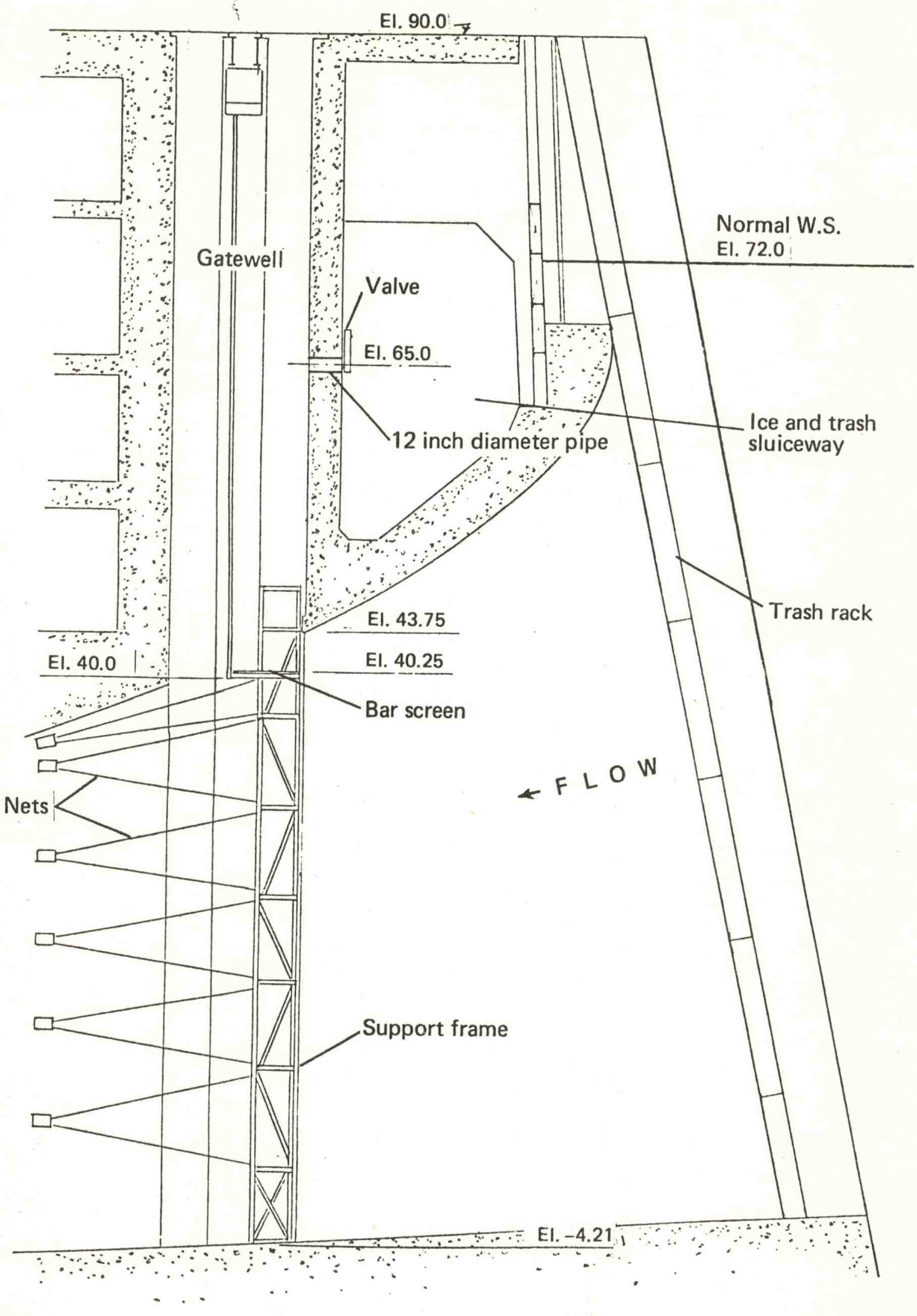


Figure 3.--Typical turbine intake at Bonneville Dam showing first prototype bar screen in position to guide fish out of intake and into gatewell.

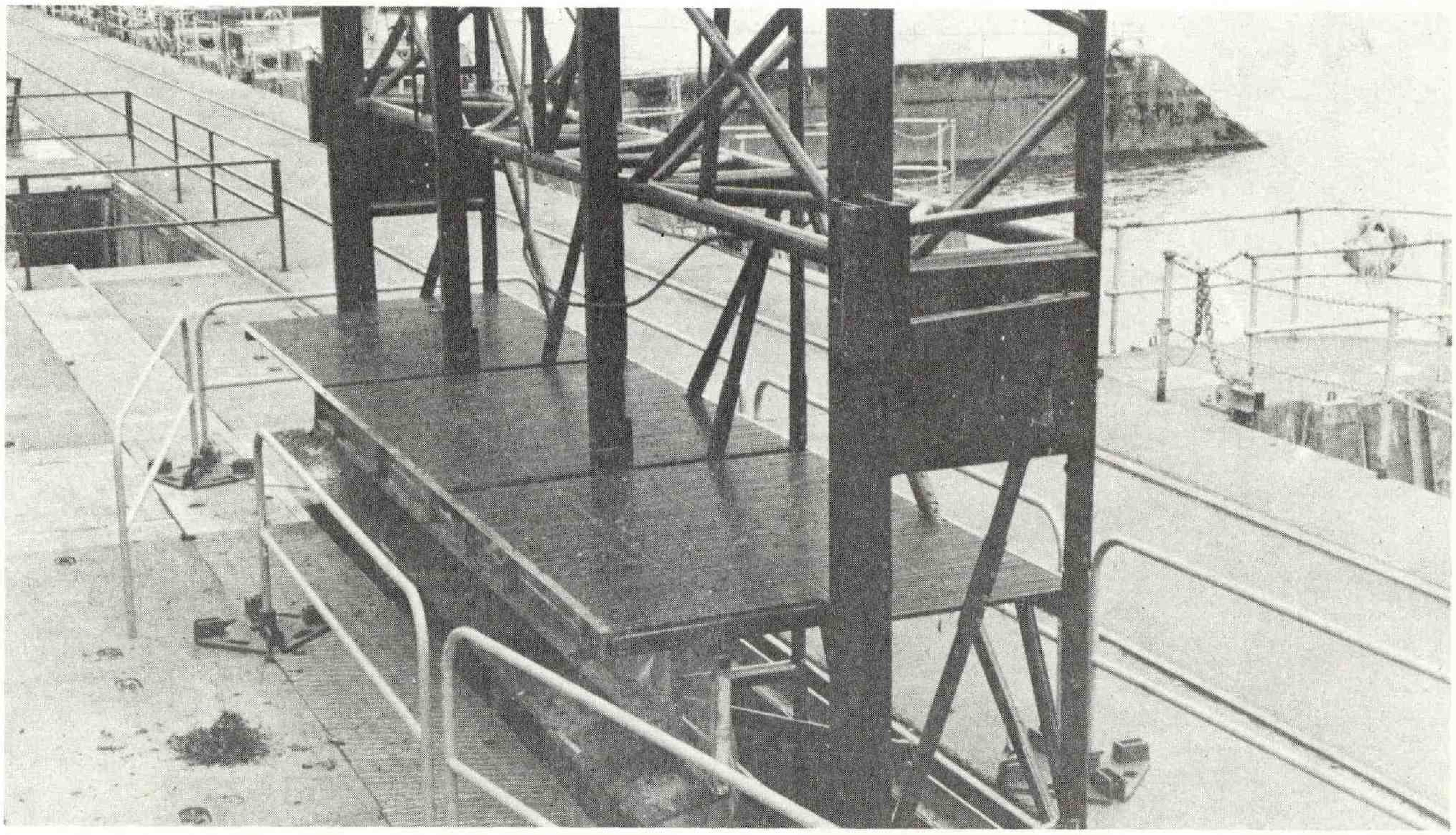


Figure 4. Bar screen tested in a turbine intake at Bonneville Dam in 1977–78.

Based on the favorable results of the 1977 tests at Bonneville Dam, a more advanced bar screen design was tested at McNary Dam. Because fingerlings are not as concentrated in the upper flows of the intakes (see Appendix A) of McNary Dam as they are at Bonneville Dam, a two-part bar screen system was designed. One section was attached to a trash rack [trash rack deflector (TD)] and the other was installed in the gate slot [gatewell deflector(GD)]. Figure 5 shows the placement of the GD in the gate slot and the TD on the trash rack.

The screen material on the GD and TD was Johnson Screen wire (No. 93 profile) made of 304 stainless steel with a 0.127 cm (0.05 inch) space between the wires. This configuration provides a 36% open area (porosity). The GD was 5.94 m (19.5 feet) wide (slightly less than the width of the intake) and 3.04 m (10.0 feet) long.

For experimental purposes, the GD (Model I) was designed so the panels at the downstream end could be placed at a different angle-to-flow than the panels at the upstream end (Fig. 6). After the GD was placed in position in the intake, the upstream panels could be operated, at 10° angle increments, through a range from a plus 20° to a minus 30° from horizontal.

The TD, 5.52 m (18.0 feet) wide by 6.10 m (20.0 feet) long, was attached to the downstream side of a trash rack section by means of a special hinged bracket. The downstream end of the TD could be raised until it touched the ceiling of the intake or be lowered until the face of the screen was parallel to the flow entering the intake. This was accomplished with an existing 100-ton gantry crane.

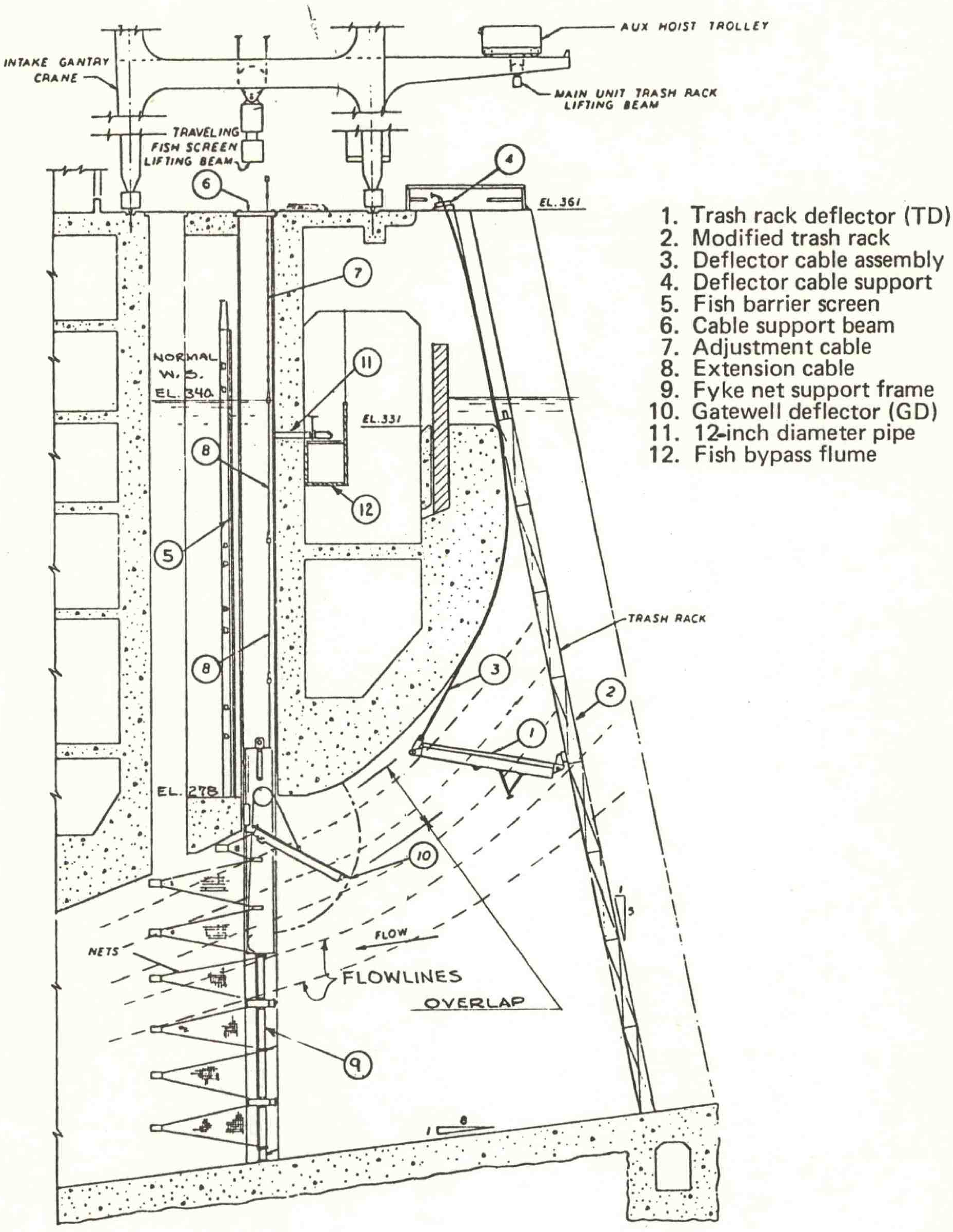


Figure 5.--Typical turbine intake at McNary Dam showing deployment of gatewell deflector and trash track deflector bar screens.

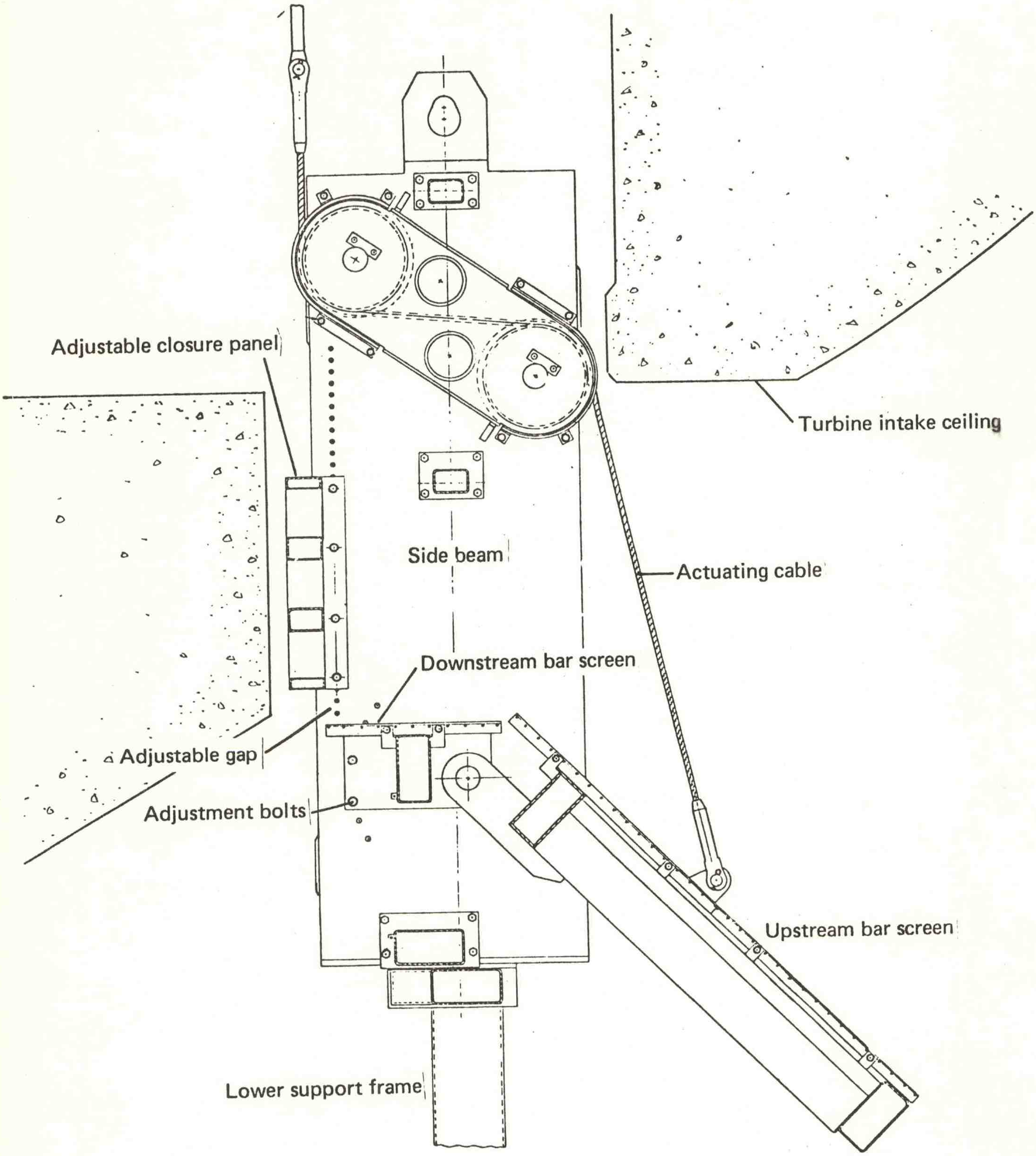


Figure 6.--Model I gatewell deflector tested at McNary Dam in 1978.

Following the tests at McNary Dam in 1978, the CofE redesigned the GD (renamed Model II) so that the upstream and downsteam panels were joined together by a single frame (Fig. 7). The overall length of the GD was increased to 4.88 m (16.0 feet) so that a greater percentage of the flow could be intercepted without increasing the angle-to-flow. The dimension of the TD remained the same. The bar screens were moved into fish-guiding position by use of cables actuated from the intake deck. In 1979, the construction costs of one prototype GD and TD assembly were $73,500 and $39,300, respectively, for a total of $112,800. The 1979 price for one STS was $112,000; however, costs based on life expectancy, routine maintenance, and repair would be much greater than for a passive screening system.

Figure 5 shows the equipment used in 1979. Three sets of bar screens (one GD and one TD=a set) were used so that all three intakes serving a single turbine could be screened. Each of the sets of bar screens utilized panels constructed of Johnson Screen wire to create different interspaces and porosities so that optimum interspace and porosities could be determined through field testing (Table 1). The support frames shown below the GD would not normally be required in an operational situation because they were only needed to support the fyke nets used for estimating the number of unguided fish. The Model II GD was designed to be operated at two elevations, 1.5 m (5.0 feet) and 2.1 m (7.0 feet) below the intake ceiling measured at the upstream side of the gatewell slot (Fig. 7).

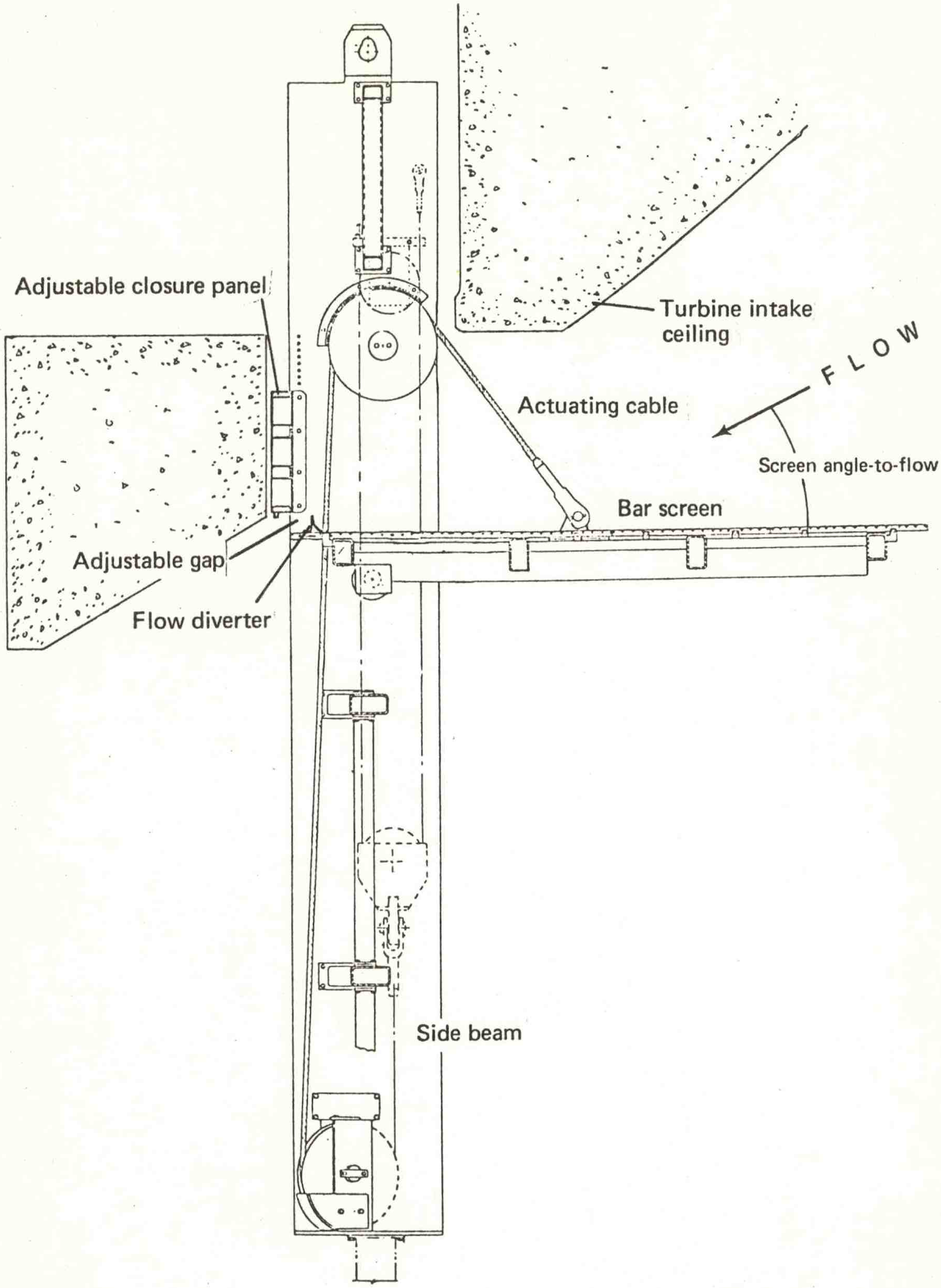
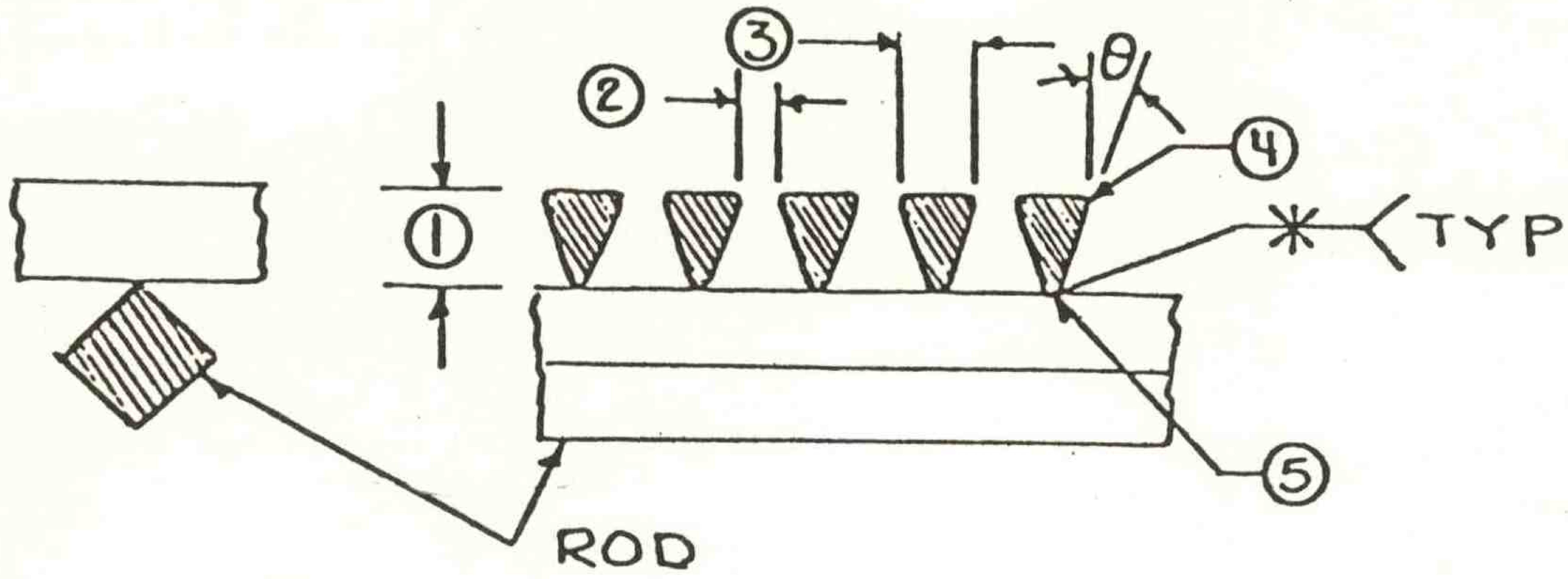


Figure 7.--Model II gatewell deflector tested at McNary Dam in 1979 shown in position, 7 feet below the intake ceiling. The device also could be set at 5 feet below the ceiling.



BAR SCREEN DETAIL

Screen panels	Dimensions mm (inches)							% open area (porosity)
	①	②	③	④	⑤	θ	ROD	
A	3.556 (0.140)	1.270 (0.050)	2.286 (0.090)	0.025 (0.010)	0.508 (0.020)	13°	12.7 ϕ (.50 ϕ)	35
B	4.623 (0.182)	2.108 (0.083)	1.905 (0.075)	0.025 (0.010)	0.508 (0.020)	7°	9.52x9.52 (.375x.375)	52
C	4.623 (0.182)	3.175 (0.125)	1.905 (0.075)	0.025 (0.010)	0.508 (0.020	7°	9.52x9.52 (.375x.375)	62

Table 1.--Pertinent dimensions and porosities (percent open area) of bar screens tested at McNary Dam in 1979.

Experience indicated that some debris would wash off the screen rather than accumulate on the screen. Accordingly, we provided an opening or gap at the terminal end of the screen to allow the debris to pass. This, of course, also provided an escape route for fish.

To monitor the passage of fish and debris through the gap, we attached a "gap" net that strained the entire flow passing through the gap. A vertical adjustable panel was installed at the downstream end of the GD to vary the gap from 0 to 15.2 cm (0.5 foot). For some tests, we attached a small flow diverter just upstream from the opening. The purpose of the flow diverter was to reduce the escapement of fish without interfering with the passage of debris.

Methods and Procedures

To evaluate the fish-guiding device for use in turbine intakes, four basic factors were considered:

1. What percent of the fish passing through the turbine intake can the guiding device be expected to intercept (vertical distribution data)?

2. What percent of the intercepted fish are being guided [fish guiding efficiency (FGE)]?

3. Is the device capable of guiding the fish without causing serious injury or stress?

4. Can the device operate effectively with the expected debris loads?

The methods used for evaluating the bar screens at Bonneville and McNary Dams were similar. Because STS's were in use at McNary Dam, we were also able to obtain data for this fish-guiding method. Vertical distribution data (Appendix A) were used to determine the number of fish that could be expected to be intercepted by the bar screens and STS.

FGE for a particular test condition was computed with the formula:

$$N = \frac{100\,G}{n}$$

N = FGE expressed as the percentage of the fish committed to the turbine intake that were intercepted and guided up into the gatewell.

n = The estimated number of fish committed to the turbine intake (the total of guided and unguided fish).

G = The number of fish guided into the gatewells.

To determine n, it was necessary to estimate the number of unguided fish. The fyke nets (Fig. 5) provided an estimate of the number of fish passing under the GD and the STS. Gap nets caught all of the fish escaping through the opening at the terminal end of the GD and the STS. The total number of unguided fish included the fyke net catches x 3 plus the gap net catch.

The guided fish were removed from the gatewell with a specially designed dip net for enumeration and assessment of quality (Swan et al. 1979).

Procedures for conducting a typical fish-guiding efficiency test were as follows:

1. The turbine was shut down to stop the passage of water and fish through the intake.

2. The gatewell deflector frame with the fyke nets attached was installed in the intake.

3. All fish in the gatewell were removed with the dip net and released.

4. The turbine was brought back into operation to begin a test.

5. The turbine was shut down to terminate a test.

6. The guided fish were removed from the gatewell by dipnetting and counted by species.

7. The GD and net frame were removed.

8. Fish were removed from all fyke nets and counted by species.

9. Fish were removed from the gap net and counted by species.

Test durations ranged from 6 to 24 h, some exclusively during the day and some exclusively during the night. Both the design and deployment of the bar screen were important in evaluating the principle for guiding fish. Some of the parameters that were examined included various guiding angles for the GD and TD; water velocities approaching the screens; screen porosity; wire interspace dimensions (between bars); a two-part system versus a one-part system (GD only); and the amount of intake flow intercepted [GD positioned 1.5 m (5.0 feet) or 2.1 m (7.0 feet) below intake ceiling].

In addition to determining FGE, we examined guided fish for signs of descaling and, at McNary Dam, measured swimming performance to determine if the fish were significantly fatigued. Fish guided by the bar screens and STS and fish that entered adjacent gatewells of their own volition (no guiding devices were present in the associated intake) were examined for descaling and swimming performance. A fish was classified as descaled if more than 10% of their scales were missing. The swimming performance tests were conducted with the use of a swimming stamina chamber (Thomas et al. 1964).

During tests conducted to assess the efficiency of backflushing as a method of cleaning the bar screens, debris was allowed to accumulate on the GD for a few hours to 7 days. To assess the extent of accumulated debris, the turbine was shut down, the GD removed, and either a picture was taken or a visual estimate was made of the accumulated debris. The GD was then lowered, backflushed for a few minutes, and removed again for comparative photographs or observations. Backflushing was accomplished by raising the leading edge of the GD to about a 40° to 50° angle above horizontal (approaching contact with the intake ceiling). A reverse flow through the bar screen occurred when the GD was in this position.

Results

Bonneville Dam

During the initial phase of the testing at Bonneville Dam, FGE's for the bar screen approached maximum expected values for some species. The FGE's for spring chinook and coho salmon fingerlings were as high as 70%. This indicated that nearly 100% of the intercepted fish were being successfully guided from the turbine intake (based upon vertical distribution data curves - Appendix A). It was also noted that the condition of these fish was not adversely affected. The descaling rate for fingerlings collected with the GD was not significantly greater than that for fish that entered gatewells volitionally.

Screen porosity tests conducted during this first phase of testing indicated that FGE was related to screen porosity. Test results showed that the FGE for spring chinook and coho salmon fingerlings dropped 28 and 22%, respectively, when the porosity of the GD was reduced from 35 to 0% (total occlusion). However, when the porosity was reduced from 65 to 35%, a reduction of similar magnitude did not occur. This implied that a screen porosity of something less than 35% was unacceptable. On the other hand, the 65% porosity screen could theoretically tolerate a 50% debris plugging before reduced FGE would occur.

The results of the tests at Bonneville Dam provided the basis for improving the design of the passive screening system and justified testing the improved system at McNary Dam.

McNary Dam

The tests at McNary Dam were directed toward evaluating the two-part bar screen by determining those parameters that would maximize FGE while maintaining low levels of stress or injury. The results of all tests conducted are tabularized in Appendix B. The following summarizes the best results in terms of bar screen design and deployment.

Bar Screen Porosity and Interspace.--Tests in 1978 with a 35% porous GD and TD showed that overlapping the devices by only 1.2 m (4.0 feet) (overlap defined in Fig. 5) caused a significant reduction in FGE indicating a severe disruption of flow. Tests in 1979 showed that screens having 52 and 62% porosity had consistently higher FGE's than those having a 35% porosity. In addition, the higher porosity GD and TD could be overlapped by as much as 1.5 m (5.0 feet) without a reduction in FGE.

Screens having an interspace of 3.2 mm (0.125 inch) gilled excessive numbers of lamprey ammocoetes. However, an interspace of 2.1 mm (0.083 inch) only caused gilling in intakes having the highest water velocities, and then primarily only at the terminal 0.6 m (2.0 feet) of the GD. An interspace of 1.3 mm (0.05 inch) (35% porosity) showed little evidence of gilling. We speculate that reducing the interspace of the 52% screen from 2.1 mm (0.083 inch) to 1.8 mm (0.07 inch) may eliminate gilling. By using the same wire size, porosity will be reduced only 4%; i.e., from 52 to 48%, and FGE will probably not be affected.

Bar Screen Deployment.--The size of fish to be guided influenced the deployment of the bar screen. For the purpose of discussion, we can divide the fish into two groups--those $>$ 70 mm in length and those $<$70 mm in length.

For fish >70 mm in length, the following observations can be made:

1. Where the angle of the screen-face to flow (angle-to-flow) exceeded 45°, excessive impingement (at least 2%) was noted. At shallower angles-to-flow, the percentage of fish intercepted by the GD alone is significantly fewer than desired. Therefore, both the GD and TD are required to obtain FGE's equivalent to the STS at McNary Dam.

2. Escapement of fish through the 15.2 cm (0.5 feet) gap at the terminal end of the scoop was reduced to 3% or less (all species considered) by employing the flow diverter and by raising the GD to the upper elevation. Even closing the gap completely to eliminate escapement proved feasible in that FGE was not impaired, and the rate of accumulation of debris on the GD was not increased.

3. A significantly higher FGE occurred during daylight hours, as shown in Figure 8. Because the bar screen is located in an area of constant darkness, a visual response is unlikely. Apparently, however, the fingerling salmonids enter the turbine intake more surface oriented during daylight hours; and, therefore, a higher percentage are intercepted by the bar screen. In the biological evaluation of this type of system, it is important that the diel behavior of the fish be considered to obtain accurate and meaningful data.

4. Best FGE was obtained when the GD (52% porosity) and TD (62% porosity) were used together with a 0.6 m (2.0 feet) overlap. At this setting, the angle-to-flow of both screens was estimated to be 30°. With this deployment, the FGE's for chinook salmon and steelhead were equal to that obtained with the STS. However, bar screens guided significantly fewer sockeye salmon than the STS (Fig. 9).

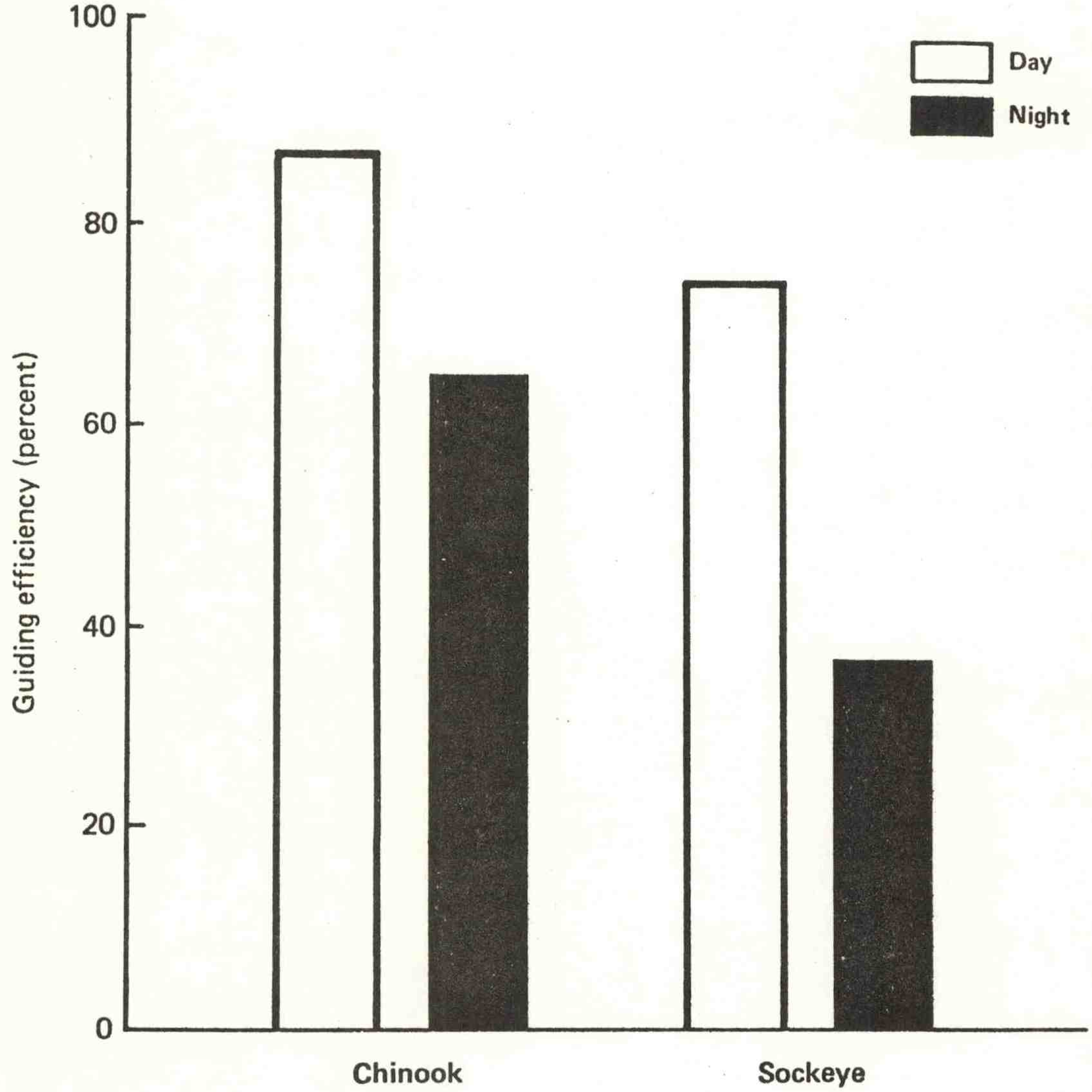


Figure 8.--A comparison of day and night fish guiding efficiencies for chinook and sockeye salmon fingerlings obtained with a passive screening system in a turbine intake at McNary Dam in 1978.

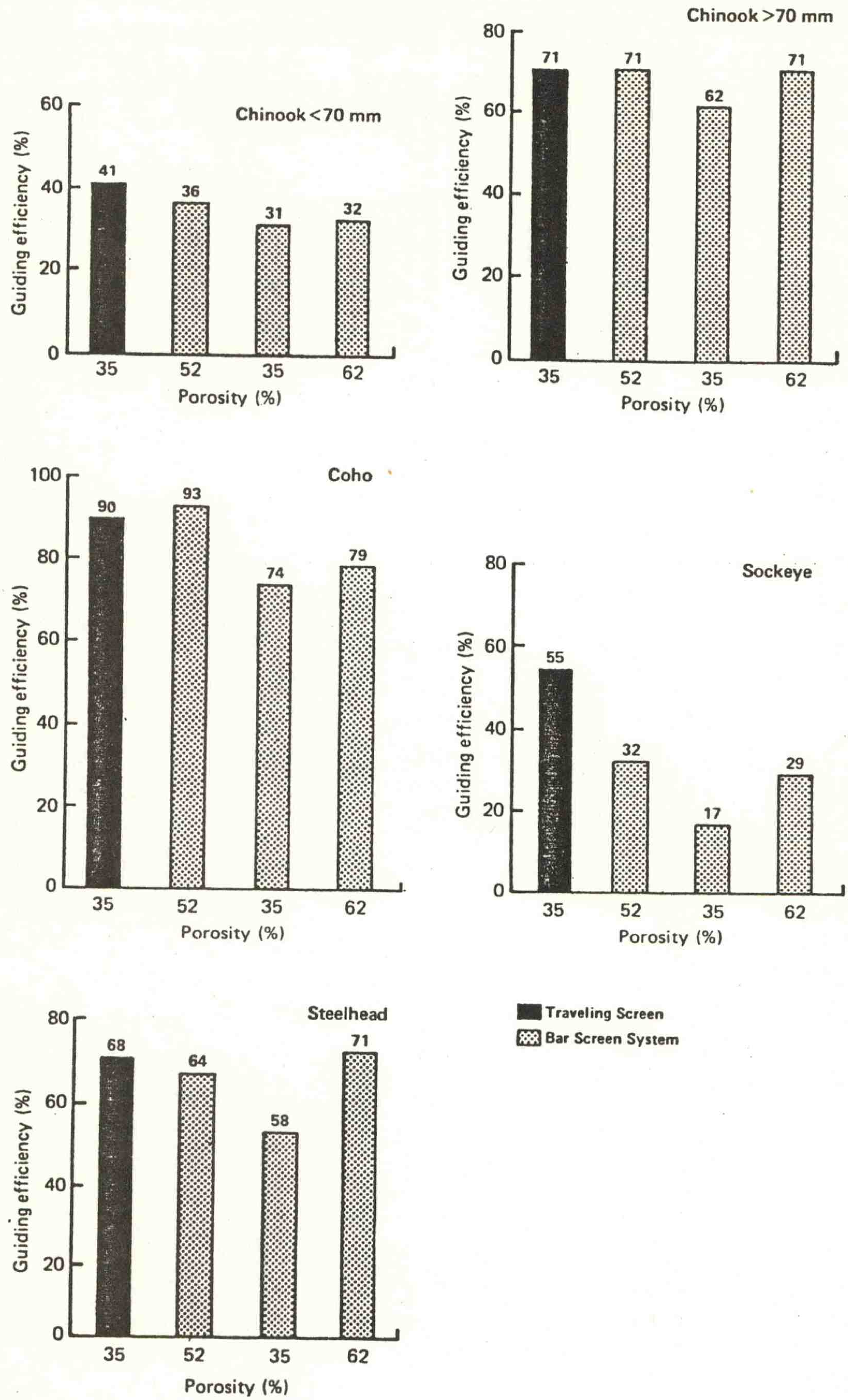


Figure 9.--Comparison of fish-guiding efficiency obtained with the submersible traveling screen and the passive bar screens (McNary Dam, 1979).

5. Percent of descaled fish (all species) was low for both the bar screen and the STS, and it was not significantly higher than the percent of descaled fish entering gatewells volitionally.

6. Chinook salmon guided by either the bar screen or the STS were not significantly fatigued by comparison with chinook salmon entering gatewells volitionally.

For fish <70 mm in length, impinging was a problem. Small chinook salmon fingerlings ranging from 35 to 70 mm in length were impinging on the GD in significant numbers during routine tests. The combination of guiding angle-to-flow and approach velocities apparently required swimming speeds in excess of the capabilities of these small fish.

According to Greenland and Thomas (1972), fall chinook salmon ranging from 34 to 40 mm in length are capable of swimming 0.18 m/s (0.6 feet/s) for 9 minutes. In general, the wild fish entering the turbine intakes were about this size in early May, but as the season progressed, the average size of the fish increased.

A series of tests were initiated on June 5 with the objective to reduce or eliminate impingement by reducing the screen angle-to-flow and reducing approach velocities (Table 2). Vector analysis was used to predict the required swimming speed for any combination of screen angle's and water velocities. As shown in Table 2, impingement was reduced or eliminated when required swimming speeds did not exceed 0.37 m/s (1.2 feet/s). Guiding angles of 30° and approach velocities as high as 0.7 m/s (2.3 feet/s) were successfully negotiated by the fish. Under this test condition, calculations show that the GD and TD together were straining about 19.82 m^3/s (700.0 $feet^3/s$) of water.

Test Series[A]	Date	Water velocity approaching the GD[B] (m/s)	(feet/s)	Guiding angle (degrees)	Required swimming velocity[C] (m/s)	(feet/s)	Observed impingement (%)
1	6/5 to 6/10	0.94	3.1	30	0.49	1.6	19.0
2	6/5 to 6/10	0.61	2.0	30	0.30	1.0	6.0
3	6/5 to 6/10	0.67	2.2	30	0.34	1.1	1.0
4	6/13 to 6/16	0.94	3.1	30	0.49	1.6	5.0
5	6/13 to 6/16	0.61	2.0	20	0.21	0.7	0.0
6	6/13 to 6/16	0.67	2.2	30	0.34	1.1	1.0
7	6/19 to 6/20	0.70	2.3	30	0.37	1.2	0.0
8	6/19 to 6/20	0.46	1.5	30	0.21	0.7	0.0
9	6/19 to 6/20	0.52	1.7	30	0.27	0.9	0.0

A Each test in a series was replicated two to five times.

B Computed approach velocities based on ambient intake velocity and bar screen porosity.

C Swimming velocities given are calculated minimums required if fish are to avoid impingement.

Table 2.--Observed impingment of fish <70 mm in length for various combinations of estimated water velocities and guiding angles for the McNary gatewell deflector - 1979.

Backflushing of Bar Screens.--For experimental purposes, the CofE gantry crane was used to backflush the GD's and TD's. We have been advised that implementing the backflush method of cleaning would be very expensive where numerous sets of bar screens are employed. For example, McNary Dam, with 14 turbines, would require 42 separate sets of screens.

During fish-guiding tests, debris accumulation on the face of the screen was negligible due to the relatively short duration of a test (24 h or less). Consequently, special long-term tests were conducted. These debris studies were designed to determine: (1) the length of time of continuous operation required to cause a serious accumulation of debris on the screens, and (2) the effectiveness of backflushing in eliminating the debris.

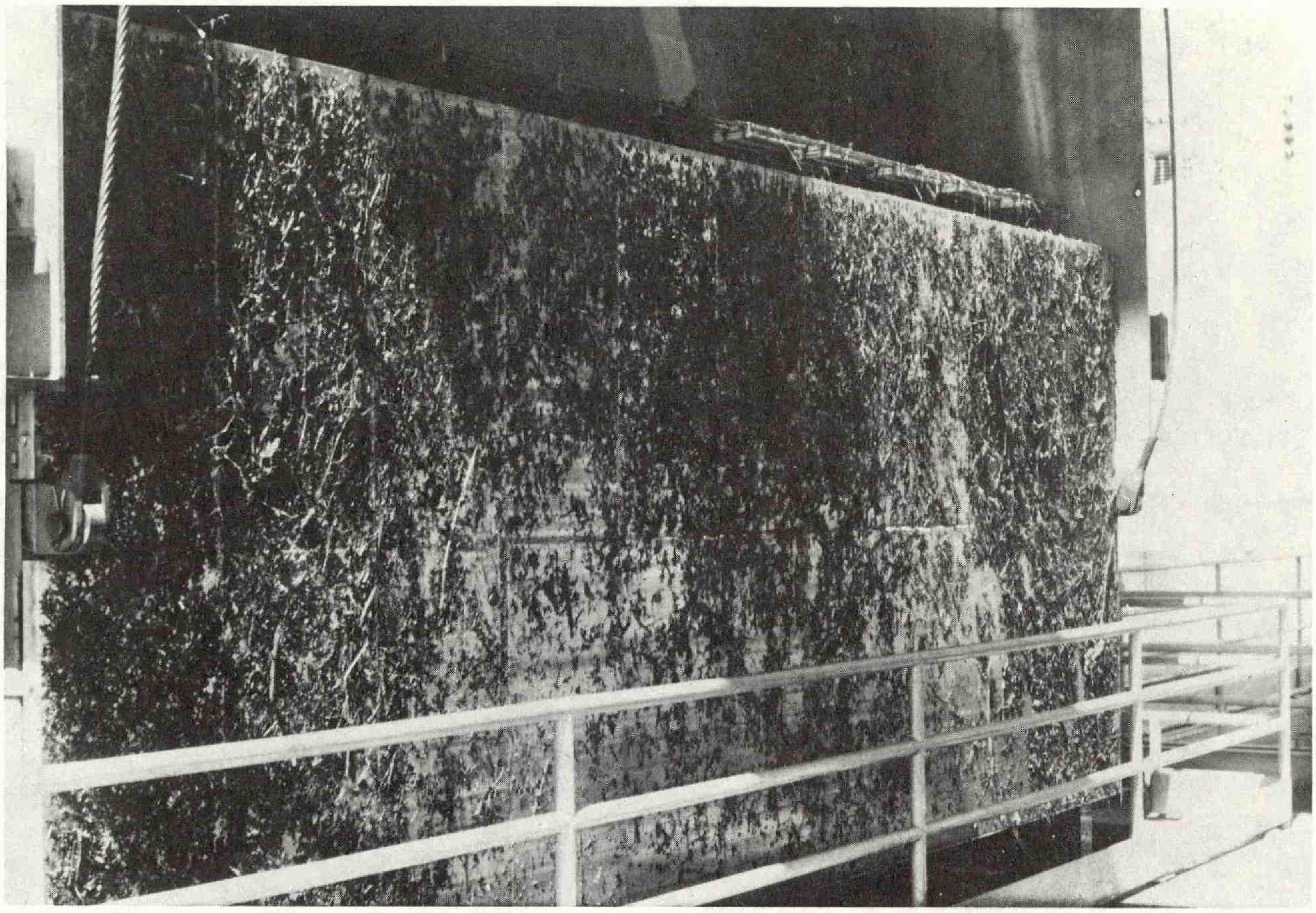
Figures 10 and 11 show the typical amount of debris accumulation after a 7-day period of operation and the amount of debris retained by the screen following a 10-min period of backflushing. Several 7-day tests were conducted; all yielded similar results.

Obviously the rate of accumulation of debris on the screen depends upon the debris load in the river at the time. However, we estimate that a conservative backflush rate would be once every 24 h. Such a rate would maintain the bar screens in a nearly clean condition most of the time.

CONCLUSIONS AND RECOMMENDATIONS

The passive bar screen appears to be a viable method for guiding fish. With proper design and deployment, this method can be used to guide salmonids as small as 35 mm in length.

However, it is more limited in application than the STS. Whether the bar screen is suitable for use at a dam will depend upon: (1) the vertical distribution of the fish, (2) the minimum size of fish encountered, and (3) the ambient water velocities in the intake.



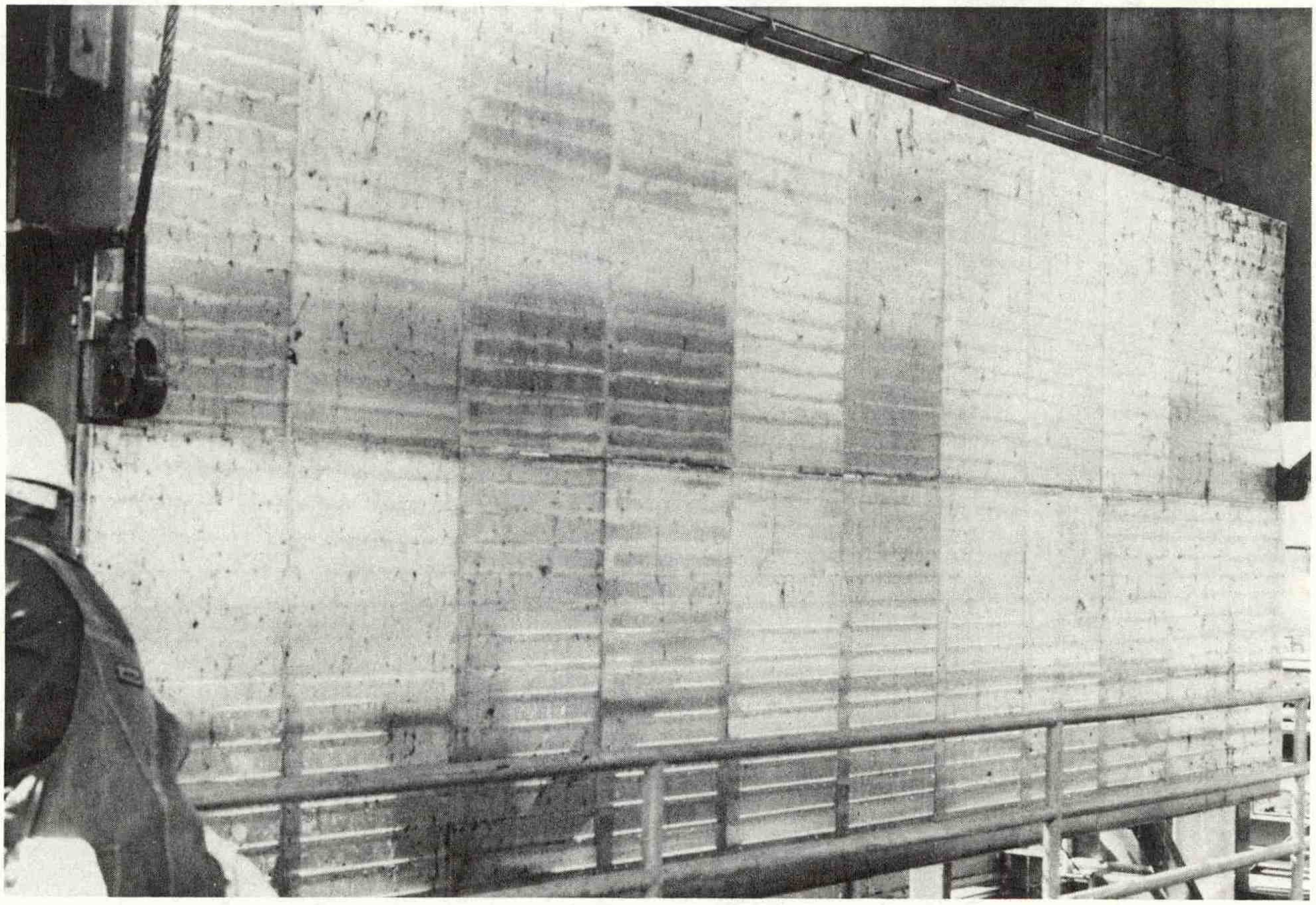


Figure 10 (top). Accumulation of debris on bar screen after 7 days of continuous operation in turbine intake at McNary Dam. The bar screen was subsequently lowered into position and backflushed for 10 minutes (see Fig. 11).

Figure 11 (bottom). A 10-minute period of backflushing removed virtually all of the 7-day accumulation of debris from the bar screen (see Fig. 10).

A method for intermittent cleaning of accumulated debris is a necessary component of a passive fish-guiding device. Because implementing the backflushing method is presently considered too costly, alternative methods should be considered, and the more promising of these evaluated under field conditions.

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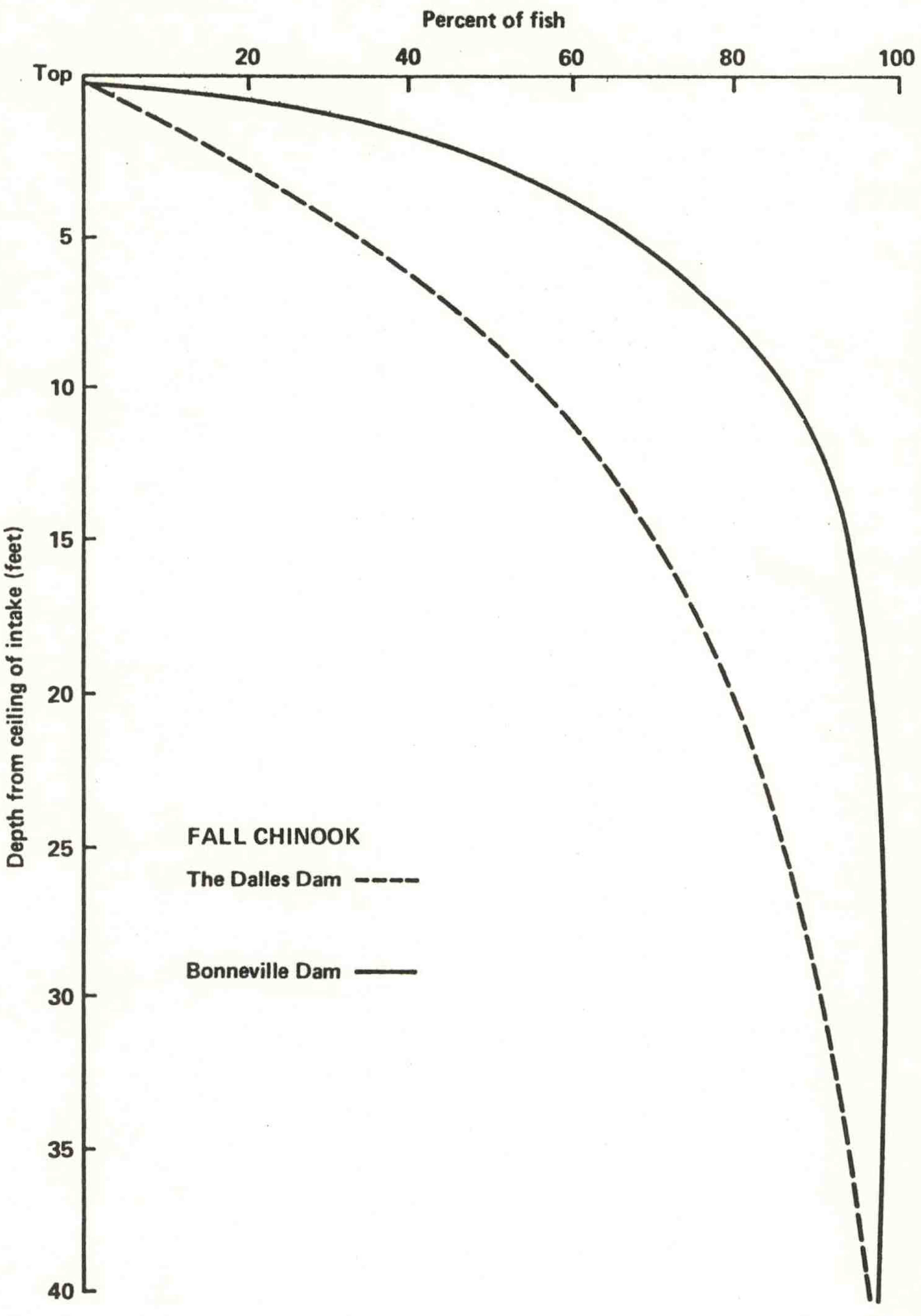
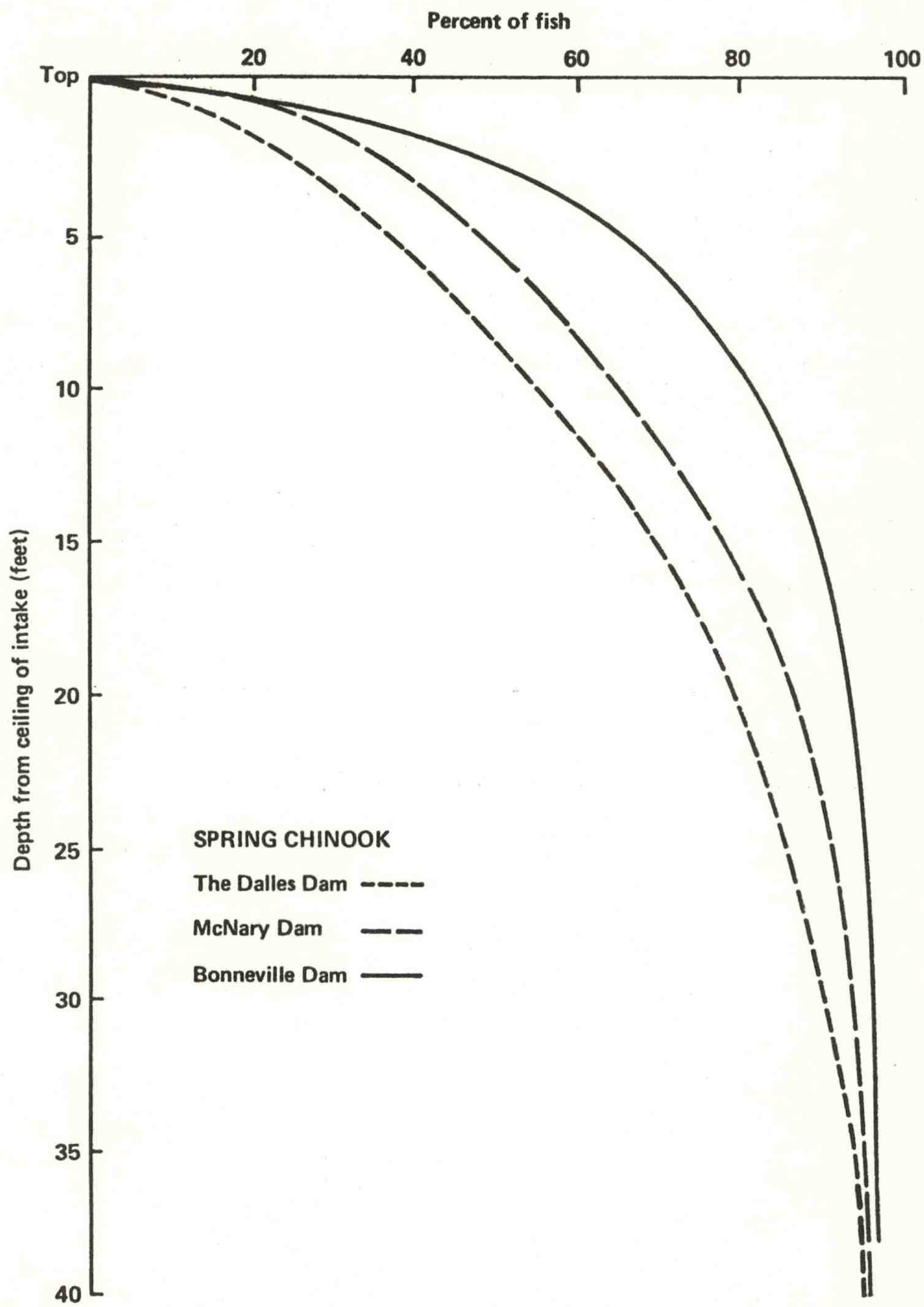
APPENDIX A

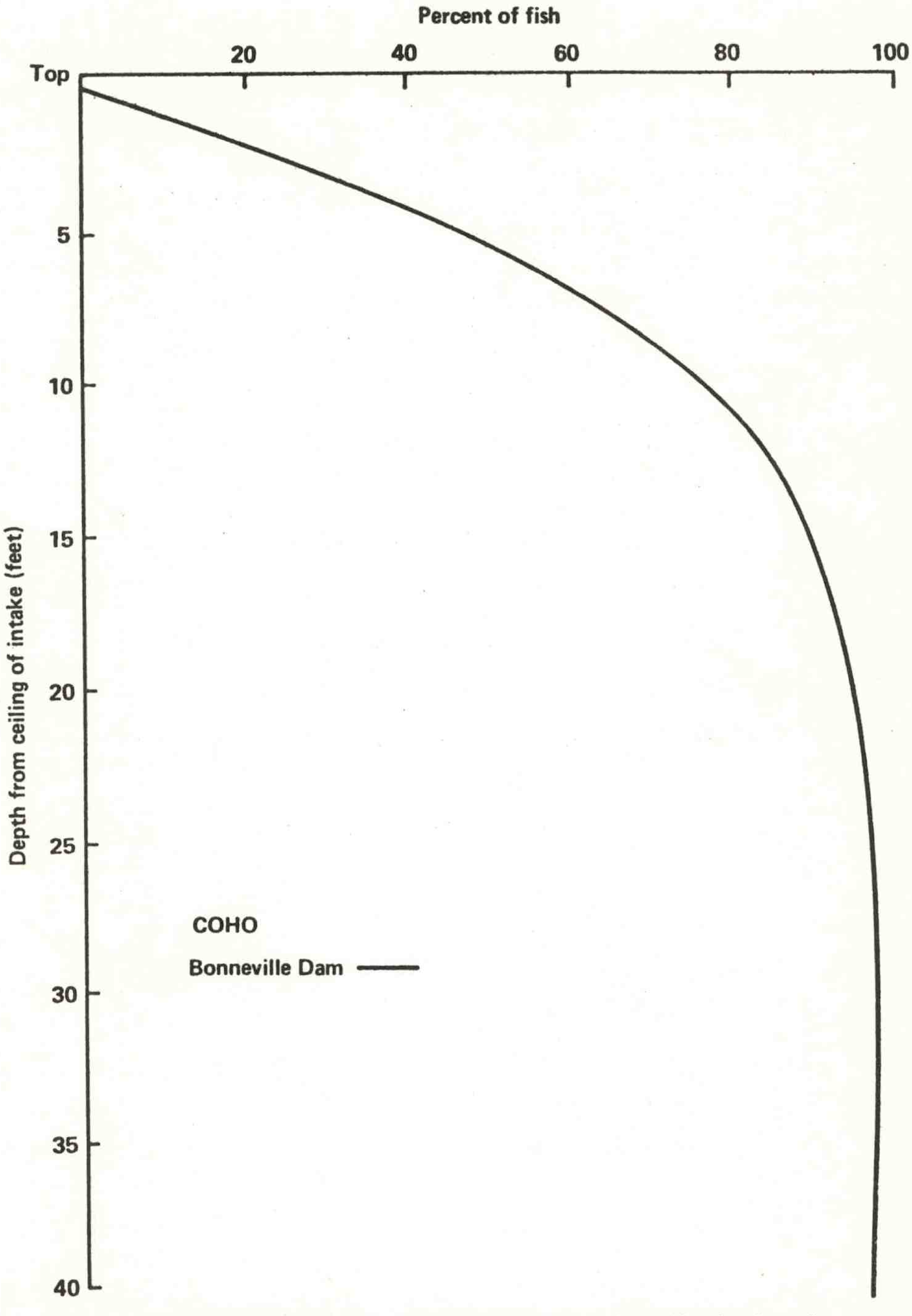
VERTICAL DISTRIBUTION DATA



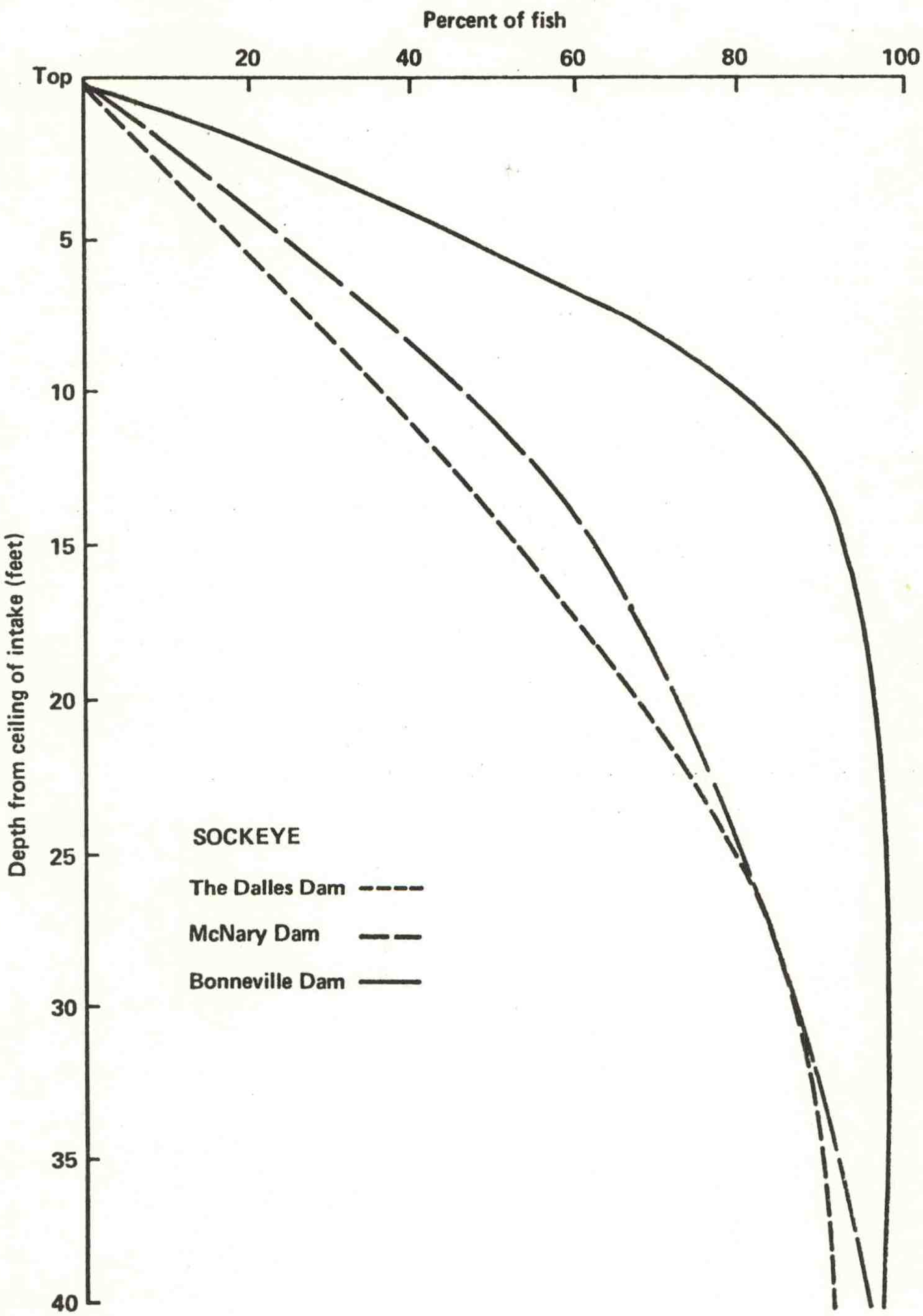
Vertical distribution of fall chinook salmon fingerlings in turbine intakes of Bonneville Dam (1975) and The Dalles Dam (1960).



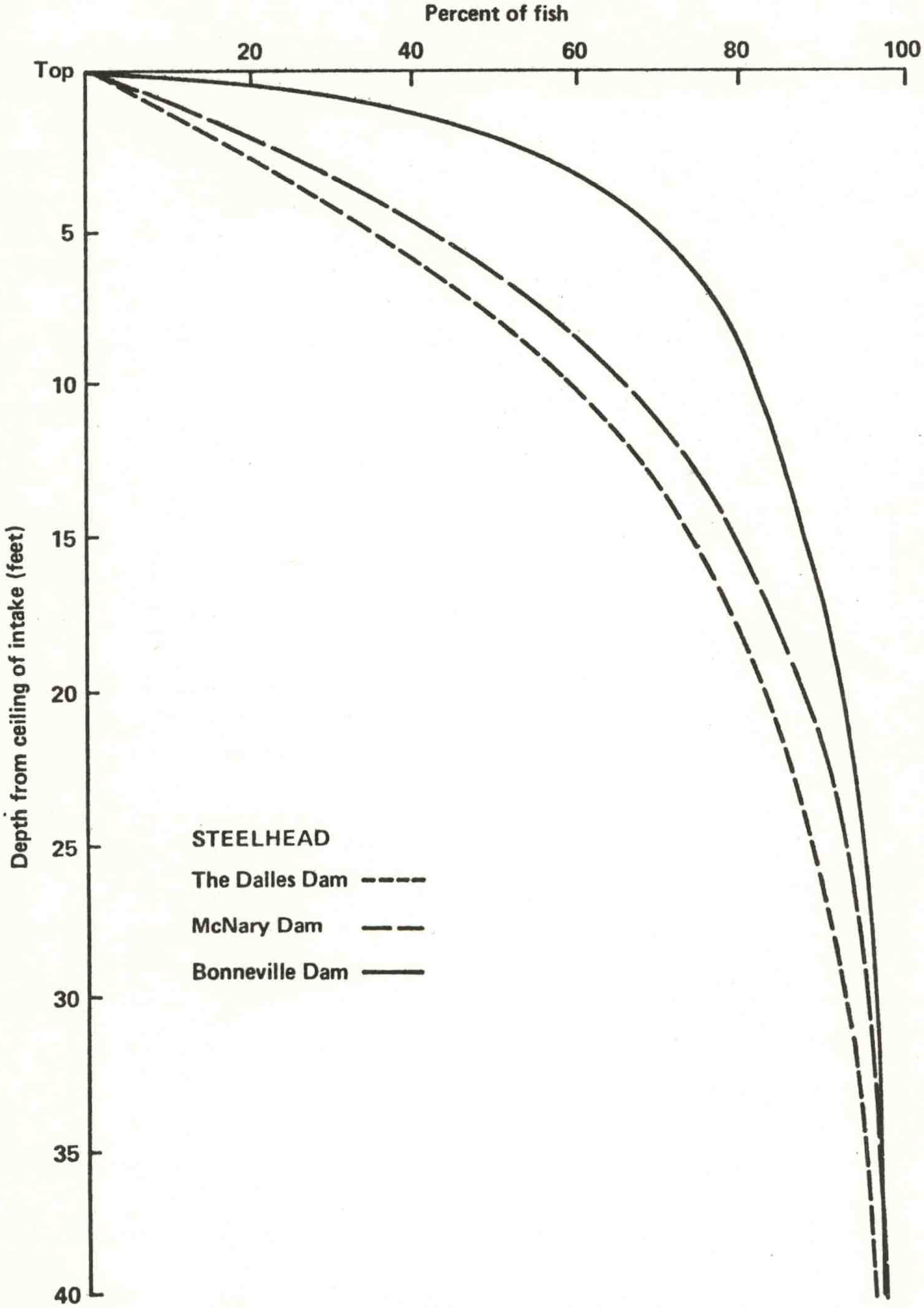
Vertical distribution of spring chinook salmon fingerlings in turbine intakes at Bonneville Dam (1975), The Dalles Dam (1960) and McNary Dam (1961).



Vertical distribution of coho salmon fingerlings in turbine intakes of Bonneville Dam (1975).



Vertical distribution of sockeye salmon fingerlings in turbine intakes of Bonneville Dam (1975), The Dalles Dam (1960) and McNary Dam (1961).



Vertical distribution of steelhead trout fingerlings in turbine intakes of Bonneville Dam (1975), The Dalles Dam (1960) and McNary Dam (1961).

APPENDIX B

DATA FOR TEST SERIES 1-13

TEST SERIES 1

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C						Gatewell 4B					
Gatewell Deflector	% Porosity 62 < To Flow 60° a/ Operating el. 270 Gap Size 6 (Inches)						% Porosity 35 < To Flow 60° Operating el. 270 Gap Size 6 (Inches)						% Porosity 52 < To Flow 60° Operating el. 270 Gap Size 6 (Inches)						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	7	4	15	26	58	73	16	2	13	31	42	48	0	2	8	10	80	100	65	3	205	273	75	76
	94	132	152	378	40	75	91	34	86	211	41	57	26	15	76	117	65	78	126	0	239	365	65	65
	10	142	181	333	54	97	84	17	166	267	62	69	139	54	138	331	42	58	75	6	128	209	61	64
	49	157	219	425	52	88	58	66	156	280	56	79	71	33	135	239	57	70	39	5	210	254	83	85
Totals	160	435	567	1162	49	86	250	119	421	789	53	68	236	104	357	697	51	66	305	14	782	1101	71	72
Chinook < 70mm	0	0	24	24	100	100	0	0	22	22	100	100	0	0	14	14	100	100	42	0	118	160	74	74
	45	15	149	209	71	78	19	8	64	91	70	79	10	1	73	84	87	88	62	4	140	206	68	70
	39	15	135	189	71	79	13	0	94	107	88	88	23	5	76	104	73	78	23	2	50	75	67	69
	52	34	164	250	66	79	52	17	132	201	66	74	39	7	97	143	68	73	29	1	132	162	80	80
Totals	136	64	472	672	71	78	84	25	312	421	74	80	72	13	260	345	75	79	156	7	440	603	73	73
Steelhead																								
Sockeye b/																								
Coho b/																								

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ No data for these conditions.

TEST SERIES 2

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C						Gatewell 4B					
Gatewell Deflector	% Porosity 62; < To Flow 50° a/; Operating el. 270; Gap Size 6 (Inches)						% Porosity 35; < To Flow 50°; Operating el. 270; Gap Size 6 (Inches)						% Porosity 52; < To Flow 50°; Operating el. 270; Gap Size 6 (Inches)						% Porosity 35; < To Flow 60°					
Trashrack Deflector	% Porosity N/A; < To Flow N/A; Overlap N/A (Feet)						% Porosity N/A; < To Flow N/A; Overlap N/A (Feet)						% Porosity N/A; < To Flow N/A; Overlap N/A (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	126	268	405	799	51	84	194	111	243	548	44	65	104	65	245	414	59	75	75	2	307	384	79	80
	237	387	708	1332	53	82	511	169	513	1193	45	60	256	128	458	842	54	70	162	11	570	743	77	78
Totals	363	655	1113	2131	52	83	651	280	756	1687	45	61	360	193	703	1256	56	71	237	13	877	1127	77	80
Chinook b/ < 70mm																								
Steelhead	84	31	174	289	60	71	69	7	114	190	62	66	29	4	96	129	74	77	43	0	114	157	73	73
	100	46	153	299	51	67	133	19	134	286	47	53	94	9	141	244	58	61	39	0	86	125	69	69
Totals	174	77	337	588	57	70	202	26	248	476	52	58	123	13	237	373	64	67	82	0	200	282	71	71
Sockeye	13	21	27	61	44	79	23	7	9	39	23	41	13	7	6	26	23	50	13	0	15	28	54	54
	42	21	39	102	38	60	65	8	10	83	12	22	29	13	15	57	13	49	19	0	33	52	64	64
Totals	55	42	66	163	41	66	88	15	19	122	16	28	42	20	21	83	20	49	32	0	48	80	60	60
Coho b/																								

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ No data for these conditions.

TEST SERIES 3

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C						Gatewell 4B					
Gatewell Deflector	% Porosity 62 < To Flow 40° Operating el. 270 a/ Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 40° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 52 < To Flow 50° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	314 441	187 181	911 943	1412 1565	65 60	78 71	739 509	71 51	888 570	1698 1130	52 50	56 55	139 97 133	13 18 7	284 193 239	436 308 379	65 63 63	68 69 65	295	7	685	987	69	70
Totals	755	368	1854	2977	62	75	1248	122	1458	2828	52	56	369	38	716	1123	64	67	295	7	685	987	69	70
Chinook b/ < 70mm																								
Steelhead	87	25 9	172 174	284 290	61 60	69 63	45 81	4 5	154 133	203 219	76 61	78 63	45 23 32	10 3 1	190 90 96	245 116 129	78 78 74	82 80 75	87	1	81	169	48	48
Totals	107	34	346	574	60	66	126	9	287	422	68	70	100	14	376	490	77	80	87	1	81	169	48	48
Sockeye	71 492	10 15	63 129	144 636	44 20	51 22	91 498	12 21	51 77	154 596	33 13	41 16	78 29 262	7 3 47	28 27 58	113 59 367	25 46 16	31 51 29	275	2	100	377	27	27
Totals	563	25	192	780	25	28	589	33	128	750	17	22	369	57	113	539	21	32	275	2	100	377	27	27
Coho b/																								

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ No data for these conditions.

c/ With flow diverter.

TEST SERIES 4

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C						Gatewell 4B					
Gatewell Deflector	% Porosity 62 < To Flow 30° Operating el. 270 a/ Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 30° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 52 < To Flow 50° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity 52 < To Flow 45° Overlap 5 (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	175 528 518	104 193 401	381 1012 1357	660 1733 2276	58 58 60	73 70 77	130 486 667	51 108 88	313 628 812	494 1222 1567	63 51 52	74 60 57	298 194	66 42	666 291	1030 527	64 55	71 63	68 178 428	13 13 7	353 740 1594	434 931 2029	81 80 79	84 81 80
Totals	1221	698	2750	4669	59	74	1283	247	1753	3283	53	61	492	108	957	1557	61	68	674	33	2687	3394	80	82
Chinook < 70mm b/																								
Steelhead	168 272 227	27 39 21	353 457 549	548 768 797	64 60 69	69 65 72	185 165 139	7 17 4	294 385 354	486 567 497	60 68 71	62 71 72	49 45	2 0	103 93	154 138	67 67	68 67	74 130 65	6 5 1	203 208 353	283 343 419	72 61 84	74 62 84
Totals	667	87	1349	2103	65	69	489	28	1033	1550	67	68	94	2	196	292	67	68	269	12	764	1045	73	74
Sockeye	74 250 943	24 27 26	85 77 460	183 354 1429	46 22 32	60 29 34	87 220 868	5 24 42	17 20 386	109 264 1296	16 .8 30	20 17 33	78 188	13 13	65 82	156 283	42 29	50 34	29 120 551	7 4 6	79 106 909	115 230 1466	69 46 62	74 48 62
Totals	1267	77	622	1966	32	36	1175	71	423	1669	25	30	266	26	147	439	34	39	700	17	1094	1811	60	61
Coho b/																								

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ No data for these conditions.

c/ With flow diverter.

TEST SERIES 5

Bar Screens

Gatewell 5A

Gatewell Deflector: % Porosity 62; < To Flow 30° a/; Operating el. 270; Gap Size 2 (Inches) c/

Trashrack Deflector: % Porosity N/A; < To Flow N/A; Overlap N/A (Feet)

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	214	77	598	889	67	76
	369	122	740	1231	60	70
Total	583	199	1338	2120	63	73
Chinook b/ < 70mm						
Steelhead	94	7	156	257	61	63
	256	7	655	918	71	72
Total	350	14	811	1175	69	71
Sockeye	580	20	189	789	24	26
	505	29	240	774	31	35
Total	1085	49	429	1563	27	31
Coho b/						

Gatewell 5B

Gatewell Deflector: % Porosity 35; < To Flow 30°; Operating el. 270; Gap Size 2 (Inches) c/

Trashrack Deflector: % Porosity N/A; < To Flow N/A; Overlap N/A (Feet)

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	318	14	396	728	54	56
	496	30	907	1433	63	65
Total	814	44	1303	2161	60	62
Chinook b/ < 70mm						
Steelhead	75	0	114	189	60	60
	185	3	642	830	77	78
Total	260	3	756	1019	76	76
Sockeye	544	11	62	617	10	12
	593	13	210	816	.26	27
Total	1137	24	272	1433	19	21
Coho b/						

Gatewell 5C

Gatewell Deflector: % Porosity 52; < To Flow 50°; Operating el. 270; Gap Size 2 (Inches) c/

Trashrack Deflector: % Porosity 52; < To Flow 45°; Overlap 5 (Feet)

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	275	32	685	992	69	72
	697	31	1029	1757	59	60
Total	972	63	1714	2749	62	65
Chinook b/ < 70mm						
Steelhead	26	0	196	222	88	88
	19	1	323	343	94	94
Total	45	1	519	565	92	92
Sockeye	421	50	341	812	42	48
	476	85	553	1114	50	57
Total	897	135	894	1926	46	53
Coho b/						

Traveling Screen

Gatewell 4B

Gatewell Deflector: % Porosity 35; < To Flow 60°

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	126	2	367	495	74	75
	107	2	417	526	79	80
Total	233	4	784	1021	77	77
Chinook b/ < 70mm						
Steelhead	49	0	106	155	68	68
	36	0	179	215	83	83
Total	85	0	285	370	77	77
Sockeye	262	47	58	367	16	29
	191	0	226	417	54	54
Total	453	47	284	784	36	42
Coho b/						

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ No data for these conditions

c/ With flow diverter

TEST SERIES 6

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C b/						Gatewell 4B					
Gatewell Deflector	% Porosity 62 < To Flow 30° a/ Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 30° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity ___ < To Flow ___ Operating el. ___ Gap Size ___ (Inches)						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity 62 < To Flow 25° Overlap 2 (Feet)						% Porosity 35 < To Flow 23° Overlap 1 (Feet)						% Porosity ___ < To Flow ___ Overlap ___ (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	110 81 194	191 115 219	605 474 1676	906 670 2089	67 71 80	88 88 91	113 94 651	72 65 84	445 339 1328	630 498 2063	71 68 64	82 81 68							100 62	8 14	514 339	622 415	83 82	84 85
Totals	385	525	2755	3665	75	90	858	221	2112	3191	66	73							162	22	853	1037	82	84
Chinook b/ < 70mm																								
Steelhead	175 58 52	30 18 4	370 166 540	575 242 596	64 69 91	70 76 91	71 36 100	8 4 4	260 151 385	339 191 489	77 79 79	79 81 80							52 45	6 3	168 75	226 123	74 61	77 63
Totals	285	52	1076	1413	78	82	207	16	796	1019	78	80							97	9	243	349	70	72
Sockeye	143 58 447	23 22 94	101 86 654	267 166 1195	38 52 55	46 65 63	87 52 561	25 13 79	39 47 519	151 112 1159	26 42 45	42 54 52							65 42	1 7	79 83	145 132	54 63	55 68
Totals	648	139	841	1628	52	60	700	117	605	1422	43	51							107	8	162	277	59	61
Coho b/																								

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.
b/ No data for these conditions.
c/ With flow diverter

TEST SERIES 7

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C b/						Gatewell 4B					
Gatewell Deflector	% Porosity 52 < To Flow 30° a/ Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 30° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity ____ < To Flow ____ Operating el. ____ Gap Size ____ (Inches)						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity 62 < To Flow 25° Overlap 2 (Feet)						% Porosity 35 < To Flow 25° Overlap 2 (Feet)						% Porosity ____ < To Flow ____ Overlap ____ (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	237 71	181 139	834 713	1252 923	67 77	81 92	528 246	69 55	589 523	1186 824	50 63	55 70							175 321	3 10	552 1061	730 1392	76 76	76 77
Totals	308	320	1547	2175	71	96	774	124	1112	2010	55	61							496	13	1613	2122	76	77
Chinook b/ < 70mm																								
Steelhead	55 55	5 4	139 175	199 234	70 75	72 76	62 32	3 1	101 98	166 131	61 75	63 76							19 23	0 1	104 111	123 135	85 82	85 83
Totals	110	9	314	433	73	75	96	4	199	297	67	68							42	1	215	258	83	83
Sockeye	379 104	32 39	373 307	784 450	68 68	52 77	412 75	33 36	282 215	727 326	39 66	43 77							227 107	1 8	337 376	565 491	60 77	60 78
Totals	483	71	680	1234	55	61	487	69	497	1053	47	54							334	9	713	1056	68	68
Coho	75 62	54 49	219 402	348 513	63 78	78 88	252 81	17 18	313 271	582 370	54 73	57 78							75 75	2 0	322 425	399 500	81 85	81 85
Totals	137	103	621	861	72	84	333	35	584	952	61	65							150	2	747	899	83	83

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ No data for these conditions.

c/ With flow diverter.

TEST SERIES 8

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C						Gatewell 4B					
Gatewell Deflector	% Porosity 52 < To Flow 40° Operating el. 270 a/ Gap Size 2 (Inches) c/						% Porosity 35 < To Flow 40° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 62 < To Flow 50° Operating el. 270 Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity 52 < To Flow 8° Overlap 1 (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	49 217	26 37	264 248	339 502	78 49	86 57	58 191	9 15	130 211	197 417	66 51	71 54	52 100	7 6	125 182	184 288	68 63	72 65	78	3	290	371	78	79
Totals	266	63	512	841	61	68	249	24	341	614	56	59	152	13	307	472	65	68	78	3	290	371	78	79
Chinook < 70mm	42 78	2 3	23 36	67 117	34 131	37 33	32 58	6 3	22 34	60 95	37 36	47 39	23 133	13 4	19 7	55 144	35 5	58 7	36	2	46	84	54	57
Totals	120	5	59	184	32	35	90	9	56	155	36	42	156	17	26	199	8	17	36	2	46	84	54	57
Steelhead	29 52	1 1	129 89	159 142	81 63	82 64	23 49	0 0	77 50	100 99	77 51	77 51	10 25	0 1	58 63	68 89	85 71	85 72	78	5	81	164	49	52
Totals	395	41	649	1085	60	64	366	36	307	709	42	47	275	52	304	631	48	56	178	12	596	786	76	77
Sockeye																								
Coho b/																								

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ No data for these conditions.

c/ With flow diverter.

TEST SERIES 9

	Bar Screens			Traveling Screen
	Gatewell 5A	Gatewell 5B	Gatewell 5C	Gatewell 4B
Gatewell Deflector	% Porosity 52 b/ < To Flow 30° a/ Operating el. 270 Gap Size 6 (Inches)c/	% Porosity 35 b/ < To Flow 30° Operating el. 270 Gap Size 6 (Inches)c/	% Porosity 62 < To Flow 50° Operating el. 272 Gap Size 0 (Inches)	% Porosity 35 < To Flow 60°
Trashrack Deflector	% Porosity 62 < To Flow 30° Overlap 2 (Feet)	% Porosity 35 < To Flow 30° Overlap 2 (Feet)	% Porosity N/A < To Flow N/A Overlap N/A (Feet)	

	5A Fyke net catch	5A Gap net catch	5A Gatewell catch	5A Total catch	5A % guided	5A % guided incl. gap	5B Fyke net catch	5B Gap net catch	5B Gatewell catch	5B Total catch	5B % guided	5B % guided incl. gap	5C Fyke net catch	5C Gap net catch	5C Gatewell catch	5C Total catch	5C % guided	5C % guided incl. gap	4B Fyke net catch	4B Gap net catch	4B Gatewell catch	4B Total catch	4B % guided	4B % guided incl. gap
Chinook > 70mm	159	76	520	755	69	79	243	37	235	515	46	53	65	6	182	253	72	74	229	5	670	904	74	74
	45	41	219	305	72	85	71	10	193	274	70	74	81	10	195	286	68	72						
Totals	204	117	739	1060	70	81	314	47	428	789	54	60	146	16	377	539	70	73	229	5	670	904	74	74
Chinook < 70mm	78	15	11	104	11	25	62	11	9	82	11	24	42	30	34	106	40	60	52	2	48	102	47	49
	91	2	4	97	4	6	117	31	3	151	2	23	104	73	21	198	11	48						
Totals	169	17	15	201	7	16	179	42	12	233	5	23	146	103	55	304	18	52	52	2	48	102	47	49
Steelhead	58	3	190	251	76	77	45	2	118	165	72	73	32	0	77	109	71	71	34	2	135	169	80	81
	26	4	79	109	72	76	26	3	43	72	60	64	30	0	71	101	70	70						
Totals	84	7	269	360	75	76	71	5	161	237	68	70	62	0	148	210	70	70	34	2	135	169	80	81
Sockeye	272	23	520	815	64	67	253	19	215	487	44	48	350	17	247	614	40	43	97	8	461	566	81	83
	113	110	66	189	35	40	165	10	30	205	.15	20	191	11	124	326	38	41						
Totals	385	33	586	1004	58	62	418	29	245	692	35	40	541	28	371	940	39	42	97	8	461	566	81	83
Coho	97	13	420	530	79	82	97	8	180	285	63	66	13	3	75	91	82	86	71	1	383	455	84	84
	29	22	182	233	78	88	68	4	186	258	72	74	16	3	98	117	84	86						
Totals	126	35	602	763	79	84	165	12	366	543	67	70	29	6	173	208	83	86	71	1	383	455	84	84

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ Two foot plywood baffle attached to the underside of the terminal end of G.D. to reduce impingement pressure.

c/ With flow diverter

TEST SERIES 10

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C						Gatewell 4B					
Gatewell Deflector	% Porosity 52 b/ < To Flow 30° Operating el. 272 a/ Gap Size 6 (Inches) c/						% Porosity 35 b/ < To Flow 30° Operating el. 272 Gap Size 6 (Inches) c/						% Porosity 62 < To Flow 30° Operating el. 272 Gap Size 6 (Inches) c/						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity 62 < To Flow 30° Overlap 2 (Feet)						% Porosity 35 < To Flow 30° Overlap 2 (Feet)						% Porosity 52 < To Flow 30° Overlap 2 (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	45	11	260	316	82	86	68	4	169	241	70	72	159	10	381	550	69	71	32	0	198	230	86	86
	55	10	186	251	74	78	107	6	126	239	53	55	81	1	168	250	67	68						
	84	11	431	526	82	84	49	3	144	196	73	75												
Totals	184	32	877	1093	80	83	224	13	439	676	65	67	240	11	549	800	69	70	32	0	198	230	86	86
Chinook < 70mm	139	2	23	164	14	15	87	11	11	109	10	20	62	27	4	93	4	33	58	20	41	119	35	51
	143	15	61	219	28	35	152	33	23	208	11	27	84	16	1	101	1	17						
	156	63	74	293	25	47	201	69	51	321	16	37												
Totals	438	80	158	676	23	35	440	113	85	638	13	31	146	43	5	194	3	25	58	20	41	119	35	51
Steelhead	16	1	82	99	83	84	23	0	67	90	74	74	42	0	118	160	74	74	29	0	71	100	71	71
	29	0	108	137	79	79	39	0	85	124	69	69	6	0	50	56	89	89						
	13	1	30	44	68	70	16	1	7	24	29	33												
Totals	58	2	220	280	79	79	78	1	159	238	67	67	48	0	168	216	78	78	29	0	71	100	71	71
Sockeye	389	3	159	551	29	30	288	4	158	450	35	36	246	20	525	791	66	69	92	8	103	203	51	55
	211	3	78	292	27	28	162	4	30	196	15	17	146	1	96	243	40	40						
	162	3	59	224	26	28	139	2	46	187	25	26												
Totals	762	9	296	1067	27	29	589	10	234	833	28	29	392	21	621	1034	60	62	92	8	103	203	51	55
Coho	6	1	76	83	92	92	16	0	53	69	77	77	87	3	395	485	81	82	6	0	56	62	90	90
	6	1	102	109	94	94	23	1	56	80	70	71	71	0	208	279	75	75						
	0	0	18	18	100	100	3	0	12	15	80	80												
Totals	12	2	196	210	93	94	42	1	121	164	74	74	158	3	603	764	79	79	6	0	56	62	90	90

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ Two foot plywood baffle attached to the underside of the terminal end of G.D. to reduce impingement pressure.

c/ With flow diverter

TEST SERIES 11

	Bar Screens																		Traveling Screen					
	Gatewell 5A						Gatewell 5B						Gatewell 5C						Gatewell 4B					
Gatewell Deflector	% Porosity 52 b/ < To Flow 30° a/ Operating el. 272 Gap Size 6 (Inches) c/						% Porosity 35 b/ < To Flow 30° Operating el. 272 Gap Size 6 (Inches) c/						% Porosity 62 < To Flow 30° Operating el. 272 Gap Size 0 (Inches)						% Porosity 35 < To Flow 60°					
Trashrack Deflector	% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)						% Porosity N/A < To Flow N/A Overlap N/A (Feet)											
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	104	1	136	241	56	57	139	1	106	246	43	43	84	1	124	209	59	60	39	5	161	205	79	81
	159	13	428	600	71	74	113	7	176	296	59	62	45	0	97	142	68	68	65	4	346	415	73	84
Totals	263	14	564	841	67	69	252	8	282	542	52	54	129	1	221	351	63	63	104	9	507	620	82	82
Chinook < 70mm	133	11	54	198	27	33	110	16	22	148	15	26	143	27	19	189	10	24	49	13	43	105	41	53
	259	14	105	378	28	31	207	34	21	262	8	21	168	116	35	319	11	47	117	42	67	226	30	48
Totals	392	25	159	576	28	32	317	50	43	410	11	23	311	143	54	508	11	39	166	55	110	331	33	50
Steelhead	23	1	73	97	75	76	16	0	43	59	73	73	6	0	53	59	90	90	6	0	39	45	87	87
	42	0	52	94	55	55	36	1	28	65	43	45	16	0	32	48	67	67	16	4	73	93	78	83
Totals	65	1	125	191	65	65	52	1	71	124	57	58	22	0	85	107	79	79	22	4	112	138	81	84
Sockeye	66	0	53	119	45	45	39	0	17	56	30	30	84	3	35	122	29	31	32	7	109	148	74	78
	327	5	161	493	33	34	285	6	24	315	8	10	198	4	66	268	25	26	123	13	234	370	63	67
Totals	393	5	214	612	35	36	324	6	41	371	11	13	282	7	101	390	26	28	155	20	343	518	66	70
Coho	10	1	43	54	80	81	16	0	21	37	57	57	10	0	41	51	80		16	2	42	60	70	73
	14	0	35	49	71	71	19	1	25	45	56	58	23	0	28	51	55		6	4	46	56	82	89
Totals	24	1	78	103	76	77	35	1	46	82	56	57	33	0	69	102	68		22	6	88	116	76	81

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ Two foot plywood baffle attached to the underside of the terminal end of G.D. to reduce impingement pressure.

c/ With flow diverter.

TEST SERIES 12

Bar Screens (Gatewells 5A, 5B, 5C) — **Traveling Screen** (Gatewell 4B)

Gatewell Deflector

- Gatewell 5A: % Porosity 52 b/; < To Flow 30°; Operating el. 272 a/; Gap Size 0 (Inches)
- Gatewell 5B: % Porosity 35 b/; < To Flow 30°; Operating el. 272; Gap Size 6 (Inches) c/
- Gatewell 5C: % Porosity 62; < To Flow 30°; Operating el. 272; Gap Size 0 (Inches)
- Gatewell 4B: % Porosity 35; < To Flow 60°

Trashrack Deflector

- Gatewell 5A: % Porosity 62; < To Flow 30°; Overlap 2 (Feet)
- Gatewell 5B: % Porosity 35; < To Flow 30°; Overlap 2 (Feet)
- Gatewell 5C: % Porosity 52; < To Flow 30°; Overlap 2 (Feet)

Gatewell 5A (Bar Screens)

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	84	0	292	376	74	74
	78	0	214	292	73	73
	113	0	212	325	65	65
	94	0	248	342	73	73
	75	0	127	202	63	63
Totals	444	0	1093	1537	71	71
Chinook < 70mm	183	2	65	250	26	26
	120	2	70	192	36	37
	130	4	43	177	24	27
	107	3	134	244	55	56
	113	0	65	178	37	37
Totals	653	11	377	1041	36	37
Steelhead	26	0	48	74	65	65
	36	0	43	79	54	54
	10	0	36	46	78	78
	16	0	22	38	58	58
	0	0	7	7	100	100
Totals	88	0	156	244	64	64
Sockeye	272	0	179	451	40	40
	217	0	126	343	37	37
	214	0	77	291	26	26
	143	0	54	197	27	27
	110	0	38	148	26	26
Totals	956	0	474	1430	33	33
Coho d/						

Gatewell 5B (Bar Screens)

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	78	6	126	210	60	63
	84	4	142	230	62	63
	123	3	177	303	58	59
	62	2	185	249	74	75
	78	1	79	158	50	50
Totals	425	16	709	1150	62	63
Chinook < 70mm	58	5	28	91	31	35
	94	14	57	165	35	43
	123	14	36	173	21	29
	113	22	100	235	43	52
	113	33	41	187	22	40
Totals	501	88	262	851	31	41
Steelhead	26	0	42	68	62	62
	36	0	27	63	43	43
	10	0	24	34	71	71
	19	0	28	47	60	60
	6	0	13	19	68	68
Totals	97	0	134	231	58	58
Sockeye	233	4	42	279	15	16
	272	7	74	353	20	22
	149	6	46	201	23	26
	149	2	23	174	13	14
	136	2	14	152	9	11
Totals	939	21	199	1159	17	19
Coho d/						

Gatewell 5C (Bar Screens)

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	65	0	166	231	72	72
	36	0	113	149	76	76
	72	0	134	206	75	75
	65	0	150	215	70	70
	32	0	90	122	74	74
Totals	270	0	653	923	71	71
Chinook < 70mm	94	0	36	130	28	28
	94	3	61	158	39	41
	110	7	32	149	21	26
	113	1	81	195	42	42
	133	1	47	181	26	26
Totals	544	12	257	813	32	33
Steelhead	10	0	35	45	78	78
	19	0	28	47	60	60
	13	0	21	34	62	62
	0	0	12	12	100	100
	0	0	3	3	100	100
Totals	42	0	99	141	70	70
Sockeye	130	0	54	184	29	29
	168	0	51	219	23	33
	68	1	53	122	43	44
	107	0	35	142	25	25
	45	0	24	69	35	35
Totals	518	1	217	736	29	29
Coho d/						

Gatewell 4B (Traveling Screen)

	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook > 70mm	139	1	303	443	69	69
	65	4	195	264	74	75
	91	6	234	331	71	73
	113	8	250	371	67	70
	75	0	257	332	77	77
Totals	483	19	1239	1741	71	71
Chinook < 70mm	107	7	66	180	37	41
	110	5	95	210	45	49
	71	7	48	126	38	44
	172	27	135	334	40	49
	172	2	132	306	43	44
Totals	632	48	476	1156	41	45
Steelhead	29	4	80	113	71	74
	26	0	31	57	54	54
	10	0	42	52	81	81
	23	0	46	69	67	67
	13	0	21	34	62	62
Totals	101	4	220	325	68	69
Sockeye	113	6	192	311	62	64
	220	3	203	426	47	48
	133	1	115	249	46	47
	81	1	139	221	63	63
	52	0	110	162	68	68
Totals	599	11	759	1369	55	59
Coho d/						

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ Two foot plywood baffle attached to the underside of the terminal end of G.D. to reduce impingement pressure.

c/ With flow diverter.

d/ No data for these conditions.

TEST SERIES 13

	Bar Screens: Gatewell 5A	Bar Screens: Gatewell 5B	Bar Screens: Gatewell 5C	Traveling Screen: Gatewell 4B
Gatewell Deflector	% Porosity 52 b/ < To Flow 3 a/ Operating el. 272 Gap Size 0 (Inches)	% Porosity 35 c/ < To Flow 20° Operating el. 272 Gap Size 6 (Inches) d/	% Porosity 62 < To Flow 30° Operating el. 272 Gap Size 0 (Inches)	% Porosity 35 < To Flow 60°
Trashrack Deflector	% Porosity 62 < To Flow 30° Overlap 2 (Feet)	% Porosity 35 < To Flow 23° Overlap 1 (Feet)	% Porosity 52 < To Flow 30° Overlap 2 (Feet)	

	5A Fyke net catch	5A Gap net catch	5A Gatewell catch	5A Total catch	5A % guided	5A % guided incl. gap	5B Fyke net catch	5B Gap net catch	5B Gatewell catch	5B Total catch	5B % guided	5B % guided incl. gap	5C Fyke net catch	5C Gap net catch	5C Gatewell catch	5C Total catch	5C % guided	5C % guided incl. gap	4B Fyke net catch	4B Gap net catch	4B Gatewell catch	4B Total catch	4B % guided	4B % guided incl. gap
Chinook > 70mm	431	0	608	1039	59	59	437	11	419	867	48	50	340	0	420	760	55	55	496	6	711	1213	59	59
	116	0	219	335	65	65	91	6	89	186	48	51	32	0	78	110	82	82	308	5	326	639	51	52
	334	0	326	660	49	49	292	5	222	519	43	44	237	0	220	457	50	50						
Totals	881	0	1153	2034	56	56	820	22	730	1572	46	48	609	0	718	1327	54	54	804	11	1037	1852	56	57
Chinook < 70mm	80	0	27	107	25	25	133	5	12	150	8	11	87	0	8	95	8	8	78	6	43	127	34	37
	78	0	39	117	33	33	90	10	28	128	22	30	93	2	37	132	28	30	130	4	40	174	23	25
	55	0	63	118	53	53	113	4	33	150	22	25	72	0	48	120	40	40						
Totals	213	0	129	342	38	38	336	19	73	428	17	21	252	2	93	347	27	27	208	10	83	301	28	31
Steelhead e/																								
Sockeye	75	0	54	129	42	42	36	1	6	43	14	16	26	0	23	49	47	47	78	2	171	251	68	69
	84	0	47	131	36	36	98	2	33	133	24	27	31	0	24	55	64	44	94	4	144	242	60	61
	72	0	39	111	35	35	97	0	17	114	15	15	88	0	28	116	24	24						
Totals	231	0	140	371	38	38	231	3	56	290	19	20	145	0	75	220	34	34	172	6	315	493	64	65
Coho e/																								

a/ Operating elevation 270 is the lower G.D. operating position and 272 is the upper position.

b/ Four foot section of 48% open area perforated plate attached to the underside of the terminal end of the G.D. to reduce impingement pressure.

c/ Two foot plywood baffle attached to the underside of the terminal end of G.D. to reduce impingement pressure.

d/ With flow diverter.

e/ No data for these conditions.

TEST SERIES SUMMARY

TEST SERIES	Gatewell 5A							Gatewell 5B							Gatewell 5C						
	Gatewell Deflector				Trashrack Deflector			Gatewell Deflector				Trashrack Deflector			Gatewell Deflector				Trashrack Deflector		
	% Porosity	< To Flow	Operating Elevation	Gap Size (Inches)	% Porosity	< To Flow	Overlap (Feet)	% Porosity	< To Flow	Operating Elevation	Gap Size (Inches)	% Porosity	< To Flow	Overlap (Feet)	% Porosity	< To Flow	Operating Elevation	Gap Size (Inches)	% Porosity	< To Flow	Overlap (Feet)
1	62	60°	270	6	N/A	N/A	N/A	35	60°	270	6	N/A	N/A	N/A	52	60°	270	6	N/A	N/A	N/A
2	62	50°	270	6	N/A	N/A	N/A	35	50°	270	6	N/A	N/A	N/A	52	50°	270	6	N/A	N/A	N/A
3	62.	40°	270	6 a/	N/A	N/A	N/A	35	40°	270	6 a/	N/A	N/A	N/A	52	50°	270	6 a/	N/A	N/A	N/A
4	62	30°	270	6 a/	N/A	N/A	N/A	35	30°	270	6 a/	N/A	N/A	N/A	52	50°	270	6 a/	52	45°	5
5	62	30°	270	2 a/	N/A	N/A	N/A	35	30°	270	2 a/	N/A	N/A	N/A	52	50°	270	2 a/	52	45°	5
6	62	30°	270	6 a/	62	25°	2	35	30°	270	6 a/	35	23°	1							
7	52	30°	270	6 a/	62	25°	2	35	30°	270	6 a/	35	25°	2							
8	52	40°	270	2 a/	N/A	N/A	N/A	35	40°	270	6 a/	N/A	N/A	N/A	62	50°	270	6 a/	52	8°	1
9	52 b/	30°	270	6 a/	62	30°	2	35 b/	30°	270	6 a/	35	30°	2	62	50°	272	0	N/A	N/A	N/A
10	52 b/	30°	272	6 a/	62	30°	2	35 b/	30°	272	6 a/	35	30°	2	62	30°	272	6 a/	52	30°	2
11	52 b/	30°	272	6 a/	N/A	N/A	N/A	35 b/	30°	272	6 a/	N/A	N/A	N/A	62	30°	272	0	N/A	N/A	N/A
12	52 b/	30°	272	0	62	30°	2	35 b/	30°	272	6 a/	35	30°	2	62	30°	272	0	52	30°	2
13	52 c/	30°	272	0	62	30°	2	35 b/	20°	272	6 a/	35	23°	1	62	30°	272	0	52	30°	2

a/ With flow diverter.
b/ Two foot plywood baffle attached to the underside of the terminal end of G.D. to reduce impingement pressure.
c/ Four foot section of 48% open area perforated plate attached to the underside of the terminal end of G.D. to reduce impingement pressure.