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OF ENGINEERS
Portland District

Hydroacoustic Studies at John Day Dam during Spring and Summer 1999

Final Report

prepared by:

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HTI Project P750

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1.0 INTRODUCTION

1.1 Project Background

Due to various factors, several runs of Pacific salmon and steelhead trout (*Oncorhynchus spp.*) on the Columbia River and its tributaries have been declining since the 1950's. One factor has been the operation of hydroelectric dams. While most downstream migrating juvenile salmon pass safely through a single dam, the cumulative turbine mortality that results from passing through several dams can be significant (Bell et al. 1967, Davidson 1965, Schweibert 1977).

The U.S. Army Corps of Engineers, Portland District (COE) is committed to increasing survival rates for fish passing its projects on the Columbia River. To date, this process at John Day Dam has entailed structured spill programs and prototype testing of a turbine intake extended-length submerged bar screen (ESBS) and juvenile bypass system (JBS). Fish migrating downstream via spill are subject to significantly lower mortality relative to turbine passage (Bell and DeLacy 1972, Heinle and Olson 1981, Raymond and Sims 1980). Surface collection is also being considered as an option for future fish bypass at John Day Dam, either as an augmentation to, or a replacement of the JBS.

To evaluate the most effective options for fish bypass and survival, the COE has funded or conducted a wide range of fisheries studies. These include hydroacoustic monitoring, tagging, radio telemetry, and many others. The COE has attempted to establish objectives and milestones for evaluating and refining the various fish bypass alternatives, and to progressively build an information base to develop the most effective alternative(s). Past studies have focused on objectives such as estimation of passage through specific routes, presence or absence data, intake screen guidance efficiency, and spill management.

To improve downstream-migrant fish passage it is necessary to first thoroughly evaluate current conditions. Baseline data, such as spatial/ temporal information on fish distributions and behavior, are necessary to evaluate any future project modifications or operational regimes.

Basic information on fish passage is necessary for several reasons. Estimates of the proportion of juvenile salmon passing the project through spill and the JBS, designated Fish Passage Efficiency (FPE), provide annual indices for comparison of various test conditions over time. Hydroacoustic monitoring provides high spatial and temporal sampling power, which is virtually unattainable through other methods, allowing continuous sampling of fish passage through the turbines and spills. These data are complementary in nature with other concurrent studies of fish passage and behavior at the project (e.g., radio tagging, PIT tagging, JBS collection, and netting programs). Together, annual studies provide a detailed data set to allow COE evaluation of the efficacy of current fish passage methods and refinement of future alternatives. Data from studies at John Day Dam have been used to continuously refine fish bypass alternatives, with the final goal of meeting mandated juvenile salmonid bypass objectives over the life of the project.

Spill has been demonstrated to be an effective method for improving juvenile salmon bypass efficiency at John Day Dam. Advantages of spill are that it can be implemented without large-scale physical modifications to the project. Limitations include the significant costs of spill due to lost power-generating capability, and nitrogen supersaturation issues at higher levels of spill. This latter concern limits the upper level of spill that can be effectively used to bypass smolt. Within these constraints, spill has been demonstrated to enhance downstream smolt passage rates at John Day Dam over levels that can be achieved with the JBS alone. Spring and summer spill programs with targeted levels of spill have typically been implemented at John Day Dam in previous years, following consultation with state, tribal and federal fisheries resource agencies.

Spill may serve as an interim additional bypass method until more efficient physical bypass alternatives (such as surface collection) are implemented. Alternatively, spill may continue as part of a longer-term fish bypass program.

In the past, voluntary spill for fish bypass purposes has been conducted at night at the majority of hydroelectric dams on the Columbia and Snake rivers. Previous studies have indicated that most downstream-migrant smolt passed the projects at dusk, dawn, and during the hours of darkness, and that spill during this period would pass the largest percentage of smolt. In addition, power demands are typically lower during the nighttime hours, and water is more readily available for spill without adverse effect on power production.

However, hydroacoustic studies at John Day Dam in 1997 and 1998 (BioSonics, Inc. 1998, 1999) indicated that daytime spill was highly effective at the site, and that significant numbers of smolt would pass downstream via the spillway during daylight hours when this passage route was available to them.

To investigate the optimal use of daytime spill for fish passage at John Day Dam, the COE designed and solicited bids for continuing hydroacoustic assessment in 1999. The study was designed as part of the larger continuing fisheries research program at John Day Dam. Hydroacoustic Technology, Inc. (HTI), as a subcontractor to R2 Resource Consultants (R2), was selected by the COE to conduct hydroacoustic evaluations of downstream migrating juvenile salmonids at John Day Dam during the spring and summer of 1999.

1.2 Site Description

John Day Dam is located at Columbia River mile 215.6, approximately 24 miles upstream of The Dalles, Oregon (Figure 1). It impounds Lake Umatilla, and has a total generating capacity of 2,160 MW. The dam spans the Washington-Oregon border and includes a navigation lock, a spillway with 20 bays (numbered north to south), and a powerhouse with 16 turbine units and 4 skeleton bays. Standard length submerged traveling screens (STS) are installed in all units, with the exception of Unit 7, which incorporates an extended-length submerged bar screen (ESBS). Turbine units are numbered 1-20 from south to north. Each turbine unit is divided into three intakes, identified as A, B, and C.

1.3 Historical Spill Effectiveness Estimates

Based on historical studies at other Columbia and Snake River hydropower dams, fisheries managers have typically assumed that juvenile salmon pass over the spillway in direct proportion to the spill level (a 1:1 fish passage-to-spill outflow ratio). Recent hydroacoustic studies at John Day Dam have reported greater than 1:1 fish passage to spill outflow ratios, indicating that spill is relatively efficient at passing outmigrants per unit water at the project.

Spillway effectiveness (the ratio of percent project fish passage via the spillway divided by percent spillway outflow) is used to estimate the relationship of relative fish passage and spillway flow. A spillway effectiveness estimate of 1.00 would be equivalent to 1:1 percent spillway fish passage-to-percent outflow.

At John Day Dam in 1998, BioSonics, Inc. (1999) estimated 24-h seasonal spill effectiveness to be 1.94 during spring and 2.10 during summer. In addition, spill effectiveness was found to be higher during the day relative to night. However, days with spill were limited for the summer estimate (n=5). Daytime spill effectiveness estimates in 1998 were 2.94 and 1.95 for spring and summer, respectively. Nighttime spill effectiveness estimates for spring were 1.16 and 1.30 for summer. Nitrogen supersaturation issues downstream limited the levels of spill that could be achieved. Spillway flow deflectors have since been installed that should allow greater spill levels before reaching dangerous total dissolved gas concentrations.

The 1997 hydroacoustic studies at John Day Dam were designed to evaluate an experimental spillway weir configuration, but also reported increased daytime spill effectiveness relative to night. With the spillway weir removed (as in 1998 and 1999), daytime spill effectiveness was estimated at 1.82 and nighttime effectiveness at 1.42 (BioSonics, 1999).

Figure 1. Location of John Day Dam on the Columbia River between Washington and Oregon State.

2.0 OBJECTIVES

The study was designed to address two specific tasks. The primary Task 1 objective was to estimate project fish passage through the powerhouse and spillway, both absolutely and per proportion discharge, in order to estimate fish passage effectiveness/efficiency between two spill regimes. A second task (Task 2) assessed the validity of the assumptions used to estimate fish entrainment using single-beam hydroacoustic techniques.

2.1 Task 1 Fish Passage Objectives

Specific Task 1 objectives included:

1) Estimation of hourly fish passage at each monitored spillbay, and for the spillway as a whole;

2) Estimation of hourly fish passage at each monitored turbine unit, and for the entire powerhouse;

3) Estimation of the proportion of fish passing the dam through each route, both absolutely (effectiveness) and per proportion of discharge (efficiency);

4) Estimation of the difference in fish passage effectiveness and efficiency between two defined 24-h spill regimes, one with 0% daytime spill and one with 30% daytime spill;

5) Estimation of horizontal and diel fish passage distributions at the spillway and powerhouse, by day/night, and spill level; and

6) Estimation of seasonal fish run timing for each study period relative to the 1999 John Day Dam smolt monitoring indices for the respective monitoring periods.

2.2 Task 2 Split-Beam Behavioral Study

Split-beam hydroacoustic techniques were used to address the following specific objectives at the representative spillway and powerhouse monitoring locations:

1) Estimate the velocities of tracked fish;

2) Estimate the angle off axis (horizontally) of tracked fish;

3) Estimate the direction of travel (upstream/downstream) of tracked fish;

4) Estimate mean trajectory in three-dimensions of tracked fish; and

5) Estimate the target strength of tracked fish.

3.0 METHODS

3.1 Task 1 Data Collection

For Task 1, single-beam hydroacoustic techniques were used to sample fish passage at all operable turbine units and 11 representative spill bays during May 1-30 (spring) and June 6-July 8, 1999 (summer). The monitored spill bay locations were randomly selected within predetermined strata based on the procedures described in Appendix C, "Statistical Synopsis for the Analysis of the 1999 John Day Dam Hydroacoustic Studies".

A blocked spillway operational regime was scheduled, with alternating 3-d periods of 30% and 0% daytime spill and a fixed 60% spill level at night. The spill regime was designed to evaluate the relative effectiveness of daytime spill as a bypass mechanism at the project via statistical comparison of fish passage between the two daytime spill regimes. Estimates of absolute fish passage through the powerhouse and spillway were used to determine project fish passage effectiveness and efficiency within each operational block. These estimates were statistically compared at a 95% confidence.

3.1.1 Single-Beam Equipment Specifications and Deployment

In order to address the Task 1 monitoring objectives, three *HTI Model 243 Hydroacoustic Systems* were deployed to sample the John Day powerhouse and spillway. Figure 2 shows the placement of each hydroacoustic system on the dam and the respective locations monitored by each system.

For the Task 1 objectives, the *Model 243 Systems* were operated in single-beam mode, sampling 6° nominal beam width transducers in 15 turbine units and 10° nominal beam width transducers at 11 spill bays. A block diagram of the each of the three Task 1 *Model 243 Split-Beam Systems* deployed during the 1999 John Day study are presented in Figures 3-5. Individual Task 1 system components are listed in Table 1.

The powerhouse monitoring transducers were deployed in-turbine on uplooking mounts attached to the downstream face of the trashrack, and aimed downstream at a 40° angle from vertical (Figure 6). All of the in-turbine installations employed armored cables from the transducer mount to the surface to protect against abrasion due to high in-turbine flow velocities. The spillway transducers were surface-mounted on pole mounts and aimed downward at a 5° vertical aiming angle downstream, toward the spill gate opening (Figure 7). All transducer mounts were located on unit center. Based on project drawings, the beam axis of the spillway transducers intersected the spill ogee 15 ft upstream of the spill gate opening, on the centerline of each monitored spill bay.

The systems operated at 420 kHz with an output pulse width of 0.18 msec. To minimize background noise impacts, all systems operated in a FM slide (chirp) mode with a broadcast bandwidth of 10 kHz and pulse width of 1.25 msec. Implementation of FM slide significantly reduced the impact of background ambient electrical noise, which can be significant at certain locations on John Day Dam. This noise may potentially obscure fish targets.

Minimum target detection thresholds (-59 dB) and pulse repetition rates (20 pings/sec) were uniform for both the Task 1 powerhouse and spillway transducer installations, and were verified by pre- and post-season laboratory calibrations.

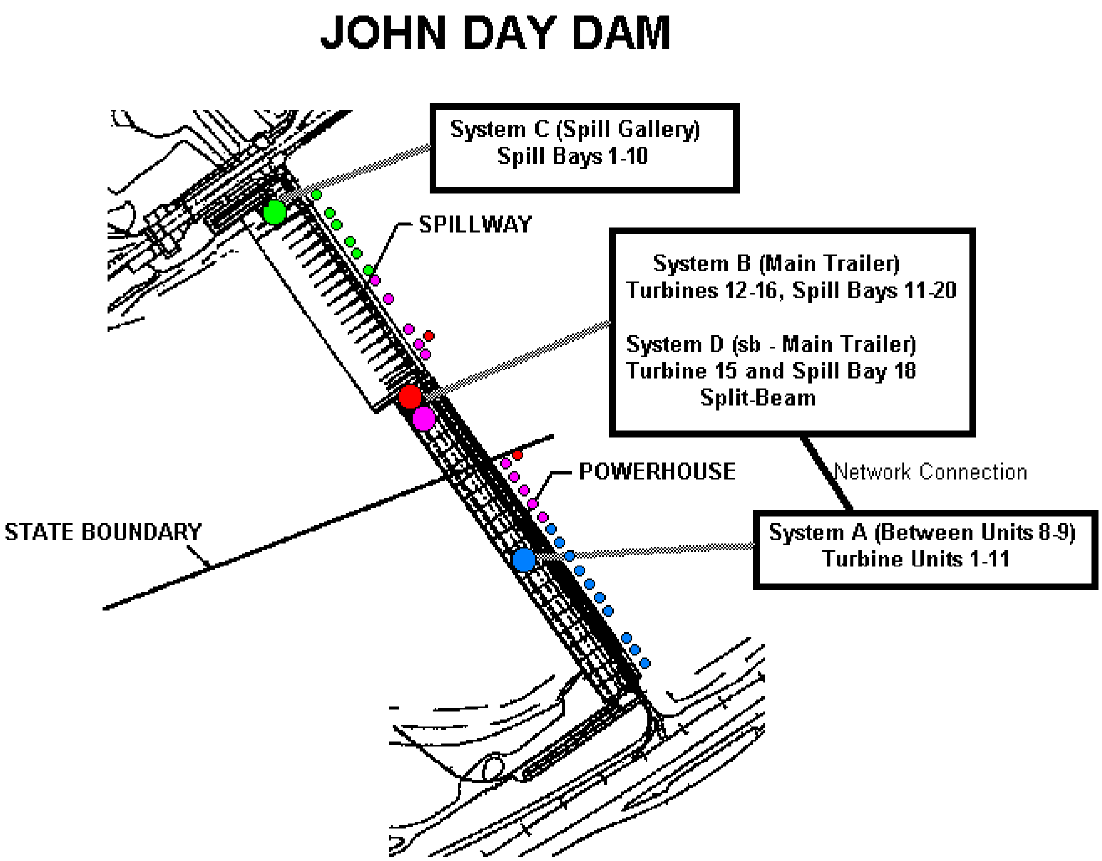


Figure 2. Plan view of the John Day Dam powerhouse and spillway showing placement of the four hydroacoustic systems used to monitor fish passage in 1999. Each system description includes the sample locations monitored by that system.

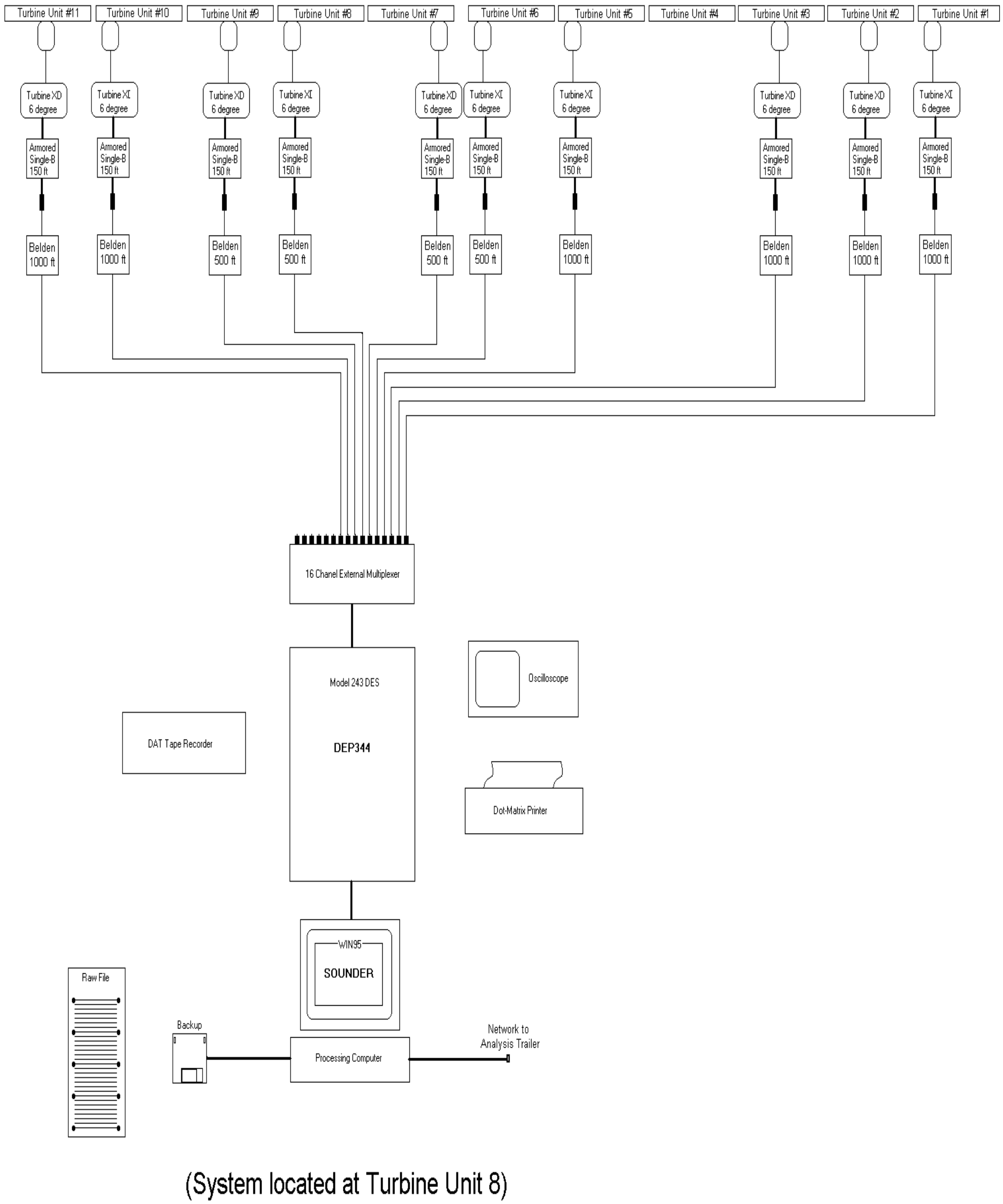


Figure 3. Block diagram of the *Model 243 Split-Beam Hydroacoustic System* –System A used in single-beam mode to monitor Turbine Units 1-3 and 5-11. This system was located at a trailer between Turbine Units 8 and 9. John Day Dam, 1999.

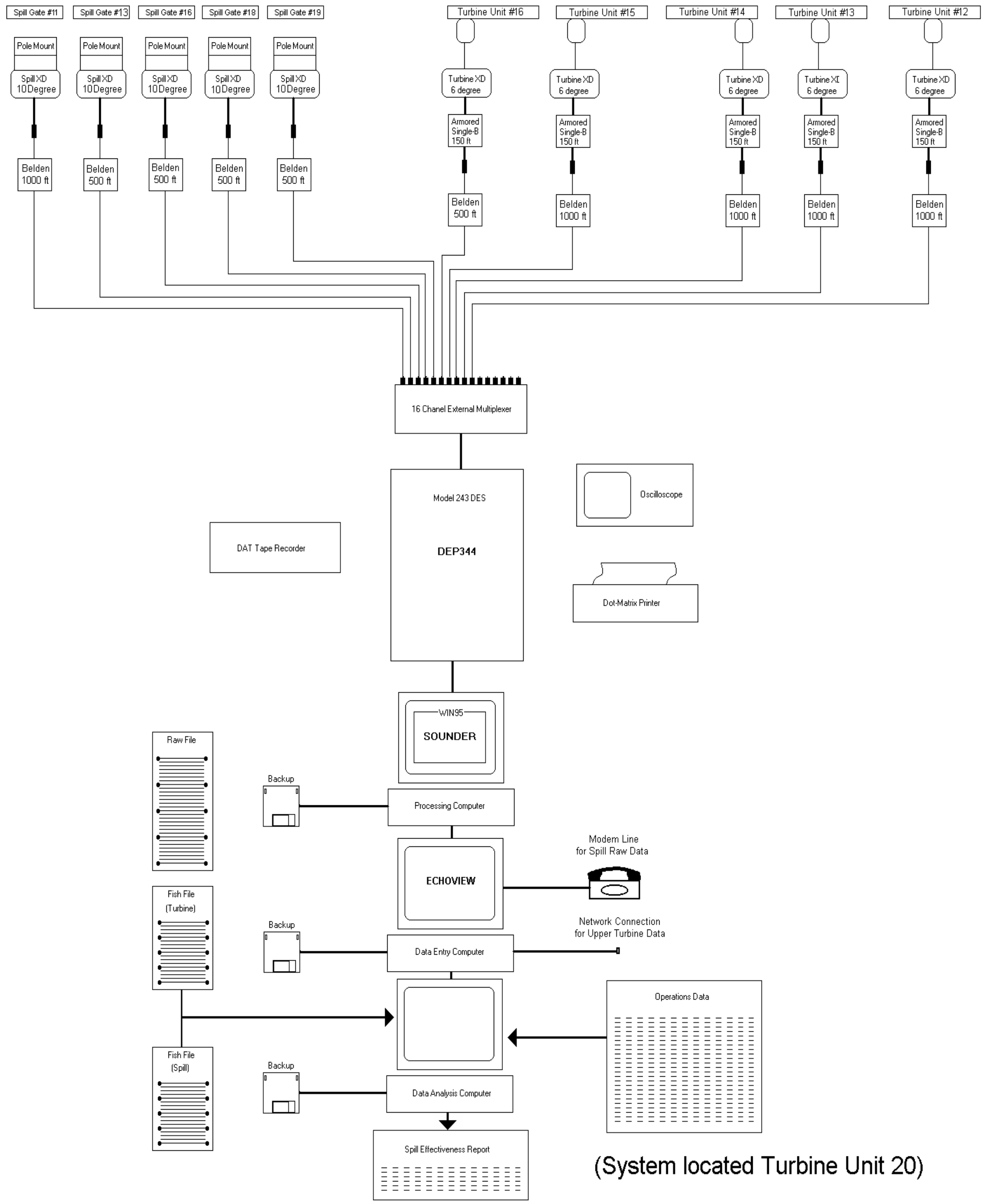


Figure 4. Block diagram of the *Model 243 Split-Beam Hydroacoustic System* –System B used in single-beam mode to monitor Turbine Units 12-16 and Spill Bays 11,13,16,18 and 19. This system was located in a trailer at future Turbine Unit 20. John Day Dam, 1999.

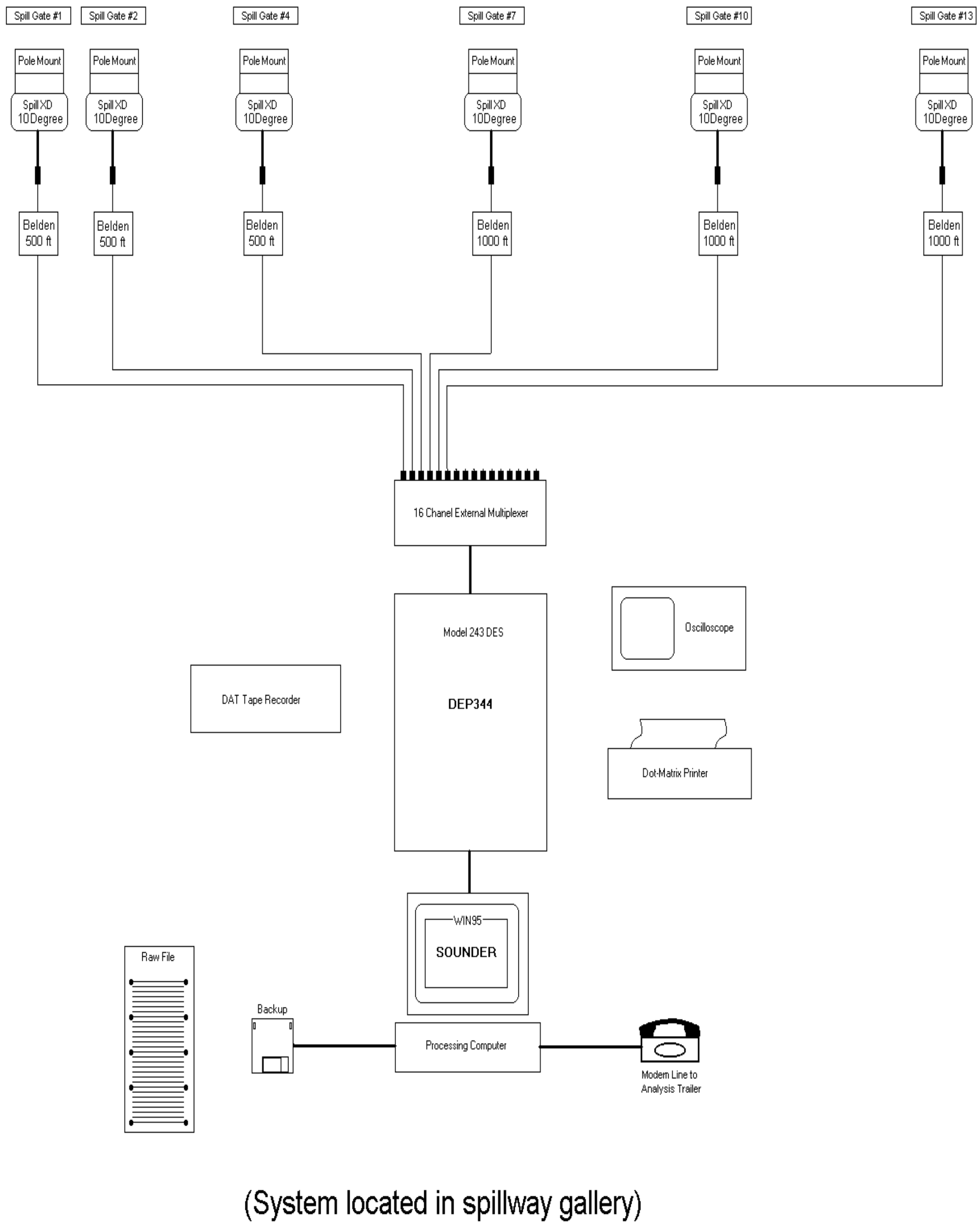


Figure 5. Block diagram of the *Model 243 Split-Beam Hydroacoustic System* –System C used in single-beam mode to monitor Spill Bays 2,4,5,7,8 and 10. John Day Dam, 1999.

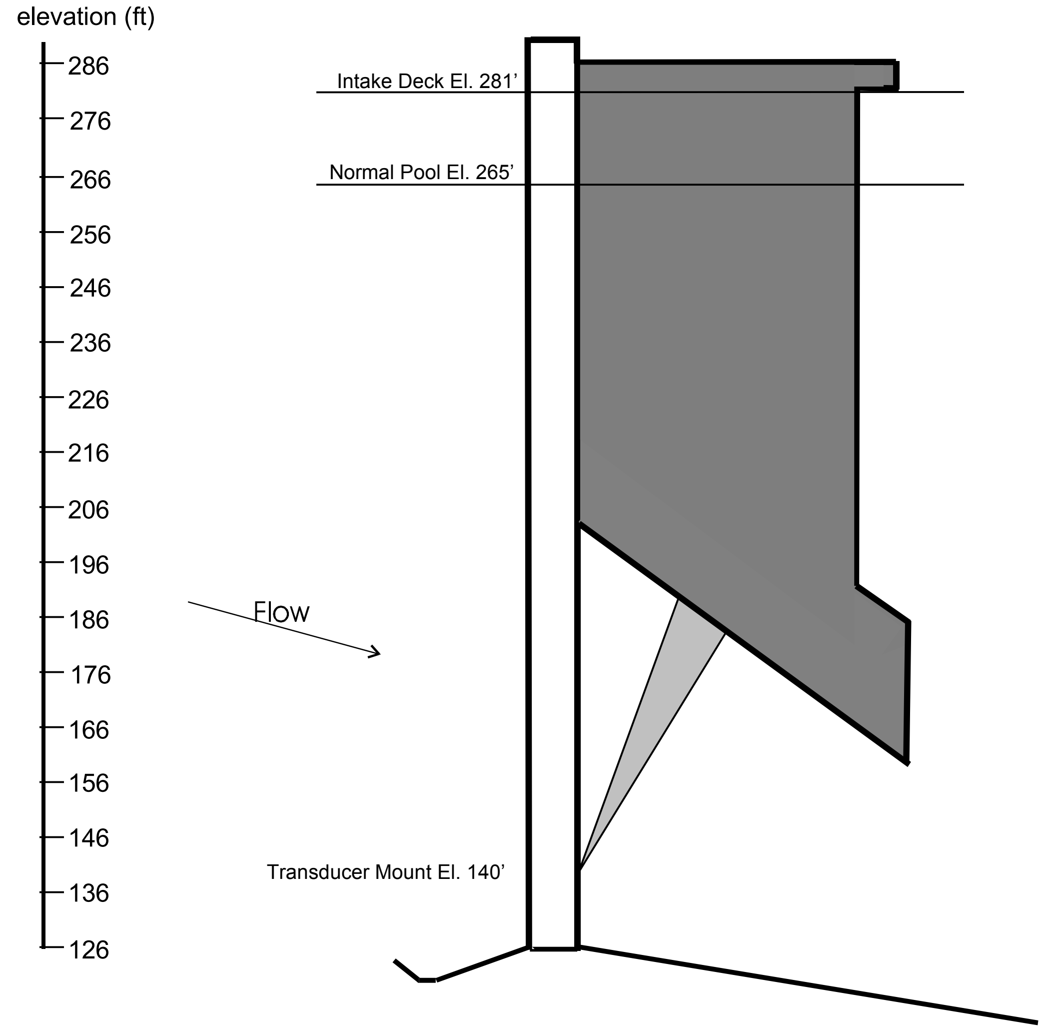


Figure 6. Cross-section of a representative John Day Dam turbine unit showing placement of the transducer, and respective elevations (transducer vertical aiming angle not to scale). John Day Dam, May 1-July 8, 1999.

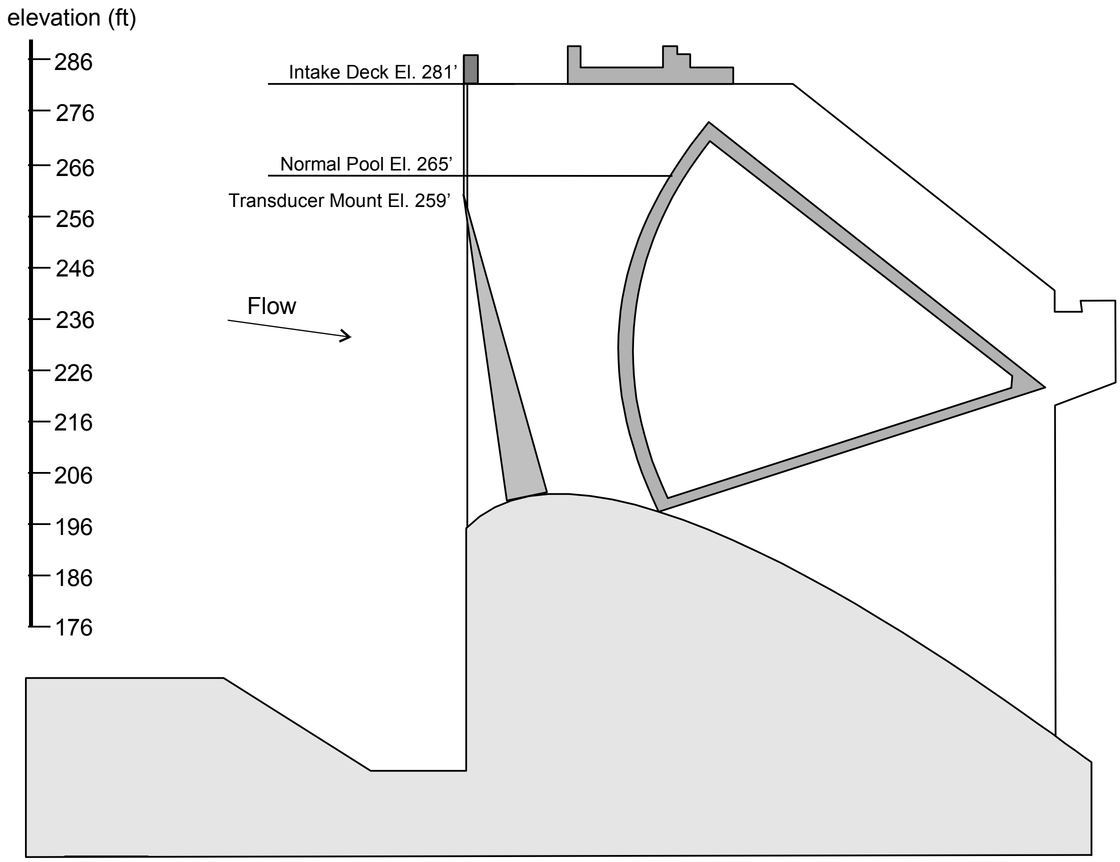


Figure 7. Cross-section of a representative John Day Dam spill bay showing placement of the transducer and the respective elevations (transducer vertical aiming angle not to scale). John Day Dam, May 1-July 8, 1999.

Table 1. Individual components included in the basic *Model 243 Split-Beam Hydroacoustic System*s used (in single-beam mode) for Task 1 FPE objectives. John Day Dam, 1999.

3	*HTI Model 243 Split-Beam Digital Echo Sounder (420 kHz), including Digital Echo Processor w/Pentium PC and printer*
3	*HTI Digital Multiplexer (16 channel)*
15	*HTI Model 513 Single-Beam Transducers (420 kHz): 10° conical beam*
11	*HTI Model 514 Single-Beam Transducers (420 kHz): 15° conical beam*
15	*HTI Model 611 Unarmored Single-Beam Transducer Cable (500 ft each)*
11	*HTI Model 611 Unarmored Single-Beam Transducer Cable (1000 ft each)*
15	*HTI Model 616 Armored Single-Beam Transducer Cable (200 ft each)*
3	*HTI DEP software: ECHOVIEW*
3	*HTI Digital Chart Recorder and printer*
3	*HTI Digital Tape Interface*
3	*Data Processing Computer (Pentium PC), Windows95/98*
3	*Oscilloscope (dual-trace)*
3	*Shipping container for Model 243 DES*
3	*56 K Modem*
3	*Uninterruptable Power Supply*

Systems A and B (each monitoring 10 transducers) were operated in a fast-multiplexed mode, effectively sampling two locations simultaneously with alternate pings. This allowed 6 samples of 2 min each per sampling location. System C, sampling the 6 transducers in the northern half of the spillway, was operated in a slow-multiplexed fashion to provide comparable sampling effort. This design resulted in 5 samples of 2 min each at System C.

As a quality-control measure and redundant data source, chart recorder echograms were collected continuously on all hydroacoustic systems during the 1999 monitoring period. These data were primarily used as a quality control measure to assess fish tracking criteria, but also served as an ultimate data backup.

3.1.2 Task 1 Equipment Calibration

The 420 kHz single-beam transducers used were laboratory-calibrated prior to and following the 1999 study period, and were selected for high transmit and receive sensitivities and low (i.e., least sensitive) side lobes. Low side lobes minimized the chances of acoustic returns from the surface or bottom obscuring fish traces on the echogram. Typical first side lobe values for the 6° nominal beam width single-beam transducers deployed in-turbine varied between –22 and –30 dB. Typical first side lobe values for the 10° nominal beam width single-beam transducers deployed at the spillway varied between –18 and –23 dB. The lowest side lobe transducers within each group were assigned to the units or spill bays with highest priority for operation. High transmit and receive sensitivities minimized the amplification required for returning echo signals before displaying the signals on the chart recorder. This also reduced the amount of amplification applied to potentially obscuring electrical interference.

Tables 2 and 3 describe the pre-season and post-season calibration parameters and data collection thresholds for the 420 kHz single-beam transducer/cable/echo sounder combinations deployed at John Day Dam in 1999.

Following completion of the study, all transducers were calibrated post-season to verify consistent performance during the monitoring period. All transducer, echo sounder and cable combinations used during the study were determined to have consistent performance characteristics relative to the pre-season calibrations. Post-season calibration verified a consistent –59 dB detection threshold at all sampling locations across the dam during the 1999 hydroacoustic study. The in-turbine transducer post-season calibration reflected a mean decrease in overall sensitivity of 0.1 dB relative to the pre-season calibration. The spillway transducer post-season calibration reflected a mean increase in overall sensitivity of 0.8 dB relative to the pre-season calibration.

Table 2. John Day single-beam turbine deployment pre- and post-season transducer calibration source levels (SL), receiving sensitivities (G_1) and corresponding on-axis detection thresholds (dB) applied during field data collection. John Day Dam, May 1-July 8, 1999.

Calibration Assignments: Turbines				Preseason Calibration			Postseason Calibration			Pre-Post Season	Based on	Based on
Sys	S/N	Location	Sounder	SL	G1	SL+G1	SL	G1	SL+G1	Difference (dB)	Pre-Season	Post-Season
A	1000803	T1	631996	214.91	-179.96	34.95	213.97	-179.54	34.43	0.52	-59.0	-58.5
A	1000804	T2	631996	215.22	-179.5	35.72	214.91	-179.22	35.69	0.03	-59.0	-59.0
A	932092	T3	319692	215.22	-179.44	35.78	214.29	-179.94	34.35	1.43	-59.0	-57.6
A	BIO-06-78	T5	631996	215.22	-179.16	36.06	214.91	-178.84	36.07	-0.01	-59.0	-59.0
A	BIO-06-75	T6	631996	215.22	-179.1	36.12	215.22	-177.71	37.51	-1.39	-59.0	-60.4
A	BIO-06-77	T7	631996	214.91	-179.33	35.58	214.91	-177.39	37.52	-1.94	-59.0	-60.9
A	BIO-06-15	T8	631996	213.97	-181.19	32.78	213.66	-179.21	34.45	-1.67	-59.0	-60.7
A	932089	T9	319692	215.85	-179.61	36.24	214.91	-178.19	36.72	-0.48	-59.0	-59.5
A	932090	T10	319692	215.22	-180.26	34.96	213.9	-179.9	34.00	0.96	-59.0	-58.0
A	932091	T11	319692	215.22	-179.52	35.70	214.29	-179	35.29	0.41	-59.0	-58.6
B	BIO-06-17	T12	631996	214.29	-181.61	32.68	214.29	-182.55	31.74	0.94	-59.0	-58.1
B	BIO-06-18	T13	631996	214.91	-180.92	33.99	214.6	-181.42	33.18	0.81	-59.0	-58.2
B	932093	T14	319692	215.22	-179.44	35.78	214.6	-179.6	35.00	0.78	-59.0	-58.2
B	BIO-06-76	T15	631996	215.22	-178.38	36.84	215.22	-179.21	36.01	0.83	-59.0	-58.2
B	BIO-06-16	T16	631996	211.47	-181.78	29.69	210.85	-181.94	28.91	0.78	-59.0	-58.2

Table 3. John Day single-beam spillway deployment pre- and post-season transducer calibration source levels (SL), receiving sensitivities (G_1) and corresponding on-axis detection thresholds (dB) applied during field data collection. John Day Dam, May 1-July 8, 1999.

										On-axis Detection Threshold (dB)		
Calibration Assignments:Spills				Preseason Calibration			Postseason Calibration			Pre-Post Season	Based on	Based on
Sys	S/N	Location	Sounder	SL	G1	SL+G1	SL	G1	SL+G1	Difference (dB)	Pre-Season	Post-Season
C	BIO-10-012	S2	319692	207.72	-187.85	19.87	207.72	-186.84	20.88	-1.01	-59.0	-60.0
C	BIO-10-075	S4	175677	206.16	-188.05	18.11	206.72	-187.25	19.47	-1.36	-59.0	-60.4
C	BIO-10-040	S5 (<5/10)	319692	207.41	-189.18	18.23	*Transducer Failure N/A*			*N/A*	-59.0	*N/A*
C	BIO-10-228	S7	175677	207.41	-187.7	19.71	208.03	-186.8	21.23	-1.52	-59.0	-60.5
C	BIO-10-013	S8	319692	209.29	-186.92	22.37	207.72	-185.97	21.75	0.62	-59.0	-58.4
C	BIO-10-017	S10	319692	210.56	-185.45	25.11	209.29	-184.17	25.12	-0.01	-59.0	-59.0
B	BIO-10-071	S11	175677	209.6	-186.36	23.24	208.97	-184.37	24.60	-1.36	-59.0	-60.4
B	BIO-10-018	S13	319692	209.6	-186.12	23.48	209.6	-184.55	25.05	-1.57	-59.0	-60.6
B	BIO-10-064	S16	319692	208.79	-188.6	20.19	208.35	-186.88	21.47	-1.28	-59.0	-60.3
B	BIO-10-014	S18	319692	208.35	-187.12	21.23	208.91	-186.83	22.08	-0.85	-59.0	-59.9
B	BIO-10-015	S19	319692	208.66	-186.06	22.60	209.29	-185.97	23.32	-0.72	-59.0	-59.7
C	BIO-10-069	S5 (>5/10)	319692	209.29	-188.51	20.78	205.85	-185.35	20.50	0.28	-59.0	-58.7

3.2 Task 2 Data Collection

For Task 2, split-beam hydroacoustic techniques were employed to provide detailed behavioral information for comparison with the concurrently collected single-beam data. Information collected at these two representative sites included fish direction-of-movement in three dimensions, target strength (fish acoustic size), velocity and other parameters. These data were used to assess if fish enumerated at the powerhouse and spillway were comparably entrained and equally detectable by the hydroacoustic system. Task 2 data were collected throughout the study period, but analyzed and reported for only the spring outmigration period, as specified by the COE.

3.2.1 Split-Beam Equipment Specifications and Deployment

In order to address Task 2, two split-beam transducers were deployed, one each at Turbine Unit 15 and Spill Bay 18. These deployments were identical to the transducer deployments for the corresponding single-beam transducers at the powerhouse and spillway (Figures 6 and 7, respectively). Transducers were placed at locations concurrently sampled by a single-beam transducer, in order to allow direct comparison of the observed fish distributions. At both sampling locations, the split- and single-beam transducers were located on the same mounts and located at the same depths and orientations. The transducers at Turbine 15 were deployed on an uplooking in-turbine mount attached to the downstream face of the trashrack and aimed downstream at a 40° angle from vertical. The transducers at Spill Bay 18 were surface-mounted and aimed downward at a 5° vertical aiming angle downstream toward the tainter gate opening.

The operating frequency of both split-beam transducers was 200 kHz, to avoid interference with the 420 kHz single-beam transducers. The transducer at Turbine Unit 15 was a 6° circular beam width unit, and a 15° circular beam width transducer was used at Spill Bay 18. The in-turbine split-beam installation used a 150 ft armored cable from the mount to the surface to protect against abrasion due to high in-turbine flow velocities.

A 200 kHz HTI *Model 243 Split-Beam Hydroacoustic System* deployed in the primary data collection trailer near Spill Bay 20 sampled both transducers for alternate 6-min intervals, such that each location was sampled 30 min/hr. The split-beam system was sampled 24 h/d, 7 d/wk during the spring monitoring period (May 1-30), with only minor interruptions. Minimum target detection thresholds (-56 dB) and pulse repetition rates (20 pings/sec) were uniform for both split-beam transducers.

Split-beam transducers were deployed at Spill Bay 18 and Turbine Intake 15, to allow transducer cables to be routed to a single, centrally located echo sounder. The closest spill bay and turbine locations were not selected (Spill Bay 20 and Turbine Unit 16) due to concerns that they may not be representative of the passage routes as a whole, due to potential boundary effects. Turbine Units 11-14 were excluded from consideration as they generally operated in synchronous condensing mode during nighttime hours. Hydraulic inflow to these units differed from the remainder of the powerhouse during this period.

The HTI *Model 243 Split-Beam Echo Sounder* used to address the Task 2 behavioral objectives operated at 200 kHz in split-beam mode and sampled two *Model 541/544 Split-Beam Transducers*. In other respects, the Task 2 system operated identically to the single-beam 420 kHz *Model 243 Systems*, employing the same data collection and analysis software. A block diagram of the Task 2 *Model 243 Hydroacoustic System* is presented in Figure 8. Individual system components are listed in Table 4.

3.2.2 Task 2 Equipment Calibration

The two deployed 200 kHz *Model 541/544 Split-Beam Transducers* were laboratory-calibrated previous to and following the 1999 Task 2 study period. Like the single-beam transducers, both split-beam transducers were selected for high transmit and receive sensitivities, and low (i.e., least sensitive) side lobes. The 6° split-beam transducer deployed in Turbine 15 had a highest side lobe of –18 dB, and the 15 ° split-beam transducer deployed at Spill Bay 18 had a highest side lobe of –25 dB. High transmit and receive sensitivities minimized the amplification required for returning echo signals before displaying the signals on the chart recorder. This also reduced the amount of amplification applied to potentially obscuring electrical interference.

Table 5 presents the pre-season and post-season calibration parameters and data collection thresholds for the 200 kHz split-beam transducer/cable/echo sounder combinations deployed at John Day Dam in 1999.

Following completion of the 1999 John Day hydroacoustic study, the two split-beam transducers were post-season calibrated to verify consistent performance over the monitoring period. Both were determined to have consistent performance characteristics relative to the pre-season calibrations. Post-season calibration verified a consistent –56 dB detection threshold at all sampling locations across the dam during the 1999 hydroacoustic study. The in-turbine transducer post-season calibration reflected an increase of 1.0 dB relative to the pre-season calibration. The spillway transducer post-season calibration reflected a mean increase in overall sensitivity of 0.6 dB relative to the pre-season calibration.

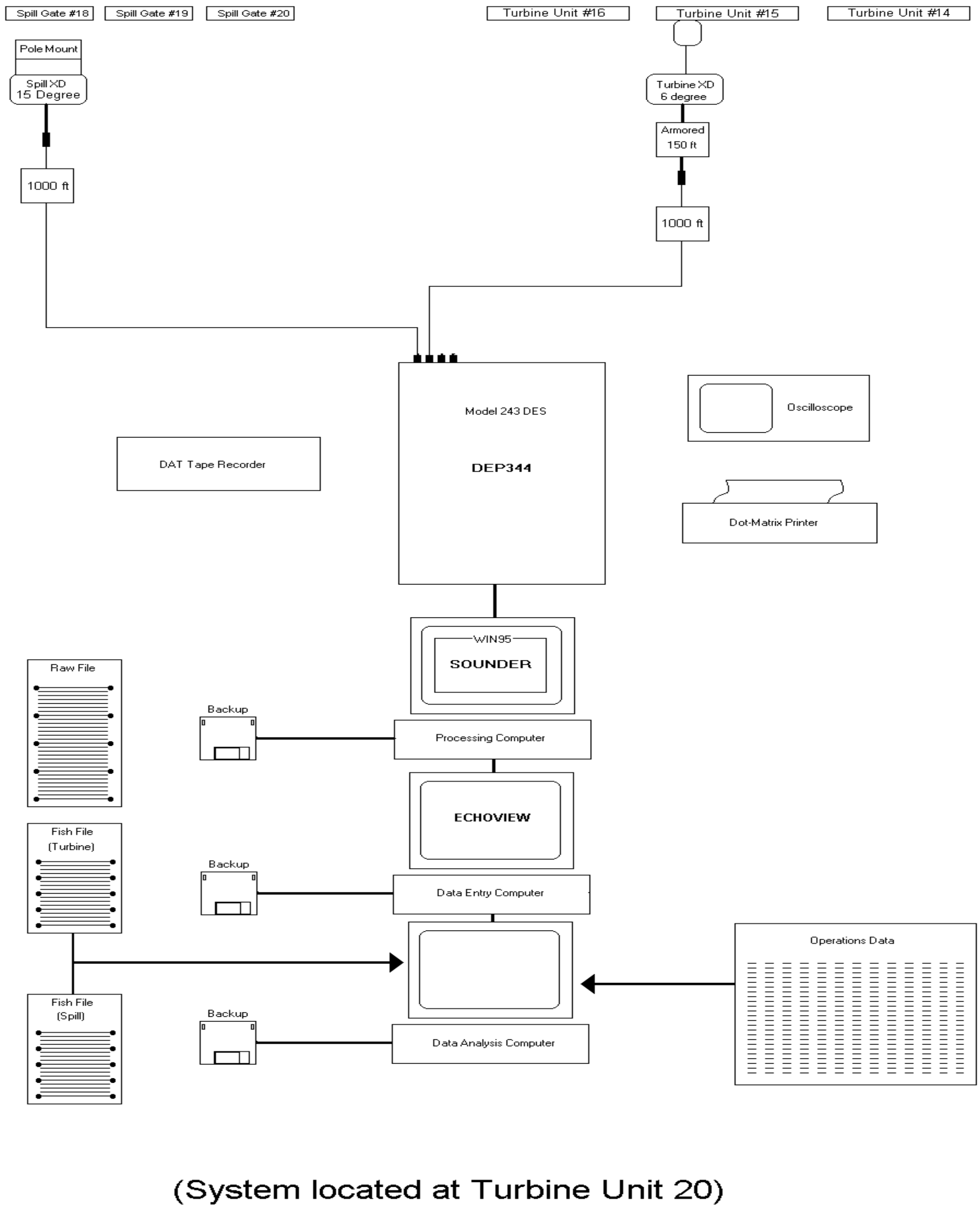


Figure 8. Block diagram of the *Model 243 Split-Beam Hydroacoustic System* used to address Task 2 fish distribution and behavioral issues at Turbine Unit 15 and Spill Bay 18. John Day Dam, 1999.

Table 4. Individual components included in the *Model 243 Split-Beam Hydroacoustic System* used for monitoring Task 2 fish behavior and trajectories. John Day Dam, 1999.

1	*HTI Model 243 Split-Beam Digital Echo Sounder (200 kHz), including Digital Echo Processor w/Pentium PC and printer*
1	*HTI Digital Multiplexer (4 channel)*
1	*HTI Model 541 Split-Beam Transducer (200 kHz): 6° circular beam*
1	*HTI Model 544 Split-Beam Transducer (200 kHz): 15° circular beam*
2	*HTI Model 641 Split-Beam Transducer Cable (250 ft each)*
2	*HTI Model 641/642 Split-Beam Transducer Cable (500 ft each)*
1	*HTI Model 646 Armored Split-Beam Transducer Cable (200 ft)*
1	*HTI ECHOVIEW DEP Analysis Software*
1	*HTI Digital Chart Recorder and printer*
1	*HTI Digital Tape Interface*
1	*Data Processing Computer (Pentium PC), Windows95/98*
1	*Digital Audio Tape (DAT) recorder*
1	*Oscilloscope (dual-trace)*
1	*Shipping container for Model 243 DES*
1	*HTI/ROS Model 661 Single-Axis Rotator*
1	*HTI Model 660-2 Rotator Controller*
2	*HTI Model 650/651 Rotator Cable (250 ft each)*
1	*56 K Modem*
1	*Standard target (200 kHz)*
1	*Uninterruptable Power Supply*

Table 5. John Day split-beam spillway deployment pre- and post-season transducer calibration source levels (SL), receiving sensitivities (G_1) and corresponding on-axis detection thresholds (dB) applied during field data collection. John Day Dam, May 1-July 8, 1999.

										On-axis Detection Threshold (dB)		
Split-Beam Calibration				**Preseason Calibration**			**Postseason Calibration**			**Pre-Post Season**	**Based on**	**Based on**
Sys	S/N	Location	Sounder	SL	G1	SL+G1	SL	G1	SL+G1	**Difference (dB)**	**Pre-Season**	**Post-Season**
D	SB-93-022	T15	319693	219.86	-169.82	50.04	219.72	-168.66	51.06	-1.02	-56	-57.02
D	SB-316616	S18	319693	209.54	-165.53	44.01	209.22	-164.64	44.58	-0.57	-56	-56.57

3.3 Fish Detectability Modeling

Before the 1999 field season, fish detectability models were generated for the in-turbine and spillway transducer deployments. These models were generated to ensure that appropriate transducer beam widths, orientation, and ping repetition rates were selected to allow consistent fish detection across all sampling locations at the site.

Target detectability is a function of velocity, transducer beam width (directivity), minimum detection threshold, acoustic size of the target, ping repetition rate, the minimum number of echo returns required to resolve a fish from background noise and fish direction of travel (chord length) through the ensonified volume. If fish velocities are too fast and/or ping rates not fast enough for a given transducer beam width; a sufficient number of ensonifications may not be obtained for detection of a fish in the range of interest.

The transducer volume over which a sufficient number of echo returns can be achieved to resolve a fish is termed the effective beam angle. This volume can be modeled if the input parameters are known.

Effective beam angle can be determined over the range of parameters and distances of interest, and optimized given the physical constraints of the area to be sampled and the physics of sound. This data can also be used to determine the effective volume sampled to extrapolate fish passage observations to a larger area. This is important when monitoring fish passage with single-beam techniques, which do not have the ability to estimate an echo beam pattern factor, or the position of a given target within the ensonified volume. Split-beam systems, such as that utilized for the 1999 John Day Task 2 objectives, provide the ability to limit the angle from the acoustic axis over which echo returns are accepted, establishing a fixed sampling volume.

Before the sampling season, the COE provided approximate maximum water velocities for the areas to be acoustically monitored in-turbine and in front of the spillway. These estimated maximum velocities were 8 fps in front of the spillway tainter gate openings, and 6 fps in the turbine penstock opening behind the trashrack. Detectability models for these two locations and estimated velocities are presented in Figures 9 and 10, respectively.

Based on the estimated maximum water velocities (8 fps, or 2.4 meters/sec) and evaluated equipment parameters, the effective spillway transducer beam angles approached full nominal beam detectability beyond a range of approximately 18 ft (5.5 m). At ranges less than 10 ft (3.3 m), targets would not return the 4 echoes required classifying them as migrant fish targets

For the in-turbine deployment at a maximum water velocity of 6 fps (1.8 meters/sec), the effective transducer beam angle approached the defined full nominal beam values beyond a range of approximately 21 ft (6.4 m). Targets would not return the 4 echoes required classifying them as migrant fish targets at ranges less than 12 ft (3.7 m).

Observed maximum fish velocities by the split-beam system during Task 2 monitoring were lower than the estimated water velocities, approximately 3.9 fps (1.2 meters/sec) in front of the spillway gate openings and 3.3 fps (1 meter/sec) in-turbine. These values were based on observed fish velocities for all fish detected by the split-beam transducers deployed at Spill Bay 18 and in Turbine 15. In general, these observed maximum target velocities were about half of the estimated maximum water velocities. Detectability models based on these lower maximum observed fish velocities are presented in Figures 11 and 12, for the spillways and turbines, respectively.

Based on the observed maximum fish velocities (3.9 fps, or 1.2 meters/sec) and evaluated equipment parameters, the effective spillway transducer beam angle approached the defined nominal beam angles beyond a range of approximately 10 ft (3.3 m). Targets would not return the 4 echoes required classifying them as migrant fish targets at ranges less than 5 ft (1.6 m).

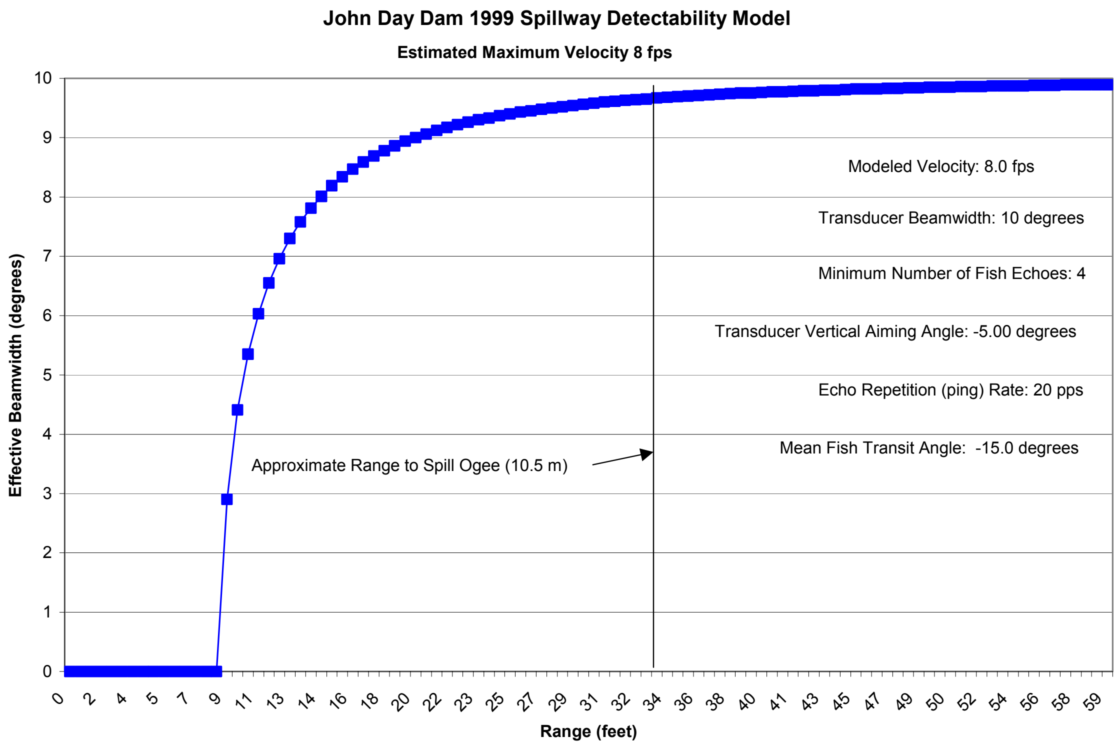


Figure 9. Detectability model for the John Day spillway transducer deployment based on a target velocity of 8.0 fps (2.4 meters/sec) and a 10° nominal transducer beam width. John Day Dam, May 1–July 8, 1999.

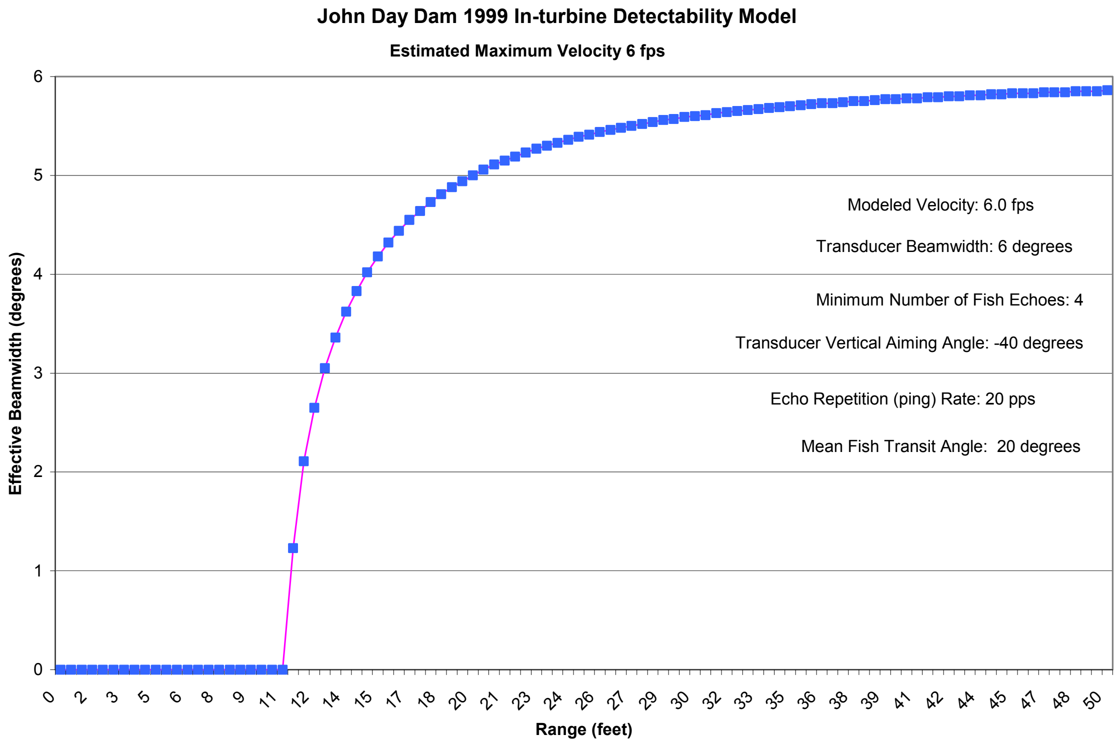


Figure 10. Detectability model for the John Day in-turbine transducer deployment based on a target velocity of 6.0 fps (1.8 meters/sec) and a 6° nominal transducer beam width. John Day Dam, May 1–July 8, 1999.

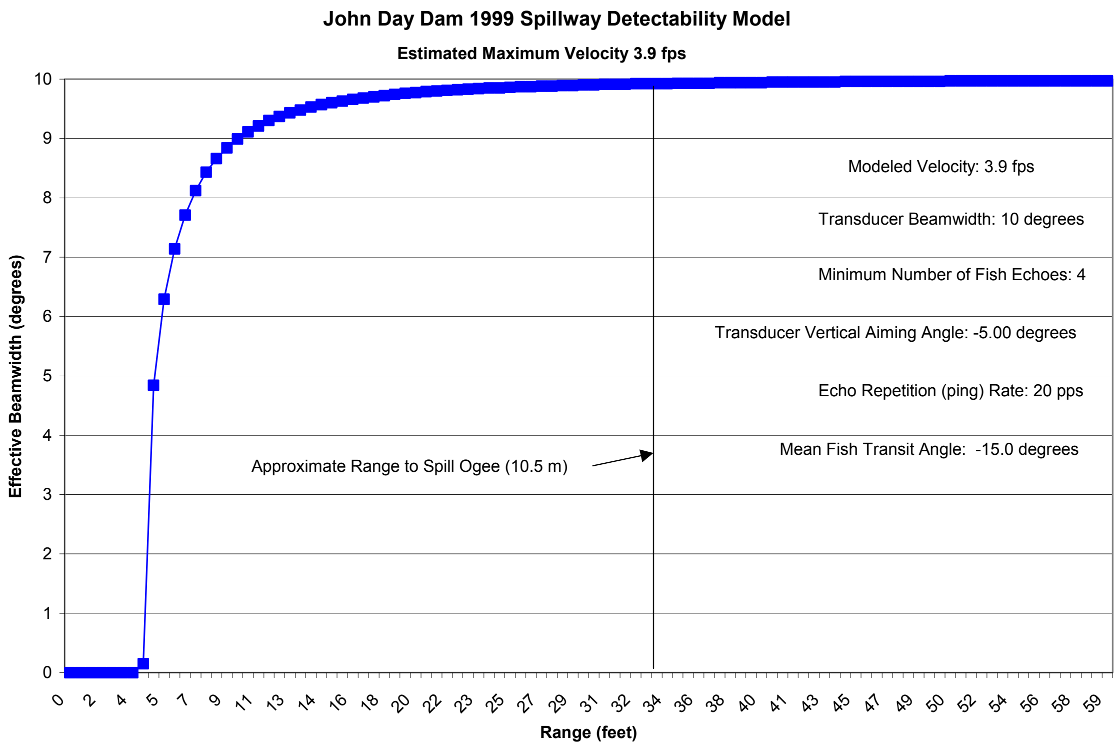


Figure 11. Detectability model for the John Day spillway transducer deployment based on the observed maximum fish velocity of 3.9 fps (1.2 meters/sec) and a 10° nominal transducer beam width. John Day Dam, May 1–July 8, 1999.

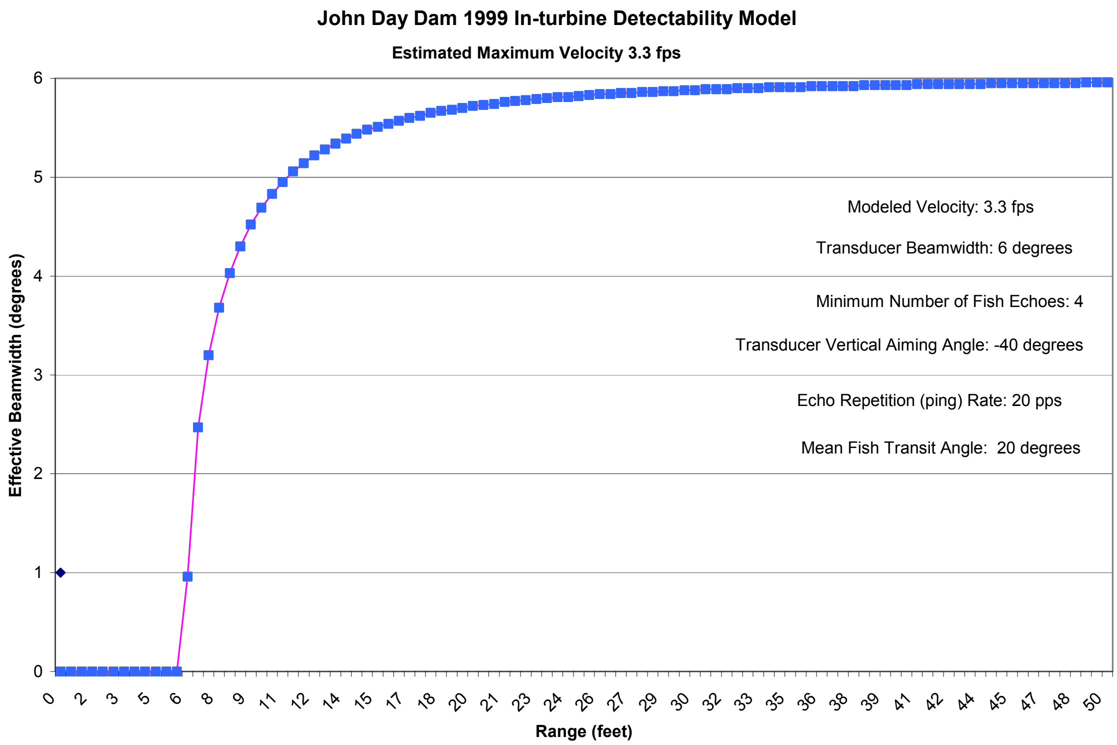


Figure 12. Detectability model for the John Day in-turbine transducer deployment based on the observed maximum fish velocity of 3.3 fps (1.0 meters/sec) and a 6° nominal transducer beam width. John Day Dam, May 1–July 8, 1999.

For the in-turbine deployment at an observed maximum fish velocity of 3.3 fps (1.0 meters/sec), the effective transducer beam angle approached the defined nominal beam angles beyond a range of approximately 12 ft (3.7 m). Targets would not return the 4 echoes required classifying them as migrant fish targets at ranges less than 7 ft (2.1 m).

Conclusions of the detectability analyses were that relatively high and uniform levels of fish detectability were achieved across the sampling ranges of interest at both locations. Fish detectability was consistent between the spillway and in-turbine deployments and was not considered to be a significant source of bias between these comparisons.

The detectability models were conservative in nature, assuming that the modeled velocities were constant across all ranges. In reality, the maximum velocities existed at mid- or extreme range, i.e. in front of the spill gate opening or the upper half of the turbine penstock opening. The maximum fish velocities observed in these areas were consistently about half of the estimated water velocity values, additionally improving overall fish detectability from the pre-season models. Smolts may have been actively resisting entrainment, exhibiting positive rheotaxis (oriented upstream and actively swimming against flow) as they were entrained into the monitored turbines and spill bays. This behavior is consistent with visual observations of entrained smolt at other dams on the Columbia River, and may explain the decreased target speeds relative to estimated water velocities.

Physical limitations limited the level of target detectability that could be achieved at the spillway and in-turbine deployments at John Day Dam. The required ranges to be sampled limited the maximum ping rate that could be achieved. The constricted in-turbine environment limited the transducer beam widths that could be employed. However, by maximizing ping rate, optimizing system operational settings, and selecting appropriate beam width transducers, fish detectability was optimized at comparable levels between the turbine and spillway monitoring locations at John Day Dam in 1999.

For single-beam transducers, the effective transducer beam angle also determines the effective sampling volume. For any given ping rate and orientation, the effective beam angle will vary with target velocity and acoustic size. In instances where the mean size of the fish population of interest is variable or transit velocities are greatly different with range, this can have a significant effect on the sampling volume/area estimate used to extrapolate fish observations into unmonitored areas. If different-size fish, variable target aspect, or transit velocities were present at differing sampling locations, such as the powerhouse and spillway, biased estimates of fish passage by route could result. If these differences were not addressed, they could introduce biases into the resulting estimates of spill effectiveness and efficiency.

For the 1999 John Day hydroacoustic study, velocity effects on effective beam angle were addressed by implementing a high sampling ping rate (20 pps). Based on the detectability models, effective beam angle variability due to varying velocity (within the estimated range of velocities present) was determined to be negligible over the sampling ranges of interest.

Effective beam angle variation due to changes in fish acoustic size over time or between sampling locations was minimized by the following procedures. Transducers with low sidelobes and steep beam pattern drop-offs were selected for monitoring purposes at both the spillway and powerhouse. A relatively low minimum on-axis detection threshold of –59 dB was implemented, approximately 7-10 dB below the minimum size smolt of interest (-49 to –52 dB). This transducer and threshold combination resulted in relatively little change in transducer effective beam width across the range of target strengths expected for outmigrant smolt. This target strength range was estimated to be –42 to –52 dB (approximately 4-15 cm in length applying Love 1977). Fish near the edge of the nominal beam width of a single-beam transducer may return amplitudes approximately 6 dB less than the on-axis values. For typical 6° in-turbine and 10° spillway transducers, effective beam angles varied only about 10-12% over this size range of targets.

The relative consistency of the transducer effective beam angles over time was verified by the generally uniform mean number of echo returns per fish observed at both the powerhouse and spillway within each study period. At the powerhouse during spring monitoring (May 1-30), individual fish returned a weekly mean of between 14.5 and 15.2 echoes. The corresponding spring spillway estimate of the mean number of echoes per fish on a weekly basis varied between 17.8 and 19.2 echoes. Mean echoes per fish on a weekly basis during the analyzed summer monitoring period were also similar within the study period, varying between 11.0 and 12.8 at the powerhouse and 16.4 and 18.3 at the spillway. This parameter indicated that the estimated sampling volumes did not vary greatly between the powerhouse and spillway within the monitored time periods over which passage statistics were calculated. The lower number of mean echo returns at the powerhouse was expected based on the smaller nominal beam width transducers deployed there (6°), relative to those at the spillway (10°). These general differences in sampling volume/cross-sectional area were addressed by the different weighting factors applied for spatial expansion of the fish passage estimates, based on the individual transducer beam angles as measured during calibration and field sampling parameters.

3.4 Data Collection Thresholds

As described in Sections 3.1.2 and 3.2.2, the Task 1 single-beam hydroacoustic systems were operated at a minimum on-axis target detection threshold of –59 dB and the Task 2 split-beam hydroacoustic system at a –56 dB threshold.

The original intent of the –59 dB single-beam threshold was to minimize variability in fish passage estimates due to changes in effective transducer beam width with varying smolt size. The relatively low threshold that could be achieved by the hydroacoustic equipment meant most smolt passed 7-14 dB or more "down" on the transducer beam patterns, where effective beam width is relatively insensitive to changes in acoustic size. The relatively narrow beam width transducers used for the single-beam monitoring at the turbines (6°) and spillway (10°) also aided in achieving the –59 dB threshold.

The 15° split-beam transducer available for monitoring at Spill Bay 18 was more subject to noise due to it's larger sampling volume, and limited the detection threshold to –56 dB for all Task 2 monitoring. The 6° in-turbine split-beam transducer at Turbine 15 could achieve a –59 dB threshold, but –56 dB was used at both split-beam transducers for the sake of comparability between monitored Task 2 locations. The HTI *EchoView* software provides the ability to "threshold up" in post-analysis, so it was decided to retain the potential benefits of the lower single-beam data collection threshold during monitoring and decide if a higher single-beam data collection threshold was warranted based on later inspection of the data set.

Additional analyses were conducted on a subset of the Task 1 single-beam passage data from both the spring and summer periods to assess the percentage of fish with detection thresholds of less than –56 dB. Randomly selected consecutive 72-h blocks of project fish passage data were evaluated for the spring (May 22-24) and summer (July 2-4) data collection periods. The percentage of fish with mean voltage amplitudes less than -56 dB was 1.2% during the evaluated spring period, indicating that smaller targets did not significantly impact the single-beam passage estimates and the Task 1 (single-beam) and Task 2 (split-beam) distributions are comparable for the concurrently monitored areas. This conclusion is supported by the spring split-beam target strength distributions, which were generally normally distributed around a mean fish TS of –46.0 dB (mode = 49.1 dB), and did not indicate biases due to threshold effects.

The analyses of the July 2-4 summer single-beam data set indicated that 13.2% of all monitored outmigrants had mean voltage amplitudes below –56 dB during the monitored period. This distribution was similar at both the powerhouse and spillway. Inspection of the summer data record indicated that these lower amplitude returns were valid fish targets, generally exhibiting swimming behavior against flow. It was presumed that the smaller fish represented zero-age chinook, which are typically present in greater numbers during the summer outmigration.

Per the COE study plan, the Task 2 split-beam behavioral data was to be analyzed and presented for only the spring 1999 outmigration period. The primary purpose of the split-beam monitoring was to confirm the basic assumptions of the single-beam passage model used at John Day Dam. Based on the investigations outlined above, outmigrants smaller than –56 dB were not present in significant numbers during the spring monitoring period. Therefore, the spring Task 1 and 2 distributions should be directly comparable, assuming the Turbine 15 and Spill Bay 18 locations are representative of the powerhouse and spillway as a whole. Task 2 data were not presented for the summer outmigration period, precluding direct comparison of these data with summer Task 1 single-beam distributions.

3.5 General Data Analysis Methods

Data analysis for both the Task 1 single-beam and Task 2 split-beam systems followed similar paths, with the exception that additional information was available from the split-beam data set during the data entry process.

Individual echo data were stored directly to each system's computer hard disk as hourly single target echo files (*.RAW* files). These hourly files were visually examined and fish traces selected from them using HTI's graphical data entry and fish tracking program *EchoView*. *EchoView* converts selected fish trace data to a Microsoft® *ACCESS*™ database, and creates separate tables within the database for echoes, tracked fish, system configurations, sampling information, and other ancillary data. All fish passage data were manually tracked from the hourly data files for both the Task 1 and 2 objectives.

Hourly tracked fish tables were appended to form a daily tracked fish table within a larger analysis database. Previously developed database "queries" selected fish traces based on migrating behavioral characteristics and time periods when turbine units and spill bays were operating. Queries then weighted fish traces based on the ratio of area sampled to intake (or spill bay) width, and performed calculations estimating fish passage, spill efficiency and effectiveness, including variance and confidence intervals.

A detailed quality control procedure was implemented at the start of the study to minimize errors due to technician subjectivity during the data entry process. These specific quality control procedures are described in the "John Day Dam 1999 Hydroacoustic Studies Quality Control Plan", submitted to the COE on April 20, 1999 and included as Appendix E in this report.

A team of five data technicians manually tracked all data, visually inspecting each fish trace. This process, although more time-consuming than implementing an automatic fish tracking algorithm, was determined to provide the most accurate estimates of fish passage in the variable sampling environment at John Day Dam. High wind and other factors can frequently introduce acoustic noise via entrained air. Background electrical interference can also be a source of false counts when using an automatic fish-tracking algorithm. Intertracker error was not included as a factor in the variance estimates surrounding the reported metrics. However, efforts were made to minimize this potential source of error by varying the hours of the day entered by each tracker and comparing hourly estimates of identical data files between trackers and relative to senior experienced HTI personnel on a daily basis.

3.6 Task 1 Data Analysis

For the Task 1 hydroacoustic data, *EchoView* was used to manually select fish traces based on pre-arranged criteria, such as minimum echoes per fish, continuity of trace type, etc. Echo returns had to fulfill four criteria in order to be classified as coming from a fish. The first of these was threshold, set at –59 dB for this study task. Appropriate detection thresholds filtered out much of the unwanted noise from various sources of acoustic and electrical interference, while retaining echoes from the smallest outmigrants of interest.

Secondly, the fish trace had to exhibit redundancy. To be classified as a valid fish target for the 1999 John Day Task 1 study, selected traces had to exhibit a minimum of four “hits” (grouped echoes) and a maximum of 60 echoes. Based on estimated water velocities, sampling pulse repetition (ping) rate and other factors, detectability models indicated that fish residence time in the sampled volume should not exceed 60 echoes. Targets with less than four echoes could not be consistently resolved from scattered noise returns. Any marked traces with echo parameters outside of these bounds were removed in the database selection process.

Thirdly, each selected fish trace had to exhibit a change in range from ping to ping that indicated it was actively migrating. These data were inferred from trace types for the single-beam systems.

Finally, each returning echo had to meet pulse width criteria to distinguish fish echo returns (typically at 0.18 msec) from interference at other pulse widths. Noise due to electrical interference is usually much narrower in pulse width than an echo from a fish, and echoes from multiple targets other than fish are typically wider.

In addition, fish within 3-m range of the spillway transducers were excluded from the final analyses. This minimum detection range was based on detectability models generated before the study. Range-specific selection criteria were not applied in-turbine, although water velocities and resultant low fish detectability generally precluded fish detection’s within 3-m, near the intake floor.

Since the ensonified acoustic beam does not cover the entire designated cross-section of each monitored turbine intake or spill bay, some of the fish passing into the intake or spill bays were not detected. The total number of fish passing each hour was estimated by weighting each fish detection by the proportion of the area sampled (at the range of the detection), and then by expanding to account for the proportion of an hour not sampled. Since the acoustic beam is conical, each individual fish detection was weighted by the following equation:

$$W_f = \frac{I_w}{2 R \tan (BW/2)}$$

where;

W_f = the weighted estimate of entrained fish,
I_w = width of designated intake or spill bay,
R = range of the fish from the transducer,
BW = the effective transducer beam width, as determined from the beam pattern plot of each specific transducer (a function of beam pattern, fish target strength, and hydroacoustic equipment parameters).

Migrant passage estimates for unmonitored turbine units and spill bays were interpolated (or extrapolated) from the closest monitored location(s). The volume of flow through an unmonitored location was multiplied by the fish-per-flow (average fish/flow in the case of interpolation) of the closest monitored location(s) to obtain an estimate of fish passage.

Daily data were reported on a 0600 h-to-0559 h basis, i.e. data reported for May 21 would encompass the time period between May 21 at 0600 h to May 22 at 0559 h.

Specific analysis methods for each objective are described below. Additional data analysis details can be found in Ransom et al. 1995.

3.6.1 Daily Run Timing

Run timing was expressed as total estimated daily passage past the dam over the entire spring or summer monitoring period. In addition to being calculated on a daily basis, cumulative run timing was also presented. On a percentage basis, cumulative run timing was by definition 0% at the start of the respective study period, and 100% at the end.

Run timing was compared to the 1999 John Day smolt index, as measured at the John Day juvenile bypass/collection facility. This index reflects observed fish bypass through the system scaled by total project outflow through the powerhouse and spillway. It is described in more detail on the DART website, www.cqs.washington.edu\dart\pass.html.

3.6.2 Spill Effectiveness and Efficiency

Spill efficiency is defined as the relative number of fish passing through the spillway divided by estimated total project passage. Spillway effectiveness is defined as the proportion of fish passing the project via spill divided by the proportion of total project water outflow through the spillway. The efficiency and effectiveness of the spillway and powerhouse were estimated hourly, daily, for day and night periods, and by spill level. These distributions are presented independently for the spring and summer monitoring periods.

Significant differences in spillway passage efficiency and effectiveness were evaluated for the two designated daytime spill levels (0% and 30%).

3.6.3 Horizontal Distribution of Fish

Horizontal distributions have been calculated from relative fish passage rates for individual turbine units and/or spill bays, and include interpolated passage estimates for unmonitored locations. These distributions are presented independently for the spring and summer monitoring periods.

3.6.4 Diel Fish Passage Rates

In order to examine temporal distributions of fish passage (diurnal fish passage), hourly fish entrainment rates were calculated and summarized. Diel fish passage rates were defined as the percentage of fish passing the entire project each hour relative to total fish passage each 24-h day. Diel passage rates were based on hourly fish passage estimates for all locations combined, and were calculated on a seasonal basis for the spring and summer monitoring periods.

3.7 Task 2 Data Analysis

Fixed-aspect hydroacoustic assessments at hydropower dams using single-beam techniques typically involve assumptions regarding fish entrainment and distribution within the area of interest. Fish passage estimates are generated based on assumptions that fish observed within the sampled area of an intake or spillway are representative of fish density across the entire cross-section of the opening. It is also assumed that the sample time within a given hour is representative of passage at that location for that hour. Techniques such as fast-multiplexing to maximize sampling time and randomized subsamples are employed to minimize temporal biases. The spatial and temporal assumptions underlying hydroacoustic fish passage estimation are generally well accepted within the scientific community, and have been applied at numerous studies at major hydroelectric projects on the Columbia and Snake rivers since the early 1980's.

A third assumption necessary for single-beam hydroacoustic monitoring is that fish in the sampled areas are actively entrained or exhibiting consistent net movement downstream into the intake or spill bay. For these reasons, the transducer beam is normally placed in either an area of high velocity, where fish are absolutely entrained, or as close to the intake/gate opening as possible. Previous to each study, water velocity profiles and other information are typically used to model optimum transducer placement and sampling parameters. These models provide recommended sampling parameters to maximize fish detectability at relatively uniform levels across differing transducer beam widths and orientations. However, optimum transducer mounting locations which provide adequate sampling volumes in areas where velocities are consistently high enough to ensure entrainment are often not available, and actual transducer placement is mandated by site constraints. Fish detectability models are frequently used to determine minimum sampling ranges and estimate the expected number of fish echo returns given water velocities, transducer beam width and other sampling parameters. However, the assumption remains that fish observed at varying locations, such as the turbine and spillway, are uniformly entrained, subject to varying selection criteria, like range, minimum number of echo returns and fish change in range.

The single-beam hydroacoustic passage model assumes that fish within a certain range from a transducer monitoring a spillbay or turbine intake opening (or fish that exhibit specific change-in-range behaviors in this range) are entrained and pass downstream.

Split-beam target tracking hydroacoustic techniques, specifically developed for scientific fish passage assessment, offer a higher degree of target resolution. They are able to track individual fish in three-dimensional space through a monitored area, providing precise estimates of fish direction-of-movement and behavior (Ehrenberg and Torkelson 1995). These techniques provide an estimate of the three-dimensional track of each fish and it's acoustic size, data unavailable with single-beam systems.

At John Day Dam, fish outmigration through the powerhouse has historically been monitored via uplooking transducers located in the turbine intakes, behind the trashracks. Fish observed in these high velocity areas inside the intakes are presumably entrained, unable to exit the intakes against flow. At the spillways, downlooking transducers near the surface monitor the area immediately in front of each instrumented spillway gate opening.

Historically, smolt observed at the John Day spillway have been strongly surface-oriented. The spatial weighting factor applied to fish near the transducer to account for unsampled area across the spillbay is relatively high in comparison to that applied to fish at depth near the tainter gate opening. Fish detected in this relatively small area of the hydroacoustic beam are weighted to a greater degree than fish at depth, as the sampled width of the intake increases as the beam spreads with range. Therefore, near-surface fish are a major component of spillway passage estimates. Based on flow velocity estimates provided by the COE and the resulting detectability models presented above., fish observed within a range of 3 m below the spillway transducers are not included in the entrainment estimates. Fish below this range are considered entrained, given reported water velocities and observed fish tracetype/trajectory behavior. However, given the near-surface smolt distribution at John Day Dam, spillway entrainment estimates are sensitive to the minimum acceptance range. Additional information regarding the depth at which fish are consistently entrained at the John Day spillway was needed to confirm the comparability of the powerhouse and spillway passage estimates.

Under Task 2 of the 1999 John Day Dam hydroacoustic monitoring study, HTI deployed split-beam transducers at Spill Bay 18 and Turbine Unit 15 in order to provide detailed fish behavioral information at these locations, assumed to be generally representative of the powerhouse and spillway. These data provide a basis for evaluating the assumptions of the single-beam passage model via distributions of observed fish direction-of-movement, velocity, target size and other parameters.

The *Model 243 Split-Beam System* used to address Task 2 objectives provided a measure of the direction-of-movement in three-dimensions for each observed fish. The data record included a detailed record of target position, acoustic size, velocity, trajectory and other descriptive parameters. These data were compared to the fish distributions observed by the single-beam transducer(s), and used to verify the assumptions used to estimate fish entrainment. The fish passage model traditionally applied to the single-beam hydroacoustic data set for dams in the Columbia River Basin assumes that fish that are within a certain range from a spill bay or turbine intake opening, or that exhibit specific change-in-range behaviors in this range, are entrained.

The *Model 243 System* outputs a detailed record of each tracked fish observation, designated the *.FSH* file. At fixed-aspect monitoring projects, the system is normally configured to output hourly data files, each uniquely identified by a prefix incorporating the Julian date/start hour and a *.FSH* suffix (i.e. *J1221300.FSH*). The file contains one data line per observed fish, with descriptive parameters. These parameters include a sequential fish identification number, start and end ping numbers associated with the fish, number of echo returns tracked for that fish, position and net movement of the fish in three-dimensional space (X, Y, and Z axes), fish target strength (acoustic size), swimming velocity, and location (such as turbine or spillway number).

In addition to the tracked fish file, other hourly data files can be output simultaneously. The *.RAW* file includes all echo returns, regardless of whether or not they were tracked as fish. The echo *(.ECH*) file presents a detailed description of each individual echo included in the tracked fish file, mapping the path of each observed target in three-dimensional space. These data were employed for the fish behavioral analyses.

Data was analyzed separately for the turbine and spillway transducers. Data was further separated by flow levels (i.e., spill percentage and turbine discharge), and by 1-meter range strata.

Individual echo data from the split-beam transducers was collected and stored in hourly files. These hourly files were visually examined and fish traces selected from them using HTI's graphical data entry and fish tracking program *EchoView*™. *EchoView* converts selected fish trace data to a Microsoft® *ACCESS*™ database, and creates separate tables within the database for echoes, tracked fish, system configurations, sampling information, and other ancillary data.

Hourly tracked fish tables were appended to form a daily tracked fish table within an analysis database. Previously developed database "queries" selected fish traces based on migrating behavioral characteristics, and time periods when turbine units and spill bays were operating. Queries then weighted fish traces based on the ratio of area sampled to intake (or spill bay) width, and performed calculations estimating fish passage, spill efficiency and effectiveness, including variance and confidence intervals.

EchoView was used to manually select fish traces based on pre-arranged criteria, such as minimum echoes per fish (four echoes), continuity of trace type, etc. For the Task 2 split-beam data set, all observed fish traces with four or more consecutive echo returns were entered into the data set, regardless of range or direction-of-movement, to provide an unbiased data set for final analyses.

Microsoft *ACCESS* queries were employed to summarize velocity, target strength, and trajectory data in 1-meter range bins, by discharge condition. Microsoft® *EXCEL*™ was used to plot distributions of fish velocity, target strength, and trajectory.

To assess the validity of the single-beam entrainment model at the spillway, mean fish trajectory profiles for the Spillway 18 monitoring location were calculated and presented in 1-m range intervals below the transducer. Estimates of total fish movement by directional axes (X, Y and Z) were also presented, as a measure of the percentage of total observed fish demonstrating behavior consistent with entrainment.

Mean fish velocity and target strength profiles were developed from data collected at Spill Bay 18, and were blocked by spill bay gate stop opening. These stops corresponded to spill bay flow rates of approximately 1.6, 2.8-3.1, 6.5 and 7.6 kcfs. When Spill Bay 18 was operated, it was primarily operated at 6.5 kcfs. Mean fish velocity and target strength profiles were also estimated at discrete flow intervals for the split-beam data collected at Turbine 15. These parameters were estimated at 2 kcfs intervals, specifically under 11, 12-14, 14-16, 16-18, 18-20 and 20-22 kcfs. Turbine 15 was operated at between 16-20 kcfs during the majority of the Task 2 spring monitoring period. Figures 13 and 14 show the relative operation of Spill Bay 18 and Turbine 15 by kcfs level, expressed as unweighted fish observations by flow. These data illustrate that relatively few data points were available to estimate fish velocity and target strength at low and high flow rates at both locations.

3.8 Statistical Analyses of Task 1 and Task 2 Data

The statistical analyses of the single-beam (Task 1) and split-beam (Task 2) data were identical, following the procedures outlined by Skalski (1999). These procedures are described in Appendix C and were designed specifically for the 1999 John Day Dam hydroacoustic study.

The variance estimates for each hourly passage estimate at each sampled location were carried forward throughout all subsequent analyses. The specified algorithms and design were implemented such that the 95% confidence intervals surrounding all metrics in the 1999 John Day report reflect both spatial and temporal variability observed in the basic sampling units.

However, it should be noted that the study design and subsequent analyses did not account for all potential sources of spatial variability. Within slot and spillbay variability were not sampled. Efforts were made to minimize between slot variability at the turbine units by randomly selecting the monitored slot (A, B or C) at each unit. Nonetheless, the statistical procedures and study design implemented in 1999 represent an improvement over previous studies at John Day Dam and should minimize uncertainty surrounding the estimates.

The only deviation from the original statistical analysis design involved comparison of the blocked spill effectiveness and efficiency values. The original blocked study design scheduled five blocks of each daytime spill level within each season (spring and summer). Seasonal

ANOVA tables comparing the five data blocks under each daytime spill condition were planned to evaluate the effect of daytime spill.

As the scheduled blocked daytime spill regime was not consistently achieved during either the spring and summer period, Dr. John Skalski recommended pooling the daily data blocks which most closely met the designed 0% and 30% daytime spill criteria for final analysis. Under this approach, confidence intervals surrounding the metrics for each pooled spill level were estimated and compared to determine if significant differences existed. All statistical procedures underwent final review and were approved by Dr. Skalski.

Dr. Skalski's alternative variance formula, termed Method 2, which incorporates a measure of slot-to-slot within turbine variance (and unmonitored spill bay variance) was employed for all estimates of variance during the 1999 study. This estimator is described on page 3 of Appendix C. Per Dr. Skalski, this variance formula tends to overestimate the true passage variance. A second formula, which ignores within turbine and unmonitored spill bay variance, termed Method 1 is presented on page 2 of Appendix C. This method underestimates the true variance. For the purposes of determining significant differences in spill effectiveness and efficiency during the study period, the more stringent variance algorithm was applied.

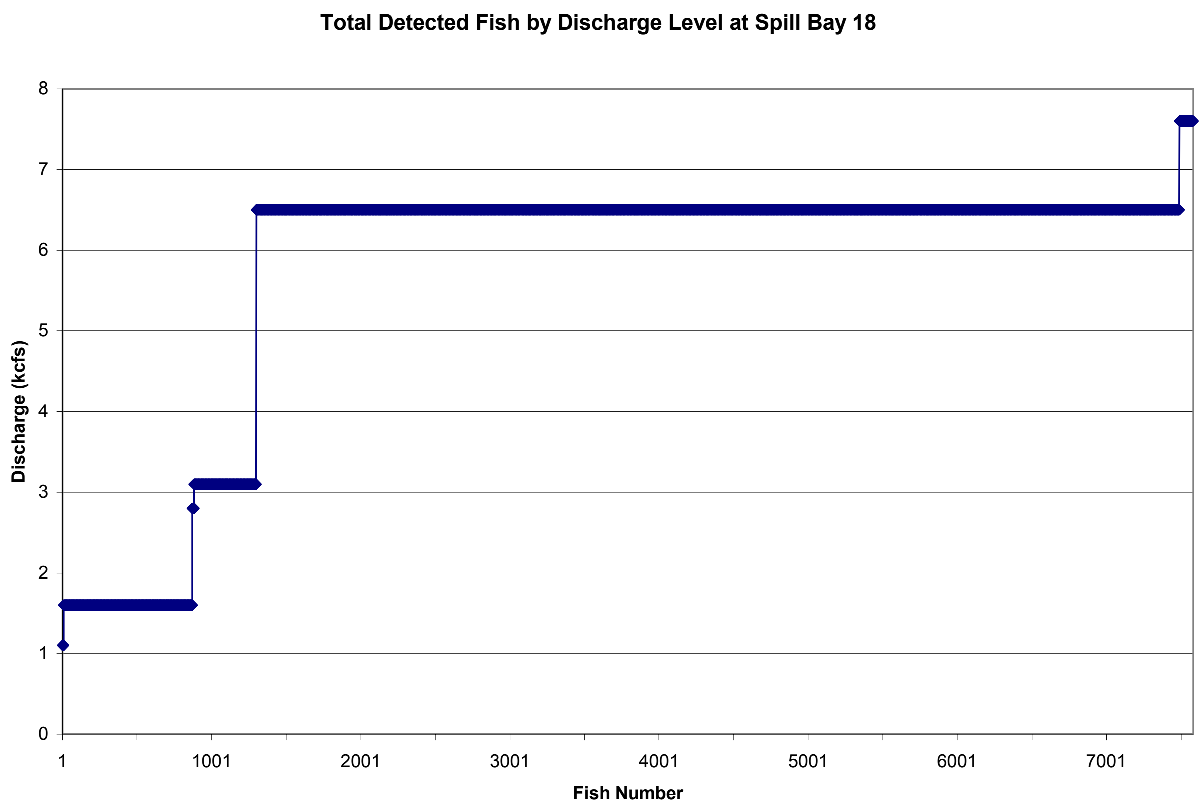


Figure 13. Number of fish detected by the Task 2 split-beam system deployed at Spill Bay 18 by discharge level. John Day Dam, May 1-30, 1999.

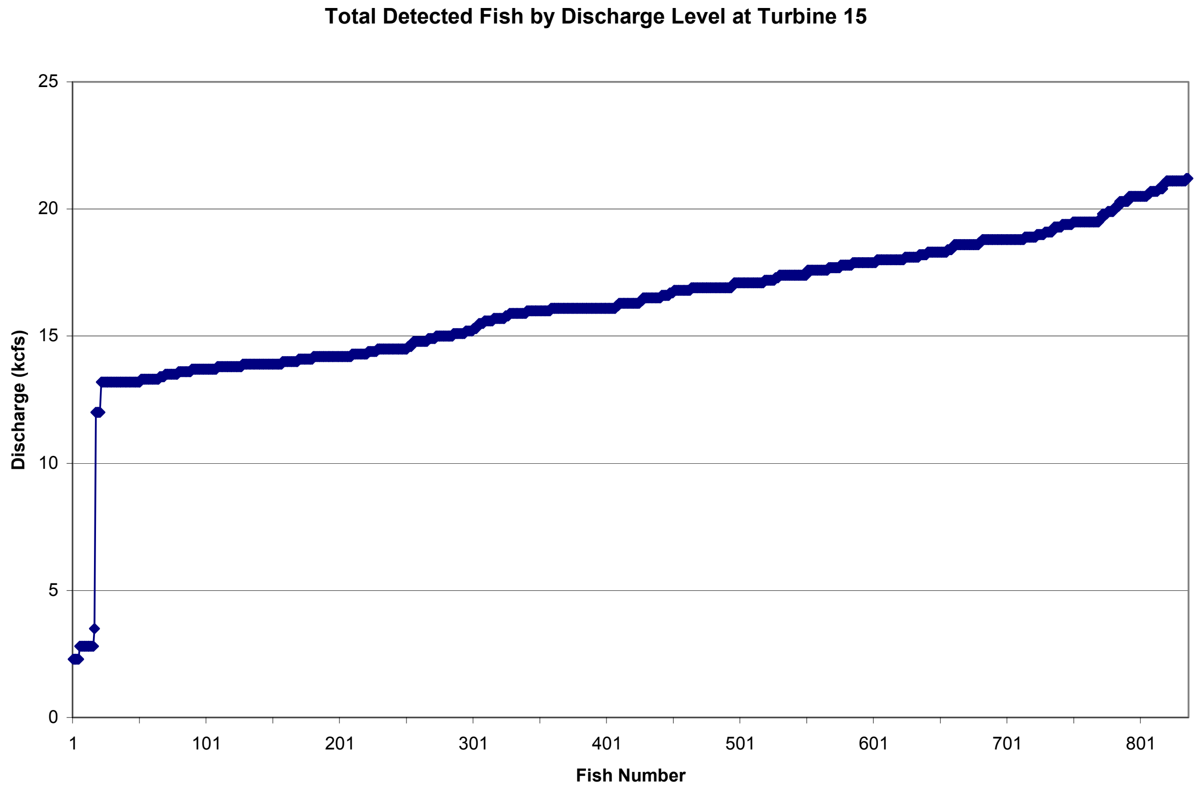


Figure 14. Number of fish detected by the Task 2 split-beam system deployed at Turbine 15 by discharge level. John Day Dam, May 1-30, 1999.

4.0 TASK 1 FISH PASSAGE RESULTS

4.1 Dam Operations

Mean estimated hourly flow through the turbine units and spill bays for the spring monitoring period are presented in Tables 6-11and Figures 15-24, respectively. Tables 8-9 and Figures 17-20 describe powerhouse operations on a mean hourly and day-night basis for the entire 30-d spring (May 1-30) and 33-d summer (June 6-July 8) hydroacoustic monitoring periods. Tables 10-11 and Figures 21-24 describe spillway operations on a mean hourly and day-night basis for the corresponding spring and 33-d summer periods.

A subset of these periods was selected for final analyses of the 1999 hydroacoustic study objectives, based on actual spillway operations during the daytime. To investigate if powerhouse operations differed for this subset, mean hourly flows by unit were calculated for the spring monitoring period. These data are presented for the analyzed 0% spring daytime spill periods in Table 6 and Figure 15 and for the analyzed 30% daytime spill periods in Table 7 and Figure 16.

In general, investigations of project operations during these subsets observed similar trends in mean powerhouse and spillway operation as described on a seasonal (full 30-d) basis. Plant operational regimes were generally repetitive within any given 24-h period within a seasonal block. Hourly reported flow for each location on a daily basis is reported in Appendix A.

Between May 1-30, Turbine Units 1-6, 8, 9 and 15 were generally operated at constant loads of between 14-18 kcfs over the entire 24-h period (Figure 15). Turbine Units 3 and 11-14 also operated continuously during daylight hours at mean loads of 14-16 kcfs, but generally reduced load to about 4-6 kcfs at 1800 hr and maintained this lower flow throughout the night, ramping up at approximately 0500 hr the following morning. Turbine Unit 16, at the north end of the powerhouse, was undergoing service and was inoperable during the majority of the spring study period. Turbine 10 operated at a relatively low fixed load of 2-3 kcfs, 24 hours per day. Turbine Unit 7 operated at an intermediate average load of about 9 kcfs between approximately 2300-1600 h, then decreased to 2 kcfs at 1800 h, followed by a rapid increase to approximately 12 kcfs at 1900 hr, then another decrease to 3 kcfs at 2100 hr. The variations in Turbine Unit 7 operation during the evening and early nighttime hours were due to National Marine Fisheries Service fyke-net tests conducted during this period.

Mean daytime (0600-1859 h) and nighttime (1900-0559 h) turbine operations during the spring monitoring period are shown in Table 8 and Figure 18. These reflect the general trend described above, with generally consistent day-night operation on a per unit basis at Turbine Units 1-10 and 15. Turbine Units 11-14 typically operated in a “synchronous condensing”, or non-generating mode between 1800-0559 h. This operational regime was reflected in the mean day-night comparison of operations. Nighttime unit flow at Turbine Units 11-14 was typically less than half of their respective daytime flows. Turbine Unit 16 was undergoing rehabilitation and was essentially not operated during the spring sampling period.

Mean 24-h turbine operations during the summer hydroacoustic monitoring period (June 6-July 8) are presented in Table 9 and Figure 19. On a 24-h basis, turbine operations were generally more uniform across the powerhouse during the summer monitoring period, relative to that observed during the spring. Turbine Units 11-14 continued to exhibit a decrease in mean generation during nighttime hours (1800-0559 h) due to periodic “synchronous condensing” operation during this period. However, this trend was much less evident than during the spring monitoring period. The remaining turbine units operated relatively constantly on a mean hourly basis, generating 24 h/d at mean flow rates of between 13-19 kcfs, with the exception of Turbine Units 7 and 16. Unit 7 operation was generally constant between 12-13 kcfs between 0800-2300 h, and decreased slightly between 2300-0800 hr to 10-11 kcfs. Unit 16 operated at a low level of approximately 3 kcfs, 24 h/d over the summer hydroacoustic monitoring period.

Mean daytime (0600-1859 h) and nighttime (1900-0559 h) turbine operations during the June 6-July 8 monitoring period are presented in Table 11 and Figure 24. These reflect the generally “flat” operation of the powerhouse during the summer period. At night, mean flow decreased through Turbine Units 11-14, and increased through Turbine Unit 1, relative to daytime operation. Turbine Unit 7 maintained lower levels of flow during both day and night relative to Turbine Units 1-15. Turbine Unit 16 came on-line between the spring and summer monitoring periods, but was operated at relatively low loading (approximately 3 kcfs) during the summer period.

Table 6. Mean spring turbine operation under 0% daytime spill operations. Data are summarized as mean kcfs and percentages on an hourly, 24-h, daytime and nighttime basis. Data are based on only the 8 day pooled data set selected for final analyses. John Day Dam, May 14-27, 1999.

John Day Spring 1999 Mean Hourly Turbine Operations - 0% Day Spill - Hydroacoustic Monitoring Period May 1-30, 1999

Hour	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T10	T11	T12	T13	T14	T15	T16
0	14.4	11.1	9.8	11.0	14.3	16.7	10.1	15.2	12.4	0.0	0.0	2.1	0.0	0.0	11.4	0.8
1	15.0	9.7	10.1	11.2	14.8	17.0	10.0	15.6	12.7	0.0	0.0	2.1	0.0	0.0	11.8	0.8
2	15.5	10.1	12.9	11.5	15.3	17.2	10.0	16.1	13.0	0.0	0.0	2.1	0.0	0.0	12.2	0.8
3	15.2	9.8	13.8	11.3	15.1	17.2	10.1	15.8	12.7	0.0	0.0	2.1	0.0	0.0	12.0	0.8
4	14.0	9.5	13.5	10.9	14.8	16.8	10.1	15.8	12.4	0.0	0.0	1.7	0.0	0.0	11.6	0.8
5	14.0	11.0	14.0	11.3	15.2	17.4	10.1	16.2	13.1	0.0	1.7	1.9	0.9	0.4	12.1	0.8
6	14.3	15.4	15.3	14.1	17.6	19.4	12.7	18.0	17.2	0.0	12.2	13.4	10.6	15.7	17.8	0.0
7	14.2	18.6	17.0	16.5	18.6	20.3	12.7	19.0	18.4	0.0	13.4	16.3	14.4	18.2	18.9	0.0
8	14.9	19.6	17.6	17.0	19.3	20.4	12.8	19.7	19.1	0.0	14.1	17.1	14.6	18.9	19.6	0.0
9	15.3	19.8	20.0	19.4	19.6	20.6	12.8	19.9	19.4	0.0	14.3	17.2	13.3	19.2	19.9	0.0
10	15.3	20.0	20.3	19.8	19.8	20.5	12.8	20.1	19.5	0.0	14.5	17.4	12.1	19.3	20.0	0.0
11	15.3	19.9	20.2	19.7	19.6	20.2	12.8	20.0	19.4	0.0	14.4	17.3	12.0	19.3	19.8	0.0
12	15.0	19.9	20.2	19.8	19.9	20.4	12.8	20.2	19.6	0.0	14.7	17.6	12.2	19.5	20.1	0.0
13	14.4	19.1	19.5	18.9	19.7	20.5	12.9	20.0	19.5	0.0	14.5	17.2	12.2	19.3	19.9	0.0
14	15.3	19.7	20.0	19.5	19.5	20.3	12.8	19.7	19.3	0.0	14.2	17.1	12.0	19.1	19.6	0.0
15	15.3	19.6	19.9	19.4	19.4	20.1	12.8	19.7	19.1	0.0	14.2	16.9	13.1	18.9	19.5	0.0
16	15.3	19.5	19.8	19.2	19.3	19.9	12.8	19.7	19.0	0.0	14.2	16.8	14.4	18.8	19.4	0.0
17	15.3	19.3	19.6	19.2	19.0	19.8	12.8	19.5	18.8	0.0	14.0	16.6	14.2	18.6	19.2	0.0
18	15.6	19.8	20.2	19.6	19.6	17.3	6.4	18.2	19.3	0.0	14.5	17.3	14.5	18.8	19.8	0.0
19	14.7	13.6	14.2	15.1	15.1	14.3	2.5	14.3	15.0	0.0	3.2	6.3	4.1	5.3	15.5	0.8
20	14.6	13.5	13.7	15.0	15.1	17.7	16.0	16.3	13.5	0.0	1.7	3.8	1.7	1.9	15.4	0.8
21	15.2	13.7	13.9	15.4	15.3	17.3	10.0	16.4	13.4	0.0	1.8	3.9	1.8	1.7	14.1	0.8
22	15.8	14.0	13.0	15.2	15.7	16.2	2.0	15.1	13.6	0.0	1.9	4.4	2.0	1.3	14.1	0.8
23	14.5	12.6	9.7	12.5	14.4	16.0	9.5	14.5	12.3	0.0	0.0	3.0	2.0	0.0	11.5	0.8
24-h Mean	*14.9*	*15.8*	*16.2*	*15.9*	*17.3*	*18.5*	*10.8*	*17.7*	*16.3*	*0.0*	*8.1*	*10.5*	*7.6*	*10.6*	*16.5*	*0.4*
24 h - %	*7.6%*	*8.0%*	*8.2%*	*8.1%*	*8.8%*	*9.4%*	*5.5%*	*9.0%*	*8.3%*	*0.0%*	*4.1%*	*5.3%*	*3.8%*	*5.4%*	*8.4%*	*0.2%*
Day Mean	*15.0*	*19.2*	*19.2*	*18.6*	*19.3*	*20.0*	*12.3*	*19.5*	*19.1*	*0.0*	*14.1*	*16.8*	*13.0*	*18.7*	*19.5*	*0.0*
Day - %	*6.2%*	*7.9%*	*7.9%*	*7.6%*	*7.9%*	*8.2%*	*5.0%*	*8.0%*	*7.8%*	*0.0%*	*5.8%*	*6.9%*	*5.3%*	*7.7%*	*8.0%*	*0.0%*
Night Mean	*14.8*	*11.7*	*12.6*	*12.8*	*15.0*	*16.7*	*9.1*	*15.6*	*13.1*	*0.0*	*0.9*	*3.0*	*1.1*	*1.0*	*12.9*	*0.8*
Night - %	*10.5%*	*8.3%*	*8.9%*	*9.0%*	*10.7%*	*11.8%*	*6.5%*	*11.0%*	*9.3%*	*0.0%*	*0.7%*	*2.2%*	*0.8%*	*0.7%*	*9.1%*	*0.6%*

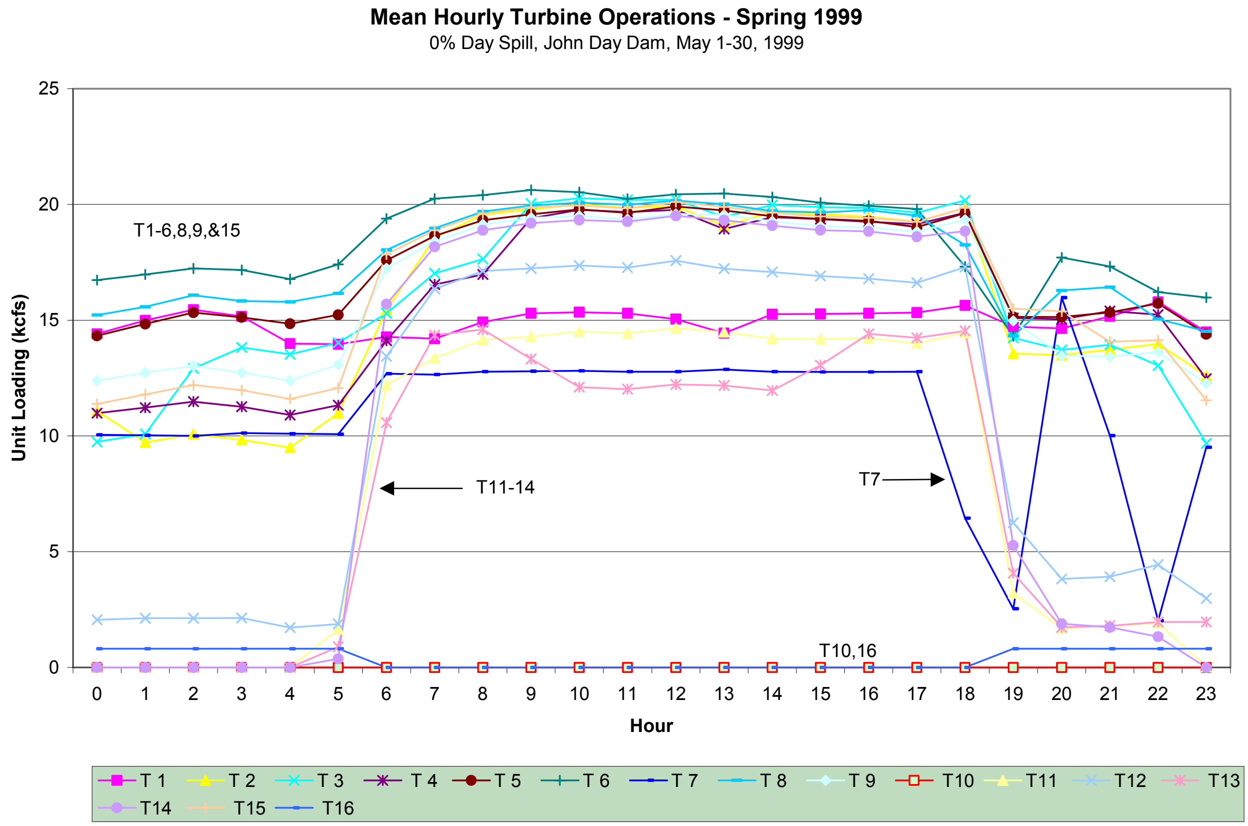


Figure 15. Mean hourly turbine operation by unit in kcfs during 0% daytime spill operations over the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

Table 7. Mean spring turbine operation under 30% daytime spill operations. Data are summarized as mean kcfs and percentages on an hourly, 24-h, daytime and nighttime basis. Based on the 8 day pooled data set meeting day spill criteria. John Day Dam, May 14-27, 1999.

John Day Spring 1999 Mean Hourly Turbine Operations - 30% Day Spill - Hydroacoustic Monitoring Period May 1-30, 1999

Hour	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T10	T11	T12	T13	T14	T15	T16
0	15.8	15.9	16.2	13.8	15.7	19.0	10.0	15.9	15.6	2.2	6.9	2.2	6.9	8.4	16.0	0.0
1	15.9	16.0	16.2	13.9	15.8	19.2	10.0	16.0	15.6	2.4	7.0	2.4	7.0	6.9	16.1	0.0
2	15.8	16.0	14.7	14.1	15.7	19.0	10.0	15.9	15.6	2.4	7.0	2.4	7.1	6.9	16.1	0.0
3	16.4	16.6	14.8	14.8	16.4	19.2	10.0	16.6	16.3	2.4	7.0	2.4	7.0	6.9	16.7	0.0
4	15.5	16.6	13.7	14.7	16.5	19.3	10.0	16.6	16.1	2.4	7.2	2.3	7.2	7.1	16.7	0.0
5	15.6	16.9	13.6	15.0	16.7	19.4	10.0	17.0	16.6	2.4	7.4	2.5	7.3	7.3	17.1	0.0
6	14.9	17.3	15.6	15.3	17.0	18.6	7.5	17.9	16.9	0.0	12.8	8.7	14.8	10.4	17.4	0.0
7	14.4	17.3	15.6	14.8	14.5	15.9	7.5	15.4	16.9	0.0	13.1	9.7	16.5	12.2	17.4	0.0
8	14.3	17.1	15.4	15.3	14.0	15.9	7.6	15.3	16.7	0.0	12.7	9.5	14.7	12.8	17.2	0.0
9	14.2	17.2	15.3	15.2	14.1	15.6	7.6	15.4	16.7	1.0	12.9	9.8	14.7	12.6	17.2	0.0
10	14.2	17.2	15.3	15.2	14.4	15.4	7.3	15.5	16.7	2.2	12.7	9.8	14.8	12.6	17.2	0.0
11	14.2	17.1	15.3	15.3	14.3	15.8	6.7	15.5	16.7	2.5	12.8	9.5	14.7	12.7	17.2	0.0
12	13.6	17.2	15.4	15.5	14.4	16.1	7.6	15.5	16.7	2.5	12.7	9.5	14.8	12.8	17.2	0.0
13	12.9	17.2	15.6	15.4	14.5	16.2	7.6	15.6	16.9	2.5	12.7	10.0	14.8	13.3	17.3	0.0
14	14.2	16.4	14.8	14.6	15.6	17.0	7.0	15.3	15.8	2.6	13.2	10.9	12.6	13.9	16.4	0.0
15	14.2	16.5	14.9	14.8	14.2	15.9	5.9	15.6	16.3	2.5	14.0	11.6	12.4	14.3	16.6	0.0
16	14.1	15.9	14.3	14.1	15.6	17.3	7.5	16.2	15.5	2.4	13.6	11.1	13.7	13.1	15.9	0.0
17	14.3	16.3	14.7	14.2	16.1	17.0	6.6	16.3	15.9	2.3	13.9	9.9	14.1	11.8	16.4	0.0
18	14.3	17.4	17.4	15.1	17.2	16.5	0.9	17.3	17.0	2.7	14.3	10.9	13.5	10.6	17.5	0.0
19	14.3	17.1	17.3	15.1	16.9	16.5	0.0	17.0	16.7	2.3	10.2	7.5	11.1	10.7	17.2	0.0
20	15.0	16.4	16.6	13.9	16.4	19.4	13.9	16.3	16.0	2.1	6.6	5.7	9.8	10.1	16.4	0.0
21	15.3	16.5	16.8	14.1	16.3	18.6	12.6	16.5	16.1	2.0	6.3	5.8	8.3	10.1	16.6	0.0
22	16.5	17.3	17.5	15.1	17.0	17.3	5.5	17.1	16.8	2.2	7.0	6.1	9.0	10.7	17.3	0.0
23	15.9	16.0	16.2	14.1	15.8	19.0	9.5	16.0	15.6	2.2	6.9	2.6	7.0	8.6	16.1	0.0
24-h Mean	***14.8***	***16.7***	***15.5***	***14.7***	***15.6***	***17.5***	***7.9***	***16.1***	***16.3***	***2.0***	***10.4***	***7.2***	***11.4***	***10.7***	***16.8***	***0.0***
24 h - %	***7.7%***	***8.6%***	***8.0%***	***7.6%***	***8.1%***	***9.0%***	***4.1%***	***8.3%***	***8.4%***	***1.0%***	***5.4%***	***3.7%***	***5.9%***	***5.5%***	***8.7%***	***0.0%***
Day Mean	***14.1***	***16.9***	***15.3***	***15.0***	***15.1***	***16.4***	***6.7***	***15.9***	***16.5***	***1.8***	***13.2***	***10.1***	***14.3***	***12.5***	***17.0***	***0.0***
Day - %	***7.0%***	***8.4%***	***7.6%***	***7.5%***	***7.5%***	***8.2%***	***3.3%***	***7.9%***	***8.2%***	***0.9%***	***6.6%***	***5.0%***	***7.1%***	***6.2%***	***8.5%***	***0.0%***
Night Mean	***15.6***	***16.5***	***15.8***	***14.4***	***16.3***	***18.7***	***9.2***	***16.4***	***16.1***	***2.3***	***7.2***	***3.8***	***8.0***	***8.5***	***16.6***	***0.0***
Night - %	***8.4%***	***8.9%***	***8.5%***	***7.8%***	***8.8%***	***10.1%***	***5.0%***	***8.9%***	***8.7%***	***1.2%***	***3.9%***	***2.1%***	***4.3%***	***4.6%***	***8.9%***	***0.0%***

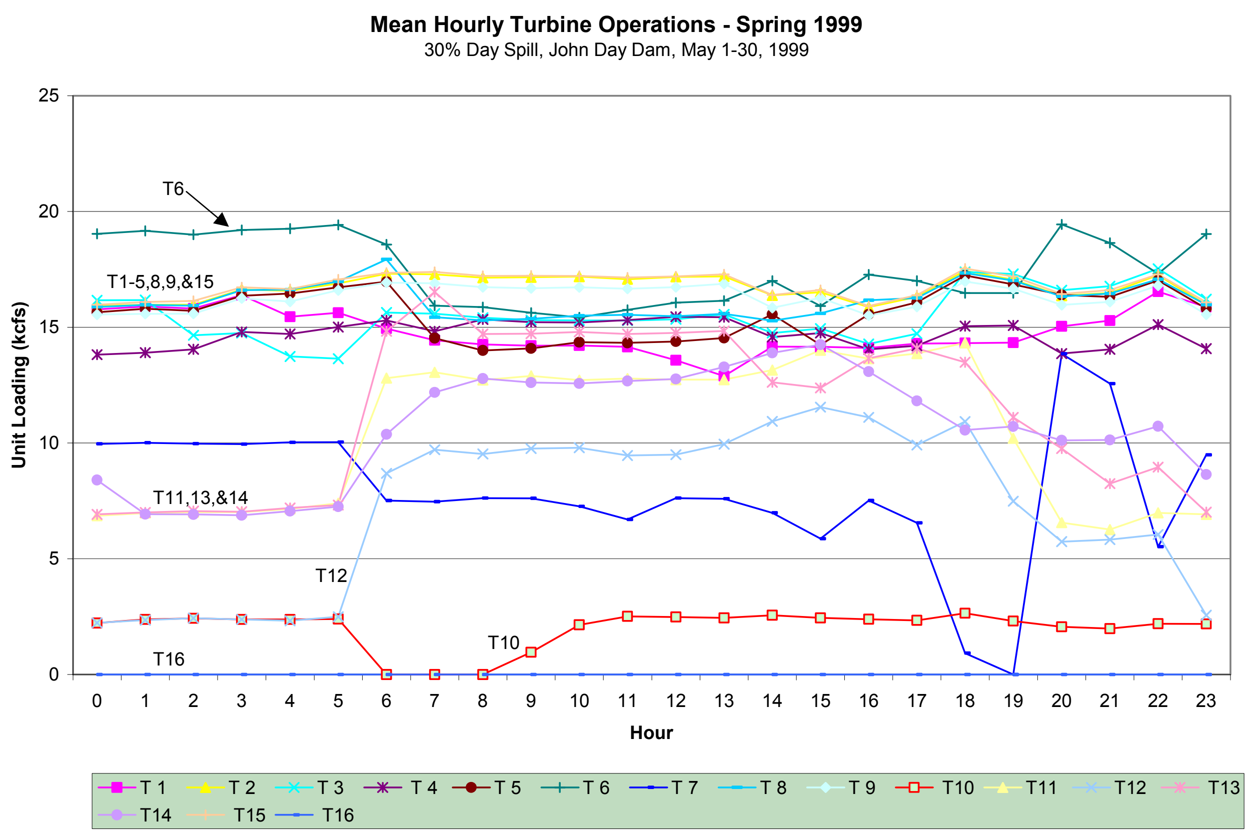


Figure 16. Mean hourly turbine operation by unit in kcfs during 30% daytime spill operations over the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

Table 8. Mean hourly turbine operation and corresponding seasonal 24-h, daytime and nighttime means on a kcfs and percentage basis for the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

John Day Spring 1999 Mean Hourly Turbine Operations - Hydroacoustic Monitoring Period May 1-30, 1999

Hour	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T10	T11	T12	T13	T14	T15	T16
0	15.7	14.3	14.2	14.2	15.6	16.9	8.0	16.2	14.9	2.4	4.2	3.4	5.6	4.6	13.3	0.2
1	15.9	13.6	14.3	14.2	15.8	17.1	8.7	16.4	15.0	2.4	4.1	3.0	5.7	4.2	13.4	0.2
2	16.1	13.8	14.8	14.1	16.0	17.1	8.7	16.6	14.8	2.5	4.7	3.1	5.9	4.2	13.7	0.2
3	16.2	14.0	15.1	14.3	16.1	17.2	8.8	16.7	15.0	2.4	4.7	3.0	6.3	4.2	13.8	0.2
4	14.8	13.9	14.3	14.1	16.1	17.1	8.8	16.7	14.8	2.5	4.8	4.7	6.9	4.3	13.8	0.2
5	14.8	14.3	14.4	14.3	16.3	17.2	8.8	17.0	15.1	2.4	6.8	5.3	7.2	6.0	14.1	0.2
6	14.7	16.6	16.3	16.1	17.5	17.8	8.8	17.9	17.3	1.9	14.3	13.7	13.2	12.8	16.0	0.0
7	14.8	17.6	16.9	16.9	17.3	17.5	9.2	17.7	17.8	1.9	14.9	14.9	14.8	14.2	16.4	0.0
8	15.0	17.9	17.0	17.2	17.5	18.2	9.5	18.0	17.9	1.9	14.4	14.5	14.5	15.0	16.7	0.0
9	15.0	17.8	17.5	17.6	17.5	18.2	8.9	17.9	17.9	2.2	14.4	14.5	14.0	15.1	16.6	0.0
10	14.9	17.6	17.4	17.4	17.2	18.0	8.7	17.7	17.7	2.5	14.2	14.2	13.5	14.9	16.4	0.0
11	14.8	17.5	16.9	17.4	17.1	18.0	8.5	17.3	17.6	2.5	14.1	14.1	13.5	15.0	16.3	0.0
12	14.4	17.6	16.7	17.4	17.2	18.0	9.4	17.2	17.6	2.6	13.7	14.2	14.0	15.5	16.4	0.0
13	14.1	17.4	16.7	17.3	17.3	18.0	9.4	17.2	17.8	2.6	13.8	14.4	13.6	15.6	16.4	0.0
14	14.7	17.3	16.6	17.2	17.5	18.3	9.2	17.1	17.4	2.6	13.7	14.6	12.9	15.2	16.1	0.0
15	14.7	17.3	16.5	17.3	17.1	17.9	8.9	17.2	17.5	2.6	14.0	14.8	13.3	15.3	16.2	0.0
16	14.7	17.1	16.1	17.1	17.5	18.3	9.5	17.4	17.3	2.6	14.1	14.8	14.8	15.1	16.0	0.0
17	14.8	16.8	16.0	17.1	17.5	18.2	9.6	17.8	17.4	2.6	14.1	14.4	14.9	14.6	16.1	0.0
18	15.0	18.3	17.9	17.7	18.2	16.5	4.6	18.0	18.0	2.6	12.4	12.5	13.8	12.7	16.7	0.0
19	15.4	16.7	16.6	16.4	16.9	15.8	2.0	16.9	16.7	2.4	7.5	8.0	8.9	8.8	15.4	0.2
20	15.9	16.3	16.1	15.9	16.7	18.5	11.6	17.1	16.0	2.4	6.9	8.2	8.5	8.0	15.4	0.2
21	16.0	16.2	16.0	15.9	16.5	17.4	7.7	17.2	15.8	2.4	6.8	8.1	8.4	7.9	14.7	0.2
22	16.4	16.1	15.5	15.8	16.4	16.2	3.4	16.6	15.7	2.3	6.7	7.6	7.9	7.6	14.4	0.2
23	15.6	15.1	14.1	14.5	15.5	16.6	7.6	15.9	14.8	2.2	5.2	4.5	6.1	5.0	13.3	0.2
24-h Mean	*15.2*	*16.3*	*16.0*	*16.2*	*16.8*	*17.5*	*8.3*	*17.1*	*16.6*	*2.4*	*10.2*	*10.2*	*10.8*	*10.7*	*15.3*	*0.1*
24 h - %	*7.6%*	*8.2%*	*8.0%*	*8.1%*	*8.4%*	*8.8%*	*4.1%*	*8.6%*	*8.3%*	*1.2%*	*5.1%*	*5.1%*	*5.4%*	*5.3%*	*7.7%*	*0.0%*
Day Mean	*14.7*	*17.4*	*16.8*	*17.2*	*17.4*	*17.9*	*8.8*	*17.6*	*17.6*	*2.4*	*14.0*	*14.3*	*13.9*	*14.7*	*16.3*	*0.0*
Day - %	*6.7%*	*7.9%*	*7.6%*	*7.8%*	*7.9%*	*8.1%*	*4.0%*	*7.9%*	*8.0%*	*1.1%*	*6.3%*	*6.5%*	*6.3%*	*6.6%*	*7.4%*	*0.0%*
Night Mean	*15.7*	*14.9*	*15.0*	*14.9*	*16.2*	*17.0*	*7.6*	*16.6*	*15.3*	*2.4*	*5.7*	*5.4*	*7.0*	*5.9*	*14.1*	*0.2*
Night - %	*9.0%*	*8.6%*	*8.6%*	*8.6%*	*9.3%*	*9.8%*	*4.4%*	*9.6%*	*8.8%*	*1.4%*	*3.3%*	*3.1%*	*4.0%*	*3.4%*	*8.1%*	*0.1%*

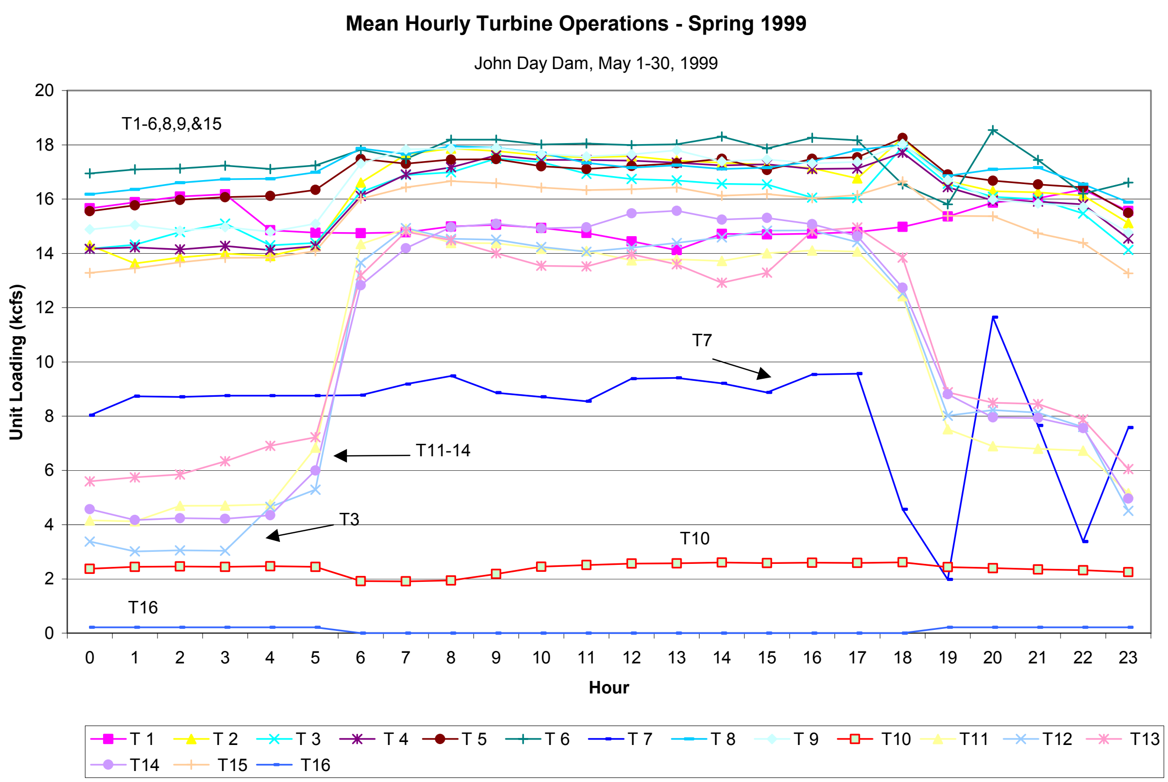


Figure 17. Mean hourly turbine operation by unit in kcfs over the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

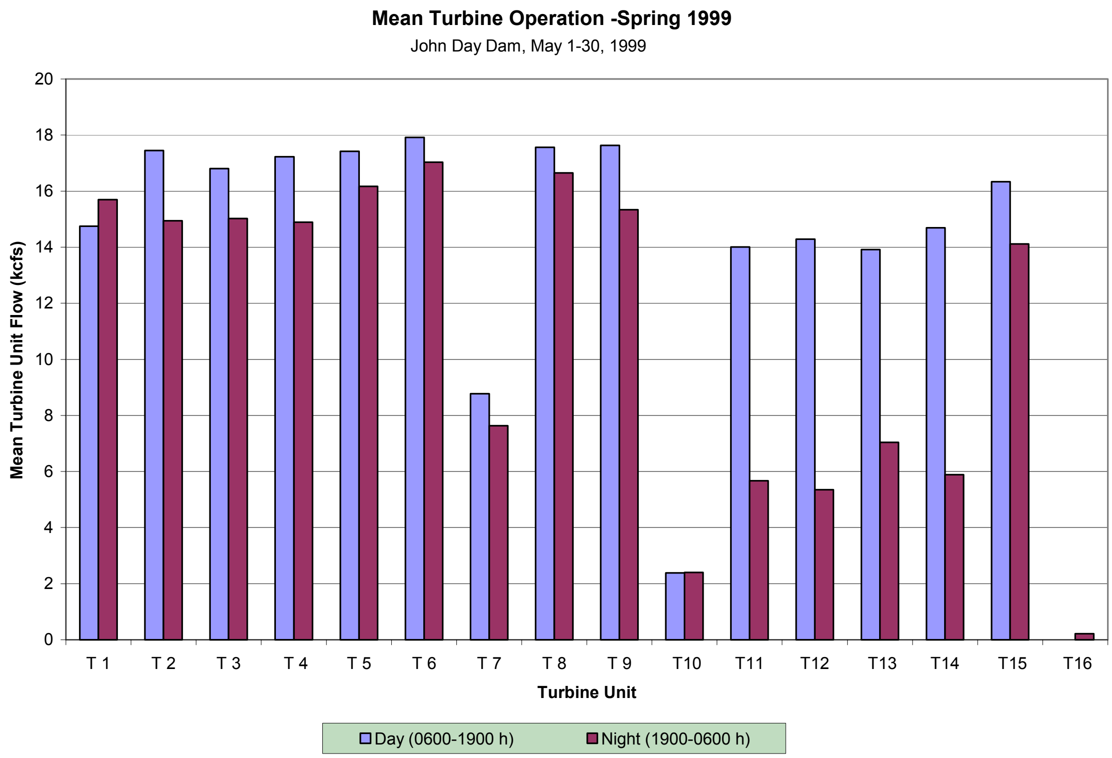


Figure 18. Mean day/night turbine unit operation in kcfs for the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

Table 9. Mean hourly turbine operation and corresponding seasonal 24-h, daytime and nighttime means on a kcfs and percentage basis for the summer 1999 hydroacoustic monitoring period. John Day Dam, June 6 – July 8, 1999.

John Day Summer 1999 Mean Hourly Turbine Operations - Hydroacoustic Monitoring Period June 6 - July 8, 1999

Hour	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T10	T11	T12	T13	T14	T15	T16
0	16.0	15.4	16.4	14.2	16.4	15.0	10.6	15.7	13.0	15.7	12.5	13.2	9.8	13.5	15.0	3.0
1	16.0	15.4	16.5	13.5	16.4	15.0	10.7	15.7	12.5	15.7	12.4	12.9	9.0	12.8	14.6	3.0
2	16.1	15.2	16.6	13.5	16.5	14.9	10.8	15.9	12.4	15.8	12.6	12.4	9.9	12.5	14.6	3.0
3	16.1	15.2	16.7	13.6	16.6	15.0	10.5	15.9	12.5	16.0	12.7	12.8	10.5	12.8	14.6	3.0
4	14.9	15.3	16.9	13.8	16.8	15.2	10.5	16.6	12.6	16.2	13.7	13.1	10.5	13.1	14.9	2.9
5	14.6	15.4	17.1	14.0	16.9	15.2	10.7	16.7	13.0	16.0	14.5	13.7	10.7	13.2	15.3	3.1
6	13.4	15.9	17.6	14.3	17.1	15.8	10.3	17.3	13.5	16.7	16.0	16.7	13.9	16.0	16.5	2.8
7	13.4	16.7	18.7	15.4	18.2	17.1	12.0	18.4	15.0	18.0	17.9	17.9	15.0	17.3	18.2	2.9
8	13.8	16.3	18.0	14.5	17.5	16.5	11.7	18.0	14.7	16.9	17.6	17.5	15.6	17.3	17.6	2.8
9	14.3	17.0	17.9	14.6	17.4	17.0	11.8	18.2	14.9	17.0	17.8	17.7	15.8	17.0	17.6	2.8
10	14.7	17.3	17.7	14.6	17.6	16.7	11.8	18.3	15.5	17.3	17.9	17.8	16.0	17.1	17.0	2.4
11	14.8	17.3	17.8	14.6	18.1	16.0	12.0	18.2	15.6	17.7	17.8	17.7	16.2	17.6	16.2	2.8
12	14.8	17.3	18.0	14.9	18.1	16.4	12.5	18.1	15.5	18.3	17.3	17.8	16.5	17.7	16.2	2.9
13	14.8	17.0	18.3	14.3	17.8	16.6	12.0	17.6	15.7	17.8	17.1	17.4	15.2	17.4	16.0	2.7
14	14.8	17.4	18.0	15.0	17.8	17.1	12.1	17.4	15.9	18.0	17.3	17.0	15.5	17.5	16.6	2.8
15	14.8	17.7	18.0	15.2	18.0	17.2	12.9	17.9	16.0	17.7	17.7	17.1	16.4	17.6	16.6	3.1
16	15.0	17.7	18.6	15.2	17.9	16.6	13.2	17.6	16.1	17.3	17.8	16.8	16.4	17.6	16.6	3.3
17	14.9	17.7	18.5	15.2	18.0	16.6	13.2	17.7	16.0	17.1	17.8	17.6	15.4	17.1	16.6	3.5
18	14.7	17.8	18.5	15.3	18.0	16.9	13.3	17.6	16.0	17.4	17.2	17.5	15.3	17.2	16.6	3.5
19	14.8	17.1	17.4	14.9	17.4	16.6	12.6	16.7	14.9	17.0	15.5	16.3	14.1	16.3	16.1	3.0
20	16.4	16.7	17.5	15.2	17.4	17.0	12.7	16.6	14.9	16.7	15.0	16.0	13.9	16.1	16.3	3.0
21	16.7	16.8	17.6	15.3	17.5	17.1	12.7	16.7	15.0	16.7	14.6	15.6	13.9	15.9	16.3	3.1
22	16.6	16.6	17.3	15.1	17.2	16.9	12.6	16.5	14.8	16.5	13.9	14.2	12.6	14.9	16.5	3.1
23	16.2	16.0	16.7	14.6	16.5	15.2	10.9	16.0	13.5	16.0	12.7	13.3	10.9	13.7	15.6	3.0
24-h Mean	***15.1***	***16.6***	***17.6***	***14.6***	***17.4***	***16.2***	***11.8***	***17.1***	***14.6***	***16.9***	***15.7***	***15.8***	***13.7***	***15.8***	***16.2***	***3.0***
24 h - %	***6.3%***	***7.0%***	***7.4%***	***6.1%***	***7.3%***	***6.8%***	***5.0%***	***7.2%***	***6.1%***	***7.1%***	***6.6%***	***6.7%***	***5.8%***	***6.6%***	***6.8%***	***1.3%***
Day Mean	***14.5***	***17.2***	***18.1***	***14.9***	***17.8***	***16.7***	***12.2***	***17.9***	***15.4***	***17.5***	***17.5***	***17.4***	***15.6***	***17.3***	***16.8***	***3.0***
Day - %	***5.8%***	***6.9%***	***7.3%***	***6.0%***	***7.1%***	***6.7%***	***4.9%***	***7.2%***	***6.2%***	***7.0%***	***7.0%***	***7.0%***	***6.3%***	***6.9%***	***6.7%***	***1.2%***
Night Mean	***15.9***	***15.9***	***17.0***	***14.3***	***16.9***	***15.7***	***11.4***	***16.3***	***13.5***	***16.2***	***13.6***	***14.0***	***11.4***	***14.1***	***15.4***	***3.0***
Night - %	***7.1%***	***7.1%***	***7.6%***	***6.4%***	***7.5%***	***7.0%***	***5.1%***	***7.2%***	***6.0%***	***7.2%***	***6.1%***	***6.2%***	***5.1%***	***6.3%***	***6.9%***	***1.3%***

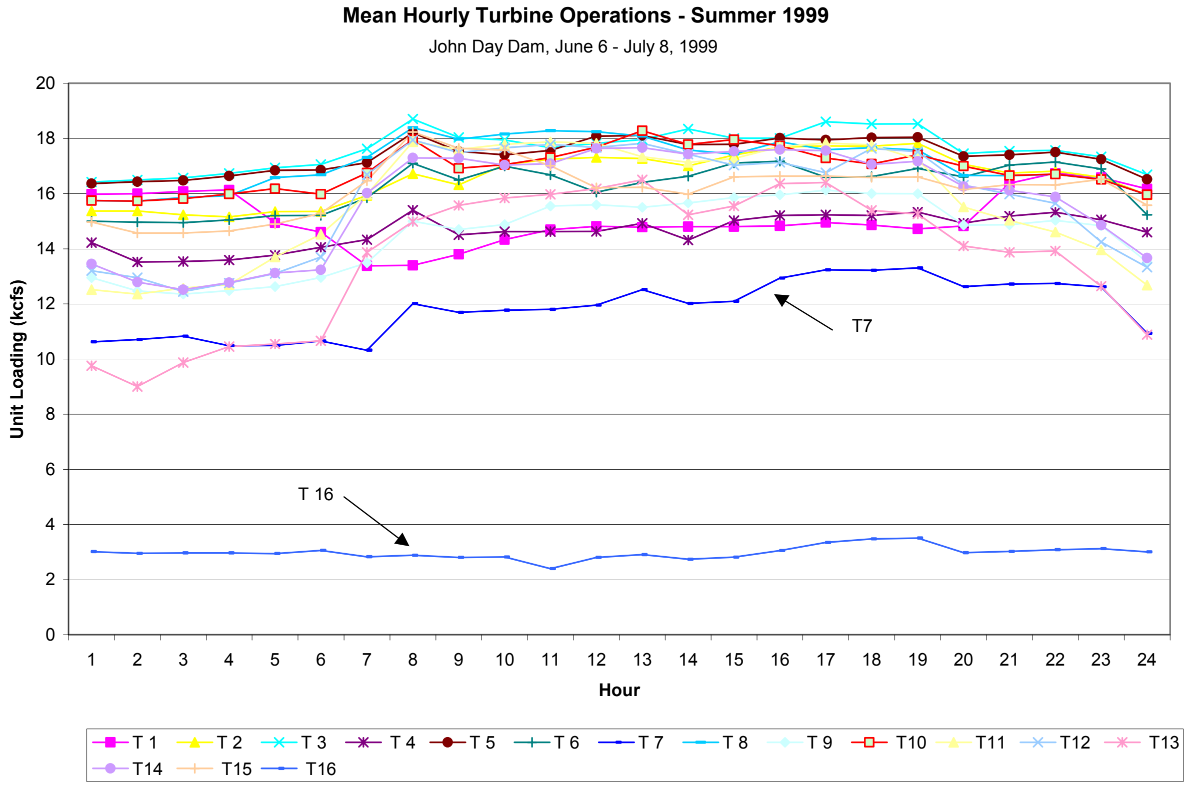


Figure 19. Mean hourly turbine operation by unit in kcfs for the summer 1999 hydroacoustic monitoring period. John Day Dam, June 6 – July 8, 1999.

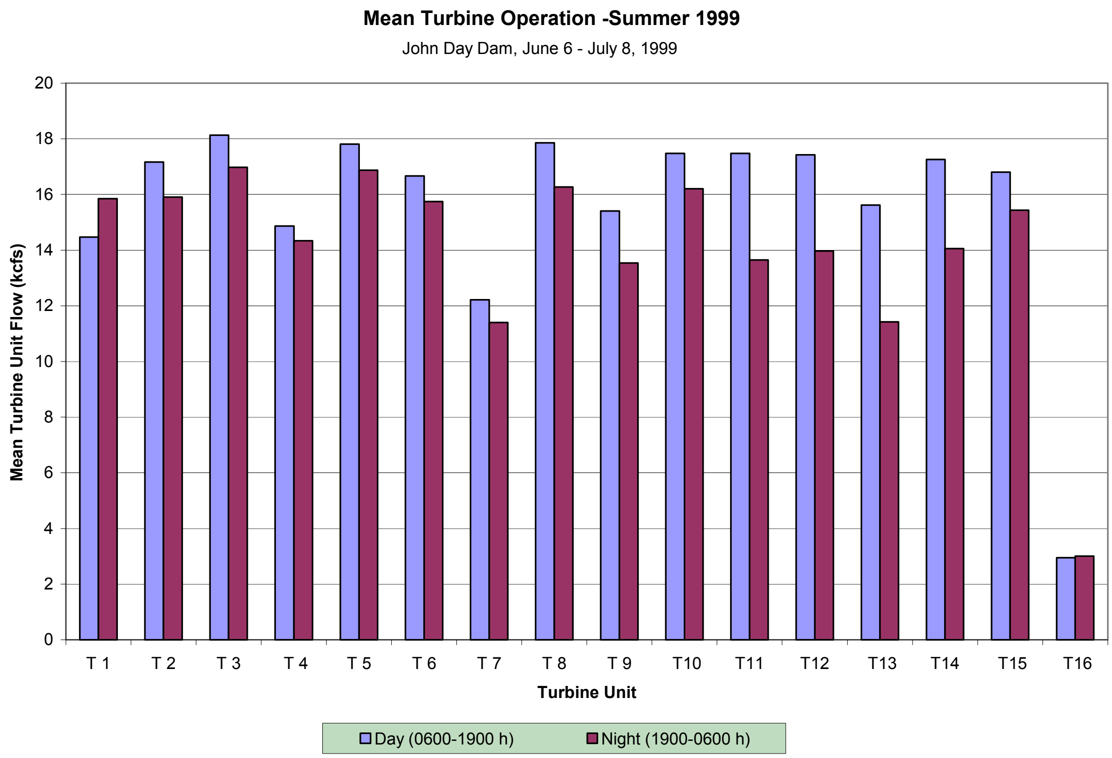


Figure 20. Mean day/night turbine unit operation in kcfs for the summer 1999 hydroacoustic monitoring period. John Day Dam, June 6 – July 8, 1999.

Table 10. Mean hourly spill bay operation and corresponding seasonal 24-h, daytime and nighttime means on a kcfs and percentage basis for the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

John Day Spring 1999 Mean Hourly Spill Operations - Hydroacoustic Monitoring Period May 1-30, 1999

Hour	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
0	6.5	6.8	6.6	6.7	6.6	6.3	6.5	6.4	6.1	6.3	5.8	5.9	5.5	6.2	6.1	6.4	6.1	6.3	6.0	4.7
1	6.5	6.8	6.6	6.7	6.6	6.3	6.5	6.4	6.1	6.3	5.8	5.9	5.5	6.2	6.1	6.4	6.1	6.3	6.0	4.7
2	6.4	6.8	6.5	6.7	6.6	6.3	6.5	6.4	6.1	6.2	5.8	5.9	5.5	6.2	6.1	6.3	6.1	6.2	5.9	4.7
3	6.4	6.8	6.5	6.7	6.6	6.3	6.5	6.4	6.1	6.2	5.8	5.9	5.5	6.2	6.1	6.3	6.1	6.2	5.9	4.7
4	6.4	6.8	6.5	6.7	6.6	6.3	6.5	6.4	6.1	6.2	5.8	5.9	5.5	6.2	6.1	6.3	6.1	6.2	5.9	4.7
5	6.4	6.8	6.5	6.7	6.6	6.3	6.5	6.4	6.1	6.2	5.8	5.9	5.5	6.2	6.1	6.3	6.1	6.2	5.9	4.7
6	3.2	5.1	4.9	4.8	4.6	4.2	3.9	3.6	3.4	3.2	3.0	2.9	2.7	2.6	2.6	2.7	2.0	1.5	0.9	0.5
7	3.5	5.2	4.9	4.9	4.7	4.2	3.8	3.7	3.5	3.4	3.1	3.0	2.8	2.7	2.8	2.8	2.3	1.7	1.4	0.9
8	3.3	5.1	4.8	4.8	4.6	3.9	3.7	3.6	3.3	3.1	2.9	2.7	2.6	2.5	2.6	2.7	2.1	1.5	1.2	0.8
9	3.2	5.0	4.7	4.7	4.5	4.1	3.6	3.7	3.4	3.2	3.0	2.9	2.6	2.6	2.6	2.8	2.2	1.5	0.6	0.3
10	3.4	5.2	5.0	4.8	4.7	4.2	3.7	3.6	3.4	3.4	3.0	2.9	2.7	2.5	2.5	2.6	2.1	1.4	0.6	0.3
11	3.2	5.2	4.9	4.9	4.7	4.1	3.8	3.6	3.4	3.2	2.9	2.7	2.6	2.4	2.4	2.5	1.9	1.1	0.6	0.3
12	3.1	5.1	4.8	4.8	4.6	4.0	3.8	3.5	3.1	3.0	2.8	2.6	2.3	2.2	2.2	2.3	1.8	0.9	0.6	0.3
13	3.1	5.1	4.8	4.8	4.5	3.9	3.8	3.3	3.1	3.1	2.8	2.6	2.4	2.3	2.2	2.2	1.7	1.0	0.8	0.5
14	3.1	5.1	4.8	4.8	4.6	4.0	3.8	3.3	3.2	3.2	2.9	2.7	2.5	2.4	2.4	2.4	1.6	1.1	0.4	0.2
15	3.2	5.2	4.9	4.9	4.6	4.1	3.8	3.5	3.3	3.2	3.0	2.8	2.6	2.5	2.5	2.4	1.8	1.2	0.4	0.2
16	3.2	5.3	4.9	5.0	4.7	4.1	3.8	3.5	3.3	3.2	2.9	2.7	2.6	2.5	2.5	2.4	1.8	1.2	0.4	0.2
17	3.1	5.1	4.8	4.8	4.5	4.0	3.7	3.4	3.2	3.1	2.9	2.7	2.5	2.4	2.4	2.4	1.8	1.2	0.4	0.2
18	4.2	5.5	5.2	5.3	5.0	4.5	4.4	4.2	4.0	4.1	3.8	3.6	3.4	3.3	3.3	3.4	2.9	2.5	2.1	1.5
19	6.4	6.8	6.6	6.7	6.6	6.3	6.5	6.4	6.1	6.3	5.8	5.9	5.4	6.1	6.1	6.3	6.1	6.2	5.9	4.7
20	6.4	6.8	6.5	6.7	6.6	6.3	6.5	6.4	6.1	6.3	5.8	5.9	5.4	6.1	6.1	6.3	6.1	6.2	5.9	4.7
21	6.4	6.8	6.5	6.7	6.6	6.3	6.5	6.4	6.1	6.3	5.8	5.9	5.4	6.1	6.1	6.3	6.1	6.2	5.9	4.7
22	6.5	6.8	6.6	6.7	6.6	6.3	6.5	6.4	6.1	6.3	5.9	5.9	5.4	6.1	6.1	6.3	6.1	6.2	5.9	4.8
23	6.5	6.8	6.6	6.8	6.6	6.3	6.5	6.4	6.2	6.3	5.9	5.9	5.5	6.2	6.2	6.4	6.1	6.3	6.0	4.8
24-h Mean	***4.7***	***5.9***	***5.6***	***5.7***	***5.5***	***5.1***	***5.0***	***4.9***	***4.6***	***4.6***	***4.3***	***4.2***	***3.9***	***4.2***	***4.2***	***4.3***	***3.9***	***3.6***	***3.2***	***2.4***
24 h - %	***5.3%***	***6.6%***	***6.3%***	***6.3%***	***6.1%***	***5.7%***	***5.6%***	***5.4%***	***5.1%***	***5.1%***	***4.8%***	***4.7%***	***4.4%***	***4.7%***	***4.6%***	***4.8%***	***4.3%***	***4.0%***	***3.5%***	***2.7%***
Day Mean	***3.3***	***5.2***	***4.9***	***4.9***	***4.6***	***4.1***	***3.8***	***3.6***	***3.3***	***3.3***	***3.0***	***2.8***	***2.6***	***2.5***	***2.5***	***2.6***	***2.0***	***1.4***	***0.8***	***0.5***
Day - %	***5.3%***	***8.4%***	***7.9%***	***7.9%***	***7.5%***	***6.6%***	***6.2%***	***5.8%***	***5.4%***	***5.3%***	***4.8%***	***4.6%***	***4.3%***	***4.1%***	***4.1%***	***4.2%***	***3.2%***	***2.2%***	***1.3%***	***0.8%***
Night Mean	***6.4***	***6.8***	***6.6***	***6.7***	***6.6***	***6.3***	***6.5***	***6.4***	***6.1***	***6.2***	***5.8***	***5.9***	***5.5***	***6.2***	***6.1***	***6.3***	***6.1***	***6.2***	***5.9***	***4.7***
Night - %	***5.2%***	***5.5%***	***5.3%***	***5.4%***	***5.3%***	***5.1%***	***5.3%***	***5.2%***	***4.9%***	***5.1%***	***4.7%***	***4.8%***	***4.4%***	***5.0%***	***4.9%***	***5.1%***	***4.9%***	***5.1%***	***4.8%***	***3.8%***

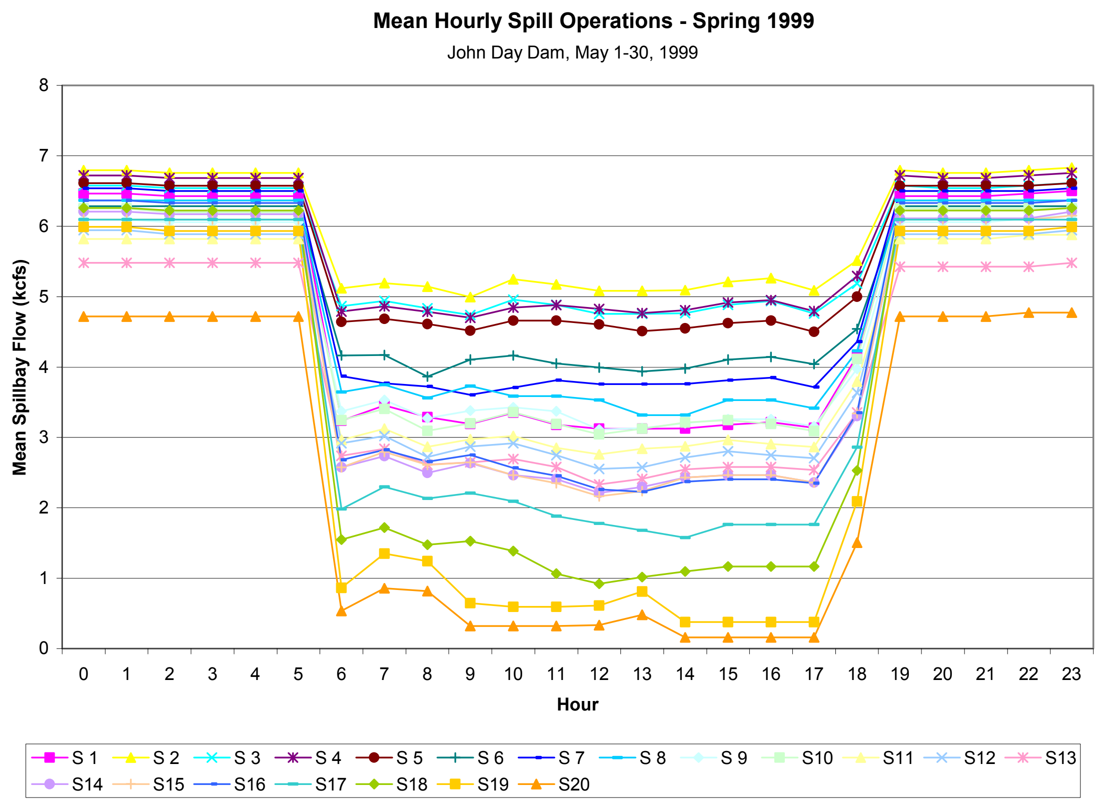


Figure 21. Mean hourly spill bay operation in kcfs for the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

Figure 22. Mean day/nighttime spill bay operation in kcfs for the spring 1999 hydroacoustic monitoring period. John Day Dam, May 1-30, 1999.

Table 11. Mean hourly spill bay operation and corresponding seasonal 24-h, daytime and nighttime means on a kcfs and percentage basis for the summer 1999 hydroacoustic monitoring period. John Day Dam, June 6-July 8, 1999.

John Day Summer 1999 Mean Hourly Spill Operations - Hydroacoustic Monitoring Period June 6 - July 8, 1999

Hour	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
0	4.5	6.6	6.6	6.4	6.4	5.3	5.1	5.4	5.1	4.5	4.1	4.4	4.0	4.1	4.4	4.0	3.7	2.6	2.4	1.9
1	4.5	6.6	6.6	6.4	6.4	5.3	5.1	5.4	5.1	4.5	4.1	4.4	4.0	4.1	4.4	4.0	3.7	2.6	2.4	1.9
2	4.5	6.6	6.6	6.4	6.4	5.3	5.1	5.4	5.1	4.5	4.1	4.4	4.0	4.1	4.4	4.0	3.7	2.6	2.4	1.9
3	4.5	6.6	6.6	6.5	6.4	5.3	5.2	5.5	5.1	4.6	4.1	4.4	4.0	4.1	4.5	4.0	3.7	2.6	2.4	1.8
4	4.5	6.6	6.6	6.5	6.4	5.3	5.2	5.5	5.1	4.6	4.0	4.5	4.0	4.2	4.5	4.1	3.8	2.6	2.7	2.0
5	4.5	6.5	6.5	6.4	6.4	5.2	5.1	5.4	5.0	4.5	3.9	4.3	3.9	4.0	4.3	3.9	3.6	2.5	2.4	1.8
6	3.8	5.8	5.8	5.6	5.5	4.7	4.4	4.4	4.1	3.5	3.2	3.2	3.1	3.0	3.0	2.9	2.3	1.3	0.7	0.5
7	3.5	5.1	5.1	5.0	4.8	4.2	4.1	4.0	3.7	3.1	2.9	3.0	2.9	2.9	2.8	2.6	2.0	1.2	0.7	0.5
8	3.5	5.2	5.1	5.0	4.9	4.1	4.0	4.0	3.7	3.0	2.9	2.9	2.9	2.9	2.8	2.7	2.0	1.2	0.7	0.6
9	3.5	5.2	5.2	5.1	5.0	4.3	4.0	4.1	3.8	3.0	2.9	2.9	2.9	2.8	2.8	2.7	2.0	1.3	0.7	0.6
10	3.2	5.0	5.0	4.9	4.9	4.1	3.9	4.0	3.7	3.0	2.8	2.8	2.8	2.8	2.8	2.7	2.0	1.3	0.8	0.6
11	3.4	5.2	5.2	5.0	5.0	4.2	4.0	4.0	3.7	3.0	2.8	2.8	2.7	2.7	2.7	2.6	1.9	1.1	0.6	0.4
12	3.4	5.2	5.2	5.0	5.0	4.3	4.0	4.1	3.8	3.1	2.9	2.9	2.8	2.8	2.8	2.7	1.9	1.1	0.6	0.4
13	3.5	5.3	5.3	5.1	5.1	4.3	4.0	4.1	3.9	3.2	2.9	2.9	2.8	2.8	2.8	2.7	1.9	1.1	0.6	0.4
14	3.4	5.1	5.1	5.0	5.0	4.0	3.9	3.9	3.7	3.0	2.8	2.8	2.7	2.7	2.7	2.6	1.8	1.0	0.6	0.4
15	3.4	5.1	5.1	5.0	5.0	4.0	3.9	4.0	3.8	3.0	2.8	2.8	2.8	2.8	2.8	2.6	1.8	1.0	0.8	0.6
16	3.4	5.2	5.2	5.0	5.0	4.1	3.9	4.0	3.8	3.1	2.9	2.8	2.8	2.8	2.8	2.6	1.9	1.1	0.8	0.6
17	3.5	5.1	5.1	5.0	5.0	4.1	3.9	4.0	3.8	3.1	2.9	2.8	2.8	2.8	2.8	2.6	1.9	1.1	0.6	0.4
18	3.6	5.3	5.3	5.2	5.1	4.3	4.1	4.1	3.9	3.2	2.9	3.0	2.9	3.0	3.0	2.7	2.0	1.2	0.7	0.5
19	4.4	6.4	6.4	6.2	6.2	5.2	5.0	5.3	5.0	4.3	4.0	4.2	3.9	4.0	4.3	3.8	3.6	2.6	2.4	1.9
20	4.5	6.6	6.6	6.4	6.4	5.4	5.1	5.5	5.2	4.5	4.1	4.3	4.0	4.1	4.5	4.0	3.7	2.6	2.4	1.9
21	4.5	6.6	6.6	6.4	6.4	5.4	5.1	5.5	5.2	4.5	4.1	4.3	4.0	4.1	4.5	4.0	3.7	2.6	2.4	1.9
22	4.5	6.6	6.6	6.4	6.4	5.4	5.1	5.5	5.2	4.5	4.1	4.3	4.0	4.1	4.5	4.0	3.7	2.6	2.4	1.9
23	4.5	6.7	6.7	6.5	6.4	5.4	5.2	5.4	5.2	4.5	4.1	4.3	4.0	4.1	4.4	4.0	3.6	2.4	2.4	1.9
24-h Mean	***3.9***	***5.9***	***5.8***	***5.7***	***5.7***	***4.7***	***4.5***	***4.7***	***4.4***	***3.7***	***3.4***	***3.6***	***3.4***	***3.4***	***3.6***	***3.3***	***2.8***	***1.8***	***1.5***	***1.1***
24 h - %	***5.1%***	***7.6%***	***7.6%***	***7.4%***	***7.4%***	***6.2%***	***5.9%***	***6.1%***	***5.7%***	***4.9%***	***4.5%***	***4.6%***	***4.4%***	***4.4%***	***4.6%***	***4.3%***	***3.6%***	***2.3%***	***1.9%***	***1.5%***
Day Mean	***3.4***	***5.2***	***5.2***	***5.1***	***5.0***	***4.2***	***4.0***	***4.1***	***3.8***	***3.1***	***2.9***	***2.9***	***2.8***	***2.8***	***2.8***	***2.7***	***1.9***	***1.1***	***0.7***	***0.5***
Day - %	***5.4%***	***8.1%***	***8.1%***	***7.9%***	***7.8%***	***6.6%***	***6.3%***	***6.3%***	***5.9%***	***4.8%***	***4.5%***	***4.5%***	***4.4%***	***4.4%***	***4.4%***	***4.1%***	***3.0%***	***1.8%***	***1.1%***	***0.8%***
Night Mean	***4.5***	***6.6***	***6.6***	***6.4***	***6.4***	***5.3***	***5.1***	***5.4***	***5.1***	***4.5***	***4.1***	***4.4***	***4.0***	***4.1***	***4.4***	***4.0***	***3.7***	***2.6***	***2.5***	***1.9***
Night - %	***4.9%***	***7.2%***	***7.2%***	***7.0%***	***7.0%***	***5.8%***	***5.6%***	***5.9%***	***5.6%***	***4.9%***	***4.4%***	***4.8%***	***4.4%***	***4.5%***	***4.8%***	***4.3%***	***4.1%***	***2.8%***	***2.7%***	***2.1%***

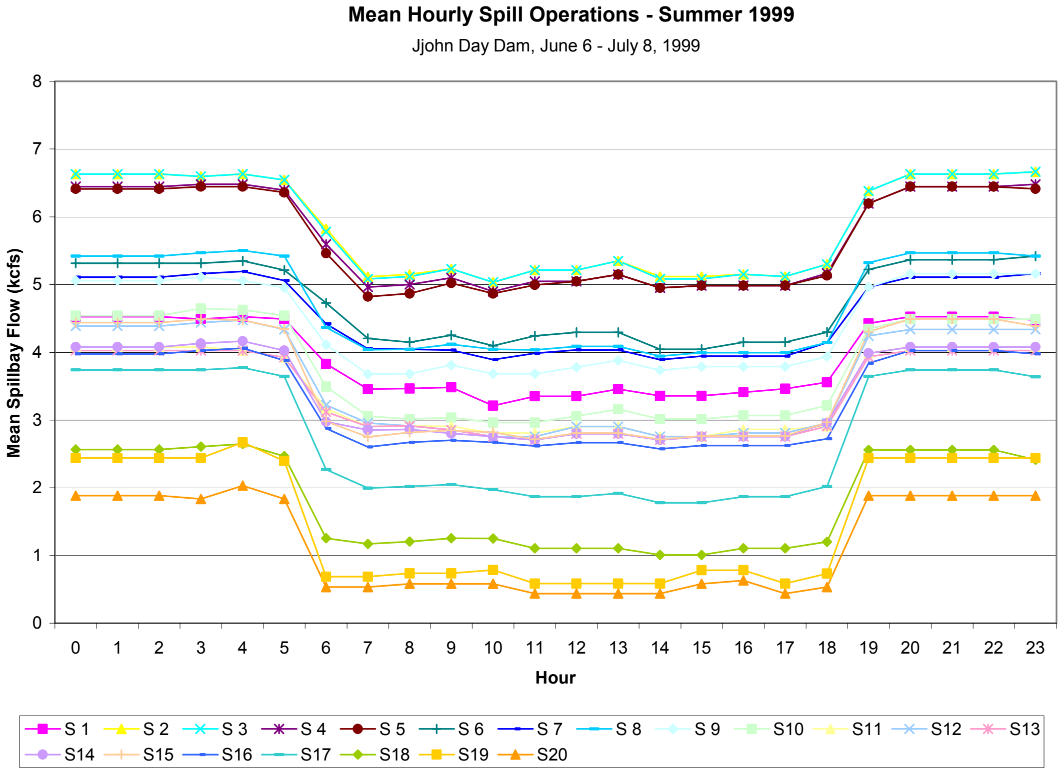


Figure 23. Mean hourly spill bay operation in kcfs for the summer 1999 hydroacoustic monitoring period. John Day Dam, June 6-July 8, 1999.

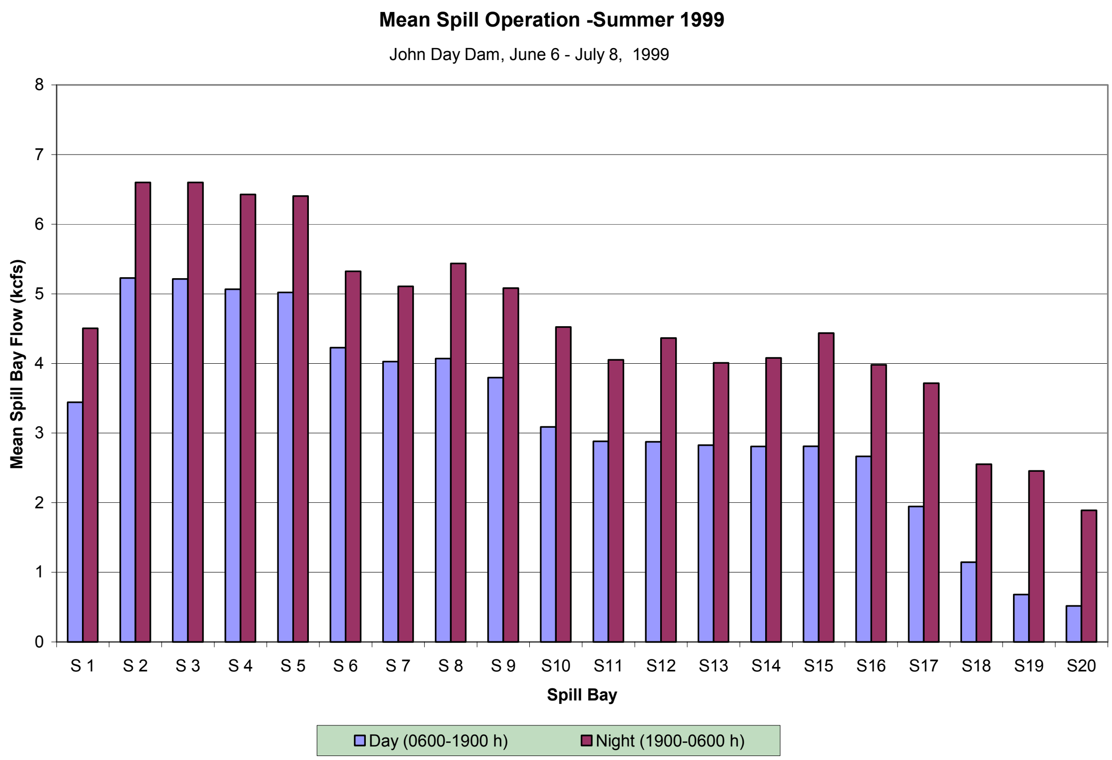


Figure 24. Mean day/nighttime spill bay operation in kcfs for the summer 1999 hydroacoustic monitoring period. John Day Dam, June 6 – July 8, 1999.

4.2 Species Composition

Historically, the spring juvenile salmonid outmigration past John Day Dam has been dominated by yearling chinook salmon *(Oncorhynchus tshawytscha)*, followed by steelhead *(O. mykiss)*, sockeye *(O. nerka)* and coho *(O. kisutch)* salmon. Sub-yearling chinook salmon are generally present in relatively low numbers, or entirely absent during the spring outmigration.

During the summer outmigration, sub-yearling chinook comprise a significant percentage of the total juvenile salmonid population, and may be predominant during some years. Yearling chinook, steelhead, sockeye and coho salmon are also typically present during the summer passage period. American shad *(Alosa sapidissima)* are typically present at John Day Dam as upstream-migrant adults from late June through July, and as downstream-migrant juveniles from late July through September.

The observed 1999 species composition for the 1999 hydroacoustic monitoring period is described in Tables 12 and 13 and Figures 25-27. This data is based on the reported observations from the John Day Dam juvenile bypass facility (JBS), as reported on the DART smolt index (www.cqs.washington.edu\dart\pass.html). Data regarding upstream adult American shad passage was obtained from John Day Dam fish ladder counts via the COE-Portland website. Juvenile shad passage was not reported on either site for the time period encompassing

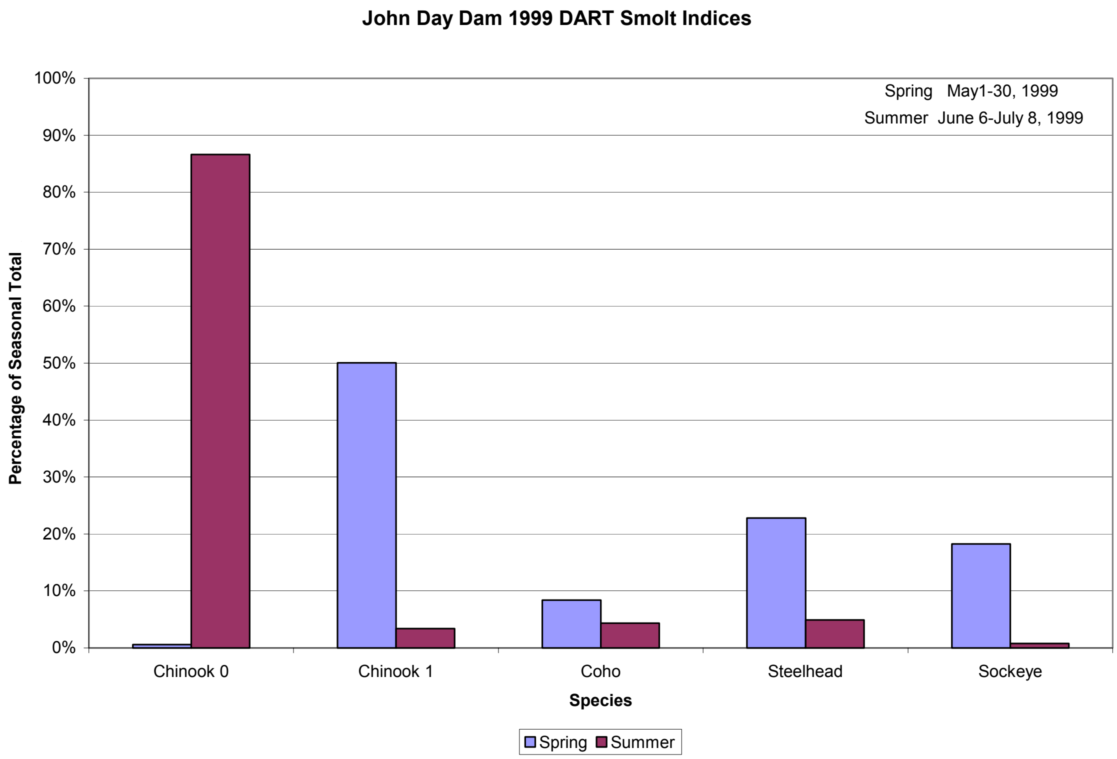


Figure 25. Percent species distribution of the spring and summer 1999 juvenile salmonid outmigration and adult shad migration at John Day Dam, May 1-30 and June 6-July 8, 1999 (DART smolt index).

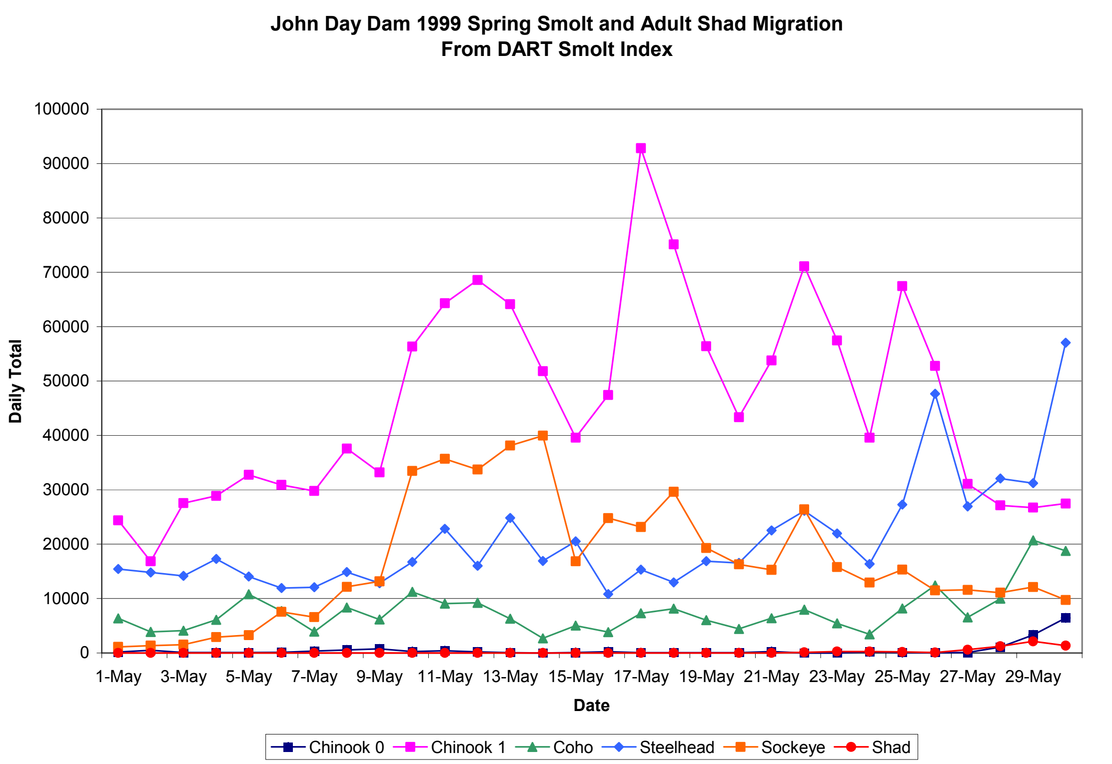


Figure 26. Daily species distribution of the spring 1999 juvenile salmonid outmigration and adult shad migration at John Day Dam, May 1-30 and June 6-July 8, 1999 (DART smolt index).

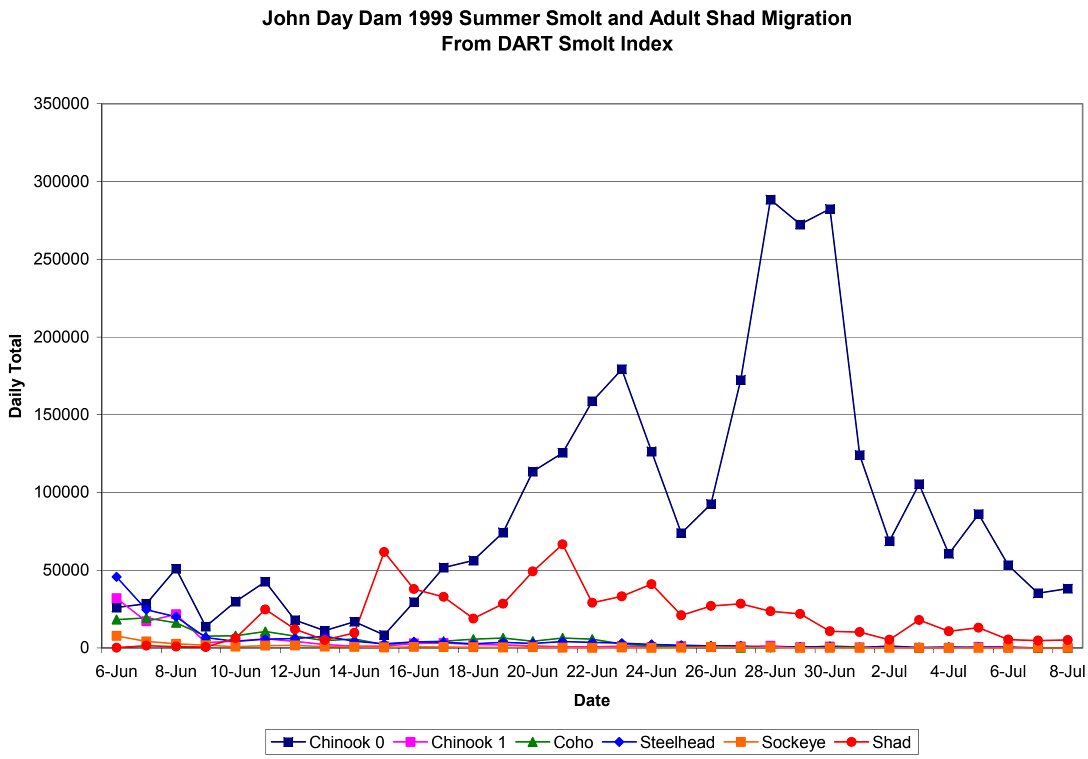


Figure 27. Daily species distribution of the summer 1999 juvenile salmonid outmigration and adult shad migration at John Day Dam, May 1-30 and June 6-July 8, 1999 (DART smolt index).

Table 12. Percent species distribution of the spring 1999 juvenile salmonid outmigration and shad migration at John Day Dam based on the DART smolt index, May 1-30, 1999.

Spring Species Index							
From DART Smolt Index							
Date	Species Smolt Composition					All	Adult
	Chinook 0	Chinook 1	Coho	Steelhead	Sockeye	Smolts	Shad
1-May	161	24371	6357	15442	1097	47428	0
2-May	497	16832	3875	14781	1327	37312	0
3-May	78	27551	4076	14182	1528	47415	0
4-May	89	28867	6093	17291	2885	55225	0
5-May	65	32737	10774	14047	3285	60908	0
6-May	98	30910	7703	11918	7547	58176	0
7-May	330	29794	3912	12096	6589	52721	0
8-May	565	37569	8346	14853	12139	73472	0
9-May	754	33202	6119	12817	13156	66048	0
10-May	254	56352	11234	16718	33471	118029	0
11-May	426	64330	9057	22826	35701	132340	0
12-May	196	68585	9221	16025	33719	127746	0
13-May	36	64121	6276	24847	38158	133438	0
14-May	9	51819	2687	16925	39955	111395	0
15-May	79	39579	5007	20504	16849	82018	0
16-May	208	47452	3838	10827	24784	87109	0
17-May	25	92843	7297	15326	23162	138653	7
18-May	33	75112	8150	12986	29643	125924	8
19-May	48	56381	6039	16860	19288	98616	10
20-May	19	43342	4421	16543	16271	80596	8
21-May	246	53777	6394	22528	15263	98208	12
22-May	15	71132	7940	26130	26400	131617	94
23-May	0	57463	5438	21974	15806	100681	243
24-May	203	39577	3403	16343	12926	72452	261
25-May	23	67488	8196	27295	15315	118317	181
26-May	45	52775	12410	47674	11504	124408	75
27-May	76	31060	6536	26950	11612	76234	585
28-May	1068	27119	9977	32096	11075	81335	1211
29-May	3296	26723	20710	31215	12102	94046	2114
30-May	6439	27470	18770	57064	9728	119471	1330
Sum	15381	1376333	230256	627083	502285	2751338	6139
Mean	512.7	45877.8	7675.2	20902.8	16742.8	91711.3	204.6
Percent	**0.6%**	**50.0%**	**8.4%**	**22.8%**	**18.3%**	**100.0%**	**100.0%**

Table 13. Percent species distribution of the summer 1999 juvenile salmonid outmigration and shad migration at John Day Dam based on the DART smolt index, June 6-July 8, 1999.

Summer Species Index							
			From DART Smolt Index				
Date	**Species Smolt Composition**					**All Smolts**	**Adult Shad**
	Chinook 0	**Chinook 1**	**Coho**	**Steelhead**	**Sockeye**		
6-Jun	26065	31834	18160	45721	7691	129471	68
7-Jun	28388	17072	19256	24615	4169	93500	1420
8-Jun	50932	21571	16179	19973	2596	111251	784
9-Jun	13815	3349	7535	6698	1675	33072	516
10-Jun	29860	4409	7816	4209	801	47095	6252
11-Jun	42507	5813	10536	5631	1454	65941	24703
12-Jun	17857	4118	7520	6043	1550	37088	11964
13-Jun	11083	2023	4676	7389	762	25933	5012
14-Jun	16767	1089	5712	4240	603	28411	9578
15-Jun	8362	1093	2083	2648	325	14511	61620
16-Jun	29488	2885	3860	3952	666	40851	37895
17-Jun	51622	3172	4263	3616	520	63193	32846
18-Jun	56164	2239	5654	2585	334	66976	18846
19-Jun	74357	1976	6432	3552	246	86563	28414
20-Jun	113479	1290	4241	2905	390	122305	49164
21-Jun	125483	706	6432	3987	155	136763	66568
22-Jun	158659	665	5604	3519	59	168506	28980
23-Jun	179220	1058	2535	2955	255	186023	33225
24-Jun	126292	539	1085	2221	52	130189	40959
25-Jun	73818	1001	1291	1736	102	77948	20938
26-Jun	92541	533	543	1283	485	95385	26967
27-Jun	172396	720	180	1260	360	174916	28394
28-Jun	288326	1280	440	257	379	290682	23586
29-Jun	272494	370	202	650	22	273738	21836
30-Jun	282284	731	1168	539	64	284786	10702
1-Jul	124027	317	468	103	40	124955	10211
2-Jul	68552	293	450	1204	27	70526	5222
3-Jul	105319	48	67	241	39	105714	17976
4-Jul	60507	0	347	520	0	61374	10611
5-Jul	85957	700	350	350	0	87357	13072
6-Jul	53042	684	234	240	6	54206	5302
7-Jul	35190	28	31	38	5	35292	4670
8-Jul	38093	3	16	70	19	38201	5134
Sum	2912946	113609	145366	164950	25851	3362722	663435
Mean	88271	3443	4405	4998	783	101901	20104.1
Percent	**86.6%**	**3.4%**	**4.3%**	**4.9%**	**0.8%**	**100.0%**	**100.0%**

hydroacoustic monitoring. The percentage totals described below are based on juvenile salmonid observations only for the respective study periods. Adult shad passage is expressed numerically in both Tables 12 and 13 and in Figures 25-27.

The observed behavior and distribution of upstream-migrant adult shad are such that their presence during the summer monitoring period was not expected to significantly impact hydroacoustic passage estimates. They are generally strongly surface-oriented and moving upstream from the fish ladders on either shore of John Day Dam. Adult shad would not be expected to dive and be detected by the in-turbine hydroacoustic deployments. It is possible that adult shad could be detected in front of the spillway by the surface-mounted downlooking spillway transducer array, although adult shad were not observed to mill in this area during the summer hydroacoustic monitoring period.

Downstream-migrant juvenile shad are similar in size to outmigrant smolt and may inflate hydroacoustic smolt passage estimates when present in significant numbers. However, the DART and USCOE-Portland websites did not report juvenile shad passage during the spring or summer hydroacoustic monitoring periods at John Day Dam in 1999.

Based on the published indices (Figure 25 and Table 12), yearling chinook comprised 50% of the total juvenile smolt outmigration during the 1999 spring monitoring period (May 1-30), followed by steelhead (23%), sockeye (18%), and coho (8%). Sub-yearling chinook (Age-0) comprised less than 1% of the observed total spring seasonal passage. Adult shad passage was observed after May 17, but was negligible relative to salmonid passage.

The run timing by species for the spring monitoring period is presented in Figure 26. Yearling chinook predominated between May 10-26. Sockeye outmigration peaked May 10-14. Relative increases in downstream passage of steelhead and coho were noted near the end of the spring study period, between approximately May 25-31. Adult shad were not observed in significant numbers during the spring monitoring period, and were non-existent before May 17.

During the 1999 summer monitoring period (June 6-July 8), sub-yearling chinook (Age-0) were predominant (87%). Yearling chinook comprised approximately 3% of the seasonal outmigration. Steelhead (5%), coho (4%), and sockeye (1%) were observed in lower proportions relative to the spring monitoring period. Adult shad passage was observed throughout the sampling period at low to moderate levels, relative to salmonid outmigration rates. If adult shad were incorporated into the summer total observed species composition estimates; they would account for approximately 16% of total observations during the summer hydroacoustic monitoring period.

Species run timing for the summer monitoring period is presented in Figure 27. All salmonid species and both chinook age-classes were represented before June 14. Following this date, Age-0 chinook were clearly predominant and yearling chinook, coho, steelhead and sockeye passage steadily declined to relatively negligible levels through the end of hydroacoustic monitoring on July 8. Age-0 chinook passage increased rapidly after approximately June 14, declined briefly between June 24-26, then peaked June 28-30 at approximately 280,000 fish per day. Sub-yearling chinook passage gradually declined after June 30 through the end of hydroacoustic monitoring on July 8.

Adult shad migration increased after June 15, and was actually predominant on June 15-16, after which it was surpassed by the increasing magnitude of sub-yearling chinook outmigration. Adult shad were observed in significant numbers between June 15-July 8, although passage was significantly less than that of sub-yearling chinook during the period. Adult shad passage was generally highest June 15-29, and declined after that date.

4.3 Project Spill Efficiency and Spill Effectiveness

A blocked spill study design was implemented to evaluate the effectiveness/efficiency of daytime spill as a fish bypass mechanism. The experimental spill design scheduled constant 60% nighttime (1900–0559 h) spill during both the spring and summer study periods. Daytime (0600-1859 h) spill was scheduled to alternate between 0% and 30% levels, each of 3-d in duration, within each 6-d study block. The 6-d block replicate design resulted in 5 block replicates within each 30-d seasonal outmigration period (spring and summer). Each 6-d block was designed to serve as a replicate to allow statistical comparison of the 0% and 30% daytime spill levels. Tables 14 and 15 present the planned 1999 spring and summer John Day spill schedule, as designed before the sampling season.

However, due to generation requirements (specifically, balancing power demand with operations required to maintain a blocked spill study regime at The Dalles Dam) and river flow, the blocked operation spill design at John Day Dam was not consistently achieved during the study period. Project spill operations at John Day Dam during both spring and summer 1999 study periods were variable, and conditions did not consistently match the blocked study design. Daytime spill occurred during some portion of all summer block replicates and in four of the five spring replicates, impacting the statistical power of the original study design. During the spring evaluation Block 4 (May 19-24) achieved a complete 72-h replicate with 0% daytime spill. Spring Blocks 2 (May 7-12) and 3 (May 13-18) each had only a few hours of daytime spill within the designated 72-h replicate, corresponding to 5% and 1% of total project outflow, respectively. Summer Blocks 5 and 6 had minimal daytime spill during the scheduled 72-h 0% daytime spill periods, corresponding to 6% and 1% of total project outflow, respectively.

Following consultation with the project statistician, Dr. John Skalski, 24-h blocks which most closely met the original 0% or 30% daytime spill condition were pooled in the final analysis. Table 16 presents the spring days selected for the final analysis. For the spring monitoring period at John Day Dam, the 0% daytime spill periods selected were May 11,12,16,17,18,22,23 and 24 (8 days total). The corresponding spring 30% daytime spill 24-h blocks selected were May 14,15,19,20,21,25,26 and 27 (8 days). A total of 16 days, of the 30 sampled during the spring monitoring period were grouped for final analysis. Fish passage data by route was pooled within each operational block. Spill effectiveness and efficiency were statistically compared at a 95% level of assurance, with the null hypothesis H_0: $\mu_1 = \mu_2$, i.e. the means of the estimators are the same between the two daytime spill conditions.

Spillway operation varied to a greater degree during the summer monitoring period, relative to that observed during the spring. A total of 10 days met spill operation criteria and were pooled for analysis, of 33 total sampled days during the monitoring period. Table 17 presents the spring days selected for the final analysis. The 0% daytime spill periods selected were June 28-29 and July 3-5 (5 days total). The corresponding summer 30% daytime spill 24-h blocks selected were July 1, 2, 6, 7 and 8 (5 days).

For both the spring and summer pooled data sets, the 0% daytime spill periods were selected based on least spill during the daytime period (0600-1859 h). All days with 0% daytime spill were selected. In some instances, days with incidental daytime spill (1-2 hours were allowed to achieve sufficient replicates for statistical comparison, per recommendations from Dr. John Skalski. The corresponding 30% daytime spill replicates for comparison were selected based on best fit with a true 30% daytime spill level and closest proximity in time to the selected 0% periods.

Table 14. Planned spring spill operational schedule, John Day Dam, May 1-30, 1999. Note: "A" blocks refer to scheduled 30% daytime spill and "B" blocks to 0% daytime spill.

John Day Dam Spring Spill Schedule

		Percent Spill Level				Percent Spill Level	
Block	Date	Day	Night	Block	Date	Day	Night
1A	1-May	30%	60%	**4A**	19-May	30%	60%
	2-May	30%	60%		20-May	30%	60%
	3-May	30%	60%		21-May	30%	60%
1B	4-May	0%	60%	**4B**	22-May	0%	60%
	5-May	0%	60%		23-May	0%	60%
	6-May	0%	60%		24-May	0%	60%
2A	7-May	30%	60%	**5A**	25-May	30%	60%
	8-May	30%	60%		26-May	30%	60%
	9-May	30%	60%		27-May	30%	60%
2B	10-May	0%	60%	**5B**	28-May	0%	60%
	11-May	0%	60%		29-May	0%	60%
	12-May	0%	60%		30-May	0%	60%
3A	13-May	30%	60%				
	14-May	30%	60%				
	15-May	30%	60%				
3B	16-May	0%	60%				
	17-May	0%	60%				
	18-May	0%	60%				

Table 15. Planned summer spill operational schedule, John Day Dam, June 6-July 8, 1999. Note: "A" blocks refer to scheduled 30% daytime spill and "B" blocks to 0% daytime spill.

John Day Dam Summer Spill Schedule

		Percent Spill Level				Percent Spill Level	
Block	Date	Day	Night	Block	Date	Day	Night
1A*	3-Jun	30%	60%	**4A**	21-Jun	0%	60%
	4-Jun	30%	60%		22-Jun	0%	60%
	5-Jun	30%	60%		23-Jun	0%	60%
1B	6-Jun	0%	60%	**4B**	24-Jun	30%	60%
	7-Jun	0%	60%		25-Jun	30%	60%
	8-Jun	0%	60%		26-Jun	30%	60%
2A	9-Jun	0%	60%	**5A**	27-Jun	0%	60%
	10-Jun	0%	60%		28-Jun	0%	60%
	11-Jun	0%	60%		29-Jun	0%	60%
2B	12-Jun	30%	60%	**5B**	30-Jun	30%	60%
	13-Jun	30%	60%		1-Jul	30%	60%
	14-Jun	30%	60%		2-Jul	30%	60%
3A	15-Jun	0%	60%	**6A**	3-Jul	0%	60%
	16-Jun	0%	60%		4-Jul	0%	60%
	17-Jun	0%	60%		5-Jul	0%	60%
3B	18-Jun	30%	60%	**6B**	6-Jul	30%	60%
	19-Jun	30%	60%		7-Jul	30%	60%
	20-Jun	30%	60%		8-Jul	30%	60%

* Hydroacoustic sampling began 6-Jun at 0500h, Block 1A not sampled

Table 16. Observed mean percent spill level for individual day (0600-1859 h) and night (1900 – 0559 h) for the spring sampling period, John Day Dam, May 1-30, 1999. 24-h periods selected for the final pooled analysis are highlighted by daytime spill operations used for grouping (0% or 30% daytime spill).

John Day Dam Spring Spill Schedule

Date	Percent Spill Level		Date	Percent Spill Level	
	Day	Night		Day	Night
1-May	32%	46%	16-May	0%	48%
2-May	31%	39%	17-May	0%	41%
3-May	31%	39%	18-May	3%	49%
4-May	25%	42%	19-May	33%	45%
5-May	29%	39%	20-May	31%	44%
6-May	9%	40%	21-May	33%	44%
7-May	31%	50%	22-May	0%	45%
8-May	28%	48%	23-May	0%	51%
9-May	31%	45%	24-May	0%	46%
10-May	16%	43%	25-May	33%	30%
11-May	0%	48%	26-May	32%	35%
12-May	0%	52%	27-May	30%	33%
13-May	31%	45%	28-May	27%	36%
14-May	31%	46%	29-May	26%	26%
15-May	21%	37%	30-May	26%	38%

Legend

0% Day Spill (cyan: 11-May, 12-May, 16-May, 17-May, 18-May, 22-May, 23-May, 24-May)

30% Day Spill (pink: 14-May, 15-May, 19-May, 20-May, 21-May, 25-May, 26-May, 27-May)

Table 17. Observed mean percent spill level for individual day (0600-1859 h) and night (1900 – 0559 h) for the summer sampling period, John Day Dam, June 6 – July 8, 1999. 24-h periods selected for the final pooled analysis are highlighted by daytime spill operations used for grouping (0% or 30% daytime spill).

John Day Dam Summer Spill Schedule

Date	Percent Spill Level		Date	Percent Spill Level	
	Day	Night		Day	Night
6-Jun	32%	32%	23-Jun	21%	20%
7-Jun	17%	31%	24-Jun	20%	25%
8-Jun	26%	33%	25-Jun	21%	21%
9-Jun	28%	28%	26-Jun	20%	22%
10-Jun	22%	33%	27-Jun	14%	22%
11-Jun	2%	35%	28-Jun	2%	22%
12-Jun	31%	34%	29-Jun	0%	22%
13-Jun	31%	37%	30-Jun	23%	24%
14-Jun	31%	36%	1-Jul	25%	24%
15-Jun	13%	32%	2-Jul	24%	32%
16-Jun	24%	29%	3-Jul	0%	24%
17-Jun	27%	27%	4-Jul	0%	32%
18-Jun	31%	23%	5-Jul	0%	38%
19-Jun	23%	24%	6-Jul	28%	49%
20-Jun	23%	24%	7-Jul	30%	46%
21-Jun	18%	23%	8-Jul	30%	54%
22-Jun	18%	22%			

Legend

0% Day Spill (28-Jun, 29-Jun, 3-Jul, 4-Jul, 5-Jul highlighted)

30% Day Spill (1-Jul, 2-Jul, 6-Jul, 7-Jul, 8-Jul highlighted)

4.3.1 Spring Monitoring Period

Table 18 presents estimated fish passage by route, mean percent spill, spill efficiency, spill effectiveness and the surrounding 95% confidence intervals for day (0600-1859 h), night (1900-0559 h) and 24-h blocks for the spring monitoring period (May 1-30, 1999). The metrics represent the mean values for the pooled dates within the spring monitoring period that met targeted daytime spill operations. This represents a total of 16 of the total 30 sampled days, 8 days each at 0% and 30% daytime spill.

Table 19 presents this data on a daily basis, for each 24-h time period grouped in the final analyses of project fish passage, spill efficiency and spill effectiveness at John Day Dam during the Spring 1999 monitoring period.

Table 18. Spring estimated turbine, spill and total dam fish passage, percent spill, mean spill efficiency and effectiveness, including surrounding 95% confidence intervals. Estimates based on pooled 16-d data set meeting targeted daytime spill criteria. John Day Dam, May 1-30, 1999.

John Day Dam - Spring 1999 Selected 16 day data set

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	All	Day	258155	24769	2648	843	260803	24771	0.3%	1%	5%	3.14	1.97
0	All	Night	532152	30574	1672246	11205	2204398	32562	47%	76%	9%	1.60	0.18
0	All	24 hr	790307	24302	1674893	7519	2465201	25438	22%	68%	5%	3.10	0.24

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	All	Day	171470	10036	1682786	20532	1854256	22853	31%	91%	4%	2.96	0.12
30	All	Night	519581	18273	1432726	13770	1952307	22881	39%	73%	6%	1.87	0.14
30	All	24 hr	691051	16318	3115512	20124	3806563	25908	35%	82%	3%	2.37	0.08

Table 19. Daily spring estimated turbine, spill and total dam fish passage, percent spill, mean spill efficiency and effectiveness, including surrounding 95% confidence intervals, for each of the 16 daily periods meeting targeted daytime spill criteria. John Day Dam, May 1-30, 1999.

John Day Dam - Spring 1999 Selected 16 day data set

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	11-May-99	Day	29058	29058	0	0	29058	29058	0%	0%	0%	0.00	0.00
0	12-May-99	Day	25251	26286	0	0	25251	26286	0%	0%	0%	0.00	0.00
0	16-May-99	Day	24430	5896	0	0	24430	5896	0%	0%	0%	0.00	0.00
0	17-May-99	Day	32790	29457	0	0	32790	29457	0%	0%	0%	0.00	0.00
0	18-May-99	Day	39941	32599	2648	843	42589	32610	3%	6%	5%	2.40	1.97
0	22-May-99	Day	41877	15507	0	0	41877	15507	0%	0%	0%	0.00	0.00
0	23-May-99	Day	36057	30823	0	0	36057	30823	0%	0%	0%	0.00	0.00
0	24-May-99	Day	28751	35109	0	0	28751	35109	0%	0%	0%	0.00	0.00
0	Total	Day	258155	24769	2648	843	260803	24771	0.3%	1%	5%	3.14	1.97

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	14-May-99	Day	17824	7155	102315	6104	120139	9405	31%	85%	5%	2.76	0.17
30	15-May-99	Day	26572	5140	141686	13193	168257	14159	21%	84%	3%	3.93	0.13
30	19-May-99	Day	13750	5809	252133	18491	265883	19382	33%	95%	2%	2.88	0.06
30	20-May-99	Day	20921	20348	257615	24576	278536	31906	31%	92%	7%	2.96	0.22
30	21-May-99	Day	14557	7024	151370	20184	165928	21371	33%	91%	4%	2.73	0.12
30	25-May-99	Day	25028	15278	327811	34773	352840	37981	33%	93%	4%	2.78	0.12
30	26-May-99	Day	31332	9918	218113	26619	249445	28407	32%	87%	4%	2.73	0.12
30	27-May-99	Day	21486	8119	231742	24247	253228	25570	30%	92%	3%	3.10	0.10
30	Total	Day	171470	10036	1682786	20532	1854256	22853	31%	91%	4%	2.96	0.12

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	11-May-99	Night	60306	29586	84831	7436	145137	30506	48%	58%	12%	1.21	0.25
0	12-May-99	Night	78460	59957	157218	7562	235679	60432	52%	67%	17%	1.28	0.33
0	16-May-99	Night	47669	24275	184541	8449	232210	25703	48%	79%	8%	1.66	0.17
0	17-May-99	Night	71611	18132	174147	7017	245758	19443	41%	71%	5%	1.74	0.13
0	18-May-99	Night	60369	24407	204859	7496	265228	25533	49%	77%	7%	1.58	0.15
0	22-May-99	Night	78336	16432	321594	19727	399931	25675	45%	80%	3%	1.79	0.08
0	23-May-99	Night	71865	52762	273188	12907	345053	54317	51%	79%	12%	1.56	0.24
0	24-May-99	Night	63536	18961	271867	20426	335403	27870	46%	81%	5%	1.77	0.10
0	Total	Night	532152	30574	1672246	11205	2204398	32562	47%	76%	9%	1.60	0.18

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	14-May-99	Night	62818	18284	179521	13608	242338	22792	46%	74%	6%	1.61	0.13
30	15-May-99	Night	46734	16579	165037	11163	211771	19987	37%	78%	6%	2.10	0.17
30	19-May-99	Night	75429	27762	190055	13908	265484	31051	45%	72%	8%	1.60	0.17
30	20-May-99	Night	76077	25964	131946	10504	208023	28008	44%	63%	8%	1.44	0.18
30	21-May-99	Night	79569	26730	214741	6108	294310	27419	44%	73%	7%	1.67	0.15
30	25-May-99	Night	60976	13745	150320	10679	211296	17406	30%	71%	5%	2.37	0.16
30	26-May-99	Night	59850	13589	238795	32349	298646	35087	35%	80%	4%	2.29	0.12
30	27-May-99	Night	58129	14660	162310	9744	220439	17603	33%	74%	5%	2.26	0.15
30	Total	Night	519581	18273	1432726	13770	1952307	22881	39%	73%	6%	1.87	0.14

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	11-May-99	24 hr	89364	22678	84831	4674	174196	23154	22%	49%	6%	2.19	0.29
0	12-May-99	24 hr	103711	42607	157218	4753	260929	42871	24%	60%	10%	2.51	0.41
0	16-May-99	24 hr	72099	17594	184541	5311	256640	18378	22%	72%	5%	3.27	0.23
0	17-May-99	24 hr	104401	15444	174147	4410	278548	16061	19%	63%	4%	3.36	0.19
0	18-May-99	24 hr	100310	19038	207507	4578	307817	19581	24%	67%	4%	2.83	0.18
0	22-May-99	24 hr	120214	18009	321594	12400	441808	21865	21%	73%	3%	3.54	0.15
0	23-May-99	24 hr	107921	35816	273188	8113	381109	36723	23%	72%	7%	3.08	0.29
0	24-May-99	24 hr	92287	18695	271867	12839	364154	22679	21%	75%	4%	3.57	0.19
0	Total	24 hr	790307	24302	1674893	7519	2465201	25438	22%	68%	5%	3.10	0.24

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	14-May-99	24 hr	80641	14073	281836	7151	362477	15785	38%	78%	3%	2.06	0.08
30	15-May-99	24 hr	73306	12763	306722	13770	380028	18775	29%	81%	3%	2.82	0.10
30	19-May-99	24 hr	89179	19189	442189	13915	531367	23703	38%	83%	3%	2.17	0.08
30	20-May-99	24 hr	96998	28391	389561	22121	486559	35991	37%	80%	5%	2.16	0.13
30	21-May-99	24 hr	94126	17458	366112	15851	460238	23580	38%	80%	3%	2.09	0.08
30	25-May-99	24 hr	86005	16416	478131	29099	564136	33410	32%	85%	3%	2.66	0.08
30	26-May-99	24 hr	91183	11610	456908	32714	548091	34713	33%	83%	2%	2.50	0.06
30	27-May-99	24 hr	79615	9934	394053	21717	473667	23881	31%	83%	2%	2.69	0.06
30	Total	24 hr	691051	16318	3115512	20124	3806563	25908	35%	82%	3%	2.37	0.08

4.3.2 Summer Monitoring Period

Table 20 presents estimated fish passage by route, mean percent spill, spill efficiency, spill effectiveness and the surrounding 95% confidence intervals for day (0600-1859 h), night (1900-0559 h) and 24-h blocks for the summer monitoring period (June 6 – July 8, 1999). The metrics represent the mean values for the pooled dates within the spring monitoring period that met targeted daytime spill operations. This represents a total of 10 of the total 33 sampled days, 5 days each at 0% and 30% daytime spill.

Table 21 presents this data on a daily basis, for each 24-h time period grouped in the final analyses of project fish passage, spill efficiency and spill effectiveness at John Day Dam during the Summer 1999 monitoring period.

Table 20. Summer estimated turbine, spill and total dam fish passage, percent spill, mean spill efficiency and effectiveness, including surrounding 95% confidence intervals. Estimates are based on the pooled 10-d data set for the period meeting targeted daytime spill criteria. John Day Dam, June 6–July 8, 1999.

John Day Dam - Summer 1999 Selected 10 day data set

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	All	Day	223304	25437	10184	1687	233488	25446	0.9%	4%	4%	4.88	2.21
0	All	Night	526174	21665	1244075	49395	1770249	53937	28%	70%	5%	2.54	0.22
0	All	24 hr	749477	24891	1254259	33125	2003737	41435	13%	63%	4%	4.75	0.36

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	All	Day	92607	18252	3132091	73620	3224698	75849	27%	97%	3%	3.54	0.10
30	All	Night	233183	15323	1083387	31237	1316569	34793	41%	82%	5%	2.01	0.16
30	All	24 hr	325790	16349	4215478	66904	4541267	68872	34%	93%	2%	2.76	0.05

Table 21. Daily summer estimated turbine, spill and total dam fish passage, percent spill, mean spill efficiency and effectiveness, including surrounding 95% confidence intervals, for each of the 10 daily periods meeting targeted daytime spill criteria. John Day Dam, June 6-July 8, 1999.

John Day Dam - Summer 1999 Selected 10 day data set

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	28-Jun-99	Day	80625	33381	10184	1687	90809	33424	2.0%	11%	4%	5.59	2.21
0	29-Jun-99	Day	71472	51206	0	0	71472	51206	0.6%	0%	0%	0.00	0.00
0	3-Jul-99	Day	30287	7611	0	0	30287	7611	0.6%	0%	0%	0.00	0.00
0	4-Jul-99	Day	20298	4398	0	0	20298	4398	0.7%	0%	0%	0.00	0.00
0	5-Jul-99	Day	20621	5879	0	0	20621	5879	0.6%	0%	0%	0.00	0.00
0	Total	Day	223304	25437	10184	1687	233488	25446	0.9%	4%	4%	4.88	2.21

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	1-Jul-99	Day	18486	18748	696023	67521	714510	70075	25%	97%	3%	3.85	0.10
30	2-Jul-99	Day	17744	17953	837356	128998	855101	130242	24%	98%	2%	4.16	0.09
30	6-Jul-99	Day	38212	33964	597552	65408	635765	73700	28%	94%	5%	3.37	0.18
30	7-Jul-99	Day	9280	9862	510118	74949	519398	75595	30%	98%	2%	3.26	0.06
30	8-Jul-99	Day	8885	7530	491041	33765	499925	34594	30%	98%	1%	3.25	0.05
30	Total	Day	92607	18252	3132091	73620	3224698	75849	27%	97%	3%	3.54	0.10

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	28-Jun-99	Night	159998	24466	238482	34504	398480	42298	22%	60%	5%	2.67	0.23
0	29-Jun-99	Night	138733	30464	302700	89899	441433	94920	22%	69%	8%	3.06	0.36
0	3-Jul-99	Night	74440	25939	358945	74122	433385	78530	24%	83%	6%	3.43	0.24
0	4-Jul-99	Night	66410	17754	110728	6201	177138	18806	32%	63%	6%	1.97	0.20
0	5-Jul-99	Night	86593	19592	233221	16204	319814	25425	38%	73%	5%	1.93	0.12
0	Total	Night	526174	21665	1244075	49395	1770249	53937	28%	70%	5%	2.54	0.22

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	1-Jul-99	Night	72631	13976	86723	13049	159354	19120	24%	54%	6%	2.28	0.25
30	2-Jul-99	Night	65549	22139	141976	11478	207526	24938	32%	68%	8%	2.14	0.23
30	6-Jul-99	Night	37529	18797	359019	69076	396547	71588	49%	91%	5%	1.87	0.09
30	7-Jul-99	Night	29101	9972	126602	16556	155702	19327	46%	81%	6%	1.76	0.12
30	8-Jul-99	Night	28373	17656	369067	26044	397440	31465	54%	93%	4%	1.71	0.08
30	Total	Night	233183	15323	1083387	31237	1316569	34793	41%	82%	5%	2.01	0.16

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
0	28-Jun-99	24 hr	240623	31614	248666	22488	489289	38797	11%	51%	4%	4.48	0.35
0	29-Jun-99	24 hr	210205	40902	302700	56506	512905	69756	11%	59%	7%	5.59	0.62
0	3-Jul-99	24 hr	104727	17814	358945	46589	463672	49879	11%	77%	4%	6.80	0.33
0	4-Jul-99	24 hr	86707	12784	110728	3898	197435	13365	15%	56%	4%	3.76	0.25
0	5-Jul-99	24 hr	107215	15097	233221	10185	340436	18211	18%	69%	3%	3.88	0.18
0	Total	24 hr	749477	24891	1254259	33125	2003737	41435	13%	63%	4%	4.75	0.36

% Day Spill Condition	Date	Period	Turbine Passage	Turbine 95% C.I.	Spill Passage	Spill 95% C.I.	Dam Passage	Dam 95% C.I.	Percent Spill	Spill Efficiency	SE 95%C.I.	Spill Effectiveness	SEF 95%C.I.
30	1-Jul-99	24 hr	91117	15996	782746	54763	873864	57051	25%	90%	2%	3.63	0.07
30	2-Jul-99	24 hr	83294	19381	979333	94599	1062626	96564	27%	92%	2%	3.36	0.07
30	6-Jul-99	24 hr	75741	25100	956571	88345	1032312	91841	37%	93%	2%	2.48	0.06
30	7-Jul-99	24 hr	38380	8989	636720	58255	675100	58944	37%	94%	1%	2.52	0.04
30	8-Jul-99	24 hr	37257	10786	860108	35789	897365	37379	41%	96%	1%	2.33	0.03
30	Total	24 hr	325790	16349	4215478	66904	4541267	68872	34%	93%	2%	2.76	0.05

4.4 Project Spill Efficiency

Figures 28 and 29 present estimated mean project spill efficiency for the nighttime (1900-0559 h) and 24-h periods, with surrounding 95% confidence intervals, for the spring and summer monitoring periods, respectively. The corresponding data values are presented in Tables 18 and 20.

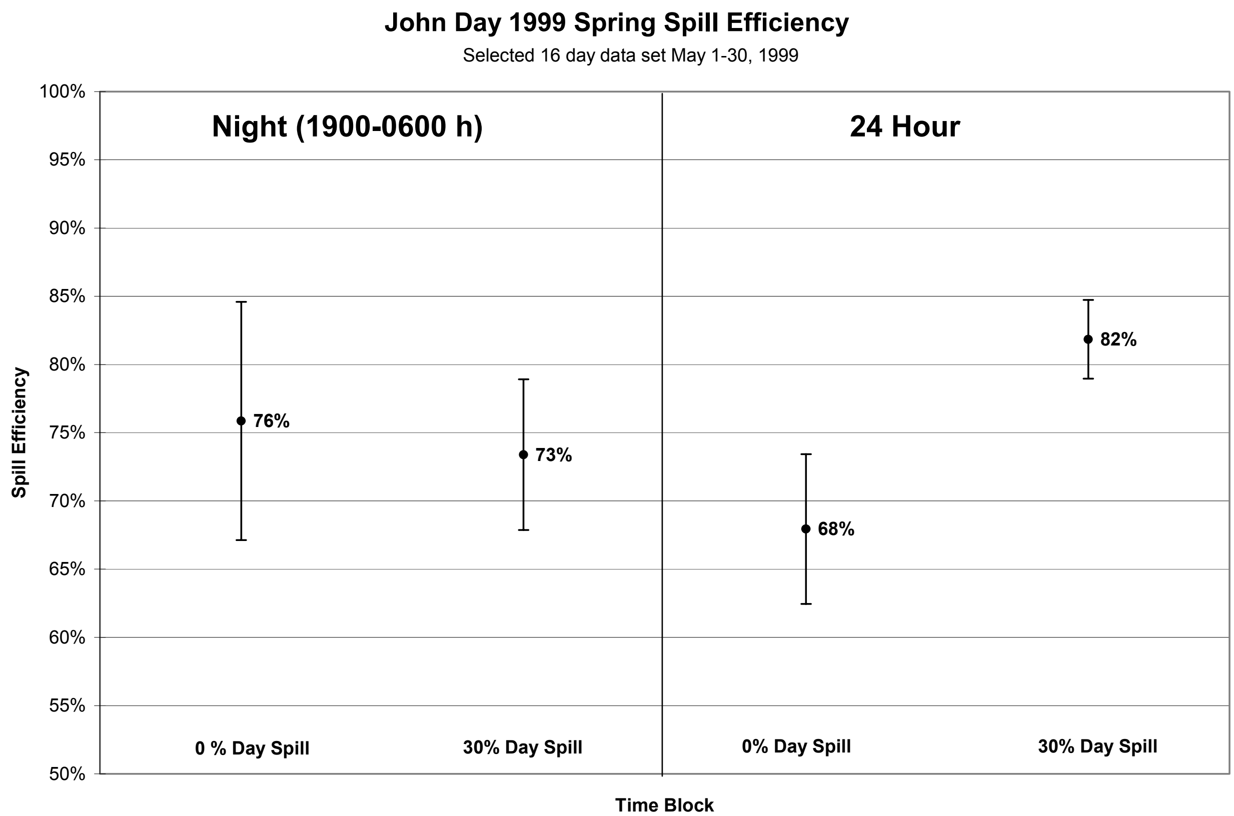


Figure 28. Estimated night and 24 hour spring spill efficiency for the pooled 16 day spring data set (0% and 30% daytime spill) with surrounding 95% confidence intervals. John Day Dam, May 1-30, 1999.

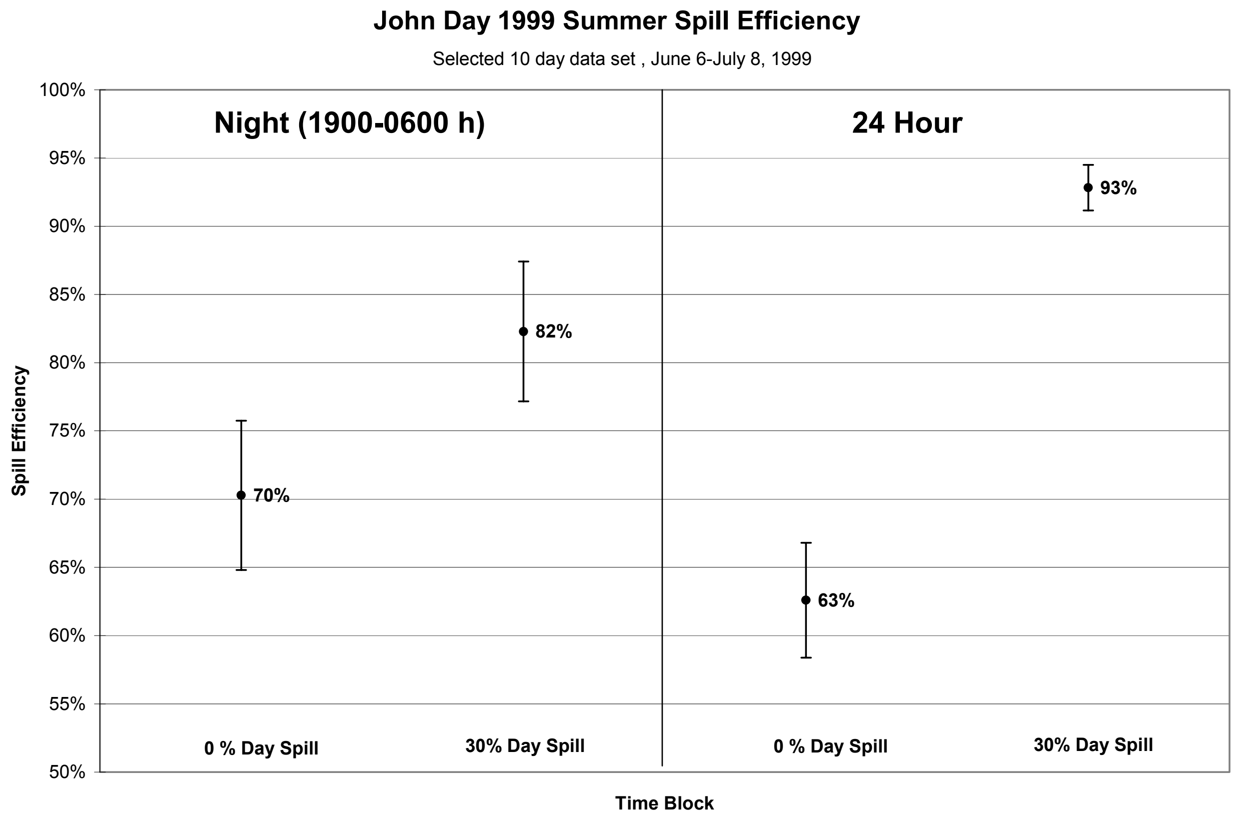


Figure 29. Estimated night and 24 hour summer spill efficiency for the pooled 10 day data set (0% and 30% daytime spill) with surrounding 95% confidence intervals. John Day Dam, June 6 – July 8, 1999.

4.5 Project Spill Effectiveness

Figures 30 and 31 present estimated mean project spill effectiveness for the nighttime (1900-0559 h) and 24-h periods, with surrounding 95% confidence intervals, for the spring and summer monitoring periods, respectively. The corresponding data values are presented in Tables 18 and 20.

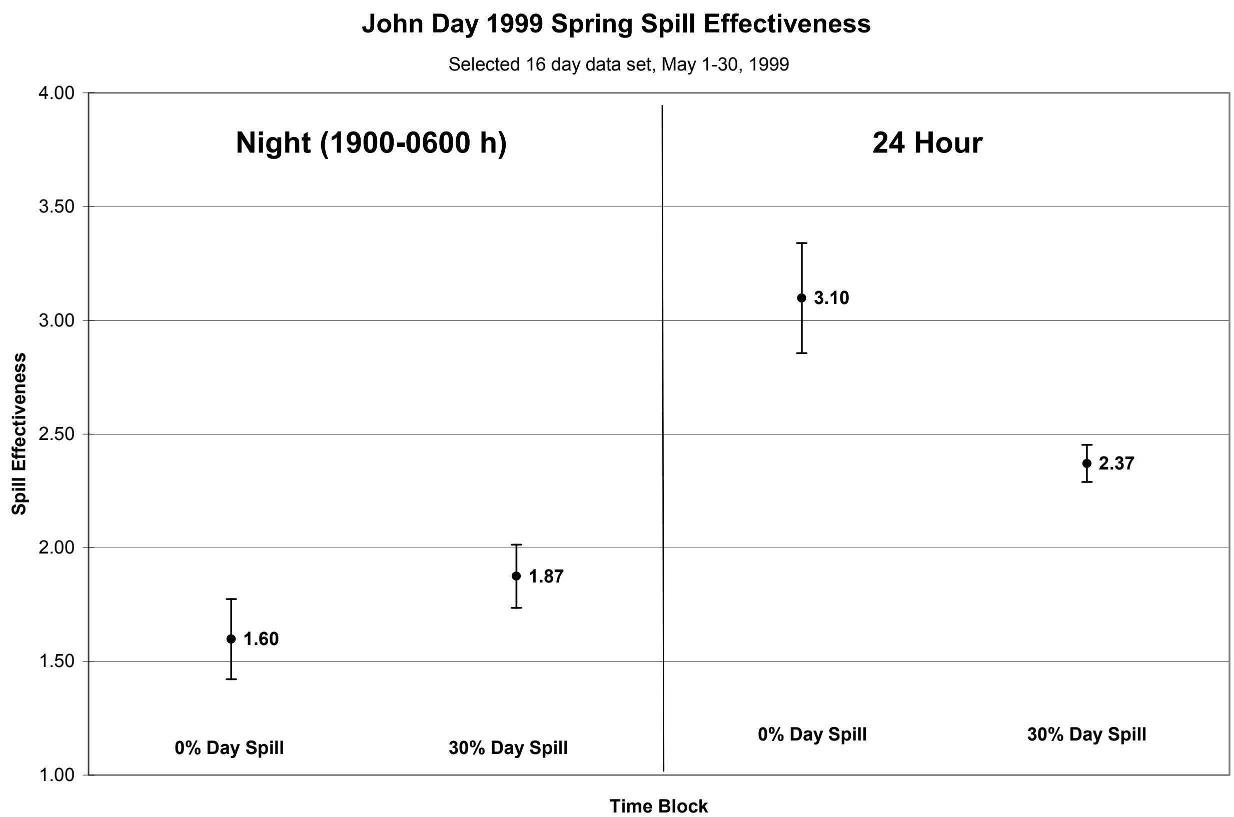


Figure 30. Estimated night and 24 hour spring spill effectiveness for the pooled 16 day spring data set (0% and 30% daytime spill) with surrounding 95% confidence intervals. John Day Dam, May 1-30, 1999.

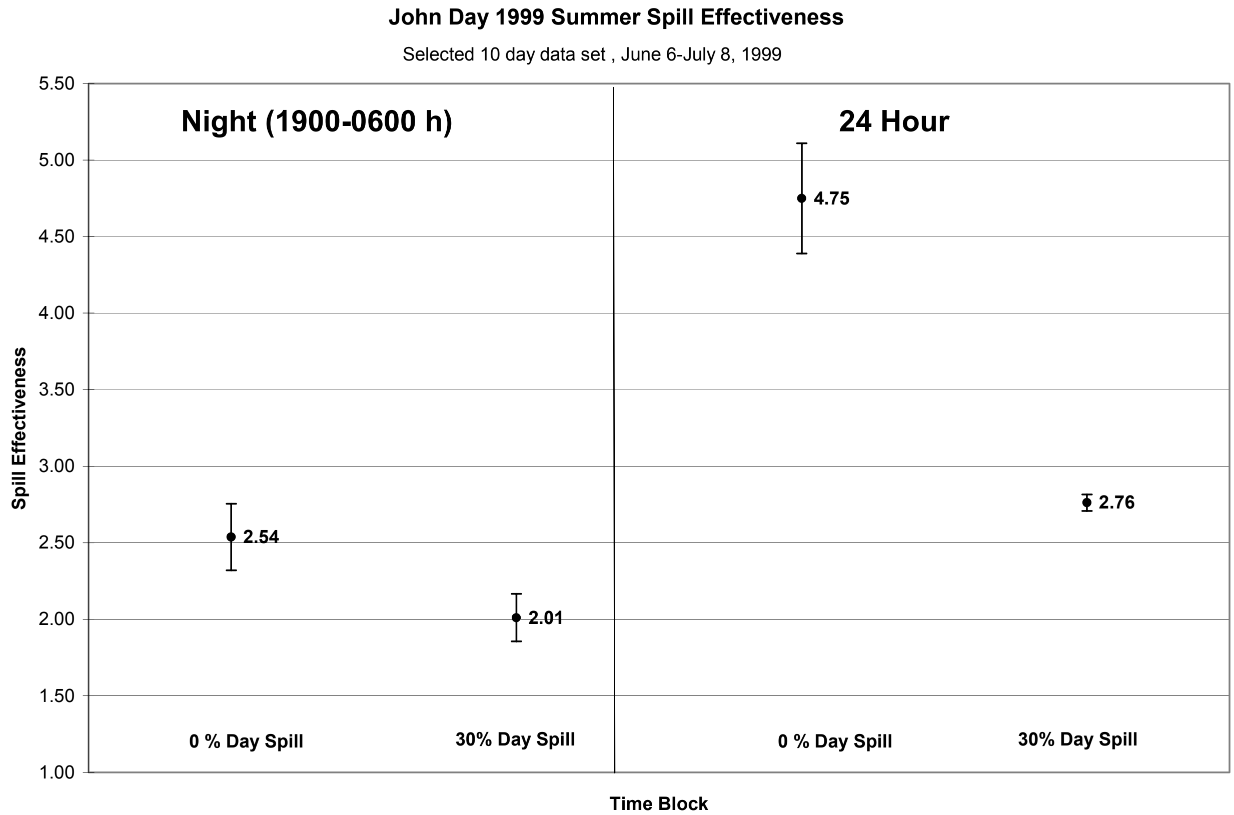


Figure 31. Summer nighttime (1900-0559 h) and 24-h summer spill efficiency for the pooled 10 day data set (0% and 30% daytime spill) with surrounding 95% confidence intervals. John Day Dam, June 6-July 8, 1999.

4.6 Project Fish Passage

4.6.1 Spring Powerhouse Fish Passage

Table 18 presents total estimated day, night and 24-h fish passage by outmigration route (powerhouse or spillway) by grouped daytime spill condition for the spring monitoring period. Only the 24-h days that met percent daytime spill targets of the study design (0% or 30%) were included in the analysis. Corresponding powerhouse fish passage data on a daily basis, for those days meeting daytime spill criteria, are shown in Table 19 for the spring monitoring period. Surrounding confidence intervals at a 95% level of assurance are given for each estimate. Hourly passage estimates, flow and sample variance for the entire 30-d spring sampling block are presented by monitored location in Appendix A.

Powerhouse fish passage estimates on a seasonal and daily basis with surrounding 95% confidence intervals are graphically presented in Figures 32-38. The statistical procedures used to calculate the variances and confidence intervals surrounding all fish passage estimates are described in Appendix C.

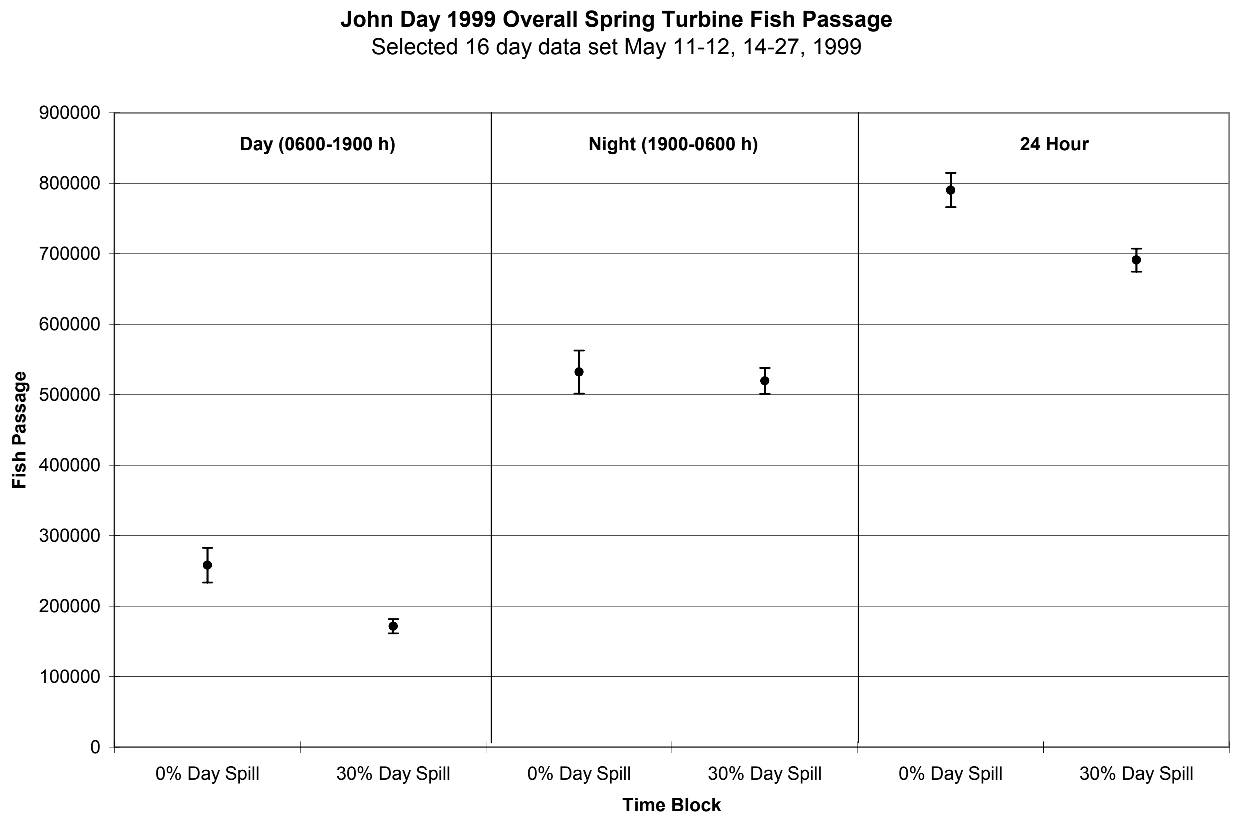


Figure 32. Estimated day, night and 24 hour powerhouse fish passage for selected 16 day spring data set (0% and 30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

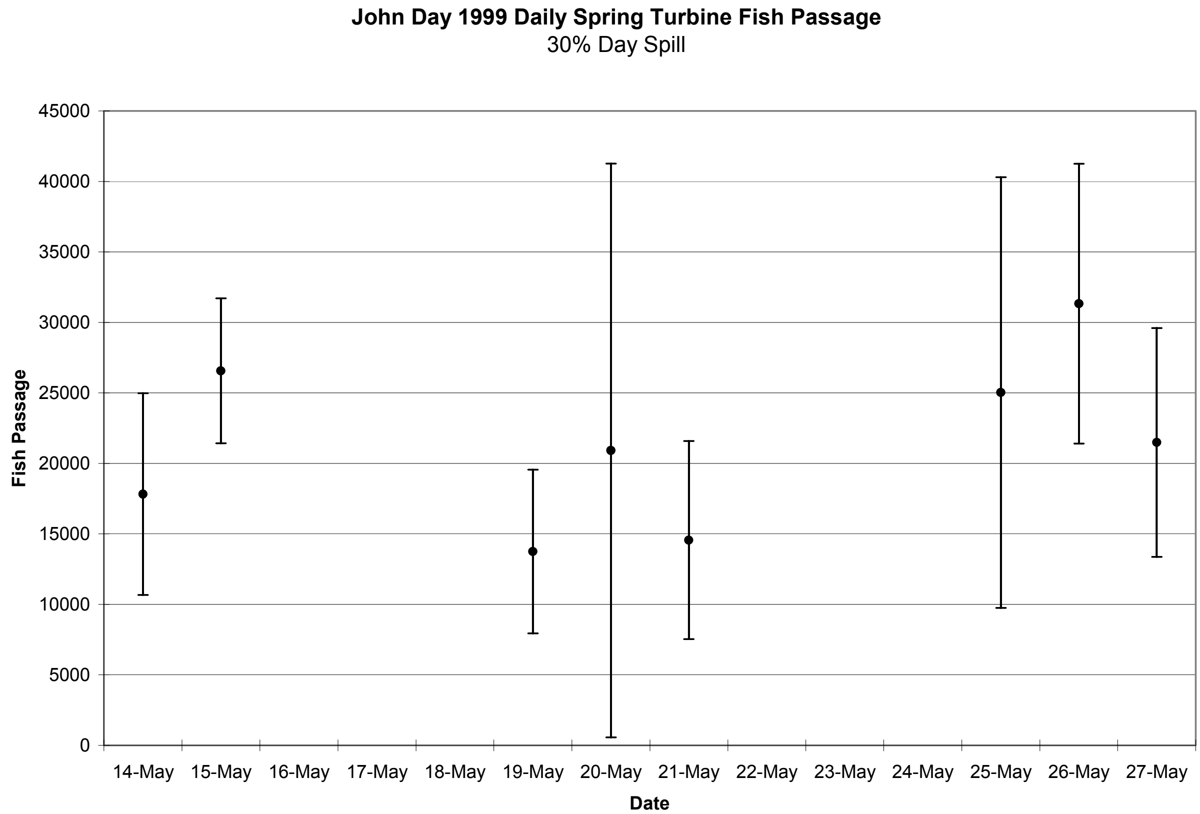


Figure 33. Estimated daytime (0600-1859h) powerhouse fish passage for selected 8 day spring data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

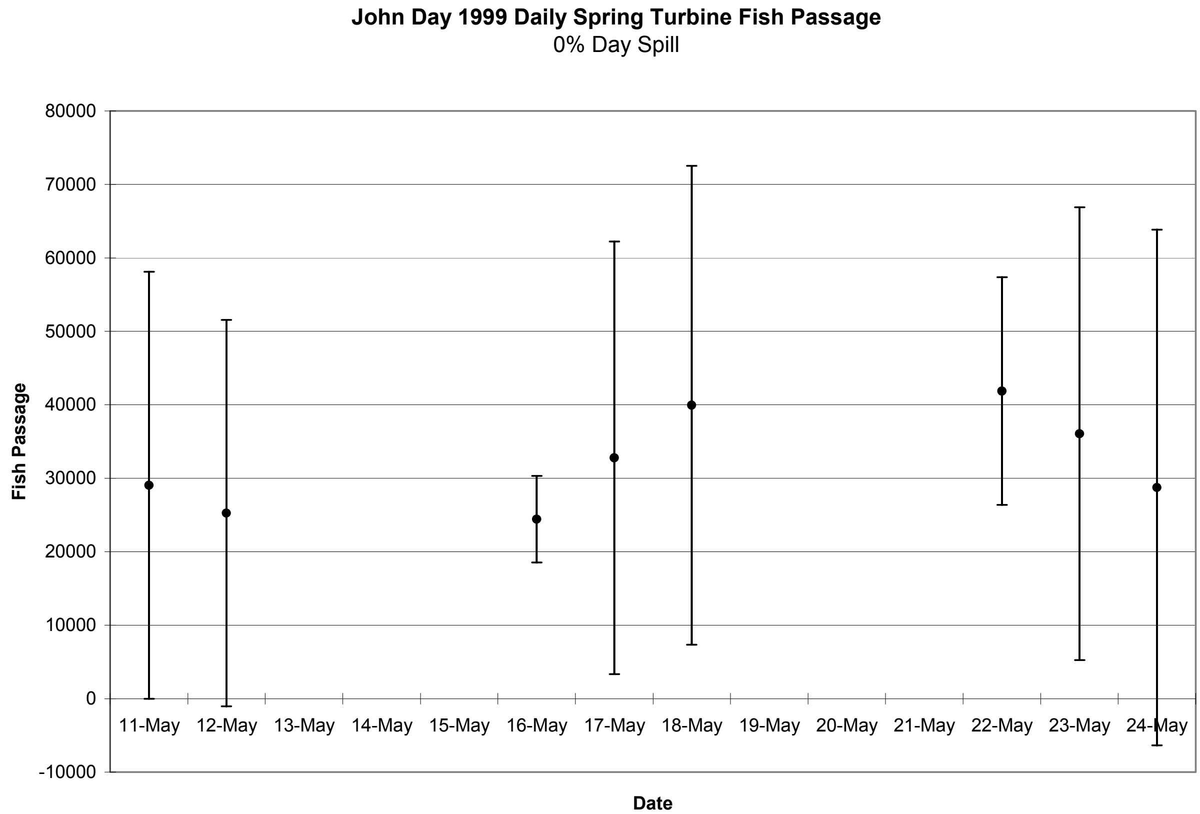


Figure 34. Estimated daytime (0600-1859h) powerhouse fish passage for selected 8 day spring data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

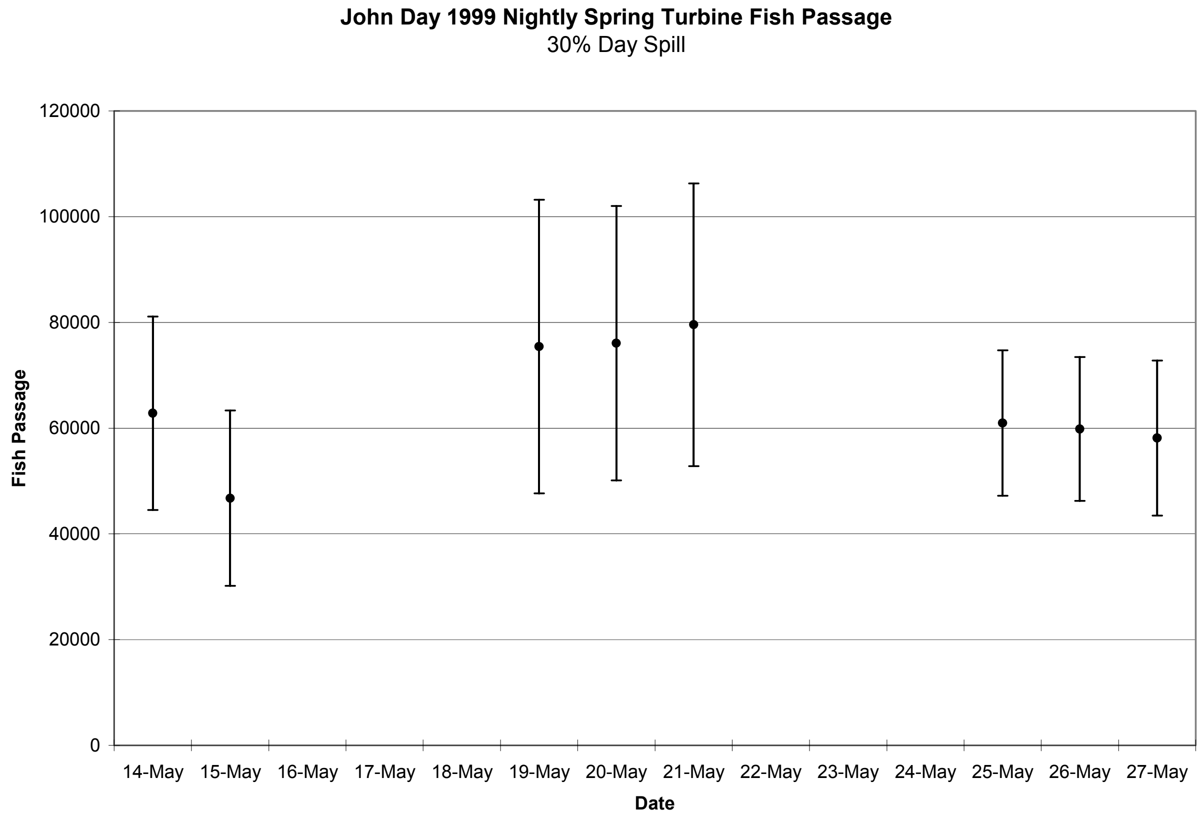


Figure 35. Estimated nighttime (1900-0559h) powerhouse fish passage for selected 8 day spring data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

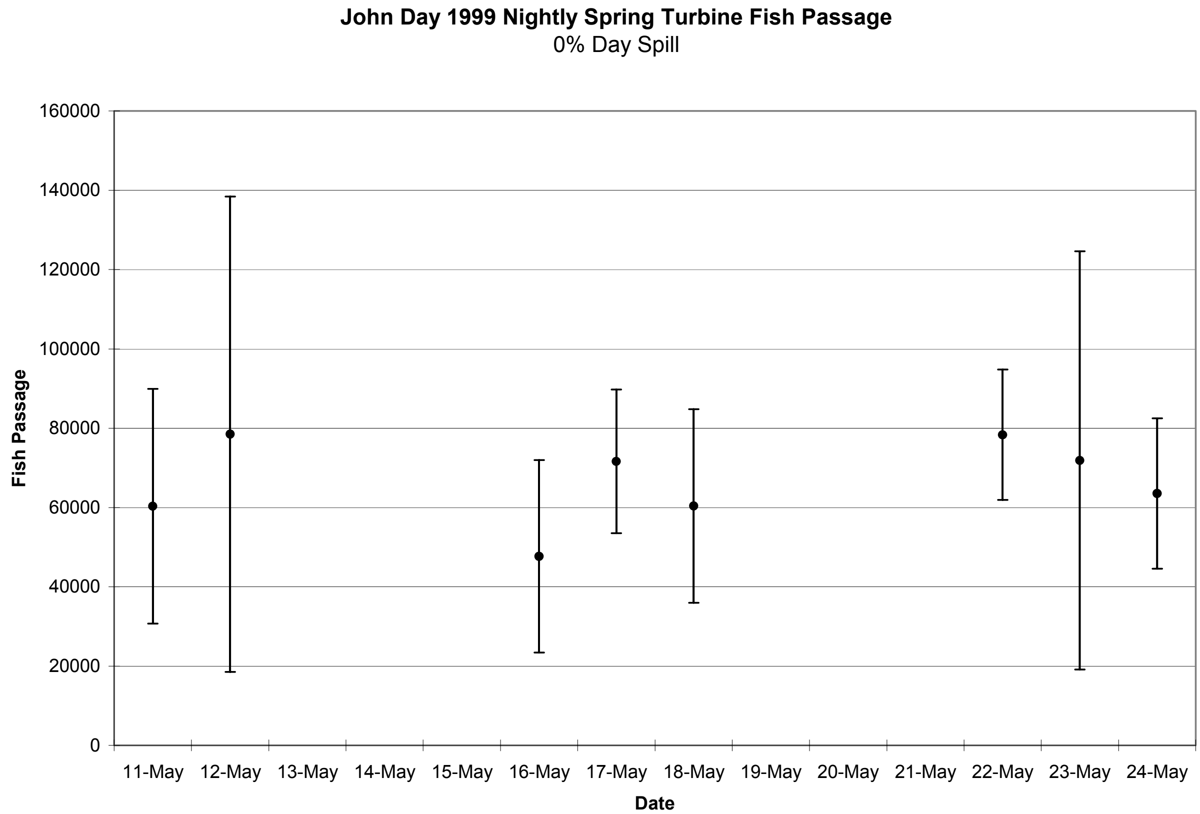


Figure 36. Estimated nighttime (1900-0559h) powerhouse fish passage for selected 8 day spring data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

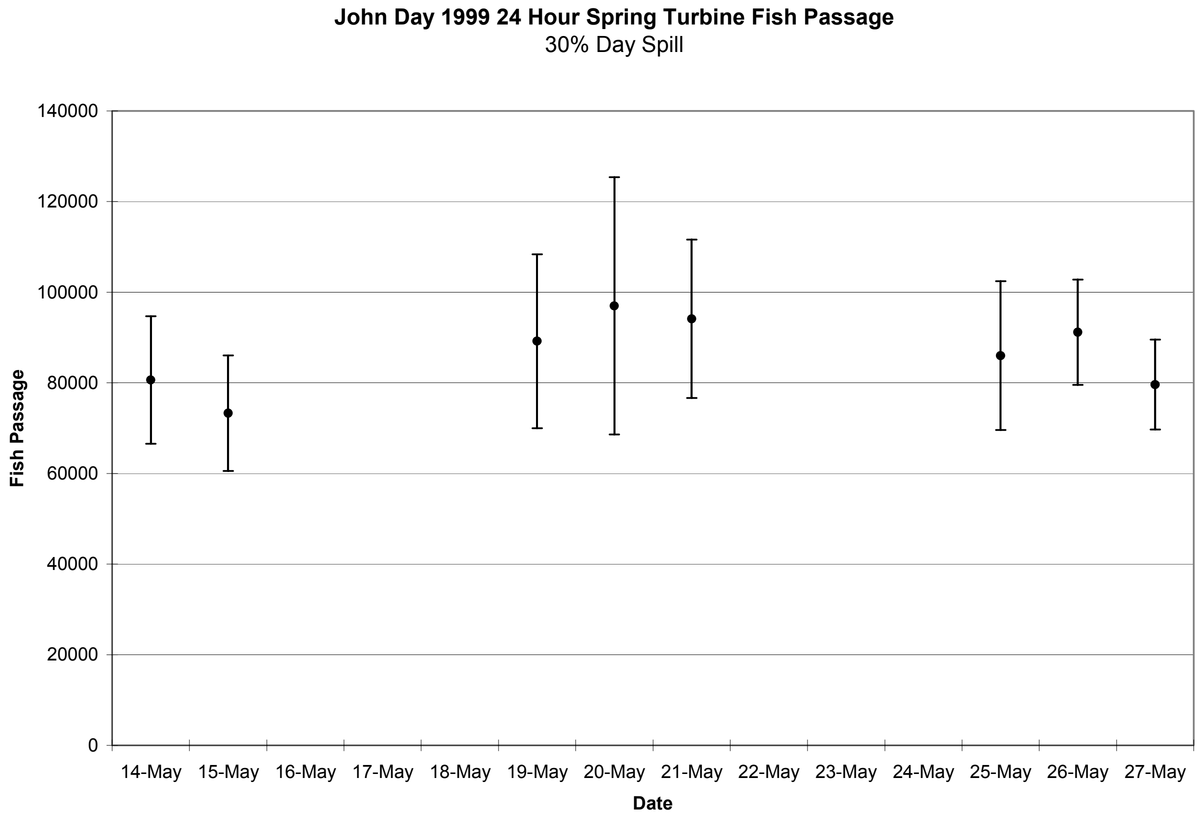


Figure 37. Estimated 24 hour powerhouse fish passage for selected 8 day spring data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

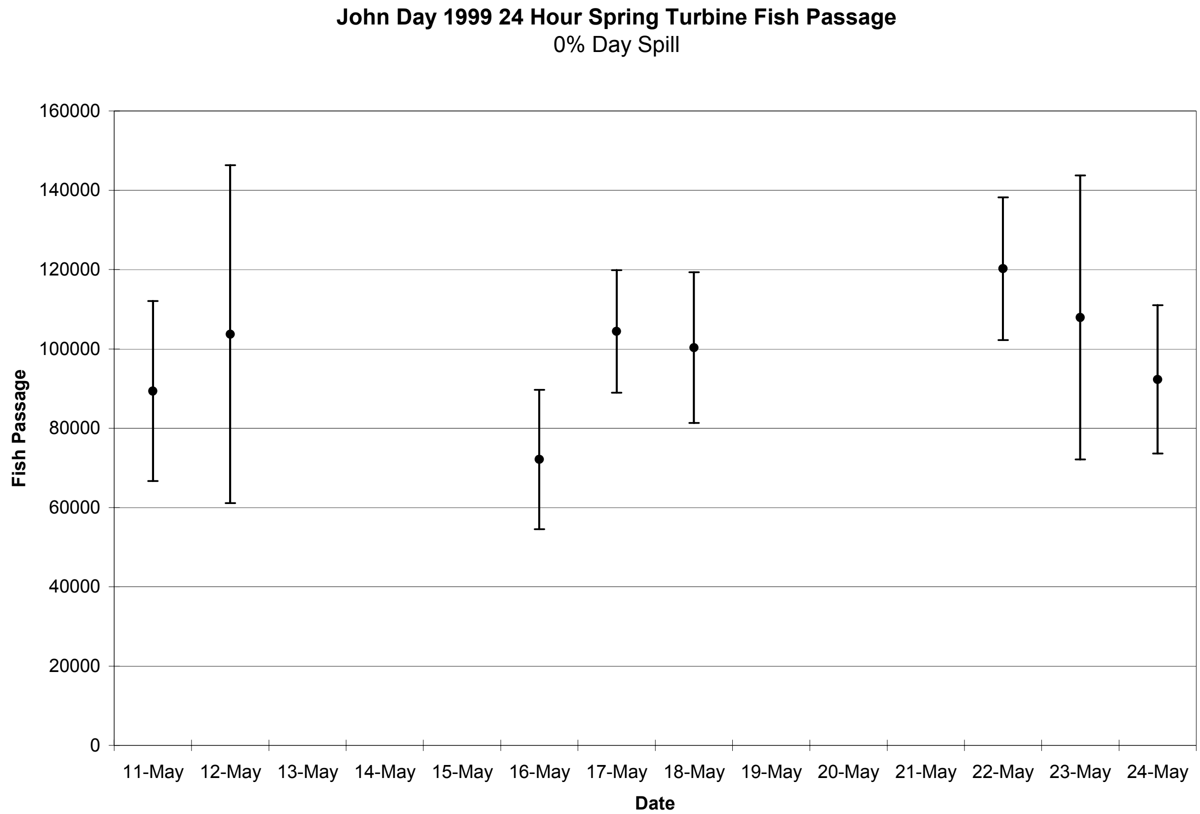


Figure 38. Estimated 24 hour powerhouse fish passage for selected 8 day spring data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

4.6.2 Spring Spillway Fish Passage

Table 18 presents total estimated day, night and 24-h fish passage by outmigration route (powerhouse or spillway) by grouped daytime spill condition for the spring monitoring period. Only the 24-h days that met percent daytime spill targets of the study design (0% or 30%) were included in the analysis. Corresponding spillway fish passage data on a daily basis, for those days meeting daytime spill criteria, are shown in Table 19 for the spring monitoring period. Surrounding confidence intervals at a 95% level of assurance are given for each estimate. Hourly passage estimates, flow and sample variance for the entire 30-d spring sampling block are presented by monitored location in Appendix A.

Spillway fish passage estimates on a seasonal and daily basis with surrounding 95% confidence intervals are graphically presented in Figures 39-45. The statistical procedures used to calculate the variances and confidence intervals surrounding all fish passage estimates are described in Appendix C.

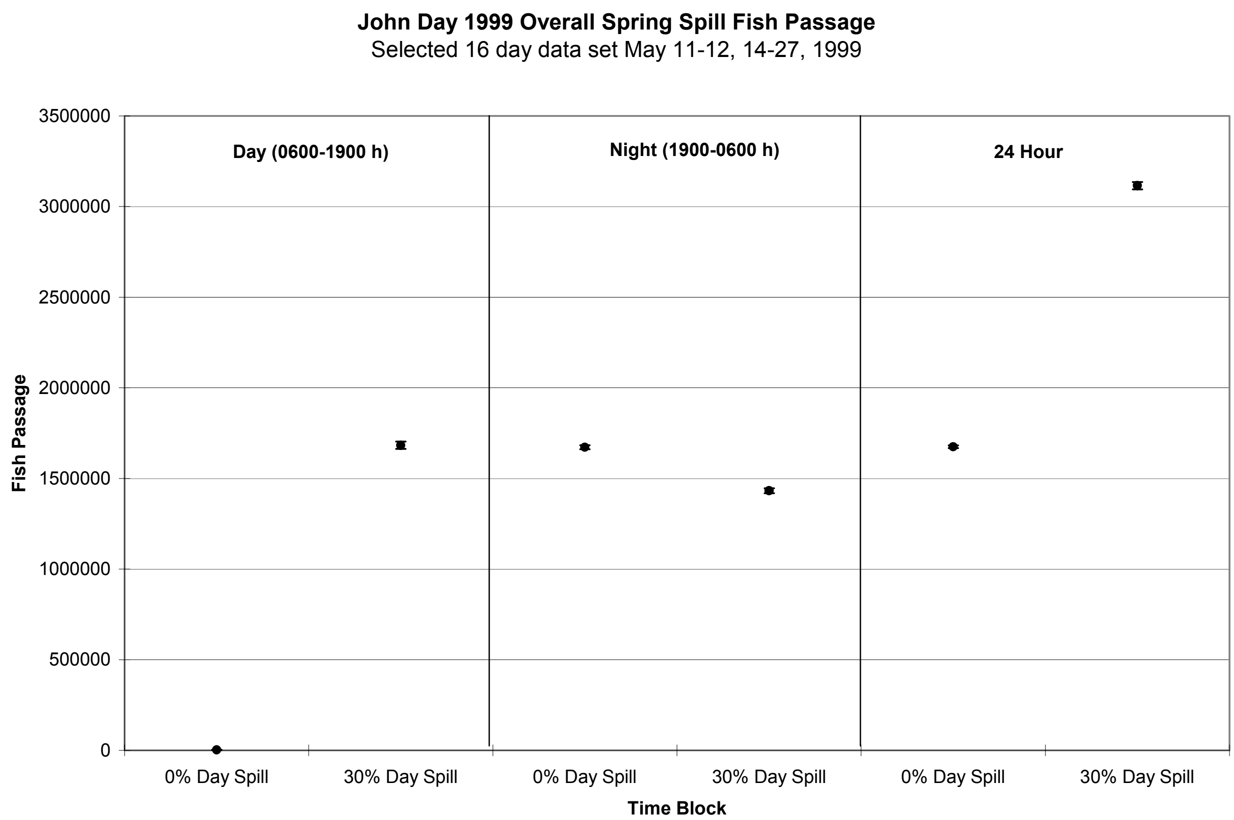


Figure 39. Estimated day, night and 24 hour spillway fish passage for selected 16 day spring data set (0% and 30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

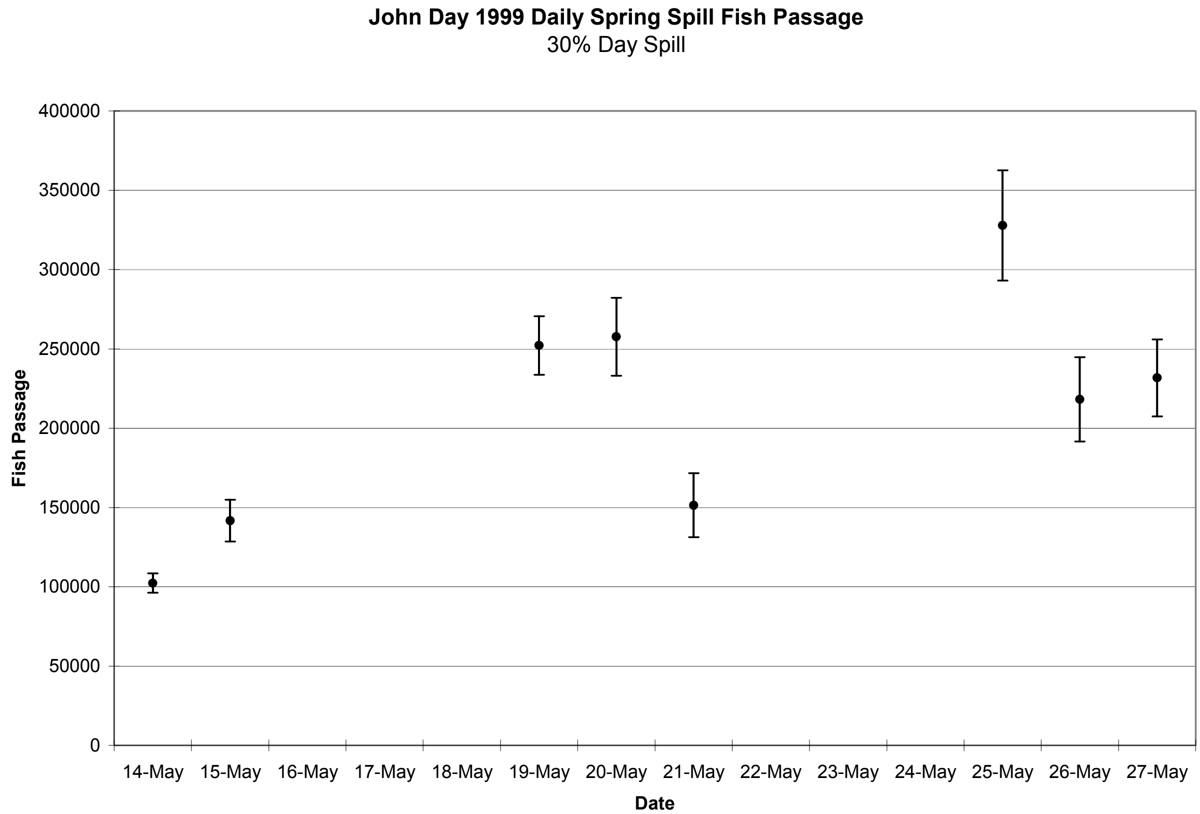


Figure 40. Estimated daytime (0600-1859h) spillway fish passage for selected 8 day spring data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

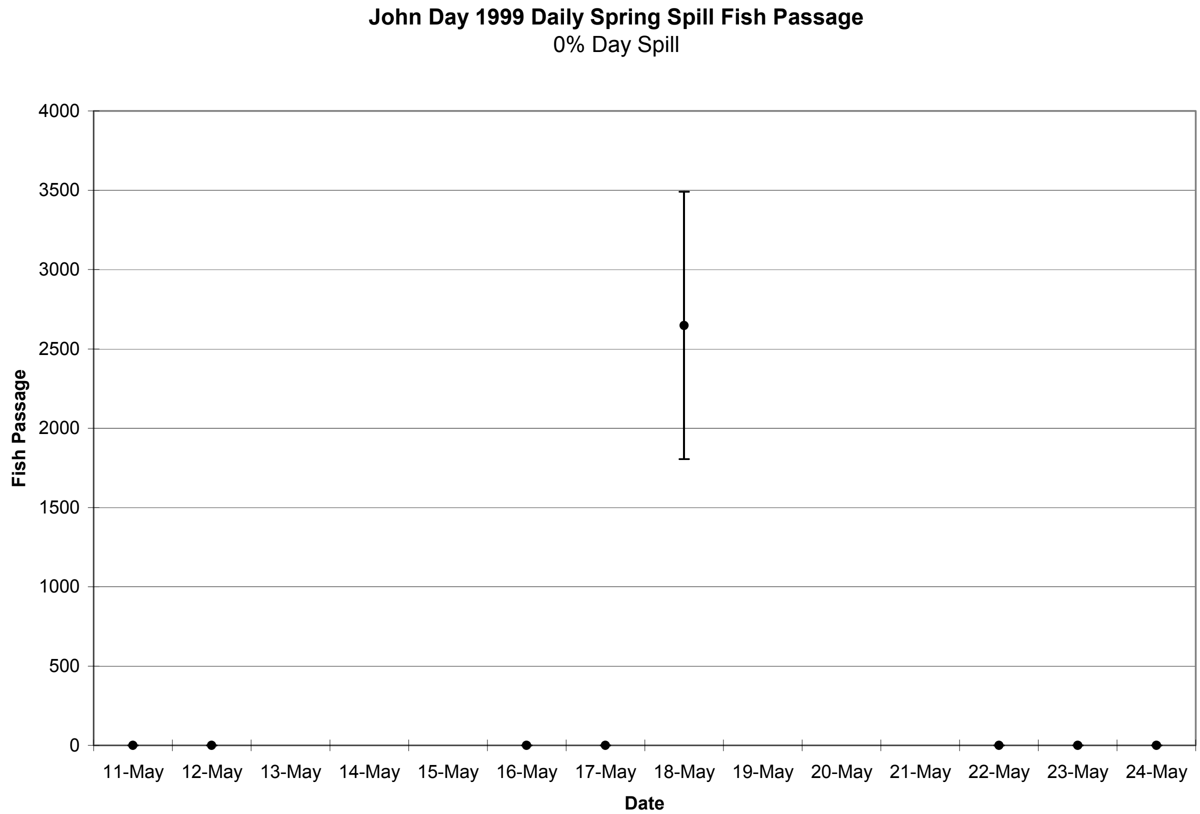


Figure 41. Estimated daytime (0600-1859h) spillway fish passage for selected 8 day spring data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

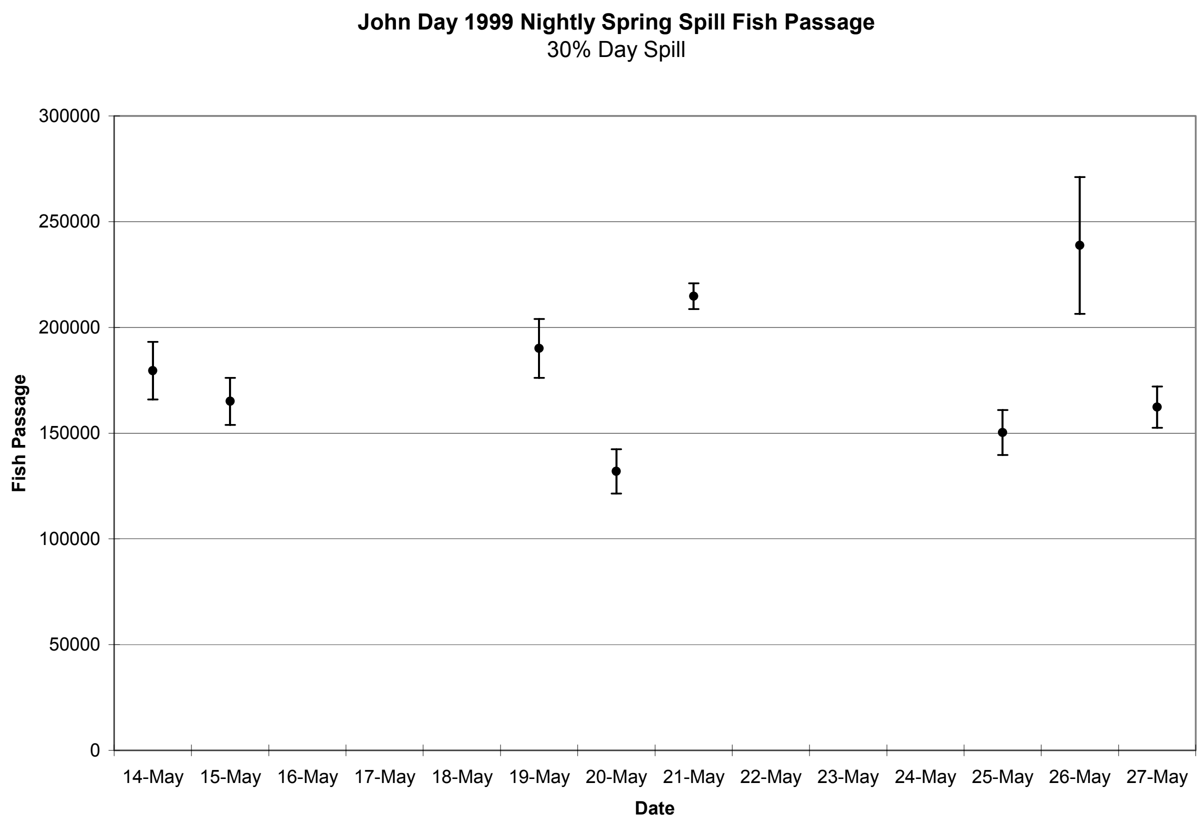


Figure 42. Estimated nighttime (1900-0559h) spillway fish passage for selected 8 day spring data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

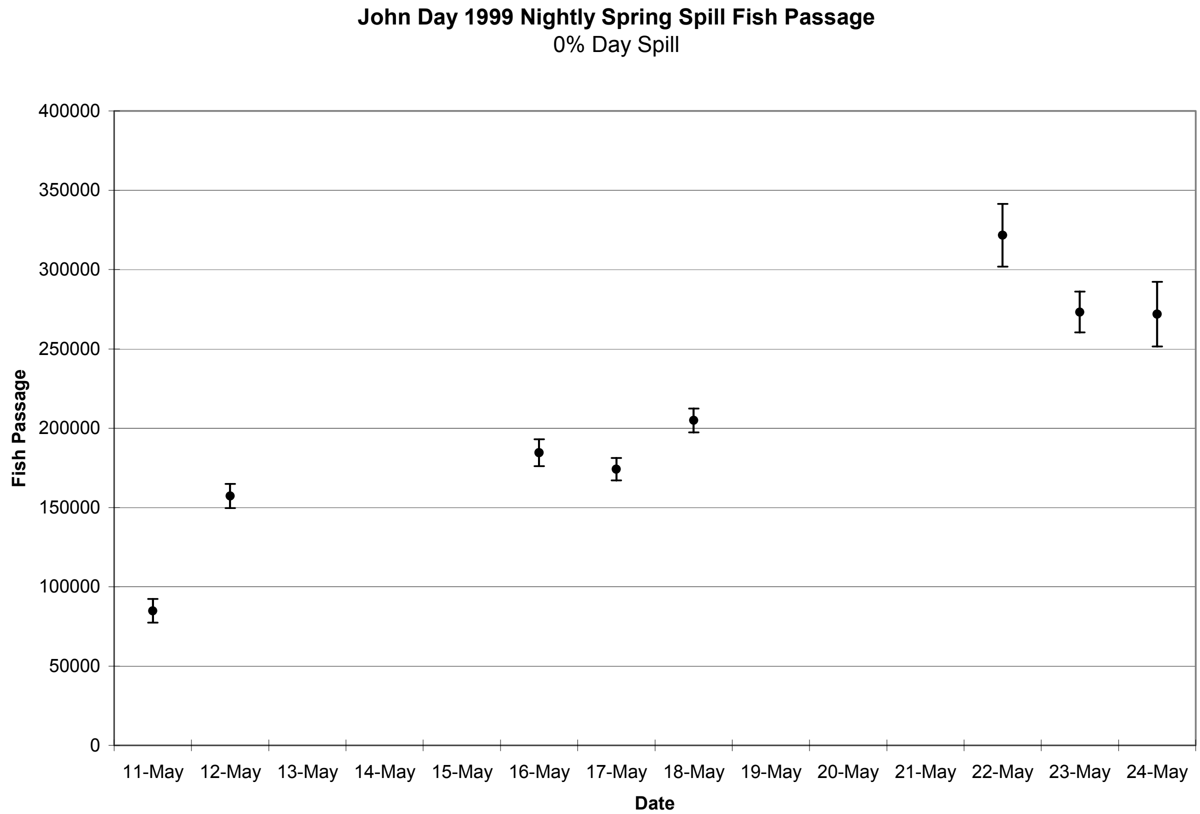


Figure 43. Estimated nighttime (1900-0559h) spillway fish passage for selected 8 day spring data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

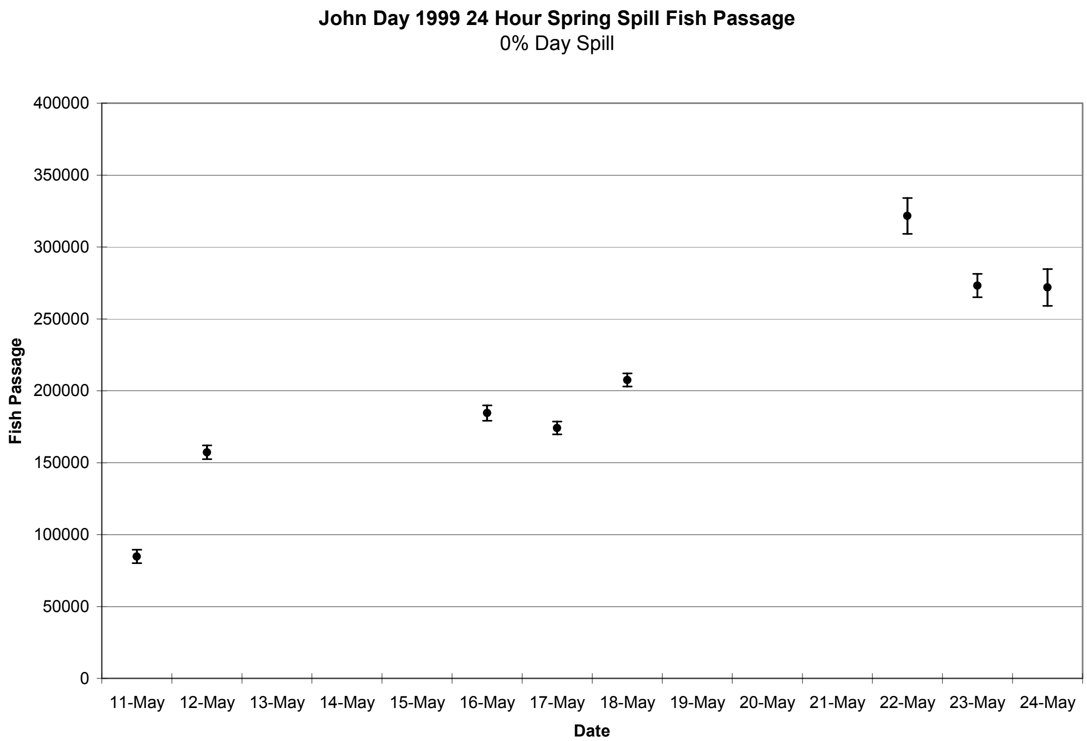


Figure 44. Estimated 24 hour spillway fish passage for selected 8 day spring data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

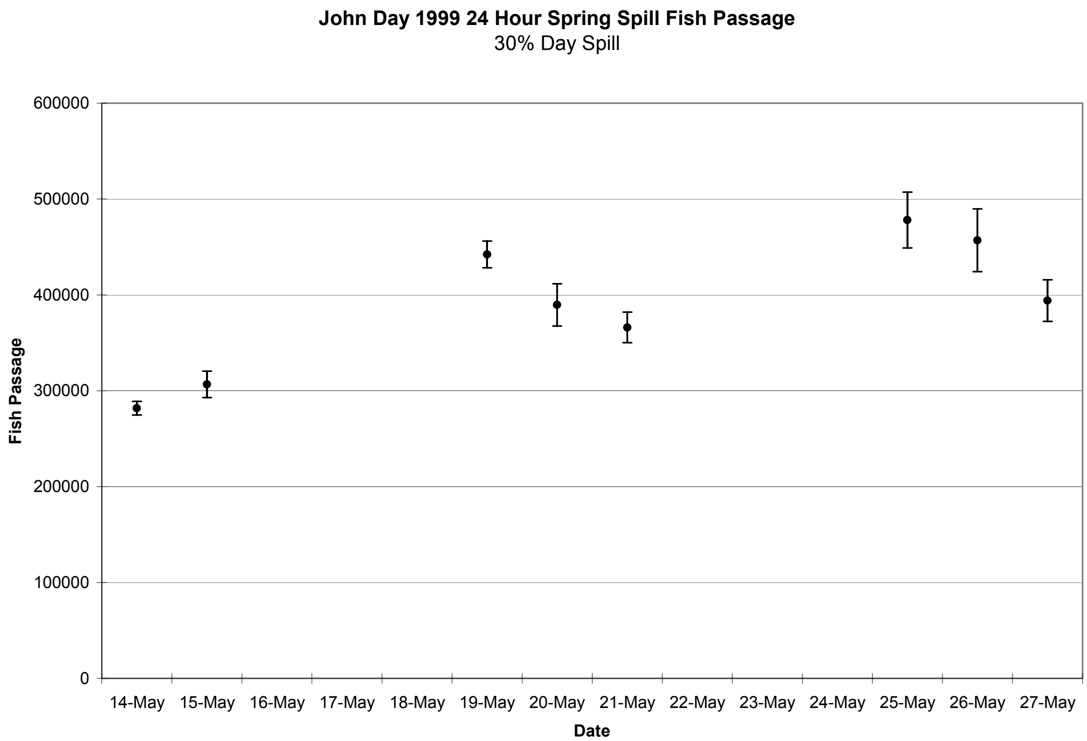


Figure 45. Estimated 24 hour spillway fish passage for selected 8 day spring data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

4.6.3 Summer Powerhouse Fish Passage

Table 20 presents total estimated day, night and 24-h fish passage by outmigration route (powerhouse or spillway) by grouped daytime spill condition for the summer monitoring period. Only the 24-h days that met percent daytime spill targets of the study design (0% or 30%) were included in the analyses. Corresponding powerhouse fish passage data on a daily basis, for those days meeting daytime spill criteria, are shown in Table 21 for the summer monitoring period. Surrounding confidence intervals at a 95% level of assurance are given for each estimate. Hourly passage estimates, flow and sample variance for the entire 33-d summer sampling block are presented by monitored location in Appendix B.

Powerhouse fish passage estimates on a seasonal and daily basis with surrounding 95% confidence intervals are graphically presented in Figures 46-51. The statistical procedures used to calculate the variances and confidence intervals surrounding all fish passage estimates are described in Appendix C.

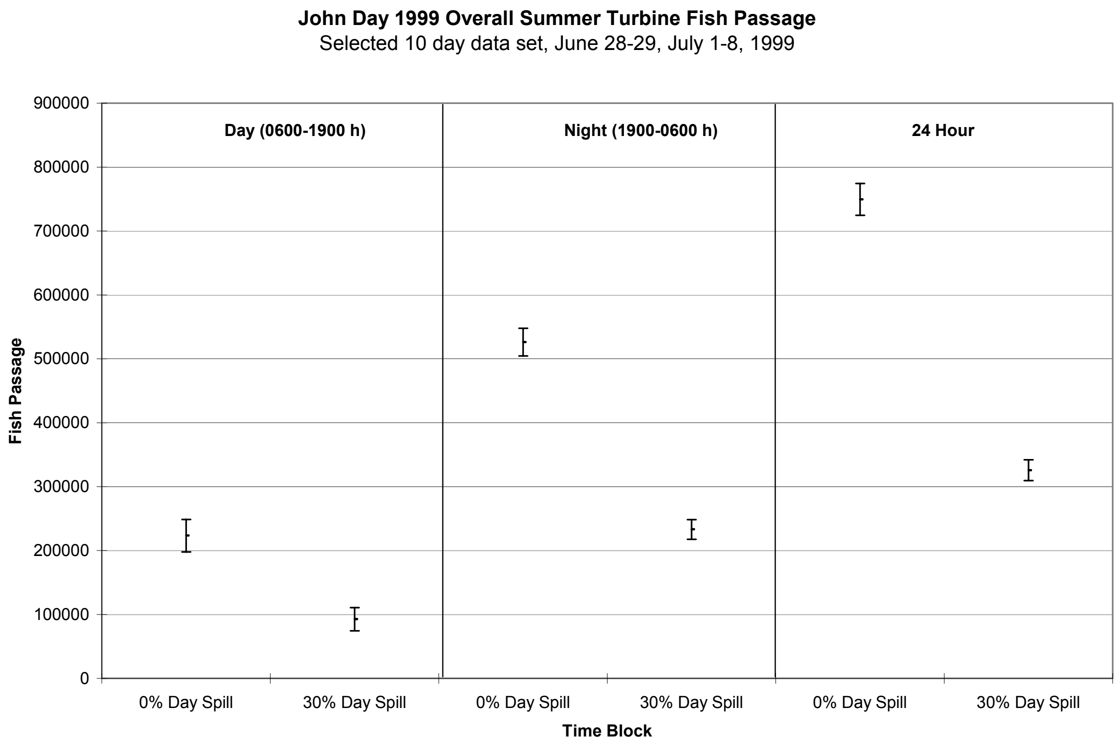


Figure 46. Estimated daytime (0600-1859h) powerhouse fish passage for selected 5 day summer data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

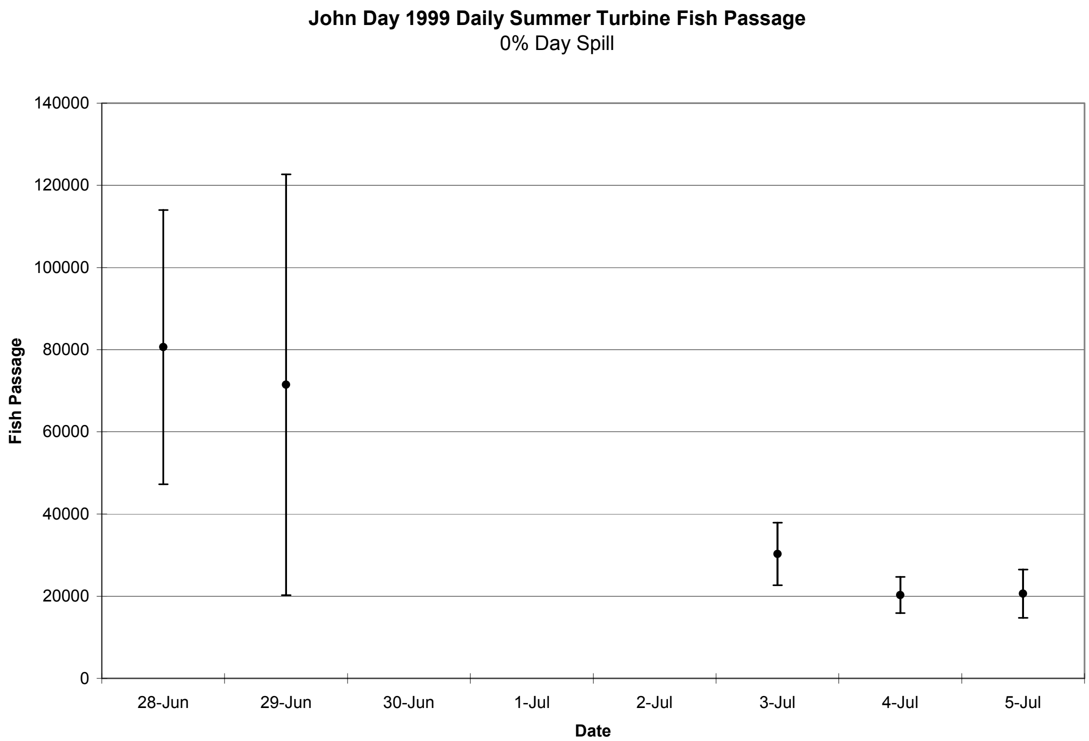


Figure 47. Estimated daytime (0600-1859h) powerhouse fish passage for selected 5 day summer data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

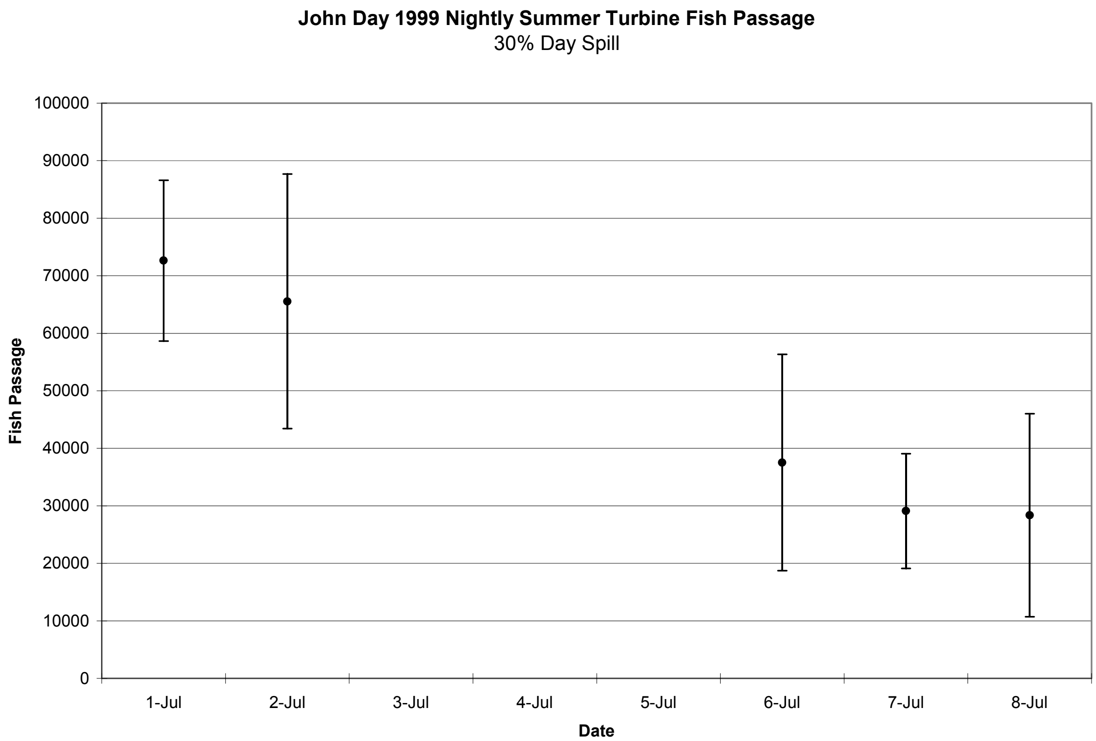


Figure 48. Estimated nighttime (1900-0559h) powerhouse fish passage for selected 5 day summer data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

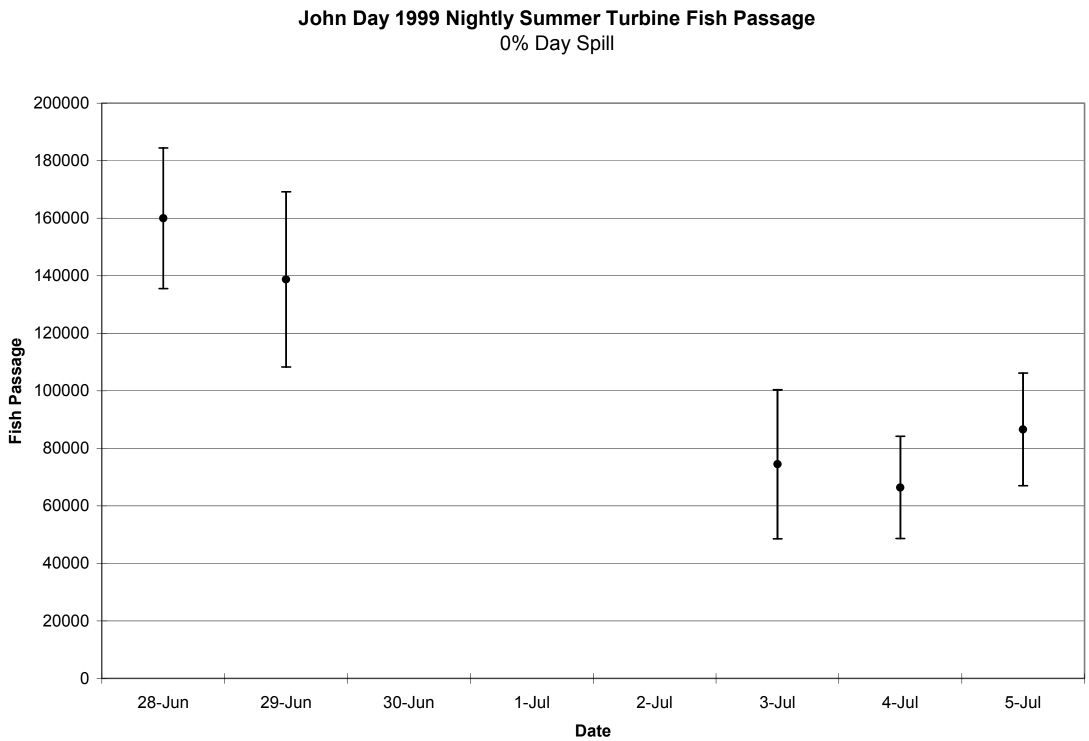


Figure 49. Estimated nighttime (1900-0559h) powerhouse fish passage for selected 5 day summer data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

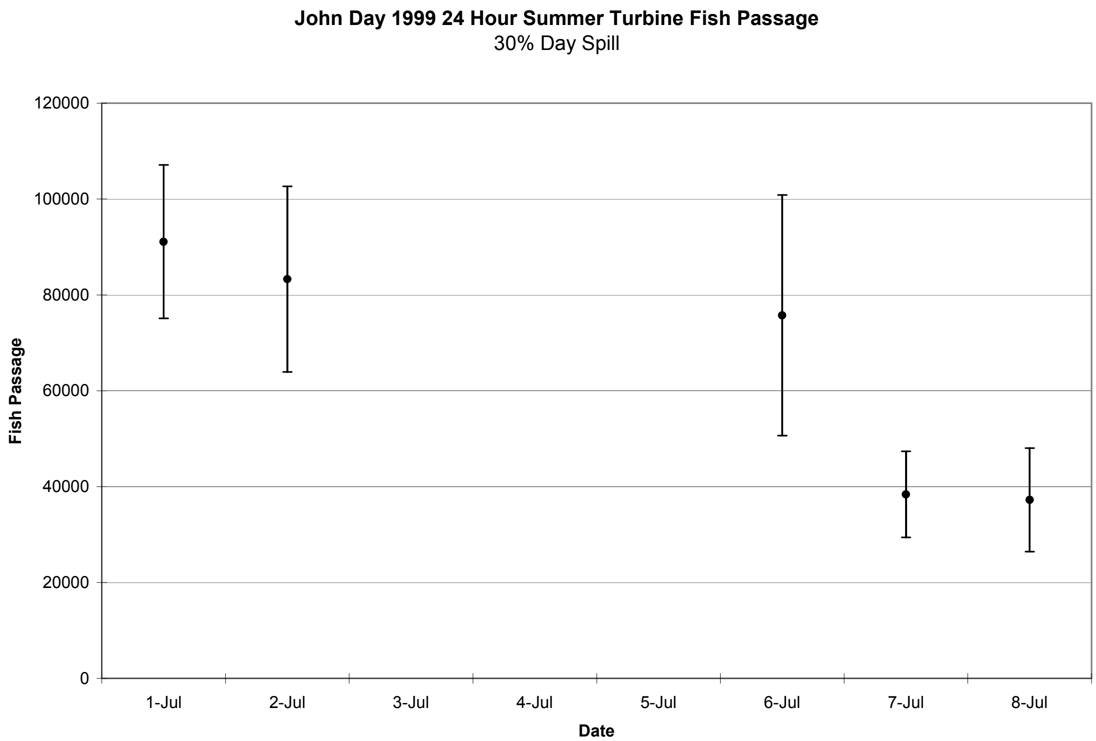


Figure 50. Estimated 24 hour powerhouse fish passage for selected 5 day summer data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

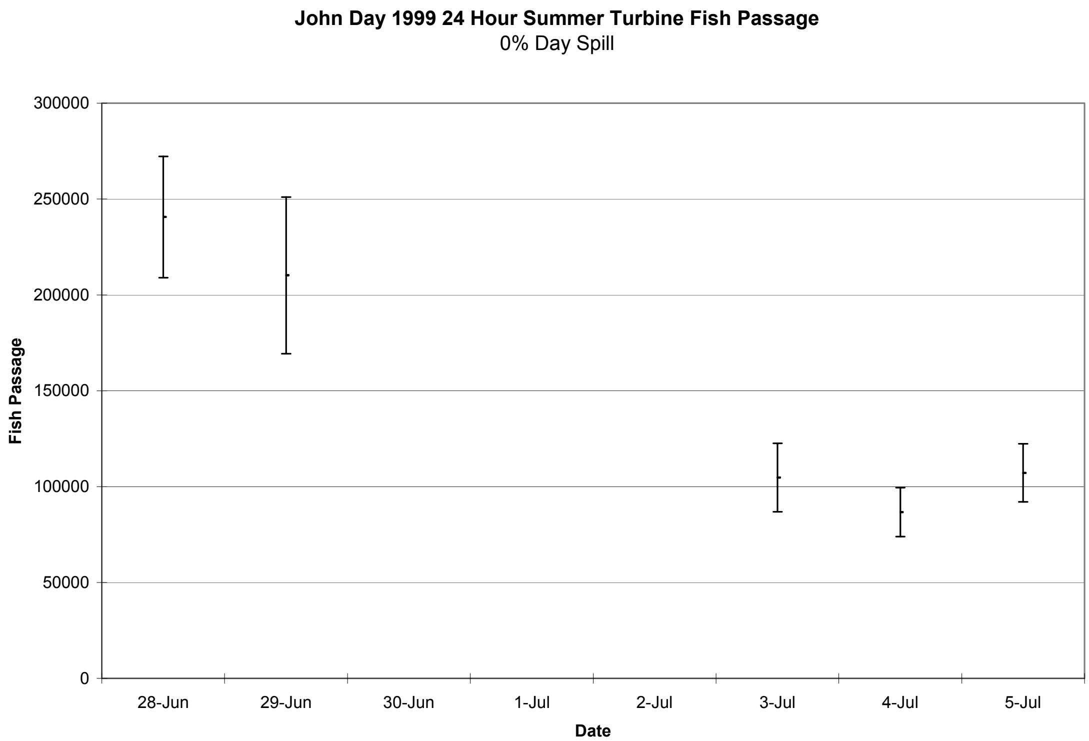


Figure 51. Estimated 24 hour powerhouse fish passage for selected 5 day summer data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

4.6.4 Summer Spillway Fish Passage

Table 20 presents total estimated day, night and 24-h fish passage by outmigration route (powerhouse or spillway) by grouped daytime spill condition for the summer monitoring period. Only the 24-h days that met percent daytime spill targets of the study design (0% or 30%) were included in the analysis. Corresponding spillway fish passage data on a daily basis, for those days meeting daytime spill criteria, are shown in Table 21 for the spring monitoring period. Surrounding confidence intervals at a 95% level of assurance are given for each estimate. Hourly passage estimates, flow and sample variance for the entire 33-d summer sampling block are presented by monitored location in Appendix B.

Spillway fish passage estimates on a seasonal and daily basis with surrounding 95% confidence intervals are graphically presented in Figures 52-58. The statistical procedures used to calculate the variances and confidence intervals surrounding all fish passage estimates are described in Appendix C.

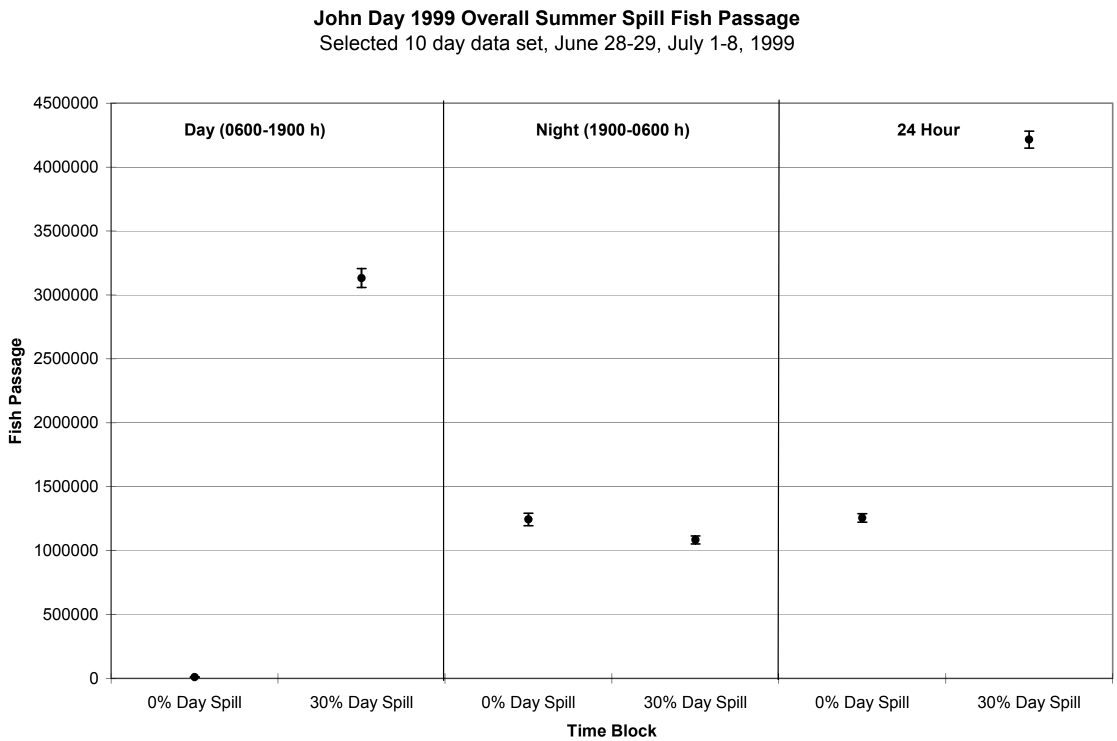


Figure 52. Estimated day, night and 24 hour spillway fish passage for selected 10 day summer data set (0% and 30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

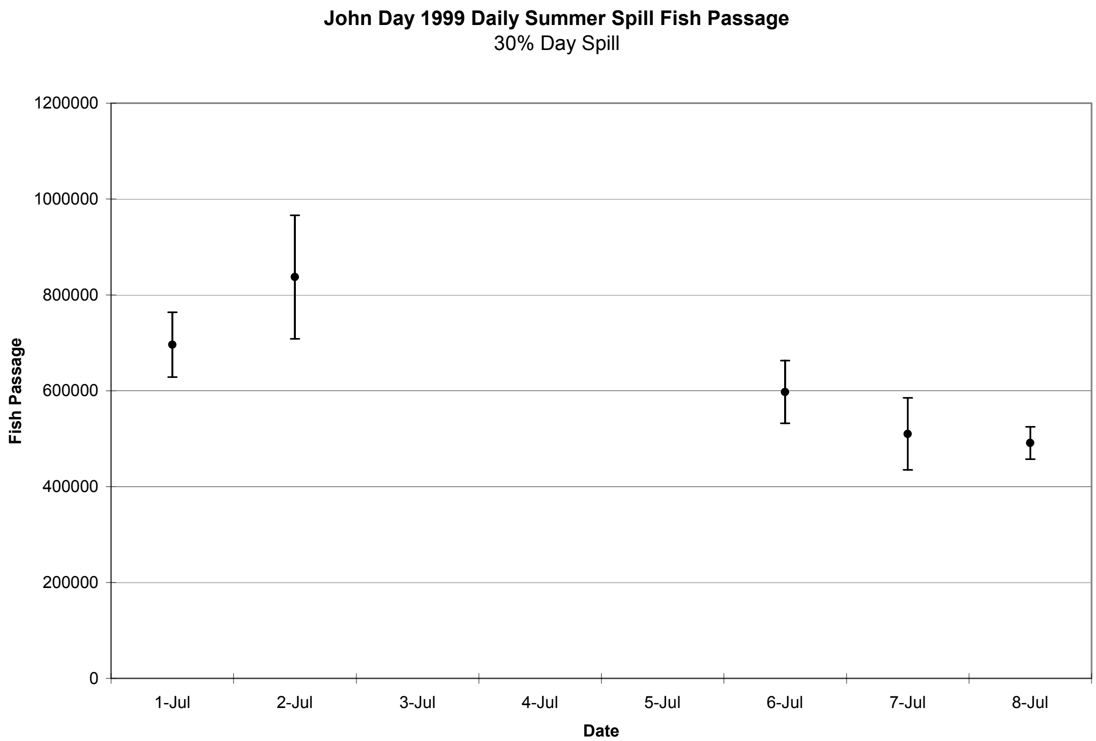


Figure 53. Estimated daytime (0600-1859h) spillway fish passage for selected 5 day summer data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

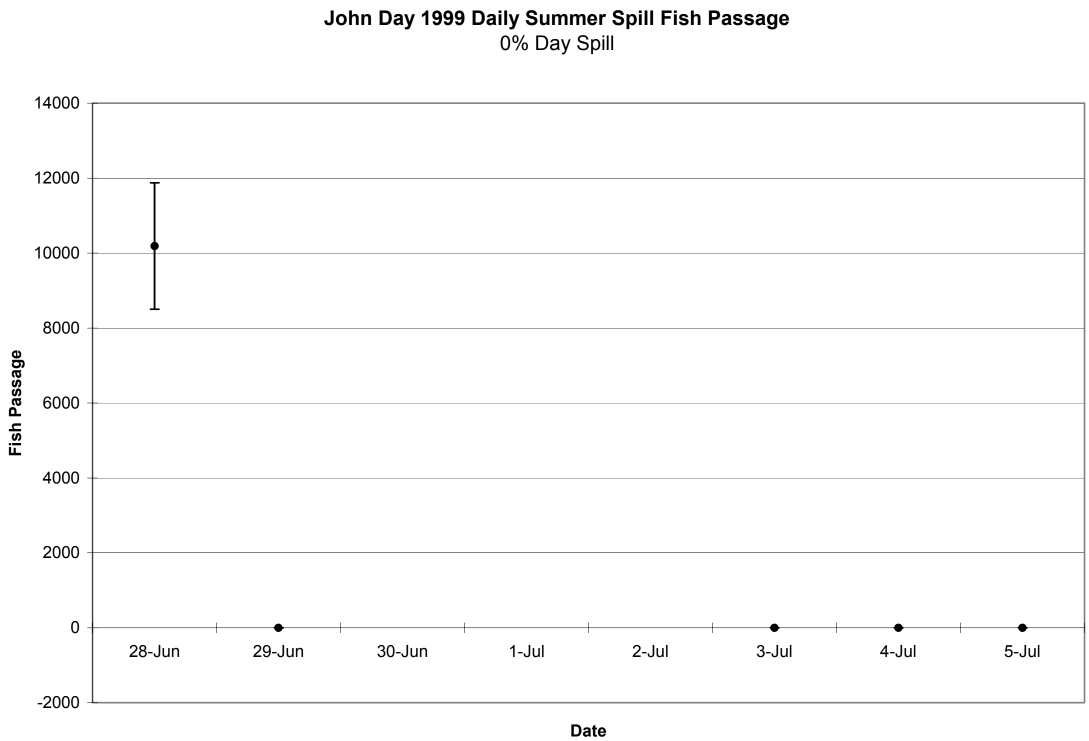


Figure 54. Estimated daytime (0600-1859h) spillway fish passage for selected 5 day summer data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

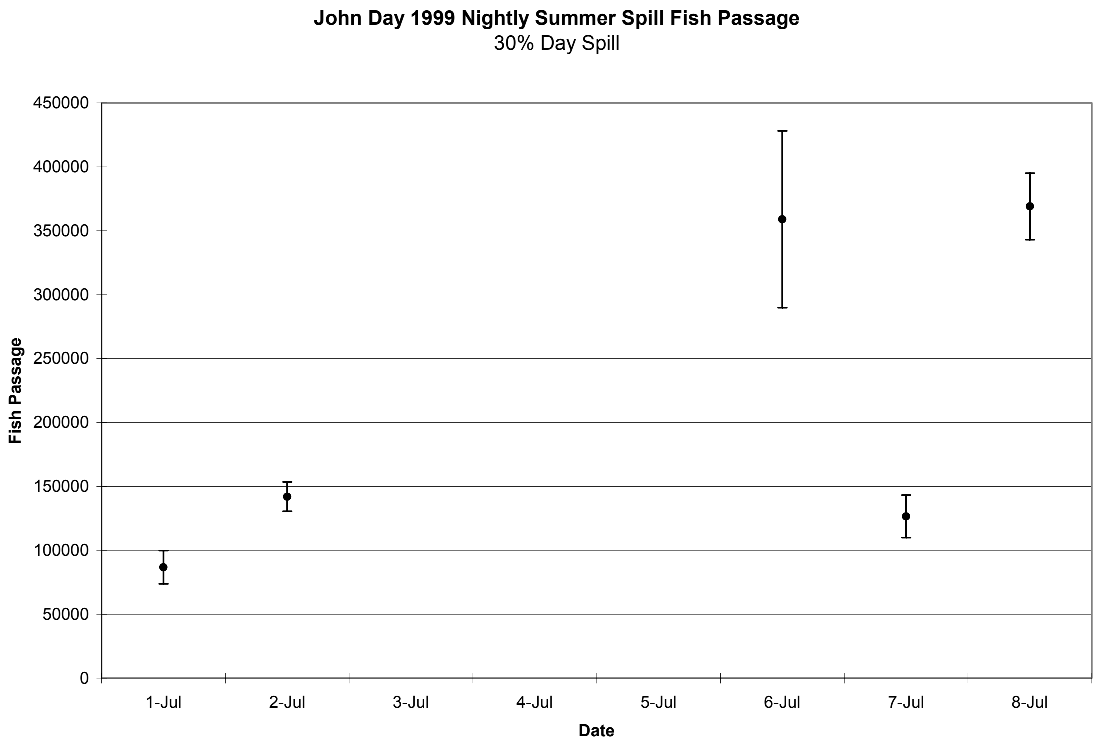


Figure 55. Estimated nighttime (1900-0559h) spillway fish passage for selected 5 day summer data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

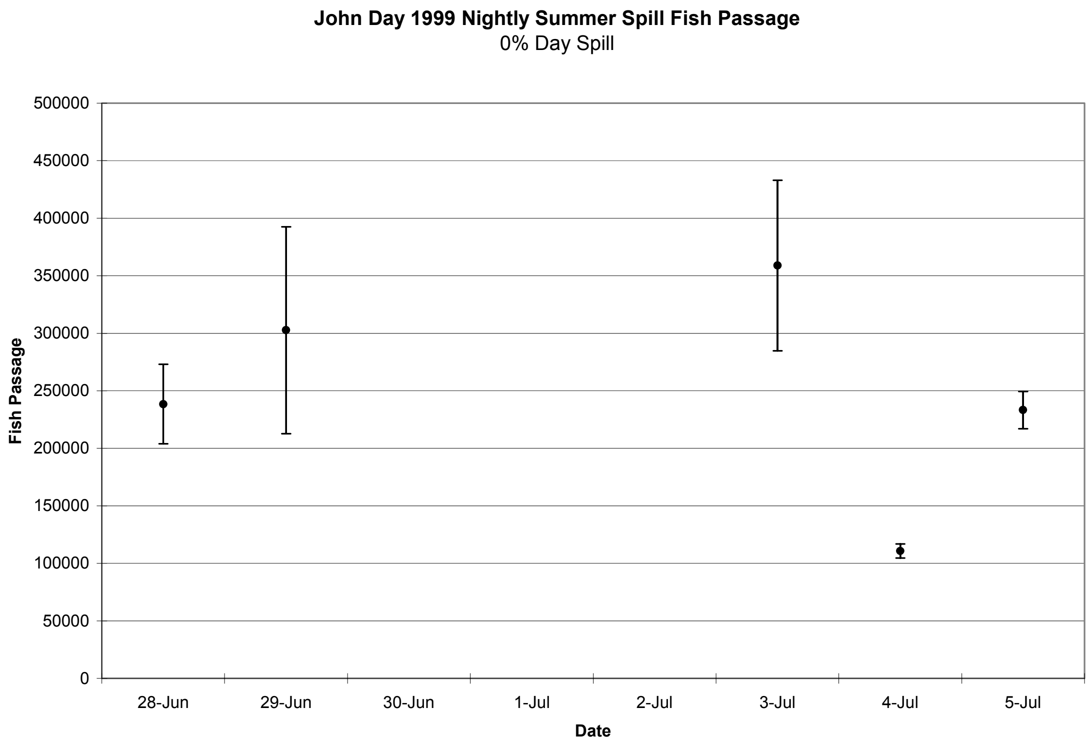


Figure 56. Estimated nighttime (1900-0559h) spillway fish passage for selected 5 day summer data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

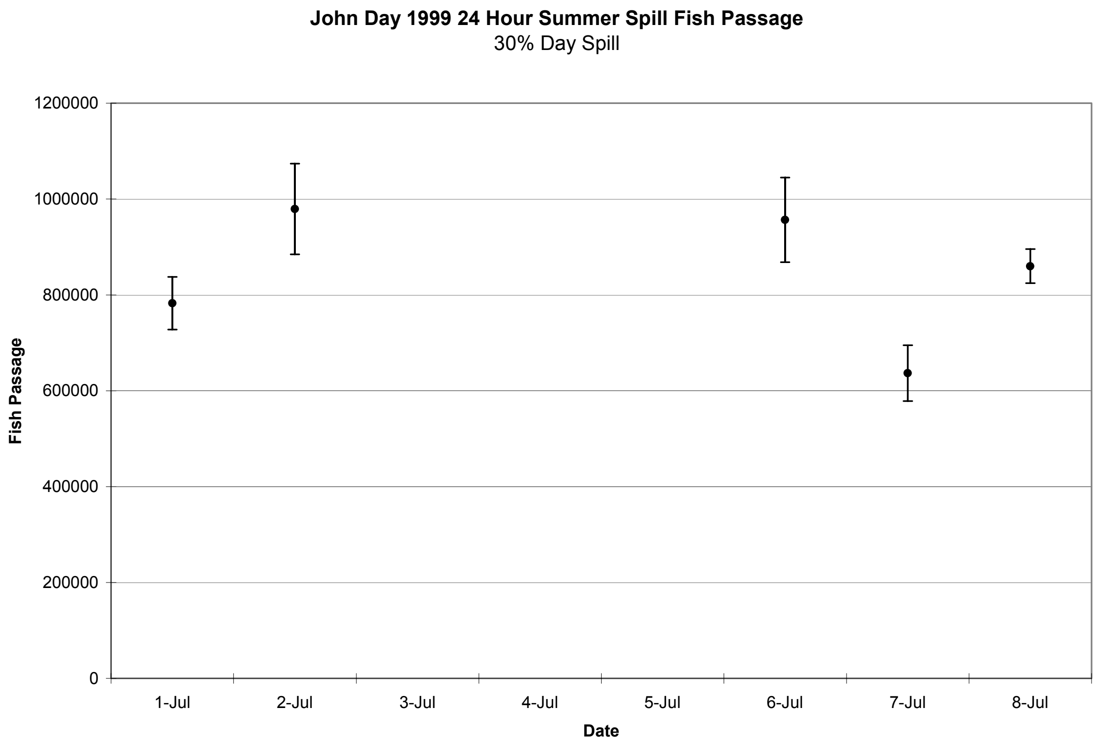


Figure 57. Estimated 24 hour spillway fish passage for selected 5 day summer data set (30% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

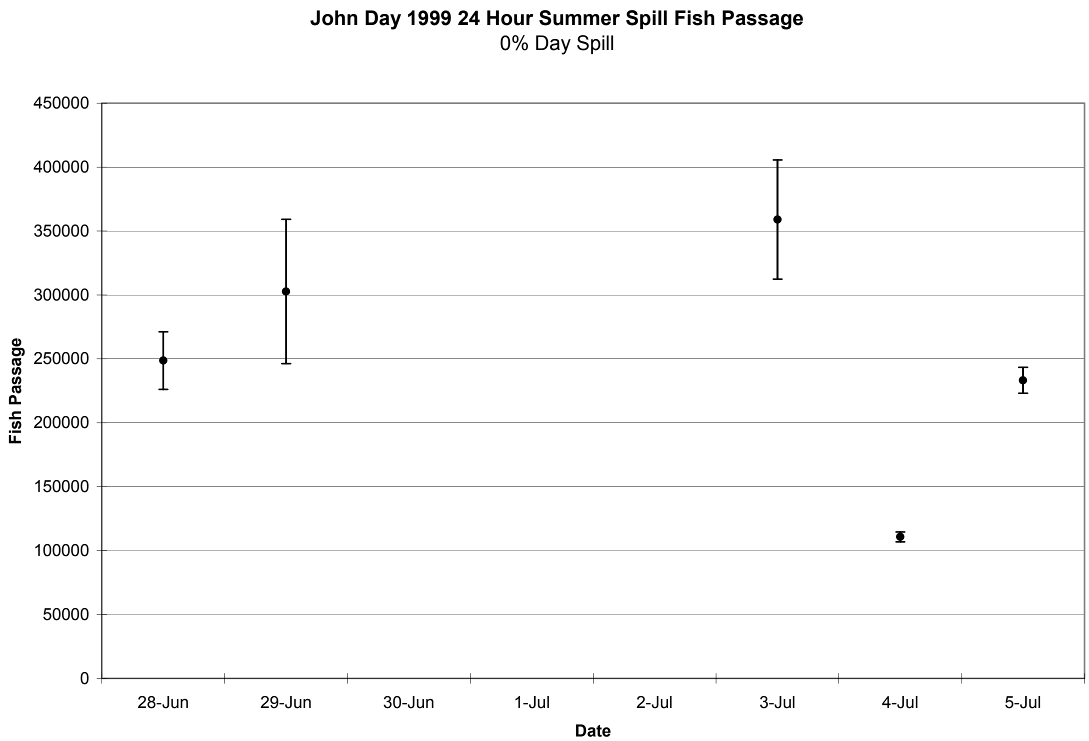


Figure 58. Estimated 24 hour spillway fish passage for selected 5 day summer data set (0% scheduled daytime spill) with surrounding 95% confidence intervals. John Day Dam, 1999.

4.7 Horizontal Distribution of Project Fish Passage

4.7.1 Daytime Spillway Horizontal Distributions

Daytime (0600–1859 h) spillway mean horizontal distributions of fish passage for the spring monitoring period are presented by mean daytime spill level (30% or 0%) in Figures 59 and 61, respectively. The corresponding figures for the summer monitoring period are presented in Figures 60 and 62. Data are expressed as mean fish passage per location per hour of operation, to remove the effects of variable plant operations.

The data set for all horizontal distributions includes only the selected 24-h periods when actual daytime spill targets of 0% or 30% were met. A few hours of minor daytime spill were included in the 0% daytime spill data set to maximize sample size for statistical purposes. These data account for the low levels of daytime spillway fish passage observed in Figures 61 and 62.

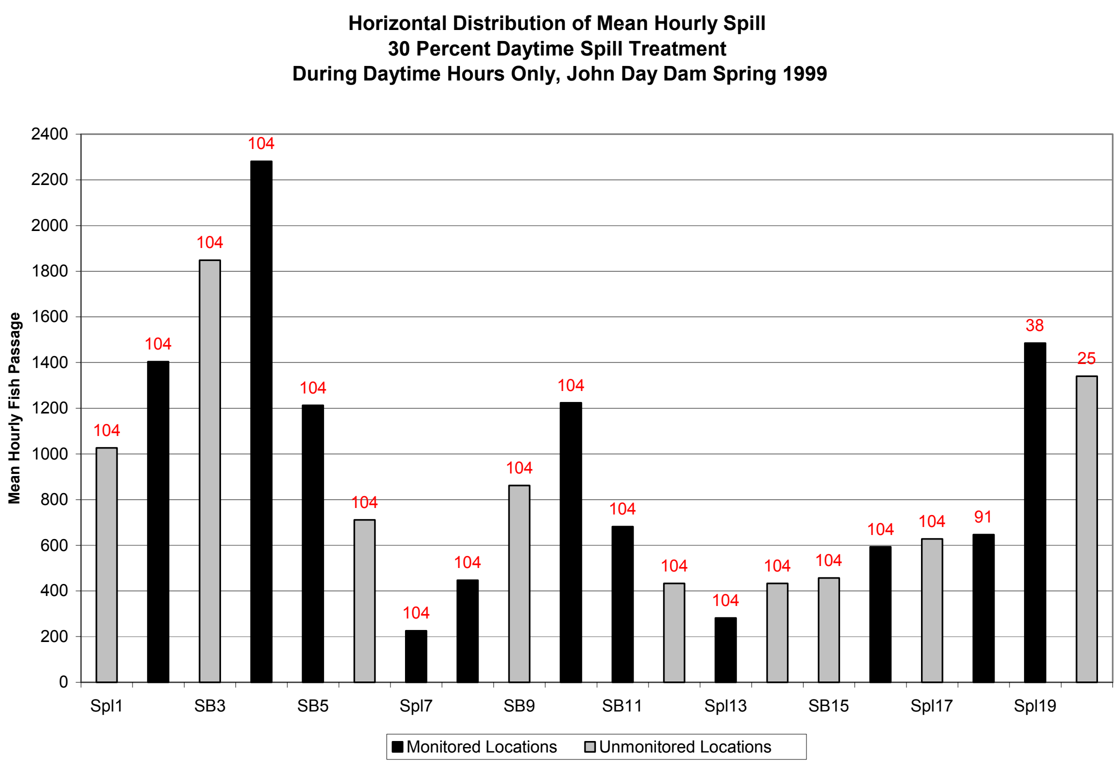


Figure 59. Horizontal distribution of spring spillway passage during daytime hours (0600-1859 h) for all periods with 30% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

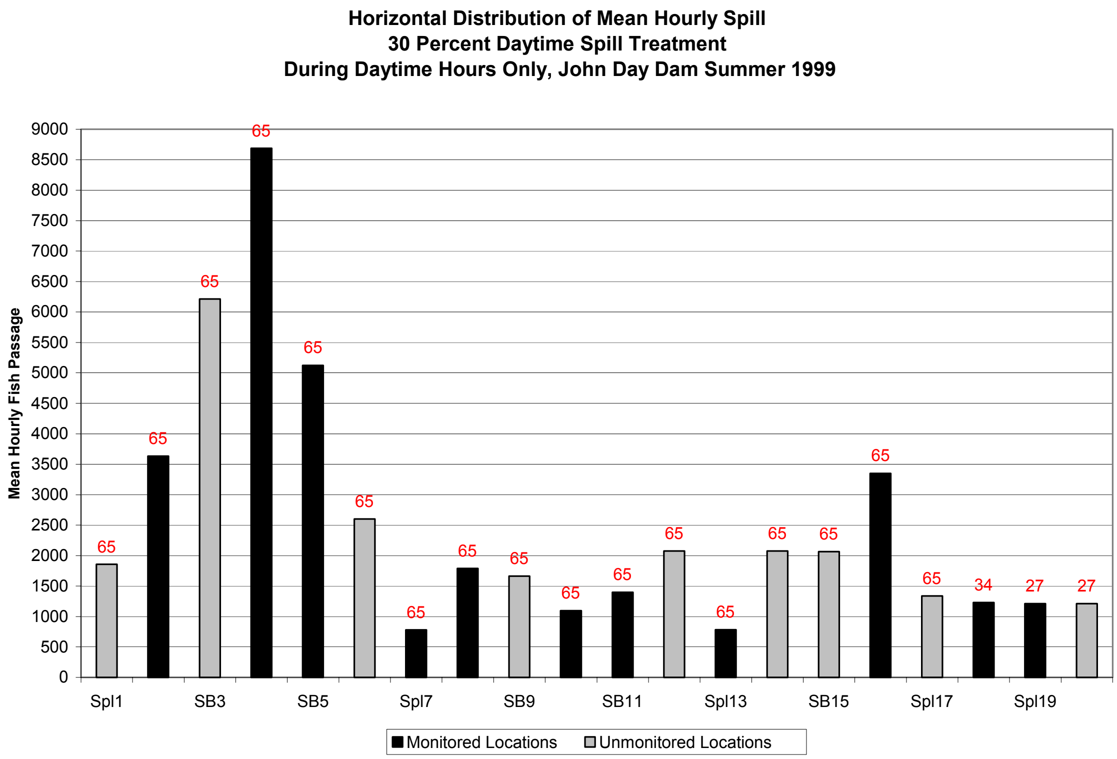


Figure 60. Horizontal distribution of summer spillway passage during daytime hours (0600-1859 h) for all periods with 30% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

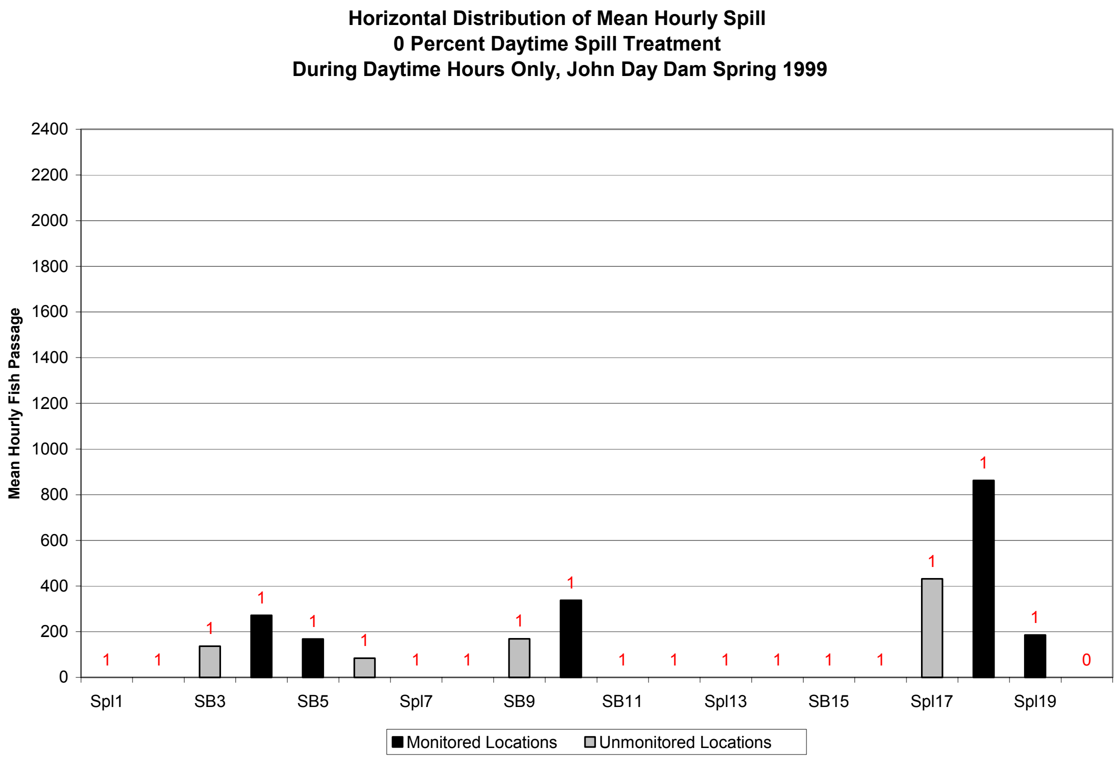


Figure 61. Horizontal distribution of spring spillway passage during daytime hours (0600-1859 h) for all periods with 0% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

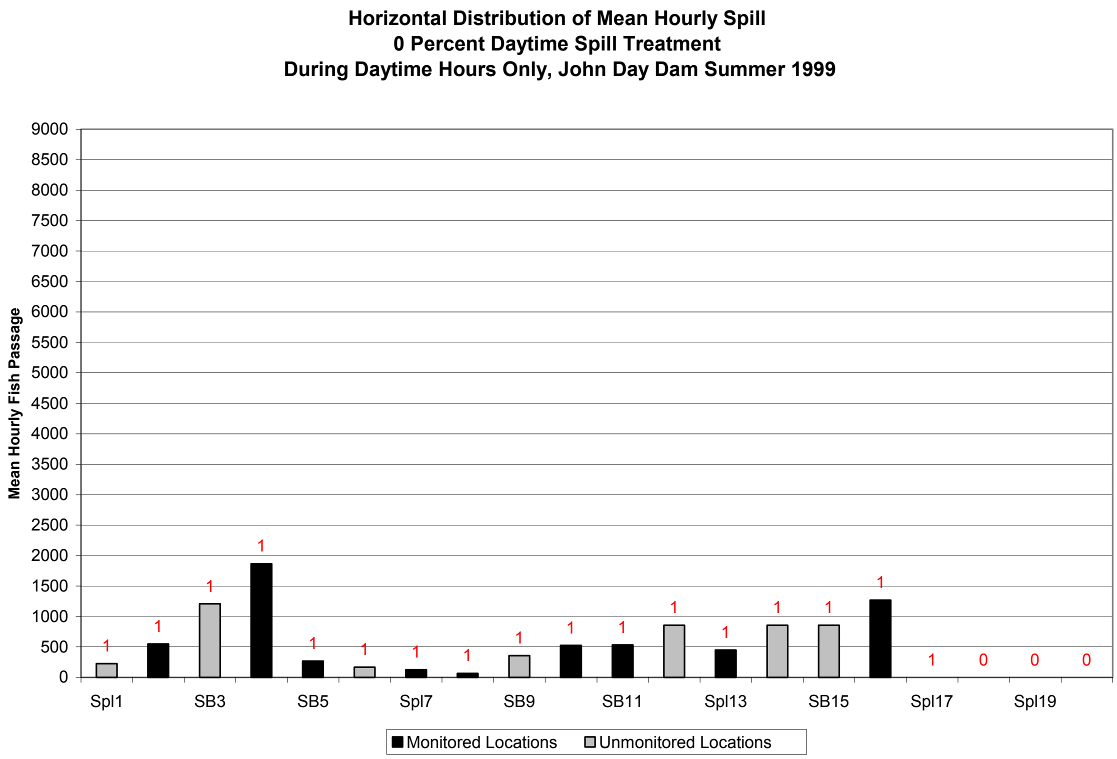


Figure 62. Horizontal distribution of summer spillway passage during daytime hours (0600-1859 h) for all periods with 0% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

4.7.2 Nighttime Spillway Horizontal Distributions

Nighttime (1900-0559 h) spillway mean horizontal distributions of fish passage for the spring monitoring period are presented by mean daytime spill level (30% or 0%) in Figures 63 and 65, respectively. The corresponding figures for the summer monitoring period are presented in Figures 64 and 66. Data are expressed as mean fish passage per location per hour of operation, to remove the effects of variable plant operations.

The data set for all horizontal distributions includes only the selected 24-h periods when actual daytime spill targets of 0% or 30% were met. As discussed previously, a few hours of daytime spill were included in the 0% daytime spill data set to maximize sample size for statistical purposes, but overall fish passage during this period was relatively negligible.

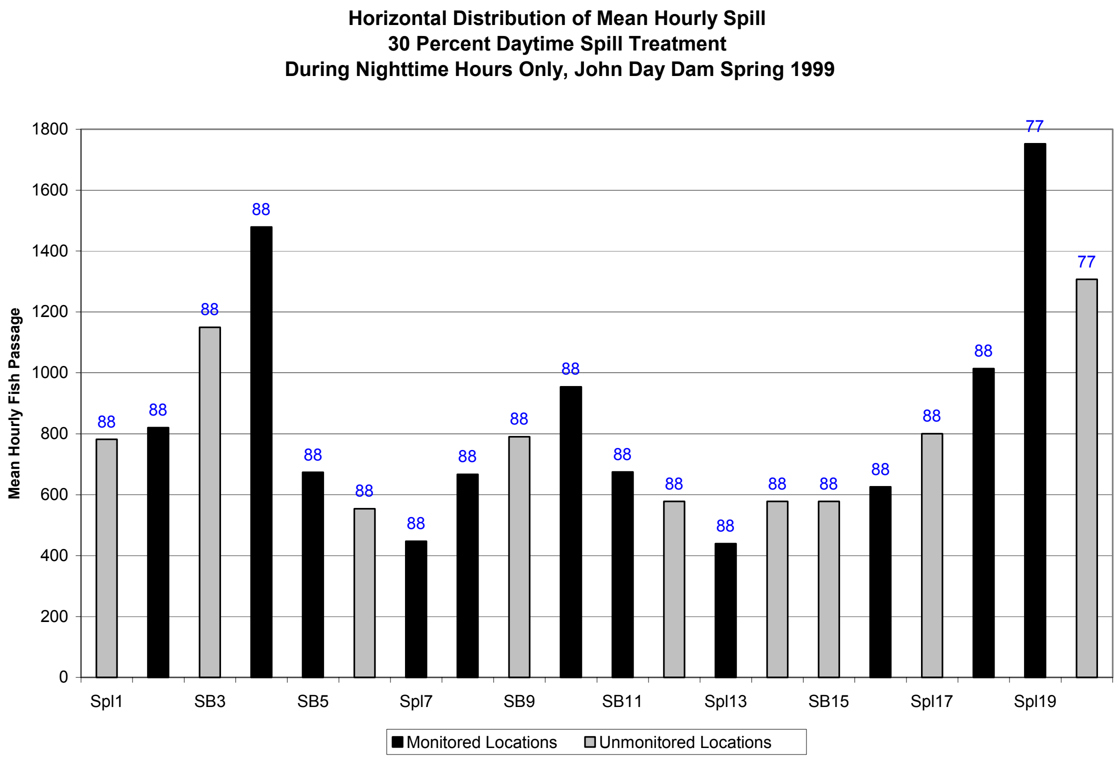


Figure 63. Horizontal distribution of spring spillway passage during nighttime hours (1900-0559 h) for all periods with 30% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

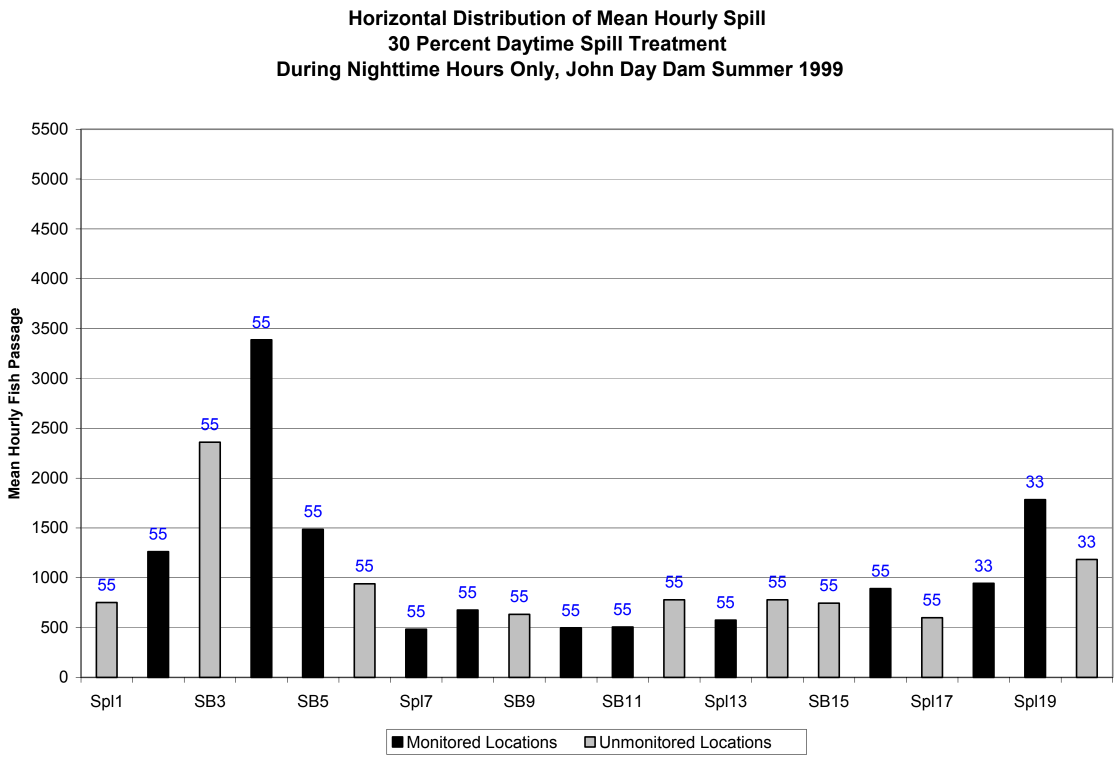


Figure 64. Horizontal distribution of summer spillway passage during nighttime hours (1900-0559 h) for all periods with 30% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

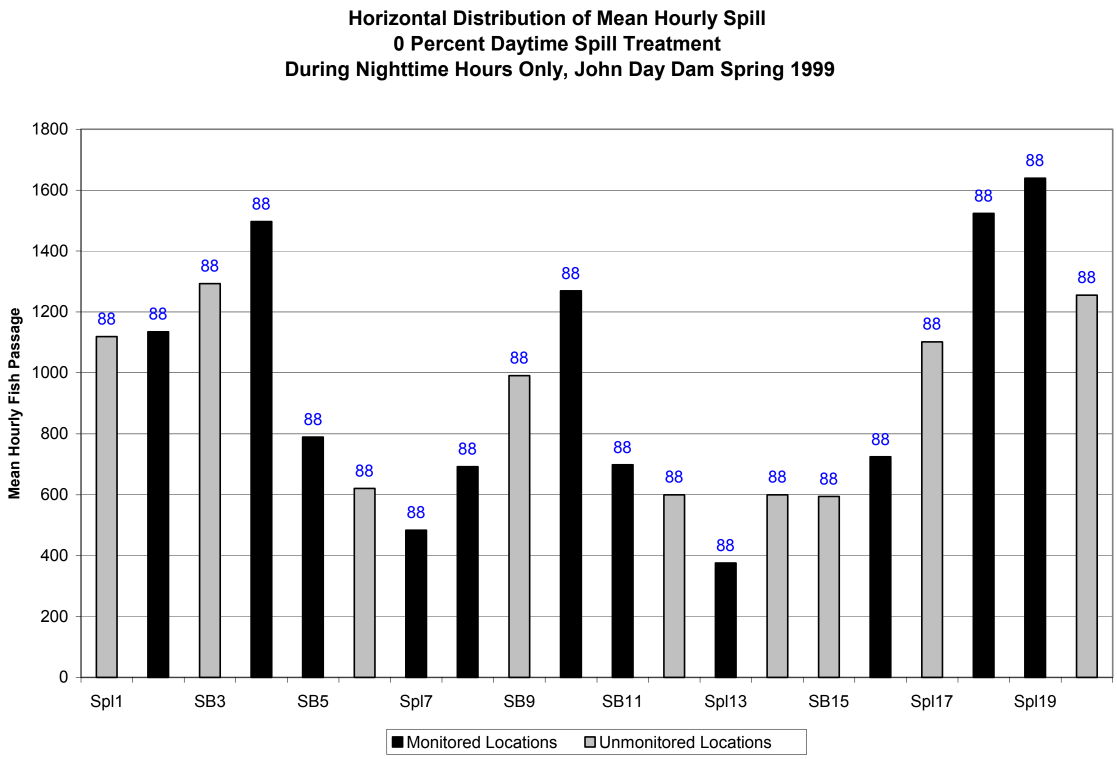


Figure 65. Horizontal distribution of spring spillway passage during nighttime hours (1900-0559 h) for all periods with 0% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

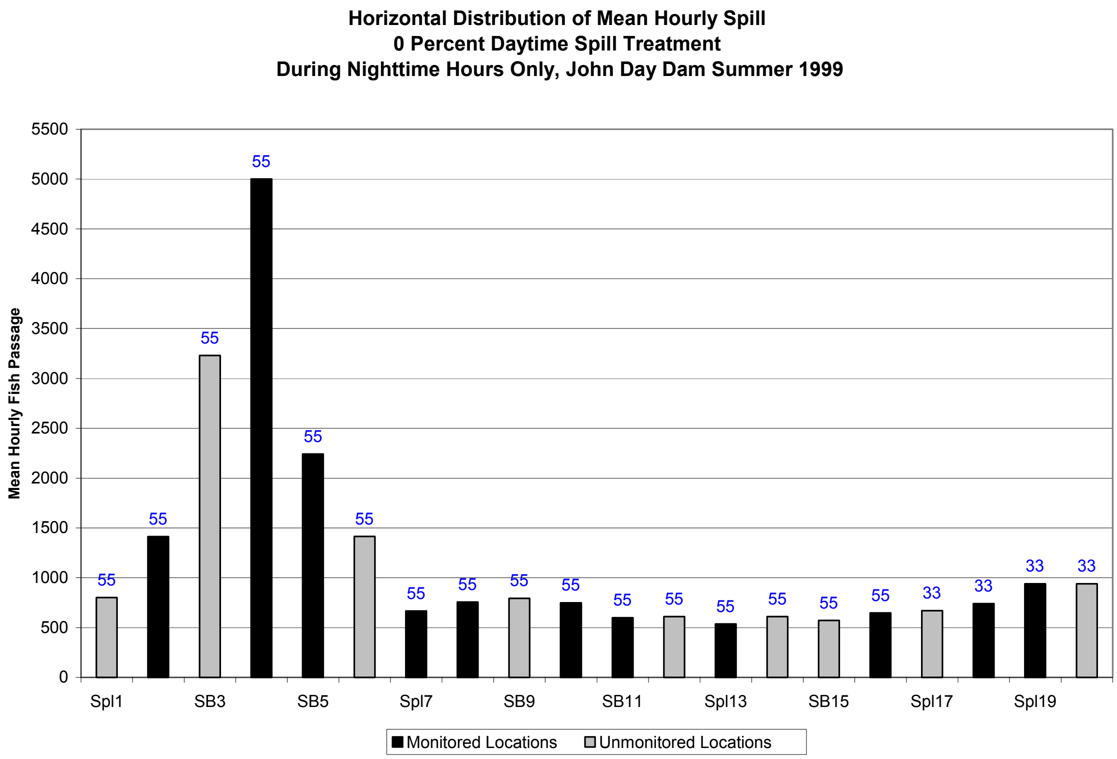


Figure 66. Horizontal distribution of summer spillway passage, during nighttime hours (1900-0559 h) for all periods with 0% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

4.7.3 24-h Spillway Horizontal Distributions

Spillway mean horizontal distributions of fish passage on a 24-h basis for the spring monitoring period are presented by mean daytime spill level (30% or 0%) in Figures 67 and 69, respectively. The corresponding figures for the summer monitoring period are presented in Figures 68 and 70. Data are expressed as mean fish passage per location per hour of operation, to remove the effects of variable plant operations.

The data set for all horizontal distributions includes only the selected 24-h periods when actual daytime spill targets of 0% or 30% were met. A few hours of daytime spill were included in the 0% daytime spill data set to maximize sample size for statistical purposes, but overall fish passage during this period was relatively negligible.

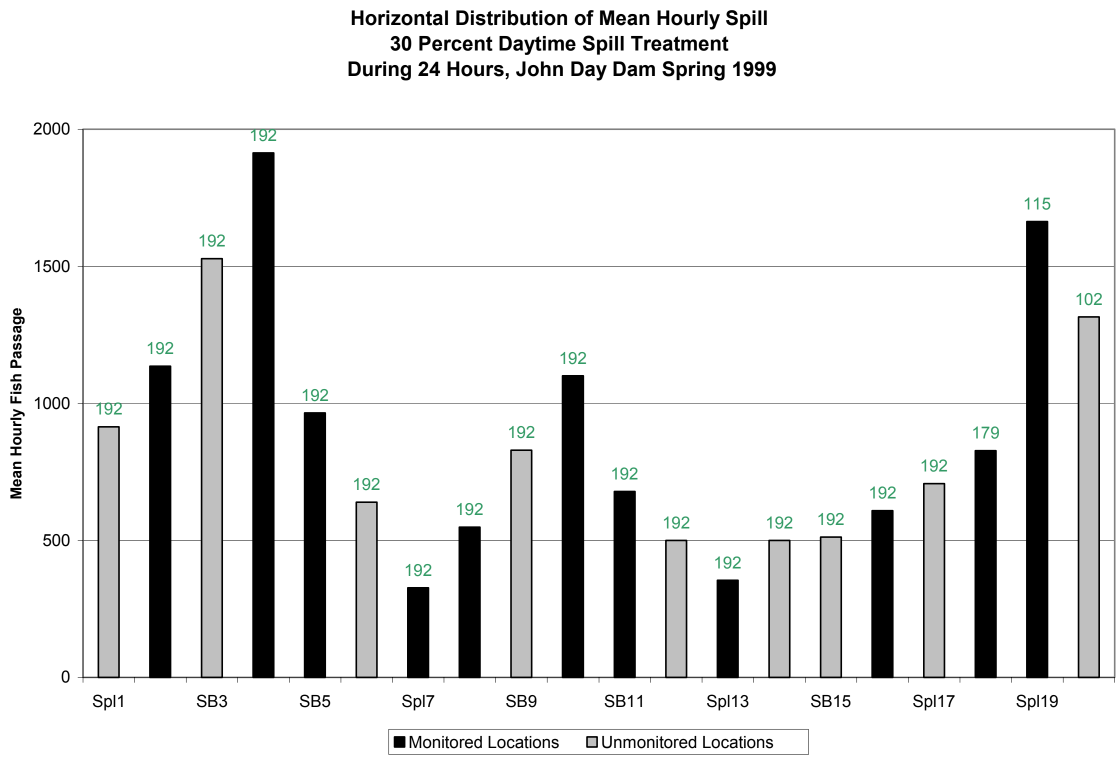


Figure 67. Horizontal distribution of spring spillway passage on a 24-h basis for all periods with 30% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

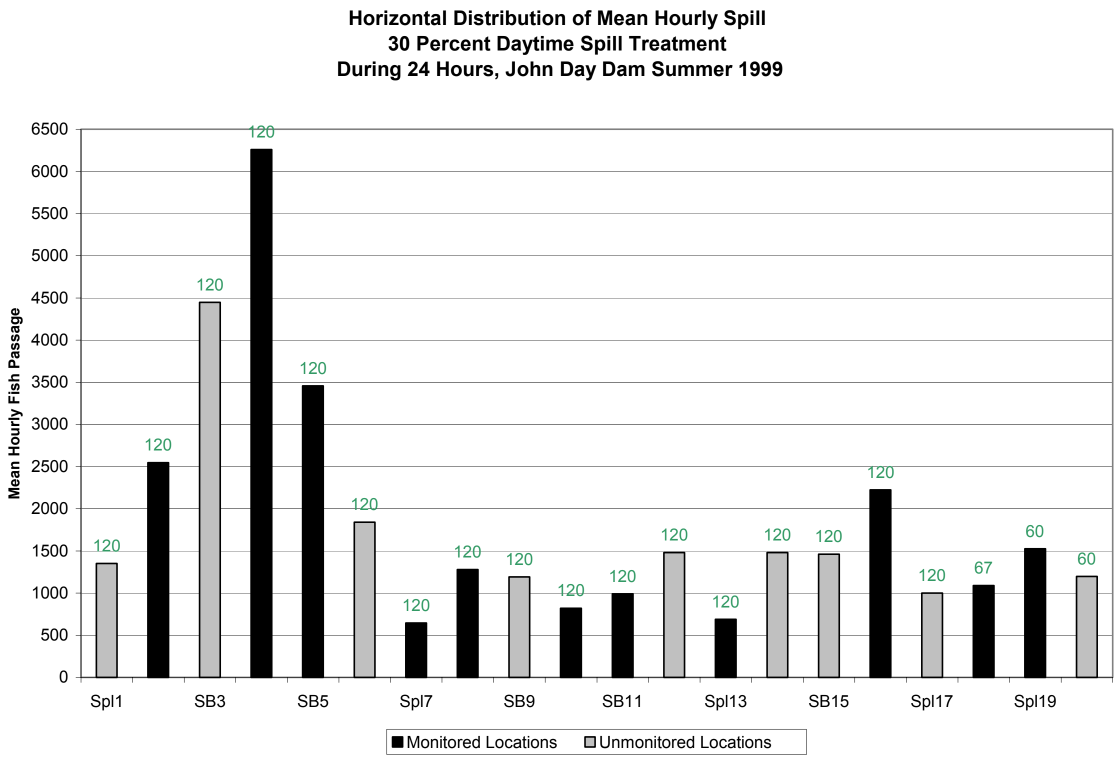


Figure 68. Horizontal distribution of summer spillway passage on a 24-h basis for all periods with 30% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

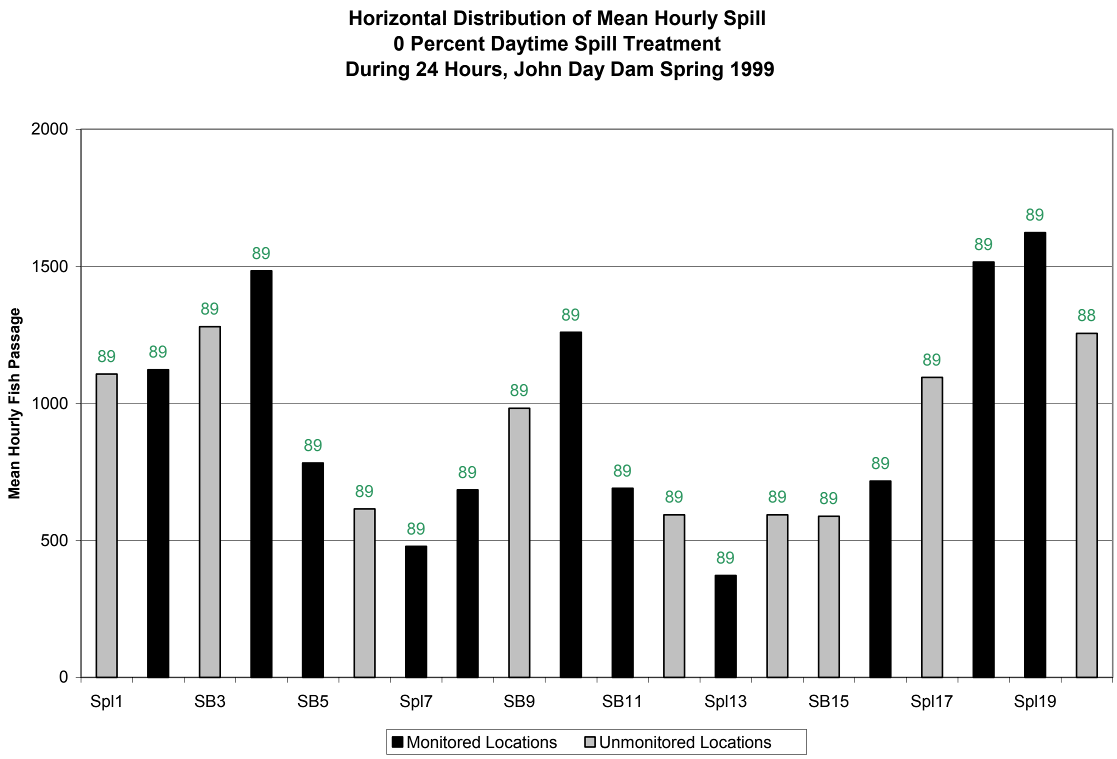


Figure 69. Horizontal distribution of spring spillway passage on a 24-h basis for all periods with 0% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

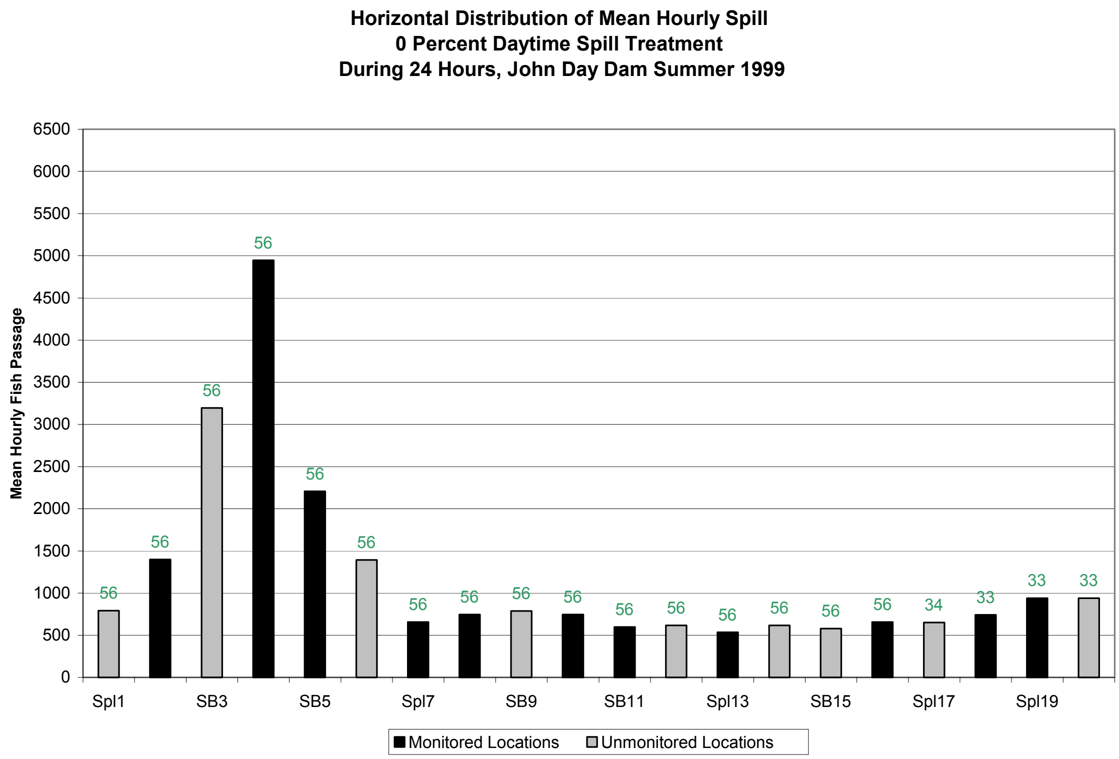


Figure 70. Horizontal distribution of summer spillway passage on a 24-h basis for all periods with 0% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

4.7.4 Daytime Powerhouse Horizontal Distributions

Daytime (0600-1859 h) powerhouse mean horizontal distributions of fish passage for the spring monitoring period are presented by mean daytime spill level (30% or 0%) in Figures 71 and 73, respectively. The corresponding figures for the summer monitoring period are presented in Figures 72 and 74. Data are expressed as mean fish passage per location per hour of operation, to remove the effects of variable plant operations.

The data set for all horizontal distributions includes only the selected 24-h periods when actual daytime spill targets of 0% or 30% were met. A few hours of daytime spill were included in the 0% daytime spill data set to maximize sample size for statistical purposes, but overall fish passage during this period was relatively negligible.

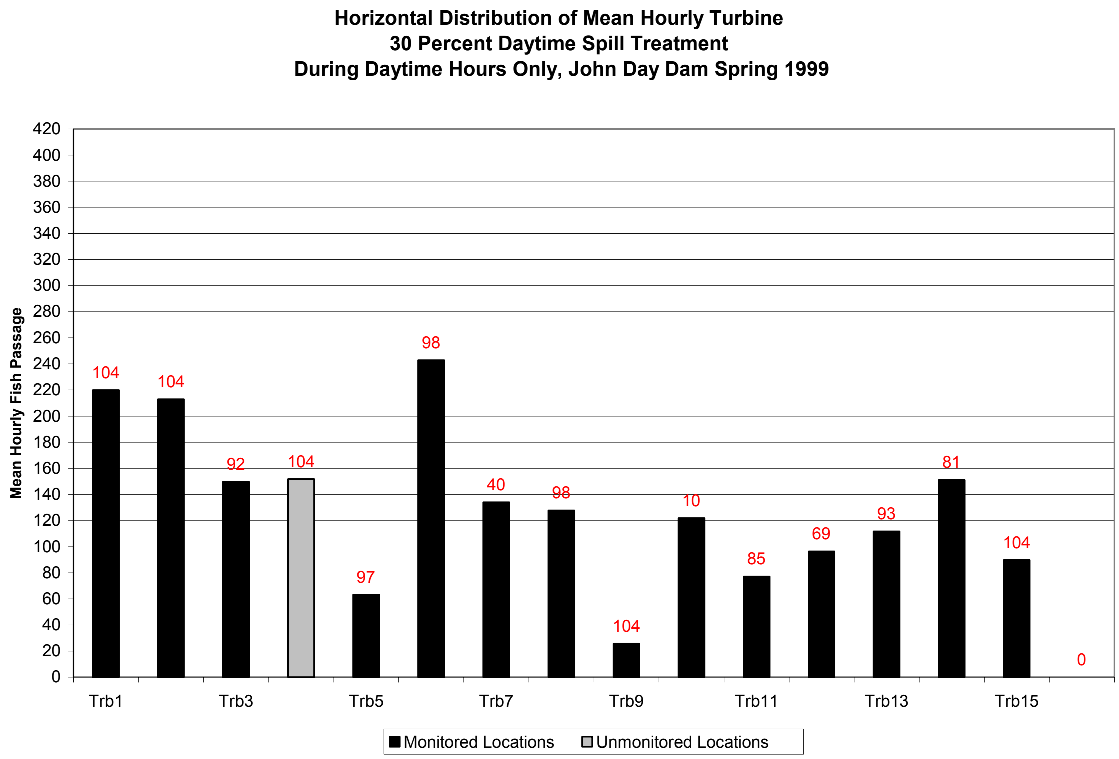


Figure 71. Horizontal distribution of spring powerhouse passage during daytime hours (0600-1859 h) for all periods with 30% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

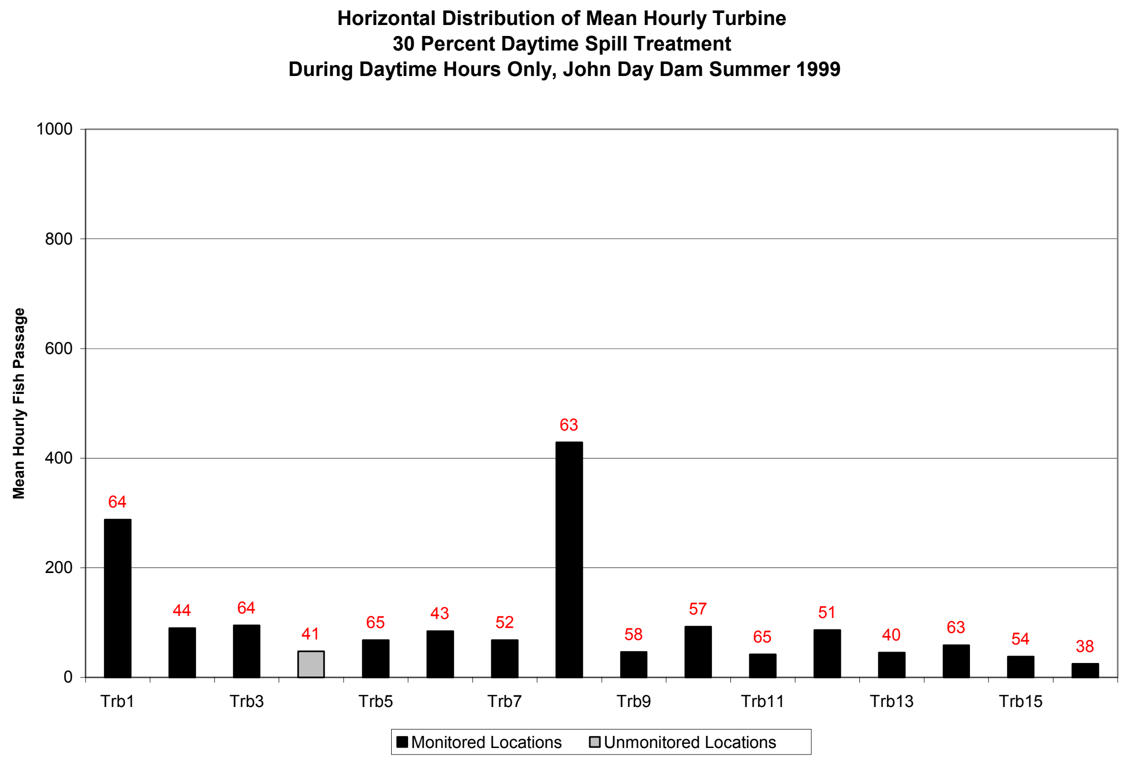


Figure 72. Horizontal distribution of summer powerhouse passage during daytime hours (0600-1859 h) for all periods with 30% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

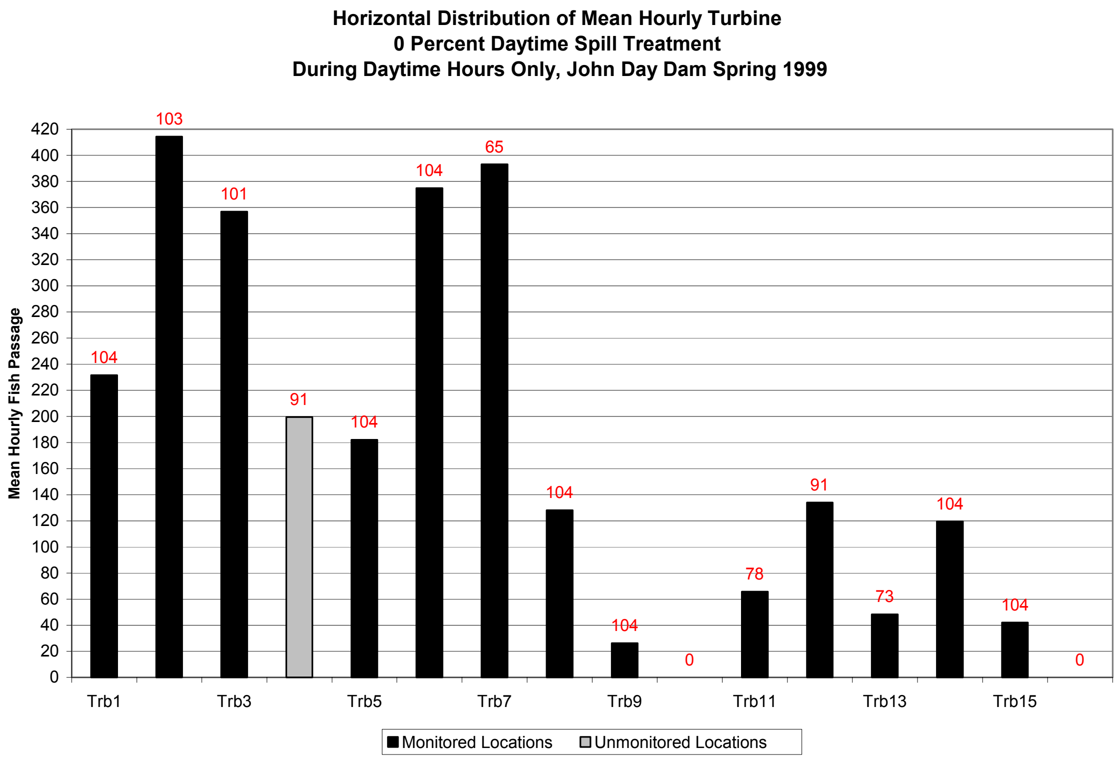


Figure 73. Horizontal distribution of spring powerhouse passage during daytime hours (0600-1859 h) for all periods with 0% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

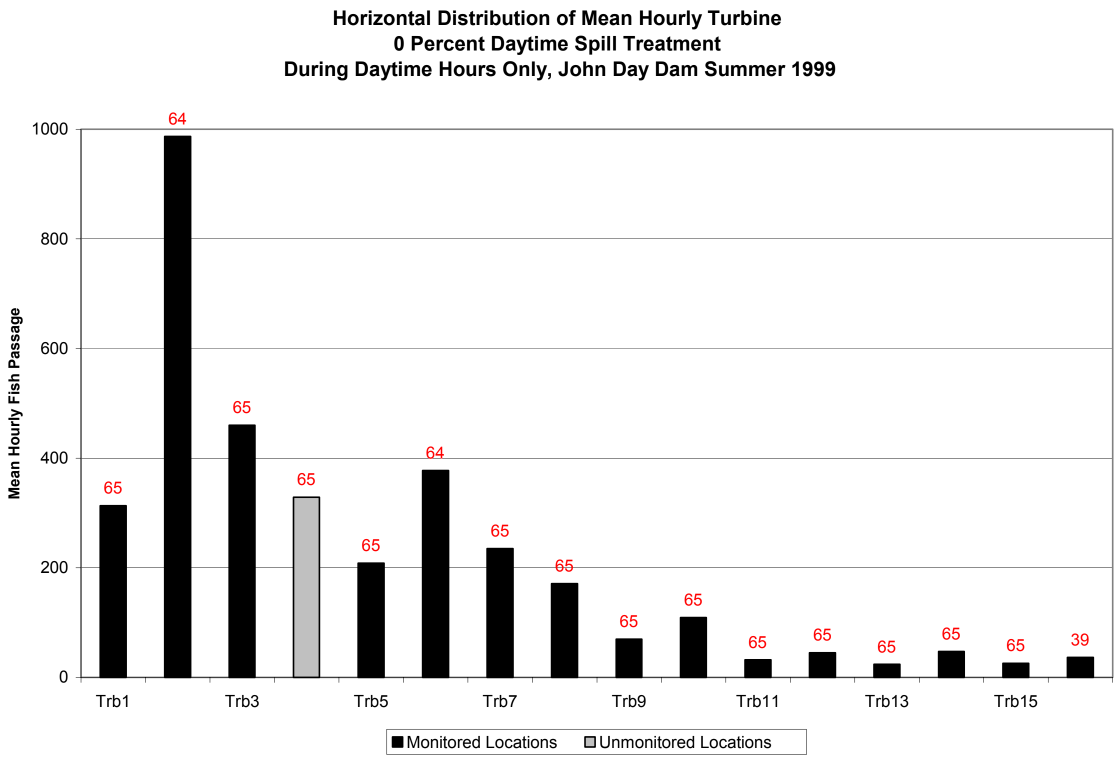


Figure 74. Horizontal distribution of summer powerhouse passage during daytime hours (0600-1859 h) for all periods with 0% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

4.7.5 Nighttime Powerhouse Horizontal Distributions

Figures 75 through 78 present nighttime horizontal distributions at the powerhouse for 30% and 0% scheduled daytime spill conditions for the spring and summer monitoring periods. Data are expressed as mean fish passage per location per hour of operation, to remove the effects of variable plant operations.

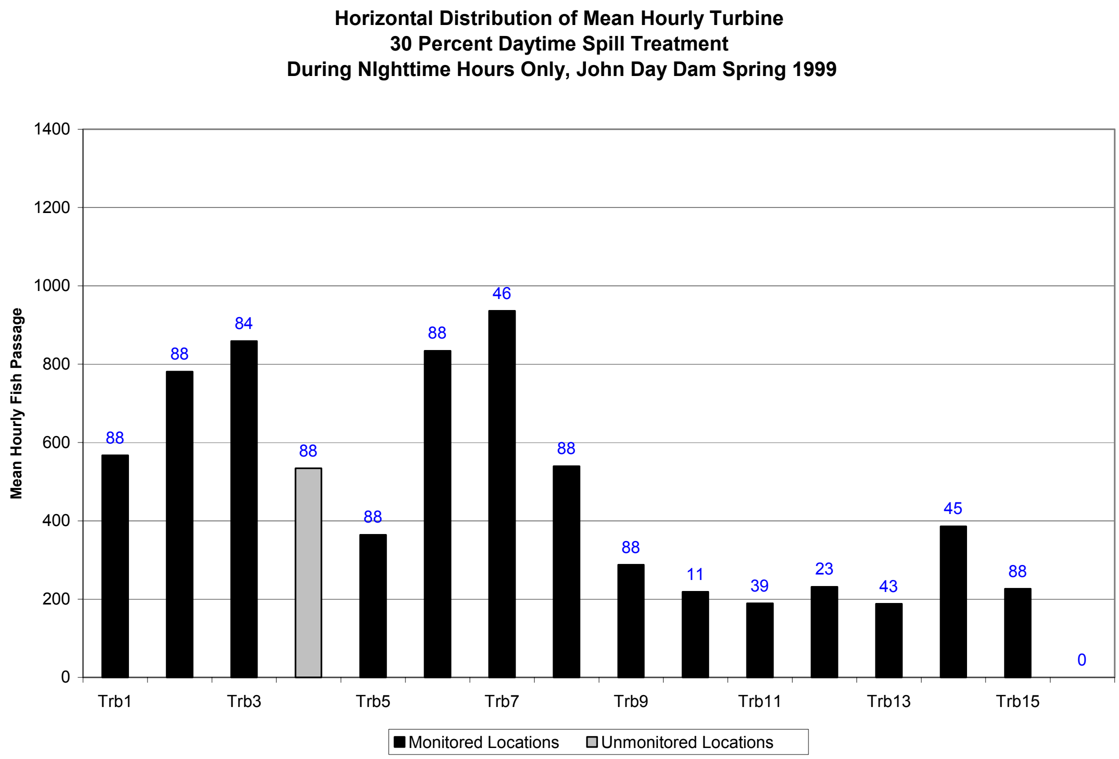


Figure 75. Horizontal distribution of spring powerhouse passage during nighttime hours (19:00 to 06:00) for all periods with 30% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

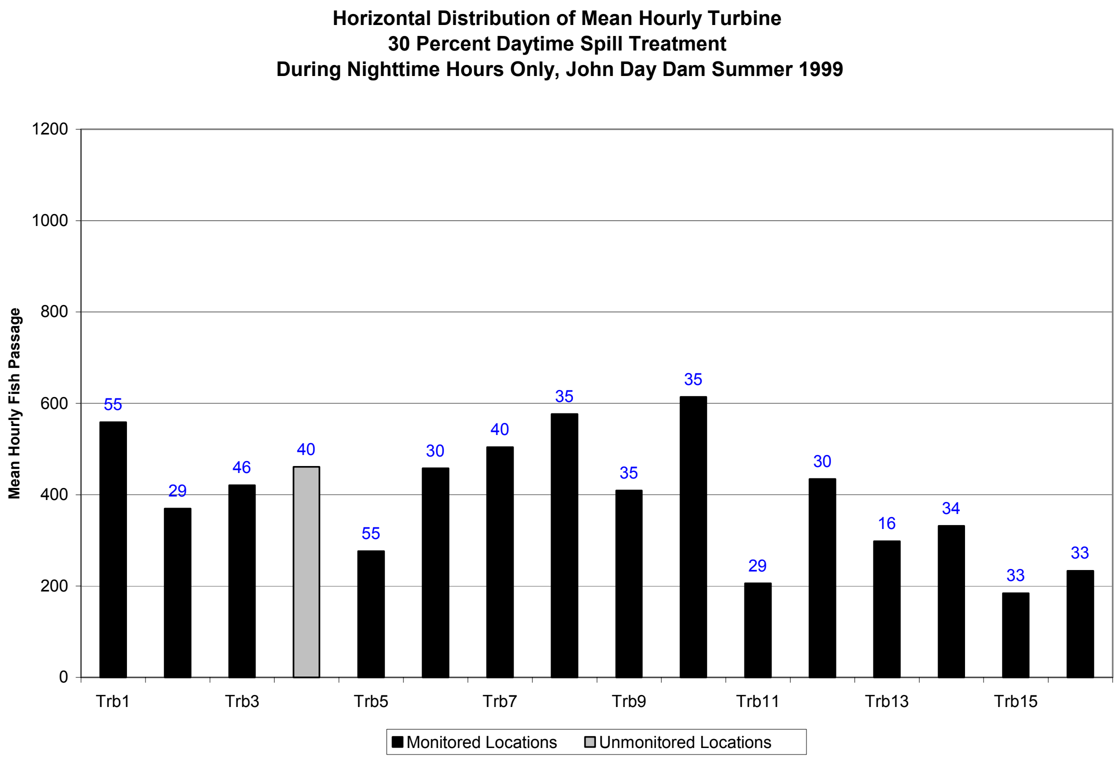


Figure 76. Horizontal distribution of summer powerhouse passage during nighttime hours (19:00 to 06:00) for all periods with 30% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

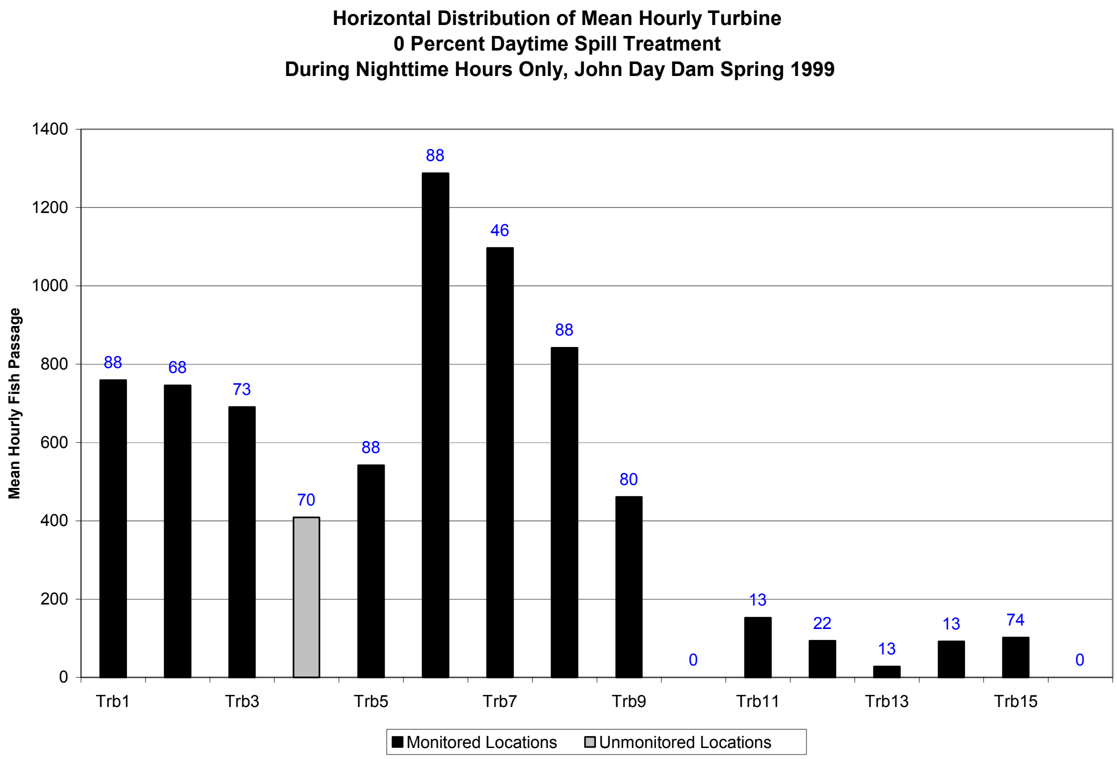


Figure 77. Horizontal distribution of spring powerhouse passage during nighttime hours (19:00 to 06:00) for all periods with 0% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation

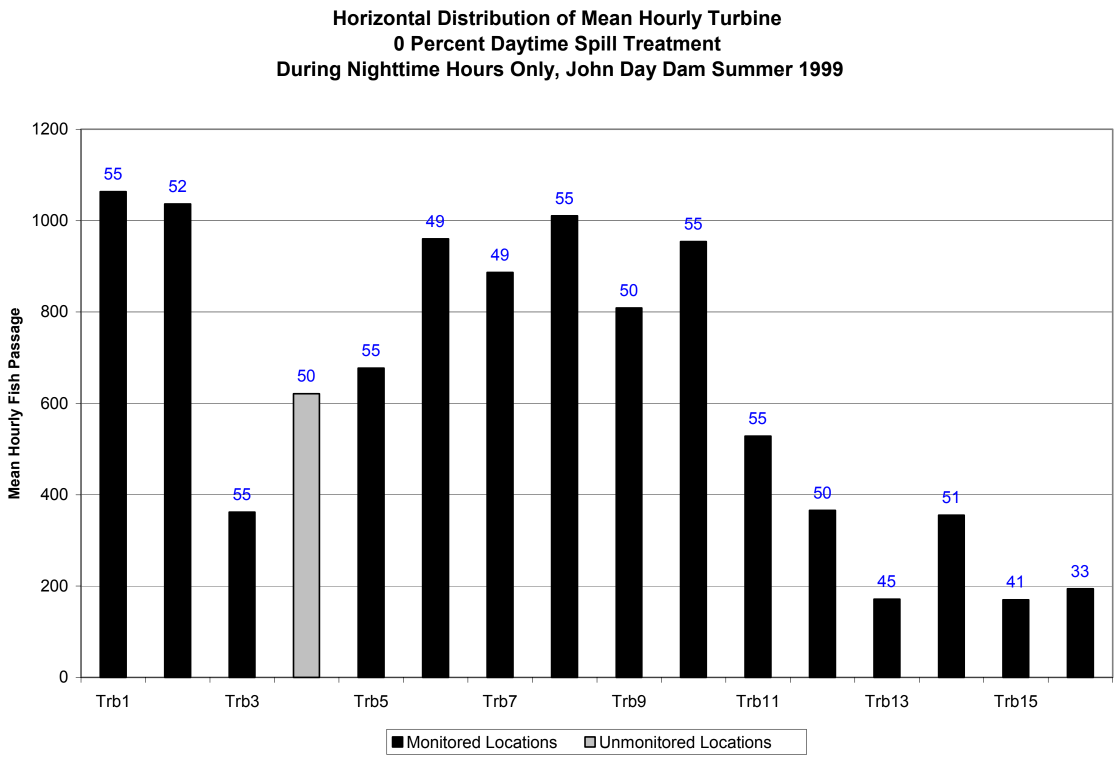


Figure 78. Horizontal distribution of summer powerhouse passage during nighttime hours (19:00 to 06:00) for all periods with 0% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

4.8 24-h Powerhouse Horizontal Distributions

Figures 79 through 82 present 24-h horizontal distributions at the powerhouse for 30% and 0% scheduled daytime spill conditions for the spring and summer monitoring periods. Data are expressed as mean fish passage per location per hour of operation, to remove the effects of variable plant operations.

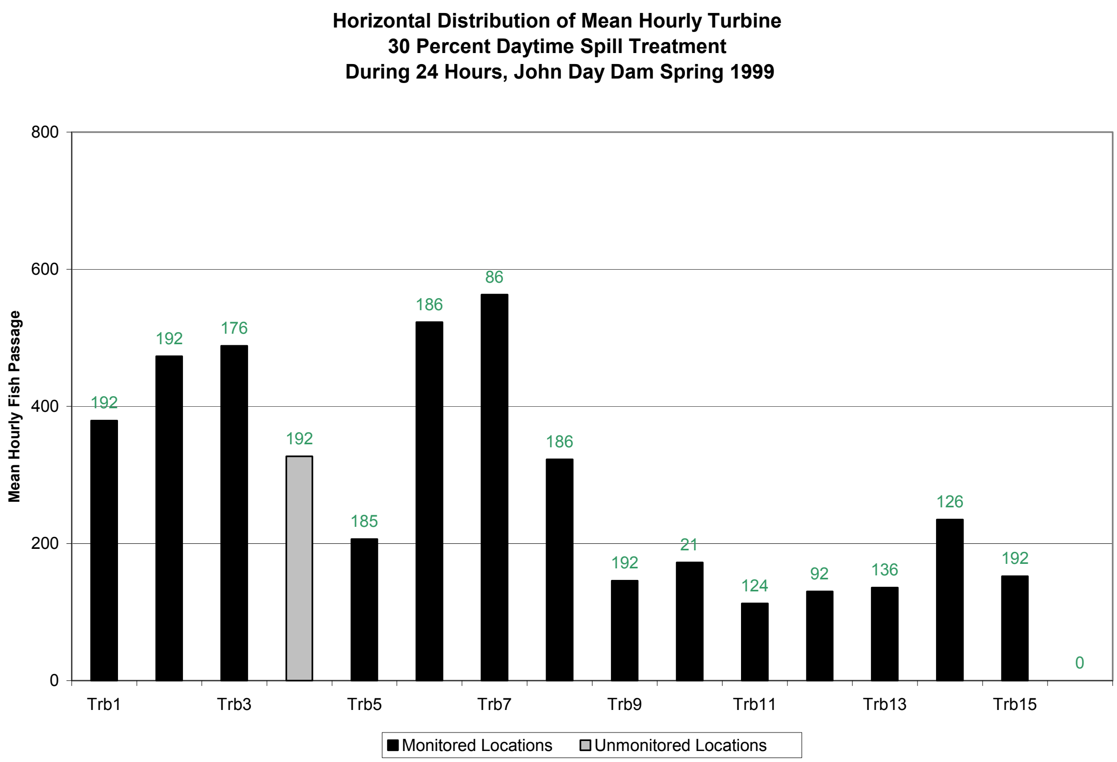


Figure 79. Horizontal distribution of spring powerhouse passage on a 24-h basis for all periods with 30% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

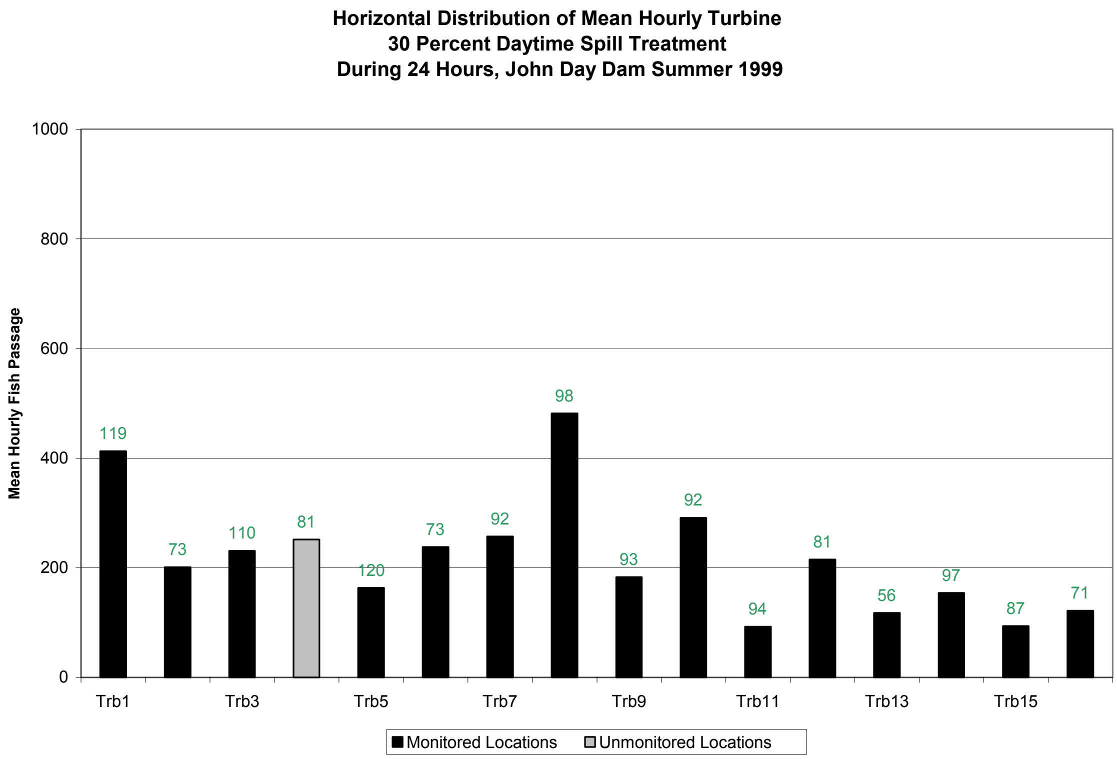


Figure 80. Horizontal distribution of summer powerhouse passage on a 24-h basis for all periods with 30% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation

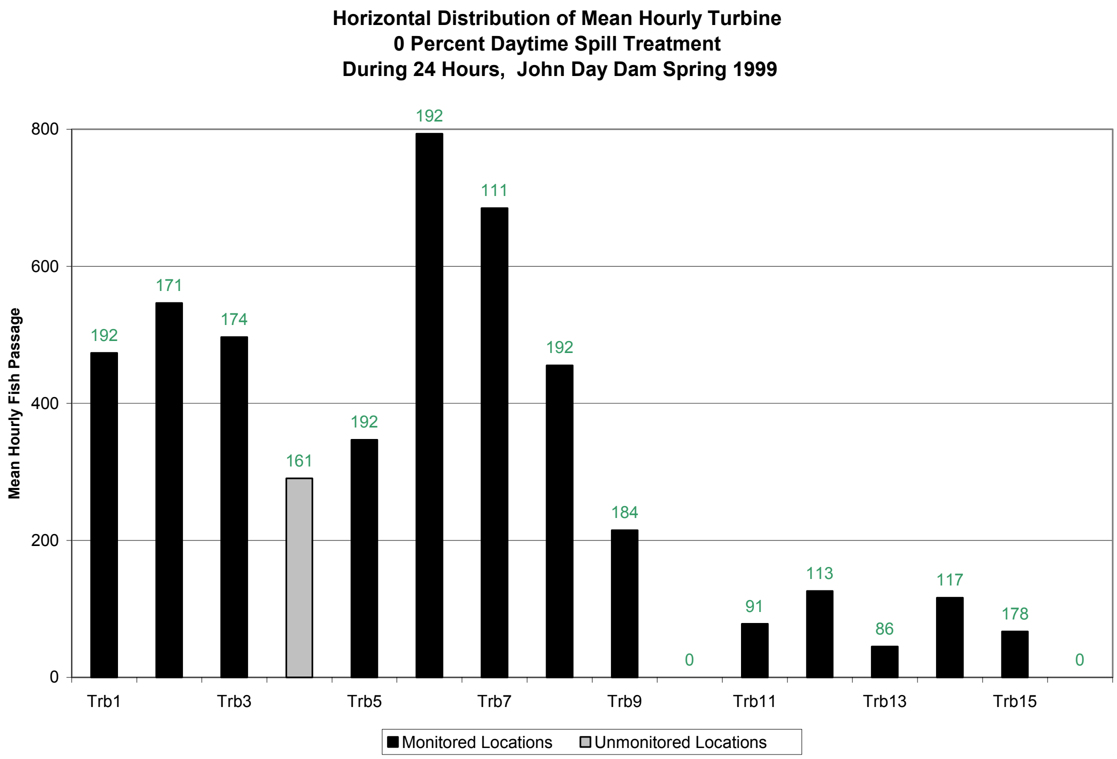


Figure 81. Horizontal distribution of spring powerhouse passage on a 24-h basis for all periods with 0% scheduled daytime spill, John Day Dam, May 1-30, 1999. Numbers above bars denote hours of operation.

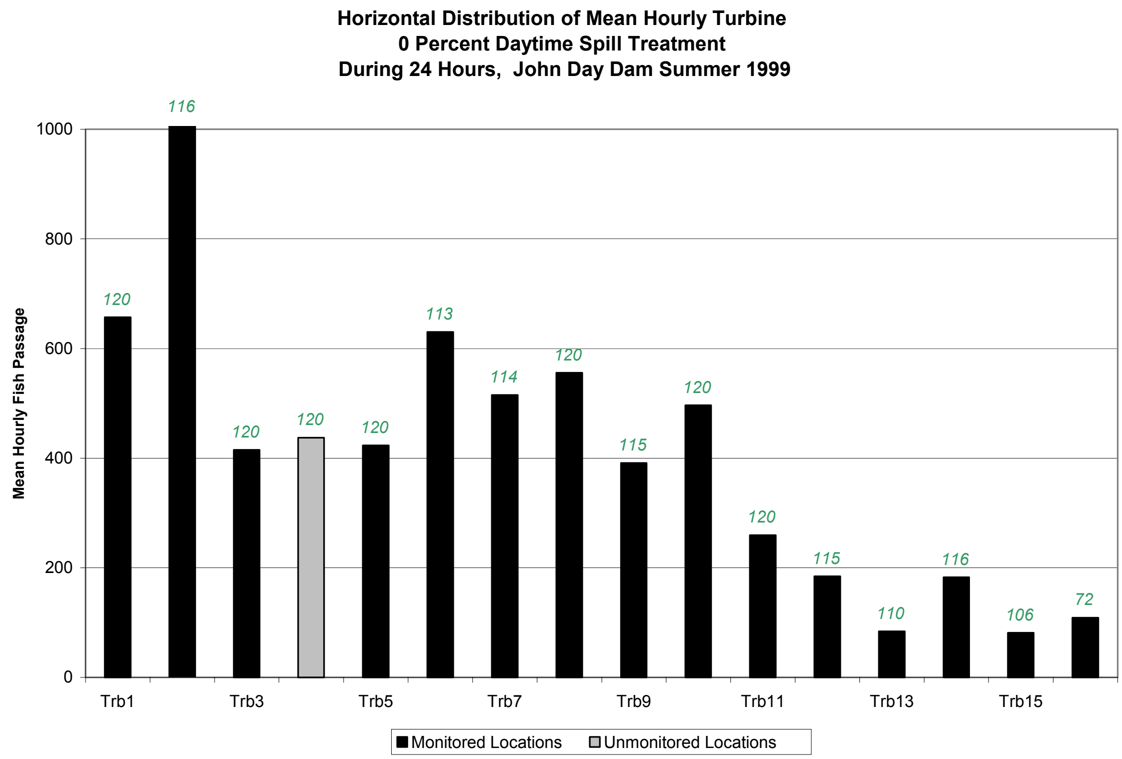


Figure 82. Horizontal distribution of summer powerhouse passage on a 24-h basis for all periods with 0% scheduled daytime spill, John Day Dam, June 6-July 8, 1999. Numbers above bars denote hours of operation.

4.9 Vertical Distribution of Estimated Fish Passage

4.9.1 24-h Spillway Vertical Distributions

Vertical distribution of estimated fish passage for all monitored spill bays combined for 24 hours is presented in Table 22 and Figures 83 and 84 for the 0% spill treatment and the 30% spill treatment during the spring monitoring period. Spillway vertical distributions for the summer treatments are shown in Table 23 and Figures 85 and 86.

As observed during previous years, fish were primarily surface oriented at the spillway during the spring. During the summer monitoring period, a change in vertical distribution was evident for those days that had 0% scheduled spill. Under 0% day spill conditions, fish appeared to be more uniformly distributed in the water column over a 24-h period.

Table 22. Vertical distribution of spring spillway passage on a 24-h basis for all periods with 0% and 30% scheduled daytime spill. John Day Dam, May 1-30, 1999.

Mid-bin Elevation (ft)	Fish Passage at 0%	Fish Passage at 30%
248	20.71%	20.12%
244	29.50%	31.78%
241	16.44%	17.45%
238	10.53%	9.80%
234	6.51%	5.39%
231	5.08%	3.02%
228	3.40%	2.24%
225	3.14%	2.32%
221	1.51%	2.16%
218	1.52%	2.23%
215	1.04%	2.37%
212	0.62%	1.12%
Grand Total	100.00%	100.00%

Table 23. Vertical distribution of summer spillway passage on a 24-h basis for all periods with 0% and 30% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

Mid-bin Elevation (ft)	Fish Passage at 0%	Fish Passage at 30%
248	8.88%	18.30%
244	12.80%	28.06%
241	8.94%	16.54%
238	8.85%	9.25%
234	7.84%	4.77%
231	7.56%	4.10%
228	8.58%	3.69%
225	9.55%	3.65%
221	13.03%	4.85%
218	11.92%	5.76%
215	1.97%	1.02%
212	0.09%	0.01%
Grand Total	100.00%	100.00%

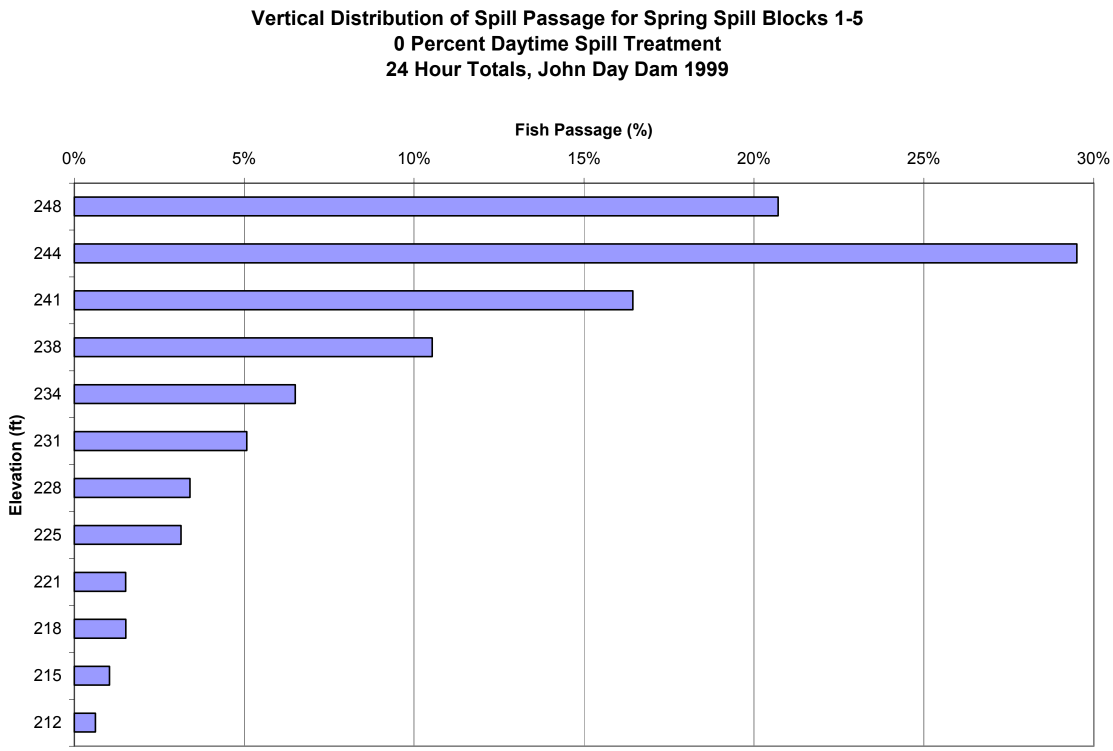


Figure 83. Vertical distribution of spring spillway passage on a 24-h basis for all periods with 0% scheduled daytime spill. John Day Dam, May 1-30, 1999.

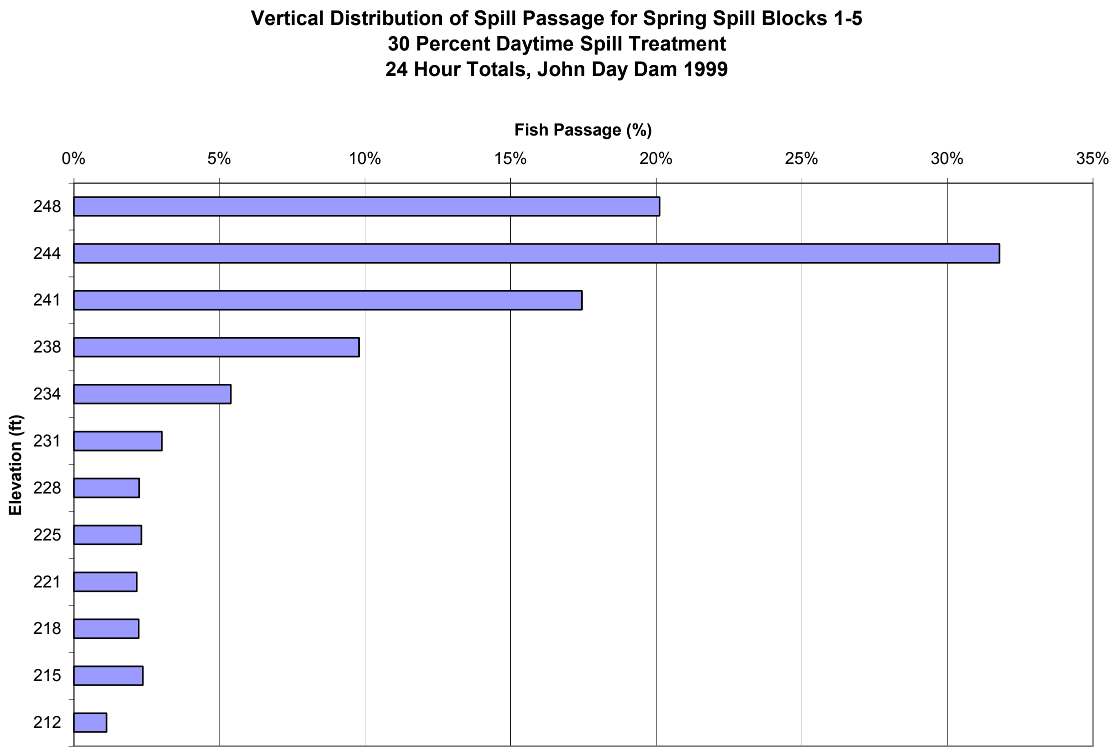


Figure 84. Vertical distribution of spring spillway passage on a 24-h basis for all periods with 30% scheduled daytime spill. John Day Dam, May 1-30, 1999.

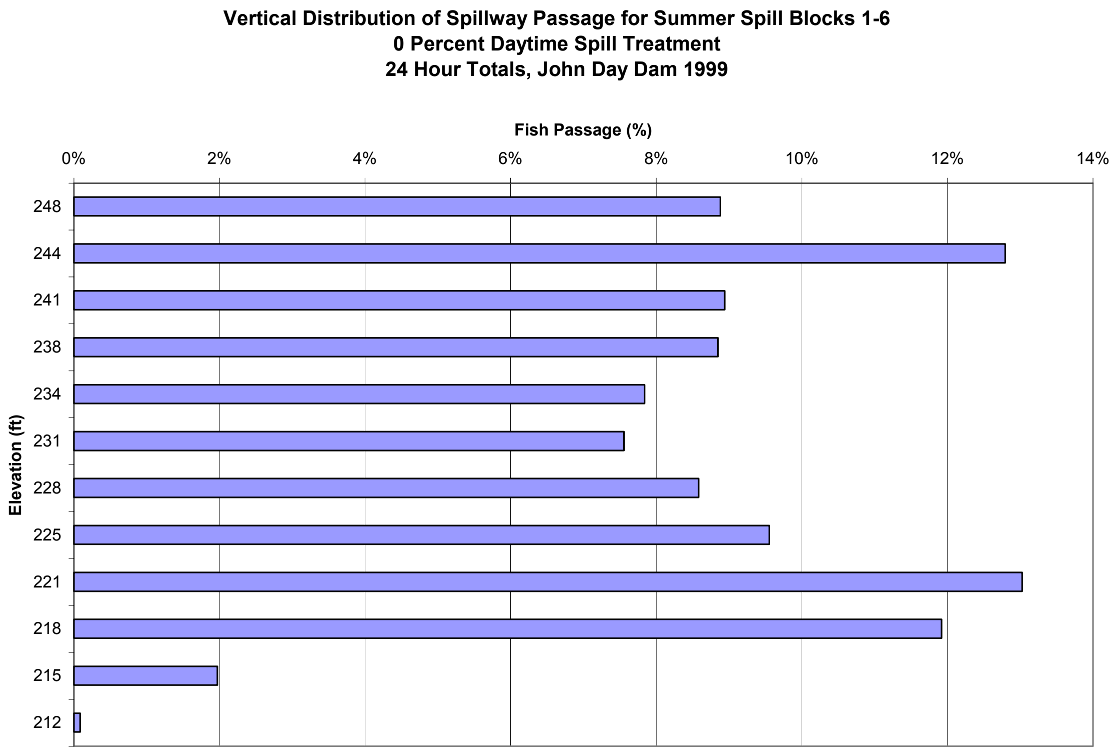


Figure 85. Vertical distribution of summer spillway passage on a 24-h basis for all periods with 0% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

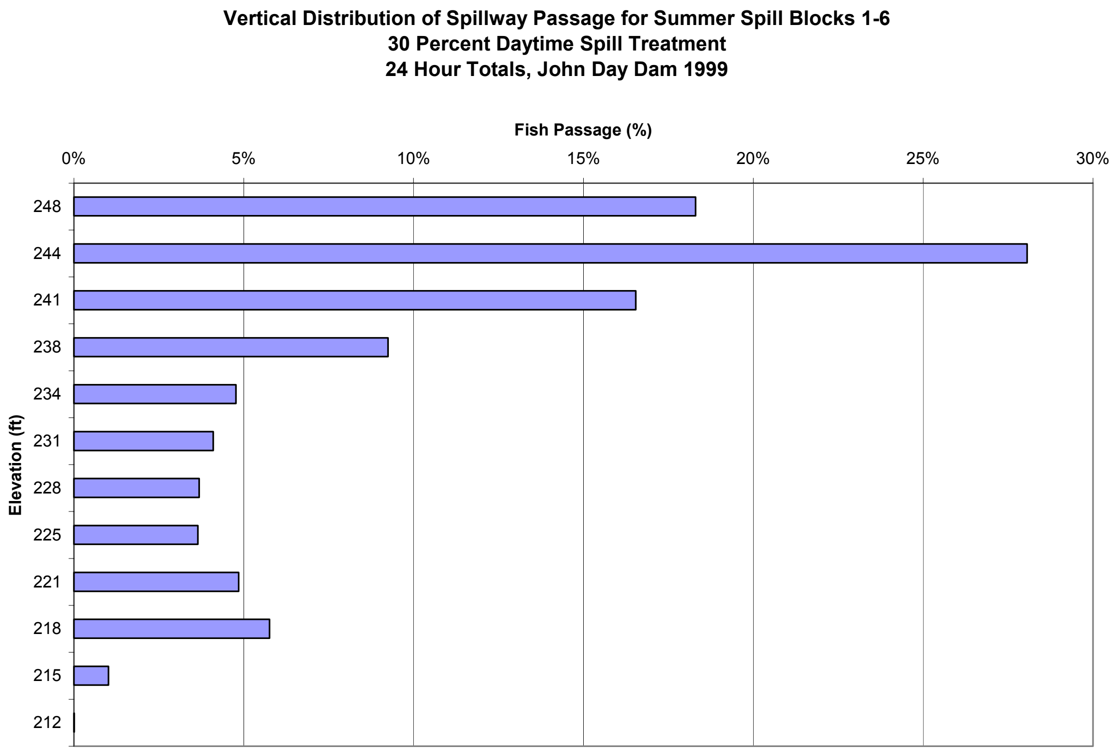


Figure 86. Vertical distribution of summer spillway passage on a 24-h basis for all periods with 30% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

4.9.2 24-h Powerhouse Vertical Distributions

Vertical distribution of estimated fish passage for all turbine units combined for 24 hours is presented in Table 24 and Figures 87 and 88 for the 0% spill treatment and the 30% spill treatment during the spring monitoring period. Turbine vertical distributions for the summer treatments are shown in Table 25 and Figures 89 and 90.

Fish were primarily surface oriented at the turbines during the 0% spill treatment periods in spring. During the 30% spill treatment periods, fish were more uniformly distributed in the water column. Similar trends were evident during the summer, but to a lesser degree than during the spring monitoring period.

Table 24. Vertical distribution of spring powerhouse passage on a 24-h basis for all periods with 0% and 30% scheduled daytime spill. John Day Dam, May 1-30, 1999.

Mid-bin Elevation (ft)	Fish Passage at 0%	Fish Passage at 30%
179	8.09%	8.21%
176	15.03%	11.37%
174	12.67%	9.48%
171	11.09%	9.03%
169	9.25%	7.76%
166	9.07%	7.46%
164	7.69%	7.32%
161	7.07%	6.27%
159	4.77%	6.57%
156	5.01%	7.10%
154	4.39%	7.31%
151	4.37%	9.15%
149	1.49%	2.96%
Grand Total	100.00%	100.00%

Table 25. Vertical distribution of summer powerhouse passage on a 24-h basis for all periods with 0% and 30% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

Mid-bin Elevation (ft)	Fish Passage at 0%	Fish Passage at 30%
179	2.19%	5.99%
176	16.06%	16.65%
174	11.33%	10.43%
171	12.42%	11.77%
169	9.59%	8.56%
166	8.75%	6.91%
164	7.55%	6.60%
161	7.78%	5.48%
159	5.73%	5.91%
156	5.27%	6.27%
154	5.50%	5.55%
151	5.26%	6.15%
149	2.57%	3.72%
Grand Total	100.00%	100.00%

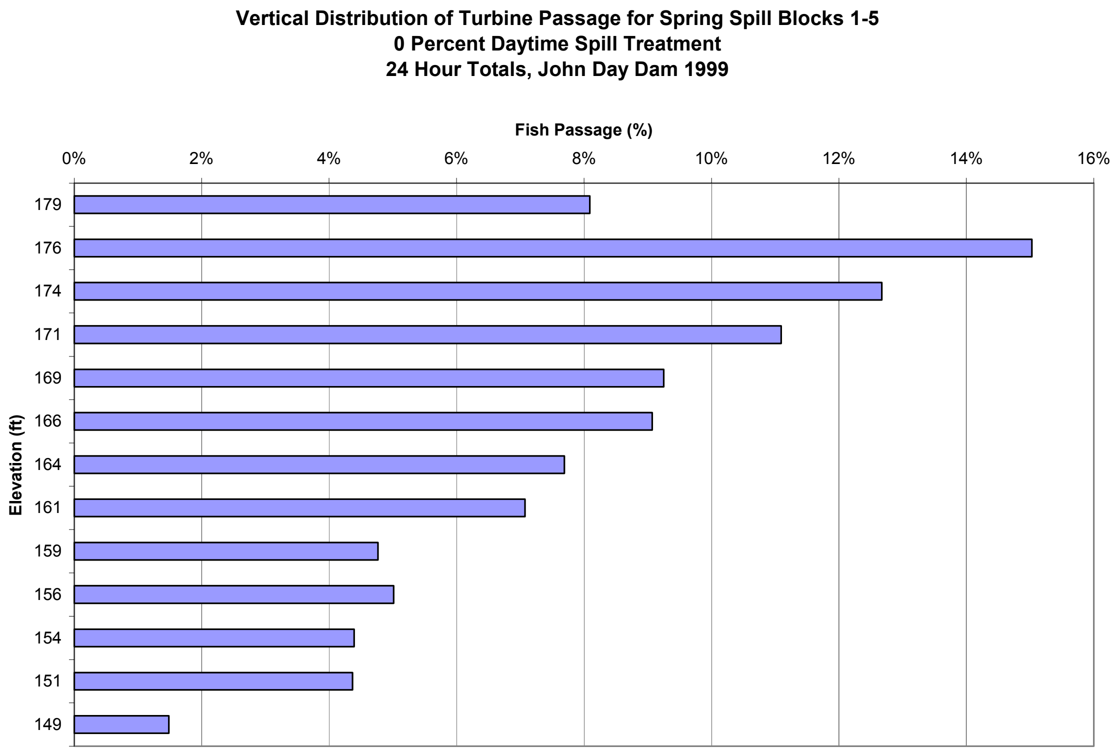


Figure 87. Vertical distribution of spring powerhouse passage on a 24-h basis for all periods with 0% scheduled daytime spill. John Day Dam, May 1-30, 1999.

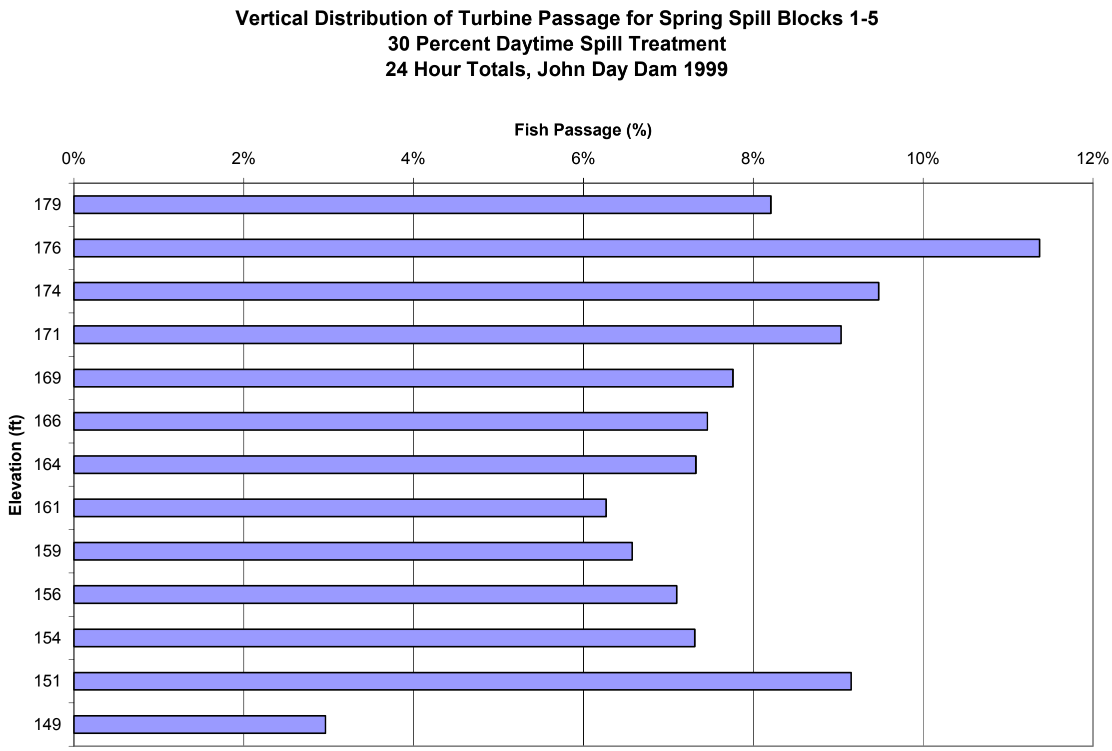


Figure 88. Vertical distribution of spring powerhouse passage on a 24-h basis for all periods with 30% scheduled daytime spill. John Day Dam, May 1-30, 1999.

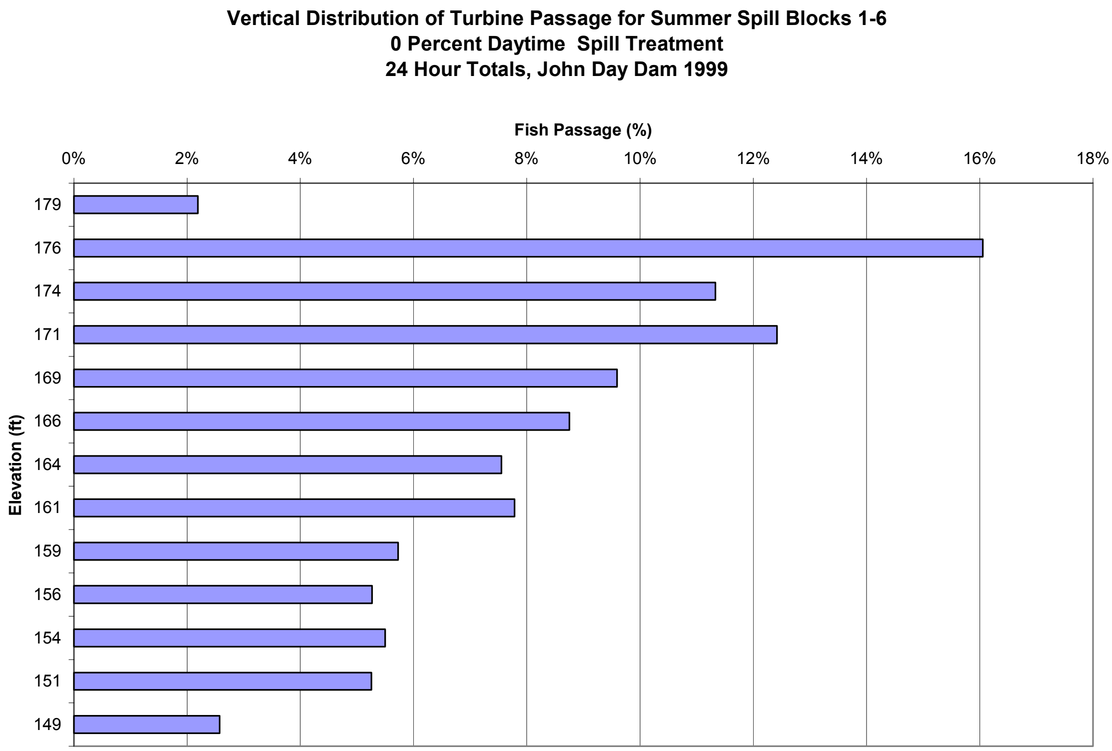


Figure 89. Vertical distribution of summer powerhouse passage on a 24-h basis for all periods with 0% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

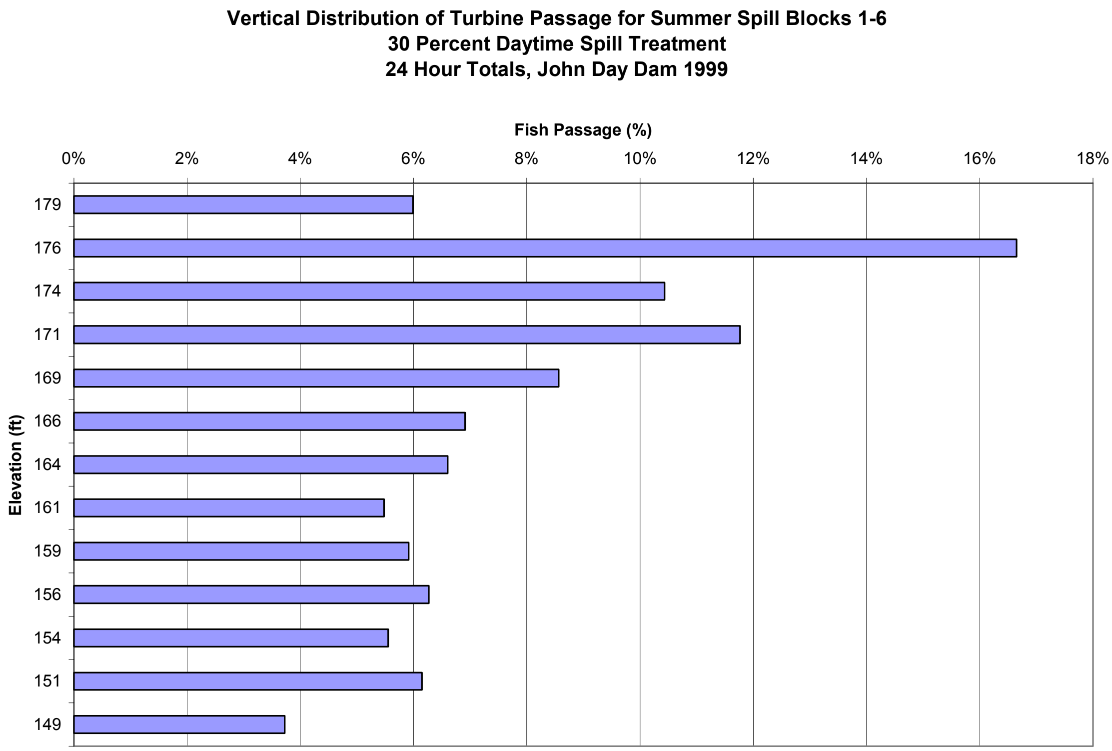


Figure 90. Vertical distribution of summer powerhouse passage on a 24-h basis for all periods with 30% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

4.10 Diel Distribution of Estimated Fish Passage

Observed diel patterns of estimated spillway fish passage are presented in Figures 91-94 for the two scheduled daytime spill conditions (30% and 0%). Separate distributions are presented for the spring and summer monitoring periods. Corresponding diel passage distributions for the powerhouse are presented in Figures 95-98.

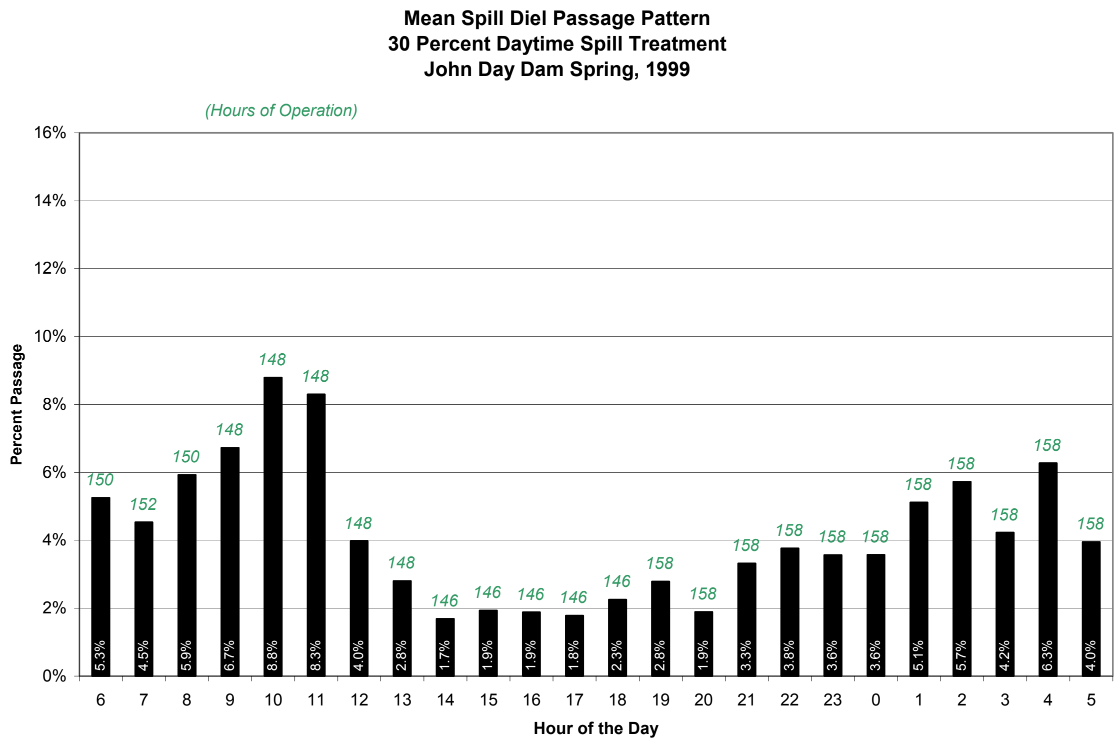


Figure 91. Spring diel passage pattern at the spillway for all 24-h periods with 30% scheduled daytime spill. John Day Dam, May 1-30, 1999.

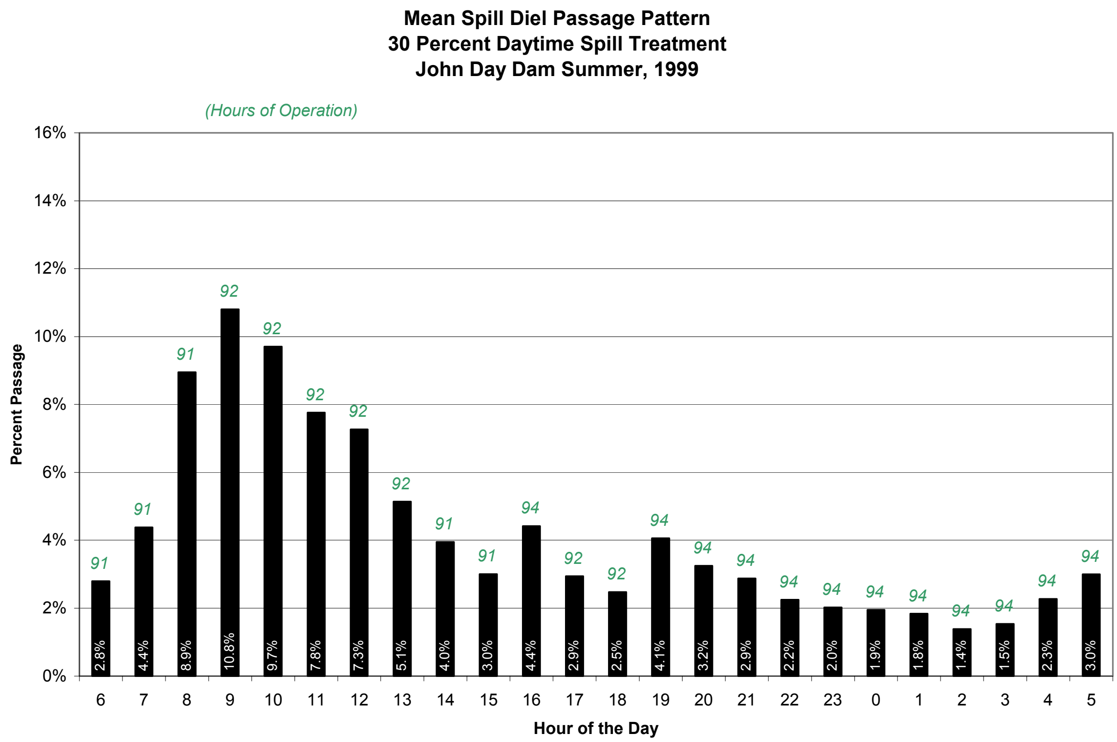


Figure 92. Summer diel passage pattern at the spillway for all 24-h periods with 30% scheduled daytime spill. John Day Dam, June 6 – July 8, 1999.

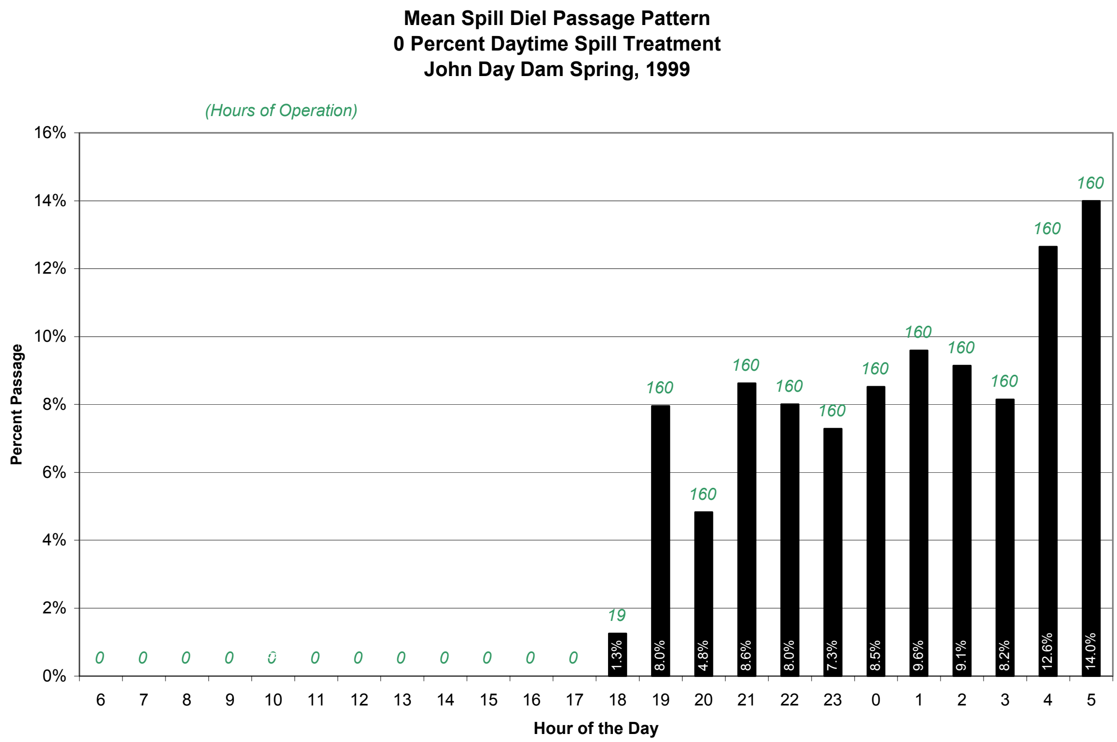


Figure 93. Spring diel passage pattern at the spillway for all 24-h periods with 0% scheduled daytime spill. John Day Dam, May 1-30, 1999.

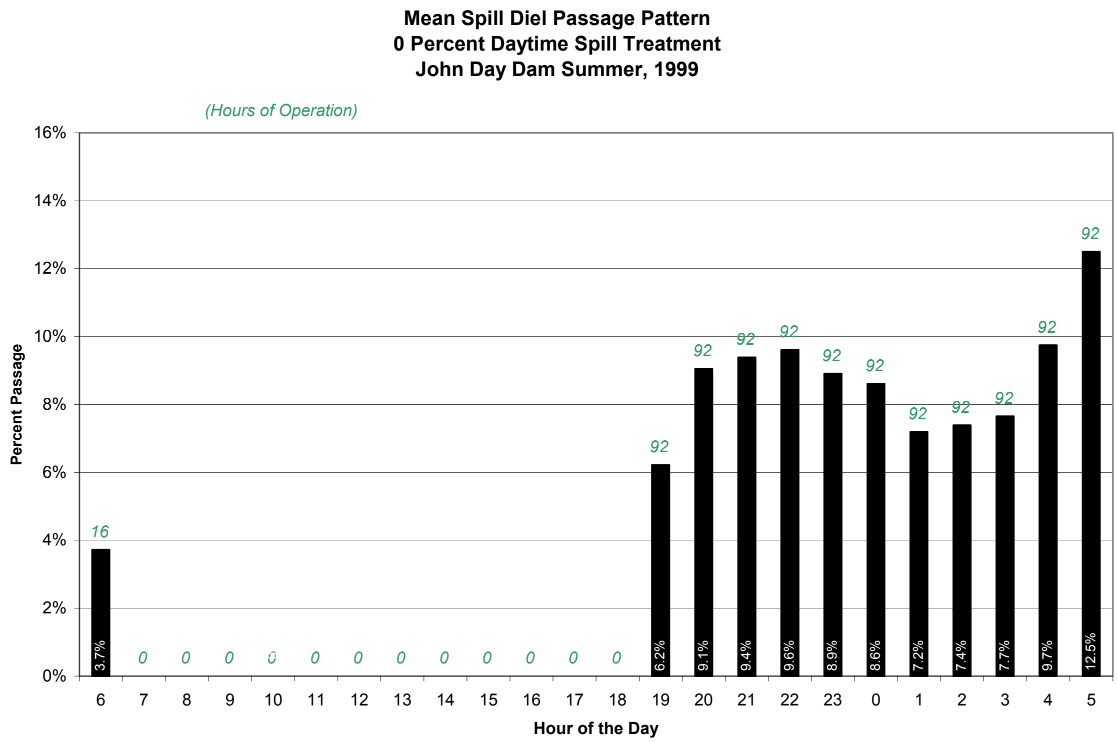


Figure 94. Summer diel passage pattern at the spillway for all 24-h periods with 0% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

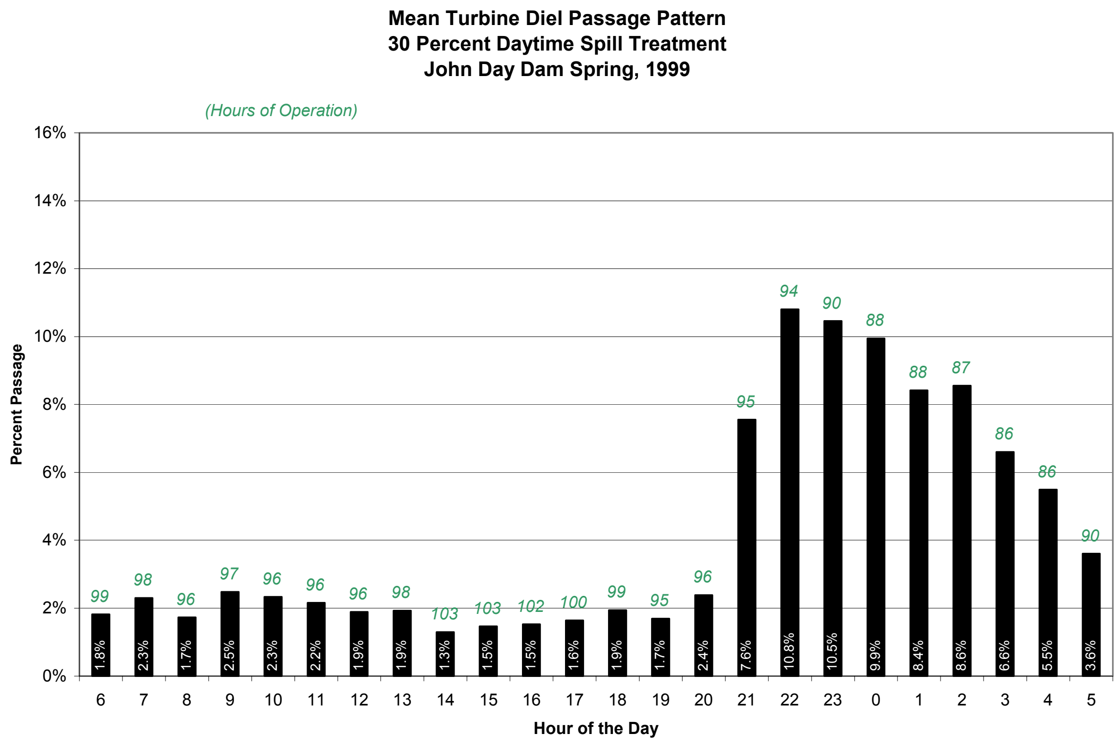


Figure 95. Spring diel passage pattern at the powerhouse for all 24-h periods with 30% scheduled daytime spill. John Day Dam, May 1-30, 1999.

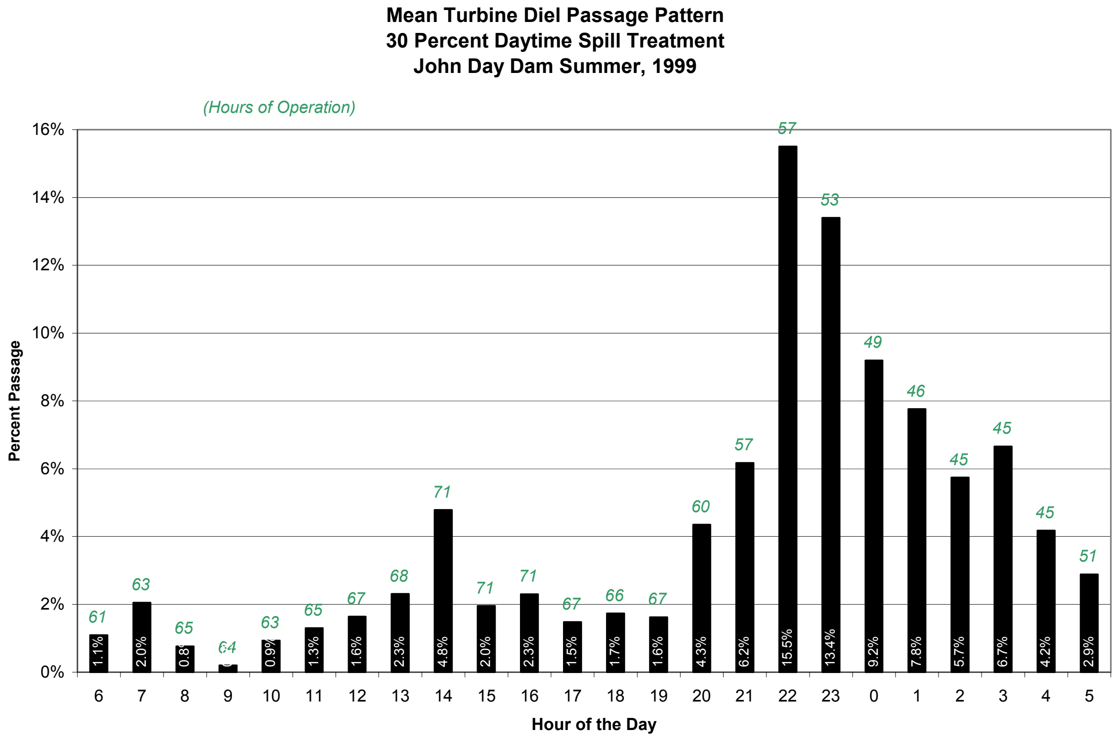


Figure 96. Summer diel passage pattern at the powerhouse for all 24-h periods with 30% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

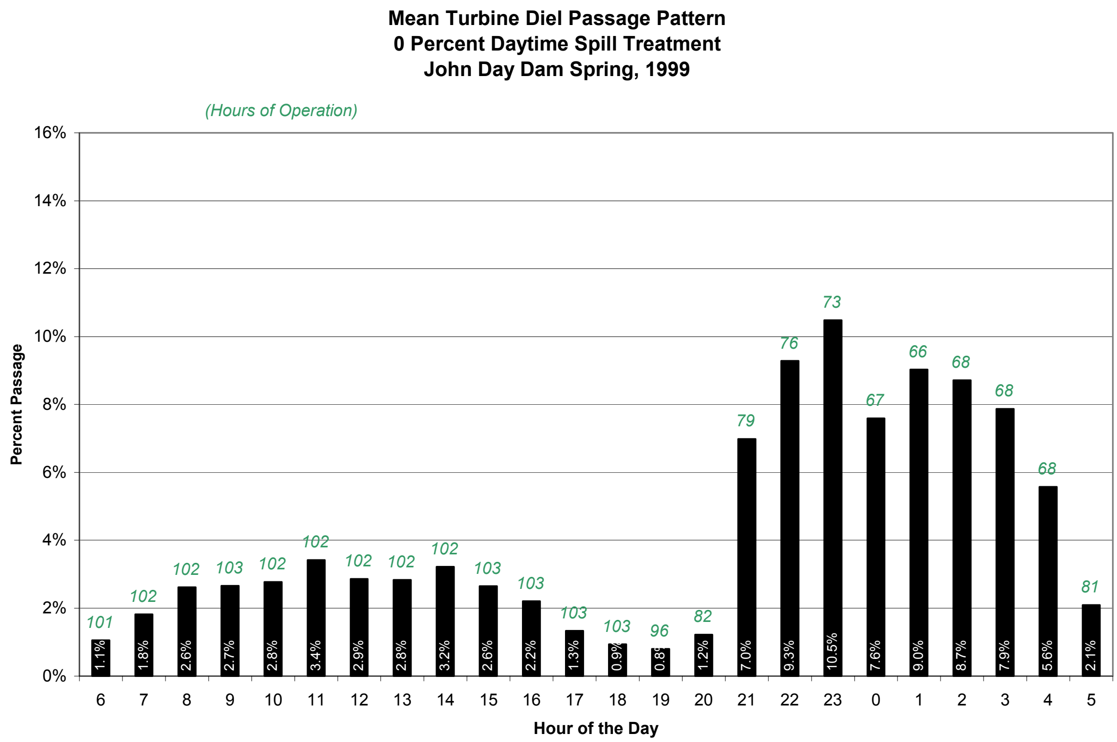


Figure 97. Spring diel passage pattern at the powerhouse for all 24-h periods with 0% scheduled daytime spill. John Day Dam, May 1-30, 1999.

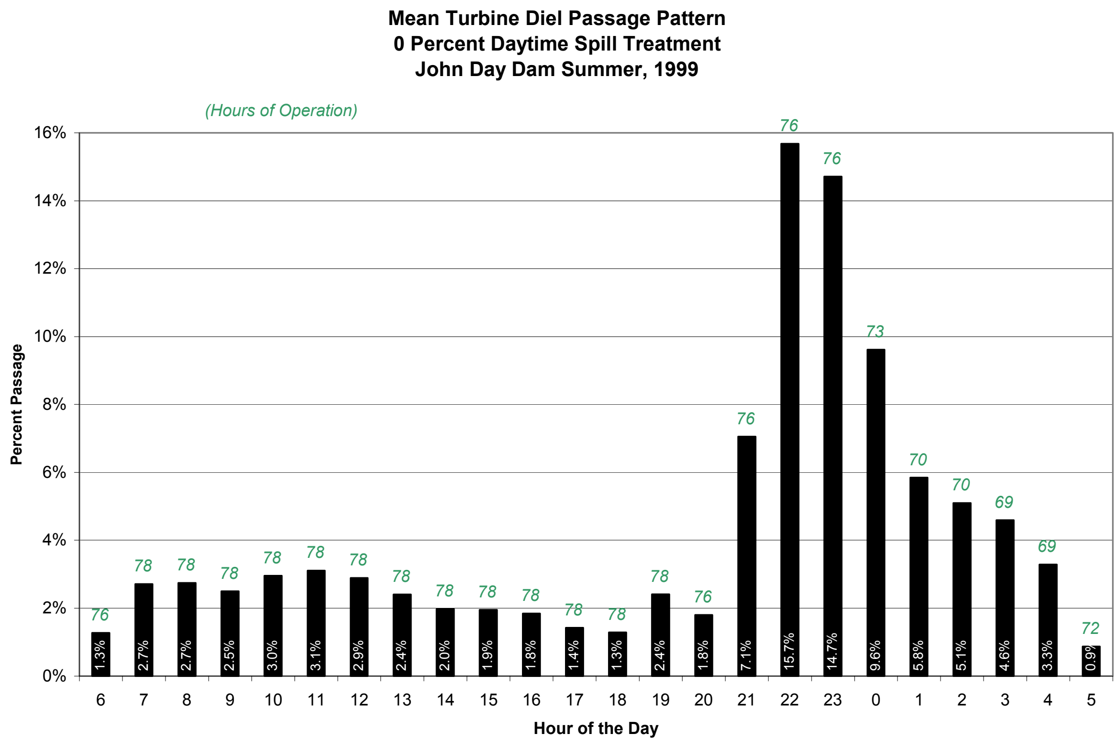


Figure 98. Summer diel passage pattern at the powerhouse for all 24-h periods with 0% scheduled daytime spill. John Day Dam, June 6-July 8, 1999.

4.11 Seasonal Run Timing and Comparison of Acoustic Estimates to Smolt Monitoring Index

4.11.1 Run Timing

Run timing for John Day Dam in Spring, 1999, is presented in Figure 99. Run timing for the summer monitoring period is presented in Figure 100. Cumulative run timing for the Spring and summer monitoring periods are shown in Figures 101 and 102. Run timing results by passage route and time period (day/night) are plotted for spring and summer monitoring periods in Figures 103 and 104.

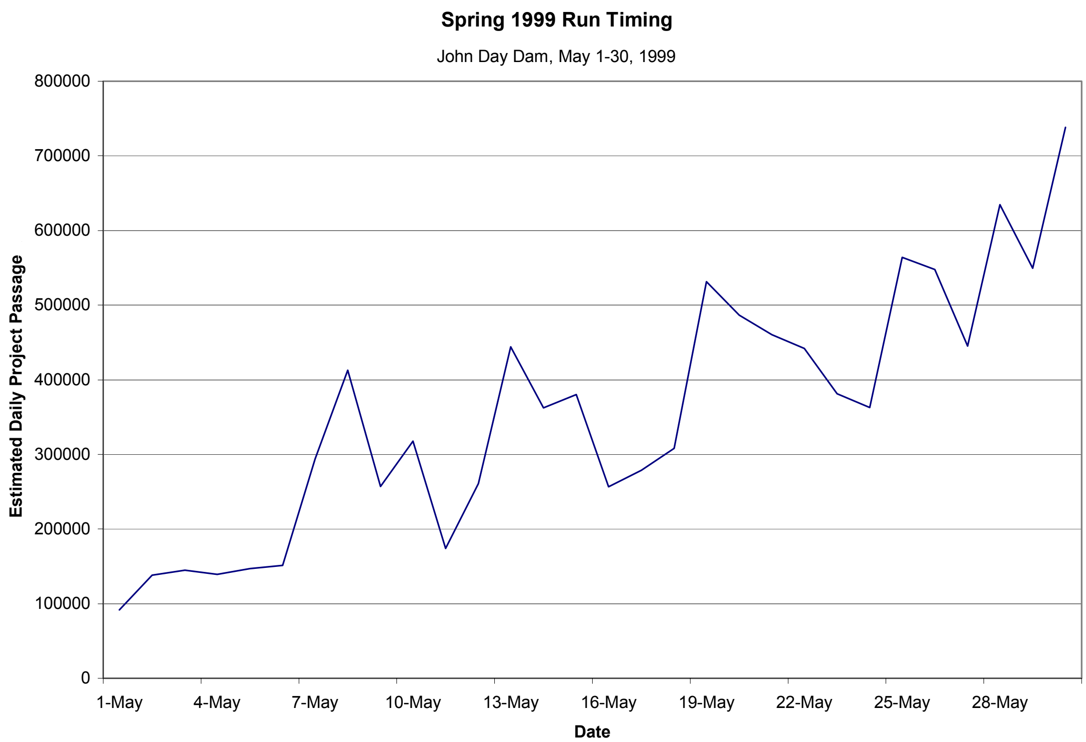


Figure 99. Seasonal spring run timing for John Day Dam, May 1-30, 1999.

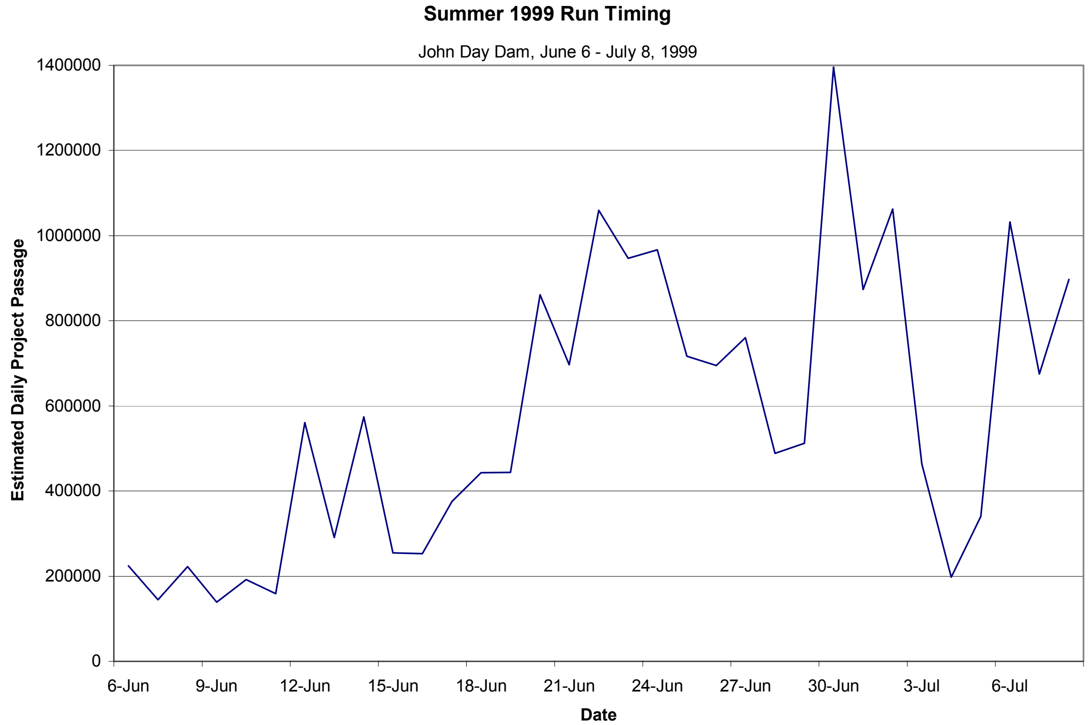


Figure 100. Seasonal summer run timing for John Day Dam, June 6 – July 8, 1999.

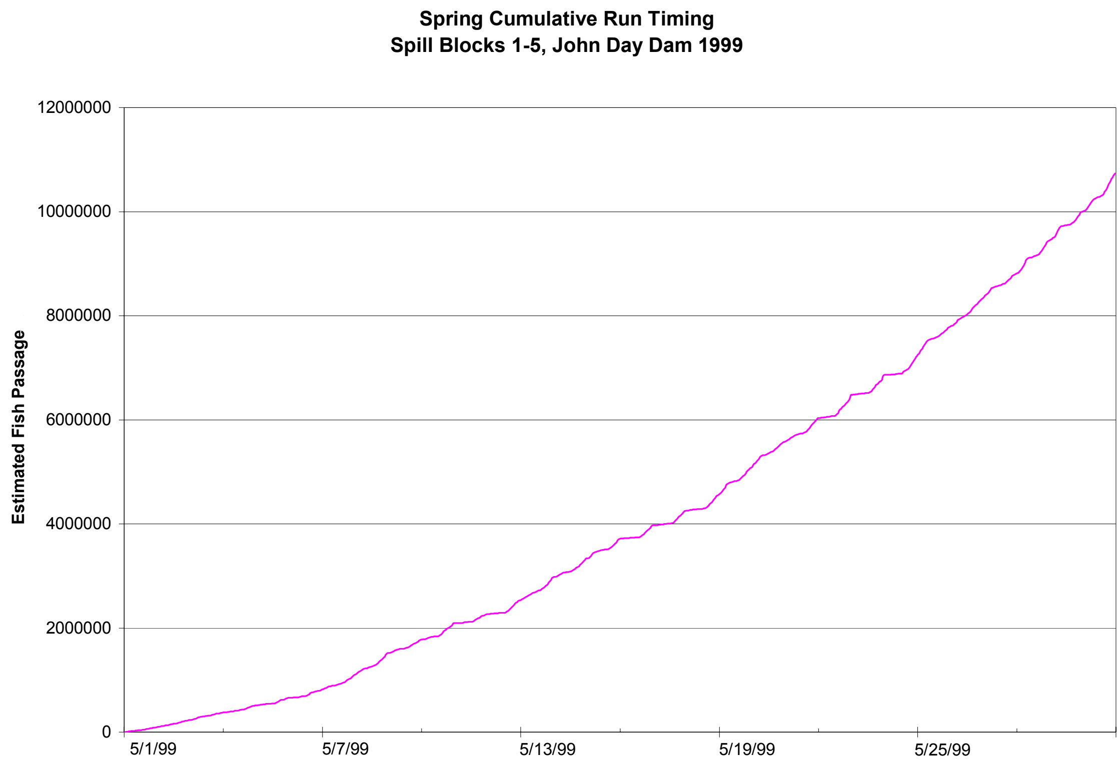


Figure 101. Cumulative spring run timing for John Day Dam, May 1-30, 1999.

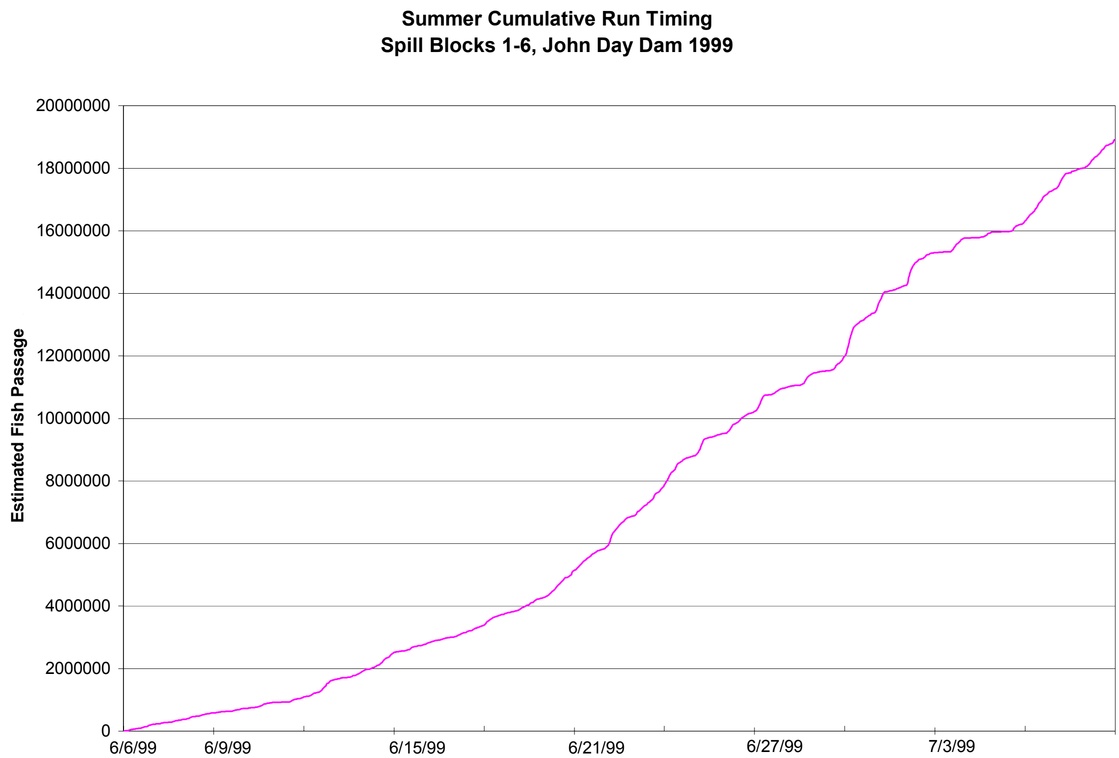


Figure 102. Cumulative summer run timing for John Day Dam, June 6-July 8, 1999.

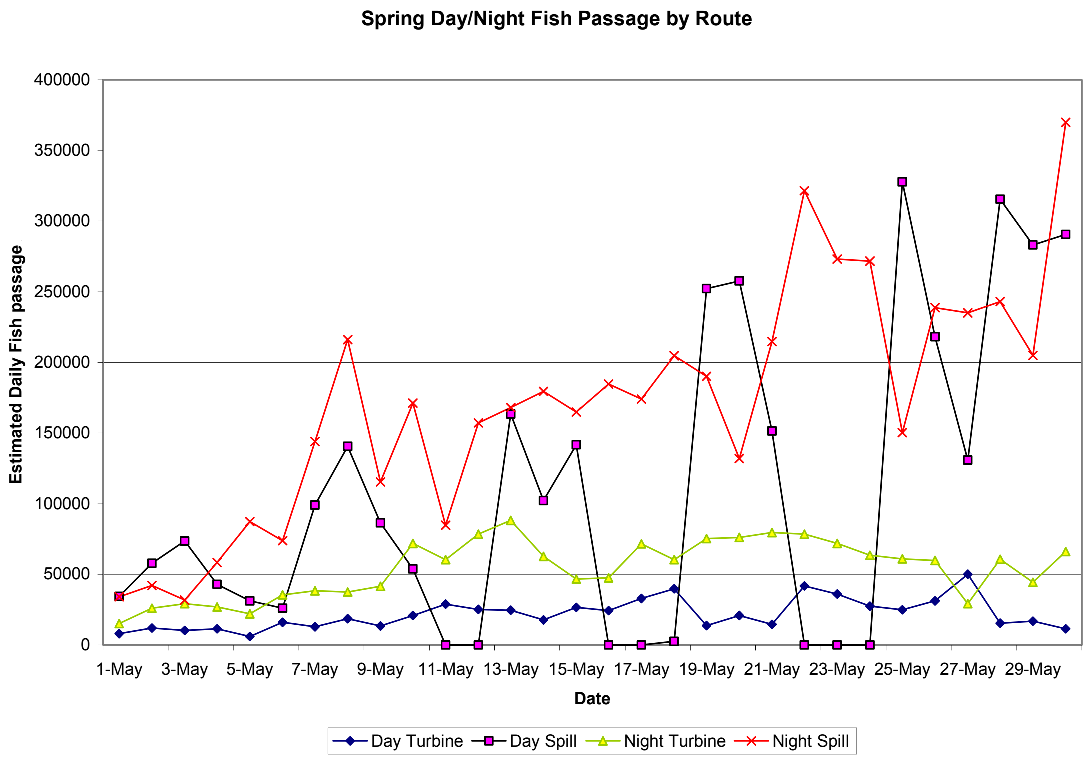


Figure 103. John Day Dam spring run timing by passage route, May 1-30, 1999.

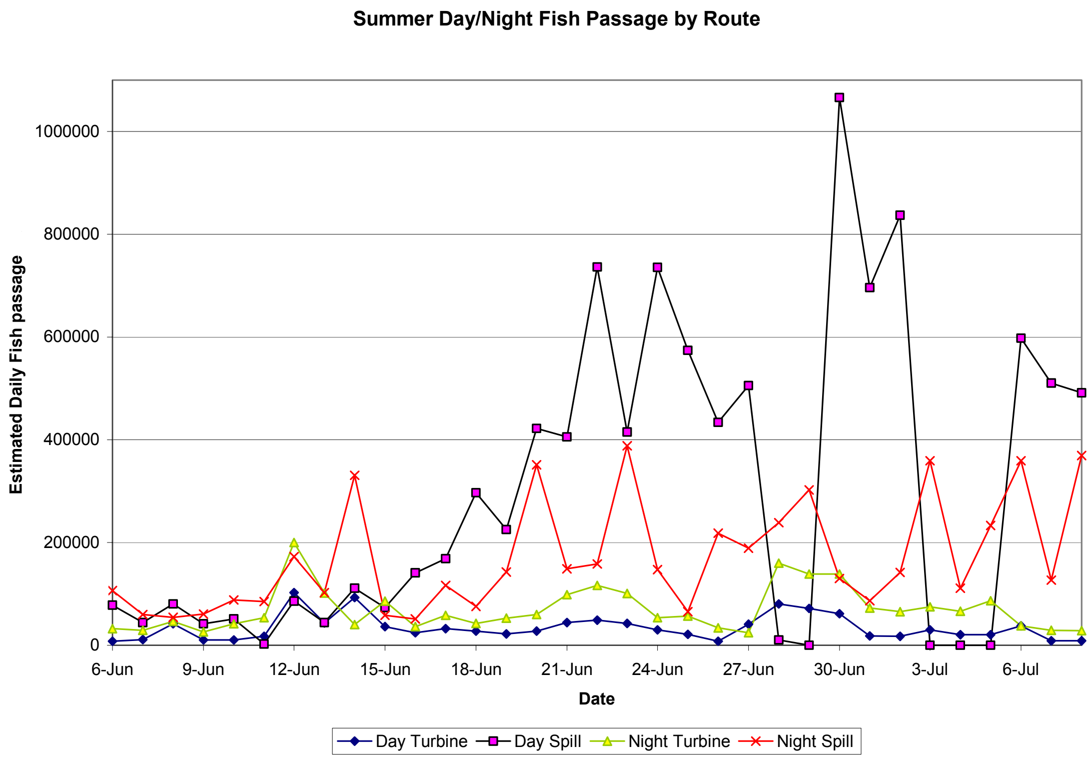


Figure 104. John Day Dam summer run timing by passage route, June 6-July 8, 1999.

4.11.2 Smolt Index Comparisons

Daily hydroacoustic fish passage estimates at John Day Dam for turbines, spills, and the entire dam are compared to the John Day Smolt Index for the spring and summer monitoring periods in Tables 26 and 27 respectively. During spring, the powerhouse acoustic estimates were highly correlated with the smolt index, (r^2 = 0.729, F = 72.5, p << 0.001). During the summer monitoring period, the powerhouse correlation was less significant when all days are included (r^2 = 0.482), but when June 12-15 are removed from the data set the significance of the correlation increases significantly (r^2 = 0.867). During June 12-15, a large amount of trash occluded the upper sections of the trash racks of units on the south end of the dam. This caused an area of low flow to form, allowing fish to exhibit holding or milling behavior within these turbines. Once these trash racks were cleared, fish densities returned to lower levels. Figure 105 plots the daily acoustic estimates of powerhouse passage with the John Day Smolt Index for the spring, while Figure 106 plots the same results for summer. The correlations were not generally significant for spillway passage or total plant passage. The JBS collects fish from the powerhouse only. This may impact the comparison with the hydroacoustic counts.

Table 26. Daily spring hydroacoustic fish passage estimates compared to smolt monitoring indices. John Day Dam, May 1-30, 1999.

	Hydroacoustic Fish Passage			John Day
Date	Turbine	Spill	Total Dam	Smolt Index
1-May	23188	68382	91569	47428
2-May	38185	99853	138039	37312
3-May	39565	105141	144707	47415
4-May	38312	101256	139568	55225
5-May	28123	118596	146719	60908
6-May	51528	100038	151566	58176
7-May	51159	243059	294218	52721
8-May	56116	356679	412794	73472
9-May	55034	201971	257005	66048
10-May	92783	225147	317930	118029
11-May	89364	84831	174196	132340
12-May	103711	157218	260929	127746
13-May	112897	331480	444378	133438
14-May	80641	281836	362477	111395
15-May	73306	306722	380028	82018
16-May	72099	184541	256640	87109
17-May	104401	174147	278548	138653
18-May	100310	207507	307817	125924
19-May	89179	442189	531367	98616
20-May	96998	389561	486559	80596
21-May	94126	366112	460238	98208
22-May	120214	321594	441808	131617
23-May	107921	273188	381109	100681
24-May	90888	271867	362755	72452
25-May	86005	478131	564136	118317
26-May	91105	456908	548013	124408
27-May	79290	365880	445170	76234
28-May	76015	558475	634490	81335
29-May	61416	488039	549454	94046
30-May	77663	660585	738248	119471

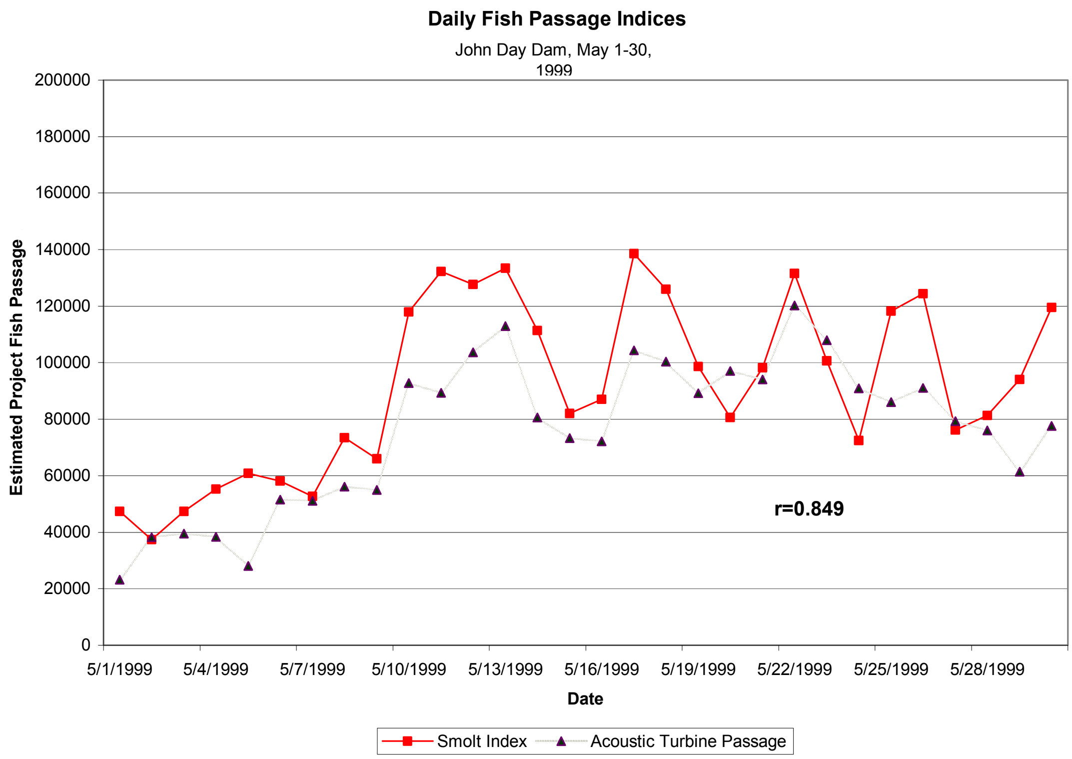


Figure 105. Daily estimated total powerhouse acoustic passage and the John Day smolt monitoring index for the spring monitoring period. John Day Dam, May 1-30, 1999.

Table 27. Daily summer hydroacoustic fish passage estimates compared to smolt monitoring indices. John Day Dam, June 6-July 8, 1999.

	Hydroacoustic Fish Passage			John Day
Date	**Turbine**	**Spill**	**Total Dam**	**Smolt Index**
6-Jun	40063	184231	224294	129471
7-Jun	40710	104022	144732	93500
8-Jun	87863	134454	222317	111251
9-Jun	36418	102167	138585	33072
10-Jun	51774	139812	191586	47095
11-Jun	71011	87266	158277	65941
12-Jun	302849	257498	560346	37088
13-Jun	145071	146067	291139	25933
14-Jun	132802	441430	574231	28411
15-Jun	122433	132005	254438	14511
16-Jun	60184	192614	252798	40851
17-Jun	90408	285463	375870	63193
18-Jun	70266	372358	442624	66976
19-Jun	75203	368290	443492	86563
20-Jun	87840	773374	861213	122305
21-Jun	142422	553908	696330	136763
22-Jun	164990	894359	1059349	168506
23-Jun	143515	803355	946870	186023
24-Jun	83480	883046	966526	130189
25-Jun	77541	639417	716957	77948
26-Jun	42161	652295	694456	95385
27-Jun	65790	694242	760032	174916
28-Jun	240228	248666	488894	290682
29-Jun	210033	302700	512733	273738
30-Jun	200413	1196120	1396533	284786
1-Jul	90607	782746	873353	124955
2-Jul	83081	979333	1062414	70526
3-Jul	104463	358945	463408	105714
4-Jul	86707	110728	197435	61374
5-Jul	107215	233221	340436	87357
6-Jul	75321	956571	1031892	54206
7-Jul	38014	636720	674734	35292
8-Jul	37257	860108	897365	38201

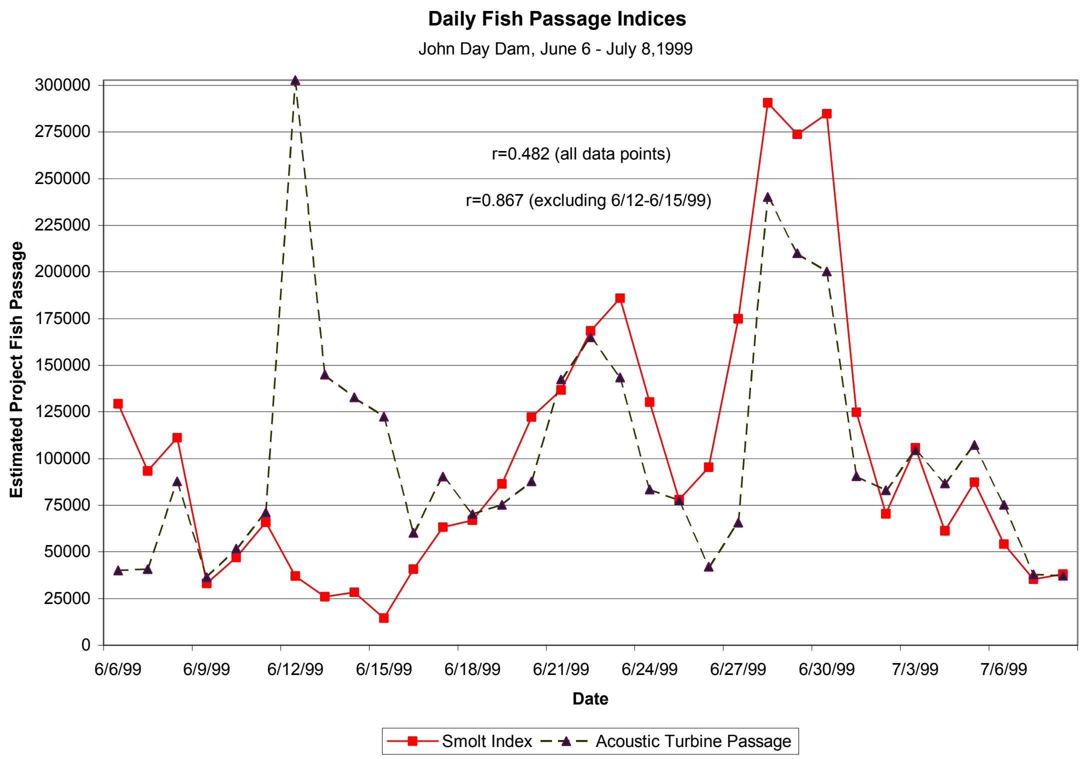


Figure 106. Daily estimated total powerhouse acoustic passage and the John Day smolt monitoring index for the summer monitoring period. John Day Dam, June 6-July 8, 1999

5.0 TASK 2 SPLIT-BEAM BEHAVIORAL STUDY RESULTS

Task 2 employed split-beam hydroacoustic techniques at Spill Bay 18 and Turbine Unit 15 to monitor fish behavior and distribution at the powerhouse and spillway. This data was used to evaluate the validity of the assumptions of the John Day Dam single-beam hydroacoustic passage model, particularly the assumption of comparable entrainment in the monitored spillway and turbine volumes.

5.1 Fish Velocities

Tables 28 and 29 present fish velocity and number of echo summaries by range bin at Spill Bay 18 and Turbine 15 for the period May1-30, 1999. Summary data is presented only for fish passing while the spill bay/turbine was operating.

Mean fish velocity, calculated by range bin and flow condition for Spill 18, ranged from a low of 0.31 m/s to a high of 1.14 m/s. Even for range bins with the highest fish velocity and flow combinations, the average number of echoes received from each target far exceeded the minimum 4 echo criteria. This indicates that for Spill 18, fish were not moving so fast that they violated the assumptions made in the detectability model.

When range bins were combined, the average fish velocity at Spill 18 increased with increasing discharge. The average velocities for the four discharge levels listed in Table 28 were 0.47, 0.59, 0.66, and 0.70 m/s, in order of increasing discharge level.

With rare exceptions, the mean number of echoes calculated by range bin and flow condition for Turbine 15 were also very high, indicating that the assumptions made in the detectability model for turbines were not violated.

The combined range bin average fish velocities at Turbine 15 were relatively constant for all six discharge levels summarized, except for the lowest discharge level of less than 11 kcfs. The overall mean fish velocities for each discharge level in Table 29 were 0.31, 0.64, 0.69, 0.68, 0.62, and 0.66 m/s in order of increasing discharge level.

Mean fish velocity profiles by 1-m range bin for Spill 18 and Turbine 15 are presented in Figures 107-116. Profiles for Spill 18 are presented at four separate discharge levels. Profiles for Turbine 15 are presented at six separate discharge levels.

There was no significant difference in velocity with range at Spill 18 during discharges less than and equal to 1.6, and equal to 7.6 kcfs. For discharges between 2.8 and 3.1 kcfs and at 6.5 kcfs mean fish velocity appeared to increase with range and peaked at 12 to 13 m. During the 1999 spillway deployment, the 12-13 m range bin was at the elevation of the spill gate opening, where water velocities were greatest.

At Turbine 15 there was no significant difference in mean fish velocity below 16 kcfs and greater than 20 kcfs operation. For discharge between 16 and 20 kcfs mean fish velocity appeared to increase with range and peak at 10 m, just below the intake ceiling.

Table 28. Fish velocities and average number of echoes by range bin for Spill Bay 18 from May 1-30, 1999. John Day Dam.

Range	n	Mean # Echoes	Std. Dev. # Echoes	Mean Velocity (m/s)	Std. Dev. Velocity (m/s)	95% Confidence Velocity (m/s)	Range	n	Mean # Echoes	Std. Dev. # Echoes	Mean Velocity (m/s)	Std. Dev. Velocity (m/s)	95% Confidence Velocity (m/s)
Spill Bay 18 Discharge <= 1.6 kcfs							Spill Bay 18 Discharge = 6.5 kcfs						
2	20	25.15	19.15	0.37	0.28	0.12	2	16	20.50	13.65	0.31	0.18	0.09
3	295	22.61	12.75	0.41	0.18	0.02	3	1289	20.65	13.62	0.43	0.27	0.01
4	206	23.67	14.18	0.47	0.19	0.03	4	1082	22.64	14.03	0.47	0.30	0.02
5	139	29.57	14.43	0.48	0.24	0.04	5	818	23.06	14.58	0.56	0.38	0.03
6	89	27.53	14.40	0.43	0.21	0.04	6	681	22.19	13.61	0.68	0.42	0.03
7	43	24.81	16.50	0.65	1.23	0.37	7	488	21.92	13.50	0.76	0.54	0.05
8	21	30.14	18.03	0.43	0.22	0.09	8	405	20.05	13.30	0.86	0.74	0.07
9	18	29.78	16.87	0.73	0.61	0.28	9	358	21.09	13.89	0.90	0.60	0.06
10	14	25.14	12.74	0.70	0.55	0.29	10	373	20.48	14.37	0.97	0.85	0.09
11	12	20.58	13.73	0.66	0.40	0.23	11	395	17.67	13.26	0.87	0.74	0.07
12	10	35.30	19.27	0.98	1.52	0.94	12	304	18.06	16.12	1.01	1.45	0.16
13	4	17.25	18.66	1.04	0.80	0.79	13	99	18.17	13.05	1.14	1.16	0.23
Spill Bay 18 Discharge = 2.8-3.1 kcfs							Spill Bay 18 Discharge = 7.6 kcfs						
2	4	12.75	5.32	0.41	0.27	0.27	3	13	12.54	7.87	0.63	0.32	0.18
3	105	19.72	11.77	0.37	0.18	0.04	4	18	22.28	14.89	0.62	0.47	0.22
4	89	22.19	12.43	0.48	0.24	0.05	5	14	19.79	13.51	0.68	0.22	0.12
5	58	23.84	15.06	0.52	0.29	0.07	6	19	24.63	13.34	0.75	0.31	0.14
6	28	24.79	15.85	0.58	0.31	0.12	7	7	8.86	4.26	0.70	0.26	0.19
7	22	23.09	14.68	0.79	1.20	0.50	8	9	18.56	12.68	0.73	0.24	0.16
8	30	20.87	15.63	0.59	0.37	0.13	9	6	12.67	8.91	0.65	0.31	0.25
9	17	28.59	16.15	0.74	0.53	0.25	10	3	23.33	0.58	1.02	0.40	0.45
10	21	19.29	17.53	0.88	0.76	0.32	11	2	17.50	14.85	0.88	0.07	0.09
11	34	15.68	14.00	1.06	0.86	0.29	13	2	17.50	0.71	0.94	0.43	0.59
12	15	16.67	12.66	1.03	1.51	0.77							
13	6	8.17	3.54	0.78	0.73	0.58							
14	3	14.67	9.07	0.34	0.34	0.38							
15	3	11.33	4.73	0.54	0.67	0.75							

Table 29. Fish velocities and average number of echoes by range bin for Turbine 15 from May 1-30, 1999. John Day Dam.

Range	n	Mean # Echoes	Std. Dev. # Echoes	Mean Velocity (m/s)	Std. Dev. Velocity (m/s)	95% Confidence Velocity (m/s)	Range	n	Mean # Echoes	Std. Dev. # Echoes	Mean Velocity (m/s)	Std. Dev. Velocity (m/s)	95% Confidence Velocity (m/s)
Turbine 15 Discharge <= 11 kcfs							Turbine 15 Discharge = 16-18 kcfs						
5	1	39.00	NA	0.18	NA	NA	2	1	19.00	NA	0.07	NA	NA
6	1	31.00	NA	0.29	NA	NA	3	24	20.88	11.90	0.53	0.36	0.14
7	1	14.00	NA	0.35	NA	NA	4	16	15.81	9.90	0.45	0.21	0.10
8	2	41.00	19.80	0.29	0.08	0.11	5	11	22.09	12.72	0.43	0.28	0.16
9	2	23.00	11.31	0.25	0.07	0.10	6	11	20.45	15.92	0.64	0.32	0.19
10	3	38.00	16.09	0.37	0.20	0.23	7	9	24.67	15.12	0.69	0.17	0.11
11	2	29.00	0.00	0.42	0.33	0.46	8	8	17.50	10.86	1.01	0.42	0.29
12	1	5.00	NA	0.12	NA	NA	9	20	13.65	8.47	0.89	0.28	0.12
14	2	25.50	24.75	0.45	0.07	0.10	10	12	15.67	12.16	0.97	0.34	0.19
15	2	16.00	1.41	0.24	0.17	0.24	11	22	15.77	8.99	0.75	0.21	0.09
							12	16	16.69	12.17	0.84	0.23	0.11
							13	26	14.19	9.20	0.91	0.58	0.22
							14	33	15.24	10.34	0.62	0.53	0.18
							15	47	21.55	11.16	0.51	0.38	0.11
Turbine 15 Discharge = 12-14 kcfs							Turbine 15 Discharge = 18-20 kcfs						
3	1	8.00	NA	0.46	NA	NA	3	25	25.24	15.41	0.37	0.40	0.16
5	3	21.00	7.21	0.57	0.05	0.06	4	20	27.80	14.03	0.47	0.23	0.10
6	6	13.00	5.69	0.80	0.16	0.13	5	12	29.83	12.07	0.54	0.35	0.20
7	12	14.42	7.50	0.84	0.28	0.16	6	12	18.17	8.13	0.89	0.65	0.37
8	5	18.40	11.01	0.88	0.53	0.47	7	7	20.00	12.22	0.83	0.33	0.24
9	11	14.91	9.90	0.77	0.34	0.20	8	6	22.00	18.35	0.77	0.20	0.16
10	12	19.75	10.35	0.63	0.13	0.07	9	10	21.30	18.95	0.88	0.28	0.17
11	8	21.88	10.03	0.72	0.19	0.13	10	9	23.44	11.85	0.91	0.34	0.22
12	8	20.63	6.25	0.68	0.15	0.10	11	14	16.07	10.43	0.42	0.41	0.21
13	13	18.23	10.11	0.58	0.32	0.17	12	9	14.44	9.48	0.94	0.29	0.19
14	32	14.69	9.93	0.43	0.30	0.10	13	8	18.88	19.34	0.70	0.39	0.27
15	22	20.00	13.16	0.66	0.56	0.23	14	24	14.58	10.63	0.55	0.61	0.25
							15	20	11.10	5.86	0.74	0.38	0.17
Turbine 15 Discharge = 14-16 kcfs							Turbine 15 Discharge = 20-22 kcfs						
3	1	11.00	NA	0.71	NA	NA	3	8	11.00	9.23	0.15	0.14	0.10
4	4	12.75	6.08	0.74	0.16	0.16	4	2	5.50	0.71	1.34	0.26	0.36
5	7	13.57	3.78	0.70	0.18	0.13	5	1	4.00	NA	1.03	NA	NA
6	7	17.14	9.01	0.81	0.24	0.18	7	2	13.00	2.83	1.03	0.06	0.08
7	11	11.00	5.97	0.79	0.13	0.08	8	1	16.00	NA	0.68	NA	NA
8	8	13.38	9.91	0.75	0.24	0.17	9	1	28.00	NA	0.47	NA	NA
9	10	19.50	11.96	0.72	0.30	0.19	10	2	17.50	12.02	1.24	0.46	0.64
10	13	13.00	11.60	0.70	0.17	0.09	11	6	10.67	4.89	0.83	0.57	0.45
11	25	20.36	14.95	0.75	0.26	0.10	12	1	28.00	NA	0.65	NA	NA
12	12	20.50	11.24	0.67	0.16	0.09	13	5	22.60	18.51	0.72	0.58	0.51
13	16	15.94	8.44	0.89	0.44	0.22	14	6	7.67	3.83	1.11	1.17	0.94
14	26	16.46	12.39	0.68	0.58	0.22	15	19	16.84	11.57	0.48	0.38	0.17
15	41	19.29	11.37	0.52	0.34	0.10							

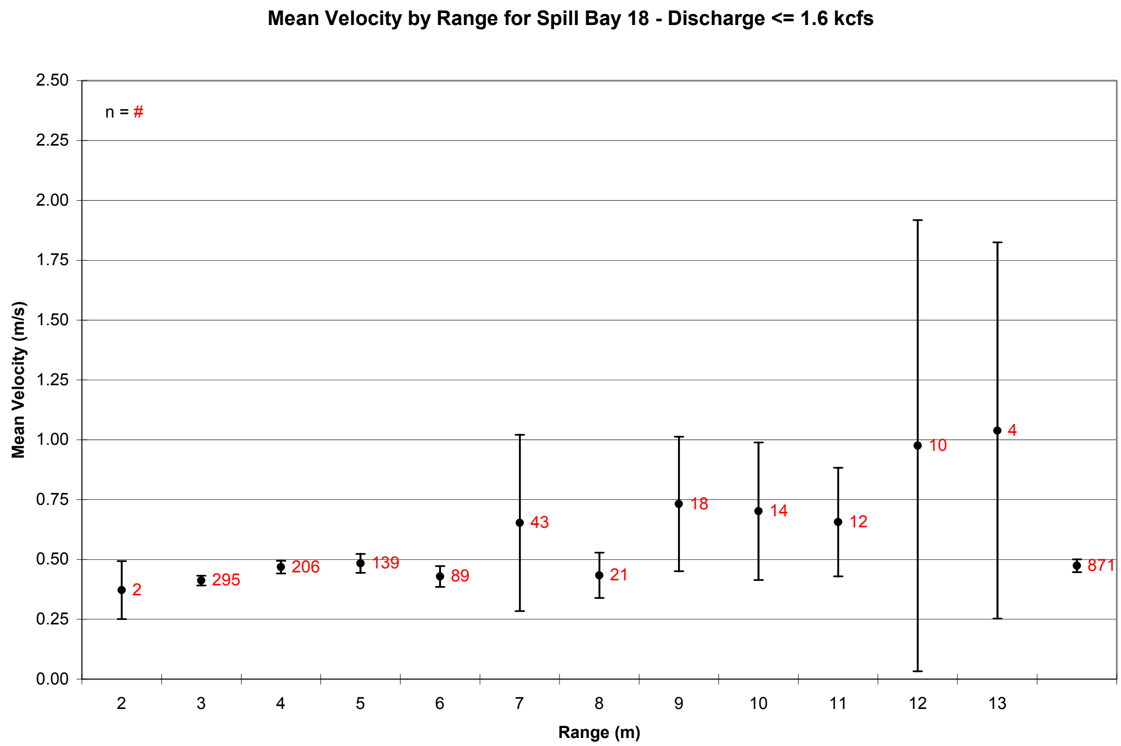


Figure 107. Observed mean fish velocity by 1 m-range bin at Spill Bay 18 during discharge of <= 1.6 kcfs. John Day Dam, May 1-30. 1999.

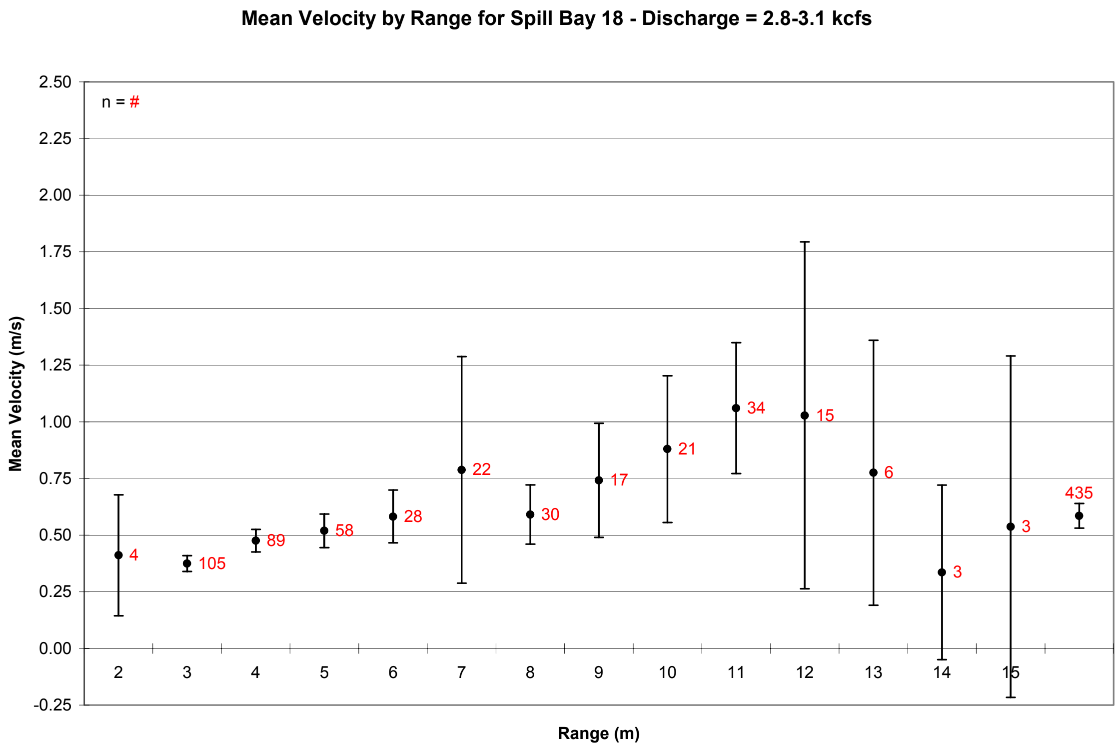


Figure 108. Observed mean fish velocity by 1 m-range bin at Spill Bay 18 during discharge of 2.8-3.1 kcfs. John Day Dam, May 1-30. 1999.

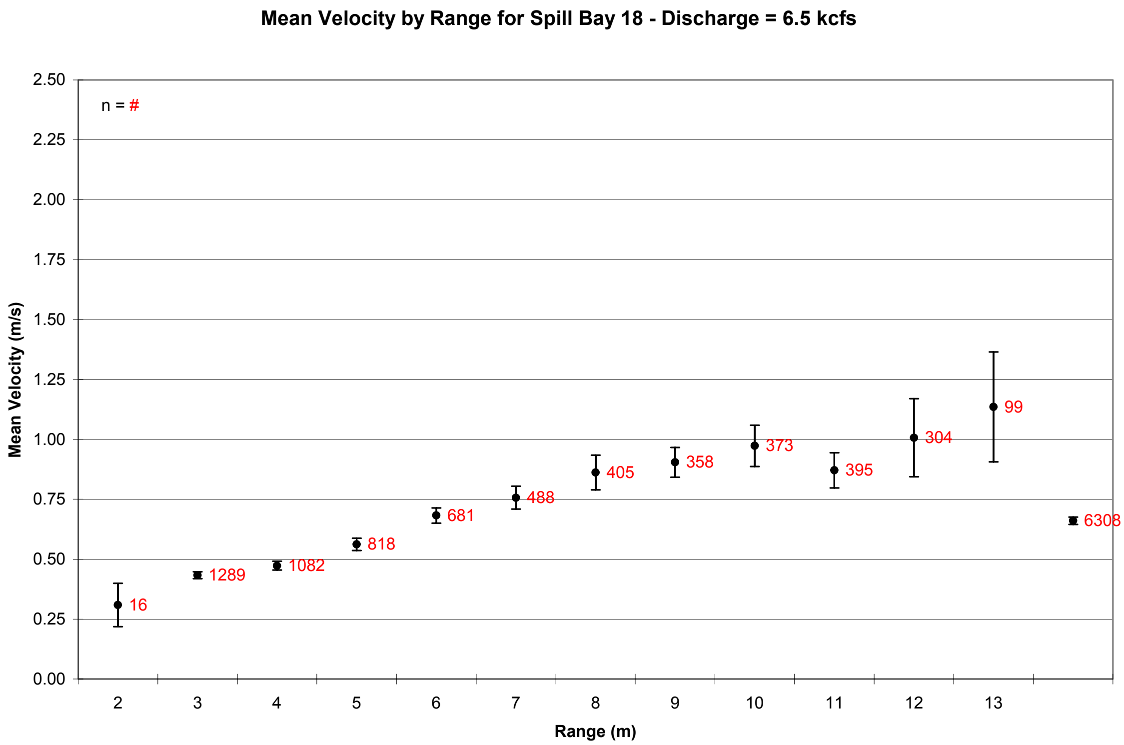


Figure 109. Observed mean fish velocity by 1 m-range bin at Spill Bay 18 during discharge of 6.5 kcfs. John Day Dam, May 1-30. 1999.

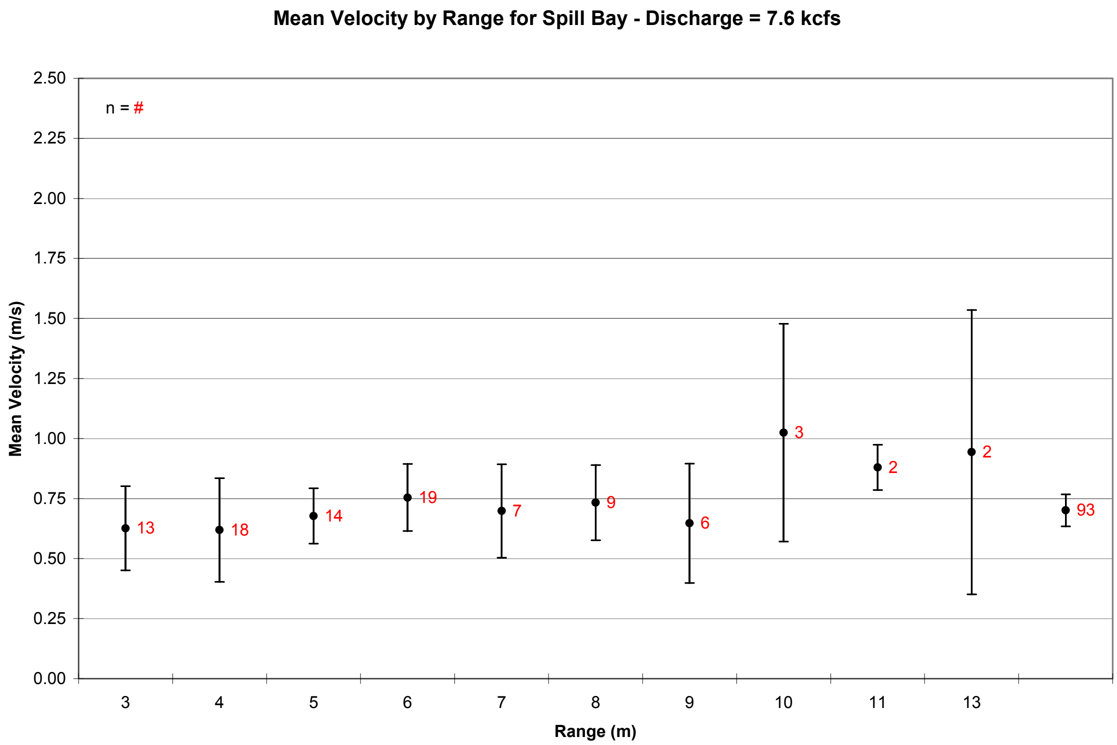


Figure 110. Observed mean fish velocity by 1 m-range bin at Spill Bay 18 during discharge of 7.6 kcfs. John Day Dam, May 1-30, 1999.

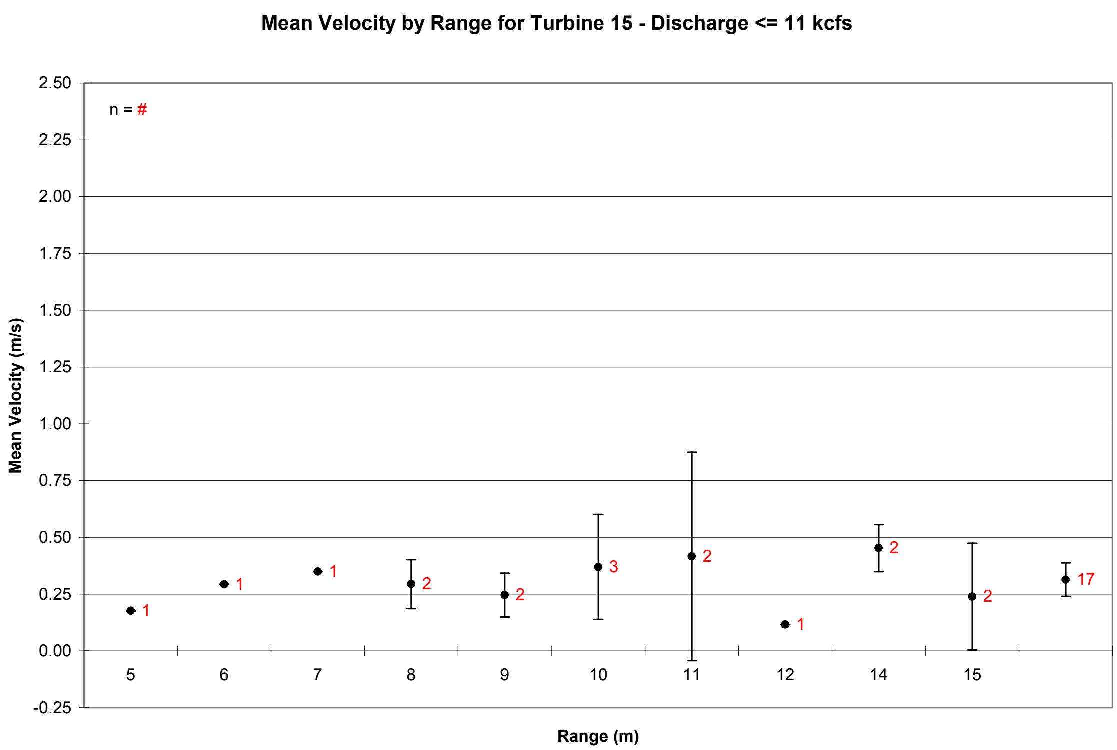


Figure 111. Observed mean fish velocity by 1 m-range bin at Turbine 15 during discharge of <=11 kcfs. John Day Dam, May 1-30, 1999.

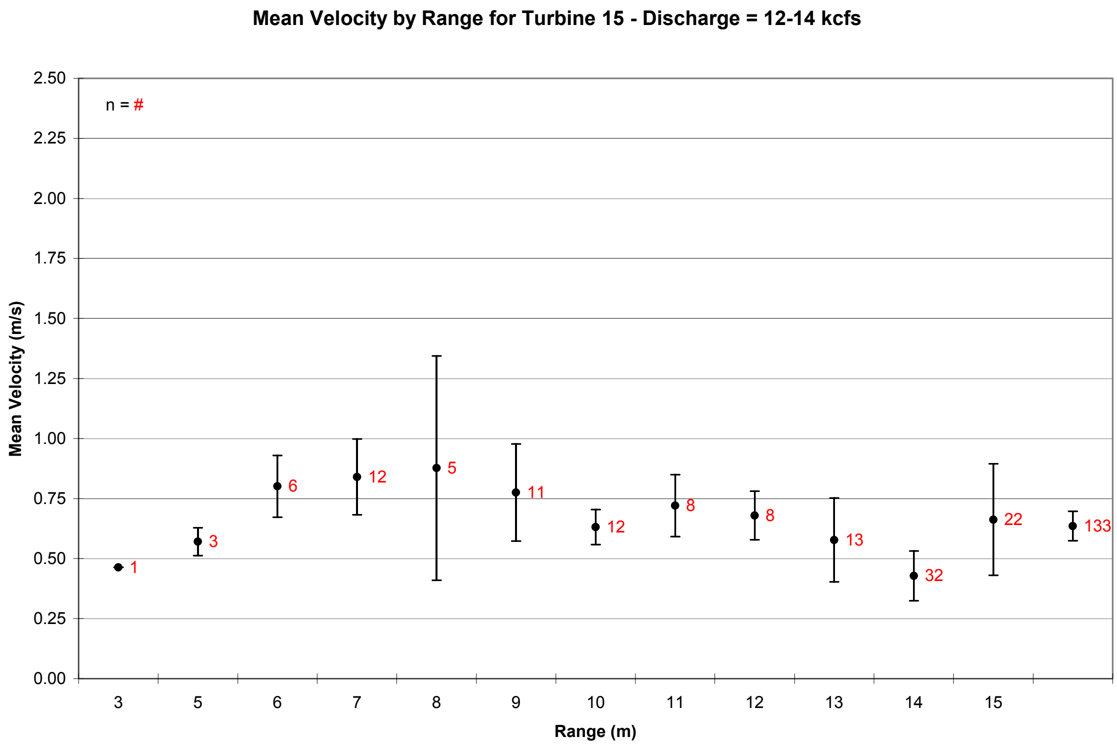


Figure 112. Observed mean fish velocity by 1 m-range bin at Turbine 15 during discharge of 12-14 kcfs. John Day Dam, May 1-30, 1999.

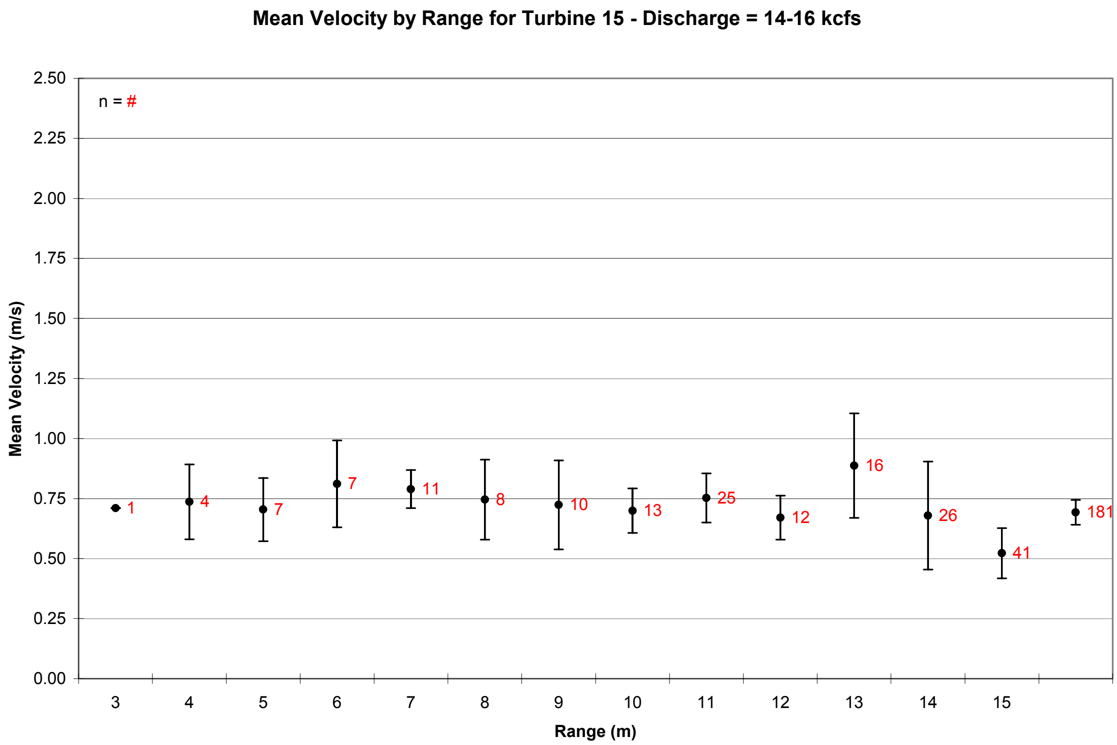


Figure 113. Observed mean fish velocity by 1 m-range bin at Turbine 15 during discharge of 14-16 kcfs. John Day Dam, May 1-30, 1999.

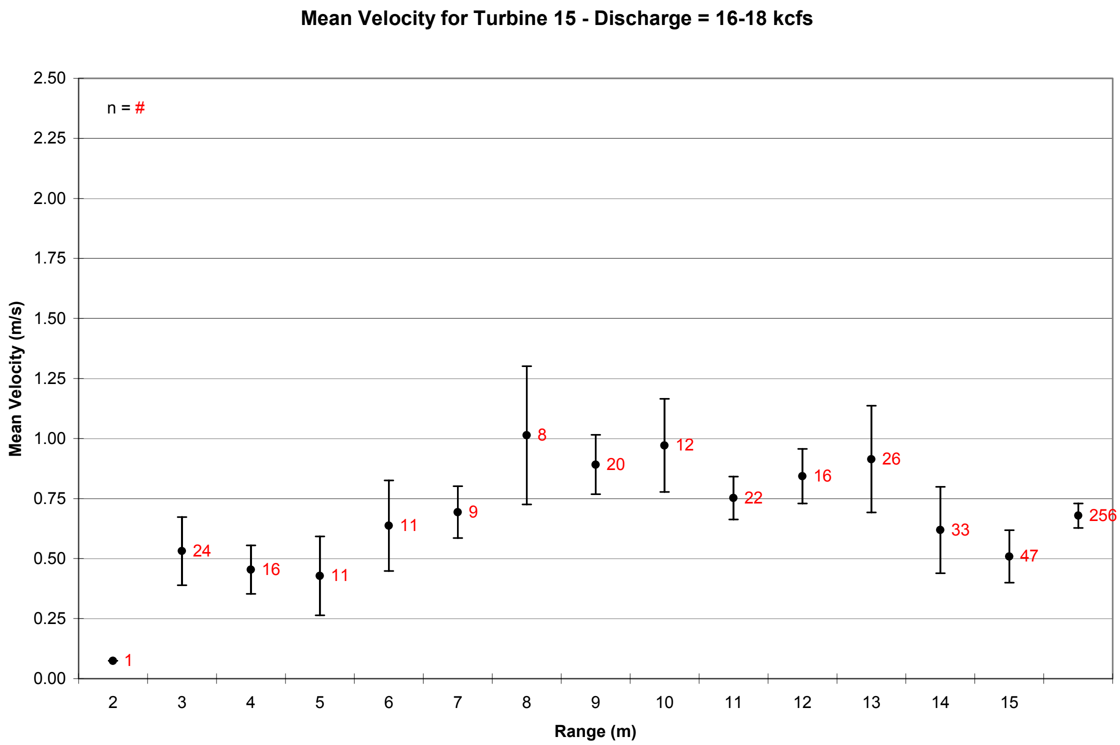


Figure 114. Observed mean fish velocity by 1 m-range bin at Turbine 15 during discharge of 16-18 kcfs. John Day Dam, May 1-30, 1999.

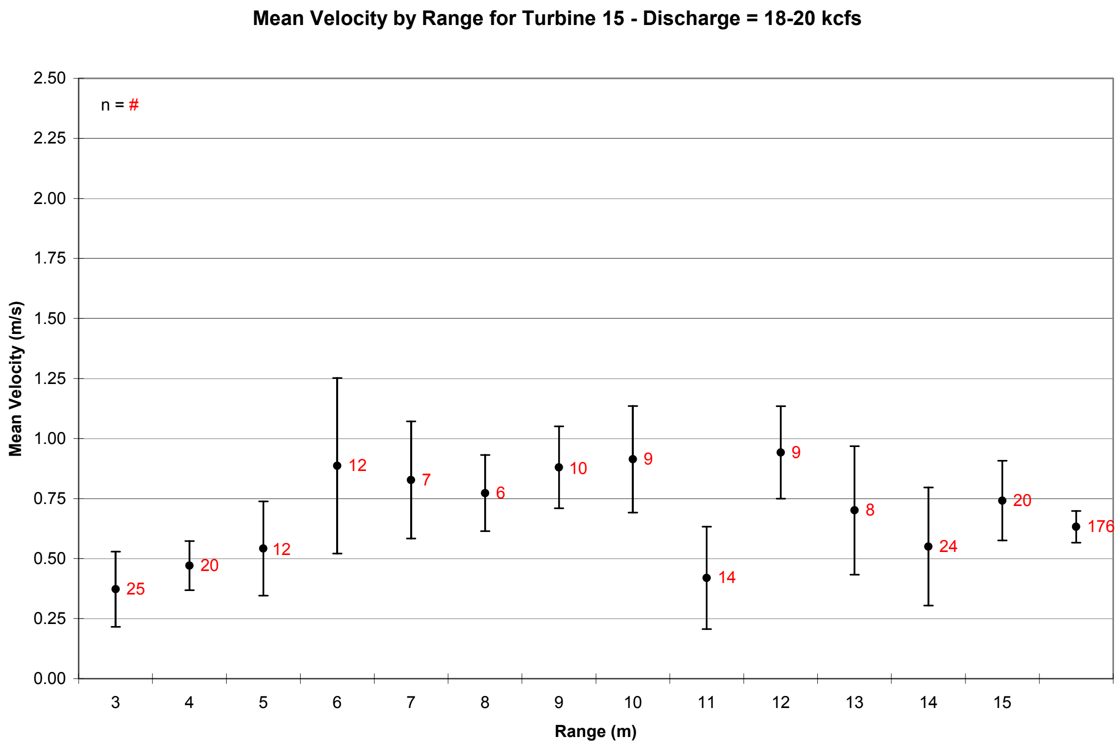


Figure 115. Observed mean fish velocity by 1 m-range bin at Turbine 15 during discharge of 18-20 kcfs. John Day Dam, May 1-30, 1999.

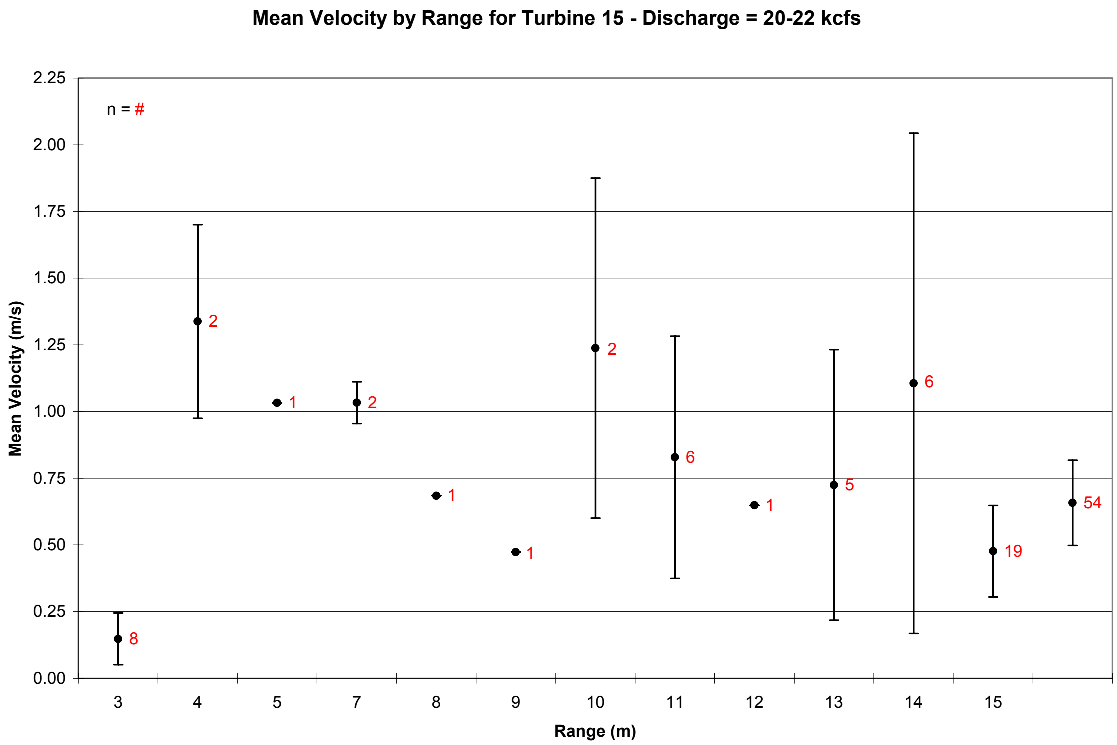


Figure 116. Observed mean fish velocity by 1 m-range bin at Turbine 15 during discharge of 20-22 kcfs. John Day Dam, May 1-30, 1999.

5.2 Fish Angle Off Axis

Table 30 presents the mean fish angle-off axis as the midpoint position of tracked fish in the X (north-south) plane by 1-m range bin (Z-axis).

Figures 117 and 118 plot the mean X (north-south) positions of each tracked fish in Spill Bay 18 and Turbine Unit 15 respectively.

There were no strong trends in the horizontal position of the tracked fish at either Spill Bay 18 or Turbine 15, indicating that within the acoustic sample volume, horizontal distribution was relatively constant. Distinct biases in distribution were not observed across either the monitored penstock or spill bay openings

Table 30. Midpoint position of tracked fish in the X (North-South) plane by range bin for Spill Bay 18 and Turbine 15. John Day Dam 1999.

Range	Spill 18		Turbine 15	
	n	Average Midpoint X	n	Average Midpoint X
3	2333	0.0366	16	0.0062
4	1986	0.0373	13	-0.0019
5	1439	0.0221	13	-0.0133
6	1026	0.0080	27	-0.0034
7	664	0.0580	40	-0.0216
8	525	0.0291	28	-0.0303
9	437	0.0021	51	-0.0512
10	446	0.0038	48	0.0220
11	482	0.1747	80	-0.0571
12	346	0.1709	53	-0.0392
13	118	-0.0211	77	-0.0538
14	---	---	131	0.0567
15	---	---	161	-0.0947

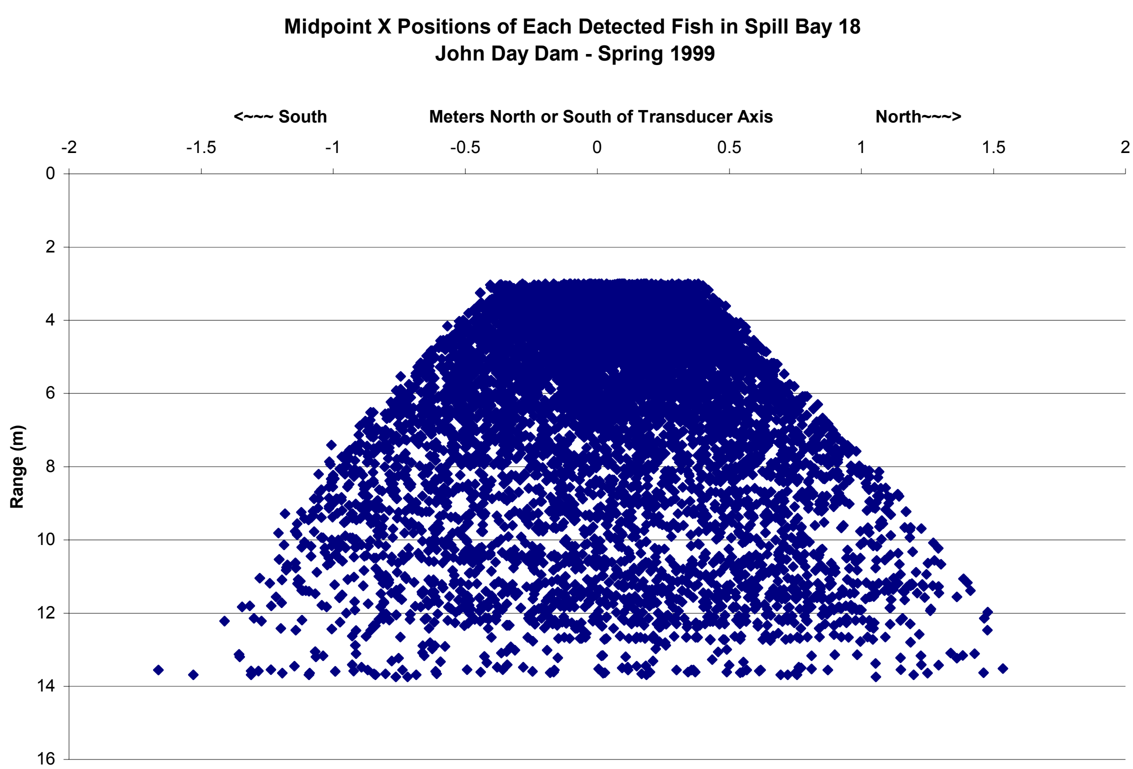


Figure 117. Midpoint X positions of all fish tracks from Spill Bay 18 as observed by the Task 2 split-beam system. John Day Dam, May 1-30, 1999.

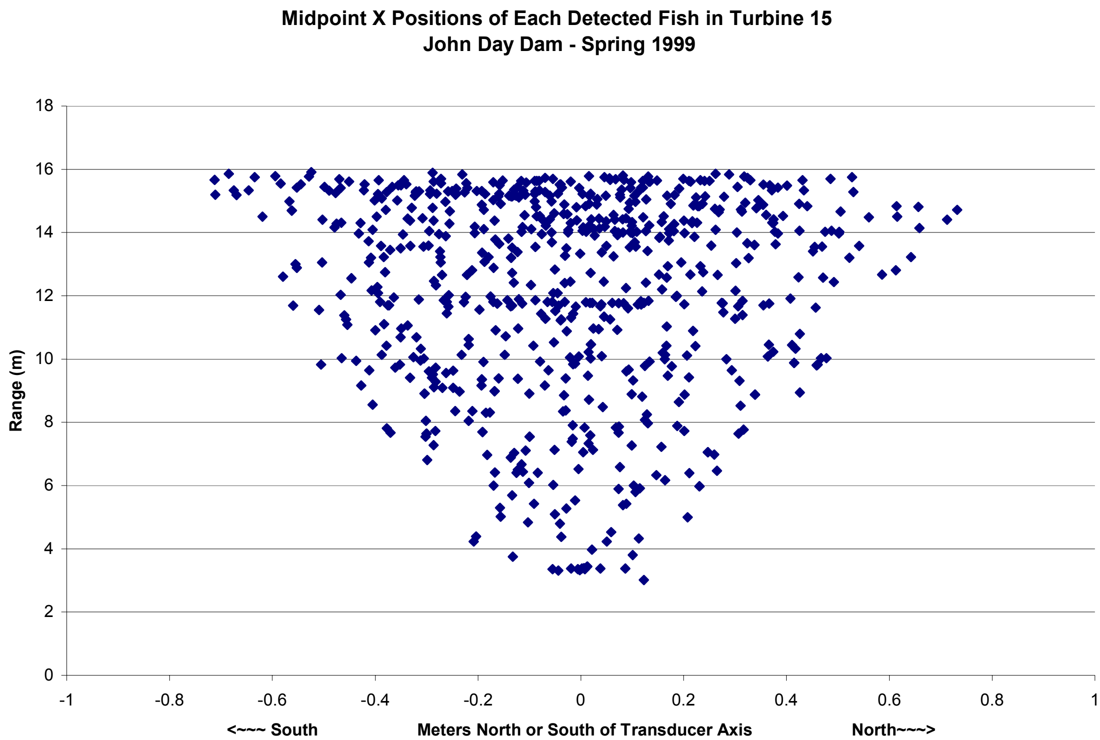


Figure 118. Midpoint X positions of all fish tracks from Turbine Unit 15 as observed by the Task 2 split-beam system. John Day Dam, May 1-30, 1999.

5.3 Fish Direction of Travel

Mean fish direction of travel upstream/downstream (i.e., in the Y direction) and north-south (i.e., in the X direction) was estimated for each 1-m range bin (Z-axis). Table 31 presents estimated fish passage (detected fish weighted for time and space) and percent estimated fish passage by direction of movement and range bin for Spill Bay 18 and Turbine Unit 15.

Figures 119-126 plot the results described in Table 31, where each plot presents either estimated passage or percent estimated passage for positive and negative directions of travel in each plane, by range bin.

Fish movement in Spill Bay 18 and Turbine 15 is consistent with entrainment. In Spill Bay 18, fish moved downstream diving toward the spill ogee. Beyond the ogee fish were observed to change direction of movement, ascending toward the spill gate. In Turbine 15, fish moved downstream diving toward the transducer.

Fish trajectory distributions at Spill Bay 18 over the May 1-30 study period observed did not exhibit large-scale milling behavior. On a seasonal basis, the majority (77%) of all observed fish exhibited net movement toward the spill gate opening, i.e. downstream (transducer Y-axis movement >0). Net downstream movement was lower near the surface (65-73% within 3 m of the transducer) and below the spill ogee (0-77% below 10 m). In the area of presumably higher flow immediately above and in front of the spillway gate opening (5-9 m range), net downstream movement was higher, varying between 82-88%.

The majority (75%) of observed fish above the Spill Bay 18 ogee exhibited diving behavior toward the spill gate opening. The frequency of this behavior increased with depth to an elevation just above the ogee. Immediately in front of the ogee, fish were generally moving straight in to the gate opening, parallel with the surface. Below the ogee, fish were generally ascending in the water column, toward the ogee elevation. These observations are consistent with estimated vertical flow patterns into the spill bays. Presumably most fish are oriented with and following this flow net.

Fish trajectory distributions in the Turbine 15 penstock indicated that the majority of fish observed in-turbine were entrained. As the transducers at the powerhouse were oriented differently than at the spillway (aimed 40° downstream perpendicular to the penstock ceiling), net fish movement in both the Y- and Z-axes of the transducer was considered to determine downstream fish movement. At Turbine 15, 90% of all observed fish exhibited net negative Y-axis direction-of-travel and/or positive Z-axis movement (increasing range) over time, consistent with turbine entrainment.

Fish horizontal approach trajectories (planar view, i.e. N-S relative to the upstream face of the dam) at Spill Bay 18 were consistently downstream, but N-S approach angles varied with range (depth). General rotations of mean horizontal fish approach vectors from south to north were observed with increasing depth. For the May 1-30 Task 2 monitoring period, mean fish approach angles were from the southeast near the surface (above 5 m range), essentially perpendicular to the face of the dam between 5-7 m range, and from the northeast below 7 m. These patterns may reflect patterns of flow upstream of Spill Bay 18.

Mean observed fish velocity at Turbine 15 was 1.3 m/sec (4.1 fps) for the spring 30-d study period. Turbine 15 fish velocities by 1-m range strata varied between 0.8 - 1.6 m/sec (1.3 - 3.6 fps), generally increasing with range toward the intake ceiling.

Mean observed fish velocity at Spill Bay 18 was 0.6 m/sec (1.9 fps) for the spring 30-d study period. Spill Bay 18 fish velocities by 1-m range strata varied between 0.4 - 1.1 m/sec (2.6 - 5.2 fps), increasing with range (depth) to the area immediately upstream of the spillway ogee, then decreasing slightly below that elevation.

Overall, 77% of all observed fish had net downstream movement toward the spill gate. Applying this factor globally to spill entrainment would reduce spill efficiency estimates by approximately 30%; i.e. a 75% spill efficiency estimate would be reduced to approximately 58%. However, several factors should be considered before applying a directional apportionment factor to total spillway entrainment estimates. These include:

1) The Spill Bay 18 split-beam transducer was located several meters upstream of the gate opening. Net downstream movement at this location may not be absolutely correlated with fish behavior immediately in front of the spill gate.

2) The downlooking transducer had a relatively small sampling volume near the surface. Vertical distributions at the spillway revealed fish were generally surface-oriented. Fish observed near the surface (within 4-m range) had lower percentages of net downstream-movement relative to fish at greater depth, but these data are based on a limited sampling volume at the center of the bay.

3) In the absence of ground-truth information on fish entrainment at the spill gate opening, any net downstream fish movement (negative transducer Y-axis travel) was assumed to be equally correlated with entrainment. Fish with only a few cm of net downstream movement were grouped with targets exhibiting 2-m or more net downstream movement. Fish may require some minimum distance made good (weighted for increasing transducer sampling volume with range) to be considered entrained.

Table 31. Total estimated and percent fish passage with range by observed net Y- and Z-axis direction-of-movement at Spill Bay 18 and Turbine Unit 15, John Day Dam, May 1-30, 1999. Note: Both transducers are oriented such that Y-axis movement corresponds to upstream-downstream and Z-axis movement to change in range from the transducer.

Estimated Total Fish Passage by Y and Z Axes

Split Beam Location	Vector	Consistent w/ Entrainment?	Estimated Fish Passage	Range Bin (m) 2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spill 18	+Y	Yes	177885	1365	57560	39698	25172	17470	10848	7463	5999	4848	3902	2523	1027	11	0
Spill 18	+Z	Yes	167670	0	53422	37834	23469	17495	10937	8109	6165	4694	3322	1890	302	22	10
Spill 18	-Y	No	52390	734	21502	11527	5638	3238	1451	1513	908	1495	2305	1727	299	22	31
Spill 18	-Z	No	62604	2099	25640	13391	7340	3213	1362	868	742	1649	2885	2360	1023	11	21
Spill 18	All	----	***230274***	***2099***	***79062***	***51225***	***30809***	***20708***	***12299***	***8977***	***6906***	***6343***	***6207***	***4250***	***1326***	***33***	***31***
Turbine 15	-Y	Yes	34818	181	3762	2250	1753	2016	2537	1572	2735	2483	3366	1872	2309	3733	4248
Turbine 15	+Z	Yes	41004	0	6815	4694	2809	2822	3081	1839	3063	2443	3415	1565	2185	3018	3255
Turbine 15	+Y	No	16760	0	5647	3038	1881	1227	618	403	426	270	334	221	485	1012	1197
Turbine 15	-Z	No	10574	181	2594	594	825	421	74	136	97	310	285	528	610	1727	2190
Turbine 15	-Y or +Z	Yes	46658	181	7991	4919	3004	2979	2858	1846	2864	2537	3557	1962	2548	4439	4975
Turbine 15	All	----	***51578***	***181***	***9409***	***5288***	***3634***	***3243***	***3156***	***1975***	***3161***	***2753***	***3700***	***2094***	***2794***	***4745***	***5445***

Percentage Fish Passage by Y and Z Axes

Split Beam Location	Vector	Consistent w/ Entrainment?	Estimated Fish Passage	Range Bin (m) 2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spill 18	+Y	Yes	77%	65%	73%	77%	82%	84%	88%	83%	87%	76%	63%	59%	77%	33%	0%
Spill 18	+Z	Yes	73%	0%	68%	74%	76%	84%	89%	90%	89%	74%	54%	44%	23%	67%	34%
Spill 18	-Y	No	23%	35%	27%	23%	18%	16%	12%	17%	13%	24%	37%	41%	23%	67%	100%
Spill 18	-Z	No	27%	100%	32%	26%	24%	16%	11%	10%	11%	26%	46%	56%	77%	33%	66%
Turbine 15	-Y	Yes	68%	100%	40%	43%	48%	62%	80%	80%	87%	90%	91%	89%	83%	79%	78%
Turbine 15	+Z	Yes	79%	0%	72%	89%	77%	87%	98%	93%	97%	89%	92%	75%	78%	64%	60%
Turbine 15	+Y	No	32%	0%	60%	57%	52%	38%	20%	20%	13%	10%	9%	11%	17%	21%	22%
Turbine 15	-Z	No	21%	100%	28%	11%	23%	13%	2%	7%	3%	11%	8%	25%	22%	36%	40%
Turbine 15	-Y or +Z	Yes	90%	100%	85%	93%	83%	92%	91%	93%	91%	92%	96%	94%	91%	94%	91%

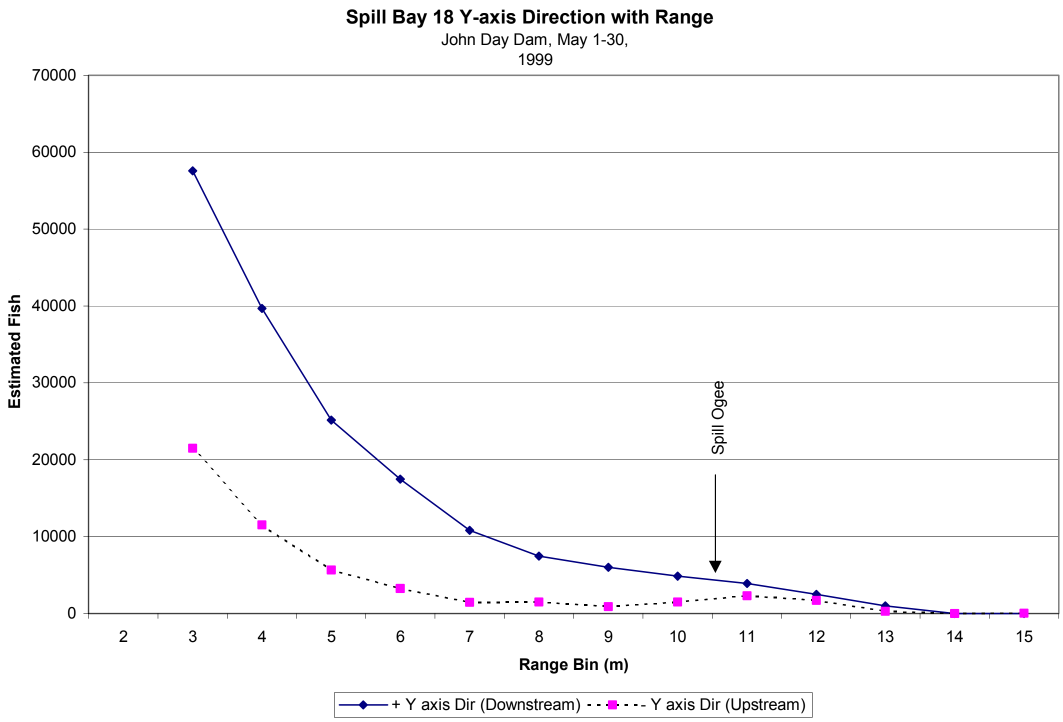


Figure 119. Estimated fish passage with range at Spill Bay 18 by Y-axis direction (upstream-downstream). John Day Dam, May 1-28, 1999. Note: positive Y-axis movement is downstream at S18 and includes all fish with net Y-axis movement >0. Negative Y-axis movement is upstream at S18 and includes all fish with net Y-axis movement >=0.

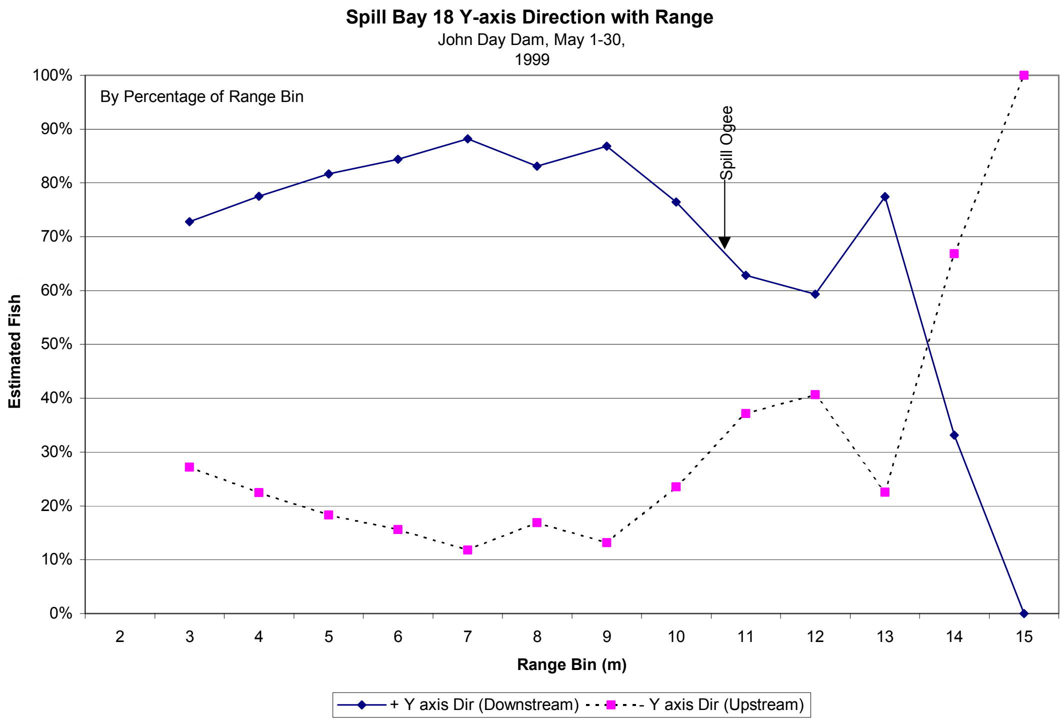


Figure 120. Percent fish passage with range at Spill Bay 18 by Y-axis direction (upstream-downstream). John Day Dam, May 1-28, 1999. Note: Each value expresses the percentage of fish in that range bin exhibiting the denoted net direction-of-movement.

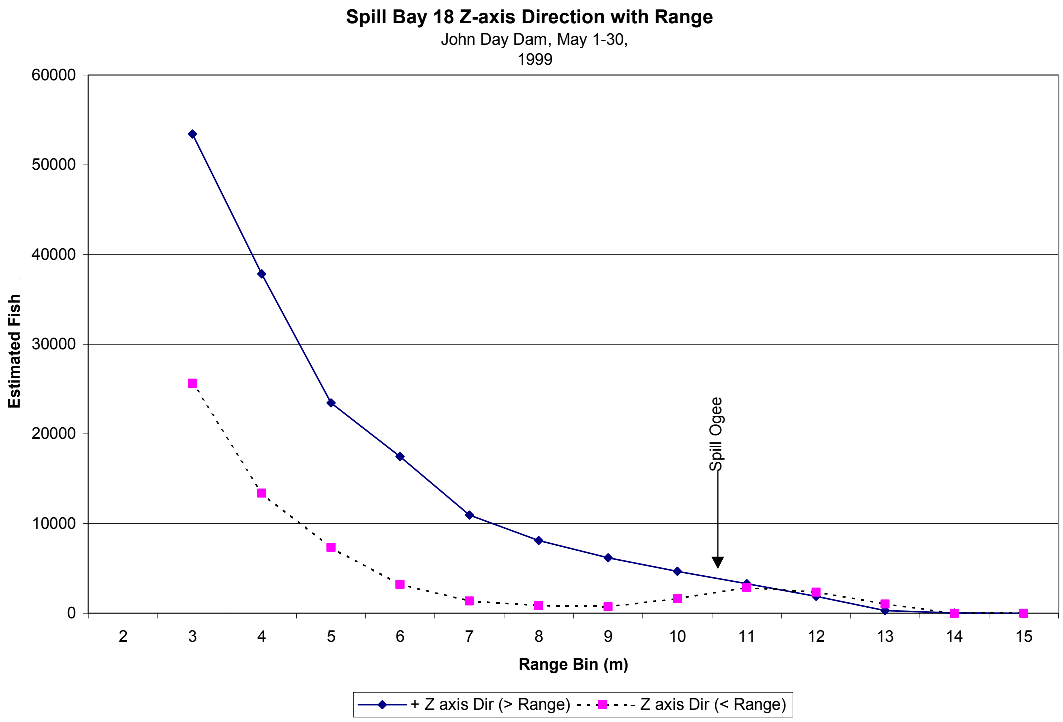


Figure 121. Estimated fish passage with range at Spill Bay 18 by Z-axis direction (range from the transducer)). John Day Dam, May 1-28, 1999. Note: positive Z-axis movement indicates increasing range consistent with diving behavior at S18 and includes all fish with net Z-axis movement >0. Negative Z-axis movement is up in the water column at S18 and includes all fish with net Y-axis movement >=0.

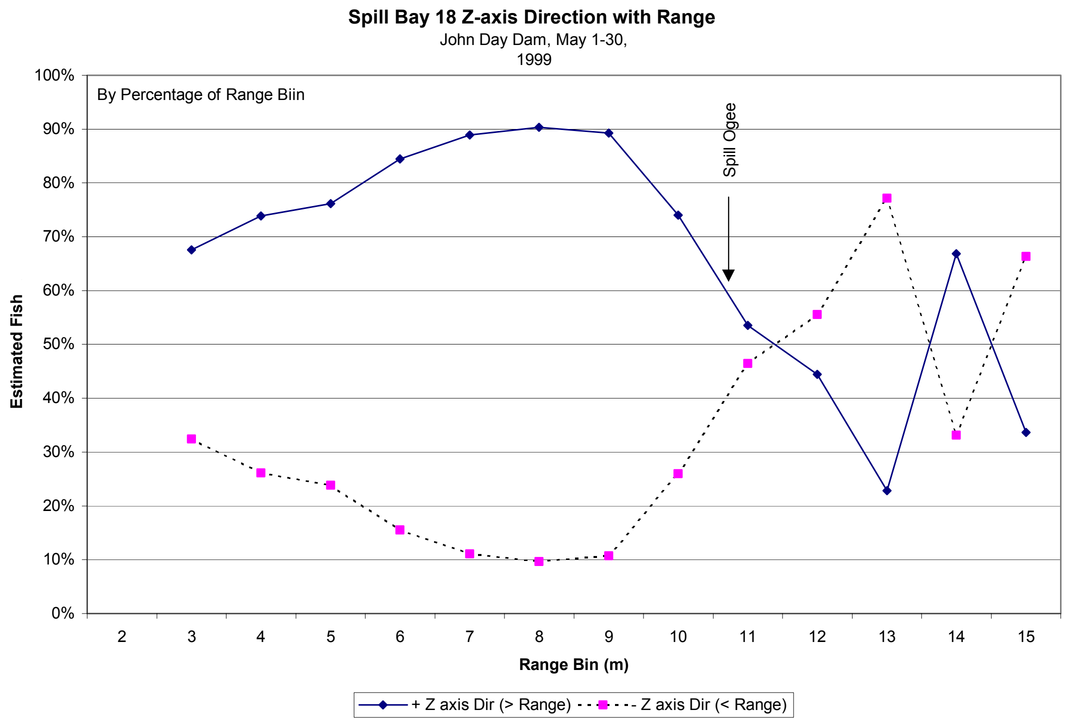


Figure 122. Percent fish passage with range at Spill Bay 18 by Z-axis direction (negative=ascending, positive=diving). John Day Dam, May 1-28, 1999. Note: Each value expresses the percentage of fish in that range bin exhibiting the denoted net direction-of-movement.

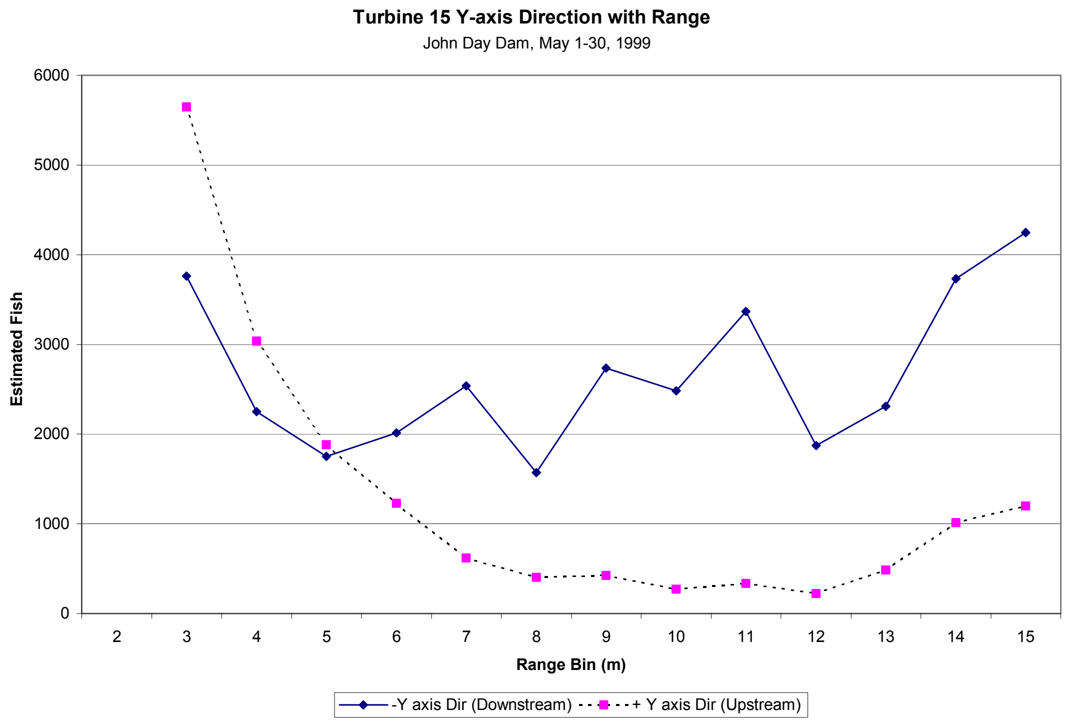


Figure 123. Estimated fish passage with range at Turbine 15 by Y-axis direction (upstream-downstream). John Day Dam, May 1-28, 1999. Note: positive Y-axis movement is generally upstream at T15 and includes all fish with net Y-axis movement >=0. Negative Y-axis movement is generally downstream at T15 and includes all fish with net Y-axis movement >0

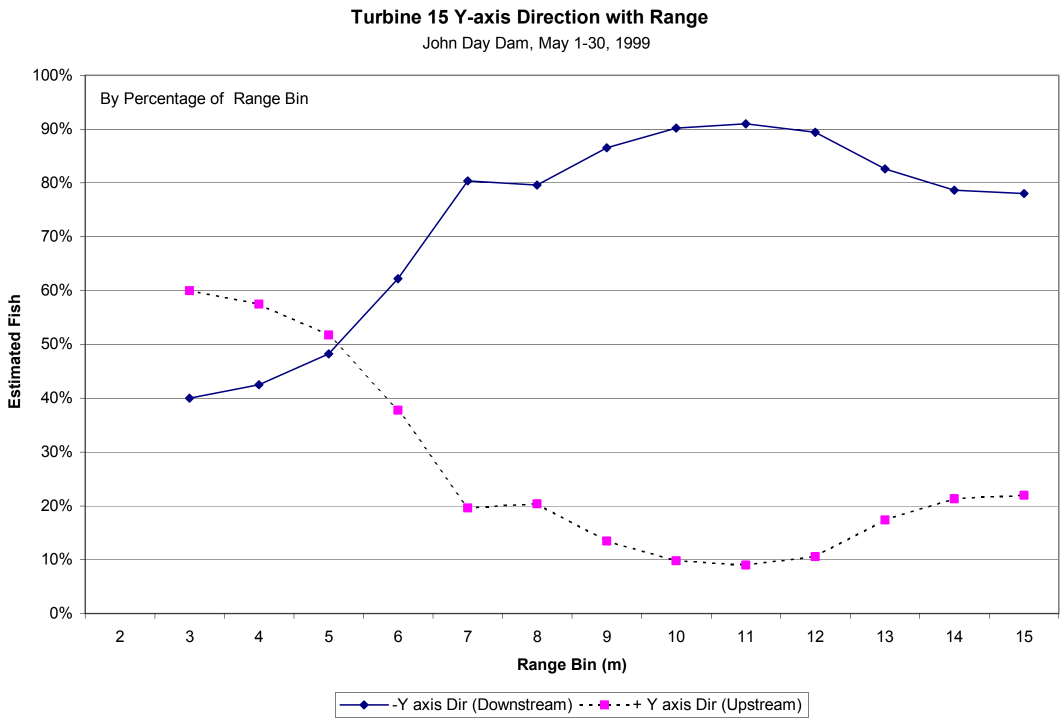


Figure 124. Percent fish passage with range at Turbine 15 by Y-axis direction (upstream-downstream). John Day Dam, May 1-28, 1999. Note: Each value expresses the percentage of fish in that range bin exhibiting the denoted net direction-of-movement.

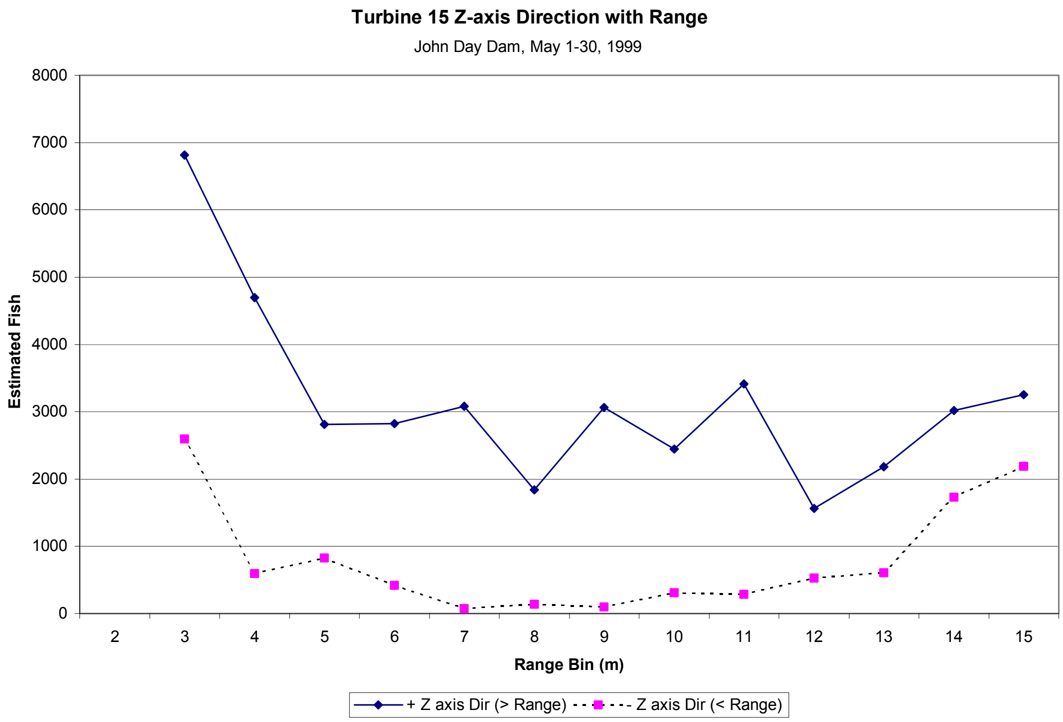


Figure 125. Estimated fish passage with range at Turbine 15 by Z-axis direction (range). John Day Dam, May 1-28, 1999. Note: positive Z-axis movement indicates increasing range consistent with movement downstream away from the transducer at T15 and includes all fish with net Z-axis movement >0. Negative Z-axis movement is toward the transducer and includes all fish with net Z-axis movement >=0.

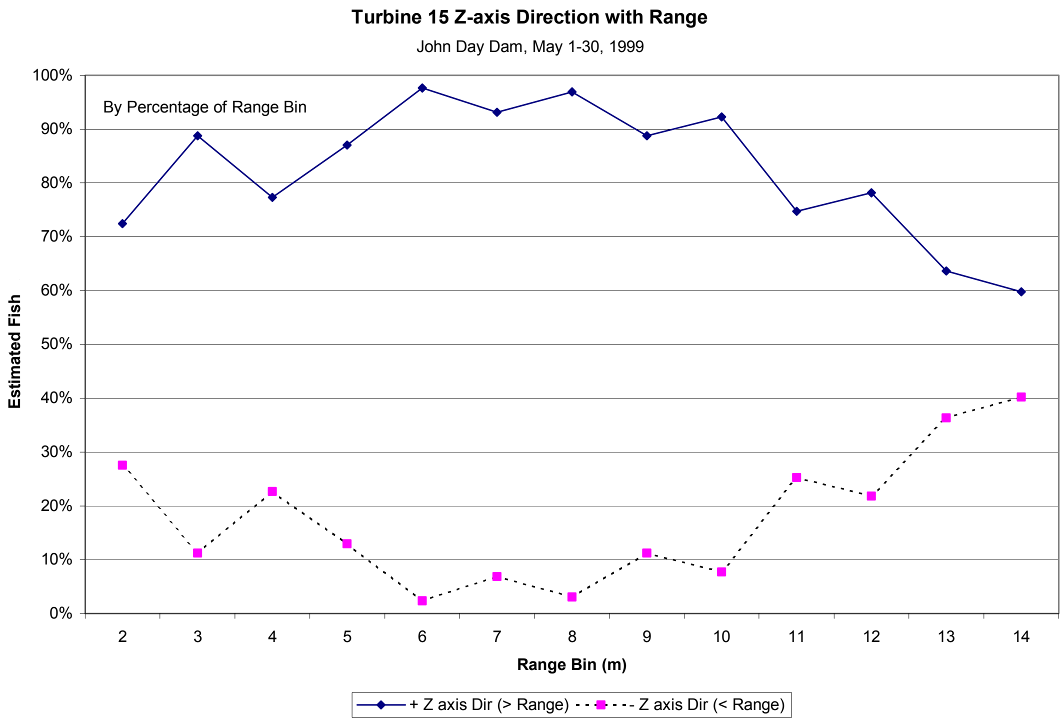


Figure 126. Percent fish passage with range at Turbine 15 by Z-axis direction (negative=toward the transducer and positive=away). John Day Dam, May 1-28, 1999. Note: Each value expresses the percentage of fish in that range bin exhibiting the denoted net direction-of-movement.

5.4 Fish Three-Dimensional Trajectory at Spill 18

The three-dimensional trajectory of fish detected at Spill Gate 18 was of special concern because fish were strongly surface oriented, well above the spill gate opening, where water velocities were low and fish may not have been entrained.

Fish mean three-dimensional trajectory profiles were calculated for each 1-m range bin, by discharge volume. Spill Gate 18 was operated at primarily three flow levels when open. These were 1.6, 3.2, and 6.5 kcfs (See Figure 13 and Section 3.7). The three-dimensional trajectory data were summarized in three groups: all spill fish regardless of unit flow, fish that passed during low spill (less than 4 kcfs), and fish that passed during high spill (greater than 4 kcfs).

Figures 127a-k present the average trajectory of all fish detected at Spill Gate 18 in the upstream-downstream (north-south, east-west) plane by 1m range bin. Confidence limits at the 95% level for each trajectory were calculated based on the mean and standard deviation of the endpoints of each trajectory line.

Figures 128a-k present the average trajectory of fish detected during spill levels less than 4 kcfs at Spill Gate 18 in the upstream-downstream (north-south, east-west) plane by 1m range bin.

Figures 129a-k present the average trajectory of fish detected during spill levels greater than 4 kcfs at Spill Gate 18 in the upstream-downstream (north-south, east-west) plane by 1m range bin.

Figures 127-129 display the observed fish approach vectors in the X-Y dimension (viewed from above) with depth at Spill Bay 18. The circles denote the transducer beam diameter at that depth midpoint, the arrows the mean fish approach vector and the paired dark lines represent the 95% error bound around the fish vector. The lengths of the red fish vectors are generally proportional to the sample size within the estimate.

With the exception of fish detected at low discharge levels near and beyond the spill ogee, all of the plots show fish trajectories indicating entrainment of the majority of fish observed within a given stratum.

Figure 130 presents a three-dimensional view of the average trajectories of fish tracks detected at Spill Bay 18 by 1-m range bin. The yellow blocks represent the mean fish entrance point into the beam and the red blocks the mean exit point. The figure is oriented such that the right side of the page represents upstream and the left side of the figure the face of the dam. As range increases, the trajectory of detected fish exhibits a gradual counter-clockwise rotation. Near the surface, fish exhibited a trajectory that was slightly toward the north, while those at far range exhibited a trajectory that was slightly toward the south.

Figure 127a-f. X-Y Trajectories of Spill 18 fish at all spill levels combined based on the Task 2 split-beam data. John Day Dam, May 1-30, 1999

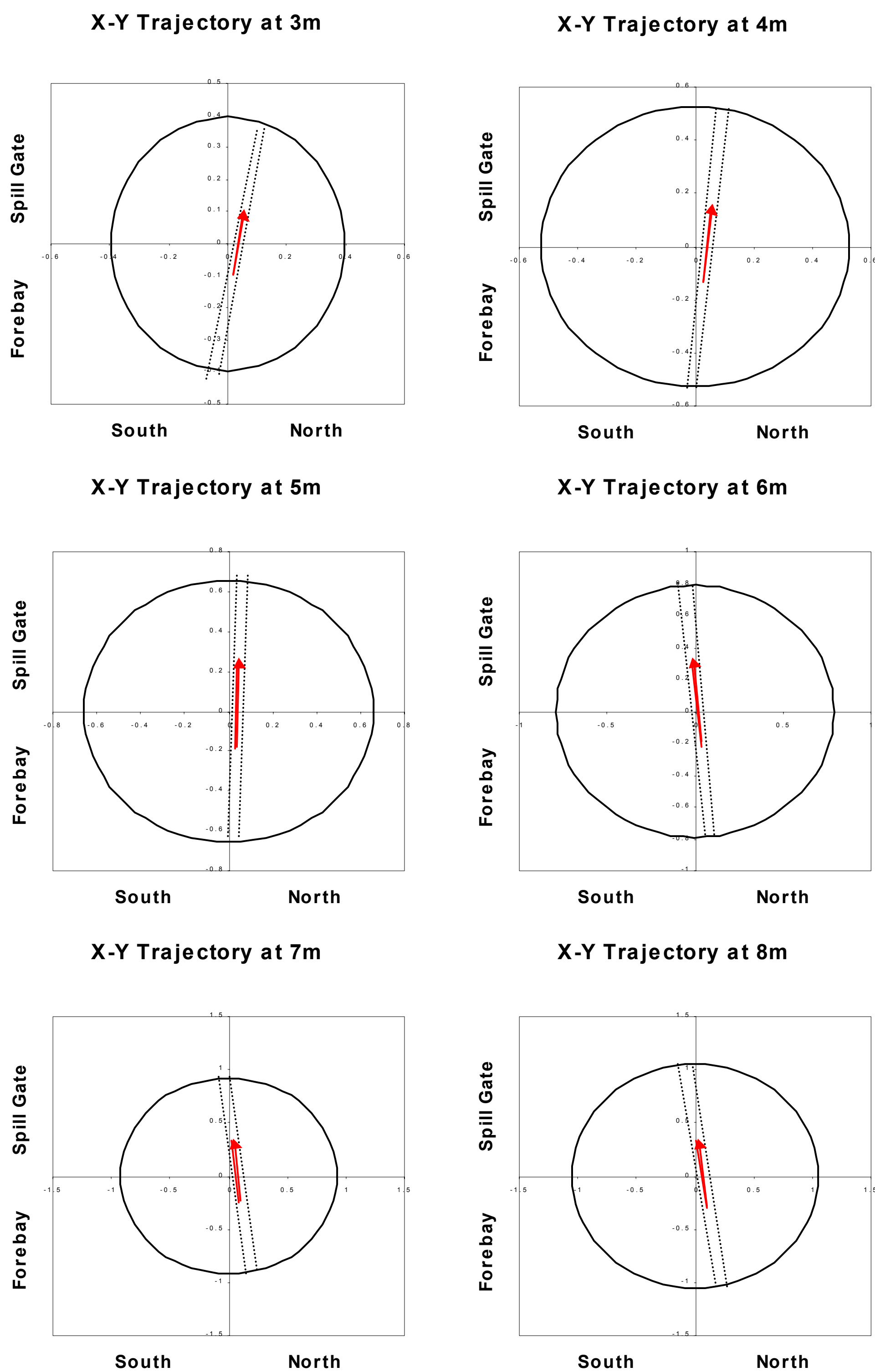


Figure 127g-k. X-Y Trajectories of Spill 18 fish at all spill levels combined based on the Task 2 split-beam data. John Day Dam, May 1-30, 1999 (cont'd).

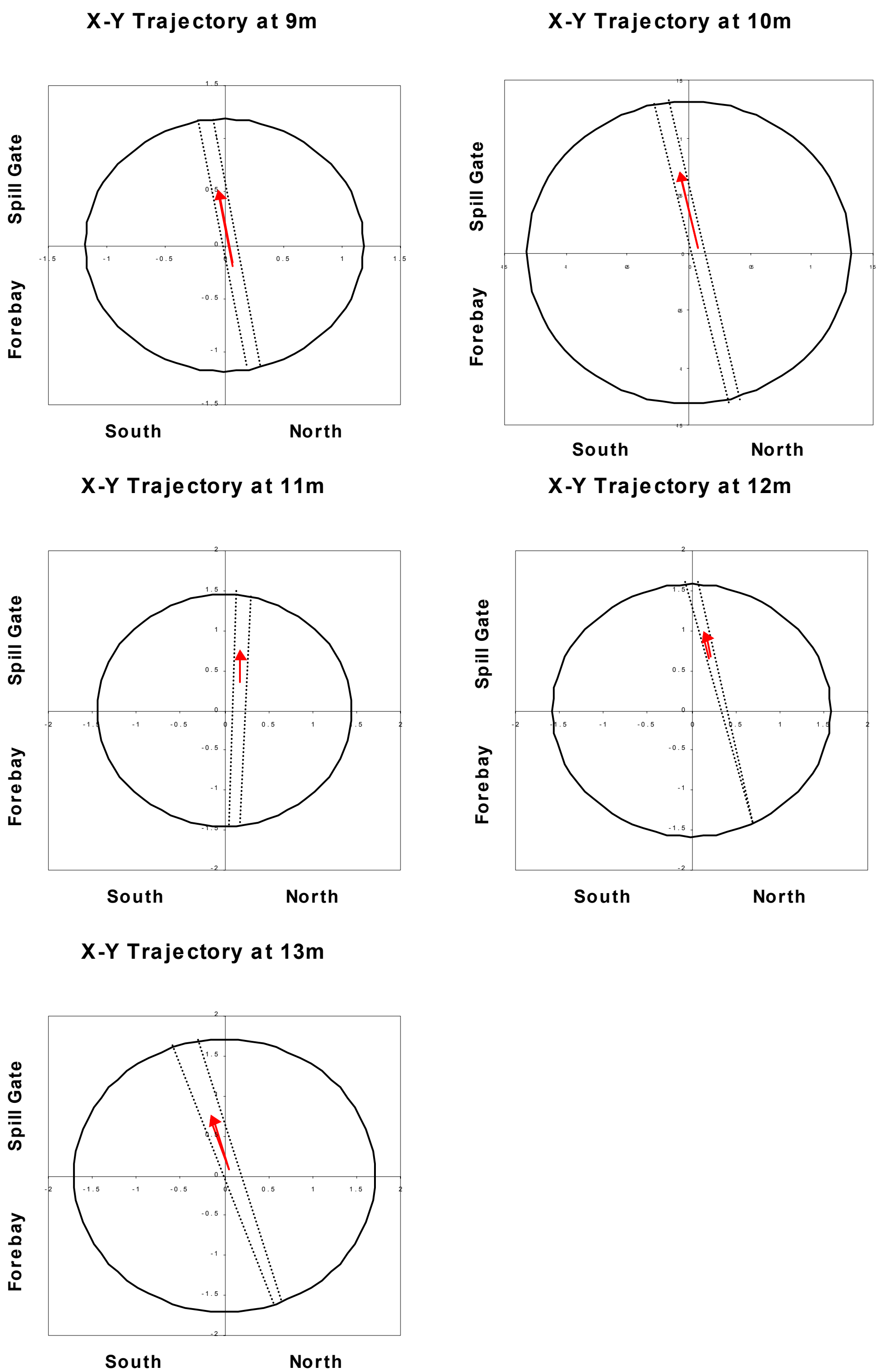


Figure 128a-f. X-Y Trajectories of Spill 18 fish at low spill levels (less than 4 kcfs) based on the Task 2 split-beam data. John Day Dam, May 1-30, 1999

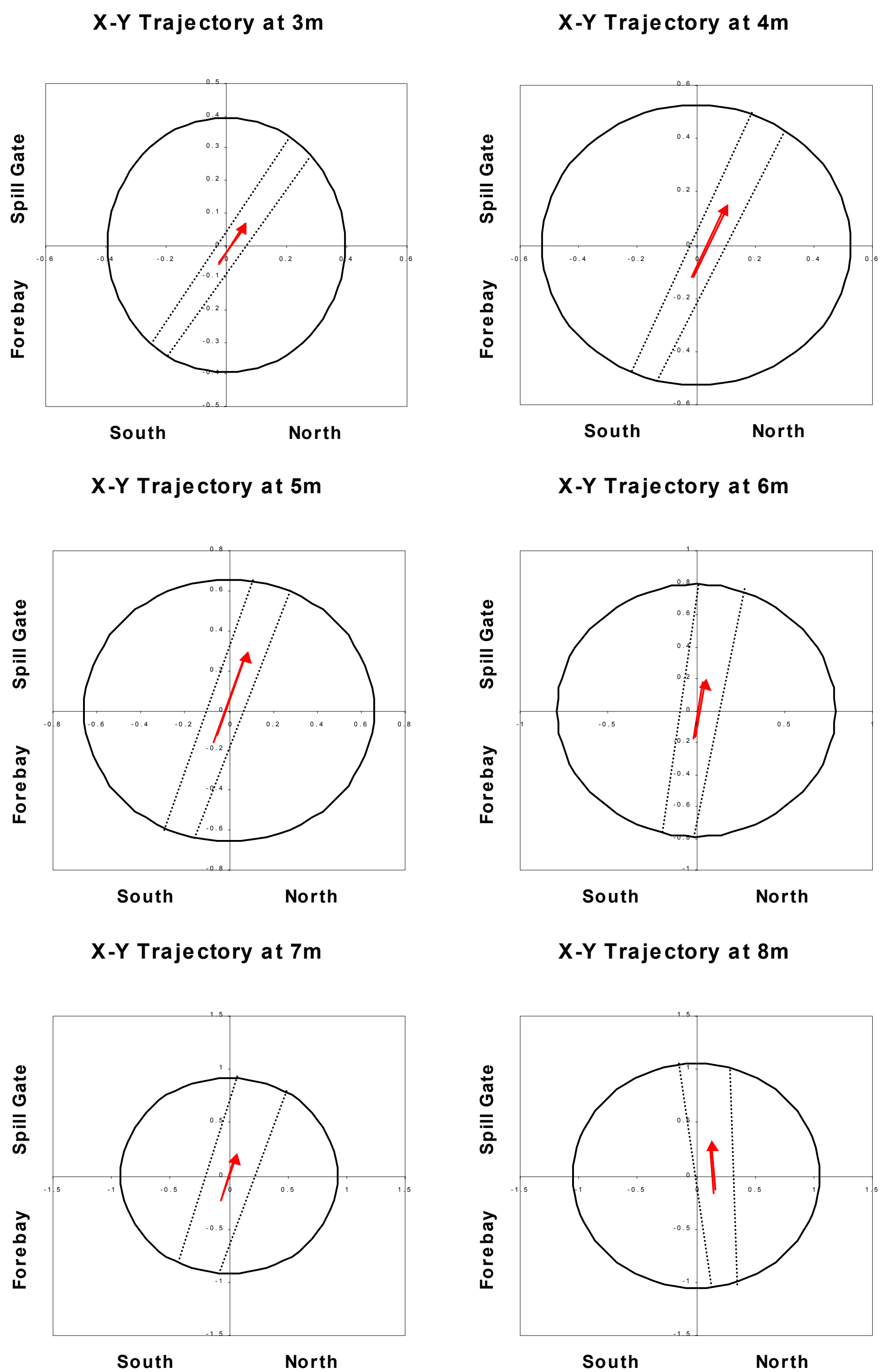
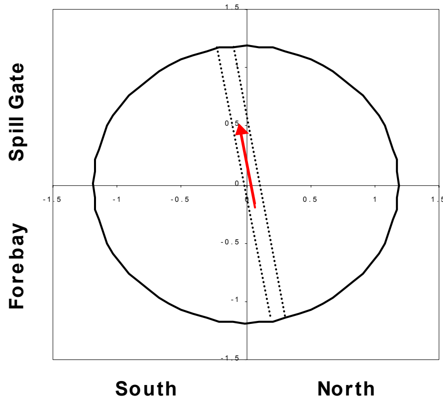
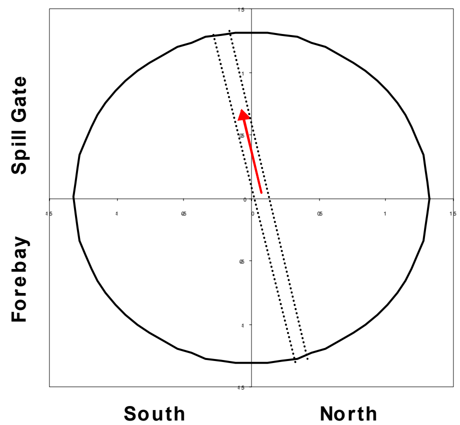


Figure 128g-k. X-Y Trajectories of Spill 18 fish at low spill levels (less than 4 kcfs) based on the Task 2 split-beam data. John Day Dam, May 1-30, 1999 (cont'd).

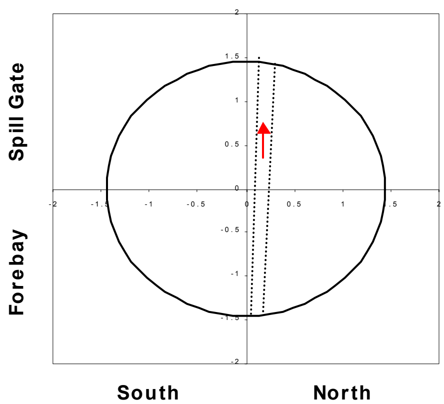
X-Y Trajectory at 9m



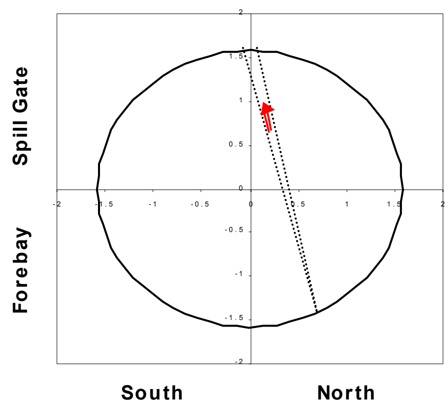
X-Y Trajectory at 10m



X-Y Trajectory at 11m



X-Y Trajectory at 12m



X-Y Trajectory at 13m

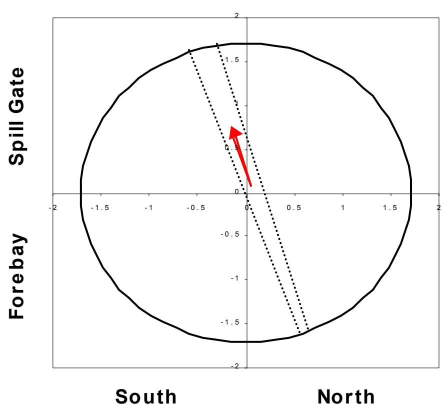


Figure 129a-f. X-Y Trajectories of Spill 18 fish at high spill levels (more than 4 kcfs). based on the Task 2 split-beam data. John Day Dam, May 1-30, 1999

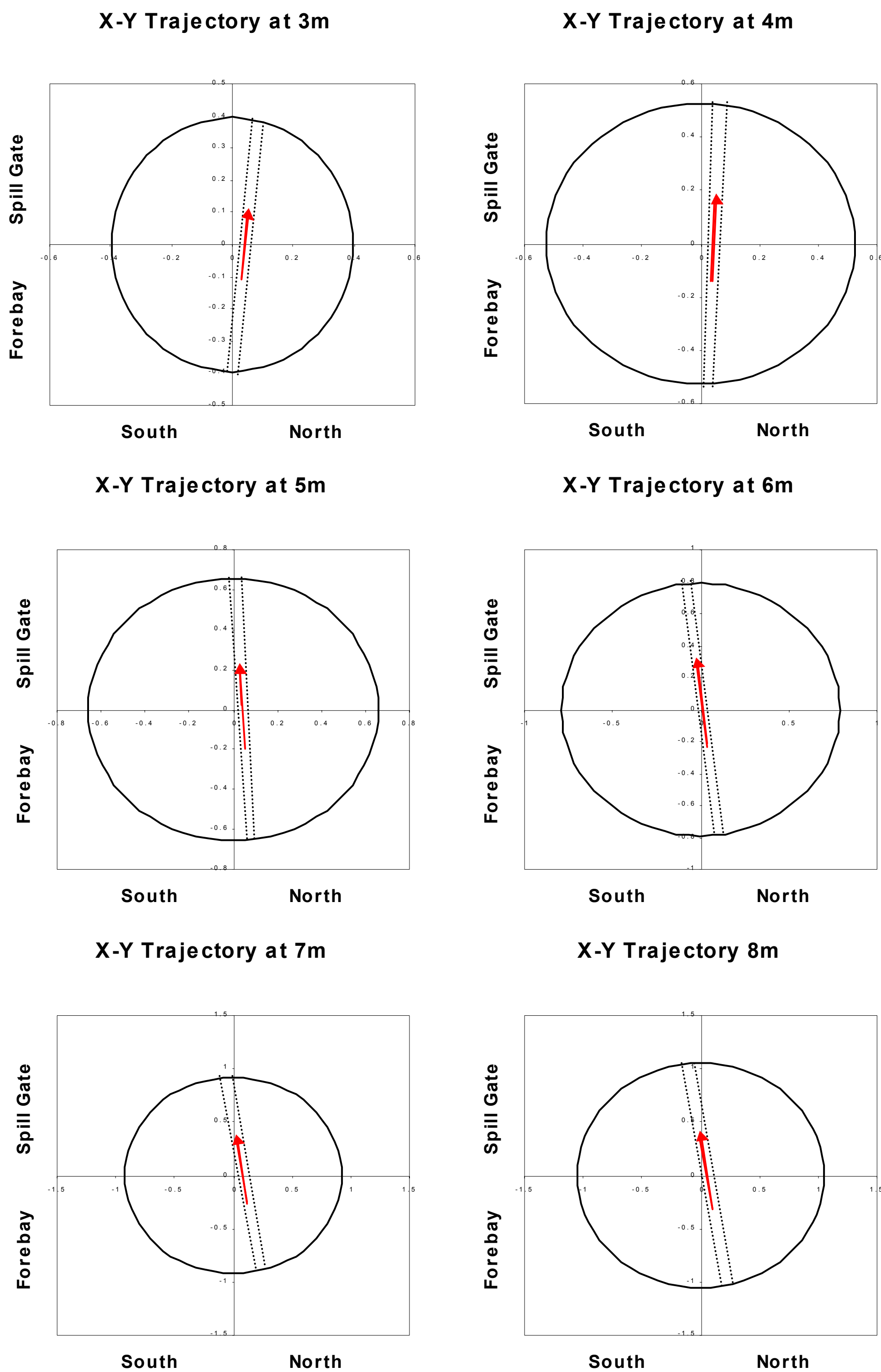
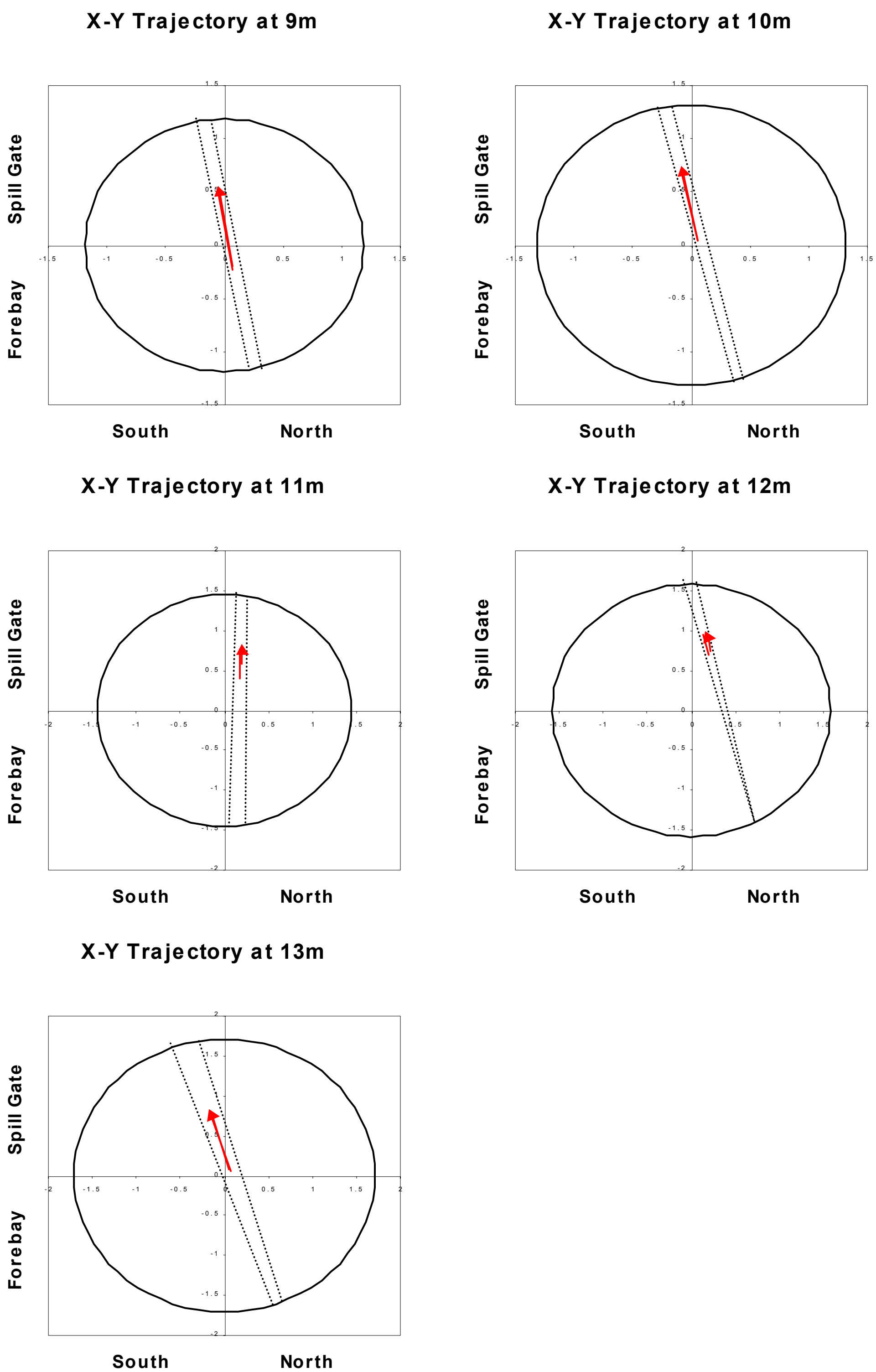


Figure 129g-k. X-Y Trajectories of Spill 18 fish at high spill levels (more than 4 kcfs) based on the Task 2 split-beam data. John Day Dam, May 1-30, 1999 (cont'd).



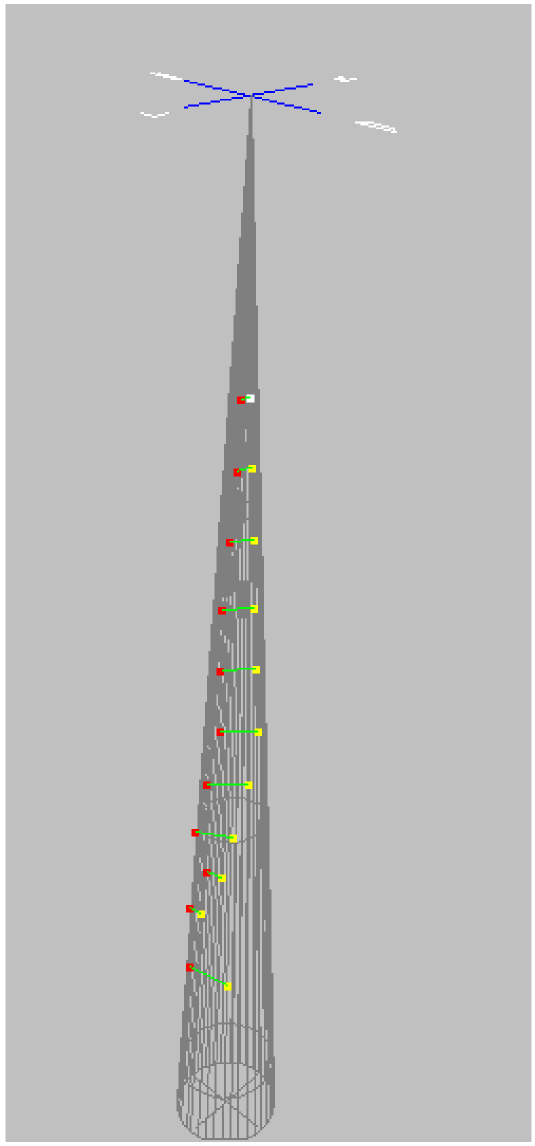


Figure 130. Three-dimensional view of average trajectories by 1-m range bin of all fish detected in Spill Bay 18 based on the Task 2 split-beam data. The yellow blocks represent the mean fish entrance point into the beam and the red blocks the mean exit point. The figure is oriented such that the right side of the page represents upstream and the left side of the figure the face of the dam. John Day Dam, May 1-30, 1999.

5.5 Fish Target Strength

Mean fish target strength (TS), or acoustic size in decibels(dB), was estimated for each 1-m range bin, by discharge volume. Tables 32 and 33 include distributions of mean TS and TS standard deviation surrounding each estimate for Spill Bay 18 during four discharge levels and for Turbine Unit 15 at six discharge levels.

Figures 131 to 140 present mean target strength profiles by range for Spill 18 and Turbine 15, including 95% confidence limits. Differences or trends in mean target strength by range could be caused by differing aspect angles of fish as they pass through the acoustic beam, or by fish size differences at different ranges.

There was no significant difference in mean target strength by range for the higher discharges. Spill Bay 18 showed a significant difference in target strength at a discharge of 2.8 to 3.1 kcfs. Target strength decreased with increasing range. Turbine 15 showed a significant difference in target strength at a discharge lower than 14 kcfs. There was no apparent trend in mean target strength by range for these discharges.

Table 32. Average target strength (dB) by range bin for Spill Bay 18. John Day Dam, Spring 1999.

Range	n	Mean TS (dB)	Std. Dev. TS (dB)	95% Confidence TS (dB)	Range	n	Mean TS (dB)	Std. Dev. TS (dB)	95% Confidence TS (dB)
Spill Bay 18 Discharge <= 1.6 kcfs					Spill Bay 18 Discharge = 6.5 kcfs				
2	20	-44.65	6.09	2.67	2	16	-49.41	3.05	1.50
3	295	-43.70	4.92	0.56	3	1289	-47.14	4.97	0.27
4	206	-44.04	4.89	0.67	4	1082	-46.63	5.20	0.31
5	139	-43.71	4.31	0.72	5	818	-45.91	5.09	0.35
6	89	-44.17	4.45	0.92	6	681	-45.68	4.55	0.34
7	43	-43.36	4.06	1.21	7	488	-45.31	4.63	0.41
8	21	-43.37	4.99	2.13	8	405	-44.89	4.18	0.41
9	18	-41.90	5.58	2.58	9	358	-45.48	3.77	0.39
10	14	-45.26	4.62	2.42	10	373	-46.15	3.86	0.39
11	12	-47.45	4.56	2.58	11	395	-47.42	3.38	0.33
12	10	-43.39	6.01	3.72	12	304	-44.20	5.18	0.58
13	4	-40.40	3.08	3.02	13	99	-42.89	4.05	0.80
Spill Bay 18 Discharge = 2.8-3.1 kcfs					Spill Bay 18 Discharge = 7.6 kcfs				
2	4	-43.83	5.88	5.76	3	13	-46.52	7.11	3.86
3	105	-45.62	5.67	1.08	4	18	-43.86	4.30	1.99
4	89	-44.57	5.47	1.14	5	14	-46.04	4.83	2.53
5	58	-45.62	5.43	1.40	6	19	-43.83	3.54	1.59
6	28	-46.58	4.74	1.76	7	7	-43.44	4.61	3.41
7	22	-43.40	5.54	2.32	8	9	-45.57	4.09	2.67
8	30	-45.78	4.31	1.54	9	6	-43.41	4.18	3.34
9	17	-45.84	3.82	1.82	10	3	-43.19	4.61	5.21
10	21	-47.42	2.58	1.10	11	2	-43.76	2.19	3.03
11	34	-47.81	3.89	1.31	13	2	-41.60	4.24	5.88
12	15	-44.70	5.22	2.64					
13	6	-45.24	7.98	6.39					
14	3	-51.91	3.81	4.32					
15	3	-53.26	1.74	1.97					

Table 33. Average target strength (dB) by range bin for Turbine 15. John Day Dam, Spring 1999.

Range	n	Mean TS (dB)	Std. Dev. TS (dB)	95% Confidence TS (dB)	Range	n	Mean TS (dB)	Std. Dev. TS (dB)	95% Confidence TS (dB)
Turbine 15 Discharge <= 11 kcfs					Turbine 15 Discharge = 16-18 kcfs				
5	1	-46.81	NA	NA	2	1	-54.34	NA	NA
6	1	-49.42	NA	NA	3	24	-46.44	5.18	2.07
7	1	-49.45	NA	NA	4	16	-48.17	4.03	1.97
8	2	-46.95	1.99	2.76	5	11	-46.94	4.16	2.46
9	2	-52.25	0.11	0.15	6	11	-46.99	4.63	2.74
10	3	-47.96	2.81	3.18	7	9	-45.55	4.51	2.95
11	2	-49.21	0.93	1.29	8	8	-48.47	2.24	1.55
12	1	-46.58	NA	NA	9	20	-47.60	2.91	1.27
14	2	-47.62	1.62	2.25	10	12	-47.77	3.64	2.06
15	2	-50.95	0.27	0.37	11	22	-49.32	4.45	1.86
		-48.83	2.21	1.05	12	16	-47.54	4.40	2.16
					13	26	-48.39	2.91	1.12
					14	33	-49.65	3.49	1.19
					15	47	-49.28	3.46	0.99
Turbine 15 Discharge = 12-14 kcfs					Turbine 15 Discharge = 18-20 kcfs				
3	1	-49.69	NA	NA	3	25	-47.68	5.46	2.14
5	3	-48.22	0.92	1.05	4	20	-43.39	6.17	2.70
6	6	-50.37	3.13	2.51	5	12	-47.89	4.49	2.54
7	12	-48.18	2.83	1.60	6	12	-45.33	5.41	3.06
8	5	-48.43	2.51	2.20	7	7	-43.66	6.56	4.86
9	11	-47.79	3.26	1.93	8	6	-45.20	3.44	2.75
10	12	-48.17	4.38	2.48	9	10	-47.14	5.04	3.12
11	8	-49.05	2.00	1.39	10	9	-45.06	3.90	2.55
12	8	-47.40	1.83	1.27	11	14	-51.97	4.52	2.37
13	13	-47.14	3.25	1.77	12	9	-47.58	2.66	1.74
14	32	-50.33	2.82	0.98	13	8	-47.14	5.64	3.91
15	22	-49.23	3.34	1.39	14	24	-50.86	2.61	1.04
					15	20	-49.90	4.59	2.01
Turbine 15 Discharge = 14-16 kcfs					Turbine 15 Discharge = 20-22 kcfs				
3	1	-49.47	NA	NA	3	8	-54.28	1.74	1.21
4	4	-45.77	2.29	2.25	4	2	-46.92	2.50	3.46
5	7	-46.48	3.02	2.24	5	1	-48.90	NA	NA
6	7	-45.81	3.70	2.74	7	2	-49.41	1.75	2.43
7	11	-50.17	2.79	1.65	8	1	-36.72	NA	NA
8	8	-50.01	2.84	1.97	9	1	-35.07	NA	NA
9	10	-47.48	4.18	2.59	10	2	-47.28	2.38	3.30
10	13	-47.11	3.59	1.95	11	6	-52.36	3.81	3.04
11	25	-46.88	4.00	1.57	12	1	-45.66	NA	NA
12	12	-46.56	3.46	1.96	13	5	-48.86	4.22	3.70
13	16	-47.93	2.47	1.21	14	6	-51.30	2.37	1.90
14	26	-48.75	3.38	1.30	15	19	-51.36	2.63	1.18
15	41	-49.71	3.26	1.00					

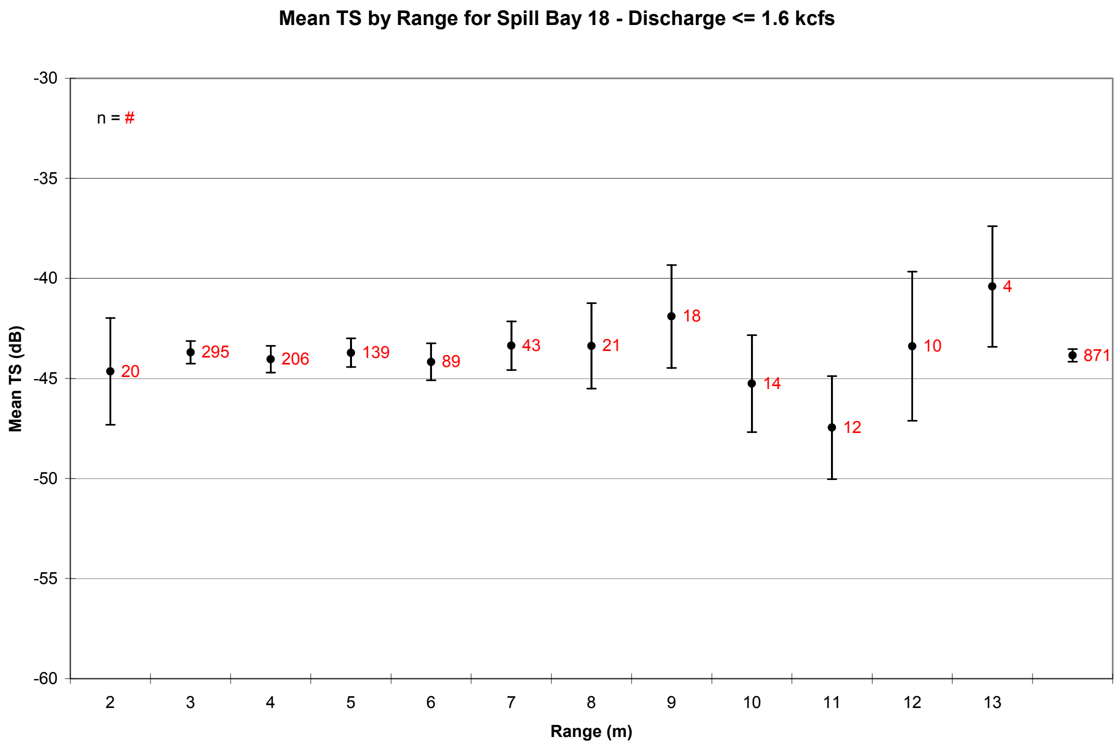


Figure 131. Average target strength (dB) by range bin for Spill Bay 18 during discharge of <= 1.6 kcfs. John Day Dam, Spring 1999.

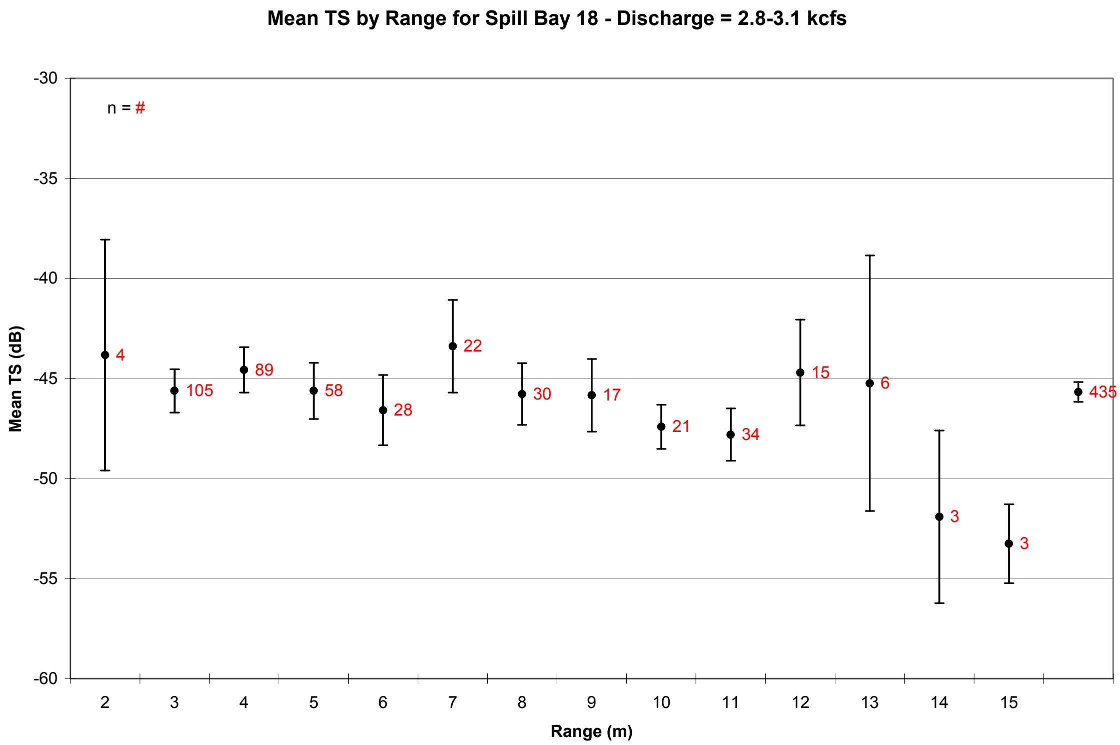


Figure 132. Average target strength (dB) by range bin for Spill Bay 18 during discharge of 2.8-3.1 kcfs. John Day Dam, Spring 1999.

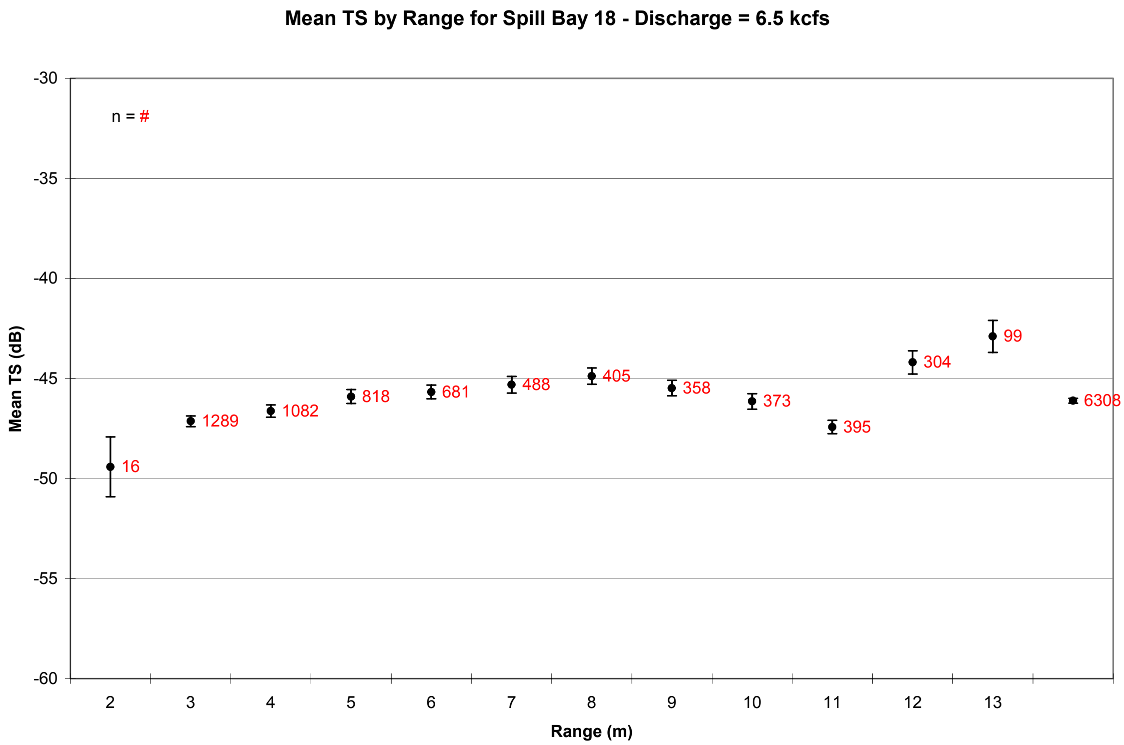


Figure 133. Average target strength (dB) by range bin for Spill Bay 18 during discharge of 6.5 kcfs. John Day Dam, Spring 1999.

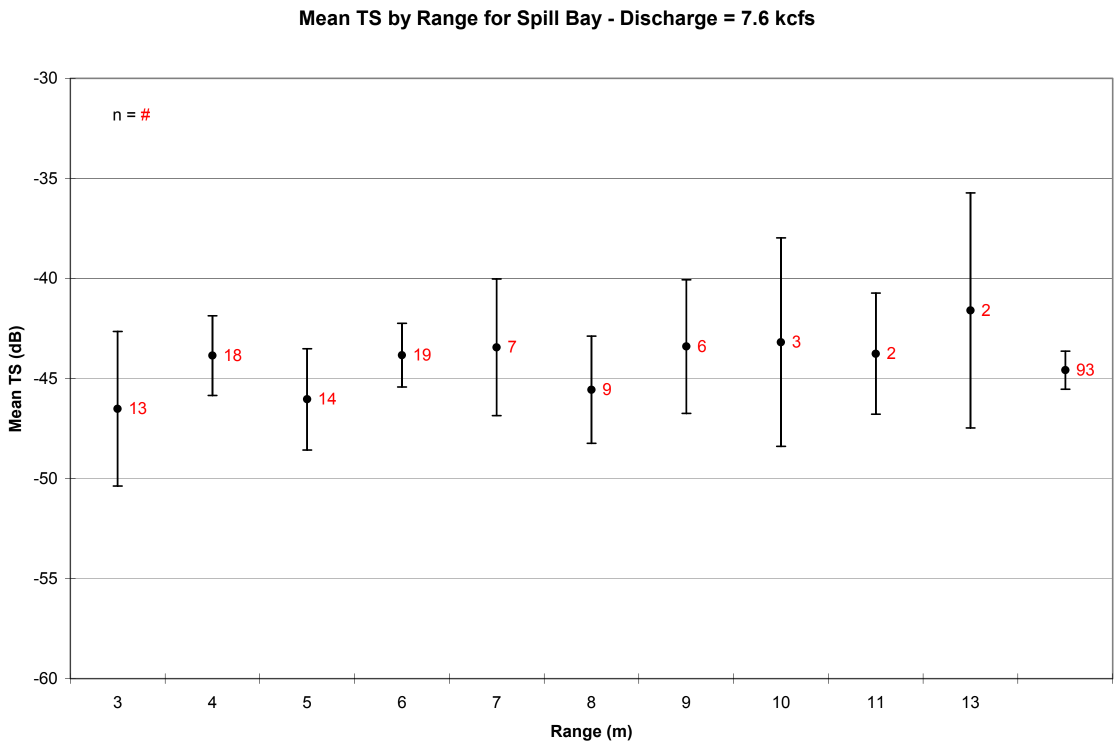


Figure 134. Average target strength (dB) by range bin for Spill Bay 18 during discharge of 7.6 kcfs. John Day Dam, Spring 1999.

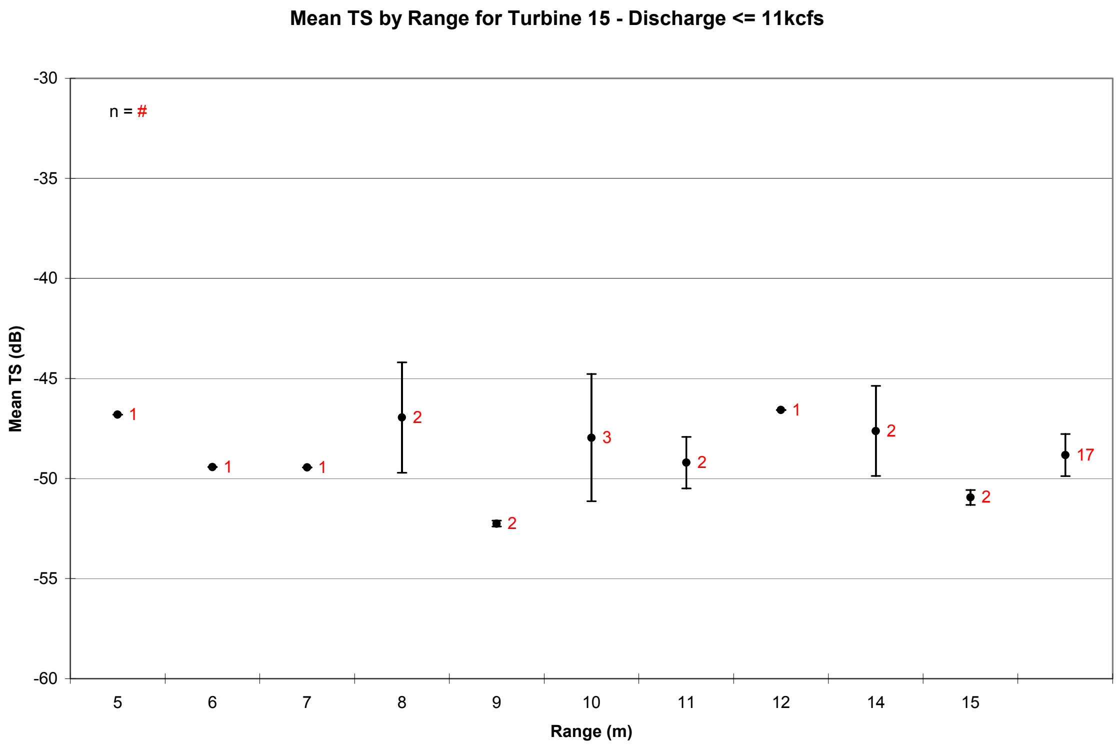


Figure 135. Average target strength (dB) by range bin for Turbine 15 during discharge of <= 11 kcfs. John Day Dam, Spring 1999.

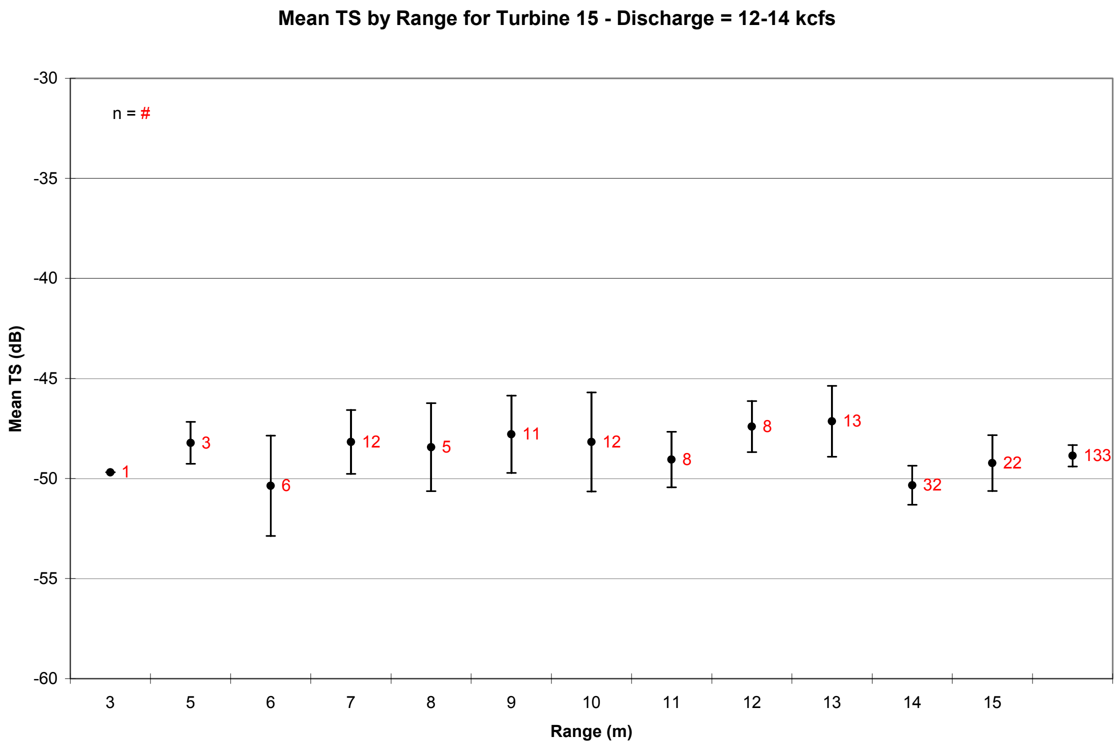


Figure 136. Average target strength (dB) by range bin for Turbine 15 during discharge of 12-14 kcfs. John Day Dam, Spring 1999.

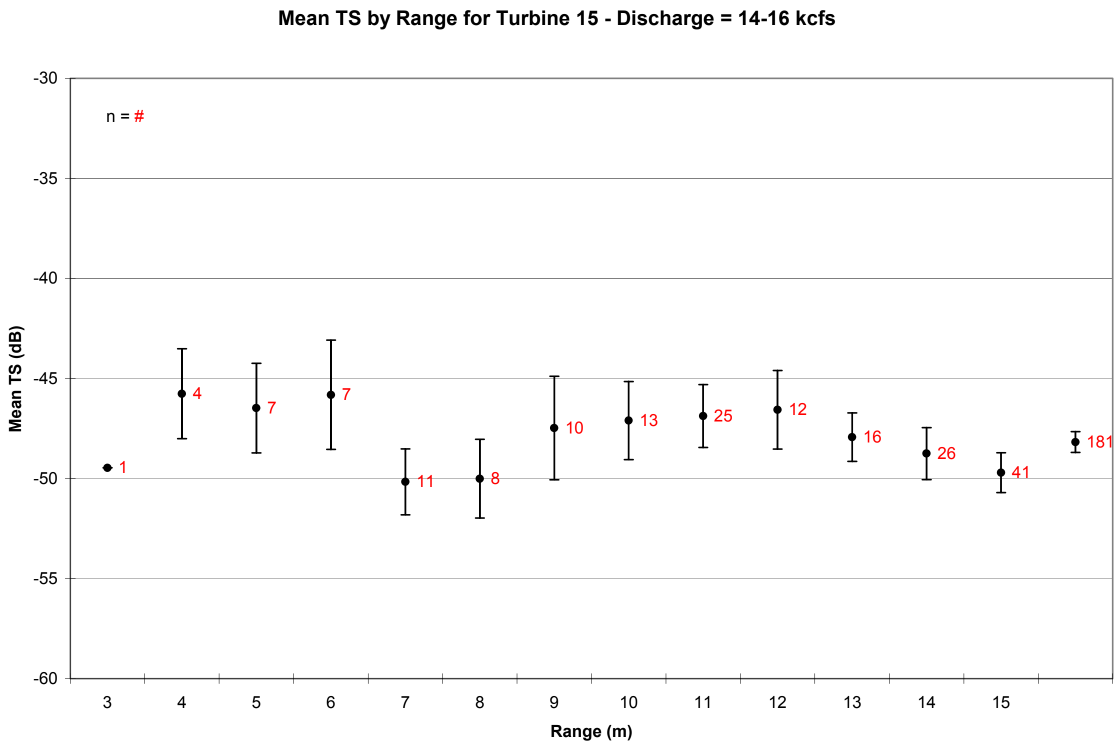


Figure 137. Average target strength (dB) by range bin for Turbine 15 during discharge of 14-16 kcfs. John Day Dam, Spring 1999.

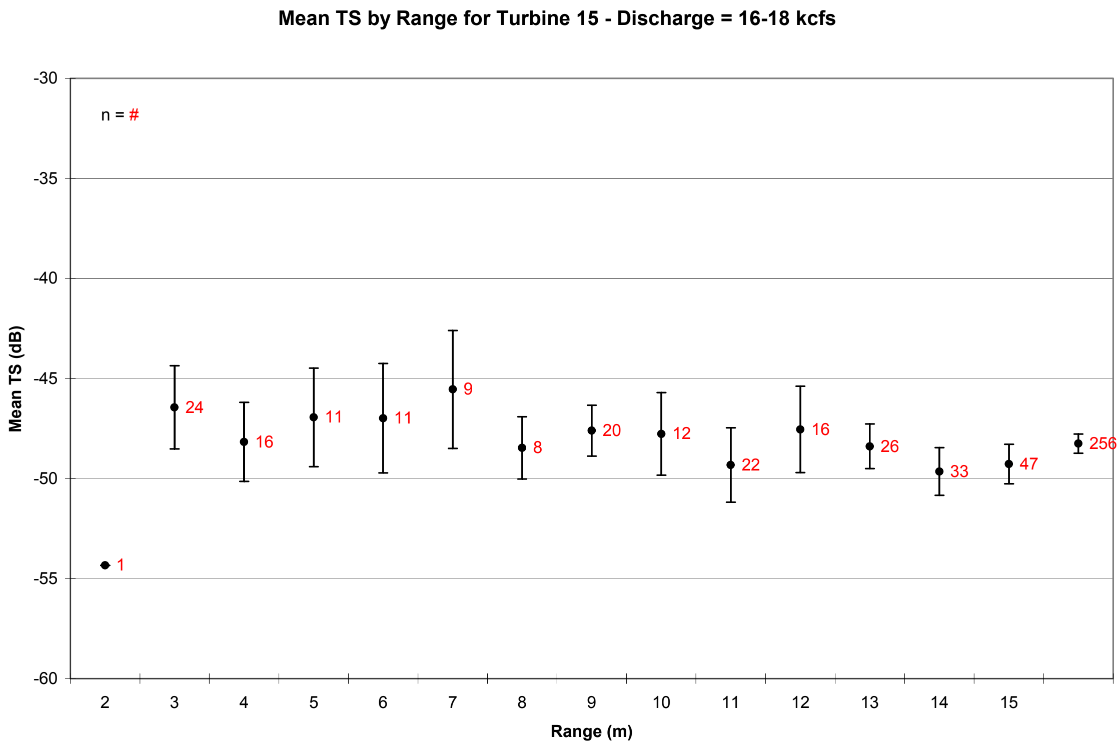


Figure 138. Average target strength (dB) by range bin for Turbine 15 during discharge of 16-18 kcfs. John Day Dam, Spring 1999.

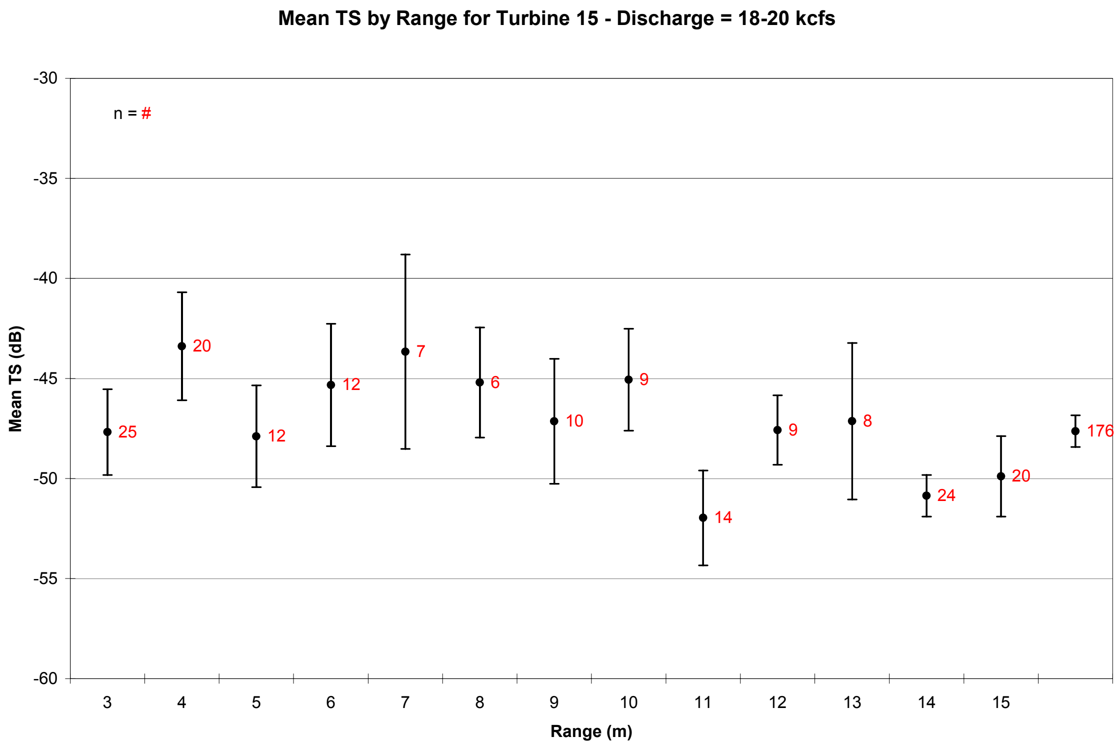


Figure 139. Average target strength (dB) by range bin for Turbine 15 during discharge of 18-20 kcfs. John Day Dam, Spring 1999.

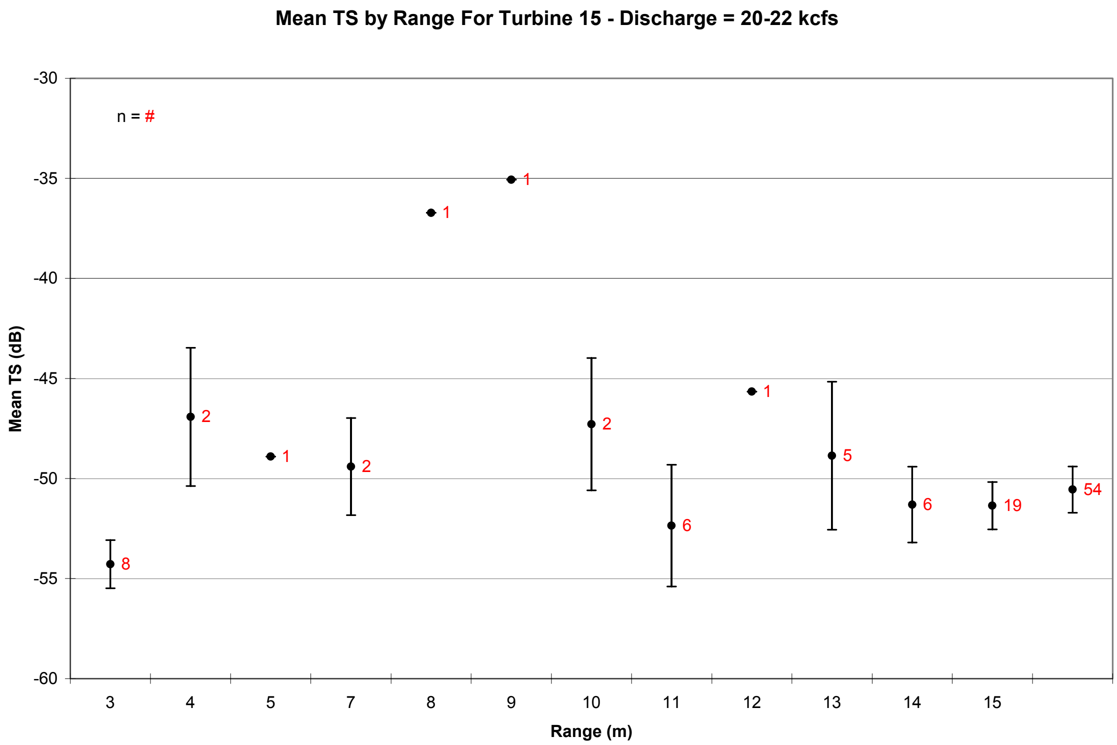


Figure 140. Average target strength (dB) by range bin for Turbine 15 during discharge of 20-22 kcfs. John Day Dam, Spring 1999.

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 Spill Efficiency

Conclusions of the 1999 John Day Dam Task 1 monitoring were that 30% daytime spill was significantly more efficient than 0% daytime spill on a 24-h basis for both the spring and summer monitoring periods. On a 24-h basis, mean spill efficiency for the pooled spring data set was estimated to be 82% during 30% daytime spill and 68% during 0% daytime spill, a statistically significant difference at a 95% confidence level. The observed differences in mean spill efficiency were greater during the summer, with the 30% daytime spill group returning a mean spill efficiency of 93% and the 0% daytime spill condition a 63% value. Again, the two summer spill efficiency estimates were significantly different.

During the spring, nighttime spill efficiency was similar during both the 30% and 0% daytime spill levels (73% and 76%, respectively), and did not differ significantly. A significant difference in nighttime spill efficiency was observed during the summer. Nighttime summer spill efficiency at 30% daytime spill (82%) was significantly higher than that observed during 0% daytime spill conditions (70%).

With the exception of the nighttime spring period, mean spill efficiency was consistently (and significantly) higher during 30% daytime spill conditions than observed at 0% conditions. The magnitude of this difference was greater on a 24-h basis than at night. Observed mean spill efficiency was highest during summer under 30% daytime spill conditions (93%, on a 24-h basis) and lowest during the summer under 0% daytime spill, also on a 24-h basis.

This data also addressed the question of whether smolt aggregate in the forebay under 0% daytime spill conditions, then migrate downstream in increased numbers at night when nighttime spill is available. Evidence of this behavior was not observed, as determined by comparison of nighttime spill efficiency under both daytime spill levels. During the summer, significantly greater nighttime spill efficiency was observed when 30% daytime spill was conducted, contrary to the assumption of outmigrant delay under 0% daytime spill. During the spring monitoring period, nighttime spill efficiency was approximately equal under both spill regimes.

Daytime turbine fish passage was significantly greater during 0% daytime spill conditions for both the spring and summer monitoring periods, indicating that smolt tended to use the downstream passage route available to them, rather than delay outmigration until nighttime spill was available.

6.2 Spill Effectiveness

On a 24-h basis, mean spill effectiveness followed an opposite trend compared to spill efficiency. Observed 24-h spill effectiveness was significantly higher during 0% daytime spill than at 30% daytime spill during both the spring and summer monitoring periods. During 0% daytime spill, estimated 24-h spill effectiveness was 3.10 during spring and 4.75 during summer. The corresponding 30% mean 24-h spill effectiveness values were 2.37 and 2.76 for the spring and summer, respectively. Observed spill effectiveness was higher during the summer than during the spring monitoring periods.

Nighttime spill effectiveness was not significantly different during the spring, 1.60 and 1.87 during 0% and 30% daytime spill levels, respectively. However, a significant difference at a 95% level was observed during the summer monitoring period. During summer, 0% daytime spill was significantly higher (2.54) than that observed for the 30% daytime spill group (2.01). This nighttime trend followed that observed on a 24-h basis, with higher spill efficiency levels observed at the lower daytime spill block (0%).

6.3 Fish Passage

The observation that daytime spill appeared to be highly efficient, but not highly effective for the majority of comparisons may be due to the magnitude of turbine fish passage during night and day. During the night, spillway operation was generally uniform, averaging 40-45% spill. Nighttime spillway fish passage was generally similar in magnitude under both daytime spill levels during the spring and summer periods, although significantly greater numbers of fish did pass under 0% daytime spill replicates. During the spring, daytime smolt passage through the spillway under 30% spill was similar to that observed through the powerhouse at night and was significantly greater than that observed at the powerhouse during the summer period.

During 0% daytime spill, the spillway was not available as a downstream-passage route. Spring powerhouse smolt passage was not significantly different at night during either daytime spill condition. The increased spill efficiency observed on a 24-h basis during spring was due primarily to passage through the spillway during daytime hours. Spill effectiveness decreased during the spring due to the increased spillway passage at night under 0% daytime spill conditions. Although greater numbers of smolt passed the spillway on a 24-h basis when daytime spill was available, nighttime spill passage through the spillway per unit volume was generally higher than during the day, impacting the 24-h spill effectiveness estimates.

During summer, significantly greater numbers of smolt passed the powerhouse at night during 0% daytime spill conditions and inversely, significantly lower fish passage through the turbines were observed at night. At the spillway during nighttime, the magnitude of total fish passage was similar under both spill conditions, although total passage was significantly greater when daytime spill was not available. However, turbine passage was significantly greater during both day and night under the 0% daytime spill replicates. The increase in nighttime spillway passage for a relatively fixed volume of water apparently impacted the overall spill effectiveness estimates to a greater degree than the ratio of fish-to-flow during the shorter daytime period.

6.4 Task 2 Split-Beam Behavioral Results

Fish trajectory distributions at Spill Bay 18 over the May 1-30 study period observed did not exhibit large-scale milling behavior. On a seasonal basis, the majority (77%) of all observed fish exhibited net movement toward the spill gate opening, i.e. downstream (transducer Y-axis movement >0). Net downstream movement was lower near the surface (65-73% within 3 m of the transducer) and below the spill ogee (0-77% below 10 m). In the area of presumably higher flow immediately above and in front of the spillway gate opening (5-9 m range), net downstream movement was higher, varying between 82-88%.

The majority (75%) of observed fish above the Spill Bay 18 ogee exhibited diving behavior toward the spill gate opening. The frequency of this behavior increased with depth to an elevation just above the ogee. Immediately in front of the ogee, fish were generally moving straight in to the gate opening, parallel with the surface. Below the ogee, fish were generally ascending in the water column, toward the ogee elevation. These observations are consistent with estimated vertical flow patterns into the spill bays. Presumably most fish are oriented with and following this flow net.

Fish trajectory distributions in the Turbine 15 penstock indicated that the majority of fish observed in-turbine were entrained. As the transducers at the powerhouse were oriented differently than at the spillway (aimed 40° downstream perpendicular to the penstock ceiling), net fish movement in both the Y- and Z-axes of the transducer was considered to determine downstream fish movement.

At Turbine 15, 90% of all observed fish exhibited net negative Y-axis direction-of-travel and/or positive Z-axis movement (increasing range) over time, consistent with turbine entrainment.

Fish horizontal approach trajectories (planar view, i.e. N-S relative to the upstream face of the dam) at Spill Bay 18 were consistently downstream, but N-S approach angles varied with range (depth). General rotations of mean horizontal fish approach vectors from south to north were observed with increasing depth. For the May 1-30 Task 2 monitoring period, mean fish approach angles were from the southeast near the surface (above 5 m range), essentially perpendicular to the face of the dam between 5-7 m range, and from the northeast below 7 m. These patterns may reflect patterns of flow upstream of Spill Bay 18.

Mean observed fish velocity at Turbine 15 was 1.3 m/sec (4.1 fps) for the spring 30-d study period. Turbine 15 fish velocities by 1-m range strata varied between 0.8 - 1.6 m/sec (1.3 - 3.6 fps), generally increasing with range toward the intake ceiling.

Mean observed fish velocity at Spill Bay 18 was 0.6 m/sec (1.9 fps) for the spring 30-d study period. Spill Bay 18 fish velocities by 1-m range strata varied between 0.4 - 1.1 m/sec (2.6 - 5.2 fps), increasing with range (depth) to the area immediately upstream of the spillway ogee, then decreasing slightly below that elevation.

Overall, 77% of all observed fish had net downstream movement toward the spill gate. Applying this factor globally to spill entrainment would reduce spill efficiency estimates by approximately 30%; i.e. a 75% spill efficiency estimate would be reduced to approximately 58%. However, several factors should be considered before applying a directional apportionment factor to total spillway entrainment estimates. These include:

4) The Spill Bay 18 split-beam transducer was located several meters upstream of the gate opening. Net downstream movement at this location may not be absolutely correlated with fish behavior immediately in front of the spill gate.

5) The downlooking transducer had a relatively small sampling volume near the surface. Vertical distributions at the spillway revealed fish were generally surface-oriented. Fish observed near the surface (within 4-m range) had lower percentages of net downstream-movement relative to fish at greater depth, but these data are based on a limited sampling volume at the center of the bay.

6) In the absence of ground-truth information on fish entrainment at the spill gate opening, any net downstream fish movement (negative transducer Y-axis travel) was assumed to be equally correlated with entrainment. Fish with only a few cm of net downstream movement were grouped with targets exhibiting 2-m or more net downstream movement. Fish may require some minimum distance made good (weighted for increasing transducer sampling volume with range) to be considered entrained.

6.5 Recommendations

Additional split-beam data should be collected at the spillway before considering apportionment of single-beam spillway passage estimates by net fish direction-of- movement. Ideally, an uplooking/downlooking pair of split-beam transducers should be used to maximize sampling volumes throughout the water column. Redeployment of the spillway mounts closer to the spill gate openings, as planned in 2000 at John Day Dam, may also improve fish direction-of-movement estimates and corresponding entrainment. If new spill mounts are deployed closer to the spillway tainter gate opening, concurrent split-beam data should be collected. Alternatively, split-beam transducers could be deployed at all monitoring locations at the spillway in future studies. Acoustic tag studies, as conducted at other Columbia River hydroelectric projects (Steig et al. 1999, Steig and Timko 1999), could provide ground truth information for comparison with split-beam entrainment estimates, as may existing radio telemetry tagging data.

Single-Beam Passage Data

The statistical data analysis procedures outlined by Skalski 1999, which were implemented at John Day Dam in 1999, should be continued in future studies. Skalski's Method 2 variance algorithm, which incorporates a measure of slot-to-slot within turbine variance (and unmonitored spill bay variance), should be used. Review and revision of the study design and statistical procedures should be conducted to minimize variance surrounding future fish passage estimates. Consideration should be given to addressing spatial sources of error, such as turbine between-slot and within-spillbay variability. Temporal variability in fish passage estimates should be addressed by maximizing sampling coverage and fast-multiplexing. Other potential sources of error, such as data entry, should also be considered.

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