U.S. Army Corps of Engineers
Walla Walla District

HYDROACOUSTIC EVALUATION OF FISH PASSAGE AND MOVEMENT AT THE LOWER GRANITE DAM REMOVABLE SPILLWAY WEIR

PRELIMINARY DATA REPORT

Task Order 0001

Biological Services Contract DACW68-02-D-0001

U.S. Army Corps of Engineers, Walla Walla District

September 5, 2002

U.S. Army Corps of Engineers
Walla Walla District

HYDROACOUSTIC EVALUATION OF FISH PASSAGE AND MOVEMENT AT THE LOWER GRANITE DAM REMOVABLE SPILLWAY WEIR

PRELIMINARY DATA REPORT

Prepared by:

S.M. Anglea, M.A. Simmons, C.S. Simmons (Battelle's Pacific Northwest Division)

E.A. Kudera

J.R. Skalski (University of Washington)

Task Order 0001

Biological Services Contract DACW68-02-D-0001

U.S. Army Corps of Engineers, Walla Walla District

September 5, 2002

Preface

This document is one in a series of reports that describe the results of the hydroacoustic evaluation at Lower Granite Dam in 2002. Summary of flow measurements in the RSW will be provided under separate cover. Individual reports in the series will be prepared according to the following schedule:

- September 1, 2002: Preliminary Data Report
- November 1, 2002: Draft Final Report
- January 15, 2003: Final Report

The emphasis of the Preliminary Data Report is on results. Methods, interpretation of results, and conclusions will be further developed in future reports. The data contained in this report are to be considered preliminary and are subject to change as analysis efforts proceed.

Contents

List of Figures

List of Tables

1. Introduction

1.1. Background

Juvenile salmonids migrating down the Snake River must pass through up to eight hydroelectric projects on their way to the ocean. Presently, these fish pass the projects through turbines, spillways, sluiceways or powerhouse bypass systems. Passage through turbine units results in relatively high levels of mortality. Bypass systems divert juvenile fish from turbine intakes, and provide considerably safer passage, but the proportion guided into the bypass systems varies considerably by fish stock, project, and time of year. Spillways are thought by many to be a relatively safe means of passage, but this method is expensive in terms of lost power generation and can result in potentially lethal levels of total dissolved gas in the river.

The concept of collecting smolts near the surface for bypass or collection is a method that is believed to have much promise, and is currently being tested. Evaluations of the prototype surface bypass/collector (SBC) at Lower Granite were performed from 1996 through 2000, with incremental increases in performance being achieved as more was learned about surface collectors and how fish respond to flow fields and other environmental variables (Anglea et al. 2002). Due to deterioration of the SBC structure (it was designed and built as a temporary structure, without protective coating), it is no longer safe to operate. As the next step in surface collection studies, the Corps constructed a Removable Spillway Weir (RSW) at Lower Granite. The RSW is installed at spill bay 1. It is designed to operate with the spill gate fully open (out of the water). Discharge through the RSW ranges between 6,000 and 11,000 cfs, depending on forebay elevation.

Much of the original SBC structure was in place, including the Simulated Wells Intake (SWI). The northernmost portion (north of unit 6) of the SBC was removed, including the bulkhead and attachment to spill bay 1. A new cutoff wall was installed on the SBC at the end of the powerhouse (unit 6) and is approximately the same depth as the SWI. The Behavioral Guidance Structure (BGS) was in the deployed position and was attached at the south end of the existing SBC, between units three and four. The SBC, SWI and BGS function as a series of occlusion devices to guide fish near the RSW.

1.2. Study Goal

The goals of the 2002 Removable Spillway Weir study at Lower Granite Dam were to describe fish passage and movement in the vicinity of and in response to the presence and operation of the RSW, in combination with the SBC, SWI and BGS.

1.3. Objectives

Evaluation of the RSW at Lower Granite Dam in 2002 (Delivery Order 0001) has three objectives: 1) determine the relative passage rates of juvenile fish through the powerhouse, spillway and over the RSW, 2) determine the behavioral characteristics of juvenile fish directly in front of the RSW, and 3) determine the efficiency and effectiveness of the RSW and conventional spillway under the proposed operational scenarios. The specific tasks follow:

1.3.1. Task 1: Fish passage enumeration and comparison at the RSW, conventional spill bays and powerhouse

1. Estimate hourly passage rates (24 h/d) of juvenile salmonids migrating over the RSW, through conventional spill bays, and into turbine intakes
2. Estimate short range (~10 ft) efficiency and effectiveness of the RSW
3. Estimate horizontal, vertical, and diel passage distributions at the RSW
4. Estimate vertical distribution within each sampled spill bay and turbine intake and horizontal distribution for the spillway and powerhouse overall
5. Statistically compare passage rate, efficiency, and effectiveness among treatments identified by regional scientists

1.3.2. Task 2: Split-beam monitoring of fish passage and behavior

1. Determine fish target strength, travel direction, velocity, and trajectory and incorporate information into hydroacoustic detectability model
2. Characterize fish movement at the RSW entrance

1.4. Site Description

Lower Granite Dam is the first dam on the Snake River (River Mile 107.5) downstream from its confluence with the Clearwater River. It is one of the Corps' highest priorities to develop surface bypass and collection systems because more smolts listed under the Endangered Species Act pass Lower Granite Dam than any other dam on the Snake River.

Lower Granite Dam has four primary structures: powerhouse, spillway, navigation lock, and an earthen dam. The powerhouse has 6 turbines operating at a nameplate capacity of 135 MW for a total generating capacity 810 MW. The total hydraulic capacity of the powerhouse is about 130 kcfs. The full power pool elevation is rated at 738 ft (above mean sea level) with the normal operating pool level between elevation 737 and 738 ft. The minimum operating pool (MOP) is elevation 733 ft. The spillway is comprised of 8 spill bays with Tainter gates. The spillway occupies approximately 512 ft of the south center portion of the dam. The crest of each spill bay is at elevation 681 ft. The top deck elevation of the entire dam is at elevation 751 ft.

1.5. Removable Spillway Weir

The RSW tested in 2002 is depicted in Figure 1. The RSW is designed as an overflow device in a spill bay. It will be hinged at the bottom to allow it to pivot out of place to restore full spillway capacity in the event of high flows. Once in operation, the flow over the RSW was regulated only by the forebay level. The RSW operates with the tainter gate completely out of the water. The approximate depth of the water flowing over the crest of the RSW is 10 feet when the forebay is at MOP.

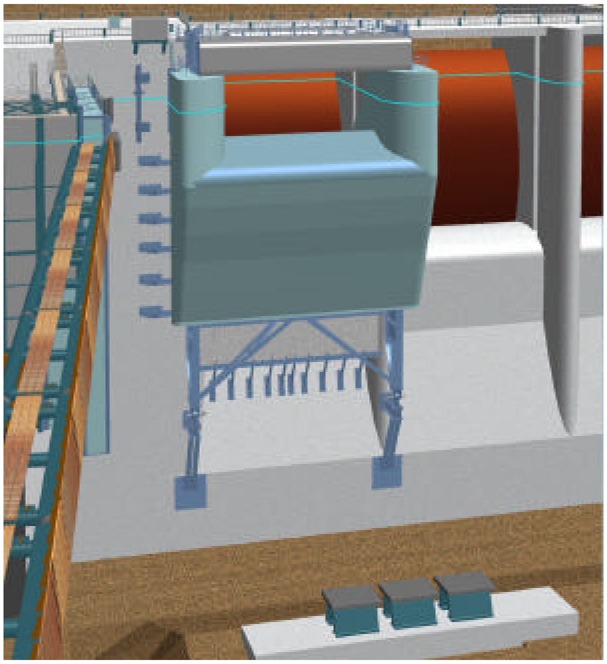


Figure 1. Image of the Removable Spillway Weir (RSW) at Lower Granite Dam.

1.6. Study Design

The study design for testing RSW performance comprised three operational scenarios. Anticipated treatments were as follows:

- Day 1: Night spill (~60 kcfs; 1800-0600 hrs) to the gas cap (BiOp Base), identified as Gas Cap.
- Day 2: 22.2 kcfs total spill; 6.7 kcfs through the RSW and an additional 15.8 kcfs through bays 2-8, identified as RSW + 16.
- Day 3: 15.2 kcfs total spill; 6.7 kcfs through the RSW and an additional 8.5 kcfs through bays 3, 5, 6, 7, and 8, identified as RSW + 8.

The study period (15 April through 7 June 2002) was partitioned into nine 6-day blocks (Table 1). Each treatment was in place for two consecutive days during each block. All treatments encompassed a 24 hr period.

Table 1. Schedule of Operations for Testing of the RSW in 2002.

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
April	**14**	**15** RSW + 16 (24 hours)	**16** RSW + 16 (24 hours)	**17** RSW + 8 (24 hours)	**18** RSW + 8 (24 hours)	**19** Gas Cap (12 hours)	**20** Gas Cap (12 hours)
	21 RSW + 16 (24 hours)	**22** RSW + 16 (24 hours)	**23** RSW + 8 (24 hours)	**24** RSW + 8 (24 hours)	**25** Gas Cap (12 hours)	**26** Gas Cap (12 hours)	**27** Gas Cap (12 hours)
May	**28** Gas Cap (12 hours)	**29** RSW + 8 (24 hours)	**30** RSW + 8 (24 hours)	**1** RSW + 16 (24 hours)	**2** RSW + 16 (24 hours)	**3** Gas Cap (12 hours)	**4** Gas Cap (12 hours)
	5 RSW + 8 (24 hours)	**6** RSW + 8 (24 hours)	**7** RSW + 16 (24 hours)	**8** RSW + 16 (24 hours)	**9** RSW + 16 (24 hours)	**10** RSW + 16 (24 hours)	**11** Gas Cap (12 hours)
	12 Gas Cap (12 hours)	**13** RSW + 8 (24 hours)	**14** RSW + 8 (24 hours)	**15** RSW + 16 (24 hours)	**16** RSW + 16 (24 hours)	**17** Gas Cap (12 hours)	**18** Gas Cap (12 hours)
	19 RSW + 8 (24 hours)	**20** RSW + 8 (24 hours)	**21** RSW + 8 (24 hours)	**22** RSW + 8 (24 hours)	**23** RSW + 16 (24 hours)	**24** RSW + 16 (24 hours)	**25** Gas Cap (12 hours)
	26 Gas Cap (12 hours)	**27** RSW + 8 (24 hours)	**28** RSW + 8 (24 hours)	**29** Gas Cap (12 hours)	**30** Gas Cap (12 hours)	**31** RSW + 16 (24 hours)	**1** RSW + 16 (24 hours)
June	**2** Gas Cap (12 hours)	**3** Gas Cap (12 hours)	**4** RSW + 16 (24 hours)	**5** RSW + 16 (24 hours)	**6** RSW + 6 (24 hours)	**7** RSW + 6 (24 hours)	

During the course of the study period, actual project operations diverged from planned operations resulting in the need to modify treatment day definitions. In order to satisfy one of the treatments, project operations had to be consistent throughout the entire 24 hr study day period (0600-0559). This resulted in some study days being excluded as the result of substantial changes in operations during the study day, i.e., turning the RSW on or off during the day. RSW performance was evaluated based on the following treatments or project operations:

- RSWGT16: Days in which the RSW was operated with training spill equal to or greater than 16 kcfs
- RSWLT16: Days in which the RSW was operated with less than 16 kcfs training spill
- Gas Cap 12hr_night: The nighttime period (1800-0600) for pure Gas Cap days (i.e., no daytime spill, no RSW)
- Gas Cap 24hr: Days in which pure Gas Cap operation was in place (i.e., no daytime spill, no RSW)

2. Methods

This section contains a brief description of the hydroacoustic sampling methods. One system each was used to monitor passage at the powerhouse, spillway, and RSW

2.1. Transducer Locations and Orientations

- Powerhouse: Six 10° single-beam and two 12° split-beam transducers sampled total powerhouse passage. Transducers were mounted to the first purlin above the sill at approximately 601 ft elevation (mean sea level) (bottom of forebay at 597 ft). Transducers were randomly placed on either the north or south side of the center vertical frame member, aimed upward and approximately 30° downstream. One of three slots was sampled for each turbine unit. Resultant aiming angle was approximately 39° with addition of trashrack slope.The randomly selected slots for each turbine were: 1A/south, 2C/south, 3B/north, 4B/south, 5A/north, and 6C/south (Figure 2 and Figure 3). Two units (T1 and T6) were also sampled from pier nose locations using single-beam transducers deployed at approximate elevation 601 ft. These transducers were aimed upward, approximately 6° upstream, and 21° to the north or south according to pier nose location.

- Spillway: Spill Bays 2, 4, 5, 6,7 , and 8 were sampled using 10° single-beam transducers while passage through spill bay 3 was sampled using a 12° split-beam transducer (Figure 2 and Figure 4).

All transducers were deployed in the center of the spill bays at approximate elevation 730 ft (surface elevation at 734.5 ft). Single-beam transducers were aimed downstream 5° and the split beam transducer was aimed 3° downstream.

- RSW: Two 12° split-beam transducers were used to monitor fish passage and movement into the RSW (Figure 2 and Figure 5). The transducers were mounted to a traversing frame at approximately elevation 694 ft. Due to electrical interference with concurrent research activities, the transducer parked were on April 24, 2002 approximately 17.5 ft on each side of the RSW centerline. The transducers monitored fish passage from these locations for the remainder of the study period.

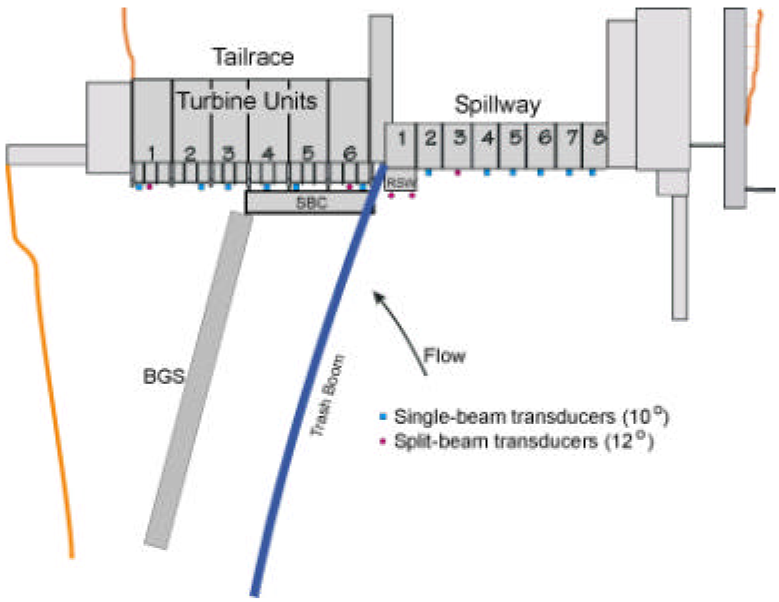


Figure 2. Plan view of Lower Granite Dam showing transducer locations.

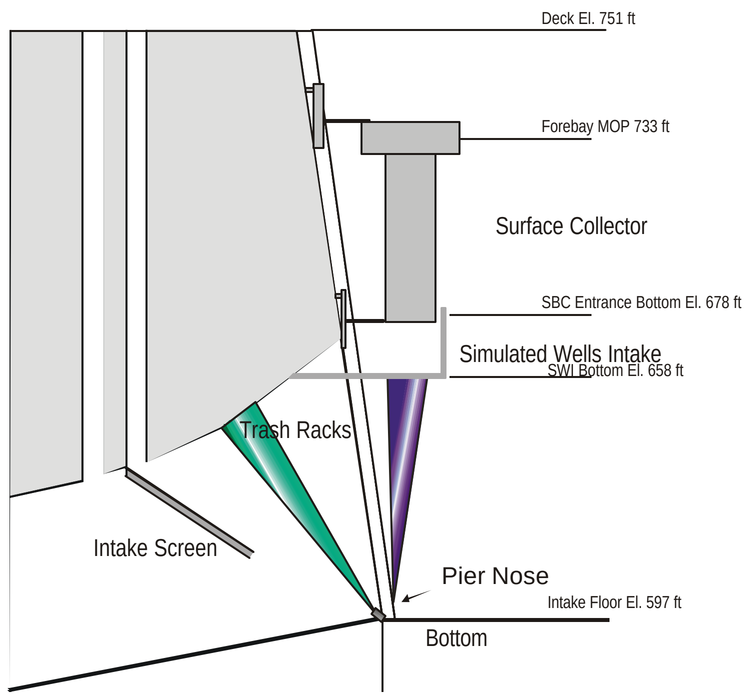


Figure 3. Side view of powerhouse showing location and approximate aiming angles of trashrack mounted and pier nose deployed transducers.

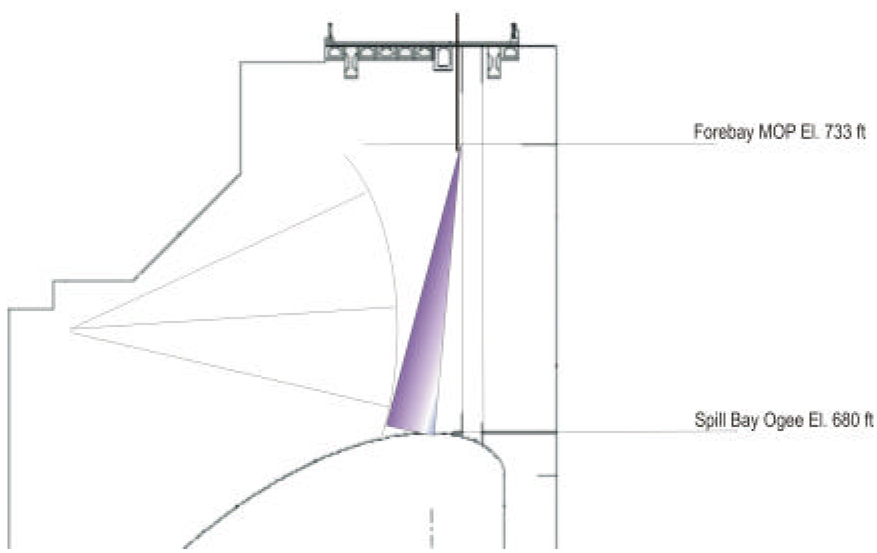


Figure 4. Side view of spillway showing transducer orientation.

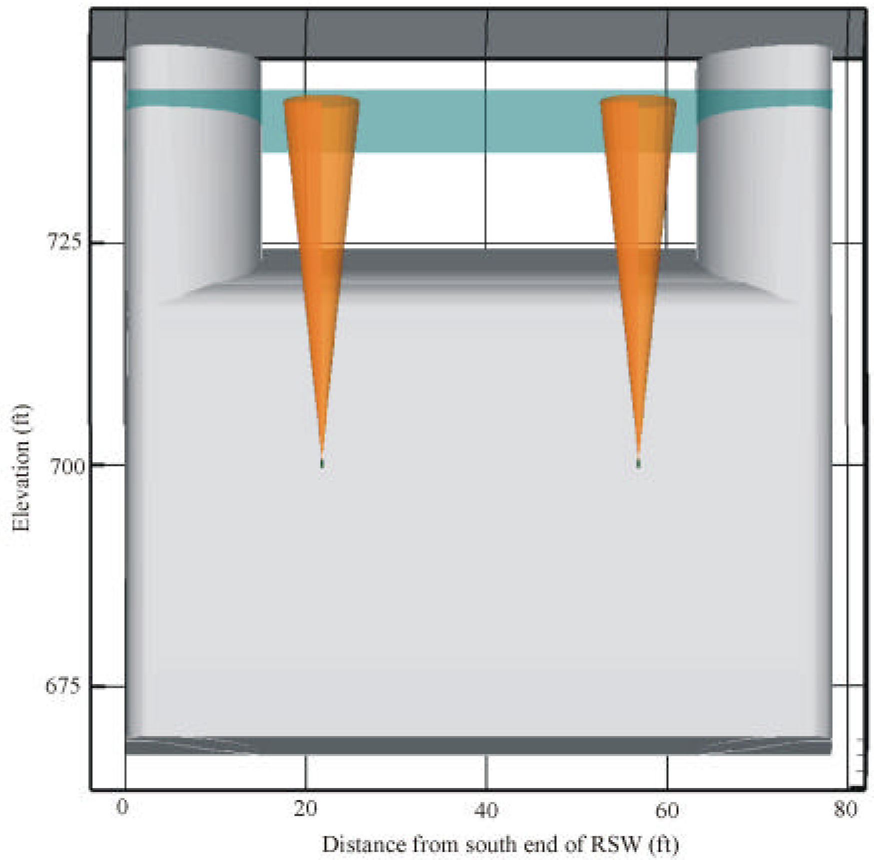


Figure 5. Front view of RSW showing fixed location of split-beam transducers.

Table 2 presents the primary metrics used to evaluate the performance of the RSW, powerhouse, and spillway passage routes.

Table 2. Definitions for parameters in the fish passage analysis.

Parameter	Descriptor	Estimator
CY	Combined RSW efficiency expresses passage through the RSW and spillway relative to total project passage.	$CY = (S_{2-8} + R) / (S_{2-8} + T + R)$, where S_{2-8} is spill bay 2-8 passage, *R* is RSW passage, and *T* is Turbine 1-6 passage
CS	Combined RSW effectiveness shows the relationship between the proportion of fish spilled through the RSW and spillway relative to proportion of water spilled.	$CS = CY * (F / (f_S + f_R)$, where *CY* is combined RSW efficiency, *F* is total project discharge, f_S is spillway discharge and f_R is RSW discharge
RY	RSW efficiency expresses passage through the RSW relative to total project passage.	$RY = R / (S_{2-8} + T + R)$, S_{2-8} where *R* is RSW passage, S_{2-8} is spill bay 2-8 passage, and *T* is Turbine 1-6 passage
RS	RSW effectiveness shows the relationship between the proportion of fish spilled through	$RW = RY * (F / f_R)$ where *RY* is RSW efficiency, *F* is total project discharge, and

	the RSW relative to proportion of water spilled.	f_R is RSW discharge
SY	Spill efficiency shows the proportion of fish spilled	$SY = S_{2\text{-}8} / (S_{2\text{-}8} + T + R)$ where $S_{2\text{-}8}$ is spill bay 2-8 passage, *R* is RSW passage, and *T* is Turbine 1-6 passage
SS	Spill effectiveness shows the relationship between proportion of fish spilled and proportion of water spilled	$SS = SY * (F / f_S)$ where *SY* is spill efficiency, *F* is total project discharge, and f_S is spillway discharge

3. Hydraulic Conditions and Migration Characteristics

This section provides data on river discharge, dam operations, species composition, and run timing during spring 2002 at Lower Granite Dam.

3.1. Hydraulic Conditions

Mean hourly project discharge was 2,363 m^3/s (83.5 kcfs) during the 2002 study period. Operations data were unavailable prior to April 18, though the study period began on April 15, 2002. Turbine discharge was relatively low throughout the study period. Overall discharge was highest during the end of the study period, in late May and early June (Figure 6). Turbine 5 was off-line throughout the entire study period and Turbine 1 was off-line after April 30, 2002. Discharge through Spill Bays 1-8 averaged 38% of outflow and mean hourly discharge through the spillway was 906 m^3/s or 32 kcfs.

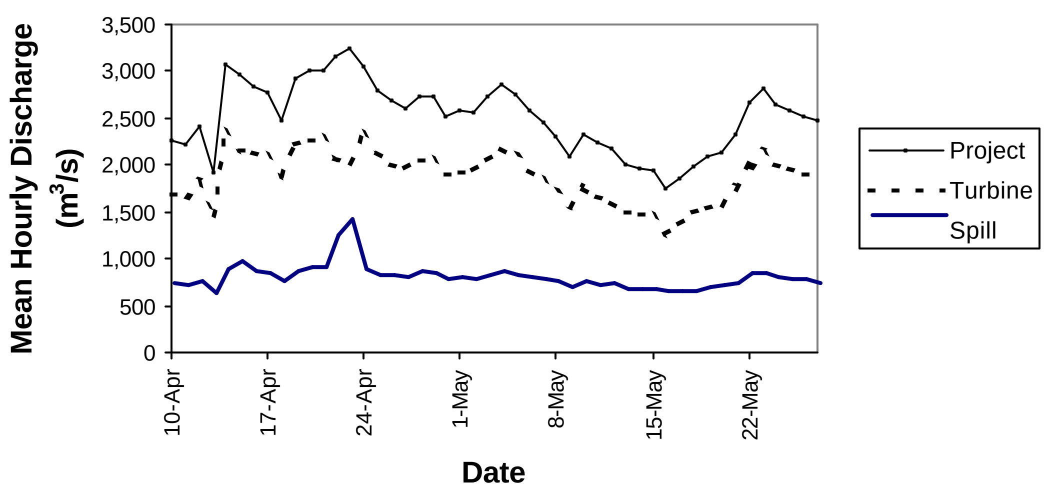


Figure 6. Hourly discharge for the total project, Turbines 1-6, and Spill Bays 1-8 at Lower Granite Dam from April 18 through June 7, 2002.

During the study period, spillway discharge was higher than anticipated due primarily to the outtages of Turbines 1 and 5. Due to the higher spillway discharge, project operations for Treatment 1

(RSW + 8) were seldom met (Figure 7). Mean hourly discharge through the spillway, including RSW discharge, was 29.3 kcfs for the RSW + 8 treatment, 39.5 kcfs for the RSW + 16 treatment, and 32.9 kcfs for the Gas Cap treatment. There was no significant difference in spillway discharge (P = 0.08) between the two RSW treatment days.

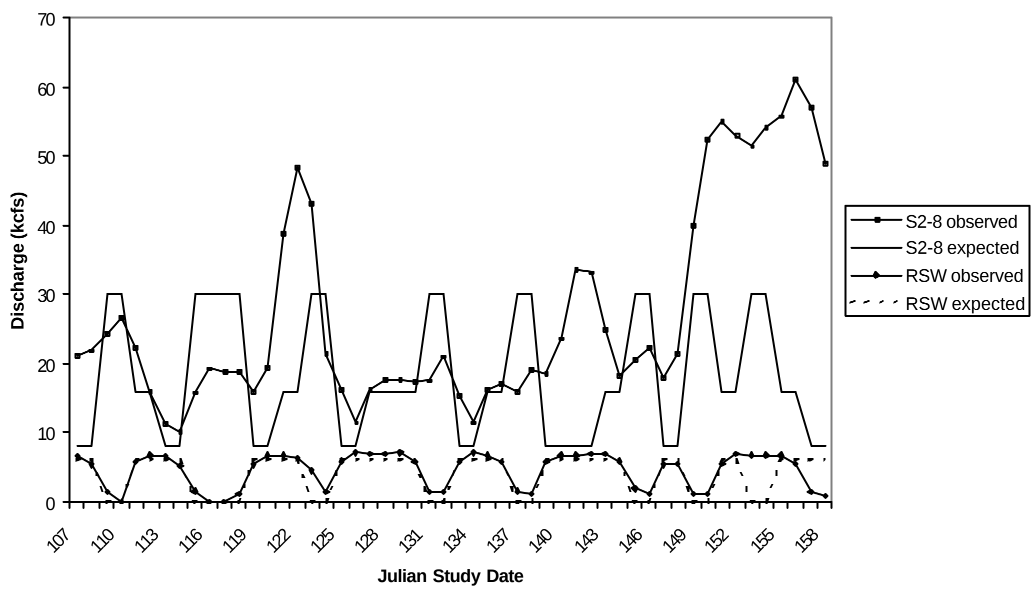


Figure 7. Daily observed and expected discharge at spill bays 2-8 and the RSW.

3.2. Migration Characteristics

The spring 2002 out-migration past Lower Granite Dam consisted primarily of steelhead (*Oncorhynchus mykiss*; 49%) and yearling chinook (*O. tshawytscha*; 47%) (Figure 8). Chinook salmon were dominant early in the study period, and again from May 1 through May 20, 2002, averaging 62% of total passage. Steelhead were predominant from May 21 through the end of the study period, averaging 68% of total passage. Passage numbers began to decline substantially after May 31, 2002. Wild sub-yearling chinook, sockeye (*O. nerka*), and coho (*O kisutch*) were also collected in bypass samples during the study period. The smolt monitoring program passage index (SMP Index) of chinook salmon and steelhead peaked on May 4 (333,835 fish per day, 73% chinook) and May 23, 2002 (221,772 fish per day, 85% steelhead), respectively (Figure 9). Daily passage of chinook salmon had a smaller peak on April 16 (83,425) and May 19 (89,531). Daily passage of steelhead demonstrated small peaks on April 28 (96,281), May 4 (88,525), and May 6 (91,657) with the highest passage occurring on May 23 (188,682).

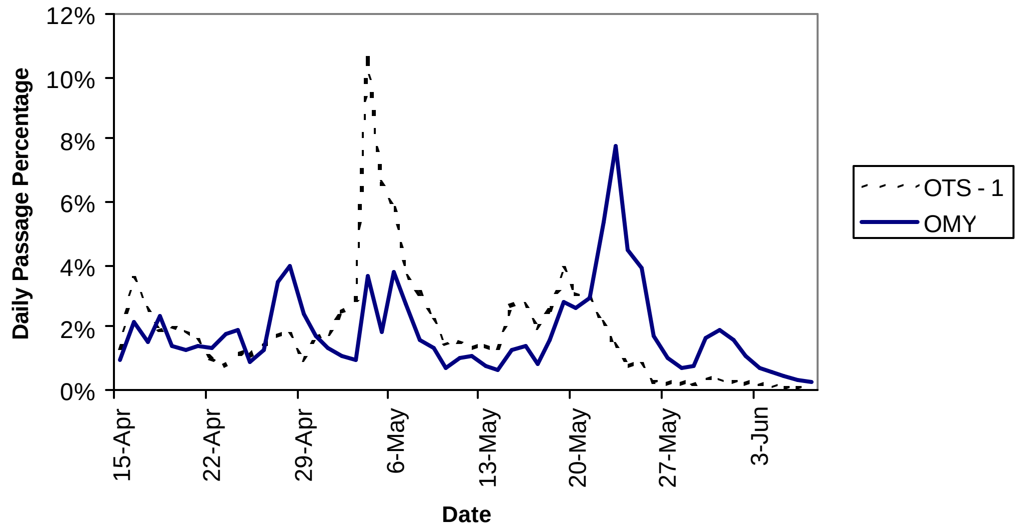


Figure 8. Daily percentages of steelhead (OMY) and chinook salmon (OTS - 1) of all fish collected at Lower Granite Dam from April 15 through June 7, 2002. (SMP data from DART http://www.cqs.washington.edu/dart/.)

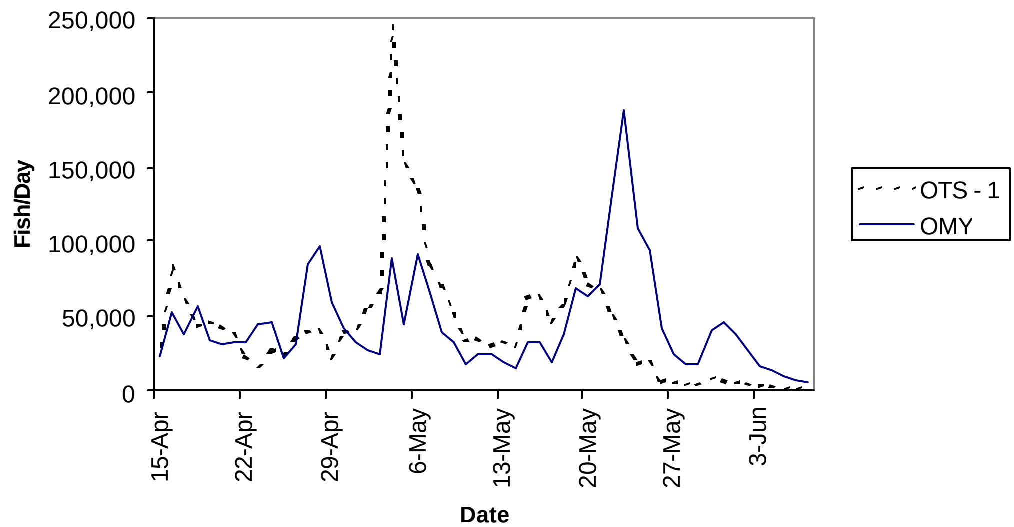


Figure 9. Daily run timing data from the Smolt Monitoring Program (SMP) at Lower Granite Dam in 2002. (SMP data from DART http://www.cqs.washington.edu/dart/.)

4. Fish Passage

Passage and performance data are presented for the period from April 18 through June 7, 2002. Due to the similarity in spillway discharge between RSW + 8 and RSW + 16 treatment days, passage data from these two treatment was combined. Confidence interval brackets in graphs are at the 95% level. We caution the reader that these data are preliminary and are subject to change as the data set undergoes further detailed scrutiny.

- The run timing curve for the period discussed in this report, comports well with the Smolt Monitoring Program (SMP) at Lower Granite Dam through the end of May (Figure 10). The hydroacoustic passage index indicated an increase in passage in the beginning of June, this peak was not reflected to the same degree in the SMP index.

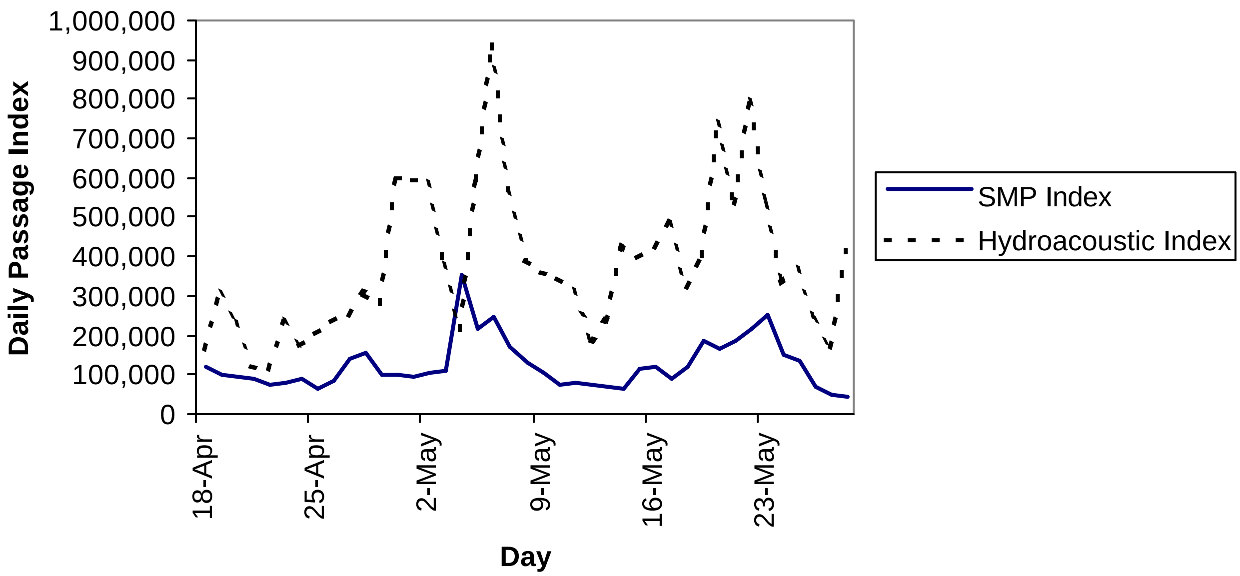


Figure 10. Daily fish passage proportions of hydroacoustic (HA) and SMP indices. (SMP data from DART http://www.cqs.washington.edu/dart/.)

4.1. Combined RSW Efficiency and Effectiveness

- Combined spill efficiency and effectiveness for the RSW treatments were higher than observed for the Gas Cap treatment (Table 3). Efficiency and effectiveness values were higher when just the 12 hr period of night spill during Gas Cap operation was included. This compares to values in 2000, using SBC Single High configuration passage, of 0.66 and 2.65 for combined spill efficiency and effectiveness, respectively (Anglea et al. 2001).

Table 3. Combined RSW efficiency and effectiveness for the RSWGT16, RSWLT16, and Gas Cap treatments.

Treatment	n (days)	Combined Spill Efficiency	Combined Spill Effectiveness
RSWGT16	11	0.78	2.19
RSWLT16	6	0.71	2.13
Gas Cap 12hr night	7	0.86	1.31
Gas Cap 24hr	7	0.66	2.01

4.2. RSW Efficiency and Effectiveness

- During the RSWGT16 treatment RSW efficiency and effectiveness was 0.62 and 7.22, respectively. During the RSWLT16 treatment, RSW efficiency increased to 0.68 and RSW effectiveness decreased to 3.47. This follows the expected trend in RSW passage, with passage through the RSW being depressed while discharge was high through the existing unmodified spill bays. RSW efficiency is highest during the higher spill configuration, due to the smaller proportion of spill passing through the RSW. SBC efficiency (R_{all}) and effectiveness (E_{all}) in 2000 for the Single High configuration of the SBC was 0.56 and 11.17, respectively (Anglea et al. 2001).

4.3. Spill Efficiency and Effectiveness

- Spill efficiency, not including RSW passage, was 0.16 during the RSWGT16 treatment and 0.03 during the RSWLT16 treatment (Table 4). Spill efficiency was substantially higher during the Gas Cap treatment.

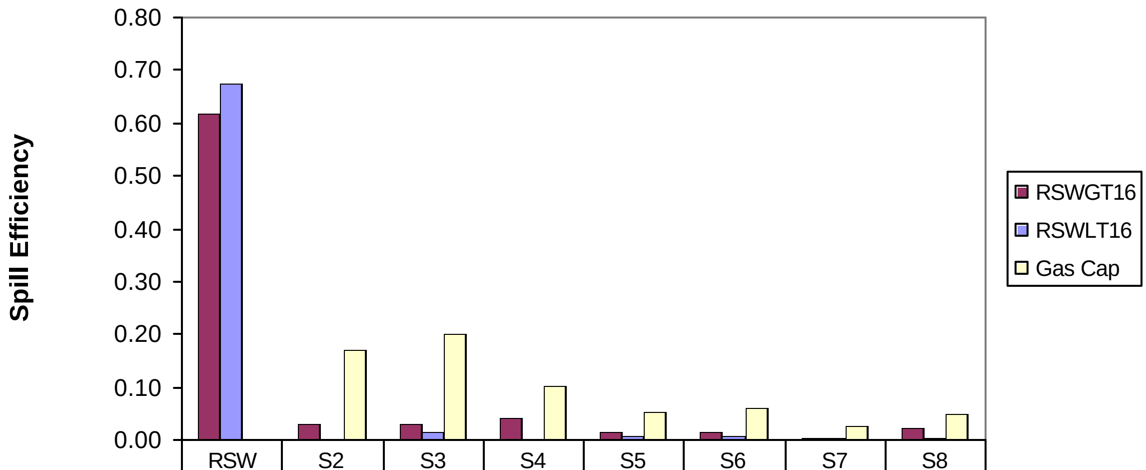
- Spill effectiveness, not including RSW passage, was 0.53 during the RSWGT16 treatment and 0.26 during the RSWLT16 treatment (Table 4). Spill effectiveness was substantially higher during the Gas Cap treatment.

Table 4. Spillway efficiency and effectiveness for the RSWGT16, RSWLT16, and Gas Cap treatments.

Treatment	n (days)	Spill Efficiency	Spill Effectiveness
RSWGT16	11	0.16	0.53
RSWLT16	6	0.03	0.26
Gas Cap 12hr night	7	0.86	1.31
Gas Cap 24hr	7	0.66	2.01

4.4. Spill Bay Efficiency and Effectiveness

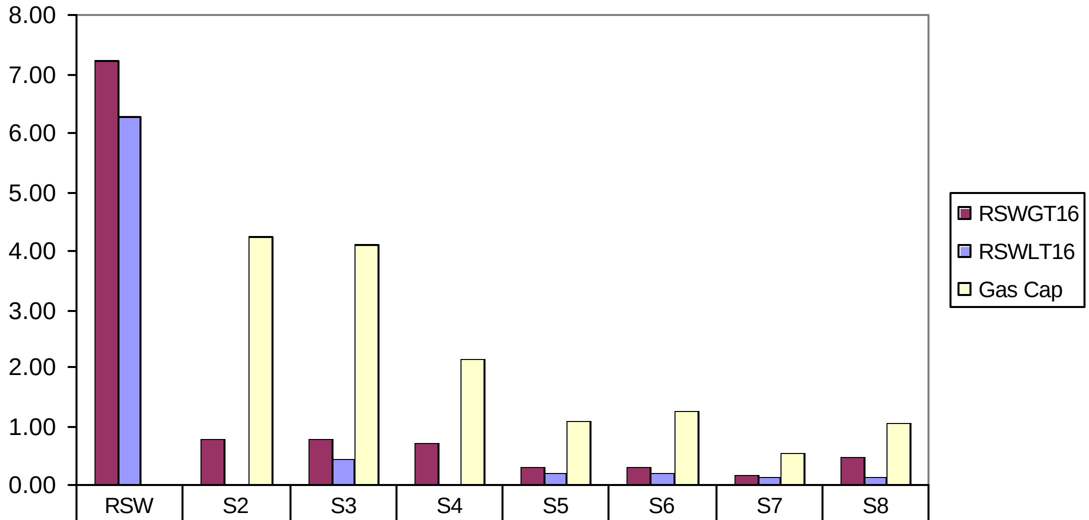
- Efficiency of an individual spill bay, including the RSW at spill bay 1, was highest at the RSW (Figure 11). During the Gas Cap treatment, efficiency was high at bays 2 and 3 and then decreased at spill bays further to the north.



	RSW	S2	S3	S4	S5	S6	S7	S8
RSWGT16	0.62	0.03	0.03	0.04	0.01	0.01	0.01	0.02
RSWLT16	0.68	0.00	0.01	0.00	0.01	0.01	0.00	0.00
Gas Cap	0.00	0.17	0.20	0.10	0.05	0.06	0.03	0.05

Figure 11. Spill efficiency of individual spill bays for the RSWGT16, RSWLT16, and Gas Cap treatments.

- The RSW at spill bay 1 was the most effective location while it was open (Figure 12). Effectiveness of spill bays 2 and 3 during the Gas Cap treatment were highest and still lower than at spill bay 1 during either RSW treatment.



	RSW	S2	S3	S4	S5	S6	S7	S8
RSWGT16	7.22	0.77	0.78	0.72	0.30	0.29	0.17	0.48
RSWLT16	6.25	0.00	0.44	0.00	0.22	0.22	0.13	0.14
Gas Cap	0.00	4.24	4.11	2.15	1.08	1.26	0.55	1.06

Figure 12. Spill effectiveness of individual spill bays for the Gas Cap separately and RSW + 8 and RSW + 16 treatments combined.

4.5. Fish Distribution and Movement at the RSW

- The horizontal distribution of fish passage and characteristics of fish passage (direction, velocity) at the RSW was determined through the application of a 3-dimensional tracking process that formed tracks on an echo by echo basis. The data set to determine fish distribution and movement is from the same raw data as that used to determine passage rates, but has undergone an independent process to identify likely fish tracks. Tracks were constructed based on the relationship of one ping/echo to the next, rather than on the overall characteristics of a collection of echoes. Depending on the particular analysis, the resultant data set was composed at a minimum of over 60,000 individual tracks.

- Data collected on June 5, 2002, while the north RSW split-beam transducer was traversing, indicated a non-uniform distribution of fish passage. Fish density immediately upstream from the pier nose extension (~66 ft from south end of RSW) was lower than at the two locations toward the middle of the north half of the RSW (Figure 13).

- Fish density was highest near the transducer (elevation 694 ft) and decreased with decreasing depth, suggesting that fish are moving up in the water column as they approach the RSW.

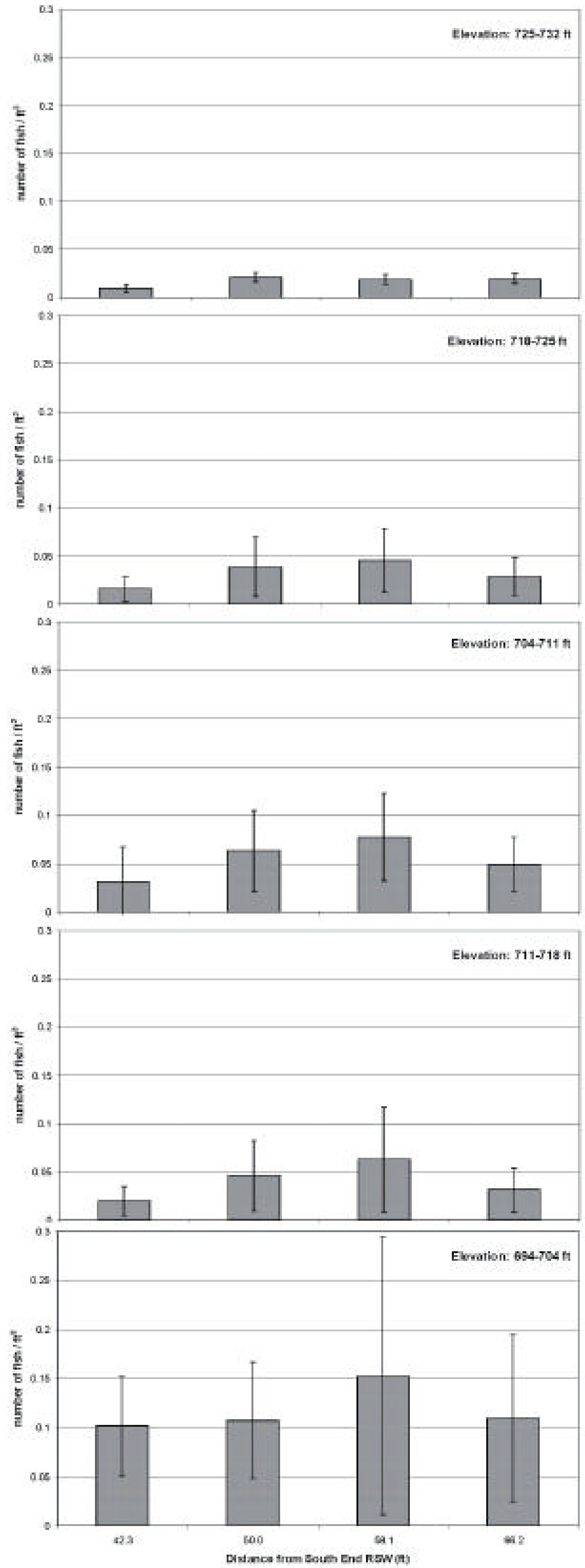


Figure 13. Density (fish/ft^3) of targets through the north half of the RSW on June 5, 2002.

- More than 90% of the fish tracks above the RSW nose were moving in a downstream direction toward the RSW while the RSW was open, while less than 45% were moving downstream while the RSW was closed (Figure 14). Figure 14 shows fish track velocity along the Y-axis (upstream-downstream) for RSW open and closed conditions. Negative values indicate downstream movement.

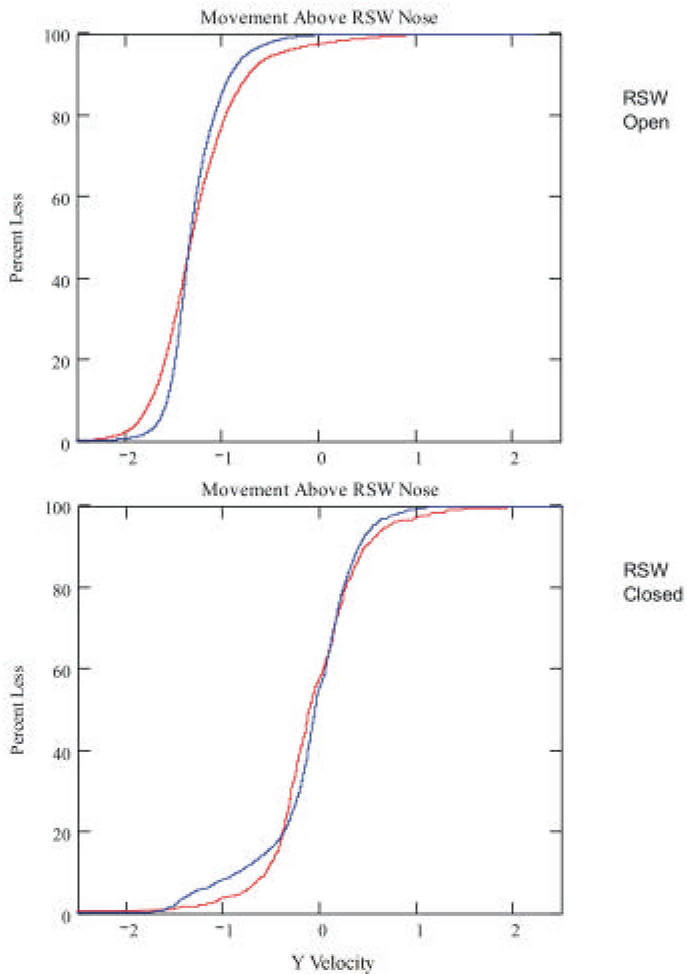


Figure 14. Velocity of fish tracks along the Y axis, above the RSW nose, for RSW open and closed conditions. Negative values indicate downstream movement, positive values indicate upstream movement. Red line represents the velocity of fish passing through the south RSW transducer, blue line represents the velocity of fish passing through the north RSW transducer.

- Vectors of fish paths, representing the median distance traveled in 2-s, indicate that fish passing through the sample volumes were directed toward the center of the RSW (Figure 15 and Figure 16). Through both sample volumes, fish tracks were steepest near the transducer and decreased in slope with decreasing depth.

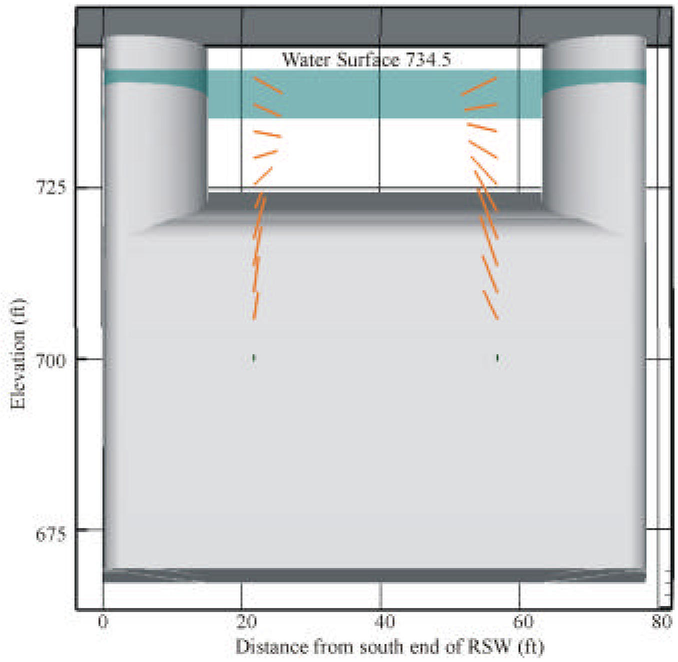


Figure 15. Front view of vectors of fish tracks passing through each RSW split-beam transducer. Vectors represent the median distance and direction traveled in 2-s.

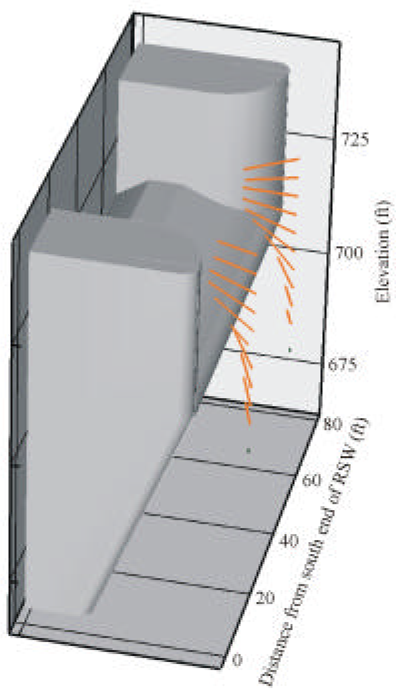


Figure 16. Side view of vectors of fish tracks passing through each RSW split-beam transducer. Vectors represent the median distance and direction traveled in 2-s.

5. Summary

This section summarizes our findings to date.

- Combined spill efficiency and effectiveness was highest for the RSWGT16 treatment days. This is likely due to the relatively large discharge volume and operation of the RSW. Efficiency and effectiveness of the Gas Cap treatment over an entire 24 hr period was lower than either treatment while the RSW was open.
- RSW efficiency was highest during the low training spill configuration while RSW effectiveness was higher during the high training spill configuration. The increase in effectiveness with increased training spill is likely due to a decrease in the proportion of discharge through the RSW.
- Estimates of individual spill bay (including the RSW) efficiencies indicate that the RSW passes substantially more fish relative to the unmodified bays, > 60% compared to < 5% for unmodified bays during RSW treatments and ≤ 20% during the Gas Cap treatment.
- The RSW was the most effective bay while the RSW was open. Spill bays 2 and 3 were the most effective during the Gas Cap treatment.
- Horizontal and vertical distributions of fish tracks through the north half of the RSW on June 5, 2002, indicate that fish density is highest near the transducer and away from the pier nose extension. Fish density decreases with decreasing depth.
- Greater than 90% of the fish tracks in front of the RSW are traveling toward the RSW while it is open indicating that fish move readily into the RSW in the location of the split-beam sample volumes.
- Vectors of fish in each RSW split-beam sample volume, indicate that fish are generally heading toward the center of the RSW. Fish tracks are ascending steeply near the depth of the transducer and decrease in slope with decreasing depth.
- The data for this report were aggregated based on the RSW being open or closed. This was due to the divergence in actual versus planned project operations. Additional effort need to be expended identifying appropriate aggregations of days or hours based on factors such as: RSW open/closed, spill 12/24 hr, day/night, and block.

6. References

Anglea, S.M., R.L. Johnson, M.A. Simmons, S.L. Thorsten, J.P. Duncan, M.A. Chamness, C.A. McKinstry, E.A. Kudera, and J.R. Skalski. 2001. Fixed-Location Hydroacoustic Evaluation of the Prototype Surface Bypass and Collector at Lower Granite Dam in 2000. Walla Walla District, U.S. Army Corps of Engineers.

Anglea, S.M., G.E. Johnson G, T.O. Wik, L.A. Reese, and A.E. Giorgi.. 2002. Development of the Surface Bypass and Collector for Juvenile Salmon and Steelhead at Lower Granite Dam 1994-2000. Walla Walla District, U.S. Army Corps of Engineers.