Estimates of Fish-, Spill-, and Sluiceway-Passage Efficiencies of Radio-Tagged Juvenile Fall Chinook Salmon at The Dalles Dam, 2000

Final Report of Research during 2000

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Summary

In 2000, the U.S. Army Corps of Engineers (COE) contracted with the U.S. Geological Survey to determine spill and fish passage efficiencies at The Dalles Dam (TDA) during a 40% continuous spill treatment. Our specific objectives were to: 1) determine the proportion of radio-tagged subyearling Chinook salmon (*O. tshawytscha*) that passed through the spillway and powerhouse (via turbines or sluiceway) at TDA and 2) obtain information on the behavior of radio-tagged fish in the near-dam area prior to passage. This was the first radio-telemetry study conducted at The Dalles Dam designed to determine fish passage efficiency (FPE), spill passage efficiency (SPE) and sluiceway passage efficiency (SLPE) of subyearling Chinook salmon.

Dam Operations: The average test condition was similar to that proposed. Mean hourly percent spill ranged from 35.4 to 43.8% during the study, with an average of 39.3% during the day period (0700 to 1859 h) and 39.3% during the night period (1900 to 0659 h). Mean hourly total discharge ranged from 107 to 281 thousand cubic feet per second (KCFS) to 305.5 KCFS during the study, with an average of 170 KCFS during the day period and 164 KCFS during the night period.

Number of Fish Released and Detected: From 28 June through 20 July, we radio-tagged and released 394 subyearling Chinook salmon. All tagged fish were released at Rock Creek, 23 km upstream from John Day Dam (JDA). The telemetry systems at TDA detected 62% of the tagged fish.

Travel Time, Arrival Time, and Approach Pattern: The median travel time of subyearling Chinook salmon from the Rock Creek release site to the TDA near-dam forebay was 48.8 h. Due to the release times (morning and evening) and the variable length of time it took individual fish to reach the dam, the hour of arrival at TDA was widely dispersed throughout the diel period.

Most fish were first detected (i.e., approached the dam) at the powerhouse. An average of 75% of the subyearling Chinook salmon arriving during the day (0700 to 1859 h) were first detected at the powerhouse and 82% of those arriving at night (1900 to 0659 h) were first detected in this area.

Behavior in the Near-Dam Forebay: The median residence times in the near-dam forebay of fish arriving during the day and night periods were 0.45 and 0.66 h, respectively. The forebay residence times were related to the area of passage, with the shortest times from fish that passed via the powerhouse, intermediate times from those passing via the sluiceway, and the longest times from fish passing via the spillway. This appeared to be due to the configuration of the dam itself rather than project operations, since the powerhouse is perpendicular to the spillway and some fish passing via the sluiceway and spillway are first detected near the powerhouse.

Fish-, Spill-, and Sluiceway-Passage Efficiencies: Most fish passed the dam via the spillway, with the powerhouse (turbine) passage the second most prevalent and the sluiceway the least prevalent. No statistically significant differences in FPE between the seven 3-d time blocks of study or between day and night periods were detected. Fish passage efficiencies, pooling data from all blocks, was 89% during the day and 86% at night. The SPE was significantly greater during the day than in the night period, but between-block differences due to low values in Block 4 prevented an overall point estimate for the study. The point estimates of SPE without data from Block 4 were 85% during the day and 73% at night. The SLPE was significantly greater during the night than in the day and no among-block differences were detected. The point estimates of SLPE were 6% during the day and 16% at night.

Introduction

A Supplemental Biological Opinion issued by the National Marine Fisheries Service (NMFS) recommended that spill volumes at dams on the Columbia and Snake rivers be maximized to increase juvenile salmonid (*Oncorhynchus* spp.) survival without exceeding the current total dissolved gas cap levels or other project-specific limitations (NMFS 1998). At The Dalles Dam (TDA), where it is believed that the spillway may not be a benign passage route during some spill conditions, the NMFS requested that spill volumes be limited to 64% of the total discharge pending the completion of ongoing studies of passage survival and spill efficiency and effectiveness.

Generally, a 1:1 relationship is assumed between the percent of total fish that pass through the spillway and the percentage of total river flow passing through the spillway (Whitney et al. 1997). However, it is estimated that spill effectiveness is greater than the 1:1 ratio at TDA and that a spill volume of only 31% of total river flow is needed to achieve 80% fish passage efficiency (FPE) for spring and summer migrants (Whitney et al. 1997). Other studies at TDA have indicated that 30% spill may be just as effective at passing juvenile salmonids as spill levels near 60% of the total discharge (NMFS 1998). Hansel et al. (2000a), in a study of passage of radio-tagged fish at TDA during spring 1999 found that the FPE of juvenile steelhead did not differ significantly during tests of 30% and 64% spill (30% spill FPE = 91%, 64% spill FPE = 95%), but the FPE of yearling Chinook salmon was significantly greater during 64% spill than during 30% spill (91% vs. 73%). The spillway and the ice-trash sluiceway are currently the main non-turbine routes of juvenile fish passage at TDA.

In 2000, the U.S. Army Corps of Engineers (COE) contracted with the U.S. Geological Survey to determine spill and fish passage efficiencies at TDA during a treatment of continuous 40%-spill passed via the juvenile spill pattern. Our specific objectives during the summer of 2000 were to: 1) determine the proportion of radio-tagged subyearling Chinook salmon (*O. tshawytscha*) that passed through the spillway and powerhouse (both turbines and sluiceway) at TDA and 2) obtain information about their behavior in the near-dam area prior to passage.

Methods

Study Site

The Dalles Dam is located on the Columbia River at river km 307 (Figure 1). The dam consists of a single powerhouse of 22 main turbine units (main units), 2 “fish units”, which

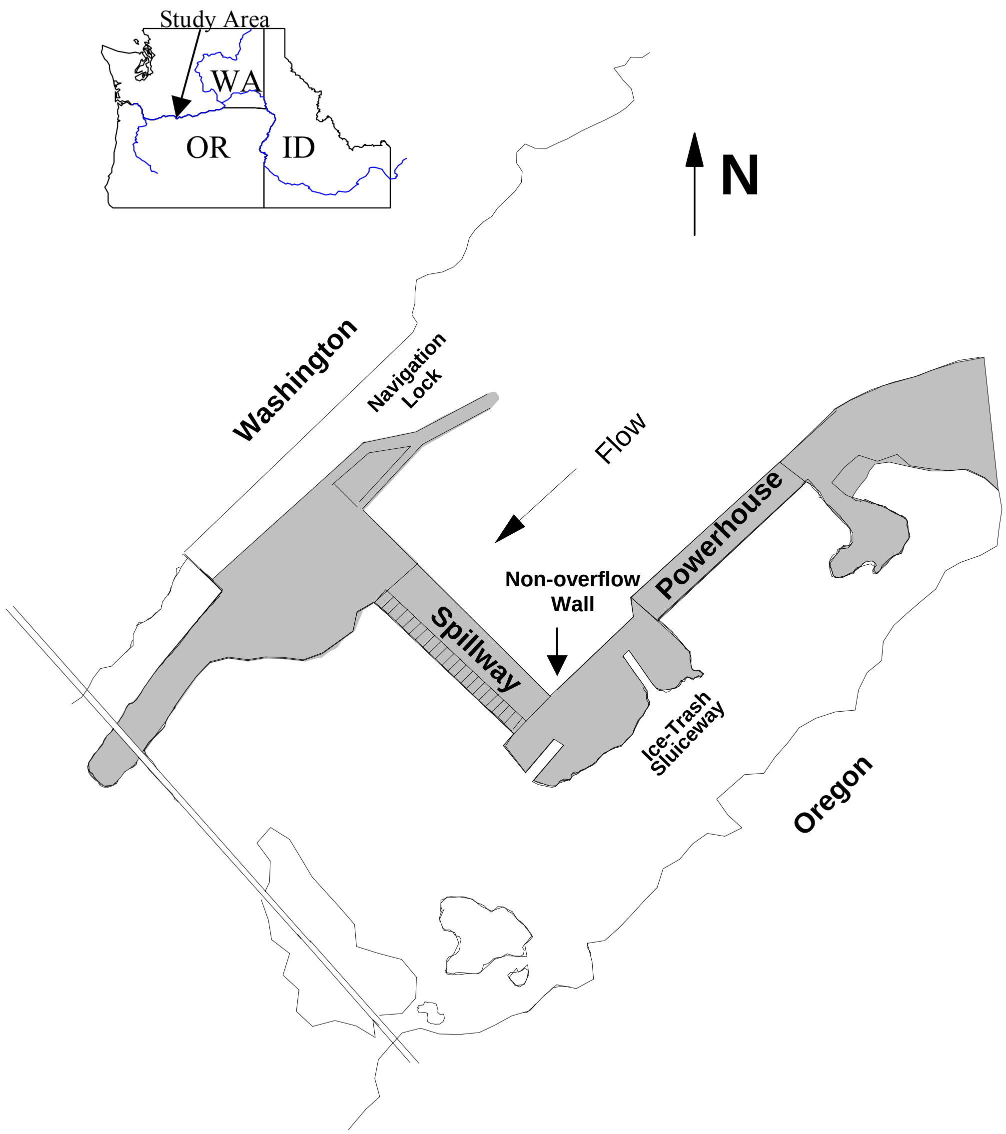

Figure 1. The Dalles Dam (river km 307) study site on the Columbia River and map indicating study site relative to the States of Washington (WA), Oregon (OR) and Idaho (ID).

generate electricity to power pumps for adult fish ladder auxiliary water supplies, and a single spillway of 23 tainter gates. The powerhouse is oriented parallel to river flow, but the spillway is perpendicular to river flow, which is unique among Federal dams on the mainstem Columbia and Snake rivers. A non-overflow wall oriented parallel to river flow connects the powerhouse and spillway. Turbine units are numbered beginning with the downstream end of the powerhouse (Fish Unit 1, Fish Unit 2, Main Unit 1, etc.) proceeding upstream to Main Unit 22. Main units have three intake slots each and fish units have two intake slots each. Spill bays are numbered from the north to south, with bay 1 nearest the Washington shore and bay 23 nearest the non-overflow wall. A navigation lock is located at the northwest end of the dam.

Dam Operations

The spill treatment used in 2000 consisted of 40% continuous spill with a juvenile spill pattern. The juvenile spill pattern emphasizes spill through the northern spill bays to avoid directing fish to the shallow areas, rocks and islands on the south side of the tailrace. Juvenile salmonids in this area have prolonged tailrace residence times in an area known to harbor predators, such as the northern pikeminnow (*Ptychocheilus oregonensis*; Shively et al. 1996, Martinelli et al. 1997, Allen et al. 2001). The number of spill bays in use during this pattern depends on the total discharge. Spill bays are used as needed beginning with the north bays and proceeding south until the desired spill volume is achieved; the amount of spill per bay is higher in north than in south bays. Hourly powerhouse and spillway discharge data were obtained from the COE (COE 2000).

Telemetry Receiving Equipment

Four-element Yagi (aerial) antennas were positioned along the forebay sides of the powerhouse and spillway to detect fish within about 100 m of the dam face, hereafter referred to as the near-dam area. Each antenna monitored an area in front of a pair of turbine units or spill bays. Eight 4-element Yagi antennas were also placed evenly along the forebay side of the non-overflow wall. The Yagi antennas were connected to SRX-400 receivers (Lotek Wireless, Newmarket, Ontario, Canada[1]), which recorded the telemetry data, following the methods of Hensleigh et al. (1999). Additional aerial antennas were used to monitor the tailrace and area near the upstream boundary of the forebay boat-restricted zone. Each SRX-400 receiver was configured to scan all antennas combined (the master antenna), until it received a signal and then cycle through individual aerial antennas (auxiliary antennas) to determine a more precise location of the transmitter.

Underwater antennas were used to monitor radio-tagged juvenile salmonids within about 10 m of each turbine unit or spill bay. Underwater dipole antennas were mounted at several elevations on the main pier noses between all main units, between Main Unit 1 and Fish Unit 2, and on the pier nose downstream of Fish Unit 1. The antennas between the downstream side of Fish Unit 1 upstream to the pier nose between main units 4 and 5 were mounted at elevations of 42.7, 36.6, 30.5 and 24.4 m (140, 120, 100 and 80 ft) above mean sea level (msl), which correspond to water depths of 6.1, 12.2, 18.3 and 24.4 m (20, 40, 60 and 80 ft) below the normal operating pool elevation of 48.8 m (160 ft) above msl (Figure 2). Underwater antennas from the pier nose between main units 5 and 6 to the pier nose upstream of Main Unit 22 were mounted at the upper three of these depths. The inputs from all underwater antennas, and four aerial antennas in the sluiceway area, were monitored using a Multiprotocol Integrated Telemetry Acquisition System (MITAS), which is a PC-based telemetry data collection system (Grant Systems Engineering, Collingwood, Ontario, Canada).

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1 Reference to trade names does not imply endorsement by the U.S. Government

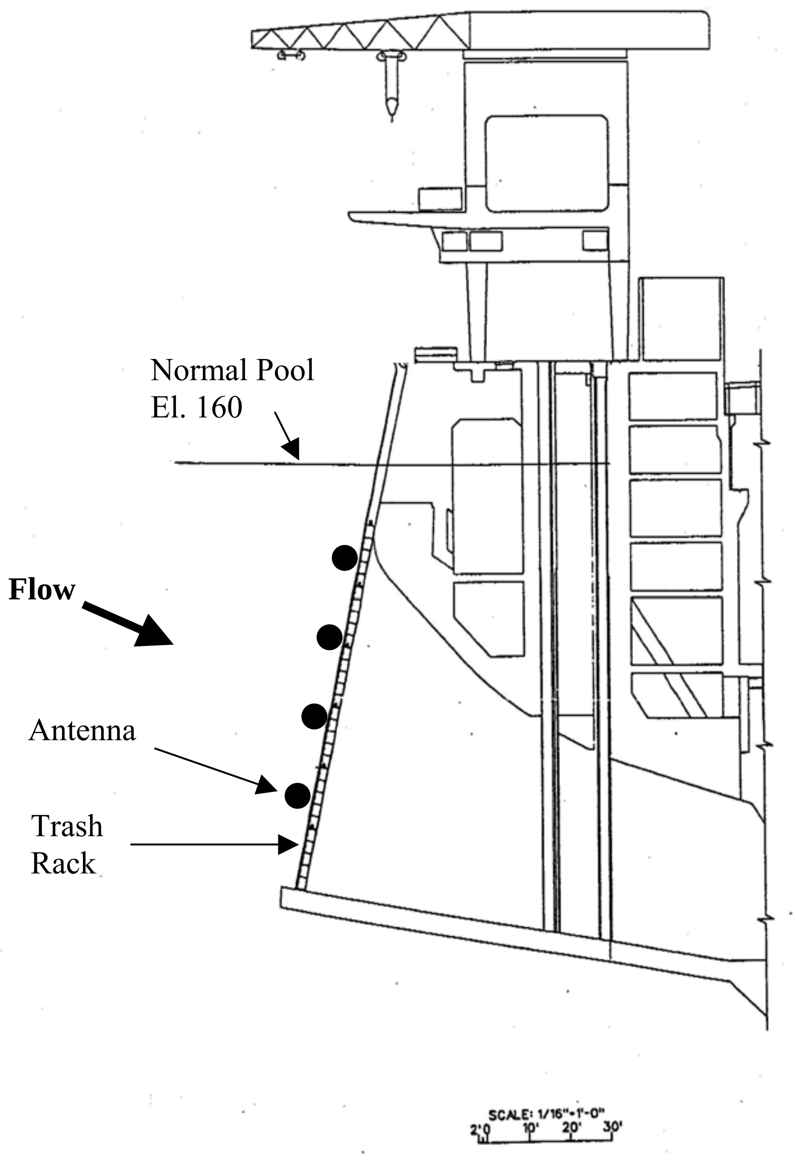

Figure 2. Cross section through a typical turbine intake at The Dalles Dam indicating normal pool elevation of 160 ft above mean sea level, trash racks, and underwater antenna locations at elevations of 140, 120, 100 and 80 feet above mean sea level. Modified from a U.S. Army Corps of Engineers schematic.

Fish Tagging, Handling, and Release

This study used radio-tagged fish from several concurrent studies at John Day Dam (JDA). The studies at JDA were designed to determine FPE, tailrace egress times, and project survival. Tagged fish for those studies were released at Rock Creek (23 km upstream of JDA) at 0800 and 2000 h. See Duran et al. (2001) and Beeman et al. (2003) for further details of the fish releases at JDA.

Subyearling Chinook salmon to be implanted with radio transmitters were obtained from the juvenile collection and bypass facility at JDA. Fish to be implanted were typically held at the collection facility for 12 to 24 h prior to tagging. Fish were considered suitable for tagging if they were free of injuries, severe descaling, external signs of gas bubble trauma, or other abnormalities.

Transmitters operating at frequencies between 150.320 and 150.580 MHz pulsing at rates of 30 or 50 pulses per minute were used in combination to allow each individual fish to be recognized. The transmitter size was 7.0 mm (diameter) x 17.0 mm and weighed 1.0 g in air and 0.7 g in water (Advanced Telemetry Systems, Isanti, Minnesota, USA, model F1410). The warranty tag life was a minimum of 8 d at 50 pulses per minute.

Transmitters were gastrically implanted using the methods of Martinelli et al. (1998). Following tagging, fish were held in tanks at the juvenile bypass collection facility for 20 to 28

h. After the holding period, the tanks were checked for mortalities and fish were transported to Rock Creek and released into the north river channel.

Data Management and Analysis

Data from radio-telemetry receivers and the MITAS system were typically downloaded every other day and imported into SAS (SAS Institute Inc., Cary, NC, USA) for subsequent proofing and analyses. The data were proofed to eliminate non-valid records including background noise, single records of a particular channel and code, records that were collected prior to the known release date and time, and records known to be fish eaten by avian predators. Generally, the minimum amount of data required to validate the presence of a radio-tagged fish was a combination of two master antenna and one auxiliary antenna detections or three master antenna detections within 1 to 2 min of each other.

The location and time an individual fish was first detected by the telemetry system monitoring the forebay antennas was considered the route and time of entrance into the near-dam area. The last detection of an individual fish on the telemetry systems monitoring the forebay (preferred method) or tailrace areas was considered the route and time of passage through the dam. However, radio-tagged fish were often detected on multiple auxiliary antennas where zones of coverage overlapped, making data reduction necessary. Fish detected on more than one auxiliary antenna within a two-minute period at the time of passage were assigned to a single passage location corresponding to the antenna where the highest strength signal was recorded, and all other records were excluded. A two-minute interval was chosen because it approximately coincided with the upper boundary of time needed to complete a scan cycle if several fish were present at any given time. Manual tracking on the dams has verified that the last detection by telemetry receiving stations is typically a good estimate of the passage route (Sheer et al. 1997; Holmberg et al. 1998; Hensleigh et al. 1999).

Fish passage efficiency (FPE) was determined as the proportion of the total number of radio-tagged subyearling Chinook salmon exiting the near-dam TDA forebay that passed via non-turbine routes (i.e., through the spillway or the ice-trash sluiceway) multiplied by 100%:

$$FPE = ((Nspillway + Nsluiceway) \div (Nspillway + Nsluiceway + Nturbine)) * 100\% \quad \text{Equation 1}$$

where *Nspillway, Nsluiceway and Nturbine* are the numbers of fish last detected at each location. Similarly, spill passage efficiency (SPE) and sluiceway passage efficiency (SLPE) were calculated as:

$$SPE = ((Nspillway) \div (Nspillway + Nsluiceway + Nturbine)) * 100\% \quad \text{Equation 2}$$

and

$$SLPE = ((Nsluiceway) \div (Nspillway + Nsluiceway + Nturbine)) * 100\% \quad \text{Equation 3}$$

Spill effectiveness was calculated as SPE divided by the proportion of total dam discharge being spilled. This index was used to help identify potential relations between spill discharges, FPE or SPE estimates, and juvenile salmonid passage behavior.

The passage data were divided into "day" and "night" periods for analysis based on the times spill operations were changed during tests of 12-h and 24-h spill at John Day Dam. Based on this criterion, the time between 0700 and 1859 h were considered "day" and those between 1900 and 0659 h were considered as "night", though these did not coincide with the actual times of daylight and darkness.

Statistical analyses comparing the passage indices calculated for day and night periods were completed using logistic regression after adjusting for differences in time blocks (see next paragraph for description of blocks). Logistic regression is not based on assumptions of linearity, normality, or homoscedasticity. Logistic regression estimates the probability of an event (e.g., passing via a non-turbine route) after converting the dependent variable to a logit (the natural log of the event occurring or not). An "odds ratio" is calculated from the odds of the dependent variable occurring in each of the two classes (i.e., day and night passage), and from this, the relative importance of the independent variables in terms of the effects on the dependent variable is estimated (similar to a beta weight in a least-squares regression). For example, if the hypothetical odds ratio between day and night FPE is 5, the probability of passing via a non-turbine route during the day is 5 times greater than during the night.

Diel passage data were split into seven time blocks to assess seasonal variation. The number of blocks used for analysis was arbitrarily determined by increasing the block sizes in 1-d increments until the number of fish detected within a day or night period was always more than

1, was generally more than 10, and the resulting estimates (i.e., FPE, SPE, or SLPE) were rarely 1 (meaning that all detected fish passed by that route). This ensured that the logistic regression would function properly. Blocks 1-6 were 3 d in duration, but block 7 was 7 d in duration to allow sufficient numbers of tagged fish to pass the dam for analysis. Examining the models' residual deviance divided by residual degrees of freedom assessed overdispersion. Ninety-five percent profile-likelihood confidence intervals were calculated for the overall odds ratio. Single seasonal estimates of the passage indices with 95% profile-likelihood confidence intervals for each diel period were calculated when there was no evidence of overdispersion or block effects.

Residence time in the near-dam area, defined as the amount of time between the first and last detections in the forebay, was calculated for each radio-tagged fish detected in the near-dam forebay area (residence times were not calculated for fish detected only at entrance and exit stations). These residence times are minimum estimates of the actual time that radio-tagged fish spent in the near-dam area due to the chance that a fish might have been in the near-dam area prior to their first detection and following their last detection. This could occur if a fish arrived in the aerial detection range before telemetry scanning receivers reached its frequency in the scan cycle (about 1 to 2 min), if a fish left the area between scan cycles, or if the fish was too deep to be detected by aerial antennas (about 10 m) and too far away to be detected by underwater antennas.

Diel approach and passage patterns among blocks were compared graphically. Diel residence times within species were compared controlling for block effects using Friedman's

Chi-square test. Results of this test and others throughout this report were considered statistically significant when $P \leq 0.05$.

The detection efficiencies of the telemetry arrays at the powerhouse and spillway were calculated using a "double array" system as described by Lowther and Skalski (1997). This method is based on the number of fish detected and undetected at each of two arrays monitoring a passage route to determine the detection probability of each array, and ultimately, the combination of the two arrays (Jim Lady, University of Washington, personal communication). In a double-array system, the detection probability of one array is calculated as:

$$P1 = 11/(11+01) \qquad \text{Equation 4}$$

where 11 denotes fish that were detected on both arrays and 01 denotes those not detected on the first array, but detected on the second. A 5-min time period between detections at both arrays was used to define the "11" capture history. The detection probability of the second array is calculated as:

$$P2 = 11/(11+10) \qquad \text{Equation 5}$$

where 10 denotes those detected on the first array, but not the second. The overall detection probability of the combined arrays is calculated as:

$$P12 = 1-((1-P1)(1-P2)) \qquad \text{Equation 6}$$

The numbers of fish detected at each array are then adjusted by dividing the numbers detected at an array by the results of Equation 6 prior to calculation of the passage indices (e.g., FPE). Thus, the adjusted FPE would be calculated as:

$$\text{Adjusted FPE} = ((Nspillway \div P12spillway) + (Nsluiceway \div P12sluiceway)) \div ((Nspillway \div P12spillway) + (Nsluiceway \div P12sluiceway) + (Nturbine \div P12turbine)) \qquad \text{Equation 7}$$

For the purpose of this exercise, the forebay aerial arrays were considered array number 1 (detection probability $P1$) and the forebay underwater arrays were considered array number 2 (detection probability $P2$) at each of the powerhouse and spillway. There was only one antenna system installed in the sluiceway (four 4-element Yagi antennas with combined inputs), so the detection efficiency associated with this route of passage could not be determined using this method.

Results

Dam Operations

The mean hourly percent spill discharges at TDA during the study period were similar to the 40% spill proposed during the design phase of the study (Table 1; Appendix A). The mean hourly percent spill was 39.3% (range 35.4 to 43.8 %) during the day and 39.3% (range 34.6 to 43.4%) during the night. Mean hourly total discharge was 170.3 thousand cubic feet per second (KCFS; range 107.1 to 270.0 KCFS) during the day and 164.3 KCFS (range 93.1 to 281.0 KCFS) at night. Up to 15 spill bays (bay numbers 1 thru 15) of the 23-bay spillway were open during the study period, depending on spill discharge.

Number of Fish Released and Detected

A total of 395 subyearling Chinook salmon were released by studies at JDA between 30 June and 20 July 2000 (Figure 3; Table 2). These fish were released at Rock Creek and had a mean fork length of 118.5 mm (range 110 to 146 mm) and a mean weight of 19.2 g (range 13.8 to 42.6 g; Appendix B). The mean fork length of subyearling Chinook salmon measured by the Pacific States Marine Fisheries Commission as part of the Smolt Monitoring Program at JDA during the period we obtained the study fish (28 June to 18 July 2000) was 107.6 mm (range 78 to 156 mm; no fish were weighed). Detailed summaries of fish tagged and released are presented in Appendix B. The mean tag-weight-to-body-weight ratio was 5.2 % (range 2.3 to 7.2 %). Telemetry equipment at The Dalles Dam detected 61.5% of the tagged subyearling Chinook salmon released at Rock Creek.

Table 1. Mean hourly percentages of total discharge spilled and mean hourly total discharge (KCFS) at The Dalles Dam during seven blocks, 01 July through 27 July 2001. Day spill discharge was considered to occur from 0700 h through 1859 h and night spill discharge was from 1900 h through 0659 h. Each block consisted of a 3-day period except block 7 which spanned a 7-day period. Std=standard deviation.

		Hourly percent spill					
	Spill	0700-1859			1900-0659		
Block	treatment	Mean	Std	Range	Mean	Std	Range
1	40	39.5	1.2	35.4-43.4	40.1	1.2	38.3-43.3
2	40	38.6	0.9	36.9-40.2	39.1	1.1	37.3-43.4
3	40	39.8	1.1	36.8-43.8	38.8	1.8	34.6-42.0
4	40	39.6	1.0	36.4-41.0	38.7	1.5	35.0-40.3
5	40	39.1	1.1	37.1-41.1	39.8	1.0	37.4-41.1
6	40	38.3	1.2	34.6-40.7	39.5	1.1	36.7-43.4
7	40	40.1	1.0	37.9-42.6	39.3	1.3	36.2-42.1

		Hourly total discharge					
	Spill	0700-1859			1900-0659		
Block	treatment	Mean	Std	Range	Mean	Std	Range
1	40	142.0	20.9	104.4-185.4	144.7	17.0	105.6-180.5
2	40	185.1	44.8	124.4-270.0	188.4	30.7	156.5-281.0
3	40	175.6	22.6	107.1-207.4	161.5	34.1	111.7-225.3
4	40	179.5	26.4	122.9-212.8	176.0	40.1	116.2-234.6
5	40	170.1	31.0	108.4-206.3	156.1	40.8	93.1-225.0
6	40	170.9	23.5	135.2-212.4	167.1	35.0	122.2-225.2
7	40	169.2	30.6	124.9-223.1	156.5	40.0	97.5-230.9

Arrival Time and Approach Pattern

The hour of arrival at TDA was dispersed throughout the diel period, but was slightly greater during the time between afternoon and evening than between midnight and noon (Figure

4). The median travel time from the Rock Creek release site to the TDA near-dam forebay was 48.8 h (range 13.3 to 189.1 h).

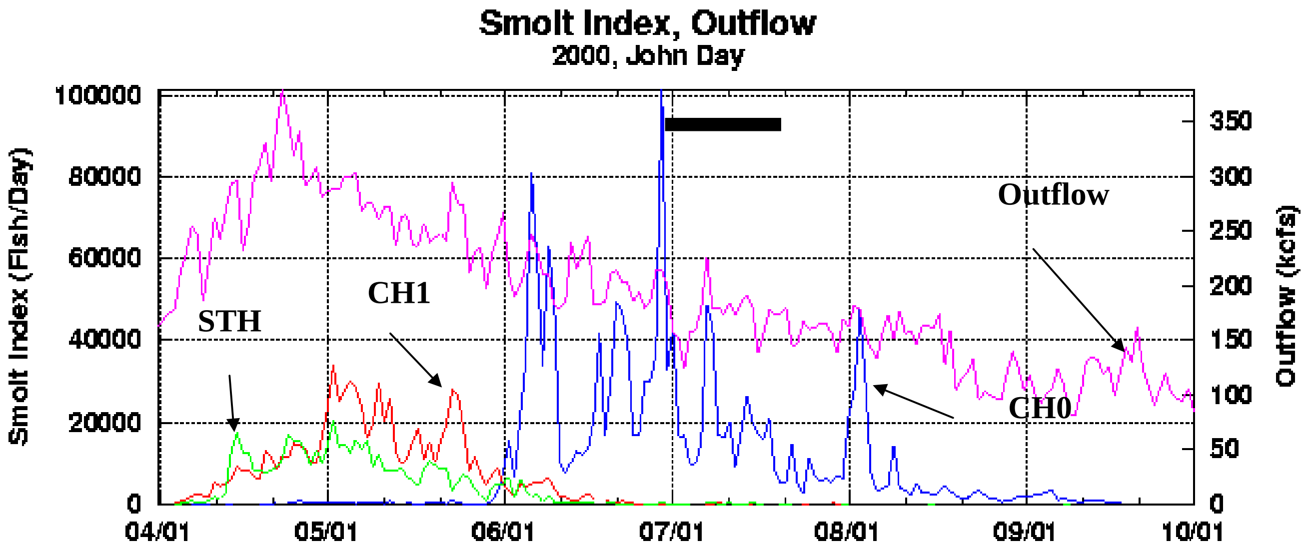

Figure 3. John Day Dam Smolt Index and project discharge (thousand cubic feet per second; kcfs) during 2000. Species depicted include wild and hatchery steelhead (STH), yearling Chinook salmon (CH1) and subyearling Chinook salmon (CH0). Horizontal black bar indicates dates CH0 were tagged at John Day Dam (30 June to 20 July) for evaluation of passage at The Dalles Dam. Original graphic was from the University of Washington's Data Access in Real Time web site at http://www.cqs.washington.edu/dart/pass.html.

Table 2. Number of radio-tagged subyearling Chinook salmon released 23 Km above the John Day Dam at Rock Creek during summer 2000 and the percent of fish detected by radio-telemetry receivers at The Dalles Dam.

Release date	Release time	Number released	Percent detected
30 June	20:00	32	68.8
02 July	08:00	19	42.1
03 July	20:00	24	62.5
05 July	08:00	33	66.3
06 July	20:00	32	68.8
08 July	08:00	32	62.5
09 July	20:00	32	62.5
11 July	08:00	29	44.8
12 July	20:00	34	44.1
14 July	08:00	32	65.6
16 July	20:00	33	72.7
17 July	09:00	32	62.5
20 July	20:00	31	67.7
Overall		395	61.5

Most tagged subyearling Chinook salmon were first detected at the powerhouse, with an intermediate proportion at the spillway and the lowest proportion at the non-overflow wall (Figure 5). As fish approached the dam during the day, 74.6% (N =103) were first detected at the powerhouse, with 6.5% (N = 9) first detected at the non-overflow wall and 18.8% (N = 26) at the spillway. First detections of fish arriving at night were greater at the powerhouse and lower at the spillway than those during the day. At night the proportions were 82.4% (N = 75) at the powerhouse, 7.7% (N = 7) at the non-overflow wall and 9.9% (N = 9) at the spillway. The proportions of first detections at the powerhouse generally decreased throughout the study period, those at the non-overflow wall increased during blocks 5 and 6, and first detections at the spillway generally increased during the study period.

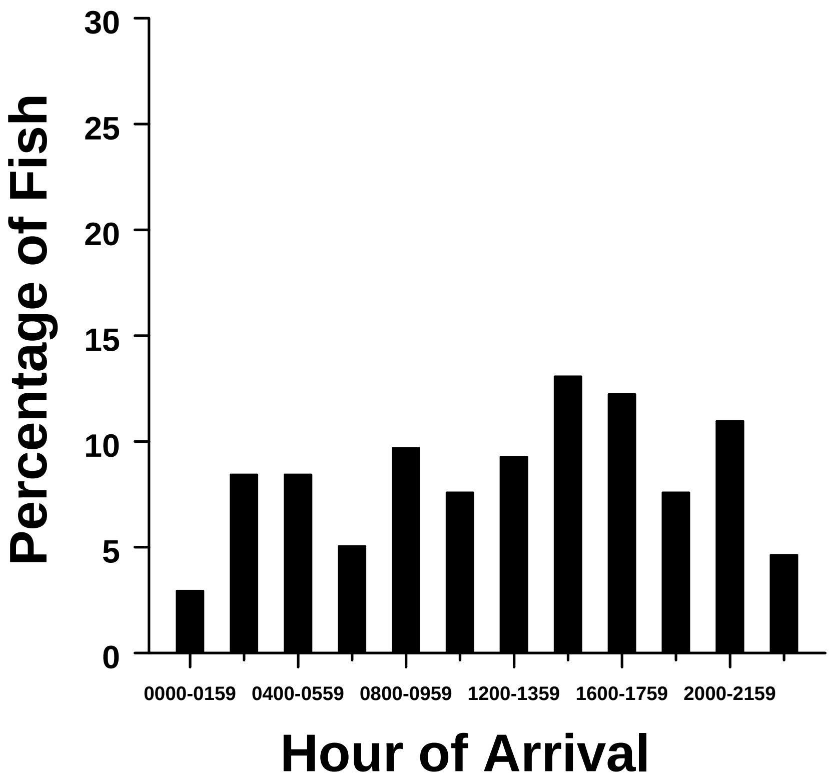

Figure 4. Diel distribution of radio-tagged subyearling Chinook salmon arrival in the near-dam forebay of The Dalles Dam among 2-h time intervals 01 July through 27 July 2000. N=sample size.

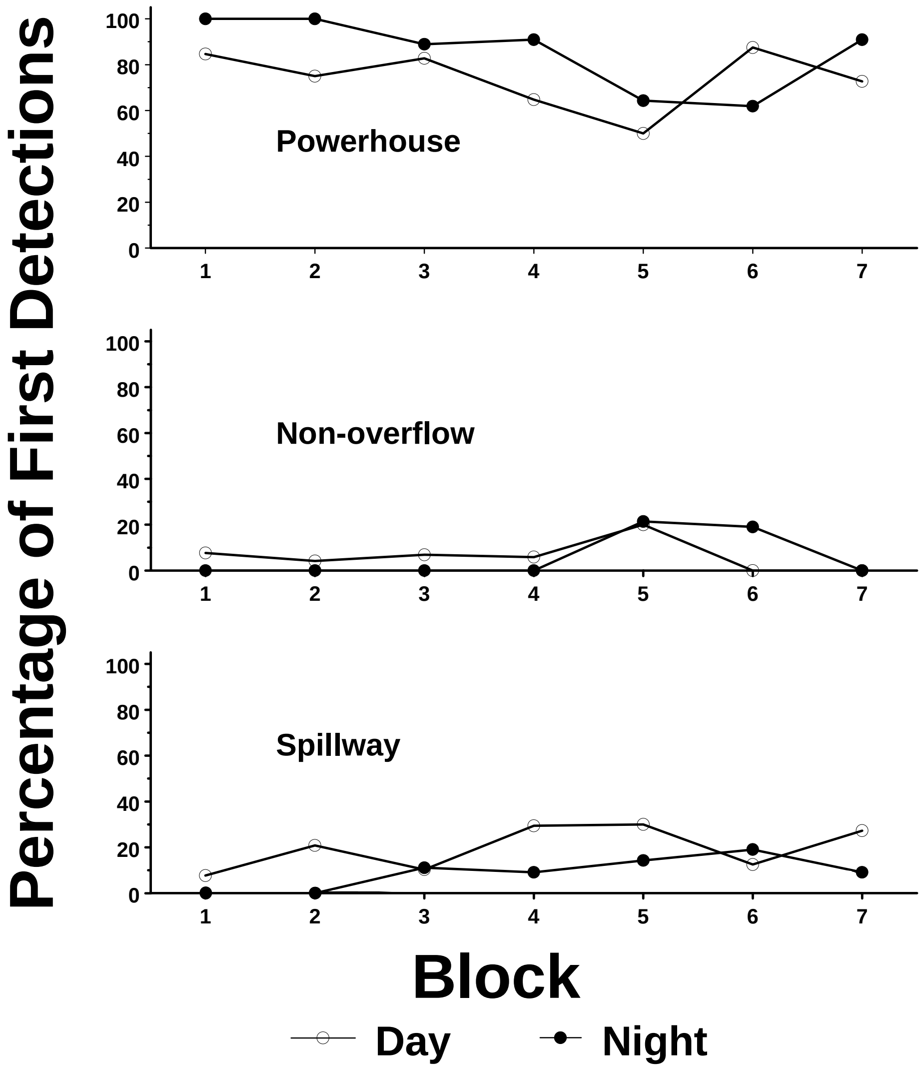

Figure 5. Distribution of subyearling Chinook salmon first detections among the powerhouse, non-overflow wall, and spillway radio-telemetry receivers in The Dalles Dam near-dam forebay during 40% spill discharge, spring 2000. Blocks represent 3-day intervals from 01 July through 27 July 2000 with the exception of block 7 which spanned a 7-day period. Day=0700-1859 h, Night=1900-0659 h. Sample sizes: day=11-29, night=9-21.

Behavior in the Near-Dam Forebay

No significant among-block differences were present in day and night residence times of subyearling Chinook salmon, so data from all blocks were pooled for an overall analysis of residence time (Kruskal-Wallis test, DF = 6 day and 6 night, all *P*s > 0.13; Figure 6). The median forebay residence time of subyearling Chinook salmon arriving during the day was 0.45 h (27.0 min) and the median residence time of those arriving at night was 0.66 h (39.6 min), which were significantly different from one another (Kruskal-Wallis test, DF = 1, $P < 0.0001$).

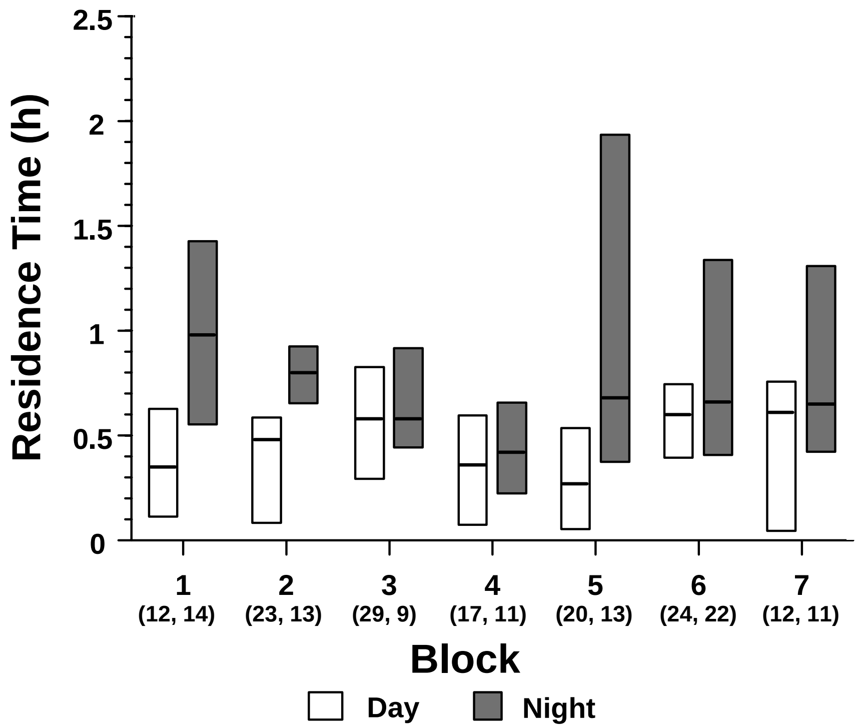

Figure 6. Twenty-fifth, 50th (median), and 75th percentiles (lower, middle, upper horizontal lines on bars) of radio-tagged subyearling Chinook salmon forebay residence times (h) by diel time of arrival during continuous 40% spill discharge at The Dalles Dam, summer 2000. Blocks represent seven 3-day intervals from 01 July through 27 July 2000, except for block 7, which is 7 days long. Diel periods: day=0700-1859 h, night=1900-0659 h. Sample sizes are shown in parentheses for day and night, respectively.

Forebay residence times were related to the distance between the upstream detection arrays and the location of passage, with the shortest residence times from fish passing via turbines, intermediate for those passing the sluiceway and longest for those passing via the spillway. Median residence times of subyearling Chinook salmon arriving at the dam during the day were 0.09 h (N = 15), 0.30 h (N = 9) and 0.49 h (N = 113) for those passing via the turbines, sluiceway and spillway, respectively. The median residence times of those arriving at night were 0.44 h (N = 14) for turbine passage, 0.49 h (N = 16) for sluiceway passage and 0.91 h (N = 63) for spillway passage.

General Route and Time of Passage

The time of day that radio-tagged fish passed TDA was similar to their time of arrival due to the relatively short forebay residence times. The passage times were spread throughout

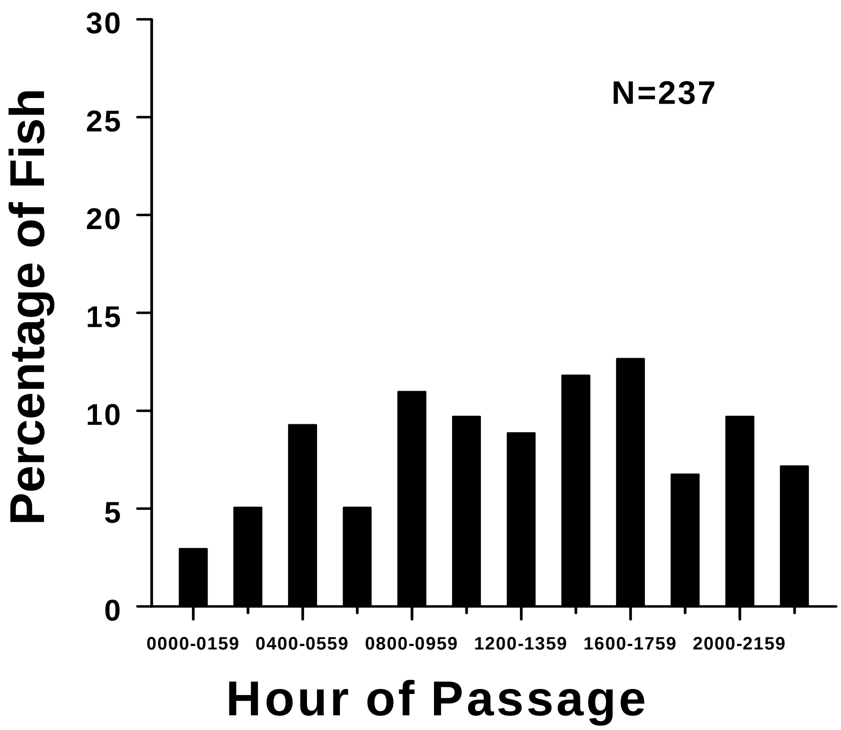

Figure 7. Diel distribution of radio-tagged subyearling Chinook salmon passage in the near-dam forebay of The Dalles Dam during 40% spill discharge, 01 July through 27 July 2000. N=sample size.

the diel period, but a slightly greater proportion of the fish passed during the day than at night (Figure 7). Diel passage data from each block are included in Appendix C.

Overall, 77.2 % percent of the subyearling Chinook salmon passed via the spillway, with 85% (N = 156) of those passing via the north half of the spillway (bays 1 to 11) and 15% (N = 27) passing via the south half (only bays 12 to 15 of the south half of the spillway were operated). A total of 12.2 % passed via the powerhouse, with 4% of those (N = 1) passing via the eastern half of the powerhouse (main units 11 to 22) and 96% (N = 28) passing via the western half (Main Unit 10 to Fish Unit 1). Overall sluiceway passage was 10.5% (N = 25).

Diel differences in the area of passage were evident at the sluiceway and spillway, but the proportion passing via the powerhouse (turbines) was similar during day and night periods in six of the seven blocks of study (Figure 8). Passage via the sluiceway was greater during the night than at day during blocks 1, 3 and 4, but was similar during the other blocks. Spillway passage was consistently greater during the day than at night and the differences were greatest during blocks 1, 3 and 4. Turbine passage was generally similar among blocks, but was greatest during Block 4.

Fish-, Spill-, and Sluiceway-Passage Efficiencies

No statistically significant diel differences in FPE were present in data from subyearling Chinook salmon (Chi-Square test controlling for block variation, DF = 1, $P > 0.34$; Figure 9, Table 3). There were also no significant differences in FPE among blocks (Chi-Square test, DF =

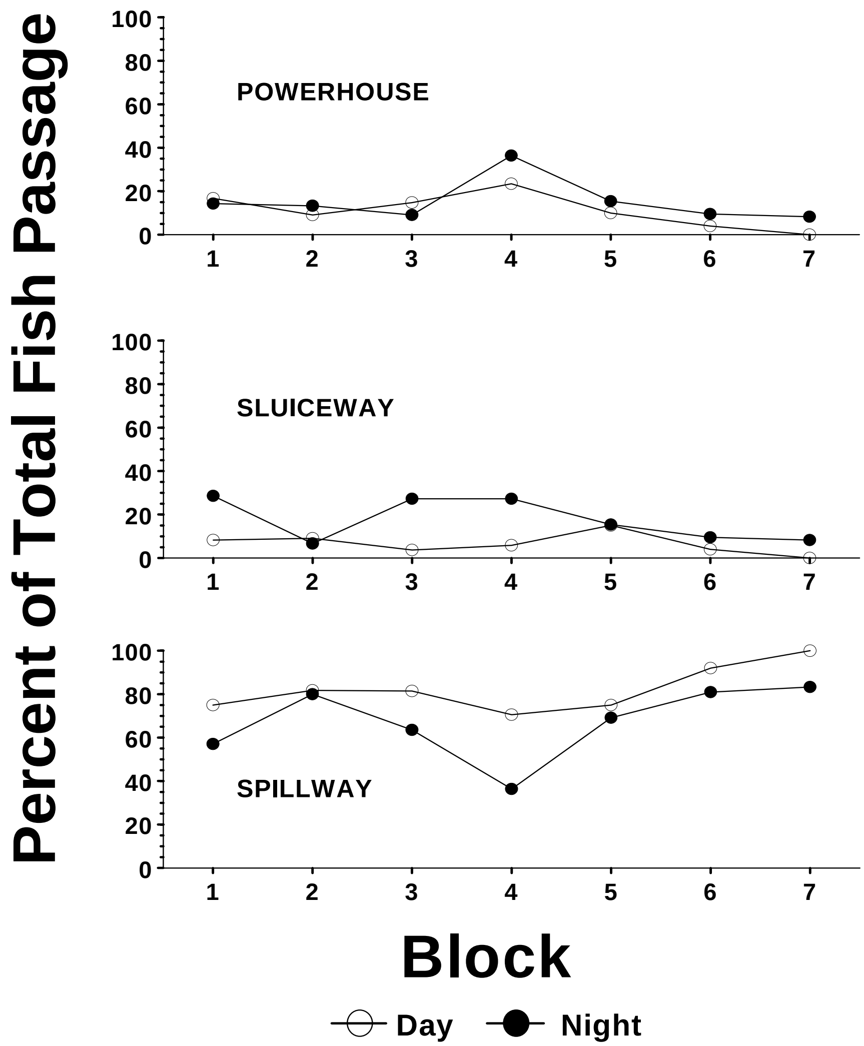

Figure 8. Percentage of radio-tagged subyearling Chinook salmon passing through the powerhouse, sluiceway, and spillway during day and night 40% spill discharge at The Dalles Dam, 01 July through 27 July 2001. Day=0700-1859 h, night=1900-0659. Sample sizes: day=12-27, night=11-21.

6, $P > 0.1$). The FPE estimates from Block 4 (76.5% day, 63.6% night) were considerably lower than those from the other blocks (day range 83.3 to 100%, night range 84.6 to 91.7%), but the difference did not result in a statistically significant difference among blocks. The point estimates and 95% confidence intervals of FPE, pooling all blocks, were 89.3 % (83.5 to 93.7%)

during the day and 85.6% (77.7 to 91.6%) during the night (Table 4).

The SPE was significantly greater during the day than during the night (Chi-Square test controlling for block variation, DF = 1, $P < 0.01$; Figure 9, Table 3). However, there were significant among-block differences (Chi-Square test DF = 6, $P < 0.01$), preventing an overall SPE estimate to be calculated with blocks pooled. The among-block differences appeared to be largely due to the data from Block 4 during the night (36.4%, see Table 3 for estimates from each block). If all data from Block 4 are omitted from analysis, the overall result is statistically similar (SPE is significantly greater during the day than the night, Chi-Square test, DF = 1, $P = 0.042$), but the between-block differences are removed (Chi-Square test, DF = 5, $P = 0.055$), making an overall pooled-block estimate valid. The overall point estimates and 95% confidence intervals of SPE after removing Block 4 were 84.6% (77.5 to 90.2%) for fish passing during the day and 73.3% (63.3 to 81.8%) for those passing at night (Table 4).

The SLPE was significantly greater during the night than during the day (Chi-Square test, DF = 1, $P < 0.02$) and no significant among-block differences were detected (Chi-Square test, DF = 6, $P > 0.4$; Figure 9, Table 3). The point estimates of SLPE and 95% confidence intervals, pooling blocks 1 thru 7, were 6.4% (3.7 to 11.3%) for fish passing during the day and 16.5% (10.0 to 24.7%) for those passing during the night (Table 4).

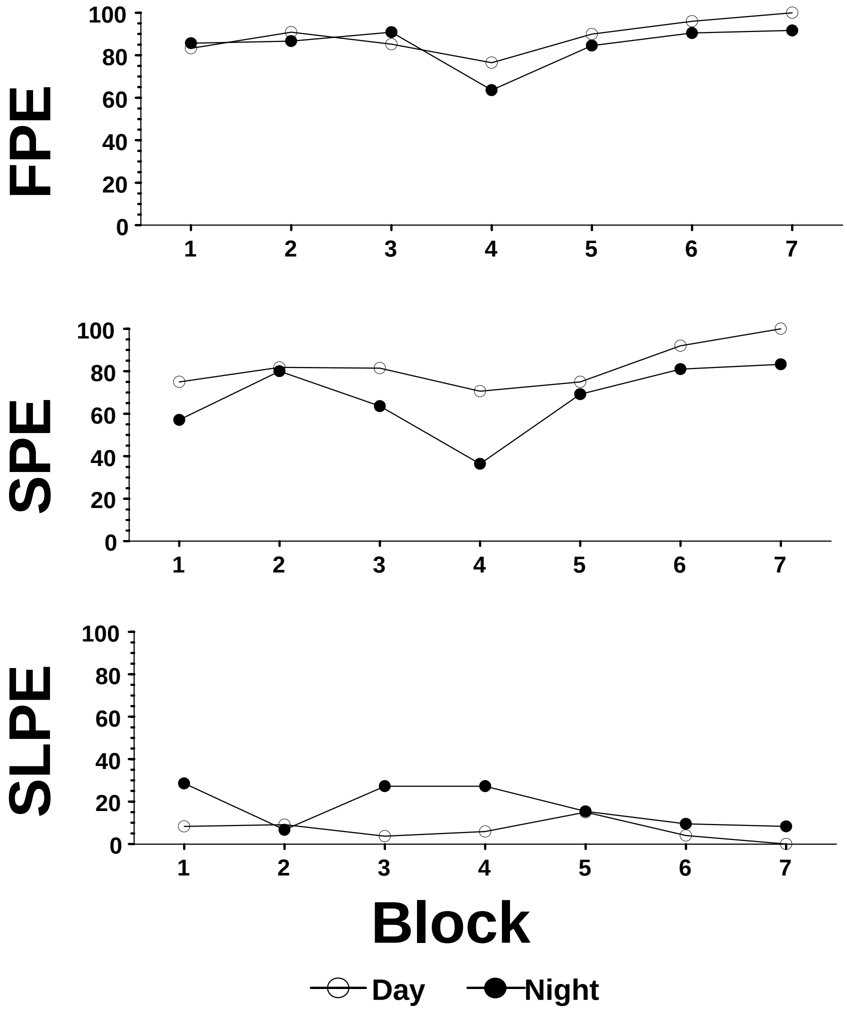

Figure 9. Subyearling Chinook salmon fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE) during continuous 40% spill discharge at The Dalles Dam, summer 2000. Blocks represent seven 3-day intervals from 01 July through 27 July, except Block 7, which was 7 d.

The spill effectiveness was greater during the day than during the night. Spill effectiveness was 2.15:1 during the day and 1.86:1 at night, based on the average 39.3% spill during both day and night periods (from Table 1) and the SPE values in Table 4.

Table 3. Estimates (Est) of subyearling Chinook salmon fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE) during day (0700-1859 h) and night (1900-0659 h) 40% spill discharge at The Dalles Dam, 01 July through 27 July 2000. N=sample size. Odds=Est/(100-Est). Odds ratio=$night_{odds}/day_{odds}$. LRCI = profile likelihood confidence interval. Test hypotheses of no overall diel effect (odds ratio=1) on fish passage for each passage index were evaluated using logistic regression after adjusting for blocks 1 through 7. Diel differences in passage were significant (*) where P <0.05.

		Diel Period						
		Day			Night			Observed
	Block	Est	N	Odds	Est	N	Odds	Odds Ratio
FPE	1	83.3	12	4.988	85.7	14	5.993	1.201
	2	90.9	22	9.989	86.7	15	6.519	0.653
	3	85.2	27	5.757	90.9	11	9.989	1.735
	4	76.5	17	3.255	63.6	11	1.747	0.537
	5	90.0	20	9.000	84.6	13	5.494	0.610
	6	96.0	25	24.000	90.5	21	9.526	0.397
	7	100.0	17	-	91.7	12	11.048	-
	Overall odds ratio adjusted for blocks 1-7 (95% LRCI)							0.677 (0.300-1.530)
	Test HO: odds ratio = 1 (no diel effect), P >0.34							
SPE	1	75.0	12	3.000	57.1	14	1.331	0.444
	2	81.8	22	4.495	80.0	15	4.000	0.890
	3	81.5	27	4.405	63.6	11	1.747	0.397
	4	70.6	17	2.401	36.4	11	0.572	0.238
	5	75.0	20	3.000	69.2	13	2.247	0.749
	6	92.0	25	11.500	80.9	21	4.236	0.368
	7	100.0	17	-	83.3	12	4.988	-
	Overall odds ratio adjusted for blocks 1-7 (95% LRCI)							0.427 (0.221-0.814)
	Test HO: odds ratio = 1 (no diel effect), P <0.01*							
SLPE	1	8.3	12	0.091	28.6	14	0.401	4.425
	2	9.1	22	0.100	6.7	15	0.072	0.717
	3	3.7	27	0.038	27.3	77	0.376	9.774
	4	5.9	17	0.063	27.3	11	0.376	5.989
	5	15.0	20	0.176	15.4	13	0.182	1.032
	6	4.0	25	0.042	9.5	21	0.105	2.519
	7	0.0	17	0.000	8.3	12	0.091	-
	Overall odds ratio adjusted for blocks 1-7 (95% LRCI)							2.93 (1.238-7.377)
	Test HO: odds ratio = 1 (no diel effect), P <0.015*							

Table 4. Estimates (Est) of subyearling Chinook salmon fish passage efficiency (FPE), spill passage efficiency (SPE), and sluiceway passage efficiency (SLPE) during day (0700-1859 h) and night (1900-0659 h) 40% spill discharge periods at The Dalles Dam, 01 July through 27 July 2000. N=sample size. LRCI = likelihood ratio confidence interval. Test hypotheses of no overall diel effect on fish passage for each passage index were evaluated using logistic regression after adjusting for block variation. The SPE estimate does not include data from Block 4.

	Diel Period					
Passage efficiency	Day			Night		
	Est	95%LRCI	N	Est	95%LRCI	N
FPE	89.3	83.5 – 93.7	140	85.6	77.7 – 91.6	97
SPE	84.6	77.5 – 90.2	123	73.3	63.3 – 81.8	86
SLPE	6.4	3.7 – 11.3	140	16.5	10.0 – 24.7	97

Table 5. Diel capture histories and detection probabilities of telemetry detection arrays at the powerhouse and spillway at The Dalles Dam, summer 2000. See text for capture history and detection probability definitions.

Capture History	Powerhouse		Spillway	
	Day	Night	Day	Night
01	10	2	34	11
10	2	5	5	7
11	3	7	76	49
Total	15	14	115	67
	Detection Probabilities			
P1	0.23	0.78	0.69	0.82
P2	0.60	0.58	0.94	0.88
P12	0.69	0.91	0.98	0.98

Table 6. Diel capture histories and detection probabilities of radio-tagged subyearling Chinook salmon at telemetry detection arrays at the powerhouse and spillway at The Dalles Dam, summer 2000. See text for capture history and detection probability definitions.

	Estimate	Day			Night		
		Raw	Adj	Diff	Raw	Adj	Diff
CH0	FPE	89.3	85.4	3.9	85.6	84.6	1.0
	SPE	84.6	79.4	5.2	73.3	68.5	4.8
	SLPE	6.4	6.0	0.4	16.5	16.0	0.5

Discussion

This was the first time radio-telemetry was used to determine FPE, SPE and SLPE of juvenile fall Chinook salmon at The Dalles Dam. A similar study was planned during 1999, but it was not completed due to shortages of available transmitters. The most important results of this study indicate that the greatest percentage of fish passed via the spillway (85% day, 73% night) followed by the powerhouse (100% - day FPE = 11% day; 100% - night FPE = 14% night) and sluiceway (6% day and 16% night). Turbine passage was slightly greater during the night than in the day, but no significant difference in project FPE was detected. The SPE was significantly greater during the day than the night and the SLPE was significantly greater at night. The decrease in SPE at night was accompanied by an increase in SLPE sufficient to result in no significant change in overall FPE between day and night periods. We found that 96% of the fish passing the powerhouse did so via the western half of the project (Fish Unit 1 to Main Unit 11).

The FPE and SPE results are similar to those from fixed hydroacoustic methods, but the trends in diel SLPE and the location of powerhouse passage are the opposite of that from the hydroacoustic method (Moursund et al. 2001). The results of the hydroacoustic study of Moursund et al. (2001) indicate the SLPE during the summer of 2000 was 9% during the day and 6% at night. Our estimates were 6% during the day and 16% at night. Moursund et al. (2001) also found that many fish during the summer period passed the powerhouse via units near the east end.

The reasons for such differences between the studies are not clear, but several differences in the studies were present. The difference in the dates of each study is likely an important factor. The hydroacoustic study of Moursund et al. (2001) was conducted between 06 June and 06 July and our study was conducted between 30 June and 20 July (dates of fish releases at Rock Creek; passage at The Dalles Dam was a median of 48 h later). Such a difference in study dates during the summer could account for the differences in passage metrics, particularly the passage of fish at the east and west portions of the powerhouse, as discharge was declining during these periods (see Figure 3) and the number and locations of operating turbines could be different. However, we did not collect project operation data that included the number and location of operating turbines during this study and the data are apparently not recorded by the project for use later, so we were unable to determine the extent of such differences between the two studies. The relatively late start of this study was due partially because we needed to wait until fish numbers and sizes were appropriate for our study, but primarily due to the last-minute change in radio transmitter manufacturers.

Differences in the methods themselves may also account for differences in results of the two studies. The hydroacoustic study of Moursund et al. (2001) assigned sluiceway passage by monitoring near the forebay side of the sluiceway entrance and was dependent on deploying transducers to obtain detections of fish committed to passage via that route, deploying the transducers far enough away from the area of interest to have an adequate sample volume in the desired area, and determining detectability of the fish within the single-beam sample volume.

The methods of Moursund et al. (2001) were designed to address these factors, but some bias may still have been present.   The radio telemetry method determined sluiceway passage by detection of tagged fish on aerial antennas placed within the sluiceway between intake 1-1 and the waterfall in the sluiceway. One possible explanation for the high night SLPE based on this method is the detection of fish outside the sluiceway on this array and their assignment to sluiceway passage if they were not subsequently detected on any other forebay array. Though the antennas were mounted in an area downstream of the sluiceway entrances, aerial antennas can have large ranges relative to underwater antennas and this explanation is plausible. If so, the greater turbine passage at night than in the day, indicating an increase in the number of fish near the powerhouse at night, could result in more false sluiceway assignments at night than during the day.   This was found to be the case in a similar study during spring 2001 (Beeman et al 2005) and was corrected in that study by reducing antennas ranges and adding an underwater array further downstream in the sluiceway. This bias may have been a factor in the differences between the hydroacoustic and radio telemetry estimates of SLPE at The Dalles Dam in 2000. However, it would only bias the sluiceway passage proportions if the fish passed via other routes and were not detected doing so. However, it seems unlikely that this would occur more at night than during the day, since the detection probabilities at the powerhouse were greater at night (0.91) than during the day (0.69). Thus, though we believe that this source of bias is possible, the available data indicates it is not probable in this case.

The fish passage indices were relatively consistent among the 7 blocks of study. The reductions in FPE and SPE and increases in SLPE during Block 4, and to a lesser extent during

Block 3, do not appear to be explained by variations in project operations or any known problems with the function of the telemetry detection arrays. The differences among blocks may represent the variation that can be expected in the block estimates, since the estimates within any one block are based on partitioning relatively few fish into one of three possible passage routes. Drawing conclusions using data from the individual blocks of this study is not an appropriate use of the data, as the study was designed to use the data from all blocks to arrive at meaningful comparisons between treatments rather than the examination of blocks individually.

Adjusting the number of fish detected at the various arrays to account for differences in detection probabilities had a greater effect on day passage indices than on night indices. This was primarily due to the low detection probability of the powerhouse array during the day (0.69) relative to the night (0.91), which was caused by reductions in the detection probability of the aerial array. The aerial array at the spillway was also less effective during the day than night, suggesting the subyearling Chinook salmon may have been migrating deeper at night than in the day, since aerial systems generally have a detection depth limit of approximately 10 m when using transmitters of this general size and power output (Beeman et al. 1998). The end result of the differences in detection probabilities between day and night periods and among passage locations was a 0.4 to 5.2% upward bias in the passage indices originally calculated. We did not revise the estimates based on this apparent bias because the detection probabilities calculated for the powerhouse arrays were based on relatively few fish (15 day and 14 night), and the resulting estimates may not reflect the true detection probabilities. However, the overall conclusions of the study would remain unchanged if they were based on the adjusted passage indices from

Table 6.

The lack of a double array in the sluiceway prevented us from calculating the detection probabilities using passing tagged fish and we recommend a second array be added to the sluiceway in future studies. A detection probability of 1.00 was assumed for the sluiceway array when adjusting for differences in detection probabilities of the various arrays, which is probably an overestimate. However, in 2000 the proportion of fish passing via the sluiceway was so small in comparison with the spillway that little difference in the outcome would be expected from reasonable differences between the detection efficiency of the sluiceway and the other passage routes.

This study was conducted using non-pulse-coded transmitters, which did not have as many unique codes per channel as those we planned to use. We had planned to use Lotek Wireless' pulse-coded transmitters and a proprietary code set with 170 unique codes per channel (i.e., frequency), but production problems at the manufacturer prevented their delivery. The non-coded transmitters we used in their place were purchased from another firm (without such a coding scheme) at two pulse rates per channel, which allowed two tags per channel rather than 170, resulting in a greater number of channels and repetitions than planned. The disadvantage of having fewer unique codes per channel is that it can result in increases in conflicts between signals of tags near the detection arrays at the same time (i.e., "collisions") and increases in receiver scan times on aerial receivers (aerial receivers typically scan channels individually on a repeating cycle and the total scan time is affected by the numbers of channels used). To accommodate the switch to the non-coded tags we reduced the number of tags released and removed aerial telemetry receivers from all tailrace arrays and used them in conjunction with those in forebay aerial arrays to reduce overall scan times; each receiver scanned ½ the channels, which reduced scan time by a factor of 2. The results of this were lower sample sizes and reductions in scan times on forebay aerial arrays at the cost of the abandonment of the tailrace aerial arrays. Doubling the receiver numbers at the forebay aerial arrays probably had the net effect of increasing the detection efficiencies of the forebay aerial arrays over what they would have been if the tailrace receivers were not moved to the forebay, but likely resulted in reduced overall detection efficiencies from those expected if the coded transmitters were used. The forebay aerial arrays are generally more useful in assigning passage locations than tailrace aerial arrays due to the longer residence times in the forebay compared to the tailrace, which are generally reflected in greater detection probabilities of forebay aerial arrays. The MITAS telemetry detection system used for the underwater arrays was reconfigured to allow detection of the non-coded transmitters, enabling the underwater antennas to be used regardless of tag type. Scan times are not an issue with the underwater MITAS system, since the reduction in ambient radio noise in underwater deployments compared to aerial deployments permits all channels to be monitored virtually simultaneously. Perhaps a more important result of changing tag types and manufacturers shortly before the planned study period was the delay of the onset of this study by 1-2 weeks while the replacement tags were manufactured.

In summary, this was the first radio-telemetry study conducted study at The Dalles Dam to determine FPE, SPE and SLPE of subyearling Chinook salmon. The results indicated that during the continuous 40% spill passed via the juvenile spill pattern there was no significant difference in FPE between day and night periods, SPE was greater during the day than the night, and SLPE was greater during the night than the day. The point estimates of the passage indices were similar to those determined during a concurrent study based on a fixed-hydroacoustic method, though differences in passage locations at the powerhouse and SLPE between the two studies were evident. Future recommendations for radio-telemetry studies of fish passage at The Dalles Dam include adding a second detection array in the sluiceway, reducing the range of aerial antennas used in the sluiceway to ensure the SLPE estimates are unbiased, and recording project operation data during the study period to allow evaluation of fish passage based the number and location of operating turbines.

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References

Allen, B., T. L. Liedtke, A. Daniel, J. Begala, M. Salway, A. McKinney, T. Baumgarte, J. Brady, E. Kinne, and J. Beeman. 2001. Movement, distribution and behavior of radio-tagged yearling Chinook salmon in the tailrace of The Dalles Dam, 2000. Prepared by the U.S. Geological Survey, Cook Washington for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Beeman, J. W., P. V. Haner, and A. G. Maule. 1998. Evaluation of a new miniature pressure-sensitive radio transmitter. North American Journal of Fisheries Management 18:458-464.

Beeman, J. W., H. C. Hansel, P. V. Haner and J. Hardiman. 2003. Estimates of fish and spill passage efficiency of radio-tagged juvenile steelhead and yearling Chinook salmon at John Day Dam, 2000. Prepared by the U.S. Geological Survey, Cook Washington for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Beeman, J. W., H. C. Hansel, P. V. Haner and K. Daniel. 2005. Estimates of the proportions of radio tagged juvenile salmonids that passed via the spillway, sluiceway and turbines during tests of sluiceway guidance improvement devices at The Dalles Dam in 2001. Prepared by the U.S. Geological Survey, Cook Washington for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

COE (U.S. Army Corps of Engineers). 2000. River Data. ONLINE. U.S. Army Corps of Engineers, Portland, Oregon, USA. Available:http://www.nwd-wc.usace.army.mil/-TMT/tdg_data/months.html [accessed July, 2000].

Duran, I. N., T. L. Liedtke, L. S. Brown, J. M. Drzewiecki, D. E. O'Donoghue, J. A. Quenette, E. M. Shoudel, J. P. Anderson, and J. Beeman. 2001. Movement, distributions and behavior of radio-tagged juvenile salmon at John Day Dam, 2000. Prepared by the U.S. Geological Survey, Cook Washington for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Hansel, H. C., J. W. Beeman, T. C. Counihan, J. M. Hardiman, B. D. Liedtke. M. S. Novick, and J. H. Plumb. 2000. Estimates of fish, spill, and sluiceway passage efficiencies of radio-tagged juvenile steelhead and yearling Chinook salmon at The Dalles Dam, 1999. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Hensleigh, J. E., R. S. Shively, H .C. Hansel, J. M. Hardiman, G. S. Holmberg, B. D. Liedtke, T. L. Martinelli, R. E. Wardell, R. H. Wertheimer, and T. P. Poe. 1999. Movement, distribution and behavior of radio-tagged juvenile Chinook salmon and steelhead in John Day, The Dalles and Bonneville dam forebays, 1997. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Holmberg, G. S., R. S. Shively, H. C. Hansel, T. L. Martinelli, M. B. Sheer, J. M. Hardiman, B. D. Liedtke, L. S. Blythe, and T. P. Poe. 1998. Movement, distribution, and behavior of radio-tagged juvenile Chinook salmon in John Day, The Dalles, and Bonneville forebays, 1996. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Lowther, A. B., and J. Skalski. 1997. The design and analysis of salmonid tagging studies in the Columbia Basin, Volume VIII. A new model for estimating survival probabilities and randomization from a release-recapture study of fall Chinook salmon (Oncorhynchus tshawytscha) smolts in the Snake River. Prepared by The University of Washington School of Fisheries, Seattle, Washington USA for the U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon, USA, contract DE-BI79-90BP02341.

Martinelli, T. L., H. C. Hansel, and R. S. Shively. 1998. Growth and physiological responses to surgical and gastric radio transmitter implantation techniques in subyearling Chinook salmon (*Oncorhynchus tshawytscha*). Hydrobiologia 371/372:79-87.

Martinelli, T. L. and R. S. Shively. 1997. Seasonal distribution, movements and habitat association of northern squawfish in two lower Columbia River reservoirs. Regulated Rivers Research and Management 13:543-556.

Moursund, R. A., K. D. Ham, B. D. McFadden, and G. E. Johnson. 2001. Hydroacoustic Evaluation of Downstream Fish Passage at The Dalles Dam in 2000. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

NMFS (National Marine Fisheries Service). 1998. Supplemental biological opinion: Operation of the federal Columbia River power system including the smolt monitoring program and the juvenile fish transportation program: A supplement to the Biological Opinion signed on March 2, 1995 for the same projects. Endangered Species Act – Section 7 Consultation, National Marine Fisheries Service, Northwest Region, Seattle, Washington, USA.

Sheer, M. B., G. S. Holmberg, R. S. Shively, T. P. King, C. N. Frost, H. C. Hansel, T. M. Martinelli, and T. P. Poe. 1997. Movement, distribution, and passage behavior of radio-tagged juvenile Chinook salmon in John Day and The Dalles Dam forebays, 1995. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Shively, R. S., T. P. Poe, and M. B. Sheer. 1996. Criteria for reducing predation by northern squawfish near juvenile salmonid bypass outfalls at Columbia River dams. Regulated Rivers Research and Management 12:493-500.

Whitney, R. R., L. D. Calvin, M. W. Erho, Jr., and C. C. Coutant. 1997. Downstream passage for salmon at hydroelectric projects in the Columbia River Basin: development, installation, and evaluation. Prepared for the Northwest Power Planning Council, Portland, Oregon, USA. #97-15.

Appendices

Appendix A. Total discharge (Totq) and spill discharge (Spill) in thousands of cubic feet per second and the percent spill at The Dalles Dam, 01 July through 31 July 2000.

Date	Hour	Spill	Totq	Percent Spill
7/1	1:00:00	74	185.0	40.0
7/1	2:00:00	62	154.6	40.1
7/1	3:00:00	62	153.8	40.3
7/1	4:00:00	62	153.6	40.4
7/1	5:00:00	62	152.5	40.7
7/1	6:00:00	62	152.7	40.6
7/1	7:00:00	62	156.7	39.6
7/1	8:00:00	62	153.7	40.3
7/1	9:00:00	62	152.5	40.7
7/1	10:00:00	59	141.4	41.7
7/1	11:00:00	56	147.0	38.1
7/1	12:00:00	56	136.7	41.0
7/1	13:00:00	56	138.6	40.4
7/1	14:00:00	64	160.3	39.9
7/1	15:00:00	64	164.6	38.9
7/1	16:00:00	64	161.5	39.6
7/1	17:00:00	64	160.4	39.9
7/1	18:00:00	64	160.9	39.8
7/1	19:00:00	64	163.0	39.3
7/1	20:00:00	64	162.8	39.3
7/1	21:00:00	64	157.1	40.7
7/1	22:00:00	64	158.0	40.5
7/1	23:00:00	64	163.5	39.1
7/1	24:00:00	64	152.5	42.0
7/2	1:00:00	64	151.0	42.4
7/2	2:00:00	54	139.6	38.7
7/2	3:00:00	54	132.3	40.8
7/2	4:00:00	54	134.2	40.2
7/2	5:00:00	54	132.6	40.7
7/2	6:00:00	54	133.0	40.6
7/2	7:00:00	54	152.4	35.4
7/2	8:00:00	54	138.6	39.0
7/2	9:00:00	54	138.7	38.9
7/2	10:00:00	54	137.2	39.4
7/2	11:00:00	54	138.9	38.9
7/2	12:00:00	60	154.1	38.9
7/2	13:00:00	68	168.3	40.4
7/2	14:00:00	68	167.9	40.5
7/2	15:00:00	68	156.7	43.4
7/2	16:00:00	68	169.1	40.2
7/2	17:00:00	68	165.4	41.1
7/2	18:00:00	60	150.4	39.9
7/2	19:00:00	60	150.0	40.0

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/2	20:00:00	60	150.2	39.9
7/2	21:00:00	60	151.1	39.7
7/2	22:00:00	60	150.4	39.9
7/2	23:00:00	60	153.4	39.1
7/2	24:00:00	60	154.3	38.9
7/3	1:00:00	60	153.8	39.0
7/3	2:00:00	60	147.7	40.6
7/3	3:00:00	50	127.9	39.1
7/3	4:00:00	50	124.5	40.2
7/3	5:00:00	50	117.5	42.6
7/3	6:00:00	50	124.3	40.2
7/3	7:00:00	50	133.7	37.4
7/3	8:00:00	50	124.4	40.2
7/3	9:00:00	50	124.5	40.2
7/3	10:00:00	50	125.2	39.9
7/3	11:00:00	50	123.8	40.4
7/3	12:00:00	50	123.8	40.4
7/3	13:00:00	50	123.6	40.5
7/3	14:00:00	40	104.5	38.3
7/3	15:00:00	40	106.3	37.6
7/3	16:00:00	42	104.9	40.0
7/3	17:00:00	42	104.4	40.2
7/3	18:00:00	42	105.1	40.0
7/3	19:00:00	42	105.9	39.7
7/3	20:00:00	42	105.6	39.8
7/3	21:00:00	42	109.6	38.3
7/3	22:00:00	56	139.7	40.1
7/3	23:00:00	56	144.7	38.7
7/3	24:00:00	60	151.7	39.6
7/4	1:00:00	60	149.3	40.2
7/4	2:00:00	60	149.0	40.3
7/4	3:00:00	60	149.5	40.1
7/4	4:00:00	60	150.4	39.9
7/4	5:00:00	60	150.4	39.9
7/4	6:00:00	60	152.2	39.4
7/4	7:00:00	60	155.9	38.5
7/4	8:00:00	60	152.7	39.3
7/4	9:00:00	60	152.6	39.3
7/4	10:00:00	60	153.8	39.0
7/4	11:00:00	60	153.8	39.0
7/4	12:00:00	60	151.9	39.5
7/4	13:00:00	60	154.2	38.9
7/4	14:00:00	60	152.5	39.3

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/4	15:00:00	60	152.1	39.4
7/4	16:00:00	60	150.7	39.8
7/4	17:00:00	60	154.1	38.9
7/4	18:00:00	74	185.4	39.9
7/4	19:00:00	74	180.5	41.0
7/4	20:00:00	64	159.9	40.0
7/4	21:00:00	64	154.4	41.5
7/4	22:00:00	64	159.6	40.1
7/4	23:00:00	64	166.5	38.4
7/4	24:00:00	64	167.1	38.3
7/5	1:00:00	64	161.9	39.5
7/5	2:00:00	60	154.5	38.8
7/5	3:00:00	60	147.7	40.6
7/5	4:00:00	60	139.5	43.0
7/5	5:00:00	60	138.5	43.3
7/5	6:00:00	55	129.3	42.5
7/5	7:00:00	50	127.2	39.3
7/5	8:00:00	50	133.2	37.5
7/5	9:00:00	50	129.8	38.5
7/5	10:00:00	50	126.2	39.6
7/5	11:00:00	50	125.3	39.9
7/5	12:00:00	50	124.4	40.2
7/5	13:00:00	50	125.2	39.9
7/5	14:00:00	50	127.4	39.2
7/5	15:00:00	65	171.3	37.9
7/5	16:00:00	65	165.1	39.4
7/5	17:00:00	65	167.8	38.7
7/5	18:00:00	65	166.4	39.1
7/5	19:00:00	65	170.8	38.1
7/5	20:00:00	65	167.0	38.9
7/5	21:00:00	74	184.6	40.1
7/5	22:00:00	74	185.7	39.8
7/5	23:00:00	74	184.7	40.1
7/5	24:00:00	74	183.2	40.4
7/6	1:00:00	68	170.4	39.9
7/6	2:00:00	68	169.3	40.2
7/6	3:00:00	68	170.2	40.0
7/6	4:00:00	68	173.2	39.3
7/6	5:00:00	68	174.1	39.1
7/6	6:00:00	68	173.6	39.2
7/6	7:00:00	68	172.0	39.5
7/6	8:00:00	68	173.3	39.2
7/6	9:00:00	68	174.8	38.9

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/6	10:00:00	68	171.6	39.6
7/6	11:00:00	68	175.5	38.7
7/6	12:00:00	68	177.9	38.2
7/6	13:00:00	68	179.3	37.9
7/6	14:00:00	68	176.5	38.5
7/6	15:00:00	68	181.4	37.5
7/6	16:00:00	68	176.5	38.5
7/6	17:00:00	68	177.2	38.4
7/6	18:00:00	68	178.9	38.0
7/6	19:00:00	68	174.9	38.9
7/6	20:00:00	68	174.6	38.9
7/6	21:00:00	68	173.5	39.2
7/6	22:00:00	68	174.9	38.9
7/6	23:00:00	68	175.8	38.7
7/6	24:00:00	68	177.5	38.3
7/7	1:00:00	68	176.8	38.5
7/7	2:00:00	68	177.6	38.3
7/7	3:00:00	74	188.0	39.4
7/7	4:00:00	74	191.5	38.6
7/7	5:00:00	74	191.0	38.7
7/7	6:00:00	74	187.7	39.4
7/7	7:00:00	80	206.5	38.7
7/7	8:00:00	80	202.3	39.5
7/7	9:00:00	80	199.2	40.2
7/7	10:00:00	84	223.7	37.6
7/7	11:00:00	84	227.8	36.9
7/7	12:00:00	94	242.5	38.8
7/7	13:00:00	94	249.0	37.8
7/7	14:00:00	98	258.1	38.0
7/7	15:00:00	98	265.7	36.9
7/7	16:00:00	98	254.9	38.4
7/7	17:00:00	98	260.3	37.6
7/7	18:00:00	102	270.0	37.8
7/7	19:00:00	106	281.0	37.7
7/7	20:00:00	97	260.2	37.3
7/7	21:00:00	97	249.4	38.9
7/7	22:00:00	97	247.5	39.2
7/7	23:00:00	97	255.0	38.0
7/7	24:00:00	80	213.3	37.5
7/8	1:00:00	80	184.2	43.4
7/8	2:00:00	66	170.2	38.8
7/8	3:00:00	66	168.4	39.2
7/8	4:00:00	66	167.3	39.5

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/8	5:00:00	60	158.1	38.0
7/8	6:00:00	60	156.5	38.3
7/8	7:00:00	60	163.2	36.8
7/8	8:00:00	60	154.9	38.7
7/8	9:00:00	64	156.7	40.8
7/8	10:00:00	64	158.5	40.4
7/8	11:00:00	64	159.9	40.0
7/8	12:00:00	64	158.7	40.3
7/8	13:00:00	64	158.5	40.4
7/8	14:00:00	64	159.4	40.2
7/8	15:00:00	72	188.6	38.2
7/8	16:00:00	72	183.5	39.2
7/8	17:00:00	72	180.1	40.0
7/8	18:00:00	80	200.9	39.8
7/8	19:00:00	80	205.5	38.9
7/8	20:00:00	80	211.3	37.9
7/8	21:00:00	88	212.9	41.3
7/8	22:00:00	88	225.3	39.1
7/8	23:00:00	80	212.4	37.7
7/8	24:00:00	72	193.1	37.3
7/9	1:00:00	64	171.5	37.3
7/9	2:00:00	64	167.4	38.2
7/9	3:00:00	64	165.1	38.8
7/9	4:00:00	63	181.9	34.6
7/9	5:00:00	52	124.2	41.9
7/9	6:00:00	52	125.8	41.3
7/9	7:00:00	60	137.1	43.8
7/9	8:00:00	60	153.9	39.0
7/9	9:00:00	74	180.7	41.0
7/9	10:00:00	74	184.4	40.1
7/9	11:00:00	74	183.8	40.3
7/9	12:00:00	74	183.5	40.3
7/9	13:00:00	74	191.6	38.6
7/9	14:00:00	74	183.3	40.4
7/9	15:00:00	74	181.1	40.9
7/9	16:00:00	74	186.7	39.6
7/9	17:00:00	74	192.9	38.4
7/9	18:00:00	74	188.1	39.3
7/9	19:00:00	74	189.1	39.1
7/9	20:00:00	74	190.0	38.9
7/9	21:00:00	74	188.3	39.3
7/9	22:00:00	74	185.4	39.9
7/9	23:00:00	68	185.7	36.6

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/9	24:00:00	63	150.1	42.0
7/10	1:00:00	54	139.7	38.7
7/10	2:00:00	42	111.7	37.6
7/10	3:00:00	42	112.7	37.3
7/10	4:00:00	42	112.7	37.3
7/10	5:00:00	42	112.4	37.4
7/10	6:00:00	42	113.2	37.1
7/10	7:00:00	42	107.1	39.2
7/10	8:00:00	60	151.6	39.6
7/10	9:00:00	60	150.8	39.8
7/10	10:00:00	60	151.7	39.6
7/10	11:00:00	80	207.4	38.6
7/10	12:00:00	80	200.7	39.9
7/10	13:00:00	80	201.5	39.7
7/10	14:00:00	80	202.9	39.4
7/10	15:00:00	80	202.9	39.4
7/10	16:00:00	80	202.6	39.5
7/10	17:00:00	80	199.7	40.1
7/10	18:00:00	70	172.2	40.7
7/10	19:00:00	70	178.0	39.3
7/10	20:00:00	70	172.2	40.7
7/10	21:00:00	70	172.1	40.7
7/10	22:00:00	70	170.7	41.0
7/10	23:00:00	70	171.7	40.8
7/10	24:00:00	58	157.3	36.9
7/11	1:00:00	48	127.2	37.7
7/11	2:00:00	48	122.3	39.2
7/11	3:00:00	48	123.8	38.8
7/11	4:00:00	48	125.5	38.2
7/11	5:00:00	56	136.9	40.9
7/11	6:00:00	60	167.1	35.9
7/11	7:00:00	60	155.5	38.6
7/11	8:00:00	68	171.6	39.6
7/11	9:00:00	68	165.7	41.0
7/11	10:00:00	68	170.8	39.8
7/11	11:00:00	76	196.9	38.6
7/11	12:00:00	76	191.1	39.8
7/11	13:00:00	76	190.8	39.8
7/11	14:00:00	76	193.5	39.3
7/11	15:00:00	80	211.2	37.9
7/11	16:00:00	80	204.7	39.1
7/11	17:00:00	80	205.7	38.9
7/11	18:00:00	84	212.8	39.5

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/11	19:00:00	84	213.8	39.3
7/11	20:00:00	84	214.0	39.3
7/11	21:00:00	84	213.8	39.3
7/11	22:00:00	84	222.7	37.7
7/11	23:00:00	84	208.6	40.3
7/11	24:00:00	65	171.9	37.8
7/12	1:00:00	45	116.2	38.7
7/12	2:00:00	45	124.7	36.1
7/12	3:00:00	45	124.3	36.2
7/12	4:00:00	45	125.3	35.9
7/12	5:00:00	45	127.0	35.4
7/12	6:00:00	45	128.6	35.0
7/12	7:00:00	45	123.5	36.4
7/12	8:00:00	45	122.9	36.6
7/12	9:00:00	68	173.2	39.3
7/12	10:00:00	68	172.2	39.5
7/12	11:00:00	68	171.0	39.8
7/12	12:00:00	68	168.5	40.4
7/12	13:00:00	68	168.4	40.4
7/12	14:00:00	68	171.6	39.6
7/12	15:00:00	80	196.2	40.8
7/12	16:00:00	80	199.5	40.1
7/12	17:00:00	80	198.0	40.4
7/12	18:00:00	80	198.9	40.2
7/12	19:00:00	80	200.6	39.9
7/12	20:00:00	88	222.3	39.6
7/12	21:00:00	88	222.8	39.5
7/12	22:00:00	88	234.6	37.5
7/12	23:00:00	80	203.0	39.4
7/12	24:00:00	72	182.1	39.5
7/13	1:00:00	60	155.7	38.5
7/13	2:00:00	56	141.5	39.6
7/13	3:00:00	56	141.5	39.6
7/13	4:00:00	56	141.5	39.6
7/13	5:00:00	50	135.3	37.0
7/13	6:00:00	56	144.6	38.7
7/13	7:00:00	56	138.4	40.5
7/13	8:00:00	56	139.8	40.1
7/13	9:00:00	56	138.4	40.5
7/13	10:00:00	56	138.2	40.5
7/13	11:00:00	70	174.7	40.1
7/13	12:00:00	70	176.9	39.6
7/13	13:00:00	70	174.6	40.1

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/13	14:00:00	84	209.6	40.1
7/13	15:00:00	84	211.5	39.7
7/13	16:00:00	84	207.8	40.4
7/13	17:00:00	84	208.5	40.3
7/13	18:00:00	84	208.9	40.2
7/13	19:00:00	90	223.6	40.3
7/13	20:00:00	90	230.7	39.0
7/13	21:00:00	90	228.0	39.5
7/13	22:00:00	90	232.6	38.7
7/13	23:00:00	82	204.7	40.1
7/13	24:00:00	74	186.8	39.6
7/14	1:00:00	74	184.7	40.1
7/14	2:00:00	60	156.1	38.4
7/14	3:00:00	56	139.2	40.2
7/14	4:00:00	56	141.5	39.6
7/14	5:00:00	56	151.0	37.1
7/14	6:00:00	56	140.7	39.8
7/14	7:00:00	64	156.2	41.0
7/14	8:00:00	64	162.2	39.5
7/14	9:00:00	75	192.4	39.0
7/14	10:00:00	75	186.7	40.2
7/14	11:00:00	82	201.9	40.6
7/14	12:00:00	82	205.8	39.8
7/14	13:00:00	82	204.3	40.1
7/14	14:00:00	82	204.1	40.2
7/14	15:00:00	82	205.3	39.9
7/14	16:00:00	82	204.8	40.0
7/14	17:00:00	82	203.6	40.3
7/14	18:00:00	82	203.6	40.3
7/14	19:00:00	82	206.3	39.7
7/14	20:00:00	90	224.8	40.0
7/14	21:00:00	90	224.2	40.1
7/14	22:00:00	90	221.6	40.6
7/14	23:00:00	90	225.0	40.0
7/14	24:00:00	80	202.5	39.5
7/15	1:00:00	68	168.2	40.4
7/15	2:00:00	56	137.7	40.7
7/15	3:00:00	56	138.1	40.6
7/15	4:00:00	56	137.1	40.8
7/15	5:00:00	56	138.0	40.6
7/15	6:00:00	56	136.5	41.0
7/15	7:00:00	56	140.5	39.9
7/15	8:00:00	56	137.4	40.8

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/15	9:00:00	56	136.4	41.1
7/15	10:00:00	68	175.2	38.8
7/15	11:00:00	68	174.7	38.9
7/15	12:00:00	68	173.9	39.1
7/15	13:00:00	68	172.1	39.5
7/15	14:00:00	78	201.6	38.7
7/15	15:00:00	78	206.3	37.8
7/15	16:00:00	78	204.5	38.1
7/15	17:00:00	78	204.7	38.1
7/15	18:00:00	78	204.3	38.2
7/15	19:00:00	78	204.0	38.2
7/15	20:00:00	78	206.2	37.8
7/15	21:00:00	78	204.2	38.2
7/15	22:00:00	78	204.1	38.2
7/15	23:00:00	70	176.1	39.8
7/15	24:00:00	70	171.4	40.8
7/16	1:00:00	56	139.9	40.0
7/16	2:00:00	56	138.0	40.6
7/16	3:00:00	56	141.2	39.7
7/16	4:00:00	56	138.6	40.4
7/16	5:00:00	56	137.1	40.8
7/16	6:00:00	56	136.2	41.1
7/16	7:00:00	44	108.4	40.6
7/16	8:00:00	44	118.1	37.3
7/16	9:00:00	52	136.2	38.2
7/16	10:00:00	52	136.2	38.2
7/16	11:00:00	52	140.2	37.1
7/16	12:00:00	52	136.3	38.2
7/16	13:00:00	52	138.2	37.6
7/16	14:00:00	52	136.4	38.1
7/16	15:00:00	60	157.1	38.2
7/16	16:00:00	60	157.6	38.1
7/16	17:00:00	60	155.6	38.6
7/16	18:00:00	54	141.3	38.2
7/16	19:00:00	50	129.7	38.6
7/16	20:00:00	60	149.8	40.1
7/16	21:00:00	60	151.6	39.6
7/16	22:00:00	60	160.5	37.4
7/16	23:00:00	60	149.3	40.2
7/16	24:00:00	38	98.7	38.5
7/17	1:00:00	38	97.0	39.2
7/17	2:00:00	38	95.0	40.0
7/17	3:00:00	38	93.1	40.8

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/17	4:00:00	38	94.9	40.0
7/17	5:00:00	48	120.7	39.8
7/17	6:00:00	48	124.0	38.7
7/17	7:00:00	56	137.6	40.7
7/17	8:00:00	56	140.0	40.0
7/17	9:00:00	56	140.1	40.0
7/17	10:00:00	56	143.3	39.1
7/17	11:00:00	56	141.9	39.5
7/17	12:00:00	56	142.9	39.2
7/17	13:00:00	59	153.4	38.5
7/17	14:00:00	59	153.6	38.4
7/17	15:00:00	59	159.1	37.1
7/17	16:00:00	59	160.4	36.8
7/17	17:00:00	76	191.6	39.7
7/17	18:00:00	76	192.5	39.5
7/17	19:00:00	76	195.5	38.9
7/17	20:00:00	76	190.3	39.9
7/17	21:00:00	76	192.6	39.5
7/17	22:00:00	76	191.3	39.7
7/17	23:00:00	68	179.6	37.9
7/17	24:00:00	68	169.9	40.0
7/18	1:00:00	58	144.1	40.2
7/18	2:00:00	52	132.3	39.3
7/18	3:00:00	52	137.7	37.8
7/18	4:00:00	52	131.9	39.4
7/18	5:00:00	52	128.6	40.4
7/18	6:00:00	52	130.9	39.7
7/18	7:00:00	58	146.9	39.5
7/18	8:00:00	63	166.5	37.8
7/18	9:00:00	63	166.1	37.9
7/18	10:00:00	63	167.0	37.7
7/18	11:00:00	63	167.1	37.7
7/18	12:00:00	63	170.1	37.0
7/18	13:00:00	75	194.6	38.5
7/18	14:00:00	75	195.0	38.5
7/18	15:00:00	75	195.6	38.3
7/18	16:00:00	81	211.4	38.3
7/18	17:00:00	81	212.2	38.2
7/18	18:00:00	81	212.4	38.1
7/18	19:00:00	83	225.2	36.9
7/18	20:00:00	86	221.6	38.8
7/18	21:00:00	86	220.4	39.0
7/18	22:00:00	80	203.7	39.3

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/18	23:00:00	70	183.5	38.1
7/18	24:00:00	70	174.0	40.2
7/19	1:00:00	60	138.2	43.4
7/19	2:00:00	50	127.9	39.1
7/19	3:00:00	50	130.5	38.3
7/19	4:00:00	48	122.2	39.3
7/19	5:00:00	48	122.9	39.1
7/19	6:00:00	48	122.7	39.1
7/19	7:00:00	54	135.2	39.9
7/19	8:00:00	54	147.8	36.5
7/19	9:00:00	54	155.9	34.6
7/19	10:00:00	64	167.9	38.1
7/19	11:00:00	64	165.9	38.6
7/19	12:00:00	64	169.9	37.7
7/19	13:00:00	70	183.1	38.2
7/19	14:00:00	70	184.9	37.9
7/19	15:00:00	70	187.8	37.3
7/19	16:00:00	76	194.5	39.1
7/19	17:00:00	76	198.3	38.3
7/19	18:00:00	76	198.9	38.2
7/19	19:00:00	82	194.2	42.2
7/19	20:00:00	82	206.1	39.8
7/19	21:00:00	82	205.6	39.9
7/19	22:00:00	82	204.7	40.1
7/19	23:00:00	82	211.8	38.7
7/19	24:00:00	82	204.4	40.1
7/20	1:00:00	70	176.8	39.6
7/20	2:00:00	60	152.7	39.3
7/20	3:00:00	54	134.1	40.3
7/20	4:00:00	54	135.6	39.8
7/20	5:00:00	54	135.1	40.0
7/20	6:00:00	54	135.2	39.9
7/20	7:00:00	54	130.4	41.4
7/20	8:00:00	54	133.9	40.3
7/20	9:00:00	54	142.4	37.9
7/20	10:00:00	64	158.8	40.3
7/20	11:00:00	64	158.8	40.3
7/20	12:00:00	64	164.0	39.0
7/20	13:00:00	70	173.2	40.4
7/20	14:00:00	70	173.2	40.4
7/20	15:00:00	70	164.3	42.6
7/20	16:00:00	70	180.3	38.8
7/20	17:00:00	80	206.5	38.7

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/20	18:00:00	80	204.6	39.1
7/20	19:00:00	80	203.9	39.2
7/20	20:00:00	80	207.3	38.6
7/20	21:00:00	80	220.7	36.2
7/20	22:00:00	80	218.5	36.6
7/20	23:00:00	76	203.0	37.4
7/20	24:00:00	76	198.3	38.3
7/21	1:00:00	64	165.4	38.7
7/21	2:00:00	56	142.8	39.2
7/21	3:00:00	56	142.0	39.4
7/21	4:00:00	38	100.8	37.7
7/21	5:00:00	38	102.1	37.2
7/21	6:00:00	50	127.3	39.3
7/21	7:00:00	50	131.4	38.1
7/21	8:00:00	60	149.0	40.3
7/21	9:00:00	60	150.9	39.8
7/21	10:00:00	68	167.9	40.5
7/21	11:00:00	68	169.8	40.0
7/21	12:00:00	80	201.1	39.8
7/21	13:00:00	80	200.1	40.0
7/21	14:00:00	88	223.1	39.4
7/21	15:00:00	88	219.9	40.0
7/21	16:00:00	88	221.9	39.7
7/21	17:00:00	88	222.1	39.6
7/21	18:00:00	88	222.4	39.6
7/21	19:00:00	88	224.4	39.2
7/21	20:00:00	88	230.9	38.1
7/21	21:00:00	88	224.2	39.3
7/21	22:00:00	80	198.3	40.3
7/21	23:00:00	72	178.8	40.3
7/21	24:00:00	72	177.4	40.6
7/22	1:00:00	52	127.2	40.9
7/22	2:00:00	52	123.4	42.1
7/22	3:00:00	40	101.7	39.3
7/22	4:00:00	40	97.5	41.0
7/22	5:00:00	52	125.1	41.6
7/22	6:00:00	52	126.4	41.1
7/22	7:00:00	52	124.9	41.6
7/22	8:00:00	52	128.6	40.4
7/22	9:00:00	52	129.7	40.1
7/22	10:00:00	56	137.8	40.6
7/22	11:00:00	56	138.4	40.5
7/22	12:00:00	62	153.2	40.5

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/22	13:00:00	62	154.9	40.0
7/22	14:00:00	74	182.1	40.6
7/22	15:00:00	74	179.2	41.3
7/22	16:00:00	74	177.4	41.7
7/22	17:00:00	62	160.6	38.6
7/22	18:00:00	62	153.8	40.3
7/22	19:00:00	62	153.8	40.3
7/22	20:00:00	62	153.5	40.4
7/22	21:00:00	54	136.3	39.6
7/22	22:00:00	54	136.8	39.5
7/22	23:00:00	54	138.1	39.1
7/22	24:00:00	54	138.5	39.0
7/23	1:00:00	54	135.9	39.7
7/23	2:00:00	54	137.3	39.3
7/23	3:00:00	54	139.1	38.8
7/23	4:00:00	54	136.4	39.6
7/23	5:00:00	54	133.6	40.4
7/23	6:00:00	50	128.5	38.9
7/27	7:00:00	44	111.6	39.4
7/27	8:00:00	44	109.1	40.3
7/27	9:00:00	44	110.3	39.9
7/27	10:00:00	52	136.0	38.2
7/27	11:00:00	52	137.5	37.8
7/27	12:00:00	58	153.5	37.8
7/27	13:00:00	68	176.4	38.5
7/27	14:00:00	68	175.6	38.7
7/27	15:00:00	68	179.8	37.8
7/27	16:00:00	84	197.1	42.6
7/27	17:00:00	92	242.1	38.0
7/27	18:00:00	92	241.0	38.2
7/27	19:00:00	92	240.7	38.2
7/27	20:00:00	92	228.5	40.3
7/27	21:00:00	84	244.7	34.3
7/27	22:00:00	84	210.3	39.9
7/27	23:00:00	70	184.7	37.9
7/27	24:00:00	64	149.4	42.8
7/28	1:00:00	52	126.0	41.3
7/28	2:00:00	52	124.3	41.8
7/28	3:00:00	52	123.0	42.3
7/28	4:00:00	52	122.6	42.4
7/28	5:00:00	52	123.8	42.0
7/28	6:00:00	52	131.9	39.4
7/28	7:00:00	52	124.1	41.9

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/28	8:00:00	52	128.9	40.3
7/28	9:00:00	52	126.5	41.1
7/28	10:00:00	52	128.1	40.6
7/28	11:00:00	52	128.7	40.4
7/28	12:00:00	52	127.1	40.9
7/28	13:00:00	52	127.2	40.9
7/28	14:00:00	56	147.6	37.9
7/28	15:00:00	64	165.3	38.7
7/28	16:00:00	64	167.3	38.3
7/28	17:00:00	64	167.4	38.2
7/28	18:00:00	64	168.9	37.9
7/28	19:00:00	74	198.7	37.2
7/28	20:00:00	92	239.2	38.5
7/28	21:00:00	92	242.1	38.0
7/28	22:00:00	97	248.8	39.0
7/28	23:00:00	97	248.4	39.0
7/28	24:00:00	85	216.1	39.3
7/29	1:00:00	70	179.4	39.0
7/29	2:00:00	50	130.9	38.2
7/29	3:00:00	42	111.0	37.8
7/29	4:00:00	42	113.7	36.9
7/29	5:00:00	48	136.8	35.1
7/29	6:00:00	48	120.0	40.0
7/29	7:00:00	48	128.6	37.3
7/29	8:00:00	48	124.5	38.6
7/29	9:00:00	48	125.3	38.3
7/29	10:00:00	60	157.2	38.2
7/29	11:00:00	64	160.9	39.8
7/29	12:00:00	64	159.3	40.2
7/29	13:00:00	70	178.0	39.3
7/29	14:00:00	80	194.0	41.2
7/29	15:00:00	80	189.4	42.2
7/29	16:00:00	80	184.8	43.3
7/29	17:00:00	80	188.4	42.5
7/29	18:00:00	72	180.6	39.9
7/29	19:00:00	72	186.3	38.6
7/29	20:00:00	80	199.4	40.1
7/29	21:00:00	80	191.3	41.8
7/29	22:00:00	80	191.9	41.7
7/29	23:00:00	60	158.9	37.8
7/29	24:00:00	60	142.1	42.2
7/30	1:00:00	60	143.9	41.7
7/30	2:00:00	56	139.6	40.1

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/30	3:00:00	56	139.4	40.2
7/30	4:00:00	56	142.6	39.3
7/30	5:00:00	56	136.1	41.1
7/30	6:00:00	56	138.4	40.5
7/30	7:00:00	56	135.9	41.2
7/30	8:00:00	56	135.9	41.2
7/30	9:00:00	56	137.5	40.7
7/30	10:00:00	56	139.9	40.0
7/30	11:00:00	50	124.7	40.1
7/30	12:00:00	50	127.9	39.1
7/30	13:00:00	50	124.7	40.1
7/30	14:00:00	50	126.6	39.5
7/30	15:00:00	50	125.6	39.8
7/30	16:00:00	40	99.2	40.3
7/30	17:00:00	40	100.6	39.8
7/30	18:00:00	40	107.4	37.2
7/30	19:00:00	60	151.6	39.6
7/30	20:00:00	60	151.2	39.7
7/30	21:00:00	60	150.2	39.9
7/30	22:00:00	60	139.1	43.1
7/30	23:00:00	48	128.1	37.5
7/30	24:00:00	48	113.7	42.2
7/31	1:00:00	38	93.7	40.6
7/31	2:00:00	38	93.5	40.6
7/31	3:00:00	38	93.0	40.9
7/31	4:00:00	38	101.0	37.6
7/31	5:00:00	38	93.5	40.6
7/31	6:00:00	38	93.7	40.6
7/31	7:00:00	38	94.9	40.0
7/31	8:00:00	60	146.1	41.1
7/31	9:00:00	60	145.8	41.2
7/31	10:00:00	60	152.5	39.3
7/31	11:00:00	60	166.7	36.0
7/31	12:00:00	75	185.8	40.4
7/31	13:00:00	75	185.3	40.5
7/31	14:00:00	75	191.2	39.2
7/31	15:00:00	75	188.0	39.9
7/31	16:00:00	75	192.0	39.1
7/31	17:00:00	80	200.7	39.9
7/31	18:00:00	80	204.0	39.2
7/31	19:00:00	80	211.0	37.9
7/31	20:00:00	97	262.3	37.0
7/31	21:00:00	97	250.7	38.7

Appendix A continued.

Date	Hour	Spill	Totq	Percent Spill
7/31	22:00:00	80	233.8	34.2
7/31	23:00:00	80	212.3	37.7
7/31	24:00:00	60	143.8	41.7

Appendix B. Fork lengths and weights of subyearling Chinook salmon released at Rock Creek, 2000. N = sample size, SD = standard deviation.

Release date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
6/30/00	20:00	32	118.9	5.0	112-132	19.0	2.7	15.1-28.5
7/02/00	08:00	19	115.5	3.4	110-122	17.7	1.8	13.8-20.0
7/03/00	20:00	24	117.4	5.9	112-132	18.9	3.2	15.8-26.8
7/05/00	08:00	33	120.5	7.3	111-146	20.9	4.3	14.7-35.6
7/06/00	20:00	32	116.8	7.1	110-137	18.8	4.1	14.2-30.3
7/08/00	08:00	32	118.1	5.2	111-131	18.6	3.1	14.5-28.1
7/09/00	20:00	32	117.5	5.8	111-135	18.9	3.2	14.9-29.3
7/11/00	08:00	29	121.6	10.0	112-152	21.8	6.4	13.8-42.6
7/12/00	20:00	34	117.3	6.7	110-142	17.9	2.7	13.6-25.0
7/14/00	08:00	32	117.2	4.7	111-127	18.3	2.7	14.4-24.6
7/16/00	20:00	33	123.2	6.3	115-139	21.0	3.2	16.3-28.7
7/17/00	08:00	31	118.4	6.2	111-137	18.3	3.2	14.4-28.8
7/20/00	08:00	31	116.6	4.0	111-128	19.0	2.3	15.9-26.7
Overall		394	118.5	6.5	110-152	19.2	3.7	13.6-42.6

Appendix C. Number of subyearling Chinook salmon passing The Dalles Dam through the turbines, sluiceway, and spillway, 01 July through 27 July 2000. Day=0700-1859, Night=1900-0659.

Block	Spill Period	Turbines	Sluiceway	Spillway	Total
1	Day	2	1	9	12
1	Night	2	4	8	14
2	Day	2	2	18	22
2	Night	2	1	12	15
3	Day	4	1	22	27
3	Night	1	3	7	11
4	Day	4	1	12	17
4	Night	4	3	4	11
5	Day	2	3	15	20
5	Night	2	2	9	13
6	Day	1	1	23	25
6	Night	2	2	17	21
7	Day	0	0	17	17
7	Night	1	1	10	12