TABLE OF CONTENTS

4.14B MIGRATORY BEHAVIOR OF RADIO-TAGGED JUVENILE CHINOOK SALMON THROUGH SWIFT RESERVOIR, 2002 (AQU 14B) ..... AQU 14B-1
4.14B.1 Study Objectives ..... AQU 14B-1
4.14B.2 Study Area ..... AQU 14B-1
4.14B.3 Methods ..... AQU 14B-4
4.14B.4 Key Questions ..... AQU 14B-11
4.14B.5 Results ..... AQU 14B-12
4.14B.6 Discussion ..... AQU 14B-30
4.14B.7 Schedule ..... AQU 14B-31
4.14B.8 References ..... AQU 14B-32

AQU 14B Appendix 1 Location of Radio-tagged Juvenile Chinook Salmon in Swift Reservoir

LIST OF TABLES

Table 4.14B-1. Summary information for three replicates of hatchery Chinook salmon smolts implanted with radio tags and released at Eagle Cliff on the Lewis River. ..... AQU 14B-13
Table 4.14B-2. Migration rate and travel time for radio-tagged Chinook salmon smolts released at Eagle Cliff on the Lewis River to Swift No. 1 underwater detection array ..... AQU 14B-15
Table 4.14B-3. Number of days radio-tagged Chinook salmon smolts were detected at the aerial or underwater system at Swift No. 1. ..... AQU 14B-19
Table 4.14B-4. Capture history matrix for radio-tagged Chinook salmon smolts observed during mobile surveys by zone of detection in Swift Reservoir. ..... AQU 14B-22
Table 4.14B-5. Number of radio-tagged Chinook salmon smolts detected by zone for each mobile survey and percent of fish detected in each zone. ..... AQU 14B-23
Table 4.14B-6. Detection summary by location and zone for radio-tagged coho smolts observed during boat tracking surveys on Swift Reservoir. ..... AQU 14B-24
Table 4.14B-7. Number and percent of detections for first, repeat and total detections of radio-tagged Chinook salmon by antenna array on the underwater antenna system at Swift No. 1. ..... AQU 14B-26
Table 4.14B-8. Detections by channel and code at fixed telemetry sites in the forebay and tailrace and within Zone 6 by mobile surveys. ..... AQU 14B-28

Table 4.14B-9. Migration behavior of radio-tagged Chinook and coho released into Swift Reservoir in 2001 and 2002, respectively.....AQU 14B-30
Table 4.14B-10. Behavior observed for radio-tagged Chinook and coho in the forebay of Swift No. 1 in 2001 and 2002, respectively....AQU 14B-31

LIST OF FIGURES

Figure 4.14B-1. Location of dams on the Lewis River in Southwest Washington.....AQU 14B-2
Figure 4.14B-2. Mean daily powerhouse discharge at Swift No. 1 Dam. .....AQU 14B-3
Figure 4.14B-3. Swift Reservoir pool elevation during the study period. .....AQU 14B-3
Figure 4.14B-4. Location of aerial antennas in the forebay Swift No. 1 and in Swift Canal. .....AQU 14B-6
Figure 4.14B-5. Side view and plan view of aerial and underwater antennas used in the forebay of Swift No. 1. All depth measurements are in meters above mean sea level. .....AQU 14B-8
Figure 4.14B-6. Delineation of Swift Reservoir zones used during boat surveys. .....AQU 14B-9
Figure 4.14B-7. Travel times and migration rates for juvenile Chinook salmon released at Eagle Cliff on the Lewis River to detection on the underwater antenna array at Swift No. 1. .AQU 14B-17
Figure 4.14B-8. Arrival distribution in numbers and cumulative percent for radio-tagged Chinook salmon detected on the underwater antenna system at Swift No. 1. .....AQU 14B-18
Figure 4.14B-9. Number of days radio-tagged Chinook salmon were detected by aerial and underwater systems at the forebay of Swift No.1. .....AQU 14B-19
Figure 4.14B-10. Percent of radio-tagged Chinook detections recorded for first, repeat and total detections on the top and bottom antenna arrays of the intake structure of Swift No. 1 Dam. AQU 14B-26
Figure 4.14B-11. Percent of radio-tagged Chinook detections recorded for first, repeat and total detections at the north, middle and south sides of the intake structure of Swift No. 1 Dam.....AQU 14B-27

4.14B MIGRATORY BEHAVIOR OF RADIO-TAGGED JUVENILE CHINOOK SALMON THROUGH SWIFT RESERVOIR 2002 (AQU 14B)

PacifiCorp and Cowlitz County PUD are interested in assessing the feasibility of installing a smolt-collection device near the intake structure of Swift No. 1 Dam. In conjunction with several other aquatic studies, this report is key to assessing the feasibility of reintroducing anadromous salmonids (*Oncorhynchus sp*.) to portions of the North Fork Lewis River. In the first year of evaluation (Miller et al. 2001) the migration behavior of radio-tagged juvenile coho salmon (*O. kisutch*) was examined. In this follow up study, we describe the migration behavior of juvenile Chinook salmon (*O. tshawytscha*). Although the species of interest in this study was Chinook salmon, we compare results of Chinook behavior with that of coho in 2001. These comparisons are an important aspect for the development and eventual deployment of an effective smolt bypass system.

An over-riding issue for the potential reintroduction of anadromous fish upstream of Swift No. 1 is whether juvenile salmonids migrate through Swift Reservoir and arrive at the face of the dam in numbers adequate to warrant the design and construction of a smolt-collection device. A fundamental consideration involves describing the migration behavior of juvenile salmonids through the reservoir. It is not clear whether the current velocities and patterns in the reservoir will effectively direct smolts through the reservoir to the dam. Thus, a description of migration behavior that encompasses aspects such as survival, migration rate, and arrival distribution at the dam along with behavior near the project, provide information to help make decisions regarding the merits of a smolt-passage facility at Swift No. 1. The purpose of this study is to provide that information for a hatchery population of Chinook salmon.

4.14B.1 Study Objectives

The study will address two primary objectives:

(1) Assess minimum survival[1] of radio-tagged Chinook smolts to Swift No. 1 Dam, and determine if radio-tagged fish passed the project.

(2) Describe migratory behavior of the radio-tagged smolts within Swift Reservoir including, travel time, migration rate, and arrival distribution. Also, describe general movement patterns in the Swift Reservoir and near the intake structure of Swift No. 1 Dam.

4.14B.2 Study Area

The North Fork of the Lewis River originates on the west slope of Mt. Adams and flows southwest for approximately 145 kilometers before emptying into the Columbia River,

[1] Minimum reservoir survival was estimated as the percentage of fish released at the head of the reservoir that were detected at the project. This estimate represents minimum reservoir survival because it cannot be adjusted for mortality associated with handling and detection efficiencies of fixed telemetry systems less than 100 percent or for slow migrating fish that may arrive at the project after the radio tag has stopped functioning.

approximately 32 kilometers north of Vancouver. There are four projects upstream from the confluence of the Lewis and Columbia rivers (Figure 4.14B-1). The upstream sequence of the four Lewis River projects is: Merwin, Yale, Swift No. 2 and Swift No. 1.

Swift No. 1 is the most upstream project on the Lewis River and is approximately 72.4 kilometers upstream from the confluence with the Columbia River. Construction of Swift No. 1 Project began in 1956 and was completed by 1958. Swift Dam is an earthfill embankment dam with a single intake and tunnel that extends down past a surge tank. Downstream of the tank, the tunnel branches into three penstocks that supply water to three 70 mw Francis generator units at the powerhouse located at the base of the dam. The intake is 44.3 meters deep (centerline) at a normal full pool elevation of 304.8 meters msl. Swift No. 1 utilizes two 15.2- by-15.5-meter taintor gates for spillway overflow. Swift Reservoir formed by the dam is approximately 18.5 kilometers long and has a surface area of about 4,000 acres at full pool. Gross storage capacity of the reservoir is 755,500 acre-feet.

Swift No. 1 Dam is a part of Lewis River complex of hydroelectric projects that generally release water for generation based on energy production, peaking, real-time load following and river and reservoir management. Mean daily powerhouse discharge during the study period ranged from 0 to 6,949 cfs (Figure 4.14B-2). Discharge at the project did not occur from 22 April to 26 April when repairs to Swift No. 2 Canal were conducted. Pool elevation during the study period varied from 984 to 998 feet above mean seal level (msl) (Figure 4.14B-3).

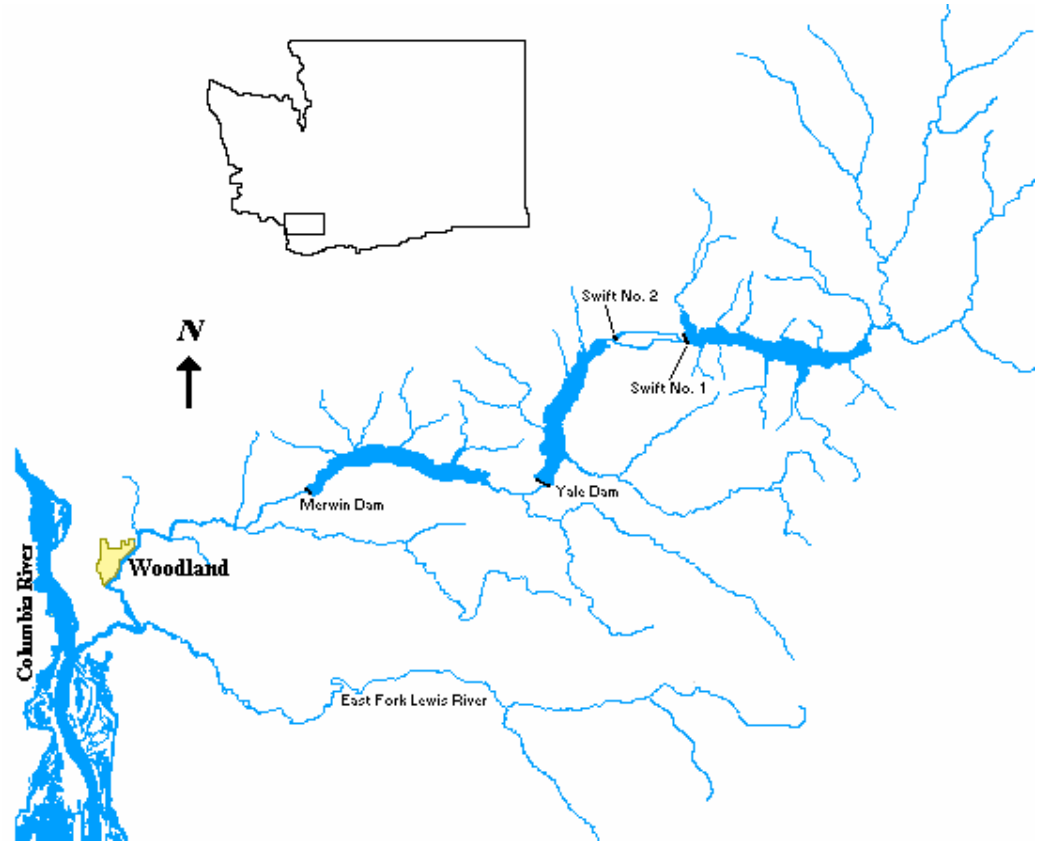


Figure 4.14B-1. Location of dams on the Lewis River in Southwest Washington.

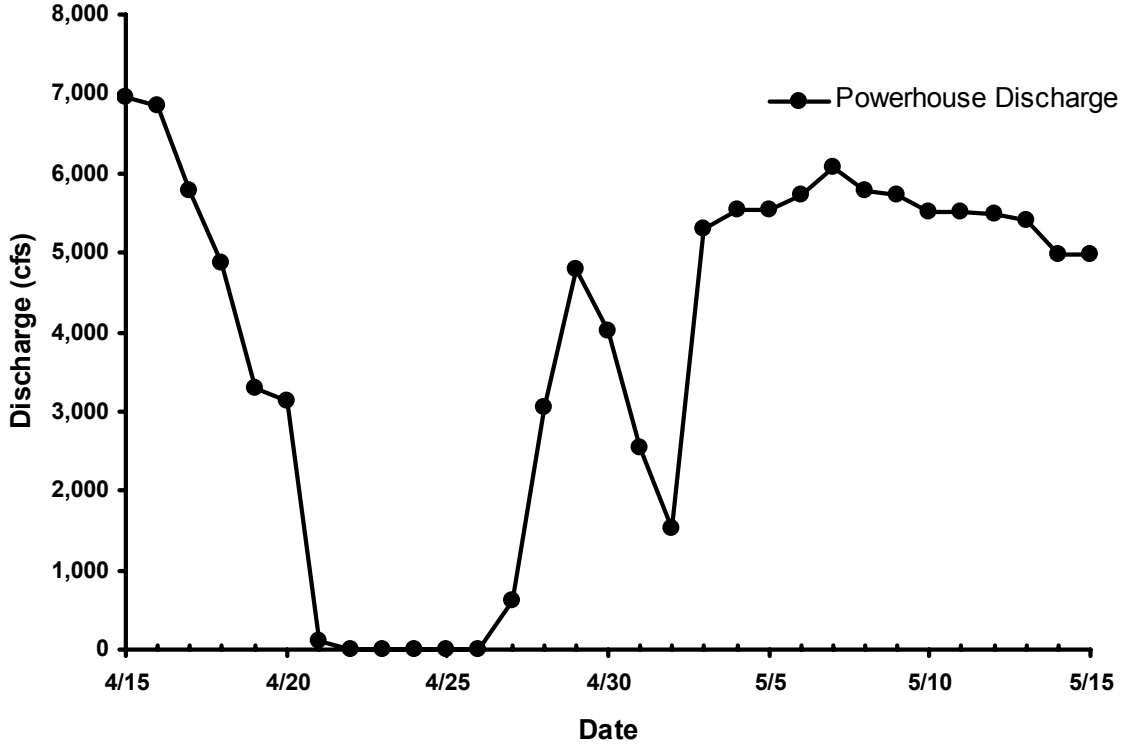


Figure 4.14B-2. Mean daily powerhouse discharge at Swift No. 1 Dam.

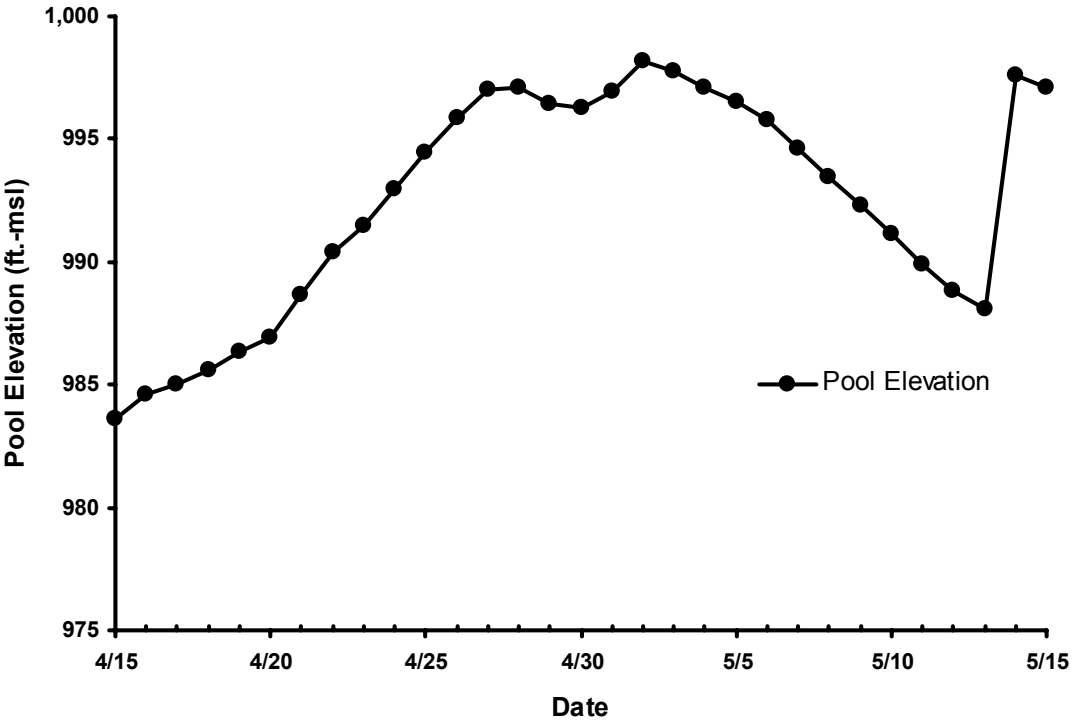


Figure 4.14B-3. Swift Reservoir pool elevation during the study period.

4.14B.3 Methods

4.14B.3.1 Radio Telemetry

Radio Transmitters

Radio transmitters used in this study were pulse-coded transmitters developed by Lotek Engineering of Newmarket, Ontario, Canada. The transmitters, model MCFT-3GM, are available on 25 unique frequencies (channels), with a total of 212 unique codes on each of the 25 frequencies within a given frequency range (i.e., 148 MHz). The transmitters were 8.2 mm in diameter and 18.9 mm in length, and weigh 1.8 grams in air and 1.0 grams in water. The transmitters were equipped with two 1.5-volt batteries that provided a total output of 3.0 volts. This configuration results in a typical operational life of 29.0 days at a 5.0 second transmission rate (1 pulse every 5.0 seconds). The transmitters were equipped with a 24-cm stainless steel external antenna, sheathed in a clear plastic material to protect the antenna.

Channel/Code Selection

We conducted noise evaluations at Swift No. 1 project before the initiation of the 2001 coho study (March 23, 2001) to assess ambient background noise at the primary study site. We did this so that we could select channel/code combinations for use in the study that would not coincide with ambient background noise at the project, which would complicate data analysis and reduce the detection efficiency. Assessments were conducted in the forebay and tailrace of the project, and were designed to determine what, if any channel/code combinations were particularly noisy at the project.

Evaluations included monitoring 10 of the possible 25 frequencies[2] within the 148 MHz range (148.320-148.500, with 20 KHz increments), with either 3 or 4-element Yagi antennas in the areas of interest for approximately 4.0 hours. In addition, we performed noise evaluations of the tailrace area, particularly around the substation with a hand-held antenna. We found that none of the available channels or codes was excessively noisy. However, we selected the four frequencies that logged the fewest ambient background events during the assessment to minimize the potential for conflict. We selected channel 1 (148.320 MHz), channel 3 (148.360 MHz), channel 6 (148.420 MHz), and Channel 8 (148.460 MHz), and used codes 1-15 for each channel. Therefore, we used a total of 60 unique channel/code combinations in this study.

Biotelemetry System

Radio-tagged fish were monitored using two radio telemetry techniques. First, we used fixed-telemetry sites at the forebay and tailrace of the dam to monitor movements near the project. In addition, we monitored radio-tagged fish with mobile-telemetry surveys in Swift Reservoir and the Swift Canal.

[2] Ten of the available 25 frequencies were evaluated since only those frequencies were available from the manufacturer at the time the assessment was conducted.

Signal input at fixed telemetry sites were balanced at each antenna so that a tagged fish at a given depth and distance from any antenna within a specified or adjacent zone would provide similar signal strengths (power) relative to one another. We amplified signal input as close to the receiving antenna as possible to offset loss associated with signal loss through coaxial cable and other electronic connections. Because individual amplifiers can vary in performance it is necessary to attenuate the signal strength at the receiver so that the signal at the receiver is equal to the signal received at the amplifier. This is accomplished by transmitting a signal of known strength through the system, and attenuating each antenna so that the signal input at the receiver is equal to the transmitted signal. This procedure was implemented for each fixed telemetry site. The following discussion provides details on each of the telemetry systems and methods for conducting the mobile surveys.

Forebay Aerial System

The forebay aerial system was located on the upstream side of the intake structure of the dam and consisted of two 3-element Yagi antennas (Figure 4.14B-4). The antennas were aimed horizontally to provide continuous coverage of the forebay from the south shore to the earthen dam. The antennas were also aimed vertically to provide maximum coverage from the face of the intake structure out to a distance of approximately 300 meters. The antennas were combined together and monitored by a single Lotek SRX receiver, which logs and stores the radio transmissions. The four frequencies or channels (1, 3, 6 and 8) were monitored for a period of 6.0 seconds for each receiver cycle, which resulted in a receiver cycle time of 24.0 seconds. Therefore, each channel was monitored for 6.0 seconds out of every 24.0-second cycle. The receiver was powered by a 12-volt deep cycle battery that was connected to a 10-amp battery charger. The battery charger was in turn powered by a 110-volt AC power supply.

Detection by this system was a function of depth and distance of the radio-tagged fish from the receiving antennas. That is, the signal strength of a fish close to the antenna at depth could be the same as a fish 300 meters from the antenna, but near the surface. Therefore, the depth and distance of a tagged fish from the receiving antenna could not be ascertained. Instead, only presence or absence could be determined. The main function this system was to record the number of fish that had arrived at the forebay of the dam to calculate survival through the reservoir.

Forebay Underwater System

The forebay underwater system was deployed to detect fish that approached the intake structure at a depth too great to be detected by the aerial system (depth > 8 meters). Because of the depth of the actual intake (the centerline of the intake at full pool was 44.3 meters), it was not possible to deploy underwater antennas at this location. Instead, we deployed bared-coax antennas at three separate transects (designated as North, Middle and South), with a shallow and deep antenna within each transect at depths of approximately 9.1 and 18.5 meters, respectively (Figure 4.14B-5). Collectively, these antennas provided detection capabilities beyond what could be obtained by the forebay aerial system. The system as a whole was designed to provide detection across the full

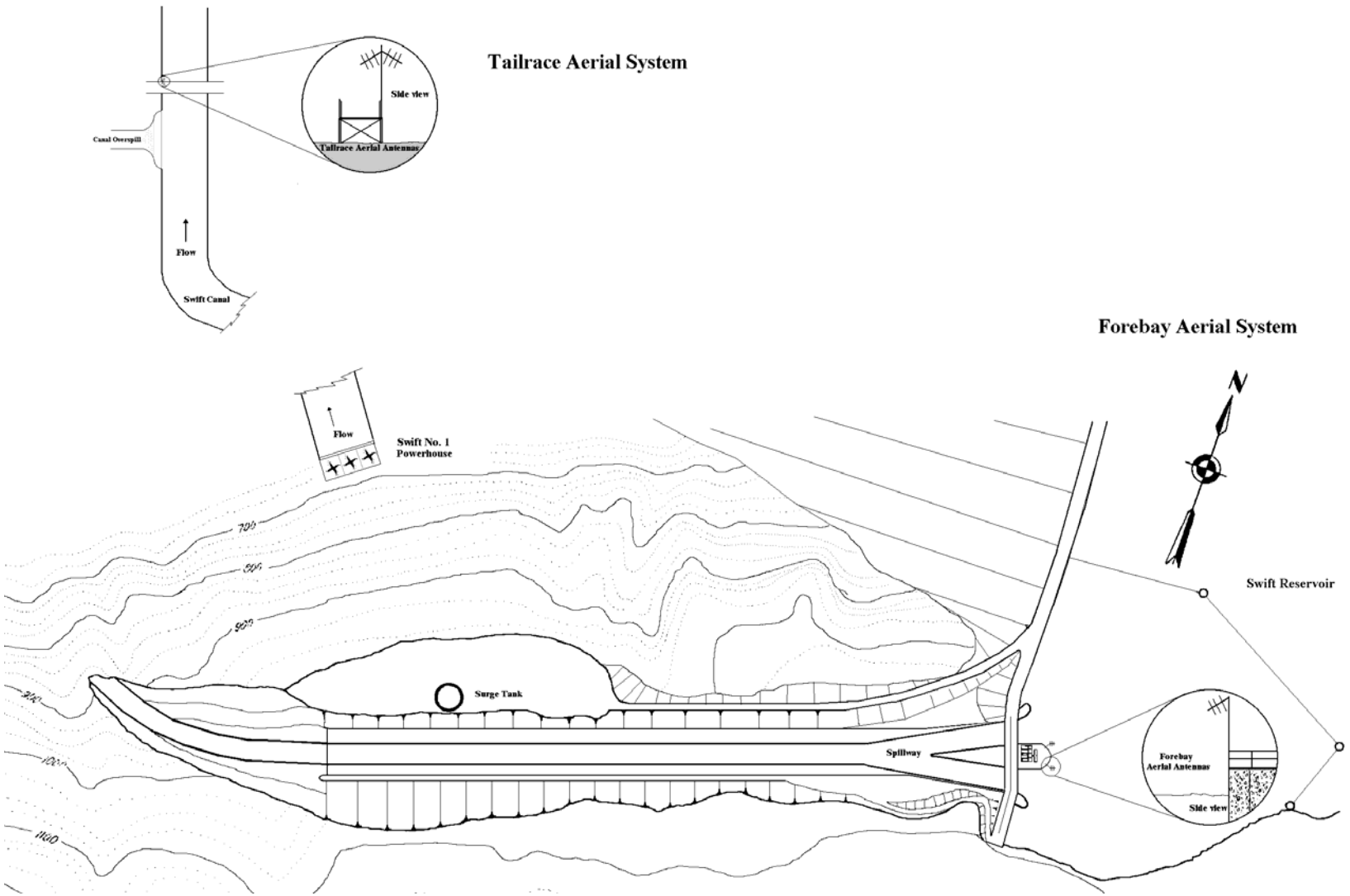


Figure 4.14B-4. Location of aerial antennas in the forebay Swift No. 1 and in Swift Canal.

width of the trashrack structure from where the aerial system coverage ended to a depth approximately 10 meters below the top of the trashracks.

Six underwater antennas were deployed for this system and were designated as North Top, North Bottom, Middle Top, Middle Bottom, South Top, and South Bottom. The underwater system was monitored with an SRX receiver and a DSP (Digital Spectrum Processor) unit and was powered by the same battery/charger system used to power the forebay aerial system.

The DSP unit allowed all channels and antennas to be monitored simultaneously, which eliminates receiver cycle time and the likelihood of missing radio transmissions.[3] Because all six antennas were monitored individually, it was possible to determine if radio-tagged fish exhibited general approach behaviors.

The primary purpose for deployment of this system was to assess migration rate, travel time, arrival distribution at the dam and behavior near the intake. The underwater system provided the most accurate means for calculating these metrics because it clearly established fish at the dam where a possible smolt collection device might be located.

To calculate migration rate, travel time and arrival distribution we assessed the length of time it took each fish from time of release to first detection by the underwater system. Migration rate is the speed in kilometers per day (Km/d) fish traveled while travel time is the number days (d) required by each fish to migrate through the reservoir. Migration rate was calculated as the quotient of reservoir length (18.5 km) divided by the number of days it took each fish to arrive at the dam. Arrival distribution is simply the number of new fish detected by the underwater system each day.

Behavior near the intake was assessed by summing the number of fish that were detected initially on each antenna. We compared the number of fish detected on the top array of antennas to the number detected by the bottom antennas to describe the vertical distribution (depth) of fish as they approached the intake structure. Likewise, we compared the number of fish first detected on the North, Middle and South antenna arrays to describe the horizontal distribution (approach orientation) of fish as the moved toward the intake structure. We performed this analysis also on the subsequent detections or repeat detections on the underwater system. To assess the amount of time fish spent near the intake we summed the number of records for each antenna. This, in part, helps describe the area where most of the fish spent most of their time near the intake structure.

Swift Canal Aerial System

The purpose of the Swift Canal aerial system was to detect radio-tagged fish that had passed through Swift No. 1 powerhouse. The system consisted of two 4-element Yagi antennas located on one side of the walkway just downstream of the canal overspill (Figure 4.14B-4). One antenna was aimed upstream, another downstream towards the middle of the canal. Since the antennas used at this site have a horizontal detection field

[3] DSP units are best used in underwater applications because they are sensitive to ambient background noise.

of 80 degrees, the canal was effectively monitored both upstream and downstream of the walkway. Detection distance from the walkway is a function of the depth of the radio-tagged fish. However, detection from the walkway upstream most likely extended past the beginning of the canal overflow and downstream to the point where the canal began to parallel Highway 503. This system was monitored by a single SRX unit, which was configured with a 6.0 sec scan time and a 22.0 sec receiver cycle time. A 12-volt RV battery supplied power to the system.

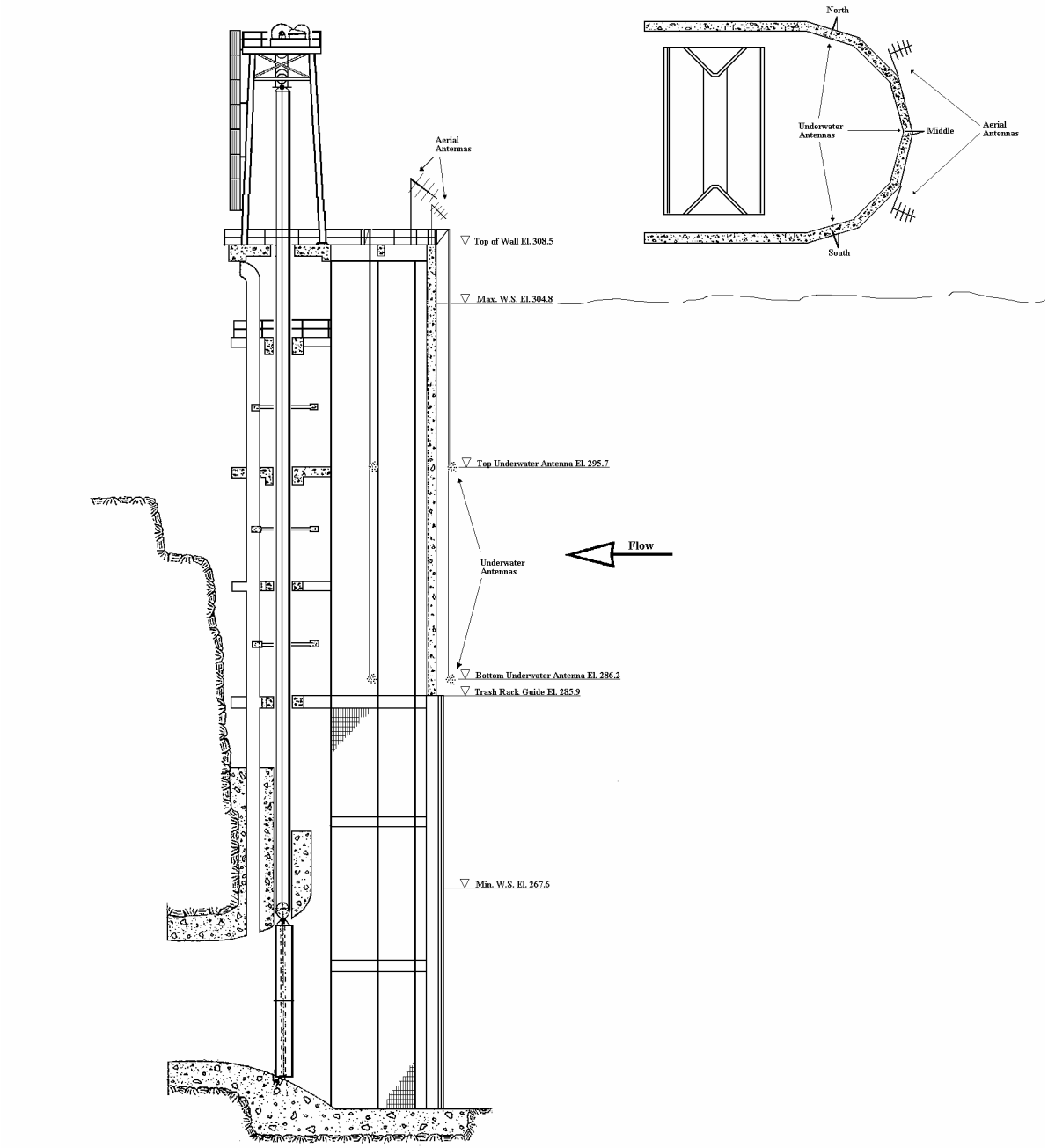


Figure 4.14B-5. Side view and plan view of aerial and underwater antennas used in the forebay of Swift No. 1. All depth measurements are in meters above mean sea level.

Mobile Telemetry Surveys

From April 16 to May 13, 2002, ten boat surveys were conducted on Swift Reservoir and several vehicle surveys along Swift Canal were used to track radio-tagged Chinook salmon. The boat was outfitted with two 4-element Yagi antennas combined together and mounted on each side of the boat. Each antenna was aimed 30 degrees off the mid-line of the boat to provide a combined detection field of approximately 140 degrees. Surveys were conducted by moving along the perimeter of the reservoir at a distance of approximately 100 to 200 meters from the shore. On most boat surveys, we also traveled through the middle of the reservoir to track fish.

When fish were detected, antennas on either side of the boat were used to locate fish by signal strength (power) or by the volume (sound) of the radio tag. We separated Swift Reservoir into six zones easily recognized by visual landmarks (Zone 1 is at the head of the reservoir and Zone 6 near the dam) (Figure 4.14B-6). These zones were used to describe the general location of fish within the reservoir. When signal strength was greater than 140 power points the location of a tagged fish was recorded with a GPS unit. At the time the data were analyzed, we assigned each channel/code combination (representing a unique fish) an identification number to represent the location of each fish on a given survey (AQU 14B Appendix 1). In areas where fish had a tendency to congregate, the boat was stopped and all channels were monitored individually until all of the fish in the detection area were logged. Individual fish were then tracked until a position could be recorded for each fish in the area.

We conducted six motor vehicle surveys of the Swift Canal from the powerhouse to the walkway. The surveys were conducted by traveling the access road along the canal from the powerhouse to the walkway with a SRX receiver outfitted with a 4-element Yagi antenna.

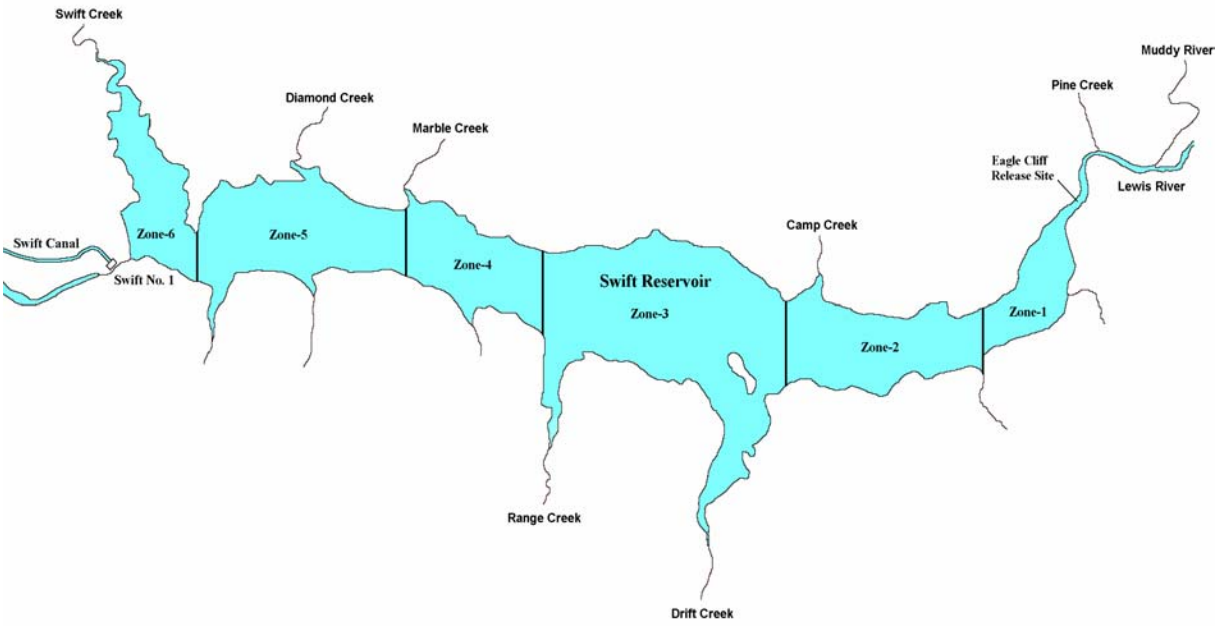


Figure 4.14B-6. Delineation of Swift Reservoir zones used during boat surveys.

4.14B.3.2 Fish Collection

Hatchery Chinook salmon were collected from the Lewis River Hatchery and transported by truck to the Pine Creek Forest Service Station. At the hatchery, fish were placed in a 1200-liter transport tank supplied with recirculated water and oxygen. All Chinook smolts used in the study were transported to the tagging facility prior to the tagging phase of the study. We transported approximately 30-40 fish for each replicate to account for rejection due to injuries, descaling or inadequate size. At the Forest Service Station, transported fish were acclimated to well water used at the site, and were held in one of two 208 liter containers prior to tagging. Fish were left undisturbed for 48 hours before tagging to reduce stress of transport and handling.

4.14B.3.3 Fish Tagging

We surgically implanted transmitters in 60 hatchery coho salmon following procedures outlined in Summerfelt and Smith (1990). We tagged three replicates with 20 fish per replicate. Surgery was conducted in three steps: (1) pre-operative MS-222 bath, (2) surgical implantation of the radio-transmitter, and (3) freshwater recovery. We anesthetized test animals in a pre-operative solution of MS-222 at 100 mg/L until fish lost equilibrium. During surgery we reduced the MS-222 concentration to 50 mg/L to maintain anesthesia. Fish were rejected for tagging if they had external injuries, scale loss greater than 20 percent, or were less than 145 mm fork length.

During surgery, the fish was placed on a V-shaped Plexiglas cradle that was integrated into a rectangular catchment tray. A hose fed through one end of the surgical cradle supplied anesthetic water to the fish during surgery. Fish were placed into the cradle and swabbed with iodine at the incision site, and sprayed with a diluted solution of Pro-polyaqua (synthetic fish mucous). We implanted radio-tags through a 1.0-cm incision between the pectoral and pelvic fins slightly off the mid-ventral line. We inserted a beveled cannula through the incision into the body cavity and slid the cannula against the body wall and pierced the skin near the vent. The radio-transmitter antenna was inserted into the cannula, and both the cannula and the antenna were pulled through the exit site. The radio-transmitter was then inserted into the body cavity and the incision closed with 2-3 sutures.

We finished the procedure with a second application of iodine over the sutures and a spray of Pro-polyaqua. Scalpel, cannula, and tweezers were immersed in isopropyl alcohol for 2–4 minutes after each fish. Radio-tagged fish were held in 18.9-liter buckets for 48 hours prior to release to facilitate recovery. Each bucket contained two radio-tagged fish separated by a clear Plexiglas partition to eliminate the possibility of the antennas becoming entangled. Numerous holes were drilled into the Plexiglas to allow water circulation, rough edges were sanded, and the partition was siliconed into place. A large moving van was used to tag, hold, and transport the tagged fish.

4.14B.3.4 Fish Release

Radio-tagged fish were transported to Eagle Cliff Park on the Lewis River approximately 200 meters upstream from Swift Reservoir. Replicates 1, 2 and 3 were released in the

afternoon on 15, 17, and 19 April, respectively, between the hours of 1100-1300. Prior to transport and release, all radio-tagged fish were scanned with an SRX receiver to verify that the radio-transmitter was functioning and coding properly. In addition, all fish were observed in the buckets prior to release to verify that no fish exhibited any signs of post-operative stress such as loss of equilibrium. At the release site, individual buckets were transported by hand to the river and fish were released away from the shoreline into the main current to encourage downstream movement into the reservoir.

4.14B.3.5 Data Management

Three separate types of data files were compiled into a single database to assess survival and migration behavior within the reservoir and near Swift No. 1 Dam. The first file contained tagging and release information for each of the tagged fish released at Eagle Cliff on the Lewis River (Table 4.14B-1). That file recorded the date and time of release and tagging information for each replicate. We also recorded fork length for each fish by channel, code, and replicate, and each fish was assigned a unique number. The second file contained all boat tracking information, which included zone and time of detection. All fish detected during boat tracking surveys were recorded by GPS and downloaded onto electronic versions of 7.5-minute maps of Swift Reservoir at least twice a week.

The third file contained information from fixed station receivers. Receivers were checked approximately every other day to ensure proper operation (i.e., battery voltage, receiver time, memory status, etc.), and downloaded at least once a week. All downloaded files (hexadecimal format) were converted to ASCII format and appended to a master receiver file. At the end of the study, all fixed station receiver files and boat tracking data were coded with a receiver number and combined into a relational database for final data analysis.

4.14B.3.6 Data Analysis

Data were analyzed to assess travel time, migration rate, arrival distribution, detection rate, intake approach behavior, and minimum survival to Swift No. 1. Before data analysis began, criteria were developed to distinguish valid detections from ambient background noise. The criteria helped to eliminate invalid detections (noise) that were recorded on fixed station receivers. The following criteria were used to eliminate invalid detections at all fixed station receivers:

(1) No fish can be detected before the date and time of release.

(2) A valid detection must have at least two hits (records) within 0.5 hrs.

(3) Valid detections cannot occur out of sequence (i.e., detection on the tailrace system cannot be valid if the fish is detected in the reservoir at a later date.

4.14B.4 Key Questions

The purpose of this study was to help assess the feasibility of reintroducing Chinook salmon to portions of the North Fork Lewis River. A key issue to understanding if potential reintroductions will be successful is to describe the survival and migration

behavior of juvenile Chinook in Swift Reservoir. That is, will the progeny of reintroduced Chinook salmon or hatchery outplants migrate to Swift No.1 Dam and survive at rates that warrant smolt-collection or passage facilities at the dam. In the first year, hatchery coho salmon were implanted with radio tags to describe survival and migration behavior. During this second year we evaluated the behavior and survival of radio-tagged juvenile Chinook salmon in Swift Reservoir. Subsequent research may focus on other salmonid species or natural migrants in conjunction with operation of a smolt-collection device. Other aquatic studies have or continue to address issues related to reintroduction, management and performance of anadromous fish in the Lewis River Basin. Collectively, these studies study will be useful in addressing or help to address the following "key" watershed questions that were identified during the Lewis River Collaborative Watershed Studies meetings:

- What types of reintroduction methods might be successful in the Lewis River Watershed and what is the potential cost and engineering feasibility of each of these methods (e.g., trap and haul, construction of fish ways, screening, stocking of fry and planting of eggs)?

- What physical, chemical, and biological conditions currently exist in project reservoirs or stream habitats that may affect anadromous fish movements and migrations, and how might potential impact resulting from these conditions be reduced?

- What types of inter-specific interactions may occur with various options for reintroducing anadromous fish?

- What types of reservoir management alternatives might increase the potential success of anadromous fish reintroductions efforts (e.g., reservoir drawdown to facilitate downstream migration of smolts)?

4.14B.5 Results

4.14B.5.1 Fish Handling

Hatchery Chinook salmon implanted with radio-transmitters varied in length from 174 to 211 mm with an average fork length of 193.5 mm (Table 4.14B-1). All fish tagged in the first replicate were released on 15 April. One fish in replicate two could not maintain equilibrium the day of release and was removed from the replicate. The tag was recovered and used to tag an additional fish in replicate three.

Well water supplied at Pine Creek Forest Service Station was tested for total dissolved gases (TDG) the previous year (Miller et al. 2001). The total dissolved gas level was less than 110 percent and temperature was near a constant 8° C. All fish transported from Lewis River Hatchery were acclimated to the Pine Creek station well water. The fish were acclimated to the well water for about one hour. The temperature at the release site on the Lewis River varied from 6 to 8° C at time of release.

Table 4.14B-1. Summary information for three replicates of hatchery Chinook salmon smolts implanted with radio tags and released at Eagle Cliff on the Lewis River.

Replicate	Fish ID	Release		Channel	Code	FKL (mm)
		Date	Time			
1	1	4/15/02	1145	1	6	190
1	2	4/15/02	1145	1	7	195
1	3	4/15/02	1145	1	8	195
1	4	4/15/02	1145	1	9	186
1	5	4/15/02	1145	1	10	182
1	6	4/15/02	1145	3	11	174
1	7	4/15/02	1145	3	12	192
1	8	4/15/02	1145	3	13	204
1	9	4/15/02	1145	3	14	195
1	10	4/15/02	1145	3	15	185
1	11	4/15/02	1145	6	1	207
1	12	4/15/02	1145	6	2	196
1	13	4/15/02	1145	6	3	194
1	14	4/15/02	1145	6	4	203
1	15	4/15/02	1145	6	5	179
1	16	4/15/02	1145	8	2	194
1	17	4/15/02	1145	8	4	186
1	18	4/15/02	1145	8	6	176
1	19	4/15/02	1145	8	8	187
1	20	4/15/02	1145	8	10	193
2	21	4/17/02	1148	1	1	202
2	22	4/17/02	1148	1	2	209
2	23	4/17/02	1148	1	3	193
2	24	4/17/02	1148	1	4	197
2	25	4/17/02	1148	1	14	192
2	26	4/17/02	1148	3	6	190
2	27	4/17/02	1148	3	7	193
2	28	4/17/02	1148	3	9	211
2	29	4/17/02	1148	3	10	191
2	30	4/17/02	1148	6	11	185
2	31	4/17/02	1148	6	12	196
2	32	4/17/02	1148	6	13	186
2	33	4/17/02	1148	6	14	189
2	34	4/17/02	1148	6	15	195
2	35	4/17/02	1148	8	1	187
2	36	4/17/02	1148	8	3	196
2	37	4/17/02	1148	8	5	204
2	38	4/17/02	1148	8	7	204
2	39	4/17/02	1148	8	9	183
3	40	4/19/02	1238	1	11	199

Table 4.14B-1. Summary information for three replicates of hatchery Chinook salmon smolts implanted with radio tags and released at Eagle Cliff on the Lewis River (cont.).

Replicate	Fish ID	Release		Channel	Code	FKL (mm)
		Date	Time			
3	41	4/19/02	1238	1	12	192
3	42	4/19/02	1238	1	13	203
3	43	4/19/02	1238	1	15	197
3	44	4/19/02	1238	3	1	205
3	45	4/19/02	1238	3	2	193
3	46	4/19/02	1238	3	3	201
3	47	4/19/02	1238	3	4	185
3	48	4/19/02	1238	3	5	196
3	49	4/19/02	1238	3	8	196
3	50	4/19/02	1238	3	16	185
3	51	4/19/02	1238	6	6	191
3	52	4/19/02	1238	6	7	197
3	53	4/19/02	1238	6	8	177
3	54	4/19/02	1238	6	9	202
3	55	4/19/02	1238	6	10	194
3	56	4/19/02	1238	8	11	186
3	57	4/19/02	1238	8	12	208
3	58	4/19/02	1238	8	13	208
3	59	4/19/02	1238	8	14	189
3	60	4/19/02	1238	8	15	192
					Mean:	193.5

Fish were tagged two days before release date.

4.14B.5.2 Migration Behavior

To describe the migration behavior of radio-tagged fish through the reservoir, we calculated travel time and migration rate for each fish from the point of release to the intake structure, using the first detection by the underwater system as the metric to indicate arrival. The underwater system provided the most accurate measure of migration time to the project since the range of the underwater antennas is approximately 9 meters, and clearly establishes arrival at the project. Conversely, depending on the depth of the tagged fish, the distance of the tagged fish to the project at the time of first detection by the aerial system could vary from a few meters to as much as a 300 meters.

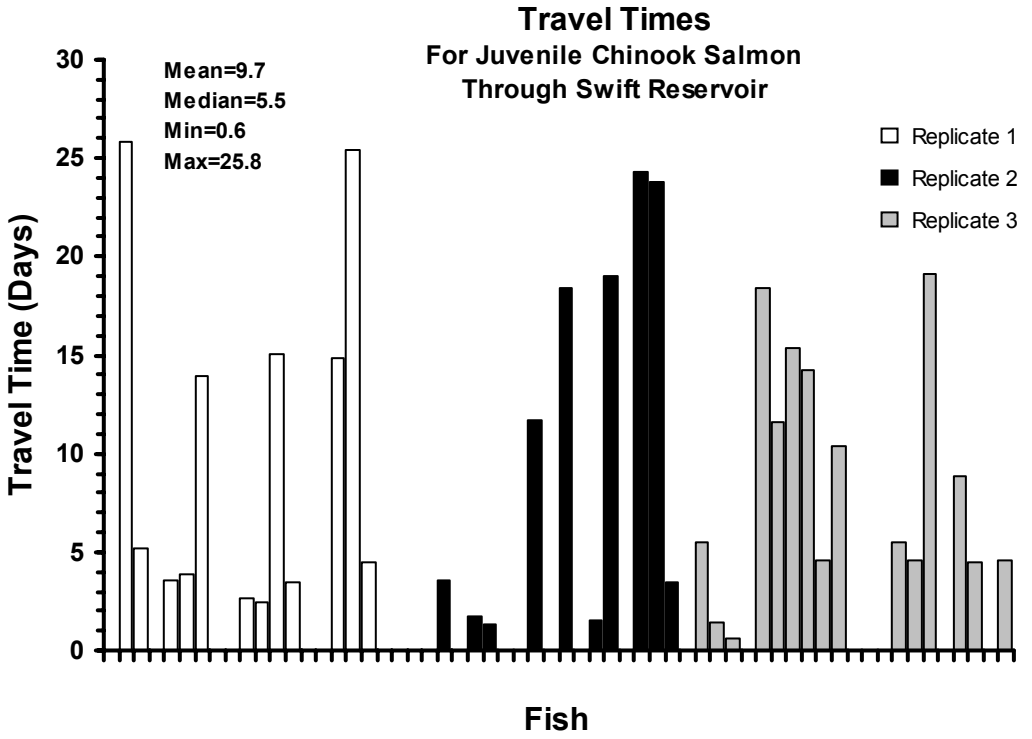
The median travel time for the 37 juvenile Chinook released at Eagle Cliff Park to detection by the underwater system at the project intake was 5.5 days and varied from 0.6 day to 25.8 days. The median migration rate to the project intake was 3.4 km/day and varied from 0.7 km/day to 28.8 km/day (Table 4.14B-2; Figure 4.14B-7).

Table 4.14B-2. Migration rate and travel time for radio-tagged Chinook salmon smolts released at Eagle Cliff on the Lewis River to Swift No. 1 underwater detection array.

Replicate	Fish ID	Channel	Code	Migration Rate (km/d)	Travel Time (days)
1	1	1	6	---	---
1	2	1	7	25.8	0.7
1	3	1	8	5.1	3.6
1	4	1	9	---	---
1	5	1	10	3.5	5.2
1	6	3	11	3.9	4.8
1	7	3	12	13.9	1.3
1	8	3	13	---	---
1	9	3	14	---	---
1	10	3	15	2.7	7.0
1	11	6	1	2.4	7.7
1	12	6	2	15.1	1.2
1	13	6	3	3.4	5.4
1	14	6	4	---	---
1	15	6	5	---	---
1	16	8	2	14.9	1.2
1	17	8	4	25.4	0.7
1	18	8	6	4.5	4.1
1	19	8	8	---	---
1	20	8	10	---	---
2	21	1	1	---	---
2	22	1	2	---	---
2	23	1	3	3.6	5.1
2	24	1	4	---	---
2	25	1	14	1.7	10.9
2	26	3	6	1.3	13.9
2	27	3	7	---	---
2	28	3	9	---	---
2	29	3	10	11.7	1.6
2	30	6	11	---	---
2	31	6	12	18.5	1.0
2	32	6	13	---	---
2	33	6	14	1.6	11.9
2	34	6	15	19.0	1.0
2	35	8	1	---	---
2	36	8	3	24.3	0.8
2	37	8	5	23.8	0.8
2	38	8	7	3.4	5.4
2	39	8	9	---	---
3	40	1	11	5.5	3.4

Table 4.14B-2. Migration rate and travel time for radio-tagged Chinook salmon smolts released at Eagle Cliff on the Lewis River to Swift No. 1 underwater detection array (cont.).

Replicate	Fish ID	Channel	Code	Migration Rate (km/d)	Travel Time (days)
3	41	1	12	1.4	13.0
3	42	1	13	0.6	28.8
3	43	1	15	---	---
3	44	3	1	18.4	1.0
3	45	3	2	11.5	1.6
3	46	3	3	15.3	1.2
3	47	3	4	14.2	1.3
3	48	3	5	4.6	4.0
3	49	3	8	10.4	1.8
3	50	3	16	---	---
3	51	6	6	---	---
3	52	6	7	---	---
3	53	6	8	5.5	3.4
3	54	6	9	4.5	4.1
3	55	6	10	19.2	1.0
3	56	8	11	---	---
3	57	8	12	8.9	2.1
3	58	8	13	4.5	4.1
3	59	8	14	---	---
3	60	8	15	4.6	4.1
			Mean:	**4.3**	**9.9**
			Median:	**3.4**	**5.5**
			Mode:	**NA**	**NA**
			Range:	**28.1**	**25.2**
			Minimum:	**0.7**	**0.6**
			Maximum:	**28.8**	**25.8**



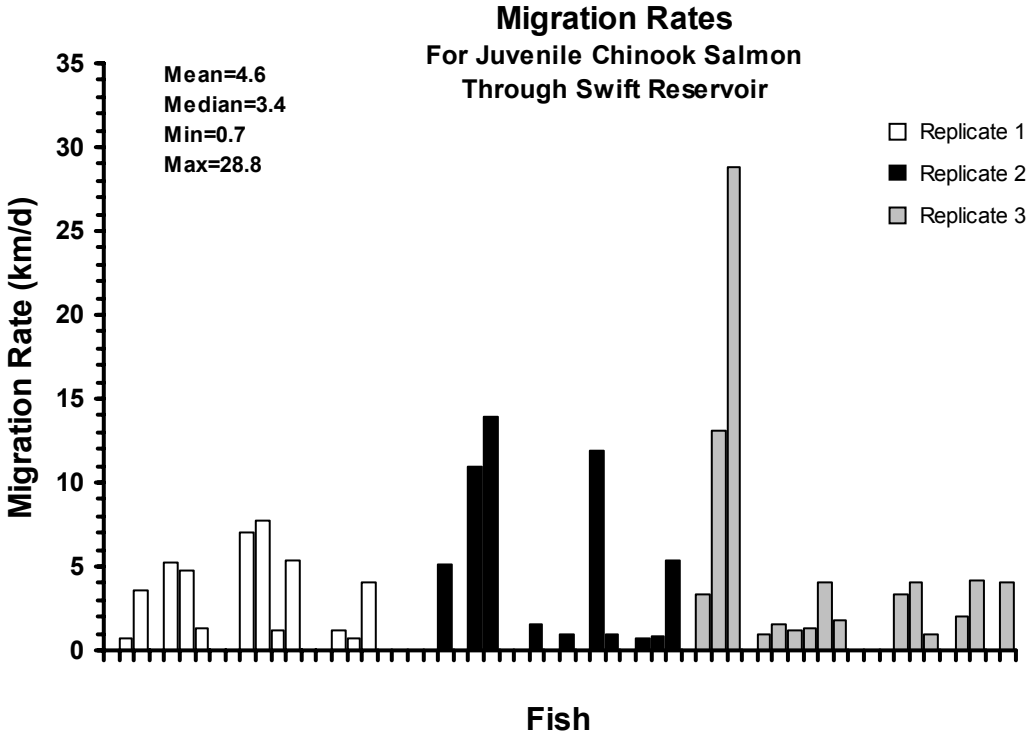


Figure 4.14B-7. Travel times and migration rates for juvenile Chinook salmon released at Eagle Cliff on the Lewis River to detection on the underwater antenna array at Swift No. 1.

4.14B.5.3 Arrival Distribution

Arrival distribution at Swift No. 1 Dam was compiled within 1.0-day intervals for fish detected at the underwater antenna system. Juvenile Chinook salmon had an extended period of arrival at the dam (1 to 26 days), although more than half (20/37) of all the fish that were detected at the project were observed within the first six days of release (Figure 4.14B-8). The greatest number of fish detected by time interval was for the periods of 4.0 to 5.0 days and 5.0 to 6.0 days after release (5 fish for both intervals).

The total number of days radio-tagged Chinook were detected near the project area was greater for the aerial system as compared to the underwater system (Figure 4.14B-9). Most Chinook were detected on each system less than nine days. The mean length of time radio-tagged Chinook were detected within the forebay was 5.7 and 3.9 days for the aerial and underwater systems, respectively (Table 4.14B-3). The maximum number of days Chinook were detected by each system was 24 days for the aerial system, and 16 days for the underwater system.

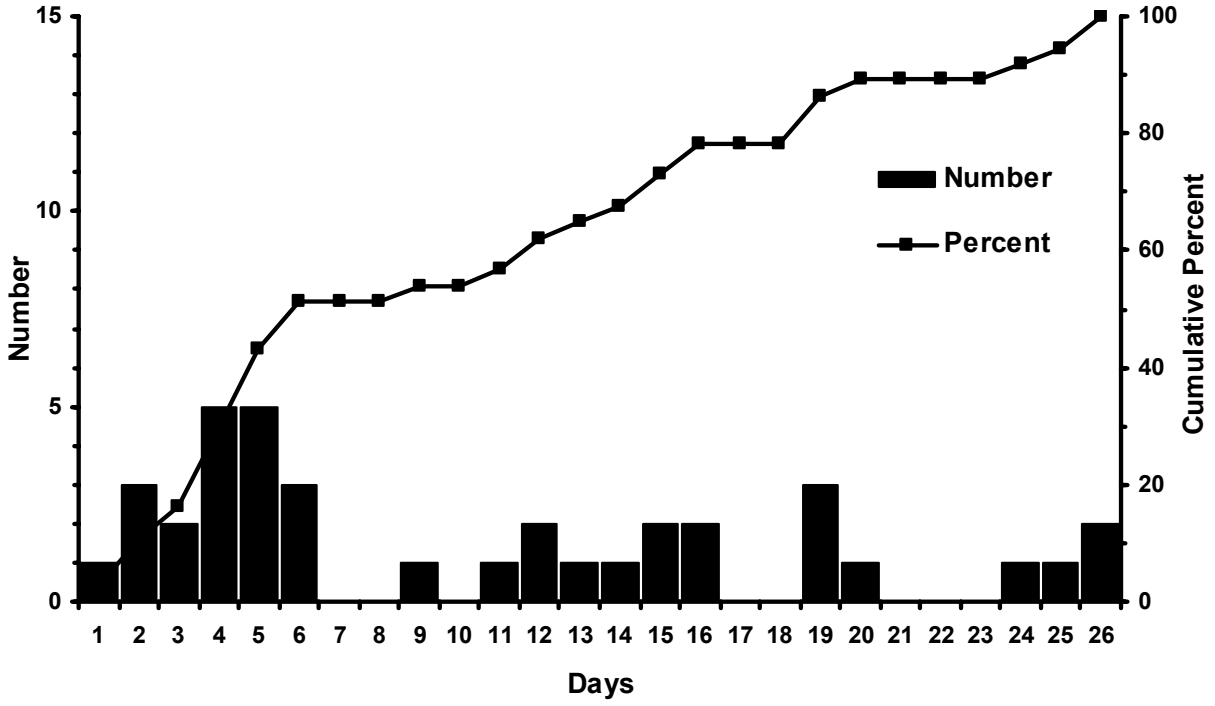


Figure 4.14B-8. Arrival distribution in numbers and cumulative percent for radio-tagged Chinook salmon detected on the underwater antenna system at Swift No. 1.

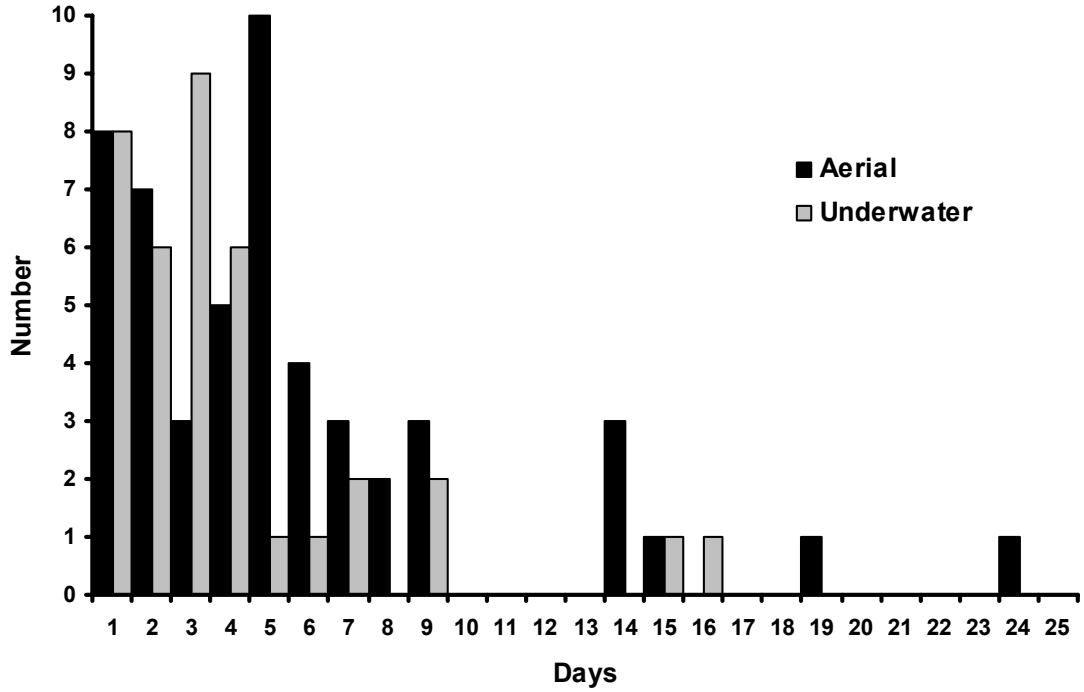


Figure 4.14B-9. Number of days radio-tagged Chinook salmon were detected by aerial and underwater systems at the forebay of Swift No.1.

Table 4.14B-3. Number of days radio-tagged Chinook salmon smolts were detected at the aerial or underwater system at Swift No. 1.

Replicate	Fish ID	Channel	Code	Number of Days Detected	
				Aerial	Underwater
1	1	1	6	1	---
1	2	1	7	5	2
1	3	1	8	1	1
1	4	1	9		---
1	5	1	10	2	1
1	6	3	11	15	9
1	7	3	12	3	2
1	8	3	13	2	---
1	9	3	14	4	---
1	10	3	15	1	1
1	11	6	1	1	1
1	12	6	2	6	4
1	13	6	3	1	1
1	14	6	4	2	---
1	15	6	5		---
1	16	8	2	5	2

Table 4.14B-3. Number of days radio-tagged Chinook salmon smolts were detected at the aerial or underwater system at Swift No. 1 (cont.).

Replicate	Fish ID	Channel	Code	Number of Days Detected	
				Aerial	Underwater
1	17	8	4	6	4
1	18	8	6	5	3
1	19	8	8	1	---
1	20	8	10	3	---
2	21	1	1	---	---
2	22	1	2	---	---
2	23	1	3	5	2
2	24	1	4	1	
2	25	1	14	6	3
2	26	3	6	2	2
2	27	3	7	1	---
2	28	3	9	---	---
2	29	3	10	5	1
2	30	6	11	2	---
2	31	6	12	8	3
2	32	6	13	4	---
2	33	6	14	2	2
2	34	6	15	7	1
2	35	8	1	---	---
2	36	8	3	4	3
2	37	8	5	5	3
2	38	8	7	3	3
3	39	8	9	---	---
3	40	1	11	9	6
3	41	1	12	6	4
3	42	1	13	5	3
3	43	1	15	---	---
3	44	3	1	14	7
3	45	3	2	9	5
3	46	3	3	14	9
3	47	3	4	14	7
3	48	3	5	7	4
3	49	3	8	4	4
3	50	3	16	4	---
3	51	6	6	5	---
3	52	6	7	9	---
3	53	6	8	5	3
3	54	6	9	19	16
3	55	6	10	7	3
3	56	8	11	2	---

Table 4.14B-3. Number of days radio-tagged Chinook salmon smolts were detected at the aerial or underwater system at Swift No. 1 (cont.).

Replicate	Fish ID	Channel	Code	Number of Days Detected	
				Aerial	Underwater
3	57	8	12	24	15
3	58	8	13	5	1
3	59	8	14	---	---
3	60	8	15	8	4
			Mean:	5.7	3.9
			Median:	5.0	3.0
			Mode:	5.0	3.0
			Range:	23.0	15.0
			Minimum:	1.0	1.0
			Maximum:	24.0	16.0

4.14B.5.4 Fish Movement Within the Reservoir

Mobile boat surveys were conducted to complement telemetry from fixed station receivers and to provide information on fish location and movement upstream from the forebay of Swift No. 1. During mobile boat surveys, 93.4 percent (57 of 60) of all fish released were detected at least once (Table 4.14B-4). The three fish that were not located by boat tracking were not detected at any other telemetry site during the course of the study.

During the 10 mobile surveys most of the detections for juvenile Chinook salmon occurred in Zone 3 (30.6%), Zone 5 (24.3%), and Zone 6 (19.8%) (Table 4.14B-5; AQU 14B Appendix 1). This observation comports well with the number of fish that migrated to zones 5 and 6 and returned to Zone 3. That is, about 38 percent (31 of 81) of the detections observed in Zone 3 were made after the fish were detected in either Zone 5 or 6. About a third (30%) of the fish exhibited this behavior. Two fish (#55 and #47) moved from Zone 5 back to Zone 3 at least twice (Table 4.14B-4). These observations indicate that many of the fish moved back upstream after they had migrated through the reservoir.

Most fish detections occurred in open water (62%) generally in Zones 3, 5 and 6 (Table 4.14B-6). The percent of fish detections that occurred along the north and south shorelines was 13 and 18 percent, respectively. Fish detections also occurred in Swift Forebay (6.3%) and Lewis River (0.4%). In general most fish were detected in deeper open water (i.e. 100 meters from the shoreline) or near the shoreline at the downstream end of the reservoir (AQU 14B Appendix 1).

Table 4.14B-4. Capture history matrix for radio-tagged Chinook salmon smolts observed during mobile surveys by zone of detection in Swift Reservoir.

				April					May					Total
Replicate	Fish ID	Channel	Code	16	18	23	25	30	2	6	8	10	13	Unique
1	1	1	6					2	5				4	1
1	2	1	7	2	3	3	4			4	5	6	6	1
1	3	1	8	2	3									1
1	4	1	9							2	3		3	1
1	5	1	10	4	6									1
1	6	3	11			5	4	5	6	5	2	3	6	1
1	7	3	12	2		2		6	4	4	3			1
1	8	3	13				4		3			3	3	1
1	9	3	14		3	3	5	3	2	3	3	4	4	1
1	10	3	15	3	6									1
1	11	6	1	3										1
1	12	6	2		3		3	6						1
1	13	6	3	2	5									1
1	14	6	4							4	4	4		1
1	15	6	5					4						1
1	16	8	2	3	2	3	5	6	5	3	3		3	1
1	17	8	4	2			5		5		6	6	6	1
1	18	8	6	3		5	5	3	2	2	3	2	1	1
1	19	8	8		3	3		5	5					1
1	20	8	10				5	4				5	6	1
2	21	1	1							2	2			1
2	22	1	2		3		6		3	2		3	2	1
2	23	1	3		2	4		3	3		3		5	1
2	24	1	4		3	3		3	3	2		5	5	1
2	25	1	14			3	6	6						1
2	26	3	6		5									1
2	27	3	7		3	3	4	3	3	3	3	3		1
2	28	3	9											---
2	29	3	10											---
2	30	6	11		3		3	5		4	3	6	3	1
2	31	6	12		3	3	6	1		3	4			1
2	32	6	13					4		3		5	3	1
2	33	6	14		3		3	3						1
2	34	6	15			4	6		4	6				1
2	35	8	1								2			1
2	36	8	3		2	2	5		3			3	5	1
2	37	8	5		3		5	3			3	4	5	1
2	38	8	7		3			5						1
2	39	8	9		3								3	1
3	40	1	11				5		4	5				1

Table 4.14B-4. Capture history matrix for radio-tagged Chinook salmon smolts observed during mobile surveys by zone of detection in Swift Reservoir (cont.).

				April					May					Total
Replicate	Fish ID	Channel	Code	16	18	23	25	30	2	6	8	10	13	Unique
3	41	1	12					5	5		5	5	5	1
3	42	1	13			3		5	6		5	5	5	1
3	43	1	15							1				1
3	44	3	1			5	6	5	4	5		6	6	1
3	45	3	2					6	5					1
3	46	3	3			4	6	5	6	5	6	6	6	1
3	47	3	4			5	3	3	5	5	6	3	6	1
3	48	3	5			6	3							1
3	49	3	8									3	6	1
3	50	3	16			5	6			5	5	5	5	1
3	51	6	6			5			6	4			6	1
3	52	6	7			6				5		5	6	1
3	53	6	8				5	6	1	3	2	3	3	1
3	54	6	9			6	5	6	3	6	6	6	5	1
3	55	6	10			4	5	5		3	5	3	3	1
3	56	8	11			5	5				2	1	2	1
3	57	8	12			6	6	6	3	6	5	6	6	1
3	58	8	13			5	4	2	1		1	1	1	1
3	59	8	14											---
3	60	8	15			6	6							1
Detections:				**10**	**21**	**28**	**31**	**30**	**27**	**28**	**27**	**29**	**33**	**57**
Fish at Liberty:				**20**	**39**	**57**	**57**	**57**	**57**	**56**	**55**	**55**	**55**	**60**
Percent Detected:				**50**	**57**	**49**	**54**	**53**	**47**	**50**	**49**	**53**	**60**	**93.4**

Table 4.14B-5. Number of radio-tagged Chinook salmon smolts detected by zone for each mobile survey and percent of fish detected in each zone.

	April					May						
Zone	16	18	23	25	30	2	6	8	10	13	Total	Percent
1	0	0	0	0	1	2	1	1	2	2	9	3.4
2	5	3	2	0	2	2	5	5	1	2	27	10.1
3	4	14	9	6	8	8	7	9	9	8	82	30.6
4	1	0	4	5	3	7	5	2	3	2	32	11.9
5	0	2	8	12	9	6	7	6	7	8	65	24.3
6	0	2	5	9	8	4	3	4	7	11	53	19.8
Total:	**10**	**21**	**28**	**32**	**31**	**29**	**28**	**27**	**29**	**33**	**268**	**100**

Table 4.14B-6. Detection summary by location and zone for radio-tagged coho smolts observed during boat tracking surveys on Swift Reservoir.

	Location					Zone						
Survey	North Shore	South Shore	Swift Forebay	Open Water	Lewis River	1	2	3	4	5	6	Total
1	2	1	0	7	0	0	5	4	1	0	0	10
2	3	4	0	14	0	0	3	14	0	2	2	21
3	3	3	0	22	0	0	2	9	4	8	5	28
4	2	4	0	26	0	0	0	6	5	12	9	32
5	2	3	6	20	0	1	2	8	3	9	8	31
6	3	8	0	18	0	2	2	8	7	6	4	29
7	7	4	2	14	1	1	5	7	5	7	3	28
8	3	6	3	15	0	1	5	9	2	6	4	27
9	4	6	3	16	0	2	1	9	3	7	7	29
10	6	9	3	15	0	2	2	8	2	8	11	33
Total:	**35**	**48**	**17**	**167**	**1**	**9**	**27**	**82**	**32**	**65**	**53**	**268**
Percent:	**13.1**	**17.9**	**6.3**	**62.3**	**0.4**	**3.4**	**10.1**	**30.6**	**11.9**	**24.3**	**19.8**	**100.0**

4.14B.5.5 Reservoir Survival

The minimum survival rate for radio-tagged Chinook salmon smolts that migrated through Swift Reservoir was 85.0 percent (51 of 60 fish) (Table 4.14B-7). This estimate was based on unique channel code detections by the aerial system at the dam. We relied on the aerial system detections to calculate the minimum survival estimate since it had the highest detection rate near the project. Furthermore, since all of the fish that were detected by the underwater system were also detected by the aerial array, there was no need to include the underwater system to establish successful passage through the reservoir

The minimum survival estimate does not take into account delayed mortality associated with fish handling, nor does it account for live fish that successfully traverse the reservoir but were not detected due to tag loss or failure. Moreover, if detection efficiencies of the telemetry system are less than 100 percent the estimate will be biased low. Finally, this estimate also does not include fish that were alive, but did not migrate completely through the reservoir and arrive at the dam.

Seven of the nine radio-tagged Chinook that were not detected by the aerial system were detected during boat surveys. The remaining two were never detected during the study period. One of the seven radio-tagged fish migrated to zone 6 but was not detected by the aerial or underwater systems at the dam. It is likely that some of the remaining fish would migrate to the project, but the operational life span of the radio tag is approximately 29 days.

4.14B.5.6 Behavior Near Intake

We used three indices to describe behavior of the 37 radio-tagged fish that were detected at the intake structure of the dam. We combined different sets of antennas to form antenna arrays to discern patterns in vertical or horizontal distribution of fish as they first approached and moved around the intake structure. We combined the south, middle and north antennas for both the top and bottom arrays to describe vertical distribution. To evaluate horizontal distribution, we combined the top and bottom antennas for each of the south, middle and north arrays. First, we looked at the antenna array where fish were initially detected as they approached the intake structure. This index defined the location where fish encountered the intake structure during their downstream migration through the reservoir. Second, we compiled the number of repeat detections at each antenna when radio-tagged fish approached the intake structure on subsequent visits. Here we separated repeat detections by a minimum of two hours from other previous detections. This index helped explain behavior as fish made repeat attempts to migrate downstream. Finally, we used the total number of detections recorded at each antenna to evaluate where fish spend most of their time near the intake structure.

For vertical distribution, we found that 97.3 percent of radio-tagged Chinook were first detected by the top antenna array (Table 4.14B-7; Figure 4.14B-10). Likewise, 95.8 percent of radio-tagged fish made repeat excursions to the top array near the intake structure (Table 4.14B-7, Figure 4.14B-10). The average number of visits to the intake structure was 5.0 visits (sum of first detections plus total for repeat detections divided by 37 fish). Finally, residence time, indicated by total number of detections, was 95.8 percent for the top array (Table 4.14B-7; Figure 4.14B-10).

Definite horizontal patterns were also exhibited at the time of first and repeat detections at the intake structure. A total of 43.3 percent of the fish were first detected by the middle array. For repeat visits, we found that 43.2 percent were detected in the north array on subsequent approaches (Table 4-14B-7; Figure 4.14B-11) and that the total number of detections was also greatest for the north array at 41.0 percent (Table 4.14B-7; Figure 4.14B-11). This indicates that radio-tagged fish, while near the intake structure, spent the greatest time on the north side.

Collectively, the results demonstrate that radio-tagged Chinook salmon smolts on their first and repeat encounters approached the intake structure in the upper 13.8 meters of the water column typically in the middle of the intake structure. However, most radio-tagged Chinook resided on the north side of the intake, indicating movement in a northerly direction after initial contact with the intake structure.

Table 4.14B-7. Number and percent of detections for first, repeat and total detections of radio-tagged Chinook salmon by antenna array on the underwater antenna system at Swift No. 1.

Array	First Detection				Repeat Detections				Total Detections			
	North	Middle	South	Total	North	Middle	South	Total	North	Middle	South	Total
Top	10	16	10	36	44	62	36	142	39,262	28,937	23,662	91,861
Bottom	1	0	0	1	2	2	2	6	1,804	735	1,482	4,021
Total	**11**	**16**	**10**	**37**	**46**	**64**	**38**	**148**	**41,066**	**29,672**	**25,144**	**95,882**
Top	27.0%	43.3%	27.0%	97.3%	29.7%	41.9%	24.3%	95.9%	41.0%	30.2%	24.6%	95.8%
Bottom	2.7%	0.0%	0.0%	2.7%	1.4%	1.4%	1.4%	4.1%	1.8%	0.8%	1.6%	4.2%
Total	**29.7%**	**43.3%**	**27.0%**	**100%**	**31.1%**	**43.2%**	**25.7%**	**100%**	**42.8**	**31.0**	**26.2**	**100%**

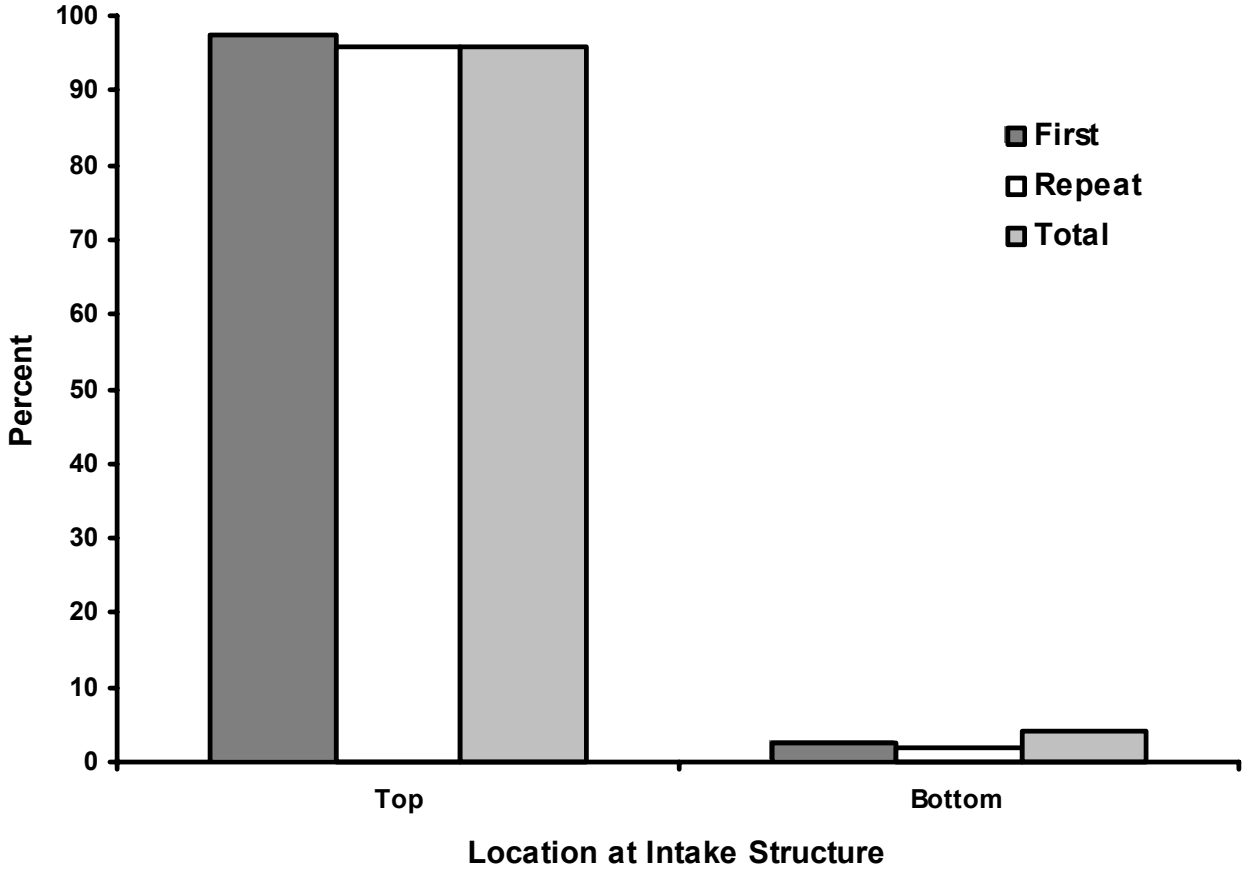


Figure 4.14B-10. Percent of radio-tagged Chinook detections recorded for first, repeat and total detections on the top and bottom antenna arrays of the intake structure of Swift No. 1 Dam.

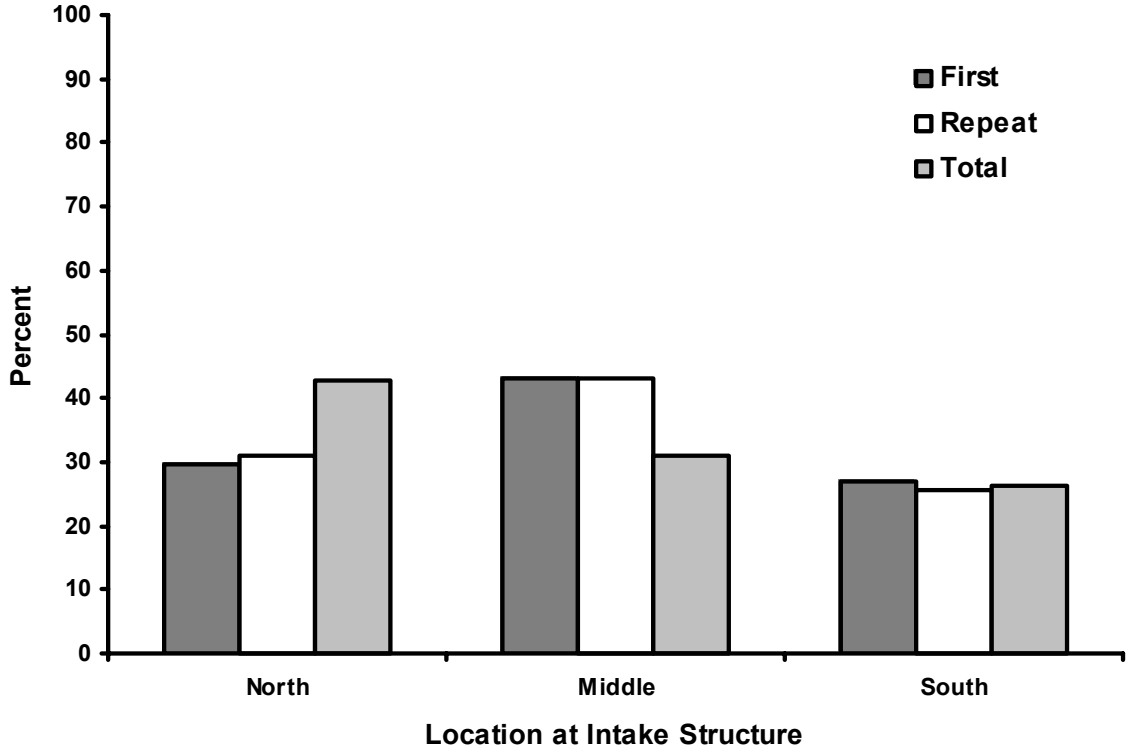


Figure 4.14B-11. Percent of radio-tagged Chinook detections recorded for first, repeat and total detections at the north, middle and south sides of the intake structure of Swift No. 1 Dam.

4.14B.5.7 Detection Rates

In order to confirm our application of the telemetry data for analysis of behavior and survival of radio-tagged fish, we compared detections by fixed station receivers within the forebay of Swift No. 1, and boat tracking surveys conducted in Zone 6 of Swift Reservoir. Collectively, a total of 52 radio-tagged Chinook were detected within zone 6 by one or more telemetry systems and methods. Of those 52 fish, 51 (98.1%) were detected near the forebay of the dam. The single fish that entered zone 6 that was not detected by the aerial system was detected during a boat survey. This fish was detected a considerable distance outside of the forebay, and therefore, was not considered as surviving to the dam.

Of the 51 fish detected near the forebay of the dam, all (100%) were detected by the aerial array, 37 (72.6%) by the underwater system at the face of the dam, and 26 (51.0%) during boat surveys. However, boat surveys in zone 6 identified six fish that were not detected by the underwater antenna system and one fish not detected by the aerial system (Table 4.14B-7). The five fish that were detected within the Swift Canal were also detected by the forebay aerial and underwater systems. The difference observed in detection rates for fixed station sites and mobile surveys were not unexpected considering

that the aerial antennas had a much larger detection zone and operated continuously during the study period.

The comparison of underwater and aerial detection rates demonstrates that the underwater system had too limited of a detection field to assess survival to the project. Clearly, some of the fish that were not detected on the underwater system survived migration through the reservoir. Instead, the underwater system is ideal for assessing travel time, arrival distribution, and behavior near the intake structure. Conversely, the aerial system is not the best system to assess travel time and arrival distribution since it is capable of detecting fish at a considerable distance, where fish could be milling prior to reaching the intake structure.

Mobile surveys were never intended to assess survival, travel time or arrival distribution; instead, the purpose of the mobile surveys was to assess migratory behavior in the reservoir. If fish were detected by mobile surveys near the project that were not detected by the aerial system, then it would be appropriate to classify these fish as having survived, and arrived at the dam. However, this was not observed during the study period, or during the 2001 study (Miller et al. 2001).

Table 4.14B-8. Detections by channel and code at fixed telemetry sites in the forebay and tailrace and within Zone 6 by mobile surveys ("1" denotes presence).

Replicate	Fish ID	Channel	Code	Forebay		Both[2]	Either[3]	Zone 6[4]	Tailrace
				Aerial[1]	Underwater[1]				Aerial
1	1	1	6	1	---	---	1	---	---
1	2	1	7	1	1	1	1	1	---
1	3	1	8	1	1	1	1	---	---
1	4	1	9	---	---	---	---	---	---
1	5	1	10	1	1	1	1	1	---
1	6	3	11	1	1	1	1	1	---
1	7	3	12	1	1	1	1	1	---
1	8	3	13	1	---	---	1	---	---
1	9	3	14	1	---	---	1	---	---
1	10	3	15	1	1	1	1	1	---
1	11	6	1	1	1	1	1	---	1
1	12	6	2	1	1	1	1	1	---
1	13	6	3	1	1	1	1	---	1
1	14	6	4	1	---	---	1	---	---
1	15	6	5	---	---	---	---	---	---
1	16	8	2	1	1	1	1	1	---
1	17	8	4	1	1	1	1	1	---
1	18	8	6	1	1	1	1	---	---
1	19	8	8	1	---	---	1	---	---
1	20	8	10	1	---	---	1	1	---
2	21	1	1	---	---	---	---	---	---
2	22	1	2	---	---	---	---	1	---
2	23	1	3	1	1	1	1	---	---
2	24	1	4	1	1	1	1	---	---
2	25	1	14	1	1	1	1	1	---
2	26	3	6	1	1	1	1	---	1

Table 4.14B-8. Detections by channel and code at fixed telemetry sites in the forebay and tailrace and within Zone 6 by mobile surveys ("1" denotes presence) (cont.).

Replicate	Fish ID	Channel	Code	Forebay		Both[2]	Either[3]	Zone 6[4]	Tailrace
				Aerial[1]	Underwater[1]				Aerial
2	27	3	7	1	---	---	1	---	---
2	28	3	9	---	---	---	---	---	---
2	29	3	10	1	1	1	1	---	---
2	30	6	11	1	---	---	1	1	---
2	31	6	12	1	1	1	1	1	---
2	32	6	13	1	---	---	1	---	---
2	33	6	14	1	1	1	1	---	---
2	34	6	15	1	1	1	1	1	---
2	35	8	1	---	---	---	---	---	---
2	36	8	3	1	1	1	1	---	---
2	37	8	5	1	1	1	1	---	---
2	38	8	7	1	1	1	1	---	1
2	39	8	9	---	---	---	---	---	---
3	40	1	11	1	1	1	1	---	1
3	41	1	12	1	1	1	1	---	---
3	42	1	13	1	1	1	1	---	---
3	43	1	15	---	---	---	---	---	---
3	44	3	1	1	1	1	1	1	---
3	45	3	2	1	1	1	1	1	---
3	46	3	3	1	1	1	1	1	---
3	47	3	4	1	1	1	1	1	---
3	48	3	5	1	1	1	1	1	---
3	49	3	8	1	1	1	1	1	---
3	50	3	16	1	---	---	1	1	---
3	51	6	6	1	---	---	1	1	---
3	52	6	7	1	---	---	1	1	---
3	53	6	8	1	1	1	1	1	---
3	54	6	9	1	1	1	1	1	---
3	55	6	10	1	1	1	1	---	---
3	56	8	11	1	---	---	1	---	---
3	57	8	12	1	1	1	1	1	---
3	58	8	13	1	1	1	1	---	---
3	59	8	14	---	---	---	---	---	---
3	60	8	15	1	1	1	1	1	---
			Total:	**51**	**37**	**37**	**51**	**27**	**5**
			Minimum Survival Estimate:	**85**					

1. Represents a unique detection for a given fish at this site.
2. Represents a detection for a given fish at both the forebay aerial and underwater sites.
3. Represents a detection for a given fish at either the forebay aerial or underwater sites.
4. Represents a unique detection for a given radio-tagged fish in Zone 6 with biweekly boat surveys.

4.14B.5.8 Fish Passage At Swift No. 1 Dam

During the course of the study, five radio-tagged fish were detected downstream from Swift No. 1 Dam within the Swift Canal by either the tailrace telemetry system or during mobile surveys. This equates to 13.5 percent (5 of 37) fish passage for fish detected at the intake structure by the underwater system and about 9.8 percent (5 of 51) of the fish detected near the project by the aerial system. The estimates of fish passage should be considered a minimum. The detection rate cannot be calculated for the tailrace system because there have been no destruction tests for this type of radio tag at the pressures encountered in the penstock (11 atm).

4.14B.6 Discussion

4.14B.6.1 Migration Behavior

The migration behavior of Chinook from this study and coho from the previous year indicate that the fish had a relatively short travel time and successfully migrated through the reservoir to the forebay of Swift No. 1. In general, radio-tagged Chinook migrated through the reservoir slower than coho and required more time to reach the project. The migration rate for Chinook was 3.4 km/d compared to 5.2km/d for coho (Table 4.14B-9). Consequently, the travel time to the project was greater for Chinook (5.5 days) than coho (3.6 days). Both Chinook and coho arrived at the project over a similar time span with about half of the radio-tagged coho and Chinook detected at the project within 4 and 6 days of release, respectively (Table 4.14B-9). Although Chinook exhibited a more protracted migration period, survival to the project was fairly high for both Chinook (85.0%) and coho (90.0%).

Table 4.14B-9. Migration behavior of radio-tagged Chinook and coho released into Swift Reservoir in 2001 and 2002, respectively.

	Migration Rate (km/d)			Travel Time (days)			Arrival Distribution (days)			Minimum Survival
Species	Median	Min	Max	Median	Min	Max	50%	Min	Max	Percent
Chinook	3.4	0.7	28.8	5.5	0.6	25.8	6	1	26	85.0 (51 of 60)
Coho	5.2	0.8	19.1	3.6	1.0	22.6	4	1	23	90.0 (54 of 60)

4.14B.6.2 Behavior Near the Project

The behavior of radio-tagged fish near the project indicates that both Chinook and coho would be susceptible to a surface-oriented collection device. The vertical distribution at the intake structure showed a consistently high detection (88%-97%) of Chinook and coho at the surface which clearly indicates that they are available for collection (Table 4.14B-10). The horizontal distribution for Chinook and coho was not as consistent but does suggest that they concentrate and move across the face of the intake structure. Despite the lack of a clear horizontal pattern, the amount of time Chinook (3.9 days) and

coho (5.8 days) spend near the intake structure suggest that multiple capture opportunities exist.

Table 4.14B-10. Behavior observed for radio-tagged Chinook and coho in the forebay of Swift No. 1 in 2001 and 2002, respectively.

Species	Behavior Near Intake			Days Present						Fish Passage
				Forebay (aerial)			Intake (underwater)			
	First	Repeat	Total	Mean	Min	Max	Mean	Min	Max	Percent
Chinook	**Vertical Distribution**			5.7	1.0	24.0	3.9	1.0	16.0	9.8% (5 of 51)
	Top (97.3%)	Top (95.9%)	Top (95.8%)							
	Horizontal Distribution									
	Middle (43.3%)	Middle (43.2%)	North (42.8%)							
Coho	**Vertical Distribution**			9.9	1.0	24.0	5.8	1.0	16.0	0% (0 of 54)
	Top (95.8%)	Top (92.7%)	Top (88.2%)							
	Horizontal Distribution									
	North (52.1%)	North (47.5%)	South (47.5%)							

The combined migration behavior of Chinook and coho suggest that they survive migration to the project at fairly high rates. Furthermore, their collective behaviors suggest that they tend to congregate at the project near the intake tower and may be there for several days. That behavior allows for multiple capture opportunities in a relatively concentrated area that would warrant deployment and testing of a prototype fish collection system. Although there were some subtle differences observed for Chinook and coho near the intake structure, those differences could diminish with the addition of attraction flow and/or guide wall(s) near the project. Results from a recent acoustic tag study (Miller et al. 2002) confirm that Chinook and coho concentrate near the project and respond to attraction flow. Fish passage in that study also showed that more Chinook passed the project than coho when attraction flow was provided.

4.14B.7 Schedule

Study objectives for assessment of migratory behavior of Chinook salmon in Swift Reservoir are complete. In part, this study as well as others have established that the migration behavior of both Chinook and coho warrant consideration of a smolt collection device located in the forebay of Swift No. 1 Dam. Currently, different types of fish passage opportunities are under evaluation for Swift Dam and will be instrumental in developing an effective smolt collection system.

4.14B.8 References

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