PRELIMINARY PROPOSAL FOR FY 2005 FUNDING

Title: Migrational Characteristics of Yearling Chinook Salmon, Sub-Yearling Chinook Salmon, and Juvenile Steelhead in the Forebay of Lower Granite Dam Relative to Removable Spillway Weir and Behavioral Guidance Structure Tests, 2005.

Study Codes: SBE-W-05-2

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PROJECT SUMMARY

INTRODUCTION

This proposal presents four objectives designed to meet research needs proposed for 2005. At this time, it is uncertain if regional priority will support conducting research activities under all the objectives. Specifically, these four objectives are: 1) to evaluate the performance of the removable spillway weir (RSW) and behavioral guidance structure (BGS) to aid the passage of yearling Chinook salmon and juvenile steelhead during the spring out-migration, 2) to estimate the survival of yearling Chinook salmon passing through the RSW and other passage routes at Lower Granite Dam, 3) to evaluate the performance of the RSW and BGS to aid the passage of subyearling Chinook salmon during the summer out-migration, and 4) estimate the survival of subyearling Chinook salmon passing through the RSW and other passage routes at Lower Granite Dam. Although radio-tagged subyearling Chinook salmon were released during the 1997 and 1998 evaluations of surface bypass concepts at Lower Granite Dam, the RSW performance and survival for subyearling Chinook salmon has not been evaluated. Furthermore, the newly modified BGS at Lower Granite Dam has not been evaluated using radio telemetry.

RESEARCH GOALS

The goal of our study is to identify the movements of individual juvenile salmonids, describe smolt distribution, and measure key physical variables in the forebay of Lower Granite Reservoir concurrent with the removable spillway weir tests. The study is designed to obtain the following information:

- The timing and route of passage for yearling and subyearling Chinook salmon and juvenile steelhead at Lower Granite Dam relative to spill, powerhouse, and removable spillway weir (RSW) operations and the position of the BGS.

- The effects of dam operations on smolt distribution and movement in the forebay of Lower Granite Dam.

- Determine the relative survival of fish with known passage routes through Lower Granite Dam.

STUDY OBJECTIVES

We propose to study the migration and passage of yearling Chinook salmon, subyearling Chinook salmon, and juvenile steelhead in the forebay of Lower Granite Dam relative to the 2005 removable spillway weir and behavioral guidance structure tests. Specifically, we wish to determine approach paths and routes of passage of juvenile fish at Lower Granite Dam relative to spill, powerhouse, RSW, and BGS operations. Research activities will be grouped under four objectives.

Objective 1: Determine the timing and route of passage for yearling chinook salmon and juvenile steelhead at Lower Granite Dam relative to spill, powerhouse, removable spillway weir, and behavioral guidance structure operations.

Objective 2: Determine the relative survival of yearling Chinook salmon with known passage routes through Lower Granite Dam.

Objective 3: Determine the timing and route of passage for subyearling Chinook salmon at Lower Granite Dam relative to spill, powerhouse, removable spillway weir, and behavioral guidance structure operations.

Objective 4: Determine the relative survival of subyearling Chinook salmon with known passage routes through Lower Granite Dam.

Note: These study objectives meet the research needs identified in SBE-W-96-1 objective 5, 6, and 7

METHODOLOGY

For all objectives, we propose to use radio telemetry techniques to obtain both survival and behavioral information for juvenile salmonids migrating past Lower Granite Dam. Because radio-tagged fish are usually detected at high rates (>80% detection probability), radio telemetry techniques are well suited to estimate survival rates with small sample sizes and desired precision of survival estimates. We will use the route-specific survival model (PRRM) developed by Skalski et al. (2001) to estimate passage and survival probabilities for the turbines, spillway, and juvenile bypass system. In addition, using the PRRM, we will estimate the overall survival probability of dam passage and survival from release to the dam.

To provide passage and survival information at Little Goose Dam, we propose to release between 1,500 and 2,000 radio-tagged. If survival estimates are not required, then radio-tagged fish can be used to obtain just passage information. We will release yearling Chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead (*Oncorhynchus mykiss*), and subyearling Chinook salmon (*Oncorhynchus tshawytscha*) to quantify their migration behavior and estimate survival rates. For most passage routes, analysis suggests that this sample size will yield survival probabilities with precision of ±0.03-0.04 (±95% confidence interval) for spring migrants and ±0.03-0.05 for summer migrants.

RELEVANCE TO THE BIOLOGICAL OPINION

The relevance of this research to the operation of the Federal Columbia River Power System and Juvenile Transportation Program is discussed in the draft Biological Opinion, July 27, 2000, 9.6.1.4.2, page 9-69.

PROJECT DESCRIPTION

BACKGROUND AND JUSTIFICATION

Reservoir drawdown, flow augmentation, and spill have been identified as potential means of improving the survival of migratory salmon smolts, thereby assisting the recovery of threatened and endangered salmon stocks. The U.S. Army Corps of Engineers (COE) has worked with regional, state, and federal resource agencies to design and implement tests to determine whether various combinations of reservoir drawdown, flow augmentation, spill, and surface bypass would provide significant biological benefits to out-migrating smolts.

During 1995, the COE directed the effort away from drawdown related issues towards studies designed to determine if surface collection techniques could increase fish guidance efficiency at the dams and thereby contribute to the recovery of threatened and endangered salmon stocks. Development of surface collection systems is based on observations which indicate that fish will readily pass obstructions to their downstream movement if they are able to discover an adequate flow net. Smith (1974) found that combined catches at shallow and deep sites in Lower Monumental Reservoir indicated 58% of the juvenile Chinook salmon and 36% of the steelhead were traveling in the upper 12 ft of the reservoir. Based on the distribution of fish and the various passage structures that have been tested, many researchers have concluded that flow nets near the surface may be more effective for passing juvenile salmonids.

Perhaps the most successful example of surface bypass is at Wells Dam. The hydrocombine design of the dam is such that the spill bays are located above the turbine intakes. Hydroacoustic studies of juvenile salmon passage indicated an average of 7% of total discharge passed over 90% of the fish (Johnson et al. 1992). At Rock Island Dam, another Mid-Columbia River dam, shallow spill bays resulted in 20% spill level passing 30% of the fish (Steig and Ransom 1991). In a review of surface spill and deep spill, Ransom and Steig (1995) estimated sluiceways typically produced a 13:1 ratio of percent total fish-to-percent total river flow passed. In contrast, the deep flow of conventional spillways passed fish at about a 1:1 ratio of fish to flow.

Recent research at The Dalles and Ice Harbor dams offers further evidence that flow nets near the surface may be more effective at passing juvenile salmonids. The ice-trash sluiceway at The Dalles Dam may pass about 40% of the juvenile salmonids during no spill conditions with smolts passing throughout most of the 24 h period (Willis 1982; Giorgi and Stevenson 1995). Swan et al. (1995) found that 53% of radio-tagged juvenile chinook salmon passed by the sluiceway at Ice Harbor Dam during spring flow conditions with considerable spill at the Dam. In pursuit of the potential benefits that surface collection and spill may have on smolt survival, the COE allocated considerable resources during 1996 towards the construction, implementation, and analysis of a surface collector prototype at Lower Granite Dam. Additional resources were allocated in 1997 and 1998 towards modification to the surface collector prototype and its analysis. In 1998, the behavioral guidance structure (BGS) was added to the forebay to divert fish away from the south half of the powerhouse to the surface bypass prototype to improve passage into the structure. Also in 1998, the simulated Wells intake (SWI) was retrofitted to back side of the surface bypass prototype to lessen the downward flow into the turbine intake in front of the surface bypass prototype. Monitoring of the BGS and SWI was incorporated into the 1998 study design. In 2002 and 2003, the COE conducted further tests of the surface collection concept by constructing a removable spillway weir at spill bay 1 at Lower Granite Dam. Inasmuch as we have used hydroacoustics and radio-telemetry in Lower Granite Reservoir since 1994, and we have successfully applied our expertise during the 1996-2003 evaluations of the surface flow bypass concepts, we propose to continue the evaluation of the RSW during the proposed 2005 tests at Lower Granite Dam.

PROJECT OVERVIEW

Hydroacoustics and biotelemetry were used concurrently at Lower Granite Dam to evaluate fish distribution and behavior relative to surface bypass collector tests during 1996-1998. Three-dimensional sonic tags and biotelemetry were used during spring 2000 surface bypass collector tests and again during the first year of the RSW evaluation in 2002. Although very useful information has been obtained from all these technologies, all have unique strengths and weaknesses. Hydroacoustic fish stock assessment is an effective means of obtaining information on numerous fish, but information about individual fish is difficult to extrapolate. Three-dimensional sonic tag technology provides three-dimensional fish tracks for individual fish, but is limited by the number of tagged fish simultaneously present in the array. Biotelemetry is an effective means of obtaining individual fish movement information, however, sample size can be restricted by costs of tags. In response to the limitation of sample size associated with biotelemetry, we propose to utilize recent advancements in biotelemetry receiving equipment to enable the release of more radio-tagged fish. During the 2000 SBC evaluation we successfully used a new data acquisition system (Multiprotocol Integrated Telemetry Acquisition System; MITAS) to collect more complete data on fish. The combination of a larger sample size and the MITAS system has enhanced our ability to determine the approach paths and routes of passage at Lower Granite Dam relative to spill conditions, powerhouse operations, surface collection concepts, and deployment of guidance/occlusion structures. We feel a larger sample size of radio-tagged fish will enable a more robust evaluation of the RSW collection concept during the summer of 2005.

CURRENT STATUS

We have conducted research at Lower Granite Dam since 1994. Detailed results from these tests can be found in the annual reports to the U.S. Army Corps of Engineers. A brief summary of pertinent information is provided below.

There is a limited amount of information on subyearling Chinook salmon relative to surface bypass tests at Lower Granite Dam. We tagged and release 199 subyearling Chinook salmon in 1997 and 295 in 1998. These data allowed us to examine the movement and passage of subyearling Chinook salmon relative to the Surface Bypass Collector (SBC) tests. Results of these tests indicated that the SBC did pass juvenile salmon, but was not effective enough to be a stand-alone-bypass alternative at Lower Granite Dam. In 2002 the COE installed and tested a Removable Spillway Weir in Spillbay 1.

During spring 2002, we tagged and released 789 yearling Chinook salmon, 390 hatchery steelhead, and 389 wild steelhead. Subyearling Chinook salmon were not included in the 2002 test. Preliminary results showed, of the fish released, we determined a route of passage for 84% (665 of 789) of yearling Chinook salmon, 94% (368 of 390; SE ± 1.2) of hatchery steelhead, and 95% (370 of 389) of wild steelhead. Of the fish we determined passage routes for, 38% (251 of 665; SE ± 1.7) of yearling Chinook salmon, 44% (162 of 368; SE ± 2.5) of hatchery steelhead, and 42% (157 of 370; SE ± 2.5) of wild steelhead passed through the RSW. Passage through the spillway was 35% (234 of 665; SE ± 1.7) for yearling Chinook salmon, 27% (99 of 368; SE ± 2.3) for hatchery steelhead, and 27% (99 of 370; SE ± 2.3) for wild steelhead. Guided turbine passage was 19% (124 of 665; SE ± 1.4) for yearling Chinook salmon, 26% (95 of 368; SE ± 2.2) for hatchery steelhead, and 23% (86 of 370; SE ± 2.1) for wild steelhead. Unguided turbine passage was 8% (56 of 665; SE ± 1.0) for yearling Chinook salmon, 3% (12 of 368; SE ± 0.9) for hatchery steelhead, and 8% (16 of 370; SE ± 1.3) for wild steelhead

We found that passage into the RSW was largely dependent on the time of day. For example, 45% (178 of 398; SE ± 2.5) of the yearling Chinook salmon, 60% (137 of 228; SE ± 3.3) of hatchery steelhead, and 56% (127 of 228; SE ± 3.3) of wild steelhead passed into the RSW during the day (from 0500 to 1959 hours). Plots of percent passage by hour of passage indicated that of all fish that passed the dam the RSW passed 58% of yearling Chinook salmon, 68% of hatchery steelhead, and 64% of wild steelhead between 1300 and 1600 hours. However, passage into the RSW during the night (from 2000 to 0459 hours) was just 27% (72 of 267; SE ± 2.7) for yearling Chinook salmon, 18% (25 of 140; SE ± 3.2) for hatchery steelhead, and 21% (30 of 142; SE ± 3.4) for wild steelhead. Over the 24 h period, we found that percent passage into the RSW was inversely related to percent passage through spill. For instance, during the day, 29% (115 of 398; SE ± 2.3) of yearling Chinook salmon, 13% (29 of 228; SE ± 2.2) of hatchery steelhead, and 15% (35 of 228; SE ± 2.4) of wild steelhead passed through spill. During the night, about one half of fish that passed the dam passed through spill. Furthermore, the percentages of fish that passed through guided and unguided turbine routes changed little over time, indicating that passage into the turbines had little affect on RSW and spill passage throughout the 24 h period.

Tests of RSW performance continued during the spring out-migration in 2003. Again, subyearling Chinook salmon were not included in the 2003 test. Results from the 2003 evaluation indicated that the RSW performed similarly as in 2002. Depending on species or rearing type, the RSW passed 58-69% of fish and BiOP spill passed 52-59% of fish, indicating that the RSW passed similar or higher percentages of fish as the currently employed management strategy. In 2003, the survival of yearling Chinook salmon was estimated to be 0.980 ± 0.023 through the RSW and 0.931 ± 0.060 through BiOP spill. Our estimates of survival for yearling Chinook salmon passing through the RSW was observed to be higher than the survival of yearling Chinook salmon passing through BiOP spill, however, this difference was not found to be statistically significant. Thus, the 2003 survival estimates suggest there is comparable survival between the RSW and BiOP spill. Although survival was estimated for yearling Chinook salmon in 2003, the survival of subyearling Chinook salmon and juvenile steelhead have never been measured with radio telemetry at Lower Granite Dam.

OBJECTIVES AND METHODOLOGY

Objective 1: Determine the timing and route of passage for juvenile yearling Chinook salmon and juvenile steelhead at Lower Granite Dam relative to spill, powerhouse, removable spillway weir, and behavioral guidance structure operations.

Note: This study objective meets the research needs identified in SBE-W-96-1 objective 6.

Rationale

Under this objective we will use radio-telemetry to examine the movements and passage routes of yearling Chinook salmon and juvenile steelhead in the forebay of Lower Granite Dam relative to RSW operations. In 2004, the COE modified the BGS that was added to the forebay of Lower Granite Dam in 1998. These modifications were intended to enhance the BGS's ability to divert fish away from the powerhouse towards the RSW. To date, the newly modified BGS has not been evaluated. Furthermore, research during 2002 and 2003 indicated that the amount of training spill during RSW operation affects both the efficiency and effectiveness of the RSW. The research we propose under this objective may be directed to evaluate either the newly modified BGS or two levels of training spill (i.e., two treatments). Likewise, the sample sizes we propose should be increased if resource managers wish to test both the modified BGS and different levels of training spill concurrently. This proposal is currently written to test two treatments, not four treatments.

We propose to release radio-tagged yearling Chinook salmon and juvenile steelhead in Lower Granite Reservoir and monitor the timing and route of passage through Lower Granite Dam during various spill, powerhouse, and removable spillway weir operations. At this time, no specific study design has been proposed for this evaluation. In previous years, the performance of the RSW was evaluated using a study design consisting of two-day treatments (RSW on with no BGS and RSW on with the BGS) randomized over a 4-day period. The 4-day blocks served as replicates over the length of the study period. The study period was typically 40-50 days long. Until further discussion occurs, we have developed this proposal under the assumption that a similar study design will be used to evaluate the RSW in 2005. During these study blocks we propose to release 1,000 radio-tagged yearling Chinook salmon and 1,000 juvenile steelhead (i.e., 500 hatchery and 500 wild steelhead), above Lower Granite Dam at Blyton Landing.

Since 1996, we have used coded radio transmitters supplied by Lotek Engineering. We surgically implanted tags in both juvenile chinook salmon and steelhead. Tagging related mortality was about 3% in 1996, less than 1% in 1997 and 1998, and less than 1.5% during 2000, 2001, 2002, and 2003. Due to the proposed sample size for the 2005 test, we may not be able to surgically implant the tags. Instead, we may use the less labor-intensive gastric tagging method. This method has been successfully used in the lower Columbia River for the last 5 years. The coded tags we propose to implant offer several features that make them ideal for studying juvenile fish movements at Lower Granite Dam. Because each tag is uniquely coded, 521 tags can broadcast on the same frequency without losing the ability to identify distinct individuals. As a result, the scan cycle of the receiver is relatively short and the probability of not detecting a fish is fairly low. Additionally, a Digital Spectrum Processor (DSP) can be used in conjunction with a receiver to scan multiple frequencies and codes simultaneously. The DSP essentially eliminates any need for a scan cycle and allows for nearly instantaneous detection of all fish within range of the antennas. We are also proposing the continued use of a relatively new data acquisitions system (Multiprotocol Integrated Telemetry Acquisition System; MITAS). The MITAS system has many advantages over the system we have used in the past (faster and multiple signal acquisition, data consolidation, real-time data views, improved system diagnostics) and should provide more complete data on fish movements upstream of the RSW.

The proposed antenna array at Lower Granite Dam will consist of about 65 aerial antennas and 190 underwater antennas (Appendix figure 1, 2, and 3). Most underwater antennas will be monitored by a MITAS system. Aerial antennas will be linked to about 15 automated data collecting receivers and will provide continuous information on fish movements at the dam. The aerial and underwater arrays will be very similar to the arrays used during 2003.

Task 1.1: Conduct further tests to optimize methods for use of coded radio-telemetry equipment at Lower Granite Dam.

Activity 1.1.1

Conduct laboratory bench tests of coded equipment to determine the best possible configuration to insure that data is collected in an efficient manner.

Schedule:

November 2004.

Activity 1.1.2

Electrical engineers will be contracted to review the objectives of our study and provide feedback to aid in optimizing the data logging system at Lower Granite Dam.

Schedule:

January through February 2005.

Task 1.2: Install fixed monitoring sites on and around Lower Granite Dam.

Activity 1.2.1

Install, calibrate, and test the underwater and aerial antenna arrays at Lower Granite Dam. The magnitude of the arrays proposed at Lower Granite Dam will require a considerable amount of time (at least 2 months) and effort to install, calibrate, and test.

Schedule:

March through May 2005.

Activity 1.2.2

Install and test underwater antennas in and around the Removable Spillway Weir and Behavioral Guidance Structure.

Schedule:

March through May 2005.

Activity 1.2.4

Depending on the condition of the existing equipment, we may need to remove and reinstall underwater antenna arrays located on the Extended Length Bar Screen at all slots on units 1-6.

Schedule:

October 2004 and February through March 2005.

Activity 1.2.5

Install, calibrate, and test fixed monitoring sites above Lower Granite Dam, within one mile below Lower Granite Dam, at the Juvenile Fish Bypass Facility, and likely two barges in the forebay of Lower Granite Dam.

Schedule:

February through March 2005.

Task 1.3: Conduct releases of yearling Chinook salmon and juvenile steelhead in Lower Granite Reservoir during the spring of 2005.

Activity 1.3.1

Continue to develop analytical procedures for examining radio-telemetry data. We will consult with statisticians as the Region reaches consensus on a design for the 2005 test.

Schedule:

Work will continue through the 2005 field season.

Activity 1.3.2

Determine release site, number of fish per release, and time interval between releases. We tentatively propose that the release site be located at Blyton Landing. This has been the primary release site used since 1996. This site appeared to be far enough upriver of the dam to allow fish to recover from the stress associated with the tagging procedure, but still allowed us to have some control over when the fish arrived at the dam. Please refer to the rational of objective #1 for discussion of the proposed number of fish to be released.

Schedule:

December 2004 through January 2005.

Activity 1.3.3

Complete the necessary Endangered Species Act documentation and obtain the necessary permits and approval to work in the Snake River.

Schedule:

December 2004.

Activity 1.3.4

Coordinate with appropriate agencies to sequester, implant tags, and release spring migrating smolts during the months of April, May, and June 2005 (the spring out-migration period).

Schedule:

February through March 2005.

Activity 1.3.5

Monitor the movements of radio-tagged fish in the forebay and tailrace areas of Lower Granite Dam relative to the tests of the RSW.

Schedule:

April through June 2005.

Task 1.4: Continue to develop and refine data reduction, storage, analysis, and transfer procedures.

Activity 1.4.1

The regional researchers and managers continue to request the results of these studies almost immediately after the field tests are completed. The data is vital for them to make informed management decisions regarding the operation of the Columbia River hydropower system. In response to these needs, we will continue to improve and refine our ability to report this data more quickly.

Schedule:

Complete by December 2004.

Task 1.5: Explore means to improve and expand information collected during subsequent field seasons.

Activity 1.5.1

Acquire and test telemetry systems manufactured by Advanced Telemetry Systems, Lotek Engineering, and other vendors if appropriate as a means to increase the resolution and accuracy of data collected on fish movements.

Schedule:

October through December 2004.

Objective 2: Determine the relative survival of yearling Chinook salmon with known passage routes through Lower Granite Dam.

Note: This study objective meets the research needs identified in SBE-W-96-1 objective 5

Rationale

Survival estimates for yearling Chinook salmon through the RSW have only been estimated during one year. Estimating survival of yearling Chinook salmon in 2005 would provide confirmation of our estimates during 2003. Because the RSW may be selected as a basin-wide management strategy to improve fish passage at dams, it may be prudent to evaluate the survival of yearling Chinook salmon to confirm our observation during 2003.

Under this objective, we propose to utilize the 1,000 yearling Chinook salmon released upstream of Lower Granite Dam under objective 1 to estimate survival through the RSW and the spillway. We also propose to release an additional 300 yearling Chinook salmon upriver of Lower Granite Dam and 460 yearling Chinook salmon in the tailrace of Lower Granite Dam (Appendix Figure 5). Our experience indicates that about 400 fish per passage route are needed to obtain reasonably precise survival estimates ($\pm$ 3-5%) during the spring out-migration. Based on the 2002 and 2003 results, and assuming that 1,300 yearling Chinook salmon are released upriver of the dam, sufficient numbers of fish are expected to pass through the RSW and spillway to determine route-specific survival for two treatments (e.g., RSW on with training spill and RSW off with BiOP spill). Based on the 2002 and 2003 results, insufficient numbers of yearling Chinook salmon are expected to pass through the powerhouse to determine route specific survival estimates for guided and unguided fish. Additional fish would need to be release to determine survival through the powerhouse.

Task 2.1: Conduct releases of yearling Chinook salmon in the tailrace of Lower Granite Reservoir during the spring of 2005.

Activity 2.1.1

Develop analytical procedures for determining paired-release survival estimates for yearling Chinook salmon through the RSW and Spillway. Since our laboratory has extensive experience conducting survival studies using radio telemetry data, much of the groundwork has been completed to accomplish this task. We will consult with statisticians prior to finalizing survival estimates tasks and objectives.

Schedule:

November 2004.

Activity 2.1.2

Install and test additional monitoring sites downstream of Lower Granite Dam through Little Goose Reservoir (Appendix Figure 5). These additional sites will be needed below the dam to collect the necessary capture history data inherent to generating survival estimates.

Schedule:

February through March 2005.

Activity 2.1.3

Monitor the movements of radio-tagged fish released above and below Lower Granite Dam to estimate relative survival of yearling Chinook salmon through the RSW and spillway during the 2005 tests of the RSW.

Schedule:

April-May 2005.

<u>Objective 3</u>: Determine the timing and route of passage for subyearling Chinook salmon at Lower Granite Dam relative to spill, powerhouse, removable spillway weir, and behavioral guidance structure operations.

Note: This study objective meets the research needs identified in SBE-W-96-1 objective 6

<u>Rationale</u>

There has never been an evaluation of subyearling Chinook salmon passage relative to the removable spillway weir. Because Snake River subyearling Chinook salmon are currently federally listed as endangered and the RSW may be selected as a basin-wide management strategy, it may be prudent to evaluate the performance of the RSW relative to migrating subyearling Chinook salmon before selecting the RSW as a management tool to aid migrating juvenile fish.

Under this objective, we propose to release radio-tagged subyearling Chinook salmon in Lower Granite Reservoir and monitor the timing and route of passage through Lower Granite Dam during various spill, powerhouse, and removable spillway weir operations. The proposed evaluation would be conducted during the June-July out-migration in 2005. At this time, no specific study design has been proposed for this evaluation. In previous years, the performance of the RSW was evaluated using a study design consisting of two-day treatments (RSW on with no BGS and RSW on with the BGS) randomized over a 4-day period. The 4-day blocks served as replicates over the length of the study period. The study period was typically 40-50 days long. Until further discussion occurs, we have developed this proposal under the assumption that a similar study design will be used to evaluate the RSW in 2005. Base on study designs from previous years of research on the RSW, we propose releasing a minimum of 1,000 radio-tagged subyearling Chinook salmon upstream of the dam to evaluate the performance of the RSW during the summer of 2005.

Task 3.1: Conduct further tests to optimize methods for use of coded radio-telemetry equipment at Lower Granite Dam.

Activity 3.1.1

Conduct laboratory bench tests of coded equipment to determine the best possible configuration to insure that data is collected in an efficient manner.

Schedule:

November 2004.

Activity 3.1.2

Electrical engineers will be contracted to review the objectives of our study and provide feedback to aid in optimizing the data logging system at Lower Granite Dam.

Schedule:

January through February 2005.

Task 3.2: Install fixed monitoring sites on and around Lower Granite Dam.

Activity 3.2.1

Install, calibrate, and test the underwater and aerial antenna arrays at Lower Granite Dam. The magnitude of the arrays proposed at Lower Granite Dam will require a considerable amount of time (at least 2 months) and effort to install, calibrate and test.

Schedule:

March through May 2005.

Activity 3.2.2

Install and test underwater antennas in and around RSW and BGS.

Schedule:

March through May 2005.

Activity 3.2.4

Depending on the condition of the existing equipment, we may need to remove and reinstall underwater antenna arrays located on the Extended Length Bar Screen at all slots on units 1-6.

Schedule:

October 2004 and February through March 2005.

Activity 3.2.5

Install, calibrate, and test fixed monitoring sites one mile below Lower Granite Dam, at the Juvenile Fish Bypass Facility, and likely two barges in the forebay of Lower Granite Dam.

Schedule:

February through March 2005.

Task 3.3: Conduct releases of subyearling Chinook salmon in Lower Granite Reservoir during the summer of 2005.

Activity 3.3.1

Continue to develop analytical procedures for examining radio-telemetry data. We will consult with statisticians as the Region reaches consensus on a design for the 2005 test.

Schedule:

Work will continue through the 2005 field season.

Activity 3.3.2

Determine release site, number of fish per release, and time interval between releases. We tentatively propose that the release site be located at Blyton Landing.

This has been the primary release site used since 1996. This site appeared to be far enough upriver of the dam to allow fish to recover from the stress associated with the tagging procedure, but still allowed us to have some control over when the fish arrived at the dam. Please refer to the rational of objective #3 for discussion of the proposed number of fish to be released.

Schedule:

December 2004 through January 2005.

Activity 3.3.3

Complete the necessary Endangered Species Act documentation and obtain the necessary permits and approval to work in the Snake River.

Schedule:

December 2004.

Activity 3.3.4

Coordinate with appropriate agencies to sequester, implant tags, and release subyearling Chinook salmon smolts during the months of June and July 2005 (the summer out-migration period).

Schedule:

February through March 2005.

Activity 3.3.5

Monitor the movements of radio-tagged fish in the forebay and tailrace of Lower Granite Dam relative to the tests of the RSW.

Schedule:

June through July 2005.

Task 3.4: Continue to develop and refine data reduction, storage, analysis, and transfer procedures.

Activity 3.4.1

The regional researchers and managers continue to request the results of these studies almost immediately after the field tests are completed. The data is vital for them to make informed management decisions regarding the operation of the Columbia River hydropower system. In response to these needs, we will continue to improve and refine our ability to report this data more quickly.

Schedule:

Complete by December 2004.

Task 3.5: Explore means to improve and expand information collected during subsequent field seasons.

Activity 3.5.1

Acquire and test telemetry systems manufactured by Advanced Telemetry Systems, Lotek Engineering, and other vendors if appropriate as a means to increase the resolution and accuracy of data collected on fish movements.

Schedule:

October through December 2004.

<u>Objective 4</u>: Determine the relative survival of subyearling Chinook salmon with known passage routes through Lower Granite Dam.

Note: This study objective meets the research needs identified in SBE-W-96-1 objective 7

<u>Rationale</u>

In addition to there not being any performance data on subyearling Chinook salmon relative to the RSW there are currently no survival estimates of subyearling Chinook salmon passing Lower Granite Dam using radio telemetry. Survival estimates are paramount in determining whether a passage enhancement structure will have an adverse affect on fish survival. Likewise, this objective is critical to determine whether or not the RSW may have adverse affect on fish survival relative to the current management strategy of using BiOP spill to pass fish.

Under this objective, we propose to utilize the 1,000 sub-yearling Chinook salmon released upstream of Lower Granite Dam under Objective 3 to estimate survival through the RSW and other passage routes at Lower Granite Dam. In addition, we propose adding 400 subyearling Chinook salmon to the upriver release as well as releasing 500 subyearling Chinook salmon in the tailrace of Lower Granite Dam (Appendix Figure 4). We will use the PRRM (Skalski et al. 2001) to estimate survival by evaluating the difference in downstream detection probabilities between the 'treatment" fish released upstream and the 'control' fish released into the tailrace (Appendix Figure 5).

To design a study capable of detecting differences in survival, it is necessary to have reliable prior knowledge about such factors as survival rates and capture probabilities. Although this data is available for spring migrants at Lower Granite Dam, this information is lacking for subyearling Chinook salmon and is expected to differ from spring migrants. Capture probabilities can substantially affect the sample size needed to obtain a given precision of a survival estimate. For example, with an estimated survival rate of 0.8, to obtain a coefficient of variation (cv) of 0.025, a sample size of 400 is needed if the capture probability is 1.00 (Burnham et al. 1987). However, if the capture probability is 0.80, the sample size must be increased to 1,300 to obtain the same precision (i.e., the cv). In 2003, we have conducted a pilot study of subyearling Chinook salmon survival through McNary Dam and found that capture probabilities ranged from 0.85 to 0.90. These capture probabilities from the McNary data indicated that our estimated required sample size of 1,300 subyearling Chinook salmon should be sufficient to achieve the desired precision at Lower Granite Dam. Because the COE has not given us a detailed study design, it is difficult for us to conduct a rigorous power analysis. We anticipate that more information will be available prior to submitting the final proposal for 2005 research. We will consult with statisticians (Skalski et al.) before the final proposal is submitted.

Based on previous research, we do not expect sufficient numbers of subyearling Chinook salmon to pass through the powerhouse to determine route specific survival estimates for guided and unguided fish. Additional fish would need to be released to determine survival through the powerhouse.

Task 4.1: Conduct releases of subyearling Chinook salmon in the tailrace of Lower Granite Reservoir during the summer of 2005.

Activity 4.1.1

Develop analytical procedures for determining route specific survival estimates for subyearling Chinook salmon through the RSW and Spillway. Since our laboratory has extensive experience conducting survival studies using radio telemetry data, much of the groundwork has been completed to accomplish this task. We will consult with statisticians prior to finalizing survival estimates tasks and objectives.

Schedule:

November 2004.

Activity 4.1.2

Install and test additional monitoring sites downstream of Lower Granite Dam (Appendix Figure 5). Additional sites will be needed below the dam to collect the necessary capture history data inherent to generating survival estimates.

Schedule:

March through May 2005.

Activity 4.1.3

Monitor the movements of radio-tagged fish released above and below Lower Granite Dam to estimate relative survival of subyearling Chinook salmon through the RSW and Spillway during the 2004 tests of the RSW.

Schedule:

June through July 2005.

Activity 4.2.4

Conduct "dead fish release". To validate assumptions of the survival model relative to false-detection rates, we propose to conduct releases of dead fish in the tailrace of the dam.

Schedule:

June through July 2005.

METHODS FOR GENERATING SURVIVAL ESTIMATES

There are assumptions associated with using the paired release-recapture model to estimate survival, some are biological and some pertain to the statistical models (Burnham et al. 1987, Skalski 1998, Skalski 1999). Much of the statistical methodology here follows that of the

USGS lower Columbia Survival Studies and the report entitled “Statistical Methods to Extract Survival Information from the John Day and The Dalles Dam Radiotag Studies” submitted to Marvin Shutters, ACOE from Dr. John R. Skalski, University of Washington. The validity of some of the assumptions listed below can be evaluated using statistical tests and others can be met through careful consideration of fish collection, holding, tagging, and detection techniques. Strict protocols are already in place for the radio-tagging techniques that will be used in this study and we will perform further statistical tests where possible to ensure that the assumptions associated with the release-recapture models are met. The assumptions are the following (Skalski 1999):

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and capture probabilities are not affected by tagging or sampling (i.e., tagged animals have the same probabilities as untagged animals).

A3. All sampling events are “instantaneous” (i.e., sampling occurs over a short time relative to the length of the intervals between sampling events).

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All individuals alive at a sampling location have the same probability of surviving until the end of that event.

A6. All tagged individuals alive at a sampling location have the same probability of being detected on that event.

A7. All tags are correctly identified and the status of fish (i.e., alive or dead) is correctly identified.

The first assumption (A1) involves making inferences from the sample to the target population. For instance, if a sample is drawn from a population of fish and the size of the radio transmitter biases your sample to include only larger members of the population, then non-statistical inferences justifying the similarity between the target population and the sample are necessary. In past radio-telemetry studies conducted by the Columbia River Research Laboratory, the size of the smallest radio transmitters available has resulted in this type of bias. However, recent advancements have led to the development of a coded radio transmitter that is much smaller than the transmitters previously available, which would allow us to include smaller fish in our sample and better represent the target population.

Assumption A2 regards making inferences to the target population. If tagging has a detrimental effect on survival, then survival estimates from the radio-tagged fish will be negatively biased (i.e., underestimated). To limit the effects of our tagging methods on our tagged fish we have used the criteria established in Adams et al. (1998a; b). The development of the smaller tags mentioned in the discussion of assumption A1 would further limit the impacts of our tagging methods on our sample fish.

Assumption A3 stipulates that mortality be negligible in the area near sampling stations so that mortality incorporated into the survival estimates occurs in the river reach in question and not during the sampling event. Our radio tagged fish spend only a brief amount of time near the antenna array relative to that spent traveling between detection locations.

The assumption of independence (A4) implies that the fate of any particular fish does not affect the fate of others. This assumption is common to all tagging studies and in a large system such as the Columbia River; there is no evidence to suggest that it is not true. Violations of A4 have little effect on the point estimate but may bias the variance estimate to be lower than it actually is.

Assumption A5 specifies that prior detection has no effect on the subsequent survival of fish. The lack of handling following initial release minimizes the risk that detection influences survival. Assumption A6 could be violated if downstream detections were affected by fish passage routes. Providing adequate coverage of the entire river or placing arrays below mixing zones will reduce the likelihood of violating this assumption.

Assumption A7 implies that fish do not lose their tags and thus, are misidentified as dead or not captured and that dead fish are not incorrectly recorded as alive. Tag loss or radio failure would negatively bias survival estimates. Typically, the retention rate of radio tagging is high suggesting that the effects of tag loss on survival estimates would be minimal. For example, with the exception of one fish that became entangled in a tank structure, Adams et al. (1998a; b) did not report any tag loss for Chinook salmon with gastric and surgically implanted transmitters during a 21 d laboratory experiment. Dead fish drifting downstream could result in false-positive detections and upwardly bias survival estimates. However, a prudent selection of detection arrays that are sufficiently spaced would minimize this occurrence. Further, as we propose, false-detection rates can be empirically evaluated by calculating rates from releases of dead fish.

Survival in all of the objectives will be estimated from paired releases at Lower Granite Dam. Survival will be estimated by the expression (Burnham et al. 1987):

$$\hat{S} = \frac{\hat{S}_{11}}{\hat{S}_{21}} \qquad (1)$$

with a variance estimate based on the Delta method (Seber 1982) of:

$$\begin{aligned} V\hat{a}r\left(\hat{S}_W\right) &\approx \left(\frac{\hat{S}_{11}}{\hat{S}_{21}}\right)^2 \left[\frac{Var\left(\hat{S}_{11}\right)}{\hat{S}_{11}^2} + \frac{Var\left(\hat{S}_{21}\right)}{\hat{S}_{21}^2}\right] \\ &\approx \hat{S}_W^2\left[\hat{C}V\left(\hat{S}_{11}\right)^2 + \hat{C}V\left(\hat{S}_{21}\right)^2\right] \end{aligned} \qquad (2)$$

where $\hat{S}_{11} =$ survival estimates for fish released above the project of interest or directly into the route of interest, and $\hat{S}_{22} =$ fish released in the tailrace of the project.

and where

$$\hat{C}V\left(\hat{\theta}\right) = \frac{\sqrt{Var\left(\hat{\theta}\right)}}{\theta}$$

In order to estimate S, the survival S_{11} is assumed to be of the form:

$$S_{11} = S \cdot S_{21}$$

leading to the relationship

$$\frac{S_{11}}{S_{21}} = \frac{S \cdot S_{21}}{S_{21}} = S. \qquad (3)$$

The equality (3) suggests two additional assumptions for valid survival estimation using the paired release-recapture protocol.

A9. Survival in the upriver segment (S) is conditionally independent of survival in the lower river segment.

A10. Releases (R_1) and (R_2) have the same survival probability in the lower river segment (S_{21}).

Assumption A9 stipulates that there is no synergistic relationship between survival processes in the two river segments (i.e., fish released above the dam that survive the first river segment are no more or less susceptible to mortality in the second river segment than fish released below the dam).

Assumption A10 is satisfied if the paired releases mix as they migrate through the second river segment but can also be satisfied if the survival process is stable during passage by the two releases. Under similar flow and spill conditions, a stable survival process should be expected.

To test whether releases within a paired release have similar survival and capture histories, likelihood ratio tests can be performed to compare models H_{1N} and H_{k-1N} and other intermediate scenarios (Burnham et al. 1987). Burnham et al. (1987) also suggest that a 2 x 2 contingency table test to determine where the capture and survival rates for the paired releases are equal at or below the first downstream antenna array (i.e., $p_{11} = p_{21}$, $S_{11} = S_{21}$, $p_{12} = p_{22}$, etc.) another indication of complete mixing. The 2 x 2 table would be of the form:

	Release	
	R_1	R_2
m_1	m_{11}	m_{21}
Z_1	z_{11}	z_{21}

where m_1 is the number of fish detected at the first downstream array for a given release and z_1 is the number of fish that were not detected at the first array but were subsequently detected at a downstream array. While the contingency table provides tests of equality of overall recapture for paired releases, it does not provide the resolution of the equal site-specific capture and survival rate for both releases. Thus, inferences regarding mixing will be largely based on the sequential use of likelihood ratio tests.

The assumption of downstream mixing can be tested at each downstream array. An R x C contingency table test of homogenous recoveries over time can be performed using a table of the form:

		Release	
		R_1	R_2
Day of detections	1		
	2		
	3		
	4		
	5		

For each paired-release, a chi-square test of homogeneity will be performed at each downstream array. Tests would be performed at $\alpha = 0.10$. Because there will be multiple release and tests across paired releases, Type I error rates should also be adjusted for an overall experimental-wise error rate of $\alpha_{EW} = 0.10$.

In any given relative survival estimation scenario presented, a number of potential models will be generated and subsequently evaluated (Burnham et al. 1987, Leberton et al. 1992). Forward-sequential and reverse-sequential procedures will be used to find the most parsimonious statistical model that adequately describes the downstream survival and capture processes of the paired-release. The most efficient estimate of spillway or reach survival will be based on the statistical model for the paired releases that properly share all common parameters between release groups

Survival estimates for all of the proposed objectives will be generated from paired replicate lots of radio-tagged fish. A weighted average of the survival estimates from the replicated releases can be calculated according to the formula (Skalski 1999):

$$\hat{\bar{S}} = \frac{\sum_{i=1}^{k} W_i \hat{S}_i}{\sum_{i=1}^{k} W_i} \qquad (4)$$

where k = number of replicate releases:

and where $\hat{S}_i$ = survival estimates from the ith release (i = 1, ..., k);

The weight W_I is calculated using the formula:

$$W_i = \frac{1}{\left(\frac{V\hat{a}r\left(\hat{S}_i\right)}{\hat{S}_i^2}\right)} = \frac{1}{CV\left(\hat{S}_i\right)^2} \qquad (5)$$

with variance

$$Var\left(\hat{\hat{S}}\right) = \frac{\sum_{i=1}^{k} W_i\left(\hat{S}_i - \hat{\hat{S}}\right)^2}{(k-1)\sum_{i=1}^{k} W_i} \qquad (6)$$

If the average is estimating a mean over some static process then weighting would be inversely proportional to the variance. However, in the release-recapture models,

$$Var\left(\hat{S}\right) \propto S^2$$

Therefore, the variance is correlated with the point estimates of survival. The weight (5) eliminates this correlation yet weights in proportion to the sampling precision (i.e., *CV*). Unfortunately, while the weighted average has been applied by others examining the survival of PIT-tagged salmonids in the Columbia River Basin, the use of this methodology for estimating mean survival using radio-tagged fish has resulted in certain estimates (e.g., those that have survival and capture probabilities near 1) having highly disproportionate weights that invariably results in estimates of average relative survival that are very near 1, despite the fact that the majority of the individual relative survival estimates are much lower than this value. While weighted averages are designed to weight the average by certain observations with given qualities or other derived variables or quantities and thus cannot be expected to represent the value that would exist given an un-weighted estimator, the use of a weighted estimator that always skews the evaluation to indicate that the survival of fish passing a given project is 1, when as researchers we know this to not be the case, is unacceptable.

The high capture probabilities possible with current radio-telemetry systems and the nature of the way the SURPH software calculates the variance of the survival estimates of the individual releases (e.g., analogous to the binomial variance formula) has resulted in this difficulty. Coordination between the USGS and the University of Washington, and subsequent efforts by University of Washington personnel have failed to resolve this problem. Consequently, we will evaluate the use of the weighted average, but will use the arithmetic mean to represent the survival of subyearling and yearling Chinook salmon if it appears that the use of the weighted estimator results in estimates that are disproportionately influenced by the aforementioned computational difficulty.

FACILITIES AND EQUIPMENT

Although some of the special or expensive equipment or services for the proposed study have been purchased during previous years of this study, there is a need for additional equipment. The purchase of the radio transmitters will perhaps be the most significant purchase for the proposed study. The coded radio transmitters manufactured by Lotek Engineering cost about $195.00 each.

Divers will be needed to assist in testing and repair of existing underwater antennas on the antennas on and around the RSW and BGS. At this time, we are unsure of the expense involved in these activities.

The USGS operates the Columbia River Research Laboratory that includes research boats, vehicles, office space, and laboratory facilities to conduct this study. Boats will be operated at cost with no additional lease cost to the project. Only department of Interior certified boat operators trained in CPR and First Aid will operate boats. In order to meet U.S. Coast Guard standards boats will be inspected by a third party. Furthermore, USGS will provide a quality control system consistent with the Good Laboratory Practices Act.

Other resources include:

- A selection of 30 boats up to 30 feet in length for work on the river.
- Two 2700 square foot storage facilities with a shop.
- 4000 square foot wet lab facility.
- A local computer network integrating state-of-the-art GIS capabilities.
- A technical staff of 60-100 fishery biologists, ecologists, and GIS specialists.
- An office and analytical laboratory in a 15,000 square foot facility.

IMPACTS

Impacts to other researchers

Because we will be using radio-telemetry technology to study the movements of the test fish, there is a great potential for interference with other studies that use the same technology. Other studies using radio tags with the same frequencies may cause interference and could cause the loss of data that would otherwise be collected. During 1994, 1995, and 1996 our ability to collect data was compromised due to radio interference caused by other researchers. An extensive coordination effort throughout the basin allowed us to minimize this problem during 1997-1998. In conjunction with coded tag manufacturers we were able to incorporate radio tags that operated on a unique frequency used only by USGS scientists. During the 2000-2001 study periods we used these modified radio tag frequencies to reduce multiple signal collisions and eliminate unwanted detections (of fish released by other researchers), and therefore increased overall data integrity. This unique tag frequency will be used during the 2005 evaluation.

Impacts to the Lower Granite Project

Pre-season installation of equipment will start in February 2005 and continue through May 2005. The equipment will be in use through the end July 2005. We are capable of installing most of the necessary equipment for the aerial arrays, and the impact to the Lower Granite project should be minimal. However, we are not equipped to repair and install all of the underwater antennas at the RSW, BGS, turbine intakes, and Extended Length Barrier Screens. At this stage in the development of the 2005 study design, the impacts to the Lower Granite Project, and the assistance we might require from Army Corp of Engineer personnel is as follows:

Underwater antennas on the RSW--We will require divers to repair and install underwater antennas on the RSW and BGS. Turbine outages and spill gate closures must be in effect during diving activities. As a result, this work must be coordinated with the Lower Granite project and should be completed prior to increased flows in the Snake River. Perhaps the most effective way to meet all the diving needs is to have all the work covered in one contract that is awarded by the COE.

Underwater antennas on Extended Length Bar Screens-- We will need the assistance of Lower Granite Project personnel to raise and lower each screen during the repair and reinstallation of underwater antennas on the ELBS. Re-installation of the ELBS telemetry arrays is dependent on the work of numerous other contractors, and therefore a more specific schedule is difficult to estimate.

COLLABORATIVE ARRANGEMENTS and/or SUB-CONTRACTS

Some of the labor needed to complete the activities outlined in this proposal my be furnished through a sub-contract with a labor service provider.

LIST OF KEY PERSONNEL AND PROJECT DUTIES

Personnel	Organization	Project Duties
Dennis Rondorf	BRD	Project Leader
Noah Adams	BRD	Principal Investigator
John Plumb	BRD	Technical Lead, implementation/coordination
Amy Braatz	BRD	Technical Lead, implementation/coordination

TECHNOLOGY TRANSFER

Development of a surface collection system is based on observations which indicate that fish will readily pass obstructions to their downstream movement if they are able to discover an adequate flow net. The data we propose to collect during the 2005 season will provide detailed information on the movements and passage routes of juvenile salmonids at Lower Granite Dam relative to removable spillway weir and guidance/occlusion structure tests. We plan to transfer information obtained from our analysis in the manners listed below. Once this information is transferred, it will be used to make decisions relative to operation of the Federal Columbia River Power System and Juvenile Transportation Program as discussed in the draft Biological Opinion, July 27, 2000, 9.6.1.4.2, page 9-69. In addition, the information will be used by other federal and state agencies, Indian Tribes, and the public to make management decisions to aid in the recovery of threatened and endangered populations of salmon in the Columbia Basin.

1. Preliminary reports to the Army Corps of Engineers. A preliminary report of our findings from the analysis will be submitted by November 1, 2005.

2. Presentation to the Anadromous Fish Evaluation Program (AFEP) in November 2005, and presentation to fisheries agencies, tribes, and the public at the Annual Research Review, 2005.

3. Expected draft report for 2005 by February 1, 2006 and final report by May 31, 2006.

4. Presentations to the Army Corps of Engineers staff and study review groups.

5. Presentations at professional meetings (i.e., American Fisheries Society) and publication of information in peer reviewed journals.

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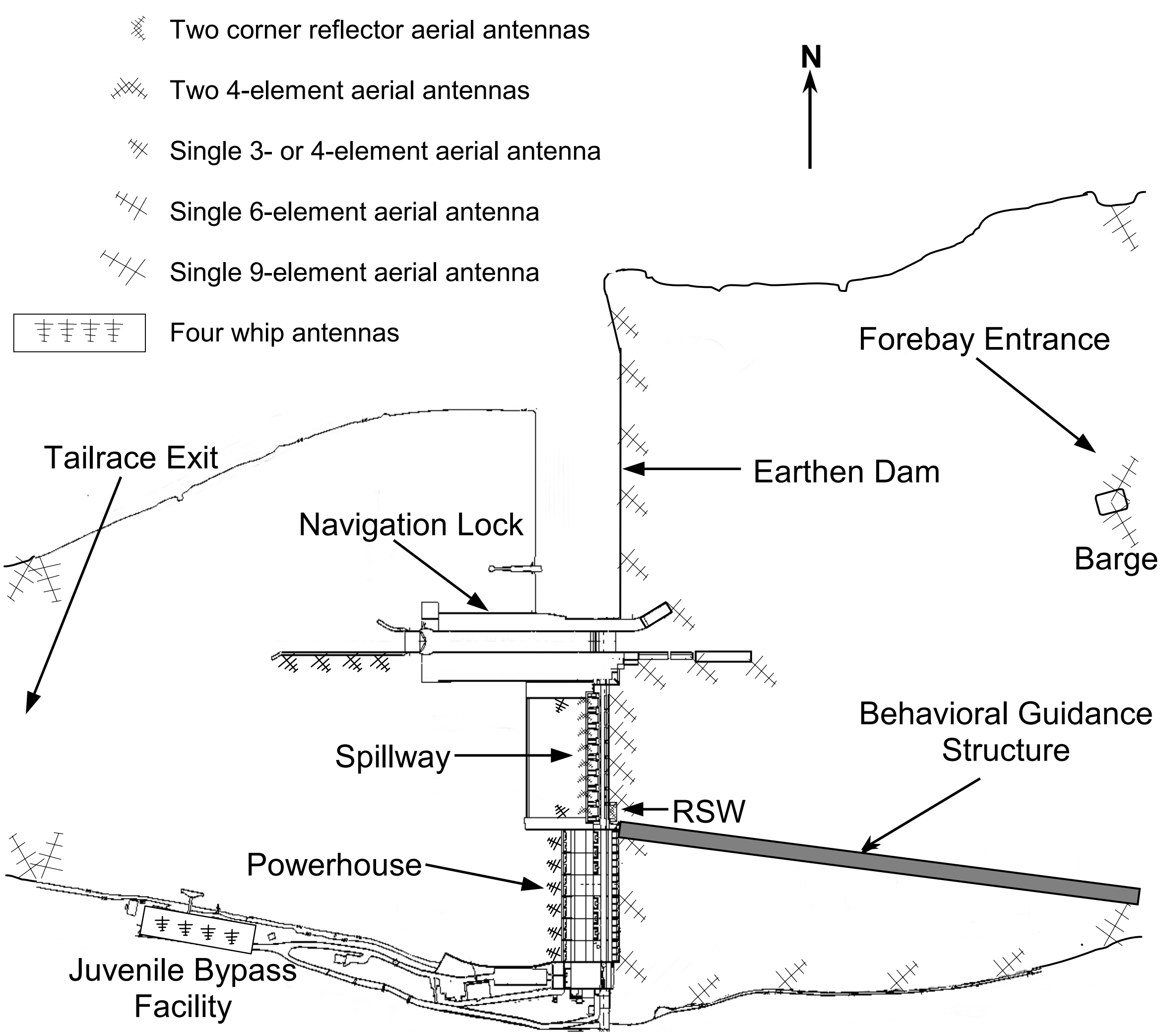
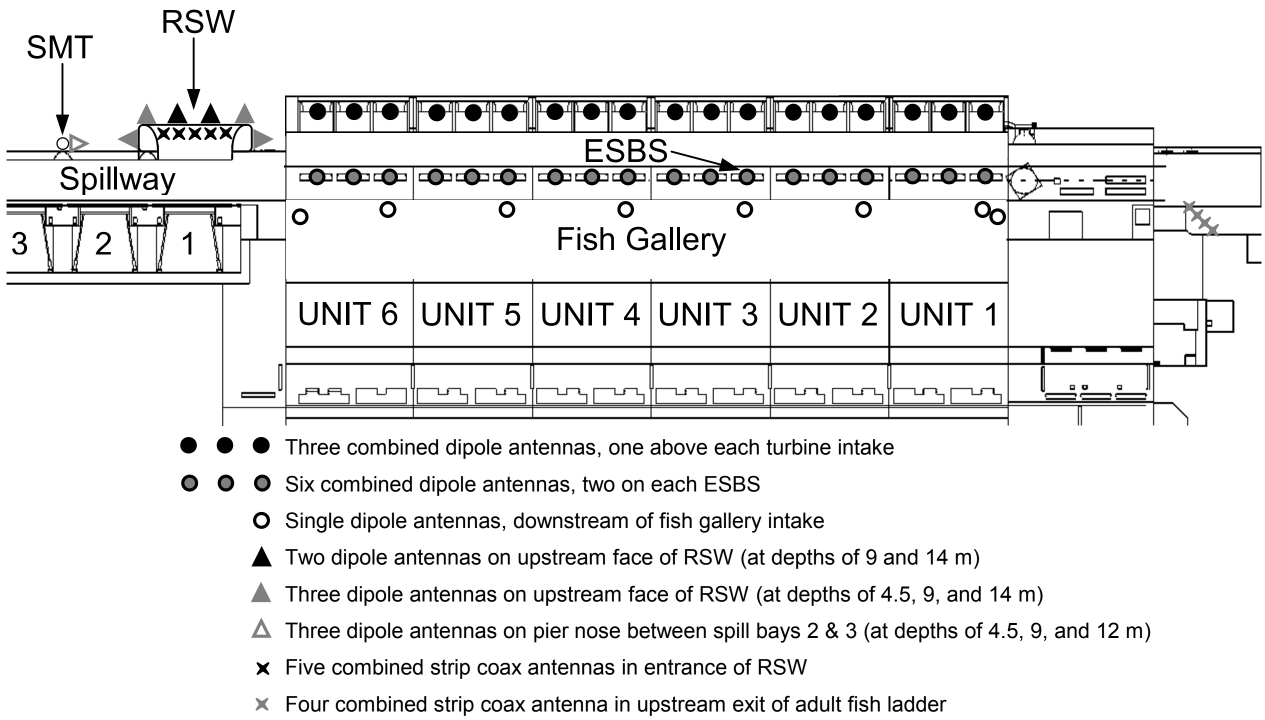
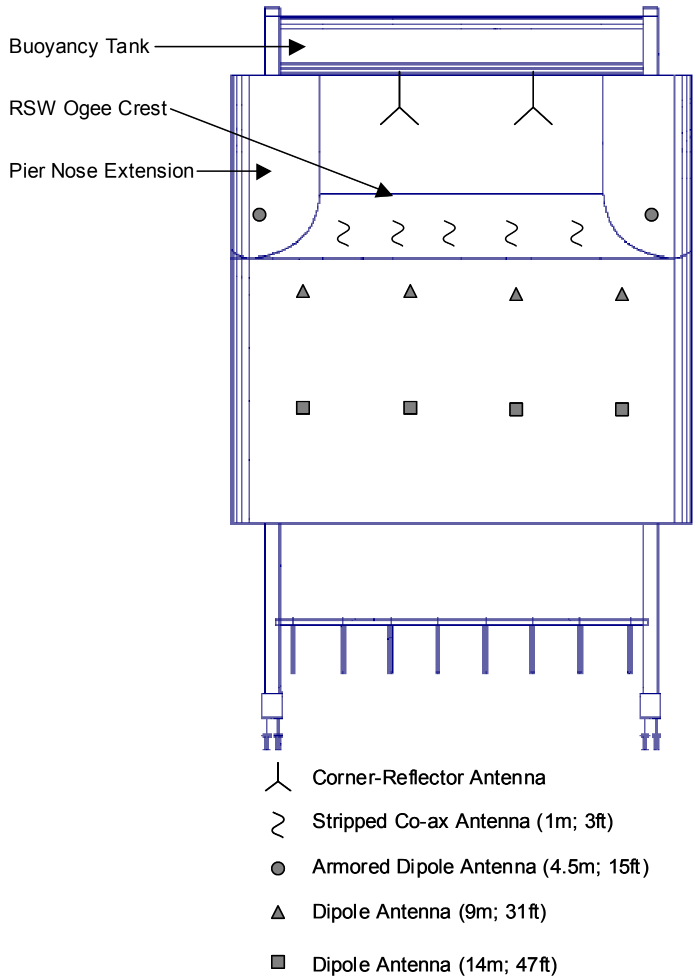


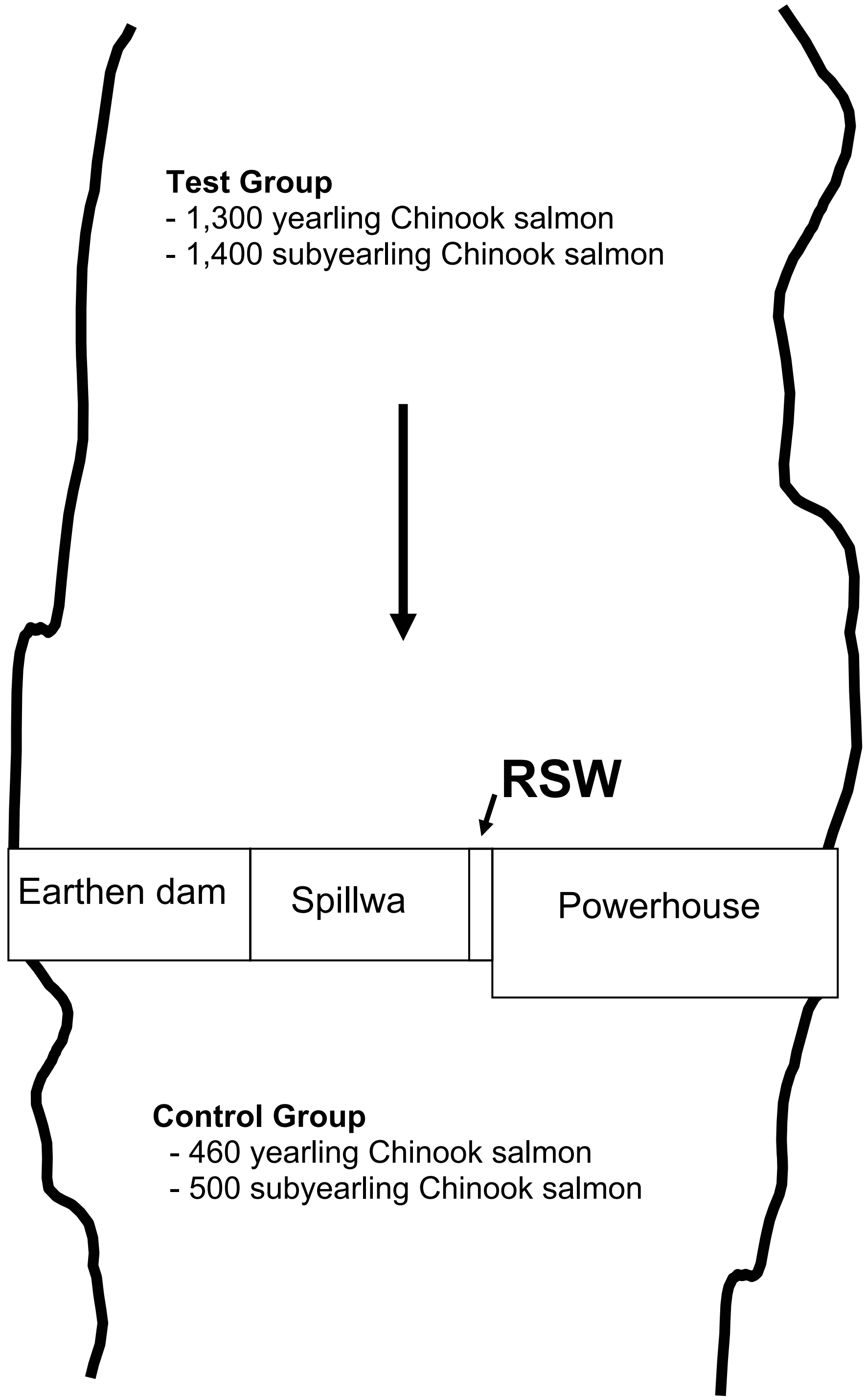
Appendix Figure 1. Plan view of proposed aerial antenna arrays at Lower Granite Dam during 2005



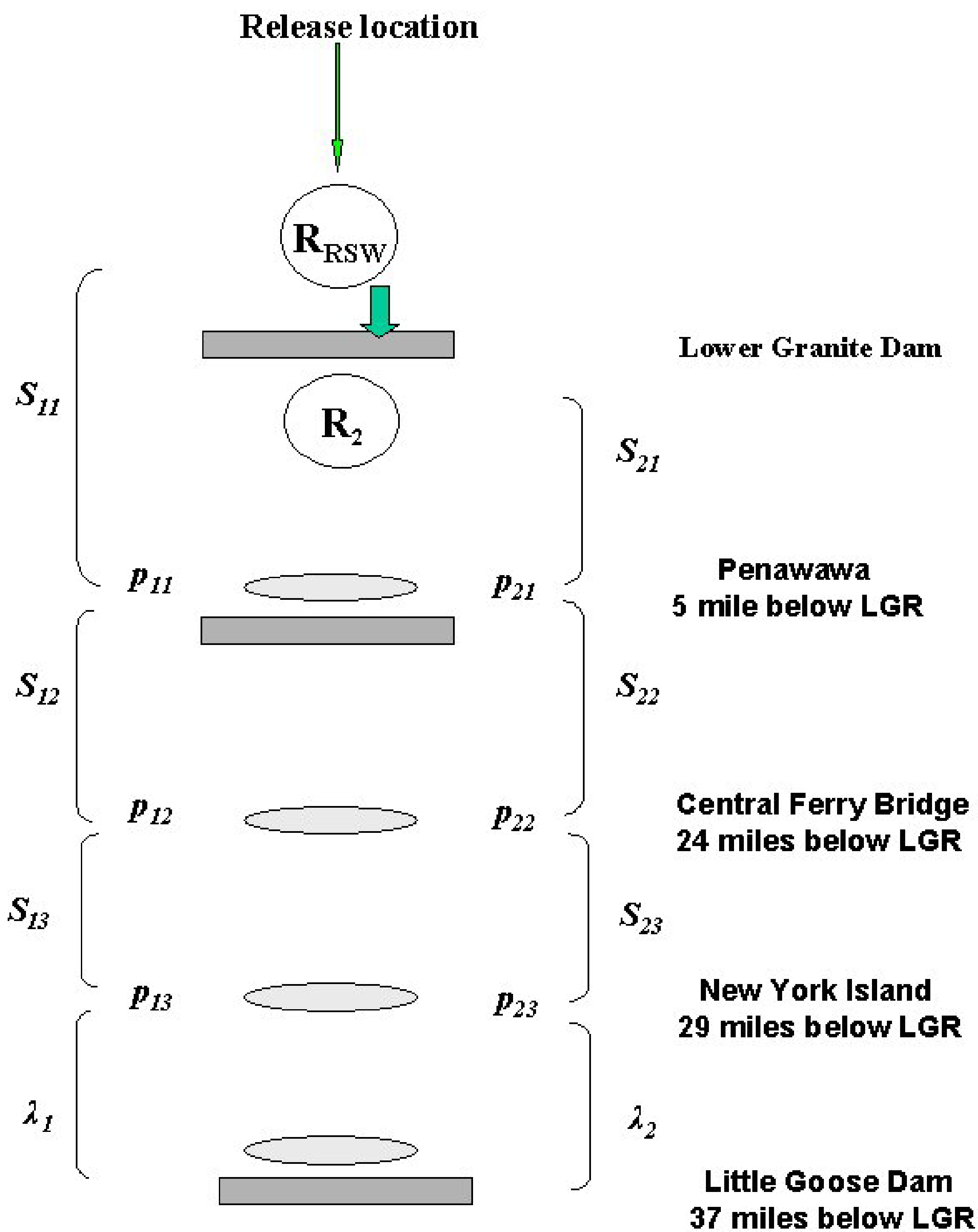
Appendix Figure 2. Schematic of proposed underwater antennas near the powerhouse of Lower Granite Dam during 2005.



Appendix Figure 3. Frontal view of Lower Granite Dam's RSW showing locations of proposed radio telemetry antennas during 2005. Numbers in parenthesis represent depth of antenna locations. Antennas without depth are aerial antennas.



Appendix Figure 4. Schematic showing proposed release of sub-yearling chinook salmon above and below Lower Granite Dam in 2005. These fish will be used to evaluate the performance of the Removable Spillway Weir (RSW) and estimated survival of fish passing through the RSW and Spillway.



Appendix Figure 5. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from releases above Lower Granite Dam and the Lower Granite Dam tailrace. Dams are represented by rectangles and ovals represent detection arrays.