FINAL PROPOSAL
SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS
ANADROMOUS FISH EVALUATION PROGRAM
2014 PROJECT YEAR

I. Basic Information

A. Title

Juvenile Salmonid Dam Passage and Survival at McNary and John Day Dams, 2014

B. Project Leaders

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C. Study Codes

SPE-W-12-4 and SPE-P-08-3

D. Anticipated Duration

August 1, 2013 to June 30, 2015

E. Date of Submission

June 12, 2013 (Preliminary)

July 15, 2013 (Final) Revised September 13, 2013

II. Project Summary

A. Project Goal(s)

The goal of this integrated study is to evaluate the overall performance of structural and operational improvements designed to benefit juvenile salmonids by estimating dam passage survival and associated metrics for yearling Chinook salmon and steelhead at McNary Dam (MCN) in spring and subyearling Chinook salmon in summer at MCN and John Day Dam (JDA) in 2014. Metrics will be evaluated relative to performance standards specified in the 2008 Federal Columbia River Power System Biological Opinion (FCRPS BiOp) and the 2008 Columbia River Fish Accords.

B. Objectives

Objectives for BiOp/Fish Accords performance evaluations for each dam are as follows:

BiOp/Fish Accords

To evaluate performance at MCN and JDA as specified in the 2008 FCRPS BiOp and the 2008 Columbia River Fish Accords, five performance measures will be estimated:

1. Dam passage survival.[(a)] Performance[(b)] should be >96% survival for spring stocks (i.e., yearling Chinook salmon and steelhead) and >93% survival for summer stocks (i.e., subyearling Chinook salmon). Survival should be estimated with a standard error (SE) <1.5%.
2. Spill passage efficiency.[(c)]
3. Forebay residence time.[(d)]
4. Tailrace egress time.[(e)]
5. Forebay-to-tailrace survival.[(f)]

Additional Metrics and Tasks

6. Fish passage efficiency also will be estimated.
7. The implementation plan will be updated to reflect 2014 procedures and protocols.
8. For JDA, all metrics listed above (Items 1-6) will be estimated separately for 2-day long 30% and 40% spill conditions that will alternate systematically during the summer study.

C. Methods

We propose to conduct the 2014 BiOp compliance tests at MCN in spring and at MCN and JDA in summer. The study will be designed and conducted as a single, integrated unit. Integrating activities across elements will permit significant economies of scale not available if planning and implementation were conducted independently for separate Anadromous Fish Evaluation Program (AFEP) projects. The proposal has a top-down structure wherein the experimental design determines the major components to implement the BiOp/Accords measures, including the number of fish implanted with micro-acoustic transmitters (AMTs) to be released, release locations and schedule, the location for receiving arrays at dam faces and in the river, the requirements for data to meet analysis model needs, and the format and schedule for presentation of results.

The Juvenile Salmon Acoustic Telemetry System (JSATS) consists of the implantation of JSATS AMTs and passive integrated transponders (PITs), cabled time-synchronized and autonomous acoustic

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(a) Dam passage survival is defined as survival from the upstream face of the dam to a standardized reference point in the tailrace.
(b) Performance as defined in the 2008 FCRPS BiOp, Section 6.0.
(c) The 2008 Fish Accords define spill passage efficiency as the fraction of fish passing a dam via the spillway and surface flow outlets,
(d) Forebay residence time is defined as the time of first detection on the forebay entrance array until the time of last detection on the dam-face array.
(e) Tailrace egress time is defined as the time of last detection on the dam-face array until the time of last detection on the array at the downstream tailrace boundary.
(f) Forebay-to-tailrace survival is defined as survival from the forebay entrance array to the tailrace egress array.

receiver systems, and data management and processing applications. The choice of JSATS as telemetry method for estimating juvenile salmonid survival is driven mostly by the relatively small size of AMTs and the high detection probabilities of arrays of underwater acoustic receivers (>98% at dam-face arrays; >95% at autonomous arrays above Bonneville Dam [BON]). JSATS AMTs will transmit at 3 pulses per second; will have median size 10.8 mm long, 5.3 mm wide, 3.4 mm thick; and will weigh 304 mg in air. AMT size was reduced significantly between 2004, when the first JSATS AMTs were implanted in fish, and the AMT used in 2012 and 2013 survival studies. Smaller AMTs hold promise for reducing AMT effects that are common to most implantation studies. If available in 2014, subyearling Chinook will be implanted with the JSATS injectable AMT that is smaller and lighter than the current surgically implanted AMT.

The proposed study for 2014 will be based on a customized experimental design adapted from Skalski (2009), which was developed for three consecutive dams on the lower Columbia River (LCR) (JDA, The Dalles Dam (TDA), and BON). The basic design involves estimating the survival of virtual releases of fish implanted with AMTs known to have passed through a dam relative to a paired-release-survival estimate for fish implanted with AMTs released at two locations in the downstream tailwater. The single-release survival estimate for fish that passed through a dam (S_1) divided by the quotient of the paired reference release survival estimates (S_2/S_3) will provide an unbiased estimate of dam passage survival. Replication of this basic design for MCN and two stocks of fish in spring will require fish releases at three locations, the deployment and servicing of the MCN time-synchronized, dam-face acoustic receiver arrays, and the deployment and servicing of seven arrays of autonomous acoustic receivers. In summer 2014, replication of the basic design for MCN and JDA will require fish releases at five locations, and deployment and servicing of dam-face arrays at MCN and JDA, and ten arrays of autonomous receivers. With the release of an adequate number of fish at appropriate times and locations to allow for mixing in common tailwaters and high detection probabilities on dam-face and autonomous arrays, the basic design will provide unbiased estimates of dam passage survival with precision that meets BiOp requirements (SE <0.015).

Estimation of spill passage efficiency, forebay residence time, tailrace egress time, and forebay to tailwater survival, as stipulated in the 2008 Columbia River Fish Accords, requires the addition of forebay entrance arrays and tailrace exit arrays at each dam. In addition, unbiased estimates of spill passage efficiency, as defined by the Fish Accords, requires detection of fish in each forebay and an assignment of a route of passage as powerhouse or spillway, based on detections on two independent dam-face arrays. With the addition of forebay entrance and tailrace exit arrays at each dam, the enhanced experimental design can yield all of the estimates required by the 2008 Fish Accords. The number of fish passing through turbines will be estimated by subtracting PIT detection estimates of juvenile bypass system (JBS) passage from acoustic estimates of total powerhouse passage. Fish passage efficiency will be estimated as the proportion of fish passing through non-turbine routes.

Estimates of required sample sizes dictate the need to surgically implant with PITs and AMTs and release 6500 live yearling Chinook salmon and 6500 juvenile steelhead in spring and 8525 live subyearling Chinook salmon in summer. Sample sizes for yearling Chinook salmon and steelhead being released at R_1, R_2 and R_3 were increased to assure that estimates met precision requirements specified in the BiOp (i.e., SE <0.015). About 50 dead fish of each run/species will be surgically implanted with

AMTs and released in the tailrace below each dam to verify that dead fish are not detected on arrays of autonomous nodes used to estimate survival. An additional 150 AMTs will be required for implantation in dead fish destined for tailrace releases and 200 more AMTs will be needed for spring and summer AMT-life studies. Therefore, a total of 21,875 AMTs will be needed for the BiOp studies described in this proposal.

Fish will be selected for implantation from run-of-river fish sampled in the JDA Smolt Monitoring Facility (SMF). Damage or infection will be noted by members of the surgical implantation crew and surgeons. Length frequencies and the condition of implanted and unimplanted fish will be compared to assess how representative implanted individuals are of the run at large. Fish will be collected in the morning, held overnight, implanted with PITs and JSATS AMTs, and held another 24–36 hours before they are released. Teams will keep a running tally of the few fish that happen to die after surgery. Those fish will be used for dead-fish releases in tailraces below study dams, and additional fish will have to be intentionally sacrificed to meet required sample sizes for implanted dead fish (50 fish per run and study dam each season).

All fish will be collected and implanted with AMTs at the JDA SMF and transported by truck to release sites. Collecting fish from a single source will eliminate fish source bias, and having the same surgeons contributing similar numbers of fish to sets of fish releases will minimize surgeon bias. Routes of travel will be adjusted so that transport times will be similar for each release in a pair of reference releases for each dam. There will be three release sites in spring (R1 to R3) and five in summer (R1 to R5). Release locations, followed in parentheses by the site name, river kilometer (rkm), and fish transport time from the JDA SMF are as follows: Port Kelley, Washington (R1; CR503; 1.8 h); MCN tailrace (R2; CR468; 1.7 h); upstream of the Blalock Islands (R3; CR451; 1.7 h); JDA tailrace (R4; CR346; 0.6 h); and Celilo, Oregon, (R5; CR325; 0.6 h). The final location "upstream of the Blalock Islands" will be determined from accessibility after a site visit. Per request during the August 22, 2013 SRWG meeting the R3 release and associated array was moved from CR422 to CR451, upstream of the Blalock Islands, due to high predation mortality through this reach of the reservoir. The R3 location change between 2012 and 2014 will not affect the virtual paired-release survival estimate at MCN because of the model design. Moving of the R3 release to CR451 will proportionally influence the S_2 and S_3 survival estimate, therefore not affecting the S_{dam} survival estimate. The rational for moving R3 upstream to CR451 is to increase the precision of the survival estimate without having to drastically increase the release numbers of fish implanted with AMTs. An array will be located at CR422 in 2014 but will not be used as a reference release site. The process of transporting and releasing fish will be standardized as much as possible. This includes equipment and oxygen and temperature monitoring systems. Successive releases of fish at sites downstream of Port Kelley, Washington (CR503), will be delayed by expected travel times through all upstream reaches so that treatment fish passing through dams mix with fish in reference releases in common downstream tailraces and tailwaters. One half of the release sequences that begin at Port Kelley will begin at 1000 hours and the other half will begin at 2200 hours so that day and night detections are represented in pooled seasonal estimates of dam passage survival for each fish stock and project. At each release site, fish will be released at five locations along a line transect across the river.

In 2014, we plan to strategically deploy double arrays of cabled hydrophones at MCN and arrays of autonomous receivers at seven cross sections of the LCR in spring. In summer, double arrays will be deployed at MCN and JDA along with ten arrays of autonomous receivers. Array names will be a concatenation of "CR" for Columbia River, and a three-digit number indicating the nearest whole rkm upstream from the mouth of the Columbia at the Pacific Ocean. Arrays located on dam faces also will have the letter "a" or "b" added as a suffix to the name to designate each of two independent groups of hydrophones that will be used to calculate the detection efficiency of a combined dam-face array using the Lincoln/Petersen single mark-recapture model (Seber 1982:59-70). In spring, arrays will be located at the MCN forebay (CR472); MCN dam face (CR470a and CR470b); MCN tailrace (CR468); upstream of the Blalock Islands (CR451); Crow Butte (CR422); JDA forebay (CR351); Celilo, Oregon (CR325); and TDA forebay (CR311). In summer, additional arrays will be located at the JDA dam face (CR349a and CR349b); JDA tailrace (CR346); Hood River, Oregon (CR275); and BON forebay (CR236).

Arrays of acoustic receivers serve several different purposes. Detections on forebay entrance arrays are used to regroup fish to form virtual releases for estimating forebay to tailrace survival and the first detection of each fish is used as a starting time for calculating forebay residence time. Detections on dam-face arrays are used to regroup fish to form virtual releases for estimating dam passage survival and to track fish passing into the powerhouse and spillway. The time of last detection on the dam-face arrays provides the end time for calculating forebay residence time and the starting time for calculating tailrace egress time. Tailrace egress arrays sample fish that passed through the dam and provide the time of last detection for calculating tailrace egress time. Survival detection arrays include dam-face arrays and arrays that are not associated with the tailrace of a dam, where the potential exists for detecting fish that died during passage through the dam. Forebay entrance and survival detection arrays will be densely populated to maximize detection efficiencies so that estimates of dam-passage survival and forebay-to-tailrace survival are based on as many fish detections as possible.

Forebay entrance and tailrace exit arrays will be located at the extent of hydraulic influence of each dam. The distance of forebay entrance arrays upstream from spillways will be about 2 km for MCN and 1.4 km for JDA. Tailrace egress arrays will be located downstream about 2 km from MCN and 3 km from JDA.

Cabled, time-synchronized hydrophones will be deployed at two elevations on every pier at spill bays and turbines, including skeleton bays at JDA. Extra hydrophones will be deployed at the ends of the spillway or powerhouse to improve detection in those areas. We expect to deploy 23 acquisition systems and 91 hydrophones at MCN, and 22 systems and 86 hydrophones at JDA. PIT detections in the JBS at both MCN and JDA will be used to identify JBS-passed fish, and AMTs tracked passing into turbines that fail to be PIT detected will be assigned to turbine passage. Spill-passage efficiency will be estimated as the proportion of fish passing the dam via the spillway as identified in the Fish Accords. Experience suggests that detection efficiencies of dam-face arrays will be very close to 100%.

Dam-passage survival for two spill-discharge treatments will be calculated at JDA for the summer season and will require a definition of spill treatments sequences and change times. For JDA in summer, the first 2-day spill treatment will begin on 6/10 at 2100 hours and will end 48 hours later when the alternate 48-h spill treatment begins, and treatments will alternate every 48 hours through 7/18. The fixed block design minimizes the variability of environmental conditions within blocks.

Findings for purposes of the BiOp and Fish Accords will be described in detail in BiOp reports for each dam. The BiOp reports will be concise but will include all information required to assess the validity of results. The intent is to report bullet-proof data, meaning that AMT-life corrections will have been made, surgeon effects accounted for, diagnostics performed and passed, assumptions tested and passed, and all quality assurance/quality control (QA/QC) steps completed. These reports will not include detailed estimates of route-specific passage and survival. Those data will have been included in a MCN technical report. The data will also be collected for JDA in summer and could be analyzed and reported, if the regional managers decide that such an analysis is warranted.

D. Relevance to the 2010 NOAA Fisheries Supplemental Biological Opinion for Operation of the Federal Columbia River Power System (FCRPS) and/or the Columbia Basin Fish Accords

During 2014, the Portland and Walla Walla Districts intend to obtain data on biological performance measures mandated in the 2008 BiOp on operation of the FCRPS and the Memorandum of Agreement between the lower river treaty tribes and the Action Agencies, called the Fish Accords. The FCRPS BiOp contains a Reasonable and Prudent Alternative (RPA) that includes actions calling for measurements of juvenile salmonid survival (RPA 52.1 and 58.1) and habitat usage (RPA 61.1 and 61.3) in the lower Columbia River and estuary. These RPAs are being addressed as part of the federal research, monitoring, and evaluation (RME) effort for the FCRPS BiOp. Most importantly, the FCRPS BiOp includes performance standards for juvenile salmonid survival in the FCRPS that the Portland District must compare its measurements against, as follows (excerpted from RME Strategy 2 of the RPA):

> <u>*Juvenile Dam Passage Performance Standards*</u> -- *The Action Agencies juvenile performance standards are an average across Snake River and Lower Columbia River dams of 96% dam passage survival for spring Chinook and steelhead and 93% dam passage survival for subyearling Chinook salmon. Dam passage survival is defined as survival from the upstream face of the dam to a standardized reference point in the tailrace.*

The Memorandum of Agreement between the Three Lower River Tribes and the Action Agencies, called the "Fish Accords," contain three requirements relevant to the 2014 survival studies (excerpted from MOA Attachment A):

> <u>*Dam Passage Survival Performance Standard*</u> -- *meet 96% dam passage survival for yearling Chinook and steelhead and 93% for subyearling Chinook and achievement of the standard is based on two years of empirical survival data...*
>
> <u>*Spill Passage Efficiency and Delay Metrics*</u> -- *Spill passage efficiency (SPE) and delay metrics under current spill conditions…are not expected to be degraded ("no backsliding") with installation of new fish passage facilities at the dams…*
>
> <u>*Future Research, Monitoring and Evaluation*</u> -- *The Action Agencies' dam survival studies for purposes of determining juvenile dam passage performance will also collect information on SPE, BRZ to BRZ survival and delay as well as other distribution and survival information. SPE and delay metrics will be considered in the performance check-ins or with COP updates, but not as principal or priority metrics over dam survival performance standards. Once a dam meets the survival*

performance standard, SPE and delay metrics may be monitored coincidentally with dam passage survival testing.

Fish Population Status Monitoring -- The Action Agencies will enhance existing fish population status monitoring performed by fish management agencies. This is to include the monitoring of juvenile fish migrations at mainstem hydroelectric dams using smolt monitoring and the PIT-detection systems.

Juvenile In-river Survival Performance Metric -- The FCRPS Action Agencies will annually measure the survival of in-river migrating fish and compare these numbers with COMPASS model estimates based on the conditions experienced and the expected benefits of completed hydro actions (SCA, In-river Juvenile Survival Appendix).

Monitor and Evaluate Migration Characteristics and River Condition -- The Action Agencies will monitor and evaluate the following biological and physical attributes of anadromous fish species migrating through the FCRPS on an annual basis: Monitor and document the condition (e.g., descaling and injury) of smolts at all dams with JBS systems, identify potential problems, and evaluate implemented solutions.

III. Project Description

A. Background

i. Problem Description

Over the past 25 years, extensive work has been conducted to improve juvenile fish passage and survival at LCR dams. The current need is to evaluate the influence improvements at each of these dams has on fish survival and metrics relative to BiOp and Fish Accord standards. Progress at dams has entailed structural and operational improvements designed to benefit juvenile salmonid passage while minimizing impacts on power production as much as possible. For example, extensive work has been done on in-turbine screen systems and JBS facilities at MCN and JDA; numerous spill-level evaluations have been conducted at both dams; and prototype top-spill weirs (TSWs) have been installed and evaluated as ways to improve juvenile fish passage performance and survival at MCN (Adams and Counihan 2009; Adams and Liedtke 2010; Adams and Evans, 2011)). Two TSWs also were installed at the JDA spillway and thoroughly evaluated in 2008 (Weiland et al. 2009). The 2008 BiOp called for performance standards and required the U.S. Army Corps of Engineers (Corps or USACE) to collect data on juvenile salmonid survival rates to compare to the BiOp standards starting in 2011. In 2010, the first official BiOp survival study was conducted at TDA, and three BiOp compliance tests were conducted at JDA, TDA, and BON in spring 2011. The summer 3-dam study for 2011 was cancelled because of exceptionally high river discharge. In 2012 two BiOp compliance studies were conducted in the spring at MCN and JDA, and in summer, BiOp compliance studies were conducted at all four lower Columbia River Dams.

In the past, route-specific survival studies were often conducted to evaluate the performance of structural or operational improvements at specific routes. In 2014, compliance testing will be streamlined to provide specific pass or fail answers using a highly prescribed study format. Data for determining route-specific passage and survival will still be collected in case there is a need to know why a dam might have failed a compliance evaluation, but such detail will not be routinely included in BiOp study reports. If the regional managers decide that route-specific information is required to determine why a standard was not met, they can fund further analyses as needed. Route-specific survival information may be critical to test structures or operations and identify new ways for improving dam-passage survival.

ii. Literature Review

Baseline biological data on fish distributions were summarized by Giorgi and Stevenson (1995) for JDA, TDA, and BON and by Anglea et al. (2001) for JDA. During the early 2000s, fish passage proportions were most often estimated using fixed-aspect hydroacoustic or radio-telemetry methods, and survival estimates with active transmitters were based on detections of radio-tagged fish above and below the dams.

The use of radio telemetry to estimate survival of implanted fish at JDA was evaluated and deemed feasible in 1999 (Counihan et al. 2002a). Survival studies of juvenile salmonids passage through JDA also were conducted in 2000 (Counihan et al. 2002b), 2002 (Counihan et al. 2006d), and 2003 (Counihan et al. 2006e). Reach survival was conducted from the release point above JDA to the JDA forebay and from the JDA dam face to the forebay of TDA (Counihan et al. 2002b and 2006a).

Before 2006, acoustic telemetry had only been used twice on Portland District projects, once at BON (Faber et al. 2001) and once at TDA (Cash et al. 2005). These studies focused on fish approach and passage. The JSATS was designed to meet the needs of passage and survival studies for juvenile salmonids in the Columbia River basin, and it avoids many of the limitations of other telemetry systems. In 2006, non-route specific survival studies were conducted at JDA, TDA, and BON to assess the feasibility of using the JSATS for estimating dam passage survival. In 2007, a JSATS acoustic telemetry survival study was conducted at the Bonneville spillway (Ploskey et al. 2008), and in 2008, a JSATS route-specific survival study was conducted at JDA, the BON spillway, and BON Powerhouse 2 (B2). In 2009, JSATS route-specific studies were conducted at JDA (Weiland et al. 2011) and B2 (Faber et al. 2011). The technology and tools for using JSATS are maturing thanks to significant advances with each year of study. The dam-face arrays deployed at JDA in 2008 detected over 99% of the juvenile salmonids surgically implanted with AMTs approaching the dam, and most approaching fish were successfully tracked. Over 98% were assigned a route of passage with high confidence. In 2009, the double array at JDA detection efficiency was 96.4% for yearling Chinook salmon, 95.6% for steelhead, and 97.9% for subyearling Chinook salmon. High detection efficiencies also were observed in survival studies conducted in 2010, spring 2011, and spring and summer 2012.

The U.S. Geological Survey used acoustic-telemetry methods to evaluate route-specific passage and survival of juvenile salmonids at MCN between 2004 and 2009 (Perry et al. 2006, 2007; Adams et al. 2008; Adams and Counihan 2009; Adams and Liedtke 2010; Adams and Evans, 2011). We made use of survival and detection probabilities in these reports to model sample sizes required to provide adequate precision for dam passage survival estimates.

iii. Site Descriptions

McNary Dam, located at Columbia River km 470, includes a navigation lock, a 399-m-long spillway with 22 vertical lift gates, and a 433-m-long powerhouse with 14 turbines (Figure 1). Temporary spillway weirs were installed at the southern end of the spillway in previous years to improve juvenile fish-passage performance. Extended-length screens are in all turbine units, and there is a full JBS terminating at a SMF located on the Oregon shore. In 2012, the JBS outfall was moved downstream and extended further into the river from the shoreline. The spillway and powerhouse are aligned and are perpendicular to the river flow. McNary Dam is operated by the Walla Walla District, USACE.

Figure 1. Aerial Photograph of McNary Dam. The Washington shore is on the upper left side of the picture (north) and the Oregon shore with the Smolt Monitoring Facility is on the lower right side (south).

John Day Dam, located at Columbia River km 349, includes a navigation lock, a 374-m-long spillway with 20 bays. The Portland District installed TSWs in spill bays 15 and 16 in 2008 and 2009. The TSWs were moved to spill bays18 and 19 near the south end of the spillway in 2010 improving juvenile salmonid passage performance. The 602-m-long powerhouse comprises 16 turbines and 4 skeleton bays that are adjacent to the spillway (Figure 2). Standard-length submerged traveling screens are in all turbine units, and there is a full JBS terminating at a SMF located on the Oregon shore.

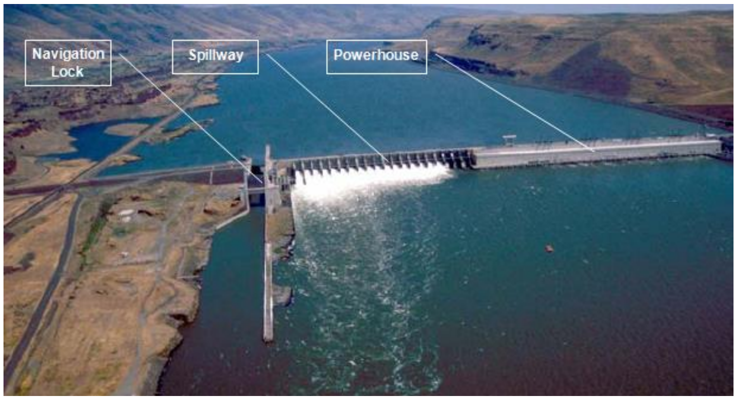

Figure 2. Aerial Photograph of John Day Dam from a Downstream Location. The Washington shore is on the left side of the picture (north) and the Oregon shore upstream of the Smolt Monitoring Facility is on the right side (south).

B. Objectives

Objectives for BiOp/Fish Accords performance evaluations for both dams are as follows:

BiOp/Fish Accords to evaluate performance at LCR dams as specified in the 2008 FCRPS BiOp and the 2008 Columbia River Fish Accords, five performance measures will be estimated:

1. Dam-passage survival. Performance should be >96% survival for spring stocks (i.e., yearling Chinook salmon and steelhead) and >93% survival for summer stocks (i.e., subyearling Chinook salmon). Survival should be estimated with a standard error (SE) <1.5%.
2. Spill passage efficiency.
3. Forebay residence time.
4. Tailrace egress time.
5. Forebay-to-tailrace survival.

Additional Metrics and Tasks

6. Fish passage efficiency also will be estimated.
7. The implementation plan will be updated to reflect 2014 procedures and protocols.
8. For John Day Dam, all metrics listed above (Items 1-6) will be estimated separately for 2-day long 30% and 40% spill conditions that will alternate systematically throughout each season.

C. Methods

All of the methods proposed for use in this study have a sound scientific basis and have been rigorously evaluated in previous JSATS studies or by other experts outside the basin. There are no methods, algorithms, or processes that have not or cannot be independently evaluated.

i. Experimental Design

The following material is excerpted from the executive summary in the *Statistical Design for the Lower Columbia River Acoustic-Tag Investigations of Dam Passage Survival and Associated Metrics* submitted by Dr. J.R. Skalski to B. Eppard on May 19, 2009.

In order to isolate dam passage survival, a modification of the classic release–recapture design will be employed (Figure 3). Using hydrophone arrays at the face of the dam, implanted fish known to have passed the dam will be used to construct a "virtual" release group. This release group will be used to estimate survival through the dam and a segment of the river downstream based on the single release-recapture model. The downstream survival detection arrays will be located to minimize the prospect of false positive detections of fish that die during dam passage. A sequential paired release below the dam will then be used to estimate the survival between the tailrace and this first downstream detection array. The quotient of the single-release estimate (S1) divided by the paired-reference-release survival estimate (S2/S3) will provide an unbiased estimate of dam passage survival.

The release-recapture model will benefit from several design aspects, helping to assure reliable estimates of dam passage survival. First, by using upstream releases, a representative group of implanted fish arriving and passing through the dam can be constructed using a set of forebay hydrophone arrays. Second, the first survival detection site can be placed sufficiently far downstream in order to avoid false positive detections from dead implanted fish carried downriver after passing through the dam. Finally, a paired release of comparably implanted and handled fish can be used to estimate survival in the reach between the dam tailrace and the first detection array. This estimate of reach survival is then used to adjust the initial survival estimate through the dam for the extended downstream array location used in avoiding dead implanted fish detections. This virtual/paired-release design will avoid potential sources of bias better than any other study design option.

The survival study of LCR dams will be coordinated as one integrated investigation based upon the study designs outlined for spring (Figure 4) and summer (Figure 5) 2014. In spring, a total of three different release sites, one virtual release of fish, a dam-face array, and six autonomous node arrays will be used to generate estimates of dam passage performance and survival for MCN (Figure 4). In summer, a total of five different release sites, two virtual releases of fish regrouped at two dam-face arrays, and nine autonomous node arrays will be used to generate estimates of dam passage performance and survival at MCN and JDA (Figure 5).

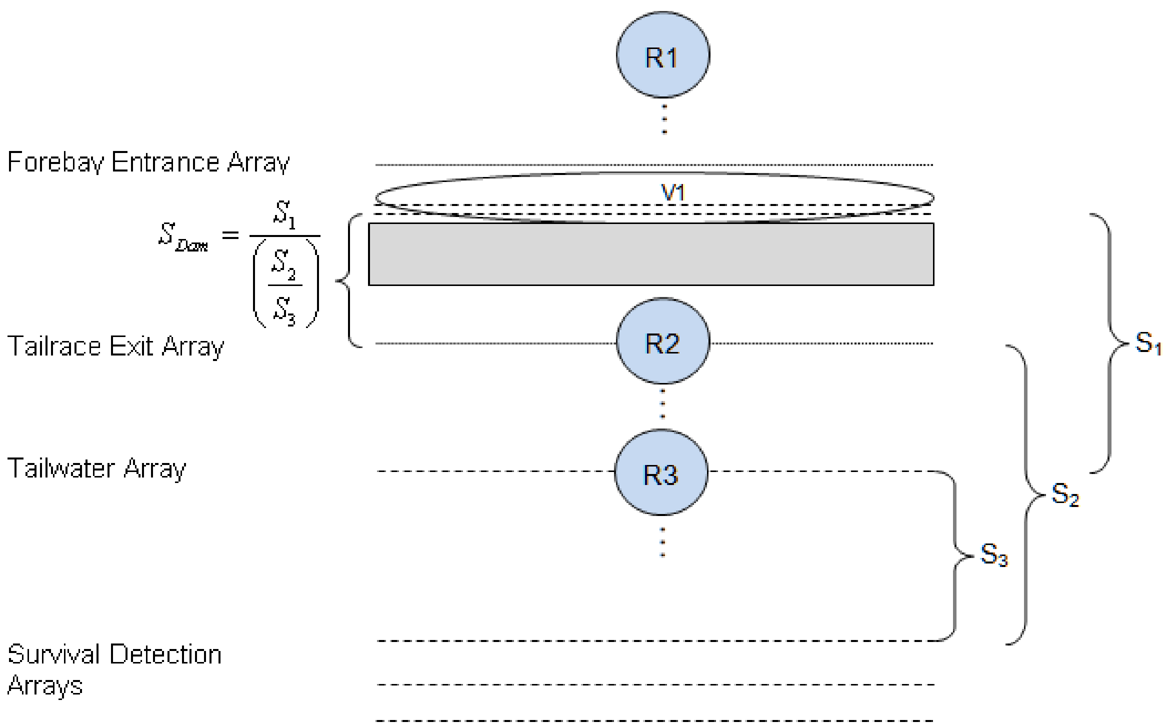

Figure 3. Study Design Diagram for a Single Dam. The diagram shows three fish release sites as blue circles (R1 to R3), forebay entrance and tailrace exit arrays as single solid lines, the two independent dam-face arrays that will be used to regroup fish to form a virtual release (V1) as closely spaced dashed lines, and four downstream survival detection arrays as single dashed lines.

All fish will be collected and implanted with AMTs at the JDA SMF in both spring and summer so that all fish are from a single source and are surgically implanted with AMTs by the same teams of surgeons throughout the study. The JDA SMF at rkm 348 is well located to provide a single source for distributing implanted fish between the most upstream site at Port Kelley (CR503 and the most downstream site at Celilo, OR (CR325). Individual surgeons will contribute similar numbers of fish to releases, and this will be important for minimizing any systematic bias associated with having multiple surgeons. Having a single surgical implantation site will allow for better control of surgeon rotations and contributions of fish to various release sites than could be achieved at multiple surgical implantation sites.

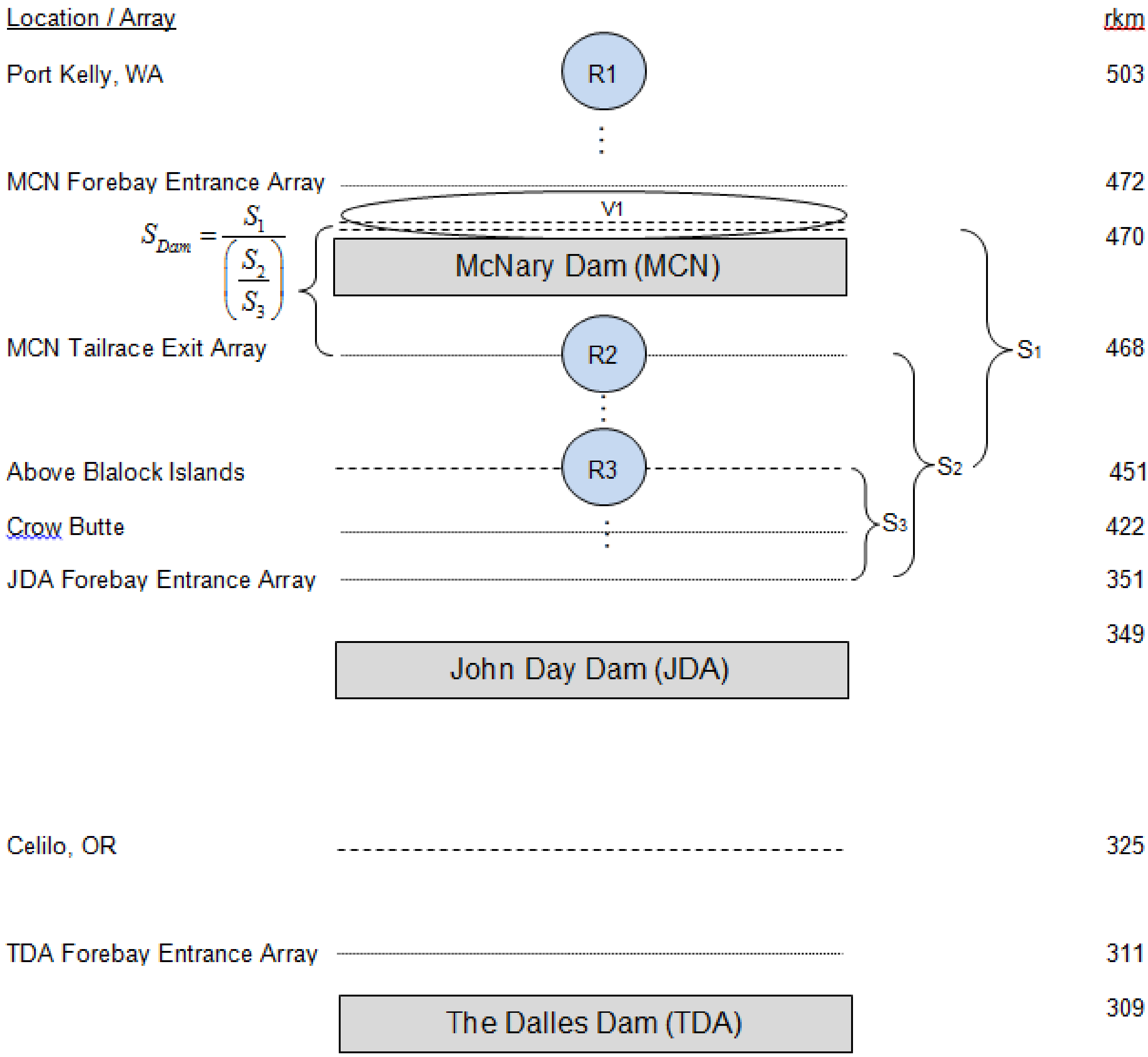

Figure 4. Diagram of the Spring BiOp/Fish Accord Compliance Evaluations at McNary Dam. Three fish release sites (R1-R3) and a virtual releases site at V1 are depicted, along with the independent dam-face detection array at MCN (double dashed lines), autonomous survival detection arrays (single dashed lines) and travel time detection arrays (single solid lines in forebays and tailraces).

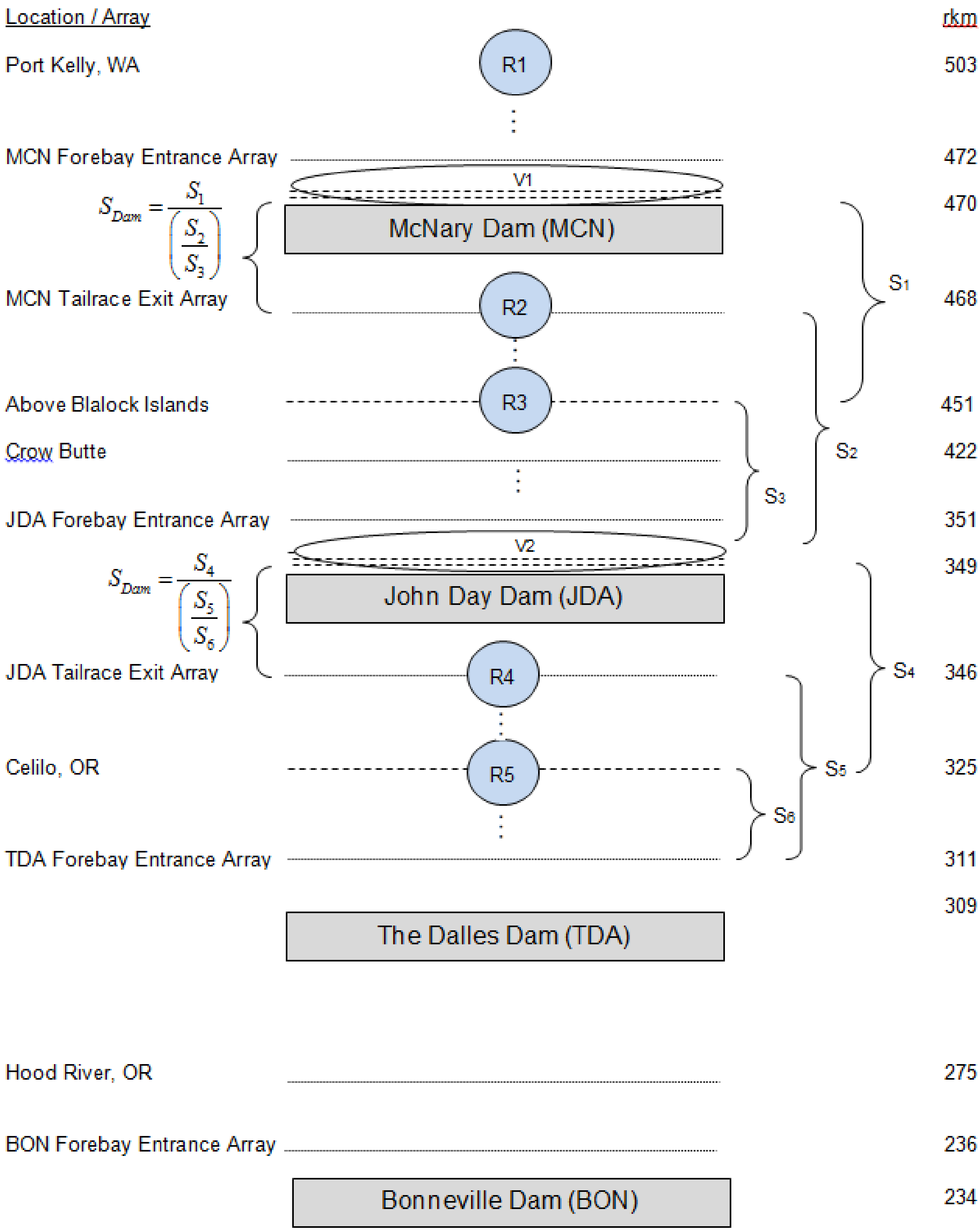

Figure 5. Diagram for the Summer BiOp Compliance Evaluations at McNary and John Day Dams. Five fish release sites (R1–R5) and two virtual release sites (V1-V2) are depicted, along with two independent dam-face detection arrays (double dashed lines), autonomous survival detection

arrays (single dashed lines) and travel time detection arrays in forebays and tailraces (single solid lines).

The process of transporting and releasing fish will be standardized as much as possible. Every truck and trailer will be equipped with an oxygen tank and oxygen distribution system. Dissolved oxygen and temperature will be monitored continuously during transport, and oxygen flow increased if necessary. In summer, ice may be hauled and added as needed to keep temperatures from increasing more than 2°C. Successive releases of fish at sites downstream of Port Kelley, Washington, at CR503, will be delayed by expected travel times for fish passing through successive reaches so that treatment fish passing through dams mix with fish in reference releases in downstream tailraces and tailwaters. One half of the release sequences that begin at Port Kelley will begin at 1000 h and the other half will begin at 2200 h so that day and night detections are represented in pooled seasonal estimates of dam passage survival for each fish stock and project. At each release site, fish will be released by boat at five locations along a line transect across the river.

Routes of travel will be adjusted so that transport times will be very similar for each release in a pair of reference releases. Transport times from the JDA SMF to various release sites are listed in Table 1.

Table 1. Transport Times from the JDA SMF to Various Release Sites. The route of shortest transport within each pair of references releases was lengthened to equalize transport times for each pair.

Season	JDA SMF to Release Site	Drive Time (h)
Spring and Summer	Port Kelley, WA (CR503)	1.8
Spring and Summer	MCN Tailrace (CR468)	1.7
Spring and Summer	Upstream of Blalock Islands (CR451)	1.7
Summer	JDA Tailrace (CR346)	0.6
Summer	Celilo, Oregon (CR325)	0.6

We used the Sample Size Model version 2.0.8 for a virtual paired-release study design to estimate numbers of fish that would need to be released (Table 2) to achieve an expected standard error <0.015 for dam-passage survival estimates. Sample size calculations for the precision of the survival studies is consistent with methods presented by Cochran (1977:75-76, 77-78), Thompson (1992:31-32), Snedecor and Cochran (1989:58), Williams et al. (2002:64), and Levy and Lemeshow (1999:70-74). We based input survival estimates on published rates, and used the lower end of published estimates of detection probabilities.

Table 2. Proposed Numbers of Fish to be Released at Three Sites in Spring and Five Sites in Summer. Spring stocks include juvenile steelhead and yearling Chinook salmon, and the summer stock includes subyearling Chinook salmon.

Release Location	Rkm	Name	Each Spring Stock	Summer Stock
Port Kelley	503	R1	2500	2525
MCN Tailrace	468	R2	2000	2000
Above Blalock Islands	451	R3	2000	2000
JDA Tailrace	346	R4		1000
Celilo, OR	325	R5		1000
Total / Stock			6500	8525

ii. Equipment

The acoustic-telemetry equipment for the 2014 USACE survival studies will consist of JSATS AMTs for surgical implantation in fish, dam-face arrays of hydrophones, and arrays of autonomous nodes. An acoustic signal emitted by an AMT implanted in a test fish is received at an underwater hydrophone and sent to a digital signal processor in a computer where the waveform is detected, decoded, and output to a hard drive (Figure 6). Supporting equipment, such as trolley pipes and acoustic releases, will be required to deploy and retrieve the equipment, depending on the type of array.

Transmitters

The acoustic transmitter used in this study will be the Advanced Telemetry System 0.31 g AMTs for surgical implantation in yearling Chinook and steelhead in spring (Figure 7). In summer subyearling Chinook will potentially be implanted with the JSATS downsized injectable AMT. All AMTs will have a 3-s PRI. Each pulse from a JSATS AMT contains a complex encoded signal that uniquely identifies the transmitting AMT without a purposeful variation in pulse duration. Based on previous AMT-life studies, nominal AMT life should be about 23 days for the 3-s AMTs.

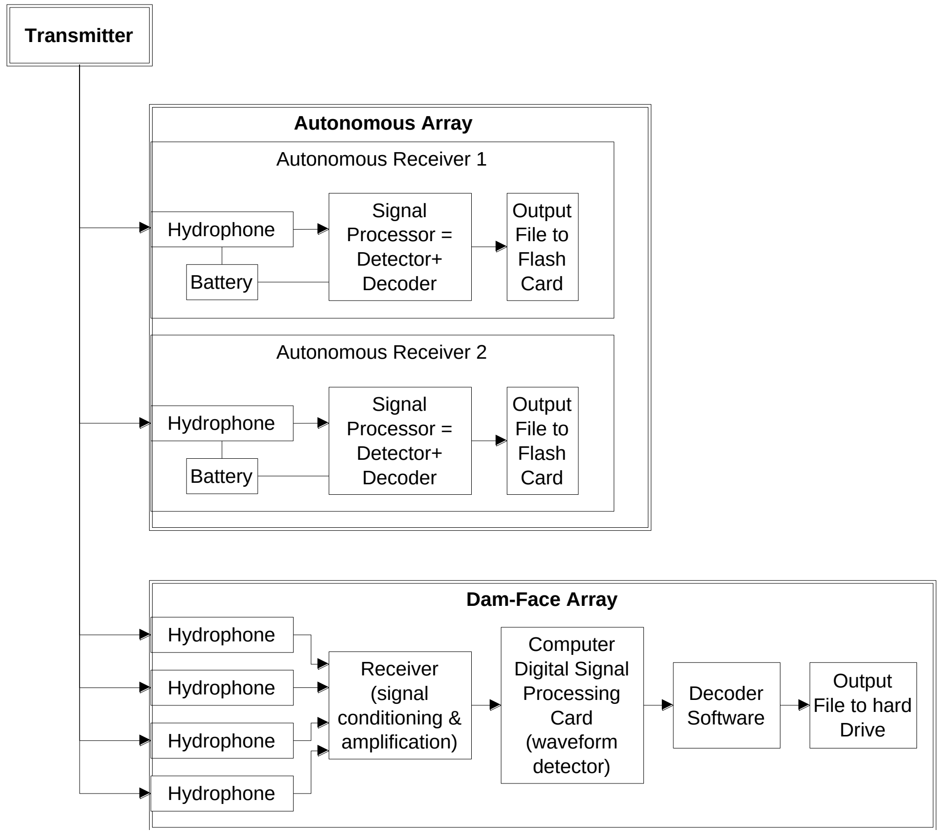

Figure 6. Acoustic Telemetry System

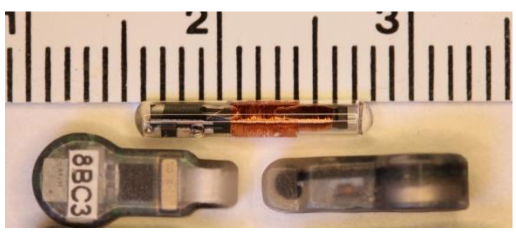

Figure 7. Ruler scale (top), the 0.31 g ATS JSATS AMTs (bottom), a PIT (Destron-Fearing Model TX1411ST; top).

Dam-Face Arrays

A modular JSATS cabled receiver consists of software, a computer, multi-function electronic cards including a global positioning system (GPS) receiver, a signal conditioning interface, four hydrophones, and four cables (Weiland et al. 2011). In the following sections, the "Modular JSATS Cabled Receiver" will be referred to as a dam-face receiver.

Dam-face elements, with the exception of hydrophones with unique characteristics and the software that controls computer function and signal processing, are off-the-shelf items. The software that controls computer function and signal processing is the property of the Corps and is made available by the Corps as needed. After competitive procurement of dam-face elements, processing and GPS cards are installed in the specified JSATS host computer following manufacturer instructions, then Corps-provided software is installed. Dam-face receiver integration is completed by connection of the signal condition interface and hydrophones.

The conditioned signal enters the signal-processing environment of the host computer where messages from JSATS AMTs are detected, decoded, and time stamped. The user may choose to output the message, time of arrival (TOA), and the message waveform. In most cases, only the decoded message and the TOA of the message will be required to meet study objectives. JSATS AMTs message detection and decoding take place in "real time" as the conditioned output from the signal conditioning interface are input to the host computer signal-processing environment. Figure 8 shows the sequence of signal processing that occurs for each hydrophone input channel. The current processing sequence provides the option to store candidate message waveforms as well as decoded AMT codes and TOA data.

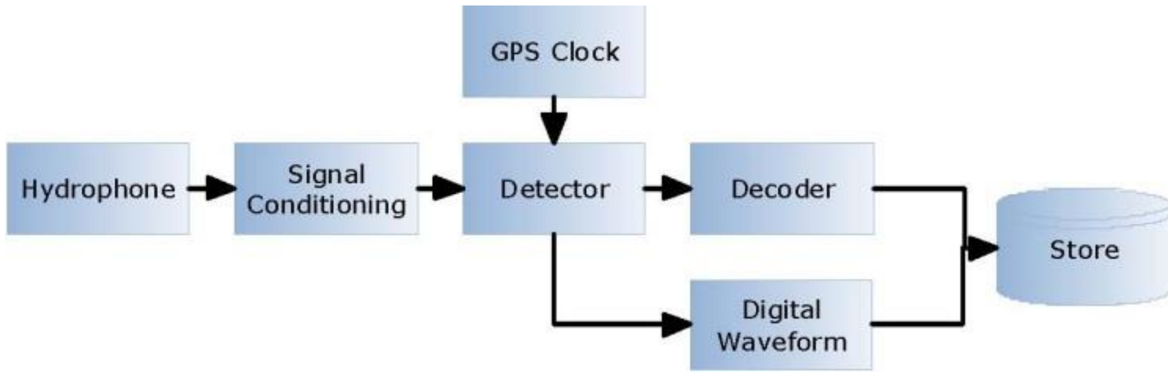

Figure 8. Flow Chart Depicting Flow of Data for the JSATS Cabled Receiver

Autonomous Node Receivers

An autonomous node receiver (AN; Figure 9) is a self-contained, battery-powered receiver that captures messages transmitted by AMTs implanted in juvenile salmon. The AN was designed for deployment throughout the Columbia and Snake river system where cabled receivers are either impractical or unsuitable (McMichael et al. 2010). The targeted application is detection of juvenile salmonids implanted with JSATS AMTs and decoding of received AMT messages. Valid decodes along with their TOAs provide data to estimate juvenile fish survival and observations of behavior. Decoded AMT messages are stored within the node and recovered when the node is serviced. Researchers filter acquired data to separate false positive decoded messages from valid decoded messages, and they perform other analyses of the acquired data to assure its validity for intended purposes.

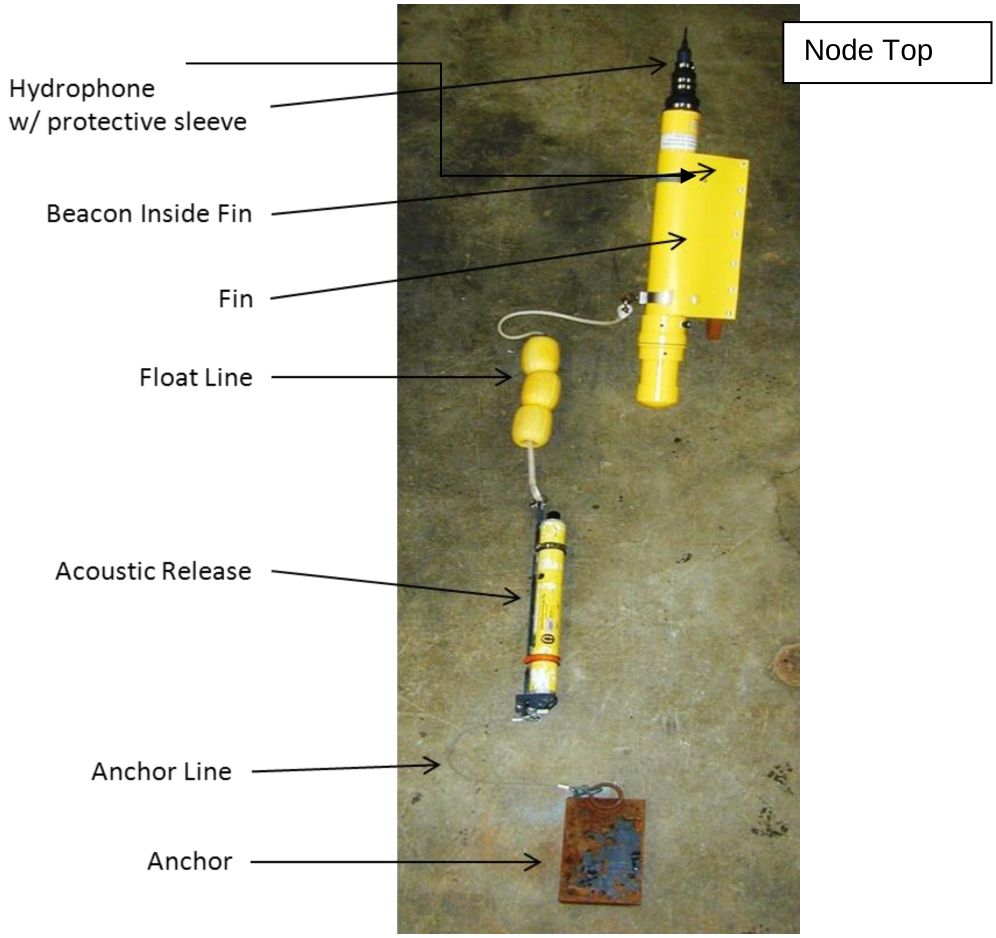

Figure 9. Autonomous Node Deployment Rigging with an Inter-Ocean Acoustic Release.

iii. Deployment

The locations of autonomous and cabled array systems were dictated primarily by the locations of dams, forebay and tailrace hydraulic influence, and professional opinion about desirable distances between fish release locations and detection arrays to avoid dead fish detections. Precise locations of autonomous arrays were influenced secondarily by the morphometry of channel cross sections to maximize the performance of autonomous node receivers. Deep narrow cross sections were preferred over wide and shallow ones to maximize AMT detectability. Locations of fish releases, arrays of autonomous nodes, and dam-face arrays are shown in Figure 10 for the spring study and in Figure 11 for the summer study.

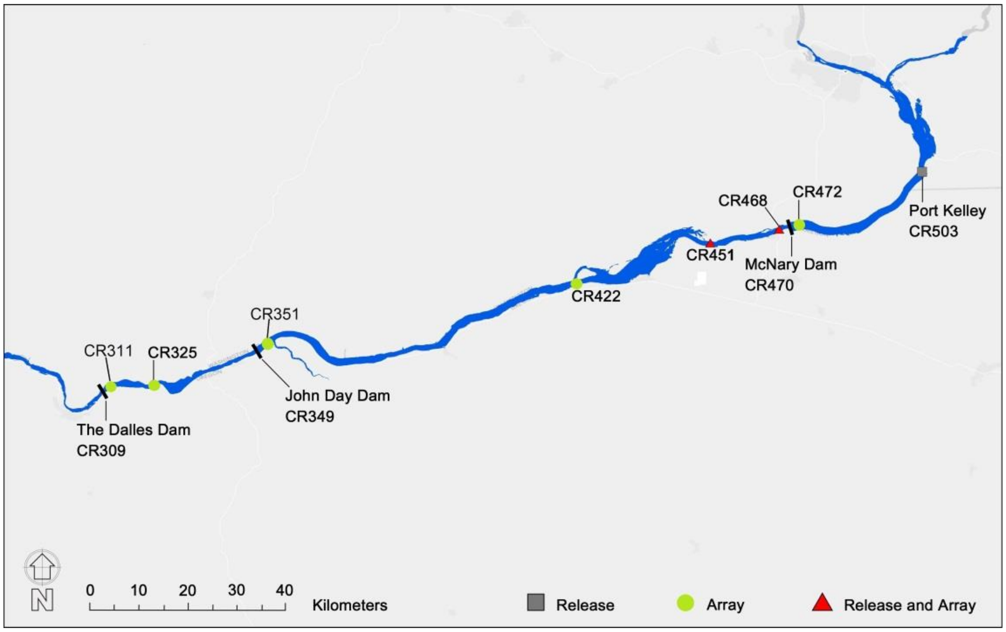

Figure 30. Map Showing Sites of Fish Releases, Dam-Face Arrays, and Autonomous Node Arrays for Spring 2014. Fish will be released from most upstream location in the study at Port Kelley but will not have an autonomous node array (grey box), two fish release sites having autonomous node arrays (red triangles), five sites will have only arrays of autonomous nodes (green circles) and a double array of cabled hydrophones will be deployed at McNary Dam. Columbia River (CR) km upstream of the river mouth and the Pacific Ocean is listed after each site label.

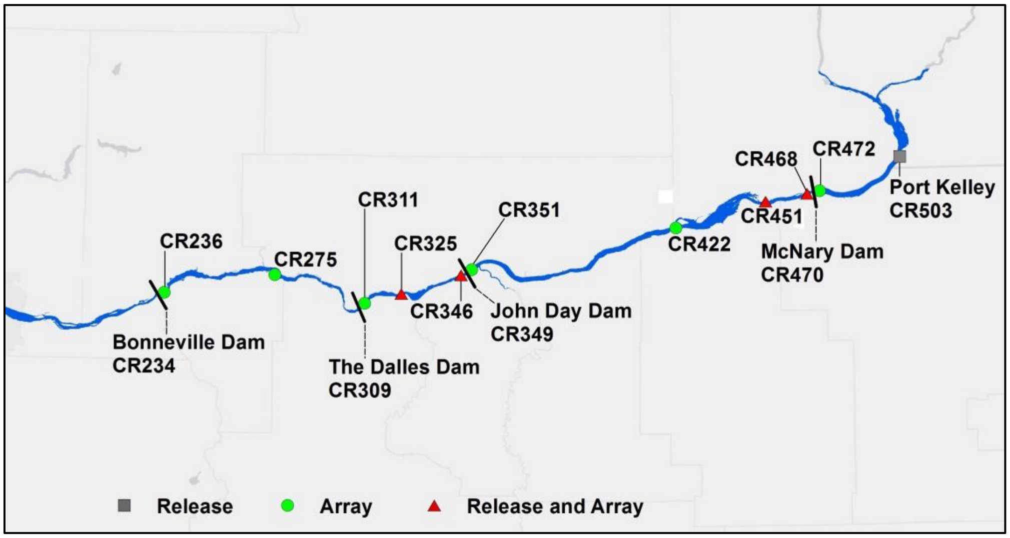

Figure 41. Map Showing Sites of Fish Releases, Dam-Face Arrays, and Autonomous Node Arrays for Summer 2014. Fish will be released from the most upstream location in the study at Port Kelley but will not have an autonomous node array (grey box), four fish release sites having autonomous nodes (red triangles), six arrays of autonomous nodes (green circles) and two double arrays of cabled hydrophones at McNary and John Day Dams. Columbia River (CR) km upstream of the river mouth and the Pacific Ocean is listed after each site label.

Dam-Face Arrays

The deployment of cabled dam-face, forebay, and tailrace arrays in 2014 (Figures 12 and 13) will be similar to highly successful deployments in the MCN Forebay in 2012 and JDA forebay from 2008 through 2012. The double arrays on the dam face had combined detection efficiency estimates that were essentially 100% for every major passage route through each dam.

Figure 12. Satellite Image of McNary Dam (MCN) (Courtesy of Google Earth) Showing Locations of Underwater Acoustic Receivers. Yellow icons show locations of slotted pipes on every pier adjacent to spill bays and turbines. Exact elevations of deployed hydrophones will be determined after a thorough evaluation of the acoustic environment in the forebay. Each pipe will receive two trolleys for deploying one deep and one shallow hydrophone at each pier. Blue icons at the ends of the dam indicate locations of single hydrophone deployments to detect fish approaching from the north or south shores. Also shown as red squares are eight autonomous nodes in a forebay entrance array located about 2 km upstream from the dam (right side) and three autonomous nodes in a tailrace egress array located about 2 km downstream of the dam.

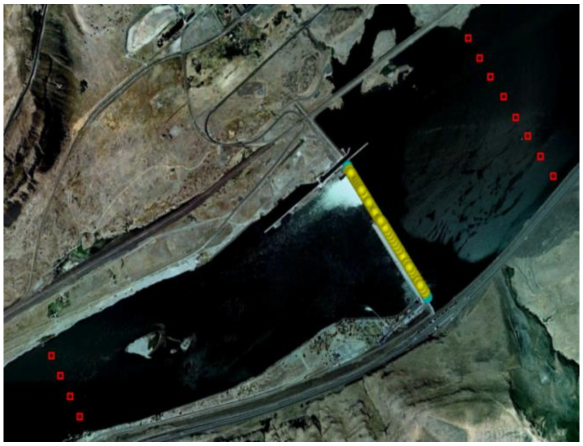

Figure 13. Satellite Image of John Day Dam (Courtesy of Google Earth) Showing Hydrophone Deployment Locations at the Spillway and Powerhouse (Yellow and Blue Icons). Spillway piers will have hydrophones deployed at two elevations: 1) 256 ft above mean sea level (MSL; 1 ft below minimum pool elevation of 257 ft and about 9.5 ft below the average pool elevation) and 2) 233 ft above MSL (about 30.5 ft deep relative to an average pool elevation). Locations on main piers between turbines also will have hydrophones at two elevations: 1) 256 ft and 2) 169 ft above MSL. Also shown as red squares, are eight autonomous nodes in a forebay entrance array (right) and four autonomous nodes in a tailrace egress array (left).

Hydrophones in a 4-hydrophone system will alternate between shallow and deep deployments and will be interleaved with hydrophones from another system to provide redundancy and two independent arrays for assigning fish passage and estimating detection efficiency. Figure 14 shows an example for hydrophones from two systems deployed at three adjacent turbines. Deployment at three adjacent spill bays would have a similar pattern.

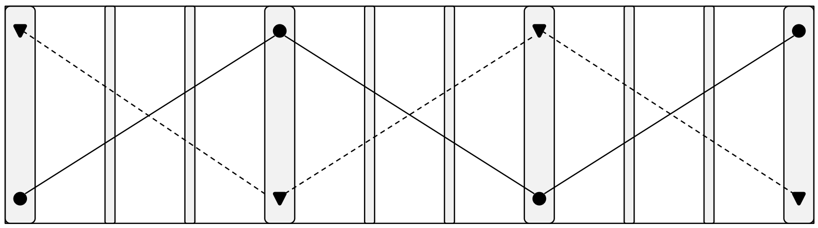

Figure 54. Upstream View of Hydrophone Deployments at Three Turbines Showing a Saw-Tooth Sampling Pattern to Independently Assign the Location of Last Detection. The circles denote the hydrophones of Array 1 and the triangles denote the hydrophones of Array 2.

iv. AMT Life Assessment

Two AMT life studies each using 100 AMTs will be conducted to support the 2014 survival studies. AMT life studies will be required for the 0.31 g, 3-s AMTs that will be implanted in yearling Chinook salmon and steelhead in spring and the downsized injectable AMT that, if available, will be implanted in subyearling Chinook salmon in summer. All AMTs in each of the lots will be thoroughly mixed, and 100 AMTs will be randomly selected from each of the AMT lots. The possibility of AMT failure will depend on travel time relative to battery life. An AMT-life curve will be constructed for each set of 100 AMTs and compared to the cumulative percent of AMTs passing tertiary arrays downstream of each dam.

AMTs in each AMT-life study will be enclosed in water-filled black plastic bags and suspended from a rotating foam ring using cable ties within a 2-m-diameter fiberglass tank. A small cut will be made on each bag to allow the ejection of air bubbles which accumulate over time inside the bag. Flow-through water will be delivered to the tank at a turnover rate sufficient to keep the foam ring rotating and maintain water temperature similar to river conditions. Four hydrophones will be used to continuously monitor the transmission activity of suspended AMTs. The four hydrophones will be cabled to a quad-channel receiver that will condition and amplify all acoustic signals. All acoustic signals will be acquired using the latest version of the JSATS Detector and decoded by the most recent version of the JSATS Decoder. Post-processing will be performed using Taglife GUI software. AMTs in each study will be monitored continuously until all AMTs fail. The life of each AMT will be expressed in hours since AMT activation.

v. Fish Implantation

AMTs will be surgically implanted in fish, and fish will be held for recovery as described below, prior to being released. Fish will be collected for this study in accordance with established permitting requirements using the sampling methods commonly employed at the JDA SMF.

Fish Collection

All fish will be collected and surgically implanted with AMTs at the JDA SMF. The JDA SMF receives fish passing through a JBS. Sampled fish typically would be returned to the river in an outfall pipe emptying into fast water in the tailrace. A small percentage of JBS-passed fish will be selected for inclusion in this survival study, and those fish will be held 2 days longer than their counterparts to allow time for surgical implantation of PIT and AMTs and recovery prior to release.

Records will be kept on all juvenile salmonids handled and collected (both target and non-target species) for accounting purposes related to the scientific collection permit. Collections will be conducted in conjunction with routine sampling at the JDA SMF to minimize the impacts of handling. Surgical candidates collected from routine target sample sizes will be accounted for under permits issued to the monitoring facilities. Additional fish required to meet research needs (beyond typical sampling goals) will be accounted for under separate federal and state permits.

Pacific States Marine Fisheries Commission (PSMFC) staff sample fish from the JBS at JDA and anesthetize them using detailed methods described by Martinson et al. (2006). PNNL staff will evaluate candidate fish for inclusion in the survival study using specific acceptance and rejection criteria listed below. Individual fish are rejected to avoid violating the statistical design assumptions A1 and A4 (see section below), which state that individuals should be a representative sample from the population of inference, and that all implanted individuals alive at a sampling location have the same probability of surviving until the end of that event, respectively. We recognize that fish condition can vary daily and between stocks, and a visual assessment of condition will be conducted during each fish collection event. We expect to reject no more than 1% of the fish over the sampling season.

Candidate fish for project acceptance

- is a spring Chinook salmon or steelhead in spring or subyearling Chinook salmon in summer
- is not previously implanted with PIT or other active transmitters
- is ≥ 95-mm fork length for the 0.31 g AMT (A study to determine the size criteria for implanting with the injectable AMT is currently underway. Results from the study will be used in determining the size of fish to be implanted) or > 300 mm in fork length
-

Exclusion criteria for Candidate fish

- exhibits descaling greater than 20% on any one flank with no regrowth of scales and mucous coat is absent
- shows evidence of infections on more than 5% on any one flank (fungus, ulcerations, etc.) or caudal fin erosion/disintegration to the degree of not present
- has inhibitory malformations (e.g., spinal deformities) that preclude proper AMT insertion or swimming ability severely compromised
- Moribund or not alive (as determined by body stiffness and/or degree of intactness)
- has physical injuries severe enough to impede performance with open wounds and active hemorrhaging on greater than 5% on any one flank

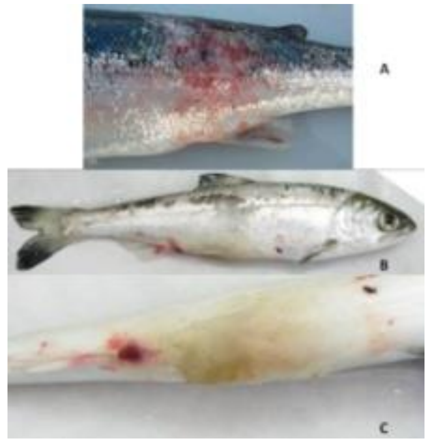

Figure 65. Examples of Severe Body Damage or Signs of Infection. A: congestion; B and C: descaling greater than 20%, indications of internal infection, possible hemorrhaging, and fungus.

Using custom software, PNNL staff will photograph and document the maladies for fish being rejected. After each collection session, the percent rejected will be calculated and recorded for the day. If a physical anomaly/malady is observed in more than 5% of the sorting table sample, the next day's fish with that condition will be considered for collection. Cumulative numbers rejected throughout each tagging season will be reported.

Implantation Procedures

All surgical procedures will follow the USACE guidelines (2011). For the summer study, if the injectable AMT is used, protocols will be developed and implemented for injection of AMTs and PITs at a production-scale. Several steps will be used in the implantation process to minimize handling impacts. Sterilization of surgical instruments will be continuous and emphasized. Each surgeon will have various sets of instruments. All instruments will be exposed to chlorohexadine-soak or hot bead sterilization to disinfect and then rinsed in distilled water prior to their use during surgery. This procedure reduces the introduction of bacteria and other harmful particulates into the incision and suture site. A synthetic water conditioner (Poly-Aqua) will be liberally used on the surgical pad to minimize mucosal surface disruption during surgical procedures.

All AMTs will be activated the day before implantation, while fish are randomly subsampled from the routine smolt-monitoring sample. Fish will be placed in 511-L tanks with in-flowing and out-flowing river water and held overnight for implantation on the next day. The use of routine smolt-monitoring samples should provide enough fish to meet the daily implantation quota except for occasionally near the beginning or at the end of a migration season when numbers in routine samples may be low.

A team of 8 to 10 people will participate in the implantation process to reduce handling time from collection to post-surgery recovery. On most days, all fish will be implanted within a 4- to 8-hour period, depending on the number of fish to be implanted with PITs and AMTs. The procedure starts with one person netting about five fish from holding tanks and transferring them to an 18.9-L capacity bucket with 10 L of fresh river water mixed with tricaine methanesulfonate (MS222) at a concentration between 80 and 100 mg/L. Fish will reach stage four anesthesia (Summerfelt and Smith 1990) prior to surgery and maintain that level throughout surgery. Anesthesia buckets will be refreshed regularly to maintain ±2 °C of current river temperatures. Anesthesia solutions will be either replaced or cooled with ice when temperatures increase more than 2°C. Individual anesthetized fish will be transferred into a 0.25-L plastic container of knockdown solution and handed to a second person who will measure its fork length (±1 mm) and weight (±0.1 g). A digitizing board and electronic scale with serial connections to a computer will facilitate accurate recording of lengths, weights, and any fish condition or damages. The person measuring and weighing fish will be stationed at the end of a line of four or five surgeons so that he or she can see who will be available to implant the next fish with a PIT and AMT. By design, surgeons will not know or be able to learn the future release location of the fish that they are implanting. Each surgeon must contribute at least one fish to each bucket of five fish so that surgeon effects are spread among all release buckets and sites. The digitizing board will have buttons with the names of all surgeons so each fish can be rapidly assigned to the next available surgeon. A third individual will scan PIT- and AMT codes into the computer, assign a PIT and AMT for a specific fish, and record fish species, run, and adipose fin status (clipped or unclipped). After a fish is weighed and measured, it will be placed back into its plastic transfer container along with a colored cork matching the color of a piece of foam stationed above the 24.6-L transport bucket receiving fish. The transfer container with fish, color coded cork, an AMT, and a PIT will be handed to one of three or four surgeons for implantation.

During surgery, each fish will be placed ventral side up and a gravity-fed anesthesia supply line will be placed into its mouth. The concentration of this “maintenance” anesthesia will be 40 mg/L. A 6- to 8-mm incision, using a surgical blade, will be made in the body cavity between the pelvic girdle and pectoral fin. A PIT will be inserted followed by an AMT. Both the PIT and AMT will be inserted toward the anterior end of the fish. The incision will be closed using 5-0 Monocryl suture using a 1x1x1x1 suture knot, as recommended by the Surgical Protocol Committee for the USACE.

After closing the incision, the surgeon will check to see whether the colored cork with the fish matches the color of a piece of foam set up near the transport bucket being filled. The color relates only to the current bucket being filled and does not relate to future fish release locations. If the colors are the same, the surgeon will place the implanted fish and colored cork into an opening in the top of a 76-mm diameter polyvinylchloride (PVC) pipe that will sluice the implanted fish and cork along the line of surgeon stations down to a dark 26.4-L transport bucket filled with aerated river water. If the cork and foam colors are different, the surgeon will place the implanted fish directly into the next transport bucket to be filled. At the end of the line of surgeons, another person will be responsible for closely observing and counting the number of fish and corks accumulating in the transport bucket. This person also is responsible for letting surgeons know what transport bucket is currently being filled (verbally and by setting out a colored piece of foam), and for switching out transport buckets and colored foam indicators after each bucket has been filled to its quota (usually five fish). When fish in transport buckets regain equilibrium, as indicated by vertical posture and active swimming, a lid will be added to the bucket, and it will be hand carried outside and placed in one of several large holding tanks with flowing river water. Fish will be held in these tanks for 18 to 24 hours.

In spring, implanted fish will be released according to a specific schedule at three locations between Port Kelley, Washington (CR503), and upstream of the Blalock Islands (CR451). In summer, implanted fish will be released at five locations between Port Kelley (CR503) and Celilo, Oregon (CR325). A specific number of fish must be implanted each day to meet the release requirements scheduled in Appendix A and B. Implanting will focus on one species and one release destination at a time, but the implantation coordinator will randomize the work order and keep destinations a secret at all times. Release numbers listed in Appendix A are for a single species, so those numbers must be doubled to account for all fish that must be transported in spring. Summer release numbers in Appendix B are specifically for subyearling Chinook salmon. There will be 32 series of releases each season, where a series is the temporal sequence of release from the most upstream release site to the most downstream site.

Surgeon Training and In-Season Assessment

Fish will be evaluated using external and internal examinations to assess condition and observe the presence and severity of injuries. These data will be used to evaluate survival model assumptions, and to monitor fish handling and implantation during execution of the project and following exposure of implanted fish to the river environment. In addition, the fish sampling effort at JDA and BON will document the variance in fish assessment between individuals selected for the survivorship models and the population-at-large. Fish assessment efforts provide the needed insurance that dam-passage survival assumptions are satisfied and indicate whether implanted fish have altered performance. Fish assessment specifically addresses BiOp measures to monitor and evaluate the biological and physical characteristics of anadromous fish species migrating through the FCRPS and to control for biological variation in the field (RME Strategy 2, RPA Action 52-55). The analyses will incorporate comparisons of length frequency distributions along with condition measures and injury observations of implanted and in-river fish to test the assumption of representativeness of implanted fish. In-season assessment allows for adaptive acceptance criteria for fish selected for implantation to run of the river.

Surgeons will note maladies and problems observed during surgery using a standardized list of likely condition observations and issues distilled from surgeon notes and condition studies in 2010, 2011 and 2012. Surgeons will be trained and have a quick reference guide to ensure that bias in note-taking between surgeons is minimized. Results will be entered into a computer daily and analyzed using custom processing software to provide timely feedback to surgeons to keep surgery as standardized and error free as possible as time since surgery training increases. Post-season processing of surgeon notes combined with fate information for released fish will allow researchers to better identify surgical problems that should preclude problem fish from being released in the future.

Fish recollected in the sort-by-code system at the BON JMF will be examined along with associated surgeon notes to provide real-time feedback to surgeons in 2014. This will allow for identifying and correcting any issues in the surgical process specific to a surgeon. For example, in 2011 and 2012 surgeons were contacted when surgeon effects were disproportionate to other surgeons and were verbally instructed how to improve practices going forward. In 2014 as in 2012, this feedback loop will allow for real-time corrections as opposed to post-season identification of surgical problems.

vi. Transport, Holding, and Release

During transport, fish will be held in specially designed buckets. Each transport bucket will have many 0.8-cm-diameter holes drilled through the upper half of its height and around its circumference. The location of holes in the upper half of the bucket will allow water to flow through each bucket when it is submerged in a large post-surgery holding tank with fresh river water flowing through it (Figure 16).

The solid bottom half of a transport bucket provides a sanctuary that retains about 13 L of water so that fish are not dewatered when buckets are moved between the holding tank and the transportation tank.

When fish regain equilibrium after surgery, the 24.6-L buckets will be covered with a fitted lid and hand carried outside to a larger holding tank with a continuous supply of river water (Figure 16). Fish will be held for at least 18 hours prior to release in the river. A sensor for monitoring water level, temperature, and dissolved oxygen will be installed and set up to automatically telephone staff if water-quality conditions are undesirable for fish. Alert limits will be set to a maximum of 21.0 °C and a minimum of 7 mg/L of oxygen. The inside of tanks will be sectioned by aluminum or PVC pipe to keep buckets upright (see photo on right side of Figure 16).

Figure16. Large Insulated Tanks for Holding Transport Buckets at the JDA SMF. Holding tanks are plumbed to allow flowing river water to pass through the tanks, each of which holds a maximum of 36 transport buckets.

The team will use insulated tanks that fit in the bed of a large pickup truck or on a trailer to transport fish from the JDA SMF to release locations. Fish buckets will be removed from the post-surgery holding tanks and loaded into the insulated tanks. These tanks will have sufficient capacity when filled with river water to submerge 9 transport buckets to a depth of 14 inches. A 2200 psi oxygen tank will be secured in the pickup bed or trailer, and a network of valves and plastic tubing will be hooked up to deliver oxygen to air stones in fish tanks. The temperature and concentration of water in tanks will be monitored continuously with portable oxygen/temperature meters from the time that fish are loaded until they are delivered to release sites. The oxygen/temperature meters and valves controlling oxygen flow will be located inside the cab of the transport truck for ease of monitoring. On hot days, ice will be transported in a small chest and will be added to tanks to keep water temperatures within 2 degrees of river temperature.

Handling impacts and stress will be minimized during transport and release in several ways. Confinement stress will be minimized by limiting fish numbers (≤5) or densities (≤10 g/L) in each transport bucket. This density limit falls within the lower density levels for transportation experiments. Transportation has been shown for most fishes to be stressful regardless of fish density (4–120g/L) and travel time (Speckler and Schreck 1980; Schreck et al. 1995; Iverson et al. 1998). In long-term rearing situations, densities over about 7.8 g/L have been observed to limit salmonid growth (Erickson et al. 1997; Wedemeyer 1997; Banks and LaMotte 2002). Most transport buckets will be loaded with five fish, although the last bucket for a release site may have fewer than five. All transport buckets will be a dark blue color to reduce stress associated with transporting fish in a small confined space. Staff will be trained to gently handle transport buckets to avoid exposing fish to impacts or loud noises, including dropping the handle against the side of a bucket. During load-up from post-surgical holding to transport vehicles, each insulated tank receiving transport buckets will be flushed with river water before it is loaded with fresh river water and fish transport buckets. On boats, transport buckets will be shaded to reduce solar heating and an air pump will be used to deliver air through plastic tubing to air stones in each bucket. Dissolved oxygen concentration and water temperature will be monitored in a subset of the buckets transported by boat.

Implanted fish will be transported from the SMF to release locations (Figures 10 and 11) according to a prescribed schedule (Appendix A and B) by prescribed routes. Slips will be rented to keep rental boats on the water whenever possible to eliminate the need to trailer a boat while hauling fish. Fish will be released by boat at five locations (numbered from 1 to 5) along a transect line across the river at each release site. On release boats, buckets will be opened to check fish condition, and all dead or dying fish will be scanned with a BioMark portable transceiver PIT scanner so that identities are established and recorded. Following established protocol, biologists will cut through gill arches of all dead fish, including any that must be euthanized to meet dead fish quotas. These dead fish will be returned to the JDA surgical implantation team coordinator, who will schedule for the dead implanted fish to be released downstream of one of the dams being studied. Analysts will later search for detections of dead fish on survival detection arrays to see if there was a violation of the assumption that implanted dead fish are not detected on downstream arrays used for estimating survival.

Boat operators will use an onboard GPS to move the boat to specific coordinates and put the motor in neutral while a crew member lowers the transport bucket into the water and tips it so that fish can swim out. The crew will record the location, bucket number, and time of release on standardized forms. Records will indicate release time to the nearest minute in Pacific Daylight Time.

vii. Data Downloading

Data accumulating on compact flash (CF) cards in autonomous nodes will be downloaded every 2 to 3 weeks when rechargeable lithium batteries are replaced. Autonomous nodes will be deployed before the first fish is released each season and will remain deployed until all JSATS AMT batteries should be dead, according to the AMT-life study. The first step in servicing a node is to trigger its acoustic release by entering a release-specific code into a transceiver that transmits an electrical signal to an underwater transducer. The transducer then translates the electrical signal into code-specific acoustic transmissions to activate a release mechanism. Upon surfacing, the autonomous node, rigging, and acoustic release will be retrieved by boat. The next step is to dry the outside of the node with a towel, open it, connect a data cable to the processing board set while batteries are still connected, and record both node and GPS clock times (hh:mm:ss) to allow for subsequent calculation of a clock offset (node time minus GPS time) in seconds. Next, the CF card is dismounted and ejected, and placed in a USB card reader so that comma-separated-variable (CSV) data files can be copied from the card to a laptop computer. The entire data file will be viewed in a text editor to verify that the autonomous node collected data throughout its deployment, records were continuous, and records included time stamps and AMT detections. If data near the end of the file include only 15-second time stamps and few or no AMT detections and batteries were not drained, the node top will be replaced with a new one, and the faulty top will be sent to the manufacturer for repair. The most common problem is damage to the hydrophone tip. The CF card will not be erased and wiped until data on the laptop have been archived in two or more locations including one offsite location. The CF card will be replaced with an empty wiped card every time nodes are retrieved. Batteries will be replaced within 18 days after node activation.

Decoded data acquired by cabled arrays will accumulate in CSV files on acquisition computers for four cabled hydrophones and will be downloaded to a USB or SATA removable drive weekly, preferably by the same staff member. Those data will be archived in at least two locations including one offsite location. Each raw data archive file will be accompanied by a document that describes variable formats.

viii. Data Management and Analysis

This section describes the raw data archive, methods for the three main stages of analysis (Figure 17), and a QA/QC plan. Raw data from the collection efforts in the field will undergo several processing and analysis steps to produce survival estimates. Standard, turnkey software based on existing programs is being developed for several of the stages. This software will be distributed to analysts so that, for example, in Stage 1 all raw data are processed and filtered in exactly the same way to create standardized clean data sets that contain the date and time of every decoded AMT reception meeting detection criteria. This program will expect variables in raw data files to adhere exactly to a prescribed format and will not function properly if formats deviate. As part of Stage 2, analysts will track fish movements in forebays using data from dam-face arrays and assign a route of passage. The analysts also will assign detection history codes (1 for detected and 0 for not detected) on each of two independent forebay arrays at each dam. Also in Stage 2, clean data sets will be manipulated to create a single capture history for every AMT released in 2014; i.e., a chronology of AMT detections on every autonomous and cabled hydrophone array from the time a implanted fish is released until it dies or leaves the study area. In Stage 3, capture histories will be analyzed to identify fish releases and arrays that will be used to estimate survival rates; a statistician will make AMT-life-corrected estimates of dam passage survival and boat-restricted zone (BRZ)-to-BRZ passage survival. Other estimates include forebay residence time and tailrace egress time.

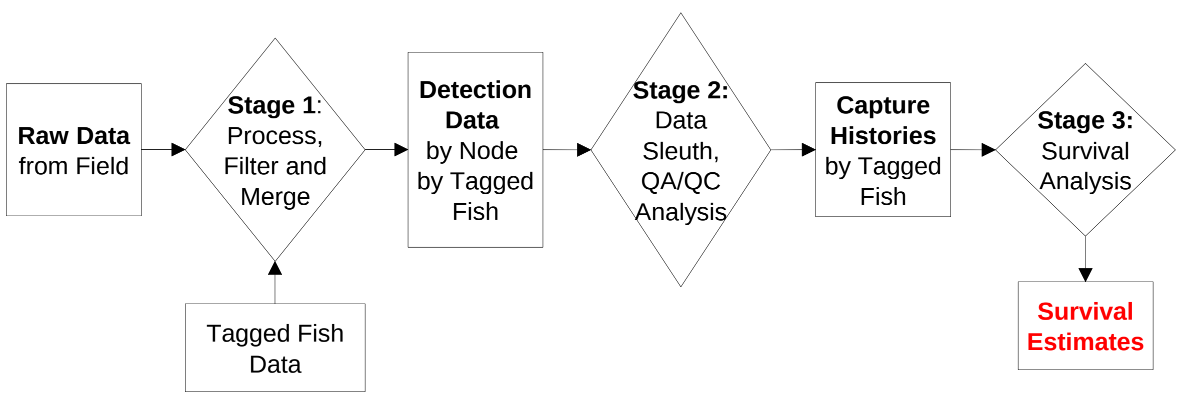

Figure 177. General Data Flow and Analysis Stages

Raw Data Archive

Raw data files will be retained as part of an auditable record for the study. There are three primary forms of raw data that will be acquired and archived: surgical implantation data, cabled dam-face array data, and autonomous array data.

Implantation data are acquired during the implantation process in CSV files. Implantation data are merged with release data that are recorded on release forms as fish are released from boats. Release data are entered into an electronic spreadsheet at the end of each day's release. The common variables that allow implantation and release data sets to be merged are release site and bucket number. Raw implantation and release data will be thoroughly proofed and archived in at least two locations, one of which will be offsite.

Cabled dam-face array data consist of raw waveforms that have a high probability of including AMT codes based on signal-to-noise ratios. Real-time decoder software will be running at the same time that detector software is identifying and saving waveform files. Output from the decoder consists of comma separated variable files with decoded signals. Systems accumulating CSV files will be checked twice daily to verify that everything is operating properly and that disk space is adequate, but data will only be downloaded weekly. Samples of these files are carefully checked and all raw CSV files will be archived separately in at least two locations, one of which will be offsite.

Autonomous node data contain a temporal CSV record of all decoded acoustic signals recorded on a CF card mounted inside an autonomous node. Node deployment and retrieval data include variables like project ID, node serial number, NODE_ID, latitude, longitude, rkm, depth, deployment date and time, recovery date and time, clock offset, and comments. Raw node data are carefully checked to confirm or adjust timekeeping. Deployment and retrieval data are recorded by hand on field sheets, entered into a spreadsheet at the end of each day, and later merged with autonomous node data by using NODE_ID as a common variable. Before merging, deployment and retrieval dates and times in field forms are cross checked against dates and times that the ambient pressure on nodes significantly increased or decreased. Pressure changes are detected by an on-board pressure sensor and recorded in the CF-card data stream. Rapid increases in pressure will occur as nodes are lowered to the river bottom, and rapid pressure reductions will occur as nodes rise from the bottom to the surface of the water. These raw node files and deployment retrieval spreadsheets will be archived in at least two locations, one of which will be offsite.

Analysis Methods

Stage 1: Filtering and Merging Raw Data to Detection Data Sets.

Only a small fraction of decoded acoustic signals recorded on any single underwater acoustic receiver represents valid detections; i.e., they occur frequently enough and in a temporal pattern approximating the modal pulse repetition interval of an AMT. Most decoded signals are from ambient sounds in the environment (noise) and yield codes that do not match AMT codes that were released. Some decoded signals will be false positive receptions of released codes, but they occur very infrequently by chance alone and practically never in a series of four or more hits with timing closely matching the expected pulse repetition rate of released AMTs.

The implantation and release, autonomous node, and cabled hydrophone data sets will be subjected to QC checks, archived, filtered, reviewed in a second QC step, and merged to create a single clean detection data set and a forebay tracking data set (Figure 18).

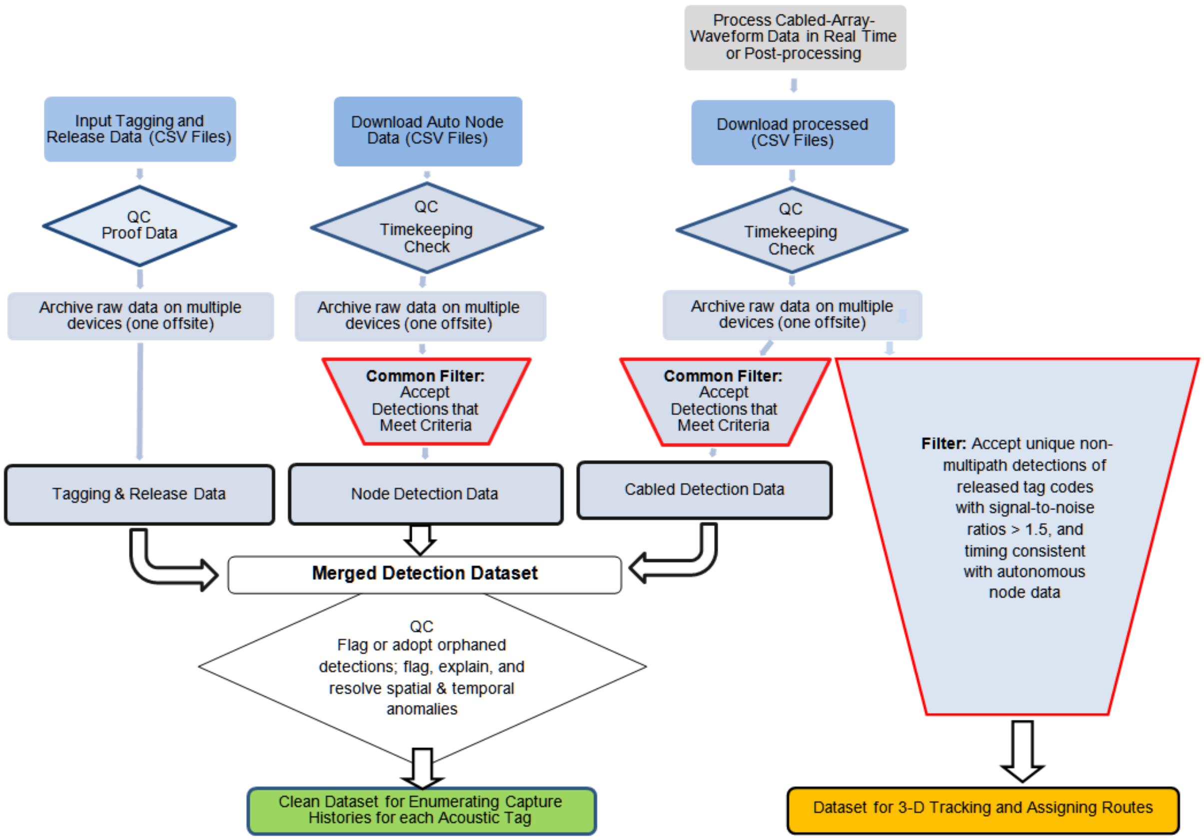

Figure18. Diagram of Stage 1 Data Flow from Acquisition through Production of Clean Data Sets. Clean data sets are suitable for enumerating capture histories for every AMT (green box) or for 3-D tracking of forebay movements to assign routes of passage at dams.

Steps for filtering raw data from individual autonomous node receivers to produce a clean detection data set (green box in Figure 18) are as follows:

Receptions of JSATS AMT codes within raw autonomous node data files are processed to produce a data set of accepted AMT-detection events. A single file is processed at a time, and no information about receptions at other nodes is used. The following two filters are employed during processing:

1. Multipath filter: For data from each autonomous node, delete all AMT-code receptions that occur within 0.156 seconds after an initial identical AMT code reception under the assumption that closely lagging signals are multipath. Initial code receptions are retained. The delay of 0.156 seconds is the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and is computed as 2(PRI_Window+12×PRI_Increment). Both PRI_Window and PRI_Increment are currently set at 0.006, which was chosen to be slightly larger than the potential rounding error in estimating PRI to two decimal places.
2. PRI filter: Retain only those series of receptions of a AMT code (or “hits”) that are consistent with the pattern of transmissions from a properly functioning JSATS AMT. Each AMT code is processed individually, and it is assumed that only a single AMT will be transmitting that code at any given time. Each autonomous node data file is processed as follows:

a. For each hit, select the list of identical hits that follow within [(Nominal_PRI×1.3×12)+1] seconds, where Nominal_PRI is the nominal number of seconds between transmissions of the AMT code (typically 3, 5, or 10 seconds). Nominal_PRI will be 3 seconds in 2014 studies. The list of Nominal_PRI by AMT code must be available as an input and typically is obtained from the AMT manufacturer.

b. Compute a list of candidate PRIs as follows:

$$Candidate\ PRI\ list = \prod_{i=1}^{12} \frac{(Time_{Hit} - Time_{Initial\ Hit})}{i}$$

where *i* is a counter that steps through the 12 possible PRI intervals that can fit between the initial hit and the end of the time window described in Step a. Round each candidate PRI to the nearest hundredth of a second and exclude candidates < Nominal_PRI × 0.651 or > Nominal_PRI × 1.3.s from the list. These coefficients were chosen to result in a range of candidate PRIs that do not include multiples of any other candidates in the list. Avoiding exact multiples in the candidate PRI list simplifies the process of identifying a mode.

c. Take the minimum mode of the list of candidate PRIs from Step b as the estimate of PRI to be used in building an event associated with the initial hit. If no mode exists, select the minimum candidate PRI as the estimate of PRI.

d. Add hits to the accepted list if their time interval from the initial hit falls within narrow bounds around even multiples of the estimated PRI from the initial hit. An acceptance window for a hit is defined by:

$$\text{Acceptance window} = i(Estimated\_PRI) \pm \left[PRI\_Window + i\left(PRI\_Increment\right)\right],$$

where PRI_Window = 0.006; PRI_Increment = 0.006, as described in Step 1; and *i* is the number of PRI intervals from the initial hit obtained by rounding (($Time_{Hit}$-$Time_{Initial\ Hit}$) / Estimated PRI) to the nearest integer.

e. Create a detection event if at least four hits remain (the initial hit plus three or more accepted hits).

f. Select the first hit after the initial hit as the new initial hit, and repeat Steps a through e above until all hits have been processed.

g. Combine any two or more detection events that overlap in time into a single detection event.

h. Repeat Steps a through g for each AMT code.

The output of this process is a data set of events that summarize accepted AMT detections for all times and locations where nodes were operating. Each unique event record includes a set of fields that indicate the ID of the fish, the first and last detection time for the event, the location of detection, and how many hits were detected within the event. This data set is combined with accepted AMT detections from the cabled arrays and PIT detections for additional QA/QC analysis prior to survival analysis.

One of the most important QC steps is to examine the chronology of detections of every implanted fish after its release to identify any detection sequences that deviate from the expected upstream to downstream progression through arrays in the river. A single detection that occurs on an upstream array after detection of the same AMT on downstream arrays may represent a false positive detection if the upstream distance traveled is >5 km, separated by one or more dams, or the upstream travel time is too fast (>5 km/h) to be reasonable for a implanted juvenile salmonid. Such false positive detections are very rare (<0.015%), usually will have close to the minimum of four hits, and are deleted from the event data set before survival analysis. Some anomalous upstream detection events are difficult to explain (e.g., duplicate AMTs or predation of implanted fish and subsequent upstream transport of an AMT by a predator), but if anomalous detections occur at the end of the chronology of detections on multiple arrays, they are deleted from the event data set.

Steps for filtering raw data from individual cabled hydrophones in dam-face arrays to produce the clean detection data set (green box in Figure 18) are described next.

Receptions of JSATS AMT codes within raw cabled hydrophone data files are processed to produce a data set of accepted AMT detection events. Detections from all hydrophones at a dam are combined for processing. The following three filters are used:

1. Multipath filter: For data from each individual cabled hydrophone, delete all AMT-code receptions that occur within 0.156 seconds after an initial identical AMT code reception under the assumption that closely lagging signals are multipath. Initial code receptions are retained. The delay of 0.156 seconds is the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and is computed as 2(PRI_Window+12×PRI_Increment). Both PRI_Window and PRI_Increment are currently set at 0.006, which was chosen to be slightly larger than the potential rounding error in estimating PRI to two decimal places.
2. Multi-detection filter: Retain receptions only if the same AMT code was received at another hydrophone in the same array within 0.3 seconds because receptions on separate hydrophones within 0.33 seconds (about 450 m of range) are likely from a single AMT transmission.
3. PRI filter. Retain only those series of receptions of a AMT code (or "messages") that are consistent with the pattern of transmissions from a properly functioning JSATS AMT. Filtering rules are evaluated for each AMT code individually, and it is assumed that only a single AMT will be transmitting that code at any given time. For the cabled system, the PRI filter operates on a message, which includes all receptions of the same transmission on multiple hydrophones within 0.3 seconds. Message time is defined as the earliest reception time across all hydrophones for that message. Detection requires that at least six messages are received with an appropriate time interval between the leading edges of successive messages. The processing steps are as follows:
   a. For each message, select the list of messages that follow within [(Nominal_PRI×1.3×12)+1] seconds. Nominal_PRI is the nominal number of seconds between transmissions of the AMT code (typically 3, 5, or 10 s). Nominal_PRI will be 3 seconds in 2014. The list of Nominal_PRI by AMT code must be available as an input and typically is obtained from a AMT manufacturer.
   b. Compute a list of candidate PRIs as follows:

$$Candidate\ PRI\ list = \prod_{i=1}^{12} \frac{\left(Time_{Message} - Time_{Initial\ Message}\right)}{i}$$

   where i is a counter that steps through the 12 possible PRI intervals that can fit between the initial message and the end of the time window described in Step a. Round each candidate PRI to the nearest hundredth of a second and exclude candidate PRIs < Nominal_PRI × 0.651 or >

Nominal_PRI × 1.3 from the list. These coefficients were chosen to result in a range of candidate PRIs that do not include multiples of any other candidates in the list. Avoiding exact multiples in the candidate PRI list simplifies the process of identifying a mode.

c. Take the minimum mode of the list of candidate PRIs from Step b as the estimate of PRI to be used in building an event associated with the initial message. If no mode exists, use the minimum candidate PRI as the estimate of PRI.

d. Add messages to the accepted list if their time interval from the initial message falls within narrow bounds around even multiples of the estimated PRI from the initial message. An acceptance window for a message is defined by:

$$\text{Acceptance window} = i(Estimated\_PRI) \pm \left[PRI\_Window + i\left(PRI\_Increment\right)\right],$$

where PRI_Window = 0.006; PRI_Increment = 0.006, as described in Step 1; and *i* is the number of PRI intervals from the initial message obtained by rounding (($Time_{Message}$-$Time_{Initial\ Message}$) / Estimated PRI) to the nearest integer.

e. Create a detection event if at least six messages remain (the initial message plus five or more accepted messages).

f. Select the first message after the initial message as the new initial message, and repeat Steps a through e above until all messages have been processed.

g. Combine any two or more detection events that overlap in time into a single detection event.

h. Repeat Steps a through g for each AMT code

The output of this process is a data set of events that summarizes accepted AMT detections for all times and locations where hydrophones were operating. Each unique event record includes a basic set of fields that indicate the ID of the fish, the first and last detection time for the event, the location of detection, and how many messages were detected within the event. This list is combined with accepted AMT detections from the autonomous arrays and PIT detections for additional QA/QC analysis prior to survival analysis. Additional fields capture specialized information, where available. One such example is route of passage, which is assigned a value for those events that immediately precede passage at a dam based on spatial tracking of implanted fish movements to a location of last detection. Multiple receptions of messages within an event can be used to triangulate successive AMT positions relative to hydrophone locations.

One of the most important QC steps is to examine the chronology of detections of every implanted fish on all arrays above and below the dam-face array to identify any detection sequences that deviate from the expected upstream to downstream progression through arrays in the river. Except for possible detections on forebay entrance arrays after detection on a nearby dam-face array 1 to 3 km downstream, apparent upstream movements of implanted fish between arrays that are >5 km apart or separated by one or more dams are very rare (<0.015%) and probably represent false positive detections on the upstream array. False positive detections usually will have close to the minimum number of messages and are deleted from the event data set before survival analysis.

Although route-of-passage assignments are not part of the detection data set, passage at a course scale (powerhouse, spillways) is required to estimate spill passage efficiency, as required by the Fish Accords.

3-D Tracking Algorithms

Acoustic tracking is a common technique that uses time-of-arrival-differences (TOADs) of coded signals at different hydrophone locations to calculate the location of a transmitting AMT. Usually, it requires a three-hydrophone array for two-dimensional (2-D) tracking and four-hydrophone array for 3-D tracking. Most tracking in this study will be three dimensional. Consider a transmitting source (AMT) in a four-hydrophone array. The boldface letters indicate matrices or vectors. The source (S) and receiver (r) position vectors are defined as

$$\mathbf{S} = (s_x, s_y, s_z)^{\mathrm{T}}$$
$$\mathbf{r}_i = (x_i, y_i, z_i)^{\mathrm{T}} \qquad i = 0,1,2,3 \tag{1}$$

The distance between transmitting source and receivers gives

$$(s_x - x_i)^2 + (s_y - y_i)^2 + (s_z - z_i)^2 = c^2(t_i + T_0)^2, \qquad i = 0,1,2,3 \tag{2}$$

Where c is the speed of sound, T_0 is the time of travel from the source to the reference receiver (receiver 0), and t_i is the TOAD between receiver i and the reference receiver. With t_i measured by the common clock, the source position vector and T_0 are the four unknowns to be solved by the four distance equations.

There are several mathematical ways to obtain the exact solutions to the equations above (Watkins and Schevill 1972; Fang 1990; Spiesberger and Fristrup 1990; Juell and Westerberg 1993; Wahlberg et al. 2001). Wahlberg et al. (2001) applied a synthesis of the methods used by Watkins and Schevill (1971) and Spiesberger and Fristrup (1990). It has the advantage of giving the same mathematical form for 2-D and 3-D array systems, and for both minimum number of receivers arrays and over-determined arrays. Assuming the first receiver is located at the origin of the coordinate system and subtracting eq. (2) for I = 0 from Eq. (2) for i = 1, 2 and 3, we obtain

$$2\mathbf{R}^T\mathbf{S} + 2c^2\mathbf{t}T_0 = \mathbf{b} \tag{3}$$

where

$$\mathbf{R} = \begin{bmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \\ z_1 & z_2 & z_3 \end{bmatrix}, \quad \mathbf{t} = \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix}, \quad \mathbf{b} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}, \text{ and } b_i = \|\mathbf{r}_i\|^2 - c^2 t_i^2 \tag{3a}$$

From Eq. (3),

$$\mathbf{S} = \mathbf{R}^{-T}(\frac{1}{2}\mathbf{b} - c^2\mathbf{t}T_0) \tag{4}$$

Substitute Eq. (4) to the relationship $\mathbf{S}^T\mathbf{S} = c^2 T_0{}^2$ gives

$$T_0 = \frac{-p \pm \sqrt{p^2 - aq}}{a} \quad (5)$$

where,

$$a = c^4 \mathbf{t}^T \mathbf{R}^{-1} \mathbf{R}^{-T} \mathbf{t} - c^2, \quad p = -\frac{1}{2} c^2 \mathbf{t}^T \mathbf{R}^{-1} \mathbf{R}^{-T} \mathbf{b}, \text{ and } q = \frac{1}{4} \mathbf{b}^T \mathbf{R}^{-1} \mathbf{R}^{-T} \mathbf{b} \quad (5a)$$

After T_0 is determined, source position (**S**) is then obtained by Eq. (4). Note that there are two possible solutions for T_0. If they are both complex, then there is no exact solution for the given configuration and TOADs. A negative T_0 is nonphysical. When there are two real, non-negative solutions, then both provide two possible locations for the source. However, the solution indicating detection downstream of the dam-face array will not be physically possible, because all dam-face hydrophones will be installed on piers and will be baffled so that they can only detect AMTs approaching from upstream.

However, an exact solution may not be available due to the nonlinearity of the four distance equations and uncertainties in exact sound speed, time measurements, and hydrophone locations. In this case, it is necessary to consider it as an optimization problem and estimate the source location by minimizing the errors. The most common methods are iterative Taylor-series methods or variant Newton-Gaussian methods, which linearize the equation using Taylor expansion and search for an approximate numerical solution iteratively by minimizing the least square error (Foy 1976). Several other approaches have been developed: Maximum likelihood (ML) algorithms (Chan and Ho 1994; Chan et al. 2006) that start from ML functions instead of linearizing the equations first and derive a close-form approximation; spherical interpolation approach (Torieri 1984); and the linear-correction approach of Cheung et al. (2004). The codes for these approximation methods were developed but not applied for JDA 2008 study because of the high success rates of exact solvers.

After the source location was obtained from 3-D tracking, a set of artificial TOADs (t_1', t_2', t_3') and T_0' was computed directly using the 3-D tracked source location for the given hydrophone locations and speed-of- sound. The total time error was then defined as

$$\Delta T = \sqrt{(\mathrm{t}_1' - \mathrm{t}_1)^2 + (\mathrm{t}_2' - \mathrm{t}_2)^2 + (\mathrm{t}_3' - \mathrm{t}_3)^2 + (\mathrm{T}_0' - \mathrm{T}_0)^2}$$

The detailed steps for 3-D tracking are as follows:

- Pool together all detections of the same signal from different hydrophones. If more than four hydrophones detected the same AMT signal, the four with the best geometry configuration for 3-D tracking are then selected (Wahlberg et al. 2001; Ehrenberg and Steig 2002). Compute TOAD directly from detection time because all hydrophones were synchronized to a universal GPS clock with accuracy within 0.4 μs.
- Apply tracking solvers to estimate 3-D locations and output solutions that are physically possible and within the pre-specified ΔT (10 μs).

- Apply order 3 median filtering (Lim 1990) for removing spurious locations and smoothing fish tracks.
- Assign a route of passage based on the y component of the last tracked location (3-D-tracking method).
- Assign a second set of passage routes based on the last two hydrophones at different piers detecting a fish (Last detection method). For example, if the two hydrophones were at Pier 1 and Pier 2 of a powerhouse, then the passage route would be assigned to powerhouse Unit 1.
- Compare the two sets of passage routes. If the difference in passage route assignment for a fish differs by more than one spill bay or turbine, its trajectory (3-D-tracking) and detection history (last detection) are checked manually.

Stage 2: Detection Data to Capture Histories

TagPro software will be used to create capture histories from the filtered detection event data. For every AMT released during the study, the software assigns a 1 to an array if a fish detection event was recorded and a 0 if the AMT was not detected. The age of each AMT (time since activation) whenever it is detected can be calculated by subtracting the time of activation from the time of detection. The resulting data set is suitable for AMT-life-corrected survival analysis to estimate dam passage survival, BRZ-to-BRZ passage survival, forebay residence time and tailrace egress times. The surgeon that implanted each AMT is a variable that can be used to study surgeon effects on survival.

The capture history for cabled arrays is similar to that for autonomous nodes except that detections are merged with data about dam passage routes and with PIT detection data from the PIT Information System (PTAGIS). The JBS PIT detections are used to reassign fish acoustically detected passing into turbines to the JBS route.

Stage 3: Capture Histories to Survival Estimates

Maximum likelihood estimation will be used to estimate dam passage survival and forebay to tailrace passage survival based on the virtual/paired-release design of Skalski (2009). In all cases, the arrays shown in Figures 4 and 5 will be used to estimate dam-passage survival and additional downstream arrays may be used included in survival models for John Day Dam and The Dalles Dam. If the survival of the most upstream releases of fish was significantly lower than that of fish released further downstream, the upstream release probably should not be used for the analysis. If dead fish were detected on the first array below a dam, then the analyst could select the next downstream array to be the primary array in a series of three arrays. It might be advantageous to pool all arrays downstream of a secondary array if precision of survival estimates could be improved. Array selection decisions rarely affect point estimates of survival but can have a significant effect on precision. Minor violations of assumptions like mixing may be inconsequential to the validity of estimates. The capture histories from all the replicate releases, both day and night, will be pooled for the AMT-life corrected survival analysis. This dam passage survival estimate for the season will be compared to the BiOp performance standards.

One advantage of the proposed study design is that the number of fish in virtual releases at successive downstream dams should increase greatly due to the pooling of fish from multiple upstream release locations. However, fish from different release locations will have spent different times in river, with different probabilities of AMT failure. A weighted average survival estimate for the virtual release will therefore be required of the form

$$\hat{S}_1 = \frac{\sum_{i=1}^{K} \frac{\hat{S}_{1i} R_i}{\left(1-\hat{f}_i\right)}}{\sum_{i=1}^{K} R_i}$$

where $\hat{S}_{1i}$ = survival estimate in the forebay-to-reservoir reach for fish from the *i*th release location $\left(i=1,\ldots,K\right)$;

R_i = number of fish in virtual release group from the *i*th release location $\left(i=1,\ldots,K\right)$;

$\hat{f}_i$ = estimated probability of AMT failure for fish from *i*th release location $\left(i=1,\ldots,K\right)$.

Correction for AMT failure will follow the methods in Townsend et al. (2006) and will be extended to multiple release groups. The equation above weights the survival estimate by the relative contribution $\left(\text{i.e., } R_i \Big/ \sum_{1}^{K} R_i\right)$ of each release location to the fish used in the virtual release group.

Releases below the dam will be distinct groups of implanted fish and will not require corrections for multiple AMT failure rates. If travel times are relatively long compared to AMT-failure times, a single correction for AMT failure as presented by Townsend et al. (2006) will be applied to each of the downstream releases.

Asymptotic 95% confidence interval estimates for dam passage survival will be calculated as

$$\hat{S}_{\text{Dam}} \pm 1.96\sqrt{\text{Var}\left(\hat{S}_{\text{Dam}}\right)}.$$

Analysis methods for other metrics are described by Skalski (2009).

ix. Quality Assurance and Control

Quality assurance and control will be critical to successful implementation of the 2014 survival studies. Besides standard QA/QC procedures, two of the main categories of QA/QC will be diagnostics and assumption testing. Fulfilling these QA/QC examinations will help ensure robust results.

Standard Procedures

Numerous standard procedures and elements are involved with QA/QC, many of which were explained above as they arose in the context of implementation. The QA/QC elements include the following:

- Develop, peer-review, and finalize the experimental design.
- Manage AMT code space.

- Optimize the design (specific 3-D locations of hydrophones) for the dam-face and autonomous arrays.
- Perform detailed acceptance testing for procured equipment.
- Train personnel.
- Perform thorough system-checks of telemetry equipment.
- Confirm hydrophone location estimates
- Have a statistician visit and inspect the entire data collection and analysis process.
- Document the percentage of fish implanted out of the total number handled.
- Document the percentage of handling mortality.
- Control for confounding biological factors in the field when possible.
- Control for sorter bias while selecting fish for implantation.
- Control for surgeon bias.
- Treat all releases the same as much as possible logistically.
- Archive raw data, including meta-data.
- Institute formal PNNL version control and documentation for analysis software.

x. Data Diagnostics

Data diagnostics, along with assumption testing (described in the next section), will ensure the data are ready for release to the region. The diagnostic process will be structured and systematic. Data diagnostics include the following topics: detection history fidelity, run timing, fish length frequency distribution, condition indices, preliminary pseudo-real-time analysis, surgeon effects, preliminary calculations of survival estimates by various factors, and preliminary determination of the capture history data set by two independent groups.

Detection History Fidelity

Detection histories for individual fish reflect their movement and survival through various reaches of the study area. To ensure data quality is appropriate for survival modeling, these histories will be evaluated for apparent anomalies in the place and time of detection relative to release time or release location and in comparison to other times and places of detection. Detection events inconsistent with release time or release location will be resolved by examining database entries on AMT release and node deployment. A sequence of detection events that suggest unreasonably rapid movement or movement across normally impassable barriers will be resolved by examining database entries on node deployments. Errors in information on node deployment or AMT release will likely affect multiple individuals, and those multiple lines of evidence will sometimes reveal a clear path to resolving the anomaly. Where no errors in node deployment or AMT release are found, it will be necessary to remove the event or events that are most likely anomalous to restore the fidelity of the detection history. The event or events with the fewest number of receptions relative to other events that create the spatial/temporal anomaly will have the greatest probability of occurring by chance, and will be removed. These types of anomalies are very rare and indicate that current data-filtering steps are robust for removing false positive detections (data indicating that a implanted fish was present when it was not present). For example, in spring 2009, we found only four such temporal/spatial anomalies out of about 68,000 detections on all deployed underwater acoustic receivers.

Run Timing

To examine the representativeness of implanted fish, we will compare species-specific daily passage from smolt monitoring programs at MCN, JDA, and BON with the release dates for implanted fish. The intent is to implant and release fish during the middle 80% of the outmigration for each species.

Comparison of Fish Representativeness

To further examine the representativeness of the implanted fish, we will compare length frequency distributions between the implanted fish and sampled fish at the JDA SMF. Separate comparisons will be made for yearling Chinook salmon, subyearling Chinook salmon, and steelhead during the period that fish are being released. The data will be reduced to cumulative frequency distributions and assessed visually. In addition, subsamples of SMF sampled fish and implanted fish will be examined to verify that the condition of implanted fish is similar to that of run-of-river fish.

Preliminary Pseudo-Real-Time Analysis

Problems with data not evident in the field during collection can be revealed during data analysis. Therefore, it is important to perform trial analyses on data soon after data collection has commenced and periodically (every 2 weeks) thereafter. This diagnostic step also provides analysts a jump-start on data analysis.

Surgeon Effects Analysis

The thorough and systematic protocols for fish implantation are intended to minimize any surgeon effect bias in the survival estimates. A diagnostic to check for surgeon effects will involve estimating survival by surgeon by species. Because fish will be allocated to surgeons in a systematic random design, survival estimates should not differ among surgeons if there is no surgeon effect. We will compare survival estimates for each stock and surgeon using analysis of variance or another multiple comparison test recommended by the project statistician.

Preliminary Calculations of Survival Estimates by Various Factors

Analogous to surgeon effects, other diagnostics will entail performing preliminary calculations of survival estimates separately by release group, reach, and release location. The idea is to examine the survival results for abnormalities. For example, if fish released at the JDA tailrace consistently had lower survivals than other release locations, it would suggest there might be an issue of some kind and lead to an examination of the release procedures for that site.

Preliminary Determination of the Filtering Results and Capture History Data Sets by Two Independent Groups

While much effort is being devoted to standardizing data analysis methods, there is an element of decision-making and interpretation on the part of the analyst. Accordingly, three analysts will verify that detection data have been filtered consistently and that identical raw data sets produce identical final capture history data sets. Their respective results will be compared and anomalies identified and reconciled.

xi. Assumption Testing

As explained in the *Statistical Design for the Lower Columbia River Acoustic-Tag Investigations of Dam Passage Survival and Associated Metrics* by Skalski (2009), the assumptions of the virtual/paired-release model and tests of the assumptions are listed in Table 3.

Table 3. Assumptions of the Virtual/Paired-Release Model and Tests of the Assumptions

Assumption	Test
A1. Individuals marked for the study are a representative sample from the population of inference.	Compare run timing distributions for the test fish versus the smolt monitoring data by species. Compare fish size and other fitness measures between implanted fish and run-at-large.
A2. All sampling events are "instantaneous." That is, sampling occurs over a negligible distance relative to the length of the intervals between sampling events.	No test; the time a implanted fish spends at a sampling array is relatively brief compared to the time of travel between arrays.
A3. The fate of each implanted individual is independent of the fate of all others.	No test; commonly accepted as true in implantation studies.
A4. All implanted individuals alive at a sampling location have the same probability of surviving until the end of that event.	Tests 2 and 3 of Burnham et al. (1987) can be used to assess whether upstream detection has an effect on downstream survival.
A5. All implanted individuals alive at a sampling location have the same probability of being detected on that event.	No test; this assumption is satisfied by placing hydrophone arrays across the breadth of the river so that all fish, regardless of location, have the same probability of detection. Lab-derived AMT-life and AMT-expulsion data will be used to assess this assumption.
A6. All AMTs are correctly identified and the status of juvenile salmonids (i.e., alive or dead), correctly assessed.	Releases of dead implanted fish at the dams will be used to confirm the absence of false positive detections due to fish dying during dam passage but being detected downriver. Furthermore, if dead fish are detected at the first detection array downstream of the dam, deployment of multiple additional arrays will allow flexibility to select arrays farther downstream to ensure this assumption is not violated. In addition, because AMT loss or failure would violate the assumption, we will perform laboratory AMT-life assessments.
A7. Survival in the lower river segment of the first reach is conditionally independent of survival in the upper river segment.	Comparison of survival estimates through the two downstream reaches formed by the three survival detection arrays for the three release groups can be used to help assess the validity of this assumption. Laboratory implanted effects research using run-of-river unimplanted, PIT-only, and AMT+PIT groups collected at the time of implanted and through the SbyC systems will be used to assess this assumption. Survival by release location and river reach will be assessed to test for implanted effects.

A8. Releases V_1, R_1, and R_2 experience the same survival probabilities in the lower river segments they share in common.	Chi-square tests of homogeneity can be used to test whether release groups V_1, R_2, and R_3 are mixed upon arrival at downriver detection sites. Laboratory implanted effects research using run-of-river unimplanted, PIT-only, and AT+PIT groups collected at the time of implantation and through the SbyC systems will be used to assess this assumption. Survival by release location and river reach will be assessed to test for implantation effects.
A9. The virtual release group is constructed of implanted fish known to have passed through the dam.	A double-detection array in the forebay increases detection probabilities close to 1.0 and will be used to test for homogeneous detection rates.
A10. All fish arriving at the dam have an equal probability of inclusion in the virtual release group, independent of passage route through the dam.	This assumption is met by having very high detection probabilities on dam-face arrays. Thus, we will estimate array detection probabilities.

D. Limitations/Expected Difficulties

There are several challenges in conducting a study of this scope:

- The key to having AMTs and receiving systems that function to specifications is to have acquisitions start in 2013 and be completed the same year so that acceptance testing occurs, and there is time to identify manufacturing problems before the 2014 field season begins.
- Logistics for releasing fish among locations need to be optimized to ensure that unstressed animals have experienced the same transport conditions and times and have the opportunity to mix in common tailwaters. Choosing appropriate transport equipment, implementing precise schedules, and monitoring travel routes and times will be very important.

E. Schedule

The milestone schedule is as follows:

1. Spring releases will occur from about 4/29 through 6/1, 2014.
2. Acoustic monitoring of AMTs will run from 4/20 through about 8/10, 2014.
3. Summer releases will occur from 6/11 through 7/17, 2014.
4. We will provide written in-season progress reports every 2 weeks during the field season when fish are being released.
5. All final spring data sets will be delivered to the Columbia Basin Research team in Seattle by July 31, 2014.
6. All final summer data sets will be delivered to the Columbia Basin Research team in Seattle by September 30, 2014.
7. Results will be presented at the AFEP in November or December 2014.
8. A draft BiOp report will be delivered for each dam and all runs of fish by December 31, 2014 (see Technology Transfer for a description). Final BiOp reports will be due not later than February 28, 2015.

9. A draft of the MCN technical report will be delivered to Walla Walla District by March 31, 2015.
10. The final MCN technical report will be delivered to Walla Walla District within one month of receiving comments on the report.

We are aware that the study design will be reviewed by various state and federal agencies, and is subject to the approval of the National Oceanic and Atmospheric Administration Fisheries under the Endangered Species Act (ESA). We understand that this means that the study design may be modified prior to the start date. We are prepared to be flexible.

F. Facilities and Equipment

This study will require 21,875 3-s JSATS AMTs and 21,875 PIT. Hardware sufficient to outfit MCN and JDA dams and monitor associated river reaches was purchased between 2010 and 2012 and is available for this study. The USACE will purchase AMTs, autonomous nodes, and cabled array systems (cables, hydrophones, amplifiers, digital signal processing cards, GPS cards, and computers) if any are needed.

We will performance test autonomous nodes and hydrophones, and if they are new and fail, we will send them back to the vendor for repair or replacement at the vendor's expense.

G. Impacts

Fish will be obtained from the JDA SMF and using sort-by-code operations at BON. A small percentage of fish (typically <0.1%) will die from handling and implanting, but those fish will be used to verify that primary arrays are far enough downstream to avoid detecting dead fish. The acoustic frequencies transmitted in this study are above those that can be detected by or injure salmon. Hydrophones are designed without sharp edges and rigging, so they are unlikely to injure fish. All necessary permits will be obtained from state and Federal agencies for the use of AMTs with ESA-listed species. Fish collection, handling, holding, and transport will be done in accordance with PNNL Institutional Animal Care and Use Committee and federal Association for Assessment and Accreditation of Laboratory Animal Care procedures for animal care and humane treatment of vertebrate animals.

There will be a large effort to install hydrophones and cables in pipes on every main pier at turbine bays and at every spill bay at each of the dams. We will coordinate closely with the Corps personnel at each project to minimize our impact on dam maintenance activities and operations.

We plan to coordinate closely with other studies to ensure that JSATS nodes are sampling continuously when fish with JSATS AMTs are passing through the study area. We also will coordinate with other researchers to avoid conflicts.

We will need 5-min interval GDAC dam operations data for each turbine unit, spill bay, and sluiceway, as well as combined discharge for each powerhouse, spillway, and sluiceway and estimates of forebay elevation for every dam studied.

H. Collaborative Arrangements and/or Sub-Contracts

PNNL plans to subcontract with John Skalski, Columbia Basin Research, and the University of Washington for help with the study design, statistical estimation, and reporting. PNNL also will subcontract with the Pacific States Marine Fisheries Commission and/or Cascade Aquatics for labor.

IV. List of Key Personnel and Project Duties

Name (Affiliation)	Duties
Mark Weiland (PNNL)	Co-Project Manager; JDA and MCN project oversight; cabled array data management
Christa Woodley (PNNL)	Co-Project Manager, Surgeon training and surgical QA/QC, acoustic data flow QA/QC, fish condition manager
James Hughes (PNNL)	System-wide installation oversight manager, MCN onsite managers; MCN cabled system management
Gene Ploskey (PNNL)	In-season reporting, data QA/QC, analysis, and transfer
Tom Carlson (PNNL)	Oversight and coordination
Jina Kim (PNNL)	Code space manager; AMT activation management; data QA/QC, data processing, data analysis, database management
Eric Fischer (PNNL)	Surgery team manager
Shon Zimmerman (PNNL)	Surgeon trainer; lead surgeon, travel coordination
Bishes Rayamajhi (PNNL)	Data processing, data QA/QC, analysis
Zhigun Deng (PNNL)	3-D tracking and route of passage
Scott Carpenter (PSMFC)	MCN cable array management
Darin Etherington (PSMFC)	Autonomous node servicing; hydrophone testing
Tyler Mitchell (PSMFC)	Autonomous node servicing; hydrophone testing
George Batten (PSMFC)	JDA cabled system management
John Skalski (CBR; UW)	Project statistician
Rich Townsend (CBR; UW)	Statistical team
Adam Seaburg (CBR; UW)	Statistical team

V. Technology Transfer

Information acquired during the proposed work will be transferred in the form of written and oral research reports. Presentations will be made at the Corps' annual AFEP Review. Technology transfer activities may also include presentation of research results at regional or national scientific and fisheries symposia, or publication of results in a scientific journal.

The BiOp reports for each dam studied will be very concise but will be sufficient for readers to evaluate the reasonableness of assumptions and results (Table 4). The data in BiOp reports will not be considered "preliminary and subject to change." The intent is to report "bullet-proof data"; this means AMT-life corrections will have been made, surgeon effects accounted for, diagnostics performed and passed, assumptions tested and passed, and all QA/QC steps completed. The reports will be used to inform the requirements for periodic Progress Reports and Comprehensive Reports for the BiOp.

Table 4. Features of the BiOp Reports

Element	BiOp Report
Objectives	Only those from the BiOp and Fish Accords
Background	Brief
Methods	Brief, but including QA/QC steps
Results	Dam passage survival; BRZ-to-BRZ survival; fish passage efficiency; spill passage efficiency; travel times (forebay residence, tailrace egress, and project passage); no route-specific estimates
Discussion	Compliance/non-compliance, next steps
Appendices	Assumption testing; capture histories

The Portland and Walla Walla District will send the BiOp reports to the fisheries managers for review under the AFEP process. In addition, the Portland and Walla Walla Districts will use the information in these reports to inform the progress and comprehensive reports by the Federal Action Agencies to the National Marine Fisheries Service as required in the BiOp.

Separate BiOp reports will be produced for each dam and will present results for all runs of fish studied in 2014. The data from the study will also be presented at the AFEP Annual Review in November or December 2014. Presentations will be considered for overall performance relative to the BiOp and for each dam separately.

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VII. Budget

A detailed budget will be provided under a separate cover.

Appendix A

Fish release schedule for spring 2014. Release series are numbered consecutively and those that begin at night are highlighted in gray and those beginning during the day are highlighted in yellow. Release sites (R1-R3) are described in Figure 4.

Day	Date	Hour	Port Kelley rkm 503	MCN Tailrace rkm 468	Crow Butte rkm 422
Tuesday	4/29	6			
		10			
		18			
		22	1		
Wednesday	4/30	6			
		10	2		
		18			
		22		1	
Thursday	5/1	6			
		10		2	
		18			
		22	3		
Friday	5/2	6			1
		10	4		
		18			2
		22		3	
Saturday	5/3	6			
		10		4	
		18			
		22	5		
Sunday	5/4	6			3
		10	6		
		18			4
		22		5	
Monday	5/5	6			
		10		6	
		18			
		22	7		
Tuesday	5/6	6			5
		10	8		
		18			6
		22		7	
Wednesday	5/7	6			
		10		8	
		18			
		22	9		
Thursday	5/8	6			7
		10	10		
		18			8
		22		9	
Friday	5/9	6			
		10		10	
		18			
		22	11		
Saturday	5/10	6			9
		10	12		
		18			10
		22		11	
Sunday	5/11	6			
		10		12	
		18			
		22	13		
Monday	5/12	6			11
		10	14		
		18			12
		22		13	
Tuesday	5/13	6			
		10		14	
		18			
		22	15		
Wednesday	5/14	6			13
		10	16		
		18			14
		22		15	
Thursday	5/15	6			
		10		16	
		18			
		22	17		

Day	Date	Hour	Port Kelley rkm 503	MCN Tailrace rkm 468	Crow Butte rkm 422
Friday	5/16	6			15
		10	18		
		18			16
		22		17	
Saturday	5/17	6			
		10		18	
		18			
		22	19		
Sunday	5/18	6			17
		10	20		
		18			18
		22		19	
Monday	5/19	6			
		10		20	
		18			
		22	21		
Tuesday	5/20	6			19
		10	22		
		18			20
		22		21	
Wednesday	5/21	6			
		10		22	
		18			
		22	23		
Thursday	5/22	6			21
		10	24		
		18			22
		22		23	
Friday	5/23	6			
		10		24	
		18			
		22	25		
Saturday	5/24	6			23
		10	26		
		18			24
		22		25	
Sunday	5/25	6			
		10		26	
		18			
		22	27		
Monday	5/26	6			25
		10	28		
		18			26
		22		27	
Tuesday	5/27	6			
		10		28	
		18			
		22	29		
Wednesday	5/28	6			27
		10	30		
		18			28
		22		29	
Thursday	5/29	6			
		10		30	
		18			
		22	31		
Friday	5/30	6			29
		10	32		
		18			30
		22		31	
Saturday	5/31	6			
		10		32	
		18			
		22			
Sunday	6/1	6			31
		10			
		18			32
		22			

Appendix B

Fish release schedule for summer 2014. Release series are numbered consecutively and those that begin at night are highlighted in gray and those beginning during the day are highlighted in yellow. Spill conditions at John Day Dam are indicated by a blue highlight for 30% spill or a light yellow highlight for 40% spill over alternating 48 h time periods. Release sites (R1-R5) are shown in Figure 5.

Day	Date	Hour	Port Kelley rkm 503	MCN Tailrace rkm 468	Crow Butte rkm 422	JDA Tailrace rkm 346	Celilo rkm 325
Wednesday	6/11	4					
		6					
		10					
		16					
		18					
		22	1				
Thursday	6/12	4					
		6					
		10	2				
		16					
		18					
		22		1			
Friday	6/13	4					
		6					
		10		2			
		16					
		18					
		22	3				
Saturday	6/14	4					
		6			1		
		10	4				
		16					
		18			2		
		22		3			
Sunday	6/15	4					
		6					
		10		4			
		16					
		18					
		22	5				
Monday	6/16	4				1	
		6			3		
		10	6				1
		16					
		18			4		
		22		5			
Tuesday	6/17	4					
		6					
		10		6			
		16				2	
		18					
		22	7				2
Wednesday	6/18	4				3	
		6			5		
		10	8				3
		16					
		18			6		
		22		7			
Thursday	6/19	4					
		6					
		10		8			
		16				4	
		18					
		22	9				4
Friday	6/20	4				5	
		6			7		
		10	10				5
		16					
		18			8		
		22		9			
Saturday	6/21	4					
		6					
		10		10			
		16				6	
		18					
		22	11				6

Day	Date	Hour	Port Kelley rkm 503	MCN Tailrace rkm 468	Crow Butte rkm 422	JDA Tailrace rkm 346	Celilo rkm 325
Sunday	6/22	4				7	
		6			9		
		10	12				7
		16					
		18			10		
		22		11			
Monday	6/23	4					
		6					
		10		12			
		16				8	
		18					
		22	13				8
Tuesday	6/24	4				9	
		6			11		
		10	14				9
		16					
		18			12		
		22		13			
Wednesday	6/25	4					
		6					
		10		14			
		16				10	
		18					
		22	15				10
Thursday	6/26	4				11	
		6			13		
		10	16				11
		16					
		18			14		
		22		15			
Friday	6/27	4					
		6					
		10		16			
		16				12	
		18					
		22	17				12
Saturday	6/28	4				13	
		6			15		
		10	18				13
		16					
		18			16		
		22		17			
Sunday	6/29	4					
		6					
		10		18			
		16				14	
		18					
		22	19				14
Monday	6/30	4				15	
		6			17		
		10	20				15
		16					
		18			18		
		22		19			
Tuesday	7/1	4					
		6					
		10		20			
		16				16	
		18					
		22	21				16
Wednesday	7/2	4				17	
		6			19		
		10	22				17
		16					
		18			20		
		22		21			

Day	Date	Hour	Port Kelley rkm 503	MCN Tailrace rkm 468	Crow Butte rkm 422	JDA Tailrace rkm 346	Celilo rkm 325
Thursday	7/3	4					
		6					
		10		22			
		16				18	
		18					
		22	23				18
Friday	7/4	4				19	
		6			21		
		10	24				19
		16					
		18			22		
		22		23			
Saturday	7/5	4					
		6					
		10		24			
		16				20	
		18					
		22	25				20
Sunday	7/6	4				21	
		6			23		
		10	26				21
		16					
		18			24		
		22		25			
Monday	7/7	4					
		6					
		10		26			
		16				22	
		18					
		22	27				22
Tuesday	7/8	4				23	
		6			25		
		10	28				23
		16					
		18			26		
		22		27			
Wednesday	7/9	4					
		6					
		10		28			
		16				24	
		18					
		22	29				24
Thursday	7/10	4				25	
		6			27		
		10	30				25
		16					
		18			28		
		22		29			
Friday	7/11	4					
		6					
		10		30			
		16				26	
		18					
		22	31				26
Saturday	7/12	4				27	
		6			29		
		10	32				27
		16					
		18			30		
		22		31			
Sunday	7/13	4					
		6					
		10		32			
		16				28	
		18					
		22					28

Day	Date	Hour	Port Kelley rkm 503	MCN Tailrace rkm 468	Crow Butte rkm 422	JDA Tailrace rkm 346	Celilo rkm 325
Monday	7/14	4				29	
		6			31		
		10					29
		16					
		18			32		
		22					
Tuesday	7/15	4					
		6					
		10					
		16				30	
		18					
		22					30
Wednesday	7/16	4				31	
		6					
		10					31
		16					
		18					
		22					
Thursday	7/17	4					
		6					
		10					
		16				32	
		18					
		22					32