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Study Plan to Measure Survival of Juvenile Chinook Salmon Through Wilsey Dam Turbines (FINAL DRAFT)

Prepared for:

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EXECUTIVE SUMMARY

In the Shuswap (Wilsey Dam) hydro system numerous interested parties have a vision of restoring salmon runs that have been obstructed from migrating into the upper Shuswap watershed since 1929. A multi-phased approach is proposed to understand life history characteristics of reintroduced Chinook salmon upstream of Wilsey Dam and the impacts of Wilsey Dam on these reintroduced salmonids.

In Phase I, we recommend that additional information be gained prior to performing survival testing. Further information is needed on juvenile Chinook salmon life history characteristics, whether the environment near Wilsey Dam is conducive to the tag technology we recommend, and what potential management decisions could be made from the results of the study.

In Phase II, we recommend additional research to determine the effects of Wilsey Dam on survival of re-established Chinook salmon. A decision process, comparison of technologies, statistical method, sampling protocol, and costs are outlined to guide decision makers on which approach to use to estimate survival at Wilsey Dam. Measuring survival of juvenile Chinook salmon will assist resource managers in determining whether reintroduction of salmonids upstream of Wilsey Dam is a viable option to increase salmonid abundance in the Shuswap River Basin.

INTRODUCTION

In 2005, a Water Use Plan (WUP) was completed for the Shuswap River (Shuswap Falls and Sugar Lake projects) that identified operational guidelines for the Wilsey Dam Generating Station (BC Hydro 2005). The proposed operating conditions in the Shuswap WUP process for the Wilsey Generating Station was to augment flows for fish from the fall through the spring, and install a new head pond structure at Wilsey Dam to improve stability of downstream flows in the river during unplanned outages (BC Hydro 2009). Minimum discharges below Wilsey Dam of 16 m^3/s (between 15 August and 31 December) and 13 m^3/s 1 January to 14 August), were established. The Consultative Committee of the Shuswap River WUP identified the need to develop and implement monitoring programs to address a number of knowledge gaps related to the potential impact of dam operations on salmonids. Bengeyfield et al. (2001) identified Chinook as the principal target species for fish passage restoration at the Wilsey Dam project. Coho, bull trout and rainbow trout are also identified as candidate species for restoring fish passage above Wilsey Dam based on historical distribution (Lister 1990).

The need for establishing a fishway at the Shuswap Falls project was recognized from the initial application to construct a dam in 1913. Fisheries agencies have assessed available habitat, and monitored adult spawner habitat utilization (Lister 1990, Triton 1994). Several potential fishway concepts were developed by Northwest Hydraulic Consultants (2002), in support of fish access to over 350,000 m^2 suitable salmonid-riverine habitat (*ibid*).

Out-migrating juvenile salmonids have two potential routes of passage past Wilsey Dam on the mainstem Shuswap River; turbines and spillways. Fish passage survival varies depending on the route of passage. As a result of reported higher mortality rates for fish passage through turbines (compared to other routes) (Iwamoto and Williams 1993), mitigation efforts usually focus on providing non-turbine passage routes for juvenile fish as a means to improve fish survival. Nevertheless, substantial numbers of juvenile fish will continue to pass through turbines; therefore, minimization of turbine-related mortality is a priority of Okanagan Nation Alliance, Fisheries & Oceans Canada (DFO), B.C. Ministry of Environment (MOE) and BC Hydro (BCRP).

Turbine operating efficiency has a relatively direct effect on fish passage survival. The relationship between survival of juvenile fish passing through turbines is positively correlated and roughly linear to the efficiency at which the turbines are operated. Bell (1990) recommended making every effort to operate turbines at best efficiency at a given head (determined by flow rate, reservoir and tailrace levels) during periods of peak fish passage to minimize fish mortality.

Purpose, and benefit of appropriate research

We propose a fish monitoring project which is intended to initially understand fish entrainment and mortality at Wilsey Dam. More accurate observation of fish use and behaviour at the base of the spillway and downstream of the dam is required to monitor fish movement in response to flows.

It is important to understand the context of this research. If we assume that based on the results of this research, potential operational or, less likely, dam modifications are made, the level of certainty of the research can be extremely important. For example, if there is an agreement between the stakeholders that if the point estimate of survival is less than 80%, modification *x, y, z* will occur. However, if the best precision that can be expected is 12% (half width of a confidence interval), and your point estimate is 85%, then the "true" value of the estimate ranges from 73-97%. However, if precision can be increased to a 5% confidence interval, then all stakeholders involved will have better confidence in the point estimate, and the owner of the project will not be having to potentially spend millions of dollars in modifications or lost generation because of imprecise estimates of mortality.

So, it is more cost effective to ensure that a high precision is obtained during a test than having to either repeat an imprecise study or make modifications that were not needed.

Phased Approach

There are many critical uncertainties concerning how Chinook salmon will respond to the effects of Wilsey Dam after they are reintroduced, and how to conduct appropriate research. As such, we recommend a phased approach be used to gain needed knowledge.

Phase I (2010-2011)

In Phase I, we recommend that additional information be gained prior to performing survival testing. Further information is needed on juvenile Chinook salmon life history characteristics, whether the environment near Wilsey Dam is conducive to the tag technology we recommend, and what potential management decisions could be made from the results of the study - which should have a direct bearing on the precision needed.

Phase II (2012-2014)

In Phase II, we recommend additional research to determine the effects of Wilsey Dam on survival of re-established Chinook salmon.

Types of mortality

It is important to distinguish the type of mortality of interest prior to conducting research to determine the effects of a hydro-project on fish. Two types of mortality are generally recognized:

Direct mortality occurs in close proximity in time and space to the causative mechanism (i.e., direct effects are localized and immediate—the impact causes mortality directly). Direct mortality is typically studied for fish passing a specific passage route (e.g., turbine or sluiceway) at a dam (Giorgi et al. in press).[4]

Indirect mortality is mortality that occurs as a consequence of the causative mechanism, but *not* in close proximity in time and space to the causative mechanism. For example, fish passing through a turbine may be disoriented and become more susceptible to predation for some distance downstream. Resulting increased predation, then, would be mortality that occurred *indirectly* because of turbine passage (Giorgi et al. in press).

Overarching Study Goals and Objectives

Measuring survival of juvenile Chinook salmon will assist resource managers in determining whether reintroduction of salmonids upstream of Wilsey Dam is a viable option to increase salmonid abundance in the Shuswap River Basin.

Goal

The goal (future vision) of this plan is to understand life history characteristics of reintroduced Chinook salmon upstream of Wilsey Dam and the impacts of Wilsey Dam on these reintroduced salmonids.

Phase I objectives:

- Describe available tagging technologies (e.g. Acoustic, Radio, PIT and Hi-Z turbine tags);
- Determine what life history characteristics and behaviour of reintroduced Chinook salmon upstream of Wilsey Dam will most likely be;
- Determine whether subyearling Chinook are appropriate test animals to conduct acoustic tag survival studies;
- Measure the acoustic environment ("noise levels") near and at Wilsey Dam;
- Investigate the use Hi-Z turbine tags to measure direct survival at Wilsey Dam.

[4] Estimates of direct mortality are typically obtained using paired-release protocols, wherein treatment and control (reference) release sites bound the effect zone of interest. The study zone is also typically compact, with tagged fish recaptured shortly (minutes) after liberation and as close to the downstream end of the impact zone as practical.

- Recommend field, data management, and reporting protocols for juvenile Chinook salmon studies on the Shuswap River.

Phase II

- Determine Chinook salmon passage timing and the proportion of fish using the two routes (spill or powerhouse) past the dam[5];
- Determine fish mortality for Chinook salmon travelling through the powerhouse at Wilsey Dam;
- Determine what (if any) additional studies are needed at Wilsey Dam.

Study Area & Study Site

The Shuswap Falls and Sugar Lake project consists of Wilsey Dam and Sugar Lake Dam located 35 km and 75 km, respectively, east of Vernon on the Shuswap River. The Sugar Lake Dam, located approximately 29 km upstream from Wilsey Dam, provides storage and flow regulation for the power generating station at Wilsey Dam (Figure 1).

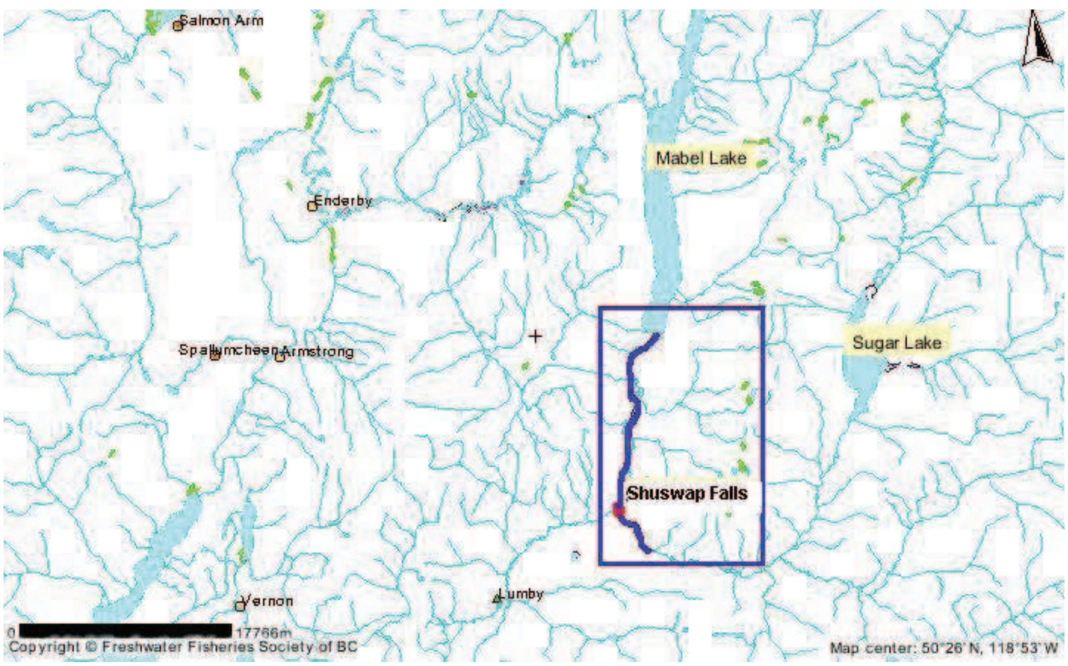

Figure 1. Map of Middle Shuswap River, Mabel Lake, and location of Shuswap Falls (Wilsey Dam Project).

[5] Route specific passage information is only needed for spring migrating fish since that will be the only time that passing through the spillways will be possible.

Wilsey Dam

The 30 m high Wilsey Dam is located 22.4 km upstream of Mabel Lake Inlet (UTM: 11U.370953E.5573055N), and at an elevation of 418 m (Figure 2; Photo Plate 1). The Wilsey Dam crest is at an elevation of 448.54 m (30 m high). Figure 2 illustrates a schematic of Wilsey Dam, where two intakes (Intake No. 1, left abutment; and Intake No. 2, right abutment) carry flow through separate penstocks along the left bank to the generating station. A non-gated spillway is located on the right bank, and constructed at a crest elevation of 444.5 m. Flashboards are installed between September and March when inflows are typically controlled by Sugar Dam releases to increase head pond elevation to 445.4 m. The spillway discharges for approximately 300 m through a rock chute into the lower river opposite the tailrace of the generating station.

The powerhouse consists of two Francis turbine units with a combined capacity of 6 MW, and a hydraulic capacity of 31.6 m^3/s Maximum withdrawals of 16.4 m^3/s and 15.2 m^3/s from Intake 1 and 2, respectively, carry inflows to two turbine units which operate under a normal head of 23.8 m. A single turbine unit operates when flows are less than 17 m^3/s, and both units are shut down when inflows are less than 8 m^3/s. Any inflows that exceed the maximum turbine capacities of the generating station are spilled (e.g., greater than 31.6 m^3/s).

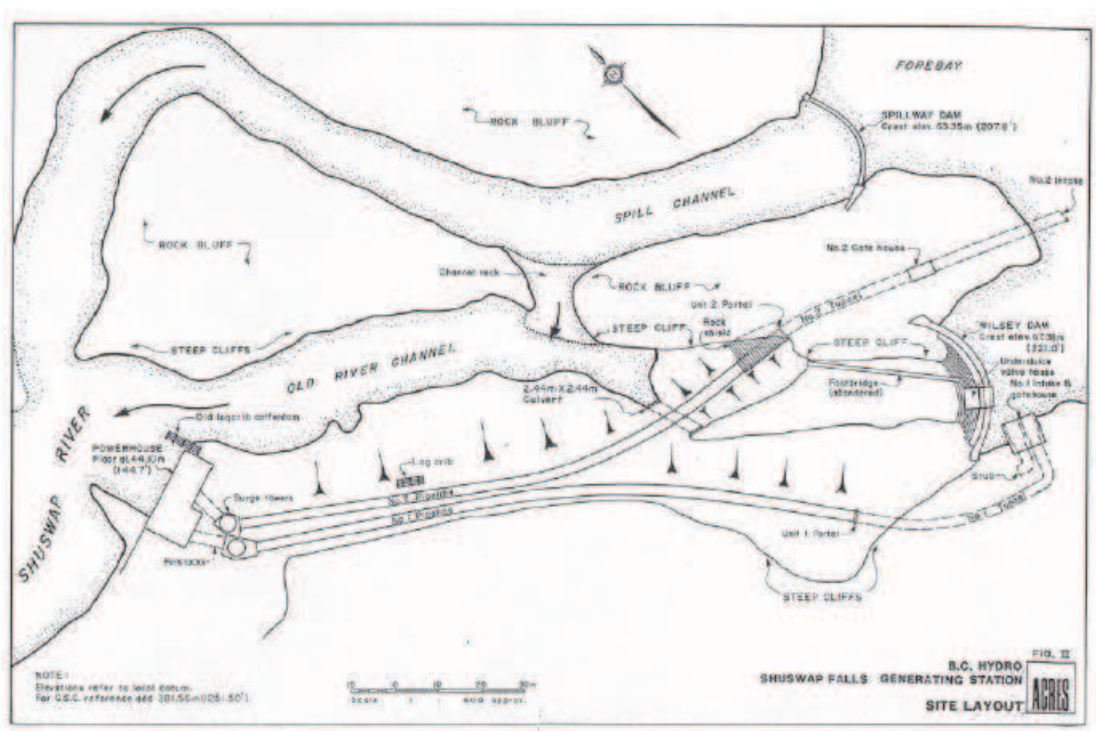

Figure 2. Site Layout of Wilsey Dam Project.

Wilsey Dam Head Pond Project Area

The section upstream the Wilsey Dam is referred to as the head pond. The head pond is 3.2 km long, and encompasses an area of 4.27 ha at maximum normal elevation (Photo Plate 2). Immediately upstream is a 2 km long canyon-like channel, with bedrock walls and deep pool habitat.

Wilsey Dam Downstream Project Area

Site visits by ONA personnel in February, 2010 confirmed potential sites for telemetry receivers. The physical habitat downstream of Wilsey Dam is wider and lower gradient (i.e., less than two degree). The active, bankfull channel varies between 50 and 75 m wide, with major evidence of debris, bank erosion, and channel aggradation.

Section A. Biological Traits, Species Interactions & Survival Assumptions.

Rearing Types, Run Timing & Size Distribution

The fish used for tagging need to be similar to the population they are emanating. Several biological characteristics, such as size, condition, and migratory behaviour should be similar to the migration patterns of the fish that will be re-established.

Chinook salmon from the Shuswap River population consists of ocean-type (subyearling migrant, age-0+) and stream-type (yearling migrant, age-1+). Scale data from 1990's indicate that over 95% of the returning adult Chinook salmon exhibit an ocean-type life history (ARC 2001).

Between June and October, subyearling Chinook (ocean-type) ranging in length from 40 to 60 mm, and average 2 g, emigrate downstream, to early-rear in Mabel Lake (Fee and Jung 1984). Typically, Shuswap Chinook fry commence emigration immediately following emergence in spring (e.g., 10% of the run), followed by 80% during the summer period, and the remaining 10% out-migrate in fall (Figure 3). Adult Chinook were outplanted in 1977 and 1994 by DFO above Wilsey Dam on a trial basis (Fee and Jung 1984, Triton 1995). Most of the progeny from these experiments migrated downstream in April and June during high flow periods (Appendix 1; Triton 1995). These fish range in length from 80 to 120 mm, and average 5 g. Detailed life history information for Shuswap Chinook salmon is summarized in NHC (2002).

Species Interactions

The Middle Shuswap River supports populations of bull trout (*Salvelinus confluentus*), rainbow trout (*O. mykiss*), cutthroat trout (*O. clarki clarki*), slimy sculpin (*Cottus cognatus*), prickly sculpin (*C. asper*), and northern pikeminnow (*Ptychocheilus oregonesis*) which all have been known to prey on juvenile Chinook.

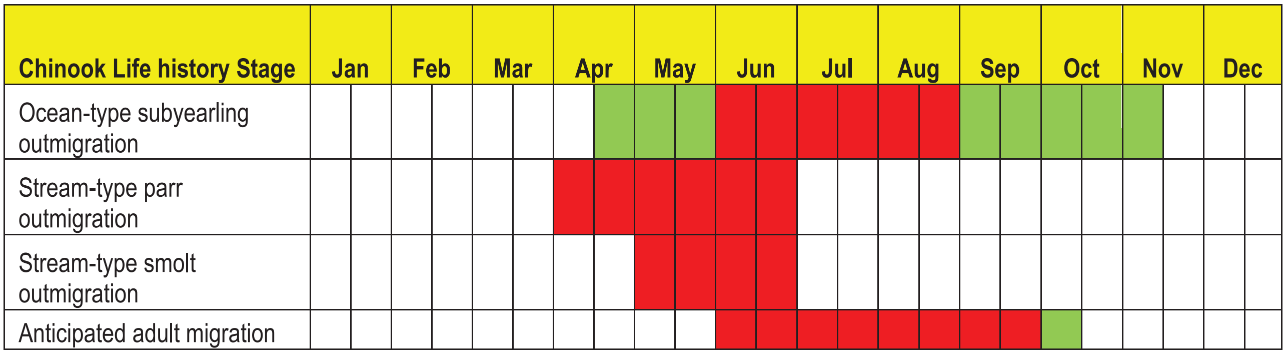

Figure 3. Life history timeline for Chinook salmon from the Shuswap River.

Juvenile Chinook Survival Assumptions

Northwest Hydraulic Consultants (2002) conducted a meta-data analysis and modeled several simulations of juvenile and adult Chinook production in the Shuswap River. General assumptions of juvenile Chinook survival included:

A1. Chinook migrate concurrent with the freshet, when spilling begins, therefore most of the Chinook use the spillway and avoid mortality,

A2. Total mortality of 2% for juvenile passing over the spillway and down the spill channel,

A3. Total project mortality of 15% for juvenile passing through the project based on turbine type, head, and flows,

A4. Entrainment percentiles, by month, varied relative to flow, as follows:

- 100% entrainment of smolts and fry from August to March (no spill),
- 71% entrainment in April,
- 15% entrainment in May and June during freshet,
- 23% entrainment in July,

Section B. Study Design Considerations

Definition of the Zone of Inference

The zone of inference is simply the segment of the hydroelectric system through which passage survival is estimated. We define the zone of inference as the dam, which includes the powerhouse (turbines) and the area of the tailrace up to the point of the release site of the control

However, we suggest that this zone of inference be agreed upon by all stakeholders, since it could have a significant impact on the amount and type of research pursued.

Statistical Methods

Most survival studies are variations of either a single or paired release model. Basic statistical models have been adapted from Burnham et al. (1987). The models rely on comparison of recoveries from known releases to generate estimates of survival. The key assumptions are similar for the various types of models, and are described in detail in Giorgi et al. (in press). The assumptions that are critical to the proposed study are described in detail in Section D (below).

Precision

The goal of this project is to estimate survival of fish passing through Wilsey Dam. Experiments are typically designed incorporating multiple releases across the migratory duration of the group of interest. The statistical precision of a particular estimate is a function of the survival rate, the detection rate and range of the tags, and sample size. The detection rates and ranges are typically limited by physical conditions or operational considerations, thus sample size is generally the only variable that can be adjusted to achieve the desired level of precision. Target levels of precision are often expressed as 95% confidence interval or as a standard error (SE) of the mean estimated survival. Sample sizes sufficient to generate estimates with standard errors on the order of 2.5% or less are generally a benchmark for studies implemented at the Columbia River (Giorgi et al. in press). For this study, it may be necessary to accept lower precision, depending on the desired outcome of the survival estimates, i.e., what potential management actions may be made based on the survival estimates.

If just direct mortality (passage only through the turbines) is desired, then a precision with a SE of 2.5% is achievable with Hi-Z turbine tags (see below). However, if that methodology is not feasible to use, then another method will need to be used that will most likely result in a much lower precision (higher confidence limits).

Effects of Tag Burden on Fish Survival and Performance

When determining the minimum fish size, researchers should select tags that minimize potential negative effects on fish while also attempting to represent a majority of the population of interest. The most common index used to determine minimum fish size is the ratio of the weight of the tag (in air) relative to the weight of the fish. This is often referred to as the tag burden expressed as a percentage of fish weight.

Laboratory investigations have been conducted to quantify tag effects on host fish. Indices of performance include monitoring swimming capability, buoyancy control, and, in some cases, predator avoidance. We agree with the recommendation of Giorgi et al. (in press) that a tag-burden maximum should be between 5% and 6.5% based on the laboratory tests conducted by Adams et al. (1998a, 1998b), Prentice et al. (1990, 1993), and Anglea et al. (2004). For example, Adams et al. (1998a) found that swimming performance of juvenile Chinook salmon was compromised relative to controls when the tag ratio exceeded about 5%. For tag ratios <5%, the authors suggested that gastrically implanted tags were more suitable for short-term studies (days), whereas surgically implanted tags were best suited to longer term studies (weeks).

Effect of tagger

A common assumption in implementing survival studies is that treatment and control groups are similar in all respects, other than the treatment condition. Giorgi et al. (in press) state that they have clear evidence from quality assurance monitoring that even under the strictest protocols, individual taggers can have an effect on fish survivability. They recommend that the tagger effect should be homogenous across experimental groups. This is most easily accomplished if all fish are tagged at one central location.

Models

There are two main models that are typically used for survival estimation. These include the single release-recapture and the paired release-recapture models. Most other models are variations on these two models.

The single release-recapture model (Skalski 1998) consists of a single release of tagged fish with a minimum of two downstream recapture locations. The focus of this design is to estimate survival through extended reaches of river. The tags must be uniquely identifiable with at least a portion of the fish detected at both of the downstream recapture sites. The main issue with this model is that the estimates of survival produced include not only the survival of the fish through the reach of interest, but they also incorporate all post-release handling and tagging-related mortality. This is of particular concern where tags are surgically implanted, since the more traumatic tagging procedure leads to a greater probability of latent handling effects being expressed. Post-release tag loss will also negatively bias survival estimates.

The paired release-recapture model (Burnham et al. 1987) was designed to solve some of the problems inherent in the single release-recapture model. This paired design consists of a group of tagged fish released at the upstream end of a zone of inference, coupled with another group released at the downstream end of the zone. The fish from both groups are detected at a minimum of two downstream recapture locations. The upstream releases should occur first, and the fish should be given time to reach the downstream end of the reach of interest. Effort is made to release the second group of fish concurrent with the period when the first group is passing the second release site. As such, both the upstream and downstream release groups travel through subsequent river reaches at the same time, thus experiencing similar conditions. Latent handling effects should be fully (or, at least, equally) expressed in both release groups by the time they are detected at the downstream arrays, and any mortality in these downstream reaches should be equal between groups. Thus, by dividing the survival rates of the two release groups, the handling effects and downstream mortality rates are cancelled out, and the quotient represents an unbiased estimate of the survival in the river reach of interest (i.e., the area between the first and second release locations). Using this method to estimate dam survival is usually unsuccessful because the forebay release will not pass through the suite of passage routes at a dam the same way as run-or-river fish. To avoid this, fish could be released farther upriver, but then the survival estimate would include not only dam passage, but also survival through parts of the forebay area. Alternatively, pairing fish known (via telemetry) to have arrived at the dam with a tailrace release will typically result in overestimates of dam passage survival because of differential handling effects downstream (Skalski et al. 2008). Two approaches have been used to overcome these problems and estimate dam passage survival, the Quadruple Release (Skalski et al. 2008), and the Virtual-Release/Paired-Release design (Skalski 2009).

The Quadruple Release design has been developed to overcome the difficulty of pairing in-river fish with newly released fish. It includes a traditional paired-release model, with one group released upstream of the forebay, and the other in the tailrace. A detection array at the dam determines the passage route of each fish, enabling route-specific passage proportions and route-specific survival estimation. Fish known to have passed through the various routes are then tracked downstream and relative survival among routes is estimated using a single release-recapture design. Finally, a paired-release survival model is used through one specific route in order to estimate absolute passage survival through the one route, with an additional release through the passage route in question. The absolute passage survival through one route, and the relative survival through all routes allows the calculation of relative survival through all routes (Skalski et al. 2008). Precision of this model can be low because of the number of parameters that must be estimated (especially if specific routes have very low passage numbers), and studies can be costly because of the number of release groups involved.

Rather than reconstructing dam passage survival from route-specific information, the Virtual-Release/Paired-Release model allows the estimation of dam passage survival using a combination of a traditional single-release and paired-release methods (Skalski 2009). A group of fish is released upstream of the dam a sufficient distance so that by the time they reach the dam face, they are behaving normally, and are distributed naturally in the river. The fish from this first release group that are known have reached the forebay comprise a ‘virtual’ release group. A traditional single-release survival model is used to estimate the survival of the virtual release group through the dam and downstream to the next detection array, located sufficiently far from the dam to avoid detections from dead tagged fish. Note that this survival estimate includes not only survival through dam passage, but also an ‘extra’ river reach downstream of the dam. In order to correct for the ‘extra’ river section, it is necessary to generate an unbiased estimate of survival through this section, and a paired-release survival model is used to do so. For the paired-release design, a treatment group is released at the upstream end of the reach in question, and a control group is released at the downstream end. The quotient of the survival estimates of these latter two groups is the unbiased estimate of survival through the ‘extra’ river reach. Hence dam passage survival is then estimated as the quotient of the single release survival to the paired release survival (Skalski 2009). These estimates of dam passage survival are more precise than the quadruple-release design, all things considered equal, because fewer parameters require estimation (Giorgi et al., in press). This is the method we are proposing to use for this study.

Alternate tagging technologies

Several different tagging methods have been developed and applied to estimate survival passage for juvenile salmonids. All of the above survival models can be carried out using any sort of uniquely identifiable tag, including PIT, acoustic, or radio tags. The sample sizes are typically dictated by the desired precision of the survival estimates. As stated above, the precision is a function of sample size and detection probability. In order to achieve a desired level of precision, sample sizes need to be larger for tags with a lower probability of detection. For example, studies using radio and acoustic tags (with detection ranges of hundred of meters) require far fewer tagged fish than those using PIT tags (with detection ranges of a few meters at most), since the probability of detection is so much higher. If the recapture rates were high enough, spaghetti tags or anchor tags could conceivably also be used. Hi-Z turbine tags have also been used to estimate route-specific survival.

The following section describes each of the available technologies, including a basic description of key assumptions, uncertainties, and potential limitations.

Acoustic Transmitters

Acoustic tags are currently used in the Columbia River to estimate the combination of direct and indirect mortality. The main tag types are produced by Hydroacoustic Technology, Incorporated (HTI), Lotek, Vemco, and Batelle National Laboratories Northwest. Tags come in a variety of sizes with a variety of battery life expectancies. Some of the tags emit unique codes (e.g., Vemco or Lotek), while others are distinguished from each other based on the frequency of transmissions. Tags based on the frequency of transmissions are easier to detect in noisy environments, however post-season data processing is arduous and expensive. In contrast, coded tags have diminished detectability in noisy environments, and can be affected by signal collisions when many tags are in the same area, yet the post season data processing is straightforward and quick.

The Lotek model MAP6_2 acoustic transmitter is a 200 kHz digital CDMA transmitter. The tag dimensions (6.2 mm × 15 mm, 1.1 g in air) make it suitable for tagging yearling Chinook and it has an expected life of 14 days (at 5 s burst rate). Its coding system has a capacity of up to 80,000 individual transmitter ID's on a single frequency. The major advantage to this tag over conventional acoustic tag technology is the large number of unique tags that can be tracked simultaneously within a hydrophone array.

The HTI model 795Lm acoustic tag is a 307 kHz pulse code transmitter. The tag dimensions (6.7 mm × 16.4 mm, 0.65 g in air) make it suitable for tagging yearling Chinook and it has an expected life of 38 days (at 3 sec burst rate). Individual tags will have slightly varying operational life due to inherent variation in batteries, and the variation in pulse width (which is used to identify a tag). Other aspects of this tag include a detection range of up to 1 km, and code-phase signal modulation (increases signal strength). This tag is small, and will allow tagging of fish greater than or equal to 13 g.

The JSAT model 2.1 acoustic tag is a 416 kHz binary phase shift keying coding transmitter. It's dimensions are 5 mm x 12 mm, 0.35 g in air, and it has an expected life of 40 days (at 5 sec burst rate). The JSAT node receiver (WHS 4000, Lotek Wireless, Newmarket, Ontario) is compact and highly sensitive unit that allows for tens of thousands of unique identifications on a single acoustic frequency. This technology has not been field tested as of 2010, and is currently being tested by the Pacific Northwest National Laboratory (Richland, WA, USA (PNNL); US Department of Energy), and the US Army Corp of Engineers (Portland, OR, USA). The operational life of the receiver is 100 days, powered by two lithium cell batteries. Other aspects of this tag include a detection range of 150 m, and will allow tagging fish greater than 7.0 gram.

The Vemco model V7-1L and V7-2L acoustic tags are a pulse code transmitter which take 3.2 s to emit the 8 pulses required to identify individual tags. As such, they do not manufacture tags with burst intervals less than 20 s. At 20 s burst intervals, the V7-1L will last 16 d, and the V7-2L will last 36 d. The V7-1L tags measure 7 mm × 18 mm (weight = 1.4 g in air) and V7-2L contain one additional battery and measure 7 mm × 20 mm (weight = 1.6 g in air).

The following table compares some of the key features of some of the acoustic tags that are on the market that could be used in a Wilsey Dam Chinook salmon survival study.

Table 1. Comparison of acoustic tags from various vendors.

<table>
<tr><th>Company/tag type</th><th>Tag model</th><th>Weight in air (g)</th><th>Size of tag (mm)</th><th>Average life (days); (burst rate)</th><th>Minimum size of fish tagged (based on 5% of body weight; g)</th></tr>
<tr><td>Lotek</td><td>MAP6_2</td><td>1.1</td><td>6.2 x 15</td><td>14 (5)</td><td>22.0</td></tr>
<tr><td rowspan="2">HTI</td><td>795Lm</td><td>0.65</td><td>6.7 x 16.4</td><td>38 (3)</td><td>13.0</td></tr>
<tr><td>800</td><td>0.5</td><td colspan="2">available in 2010</td><td>10.0</td></tr>
<tr><td>JSATS</td><td>2.1</td><td>0.35</td><td>5 x 12</td><td>40 (5)[a]</td><td>7.0</td></tr>
<tr><td rowspan="2">Vemco</td><td>V7-1L</td><td>1.4</td><td>7 x 18</td><td>16 (20)</td><td>28.0</td></tr>
<tr><td>V7-2L</td><td>1.6</td><td>7 x 20</td><td>36 (20)</td><td>32.0</td></tr>
</table>

[a] This tag has not been field tested as of March 2010, so this tag life estimate has not been confirmed.

Radio Tags

Radio tags have been used successfully to estimate survival for many studies (e.g., Robichaud et al. 2003). The main tag type, manufactured by Lotek, is a coded transmitter which allows over 500 unique codes on a single frequency, thereby reducing the need for additional frequencies (and the corresponding reduction in overall scan time). Tags come in a variety of sizes with a variety of battery life expectancies, but the smallest is the model NTQ-1, which measures 5 mm × 3 mm × 10 mm (weight = 0.25 g in air). This is the smallest tag available. At 5 s burst intervals, this tag will last 21 d. Another model is the NTQ-2, which is the same size, weighs 0.3 g in air, and will last 33 d. These two tags will allow tagging of fish weighing 5 and 6 g, respectively. The disadvantage of radio tags is their external antenna, which must be threaded through the side of the fish (thus increasing invasiveness of surgery, and increasing surgical duration), where it dangles externally alongside the fish. The presence of the antennas could theoretically reduce survival of radio-tagged fish relative to acoustic-tagged individuals.

PIT Tags

Passive Integrated Transponders (PIT) has no battery, and remains inactive until read with a scanner. The scanner sends a low frequency signal to the microchip within the tag providing the power needed to send its unique code back to the scanner. PIT tags are designed to last the life of the animal providing a reliable, long term identification method. PIT tags come in a variety of sizes, but typically measure 12.5 mm × 2.07 mm (weight = 0.102 g). These tags are so small that they can be injected into fish using a syringe. The minute size of the tags allows for very small fish to be tagged. However, the detection range is very small; tags must come within about one meter of a scanner to be identified. In areas where no fish bypass structures are in place, there is not an area where fish can be concentrated enough to effectively scan them for tags. As a result, we do not recommend this technology for the proposed study.

Hi-Z Turbine Tags

Hi-Z turbine tags (also known as “balloon” tags) can also be used to estimate route-specific survival. These tags require that the fish be released directly into the passage route of interest (e.g., Normandeau and Skalski 1997). They should be considered only when an estimate of direct mortality is required. If the objective of the study is to measure mortality beyond just the turbines, or some estimate of indirect mortality, then they should not be considered.

Hi-Z turbine tags normally requires a paired release study, and appropriate conditions in the tailrace of the dam being studied so fish can be recaptured immediately downstream of the project. The “control” group for the fish are released usually in the draft tube of the dam, while the “test” group is released within the turbine intake, immediately upstream of the turbines.

Key Considerations

The following section outlines key considerations and limitations for each of the potential tagging technologies.

Are test fish appropriate research animals?

Many factors need to be considered when developing a survival study (see above). One of the main concerns is whether the fish used will represent the population of interest. Because Chinook salmon were extirpated upstream of the Wilsey Dam site, understanding the anticipated life history characteristics (e.g., timing of migration, size at migration, etc.) is essential prior to using a certain life stage (yearling or subyearling), and especially size of fish to estimate survival.

Size of fish

It appears that ocean-type Chinook appear to predominate the Shuswap River. In general, ocean-type Chinook begin their migration downstream shortly after their emergence from the gravel. As stated above, most of these fish are expected to be between 40-60 mm upon their migration in the summer. This size of fish is too small to tag (not even PIT tag tags)(Brown et al. 1999). Therefore it will be necessary to find a surrogate life stage, or sized fish to meet the 120 mm fork length size limit suggested by Adams et al. (1998a). Giorgi et al. (in press) suggest that a tag burden maximum between 5% and 6.5% is justified. Using a 5% tag burden limit, the minimum weight of taggable fish would be as follows:

Table 2. Minimum weight of fish used for survival studies based on technology used.

Tag type/ model	Tag weight (g)	Minimum size of fish (no greater than 5% body weight)
PIT	0.102	2.04
Lotek NTQ-1 radio tags	0.25	5.0
JSAT 2.1 acoustic tags	0.35	7.0
HTI 795Lm acoustic tags	0.65	13.0
Lotek MAP acoustic tags	1.1	22.0
Vemco V7-1L acoustic tags	1.4	28.0

Another consideration limiting the size of taggable fish is the tag volume. Volume can affect swimming ability, or restrict air bladder inflation, thereby compromising the ability to regulate buoyancy.

Tags may affect fish behaviour regardless of tag burden. For example, radio tags with external antennas may affect swimming behaviour due to increased drag caused by the protruding antenna (Anglea et al. 2004). Acoustic tags and PIT tags have no external antenna. Also, sample sizes may need to be very large for tag types with limited detection range (e.g., PIT tags). Since the acquisition of very large numbers of run-of-river fish can be difficult, it is often necessary to use hatchery fish as surrogates for natural populations in PIT tag studies. As the survival of hatchery fish may differ from that of wild fish (not only as a result of potential size differential), care must be taken when extrapolating the results of hatchery survival studies to the wild population.

Behavior of fish

One key concern of conducting survival studies is whether the tagged population will mimic not only the size of the fish they are representing, but also, more importantly, their behavior. This is a major concern if the objective of the study is to measure project survival, and less so for dam survival (depending on the technology used).

For project survival, it is important for the tagged fish to behave similarly to the fish they represent as they enter the forebay and choose the route of passage through the dam. For direct survival, depending on the technology used, it may make less of a difference how fish are behaving unless how and where they enter the turbine intake affects the survival estimate. This would be less of a concern at Wilsey Damn because fish reach the turbine intake through a penstock (Figure 2).

The use of hatchery fish is sometimes necessary because of sample size requirements (depending on the technology used) and the feasibility of capturing large numbers of fish needed to reach sample size requirements. Unfortunately, hatchery fish freshly released from the hatchery environment rarely behave similarly to the wild population they are being used for (need citation here of CPUD study). Behavior and subsequent survival could be biased (usually downward), and hence management decisions could be made on seriously flawed conclusions. Care must be taken on exactly what information is gleaned when hatchery fish are used as surrogates for wild fish.

Are passage conditions during experiments representative of conditions that re-established Chinook will encounter?

In order to ensure that experimental subjects are representative of the conditions that re-established Chinook will face, releases should be conducted over the duration of the expected migratory period (mid-June to late August).

Are there any sources of bias not controlled by the survival model?

In order to account for the possibility that survival varies over time, releases will be conducted over the duration of the expected migratory period of subyearling Chinook (June to August). Spatial differences between test fish and run of river fish can also bias survival estimates. If test fish are released into the forebay at a location where they would not normally occur (due to flows or bathymetry, etc), then they may choose their passage route differently than run of river fish. If project survival is measured, the upstream release group should be released far enough upstream of the dam, at a sufficient distance so that by the time they reach the dam face, we assume they are behaving normally, and are distributed naturally in the river.

If acoustic tags are used to measure project survival, then the position of the receiver arrays could also potentially bias the survival results. If latent post-release mortality is expected, then the detection arrays should be located far enough downstream of the release site that dead tagged fish would not be expected to drift into the array's detection range. If dead fish are detectable in the arrays, the survival will be overestimated.

Another consideration for the paired release group is that latent handling effects should be fully expressed in both release groups by the time they are detected at the downstream arrays. If the arrays are located too close to the release location of the downstream pair, then latent effects may be more fully expressed in treatment group vs. the control group, causing survival underestimation. This consideration may be counter-acted by the battery life limits of the transmitters, depending on the travel rate of the fish. The downstream detection arrays cannot be located so far from the release locations that the transmitter batteries may die before the fish reaches them. Since the upstream release group, which has farther to travel, is more likely to have battery failure than the downstream release group, survival estimates could be underestimated.

Are release and recovery samples sufficient for statistical precision?

To achieve a desired level of statistical precision, sample sizes need to be very large for tag types with limited detection range (e.g., PIT tags). For tag types with larger detection ranges, sample sizes can be much lower, allowing the use of run-of-river fish.

Precision-at-sample-size modelling allows predictions of the level of precision (the half width of a 95% confidence interval) associated with dam survival estimates. For this example, we used the Virtual-Release/Paired-Release model design. We varied dam survival from 80% to 95%, detection probability from 85% to 95%, and sample size from 50 to 400 tags. Survival through downstream river reaches was assumed to be 95%, and 90% of the upstream release group was assumed to reach the dam to become part of the virtual release group. The results show that approximately 10% (95% confidence interval) is about the best precision that can be expected under the assumptions used above. If subyearlings are used as the sample population, a more conservative estimate of survival (i.e., 60 % to 90%) may be warranted.

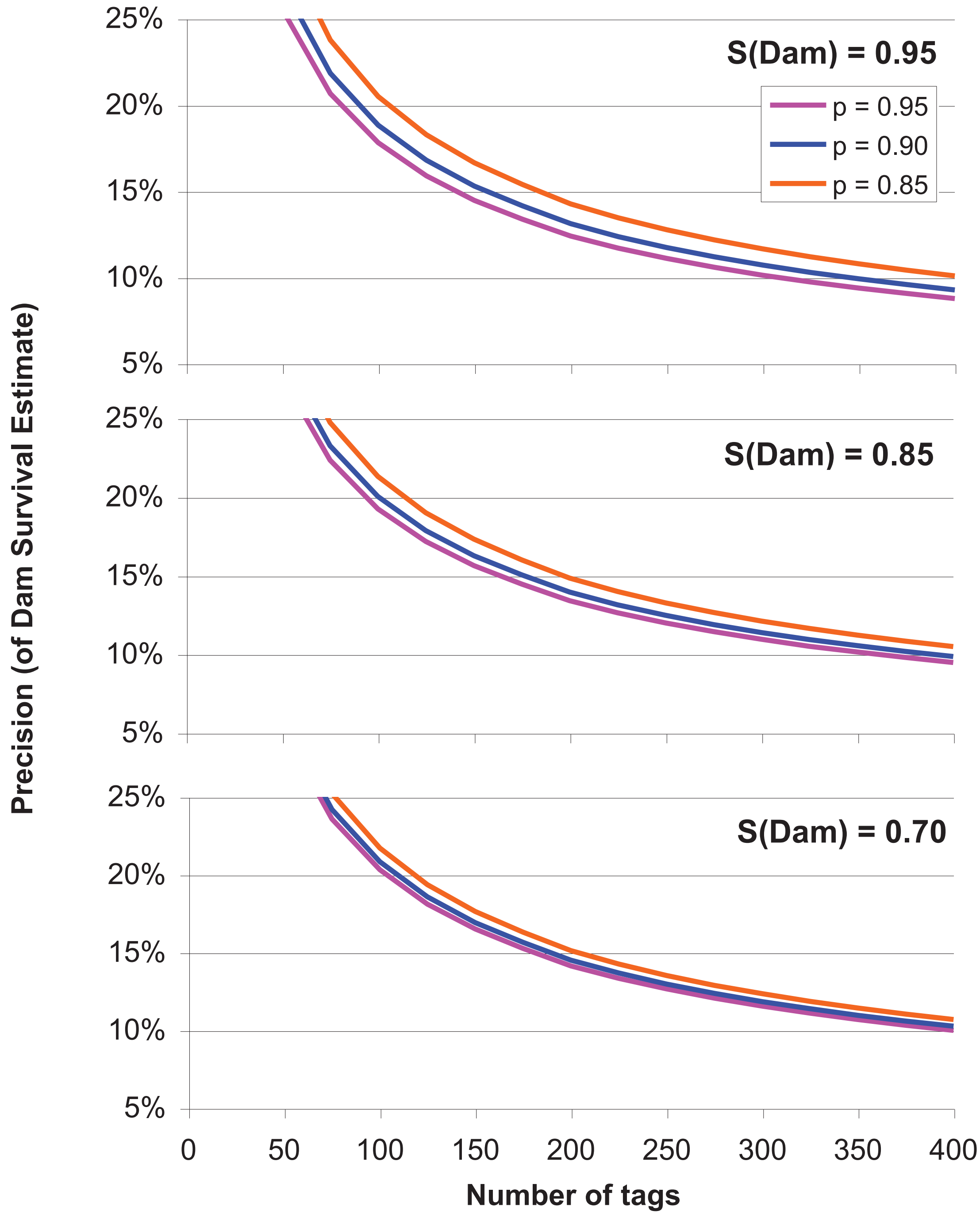

Figure 4. Precision of dam survival estimates, depending on the number of tags released (divided among three release sites), the survival rate of fish passing the dam, and the probability of detection at the downstream arrays.

Section C. Phased Approach to Estimate Juvenile Chinook Passage Survival at Wilsey Dam

Study Design

Phase I

We suggest the following be done in 2010 and 2011:

2010

- Collect data on acoustic noise levels in the forebay, dam site, and potential downstream detection sites and estimate the detection probabilities at all potential acoustic arrays with field surveys to optimize the acoustic telemetry array;
- Release subyearling Chinook to estimate travel and conversion rates from the release site to the dam;
- Determine the zone of inference with stakeholders;
- Determine how the information developed from survival studies at Wilsey Dam will be used to make management decisions or dam modifications;
- Based on the zone of inference and how the information will be used, determine which tag technology to use in Phase II.

Optimization of Acoustic Telemetry Array

During the first year of study, optimizing the receiver mooring system is essential to minimizing gear and data loss in areas where acoustic noise is prevalent. Reception efficiency tests can range from 0% to 100% depending on the mooring system and noise levels in the environment. Methods to improve the percentage of known transmission that are detected while the receiver is in known range of the transmitter are outlined in Clements et al. (2005).

Travel and conversion rates

We will release 25 subyearling Chinook at potential survival study release sites upstream of Wilsey Dam to estimate travel rate to Wilsey Dam. Data gathered from this trial will be used to validate our study population, technology, and the sampling plan outlined for Phase II.

Zone of inference

Which technology will be used to estimate survival at Wilsey Dam should depend primarily on the zone of inference and how the information will be used (see below). We suggest that the stakeholders involved in this process, including BC Hydro convene to determine the exact geographic boundaries that are of concern.

How information will be used

Prior to implementation of a study to estimate survival, there should be a clear understanding by all stakeholders how the information will be used. This could have a direct bearing on the technology used, or the number of fish used to reach specific precision targets.

We suggest that all stakeholders convene to determine how the information obtained from any survival study will be used and for what purpose. To illustrate the importance of this factor, we developed Figure 4, which relies on hypothetical results and modifications to operations or the dam.

Tag technology

Based on Figure 4, the technology used to estimate survival at Wilsey Dam should rely on the size of fish being used, the zone of inference, the acoustic noise level at the dam, and the level of confidence needed to make decisions (the level of confidence can be gained by either the method (e.g., Hi-Z tags need small sample size), or sample size (e.g., acoustic tags).

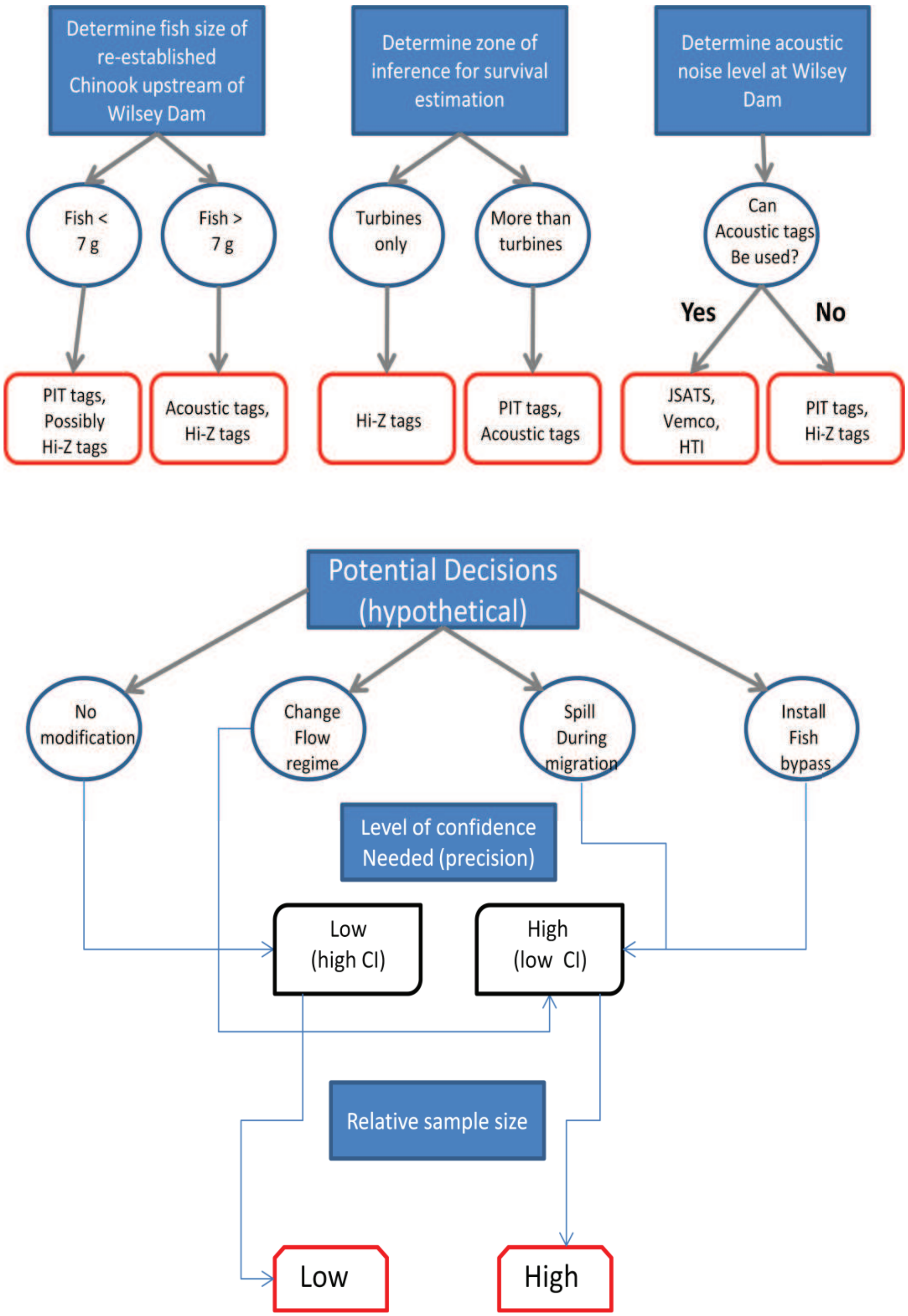

Figure 5. Theoretical decision chart to determine which technology to use to estimate survival at Wilsey Dam.

Phase II

In the following section, we demonstrate how studies could be carried out based on the different technology used. As suggested above, we recommend that all stakeholders first determine what fish size is available, the zone of inference, and precision needs before choosing which technology to employ.

Acoustic tags

Because of their small size, we recommend JSATS model 2.1 acoustic tags if acoustic technology is chosen. The main purpose of the study is to estimate survival rates for juvenile Chinook salmon passing through the Wilsey Dam (this estimate would include the area downstream of the detection array in the forebay, the penstock and the area in the tailrace to the point of the release of the first control group). Travel time (from the point of release to the detection array in the forebay) and passage route will be estimated also.

Between 15 June and 15 August, 270 acoustic-tagged Chinook subyearlings (including 45 dead fish) will be released in 3 replicates of fish. Tagged fish will be released at three locations: Highway 6 Release Site 1 (RS-1) (located 5.8 km upstream of the dam; UTM 11U. 0373787E. 5570029N; Photo Plate 3); Canyon Tailrace Pool RS-2 (located in the tailrace of the dam, 100 m from the structure, just outside the boil; UTM 11U. 0370911E. 5573089N); and at the Shuswap Hatchery RS-3 (located 1.8 km downstream of dam near at the site of the first downstream detection array; UTM 11U.370523E. 5573649N) (Photo Plate 4). Release dates were chosen to cover the main period of downstream migration of the salmon subyearling. The proposed number of tags was based on modelled precision-at-sample-size for the dam survival estimates (Figure 3).

Hydrophone arrays will be deployed at the face of the dam (a combination of 3 receivers to triangulate 2-D positioning relative to the spillway and power house; Photo Plate 5), and at three locations downstream of the dam, including: DS Array 1 (located 4.7 km downstream of dam (UTM 11U. 370875E. 5576178N), DS Array 2 Lawrence Road (located 9 km downstream of dam; UTM 11U. 372347E. 5579898N; Photo Plate 6 and 7), and Mabel Lake Inlet (located 22.4 km downstream of dam; UTM 11U. 374870E. 5587784N) (Photo Plate 8 and 9).

There will be two treatments over the duration of the study period: low flow (August) and high flow (June). Survival will be calculated separately for each treatment, but it is unlikely that differences will be distinguishable statistically, as the samples sizes were selected to meet a precision goal for the whole study-period, rather than for each of the treatments separately. Survival will be estimated using the virtual-release/paired-release design (Skalski 2009; see description above).

Telemetry Equipment & Arrays

Tagged fish passing each monitoring site will be detected on hydrophones. Operational tests will be conducted regularly to ensure optimal performance.

Transmitter Tags

The acoustic transmitters will be JSAT model 2.1 (Lotek Wireless, Newmarket, ON, Canada), which measure 12 mm × 5 mm, and weigh 0.4 g in air (0.3 g in water). This model of tag transmits a coded acoustic pulse every 5 s (for a total of 40 days). The acoustic pulses contain unique codes that permit identification of each specific tag by the receiver.[6]

Prior to implementing the study, detection rates and distances will be estimated by: 1. attaching a transmitter to monofilament line at a depth of 1.5 m, 2. attaching the line with transmitter to a float, and 3) releasing the tag upstream of the array and allowing the tag to pass upstream and downstream of the array (within 200 m). This procedure should be repeated a minimum eight times. During the study, test tags will be strategically placed on the hydrophone arrays to collect baseline information on system performance and functionality. In addition 5% of tags will be used to determine tag life during the test using tags that were produced in the same batch as ones being used in the test.

Receivers

A total of 9 receivers will be deployed in the study area. The receivers will be Lotek Wireless WHS model 4000. The WHS 4000 receivers are compact all-in-one receivers/hydrophone units, which can be deployed for the duration of the study, and downloaded upon retrieval.

The complete detection setup will consist of 4 arrays. The first array will be located in the forebay, close to the dam-face. This array will include 3 WHS 4000, in order to maximize detection efficiency. Fish detected at this array will become part of the “treatment group” for the estimation of dam-passage survival (i.e., they will comprise the “virtual release group”, V1, see above). The treatment groups for the estimation of route-specific survival will be comprised of fish whose last forebay detections are on receivers located near the spillway or near the turbines.

The remaining three arrays will be located at Cartwright Road-Shuswap Hatchery, Lawrence Road and Mabel Lake Inlet, and will include 2WHS 2000 receivers at each site, respectively. The arrays at each of these sites will be designed to maximize detection probability. The arrays will be deployed in low-noise areas where the river channel is relatively constricted, and minimally braided, in order in maximize the probability that an acoustic tagged fish will come within line-of-site detection range of the WHS receivers. Access to all sites is reasonable.

[6] As noted earlier, this tag has not been field tested. The information is based on estimates from the manufacturer.

Hi-Z turbine tags

Turbine passage survival will be assessed using a controlled experimental design with a repeated measures statistical analysis using Hi-Z tags described by Heisey et al. (1992; Normandeau Associates Inc, Bedford, NH, USA). The Hi-Z tag allows estimates of direct effects of turbine passage without causing mortality or injury during recapture by forcing the tagged fish to the water surface for retrieval. In addition to the Hi-Z tag, each fish will be given a unique, numbered radio tag (Lotek, Newmarket, ON, Canada), and a visual implant (VI) tag, (Northwest Marine Technology, WA, USA) prior to release for tracking survival of individual fish and easier detection for recapture.

Marked fish will be released upstream of the operating turbine and then retrieved following passage through the unit. If possible, the test group will be released into the surge tower (downstream end of penstocks) or an induction system can be constructed to release them in the penstock intakes. The experiment will be repeated several times to achieve a predetermined level of statistical power to be agreed upon by the project stakeholder group.

A control group of marked fish will receive identical treatment, with the exception that the fish will pass through a bypass structure. Use of the bypass structure for the control group will establish whether the assumption of high survival is correct. The control group would be released possibly within the draft tube (exit of the turbine). Two boats are located downstream of the project for recovery of tags, following inflation.

Upon recapture of the fish in the downstream area, the HI-Z and radio tags are quickly removed and the fish are transported to onshore holding tanks for latent mortality evaluation (48 hours). Since each fish is uniquely identified by the VI tag, treatment and control groups are held in the same tank environment for 48 hr holding period. Following the holding period, or when the fish die, thorough examination for injuries is conducted and photographic record is made of the fish with injuries.

Section D. Field, Analytical and Reporting Protocols

Tag Testing & Tag Management (if acoustic tags are used in Phase II)

The tags purchased for the study will be sent in 2 separate shipments to avoid on-shelf battery decay of the tags used in the later part of the study. Tags will be tested the night before they are implanted into fish. A tag will be assumed to be functional if it codes at least three times on a receiver. Tags will be disinfected in a germicidal solution (diluted chlorhexidine solution) for at least one hour, and then rinsed in distilled water prior to implantation. All tags will be checked a final time approximately 1-2 hours prior to the release of tagged fish.

Fish Collection, Handling, & Tagging Procedures

Fish Collection

Fish from Shuswap Hatchery will be used as surrogate run of the river Chinook. Depending on the technology used, a total of 125% of the sample size needed of Chinook will be dipped from rearing troughs, sorted for size, and transferred to separate rearing containers. A maximum tag weight to body weight ratio of 5% will be used to calculate minimum fish size.

Water temperature and dissolved oxygen will be monitored to maintain oxygen levels between 9-12 mg/l and water temperatures within 2 °C of ambient river water. Fish will be held for one day (15-36 h) prior to tagging. To minimize stress during the surgery, fish will not to be fed while held in the pre-tagging containers.

Tagging

Acoustic tags

Surgical procedures are adapted from Adams et al. (1998) and Robichaud et al. (2003). Tagging will occur inside an aseptic room, at the Shuswap Hatchery. On tagging day, fish will be randomly selected singly from the pre-holding container, and transferred into a buffered anaesthetic bath (containing tricaine methanesulfonate; MS222) using a sanctuary dip-net. The fish should take between 2 and 4 minutes to loose equilibrium and be ready for tagging. The concentration of the anaesthetic will be adjusted up or down to ensure that equilibrium is lost within that timeframe. If loss of equilibrium takes less than one minute or greater than 5 minutes, the fish will be rejected. The time that each fish is in the sedative bath will be recorded.

Once the fish loses equilibrium, the surgeon will visually screen the fish for fungus, disease, descaling, bloated belly, or any obvious abnormalities. The fish will be transferred (using a sanctuary dip-net) to a scale and weighed to the nearest 0.1 g. The data recorder will document the start and end time of surgery. The fish will then be measured to the nearest millimetre. Fish that are of adequate condition and above the minimum weight limit will be placed on the surgery table ventral side up. Anaesthetic will be administered into the mouth and over the gills using a tube and gravity feed. A scalpel will be used to make an incision, approximately 8 mm in length, about 3 mm away from and parallel to the mid-ventral line. The tag will be gently pushed into the body cavity, where it will lie directly under the incision. Two interrupted sutures will be used to close the incision. Just prior to the last stitch, the gravity feed tube will be switched from aesthetic to untreated river water, to commence the recovery process.

At the end of the surgical procedure, the tagged fish will be transferred into labelled 20 L recovery buckets. All surgical tools (scalpels, forceps, and scissors) will be disinfected in a germicidal solution for at least 15 minutes between uses, and will be rinsed in distilled water immediately before use. The length, weight, tag code, duration of the sedative exposure, and time out of water will be recorded for each tagged fish.

Hi-Z turbine tags

The balloon tag is a chemically based tag which is activated by injecting 1 to 1.5 ml of liquid catalyst into the tag prior to release. The tagging procedure will follow the protocols following Heisey et al. (1992). Anesthetised fish are tagged at the release site with a Hi-Z turbine tag through the musculature below the dorsal fin. A miniature radio tag is also placed through the musculature below the adipose fin that enables easier detection within the tailrace. In addition, a visual implant tag is inserted in the adipose eye lid for tracking 48 hr survival of each individual smolt after recapture. Fish will be recovered in a continuous supply of fresh water for a minimum of 30 minutes prior to release.

Post-tagging Recovery

Acoustic tags

Immediately after surgery, tagged fish will be transferred to a 20 L oxygenated recovery bucket where they are monitored until they regain equilibrium and normal breathing movements, and begin swimming. Two fish will be held per bucket for 15-24 hours before release. Recovery buckets will be kept on flow-through river water in a dark cool place. The recovery container will also serve as the release container. Important features of the recovery containers include:

- Sufficient space to accommodate two fish per container without overcrowding;
- No sharp edges or rough surfaces to catch or snag fish;
- Small size and a handle to allow for easy transport by one person;
- Lids that are secure to prevent fish from jumping out during holding and transport, but easily removed during release;
- An opening in the lid that allows continuous water flow and oxygen supply; and
- A PVC overflow spout with control valve to prevent spillage during transport.

Fish will be checked only twice during the post-tagging recovery period to minimize disturbance stress. Fish will be checked a few hours after tagging to ensure recovery from the anaesthesia; and general pre-release health conditions were checked immediately before release. Dissolved oxygen, water flow, and water temperature are measured throughout the post-tagging recovery period.

Release Procedures

Pre-transport Protocol

Acoustic tags

Approximately 15 min prior to transport from the Shuswap Hatchery, dissolved oxygen and water temperature will be measured in two of the release containers. Occasionally fish from one of the containers will be sacrificed for dead fish releases. The fish for dead-release will be exposed to a lethal dose of MS222 solution (167 mg/L) and have their gills cut with scissors to ensure they do not recover following release. Water flow to all release containers will be shut off 5 min prior to departure to the release sites. A 365 ml frozen water bottle will be placed in each container to prevent water temperatures from rising during transport, and all containers will be placed in plywood racks within a transport van. Air stones will be placed in each bucket, and the oxygen flow inspected regularly.

Transportation

Dissolved oxygen and water temperature will be measured in two buckets upon arrival at the release site. The transport time (the period between shutting the water flow at the holding area and beginning water recirculation at the release site) will be standardized for all release groups, to ensure that all fish are handled identically. For releases, buckets will be immersed in the river, to acclimate water temperature.

Releases

Acoustic tags

ONAFD reviewed available sites for release on Shuswap River upstream of Wilsey Dam. Two options are available. The preferred site is located approximately 5.8 km upstream of the dam. It appears to be accessible by vehicle. At this site, the river is 20 m wide, bank substrate consists of bedrock, and the channel configuration is straight with a gradient of 10%. A second option is on the right bank, near the bridge, 300 m upstream the dam. At this site, the river is 20 m wide, bank substrate consists of bedrock, and the channel configuration is straight with a gradient of 5%. Locations for release downstream of the dam include the dam tailrace (about 100 m from the dam, outside of the boil), and Shuswap Hatchery (locating 1.8 km downstream of the dam).

Releases will be made in high flow areas to minimize the number of fish that linger near the release site. Dissolved oxygen and temperature of the river water, and release time will be recorded. The upstream release group will be released first, and given time to reach the first downstream release location. The second release group will be released at the approximate time when the first release group passes the second release site. Similarly, the third release group will be released at the approximate time when the first and second release groups pass the third release site. We anticipate that the second release group will be released 48 hours following the first, and that the third group will be released one-half-hour following the second.

Dead tagged fish will be released at each site along with the live study fish. Transmitters continue to operate as dead fish are swept downstream by the current. It is important to confirm that dead fish do not drift downstream far enough to get detected at downstream telemetry arrays. If the dead fish are detected downstream, then it cannot be confirmed that any of the study fish are alive at the time of detection. To avoid this problem, field tests will be conducted to ensure the downstream detection sites are located properly.

Hi-Z turbine tags

An induction system will be developed to release test fish into the appropriate location (surge towers or intake of the penstock). For the control release, further recon will be needed to determine the exact location, but it will be as close to the outflow of the turbine as possible.

Data Management

Release Data

The release crew will record release data and the tagging crew will enter and verify the data in an Excel spreadsheet. After each release, the electronic database will be updated, backed up and emailed to ONAFD for further validation and analysis. Every day, all electronic data files will be backed up on an external hard drive.

Fish Detection Data

Acoustic tags

Fish detection data will be downloaded once after a trial run involving only dead fish, and then again at the end of the study period. Data logged by the receivers will downloaded to a laptop computer using a JSAT beta-software program developed by Lotek Wireless (Henry Tam, Lotek Wireless, pers. comm.). Data from the beta-JSAT software program will be imported into a database program for post-processing.

Hi-Z turbine tags

Fish will be recaptured and held for 48 hours. All injuries and mortalities will be reported.

Analytical Methods

Travel Times

Acoustic tags

Times required to pass from one reference location to another (i.e., to pass successive river sections) will be calculated as the time between the last detection at an upstream reference location and the first detection at a more downstream reference location, with no subsequent upstream detections. Medians will be used to describe average travel times (and hence rates) since the distribution of values will likely be strongly skewed to the right (i.e., most fish will take longer than the median to pass). Confidence limits of the medians will be calculated using the method described in Zar (1984).

Detection Efficiencies

Acoustic tags

Detection efficiencies will be calculated at each receiver array as the proportion of "available" fish that were actually detected. "Available" fish will include all those detected at or downstream of the array in question, since those located downstream must have passed through the area.

Fish Passage Efficiency

Acoustic tags

The fish passage routes will be calculated as the proportion of fish that pass the dam via both passage routes. This will only be possible for the releases that occur during June, since there is generally no spill after that.

Flow Effectiveness

Depending on the information obtained from the pilot study year, recommendations for flow modifications may warrant more intensive study. Increasing the sample size from a single, high-flow release to repeated, high-flow releases will be required to base survival estimates in response to flows (high versus low). If the objectives of the study are required to address flow medications, then flow effectiveness will be calculated as the proportion of fish traveling through a passage zone relative to the proportion of flow through that zone. Daily flow measurements at each passage zone will be provided by the dam operators, and will be averaged over several time blocks (or over the whole study period) to calculate relative flow through each passage zone.

Survival Modelling

Acoustic tags

In this section, we describe a model used to estimate the survival of Chinook subyearlings through the dam structure of Wilsey Dam. The same model can be used to estimate route-specific survival, though at lower levels of statistical precision.

The "virtual-release/paired-release" design (Figure 5) allows the estimation of dam passage survival using a combination of a traditional single-release and paired-release methods (Skalski 2009). A group of fish will be released upstream of the dam (R_1) a sufficient distance so that by the time they reach the dam face, they are behaving normally, and are distributed naturally in the river. The fish from this first release group that are known to have reached the forebay will comprise the 'virtual' release group (V_1). A traditional single-release survival model will be used to estimate the survival of the virtual release group through the dam and downstream to the next detection array, located sufficiently far enough downstream from the dam to avoid detections from dead tagged fish (S_1). Note that this S_1 estimate includes not only survival through dam passage, but also an ‘extra’ river reach downstream of the dam (Figure 5). In order to correct for the ‘extra’ river section, it is necessary to generate an unbiased estimate of survival through this section. To do so, a paired release survival model will be used. For the paired-release design, a treatment group (R_2) is released at the upstream end of the reach in question, and a control group (R_3) is released at the downstream end. The quotient of these survival estimates of these latter two groups (S_2/S_3) is the unbiased estimate of survival through the ‘extra’ river reach. Hence dam passage survival is then estimated as the quotient of the single release to the paired release,

$$\hat{S}_{\text{Dam}} = \frac{\hat{S}_1}{\left(\frac{\hat{S}_2}{\hat{S}_3}\right)} = \frac{\hat{S}_1 \hat{S}_3}{\hat{S}_2}.$$

The variance will be estimated as:

$$\left(\frac{1}{\hat{S}_2^2} - \frac{V\hat{a}r(\hat{S}_2)}{\hat{S}_2^4}\right)\left[\hat{S}_1^2 V\hat{a}r(\hat{S}_3) + \hat{S}_3^2 V\hat{a}r(\hat{S}_1) - V\hat{a}r(\hat{S}_1)V\hat{a}r(\hat{S}_3)\right] + \frac{(\hat{S}_1\hat{S}_3)^2}{\hat{S}_2^4} V\hat{a}r(\hat{S}_2)$$

Asymptotic 95% confidence intervals will be calculated as:

$$\hat{\theta} \pm Z_{1-\frac{\alpha}{2}} \sqrt{Var\left(\hat{\theta}\right)}.$$

The parameters for the initial model include:

S_1 = probability that a fish in group V_1 survived to Array 1;

S_{12} = probability that a fish in group V_1 survived to Array 2;

S_2 = probability that a fish in group R_2 survived to Array 2;

S_3 = probability that a fish in group R_3 survived to Array 2;

p_{11} = probability that a fish in group V_1 that survived Array 1 was detected there;

p_{12} = probability that a fish in group V_1 that survived Array 2 was detected there;

p_{22} = probability that a fish in group R_2 that survived Array 2 was detected there;

p_{32} = probability that a fish in group R_3 that survived Array 2 was detected there;

λ_1 = probability that a fish in group V_1 survived to Array 3 *and* was detected there;

λ_2 = probability that a fish in group R_2 survived to Array 3 *and* was detected there; and

λ_3 = probability that a fish in group R_3 survived to Array 3 *and* was detected there;

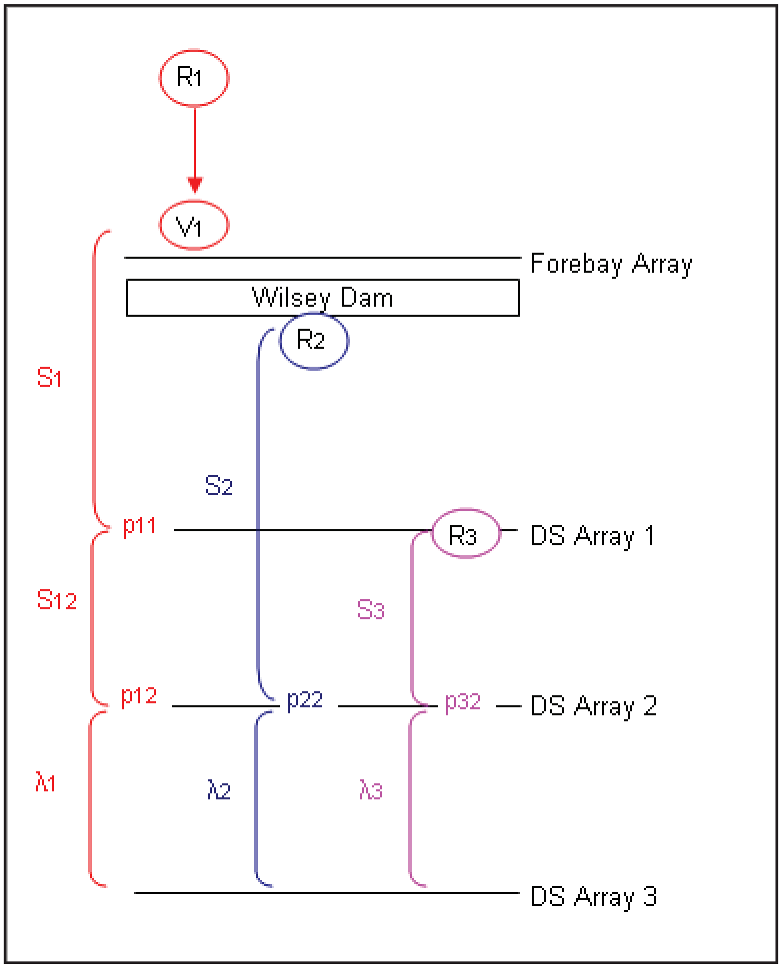

Figure 6. Schematic of the virtual-release/paired-release design with release R_1 that provides the fish for virtual release (V_1), releases R_2 and R_3, and specific survival (S) and detection probabilities (p) of interest.

Each release will be modeled as an independent multinomial distribution that describes the probability of the observed downstream detection histories. Table 3 summarizes the probability of occurrence of each of the possible downstream detection histories, in terms of the model parameters. These probability functions allow the model parameters to be fit using the observed detection history data. Note that in the final analysis, some of the downstream parameters shared by both release groups may be set equal to one another (i.e., $p_{12} = p_{22} = p_{32}$; or $\lambda_1 = \lambda_2 = \lambda_3$). Should a more parsimonious model be appropriate (most parsimonious model will be selected using AIC, Akaike information criterion), fewer unique parameters would be estimated, thereby reducing the standard errors of the remaining parameters.

Table 3. Detection histories and expected values for the three release groups. Every possible detection history is shown for the three release groups at the three downstream detection arrays. 1 = detected at the array; 0 = not detected at the array; x = released downstream of array, or not being parameterized.

Array 1	Array 2	Array 3	Probability Function
V_1 Release Group			
1	1	1	$S_1 p_{11} S_{12} p_{12} \lambda_1$
0	1	1	$S_1 (1-p_{11}) S_{12} p_{12} \lambda_1$
1	0	1	$S_1 p_{11} S_{12} (1-p_{12}) \lambda_1$
0	0	1	$S_1 (1-p_{11}) S_{12} (1-p_{12}) \lambda_1$
1	1	0	$S_1 p_{11} S_{12} p_{12} (1-\lambda_1)$
0	1	0	$S_1 (1-p_{11}) S_{12} p_{12} (1-\lambda_1)$
1	0	0	$S_1 p_{11} \left[(1-S_{12}) + S_{12} (1-p_{12})(1-\lambda_1) \right]$
0	0	0	$(1-S_1) + S_1 (1-p_{11}) \left[(1-S_{12}) + S_{12} (1-p_{12})(1-\lambda_1) \right]$
R_2 Release Group			
x	1	1	$S_2 p_{22} \lambda_2$
x	0	1	$S_2 (1-p_{22}) \lambda_2$
x	1	0	$S_2 p_{22} (1-\lambda_2)$
x	0	0	$(1-S_2) + S_2 (1-p_{22})(1-\lambda_2)$
R_3 Release Group			
x	1	1	$S_3 p_{23} \lambda_3$
x	0	1	$S_3 (1-p_{23}) \lambda_3$
x	1	0	$S_3 p_{23} (1-\lambda_3)$
x	0	0	$(1-S_3) + S_3 (1-p_{23})(1-\lambda_3)$

Model Assumptions

The assumptions of the single release-recapture model are the following:

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

A2. Tagging or sampling does not affect survival and capture probabilities. That is, tagged animals have the same probabilities as untagged animals.

A3. All sampling events are "instantaneous". That is, sampling occurs over negligible distance and negligible time relative to that between sampling locations and between sampling events.

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

A5. All tagged individuals alive in an area of interest have the same probability of surviving to the next downstream sampling location.

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

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

The first assumption (A1) concerns the validity of making inferences from the sample to the target population. For example, if inferences are sought to wild Chinook fry, then the tagged fish should not be hatchery-derived. Otherwise, non-statistical inferences are necessary to justify the similarity between the target population and the tagged fish. These assumptions could also be violated, for example, if fish selected for acoustic-tagging were larger on average than the general population, which will most likely be the case.

Assumption A2 again relates to the validity of making inferences to the population of interest (i.e., untagged fish). If tagging has a detrimental effect on survival, then survival estimates from the acoustic-tagged fish will tend to be negatively biased (i.e., underestimated).

The third assumption (A3) specifies that mortality is negligible immediately in the vicinity of the sampling stations, so that the mortality being estimated is entirely attributed to the river reaches in question and not to events that occur during sampling. In the case of emigrating Chinook, the area monitored by a hydrophone array is small relative to the size of the river reaches in question. This assumption must be met only for the sake of mathematical convenience and should be fulfilled by the nature of the emigration dynamics and deployment of the detection arrays.

The assumption of independence (A4) implies that the survival or death of one fish has no effect on the fates of others. In the larger river system with tens of thousands of fish, this is likely true. This assumption is common to all tag analyses, and there is little or no evidence collected to suggest it is not generally true. Nevertheless, violations of assumption A4 have little effect on the point estimate but might negatively bias the variance estimate.

Assumption A5 specifies that a fish's prior detection history has no effect on subsequent survival. This can be assessed from the detection histories of the individual fish. The lack of handling following initial release further minimizes the risk that subsequent detections influence survival. Similarly, assumption A6 could be violated if upstream passage routes influenced downstream detections. Violation of this assumption is minimized by placing detection arrays across the breadth of the river, or downstream of the mixing-point, below which fish using the various dam passage routes are intermingled.

Assumption A7 implies that the fish do not lose their tags (and hence are misidentified as dead). Tag loss and tag failure would tend to result in a negative bias (i.e., underestimation) of survival rates. The use of surgically implanted tags should minimize the chance of tag loss, and the possibility of tag failure will primarily depend on travel time relative to battery life. Assumption A7 also implies that dead fish are not falsely recorded as alive at detection locations. Dead fish drifting downstream could result in a false-positive detection and upwardly bias survival estimates. For this reason, the first downstream detection arrays must be located relatively far from the tailrace of the dam.

In order to estimate survival components from the paired-releases, two additional assumptions for valid survival estimation are necessary. These assumptions are:

> A8. Survival in the lower river segments is conditionally independent of survival in the upper river segments.
>
> A9. Paired groups (e.g., R_2 and R_3) experience the same probability of survival in the river segments that are common to both.

Assumption A8 implies there is no synergistic relationship between survival processes in the two river segments. In other words, fish that survive the first river segment are no more or less susceptible to mortality in the second river segment than fish released in the second river segment. Assumption A9 is satisfied by the in-river mixing of the release groups but can also be satisfied if the survival processes are stable over the course of fish passage by the releases. A stable survival process might well be expected for one to a few days under similar flow and spill conditions.

The virtual/paired-release design includes the following additional assumptions:

> A10. Survival in the lower river segment of the first reach is conditionally independent of survival in the upper river segment.
>
> A11. Releases V_1 , R_2 , and R_3 experience the same survival probabilities in the lower river segments they share in common.
>
> A12. V_1 is constructed of tagged fish known to have passed through the dam.
>
> A13. All fish arriving at the dam have an equal probability of inclusion in V_1, independent of passage route through the dam.

Assumption A11 implies there is no synergistic relationship between survival processes in the two river segments of the first reach. In other words, fish that survive the first river segment are no more or less susceptible to mortality in the second river segment than fish released in the second river segment. This is the reason the virtual-release groups are not simply paired with tailrace release groups. Such a paired design would match a 'veteran' tag groups with a new release. While the veteran fish may have fully expressed any post-release handling mortality, the fresh release group would not. The result is the 'appearance' of reduced survival in the downstream release group relative to the upstream, and thus dam survival would be overestimated. By pairing the veteran group with the unbiased results of a paired-release model, handling effects can be cancelled.

Assumption A12 is satisfied by the in-river mixing of the release groups but can also be satisfied if the survival processes are stable over the course of fish passage by the releases. A stable survival process might well be expected for one to a few days under similar flow and spill conditions.

Assumptions A13 and A14 refer to need for the sample fish to be representative of the untagged fish of interest. By placing the hydrophone arrays directly at the dam face, the probability of including only live fish in V_1 is improved. Should fish included in V_1 die prior to dam passage, the dam survival estimates will be underestimated. To meet Assumption A14, detection rates of the forebay array need to be uniform across the dam face to insure fish are equally likely to be included in V_1 regardless of the their passage route.

Many of these assumptions can be met through study design. Most can also be tested using a series of tests described in Burnham et al. (1987).

Hi-Z turbine tags

The release and recapture data are analyzed by a likelihood ratio test to determine whether recapture probabilities are similar for dead and alive fish (Skalski 1992). The likelihood model was based on the following assumptions:

1. The fate of each fish is independent,
2. The control and treatment fish come from the same population of inference and share that same survival probability,
3. All alive fish have the probability of recapture,
4. All dead fish have the same probability of recapture, and
5. Turbine passage survival and survival to the recapture point are conditionally independent.

Additionally, handling, tagging, and release do not differentially affect survival rates of treatment and control groups; treatment and control fish are equally vulnerable to recapture; and recapture crews do not differentially select retrieval of either group.

The likelihood model has four parameters and four sufficient statistics. The maximum likelihood estimators associated with this likelihood model are:

$$\hat{\tau} = \frac{a_T R_C}{R_T a_C}$$

$$\hat{S} = \frac{R_T d_C a_C - R_C d_T a_C}{R_C d_C a_T - R_C d_T a_C}$$

$$\hat{P}_A = \frac{d_C a_T - d_T a_C}{R_T d_C - R_C d_T}$$

$$\hat{P}_D = \frac{d_C a_T - d_T a_C}{R_C a_T - R_T a_C} .$$

Where:

R_C	=	Number of control fish
R_T	=	Number of treatment fish released into the turbine
a_c	=	Number of control fish recaptured alive
d_c	=	Number of control fish recaptured dead
a_T	=	Number of treatment fish recaptured alive
d_T	=	Number of treatment fish recaptured dead
S	=	Probability fish survive from release point of the controls to recapture
P_A	=	Probability a live fish is recaptured
P_D	=	Probability a dead fish is recaptured

τ = Probability a treatment fish survives to recapture point

$1-\hat{\tau}$ = Turbine-related mortality

The turbine passage survival or the turbine-related mortality is estimated with the formula:

$$1-\hat{\tau} = \frac{R_T a_C - R_C a_T}{R_T a_C}.$$

The variance and standard error of the estimated turbine passage mortality or turbine survival is:

$$Var(1-\hat{\tau}) = Var(\hat{\tau}) = \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_A)}{R_T} + \frac{(1-SP_A)\tau}{R_C}\right]$$

$$SE = \sqrt{Var(1-\hat{\tau})}\ .$$

The 90% confidence intervals on the estimated survival can be calculated using the profile likelihood method (Hudson 1971). This profile likelihood method constructs confidence intervals without the need to assume normality of the parameter estimates and is generally assumed superior to the normal approximations.

Statistical Methods

Acoustic tags

When only two groups were being compared, two-tailed t-tests will be used; otherwise ANOVAs will be used. The non-parametric equivalent (the Kruskal Wallis Test) will be used when data are non-normally distributed. Comparisons among survival estimates will be made using Z-tests.

Reporting Protocols

A critical component of this study will be the completion of a detailed report outlining all efforts and results used for the project. The final report will describe an operational plan for Wilsey Dam during juvenile Chinook out-migration. Components of the report will include rationale for the study, detailed methods and protocols, detection rates, and recommendations regarding the feasibility of the technique for long term planning of Wilsey Dam operation. Included in the recommendations will be a standardized protocol for acoustic operations on Middle Shuswap River (and Wilsey Dam) and associated start-up and operational annual costs (equipment and labor) of the proposed system design. A final report will be provided in hardcopy and PDF format with all raw data to be provided as appendices. As part of regular communication, quarterly progress reports outlining complete tasks, upcoming tasks to initiate, and a comparison of budgeted and actual expenditures. All data will be delivered to the client on optical media.

Operational Schedule & Budget

Acoustic tags

There are 5 main tasks associated with this project:

a) Planning & Design Review: Project service providers will participate in initial study planning and design discussions with the Study Team with representation by BC Hydro, DFO, and MOE. The schedule of activities will be refined according to the project needs and technical aspects of the study design and general methods will be reviewed with the study team to ensure all study objectives will be achieved using the equipment and effort as outlined in this report.

b) Deploy & Test Acoustic Arrays: This task is critical to the success of this project, and must include a site visit to coordinate installation of acoustic arrays. The initial site assessment will result in the selection of the optimum sites to conduct the study, and prioritization of the other potential sites. Landownership is a potential issue that may need to be addressed. The deployment and testing process is expected to take 3-4 days.

c) Operate & Maintain Acoustic Systems: During the course of the field work, equipment will be inspected daily, repaired or replaced when malfunctioning as needed to assure data collection is not interrupted during the field season. Initial data collection will begin one month prior to tagging for monitoring environmental "noise" and refine operational and maintenance schedules. A sufficient level of effort will ensure the systems are operated 24 hr/day and 7 day/week during the study period, and that any downtime is minimized. Acoustic data will be managed with the utmost care.

d) Tag and Release Fry: We recommend the Wilsey Dam Study Team work closely with the Shuswap Hatchery to leverage equipment and facility use for the collection, holding, tagging, processing and release of fish.

e) Data Management, Analyses & Reporting: The study team should ensure all data management, analyses, and reporting is met as outlined in this report.

Date	Event/Deliverable
1 February to 15 February	Finalize study design with BC Hydro
16 February to 15 March	Install & test acoustic arrays
15 May to 15 September	Operate and Maintain Acoustic System
15 June to 15 August	Tag and release Chinook subyearlings
15 July to 31 October	Conduct analysis of acoustic data and develop preliminary conclusions and recommendations
1 November to 31 December	Reporting

Equipment malfunction and weather are the main risks associated with this project. The study team selected should be well qualified to deal with either of these possibilities. This project will be jointly conducted by DFO, MOE, BC Hydro, and ONAFD. The fisheries study team should include qualified experts with a background in: fish behaviour, hydro system fish passage, biotelemetry, electronic technology, and biometry.

Budget

The total estimated cost of Phase I and Phase II is $62,000, and $192,650, respectively. The detail budgets are described in Appendices 2 and 3. The cost of assessing direct mortality at the turbine (Hi-Z-radio tag combination) or assessing 'project' survival (Acoustic tags) is estimated at $192,650.

Recommended Next Steps

The following recommendations are based on information gathered to date, and outlined in this report.

1. Assign agency personnel currently involved in survival and behaviour studies of juvenile salmon at Wilsey Dam Project the task of reviewing, editing, and finalizing a detailed study plan to accomplish the objective of measuring the impact on juvenile Chinook salmon.

2. Commence discussions with hydro system operators to develop a schedule to fit the study design.

3. Fund a pilot project (Phase I) to monitor 25 acoustic-tagged, juvenile Chinook (yearlings and subyearlings) during June and August to assess equipment performance and fish behaviour. A report of the trial will summarize:
    a. Efficiency trials using acoustic telemetry arrays at pre-selected sites,
    b. A decision process to determine the zone of inference for future studies,
    c. How the information collected will be used for system management decisions; and
    d. Which technology is suited for future studies and project objectives.

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APPENDICES

Appendix 1. Mean daily discharge (cms-1) at Water Survey Canada gauge on the Shuswap River near Lumby (WSC#08LC003; 1989-2009; http://www.wsc.ec.gc.ca/stflo/).

Day	Jan	Feb	Mar	Apr	May [a]	Jun [a]	Jul [a]	Aug [a]	Sep	Oct	Nov	Dec
1	21.1	20.1	19.1	24	67.8	164	125	44.6	29.4	27.7	29	24.4
2	21.1	20	18.7	24.9	68.9	168	122	42.3	29.1	28	28.3	24.4
3	21.1	20.1	18.3	25.7	70.6	171	117	40.7	29.3	28.6	28.1	24.1
4	21.2	20	18.1	26	71.5	170	115	40.5	29.1	28.4	27.7	24.3
5	21.3	20	18.8	26.5	73	172	108	41.2	29.2	28	26.9	24.2
6	21.4	20	18.7	27.1	75.5	174	106	40.9	29.4	28.2	27	24.1
7	21.3	20	18.5	27.8	78.1	174	103	39.7	29.3	28	26.7	23.9
8	21.2	19.9	18.7	29	79.5	176	98.9	38.6	29.3	27.5	26.5	23.8
9	21.3	19.8	18.7	29.7	83.4	176	96.7	38.1	29.1	28.2	26.3	23.4
10	21	19.8	19	30.8	86.6	176	94.4	37.8	28.8	28.2	26.7	23.6
11	21.4	19.8	19.1	31.5	89.9	172	93.5	37	29.5	28.3	26.4	23.2
12	21.3	20	19.4	32.5	96.3	167	93.7	36.2	29	28.2	26	23.2
13	21.3	19.9	19.3	33.9	98.9	167	91.2	36.6	30.2	28.7	26.3	23.1
14	21.1	20	19	35.2	105	167	89.1	36.7	30	28.8	26.4	23.1
15	21.3	19.9	18.7	37.1	109	167	86.2	35.6	30	28.7	27	22.7
16	21.3	19.6	18.6	38.6	113	166	84.7	35	30.1	28.9	26.9	22.5
17	21.2	19.7	18.9	39.8	116	164	82.5	33.8	29.9	28.7	26.8	22.6
18	21.2	19.7	19.4	42.4	120	160	79.6	33.4	30.7	28.3	26.8	22.6
19	21.1	19.9	19.8	45	123	157	75.2	32.7	30.5	28.5	26.6	22.5
20	20.8	19.9	20.3	47.2	126	153	70.6	32.1	29.7	29	26.4	22.8
21	20.7	19.8	20.7	48.1	129	150	66.9	31.8	29.6	28.8	26.4	22.3
22	20.6	19.9	21.1	50.3	135	150	63.7	31.5	29.5	29.2	26.5	22.4
23	20.5	20.1	21.5	52.3	140	150	61.5	31.4	28.6	29.3	26.7	23
24	20.7	20.1	21.9	54.5	144	148	59.3	31.5	28.1	29.7	26.8	22.7
25	20.5	19.8	22.3	55.9	146	147	57.5	31.9	28.6	29.7	26.7	22.2
26	20.7	19.7	22.5	57.6	149	141	55.6	31.5	29.3	29.8	26.2	21.9
27	20.5	19.6	22.8	59.3	151	138	53.9	31.7	29.1	29.5	26.1	22
28	20.5	19.2	23.3	62.8	154	134	52.6	32.2	28.9	30.2	25.8	22.3
29	20.5	17.3	23.4	65.1	161	130	50.8	32	29.1	29.6	25.6	22.2
30	20.5		23.6	67.4	160	129	49.2	30.3	28.6	29.6	25.5	21.9
31	20.5		23.8		161		46.8	29.9		29.3		21.7

[a] Study period shaded grey.

Appendix 2. Summary of monthly budget for juvenile Chinook survival study at Wilsey Dam (Phase I).

Units	**Wilsey Dam Juvenile Study**	Cost/Unit	Total	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	Personnel time														
	Senior Scientist			1	0	0	0	1	0	0	0	0	0	1	3
	Biologist			3	3	2	2	5	0	5	1	1	1	1	24
	Telemetry Tech			3	3	2	2	5	0	5	0	0	0	0	20
	Tagger 1			0	0	0	0	2	0	2	0	0	0	0	4
	Tagger 2			0	0	0	0	2	0	2	0	0	0	0	4
	Tech 1			0	0	0	0	5	0	5	0	0	0	0	10
	Tech 2			0	0	0	0	5	0	5	0	0	0	0	10
	Personnel cost														
	Senior Scientist	1000		1,000	0	0	0	1,000	0	0	0	0	0	1,000	3,000
	Biologist	650		1,950	1,950	1,300	1,300	3,250	0	3,250	650	650	650	650	15,600
	Telemetry Tech	450		1,350	1,350	900	900	2,250	0	2,250	0	0	0	0	9,000
	Tagger 1	400		0	0	0	0	800	0	800	0	0	0	0	1,600
	Tagger 2	400		0	0	0	0	800	0	800	0	0	0	0	1,600
	Tech 1	250		0	0	0	0	500	0	500	0	0	0	0	1,000
	Tech 2	250		0	0	0	0	1,250	0	1,250	0	0	0	0	2,500
Units	Disbursements	Cost/Unit	Total												
25	Acoustic Tags	360	**9000**			9,000									9,000
3	Hydrophones	1200	**3600**		900	900	900	900	900	900	900	900			7,200
1	Fish Release Truck & Aerat	1000	**1000**					1,000		1,000					2,000
1	Surgery Tagging Trailer	1000	**1000**					1,000		1,000					2,000
3	Hydrophone Mounts	500	**1500**		375	375	375	375	375	375	375	375			3,000
	Equipment rental		**250**			63	63	63	63	63	63	63			438
	Accomodation		**2200**					550		550					1,100
4	Travel	1000	**4000**					1,000		1,000					2,000
	Meals		**1800**					450		450					900
	Totals			**4,300**	**4,575**	**12,538**	**3,538**	**15,188**	**1,338**	**14,188**	**1,988**	**1,988**	**650**	**1,650**	**61,938**

Appendix 3. Summary of monthly budget for juvenile Chinook survival study at Wilsey Dam (Phase II).

Units	Wilsey Dam Juvenile Study	Cost/Unit	Total	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
	Personnel time															
	Senior Scientist			1	1	1	1	1	1	1	0	1	0	0	0	8
	Biologist			3	3	3	3	3	2	2	2	2	2	2	2	29
	Telemetry Tech			5	0	7	7	7	7	5	1	1	0	0	0	40
	Tagger 1			0	0	5	5	5	0	0	0	0	0	0	0	15
	Tagger 2			0	0	5	5	5	0	0	0	0	0	0	0	15
	Tech 1			0	0	5	5	5	0	0	0	0	0	0	0	15
	Tech 2			0	0	5	5	5	0	0	0	0	0	0	0	15
	Personnel cost															
	Senior Scientist	1000		1,000	1,000	1,000	1,000	1,000	1,000	1,000	0	1,000	0	0	0	8,000
	Biologist	650		1,950	1,950	1,950	1,950	1,950	1,300	1,300	1,300	1,300	1,300	1,300	1,300	18,850
	Telemetry Tech	450		2,250	0	3,150	3,150	3,150	3,150	2,250	450	450	0	0	0	18,000
	Tagger 1	400		0	0	2,000	2,000	2,000	0	0	0	0	0	0	0	6,000
	Tagger 2	400		0	0	2,000	2,000	2,000	0	0	0	0	0	0	0	6,000
	Tech 1	250		0	0	1,250	1,250	1,250	0	0	0	0	0	0	0	3,750
	Tech 2	250		0	0	1,250	1,250	1,250	0	0	0	0	0	0	0	3,750
Units	Disbursements	Cost/Unit	Total													
270	Acoustic Tags/Hi-Z tags	360	**97200**			97,200										97,200
9	Hydrophones/ Radio Rx	1200	**10800**			2,700	2,700	2,700	2,700							10,800
1	Fish Release Truck & Aerat	1000	**1000**			1,000	1,000	1,000	1,000							4,000
1	Surgery Tagging Trailer	3500	**3500**			3,500										3,500
9	Hydrophone Mounts	500	**4500**			1,125	1,125	1,125	1,125							4,500
	Equipment rental		**300**			75	75	75	75							300
	Accomodation		**2200**			550	550	550	550							2,200
4	Travel	1000	**4000**			1,000	1,000	1,000	1,000							4,000
	Meals		**1800**			450	450	450	450							1,800
	Totals			**5,200**	**2,950**	**120,200**	**19,500**	**19,500**	**12,350**	**4,550**	**1,750**	**2,750**	**1,300**	**1,300**	**1,300**	**192,650**

PHOTOPLATES

Photo Plate 1. Aerial photo of Wilsey Dam, BC.

Photo Plate 2. Upstream of Wilsey Dam forebay, left bank.

Photo Plate 3. Access from Highway 6, left bank, for releasing juvenile chinook.

Photo Plate 4. Location of downstream release sites, relative to Wilsey Dam project.

Photo Plate 5. Aerial photo of Wilsey Dam, and location of potential underwater hydrophones (Forebay arrays).

Photo Plate 6. Aerial photo of downstream Station 2Array, Middle Shuswap River.

Photo Plate 7. Right bank, downstream of Lawrence Road, steel-bridge crossing access to downstream Station 2 Array, Middle Shuswap River.

Photo Plate 8. Aerial photo of downstream Station 3 Array, upstream of Mabel Lake.

Photo Plate 9. Right bank, upstream photo of downstream Station 3 Array, Middle Shuswap River.