Anadromous Fish Evaluation Program
Final Research Proposal
FY2005 Project Year

I. BASIC INFORMATION

A. TITLE

Hydroacoustic Evaluation of Fish Passage for Surface Flow Bypass Development at The Dalles Dam in 2005

B. PRINCIPAL INVESTIGATORS

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C. STUDY CODES

SBE-P-00-17 (TDA surface bypass studies),
with relevance to SPE-P-00-08 (TDA survival studies)

D. DURATION

January 1, 2005 to December 31, 2005

E. DATE OF SUBMISSION

August 3, 2004

II. PROJECT SUMMARY

A. GOAL

The goal of this study is to provide information on smolt passage at The Dalles Dam that will support decisions on operations to enhance sluiceway and spill passage, reduce turbine passage, and thereby improve smolt survival at the dam.

B. OBJECTIVES

The objectives of the hydroacoustic evaluation of the run-at-large during separate spring (48-day, April 18 to June 4) and summer (42-day, June 5 to July 16) study periods in 2005 at The Dalles Dam are to:

1. Estimate spill passage efficiency[1] and effectiveness, sluice passage efficiency and effectiveness, and fish passage efficiency.

   Efficiency and effectiveness estimates from hydroacoustics are used to summarize fish passage for the run-at-large during the spring and summer migration seasons. Because similar methods have been applied in the last six years at The Dalles Dam, the metrics can be compared across years. This provides fisheries managers with data on trends and patterns in fish passage that they can use to make decisions on project operations and fish protection design efforts.

2. Estimate diel, vertical, and horizontal fish distributions at the powerhouse and spillway.

   Fish distribution is fundamental to understanding fish passage data. Distribution data are also used to aid design of project operations and structures intended to increase smolt survival.

3. Evaluate the effect sluiceway skimmer gate operation on fish passage into the sluiceway. Treatments will include selected combinations of open gates in the west (MU 1-1, 1-2, 1-3) and east (MU 18-1, 18-2, 18-3) regions of the powerhouse.

   In 2003, engineers determined that the sluiceway at The Dalles Dam was at less than maximum hydraulic capacity when the three chain gates at MU 1 were open, i.e., additional gates could be utilized. In 2004, sluice operations with west vs. west+east open gates are being evaluated. The management questions are how many, in what combinations, and where should sluice gates be opened to serve as a surface bypass for juvenile salmon and steelhead? Because of inter-annual variability in fish passage, sluice operations will be evaluated in 2005.

4. Integrate hydraulic data with fish movement, distribution, and passage data at the sluiceway.

   The sluiceway at The Dalles Dam is a functional surface flow bypass. Previous studies used fish movement data to determine the zone of entrainment for the sluiceway flow net (Johnson et al. 2001; Hedgepeth et al. 2002; Johnson et al. In Press). These studies, however, did not analytically integrate the fish movement data with hydraulic data because the appropriate hydraulic data became available after the studies were completed. Given the hydraulic tools now available and advanced imaging sonar methods (DIDSON) to track fish in the nearfield of the sluiceway (< 10 m), there is an excellent opportunity to improve understanding of fish behavior for the purpose of designing methods to enhance sluiceway passage. This approach is currently being applied for the FY2004 study; we will build upon this work in FY2005.

5. Provide recommendations for long-term measures to enhance sluiceway and spillway passage and reduce turbine passage.

[1] By definition, "efficiency" is the proportion of fish passing a given route and "effectiveness" is the fish:flow ratio (proportion fish divided by proportion water through a particular route).

We will discuss and interpret the collective information from this study and other studies as it pertains to long-term smolt protection measures at The Dalles Dam.

C. METHODOLOGY

The recommended methods will involve state-of-the-science hydroacoustic data collection and analysis methods. Fixed-location hydroacoustic techniques (explained in general by Thorne and Johnson 1993 and in detail by Ploskey et al. 2003) will be used to estimate fish passage rates at the spillway, sluiceway, and turbines. Acoustic imaging techniques (Dual-frequency identification sonar; DIDSON) will be used to track fish near the sluiceway. We plan to conduct hydroacoustic sampling 24 h/d during 48-day spring (April 18 to June 4) and 42-day summer (June 5 to July 16) study periods. Hydroacoustics complements acoustic and radio telemetry techniques because, although the data are not species-specific, it non-obtrusively samples a large number of fish to provide composite fish passage metrics for the run-at-large and can be applied to provide high resolution of fish movements within 10 m of sluice and spill gates.

D. RELEVANCE TO THE BIOLOGICAL OPINION

This project is relevant the Reasonable and Prudent Alternative of the National Marine Fisheries Service's (NMFS) Biological Opinion on operation of the Federal Columbia River Power System (NMFS 2000). In Action 68, the NMFS stated, *"The Corps and BPA shall continue spill and passage survival studies at The Dalles Dam…"* Furthermore, Action 85 says, *"The Corps shall continue to develop and evaluate improved fish-tracking technologies and computational fluid dynamics (numerical modeling)…"* And, Action 86 states, *"The Corps shall continue to investigate a way to increase entry rates of fish approaching surface bypass/collector entrances."*

III. PROJECT DESCRIPTION

A. BACKGROUND

Recent research (1999-2002) indicates that between 8 and 50% of the juvenile salmon that pass The Dalles Dam (TDA), do so through turbines (Ploskey et al. 2002). Turbine intake occlusions were tested at TDA in 2001 and 2002 to determine if blocking the upper half of turbine intakes at the trashracks might significantly reduce turbine entrainment. Results from this research indicate that the occlusions were not as effective at reducing turbine passage as was hoped and in some cases, even increased turbine passage (Beeman et al. 2002; Johnson et al. 2003). Additionally, survival of fish passing the spillway at TDA is lower relative to other projects on the lower Columbia River (Ploskey et al. 2002), so efforts to improve spillway survival are currently being pursued at TDA. But, regardless of the level of success in improving spillway survival at TDA, efforts also need to be made to minimize turbine passage in the long-term.

In 2004, sluiceway operations included opening the east gates (MU 18-1, 18-2, and 18-3) in conjunction with the usual west gates (MU 1-1, 1-2, and 1-3). Juvenile fish passage is being compared for two treatments: west gates only vs. west+east gates. The null hypothesis is that opening the east gates in conjunction with the west gates causes no significant increase in fish passage[2] into the sluiceway. Data from the 2004 study are still being collected and analyzed. A similar sluiceway operations study is

[2] The response variables will be sluiceway passage, sluiceway efficiency relative to the local turbine units, sluiceway efficiency relative to the whole powerhouse, and fish passage efficiency for the entire dam.

needed in 2005 because , besides inter-annual variability in fish passage, the results from 2004 may lead to new ways to optimize sluiceway passage.

Studies in the late 1990 and early 2000 years generally focused on fish passage and survival at TDA, though little information on distribution and approach paths of fish entering the forebay and passing the dam exists. In 2003, a hydroacoustic study was initiated to collect general information on fish distribution (vertical and horizontal) in the forebay of TDA. Additional, detailed information on individual fish approach paths and their passage fate needs to be coupled with population level fish distribution information to get a more complete description of how juvenile salmon enter TDA forebay and pass the dam. Recent developments in integrating computational fluid dynamic (CFD) model outputs and individual fish behavior data show promise at modeling fish response to hydraulic and structural elements they may encounter approaching a dam during their emigration. A fish/flow modeling approach may be useful in determining an optimal design and location of turbine passage reduction structures such as a forebay physical guidance device or a powerhouse surface flow bypass system. The 2004 is applying a fish:flow model to fish movement in the nearfield (within 10 m)of the west and east sluice entrances. A goal of the 2005 study is similar, that is, provide information on smolt passage at The Dalles Dam that will support decisions on long-term measures to enhance sluiceway and spill passage and reduce turbine passage in order to improve smolt survival at the dam.

B. OBJECTIVES

The objectives of the hydroacoustic evaluation of the run-at-large during separate spring (48-day, April 18 to June 4) and summer (42-day, June 5 to July 16) study periods in 2005 at The Dalles Dam are to:

1. Estimate spill passage efficiency[3] and effectiveness, sluice passage efficiency and effectiveness, and fish passage efficiency.

   Efficiency and effectiveness estimates from hydroacoustics are used to summarize fish passage for the run-at-large during the spring and summer migration seasons. Because similar methods have been applied in the last six years at The Dalles Dam, the metrics can be compared across years. This provides fisheries managers with data on trends and patterns in fish passage that they can use to make decisions on project operations and fish protection design efforts.

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   Fish distribution is fundamental to understanding fish passage data. Distribution data are also used to aid design of project operations and structures intended to increase smolt survival.

3. Evaluate the effect sluiceway skimmer gate operation on fish passage into the sluiceway. Treatments will include selected combination of open gates in the west (MU 1-1, 1-2, 1-3) and east (MU 18-1, 18-2, 18-3) regions of the powerhouse.

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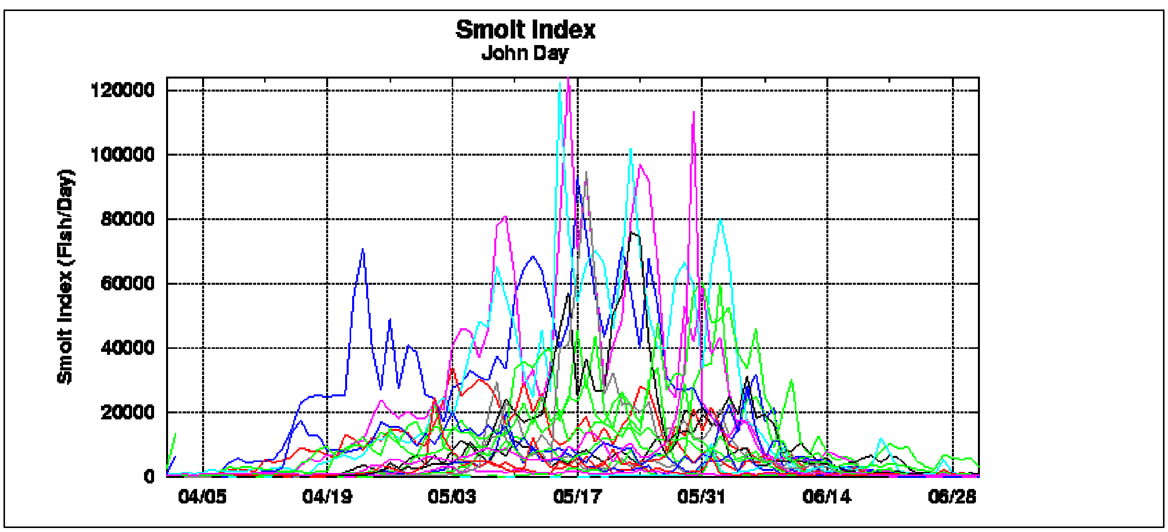
5. Provide recommendations for long-term measures to enhance sluiceway and spillway passage and reduce turbine passage.

   It will be important to discuss and interpret the collective information from this study and others as it pertains to long-term smolt protection measures at The Dalles Dam.

C. STUDY PERIOD

Separate spring and summer study periods were established by examining the 5-year record of smolt passage indices from John Day Dam (Figure 1). John Day Dam, the nearest upstream dam with smolt monitoring facilities, is representative of The Dalles Dam because travel times between the two projects are about 1 day based on radio telemetry data (J. Beeman, USGS-BRD, pers. comm.). During spring, yearling salmon and steelhead predominate the downstream migration (Figure 1). During summer, subyearling chinook salmon dominate (Figure 1). Based on the previous five years (1999-2003), the emigration generally has started to increase in magnitude by April 18. The demarcation between spring and summer emigrations is around June 5/6. Although the outmigration in summer can be protracted, the peak has usually passed by mid-July when adult shad begin to be present in noticeable numbers. Therefore, the study periods will be: spring = April 18 to June 4 (48 days) and summer = June 5 to July 16 (42 days).



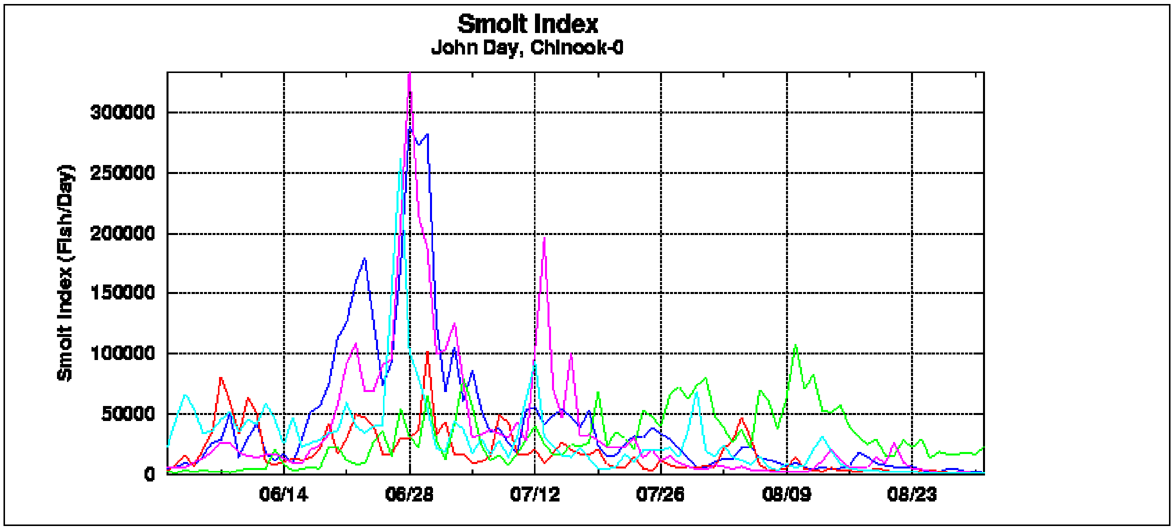


Figure 1. Smolt indices from John Day Dam (1999-2000) for yearling (top) and subyearling (bottom) salmonid migrations.

D. METHODS

General

To estimate fish passage rates and distributions, we propose to use a combination of single- and split-beam transducer deployments. This approach uses the acoustic screen model to determine passage rates. Split-beams will be used to provide data to determine weighting factors, assess assumptions of the model, and determine the magnitude of any biases. Single- and split-beam transducers will be deployed to sample fish passage at the spillway, ice and trash sluiceway, and turbines. All transducers will be randomly placed horizontally within a passage route (e.g., west, middle, or east at the powerhouse and north, middle, south at the spillway.) Transducer sampling volumes will be strategically placed to minimize ambiguity in ultimate fish passage routes and potential for multiple detections of fish that are not entrained.

In general, a hydroacoustic system consists of an echosounder, cables, transducers, an oscilloscope, and a computer system. Echosounder and computer pairs will be plugged into uninterruptible power supplies. An echosounder generates electric signals of specific frequency and amplitude and at the required pulse durations and repetition rates, and cables conduct those transmit signals from the echosounder to transducers and return data signals from the transducers to the echosounder. Transducers convert voltages into sound on transmission and sound into voltages after echoes return to the transducer. The oscilloscopes will be used to display echo voltages and calibration tones as a function of time, and the computer system will control echosounder activity and record data to a hard disk. The 420 kHz, circular, single- or split-beam Precision Acoustic Systems (PAS) transducers will be controlled by PAS 103 echosounders and Hydroacoustic Assessments' HARP software running on Pentium-class computers.

To determine fish movements at the sluiceway, we will use the Dual Frequency Identification Sonar (DIDSON). The DIDSON was designed to bridge the gap between existing sonar, which can detect acoustic targets at long ranges but cannot record the shapes or sizes of targets and optical systems, which can videotape fish in clear water but are limited at low light levels or when turbidity is high. It has a high resolution and fast frame rate designed to allow it to substitute for optical systems in turbid or dark water. This tool was successfully applied The Dalles Dam in 2002 research on predator distributions relative to the J-occlusions (Johnson et al. 2003) and in 2004 research on the sluiceway (unpublished data).

Sampling Intensity

The proposed sampling intensity minimizes the duration per sample and maximizes the number of samples, as recommended by Skalski et al. (1993). We do not propose to "fast-multiplex" (sample two locations simultaneously) on the same system at the spillway, because it is more important to maximize the pulse repetition rate and, hence, detectability (Table 1).

Table 1. Hydroacoustic Sampling Intensity for Fish Passage Estimation

Route	Sample Intervals per Hour	Minutes Sampled per Hour
Turbine Intakes	15	15
Spillway	10	10
Sluiceway	15	15

Sampling Locations and Orientations

Turbine Intakes. One randomly selected intake (intakes 1, 2, or 3) within each of the 22 main turbine units (except those that will be off-line) and the two fish turbine units (intakes 1 or 2) will be monitored. We will use 6° circular single-beam transducers (first side lobe about -30 dB) for sampling the powerhouse. In addition, one 6° circular split-beam transducer will be used for sampling at one of the powerhouse locations. The split beam data are used in the detectability calculations and will replace the single beam at that particular location. Trash rack J-mounts will be used with transducers aimed upward 23° and downstream so that the beam is perpendicular to the intake ceiling (Figure 2). The pulse repetition rate for all turbine transducers will be 20 pings/s.

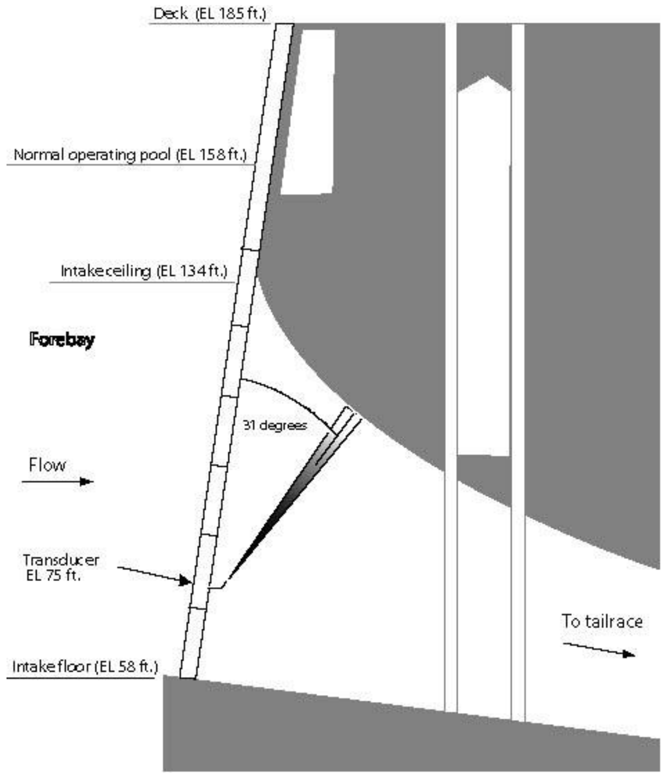


Figure 2. Turbine Intake Sampling Orientation

Sluiceway. To sample fish passage into the sluiceway, we plan to deploy two 6° circular, split-beam transducers at each of the three sluice gates of Main Units 1 and 18 (assuming the sluice gates there will be the ones opened). These transducers will be aimed horizontally across the sill from mount locations on adjacent pier noses (Figure 3). This deployment, which was successfully tested in fall 2003 when juvenile shad were passing the dam, and was used in 2004. It provides a distinct improvement over previous hydroacoustic sampling because the sampled fish are *entrained* in sluice flow. The pulse repetition rate at the sluiceway will be 33 ping/s. In addition, a DIDSON acoustic camera will be mounted on a dual-axis rotator to sample fish movements in the immediate vicinity (within 10 m) of the sluice gates at west (1-1, 1-2, and 1-3) and east[4] (18-1, 18-2, and 18-3) regions of the powerhouse.

[4] Subject to final approval by the FFDRWG.

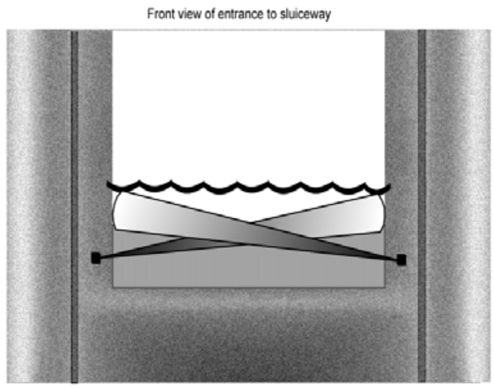


Figure 3. Front View of an Intake Showing a Pair of 6-Degree Transducers Angled Across and Back Toward the Surface of the Water

Spillway. We propose to deploy transducers systematically in 10 of 23 spill bays. We will use the spillway pole mounts designed and fabricated in 1999. Eight of 10 selected spill bays (Bays 1-10) will be monitored using 10° circular, single-beam transducers (first side lobe -25 dB) deployed on a pole mount located under the deck plates. Spill Bays 2 and 4 each will be monitored using two 10° split-beam transducers and one 10° single beam transducer. The split-beam transducer allows us to collect detectability data under a broader range of spill gate openings. The intensive sampling at Bays 2 and 4 is intended to provide vertical and horizontal distribution and trajectory data to help interpret fisheries and modeling data from the TDA spillway improvements study. All transducers will be mounted on the bottom of poles (approximate El. 46.9 m or 154 ft) aimed downward about 8° downstream (Figure 4). The pulse repetition rate at the spillway will be 30 pings/s.

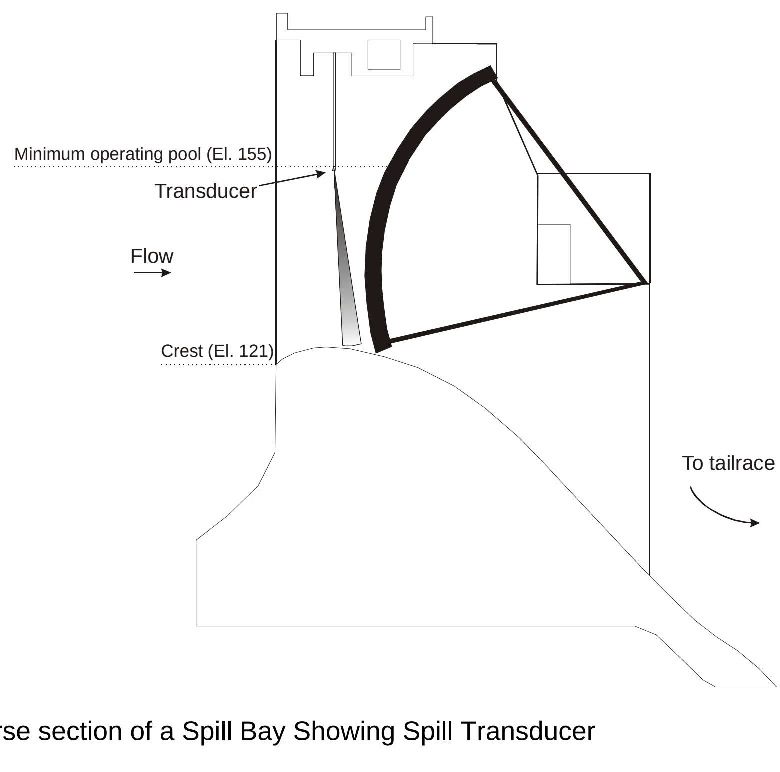


Figure 4. Transverse section of a Spill Bay Showing Spill Transducer

Hydroacoustic Systems

The following table (Table 2) contains a summary of the nine hydroacoustic systems and 46 transducers proposed for this study. Before deployment, all hydroacoustic equipment will be transported to Seattle, Washington, where Precision Acoustic Systems (PAS) will electronically check the echosounders and transducers and calibrate the transducers using a standard transducer. After calibration, we will calculate receiver gains to equalize the output voltages among transducers for on-axis targets ranging in hydroacoustic size from –56 to –36 dB || 1μPa at 1 m. Lengths of fish corresponding to that acoustic size range would be about 1.3 and 11 inches, respectively, for fish insonified within 21° of dorsal aspect.

Table 2. Hydroacoustic Systems

System	Type	Route	Location(s)	No. Transducers
1	Single	Turbine Intakes	FU1-2, MU1,2,5,7	6
2			MU8-14	7
3			MU15-22	8
4		Sluiceway	1-1, 1-2, 1-3	6
5			18-1, 18-2, 18-3	6
6		Spillway	Bays 1-10	10
7	Split	Turbine Intakes	Random	1
8		Sluiceway	MU 1-1, 1-2, 1-3	6
9			MU 15-1, 15-2, 15-3	6
10		Spillway	Bays 2 and 4	4
Total	Single	6 systems	---	43
	Split	4 systems	---	17

Experimental Design

A rigorous experimental design will be implemented to compare sluice passage rates and efficiencies for the purpose of improving sluice gate operations to maximize sluice fish passage. A calculation[5] was made to determine the relative detectable difference between sample means using daily sluice passage data from 2002. The calculation assumed we had a certain number of treatments (two or three) and desired a power of 0.80 for a two-tailed significance level of 0.05. For summer 2002 data, the results of this analysis were:

- Total number of treatments = 2, detectable difference = 31%
- Total number of treatments = 3, detectable difference = 42%

Three possible treatments for evaluation in 2005 are:

[5] Sample size calculations will be performed using 2004 data when they are available. The results from the pre-season sample size work for the 2004 study are presented as an example.

- Treatment 1 – West only (1-1, 1-2, 1-3 open)
- Treatment 2 – West and Full East (1-1, 1-2, 1-3 and 18-1, 18-2, 18-3 open)
- Treatment 3 – West and Partial East (1-1, 1-2, 1-3 and 18-2 open)

The comparison of the sluice gate treatments (Objective 3) will require a randomized block experimental design. A given treatment will be in place for 1 day and blocks will be two or three days long. Thus, over the course of each 44-day spring and summer study period there will be 22 blocks for a 2-treatment test or 14 blocks for a 3-treatment test. The FFDRWG will determine the number of treatments at a later date.

Hydroacoustic Data Processing

All data files acquired during the study will be processed with automated tracking software after the software has been carefully calibrated for every transducer. The autotracker tracks almost all linear traces of echoes meeting liberal tracking criteria and then tracked traces are filtered to exclude non-fish using filters derived for every transducer during the calibration process. We will verify the performance of the autotracker by having a pool of technicians to manually track a subset of approximately 2% of all of the data from each deployment. Early in spring technicians will be asked to track some identical data sets from every deployment to evaluate interpersonal differences and to provide for quality control. For each deployment, mean manual tracker counts will be regressed on autotracker counts and the resulting regression equations will be used to correct the autotracker results (as in Ploskey et al. 2003).

Acoustic counts of juvenile salmon acquired at spill bays, and turbine intakes will be expanded based upon the ratio of intake width to beam diameter at the range of detection:

$$\text{Expanded Numbers} = OW / (MID\_R \times TAN(EBA/2) \times 2), \qquad (1)$$

where, OW is opening width in m, MID_R is the mid-point range of a trace in m, TAN is the tangent, and EBA is effective beam angle in degrees. For sluiceways, opening height (OH) will be substituted for OW in Equation 1, and it will be calculated as forebay elevation minus weir crest elevation. Effective beam angle depends upon the detectability of fish of different sizes in the acoustic beam and is a function of nominal beam width and ping rate (pings/s) as well as fish size, aspect, trajectory, velocity, and range.

We will model detectability to determine effective beam widths using fish velocity data by 1-m strata and target strength data from the split-beam transducers, as well as flow velocity data by 1- m strata from the computational fluid dynamics (CFD) model. These data and other hydroacoustic-acquisition data (e.g., beam tilt, ping rate, target-strength threshold, number of echoes, and maximum ping gaps) will be entered into a stochastic detectability model. Effective beam angles for every 1-m range strata (EBA in Equation 1) will be used to expand every tracked fish at its range of detection to the width of the turbine intake.

We know of no other detectability model that incorporates all of these factors. One of the most important factors affecting estimates of effective beam width is the minimum echo-pattern criterion (e.g. a core of 4 echoes in 5 pings), which can only be modeled stochastically. An effective beam angle for a nominal 7-degree beam may become asymptotic with increasing range at 7 or 8 degrees if an echo-pattern criterion is not modeled. However, modeling detectability for four collinear echoes in five pings (allowing a 1-ping gap) may top out at 6 or 7 degrees. Requiring four collinear echoes in four pings (allowing no gap in the core of a trace) may top out at only 3 degrees. The target strength of fish also has a major effect on detectability and effective beam width. It is deployment dependent because target strength depends in part on the orientation of fish as they pass through a hydroacoustic beam.

Within-hour counts of fish will be expanded spatially to the width of every passage route and temporally to estimate hourly passage and its variance. Counts and variances also will be expanded to estimate passage for spill bays and turbine intakes that were not sampled. Fixed-aspect hydroacoustic data will be combined with project operations data to estimate passage efficiency and effectiveness, where appropriate. To account for the slot-to-slot variance within turbine units as well as temporal variances, the sampling scheme at each powerhouse will be viewed as a stratified random sampling scheme. Using pairs of consecutive turbine units, we will assume that 2 of 6 intake slots were randomly selected for monitoring within each stratum. The second stage of sampling was the sampling of time intervals within the slot-hour. For example, a conservative variance estimator for unguided fish at Powerhouse 2 would be as follows:

$$V\hat{a}r\left(\hat{H}U\right)=\sum_{g=1}^{5}\frac{L_g^2\left(1-\frac{l_g}{L_g}\right)s_{\hat{U}_g}^2}{l_g}+\sum_{g=1}^{5}\left[\frac{L_g\sum_{k=1}^{l_g}V\hat{a}r\left(\hat{U}_{gk}\right)}{l_g}\right] \quad (1)$$

where

L_g = number of turbine intake slots in the gth stratum $\left(g=1,\ldots,5\right)$ (here, $l_g=6$);

l_g = number of turbine intake slots sampled in the gth stratum $\left(g=1,\ldots,5\right)$ (here, $l_g=2$);

$$s_{\hat{U}_g}^2=\frac{\sum_{k=1}^{l_g}\left(\hat{U}_{gk}-\hat{\bar{U}}_g\right)^2}{\left(l_g-1\right)};$$

$$\hat{\bar{U}}_g=\frac{\sum_{k=1}^{l_g}\hat{U}_{gk}}{l_g};$$

$$\hat{U}_{gk}=\sum_{i=1}^{d}\sum_{j=1}^{23}\frac{R_{ijgk}}{r_{ijgk}}\sum_{l=1}^{r_{ijgk}}b_{ijkl};$$

$$V\hat{a}r\left(\hat{U}_{gk}\right)=\sum_{i=1}^{d}\sum_{j=1}^{23}\left[\frac{R_{ijgk}^2\left(1-\frac{r_{ijgk}}{R_{ijgk}}\right)s_{b_{ijgk}}^2}{r_{ijgk}}\right];$$

and where

r_{ijgk} = actual number of time intervals sampled in the *j*th hour $\left(j = 1, \ldots, 23 \right)$ of the *i*th day $\left(i = 1, \ldots, d \right)$ at the *k*th intake slot $\left(k = 1, \ldots, l_g \right)$ in the *g*th stratum $\left(g = 1, \ldots, 5 \right)$ (i.e., nominally 15 1-minute samples);

R_{ijgk} = number of possible time intervals that could be sampled in the *j*th hour $\left(j = 1, \ldots, 23 \right)$ of the *i*th day $\left(i = 1, \ldots, d \right)$ at the *k*th intake slot $\left(k = 1, \ldots, l_g \right)$ in the *g*th stratum $\left(g = 1, \ldots, 5 \right)$ (i.e., nominally 60 1-minute samples);

b_{ijgkl} = estimated unguided fish passage in the *l*th sample $\left(l = 1, \ldots, r_{ijgk} \right)$ in *j*th hour $\left(j = 1, \ldots, 23 \right)$ of the *i*th day $\left(i = 1, \ldots, d \right)$ at the *k*th intake slot $\left(k = 1, \ldots, l_g \right)$ in the *g*th stratum $\left(g = 1, \ldots, 5 \right)$;

$$s_{b_{ijgk}}^2 = \frac{\sum_{l=1}^{r_{ijgk}} \left(b_{ijgkl} - \overline{b_{ijgk}} \right)^2}{\left(r_{ijgk} - 1 \right)};$$

$$\overline{b_{ijgk}} = \frac{\sum_{l=1}^{r_{jgk}} b_{ijgkl}}{r_{ijgk}}.$$

Hydroacoustic Data Analysis

We will calculate fish-passage metrics, including passage proportions relative to passage at other routes (efficiency) and passage proportions relative to flow proportions (effectiveness), and analyze seasonal, diel, and distribution trends. Fish passage sums and variances will be combined to estimate the spring and summer fish-passage efficiency for the entire Project and its 95 % confidence interval using the methods of Skalski et al. (1996). Seasonal, diel, and distribution trends in fish passage and major will be plotted graphically, examined, and discussed. Regression analyses will be used to describe relations between major metrics and percent spill and spill volume. We will make statistical comparison of fish passage among units and intakes using Proc Mixed (SAS) and will included repeating Julian day in a design to account for autocorrelation within location conditions. We will compare fish passage and sluice efficiencies of east and west sluiceway entrances using a paired t-test on paired treatments within blocks in spring and summer.

Analysis of Fish Movement and Hydraulic Data at Sluiceway Entrances

DIDSON samples of fish movement data at a west sluice entrance will be analyzed and integrated with hydraulic data from computational fluid dynamics model runs provided by the Corps. The methods will be the same as those for evaluation of fish movements and entrance efficiency at the B2 Corner Collector. (See the proposal for SBE-P-00-07, Hydroacoustic Evaluation of Fish Passage at Bonneville Dam in 2005.) The goal of this field study is to identify hydraulic and physical conditions that are conducive to or inhibiting to passing juvenile salmon at the TDA sluiceway. The relationship between entrance conditions and fish responses within about 10 m of surface passage routes is a critical uncertainty in the widespread development of successful surface collectors.

We will evaluate smolt approach behavior upstream of the sluiceway at MU 1 and MU 18 to examine fish behavior and to estimate entrance efficiency for each of three consecutive 24 h periods in early, mid, and late spring and summer (nine 24 h samples each season). An acoustic camera and acoustic Doppler current profiler (ADCP) will be used to sample the sluiceway nearfield (< 10 m) to obtain data on smolt movements, smolt entrance efficiencies, and flow. We also will characterize flow by tracking drogues with the acoustic camera at the beginning of each site visit and have the District run a computational fluid dynamics (CFD) model for the same set of dam operations that prevailed during fish sampling. Physical dimensions and characteristics, dam operations, weather conditions (wind speed, wind direction, and illumination), and species computation data from the John Day Dam juvenile bypass system will be included in the database.

We will record movements of approaching fish and flow during four 5-h periods that include mid-day, mid-night, dawn, and dusk. Each 5-h sampling period will be separated from the next 5-h period by 1 hour. Sampling will consist of recording movements and fates of approaching fish with an acoustic camera and water velocity with a small-footprint ADCP. The acoustic camera will record movies of approaching smolts and their fate at each surface entrance. We also plan to track 6-10 drogues scattered throughout the entrance area with the acoustic camera at the beginning of every site visit to characterize flow fields with the same device that will be used to sample fish. After tracking drogues, we will rotate the ADCP horizontally throughout the area upstream of the entrance and record a spatial series of samples to characterize initial flow conditions, but we will locate the 6° footprint of the ADCP in a fixed location to sample the center of the fish tracking area during fish sampling. The ADCP and relevant dam operations data will be used to characterize the temporal variability in hydraulic conditions at the entrance to each passage route during fish sampling. We will use the operations data to set up CFD model runs, and drogue and ADCP data to validate the CFD estimates of entrance hydraulics.

We want to initiate fish tracking in randomly selected areas where fish have a choice about entering the sluiceway or swimming away. Therefore, we must identify the zone where fish can no longer avoid being entrained (i.e., the entrainment zone) by observing hundreds of approaching fish with the acoustic camera. Sampling upstream of the entrainment zone is important because fish have no choice after they are entrained, and we do not want to compare the entrance efficiency of entrained fish at one site with that of un-entrained fish at another site. Track initiation zones will be randomly selected as a combination of three aiming angles and several range intervals from the acoustic camera. Numbers and the behavior of any predators that happen to be detected also will be recorded because predation is a factor determining the acceptability of a passage route.

We will estimate metrics designed to assess the acceptability of entrances to smolts and enter them into a database so that they can be compared to similar statistics compiled from field trips to sample other surface bypass routes with exactly the same methods. Entrance acceptability data from different surface routes and times each season will be analyzed to rank the routes based upon entrance efficiency, which is the first step in determining what smolts prefer. We define entrance efficiency as the number of fish that passed into the entrance divided by the number that were initially detected in a specific zone upstream of the entrainment zone and that were successfully tracked moving into or away from the entrance. The second, more important step will be to analyze independent variables describing the physical environment of each surface route to assess the relative importance of those factors on entrance efficiency and smolt movements.

We will continue developing an automated system for identifying and tracking fish movements in acoustic camera images so that track statistics can be rapidly extracted and saved. Fish positions through time will be converted to 3-dimensional coordinates from frame-by-frame integration of dual-axis rotator coordinates, time, and fish position in the acoustic camera field of view. The product of this objective will facilitate processing of acoustic camera data in this project and in future projects funded by the Corps of Engineers.

We will analyze the data on fish movement and fate relative to physical characteristics of the sluiceway entrances to compare entrance efficiency among the three sampling times each season and compare to results for the Bonneville Second Powerhouse Corner Collector entrance, which will be sampled similarly in 2005. The null hypothesis will be that fish behavior and entrance efficiencies do not differ among the entrances or times. Time of sampling likely will affect the species composition of detected fish. We also will examine fish movement and flow data to determine which hydraulic variables such as velocity, acceleration, shear, and turbulence have the greatest effect on entrance efficiency and characteristics of fish movements (e.g., track duration, linearity, lateral displacement, and change in orientation) at the entrances. Other independent variables would include prevailing weather conditions and species composition.

To analytically integrate fish and flow data in the nearfield of the TDA sluiceway, we will continue sluiceway surface bypass research that was started in 2000 and 2001 (Johnson et al. 2001 and Hedgepeth et al. 2002, respectively). Fish movement data from the DIDSON will be merged with flow field data from the ADCP and CFD model to examine the association between fish movements and characteristics of the hydraulic and physical environment. From this basis, we will develop a three-dimensional fish movement model for the immediate nearfield of the sluiceway.

In addition, we will work with Corps of Engineers researchers applying the Numerical Fish Surrogate (NFS) to model fish movements in the TDA forebay and ultimate passage at the dam. The DIDSON fish tracks coupled with ADCP velocity data collected in this study will provide finer scale data than is possible with three-dimensional acoustic telemetry data. These data will be used to validate the NFS as applied to fish movements in the immediate nearfield of the sluiceway entrances at TDA. This region is where surface-oriented fish make decisions about remaining in the surface layer or moving downward toward the bulk flow into turbines.

In conclusion, the culmination of the analysis and modeling of fish movements at the TDA sluiceway entrances will provide information about smolt response to environmental features in this critical region. This new knowledge will be applicable to bioengineering efforts directed at enhancing the sluiceway as a surface flow bypass for the TDA powerhouse.

D. LIMITATIONS/EXPECTED DIFFICULTIES

We expect few difficulties with completing the planned objectives. However, clear and timely communication between Battelle and the Corps will be essential. We have successfully worked with Corps personnel at mainstem hydroelectric projects in the Columbia River Basin and at The Dalles Dam specifically.

E. EXPECTED RESULTS AND APPLICABILITY

The results from this study and others will provide the region with information to make decisions regarding long-term smolt protection measures at The Dalles Dam. Currently, spillway stilling basin improvements are the top priority. As this work progresses, information on fish passage project-wide can be used to understand the proportion of fish affected by the spillway improvements, and can be incorporated into total project survival estimates accordingly. But, even with spillway improvements, large numbers of fish will be passing through the 22-unit powerhouse. Therefore, the sluiceway surface bypass becomes a critical element of the suite of smolt protection techniques at TDA. The results from this study will help improve sluiceway operations to the benefit of downstream migrants.

F. FACILITIES AND EQUIPMENT

All of the hydroacoustic equipment necessary for this study, including the DIDSON, is owned by the Corps of Engineers, Portland District. This study, as proposed, will require the purchase of some additional equipment and replacement of faulty cables or computer parts.

PNNL will provide the crane services necessary to deploy the spillway mounts.

The Corps would provide the diving services necessary to deploy the trashrack mounts for the turbine intake transducers.

G. IMPACTS

Test Fish: Test fish will not be needed.

Other Research: We plan to coordinate closely to assure that sampling efforts are complementary with the acoustic and radio telemetry studies in the forebay of TDA in 2005. The composite results from these studies will provide a thorough understanding of forebay and nearfield fish movement patterns and fish passage efficiencies.

Hydropower Project: The transducers for monitoring powerhouse passage are diver installed and removed. This involves dive safety program coordination and unit outages. Penetration dives will *not* be necessary. The spillway mounts require spillway outages for installation and removal. All diving and crane usage will occur only after receiving approval form the Corps regarding the safety of the procedures and equipment.

H. SCHEDULE FOR MILESTONES AND DELIVERABLES

We anticipate that this study will last four years (2005-2007). We are aware that the study design will be reviewed by various State and Federal agencies, and is subject to the approval of the National Marine Fisheries Service under the Endangered Species Act. We understand that this means that the study design may be modified before the start up date. The following table (Table 3) shows the milestone and deliverable schedule for FY05 work.

Table 3. Schedule for Milestones and Deliverables

Date	**Milestone**	**Deliverables**
January 1, 2005	Start study	
April 18	Deployment complete; start data collection	
June 4	End data collection for spring study	
June 5	Start data collection for summer study	
July 16	End data collection for summer study	
October 31	Draft report	✓
November 15	AFEP presentation	✓
December 31	Draft final report	✓
60 days after receipt of comments	Final report	✓

I. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

This study would be led by Pacific Northwest National Laboratory (PNNL) and performed in collaboration with subcontractors (to be determined).

J. LIST OF KEY PERSONNEL

Key personnel and their roles are summarized in Table 4.

Table 4. Key Personnel

Role	Name	Organization
Principal Investigator/ Project Manager	Gary Johnson	PNNL
Co-Principal Investigator	Gene Ploskey	PNNL
Statistician	John Skalski	UW
CFD Modeler	Marshall Richmond	PNNL
NFS Modeler	Andy Goodwin	COE
Hydroacoustician/Computer Programmer	John Hedgepeth	Tenera, Inc.
Fish tracking programmer	Kenneth Ham	PNNL

K. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports. A draft report will be submitted on October 31, 2005. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review in November 2005. A draft final report will be provided to the COE by December 31, 2005, and the final report will be completed 60 days after review comments are received. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia and publication of results in scientific journals.

IV. REFERENCES

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V. BUDGET

A detailed budget will be provided under a separate cover.