Study Plan for the Estimation of Juvenile Steelhead Survival Using Acoustic-Tags at Wanapum and Priest Rapids Dams in 2008

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Table of Contents

List of Figures

List of Tables

1.0 Introduction

On May 3, 2004, the National Marine Fisheries Service (NMFS - then referred to as NOAA Fisheries) issued its Biological Opinion of the effects of the proposed action on listed species, in accordance with Section 7 of the Endangered Species Act of 1973 as amended (16 USC 1531 et seq.), regarding the Federal Energy Regulatory Commission's (FERC's) proposed action amending Public Utility District No. 2 of Grant County's (Grant PUD's) existing license for the Priest Rapids Hydroelectric Project (Project) to authorize implementation of an Interim Protection Plan for listed anadromous salmonids. On December 16, 2004, FERC adopted the Biological Opinion, which includes NOAA Fisheries' Reasonable and Prudent Alternatives (RPAs) and Incidental Take Statement for Upper Columbia River (UCR) spring-run Chinook salmon (*Oncorhynchus tschawytscha*) and UCR steelhead (*O. mykiss*).

Grant PUD has initiated several fish protection measures including flow management and spill programs, structural changes to the Project, and habitat protection. The first of 40 RPAs in the Biological Opinion establishes performance standards (i.e. survival rates) for both upper Columbia River steelhead and upper Columbia River spring-run Chinook salmon migrating through the Project. The standards are 95% juvenile dam passage survival and 93% juvenile single project (one reservoir and dam) passage survival. Grant PUD has been directed to use dam and reservoir smolt survival studies to evaluate progress towards meeting these performance standards. RPA No. 1 of the Biological Opinion also provides that when the arithmetic average of three consecutive survival estimates meets or exceeds the performance standard, then the standard has been met for that ESA-listed anadromous salmonid species.

In the past, Grant PUD has released radio- and PIT-tagged juvenile anadromous salmonids (i.e. yearling Chinook) as part of the continuing effort to monitor and evaluate survival of fish migrating through the Priest Rapids Project. Grant PUD's proposed survival and three-dimensional tracking studies for 2008 are designed to provide relevant information and empirical evidence on survival rates and behavior of run-of-river steelhead as they migrate through the Priest Rapids Project with the use of acoustic-tag technology. Grant PUD submits the following study plan for conducting these studies.

2.0 Objectives

This study plan describes Grant PUD's proposal to conduct survival studies at Wanapum and Priest Rapids dams during the spring 2008 smolt outmigration, using acoustic-tag tracking techniques. The following tasks will be addressed:

Task 1) Estimate project survival for steelhead smolts passing Wanapum and Priest Rapids dams, using the paired-release model;

Task 2) Estimate the relative route-specific survival for steelhead smolts at Wanapum and Priest Rapids dams;

Task 3) Estimate migration rate, detection efficiency, and arrival distribution of steelhead smolts at Wanapum and Priest Rapids dams;

3.0 Site Description

3.1 Wanapum Dam

Wanapum Dam (Figure 1a) is located on the Columbia River at river mile (RM) 416, 18 miles upstream of Priest Rapids Dam and 38 miles downstream of Rock Island Dam. Typical operational elevation of the forebay is 570 ft above MSL and the depth of the forebay at the powerhouse is approximately 110 ft (460 ft relative to elevation 570 ft). Normal operating head is 80 ft. The dam has a 1,540 foot-long powerhouse, oriented approximately perpendicular to river flow, and an 832 foot-long spillway at approximately a 45° angle to flow. Wanapum Dam has two fish ladders, one located at the east end of the powerhouse and the other located at the west end of the spillway.

The powerhouse has 10 Kaplan turbine units, numbered from north to south. Three of the original turbines have been replaced with a new advanced turbine design, referred to as the "advanced turbine." Both original and advanced are Kaplan designs. To date, turbine units W4, W8 and W10 have been replaced with advanced turbines and turbine unit W9 is scheduled to be replaced. Upon completion of the turbine upgrades, estimated to be in 2012, the Wanapum Development will include a total of ten advanced turbine units with a total rated capacity of 1,125 MW (112.5 MW each), connecting to ten generators with a total rated capacity of 1,038 MW (103.8 MW each). The purpose of replacing the original turbines with the advance design turbines is to improve fish passage survival and increased turbine efficiency.

There are additional intake structures for six potential future units in an area between the powerhouse and spillway. One of the six potential future units, Future Unit 11, has been modified into the Wanapum Future Unit Fish Bypass (WFUFB), a surface flow bypass for the passage of downstream migrant salmonids. Construction on this bypass is scheduled to be completed prior to the 2008 spring outmigration. The bypass opening, positioned in the forebay directly south of turbine unit W-10, is 18.5 ft wide and has an adjustable depth of up to 75.8 ft. The total surface spill is adjustable and was designed at four increments of 5 kcfs, 10 kcfs, 15 kcfs, and 20 kcfs. The total length of the bypass design is 290 ft and the exit chute width increases to 90 ft. The exit chute is elevated and curved to evenly spread the discharge flow and minimize total dissolved gas in the tailrace.

The spillway contains 12 Tainter gates, each 65-ft tall by 50-ft wide. These gates open at the bottom to produce submerged spill at a depth of 65 ft. A surface flow spillway bulkhead is in place at Spillbay 12. A surface-skimming sluiceway is located at the north end of the spillway. It is 20-ft wide and normally spills up to 10 ft of surface water per second (1.9 kcfs).

3.2 Priest Rapids Dam

Priest Rapids Dam (Figures 1b) is located on the Columbia River at RM 397, 18 miles downstream of Wanapum Dam and approximately 70 miles upstream of the confluence of the Snake and Columbia rivers. Normal maximum forebay elevation is 488 ft above mean sea level (MSL), and the normal operating head is 78 ft.

The dam has a 1,025 foot-long powerhouse located at the northeast end, oriented approximately perpendicular to river flow, and a 1,152 foot-long spillway on the southwest end of the dam. The Priest Rapids development contains ten vertical shaft turbines, with a total capacity of 855 MW

(85.5 MW each) and connecting to ten generators having a total rated capacity of 955.6 MW. Each turbine unit has three intake slots.

The spillway contains 22 Tainter gates, each 40-ft wide and 50-ft tall. These gates rest on the ogee at 50 ft in depth (elevation 436 ft), and when opened they produce a submerged bottom-spill at a depth of 60 ft. Each spill gate passes an average of 6-10 kcfs under normal operating conditions. A surface sluiceway is located between the powerhouse and spillway (TG-22) and provides opportunity to pass water downstream via a surface opening. The sluiceway opens from the top, as opposed to the spillway Tainter gates, and the discharge of the sluiceway is approximately 2 kcfs.

In 2006, a surface flow prototype top-spill bulkhead was installed for testing of fish behavior and passage efficiency at Spillbays 19 and 20 (**Error! Reference source not found.** and 5). The prototype is 100-ft wide and typically spills up to 16 kcfs (8 kcfs per spill bay) of surface water. Similar to the sluiceway, the top-spill gates open from the top to release water downstream.

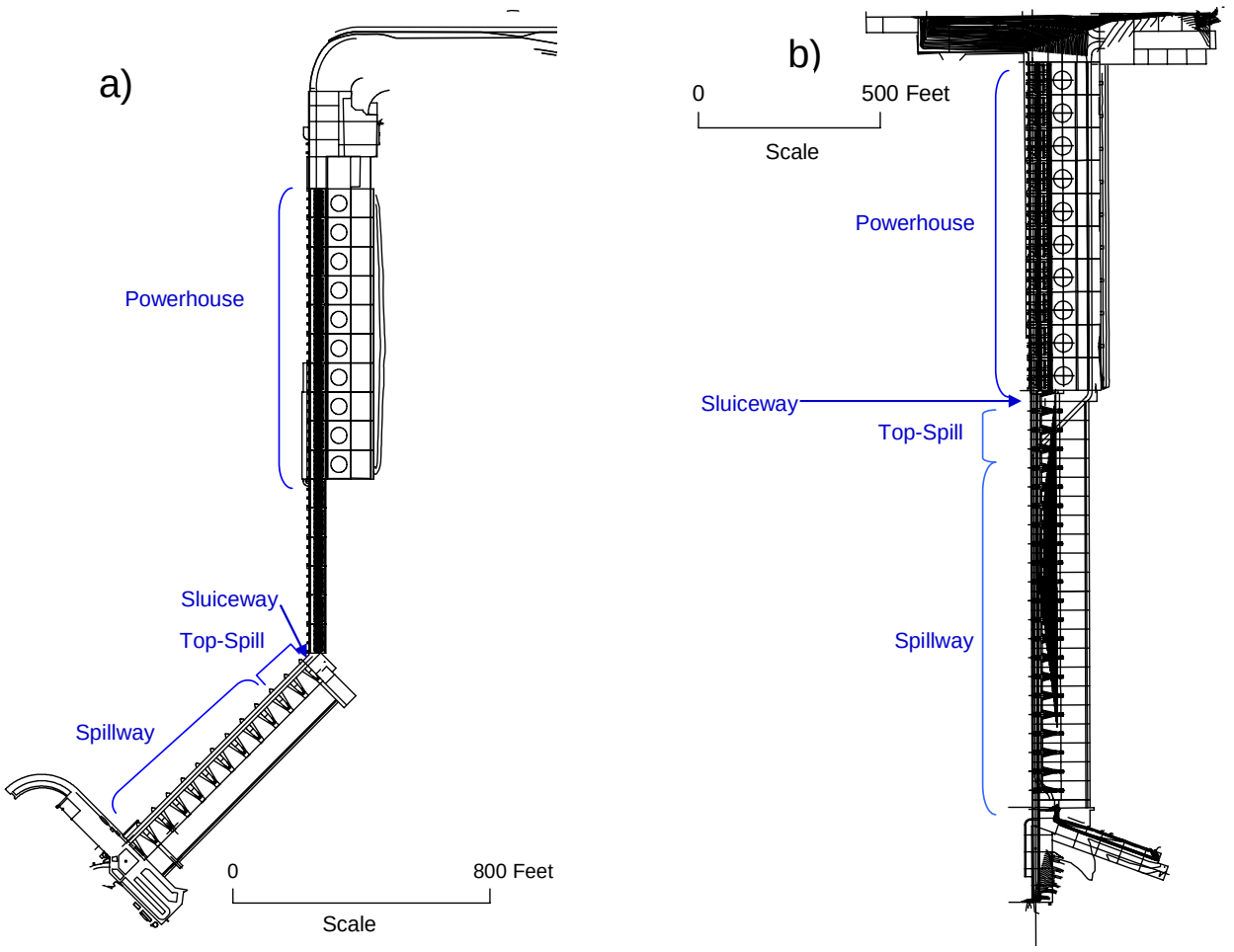

Figure 1 Plan view of Wanapum (a) and Priest Rapids dams (b).

4.0 Methods

4.1 Study Design

Acoustic-tag methods used to monitor tagged fish at the various detection sites in 2008 will be very similar to those employed at Wanapum and Priest Rapids dams in 2007, 2006, and 2004 (Timko et al. 2007 *draft*, Timko et al. 2006, Robichaud et al. 2005), as well as at Rocky Reach Dam (HTI 1997, Steig 1999a, Steig 1999b, Steig et al. 1999, Steig 2000, Steig and Timko 2000, Steig et al. 2001), and at Rock Island Dam (Steig et al. 2002, Skalski et al. 2003a, Skalski et al. 2003b, Skalski et al. 2005, Steig et al. 2005).

The following tasks/objectives developed for the juvenile steelhead survival evaluation are listed below:

4.1.1 Task 1: Estimate Project Survival for Steelhead Smolts

Wanapum and Priest Rapids project (dam and reservoir) survivals will be estimated using the paired-release model, following the methods of Skalski et al. (2005) and Steig et al. (2005). The general paired-release methodology study design to estimate project survival at Wanapum and Priest Rapids dams in 2008 is consistent with the survival studies conducted at Wanapum and Priest Rapids dams in 2006 (Skalski et al. 2006; Timko et al. 2006). Table 1 summarizes the number of fish to be released by site. Paired releases of 650 run-of-river steelhead tagged with acoustic transmitters will be made in each of the tailraces of Rock Island, Wanapum and Priest Rapids dams (Figure 2 and Table 1). There will be 22 replicates at each site, with approximately 30 fish per replicate.

The Wanapum Dam project (dam and reservoir) survival fish will be monitored at Wanapum Dam (Figure 3) and at two sites downstream of the dam that were used during the 2007 and 2006 studies, one of these near Mattawa at RM 409 (Figure 4a), and the other at Priest Rapids Dam (Figure 5). The Riverside Road array would be located 7 miles downstream from Wanapum Dam, and Priest Rapids Dam is 12 miles downstream from there. Two optional additional detection sites for the Wanapum reservoir are the Chelan County PUD acoustic-tag detection sites at Crescent Bar (RM 443) and Sunland Estates (RM 431).

The Priest Rapids project (dam and reservoir) survival fish will be monitored as during the 2007 and 2006 studies at two sites downstream of the dam, south of Priest Rapids Dam, at the Vernita Bridge, RM 388 (Figure 4b), and in the Hanford Reach near the Ringold Hatchery, at RM 384 (Figure 4c). The Vernita Bridge array would be located 11 miles downstream from Priest Rapids Dam, and the Ringold site is 4 miles downstream from there. Table 2 summarizes the release and detection locations for acoustic-tag projects. To verify the operating life of the tags, a life test of 50 tags will be conducted for the steelhead study. These tags will be tested in surgically implanted fish that will be held in continuously cycled river water in a holding tank, similar to the survival study fish holding tanks.

Table 1 Number of juvenile salmonids to be tagged and released for Wanapum and Priest Rapids dams 2008 acoustic-tag study and tag life test.

Release Location	Steelhead
Rock Island Dam Tailrace	650
Wanapum Dam Tailrace	650
Priest Rapids Dam Tailrace	650
Tag Life Tests	50
Total Tags	2,000

Table 2 Release and detection locations of acoustic-tagged steelhead smolts for the Wanapum and Priest Rapids dams spring 2008 study.

Location	Acoustic-tags
Rock Island Dam Tailrace	Release
Crescent Bar	Detection (Chelan Co. PUD)
Sunland Estates	Detection (Chelan Co. PUD)
Wanapum Dam	Detection
Wanapum Dam Tailrace	Release
Riverside Road/Mattawa	Detection
Priest Rapids Dam	Detection
Priest Rapids Dam Tailrace	Release
Vernita Bridge	Detection
Ringold Hatchery	Detection

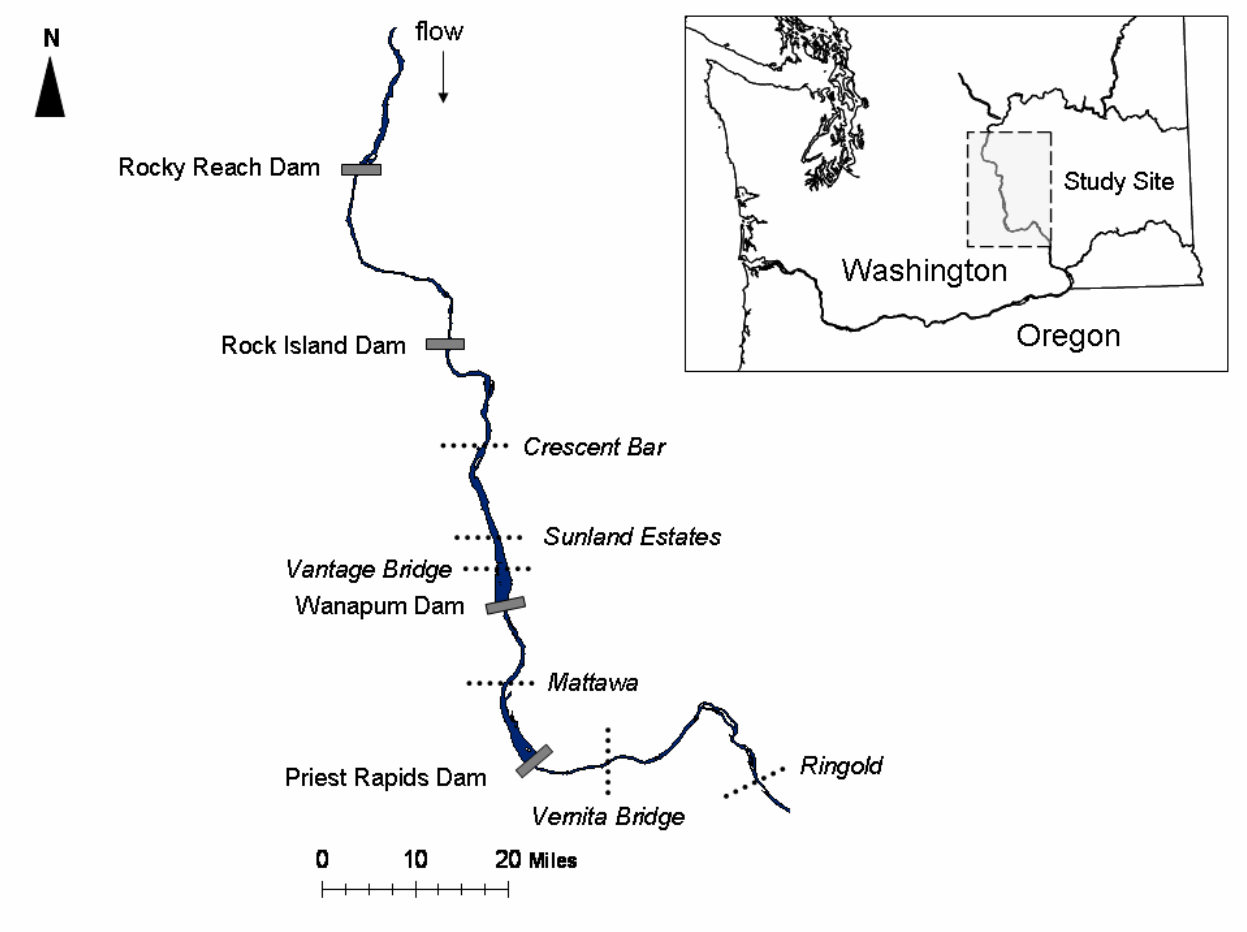

Figure 2 **Plan view of the acoustic-tag sampling sites showing the proposed hydrophone detection arrays for monitoring acoustically tagged fish for the 2008 smolt survival study.**

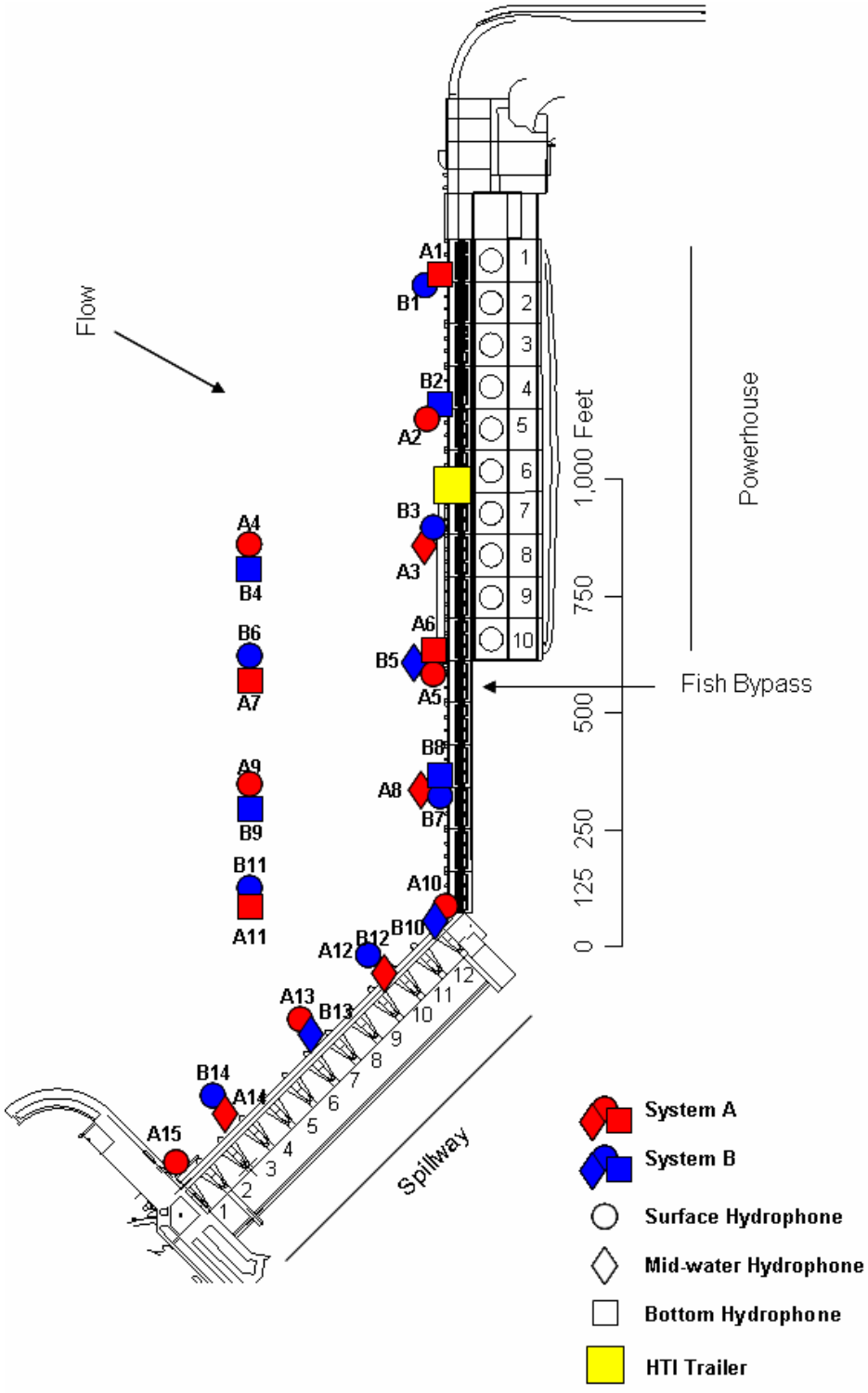

Figure 3 Wanapum Dam proposed hydrophone locations for the spring 2008 acoustic-tag study.

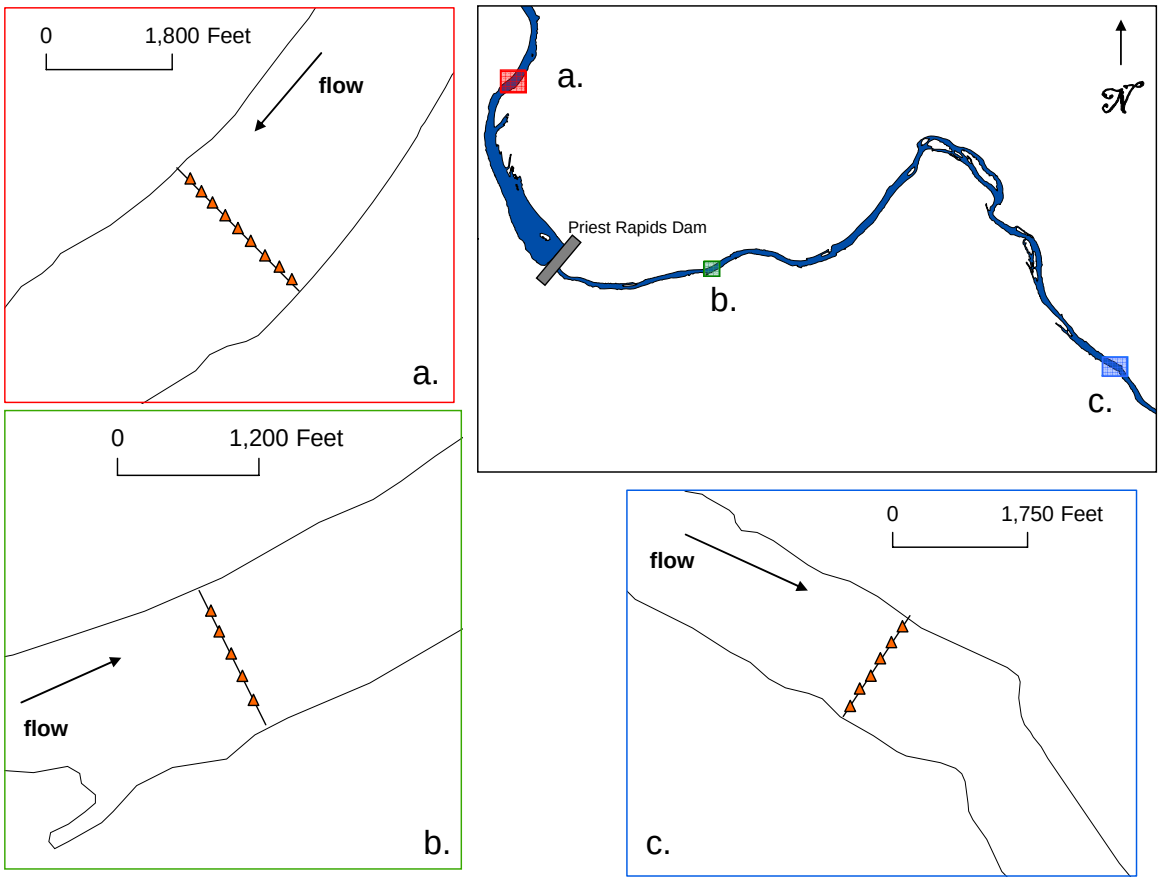

Figure 4 **Locations of 2008 in-river detection arrays: a) Mattawa (RM 394), b) upstream of Vernita Bridge (RM 374), and c) upstream of the WDFW Ringold Fish Hatchery (RM 349). Hydrophones are represented by orange triangles.**

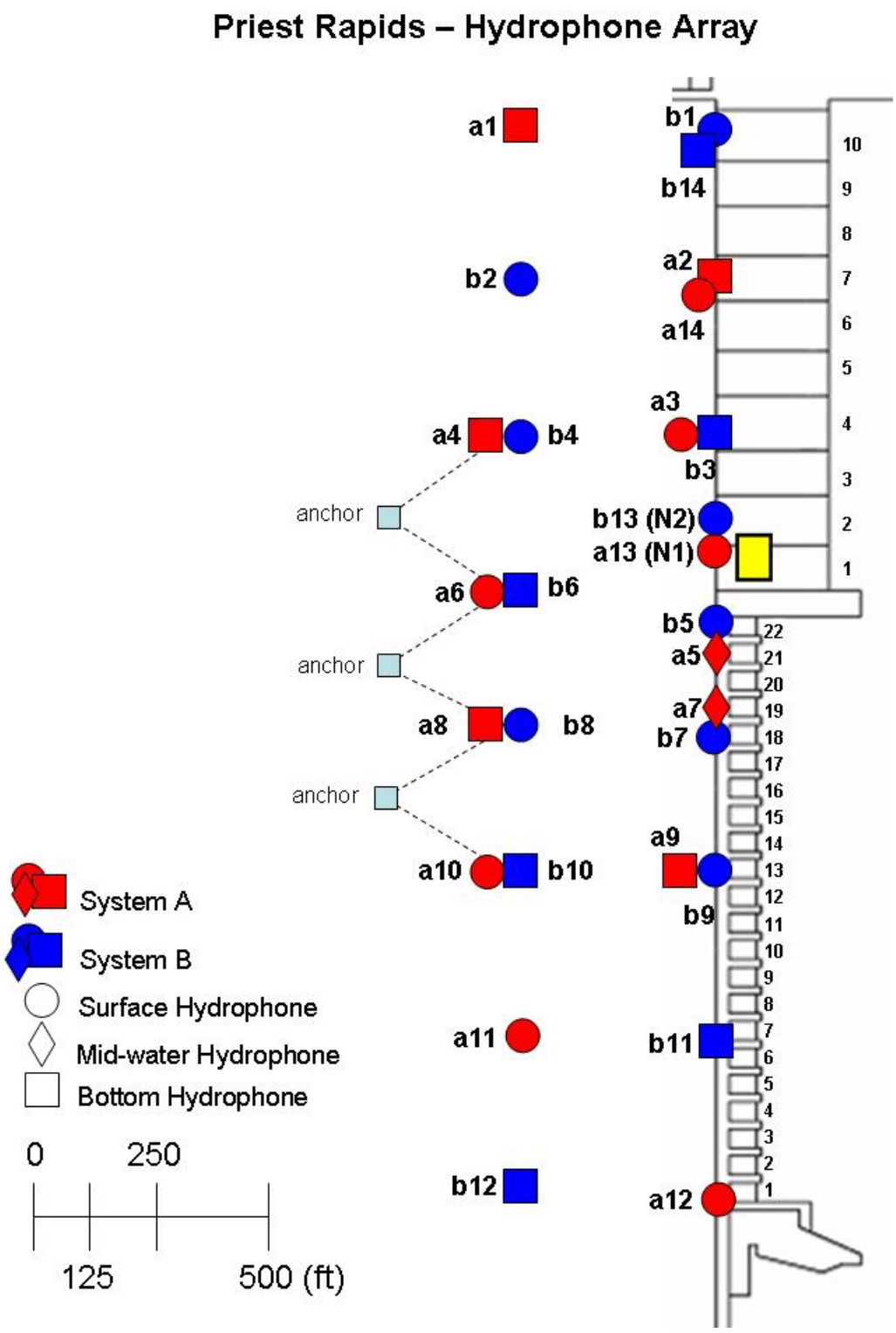

Figure 5 Priest Rapids Dam proposed hydrophone locations for the spring 2008 acoustic-tag study.

4.1.2 Task 2: Estimate Route-Specific Survival for Steelhead at Wanapum and Priest Rapids Dams

Following the methods employed by Skalski et al. (2005) and Steig et al. (2005), for tagged steelhead smolts, relative route-specific survival will be estimated at Wanapum and Priest Rapids dams. At each dam, route-specific survival will be estimated for the powerhouse, spillway, sluiceway, top spill, and surface bypass individually (where these routes are available).

4.1.3 Task 3: Estimate Migration Rate, Detection Efficiency, and Arrival Distribution of Downstream Migrants

The migration rates, detection efficiencies, and arrival distributions (i.e., horizontal distributions) of downstream migrating steelhead smolts will be estimated for Wanapum and Priest Rapids dams.

4.2 Acoustic-Tag Receiver System Design

HTI *Model 290-series Acoustic Tag Receiver Systems* (ATR) will be used to monitor the presence or absence of tagged fish. Each ATR system supports up to 16 hydrophones and operates at 307 kHz, which has been found (HTI 1997) to be an optimum frequency for use at the numerous hydropower dams where the system has been used to date. The ATR receives and automatically stores tag detections for each hydrophone simultaneously.

4.2.1 Wanapum Downstream In-River Acoustic System

An ATR system will be deployed in the river downstream of Wanapum Dam near Mattawa at Riverside Road and will utilize eight hydrophones deployed across the river (Figures 2 and 4a). Another ATR system will be deployed in the river downstream of Wanapum Dam at Priest Rapids Dam and will use 16 hydrophones deployed across the river (Figure 5). The primary objective of these systems is to detect acoustically tagged fish for the survival estimates (Table 2). Received signals will be synchronized in order to determine time of arrival for each detected pulse.

4.2.2 Priest Rapids Downstream In-River Acoustic Systems

An ATR system will be deployed in the river downstream of Priest Rapids at Vernita Bridge and will utilize eight hydrophones deployed across the river (Figures 2 and 4b). Another ATR system will be deployed in the river downstream of Priest Rapids Dam at Hanford Reach and will use eight hydrophones deployed across the river (Figures 2 and 4c). The primary objective of these systems is to detect acoustically tagged fish for the survival estimates (Table 2). Received signals will be synchronized in order to determine time of arrival for each detected pulse.

4.2.3 Acoustic-Tags

The HTI Model 795E Acoustic-tag will be used for the 2008 survival study will be approximately 6.8 mm in diameter by 18 mm long, and weigh 1.5 g in air, with an average operating life of 32–36 days, based on 2003-2006 tag life tests reported by Skalski et al. (2003b, 2005, 2006) and Steig et al. (2005). Ping rate, pulse width, and individual tag ID will be programmed in the field. Up to 50,000 individual tags can be uniquely coded. For Model 795E Acoustic Tags the transmission rate (i.e. ping rate) can be set from 50 pings/sec to 1 ping every

16 sec, with pulse widths from 0.5 msec to 5 msec, with either a standard CW pulse or an encoded pulse. The ping rate will be set at 1 ping every 4-8 sec, with a pulse width of 1.0 msec.

4.3 System Deployment

The ATR systems and equipment require installation and testing in the field at each site. HTI will be responsible for these installations with the assistance of Grant PUD personnel. The installation of some of the hydrophones will require the assistance of Grant PUD mechanics, and possibly divers.

4.4 Fish Handling

The sections below (4.4.1-4.4.4) describe fish collection and holding, tag, post-tagging recovery and release procedures.

4.4.1 Fish Collection and Holding

Grant PUD will contract separately with LGL, Limited to handle, tag, hold and release tagged smolts. Fish collection, handling and tagging will be follow the procedures employed during the 2007 (Timko et al. 2007 draft) acoustic-tag tracking study conducted at Wanapum and Priest Rapids dams. Each day test fish will be obtained and held in a "sanctuary box." **[The source of fish for conducting this survival study is this pending, waiting for final review of the 2007 Fish Source Comparison Study that was conducted to evaluate a source of test fish for Grant PUD's survival studies.]** The sanctuary box will be kept on flow-through river water up until the time at which it will be transported to the tagging facility at Wanapum Dam. During transport (on the back of a flatbed), oxygen will be bubbled into the sanctuary box. Upon arrival at the tagging facility at Wanapum Dam, the box will be plumbed with flow-through river water.

Sanctuary boxes are 6-ft long, 2-ft wide, 2.7-ft deep (with a water line at 2.5 ft) and hold approximately 220 gallons. The rate at which river water will be circulated into the tanks is approximately 6.2 gal /min, which will replace the entire volume every 36 minutes. The lids of the boxes will be partially made with transparent Plexiglas so light can enter, allowing for the smolting process to continue at a typical rate. Lids will be secured with metal clasps to prevent fish from jumping out.

While the fish are in the sanctuary boxes, personnel will measure dissolved oxygen (DO) and water temperature twice a day using a calibrated oxygen/temperature monitor. The goal is to maintain oxygen levels at 9-12 mg/L and water temperatures within 2^{o}C of ambient river water. There will be two pumps that supplied water to the tanks from the fish ladder. One of the pumps will be on a backup generator in case of a power failure.

Fish will be held for two days in the sanctuary boxes before being tagged. In order to minimize stress during the surgery, fish will not be fed while being held.

4.4.2 Tagging

The surgical implantation procedures used will be based on the methods outlined in Adams et al. (1998) and used during the acoustic-tag studies at Wanapum and Priest Rapids dams conducted in 2007 (Timko et al. 2007 draft).

Tagging will take place inside the tagging trailer next to the sanctuary boxes at Wanapum Dam on the right bank. On tagging days, steelhead smolts will be dipped from the sanctuary boxes, and temporarily transferred to a large plastic container (supplied with a continuous flow of river water) located near the surgical tables.

Individual fish will be transferred to a light anesthetic bath containing tricaine methanesulfonate (MS222; 13.9 mg/L) and held for approximately 3 minutes. After the light anesthetic, fish will be transferred to a stronger anesthetic bath (MS222; 72 mg/L) and held for approximately 3 minutes or until the fish losses equilibrium. Anesthetized fish will be measured to the nearest millimeter, and weighed to the nearest tenth of a gram. If a fish is smaller than 147 mm, or larger than 200 mm, or if there are visible signs of injury or disease, the fish will not tagged. Anesthetized fish will be placed on a Plexiglas surgical table in order to stabilize the fish's body during surgery. The surgical table will be soaked with Stress Coat (Aquarium Pharmaceuticals, Inc. Chalfont, PA) to minimize scale loss and maintain the exterior mucous coat. Fish will be placed ventral side up on the surgical pad, and their gills will be continuously flushed with anesthetic solution (MS222, 16.7 mg/L) fed through a tube placed in the mouth of the fish. About 1 minute prior to completion of surgery, the flow of anesthetic solution will be replaced with fresh river water to start the recovery process. River water supplied from within the fish ladder entrance will serve as the water source during tagging operations.

To implant the transmitter in the fish, a 1 cm incision will be made 3 mm away from and parallel to the mid-ventral line starting about 3 mm anterior to the pelvic girdle. The incision will be only deep enough to penetrate the peritoneum (Adams et al, 1998). The transmitter will be implanted with the transducer (the ceramic tip of the tags) pointing towards the head of the fish. Tags will be positioned horizontally directly under the incision. An intraperitoneal antibiotic will be pipetted (30 μL) into the incision to prevent infection. The incision will be closed with three interrupted, absorbable sutures evenly spaced across the incision. A small amount of a cyanoadhesive compound (Vetbond) will be applied to the incision to secure the sutures in place. Surgical equipment will be disinfected with a diluted germicidal solution after each fish.

4.4.3 Post-Tagging Recovery

Immediately after surgery, tagged fish (1 fish per bucket) will be moved to 5 gallon oxygenated recovery buckets where they will be monitored until they gain equilibrium and begin regular swimming and breathing movements. Recovery buckets will then be placed on shelves in a recovery room, adjacent to the tagging trailer. Each bucket will have an opening in the lid that allowed for continuous water flow, and a PVC overflow spout. Dissolved oxygen and water temperature will be measured twice a day. The recovery room will be supplied with two redundant pumps in case of pipe blockage in one. Water flow to the recovery buckets will be checked at least twice a day.

Two days after tagging, the tagged fish will be moved into fly tanks (approximately 30 fish per tank). The fly-tanks are similar to the sanctuary boxes except that there is no Plexiglas window, there is an external “fin,” and the bottom of the tank slopes towards an outflow hole (in order to ensure that fish slide from the tank upon release). Fish will be held in the fly tanks for several hours, up until their release into the river.

4.4.4 Release Procedures

Approximately 3 hours prior to departure from the Wanapum Dam holding site, DO and water temperature will be measured in the fly tanks. Measurements will be taken immediately before and immediately after the tagged fish are transferred into the fly tanks.

For all releases, water flow to the fly tank will be shut off 10 minutes prior to departure. An oxygen tank, attached to each fly tank will provide oxygenation to the water during transport. Fly tanks will be attached to a helicopter by a long cable, and will be transported to their release site. The helicopter will lower the fly tank to within about 1 m of the water, and will trigger a release mechanism that will open a valve near the bottom of the fly tank, causing the fish to pour out into the river. It will take approximately 60 sec for the fly tank to be emptied into the river.

4.5 Data Collection

Time for all received signals will be synchronized in order to determine time of arrival for each detected pulse. The individual echoes will be entered in digital format into a database using the HTI software package *MarkTags*.

4.6 Data Analysis

There are three phases associated with preparing the databases required for the survival analyses: I) data detection during the field season; II) data marking and tracking during and after the field season; and III) data quality control during and after the field season. The specific data processing steps included in each phase are listed below:

4.6.1 Phase I: Data Detection during the Field Season

1. Detection of acoustic-tag codes for each fish in all release groups.
2. Verification and data input of all the fish and tag release data.
3. Continuous verification of the operation of all of the ATR systems.
4. Collection and backup of all raw acoustic-tag data.

4.6.2 Phase II: Data Marking and Tracking during and after the Field Season

All acoustic-tag data files will be tracked using the *MarkTags* tracking software. Lists of all detected fish will be determined daily.

4.6.3 Phase III: Data Quality Control during and after the Field Season

1. The data will be constantly verified during and after the field season to ensure the integrity of the acoustic-tag database.
2. The Project Leaders in charge of each of the study tasks will review the data on a daily basis.

4.7 Statistical Analysis

Statistical analysis support will be provided by Dr. John Skalski and will consist of the tasks that are described below. The intent of these tasks is to provide integrated statistical support from study design through data analysis, and interpretation of results. These tasks will be coordinated with the field efforts of HTI.

Statistical tasks will include development of likelihood models used in the analysis of the acoustic-tag data. The likelihood models for the acoustic-tag analyses will be based on the statistical principles reported in Skalski et al. (1998). The statistical models are uniquely tailored for each study, taking into account detection locations, passage routes at the hydroelectric projects and release locations. The 2008 statistical models will be modifications of those employed at Rock Island Dam and Rocky Reach Dam 1999-2005. The 2008 statistical model incorporates a route specific survival design. Statistical development will precede the field study to assure the data generated by the field studies will be compatible with model structure and design specifications. A statistical synopsis will be prepared for peer review.

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