# ADULT PACIFIC LAMPREY PASSAGE AND BEHAVIOR STUDY
# (Adult Lamprey Passage Study)

## WELLS HYDROELECTRIC PROJECT

## FERC NO. 2149

## FINAL REPORT
## REQUIRED BY FERC

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# ABSTRACT

An adult Pacific lamprey (*Lampetra tridentata*) passage and behavior study was conducted at Wells Dam in 2007 in accordance with the Integrated Licensing Process (ILP) promulgated by the Federal Energy Regulatory Commission (FERC). The goal of this study was to evaluate the effect of the Wells Project and its operations on adult Pacific lamprey upstream migration and behavior as it relates to fishway passage, timing, and downstream passage events (drop back) through the dam. This information will be used to help identify potential areas of passage impediment within the Wells fishways. Specific objectives of the study include: 1) conducting a literature review of existing adult Pacific lamprey passage studies at Columbia and Snake river dams; 2) identifying and implementing methods for capturing adult Pacific lamprey at Wells Dam; 3) documenting the timing and abundance of radio-tagged lamprey passage through Wells Dam; 4) determining whether adult lamprey are bypassing the adult counting windows at Wells Dam; 5) where sample size is adequate, estimating passage metrics including fishway passage times and efficiencies, residence time between detection zones, and downstream passage events (drop back); and 6) if necessary, identifying potential areas of improvement to the existing upstream fish passage facilities for the protection and enhancement of adult lamprey at the Wells Project.

A review of past adult lamprey passage studies indicated commonalities among lamprey behavior at hydroelectric projects and trapping methodologies were developed to capture adult lamprey at Wells Dam. During the 2007 study, 21 lamprey were captured, surgically radio-tagged and released. Of these fish, 10 were released into the tailrace and 11 were released into the fishway between mid-August and early October. One tailrace-released fish was recaptured and re-released into the fishway, bringing total ladder releases to twelve. Ten of the twelve (83%) lamprey released into the middle fishway successfully ascended, with a median upper fishway passage time of 7.9 hours. Seven of the ten (70%) lamprey released into the tailrace were detected at the outside of a fishway entrance. Only one of these seven (14%) lamprey entered into the collection gallery and ascended the fishway with a lower fishway passage time of 6.1 hours and upper fishway passage time of 5.9 hours. This fish, along with at least one mid-ladder release, traveled through some portion of the auxiliary water supply (AWS) chamber. Including one tailrace-released fish, 6 of 11 (55%) tagged lamprey that ascended the upper fishway were detected inside the video bypass area. Three of the eleven (27%) fish that exited the ladder passed through the upper fish ladder without being observed at the counting window. No drop backs were detected by fish that exited the fishway. These results suggest that, similar to observations at other Columbia River dams, lamprey are having difficulty negotiating the fishway entrances and appear to be largely bypassing the adult counting windows. Unlike other dams, lamprey at Wells are passing the upper fishway at high rates, in a reasonable amount of time, and with negligible drop back within the ladder.

# 1.0 INTRODUCTION

## 1.1 General Description of the Wells Hydroelectric Project

The Wells Hydroelectric Project (Wells Project) is located at river mile (RM) 515.6 on the Columbia River in the State of Washington (Figure 1.1-1). Wells Dam is located approximately 30 river miles downstream from the Chief Joseph Hydroelectric Project, owned and operated by the United States Army Corps of Engineers (COE); and 42 miles upstream from the Rocky Reach Hydroelectric Project owned and operated by Public Utility District No. 1 of Chelan County (Chelan PUD). The nearest town is Pateros, Washington, which is located approximately 8 miles upstream from the Wells Dam.

The Wells Project is the chief generating resource for Public Utility District No. 1 of Douglas County (Douglas PUD). It includes ten generating units with a nameplate rating of 774,300 kW and a peaking capacity of approximately 840,000 kW. The design of the Wells Project is unique in that the generating units, spillways, switchyard, and fish passage facilities were combined into a single structure referred to as the hydrocombine. Fish passage facilities reside on both sides of the hydrocombine, which is 1,130 feet long, 168 feet wide, with a crest elevation of 795 feet in height.

The Wells Reservoir is approximately 30 miles long. The Methow and Okanogan rivers are tributaries of the Columbia River within the Wells Reservoir. The Wells Project boundary extends approximately 1.5 miles up the Methow River and approximately 15.5 miles up the Okanogan River. The surface area of the reservoir is 9,740 acres with a gross storage capacity of 331,200 acre-feet and usable storage of 97,985 acre feet at the normal maximum water surface elevation of 781 above mean sea level (msl) (Figure 1.1-1).

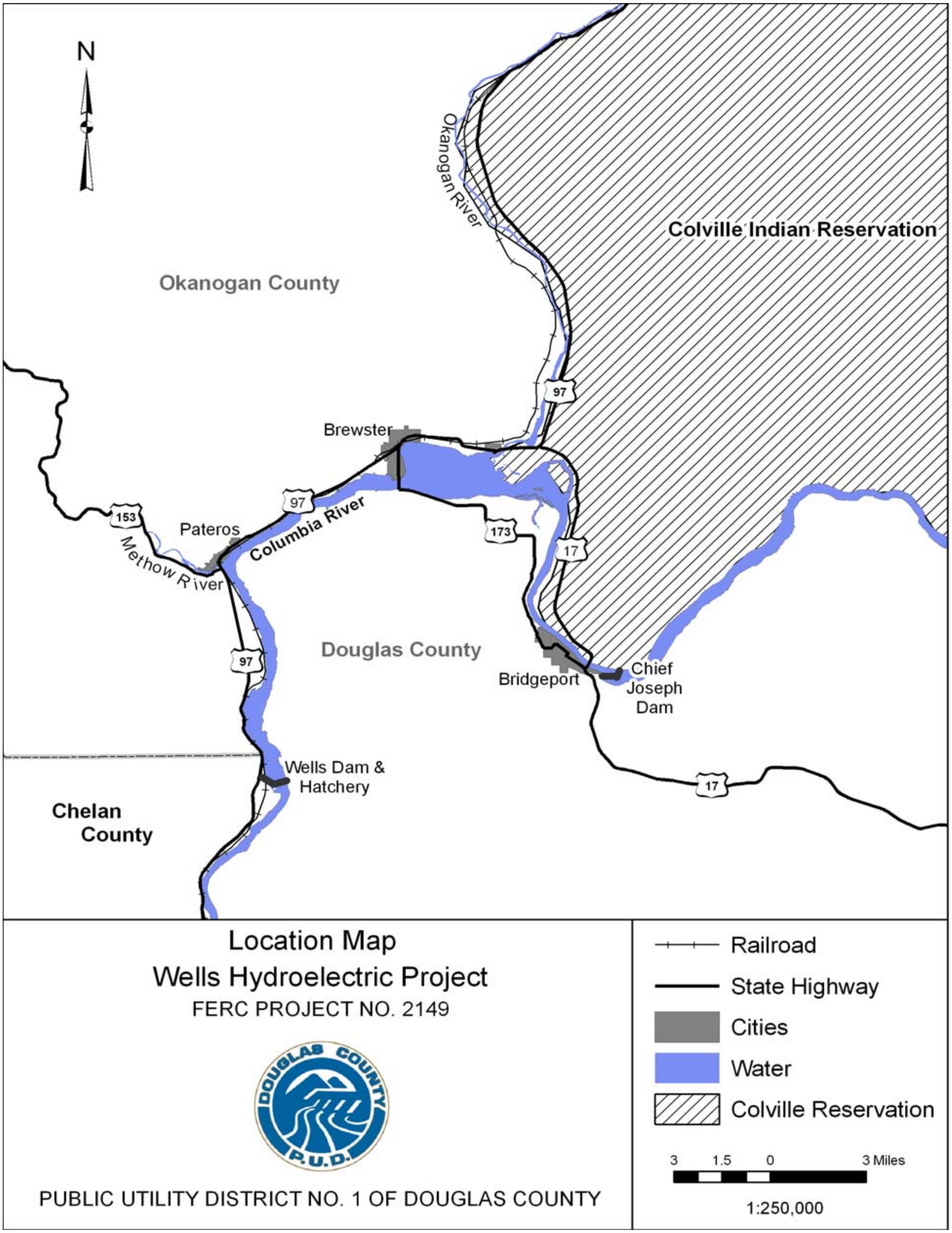



**Figure 1.1-1 Location map of the Wells Project**

## 1.2 Relicensing Process

The current Wells Project license will expire on May 31, 2012. Douglas PUD is using the Integrated Licensing Process (ILP) promulgated by Federal Energy Regulatory Commission (FERC) Order 2002 (18 CFR Part 5). Stakeholders consisting of representatives from state and federal agencies, tribes, local governments, non-governmental organizations and the general public have participated in the Wells Project ILP, from a very early stage, to identify information needs related to the relicensing of the Wells Project.

In August 2005, Douglas PUD initiated a series of Resource Work Group (RWG) meetings with stakeholders regarding the upcoming relicensing of the Wells Project. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to identify resource issues and to develop preliminary study plans prior to filing the Notice of Intent (NOI) and Pre-Application Document (PAD). The RWGs were formed to discuss issues related to the Wells Project and its operations.

The primary goals of the RWGs were to identify resource issues and potential study needs in advance of Douglas PUD filing the NOI and PAD. Through 35 meetings, each RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. An Issue Statement is an agreed-upon definition of a resource issue raised by a stakeholder. An Issue Determination Statement reflects the RWGs' efforts to apply FERC's seven study criteria to mutually determine the applicability of each individual Issue Statement. Agreed-Upon Study Plans are the finished products of the informal RWG process.

Douglas PUD submitted the NOI and PAD to FERC on December 1, 2006. The PAD included the RWGs' 12 Agreed-Upon Study Plans. The filing of these documents initiated the relicensing process for the Wells Project under FERC's regulations governing the ILP.

On May 16, 2007, Douglas PUD submitted a Proposed Study Plan (PSP) Document. The PSP Document consisted of the Applicant's Proposed Study Plans, Responses to Stakeholder Study Requests and a schedule for conducting the Study Plan Meeting. The ILP required Study Plan Meeting was conducted on June 14, 2007. The purpose of the Study Plan Meeting was to provide stakeholders with an opportunity to review and comment on Douglas PUD's PSP Document, to review and answer questions related to stakeholder study requests and to attempt to resolve any outstanding issues with respect to the PSP Document.

On September 14, 2007, Douglas PUD submitted a Revised Study Plan (RSP) Document. The RSP Document consisted of a summary of each of Douglas PUD's revised study plans and a response to stakeholder PSP Document comments.

On October 11, 2007, FERC issued its Study Plan Determination based on its review of the RSP Document and comments from stakeholders. FERC's Study Plan Determination required Douglas PUD to complete 10 of the 12 studies included in its RSP Document. Douglas PUD has opted to complete all 12 studies to better prepare for the 401 Water Quality Certification process conducted by the Washington State Department of Ecology (Ecology) and to fulfill its commitment to the RWGs who collaboratively developed the 12 Agreed-Upon Study Plans with

Douglas PUD. These study plans have been implemented during the designated ILP study period. The results from the study plans have been developed into 12 Study Reports. Each report is included in Douglas PUD's Initial Study Report (ISR) Document, which is scheduled for filing with FERC on October 15, 2008.

This report completes the 2007 Adult Lamprey Passage Study.

# 2.0 GOALS AND OBJECTIVES

The goal of this study is to evaluate the effect of the Wells Project and its operations on adult Pacific lamprey upstream migration and behavior as it relates to fishway passage, timing, and downstream passage events (drop back) through the dam. This information will be used to identify potential impediments to passage within the Wells fishways.

Specific objectives of the study include:

- Conduct a literature review of existing adult Pacific lamprey passage studies at Columbia and Snake river dams;
- Identify methods for capturing adult Pacific lamprey at Wells Dam;
- Document the timing and abundance of radio-tagged lamprey passage through Wells Dam;
- Determine whether adult lamprey are bypassing the adult counting windows at Wells Dam;
- Where sample size is adequate, estimate passage metrics including fishway passage times and efficiencies, residence time between detection zones, and downstream passage events (drop back); and
- If warranted, identify potential areas of improvement to existing upstream fish passage facilities for the protection and enhancement of adult lamprey at the Wells Project.

# 3.0 STUDY AREA

The study area includes Wells Dam, the Wells Dam tailrace, and the Wells Dam forebay (Figure 1.1-1).

# 4.0 BACKGROUND AND EXISTING INFORMATION

Pacific lamprey are present in most tributaries of the Columbia River and in the mainstem Columbia River during their migration. Lamprey have cultural, utilitarian and ecological significance in the basin since Native Americans have historically harvested them for subsistence, ceremonial and medicinal purposes (Close et al., 2002). As an anadromous species, they also contribute marine-derived nutrients to the basin. Little specific information is available on the life history or status of lamprey in the mid-Columbia River watersheds. They are known to occur in the Methow, Wenatchee and Entiat rivers and recently have been captured during juvenile trapping operations in the Okanogan River (BioAnalysts, 2000).

In general, adults are parasitic on fish in the Pacific Ocean while ammocoetes (larvae) are filter feeders that inhabit the fine silt deposits in backwaters and quiet eddies of streams (Wydoski and Whitney, 2003). Adults generally spawn in low-gradient stream reaches in the tail areas of pools and in riffles, over gravel substrates (Jackson et al., 1997). Adults die after spawning. After hatching, the ammocoetes burrow into soft substrate for an extended larval period filtering particulate matter from the water column. The ammocoetes undergo a metamorphosis, between 3 and 7 years after hatching, and migrate from their parent streams to the ocean from October to April (Close et al., 2002). Adults typically spend 1-4 years in the ocean before returning to freshwater tributaries to spawn.

Pacific lamprey populations of the Columbia River have declined in abundance over the last 40 years according to counts at dams on the lower Columbia and Snake rivers (Close et al., 2002). Starke and Dalen (1995) reported that adult lamprey counts at Bonneville Dam regularly exceeded 100,000 fish in the 1960s and more recently have ranged between 20,000 and 120,000 for the period 2000-2004 (DART- www.cqs.washington.edu/dart/adult.html).

Close et al. (2002) identified several factors that may account for the decline in lamprey counts in the Columbia River Basin. These include reduction in suitable spawning and rearing habitat from flow regulation and channelization, pollution and chemical eradication, reductions of prey in the ocean, and juvenile and adult passage problems at dams (Nass et al., 2005).

Returning adult Pacific lamprey have been counted at Wells Dam since 1998. Between the years of 1998 and 2007, the number of lamprey passing Wells Dam annually has averaged 350 fish and ranged from 21 fish in 2006 to 1,410 fish in 2003 (Table 4.0-1). The relatively small number of adult lamprey observed at Wells Dam can be attributed to fact that the Wells Project is the last passable dam on the mainstem Columbia River and the fact that the Wells Project is over 500 miles upstream from the Pacific Ocean. Pacific lamprey counts for Columbia and Snake river dams are presented in Table 4.0-1 and 4.0-2.

**Table 4.0-1 Pacific lamprey counts at Columbia River mainstem dams, by dam and year, 1997-2007.**

| Year | Bonneville | The Dalles | John Day | McNary | Priest Rapids | Rock Island | Rocky Reach | Wells |
|---|---|---|---|---|---|---|---|---|
| 1997 | 20,891 | 6,066 | 9,237 | . | . | . | . | . |
| 1998 | . | . | . | . | . | . | . | 343 |
| 1999 | . | . | . | . | . | . | . | 73 |
| 2000 | 19,002 | 8,050 | 5,844 | 1,281 | . | 822 | 767 | 155 |
| 2001 | 27,947 | 9,061 | 4,005 | 2,539 | 1,624 | 1,460 | 805 | 262 |
| 2002 | 100,476 | 23,417 | 26,821 | 11,282 | 4,007 | 4,878 | 1,842 | 342 |
| 2003 | 117,035 | 28,995 | 20,922 | 13,325 | 4,340 | 5,000 | 2,521 | 1,410 |
| 2004 | 61,780 | 14,873 | 11,663 | 5,888 | 2,647 | 2,362 | 1,043 | 647 |
| 2005 | 26,667 | 8,361 | 8,312 | 4,158 | 2,598 | 2,267 | 404 | 214 |
| 2006 | 38,941 | 6,894 | 9,600 | 2,459 | 4,383 | 1,326 | 370 | 21 |
| 2007 | 19,304 | 6,083 | 5,753 | 3,454 | 6,593 | 1,300 | 696 | 35 |
| Total | 432,043 | 111,800 | 102,157 | 44,386 | 26,192 | 19,415 | 8,448 | 3,502 |
| Min | 19,002 | 6,066 | 4,005 | 1,281 | 1,624 | 822 | 370 | 21 |
| Max | 117,035 | 28,995 | 26,821 | 13,325 | 6,593 | 5,000 | 2,521 | 1,410 |
| Average | 48,005 | 12,422 | 11,351 | 5,548 | 3,742 | 2,427 | 1,056 | 350 |
| SD | 37,162 | 8,364 | 7,611 | 4,417 | 1,631 | 1,632 | 750 | 416 |

**Table 4.0-2 Pacific lamprey counts at Snake River mainstem dams, by dam and year, 1996-2007.**

| Year | Ice Harbor | Lower Monumental | Little Goose | Lower Granite |
|---|---|---|---|---|
| 1996 | 737 | . | . | 490 |
| 1997 | 668 | . | . | 1,122 |
| 1998 | . | . | . | . |
| 1999 | . | . | . | . |
| 2000 | 315 | 94 | 71 | 28 |
| 2001 | 203 | 59 | 104 | 27 |
| 2002 | 1,127 | 284 | 365 | 138 |
| 2003 | 1,702 | 476 | 660 | 282 |
| 2004 | 805 | 194 | 243 | 122 |
| 2005 | 461 | 222 | 213 | 42 |
| 2006 | 277 | 175 | 125 | 35 |
| 2007 | 290 | 138 | 72 | 34 |
| Total | 6,585 | 1,642 | 1,853 | 2,320 |
| Min | 203 | 59 | 71 | 27 |
| Max | 1,702 | 476 | 660 | 1,122 |
| Average | 659 | 205 | 232 | 232 |
| SD | 469 | 130 | 200 | 346 |

Lamprey pass Wells Dam from early July until late November with peak passage times between mid-August and late October (Figure 4.0-1). In all years since counting was initiated, Pacific lamprey counts at the east fish ladder are greater than at the west fish ladder. It is important to note that historically, counting protocols were designed to assess adult salmonids and did not necessarily conform to lamprey migration behavior (Moser and Close 2003). Traditional counting times for salmon did not coincide with lamprey passage activity which occurs primarily at night; the erratic swimming behavior of adult lamprey also makes them inherently difficult to count (Moser and Close, 2003). Furthermore, Beamish (1980) noted that lamprey overwinter in freshwater for one year prior to spawning. Consequently, lamprey counted in one year may actually have entered the system in the previous year (Moser and Close, 2003) which confounds annual returns to the Columbia River Basin. It is unknown to what degree these concerns are reflected in Columbia River lamprey passage data. However, it is important to consider such caveats when examining historic lamprey count data at Columbia River dams including Wells Dam.

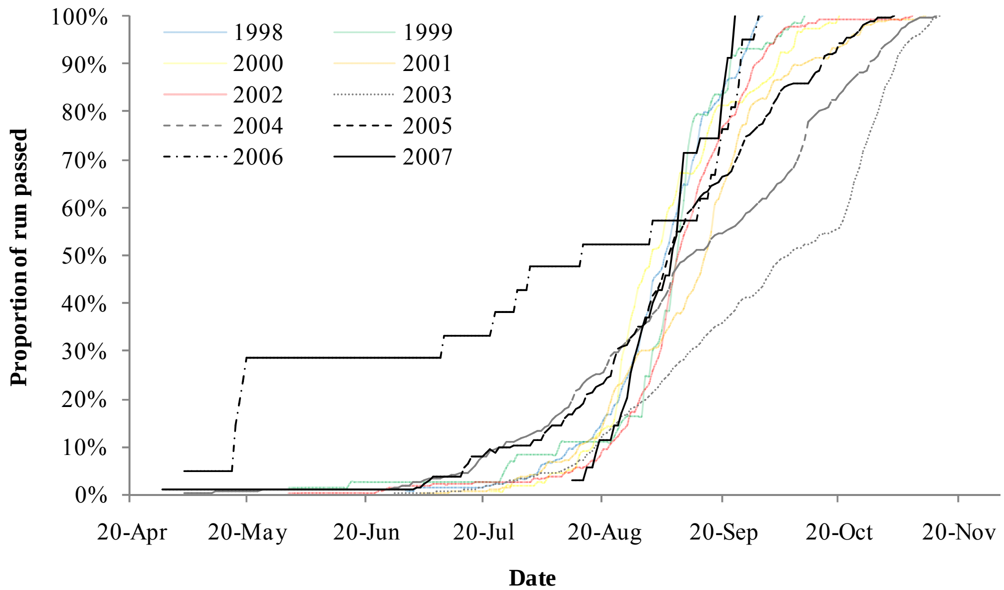



**Figure 4.0-1** **Run timing of Pacific lamprey at Wells Dam by year, 1998-2007. Years 1998-2002 are lightened to allow better view of past five years (in grayscale).**

Until recently, relatively little information was available on Pacific lamprey in the mid-Columbia River Basin. However, with increased interest in the species coupled with a petition for listing under the Endangered Species Act, the mid-Columbia PUDs have initiated studies to investigate Pacific lamprey passage and migratory behavior in their respective project areas.

The study of adult Pacific lamprey migration patterns past dams and through reservoirs in the lower Columbia River has provided the first data sets on lamprey passage timing, travel times, and passage success at hydroelectric projects (Moser et al., 2002a; Moser et al., 2002b). These studies have shown that approximately 90% of the radio-tagged lamprey released downstream of Bonneville Dam migrated back to the tailrace below Bonneville Dam; however, less than 50% of the lamprey which encountered a fishway entrance actually passed through the ladder exit at the dam (Nass et al. 2005).

Similar collection and passage efficiency results were observed at Rocky Reach, Wanapum and Priest Rapids dams during tagging studies conducted at those projects (Nass et al., 2003; Stevenson et al., 2005).

Of the 125 radio-tagged lamprey released approximately 7 kilometers downstream of Rocky Reach Dam, 93.6% were detected at the project, and of those fish, 94.0% entered the fishway. Of the fish that entered the Rocky Reach fishway, 55.5% exited the ladder.

During studies at Wanapum and Priest Rapids dams in 2001 and 2002, a total of 51 and 74 lamprey were radio-tagged and released downstream of Priest Rapid Dam, respectively. Over the two years of study, the proportion of fish that approached the fishway that exited the ladders was 30% and 70% at Priest Rapids and 100% and 51% at Wanapum Dam in 2001 and 2002, respectively.

Two recent reviews of Pacific lamprey (Hillman and Miller 2000; Golder Associates Ltd. 2003) in the mid-Columbia River have indicated that little specific information is known on their status (Stevenson et. al., 2005).

In 2004, Douglas PUD contracted with LGL Limited to conduct a lamprey radio-telemetry study at Wells Dam in coordination with Chelan PUD, which was conducting a similar study at Rocky Reach Dam. A total of 150 lamprey were radio-tagged and released at or below Rocky Reach Dam. The radio-tags used in this study had an expected operational life of 45 days (Nass et al., 2005). It is important to note that because of the release site of the fish was over 50 miles downstream of Wells Dam, the value of the study was limited by the relatively small numbers of tagged fish observed at Wells (n=18) and the fact that many of the radio-tags detected at Wells Dam were within days of exceeding their expected battery life.

With that stated, the 2004 study at Wells was implemented through a combination of fixed-station monitoring at Wells Dam and fixed-stations at tributary mouths. Collectively, these monitoring sites were used to determine migration and passage characteristics of lamprey entering the Wells Project area. Of the 150 adult lamprey released at or below Rocky Reach in 2004, 18 (12% of 150) were detected in the Wells Dam tailrace, and ten (56% of 18) of these were observed at an entrance to the fishways at Wells Dam. Two of the 10 lamprey approached both fishways to produce 12 total entry events. A total of 3 radio-tagged lamprey passed Wells Dam prior to expiration of the tags, resulting in a Fishway Efficiency estimate of 30% (3 of 10) for the study period. A single lamprey was detected upstream of Wells Dam at the mouth of the Methow River (Nass et al., 2005).

For lamprey that passed the dam, the majority (92%) of Project Passage time was spent in the tailrace. Median time required to pass through the fishway was 0.3 days and accounted for 8% of the Project Passage time (Nass et al., 2005).

Although the 2004 study at Wells provided preliminary passage and behavioral information for migrating adult lamprey, the limited observations due to the small sample size (n=18) is insufficient to address the objectives set forth in Section 2.0 with statistical confidence.

## 4.1 Aquatic Resource Work Group

As part of the relicensing process for the Wells Project, Douglas PUD established an Aquatic Resource Work Group (Aquatic RWG) which began meeting informally in November, 2005. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to collaboratively identify potential resource issues related to Project operations and relevant to relicensing, and to develop preliminary study plans to be included in the Wells Pre-Application Document (PAD) (DCPUD, 2006).

Through a series of meetings, the Aquatic RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. An Issue Statement is an agreed-upon definition of a resource issue raised by a stakeholder. An Issue Determination Statement reflects the RWG's efforts to review the existing project information and to determine whether an issue matches with FERC's seven criteria and would be useful in making future relicensing decisions. Agreed-Upon Study Plans are the finished products of the informal RWG process.

Based upon these meeting and discussions, the Aquatic RWG proposed to include a radio-telemetry study to assess lamprey behavior as it relates to passage, timing, drop back and upstream migration. The need for this study was agreed to by all of the members of the Aquatic RWG, including Douglas PUD. This study will help to inform future relicensing decisions and will fill data gaps that have been identified by the Aquatic RWG.

The Issue Statement and Issue Determination Statement listed below were included in the PAD (section number included) filed with FERC on December 1, 2006:

### 4.1.1 Issue Statement (PAD Section 6.2.1.3)

The Wells Project may affect adult Pacific lamprey behavior related to ladder passage, timing, drop back and upstream migration.

### 4.1.2 Issue Determination Statement (PAD Section 6.2.1.3)

Work group members have determined that this issue has a tie to the Project as it relates to lamprey migration through Wells Dam. Preliminary passage information has been collected at Wells Dam; however, the sample size of the study was limited and additional information is needed. A radio-telemetry study would be feasible to address passage, timing, drop back and upstream migration. The results of an adult lamprey passage study would be useful during the development of Protection, Mitigation and Enhancement (PME) measures.

The resource work group agreed that a radio-telemetry study to assess lamprey behavior as it relates to passage, timing, drop back and upstream migration should be conducted at Wells Dam during the two-year ILP study period.

## 4.2 Project Nexus

The Wells Project may affect adult Pacific lamprey behavior related to ladder passage, timing, drop back and upstream migration. This issue has a tie to the Project as it relates to lamprey migration through Wells Dam. Potential problems facing successful passage of adult Pacific lamprey at dams may be related to their unique method of movement and specific areas within fishways. Specifically, adult Pacific lamprey at other projects have experienced difficulty passing over diffusion gratings and through areas of high velocity, bright light and through orifices with squared, un-rounded edges. Typically, lamprey move through an adult fishway in a repeated series of motions consisting of attaching to the ladder floor with their mouths, surging forward, and re-attaching. The physiological response of adult Pacific lamprey to exhaustive exercise may be immediate, sometimes severe, but short-lived (Mesa el al., 2003). This may suggest that lamprey have difficulty negotiating fishways with high current velocities.

Two recent reviews of Pacific lamprey (Hillman and Miller, 2000; Golder Associates Ltd. 2003) in the mid-Columbia River have indicated that little specific information is known on their status. The 2004 study at Wells Dam provided preliminary information about the migration characteristics of adult Pacific lamprey through Wells Dam. However, it is important to note that the study was compromised by the relatively small numbers of tagged fish observed at the Project (n=18) and the fact that many of the radio-tags detected at Wells Dam were within days of exceeding their expected battery life. Combined, these factors suggest that additional lamprey passage information is needed at Wells Dam.

The proposed lamprey radio-telemetry study will assist in providing the information needed as identified by the Aquatic RWG and will inform the development of future license requirements.

# 5.0 METHODOLOGY

## 5.1 Literature Review

The literature review consisted of a search of all existing information currently available on adult Pacific lamprey passage studies at Columbia and Snake river dams. This search examined the availability of information from peer-reviewed journals, federal and state publications, academia, private industry, and grey literature. References cited from the initial literature search that are of relevance to the subject matter were also collected and added to literature database.

## 5.2 Telemetry Study Period

Adult Pacific lamprey were collected, sampled and tagged at Wells Dam during the 2007 peak migration period of August and September. To address lamprey passage characteristics, fixed station telemetry monitoring in the Wells Project took place from August through November 2007.

## 5.3 Capture, Tagging, and Release of Lamprey

### 5.3.1 Trapping

Adult lamprey traps were designed by Douglas PUD and LGL biologists and hydromechanics in the spring of 2007 (Appendix A). Lamprey traps used at Rocky Reach Dam were used as a base template, though modifications were made to better suit fishways at Wells Dam. The 0.6×0.4×0.6 m aluminum holding box sits along the fishway wall on the upstream side of an overflow weir. The trap passively captures fish that travel over the weir through an overflow slot adjacent to the fishway's outer wall. The trap's funnel guides lamprey from the wall and weir sill into a chute that leads to a holding box. The entire trap is affixed to the fishway wall by a track that allows operators to raise the unit out of the fishway for fish removal and cleaning (Figure 5.3-1). Traps are located between pools #39 and #40 in both fishways. The traps are numbered in ascending order, from the west most (Trap 1) to the east most (Trap 4) trap.

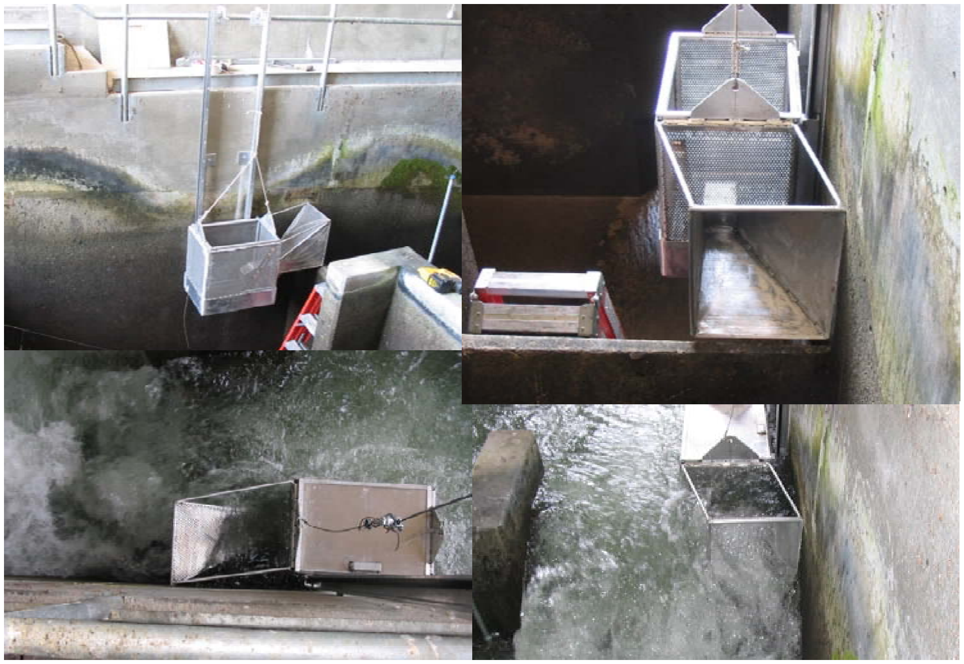


**Figure 5.3-1 Douglas PUD adult lamprey trap, 2007. Views (clockwise from top left) from the side (at installation), front (at installation), front (active), and top (active) in the east fishway of Wells Dam.**

Expected trap efficiency was based on the following assumptions: 1) only a small portion of lamprey will utilize the weir orifice to pass between fishway pools; 2) lamprey will be attracted to the reduced flow and ease of travel along the fishway wall; 3) trap escapement will be negligible; and 4) lamprey will not drop back upon encountering the trap. These assumptions were based on flow measurements, documented swimming capabilities of adult lamprey (see literature cited), and observed behavior at fishways of other hydroelectric projects (Chris Peery, University of Idaho, personal communication).

Trapping was initiated following the first observed lamprey at the Wells fish counting stations (12 August) and continued over a ten week period from the weeks ending on 19 August through 21 October, 2007. Traps were fished five or six days per week and checked twice daily during the morning (6:00-10:00 hrs) and evening (15:00-17:00 hrs). All fish were identified, enumerated, and bycatch was released into the fishway upstream of the trapping location. Lamprey were immediately transferred by covered buckets to insulated 1.0×0.5×0.5 m, 113 L holding tanks (Igloo MaxCold 120©) with flow-through river water (± 2°C fishway temperature, 9-12 mg/L dissolved oxygen). The maximum capacity for each tank was set at eight lamprey (roughly 30 grams of fish per liter of water), and maximum holding time prior to tagging was set at 36 hours (M. Moser, NOAA, personal communication; Molly Haddock, WDFW, personal communication).

During the latter half of the project and following discussions with the Aquatic RWG, additional lamprey were supplied to the study from trapping efforts at Rocky Reach Dam (42 miles downstream). The supplementation was in response to the low numbers of lamprey observed at

Wells Dam and the desire to meet the proposed sample size target of the study (n=40). Lamprey captured at Rocky Reach Dam from 19 September to 2 October were moved to holding tanks by Chelan or Douglas PUD employees. LGL biologists visited the Rocky Reach Dam three days a week to transport fish to Wells Dam for tagging (with the 36 h maximum holding time still in place). Fish were transported by truck in a 113 L cooler filled with river water. An air tank and air stones were used to maintain proper oxygen levels. The 42-mile trip generally took an hour and lamprey were tagged as soon as possible (20-60 minutes after arrival at Wells Dam).

### 5.3.2 Tagging and Release

Model NTC-4-2L Nano Tags (Lotek® Newmarket, Ontario) with an 87 day battery life were used for all lamprey. The tags were set up in 5.0 second burst rates on a frequency of 148.320 MHz (channel 1), codes 100-119 and 130-149. Tag dimensions were 18.3 mm (length) by 8.3 mm (diameter), with a dry weight of 2.1 grams – less than 0.8% of total body weight for all lamprey. Research has shown that tagged and un-tagged lamprey perform similarly with radio-tags at 7.4 g or less provided adequate recovery time (Close et al., 2003). Tags were sequenced, activated, and tested prior to each surgery.

Surgical tagging methods were based on techniques described by Moser et al. (2002a), Close et al. (2003), and Stevenson et al. (2005), in combination with LGL Limited guidelines for surgical tag implantation. The tagging area was prepared with a tub containing a heavy sedation mixture and two surgery buckets, one containing a light sedation mixture and the other river water. Clove oil was used as an anesthetic, with the heavy sedation mixture prepared at 1.2 mL to 20 L of river water, and the light sedation at 1.2 mL to 10 L of river water. A few drops of Stress Coat (Aquarium Pharmaceuticals, Inc. Chalfont, PA) were added to all containers and the surgery trough to minimize effects of handling. The surgery trough was made of sectioned PVC tubing, angled to allow pooling near the head and gills of the lamprey. Tubing from the surgery buckets to the trough allowed controlled flow of either the light sedation mixture or water over the gills of the lamprey (Figure 5.3-2). Surgery tools were placed alongside the surgery trough and the radio-tag was activated and tested.

Lamprey were transferred to the heavy sedation tub prior to surgery. Fish would generally lose equilibrium after a few minutes and were usually adequately anesthetized within eight minutes. The lamprey was then removed from the solution, weighed to the nearest gram, measured to the nearest 0.5 cm (length and girth), and placed into the surgery trough. The light sedation bucket was activated to maintain unconsciousness during the procedure. A 1.5-2.0 cm incision was made approximately 1 cm above the ventral midline with the posterior end of the cut ending in line with the anterior insertion of the first dorsal fin. The catheter was inserted and pushed through the outside wall of the stomach cavity, approximately 3 cm posterior to the incision (Figure 5.3-3). The radio-tag antenna was threaded through the catheter and the tag was inserted into the stomach cavity. Liquimycin was applied to the stomach cavity and 2-3 sutures were used to close the incision. A 19-mm needle was used, with 3-0 absorbable surgical sutures. A light coat of Polysporin ointment was applied to the closed incision and the fish was subsequently moved to the recovery tank.

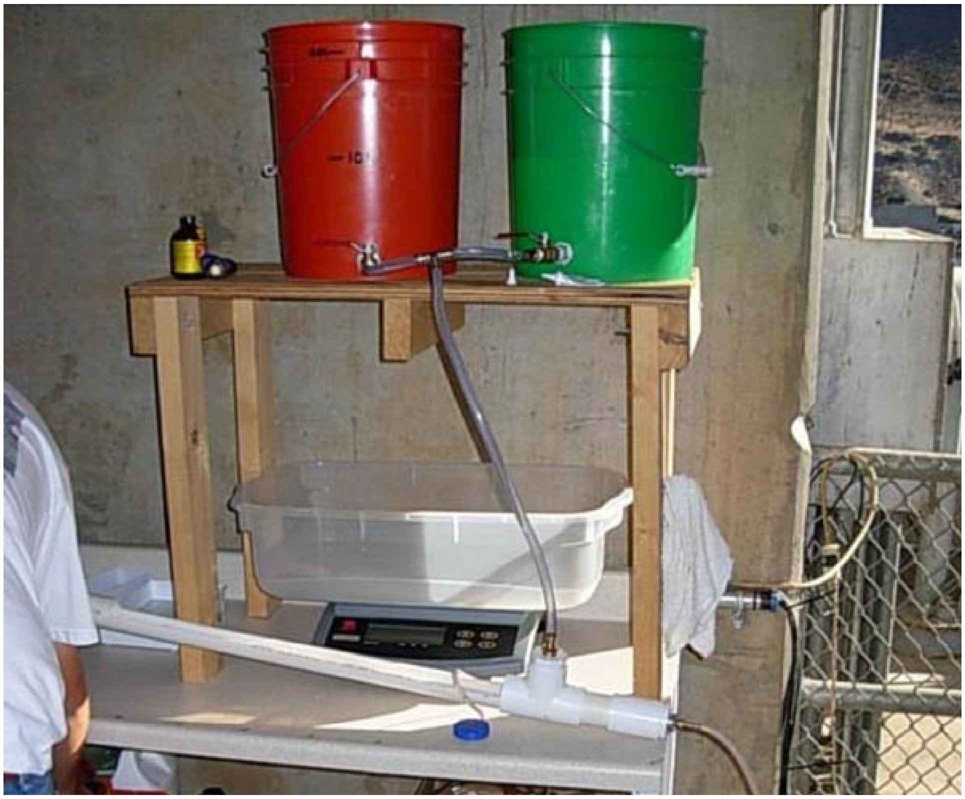


**Figure 5.3-2 Lamprey tagging trough, surgery buckets, scale, and platform.**

**Figure 5.3-3 Radio-tag and data form (left) and incision and catheter prior to tag insertion during the surgery process.**

Fish were transferred to the release container following roughly one hour in the recovery tank. A 19 L bucket was used for fishway releases. The bucket was placed into the recovery tank and the lamprey was collected (i.e., scooped) with 8-10 L of water. The covered bucket was lowered by rope into Pool #43 (between the above trap and below trap antennas), the lid was removed, and the lamprey was allowed volitional release from the container into the fishway. A 6" PVC tube approximately 1.2 meters long was used for tailrace releases. The container was closed at the bottom end to retain water and had attachment rings at both ends. The tube was filled with approximately 15 L of river water and a tagged lamprey was inserted head-first into the container.  The tube was then lowered upright by a pulley system into the tailrace.  The "head" or downward side of the tube was then lifted to allow the fish to back out of the container into the tailrace.  Both release methods typically took less than 10 minutes.

## 5.4 Telemetry Array

### 5.4.1 Fixed Stations

The movement and passage of radio-tagged lamprey were documented by combining detection data collected using underwater and aerial antenna arrays (dipoles and yagi antennas) at Wells Dam (Figure 5.4-1).  The arrays were designed to monitor movements of radio-tagged lamprey from the Columbia River into the fishway entrances and through the exits at Wells Dam, and were also designed to detect downstream passage movements.  Aerial antennas were used in the tailrace, at remote stations on tributary mouths, and during mobile tracking.  Underwater antennas were used in the fishways.  A total of 8 Lotek telemetry receivers, monitoring multiple arrays (6 at Wells Dam, 1 at Methow River, and 1 at Okanogan River) were used during the study.

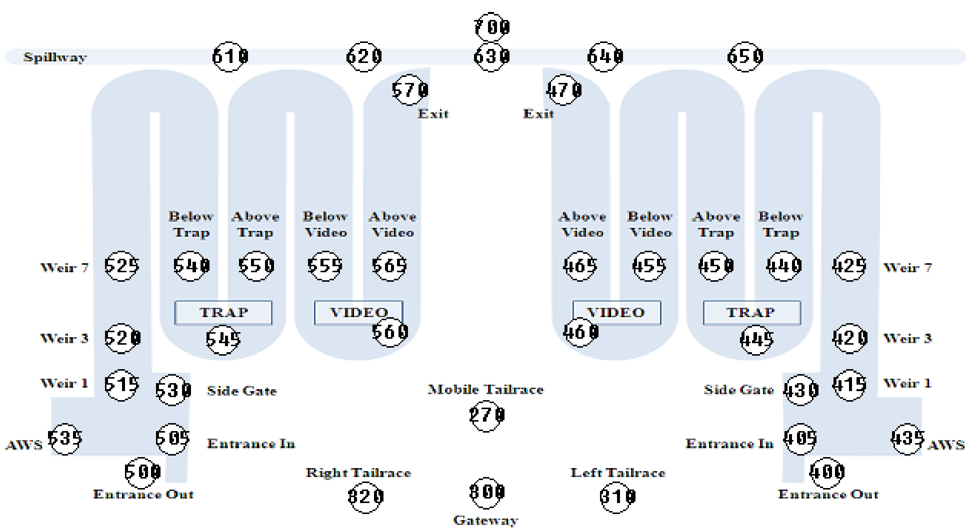



**Figure 5.4-1 Radio-telemetry array at Wells Dam by station number, 2007. Underwater arrays were added to the video bypass (stations 560 and 460) to determine use by tagged lamprey.**

### 5.4.2 Mobile Tracking

Mobile tracking was conducted by boat in a 2 km reach of the river below Wells Dam.  Tracking was recorded using Global Positioning System (GPS) with a built-in data logger.  Twin three-element aerial antennas were mounted to a post and secured in the boat.  Surveys were conducted by transects running upstream and downstream in the river with the aerials pointed in opposite directions, and usually at each bank.

#### 5.4.3 Data Analyses

The data collected was analyzed using Telemetry Manager, Ascent and other computer programs developed in Visual FoxPro by LGL Limited. In order to differentiate detection locations and streamline analyses, individual antennas were grouped into "zones" that define pivotal areas of interest, such as individual fishway entrances and exits (Nass et al., 2005).

Telemetry Manager imports raw ASCII data files downloaded from the Lotek SRX receivers. After importing the raw files, Telemetry Manager constructs an initial database containing records for each logged data transmission from the tagged fish. Telemetry Manager then edits the database to remove records that do not meet the criteria identified for valid data records. Examples of invalid data include background noise at the Project, records with a signal strength that are below a given threshold, single records for a given fish-location combination, and records that were recorded before the official release time and date. After filtering the invalid records, Telemetry Manager constructs an operational database that summarizes the time of arrival and departure from each zone of interest ("benchmark times").

#### 5.4.4 Definition of Passage and Residence Times

Strategic deployment of receivers and antennas made it possible to determine the amount of time that each lamprey spent in the tailrace, fishway entrances, and fishways. Passage times were calculated from benchmark dates and times corresponding to the first and last detection of a given radio-tagged lamprey at specific locations. At Wells Dam, the benchmark times for lamprey that pass the Project were:

1. first detection in the tailrace,
2. first detection at the fishway entrance of passage,
3. last detection at the fishway entrance of passage, and
4. last detection at the fishway exit.

From these benchmark times, passage times were calculated for the following passage segments:

| Segment | Time | Name |
|---|---|---|
| A) | 1 to 2 | Tailrace Passage time |
| B) | 2 to 3 | Entrance Passage time |
| C) | 3 to 4 | Fishway Passage time |
| D) | 1 to 4 | Project Passage time |

From the benchmark times at each of the monitored locations, the passage times and passage efficiencies (proportions) were calculated for each radio-tagged lamprey where,

Passage Efficiency for a section of the fishway = No. tags at a fishway detection zone (above)/ No. tags at the fishway zone (below), or No. tags at a fishway detection zone / No. tags at an entrance.

It then follows that:

Fishway Efficiency = No. of tags at an exit / No. of tags at an entrance.

In addition to the above standard passage segments, detailed analyses of the time lamprey spent in and between detection zones (i.e., residence time) in the Wells Dam fishways were conducted.

The primary residence time analyses include:

- Entrance – at the entrance (first to last detection),
- Between the Entrance and Upper Collection Gallery (last detection to first detection),
- Upper Collection Gallery - the first vertical wall in the fishway (first to last detection),
- Between Upper Collection Gallery and Fishway Transition (last detection to first detection),
- Fishway Transition – first section of orifice weirs which are usually inundated with water depending on the water elevation in the tailrace (first to last detection),
- Between Fishway Transition and Below Trap (last detection to first detection),
- Below Trap - just downstream of the adult trapping facility (first to last detection),
- Between Below Trap and Above Trap (last detection to first detection),
- Above Trap – mid-point in series of orifice weirs between the trap and the Video Station (first to last detection),
- Between Above Trap and Below Video (last detection to first detection),
- Below Video – just downstream of the Video Station (first to last detection),
- Between Below Video and Above Video (last detection to first detection),
- Above Video – just upstream of the Video Station (first to last detection),
- Between Above Video and Exit (last detection to first detection), and
- Exit- fishway exit to forebay (first to last detection).

The residence and passage times for each radio-tagged lamprey are determined by working backwards through a sequence of detections. The fishway of ultimate passage and the respective passage time are determined by identifying a sequence of detections in the ascent of a fishway, starting with detections in a fishway exit zone.

### 5.4.5 Definition of Downstream Passage Events and Drop Back

For the purpose of analysis, a downstream passage event is defined as a tag that is detected at a fishway exit and subsequently detected in the tailrace or a fishway entrance without any detections at antennas monitoring the inside fishway zones. Drop back is defined as those tags in a fishway detection zone that are subsequently detected in zones directly downstream in the fishway.

# 6.0 RESULTS

## 6.1 Literature Review

### 6.1.1 Lower-Columbia River Dams

Millions of dollars and dozens of programs have been dedicated to Pacific lamprey research and restoration since 1994 when the Bonneville Power Administration (BPA) funded studies on the Umatilla Indian Reservation (Stone, 2004). Since then, a majority of this research has been conducted by federal, state, and academic institutions on the lower-Columbia River (e.g., Close et al., 1995; Jackson et al., 1997; Close et al., 2002). Radio-telemetry work to examine adult lamprey interactions with lower Columbia River dams began in 1997, ultimately leading to several peer-reviewed publications on entrance efficiency (Moser et al., 2002a), passage efficiency (Moser et al., 2002b), migration rates (Moser et al., 2005), and population status (Moser and Close 2003). This is the most substantial body of work regarding Pacific lamprey and their migratory behavior in the Pacific Northwest. The resulting publications detailed the following information for the first time:

- Most (~90%) lamprey re-approach hydroelectric projects after being radio-tagged and released downstream.
- Entrance efficiency (successful entrants divided by the number that approach) of adult lamprey is around 50% at lower Columbia River dams. Approaches are more frequent during the night (22:00-01:00) and lamprey typically make multiple entrance attempts.
- Entrance type and configuration has a significant effect on entrance efficiency, and increased attachment surface may be more important than decreased water velocity.
- Passage success through fishways is generally lowest in collection galleries and transition zones, often in areas with inadequate attachment surfaces (e.g., diffuser grating, 90° corners). Passage through fish counting areas is also low in some cases, likely due to the bright lights, confusing currents, and narrowing channels with relatively higher water velocities.
- Counts at hydroelectric dams are often unreliable and can be misleading, regularly underestimating losses between dams and exaggerating time to pass through reservoirs.
- Overall passage efficiency (number that ascended the fishway divided by the number that approach) of lamprey is 38-47% at Bonneville Dam, 50-82% at The Dalles Dam, and generally less than 40% at John Day Dam. The median passage time from first detection at an entrance to fishway exit ranges from 2.0 to 5.7 days at these dams. Little to no drop back occurs once lamprey have successfully ascended a fishway and passed a dam.
- Travel times between Bonneville, The Dalles, and John Day dams (i.e., time to migrate through the reservoirs between each dam) are generally on the order of 3-4 days between projects.
- On average, only 3% of lamprey tagged below Bonneville were detected upstream from John Day on the Columbia River, largely due to low passage efficiency and the movement of some fish into Columbia River tributaries (e.g., Deschutes River).

These findings have led to more detailed research to identify obstacles, develop passage improvements, and to better understand physiological performance of lamprey while migrating through Columbia River dams (Mesa et al., 2001; Close et al., 2003; Mesa and Moser 2004).

### 6.1.2 Mid-Columbia River Dams

Radio-telemetry studies have been completed at four of the five passable mid-Columbia dams (Priest Rapids, Wanapum, Rocky Reach, and Wells (discussed earlier) dams) to evaluate adult Pacific lamprey passage (Figure 6.1-1). Study results from Priest Rapids and Wanapum dams (2001-2002) indicated that entrance efficiency averaged over 50% at both dams (Nass et al. 2003). Overall passage efficiency was 30-70% at Priest Rapids Dam and over 50% at Wanapum Dam. Decreased passage rates were noticed at count stations in both dams, and in the lower fishway at Priest Rapids Dam, presumably due to similar conditions identified by Moser et al. in lower Columbia River dams (2002a; 2002b). Median total fishway passage times (first detection at fishway entrance to exit) at Priest Rapids and Wanapum dams ranged from 1.1 to 1.8 days. Overall, these data suggest that passage through these two dams is comparable to lower Columbia River dams, though overall passage efficiency and median total passage times are considerably lower.

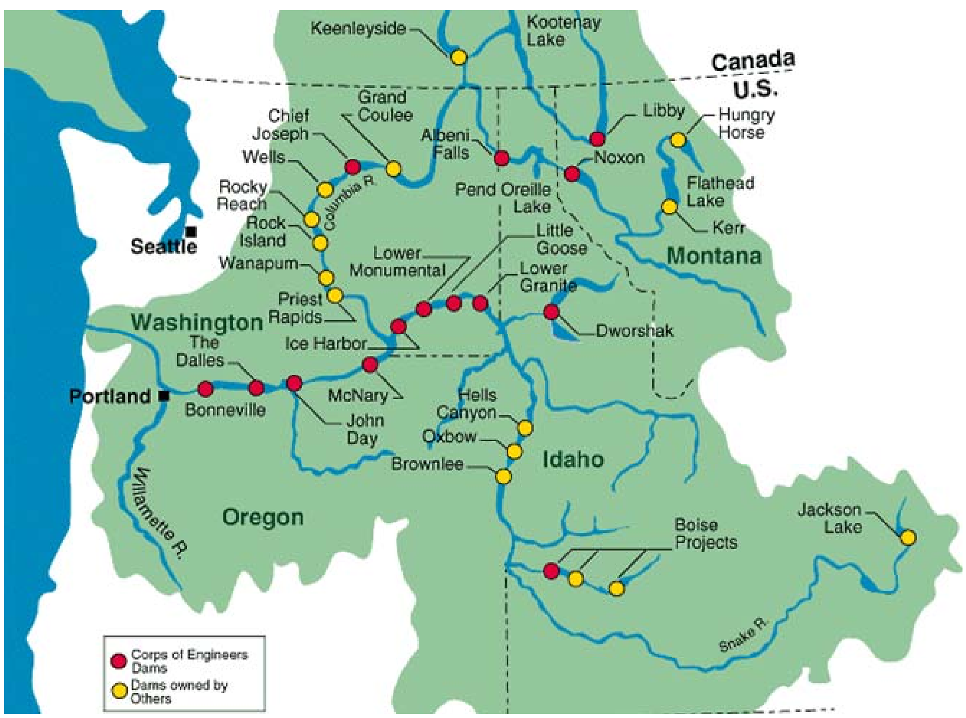



**Figure 6.1-1 Columbia River system dams (from www.nwd-wc.usace.army.mil/report/colmap.htm).**

Radio-telemetry work conducted at Rocky Reach Dam in 2004 indicated that fishway passage efficiency of tagged adult lamprey was over 50% (Stevenson et al. 2005). Radio-tagged adult lamprey at Rocky Reach Dam had the highest entrance efficiency (94%) and drop back rate (22%) of all the previously studied mainstem dams. To account for fish that re-ascended, a "Net

Ladder Passage Efficiency" (NLPE) was calculated to provide a comparative measure of the number of tagged lamprey detected in the tailrace to the number that ultimately ascended the fishway. The NLPE was greater at Rocky Reach (47%) than observed at other mainstem dams, except for Wanapum Dam (48.9%). However, this metric may be slightly misleading by negating the energetic costs of re-ascent and potential consequences to survival and reproduction (Mesa et al. 2001). Exclusion of these fish equals an overall passage efficiency of 42%. Results also indicated that a portion (>15%) of tagged lamprey that did not successfully pass the dam were last detected in the fishway, with some of those fish likely entering into the attraction water system. Median migration rates of tagged lamprey through the Rocky Reach fishway were reported at 1.0 m/min from the base of the lower fishway to the flow regulation diffuser (~60 m downstream of the exit), and less than 0.1 m/min from the diffuser to the fishway exit. The slowest median rates were observed through the upper section of the fishway. This observation may be attributed to the diffuser, Pickett barrier, public viewing windows, and fish counting station located in the upper fishway. Median total fishway passage time at Rocky Reach Dam was less than 1.0 day (Stevenson et al. 2005). Aside from the substantially greater entrance efficiency and drop back rate, these data suggest that overall passage efficiency through Rocky Reach Dam is comparable to other Columbia River dams.

### 6.1.3 Snake River Dams

Radio-telemetry work to assess Pacific lamprey behavior at the four passable lower Snake River dams (Figure 6.1-1) began in 2005 (Peery et al., 2006). The ongoing research is intended to collect baseline information on potential obstacles and passage success of migrating adult lamprey. Fish counts at these dams suggest that few lamprey that pass McNary Dam are observed at Ice Harbor Dam (12% on average), and an average of roughly 650 adult lamprey ultimately pass the project annually since 2000 (range 290-1,702; DART 2008). Researchers have reported an entrance efficiency of less than 50% for Ice Harbor Dam, although this is based on a small sample size from preliminary work (Peery et al., 2006). Further research is planned to obtain more detailed information and determine what set of conditions are associated with the decision made by adult lamprey to enter the Snake River or continue up the Columbia River (Peery et al., 2006).

## 6.2 Capture, Tagging, and Release of Lamprey

### 6.2.1 Trapping

The four adult lamprey traps were checked 112 times each over the 10-week trapping period (56 days of effort per trap). Trapping was extended past the original end date of 30 September in hopes of catching more lamprey, but ended unsuccessfully after three additional weeks in October. Four hundred ninety-nine (499) fish were caught, including 21 jack Chinook salmon (*Oncorhynchus tshawytscha*), 388 chub/suckers (peamouth *Mylocheilus caurinus,* chiselmouth *Acrocheilus alutaceus,* and suckers (Catostomids)), 6 Pacific lamprey, 9 rainbow trout/steelhead (*O. Mykiss*), 68 pikeminnow (*Ptychocheilus oregonensis*), and 7 jack sockeye salmon (*O. nerka*) (Table 6.2-1). A majority of the total catch was composed of chubs, suckers, and pikeminnow (91%), and numbers were greatest during the third week of trapping (week ending 2 September, Table 6.2-2). Over 60% of the total catch and 100% of all lamprey were removed during the morning checks (i.e., fish were captured overnight and early morning), leaving only bycatch observed during daytime trapping effort (37% of the total trapped).

**Table 6.2-1 Total fish captured by species and trap number (traps labeled west to east), 2007.**

| Species | Trap 1 | Trap 2 | Trap 3 | Trap 4 | Total | Percent |
|---|---|---|---|---|---|---|
| Chinook salmon | 4 | 3 | 1 | 13 | 21 | 4.2% |
| Chub/Sucker | 78 | 51 | 55 | 204 | 388 | 77.8% |
| Pacific Lamprey | 2 | 2 | 1 | 1 | 6 | 1.2% |
| *O. Mykiss* | . | 3 | . | 6 | 9 | 1.8% |
| Pikeminnow | 10 | 8 | 18 | 32 | 68 | 13.6% |
| Sockeye salmon | . | 2 | 4 | 1 | 7 | 1.4% |
| Total | 94 | 69 | 79 | 257 | 499 | 100% |

**Table 6.2-2 Total fish captured by species and week of trapping, 2007.**

| | Week of trapping (weeks ending 08/19 through 10/21) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
| Chinook salmon | 1 | . | 1 | 15 | 3 | 1 | . | . | . | . | 21 |
| Chub/Sucker | 26 | 16 | 337 | 6 | . | 3 | . | . | . | . | 388 |
| Pacific Lamprey | 4 | . | . | 1 | 1 | . | . | . | . | . | 6 |
| *O. Mykiss* | 4 | . | 1 | . | 4 | . | . | . | . | . | 9 |
| Pikeminnow | 3 | 4 | 21 | 27 | 12 | 1 | . | . | . | . | 68 |
| Sockeye salmon | 6 | 1 | . | . | . | . | . | . | . | . | 7 |
| Total | 44 | 21 | 360 | 49 | 20 | 5 | 0 | 0 | 0 | 0 | 499 |

Six lamprey were caught, four of which were caught in the first week of trapping. All fish were in excellent condition at the time of capture. Four lamprey were caught in Trap 1 and Trap 2 (the west fishway traps), and two lamprey were caught in Trap 3 and Trap 4 (the east fishway traps). Trapping efficiency was much lower than expected as indicated by counts at the video count station located upstream of the traps. Out of the 35 lamprey observed by fish enumerators, only 12 were handled by LGL/Douglas PUD biologists, indicating that at least 23 lamprey bypassed the trap. Considering that some portion of lamprey that ascend Wells Dam fishways were bypassing the count station (discussed later), it is reasonable to believe that trapping efficiency in 2007 was less than 25%.

Traps appeared to operate well, except Trap 3 where upwelling sometimes created a gap between the trap entrance and the weir sill (first noticed on 6 September). Weight was added to the trap beginning 8 September to help maintain its position. To test escapement, an adult lamprey that did not meet size criteria for tagging was placed in Trap 3 during an evening check on 21 September. The fish was gone the following morning indicating that trap escapement was also a potential issue. This was not recognized until the end of the lamprey migration and no modifications were made to the traps.

Fifteen lamprey were transferred from Rocky Reach Dam on 6 occasions between 20 September and 3 October. Though additional handling occurred with these fish, there were no indications of problems with the transport, and fish behaved similarly to lamprey captured at Wells Dam.

Lamprey captured at Rocky Reach Dam were slightly larger than fish from Wells (1% longer, 9% heavier, and 3% thicker on average), though this difference was not significant.

### 6.2.2 Tagging and Release

Twenty-one (21) lamprey were tagged between 14 August and 2 October (Appendix B). These fish averaged 66 cm in total length (54-73 cm) and 0.42 kg in weight (0.27-0.53 kg). The girth of these fish averaged 10.4 cm, ranging from 9.0 to 11.5 cm. Two fish were identified as females when oocytes were noticed during surgery. Sex was not determined in any other lamprey. Total surgery time averaged 13.7 minutes (9.5-21.5 min), including an average 7.9 minutes (5.3-16.8 min) of heavy sedation and 5.8 minutes (4.1-10.5 min) of light sedation/surgery. Recovery time averaged 1.5 hours (0.8-2.6 hrs) excluding one fish that was held overnight (16 hrs) to ensure adequate recovery after irregular bleeding during surgery. Fish generally showed immediate signs of recovery and appeared to be in good to excellent shape prior to release.

## 6.3 Telemetry Array

Fixed stations were downloaded bi-weekly throughout the study period. No problems occurred with receivers or antenna arrays. Two mobile tracking surveys also were completed. The first survey was conducted on 18 September to search for tagged lamprey below the dam. Several transects were completed across the tailrace with no detections. One tag (later considered to be a shed or mortality) was detected in the alcove area of the east tailrace. A snorkel survey of this area was conducted to look for the fish, tag, or any evidence. The substrate was mostly covered by large riprap and most of the crevasses could not be examined. No lamprey were observed and the tag was not recovered. Another mobile tracking survey was conducted on the evening of 23 October to search for 9 tagged lamprey below the dam. The survey was scheduled for the evening (sundown to past midnight) in hopes of increased activity and detection ability of the nocturnal fish. Five of the nine missing tags were detected, three of which were found using a deep-water (10-25 m) antenna in the tailrace.

The DIDSON was deployed during the mobile survey conducted on 18 September to assess the value for imaging lamprey on or near structures along the face of the dam. The DIDSON was deployed from a pole mount and aimed either downward or laterally at variable depths, and imaging data were collected as the boat moved slowly along the dam face. Areas surveyed included spillway structures at turbine units 1, 2, 9 and 10, guidance walls and entrances to fishways, and riprap areas at the east and west ends of the dam. No lamprey were observed, though numerous images resembling adult salmonids were collected. Given the high resolution images of structure and individual fish that were acquired, the DIDSON would have likely captured images of lamprey had they been present during the survey.

Thirty-five (35) lamprey were observed by fish enumerators between 12 August and 23 September. Water temperatures averaged 19.7 °C (range 18.3-20.4 °C) during lamprey observations and fish were equally distributed between ladders (± 3%). Similar to observations at other dams on the Columbia River, lamprey movement in Wells Dam fishways occurs almost exclusively at night. The earliest (in relation to midnight) observation in 2007 occurred at 15:56

and the latest occurred at 10:46, though a few of these outliers may be fish that were recently tagged and released above the trapping area. The average time for all observations was 2:53 (± 4:41 SD), and roughly 90% of lamprey were observed between 8:00 PM and 8:00 AM (Figure 6.3-1).

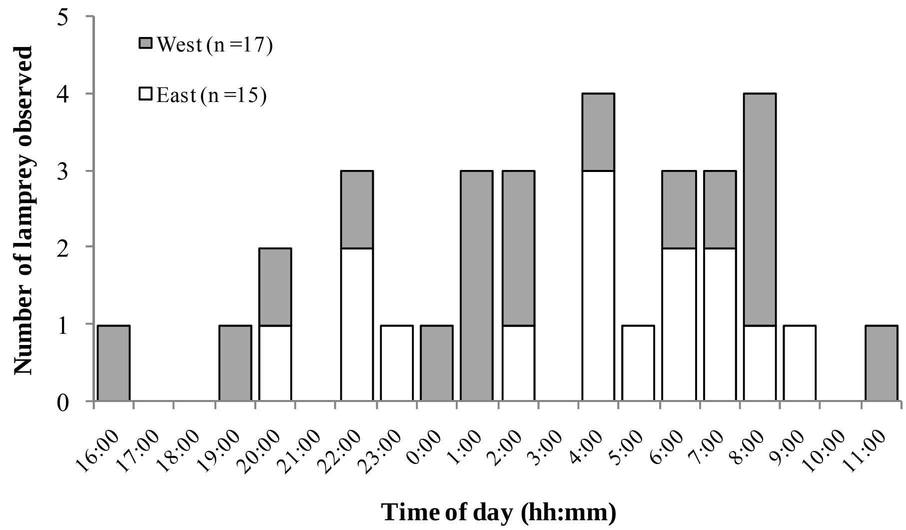



**Figure 6.3-1 Number of lamprey observations at Wells fish counting stations by ladder and time, 2007.**

### 6.3.1 Data Analyses

#### 6.3.1.1 Detections

Nineteen (19) of the 21 tagged lamprey were detected at some point subsequent to their release. One fish (Fish 101) was never detected following release into the west tailrace, and another (Fish 100) shed the tag or died near the release site. The remaining 19 fish were detected a total of 179 (including 19 detections at release) separate times at fixed and mobile stations. The number of hits at each station ranged from a few hits over a couple seconds to as many as 1,661 hits over a 68-hour period, when Fish 130 remained in the east tailrace detection zone between early 22 August and late 24 August. The earliest fixed station detection occurred on 14 August and the last occurred 3 October near midnight outside the east fishway entrance. The period of detections likely coincides with migratory activity of lamprey in the immediate area (lamprey observations at the fish counting window ranged from 12 August to 23 September).

The number of post-release detections ranged from 0 (Fish 101) to 31 (Fish 102), with an average of 7.6 individual detections per fish. By excluding the lamprey released into the fishways and a fish that sat in between the west and east tailrace detection zones (Fish 118, 16 sequences on 14 August), the average number of individual detections per fish drops to 1.8 (range 0-7). This suggests that the ability to detect tagged lamprey outside the fishways and below the dam is extremely low, likely due to the depth limitations of aerial arrays and limited number of underwater antennas (only located at the outside of each fishway entrance).

The duration of detections (i.e., sequential hits) in all zones ranged from less than one minute to over 68 hours (average 1.82 hours) (Table 6.3-1). Zones where detections averaged over one hour include both tailrace aerial arrays, outside both fishway entrances, both trapping areas (below trap antenna), and both fishway exits. Detections at the west video bypass also averaged over one hour (1:47), though two of the ten detections there exceeded eight hours. Zones where detections averaged less than one hour (often on the order of minutes) included the above trap, below video, and above video zones in both fishways. The average detection length at the east video bypass (0:02) and inside the east fishway entrance (0:17) were also short, though no detections occurred inside the west fishway entrance and data from the west video bypass were skewed by two outliers.

**Table 6.3-1 Time spent within detection zones in the Wells Project Area by tagged lamprey by zone, 2007 (zone descriptions in Figure 5.4-1). Zones where detections averaged over one hour are in bold.**

| Zone | Statistics | | Zone | Statistics | | Zone | Statistics | |
|---|---|---|---|---|---|---|---|---|
| **310** | Min | 0:00 | **440** | Min | 11:08 | **540** | Min | 0:01 |
| (n=11) | Max | 68:20 | (n=2) | Max | 20:10 | (n=3) | Max | 2:54 |
| | Average | 6:18 | | Average | 15:39 | | Average | 1:54 |
| **320** | Min | 0:00 | 445 | Min | 0:01 | 550 | Min | 0:09 |
| (n=10) | Max | 6:16 | (n=6) | Max | 0:19 | (n=5) | Max | 0:21 |
| | Average | 1:40 | | Average | 0:10 | | Average | 0:13 |
| **400** | Min | 0:00 | 450 | Min | 0:06 | 555 | Min | 0:00 |
| (n=13) | Max | 38:06 | (n=6) | Max | 0:15 | (n=10) | Max | 5:07 |
| | Average | 2:57 | | Average | 0:10 | | Average | 0:42 |
| 405 | Min | 0:04 | 455 | Min | 0:01 | 560 | Min | 0:03 |
| (n=7) | Max | 1:00 | (n=9) | Max | 0:14 | (n=11) | Max | 1:39 |
| | Average | 0:17 | | Average | 0:07 | | Average | 0:26 |
| 415 | Min | 0:00 | 460 | Min | 0:02 | **565** | Min | 0:01 |
| (n=3) | Max | 0:00 | (n=9) | Max | 0:30 | (n=10) | Max | 8:15 |
| | Average | 0:00 | | Average | 0:10 | | Average | 1:47 |
| 420 | Min | 0:00 | 465 | Min | 0:00 | **570** | Min | 1:22 |
| (n=1) | Max | 0:00 | (n=5) | Max | 0:05 | (n=5) | Max | 2:38 |
| | Average | 0:00 | | Average | 0:02 | | Average | 2:03 |
| 425 | Min | 0:21 | **470** | Min | 0:17 | 871 | Min | 0:01 |
| (n=1) | Max | 0:21 | (n=6) | Max | 4:01 | (n=1) | Max | 0:01 |
| | Average | 0:21 | | Average | 1:24 | | Average | 0:01 |
| 435 | Min | 0:11 | **500** | Min | 0:00 | 872 | Min | 0:02 |
| (n=2) | Max | 0:43 | (n=4) | Max | 22:17 | (n=1) | Max | 0:02 |
| | Average | 0:27 | | Average | 9:12 | | Average | 0:02 |

#### 6.3.1.2 Movements

The 19 tagged lamprey made a total of 138 directional movements between detection zones subsequent to the first detection after release, averaging 7 moves per fish (range 1-30). The most frequent moves were between the west and east tailrace arrays (though detections may overlap in some instances), between the below video, the video bypass, and above the video antennas, and between the inside and outside entrance antennas in the east fishway (Table 6.3-2). Interaction to, from, and within the video area of both fishways accounted for the largest majority of movements (73 movements, or 52% of total). These movements fell into 17 different direction classifications of only 11 lamprey indicating substantial interactions with the bypass and window chute. The duration of movements between zones (i.e., difference between the first observation at the current zone and first observation at the previous zone) averaged over 18 hours in the tailrace and 3 hours in the fishway (average excludes movements to mobile tailrace, Methow River, time in trapping area, and release to first detection). Movements in the tailrace ranged from less than 30 seconds between the inside and outside entrance antennas, to nearly 200 hours between the east and west fishway entrances. Movements in the fishways ranged from roughly one minute between Weirs 1 and 3, to over 17 hours between the video bypass and above video antennas (Table 6.3-2). No drop backs occurred throughout the monitoring period. That is, none of the tagged lamprey that exited the fishway were subsequently detected below the dam. Two of the radio-tagged lamprey that exited the Wells Dam fishways were later detected entering the Methow River.

**Table 6.3-2 Movements made by tagged lamprey at Wells Dam by frequency of occurrence, 2007.**

| From (detection zone) → to (detection zone) | Count | Min | Max | Average |
|---|---|---|---|---|
| West Tailrace → East Tailrace | 8 | 0:07 | 6:16 | 2:03 |
| West Below Video → West Above Video | 8 | 0:01 | 5:11 | 0:52 |
| East Tailrace → West Tailrace | 7 | 0:01 | 0:22 | 0:04 |
| West Above Video → West Video Bypass | 7 | 0:00 | 1:40 | 0:27 |
| East Entrance Out → East Entrance In | 6 | 0:00 | 0:12 | 0:03 |
| East Entrance In → East Entrance Out | 6 | 0:00 | 0:16 | 0:07 |
| East Trap → East Above Trap | 6 | 0:16 | 2:18 | 0:45 |
| East Above Trap → East Below Video | 6 | 1:34 | 7:59 | 3:30 |
| East Below Video → East Above Video | 6 | 0:01 | 16:56 | 2:55 |
| East Above Video → East Exit | 6 | 0:25 | 1:20 | 0:57 |
| West Above Trap → West Below Video | 5 | 2:22 | 6:22 | 3:59 |
| West Video Bypass → West Above Video | 5 | 0:08 | 17:25 | 3:43 |
| East Below Video → East Video Bypass | 4 | 0:05 | 0:15 | 0:10 |
| West Below Video → West Video Bypass | 4 | 0:02 | 0:21 | 0:13 |
| West Video Bypass → West Below Video | 4 | 0:00 | 8:17 | 2:16 |
| East Tailrace → East Entrance Out | 3 | 47:57 | 110:54 | 75:56 |
| East Video Bypass → East Below Video | 3 | 0:00 | 0:15 | 0:05 |
| East Video Bypass → East Above Video | 3 | 0:07 | 0:17 | 0:12 |
| West Below Trap → West Above Trap | 3 | 0:31 | 3:41 | 2:06 |
| West Above Video → West Below Video | 3 | 0:10 | 1:15 | 0:38 |
| West Above Video → West Exit | 3 | 0:47 | 1:41 | 1:12 |
| West Tailrace → East Trap | 2 | 0:53 | 4:38 | 2:46 |
| East Entrance Out → Mobile Tailrace | 2 | 671:12 | 1560:01 | 1115:36 |
| East Entrance Out → West Entrance Out | 2 | 118:18 | 194:58 | 156:38 |
| East Entrance In → East AWS | 2 | 0:09 | 0:55 | 0:32 |
| East AWS → East Weir 1 | 2 | 0:11 | 0:44 | 0:27 |
| East Below Trap → East Trap | 2 | 11:24 | 20:25 | 15:55 |
| East Above Video → East Video Bypass | 2 | 0:10 | 0:21 | 0:16 |
| West Video Bypass → West Exit | 2 | 0:17 | 0:50 | 0:34 |
| East Tailrace → Mobile Tailrace | 1 | 694:51 | 694:51 | 694:51 |
| East Entrance In → East Weir 1 | 1 | 1:03 | 1:03 | 1:03 |
| East Weir 1 → East Entrance In | 1 | 0:00 | 0:00 | 0:00 |
| East Weir 1 → East Weir 3 | 1 | 0:00 | 0:00 | 0:00 |
| East Weir 1 → East AWS | 1 | 0:00 | 0:00 | 0:00 |
| East Weir 3 → East Weir 7 | 1 | 0:09 | 0:09 | 0:09 |
| East Weir 7 → East Trap | 1 | 1:20 | 1:20 | 1:20 |
| East AWS → East Entrance In | 1 | 0:01 | 0:01 | 0:01 |
| East Trap → East Below Trap | 1 | 3:30 | 3:30 | 3:30 |
| East Above Video → East Below Video | 1 | 0:11 | 0:11 | 0:11 |
| East Exit → Methow A1 | 1 | 92:12 | 92:12 | 92:12 |
| East Exit → Methow A2 | 1 | 50:11 | 50:11 | 50:11 |
| West Entrance Out → Mobile Tailrace | 1 | 41:31 | 41:31 | 41:31 |
| West Entrance Out → East Tailrace | 1 | 3:34 | 3:34 | 3:34 |
| West Entrance Out → West Tailrace | 1 | 105:32 | 105:32 | 105:32 |
| West Entrance Out → East Entrance Out | 1 | 0:57 | 0:57 | 0:57 |

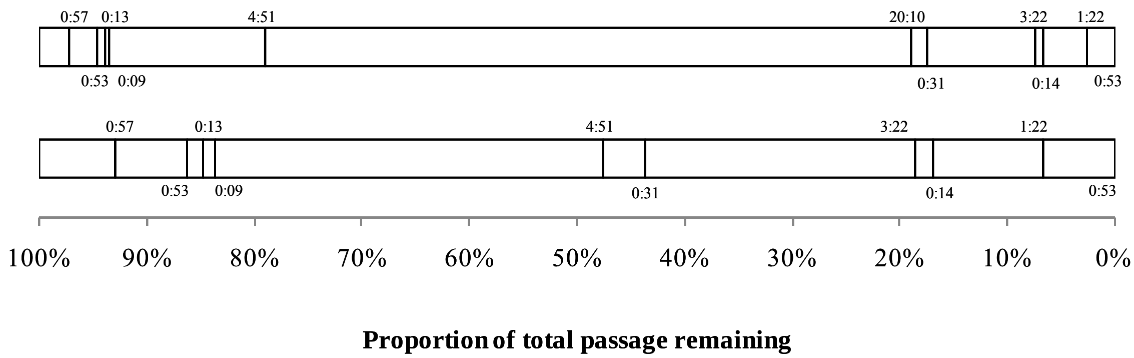
#### 6.3.1.3 Fishway Passage Metrics

Entrance and Passage Efficiency

Excluding the tag that was likely a shed or mortality, 78% (7 of 9) of tagged lamprey released into the tailrace approached either fishway entrance. These fish made 17 separate approaches to the west (n = 4) and east (n =13) fishways. Only one lamprey successfully entered the collection gallery, indicated by detections on the antenna located on the inside of the fishway entrance. This results in an overall entrance efficiency of 14% (1 successful entrant out of 7 lamprey that approached). The low sample size prohibits the ability to make any conclusions about the difference in success between the west and east fishways (0/3 versus 1/4, respectively). The one lamprey that made it past the entrance and into the lower fishway successfully ascended Wells Dam. This results in a fishway efficiency of 100%, though little can be determined by one fish. Over 80% (10 of 12) of the tagged lamprey released into the fishway successfully ascended the fish ladder. The two that did not pass through the ladder prior to their tag expiring included one that rejected the fishway by traveling through the Auxiliary Water Supply (AWS) to the collection gallery and another that disappeared in between detection zones.

Project Passage

Only one tagged lamprey made a complete ascent through a fishway at Wells Dam in 2007. Fish 102 was released into the east tailrace on 6 September and began ascent in the east fishway two days later following nearly one hour of detections on the inside and outside entrance antennas. Within minutes of entering the collection gallery, Fish 102 was detected in the AWS chamber until reaching Weir 1 53 minutes later. Travel times from Weir 1 to Weir 3 and Weir 7 were relatively fast at only 23 minutes (less than 5 minutes per pool) (Figure 6.3-2). Travel from Weir 7 to the first detection at the below trap antenna took nearly 5 hours at roughly 9 minutes per pool (33 pools). Fish 102 then spent just over 20 hours in the detection zone of the below trap antenna. Data is not available to suggest whether the fish was interacting with the lamprey trap or another obstacle, resting, stopped migrating during the day (the pause occurred from 4:36 to past midnight), or a combination of these factors; although, the trap was not engaged until ~15:00 to 17:00 that day. The fish then made it to the above trap antenna in 31 minutes. This was the quickest rate observed in 2007 at less than 4 minutes per pool. The remaining segments of the ascent were all within the distribution observed for other upper fishway ascents of fishway-released lamprey. Altogether, the total fishway passage time for Fish 102 was 32:41, including a 6:07 lower fishway passage, a 5:53 upper fishway passage, 20:10 at the below trap antenna, and 0:31 below the above trap antenna. Rates of ascent were faster in the lower fishway (about 10 minutes per pool) than the upper fishway (about 15 minutes per pool), though pools #1-56 are 1.2 m (4 feet) shorter than the 4.9 m (16 feet) pools from #57 to #73.




| Detection benchmark | Date/Time | Time difference | Running total |
|---|---|---|---|
| First approach to entrance | 9/8/07 21:31 | 0:00 | 0:00:00 |
| First detection at inside entrance | 9/8/07 22:28 | 0:57 | 0:57:00 |
| First detection at Weir 1 | 9/8/07 23:22 | 0:53 | 1:50:39 |
| First detection at Weir 3 | 9/8/07 23:35 | 0:13 | 2:03:46 |
| First diction at Weir 7 | 9/8/07 23:44 | 0:09 | 2:12:53 |
| First detection at below trap | 9/9/07 4:36 | 4:51 | 7:04:16 |
| Last detection at below trap | 9/10/07 0:46 | 20:10 | 27:14:25 |
| First detection at above trap | 9/10/07 1:17 | 0:31 | 27:45:55 |
| First detection at below video | 9/10/07 4:40 | 3:22 | 31:08:12 |
| First detection at above video | 9/10/07 4:54 | 0:14 | 31:22:45 |
| First detection at exit | 9/10/07 6:16 | 1:22 | 32:45:07 |
| Last detection at exit | 9/10/07 7:10 | 0:53 | 33:38:55 |

**Figure 6.3-2 Graphical and tabular timeline of the only complete fishway ascent by a tagged lamprey (Fish 102), 2007. The topmost timeline (total passage = 32:42 + approach) includes the 20+ hours spent at the below trap detection zone. The bottom timeline (total passage = 12:31 + approach) excludes the duration spent in the below trap detection zone.**

<u>Upper Fishway Passage and Video Bypass</u>

A total of 11 tagged lamprey successfully ascended the upper fishway at Wells Dam between 6 and 23 September. This includes 9 of the 11 fishway-released lamprey, the additional fishway release of a recaptured fish (Fish 130), and one of the lamprey released into the tailrace (Fish 102). Upper fishway passage times in both ladders ranged from 2.8 to 29.1 hours, with median and average times slightly shorter in the east fishway (Table 6.3-3). This difference is not significant and removing the unusually quick fish (Fish 110) and the three unusually slow fish (Fish 106, 111, and 112) brings the difference in average upper fishway passage between ladders within 3% of each other.

**Table 6.3-3 Descriptive statistics of upper fishway passage times of tagged lamprey at Wells Dam by fishway, 2007.**

| Statistic | Fishway East | Fishway West | Fishway All |
|---|---|---|---|
| Minimum | 2:48:38 | 5:11:07 | 2:48:38 |
| Maximum | 24:16:15 | 29:05:13 | 29:05:13 |
| Median | 6:53:03 | 9:44:29 | 7:53:06 |
| Average | 9:11:26 | 15:07:51 | 11:53:26 |
| Standard deviation | 7:45:01 | 11:03:20 | 9:24:36 |

The three unusually slow lamprey had numerous and extended detections on the video area antennas (below video the count window, the video bypass, and above the video count window) and similar passage times (Table 6.3-4). The radio-telemetry data show that these three fish all spent several hours in the video area during daylight hours, presumably resting. Fish 106 spent roughly 5 hours (7-12:00) in the detection zone of the below video antenna, and moved into the video bypass for 8 hours (12-20:00) before continuing ascent. Likewise, Fish 111 spent about 8 hours (6-14:00) in the west video bypass, and Fish 112 spent 17 hours -(4-21:00) between the below video and above video detection zones before continuing ascent. The travel times of these fish were also similar, reaching the above trap antenna around 23:00 and completing ascent just over 24 hours later. The starting times of the upper fishway ascent for these fish also were the three latest for all lamprey released into the fishway. Had the three slower fish continued their ascent without stopping to rest in the video area, their passage times would have been similar to fish that ascended without stopping (Table 6.3-5).

**Table 6.3-4 Upper fishway passage times of tagged lamprey at Wells Dam by fishway, 2007. Fish that spent extended time in the video area are highlighted with red font.**

| Fish number | Fishway | First observation at above trap antenna | Last observation at fishway exit antenna | Upper fishway passage time |
|---|---|---|---|---|
| 102 | East | 9/10/08 1:17 | 9/10/08 7:10 | 5:53:00 |
| 108 | East | 9/20/08 20:16 | 9/21/08 1:03 | 4:46:43 |
| 109 | East | 9/20/08 20:32 | 9/21/08 4:25 | 7:53:06 |
| 110 | East | 9/20/08 21:50 | 9/21/08 0:38 | 2:48:38 |
| 112 | East | 9/22/08 23:38 | 9/23/08 23:54 | 24:16:15 |
| 130 | East | 9/6/08 13:46 | 9/6/08 23:17 | 9:30:54 |
| 103 | West | 9/13/08 14:59 | 9/14/08 0:43 | 9:44:29 |
| 104 | West | 9/20/08 20:48 | 9/21/08 1:59 | 5:11:07 |
| 105 | West | 9/20/08 20:41 | 9/21/08 3:25 | 6:43:51 |
| 106 | West | 9/20/08 22:53 | 9/21/08 23:47 | 24:54:33 |
| 111 | West | 9/21/08 22:55 | 9/23/08 4:00 | 29:05:13 |

**Table 6.3-5 Descriptive statistics of upper fishway passage times of tagged lamprey at Wells Dam by grouping (short or long), 2007. The "long" group included three lamprey that spent extended time in the video bypass area.**

| | Grouping | | |
|---|---|---|---|
| Statistic | Short (n = 8) | Long (n = 3) | All |
| Minimum | 2:48 | 24:16 | 2:48 |
| Maximum | 9:44 | 29:05 | 29:05 |
| Median | 6:18 | 24:54 | 7:53 |
| Average | 6:33 | 26:05 | 11:53 |
| Standard deviation | 2:23 | 2:36 | 9:24 |

The remaining tagged lamprey (i.e., those that did not spend extended time in the video area) had upper fishway passage times ranging from just under 3 hours (Fish 110) to nearly 10 hours (Fish 103). These median and average upper fishway passage times (6:18 and 6:34, respectively) for these fish are 75% lower than those of the longer group and likely representative of the time it takes a lamprey to travel from the above trap area to the exit of either fishway (Table 6.3-5). Water flow from the above trap antenna (Pool #47) to Pool #56 is maintained at a constant 48 cfs, with each pool containing overflow weirs and two 18×15" orifices. Water flow in the remaining portion of the fishway (pools #57-73) ranges from 31-44 cfs, depending on reservoir elevation, with pools containing two 30×16.5" orifices and no overflow weirs. Based on observed upper fishway passage times in 2007 (excluding the three fish that spent extended time in the video area), lamprey successfully ascend this portion of the fishway at an average rate of nearly 15 minutes per pool, ± 5 minutes standard deviation. This equates to an ascent rate of over 0.3 m/min.

The upper fishway passage time can be divided into four segments: 1) the first detection at the above trap antenna to the first detection at the below video count window antenna; 2) the first detection at the below video count window antenna to the first detection at the above video count window antenna; 3) the first detection at the above video count window antenna to the first detection at the exit; and, 4) the first detection at the exit to the last detection at the exit. Over half of upper fishway passage was usually spent traveling between the above trap and below video count window antennas. This portion of the fishway includes 17 of the 27 pools (63%) in the metric, and typically accounted for over 50% of the total time (Table 6.3-6). Average passage time through this segment was slightly below (faster) the average rate of 15 minutes per pool. The time spent between the first detection at the below and above video count window antennas (Pool #64) accounted for less than 5% of the upper fishway passage time for all fish. Average passage time through this segment (one pool) was nearly equal to the average rate of 15 minutes per pool. Time spent between the first detection at the above video count window antenna and the first detection at the exit (8 pools) usually accounted for 15% of the total time, though three fish spent over 18 hours there. Otherwise, passage through this segment was substantially below (nearly 50% faster) the average rate of 15 minutes per pool. Time spent within the detection zone of the fishway exit antenna usually accounted for 25% of the upper fishway passage time. Only four of the eleven fish that exited the fishway passed this pool in under one hour, with average passage through this segment substantially above the average rate of 15 minutes per pool, though this detection zone is much larger than those in other pools. A summary of tagged lamprey passage metrics is shown in Table 6.3-6.

**Table 6.3-6 Descriptive statistics of segmented upper fishway passage times of tagged lamprey at Wells Dam, 2007. The first detection at the above trap antenna is considered the start of upper fishway passage (i.e., 0:00).**

| | Segment | Time elapsed from previous zone: 1st detection Below video | 1st detection Above video | 1st detection at Exit | Last detect. at Exit | Total |
|---|---|---|---|---|---|---|
| All fish | Min | 1:34 | 0:03 | 0:20 | 0:17 | 2:48 |
| | Max | 7:59 | 0:46 | 21:10 | 4:01 | 29:05 |
| | Median | 2:51 | 0:14 | 1:20 | 1:32 | 7:53 |
| | Average | 3:43 | 0:18 | 6:10 | 1:42 | 11:53 |
| | SD | 2:07 | 0:12 | 8:53 | 1:07 | 9:24 |
| Excluding resting fish | Min | 1:34 | 0:03 | 0:20 | 0:17 | 2:48 |
| | Max | 7:59 | 0:29 | 1:54 | 4:01 | 9:44 |
| | Median | 2:41 | 0:14 | 1:06 | 1:36 | 6:18 |
| | Average | 3:36 | 0:16 | 1:00 | 1:42 | 6:33 |
| | SD | 2:16 | 0:08 | 0:33 | 1:20 | 2:23 |

**Table 6.3-7 Summary of tagged lamprey release, passage times, and location last detected.**

| Fish | Release date | Release location | Passage times: Upper | Lower | Total | Bypass | Last location | Notes* |
|---|---|---|---|---|---|---|---|---|
| 130 | 9/6 | East fishway | 9:30 | . | . | Yes | Exit | Second release |
| 107 | 9/20 | East fishway | . | . | . | . | East tailrace | Fishway reject, AWS |
| 108 | 9/20 | East fishway | 4:46 | . | . | No | Exit | . |
| 109 | 9/20 | East fishway | 7:53 | . | . | Yes | Exit | . |
| 110 | 9/20 | East fishway | 2:48 | . | . | Yes | Exit | . |
| 112 | 9/22 | East fishway | 24:16 | . | . | Yes | Exit | Long at video bypass |
| 103 | 9/13 | West fishway | 9:44 | . | . | No | Exit | . |
| 104 | 9/20 | West fishway | 5:11 | . | . | Yes** | Exit | . |
| 105 | 9/20 | West fishway | 6:43 | . | . | Yes | Exit | . |
| 106 | 9/20 | West fishway | 24:54 | . | . | Yes | Exit | Long at video bypass |
| 111 | 9/21 | West fishway | 29:05 | . | . | Yes | Exit | Long at video bypass |
| 114 | 9/22 | West fishway | . | . | . | . | Below trap | Probable AWS exit |
| 118 | 8/14 | East tailrace | . | . | . | . | East tailrace | . |
| 102 | 9/6 | East tailrace | 5:53 | 6:07 | 32:42 | Yes | Exit | Only complete ascent |
| 113 | 9/22 | East tailrace | . | . | . | . | East entrance | . |
| 119 | 10/3 | East tailrace | . | . | . | . | East entrance | . |
| 130 | 8/14 | West tailrace | . | . | . | . | Recaptured | Released in fishway |
| 100 | 8/16 | West tailrace | . | . | . | . | West tailrace | Tag shed/mortality |
| 101 | 8/16 | West tailrace | . | . | . | . | Release site | . |
| 115 | 9/22 | West tailrace | . | . | . | . | East tailrace | . |
| 116 | 9/25 | West tailrace | . | . | . | . | East entrance | . |
| 117 | 9/28 | West tailrace | . | . | . | . | West entrance | . |

# 7.0 DISCUSSION

## 7.1 Conduct a Literature Review of Existing Adult Pacific Lamprey Passage Studies at Columbia and Snake River Dams

The literature review confirmed methodologies used in the Wells Dam study and provided insight to commonalities among adult Pacific lamprey behavior and interactions with hydroelectric dams throughout the Columbia and Snake rivers. Mainly, researchers have confirmed that fishway entrance efficiency is generally low (≤ 50%) among all hydroelectric projects. Further, project passage times are comparatively slow throughout the basin. Much of this may be accredited to entrance difficulties and problematic areas within fishways (e.g., diffuser grating, 90° corners).

## 7.2 Identify Methods for Capturing Adult Pacific Lamprey at Wells Dam

Results of the 2007 study suggest that the current method of trapping adult Pacific lamprey in Wells Dam fishways is less efficient than anticipated. This conclusion is based on evidence indicating that only a small portion of lamprey utilized the weir orifice to pass between fishway pools, and the fact that adult lamprey were able to escape out of the traps in between trap inspections. The fact that at least half of the lamprey passed the trapping area in both fishways suggests that they are traveling through the orifice or traveling above the overflow weir away from the wall. Since the latter seems unlikely, it is reasonable to believe that a majority of lamprey traveled through the orifice. This was expected, though not to this extent (≥80%). It is possible that the fish are unable to detect the flow reduction offered by the trap once they are committed to travelling along the bottom of the fishway. Lamprey have been observed regularly passing through orifices using burst and attach movements at other dams on the Columbia River (C. Peery, University of Idaho, personal communication). Results also suggest that the assumption regarding escapement is invalid. This was confirmed by the untagged fish leaving Trap 3, indicating that escapement is, at the very least, possible. The detection history of Fish 102 (the only complete fishway ascent) added to this suspicion when over 20 hours of detections were recorded at the below trap antenna. Interestingly, the detections occurred on a Sunday and the fish was present for at least 10 hours before the trap was lowered. The period of inactivity also occurred during the period of day when lamprey are generally inactive. However, the fish did not leave the detection zone until past midnight indicating that interaction with the trap and escapement remains a possibility.

Since fewer lamprey were observed than the target sample size, modifications should be made to increase trapping efficiency and decrease escapement. A mechanism to limit orifice passage is recommended to increase trapping efficiency. This could be achieved by installing a perforated plate on the fishway floor roughly 0.5 m downstream, upstream, and through the orifice. This would prevent lamprey from passing through the orifice by the typical burst and attach movements since suction to perforated surfaces is unlikely. Lamprey are usually unable to pass through weir orifices by free-swimming only and often search other passage routes throughout the water column after failing orifice passage. This has been observed by video monitoring at other projects on the Columbia River and orifice exclusion has been shown to increase trapping efficiency (C. Peery, University of Idaho, personal communication). The use of a floor plate also eliminates the potential to influence orifice passage of other species, especially salmonids. Lastly, a funneled flap constructed of plastic mesh on the chute leading into the holding box is recommended to decrease trap escapement. Similar designs are used at Bonneville Dam to ensure one-way travel through lamprey passage systems (Jonathan Rerecich, U.S. Army Corps of Engineers, personal communication), and flexible funnels are used in most fish traps (fyke nets, minnow traps, eel pots, etc.). This trap modification should make escapement more difficult by promoting one-way movement into the holding box.

## 7.3 Document the Timing and Abundance of Radio-Tagged Lamprey Passage through Wells Dam

The use of the radio-telemetry data from the 2007 study to document timing and abundance of lamprey passage at Wells Dam is not practical due to the small number of fish captured in Wells fishways (n = 6) and complete fishway ascents (n =1). Therefore, data retrieved from DART (2008) were used to make reasonable conclusions about migratory length, timing, and abundance. Although lamprey enumeration at dams lacks total precision, counts are likely highly correlated to absolute numbers and therefore can provide insight to the timing, length, and size of migrations.

On average, lamprey observations at Wells Dam begin 12 June, though these data are highly variable among years (SD ± 36 days). Counts start as early as 28 April (2005) or as late as 12 August (2007). Based on what is known about Pacific lamprey life history, earlier observations are likely fish that overwintered in the system (Close et al., 2002; Moser and Close 2003). Migration reaches mid-point by 8 September on average, with considerable reliability (SD ± 13 days). Likewise, 75% of the run will pass by 24 September on average (SD ± 15 days). The last lamprey to pass Wells Dam will do so by 22 October, on average (SD ± 21 days), ranging from 23 September (2007) to 15 November (2003). Based on this information (shown by year with descriptive statistics in Table 7.3-1), the bulk of the Pacific lamprey migration will occur between the last calendar week in August and the third week in September (Figure 4.0-1).

**Table 7.3-1 Run timing of Pacific lamprey at Wells Dam, by year, distribution of run, total lamprey observed, length of migration, and fish per day, 1998-2007. Descriptive statistics are listed at bottom of table.**

| Year | Start date | 25% | 50% | 75% | Finish date | Total lamprey | Length of run | Average fish/day |
|---|---|---|---|---|---|---|---|---|
| 1998 | 30-Jun | 27-Aug | 5-Sep | 14-Sep | 30-Sep | 343 | 92 | 3.7 |
| 1999 | 31-May | 1-Sep | 9-Sep | 12-Sep | 11-Oct | 73 | 133 | 0.5 |
| 2000 | 22-Jul | 25-Aug | 2-Sep | 16-Sep | 20-Oct | 155 | 90 | 1.7 |
| 2001 | 4-Jul | 26-Aug | 16-Sep | 24-Sep | 11-Nov | 262 | 130 | 2.0 |
| 2002 | 31-May | 2-Sep | 9-Sep | 19-Sep | 8-Nov | 342 | 161 | 2.1 |
| 2003 | 27-Jun | 6-Sep | 7-Oct | 28-Oct | 15-Nov | 1,410 | 141 | 10.0 |
| 2004 | 4-May | 19-Aug | 12-Sep | 11-Oct | 14-Nov | 647 | 194 | 3.3 |
| 2005 | 28-Apr | 22-Aug | 6-Sep | 27-Sep | 3-Nov | 214 | 189 | 1.1 |
| 2006 | 4-May | 19-May | 15-Aug | 20-Sep | 29-Sep | 21 | 148 | 0.1 |
| 2007 | 12-Aug | 27-Aug | 7-Sep | 14-Sep | 23-Sep | 35 | 42 | 0.8 |
| Min | 28-Apr | 19-May | 15-Aug | 12-Sep | 23-Sep | 21 | 42 | 0.1 |
| Max | 12-Aug | 6-Sep | 7-Oct | 28-Oct | 15-Nov | 1,410 | 194 | 10.0 |
| Median | 13-Jun | 26-Aug | 8-Sep | 19-Sep | 27-Oct | 238 | 137 | 1.9 |
| Average | 12-Jun | 17-Aug | 8-Sep | 24-Sep | 22-Oct | 350 | 132 | 2.6 |
| Stand Dev. | 36 | 32 | 13 | 15 | 21 | 416 | 47 | 2.9 |

The length of the adult lamprey migration at Wells Dam (i.e., time between the first and last observations) averages approximately 19 weeks (> 4 months), with considerable variation among years (SD ± 47 days). Observations will span well over 5 months some years (e.g., 2004), and last only 3 months in others (1998, 2000). For unknown reasons, the 2007 migration was the shortest yet, lasting only 42 days. This may have been shorter if lamprey were not transferred from Rocky Reach Dam in late September. Regardless, the variability in migration length among years is largely influenced by observations of few lamprey during the spring months. Half of the recorded years have had few lamprey observations in April and May. Despite these differences, the majority of the adult Pacific lamprey migration through Wells Dam will occur over a three to four week period (Table 7.3-1). The length of migration also has somewhat of a positive linear correlation with migration size, with larger migrations spanning over a greater time span (R2 = 0.27, when excluding 2003).

Total adult lamprey counts at Wells Dam average 350 fish, also with significant variation among years (SD ± 416 lamprey). This is largely due to three outliers, including one abnormally large run (1,410 lamprey in 2003), and two unusually small runs (56 combined lamprey observations between 2006 and 2007). Only one other year had a substantially low (75% below average) run. In 1999 only 73 lamprey were observed passing Wells Dam. Likewise, only one other year had a substantially high (75% above average) run – 647 lamprey were observed in 2004 following the record high in 2003. Although the total observed adult lamprey at Wells Dam have declined in recent years, similar trends have been noticed downstream at Rocky Reach and Rock Island dams (Figure 7.3-1).

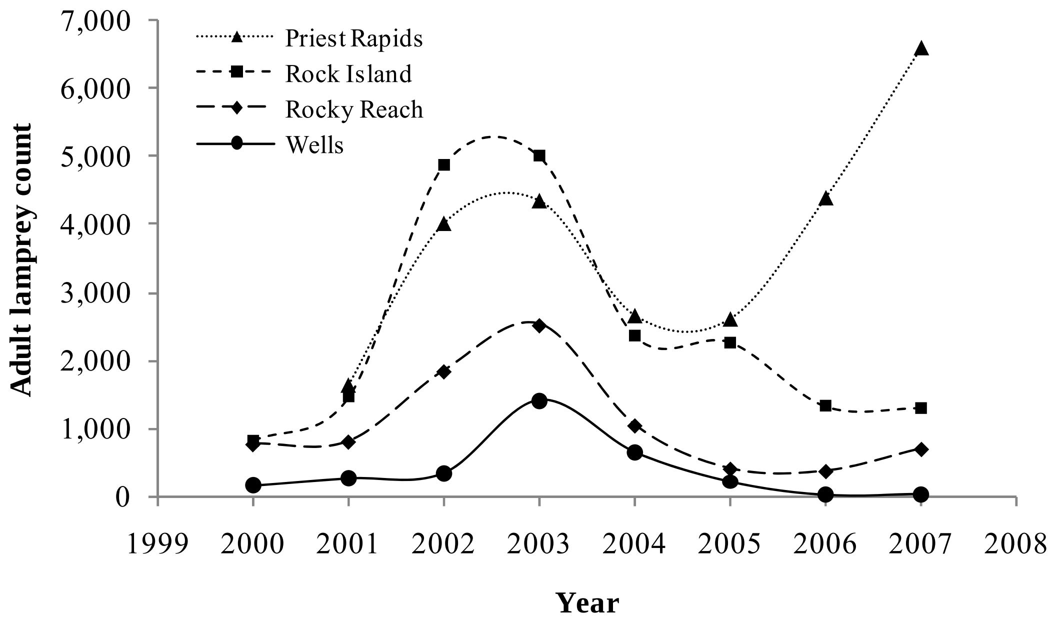



**Figure 7.3-1 Lamprey counts at mid-Columbia River dams, 2000-2007, by project.**

## 7.4 Determine Whether Adult Lamprey are Bypassing the Adult Counting Windows at Wells Dam

Eleven tagged lamprey passed the fish counting facilities in both fishways with detections on at least two of the three antennas at each Video Station. Nine of these fish were detected by the video bypass antenna, although three fish were detected for less than 20 seconds and probably did not completely enter the bypass. Eight of these lamprey were not counted at the video window, and two fish had zero detections on the above video antenna. These results indicate that radio-telemetry detection efficiency of tagged lamprey at the counting facilities is 100%, and, though a few detections may be spurious, a majority of tagged lamprey were interacting with the video bypass system at some point during ascent. Further, visual detections at the count windows could be significantly lower (e.g., under estimating by 73% according to these data) than the actual total number of lamprey passing the fish counting facilities.

Based on these conclusions and the results of segmented upper fishway passage metrics, it appears that the use of the video bypass is an enumeration issue, rather than a passage concern. Aside from the three fish that spent extensive time in the video area presumably resting, tagged lamprey generally move through this portion of the fishway efficiently and at above average speeds. Structural modifications to encourage passage by the video window are not recommended at this time. However, further consideration should be given regarding effective monitoring of lamprey passage through the video bypass depending on the importance of accurate counts at the project.

## 7.5 Where Sample Size is Adequate, Estimate Passage Metrics Including Fishway Passage Times and Efficiencies, Residence Time Between Detection Zones, and Downstream Passage Events and Drop Back

Passage of lamprey through Wells Dam consists of several segments, including approach, lower fishway passage, and upper fishway passage. A majority of tagged lamprey released into the tailrace approached an entrance more than twice on average. However, successful approaches were low (6%), as was overall entrance efficiency (1 out of 7, or 14%). These results suggest that tagged lamprey are able to approach the entrance, but most are unable to negotiate entry. The only lamprey that entered the collection gallery successfully ascended the lower fishway, and 83% of fish that were at or above Pool #40 successfully ascended the upper fishway. Of the two fish that did not ascend the upper fishway prior to tag expiration, one rejected the fishway and the other was never detected subsequent to release. The first fish was detected at the below trap antenna, followed by detections in the Auxiliary Water Supply (AWS) chamber and a descending sequence through the collection gallery and to the entrance. This sequence, particularly the lack of detections at three in-ladder antennas between the two zones, suggests that this fish travelled through some portion of the AWS beneath the fish ladder. The second fish was never detected subsequent to the in-ladder release. Considering that the detection efficiency of fishway antennas is near 100%, it is probable that the fish entered the AWS through diffuser grating in the fishway floor below Pool #22. All of the tagged lamprey that reached the count station completed their ascent. This suggests that lamprey are capable of negotiating the upper fishway with a high level of success, although a portion of fish will interact with the AWS with some of those ultimately failing to ascend the fishway. Since only one tagged lamprey made a complete fishway ascent in 2007, data for approach and lower fishway passage times are limited to one observation. For this fish, approach was 49.0 hours, including 1.0 hour (2% or approach) of negotiating the entrance, and the lower fishway passage time was 6.1 hours. Median upper fishway passage time was 7.9 hours (n = 11), or 6.3 hours when excluding the three outliers. These passage times are within acceptable levels compared to studies at other Columbia Basin dams, suggesting that once inside and committed to the fishway, adult lamprey are able to negotiate the Wells Dam in reasonable time. Since no tagged lamprey dropped back through the Wells Dam subsequent to exiting the fishway (n = 11), drop back appears to be little or no concern at this point.

Altogether, these results suggest that: 1) lamprey have difficulty negotiating the entrances to Wells fishways; 2) some lamprey interact with the AWS; and 3) lamprey have high passage efficiency in reasonable time once inside the fishway. However, these statements are based on a limited amount of data (only 13 tagged lamprey were detected inside the fishway) and therefore lack the ability to answer questions surrounding passage of Wells Dam. The first recommendation to improve the ability to estimate fishway passage metrics and efficiency is to increase the number of tagged fish released at Wells Dam. This can be accomplished by increasing trap efficiency and decreasing escapement (discussed earlier), and supplementing catch with lamprey from Rocky Reach Dam to ensure sample size targets are met. Based on the detection histories of lamprey obtained from Rocky Reach Dam in 2007, there is no evidence to suggest that their behavior is different from those captured at Wells Dam. This is further supported by the observation that none of the radio-tagged lamprey that were obtained from

Rocky Reach Dam and released at Wells Dam were later detected leaving the Wells Project, at Rocky Reach Dam, or at the Entiat River. An increased sample size would ultimately increase precision of estimates and help clarify conclusions made from the 2007 data.

The second recommendation to improve the ability to estimate fishway passage metrics and efficiency is to decrease the number of tagged lamprey released in the trapping area (i.e., mid-fishway releases), increase releases into the tailrace, and add a release location within the collection gallery near the side gate entrance. Since upper fishway passage data suggests that lamprey passage through this portion of Wells Dam is both timely and efficient, there would be little benefit to continue mid-fishway releases aside from further investigation of interactions with the AWS and video bypass area. Although the video bypass is not a passage issue but rather a monitoring issue (discussed earlier), increased tailrace releases would provide more data regarding entrance efficiency since a majority of tagged lamprey will approach either fishway entrance (based on 2007 results and Nass et al., 2005). This should be a priority considering the small number of successful entrants in 2007 (one lamprey) and indication that this may be the most difficult area for lamprey to negotiate. Releasing tagged lamprey into the collection gallery of both fishways would provide better insight to the ability of lamprey to negotiate the collection gallery after entrance into the fishway, the transition zone into the fishway ladder, and the lower fishway.

The last recommendation to improve the ability to estimate fishway passage metrics and efficiency is to reconsider fixed and mobile radio-telemetry monitoring throughout Wells Dam. Aside from the recently installed antennas in the video bypass and outside both fishway entrances, monitoring at Wells Dam has been generally designed for detecting movements of adult salmonids. This layout has proved to be inadequate in two general areas: the tailrace and the AWS system. Results from the 2007 study indicate that tagged lamprey regularly travel lower in the water column and at slower rates than salmonids, equating to fewer detections on the tailrace aerial arrays. Further, the smaller radio-tags implanted in lamprey have a smaller detection range and shorter tag life than tags typically used in salmonid studies (J. Murauskas, LGL Northwest, unpublished data). Additional deep-water mobile surveys at night (previously described) during the peak of the lamprey migration are recommended to better understand movements below the dam. The 2007 data also indicate that some lamprey interact with the AWS system, particularly in the collection gallery and below the fishway ladder downstream of Pool #22. Since access to this area is limited to fishes smaller than adult salmonids, monitoring in the AWS has been limited to one antenna in each fishway (Figure 5.4-1). Consideration of adjusting this antenna and possibly adding detection zones near the fishway transition zone and below the lower ladder is recommended to better understand movements through and use of the AWS system by migrating lamprey.

## 7.6 If Necessary, Identify Potential Areas of Improvement to Existing Upstream Fish Passage Facilities for the Protection and Enhancement of Adult Lamprey at the Wells Project

Based on the limited data collected in 2007, we were not able to identify area for potential fishway improvement.

# 8.0 STUDY VARIANCE

Variance in the FERC approved study plan includes the following:

- The proposed sample size for tagged lamprey was not met in 2007. Only 19 of the 40 allocated radio tags were deployed due to the small number of lamprey observed at Wells Dam in 2007 (n = 35).
- In an effort to achieve sample sizes, Douglas PUD received concurrence from the Aquatic RWG to collect adult lamprey from Rocky Reach Dam and to tag and release them at Wells Dam (see ISR Document, Appendix E – Summary of Consultation, pages 30-39).

Following discussions with members of the Aquatic RWG, Douglas PUD is in the process of implementing a second adult lamprey passage study (2008) (see ISR Document, Appendix E – Summary of Consultation, pages 75-84).

# 9.0 ACKNOWLEDGMENTS

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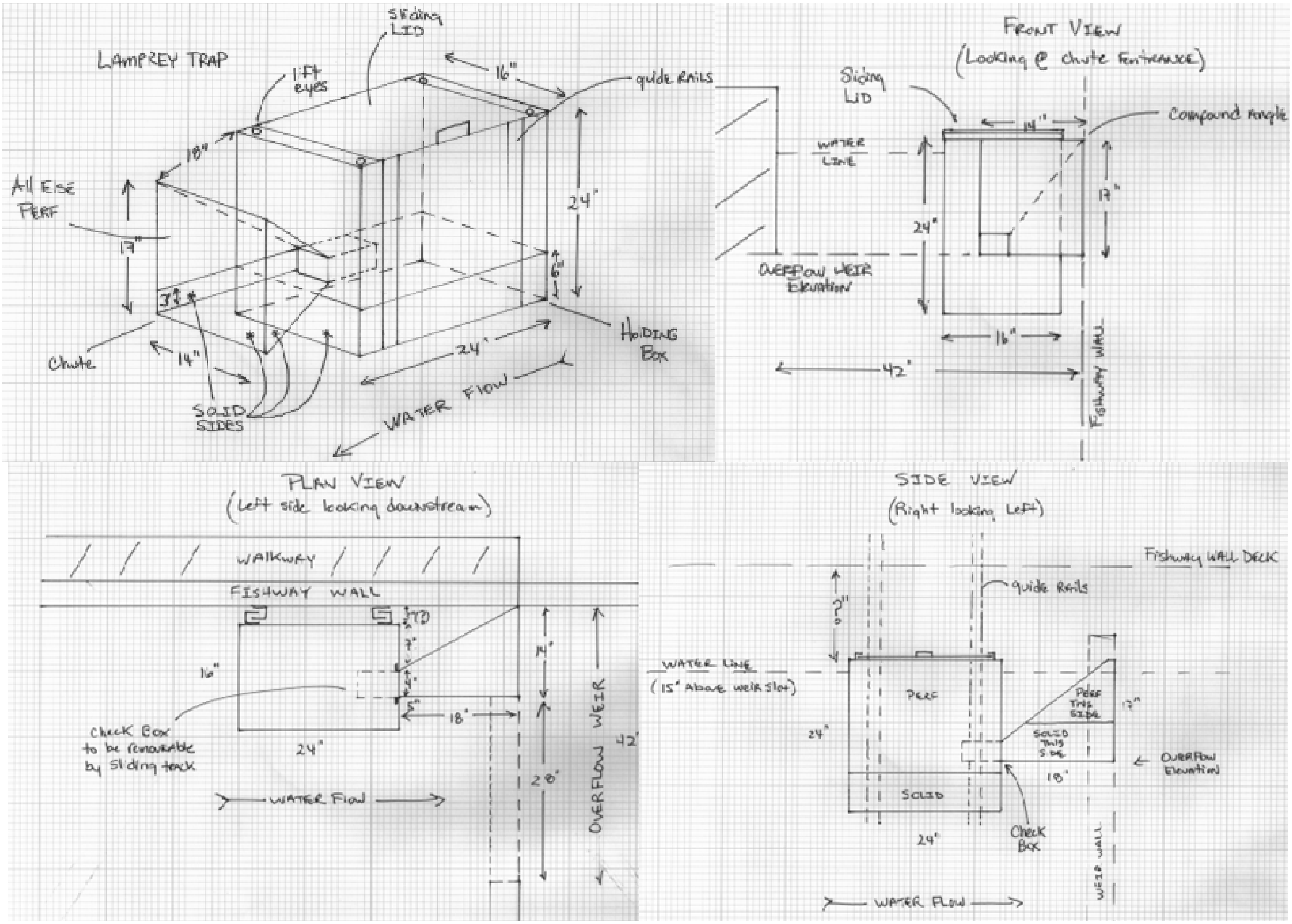
# Appendix A

## Wells Dam Adult Lamprey Trap Draft Schematics, 2007



LAMPREY TRAP
Sliding LID
lift eyes
16"
guide RAILS
18"
All Else PERF
17"
24"
6"
3"
Chute
14"
24"
HOLDING BOX
SOLID SIDES
WATER FLOW
FRONT VIEW
(Looking @ chute Entrance)
Sliding LID
14"
Compound Angle
WATER LINE
24"
17"
OVERFLOW WEIR Elevation
16"
42"
FISHWAY WALL
PLAN VIEW
(Left side looking downstream)
WALKWAY
FISHWAY WALL
16"
14"
18"
24"
28"
42"
Check Box to be removable by sliding track
WATER FLOW
OVERFLOW WEIR
SIDE VIEW
(Right looking Left)
Fishway WALL DECK
guide Rails
?"
WATER LINE
(15" Above weir slot)
PERF
24"
PERF THIS SIDE
SOLID THIS SIDE
17"
OVERFLOW Elevation
18"
SOLID
24"
Check Box
WEIR WALL
WATER FLOW

# Appendix B

## Tagged Lamprey at Wells Dam, 2007

| Date | Trap | Capture location | Code (Ch 1) | Length (cm) | Weight (kg) | Girth (cm) | Heavy Anesth. | Start Surgery | Start Recovery | Release Time | Release Location |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14-Aug | Trap 3 | East fishway | 118 | 65.0 | 0.445 | 11.0 | 15:14:30 | 15:20:30 | 15:31:00 | 8:06:00 | East Alcove |
| 14-Aug | Trap 2 | West fishway | 130 | 64.0 | 0.404 | 10.5 | 16:14:00 | 16:22:00 | 16:28:00 | 17:50:00 | West Alcove |
| 16-Aug | Trap 1 | West fishway | 100 | 60.0 | 0.310 | 9.0 | 9:20:30 | 9:27:00 | 9:33:00 | 12:09:00 | West Alcove |
| 16-Aug | Trap 1 | West fishway | 101 | 67.0 | 0.400 | | 10:04:00 | 10:11:00 | 10:17:00 | 12:15:00 | West Alcove |
| 6-Sep | Trap 4 | East fishway | 102 | 68.6 | 0.370 | 10.0 | 11:28:00 | 11:37:55 | 11:42:59 | 13:50:00 | East Alcove |
| 13-Sep | Trap 2 | West fishway | 103 | 66.0 | 0.446 | 10.7 | 12:46:48 | 12:54:22 | 13:00:27 | 14:27:00 | West In-ladder |
| 20-Sep | | Rocky Reach | 104 | 67.0 | 0.506 | 11.5 | 13:59:33 | 14:06:33 | 14:11:20 | 16:15:00 | West In-ladder |
| 20-Sep | | Rocky Reach | 105 | 68.0 | 0.438 | 10.5 | 14:14:40 | 14:19:59 | 14:25:00 | 16:15:00 | West In-ladder |
| 20-Sep | | Rocky Reach | 106 | 64.0 | 0.484 | 11.5 | 14:19:30 | 14:36:16 | 14:40:57 | 16:15:00 | West In-ladder |
| 20-Sep | | Rocky Reach | 107 | 69.0 | 0.494 | 11.0 | 14:54:50 | 15:00:15 | 15:04:20 | 16:49:00 | East In-ladder |
| 20-Sep | | Rocky Reach | 108 | 69.0 | 0.430 | 10.0 | 15:08:00 | 15:15:50 | 15:20:10 | 16:42:00 | East In-ladder |
| 20-Sep | | Rocky Reach | 109 | 63.0 | 0.408 | 10.3 | 15:23:50 | 15:29:30 | 15:34:00 | 16:50:00 | East In-ladder |
| 20-Sep | | Rocky Reach | 110 | 62.0 | 0.360 | 10.0 | 15:39:00 | 15:46:30 | 15:51:00 | 16:40:00 | East In-ladder |
| 21-Sep | | Rocky Reach | 111 | 54.0 | 0.270 | 9.0 | 13:31:10 | 13:37:42 | 13:46:00 | 15:06:00 | West In-ladder |
| 22-Sep | | Rocky Reach | 112 | 61.0 | 0.356 | 10.0 | 10:18:07 | 10:26:15 | 10:31:00 | 11:46:00 | East In-ladder |
| 22-Sep | | Rocky Reach | 113 | 68.0 | 0.484 | 11.0 | 10:33:40 | 10:43:20 | 10:48:00 | 11:52:00 | East Alcove |
| 22-Sep | | Rocky Reach | 114 | 69.0 | . | 11.0 | 10:44:00 | 10:53:00 | 11:00:00 | 12:31:00 | West In-ladder |
| 22-Sep | | Rocky Reach | 115 | 73.0 | 0.528 | 11.0 | 11:06:00 | 11:13:00 | 11:18:00 | 12:20:00 | West Alcove |
| 25-Sep | | Rocky Reach | 116 | 64.0 | 0.384 | 10.0 | 10:05:08 | 10:12:09 | 10:17:30 | 11:20:00 | West Alcove |
| 28-Sep | | Rocky Reach | 117 | 64.0 | 0.404 | 10.0 | 11:12:00 | 11:19:30 | 11:25:00 | 12:30:00 | West Alcove |
| 3-Oct | | Rocky Reach | 119 | 71.0 | 0.502 | 11.0 | 10:06:43 | 10:17:50 | 10:26:20 | 11:34:00 | East Alcove |