U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

2011 Reconnaissance Level Assessment of Fish Ladders at The Dalles, John Day and McNary Dams for Upstream Passage of Adult Pacific Lamprey

FY 2011 Annual Report

David A. Wills

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
Vancouver, WA 98683

On the cover: *Dewatered John Day Dam South adult fish ladder. Image by David Wills, USFWS.*

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and authored by

David A. Wills

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

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2011 ANNUAL REPORT

David A. Wills[1]

U.S. Fish and Wildlife Service
Columbia River Fishery Program Office
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

Abstract

Although Pacific lamprey (*Entosphenus tridentatus*) were historically widespread and relatively abundant, recent observations of the reduction of abundance and distribution have raised concerns regarding the status and trend of the species. Observational trends suggest that the current populations are declining from historical numbers, particularly in the Columbia River Basin. The U.S. Fish and Wildlife Service (Service) recognized the need for a comprehensive plan to conserve and restore Pacific lamprey and determined that a systematic fishway evaluation survey for adult lamprey passage at each of the eight mainstem dams in the lower Columbia and Snake rivers was needed. The challenge was to integrate the biological information on lamprey passage capabilities with the physical and hydraulic characteristics of the adult fishways to produce a consistent, systematic evaluation to inform priorities or the sequence of actions to be taken to improve adult lamprey passage, while not degrading adult salmonid passage. The goal of this report was to present the results and recommendations of reconnaissance level inspections conducted at The Dalles, John Day and McNary dams from 2011 and develop a foundation for a complete systematic survey of the fishways at the eight dams of interest. The Service accompanied USACE biologists and engineers, along with other co-managers, and inspected dewatered fishways at The Dalles, John Day and McNary dams on January 31, February 4, 10 and 14, 2011 just prior to the ladders being watered up for the 2011 fish passage season. Documentation with specific ladder metrics (length, width, slope, velocities, etc.) for fishways were obtained from readily available documents and reports and USACE project biologists. Results of the assessments cover the powerhouse collection channel, collection channel entrances and fishways (ladders) for each dam, with specific observations (OB), concerns (C), or data needs (DN) listed. The assessment along with the other information (Pacific lamprey biology and physical capabilities, previous passage research) feeds into recommendations for a systematic fishway survey and evaluation process.

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[1] ddwills@fws.gov

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Introduction

Although Pacific lamprey (*Entosphenus tridentatus)* were historically widespread and relatively abundant, recent observations of the reduction of abundance and distribution have raised concerns regarding the status and trend of the species. These observed declines may be a result of reduced quantity and quality of spawning and rearing habitats, impacts associated with hydropower and irrigation diversion passage and entrainment, and mortality from predation (Luzier et al. 2011). Although accurate abundance data for Pacific lamprey are difficult to obtain, observational trends suggest that the current populations are declining from historical numbers, particularly in the Columbia River Basin.

Historically, lamprey passing Bonneville Dam, the lowermost passage barrier in the Columbia River Basin, numbered in the hundreds of thousands. The highest recorded count at Bonneville Dam was 379,509 in 1969 (USACE 2012a). In recent years, counts at Bonneville indicate a dramatic decline in the number of adult lamprey returning to the Columbia River. Continuing threats such as barriers to mainstem and tributary passage, streamflow management, stream and floodplain degradation, and reduced water quality are impacting all freshwater life stages.

In response to the growing concern for the status of Pacific lamprey, the U.S. Army Corps of Engineers (USACE) finalized their Pacific Lamprey Passage Improvements Implementation Plan 2008 – 2018 (USACE 2009). Funding commitments came from formal Memorandum of Agreements (MOA) with the Accord Treaty Tribes (Umatilla, Warm Springs, and Yakama) and the Columbia River Inter-Tribal Fish Commission (CRITFC) in 2008, called the Tribal Accords. In addition, because of the cultural, subsistence, and ecological values associated with Pacific lamprey, and the decline in abundance, the Native American Columbia River treaty tribes (Nez Perce, Umatilla, Yakama, and Warm Springs) developed their own restoration plan (CRITFC 2011). The first objective listed in their plan is to improve lamprey mainstem passage, survival, and habitat.

The U.S. Fish and Wildlife Service (Service) also recognized the need for a comprehensive plan to conserve and restore Pacific lamprey. To that end, the Service worked with various Federal, State, and local governmental agencies, Native American tribes, scientific institutions, consultants, non-profit groups, utility companies, private landowners and others from California to Alaska to develop a comprehensive conservation initiative for Pacific lamprey (Luzier et al. 2011). The Service also conducted a risk analysis for lamprey and found that "The NatureServe rank indicates that Pacific Lamprey geographic population groupings are at 'high risk' throughout much of the Columbia River basin, particularly in the Snake River, the Mid-Columbia region and the Upper Columbia" (Luzier et al. 2011).

The Service determined that a systematic fishway evaluation survey for adult lamprey passage at each of the eight mainstem dams in the lower Columbia and Snake rivers is needed. The goal of this work would be to complete a systematic adult fishway evaluation survey at each Federal Columbia River Power System (FCRPS) projects and integrate it with biological information on lamprey passage capabilities. The purpose is to provide a consistent, systematic evaluation to inform priorities or the sequence of actions to be taken to improve adult passage, while not degrading adult salmon passage.

Since the USACE prioritization process from their 10-year plan indicated that Bonneville Dam was the highest priority location to improve lamprey passage, the Service chose to start onsite inspections and evaluations of fishways at Bonneville Dam with a reconnaissance level inspection and to develop a concept of a systematic fishway survey and evaluation process (USFWS 2012). At the same time the Service inspected available fishways at The Dalles, John Day and McNary dams. The goal of this report is to present the results and recommendations of those reconnaissance level inspections conducted at The Dalles, John Day and McNary dams from 2011 to prepare the basis for a complete systematic survey. Topics covered in this report include:

- a brief introduction to Pacific lamprey and the Columbia River Basin area of concern
- background information on The Dalles, John Day and McNary dams and what is readily known about:
    - the physical structure and operations of the fish passageways
    - historic lamprey passage
    - previous lamprey and passage research
- a review of the ***USACE Pacific Lamprey Passage Improvements Implementation Plan 2008-2018*** (USACE 2009) as it pertains to The Dalles, John Day and McNary dams
- the results of the USFWS reconnaissance level surveys and assessments
- components of a systematic fishway survey and evaluation
- an overview of USACE's newly implemented systematic fishway survey, and
- a summary of USFWS recommendations and priority needs at The Dalles, John Day and McNary dams.

Pacific Lamprey Life Cycle

The following summary of Pacific lamprey life cycle information comes from Streif (2008). Pacific lampreys spawn in similar habitats to salmon; in gravel bottomed streams, at the upstream end of riffle habitat, typically above suitable ammocoete habitat. Spawning occurs between March and July depending upon location within their range. Hatched ammocoetes (larvae) drift downstream to areas of low velocity and fine substrates where they burrow, grow, and live as filter feeders for 3 to 7 years and feed primarily on diatoms and algae. Several generations and age classes of ammocoetes may occur in high densities. Metamorphosis to macropthalmia (juvenile phase) occurs gradually over several months as developmental changes occur, including the appearance of eyes and teeth. When metamorphosis is complete, the macropthalmia leave the substrate and enter the water column. They migrate downstream to the ocean between late fall and spring where they fully mature into adults. After spending 1 to 3 years in the marine environment as parasitic feeders on fish, Pacific lampreys cease feeding and migrate to freshwater between February and June. They are thought to overwinter and remain in freshwater habitat for approximately one year before spawning where they may shrink in size up to 20 percent. Most upstream migration takes place at night. Adult size at the time of migration ranges from about 15 to 25 inches.

Pacific Lamprey Physical Abilities and Characteristics

The swimming capabilities and characteristics of adult Pacific lamprey are very different from adult salmonids. Salmon are strong swimmers usually found in the upper water column. They are most active diurnally. Pacific lamprey, however, are relatively weak swimmers, primarily found low in the water column. Juvenile salmonids migrating downstream are safely guided away from the turbines by the fish bypass screens at the turbine entrances of the mainstem dams. However, juvenile and larval lamprey that are bypassed are more likely to be impinged on the screens and suffer injuries or death than juvenile salmonids.

Fish ladder conditions designed for anadromous salmonids are generally not suitable for adult lamprey. Adult salmon migrating upstream are attracted to and enter relatively high flows and are unaffected by 90° corners typically found at the fishway entrances and on weirs and orifices. Once inside fishways, adult salmon are guided and excluded from areas of potential danger by diffuser grates and picketed leads. The adult lamprey can pass through typical diffuser gratings and picketed leads and quite often are lost and perish in areas migrating fish should not be in. Adult lamprey can, though, climb vertical walls and move in very shallow water, a trait not shared by adult salmon.

Study Area – Lower Columbia and Snake River Basins

Pacific lampreys were historically widespread from Baja California, Mexico north to the Gulf of Alaska and Aleutian Islands (Close et al. 2002; USFWS 2004), and along the Pacific Rim to Japan (Luzier et al. 2011). Along the west coast of North America, Pacific lamprey distribution extended far inland up major river systems, including the Columbia and Snake Rivers (Wydoski and Whitney 2003). Due to mainstem and tributary passage barriers, water management, and habitat and water quality degradation, the distribution and abundance of Pacific lamprey in Washington, Oregon, Idaho, and California has declined (Luzier et al. 2011; Wydoski and Whitney 2003). In the Columbia River Basin, the four lower Columbia River mainstem hydropower dams and the four lower Snake River mainstem hydropower dams are the nexus of fish passage issues for anadromous Pacific lampreys (Figure 1). The average annual flow for the Columbia River at The Dalles, Oregon is approximately 190,000 cubic feet per second (cfs)(WDOE 2012), with the annual discharge rate ranging from 120,000 to 260,000 cfs. The basin's maximum historical unregulated peak discharge, calculated at The Dalles, Oregon, was 1,240,000 cfs in 1894.

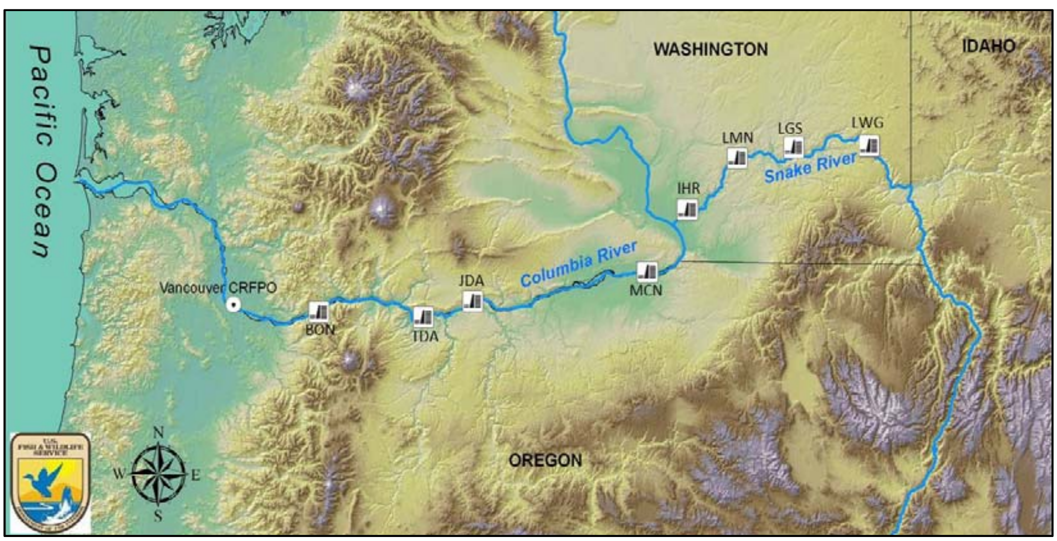

Figure 1. Lower Columbia River and Lower Snake River federal hydropower projects.

The four lower Columbia River hydropower dams downstream from the confluence of the Snake River include Bonneville [BON], The Dalles (TDA), John Day (JDA), and McNary (MCN). The Snake River enters the Columbia at river mile (RM) 324.2. The lower Snake hydropower dams below the confluence of the Clearwater River (Snake RM 139) include Ice Harbor (IHR), Lower Monumental (LMN), Little Goose (LGS), and Lower Granite (LWG) lying 432 river miles above the mouth of the Columbia River. All are owned and operated by the USACE. These eight hydropower projects and 23 additional upstream hydropower projects in the Columbia and Snake basins make up the Federal Columbia River Power System (FCRPS). The USACE and the Bureau of Reclamation (USBR) are the owners and operators of all 31 of the federally owned hydropower dams in the Columbia and Snake River basins.

Mainstem dam passage counts for lamprey began in 1938, and there have since been dramatic fluctuations of adult lamprey numbers migrating upstream past Bonneville Dam on the Columbia River (Figure 2). Fluctuations in numbers of Pacific lamprey including overall declines have occurred throughout the lower Columbia/Snake River Basins within recent history (Table 1).

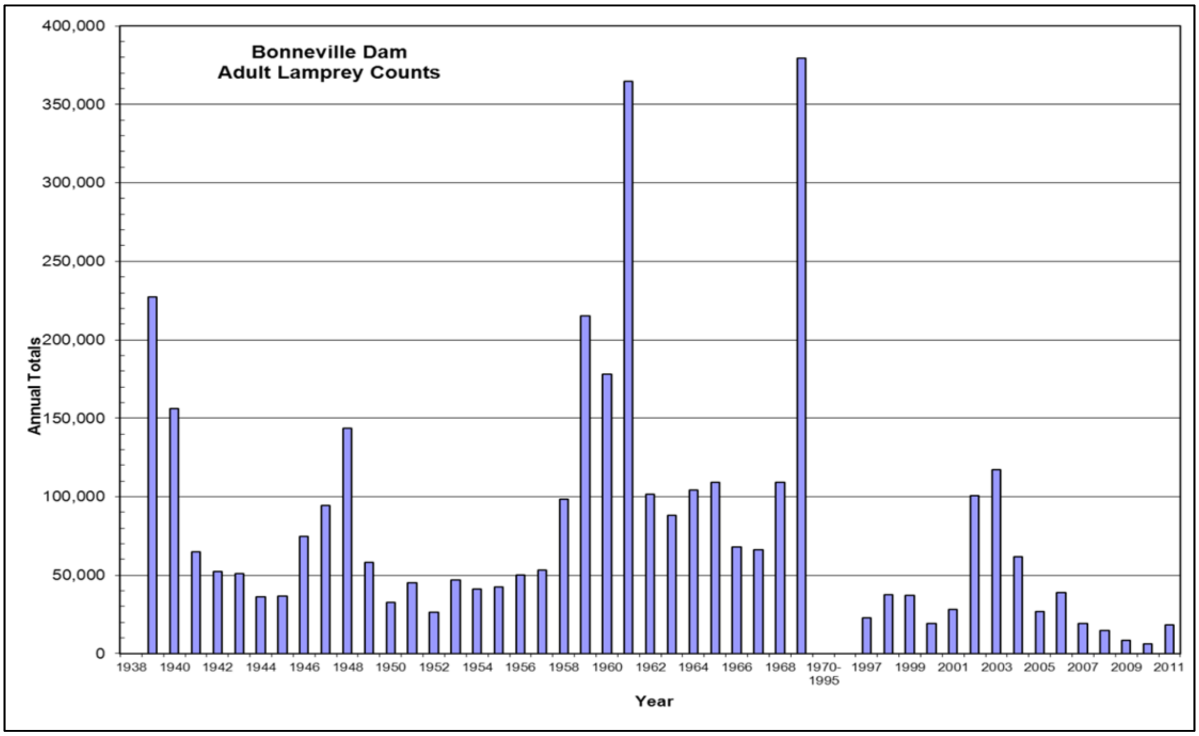

Figure 2. Window counts of adult Pacific lamprey at Bonneville Dam, 1939-2011 (USACE 2012a).

Table 1. Adult Pacific lamprey daytime window counts at lower Columbia and lower Snake River dams, 2000-2011 (USACE 2012a).

Project	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Bonneville	19,002	27,947	100,476	117,029	61,780	26,664	38,941	19,313	14,562	8,622	6,234	18,315
The Dalles	8,050	9,061	23,417	28,995	14,873	8,361	6,894	6,075	4,599	2,318	1,726	5,003
John Day	5,862	4,005	26,821	20,922	11,663	8,312	9,600	5,740	6,625	2,044	1,662	3,566
McNary	1,281	2,539	11,282	13,325	5,888	4,158	2,456	3,454	1,530	676	825	868
Ice Harbor	315	203	1,127	1,702	801	461	277	290	264	57	114	269
Lower Monumental	94	60	284	476	195	222	175	138	145	58	44	99
Little Goose	71	104	365	660	241	211	125	72	104	34	29	80
Lower Granite	28	27	138	282	122	40	35	34	61	12	15	48

Mainstem Fishways

Fish ladders at the mainstem dams have been designed to attract and pass adult salmonids. Therefore, fish ladder flow conditions are driven by salmon passage criteria with depth over ladder weirs at 1.0 ± 0.1 feet during the fish passage season from March 1 through November 30 (USACE 2012b). Using periods of high American shad (*Alosa sapidissima*) passage at Bonneville Dam (≥5,000 shad per day) as the management key, the weir head criteria at The Dalles is raised to 1.3 ± 0.1 feet. The additional head makes more space available for the surface oriented shad to pass, thus reducing congestion at the orifices below, minimizing delays for salmonid passage. Because of the design of the ladder weirs, a consistent hydraulic head is maintained over the tops and through the bottom orifices of the weirs which produces a velocity of 8 feet per second (fps) (Clay 1995). The main ladder sections are typically pools with weirs having overflows, and bottom orifices. A one foot head drop between pools in a fishway has been used as a standard for Pacific salmon for 50 years (Clay 1995). Target velocities for the orifices and overflows are 8 fps for salmon passage. The typical ladder slope is 1:16. The window count slot station section is narrowed by picketed leads to a width of about 3 feet. A mechanical crowder can narrow the gap to about 18 inches if visibility becomes difficult. The sections above the count windows may be vertical slot, removable, or tilting weirs for flow control into that section due to fluctuation of the forebay elevation.

All fishways have a diffuser system that supplies auxiliary water to specific areas of the structure in order to maintain hydraulic criteria for salmon passage. Typical diffuser gratings in the USACE mainstem dams have a 1.0 inch gap designed to keep adult salmon out of the auxiliary water supply system (AWS). Adult lamprey can readily pass through this gap and become lost and trapped in segments of the AWS system, especially when the ladders are dewatered. When old grates or picketed leads need to be replaced or problem areas are identified, the USACE has begun installing replacements with a 0.75 inch gap to reduce passage delay and mortality of adult lamprey.

Each project powerhouse has a collection channel that provides an adult passageway for fish to enter at the end furthest away from the fish ladder and more easily transit across the face of the powerhouse to the ladder entrance without encountering turbine intakes. Water flows from the ladder into the collection channel with auxiliary water added to maintain the flow criteria from diffusers located within the channel. A water velocity of 1.5-4.0 fps is maintained in the collection channel, with 2 fps considered the optimum velocity.

The Dalles Dam

Background

The Dalles Dam was authorized for power and navigation purposes in 1950. Other uses include fisheries, recreation, irrigation and water quality. The dam is located on the Columbia River at about RM 192 by the city of The Dalles, Oregon. The project type is “run-of-river” with minimal storage capacity. The project was completed with the first 14 turbine units in 1960. Turbine units 15-22 were completed in 1973. Hydraulic capacity is 375,000 cfs. Nameplate generation capacity is 1780 megawatts (MW).

The maximum forebay elevation behind The Dalles Dam (Lake Celilo) is 182.3 feet above mean sea level (msl), though the normal operational full pool is 160 feet msl and the normal minimum pool elevation is 155 feet msl (USACE 1989). Depending upon the time of year and river conditions, the tailwater elevation may range from 72 feet msl to over 89 feet msl. This results in a typical vertical ladder elevation change of about 77 feet that adult lamprey must negotiate during the fish passage season.

The Dalles Dam has four entrances that lead to a spillway entrance transportation channel and a powerhouse collection channel and two adult ladders, (Figure 3). More detailed information can be viewed in the figures A1 through A4 in Appendix A.

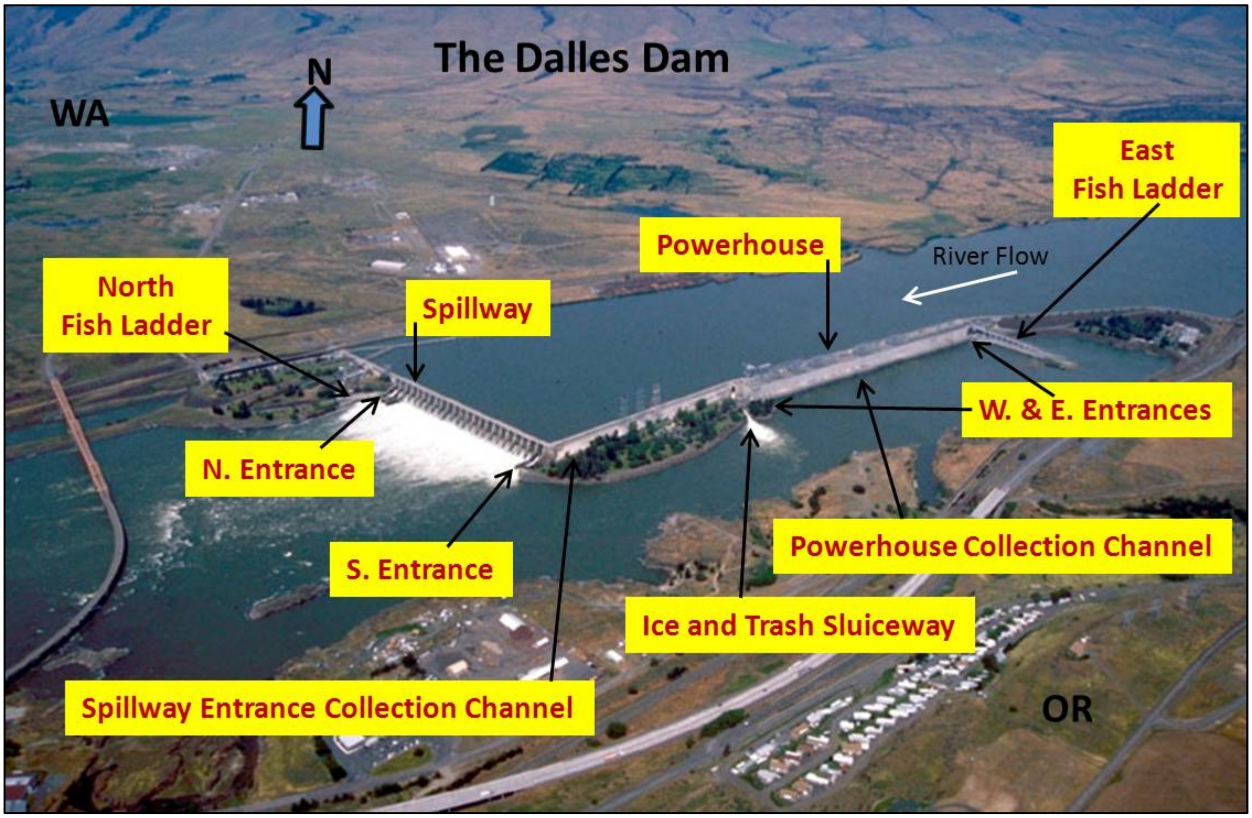

Figure 3. Overview of The Dalles Dam and fishways. Image by USACE.

The North Fish Ladder has an entrance only at the north end of the spillway. Fish that pass via this route exit the ladder near the navigation lock on the Washington shore. There is an adult fishway entrance at the south end of the spillway, but this entrance leads to the spillway entrance (or adult) transportation channel which transits the length of the island and powerhouse and merges with the junction pool at the base of the East Fish Ladder. Two other fishways merge at this junction pool. One is the powerhouse collection channel with the entrance at the west end of the powerhouse. Fish entering here also transit the length of the powerhouse to the East Fish Ladder, but this is a separate channel from the spillway collection channel. The third fishway is the East Entrance. Fish entering here pass into the East Fish Ladder junction pool. From the junction pool fish ascend and exit the East Fish Ladder well upstream of the west end of the powerhouse.

To document the physical environment adult lamprey encounter in attempting to pass over The Dalles Dam, a matrix has been made (Table 2) to list the physical and hydraulic information for all of the fishway structures. The information was gathered from readily available documentation and passage studies and reports. Some of the physical and hydraulic information to fully describe the structures is missing from the table and needs to be obtained.

Table 2. Known and unknown (?) physical and hydraulic information for The Dalles Dam fishway structures (n/a = not applicable).

Fishway	Section[a]	Dimensions[b]	Type of Weirs[c]	No. of Weirs in Section	Elev (ft msl)	Velocities: overflows, slots and orifices	Velocities: section or between weirs
Powerhouse Collection Channel							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	channel	?	n/a	n/a	tailwater	n/a	1.5-4 ft/s
Adult Transportation Channel							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	channel	?	n/a	n/a	tailwater	n/a	1.5-4 ft/s
East Fishway Ladder							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	junction pool	?	n/a	n/a	tailwater	n/a	?
3-	ladder section 1	?	OF+O	34	71-104	8-9 ft/s	?
4-	turning pool 1	?	n/a	n/a	104-105	n/a	?
5-	ladder section 2	?	OF+O	48	105-152	8-9 ft/s	?
6-	turning pool 2	?	n/a	n/a	152-153	n/a	?
7-	count window	?	OF+O	1	153-154	?	?
8-	flow control	?	RW+O	4	154-157	8-9 ft/s	?
9-	exit	?	TW+O	2	forebay	n/a	?
North Fishway Ladder							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	lower junction pool	?	n/a	n/a	tailwater	n/a	?
3-	ladder section 1	?	OF+O	80	71-151	8-9 ft/s	?
9-	count window	?	n/a	n/a	151-152	?	?
10-	flow control	?	VS+O	7	152-157	8-9 ft/s	?
11-	exit	?	n/a	2	158-159	8-9 ft/s	?

[a] includes entrance sections and junction pools, if present.

[b] i.e. section length, width, depth; weir dimensions and placement; orifice and slot placement and dimensions.

[c] OF = overflow weir; VS = vertical slot weir; RW = removable weir; TW = telescoping weir; O = orifice.

Historic Lamprey Passage

Total, direct window counts of lamprey passage for all ladders at The Dalles Dam from 1957 through 2011 (Table 3) ranged from 352,444 in 1961 to 1,726 in 2008. Daytime window counts were the only method of enumerating adult lamprey passing The Dalles Dam through 2011. Nighttime video counts were begun in 2012.

Table 3. Counts of adult Pacific lamprey at The Dalles Dam, 1957-2011 (USACE 2012a).

Year	Window[1]	Video	LPS	Total
1957	63,099	n/a	n/a	63,099
1958	144,253	n/a	n/a	144,253
1959	296,713	n/a	n/a	296,713
1960	259,208	n/a	n/a	259,208
1961	352,444	n/a	n/a	352,444
1962	83,550	n/a	n/a	83,550
1963	79,530	n/a	n/a	79,530
1964	64,252	n/a	n/a	64,252
1965	45,180	n/a	n/a	45,180
1966	43,383	n/a	n/a	43,383
1967	28,309	n/a	n/a	28,309
1968	57,629	n/a	n/a	57,629
1969	167,250	n/a	n/a	167,250
1970-1998	No Data	n/a	n/a	n/a
1999	10,410	n/a	n/a	10,410
2000	8,050	n/a	n/a	8,050
2001	9,061	n/a	n/a	9,061
2002	23,417	n/a	n/a	23,417
2003	28,995	n/a	n/a	28,995
2004	14,873	n/a	n/a	14,873
2005	8,361	n/a	n/a	8,361
2006	6,894	n/a	n/a	6,894
2007	6,075	n/a	n/a	6,083
2008	4,599	n/a	n/a	4,599
2009	2,318	n/a	n/a	2,318
2010	1,726	n/a	n/a	1,726
2011	5,003	n/a	n/a	5,003

[1] Typically April 1 through October 31, 4 AM to 8 PM (PST).

Cumulative run passage timing based on daytime window counts from 1999 through 2011 (Table 4) indicates that the mean peak passage date is July 26, with the first and last adult lamprey being recorded, on average, on May 28 and October 18, respectively.

Table 4. Adult Pacific lamprey migration timing at The Dalles Dam for 1999-2011(USACE 2012c).

	Day of Percent Cumulative Run Passage								No. of Mid
Year	First	1%	5%	10%	50%	90%	95%	Last	80% Days
1999	5/27	6/15	6/27	7/8	8/31	9/11	9/20	10/20	66
2000	5/25	6/6	6/20	6/25	7/25	9/4	9/17	10/23	72
2001	5/22	6/4	6/21	6/28	7/25	9/1	9/13	10/19	66
2002	6/2	6/20	6/29	7/4	7/29	9/3	9/13	10/20	62
2003	5/30	6/12	6/27	7/3	7/23	8/27	9/10	10/30	56
2004	5/23	6/8	6/22	6/26	7/15	8/26	9/12	10/26	62
2005	5/11	6/11	6/19	6/26	7/12	8/12	8/26	10/26	48
2006	6/1	6/14	6/25	6/30	7/23	8/29	9/9	10/17	61
2007	4/25	6/10	6/29	7/8	7/17	8/15	8/26	10/7	39
2008	6/18	6/26	7/1	7/4	7/26	8/24	8/31	10/16	52
2009	6/5	6/12	6/18	6/23	7/19	8/20	9/2	10/10	59
2010	6/12	6/21	6/30	7/4	7/25	8/31	9/9	10/10	59
2011	6/17	7/3	7/13	7/18	8/8	9/3	9/12	10/19	48
	-------	-------	-------	-------	-------	-------	-------	-------	-------
Min	4/25	6/4	6/18	6/23	7/12	8/12	8/26	10/7	51
Max	6/18	7/3	7/13	7/18	8/31	9/11	9/20	10/30	56
Mean	5/28	6/14	6/26	7/2	7/26	8/27	9/8	10/18	58

John Day Dam

Background

John Dam was authorized for flood control, power and navigation purposes in 1950. Other uses include fisheries, recreation, irrigation and water quality. The dam is located on the Columbia River at about RM 216 near the city of Rufus, Oregon. The project type is “storage” with 534,000 acre feet of useable storage capacity. The project was completed with 16 turbine units in 1971. Four skeleton bays exist, but turbine units have not been installed. Hydraulic capacity is 322,000 cfs. Nameplate generation capacity is 2160 MW.

The maximum forebay elevation behind John Day Dam (Lake Umatilla) is 276.5 feet above mean sea level (msl), though the normal operational full pool is 268 feet msl and the normal minimum pool elevation is 257 feet msl (USACE 1989). Depending upon the time of year and river conditions, the tailwater elevation may range from 158 feet msl to over 169 feet msl. In a typical year during the fish passage season the vertical ladder elevation change is about 101-102 feet (range 96-105) that adult lamprey must negotiate.

John Day Dam has three entrances that lead to a powerhouse collection channel and two adult ladders, (Figure 4). More detailed information can be found in Appendix B; Table B-1, Figures B-1 and B-2.

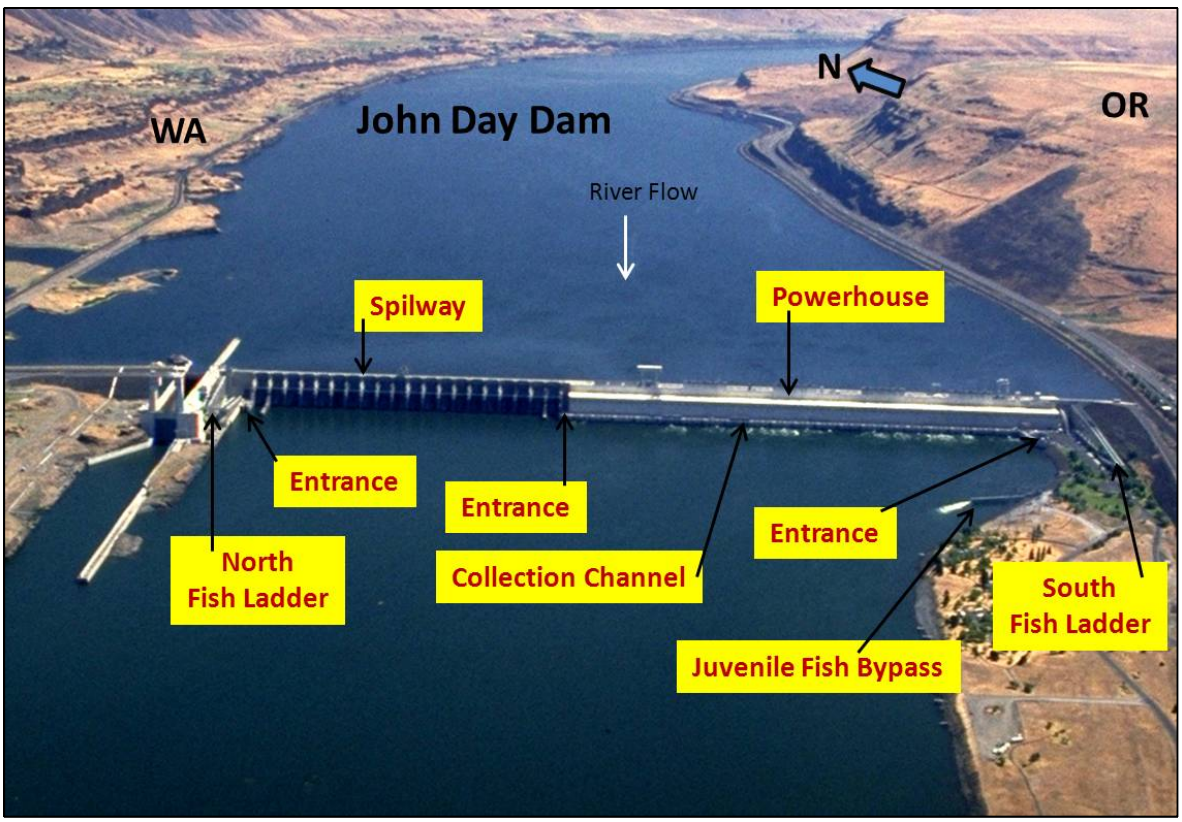

Figure 4. Overview of John Day Dam and fishways. Image by USACE.

The North Fish Ladder has an entrance only at the north end of the spillway. Fish that pass via this route exit the ladder near the navigation lock on the Washington shore. There is an adult fishway entrance at the south end of the spillway, but this entrance leads to the powerhouse (or adult) transportation channel which transits the length of the powerhouse and merges with the South Fish Ladder entrance at the base of the South Fish Ladder. Fish entering here pass into the South Fish Ladder, ascend and exit the ladder near the south end of the powerhouse.

To document the physical environment adult lamprey encounter in attempting to pass over John Day Dam, a matrix has been made (Table 5) to list the physical and hydraulic information for all of the fishway structures. The information was gathered from readily available documentation and passage studies and reports. Some of the physical and hydraulic information to fully describe the structures is missing from the table and needs to be obtained.

Table 5. Known and unknown (?) physical and hydraulic information for John Day Dam fishway structures (n/a = not applicable).

Fishway	Section[a]	Dimensions[b]	Type of Weirs[c]	No. of Weirs in Section	Elev (ft msl)	Velocities: overflows, slots and orifices	Velocities: section or between weirs
Powerhouse Collection Channel							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	channel	?	n/a	n/a	tailwater	n/a	1.5-4 ft/s
South Fish Ladder							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	junction pool	?	n/a	n/a	tailwater	n/a	?
3-	ladder section 1	?	OF+O	39	155-193	8-9 ft/s	?
4-	count window	?	n/a	n/a	193-194	?	?
5-	ladder section 2	?	OF+O	13	194-206	8-9 ft/s	?
6-	turning pool 1	?	n/a	n/a	206-207	n/a	?
7-	ladder section 3	?	n/a	42	207-248	8-9 ft/s	?
8-	flow control	?	VS+O	19	249-267	8-9 ft/s	?
9-	exit	?	n/a	n/a	forebay	n/a	?
North Fish Ladder							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	ladder section 1	?	OF+O	20	155-174	8-9 ft/s	?
3-	turning pool 1	?	n/a	n/a	174-175	n/a	?
4-	ladder section 2	?	OF+O	30	175-204	8-9 ft/s	?
5-	turning pool 2	?	n/a	n/a	204-205	n/a	?
6-	ladder section 3	?	OF+O	30	205-234	8-9 ft/s	?
7-	turning pool 3	?	n/a	n/a	234-235	n/a	?
8-	ladder section 4	?	OF+O	5	235-239	8-9 ft/s	?
9-	turning pool 4	?	n/a	n/a	239-240	n/a	?
10-	ladder section 5	?	OF+O	9	240-248	8-9 ft/s	?
11-	count window	?	n/a	n/a	248-249	?	?
12-	flow control	?	VS+O	19	249-267	8-9 ft/s	?
13-	exit	?	n/a	n/a	forebay	n/a	?

[a] includes entrance sections and junction pools, if present.

[b] i.e. section length, width, depth; weir dimensions and placement; orifice and slot placement and dimensions.

[c] OF = overflow weir; VS = vertical slot weir; O = orifice.

Historic Lamprey Passage

Total, direct window counts of lamprey passage for all ladders at John Day Dam from 1968 through 2011 (Table 6) ranged from 52,314 in 1969 to 1,662 in 2010. Daytime window counts were the only method of enumerating adult lamprey passing John Day Dam through 2011. Nighttime video counts were begun in 2012.

Table 6. Counts of adult Pacific lamprey at John Day Dam, 1968-2011 (USACE 2012a).

Year	Window[1]	Video	LPS	Total	Year	Window[1]	Video	LPS	Total
1968	21,669	n/a	n/a	21,669	2004	11,663	n/a	n/a	11,663
1969	52,314	n/a	n/a	52,314	2005	8,312	n/a	n/a	8,312
1970-1998	No Data	n/a	n/a	n/a	2006	9,600	n/a	n/a	9,600
1999	9,872	n/a	n/a	9,872	2007	5,740	n/a	n/a	5,740
2000	5,862	n/a	n/a	5,862	2008	6,625	n/a	n/a	6,625
2001	4,005	n/a	n/a	4,005	2009	2,044	n/a	n/a	2,044
2002	26,821	n/a	n/a	26,821	2010	1,662	n/a	n/a	1,662
2003	20,922	n/a	n/a	20,922	2011	3,566	n/a	n/a	3,566

[1] Typically April 1 through October 31, 4 AM to 9 PM (PST).

Cumulative run passage timing based on daytime window counts from 1999 through 2011 (Table 7) indicates that the mean peak passage date is July 16, with the first and last adult lamprey being recorded, on average, on May 2 and October 30, respectively.

Table 7. Adult Pacific lamprey migration timing at John Day Dam for 1999-2011 (DART 2012).

	Day of Percent Cumulative Run Passage								No. of Mid 80% Days
Year	First	1%	5%	10%	50%	90%	95%	Last	
1999	5/16	5/30	7/16	7/26	8/20	9/24	10/1	10/31	61
2000	5/8	5/27	6/30	7/5	8/7	9/4	9/17	10/25	62
2001	4/30	5/21	6/13	6/24	7/24	9/5	9/21	10/29	74
2002	5/5	6/16	7/6	7/13	8/9	9/12	9/20	10/30	62
2003	4/24	5/23	6/17	7/2	7/27	8/30	9/12	10/30	60
2004	4/5	5/11	6/23	6/29	7/23	9/6	9/21	10/30	70
2005	4/20	5/19	6/23	7/1	7/24	8/31	9/12	10/31	62
2006	5/12	6/23	7/2	7/5	7/24	8/31	9/14	10/29	58
2007	4/2	5/20	7/6	7/10	7/25	8/26	9/10	11/30	48
2008	5/14	6/15	7/7	7/13	8/6	9/7	9/15	10/25	57
2009	5/15	5/22	6/22	6/30	7/23	8/15	8/23	10/20	47
2010	5/10	5/23	7/5	7/10	8/2	8/23	9/5	10/31	45
2011	5/22	7/11	7/19	7/25	8/9	9/6	9/15	10/21	44
	-------	-------	-------	-------	-------	-------	-------	-------	-------
Min	4/2	5/11	6/13	6/24	7/23	8/15	8/23	10/20	53
Max	5/22	7/11	7/19	7/26	8/20	9/24	10/1	11/30	61
Mean	5/2	5/21	6/17	6/24	7/16	8/16	8/26	10/30	54

McNary Dam

Background

McNary Dam was authorized for power and navigation purposes in 1945. Other uses include fisheries, recreation, irrigation and water quality. The dam is located on the Columbia River at about RM 216 by the city of Umatilla, Oregon. The project type is “run-of-river” with minimal storage capacity. The project was completed with 14 turbine units in 1957. Hydraulic capacity is 232,000 cfs. Nameplate generation capacity is 980 MW.

The maximum forebay elevation behind McNary Dam (Lake Wallula) is 357 feet above mean sea level (msl), though the normal operational full pool is 340 feet msl and the normal minimum pool elevation is 335 feet msl (USACE 1989). Depending upon the time of year and river conditions, the tailwater elevation may range from 263 feet msl to 273 feet msl. In a typical year during the passage season the vertical ladder elevation change is about 73 feet (range 68-76) that adult lamprey must negotiate.

McNary Dam has three entrances that lead to a powerhouse collection channel and two adult ladders, (Figure 5). More detailed information can be found in Appendix C; Table C-1 and Figure C-1.

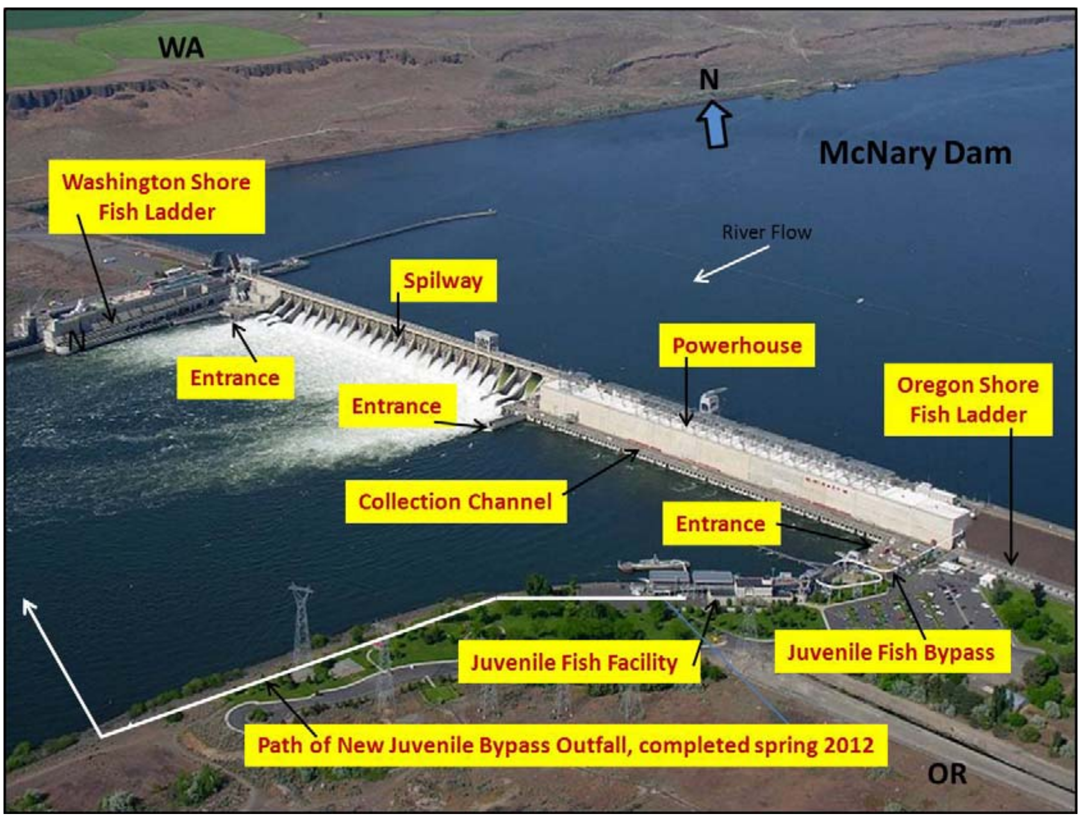

Figure 5. Overview of McNary Dam and fishways. Image by USACE.

The Washington Shore Fish Ladder has an entrance only at the north end of the spillway. Fish that pass via this route exit the ladder on the north side of the base of the navigation lock on the Washington shore. There is an adult fishway entrance at the south end of the spillway, but this entrance leads to the powerhouse (or adult) transportation channel which transits the length of the powerhouse and merges with the South Fishway entrance at the base of the Oregon Shore Fish Ladder. Fish entering here pass into the ladder, ascend and exit the ladder well east of the south end of the powerhouse.

To document the physical environment adult lamprey encounter in attempting to pass over McNary Dam, a matrix has been made (Table 8) to list the physical and hydraulic information for all of the fishway structures. The information was gathered from readily available documentation and passage studies and reports. Some of the physical and hydraulic information to fully describe the structures is missing from the table and needs to be obtained.

Table 8. Known and unknown (?) physical and hydraulic information for McNary Dam fishway structures (n/a = not applicable).

Fishway	Section[a]	Dimensions[b]	Type of Weirs[c]	No. of Weirs in Section	Elev (ft msl)	Velocities: overflows, slots and orifices	Velocities: section or between weirs
Powerhouse Collection Channel							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	channel	?	n/a	n/a	tailwater	n/a	1.5-4 ft/s
Oregon Shore Fish Ladder							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	junction pool	?	n/a	n/a	tailwater	n/a	?
3-	ladder section 1	?	OF+O	58	248-305	8-9 ft/s	?
4-	fish viewing room	?	n/a	n/a	305-306	?	?
5-	ladder section 2	?	OF+O	28	306-333	8-9 ft/s	?
7-	count window	?	OF+O	n/a	333-334	?	?
8-	flow control	?	TL+O	7	334-340	8-9 ft/s	?
9-	exit	?	AW	1	forebay	n/a	?
Washington Shore Fish Ladder							
1-	entrance	?	n/a	n/a	tailwater	n/a	8-9 ft/s
2-	ladder sections 1	?	OF+O	?	248-???	8-9 ft/s	?
3-	turning pool	?	n/a	n/a	?	n/a	?
4-	ladder sections 2	?	OF+O	?	???-336	8-9 ft/s	?
5-	count window	?	n/a	n/a	336-337	?	?
6-	flow control	?	TL+O	7	337-343	8-9 ft/s	?
7-	exit	?	AW	1	forebay	n/a	?

[a] includes entrance sections and junction pools, if present.
[b] i.e. section length, width, depth; weir dimensions and placement; orifice and slot placement and dimensions.
[c] OF = overflow weir; VS = vertical slot weir, TL = tilting weir; AW = adjustable weir; O = orifice.

Historic Lamprey Passage

Total, direct window counts of lamprey passage for all ladders at McNary Dam from 1954 through 2011 (Table 9) ranged from a peak of 26,119 in 1961 to 676 in 2009. Until 2009, daytime window counts were the only method of enumerating adult lamprey passage at McNary Dam.

Table 9. Counts of adult Pacific lamprey at McNary Dam, 1954-2011 (USACE 2012a)*.

Year	Window[1]	Video[2]	LPS	Total
1954	938	n/a	n/a	938
1955	556	n/a	n/a	556
1956	970	n/a	n/a	970
1957	2,748	n/a	n/a	2,748
1958	10,565	n/a	n/a	10,565
1959	19,807	n/a	n/a	19,807
1960	13,960	n/a	n/a	13,960
1961	26,119	n/a	n/a	26,119
1962	14,027	n/a	n/a	14,027
1963	9,965	n/a	n/a	9,965
1964	6,173	n/a	n/a	6,173
1965	7,362	n/a	n/a	7,362
1966	5,410	n/a	n/a	5,410
1967	1,516	n/a	n/a	1,516
1968	1,568	n/a	n/a	1,568
1969	3,069	n/a	n/a	3,069
1970-1995	No Data	n/a	n/a	n/a

Year	Window[1]	Video[2]	LPS	Total
1996	3,628	n/a	n/a	3,628
1997	4,213	n/a	n/a	4,213
1998	3,393	n/a	n/a	3,393
1999	1,050	n/a	n/a	1,050
2000	1,281	n/a	n/a	1,281
2001	2,539	n/a	n/a	2,539
2002	11,282	n/a	n/a	11,282
2003	13,325	n/a	n/a	13,325
2004	5,888	n/a	n/a	5,888
2005	4,158	n/a	n/a	4,158
2006	2,456	n/a	n/a	2,456
2007	3,454	n/a	n/a	3,454
2008	1,530	n/a	n/a	1,530
2009	676	666	n/a	1,342
2010	833	345	n/a	1,178
2011	866	522	n/a	1,388

*2009-2011 data from USACE 2010 and 2012c.

[1] Typically April 1 through October 31, 4 AM to 8 PM (PST).

[2] July 1 to September 30, 8 PM to 4 AM (PST).

Cumulative run passage timing based on daytime window counts from 1999 through 2011 (Table 10) indicates that the mean peak passage date is July 25, with the first and last adult lamprey being recorded, on average, on May 24 and October 23, respectively.

Table 10. Adult Pacific lamprey migration timing at McNary Dam for 1999-2011 (DART 2012).

	Day of Percent Cumulative Run Passage								No. of Mid
Year	First	1%	5%	10%	50%	90%	95%	Last	80% Days
1999	5/29	7/16	7/24	7/30	8/20	9/26	10/1	10/13	59
2000	5/27	6/24	7/8	7/18	8/11	9/21	9/29	10/20	66
2001	5/25	6/16	6/27	7/3	7/28	9/11	9/23	10/22	71
2002	6/16	7/8	7/21	7/25	8/17	9/17	9/25	10/26	55
2003	5/31	6/30	7/11	7/17	8/6	9/10	9/21	10/30	56
2004	5/20	6/6	6/30	7/8	7/29	9/9	9/20	10/22	64
2005	5/26	6/16	6/29	7/5	8/4	9/7	9/16	10/22	65
2006	6/1	6/29	7/10	7/14	8/20	9/18	9/27	10/22	67
2007	4/13	6/25	7/11	7/18	8/6	9/5	9/14	10/28	50
2008	5/6	6/29	7/16	7/22	8/14	9/7	9/19	10/16	48
2009	5/14	6/15	7/6	7/14	8/6	9/4	9/14	10/22	53
2010	5/10	7/11	7/17	7/22	8/8	9/2	9/16	10/31	43
2011	7/10	7/19	7/30	8/3	8/23	9/12	9/19	10/25	41
	-------	-------	-------	-------	-------	-------	-------	-------	-------
Min	4/13	6/6	6/27	7/3	7/28	9/2	9/14	10/13	62
Max	7/10	7/19	7/30	8/3	8/23	9/26	10/1	10/31	55
Mean	5/24	6/15	6/27	7/3	7/25	8/24	9/2	10/23	53

Previous Lamprey Passage Research

Adult and sub-adult lamprey passage research in the laboratory and at mainstem dams in the Columbia and Snake Rivers has been ongoing for many years. A brief synopsis of studies from 1994 through 2011 is found in Appendix D. Following is a summary of important findings relative to adult Pacific lamprey passage at mainstem dams in the lower Columbia River overall, and specifically at The Dalles, John Day and McNary dams.

Radio-tagged lamprey were released downstream from Bonneville Dam from 1997 through 2000 (Moser et al. 2002b) to investigate lamprey passage efficiency through/over the lower Columbia River dams. Passage efficiency is defined as the number of fish that passed through each fishway and over the dam relative to the number that approached (includes the fish that did not enter the ladder, entered and fell back out, and successfully passed over the dam). The passage efficiency of lampreys at The Dalles Dam ranged from 50–82%, and passage times ranged from 2.0 to 4.0 d. In contrast, Bonneville Dam passage efficiency was 38–47%, and the median time required to pass over the dam ranged from 4.4 to 5.7 d. Passage efficiency was the lowest at John Day Dam, about 28% (up to about-55%), but was based on very few fish. From 1997 through 1999 few lampreys were detected at John Day Dam and none were detected at McNary Dam. However, in 2000 13 fish were detected at McNary Dam from 23 fish that passed over John Day Dam. Of these fish, 11 (85%) successfully passed over McNary Dam. Indications (Moser et al. 2002b) were that lamprey had the greatest difficulty entering fishways, particularly at spillway entrances where turbulence was greatest. After entering the fishways, though, lampreys had the greatest difficulty passing through the collection channels and transition areas that lacked attachment sites. Once in the ladder proper a high passage success was documented despite maximum current velocities that could exceed 2.4 m/s “(7.9 fps). Lamprey were delayed and fell back most frequently upstream from the count station in the serpentine weir sections.

Lamprey were most active at the fishway entrances during the night, and individual fish often made multiple entrances (Moser 2002a) and lamprey rarely fell back downstream after successfully passing over a dam.

Passage efficiencies through the two fishways at The Dalles Dam were similar to each other, though more lamprey approached the Oregon shore (East) fishway (64%) than the fishway on the Washington shore (36%) (Moser et al. 2002a).

At John Day Dam more fish approached entrances to the powerhouse fishway system on the Oregon shore than approached entrances to the fishway on the Washington shore (71% vs. 29%, respectively). The entrance efficiencies, though, were similar for the two fishways (73% South and 72% North) (Moser et al. 2002a).

Passage efficiencies through the longer and more complex collection channel and transition areas at the John Day South fishway were lower (81 and 77%) than through the same areas of the North fishway (100 and 94%). Once past the transition area, all lamprey that entered the ladder area at the South fishway successfully passed upstream. However, 41% of the lamprey that entered the ladder area at the North fishway fell back downstream before reaching the count station (Moser et al. 2002a).

In 2002 a total of 201 adult lamprey were trapped at Bonneville Dam and radio-tagged, then released downstream below the dam. Passage was monitored at Bonneville, The Dalles and John Day dams. The overall passage efficiency was 66% at The Dalles Dam and 50% at John Day Dam (Moser et al. 2005). In comparison, the passage efficiency at Bonneville Dam was 48%.

Radio-tagging studies in 2009 with 596 tagged lamprey and in 2010 with 312 tagged lamprey (Claybough et al. 2010 and 2011) calculated lamprey passage efficiencies over the four lower Columbia River dams (Table 11). Although 34 of the lamprey that passed over Bonneville Dam were detected inside the fishways of John Day Dam in 2010, with 32 passing over, passage efficiencies could not be calculated because entrances were not monitored for the total number of lamprey approaching that year.

Table 11. Adult lamprey passage efficiencies over lower Columbia River dams in 2009 and 2010.

Year	BON	TDA	JDA	MCN
2009	39-42%	67%	50%	80%
2010	46-47%	75%	n/a*	60%

*Entrances were not monitored in 2010.

The conclusions from both years indicated that transition pools and serpentine weir sections continued to present passage problems for adult lampreys, along with some entrance areas. The mechanisms for passage failure remained poorly understood, but likely were related to a combination of operational and structural challenges that includes high water velocities and turbulence, sharp-edged steps and corners, poor attachment surfaces, and confusing attraction cues.

Keefer et al. (2012) continued passage escapement studies in 2011 with half-duplex (HD) PIT tagged adult lamprey released below Bonneville Dam. The HD-PIT study results are available from 2005. The fish were monitored through the four lower Columbia River dams through a variety of HD-PIT arrays that included arrays at the tops of all the fish ladders. Escapement estimates from release to each dam and from the top of each dam to the top of the next upstream dam are presented in Table 12 and Table 13, respectively.

Table 12. Total escapement of half-duplex PIT tagged adult lamprey from the release point below Bonneville Dam to the top of each dam in the lower Columbia River from 2005 to 2011. From Keefer et al. 2012.

Reach	2005 (n=841)	2006 (n=2000)	2007 (n=757)	2008 (n=607)	2009 (n=308)	2010 (n=13)	2011 (n=800)
Release - top of BON	53%	41%	52%	52%	47%	58%	58%
Release - top of TDA	---	28%	33%	27%	25%	23%	30%
Release - top of JDA	---	19%	17%	18%	14%	15%	24%
Release - top of MCN	5%	4%	5%	5%	2%	---	8%

Table 13. Total escapement of half-duplex PIT tagged adult lamprey between dams in the lower Columbia River from 2005 to 2011. From Keefer et al. 2012.

Reach	2005 (n=841)	2006 (n=2000)	2007 (n=757)	2008 (n=607)	2009 (n=308)	2010 (n=13)	2011 (n=800)
Release - top of BON	53%	41%	52%	52%	47%	58%	58%
top of BON - top of TDA	n/a	67%	63%	52%	52%	38%	52%
top of TDA - top of JDA	n/a	69%	52%	66%	56%	67%	80%
top of JDA - top of MCN	n/a	21%	27%	26%	16%	---	34%

Lamprey escapement for the downstream release group past Bonneville Dam (58%) was higher in 2011 than estimates in HD-PIT samples from 2005-2009 (41-52%) and similar to the 2010 estimate of 58%, though there were only 13 tagged fish released in 2010. Also in 2011, a higher percentage passed John Day Dam (24%) and McNary Dam (8%) from the initial release point than in previous studies, 14-19% past John Day Dam and 2-5% past McNary Dam. Dam-to-dam estimates in 2011 were also higher than in previous years for the The Dalles Dam to John Day Dam (80%) and John Day Dam to McNary Dam (34%) reaches. These estimates were high even with the high-flow conditions experienced in 2011.

The median passage time in 2011 for the fish released below Bonneville Dam (about 3 km downstream) was 10.2 days (< 1 km per day) to the top of Bonneville Dam. The median times between the tops of the successive dams were 4.3 days (17 km per day) between Bonneville and The Dalles dams, 3.4 days (11 km per day) between The Dalles and John Day dams, and 9.1 days (14 km per day) between John Day and McNary dams.

The increase in upstream escapement in 2011, compared to previous years, was speculated (Keefer et al. 2012) to likely be the result of environmental factors (very high river discharge initially attracting more lamprey over Bonneville Dam Bradford Island ladder, cooler water temperatures extending the migration further into summer), operational changes at the dams (reduced nighttime velocities at Bonneville fishway entrances and structural) and the accumulation of structural changes (orifice rounding, diffuser plating, weir modifications, adding ramps to raised orifices, raising picket leads, blocking access to routes without exits, etc.).

The typical picket leads and diffuser grating gaps in the USACE projects have been 1.0 inch (2.5 cm). Adult lamprey can pass through this gap and become lost and trapped in segments of the AWS system, especially when the ladders are dewatered. Moser et al. (2007) evaluated the ability of adult lamprey to pass through vertical gaps representing the gaps in picket leads and diffuser gratings. The objective of the study was to determine the gap sizes that will exclude migrating adult Pacific lamprey in the Columbia River Basin. Gap widths of 2.5, 2.2, 1.9, 1.6, or 1.3 cm were evaluated. No lamprey passed through the gap sizes of 1.9 cm or less, whereas all lamprey were able to volitionally pass through the 2.5-cm gap and 47% passed through the 2.2-cm gap. Using this information, the USACE conducted a field test of the 1.9-cm grating at John Day Dam, confirming the study findings.

The USACE (2009) has established a 0.75 inch gap (1.9 cm) as the new criteria when old grates need to be replaced or problem areas are identified. Installation for specific diffusers will occur after hydraulic modeling confirms no problems with ladder performance and concerns about the diffuser becoming clogged with debris are addressed. Most water intake screens are at a one inch gap and would pass debris that would likely clog 0.75 inch diffuser grating, which can lead to high pressure blowing out the diffuser grating and allow fish to enter dead end areas where they would perish. Repairing blown out diffusers during the fish passage season would require the ladder to be dewatered for a significant amount of time, impacting an important passage route for anadromous salmonids.

Mesa et al. (2003) performed laboratory experiments on adult Pacific lamprey and derived the first quantitative measures of their swimming performance. They used tagged and untagged lamprey to determine their critical swim speed. Critical swimming speed (U_{crit}) is a standard measurement to assess swimming capabilities of fishes. U_{crit} data are commonly used to establish water velocity criteria for lack of a better alternative (Peake 2004). Lamprey U_{crit} was measured by starting with a low water velocity and then increasing water velocity every 30 minutes until the lamprey fatigued. Fatigue occurred when the lamprey became impinged on the downstream screen despite three successive attempts to dislodge it. U_{crit} was 86.2 cm/s (2.8 fps) for untagged lamprey and 81.5 cm/s (2.7 fps) for radio tagged lamprey.

Three swimming capability categories of concern for fish and the development of passage fish facility structures were defined by Bell (1991); cruising (a speed that can be maintained for long periods of time (hours), sustained (a speed that can be maintained for minutes), and darting (a single effort, not sustainable). The definition of sustained speed seems to most closely align with the U_{crit} measure from Mesa (2003). Although data for Pacific lamprey were not cited, Bell (1991) did reference sustained and darting (burst) speeds of adult Sea Lamprey (*Petromyzon marinus*) at about 3 fps and 7 fps, respectively. Video monitoring of new lamprey orifices cut into the bottom of the tilting-weir supports at the exit section of the McNary Dam Oregon shore fish ladder (USACE 2011) has provided visual documentation of adult lamprey successfully attaining a burst speed of at least 8 fps as the adult lamprey passed through the six inch distance of the orifice to reach a safe hold on the upstream side.

In an effort to determine if reduced fishway entrance velocities improved adult lamprey entrance efficiency, Johnson et al. (2012) used radio-tagged adult lamprey at Bonneville Dam to test the “control” standard velocity (for salmon entrance criteria) of >1.98 m/s (6.5 fps), versus a “reduced” velocity of about 1.2 m/s (3.94 fps), and a near zero or “standby” velocity used when cleaning the ladder water intake trash racks. Lamprey entrance efficiencies were significantly higher with the reduced velocity (26–29%) than with the control velocity (13–20%) or with the near zero standby velocity (5–9%). “However, overall passage efficiency at the dam was relatively unchanged, suggesting that additional passage bottlenecks for Pacific lampreys exist upstream from fishway entrances” (Johnson et al. 2012). As a component of current standard operation, during nighttime spill hours from June 1 through August 31, the Washington Shore fish ladder is operated to provide 0.5 feet of entrance head at all Powerhouse 2 entrances, rather than the daytime entrance head of 1 foot required for salmon passage.

Keefer et al. (2010) looked at some of the challenges adult Pacific lamprey have with passing certain structures found in fishways. Using an experimental fishway constructed at the Bonneville Dam adult fish facility and work done in the Bonneville ladders, they documented that steps and other 90° corners on bulkhead slots or orifice openings were problematic for lampreys. The fish were unable to release their hold, lunge forward and reestablish their grip before being swept downstream. In areas where bottom grates (diffuser) are installed, lamprey were not able to attach themselves and maintain their position in areas of high water velocity. Finally, wide slots in various entrances and along fishways (for bulkheads or stoplogs) created turbulent flow and probably impacted adults trying to swim past.

USACE Pacific Lamprey Passage Improvements Implementation Plan 2008-2018

The USACE finalized their Pacific Lamprey Passage Improvements Implementation Plan 2008 – 2018 (USACE 2009) with the goal "to improve both juvenile and adult lamprey passage and survival through the FCRPS as a part of a regional effort to immediately arrest the decline of Pacific lamprey populations within the Columbia Basin and to quickly and substantially contribute towards rebuilding these populations to sustainable, harvestable levels throughout their historic range." Commitments made by the USACE for adult lamprey included in this 10 year plan are to:

1) Address adult lamprey passage in the mainstem hydropower projects using PIT/radio-telemetry to determine overall effectiveness.
2) Develop numerical passage metrics through the Lamprey Technical Workgroup.
3) Conduct site inspections of each dewatered fish ladder.
4) Evaluate, fully develop and implement as warranted lamprey auxiliary passage systems (LPS).
5) Evaluate reducing entrance flows at night to assist lamprey entrance passage; and as warranted, expand through FCRPS mainstem dams.
6) Complete keyhole entrances at Cascade Island 2009 and John Day North 2010-2011, then implement, as warranted, throughout FCRPS mainstem dams.
7) Inventory all picketed leads, fish way cracks, blind openings and ladder exits. Begin replacing existing grating with new ¾-inch grating in most identified problem areas.
8) Round sharp corners, as warranted.
9) Develop feasibility, techniques, and protocols for counting.

The USACE prioritized their efforts to improve lamprey passage based on two criteria:

- where passage efficiency is the poorest
- where the affected numbers of Pacific lamprey are the highest

Bonneville Dam was the top priority FCRPS project to be addressed based on these criteria and the current state of knowledge at that time. Following in priority were John Day Dam, McNary dams, the Snake River dams, and The Dalles Dam. The USACE identified the following major tasks for passage improvements above Bonneville Dam, along with their target completion dates:

1) The Dalles Dam
   - No major activities were planned until other dams are addressed because of existing high passage rates (74%) compared to other dams.
2) John Day Dam
   - North Ladder exit section modification with lamprey improvements; winter 2009-2010 installation.
   - North Ladder entrance modifications - 2010 to 2012.
   - Design work ongoing.
3) McNary Dam
   - Oregon shore ladder entrance modifications - 2011 to 2013.
   - Design development beginning in 2009.
4) Snake River dams
   - Ladder entrance modifications - 2014 to 2017.

Annual Progress

Annual progress updates for 2009 through 2011 (USACE 2010, USACE 2011, and USACE 2012d) have tracked the implementation of these tasks, and the development and implementation of any new ideas endorsed for research or construction. The status of the original tasks from the 10 year plan follow below.

John Day Dam - North Ladder Exit Section:

Plans were finalized in 2009 for the exit section modifications including many lamprey improvements. Implementation occurred in the winter period 2009-2010. Pre, during and post construction views are shown in Figures 6-8. The completed extensive modifications to exit section and count station of JDA North Fish Ladder, with multiple improvements for lamprey, included:

- Removed right angle step at vertical slot and sill baffle in forebay transition section.
- Modified 2nd baffle (remove 2.5-foot sill and add rounded orifice) in forebay transition.
- Removed all 18 serpentine weirs + holey wall and replaced with 23 weirs with 15- to 18-inch rounded vertical slots and rounded 18- x 18-inch orifices.
- Provided a smooth contiguous floor surface through all orifices from count station to exit.
- Provided resting areas to wall sides of orifices.
- Raised Count Station floor one foot to match invert at new weir 1 to allow for smooth floor transition.
- Added 12-inch-wide metal plates over left side of floor diffuser grating in pool just upstream of count station.
- Removed 23-inch ramp through count slot and lower viewing window.
- Replaced antiquated crowder, adding new transition farings and horizontal vanes to reduce confusing uplifting flows just upstream of count station slot.

Figure 6. John Day North fish ladder exit section, before reconstruction. Image by USACE.

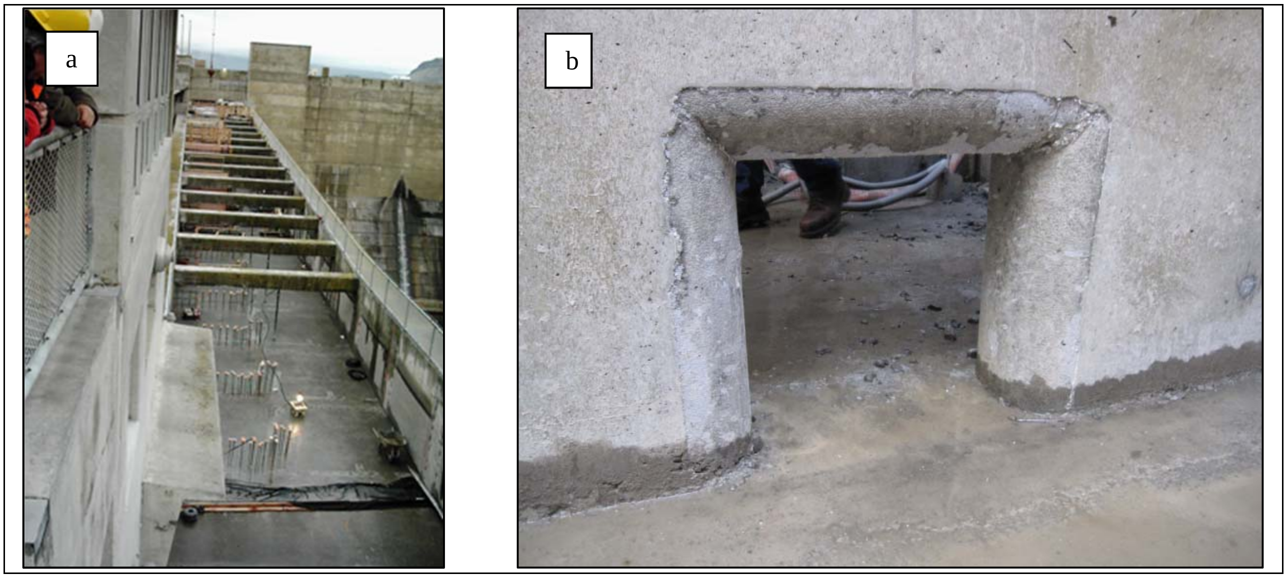

Figure 7. John Day North fish ladder during construction. a. Gutted exit section. b. Unfinished rounded edges on new bottom orifices. Images by USFWS.

Figure 8. John Day North fish ladder post construction, new flow control vertical slot weirs. Image by USFWS.

John Day Dam - North Ladder Entrance:
Continued John Day (JDA) north ladder entrance and auxiliary water system (AWS) modification designs in 2009 and 2010. Plans were finalized in 2011. Implementation planned for winter in-water work periods of 2011-12 and 2012-13. Changes that are expected to aid lamprey include:

- Install modified keyhole entrance and velocity reducing structures on the ladder floor (Figures 9 and 10).
- Install LPS inside entrance.
- Smooth and round corners wherever possible.
- Provide safe resting areas in relatively quiet areas.
- Replace existing diffuser gratings with ¾-inch lamprey criteria grating.
- Install lamprey diffuser plating at collection channel and lower ladder diffusers.

Figure 9. Keyhole fish ladder entrance weir at the John Day North Fish ladder, installed winter 2011-12. Image by USACE.

Figure 10. Bollard array installation at the floor of the entrance area of the John Day North Fish Ladder (March 2012). From USACE (2012d).

McNary Dam – South Ladder Entrance:
Initiated design development including hydraulic and physical modeling in 2009 and continued in 2010. In 2011 the McNary Dam (MCN) south ladder entrance physical model (located at the Engineer Research and Development Center (ERDC) in Vicksburg, MS) was used to select a prototype lamprey entrance structure design.

New Tasks Identified Following the Release of the USACE 10-Year Plan
Planning new project construction and research is a dynamic that is continually changing and evolving based on current research and monitoring results. These results are discussed and the next steps developed in the closed USACE/Tribal Accord process, and the USACE's regional Anadromous Fish Evaluation Program (AFEP) process open to all managers. New actions are added to the living "to do list" as they develop.

The USACE's 2011 progress report (USACE 2012d) for their 10 year plan summarized completed and planned actions into two tables, which included items original to the plan and those items subsequently appended to the list of actions. Their first summaries (Tables 13, 14, 15) listed planned and completed minor fishway modifications. A separate summary (Table 16) listed completed and planned major fishway implementation and operational actions to improve lamprey passage.

Table 14. USACE summarized list of planned and completed minor fishway modifications at The Dalles Dam to improve lamprey passage. Taken from USACE (2012d).

ITEM	Description	Date Completed
1	East Ladder -Modify (ramp or remove) 3 junction pool stub walls. Stub walls used to prevent debris accumulation under bulkhead slot; bulkheads have not been used for >15 years here.	
2	East Ladder -Modify (ramp or chamfer) orifices of lowest overflow weir in ladder (bottom of transition pool)	
3	East Ladder -Modify (ramp) orifices of overflow weir just upstream of 180-degree bend (Weir 105)	Jan 2012
4	East Ladder – Modify (ramp) orifices of overflow weir just downstream of count station (Weir 153)	Jan 2012
5	East Ladder -Modify (ramp or lamprey orifices) Weirs 154-157.	
6	East Ladder -Install brushes or inserts in entrance and exit weir guides (all) to deter lamprey impingement/crushing.	
5	East Ladder – Remove bubbler-beam; fill in bubbler-beam gap at base of count window to improve lamprey counts and increase attachment surface in count slot.	Jan 2011
6	North Ladder -Modify (ramp or chamfer) weir orifices in lower (rock) section (4" radius).	Jan 2010
7	North Ladder -Install inserts or brushes in entrance and exit weir guides to deter lamprey impingement/crushing.	
8	North Ladder -Install diffuser plating over grating in count station area.	
9	East Ladder -Replace "eel plate" seals on upstream side of exit weirs to prevent lamprey from getting stuck behind guides. *Note: Though replacing these seals was needed, this may not have been a particularly effective passage improvement for lamprey.*	Jan 2012
10	East Ladder -Raise picket lead sections by 1" at count station to improve lamprey access to AWS area (and passage).	Dec 2010
11	East Ladder -Raise picket lead sections by 1" at count station to improve lamprey access to AWS area (and passage).	Jan 2011

Table 15. USACE summarized list of planned and completed minor fishway modifications at John Day Dam to improve lamprey passage. Taken from USACE (2012d).

ITEM	Description	Date Completed
1	South Ladder - Modify (round upper edge or install grating)12-ft depression just upstream of SE1 weir.	
2	South Ladder - Remove or plate over chain link grating/wall diffuser. This diffuser is no longer used.	
3	South Ladder - Replace 1" grating with 3/4" grating at upper section diffuser grating; replace trash racks with 5/8" gaps.	
4	South Ladder - Install new hydraulic sills at exit flow control weirs.	
5	South Ladder - Modify (ramp or chamfer) the 6" rise in floor at the stub wall, under road deck at half duplex PIT antennae.	
6	South Ladder - Install brushes in entrance and exit weir guides (all) to deter lamprey impingement/crushing.	
7	North Ladder - Modify (ramp) 1-ft sill at first upstream weir at count station section. MAR 20101	Mar 2010[1]
8	North Ladder - Exit section hydraulic sills? MAR 20101	Mar 2010[1]
9	North Ladder - Modify (ramp or ?) 1-ft sill at exit stub wall.	Mar 2010[1]
10	North Ladder - Modify count station section floor (raise by 1-ft) or install ramp to eliminate 1-ft rise at orifice opening.	Mar 2010[1]
11	Raise picket lead sections by 1" at SFL count station to improve lamprey access to AWS area (and passage).	Feb 2011
12	Raise picket lead sections to 1" at NFL count station to improve lamprey access to AWS area (and passage).	Jan 2009

[1] John Day North Fish Ladder count station and exit section modifications addressed these problem areas.

Table 16. USACE summarized list of planned and completed minor fishway modifications at McNary Dam to improve lamprey passage. Taken from USACE (2012d).

ITEM	Description	Date Completed
1	MCN Oregon Shore fishway diffuser plating: Install diffuser plating on all diffusers during winter maintenance periods.	Jan 2010
2	MCN Oregon Shore fishway: Install lamprey orifices and temporary slide gates into the tilting weirs.	Jan 2010
3	MCN Oregon Shore fishway lamprey orifice gate removal: Remove the temporary slide gates at the lamprey orifices.	Jan 2011
4	MCN Oregon Shore fishway: Lift entrance weir by 16 inches to provide deeper entrance alternative for adult lamprey. Note: This is an experimental precursor for the planned MCN South entrance prototype installation.	Feb 2012
5	MCN Washington Shore fishway diffuser plating: Install diffuser plating on all diffusers pending ability to access the fishways and diffusers during winter maintenance periods.	
6	MCN Rounding of corners in ladder: Fillet or knock off sharp corners, typically at existing fish orifices.	
7	MCN Viewing window cleanup: Remove sharp-edged steel members, tighten gap dimensions to 3/4" max, provide smooth continuous surfaces in high velocity, remove vertical obstacles.	Jan 2010
8	MCN Counting window cleanup: remove vertical obstacles, block up picketed lead panels to provide 1-1/2" gap, etc.	Jan 2010
9	MCN Ramp near counting station just upstream of weir 333; provide steel or concrete lamprey ramp at vertical obstacle.	
10	MCN Install ingress and egress ramps on diffuser grate plating installed in 2010; Elevation difference between diffuser grating plates and adjacent fish orifice invert result in vertical obstacle for lamprey. Provide welded steel ramps from top of diffuser plates to orifice inverts and epoxy any resulting gaps.	

Table 17. USACE list of completed and planned major fishway implementation and operational actions at The Dalles, John Day and McNary dams to improve lamprey passage. Taken from USACE (2012d).

ITEM	**Description**	**Date Completed or Adopted**
JDA	Rebuilt north ladder exit section from count station up incorporating lamprey criteria modifications (contiguous smooth bottom, plates, rounded orifices, rest areas, etc.)	Spring 2010
JDA	North ladder entrance modifications incorporating lamprey criteria (variable width weir, bollards, LPS, new diffuser gratings, plates, fishpumps, etc)	Spring 2013
MCN	Delay installation of extended screens	April 2009
MCN	Modify south shore ladder incorporating lamprey criteria (plates, ramps, removal of obstacles, orifices in tilting weirs at exit section	Spring 2010
MCN	Installation of prototype lamprey entrance structure at South Shore Ladder	2013[1]
SYS	Established new smaller gap ladder diffuser screen criteria	2008
SYS	Initiate night video counting at BON, MCN, & LGR as part of long term counting program (O&M)	Spring 2009[2]

[1] Now postponed until passage evaluations for 2012 are completed.

[2] Nighttime video counts were begun at The Dalles and John Day dams+ in 2012.

<u>Lamprey Implementation and Research Actions Planned for 2012 (USACE 2012d)</u>

The following is the preliminary list of USACE priority items for funding of lamprey passage improvements and studies in FY2012. It was based on ongoing planning discussions and meetings with regional co-managers. A critical part of how much can be accomplished depends on project cost estimates, fishway maintenance needs and available access, and results of 2011 studies.

The following is the preliminary list of USACE priority items for funding of lamprey passage improvements and studies in FY2012. It was based on ongoing planning discussions and meetings with regional co-managers. A critical part of how much can be accomplished depends on project cost estimates, fishway maintenance needs and available access, and results of 2011 studies.

1. Structural and Operation Implementation

- Initiate 2-year construction project for JDA North Fish Ladder entrance improvements, including features designed to improve adult lamprey passage.
- Complete alternatives evaluation and design work for MCN South Fish Ladder entrance (anticipated Winter 2012-2013 construction).
- Implement small-scale fixes in adult fishways at TDA.

- Continue operations designed to improve lamprey passage, such as reduced night time flow operations at MCN, and delayed installation of extended bar screens at turbine intakes at MCN to reduce impacts to downstream migrating juvenile lamprey.
- Replace JBS raceway tail screens with juvenile lamprey friendly screen material (11.5 mm on diagonal woven wire mesh screen) and extend raceway waste water outfall to reach the river under all tailwater conditions.
- Complete design of prototype structure for reducing or eliminating juvenile lamprey entrainment in turbine cooling water strainers.

2. Research, Monitoring, and Evaluation

- Continue night time lamprey video window counts at MCN and LGR. In 2012, night time lamprey counting coverage will also include TDA and JDA.
- Continue evaluation of effects of ladder modifications and improvements on lamprey passage at TDA, and JDA, with particular attention to initial modifications to JDA North Fish Ladder entrance (2-year construction project).
  - Evaluation tools will include half-duplex PIT tags, DIDSON acoustic cameras, counts, and video.
- Initiate comprehensive synthesis of existing adult lamprey passage data and development of a tool that will assist regional managers in discussions about identifying, prioritizing, and tracking lamprey passage improvements.
- Complete evaluations of adult lamprey passage behind picket leads at TDA, JDA, MCN, and IHR to determine whether video tools can be used to improve lamprey counts.
  - Continue evaluation of alternative locations for estimating adult lamprey counts at MCN and IHR.
  - Evaluate alternative locations for estimating adult lamprey counts at TDA North and JDA North fishways.
  - *Note: 2012 season results will be used to determine, in consultation with regional partners, the future direction and management needs with respect to lamprey counts.*
- Evaluate effects of fishway improvements at MCN, including lifting a fishway entrance weir at MCN South Fish Ladder by 16 inches.

2011 Assessment Of Adult Fishways at The Dalles, John Day and McNary Dams

<u>Methods</u>

The USACE conducts annual visual inspections of dewatered fishways during the winter maintenance period, typically December through March. The inspections are done by USACE biologists and engineers. Interested co-managers may be allowed to accompany them.

The Service accompanied USACE biologists and engineers, along with other co-managers, and inspected dewatered fishways at The Dalles, John Day and McNary dams on January 31, February 4, 10 and 14, 2011 just prior to the ladders being watered up for the 2011 fish passage season. Documentation with specific ladder metrics (length, width, slope, velocities, etc.) for fishways were obtained from readily available documents and reports and USACE project biologists. Field notes and photos were taken to record areas needing repair and to identify any new lamprey passage concerns for later regional discussion. This inspection was viewed as a reconnaissance level inspection to become familiar with the structures, identify areas of concern, and note areas with information gaps. The expectation was this inspection and other information would then feed into the development of the systematic fishway survey and evaluation.

The reconnaissance inspection results follow, with specific observations (**OB**), concerns (**C**), or data needs (**DN**) listed. These needs were linked to physical and biological capabilities/limitations and needs of lamprey identified from the previous research discussed above, and can be categorized as; swimming strength/speed (SS), body shape/size (BS), holding/resting structure (HR), and stress (ST).

The approach areas downstream of The Dalles, John Day and McNary Dam ladder entrances were not a part of the reviews, but represent a critical gap in our full understanding of upstream lamprey passage. We have identified the following are needs and concerns.
DN- Determine how adult lamprey approach the ladder entrances. (SS, HR)
DN- Map the bathymetry and substrate of the approaches external to the ladder entrance. (HR, BS)
DN- Determine associated velocity distribution, magnitude, and direction. (SS)
C- Evaluate for potential impacts to adult lamprey. (SS, HR, BS)

Results

The Dalles Dam

1) Powerhouse Collection Channel

Access to the collection channel at The Dalles was not possible, but the structure would be similar to the collection channel seen at Lower Granite Dam (Figure 11). All of the floating orifice gates (FOG) were closed about 2000, thus there is no concern for losing lamprey back into the tailrace. Because the FOGs are closed, the diffusers inside the collection channel are not operated, except for the diffusers at each end of the channel.

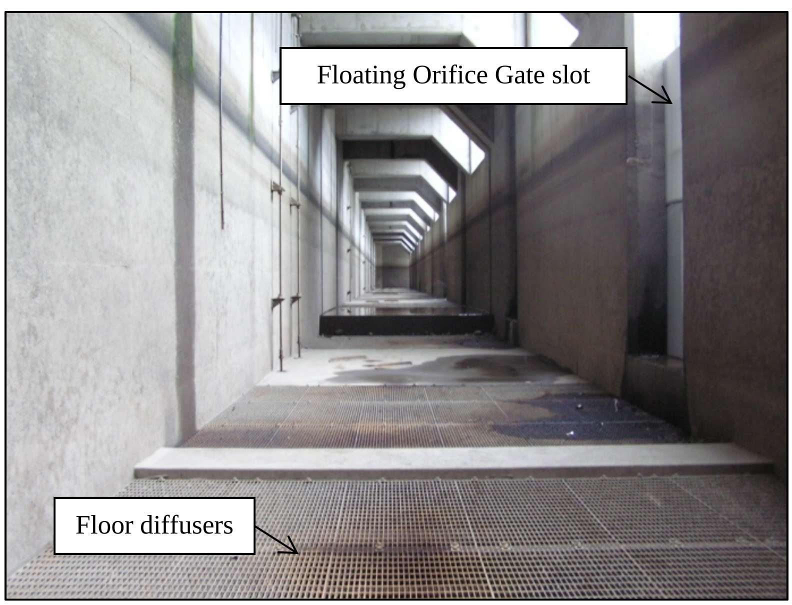

Figure 11. Lower Granite Dam powerhouse collection channel. Viewed from downstream flow end. The project tailrace is to the right. Image by D. Benner.

DN- Shape, dimensions of structure. (SS, HR)
DN- Identify all square corners, steps, dead ends, openings. (SS, HR, BS)

2) <u>Spillway Entrance (Adult) Transportation Channel</u>
Access to this collection channel at The Dalles was not possible.
DN- Shape, dimensions of structure. (SS, HR)
DN- Identify all square corners, steps, dead ends, openings. (SS, HR, BS)
DN- Locations, extent of diffusers. (BS, HR, SS)

3) <u>East Fish Ladder</u>
Entrance weir guides (Figure 12) have worn seals.

Figure 12. The Dalles East Fish Ladder weir entrance. Image by D. Benner.

C- Guides could provide hiding places for lamprey with the potential for crushing when the weir makes adjustments. Install brush or rubber seals to deter lamprey entry. (ST)

This junction pool (Figure 13) is the convergence area of the three entrances to the ladder (East Entrance. Powerhouse Collection Channel and Spillway Entrance transportation Channel). The floor is entirely diffuser plating which allows auxiliary water to be added to maintain flow and depth criteria in the entrance section for adult salmonid passage.

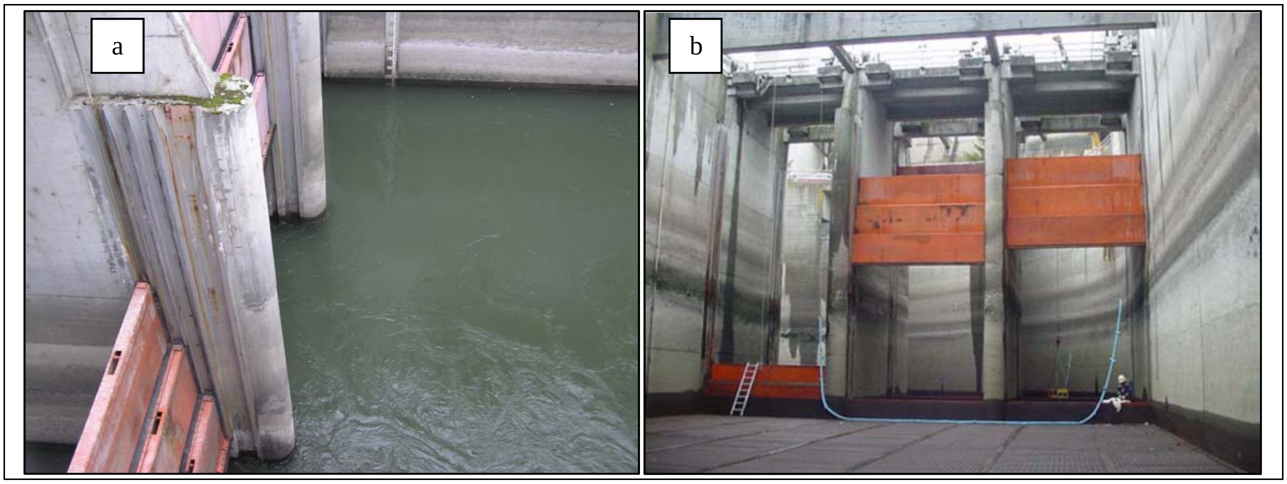

Figure 13. The Dalles East fish ladder junction pool. a. Watered up. b. Dewatered. Image a by D. Benner. Image b by USACE.

OB- It had already been identified that either adding lamprey orifices at the bottom of the concrete stub wall on the far right in Figure 13b (East ladder entrance), or removing it, would likely benefit lamprey passage over this 90° corner. (SS, HR, ST)

The lower ladder diffuser sections were visible (Figure 14). It was discussed that attaching plating along wall between weirs in connection with plating in front of orifice would give lamprey a good attachment surface between weirs and wouldn't be a drastic reduction in the total diffuser opening area.

Figure 14. The Dalles East fish ladder lower diffuser section. Water flow moves right to left. Image by D. Benner.

C- C- Install plating along wall between weirs in connecting with plating in front of the downstream orifice to provide better attachment and passage for lamprey. (SS, HR, ST)

The bottom orifices at both turning pools in the East ladder (Figure 15) are stepped up above the floor of the ladder and present a 90° bend for lamprey to navigate.

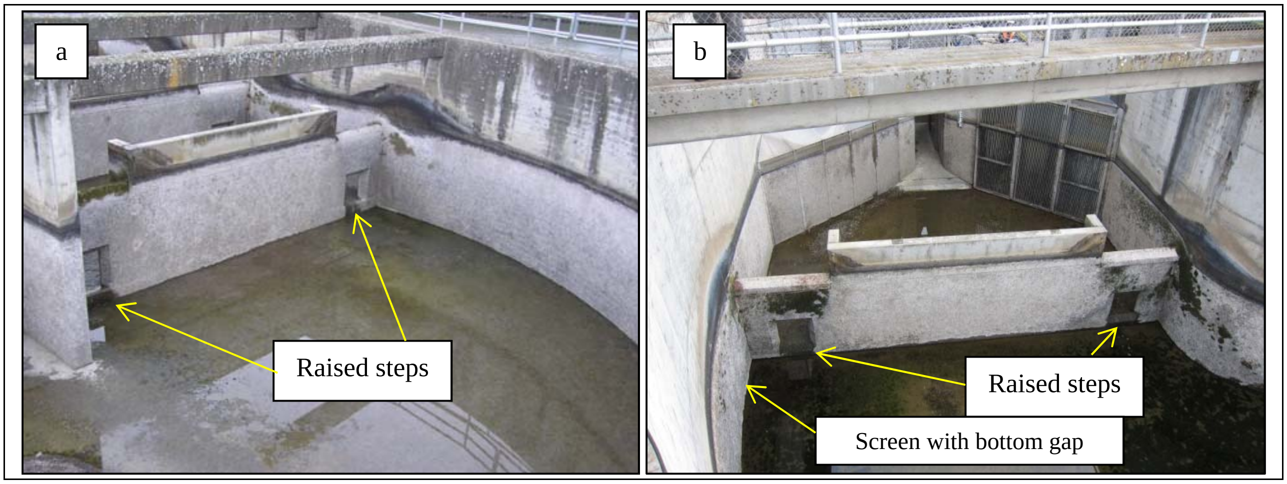

Figure 15. The Dalles East fish ladder. a. Turning pool 1, looking upstream. b. End of turning pool 2, the count station is above the weir. Image a by D. Benner. Image b by G. Fredricks.

OB, C- Install ramps to provide better attachment and passage for lamprey. (SS, HR, ST)
OB, C- Diagonal screened enclosure should have gap at the bottom reduced.

Based on these observations above ramps were installed at orifices in both turning pools (Figure 16) in January 2012 during the winter work period.

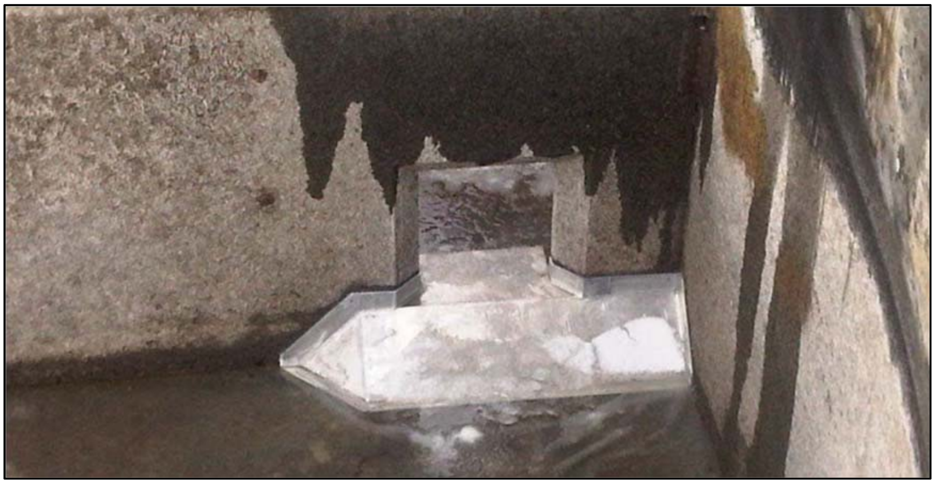

Figure 16. The Dalles East fish ladder raised orifice in turning pool 1 with new ramp for lamprey passage. From USACE (2012d).

The ladder count station (Figure 17) has a mechanical crowder that can narrow the gap to about 18 inches if visibility becomes difficult for the observer/fish counter. The maximum width is not specified in the Fish Passage Plan (USACE 2012b).

Figure 17. The Dalles East fish ladder count station.

OB, C- Install brushes or seals around base of count station crowder to prevent loss and injury. (BS, HR)
OB, C- Fill in the expansion joints and unused screen/bulkhead guides downstream and upstream of the count station area to aid passage. (BS, HR)

Above the count window are four removable flow control weirs with orifices stepped above the floor (Figure 18).

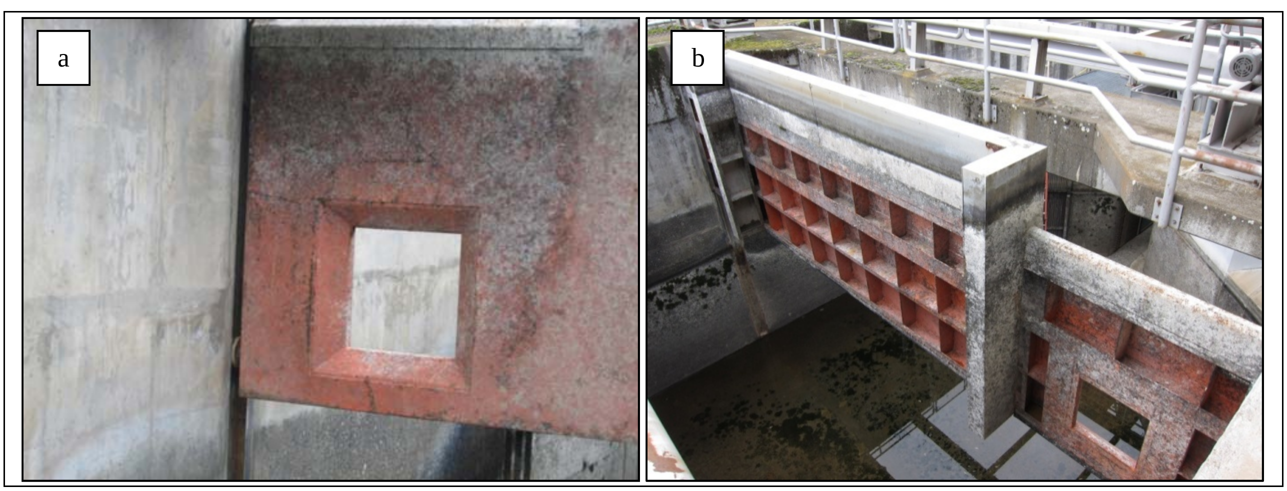

Figure 18. The Dalles East fish ladder. Removable flow control weir with orifice located upstream of the count window. a. Downstream face. b. Upstream face. Image a by D. Benner. Image b by G. Fredricks.

OB, C- Install ramps on downstream face to provide better attachment for passage. (SS, HR, ST)

4) North Fish Ladder

The floor of the fishway entrance rises straight up approximately three to four feet as it meets the diffuser floor. This is about a 40 foot distance (Figure 19).

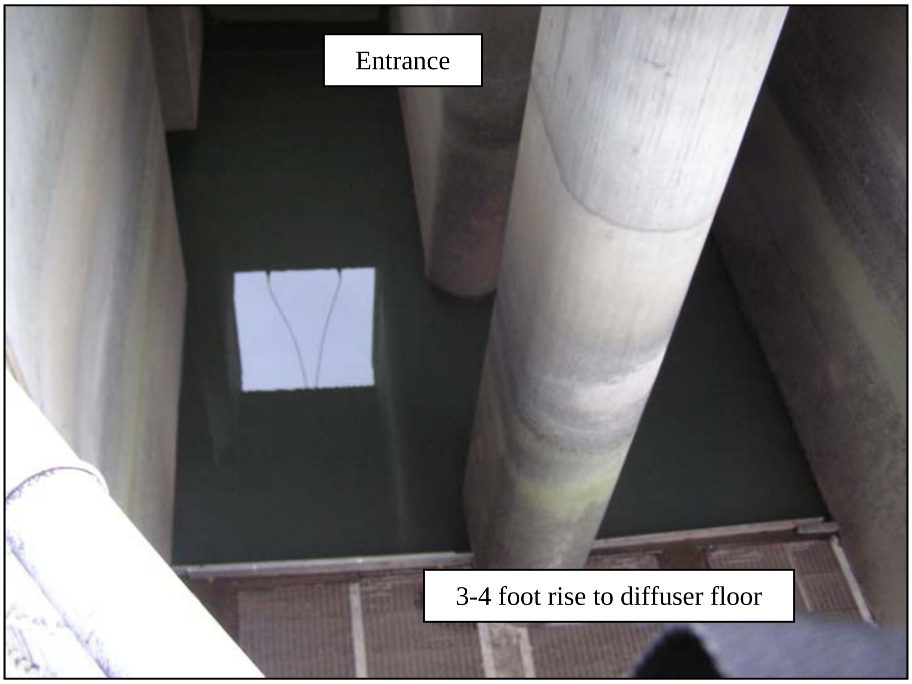

Figure 19. The Dalles North fish ladder entrance. Image by D. Benner.

OB, C- Possible location for lamprey ramps.

The north ladder begins as a combined man-made and natural rock channel (Figure 20). The channel floor is natural rock in between the weir sections with diffusers. The bottom orifices are stepped up to one foot above the natural floor sections between the diffuser sections.

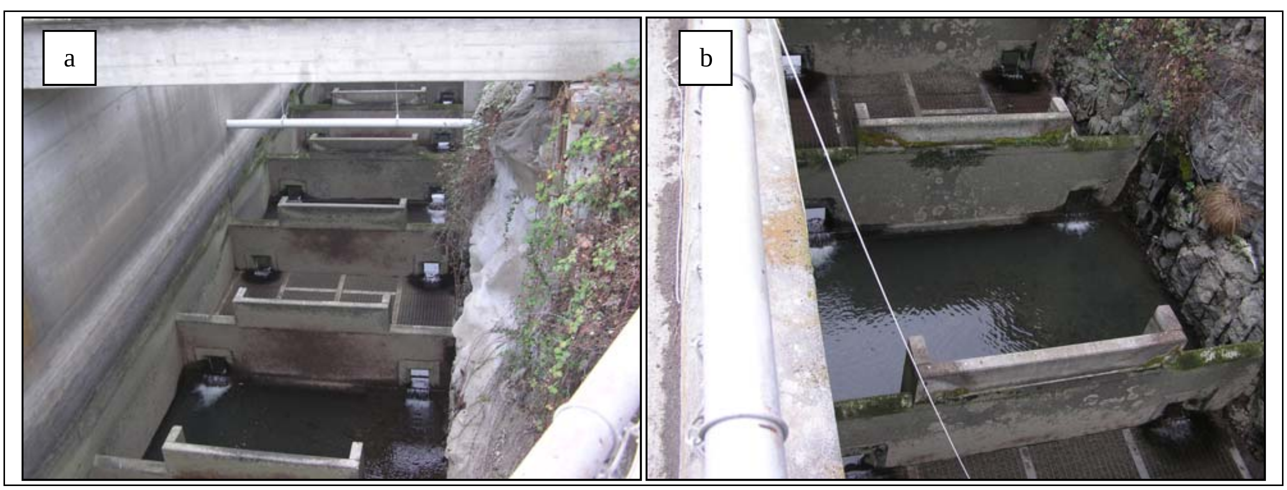

Figure 20. The Dalles North fish ladder with man-made and natural rock walls. Images by D. Benner.

OB, C- OB, C- Install from the natural floor to the orifices to provide better attachment for passage. (SS, HR, ST)

Many of the diffusers in between weirs that are no longer used are nearly filled in with rock from the channel (Figure 21).

Figure 21. Unused diffuser section in The Dalles north ladder filled in with rock. Image by D. Benner.

OB, C- Add plating at each side on the diffuser in front of the orifice to provide attachment structure for better passage. (SS, HR, ST)

In the mid-section of the north ladder the channel transitions into all natural rock (Figure 22). Submerged orifices here are raised above the natural rock floor to be flush with the diffuser floor.

Figure 22. The Dalles North ladder, mid-ladder section. Submerged orifices are raised above the natural rock floor. Image by D. Benner.

OB, C- Install ramps from natural rock floor to the orifice to provide for attachment and passage. (SS, HR, ST)

At the new diffuser gratings just upstream of the count station (Figure 23) several of the new clips used to anchor this diffuser grating were found to have already been failing during the inspection.

Figure 23. The Dalles Dam North ladder diffuser section above the count station.

OB, C- All anchors were to be checked and replaced if necessary. (ST)
OB, C- Plate the grating directly in front of the orifice to provide holding/resting launch pad. (SS, HR, ST)

The flow control section upstream of the count station has slotted weirs, some flush with floor and others raised, and one submerged orifice flush with the ladder floor (Figure 24).

Figure 24. The Dalles Dam North ladder vertical slot flow control section above the count station. Image by D. Benner.

OB- Orifices are flush with the floor, which provides better lamprey passage.

The vertical slotted weir section has old bulkhead slots (Figure 25) that are no longer in use (note electrical conduit installed across the slots).

Figure 25. The Dalles Dam North ladder vertical slot section with old bulkhead slots. Image by D. Benner.

OB, C- Fill in and smooth over the lower portions of the unused bulkhead slots. (SS, HR, ST)

John Day Dam

1) Powerhouse Collection Channel

Access to the collection channel at The Dalles was not possible, but the structure would be similar to the collection channel seen at Lower Granite Dam (Figure11), with operating FOGs and diffusers.

DN- Shape, dimensions of structure. (SS, HR)
DN- Identify all square corners, steps, dead ends, openings. (SS, HR, BS)
DN- Locations, extent of diffusers. (BS, HR, SS)

2) South Fish Ladder

Between the entrance and the collection channel at John Day South Ladder there is a triangle shaped depression that goes about four feet deep down to diffusers (Figure 26). Thee diffusers in this triangle area are not used, so this depression could be filled in with concrete making it the same elevation as the entrance floor and collection channel floor or the diffuser gratings just covered completely. The inspection group was told there is not a great deal of delay in this area so simply the addition of bollards on the concrete lip to the collection channel or reducing nightime entrance head differentials may be the most cost effective way to benefit lamprey passage.

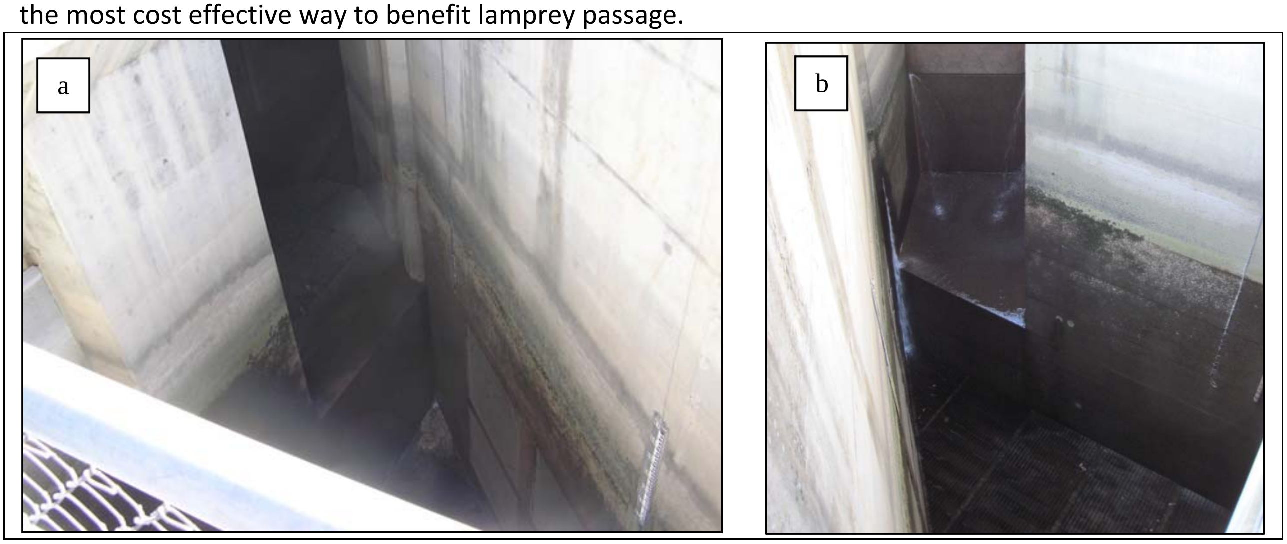

Figure 26. John Day South ladder, junction between the entrance and the collection channel. Image a. by D. Benner. Image b. by USFWS.

DN- Determine water velocity distribution, magnitude, and direction. (SS, HR, ST)

There is an extensive area of diffusers in the lower section of the John Day South ladder (Figure 27) with open grating continuous between bottom orifices.

Figure 27. John Day South ladder, lower diffuser sections.

OB, C- Install plating above and below each orifice to provide holding structure for lamprey to rest before and after passing through the orifice. (SS, HR, ST)

Above the lower diffuser section of the ladder overflow weirs with bottom orifices flush with the floor extend all the way up the count station and continue to the upper flow control weirs (Figure28xa). Several expansion joints exist along the ladder (Figure 28b).

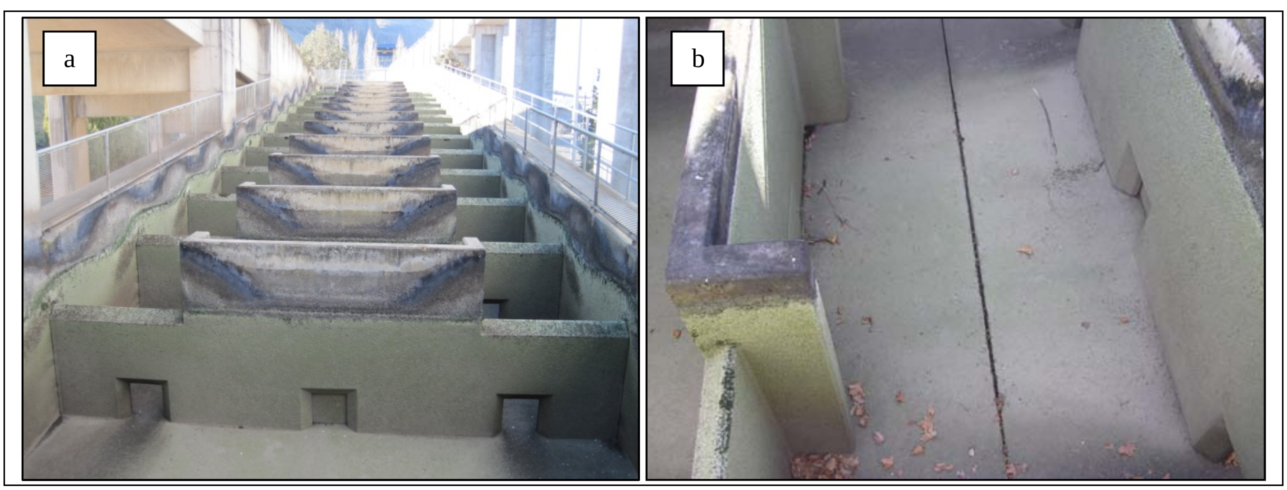

Figure 28. John Day South ladder. a. Overflow weirs with bottom orifices. a. Expansion joints in the ladder.

OB, C- The expansion joints in the high velocity areas could be filled and smoothed to provide an uninterrupted pathway between orifices. (SS, HR, ST)

The floor of the count station slot and window (Figure 29) is flush with the floor of the ladder with no recesses for lamprey to hide in.

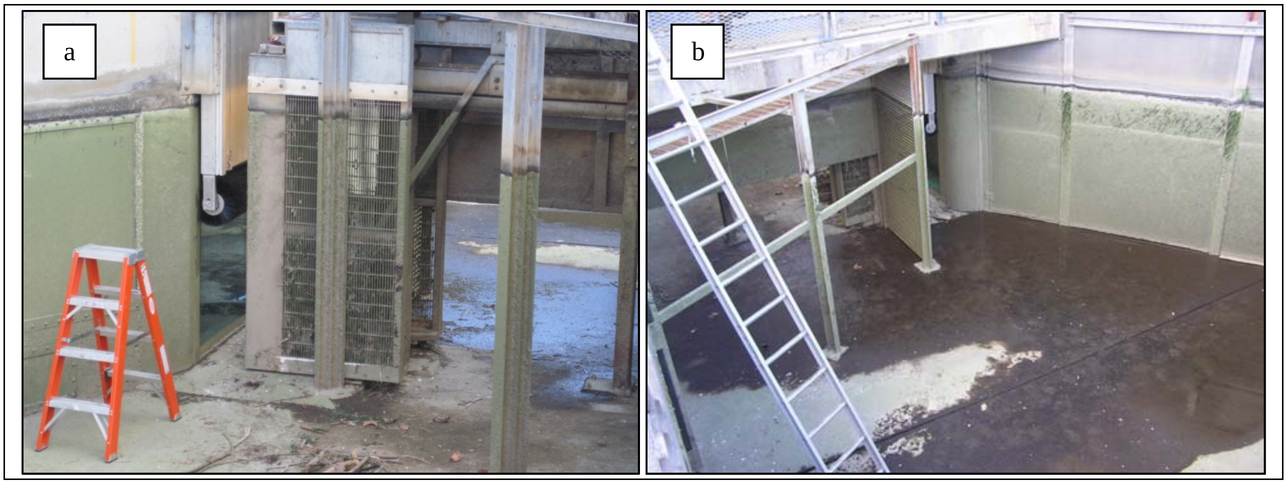

Figure 29. John Day South ladder count station, screens are removed. a. Entrance to slot. b. Exit from slot. Image a by USFWS. Image b by D. Benner.

OB, C- Install smooth plates on the grating just outside of the exit slot to provide holding structure for lamprey to rest after passing through the slot. (SS, HR, ST)

The vertical slot flow control weirs in the upper portion of the ladder all have bottom orifices flush with the floor of the ladder. The 11 uppermost weirs have 1 or 2 mechanical closure flaps at the bottom of the slot to adjust flow as necessary (Figure 29a). The lowermost control weirs have no adjustable flaps (Figure29xb).

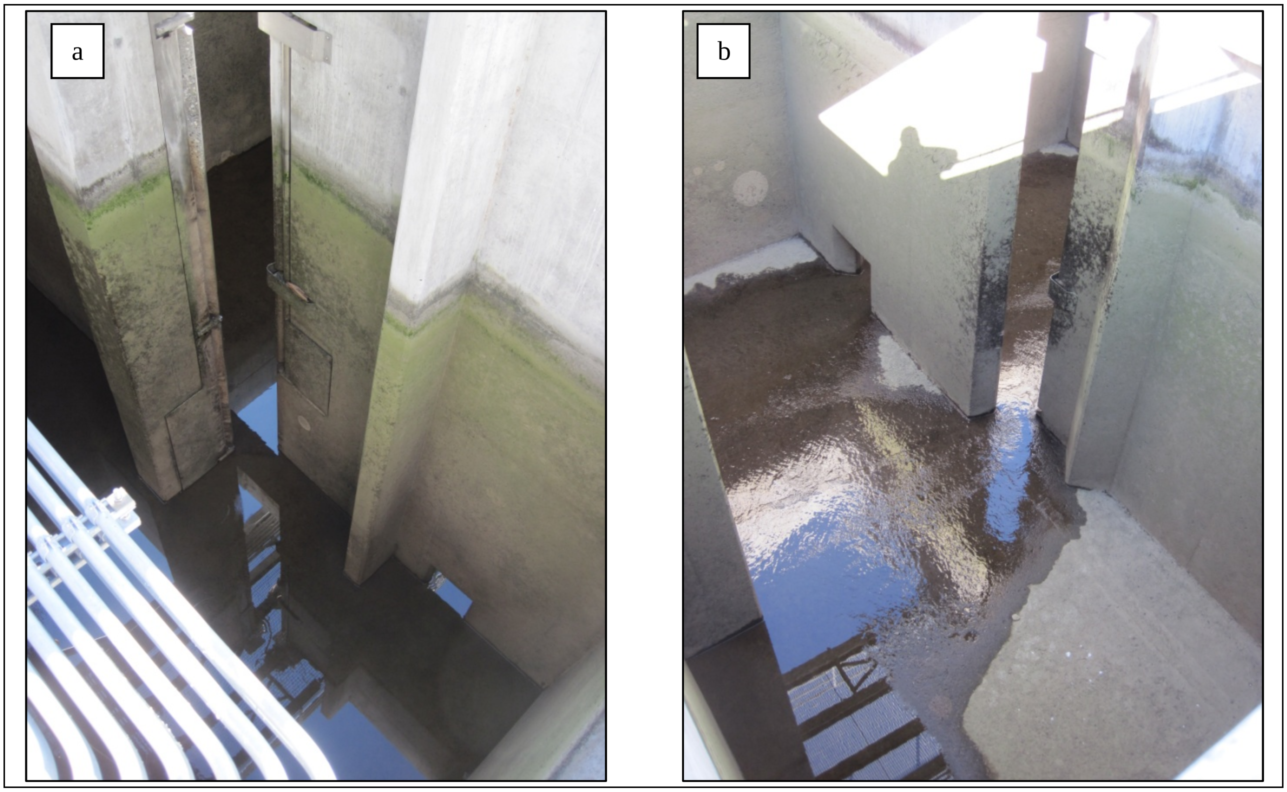

Figure 30. John Day South ladder flow control weirs. A. Slots with mechanical flaps to adjust flow. B. Slots with no mechanical flaps. Images by USFWS.

The ladder exit (Figure 31) is a 20 foot deep slot with reported flows of two fps.

Figure 31. John Day South ladder exit to the forebay. Image by USFWS.

3) <u>North Fish Ladder</u>

The John Day North ladder was not dewatered and thus was not included in the inspections. Completed major improvements are discussed above in Section IX, minor improvements are listed in Table 14.

McNary Dam

1) Powerhouse Collection Channel

Access to the collection channel at The Dalles was not possible, but the structure would be similar to the collection channel seen at Lower Granite Dam (Figure 11), with operating FOGs and diffusers.

DN- Shape, dimensions of structure. (SS, HR)
DN- Identify all square corners, steps, dead ends, openings. (SS, HR, BS)
DN- Locations, extent of diffusers. (BS, HR, SS)

2) Oregon Shore (South) Fish Ladder

The lower section of the McNary South ladder has three sections of diffuser grating where the USACE has installed plated pathways about 18 inches wide along the sides of the diffusers and in front of the submerged orifices of the weirs. These weirs are usually below the tailwater elevation (Figure 32).

Figure 32. Lower McNary South fish ladder. Image by D. Benner.

About 18 inches beyond the last weir before the McNary South ladder count station the ladder floor rises about six inches creating a 90° lip immediately beyond the orifices lamprey must pass through (Figure 33). A four inch pipe runs along the ladder floor through the ? orifice and into the stepped floor upstream of the orifice. It could not be explained at that time what the purpose of the pipe was. The pipe runs about 100 yards down, through the orifices of the lower weirs and then makes a 90° turn to the right through the ladder wall.

Figure 33. First weir below the McNary South ladder count station with 90° rise of floor directly upstream of the orifices. Image by USFWS.

OB, C- Ramps should be installed from the upstream side of the orifices to the top of the floor rise to provide better passage for lamprey. (SS, HR, ST)
Ob, C- Pipe running through the north orifices should be removed, if possible. (SS, HR, ST)
OB, C- Old, unused bulkhead slots on the walls of fishway should be filled. (SS, HR, ST)

The McNary South ladder count station slot entrance is ramped and sides are smoothed (Figure 34a). The exit end of the slot has a sharp drop, with mostly smooth, solid sides (Figure 34b), but some gaps exist.

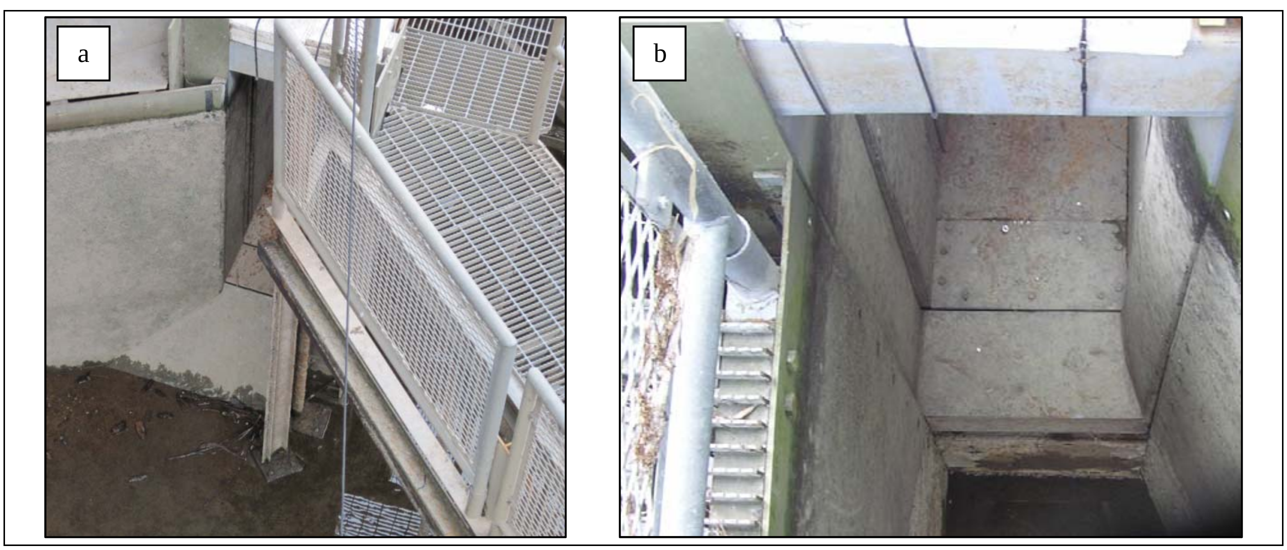

Figure 34. The McNary South ladder count station. a. Slot entrance. B. Slot exit. Image a. by USFWS. Image b. by D. Benner.

Ob, C- Gaps in exit slot should be filled and smoothed. (SS, HR, ST).
DN, C- Flow velocities and directions should be determined in the area where the exit slot depply drops off to assess impacts to lamprey. Ramping the end may be needed. (SS, HR, ST).

The McNary Oregon Shore fish ladder ends with the count station and flow control weirs built into a monolith on the forebay side of the dam (Figure 35). The flow is controlled by variable tilting weirs that adjust to the forebay elevation.

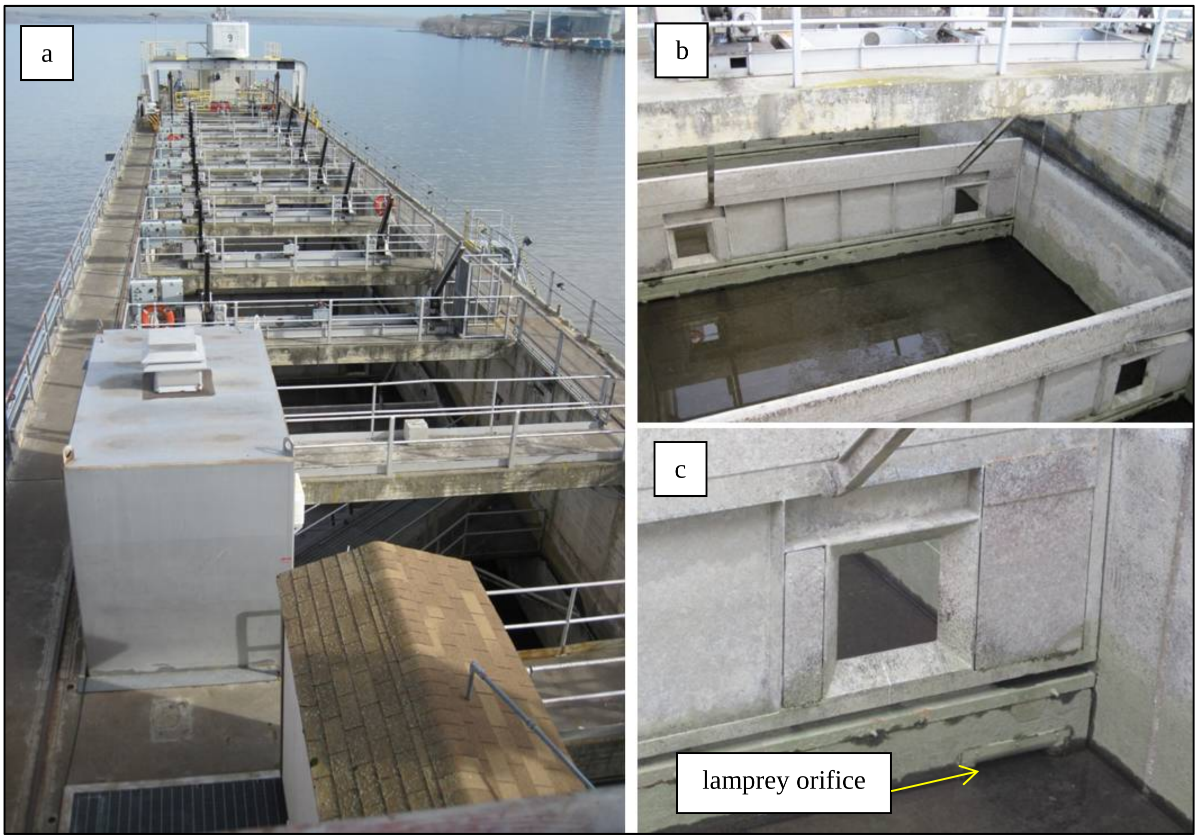

Figure 35. The McNary Oregon Shore fishway exit section. a. Exit section, count station is down in the ladder in the left foreground area. B. Tilting weir with salmon orifices. C. Close-up of tilting weir showing lamprey orifice built into the stub wall. Images by USFWS.

Directly upstream of the count station is a stub wall about one foot high (Figure 36). There are a few small debris orifices drilled through the bottom that are too small for adult lamprey to use.

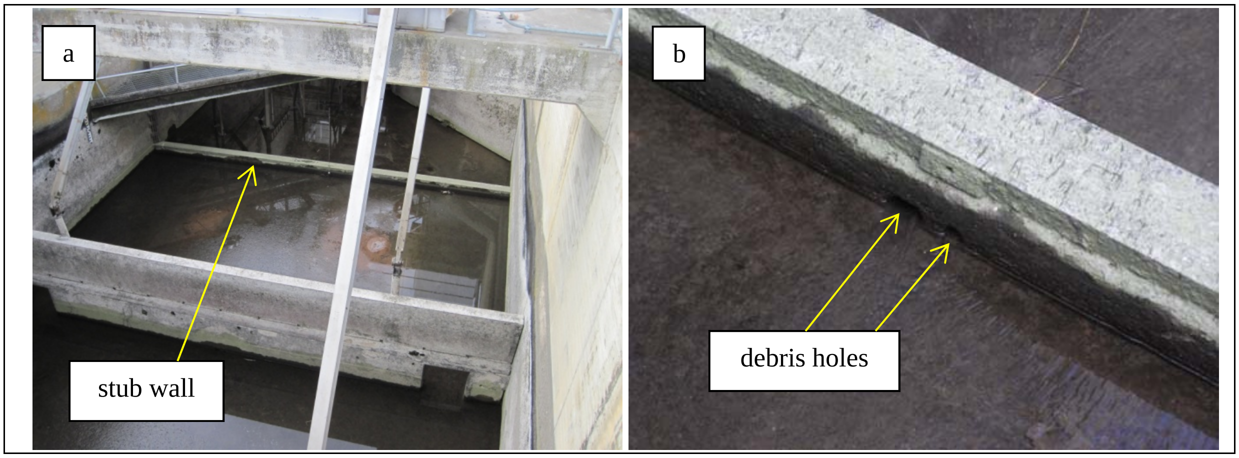

Figure 36. McNary South Ladder immediately upstream of count station. a. One foot high stub wall between count station and first tilting weir. b. Close up of small debris holes in stub wall. Image a. by USFWS. Image b. by D. Benner.

OB, C- The stub wall should either be ramped or the small debris orifices enlarged to accommodate lamprey passage. (SS, HR, ST)

Along the sides of the this tilting weir section are several grates which permit juvenile fish to enter the ladder after being screened away from the irrigation water diversions (Figure 37). The grates exclude adult salmon from entering this dead end route.

Figure 37. McNary South ladder tilting weir section, with auxiliary water trash racks. Image by USFWS.

DN, C- The gaps in all auxiliary water trash racks should be checked to make sure adult lamprey do not enter and become trapped in the dead end route. (BS, ST)

Between the last tilting weir and the fishway exit there is a V-shaped stub wall that is approximately 2-3 feet high (Figure 38). Upstream of this wall the floor elevation rises several inches to a sharp corner.

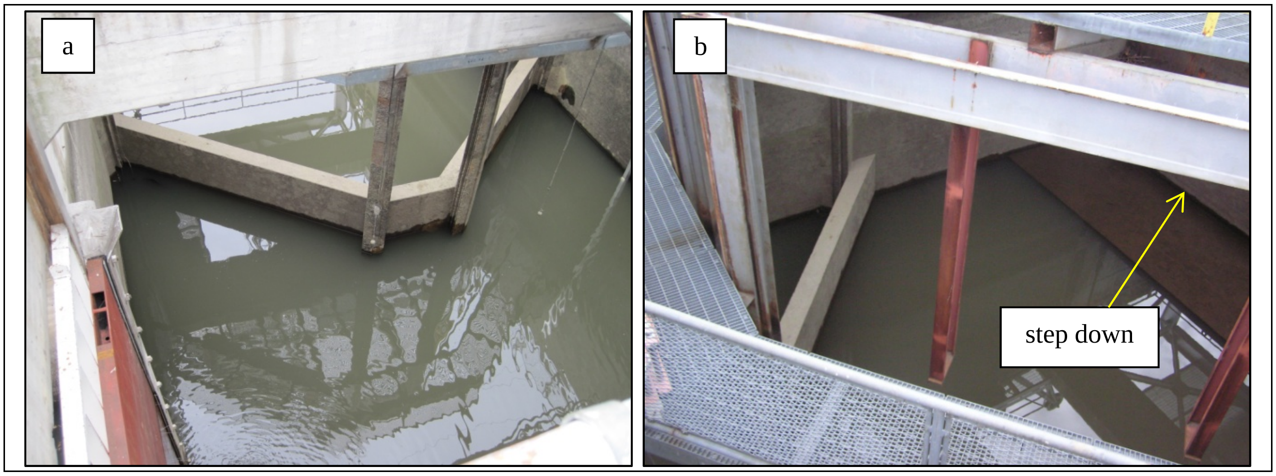

Figure 38. McNary South fish ladder exit section between the count station and the fishway exit. a. V-shaped stub wall that is approximately 2-3 feet high. b. 6 inch step down in floor elevation. Image a. by USFWS. Image b. by D. Benner.

OB, C- Install lamprey passage orifices at the bottom of the V-wall. (SS, HR, ST)
OB, C- Install ramps for lamprey passage down the floor step. (SS, HR, ST)

The bottom sill of exit gate is approximately one foot up from the floor of fishway (Figure 39). The vertical edges of exit gate extend out from the wall, creating a small ridge next to the exit.

Figure 39. McNary South ladder exit gate. Image by USFWS.

OB, C- Install a ramp for lamprey to more readily reach the exit. (SS, HR, ST)
OB, C- Fill in the wall around the vertical exit sides to make to make a smoother pathway for lamprey. (SS, HR, ST)

3) Washington Shore (North) Fish Ladder

The McNary Dam North fish ladder was not completely dewatered for the inspection. The fishway floor in the lower section above the entrance was discussed as potentially problematic for lamprey (Figure 40). Reportedly, the bottom of the fishway in this area is irregular with multiple potential obstacles.

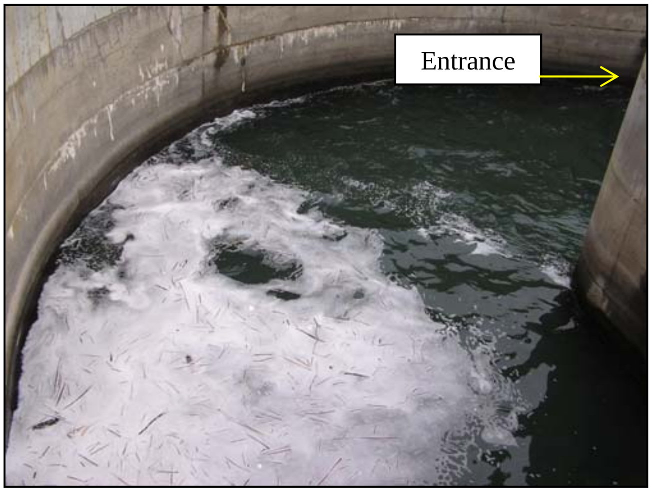

Figure 40. McNary Dam North ladder, turn at the bottom of the ladder just upstream of the entrances. Image by D. Benner.

C, DN- Evaluation of this section is needed when this area of the fishway can be dewatered below tailwater. (SS, HR, ST)

The North ladder sections above the entrances are typical overflow weirs with bottom orifices flush with the floor (Figure 41).

Figure 41. McNary Dam North ladder section 2, looking down the ladder. Image by D. Benner.

There are old, unused bulkhead slots along the wall below the count station (Figure 42) that could impede lamprey passage.

Figure 42. McNary North Ladder downstream of count station with old bulkhead slots in the wall. Image by D. Benner.

Ob, C- Old bulkhead slots sould be filled/smoothed. (SS, HR, ST)

At the last weir before the count station the orifices are elevated approximately ½ foot above the ladder floor on the downstream side (Figure 43). A wide depression in the floor runs the length of the weir on the upstream side.

Figure 43. McNary North ladder imediatley downstream of count station with elevated orifices on the downstream (right) side. Image by D. Benner.

Ob, C- Add ramps to the orifice sills for better lamprey passage. (SS, HR, ST)
Ob, C- Fill the depression immediately above and to the sides of the orifices to provide attachment areas for passing lamprey. (SS, HR, ST)

The McNary North ladder count station slot entrance and exit ramps are concrete but are very steep, nearly a 90° angle (Figure 44).

Figure 44. The McNary North ladder count station exit slot. Image by D. Benner.

Ob, C- Modify ramps to a shallower angle to aid lamprey passage. (SS, HR, ST)

The McNary North ladder flow control and exit section with tilting weirs (Figure x) is located along the south side of the navigation lock. The count station is down in the ladder in the left foreground of Figure 45.

Figure 45. McNary Washington shore ladder tilting weir flow control and exit section. Image by D. Benner.

Some of tilting weir orifices are elevated from the fishway floor on the downstream side. The upstream face of the tilting weirs are mostly smooth and can provide attachment locations for lamprey (Figure 46a). The downstream faces could be plated around perimeter of orifice opening to provide smooth attachment locations for lamprey as they prepare to pass through the orifice (Figure 46b).

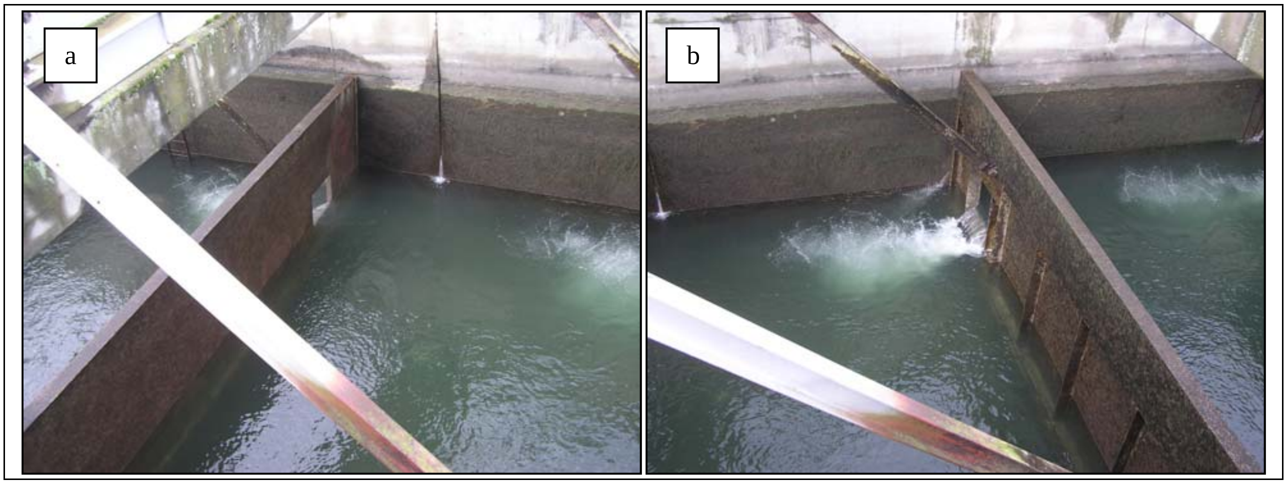

Figure 46. McNary North ladder tilting weirs. b. Downstream face of weir. b. Upstream face of weir. Images by D. Benner.

Ob,C- Add ramps to the elevated orifices or cut lamprey orifices through the stub walls flush with the floor of the ladder. (SS, HR, ST)
Ob,C- Plate a portion around the orifice to provide a smooth surface for lamprey attachment. (HR, ST)

Conclusions and Management Implications

Recommended Components of a Systematic Fishway Survey and Evaluation

Based on the reconnaissance level survey the Service did at Bonneville Dam (USFWS 2012) the Service developed a list of recommended components and information that should be collected for each fishway at each hydro project to complete a systematic review of passage structures. Specific types of needed data associated with each component were recommended. The list is presented again below.

- **Approach to Fish Ladder Entranceways**
  - Bathymetric river profile (X,Y,Z) leading to fish ladder entrance
  - Substrate characteristics
  - Water velocity distribution, magnitude, and direction

- **Fish Ladder Entranceways**
  - Ladder entrance water velocity distribution, magnitude, and direction; shape, dimensions, characteristics, and bottom structure and water velocities through any bottom velocity reducing structures

- Identify all 90° corners or steps
- Locations, extent, and grate size of auxiliary water supply (AWS) diffusers

➢ **Powerhouse Collection Channels**
- Shape, dimensions
- Water velocity distribution, magnitude, and direction
- Identify all 90° corners, steps, dead ends
- Locations, extent, and grate size of AWS diffusers

➢ **Junction (Transition) Pools**
- Shape, dimensions
- Water velocity distribution, magnitude, and direction
- Identify all 90° corners, steps, dead ends
- Locations, extent, and grate size of AWS diffusers

➢ **Fish Ladder Components**
- Overflow weir, vertical slot weir, orifices
  - Type, locations, dimensions
  - Identify all 90° corners, steps
  - Water velocity characteristics
- Pools between weirs, turning pools
  - Width, length, depth
  - Head differential
  - EDF (energy dissipation factor)
  - Water velocity distribution, magnitude, and direction
- Distances between adequate lamprey attachment surfaces and holds
- Identify all 90° corners, steps, dead ends
- Locations, extent and grate size of AWS diffusers

➢ **Adult Lamprey Passage Systems (LPS)**
- Approach to LPS entranceway
  - Bathymetric river profile (X,Y,Z) leading to LPS entrance
  - Substrate characteristics
  - Water velocity distribution, magnitude, and direction
- LPS entrance velocity
- Dimensions
- Slope, distance
- LPS exit location

➢ **Count Window Channel**
- Slot dimensions, crowder range
- Water velocity distribution, magnitude, and direction
- Structure and holding surfaces for lamprey
- Identify all 90° corners, steps
- Locations, extent, and grate size of AWS diffusers

- **Fish Ladder Exits**
  - Exit pool dimensions
  - Water velocity distribution, magnitude, and direction
  - Structure and holding surfaces for lamprey
  - Trash rack dimensions

The development and application of a systematic fishway survey and evaluation of physical conditions in the upstream passage facilities at the eight Columbia and Snake River FCRPS hydro projects will provide the information to determine the suitability of those conditions for upstream passage of adult lamprey. Suitability will be a function of the physical and biological capabilities of adult lamprey. Since upstream passage facilities were initially designed for anadromous salmonids, hydro-system operators and fishery managers need detailed information on how those conditions may affect adult lamprey passage success. With consistent application of a systematic survey of mainstem passage facilities, managers will have the information needed to identify specific areas within passage facilities that are problematic for adult lampreys, develop solutions for any problem areas, and prioritize implementation of corrective actions.

The objective of the surveys should be to identify the structures that comprise upstream passage systems at each of the mainstem hydro projects, collect the data to describe the physical and hydraulic conditions associated with the components of the structures, identify knowledge or information gaps, integrate the physical data with biological capabilities of adult lamprey, and develop recommended studies or corrective actions where required. A data management system should be developed to facilitate data analysis and modeling, and to provide results of the surveys, analysis, and modeling in a consistent and organized manner to the Regional Managers.

After gathering the specific fishway data at each project, the next step would be to integrate fishway-specific physical and hydraulic data with biological characteristics for adult lamprey, evaluate and determine if there are potential problem areas within each fishway system. This process will be critical to understanding the external and internal ladder environment and evaluating potential ladder passage impacts to lamprey. Regional lamprey passage discussions should move forward from this knowledge base to prioritize needed studies and physical or operational improvements for lamprey passage system wide, as well as at each individual project.

USACE Regional AFEP Systematic Fishway Survey

The USACE has now funded a systematic fishway survey effort beginning with Bonneville Dam in 2012 called the ***Systematic Adult Lamprey Passage Documentation***. The management purpose of this work is to facilitate regional discussion of lamprey passage improvement planning and prioritization, and to develop a more accurate, consistent, and useful method for:

1. Synthesizing and reporting adult Pacific lamprey passage study results to the region;
2. Documenting existing structural fishway conditions at each project;
3. Documenting known and suspected lamprey passage problem areas and fishway features, and their severity, for each fishway (operational and structural);
4. Tracking implementation of the USACE Pacific Lamprey Passage Improvements Implementation Plan: 2008-2018 and additions.

Objectives include:

1. Complete a data inventory and synthesis to facilitate deliberation on adult lamprey passage planning and prioritization.
    a. Synthesis of adult lamprey passage evaluations (1997-2011).
    b. Map basic hydraulics of each of the major fishway sections (e.g. overflow weirs, orifices, etc.), including velocity estimates and relative turbulence.
2. Develop a reference tool for USACE staff and regional fish managers to identify lamprey passage problem areas, diagnose potential causes, identify potential solutions, and systematically track passage improvement implementation and evaluations.
    a. Incorporate results into a 3D, open-source model of the Bonneville Washington Shore Fish Ladder.
    b. Conduct a regional workshop to review model assumptions, functions, and methodology. Incorporate results into model.
3. Integrate results of Year 1 objectives into an addendum to the USACE Pacific Lamprey Passage Improvements Implementation Plan: 2008-2018.

The objectives above should be largely completed by January 2013. The information collected by this project should fill in the critical information gaps about Bonneville dam fishways.

The work is proposed to continue in 2013 as the ***Synthetic Evaluation of Adult Pacific Lamprey Passage***, with the objectives to:

1. Generate 3D models of other dams and fishways, incorporating findings from Year 1. Work with USACE staff and regional fish managers to update list of potential structural and operational modifications that could address each identified problem area.
2. Under guidance from USACE staff and regional fish managers, update 3D model to include capability for tracking potential and implemented passage improvement actions, including ranking considerations from Objective 2.

At this time there is no long term commitment to continue the systematic surveys beyond Bonneville Dam. Planning for USACE funded projects occur on an annual basis prior to each fiscal year under the AFEP program. Projects are evaluated and prioritized based on current needs and available funds.

Recommendations

The Service should remain attentive and closely involved with the systematic survey project funded by the USACE through the AFEP process. As the AFEP survey results become available, the Service will develop scientifically-based recommendations to the USACE on the structure and operations of the inspected ladders and fishways to improve adult Pacific lamprey survival and reduce migration delays. Specifically, annually develop a Service list of prioritized recommendations for improvements in structures and operations to be delivered to the USACE, tribes, and state fisheries co-managers for discussion and consensus building on the approach to, and prioritization of future needs at Bonneville Dam for adult lamprey passage.

1) Service Fishway Inspections

a) Service biologists should actively participate in the annual USACE ladder inspections at the eight USACE projects in the lower Columbia and Snake Rivers to track improvements, identify new concerns, and merge with available data from the AFEP systematic survey. Annually develop a

Service prioritized list of fishway improvements for adult lamprey passage to share and discuss with our co-managers.

2) Regional AFEP Systematic Fishway Survey

a) The USACE should continue the Regional AFEP Systematic Fishway Survey with the seven remaining mainstem USACE projects in the Lower Columbia and Snake Rivers, beginning with John Day and McNary dams. Complete these surveys as soon as possible, ideally well before the end of the USACE's ten year plan in 2018.

b) Service biologists should track the completion of the regional AFEP systematic surveys for all fishways. Merge those results with the specific unknown physical and hydraulic elements of the fishway structures and the data needs and concerns from the Service inspections.

c) Based on the results from 1a and 2b, Service biologists should annually develop a list of prioritized actions needed for lamprey passage.

3) Overall Processes

a) The Corps should continue work to complete the planned minor and major fishway modifications for The Dalles, John Day and McNary dams identified in Tables 11, 12 and 13 above.

b) Service biologists should maintain close attention to the annual timelines and schedules of, and actively participate in, the USACE's Anadromous Fish Evaluation Program (AFEP) process, which develops and funds the research on lamprey passage.

c) Service biologists should remain actively engaged in the USACE's Fish Facility Design and Review Work Group (FFDRWG) which discusses and reviews new design ideas for passage structures at the dams.

d) Service biologists should remain actively engaged in the USACE's monthly Fish Passage Operations and Maintenance (FPOM) group, which discuss and reviews real time operational effects of existing passage structures at the dams and makes recommendations to the FFDRWG on new structural concerns regarding the fishways as they arise.

Acknowledgements

I wish to acknowledge and thank the Corps of Engineers for access to the projects and assistance with information for the visual inspections conducted at the projects. Specific thanks go to project biologists Robert Cordie (The Dalles Dam), Myro Zyndol (John Day Dam) and Carl Dugger (McNary Dam), as well as to Portland District biologist Sean Tackley for their patient help and assistance.

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APPENDIX A.

Diagrams of The Dalles Dam and the fishways, courtesy of USACE.

Table A-1. Adult fishways and entrances at The Dalles Dam.

Figure A-1. The Dalles Lock and Dam.

Figure A-2. The Dalles Dam North Fish Ladder and Spillway.

Figure A-3. The Dalles Dam South and West Fish Ladder Entrances.

Figure A-4. The Dalles Dam East Fish Ladder.

Table A-1. Adult fishways and entrances at The Dalles Dam.

The Dalles Dam (TDA)	Entrance Name (code)	Notes
Adult Transportation Channel	South Entrances (S-1 & S-2)	at west end of powerhouse, across powerhouse to East Ladder junction pool and East Ladder Exit
Powerhouse Collection Channel	West Entrances (W-1, W-2 & W-3)	at south corner of powerhouse, across powerhouse to East Ladder junction pool and East Ladder Exit
East Ladder	East Ladder Entrances (E-1, E-2 & E-3)	at east end of powerhouse, into East Ladder junction pool and East Ladder Exit
North Ladder	North Ladder Entrances (N-1 & N-2)	at north end of spillway, into North Ladder and North Ladder Exit

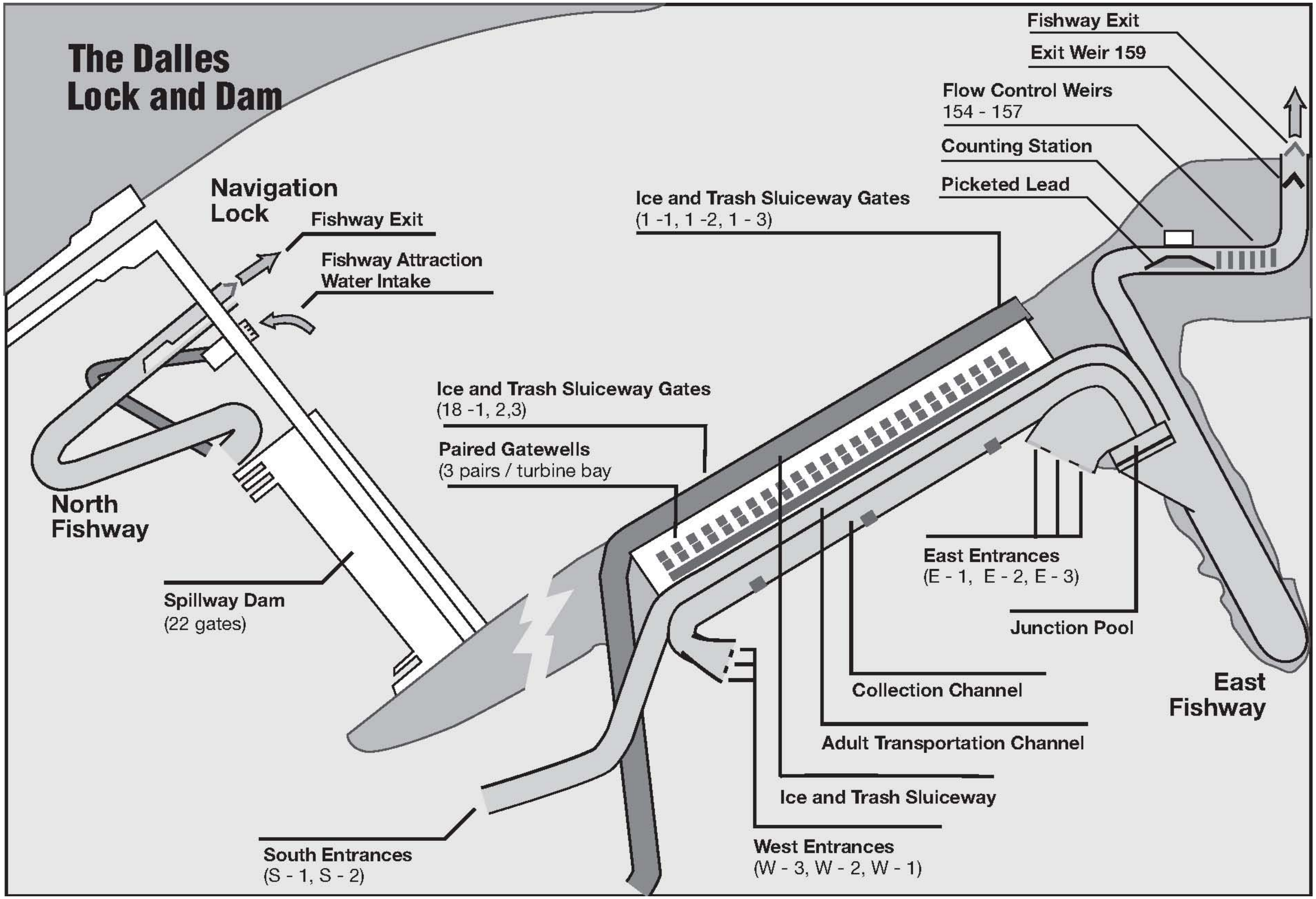

Figure A-1. The Dalles Lock and Dam (courtesy of USACE).

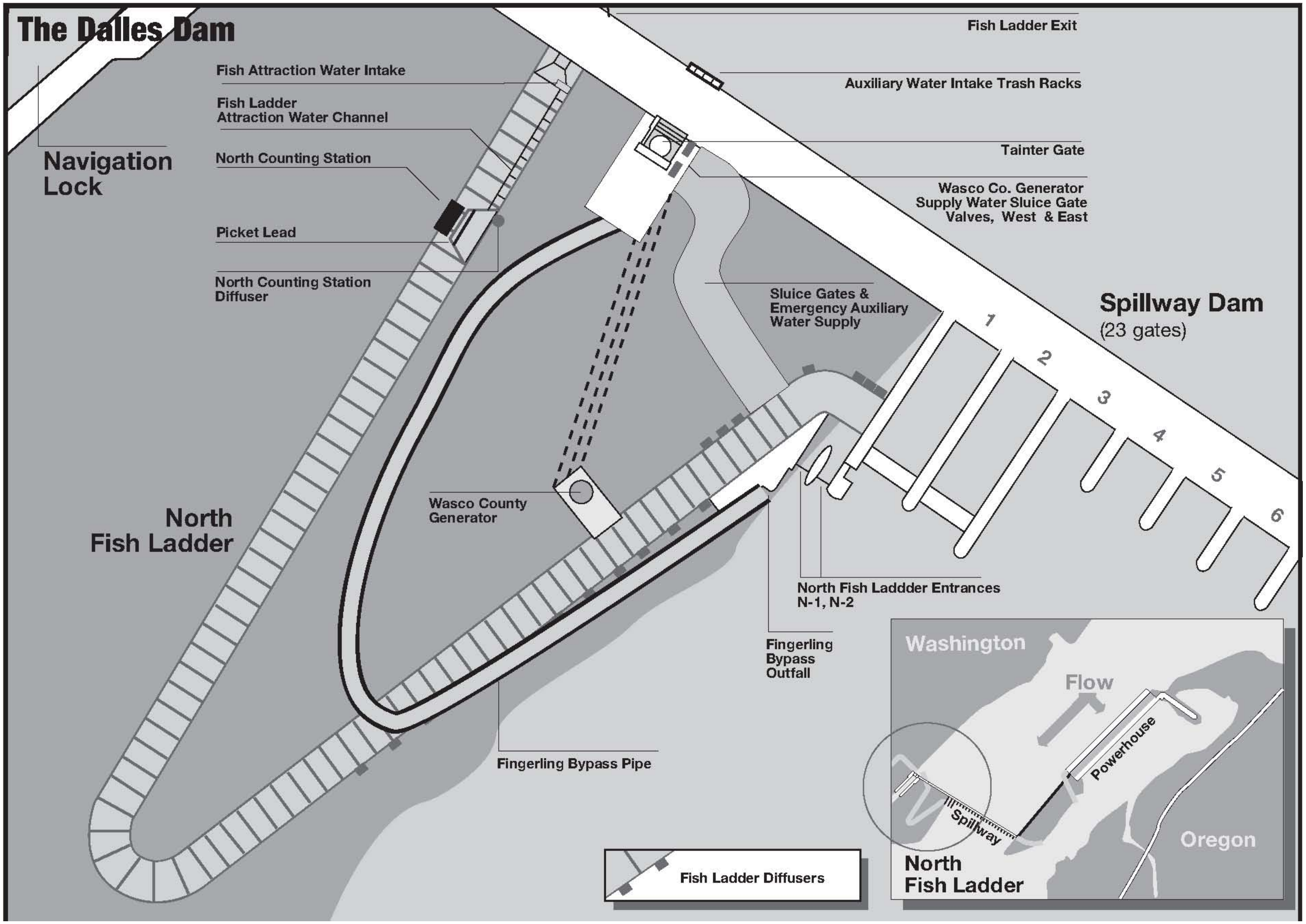

Figure A-2. The Dalles Dam North Fish Ladder and Spillway (courtesy of USACE).

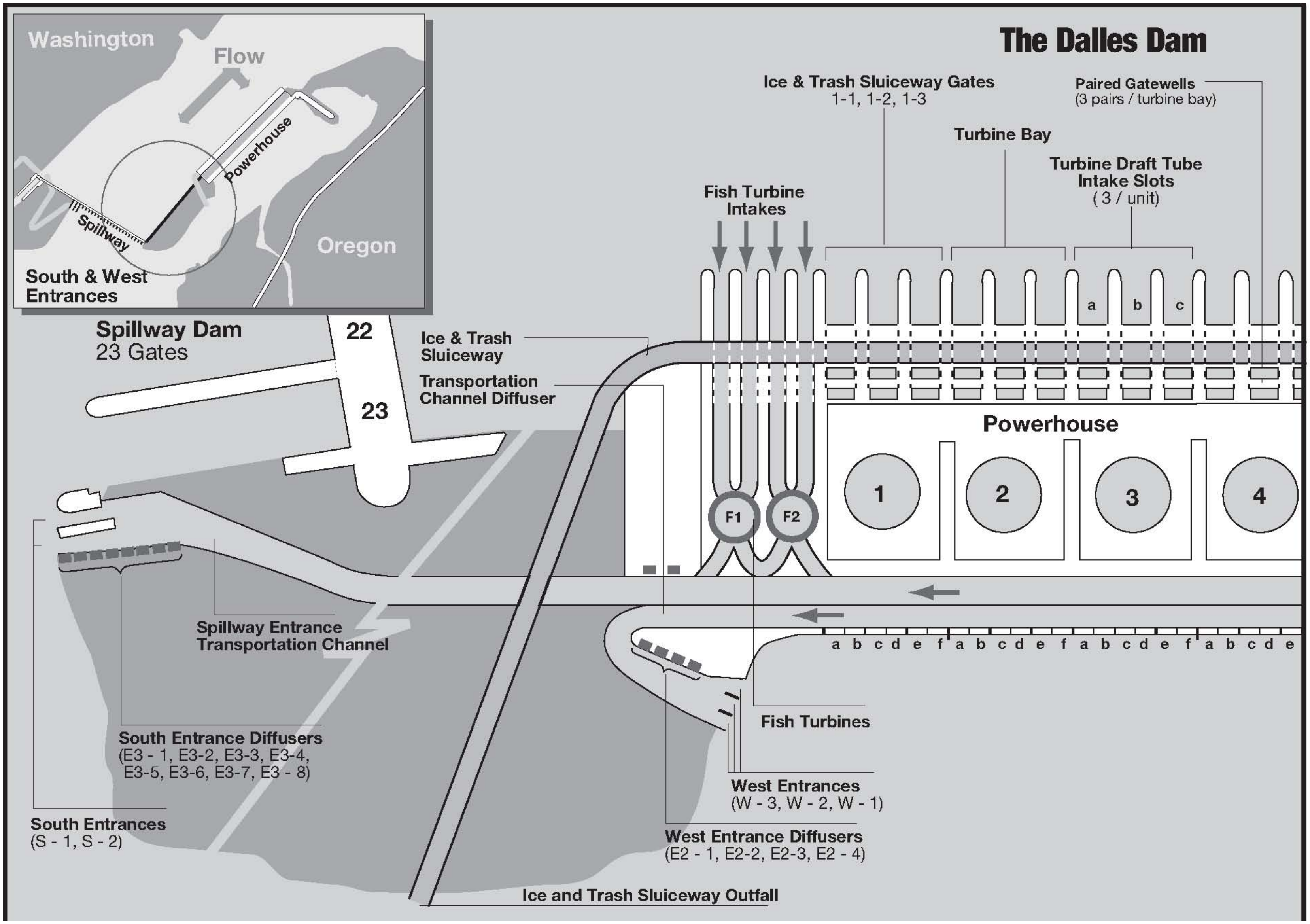

Figure A-3. The Dalles Dam South and West Fish Ladder Entrances (courtesy of USACE).

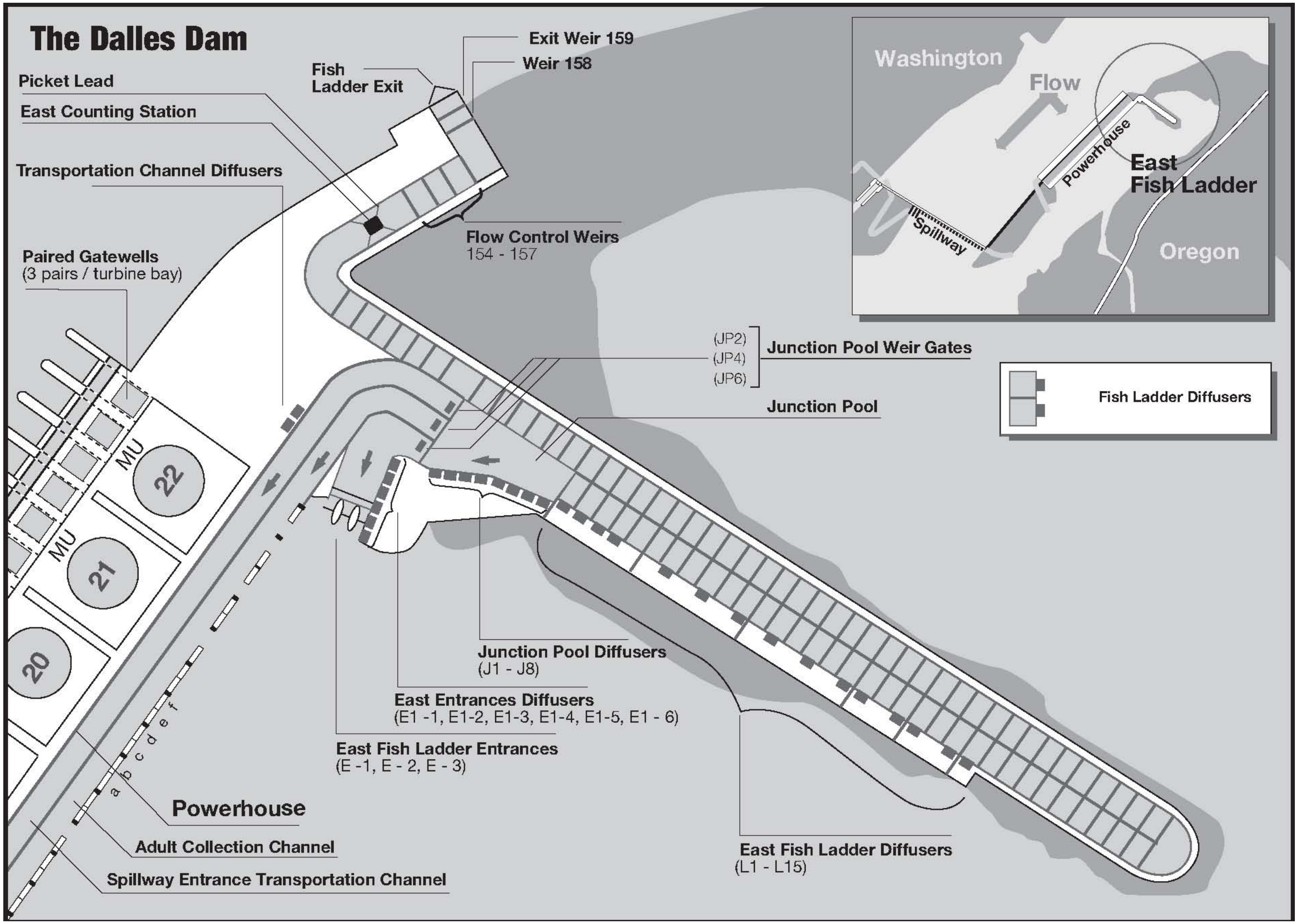

Figure A-4. The Dalles Dam East Fish Ladder (courtesy of USACE).

APPENDIX B.

Diagrams of John Day Dam and the fishways, courtesy of USACE.

Table B-1. Adult fishways and entrances at The Dalles Dam.

Figure B-1. John Day Dam North Fish Ladder and Spillway.

Figure B-2. John Day Dam South Fish Ladder and Powerhouse Collection System.

Table B-1. Adult fishways and entrances at John Day Dam.

John Day Dam (JDA)	Entrance Name (code)	Notes
South Fish Ladder	South Fish Ladder Entrance (SE-1)	at south end of powerhouse, into South Fish Ladder and South Fish Ladder Exit
Powerhouse Collection Channel	North Collection System Entrances (NE-1 & NE-2)	at north end of powerhouse, into Collection Channel, south to South Fish Ladder and Exit
North Fish Ladder	North Fish Ladder Entrances (EW-1 & EW-2)	at north end of spillway, into North Fish Ladder and North Fish Ladder Exit Exit

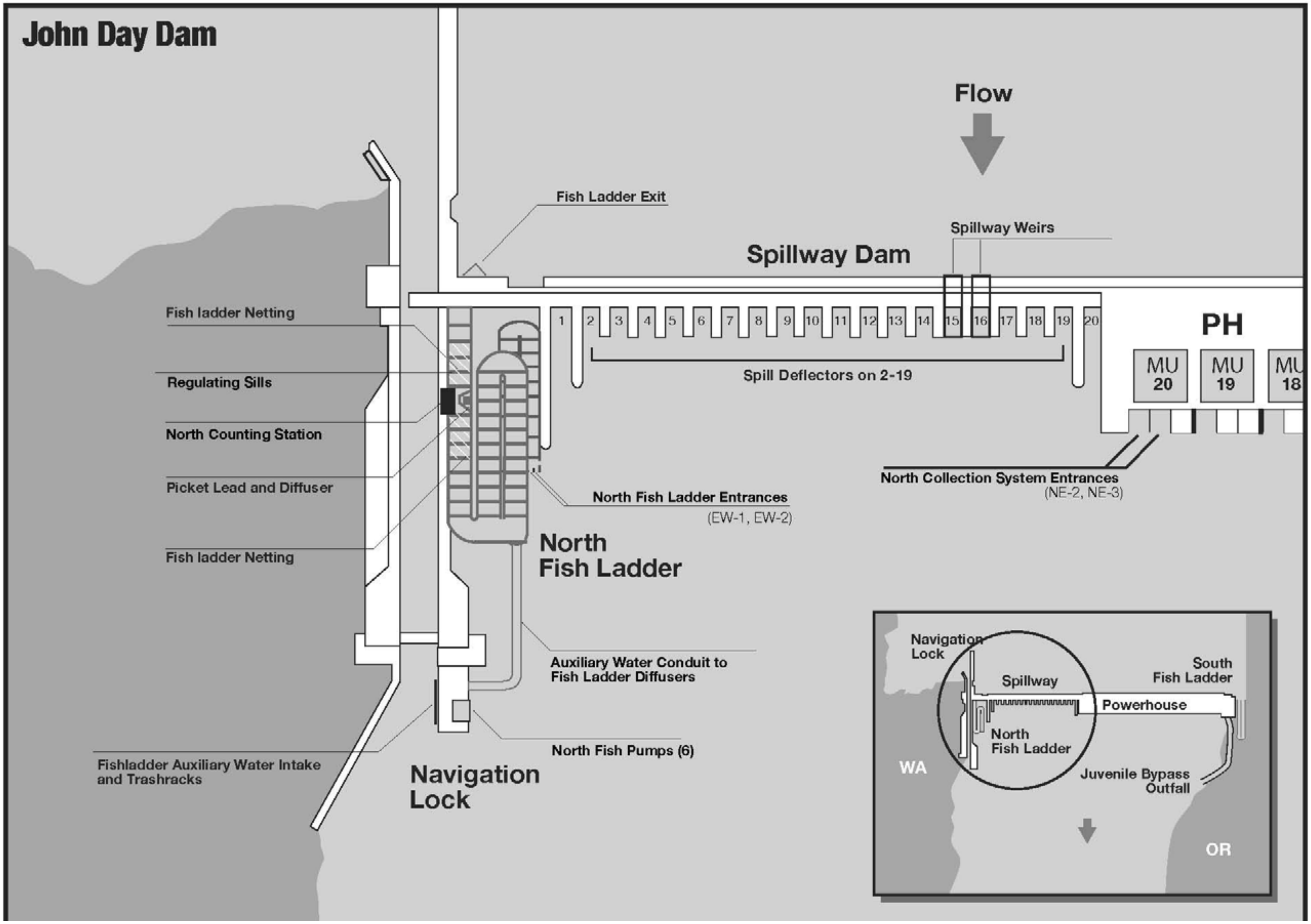

Figure B-1. John Day Dam North Fish Ladder and Spillway (courtesy of USACE).

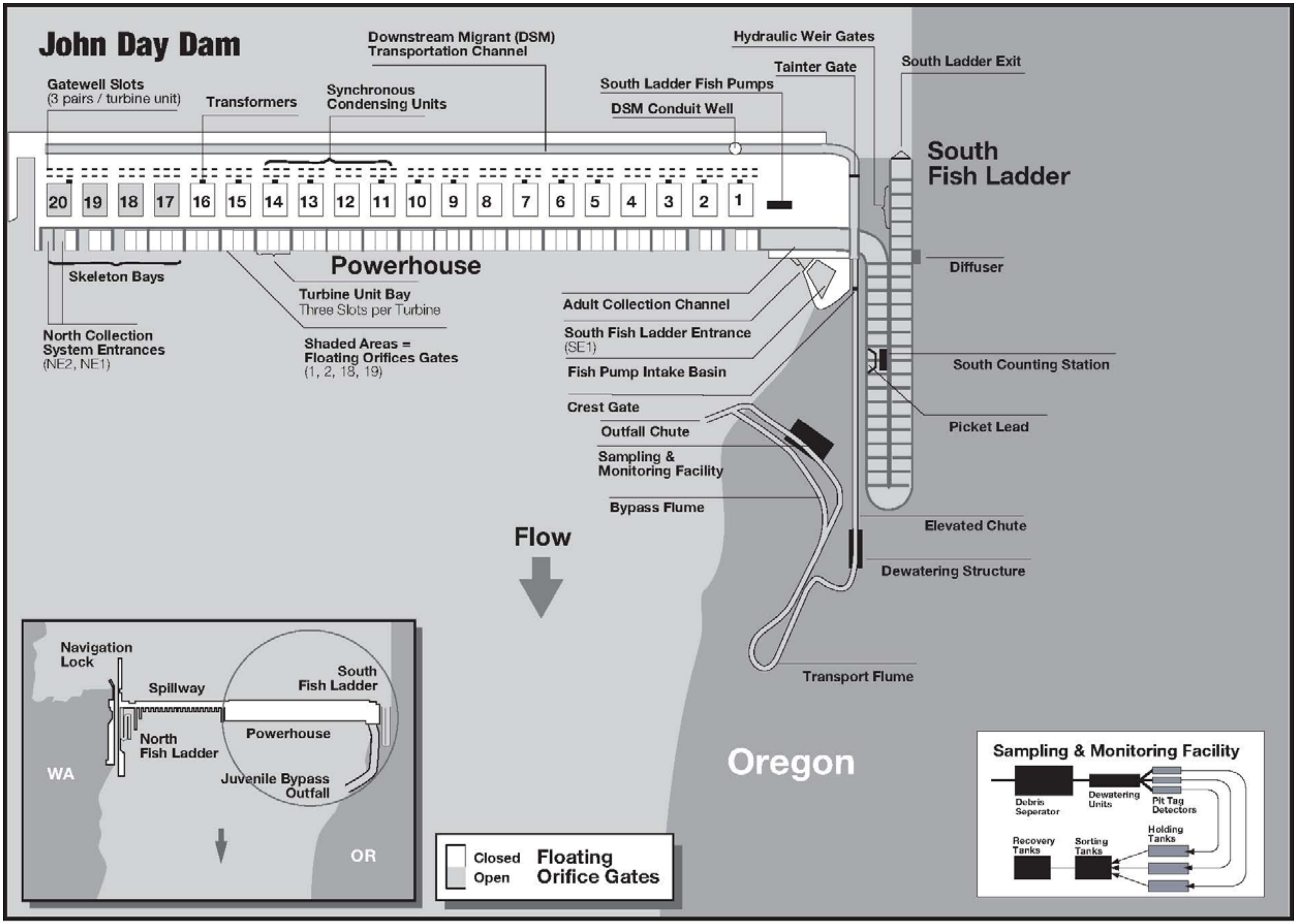

Figure B-2. John Day Dam South Fish Ladder and Powerhouse Collection System (courtesy of USACE).

APPENDIX C.

Diagram of McNary Dam and the fishways, courtesy of USACE.

Table C-1. Adult fishways and entrances at McNary Dam.

Figure C-1. McNary Lock and Dam (courtesy of USACE).

Table C-1. Adult fishways and entrances at McNary Dam.

McNary Dam (MCN)	Entrance Name (code)	Notes
Oregon Shore Fish Ladder	Oregon Shore Ladder Entrances (SFE-1, SFE-2)	at south end of powerhouse, into Oregon Shore Fish Ladder and Oregon ladder Exit
Powerhouse Collection Channel	Powerhouse Collection Entrances (NFE-2 & NFE-3)	at north end of powerhouse, into collection channel, south to Oregon ladder and ladder Exit
Washington Shore Fish Ladder	Washington Shore Ladder Entrance (WFE-1 & WFE-2)	at north end of spillway, into Washington Shore Fish Ladder and Washington ladder Exit

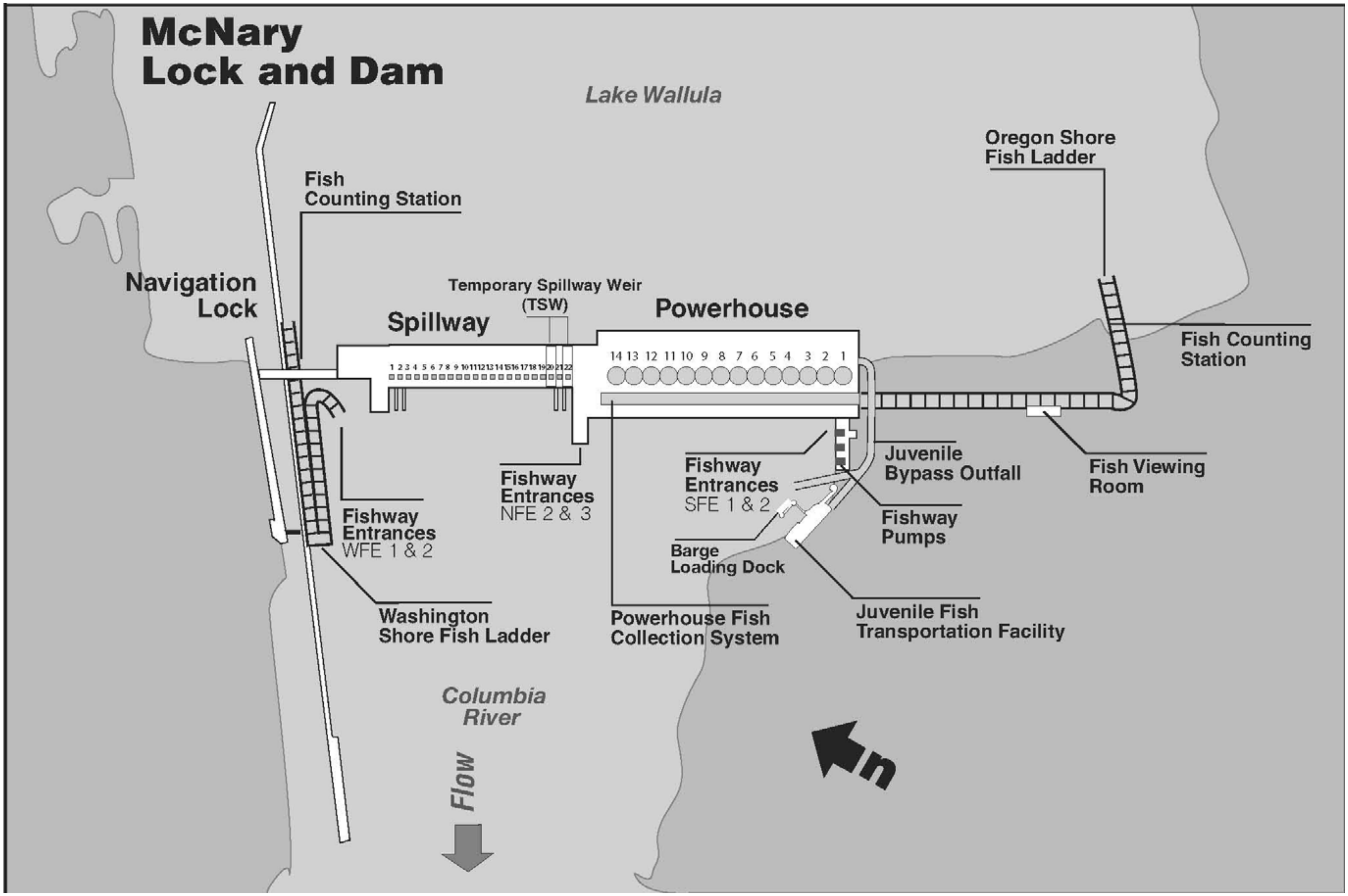

Figure C-1. McNary Lock and Dam (courtesy of USACE).

APPENDIX D.

Summary of previous adult lamprey passage research and implementation applicable for passage at The Dalles, John Day and McNary Dams. Taken from USACE 2009, 2010, 2011, 2012c and Luzier et al. 2011.

1994

- Pacific Lamprey Passage Studies Program was initiated in June of 1994 with requests issued by the USACE for preliminary proposals
- USACE Fishery Field Unit reviewed the literature and historic passage records to characterized run timing, diel passage, and passage numbers, and compiled areas of potential problems for adult and juvenile passage based on observations and discussions with researchers.
- Underwater camera observations of fish through orifices in BON2 ladder section found some lamprey spent substantial time in or near orifices.

1997

- Radio tagging
  a) 147 radiotagged lamprey released below BON.
  b) 88% returned to BON dam.
  c) 38% BON passage efficiency. 1 fallback fish.
  d) 55% TDA passage efficiency from BON.
  e) Too few fish at JDA for meaningful passage estimates.

1998

- Radio tagging
  a) 205 radiotagged lamprey released below BON to evaluate passage upstream.
  b) 89% returned to BON dam.
  c) 40% BON passage efficiency. 1 fallback fish.
  d) 63% TDA passage efficiency - 4% fallback.
  e) Too few fish at JDA for meaningful passage estimates.

1999

- Radio tagging
  a) 197 radiotagged lamprey released below BON to evaluate passage upstream.
  b) 92% returned to BON dam.
  c) 45% BON passage efficiency. 4 fallback fish.
  d) 50% TDA passage efficiency.
  e) Too few fish at JDA for meaningful passage estimates.
- Swimming performance - applicable at all projects
  a) Lab tests found adult lamprey critical swim speed of 0.86 m/sec, burst speed to 2.1m/sec, and that they recovered quickly from a single stressor exposure (USGS-Cook Lab).
- Passage improvement design and implementation – adult experimental fishway – applicable at all projects
  a) Baseline passage rates under normal fishway ladder conditions were established.
  b) Adding velocity refuges reduced passage times, did not affect success.

2000

- Radio tagging
  a) 299 radiotagged lamprey released below BON.
  b) 87% returned to BON dam.
  c) 47% BON passage efficiency. 3.3% (4) fallback.
  d) 82% TDA passage efficiency .
  e) 55% JDA passage efficiency - 17% fallback.
- Count window lighting
  a) Did not affect adult passage.
- Juvenile lamprey swim behavior
  a) Impingement problems (15-75%) at 1/8 inch extended length bar screens that increased with flow rates and time, but little problem with 1/8 traveling screen mesh or 3/32 bar screen.
  b) Exposure to simulated shear and pressure changes indicate turbine passage may be fairly benign as no injuries to juveniles were found.
  c) Light from the sides or above eliciting a diving response in lab studies of juveniles.
- Juvenile tagging
  a) OSU studies on juvenile tagging protocols found existing active tags are too large.
  b) External tags are poorly tolerated by the animal.
  c) Short term PIT tag studies on larger sized juveniles (>150 mm) may work.
  d) Fungus growth on handled juveniles are a problem.
- Passage improvement design and implementation – adult experimental fishway
  a) Daytime passage was less successful than nighttime passage; artificial nighttime light could reduce passage success.
  b) Adding a 20.3 cm step at the base of an orifice reduced passage rates from 69 to 49%. Diffuser gratings slowed passage but this difference disappeared when a plate was attached.
  c) Simulated count windows found no effects on passage with or without simulated count window lights or picketed lead weirs.

2001

- Radio tagging
  a) Drought year - very low flow and reduced spill.
  b) 298 radiotagged lamprey released below BON.
  c) 93% returned to BON dam.
  d) 46% BON passage efficiency. 12% fallback.
  e) 73% TDA passage efficiency - 7% fallback.
  f) 53% JDA passage efficiency - 36% fallback.
- Rounding of entrance bulkheads
  a) Evaluations at Cascade Island
  b) Researchers concluded that improved entrance efficiency based on a 11% increases over previous 2 years (51.5 vs. 62.5%).
- Reduced flow at spillway entrances
  a) Evaluations found no passage improvements but controlling entrance test velocities was problematic.
- Passage efficiency
  a) High efficiency exists through ladder sections.
  b) Entrances, collection, transition areas and serpentine weirs are problematic.

2002

- Radio tagging
  a) 201 radiotagged lamprey released below BON.
  b) 96% returned to BON dam.
  c) 48% BON passage efficiency. 1 fallback fish.
  d) 66% TDA passage efficiency - 1 fallback fish.
  e) 50% JDA passage efficiency - 35% fallback.
- Underwater and acoustic camera investigations (FFU)
  a) Limited evaluation of floor plates on diffusers between weirs in BON 2 transition pools found no evidence of preferential use of orifices with plates and limited use of the plates, suggesting adult lamprey may move laterally to the walls.
- Diffuser plating
  a) 41 cm wide plates over diffuser gratings in BON2 ladder transition section resulted in an increase in passage efficiency through that section (weir 1-10) compared to 2000 (72 vs.82%) but efficiency dropped to 74% in 2002.
- Serpentine weirs and the area immediately downstream of weir 1 in BON2 transition section of the ladder were found to be major passage problems.
- Yearly chemical/hormonal cycle of adult Pacific lamprey (USGS-Cook)
  a) Evaluations found no differences between fish that did or did not pass; that there were few indications of any migratory related changes.
- 2002 Passage Improvement Design and Implementation
  a) Lamprey Passage Systems (LPS)
     (i) First prototype sections of an LPS designed and installed in the Bradford Island Exit AWS channel show some promise to pass fish.
  b) Adult experimental fishway
     (i) Tests on a simulated entrance weir found increases in passage rates from 4% with 45.7 cm of head to 78% with 15.2 cm of head.
     (ii) Rounding the bulkhead shape increased passage rates from 34 to 41%.
     (iii) Offering a side channel with reduced velocities increased passage from 3 to 44%.

2003

- Passage improvement design and implementation
  a) Lamprey Passage Systems (LPS) - Bradford Island AWS Channel
     (i) Three prototype collection structures were built and evaluated in both an upstream and downstream configuration to evaluate effectiveness at collecting adults. 5458 adults were collected and 1089 were marked and rereleased in the channel to estimate treatment efficiency. Downstream-oriented ramps performed the best, recapturing 18%.
  b) Diffuser Grating
     (i) Preliminary tests of grating gap size found adults pass readily through 1 inch gap but do not in ¾ inch gap openings.
  c) Dewatering procedures
     (i) Methods altered to reduce impacts to lamprey; diversion pipes from upper diffuser chambers to tailwater (JDA), use of orifice blockers to sustain pools above weirs at key points to keep fish is water for salvage, more equipment and personnel, start salvage early in the week.

2004

- Passage improvement design and implementation
  a) Lamprey Passage Systems (LPS) - Bradford Island AWS Channel
    (i) System was extended to include PIT readers, resting boxes a volitional egress section to forebay.
    (ii) 7,500 adults (21% of Bradford Island passage) passed via LPS from mid-June to mid-September.
    (iii) 25% of tagged fish released in AWS passed via LPS; median time of 1 hour from first rest box to exit.
  b) Adult experimental fishway
    (i) LPS collection test ramp evaluations found
      a) Passage efficiency (88%+) did not differ among flows but mean passage times were considerably faster with reduced flows.
      b) Passage efficiency (90+%) did not differ among flows but mean passage times were slowest (0.84 hr) for 35 degrees ramp that 45 and 60 degree slope ramps (0.31hr and 0.40 hrs, respectively).
      c) Adding adults above the ramp as a potential olfactory attractant did not improve passage.

2005

- Half Duplex PIT Tag Study
  a) Half duplex PIT tag readers were installed at Bradford Island auxiliary water channel, at the entrance to BON Washington Shore ladder, and at MCN and IHR ladder entrances and exits. Initial efforts involved testing detection rates and refining systems.
  b) Lamprey that successfully migrated to upstream sites were significantly larger than unsuccessful fish (mean weights of 570 vs. 508grams). Condition factor declined as fish migrated from BON to MCN and ICE.
- Radio tagging
  a) 40 dual tagged (radio and PIT) released below MCN.
  b) 52.5% returned to MCN tailrace.
  c) 61.9% (13 of 21) dam passage efficiency at MCN.
  d) Fish had problems passing ladder areas similar to other dams; entrances, transition sections, and exit areas associated with auxiliary water channels.
- Passage improvement Design and Implementation
  a) Lamprey Passage Systems (LPS) - Bradford Island AWS Channel
    (i) No changes in passage metrics were found between 2 flow levels tested in the LPS.
  b) Adult experimental fishway
    (i) LPS collection test flume evaluations found
      a) When presented with 3 alternative choices (left wall, mid channel, and right wall) with varying flow rates, lamprey preferred routes adjacent to walls;
      b) Increasing flows differentially to mid channel could increase its use but with increased passage times.
  c) Diffuser Grating
    (i) In NMFS vertical gap size volitional passage testing, 100% of adult Pacific lamprey (mean length 67.5cm) passed 2.5cm gaps, 47% through 2.2cm gap, and none passed through 1.9cm gaps.

2006

- Half Duplex PIT Tag Study
  a) PIT Conversions
    (i) Half duplex PIT systems added to tops of ladders at BON2, TDA, and JDA.

Reach Conversion	
Reach	% Conversion
Release - BON top	41.1%
BON top - TDA top	67.9%
TDA top - JDA top	68.3%
JDA top - MCN top	34.1%

    (ii) Median travel times from dam top of ladder to dam top of ladder were;
      a) 5.1 days BON – TDA.
      b) 4.1 days TDA – JDA.
      c) 12.8 days JDA – MCN.
    (iii) Lamprey that successfully migrated to upstream sites were significantly larger than unsuccessful fish (mean weights of 541 vs. 504grams).
    (iv) Eleven fish tagged in 2005 overwintered and were detected at dams in 2006; 5 at BON.
- Hydraulic analysis of adding lamprey PIT antenna in the exit area of JDA north ladder found no problems; an increased head differential of 0.01 to 0.02 feet depending on forebay elevation with no measurable effects downstream.
- Radio tagging
  a) 40 dual tagged (radio and PIT) released below MCN, 20 released below IHR;
  b) 45% returned to MCN Dam, 65% to IHR Dam;
  c) 61% (11 of 18) dam passage efficiency at MCN, 77% (10 of 13) at IHR;
  d) Fish had problems passing ladder areas similar to other dams; entrances, transition sections, and exit areas associated with auxiliary water channels;
  e) Condition factor declined as fish migrated from BON to MCN and ICE.
- Passage improvement design and implementation
  a) Adult experimental fishway
    (i) LPS collection test ramp evaluations found;
      a) Passage behavior, efficiency, and times were not altered or different by the addition of either or 2 rest box design.
      b) Using water jets, air bubbles, and waterfall action to attract fish to base of ramp did significantly improve passage.
  b) Diffuser Grating
    (i) In NMFS dewatering simulations, 86% of adult Pacific lamprey (mean length 67.5cm) passed through a grating with 2.5 cm bar spacing but none passed through a 1.9cm bar spacing.
    (ii) A ¾ inch (1.9cm) gap diffuser grating was installed at pool 16 just above the JDA north ladder count station. No adult lamprey were found beneath it during winter dewatering even though it has a history of stranding.

2007

- Radio tagging
  a) Summary of 1997-2002 and 2007 radio tagged fish data for BON, TDA, and JDA . Fish tagged in 2007 were considerably smaller.

    (i) 75% TDA passage efficiency. 29% fallback fish (highest percent ever).
    (ii) 82% (9 of 11) JDA passage efficiency; 2 (22%) fallback fish

- Nighttime Entrance Velocity Reduction Test
  a) Passage efficiency increased at both the north and south entrances with velocities reduced to approximately 4 ft/s with 0.5 ft of head differential; however increases in the total number of fish entering only occurred at the north entrances which had higher velocities under normal conditions. The south entrances showed a net reduction in the number of fish entering as a result of a reduction in attraction to the entrance, likely related to the reduced flows. At the north entrance, where normal flow velocities are considerably higher than the south entrances, both entrance efficiency and numbers entering increased.
- PIT Data
  a) Reach Conversions and Detection rates

Reach Conversion	
Reach	% Conversion
Release - BON top	51.9%
BON top - TDA top	62.8%
TDA top - JDA top	52.2%
JDA top - MCN top	27.1%

  b) Median travel times from dam top of ladder to dam top of ladder.
    (i) 4.0 days BON - TDA.
    (ii) 4.3 days TDA – JDA.
    (iii) 8.8 days JDA – MCN.
  b) Radio-tagged based conversions were much lower than PIT based conversions pointing to possible radiotag effects or failures.
  c) Lamprey that successfully migrated to upstream sites were significantly larger than unsuccessful fish.
  d) Preliminary Ladder Window Counts at BON and TDA dams
    (i) Tabulated by video at night and by counters during the day
  e) Pheromone Tests
    (i) NMFS built a Y-maze and did initial testing of the effects of current velocity, ambient larval pheromone, and ammocoete washings on lamprey movements
  f) NMFS MCN radio tag and PIT studys
    (i) 59 dual tagged (radio and PIT) released below MCN
    (ii) 28% returned MCN Dam
    (iii) 86% (12 of 14) dam passage efficiency at MCN
- Passage improvement design and implementation
  a) JDA north ladder modifications tested
    (i) The new exit section and count station were evaluated in a 1:5 scale physical model.
  b) Diffuser Grating
    (i) In-ladder inspections found most ladder floor diffuser gratings are not supported adequately to hold required load and will need modification.
    (ii) Intake trash racks leading to diffuser pools will also need to be replaced with ¾ inch gaps if diffusers are changed to prevent debris build up below diffusers.
    (iii) BON, TDA, and JDA develop list of diffuser gratings with history of lamprey strandings and mortalities.

2008

- Lamprey Passage Studies Research, Design Development, and Implementation:
  a) Evaluating effects of ladder modifications and improvements on lamprey passage at BON.
  b) Obtain/improve baseline passage metric information at upstream dams (JDA, MCN, and Snake River dams if adequate sample sizes)
  c) Determine problem areas, prioritization, and evaluate effects of future improvements.
  d) Second year of evaluation of new BON WA ladder AWS channel Lamprey passage system.
  e) Evaluate effects of radiotags on adult lamprey passage behavior.
  f) Lab flume tests of bottom velocity reducing structures as a part of new entrance designs.
  g) Second year of study of methodology to improve lamprey counts at dams, including night video counts at window and tabulation of LPS passage.
  h) First year of lab evaluations of the effects of juvenile lamprey pheromones on adult migration.
  i) Finalizing designs for new lamprey safe diffuser gratings, intake screens, and prioritization. Grating replacements planned to begin winter maintenance period 09-10.
  j) Finalizing designs of new entrance shape, bottom structure, and connections to LPS systems to improve entrance efficiencies for lamprey.
  k) Tagging Studies
     (i) PIT Data
        1. Twice as many PIT tagged fish made it from release to the top of BON dam compared to radiotagged fish (26 vs. 52%), 12% more from top of BON to top of TDA, and 23% more from top of TDA to top of JDA, indicating radiotagging negatively effects adult performance . This tagging effect and smaller median sized fish being captured at BON makes it more difficult to assess relative passage improvements related to modifications. As was found over the last several years, larger fish were more likely to pass farther upstream.
     (ii) Nighttime Entrance Velocity Reduction Evaluation (0 ft head)
        1. PH2 fishway velocities at Bonneville Dam were manipulated by placing fish units on standby to float debris off of the trash racks. Shutting off fish units occurred only at night (typically between 2200 and 0430) to minimize potential effects on adult salmonid passage. This created 0 ft of head difference and minimum velocities at the entrances. Passage during the 0 head difference condition was compared to nights with normal head. Preliminary results indicate that passage efficiency may be negatively affected by this operation.
  l) JDA north ladder entrance section design development moves to alternative evaluation report phase and includes many lamprey features; fixed weir, improved AWS water distribution, floor velocity reducing structures, smaller gapped diffusers in all alternatives.
  m) Diffuser Grating
     (i) New designed ¾ inch diffuser gap grating developed that does not alter flows or ladder hydraulics.
     (ii) Concerns about large quantities of galvanized steel grating being replace at one time leads to adding powdercoating to new grating design criteria.

2009

- Lamprey Passage Studies Research, Design Development, and Implementation:
  a) Evaluated effects of ladder modifications and improvements on lamprey passage at Bonneville and upstream dams.

b) Finalized the plans for the exit section modifications at JDA north ladder including many lamprey improvements.
c) Continued John Day (JDA) north ladder entrance and auxiliary water system (AWS) modification designs for planned installation in 2011-2014 including a modified keyhole entrance.
d) Initiated design development of new entrances for Bonneville Dam Second Powerhouse north downstream and McNary Dam (MCN) south ladder entrances including hydraulic and physical modeling.
e) Initiated first of two years of flow reduction evaluations at MCN south entrance.
f) Obtained/improved baseline passage metric information at upstream dams (TDA, JDA, MCN, and Snake River dams) to better determine problem areas.
g) Initiated nighttime lamprey video window counts at BON, MCN, and Lower Granite Dam (LGR) as a new part of long term O&M funded fish counting contracts.
h) (System) Initiated a 2-year study of materials, sizes, and shape criteria for a functional juvenile lamprey active tag.
i) (System) Developed specs and contracting for acoustic mobile tracking system to begin determining fate of adults in reservoirs.

2010

- Lamprey Passage Studies Research, Design Development, and Implementation:

a) Evaluated effects of ladder modifications and improvements on lamprey passage at Bonneville and upstream dams. Preliminary results indicated an increase in dam passage efficiency at BON and higher dam to dam conversion rates.
b) Underwater video evaluations at Cascade Island LPS used to investigate where there may be passage problems within the prototype system.
c) Second year of evaluations of prototype Bonneville Dam Cascades Island entrance weir, bottom structure, and LPS system. Preliminary results show improved lamprey entrance efficiency but continue to show high levels of ladder drop out. Efforts to address this, such as installing resting boxes, will begin in 2011. Results in 2010 showed limited effects on salmon passage. Hydraulic anomalies from unusually high diffuser flows in the entrance area and a slipped orifice cover may have accounted for first year delays for salmon.
d) Completed extensive modifications to exit section and count station of JDA North Fish Ladder, with multiple improvements for lamprey.
e) Continued working to finalize the plans for the entrance, transition pool, and auxiliary water supply (AWS) modifications at JDA North Fish Ladder including many lamprey improvements.
f) McNary Dam (MCN) south ladder entrances physical model at ERDC was used to develop alternative lamprey entrance designs.
g) Initiated second year of flow reduction evaluations at MCN south entrance.
h) Results of evaluations of salmon behavior at the new lamprey orifices in the MCN south ladder exit area indicated few if any problems with delay or injury. New lamprey orifices pass 50% of the lamprey seen on video observations.
i) Initiated feasibility evaluations of nighttime flow reductions at Ice Harbor Dam.
j) Obtained/improved baseline passage metric information at upstream dams (TDA, JDA, MCN, and Snake River dams) to better determine passage problem locations.
k) Continue nighttime lamprey video window counts at BON, MCN, and Lower Granite (LWG).

l) Lifted picketed leads at BON Washington Shore AWS channel to allow improved access to LPS. Preliminary results show 3-fold increase in use of the LPS and fewer lamprey falling back through count station.

2011

- Lamprey Passage Studies Research, Design Development, and Implementation:
  a) Finalized the plans for the entrance modifications and awarded a constructioncontract for the John Day Dam (JDA) North Fish Ladder, including many lamprey improvements.
  b) McNary Dam (MCN) south ladder entrance physical model (located at Engineer Research and Development Center (ERDC) in Vicksburg, MS) was used to select a prototype lamprey entrance structure design.
  c) Continued to implement night time flow reductions at BON Washington Shore Fish Ladder and the MCN South Fish Ladder entrances.
  d)
  e) Obtained/improved baseline passage metric information at upstream dams (TDA, JDA) to better determine passage problem locations.
  f) Evaluated passage of adult lamprey behind picket leads at TDA, JDA, MCN, and Ice Harbor Dam (IHR) to determine whether video tools can be used to improve lamprey counts.
  g) Continued nighttime lamprey video window counts at BON, MCN, and Lower Granite (LGR).
  h) Continued to implement night time flow reductions at BON Washington Shore Fish Ladder and the MCN South Fish Ladder entrances.

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

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