TECHNICAL MEMORANDUM

Chelan PUD – Tumwater Fishway Improvements

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Introduction

This memorandum documents the feasibility of improvements at the Tumwater Dam Fishway to enhance the upstream migration of Pacific Lamprey (*Entosphenus tridentatus*). This memorandum also summarizes the results of an alternatives review workshop and identifies steps for implementation of the preferred alternative.

Background

Pacific Lamprey are an anadromous species historically present throughout the Columbia River system, including upstream of Tumwater Dam on the Wenatchee River. Lamprey ammocoete (larvae) were previously documented both above and below Tumwater Dam (Hays, 1981). Until recently, passage of lamprey adults via the existing fishway had not been documented since 1995 (Chelan PUD, 1995).

Adult lamprey fitted with passive integrated transponder (PIT) tags were released in the vicinity of Tumwater Dam by the Yakama Nation in August/September 2016, and again in 2017. As of September 2017, seven lamprey have been documented in the fish viewing window at Tumwater Dam (WDFW, 2017). Prior to the Yakama Nation Translocation of Lamprey in the Wenatchee in 2016 and 2017, lamprey have only been detected downstream of Tumwater Dam in the lower reaches of the Wenatchee River (Johnsen, 2012). It has been suggested that construction of the existing fishway in 1987 and the start of continuous salmon trapping operations in 2004 may have contributed to the absence of lamprey above Tumwater Dam (Rainey, 2015).

An initial assessment of lamprey passage at Tumwater Dam Fishway was prepared in 2015 (Rainey, 2015) by the U.S. Fish and Wildlife Service (USFWS). Various structural modifications were considered to facilitate passage. Any modifications adjacent to the Tumwater Dam or Fishway for lamprey passage would constitute a voluntary action on the part of the District; there is no explicit license requirement to modify the fishway to improve lamprey passage, nor is the District able to fund off-license mitigation. However, given the District's desire to conduct its operations in an environmentally-mindful way and to maintain integrity with stakeholders and customer-owners, the District is interested in exploring cost-effective ways to improve lamprey passage at the Tumwater Dam Fishway.

Purpose

The purpose of this memorandum is to document the feasibility of improving upstream passage for Pacific Lamprey at Tumwater Dam, while maintaining the continued successful passage of salmonids via the existing fishway. A total of ten alternatives were evaluated against various technical, biological, economic and other criteria. A preferred alternative is selected for further evaluation in the future.

This technical memorandum includes the following sections:

- Key Design Criteria
- Lamprey Passage Alternatives
- Evaluation Methodology and Criteria
- Alternatives Evaluation
- Preferred Alternative
- Implementation of Preferred Alternative
- Summary and Conclusions
- References
- Attachments

Key Design Criteria

Lamprey biology, migration and passage at dams is a relatively recent focus for fisheries managers in the Pacific Northwest and significant research has been undertaken in the past few years. However, much remains unknown about lamprey life history, behavior and swimming capability. As such, lamprey passage facilities are still considered experimental by many agencies, including the USFWS and the National Marine Fisheries Service (NMFS).

A site visit to Tumwater Dam (Attachment 1) and a literature review (Attachment 2) were conducted to understand existing conditions at the site and to collect available lamprey passage design criteria. The initial USFWS assessment report (Rainey, 2015) was reviewed (Attachment 3), and a biological assumptions memo (Chelan PUD, 2017) was also developed (Attachment 4). In addition, features and configurations common to existing, successful lamprey passage facilities located elsewhere in the Pacific Northwest were evaluated. The following provides a preliminary summary of lamprey passage design criteria applicable to the Tumwater Dam and fishway, including both biological, and hydrologic and hydraulic considerations. It should be noted that a key design consideration for all lamprey passage alternatives is the ability to maintain the continued successful passage of salmonids through the existing fishway.

Lamprey Biology. Key biological design criteria include the following:

- Adult lamprey likely over-winter in freshwater prior to finishing their final migration and spawning, and there is documented evidence of them spending up to two full years in freshwater prior to spawning.
- For the purposes of this study, adult lamprey migration timing in the Wenatchee River is assumed to be from late June through September (Chelan PUD, 2017). Spawn timing is assumed to be approximately June through August.
- Lamprey must travel approximately 805 river kilometers (500 miles) from the Pacific Ocean to reach Tumwater Dam in the Wenatchee River.
- Lamprey migrating upstream are attracted to the upstream terminus of flow, similar to salmonids (Rainey, 2015).
- Lamprey do not strictly avoid areas of high velocity since they are attracted to high-volume and high-velocity flow as hydraulic cues to swim upstream (USFWS, 2017).
- Lamprey avoid areas of high water velocity within fishways and seek out attachment surfaces for resting (Keefer, 2011 and USFWS, 2017).
- Lamprey are most active within fishways at night (Keefer, 2011 and Rainey, 2015).
- Maximum lamprey burst speeds are on the order of 8-9 fps and sustained swimming speeds are on the order of 2-4 fps (Kirk, 2015; Rainey, 2015 and USFWS 2017).
- Turbulence, other confusing hydraulic stimuli, and extended durations of high-velocity flows may delay and/or impede lamprey passage (USFWS, 2017).

- Lamprey have the ability to ascend steep surfaces utilizing the suction from their oral disk.
- The location of the entrance and the attractiveness of the entrance are key aspects of a lamprey passage structure (LPS).
- A maximum spacing of ¾-inch on diffusers and grating is recommended for exclusion (Moser, 2008), and smaller gaps may be warranted in the upper Columbia River basin tributaries where lamprey adults are smaller in size (USFWS, 2017).
- Rounded edges on vertical walls and plating on floor diffusers and/or grating provide lamprey attachment points for resting.
- 20-inch wide ramps with a water depth of approximately 1.2 inches have been effective for lamprey passage at the U.S. Army Corps of Engineers (USACE) Bonneville Dam and elsewhere on the main-stem Columbia River (Moser, 2010); other successful passage structures are located at low-head projects on the Umatilla River.

Based on the initial assessment (Rainey, 2015) and the results of this study, it is suspected that the following features of the existing vertical slot fishway at Tumwater Dam may impede or delay lamprey passage:

- The 12- and 24-inch high sills located at the fishway entrances and the 12-inch high sills located at each vertical slot baffle.
- The auxiliary water supply (AWS) system, including the potential for false attraction to the energy dissipation chamber adjacent to the entrance pool via the wall diffuser with 1-inch clear spaces.
- Excess energy and turbulence associated with the unique shape of the fishway pools at Tumwater, i.e. short length and wide width, in comparison to other standard vertical slot fishways.
- PIT tag detectors located at Baffle Nos. 15 and 18 which increase the length of the high-velocity jet at these baffles.
- High through-gate velocities near Pool No. 19 at the entrance to the fish trapping chamber and associated delays in the upper portion of the fishway during operation of the trap, particularly during periods of moderate to high streamflow; various trapping operations occur essentially year-round, except when the fishway is dewatered for the annual inspection and maintenance during a single week in February.
- Exposed aggregate resulting from scour and erosion in the fishway floors and walls which may affect the ability of lamprey to attach for resting in these areas; large scour areas in the Tumwater Fishway were repaired in 2015 (some small scour areas remain).

Additional lamprey biological and behavioral information is provided in the Attachments.

Hydrology and Hydraulics. The Wenatchee River within Tumwater Canyon including the spillway apron below Tumwater Dam are high-energy, turbulent environments that may present a significant obstacle to weak-swimming species such as lamprey. In general, successful lamprey passage occurs under conditions that vary substantially from conditions normally appropriate for salmonids. The numbers of adult lamprey historically moving through Tumwater Canyon, both before and after construction of Tumwater Dam, are unknown.

Streamflow and river stage information was evaluated in an attempt to characterize conditions suitable for lamprey passage. Streamflow information was obtained from USGS Gage 12457000 Wenatchee River at Plain, WA. Stage data was developed from the fishway design documents (CH2M, 1986) and field measurements taken in 2003.

The existing Tumwater fishway was designed to provide passage for salmonids up to a streamflow of approximately 6,000 cfs. This is less than the typical 5 percent exceedance high design flow of 7,500 cfs, which reflects the unique configuration of the fishway and the high energy of the River at this location within Tumwater Canyon. Per discussions with the project team, a streamflow of 3,000 cfs was identified as a potential upper limit for lamprey passage. This streamflow is exceeded approximately 24 percent of the time on an annual basis, and is exceeded approximately 47 percent of the time during the month of July. The maximum gross head at the fishway of approximately 20 feet occurs during the 95 percent exceedance low design flow. Additional hydrologic and hydraulic information is provided in Attachment 5.

Table 1. Hydrology and Hydraulics
Chelan PUD Tumwater Fishway Modifications

Design Event	Streamflow (cfs)	Headwater Stage (feet[a])	Tailwater Stage (feet[a])	Gross Head (feet)
Flood of Record (30 November 1995)	32,900	-	-	-
5 Percent Exceedance	7,500	1,490.2	1,471.8	18.4
Upper limit of Wenatchee River streamflows passable by salmonids[b,c]	6,000	1,489.6	1,471.3	18.3
Potential upper limit of Wenatchee River streamflows passable by lamprey	Say 3,000	1,488.6	1,470.3	18.3
95 Percent Exceedance	401	1,487.2	1,467.4	19.8

Table Notes:

[a] NGVD29 assumed.
[b] CH2M, 1986.
[c] Streamflow at which stop logs are installed for protection of the fishway.

Per discussions with the fishway operators, it is understood that a hydraulic differential of approximately 1.1 feet is typically maintained at the fishway entrances. This results in an average velocity of approximately 5.9 fps at the entrance. The velocity at the vertical slot baffles averages approximately 5.5 fps over the range of conditions. The centroid of the water jet at both locations will have a velocity higher than the average, while lower velocities will exist at the perimeter. The average velocities at both locations are within the burst speed capability of lamprey.

Lamprey Passage Alternatives

A total of ten lamprey passage alternatives were developed for evaluation. The following provides a brief description of each alternative and a summary of selected advantages and disadvantages. It should be noted that the order in which the alternatives are presented below reflects the order in which they were developed, not necessarily their preference for implementation.

1. Modify Existing Sluice Gate Channel. A lamprey passage entrance located on the right (southwesterly) bank may be able to take advantage of favorable river hydraulics during certain streamflow conditions. The shape of the Dam appears to direct most of the hydraulic energy towards the existing fishway on the left bank, leaving an area of calmer water adjacent to the right bank.

The right abutment of the Dam includes an abandoned penstock intake and trash sluice, both of which have been plugged with concrete. An excavated channel and ramp up to the trash sluice opening could be provided for lamprey passage. A motorized ramp weir would follow the forebay water surface elevation (WSEL) and regulate gravity flows into the passage facility. A connection to the existing single-phase power feed, as well as an instrumentation and controls (I&C) system would likely be required.

Advantages:

- Favorable approach and entrance conditions per Rainey, 2015.
- Construction could be largely independent of fish trapping activities and other ongoing operations at the existing fishway, and it would be possible to schedule the work to occur during the regulatory in-water work period (say 1 to 31 July), and/or during the late fall low-flow period on the Wenatchee River.
- No modifications with potential impacts to salmonid passage would have to be made within the existing fishway.

Disadvantages:

- Not located at upstream terminus of flow.
- Access to the right bank is difficult and would likely have to be provided via crane or trestle during construction, and via boat for year-round operations and maintenance.
- Environmental permits for work in the riparian area (below ordinary high water) would have to be obtained, likely along with an endangered species act (ESA) consultation.
- No utilities aside from single-phase power in this area.
- Field observations indicate an increased potential for lamprey to fall back over the Dam along the right bank; however, the forebay pool (Jolanda Lake) appears to be calm in this area and there may be sufficient depth below the crest of the Dam to provide refuge.
- Stakeholder perception associated with an expanded structure and/or footprint at Tumwater Dam.

Lamprey Passage Alternatives
(Not necessarily in order of preference for implementation)

1. Modify Existing Sluice Gate Chamber

2a. Channel Across Apron and Ramp Over Dam (Right Bank)

2b. Channel Across Apron and Ramp Over Dam (Left Bank)

3a. LPS Attached to Abutment (Right Bank)

3b. LPS Attached to Abutment (Left Bank)

4. LPS Within Existing Fishway

5. Ramps at Sills Within Existing Fishway

6. Orifices at Baffles Within Existing Fishway

7. Operational Modifications

8. Do Nothing

2a and 2b. Channel Across Apron and Ramp Over Dam (right and left banks). A concrete wall and/or steel panels could be used to isolate a channel against either abutment, creating a ramp utilizing the existing apron that is passable for lamprey. The PGE Willamette Falls project was noted as having similarities with this alternative. A motorized ramp weir would provide a gravity water supply.

This concept would require modifications to the physical structure of the Dam. The passage channels would also have the potential to interfere with existing modifications on the Dam and spillway apron which are intended to reduce false attraction for salmonids.

Advantages:

- Located at upstream terminus of flow (2b left bank).
- Construction could be largely independent of fish trapping activities and other ongoing operations at the existing fishway, and it would be possible to schedule the work to occur during the regulatory in-water work period (say 1 to 31 July), and/or during the late fall low-flow period on the Wenatchee River.
- No modifications with potential impacts to salmonid passage would have to be made within the existing fishway.

Disadvantages:

- Potential impacts to hydraulic capacity of the existing spillway.
- Access to the right bank is difficult and would likely have to be provided via crane or trestle during construction, and via boat for year-round operations and maintenance (2a right bank).
- Environmental permits for work in the riparian area (below ordinary high water) would have to be obtained, likely along with an ESA consultation (2a right bank).
- No utilities aside from single-phase power in this area (2a right bank).
- Stakeholder perception associated with an expanded structure and/or footprint at Tumwater Dam.
- Field observations indicate an increased potential for lamprey to fall back over the Dam along the right bank; however, the forebay pool (Jolanda Lake) appears to be calm in this area and there may be sufficient depth below the crest of the Dam to provide refuge (2a right bank).
- May impact the hydraulic signature and attraction flows at the entrances to the existing fishway (2b left bank).

3a and 3b. LPS Attached to Abutment (right and left banks). LPS structures would be placed within the spillway and braced to the abutment walls at locations similar to Alternatives 2a and 2b. Pumps or motorized ramp weirs would be utilized to provide flow into the passage facility.
Advantages:

- Located at upstream terminus of flow (3b left bank).
- Construction could be largely independent of fish trapping activities and other ongoing operations at the existing fishway, and it would be possible to schedule the work to occur during the regulatory in-water work period (say 1 to 31 July), and/or during the late fall low-flow period on the Wenatchee River.
- No modifications with potential impacts to salmonid passage would have to be made within the existing fishway.

Disadvantages:

- Susceptible to damage, especially during flood events.
- Potential impacts to capacity of the existing spillway.
- Access to the right bank is difficult and would likely have to be provided via crane or trestle during construction, and via boat for year-round operations and maintenance (3a right bank).
- No utilities aside from single-phase power in this area (3a right bank).
- Field observations indicate an increased potential for lamprey to fall back over the Dam along the right bank; however, the forebay pool (Jolanda Lake) appears to be calm in this area and there may be sufficient depth below the crest of the Dam to provide refuge (3a right bank).

4. LPS Within Existing Fishway. Fabricated aluminum ramps would be installed outside the existing fishway at the high- and low-flow entrances. Another fabricated aluminum ramp would be installed within the entrance pool and located between the first vertical slot and the AWS diffuser. The ramp would ascend upwards at a 1:1 slope and would likely be required to penetrate the first vertical slot baffle (and possibly multiple baffles). It would then travel upstream just above the deck grating in the lower fishway. The ramp would transition into the earthen fill area located between the fishway and the original left abutment of the Dam. The ramp would then either ascend to a pumped upwell box and pipe return to the forebay, or lead to a motorized ramp weir adjacent to the fishway exit pool just downstream of the trashracks. The ramp weir option would have a gravity water supply. The LPS would be covered to avoid bird and carnivore predation.

Advantages:

- Less susceptible to damage from flood events.
- Good site access for operations and maintenance.
- Utilities readily available.
- Environmental and permitting requirements are minimized relative to the other alternatives; however, an ESA consultation would still likely be required.

Disadvantages:

- Construction would be dependent on salmon trapping activities and other ongoing operations at the existing fishway.
- The LPS has the potential to impact salmonid passage, particularly within the entrance pool, and may require prototyping and/or additional modifications to minimize such impacts.

5. Ramps at Sills Within Existing Fishway. Fabricated aluminum ramps would be installed outside the existing fishway at the high- and low-flow entrances. Additional fabricated aluminum or concrete ramps would be installed at the 12-inch tall sills located at each vertical slot baffle (19 total). Modifications to the upper fishway including the trapping chamber would be required to facilitate lamprey passage during operation of the trap. The floor diffuser at this location may have to be replaced or modified with aluminum plate. An LPS could also potentially be required within the fish trapping chamber to provide an expedited route to the forebay for lamprey.

Advantages:

- Less susceptible to damage from flood events.
- Good site access.
- Power and other utilities are readily available.
- Environmental and permitting requirements are minimized relative to the other alternatives; however, an ESA consultation would still likely be required.
- Low capital costs.
- Minimal operations & maintenance (O&M) requirements.

Disadvantages:

- Construction would be dependent on salmon trapping activities and other ongoing operations at the existing fishway.
- Modifications within the existing fishway could have potential impacts to salmonid passage, with slightly greater impacts than Alternative No. 4, due to the need to modify the vertical slots in each pool and to make modifications within the trapping chamber.

6. Orifices at Baffles Within Existing Fishway. Fabricated aluminum ramps would be installed outside the existing fishway at the high- and low-flow entrances. Orifices would be constructed through the side of each baffle wall, flush with the floor near the corner of the pool where velocities are relatively low. This work could likely not be accomplished with a coring machine, and would require removal of a larger piece of the baffle wall. The orifice would then be formed and cast. Similar to Alternative No. 5, modifications to the trapping chamber floor diffuser and the provision of an LPS at this location could also potentially be required.

Advantages:

- Less susceptible to damage from flood events.
- Good site access.
- Power and other utilities are readily available.
- Environmental and permitting requirements are minimized relative to the other alternatives; however, an ESA consultation would still likely be required.
- Minimal operations & maintenance (O&M) requirements.

Disadvantages:

- The construction schedule is depended on salmon trapping activities and other ongoing operations at the existing fishway.
- Modifications within the existing fishway have the potential to impact salmonid passage.

7. Operational Modifications. This alternative considers potential modifications to operation of the existing fishway and trap to improve lamprey passage. Such modifications could include reduction in AWS flows during the night to reduce velocities at the fishway entrance, suspension of trap operations during periods of peak lamprey migration, and/or other operational changes. Operational modifications have the potential to be implemented independently or in conjunction with other lamprey passage alternatives.

Advantages:

- No construction impacts.
- Environmental and permitting requirements are minimized.
- Relatively easy to implement, evaluate and adapt.

Disadvantages:

- Could affect the District's ability to meet HCP hatchery and permit obligations.
- Operational modifications alone may not be sufficient to provide adequate passage for lamprey.

8. Do Nothing. This alternative would maintain the status quo, with no improvements or modifications at the Tumwater Dam or Fishway to improve lamprey passage.

Advantages:

- Requires no further investment of time or resources by the District.
- Allows additional lamprey passage research and development to occur elsewhere before a system is implemented at the Tumwater Dam or Fishway.

Disadvantages:

- Does not address stakeholder concerns.

Evaluation Methodology and Criteria

The ten alternatives were evaluated according to various technical, biological, economic and other criteria as described in the Cost/Benefit Evaluation Matrix in Attachment 6. The alternatives were rated on a scale of one to five, with five being the best, and then ranked according to their total rating. The evaluation criteria were also individually weighted in an effort to consider their relative importance. Impacts to current operations and all biological criteria were deemed the most important. A gravity vs. pumped water supply, and the ability to prototype and/or test, were deemed the least important criteria.

Alternatives Evaluation

Alternative No. 4, *Lamprey Passage System (LPS) Within Existing Fishway,* was ranked the highest out of the ten alternatives. It provides very good biological performance while minimizing O&M requirements as well as risks due to permitting. Conceptual figures of this alternative are provided in Attachment 7.

Alternative No. 5, *Ramps at Sills Within Existing Fishway,* was ranked second even though it is anticipated to have poor biological performance (due to the configuration of the existing trap) and greater impacts to current operations at Tumwater Dam Fishway. Lamprey passage issues related to the configuration of the trap and trapping operations at Tumwater Dam Fishway are not specifically addressed by this alternative. However, this alternative is similar in concept to ramps installed at Rocky Reach in 2011 and 2012 that significantly improved lamprey passage. Conceptual figures of this alternative are provided in Attachment 7.

The alternatives located on the right bank (Alternative Nos. 1, 2a, 3a) were generally ranked low due to concerns related to site access both during construction and long-term operations, the lack of utilities and potential environmental impacts and permitting requirements. Alternative No. 8, *Do Nothing*, was also ranked low given the District's values of stewardship and trustworthiness for customer-owners and stakeholders.

Preferred Alternative

Alternative No. 4, *Lamprey Passage System (LPS) Within Existing Fishway,* appears to best meet the defined criteria while achieving overall project objectives. The LPS would include the following key features:

- Ramps at existing fishway entrances.
- LPS entrance ramp.
- LPS transport ramp and rest boxes.
- LPS exit structure.

Ramps at existing fishway entrances. The existing fishway includes three entrances. The low- and high-flow entrances would be modified with aluminum ramps to provide a transition from the existing concrete sill to the perched invert of the gate opening. The middle entrance would not be modified. The ramp at the low-flow entrance would be approximately 12 inches high and the ramp at the high-flow entrance would be approximately 24 inches high. Primary slopes of approximately 2H:1V and 1H:1V respectively would be provided. Small adjustments to these dimensions may be necessary given the planned installation of PIT tag detectors at the entrances. It is anticipated that the ramp modifications would have little to no impact on salmonid passage.

It is anticipated that the ramps would be fabricated from ¼-inch aluminum or steel plate and would be anchored to the existing concrete with adhesive anchors. Special attention would be required to ensure the ramps are free from burrs and sharp edges, and fit tightly against existing surfaces to minimize gaps. It is anticipated that a cofferbox with a dewatering system and/or dive work would be required to facilitate installation of the ramps.

If the entrance ramps alone are found to be ineffective at attracting lamprey into the fishway, operational measures such as nighttime flow reductions could also be implemented. This would include nightly throttling or shutdown of the AWS system. Associated flow reductions could reduce the average velocities at the fishway entrances from approximately 5.9 to 4.4 cfs, which would presumably be easier for lamprey to negotiate. The AWS system is not automated so additional staff time would be required to implement this measure. In addition, the potential for negative impacts to salmonid passage should be considered.

LPS entrance ramp. The entrance ramp would likely be located within the existing fishway entrance pool and would consist of an open-top aluminum ramp 20 inches wide and rising on a 1H:1V slope. The ramp would ascend through a saw-cut opening in the first vertical slot baffle and guide lamprey into Rest Box No. 1, located above existing fishway Pool No. 2. The specific location, configuration and number of entrance ramps would need to be determined during design. Based on the site visit, a location approximately five feet downstream of the first baffle and immediately adjacent to the AWS system wall diffuser appears to provide an ideal location for the toe of the entrance ramp.

Prototype testing is recommended to allow optimization of the LPS entrance location and configuration. Initial testing could potentially consist of only the entrance ramp and first rest box to confirm their effectiveness prior to implementing the remainder of the improvements. A temporary water supply with backup would be provided. The ramp and rest box would accommodate cameras and perhaps PIT tag detectors to support monitoring efforts. It is anticipated that any collected lamprey would be transported by hand by District staff from the rest box to the forebay. This prototype program would allow for the rapid testing and evaluation of multiple entrance configurations.

The need for modifications to the existing AWS system wall diffuser could also be evaluated at this time. The existing wall diffuser has 1-inch clear gaps which exceed the ¾-inch gaps recommended for lamprey exclusion (Moser, 2008). Operational modifications, for example reduced flow at night and/or suspension of trapping operations, could also be evaluated.

LPS transport ramp and rest boxes. The first rest box would provide a 90-degree turn and the ramp would continue ascending through the deck grating to Rest Box No. 2 located on the south side of the existing fishway near Pool No. 2. The transport ramp would then continue ascending at an approximate 8H:1V slope, matching the slope of the existing fishway for a distance of approximately 180 feet. A third rest box would be located near Pool No. 10 and a fourth rest box would be located near the upwelling box and exit pipe located near the existing fishway exit. The total elevation gain would be approximately 37 feet from the invert of the entrance pool water surface elevation of approximately 1,463.2 to a location approximately 4 feet above the deck at the fishway exit at elevation 1,500.0.

The ramp and rest box structures of the LPS would be constructed from ¼ inch polished aluminum, providing a hard, smooth surface for effective lamprey attachment, and stainless steel fasteners to minimize corrosion (Moser, 2011). The cross section of all ramps would be rectangular, with a width of 20 inches and a height of 6 inches. Similar dimensions were found to be effective for lamprey passage at existing facilities at the USACE Bonneville Dam and elsewhere (Moser, 2011 and Zorbott, 2015).

Rest boxes are similar to resting pools in salmonid fishways and are beneficial for passages with long transport ramps or passages that have a significant elevation gain (Keefer, 2011). In addition to providing an area for lamprey to rest, they can be utilized to facilitate transitions at turns or angle points within the LPS. The entrance into each rest box would utilize a plastic mesh fyke to prevent drop-back of lamprey ascending the LPS (Moser, 2010). The upstream wall of each rest box has a 1H:1V slope to eliminate any sharp corners that would impede passage. Each rest box would be specifically designed to accommodate the available space and required geometry, but would provide a minimum water volume of approximately 15 to 20 cubic feet (Moser, 2006). Each box would include a drain. Provisions for video cameras and/or visual observation by the operators would also be made.

LPS exit structure. At the upstream end of the LPS, lamprey would ascend through an upwelling box providing attraction flows and then fall through the exit pipe into the forebay. The exit pipe would be lined with a perforated plastic mesh, and would be sufficiently angled to prevent lamprey attachment while minimizing impact velocities into the forebay. The total drop height would range from approximately 10 to 13 feet for the headwater elevations associated with the 5 and 95 percent exceedance streamflows respectively.

The water supply into the upwelling box would be regulated to maintain a depth of approximately 1.2 inches (3 cm) (Moser, 2006) on the ramps sloped at 8H:1V. Approximately 0.7 cfs of flow would be necessary to maintain this depth. An additional flow of approximately twice this amount, or 1.4 cfs, would be directed with flow vanes towards the forebay to swiftly convey lamprey through the exit pipe. As such, the total flow necessary would be on the order of 2.1 cfs. An approximate 6 to 10 horsepower pump would provide this water supply. The pump would be located in the existing intake bay downstream of the AWS trashracks. A backup pump could be provided if necessary. An approximate 8-inch diameter discharge would be required. It is anticipated that the existing power supply would be adequate; however, this should be evaluated as part of the design. Single-phase motors may also be available.

A gravity-fed system utilizing a motorized ramp gate located adjacent to the fishway exit pool was evaluated; however, this arrangement would drive the entire LPS below the deck of the existing fishway and would require the negotiation of many more structural conflicts.

Implementation of Preferred Alternative

Construction would likely utilize the typical fishway outage period during the month of February. An extension of this typical outage may be necessary; however, it is anticipated that metal fabrication and preparatory work for components located above the fishway deck could take place outside this period.

Development of a detailed design should consider how the ramps located at the existing fishway entrances would be installed. It is anticipated that a cofferbox with a dewatering system and/or dive work may be necessary. Such activities could have a significant impact to the overall cost of the project. Also, given the typical weather conditions in February for the project site, special provisions may be necessary to accomplish the work.

Order-of-magnitude construction costs were developed for the preferred alternative, and are consistent with an Association for the Advancement of Cost Engineering (AACE) International Class 5 estimate (+100%, -50%). The base construction cost estimate is $490,000 (year 2016 $), and may potentially vary from approximately $245,000 to $980,000, depending on the final scope of the project. Additional detail for this estimate is provided in Attachment 9. Construction costs were also developed for Alternative No. 5 (the second-highest ranked alternative) for comparison.

Other considerations for implementation of the preferred alternative include the following:

- A comprehensive permitting strategy should be developed, including coordination with the Rocky Reach Fish Forum (RRFF) and the Habitat Conservation Plan (HCP) Coordinating and Hatchery Committees; it is anticipated that a Biological Assessment (BA) would be required. In addition, FERC must approve any proposed modifications to the fishway prior to construction.
- Prototype testing, including identification of an optimal LPS entrance location and configuration, should be assumed as part of the overall project.
- The need for modifications to the existing AWS wall diffuser along with any operational modifications to facilitate lamprey passage should also be evaluated.
- The configuration of any water supply piping and/or the LPS on the deck of the existing fishway structure should be reviewed in light of operator safety considerations, i.e. trip and/or fall hazards.
- The current electrical system at the facility should be evaluated to determine the need for single- or three-phase pump motors and the need for a backup power supply.
- Modifications to the existing I&C system, including alarms, should be included to notify operators of issues such as pump failures, etc.
- A biological monitoring and evaluation (M&E) plan should be developed in conjunction with the prototype LPS to evaluate the effectiveness of the entrance and overall lamprey passage.
- The provision of video cameras and/or PIT tag detectors within the LPS may be required to support M&E objectives.

- The project should be coordinated with other efforts to enhance lamprey passage throughout the Wenatchee River as they arise, for example additional radio-telemetry studies and/or the introduction of juveniles upstream to establish pheromone scent to attract adults.

Summary and Conclusions

Project implementation would require coordination with the agencies and the approval of the HCP Coordinating Committee and FERC. Prototype hydraulic testing and a biological M&E program would be proposed to facilitate this process. Key issues to be addressed are the need for, and the location and configuration of the LPS entrance; the need to modify the existing AWS wall diffuser; the need for operational modifications; and the timing of in-water work during construction.

Potential risks and uncertainties include the following:

- Modifications to the existing fishway may result in impacts to existing salmonid passage; however, such impacts are assumed to be minimal with the preferred alternative and would be confirmed during final design.
- Any modifications to the existing fishway could require federal ESA consultation and FERC approval for listed species using the existing fishway, due to its association with the Rocky Reach license.
- Lamprey life history, behavior and swimming capability is not well understood and as such, design criteria is not well established; lamprey passage systems are considered experimental technology.
- Ongoing prototype testing and/or monitoring and evaluation programs may be required.
- It is anticipated that the actual construction work would be limited to periods when the existing fishway is not in operation, or when operations can be suspended for a short time to allow construction of key components while minimizing impacts to salmon and steelhead. The work should be carefully planned to not impact the District's ability to meet its HCP hatchery obligations. The limited work windows, potentially in winter months with adverse weather conditions and in-water work, may increase construction costs and the time required to implement a project.

References

Bonneville Power Administration (BPA) Office of Power and Resources Management. 1986. *Environmental Assessment, Tumwater Dam and Dryden Dam Fish Passage Projects.* January

CH2M HILL. 1986. *Fishway Headwater and Tailwater Rating Curve Development.* Prepared for PUD No. 1 of Chelan County, WA. 2 January.

CH2M HILL. 1986a. *Biological Criteria Affecting Design and Construction of Fisheries Facilities at Tumwater and Dryden Dams.* Prepared for PUD No. 1 of Chelan County, WA. 9 January.

CH2M HILL. 1986b. *Tumwater/Dryden Fishways and Dryden Weir.* Record Drawings. April.

Chelan PUD. 1995. *Tumwater Fishway Daily Report of Fish Counters, 14 July 2015.*

Chelan PUD. 2004. *Tumwater Dam, Fish Passage and Wild Stock Supplementation and Collection Improvements.* Presentation by Gene Yow, Shaun Seaman and Courtney Hill. 11 October.

Chelan PUD. 2010. *Rocky Reach Fishway Modifications for Improved Lamprey Passage – Phase I, Small Works Project No. 10-SW21.* Construction Drawings. 10 December.

Chelan PUD. 2012. *Rocky Reach Fishway Modifications for Improved Lamprey Passage – Phase II.* Construction Drawings. 24 February.

Chelan PUD. 2012a. *Tumwater Fishway Operations and Maintenance Instructions (OMI).* 30 January.

Chelan PUD. 2015. *Annual Fish Counts – Rocky Reach and Rock Island Dams, 1995-2015.*

Chelan PUD. 2017. *Pacific Lamprey Biological Knowledge and Assumptions Supporting the TWD Lamprey Passage Feasibility Study.* 31 January.

Hays, Steve. 1981. *Tumwater Dam Redevelopment, Fisheries Surveys.* USFWS.

Hemstrom, Steve. 2016. *Pacific Lamprey Migration in the Mid-Columbia: A Review of Adult Passage at Rocky Reach Dam.* Public Utility District No. 1 of Chelan County, WA. Presented to American Fisheries Society. March.

Johnsen, A. and Nelson, N.M. 2012. *Surveys of Pacific Lamprey Distribution in the Wenatchee River Watershed 2010-2011.* U.S. Fish and Wildlife Service, Leavenworth, WA.

Keefer, M.L. and Moser, M.L., et. al. 2009. *Effects of Body Size and River Environment on the Upstream Migration of Adult Pacific Lampreys*. North American Journal of Fisheries Management.

Keefer, M.L. and Moser, M.L., et. al. 2011. *Behavior of Adult Pacific Lamprey in Near-Field Flow and Fishway Design Experiments.* Department of Fish and Wildlife Sciences, College of Natural Resources, University of Idaho. Northwest Fisheries Science Center, National Marine Fisheries Service. Fisheries Management and Ecology Journal. 18: 177-89.

Kemp, Paul. S., et. al. 2010. *The Influence of Discharge and Temperature of the Ability of Upstream Migrant Adult River Lamprey (Lampetra Fluviatilis) to Pass Experimental Overshot and Undershot Weirs.* School of Civil Engineering and the Environment, University of Southampton.

Kirk, Mark A., et. al. 2015. *Characterization of Adult Pacific Lamprey Swimming Behavior in Relation to Environmental Conditions within Large-Dam Fishways.* Department of Fish and Wildlife Sciences, College of Natural Resources, University of Idaho. Transactions of the American Fisheries Society.

Lampman, Ralph. 2015. *Tumwater Dam Fish Ladder Investigations, Yakama Nation Fisheries Resources Management Program, Pacific Lamprey Project.* 18 February.

Moser, M.L., et. al., 2006. *Development and evaluation of a lamprey passage structure in the Bradford Island auxiliary water supply channel, Bonneville Dam, 2004. Seattle, Northwest Fisheries Science Center, National Marine Fisheries Service.*

Moser, M.L., et. al., 2008. *Grating size needed to protect adult Pacific lampreys in the Columbia River basin.* North American Journal of Fisheries Management, 28(2), pp.557-562.

Moser, M.L., et. al. 2010. *Development of passage structures for adult pacific lamprey at Bonneville Dam, 2007-2008. Report to US Army Corps of Engineers, Portland District, Portland, Oregon*.

Moser, M.L. et. al. 2011. *Development of Pacific Lamprey Fishways at a Hydropower Dam.* Northwest Fisheries Science Center, National Marine Fisheries Service. Fisheries Management and Ecology. 18: 190-200.

Ott Water Engineers. 1984. *Final Report, Tumwater Falls and Dryden Dam Fish Passage Project.* Prepared for BPA. May.

Rainey, Steve, et. al. 2015. *Draft Rapid Assessment of Adult Lamprey Passage at Tumwater Dam*. 4 August.

Reinhardt, U.G., et. al. 2008. *Pacific Lamprey Climbing Behavior.* NRC Press. September

Tackley, Sean C. 2013. *Adult Pacific Lamprey Passage at Mainstem Columbia and Snake River Dams: An Overview of Efforts by the U.S. Army Corps of Engineers. U.S. Army Corps of Engineers, Portland District.*

U.S. Army Corps of Engineers. 2009. *Pacific Lamprey Passage Improvements Implementation Plan 2008-2018.* July.

U.S. Fish and Wildlife Service. 2010. *Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (Entosphenus tridentatus).* April.

U.S. Fish and Wildlife Service. 2017. *Technical White Paper: Practical Guidelines for Incorporating Adult Pacific Lamprey Passage at Fishways April 2017 FINAL DRAFT to the Lamprey Technical Workgroup.* 25 April.

Washington Department of Fish and Wildlife. 2017. Personal Communication by Catherine Willard, Chelan PUD. 14 September.

Zorbott, Hattie, et. al. 2015. *Technical Report 2015-5 Design Guidelines for Pacific Lamprey Passage Structures*. Prepared for U.S. Army Corps of Engineers, Portland District.

Attachments

Attachment 1 – Kickoff Meeting and Site Visit Notes
Attachment 2 – Literature Review
Attachment 3 – Initial Assessment Report
Attachment 4 – Biological Assumptions Memorandum
Attachment 5 – Hydraulics and Hydrology
Attachment 6 – Alternatives Review Workshop Notes
Attachment 7 – Conceptual Figures
Attachment 8 – Construction Schedule
Attachment 9 – Construction Cost Estimates

Attachment 1 – Kickoff Meeting and Site Visit Notes

Chelan PUD Tumwater Fishway Modifications – Kick-off Meeting and Site Visit

ATTENDEES:

Ian Adams/Chelan PUD
Justin Fletcher/Chelan PUD
Steve Hemstrom/Chelan PUD
Chris Nystrom/Chelan PUD
Alene Underwood/Chelan PUD
Aaron George/CH2M
James Kapla/CH2M

PREPARED BY: CH2M

LOCATION: Chelan County PUD Headquarters, Wenatchee, WA (Kick-off Meeting)
Tumwater Dam, Leavenworth, WA (Site Visit)

MEETING DATE: 2 August 2016

Action Items

No.	Responsibility	High Priority	Date Completed	Task Description
1	Chelan PUD or CH2M	X	22 Aug 2016	Locate copy of original Fishway Supporting Design Report (circa 1986), including headwater and tailwater curves.
2	Steve Hemstrom/ Chelan PUD		8 Aug 2016	Provide brief summary of historical lamprey presence in the Wenatchee River, and associated River hydraulics/geomorphology.
3	Chelan PUD			Provide details of proposal to install PIT tag detector at baffle located immediately upstream of the fishway entrance pool; District noted internal discussion of this item would occur during the first week of August.
4	Chelan PUD and CH2M	X	Ongoing	Locate literature/papers concerning lamprey passage methods, criteria and guidelines employed in the Columbia River basin and elsewhere.
5	Chelan PUD		4 Aug 2016	Provide a copy of current fishway and trap OMI.
6	Justin Fletcher/ Chelan PUD		4 Aug 2016	Provide summary of District's "business case" outline for consideration when developing the Feasibility Study.
7	CH2M		22 Aug 2016	Provide copy of proposed outline for Feasibility Study.
9	Justin Fletcher/ Chelan PUD		5 Aug 2016	Provide photos of lamprey ramps added to the flow regulation section of Rocky Reach fishway.
10	Steve Hemstrom/Chelan PUD		16 Aug 2016	Provide USFWS reference for recommended AWS diffuser gap size. USFWS recommends 1.9-centimeter gaps (0.748 inches).
11	Justin Fletcher/ Chelan PUD	X	3 Aug 2016	Confirm proposed Workshop date of 23 August.

Notes

Kick-off Meeting – 9:00 a.m. to 11:30 a.m.

Introduction:

Name	Role
Ian Adams/Chelan PUD	Hatcheries Operations and Maintenance Coordinator
Justin Fletcher/Chelan PUD	District Project Manager
Steve Hemstrom/Chelan PUD	Senior Fisheries Biologist
Chris Nystrom/Chelan PUD	Fishway Operator
Alene Underwood/Chelan PUD	Fish and Wildlife Manager
Aaron George/CH2M	Civil/Hydraulics Engineer
James Kapla/CH2M	CH2M Project Manager

Project Overview

1. Purpose and regulatory drivers; stakeholders

    - The Tumwater Dam is not a FERC-licensed facility since it doesn't generate power; however, the fishway and trap are included in the 2009 Rocky Reach FERC license due to the broodstock collection that occurs on-site. This activity supports project obligations associated with the Rocky Reach Habitat Conservation Plan (HCP).
    - The Rocky Reach Fish Forum (RRFF) guides implementation of water quality and non-salmon fish measures in the Rocky Reach FERC license. The HCP is implemented via the HCP Coordinating Committee which has purview over the passage of Plan species at Tumwater Dam, and would likely be involved in the review of any proposed modifications. The HCP Hatchery Committee is concerned with operation of the trap and broodstock collection to meet project obligations.
    - All parties to the RRFF are interested in and are advocates for lamprey passage at Tumwater Dam. The final Feasibility Study will be shared with all interested stakeholders, including at a minimum the Yakama Nation, USFWS and WDFW.
    - Any modifications to the Tumwater Dam or fishway for lamprey passage would constitute a voluntary action on the part of the District, meaning there is no license requirement to modify the fishway. The proposed project however aligns with the District's values of stewardship and trustworthiness for customer-owners and stakeholders.

2. Existing studies, information and data

    Historical Presence

    - Very limited evidence exists of lamprey located upstream of Tumwater Dam (Hays, 1981); however, it is assumed that they were historically present in this reach, at an unknown abundance. Electrofishing efforts above Tumwater Dam a few years ago found no juvenile lamprey.

- Lamprey are known to pass Dryden Dam (located downstream from Tumwater); however, their numbers and passage route (i.e., over the dam or through the fishways) are unknown. Lamprey passage has also been documented in the Yakima River Basin (at the Roza and Cowiche Dams), and in the Umatilla River.
- It is suspected that juvenile pheromones attract the adult lamprey upstream. No juvenile lamprey are known inhabit areas upstream of Tumwater dam; therefore, it is assumed that very few, if any, adults would move upstream without juveniles being planted.
- The Yakama Tribe recently reintroduced adult lamprey above Tumwater Dam. Approximately 100 adults were released into and above Lake Jolanda, 30 were released within the fishway, 30 were released just downstream of Tumwater Dam, and 50 were released in the lower Wenatchee River. Up to 600 lamprey will be released next year in the Columbia River.

<u>Studies and Data</u>

- **2015 Draft Rapid Assessment of Adult Pacific Lamprey Passage at Tumwater Dam.** Data in this report should be independently verified. The District noted that there is uncertainty surrounding conclusions made in the report regarding lamprey and salmon behavior. It was noted that spawning is estimated to occur in June and July, but this is not definitively known. More data will be available after this coming year when additional passive integrated transponder (PIT) tag data is available from the District's 2016 passage and escapement study.
- **2004 Radio-telemetry Study.** It was noted that the river geomorphology and hydraulics between Dryden Dam downstream and Tumwater Dam are likely barriers to lamprey passage during certain streamflow conditions, especially large flow events. In addition, radio tags are documented to cause detrimental effects to adult lamprey physiology and swimming capability.

<u>Existing Fishway</u>

- All three Tumwater Dam fishway entrances are utilized at different times depending on tailwater depth. The "middle" entrance is used the least. This year for example, the fishway entrance was transitioned directly from the "lower" entrance to the "upper" entrance when streamflows decreased.
- The vertical slots within the Tumwater fishway are 12 inches wide and sills are installed at the invert. It is suspected that the sills may adversely impact or block lamprey passage. Exposed aggregate within the fishway walls and floors may also affect the ability of lamprey to attach and then burst-swim through these areas.
- Any modifications to the existing fishway pools will need to consider the resulting pool volume and energy dissipation factor (EDF).
- The District is also evaluating changes to the existing Alaskan steeppass entrance to the trap, which is currently 14 inches wide and may be too small for some salmonids.
- The existing power supply at the site should be adequate to run a small pump. The existing power is single phase with no backup.
- The USFWS has specifications for clear gap spacing at auxiliary water supply (AWS) system diffusers for lamprey of 1.9 cm (0.748 inches). On the lower Columbia River, ¾-inch clear spacing is typical.

- Continuous trapping (24 hours per day/7days per week) was conducted from 2004 to 2010; however, it was determined that associated delays and over-crowding were causing salmon and steelhead to reject the fishway. Operations have been modified accordingly, with continuous trapping now only taking place from approximately March through 15 July.
- The fishway has existing PIT tag detectors at pools 15 and 18. Another PIT tag detector will be installed at the first baffle in February 2017.
- NMFS requires fishways to provide passage for a broad range of streamflows from 95% to the 5% exceedance. Flows greater than 6,000 cfs at Tumwater Dam make passage difficult for salmonids. Any fishway modifications for lamprey would likely target a narrower range of streamflows, including typical streamflows during the period of migration, and other times when conditions are optimum for lamprey passage.
- Streamflow data should be obtained from USGS Gage Station 12457000 Wenatchee River at Plain, WA.

3. Project scope, schedule and deliverables
    - CH2M will provide an outline of the Feasibility Study at the Alternatives Review Workshop. The District requests a standalone CH2M report that will be utilized to generate an internal District "business case" document.
    - The Feasibility Study schedule will be shifted approximately 1 week later than shown on the original schedule due to the later notice to proceed. A preliminary date of Tuesday 23 August is proposed.
    - It was noted that the District initially planned for possible construction of modifications in 2018, should permits be obtained in a timely manner. However, construction in 2019 was discussed as possibly being preferable to allow adequate time to explore the various alternatives and to coordinate with interested parties. The schedule is flexible since this is a voluntary project.
    - It is anticipated that the actual construction work will be limited to periods when trapping is not taking place within the existing fishway. The limited work window, potentially in winter months with adverse weather conditions, may increase construction costs.

Preliminary Discussion of Alternatives

Right Bank

1. **Modify existing sluice gate channel**. A fishway entrance located on the right bank may be able to take advantage of favorable river hydraulics during certain streamflow conditions for lamprey approaching the Dam from this area. The shape of the Dam appears to direct most of the hydraulic energy towards the existing fishway on the left bank, leaving an area of calmer water next to the right bank. A lamprey passage entrance in this location has also been noted as being preferred by Steve Rainey, USFWS consultant.

   The right abutment of the Dam includes a penstock intake and trash sluice, both of which have been plugged with concrete. An excavated channel and ramp up to the trash sluice opening could be provided for lamprey passage. A motorized ramp weir would follow the forebay and regulate flows into the fishway. A power feed and instrumentation and controls (I&C) would likely be required; however, it may be possible to use solar panels and a battery to operate this system.

If found to be a good option from a biological and engineering perspective, then it may be worth pursuing the environmental permits for development of the right bank, in conjunction with obtaining an agreement from FERC that Tumwater Dam will not be drawn into the Rocky Reach license. It is noteworthy that WDFW has stated openly that it is not in favor of a right bank fishway due to the environmental impacts associated with developing access to the site, particularly related to the removal of riparian vegetation.

Potential advantages include the following:

- The construction schedule can be largely independent of salmon trapping activities and other ongoing operations at the existing fishway, and it would be possible to work in the fall during the low-flow conditions on the Wenatchee River, say 1 to 31 July.
- No modifications with potential impacts to salmonid passage would have to be made within the existing fishway.

Potential disadvantages include the following:

- Stakeholder perception that this could be a modification to the Dam structure itself.
- Access to the right bank is difficult and would likely have to be provided via crane or trestle during construction, and via boat for ongoing operations and maintenance. Environmental permits for work in the riparian area (below ordinary high water) would also have to be obtained.
- There is believed to be increased potential for lamprey to fall back over the Dam along the right bank, although this issue is not well defined at this point. The forebay pool (Jolanda Lake) appears to be calm in this area and there may be sufficient depth below the crest of the Dam to provide refuge.

<u>Right or Left Bank</u>

1. **Channel across apron and ramp over dam.** A concrete wall and/or steel panels could be used to isolate a channel against either abutment, creating a natural ramp passable for lamprey. The PGE Willamette Falls project was noted as having similarities with this alternative. A motorized ramp weir would provide a gravity water supply.

   This concept would require modifications involving the actual dam structure and has the same potential to draw the project into the Rocky Reach license as noted above for the right bank passage alternative. The modifications would also have the potential to interfere with previous modifications on the dam and apron which are intended to reduce attraction for salmonids.

<u>Left Bank</u>

1. **Lamprey passage system (LPS) within existing fishway.** Fabricated steel ramps would be installed outside the existing fishway at the upper and lower entrances. Another fabricated steel ramp would be installed within the entrance pool and located between the first vertical slot and the AWS diffuser. The ramp would ascend upwards at a 1:1 slope and would likely be required to penetrate the first baffle (and possibly multiple baffles). It would then travel upstream just below the grating in the lower fishway. The ramp would transition into the earthen fill area located between the fishway and the original left abutment of the dam. The ramp would then re-enter the fishway in the exit pool just downstream of the trashracks. The ramp would be covered to avoid bird and carnivore predation, and would have either a gravity water supply (via motorized ramp weir) or a pumped water supply.

2. **Ramps at sills within existing fishway.** Fabricated steel ramps would be installed outside the existing fishway at the upper and lower entrances. Additional fabricated steel ramps would be installed at the 12-inch wide sills at each vertical slot (19 total). An LPS would also be

required within the fish trapping chamber. The floor diffuser at this location would likely have to be replaced.

It was noted that it is likely best to have lamprey separated near the entrance to the fishway (Left Bank Alternative No. 1) due to large influxes of sockeye that cause crowding. When the fishway becomes crowded it could cause lamprey to reject the fishway.

3. **Orifices at baffles within existing fishway.** Fabricated steel ramps would be installed outside the existing fishway at the upper and lower entrances. Orifices would be constructed through the side of each baffle wall, flush with the floor near the corner of the pool where velocities are relatively low. This work could likely not be accomplished with a coring machine, and would require removal of a larger piece of the baffle wall. The orifice would then be formed and cast. An LPS would also be required within the fish trapping chamber. The floor diffuser at this location would likely have to be replaced.

Site Visit – 1:30 p.m. to 3:45 p.m.

- At the time of site visit, discharge of the Wenatchee River was approximately 910 cfs at USGS gage 12457000 Wenatchee River at Plain, WA.
- The discharge of the Wenatchee River was approximately 1,340 cfs at USGS gage 12459000 Wenatchee River at Peshastin, WA.

AWS System

- One slide gate controls water withdrawals through all three AWS trashracks in the forebay.
- If lamprey were to utilize the existing fishway, it would be difficult to exclude them from the AWS energy dissipation chamber adjacent to the fishway entrance pool.
- The existing AWS diffuser wall screens at the entrance pool have an open spacing of approximately one inch, and require cleaning every two weeks on average. If these diffusers were changed to a finer spacing, velocities would increase, and debris cleaning would be required on a more frequent basis.
- Wall diffuser velocities appear to be highest at the downstream end of the entrance pool, with a relatively calm area located adjacent to the first baffle.
- It is anticipated that velocities further upstream within the AWS system, namely the 36–inch diameter conveyance pipe, prohibit lamprey passage via this route.

Fishway

- The two fishway exit trashracks are located directly downstream from the AWS entrances. Flows into the fishway, or alternatively the trapping chamber, are controlled by several slide gates.
- At time of site visit, water depth at fishway entrance staff gage was approximately 4’-6”.
- The fishway operators try to maintain a 1.1-foot differential across the fishway entrance gate as measured by the staff gages. Per the operators, the fishway can be operated without any AWS water while still maintaining a 0.6 to 0.7 foot differential.
- Spalling of concrete was primarily visible on the abutment wall that is part of the original dam structure. It runs parallel with the upper portion of the fishway, from approximately Pool No. 9 to the exit pool. Spalling is occurring to a lesser extent on the lower portion of the fishway wall exposed to the river which abuts the concrete apron of the Dam. It is understood that areas of aggregate are exposed in selected areas within the fishway itself.

- The fishway entrance gates may need to be replaced in the near future according to District staff.
- If separate lamprey passage is implemented, potential delay for salmonids within the existing fishway will need to be addressed.
- It was noted that there was likely more potential for fallback of lamprey over the top of the dam if they were to exit a fishway located on the right bank. This is because they would have to traverse parallel alongside the upstream face of the Dam to continue their up-river migration. A left bank passage route would allow lamprey to swim upstream and away from the Dam as soon as they exit.
- It is unknown if lamprey desire to pass Tumwater Dam given that juvenile lamprey pheromone signal is no longer present upstream. One potential passage issue identified for adult lamprey is the 24 hour/7 days per week broodstock trapping in the fishway.

Figure 1. Fishway Entrance, Right Abutment and Tailwater
Chelan PUD Tumwater Fishway Modifications

Figure 2. Left Abutment and Fishway
Chelan PUD Tumwater Fishway Modifications

Figure 3. Fishway Exit and Trap Area
Chelan PUD Tumwater Fishway Modifications

Figure 4. Fishway Vertical Slot, Modified from 15 to 12 inches
Chelan PUD Tumwater Fishway Modifications

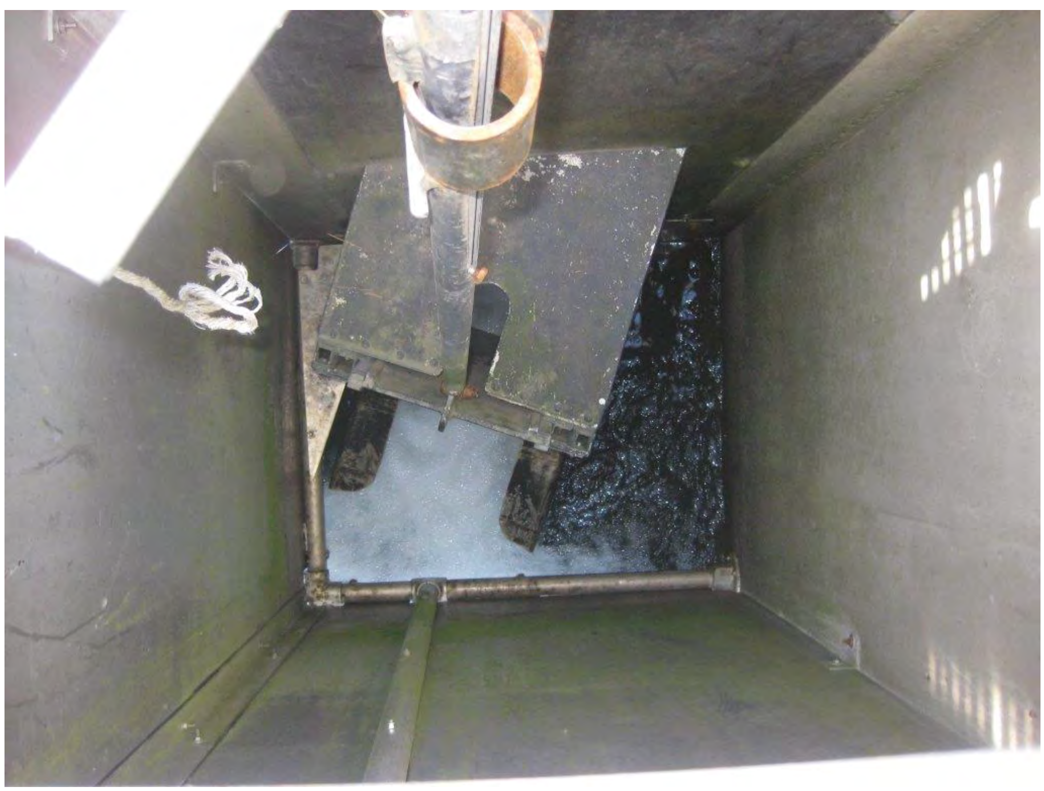

Figure 5. Entrance to Alaskan Steeppass in Fish Trapping Chamber
Chelan PUD Tumwater Fishway Modifications

Chelan PUD Tumwater Fishway Modifications – Kick-off Meeting and Site Visit

MEETING DATE: 2 August 2016

MEETING TIME: 9:00 a.m. PDT

VENUE: District Headquarters, Wenatchee, WA (Conf. Rm. Eng. Svc. Library HQ 1st Flr. [10-20]), and Tumwater Dam, near Leavenworth, WA

District Headquarters

Introduction 9:00-9:15

1. Introductions
2. Roles and responsibilities
3. Purpose and goals of the meeting

Project Overview 9:15-10:30

1. Project purpose and regulatory drivers; stakeholders
2. Existing studies, information and data
3. Project scope, schedule and deliverables
4. Critical success factors

Preliminary Discussion of Alternatives..10:30-11:30

1. Identify design criteria
2. Discuss risks and/or constraints
3. Review and discuss potential alternatives

Travel to Tumwater Dam and Lunch 11:30-1:00

Tumwater Dam

Site Visit 1:00-2:30

4. Safety minute
5. Observe fishway operations
6. Evaluate potential alternatives

Summary and Wrap-Up.. 2:30-3:00

1. Information needs
2. Action items
3. Review project schedule


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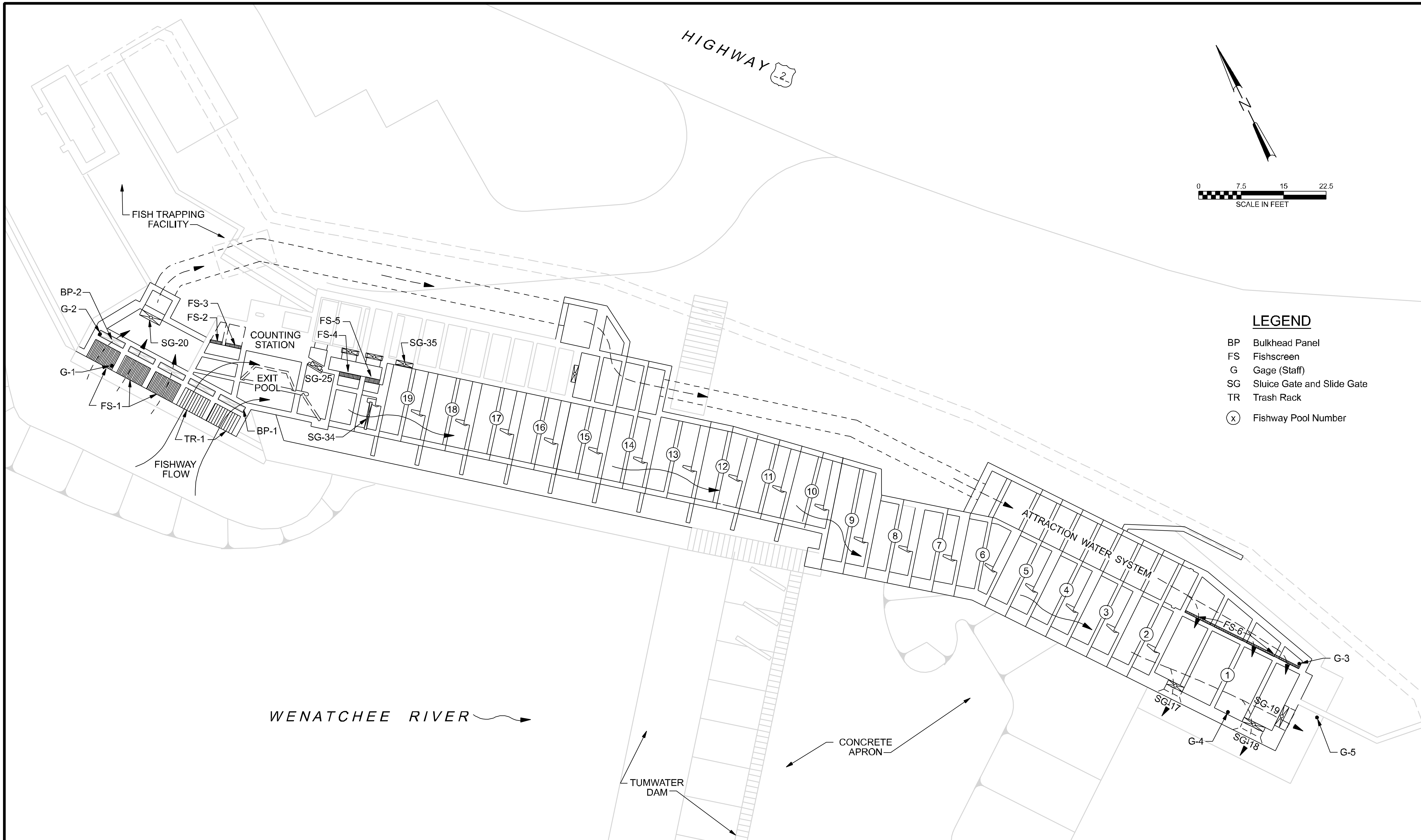
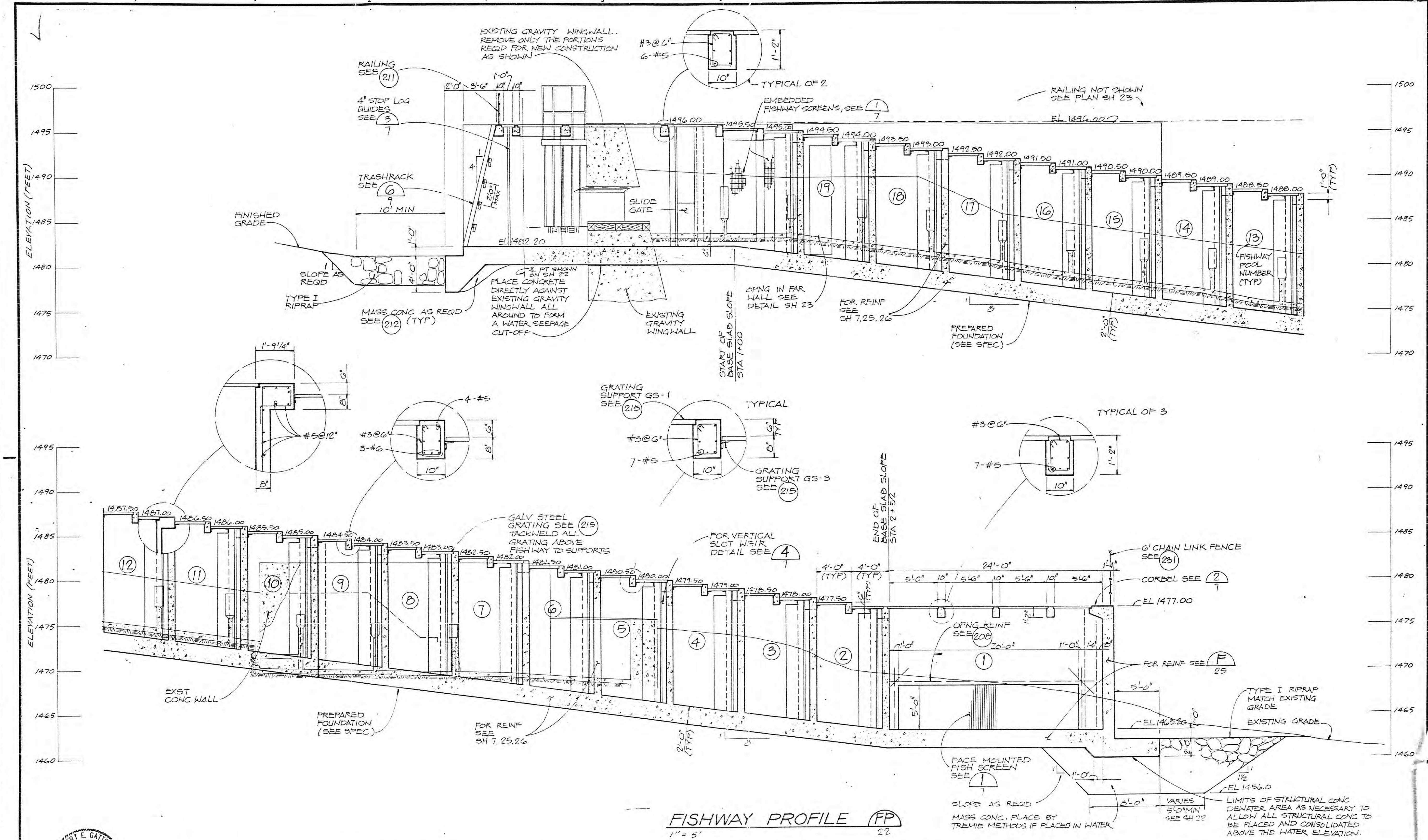


PUBLIC UTILITY DISTRICT NO. 1
OF CHELAN COUNTY, WASHINGTON

Figure 6-1
TUMWATER FISHWAY



FISHWAY PROFILE FP/22

1" = 5'

ROBERT E. GATTON — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

CH2M HILL

DSGN	D. WERMCRANTZ
DR	B. LAZARO
CHK	
APVD	R.E. GATTON

NO.	DATE	REVISION	BY	APVD

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PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WASHINGTON

TUMWATER/DRYDEN FISHWAYS AND DRYDEN WEIR

TUMWATER FISHWAY PROFILE

SHEET	24 of 33
DWG NO	24
DATE	APRIL 1986
PROJ NO	S20299.T1

PROJ NO. CONTRACT | OVERLAY SCREEN | 24 B | 24.1 B

Attachment 2 – Literature Review

Category	Source Title	Notes	Citation
Fish Behavior	Behaviour of adult Pacific lamprey in near-field flow and fishway design experiments	- Lamprey are inefficient in turbulent, high velocity areas such as weir orifices and some fishway entrances. They overcome by swimming with an attach-and-burst technique by using their oral discs to attach to substrate and hold position. This can be ineffective at fishway openings, sites lacking suitable attachment surfaces, when velocities are too high, or when confusing stimuli attract to impassable areas. - Lamprey generally oriented to the substratum and walls, rarely swimming in mid-channel or high in the water column. - Lamprey were attracted to higher flow, but had difficulty passing when a low-velocity alternative route was not present, and preferentially used low velocity routes whenever they were available. - For lamprey to identify the ramp as a passage route, limited to no other upstream passage routes were available. A balance of concentrated flow to attract lamprey to collection areas then lower flow on the ramp structure for optimal passage may be best. - Localized attraction to the ramp with water falling onto the ramp from above, water jets, and air bubbles had limited effect on lamprey use of a collector ramp. - Not clear if rest areas were used, though they did not have a negative effect in the test. They are recommended for inclusion as a conservative feature especially on passages that are long or had higher elevation gain. - Fishways with flow control metal grating on the floors and walls provide poor attachment surfaces and confusing attraction flows. - Daytime activity and passage of lamprey in the experiments was limited. Most activity was at night.	Keefer, M. L., C. A. Peery, S. R. Lee, W. R. Daigle, E. L. Johnson, and M. L. Moser. 2011. "Behaviour of adult Pacific lamprey in near-field flow and fishway design experiments." *Fisheries Management and Ecology* . 18: 177-89.
	Development of Pacific lamprey fishways at a hydropower dam	- Pacific lamprey are attracted to and accumulate in the AWS channels - Pacific lamprey are most likely to find and use an LPS collector when there is no readily accessible upstream alternative (such as in the AWS channel). - Attachment is most effective on hard, smooth surfaces, like polished aluminum - Ramp angle had little effect on lamprey passage success. - Short steep ramps with low flow were optimal for Pacific lamprey passage. At Branford Island lamprey passed more efficiently and in less time when a single steep ramp was divided into two short, but steep ramps. Similar improvements in efficiency and time were noted when crests at the top of each ramp were widened to reduce velocity and increase surface area for attachment. - Lamprey passage increased in ramp structures over time. Two factors believed to be responsible: First, the metal structures may be more acceptable to lamprey from an olfactory perspective as the metal ages (new metal surfaces may repel them to some extent). Second, structural modifications were made to split one longer ramp into two shorter ramps, and the ramp crests were widened. - Open ramps oriented downstream were found to be the most effective, though all designs and orientations were used by some fish.	Moser, M. L., M. L. Keefer, H. T. Pennington, D. A. Ogden, and J. E. Simonson. 2011. "Development of Pacific Lamprey Fishways at a Hydropower Dam." *Fisheries Management and Ecology.* 18: 190-200.
	THE INFLUENCE OF DISCHARGE AND TEMPERATURE ON THE ABILITY OF UPSTREAM MIGRANT ADULT RIVER LAMPREY (LAMPETRA FLUVIATILIS) TO PASS EXPERIMENTAL OVERSHOT AND UNDERSHOT WEIRS	- Aimed to understand swimming capability and behavior in relation to temperature and flow, under the assumption that climate change would result in higher discharge at rivers and warmer water temperatures over time. - Passage rates were close to zero when maximum velocities exceeded 1.5 m/s - Temperature was found to have a positive correlation with the probability of lamprey approaching weirs along the sidewall but did not affect any other parameter assessed. This is possibly due to lamprey selecting an energy minimizing strategy at higher temperatures to offset a potential decrease in endurance. - Lamprey were more rapid in approaching overshot weirs due to the substrate level being more protected, though less able to pass. Lamprey were more likely to attach and burst at undershot weirs due to higher velocities along the substrate where they tend to stay, however they were more effective at eventually passing the undershot weir.	Kemp, Paul S., Iain J. Russon, Andrew S. Vowles, and Martyn C. Lucas. 2011. "THE INFLUENCE OF DISCHARGE AND TEMPERATURE ON THE ABILITY OF UPSTREAM MIGRANT ADULT RIVER LAMPREY (LAMPETRA FLUVIATILIS) TO PASS EXPERIMENTAL OVERSHOT AND UNDERSHOT WEIRS". *River Research and Applications* . 27: 448-498
	Characterization of Adult Pacific Lamprey Swimming Behavior in Relation to Environmental Conditions within Large-Dam Fishways	- Observed Pacific lamprey behavior at fishways at John Day Dam and Bonneville Dam. - Lamprey were observed swimming along the substrate and channel wall at John Day Dam as was noted in previous research, though the lamprey were observed free-swimming in the open water column at Bonneville. This is beleived to be a result of lower velocities at Bonneville that were implemented at night (~1.2 m/s) to improve lamprey passage - enabling free-swimming (they did not need to attach for refuge and burst to move upstream). - Lamprey guidance may be dependant on orientation to both hydraulic and substrate cues. Bonneville had a much deeper entrance channel with the high velocity attraction plume near the surface. Previous research suggested that lamprey would have diffuculty locating entrances in the upper water column since they stay near the substrate, but this was not the case. Given lower velocities in the deep channel, they will be attracted to free swim towards the attraction plume. This suggests that hydraulic cues may be the primary orientation cue over substrate guidance. - Bollard field at John Day Dam intended to reduce velocities appears to be creating more turbulance which causes the lamprey to attach and progress more slowly upstream. - No response to swimming over diffusor grating was observed in the low velocity Bonneville Dam junction pool, though it is suspected that it would have more of an impact on passage ability at high velocity locations where the lamprey would be attempting to attach. - Predatory avoidance behavior was evident with minimal passage when forced into areas with white sturgeon. - Poor lamprey passage was observced for transition areas with submerged weirs. - Estimated maximum sustainable swim speed for Pacific lamprey is approximately 0.86 m/s. Bust speeds up to ~3.9 m/s have been observed over short distances. - More effective passage with short burst-swimming distances as opposed to sustained high velocity fields greater than 0.86 m/s as noted above. John Day Dam had an 80 meter stretch with velocities of ~1.5 m/s that were a "velocity barrier" to the lamprey due to their low endurance.	Kirk, Mark A., Christopher C. Caudill, Eric L. Johnson, Matthew L. Keefer, and Tami S. Clabough. 2015. "Characterization of Adult Pacific Lamprey Swimming Behavior in Relation to Environmental Conditions within Large-Dam Fishways." *Transactions of the American Fisheries Society.* 144: 998-1012.
	Passage of Radio-tagged Adult Pacific Lamprey at Yakima River Diversion Dams 2014 Annual Report Phase 3: Roza and Cowiche Dams Ann	Passage of lamprey was seen in both spring and fall at diversion dams on the Yakima River and tributaries including Naches River, with seasonal passage advantages seen in the fall (lower flow conditions) at middle river dams (Cowiche, Wapato, Sunnyside), while seasonal advantage was seen in the spring at lower river dams (Wanawish, no distinct seasonal advantage at Prosser which is a lower river dam). For both the Cowiche Dam and Roza Dam, Spring passage attempts were generally seen in April and May, while Fall attempts were seen in Semptember.	

Category	Source Title	Notes	Citation
	Evaluation of Barriers to Pacific Lamprey Migration in the Eel River Basin	- Critical swimming speed of approximately 0.86 m/s, Burst swimming speed of approximately 2.7 m/s for Pacific lamprey (indirect measurement of water velocity at which minimal passage occured in a study). These values are slightly less than typical values found for sea lamprey from other regions. - Daigle et al. (2005) observed that lampreys are most vulnerable to displacement during the periods between successive attachments, noting that rapid changes in water velocity or direction can prevent fish from reattaching. - Due to their body type, poor swimming ability, and lack of paired fins, Pacific lampreys have extremely limited ability to leap. Consequently, their upstream passage is expected to be precluded by most culverts or other impediments that are perched above the water surface elevation or that have an overhanging ledge (Moser and Mesa 2009) - Conservatively assumed Pacific lampreys require water depths of at least 3 cm (0.1 ft) for successful passage, based on evidence from Moser et al. (2011) indicating they can pass inclined ramps with water depths of 3 cm. It is likely that individuals can swim for short distances through shallower water, but we leaned towards being conservative. - Pacific lamprey have difficulty passing features that have squared corners such as vertical steps or vertical slot weirs in fish ladders (Moser et al. 2002, Daigle et al. 2005, Keefer et al. 2010). Such sharp angles prevent lampreys from maintaining attachment as they move around a corner (Moser et al. 2002, Moser and Mesa 2009). These same studies demonstrated that Pacific lampreys have significantly higher passage success through fishways with rounded, instead of squared, corners on bulkheads. - Table 2-5 provides a summary of factors affecting adult Pacific Lamprey passage	Stillwater Sciences. February 2014, prepared for Wiyot Tribe
Guidelines/Design Criteria	Cougar Dam Fish Collection Facility - Design Recommendations for Pacific Lamprey	- Attachment surfaces should be smooth and rounded. - Lamprey movement through artificial structures is best accomplished if both the wall and floor surface (adjacent to each other) are available to move along (e.g., orifices should provide a flush floor and one flush wall for lamprey passage, without sharp edges (Figure 1)). - Water velocities should be less than 4 ft/sec. - The primary adult migration period is June through mid-September, but lamprey are also seen from May through November (may need additional data on timing). - Lamprey move primarily at night; artificial light will affect their migratory behavior so limit artificial light during nighttime hours. - Lampreys are known to find and squeeze into small openings. Please keep this in mind as the design of the collection facility evolves. - Smooth, rounded surfaces not only provide better passage for lampreys but are likely better for salmonids as it better replicates those things found in nature, which usually does not have straight edges, sharp comers, and straight sides. (pers. comm., Mary Moser- NMFS, Seattle).C14 Entrance: The 4-foot wide smooth floor alone is a sufficient portal for lamprey passage as long as the flow is less than 4 feet per second. Additionally, lamprey passage could be improved by sliding in a frame in the bulkhead slot so there are flush surfaces. This way there would be no need to round the comers in the entrance. The frame can be made inexpensively and removed when not needed. Gratings: Grating sizes on the AWS (attraction water supply) and the false weir should have 1/2 inch openings with a maximum of 3/4 inch.	
	60% Design Review Comments for Foster Upstream Passage Facility and Fish Passage Designs for Pacific Lamprey	1. Incorporate the February 2007 recommendations for the Cougar T&H into the Foster T&H (see attached document), as appropriate. 2. Orifices should be aligned from weir to weir and located 6 inches from the wall of the fishway. 3. The AWS should be adjustable, so that lower velocities (~4 ft/sec) could be provided to encourage lamprey passage, such as during the night when most lamprey and few salmon typically migrate. 4. "Slots" (such those as for bulkheads or perhaps joints of the ladder along the wall and/or floor of the fishway) that create an indention should be limited. For those that are necessary, there should be inserts to create a smooth continuous surface for lamprey to attach. Alternatively, the slots could stop 6-8 inches above the floor to maintain a flat continuous surface for attachment, which would require a different bulkhead design to accommodate this adjustment. 5. Diffusers should be located on the walls of the fishway and not the floors. Ideally, the wall diffusers should not be located in the lower 6 inches of the wall. If existing diffusers are present immediately upstream of the entrance or an orifice, placing a flat plate on the floor for lamprey to attach improves passage conditions. 6. As current staff of the FWS understands, the concept promoted at Cougar was to allow volitional lamprey passage into a holding pool, and collect them out of this pool using a lamprey ramp system, such as described in the attached 2007 comments on the Cougar T&H facility. For a T&H facility, these ramps will presumably terminate in holding boxes for transport. Thus, to the extent possible, please factor in the existing design a location/space for these ramps and holding/transport boxes, so that if needed in the future, these facilities can be easily accommodated.	
	Grating Size Needed to Protect Adult Pacific Lampreys in the Columbia River Basin	USFWS' recommendation of screen size opening to exclude adult lampreys from unwanted places in fishways is 1.9 cm, which is about 0.748 inches.	
	Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (Entosphenus tridentatus)	- Adult lampreys spawn generally between March and July in gravel bottom streams - Timing of instream activities is critical to avoid adversely affecting spawning adults and dewatering or disrupting existing nests. Critical time periods include the following: • Dependent on location within their distribution range, adult lampreys can be present at spawning areas and preparing to spawn from February to September. The peak period within the Columbia River basin is primarily from March 1 through July 1 in lower and mid elevation reaches;	U.S. Fish and Wildlife Service. April 2010.
	Owner USACE Location Bonneville Dam (Cascade Island and Washington Shore) River Columbia	- Modifications to existing fishway were focused where passage is worst and the greatest number of fish are affected. - Implemented nighttime flow reductions at Bonneville Dam in 2010. Installed Lamprey Passage Structures (LPSs, lamprey ramps) at Cascade Island in 2009 - most effective if installed in dead	
	Owner USACE	- LPS installed to bypass serpentine weirs near the top of the Bonneville Dam fishway. Fish were	

Category	Source Title	Notes	Citation
Existing Lamprey Passage Sites	Location Bonneville Dam (Bradford Island) River Columbia	found to often enter the AWS channel and have no exit. - LPS has total elevation gain of 7.9 m over a distance of 35.6 m, and featured 4 rest boxes. (Distances from more recent Articles)	
	Owner USACE Location Bonneville Dam (Washington Shore) River Columbia	- The new Washington Shore LPS and counter were completely operational by 25 June 2007. The LPS featured a novel "switch-back" design and full-width crests at the top of each of its 45° ramps. The structure allowed lamprey to ascend 9 m along its entire 19.1-m course and volitionally exit into the Washington Shore fishway near its terminus.	
	Owner USACE Location John Day Dam River Columbia	Included lamprey features at count station and upper ladder modifications. In 2010, installed 3/4" grating, rounded corners, plating over gaps, etc at upper north fish ladder and count staion. In 2013 at entrance, implemented new AWS pumps and removed lower ladder weirs to improve	
	Owner USACE Location McNary Dam River Columbia	Implemented nighttime flow reductions in 2011 at McNary Dam. Oregon shore fish ladder entrance modifications include a "ported hood box" which sits below the entrance weir - designed to exclude salmon but allow an alternative lower velocity entrance for lamprey.	
	Owner USBR Location Multiple low head diversion dams along the Umatilla River River Umatilla River	- LPS over low head diversion dam which has pipe back down on exit end. The exit of The lamprey ramp was a specific concern discussed during The site visit. This site provides more insight as to whether a ramp exit can work that releases above The upstream water surface or has to slope back down to it.	Presentation, NWFSC, NMFS, NOAA, Confederated Tribes of the Umatilla Indian Reservation DNR
Tumwater-Specific Data	Surveys of Pacific Lamprey Distribution in the Wenatchee River Watershed 2010 – 2011	- from April to November the fishway is manipulated to only allow passage during daylight hours so all upstream migrating salmonids can be sampled by fisheries personnel (Chelan County PUD 2011). Because Pacific lampreys move primarily at night this operations schedule may also have a significant impact on lamprey passage. It is possible that opening the fishway during night hours may allow for some passage of Pacific lampreys above the dam. Another possible solution to aid in returning Pacific lamprey to their historic distribution within the Wenatchee River is a lamprey passage structure (LPS) (Reinhardt et al. 2008). LPS have been installed at Bonneville Dam and some Columbia River tributary dams and provide Pacific lampreys with a series of inclined ramps on which they can "climb" over the dam. This method may be preferred by salmonid researchers as their sampling would continue unchanged, however, radio-telemetry studies would be necessary to determine if a suitable location exists for a LPS.	
	Presentation by Steve Rainey on Rapid Assessment of Adult Pacific Lamprey Passage at Tumwater Dam	It is probably that most lamprey are not able to pass fully-opened SG's 21 and 22 during fish trapping operations at mid-range and higher river stages (Velocity ~6 fps at low river stage, ~9.1 fps at high river stage). Recommendations: 1. Conduct a telemetry study to assess whether lamprey are able to enter the Tumwater fishway-trap, as on the Yakima (both spring and fall periods) 2. Identify whether there is a location within the ladder where lamprey are not able to pass upstream during trapping and non-trapping operations. 3. Confirm or disprove preliminary assessment that SG's 21 and 22 are lamprey blockages at mid-range and higher river stages.	

Attachment 3 – Initial Assessment Report

Draft Rapid Assessment of Adult Pacific Lamprey Passage at Tumwater Dam

Prepared by: Steve Rainey, Consultant, US Fish and Wildlife Service and Rapid Assessment Team (Mary Moser, Chris Peery, Ralph Lampman, Mark Nelson, Patrick Verhey, Steve Lewis, Steve Hemstrom, Bill Christman, R.D. Nelle-Leader)

Comments collated by: Steve Rainey and Barb Kelly-Ringel (FWS)

August 4, 2015

Abstract

Pacific lamprey were historically present upstream of Tumwater Dam, but the numbers and extent of distribution is unknown. Recent juvenile Pacific lamprey surveys by USFWS (Johnsen, A. and M.C. Nelson. 2012) did not identify the presence of lamprey in the Wenatchee River upstream of Tumwater Dam, while lamprey were found throughout the downstream river section. Two factors approximately correlate to the absence of lamprey above the dam: (1.) a ladder-trap combination designed for improved salmon and steelhead in the 1980's, and (2.) commencement of fish-trapping operations in the 1990's. A multidisciplinary rapid-assessment team of lamprey and fish passage specialists (AT) was convened by the U.S. Fish and Wildlife Service, and coordinated with the Rocky Reach Fish Forum, to address whether design and operation of the Tumwater Dam fish ladder and trap contribute to the absence of lamprey above the dam, and to identify a recommended approach that will potentially lead to fishway-trap passage improvements. This report collates AT inputs on lamprey passage behavior, describes hydraulic conditions, and lists possible lamprey passage impediments and uncertainties that need to be further interrogated. Impeded lamprey passage was considered in the context of both the non-trapping and trapping operational modes. Recommended for additional consideration were: elevated sills at entrances and weir slots, delay in the lower fishway auxiliary water system, PIT detectors at weirs 15 and 18, and trapping mode adult holding pool supply gates. Possible structural corrective measures are ramps at elevated sills, and lamprey passage devices at left and/or right dam abutments. No single confirmed blockage impediment was identified that would explain the current absence of lamprey upstream of Tumwater Dam. The AT recommends a radio-telemetry study to first identify where blockages may be occurring either below or in the Tumwater Dam fishway-trap. Structural passage improvements should be on the basis of telemetry results.

1. Introduction

Pacific lamprey were historically present upstream of Tumwater Dam, but the extent of distribution is unknown. Recent juvenile Pacific lamprey surveys by USFWS (Johnsen, A. and M.C. Nelson. 2012) did not collect lamprey in the Wenatchee River upstream of Tumwater Dam, while lamprey were found throughout the downstream river section. Reasons for the apparent absence of Pacific lamprey upstream of Tumwater Dam are not fully understood, but may have resulted from reconstruction of the fishway in 1987 for improvement of salmon and steelhead passage, operations of the fish trap, or other causes. To better understand if Tumwater Dam and the fishway-trap preclude or substantially reduce Pacific lamprey passage above Tumwater Dam, an assessment of passage at the dam, fishway, and trap was initiated by the Rocky Reach Fish Forum (RRFF). A mid-February to March 2015 dewatering of Tumwater Dam's fishway and trap was previously scheduled to provide Chelan County Public Utility District (CCPUD) contractor's access to the upstream fishway to perform concrete maintenance work, and other routine off-season maintenance. Members of the RRFF, United States Fish and Wildlife Service (USFWS), and their designees agreed to conduct a "rapid assessment" of Tumwater Dam and the fishway-trap to better understand the nature of obstacles to adult Pacific lamprey passage. This method is based on previously conducted rapid assessment of the lower Yakima River irrigation dams conducted in 2012.

For the purposes of this document, the term "rapid assessment" of adult Pacific lamprey passage at Tumwater Dam and the fishway-trap is defined as an investigation in a short time frame (conference calls and one day site visit). The entire "rapid assessment process" includes assembling of a multidisciplinary group of lamprey passage experts, convening conference calls, reviewing the design drawings of the Tumwater Dam fishway and trap, conducting a site visit at Tumwater Dam during dewatering of the fishway, compiling assessment teams comments, and writing a report of findings describing the potential physical constraints to adult lamprey passage at Tumwater Dam. The multidisciplinary team includes experts with knowledge of lamprey upstream passage behavior and/or fish passage facilities design that provided comments to this document based on professional judgment and previous fish passage experience.

This assessment is for the purposes of evaluating potential lamprey passage features within the Tumwater Dam fish ladder and identifying possible passage improvements. Structural ladder improvements are only part of the overall passage uncertainties at this site. Others include whether lamprey can reach the fish ladder in the highly turbulent tailrace environment, and at what streamflow magnitudes. A future telemetry study would better identify lamprey behavior in the tailrace and ladder-trap, and would likely occur before initiating structural lamprey passage improvements.

The assessment team (AT) includes members from the RRFF and outside individuals with Pacific lamprey passage expertise, with R.D. Nelle (USFWS) as the Team leader for the February 18, 2015 site visit. Primary AT members include:

- Mary Moser- U.S. National Oceanic and Atmospheric Administration (NOAA) – lamprey passage Research Fishery Biologist
- Chris Peery-USFWS –Fish Biologist - fish passage
- Ralph Lampman- Yakima Nation Fisheries (YNF) Lamprey Research Biologist
- Mark Nelson-USFWS – Fish Biologist
- Steve Rainey- USFWS fish passage engineer consultant
- R.D. Nelle- USFWS – Supervisory Fish Biologist
- Patrick Verhey- Washington Department of Fish and Wildlife (WDFW) – Renewable Energy Biologist
- Steve Lewis-USFWS – Hydropower and Alternative Energy Coordinator
- Bill Christman- CCPUD – Chief Engineer, Dam Safety
- Steve Hemstrom –CCPUD - Senior Fish Biologist

Mary Figure 1. Assessment Team – Front row: Mark Nelson, Patrick Verhey, Moser; Back row: Steve Rainey, R.D. Nelle, Chris Peery, Steve Lewis, Ralph Lampman

The Tumwater Dam dewatered fishway site visit occurred on February 18, 2015. Some AT members descended into the dewatered fishway and trap, to assess potential physical lamprey passage blockages. The lower third of the fishway was not dewatered. Barb Kelly Ringel (USFWS) took notes for those descending into the fishway. Ken Muir provided photography and video support.

Those providing additional information for the AT at the site visit included:

- Thad Mosey-CCPUD knowledge of Tumwater Dam and operations
- Ian Adams-CCPUD knowledge of Tumwater Dam and operations
- McLain Johnson-WDFW supervisor of trap operations
- Mike Hughes-WDFW daily operations of trap
- Danny Diedricksen-WDFW screen shop
- Ann Grote- USFWS Lamprey passage researcher
- Paul Wagner-CCT-Lamprey biology (also descended into the dewatered fishway)
- Tyler Sellars, CCPUD Construction Manager
- Tracy Hillman- BioAnalysts, RRFF Facilitator

Comments from each AT member were collated and organized for this document. A draft report was prepared and distributed, and response comments were collated in preparation of the final report. Hydraulic information (including velocities at fish ladder slots, entrances, diffusers, steep-pass, gates, and other features) was also integrated. In some cases where there was disagreement on recommended changes, FWS views were sustained. These can be debated at a later time. Due to these differences in perspectives, a 2nd draft report was prepared, in an effort to reconcile outstanding issues.

2. **Pacific Lamprey – Passage Behavior and Biology**

The following is a list of AT comments on known lamprey upstream passage behavior:

- Lamprey need slower water, relative to salmonids, to move and attachment to surfaces that enable resting during passage
- They seek the upstream-most tailwater location below barriers, similar to salmon, if hydraulic conditions allow.
- Sustained swimming speed up to 4 ft/s – they prefer to swim lower in water column at all velocities
- Burst speed up to 8 ft/s (between attach locations) Turbulent water makes attachment to walls and floors more difficult
- Adults primarily pass at night
- Adults approach slots, orifices, and other openings primarily from the channel bottom
- Smooth surfaces are needed for attachment by suction in fast water conditions, such as to rounded river rock.
- Lamprey can ascend very steep structures, and are able to ascend falls that salmon could not pass because of ability to use suction from oral disc.
- Lamprey are less likely to climb a surface with algae, or if a concrete surface is eroded/pitted, both of which inhibit suction. Also, lamprey are less likely to climb new structural surfaces (lamprey passage structure experience).
- Lamprey approaching barriers in the tailrace will explore extensively looking for a passageway upstream.
- Adults will not home to their natal streams to spawn. Pheromones of juveniles are considered one of the attractants to upstream migrating adults, signaling presence of successful spawning locations/rearing.
- They will move through fish ladders full of other fish (with the possible exception of sturgeon). An example is shad lower Columbia River dams, where lamprey still ascend with wall-to-wall shad in ladders.
- They are extremely sensitive to human and likely other scents in water. At Willamette Falls, placing a hand in water above them causes them to release their suction and fall.
- Adult lamprey transported above one barrier will move upstream until they encounter another barrier, even in absence or with low pheromone signal. (Umatilla and Nez Perce tribe translocation projects.) Also, there is evidence of adult lamprey volitionally accessing new habitat after dam removal (Elwa and Hood Rivers)
- Upstream migration in the Columbia River occurs primarily from mid-July through October at Rocky Reach Dam. Many lamprey overwinter before finishing migration and spawning the following spring (March-June). On the Umatilla River, half the lamprey enter in August and overwinter before spawning, while half enter in May and spawn that same year.
- Optimum lamprey spawn temperature is likely14-15ºC. Spawning timing in the Wenatchee and Entiat rivers is likely April – July.

3. Wenatchee Pacific Lamprey Presence – Historic and Current

November 1998 was the last documented presence of lamprey in the Tumwater Dam ladder (Steve Hemstrom, CCPUD). Eight adult lamprey were observed passing and counted through the Tumwater Dam fishway window on July 15, 1995 (Chelan PUD fish counting files, 1995). These observations in 1995 and 1998 occurred after the Tumwater Dam fishway was re-constructed in 1987. Also, see "Surveys of Pacific Lamprey Distribution in the Wenatchee River Watershed, 2010-2011" (Johnson and Nelson, 2012).

4. Wenatchee River Hydrology (Peshastin)

The Peshastin USGS streamflow gage is downstream of the Icicle Creek confluence, but is the nearest to the Tumwater Dam site, and should be within 10% or so of the corresponding flow at Tumwater Dam. Flow on February 18, during the tour, was reported at 4,380 cfs. This is over twice the mean flow for the month of February, nearly twice the mean flow during the March – June spring migration, and over twice the mean flow during the mid-July - October lamprey migration.

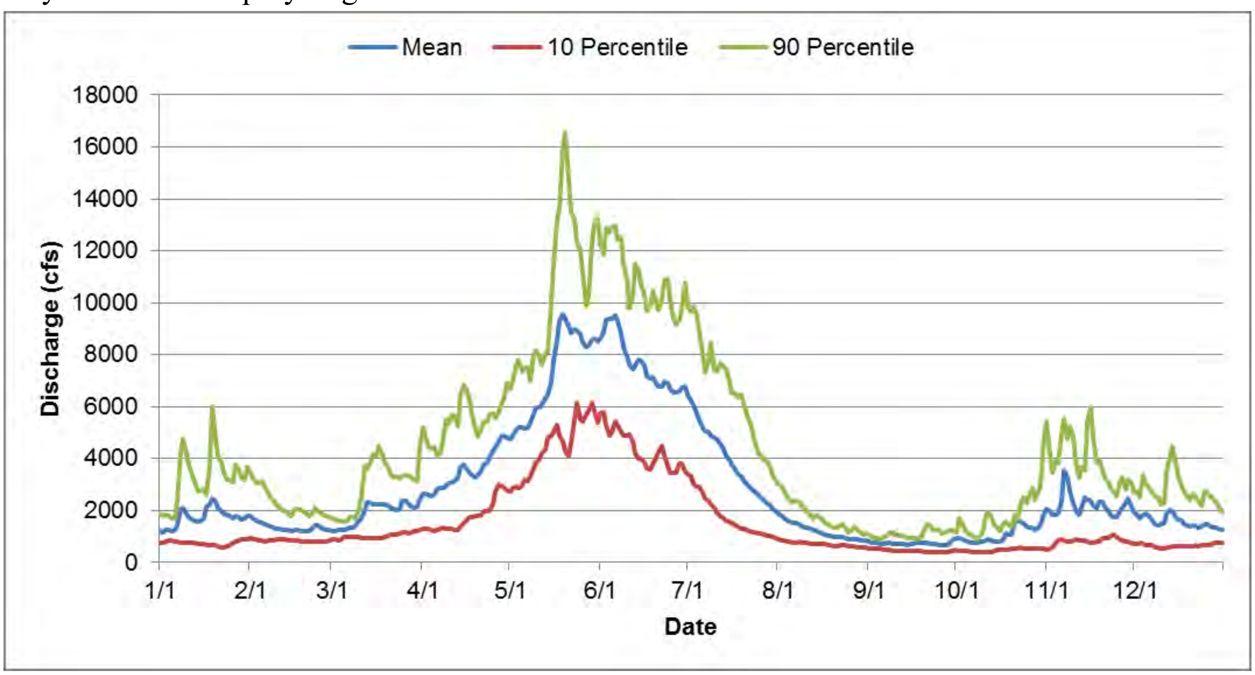


Figure 2. Streamflow data from Peshastin, 2000-14

Lamprey Passage During Non-Trapping Operations

5. Upstream-Migrating Lamprey Approach to the Tumwater Dam Ladder

The following features and conditions influence lamprey passage as they approach the Tumwater Dam fish ladder.

- *Dam configuration* – Tumwater Dam has a maximum design head of 20 ft, and has a concrete ogee longitudinal section configuration, with apron extending to just above the low design tailwater elevation. The crest elevation is 1487.0, and total dam crest length is 420 ft. The left section of the dam, which ties into the large training wall and fishway, is approximately 100 ft long. It bends approximately 60 degrees left in the downstream direction, to an additional dam crest length approximately 300 ft.

- *Tailrace Hydraulics* – Discharge on the day of the AT site visit was reported as 4,380 cfs (Figure 3). The tailrace was extremely turbulent, but adult salmonids pass in large numbers at this flow magnitude. It is uncertain whether adult lamprey could approach the left shore fishway at this discharge. Adjacent to the fishway, flow passing down the ogee and onto the apron creates a hydraulic jump when high tailwater backwatered the apron. A standing wave upstream of the entrances occurred on the day of the site visit. Aerated and fast water is present in this area (see photos).

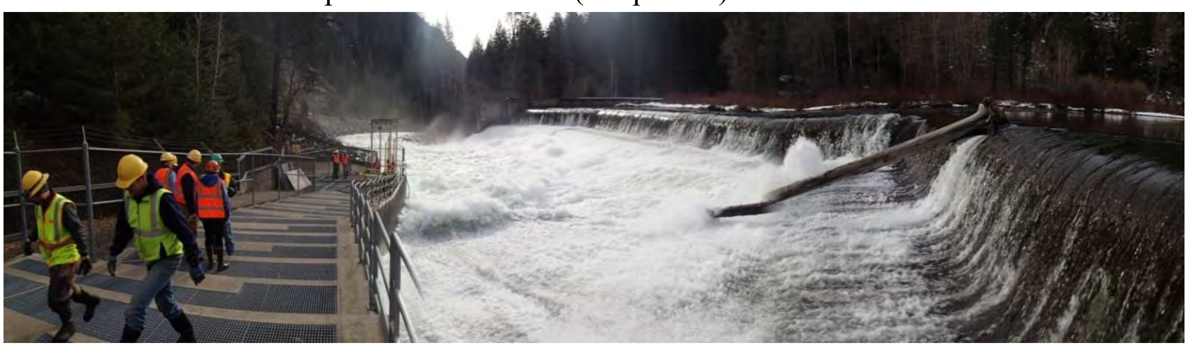


Figure 3. February 18, 2015 site visit trailrace hydraulic conditions at 4380 cfs (Peshastin gage)

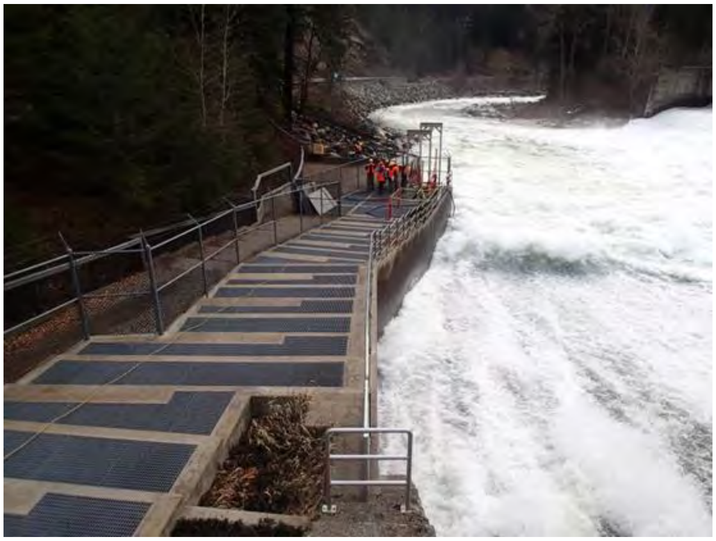
- *Dam Dog-leg* Jet - The approximate 60 degree corner of the dam creates a "dog-leg", and a distinct larger jet in the tailrace is caused from flow converging immediately downstream of the adjacent dam crests (Figure 4). Dam crest dog-leg jet merges on the dam apron, and extends across river at an angle below fishway (see in photo below at low streamflow). Adjacent to the fishway, flow passes down the ogee and onto the apron, before entering tailwater at high velocity. A standing wave upstream of the fishway entrances occurs at high flows. Water is aerated and turbulent in this area (see photos).

Figure 4. Dam Dog-leg Jet (jet extends diagonally to left shore near the fishway). Note that this is a previous photo during relatively low discharge period

- *Probable Lamprey Behavior Approaching Tumwater Dam* - In studies at mainstem Columbia River dams, lamprey approached dams similar to salmonids, attracted to the upstream terminus of flow. But when flow is too fast and turbulent they will seek alternate routes to ascend. Where they first approach Tumwater Dam will be highly dependent on river conditions at the time. If the majority of flow is along the left bank, lamprey ascend along the lower velocity right half of the channel to the right dam abutment, move upstream along the apron to the dam dog-leg, then cross over to the left abutment fishway-trap.
- *Probable High Design Approach Flow for Salmon/Lamprey* - The fish ladder "high design streamflow" is a term commonly used to identify the upper stream discharges for which salmon/steelhead and lamprey are expected to be able to find, enter, and pass the fishway. Observations during the AT's February 18, 2015 site visit suggested salmon would need to overcome the extremely turbulent tailrace hydraulic conditions (Figures 5 and 6) to find and enter the fishway. Discharge was 4380 cfs (Hemstrom), which appeared impassable. Yet a CCPUD review of daily discharges at Peshastin for 86 years of record shows daily averages of 8566 and 4389 cfs for the months of June and July, respectively, when Tumwater Dam fish ladder salmon counts are strong. This suggests futility of estimating the high design streamflow for salmon and steelhead at Tumwater Dam. As lamprey have lower swimming speeds and endurance, it is questionable whether lamprey could pass at the discharge observed on the day of the AT site visit (4380 cfs - Peshastin). Subjectively, it is likely flows would need to be

lower than 3000 cfs for lamprey to pass. However, mean flows for post-spring freshet lamprey return months of mid-July through October are less than 2000 cfs (See Section 4 – Hydrology). Average flows up to 3000 cfs occur during pre-freshet lamprey return months of March and April.

- *Probable Approach to Dam from Downstream at Passable Flows* - A right bend in the river channel occurs just downstream of Tumwater Dam, with higher velocities along the left shore, which is the Highway 2 embankment and is armored by large rip-rap boulders. This likely means both salmonids and lamprey approach the dam using lower velocities at the right half of the river channel, and encounter the right dam abutment first. However, as both species seek the upstream-most terminus when trying to pass, and assuming flows are not too high, it is likely they will attempt to cross to the left shore and find/use the fishway to pass. The left fishway location still is considered to be in the optimum location for salmon. It is probable that some lamprey would pass at the right abutment at mid-range and higher streamflows, if a lamprey passage device were installed there. However, most would potentially continue upstream of a hypothetical right bank fishway at lower flows - to the upstream terminus left fishway location. At intermediate and higher streamflows, tailwater turbulence becomes more prohibitive, and it is likely they are unable to approach the left fishway.
- *Downstream of Tumwater Dam* - The downstream Highway 2 embankment was washed out during 1997 flooding. Repair of the embankment occurred at that time. Due to the appreciable energy of flood flows and the vertical drop from the dam, channel degradation also occurred. Large boulders that would withstand future flood-level streamflows and not be displaced had to be positioned downstream of the dam, for the purposes of (1.) maintaining tailwater elevations for the fish ladder to be accessible to fish, and (2.) preventing undermining of the dam.



Figures 5 and 6. Turbulent tailwater adjacent to fishway on day of site visit

6. Fish Ladder Entrances

The following is a description of configuration, hydraulic conditions, and probable lamprey behavior at the Tumwater Dam fish ladder entrances:

- There are two lateral entrances on the side of ladder entrance pool. The upper entrance is for low-flow operation, and is 3 ft wide x 5 ft high (90 cfs). The middle, lateral flow entrance is 4 ft wide x 5 ft high (120 cfs). The lower longitudinal entrance discharges parallel to the left shoreline, and is also 4 ft wide x 5 ft high. It is the high-flow entrance.
- The above fishway entrance discharges are designed for operation of one fishway entrance at a time, with 1-ft hydraulic drop from entrance pool to tailwater. Staff gages in the entrance pool and on the external fishway wall are monitored by operators to assure appropriate entrance operations.
- The existing upper-most, low-flow fishway entrance invert elevation is 1462.2, which suggests that the low design tailwater elevation is 1466.2. The high-flow entrance invert is at el. 1464.2, with a high design tailwater elevation of 1468.2. (Note that the high design tailwater elevation correlates to the high design discharge. However, the tailwater rating curve is in the design report for the fish ladders at Dryden and Tumwater dams, which is not currently available.)
- Fishway entrances each have interior-mounted vertical guides on each side of the 5-ft high entrance closure gates, and extend the full height of each gate. Side flow contraction starts at the upstream end of these guides, and the hydraulic drop results in increase in the jet velocity as it enters the tailrace. Velocity at the upstream end of gate guides is approximately 6 ft/s, but increases to 8 ft/s maximum when head differential from entrance pool to tailwater surfaces is 1.0 ft. At a 1.5 ft differential (which may sometimes be in operation for stronger salmonid attraction), jet velocity at the upstream

end of gate guides is approximately 7.4 ft/s, which increases to 9.8 ft/s just downstream of the entrance opening.

- A concrete footing extends beyond the exterior fishway exterior wall 4 ft to the side, and 5 ft in the downstream direction. (These footings are shown in Drawing # 25, section F, and Drawing #24 – Profile, respectively, from the design-construction drawings provided to the AT.) The flat footing surfaces are 1-ft below the fishway entrance sill elevation, and potentially aid lamprey approach to the fishway entrances, under the entrance jet. However, if the footing surfaces are rough, or cobbles have accumulated on the footing surface, lamprey access to the entrance(s) may be impeded.
- Entrance sills about 1 ft above the apron, would be a challenge for lamprey to negotiate under standard salmon operation criteria (6 – 9 fps at the entrance port, and 8 to 12 ft/s attraction flow jet velocity, immediately downstream of the entrance). One possible improvement is to add ramps from exterior aprons to the entrance sill. Ramps upstream of entrance sills would likely not improve lamprey passage.
- Probable lamprey behavior passing fishway entrances - It is probable that lamprey attracted by the fishway entrance attraction flow would approach along the channel bottom, just below the entrance attraction jet. They should be able to get very close to the bottom of the entrance jet as it emerges from the entrance port. It is probable that some could accelerate through the entrance in a short burst of swimming speed, and enter the more quiescent entrance pool. However, it is probable that many would be blown back by the jet, and attempt to re-ascend again. The vertical drop of the exterior fishway wall to the top of the footing is difficult for lamprey to pass, compared to likely improved passage if a sloped ramp were placed under the entrance jet. Standard salmon operation criteria entails 8 to 12 ft per second (fps) entrance attraction flow at a point just downstream of the exterior entrance wall, and a 6-9 fps velocity at the interior wall contraction edges.
- An exit pipe in the training wall downstream of the high-flow fishway entrance is perched above tailwater and discharges water used for processing salmon and steelhead. It likely has scent of humans, MS-222, any other exogenous chemicals used or scents. This may discourage ascension in the small downstream plume along the left shoreline. This impact is does not likely extend too far, as mixing and dilution are probable.
- The Tumwater Dam entrances are the same size as, and are operated similarly to, fishways at Sunnyside and Wapato dams on the Yakima River, where lamprey passage was documented by USFWS (Passage of radio-tagged adult lamprey at Yakima River diversion dams, Grote, et al, 2014).

7. Vertical-Slot Fishways Design at Other Sites:

During the 1980’s, many upstream passage fishways were designed/constructed on the Yakima, Umatilla, and Wenatchee rivers (Tumwater and Dryden dams) to improve salmon and steelhead passage. These were generally funded by Bonneville Power Administration, and designed by the US Bureau of Reclamation and private entities (consultants), with full and consistent review by NOAA Fisheries and Washington Department of Fish and Wildlife fish passage engineers. Most of these upstream fishways were vertical slot ladders, using the same design criteria as at Tumwater Dam. Some of those criteria are listed below:

- Vertical slot widths – 12 and 15 inches
- Minimum depth – 5 ft
- 8 ft wide and 10 ft long pools
- Maximum 1 ft drop between pools (Figure 7)
- Highest vertical slot fishway (VSF) design was at Tumwater Dam (20 ft), next highest VSF's in the BPA funded, 1980's period, were approximately 12 ft high
- Inflow energy assumed to be fully dissipated in each pool (see Energy Dissipation Coefficient in NOAA Criteria - NOAA, 2011, which controls pool turbulence)
- Slots are typically located so that the slot jet dissects the pool (for best energy dissipation)
- The floor of the vertical slot would likely be the preferred route of passage between pools. However, the addition of sills when slots were narrowed at Tumwater Dam may block or impede lamprey passage. There are no other cases of slot sills for vertical slot fishways built in the 1980's or 90's on the Yakima, Umatilla, or Wenatchee rivers. Thus, it is unknown whether lamprey are blocked by 12-in high slot sills.
- Fishway floors are sloped at 1 ft rise per 10 ft run
- At 1.0-ft drop per slot, flow through slots = 6 ft/s, and the slot jet accelerates to 8 ft/s a short distance downstream of the slot, before expanding
- Vertical slot flow dissects the pool volume, spreads in each pool, and creates back current swirls on each side of the inflow jet, thereby dissipating energy (turbulence) in each pool. In normal pools, slot jet center line is aligned to impact the opposite wall at a point ~70% of the length of the pool.
- Importance of the jet alignment in efficiently dissipating inflow energy, and avoiding lateral surging was reinforced at Tumwater Dam (see below).
- Many of the vertical slot fishways were suitable for 10-12 ft high diversion dams, and operated 95% of the time at higher streamflows and lower total static heads. Higher tailwater backwaters the lower ladder, reduces pool differentials in the lower ladder, and lowers velocities in the lower vertical slots. This is commonly referred to as a "backwater effect."

Figure 7. Example of vertical slot ladder pool and slot flow hydraulic conditions – note pools include both aerated turbulent flow near the slot jet, and lower turbulence, green water further from the jet

8. Tumwater Dam Vertical Slot Fishway Design and Modifications

While fish ladder design criteria were essentially the same for Tumwater Dam fish ladder and other fish ladders designed and built in the 1980's, site conditions at Tumwater Dam were somewhat different and called for appropriate design criteria changes and these included the following:

- The Tumwater Dam fishway had structural design constraints due to the large pre-existing longitudinal training wall, which is still present. After selection of the optimum fishway entrance location, at the upstream terminus of fish movement in the tailwater of Tumwater Dam, it was necessary to select a 1:8 slope (8 ft long x 12 ft wide pools), in order to prevent undermining of the training wall.
- 15-in wide, full depth vertical slots were initially selected for design
- Initial water-up resulted in 3 ft high lateral surging, as the slot jet did not dissect pool volume. CCPUD, BPA, and the agencies and tribes immediately approved a means of stopping the surging, and the contractor made the modifications before demobilizing. Stub wall nose plates were fabricated and bolted to the stub wall side of the slots. This reduced slot width to 12 in, improved the jet direction to more nearly dissect each pool,

and a 1-ft high sill was added to reduce slot depth. Reduced width and depth of each slot lowered inflow to each pool, thereby reducing pool turbulence and surging, without compromising salmonid passage. (Figure 8)

- It is unknown whether the 12-in high retrofitted sills constitute a blockage to lamprey at Tumwater Dam. No bottom sills are at other fishways in the Yakima, Umatilla, or Wenatchee rivers, and there is no documented indication whether sills impede upstream passage.

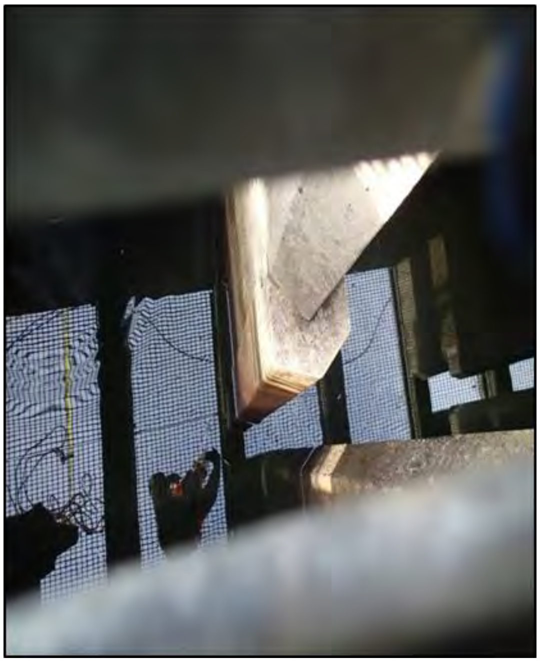


Figure 8. Typical stub wall slot nose extension   Figure 9. Nose extension gap

- It is important to note that the 12 inch and 15 inch slot widths both still are designed for a 1-foot drop. This means that jet velocities at the spring point of the slot are the same, as are the convergence jet velocities just downstream.
- Small gaps at upstream vertical edge of steel stubwall nose plate extensions were noted during the tour. These could adversely impact lamprey passage. (See Figure 9)
- The 1 ft high x 1 ft wide x 8 inch thick sill has a 3-inch wide top. Most sills have chamfers on the downstream face (Figure 10). Not all of the sills have the same sill design, some simply angled from the floor to attain the 3-inch top width.

Figure 10. Sill at base of typical Tumwater Dam fish ladder slot

- One question by the AT was whether a 2 inch orifice at the bottom of each weir could be used as a passage route. These could be placed, but likely at considerable expense relative to likely benefit. Reason is that flow would contract to pass through the small orifice, then expand before exiting the downstream weir wall face. If so, orifice exit velocities would be the same as with the slot. Location of the small orifice near the floor may be a little better, but with no hydraulic benefit.

Fish Counting and Exit Channel:

Lamprey passing slot #19 during non-trapping operations, or that enter from the trap holding pool through the floor diffusers, open control gates, and wall diffusers back into the ladder, enter the fish counting and exit channel area.

- Counting window (Figure 11) was designed to control temperature and humidity, for video counting

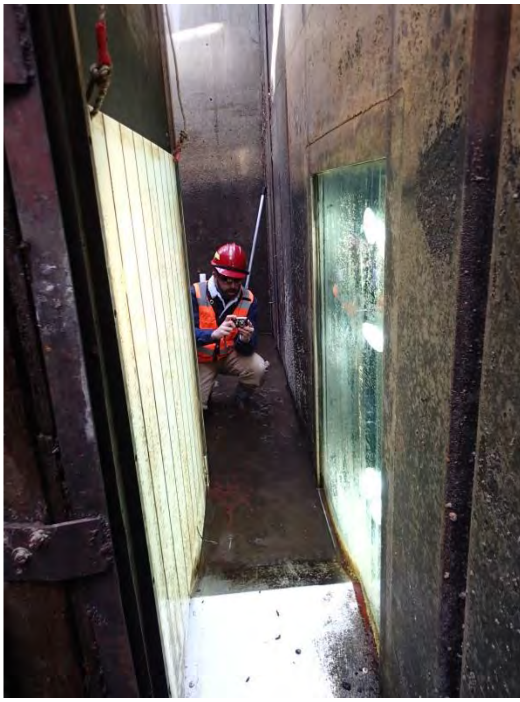
 

Figure 11 and Figure 12. Counting window and upstream picket lead crowder.

- Counting during fish trapping operations occurs by Washington Department of Fish and Wildlife trap personnel, and trap counts are reported and included in the total passage count. Fish counting at the counting window is discontinued during this period.
- Counting continues whenever diversion of fish into the adult holding pool is discontinued.
- Laminated window extends from floor to ceiling.
- Metal ramp at lower edge, moves fish up so they can be counted.
- 2 ft/s velocities occur in the narrowed channel at the counting window, so adding the ramp did not retard lamprey passage.
- Video view is of the entire window to be sure to capture fish moving at different depths.
- Lights are included for video recording at night.
- A plywood board is present as background with vertical marks to record fish lengths.
- Angled picket weirs are used to narrow the approach and guide fish into the narrow (approximately 2-ft wide) counting channel by the counting window. (Figure 12)
- Downstream and upstream angled picket leads with 1-inch openings are in the channel opposite to the counting window. (Figure 13) The upstream and downstream angled pickets serve as crowders for guiding salmon past the counting window. However, lamprey are likely able to pass through the pickets, and some likely would not be counted

Figure 13 – Upstream-looking view of picket leads, counting window, and emergency trap adult return port (with gate in upward and open position)

- Debris gets caught in the picket weirs, and in area between the weirs, and must be removed occasionally by operators, on an as-needed basis.
- Aluminum (or steel?) floor ramp, gently angled up then down, would be good surface for lamprey suction and passage.

Lamprey Passage – Vertical Slot Fish Ladders

The following comments pertain to lamprey passage through vertical slot fish ladders in general:

- As streamflow increases and backwaters the lower ladder pools, slot velocities are lower and lamprey passage becomes less difficult in these lower pools. However, entrance velocities remain the same.
- Therefore, lamprey having entered through the fishway entrance are able to more readily pass upstream through the lower ladder slots and pools.
- Whereas 10-12 ft high fishways may be backwatered up to 5-6 pools, only 5-7 upper ladder pools with a full 1-ft drop need to be passed by lamprey.
- At Tumwater Dam fishway, if the first lower 5-6 pools are backwatered , another 14-15 pools with full 1-ft drops at slots need to be passed presenting a more difficult challenge for upstream lamprey passage.

- Lamprey telemetry passage studies on the Yakima River show that some lamprey pass upstream of the VSF's at studied sites. However, none of the referenced Yakima VSF sites included 1-ft high sill at the bottom of each slot.
- At Tumwater Dam, it is unknown whether lamprey can readily find and enter the left bank fishway, and at what flows. It is also unknown whether they can ascend the fishway vertical slot pools, with 1-ft high sills, once they enter the fishway.
- It is important to note that while there are some pool configuration differences between the Yakima River dams and Tumwater Dam fishways (1-ft high bottom sills in each slot at Tumwater Dam), the hydraulic conditions (velocities) at the fishway entrances are the same, as are hydraulic conditions at the slots. The Tumwater Dam sills in each slot may make lamprey passage more difficult or even impassable. Evidence collected by Public Utility District No. 2 of Grant County for the Priest Rapids Hydroelectric Project suggests that upstream lamprey passage was impeded by perched orifices comprised of sills and remedied through the installation of ramps on the downstream side of these perched orifices.

Interior Fish Ladder Floor and Wall Erosion

Tumwater Dam is in a steep canyon, with a steep hydraulic gradient that carries suspended bed load of fine and coarse sediment, cobbles, and even boulders during higher flows. Sands and gravels are drawn into the fishway, and create sand-blasting like forces in each pool. Fish ladder wall and floor erosion are common in steep gradient streams such as the Wenatchee River. The CCPUD had a contractor on-site during the tour to dewater the ladder and re-finish more significant wall and floor erosion locations, an ongoing maintenance problem at the Tumwater Dam fishway. Signs of moderate wall and floor erosion were evident in each pool. Erosion of ladder walls and floors can impede upstream passage through ladder vertical slots between pools, by reducing the ability of lamprey to stop and hold using oral suction (as is easier for smooth surfaces). Specific tour comments received on this topic include:

- Fishway hydraulics are creating places where the concrete wall is pitting (localized and severe erosion), indicating forceful scouring flows. (Figures 14 and 15) Sediment and gravel bedload during high flows is suspended, and is directly responsible for the extent of concrete surface erosion of fine sediment, leaving exposed larger aggregate (rounded gravel) on the fishway floor. Hydraulic conditions without the same magnitude of sediment (such as on flatter gradient streams, or below storage dams) would not erode wall surfaces as quickly.
- Piles of gravel up to several inches deep (and extending above the dewatered fishway pool water surface) were observed in pools immediately downstream of VSF stub walls. This is a location near the floor, and immediately adjacent to the slot high-velocity jet, where turbulence is low enough for gravel to settle, and reach equilibrium during fishway operations. (Figure 16)

- Wall erosion (erosion of fine aggregate/ sand) was observed on the downstream side of each baffle wall, just above floor level, and in the lower 6-8 ft of each slot. Same observed at the opposite corner, low on the side wall. Erosion of fine aggregate was also observed on the left wall of each pool near the floor.
- Walls have also severely eroded at some isolated locations, exposing coarse aggregate, and deeper pitting. More severe pitting locations were to be re-finished by a contractor.

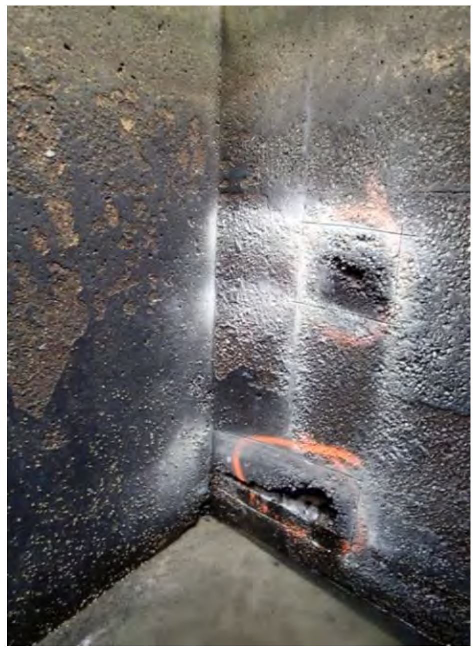



Figure 14 and Figure 15. Spalling concrete in slot surface and pool sidewall corner of Tumwater Dam fish ladder

Figure 16- Sediment and gravel accumulations downstream of slot stub walls

PIT Detector Arrays for Salmonid and Lamprey Passage

Due to trapping operations, and subsequent delay of upstream sockeye passage, PIT detectors were installed to identify the extent of delay. These detectors influence lamprey passage as follows:

- PIT arrays at Slots 15 and 18 are used to assess salmon passage delays. (Figures 17 and 18)
- There was some support for using additional PIT arrays (or reposition the PIT arrays at slots 15 and 18) for future lamprey passage monitoring. However, PIT arrays can only tell whether fish passed a transect point. They can't tell exactly where fish have difficulties passing.

It is expected that the two PIT arrays will result in incrementally more challenging hydraulic conditions for lamprey passage, due to the greater length of flow (approximately 15 inches) from the upstream to downstream PIT detector longitudinal length. Rather than a 6 fps velocity flow at the typical slot perimeter, the longer "tube like" condition contrasts the slot configuration, and is more like a short channel. Velocity in this short length increases from approximately 6 fps at the upstream end to 8 fps at the downstream end.

Figure 17 and 18. PIT detectors with short-channel flow at Slots 15 and 18

9. Auxillary Water System (AWS):

Lamprey entering the ladder through entrances into the entrance pool (pool #1) can either ascend through vertical slots to the upper ladder, or enter through AWS add-in diffusers into the AWS. The following is a description of features encountered for those entering the AWS:

- As pool to pool flow in the ladder (24 – 40 cfs) must have its energy (turbulence) dissipated in each pool, the fish ladder pool volumes are dictated in design, and the ladder footprint size is determined.
- The AWS enables additional attraction flow (56 – 80 cfs) to be bypassed through fine trash racks in the forebay pool (Figure 19), and directed to the lowest AWS pool, after its energy has been dissipated by passage past baffles.
- The lowest AWS pool is to the left of the entrance pool, and contributes flow that passes wall diffusers at 1 ft/s average velocity to join the ladder pool flow, thereby composing fishway attraction flow that discharges from one of the three fishway entrances into tailwater during normal operations.
- The AT did not believe the AWS channel would pose a significant passage problem to lamprey other than as a source of passage delay. They speculated lamprey would readily enter the channel, find that it was a dead end, and exit back through wall diffusers to ladder pool #1. (While this exit behavior is typical for salmon, confirmation of fallback/exit behavior for lamprey at this site is recommended.)
- The AWS is designed to keep salmon from entering, but lamprey are able to enter through entrance pool wall diffusers. Chelan PUD reports (Thad Mosey, CPUD, personal communication) that no lamprey have been observed or recovered in the AWS system after de-watering for annual maintenance. As lamprey are able to pass through similar 1-inch add-in diffuser bars at other locations, this suggests that lamprey entering the AWS may be able to safely pass back downstream through diffusers and into the entrance pool.
- During non-trapping operations, flow routed through the coarse trash rack to the lower ladder, at which flow is controlled by the upper fishway slot. AWS flow is controlled by a downward-closing slide gate, just downstream of the fine AWS trash rack intake.
- The tailwater and pool #1 staff gages are read by the operator, who then opens or closes the AWS gate downstream of the AWS trash rack to attain a 1.0 ft drop at the entrance. AWS flow passes the AWS gate, into a pipeline, then emerges near pool #15, where it passes a covered channel with descending baffle walls, where energy is dissipated.

- Ladder is designed for 5 ft minimum depth.

Figure 19. Tumwater AWS and lower ladder trash racks

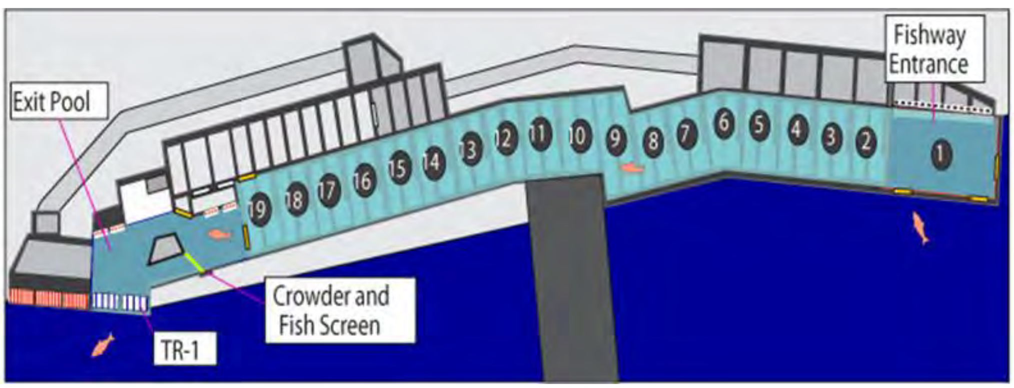


Figure 20. Fish ladder pool water and salmon access in light blue – non-trapping operational mode (AWS shown in gray, but not labeled)

10. Pacific Lamprey Ladder Passage During Non-trapping Operations:

A graphic of the Tumwater Dam fish ladder in the non-trapping mode appears in Figure 20. This section lists factors influencing probable lamprey passage behavior during this mode of operation.

- Lamprey passing a fishway entrance and entering pool #1, which is more quiescent than the tailrace, could enter the AWS system through the 1-inch clear add-in wall diffusers, and advance part way up the covered AWS baffles, where there is appreciable turbulence. The ability of lamprey to ascend this turbulent channel and enter the AWS pipe outlet, near pool 15, is highly unlikely.

- Since there is a contraction of flow in the flow jet as it passes through each vertical slot, lamprey can potentially approach to within a few inches of the jet perimeter along the baffle wall, then surge through the slot and upstream into the next pool. However, it is likely that many would be swept back by the jet when trying to pass, due to 6-8 fps slot velocities.
- Presence of the 1-ft high bottom sill would make slot approach and passage from the floor more difficult than at ladders with no slot sills. Mark Nelson and other AT members believe this feature may be primarily responsible for the absence of lamprey above Tumwater Dam.
- It would be much easier for lamprey to ascend the lower slots in the ladder (up to slot 8 or so), during which pools are backwatered at moderate to higher tailwater elevations. Slot depth increases, and ladder flow is nearly the same. Thus, the lower ladder slot velocities are reduced, and more passable for lamprey.
- Slots 8 and above have a full 1-ft drop at all streamflows.
- Passage at slots 15 and 18 is incrementally more difficult due to PIT detector, short channel flow conditions
- While lamprey passage at similarly-designed vertical slot ladders on the Yakima is documented, the Tumwater Dam fish ladder has a 20-ft vertical drop to pass, versus twelve feet or less at the Yakima River ladders. Thus, lamprey ascension through the ladder pools at Tumwater Dam requires more energy expenditure.
- There is a perceived need to provide attachment features for lamprey at slots and entrances. It is probable that pitted floors and walls make it more difficult for lamprey to attach using suction.
- There was a question whether floor ramps upstream and downstream of slot sills would be appropriate. A possibility is to extend outward about 1ft on both sides of each slot, so that lamprey can attach immediately downstream of the slot, and outside of the flow jet. The downstream ramp would likely be more beneficial than the upstream ramp, as hydraulic conditions are more severe.
- Ramps upstream of sills incrementally change the bottom flow contraction coefficient of the slot jet, but not the side contraction coefficient. Thus, there should be no major slot jet hydraulic change if upstream ramps are installed.
- A 2-in high gap was suggested for the bottom of the baffle wall or sill, as an alternative passage route. This raises the question of whether structurally, holes of perhaps 12-in width x 2-in height can be saw-cut in each weir for a near-floor passage route. (Hydraulics would be short-tube type flow, where the jet expands before leaving the rectangular orifice on the downstream side. Flow velocity would likely be a uniform 8 ft/s at the downstream end. Location of such a horizontal bottom slot will be important. Map of velocities in the pools along the floor would help identify likely locations for such a slot.

- Gaps on upstream vertical side of metal plating for the VSF stub-wall nose plate extensions (Figure 10) are at a location where lamprey would lose suction.
- It is possible that Pacific lamprey could pass without detection at the 1) video counting window, and 2) in the trap. Implications: Lamprey could pass through picketed leads and bypass the count window without being detected. The probability that lamprey would all bypass the count window is low.

Lamprey Passage During Trapping Operation

Between 2004-2013, the fish trap was operated 7 days a week for 24 hrs between mid-July and August 31, for a non-PUD funded study. Since 2011, trapping operations at Tumwater Dam vary during the year. From roughly mid-February to mid-June, the trap is operated 24 hours/7 days/week manned or unmanned trapping steelhead for pHOS (proportion of hatchery-origin spawners) management. From June to mid-July, the trap is actively manned 24 hours/7 days/week utilizing two-three person crews. If during this time period staff is not available to keep the trap operating continuously, the trap is opened to allow for nighttime passage. From mid-July through the end of August the trap is operated 3 days/week for up to 16 hours/day, no more than 48 hours per week. From September until December, the trap returns to 24 hours/7 days/week manned or unmanned trapping. During all trapping, real time monitoring of fish passage time is conducted by WDFW and CCPUD as follows: the two PIT tag antennae arrays within the Tumwater Dam fishway (weirs 15 and 18), are monitored and detections of previously PIT tagged fish will be evaluated to determine the median passage time of fish between first detection at weir 15 and last detection at weir 15 or weir 18. Median passage estimates are updated with every 10 PIT-tagged fish encountering weir 15. If the median passage time is greater than 48 hours, trapping ceases and fish are allowed to exit via the ladder into the forebay (i.e., bypass the trap). If trapping is stopped, PIT monitoring continues and trapping is resumed only when the median fish passage time is less than 24 hours.

11. Steps to Initiate Trapping Operations

Figure 21 depicts upper Tumwater Dam fish ladder and trap during the trap-operation mode. During trapping periods, a bulkhead is lowered into slot 19 (Figure 22), and flow is forced into the fish trapping loop at the top of the fish ladder. A vee-trap bulkhead is raised, and salmon are routed into the trapping chamber adjacent to the ladder counting and exit channel. Flow passing the counting window and angled pickets is routed through two1-inch clearance vertical diffuser panels in the left wall, then through 48-in x 48-in and 30-in x 30-in downward closing gates, to a chamber under the adult trap chamber. Flow then upwells through 1-in floor diffusers (Figure 23), then circles around and passes the vee-trap (Figure 22) into pool 18. This flow, plus a few cfs from the steep-pass fish ladder, constitutes the total ladder flow during trapping.

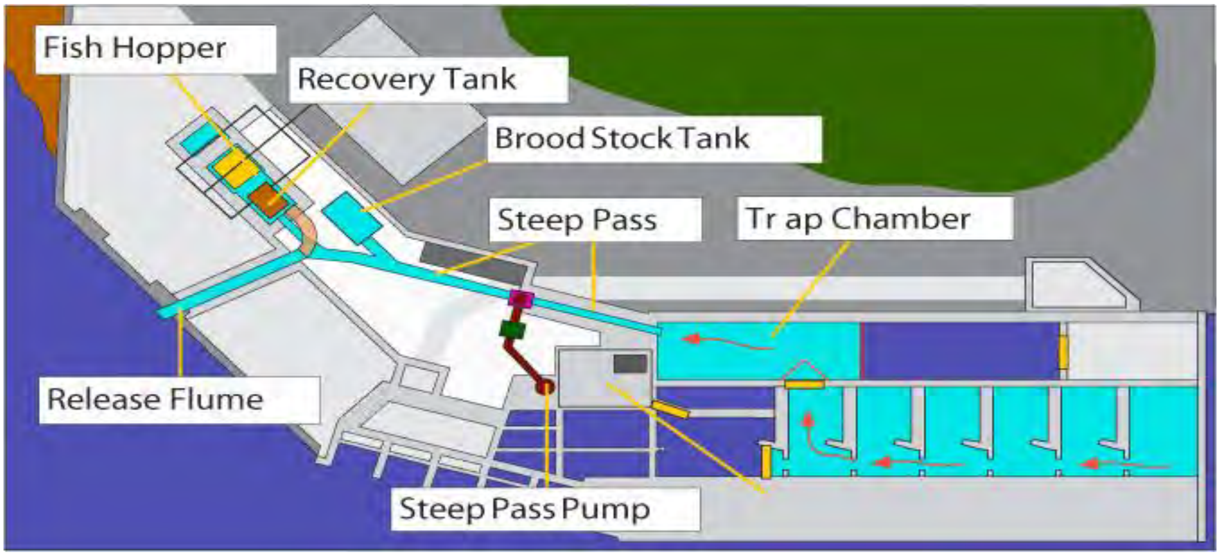


Figure 21. Upper Tumwater Dam ladder trapping facilities (arrows represent upstream fish movement)

Figure 22 – Closure bulkhead to initiate trapping operations, at Weir 19

Pacific Lamprey Passage During Salmon and Steelhead Trapping Operations

Broodstock collection at the Tumwater Dam fishway has occurred in some form since the 1990's, and trapping protocols are consistent with NMFS Section 10(A)(1)(a). The uncertainty relative to lamprey is whether upstream passage is blocked during trapping operations, due to either hydraulic conditions, or small openings in diffuser gratings. The following are AT observations:

- A preliminary hydraulic analysis of flow through the trap holding pool (before June 30, 2015 readings at the fishway) suggested lamprey may be blocked trying to pass above the trap holding pool. Section Dwg J/23, on page 26 of the Tumwater Dam fish ladder design drawings (which were provided to the AT prior to the February 18 site visit) shows the 30-inch x 30-inch and 48-inch x 48-inch trap water supply gates. During trapping operations, flow passes from the upper ladder exit channel through the two vertical 1-inch clear wall diffuser panels (located downstream of the counting station), then downward through the supply gates, and upward through 1-inch clear floor diffusers in the trap holding pool. The flow magnitude is sufficient to pass through the vee-trap to pool 19, and composes the entire lower ladder flow. Washington Department of Fisheries operator Nate Dietrich stated that normal operation is to leave the two supply gates fully-opened, and just open-close the weir 19 bulkhead, and close-open the vee-trap bulkhead, when changing to/from trapping operations. According to Matt, the two supply gates must be partially closed during high flows, which increases hydraulic drop at the two gates.

- A major concern relates to head loss at the two supply gates. If lower ladder flow is in the same range as during non-trapping operations (25 – 40 cfs), the hydraulic drop at the partially- opened gates could be excessive for lamprey passage.
- Conditions immediately upstream and downstream of the gates combined with gate velocities may be a challenge relative to lamprey passage. Lamprey must pass through the supply gates, then upward through a confined downwell (gate invert elevations are below the exit channel floor) and through vertical wall diffuser panels to reach the more quiescent exit channel. An important question is whether lamprey are able to pass this composite of features, with only the possible use of downwell walls for suction/resting.
- On the June 30, 2015 Tumwater Dam fishway site visit with Ian Adams (CCPUD) and operator Nate Dietrich (WDFW), trap supply gate operations were described, and measurements were taken to determine hydraulic loss across the gates for that day's river flow (approximately 1900 cfs at Peshastin gage, and 1500 cfs at Tumwater Dam). Flow was extremely low for this time of year. Differential across the gates and from the exit channel to trap pools was 0.55 ft, and from trap pool across the vee-trap to pool 19 was 0.33 ft. Gate velocities were approximately 4 fps. Conclusion is that the composite wall diffusers, downwell, and fully-opened gates probably do not constitute a blockage during this low flow condition.
- As project flow and forebay elevation increase, however, the exit channel water surface immediately upstream of the supply gates rises. Nate explained the adult holding pool water surface is maintained to the extent possible at the bottom elevation of the shroud around and just above the steep-pass entrance (Figure 23). Reason is to minimize jumping injuries of adult salmon and steelhead. A weir gate at the downstream end of the adult holding pool (downstream of a full diffuser panel barrier) passes progressively more bleed-off flow as river stage increases, thereby suppressing rising water surface in the holding pool. Thus, the exit channel to holding pool differential increases, potentially to above 1.0 ft (6 fps at the gate

openings). Field confirmation of supply gate openings and differentials at different streamflows is needed to determine whether head exceeds 1.0 ft, which is deemed a probable lamprey blockage.

- If lamprey could pass upstream to pool 18, they would likely be able to pass the vee-trap (Figure 23) and floor screens (Figure 24), then potentially be blocked at the control gates at mid-range and higher river flows. However, upstream passage into and up the fishway is considered more hydraulically challenging at the mid-range and higher flows. Thus, lamprey would probably only be passing at lower flows where trap supply gate differential is $\leq$ 1.0 ft. Thus, there is reduced risk of lamprey blockage at the supply gates.
- Vee-trap opening velocity is less than 2 ft/s, and through angled vee openings is slightly lower. Lamprey passage through the vee trap (Figure 22) should not be a problem.

Figure 23. Vee-trap entrance

Figure 24. Floor screens and steep-pass

- There was a question if lamprey would be deterred from entering the trap because of the number of salmon. Mary Moser was not so concerned because in lower Columbia River lamprey move upstream with shad, where there can be thousands wall to wall. Those dams have larger pool areas, however. Also, salmon are likely to be more dispersed at different trap pool depths, where lamprey will be more near the bottom. However, this view was not shared by all AT members.
- Mary was concerned with the trapping schedule because lamprey need to pass at night. Trapping includes steep-pass operations and attraction flow passing the adult holding pool at all hours and whether operators are present or not, during trapping months. Only from July 16 to August 31 is the ladder completely open part of the time, with no steep-pass or trapping 4 days per week.

- Note that a steep-pass fish ladder (Figures 24 and 25) is typically a length of aluminum channel, with closely spaced wall and floor baffles. Water tumbles as it passes down the ladder, and can be placed at a slope of up to 28%, and will provide highly turbulent but low average velocity (approximately 2 ft/s) through the opening between and above baffles. Some salmon species will not pass a steep-pass ladder, and fall back can be lethal to any species. Once a fish starts to ascend, they must power to the top. Steep-pass fishways are not suited for lamprey passage.

Figure 25 – False weir at top of steep-pass

- Although lamprey passage through steep-pass ladders has been documented, the protruding steep-pass entrance (Figure 24) is not conducive to lamprey suction near the ladder entrance that would increase the potential for passage, such as if the steep-pass ladder entrance were flush with the trap pool wall.
- Washington Department of Fisheries trapping personnel have never seen a lamprey come up the Tumwater Dam steep-pass and into the trapping facilities.

Lamprey Passage through Existing Pipes

Some AT members posed the idea of alternative passage routes, including passage through existing water supply or drain pipes. The following address passage of lamprey through existing pipes:

- Existing pipes are either drain pipes, which intermittently pass water, or water supply pipes, which entail excessive velocities, and flow-control gates that create barriers relative to lamprey swim speeds.

- Modifying any of these pipes to pass lamprey would compromise their current use.
- It is not feasible to modify existing piping to pass lamprey.

Lamprey Passage through Fishway Exit Trash Racks

The following addresses lamprey passage through coarse and fine trash racks:

- The ladder trash racks (Figure 19) draw pool-to-pool and AWS flow from Lake Jolanda. Fish passing the coarse trash rack enter a zone of slow water habitat with small substrate.
- Coarse trash rack clearance between bars is approximately 8 inches, and is designed for salmon passage. Fine AWS trash racks have a clearance of 1-7/8 inches, and are designed to minimize debris entry into the interior fish ladder.
- Trash rack design velocities are less than 2 fps
- Upstream-migrating lamprey should readily pass both coarse and AWS fine trash rack openings.

12. Dam Face

Dam face observations, relative to upstream lamprey passage, include:

- Figure 26 shows erosion of concrete, and exposed aggregate can be seen.
- Dam face is has an ogee longitudinal section, with a steep-gradient apron (Figure 27).
- See also Section 5 for discussion of dam configuration.

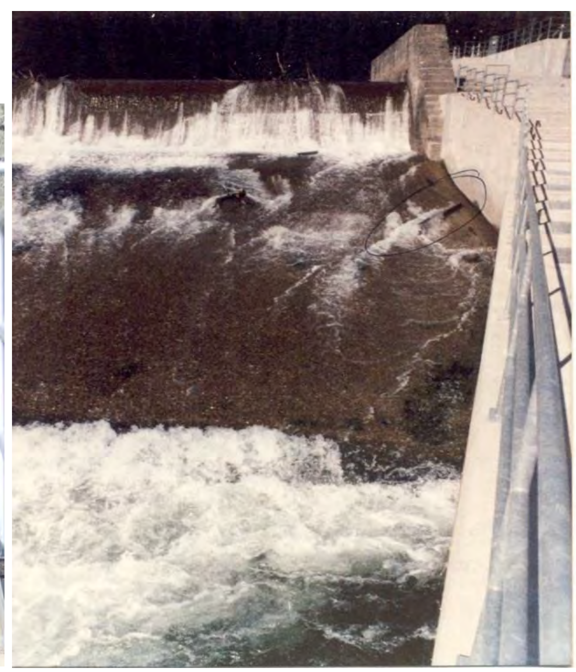


Figure 26 – Flow over dam ogee

Figure 27 – Concrete apron, ogee in background

- Salmon are attracted to flow passing down the dam face, and have been observed jumping and/or swimming onto the apron (Steve Rainey personal observations, June 30, 2015). See Figure 26.
- Velocities on the apron are approximately 15 - 25 ft/s, depending on total river flow. Greater apron velocities and flow depths occur at higher river flows.
- At 20 ft height, it is possible that lamprey could pass the dam at abutments, but passage over the apron and ogee dam crest is unlikely.
- A lamprey passage device, similar to those at Bonneville Dam and 3-Mile Dam (Umatilla River, Oregon) could potentially improve passage at both Tumwater Dam abutments.

13. After-Site Visit Meeting Discussion/Comments

Although not the purpose of ladder visit, the AT was asked to insert other options to pursue for Pacific lamprey passage at Tumwater Dam. Discussion at the PUD building in Leavenworth occurred after the tour, and comments were submitted separately. (Note that not all AT members were able to attend the post-tour meeting.)

- Chris Peery favored a ramp or LPS-like structure at the right abutment as a good alternative to investigate rather than attempting to retrofit the existing salmon fishway to make it lamprey-friendly.
- PIT tag studies should be able to determine if lamprey are entering the fishway and ascending to pools 15 and 18.
- A left bank LPS-like structure is a consideration, depending on telemetry results
- Radio telemetry studies may be better at evaluating behavior of lamprey below the dam, and how far they could ascend once they enter the fish ladder. This would include identifying the percentage of tagged fish reaching the fishway, the percentage of fish entering the fishway, and the percentage of fish ascending the fishway.
- As there is no indication lamprey are being detected at the count window, implication is there are none fully ascending the fishway at present.
- There is an apparent absence of pheromones due to absence of lamprey juveniles upstream of the dam. The need for possible remedies would best be addressed before any future passage study is conducted.
- It was recommended that an assessment of lamprey behavior inside and outside the ladder be confirmed, before investing in structural improvements.
- Upstream and downstream ramps at each 1-ft high slot sill, and at fishway entrances, were recommended
- There were concerns over historical trapping operations for a non-PUD study that took place between 2004 and 2010 which blocked the fishway completely all day and night from April through July and resulting effects that may have affected lamprey passage, and legacy effects on upstream abundance remaining today.

14. Discussion

Features and operations of both the fish ladder and trap were observed in a dewatered state, and hydraulic analysis of different parts of the ladder were conducted and summarized herein. Non-trapping and trapping operations were studied. There is no clear evidence of upstream passage impediment that would account for absence of lamprey upstream of Tumwater Dam was observed; however, several observations are noted below that require further investigation. These include:

- The fish ladder and trap are dewatered annually. No lamprey adult observations have been documented by CCPUD.
- Lamprey access to the fishway is more likely during lower flow periods (<3000 cfs at Peshastin gage), as tailwater turbulence increases to a potentially prohibitive range for lamprey at greater streamflows.
- Trap supply gates from the fishway exit channel to adult holding pool have greater head differentials (1-ft head) and velocities (6 fps at the partially-opened gate, 8 fps at the fully-contracted jet immediately downstream) and may constitute a blockage at higher flows. But no blockage at these gates is expected at <3000 cfs.
- Potential blockages were identified, including 1-ft high slot sills, PIT-detectors, and 1-ft high entrance sills perched above horizontal footings in the tailrace.
- If features within the Tumwater Dam fishway-trap constitute a barrier to lamprey, they will have to be identified on the basis of observed behavior. The most comprehensive means of identifying blockages is a radio-telemetry study.

15. Recommendations

The following are AT recommendations for discussion in the Rocky Reach Fish Forum. (Note that the AT did not meet and formally adopt these recommendations; they have been developed from AT inputs within this report.):

- Use this report as a basis for discussion within the RRFF of appropriate next steps to reconcile lamprey passage uncertainties/concerns at Tumwater Dam.
- Delay structural fishway-trap modifications for lamprey improvements (ramps, lamprey passage devices, etc,) until after affirming actual lamprey blockage on the basis of observed passage behavior.
- Conduct upstream lamprey passage telemetry study at Tumwater Dam to identify locations of passage impediments – both interior and exterior. Prepare a plan of required steps to be reconciled prior to the study, such as introduction of juveniles upstream to establish pheromone scent.
- Prepare a list of tentative telemetry study objectives, including (1) rate of lamprey approach to the left fishway at different streamflows, (2) rate of lamprey entry to the left fishway at different streamflows, (3) whether lamprey passing into the AWS are able to exit and subsequently ascend the lower fishway pools, (4) whether there is delay at either the entrances or slots due to 12-inch high sills, (5) rate of lamprey ascension to pool 18, (6) delay at the trap supply gates, (7) delay at other features

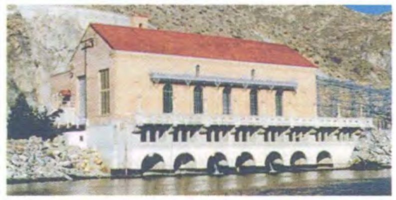
within the fishway, such as the PIT detection slots, and (8) rate of passage to Lake Jolanda, and other. Documentation of streamflows during observed blockages should be included.

- Further assess trap supply gate differentials between the fishway exit channel and fish holding pool, making note of streamflows and supply gate settings, to assess if and when supply gates are a barrier to lamprey passage.

Literature Cited

1. Grote, A. and M.C.Nelson., Yonce, C., Johnsen, A., Sulak, D.J., and Nelle, R.D. 2014. Passage of radio-tagged adult Pacific lamprey at Yakima River diversion dams: 2013 Annual Report. U.S. Fish and Wildlife Service, Leavenworth WA.
2. Johnsen, A. and M.M. Nelson. 2012. Surveys of Pacific lamprey distribution in the Wenatchee River watershed 2010-2011. U. S. Fish and Wildlife Service, Leavenworth WA.
3. National Oceanic and Atmospheric Administration (NOAA) Fisheries – Anadromous Salmonid Passage Facility Design. Northwest Region. 2011.

Attachment 4 – Biological Assumptions Memorandum


PUBLIC UTILITY DISTRICT NO. 1 *of* CHELAN COUNTY
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MEMORANDUM

DATE: January 31, 2017

TO: Justin Fletcher, Chelan PUD

FROM: Steve Hemstrom, Chelan PUD

SUBJECT: Pacific Lamprey biological knowledge and assumptions supporting the TWD Lamprey Passage Feasibility Study

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This memo provides biological information that is known about adult Pacific Lamprey passage timing and behavior in the mid-Columbia River and biology-based assumptions of unknown information. It describes assumptions of adult lamprey behavior in the Wenatchee River and interactions with Tumwater Dam. This memo is intended to assist with development of alternatives for the lamprey passage feasibility study at Tumwater Dam on the Wenatchee River.

Knowledge is limited about adult Pacific Lampreys that move into the Wenatchee River each year. Agencies and tribes have conducted very few studies on adult lamprey in the Wenatchee River. Chelan PUD is in progress with a 2016 PIT Tag passage study that is aimed at assessing Rocky Reach Dam passage and tributary escapement rates. Adult lampreys are difficult study because they are non-philopatric - that is adults may not return and are not obligated to return to their natal stream of origin to spawn. Adult lampreys are cryptic and strongly photonegative. They avoid lighted conditions when they can. During upstream freshwater migration, and overwintering periods, adults may hide in dark boulder pockets or under large submerged wood or plant mat debris. They move upstream mostly at night in stream environments.

Mainstem Adult Pacific Lamprey Passage

Timing of passage and fishway counts of adult Pacific Lamprey at both Rock Island and Rocky Reach dams are tracked 24 hours per day, seven days per week, 14 April through 15 November at both Projects. Adult lamprey passage typically peaks in August at both Projects; the July through September period typically encompasses greater than 90% of adult passage at both Projects. Table 1 contains total monthly passage counts of Pacific Lampreys at both Rock Island and Rocky Reach in 2016. Very few lampreys pass through mainstem fishways in April-June, or November, even though fishways are open and operating.

Table 1. Monthly fishway passage counts of adult Pacific Lamprey at Rock Island and Rocky Reach dams, April 14 – November 15, 2016.

	May	June	July	August	September	October	November
RIS Total Lamprey Count	0	36	278	1,912	1,162	547	4
RRH Total Lamprey Count	0	6	222	1,992	1,159	214	2

In the 17-year period 2000 to 2016, the earliest lamprey observed in the Rock Island fishway count-windows (three separate ladders each with count window) is 26 May (Figure 1). The 17-year mean date of first lamprey passage at Rock Island is 18 June; the median first passage date is 21 June. The duration of time for the middle 90% of the lamprey run to pass Rock Island Dam is 55 days on average, July through September (Figure 1). The 17-year cumulative April-June count of adult lampreys passing Rock Island is only 140 lampreys total (Figure 1).

The earliest date of first lamprey passage from the fishway count window at Rocky Reach Dam is 8 June in the period 2000-2016. The mean date of first passage at Rocky Reach in this 17-year period is 5 July; the median date of first passage is 7 July. The total cumulative 17-year count of adult lampreys in the months of April through June at Rocky Reach is only 11 individuals (Figure 2).

Figure 1. Dates of first adult Pacific Lamprey passage observed at Rock Island Dam, 2000-2016.

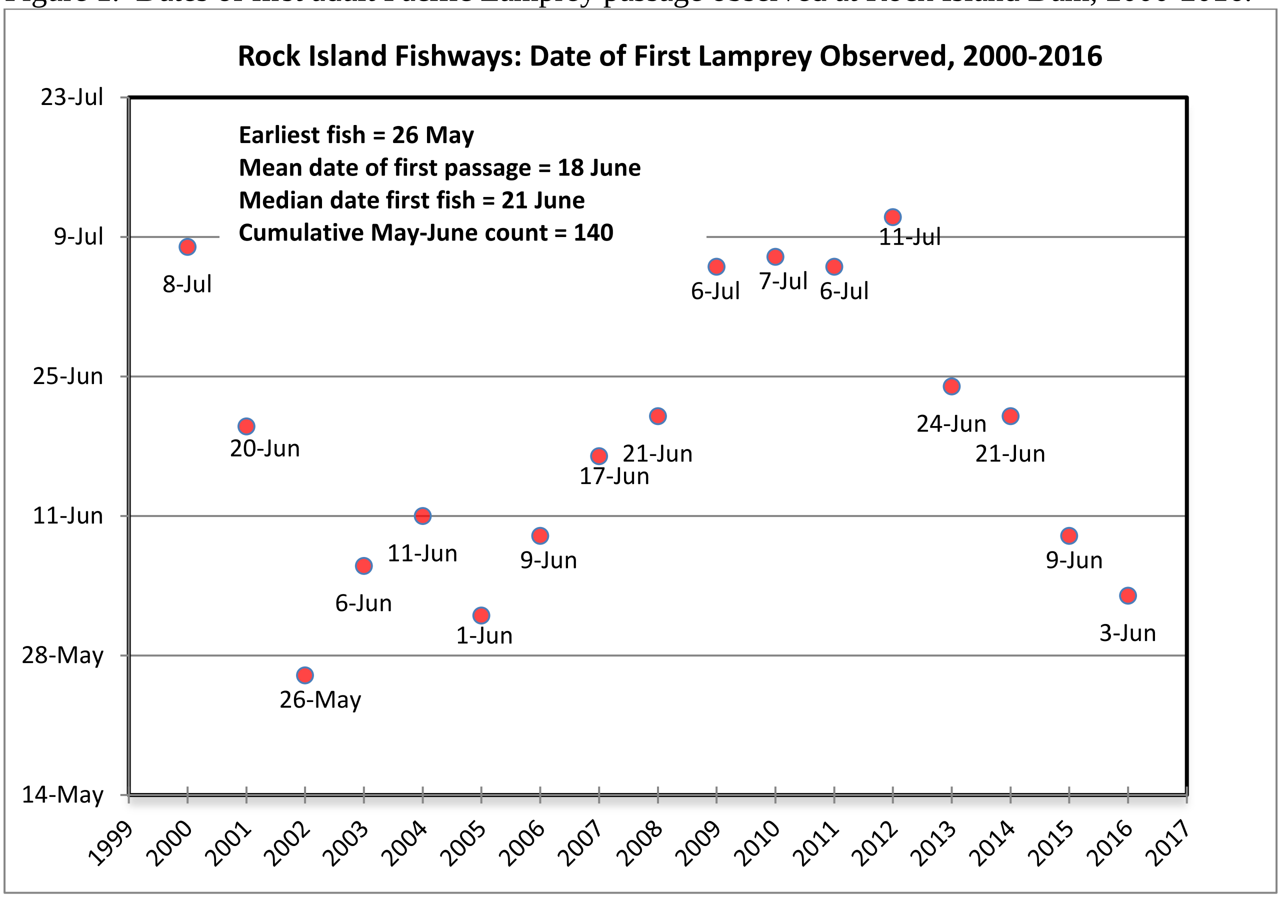


Figure 2. Dates of first adult Pacific Lamprey passage observed at Rocky Reach Dam, 2000-2016

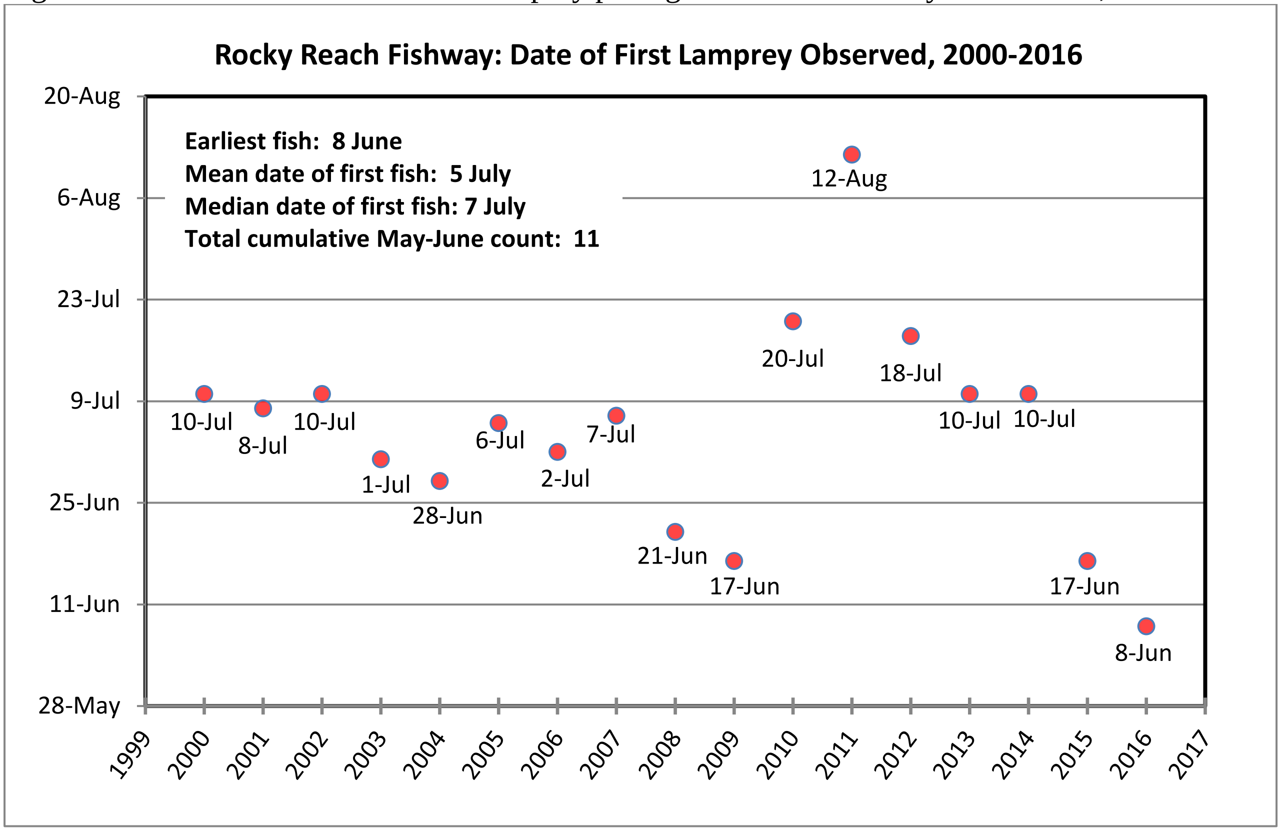


Figure 3 shows the total annual season-wide counts of Pacific lamprey at Rock Island and Rocky Reach dams from 2000 through 2016. Total counts in this period vary widely, ranging from a low in 2010 (RIS-268; RRH-318) to a high in 2014 (RIS-4,600; RRH-3,799). The 17-year mean annual total lamprey count at Rock Island Dam is 2,108 lampreys; the mean count for this period at Rocky Reach is 1,185 lampreys.

Dam conversion rates for Pacific lamprey based same-year passage counts and count differences between Rock Island and Rocky Reach is demonstrated in Figures 4-6 and ranges from 6.4% 1996 to 98.6% in 2015. Significant improvements were completed in 2011 to the Rocky Reach fishway to aid adult Pacific Lamprey passage. Benefits of these modifications are recognizable in count conversions between Rock Island and Rocky Reach (Figures 4-6).

Figure 3. Total annual fishway counts of adult lampreys at Rock Island and Rocky Reach dams.

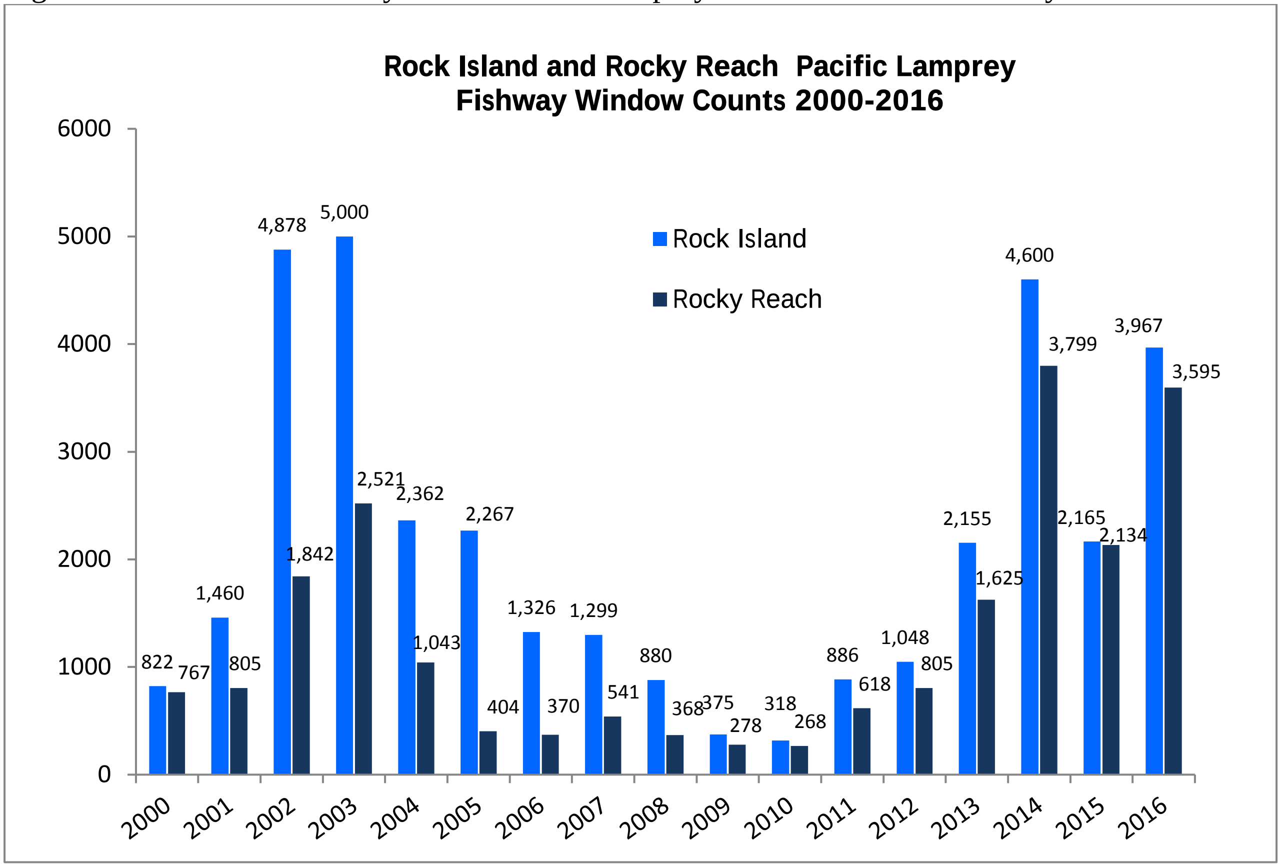


Figure 4. Adult lamprey fishway count conversion rates, Rock Island to Rocky Reach, 2000-2016.

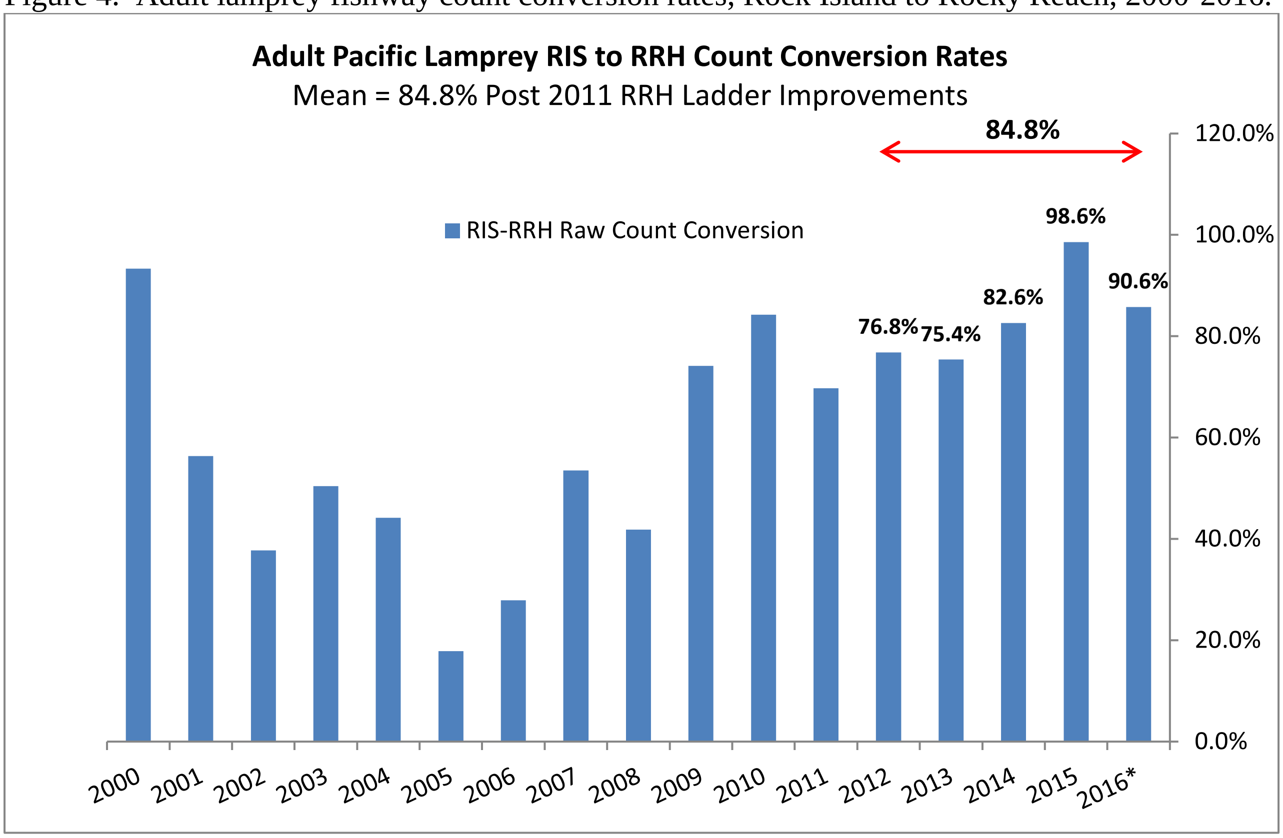


Figure 5. Pacific lamprey Rock Island to Rocky Reach unadjusted fishway window count conversion rates 1983-2016.

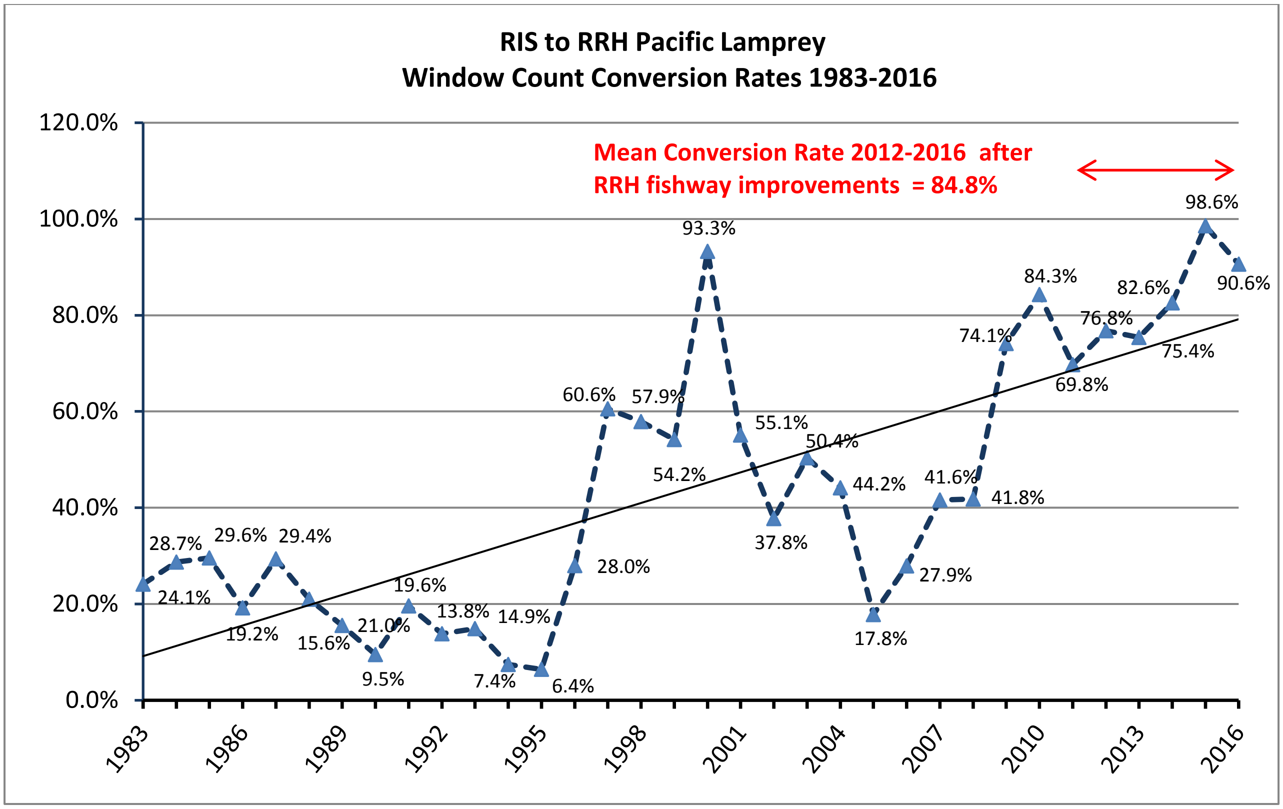
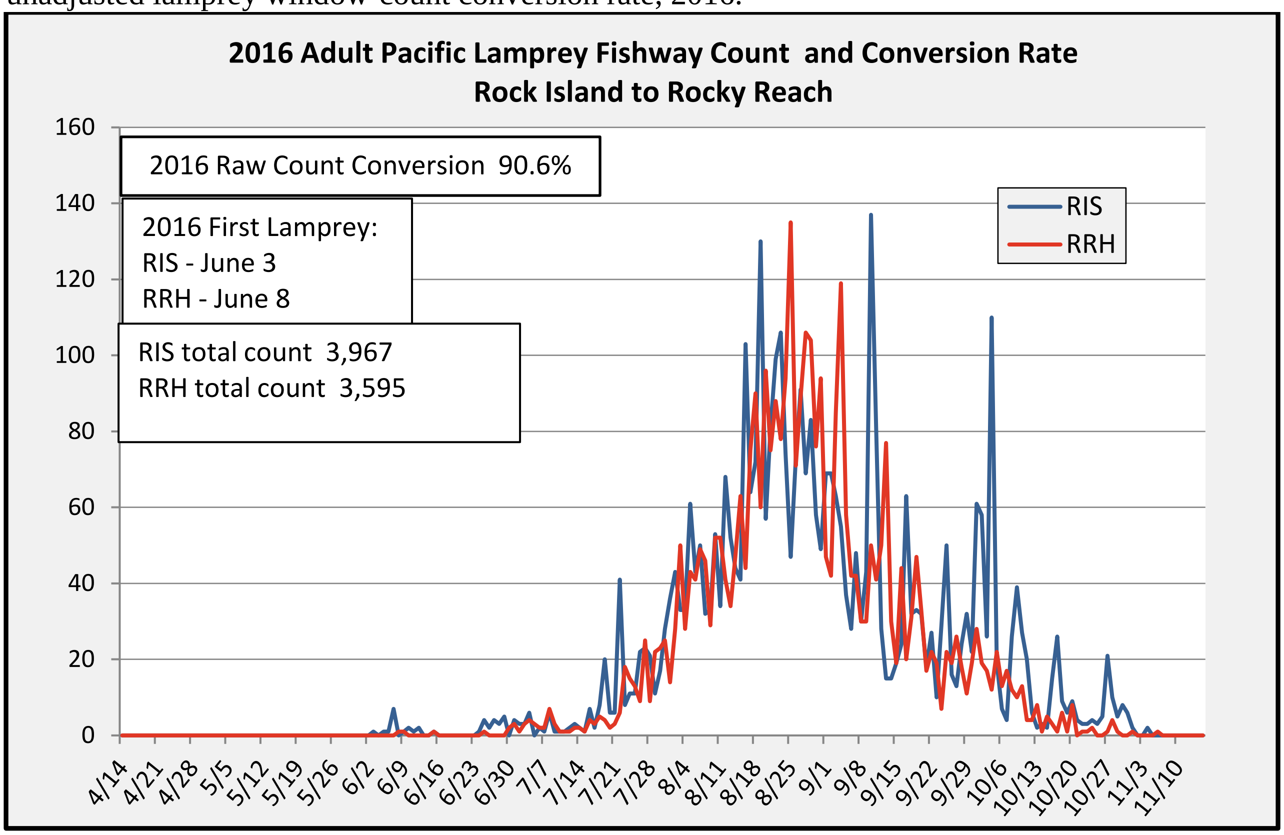


Figure 6. Adult Pacific Lamprey run timing at Rock Island Dam to Rocky Reach dams and unadjusted lamprey window-count conversion rate, 2016.



2016 Rocky Reach Adult Lamprey PIT Tag Passage and Escapement Study

In 2016, Chelan PUD trapped, tagged, and transported 211 adult lampreys up from Priest Rapids Dam to conduct a dam passage and escapement rate study at Rocky Reach. Lampreys were single tagged with a full-duplex (FDX) PIT tag. All fish were re-released at Kirby Billingsley Hydro Park (KBH), approximately 7.5 river miles downstream of the Wenatchee River confluence. Lampreys were released from 3 August to 17 August, 2016.

As of 31 December, 2016, 169 of the 211 lampreys released in August 2016 at KBHP have been detected somewhere (80.1%). Only five of the total 211 lampreys released (though perhaps more undetected) have volitionally entered the Wenatchee River (initial escapement 2.4%), and five of the 169 total detected fish (3.0%) are in the Wenatchee. The range of travel times for these five fish, from release to first PIT detection inside the Wenatchee River, was 0.5 to 13.6 days. This demonstrates the variable migration times exhibited by individual lampreys. None of the 211 tagged lampreys have been detected in the Entiat River or at Tumwater Dam. However, 164 of the 211 (77.7%) released lampreys were detected within the Rocky Reach fishway, with 163 verified to have exited the top of the Rocky Reach fishway (99.4% fishway passage rate).

Biological Assumptions-Wenatchee River Pacific Lamprey at Tumwater Dam

Wenatchee River Escapement Based on Mainstem Counts

Counts of adult lampreys passing through the fishways at both Rock Island Dam and at Rocky Reach Dam each year is known. These numbers are helpful to approximate the number of adults available to enter the Wenatchee River and available to pass Tumwater Dam (Table 2). The actual annual passage count differences between Rock Island Dam and Rocky Reach Dam are not known for certain because "fall back" of adult lamprey through dam routes other than the fishway, and possible subsequent re-count of twice passing lampreys ae unknown; however, re-count rates are believed to be very small based on radio-telemetry and PIT tag studies. Additionally, escapement rates are unknown because the numbers of adult lampreys that entered freshwater the previous year and may have overwintered somewhere between Rock Island and Rocky Reach dams or in the lower Wenatchee River, are now available to move upstream or enter the Wenatchee to spawn or approach Tumwater Dam.

The Wenatchee River mouth is approximately 24.9 km above Rock Island Dam and 8.4 km downstream of Rocky Reach Dam. We know that adult lamprey enter the Wenatchee River to spawn, how many enter and spawn is not known precisely. Comparison of full-season fishway window counts at Rock Island Dam and Rocky Reach Dam (Figure 3) suggests that escapement rates into the Wenatchee are variable, with perhaps 50 to 800 adults entering annually in recent years based on count conversions between the two Projects. Once in the Wenatchee, we know some adult lamprey spawn above the Dryden Irrigation Canal water in-take site. Chelan PUD observes and recovers lamprey ammocoetes that rear in the canal sediments every year; most years recovery number is in the thousands of larvae. Recovery takes place during the season-end canal dewatering process.

Table 2. Potential Wenatchee River lamprey escapement numbers based on full-season fishway lamprey count differences at Rock Island and Rocky Reach dams, 2010-2016.

Year	Rock Island Count	Rocky Reach Count	Count Difference Escapement Potential
2010	318	268	50
2011	886	618	268
2012	1,048	805	243
2013	2,155	1,625	530
2014	4,600	3,799	801
2015	2,165	2,134	31
2016	3,967	3,595	372

Migration Timing to Tumwater Dam

Tumwater Dam is located at approximately river mile 32.7 on the Wenatchee River. The last adult lampreys observed passing Tumwater Dam occurred in 1995 when fish-counter video observed eight adult lampreys passing on the same day on 15 July (Chelan PUD unpublished fish count data 1995). The time of day is noted in the fish-count sheets for these lamprey passage events in the July 15, 1995. Since that day, no lampreys have been observed passing Tumwater Dam that Chelan PUD is aware of. The USFWS conducted electrofishing surveys in 2012 in the upper Wenatchee above Tumwater Dam to document any presence of juvenile lamprey (Yonce and Nelle, 2012). They found no rearing juvenile lamprey in multiple surveys. Juvenile lampreys may rear in sediments for four to seven years after eggs hatch, which helps confirm that based on electrofishing surveys, passage has likely not occurred recently at Tumwater Dam.

Given that no direct studies have occurred, migration timing is based on professional knowledge of agency and tribal lamprey biologists. In the Yakama River, the Yakama Nation noted that approximately 10% of the spring lamprey migration passes at flows above 4,400 cfs (Lampman 2015). At Tumwater Dam, flows typically range from 800-1,400 cfs during the fall migration August-October and 1,700-8,000 cfs in the spring and around 4,000 cfs in July.

Chelan PUD’s best assumption of adult lamprey arrival timing at the Tumwater Dam site is first of July through late August. Because lamprey don’t begin to move past Rock Island or Rocky Reach in the mainstem until July, it seems improbable they would initiate migration up through the Tumwater Canyon to the Tumwater Dam site prior to July in most years. It also unlikely that overwintered lamprey already in the lower Wenatchee or Tumwater Canyon would begin to move upstream to towards Tumwater Dam prior to late June or early July, depending on flow and temperature conditions. We therefore in the future should assume that if Pacific lampreys intend to pass Tumwater Dam to spawn in the current year, they would be at Tumwater from late June through late July, maybe even early August, depending Wenatchee temperatures and hydrograph conditions. Lampreys migrating in their first freshwater year, pre-overwintering could be present July-September at Tumwater Dam.

Spawn Timing in the Wenatchee

The US Fish and Wildlife Service (USFWS) believes Pacific lamprey spawning occurs in the Wenatchee River on the backside of the hydrograph in the summer—likely in the period July through August, depending on the water year, individual lampreys migration timing past Rock

Rocky Reach and Rock Island Dam (Figures 7 and 8 photos) and entry time and overwintering location in the Wenatchee River. USFWS noted they have “no direct observations to back that up this spawn timing supposition”, except for one an adult carcass reported in the month of July and YOY larvae sampled that were sampled in September (A. Grote, USFWS, personal communication January 26, 2017).

Spawn timing is therefore largely inferred from the Entiat River, where USFWS does have some recent spawning data. Active Pacific Lamprey nests have been observed in the Lower Entiat River as early as June 9 in 2016, and as late as the first week of August in 2014. The USFWS recovered a spawned out carcass from the Entiat in mid-September 2016(A. Grote, USFWS, personal communication January 26, 2017).

Most of the information on lamprey spawning in the Entiat and Wenatchee rivers comes incidentally from spring steelhead surveys, and late summer/fall Chinook surveys. USFWS indicated that without salmonid surveys running in mid to late summer (when USFWS presume much of the spawning happens) they do not have funding or directive to get direct confirmation on adult lamprey spawner abundance or spawning time.

Figure 7. Adult lamprey passing through the Rocky Reach fishway count window, 11 August, 2014.

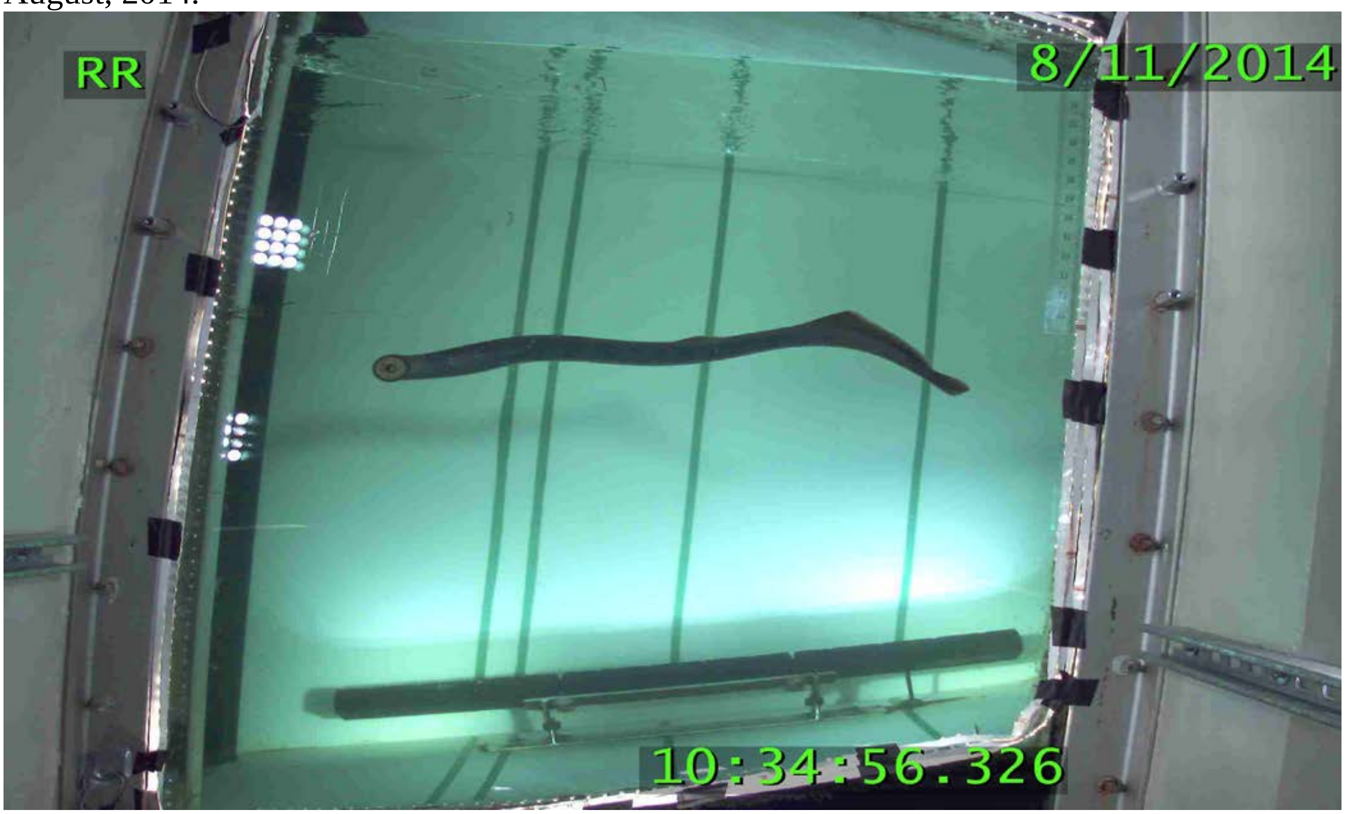
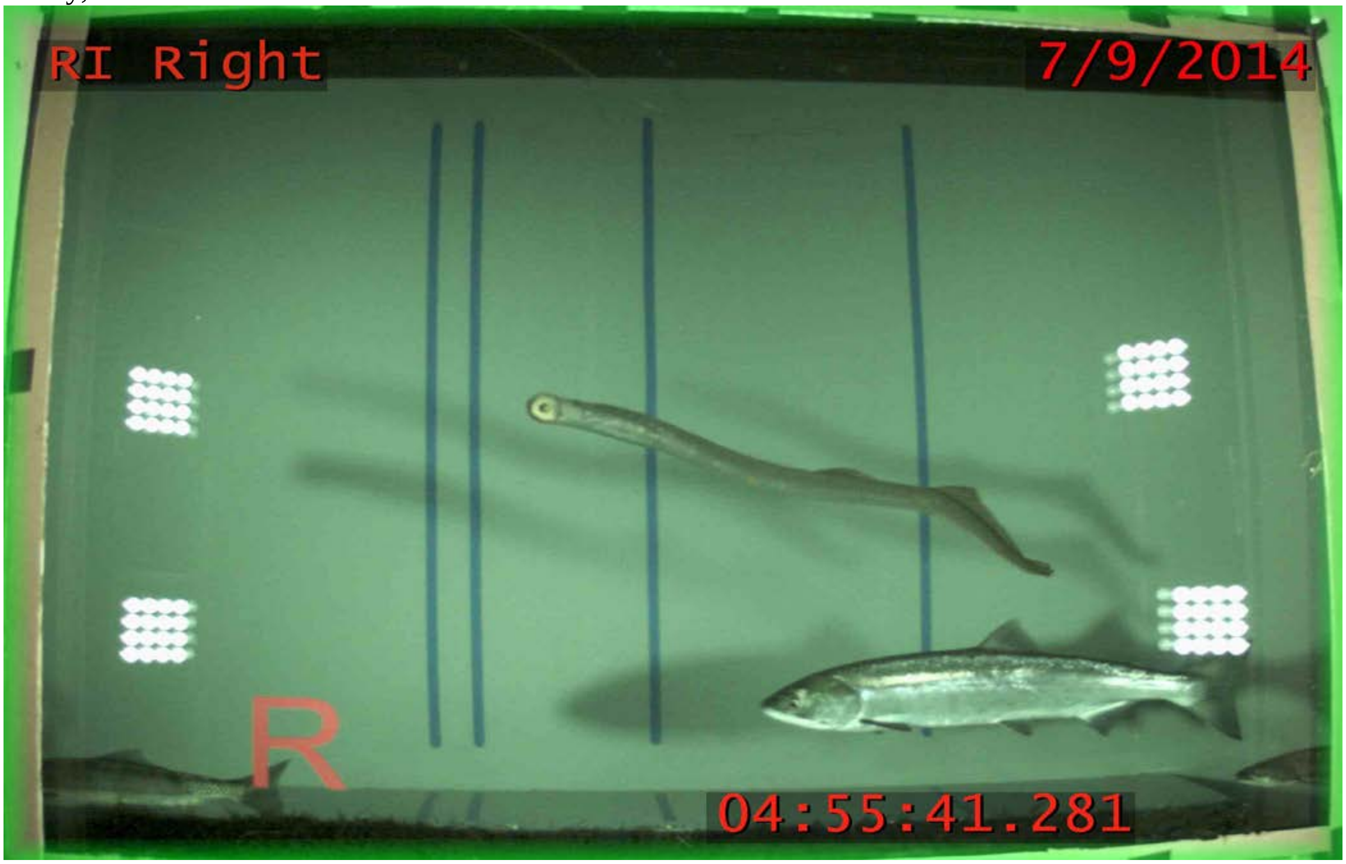


Figure 8. Adult lamprey passing through the Rock Island right bank fishway count window on 9 July, 2014.



REFERNCES

Chelan PUD. 1995. Daily Report of Fish Counters Tumwater Dam. Tumwater Dam fishway unpublished fish count data, 14 July through 17 July, 1995.

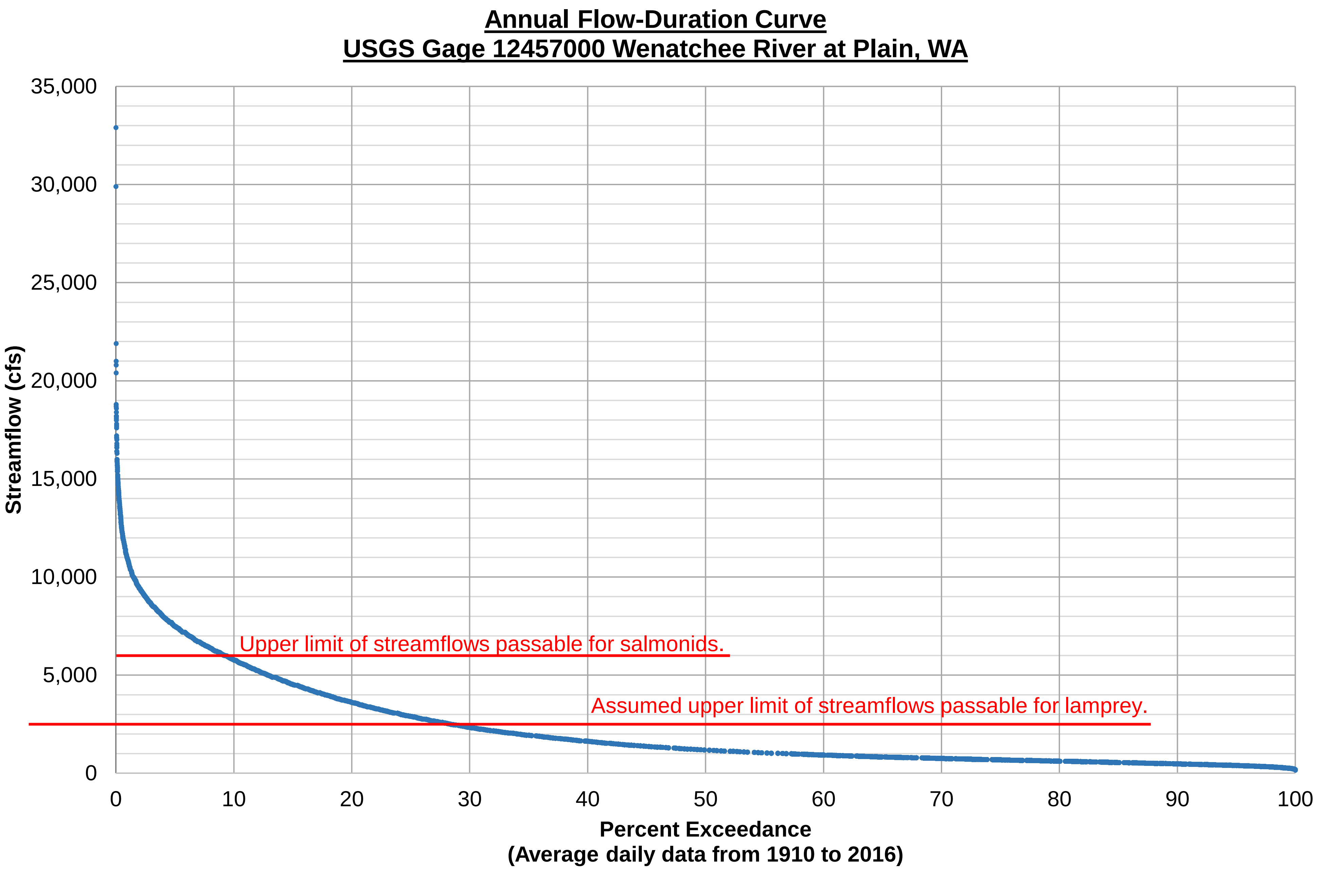
Keefer, M.L, C.T. Boogs, C.A. Peery, and M.L. Moser. 2009. Adult Pacific Lamprey Migration in the Lower Columbia River: Radiotelemetry and Half-Duplex PIT Tag Studies. Technical Report. US Army Corp of Engineers, Portland, Ore. 2009.

Lampman, R. 2015. Tumwater Dam Fish Ladder Investigations. Yakama Nation Fisheries Resources Management Program, Pacific Lamprey Project. February 18, 2015.

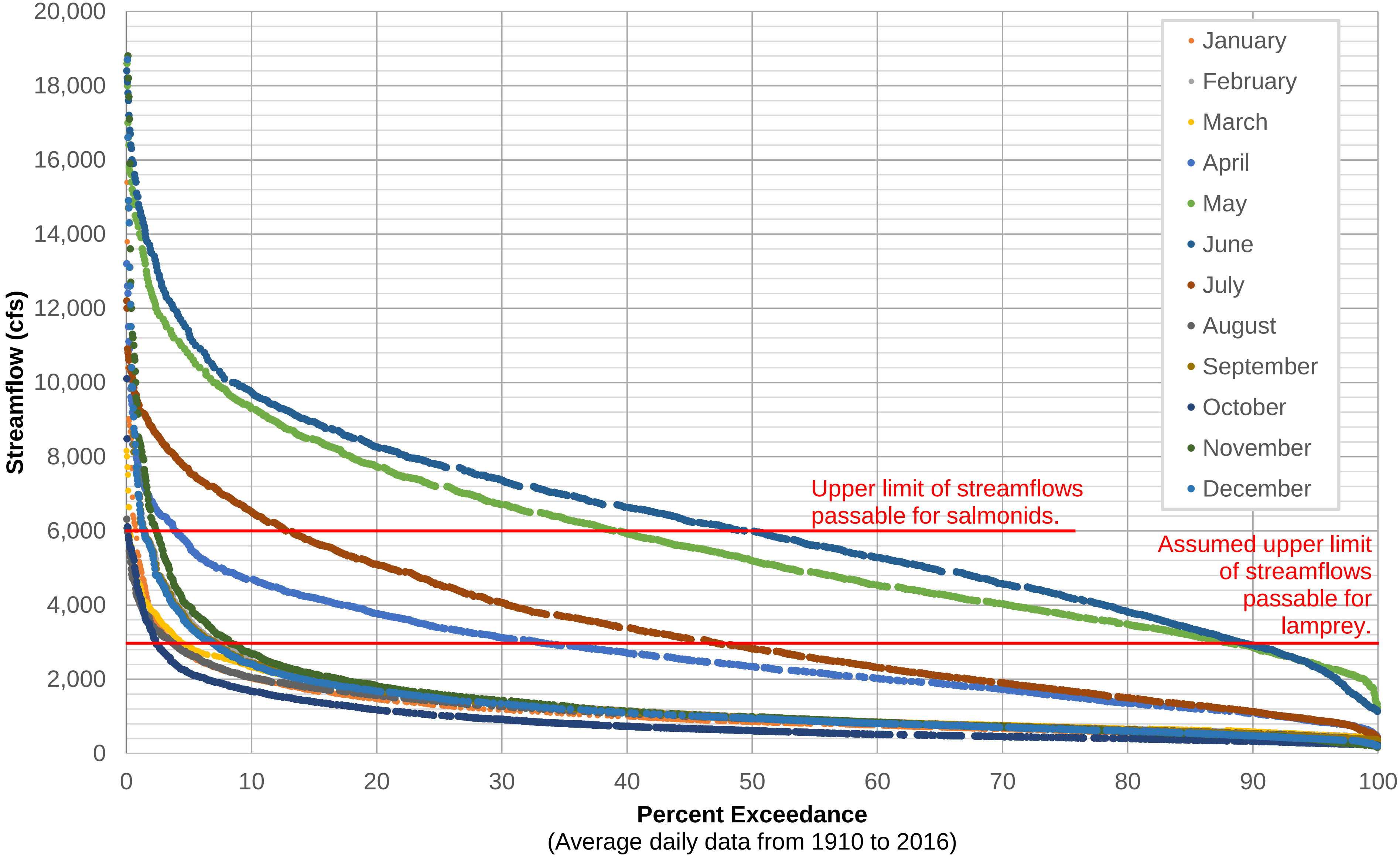
Grote, Ann. 2017. Personal communication on Pacific lamprey spawn-timing in the Wenatchee and Entiat river basins. U.S. Fish and Wildlife, Leavenworth, WA. 2017.

Younce, C. and R.D. Nelle. 2012. Provisional Data from Pacific Lamprey Probability of Occurrence Study in the Wenatchee River. US. Fish and Wildlife Service Mid-Columbia River Fishery Resource Office, Leavenworth, WA.

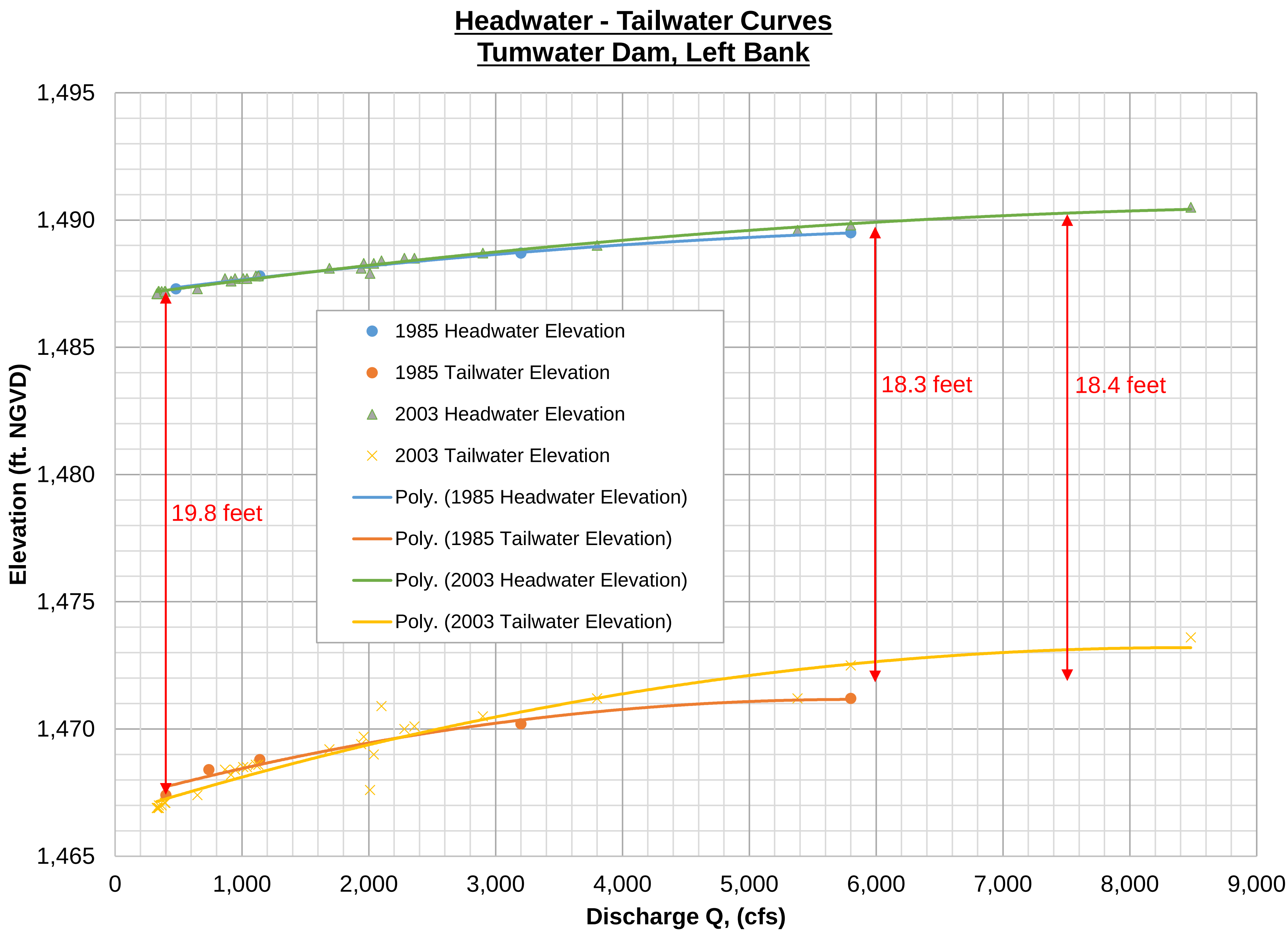
Attachment 5 - Hydraulics and Hydrology


Annual Flow-Duration Curve
USGS Gage 12457000 Wenatchee River at Plain, WA
Streamflow (cfs)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
10
20
30
40
50
60
70
80
90
100
Upper limit of streamflows passable for salmonids.
Assumed upper limit of streamflows passable for lamprey.
Percent Exceedance
(Average daily data from 1910 to 2016)
12/14/2016

Flow-Duration Curves
USGS Gage 12457000 Wenatchee River at Plain, WA



12/14/2016


Headwater - Tailwater Curves
Tumwater Dam, Left Bank
1,495
1,490
1,485
1,480
1,475
1,470
1,465
Elevation (ft. NGVD)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Discharge Q, (cfs)
1985 Headwater Elevation
1985 Tailwater Elevation
2003 Headwater Elevation
2003 Tailwater Elevation
Poly. (1985 Headwater Elevation)
Poly. (1985 Tailwater Elevation)
Poly. (2003 Headwater Elevation)
Poly. (2003 Tailwater Elevation)
19.8 feet
18.3 feet
18.4 feet

Attachment 6 – Alternatives Review Workshop Notes

Chelan PUD Tumwater Fishway Modifications – Alternatives Review Workshop

ATTENDEES:

Ian Adams/Chelan PUD
Justin Fletcher/Chelan PUD
Steve Hemstrom/Chelan PUD
Thad Mosey/Chelan PUD
Chris Nystrom/Chelan PUD
Alene Underwood/Chelan PUD
Aaron George/CH2M
James Kapla/CH2M

PREPARED BY: CH2M

LOCATION: Chelan County PUD Headquarters, Wenatchee, WA

MEETING DATE: 23 August 2016

Action Items

No.	Responsibility	High Priority	Date Completed	Task Description
1	CH2M and Steve Hemstrom/Chelan PUD		CH2M: 25 Aug 2016 Chelan PUD:	CH2M to identify reference site on Umatilla River with dual LPS collection ramp over the existing fishway entrance: **Three Mile Falls Diversion Dam.** Steve Hemstrom/Chelan PUD to reach out to contact for more information about the LPS at this site.
2	CH2M		23 Sept 2016	Define the range of design flow under which the LPS will operate in the Draft Feasibility Study.
3	Chelan PUD		24 Aug 2016	Provide electronic copy of fisheries survey documenting lamprey at Tumwater Dam pre-fishway; Hays 1981 Tumwater Dam Re-development Fisheries Surveys.
4	Chelan PUD and CH2M	X	26 Aug 2016	Determine date for submittal of Draft Feasibility Study, specifically whether 2 week extension will be acceptable
5	Chelan PUD		27 Sept 2016	Determine if it will be possible to release Pacific lamprey near potential LPS exit adjacent to existing fishway exit for visual observation of behavior and fall back potential. Date of upcoming release was noted as either 8 or 9 September 2016.

Previous Unaddressed Action Items

No.	Responsibility	High Priority	Date Completed	Task Description
3	Chelan PUD			Provide details of Biomark proposal to install PIT tag detector at baffle located immediately upstream of the fishway entrance pool; District noted internal discussion of this item would occur during the first week of August.

All other action items from the Kick-off Meeting and Site Visit have been addressed.

Notes

Alternatives Review Workshop – 9:00 a.m. to 2:30 p.m.

Introductions:

Name	Role
Ian Adams/Chelan PUD	Hatcheries Operations and Maintenance Coordinator
Justin Fletcher/Chelan PUD	District Project Manager
Steve Hemstrom/Chelan PUD	Senior Fisheries Biologist
Thad Mosey/Chelan PUD	Fisheries Biologist
Chris Nystrom/Chelan PUD	Fishway Operator
Alene Underwood/Chelan PUD	Fish and Wildlife Manager
Aaron George/CH2M	Civil/Hydraulics Engineer
James Kapla/CH2M	CH2M Project Manager

Design and Evaluation Criteria

- CH2M presented a summary of literature review findings. This covered various aspects of lamprey passage including the following:
  - Pacific Lamprey behavior.
  - General lamprey passage design criteria.
  - Lamprey passage system (LPS) -specific design criteria.
  - Overview of current LPS technologies implemented at existing sites.
- CH2M also presented key hydraulic design considerations including the following:
  - Annual and monthly flow duration curves for USGS Gage 12457000, Wenatchee River at Plain, WA.
  - Left bank headwater – tailwater curves for Tumwater Dam.
  - Table depicting discharge, headwater stage and tailwater stage at the 5% and 95% exceedance flows.

- Key points of discussion during the presentation of the literature review findings and the hydraulic design considerations were as follows:
  - The location of the entrance and the attractiveness of the entrance are key aspects of a lamprey fishway.
  - The term “fall back” should be used to describe upstream migrants that are carried downstream via a spillway or turbine passage.
  - The term “drop back” should be used to describe upstream migrants that are carried or move downstream while ascending a fishway.
  - Steve provided a rough estimate of Pacific Lamprey passage timing at Tumwater Dam: March through April and July through October. These potential passage windows are not confirmed, just a best guess of the most likely timing.
  - An upper limit of design streamflows for the LPS will need to be defined. A discharge of approximately 3,000 cfs was thought to be reasonable at approximately the 25% exceedance flow. This criteria is to be more clearly defined within the Draft Feasibility Study. The upper limit for salmon passage is a streamflow of approximately 6,000 cfs.
  - Passage of lamprey above Tumwater dam before construction of the current fishway was documented in the Hays 1981 Tumwater Dam Re-development Fisheries Surveys.

Review of Alternatives

CH2M introduced a preliminary list of evaluation criteria which was discussed and refined by the group. Weighting of each criteria was also completed to emphasize items that are considered more important to the overall success of the project. Concept-level sketches of each alternative were then presented prior to evaluation and ranking of alternatives. The full evaluation matrix is provided as an attachment to this Meeting Summary. The final list of evaluation criteria was as follows:

- Technical Evaluation Criteria
  - **Impacts to Current Operations.** Impacts to operation of existing fishway and trap. Additional debris removal.
  - **Gravity vs. Pumped Water Supply.** Does the alternative have the ability to operate with a gravity water supply?
  - **Additional O&M Requirements.** Expanded operations (i.e. at night), seasonal installation of equipment, right bank facility.
  - **Ability to prototype and/or test.** Proof of concept. Easily modified.
  - **Constructability.** Complexity of construction and construction schedule. Can the solution be installed within the annual fishway outage or the Wenatchee River in-water work period?
- Biological Evaluation Criteria
  - **Fishway Entrance Conditions/ Attractiveness.** Will the hydraulic signature of entrance successfully attract lamprey?
  - **Lamprey Passage Performance.** Does the alternative create hydraulic differentials, entrance velocities and transport velocities that facilitate safe and timely fish passage?
  - **Impacts to ESA-listed Salmonids.** Does the alternative adversely affect key species?
- Economic and Other Evaluation Criteria
  - **Project Cost (Engineering and Construction).** Relative cost based on collective knowledge of similar projects.
  - **O&M Cost.** Does the alternative result in a significant increase in O&M costs? Is it susceptible to debris fouling, damage, and/or equipment wear & tear? Is there an energy cost?

   - **Permitting and Legal.** Environmental impacts. FERC license and HCP coordination.
   - **Ability to Obtain Acceptance by Stakeholders.** Does the alternative have specific advantages that could be endorsed by the various stakeholders, including NMFS, FWS, WDFW and the Tribes?

- Additional discussions are summarized as follows:
  - Ramps should be provided at two of the three existing fishway entrances (high and low, not middle) to facilitate lamprey passage into the entrance pool.
  - The existing power supply at the site should be adequate to run a small pump. Single phase distribution is converted to three phase power via rotary phase converter; no backup power source is available.
  - The pumped water supply for an LPS system would be on the order of 3 to 5 cfs, say on the order of a 25 Hp pump.
  - Alternatives that involve the pouring of concrete would generally be viewed less favorably by stakeholders due to environmental impacts. This includes alternatives utilizing the existing sluice gate channel on the right abutment (Alternative 1) and channels on the dam and spillway apron (Alternatives 2a and 2b).
  - The existing trapping that occurs at the facility is obligatory and must not be impeded in the future.
  - The configuration of any water supply piping and/or LPS exit should be reviewed in light of operator safety considerations.
  - Video cameras would likely be part of any ongoing M&E program for the proposed fishway.

Pacific Lamprey Behavior Summary

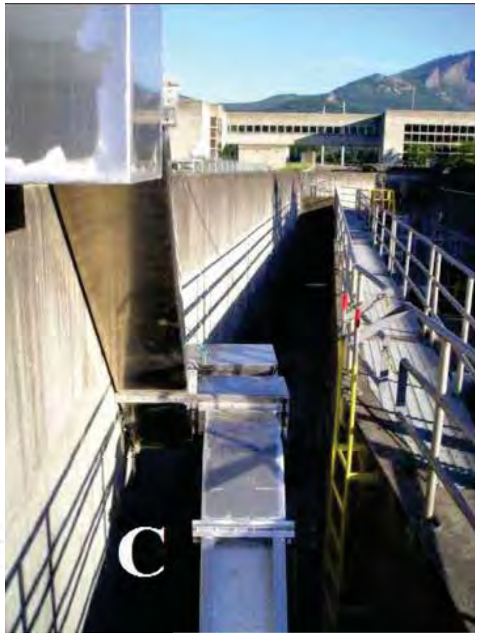
- Primarily active at night, artificial light can negatively impact activity.
- Spawning generally occurs March – July, though may be present in spawning areas February through September
- Believed to follow both hydraulic and substrate guidance cues
  - Hydraulic cues dominate in low velocity conditions, enabling free-swimming in the middle/upper water column.
  - In higher velocities, lamprey will swim along the bottom and side wall surfaces to stay close to potential attachment points.
- Critical swimming speed = ~**2.8 fps** (0.86 m/s); i.e. maximum sustained speed
- Max burst swimming speed = ~**8.9 fps** (2.7 m/s); i.e. velocity barrier for nearly all lamprey
- Poor swimmers in turbulence - attach more frequently for longer time periods, causing delayed passage; may be washed downstream.
- Predatory avoidance behaviors - will avoid areas crowded with predators

General Design Criteria Summary

- Attachment surfaces should be smooth and rounded. Pacific lamprey have difficulty passing features that have squared corners such as vertical steps or vertical slot weirs
- 3/4” grating recommended by USFWS for adult lamprey exclusion
- Diffusers on floors and low on walls can cause passage problems, especially in higher velocity conditions where lamprey are seeking to attach. Flat plates should be provided for attachment at these diffusers.

Lamprey Passage System (LPS) Design Criteria

- Smooth surface of polished aluminum is an ideal attachment surface
- Pacific lamprey are most likely to find and use an LPS collector when there is no readily accessible upstream alternative
- 20” wide ramps with 1.2” water depth have been effective at Bonneville Dam sites
- Collector ramp should be open on top to allow entrance at any water level, then covered for remainder of LPS if predation is possible from birds, etc.
- Wide range of ramp angles can be accommodated, though rest boxes should be more frequent with steeper angle. Bonneville LPS systems use up to 60 degree ramps (Cascade Island), though lesser slopes are used more freuently.
- Rest boxes are critical, can be made uni-directional with short section of plastic mesh which lamprey cannot attach to; must continue upstream.
- Exit can use an upwelling box at the high point of the LPS with an exit slide pipe on opposite end to allow release below the high point. Pipe should be steep and lined with rolled perforated plate to avoid lamprey attachment.
- Overnight flow reduction through fishway has been shown to improve lamprey passage at Bonneville sites



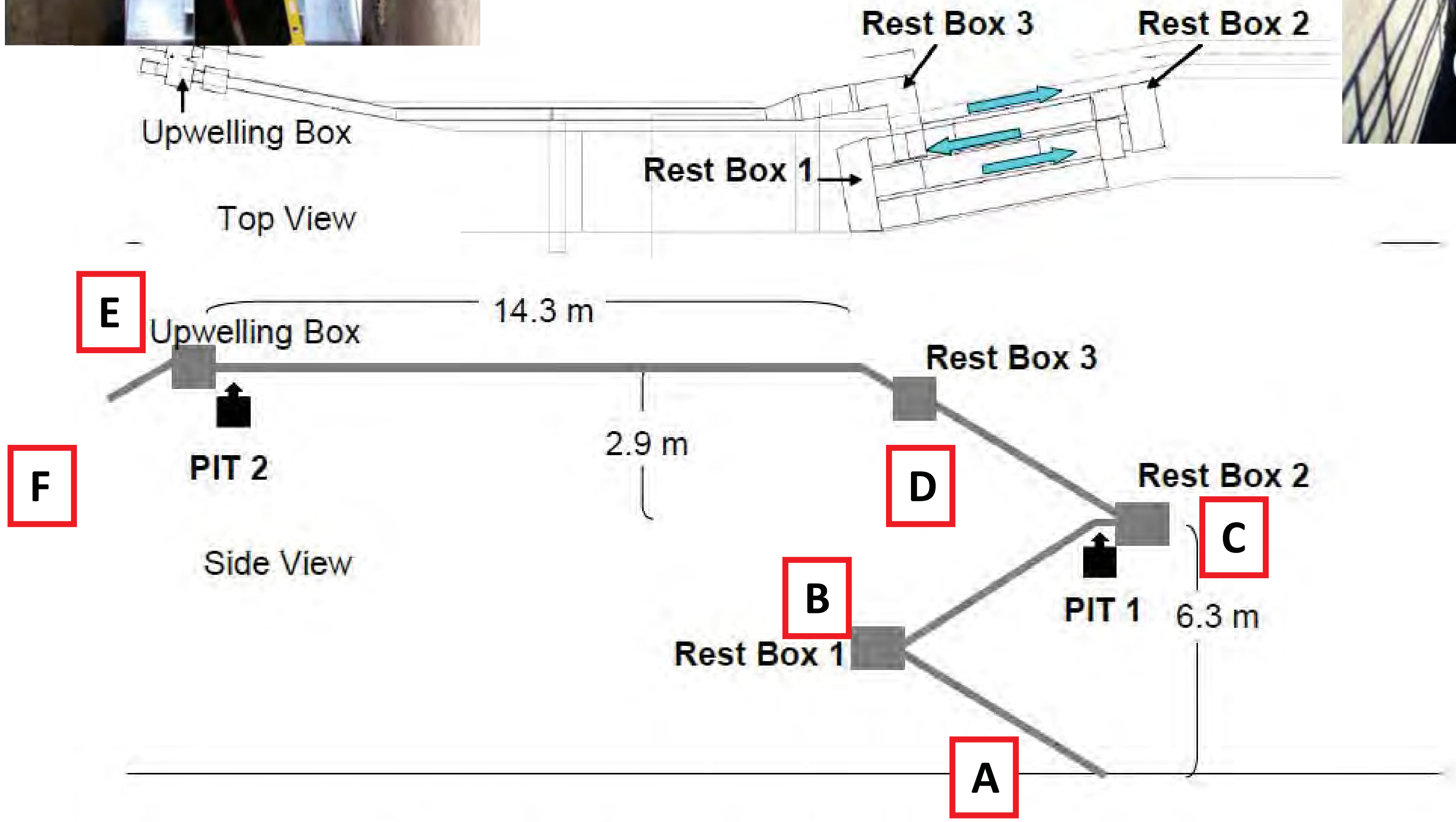
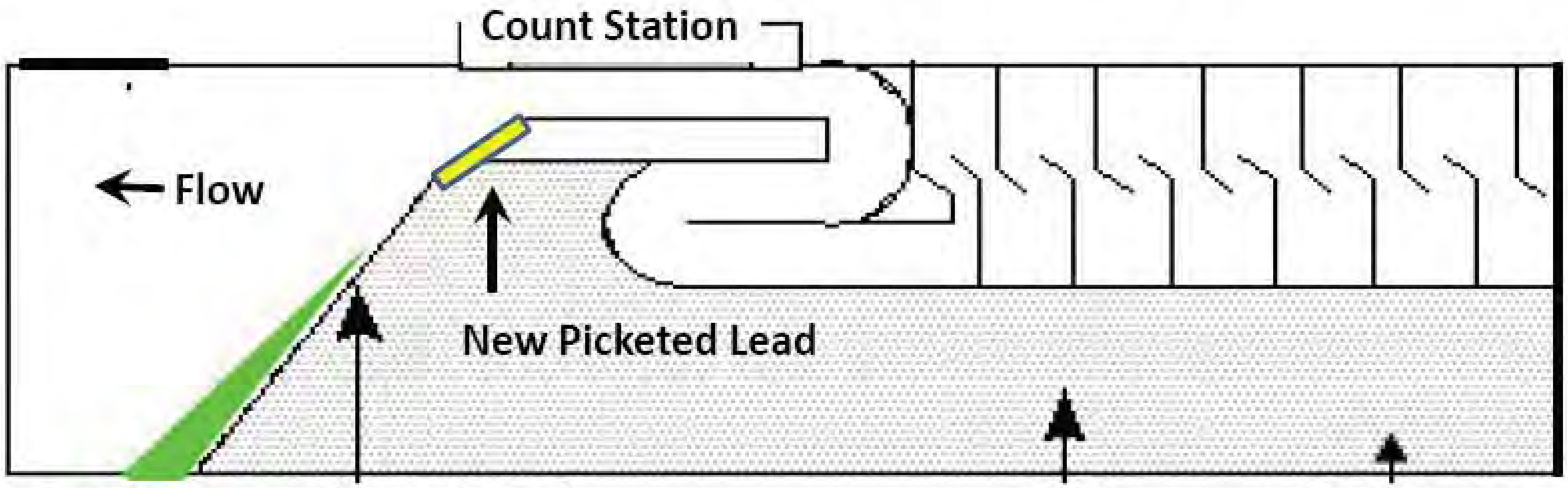


Figure 5 Schematic of the Washington Shore AWS LPS. *(Moser, et.al., 2010)*

Modifications at Bradford Island Fishway



Increased access to AWS channel via metal ramp

Reduced access to area behind count station crowder

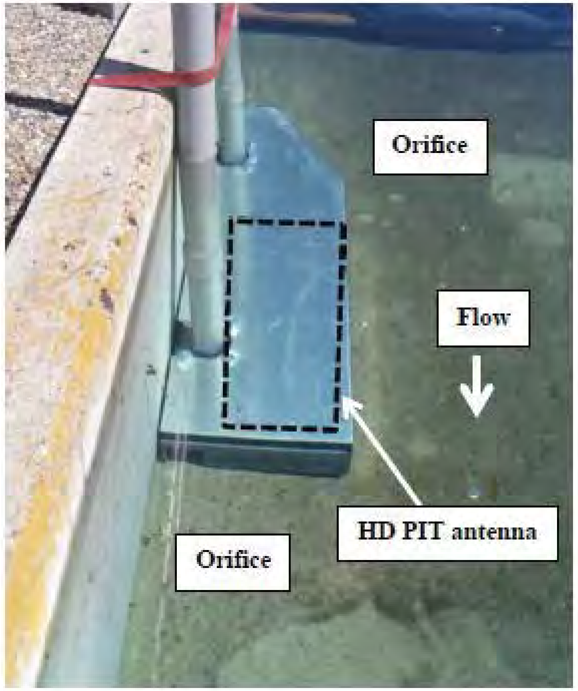
Experimental Vertical “Wetted-Wall” proposed at Bonneville Dam

- 5.4 ft high x 18 inch wide
- Lamprey climbing success from trials shows that a vertical wetted wall can be a useful to collect lamprey, particularly from constrained areas, and direct them to alternative passage routes. May also be useful in guiding lamprey over small barriers or into larger passage systems.

Refuge Boxes at Bonneville Dam

- Provide refuge for lamprey to reside during daylight that may otherwise have fallen back downstream
- May support passage for some lamprey that would have fallen back, but overall the fish using the refuge were less likely to pass than those which did not seek refuge

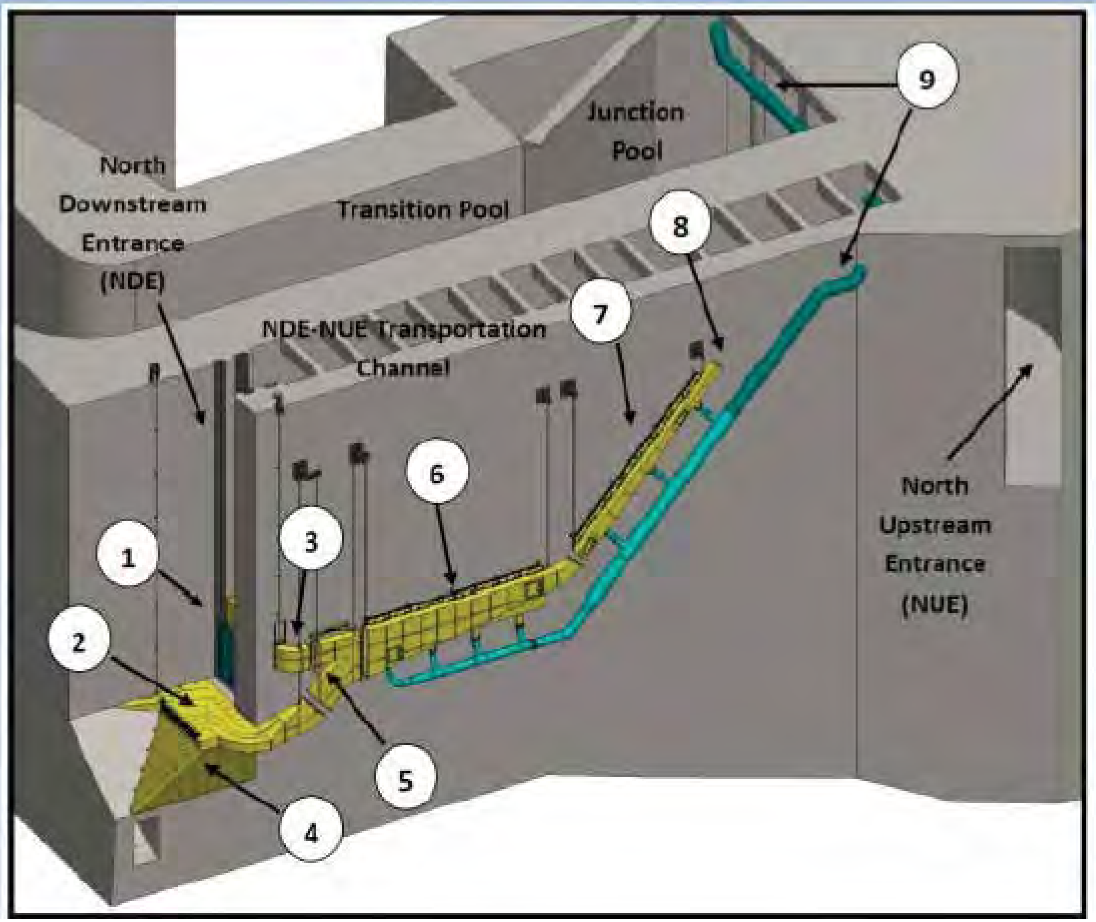
Figure 16. Location of refuges in the Washington Shore AWS channel and fishway at Bonneville Dam.



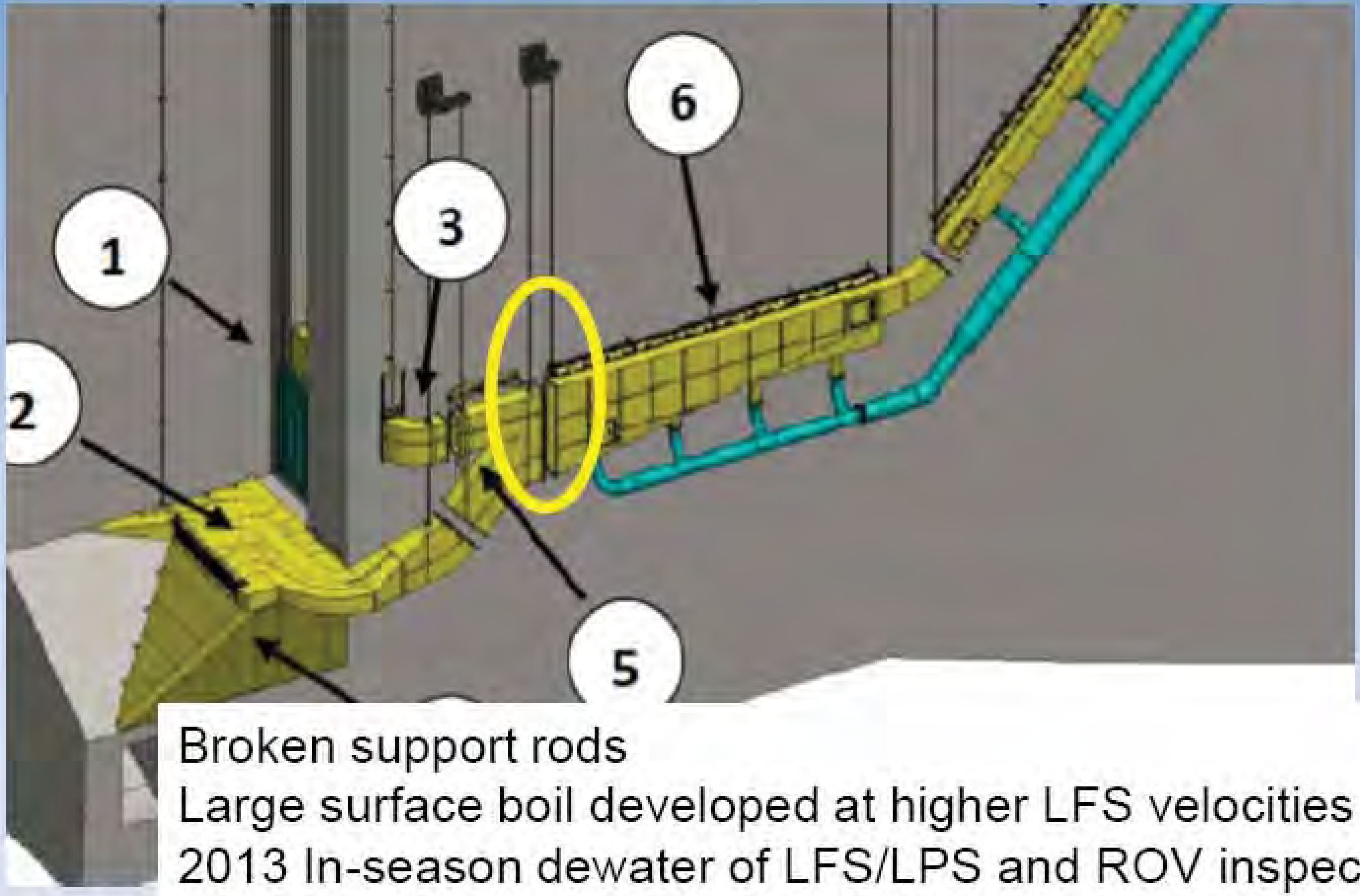
Lamprey Flume System (LFS)

Lower Unit

USACE Design/Contractor Built



Lamprey Flume System (LFS)
USACE Design, contractor built (Fowler)



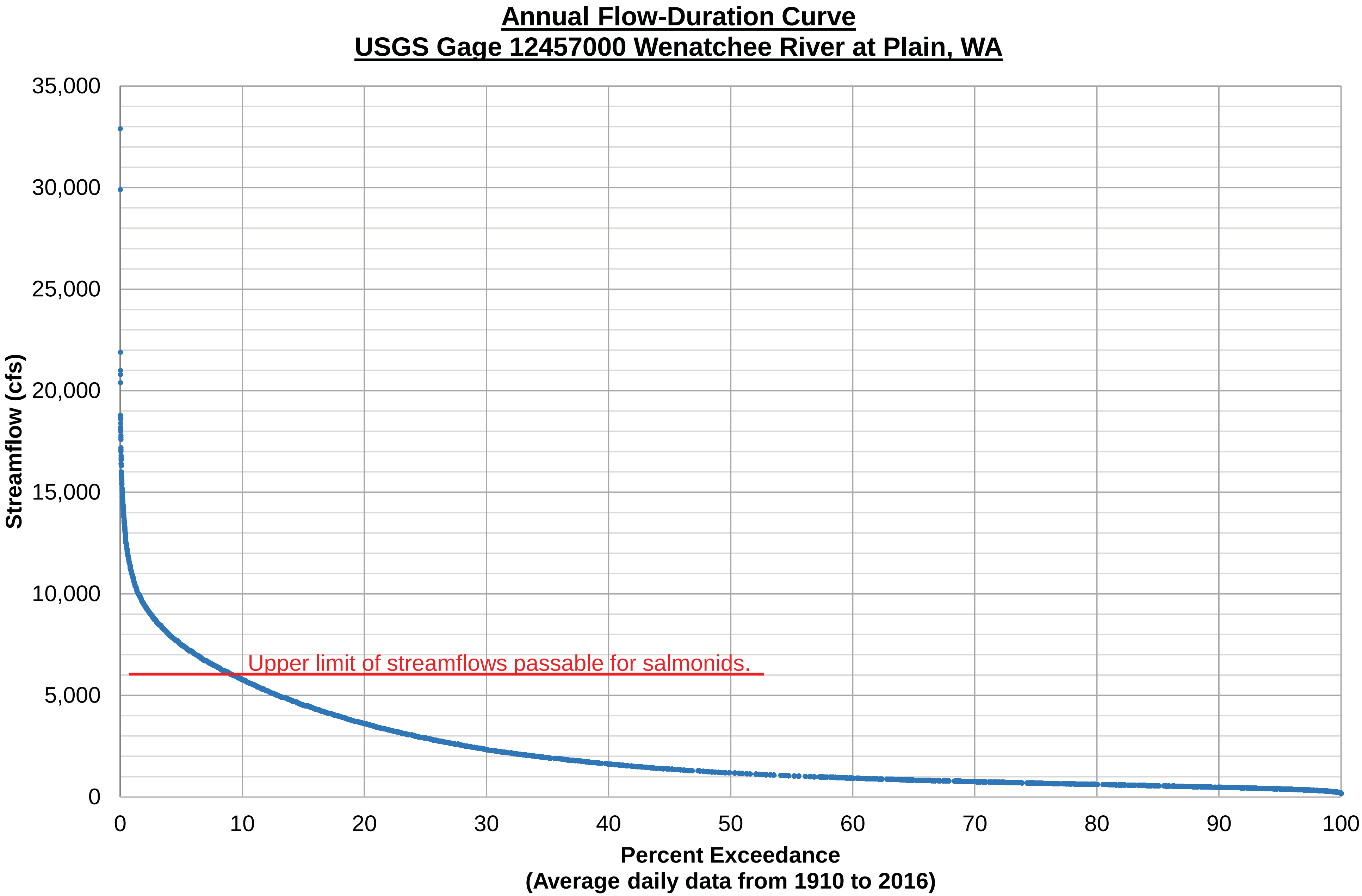
Broken support rods
Large surface boil developed at higher LFS velocities
2013 In-season dewater of LFS/LPS and ROV inspection
Fall 2013 Repairs including HD-PIT antennas
Entrained air in LFS water supply persists = "Bubble Curtain"

Umatilla River

From presentation "Aids to Adult Pacific Lamprey Passage at Obstacles in the Umatilla River: A Bag of Tricks".
- NWMFSC, NMFS, NOAA, Confederated Tribes of the Umatilla Indian Reservation

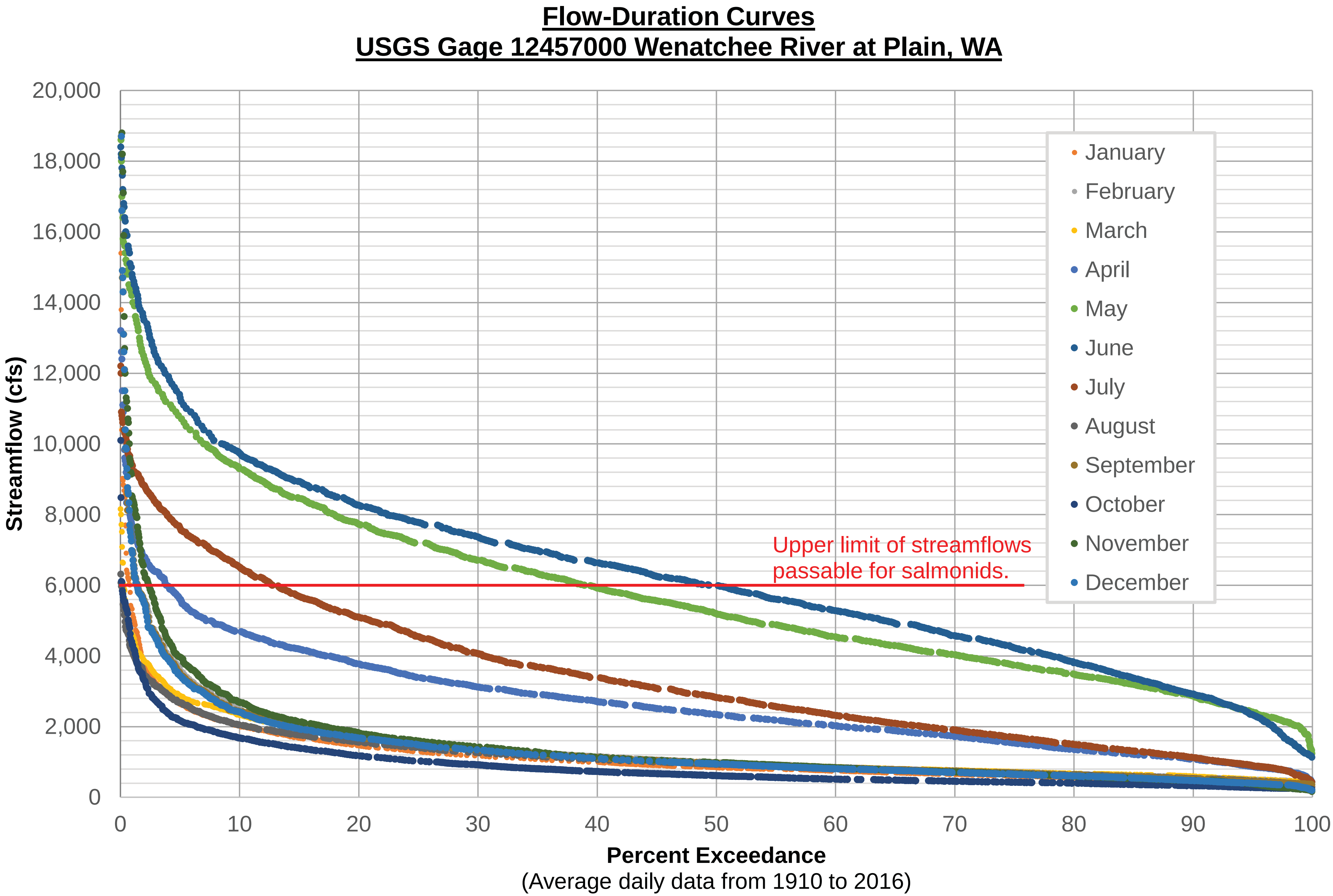
Umatilla River

From presentation “Aids to Adult Pacific Lamprey Passage at Obstacles in the Umatilla River: A Bag of Tricks”.
- NWMFSC, NMFS, NOAA, Confederated Tribes of the Umatilla Indian Reservation



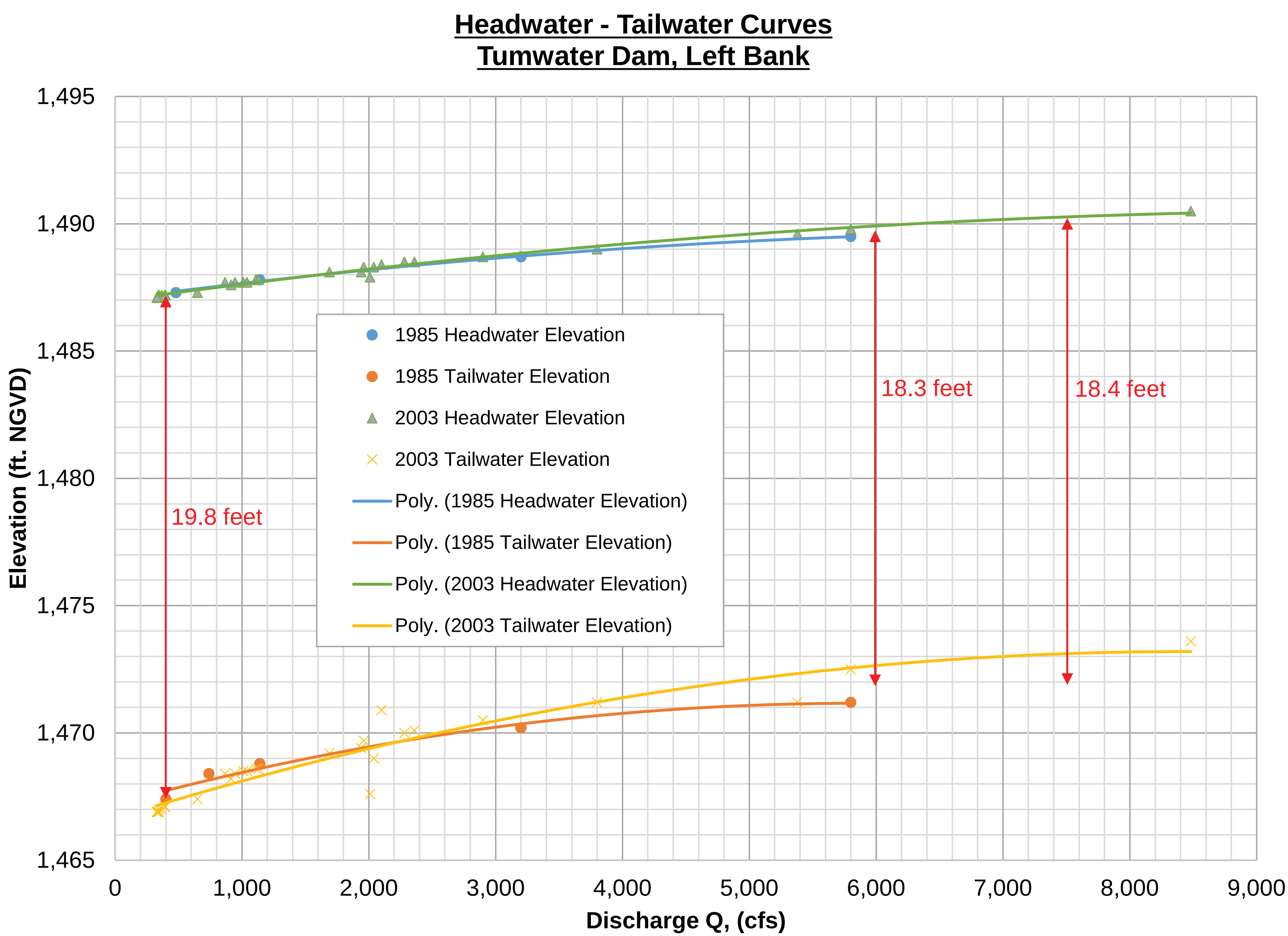
Annual Flow-Duration Curve
USGS Gage 12457000 Wenatchee River at Plain, WA
Streamflow (cfs)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Upper limit of streamflows passable for salmonids.
0
10
20
30
40
50
60
70
80
90
100
Percent Exceedance
(Average daily data from 1910 to 2016)

8/22/2016

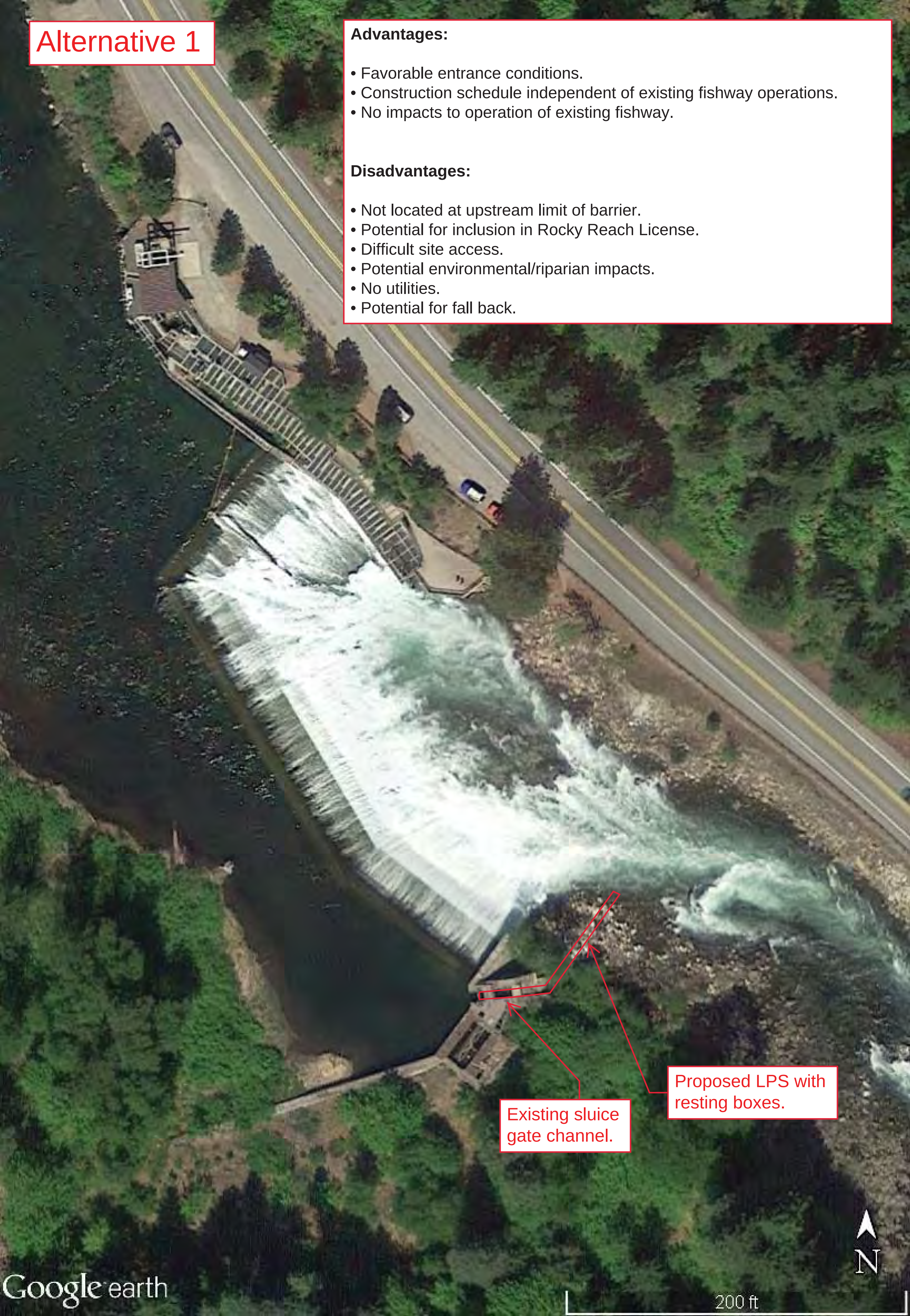


Flow-Duration Curves
USGS Gage 12457000 Wenatchee River at Plain, WA
Streamflow (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Percent Exceedance
(Average daily data from 1910 to 2016)
Upper limit of streamflows passable for salmonids.
January
February
March
April
May
June
July
August
September
October
November
December

8/22/2016


Headwater - Tailwater Curves
Tumwater Dam, Left Bank
Elevation (ft. NGVD)
Discharge Q, (cfs)
1,495
1,490
1,485
1,480
1,475
1,470
1,465
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
1985 Headwater Elevation
1985 Tailwater Elevation
2003 Headwater Elevation
2003 Tailwater Elevation
Poly. (1985 Headwater Elevation)
Poly. (1985 Tailwater Elevation)
Poly. (2003 Headwater Elevation)
Poly. (2003 Tailwater Elevation)
19.8 feet
18.3 feet
18.4 feet

Month	Discharge (cfs)		Headwater Stage (ft, NGVD29 per 2003 Curve)			Tailwater Stage (ft, NGVD29 per 2003 Curve)		
	5% Exceedance	95% Exceedance	5% Exceedance	95% Exceedance	Range (ft)	5% Exceedance	95% Exceedance	Range (ft)
FULL DATA SET	**7,500**	**401**	**1,490.56**	**1,487.28**	**3.29**	**1,472.89**	**1,467.29**	**5.60**
January	2,640	390	1,488.64	1,487.27	1.37	1,470.03	1,467.27	2.76
February	2,760	412	1,488.70	1,487.28	1.42	1,470.15	1,467.30	2.85
March	2,870	502	1,488.76	1,487.34	1.42	1,470.26	1,467.43	2.83
April	5,620	868	1,489.99	1,487.58	2.40	1,472.29	1,467.93	4.35
May	10,800	2,410	1,491.06	1,488.51	2.55	1,472.40	1,469.79	2.61
June	11,300	2,330	1,491.08	1,488.47	2.61	1,472.16	1,469.71	2.45
July	7,620	893	1,490.59	1,487.60	2.99	1,472.90	1,467.97	4.94
August	2,680	456	1,488.66	1,487.31	1.35	1,470.07	1,467.37	2.71
September	1,310	329	1,487.87	1,487.23	0.64	1,468.51	1,467.18	1.33
October	2,170	277	1,488.38	1,487.19	1.19	1,469.53	1,467.11	2.42
November	3,970	379	1,489.31	1,487.26	2.05	1,471.24	1,467.26	3.98
December	3,440	396	1,489.05	1,487.27	1.78	1,470.79	1,467.28	3.52



Alternative 1
Advantages:
• Favorable entrance conditions.
• Construction schedule independent of existing fishway operations.
• No impacts to operation of existing fishway.
Disadvantages:
• Not located at upstream limit of barrier.
• Potential for inclusion in Rocky Reach License.
• Difficult site access.
• Potential environmental/riparian impacts.
• No utilities.
• Potential for fall back.
Existing sluice gate channel.
Proposed LPS with resting boxes.
N
200 ft
Google earth


Alternatives 2a and 2b
Advantages:
• Construction schedule independent of existing fishway operations.
• No impacts to operation of existing fishway.
• Located at upstream limits of barrier.
Disadvantages:
• Potential for inclusion in Rocky Reach License.
• May impact spillway capacity.
Additional Disadvantages for Right Bank Alternative 2a:
• Difficult site access.
• Potential environmental/riparian impacts.
• No utilities.
• Potential for fall back.
2b
2a
Proposed ramp, typical.
N
Google earth
200 ft

Alternatives 3a and 3b

Advantages:

- Construction schedule independent of existing fishway operations.
- No impacts to operation of existing fishway.
- Located at upstream limits of barrier.

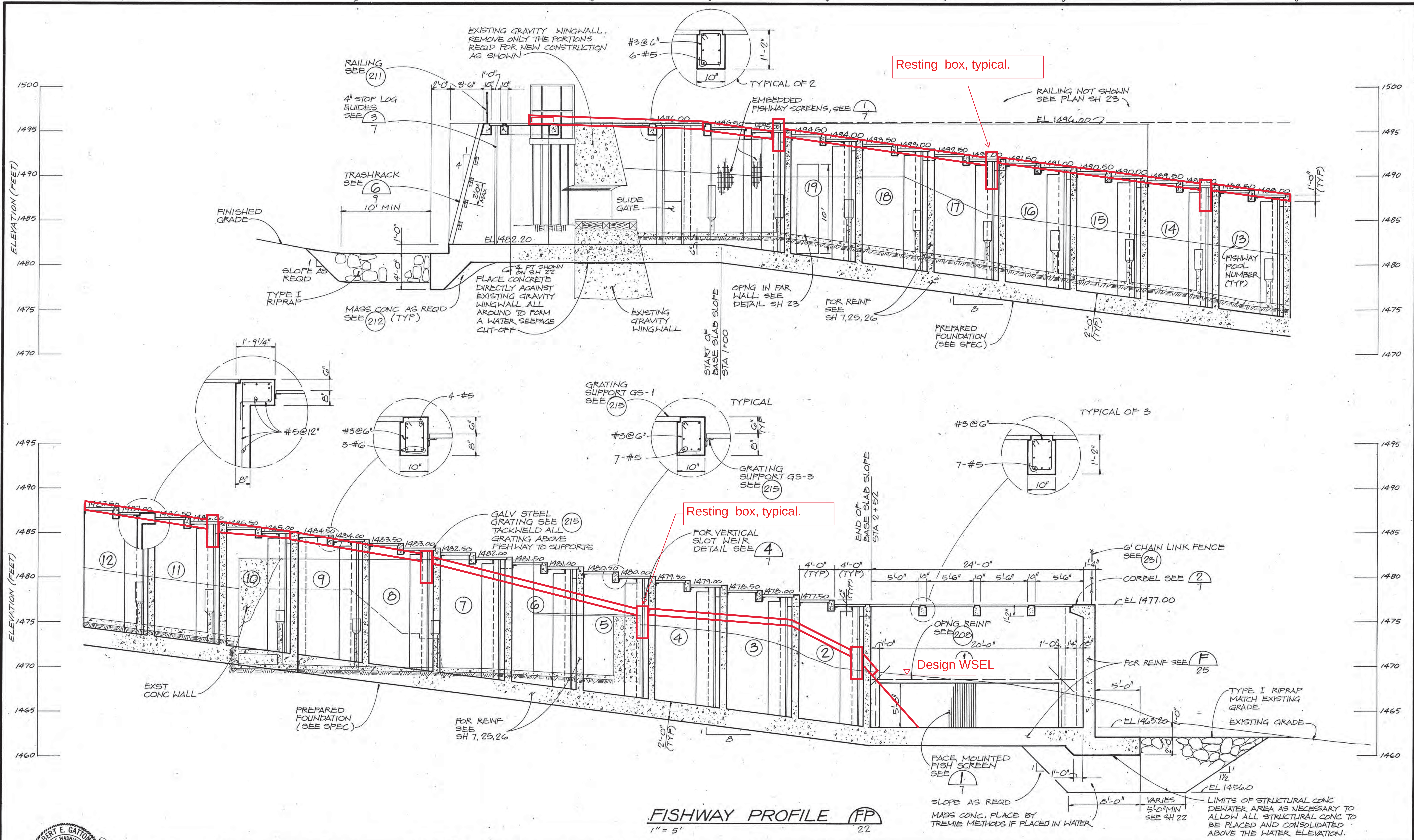
Disadvantages:

- Potential for inclusion in Rocky Reach License.
- Susceptible to damage, especially during flood events.

Additional Disadvantages for Right Bank Alternative 3a:

- Difficult site access.
- Potential environmental/riparian impacts.
- No utilities.


Alternative 4
Advantages:
• Less susceptible to damage from flood events.
• Good site access.
• Utilities are available.
• Environmental and permitting requirements are minimized.
Disadvantages:
• Construction schedule has to accommodate existing fishway and trap operations.
• May affect operation of existing fishway.
Proposed LPS with pumped forebay exit.
Google earth
N
200 ft



ROBERT E. GATTON — REGISTERED PROFESSIONAL ENGINEER — STATE OF WASHINGTON

CH2M HILL

DSGN D. WERMCRANTZ		7/24/87	RECORD DRAWINGS	KRW	LDB	
DR B. LAZARO						
CHK M.J. Hoyley						
APVD R.E. GATTON	NO.	DATE	REVISION	BY	APVD	

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PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WASHINGTON

TUMWATER/DRYDEN FISHWAYS AND DRYDEN WEIR

TUMWATER FISHWAY PROFILE

SHEET	24 of 33
DWG NO.	24
DATE	APRIL 1986
PROJ NO.	S20299.T1

DSGN	D. WERMCRANTZ	7-24-87	
DR	B. LAZARO		
CHK	M. HOYRUP		
APVD	R.E. GATTON		

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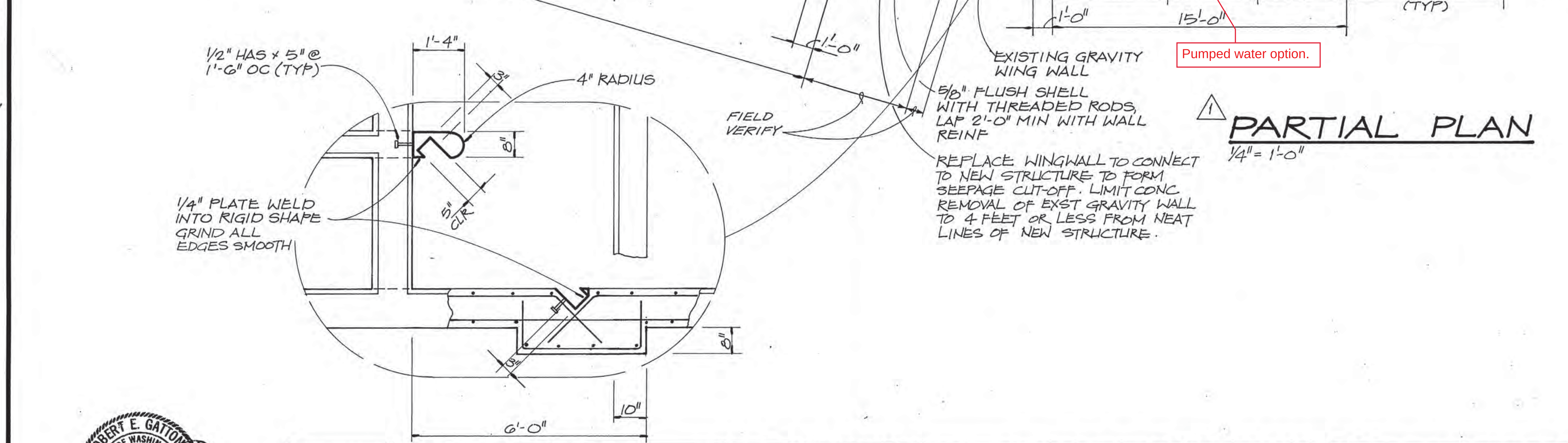
TUMWATER/DRYDEN FISHWAYS AND DRYDEN WEIR

TUMWATER PARTIAL PLAN

SHEET	22B of 33
DWG NO.	22B
DATE	JUNE 1986
PROJ NO.	S20299.T1



PARTIAL PLAN
1/4" = 1'-0"

TUMWATER GATE SCHEDULE

GATE NO.	TYPE	OPNG SIZE (W × H)	BOT SILL EL	OPERATING DECK EL	NET SEATING HEAD	THIMBLE DEPTH	OPERATOR (ALL MANUAL)
17	SLUICE, BOTTOM CLOSURE	36"×60"	1463.2	1477.0	10	12"	GEAR OPERATED FLOOR STAND
18	SLUICE, BOTTOM CLOSURE	48"×60"	1463.2	1477.0	10	12"	-DO-
19	SLIDE	48"×60"	1464.2	1477.0	10	N/A	-DO-
20	SLUICE BOTTOM CLOSURE	48"×48"	1482.2	1496.0	11	12"	-DO-
21	SLIDE, BOTTOM CLOSURE	36"×36"	1477.5	1496.0	12	N/A	-DO-
22	SLIDE BOTTOM CLOSURE	30"×30"	1478.0	1496.0	12	N/A	-DO-
23	SLIDE	12" DIA	1483.5	1496.0	11	N/A	HAND WHEEL ON FLOOR STAND
24	SLIDE, DOWNWARD OPNG	36"×60"	1485.0	1496.0	6	N/A	HAND WHEEL ON FLOOR STAND
25	SLIDE, SEE 8/6	24"×48"	1483.0	1496.0	7	N/A	-DO-
26	SLUICE	30"×48"	1487.5	1496.0	6	18"	GEAR OPERATED FLOOR STAND
27	SLUICE	24" DIA	1485.5	1496.0	8	18"	-DO-

ROBERT E. GATTON, STATE OF WASHINGTON, REGISTERED PROFESSIONAL ENGINEER

CH2M HILL

DSGN D. WERMCRANTZ
DR R. FRIBERG
CHK M. L. HOYRUP
APVD R.E. GATTON

7-24-87

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NO.	DATE	REVISION	BY	APVD
1	5/16/86	GENERAL REVISIONS PER ADDENDUM NO. 1	LDB	REG
	7-24-87	RECORD DRAWINGS	KRW	LDB

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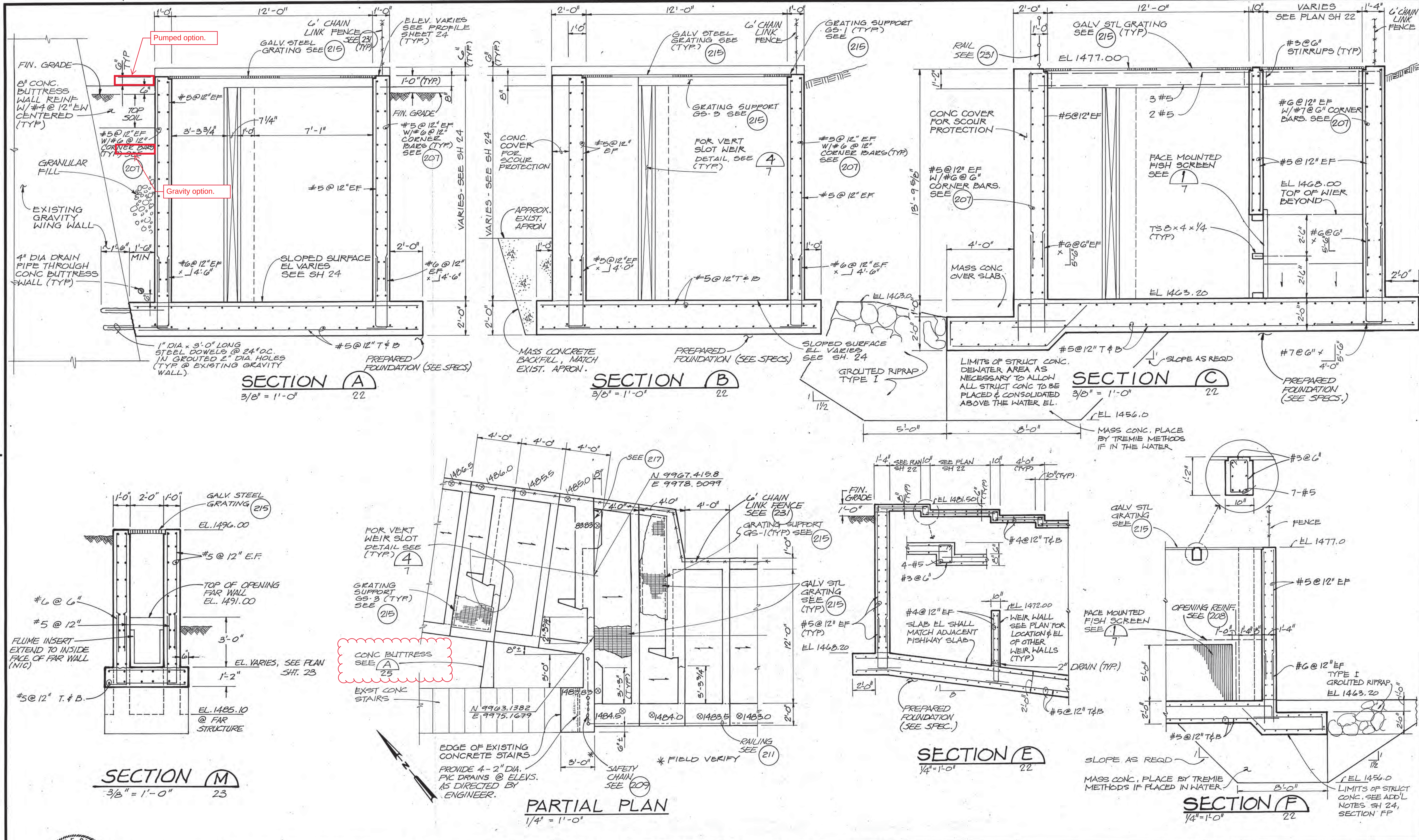
PUBLIC UTILITY DISTRICT NO. 1
OF CHELAN COUNTY, WASHINGTON

TUMWATER/DRYDEN FISHWAYS
AND DRYDEN WEIR

TUMWATER FISHWAY & TRAP PLAN

SHEET 23 of 33
DWG NO. 23
DATE APRIL 1986
PROJ NO. S20299.T1



ROBERT E. GATTON — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

CH2M HILL

DSGN	D. WERMCRANTZ		7/24/87	RECORD DRAWINGS	KRW	LDB
DR	R. FRIBERG			THESE RECORD DRAWINGS HAVE BEEN PREPARED, IN PART, ON THE BASIS OF INFORMATION COMPILED BY OTHERS. THEY ARE NOT INTENDED TO REPRESENT IN DETAIL THE EXACT LOCATION, TYPE OF COMPONENT NOR MANNER OF CONSTRUCTION.		
CHK	M L Hoying					
APVD	R.E. GATTON	NO.	DATE	REVISION	BY	APVD

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0 — 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WASHINGTON

TUMWATER/DRYDEN FISHWAYS AND DRYDEN WEIR

TUMWATER FISHWAY SECTIONS

SHEET	25 of 33
DWG NO.	25
DATE	APRIL 1986
PROJ NO.	S20299.T1


'86 12 31

CH2MHILL

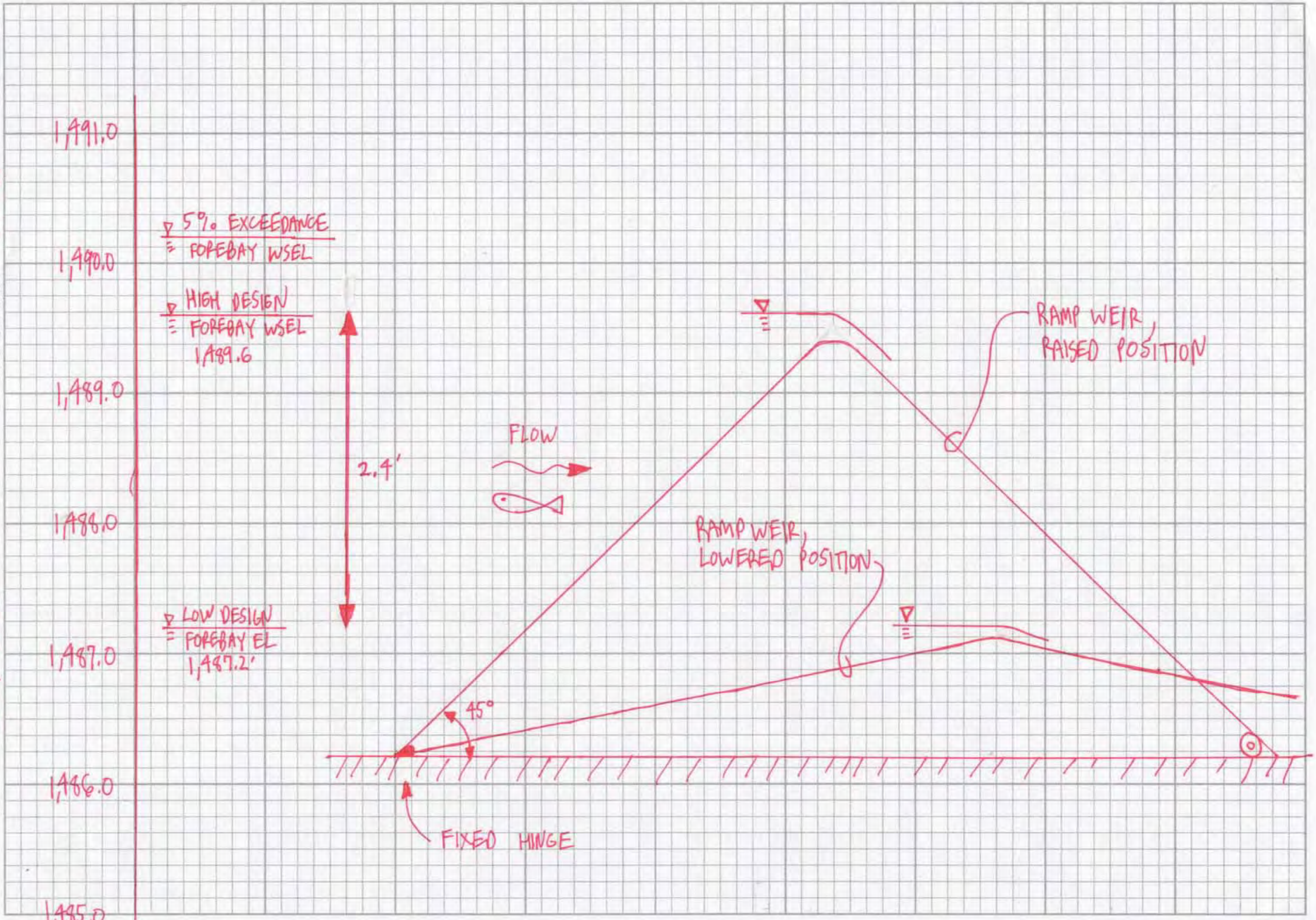
SUBJECT: CHELAN PUD TUMWATER FISHWAY MODIFICATIONS RAMP WEIR

BY: JGK

SHEET NO. 1 of 1

DATE: 21 AUG 2016

PROJECT NO. 680819



Chelan PUD Tumwater Fishway Modifications
Cost/Benefit Evaluation Matrix
23 August 2016

The purpose of this matrix is to facilitate an evaluation of various lamprey passage alternatives at Tumwater Dam, and to rate and prioritize the alternatives for further evaluation.

Alternative		Description	Technical Evaluation Criteria					Biological Evaluation Criteria			Economic and Other Evaluation Criteria				Total Rating	Rank	Notes
			Impacts to Current Operations	Gravity vs. Pumped Water Supply	Additional O&M Requirements	Ability to Prototype and/or Test	Constructability	Fishway Entrance Conditions/ Attractiveness	Lamprey Passage Performance	Impacts to ESA-listed salmonids	Project Cost (Engineering and Construction)	O&M Cost	Permitting/Legal	Ability to Obtain Acceptance by Stakeholders			
		Criteria Weighting	**4**	**1**	**3**	**1**	**3**	**5**	**5**	**5**	**2**	**2**	**3**	**3**			
1	Modify Existing Sluice Gate Channel.		5	5	1	1	1	2	5	5	1	4	1	2	111	8	Assumed gravity water supply.
2a	Channel Across Apron and Ramp Over Dam	Right Bank	5	5	1	1	1	3	3	5	2	4	1	2	108	10	
2b	Channel Across Apron and Ramp Over Dam	Left Bank	4	5	4	2	2	4	4	3	2	4	1	3	120	5	
3a	LPS Attached to Abutment	Right Bank	5	1	1	2	1	3	4	5	3	3	1	3	113	7	
3b	LPS Attached to Abutment	Left Bank	4	1	3	3	3	4	5	4	4	3	1	4	132	3	
4	LPS Within Existing Fishway		3	1	4	2	3	4	5	4	3	4	5	4	142	1	Assumed pumped water supply. Assumed prototyping of entrance location.
5	Ramps at Sills Within Existing Fishway		1	3	5	5	5	4	1	5	5	5	4	3	133	2	
6	Orifices at Baffles Within Existing Fishway		1	3	5	1	2	4	1	5	4	5	4	3	118	6	
7	Operational Modifications	Low-flow operations in evening.	2	3	5	5	5	5	1	2	3	3	5	3	122	4	
8	Do nothing	Existing operations.	5	3	5	3	3	1	1	5	5	5	1	1	111	8	Does not support District's environmental stewardship objectives, nor does it address stakeholder concerns.

Summary of Evaluation Criteria:

Technical Evaluation Criteria
Impacts to Current Operations. Impacts to operation of existing fishway and trap. Additional debris removal.
Gravity vs. Pumped Water Supply. Does the alternative have the ability to operate with a gravity water supply?
Additional O&M Requirements. Expanded operations (i.e. at night), seasonal installation of equipment, right bank facility.
Ability to prototype and/or test. Proof of concept. Easily modified.
Constructability. Complexity of construction and construction schedule. Can the solution be installed within the annual fishway outage or the Wenatchee River in-water work period?

Biological Evaluation Criteria
Fishway Entrance Conditions/ Attractiveness. Will the hydraulic signature of entrance successfully attract lamprey?
Lamprey Passage Performance. Does the alternative create hydraulic differentials, entrance velocities and transport velocities that facilitate safe and timely fish passage?
Impacts to ESA-listed Salmonids. Does the alternative adversley affect key species?

Economic and Other Evaluation Criteria
Project Cost (Engineering and Construction). Relative cost based on collective knowledge of similar projects.
O&M Cost. Does the alternative result in a significant increase in O&M costs? Is it susceptible to debris fouling, damage, and/or equipment wear & tear? Is there an energy cost?
Permitting and Legal. Environmental impacts. FERC license and HCP coordination.
Ability to Obtain Acceptance by Stakeholders. Does the alternative have specific advantages that could be endorsed by the various stakeholders, including NMFS, FWS, WDFW and the Tribes?

Summary of Rating Criteria:

5 Good
4
3 Neutral
2
1 Poor

Chelan PUD Tumwater Fishway Modifications – Alternatives Review Workshop

MEETING DATE: 23 August 2016

MEETING TIME: 9:00 a.m. PDT

VENUE: District Headquarters, Wenatchee, WA
(Conf. Rm. Eng. Svc. Library HQ 1st Flr. [10-20])

Introduction 9:00-9:15

1. Introductions
2. Purpose and goals of the meeting

Design and Evaluation Criteria 9:15-10:30

1. Results of literature review
2. Confirm design criteria
3. Confirm alternatives evaluation criteria

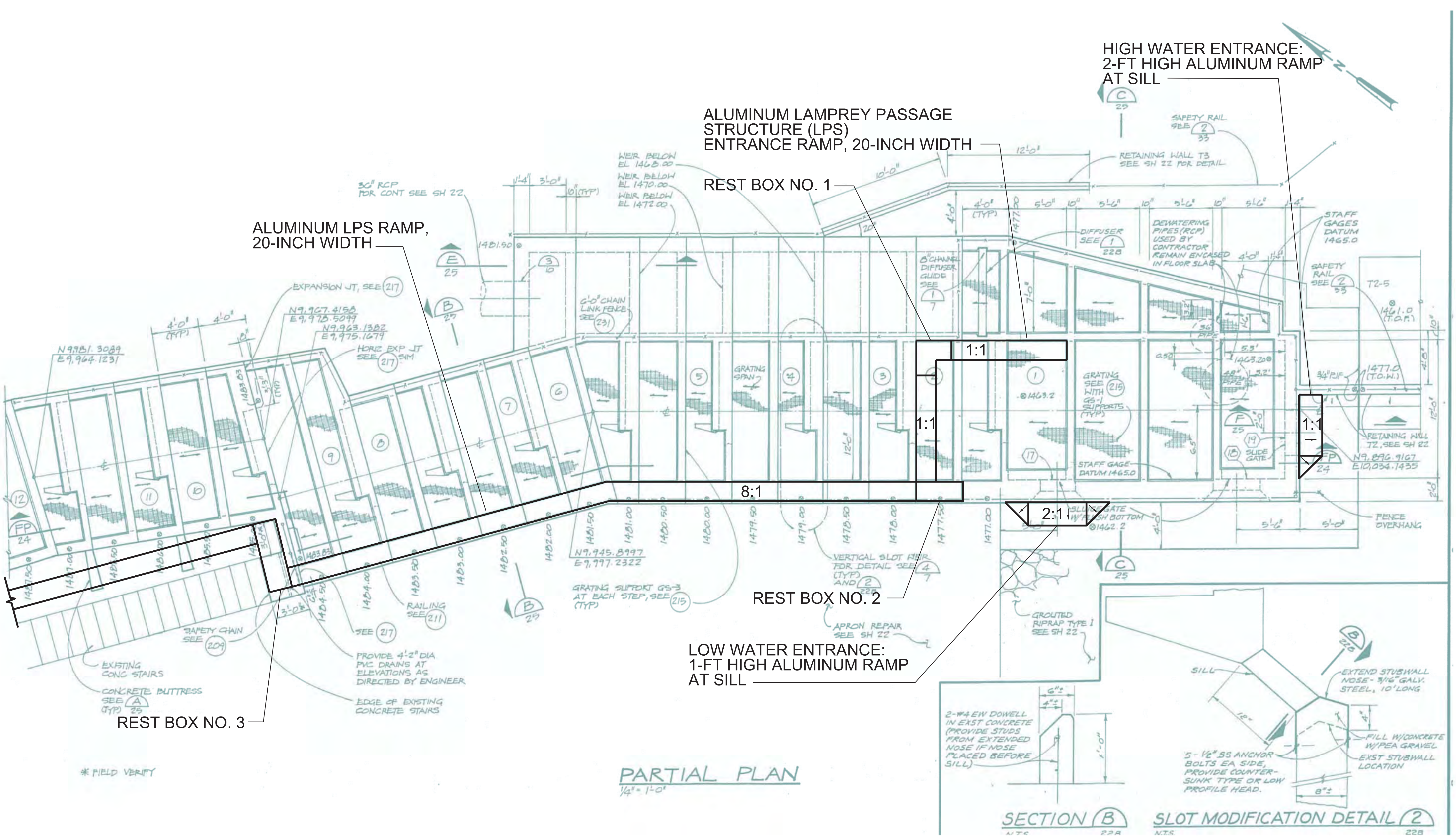
Review of Alternatives 10:30-2:00

1. Develop, review and discuss alternatives
2. Evaluation and prioritization of alternatives

Summary and Wrap-Up 2:00-2:30

1. Information needs
2. Action items
3. Review project schedule

Attachment 7 – Conceptual Figures



PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WA
TUMWATER FISHWAY MODIFICATIONS

FIGURE 1A - ALTERNATIVE NO. 4
LPS WITHIN EXISTING FISHWAY - LOWER PLAN

ch2m:

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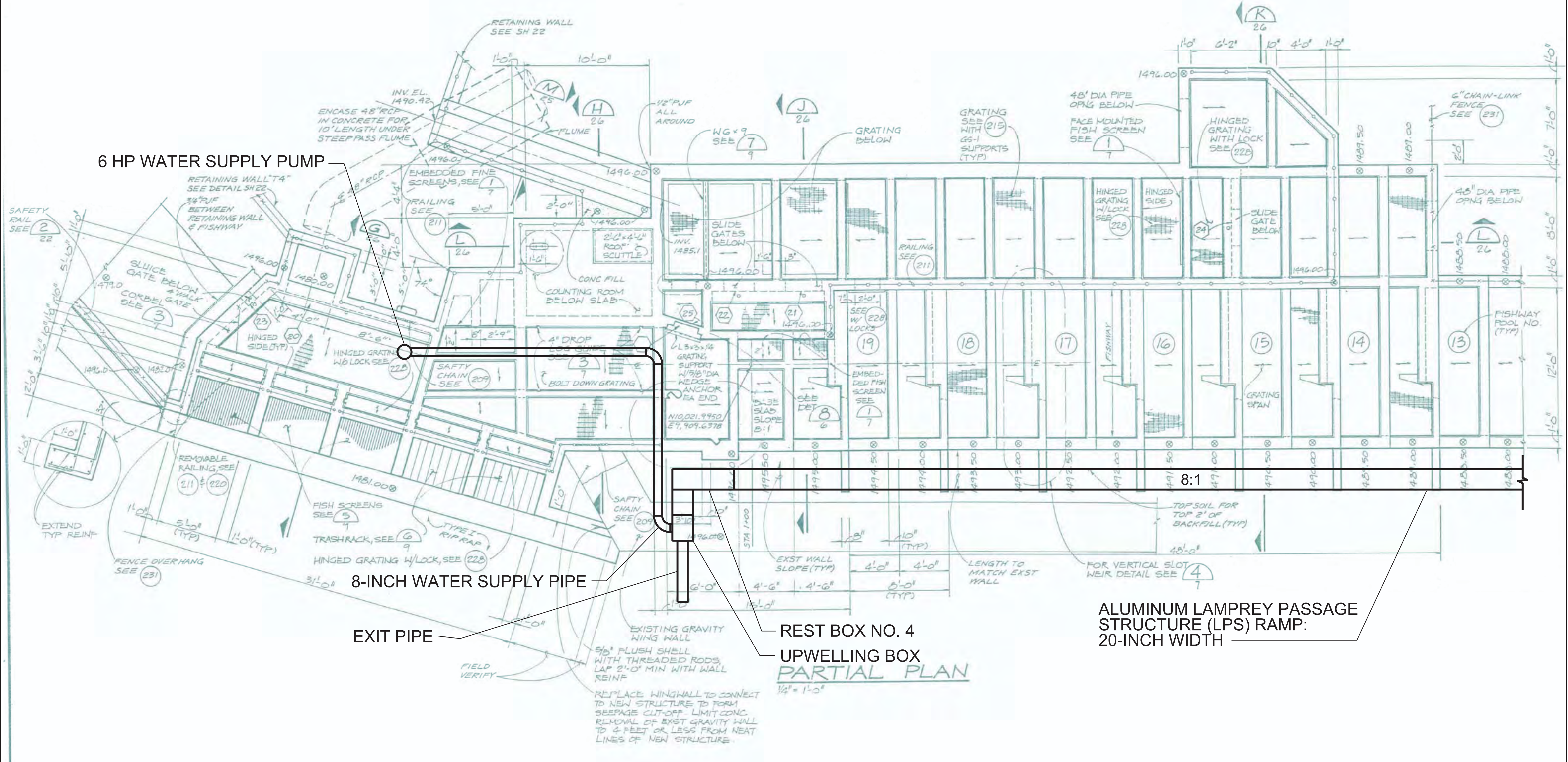
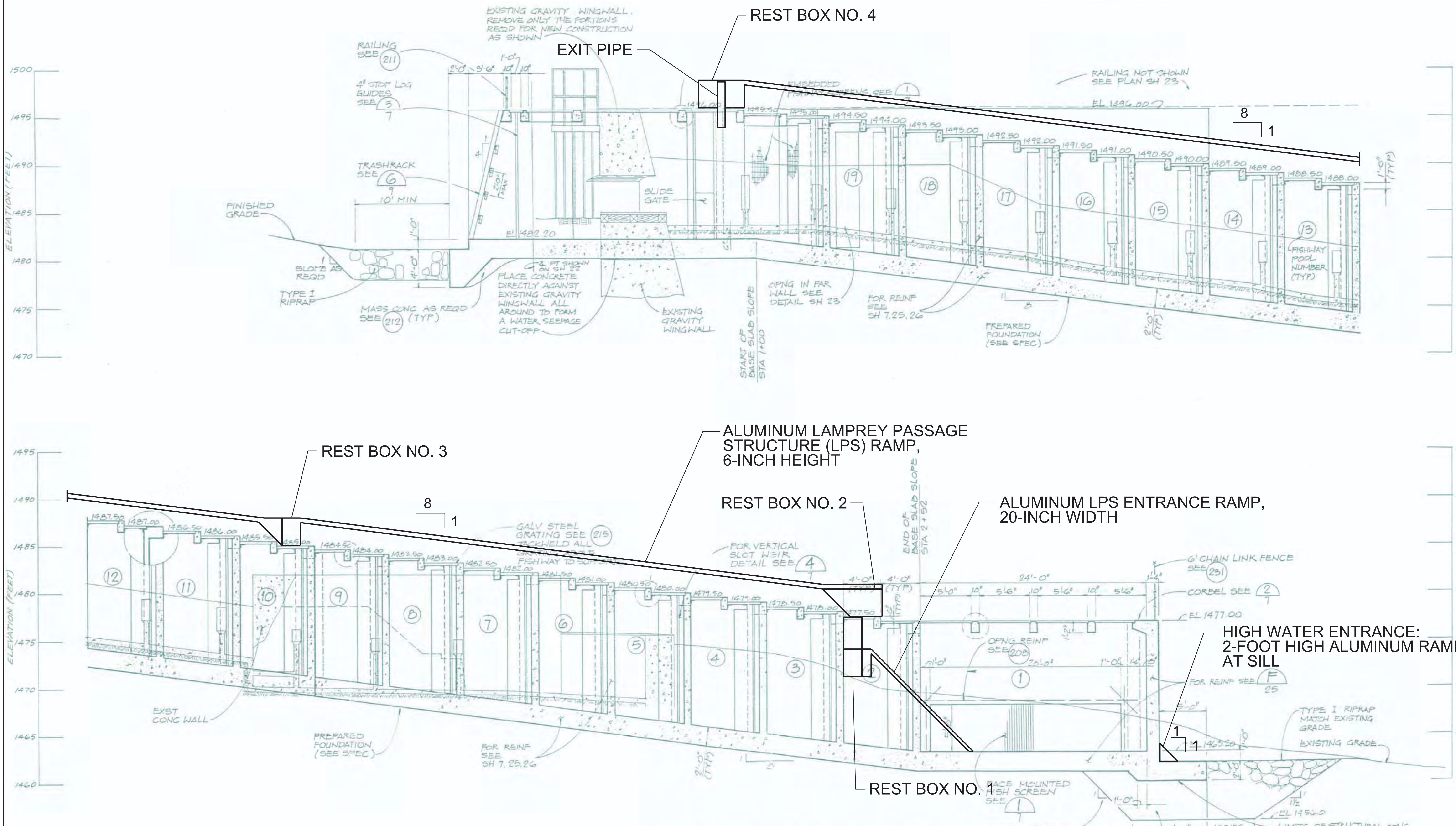


PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WA
TUMWATER FISHWAY MODIFICATIONS

FIGURE 1B - ALTERNATIVE NO. 4
LPS WITHIN EXISTING FISHWAY - UPPER PLAN

ch2m:



PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WA
TUMWATER FISHWAY MODIFICATIONS

FIGURE 1C - ALTERNATIVE NO. 4
LPS WITHIN EXISTING FISHWAY - PROFILE

ch2m:

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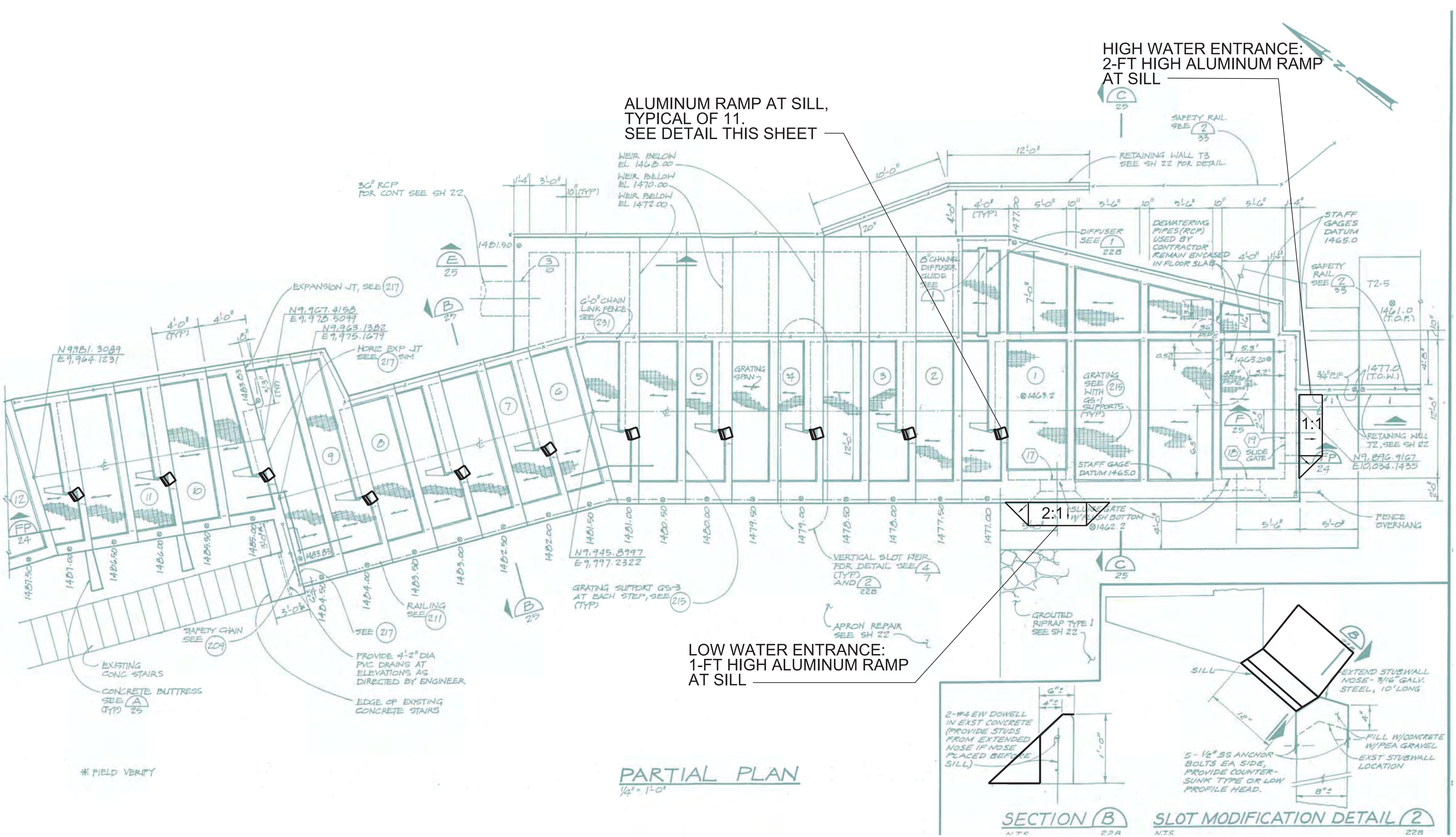
PLOT TIME: 4:37:10 PM



PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WA
TUMWATER FISHWAY MODIFICATIONS

FIGURE 2A - ALTERNATIVE NO. 5
SILL RAMPS WITHIN EXISTING FISHWAY - LOWER PLAN

ch2m:

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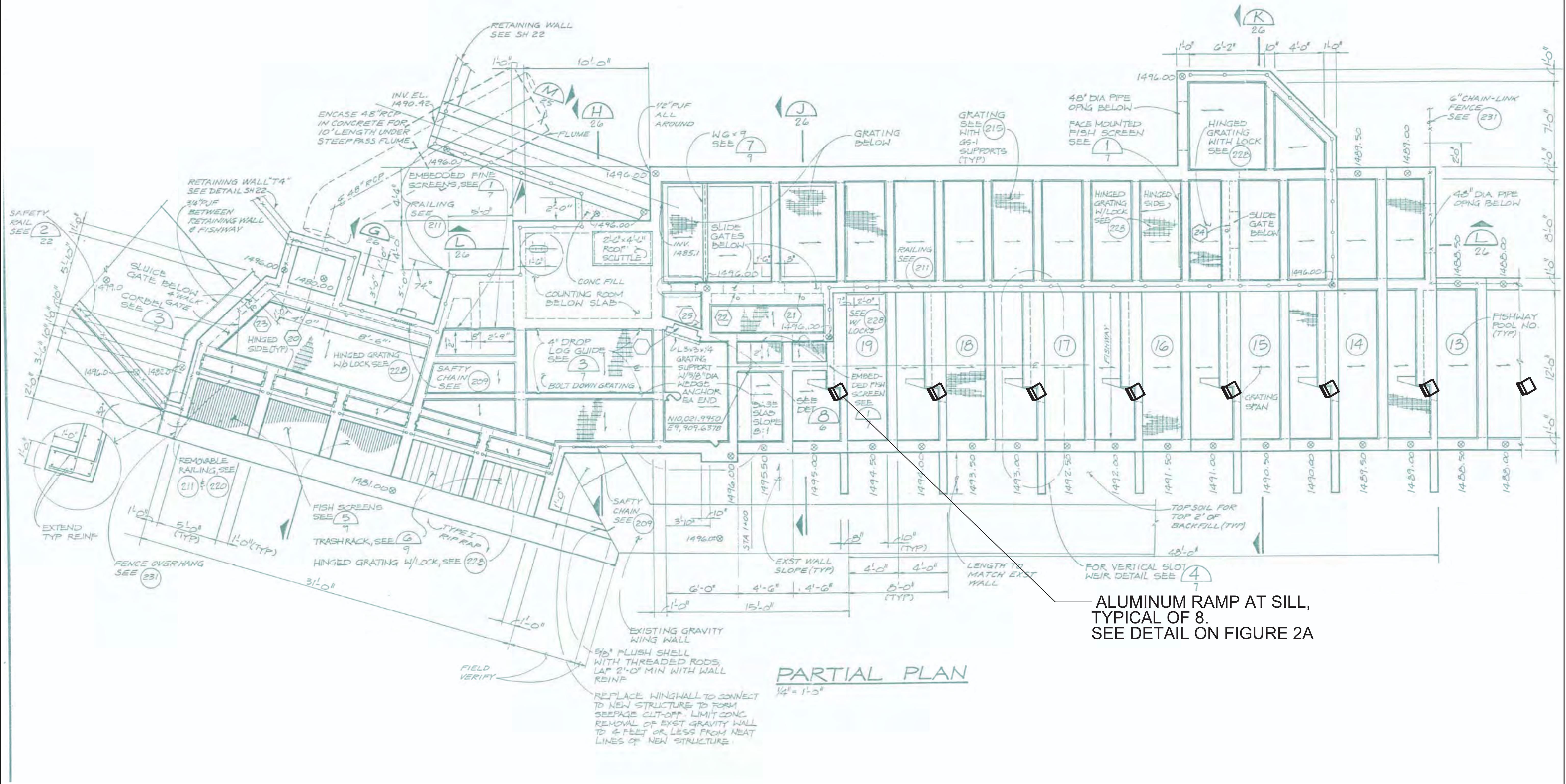


PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY, WA
TUMWATER FISHWAY MODIFICATIONS

FIGURE 2B - ALTERNATIVE NO. 5
SILL RAMPS WITHIN EXISTING FISHWAY - UPPER PLAN

ch2m:

FILENAME: CHELAN-23-1 PLOT DATE: 10/6/2016 PLOT TIME: 4:28:43 PM

Attachment 8 – Construction Schedule

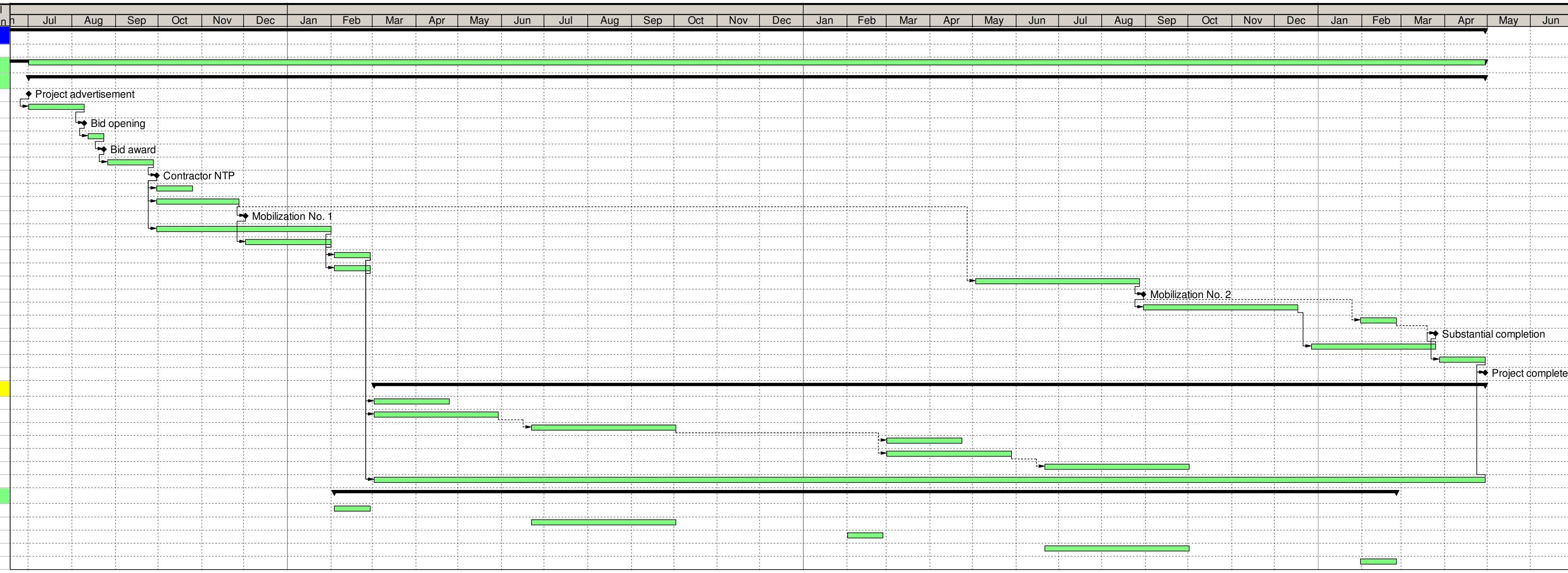
PUD No. 1 of Chelan County, WA

Tumwater Fishway Improvements Draft

Example Construction Schedule

2 March 2017 (rev. 21 September 2017)

Activity Name	Start	Finish	Original Duration
Chelan PUD Tumwater Fishway Modifications	01-Aug	29-Apr	1468
Consultant NTP	01-Aug		0
Consulting Engineering	01-Aug	29-Apr	1468
Construction	01-Jul	29-Apr	728
Project advertisement	01-Jul		0
Contractor bid preparation	01-Jul	09-Aug	29
Bid opening		09-Aug	0
Evaluation of bids	12-Aug	23-Aug	10
Bid award		23-Aug	0
Contract administration	26-Aug	27-Sep	24
Contractor NTP	30-Sep		0
Contractor field survey / design verification	30-Sep	25-Oct	20
RFIs and submittals	30-Sep	27-Nov	43
Mobilization No. 1	02-Dec		0
Equipment procurement, material fabrication and delivery No. 1	30-Sep	31-Jan	86
Site preparation	02-Dec	31-Jan	43
Construct entrance ramps within cofferboxes	03-Feb	28-Feb	20
Construct prototype LPS entrance	03-Feb	28-Feb	20
Equipment procurement, material fabrication and delivery No. 2	03-May	27-Aug	85
Mobilization No. 2	30-Aug		0
Construct LPS flume and exit (with short outages in October)	30-Aug	17-Dec	80
LPS entrance modifications (if required)	31-Jan	25-Feb	20
Substantial completion		25-Mar	0
Operator training, O&M manuals and record drawings	27-Dec	25-Mar	65
De-mobilization	28-Mar	29-Apr	25
Project complete		29-Apr	0
Prototype Testing	02-Mar	29-Apr	559
Video monitoring Year 1	02-Mar	24-Apr	40
Hydraulic testing Year 1	02-Mar	29-May	64
Capture, PIT tag and release lamprey below Dam Year 1	22-Jun	02-Oct	73
Video monitoring Year 2	01-Mar	23-Apr	40
Hydraulic testing Year 2	01-Mar	28-May	65
Capture, PIT tag and release lamprey below Dam Year 2	21-Jun	01-Oct	75
Prototype testing of LPS entrance, location and configuration	02-Mar	29-Apr	559
Project Constraints	03-Feb	25-Feb	534
Annual fishway shutdown Year 1 (with intermittent operation)	03-Feb	28-Feb	20
Potential lamprey migration timing Year 1	22-Jun	02-Oct	73
Annual fishway shutdown Year 2	01-Feb	26-Feb	20
Potential lamprey migration timing Year 2	21-Jun	01-Oct	75
Annual fishway shutdown Year 2 (with intermittent operation)	31-Jan	25-Feb	20



Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

TASK filter: All Activities

Attachment 9 – Construction Cost Estimates

ch2m

Chelan PUD - Tumwater Fishway Modifications
Alternative No. 4 - Lamprey Passage Structure (LPS) Within Existing Fishway

Date: 22 December 2016
By: A. George
Checked By: J. Kapla

Note: The following provides an order-of-magnitude construction cost estimate for initial planning purposes only. This estimate is assumed to be equivalent to an Association for the Advancement of Cost Engineering (AACE) International Class 5 estimate (+100%, -50%).

Capital Costs

No.	Item Description	Quantity	Unit	Unit Cost (2016)	Total Cost	Notes
1	Construction survey and general site work	1	LS	$ 15,000	$ 15,000	
2	Fabricated steel entrance ramps	2	EA	$ 7,500	$ 15,000	
3	Cofferbox and/or dive work for installation	1	LS	$ 40,000	$ 40,000	
4	Fabricated aluminum LPS	1	LS	$ 52,500	$ 52,500	1/4-inch aluminum sheet metal. Approximately 3,500 lbs. total.
5	Saw cut penetrations in existing baffles	1	LS	$ 4,000	$ 4,000	
6	LPS supports	36	EA	$ 750	$ 27,000	Supports every 5 linear feet.
7	Water supply pump, throttling valve and discharge piping	1	LS	$ 45,000	$ 45,000	Includes 10 hp submersible pump (2 ea) and 8-inch discharge piping to upwelling box
8	Upwelling box and exit pipe	1	LS	$ 35,000	$ 35,000	Includes 10-inch diameter exit pipe lined with perforated plastic sheeting
9	Electrical and I&C	1	LS	$ 25,000	$ 25,000	Includes portable backup generator. No heat trace is assumed.
10	Monitoring equipment	1	LS	$ 45,000	$ 45,000	Camera monitoring system. PIT tag detectors not included.
11	Replace existing AWS wall diffusers	1	LS	$ 37,500	$ 38,000	100 SF panel.
12	Mobilization and demobilization	1	LS	$ 50,000	$ 50,000	
				Subtotal:	$ 392,000	
				Contingency @ 25%:	$ 98,000	
				Total Construction Cost (Baseline):	**$ 490,000**	Does not include Washington State sales tax (WSST).
				Total Construction Cost (High):	$ 980,000	+100%
				Total Construction Cost (Low):	$ 245,000	-50%

Operations and Maintenance Costs

No.	Item Description	Quantity	Unit	Unit Cost (2016)	Total Cost	Notes
1	Water supply pump energy	1	LS	$ 16,500	$ 16,500	
2	O&M labor	0.25	FTE	$ 100,000	$ 25,000	Assumed to be approximately 5% of capital cost.
3	M&E labor	0.80	FTE	$ 100,000	$ 80,000	Total field and office time.
4	Routine maintenance	1	LS	$ 10,000	$ 10,000	Assumed to be approximately 2% of capital cost.
				Subtotal:	$ 132,000	
				Contingency @ 25%:	$ 33,000	
				Total Annual O&M Cost:	**$ 165,000**	
				Present Worth Annual O&M Cost:	**$ 2,271,000**	Assumes a 6% real discount rate and a period of 30 years.

Chelan PUD - Tumwater Fishway Modifications
Alternative No. 5 - Ramps at Sills Within Existing Fishway

Date: 22 December 2016
By: A. George
Checked By: J. Kapla

Note: The following provides an order-of-magnitude construction cost estimate for initial planning purposes only. This estimate is assumed to be equivalent to an Association for the Advancement of Cost Engineering (AACE) International Class 5 estimate (+100%, -50%).

Capital Costs

No.	Item Description	Quantity	Unit	Unit Cost (2016)	Total Cost	Notes
1	Construction survey and general site work	1	LS	$ 10,000	$ 10,000	
2	Fabricated steel entrance ramps	2	EA	$ 7,500	$ 15,000	
3	Cofferbox and/or dive work for installation	1	LS	$ 40,000	$ 40,000	
4	Fabricated aluminum sills	19	EA	$ 1,000	$ 19,000	1/4-inch aluminum sheet metal.
5	Replace existing trap floor diffuser	1	LS	$ 16,500	$ 17,000	110 SF. No auxiliary LPS is assumed for the purposes of this estimate.
6	Electrical and I&C	1	LS	$ 7,500	$ 8,000	
7	Monitoring equipment	1	LS	$ 40,000	$ 40,000	Camera monitoring system. PIT tag detectors not included.
8	Replace existing AWS diffusers	1	LS	$ 37,500	$ 38,000	100 SF panel.
9	Mobilization and demobilization	1	LS	$ 30,000	$ 30,000	
				Subtotal:	$ 217,000	
				Contingency @ 25%:	$ 54,000	
				Total Construction Cost (Baseline):	**$ 271,000**	Does not include Washington State sales tax (WSST).
				Total Construction Cost (High):	$ 542,000	+100%
				Total Construction Cost (Low):	$ 136,000	-50%

Operations and Maintenance Costs

No.	Item Description	Quantity	Unit	Unit Cost (2016)	Total Cost	Notes
1	O&M labor	0.15	FTE	$ 100,000	$ 15,000	Assumed to be approximately 5% of capital cost.
2	M&E labor	0.80	FTE	$ 100,000	$ 80,000	Total field and office time.
3	Routine maintenance	1	LS	$ 5,000	$ 5,000	Assumed to be approximately 2% of capital cost.
				Subtotal:	$ 100,000	
				Contingency @ 25%:	$ 25,000	
				Total Annual O&M Cost:	**$ 125,000**	
				Present Worth Annual O&M Cost:	**$ 1,721,000**	Assumes a 6% real discount rate and a period of 30 years.