US Army Corps
of Engineers®
Portland District

DESIGN DOCUMENTATION REPORT NO. 1

THE DALLES DAM
LYLE, WASHINGTON

FY19 FISH ACCORDS LAMPREY PASSAGE – THE DALLES DAM

90 Percent DDR
September 2022

EXECUTIVE SUMMARY

1. INTRODUCTION

This Design Documentation Report (DDR) covers the alternatives evaluation and the selected plan for the east fish ladder lamprey collection system. This report describes the project background and outlines technical aspects of the selected plan.

There is no existing lamprey collection at the east fish ladder of The Dalles Dam. This PDT seeks to design and install a lamprey collector that will draw from the junction pool at the east entrance where the adult collection channel, spillway entrance transportation channel, and the east fish ladder channel all converge. The PDT will consider alternatives for a gravity-fed watering system supplied by the fish ladder, and a pumped system. These upgrades to the lamprey collection system will be made during the FY23 in-water work period.

In addition to lamprey collection at the east ladder, this PDT will provide two upgrades for lamprey passage through the fish ladder systems. First, slot fillers will be designed and built for the existing gates at all fish ladder entrances throughout the project. This includes both the east and north ladders. Second, the removable exit section weirs in the east ladder will be notched to improve hydraulic conditions for lamprey passage.

2. PURPOSE

The purpose of this project is to provide lamprey collection at the east fish ladder and improve lamprey passage through all the fish ladders at The Dalles Dam.

3. PROJECT LOCATION

This project is located at The Dalles Dam. Most of the scope of work is at tailrace level near the east fish ladder entrance.

4. DESCRIPTION OF FACILITY

The east ladder system routes from tailrace to forebay at the east end of the powerhouse. There are entrances at east end of the powerhouse, the west end of the powerhouse, and the south end of the spillway. The three channels coming from these entrances combine in a junction pool near the east entrance.

The Dalles Dam also has a fish ladder system on the Washington shore which will receive slot fillers at the entrance as part of this project.

5. CONSTRUCTION ACCESS

The contractor will need to coordinate activities and laydown space with Project. Most of the work will be performed by a contractor, but the east ladder exit weir modifications will be performed in-house. Crane placement for that work may conflict with installation of the lamprey collection system water supply pipe and close coordination will be necessary.

6. CONSTRUCTION SCHEDULE

Construction will occur during the FY24 dewatering period.

7. OPERATIONS DURING CONSTRUCTION

The fish ladder will be de-watered and completely offline during construction. Other functions of The Dalles Dam will not be disturbed during construction.

8. COST

The total cost of construction was estimated at approximately $4.2M based on the 60% milestone plans and specifications. The cost estimate will be further refined for the upcoming BCOES deliverables.

CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS

Acronym	Description
AFF	Adult Fish Facility
APE	Area of Potential Effects
AWSBS	Auxiliary Water System Backup System
BOR	Bureau of Reclamation
BPA	Bonneville Power Administration
CRFM	Columbia River Fish Mitigation Program
CRITFC	Columbia River Inter-Tribal Fish Commission
CRS	Columbia River System
DDR	Design Documentation Report
DoD	Department of Defense
EIS	Environmental Impact Statement
EM	Engineer Manuals
ER	Engineer Regulations
ESA	Endangered Species Act
FCRPS	Federal Columbia River Power System
HMI	Human-Machine Interface
HSS	Hydraulic Steel Structure
IO	Input/Output
LPS	Lamprey Passage Structure
MOA	Memorandum of Agreement
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NGVD	National Geodetic Vertical Datum 1929
NMFS	National Marine Fisheries Service
OBE	Operational Basis Earthquake
PCF	Pounds Per Cubic Foot
PDT	Product Development Team
PLC	Programmable Logic Controller
RME	Research, monitoring, and evaluation

ROD	Record of Decision
SCADA	Supervisory Control and Data Acquisition
SHPO	State Historic Preservation Officer
THPO	Tribal Historic Preservation Officer
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
VAC	Voltage Alternating Current

SECTION 1 - PURPOSE AND INTRODUCTION

1.1 INTRODUCTION

The U.S. Army Corps of Engineers' (Corps) FY2020 Work Plan included $20M in the Columbia River Fish Mitigation Program (CRFM) to complete all lamprey work contemplated in the 2019-2023 FCRPS (Federal Columbia River Power System) Fish Accords. These are 'no year' funds and thus can be carried in to out-years as needed to implement the program.

The goal of the Corps' Pacific Lamprey (Entosphenus tridentatus) passage improvement efforts is to improve both juvenile and adult lamprey passage and survival through the eight Corps multi-purpose dams on the lower Columbia and Snake rivers (CRS Project), contributing to a regional effort to arrest the decline of Pacific lamprey populations in the Columbia Basin and rebuild their populations to sustainable and harvestable levels.

1.1.1 2020 CRS Proposed Action

In September 2020, the Corps signed a Record of Decision (ROD) adopting the Preferred Alternative described in the Action Agencies' (BPA, BoR, Corps) Final Environmental Impact Statement (EIS) for the long-term coordinated operation and management of the CRS Project. Several adult and juvenile lamprey passage improvement measures were considered in the EIS and integrated into the EIS's Selected Alternative. The Selected Alternative included two measures pertinent to the fishways at The Dalles Dam. (1) A measure to expand the network of Lamprey Passage Structures (LPS) to bypass impediments in existing fish ladders with new structures at Bonneville Dam's Bradford Island and Washington Shore fish ladders, The Dalles Dam's east fish ladder, and/or John Day Dam's south fish ladder and (2) Modify existing fish ladders, incorporating lamprey passage features and criteria (ramps to submerged weir orifices, diffuser plating to provide attachment surfaces, diffuser grating with smaller gaps, refuge boxes, wetted walls, rounded weir caps and closure of floating orifice gates) into ladder modifications at the lower Snake and Columbia River dams.

1.1.2 Columbia Basin Fish Accords MOA

From 2008-2018, the Corps addressed many adult and juvenile lamprey passage issues and RM&E needs at its Columbia and Snake River dams using Columbia River Fish Mitigation program (CRFM) funding in accordance with commitments made through the 2008 Columbia Basin Fish Accords Memorandum of Agreement (MOA) between the Three Treaty Tribes and FCRPS Action Agencies.

In 2018, an extension to the Columbia Basin Fish Accords MOA was negotiated and further extended in a 2020 MOA without change to the commitments. The 2018/2020 Fish Accords extensions included a commitment by the Corps to seek funding to finalize and implement a plan to continue to improve Pacific Lamprey passage conditions at Corps dams, to include additional adult lamprey passage improvements at Corps dams.

1.1.3 Pacific Lamprey Passage Improvements Implementation Plan

The Corps coordinated with the Treaty Tribes and Columbia River Inter-Tribal Fish Commission (CRITFC) 2018-2020 to develop and prioritize a list of actions that could be accomplished should funding be received to implement the measures in the 2018/2020 Accords extension. When Work Plan funding was received in 2020, the prioritized list of actions developed by the Corps-Tribal Lamprey Work Group (CTLWG) became the basis for the Corps' Pacific Lamprey Passage Improvements Implementation Plan (Implementation Plan), finalized in May 2021. The purpose of the Implementation Plan is to identify high priority passage improvements and RM&E, and estimate program costs by fiscal year, to be implemented with the $20M received.

Adult lamprey passage improvements in the Implementation Plan are intended to meet the adult passage commitments in the 2020 CRS Proposed Action to modify the Bonneville ladder serpentine weirs, expand the network of LPSs and incorporate lamprey passage features in the existing ladders. All structural or operational changes intended to improve passage conditions for Pacific lamprey will be coordinated with the Services to ensure neutral to beneficial effects on ESA-listed species. At Bonneville Dam, the Washington Shore serpentine weirs will undergo a major redesign, converting them to an Ice Harbor-style vertical slot with submerged orifices configuration while the Bradford Island serpentine weirs will undergo extensive minor modifications, incorporating lamprey specific passage features into the existing configuration. New LPSs will be constructed at Bonneville Dam's Bradford Island and Washington Shore ladders and The Dalles Dam's east fish ladder and improvements will be made to the existing LPSs at Bonneville and John Day dams. The Implementation Plan also prescribes several modifications to the existing ladders at Bonneville, The Dalles, John Day, McNary, and Lower Monumental dams to incorporate lamprey passage features at the fishway entrances, salmon orifices, and diffuser grating.

1.2 PROJECT DESCRIPTION

Design and install adult lamprey passage improvements identified in the Pacific Lamprey Passage Improvements Implementation Plan for implementation at The Dalles Dam. Major scope items include:

1) Design and install a new LPS at The Dalles East Fish Ladder junction pool.

2) Design and install bulkhead/weir guide slot covers at all four fishway entrances at The Dalles Dam.

3) Modify the elevated submerged orifices in The Dalles East Fish Ladder exit weirs 154-157 to provide better lamprey passage options through the four control weirs at the upstream end of the fishway.

1.3 PROJECT OBJECTIVES

The objective is to improve lamprey passage at The Dalles Dam, with neutral to beneficial effects on ESA-listed species.

1.4 PREVIOUS STUDIES AND REPORTS

The design of this project will be based on the success and lessons learned from lamprey passage RM&E and improvements implemented 2008-2018. Similar LPSs were installed at Bonneville Bradford Island (2006), Bonneville Washington Shore (2007 & 2013) and John Day North (2013) fishways.

1.5 PROJECT CONSTRAINTS

1.5.1 Environmental

All structural or operational changes intended to improve passage conditions for Pacific lamprey will be coordinated with the Services to ensure neutral to beneficial effects on ESA-listed species.

1.5.2 Construction

Construction in the fish ladder can only occur during the winter maintenance period, which is December 1st through February 28th.This PDT's intent is to complete plans and specifications and award before winter 2022, so that construction can occur during the winter 22-23 dewatering period.

1.5.3 Cost

This project is funded by the FY20 Work Plan budget and was initially estimated at a total of $670k. Any increases to that initial allocation will compete with the other concurrent lamprey passage projects along the lower Columbia River.

SECTION 2 - BIOLOGICAL DESIGN CONSIDERATIONS AND CRITERIA

2.1 PRIMARY SPECIES OF CONCERN

Pacific Lamprey and Salmonid spp. Chinook, Coho, Steelhead and Sockeye make up the bulk of salmonids that pass over The Dalles. Chum and Pink Salmon pass as well as Bull Trout and other resident species. The annual lamprey run overlaps most significantly with summer chinook, Steelhead, and sockeye (Figure 2-1).

2.2 OTHER SPECIES

White Sturgeon use the lower segments of the fishway and occasionally pass through the ladder. Other species that use the ladder but aren't counted include Pikeminnow, Smallmouth bass, Carp, and wide varieties of suckers, minnows, sculpins and panfish. Shad are an invasive species, and their population has been growing rapidly. Their passage season overlaps that of lamprey, as well as chinook (spring and summer) and sockeye. During shad passage season (≥ 5,000 shad/day/count station), water depth over fish ladder weirs is maintained at 1.3 feet (±0.1 foot) to encourage shad to go over the top of weirs and reduce crowding at the orifice openings. Outside the shad passage season (< 5,000 shad/day/count station), water depth over fish ladder weirs is maintained at 1.0 foot (±0.1 foot) (2021 Fish Passage Plan, http://pweb.crohms.org/tmt/documents/fpp/).

2.3 SUMMARY OF RESEARCH TO DATE

Keefer et al. (2013) used migration histories from radio-tagged Pacific lamprey to identify locations of poor passage ("bottlenecks") in the fishways at Bonneville Dam. The serpentine control sections of the Bradford Island and Washington Shore ladders exhibited high turn-around rates combined with low probability of additional passage attempts, resulting in a high passage failure rate compared to other segments of the ladders. High velocities and turbulence characteristic of serpentine sections are the likely cause of the high turn-around rates in these segments and remediation for those negative hydraulic conditions should reduce turnarounds and increase overall passage success.

2.4 BIOLOGICAL CONSIDERATIONS

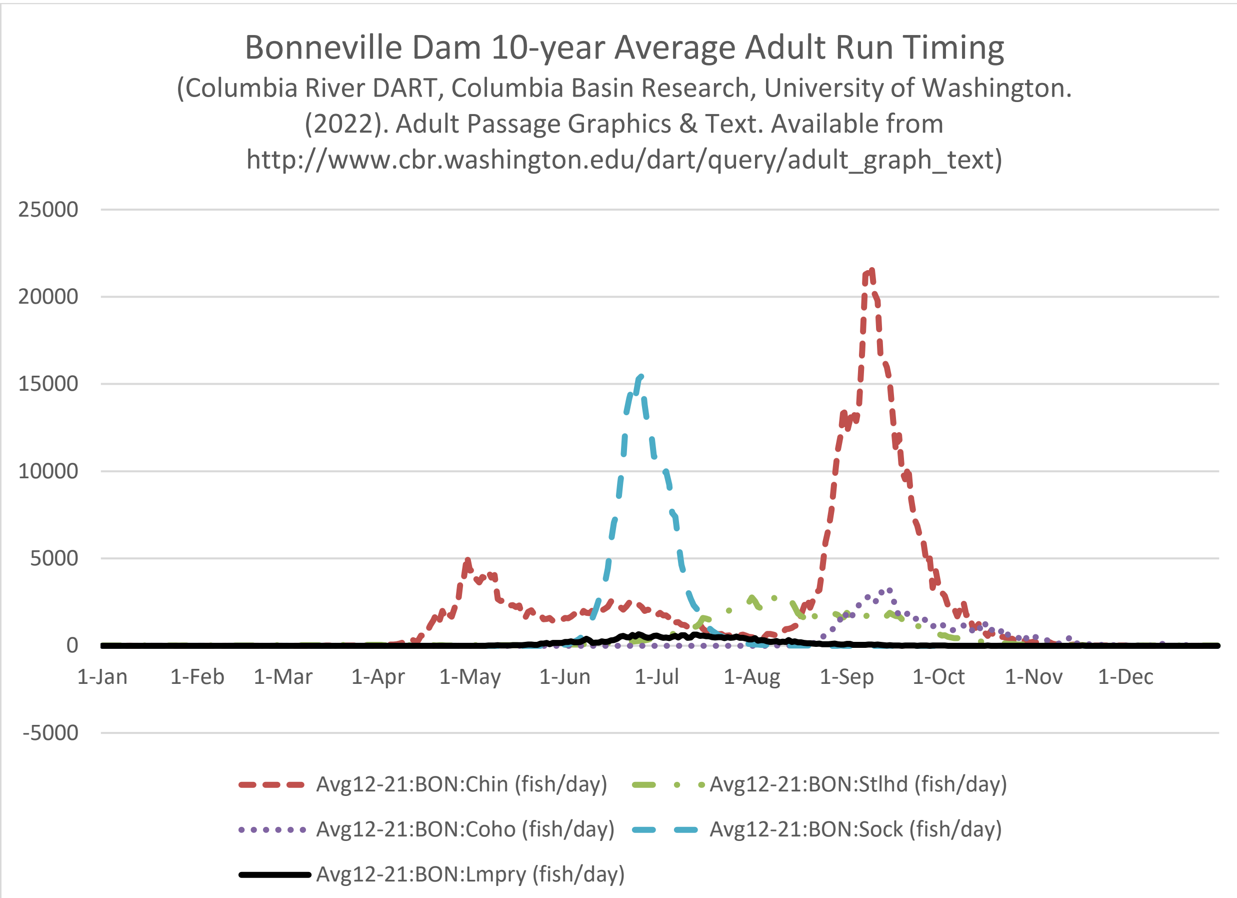
2.4.1 Winter Maintenance Period

The Dalles' annual winter maintenance period is December through February (2021 Fish Passage Plan, http://pweb.crohms.org/tmt/documents/fpp/). Fishway dewatering for maintenance at The Dalles Dam includes north and south ladder systems, so that no upstream passage is available during the winter.

2.4.2 Fish Passage Season

The adult fish passage season is March through November; however, upstream migrants are present throughout the year and adult passage facilities are operated year-round (2021 Fish Passage Plan, http://pweb.crohms.org/tmt/documents/fpp/). 10-year average run timing (fish/day) for the species of concern passing Bonneville Dam are shown in Figure 2-1.

Figure 2-1. 10-year average run timing at Bonneville Dam



2.5 BIOLOGICAL CRITERIA

Design criteria for lamprey come from:

Pacific Lamprey Technical Workgroup. 2017. Practical guidelines for incorporating adult Pacific lamprey passage at fishways. June 2017. White Paper. 47 pp + Appendix. Available online: https://www.fws.gov/pacificlamprey/mainpage.cfm

Zobott, H. A., C. C. Caudill, M. L. Keefer, R. Budwig, K. Frick, M. Moser, and S. Corbett. 2015. Technical Report 2015-5, Design Guidelines for Pacific Lamprey Structures. Jointly prepared Report from University of Idaho Department of Fish and Wildlife

Sciences and National Marine Fisheries to U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

2.5.1 Relevant Lamprey Passage Criteria (from USFWS, 2017)

- Max. slot width (lamprey) = no criteria
- Min. slot width (lamprey) = 1.0 ft (Pacific Lamprey Technical Workgroup White Paper, 2017, Table 3)
- Max. slot velocity (lamprey) = 8 ft/s (Pacific Lamprey Technical Workgroup White Paper, 2017, Table 2)
- Min. slot velocity (lamprey) = no criteria
- Max. orifice velocity (lamprey) = 8 ft/s (Pacific Lamprey Technical Workgroup White Paper, 2017, Table 2)
- Min. orifice velocity (lamprey) = no criteria
- Max. slot head drop (lamprey) = 1.5 ft (Pacific Lamprey Technical Workgroup White Paper, 2017, Table 1)
- Min. slot head drop (lamprey) = no criteria

2.5.2 Relevant Salmonid Passage Criteria (NMFS, 2011)

- Max. slot width (salmon) = no criteria
- Min. slot width (salmon) = 1.0 ft (NMFS, Anadromous Salmonid Passage Facility Design, 2011, pg. 35)
- Max. slot velocity (salmon) = 12 ft/s (NMFS, Anadromous Salmonid Passage Facility Design, 2011, pg. 26)
- Min. slot velocity (salmon) = no criteria
- Max. orifice velocity (salmon) = no criteria
- Min. orifice velocity (salmon) = no criteria
- Max. slot head drop (salmon) = 1.0 ft (NMFS, Anadromous Salmonid Passage Facility Design, 2011, pg. 45)
- Min. slot head drop (salmon) = 0.25 ft (NMFS, Anadromous Salmonid Passage Facility Design, 2011, pg. 45)

2.5.3 Relevant LPS Design Criteria

General best practice design guidelines for each component of a Pacific LPS are provided in Zobott et al., 2015.

2.6 POST-CONSTRUCTION EVALUATION

Post-construction evaluation will be accomplished with an adult fish passage study using radio or acoustic telemetry beginning in the 2025 fish passage season.

SECTION 3 - HYDRAULIC DESIGN

This chapter describes the hydraulic design of specific features pertinent to the proposed lamprey improvements at The Dalles Dam.

3.1 DESIGN REFERENCES

Clabough, T. S., E. L. Johnson, M. L. Keefer, C. C. Caudill, C. J. Knoyes, J. Garnet, L. Layng, T. Dick, M. L. Jepson, K. Frick, S. Corbett, and B. J. Burke. 2015. Technical Report 2015-10-Final; Evaluation of Adult Pacific Lamprey Passage at Lower Columbia River Dams and Behavior in Relation to Fishway Modifications at Bonneville and John Day Dams – 2014. Jointly prepared Report from University of Idaho Department of Fish and Wildlife Sciences and National Marine Fisheries to U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Kemp, P. S., T. Tsuzaki, and M. L. Moser. 2009. Linking behavior and performance: intermittent locomotion in a climbing fish, Journal of Zoology 277: 171-178.

Mesa, M. G., J. M. Bayer, and J. G. Seelye. 2003. Swimming Performance and Physiological Responses to Exhaustive Exercise in Radio-Tagged and Untagged Pacific Lamprey, Transactions of the American Fisheries Society 132:483-492.

Miller, 1990. *Internal Flow Systems*

National Marine Fisheries (NMFS), Northwest Region, NOAA. 2011 Anadromous Salmonid Passage Facility Design.

USACE, Waterways Experiment Station. 1986, Hydraulic Design Criteria.

USACE, The Dalles Dam East Fish Ladder As-constructed (DDF) Drawings, 1953.

USACE, Walla Walla and Portland Districts. Design Document Report, The Dalles East Fish Ladder Auxiliary Water Supply Backup System, 2017.

USACE, Northwester Division, Columbia Basin Water Management, Reservoir Control. 2021 Fish Passage Plan, Lower Columbia & Lower Snake River Hydropower Projects, March 1, 2021 – February 28, 2022. June 2021.

Zobott, H. A., C. C. Caudill, M. L. Keefer, R. Budwig, K. Frick, M. Moser, and S. Corbett. 2015. Technical Report 2015-5, Design Guidelines for Pacific Lamprey Structures. Jointly prepared Report from University of Idaho Department of Fish and Wildlife Sciences and National Marine Fisheries to U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

3.2 DESIGN ASSUMPTIONS

The following assumptions pertain the hydraulic design of key components of the proposed lamprey improvements.

3.2.1 Hydrologic Conditions

Lamprey systems must be able to function within the expected range of forebay and tailwater elevations. The following water elevations are provided in National Geodetic Vertical Datum (NGVD) 1929.

3.2.1.1 Forebay Elevations

The forebay elevations are controlled by the difference between Project inflow and discharge operations. The forebay usually runs near median forebay elevation 158.8 feet during the Lamprey passage season (June - September).

- Minimum: 155 feet
- Maximum: 160 feet
- Median: 158.8 feet
- Normal range: 157.0 – 159.5 feet
  - Forebay is within the normal range 98% of time based on daily forebay data collected between 1990-2021.

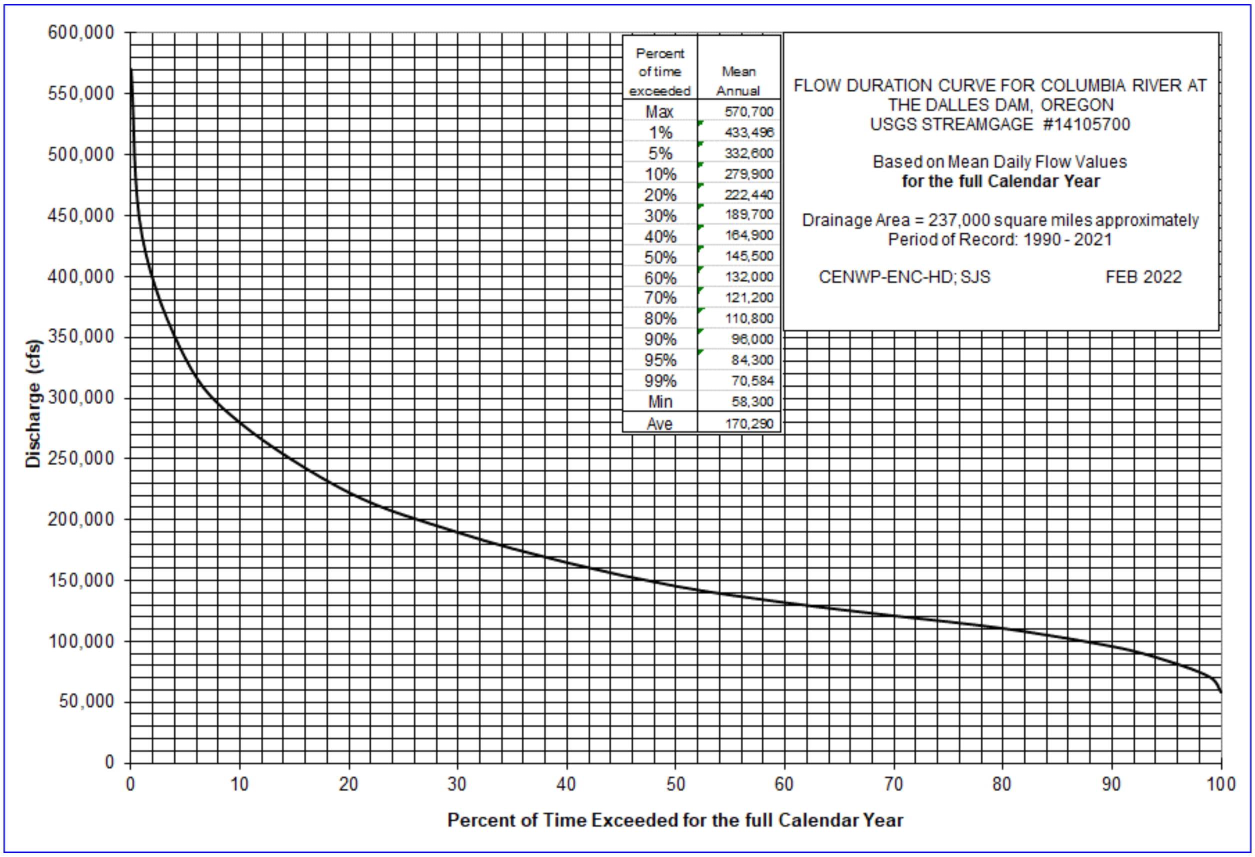
3.2.1.2 The Dalles River Flow Rates and Discharge Duration Curves

Pertinent mean daily river flow rates over the year (record 1990 - 2021) include:

- Minimum 58.3 kcfs
- 95% exceedance 84.3 kcfs
- 90% 96.6 kcfs
- 70% 121.2 kcfs
- Median (50% exceedance) 145.1 kcfs
- Average annual 170.3 kcfs
- 30% 189.7 kcfs
- 10% 279.9 kcfs
- 5% exceedance 333.6 kcfs
- Maximum 570.7 kcfs

The Dalles river flow duration curves fare defined as the flow rate versus percent of time exceeded on a daily or hourly basis. Figure 3-1 provides a chart showing daily discharge versus percent of time (days) in which the project discharge was exceeded during the calendar year. This chart is based on a mean daily discharge record from 1990 - 2021.

Figure 3-1. The Dalles Project Discharge versus Percent of Time Exceeded for the Calendar Year



Peak lamprey passage times occurs at The Dalles during June through mid-September, partly when flow rates are historically higher than in the calendar year. The spring freshet usually occurs sometime in late May through early July. June is on average the highest flowing month.

Figure 3-1 provides a chart showing daily discharge versus percent of time (days) in which the project discharge was exceeded during the June through September. This chart is based on a mean daily discharge record from 1990 - 2021. Figure 3-3 shows the Figure 3-2 data in tabular form and includes the calendar year (annual) data for comparison.

Figure 3-2. The Dalles Project Discharge versus Percent of Time Exceeded for the June - September

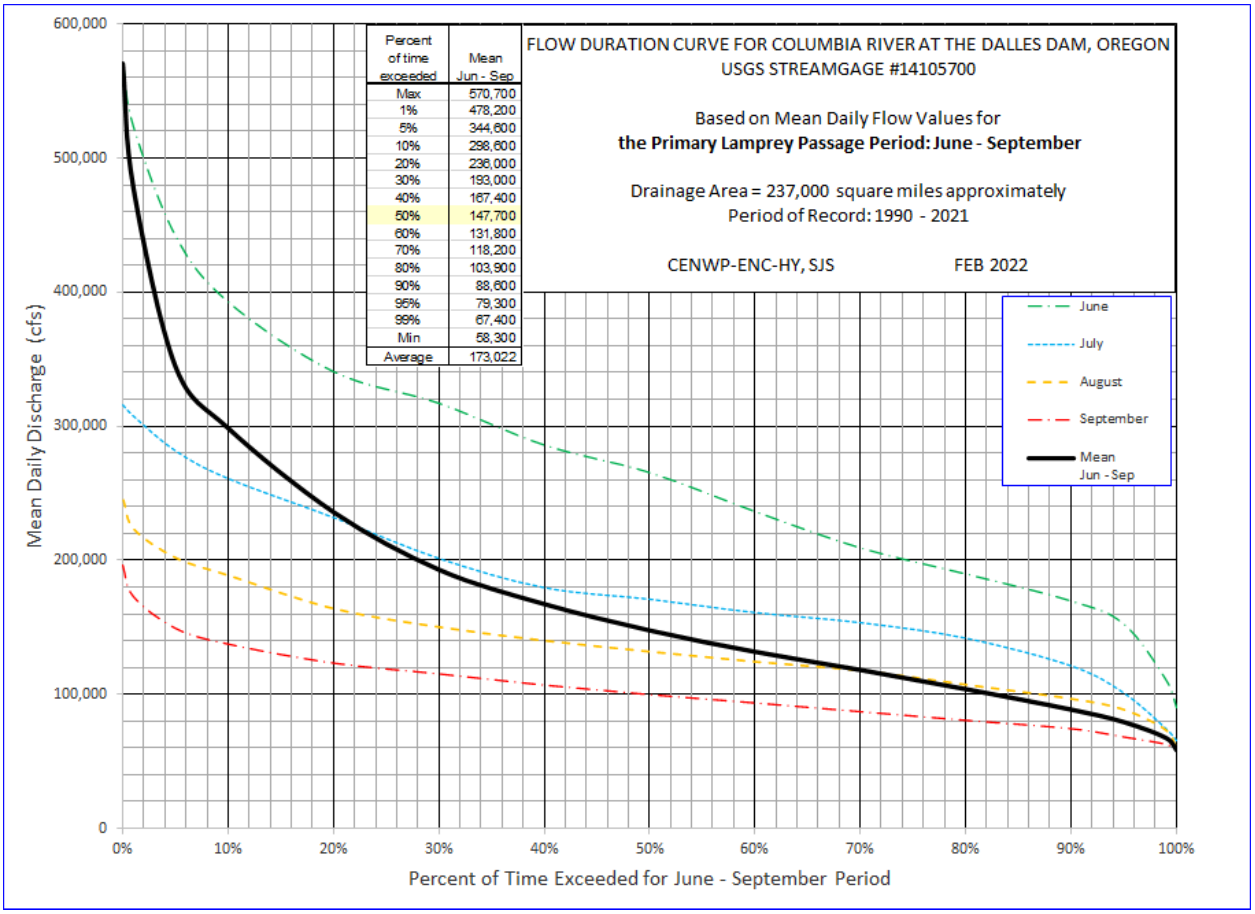


Figure 3-3. Discharge versus Percent of Time Exceeded for the June – September.

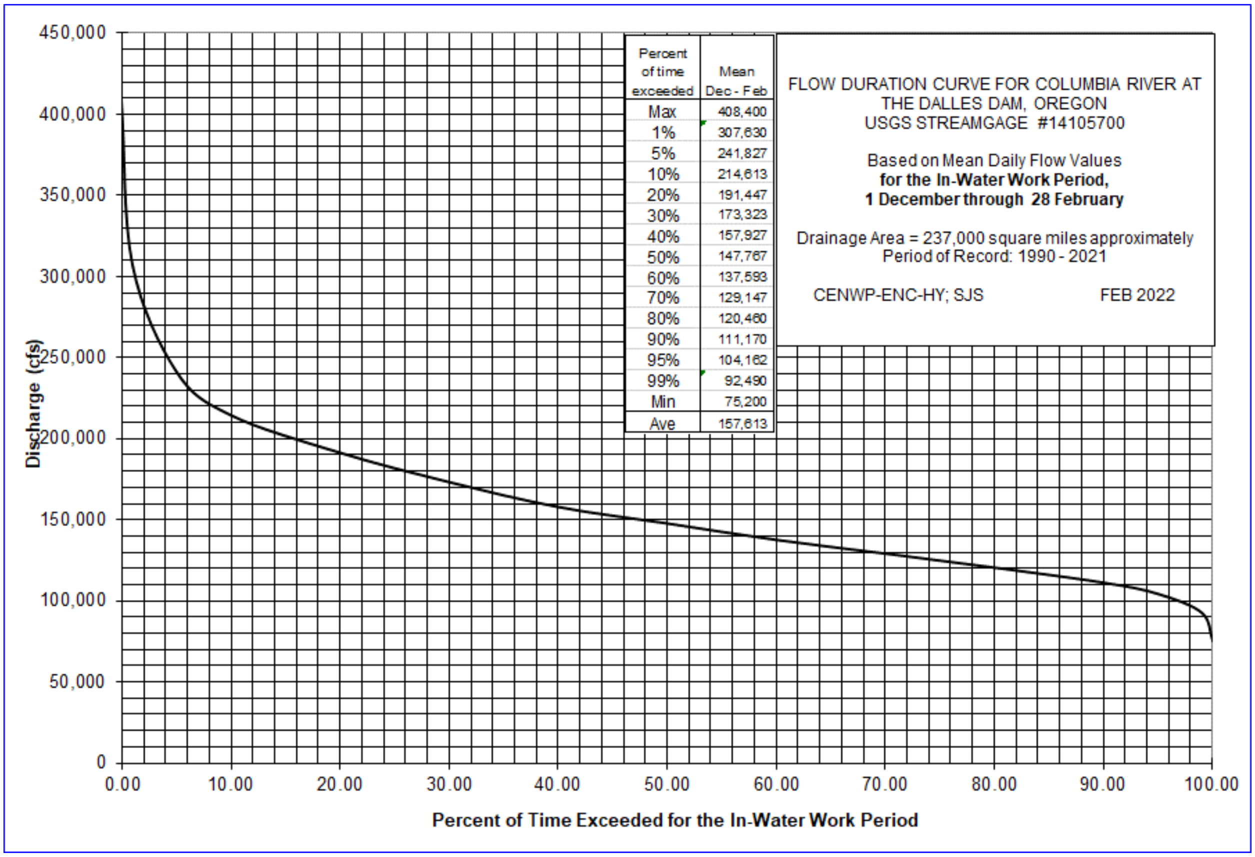
The Dalles Lock and Dam: Discharge Duration Data during June - September
Mean Daily Project Flow Rates, June 1 Thru September 30
(Period of Record 1990 -2021)

Percent of time exceeded	Annual	June - Mid Sept. (Peak Lamprey Passage Period)				
		June	July	August	September	Mean Jun - Sep
Max	570,700	570,700	316,400	245,000	196,400	570,700
1%	433,496	523,849	308,049	223,264	173,049	478,200
5%	332,600	442,205	282,030	201,860	149,305	344,600
10%	279,900	392,910	261,210	188,790	137,550	298,600
20%	222,440	340,920	232,080	164,000	123,340	236,000
30%	189,700	317,300	201,440	150,330	115,290	193,000
40%	164,900	286,146	179,600	140,220	106,940	167,400
50%	145,500	265,600	170,950	132,000	99,800	147,700
60%	132,000	236,560	160,960	124,460	93,600	131,800
70%	121,200	209,370	153,390	117,840	87,110	118,200
80%	110,800	189,960	141,780	107,420	80,660	103,900
90%	96,000	169,800	121,000	96,870	74,370	88,600
95%	84,300	152,550	100,690	88,895	68,180	79,300
99%	70,584	110,931	74,002	73,752	62,695	67,400
Min	58,300	90,200	65,100	61,000	58,300	58,300
Average	170,290	272,327	181,213	137,070	103,399	173,022

Construction inside or in near proximity to the fish ladder must be completed during the in-water work period. The official in-water work period is between December 1 – February 28. Figure 3-1 provides a chart showing daily discharge versus percent of time (days) in which the project discharge was exceeded during the In-water work period. This chart is based on a mean daily discharge record from 1990 - 2021.

Extensions of the in-water work period are sometimes permitted in coordination with the fishery agencies. If so, the extension is more likely to be granted in late November instead of earlier March, when more juvenile salmon are on the move.

Figure 3-4. The Dalles Project Discharge versus Percent of Time Exceeded for the In-Water Work Period.

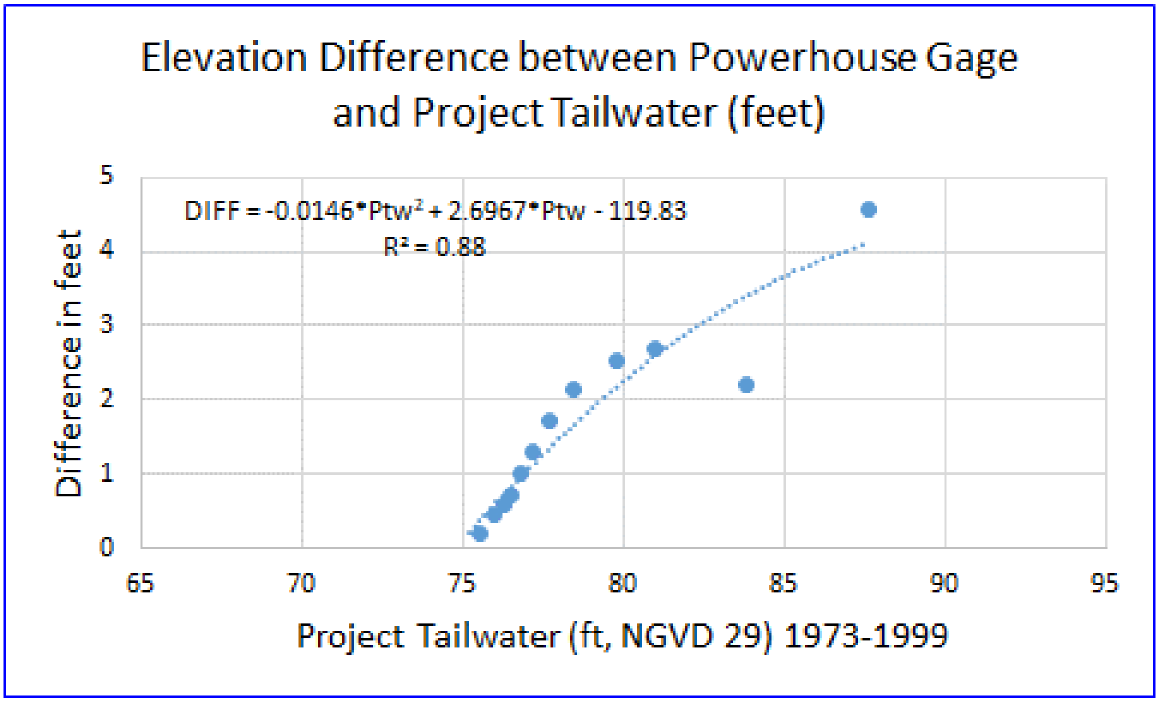


3.2.1.3 The Dalles Tailwater Elevations

The Dalles Dam tailwater elevations are dependent on project discharge and Bonneville Dam operations. The East Entrance of the East Fish Ladder is located at the east end of the powerhouse. The powerhouse outflows are released in a direction perpendicular to the receiving powerhouse channel. This causes the tailwater levels to backup higher than the reported project tailwater elevation. Tailwater data historically collected at the powerhouse gage is the most representative of the tailwater elevations experienced at the East Entrance of the East Fish Ladder. The powerhouse gage is located between units 8 and 9 (out of 22 units), or approximately 40% of the distance between the West and East entrances of the East Fish ladder.

Data from the Powerhouse gauge is no longer available. The available official Project tailwater data was collected for the 1990 – 2021 record. The Powerhouse tailwater for the same period of record was estimated by an adjustment based on a comparison between Powerhouse and Project gauges from the 1973 – 1999 records. The relationship and correlated equation for difference (DIFF) in feet as a function of Project Tailwater (Ptw) is shown in Figure 3-5. The difference was set to zero for Project tailwater elevations below 75 feet.

Figure 3-5. Elevation Difference between Powerhouse and Project Tailwater Gauges.



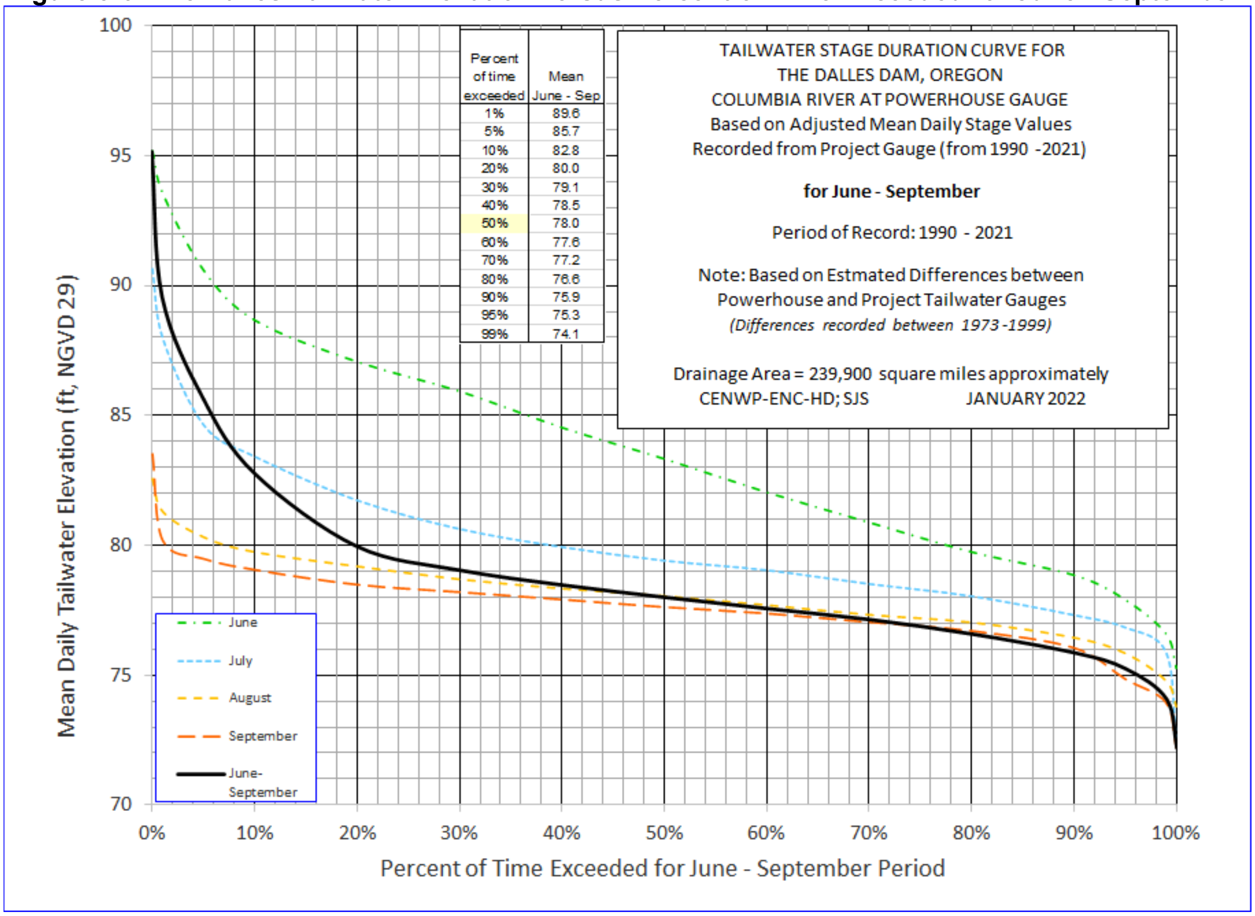
The project minimum operating tailrace elevation is regulated by the USACE Reservoir Control Center to be 70 feet per the USACE 2021 Fish Passage Plan. This is done to maintain at least 8-feet of tailwater submergence above the multiple TDA fish ladder entrance inverts at 62 feet. The Project tailwater has exceeded this minimum tailwater 100% of the time between 1990 - 2021.

As noted previously, the peak lamprey passage period occurs between June and mid-September. Daily tailwater elevations versus percent of time (days) in which the tailwater elevation was exceeded is shown in Figure 3-6 for the June through September period. This chart is based on the adjusted daily tailwater record from 1990 - 2021.

Based on the adjusted daily data collected between 1990 - 2021, the pertinent daily powerhouse tailwater elevations include:

- Minimum 72.2 feet
- 95% exceedance 76.1 feet
- Median (50% exceedance) 78.8 feet
- 5% exceedance 87.3 feet
- Maximum 95.2 feet

Figure 3-6. The Dalles Tailwater Elevation versus Percent of Time Exceeded for June - September.

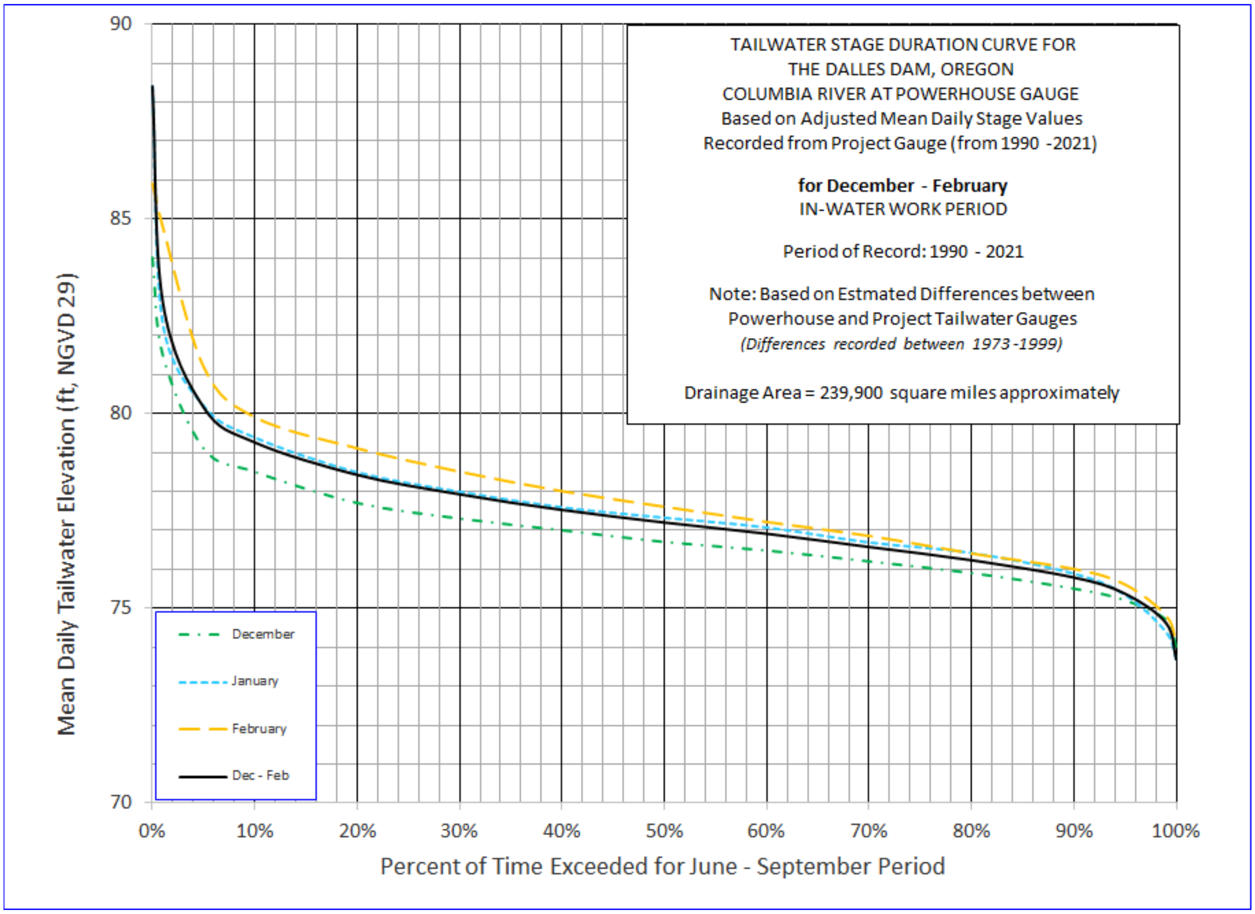


The lowest rest box needs to be located above the maximum expected level expected in the Junction pool. The pool water levels will be about 2.5 feet higher than the tailwater elevation.

The adjusted Powerhouse tailwater elevations versus percent of day exceeded during the in-water work period (December – February) is shown Figure 3-7 in for same length of record as in the previous figures.

The 1% annual exceedence (i.e.,100-year flow event) flow rate at The Dalles 680,000 cfs. Depending on the forebay elevation at Bonneville Dam, the 1% annual exceedance tailwater will be between 96.3 – 97.6 feet.

Figure 3-7. The Dalles Tailwater Elevation versus Percent of Time Exceeded for In-Water Work Period.



3.2.2 Lamprey Passage System (LPS) Assumptions and Design Features

A lamprey passage system (LPS) is the system devised to separately pass the adult lamprey outside of the fish ladder. A LPS system will include some or all the following components: lamprey entrance unto the LPS, climbing ducts, travelling ducts, alternatives series of chutes and pools, rest boxes or rest areas, water supply intakes (pump or gravity), PIT Tag detectors, and collection boxes or upwelling boxes with LPS exits.

The currently proposed scope will utilize all the above except the upwelling boxes and LPS exits. However, descriptions and criteria are provided for all components, as that they may incorporated in subsequent phases of the LPS improvements.

3.2.2.1 LPS Water Supply Sources

Pumped water sources are required for LPS systems where Lamprey are released to the Forebay. Otherwise, the feasibility of a gravity water supply should be explored.

Gravity water supplies are generally more reliable than pumped supplies and typically have lower O&M costs. However, where gravity water supplies are not feasible, a configuration with two pumps that run continuously to make up the required flow rate for the LPS is recommended.

For each standard 20-inch wide LPS, recommend a design flow of 124 gpm (0.28 cfs). The water source should be sized about 20 - 40% higher than the computed LPS requirement to allow for adjustments. This should cover the additional water 18-20 gpm recirculation flow requirements for the lamprey collection boxes specified by Tribal biologists.

Screening to exclude juvenile salmonid fish is required at the intake of the water supply sources whether pumped or gravity source.

Pumped Water Supply

For each standard 20-inch wide LPS, two 62 gpm pumps are recommended. The two pump outputs would be combined through a manifold (with one-way valves) to achieve a target flow rate of 124 gpm. The rationale is that if one pump fails, the LPS will still operate at 62 gpm, which could sustain the lamprey already in the LPS while the pump is being repaired.

Pumps sizes are selected to exceed (by 20% to 40%) the anticipated required flow rate and a throttle valve is used to adjust the flow rate down to an optimum level. Other control options include orifices or dump valves (for excess flow). Coordination with Mechanical Design is needed in designing the means of control to assure the pump is operating at the preferred efficiency. Care must be taken if using variable frequency drive (VFD) controllers because they add noise to the power distribution system from which they are powered. This may disturb RFID antennas commonly in the same vicinity of the LPSs.

Gravity Water Supply

Similar to pump sources, the gravity water supply should be designed to exceed the required water supply be 20 – 40% to allow for adjustments. Based on the standard 20-inch wide LPS, the design flow should be 124 gpm (0.28 cfs).

In addition, Tribal LPS operators recommend between 15 -18 gpm allocated for the Collection box to sustain the trapped lamprey.

The design flow rate is rounded up to at least 160 gpm (0.36 cfs) to account the combined LPS and tank requirement and allow room for flow adjustment and optimization.

A 4-inch diameter pipe has been estimated to be sufficient to pass the required flow.

3.2.2.2 LPS Entrances

An LPS entrance represents the downstream end of the LPS which is attached to the invert at a strategic location within a fish ladder or fish ladder auxiliary water channel to effectively draw lamprey into the LPS system. The LPS entrance typically employs a climbing duct to help the lamprey climb out of the fish ladder. The best placement of an LPS entrance is in an area where fish have been observed to aggregate, areas with structural guidance, and/or provide an open duct ramp to the collector.

Compilation of biological research indicates the fish seem to use the LPS most often when passage rates at alternative routes are low and thus entrance of a LPS may be more common in areas where lamprey are “milling”. The design should orient the initial climb of the LPS with the flow of water at a location where lamprey densities are high, are likely to be milling, areas with potential structural guidance (walls or constrictions), and with low to moderate flow rates. The usual deployment of the structures is along a fishway wall with the initial climbing ramp extending all the way to the bottom of the fishway.

The entry ramps of the climbing section can be either open or closed. The open ramps do not have a cover, are generally attached to a fishway wall, and allow access to the ramp at any point within the water column. The ramps should be closed above normal water levels to prevent predation and buildup of algae. The closed duct entry ramps have lids that prevent access to the climbing ramp except at collection points, generally at the bottom or sides of the fishway. The climbing duct has supercritical, thin flow that the fish climb through with varying velocities all above the critical swim velocity.

3.2.2.3 Climbing Ducts

Climbing ducts are intended to allow “burst-and-attach” movement for partially submerged adult lamprey. Pacific lamprey can ascend vertical surfaces with sheeting flow and velocities of approximately 12 ft/s (Kemp et al. 2009). The typical width of a climbing duct is 20 inches, and the recommended slope is 45° (1 ft/ft) (Zobott et al. 2015).

Sometimes magnets are placed into the climbing ducts to break up the flow and provide interim shelter to the climbing Lamprey. This has been successfully applied int the LPS at the Bonneville Adult Fish Facility (AFF).

3.2.2.4 Traversing Ducts

Traversing ducts are intended to allow free anguilliform swimming for adult lamprey. This requires the flow velocity to be below the critical swim speed (an estimate of the swim speed that can be maintained without fatiguing) of adult Pacific lamprey, which has been estimated to be approximately 2.6 ft/s (Mesa et al. 2003). Additionally, the flow depth must be adequate to allow free swimming of lamprey. The design duct can assure an adequate depth using circular conduits and by matching the optimum (i.e., ‘best practice’) velocity of 1.0 ft/s (Table 1, Zobott et al. 2015).

The geometry of the ducts controls the hydraulic conditions within the duct. Round, thin-walled aluminum conduits can be used for the traversing ducts, in which available outside diameters (OD) include 10-inch to 12-inches. Figure 3-8 below shows flow normal depths and velocities for 10-inch to 12-inch diameter ducts and flow combinations for a range on Manning's roughness (n) values. The slopes of the traversing ducts are set to provide the optimum 1 ft/s at the normal design flow of 124 gpm.

Figure 3-8. Normal Depth Results Pipe ID, Discharge, Slope and Manning's n

		Discharge			Design N	*n =*	*0.009*	High N	*n =*	*0.011*	Low N	*n =*	*0.008*
Pipe OD	Pipe ID	(Q)	slope		Depth Yn	Velocity	% Flow	Depth Yn	Velocity	% Flow	Depth Yn	Velocity	% Flow
inches	inches	GPM	ft per 1/4"	ft/ft	in	ft/s	Area	in	ft/s	Area	in	ft/s	Area
10.0	9.87	62	70	0.00030	3.4	0.84	31%	3.8	0.72	36%	3.2	0.91	29%
12.0	11.87	62	70	0.00030	3.2	0.82	22%	3.6	0.71	25%	3.0	0.89	20%
10.0	9.87	124	70	0.00030	5.1	1.00	52%	5.2	0.86	42%	4.3	1.09	33%
12.0	11.87	124	70	0.00030	4.6	1.00	36%	5.2	0.86	42%	4.3	1.09	33%

Traversing ducts can also be rectangular. They can be reduced from the normal 20-climbing duct width to increase depth. For example, a 12-inch-wide flume provides at least 3-inches depth at 1 ft/s velocity for the normal 124 gpm flow rate.

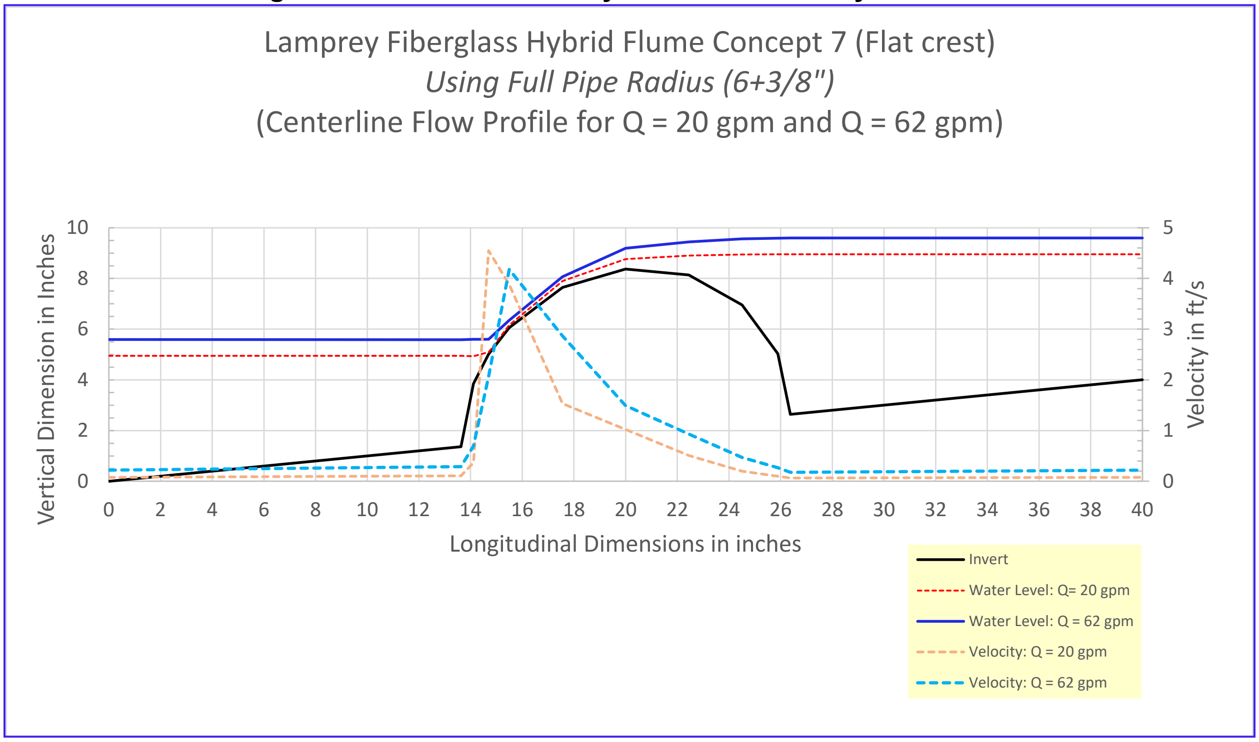
3.2.2.5 Alternative Hybrid Flumes

An alternative means of passing lamprey is a hybrid flume. This design consists of a rectangular flume with periodic sections of half round pipe. Thin flow cascades over the crest and downslope of the half round, and pools behind the next half-round section. This design is intended to rest atop a low sloped (e.g., 10%) ladder side wall and would replace the normal series of climbing and travelling ducts.

Figure 3-9 shows a schematic and hydraulic profile of a 16.3-inch-wide hybrid flume that was tested for lamprey passage at the Bonneville adult fish laboratory. The 6.375-inch radius half round sections were spaced at intervals of 40 inches over a 10% slope. The black line represents the flume invert (fully radiused, not mitered round surface as shown). The dark blue represents the water surface profile at 62 gpm, the dashed red line is the water surface for 20 gpm. The velocities are shown in the lighter dashed lines and are similar at different locations regardless of flow rate.

One potential concern with the hybrid flume may be the accumulation of water temperature in the passage of flow down a long hybrid flume. This can be in part alleviated with higher flow and perhaps some shading.

Figure 3-9. Schematic and Hydraulic Profile of Hybrid Flume



The hybrid flume will not be featured in this phase of work but may be an integral part of a future phase of work, where the LPS is extended upstream of the current collection box.

3.2.2.6 Resting Boxes

Rest boxes are structures that have pools of water with low velocities that act as rest and recovery areas during bouts of climbing, act as daytime refuges, provide for direction changes, and limit down-migration as the fish move up through the LPS. The rest boxes and upwelling boxes control fish passage direction with internal fykes. Direction changes of the LPS within climbing sections are always made with rest boxes. Minimum recommended volume of each rest box is 11.4 ft^3.

Alternative rest areas represent a deepening of the rectangular flume just upstream of the radiused transition at the top end of the climbing duct. This allows lamprey to rest before proceeding to the next segment of climbing flume. This rest area can be done in lieu of a standard rest box in locations that can often be submerged by high water levels due to high tailwater influences (such as in the B-Branch entrance pool 1 at Bonneville Dam). A disadvantage to the rest area is that lamprey may choose to go back down the climbing duct.

3.2.2.7 Upwelling Boxes

Upwelling boxes are used where lamprey fish are to be passed directly to the forebay or some other designated exit pool. If the destination is the forebay, pumps must be used to supply the upwelling boxes because they must be elevated above the forebay pool.

Pumps discharge into an upwelling chamber at the upstream end of the lamprey passage system. There is a continuous fyke through the middle of the upwelling box. The pumped inflow discharges into the fyke to be divided in two directions. Most of the pump flow goes to one end of the fyke to initiate about 62 gpm flow to the traversing duct and the lamprey passage system. At the other end of the fyke, 10 -15 gpm will flow to the lamprey exit. There are two fixed elevation weirs inside the upwelling chamber to control or monitor the discharge rates. The main weir has been a 4-inch deep by 20-inch-long V-notch weir to measure the water supply to the side chamber with the fyke that flows to the LPS system (62 gpm). The other weir is an adjustable width rectangular weir to control drainage discharge as needed to shave off the excess between pump inflow and LPS water supply.

Upwelling boxes will not be featured in this phase of work but may be a part of a future phase of work, where the LPS is extended upstream of the current collection box and lamprey are directed to the forebay or some other selected upper pool in the fish ladder.

3.2.2.8 LPS Exits

LPS exits should be placed to minimize predation and fallback into the fish ladder, powerhouse or spillway. The angle of the exit should also be considered to minimize stress, distance of fall to water surface, and resistance to exit flows. Excess water in the exit outflow conduit needs to be dewatered prior to the lamprey counter location so that the detection paddle will be triggered by lamprey passage instead of discharge.

The normal and desired exit discharge is 10-15 gpm (0.022 - 0.033 cfs). Previous outfalls have used sloping 8-inch PVC pipe. At Bonneville Dam for both Washington Shore outfall and Bradford Island, the outfall flume design was revised to a rectangular configuration. A rectangular outfall flume offers the advantage of a radiused invert slope to transition the invert gradebreak from horizontal to sloping flume. Also longitudinally oriented bar screen is used to provide a porous bottom and prevent lamprey attachment in attempts to reverse their direction to the downward flow and slope. The width of the rectangular flume was optimized to best match the crest outflow conditions of an 8-inch pipe under 10m -15 gpm. Using critical depth calculations for both round and rectangular flume shapes, the respective flow parameters over the upstream crest could be compared to determine the best match. Based on the comparative results shown in Figure 3-8. Normal Depth Results Pipe ID, Discharge, Slope and Manning’s n, a flume width of 3.25 inches was selected.

LPS exits will not be featured in this phase of work but may be a part of a future phase of work, where the LPS is extended upstream of the current collection box and lamprey are directed to the forebay or some other selected upper pool in the fish ladder.

Figure 3-10. Comparative Critical Depth Parameters for Existing Round and Proposed Rectangular Outfall Flumes

Critical Depth in Circular flume

PVC SDR 80 assummed

g = **32.2** ft/s^2 ρ = 1.94 slugs/ft^3

2g = **64.4** ft/s^2 γ = 62.40 lbf/ft^3

Pipe dimensions In)		Inside Diameter (D)		Discharge (Q)		Yc Critical depth		Area	Velocity	T width	Energy	
OD	TH	inches	(ft)	GPM	(cfs)	ft	in	ft^2	ft/s	(ft)	(ft)	in
8.625	**0.530**	7.565	0.63	**10**	0.02	0.068	0.82	0.018	1.22	0.39	0.09	1.10
8.625	**0.530**	7.565	0.63	**12**	0.03	0.075	0.90	0.021	1.28	0.41	0.10	1.20
8.625	**0.530**	7.565	0.63	**15**	0.03	0.084	1.00	0.025	1.36	0.43	0.11	1.35

Critical Depth in Rectangular flume

B9 bars (Reference Hendrick Screen Company Profile bar speciifcations):

Depth of Bars = **1/8** inch = 0.010 feet   Bar width = **0.14** inch

Revised design is to make the ogee invert a continuous sill   Neglect gaps between bars

Opening Width		Discharge (Q)		Bar Opening		Yc Critical depth		Area	Velocity	T width	Energy	
inches	(ft)	GPM	(cfs)	in	ratio	ft	in	ft^2	ft/s	(ft)	(ft)	in
3.50	0.29	**10**	0.02	**0.5**	0.781	0.057	0.68	0.017	1.35	0.29	0.08	1.02
3.50	0.29	**12**	0.03	0.5	0.781	0.064	0.77	0.019	1.43	0.29	0.10	1.15
3.50	0.29	**15**	0.03	0.5	0.781	0.074	0.89	0.022	1.55	0.29	0.11	1.33
3.25	0.27	**10**	0.02	**0.5**	0.781	0.059	0.71	0.016	1.38	0.27	0.09	1.07
3.25	0.27	**12**	0.03	0.5	0.781	0.067	0.81	0.018	1.47	0.27	0.10	1.21
3.25	0.27	**15**	0.03	0.5	0.781	0.078	0.93	0.021	1.58	0.27	0.12	1.40
3.00	0.25	**10**	0.02	**0.5**	0.781	0.063	0.75	0.016	1.42	0.25	0.09	1.13
3.00	0.25	**12**	0.03	0.5	0.781	0.071	0.85	0.018	1.51	0.25	0.11	1.27
3.00	0.25	**15**	0.03	0.5	0.781	0.082	0.99	0.021	1.63	0.25	0.12	1.48

In the outfall flume sections, the 10-15 gpm discharge will be largely dewatered prior to the exit outfall. In short steep (~ 45 degrees) outfalls, the water will be dewatered as soon as possible with the assumption that the longitudinally oriented bars will retain a wet surface to the outfall. With a longer milder sloped outfall flume, such as at Bonneville's Bradford Island, the dewatering must be done incrementally or have some incrementally add-in water applied from above to assure wet bars to the outfall.

3.2.2.9 LPS Drainage

The LPS system must be designed to allow for maintenance, which may include drainage. Drainage is also used to fine tune the flow into the headboxes that feed the lamprey traversing ducts—as the pumps or gravity intakes must be somewhat oversized to assure the required discharge rates. Provisions will be provided to allow fish to be salvaged during the drainage operations (likely refuge pools in resting boxes).

3.2.3 East Fish Ladder Exit Section Weir Modifications

The Exit (or Control) Section of the East Fish Ladder regulates the inflow from the forebay to provide a means of salmon and Lamprey exit to the forebay and assures a constant weir head in the downstream fish ladder system. The Exit Section consists of a system of four mechanically removable weirs (Weirs 154 – 157) and two routinely adjustable weirs (Weirs 158 – 159).

The removable weirs are designated by their overflow crest elevations. Each weir has two sharp crested 2-foot 2-inch square orifices, in which the orifice inverts are located 6 feet below the weir crests. The concrete invert to the Exit Section is a constant elevation 147 feet. Consequently, all orifices in the removable weirs are perched above the concrete floor by 1 – 4 feet depending on the weir. (There are no orifices in the adjustable Weirs 158-159.) The perched and sharp crested orifices in the removable weirs represent an obstacle to Lamprey passage. Lamprey are denied the normal flush concrete surface through the orifices that exist in the normal fish ladder downstream of the Exit Section.

The following bullets summarize the removable Exit Weir Geometry:

- Concrete invert Elevation = 147 feet NGVD 29

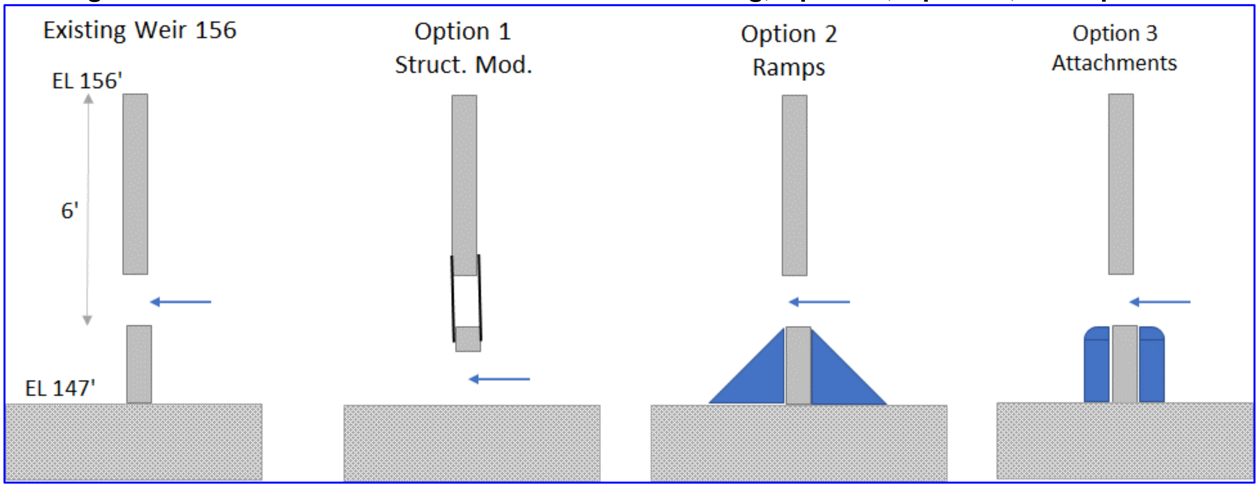
Exit Weir	Weir Height	Orifice Invert above floor
o 154	7 feet	1 foot
o 155	8 feet	2 feet
o 156	9 feet	3 feet
o 157	10 feet	4 feet

Three potential alternatives to improve lamprey passage through the removable weirs include:

- 1. Structurally modify the removable weirs:
    - Cover existing orifices
    - Cut and install new radiused orifices flush with the concrete invert.
- 2. Build 45º ramps up to the orifice inverts
    - Ramps would be between 1 – 4 feet high.
    - Ramps on both sides of orifices
    - Ramps attached to concrete floor
- 3. Radiused attachments to weir sides.
    - Vertical attachment that radius into orifice invert
    - Minimum attachment width and radius = 4 inches
    - Attachments on both sides of weir

Figure 3-11 shows elevation view schematics of the existing removable Weir 156. Moving from left to right, the schematics are presented in the following order: existing Weir 156, Option 1 (Structural Modifications), Option 2 (Ramps attached to floor), and Option 3 (Radiused attached to weirs).

Figure 3-11. Elevation Schematics of Weir 157: Existing, Option 1, Option 2, and Option 3



3.3 DESIGN CRITERIA

The following design criteria pertain the hydraulic design of key components of the proposed lamprey improvements.

3.3.1 Lamprey Passage System (LPS) Criteria

Most of the following LPS criteria are obtained from Zobott, et.al. 2015. Technical Report 2015-5, Design Guidelines for Pacific Lamprey Structures. Additional criteria are derived from engineering experience and judgement, and biological consultation.

3.3.1.1 LPS Flow Rates

- Design flow rate = 124 gpm (0.28 cfs) for standard 20-inch wide LPS flumes
  - Minimum interim operating flow rate = 62 gpm (0.14 cfs)
- Total system flow requirements are comprised by the number of branches that collect lamprey from entrance, ladder, or auxiliary water channels.
- For alternate LPS widths, the design flow rate will be 6.2 gpm (0.014 cfs) per inch if LPS width.
- Design flow rates per 20-inch flume is raised to 150 – 160 gpm to allow for adjustability and incorporate Lamprey holding criteria.

3.3.1.2 Intake Screens for LPS Water Supply Sources

- Intake screens are required to meet fish passage facility requirements for juvenile salmon detailed in NMFS (2011).
- The applicable requirements indicate an approach velocity less than 0.2 ft/s and a maximum square screen mesh size of 3/32 of an inch to prevent impingement or entrapment of juvenile salmonids.

- Screen must be accessible for periodic cleaning.
- The above criteria might be waived if it can be shown that the risk of entraining juvenile fish is very low at the source.
    - This would have to be coordinated with the fishery agencies.

3.3.1.3 LPS Entrance Ramps

- LPS entrance ramp must be attached to invert and should not hinder adult salmon passage.
- Ramps should be open below typical water surface.
- Ramps should be closed above typical water surface.
- Maximum recommended ramp slope = 58 degrees
- Recommended ramp slope = 45 degrees

3.3.1.4 Climbing Ducts

- Maximum recommended duct slope = 58 degrees (used at Cascades Island)
- Recommended duct slope = 45 degrees
- Recommended mean flow velocity is 7.9 – 11.8 ft/s (Zobott et al. 2015).
    - Table 3-1 below shows flow normal depths and velocities for two flow scenarios at design Manning's n (0.009).

Table 3-1. Climbing Duct Hydraulic Data, Design n = 0.009

Duct Width	Flow	Normal Depth	Flow Velocity	Duct Slope (ft/ft)
20 in	0.14 ft^3/s (62 gpm)	0.13 in	7.9 ft/s	1.0 (45°)
20 in	0.28 ft^3/s (124 gpm)	0.19 in	10.4 ft/s	1.0 (45°)

3.3.1.5 Travelling or Traversing Ducts

- Can be rectangular or round.
- Minimum depth = 2 inches
- Minimum Velocity = 0.5 ft/s
- Optimum Velocity = 1 ft/s
- Maximum velocity = 1.6 ft/s

3.3.1.6 Hybrid Flumes

- Recommended flume width = 16.3 inches
- Recommended half round height = 6 3/8 inches
- Recommended crest spacing = 40 inches

- Minimum recommended flow = 62 gpm

3.3.1.7 Rest Boxes (or Rest Areas)

- Minimum recommended volume of each rest box is 11.4 ft³.
- Minimum recommended depth in a rest area is 4 inches.
- Minimum recommended length of each rest area including traversing duct is 20 ft.

3.3.1.8 Upwelling Boxes

- Water supply to upwelling boxes need to exceed the sum of flows to LPS (minimum 62 gpm and Exit flume (10 -15 gpm) by at least 20%.
- Upwelling boxes require redundant pumps for water supply.
- Upwelling boxes require measurement of flow to going to LPS
- Upwelling boxes drainage control & measurement

3.3.1.9 LPS Exit Flumes

- Exit flume can be round (8-inch typical) or rectangular.
- Recommended exit discharge is 10-15 gpm (0.022 - 0.033 cfs).
- Exit flume surface must prevent lamprey attachment that may allow them to climb
- Exit flume slope can vary between 25 – 45 degrees
- Most of water used to move the lamprey out to the flume is typically dewater going down the flume but surface must remain wet to assure lamprey are sliding

3.3.1.10 LPS Drainage

- Drainage must be adjustable by means of either valve or adjustable weir.

3.3.2 East Fish Ladder Exit Section Weir Modifications

- Maximum bottom plate thickness = 3/8 inch (if Option 1 applied
    - Upstream and downstream edges shall be tapered at a rate of no less than 2 horizontal to 1 vertical.
    - Radius sides and top of new orifice opening
- Maximum Ramp angle = 45 degrees (if Option 2 applied)
- Minimum radius = 4 inches (if Option 3 applied)

3.4 DESIGN METHODS

Normal one-dimensional calculations will be prepared in development of design features, operations, and PDT support.

3.5 DESIGN FEATURES

The proposed design of the primary hydraulic design features are described in the section. The primary features include the LPS water supply pipe system, the LPS climbing duct and traversing flume systems, and modifications of the East Fish Ladder Exit Section Weirs.

3.5.1 LPS Water Supply

The estimated design flow rate for a 20-inch LPS is 160 gpm (0.36 cfs). The current design at the Dalles has two 20-inch flumes to be installed on side of the Junction Pool. (The Junction Pool is located between the East Entrance and the base of the lower ladder weirs.) This gives a total width of 40-inch for both flumes with a total flow requirement of 320 gpm (0.71 cfs). There is ample flow supply to both allow for flow adjustment and provide for the collection box lamprey holding requirement (20 gpm).

3.5.2 Water Supply Pipe and Valves

The new LPS water supply pipe will wye off from the 12-inch filling pipe for the East Fish Ladder AWS Backup System. This pipe is located in the sublevel valve room within the concrete dam structure and beneath the upper fish ladder. From there, the pipe will run adjacent to the existing 6-inch irrigation supply pipe and vertically rise out through an existing hatch outside the valve room and dam structure. The LPS supply pipe will then be routed through the existing (and obsolete) fish elevator conveyance channel and ultimately routed the collection box and flumes on the east side of the Junction Pool.

Since the 12-inch AWS Backup filling pipe is supplied from the forebay (Minimum 155 ft, maximum 160 ft), the total head is 39 - 44 feet at over the range of forebay pool (forebay minus the collection box water surface elevation (116 ft).

Aside from a number of branches dedicated to the filling and drainage of different segments of the AWS backup system penstock, there is a 6-inch irrigation pipe that branches off the same 12-inch fill pipe.

While the size of the upstream isolation valve should match the proposed 4-inch PVC pipe size, the size of the downstream control valve should be downsized to 3-inches to assure the valve is operated between 20 - 70º for more accurate and adjustable flow controllability.

Summary Design Bullets:

- Design flow rate:

  - LPS + Collection Box: 320 gpm = 0.71 cfs

- Upstream Head:
  - Forebay Elevation: 155 - 160 feet, NGVD 29
  - Total Reliable Upstream Head: 155 feet, NGVD 29

- Downstream Elevation
  - 185 Tailrace Deck: 111 feet, NGVD 29
  - Height of Collection Box: 5 feet
  - Downstream Collection Box Elevation: 116 feet, NGVD 29
- Available operating head: 39 feet

- Pipeline:
  - Pipe length ≈ 405 feet
  - Sum of minor loss coefficients: 4.78
  - Pipe Diameter = 4-inches

- Valves
  - Upstream isolation 4-inch gate, ball, or butterfly valve
  - Downstream control 3-inch butterfly, ball, or globe valve

An isometric view of the LPS supply pipeline is shown in MP-501 on the plan drawings.

The computations for LPS flow requirements, pipe sizing and valve sizing for effective controllability were jointly prepared by Mechanical and Hydraulic Design and is provided in Appendix B, Item B-1.

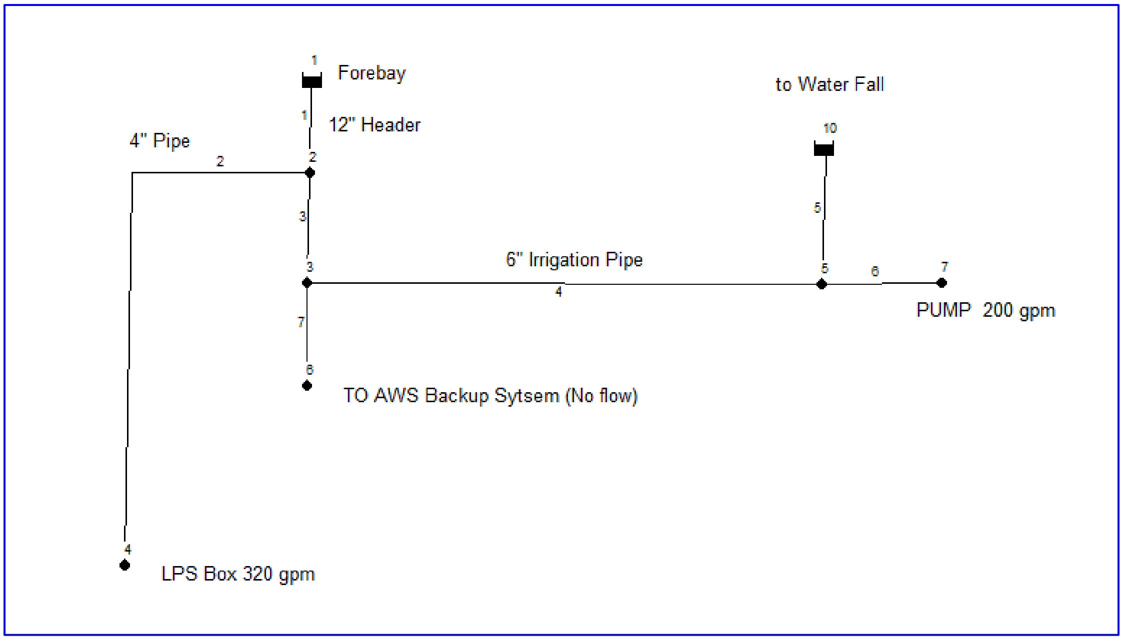
3.5.2.1 Interference from Other Water Supply Uses

The LPS water supply will be disrupted whenever there a filling operation of the AWS Backup System (ASWBS) Penstock. However, the AWSBS filling operations lasts less than an hour and has only occurred during winter or early spring months, outside of Lamprey passage season. It is possible that future AWS Backup System filling operations will occur during Lamprey season and should be coordinated with the Lamprey trap operators, so they can collect fish prior to the disruption. Given the low LPS flow (0.71 cfs), continued operation of the LPS supply system does not interfere with the much larger volumes of flow involved in the AWS backup System filling operations.

Another competing water usage (that is connected to the same 12-inch filling pipe) is the irrigation system supplied by an existing 6-inch pipe. Irrigation water is piped approximately 1500 feet to a pump-assist sprinkler irrigation system for the park located near the administration buildings. The 200-gpm pump receives the water from downstream end of the 6-inch pipe and boosts the pressure for the park's sprinkler system. An additional 0.4 – 0.5 cfs is diverted to a water fall upstream of the wye to the pump.

The irrigation and LPS systems will be operating simultaneously during the summer months. To assure no impact to the operation of the irrigation system, the simultaneous operation of the LPS should not prevent a positive the pump feed pressure or cause it drop below the Net Positive Suction Head. Likewise, the operation of the irrigation system should not impact the LPS supply flow.

Figure 3-12. Plan EPANet Schematic of LPS and Irrigation Supply Pipe Systems



According to the EPANet pipe network model, the LPS system flow requirements have near non-detectable effects on the irrigation system and vice versa. The EPANet results are provided in Appendix B, Item B-2.

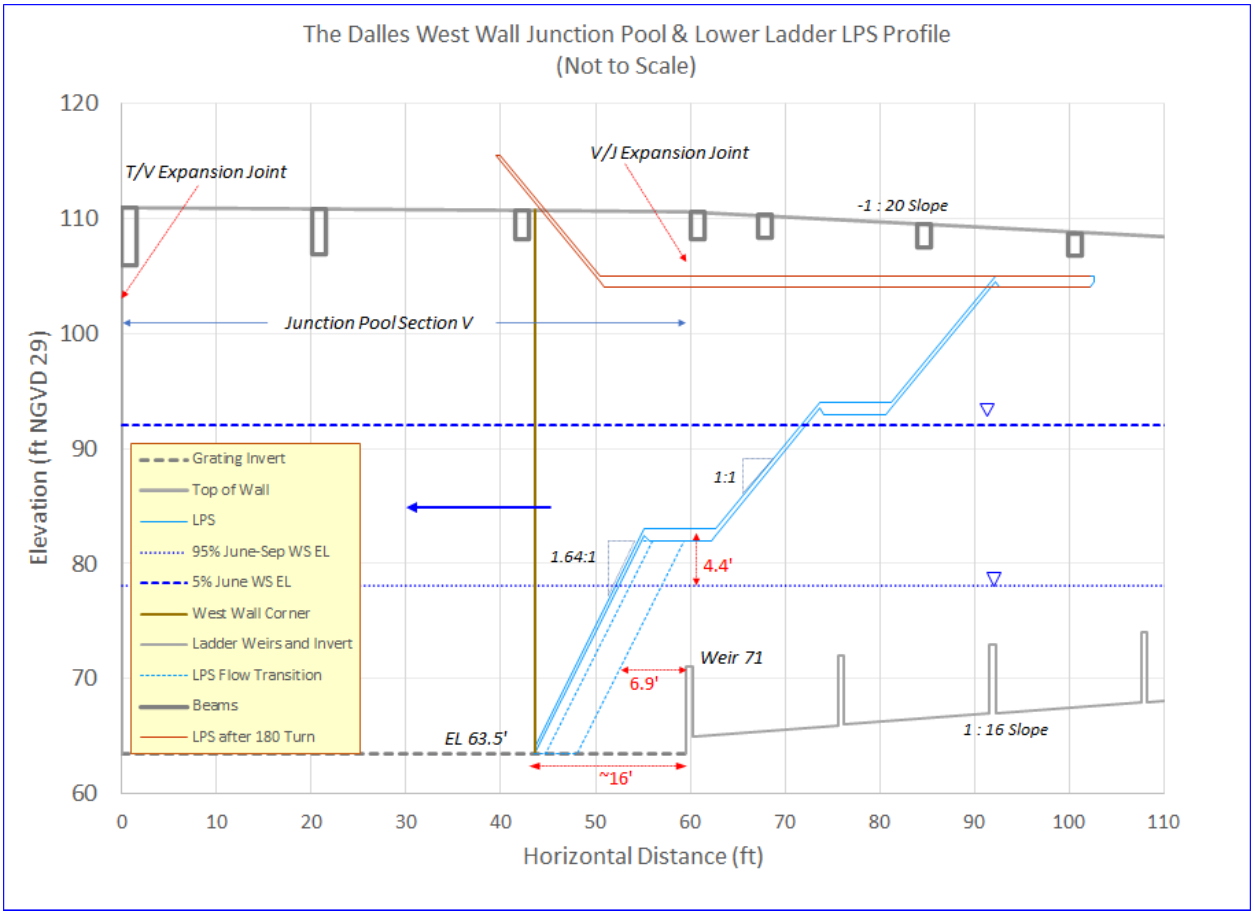
3.5.3 LPS Flumes

Two LPS flumes will rise out of the flow and run up both sidewalls in the upstream half of the junction pool of The Dalles East Fish Ladder, ultimately to the collection box on the east side of the pool. A schematic plan view of the lower portion of the LPS alignment is shown in Figure 3-13. The blue rectangles represent the steep climbing ducts and the level white rectangles represent the level traversing flume sections. The greens arrows indicate the direction of view for the subsequent elevation views of the LPS alignments.

The west wall junction pool and lower ladder LPS vertical alignment is shown in Figure 3-14. The more extreme slope of 1.64 to 1 is taken higher than the standard 11 feet rise (or 1 to 1 slope), but only 4.4 feet above the 95% exceedance water level for the Lamprey season in the ladder. A similar (albeit with double height) design was used at Cascades Island at Bonneville Dam. (Note: Station 0 in the elevation views are located at the T/V joint in the plan view, Figure 3-13.)

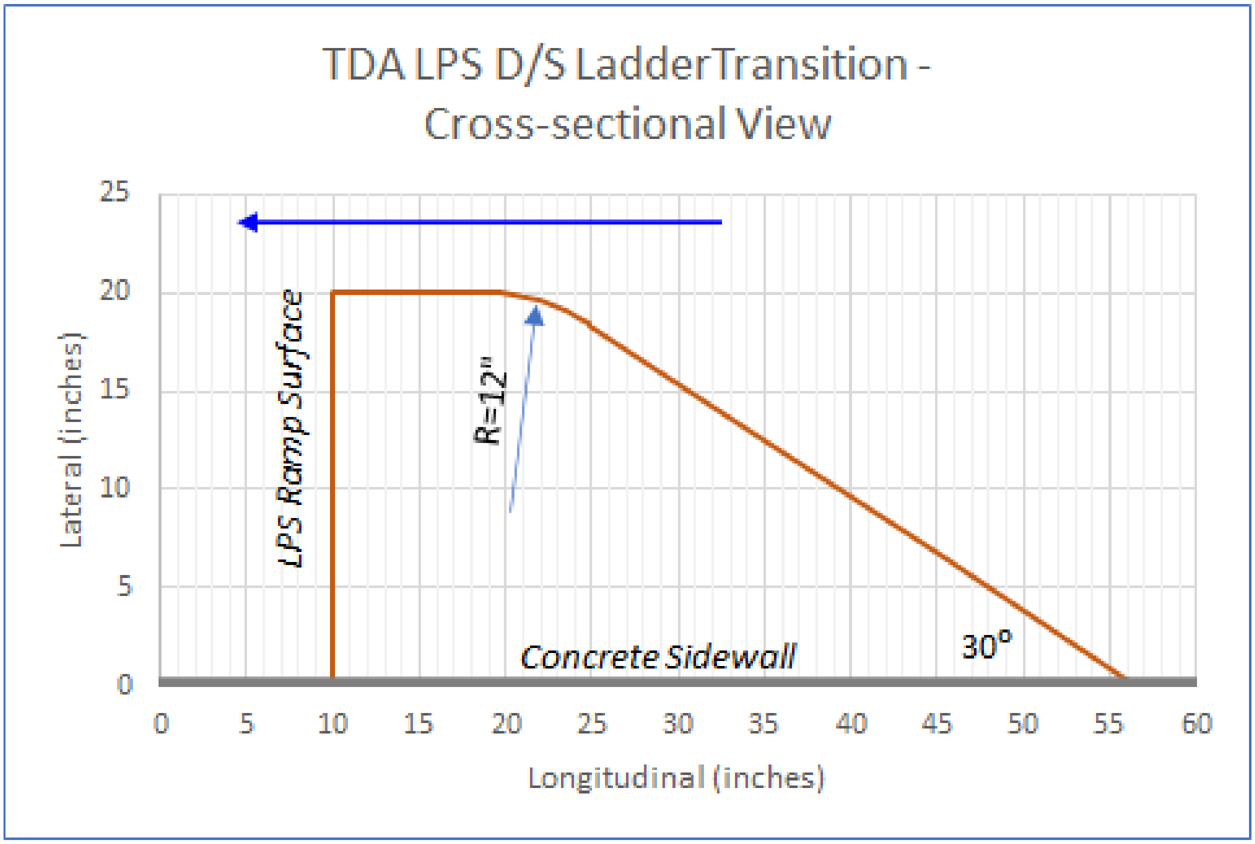
Figure 3-13. The Dalles Junction Pool Plan View and Lower LPS Alignments

Figure 3-14. The Dalles West Wall Junction Pool & Lower Ladder LPS Profile



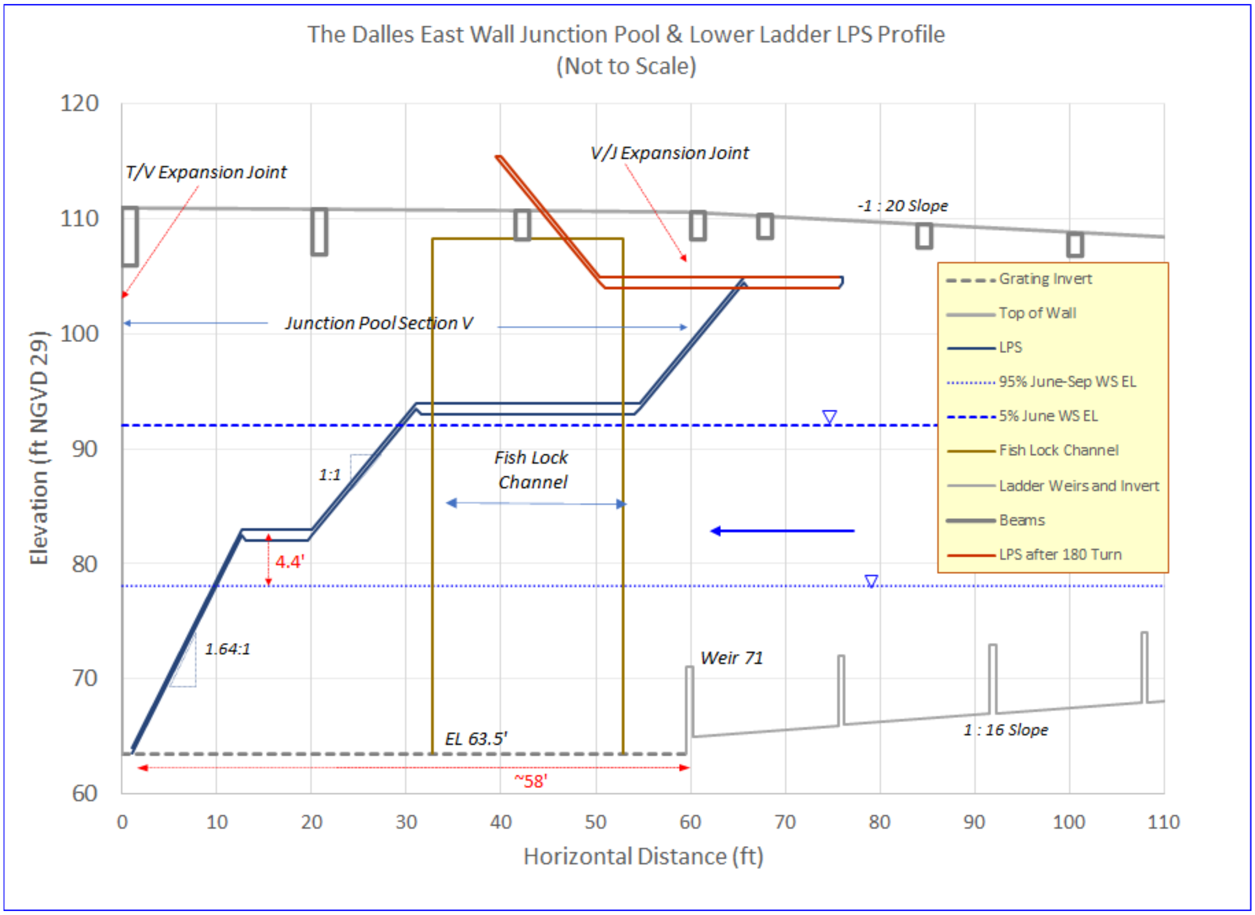
The proximity of the west-wall LPS to weir 71 necessitates a flow deflection transition on the upstream side of the LPS to minimize the flow disruption in the vicinity of the weir crest (see Figure 3-15 for proposed plan view of deflector transition). Bonneville Second Powerhouse Adult Fish Facility (AFF) used a similar approach with a closer proximity (~ 3.4 feet) to the crest of the bottom weir in the ladder exiting the AFF laboratory.

Figure 3-15. The Dalles Flow Deflection Transition for West Wall LPS



The east wall junction pool and lower ladder LPS vertical alignment is shown in Figure 3-16. It differs from the well wall LPS by starting midway through the junction pool. This allows for the traversing duct to span across the fish lock channel. This change was necessary to assure climbing ducts could be reliably attached to concrete walls as the hydraulic forces acting on the climbing ramp are significantly higher than the traversing flumes. Since the structure is further downstream than the west wall LPS, a flow deflection transition is not necessary.

Figure 3-16. The Dalles East Wall Junction Pool & Lower Ladder LPS Profile



3.5.3.1 Drag Loads on LPS Climbing Ducts

The ambient fish ladder channel flow imparts drag loads primarily on the climbing ducts. Assuming a high design channel velocity of 4.5 ft/s, drag load (Fd) is determined to be 66 lbs per foot of vertical LPS height, as shown in following equation:

$$Fd = \frac{\rho}{2} \cdot CD \cdot Ap \cdot V^2$$

Where:

Fd = Drag Load in lbs/ft

ρ = Water density = 1.94 slugs/ft^3

CD = Drag Coefficient = 2
(Ref: Engineering Fluid Mechanics, Roberson, Crowe, 1975)

Ap = Area projected into flow = 1.67 ft^2/per vertical foot of LPS duct

V = Maximum Velocity in Ladder Channel = 4.5 ft/s

Fd = 66 lbs per foot of vertical height in LPS duct.

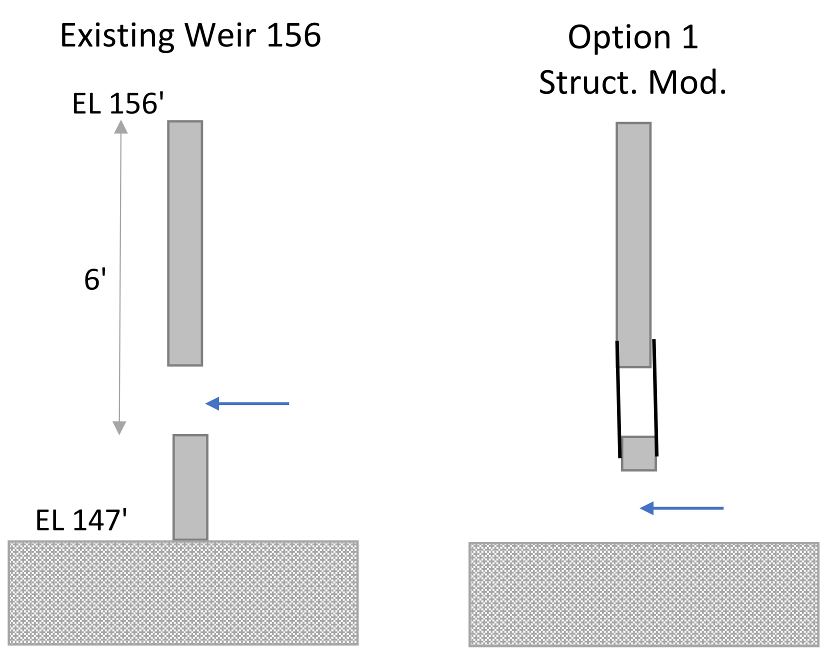
3.5.4 East Fish Ladder Exit Section Weir Modifications

In coordination with the fishery agencies (FDRWG), Option 1 (new orifice flush with invert) was the most preferred of the options shown in Figure 3-11. If it is determined that Option 1 is too costly or infeasible in terms of schedule, then the agencies preferred Option 2 (added ramps) or Option 3 (narrower radiused add-ons). These considerations factor in maximizing benefits to Lamprey passage and minimizing impacts to salmon passage.

Other alternatives discussed involved adding a 1.5-inch Lamprey orifice at the bottom of the drop-in-weirs. One option was to simply add a 1.5-inch blockage in the floor, leaving openings the orifice locations. However as this raises the weir structures 1.5 inches, this would deprive water over the overflow weirs and unacceptably cause the weir crests to be at least 1.5-inches above the downstream pool surfaces. In response and trying to avoid reducing the flow over the overflow weirs, a suggestion to block the height the existing perched orifices by an equivalent 1.5 inches was deemed unacceptable by the agencies. Alternatively, cutting a new 1.5-inch without reducing the height of the perched orifices will again deprive flow over the overflow weirs, as the exit flow is controlled by the recorded ladder head at Weir 153, located just downstream of the Count Station.

Option 1 (Right figure, Figure 3-17) requires cutting out a new orifice opening to be flush with the invert. A new fabricated orifice cover would be inserted over the cut surfaces to assure similar hydraulics and fish friendly surfaces. The existing perched orifices would be covered with plating.

Figure 3-17. Elevation Schematics of Weir 156: Existing and Option 1



SECTION 4 - STRUCTURAL DESIGN

The Dalles Lamprey Passage work has structural features of which will be constructed using a combination of new and existing concrete, stainless steel, and carbon steel as described in the following paragraphs.

4.1 DESIGN REFERENCES

The structural design will conform to applicable Engineer Manuals (EM), Engineer Regulations (ER), Engineer Technical Letters, Technical Manuals, and Industry Codes.

- EM 1110-2-2000 - Standard Practice for Concrete.
- EM 1110-2-2104 - Strength Design for Reinforced Concrete Hydraulic Structures.
- ETL 1110-2-584 - Design of Hydraulic Steel Structures
- ER 1110-2-1806 - Earthquake Design and Analysis for Corps of Engineers Projects.
- American Association of State Highway and Transportation Officials AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS - 9th Edition
- American Concrete Institute (ACI 318-19) - Building Code Requirements Reinforced Concrete.
- American Institute of Steel Construction (AISC) – AISC 15th Edition
- American Welding Society, Structural Welding Codes, Current Editions.
- American Society of Civil Engineers (ASCE) 7-16 - Minimum Design Loads for Buildings and Other Structures.
- UFC 1-200-01 - DoD Building Code
- UFC 3-301-01 - Structural Engineering

4.2 ASSUMPTIONS

The following describes the design assumptions made:

- Structural elements for lamprey passage require rounded corners and flush surfaces to navigate the fish ladder.
- Lampreys tend to swim near the edges of a channel or river.
- Lamprey can swim at any elevation in the water column but tend stay lower in high flow areas.

4.3 DESIGN CRITERIA

The design criteria below contain references and material properties.

4.3.1 Materials

The material properties for the new and existing structures are described below.

Existing Concrete

F'c = 2,500 psi (AASHTO Manual for Bridge Evaluation, prior to 1959)

New Concrete

Structural Concrete: minimum F'c = 4,500 pounds per square inch (psi) at 28 days (ACI 318-19)
Precast Concrete: F'c = 5,000 psi at 28 days (ACI 318-19)

Grout

F'c = 5,000 psi at 7 days (ACI 318-19)

Structural Steel

Bars, plates, and angles: Fy = 50,000 psi (ASTM A572, Grade 50)
HSS Round: Fy = 46,000 psi (ASTM A500, Grade C)
HSS Rectangular: Fy = 50,000 psi (ASTM A500, Grade C)

Fasteners

High Strength Bolts, fu = 120,000 psi (ASTM Gr. A325)
Nuts (ASTM A563)
Washers (ASTM F436)

Rub Blocks

UHMW (ASTM D638, D790, D732)

4.4 DESIGN STANDARDS

This section describes the general building and design standards, as well as the design loads.

4.4.1 General

Concrete: Concrete, precast concrete, and prestressed concrete design will conform to EM 1110-2-2104 for hydraulic structures and ACI 318-19 for other structures. Concrete construction will also conform to EM 1110-2-2000.

Structural Steel and CRES: Designs for features made of these materials will conform to ETL 1110-2-584 for hydraulic steel structures and to AISC “Specifications for Structural Steel Buildings” for other structure features. All welding will conform to the American Welding Society Structural Welding Code, Current Edition, for the appropriate material. The vinyl paint system for the structural members on this project will be 5-E-Z.

Hydraulic Structures: For structural design, hydraulic structures are all permanent structures fully or partially submerged. Non-hydraulic structures include all temporary structures and features that are not submerged.

Lamprey Passage Structures: These structures consist of aluminum and will conform to the 2020 Aluminum Design Manual and will be designed by the mechanical engineer.

4.4.2 Design Loads

Risk Category and Importance Factors: All structures as part of this project are designed as Risk Category I. Importance factors are selected accordingly.

Dead loads: The structural system for all features will be designed and constructed to safely support all dead loads, permanent or temporary, including but not limited to self-weight, concrete, metal, and fixed equipment. Concrete weight is assumed to be 150 pounds per cubic foot (pcf). Steel weight is assumed to be 490 pcf (0.283 pcf) per AISC manual.

Wind: Wind loading is determined in accordance with ASCE 7-16, Chapters 26 to 30. The design wind speed is 115 MPH.

Snow: Snow loading is determined in accordance with ASCE 7-16, Chapter 7. Ground snow load is 24 PSF and structural engineers of Oregon requirements.

Ice: Ice loading is determined in accordance with ASCE 7-16, Chapter 10.

Hydrostatic/Hydrodynamic: Permanent structural features exposed to flow of the stream shall be designed to resist static and hydrodynamic forces due to river flows of a 100-year event.

Seismic: Seismic loads will be based on requirements of the International Building Code 2018 and ASCE 07-16 documents. These loads are based on the operational basis earthquake (OBE). The inertial dynamic force due to water is determined using Westergaard’s equation:

$$p = \frac{7}{8} * \gamma_w * a_c * \sqrt{Hy}$$

p = lateral pressure at a distance y below the pool surface

γ_w = unit weight of water

a_c = maximum acceleration of pier or lock wall (a fraction of gravitational acceleration, g)

H = pool depth to dam foundation
y = distance below the pool surface

Inertial forces due to the self-weight and gravity loads are generally insignificant when compared to the force due to water and don't need to be considered for this project.

Ground motions for this region are:

- Site Class B (assumed, dam built on rock)
- S_s = 0.45, S_1 = .207 (USGS Online Seismic Ground Motions)
- S_{DS} = 0.27, S_{D1} = 0.111 (USGS Online Seismic Ground Motions)

Silt: Silt loads are based on a 1" thick layer of silt which shall be assumed to be acting in all areas where silt can accumulate without the ability to drain. The unit weight of silt is 90 lb/ft^3.

4.5 NEW STRUCTURAL FEATURES

The Dalles Dam has four fish entrances: East, West, North, and South. The East and West entrance bays have a shorter span but have an additional, 3rd entrance bay. The North and South entrance bays have a longer span with only 2 entrance bays. The entrance bay at the North entrance closer to the Oregon side is not in use by project staff and will not require any work on this project.

The following list includes the new structural features for this project:

- Frame Slot Fillers (All entrances)
- Slot Filler Storage Rack (All entrances)
- Plate Slot Covers (All entrances)
- Vehicle Bollards for Collection Box (East entrance collection box)
- Minor Modifications to the serpentine section of the junction pool (East Entrance)

Frame Slot Filler:
Frame style slot fillers will be required at all fish entrances besides one bay at the North entrance (see above). There will be a total of 9 slots across the four entrances that require slot fillers. Each slot filler consists of 3 stacking pieces, for a total height of 39'. All three stacked pieces will be identical.

The frame slot fillers will fit into the most downstream slot in the fish entrance. This is considered the bulkhead slot. The slot fillers can be easily removed when the bulkheads are needed to stop flow into the channel. This is consistent all entrances. However, the guide slot dimensions at their respective entrances are different. The North and South have longer spans (15'-0") and a 11.25" slot width. The East and West have the shorter spans (8'-8") and a 10.25" slot width. Both have a slot depth of 3.5".

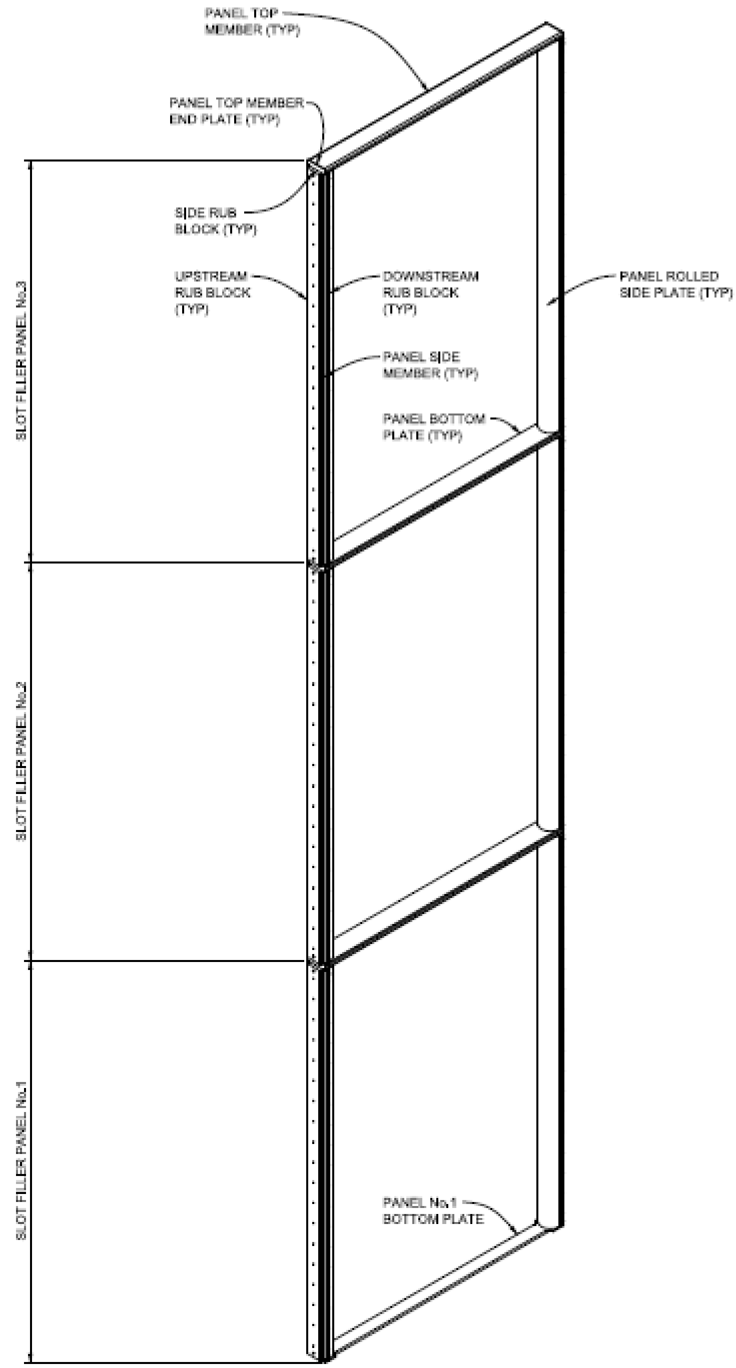
The frame consists of two 13’ HSS vertical members, one horizontal HSS member (15’ long (N/S) or 8’-8” long (E/W)), and a ½” thick bottom plate with 45-degree sloped edges to ease lamprey access into the ladder. HSS members for all frames and entrances will be 8x2x5/16”. HSS members are not available in all sizes and do not come in the ideal size for this work. So, a best fit was determined at for both slots at an 8x2x5/16” sized HSS member.

Each filler will have rub blocks on the US, DS, and out to out edges. The UHMW-PE rub blocks have been dimensioned to minimize the space between the slot filler and the guide slot. Lamprey are known to like small and dark areas, like a small gap. Tolerance for the frame and rub block have been designed to be 0.25” in all directions (US/DS and out to out).

This style slot filler does not affect the use of any of the other four slots and will utilize the existing lifting device used for the bulkheads that go in the same slot. The telescoping weir and any other features in the adjacent slots can operate without any issue from the slot filler. As noted previously, the slot fillers will occupy the bulkhead slot. The fillers must be removed to utilize the stop logs. Because of this, the slot fillers must be removed under flow via a lifting beam. The new slot fillers will utilize the existing lifting beams at the dalles fish entrances. The lifting beams automatically attach to 1.5” diameter steel pins on each slot filler.

Below shows the slot fillers to be used.

Figure 4-1. Frame style slot filler to be used for this project



A total of 3 slots will need frame fillers at the North and South entrances (wider span openings) and 6 total slots will need them at the East and West entrances (shorter span openings).

The slot fillers will be lifted and lowered into their respective slots with the existing Entrance Bulkhead automatic lifting beam. The slot fillers will utilize the same attached setup as the bulkheads. This will allow project staff to remove the slot fillers while there is still active flow in the channel. The lifting beam will attach to a 1.5” diameter steel rod, attached to each section of fillers. A penetration on the bottom plates of each filler is required to allow the lifting lugs space to live.

Slot Filler Storage Rack:
The purpose of the slot filler storage rack is to allow project staff to store the slot fillers when the entrance bulkheads are needed because they will live in the same slot. Each rack fits one set of three slot fillers. Therefore, the East/West will each need three storage racks while the North/South only required two racks due to only two bays. The larger racks will be 12’ tall x 15’-10/5” wide x 51.25” wide (3 racks total at the North/South entrances). The smaller racks will be 12’ tall x 9’-6.5” wide x 51.25” wide (6 racks total at the East/West entrances). Therefore, there will be a total of 9 racks, 3 the larger size and 6 the smaller size.

The racks will be constructed out of square HSS members and a bottom plate. The square HSS members will create a frame and the slot fillers will rest on the bottom plate. The rub surfaces of the rack will be lined with UHMW rub blocks in order to protect the paint system on the fillers.

The storage racks can be lifted and moved with or without the slot fillers. They are lifted by two 3/8” lifting lugs.

Plate Slot Covers:
The purpose of the plate slot covers is to ease lamprey access into the fishway by covering the 4 adjacent guide slots, upstream of the Slot Filler Frame slot (described above). At all entrances, there is a 3-slot telescoping weir that controls the flow and water level of the ladder. The weirs must stay in their slot for the fish ladders to function. Therefore, frame slot fillers (above) are not an option due to the weirs occupying the slots. Thus, a plate slot cover was determined to be our best option. There are several smaller entrances at The Dalles Dam that utilize a similar type design. One example is shown below:

Figure 4-2. Existing plate slot cover at The Dalles Dam

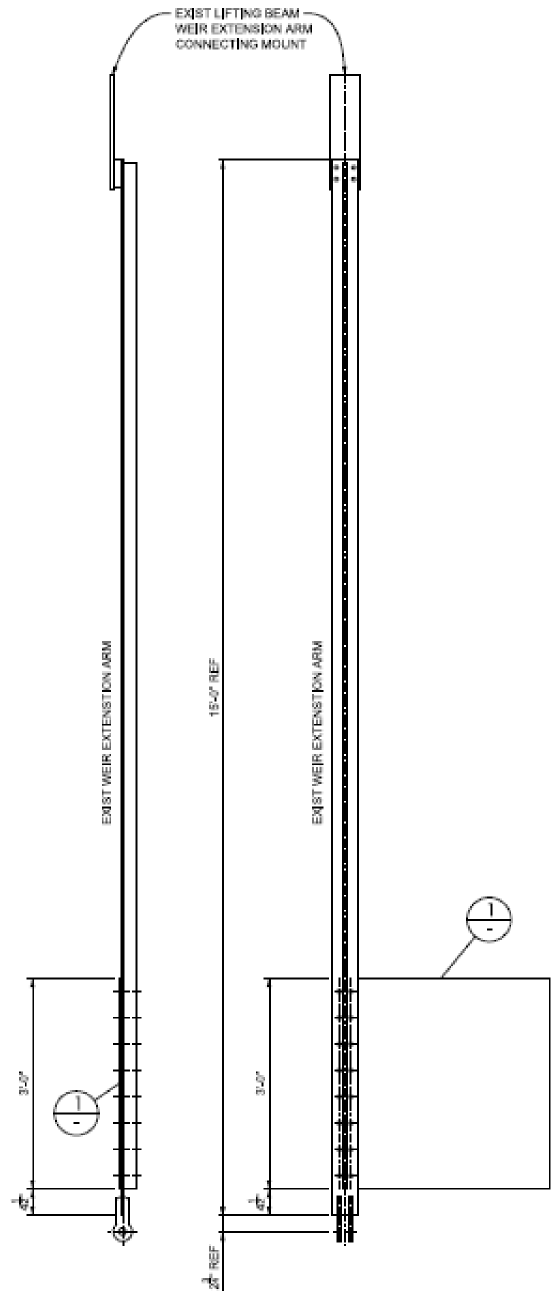
Ideally, the plate would span from the top of the weir to water level, roughly 15'. However, due to the lifting beam rating (20 kip) and older machinery equipment, this is deemed not possible. The machinery equipment at the North/South entrance is the same as the East/West entrance even though the North/South spans are roughly twice in length. The telescoping weirs at the North/South entrance weigh an estimated 15 kip (weight was not shown on plans), with two additional 15' tall steel plates it's not possible to do this style design. The fish biologists have determined the most lamprey friendly option is to use the tallest possible plate, 3' (given the machinery limitations), placed as close to the top of weir as possible.

The new plate slot cover will be attached to the existing lifting beam weir extension arms. The lifting beam has an extension arm within the guide slot that connects to the weir to control the weir elevation. The extension arms are 0.5" thick and appear to be in good condition at all entrances. The plate cover will bolt to the arms and extend upstream to cover the 3 adjacent slots (the extension arm covers up one of the four remaining slots).

With input from the hydraulic engineer, each slot cover plate has been designed for 2' of hydrostatic head. Though, the plates will not feel this full load (plate is not directly in flow path) it is the more conservative design.

The plate will be 3' tall, span the distance of the 4 slots (3'-2.1875" wide (North and South), 3'-1.1875" wide (East and West)), and 3/8" thick. Shown below:

Figure 4-3. The Dalles Dam, plate slot cover attached to lifting beam



There are 9 entrances, for a total of 18 plate slot covers. 6 plate slot covers will be required for the North and South at 3'-2.1875" wide. 12 plate slot covers will be required for the East and West at 3'-1.1875" wide. The other dimensions shall remain constant.

Vehicle Bollards:
For this work, a new lamprey collection box will be required for the East fish entrance.

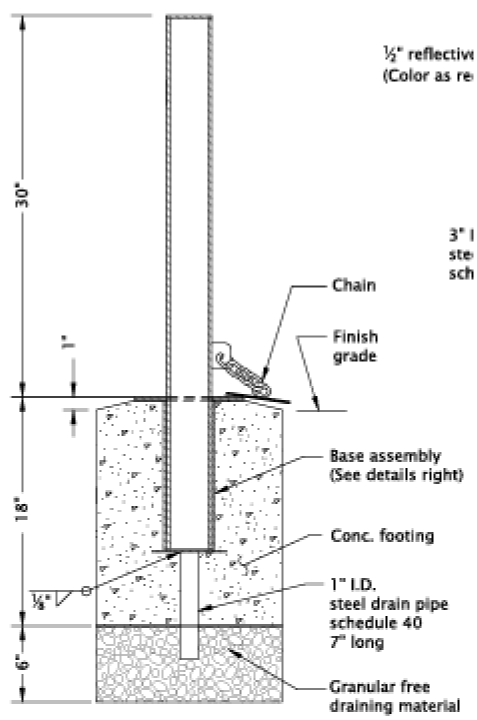
The lamprey trap box will only operate roughly 4 months of the year. Therefore, it is important that the project staff can move the box and bollards and place them storage during the lamprey off season. This region of the dam has a lot of frequent work/projects that require a lot of ground space.

Because this is such a high trafficked region, it is important to protect the collection box with vehicle bollards. These bollards will not be rated for high-speed crashes (35 mph) and will not follow the DoD anti-terrorism bollard standard (K-rated). High speed rated bollards are overdesigned for this work. The speed limit at the dam is 20 mph and it is tucked away in a corner of a parking lot. Full speed crashes are not likely in this region. The main purpose is a visual warning of the lamprey box location.

The bollards will be 30" tall and spaced 3' on center. Each bollard must be removeable. This will allow the bollards to be removed and replaced whenever the collection box is in use. This will allow the dam operations to function normally.

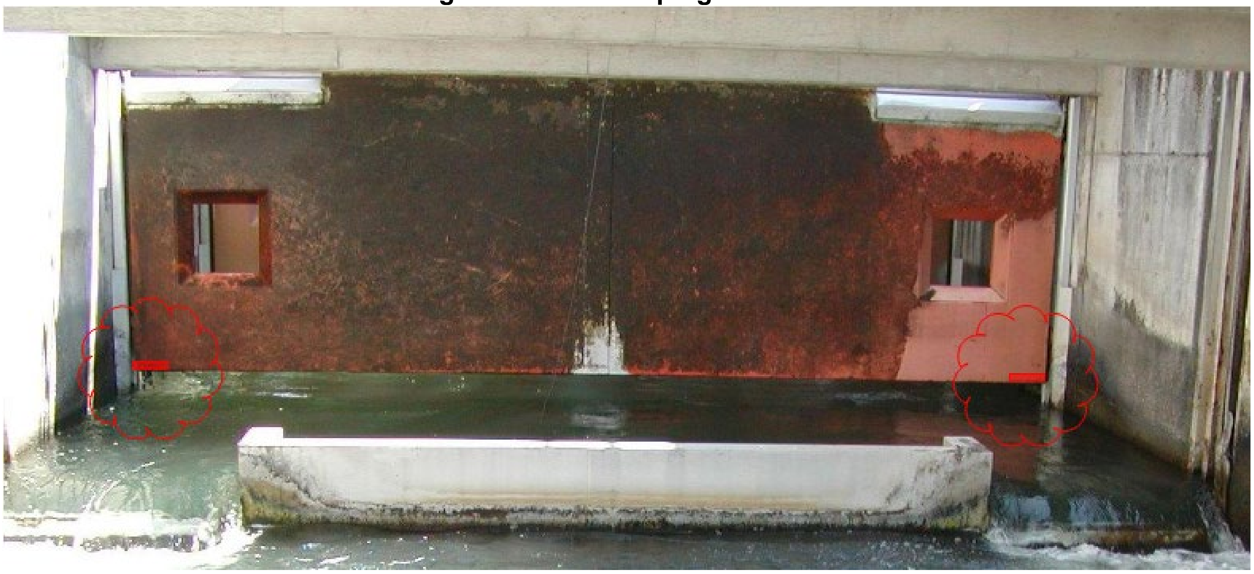
A snip it of a possible bollard detail is shown below:

Figure 4-4. Typical removable bollard, Oregon Standard Detail RD130



Minor Modifications to the fish entrances: There is one main minor mod with several other smaller mods. The main minor mod is to cut 1.5"x16" lamprey orifices in the corners of the telescoping entrance weirs. Lamprey can now pass the weirs without deviating from the channel floor. Several 3/8" thick, A36 plates will be attached to the bottom end of the cut weir. The weir mod is shown below:

Figure 4-5. Telescoping weir mod



The other modifications include rounded corners within the junction pool and ladder, lamprey rest boxes on the channel floor, lamprey orifices within the fish ladder, and roughen the floors and walls in high velocity areas.

However, these items will be designed and installed by The Dalles dam project staff, prior to the rest of the work in this DDR. The structural scope for these modifications is to check and ensure the work done by project staff and hydraulic design does not compromise the structural integrity of the control section. The drafting for this work will not be done by the Portland district.

4.6 REMOVAL OF STRUCTURAL FEATURES

This section describes the planned features to be removed. As it stands, no features require complete demolition. However, the minor modifications to the serpentine section will require grinding and minor concrete cutting for rounded corners and lamprey orifices.

4.7 DESIGN CALCULATIONS

Design calcs are provided in Appendix A. Calcs from the John Day North entrance and Bonneville Cascades Island entrance work will be used as a reference. Calcs will be done by hand, a model is not needed for this portion of work.

SECTION 5 - MECHANICAL DESIGN

5.1 GENERAL

5.1.1 Mechanical Scope

The mechanical scope for this project includes the following: design of flume components and a trap box for a lamprey passage system (LPS) in the junction pool entrance at El. 66.5 ft; and a water supply system for the LPS.

5.1.2 Design Requirements

The key requirements of the mechanical design as of the 60% milestone are summarized below.

- Geometry/Material: channel geometry and material properties should be limited as follows, per Technical Report 2015-5:
    - Channel slope < 60º
    - Surface roughness: The ratio of surface roughness to flow depth should result in a hydraulically smooth flow of 125 Ra.

- Biological constraints
    - The flume design must adhere to the biological requirements outlined in section 2.5.
    - The water supply must be screened according to the requirements outlined in section 2.5.2.

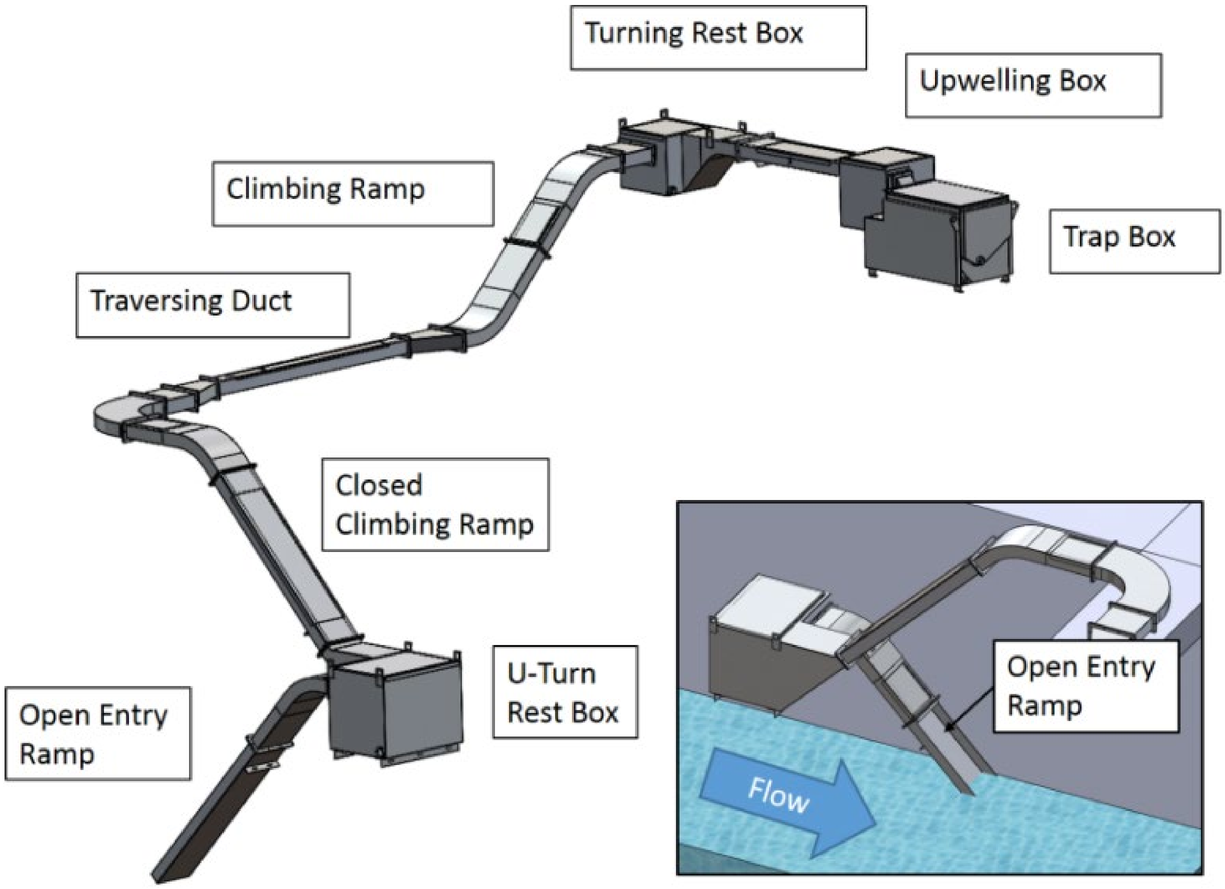
- Hydraulic constraints
    - The flume design must adhere to the hydraulic requirements outlined in section 3.5.3.
    - The water supply must be able to provide the design flow rate outlined in section 3.5.1.

5.2 LAMPREY PASSAGE SYSTEM

There are two concepts for a lamprey passage system. Both flume concepts will be constructed of 6061 or 5052 aluminum. The material will be selected in the 60% phase.

Figure 5-1 below shows a general diagram of a lamprey passage system as defined in Technical Report 2015-5.

Figure 5-1. LPS General Diagram



5.2.1 Cascade Island LPS

This concept replicates the mechanical features of the typical LPS systems used at USACE facilities. Mechanical features of this concept are as follows:

5.2.1.1 Entry Ramp

The entrance section extends to the fish ladder floor and is of open construction. Open construction allows lamprey to access the ramp at any elevation within the water column. Structural loading of the entrance is addressed in section 4.4.2.

This LPS would have two entry ramps in the junction pool. One entry ramp would be located at the east powerhouse fish entrance channel. The other entry ramp would be located on the opposite side of the junction pool at the fish transportation channel. The fish collection channel in the middle would require baffles or some other means of guiding lamprey to one of the two entry ramps.

5.2.1.2 Flumes

Flume segments are divided into climbing flumes, also called ramps, and traversing flumes, also called ducts. Climbing flumes are C-shaped with a flange and ring seal to connect sections. A lid is bolted to the top of the climbing section to allow access as needed. Climbing sections are a continuous section with no joints.

Traversing flume sections are also C-shaped and contain the features described above, except they may be constructed in segments.

5.2.1.3 Rest Boxes

Rest boxes are utilized after climbing segments and at intervals as described in section 3. These boxes provide a refuge for lamprey to recuperate after long or difficult travel segments. Each rest box will have a lid and drain to facilitate maintenance.

5.2.1.4 Upwelling Box

The upwelling box is located at the end of the flume. It is similar to a rest box but includes a connection to the water supply and the exit chute. The upwelling box connects to the water supply through a head box to provide even flow, adjustable flow, and measurable flow. The head box contains a water supply compartment, flume side compartment, and drain side compartment. An adjustable weir is used to control the drain side flow. A calibrated, notched weir on the flume side is used to indicate flow rates. The invert of the notch is to be at or slightly above the top if the incoming flume segment. The exit segment is elevated in relation to the incoming flume so that 10-20 gpm is flowing towards the exit. A screen separates the flume from the upwelling box to prevent lamprey passage outside of the flume. Screen criteria is defined in Section 2.

5.2.1.5 Exit Chute to Trap Box

The exit chute connects the upwelling box to the trap box and consumes 10 to 20 percent of the supply water. Water flowing through the exit chute is accelerated beyond the swimming ability of pacific lamprey. The chute is rectangular and employs bar screen to prevent lamprey attachment as they exit the flume.

5.2.2 Low Angle Weired Lamprey Passage System (LAW LPS)

This system incorporates low-angled weired flume sections to eliminate the need for rest boxes. The weired sections creates pools for resting while also eliminating bottlenecks and reducing maintenance requirements. Per Technical Report 2019-3, weired flume sections promote passage motivation, ease of passage, and reduces required passage time. Features of this concept are as follows:

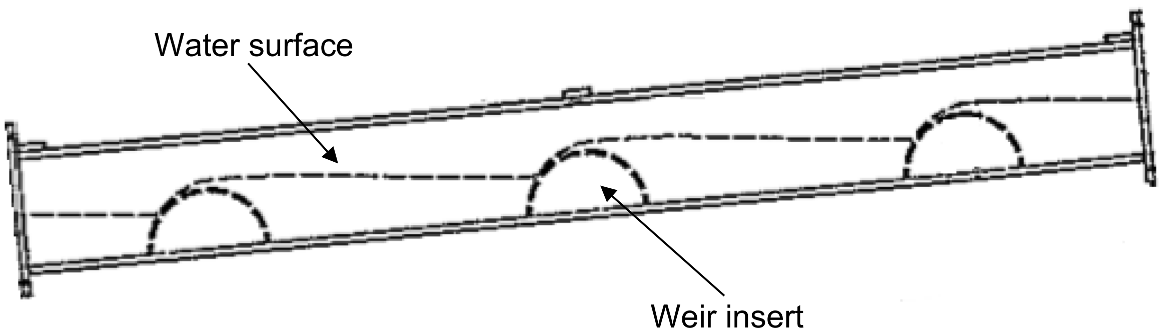
5.2.2.1 Entrance

The entrance section will be the same as in section 5.2.1.1.

5.2.2.2 Low angle weired flumes

Flume sections are C-shaped with a flange and ring seal to connect sections. A lid is bolted to the top of each section to allow access as needed. Each section is 10 feet long and includes three equally spaced weirs. The flume sections are constructed with a 10º angle from horizontal to create pools and facilitate climbing. Figure 5-2. Prototype Low Angle Weired Flume below shows a USACE developed prototype, also called a "hybrid flume", tested by the University of Idaho in 2018. The low angle weired flume would be of similar geometry.

Figure 5-2. Prototype Low Angle Weired Flume Section



The pools formed by the weirs may experience an increase in temperature due to heat transfer between the pools and the flume structure. This can be mitigated in several ways: shading the flume to reduce radiation heat transfer, coating the exterior of the flume in a material with low surface emissivity to reduce radiation heat transfer, adding a layer of material with low thermal conductivity to the flume, or by installing a simple heat exchanger to transfer heat from the flume into coolant water. The heat exchanger would use copper heat pipes to transfer heat from the flume structure into a water pipe beneath the flume containing flowing water diverted from the LPS supply. The simplest method would be to coat the top and sides of the flume to reduce radiation heat transfer.

5.2.2.3 Weirs

Weirs are constructed from half sections of 12-inch diameter aluminum piping. These sections can be bolted or welded into position.

Bolting the weirs allows for greater flexibility in weir spacing, weir replacement, and weir upgrades should a superior weir geometry be discovered. Bolted connections are more difficult to seal and may introduce corrosion risk if dissimilar materials are used.

Welding the weirs creates a permanent, sealed connection. The welded weirs would not be replaceable or adjustable and would require replacement of the flume section to adapt to changing conditions.

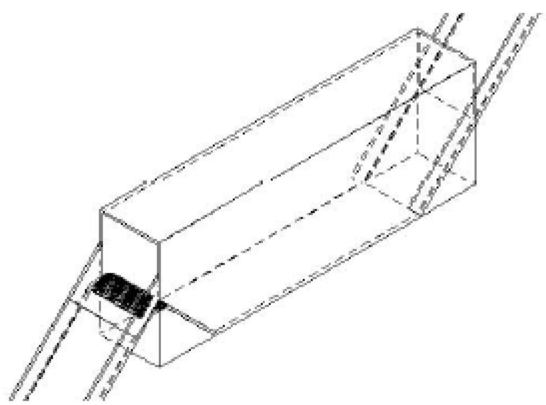
A bolted weir is recommended for this concept due to the superior flexibility of the design. Sealing may be accomplished with the use of a neoprene sheet between the weir and the flume or by placing O-rings at the bolted connection.

5.2.2.4 Broad Crested Weir Style Rest Box

A rest basin is located at the junction of the two-entry flume runs and would output to the upwelling box. Technical Report 2008-10 indicates that the type of rest box causes only minor changes in lamprey performance with the associated ramps being of greater influence. The basin proposed here is a broad-crested weir style rest box as shown in Figure 5-3. Broad-Crested Weir Style Rest Box below. This rest box is easier to maintain and fabricate than the rest box style used at Cascade Island and similar LPS structures.

This rest box is designed to be removed and replaced with a LAW LPS section to support future extension of the LPS system.

Figure 5-3. Broad-Crested Weir Style Rest Box



5.2.2.5 Upwelling Box

The upwelling box will be the same as in section 5.2.1.4.

5.2.2.6 Exit Chute to Trap Box

The exit chute will be the same as in section 5.2.1.5.

5.2.3 WATER SUPPLY SYSTEM

5.2.3.1 Gravity Feed

The recommended solution would divert the design flow required for the LPS from an auxiliary penstock which also feeds irrigation systems and auxiliary water system (AWS) valve priming. The flow rate of the gravity feed system will be designed to exceed the design flow rate and can be controlled by a valve adjacent to the tap off the penstock.

A gravity fed water supply system requires less maintenance than a pumped system but requires a greater level of monitoring. Water is supplied by the auxiliary penstock, meaning the LPS would be subject to the conditions of the irrigation system and AWS valve priming operations. Project Operations has determined these systems will not interfere with the water supply during lamprey passage season.

5.2.3.2 Pumped Supply

A pumped supply system would use two pumps whose combined flow would be capable of exceeding the design flow rate. The use of two pumps creates a redundancy in the system, allowing flow to continue to the LPS should one pump fail. This system would require more maintenance than the gravity feed system and is considered less reliable. Location of the pumped supply is less constrained than the gravity feed system as the pumps can be sized as needed to overcome friction losses.

The most likely location would be the water supply conduit that runs parallel to the junction pool. Location of the pumped supply will be determined during the 60% phase.

5.3 SELECTED DESIGN DESCRIPTION

The PDT has received approval to proceed with the gravity-fed system described in section 5.2.3.1.

5.3.1 Selected Components

To be completed in the final design package.

5.4 REFERENCES

M.L Keefer, W.R. Daigle, C.A. Peery, and M.L. Moser. 2008. Technical Report 2008-10, Adult Pacific Lamprey Bypass Structure Development: Tests in an Experimental Fishway.

S.A. Hanchett and C.C. Caudill. 2019. Technical Report 2019-3, Evaluating the Influence of Past Experience on Swimming Behavior and Passage Success in Adult Pacific Lamprey Using Experimental Flumes and Accelerometer Telemetry.

Zobott, H. A., C. C. Caudill, M. L. Keefer, R. Budwig, K. Frick, M. Moser, and S. Corbett. 2015. Technical Report 2015-5, Design Guidelines for Pacific Lamprey Structures

SECTION 6 - ELECTRICAL DESIGN

6.1 PURPOSE

This section serves as a discussion and presentation of the anticipated work for power and control systems in support of The Dalles Fish Accords Lamprey Project.

6.2 DESIGN STANDARDS

- UFC 3-501-01: Electrical Engineering, 2019
- NFPA 70: National Electric Code, 2020
- UFC 4-010-06: Cybersecurity of Facility-Related Control Systems 2017
- UFC 3-580-01: Telecommunications Interior Infrastructure Planning and Design 2016

6.3 DESIGN ASSUMPTIONS

New electrical upgrades were considered as part of the new lamprey collection system at the at the east fish ladder junction pool. The upgrades consisted of two options, gravity fed and pumped water. The gravity fed option would not require the installation of new power distribution. The pumped water option would require routing cable and conduit from an available distribution panel with enough available capacity to run the pumps. Any requirements for new power distribution would need to be verified with project staff. The assumptions for each of the alternatives are as follows.

The gravity fed system:

- A sensor would be installed to monitor water level in the lamprey integrated headbox.
- A signal will be sent to the fish facilities centralized HMI through the Fish SCADA system if the sensor indicates abnormal water levels below pre-determined set points. This would be complete once the Fish SCADA upgrades are implemented.
- Functionality of any indication, monitoring and control equipment would be determined by operations staff.

The pumped water system:

- All assumptions and requirements for the gravity fed option would also apply to the pumped water system.
- Two pumps would be run at the same time to provide redundancy.
- There would be an alarm system that would notify the control room if either pump were to lose power.

For either alternative the integrated headbox would need to be removed and reinstalled once a year. The water level sensor would need to have the capability of disconnecting and reconnecting to the Fish SCADA system. For this reason, it is recommended that a plug and cord system be utilized to connect integrated headbox to the Fish SCADA system and to disconnect when not in use.

It should also be noted that at this stage of project development the project staff is determining if they will be procuring and installing the electrical equipment. This is in addition to determining viable routing of the control circuit to the integrated headbox location from the East Entrance PLC Cabinet.

6.4 DESIGN CRITERIA

6.4.1 Code and Standards Requirements

All new electrical design will be performed in accordance with USACE standards, engineering manuals and regulations. In addition, all NFPA 70 requirements will be met.

6.4.2 Electrical Design Constructability

Electrical design for the new pumping or control systems should consider constructability and ease of installation when determining new cable and conduit routing. This is in addition the installation of any new electrical equipment.

6.5 DESIGN CONSTRAINTS

6.5.1 Load Center Capacity

If additional electrical loads are required, the new electrical system would need to be fed from a distribution panel with enough available capacity to provide adequate power to new equipment.

6.5.2 Cable and Conduit Routing

New cable and conduit routing from the East Entrance PLC Cabinet to new electrical installations must be capable of meeting voltage drop requirements. In addition, verification will be needed that there are no physical obstructions to any new buried cable and conduit runs.

6.6 SYSTEM LEVEL ALTERNATIVES AND RECOMMENDATIONS

6.6.1 Alternative 1 – Gravity Fed Water Supply

Design includes implementing a level or float switch in the integrated headbox. Water levels would be monitored through the sensor, and an alarm would notify the fish facilities through an HMI panel if certain low set points are met. A terminal panel would be installed near the integrated headbox location for local water level indication. A receptacle for the sensor plug would also be mounted near integrated headbox location.

The East Entrance PLC will be used to connect to Fish SCADA once the upgraded system is in place.

6.6.2 Alternative 2 – Pumped Water Supply

The pumped water supply alternative would include all components of the gravity fed option in addition to the following features. Design includes power delivery from a distribution panel to a new pump motor control panel in addition to the new pumps. Remote monitoring would require an I/O panel installation. Design would also provide the ability to operate the pumps locally. A distribution panel with enough capacity for the new pump motor loading would need to be located and verified for use by project staff.

6.7 DESIGN CALCULATIONS

6.7.1 Conduit Fill Calculations

If any new cable is run through existing conduit or if new conduit is installed conduit fill calculations will be required.

6.7.2 Voltage Drop Analysis

Voltage drop will be analyzed to ensure that there is less than 2% voltage drop across all inline feeders and less than 3% voltage drop at the branch circuit to each load.

6.7.3 Control and Indicating System Design

Design intent is to have monitoring and alarm ability for motor status of any required pumps and for any required sensors. Project staff verified that the existing East Entrance PLC can be used as a connection point for the integrated headbox to the upgraded Fish SCADA system.

6.8 DESIGN DECISIONS

The current design decisions assume that the gravity fed option will be implemented. Additional electrical design decisions will be provided when project staff has decided on cable routing and if project staff will perform the electrical installation.

6.9 DESIGN RECOMMENDATIONS

The current recommendations assume that the gravity fed option will be implemented. Additional electrical design recommendations will be provided when project staff has decided on cable routing and if project staff will perform the electrical installation.

SECTION 7 - ENVIRONMENTAL AND CULTURAL RESOURCES

Compliance with all applicable cultural resources laws and regulations will be required. Per Section 106 of the National Historic Preservation Act of 1966 (implementing regulations 36 CFR 800), any federal undertakings that may directly or indirectly effect historic properties will require consultation with the State Historic Preservation Officer (SHPO), tribes and Tribal Historic Preservation Officers (THPOs), and other interested parties, as appropriate. Additionally, any action involving ground disturbance could require an archaeology survey. Consultation with SHPO and any Tribes that ascribe cultural associations and significance within the Area of Potential Effects (APE) will be required.

The Dalles Dam is eligible for listing in the National Register of Historic Places. The north and east fish ladders and the south end fish channel are all identified in the nomination as contributing resources. Certain actions might meet “Attachment 6: Routine Activities…that do not require Section 106 consultation” in the Systemwide Programmatic Agreement for the Federal Columbia River Power System. If these requirements are met, no separate consultation will be needed, and the project will be documented in an Annual Report. Any alterations that will diminish the characteristics that qualify the property for listing, beyond those rehabilitation and replacement actions that meet the Secretary of the Interior's Standards, will likely be considered an adverse effect. If adverse effects cannot be feasibly avoided, appropriate mitigation measures will need to be determined in consultation with SHPO, tribes and THPOs, and other interested parties, captured in a Memorandum of Agreement (MOA), and then carried out by the Corps within the agreed upon timeframe and funded by the project.

SECTION 8 - OPERATIONS AND MAINTENANCE

8.1 SAFETY

All work should be completed following Hazardous Energy Control Program (HECP) protocols to ensure the health and safety of personnel. All necessary personal protective equipment (PPE) and safety pagers must be worn at all times while at The Dalles Dam. Safety meetings will be performed daily prior to working.

8.2 SECURITY

Security protocols should be followed while at The Dalles Dam. Doors should remain closed and locked when not in use. Only areas cleared for use should be accessed. Badges must be visible at all times while on project. When guest badges are needed, requests are be made through The Dalles personnel. All guest badges must be picked up and dropped off at the front gate daily.

8.3 DESIGN DECISIONS

The current plan is to have a gravity fed system supply water to the lamprey passage system, routing pipe through the abandoned fish lock channel. Scope of work also includes installing slot fillers at all fish ladder entrances. Project Staff will install notches on the four removable exit section weirs. The existing weirs have lead-based paint, so proper mitigation procedures will be implemented for this work. The weirs will be removed for this work to prevent loose pieces of lead paint from getting into the ladder system.

8.4 DESIGN RECOMMENDATIONS

In order to monitor LPS water levels remotely, a water level sensor will be installed in the collection tank. This will be tied into the fisheries SCADA system.

8.4.1 GENERAL

The east fish ladder at The Dalles is operated following Fish Passage Plan (FPP) guidelines. Any deviations from the FPP must be coordinated, in advance, through The Dalles staff.

8.4.2 MAINTENANCE

Winter maintenance is performed annually on the east fish ladder. Outage times vary but are typically 1-2 months long (depending on maintenance needs). The ability to perform LPS maintenance outside this window varies by component. Maintenance repairs are costly, and any modifications to the LPS should be performed using the simplest designs possible.

8.5 COMMISSIONING

Any LPS modifications should have low operation and maintenance (O&M) designs. Onsite personnel have numerous daily tasks, and as such the LPS should require minimal project oversight (both in and out of operation).

SECTION 9 - COST AND CONSTRUCTION

9.1 GENERAL

This section presents the cost estimate for the The Dalles FY19 Fish Accords Lamprey as presented in this DDR. The total project cost (design and construction) estimated at the 60% DDR/P&S phase is $4.2 million. The construction cost and design/managements costs are estimated to be $3.1 million and $1.1 million respectively. These values include a 33.75% contingency and an average 5.34% escalation. The construction contract is expected to take 12 months and on-site construction is anticipated to take up to 4 months.

9.2 CRITERIA

Engineer Regulation 1110-2-1302, Engineering and Design Civil Works Cost Engineering, provides policy, guidance, and procedures for cost engineering for all Civil Works projects in the USACE. For a project at this phase, the cost estimates are to include construction features, lands and damages, relocations, environmental compliance, mitigation, engineering and design, construction management, and contingencies. The cost estimating methods used are to establish reasonable costs to support a planning evaluation process. The design is at a preliminary level and the cost estimate is at a similar level.

9.3 BASIS OF THE COST ESTIMATE

The cost estimate is based on engineering calculations from the design team and data presented in the DDR. The estimate is calculated with the Micro Computer Cost Estimating System (MCACES) MII, using historical data, labor and equipment crews, quantities, production rates, and material prices. Prices are updated to February 2022 in MII and escalated to the midpoint of construction on the total project cost summary sheet.

9.4 COST ITEMS

The cost estimate includes costs for engineering for plans and specifications, construction costs, engineering during construction, construction management for supervision and administration, escalation costs, and contingency to account for unforeseen details at this level. Other possible costs are not shown separately, such as lands and damages, relocations, cultural resources, environmental mitigation, environmental compliance, and hazardous, toxic and radiological waste (HTRW) costs. These costs are either not applicable or integrally part of the construction costs and are included in the construction features. Escalation costs to account for inflation are applied according to Engineer Manual (EM) 1110-2-1304, Civil Work Construction Cost Index system.

9.5 COST AND SCHEDULE RISK

An abbreviated cost and schedule risk analysis will be completed to determine a risk-based contingency to add to the cost estimate. The following risks were identified based on past lamprey project risks and other fish ladder work.

- Project Management and Scope Growth: The Weir Exit Modification scope is not fully developed. The PDT will select one option and if weirs are to be replaced. This plays a significant and possible risk to the current cost estimate.
- Acquisition Strategy: The acquisition strategy has not been selected, and sole source selection is unlikely but would have critical impact on current cost estimate.
- Technical Design & Quantities: The Weir Exit Modification option is not selected, and the quantities have not been completely developed. This is a significate and possible risk to the current cost estimate.
- Cost Estimate Assumptions: The Weir Exit Modification option is not selected, and the current cost estimate is based on conversations with PDT, which does not have enough detail. Also, the metal pricing and fabrication are historical rates and do not include the installation price. At this time, it is assumed that The Dalles Project Office will procurement and install electrical, so is not reflected in the current cost estimate. These play a signification and possible risk to the current cost estimate.

9.6 ACQUISTION STRATEGY AND SUBCONTRACTING PLAN

The cost estimate assumes that competitive pricing will be obtained from the small business community. The work is not complicated so an invitation for bid (low bid) is more likely than a request for proposals (lowest price technically acceptable or best value).
The cost estimate assumes a structural contractor will act as the prime and the rest of the work will be subcontracted.

9.7 FUNCTIONAL COSTS

9.7.1 Planning Engineering and Design (30 Account)

Engineering and design costs are determined from the budgets for the expected design and engineering effort. These costs include engineering costs for design and development of a contract package (plans and specifications), Portland District review, contract advertisement, award activities, and engineering during construction. This effort is estimated to cost $730,000 for the plans and specifications phase.

9.7.2 Construction Management (31 Account)

Construction management costs are determined from the budget of the expected effort for supervision, administration, and quality assurance for the construction contract. This effort is estimated to cost $365,000.

9.7.3 Annual Operations and Maintenance

Annual operations and maintenance costs are not expected to change significantly.

9.8 SCHEDULE

The lamprey work will be constructed during the winter 2023/24 IWW period of December 2023 through February 2024. A potential schedule of work will be created to validate that the project can be completed within the IWW period. It is unlikely that this work will be split into multiple dewatering period; therefore, the contractor may need to work overtime to complete the work before the end of the IWW period.

9.9 SCOPE & CONSTRUCTION METHODS

Most of the work for this project must be accomplished during the three-month dewatering period. It is assumed that the contractor will procure all materials needed for the job prior to the start of construction. This includes all fabricated features of work that can be created off site prior to the install, including weir entrance frame slot fillers and guide slot plate covers; lamprey flume sections, rest boxes, and collection box; bollards, and new weir exits.

The main features of this project are the weir entrance modifications, lamprey passage structure, and weir exit modifications. Quantities were provided by the PDT and drawings. The frame slot filler estimate is based on the number of slots (9), total steel weight (43,500 lbs.) and number of days to complete the work (9), with four millwrights and one crane operator. The guide slot plate cover estimate is based on the number of covers (18), total steel weight (3,600 lbs.), the number of days to complete the work (3), with four millwrights and one crane operator. The lamprey passage structure estimate is based on the mechanical and structural contactor work. The LPS estimate is based on sub-features, water supply parts and mounts, square feet of aluminum, bollards, fabrication hours, and installation. The weir exit modification estimate is based on the DDR Option 1 and to fabricate four new weirs. The estimate was based on the estimated total steel weight (68,000 lbs.).

Electrical was not included in this estimate since it will be procured and installed by The Dalles project office.

9.10 OPERATIONS DURING CONSTRUCTION

LPS work is unlikely to cause any significant impacts to operations (unit outages, road or bridge closures, night work, etc.). Minor coordination will be required like any construction contract at the dams. Additional coordination may be required to facilitate required fish ladder maintenance that will occur at the same time as the contract work.

9.11 CONTRACTOR OPERATIONS

9.11.1 Concurrent Work on the The Dalles Fish Ladder

There is no other major construction anticipated for The Dalles east fish ladder during this period of work. Annual fish ladder maintenance will be required during construction.

Operations anticipates this work will take approximately 1 to 2 weeks and can happen simultaneously; however, there may be conflict between crane access during this period. The contractor will need to coordinate with operations to prevent work interruptions.

9.11.2 Contractor Work, Office, Staging, Parking

The fish ladder has adequate staging area in the vicinity of the work site. Coordination with project staff will be required during the plans and specifications phase to determine an acceptable staging area. Onsite construction will require parking for a crew of ten, a crane, a forklift, and about 1,000 SF of staging area to stage flume sections prior to installation.

9.11.3 Load Restrictions

Load limit restrictions on several bridges must be considered in any plan to deliver equipment and materials to the job site.

9.11.4 Environmental Controls

All federal, state, and local laws and regulations will be complied with concerning this work. Environmental controls should be minimal as no ground disturbing activities are anticipated.

9.11.5 Material Handling

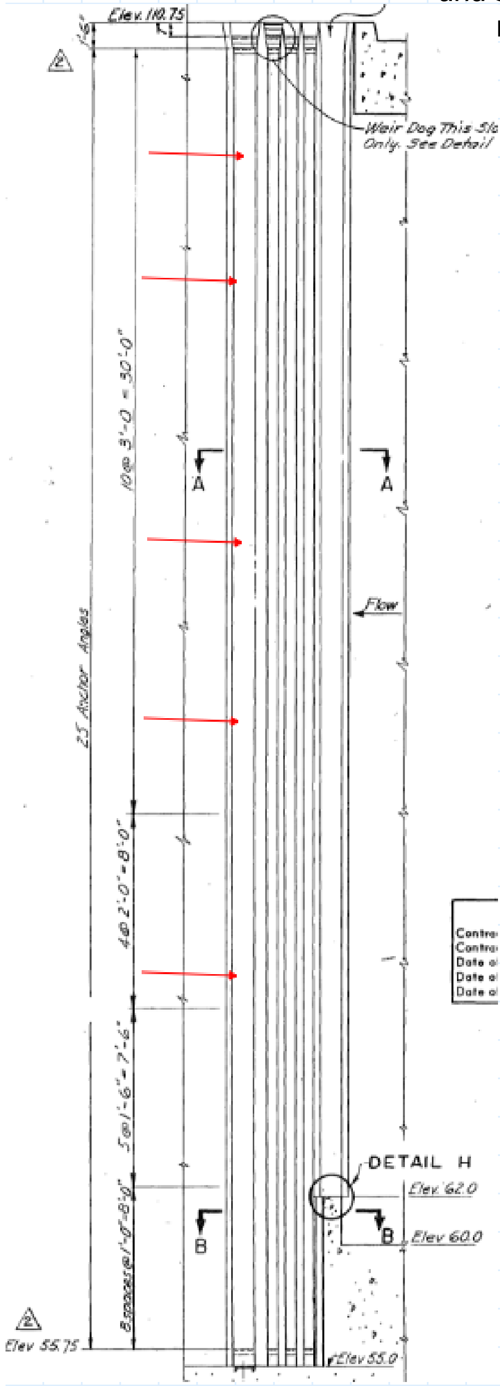
The contractor must provide their own crane for this work.

APPENDIX A - STRUCTURAL CALCS

Slot Filler Calcs

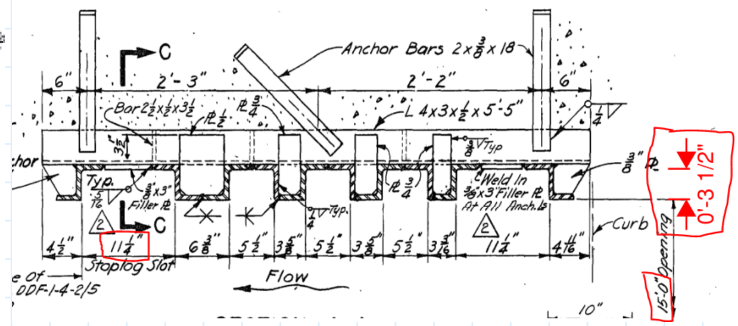
TDA DS Slot Fillers
Design Calcs

Goal: Fill the downstream slot with slot fillers to EL 94'.

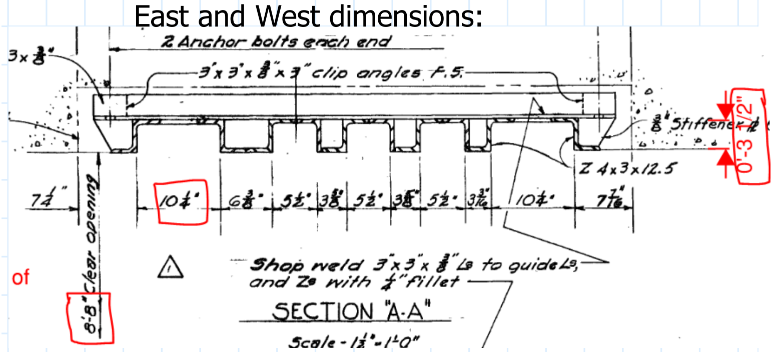


North/South and East/West have different slot width dimensions, and span distances, so the North/South will be designed in this rt due to the longer spans yet same members.

North and South dimensions:



East and West dimensions:



Constants:

$head := 2\ ft \qquad lbperft_{8x2x5.16} := 23.34\ \frac{lbf}{ft}$

Height of fillers: $H_{total} := 94\ ft - 55\ ft = 39\ ft$

Height of sections: $H_{section} := \frac{39\ ft}{3} = 13\ ft$

Thickness bottom plate: $t_{plate} := 0.75\ in$

Weight of steel: $w_{steel} := 490\ \frac{lbf}{ft^3}$

Weight of water: $w_{water} := 62.4\ \frac{lbf}{ft^3}$

Width of bottom plate: $width_{plate} := 8\ in$

North/South:

$Span_{N.S} := 15\ ft + 4\ in$

$slotwidth_{N.S} := 11.25\ in$

East/West:

$Span_{E.W} := 8\ ft + 8\ in$

$slotwidth_{E.W} := 10.25\ in$

TDA DS Slot Fillers
Design Calcs

Sizing HSS Members/Rub Blocks: all tolerances to be 0.25" each side.
Choose HSS 8x2x5/16 for all entrances (due to HSS sizing availability)

North/South entrances:
slot dimensions are 11.25" wide and 3.5" deep.

US/DS Rub Blocks: HDPE
Thickness: (11.25" - 8" - 0.25" - 0.25")/2 = 1.375 in
Width: 2" to prevent lamprey to get into slot

Out to Out Rub Blocks: HDPE
Thickness: (3.5" - 2" - 0.25") = 1.25 in
Width: 6" seems reasonable

East/West entrances:
slot dimensions are 10.25" wide and 3.5" deep.

US/DS Rub Blocks: HDPE
Thickness: (10.25" - 8" - 0.25" - 0.25")/2 = 0.875 in
Width: 2" to prevent lamprey to get into slot

Out to Out Rub Blocks: HDPE
Thickness: (3.5" - 2" - 0.25") = 1.25 in
Width: 6" seems reasonable

Controlling Section: All HSS members at all entrances will be 8x2x5/16" in the slots and 8x3x5/16" for the center stiffener. The North/South sections will control because the span distance is almost double.

Weight of Sections: (North and South Entrances)

$$Weight_{vertical} := 3 \cdot H_{section} \cdot lbperft_{8x2x5.16} = 910.26\ lbf$$

$$Weight_{horizontal} := Span_{N.S} \cdot lbperft_{8x2x5.16} = 357.88\ lbf$$

$$Weight_{bottomplate} := Span_{N.S} \cdot t_{plate} \cdot width_{plate} \cdot w_{steel} = 313.056\ lbf$$

Weight of Sections: (East and West Entrances)

$$Weight_{vertical.2} := 3 \cdot H_{section} \cdot lbperft_{8x2x5.16} = 910.26\ lbf$$

$$Weight_{horizontal.2} := Span_{E.W} \cdot lbperft_{8x2x5.16} = 202.28\ lbf$$

$$Weight_{bottomplate.2} := Span_{E.W} \cdot t_{plate} \cdot width_{plate} \cdot w_{steel} = 176.944\ lbf$$

Weight of controlling section (North and South) all three sections are the same weight) factored, with 5% misc weight for lifting lugs and rub blocks.

$$Weight_{controls} := 1.2 \cdot \left(Weight_{vertical} + Weight_{horizontal} + Weight_{bottomplate}\right) \cdot 1.05 = 1992.306\ lbf$$

$$Weight_{EastandWest} := 1.2 \cdot \left(Weight_{vertical.2} + Weight_{horizontal.2} + Weight_{bottomplate.2} \cdot 1.05\right) = 1557.998\ lbf$$

Load Factors: Not necessarily a lift gate but it is a lift slot filler. The closest example to the filler designed in this report.

Use the following Load Cases (ETL 1110-2-584 Table E-1)

	Load Combo	gD	gG	gHs	gHd	gQ	gEQ
Strength I	1	1.2	1.6	1.4	0	0	0
Strength I	2	1.2	1.6	1.4	1.6	0	0
Strength II	3	1.2	1.6	0	0	0	0
Extreme (open)	4	1.2	1.2	0	1	1.2	0
Extreme (closed)	5	1.2	1.2	1.2	0	0	1

Loading:
1. Max pool in slot. (hydrostatic, (weir is in its slot with max tailwater pool))
2. Lifting from Slot Gate Jammed (dead load + machinery)
3. Lifting from lay down, horizontal (dead load on lugs with perp loading (see below))
4. Uplift on bottom plate (hydrostatic)

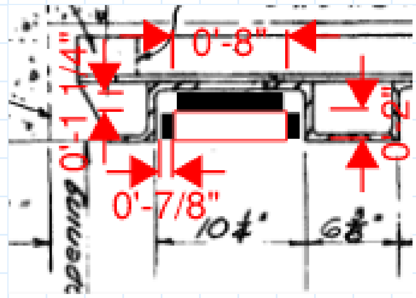
Check Hydrostatic loading: 2 feet of differential head, max pool filler in slot

Factored hydrostatic pressure:

$$q := head \cdot w_{water} \cdot 1.4 = 174.72 \ \frac{lbf}{ft^2}$$

Check Vertical Members:
HSS 8x2x5/16 in strong axis direction

$H_{section} = 13 \ ft$



Distributed load:

$$w_{vertical} := q \cdot 2 \ in = 29.12 \ \frac{lbf}{ft}$$

Treat as simply supported beam with uniform distributed load:

$$V_{vertical} := \frac{H_{section} \cdot w_{vertical}}{2} = 0.189 \ kip$$

$$M_{vertical} := \frac{w_{vertical} \cdot H_{section}^{\ 2}}{8} = 0.615 \ kip \cdot ft$$

Check Bending/Shear/Deflection:

Bending, AISC F7 Rectangular HSS

$\phi := 0.9$
$F_y := 50 \ ksi$
$Z_x := 11.6 \ in^3$

Yielding: F7-1

$$\phi M_{n1} := F_y \cdot Z_x \cdot \phi = 43.5 \ kip \cdot ft$$

Flange Local Buckling:

$E := 29000 \ ksi$

Compact/Non compact/Slender:

Flanges HSS $b.over.t := 3.87$ $\lambda_p := 1.12 \cdot \sqrt{\frac{E}{F_y}} = 26.973$ $\lambda_r := 1.4 \cdot \sqrt{\frac{E}{F_y}} = 33.716$

b.over.t is less than λ_r and λ_p therefor the flanges are compact

Therefor, flange local buckling does not apply.

Web Local Buckling:

Compact/Non compact/Slender:

Walls HSS $b.over.t := 3.87$ $\lambda_r := 1.4 \cdot \sqrt{\frac{E}{F_y}} = 33.716$

b.over.t is less than λ_r therefor the walls are compact

Therefor, web local buckling does not apply.

Lateral-Torsional Buckling: $r_y := 0.802\ in$ $A_g := 5.26\ in^2$

$L_b := 13\ ft$ $J := 10.9\ in^4$ $M_p := F_y \cdot Z_x = 48.333\ kip \cdot ft$

$$L_p := 0.13 \cdot E \cdot r_y \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 3.289\ ft$$

Lb is greater than Lp use eq F7-13 $S_x := 8.43\ in^3$

$$L_r := 2 \cdot E \cdot r_y \cdot \left(\frac{\sqrt{J \cdot A_g}}{0.7 \cdot F_y \cdot S_x} \right) = 99.479\ ft$$

Lb is less than Lr, use F7-11 $C_b := 1$

$$\phi M_{n2} := \phi \cdot E \cdot C_b \cdot \left(\frac{\sqrt{J \cdot A_g}}{\frac{L_b}{r_y}} \right) = 84.667\ kip \cdot ft \quad < \ \phi M_{n1}$$

Check ϕM_{n1} and actual moment:

$$\phi M_{n1} > M_{vertical} = 1$$

Check Shear: AISC G4 $k_v := 5.34$ $A_w := 2 \cdot 8\ in \cdot \frac{5}{16}\ in = 5\ in^2$

Cv2: $h.over.t_w := 24.5 \ < \ 1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 61.218$ therefor: $C_{v2} := 1$

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 135\ kip$$

Check: ϕV_n >Vvertical

$$\phi V_n > V_{vertical} = 1$$

$$I_x := 38.2\ in^4$$

Deflection: L/240

$$\Delta_{actual} := \left(\frac{5 \cdot w_{vertical} \cdot H_{section}^{\ 4}}{384 \cdot E \cdot I_x} \right) = 0.017\ in$$

$$\Delta_{max} := \frac{H_{section}}{240} = 0.65\ in$$

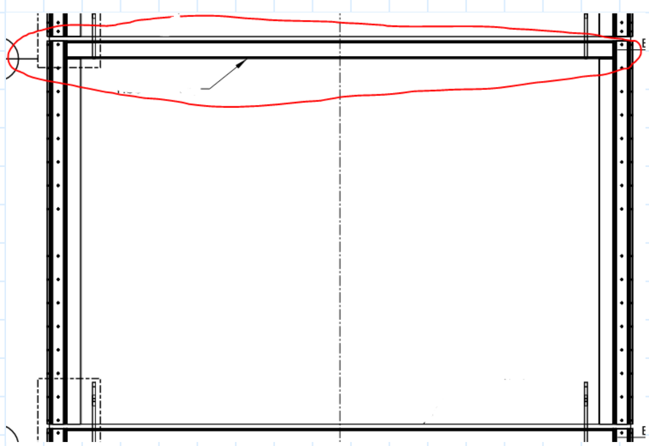
$$\Delta_{max} > \Delta_{actual} = 1$$

Check Top Horizontal Members for hydraulic loading:
HSS 8x2x5/16 in strong axis direction. The only difference between this and vertical members is the span distance. Both are loaded in the strong axis orientation

$$Span_{N.S} = 15.333\ ft$$

Distributed load:

$$w_{vertical} := q \cdot 2\ in = 29.12\ \frac{lbf}{ft}$$



Treat as simply supported beam with uniform distributed load:

$$V_{vertical} := \frac{Span_{N.S} \cdot w_{vertical}}{2} = 0.223\ kip$$

$$M_{vertical} := \frac{w_{vertical} \cdot Span_{N.S}^{\ 2}}{8} = 0.856\ kip \cdot ft$$

Check Bending/Shear/Deflection:

Bending, AISC F7 Rectangular HSS

$\phi := 0.9$

$F_y := 50\ ksi$

$Z_x := 11.6\ in^3$

Yielding: F7-1

$$\phi M_{n1} := F_y \cdot Z_x \cdot \phi = 43.5\ kip \cdot ft$$

Flange Local Buckling:

$E := 29000\ ksi$

Compact/Non compact/Slender:

Flanges HSS $b.over.t := 3.87$ $\lambda_p := 1.12 \cdot \sqrt{\frac{E}{F_y}} = 26.973$ $\lambda_r := 1.4 \cdot \sqrt{\frac{E}{F_y}} = 33.716$

b.over.t is less than λ_r and λ_p therefor the flanges are compact

Therefor, flange local buckling does not apply.

Web Local Buckling:

Compact/Non compact/Slender:

Walls HSS $b.over.t := 3.87$ $\lambda_r := 1.4 \cdot \sqrt{\frac{E}{F_y}} = 33.716$

b.over.t is less than λ_r therefor the walls are compact

Therefor, web local buckling does not apply.

Lateral-Torsional Buckling:

$r_y := 0.802\ in$ $A_g := 5.26\ in^2$

$L_b := Span_{N.S} = 15.333\ ft$ $J := 10.9\ in^4$ $M_p := F_y \cdot Z_x = 48.333\ kip \cdot ft$

$$L_p := 0.13 \cdot E \cdot r_y \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 3.289\ ft$$

Lb is greater than Lp use eq F7-13

$S_x := 8.43\ in^3$

$$L_r := 2 \cdot E \cdot r_y \cdot \left(\frac{\sqrt{J \cdot A_g}}{0.7 \cdot F_y \cdot S_x} \right) = 99.479\ ft$$

Lb is less than Lr, use F7-11 $C_b := 1$

$$\phi M_{n2} := \phi \cdot E \cdot C_b \cdot \left(\frac{\sqrt{J \cdot A_g}}{\frac{L_b}{r_y}} \right) = 71.783\ kip \cdot ft \quad < \ \phi M_{n1}$$

Check ϕM_{n1} and actual moment:

$$\phi M_{n1} > M_{vertical} = 1$$

Check Shear: AISC G4 $k_v := 5.34$ $A_w := 2 \cdot 8\ in \cdot \frac{5}{16}\ in = 5\ in^2$

Cv2: $h.over.t_w := 24.5 < 1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 61.218$ therefor: $C_{v2} := 1$

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 135\ kip$$

Check: ϕV_n >Vvertical

$$\phi V_n > V_{vertical} = 1$$

$I_x := 38.2\ in^4$

Deflection: L/240

$$\Delta_{actual} := \left(\frac{5 \cdot w_{vertical} \cdot Span_{N.S}{}^4}{384 \cdot E \cdot I_x} \right) = 0.033\ in$$

$$\Delta_{max} := \frac{H_{section}}{240} = 0.65\ in$$

$$\Delta_{max} > \Delta_{actual} = 1$$

Check Horizontal Bottom Plate:
Orientated in strong axis direction, 8" wide and 7/8" thick, with tapered edges

Due to height of plate (7/8") and the orientation of loading (strong axis) the bottom plate does not need to be checked for the hydrostatic loading.

Check: Pulling out of slot/Gate Jammed: ASME BTH CHPT 3/AISC

This check will ensure the top member does not fail due to bending from lifting from the lugs. Assume all water will drain from the weir.

Check when top beam (HSS 8x2x5/16") of the controlling section when lifting out of water for minor axis bending and shear:

$$Weight_{controls} = 1.992\ kip \qquad weight_{water} := 0\ lb$$

assumed weir is slowly lifted so it drains

Determine additional load from friction due to hydrostatic loading in guide slot:

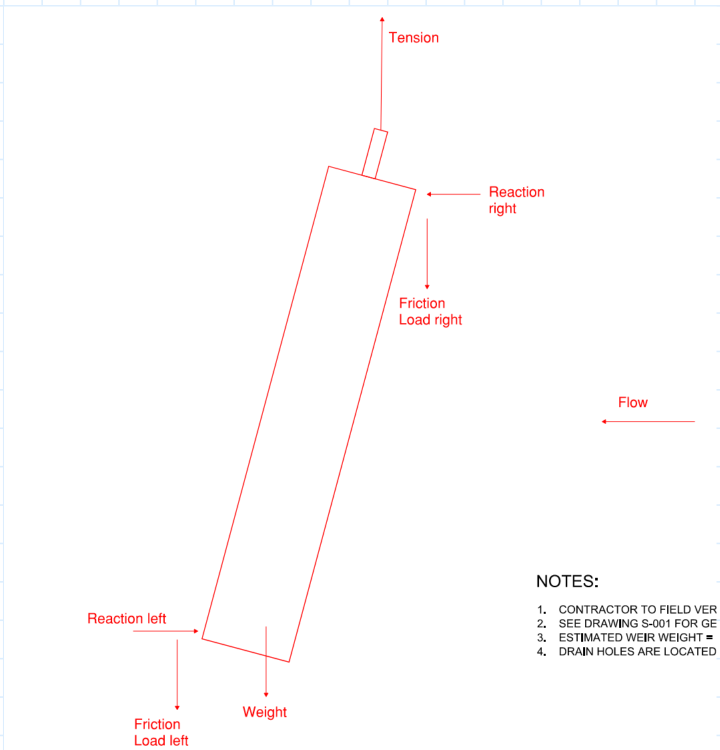
Determine the area on the slot filler in which the two feet of head acts upon.

$$Surface_{area} := \left(2 \cdot H_{section} \cdot 2\ in\right) + \left(Span_{N.S} \cdot 2\ in\right) + \left(Span_{N.S} \cdot t_{plate}\right) = 7.847\ ft^2$$

Force of flow:

$$F_{flow} := head \cdot Surface_{area} \cdot w_{water} = 0.979\ kip$$

FBD: Determine Tension force below:



Some of forces in X:

reaction right + flow = reaction left

Some of forces in Y:

Tension = weight + friction load.left + friction.right
Friction load: nu * normal force (reaction)

Coef of friction, UHMW to steel: nu = 0.14 (http://www.garlandmfg.com/pdf/Extrusions.pdf)

Tension = 2.004 kip + (reaction*0.14) + (reaction*0.14)

2.004 = x - 0.28y

Some of moments about right top corner:

(Tension*(8"/2)) + (Fflow*(2/3)*h = (weight*(8"/2)) + (reaction.left*h) + (friction load.left*8")

0.334*Tension + 9.52 kipft= 0.668 kipft + 13ft*reaction + 0.0933 ft*reaction

0.334 x = -8.852 + 13.0933 y

x = -26.5 + 39.2y

"Tension" (x) and "Reaction" (y) are unknown, solve for them: two eqs two unks

2.004 = x - 0.28y
x = -26.5 + 39.20y

x = 2.21
y = 0.732

Check some of forces in Y to make sure numbers are correct:
- Tension = weight + friction load.left + friction.right

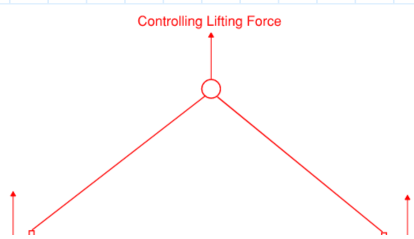
2.004 = 2.21 - 0.28(0.732) = 2.005 (left equal right > FBD is correct)
not exact due to rounding

$$Lifting_{force} := 2.21\ kip$$

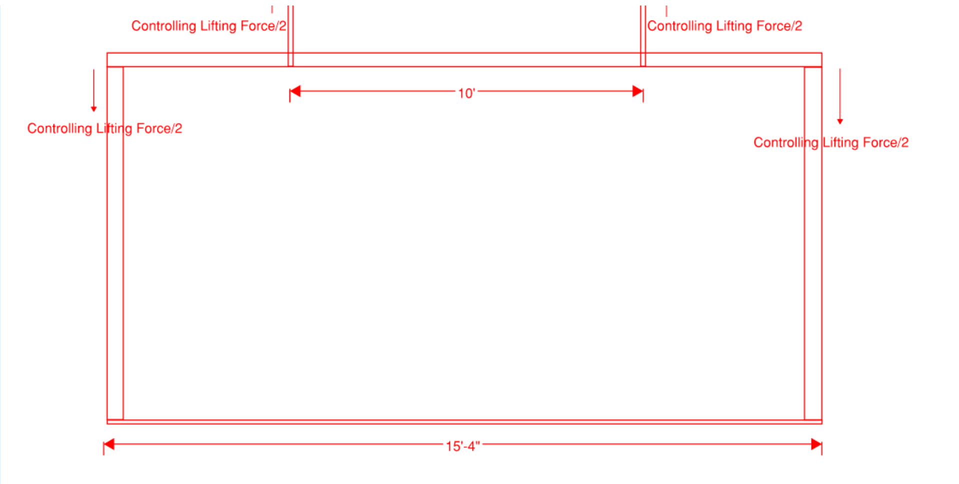
Controlling lifting force with machinery load factor (DL factor was used above)

$$W_{controlling} := Lifting_{force} \cdot 1.2 = 2.652\ kip$$

FBD: A middle stiffener has been added. This FBD is more conservative

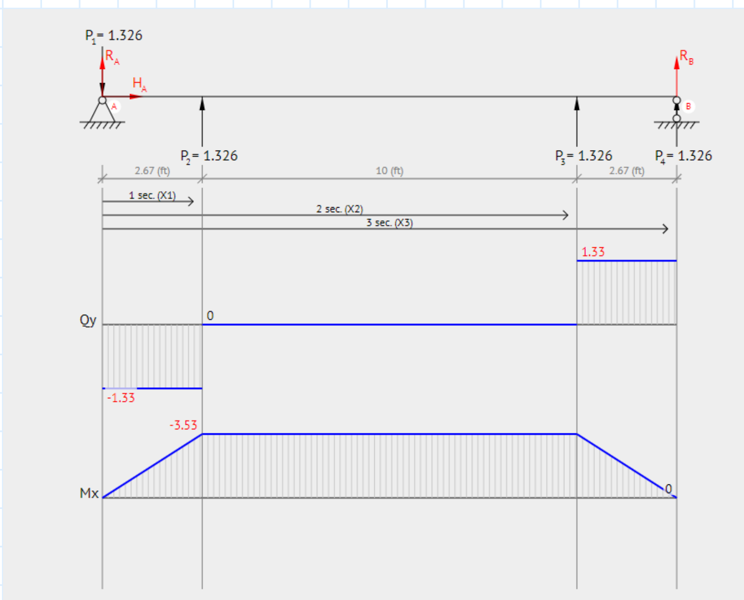


TDA DS Slot Fillers
Design Calcs



$$W_{controls.2} := \frac{W_{controlling}}{2} = 1.326 \; kip$$

Moment/Shear Diagram: In top beams from lifting



https://beamguru.com/online/beam-calculator/

$$V_{max} := 1.33 \; kip$$

$$M_{max} := 3.53 \; kip \cdot ft$$

ASME BTH 3-25: Minor axis bending of compact sections:

$N_d := 2$ (Cat A lifters)

$$S_y := 3.38 \; in^3$$

$$F_{yTube} := 50 \; ksi$$

$$F_b := \frac{1.25 \cdot F_y}{N_d} = 31250 \; psi$$

$$F_{b.actual} := \frac{M_{max}}{S_y} = 12532.544 \; psi$$

$$F_{yTube} > F_{b.actual} = 1$$

Check Tension In Vertical Members with controlling lifting force: AISC Chapter D

Max Tension in vertical members: $W_{controls.2} = 1.326\ kip$

Tensile Yielding D2-1: $F_y := 50\ ksi$ $A_g := 8.76\ in^2$

$\phi Pn := \phi \cdot F_y \cdot A_g = 394.2\ kip$

$\phi Pn > W_{controls.2} = 1$

Tensile Rupture D2-2: $F_u := 65\ ksi$ $A_e := A_g$

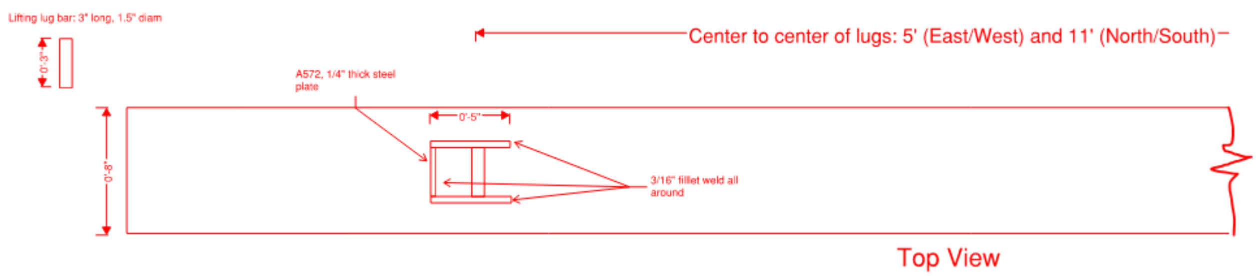
$\phi Pn := \phi \cdot F_u \cdot A_e = 512.46\ kip$

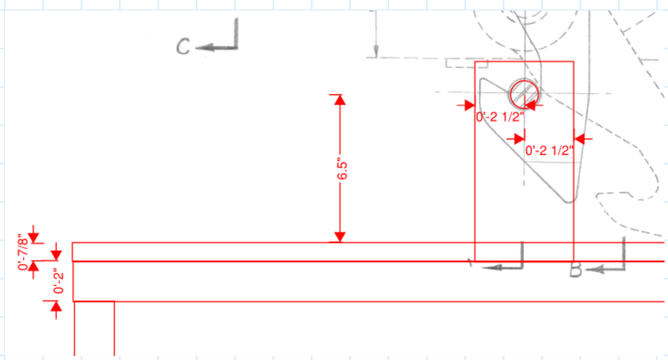
$\phi Pn > W_{controls.2} = 1$

Lifting Lug Design: ASME BTH

The slot fillers will utilize an automatic lifting beam in order to remove them under flow. The lifting beams lift 1.5" diameter lift lug/bar

Geometry





Lug spacing: North/South Entrance: $C.to.C_{N.S} := 11\ ft$ (DDF-1-3-2/13)

East/West Entrance: $C.to.C_{E.W} := 5\ ft$ (DDF-1-3-5/13.1)

ASME BTH Lifter Classifications:

Design Category: B (due to harsh environment) $N_d := 3$
Service Class: 0 (Load cycles is 0-20,000)

Check lifting pin/bar for Shear and Flexure:
1.5" diam, A572 solid round bar. $L_{pin} := 3\ in$ $D_{pin} := 1.5\ in$

Loading: $W_{controlling} = 2.652\ kip$ $A_{pin} := \frac{\pi \cdot D_{pin}^2}{4} = 1.767\ in^2$

$$P := \frac{W_{controlling}}{A_{pin}} = 1500.725\ psi$$

Flexure, ASME BTH, Chapter 3-2.3.3:

$$\frac{L_{pin} \cdot D_{pin}}{{D_{pin}}^{2}} < \frac{0.08 \cdot E}{F_y} = 1$$ (therefore us EQ 3-6)

$$F_b := \frac{1.25\ F_y}{N_d} = 20833.333\ psi$$ (eq 3-6)

$$F_b > P = 1$$

Shear, ASME BTH, Chapter 3-2.3.6:

$$F_v := \frac{F_y}{N_d \cdot \sqrt{3}} = 9622.504\ psi$$

$$F_v > P = 1$$

Check the pin attachment plates for tension: ASME BTH 3.3.3 Pinned Connections

BTH, slenderness, tensile strength through a pinhole (3-45), single plane fracture strength beyond the pin hole (3-49) 3-3.3.1, double plane shear strength beyond the pinhole (3-50), bearing stress (3-53).

$h_{lug} := 6.5\ in$ $\quad W_{controlling} = 2.652\ kip$ (assume one lug broke and total force is lifted by 1 lug)

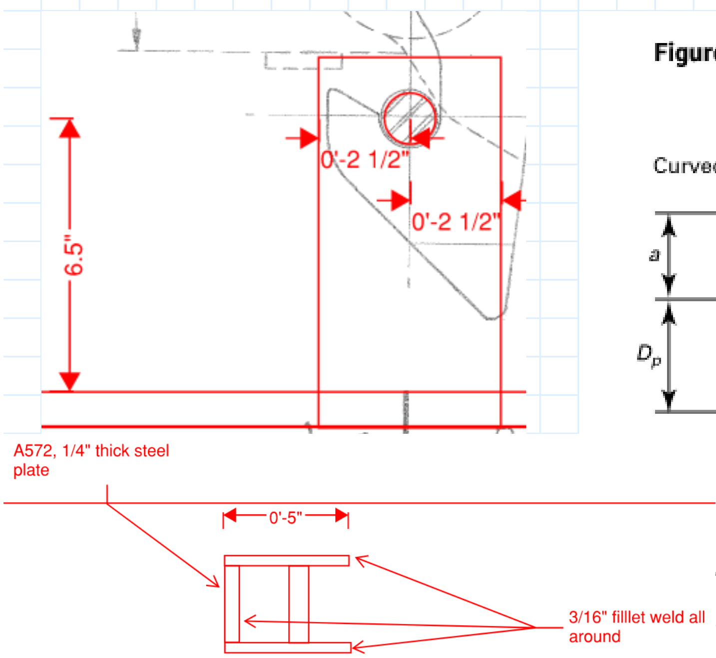
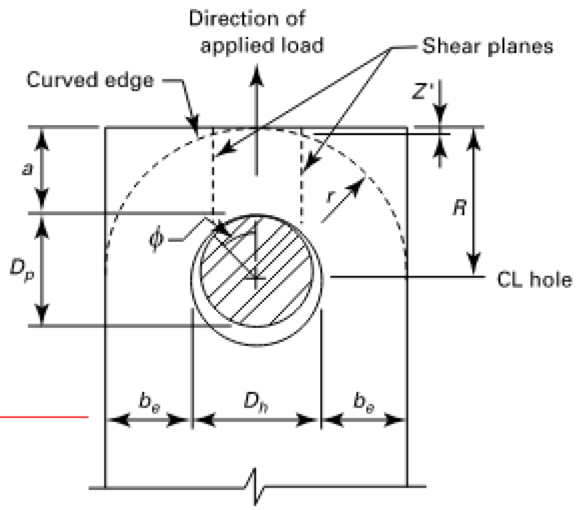


Figure C-3.3.1-1 Pin-Connected Plate Notation



Static strength of the plates: ASME BTH EQ, 3-45

$F_y := 50\ ksi$

$D_p := 1.5\ in$ $D_h := 1.5\ in$

$F_u := 70\ ksi$

$t_{lug} := 0.25\ in$ $R := 2\ in$

$b_e := 1.75\ in$

$width_{lug} := (b_e \cdot 2) + D_h = 5\ in$

$$C_r := 1 - 0.275 \cdot \sqrt{1 - \frac{D_p^2}{D_h^2}} = 1$$

beff = 4t < be $b_{eff} := 1\ in$

$$\phi := 55 \cdot \frac{D_p}{D_h} = 55$$

$a := 1.25\ in$

$$A_v := 2 \cdot \left(a + \frac{D_p}{2}(1 - \cos(\phi))\right) \cdot t_{lug} = 0.992\ in^2$$

Allowable tensile strength through the pinhole, Pt:

$$P_t := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot 2 \cdot t_{lug} \cdot b_{eff} = 9.722\ kip$$

Allowable single plane fracture strength beyond the pinhole, Pb:

$$P_b := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot \left(1.13 \cdot \left(R - \frac{D_h}{2}\right) + \frac{0.92 \cdot b_e}{1 + \left(\frac{b_e}{D_h}\right)}\right) \cdot t_{lug} = 10.478\ kip$$

Allowable double plane shear strength beyond the pinhole, Pv:

$$P_v := \frac{0.70 \cdot F_u}{1.2 \cdot N_d} \cdot A_v = 13.498\ kip$$

Bearing Stress, Fp:

$A_{lug} := ((b_e \cdot 2) + D_h) \cdot t_{lug} = 1.25\ in^2$

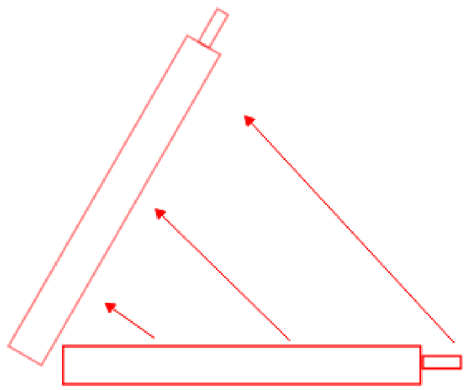
$$F_p := \frac{0.63 \cdot F_y}{N_d} = 10.5\ ksi$$

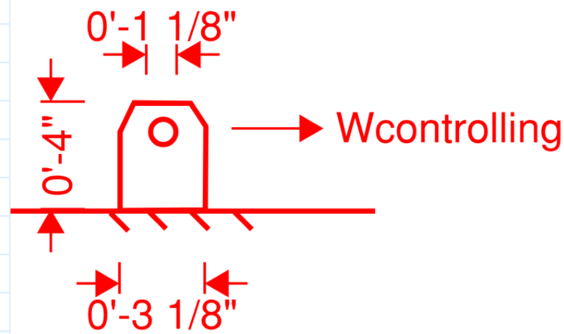
$$P_p := F_p \cdot A_{lug} = 13.125\ kip$$

$W_{controlling} = 2.652\ kip$ (max lifting force, max hydrostatic with friction)

$$P_p > W_{controlling} = 1$$

Check lifting from lugs when frames are laid down:





Treat lug as simply supported beam, major axis

Max Shear: $V_{max} := W_{controlling} = 2.652\ kip$

Max Moment: $M_{max} := W_{controlling} \cdot (h_{lug} - 1\ in) = 1.216\ kip \cdot ft$

Actual Deflection: $I := 2.54\ in^4$ $E := 29000\ ksi$

$$\Delta_{actual} := \frac{W_{controlling} \cdot (h_{lug} - 1\ in)^2}{6 \cdot E \cdot I} \cdot ((3 \cdot h_{lug}) - (h_{lug} - 1\ in)) = 0.00254\ in$$

Check Flexure: AISC F11 Rectangular Bars $\phi := 0.9$ $Z := 2.44\ in^3$ $S_x := 1.63\ in^3$

Yielding: $L_b := h_{lug} - 1\ in = 5.5\ in$ $d := 3.125\ in$ $t_{lug} := 1\ in$ $F_y := 50\ ksi$

$$\frac{L_b \cdot d}{t_{lug}^2} = 17.188 \quad < \quad \frac{0.08 \cdot E}{F_y} = 46.4$$

$$\phi M_n := min(F_y \cdot Z, 1.6 \cdot F_y \cdot S_x) \cdot \phi = 9.15\ kip \cdot ft$$

$$\phi M_n > M_{max} = 1$$

LTB: does not apply because $\frac{L_b \cdot d}{t_{lug}^2} = 17.188 \quad < \quad \frac{0.08 \cdot E}{F_y} = 46.4$

Check Shear: AISC G4 $C_{v2} := 1$ $A_w := d \cdot t_{lug} = 3.125\ in^2$

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 84.375\ kip$$

$$\phi V_n > V_{max} = 1$$

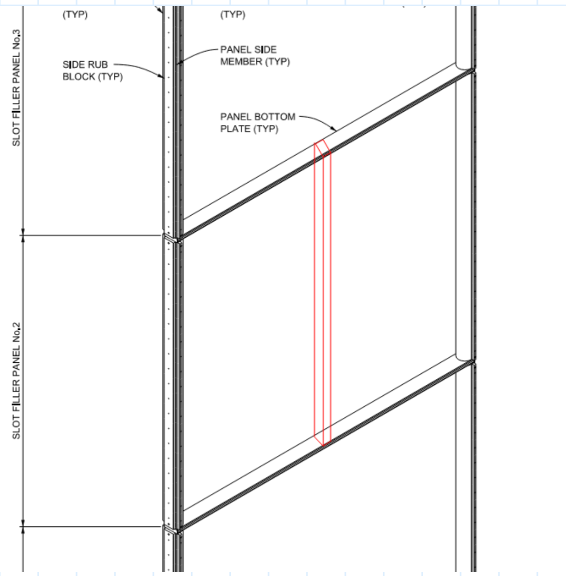
Check Deflection: L/240

$$\Delta_{max} := \frac{h_{lug}}{240} = 0.027\ in$$

$$\Delta_{max} > \Delta_{actual} = 1$$

Design Middle Vertical Stiffener:

The purpose of the middle stiffener is to reduce vibration/racking a provide additional buckling support for the weight of the automatic lifting beams

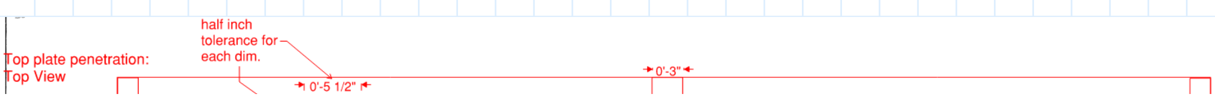


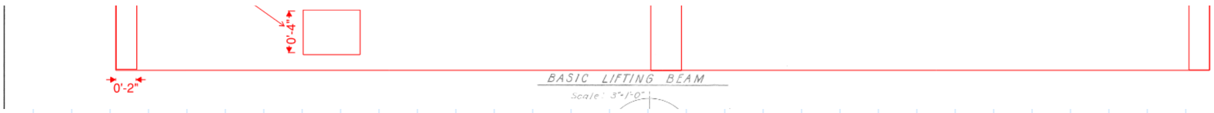
This stiffener will be the same size (if not larger) than the two side HSS members. Therefor no specific checks are required for this member

$H_{section} = 13\ ft$

Choose HSS 8x4x5/16"

Check Uplift on bottom plate: try 0.75" bottom plate (assumed welded to vertical tubes (fixed at ends)) AISC Chapter F in minor axis direction, with penetrations for lift lugs.





Geometry:

Length of span, middle stiffener breaks span up: $L_{span} := \frac{Span_{N.S}}{2} = 7.667\ ft$

Thickness of plate: $t_{plate} := \frac{7}{8}\ in$

Width of Plate: $b_{plate} := 7\ in$ (Incorporates sloped edges @ 45 degree)

Moment Inertia: $I_{plate} := \frac{b_{plate} \cdot t_{plate}^{3}}{12} = 0.391\ in^4$ (minor axis direction)

Section Modulus: $S_{plate} := \frac{b_{plate} \cdot t_{plate}^{2}}{6} = 0.893\ in^3$ (minor axis direction)

Plastic Section Modulus: $Z_{plate} := \frac{b_{plate} \cdot t_{plate}^{2}}{4} = 1.34\ in^3$ (minor axis direction)

Loading:

Hydrostatic pressure: $q = 174.72\ psf$

Plate Uplift: $Uplift := q \cdot width_{plate} = 116.48\ \frac{lbf}{ft}$

$$Shear_{bottomplate} := \frac{5 \cdot Uplift \cdot L_{span}}{8} = 0.558\ kip$$

$$Moment_{bottomplate} := \frac{Uplift \cdot L_{span}^{2}}{8} = 0.856\ kip \cdot ft$$

Check Flexure: AISC F11 Minor Axis

Yielding: minor axis

$$\phi M_n := min\left(F_y \cdot Z_{plate}, 1.6 \cdot F_y \cdot S_x\right) \cdot \phi = 5.024\ kip \cdot ft$$

Use eq F11-3: Lb*d/t^2 > 1.9E/Fy

$$F_{cr} := \frac{1.9 \cdot E \cdot C_b}{\frac{L_{span} \cdot b_{plate}}{t_{plate}^{2}}} = 65506.114\ psi$$

$$\phi M_n := F_{cr} \cdot S_x = 8.898\ kip \cdot ft$$

Check:

$$min(\phi M_n) > Moment_{bottomplate} = 1$$

Check with penetration: AISC F13, Strength reductions for members with holes in tension flange

$F_u = 70\ ksi$

$$A_{fg} := b_{plate} \cdot t_{plate} = 6.125\ in^2$$

$$\frac{F_y}{F_u} = 0.714$$

$$A_{fn} := (b_{plate} - 3.5\ in) \cdot t_{plate} = 3.063\ in^2$$

$$Y_t := 1$$

Check: $F_u \cdot A_{fn} > Y_t \cdot F_y \cdot A_{fg} = 0$

Therefore the penetrations need to be considered.

Moment capacity with penetrations: F13-1

$$\phi M_n := \frac{F_u \cdot A_{fn}}{A_{fg}} \cdot S_{plate} = 2.605\ kip \cdot ft$$

Check: $\phi M_n > Moment_{bottomplate} = 1$

Shear Capacity: AISC Chapter G6, Weak Axis Shear

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot (b_{plate} - 3.5\ in) \cdot t_{plate} \cdot C_{v2} = 82.688\ kip$$

$$\phi V_n > Shear_{bottomplate} = 1$$

Check Deflection:

$E := 29000\ ksi$

$$\Delta_{plate} := \frac{Uplift \cdot L_{span}^{4}}{\ldots} = 0.332\ in$$

$$185 \cdot E \cdot I_{plate}$$

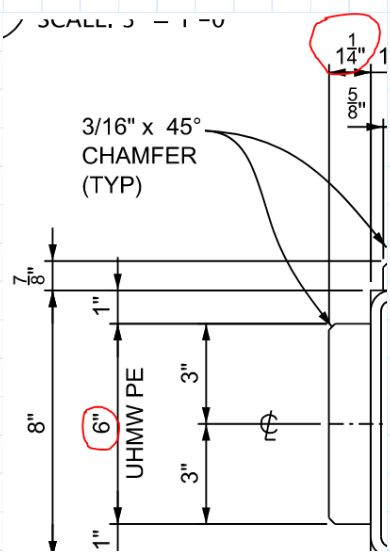
(HD said roughly 0.5" or less is okay for lamprey)

Check on other span: (E/W at 8'-8")

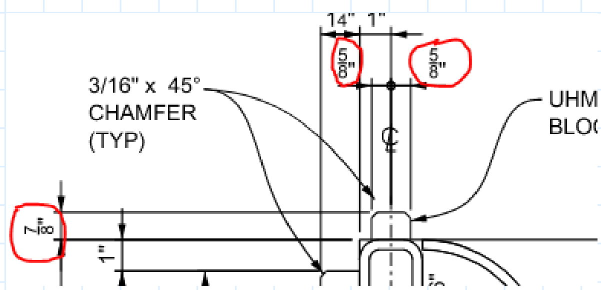
$$\Delta_{plate} := \frac{Uplift \cdot (4\ ft + 4\ in)^4}{185 \cdot E \cdot I_{plate}} = 0.034\ in$$

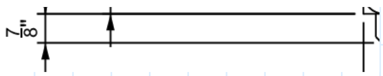
Rub Block Design: UHMW Rub Blocks

Geometry:
Out to Out:



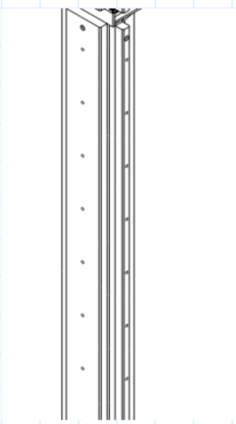
Upstream/Downstream:





Countersunk head design

Loading: Assume same loads as vertical members, including load on middle stiffener



Line load on rub block (see above)

$q = 174.72\ psf$ (hydrostatic load)

$w_{vertical} = 29.12\ \frac{lbf}{ft}$ (along height of gate)

$P := 2 \cdot w_{vertical} \cdot H_{section} = 0.757\ kip$ (total force on rub block, with force on middle stiffener)

Geometry, downstream rub block:

$L_{block} := 1\ in$ $t_{block} := 1.25\ in$ $h_{block} := H_{section} = 13\ ft$

Force over area:

$$\sigma_{block} := \frac{P}{L_{block} \cdot h_{block}} = 4.853\ psi$$

Capacity: see UHMW Material Specs (https://www.technicalproductsinc.com/pdf/Specs/UHMW%20Specs.pdf)

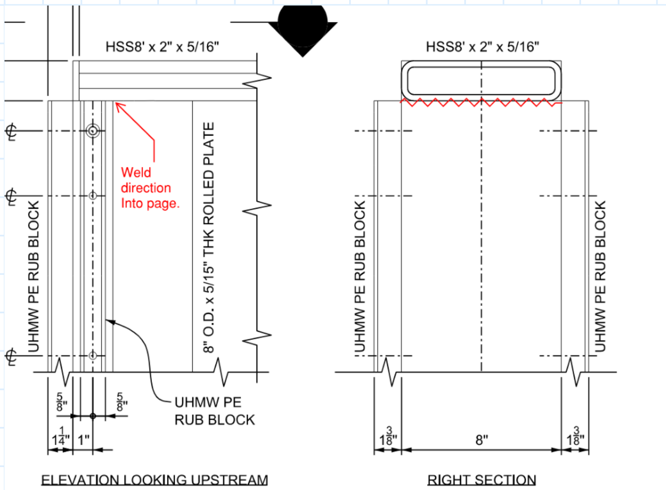
Bearing strength: $\sigma_{capacity} := 3000\ psi$ (D695)

Check:

$$\sigma_{capacity} > \sigma_{block} = 1$$

Weld Design: AISC Chapter J. See Bon 1 Weir Calcs for most weld calcs.

1. Weld from vertical HSS members (0.291" thick) to top HSS member (0.291" thick)



$L_{weld} := 8\ in$

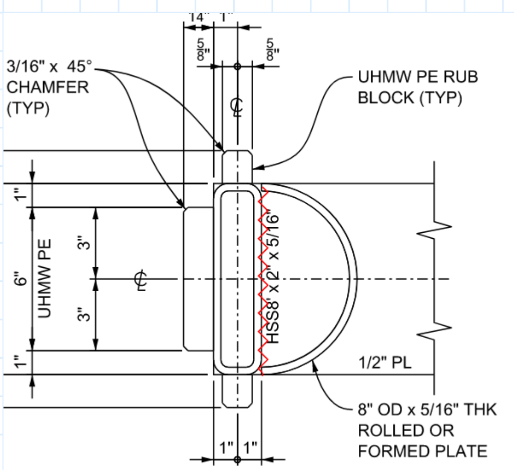
Minimum sized fillet weld: AISC J2.4
3/16"

Controlling Load:

Weight of structure

$Weight_{controls} = 1.992\ kip$

2. Weld from bottom plate (7/8" thick) to vertical HSS members (0.291" thick)



$L_{weld} := 7\ in$ (the weld on the bottom plate is 7" long not 8" due to the sloped edges)

Minimum sized fillet weld: AISC J2.4
3/16"

Check Fatigue:
Determine, Cf, Fth, table 2.5: Case 1.1

Stress category: C

$C_f := 44 \cdot 10^8$ $\qquad F_{th} := 24\ ksi$

Number of cycles: $\qquad Years := 100$

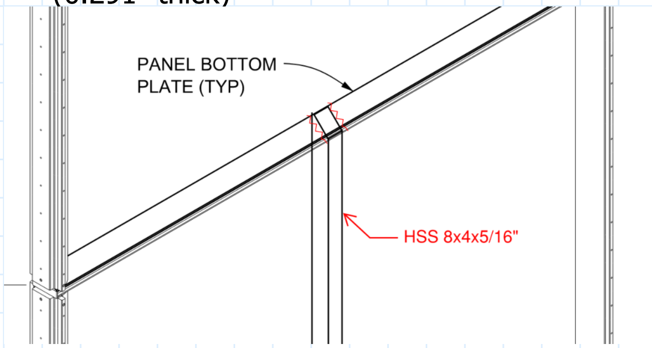
$$N := \frac{3}{4} \cdot 365 \cdot (Years) = 27375$$

Fsr:

$$F_{SR} := \left(\frac{C_f}{N}\right)^{0.333} \cdot ksi = 54.154\ ksi$$

$F_{SR} > F_{th} = 1$ (therefore, even with a 100 year design life, fatigue will not be controlling)

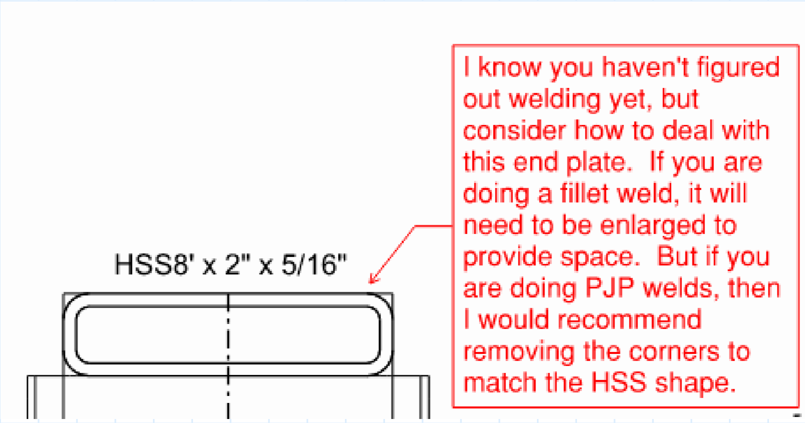
3. Weld from Bottom Plate/top HSS (0.75" thick/0.291" thick) member to vertical HSS stiffener (0.291" thick)



$L_{weld} := 2 \cdot 8\ in = 16\ in$

Minimum sized fillet weld: AISC J2.4
3/16"

5. Weld End Cap (5/16" thick) to HSS member (0.291" thick)



Slot Filler Rack Calcs

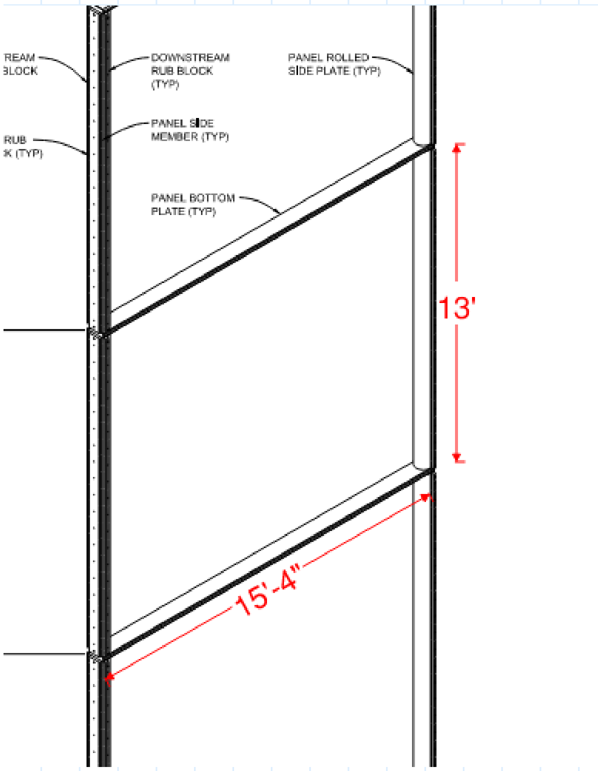
The Dalles Lamprey
Slot Filler Storage Rack

Goal: Create a place to store the slot filler assemblies (each bay required 3 fillers, East and West entrances have 3 bays, North and South has 2 bays)

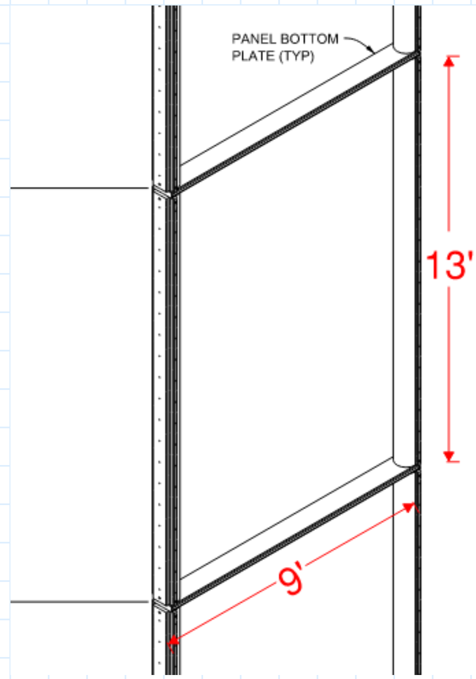
Geometry:

Slot filler assembly:

North and South Entrances:

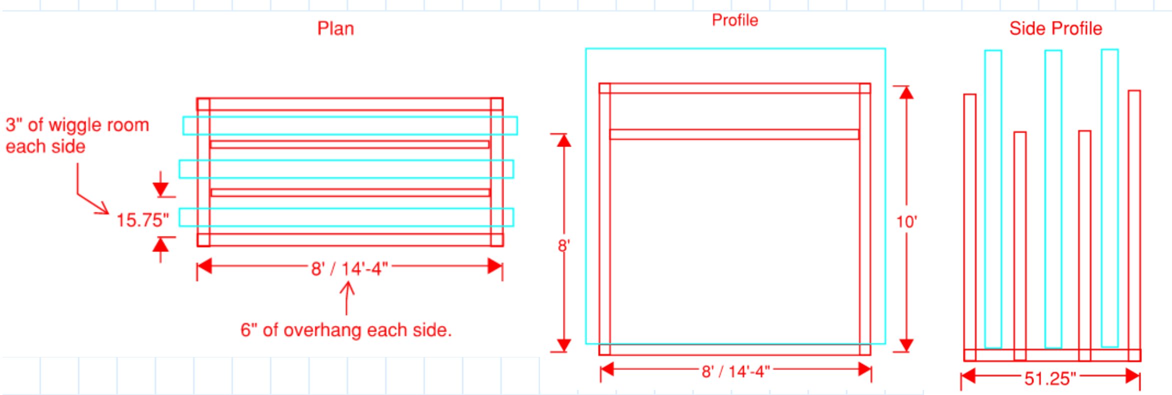


East and West Entrances:



Design the larger rack and size the smaller one based on those calcs. The bigger rack will control due to high loads.

Slot Filler Storage Rack:

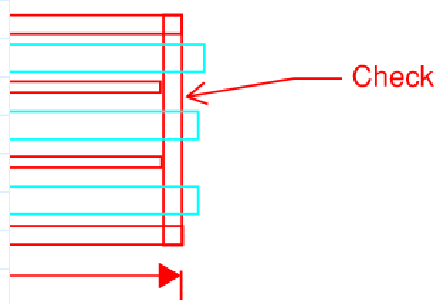


Loading:

Load conditions:

1. Slot fillers on storage rack
2. Lifting
3. Slot filler assembly hitting rack

Slot Fillers on storage rack: Check bottom bearing members



Member: TRY HSS 3x3x1/4

$E := 29000\ ksi$ $F_y := 50\ ksi$

Geometry:
$L_{base} := 51.25\ in$

Weight of slot filler: $Weight_{filler} := 2000\ lbf$ (from Slot Filler Calcs)

half the weight of the fillers to each bearing member, 3 fillers each rack

Point loads: $W_{controls} := \frac{Weight_{filler}}{2} = 1\ kip$

Max Shear/Moment/Deflection: https://clearcalcs.com/freetools/beam-analysis/us

$M_u := 1740\ lbf \cdot ft$ $V_u := 1500\ lb$ $\Delta := 0.036\ in$

Check compactness, flexure, shear, deflection of HSS 3x3x1/4:

Compact/Noncompact: AISC B4.1a

Walls: $b.over.t := 9.88$ $> 1.4 \cdot \sqrt{\frac{E}{F_y}} = 33.716$ (therefore walls are compact)

Flanges: $h.over.t := 9.88$ $> 1.12 \cdot \sqrt{\frac{E}{F_y}} = 26.973$ (therefore flanges are compact)

Flexure: AISC Chapter F7 $\phi := 0.75$ $Z_x := 2.48\ in^3$

$\phi M_n := \phi \cdot F_y \cdot Z_x = 7750\ lbf \cdot ft$

$\phi M_n > M_u = 1$

Shear: AISC Chapter G7

$C_v := 1$

$t_f := 0.233\ in$

$A_w := t_f \cdot 3\ in = 0.699\ in^2$

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_v = 15.728\ kip$$

Deflection: L/120

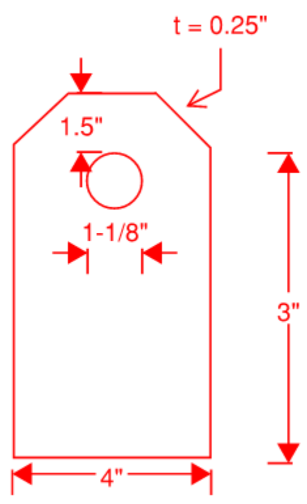
$$\Delta_{allowable} := \frac{L_{base}}{240} = 0.018\ ft$$

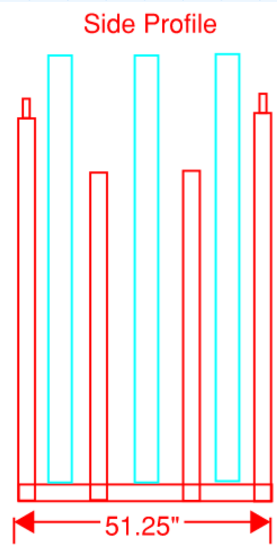
$\Delta_{allowable} > \Delta = 1$

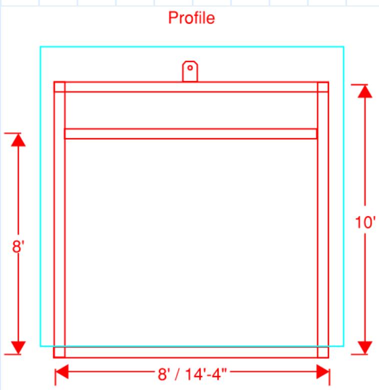
Design of Lifting lugs: ASME BTH

BTH, slenderness, tensile strength through a pinhole (3-45), single plane fracture strength beyound the pin hole (3-49) 3-3.3.1, double plane shear strength beyond the pinhole (3-50), bearing stress (3-53).

Geometry:







$w_{HSS3x3x0.25} := 8.81\ \frac{lbf}{ft}$

$w_{HSS2x2x0.25} := 5.41\ \frac{lbf}{ft}$

Distance between eyes: $C.to.C_{eyes} := 48\ in$

Weight of three slot fillers: $Weight_{slotfillers} := 3 \cdot Weight_{filler} = 6\ kip$

Weight of rack: North and South (larger racks)

$$Weight_{base} := \left(2 \cdot 14.33\ ft \cdot w_{HSS3x3x0.25}\right) + \left(2 \cdot 4.27\ ft \cdot w_{HSS3x3x0.25}\right) = 327.732\ lbf$$

$$Weight_{verticals} := \left(6 \cdot 12\ ft \cdot w_{HSS3x3x0.25}\right) + \left(4 \cdot 10\ ft \cdot w_{HSS2x2x0.25}\right) = 850.72\ lbf$$

$$Weight_{laterals} := \left(2 \cdot 14.33\ ft \cdot w_{HSS2x2x0.25}\right) + \left(2 \cdot 14.33\ ft \cdot w_{HSS3x3x0.25}\right) + \left(2 \cdot 4.27\ ft \cdot w_{HSS2x2x0.25}\right) = 453.747\ lbf$$

$$Weight_{bottomplate} := \left(\left(15\ ft + 10.5\ in\right) \cdot 45.25\ in \cdot 0.25\ in \cdot 490\ pcf\right) = 611.091\ lbf$$

Weight of empty rack, factored and 5% misc weight:

$$Weight_{rackempty} := 1.2 \cdot \left(1.05 \cdot \left(Weight_{base} + Weight_{verticals} + Weight_{laterals} + Weight_{bottomplate}\right)\right) = 2826.545\ lbf$$

Weight of rack with slot fillers:

$$Weight_{rack} := Weight_{rackempty} + Weight_{slotfillers} = 8.827\ kip$$

Weight of rack: East and West(smaller)

$$Weight_{base.2} := \left(2 \cdot 8\ ft \cdot w_{HSS3x3x0.25}\right) + \left(2 \cdot 4.27\ ft \cdot w_{HSS3x3x0.25}\right) = 216.197\ lbf$$

$$Weight_{verticals.2} := \left(6 \cdot 12\ ft \cdot w_{HSS3x3x0.25}\right) + \left(4 \cdot 10\ ft \cdot w_{HSS2x2x0.25}\right) = 850.72\ lbf$$

$$Weight_{laterals.2} := \left(2 \cdot 8\ ft \cdot w_{HSS2x2x0.25}\right) + \left(2 \cdot 8\ ft \cdot w_{HSS3x3x0.25}\right) + \left(2 \cdot 4.27\ ft \cdot w_{HSS2x2x0.25}\right) = 273.721\ lbf$$

$$Weight_{bottomplate.2} := \left(\left(9\ ft + 4\ in\right) \cdot 45.25\ in \cdot 0.25\ in \cdot 490\ pcf\right) = 359.277\ lbf$$

Weight of empty rack, factored and 5% misc weight:

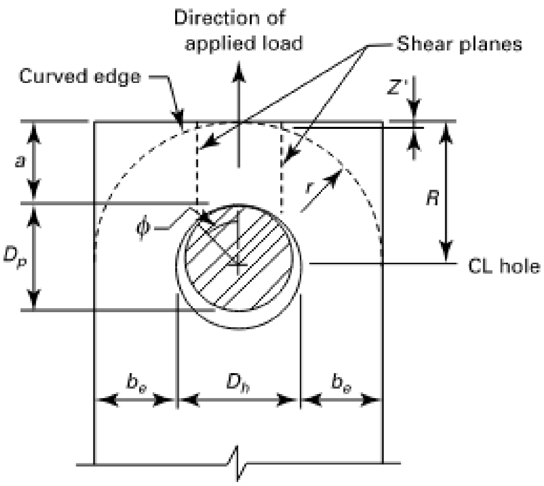
$$Weight_{rackempty.2} := 1.2 \cdot \left(1.05 \cdot \left(Weight_{base.2} + Weight_{verticals.2} + Weight_{laterals.2} + Weight_{bottomplate.2}\right)\right) = 2141.893\ lbf$$

Weight of rack with slot fillers:

$$Weight_{rack.2} := Weight_{rackempty.2} + \left(3 \cdot 1500\ lbf\right) = 6.642\ kip$$

Design lift lug: ASME BTH Chapter 3

Figure C-3.3.1-1 Pin-Connected Plate Notation



Static strength of the plates: ASME BTH EQ, 3-45

$F_y := 50\ ksi$

$D_p := 1\ in$ $\quad D_h := 1\ in + \frac{1}{8}\ in = 1.125\ in$ $\quad F_u := 58\ ksi$ $\quad N_d := 3$ (cat B lifter)

$t := \frac{3}{8}\ in$ $\quad R := 2\ in$ $\quad b_{eff} := 1\ in$ $\quad b_e := 1.4375\ in$

beff = 4t < be

$$C_r := 1 - 0.275 \cdot \sqrt{1 - \frac{{D_p}^2}{{D_h}^2}} = 0.874$$

$$\phi := 55 \cdot \frac{D_p}{D_h} = 48.889 \qquad a := 1.5\ in$$

$$A_v := 2 \cdot \left(a + \frac{D_p}{2}\left(1 - \cos(\phi)\right)\right) \cdot t = 1.428\ in^2$$

Allowable tensile strength through the pinhole, Pt:

$$P_t := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot 2 \cdot t \cdot b_{eff} = 10.561\ kip$$

Allowable single plane fracture strength beyond the pinhole, Pb:

$$P_b := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot \left(1.13 \cdot \left(R - \frac{D_h}{2}\right) + \frac{0.92 \cdot b_e}{1 + \left(\frac{b_e}{D_h}\right)}\right) \cdot t = 11.643\ kip$$

Allowable double plane shear strength beyond the pinhole, Pv:

$$P_v := \frac{0.70 \cdot F_u}{1.2 \cdot N_d} \cdot A_v = 16.101\ kip$$

Bearing Stress, Fp:

$$A_{lug} := 4\ in \cdot t = 1.5\ in^2$$

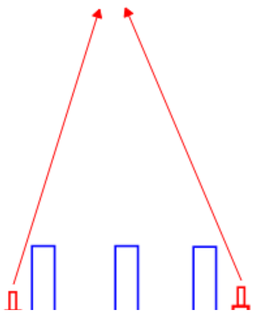
$$F_p := \frac{0.63 \cdot F_y}{N_d} = 10.5\ ksi$$

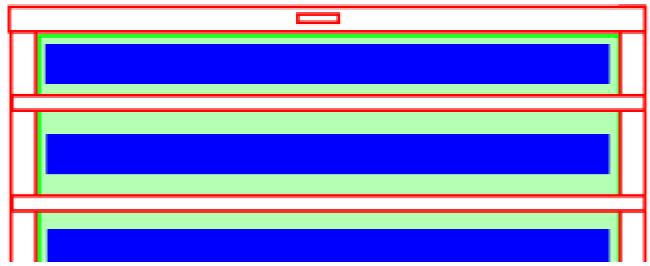
$$P_p := F_p \cdot A_{lug} = 15.75\ kip$$

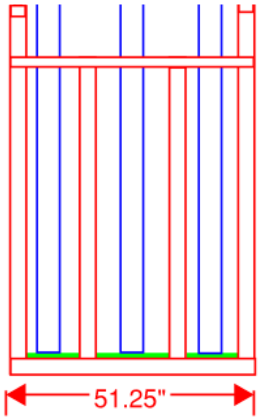
Check:

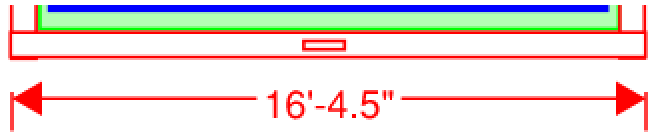
$$min\left(P_t, P_b, P_v, P_p\right) > Weight_{rack} = 1$$

Check top HSS members in bending due to lifting from lugs:









$L := 16\ ft + 4.5\ in$

Loads:

$Weight_{rack} = 8.827\ kip$

Weight per HSS member/lug: $P := \frac{Weight_{rack}}{2} = 4.413\ kip$

Max shear/moment/deflection: $V_u := \frac{P}{2} = 2.207\ kip$

$I_x := 3.02\ in^4$

$M_u := \frac{P \cdot L}{4} = 18.067\ kip \cdot ft$

$\Delta := \frac{P \cdot L^3}{48 \cdot E \cdot I_x} = 7.965\ in$

Check Flexure: AISC Chapter F7

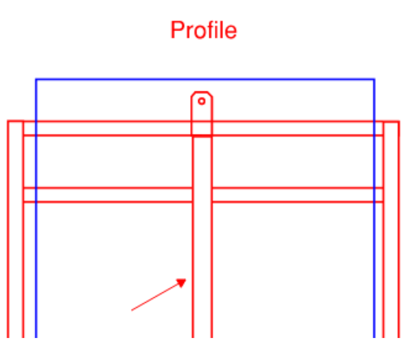
$\phi := 0.9$

$\phi M_n := \phi \cdot F_y \cdot Z_x = 9.3\ kip \cdot ft$

$\phi M_n > M_u = 0$

Check fails. Therefore, use a middle stiffener to support HSS lifting. This will also reduce deflection

Check Middle Stiffener:

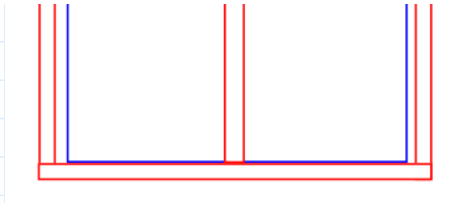


Assume middle stiffener will
take full lifting load

$Weight_{rack} = 8.827\ kip$

$L := 12\ ft$

Check slenderness: $r := 1.11\ in$



$\frac{L}{r} = 129.73$ (not slender)

$A_g := 2.44\ in^2$

Check Tension: AISC D2

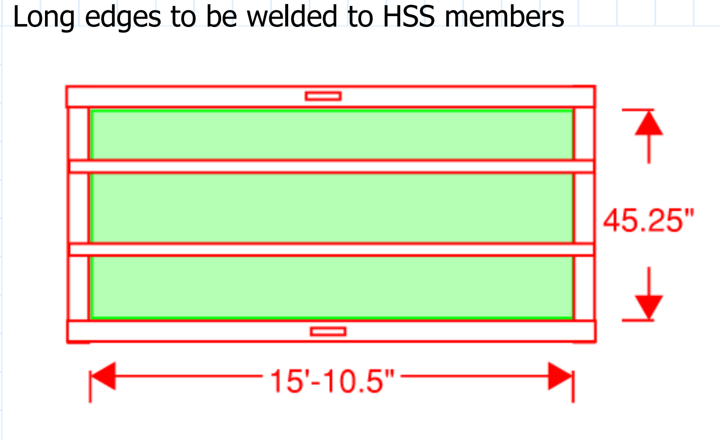
$$\phi P_n := \phi \cdot F_y \cdot A_g = 109.8\ kip$$

$$\phi P_n > Weight_{rack} = 1$$

Check bottom plate: Roark Stress and Strain, Table 11.4, Case 6 Long edges fixed

$t := 0.25\ in$

Long edges to be welded to HSS members



$a := 15.875\ ft$

$b := 45.25\ in$

$\frac{a}{b} = 4.21$

$\beta := 0.5$

$\alpha := 0.0285$

Loading: assume total weight over 1/2 of the area

$$q := \frac{Weight_{slotfillers}}{(a \cdot b \cdot 0.5)} = 200.461\ \frac{lbf}{ft^2}$$

$$\sigma_{max} := \frac{\beta \cdot q \cdot b^2}{t^2} = 22803.15\ psi$$

$$\gamma_{max} := \frac{\alpha \cdot q \cdot b^4}{E \cdot t^3} = 0.367\ in$$

$\rho := 1.2$

Capacity:

$\Omega := 1.67$ (ASCE design Safety factor)

$$\sigma_{all} := \frac{F_y}{\Omega \cdot \rho} = 24950.1\ psi$$

$$\Delta_{allowable} := \frac{a}{240} = 0.794\ in$$

Check:

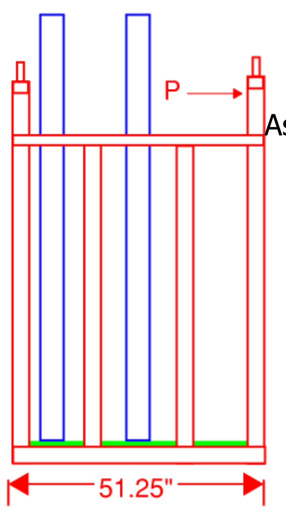
$$\sigma_{all} > \sigma_{max} = 1$$

$$\Delta_{allowable} > \gamma_{max} = 1$$

Check outer vertical members for flexure:

$$L := 12\ ft$$

$$I_x = 3.02\ in^4$$



Assume this piece doesn't exist

Loading with P = 500 lb: cantilevered beam with point load on end

$$V_u := 500\ lbf$$

$$M_u := L \cdot V_u = 6\ kip \cdot ft$$

$$\Delta := \frac{V_u \cdot L^3}{3 \cdot E \cdot I_x} = 5.682\ in$$

required stiffener tying all vertical members on each side

Capacity: AISC Chapter F7

$$\phi := 0.9$$

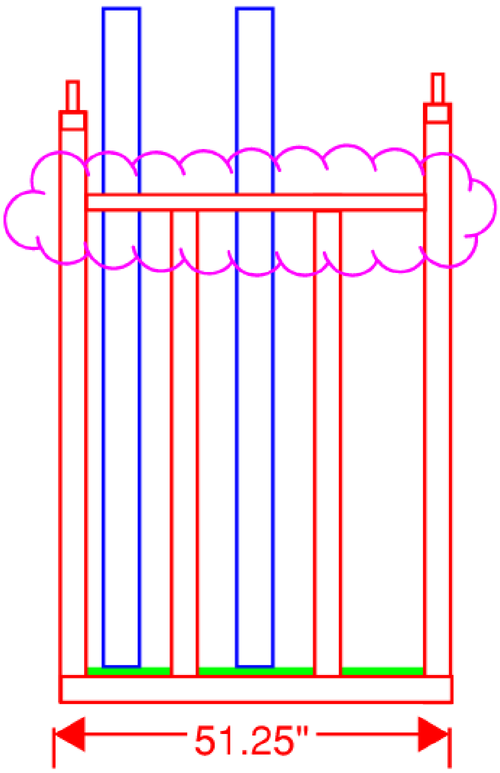
$$\phi M_n := \phi \cdot F_y \cdot Z_x = 9.3\ kip \cdot ft$$

$$\phi M_n > M_u = 1$$

Therefore, this section works, besides the deflection.

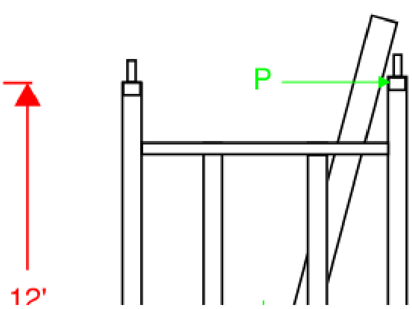
Lateral Stiffener:

HSS 2x2x1/4



$L := 45.25\ in$

Check overturning:

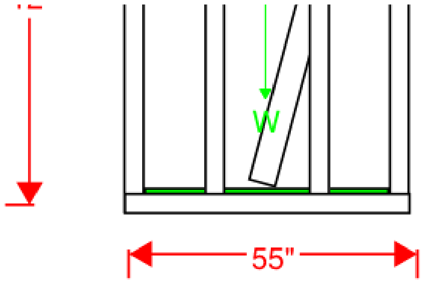


Find P, Some of moments about bottom right corner: with weight of empty rack and one slot filler

Weight of full rack: $Weight_{rack} = 8.827\ kip$

Weight of rack with one filler:

$Weight_{2.3.rack} := Weight_{rack} - (2 \cdot Weight_{filler}) = 4.827\ kip$



Some of moments:

P*12' = Weight2.3rack*2.13'

$$P := \frac{Weight_{2.3.rack} \cdot 2.29\ ft}{12\ ft} = 0.921\ kip$$

It is reasonable to assume a 2k lb slot filler cannot produce a .921 kip force at the top of the storage rack by leaning. Therefore, the rack is stable. However, the more wide the more stable.

Slot Cover Plate Calcs

Goal: fill the guide slots with a plate attached to the lifting beam

Geometry/Constants: (design north and slot cover because the plate is 1" bigger)

$t_{liftingbeam} := 0.5\ in$ $width_{liftingbeam} := 5\ in$ $\gamma_{water} := 62.4\ \frac{lbf}{ft^3}$

$t_{plate} := \frac{5}{8}\ in$ $width_{plate} := 38.1875\ in$ $h_{plate} := 3\ ft$

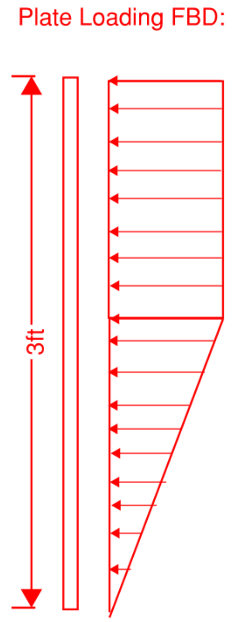
$weight_{steel} := 490\ \frac{lbf}{ft^3}$ $Area_{plate} := width_{plate} \cdot h_{plate} = 9.547\ ft^2$

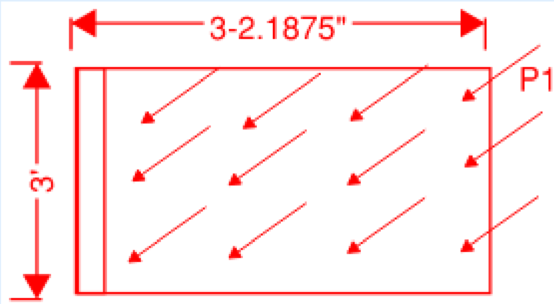
$head := 2\ ft$ $d_{bolt} := \frac{5}{8}\ in$ $\phi_{bolt} := 0.75$ (AISC Chapt J)

$\phi_{plate} := 0.9$ (AISC Chapt F/G)

Loading: (from hydraulic engineer)
-2' equivalent head differential with opening at top and bottom (no pressure at bottom)
-1.4 LRFD Hydrodynamic Factor (ETL 1110-2-584, Lift Gate/Closer Gate Hydrostatic factor)

FBD: (by HD)   Assumed constant 2' head for conservative design





Weight of plate:

$Weight_{plate} := weight_{steel} \cdot Area_{plate} \cdot t_{plate} = 243.644\ lbf$

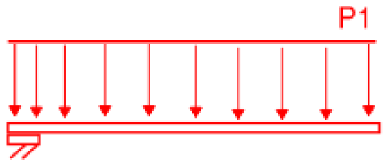
Linear Force on Plate, per foot of plate:

$P := 1.4 \cdot head \cdot \gamma_{water} = 174.72\ \frac{lbf}{ft^2}$

Linear Force on Plate: over height

$P_1 := P \cdot h_{plate} = 524.16\ \frac{lbf}{ft}$

Design Plate:



$h_{plate} = 3\ ft$ $\qquad width_{plate} = 3.182\ ft$

$E := 29000\ ksi$ $\qquad I := \dfrac{h_{plate} \cdot t_{plate}^{3}}{12} = 0.732\ in^{4}$

$V_{max} := P_1 \cdot (width_{plate} - width_{liftingbeam}) = 1.45\ kip$

$$M_{max} := \frac{P_1 \cdot (width_{plate} - width_{liftingbeam})^{2}}{2} = 2.005\ kip \cdot ft$$

$$\Delta_{max} := \frac{P_1 \cdot (width_{plate} - width_{liftingbeam})^{4}}{8 \cdot E \cdot I} = 0.312\ in$$

Check Flexure: AISC F11 Rectangular Bars and Rounds $\qquad F_y := 36\ ksi$

Yielding:

$Z_x := \dfrac{h_{plate} \cdot t_{plate}^{2}}{4} = 3.516\ in^{3}$ $\qquad S_x := \dfrac{h_{plate} \cdot t_{plate}^{2}}{6} = 2.344\ in^{3}$

$$\phi_{plate} M_n := min(\phi_{plate} \cdot F_y \cdot Z_x, \phi_{plate} \cdot 1.6 \cdot F_y \cdot S_x) = 9.492\ kip \cdot ft$$

$$\phi_{plate} M_n > M_{max} = 1$$

$$\text{if}(\phi_{plate} M_n > M_{max}, \text{“OK”}, \text{“No Good”}) = \text{“OK”}$$

LTB:

$\dfrac{width_{plate} \cdot h_{plate}}{t_{plate}^{2}} = 3519.36$ $\quad \square < \square \quad$ $\dfrac{0.08 \cdot E}{F_y} = 64.444$

The case above is untrue therefor LTB does apply, however the plate is bent about minor axis, So LTB does NOT apply (F11.2.d) No need for checks below.

$\dfrac{width_{plate} \cdot h_{plate}}{t_{plate}^{2}} = 3519.36$ $\quad \square > \square \quad$ $\dfrac{1.9 \cdot E}{F_y} = 1530.556$

Therefor us EQ F11-3 and F11-4 $\qquad C_b := 1$

$$F_{cr} := \frac{1.9 \cdot E \cdot C_b}{\dfrac{width_{plate} \cdot h_{plate}}{t_{plate}^{2}}} = 15656.256\ psi$$

$$\phi_{plate} M_n := \phi_{plate} \cdot F_{cr} \cdot S_x = 2.752\ kip \cdot ft$$

$$\phi_{plate} M_n > M_{max} = 1$$

Check Shear: AISC G4 Singly and Doubly Symmetric Members

$A_w := h_{plate} \cdot t_{plate} = 22.5\ in^2$

$C_{v2} := 1$

$$\phi_{plate}V_n := \phi_{plate} \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 437.4\ kip$$

$$\phi_{plate}V_n > V_{max} = 1$$

Check Deflection: limits L/120

$$\Delta_{max} := \frac{P_1 \cdot (width_{plate} - width_{liftingbeam})^4}{8 \cdot E \cdot I} = 0.312\ in$$

$$\frac{width_{plate}}{120} = 0.318\ in$$

$$\frac{width_{plate}}{120} > \Delta_{max} = 1$$

Check: in plane Bending from self weight of new plate

Load: $Weight_{plate} = 243.644\ lbf$

Distributed load:

$$w_u := \frac{Weight_{plate}}{width_{plate}} = 76.563\ \frac{lbf}{ft}$$

Moment:

$$M_u := \frac{w_u \cdot width_{plate}^2}{2} = 0.388\ kip \cdot ft$$

Shear:

$$V_u := w_u \cdot width_{plate} = 0.244\ kip$$

Check flexure AISC F11:
Yielding:

$$Z_y := \frac{width_{plate} \cdot t_{plate}^2}{4} \qquad S_y := \frac{width_{plate} \cdot t_{plate}^2}{6}$$

$$\phi_{plate}M_n := min\left(\phi_{plate} \cdot F_y \cdot Z_y, \phi_{plate} \cdot F_y \cdot S_y\right) = 6.713\ kip \cdot ft$$

LTB:

$$\frac{width_{plate} \cdot h_{plate}}{t_{plate}^2} = 3519.36 \quad < \quad \frac{0.08 \cdot E}{F_y} = 64.444$$

therefor LTB does not apply.

$$\phi_{plate} M_n > M_u = 1$$

Check Shear: AISC G4 $A_w := width_{plate} \cdot t_{plate} = 23.867\ in^2$

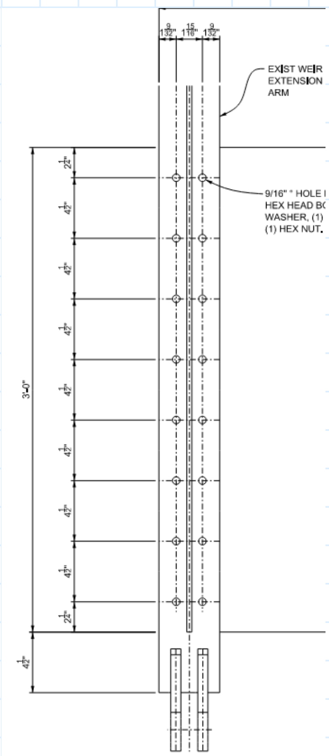
$$\phi_{plate} V_n := \phi_{plate} \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 463.978\ kip$$

$$\phi_{plate} V_n > V_u = 1$$

Check extension arms tension capacity with new bolt holes on arms:

Geometry for lifting arms: "Solid rectangular section" a is the longer side

$a := 15\ ft$ $b := 4.5\ in$ $L := a = 15\ ft$ $t_{arm} := 0.5\ in$



$d_{hole} := \frac{3}{4}\ in$ $n_{boltsline} := 8$

Removed steel area in a line:

$$A_{removed} := \pi \frac{d_{hole}^2}{4} \cdot n_{boltsline} = 3.534\ in^2$$

Check Lifting Arms for Torsion, AISC H3 "Non-HSS Members subject to torsion and combined stress:
OR use roark stress and strain pg. 389

torsion = load * moment arm > then divide by area to get stress

then use H3-7.

How to calc torsional deflection?

treat both ends of arms as fixed. and determine bolt capacity.

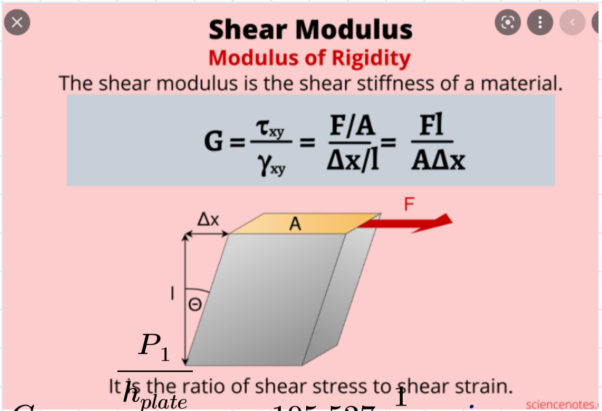
Torsion: Roark Chapter 10, Non circular bar torsion:

$\theta := 0.5\ rad$ (assumed)

K:

$$K := a \cdot b^3 \cdot \left(\frac{16}{3} - 3.36 \cdot \frac{b}{a} \cdot \left(1 - \frac{b^4}{12 \cdot a^4}\right)\right) = \left(8.61 \cdot 10^4\right)\ in^4$$ (table 10.1)

G: roark chapt 10.2



$\Delta_x := \Delta_{max} = 0.312\ in$

$$G := \frac{\frac{P_1}{h_{plate}}}{\left(t_{arm} \cdot b\right) \cdot \Delta_x} = 105.527\ \frac{1}{L} \cdot psi$$

$v := \square$

$E := 30 \cdot 10^6\ psi$

$$G := \frac{E}{2 \cdot (1 + v)} = ?$$

(shear modulus, shear stress over shear strain)

$$T := \frac{\theta}{L} \cdot K \cdot G = ?\ psi$$ (eq 10.2-1)

$$\tau_{max} := \frac{3 \cdot T}{8 \cdot a \cdot b^2} \cdot \left(1 + 0.6095 \cdot \frac{b}{a} + 0.8865 \cdot \left(\frac{b}{a}\right)^2 - 1.8023 \cdot \left(\frac{b}{a}\right)^3 + 0.9100 \cdot \left(\frac{b}{a}\right)^4\right) = ?\ kip$$

Design Bolted Connection: AISC J3 $F_{nv} := 27\ ksi$ (AISC Table J3.2, A307)

$$A_b := 16 \cdot \frac{\pi \cdot {d_{bolt}}^2}{4} = 4.909\ in^2$$

Check Shear,EQ J3-1: $\phi_{bolt} Rn := \phi_{bolt} \cdot F_{nv} \cdot A_b = 99.4\ \textbf{kip}$

Check: $\phi_{bolt} Rn > V_{max} = 1$

Check: Bolt couple to resist fixed end moment (one row in tension, other row bearing)

APPENDIX B- HYDRAULIC DESIGN CALCULATIONS

Item 1: The Dalles LPS Flow, Pipe and Valve Size Requirements

Purposes:

- Estimate flow requirements,
- Size pipe for flow requirements
- Size valve for control of design flow requirements

Item 2: The Dalles LPS EPANet Analysis

Purposes:

- Develop EPANet Pipe Network Model of LPS 4” pipe with main 12” header and 6” Irrigation pipe.
- Run simultaneous operation of LPS and Irrigations systems
  - Run simulations that alternately close one of the systems
  - Confirm the changes in LPS or Irrigation outlet pressures are small

Item 1: The Dalles LPS Flow, Pipe and Valve Size Requirements

Purposes:

- Estimate flow requirements,
- Size pipe for flow requirements
- Size valve for control of design flow requirements

The Dalles East Adult Fish Ladder LPS Flow Requirements & Supply Pipe Sizing

Determine water supply requirements and pipe and valve sizes
Size Pipe for ultimate, Control valves for initial flow requirements

		Date
Prepared by	DDP	1/24/2022
Checked by	SJS	2/7/2022

References:
USACE, The Dalles East Fish Ladder AWS Backup System - As Constructed, September 2019. M-100 series, Field sketches and FS050, 1
USACE, The Dalles Lock & Dam Visitor Facilities & Irrigation System As-Builts 1975. DDG-40-5 series
Hydraulic Design Criteria (HDC), USACE-Waterways Experiment Station (1986)
Miller (1990), Internal Flow Systems
Zobott, et.al. (2015) Technical Report 2015-5, Design Guidelines for Pacific Lamprey Structures.

Lamprey Collection Box Holding Criteria: 15 -18 gpm **USE:** **20** gpm
--- based on recommendations from Tribal coordination (via Jacob McDonald, PM-E), August 17, 2021

Number, width of LPS Flumes and Water Supply Requirements:

Standard LPS width =	**20**	inches	Zobott (2015)
Standard Criteria per 22-inch flume =	**124**	gpm	Zobott (2015)
Design Practice per 22" flume =	**160**	gpm	allows for adjustment cushion
Flow rate per inch of flume =	8.00	gpm/in	& covers holding tank requirements

Required flumes in Junction Pool Channels:

	Number	width	
West Wall, JP	**1**	**20**	inch
East Wall, JP	**1**	**20**	inch
Total LPS widths =		40	inches

Total Ultimate Flow requirement = 320 gpm = 0.71 cfs

Elevations (ft NGVD 29):	Minimum	Normal	Maximum	
Fb = Forebay Elevation:	**155**	**158.7**	**160**	DDF-1-4-5M series
Deduct potential screen & intake loss (ft)=	**1**	**0.5**	**0**	
Zh = Supply Elevation Head =	154	158.2	160	
Tailrace Deck Elevation at Collection Box	**111**	**111**	**111**	DDF-1/4-5V series
Yb = Height of collection box (ft) =	**5**	**5**	**5**	
Ha = Available head (ft) =	38	42.2	44	

	Label	Number	K		
Intake	Ki	**1**	**0.5**		
Open valves		**2**	**0.4**	Miller Fig.	2 drain and 1 control valve (MP-501)
Elbows	Kb				
90	Kb	**4**	**0.22**	HDC Chart 228-1	
45	Kb	**10**	**0.16**	HDC Chart 228-1	
22.5	Kb	**0**			
exit	Ke	**1**	**1**		
sum K	Σ K =		4.78		

Smooth wall PVC pipe

Length of Pipe ≈	**405.4**	feet	White, F.M. "Fluid Mechanics", 7th Ed
Ks = pipe roughness =	**0.000005**	feet =	0.00006 inches
v = H_2O Kinematic viscosity =	1.41E-05	ft/s^2	

Prefer valve openings between 20 - 70 degrees for control

Kv -Valve loss coefficients (versus Vo)

Valve Opening (Vo)	20	45	70	degrees
Butterfly valve	105	10	1.5	Miller fig. 14.19
Ball Valve	100	10	1.5	Miller fig. 14.17

Butterfly Miller fig. 14.19

Kv	Vo degrees	Log(Kv) /Vo
0.2	90	-25.13
0.5	80	-20.96
1.5	70	-30.34
10	45	-24.48
105	20	-13.21
600	10	-8.18
10000	0	

Standard Steel Pipe (inches)

COLEBROOK - WHITE

$$\frac{1}{\sqrt{f}} = -2 \, \text{LOG}\left(\frac{K_s/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$$

	Nominal Size	3	4	5	6	8	
	OD (in.)	3.5	4.5	5.563	6.625	8.625	
	t	0.216	0.237	0.258	0.28	0.322	
	ID (in)	3.068	4.026	5.047	6.065	7.981	
	Area (ft^2)	0.051	0.088	0.139	0.201	0.347	
	Velocity (ft/s)	13.9	8.1	5.1	3.6	2.1	
	ID/Ks	51,133	67,100	84,117	101,083	133,017	
	RE	2.5E+05	1.9E+05	1.5E+05	1.3E+05	9.7E+04	
	f	0.009	0.009	0.008	0.008	0.008	HD 224-1/1 Colebrook-White Eqtn.
	fL/ID	0.330	0.252	0.201	0.167	0.127	
	ΣK	4.78	4.78	4.78	4.78	4.78	
Headloss	HL	15.3	5.1	2.0	1.0	0.3	HL = (fL/D + ΣK) * V^2/2g

Remaining available head for valve control (Hav) = Ha(min) - HL

	3	4	5	6	8	
Hva	22.7	32.9	36.0	37.0	37.7	Hva = Ha(min) - HL

Headloss Butterfly Valve head loss (HLv) = Kv(Vo) * V^2/2g

valve °	3	4	5	6	8	
20	314	106	43	21	6.9	
45	30	10.1	4.1	2.0	0.7	
70	4.5	1.5	0.6	0.3	0.1	
Required Kv	7.6	32.6	87.9	188.8	576.2	Req. Kv = Hva/(V^2/2g)
Valve Opening (°)	49	32	22	17	10	Vo = f(Req. Kv) in degrees
Valve % opening	54%	36%	24%	18%	11%	Vo in % opening

USE 4 inch pipe More available pipe size

<u>Check on Valve's operability at maximum available head:</u>

LPS number = **2**

Initial LPS Q = 320 gpm = 0.71 cfs

Neglect headloss in 4" pipe

Maximum available head (Ha(max)) = 44 feet

Nominal Size	3	4	5	6	8	
Velocity (ft/s)	13.9	8.1	5.1	3.6	2.1	
Remaining available head for valve control						
Hva	44.0	44.0	44.0	44.0	44.0	
Hva within limits?	OK	OK	High	High	High	
Required Kv	14.7	43.6	107.6	224.4	672.8	
Est. valve Opening	41	29	20	16	10	degrees
Valve % opening	45%	33%	22%	17%	11%	

USE 3 inch Control Valve

Item 2: The Dalles LPS EPANet Analysis

Purposes:

- Develop EPANet Pipe Network Model of LPS 4” pipe with main 12” header and 6” Irrigation pipe.
- Run simultaneous operation of LPS and Irrigations systems
  - Run simulations that alternately close one of the systems
  - Confirm the changes in LPS or Irrigation outlet pressures are small

The Dalles East Adult Fish Ladder LPS Supply Pipe EPANet Results

EPANet Pipe network analyses to confirm new LPS pipeline will not interfere with existing Irrigation system and vice versa.

		Date
Prepared by	CSM	2/4/2022
Checked by	SJS	2/7/2022

References:

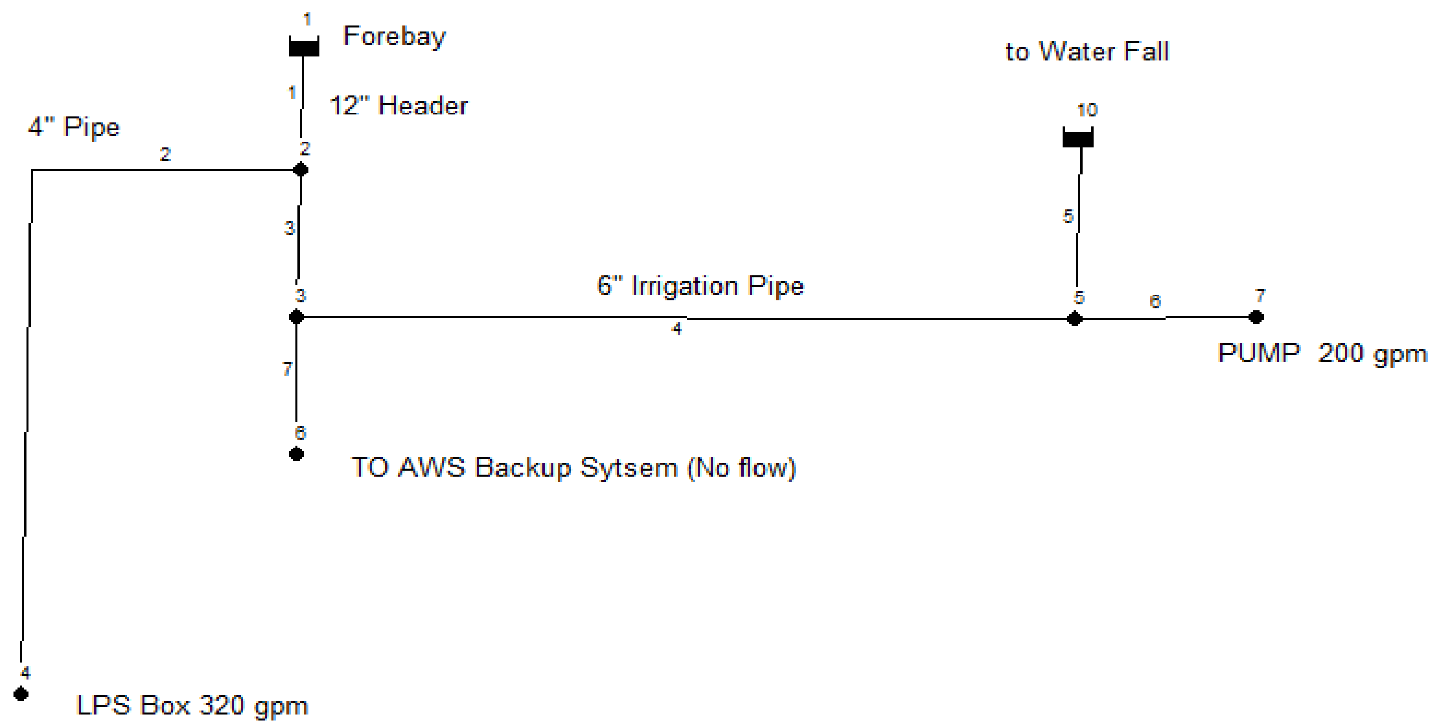
USACE, The Dalles East Fish Ladder AWS Backup System - As Constructed, September 2019. M-100 series, Field sketches and FS050, 1
USACE, The Dalles Lock & Dam Visitor Facilities & Irrigation System As-Builts 1975. DDG-40-5 series
Hydraulic Design Criteria (HDC), USACE-Waterways Experiment Station (1986)
Miller (1990), Internal Flow Systems

The following EPANet results confirm that the simultaneous operations of the LPS and Irrigation system will have minimal impacts on each other's operation:

Pressure difference at LPS box between open and closed Irrigation system:	0.07	psi
Pressure difference at Irrigation Pump feed between open and closed LPS system:	0.00	psi

The EPANet results for a simultaneous operation is provided in the following pages

- Plan schematic of Pipe Network
- Table of Nodes (Reservoirs and junctions) with elevations, head, pressure and demand
- Table of Links (pipes) with lengths, diameters, wall roughness, minor loss coefficients, flows and velocities


1
Forebay
1
12" Header
4" Pipe
2
2
3
3
6" Irrigation Pipe
4
7
6
TO AWS Backup Sytsem (No flow)
to Water Fall
10
5
5
6
7
PUMP 200 gpm
4
LPS Box 320 gpm

Espinet Results

Network Table - Nodes

Description	Node ID	Elevation ft	Demand CFS	Head ft	Pressure psi
Forebay	Resvr 1	155	-1.59	155.00	0.0
Wye to LPS	Junc 2	90	0	154.82	28.1
Wye to Irr. Pp.	Junc 3	0	0	154.81	67.1
LPS Box	Junc 4	116	0.71	129.00	5.6
Wye to Pump	Junc 5	0	0	131.62	57.0
AWSBS	Junc 6	112	0	154.81	18.6
Pump	Junc 7	120	0.45	128.12	3.5
Water fall	Resvr 10	120	0.43	120.00	0.0

Network Table - Links

	Link ID	Length ft	Inside Diameter in	Roughness 10^{-3} ft	Σ Minor Loss Coef.	Pipe Flow CFS	Velocity fps	Unit Headloss ft/Kft	Nodes u/s	Nodes d/s
12" Header	Pipe 1	50	11.5	0.1	1.55	1.59	2.21	3.7	1	2
4" LPS Supply	Pipe 2	405	4.026	0.1	4.78	0.71	8.03	63.7	2	4
12" Header	Pipe 3	10	11.5	0.1	0.4	0.88	1.23	0.9	2	3
6" Irrigation	Pipe 4	1500	6.06	1	4	0.88	4.42	15.5	3	5
6" to Water Fall	Pipe 5	10	6	1	152	0.43	2.21	1161.6	5	10
3" to Pump	Pipe 6	10	3.07	1	1.8	0.45	8.75	348.8	5	7
12" to AWSBS	Pipe 7	50	11.5	0.1	3	0	0	0	3	6