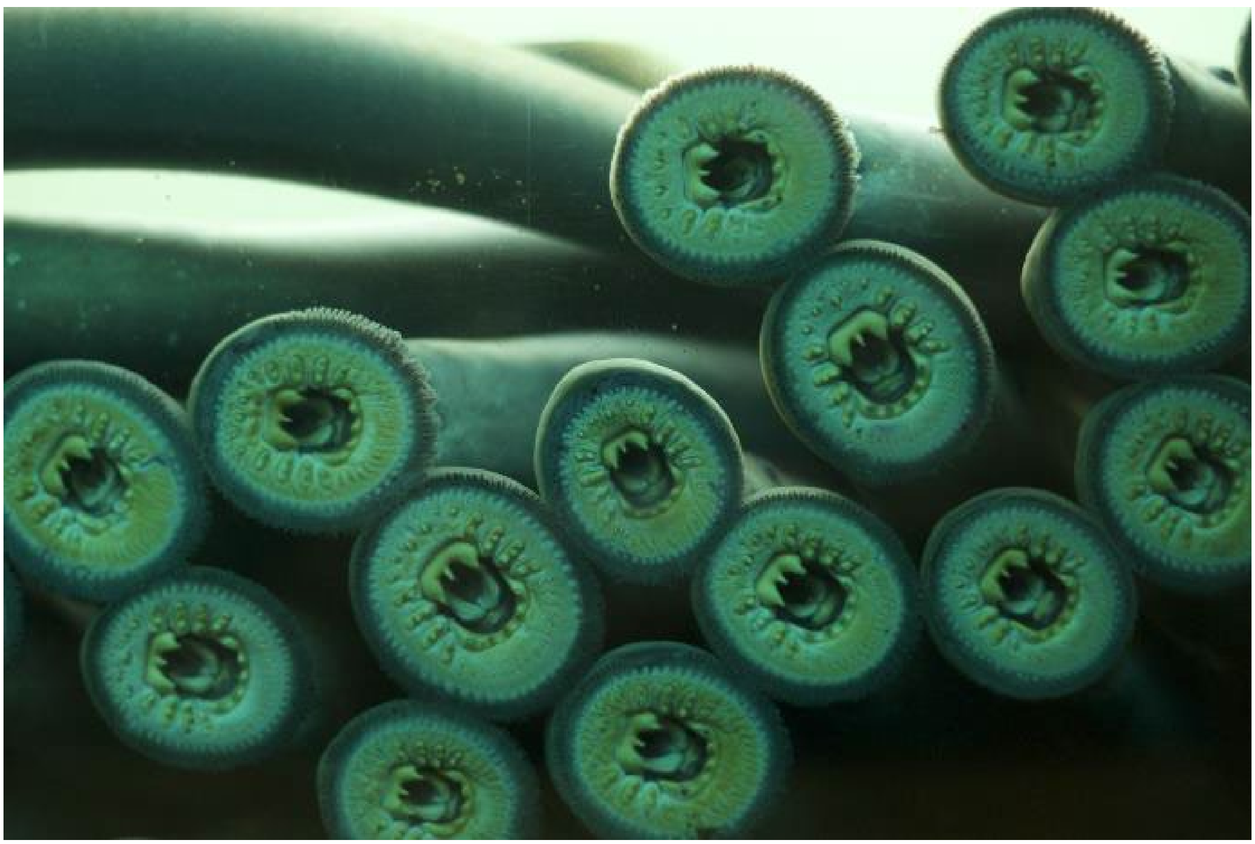
US Army Corps
of Engineers®
Portland District

DESIGN DOCUMENTATION REPORT NO. 1

BONNEVILLE DAM
BRADFORD ISLAND FISH LADDER
CASCADES LOCKS, OREGON

FY19 FISH ACCORDS LAMPREY PASSAGE – BONNEVILLE BRADFORD ISLAND



90 Percent DDR
August 2022

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EXECUTIVE SUMMARY

1. INTRODUCTION

This Design Documentation Report (DDR) covers design for the Bonneville Bradford Island Entrance Improvements and Lamprey Collection System. This report describes the project background and outlines technical aspects of the selected plan.

The Bonneville Bradford Island fish ladders have low lamprey passage rates. It was determined that the B-Branch entrance would be modified to improve lamprey passage based on previous improvements on the Cascades Island fish ladder and the John Day north ladder entrances. The entrance improvements will be made during the FY24 in-water work period.

The entrance improvements will be beneficial to both lamprey and salmon. The improvements for lamprey include rounded corners on the fixed entrance weir, making the invert flush with the ladder floor, and inserting slot fillers in the stop log slots when the Sea Lion Exclusion Device (SLED) is not in use. The improvements for salmon include lowering the weir invert 4 feet and the entrance head and channel velocity criteria will be met at a larger range of tailwater elevations than the existing weir. A new Lamprey Passage System (LPS) will be installed in the entrance approach pool and will provide passage for lamprey up to a new collection box.

In addition to the proposed entrance improvements, minor modifications are also proposed in the existing serpentine exit section. The modifications include rounding of the sharp protruding corners that hinder lamprey passage and additional refuge boxes and lamprey orifices.

The total cost of construction will be estimated for the next milestone as Cost Engineering begins to develop estimates based on the plans and specifications.

2. PURPOSE

The purpose of this project is to improve lamprey passage through the Bradford Island fish ladder system and provide lamprey collection.

3. PROJECT LOCATION

This project is located at the B-Branch entrance to the Bradford Island fish ladder system at the Bonneville Dam. The proposed lamprey collection system will be located near the B-Branch entrance.

4. DESCRIPTION OF FACILITY

The Bradford Island fish ladder system has multiple entrances at Powerhouse 1 for the A-Branch and at the south end of the spillway for the B-Branch. Both branches converge in a junction pool located near the visitor's center, and then exit into the Powerhouse 1 forebay on the south side of Bradford Island.

5. CONSTRUCTION ACCESS

TBD – this section will be updated at a later stage in the development of plans and specifications.

6. CONSTRUCTION SCHEDULE

TBD, at this point we're assuming 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 Bonneville Dam will not be disturbed during construction.

8. COST

The construction cost was estimated at $3.95M per the 60% plans and specifications. This figure includes contingency. The cost estimate will be further refined based on the 90% plans and specifications and presented in the next milestone review.

CONTENTS

TABLES

FIGURES

APPENDICES

PREVIOUS AND PLANNED REPORTS

Number	Title	Date
DM 1	Bonneville Dam, Design Memorandum 1 Modifications for Peaking, USACE Portland District	1971
	Bonneville and John Day Dams Lamprey Passage Structure Development and Improvement, Phase I Design Document Report 90% Draft, USACE Portland District	2015
	Operations Manual: Bonneville Dam Lamprey Passage Structures Bradford Island Auxiliary Water Supply LPS, provided by Northwest Fisheries Science Center, National Marine Fisheries Service for USACE Portland District	2015
	Bonneville Dam Lamprey Passage Structure Development and Improvement, Phase II Design Document Report 90% Draft, USACE Portland District	2018
	Operations Manual: Bonneville Dam Lamprey Passage Structures Washington Shore Auxiliary Water Supply LPS provided by Northwest Fisheries Science Center, National Marine Fisheries Service for USACE Portland District	2015

ACRONYMS

Acronym	Description
AFF	Adult Fish Facility
AISC	American Institute of Steel Construction
APE	Area of Potential Effects
AWS	Auxiliary Watering System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFD	Computational Fluid Dynamics
CFS	Cubic Foot/Feet per Second
CRFM	Columbia River Fish Mitigation Program
CRITFC	Columbia River Inter-Tribal Fish Commission
CRS	Columbia River System
CTLWG	Corps-Tribal Lamprey Work Group
DDR	Design Documentation Report
EGC	Equipment Grounding Conductor
EIS	Environmental Impact Statement
EL	Elevation
EM	Engineer Manuals
ER	Engineer Regulations
ESA	Endangered Species Act
FCRPS	Federal Columbia River Power System
FEIS	Final Environmental Impact Statement
FOPC	Fiber Optic Patch Cabinet
FPOM	Fish Passage Operations & Maintenance
GPM	Gallon(s) per minute
HMI	Human-Machine Interface
HSS	Hydraulic Steel Structure
HTRW	Hazardous, Toxic and Radiological Waste
I/O	Input/Output
IGE	Independent Government Estimate
IWW	In-Water Work Window
LAWPS	Low Angle Weired Passage System
LPS	Lamprey Passage System
MCACES	Micro Computer Cost Estimating System
MOA	Memorandum of Agreement
MPH	Miles Per Hour
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association

NGVD	National Geodesic Vertical Datum
NMFS	National Marine Fisheries Service
NPS	National Park Service
O&M	Operations and Maintenance
OBE	Operational Basis Earthquake
OD	Outside Diameter
PCF	Pounds Per Cubic Foot
PDT	Product Development Team
PIT	Passive Integrated Transponder
PSF	Pounds Per Square Foot
RFID	Radio Frequency Identification
RGS	Rigid Galvanized Steel
RME	Research, Monitoring, and Evaluation
ROD	Record of Decision
SCADA	Supervisory Control and Data Acquisition
SHPO	Oregon State Historic Preservation Officer
SLED	Sea Lion Exclusion Device
THPO	Tribal Historic Preservation Officer
UFC	Unified Facilities Criteria
USACE	United States Army Corps of Engineers
VAC	Volts Alternating Current
VFD	Variable Frequency Drive

SECTION 1 - PURPOSE AND INTRODUCTION

1.1 INTRODUCTION

The ultimate goal of the Corps' Pacific Lamprey (Entosphenus tridentatus) passage efforts is to understand and improve both juvenile and adult lamprey passage and survival through the eight Corps multi-purpose dams on the lower Columbia and Snake rivers (Columbia River System 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. The U.S. Army Corps of Engineers' (Corps) FY20 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.

1.2 BACKGROUND

1.2.1 2020 CRS Proposed Action

In September 2020, the Corps signed a Record of Decision (ROD) adopting the Preferred Alternative described in the Action Agencies' (Bonneville Power Administration, Bureau of Reclamation, Corps) Final Environmental Impact Statement (FEIS) for the long-term coordinated operation and management of the Columbia River System (CRS) Project. Several adult and juvenile lamprey passage improvement measures were considered in the Environmental Impact Statement (EIS) and integrated into the EIS's Selected Alternative. The Selected Alternative included the following structural measures to improve lamprey survival:

- Bypass screen modifications for juvenile lamprey passage. The Corps will replace existing extended-length bar screens with screens designed to reduce juvenile lamprey entanglement at Little Goose and Lower Granite dams. The upgrades would occur when existing screens need replacement.
- Bonneville ladder serpentine weir modifications. This measure would modify the serpentine-style flow control sections of Bonneville Dam's Washington Shore and Bradford Island fish ladders to improve passage conditions for adult lamprey and likely reduce stress and delay for adult salmon, steelhead, and bull trout.
- Expand network of LPS's to bypass impediments in existing fish ladders. New structures may be installed 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.
- Modify turbine cooling water strainer systems to safely exclude Pacific lamprey and other juvenile fish.
- Modify existing fish ladders, incorporating lamprey passage features and criteria into ladder modifications at the lower Snake and Columbia River dams. Modifications may include 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.

1.2.2 Columbia Basin Fish Accords MOA

From 2008-2018, the Corps addressed many adult, juvenile, and larval lamprey passage issues and research, monitoring and evaluation (RME) needs at its Columbia and Snake River dams using 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, a new Columbia Basin Fish Accords MOA was negotiated then further extended in a 2020 MOA without change to the commitments within. The 2018/2020 Fish Accords extensions include commitments by the Corps to:

1. Continue coordinating and collaborating on Pacific Lamprey issues through participation in the Pacific Lamprey Conservation Agreement, interagency meetings, and technical workgroup meetings, including the U.S. Fish and Wildlife Service's Lamprey Technical Workgroup.
2. Continue counting adult lamprey that pass Lower Columbia and Snake River dams.
3. Provide access to the Tribes to collect adult lamprey at Corps dams in support of tribal restoration actions.
4. Operate and maintain existing lamprey passage facilities.
5. Integrate lamprey design considerations into future Columbia River Basin plans for adult and juvenile salmonid passage facilities.
6. <u>*Seek funding*</u> to finalize and implement a plan to continue to improve Pacific Lamprey passage conditions at Corps dams, to include:
    a. Additional adult lamprey passage improvements at Corps dams
    b. Develop/implement a strategy to obtain more accurate adult counts at Corps dams
    c. Develop/implement an RM&E plan regarding adult lamprey migration behavior and fate above Bonneville
    d. Develop/implement a juvenile lamprey RM&E plan

1.2.3 NWD 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 Northwestern Division's 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 RME, and estimate program costs by fiscal year, to be implemented with the $20M received. The Implementation Plan will be updated annually to adapt to changes in priorities and project budgets.

1.3 PROJECT DESCRIPTION

The project scope is divided into three parts:

1.3.1 Entrance Modifications

Modify the B-branch fish ladder entrance to improve lamprey passage. This includes a variable-width entrance weir with rounded edges, guide slot fillers or covers to aid lamprey passage along the walls, and bollards on the channel floor for hydraulic refuge.

1.3.2 Lamprey Collection

Provide an alternate route for lamprey entering the B-branch of the Bradford Island fish ladder. Fish would climb up a flume structure to a holding tank on the deck of the dam and be transported upstream by Tribal fisheries personnel. This will be designed so that in the future we could extend the system to provide volitional passage to the Bonneville forebay. This Product Development Team (PDT) will have to decide if the future volitional passage system will terminate on the north or south side of Bradford Island, which will determine where we place the collection box for the current scope of work.

1.3.3 Serpentine Section Extensive Minor Mods

Upgrade the serpentine section of the Bradford Island fish ladder to improve lamprey passage by rounding corners, providing refuge boxes, and lamprey orifices.

1.4 PROJECT OBJECTIVES

The objectives are to increase lamprey passage through the Bradford Island fish ladder and install a lamprey collection system which can be extended in the future to provide volitional passage over the dam.

1.5 PREVIOUS STUDIES AND REPORTS

The design of this project will be based on the success and lessons learned from lamprey passage systems on Bradford Island, Cascades Island and on the Washington Shore.

1.6 PROJECT CONSTRAINTS

1.6.1 Environmental

Any modifications to the existing fish ladders cannot be detrimental to salmon passage. The Bradford Island Upland Operable Unit of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) area of study and remediation is located on the eastern third of Bradford Island, with the boundary being in-line with the spillway. This project will not require any excavation within the eastern part of the island within the CERCLA study.

1.6.2 Construction

Construction in the fish ladder can only occur during the winter maintenance period, which is November 30th through February 27th. This PDT's intent is to complete plans and specifications and award before winter 2023, so that construction can occur during the winter 23-24 dewatering period.

1.6.3 Cost

This project is funded by the FY2020 Work Plan budget and has been allocated $2.3M for design and construction. Any increases above 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 DESIGN REFERENCES

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

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.

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

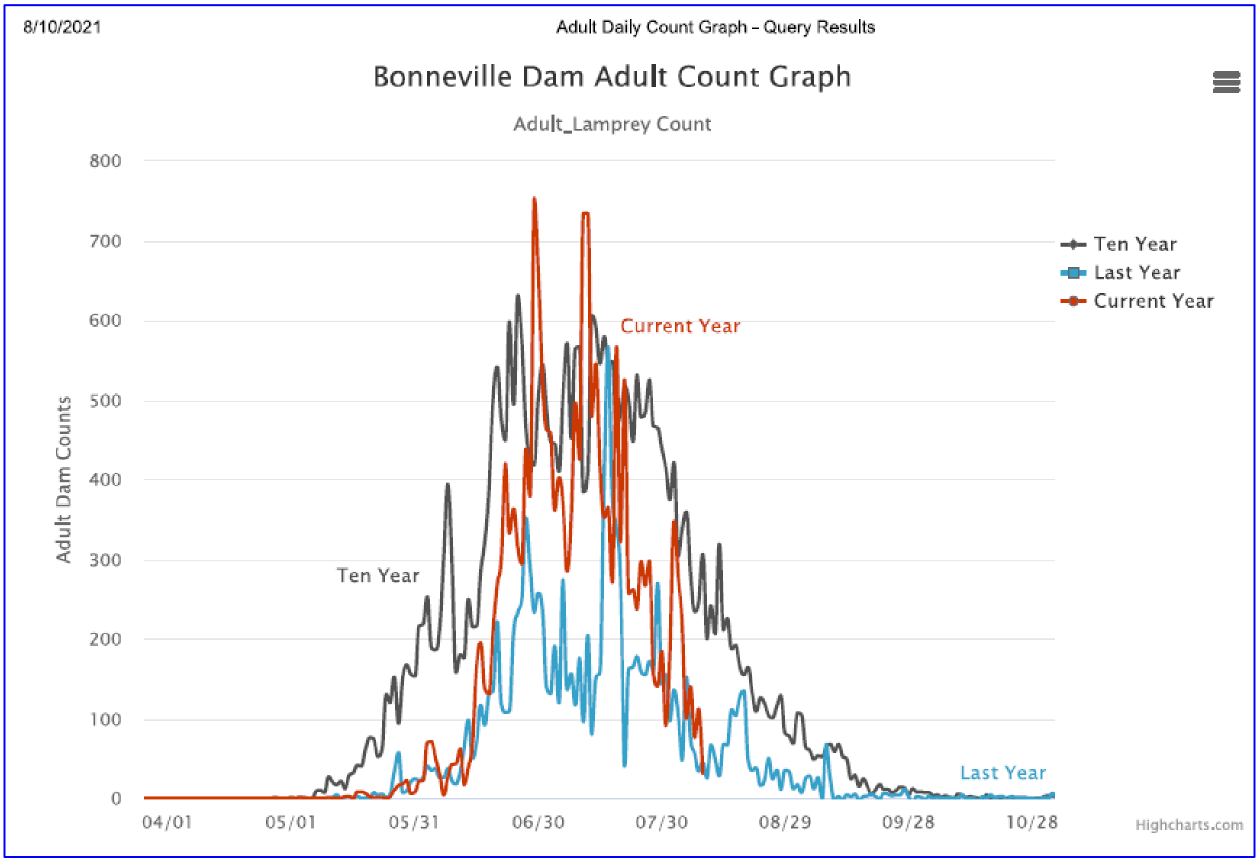
Keefer, M.L. C.C. Caudill, T.S. Clabough, M.A. Jepson, E.L. Johnson, C.A. Peery, M.D. Higgs and M.L. Moser. 2013. Fishway passage bottleneck identification and prioritization: a case study of Pacific lamprey at Bonneville Dam.

2.2 DESIGN ASSUMPTIONS

Identical entrance improvements were implemented at the Cascades Island spillway entrance in 2009. Post-construction evaluation of the Cascades Island spillway entrance improvements demonstrated entrance efficiency was significantly higher in the post-modification years (2009 = 59.5%; 2010 = 61.1%) than pre-modification years (2008 = 33.3%; 2007 = 0.50; $P<0.001$), suggesting some post-modification benefit for lampreys (Clabough 2011). We expect to realize similar fish passage benefits at the Bradford Island spillway entrance with a similar design.

The primary Lamprey passages season at Bonneville runs from May through August. Peak passage occurs in June & July. Figure 2-1 shows a 10-year average of lamprey passage at Bonneville.

Figure 2-1. Bonneville Project Discharge versus Percent of Time Exceeded for the Calendar Year.



2.3 DESIGN CRITERIA

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 Endangered Species Act (ESA) listed species. All in-water work will occur during the annual in-water work window (December-March) and all components of the fishway will operate normally in accordance with the Fish Passage Plan and within National Marine Fisheries Service (NMFS) operation criteria between April and November.

2.3.1 LPS Design Criteria

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

2.3.1.1 *Max elevation gain between rest boxes*

The better-performing LPS's at Bonneville Dam have a maximum elevation gain between rest boxes less than 11.5 feet.

2.3.1.2 *Entrance location*

LPS entrance(s) should be located where lamprey milling is observed. Keefer et al. 2013 analyzed 10 years of radio telemetry data and present data suggesting 49% (263 out of 541 recorded entry events) of lamprey that entered the Bradford Island B-branch fishway turned around and exited back to the tailrace before reaching the first submerged weir. Aside from the entrance itself, the fishway segment between the entrance weir and submerged weirs is the biggest lamprey passage bottleneck in the B-branch fishway. Lamprey milling has been observed immediately downstream of the first submerged weir (Derugin, personal comm.) and is assumed to occur in the fishway entrance channel and fish lock approach channel.

2.3.1.3 *Traversing duct*

Traversing duct sections should be nearly horizontal with a maximum slope of 0.0035, duct width should be between 0.7 and 1.6 feet with a minimum turning radius of 1.6 feet and 16-degree contraction angle. Mean velocity in the traversing section should be 1.0 ft/sec with no velocity exceeding 3.0 ft/sec.

2.3.1.4 *Climbing duct*

Target slope for climbing ducts should be 1:1. Ducts should be oriented downstream and 1.64 feet wide with no contractions. Mean velocity in the climbing section should be 7.9-11.8 ft/sec.

2.3.2 Entrance Weir design criteria

NMFS (2011) provides specific biological criteria and guidelines for fishway entrances.

2.3.2.1 *Hydraulic drop*

The fishway entrance head must be designed to operate from 0.5 to 2.0 feet and maintained between 1.0 and 1.5 feet.

2.3.2.2 *Dimensions*

The minimum fishway entrance width should be 4 feet, minimum entrance depth should be 6 feet.

2.3.2.3 *Flow conditions*

Discharge through the entrance weir should be streaming flow. Plunging flow induces jumping that may cause injury and a potential passage barrier for some species.

2.3.2.4 *Entrance pool velocity*

Velocities between the entrance weir and the first fishway weir must be between 1.5 and 4.0 ft/s. Further reduction in velocity near the fishway floor to benefit lamprey will be accomplished with bollards.

2.4 DESIGN RECOMMENDATIONS

2.4.1 LPS Entrance location

LPS entrance(s) should be located where lamprey milling is observed. Keefer et al. 2013 analyzed 10 years of radio telemetry data and present data suggesting 49% (263 out of 541 recorded entry events) of lamprey that entered the Bradford Island B-branch fishway turned around and exited back to the tailrace before reaching the first submerged weir. Aside from the entrance itself, the fishway segment between the entrance weir and submerged weirs is the biggest lamprey passage bottleneck in the B-branch fishway. Lamprey milling has been observed immediately downstream of the first submerged weir (Derugin, personal comm.) and is assumed to occur in the fishway entrance channel and fish lock approach channel. An LPS entrance in the fishway entrance channel at the upstream end of the bollard field is the highest priority. Future PDTs may consider additional LPS entrances in the transition channel (downstream from the first submerged weir) and the “cul-de-sac” approach channel to the decommissioned fish lock.

SECTION 3 - HYDRAULIC DESIGN

This chapter describes the hydraulic design of specific features pertinent to the proposed lamprey improvements at Bradford Island Fish ladder.

3.1 DESIGN REFERENCES

AECOM, Inc. Bonneville Cascade Island Prototype Entrance Modification for Improved Lamprey Passage, CFD Modelling Final Report. Document No. 09000-449-402. Prepared for USACE, Portland District. February 27, 2009.

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.

ENSR Corporation, April 2008. John Day North Physical Hydraulic Model Study Final Report. Prepared for USACE Portland District, 2008.

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.

Northwest Hydraulics Consultants, 2000. Fish Ladder Pit Tag Detector Antenna Weir, Hydraulic Model Study. Prepared for USACE Portland District, 2000.

USACE, Division Hydraulic Laboratory, U.S. Army Engineer Division, North Pacific. 1973. Modification of Fishladders, Bonneville; Oregon and Washington. Hydraulic Model Investigation.

USACE, Portland District. 1974. Bonneville Lock and Dam, Modification for Peaking, Fish Facilities. As-Constructed drawings.

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USACE, Portland District. 2003 Bonneville Lock and Dam: Hydraulic Evaluation of Lower Columbia River Adult Bypass Systems (HELCRABS) Bradford Island A Branch Interim Evaluation Report. 80% Draft, 2003.

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USACE, Portland District, John Day Lock and Dam North Fish Ladder Entrance Improvements Plans and Specifications As-Constructed. April 7, 2015.

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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 Geodesic 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 74.5 feet during the juvenile salmon fish passage season (March – November).

- Minimum: 70 feet
- Maximum: 77 feet

- Normal range: 72 – 76.5 feet
    - Forebay is within the normal range 98% of time.
    - Lowest Forebay in last 10 years was 72 feet.

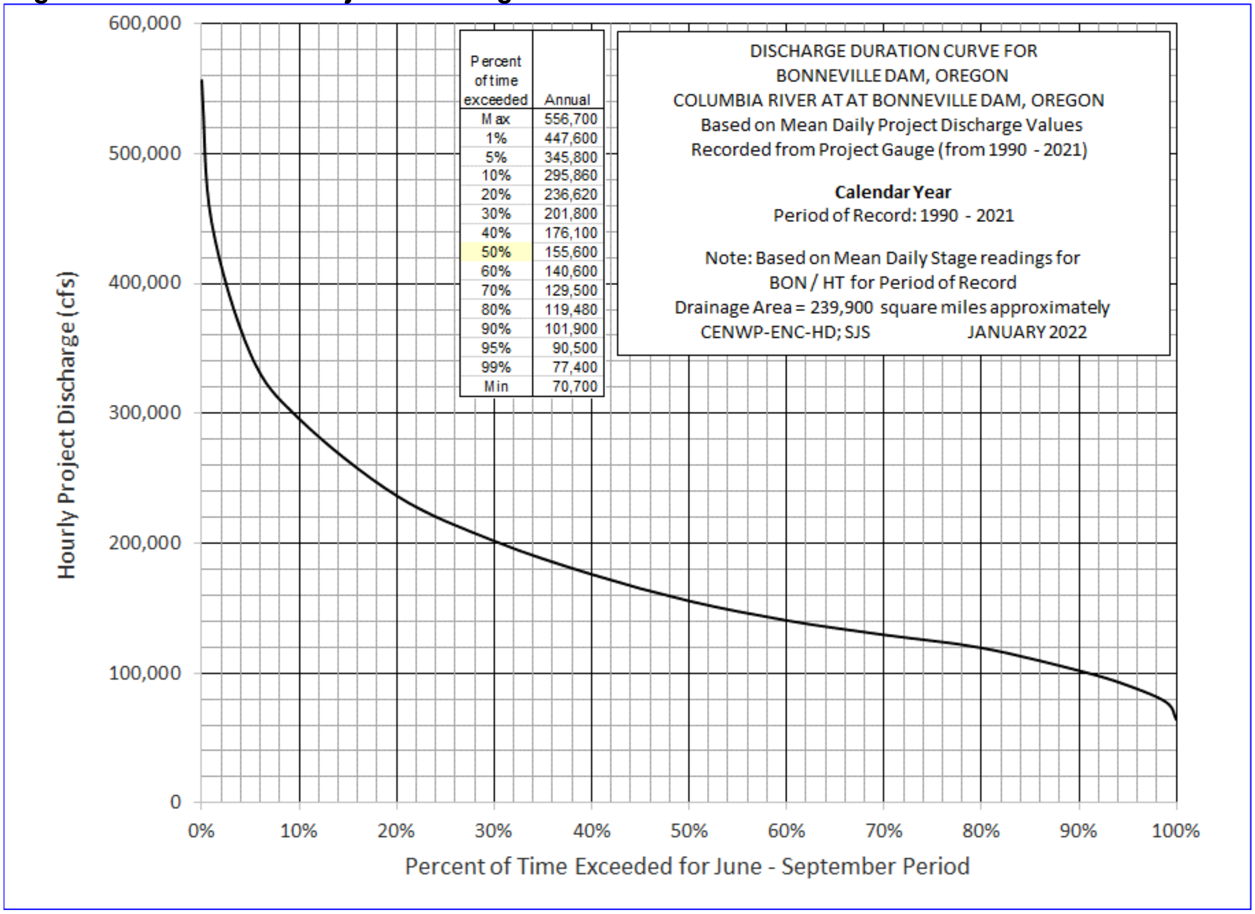
3.2.1.1 *Bonneville River Flow Rates and Discharge Duration Curves*

Pertinent hourly river flow rates in cubic feet per second (CFS) over a 1990 – 2021 record include:

- Minimum 70.7 kCFS
- 95% exceedance 90.3 5 kCFS
- 90% 101.9 kCFS
- 70% 129.5 kCFS
- Median (50% exceedance) 155.6 kCFS
- 30% 201.8 kCFS
- 10% 295.9 kCFS
- 5% exceedance 345.8 kCFS
- Maximum 556.7 kCFS

The Bonneville river flow duration curves fare defined as the flow rate versus percent of time exceeded on a daily or hourly basis. Figure 3-2 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 an hourly discharge record from 1990 - 2021.

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



Peak lamprey passage times occurs at Bonneville during May through August, 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 3-2 provides a chart showing daily discharge versus percent of time (hours) in which the project discharge was exceeded during the May through August. This chart is based on a mean daily discharge record from 1990 - 2021. Table 3-1 shows the Figure 3-2 data in tabular form and includes the calendar year (annual) data for comparison.

Figure 3-2. Bonneville Project Discharge versus Percent of Time Exceeded for the May - August.

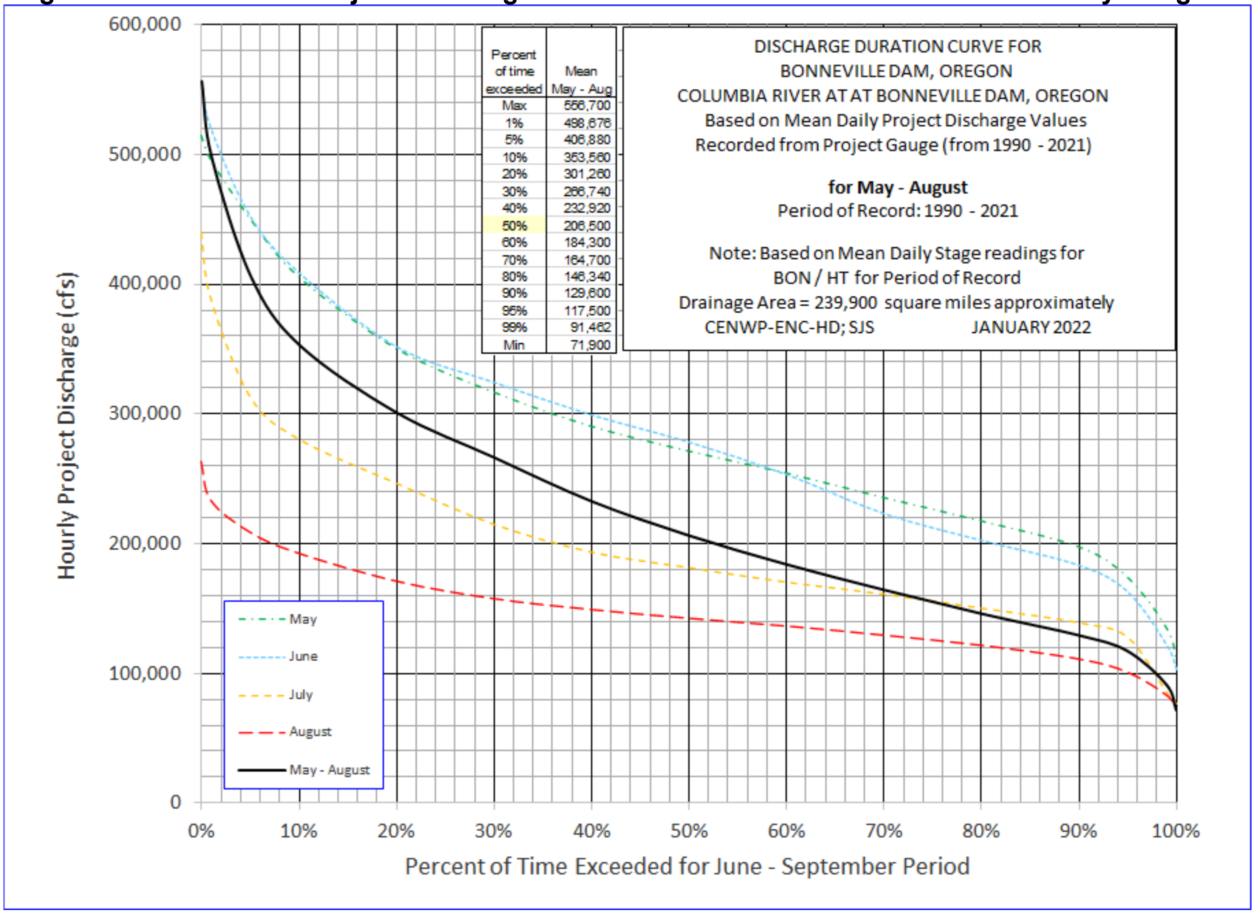


Table 3-1 Tabular Data of Discharge versus Percent of Time Exceeded for the May - August.

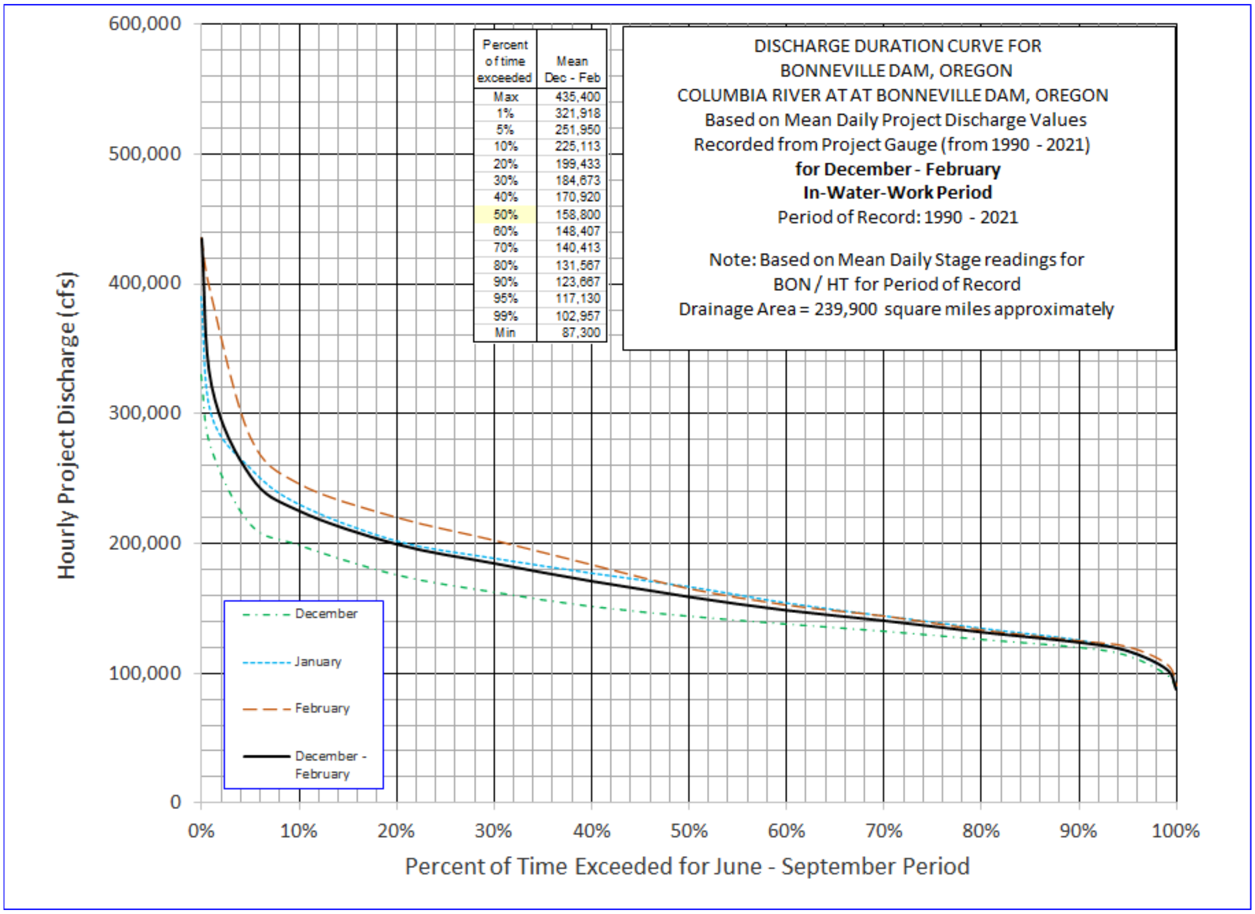
Bonneville Lock and Dam
Mean Daily Project Discharge for May - August
(Period of Record 1990 - 2021)

Percent of time exceeded	Annual	Spring/Summer Freshet Period					
		April	May	June	July	August	Mean May - Aug
Max	556,700	468,000	515,000	556,700	439,900	263,200	556,700
1%	447,600	437,676	496,200	520,108	388,930	233,172	498,676
5%	345,800	370,300	451,030	452,785	313,350	208,645	406,880
10%	295,860	336,500	405,970	409,060	280,500	192,410	353,560
20%	236,620	296,640	350,680	351,980	246,400	170,920	301,260
30%	201,800	264,520	316,970	324,430	214,700	157,400	266,740
40%	176,100	236,800	290,720	299,360	193,200	149,000	232,920
50%	155,600	217,600	271,550	278,400	181,200	142,250	206,500
60%	140,600	191,700	254,600	253,440	170,000	136,300	184,300
70%	129,500	169,660	235,670	223,300	160,700	129,200	164,700
80%	119,480	152,140	217,600	202,680	149,900	121,400	146,340
90%	101,900	131,900	197,610	183,460	138,600	110,790	129,600
95%	90,500	122,930	173,895	162,850	127,150	100,490	117,500
99%	77,400	106,906	134,201	121,570	84,170	82,514	91,462
Min	64,200	93,500	109,300	103,100	75,900	71,900	71,900

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 3-3 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 an hourly 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.

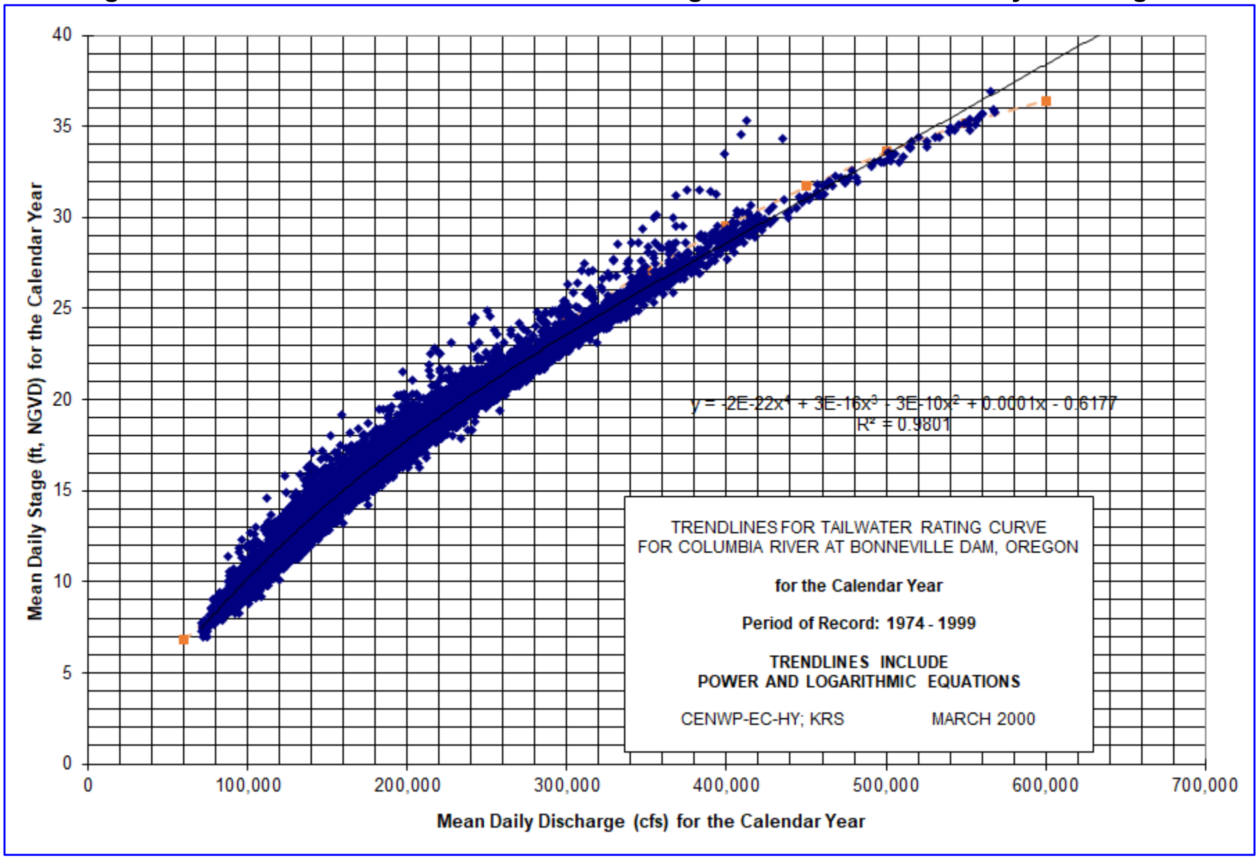
Figure 3-3. Bonneville Project Discharge versus Percent of Time Exceeded for the In-Water Work Period.



3.2.1.2 *Tailwater versus Project Outflow Rating Curves*

Bonneville tailwater elevations are dependent on project discharge and tidal influences. Figure 3-4 provides a chart showing daily tailwater elevation rating curve versus mean daily project discharge. This chart was previously developed by CENWP-EC-HY based on daily records from 1974 - 1999.

Figure 3-4. Bonneville Tailwater Elevation Rating Curve versus Mean Daily Discharge.



3.2.1.3 *Tailwater Elevations*

Bonneville tailwater elevations are dependent on project discharge and tidal influences. Figure 3-5 provides a chart showing hourly[1] tailwater elevation versus percent of time (days) in which the tailwater elevation was exceeded. This chart is based on a daily tailwater record over the calendar year from 1990 - 2021.

As noted previously, the peak lamprey passage period occurs between May - August. Hourly tailwater elevations versus percent of time (hours) in which the tailwater elevation was exceeded is shown in Figure 3-6 for the May -August period. This chart is based on an hourly tailwater record from 1990 - 2021.

[1] Mean daily tailwater elevations were not available before 2008.

Figure 3-5. Bonneville Tailwater Elevation versus Percent of Time Exceeded for the Calendar Year.

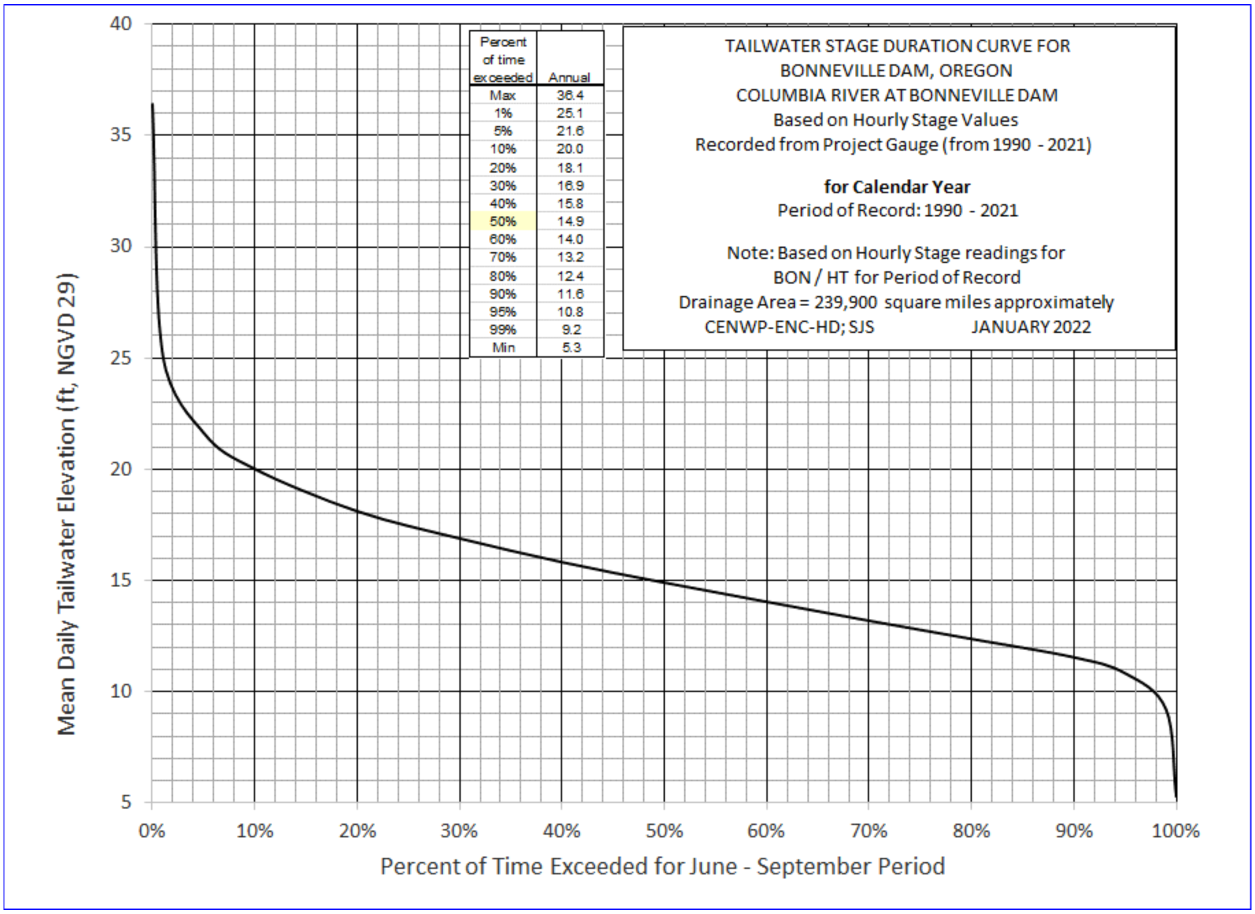
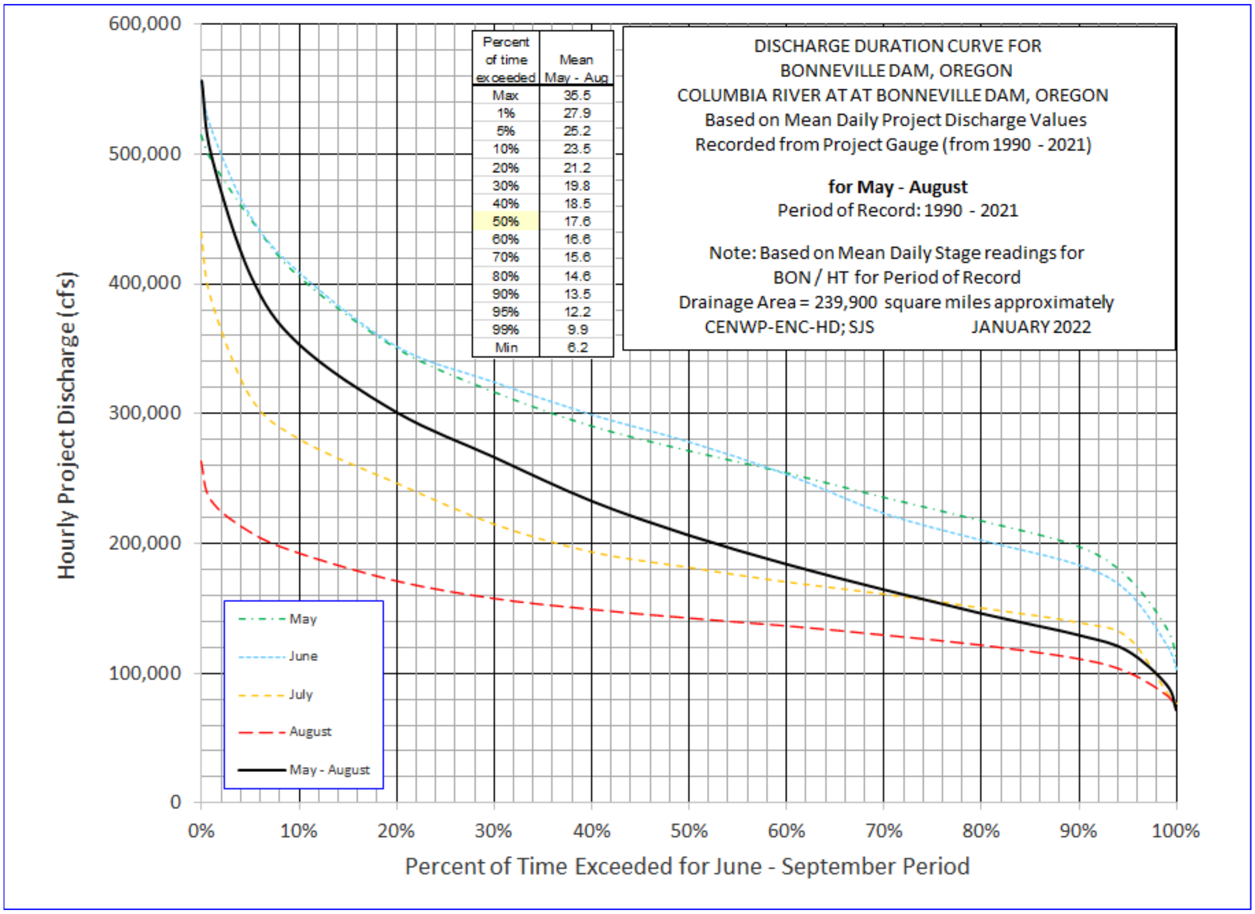


Figure 3-6. Bonneville Tailwater Elevation versus Percent of Time Exceeded for May – August.



Pertinent daily tailwater elevations during the May - August time frame include:

- Minimum 6.2 feet
- 95% exceedance 12.2 feet
- Median (50% exceedance) 17.6 feet
- 5% exceedance 25.2 feet
- Maximum 35.5 feet

The lowest rest box needs to located above the maximum expected level expected in Pool 1 of the fish ladder entrance, or approximately elevation (EL) 40 feet. The pool water levels will be about 2 feet higher than the tailwater elevation.

3.2.2 B-Branch Fish Ladder Entrance

Modifications to the B-Branch fish ladder entrance to are proposed to improve access for adult lamprey. The modifications will include a new variable width entrance structure and a system of bollards on the floor. These modifications will be largely equivalent to the modifications installed in 2008 at the entrance of Cascades Island fish ladder, a mirror image of B-Branch fish ladder.

3.2.2.1 *Variable Width Entrance Structure*

The entrance structure is a steel insert that is installed in existing bulkhead slots. The design of the entrance opening will be identical to that used at Cascades Island. This design was thoroughly evaluated in terms of flow rate analyses, a computational fluid dynamics (CFD) model, agency coordination and prototype testing. The performance of this entrance structure has been tested since 2009.

Figure 3-7 shows an elevation view (looking downstream) of the shape and relative position of the entrance opening within the 35-foot-wide entrance approach channel. The median tailwater elevation is indicated by the dashed blue line (Med TW). There are two existing sluice gates on the south (shore) side of the entrance bay that will be rarely used after the new entrance structure is installed.

The dimensions of the entrance structure are the following:

- Invert Elevation = 2 feet NGVD 29
- Lower width = 14 feet below elevation 10 feet
- Upper width = 5 feet above elevation 18 feet

3.2.2.2 *Floor Bollards*

Bollards will be installed on the floor of the entrance bay in a similar pattern that was applied at Cascade Island. The bollards will be attached to metal plating panels that will be attached to the concrete invert. The purpose of the bollards is the lower the velocities near the invert to allow easier access for the lamprey.

Figure 3-8 shows the general plan of the bollard layout (gray shading). The two red rectangles on the upper right represent the location of the new entrance structure. The lower blue rectangle represents the new LPS to which the bollards are guiding the fish.

There are two proposed differences with the B-Branch and the existing Cascade Island bollards:

- Bollards will guide lamprey to the south side of the entrance approach channel instead of the north side as at Cascades Island
- Bollards will be paddle shaped instead of round cylinders
    - Paddles were used in later design at John Day North Ladder and are believed more effective at reducing the velocity near the invert.
    - Paddles will be oriented in location specific directions to optimally create flow resistance and thereby reduce velocity near the invert.

Figure 3-9 shows a plan schematic of the arrangement of paddle-shaped bollards applied at John Day North Fish Ladder Entrance. The upper left corner shows the general paddle bollard design. The rounded-edge red rectangles represent the sides of the variable width entrance structure (similar in concept as proposed with B-Branch). The blue arrows represent general flow patterns and show the manner in which the paddle bollards provide flow resistance and shelter for lamprey. The orientation of the paddles was determined from CFD simulations through the variable-width entrance structure prior to adding the bollards. The paddles were angled to be perpendicular to the directions of the flow vectors in the vicinity of the paddle locations.

3.2.2.3 *Post construction prototype measurements versus CFD results*

Post construction prototype entrance flow measurements were taken at John Day North and Bonneville Cascade Island fish ladders. Post construction flow measurements indicated that the CFD overestimated the John Day entrance flow rate for equivalent tailwater and entrance head by approximately 30%. Conversely, the post-construction entrance flow rates were underestimated at Bonneville Cascade Island by the Cascade Island CFD model at equivalent tailwater and entrance head.

Figure 3-7. Proposed B-Branch Variable Width Entrance Structure.

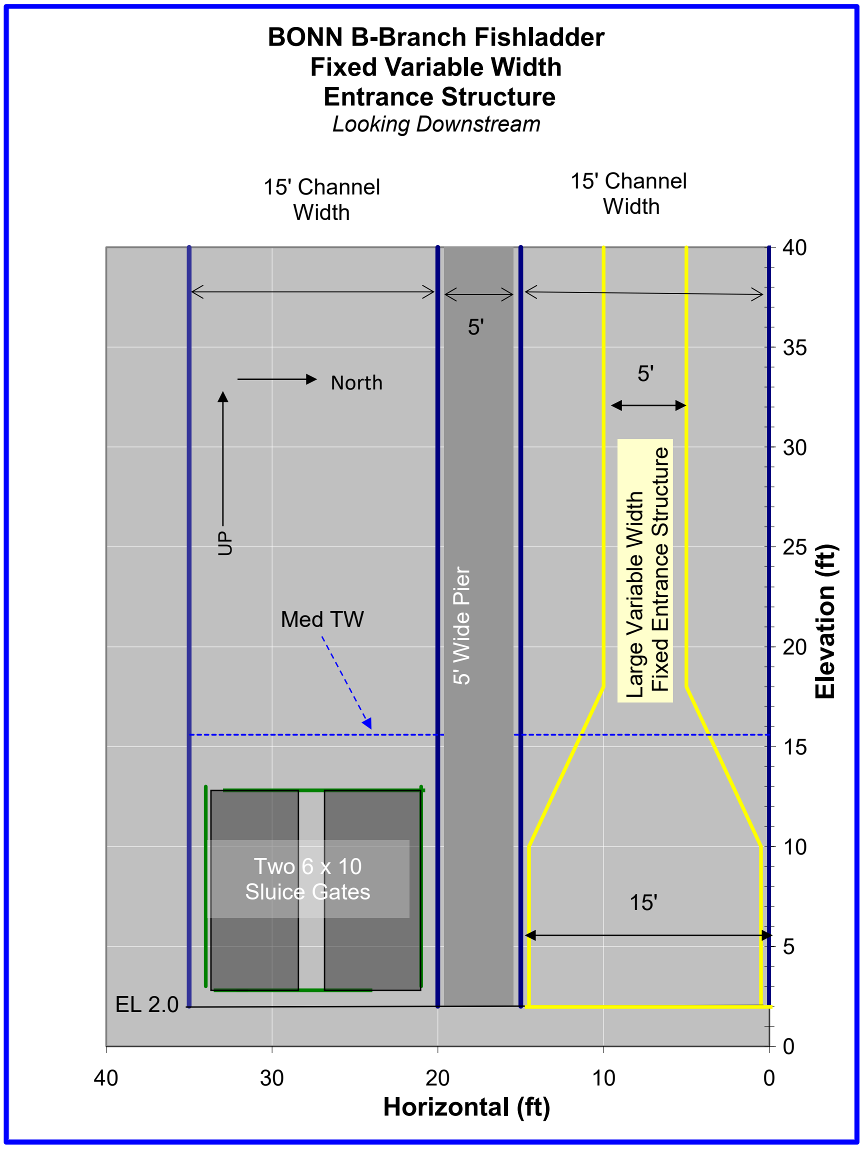


Figure 3-8. Preliminary B-Branch Entrance Bollard Plan.

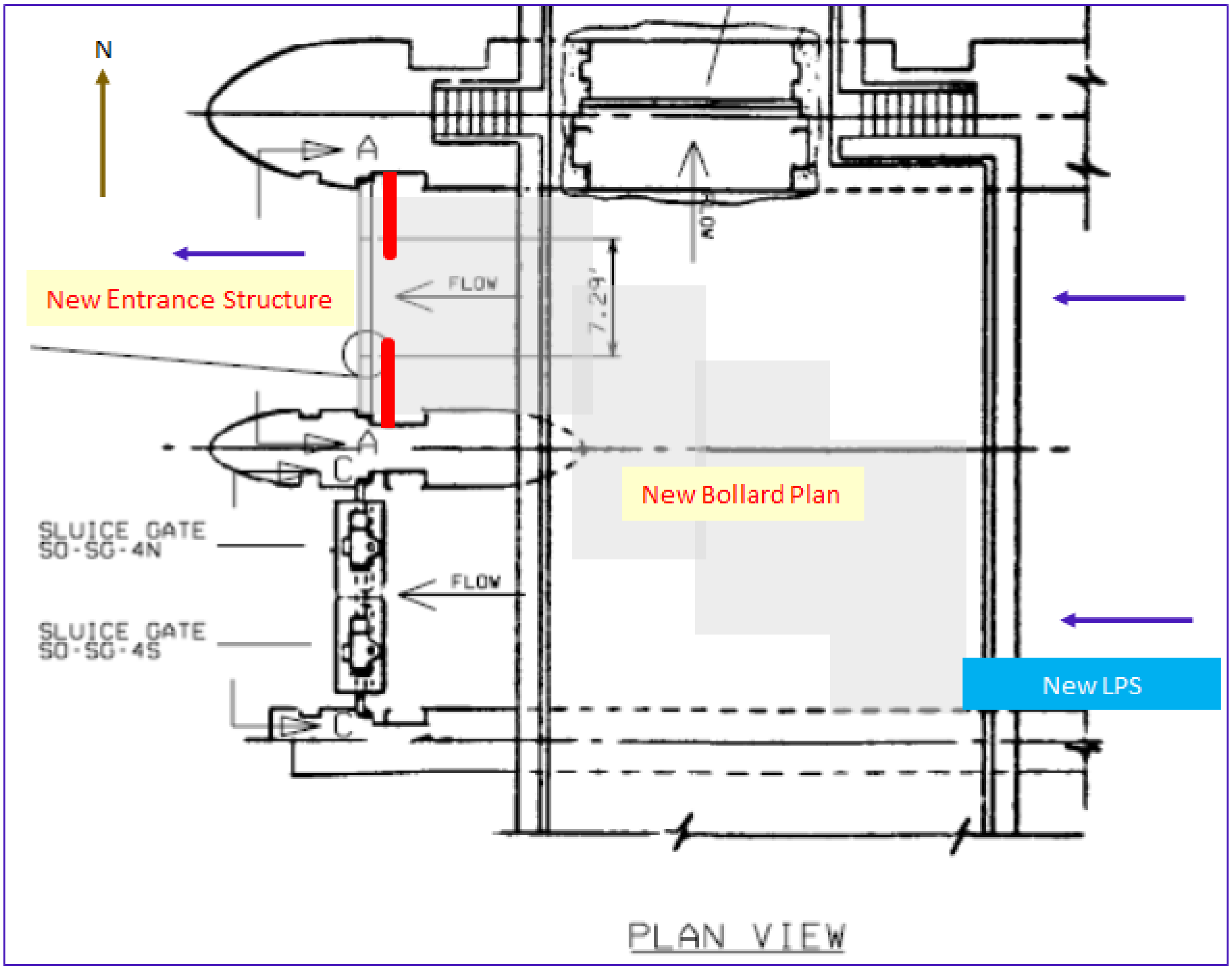
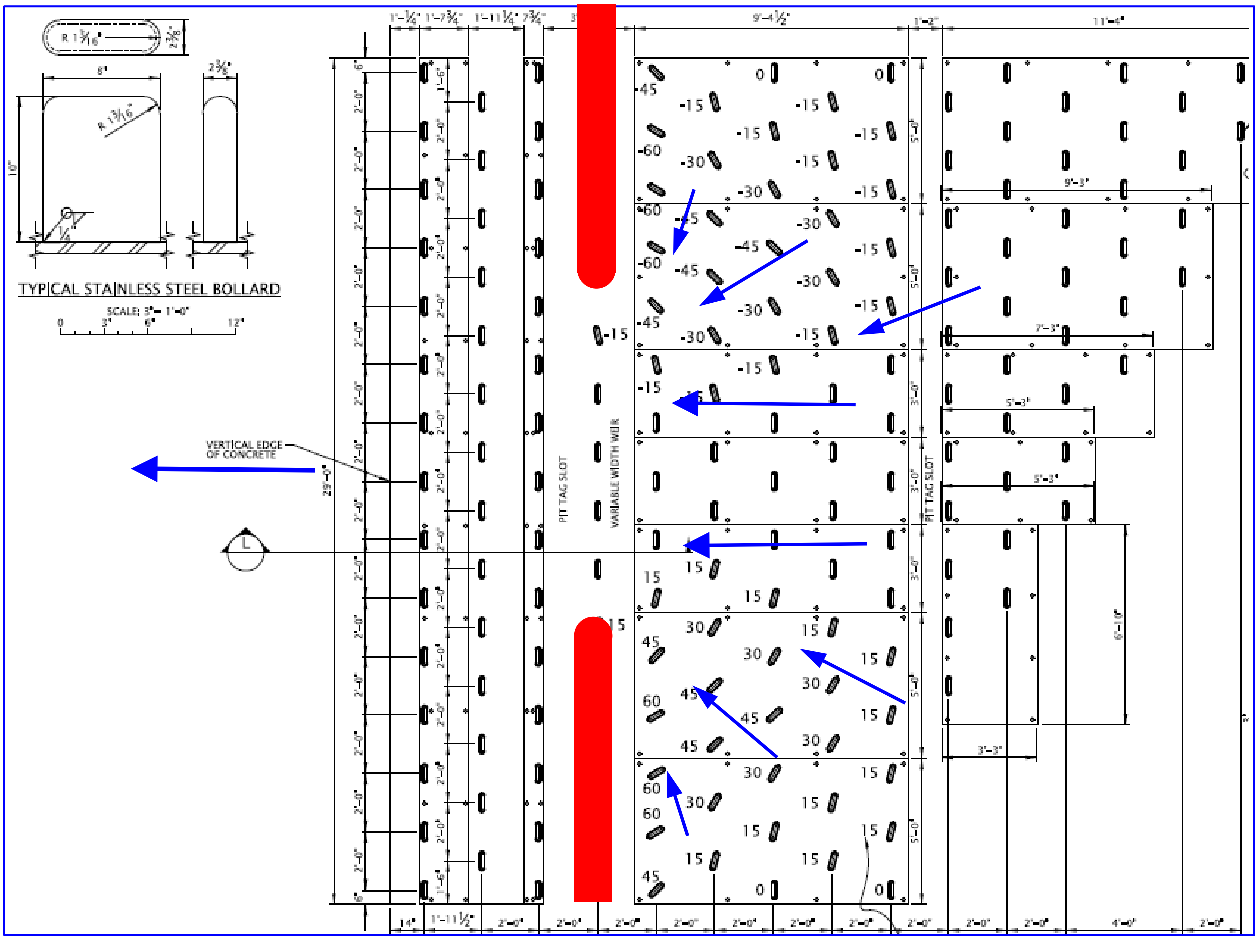


Figure 3-9. Plan Schematic of Paddle Bollard Arrangement at John Day North Fishladder.



* Excerpt Sheet SN101A, USACE (2015) John Day Lock and Dam North Fish Ladder Entrance Improvements Plans and Specifications, As-Constructed.

3.2.3 Lamprey Passage System (LPS) Assumptions and Design Features

An LPS is the system devised to separately pass the adult lamprey outside of the fish ladder. An LPS system will include some or all of 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), upwelling boxes, Passive Integrated Transponder (PIT) tag detectors and LPS exits.

3.2.3.1 *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 operations and maintenance (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 gallon per minute (GPM), equivalent to 0.28 CFS.

Screening to exclude juvenile salmonid fish is required at the intake of the water supply source 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. Therefore, the water supply flow should be 150 - 160 GPM. 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, which in turn may disturb radio frequency identification (RFID) antennas.

Gravity Water Supply

Similar to pump sources, the gravity water supply should be designed to exceed the required water supply by 20 – 40% to allow for adjustments and Lamprey holding. Based on the standard 20-inch wide LPS, the design LPS flow should be 124 GPM (0.28 CFS). Therefore, the water supply flow should be 150 - 160 GPM.

3.2.3.2 *LPS Entrances*

A 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 location is best determined through coordination with the Project Biologists and Fish Field Unit staff, who provide critical field knowledge, judgement and observational history. 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 flow, characterized by shallow rapid flow with of velocities above the critical swim velocity. Lampreys climb through this thin nappe of flow by means of attachment.

3.2.3.3 *Specific LPS Entrance Location at B Branch*

The B Branch LPS entrance location will match the mirror image location as used at Cascades Island. At B Branch, the LPS will be located on the south wall of the south entrance channel, or shore-side entrance channel wall.

The design of the Cascades Island LPS location was heavily vetted through a combination of CFD modelling and biological assessment. The key biological assessment is that the lamprey will move toward the slower positive velocity areas. The intent of the hydraulic design is to provide a lower velocity path to the LPS entrance ramp, where lowest positive flow in the channel cross-section is located. With the addition of the variable width entrance weir, the sluice gates located in the adjacent shore side entrance bay are almost never used. Thus, the shore side wall (north wall of north entrance bay at Cascades Island, or south wall of the south entrance bay at B Branch) was deemed the best location to install the lamprey entrance ramp. This has proven to be a successful lamprey collection site in spite of the initial 38.6-foot initial lift in the climbing duct sloped at 1.64 to 1 (not being duplicated at B Branch).

The biological assessment remains the same as assumed during the Cascades Island design concerning the best entrance ramp location for collection of Lamprey. However additional LPS entrance locations are planned for the future (such as the opposite side of the channel downstream of the channel bend where flow is slower).

3.2.3.4 *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 feet per second (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). Normal maximum raise heights is 11 -11.5 feet.

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).

3.2.3.5 *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 by the use of 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. Rectangular flumes between 0.7 – 1.6 feet are often used, with the goal of maintaining the optimum 1 ft/s velocity under normal operating conditions.

Round, thin-walled aluminum conduits can also be used for the traversing ducts, in which available outside diameters (OD) include 10-inch to 12-inches. Table 3-2 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.

Table 3-2 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%

PIT tag detectors are typically installed in the traversing ducts where the channel velocities are low. Circular PIT's are more efficient. If the surrounding ducts are rectangular, then transitions from rectangular to round (and back) should be applied.

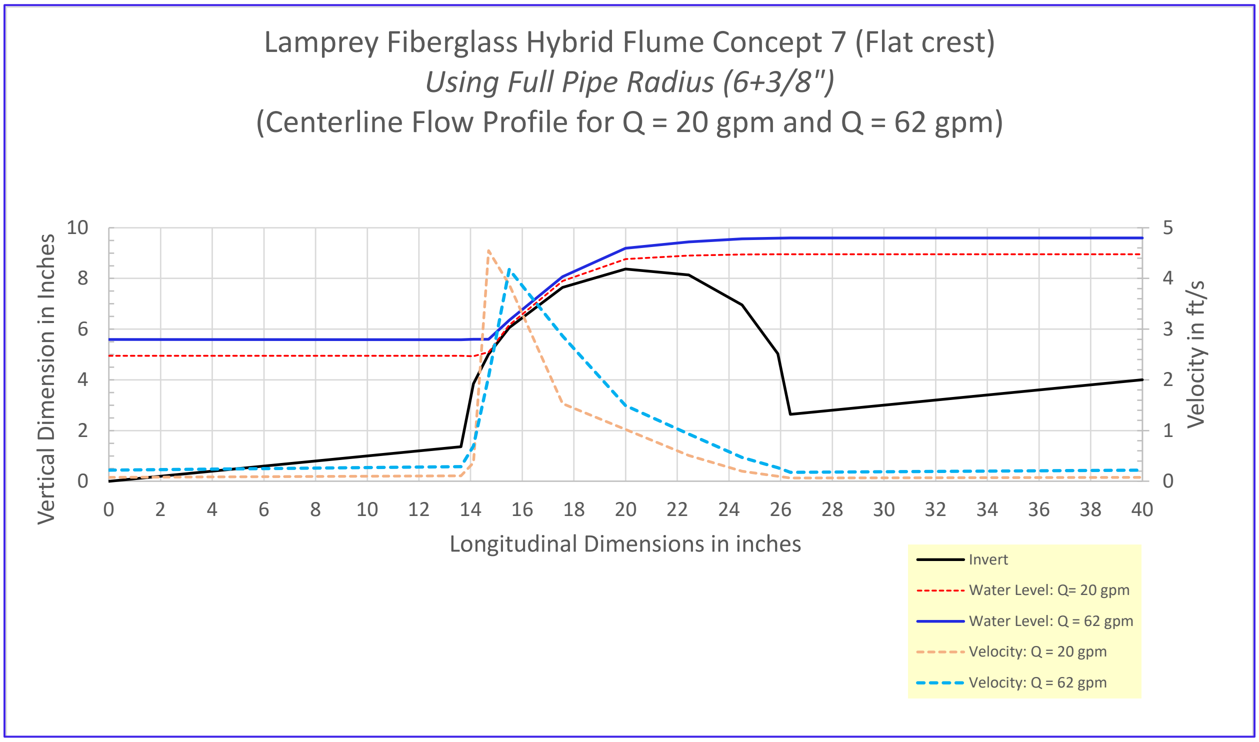
3.2.3.6 *Alternative Hybrid Flumes*

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 3-10 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 3-10. 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 proposed location of the new collection box.

3.2.3.7 *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). A disadvantage to the rest area is that lamprey may choose to go back down the climbing duct.

Rest boxes in the exit section are different configurations than used in LPS system. They are described in section.

3.2.3.8 *Collection Boxes*

Collections boxes are effectively end-of-the-run LPS rest boxes. The LPS terminates at the collection box, where Lamprey are trapped and collected for upstream out planting. The volume of the collection box must be sized larger than the typical rest box depending on expected Lamprey traffic and transport frequencies. Tribal Lamprey operators recommend approximately 15 -18 GPM recirculation flow to maintain Lamprey while being held.

The proposed new collection box will be located just southwest of the bridge across the lower B Branch fish ladder at the top of bridge level.

3.2.3.9 *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 proposed collection box location and lamprey are directed to the forebay or some other selected upper pool in the fish ladder.

3.2.3.10 *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. 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 grade break 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 10 -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 Table 3-3, a flume width of 3.25 inches was selected.

Table 3-3 Comparative Critical Depth Parameters for Existing Round and Proposed Rectangular Outfall Flumes

Critical Depth in Circular flume							**g =**	**32.2**	ft/s^2	ρ =	1.94	slugs/ft^3
PVC SDR 80 assummed							**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 the longer milder sloped outfall flume at Bradford Island, either the dewatering must be done incrementally or have some incrementally add-in water applied from above to assure wet bars to the outfall.

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 proposed collection box and lamprey are directed to the forebay or some other selected upper pool in the fish ladder.

3.2.3.11 *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 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).

The drainage valves are typically manual and left set and leave after initial adjustments.

3.2.4 Modifications to Bradford Island Exit Section

Modification to the existing serpentine Bradford Island exit section have been requested. Proposed modification is to radius the protruding edges and corners that hinder lamprey attachment in proceeding up the exit section. The edges and corners should have a minimum 4-inch radius and should not significantly alter the existing hydraulic performance, such as head differential between pools However, an analysis is being performed at 90% DDR to assure that the combination of rounding corners and the added Lamprey orifices do not increase the flow in the Exit Section channel. Adding radiused material at PIT designated slots may be difficult. Coordination with the PIT designers will be needed to assure both passage and PIT objectives have been met.

The existing serpentine section has 18 slots (including the exit to Forebay slot) and 17 pools. The slot widths vary from:

- 2.13 feet at exit slot (slot for exit gate)
- 1.85 feet at the upstream end (slot 17)
- 3.75 feet at the downstream end (slot 1)

The head differentials between pools vary on average for the following Forebay elevations:

- 0.12 feet at minimum Forebay 70
- 0.36 feet at median Forebay 74
- 0.53 feet at maximum normal Forebay 77

3.2.4.1 *Rest Boxes in Exit Section*

Rest boxes in the exit section are different configurations than described for the LPS system. These are attached in strategic locations along the invert of the exit section rather than inline along a LPS alignment. Five rest boxes were installed in a previous Lamprey minor mods project.

Rest boxes within the serpentine exit section should have adequate clearance from PIT Tag antennas if constructed of a magnetic material.

3.3 DESIGN CRITERIA

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

3.3.1 B Branch Fish Ladder Entrance Improvements

The fish ladder entrance typically represents the most difficult environment for lamprey passage with the combination of high flow velocities (10 -12 ft/s) and abrupt concrete edges and sharp-edged slots for bulkheads or telescoping weirs. The following criteria pertain to provisions for lamprey attachment and reduces the velocities near the invert.

3.3.1.1 *Variable Width Entrance Structure*

The following criteria provide means for lamprey passage via attachment and thrust mechanisms through the high velocity entrance portal:

- Minimum radius of entrance opening edges is 4-inches.
- Bottom of opening flush with invert.

3.3.1.2 *Bollard Paddles*

The bollard shape and spacing will match those installed at John Day North Fish Ladder. This design was evaluated in a CFD model study (USACE 2010) and shown to effectively reduce the reduce the velocities near the invert.

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- Paddles will be 10 inches tall x 8 inches long x 2 3/8 inches wide.
- Paddle will have radiused edges and corners to prevent fish injury.
- Paddle orientation angles will be in adjusted in 15^{o} increments.
    - The most common angle will be perpendicular to the channel alignment and general direction of flow. Angles will be different approaching the sides of the entrance opening.

3.3.2 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.

3.3.2.1 *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.

3.3.2.2 *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.

3.3.2.3 *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 (used at Cascades Island)
- Recommended ramp slope = 45 degrees
- Recommended height of ramp before level traversing duct = 11 feet

3.3.2.4 *Climbing Ducts*

- Maximum recommended duct slope = 58 degrees (used at Cascades Island).
- Recommended duct slope = 45 degrees.
- Recommended height of climbing duct before level slope or rest box = 11 feet.
- Recommended mean flow velocity is 7.9 – 11.8 ft/s (Zobott et al. 2015).
  - Table 3-4 below shows flow normal depths and velocities for two flow scenarios at design Manning's n (0.009).

Table 3-4 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°)

3.3.2.5 *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.

3.3.2.6 *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.

As noted in 3.2.3.5, hybrid flumes will not be applied in this phase.

3.3.2.7 *Rest Boxes (or Rest Areas)*

- Minimum recommended volume of each rest box is 11.4 ft^3.
- Minimum recommended depth in a rest area is 4 inches.
- Minimum recommended length of each rest area including traversing duct is 20 ft.

3.3.2.8 *Collection Box*

- Minimum recirculation flow = 20 GPM.
- Volume shall be coordinated with Project biologists.
- Drainage capability must be provided.

3.3.2.9 *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.

As noted in 3.2.3.8, upwelling boxes will not be applied in this phase.

3.3.2.10 *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.

As noted in 3.2.3.9, LPS exits will not be applied in this phase.

3.3.2.11 *LPS Drainage*

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

3.3.3 Modifications to Bradford Island Exit Section

- Minimum 4-inch radius for protruding edges and corners.
- Modifications to protruding edges and corners can be either:
  - Grounded concrete to match minimum radius.

        - Needs strict specification and strong quality assurance.
    - Radiused membrane covering edges and corners.
        - Material can be stainless steel or polyester.
        - Radiused or countersunk anchor bolts.
        - Tapered transitions from membrane to existing concrete surface.
- Alternations should not alter estimated head differentials by more than ±0.2 feet.
    - Head differential shall not exceed maximum head differential 1 foot (per NMFS Criteria).
- Alterations shall not increase flow rates approaching the Count Station.
- Alterations shall not increase average slot velocities by more the 10%.

3.4 DESIGN METHODS

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

The streamlines from the Cascade Island CFD model (AECOM 2009) will be used to set the bollard paddle angles for the B-Branch entrance. As CFD modeling has already been done for the mirror image Cascade Island and the similar John Day North fish ladder entrances, an additional CFD model is unnecessary.

3.5 DESIGN FEATURES

3.5.1 B Branch Fish Ladder Entrance Improvements

The fish ladder entrance typically represents the most difficult environment for lamprey passage with the combination of high flow velocities (10 -12 ft/s) and abrupt concrete edges and sharp-edged slots for bulkheads or telescoping weirs. The following criteria pertain to provisions for lamprey attachment and reduces the velocities near the invert.

3.5.1.1 *Variable Width Entrance Structure*

As already noted in section 3.2.2.1, the same configuration used at the Cascade Island Fish Ladder entrance will be used at Bonneville. See previous Figure 3-7 for an elevation view (looking downstream) of the shape and relative position of the entrance opening within the 35-foot-wide entrance approach channel. Also see Figure 4-1 in section 4.5 for structural elevation view of the entrance structure. This entrance structure will be inserted in the existing weir slots in the north 15-foot-wide channel upstream (west) of the main 35-foot width channel.

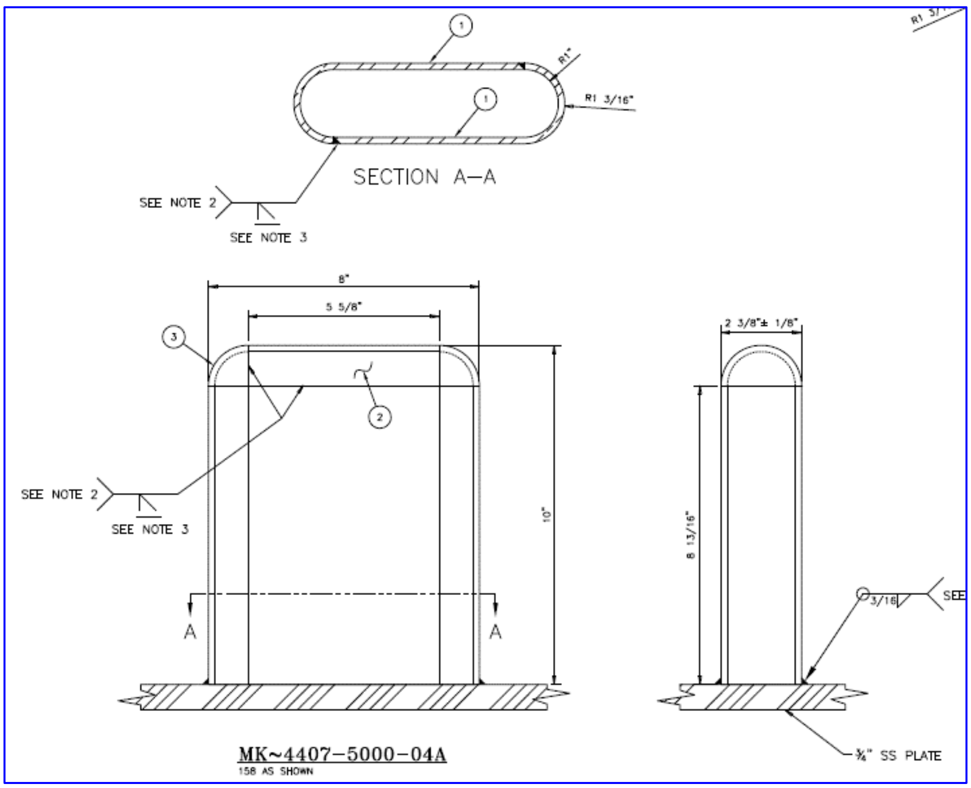
The dimensions of the entrance structure are the following:

- Invert Elevation = 2 feet NGVD 29
- Lower width = 14 feet below elevation 10 feet
- Upper width = 5 feet above elevation 18 feet
- Minimum structure thickness = 8 inches
    - Assures minimum 4-inch radius rounding.

3.5.1.2 *Bollard Alignment and Patterns*

The bollard shape and spacing will match those installed at John Day North Fish Ladder. The individual bollards will be spaced 2 feet apart on centers. With the 8-inch-wide bollards, this leaves 16-inch gaps between the bollards. The rows of bollards will also be spaced 2 feet apart on centers. The locations of the bollards also assure a minimum 2-inch gap between edge of bollard and sidewall. Figure 3-11 shows the detailed configuration of the bollards.

Figure 3-11. Bollard Details

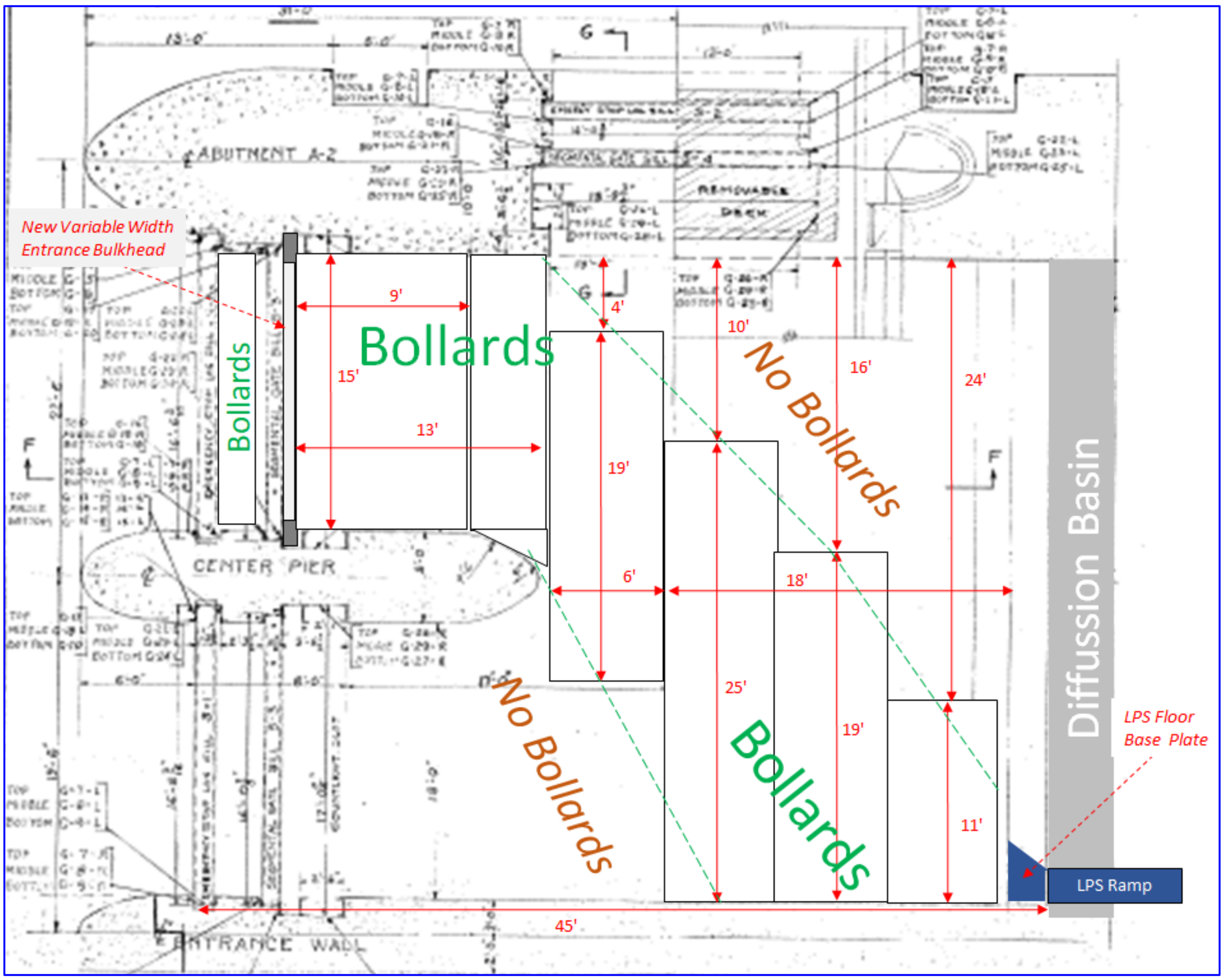


** Excerpt Sheet SN101D, USACE (2015) John Day Lock and Dam North Fish Ladder Entrance Improvements Plans and Specifications, As-Constructed.

The design layout of the plating and general locations of the bollard areas are shown in Figure 3-12. The actual width of the plates will vary per Structural discretion for constructability and transport functionality.

The plates will need to make room two to three PIT floor strips. These are approximately 11-12 inches wide and can be fit between plates in a manner that does not disrupt the bollard spacing. Except for one located between the bulkhead slot and new variable width entrance structure, the other PIT strip locations have yet to be determined.

Figure 3-12. Bollard Plating Plan

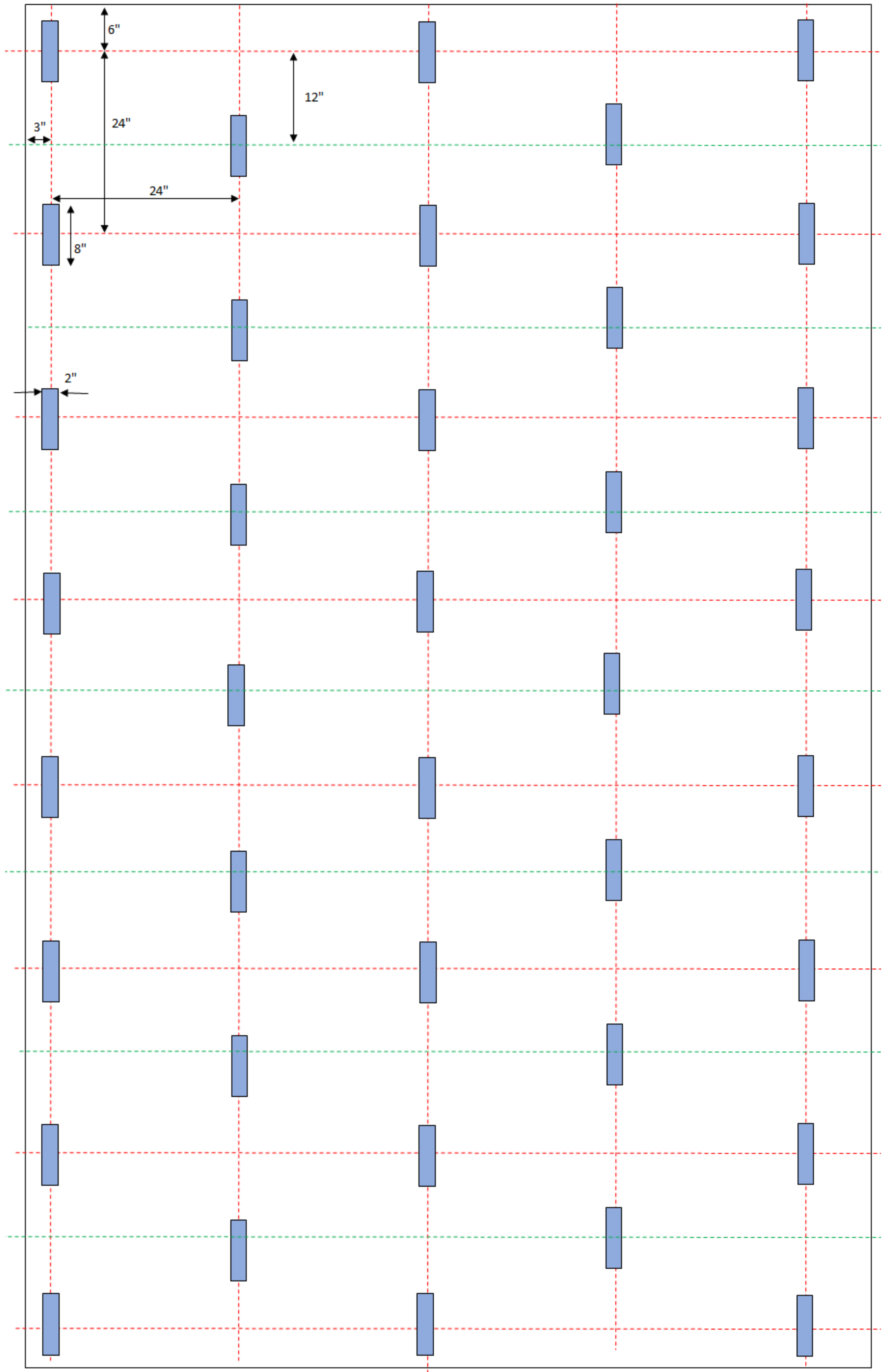


*** Excerpt T-8-4 (Collection Bay, Bradford Island Fish Ladder, Regulating Gate & Emergency Stop Log Guides, General Plan); Bonneville Power Navigation Project, W698 ENG. 575, 10/22/1935.

The spacing of the bollards for the 15-foot-wide x 9-foot-long plate is shown in Figure 3-13. This spacing starts immediately downstream of the Variable Width Entrance Bulkhead. This spacing continues in the same pattern in the downstream plates.

There will also be at least one row of bollards between the slots for the bulkhead and Variable Width Entrance Bulkhead (See small box labeled ‘Bollards’ left of Variable Width Entrance Bulkhead in Figure 3-12).

Figure 3-13. Bollard Spacing Plan



The orientation of the paddle bollards will be primarily perpendicular to the general direction of flow as shown in Figure 3-13. However, the orientation of a few paddle bollards will deviate from this general pattern, as indicated in previous Figure 3-9 from John Day North Fish Ladder. The results from the Cascade Island CFD model (AECOM 2009) are shown in Figure 3-14 (general entrance and bollard plan) and Figure 3-15 (detailed plan of the entrance weir channel). Both figures show the velocity contours and streamlines at different levels above the invert (Elev. 2.0 feet) under median Tailwater 18-foot flow conditions. The upper figure (z-1, with the round bollards) in each figure represents 4 inches above the invert and the lower figure (z-2, without bollards) represents about 1/3 of the depth in the water column, or about 6 feet above the invert (accounting for about 1.5 feet entrance head above tailwater 18).

The curving area around the downstream end of the pier will need adjustments of the bollard orientations by 15 - 30 degrees. Those bollards will be rotated about the center of the bollard under the already established spacing. The refined orientations will be provided in the 90% DDR after preliminary structural drawings have been developed.

Figure 3-14. Cascade Island CFD Results (Excerpt Fig. 14-11, AECOM 2009)

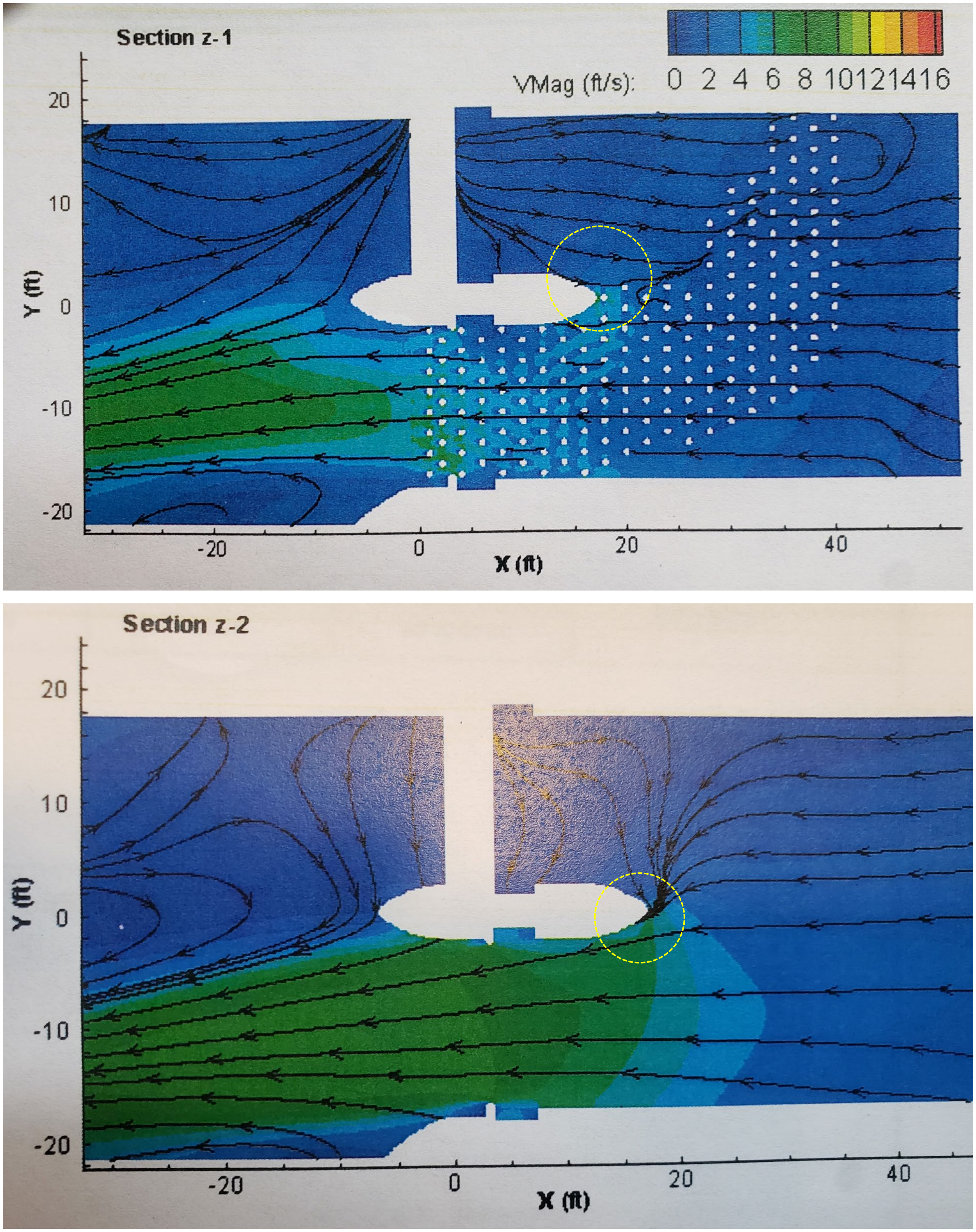
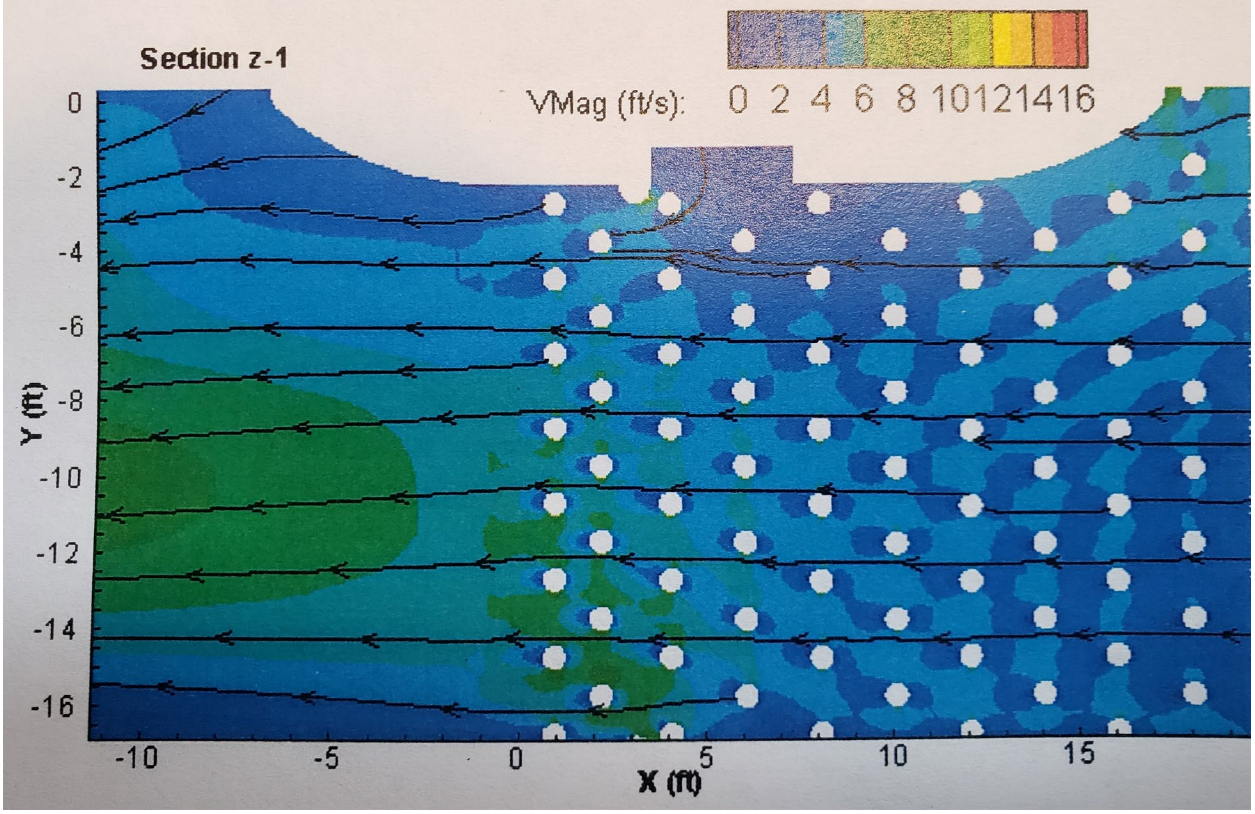
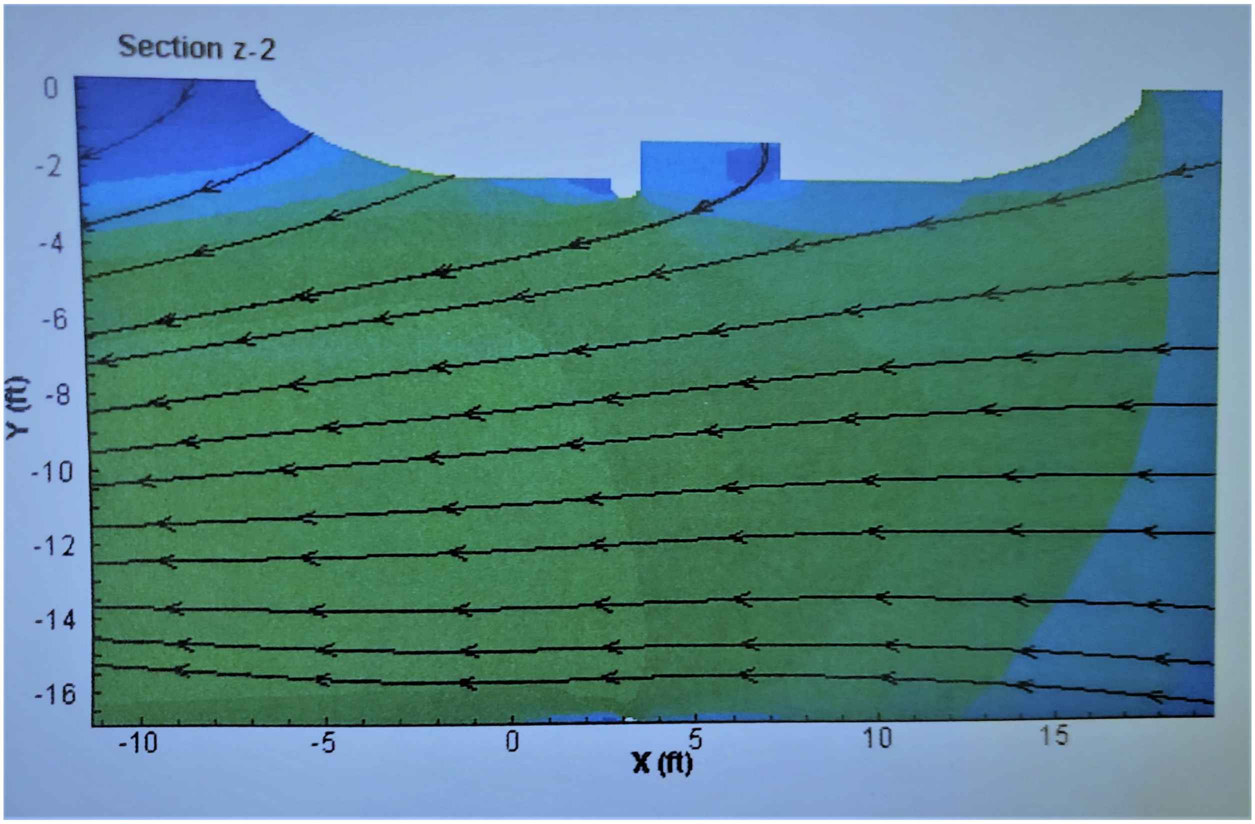


Figure 3-15. Cascade Island CFD Results (Excerpt Fig. 4-12, AECOM 2009)





3.5.2 LPS Alignment

The LPS alignment must provide a Lamprey access route from the channel invert in the entrance channel at elevation 2.0 feet to the collection box on the south side of the fish ladder at approximately 60 – 65 feet. Figure 3-16 shows a plan view of the proposed LPS alignment. Figure 3-17 provides an elevation view of the LPS (indicated by blue in the figure) on the south side of the entrance bay and north side of the main ladder pier, that divides the entrance bay from the lower ladder section with weirs and orifices.

The toe of the LPS entrance ramp is located horizontal distance (X) = 61 feet and elevation (Z) = 2 feet; and the level traveling section is radiused around the ladder pier and located at X = 95 feet and Z = 31.5 to 32.5 feet).

The proposed rise of the initial climbing duct is 19 feet with a slope of 1.73 (or 60º), similar to the initial rise at Cascades Island (1.64 slope or 58.6º). However, the initial rise at Cascades Island is double the height at 38.6 feet. Also, the maximum lamprey climbing distance above the 95% May- August water surface elevation in this steeper duct will be only about 8 feet. Once reaching EL 21 feet, the initial climbing duct channel is followed by a deepened and level traversing channel, where Lamprey can rest before proceeding to the next climbing section.

Once above EL 23 feet, the LPS rises in a series of 45 degree climbing sections, again followed by deepened and level traversing channels (indicated by white and labeled with an elevation) where Lamprey can rest before proceeding to the next climbing section. The raise of each climbing section thereafter is no higher than the maximum 11 feet, with lower raises where elevation adjustments are needed to navigate under the bridge structure and over the top of the ladder channel to the south shore. Pertinent features such as Entrance Pier, Weir Channel, Ladder Pier, Lower Ladder, Bridge, and location of proposed Variable Width Entrance Bulkhead are labeled in Figure 3-16.

A Biological priority is to place the toe of the LPS ramp as far upstream as possible, as Lamprey must move southward from the weir channel to the ladder pier wall to intercept the LPS alignment. The toe of the LPS ramp cannot be located upstream of the diffuser basin, as the depression in the invert represents a physical limitation. Another biological preference is that the LPS elevation reach most or all of the water column prior to rounding the pier during the peak Lamprey passage period (May-June) when tailwater elevations are generally higher. The 5% May – August exceedance water surface elevation is shown along with the 95% exceedance level for the same period. Figure 3-17 shows that the proposed LPS alignment reasonably meets these biological priorities.

One or more additional LPS alignments are likely to be added in either this phase or a future phase pending biological assessment. There will likely be an LPS on the opposite side of the channel downstream of the pier.

Figure 3-16. B Branch LPS alignment, Plan View

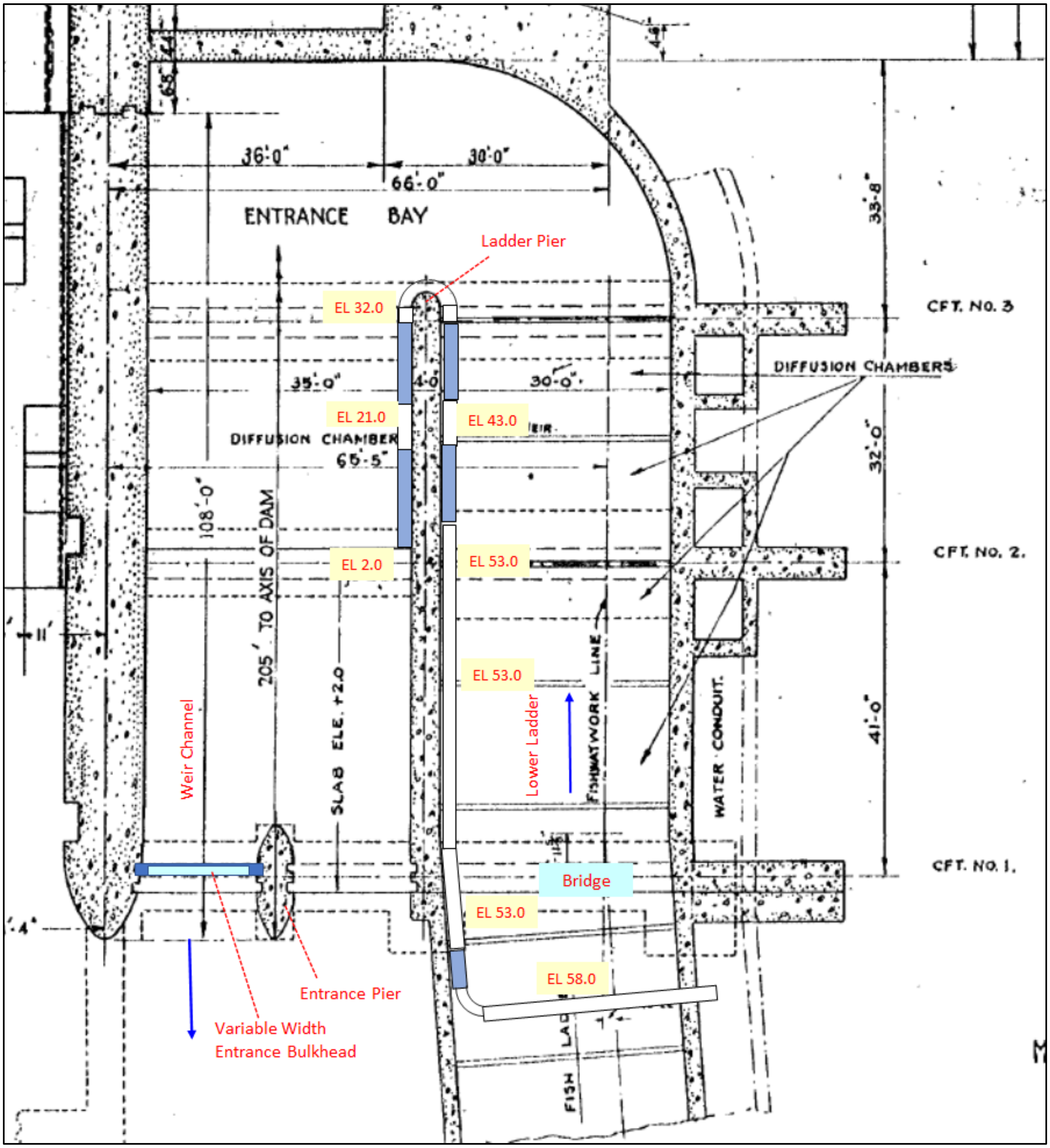
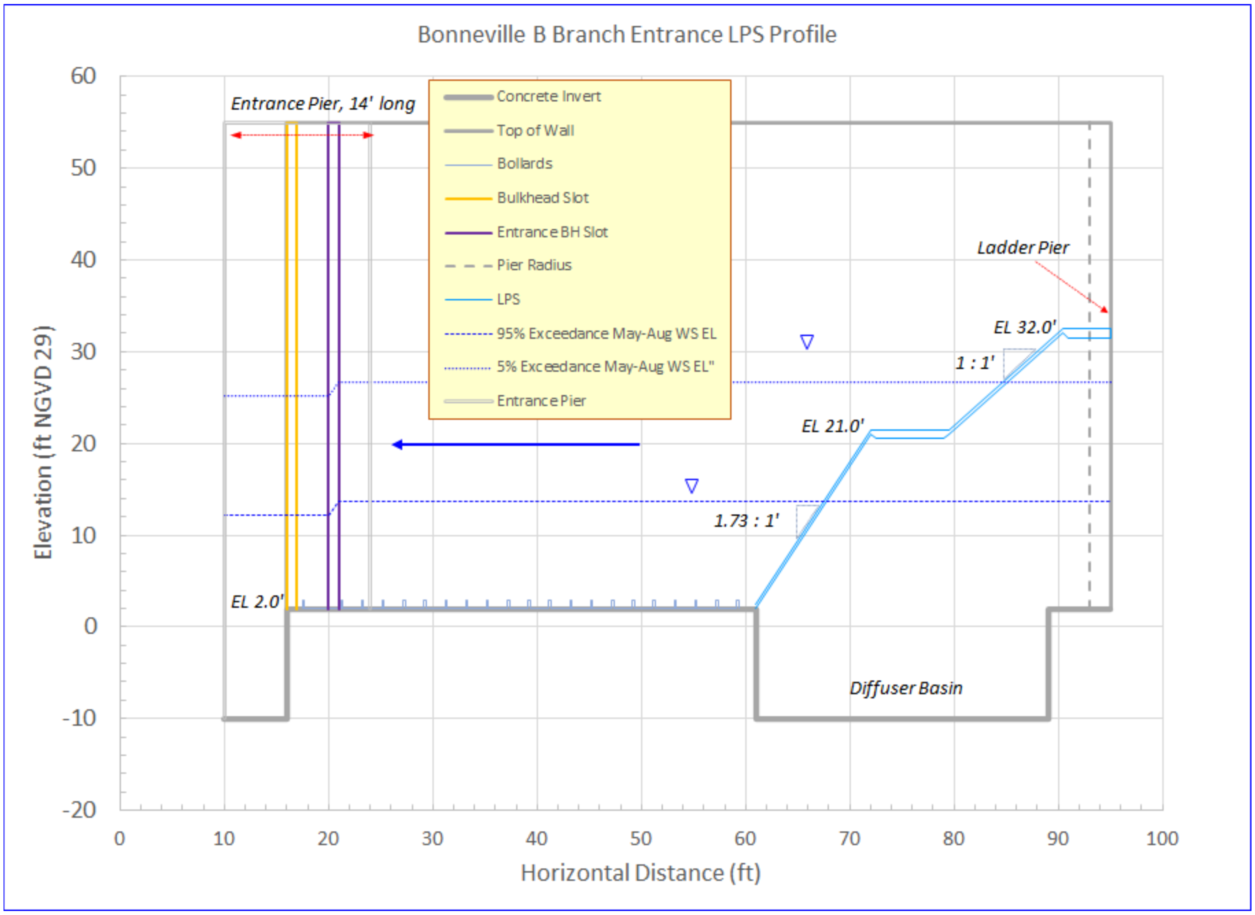


Figure 3-17. B Branch LPS alignment through Entrance Bay to Pier, Elevation View

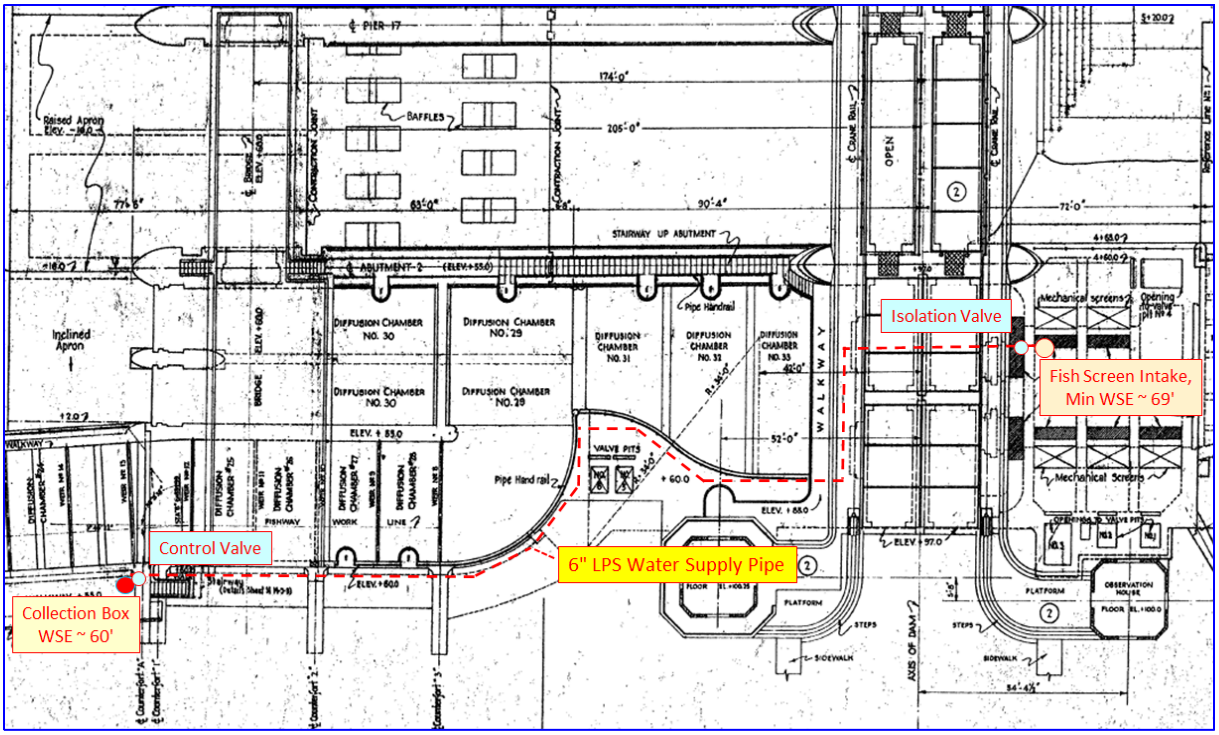


3.5.3 LPS Water Supply

The estimated design flow rate for a potential three standard sized LPS's is 480 GPM (1.1 CFS). There is ample flow supply to both allow for flow adjustment and provide for the collection box lamprey holding requirement (20 GPM). The LPS water supply pipe will be oversized to allow capacity for the potential future two additional LPS's.

The proposed water supply source is gravity fed from an existing auxiliary watering system (AWS) sump for the B Branch diffusers located behind existing fish elevator containment bulkheads. The new 6-inch diameter supply pipe will pass through a new replacement bulkhead equipped with an isolation valve (gate or butterfly). The supply pipe will be routed through an obsolete juvenile bypass channel. Once outside of the fish elevator structure and west of the spillway bridge, the pipe can be routed westward along the top of the existing tailrace deck (elevation 60 feet) and avoiding areas of routine traffic access to ultimately connect to the new collection box at the foot of the stairs southwest of the bridge over the entrance bay. A preliminary plan view of the LPS supply pipeline (dashed red line) is shown in Figure 3-18. Pertinent features such as the approximate locations intake juvenile fish screen, isolation valve, control valve and collection box.

Figure 3-18. Preliminary LPS Water Supply Pipeline Alignment, Plan View



The minimum available head to the water supply system is the minimum forebay (70 feet) minus an assumed 1-foot screen loss minus collection box water surface elevation (60 feet) = 9 feet. The maximum available head is 17 feet at maximum forebay (77 feet) and neglecting screen or intake losses.

Given that the system demands are anticipated to increase with the addition of future LPS's, the pipe is oversized for initial usage. While the size of the upstream isolation valve should match the 6-inch pipe size, the size of the initial downstream control valve should be downsized to 4-inches to assure the valve is operated between 20 - 70° for more accurate and adjustable flow controllability.

Summary Design Bullets:

- Design flow rate :
  - Phase 1 (1 LPS): 160 GPM = 0.36 CFS
  - Ultimate (3 LPS's): 480 GPM = 1.07 CFS
- Minimum screen area = 5.4 ft
- Available operating head:
  - Minimum ≈ 9 feet
  - Maximum ≈ 17 feet
- Pipe length ≈ 350 feet

- Pipe Diameter = 6-inches
- Valves
  - Upstream isolation 6-inch gate, ball, or butterfly valve
  - Downstream control 4-inch butterfly, ball, or globe valve

The computations for LPS flow requirements, pipe sizing and valve sizing for effective controllability are provided in Appendix C, Item C-1.

3.5.4 Bradford Island Exit Section

Improvements in the Bradford Island Exit Section will include radiused plating around sharp corners and additional 1.5-inch-high Lamprey orifices (four were installed in 2015).

3.5.4.1 *Rounded Plating Around Existing Exit Section Slots Alternative*

Full depth plating has been considered to provide rounded or radiused surface over the sharp cornered baffled slot opening in the existing Serpentine section of the Bradford Island Exit Section. Figure 3-19 shows a plan schematic of the proposed plating (turquoise lines) in standard Serpentine slots. Also note the detail in the lower right corner on the manner in which the plating tapers at the end for easier Lamprey transition from concrete to plate and vice versa. In the upper right, there are other details on providing a radiused cover over existing vertical piping along the sidewalls, observed to have been a chronic impediment to Lamprey passage. The plating is designed to tie into the existing concrete sides and provide minimum 6-inch radiused surfaces around the sharp corners.

The exit slot for the Exit Gate at the upstream end of the Exit Section is another known cause of lamprey delay or fall back. Aside from the high slot velocity and sharp corners and gate slots, the Biologists also attribute Lamprey fatigue at this point of the journey through the difficult Serpentine section. Figure 3-20 provides the proposed plating for the west side (i.e. corner) of the exit slot. The east side is a flush wall and does not need plating. Slot fillers for the Exit Gate were considered by the PDT and were determined to be infeasible. The gate is continually deployed in a raised position, and the project needs to be able to close the gate quickly in the event on an oil spill.

Figure 3-19. Bradford Island Exit Section Improvements: Plating over Baffle Corners, Plan View

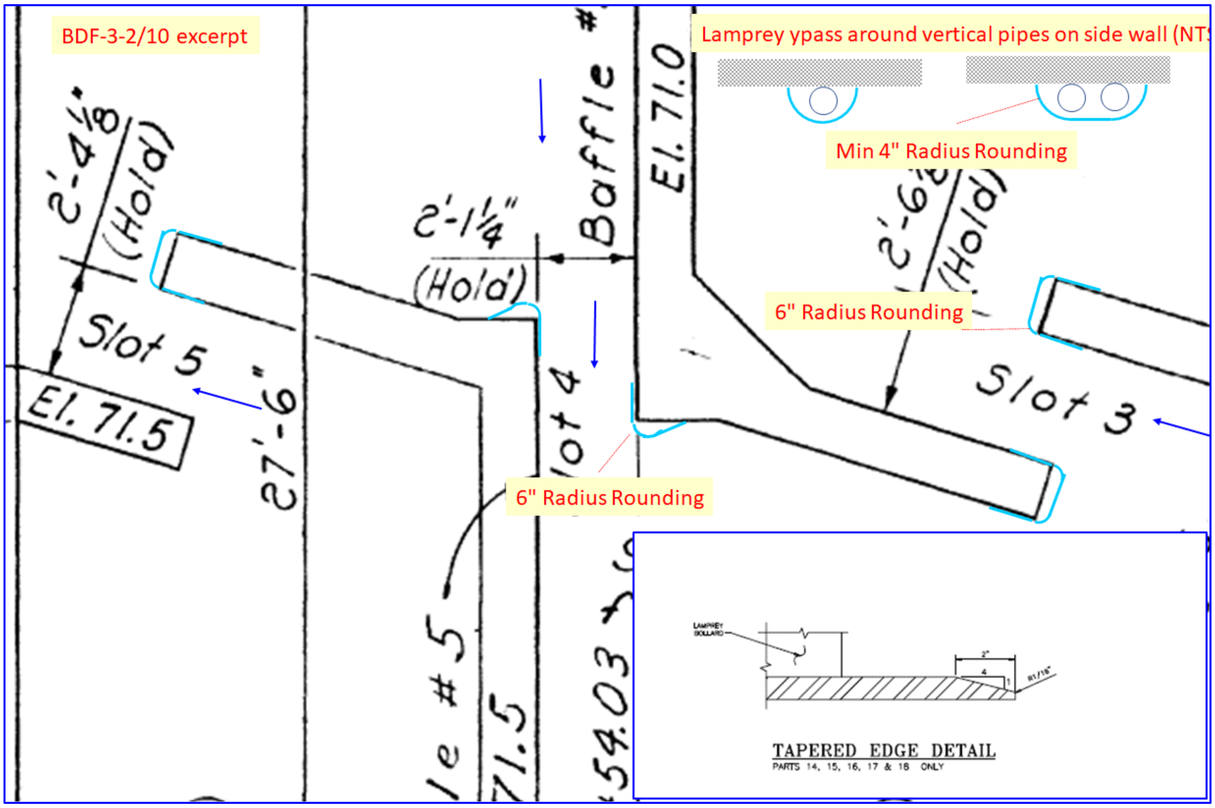
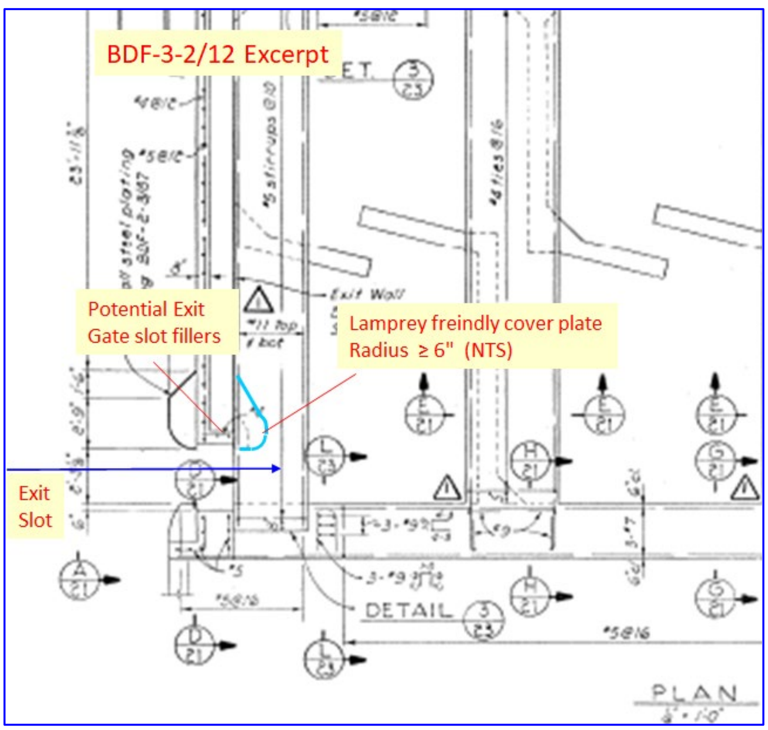


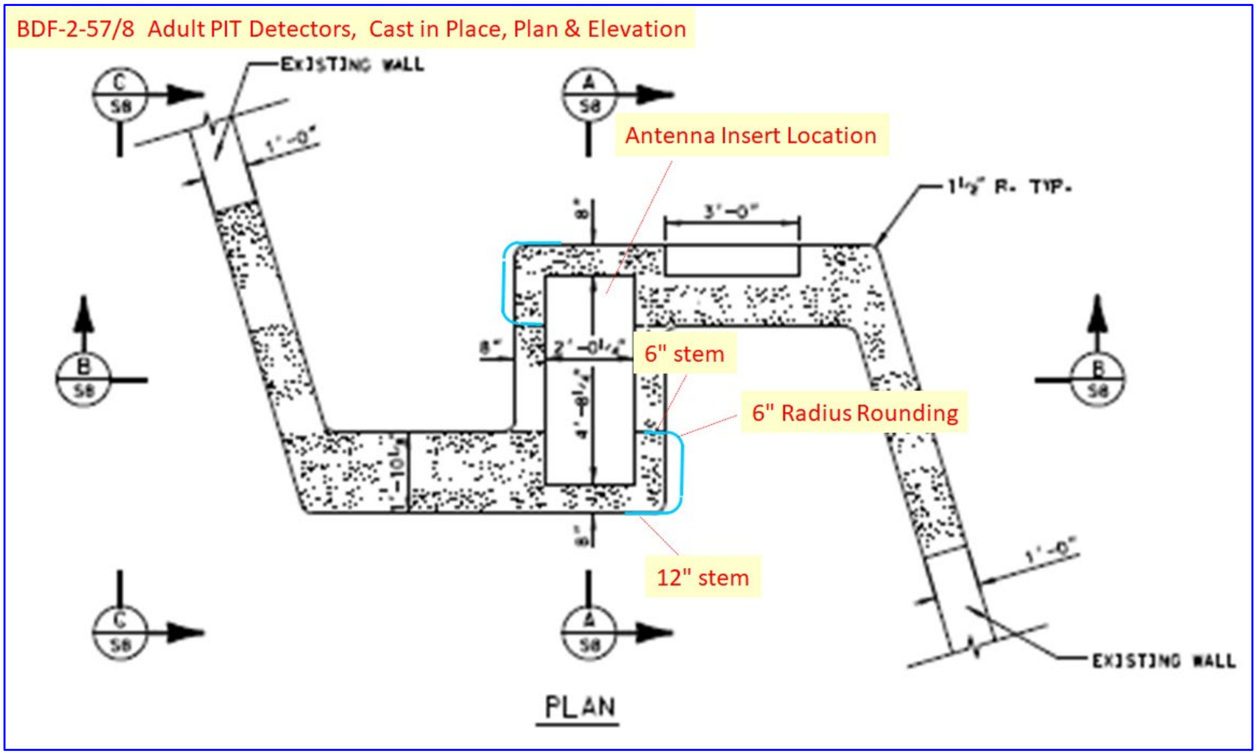
Figure 3-20. Bradford Island Exit Section Improvements: Plating into Exit Gate Opening, Plan



The plating material is up to the discretion of structural design. However, the plating material and means of anchoring will need to be non-metallic at the four PIT slots.

Figure 3-21 provides the proposed (non-metallic) plating for baffles where the PIT antennas were deployed. The baffles for the 2005 PIT installation were made wider (22 1/8 inches) than the standard baffle. The plating cannot overlap or protrude into the antenna space, indicated by the PIT insert block-out shown in the figure.

Figure 3-21. Bradford Island Exit Section Improvements: Plating over PIT Baffle, Plan



The hydraulic performance of the Serpentine slots was evaluated to assure that the modified Exit Section flow will not be increased (See sub-section 3.5.4.3 for more explanation). The results are described in the following subsection and show that the proposed modifications do not meet the design criteria.

3.5.4.1.1 Hydraulic Evaluation of Rounded Plating in Exit Section Alternative

A one-dimensional (1-D) model was assembled to simulate flow through the existing Serpentine exit section including Bleed-off and Add-in orifices adjacent to the exit channel. Exit channel inflow and boundary water surface elevations from the original physical model (USACE, 1973) under a range of four forebay conditions were utilized. In addition, the computed Bradford Island weir 67 discharge at 1-foot ladder head from the HELCRABS report (USACE, 2003) was required to estimate the flow rates in the adjacent AWS channel. (The AWS channel receives flow from Bleed-off orifices and discharges flow through Add-in orifices. The outflow from the AWS channel combines with the outflow from the Count Station (and picket lead) to comprise the flow over Weir

67 located downstream of the Count Station.) Using the model exit channel inflow (Q_{18}) for upper forebay model elevations (76.5 and 74 feet NGVD 29), an average discharge coefficient (Cd) was estimated through the first (upstream) six slots with known constant slot flow rates (slots 13-18 are upstream of Bleed-off orifices) and average head drop per slot. The 1-D model setup and steps are listed in the following bullets:

- Bs6 = Average slot width for upstream Slots 13-18 = 1.95 feet
- Q_{18} = Exit slot 18 inflow for given Forebay elevation.
  - Constant flow Q_{18} through Slots 13-18 (Upstream of Bleed-off Orifices).
- DHa = Average head drop per slot = (Forebay – Weir 67 head)/18 slots
  - Weir 67 head = 68 feet
  - Assumption: head drops through upper six slots match overall average
- Y6a = Estimated depth midway through the upper six slots
  - Y6a = (Forebay – 3 * DHa) – Invert (EL 63.0)
- Cd = Average slot discharge coefficient (Cd) = Q_{18}/(Bs6 * Y6a) *1/sqrt(2g* DHa)
  - Q_{18} = Exit slot 18 inflow for given forebay elevation
- Q_{67} = Total flow approaching Weir 67 = 192 cfs based on HELCRABS model results (USACE, 2003)
- Q_{AWS} = Inflow to AWS channel adjacent to Slot 18
  - $Q_{AWS} = Q_{67} – Q_{18}$
- Qa = Flow approaching the Count Station (prior to trashrack or picket lead)
- Perform backwater model starting upstream of Count Station (Qa) and downstream of Slot 1.
  - Guess Qa and adjust until computed and model Forebay elevations match
  - Compare computed and model Exit slot 18 flow rates (Q_{18})

The upper 3rd portion of Table 3-5 shows the capability of the 1-D model to simulate the physical model results of the existing Serpentine Exit Section. Note that the emphasis in accuracy was focused on the higher forebay conditions which represent higher velocity conditions through the exit section.

The previous bulleted steps were repeated for the modified Serpentine Exit Section with the added radiused plates. The assumed plate thicknesses (0.25 inch) were deducted from the slot widths. Most importantly, the discharge coefficient was revised to represent the increased hydraulic efficiency. The revision was based on the ratio of radiused ladder orifices to standard sharp edged ladder orifices:

- % increase for radiused slot openings = CDro/CDo - 1 = 0.80/0.67 -1 = 20%
  - CDro = CD for radiused ladder orifices = 0.80
    - Inferred from ENSR (2008) and confirmed in Protype type measurements at Cougar Adult Fish Facility
  - CDo = CD for conventional ladder orifices = 0.67

  - Inferred from Northwest Hydraulics (2000) physical model
- Based on the 20% increase, the revised CD = 1.27

The middle 3rd portion of Table 3-5 shows the results for the modified Exit Section.

Table 3-5 Summary 1-D Exit Section Model Results

Existing Serpentine Exit Section Model Results					Cd =	1.06			
Forebay (FB) Elevation (ft NGVD 29)		Δ FB	Qa Appr to CS	Q_{18} Exit Slot 18 Inflow cfs		Difference Δ Q_{18}		Σ Qbo Bleed off	Σ Qai Addin
Model	Computed	ft	cfs	Model	Comp.	cfs	%	flow cfs	flow cfs
76.50	76.51	0.01	85.6	137.1	135.7	-1.4	-1.0%	53.8	3.7
74.00	74.00	0.00	74.6	95.3	93.9	-1.4	-1.5%	28.4	9.1
72.00	72.00	0.00	65.9	57.7	59.5	1.8	3.1%	2.7	9.2
70.00	70.01	0.01	54.0	32.2	35.1	2.9	9.1%	0.0	18.9

Modified Serpentine Exit Section Model Results					Cd =	1.27			
Forebay (FB) Elevation (ft NGVD 29)		Δ FB	Qa Appr to CS	Q_{18} Computed Exit Slot 18 Inflow cfs		Difference Δ Q_{18}		Σ Qbo Bleed off	Σ Qai Addin
Model	Computed	ft	cfs	Existing	Modified	cfs	%	flow cfs	flow cfs
76.50	76.50	0.00	106.5	135.7	160.0	24.3	17.9%	56.7	3.3
74.00	74.00	0.00	88.8	93.9	111.5	17.6	18.7%	30.7	8.0
72.00	72.00	0.00	76.6	59.5	71.3	11.8	19.9%	2.8	8.1
70.00	70.00	0.00	59.8	35.1	42.1	7.0	19.8%	0.0	18.9

Summary Comparison of Modified versus Existing Serpentine Sections								
	Qa Approach Flow to Count Station				Q_{18} Exit Slot 18 Q			
Forebay	Existing	Modified	Δ Qa		Existing	Modified	Δ Q_{18}	
ft	cfs	cfs	cfs	% diff.	cfs	cfs	cfs	% diff.
76.50	85.6	106.5	20.9	24%	135.7	160.0	24.3	18%
74.00	74.6	88.8	14.2	19%	93.9	111.5	17.6	19%
72.00	65.9	76.6	10.7	16%	59.5	71.3	11.8	20%
70.00	54	59.8	5.8	11%	35.1	42.1	7.0	20%

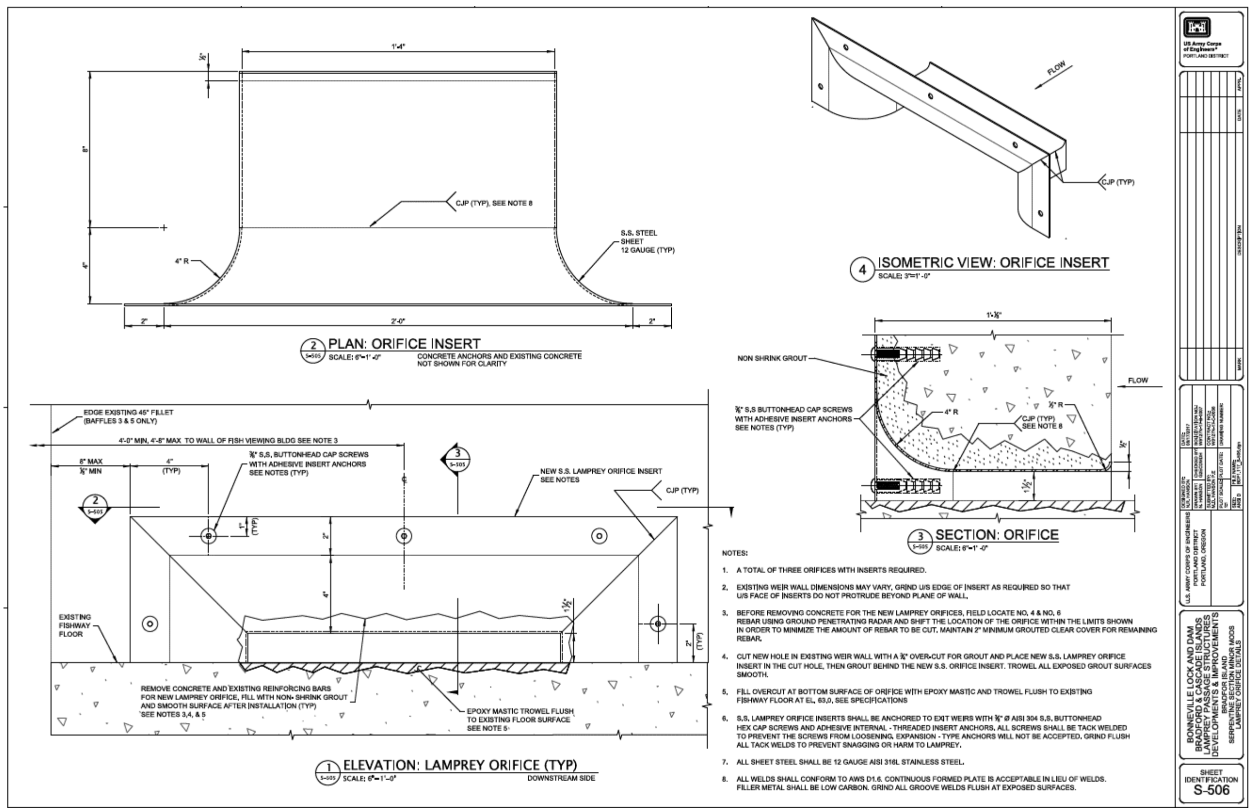
The bottom 3rd portion of Table 3-5 shows the comparative increases for modified Exit Section with respect to the existing Exit Section. In general, flows (and also velocities) are generally increased about 20%. The 24% increase for the flow approaching the Count Station at Forebay 76.5 is especially troubling, as this could overwhelm the existing upstream trashrack and force excessive velocities through the Count Station slot.

The above data shows that the proposed modifications does not meet the design criteria, in particularly with the increased flow approaching the count window.

3.5.4.2 *Lamprey Orifices*

In 2017-18, three 1.5-inch x 16-inch Lamprey orifices were installed during the Phase I Lamprey Improvements at Bradford Island Exit Section. At the time, closure gates and cameras were installed in case the orifices proved to be a cause of delay for the listed salmon species. Subsequent testing and monitoring indicate that the orifices are not a cause of delay to the salmon and have also often been a successful means of passage for the Lamprey. These orifices in effect offer a short cut for the Lamprey that would otherwise be forced to struggle through the Serpentine slots. The design of the lamprey orifice (used in Phase I Lamprey Improvements) is shown in Figure 3-22.

Figure 3-22. Lamprey Orifice



The orifices require some concrete excavation, followed by stainless steel plate insertions that are grouted in. The downstream face of the orifice is radiused 4-inches to provide means of attachment into the orifice. There is minimal radiusing on the upstream side, as the velocity is normally higher on the downstream side due to flow contraction. This is also done to reduce the overall flow increase in flow through the Serpentine exit section.

The design intent is to provide Lamprey orifices in the wall perpendicular to the direction of flow on both sides of the Serpentine Channel. There are a total of 16 baffle walls (8 on each side) that can house a lamprey orifice. Three walls on the east downstream side already have orifices, so 13 additional orifices. Assuming a discharge coefficient of 0.75, the estimated flow through each orifice is about 0.5 – 1 CFS, depending on forebay elevation. This will cause a small overall increase in flow through the exit section, whereas the head drop and flow through the Serpentine baffles will remain the same.

3.5.4.3 *Analyses of Potential Flow Increases and Modification of Bleed-Off Orifices*

The combination of rounding the corners in the serpentine section and the new lamprey orifices may increase the overall flow through the Exit Section at equivalent Forebay elevations. An increase in general pool velocities and flow approaching the Count Station is undesirable. The upstream trash rack at the Count Station is currently at operating capacity. In the 90% DDR, an analysis will be completed to check on the potential increase in flow. The solution to address this concern is to increase the heights (and/or widths) of the bleed-off orifices. These orifice plates provide significantly smaller openings than the concrete windows, so replacing these orifices plates will be a simple matter during construction if needed. The pending analyses will utilize comparative data from the previous physical model studies John Day South (conventional sharp cornered) and John Day North (rounded corners). The sensitivity to the variability of the coefficients will be tested to assure a robust solution. Ultimately, the flow (particularly at high forebays) can be reduced by some amount, but not increased.

SECTION 4 - STRUCTURAL DESIGN

The Bonneville Bradford Island Lamprey Passage work has structural features that will be constructed using a combination of new and existing concrete, stainless steel, and carbon steel as described in the following paragraphs. Some structural features will likely be removed.

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
- EM 1110-2-2107 - 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) - Design Manual (2008 with 2009 Interim)
- American Association of State Highway and Transportation Officials (AASHTO) – Manual for Bridge Evaluation 2018 (Prior to 1959 section)
- American Concrete Institute (ACI 318-19) - Building Code Requirements Reinforced Concrete
- American Institute of Steel Construction (AISC) – AISC 360
- American Society of Civil Engineers (ASCE) 7-22 - Minimum Design Loads for Buildings and Other Structures
- International Building Code, 2018

4.2 DESIGN ASSUMPTIONS

The following describes the design assumptions made:

Lampreys require rounded corners and flush surfaces to navigate the fish ladder.

Routing of an LPS structure to the east end of Bradford Island is not possible due to mitigation work.

The weir shape for this entrance will be the same as the Cascade Island weir shape.

4.3 DESIGN CRITERIA

The design criteria below contain reference 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, 2018, prior to 1959)

New Concrete

Structural Concrete: minimum f'c= 4,000 pounds per square inch (psi) at 28 days
Precast Concrete: f'c= 5,000 psi at 28 days

Grout

f'c=5,000 psi at 7 days.

Existing Steel Reinforcement

fy = 33,000 psi (AASHTO MBE, prior to 1954)

New Steel Reinforcement

fy = 60,000 psi (ASTM A615)

Structural Steel

(ASTM A36) Bars, beams, plates, and angles: fy = 36,000 psi
(ASTM A992) Beams: fy = 50,000 psi
(ASTM A500, Grade B) Round Shape: fy = 42,000 psi
(ASTM A500, Grade B) Structural Tube: fy = 50,000 psi
(ASTM A53, Grade B) Pipe: fy = 35,000 psi
(ASTM A572, Grade 50) Plates, bars, and beams: fy = 50,000 psi

Corrosion Resisting Steel (CRES)

(ASTM A276, Type 304) Bars, angles, and plates: fy = 30,000 psi
(ASTM A276, Type 304L) Bars, angles, and plates: fy = 25,000 psi

Structural Aluminum

(Type 6061-T6) Bars, plates, tubes, and shapes: Fty = 35,000 psi
(Type 5052-H32) Sheets: Fty = 26,000 psi

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 318-18 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 EM 1110-2-2105 for hydraulic steel structures and to American Institute of Steel Construction (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.

Hydraulic Structures: For structural design, hydraulic structures are all permanent structures. 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 2015 Aluminum Design Manual. The LPS is designed by others on this PDT.

4.4.2 Design Loads

Risk Category and Importance Factors: All structures as part of this project are designed as Risk Category II. 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. Aluminum unit weight of 0.098 pounds per cubic inch (170 PCF) will be used and is based on Aluminum Association values for structural shapes and plates.

The max weight of the weir sections is approximately 5500 pounds.

Wind: Wind loading is determined in accordance with ASCE 7-16, Chapters 26 to 30. The design wind speed is 98 miles per hour (MPH).

Snow: Snow loading is determined in accordance with ASCE 7-16, Chapter 7. Ground snow load is 44 pounds per square foot (PSF).

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. All structures are designed for 3 feet of hydrostatic head. The max head differential between the water within the ladder and water in the tailrace is 3 feet.

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 (BPH2Phase1Rpt11302012_Seismic.pdf)
- S_s = 0.612, S_1 = .0277 (USGS Ground Motion, ASCE 7-16)
- S_{DS} = 0.367, S_{D1} = 0.148 (USGS Ground Motion, ASCE 7-16)

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 following list includes the new structural features for this project:

- Variable Width Weir
- Counterweight Slot Cover
- Lamprey Bollards
- Trash Rack
- Concrete Weir
- Lamprey Collection Box

- Shade Structure
- Minor Modifications to the serpentine section of the junction pool

Variable Width Weir: A new weir will replace the old, non-varied width weir. The relevant weir slot is located at the entrance of the Bradford Island fish ladder. The old weir lived in the “Segmental Gates” slot shown below. The new weir will live in the “Regulating Weir” slot. The larger slot will provide a better, stronger design for the weir itself. Project staff noted that the “Regulating Weir” slot does not get used.

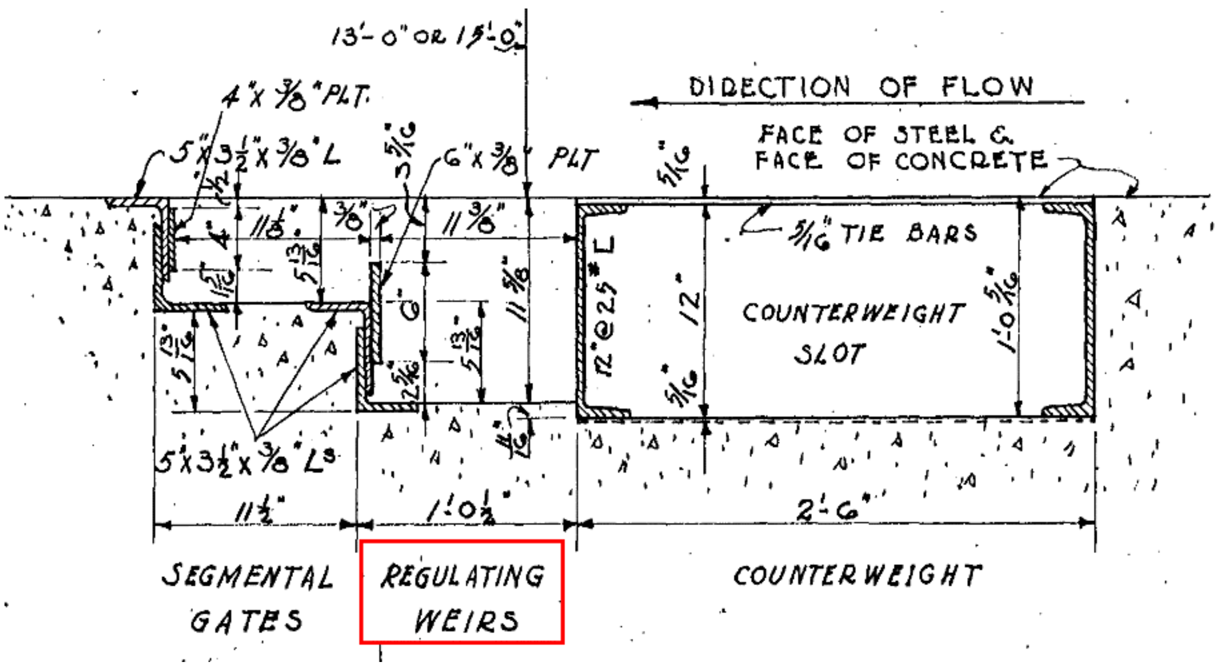


Figure 4-1: Variable Width Weir Slot shown in Red

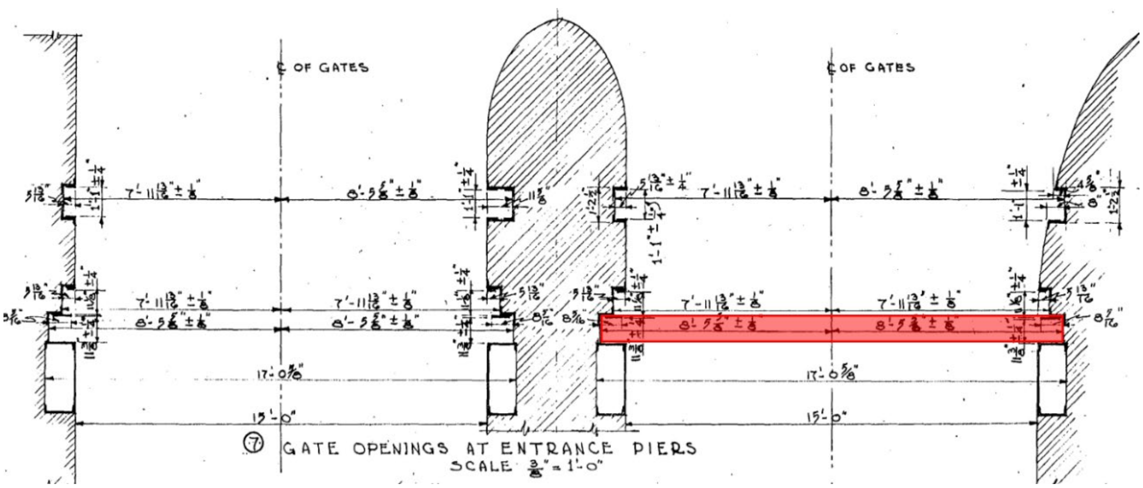


Figure 4-2: Plan View Showing the Entrance Slots and The Relevant Slot for the Weir

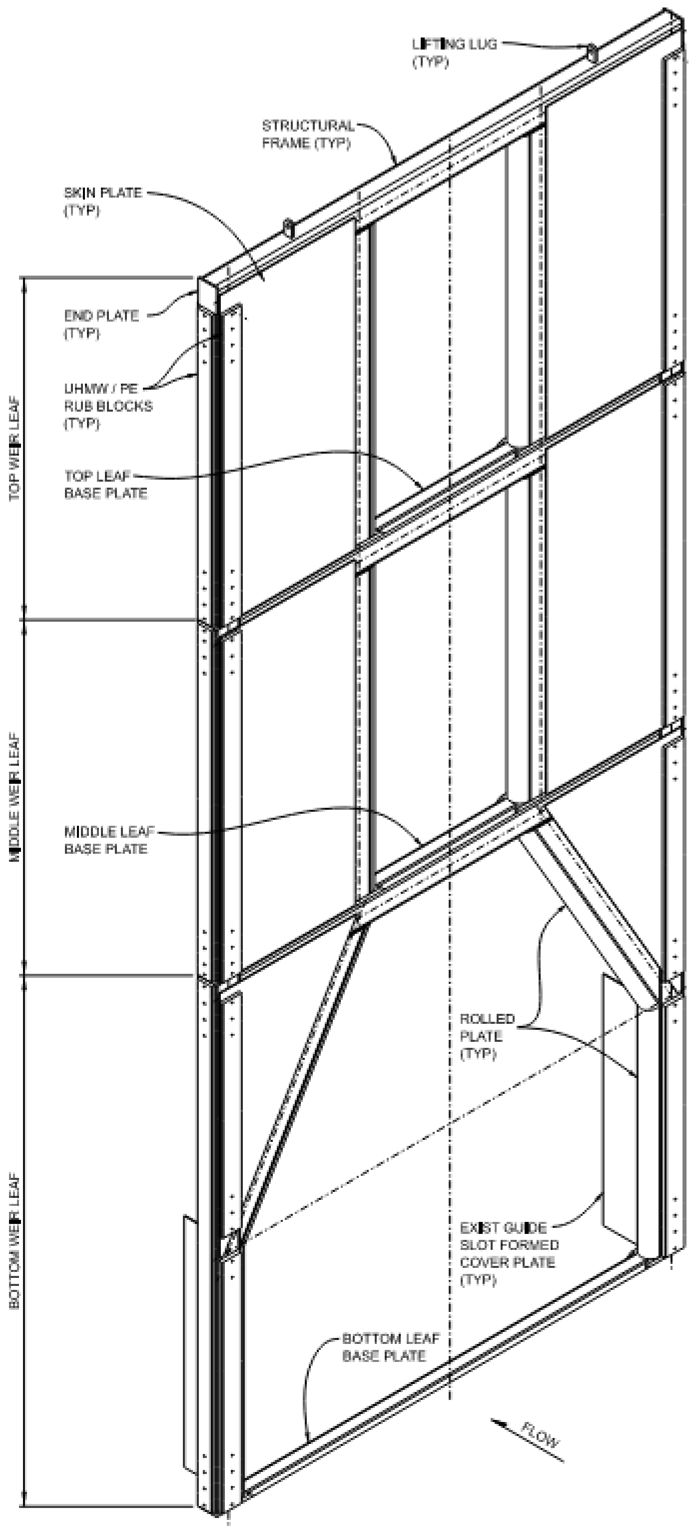
The existing Cascade Island weir and new Bradford Island weir will be almost identical. The main difference is that the Bradford Island weir will have three stacking segments versus one large 38’ tall weir. Both weirs operate the same. However, it is very challenging for project crew to remove and place it into its slot because the guide slots have become misaligned since original construction. The new weir will utilize shorter segments to allow for more misalignment in the guides.

The three sections stack together for total weir height of 38 feet. 38 feet is required to account for the tailwater high water mark. The top two sections are identical and shorter (11 feet), while the lower section is 16 feet tall. The opening of the top two sections is constant at 5 feet wide. The bottom section opening, which spans the whole channel width (14 feet) at the bottom, gradually varies to a 5-foot-wide opening at the top.

The weir frames will consist of rectangular hydraulic steel structure (HSS) members with attached 4” radiused rounded plates at the opening to allow easier fish and lamprey entrance. Each weir section will have a 1.5” bottom plate. The bottom plates will be sloped at 45 degrees on upstream and downstream edges to allow lamprey into and out of the channel. The weir will utilize a ½” skin plate on only the upstream side. The downstream side will not require a skin plate. Lifting lugs are 1” thick and orientated in the upstream-downstream direction and were designed in accordance with ASME BTH manual. The weir can be removed via a crane and chain rope. The same way the old weir was removed.

UHMW-PE rub blocks will be used along the full height of the weir in its slot. The upstream/downstream rub blocks will be 1.25” thick. The out to out rub blocks will be 1.375” thick. The rub block thickness was based on strength and geometry of the slot and weir in the slot. All rub blocks will be attached using 5/8” countersunk screws.

Because lamprey tend to swim near the walls of channels, the “Segmental Gates” slot must be covered to keep lamprey from going places they shouldn’t. By attaching a metal plate to the weir, the other slot can be covered and protected from lamprey entering. This plate will be 3/8” thick by 16” long by 10’ high. The slot cover only needs to be attached to the lower 10’ of the weir because of the orientation of the opening. The upper segments only have a 5’ opening. Therefore, the lamprey would need to swim into the ladder and immediately turn 90 degrees and swim roughly 6’. A plan view of the weir with the plate cover is shown below.



ISOMETRIC - WEIR UPSTREAM SIDE

Counterweight Slot Cover: The counterweight slot is another area of concern for lamprey passage. The slot consists of a metal frame with transverse tie bars along the full height of the entrance channel. This presents a large area in which lamprey can get stuck, reduce passing numbers, or even die. Therefore, it is important to keep lamprey out of this slot. The counterweight slot is shown below

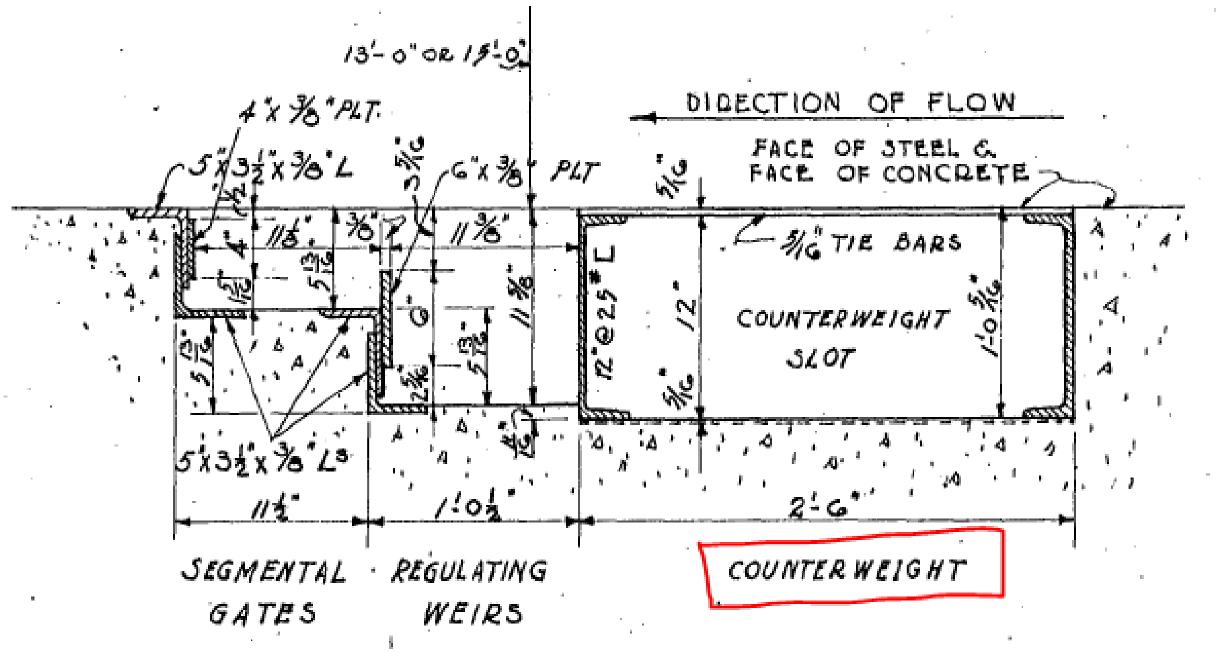


Figure 4-3: Counterweight Slot Shown in Red

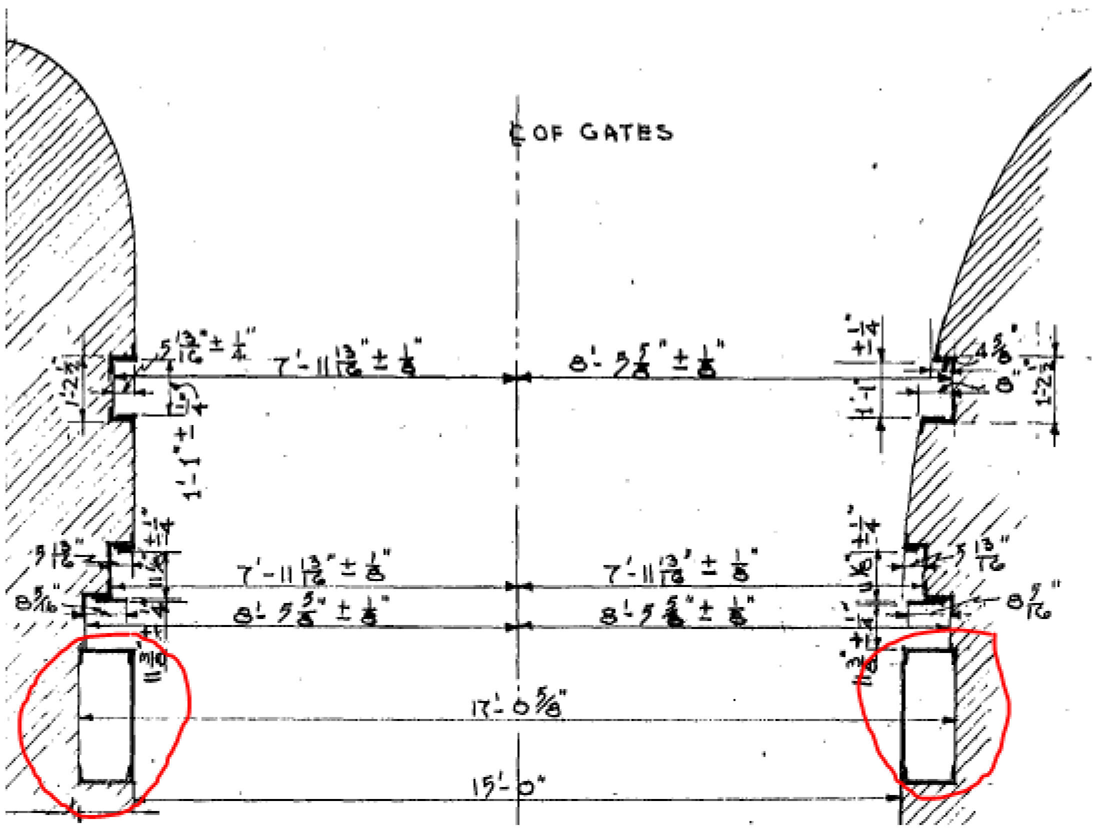


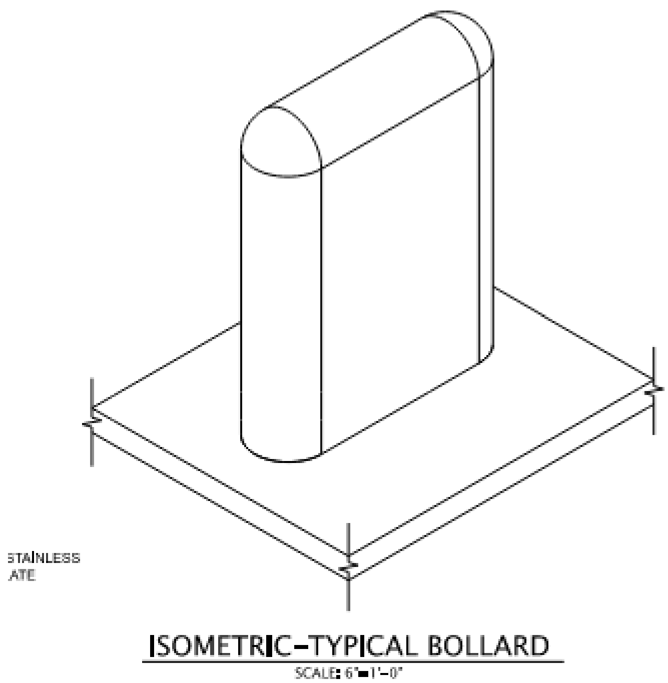
Figure 4-4: Plan View Showing the Entrance Slots and The Relevant Slot for the Counterweight Slot Cover

The counterweight slot cover will act as a barrier for lamprey getting into the slot. A 3/8” thick by 2’-3” wide by 38’ tall, A36 plate, will be welded to the outside of the slot to keep lamprey out. The welds and egdes of the plate will then be ground flush, to allow lamprey to burst and attach if needed.

The plates will be installed in smaller workable sized sections (roughly 4’) with small gaps between them to equalize pressure.

The existing counterweight slot will need rehab in order to attach the new plate cover. The tie bars and channel members are deflected in several areas. The extents of the rehab will be determined during construction.

Lamprey Bollards: The purposed of the lamprey bollards is to ease navigation, slow water flow, and direct lamprey throughout the ladder. They consist of bent 3/16" stainless steel plates and are 10 inches tall. The bollards have rounded edges for lamprey attachment. The proposed shape stems from the bollards at the John Day North entrance, as they were deemed the most effective. In contrast, to the more domed shaped bollard, which was used at the Cascades Island entrance, which was deemed less effective. See the images below for a plan and elevation of the new bollard shape.



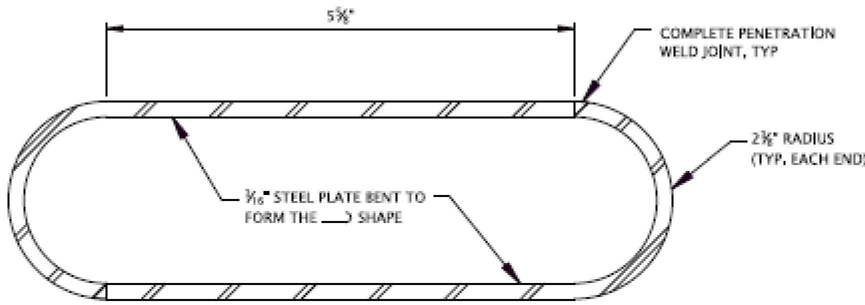
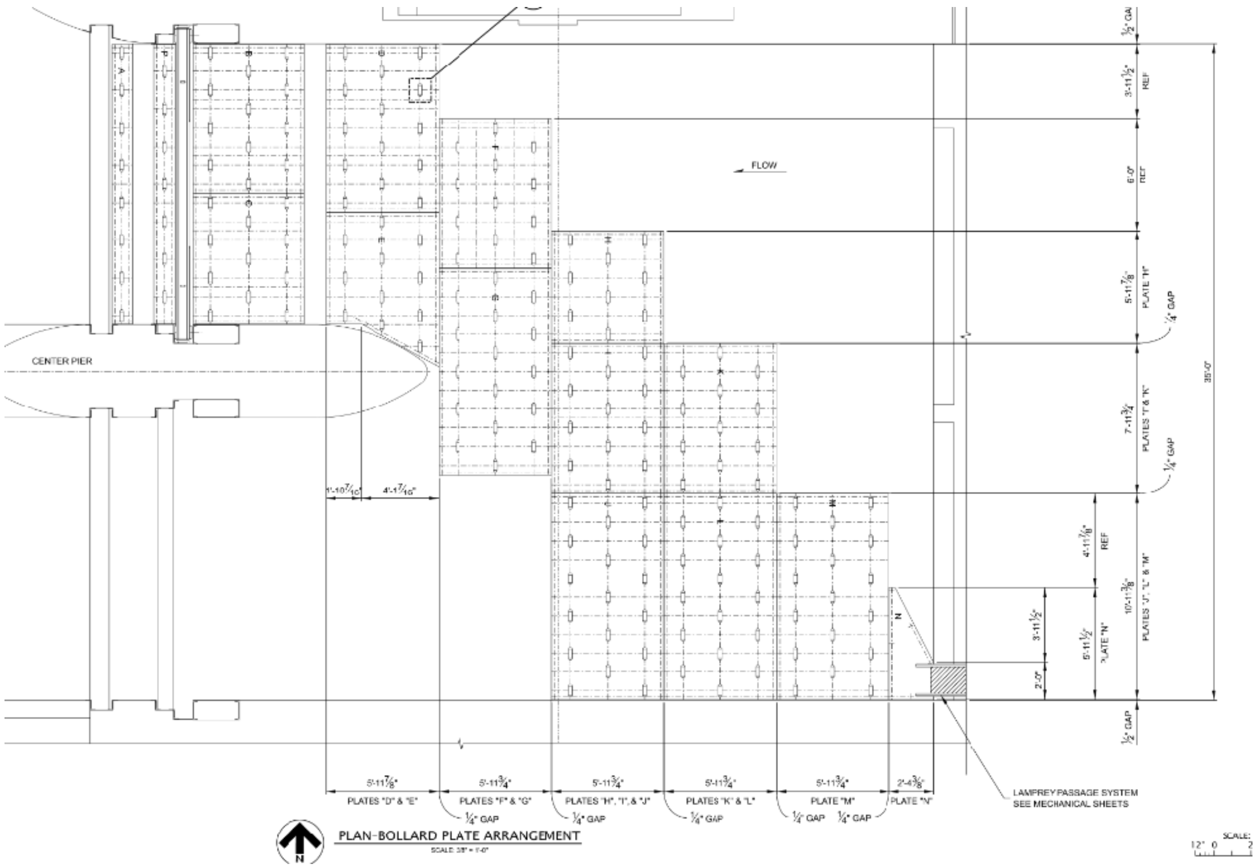


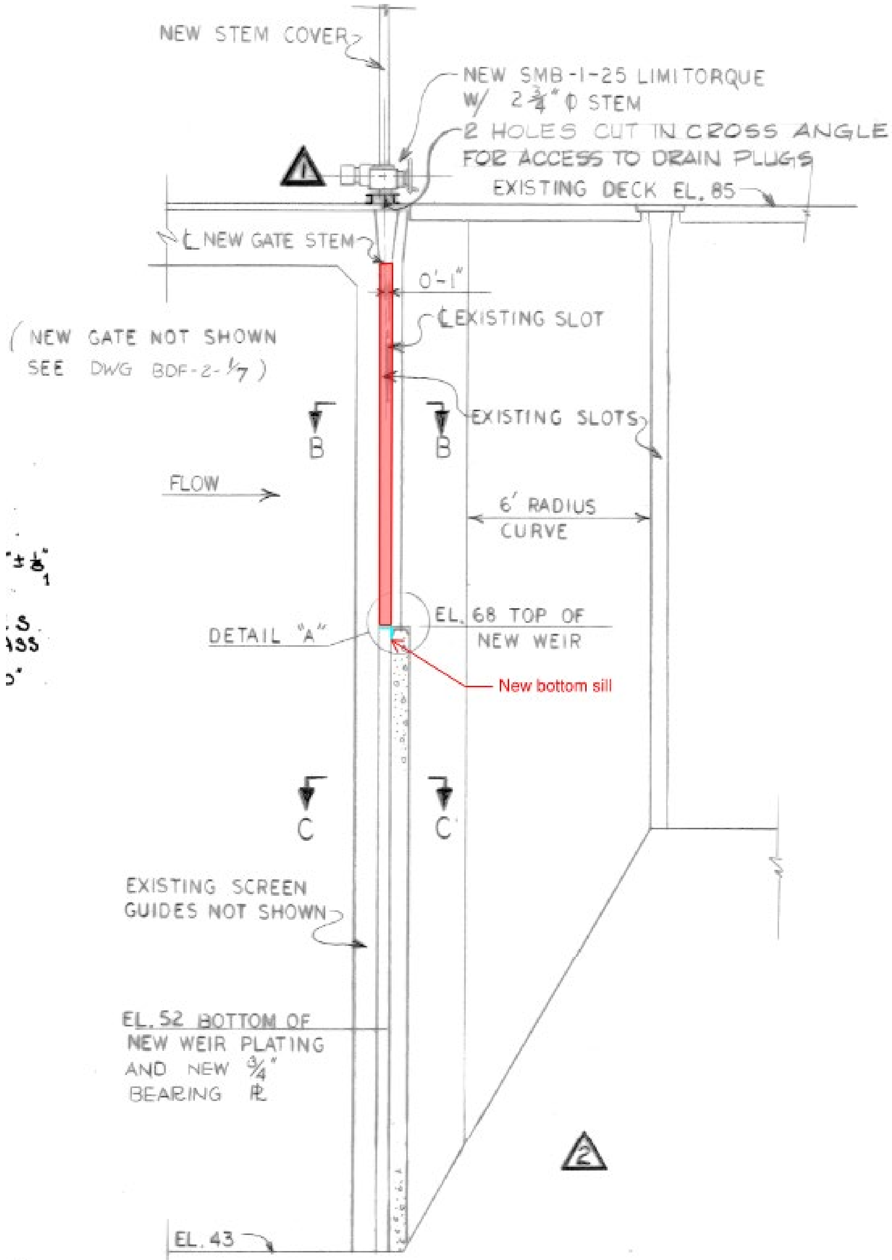
Figure 4-5: Plan View of Bollard shape.

The bollard layout plan is shown below. The orientation of the plates and bollards on the plates is such that they will guide the lamprey towards the LPS. Each plate is 1” thick stainless steel and is anchored to the ladder floor with 5/8” stainless steel anchors.

The spacing of the bollards is shown below. This was determined by the hydraulic engineer.



Trash Rack: A new trash rack is required to keep debris out of the LPS water supply pipe. The new rack will be positioned just upstream of the pipe and in an old sluice gate slot at the dam forebay. The trash rack slot is shown below on sheet BDF-2-1/4:



The rack will require a new sill at EL 68'. There is no need to use a trash rack below this elevation. The new sill will consist of a L8x8x1/2", welded to the existing concrete weir and its steel cap.

The rack is 4' wide by 11' tall and will be used during lamprey passage season. The rack will be from EL 68 to EL 79', 1 foot higher than concrete weir downstream. Project staff can lift the rack via machinery and brush of the debris on the trash rack bars.

The rack itself consists of four lateral HSS 6x2x3/8” members, each 4’ long. These members will resist the main lateral forces and support the trash rack bars. The ½” thick end plates will be used to tie the structure together. The type of trash rack bars will be determined for the next submission. However, for now, the PDT has assumed ½” spacing of bars.

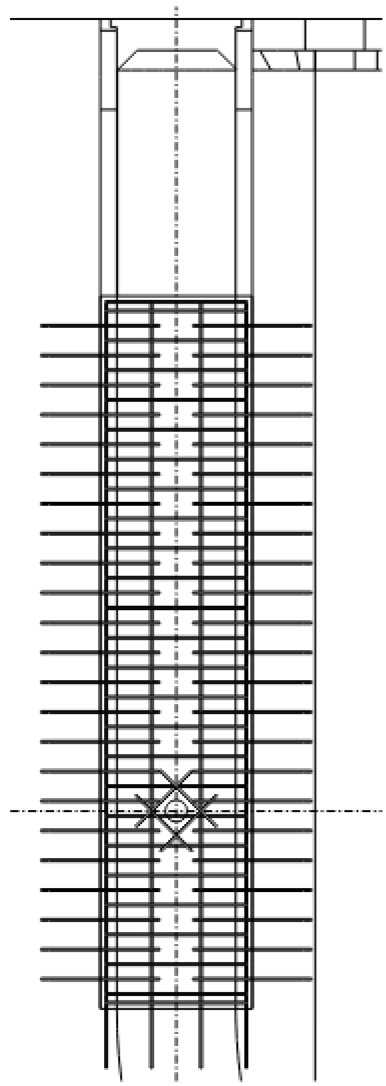
1” thick lifting lugs will be used. Unlike most gates, the lifting lugs will be attached to one of the middle members to reduce the height of the trash rack hoist on the forebay deck.

The rack will utilize guide plates attached to the out to out ends. This is required because the rack will not fit into the slot. The slot is 6.25” wide. The HSS is 6” wide without the grating bars or rub blocks.

The rack will require new machinery and a new hoist frame. Both will be designed by the mechanical engineer.

Concrete Weir: A new concrete weir will be constructed in the SL-30 slot (stoplog slot). This is required because of the removal of the upstream sluicegate. Without the sluicegate in the slot there is no way of stopping flow in the fingerling channel, hence the use of the concrete weir.

The existing stop logs in SL-30 will be removed, and concrete will be poured to EL 78. The slot is 9” wide, the length of the channel is 3’-10”, and the channel is 18’ high (EL 60 to EL 78).



A ELEVATION LOOKING EAST
SCALE: 1/2" = 1'-0"

The slot is comprised of two steel channels, with a 9” gap between them. The slot is in deteriorating condition and will need minor rehab work prior to the concrete pour. The channels and slot condition can be seen below:

The concrete weir will utilize #5 rebar in the horizontal and vertical directions. The weir will be tied into the existing structure using dowels on the side walls and floor.

The weir will require a pipe penetration at EL 65' for the LPS water supply pipe. The penetration must be cast in place in order to properly reinforce the area around the opening. A steel through fitting with flanges will be used to connect the pipe to the concrete weir. One important aspect is that this pipe must easily be capped when the LPS is not in use, a through fitting should accomplish this. The through fitting must have 1.5" of concrete cover in all directions. The specifics of the through fitting will be determine for the next submission.

Lamprey Collection Box: The LPS will route the lamprey into a collection box located near the fish ladder entrance. See below for the location of the box. This location was picked because of the proximity to the LPS, and it will be out of the way for any other project site needs.

Figure 4-6: Lamprey Collection Box Location

The collection box will be a new feature designed by the mechanical engineers. See the mechanical design section below for more information.

Shade Structure: A shade structure is required to cover the collection box to better regulate the water temperature. A pergola and shade screen options were researched and deemed to be not as effective as needed. Pergolas were effective dealing with morning and evening sun, however when the sun is high in the sky it is less than 50% effective. The shade screen would likely not last a whole season given the weather conditions at Bonneville.

The preferred option is a small gazebo like shade structure with a roof. This will be contractor furbished and can be purchased from a local supplier. The structure must provide shade to a 4’ wide by 12’ long area. Below is a possible solution:

Figure 4-7: Possible Type Structure from Online Retailers

Calculations from the mechanical engineer has shown that the shade structure is likely not needed. The main contributing factor to a high-water temperature in the LPS is the ambient temperature, vs UV rays.

Minor Modifications to the serpentine section of the junction pool: The modifications to the serpentine section include rounded corners within the junction pool and ladder, lamprey rest boxes on the channel floor, lamprey orifices within the fish ladder with antennas for PIT tag detection and roughen the floors and walls in high velocity areas. See the Hydraulic design section for additional info.

The structural scope for these modifications is to check and ensure the work done does not compromise the structural integrity of the control section and ladder. This work will be completed outside of the main contract.

4.6 REMOVAL OF STRUCTURAL FEATURES

The old weir at the fish ladder entrance will be removed to make room for the new Variable Width Weir. The new weir will utilize the same lifting style as the old weir (crane and chain rope).

The existing sluice gate in the trash rack slot will be removed. It is currently inoperable due to the existing machinery. The machinery will also be removed and replaced with a new hoist.

The minor modifications to the serpentine section will required grinding and minor concrete cutting for rounded corners and lamprey orifices.

4.7 DESIGN CALCULATIONS

Design calcs have been included for the Variable Width Weir, Counterweight Slot Cover, Lamprey Bollards, Trash Rack and Concrete Weir. The calcs were done by hand, a model is not needed for this type of work.

4.8 DESIGN DECISIONS

Some design decisions remaining for the next submission include; pipe through fitting on concrete weir, specifics on the trash rack hoist frame, decision to use a shade structure, and type of trash rack bars.

SECTION 5 - MECHANICAL DESIGN

5.1 GENERAL

5.1.1 Mechanical Scope

The mechanical scope for this project includes design of flume components for an LPS from the fish ladder entrance to a nearby collection box and a water supply system for the LPS.

5.1.2 Design Requirements

The key requirements of the mechanical design as of the 90% milestone are summarized below.

- Geometry: channel geometry should be limited as follows, per Technical Report 2015-5 and Section 3:
  - Channel slope = 45º.
  - Surface roughness: The ratio of surface roughness to flow depth should result in a hydraulically smooth flow.

- Biological constraints
  - The flume design must adhere to the biological requirements outlined in 2.3.1

- Hydraulic constraints
  - The flume design must adhere to the hydraulic requirements outlined in 3.3.2.
  - The water supply must be able to provide the design flow rate outlined in 3.5.3.

5.2 SELECTED ALTERNATIVE

5.2.1 Lamprey Passage Structure

The selected alternative is based on the mechanical features of the LPS used at the Bonneville AFF. The LPS will be constructed of 5052-H34 aluminum. The primary means of fabrication is to be cold bending from 3/16” sheet metal patterns. It is assumed that the sheet metal patterns will be water jet cut for repeatability, economy, and to avoid heat warping that can be caused by other fabrication processes.

The LPS has been developed utilizing the flume path defined in 3.2.3. Figure 5-2 below shows an overall view of the LPS, including the features of the climbing section.

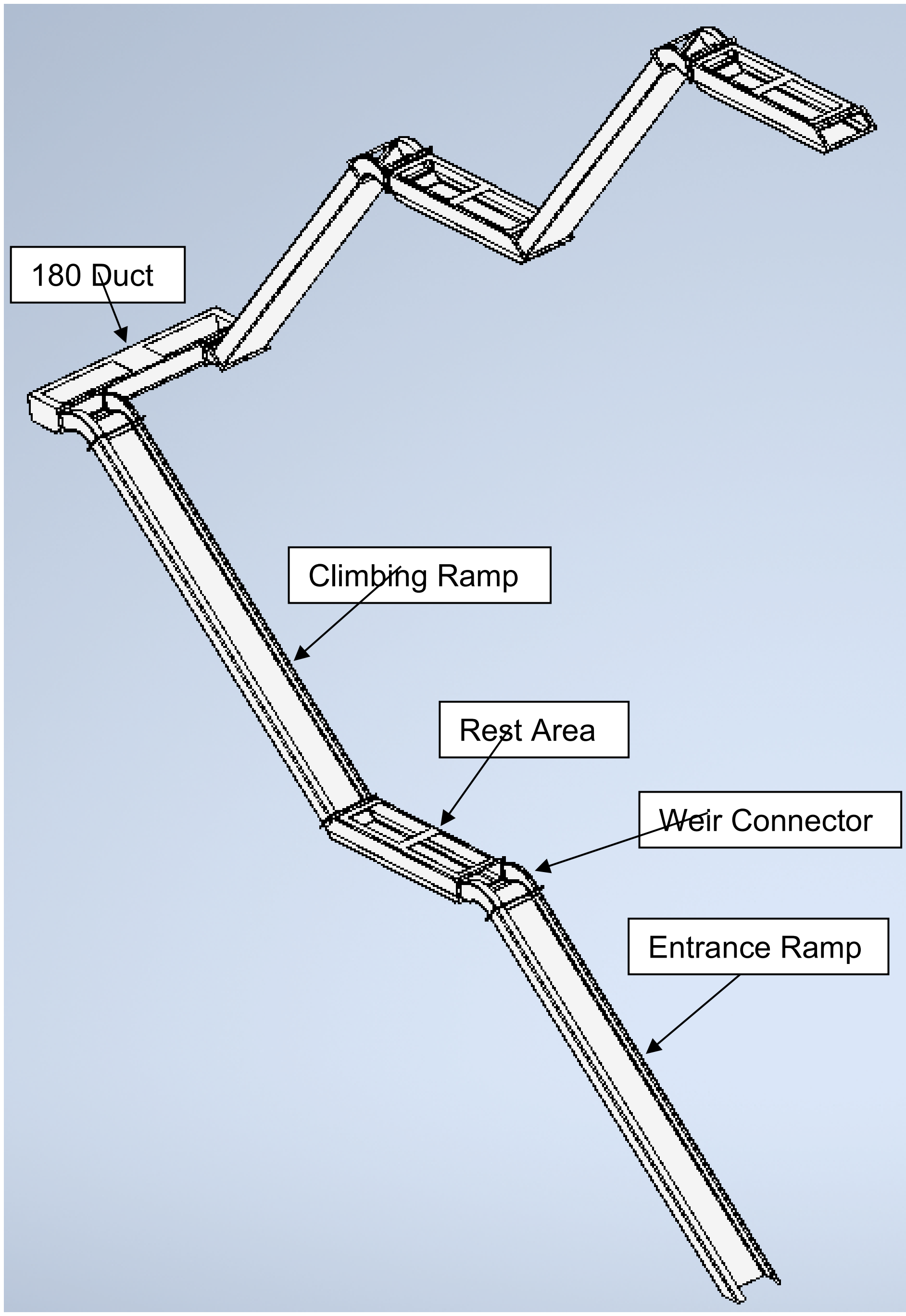


Figure 5-1: LPS Features, Climbing Section

5.2.1.1 *Entrance 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.

5.2.1.2 *Flume*

Flume segments are divided into climbing ramps and traversing ducts. The climbing ramps are angled at 45º. The internal width of a climbing ramp is 22 inches. The internal height of a climbing ramp is 8 inches. Flumes are cold formed from 5052-H34 aluminum with a minimum bend radius of 9/16 inch. This provides a curved surface to facilitate lamprey movement between horizontal and vertical planes. Flume sections outside the water column will have hinged covers. Each flume has welded flanges for bolted connections between sections.

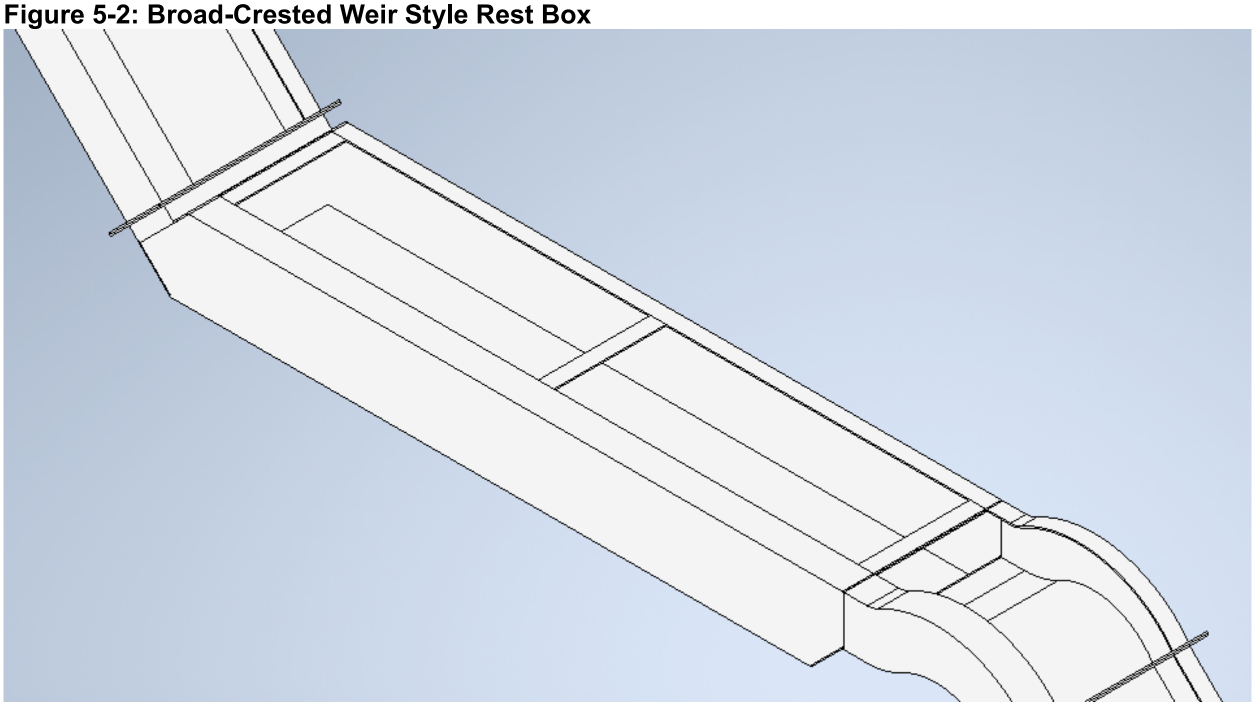
Traversing ducts

5.2.1.3 *Rest Boxes*

Rest boxes are utilized after climbing segments and at intervals as described in section 3.2.3.6. These boxes provide a refuge for lamprey to recuperate after long or difficult travel segments. Research shows that the type of rest box causes only minor changes in lamprey performance, with the associated ramps being of greater influence (Keefer, v). The selected concept uses broad-crested, weir style rest boxes. This rest box is easier to maintain and fabricate rather than other rest box styles used in existing LPS systems at the Bonneville project. The rest box will have a cover and a drain, detailed in the 90% submittal.

The rest box will be cold formed from 5052-H34 aluminum with a minimum bend radius of 9/16 inch to match the connecting flumes. The entrance and exit ramps of the rest box are angled at 45 degrees. The entrance and exit has an internal width of 22 inches and an internal height of 8 inches. The depth of the rest box is 4 inches.

Figure 5-2: Broad-Crested Weir Style Rest Box



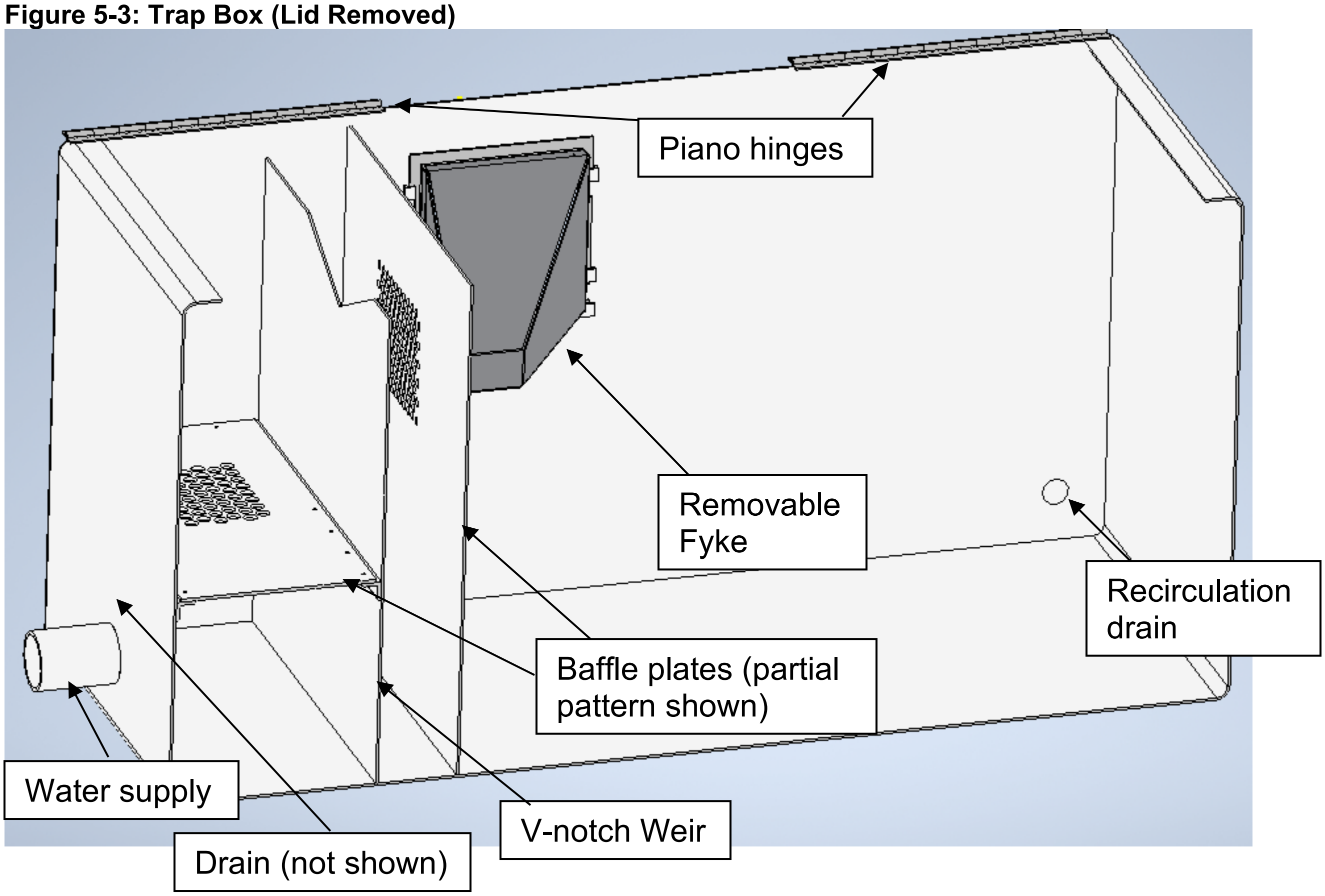
XX below shows the features of the traversing section of the system.

5.2.1.4 *Trap Box*

The trap box, also called a collection tank, is located at the end of the flume. The trap box connects to the water supply through a head box to provide an adjustable, measurable, laminar flow to the collection area of the trap. The head box contains a connection to the water supply, a drain, a two baffle plates to provide screening, and a calibrated, V-notch weir on the flume side to indicate flow rates. The invert of the notch is to be at or slightly above the top if the incoming flume segment. A fyke separates the flume from the trap box to prevent lamprey passage outside of the flume.

Figure 5-4: Trap Box (Lid Removed) below shows an isometric view of the trap box and identifies the major features.

Figure 5-3: Trap Box (Lid Removed)



5.2.2 Hybrid Flume Alternative

The alternative concept is a low angle weired passage system (LAWPS), also called a hybrid flume. It is the PDT's recommendation that future extensions of this LPS system utilize hybrid flumes. Research shows that weired flume sections promote passage motivation, ease of passage, and reduce required passage time (Hanchett and Caudill, v-vi). The incorporation of weirs eliminates the need for rest boxes by creating pools between each weir. The elimination of rest boxes reduces the amount of monitoring and maintenance required. Additionally, the hybrid flume is intended to run at the top of the fish ladder walls, which increases accessibility for maintenance operations.

Features of this concept are as follows:

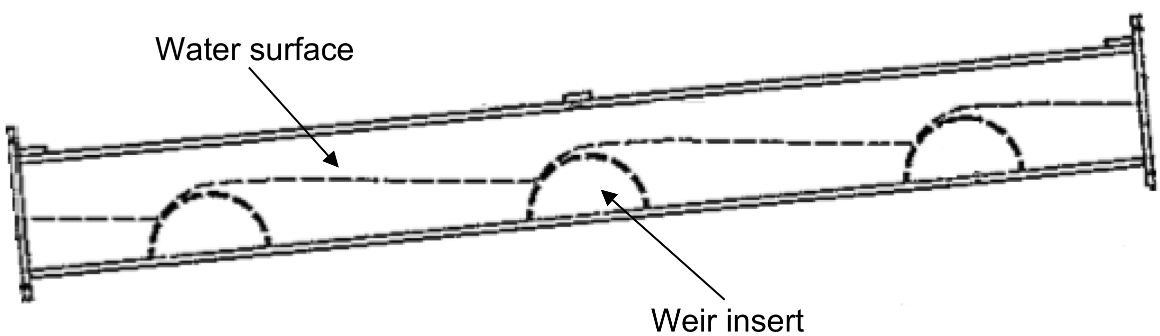
5.2.2.1 *Entrance*

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 5-3: 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 5-4: Prototype Low Angle Weired Flume



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 incorporate a shade structure. Shade structures require the lowest amount of maintenance and may provide additional protection from the elements. Shade structures are the recommended alternative for thermal control.

The flumes may be fabricated in one of two ways: cold formed from 5052-H32 aluminum sheet with insertable weirs, or press formed as a single component. Press forming is recommended for long flume runs, or in the case of multiple projects utilizing this design, to take advantage of cost reductions due to economy of scale and reduced installation labor.

5.2.2.3 *Insertable 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.

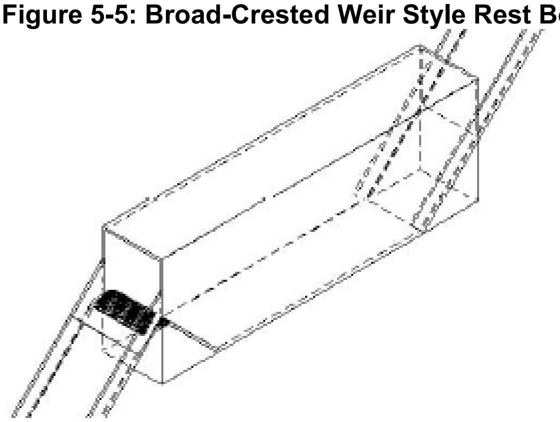
Welding the weirs creates a permanent, sealed connection. The welded weirs would not be replaceable or adjustable and would require replacement of the flume section to adapt to changing conditions.

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 before the climbing section into the upwelling box. 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 allows lamprey to rest, if they choose, before the ascent into the upwelling box. This rest box is identical to the rest box described in section 5.2.2.4.

Figure 5-5: Broad-Crested Weir Style Rest Box



5.2.2.5 *Trap Box*

The trap box is the same as the box detailed in section 5.2.1.4.

5.2.3 WATER SUPPLY SYSTEM

The water supply system will be a gravity feed from the defunct juvenile fish passage structure located upstream of the Bradford Island B-branch fish ladder entrance. The water supply will be detailed in the 90% submittal.

5.3 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 Bonneville Fish Accords Lamprey Project.

6.2 DESIGN REFERENCES

- 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 B-Branch Fish ladder Entrance. The upgrades consisted of two possible options, gravity fed and pumped water. The gravity fed option would not require pumps, though new power distribution would need to be routed and installed for the pumped water option. Any requirements for new power distribution would need to be verified with operations staff. Design decisions were based on the understanding that there will be additional volitional passage as part of future projects. 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 head box.
- A signal would need to be sent to the fish facilities through the existing supervisory control and data acquisition (SCADA) system if the sensors detect abnormal water levels below a pre-determined set point.
- 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.
- Both 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 loses power.
- New electrical design for the pumped water supply alternative would be comparable to the existing Washington Shore LPS pump and control system.

It should also be noted that Bonneville project staff will be procuring and installing all electrical equipment associated with this project.

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 and/or control systems should consider constructability and ease of installation when determining new cable and conduit routing and the addition of any new electrical equipment.

6.5 DESIGN CONSTRAINTS

6.5.1 Load Center Capacity

New electrical systems would need to be fed from 120 volts alternating current (VAC) panels with enough available capacity to accommodate the loading of any new electrical equipment.

6.5.2 Cable and Conduit Routing

New cable and conduit need to be routed to the input/output (I/O) panel so that the cables are protected from damage and routed in a way that minimizes voltage drop as much as possible.

6.6 SYSTEM LEVEL ALTERNATIVES AND RECOMMENDATIONS

6.6.1 Alternative 1 – Pumped Water Supply

Design includes power delivery from a load center routed in conduit to a pump motor control panel. Remote monitoring would require an I/O panel with communications to allow for status indication. Design would also provide the ability to operate the pumps locally. A potential power source for this option would be from the south tower.

A float switch installed in the lamprey integrated head box would monitor water level and signal an alarm if a low-level set point is met. Last, an alarm would alert the control room if either pump were to fail.

6.6.2 Alternative 2 – Gravity Fed Water Supply

As with the pumped water supply alternative - design includes implementing a float switch in the lamprey integrated head box to monitor water levels. An alarm would notify the fish facilities if a low set point is met. A remote I/O Panel would be installed near the B-Branch entrance if an existing panel is not available. It should be noted that the gravity fed option is dependent upon whether the integrated head box will be located below the top of the dam.

6.7 DESIGN CALCULATIONS

6.7.1 Voltage Drop Analysis

Voltage drop calculations were performed to verify that there was less than 2% voltage drop across all inline feeders and less than 3% voltage drop at the branch circuit to each load.

6.8 CONTROL AND INDICATING SYSTEM DESIGN

Design intent was to have monitoring and alarm ability for required sensors. The control signals would be integrated into an existing fiber optic network through a remote I/O panel and fiber optic patch cabinet. Project staff would be notified of low water levels though a fish facilities human-machine interface (HMI) panel.

6.9 DESIGN DECISIONS

Based on input from operation staff, the product development team and existing site conditions the following electrical design decisions were made. During this phase of work there will be no pumping system required as a gravity fed option is a viable and preferred option. The electrical sensor requirements consist of a float switch in the lamprey integrated head box to monitor water level. The sensor will notify operations staff through the exiting SCADA system if a low-level set point is reached.

Project staff identified two separate power panels in the South Tower with enough spare capacity to power the new I/O panel electrical equipment. The circuit for the I/O panel heater would be run from DSCR1 at EL.85. The remaining I/O power would be run from the preferred AC Panel MDCH1 at El. 72.5. Each power circuit would consist of 2#12 cables with 1#12 equipment grounding conductor (EGC). The fiber optic connection consists of a 6-strand, single mode, fiber optic cable that would connect to the existing SCADA system at FOPC-2 in the communications room at EL 85.

Proposed cable and conduit routing from the existing 120 VAC panels and fiber optic patch cabinet to new electrical installations were verified by project staff and are as follows. The three new circuits would be routed in a combination of cable trays and rigid galvanized steel (RGS) within the South Tower to an embedded electrical duct bank in the walkway north of the South Tower, at El. 85. On the north end of the duct bank the two power cables will be routed in a single, one-inch RGS conduit down the abutment stairs to the B-Branch Control Cabinet Enclosure where they will connect to the I/O panel. The new fiber optic cable will be routed from the duct bank in a separate ¾ inch RGS conduit, parallel to the I/O power circuit, to the I/O panel. From the I/O panel the cable for the float switch will be routed in ¾ inch RGS along the handrail of the adjacent bridge. The conductor sizes for this circuit would be 2#14 and 1#14 EGC. At the south end of the bridge the cable will be routed underneath the bridge to the lamprey integrated head box location.

6.10 DESIGN RECOMMENDATIONS

The recommendations for the new electrical design were as follows. A float switch would be added to the new lamprey integrated head box to monitor for a low water level set point. This sensor circuit would be routed into a new remote I/O panel located in existing B-Branch Spillway Control Cabinet Enclosure. Power and communications circuits would be routed to here from the South Tower, where the fiber optic circuit would connect to the existing SCADA system.

This was determined to be the best design solution for a couple of reasons. First, the routing of the cable and conduit from the South Tower to the B-Branch Control Cabinet Enclosure is relatively straight forward and free of obstructions that could make the constructability of the project difficult. Second, adding the remote I/O panel near the lamprey integrated head box would enable the addition of future sensors. If new indication, monitoring or alarm sensors are needed for future volitional passage requirements they could be added to the existing system with minimal effort.

SECTION 7 - ENVIRONMENTAL AND CULTURAL RESOURCES

7.1 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 Oregon State Historic Preservation Officer (SHPO), Indian tribes and Tribal Historic Preservation Officers (THPOs), National Park Service (NPS), and other interested parties, as appropriate. Additionally, any action involving ground disturbance could require an archaeology survey or monitoring. Consultation with SHPO, NPS, and any Indian tribes that ascribe cultural associations and significance within the Area of Potential Effects (APE) will be required.

Bonneville Dam is listed in the National Register of Historic Places and has been designated a National Historic Landmark. The Bradford Island fish ladders are identified in the nomination and are within the historic property boundary. Any alterations that 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. Per Section 110(f) of the National Historic Preservation Act, the Corps must take actions, to the maximum extent feasible, that would minimize or avoid any adverse effects. If adverse effects cannot be feasibly avoided, appropriate mitigation measures will need to be determined in consultation with SHPO, NPS, Indian tribes and THPOs, and other interested parties, captured in an MOA, and then carried out by the Corps within the agreed upon timeframe and funded by the project.

7.2 ENVIRONMENTAL COMPLIANCE

Corps projects must comply with numerous Federal environmental laws, rules, and regulations. Compliance with State or local environmental regulations may also be required. Typically, it is during the Plans and Specification phase (60% DDR) that the Corps prepares environmental clearance documents, so that compliance is complete before construction. CENWP-PM-E coordinates the environmental compliance process, with the exception of the Fish Passage Operations & Maintenance (FPOM) coordination for ESA compliance, which is conducted by PME-F or OD-T and documented by PME-E in the National Environmental Policy Act (NEPA) decision document.

All actions that are Federally funded, constructed, or permitted must comply with the NEPA. The District Commander is the official responsible for compliance with NEPA for actions within the district boundaries. The BON1 Lamprey Passage project will likely require the Corps to prepare a NEPA document called a Record of Environmental Consideration which utilizes a categorical exclusion (see 33 CFR 230.9(b)).

The status of other environmental clearances for the BON1 lamprey passage project is:

- Endangered Species Act (ESA) Section 7. Species under jurisdiction of National Marine Fisheries Service – addressed through Columbia River System Operation BiOp routine maintenance provisions, which includes the coordination with the FPOM interagency workgroup.
- ESA Section 7 – Species under jurisdiction of US Fish and Wildlife Service – No effect. These species are not present in the action area.
- Marine Mammal Protection Act – Not applicable. Disturbance will not impact marine mammals.
- Fish and Wildlife Coordination Act – Not applicable. Not a water control project.
- Bald and Golden Eagle Protection Act – Not applicable. Eagles not nesting in work area and no other take of eagles will occur.
- Clean Water Act Section 401 water quality certification – not needed as work area is totally isolated from active flow and work does not result in discharges to water bodies.
- Clean Water Act 404b1 analysis – not needed, as long as there is no fill into waters of the U.S.
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – Since the activity is immediately downstream (within ½ mile) of the Upland Operable Unit for the Bradford Island CERCLA site of the PDT will work with Bradford Island USACE Project Manager on determining the risk of disturbing contaminated sediments and the potential of the proposed action to interfere with future remedial investigations and activities. This process is detailed in the *Evaluation of Operations and Maintenance (O&M) near Bradford Island NPL site* Standard Operating Procedure (SOP). The SOP follows a process that utilizes the Bradford Island team's expertise to identify and ensure there is minimal risk from O&M activities.

SECTION 8 - OPERATIONS AND MAINTENANCE

8.1 OPERATIONS

8.1.1 General

- On/Off Procedures:
  - Start-up considerations
    - De-winterization
    - Alarms
  - Shut down considerations
    - Fish Salvage
    - Winterization
- Water intake system
  - Cleaning
  - Troubleshooting
- Water Level Alarm System
- Antenna System
- Collection of fish
  - Sized appropriately to easily collect lamprey without undue stress of "chasing"

8.1.2 Maintenance

[Next Milestone]

8.2 SAFETY

No one shall attempt to access any portion of the system that is not immediately accessible from behind handrails unless a fall protection plan is in place. Rest boxes located on the B-Branch entrance pier will need to be accessed by crane for maintenance and cleaning.

As much of the traversing sections as possible are built along rail systems to be accessible to personnel.

Security - This area is behind a locked security perimeter and not accessible to the public.

The collection box and rest boxes are to have latches that are secured to prevent predation.

SECTION 9 - COST AND CONSTRUCTION

9.1 GENERAL

This section presents the cost estimate for the Bonneville 1 FY19 Fish Accords Lamprey, Bradford Island Fish Ladder as presented in this DDR. The total project cost (design and construction) estimated at the 60% DDR/P&S phase is $5.32 million. The construction cost and design/managements costs are estimated to be $3.85 million and $1.47 million respectively. These values include a 24.5% contingency and an average 5.4% escalation. The construction contract is expected to take 12 months and on-site construction is anticipated to take up to 4 months. The total project cost summary sheet, risk analysis, and construction schedule can be found in the Cost & Construction Appendix.

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 October 2021 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.

- Scope Growth: Major features of the scope have been defined but project is going through Plans and Specifications and DDR at the same time. It is possible that more changes occur with a moderate cost impact.
- Acquisition Strategy: Sole source is unlikely but would have critical impact on cost.
- Restricted Work Window: Limited Fish Ladder closure window may lead to increased cost if contractor runs into delays.
- Cost Estimate: Contractor bids for the WA shore Lamprey Flume project came in much higher than the independent government estimate (IGE). Estimate for this project will be updated using new information, but cost assumptions may still be too low.

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 mechanical 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 $985,000 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 $485,000.

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 in-water work window (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 Guide slot fillers/covers, Bollard floor plates (in multiple pieces), Lamprey flume sections, & Lamprey boxes.

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 Bradford Island Fish Ladder

There is no other major construction anticipated for the Bradford Island fish ladder during this period of work. Biennial 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 square feet 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

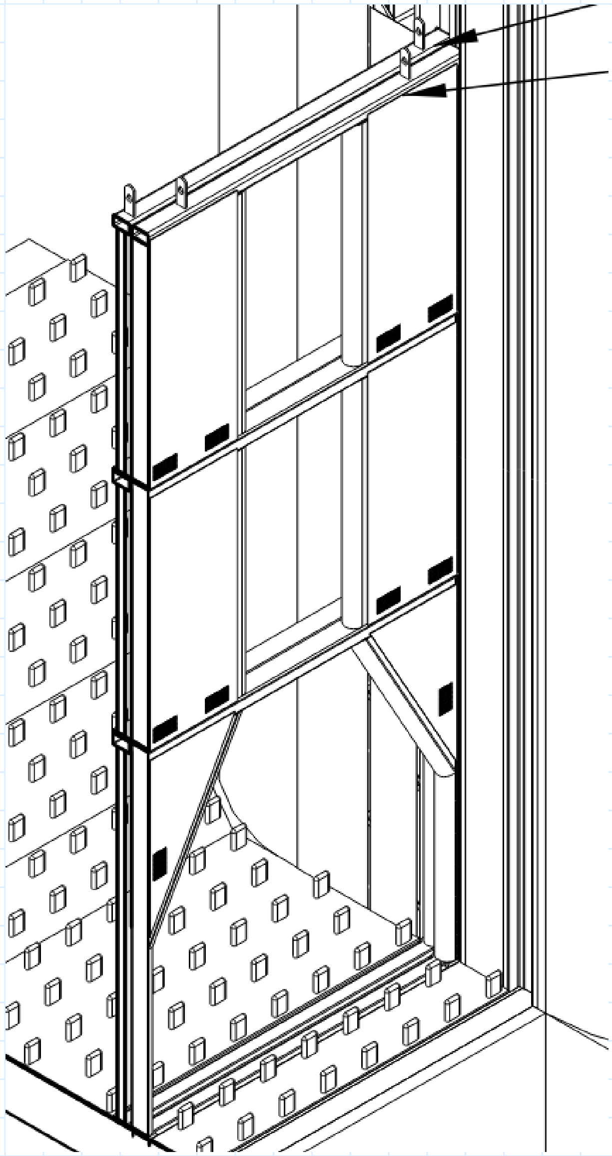
The contractor must provide their own crane for this work.

Appendix A - 90% Structural Design Calcs

Contents:

FY 19 Bonn Bradford Island Lamprey
Multi-Section Weir Design Calcs
Collin Porter

Multi section weir calcs



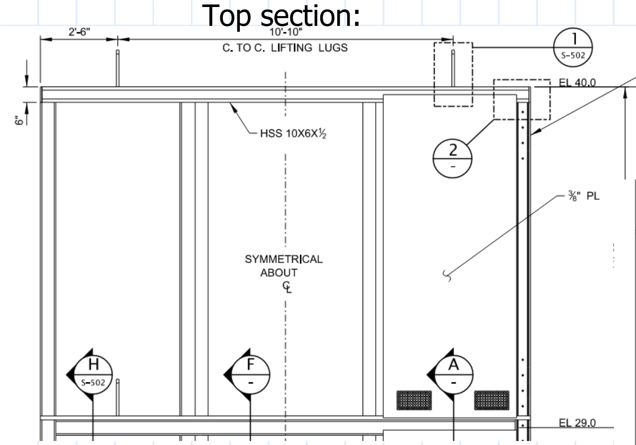
Summary of Document:
1. Geometry/Constants
2. Weight of weir sections
3. Slot Geometry/Loading and Load factors
4. Upper and Middle Skin Plate Design
5. Upper and Middle Horizontal and Vertical Member Design
6. Top Member(s) Design for lifting out of water
7. Bottom Section Vertical/Diagonal Member design
8. Gate Jammed Check
9. Lifting Lug Design

FY 19 Bonn Bradford Island Lamprey
Multi-Section Weir Design Calcs
Collin Porter

Structure Classification:

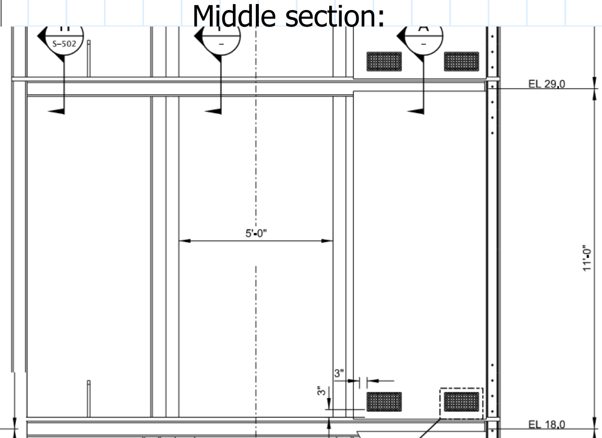
Multi-Section Weir Calcs

Top section:

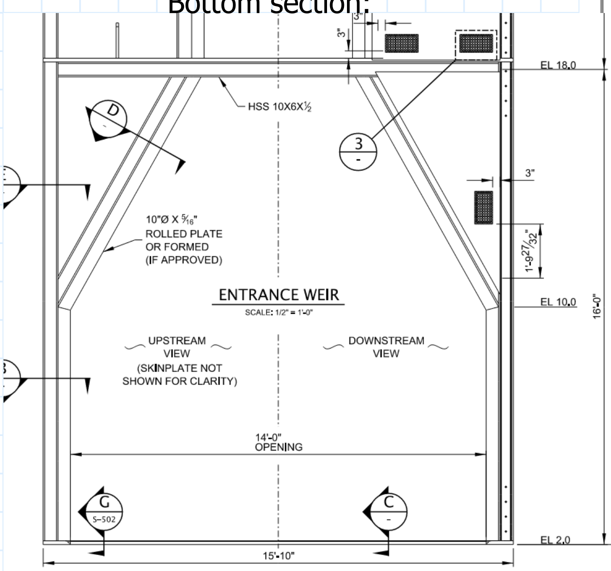


To do:
1. Welds

Middle section:



Bottom section:



Geometry/Constants:

Thickness skinplate: $t_{skin} := \frac{3}{8}\ in$

Height of Members:

$h_{top} := 11\ ft$

$h_{middle} := h_{top} = 11\ ft$

$h_{bottom} := 16\ ft$

Length of Structure: actual (width of slot - 1/4" tolerance each side - 1.5 in for rub blocks (2-.75" blocks))

$$L_{actual} := 2 \cdot \left(7\ ft + 11\ in + \frac{13}{16}\ in\right) - \frac{1}{4}\ in - \frac{1}{4}\ in - 1.5\ in = 15.802\ ft$$

Length of Diagonal members:

$$L_{diag} := \sqrt{(5\ ft)^2 + (8\ ft)^2} = 9.434\ ft$$

Length for Design: slot to slot (more conservative)

$$L := 2 \cdot \left(7\ ft + 11\ in + \frac{13}{16}\ in\right) = 15.969\ ft$$

Length between lifting lugs:

$L_{lugs} := 10\ ft$

Weight per foot:

$w_{10x6x5.16} := 31.84\ \frac{lbf}{ft}$

Bottom plates:

$t_{plate} := 1.5\ in$ $\quad width_{plate} := 10\ in$

$w_{10x6x3.8} := 37.69\ \frac{lbf}{ft}$ $\quad w_{steel} := 490\ pcf$

Weight of Structure:

Top section: 4 - 11' vertical members(HSS 10x6x5/16), top member (HSS 10x6x5/16), bottom plate (10"x1.5"), 2 skin plates (11'x5.42'x3/8") , 5% misc weight

$w_{top.vert} := h_{top} \cdot w_{10x6x5.16}$ $\quad w_{top.horiz} := L \cdot w_{10x6x5.16}$

$w_{bot.plate} := width_{plate} \cdot t_{plate} \cdot L \cdot w_{steel}$ $\quad w_{upper.skinplate} := h_{top} \cdot 5.42\ ft \cdot t_{skin} \cdot w_{steel}$

$$W_{top} := 1.05 \cdot \left(\left(w_{top.vert} \cdot 4 \right) + w_{top.horiz} + w_{bot.plate} + \left(w_{upper.skinplate} \cdot 2 \right) \right) = 4.778\ kip$$

Middle section: 4 - 11' vertical members (HSS 10x6x5/16), top member (HSS 10x6x5/16"), bottom plate (10"x1.5"), 2 skin plates (11'x5.42'x3/8"), 5% misc weight

Top and middle sections are identical thererfor: $W_{middle} := W_{top} = 4.778\ kip$

Bottom section: 2 - 16' vertical members (HSS 10x6x5/16), top member (HSS 10x6x3/8"), bottom plate (1.5"x10"), 2 diagonal members (HSS 10x6x5/16"), 2 smaller 3/8" skin plates (.5*5'*8'), 5% misc weight

$w_{bot.vert} := h_{bottom} \cdot w_{10x6x5.16}$ $\quad w_{bot.plate} := width_{plate} \cdot t_{plate} \cdot L \cdot w_{steel}$

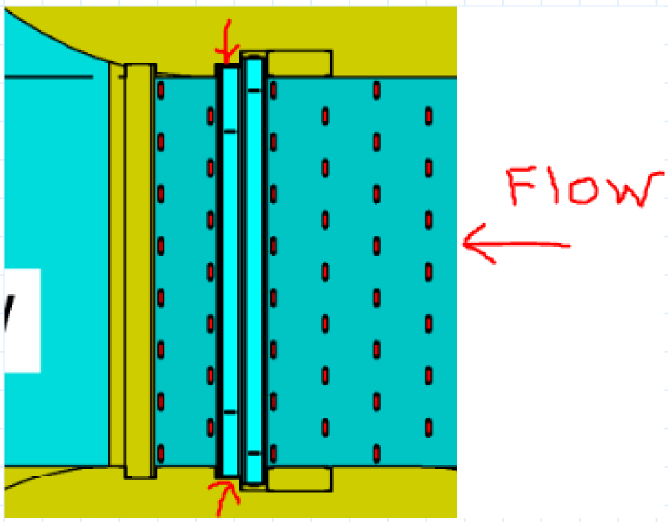
$w_{bot.horiz} := L \cdot w_{10x6x3.8}$ $\quad w_{lower.skinplate} := \left(.5 \cdot 5\ ft \cdot 8\ ft \right) \cdot t_{skin} \cdot w_{steel}$

$w_{diag} := L_{diag} \cdot w_{10x6x5.16}$

$$W_{bot} := 1.05\ \left(2 \cdot w_{bot.vert} + w_{bot.horiz} + 2 \cdot w_{diag} + 2 \cdot w_{lower.skinplate} + w_{bot.plate} \right) = 3.832\ kip$$

Gate slot geometry:
*Note: The Entrance weir slot is small slot (least wide) not touching the counterweight slot. Shown with arrows.

The slot touching the counterweight slot is the slot required for a slot filler, NOT weir.



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

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

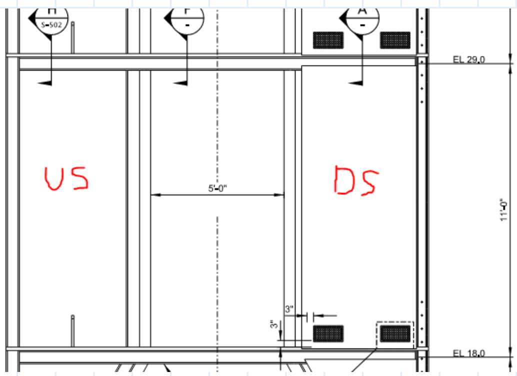
	Load Combo	gD	gG	gHs	gHd	gQ	gEQ
Strength I	1	1.2	1.6	1.4	0	0	0
Strength I	2	1.2	1.6	1.4	1.6	0	0
Strength II	3	1.2	1.6	0	0	0	0
Extreme (open)	4	1.2	1.2	0	1	1.2	0
Extreme (closed)	5	1.2	1.2	1.2	0	0	1

Loading:
1. Max pool in slot. (hydrostatic. (weir is in its slot with max tailwater pool))

2. Lifting from Slot (dead load) (Also included friction from potential head differential)
3. Gate Jammed (dead load + machinery)
4. Lifting from lay down, horizontal (dead load on lugs with perp loading (see below))

Skin Plate Design: Roark Stress and Strain, Table 11.4 "Formulas for flat plates with straight boundaries and constant thickness" Case 8 "Rectangular Plate, Fixed all edges"

Check: Large skin plates (5'-5" x 11' x 3/8") on Middle and Top sections



$\propto := 1.2$ $\quad F_y := 50\ ksi$

$E := 29000\ ksi$ $\quad t_{skinplate} := \frac{3}{8}\ in$

$H_s := 1.4$ (hydrostatic load factor)

Check Case #8: all edges fixed (drain grates are on downstream side)

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

$\beta_5 := 0.1304$ $\quad x := 0.0016$ $\quad a := 5\ ft + 5\ in$ $\quad b := 11\ ft$ $\quad \frac{a}{b} = 0.492$

Loading: (3 ft hydrostatic head)

$q := 3\ ft \cdot 62.4\ \frac{lbf}{ft^3} = 187.2\ \frac{lbf}{ft^2}$

$Area_{skinplate} := a \cdot b = 59.583\ ft^2$

Force of water per skin plate (2 plates per middle and top sections):

$$F_{skinplate} := H_s \cdot Area_{skinplate} \cdot q = 15.616\ kip$$

Stress:

$\sigma_{all} := \frac{F_y}{(\Omega \cdot \propto)} = 24.95\ ksi$ $\quad \sigma_{max} := \frac{\beta_5 \cdot q \cdot b^2}{t_{skinplate}^{\ 2}} = 21.004\ ksi$

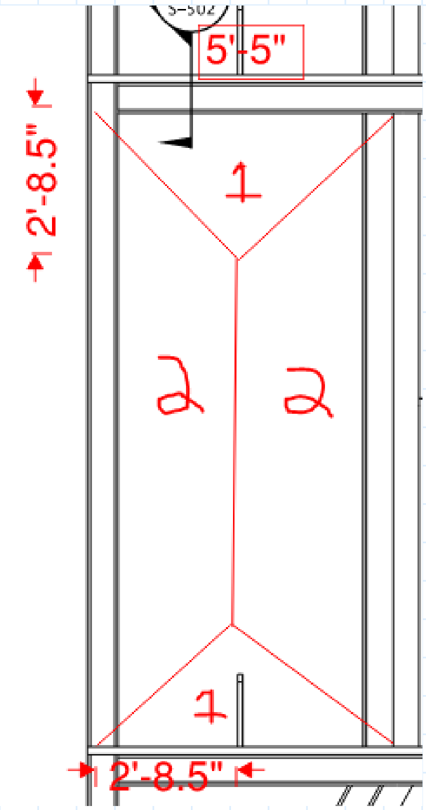
$\sigma_{all} > \sigma_{max} = 1$

Deflection:

$y_{all} := \frac{b}{240} = 0.55\ in$ $\qquad y_{max} := \frac{x \cdot q \cdot b^4}{E \cdot t_{skinplate}^{\ 3}} = 0.413\ in$

$y_{all} > y_{max} = 1$

Member Design: Check members with hydrostatic loading from the skin plate and trib area:



Trib areas:

$Trib_1 := \frac{1}{2} \cdot a \cdot (2\ ft + 8.5\ in) = 7.335\ ft^2$

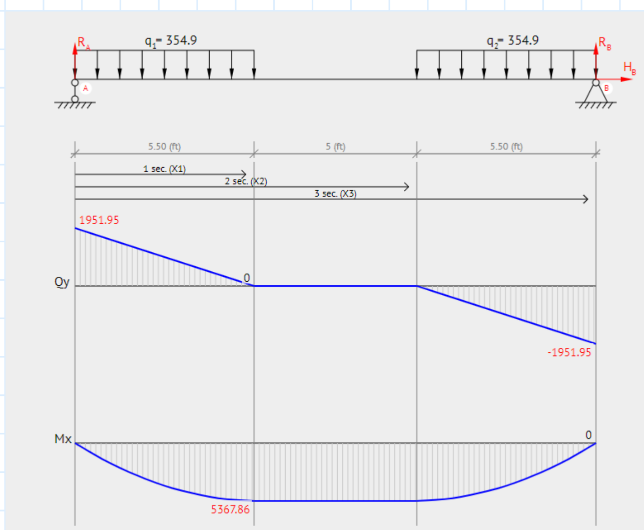
$Trib_2 := \frac{h_{middle} + (h_{middle} - (2 \cdot (2\ ft + 8.5\ in)))}{2} \cdot (2\ ft + 8.5\ in) = 22.457\ ft^2$

Factored Forces on vertical and horizontal members:

$F_1 := H_s \cdot Trib_1 \cdot q = 1.922\ kip$

$F_{1perfoot} := \frac{F_1}{a} = 354.9\ \frac{lbf}{ft}$

Shear and Moment accross horizontal member,
2 skin plates with the 5' opening in the middle:



$V_1 := 1951.95\ lbf$ $\qquad M_1 := 5367.86\ lbf \cdot ft$

Shear and Moment across vertical member simple supported distributed load, 11' in height:

$F_2 := H_s \cdot Trib_2 \cdot q = 5.885\ kip$ $\qquad F_{2perfoot} := \frac{F_2}{h_{middle}} = 535.039\ \frac{lbf}{ft}$

$V_2 := \frac{F_{2perfoot} \cdot h_{middle}}{2} = 2942.713\ lbf$ $M_2 := \frac{F_{2perfoot} \cdot h_{middle}^2}{8} = 8092.459\ lbf \cdot ft$

Check Members with AISC Chapter F and G:

Horizontal: HSS 10x6x5/16 (strong axis orientation) $\phi := 0.9$

$Z_x := 28.8\ in^3$

Yielding: (F7-1)

$\phi Mn := \phi \cdot F_y \cdot Z_x = 108\ kip \cdot ft$

$\phi Mn > M_1 = 1$

Check Compactness: $E := 29000$

Web: $h.over.t := 31.4$ $\lambda_w := 2.42 \cdot \sqrt{\frac{E}{46}} = 60.762$

$\lambda_w > h.over.t = 1$ compact web = no web local buckling

Flange: $b.over.t := 17.6$ $\lambda_f := 1.12 \cdot \sqrt{\frac{E}{46}} = 28.121$

$\lambda_f > b.over.t = 1$ compact flange = no flange local buckling

Lateral-Torsional Buckling: if Lb < Lp LTB does not apply $E := 29000\ ksi$ $J := 118\ in^4$

$L_b := 5\ ft$ (opening of weir) $A_g := 2 \cdot \frac{5}{16}\ in \cdot 10\ in = 6.25\ in^2$

$r_y := 2.47\ in$

$M_p := F_y \cdot Z_x$

Lp: $L_p := 0.13 \cdot E \cdot r_y \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 14.634\ ft$

$L_b < L_p = 1$ (therefor LTB does not apply and this member passed flexure)

Shear: (G4-1) $A_w := A_g$

$\phi Vn := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = ?$

Cv2: $k_v := 5$

$h_{over}tw := 31.4$

$1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 59.237$

$h_{over}tw < 1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 1$ therefor, $C_{v2} := 1$

$\phi Vn := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 168.75\ kip$

$\phi Vn > V_1 = 1$

Horizontal: Bottom plate (L x 10" x 1.5") (strong axis orientation)

$d := 10\ in$

Yeilding: F11-1

$\frac{L \cdot d}{t_{plate}^2} = 851.667 \; > \; \frac{0.08 \cdot E}{F_y} = 46.4$

$S_x := \frac{d \cdot t_{plate}^2}{6} = 3.75\ in^3$

$Z_x := \frac{d \cdot t_{plate}^2}{3} = 7.5\ in^3$

$\phi Mn := \phi \cdot 1.6 \cdot F_y \cdot S_x = 22.5\ kip \cdot ft$

$\phi Mn > M_1 = 1$

Lateral Torsional Buckling: F11-3

$\phi Mn := \phi \cdot F_{cr} \cdot S_x = ?$

$C_b := 1$ (eq F1-1)

$F_{cr} := \frac{1.9 \cdot E \cdot C_b}{\frac{L \cdot d}{t_{plate}^2}} = 64.697\ \frac{kip}{in^2}$

$\phi Mn := \phi \cdot F_{cr} \cdot S_x = 18.196\ kip \cdot ft$

$\phi Mn > M_1 = 1$

Shear: G4-1

$A_w := d \cdot t_{plate} = 0.104\ ft^2$

$\phi Vn := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 405\ kip$

$\phi Vn > V_1 = 1$

Vertical: HSS 10x6x5/16 (weak axis orientation)

$\phi := 0.9$
$Z_y := 20.2\ in^3$

Yielding: (F7-1)

$$\phi Mn := \phi \cdot F_y \cdot Z_y = 75.75\ kip \cdot ft$$

$$\phi Mn > M_2 = 1$$

Check Compactness: $E := 29000$

Web: $h.over.t := 31.4$ $\lambda_w := 2.42 \cdot \sqrt{\frac{E}{46}} = 60.762$

$\lambda_w > h.over.t = 1$ compact web = no web local buckling

Flange: $b.over.t := 17.6$ $\lambda_f := 1.12 \cdot \sqrt{\frac{E}{46}} = 28.121$

$\lambda_f > b.over.t = 1$ compact flange = no flange local buckling

Lateral-Torsional Buckling: if Lb < Lp LTB does not apply $E := 29000\ ksi$ $J := 118\ in^4$

$L_b := h_{middle}$ (opening of weir)

$A_g := 2 \cdot \frac{5}{16}\ in \cdot 6\ in = 3.75\ in^2$
$r_x := 3.66\ in$
$M_p := F_y \cdot Z_y$

Lp:

$$L_p := 0.13 \cdot E \cdot r_x \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 23.948\ ft$$

$L_b < L_p = 1$ (therefor LTB does not apply and this member passed flexure)

Shear: (G4-1) $A_w := A_g$

Cv2: (G2-2) $k_v := 5$

$h_{over}tw := 31.4$

$$1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 59.237$$

$$h_{over}tw < 1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 1$$ therefor, $$C_{v2} := 1$$

$$\phi Vn := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 101.25\ kip$$

$$\phi Vn > V_1 = 1$$ (therefor this member passes shear checks)

Check Vertical Beams: bending when lifting from horizontal to vertical

$W_{middlefactored} := W_{bot} \cdot 1.2 = 4.598\ kip$ (weight factored) $\qquad h_{middle} = 11\ ft$

$w_{weir} := \frac{W_{middlefactored}}{2} = 2.299\ kip$ (2 beams)

$w_{weirperft} := \frac{w_{weir}}{h_{middle}} = 0.209\ \frac{kip}{ft}$ (load per foot per side)

$$M_{weir} := \frac{w_{weirperft} \cdot h_{middle}^{2}}{8} = 3.161\ kip \cdot ft$$

$$V_{weir} := \frac{w_{weirperft} \cdot h_{middle}}{2} = 1.149\ kip$$

$$\phi Mn > M_{weir} = 1$$

$$\phi Vn > V_{weir} = 1$$

FY 19 Bonn Bradford Island Lamprey
Multi-Section Weir Design Calcs
Collin Porter

Design of top members for lifting out of water: ASME BTH Chapter 3
This check will ensure the 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 10x6x5/16") of middle section (heaviest) when lifting out of water for minor axis bending and shear:

$W_{middle} := W_{top} = 4777.856\ lbf$ $weight_{water} := 0\ lb$ assumed weir is slowly lifted so it drains

Additional lifting force required for lifting under flow and friction in the slot + LRFD dead load factor (1.2):

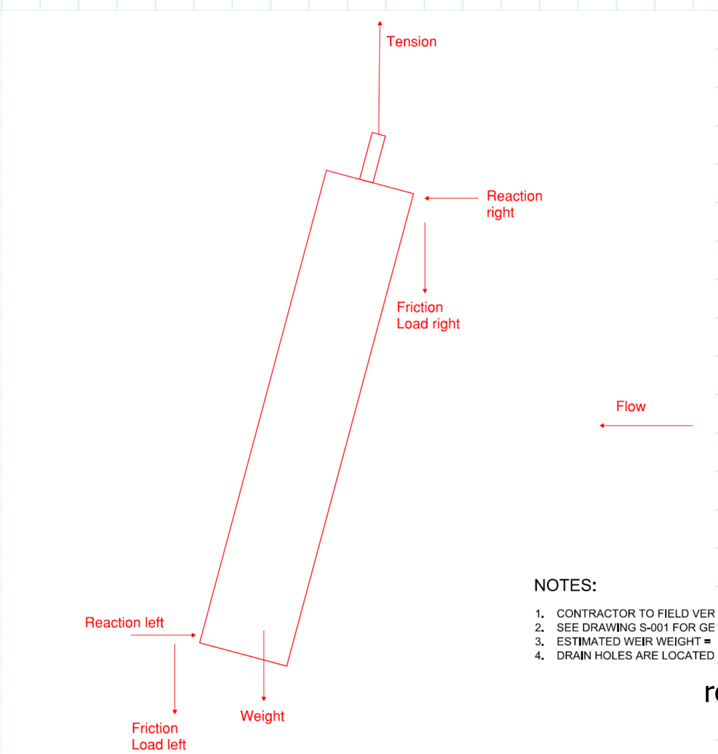
$W_{factored} := 1.2 \cdot W_{middle} = 5.733\ kip$ (factored)

Additional load from friction due to hydrostatic loading in guide slot: $\gamma_w := 62.4\ \frac{lbf}{ft^3}$

Using the planset and BlueBeams "Area" feature to determine the area of the top/middle weir in contact with flow (3' of head): $A_{weir} := 121.7\ ft^2$

Force of flow:

FBD:



$F_{flow} := 3\ ft \cdot A_{weir} \cdot \gamma_w = 22.782\ kip$

Determine extra tension

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 = 5.733 kip + (reaction*0.14) + (reaction*0.14)

5.733 = x - 0.28y

Some of moments about right top corner:

(Tension*(10"/2)) + (Fflow*(2/3)*h = (weight*(10"/2)) + (reaction.left*h) + (friction load.left*10")

Tension/5" + 167.1 kipft= 2.39 kipft + 11ft*reaction + .116ft*reaction

x/5" = -164.71 + 11.116 y

x = -392.2 + 26.47y

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

x = 9.99
y = 15.19

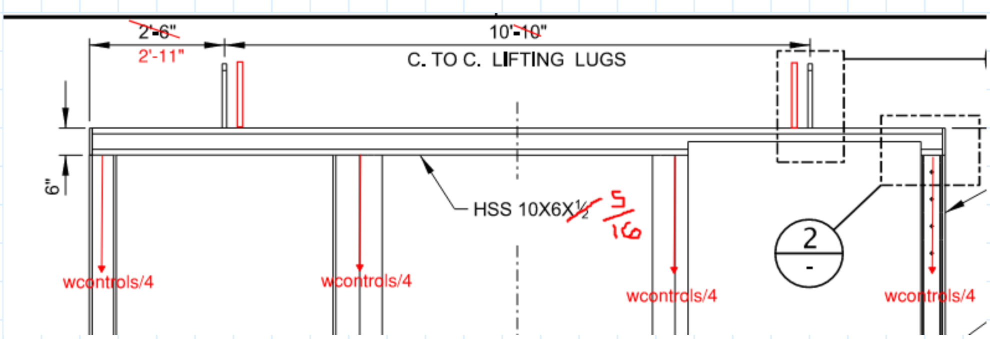
Check some of forces in Y to make sure numbers are correct:
- Tension = weight + friction load.left + friction.right

9.99 kip = 5.733 kip + 2*(0.14*15.19) = 9.99 kip (left equal right > FBD is correct)

$$Lifting_{force} := 9.99\ kip$$

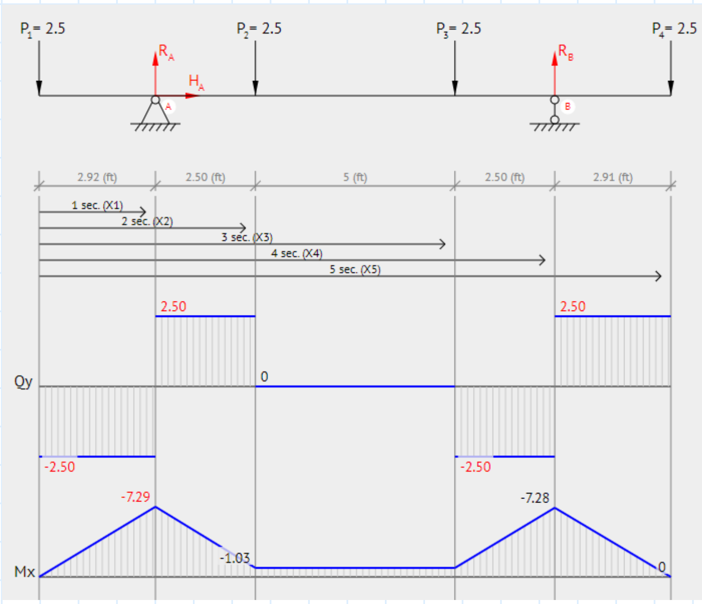
$$W_{controlling} := Lifting_{force} = 9.99\ kip$$

FBD:



$$W_{controls.4} := \frac{W_{controlling}}{4} = 2.498\ kip$$

Moment/Shear Diagram:



$V_{max} := 2.5\ kip$

$M_{max} := 7.29\ kip \cdot ft$

ASME BTH 3-25: Minor axis bending of compact sections: $N_d := 2$ (Cat A lifters)

$S_y := 17.8\ in^3$

$F_{yTube} := 50\ ksi$

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

$$F_{b.actual} := \frac{M_{max}}{S_y} = 4914.607\ psi$$

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

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

Max Tension in vertical members: $W_{controls.4} = 2.498\ kip$

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

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

$$\phi Pn > W_{controls.4} = 1$$

FY 19 Bonn Bradford Island Lamprey
Multi-Section Weir Design Calcs
Collin Porter

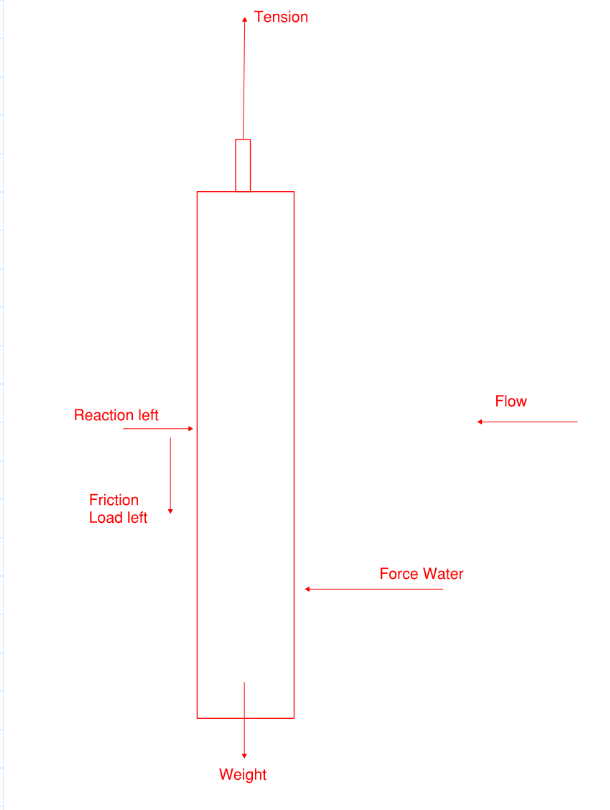
Tensile Rupture D2-2:

$F_u := 65\ ksi \qquad A_e := A_g$

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

$$\phi Pn > W_{controls.4} = 1$$

Check alternative FBD:



Some of Forces in X Direction: Force of flow = reaction left

$$F_{flow} = 22.782\ kip$$

Some of Forces in Y Direction: Tension = weight + friction load left

Tension = weight + .14*reaction left

$$W_{factored} = 5.733\ kip$$

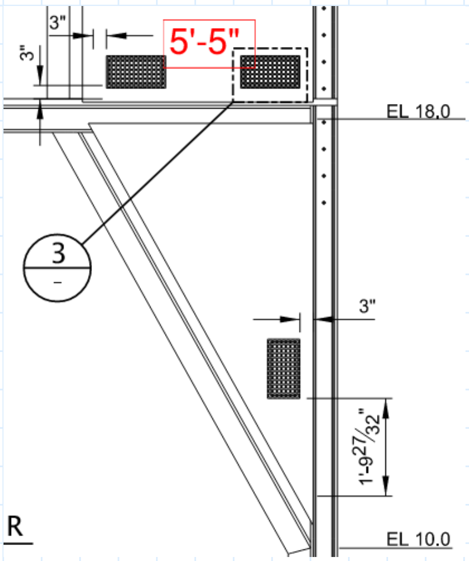
Tension = 5.733kip + .14*22.782 kip

Tension = 8.922

Some of Moments about Bottom Left Corner: not needed all unks are solved for

This tension is lower than the tension used above, therefor use the lifting force from above for the max lifting force.

Design 16' Vertical beams: 2 vertical beams on the bottom section take the load from bottom skin plates.



Assume vertical beams take all load:

Pressure: $q = 187.2\ psf$
$a = 5.417\ ft$

$$A_{diag} := \frac{1}{2} \cdot a \cdot 8\ ft = 21.667\ ft^2$$

$$F_{diagonal} := H_s \cdot q \cdot A_{diag} = 5.678\ kip$$

$$F_{perfoot} := \frac{F_{diagonal}}{8\ ft} = 0.71\ \frac{kip}{ft}$$

Beam tables: Uniform Load Partially Distributed at one end:

$$V_{max} := \frac{F_{perfoot} \cdot 8\ ft}{2 \cdot h_{bottom}} \cdot \left(\left(2 \cdot h_{bottom} \right) - 8\ ft \right) = 4.259\ kip$$

$$M_{max} := \frac{{V_{max}}^2}{2 \cdot F_{perfoot}} = 12.776\ kip \cdot ft$$

(Max moment from gate jammed and hydrostatic loading was less, this controls for vertical beams)

HSS 10x6x5/16 (weak axis orientation)

$\phi := 0.9$
$Z_y := 20.2\ in^3$

Yielding: (F7-1)

$$\phi Mn := \phi \cdot F_y \cdot Z_y = 75.75\ kip \cdot ft$$

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

Check Compactness: $E := 29000$

Web: $h.over.t := 31.4$ $\lambda_w := 2.42 \cdot \sqrt{\dfrac{E}{46}} = 60.762$

$\lambda_w > h.over.t = 1$ compact web = no web local buckling

Flange: $b.over.t := 17.6$ $\lambda_f := 1.12 \cdot \sqrt{\dfrac{E}{46}} = 28.121$

$\lambda_f > b.over.t = 1$ compact flange = no flange local buckling

Lateral-Torsional Buckling: if Lb < Lp LTB does not apply $E := 29000\ ksi$ $J := 118\ in^4$

$L_b := h_{bottom}$ (opening of weir) $A_g := 2 \cdot \dfrac{5}{16}\ in \cdot 6\ in = 3.75\ in^2$

$r_x := 3.66\ in$

$M_p := F_y \cdot Z_y$

Lp:

$$L_p := 0.13 \cdot E \cdot r_x \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 23.948\ ft$$

$L_b < L_p = 1$ (therefor LTB does not apply and this member passed flexure)

Shear: (G4-1) $A_w := A_g$

Cv2: (G2-2) $k_v := 5$

$h_{over}tw := 31.4$

$$1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 59.237$$

$h_{over}tw < 1.1 \cdot \sqrt{\dfrac{k_v \cdot E}{F_y}} = 1$ therefor, $C_{v2} := 1$

$$\phi Vn := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 101.25\ kip$$

$\phi Vn > V_1 = 1$ (therefor this member passes shear checks)

Check: bending when lifting from horizontal to vertical

$W_{botfactored} := W_{bot} \cdot 1.2 = 4.598\ kip$ (weight factored) $h_{weir16} := 16\ ft$

$$w_{weir} := \frac{W_{botfactored}}{2} = 2.299\ kip$$ (2 beams)

$$w_{weirperft} := \frac{w_{weir}}{h_{weir16}} = 0.144\ \frac{kip}{ft}$$ (load per foot per side)

$$M_{weir} := \frac{w_{weirperft} \cdot h_{weir16}^{\ 2}}{8} = 4.598\ kip \cdot ft$$

$$V_{weir} := \frac{w_{weirperft} \cdot h_{weir16}}{2} = 1.149\ kip$$

$$\phi Mn > M_{weir} = 1$$

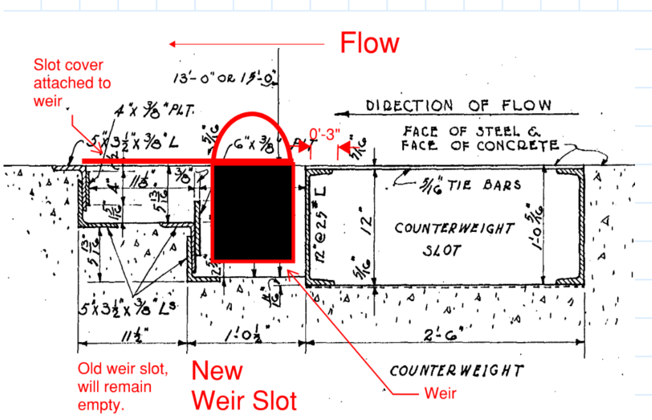
$$\phi Vn > V_{weir} = 1$$

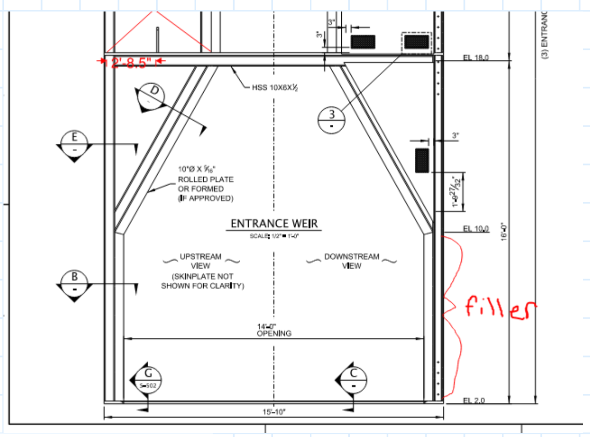
Design of Diagonal Members on Bottom section:

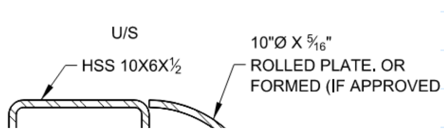
$$L_{diag} = 9.434\ ft$$

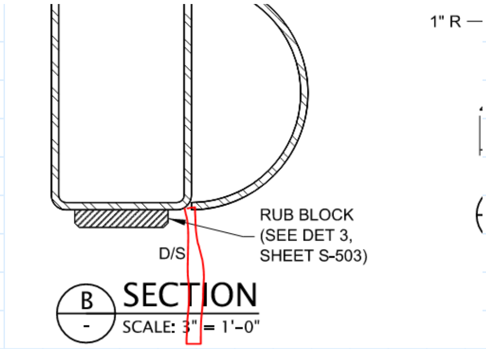
The length of the diagonal is less and braces less load than the 11' and 16' vertical members, which passed the required checks. Therefor, the diagonal members will be the same size as the vertical members: **HSS 10x6x5/16**

Design slot filler attachment to weirs:





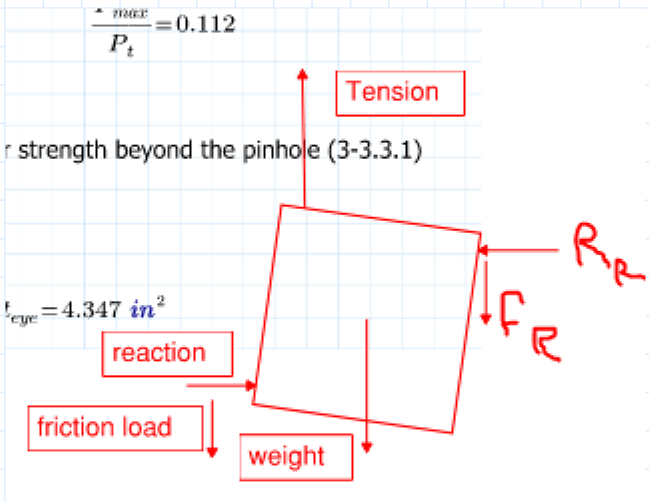



1" R
RUB BLOCK
(SEE DET 3,
SHEET S-503)
D/S
B
-
SECTION
SCALE: 3" = 1'-0"

FY 19 Bonn Bradford Island Lamprey
Multi-Section Weir Design Calcs
Collin Porter

Check Load Case Gate Jammed: Determine lifting force, One side lifting/gate jammed, middle/top 11' sections control due to weight.

FBD:



$W_{factored} = 5.733\ kip$

$L = 15.969\ ft$

Unks: 1. reaction left =reaction right
2. Friction load left = Friction load right
3. Tension

Some of forces in X: reaction.left = reaction.right

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 = 5.733 kip + (reaction*0.14) + (reaction*0.14)

5.733 = x - 0.28y

Some of moments about right top corner:

(Tension*(L-2.92')) = (weight*(L/2)) + (reaction.left*h) + (friction load.left*L)

Tension = (45.78 kipft + 11ft*reaction + (0.14*reaction*11ft)) / (15.969-2.92 ft)

3.51 = -.843y - 0.118y + x

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

5.733 = x - 0.28y
3.51 = -.843y - 0.118y + x

x = 6.65
y = 3.26

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

6.65 kip = 5.733 kip + 2*(0.14*3.26) = 6.65 kip (left equal right > FBD is correct)

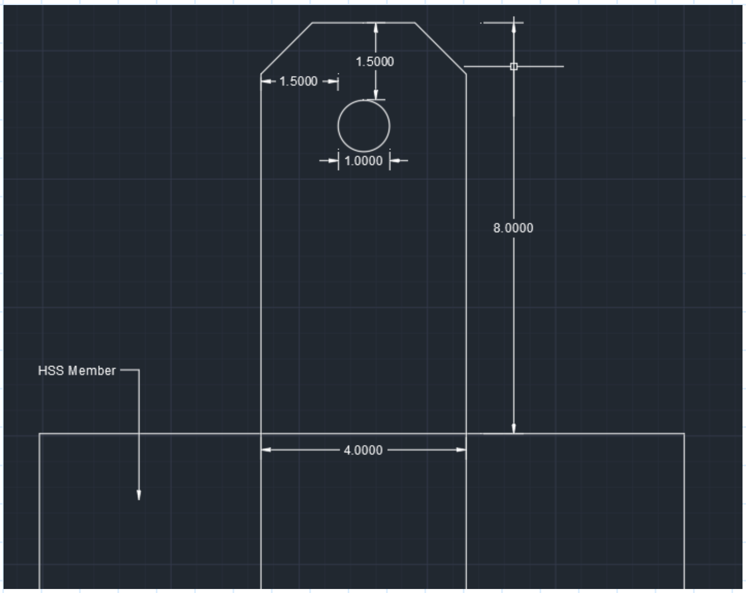
$$Lifting_{force} := 6.65\ kip$$

Design of Lifting lugs: ASME BTH

Lugs required on all sections $C.to.C_{eyes} := 10\ ft$

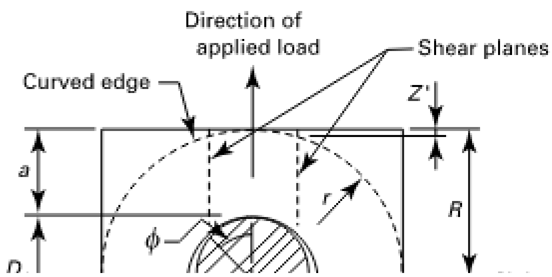
BTH, slenderness, tensile strength through a pinhole (3-45), single plane fracture strength beyound the pin hole (3-49) 3-3.3.1, double plane shear strength beyond the pinhole (3-50), bearing stress (3-53).

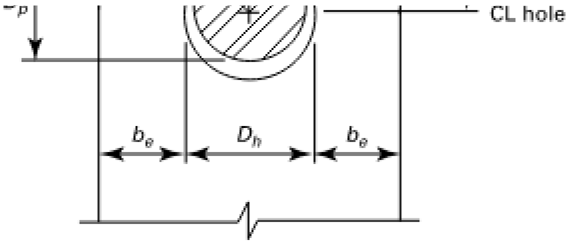
Geometry:



$W_{controlling} = 9.99\ kip$

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)

$t := 1\ in$ $\quad R := 4.5\ in$ $\quad b_{eff} := 1.5\ in$ $\quad b_e := 2\ in$

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

beff = 4t < be

$$\phi := 55 \cdot \frac{D_p}{D_h} = 48.889 \qquad a := 4.5\ in$$

$$A_v := 2 \cdot \left(a + \frac{D_p}{2}\left(1 - \cos(\phi)\right)\right) \cdot t = 9.807\ in^2$$

Allowable tensile strength through the pinhole, Pt:

$$P_t := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot 2 \cdot t \cdot b_{eff} = 42.244\ kip$$

Allowable single plane fracture strength beyond the pinhole, Pb:

$$P_b := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot \left(1.13 \cdot \left(R - \frac{D_h}{2}\right) + \frac{0.92 \cdot b_e}{1 + \left(\frac{b_e}{D_h}\right)}\right) \cdot t = 71.981\ kip$$

Allowable double plane shear strength beyond the pinhole, Pv:

$$P_v := \frac{0.70 \cdot F_u}{1.2 \cdot N_d} \cdot A_v = 110.601\ kip$$

Bearing Stress, Fp: $\quad A_{brg} := 3\ in \cdot t = 3\ in^2$

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

$$P_p := F_p \cdot A_{lug} = 31.5 \ kip$$

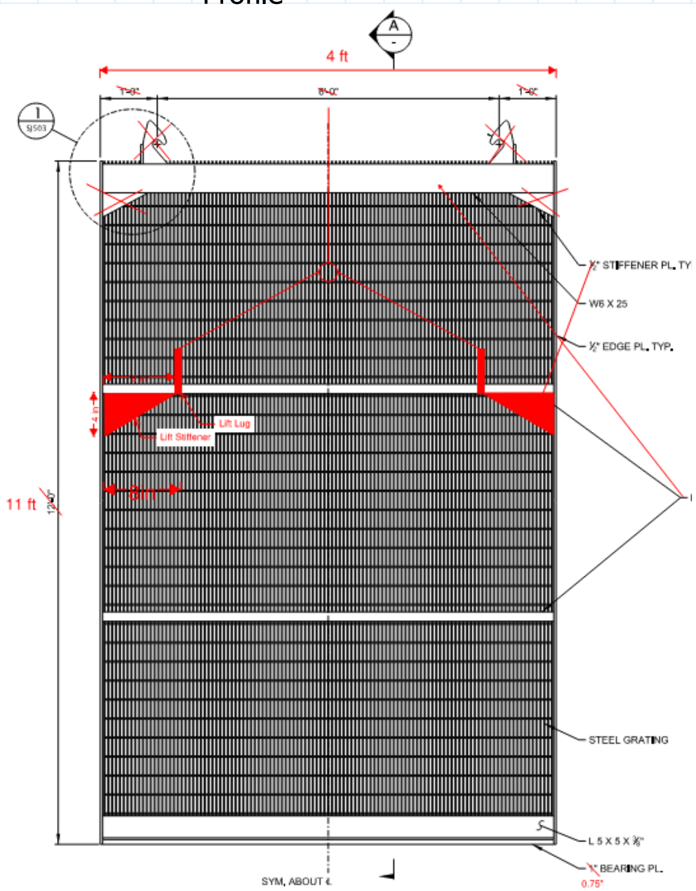
$W_{controlling} = 9.99 \ kip$ (max lifting force, max hydrostatic with friction)

$$P_p > Lifting_{force} = 1$$

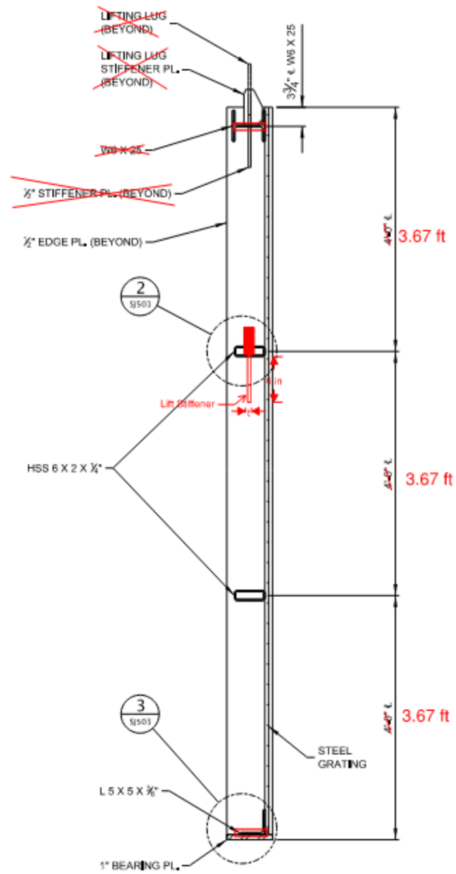
Bon 1 Trash Rack Design
6/17/22

Goal: Design a trash rack for the LPS water intake at the day forebay. Remove existing sluicegate and replace with trash rack in the same slot.

Profile



Side Profile



Contents:

Bon 1 Trash Rack Design
6/17/22

Head: From hydraulic engineer: max normal high flow el. 78, trash rack must be 1' higher than bulkhead (SL-30) downstream. Therefore the trash rack will be built to EL. 79

use 1/2" spacing of bars for now

General Geometry:

height of trash rack: $h_{rack} := 79\ ft - 68\ ft = 11\ ft$ (el. 68 (top of sill) to el. 79)

width of trash rack: $width_{rack} := 4\ ft$

out to out including slot: $width_{outtoout} := 4\ ft + 9\ in$ (rack does not fit in slot, guides attached to end are used)

thickness of trash rack: $t_{rack} := 7\ in$ (depth of girder) (match HSS member+grating (assume 1"))

Existing slot:

length of slot: $L_{slot} := 6.25\ in$

width of slot: $depth_{slot} := 4\ in$

Risk Category: I (no life loss) (ASCE Table 1.5-1)

Structure Classification: The trashracks are not classified as a Hydraulic Steel Structure, since they are not used for life safety. However the structure will be designed in accordance with the ETL 1110-2-584 as much as possible. ETL 1110-2-584 does not have a specific provisions on trashracks however EM 1110-2-2400 gives some direction in section 5. The design load for trash racks per the EM, is the trashrack structure should be designed to withstand hydraulic pressure based on velocity head loss with a minimum design head of 5 ft.

Treat trash rack as vertical lift gate

Load cases:

1. Gate in its slot (resting on plate) (max hydrostatic, max impact, seismic)
2. Lifting while gate is jammed
3. Pulling out of slot via lugs

Load Combos: ETL 584

Table E-1. Load Factors for Lift Gates.

Load Cases	Loads/Load Factors							
	D	G	H_s	H_d	Q	EV	IM	EQ

Bon 1 Trash Rack Design
6/17/22

Limit State	Description	Case	γ_D	γ_G	γ_{Hs}	γ_{Hd}	γ_Q	γ_{EV}	γ_{IM}	γ_{EQ}
Strength I	Gate Closed	1	1.2	1.6	1.4	0	0	1.2	0	0
Strength I	Gate Closed	2	1.2	1.6	1.4	1.6	0	0	0	0
Strength II	Gate Open	3	1.2	1.6	0	0	0	1.3	0	0
Extreme	Gate Open	4	1.2	1.2	0	1.0	1.2	0	0	0
Extreme	Gate Closed	5	1.2	1.2	1.2	0	0	0	1.0(1)	1.0(1)
Fatigue I	Finite Life	4a	0	0	1.0	1.0	0	1.0	0	0
Fatigue II	Infinite Life	4b	0	0	1.0	1.0	0	1.0	0	0

Notes: (1) Select one at a time

E.3.5. Load and Resistance Factor Design. Appendix C includes design requirements using LRFD for lock lift gates.

EM_1110-2-2400"

Loads:

1. Hydrostatic/debris (high flow mark at el 77)
2. Hydrodynamic
3. Impact
4. Self weight
5. Seismic

Loads:

Hydrostatic load:

$\gamma_w := 62.4\ pcf$

Static pressure: depends on the height of debris blockage

The trashracks are not classified as a Hydraulic Steel Structure, since they are not used for life safety. However the structure will be designed in accordance with the ETL 1110-2-584 as much as possible. ETL 1110-2-584 does not have a specific provisions on trashracks however EM 1110-2-2400 gives some direction in section 5. The design load for trash racks per the EM, is the trashrack structure should be designed to withstand hydraulic pressure based on velocity head loss with a minimum design head of 5 ft.

Height of debris blockage/
max height of flow:

$h_{blockage} := 5\ ft$

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Pressure: $H_s := h_{blockage} \cdot \gamma_w = 0.312 \ \frac{kip}{ft^2}$ (controls)

Factored Hydrostatic: 1.4 $H_s := H_s \cdot 1.4 = 0.437 \ \frac{kip}{ft^2}$

Max tributary area: $Trib_{area} := 3.67 \ ft$

Line load: $Line_{load} := H_s \cdot Trib_{area} = 1.603 \ \frac{kip}{ft}$

Max Hydrostatic Shear/Moment: $V_{u.Hs} := \frac{Line_{load} \cdot width_{rack}}{2} = 3.206 \ kip$ (controls)

$$M_{u.Hs} := \frac{Line_{load} \cdot width_{rack}^{\ 2}}{8} = 3.206 \ kip \cdot ft$$

Hydrodynamic (drag): ASCE C5.4-4

According to mechanical engineer, "assume the rack will only be lifted while the intake valve is closed" meaning no drag with the valve closed

Drag coeff: $C_d := 1.5$ (Shape Factor, per hydraulics. Table 11-1, Roberson & Crowe (1975) Engineering Fluid Mechanics)

Density of water: $\rho := 1.9 \ \frac{slug}{ft^3}$

Fluid velocity: $V := 0.373 \ \frac{ft}{s}$ (per hydraulics, 0.25 ft/s divided by porosity, 0.67)

Projected area of the debris accumulation into flow, A: $A := 5 \ ft^2$

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$$Drag := \frac{1}{2} \cdot C_d \cdot \rho \cdot A \cdot V^2 = 0.001\ kip$$ $F = (1/2)C_D \rho A V^2$ (C5.4-4)

Factored drag load: $H_D := Drag \cdot 1.6 = 0.002\ kip$

Downpull is a horizontal load that acts on the center of the screen

Max drag Shear/Moment:

$$V_{u.Hd} := \frac{H_D}{2} = \left(7.93 \cdot 10^{-4}\right)\ kip$$

$$M_{u.Hd} := \frac{H_D \cdot width_{rack}}{4} = 0.002\ kip \cdot ft$$

Impact Load: ASCE C5.4-3 $F = \frac{\pi W V_b C_I C_O C_D C_B R_{max}}{2 g \Delta t}$ (C5.4-3)

Debris weight: $W := 4\ kip$ (4k is standard for west coast log)

Velocity of object: $V_b := V = 0.373\ \frac{ft}{s}$

gravity: $g := 32.2\ \frac{ft}{s^2}$

impact duration: $t := 0.03\ s$ (natural period is .01)

Importance coef: $C_I := 0.6$ (Table C5.4-1, risk category I)

orientation coef: $C_O := 0.8$ (always 0.8)

depth coef: $C_D := 1$ (Fig C5.4-1, depth greater than 5')

blockage coef: $C_B := 0.2$ (Table C5.4-3, moderate screening, flow path 10ft wide)

max response ratio for impulse load: $R_{max} := 1.5$ (Table C5.4-4, ratio greater than 1.4)

$$Impact := \frac{\pi \cdot W \cdot V_b \cdot C_I \cdot C_O \cdot C_D \cdot C_B \cdot R_{max}}{2 \cdot g \cdot t} = 0.349\ kip$$

Factored Impact: $I_L := Impact \cdot 1 = 0.349\ kip$

$$V_{u.I} := \frac{Impact}{2} = 0.175\ kip$$

$$M_{u.I} := \frac{Impact \cdot width_{rack}}{4} = 0.349\ kip \cdot ft$$ (controls)

Dead Load, factored: with 5% misc weight and 1.2 DL factor.

Weight of rack:
bar size = 2-1/4" x 3/16" , capacity of of 533 psf at 6' span
approx psf: $w_{rack} := 15.6\ psf$

Area of rack: $A_{rack} := h_{rack} \cdot width_{rack} = 44\ ft^2$

$$W_{rack} := w_{rack} \cdot A_{rack} = 0.686\ kip$$

Weight of end plate:
thickness of end plate: $t_{end} := 0.5\ in$

$$W_{endplate} := h_{rack} \cdot t_{rack} \cdot t_{end} \cdot 490\ pcf = 0.131\ kip$$

Weight of HSS members: assume HSS 6x2x3/8", plf = 17.27 lb/ft

$$W_{girder} := 4 \cdot width_{rack} \cdot 17.27\ \frac{lbf}{ft} = 0.276\ kip$$

Weight of lift lugs/Stiffeners: new gate must use existing lifting equipment

$$W_{liftlug} := 100\ lbf$$

$$W_{total} := 1.2 \cdot \left(\left(W_{rack} + 2 \cdot W_{endplate} + W_{girder} + W_{liftlug}\right) \cdot 1.05\right) = 1.669\ kip$$

Seismic Loading: ETL 1110-2-584, 3.2.3.6

Westergaard's eq: determine lateral pressure at base of rack (zero pressure at top)

max. acceleration of pier: $a_c := .0597$ (https://earthquake.usgs.gov/hazards/interactive/)

pool depth to dam foundation: $H := 77\ ft - 43\ ft = 34\ ft$

distance below the pool surface: $y := 11\ ft$

$$p := \frac{7}{8} \cdot \gamma_w \cdot a_c \cdot \sqrt{H \cdot y} = 0.063\ \frac{kip}{ft^2}$$

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Factored Seismic: load factor of 1 $E := 1 \cdot p = 0.063 \ \frac{kip}{ft^2}$

Trib area: $Trib_{area} = 3.67 \ ft$

Line load: $E_{LL} := E \cdot Trib_{area} = 0.231 \ \frac{kip}{ft}$

Shear/Moment:

$$V_{u.E} := \frac{width_{rack} \cdot E_{LL}}{2} = 0.463 \ kip \qquad M_{u.E} := \frac{E_{LL} \cdot width_{rack}^{\ 2}}{4} = 0.925 \ kip \cdot ft$$

Load Combos:

Table E-1. Load Factors for Lift Gates.

Load Cases			Loads/Load Factors							
			D	G	H_s	H_d	Q	EV	IM	EQ
Limit State	Description	Case	γ_D	γ_G	γ_{Hs}	γ_{Hd}	γ_Q	γ_{EV}	γ_{IM}	γ_{EQ}
Strength I	Gate Closed	1	1.2	1.6	1.4	0	0	1.2	0	0
Strength I	Gate Closed	2	1.2	1.6	1.4	1.6	0	0	0	0
Strength II	Gate Open	3	1.2	1.6	0	0	0	1.3	0	0
Extreme	Gate Open	4	1.2	1.2	0	1.0	1.2	0	0	0
Extreme	Gate Closed	5	1.2	1.2	1.2	0	0	0	1.0(1)	1.0(1)
Fatigue I	Finite Life	4a	0	0	1.0	1.0	0	1.0	0	0
Fatigue II	Infinite Life	4b	0	0	1.0	1.0	0	1.0	0	0
Notes: (1) Select one at a time										

E.3.5. Load and Resistance Factor Design. Appendix C includes design requirements using LRFD for lock lift gates.

Controlling lateral load case: 5 (1.4 Hs, 1.0 Im, and 1.0 EQ)
Controlling vertical load case: 2 (1.2 DL + 1.6 HD)

Controlling factored loads:

Horizontal: $V_u := V_{u.Hs} + V_{u.I} + V_{u.E} = 3.843 \ kip$

Vertical: $Lift_{Load} := W_{total} + H_D = 1.671 \ kip$

$M_u := M_{u.Hs} + M_{u.I} + M_{u.E} = 4.481 \ kip \cdot ft$

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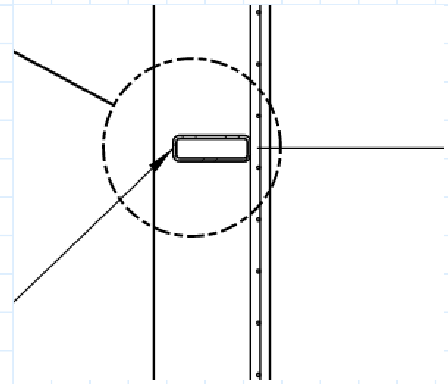
Design Girders: 11' tall gate, 3.67' spacing = 4 members
Chose HSS 6 x 2 x 3/8" for horizontal members

Inputs: $\phi := 0.9$ $F_y := 46\ ksi$ (A500 Grade B) $Z_x := 7.93\ in^3$

$E := 29000\ ksi$ $I_x := 17.1\ in^4$ $t_w := 0.349\ in$



AISC Chapter F: F7

Check Yielding of major axis, F7-1: (hydraulic loading)

$$\phi M_n := \phi \cdot F_y \cdot Z_x = 27.359\ kip \cdot ft$$

$$\phi M_n > M_u = 1$$

welding note: if forces are at right angles, weld force needs to be summed in x and y and sqrt.

Check Flange Local Buckling of major axis, F7-2:

This section is compact, via table 1-12a (flange width < 10in and web height < 20in)
Therefore, flange local buckling does not apply.

Check Web Local Buckling of major axis, F7-3:

This section is compact, via table 1-12a (flange width < 10in and web height < 20in)
Therefore, web local buckling does not apply.

AISC Chapter G: G5 Rectangular HSS members

$C_{v1} := 1$ $A_w := 2 \cdot (t_w \cdot 0.93) \cdot 6\ in = 3.895\ in^2$ (assumed ERW welded)

Check shear, G2-1:

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v1} = 96.748\ kip$$

$$\phi V_n > V_{u.Hs} = 1$$

Check deflection: simply supported, uniformly loaded beam

Check Hs deflection $$\Delta_{Hs} := \frac{5 \cdot Line_{load} \cdot width_{rack}^{\ 4}}{384 \cdot E \cdot I_x} = 0.019\ in$$

Check Impact deflection: $$\Delta_{Impact} := \frac{I_L \cdot width_{rack}^{\ 3}}{48 \cdot E \cdot I_x} = 0.002\ in$$

Allowable: $$\Delta_{allowable} := \frac{width_{rack}}{240} = 0.2\ in$$

$$\Delta_{allowable} > \Delta_{Hs} + \Delta_{Impact} = 1$$

Design weld from HSS Members to End Plates: AISC Chapter J2

Loading: (shear+moment loading on HSS members)

$V_u = 3.843\ kip$
$M_u = 4.481\ kip \cdot ft$

$F_{u.Filler} := 70\ ksi$ (Fy of 50 ksi)

Length of Weld: 2, 6" legs

$A_w := 2 \cdot 6\ in = 12\ in$

Combined stresses:

$S_w := \frac{2 \cdot (6\ in)^2}{6} = 0.083\ ft^2$

$f_v := \frac{V_u}{A_w} = 0.32\ \frac{kip}{in}$ $f_b := \frac{M_u}{S_w} = 4.481\ \frac{kip}{in}$

$Netforce := \sqrt{f_v^2 + f_b^2} = 4.492\ \frac{kip}{in}$

Determine Weld Size: J2.4

$t_w = 0.349\ in$ (web thickness of HSS)
$t_{endplate} := 0.5\ in$ (thickness of end plate)

Size of fillet weld: Table J2.4

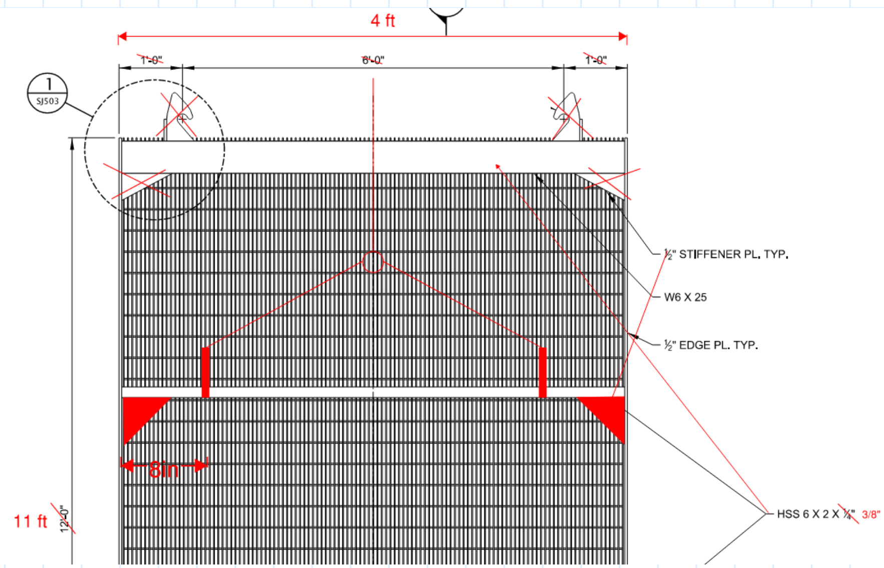
$weld_{size} := \frac{3}{16}\ in$

$\phi := 0.75$

Weld Strength: $\phi R_n := \phi \cdot 0.707 \cdot F_{u.Filler} \cdot weld_{size} = 6.96\ \frac{kip}{in}$

$\phi R_n > Netforce = 1$

Check Lifting: top (or middle) HSS member to withstand flexure from lifting on web in minor axis direction due to location of lifting lugs.



Loading: is combination of both weight of structure and pulldown

$W_{total} = 1.669\ kip$ (factored weight of gate at 8" from ends)

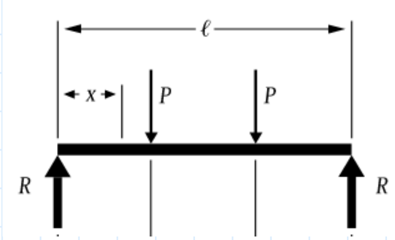
$H_D = 0.002\ kip$ (factored pulldown load)

$Lift_{Load} := W_{total} + H_D = 1.671\ kip$ (at each lug, more conservative to not divide by 2)

$L_{gird} := width_{rack} = 4\ ft$

$a := 8\ in$

FBD:



P = lift lugs
R = weight of structure

Moment/Shear:

$V_u := Lift_{Load} = 1.671\ kip$

$M_u := Lift_{Load} \cdot a = 1.114\ kip \cdot ft$

AISC Chapter F7: Rectangular HSS members bent about their minor axis $Z_y := 3.46\ in^3$

Yielding, F7-1:

$\phi M_n := \phi \cdot F_y \cdot Z_y = 9.948\ kip \cdot ft$

$\phi M_n > M_u = 1$

Flange Local Buckling of minor axis, F7-2:

This section is compact, via table 1-12a (flange width < 10in and web height < 20in)
Therefore, flange local buckling does not apply.

Web Local Buckling of minor axis, F7-3:

This section is compact, via table 1-12a (flange width < 10in and web height < 20in)
Therefore, web local buckling does not apply.

AISC Chapter G7: Weak axis shear in symmetric shapes $k_v := 1.2$

H over tw: $14.2 < 1.1 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 30.255$ therefore $C_v := 1$

G2-1: $A_w := 2 \cdot (t_w \cdot 0.93) \cdot 2\ in = 1.298\ in^2$ (assumed ERW welded)

$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_v = 26.874\ kip$

$\phi V_n > V_u = 1$

Check deflection when lifting: simply supported, concentrated load at center $I_y := 2.77\ in^4$

$$\Delta_{max} := \frac{Lift_{Load} \cdot a}{24 \cdot E \cdot I_x} \left(3 \cdot L_{gird}^{\ 2} - 4 \cdot a^2\right) = 0.007\ in$$

$$\Delta_{allowable} := \frac{L_{gird}}{240} = 0.2\ in$$

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

Design Lifting Lugs: using ASME BTH, Chapter 3
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).

Factored Weight of structure: $Lift_{Load} = 1.671\ kip$

Assume one lifting lug feels the structures total weight, even though it will be lifted with both lugs

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ASME BTH Lifter Classifications:

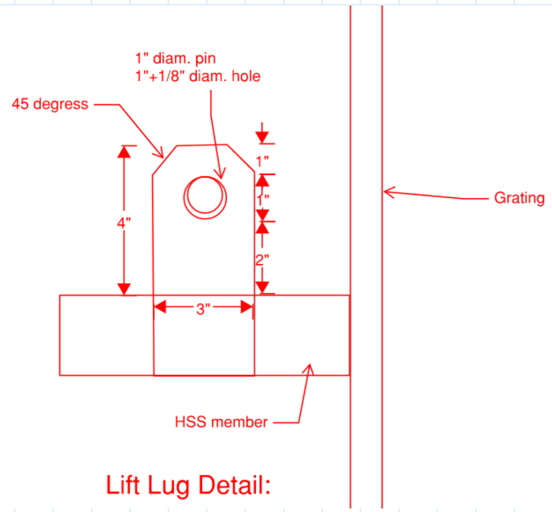
Service Class: determine number of cycles, assume 50 year life

$\#_{cycles} := 365 \cdot 50 = 18250$ (assume the rack is cleaned daily, conservative)

Service class due to number of cycles (less than 20k) = 0

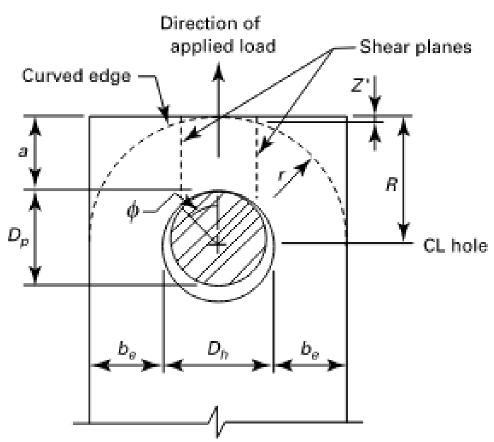
Design Category: A (loads are defined and predictable, and Service class 0)

Geometry:



Lift Lug Detail:

Figure C-3.3.1-1 Pin-Connected Plate Notation



$D_p := 1\ in$ $D_h := 1\ in + \frac{1}{8}\ in = 1.125\ in$ $F_u := 58\ ksi$ $N_d := 2$ (cat A lifter)

$t_{lug} := 0.5\ in$ $R := 1.5\ in$ $b_e := 1\ in$ $F_y := 36\ ksi$

$C_r := 1 - 0.275 \cdot \sqrt{1 - \frac{D_p^2}{D_h^2}} = 0.874$ beff = 4t < be $b_{eff} := b_e = 1\ in$

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

$$\phi_{BTH} := 55 \cdot \frac{D_p}{D_h} = 48.889 \qquad a := 1\ in$$

$$A_v := 2 \cdot \left(a + \frac{D_p}{2} \left(1 - \cos\left(\phi_{BTH}\right)\right)\right) \cdot t_{lug} = 1.404\ in^2$$

Allowable tensile strength through the pinhole, Pt:

$$P_t := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot 2 \cdot t_{lug} \cdot b_{eff} = 21.122\ kip$$

Allowable single plane fracture strength beyond the pinhole, Pb:

$$P_b := C_r \cdot \frac{F_u}{1.2 \cdot N_d} \cdot \left(1.13 \cdot \left(R - \frac{D_h}{2}\right) + \frac{0.92 \cdot b_e}{1 + \left(\frac{b_e}{D_h}\right)}\right) \cdot t_{lug} = 16.332\ kip \qquad \text{(controls)}$$

Allowable double plane shear strength beyond the pinhole, Pv:

$$P_v := \frac{0.70 \cdot F_u}{1.2 \cdot N_d} \cdot A_v = 23.743\ kip$$

Bearing Stress, Fp:

$$A_{lug} := 3\ in \cdot t_{lug} = 1.5\ in^2$$

$$F_p := \frac{0.63 \cdot F_y}{N_d} = 11.34\ ksi$$

$$P_p := F_p \cdot A_{lug} = 17.01\ kip$$

Check: Pb controls

$P_b > Lift_{Load} = 1$

(friction was ignored, however one lifting lug has 8 times the required capacity, friction is always a portion of the weight, never multiple times bigger than the weight.)

Design Weld from Lift Lug to HSS

Loading: (weight of gate to one lug)

$Lift_{Load} = 1.671\ kip$

$F_{u.Filler} := 60\ ksi$ (Fy of 36 ksi)

Length of Weld: 2, 3" legs

$A_w := 2 \cdot 3\ in = 6\ in$

Force over length:

$$f_v := \frac{Lift_{Load}}{A_w} = 0.278\ \frac{kip}{in}$$

Determine Weld Size: J2.4

$t_w = 0.349\ in$ (web thickness of HSS)

$t_{lug} := 0.5\ in$ (thickness of lug)

Size of fillet weld: Table J2.4

$$weld_{size} := \frac{3}{16}\ in$$

$\phi := 0.75$

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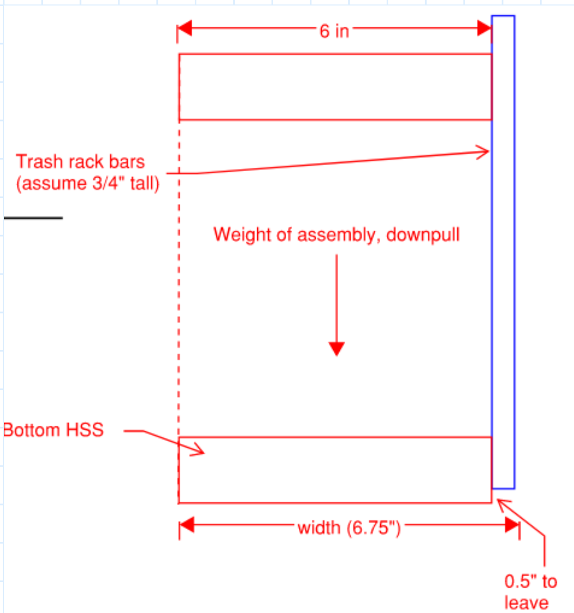
Weld Strength: $\phi R_n := \phi \cdot 0.707 \cdot F_{u.Filler} \cdot weld_{size} = 5.965 \ \frac{kip}{in}$

$\phi R_n > f_v = 1$

Design Bottom Member: Bottom HSS attaches to the trash rack grating and end plates
Chose HSS 6x2x3/8"



Loading
Check Horizontal loads: Flexure/Shear has already been checked on the same sized member

Check vertical loads: $Lift_{Load} = 1.671 \ kip$ (includes factored, structure weight and pull down)

Location of load = centerspan, is most conservative

Determine shear and moment of simple beam with point load at center:

$$V_u := \frac{Lift_{Load}}{2} = 0.835 \ kip$$

$$M_u := \frac{Lift_{Load} \cdot L_{gird}}{4} = 1.671 \ kip \cdot ft$$

HSS Geometry: same as above (see above)

$t_{web} := 0.349 \ in$ $r_u := 0.760 \ in$

room for weld and to protect bearing bars

Laterally unbraced length of member: $L_c := 2\ in$ (height of HSS)

Check Compression: AISC J4

$\frac{L_c}{r_y} = 2.632$ $\frac{L_c}{r_y} < 25 = 1$ Therefore, use EQ J4-6

$A_g := 2 \cdot (L_c \cdot t_{web})$ $\phi = 0.75$

Compressive strength, EQ J4-6:

$$\phi P_n := \phi \cdot F_y \cdot A_g = 37.692\ kip$$

$$\phi P_n > Lift_{Load} = 1$$

Check Deflection, from flexure: L/240

$I := 8.76\ in^4$

$$\Delta_{max} := \frac{5 \cdot \frac{Lift_{Load}}{L_{gird}} \cdot {L_{gird}}^4}{384 \cdot E \cdot I} = 0.009\ in$$

$$\Delta_{allowable} := \frac{L_{gird}}{240} = 0.2\ in$$

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

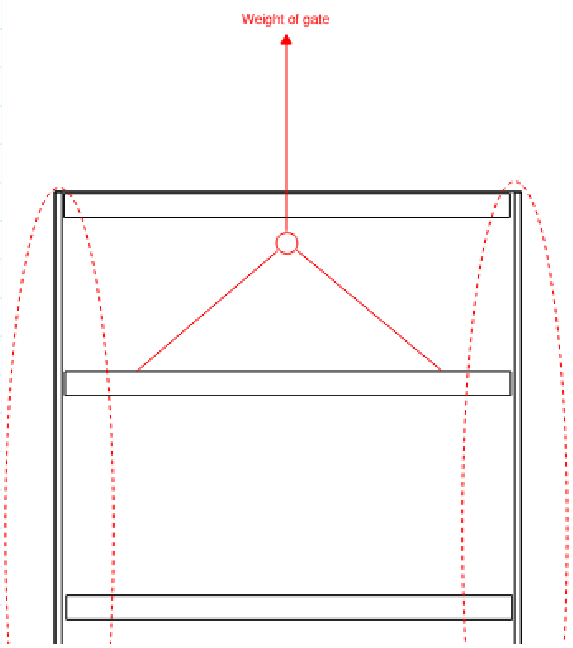
Check Bearing on concrete: Gate resting on its bottom HSS member $A_1 := 6\ in \cdot L_{gird} = 288\ in^2$

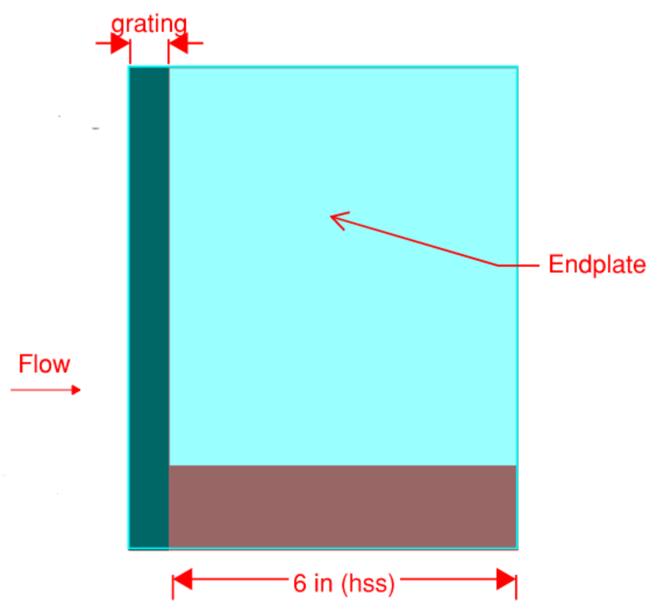
AISC J8, EQ J8-1: on the full area of concrete support $\phi := 0.65$ $f'_c := 4000\ psi$

$\phi P_p := \phi \cdot 0.85 \cdot f'_c \cdot A_1 = 636.48\ kip$

$\phi P_p > Lift_{Load} = 1$

Design End Plates: 0.5" thick end plate on both left and right side.





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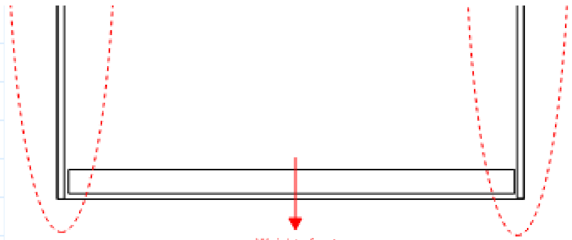

Geometry:

$t_{endplate} := 0.5\ in$ $\quad w_{endplate} := 6\ in$ (matches HSS dim)

$h_{endplate} := h_{rack} = 11\ ft$

$$Z_x := \frac{h_{endplate} \cdot t_{endplate}^{\ 2}}{4} = 8.25\ in^3 \qquad S_x := \frac{h_{endplate} \cdot t_{endplate}^{\ 2}}{6} = 5.5\ in^3$$

Vertical loads:

Each end plate feels 1/2 of the gate weight. Assume it is lifted slowly so the weight of water is not considered.

$$Lift_{Load} = 1.671\ kip$$

Horizontal loads:

Assume the horizontal loads will be transferred from the rack to the end plates and into the guides.

$$V_u := V_{u.Hs} + V_{u.I} + V_{u.E} = 3.843\ kip \qquad M_u := M_{u.Hs} + M_{u.I} + M_{u.E} = 4.481\ kip \cdot ft$$

Check end plate for tension: Vertical loads

$$I_y := \frac{t_{endplate}^{\ 3} \cdot w_{endplate}}{12} \qquad A_g := w_{endplate} \cdot t_{endplate}$$

Check Slenderness: AISC D1

Determine, r: $r := \left(\frac{I_y}{A_g}\right)^{0.5}$

Slenderness: $\frac{h_{rack}}{r} < 300 = 0$ (however, there is no max slenderness for tension, D1)

Check tensile yielding in gross section: D2-1 $\quad A_g := w_{endplate} \cdot t_{endplate} = 3\ in^2$

$$\phi P_n := \phi \cdot F_y \cdot A_g = 70.2\ kip$$

Check tensile rupture in net section: D2-2 $\phi_t := 0.75$ $F_u := 65\ ksi$ $A_e := A_g = 3\ in^2$ (no bolt or pin holes)

$$\phi_t P_n := \phi_t \cdot F_u \cdot A_e = 146.25\ kip$$

$$\phi P_n > Lift_{Load} = 1$$

Check end plate for shear and moment: Horizontal loads $L_b := 3.67\ ft$ (spacing of horiz members)

Check moment: AISC F11, Rectangular Bar bent around major axis $\frac{L_b \cdot w_{endplate}}{t_{endplate}^2} = 1056.96$ ▯<▯ $\frac{0.08 \cdot E}{F_y} = 64.444$

$$\phi M_n := \phi \cdot min\left(F_y \cdot Z_x, 1.6 \cdot F_y \cdot S_x\right) = 16.088\ kip \cdot ft$$

(therefore LTB does not apply)

$$\phi M_n > M_u = 1$$

Check shear: AISC G4, Symmetric members $A_w := t_{endplate} \cdot w_{endplate} = 3\ in^2$ $C_{v2} := 1$

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 42.12\ kip$$

$$\phi V_n > V_u = 1$$

Check deflection: L/240

$$\Delta_{allowable} := \frac{h_{endplate}}{240} = 0.55\ in$$

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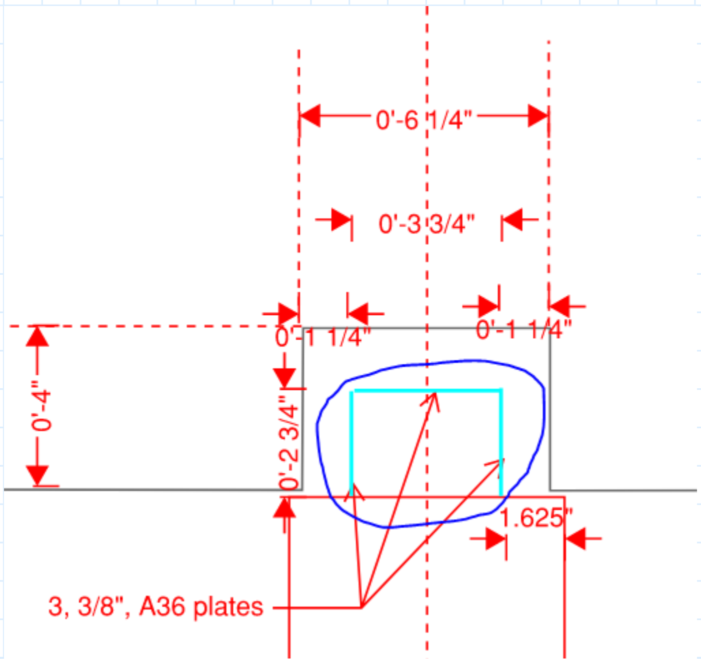
$$\Delta_{actual} := \frac{5 \cdot \frac{V_u}{h_{endplate}} \cdot h_{endplate}^{4}}{384 \cdot E \cdot I_y} = 63.505\ in$$ (huh?)

Guide plate design: The trash rack is to wide for its slot. 3 guide plates will be used to keep the trash rack centered and in its slot.



Geometry: $F_y := 36\ ksi$ (A36 steel) $h_{plate} := 1\ ft$ (design in per ft)

$t_{plate} := \frac{3}{8}\ in$ $l_{plate} := 2.75\ in$ $Z_y := \frac{h_{plate} \cdot t_{plate}^{2}}{4} = 0.422\ in^3$

$S_y := \frac{h_{plate} \cdot t_{plate}^{2}}{6} = 0.281\ in^3$

Loads: The downstream guide plate will feel the full hydrostatic moment and shear (rack is loaded and load is transferred through plate into slot).

Factored hydrostatic: $H_s = 0.437\ \frac{kip}{ft^2}$

Determine total load over full area:

$$H_t := H_s \cdot h_{rack} \cdot width_{rack} = 19.219\ kip$$

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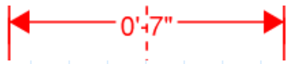
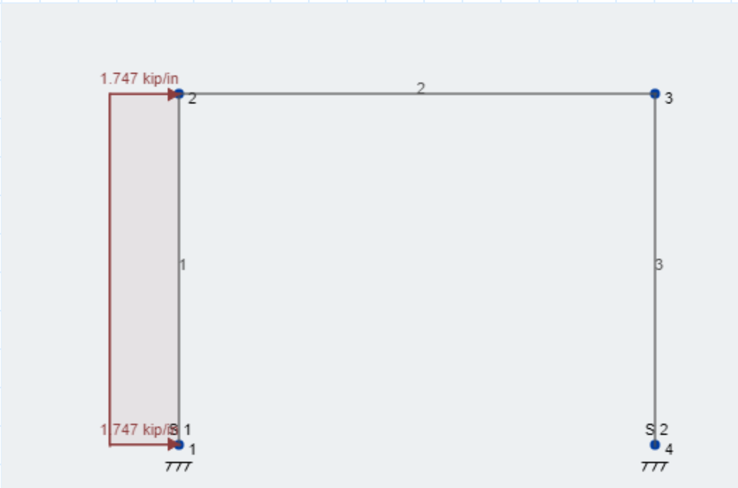


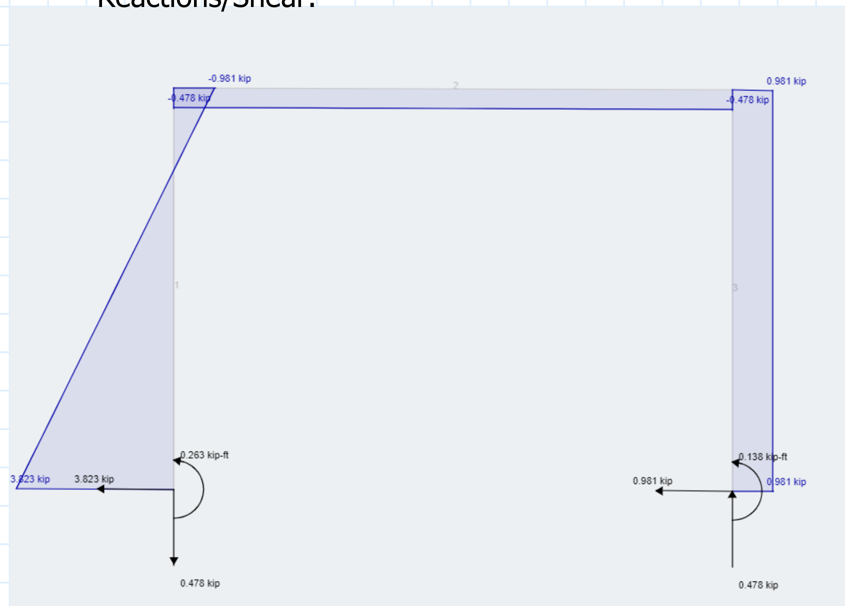
Determine line load over height:

$$L_L := \frac{H_t}{h_{rack}} = 1.747\ \frac{kip}{ft}$$

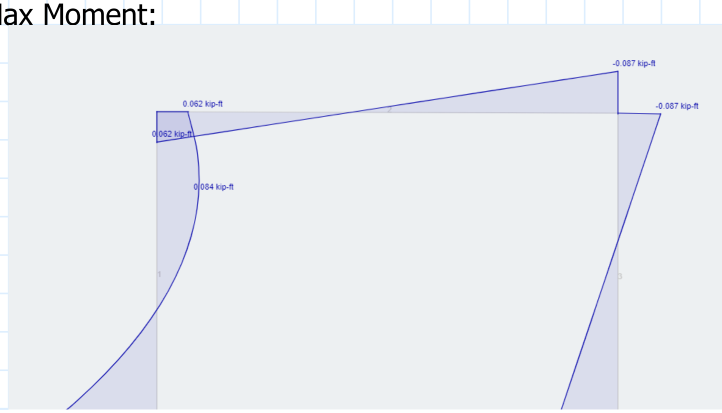
Moment and Shear: Moment frame, determine using online program (https://platform.skyciv.com/structural)



Reactions/Shear:



Max Moment:

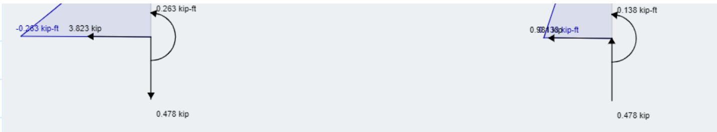


Left Plate (3/8"x2.75" long) controls: (from calculator)

$$V_u := 3.823\ kip$$

$$M_u := 0.263\ kip \cdot ft$$

$$A_u := 0.478\ kip$$ (axial load)



Check Moment, AISC F11:

Check Yielding, F11-1:

$$\phi M_n := min\left(\phi \cdot F_y \cdot Z_y , \phi \cdot 1.6 \cdot F_y \cdot S_y\right) = 0.823\ kip \cdot ft$$

$$\phi M_n > M_u = 1$$

Check LTB, F11-2: Bar is bent about minor axis, therefore, the limit state of LTB doesnt apply

Check Shear, AISC G6, weak axis shear in symmetric shapes:

$b_f := l_{plate} = 2.75\ in$ $\phi := 0.75$ $k_v := 1.2$

Determine, Cv: $\dfrac{l_{plate}}{t_{plate}} < 1.1 \cdot \sqrt{\dfrac{k_v \cdot E}{F_y}} = 1$ therefore, $C_{v2} := 1$ (G2-3)

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot l_{plate} \cdot t_{plate} \cdot C_{v2} = 16.706\ kip$$

$$\phi V_n > V_u = 1$$

Check Combined Forces, AISC H1-2: Axial and Flexure in same leg

Axial load, (model): $A_u := 0.478\ kip$

Moment: $M_u = 0.263\ kip \cdot ft$

Required axial strength: $P_r := A_u = 0.478\ kip$

Design axial strength: $P_c := \phi \cdot F_y \cdot l_{plate} \cdot t_{plate} = 27.844\ kip$

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Required flexural strength: $M_r := M_u = 0.263\ kip \cdot ft$

Design flexural strength: $M_c := \phi \cdot F_y \cdot Z_y = 0.949\ kip \cdot ft$

check, $\frac{P_r}{P_c} = 0.017$ < 0.2 use eq H1-1b

$$\frac{P_r}{2 \cdot P_c} + \left(\frac{M_r}{M_c}\right) = 0.286 \quad < 1$$ (therefore, section is adequate)

$$I := \frac{t_{plate}{}^3 \cdot l_{plate}}{12} = 0.012\ in^4$$

Check deflection: L/240

$$\Delta_{allowable} := \frac{l_{plate}}{240} = 0.011\ in$$

$$\Delta_{actual} := \frac{L_L \cdot l_{plate}{}^4}{8 \cdot E \cdot I} = 0.003\ in$$

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

Design weld from end plate to guide plate:

Loading: (shear+moment loading on HSS members/end plates)

$V_u := 5.776\ kip$

$M_u := 8.346\ kip \cdot ft$

$F_{u.Filler} := 60\ ksi$ (Fy of 36 ksi)

Length of Weld: 1 leg along full height

$A_w := h_{rack} = 11\ ft$

$$S_w := \frac{2 \cdot (h_{rack})^2}{6} = 40.333\ ft^2$$

Combined stresses:

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$$f_v := \frac{V_u}{A_w} = 0.044 \ \frac{kip}{in} \qquad f_b := \frac{M_u}{S_w} = 0.017 \ \frac{kip}{in}$$

$$Netforce := \sqrt{{f_v}^2 + {f_b}^2} = 0.047 \ \frac{kip}{in}$$

Determine Weld Size: J2.4

$t_{endplate} := 0.5 \ in$ (thickness of end plate)

$t_{plate} = 0.375 \ in$ (thickness of guide plate)

Size of fillet weld: Table J2.4

$$weld_{size} := \frac{3}{16} \ in$$

$\phi := 0.75$

Weld Strength: $\phi R_n := \phi \cdot 0.707 \cdot F_{u.Filler} \cdot weld_{size} = 5.965 \ \frac{kip}{in}$

$\phi R_n > Netforce = 1$

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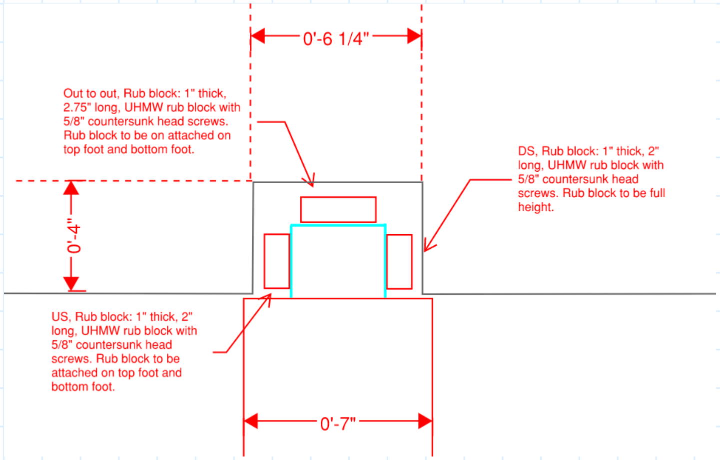
Rub block design: UHMW rub block on each side of seal guide plates



Loading: Assume same loads as guide plates, left plate controls

Line load on rub block (see above)

$L_L = 1.747 \dfrac{kip}{ft}$ (along height of gate)

$P := L_L \cdot h_{rack} = 19.219\ kip$ (total force on rub block)

Geometry, downstream rub block:

$L_{block} := 2\ in$ $t_{block} := 1\ in$ $h_{block} := h_{rack} = 11\ ft$

Force over area:

$$\sigma_{block} := \frac{P}{L_{block} \cdot h_{block}} = 72.8\ psi$$

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

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

Check:

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

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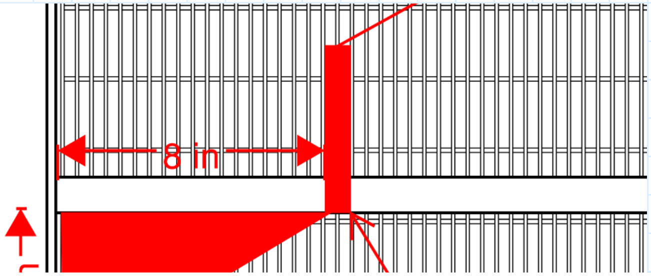
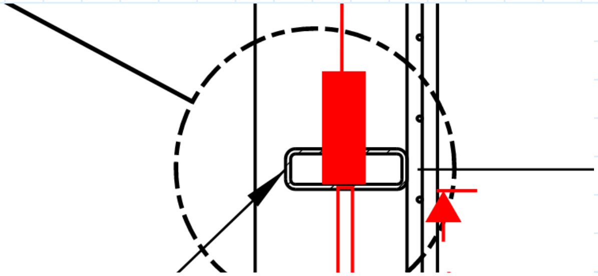
Grating Design/Type:

Lifting Stiffeners:

Profile:



Plan:



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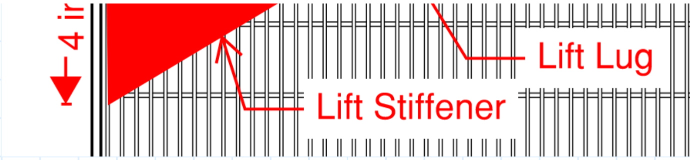
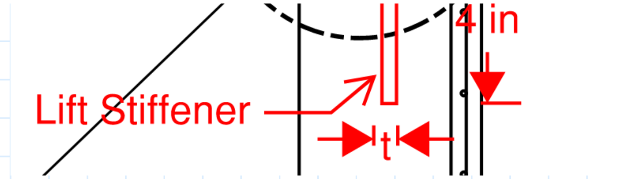




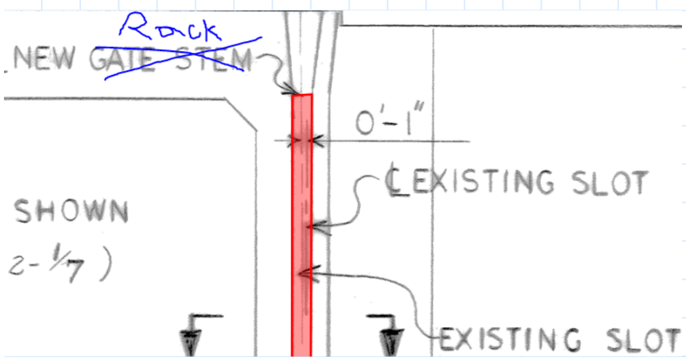
$h_{stiffener} := 4\ in$ $l_{stiffener} := 8\ in$ $t_{stiffener} := \frac{3}{8}\ in$ A36 plate

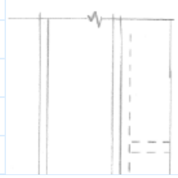
Weld size: 3/16" fillet weld, full length both sides to HSS member and end plate

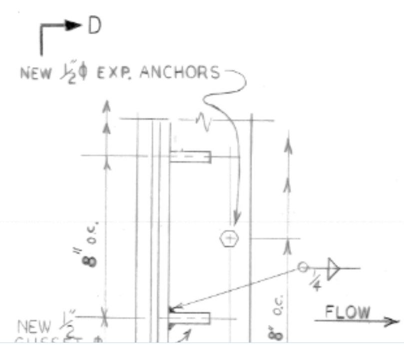
Trash Rack Slot, bottom sill:

The trash rack will be placed into an old sluice gate slot. The slot bottom is at EL 52'. However, the top of the weir just downstream is at EL 68. Therefore the trash rack will only need to live from EL 68' to the high flow mark at EL. 79', 11 ft tall.

A new sill will constructed at EL 68 in order to not have the rack be fully suspended when feeling flow.







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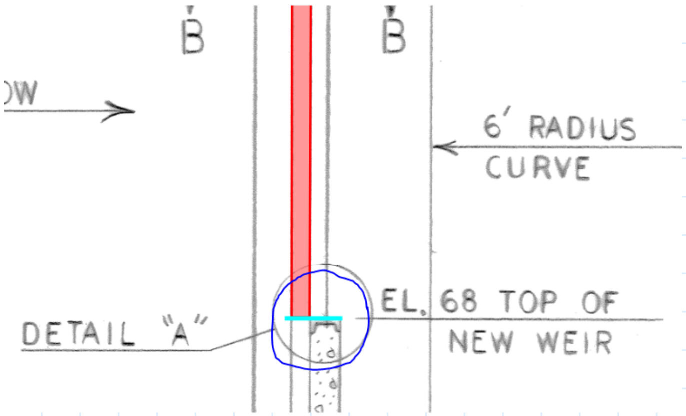
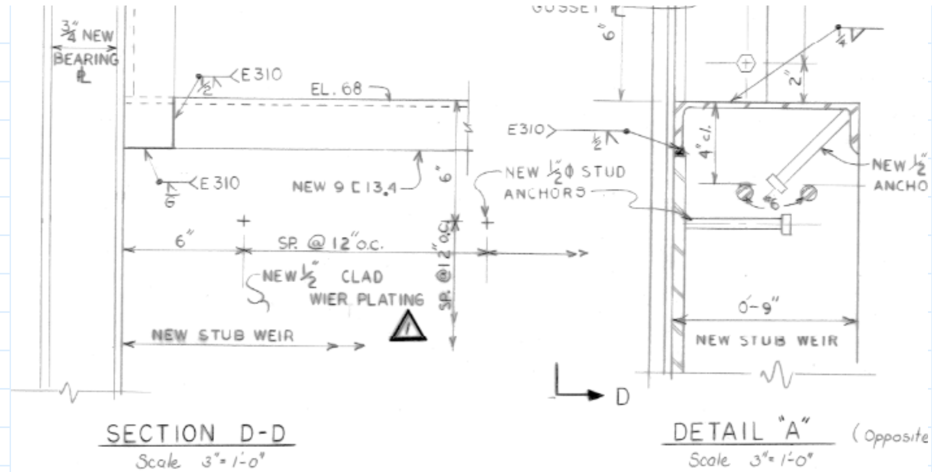




Loads: $Lift_{Load} = 1.671\ kip$

Line load along bottom: $L_{L.weight} := \dfrac{Lift_{Load}}{width_{rack}} = 0.418\ \dfrac{kip}{ft}$

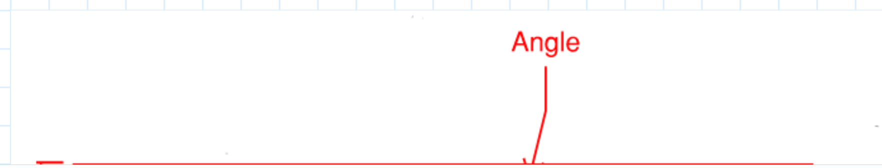
Determine shear and moment of simple beam uniformly loaded:

$$V_u := \frac{L_{L.weight} \cdot width_{rack}}{2} = 0.835\ kip$$

$$M_u := \frac{L_{L.weight} \cdot width_{rack}^{\ 2}}{8} = 0.835\ kip \cdot ft$$

Design new support: Use steel angle members anchored to existing concrete weir.

Geometry:



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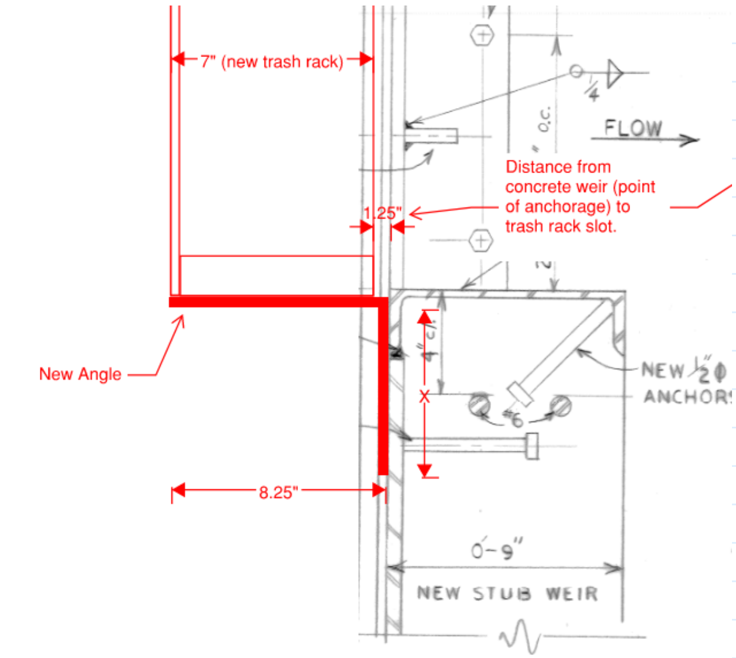

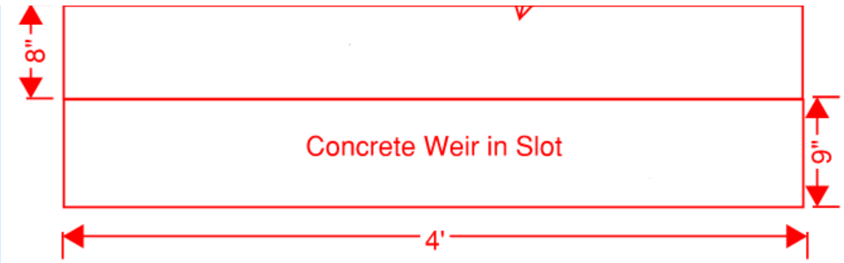

Chose L8x8x1/2" angle:

$L_{angle} := 4\ ft$ $\quad A_g := 7.84\ in^2$ $\quad S_y := 8.36\ in^3$

$t_{angle} := 0.5\ in$ $\quad b_{angle} := 8\ in$ $\quad L_b := L_{angle} = 4\ ft$

$C_b := 1$

Check Flexure, AISC F10: Single Angles

Yielding: $\phi M_n := \phi \cdot 1.5 \cdot F_y \cdot S_y = 28.215\ kip \cdot ft$

$\phi M_n > M_u = 1$

Lateral Torsional Buckling: (with lateral torsional restraint at the point of max moment, (full length))

$$\phi M_{cr} := \phi \cdot 1.25 \cdot \left(\frac{0.58 \cdot E \cdot b_{angle}^{\ 4} \cdot t_{angle} \cdot C_b}{L_b^{\ 2}} \right) \cdot \left(\sqrt{1 + 0.88 \cdot \left(\frac{L_b \cdot t_{angle}}{b_{angle}^{\ 2}} \right)^2} - 1 \right) = 70.166\ kip \cdot ft$$

(seems really high)

$\phi M_{cr} > M_u = 1$

Leg Local Buckling: Use EQ F10-6

Determine leg slenderness: B4.1b

$$0.54 \cdot \sqrt{\frac{E}{F_y}} = 15.326 \quad < \quad \frac{b_{angle}}{t_{angle}} = 16 \quad < \quad 0.91 \cdot \sqrt{\frac{E}{F_y}} = 25.828$$

(therefore, section is noncompact, check Leg Local Buckling)

$$S_c := 0.8 \cdot S_y = 6.688 \ in^3$$

$$\phi M_n := \phi \cdot F_y \cdot S_c \cdot \left(2.43 - 1.72 \cdot \left(\frac{b_{angle}}{t_{angle}}\right) \cdot \sqrt{\frac{F_y}{E}}\right) = 21.976 \ kip \cdot ft$$

$$\phi M_n > M_u = 1$$

Check Shear, AISC G3: Single Angles and Tees

$$C_{v2} := 1$$

$$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot b_{angle} \cdot t_{angle} \cdot C_{v2} = 64.8 \ kip$$

$$\phi V_n > V_u = 1$$

Check Deflection: L/240

$$I := 48.8 \ in^4$$

$$\Delta_{allowable} := \frac{L_{angle}}{240} = 0.2 \ in$$

$$\Delta_{actual} := \frac{5 \cdot L_{L.weight} \cdot L_{angle}^{\ 4}}{384 \cdot E \cdot I} = 0.002 \ in$$

Connection Design: Design bolted connection from angle to existing concrete weir. Existing concrete weir is covered with 0.5" thick steel plate

Loading: Same as loads on angle. Loads are transfered from angle leg into the other leg and connected to the weir

$$V_u := \frac{L_{L.weight} \cdot width_{rack}}{2} = 0.835\ kip$$

$$M_u := \frac{L_{L.weight} \cdot width_{rack}^2}{8} = 0.835\ kip \cdot ft$$

$$d_{bolt} := \frac{5}{8}\ in \qquad A_b := \frac{\pi \cdot d_{bolt}^2}{4} = 0.307\ in^2$$

Bolts: AISC Chapter J

$F_{nv} := 27\ ksi$ (A307 bolts)

Minimum Spacing: J3-2

$$Min_{spacing} := 2.67 \cdot d_{bolt} = 1.669\ in$$

Minimum edge distance, J3-4:
7/8"

Max Spacing/Edge Distance: J3-5

Max Edge distance: 12*thickness of connected part

$$Edge_{distance} := 12 \cdot t_{angle} = 6\ in$$

Max Longitudinal Spacing: 12"

Shear strength of Bolt: J3-1

$\phi := 0.75$

$$\phi R_n := \phi \cdot F_{nv} \cdot A_b = 6.213\ kip$$

$$\phi R_n > V_u = 1$$

Bearing and Tearout strength: J3-10

$F_u := 58\ ksi$

Bearing: J3-6b

$\phi R_{nb} := \phi \cdot 3 \cdot d_{bolt} \cdot t_{angle} \cdot F_u = 40.781\ kip$

Tearout: J3-6d

$\phi R_{nt} := \phi \cdot 1.5 \cdot Edge_{distance} \cdot t_{angle} \cdot F_u = 195.75\ kip$

$\phi R_{nb} > V_u = 1$

Check concrete tearout strength:

Table 17.5.1.3.1—Critical spacing

Failure mode under investigation	Critical spacing
Concrete breakout in tension	$3h_{ef}$
Bond strength in tension	$2c_{Na}$
Concrete breakout in shear	$3c_{a1}$

$c_{a1} := \frac{8\ in}{2} = 4\ in$

Weld angle to concrete cap:

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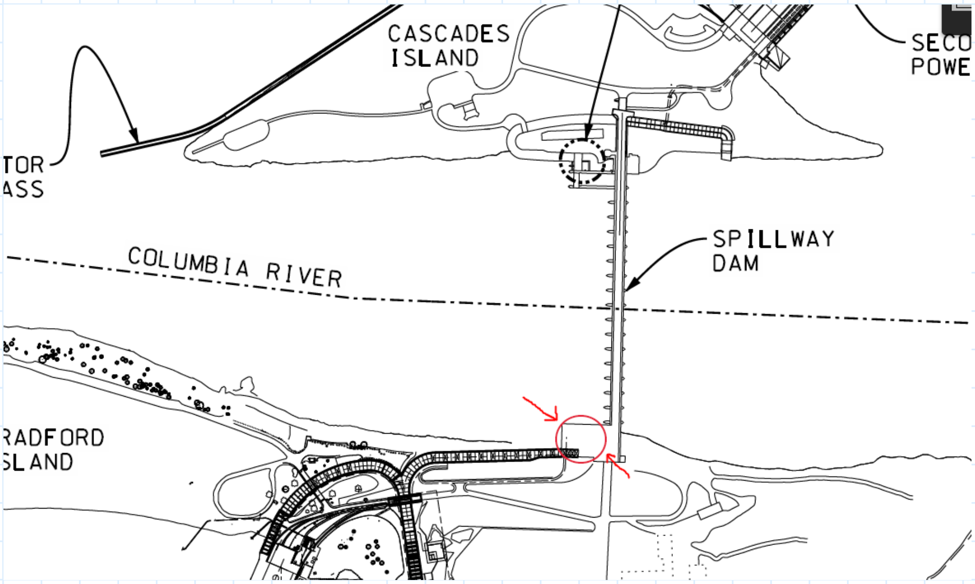
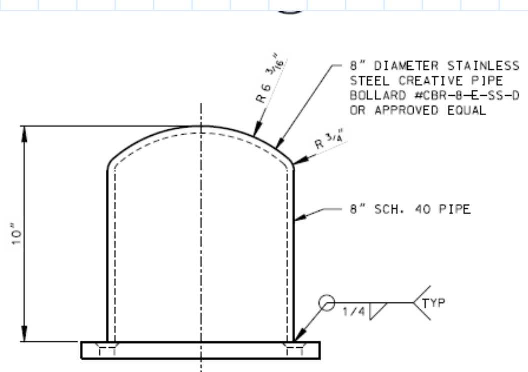
Fracture Critical Members:

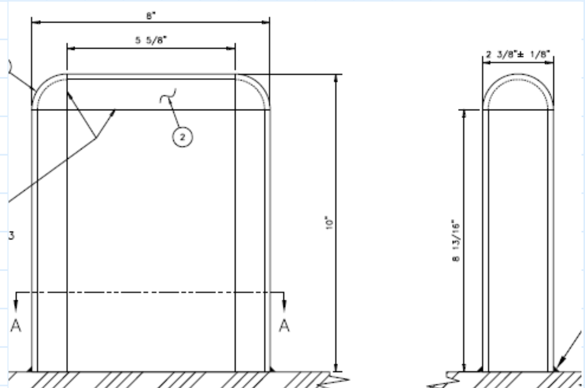
Component #:	Description:	Fracture Critical (Y/N) (must be in tension)
1	Lifting Lugs	Y
2	Lifting stiffeners	N
3	Steel Grating	N
4	Girders	Y
5	End plate	Y
6	Base plate	N
7	Guide plate	N
8	Rub Blocks	N

FY 19 Bonn Bradford Island Lamprey
Lamprey Bollard Design Calcs 6/14/21
Collin Porter

General:
Design calcs for the new Lamprey Bollards for the Bradford Island fish entrance. The shape of these bollards are the same as the John Day North Fish Ladder. These were found to be more efficient than the bollards on the other fish ladder entrance on Cascades island. However, the layout will match cascades island's bollards due to their symmetry.







The image on the left are the Cascades Island bollards which will not be used. The bollards to the right will be used and were constructed at John Day North Fish Ladder.

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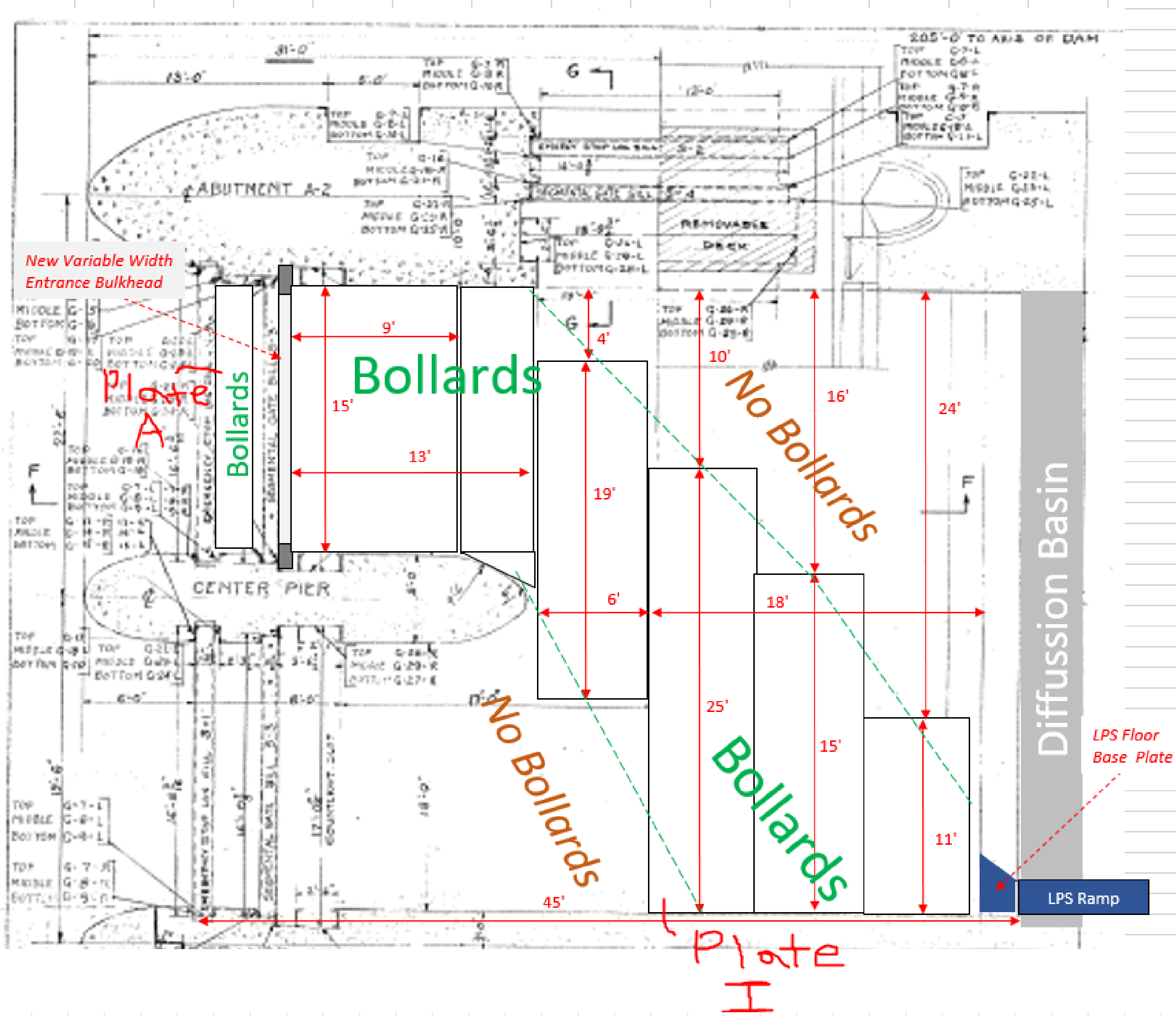

Quantities:

Steel plate area (0.75" thick):

$$PL_{area} := (2.33\ ft \cdot 15\ ft) + (15\ ft \cdot 13\ ft) + (6\ ft \cdot 19\ ft) + (25\ ft \cdot 6\ ft) + (15\ ft \cdot 6\ ft) + (11\ ft \cdot 6\ ft) = 649.95\ ft^2$$

Bollards: (every 2')

$$\#_{bollards} := (8 \cdot 2) + (8 \cdot 6) + (3 \cdot 10) + (3 \cdot 13) + (8 \cdot 3) + (6 \cdot 3) = 175$$

Sling: 1 Contractor designed lifting sling type assembly

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Hold Down Anchors for Bollards:
Bollards are attached to various shaped steel plates. Check the smallest and largest plates.

Bollard info: 3/16" steel plate bent into bollard shape, for simplicity assume bollard is square.
Bollards attach to 1" thick steel plates orientated to guide them to the LPS structure.

$t_{bollard} := \frac{3}{16}\ in$

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

$Height_{bollard} := 10\ in$

$thickness_{plate} := 0.75\ in$

$Length_{bollard} := 8\ in$

$\#bollards_{PlateA} := 7$

$Width_{bollard} := 2.375\ in$

$\#bollards_{PlateI} := 25$

$$Weight_{Bollard} := \left(\left(Height_{bollard} \cdot Length_{bollard} \cdot t_{bollard} \cdot 2\right) + \left(Height_{bollard} \cdot Width_{bollard} \cdot t_{bollard} \cdot 2\right) + \left(Length_{bollard} \cdot Width_{bollard} \cdot t_{bollard}\right)\right) \cdot w_{steel}$$

$$Weight_{Bollard} = 12.043\ lbf$$

Total weight of all steel:

$$Total_{weight} := \left(\#_{bollards} \cdot Weight_{Bollard}\right) + \left(PL_{area} \cdot w_{steel} \cdot thickness_{plate}\right) = 22.012\ kip$$

Hydraulic Loading:

Drag:

Force due to velocity on one bollard, from Hydraulic Engineer:

$$F_d := 130\ lbf$$

Hydrodynamic load factor: $H_d := 1.6$ (usual loading)

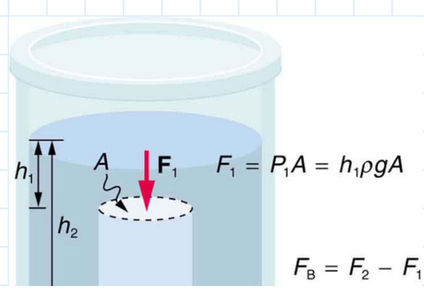
Factored force: $F_{drag} := F_d \cdot H_d = 208\ lbf$

Uplift:

Air trapped in bollards: $Volume_{air} := Height_{bollard} \cdot Length_{bollard} \cdot Width_{bollard} = 0.11\ ft^3$

$Pressure_{38feet} := 31.58\ psi$

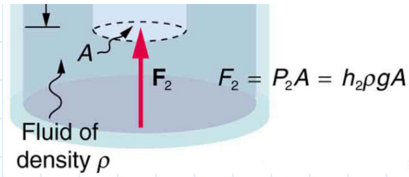
$Volume_{air} \cdot Pressure_{38feet} = 500.017\ ft \cdot lbf$



$A := Length_{bollard} \cdot Width_{bollard}$

$h := 38\ ft$ $\gamma := 62.4\ \frac{lbf}{}$

ft^3



$$F_{uplift} := H_d \cdot h \cdot \gamma \cdot A = 500.587\ lbf$$

Anchors:
Use Stainless steel wedge anchors.

Choose: 3/8"x2-1/4" Stainless steel wedge anchor with min embedment of 1-1/2". Shear strength is 3238 lbs. Pull out strength is 1223 lbs.

https://www.concretefasteners.com/3-8-x-2-1-4-stainless-steel-wedge-anchor/

$$Anchor_{shear} := 3238\ lbf$$

$$Anchor_{pullout} := 1223\ lbf$$

Number of bollards per anchor: shear

$$Bollards_{per.anchor} := \frac{Anchor_{shear}}{F_{drag}} = 15.567$$

Number of bollards per anchor: pullout

$$Bollards_{per.anchor} := \frac{8 \cdot Anchor_{pullout}}{19 \cdot F_{uplift}} = 1.029$$ (pullout controls)

Number of anchors required per bollard:

One anchor: 2 bollards
Two anchor: 4 bollards
Three: 7 bollards
Four: 9 bollards
Five: 12 bollards
Six: 14 bollards
Seven: 17 bollards
Eight: 19 bollards

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Lifting Plates: Determine pick points and overhangs. Per 1' strip into page.

Try: $X := 8\ ft$ $\quad Y := 20\ ft$ $\quad Overhang := \frac{Y - X}{2} = 6\ ft$

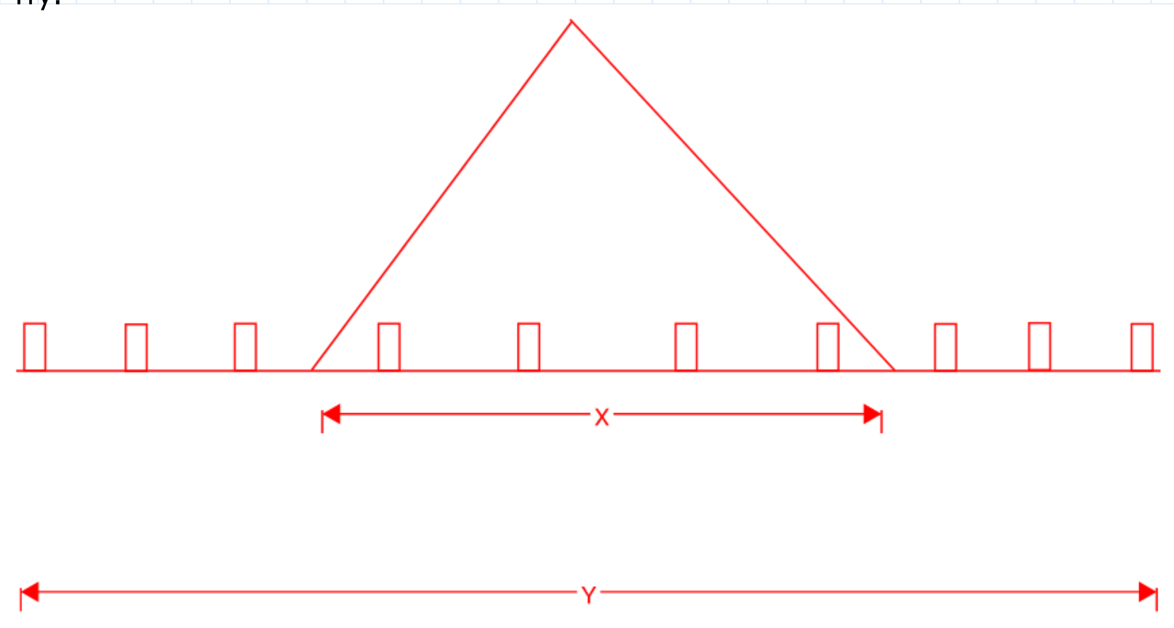
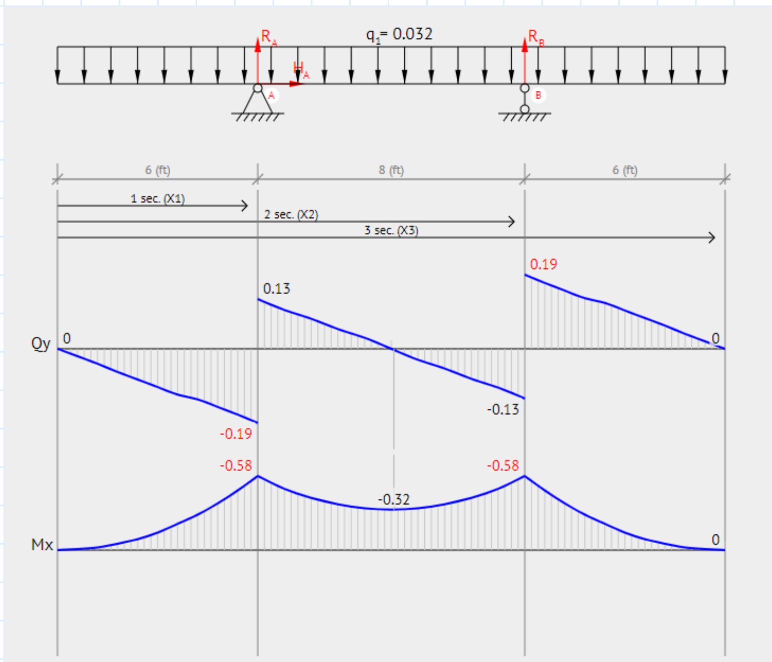


Plate and Bollard Dead load: for a 1' strip

$$DL := 1.2 \cdot \left(\frac{1\ ft \cdot Y \cdot thickness_{plate} \cdot w_{steel} + \left(Weight_{Bollard} \cdot 10 \right)}{Y} \right) = 0.044\ \frac{kip}{ft}$$

Max moment and shear:



$M_{max} := 0.58\ kip \cdot ft$
$V_{max} := 0.13\ kip$

Check Bending: AISC F11 Rectangular Bars and Rounds $\quad \phi := 0.9$

$$Z := \frac{1\ ft \cdot thickness_{plate}^{\ 2}}{3} = 2.25\ in^3$$

$$S := \frac{1\ ft \cdot \left(thickness_{plate}\right)^2}{6} = 1.125\ in^3$$

$$I := \frac{1\ ft \cdot thickness_{plate}^{\ 3}}{12} = 0.422\ in^4$$

$E := 29000\ ksi$
$F_y := 36\ ksi$

Check Yielding F11-1:

$$\frac{Y \cdot 1\ ft}{thickness_{plate}^{\ 2}} = 5120 \quad < \quad \frac{0.08 \cdot E}{F_y} = 64.444$$

Phi Mp: min of: $\phi \cdot F_y \cdot Z = 6.075\ kip \cdot ft \quad < \quad \phi \cdot 1.6 \cdot F_y \cdot S = 4.86\ kip \cdot ft$

$$\phi Mp := \phi \cdot 1.6 \cdot F_y \cdot S = 4.86\ kip \cdot ft$$

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

Check Lateral Torsional Buckling F11-2:

for bars with Lb*d/t^2 < 0.08E*Fy , LTB does not apply.

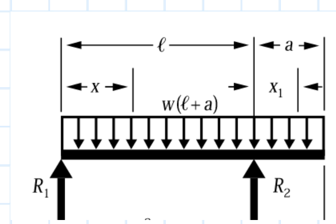
$$\frac{Y \cdot 1\ ft}{thickness_{plate}^{\ 2}} = 5120 \quad < \quad \frac{0.08 \cdot E}{F_y} = 64.444$$

LTB does not apply

Deflection: check center and overhang $E := 29000\ ksi$

overhang: $a := 6\ ft$ $x_1 := 3\ ft$

center span: $l := 8\ ft$



$$\Delta_{center} := \frac{5 \cdot DL \cdot (l)^4}{384 \cdot E \cdot I} = 0.331\ in$$

$$\Delta_{overhang} := \frac{DL \cdot x_1}{24 \cdot E \cdot I} \left(4 \cdot a^2 \cdot l - l^3 + 6 \cdot a^2 \cdot x_1 - 4 \cdot a \cdot x_1^{\ 2} + x_1^{\ 3}\right) = 0.853\ in \text{ (controls)}$$

Check: deflection limit L/120 for construction: $\frac{Y}{120} = 2\ in$

$$\frac{Y}{120} > \Delta_{overhang} = 1$$

Therefore, overhangs will work.

TRY using a 10' long plate, with no overhangs

Plate and Bollard Dead load: for a 1' strip $l_{10ft} := 10\ ft$

$$DL_{10ft} := 1.2 \cdot \left(\frac{1\ ft \cdot l_{10ft} \cdot thickness_{plate} \cdot w_{steel} + \left(Weight_{Bollard} \cdot 5\right)}{l_{10ft}} \right) = 0.044\ \frac{kip}{ft}$$

(DL doesnt change)

Check Bending: AISC F11 Rectangular Bars and Rounds $\phi := 0.9$

$$Z := \frac{1\ ft \cdot thickness_{plate}^{\ 2}}{3} = 2.25\ in^3$$

$$S := \frac{1\ ft \cdot \left(thickness_{plate}\right)^2}{6} = 1.125\ in^3$$

$$Mmax := \frac{DL_{10ft} \cdot l_{10ft}^{\ 2}}{8} = 0.55\ kip \cdot ft$$

$$V_{max} := DL_{10ft} \cdot l_{10ft} = 0.44\ kip$$

$E := 29000\ ksi$

Check Yielding F11-1: $F_y := 36\ ksi$

$$\frac{l_{10ft} \cdot 1\ ft}{thickness_{plate}^{\ 2}} = 2560 \quad < \quad \frac{0.08 \cdot E}{F_y} = 64.444$$

Phi Mp: min of: $\phi \cdot F_y \cdot Z = 6.075\ kip \cdot ft \quad < \quad \phi \cdot 1.6 \cdot F_y \cdot S = 4.86\ kip \cdot ft$

$$\phi Mp := \phi \cdot 1.6 \cdot F_y \cdot S = 4.86\ kip \cdot ft$$

$$\phi Mp > Mmax = 1$$

Check Lateral Torsional Buckling F11-2:

for bars with Lb*d/t^2 < 0.08E*Fy , LTB does not apply.

$$\frac{l_{10ft} \cdot 1\ ft}{thickness_{plate}^{\ 2}} = 2560 \quad < \quad \frac{0.08 \cdot E}{F_y} = 64.444$$

LTB does not apply

FY 19 Bonn Bradford Island Lamprey
Lamprey Bollard Design Calcs 6/14/21
Collin Porter

Deflection:

$$I := \frac{1\ ft \cdot thickness_{plate}^{\ 3}}{12} = 0.422\ in^4 \qquad E := 29000\ ksi$$

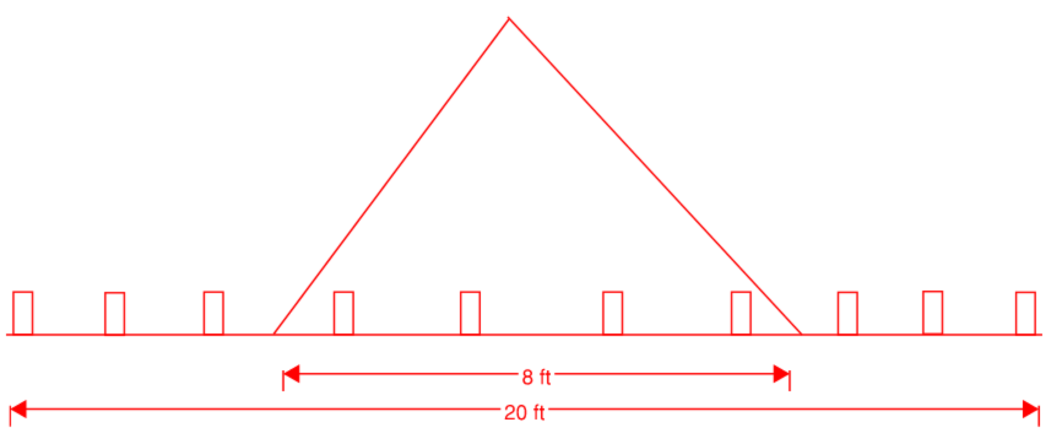
$$Deflection := \frac{5 \cdot DL_{10ft} \cdot (l_{10ft})^4}{384 \cdot E \cdot I} = 0.809\ in$$

Check: deflection limit L/120 for construction: $\frac{l_{10ft}}{120} = 1\ in$

$$Deflection < \frac{l_{10ft}}{120} = 1$$

Therefore, 10 foot sections with 10 foot c.to c. pick points will work.
However, 10 foot sections aren't required, just use 8' with overhangs.

Therefore, use:
20' long (or shorter) sections with 6' of overhang (or less) each side



Check lamprey bollards Strength in Bending/Shear/Tension:

$F_{bollard} := F_d \cdot H_d = 208\ lbf$ (Factored force on bollards from HD engineer)

$Height_{bollard} = 10\ in$

$Length_{bollard} = 8\ in$

Use a HSS 8x2x3/16 with 10" height to emulate the bollard shape.

$Width_{bollard} = 2.375\ in$

$I_y := 2.39\ in^4$

$Z_y := 2.70\ in^3$

$Moment_{bollard} := F_{bollard} \cdot Height_{bollard} = 0.173\ kip \cdot ft$

$Shear_{bollard} := F_{bollard} = 208\ lbf$

$F_{uplift} = 500.587\ lbf$

$$Deflection := \frac{F_{bollard} \cdot \left(Height_{bollard}\right)^3}{3 \cdot E \cdot I_y} = 0.0010003\ in$$

AISC F7 Flexure of Square and Rectangular HSS: $\phi := 0.9$ $F_y := 36\ ksi$

Yielding: F7-1 $\phi Mn := \phi \cdot F_y \cdot Z_y = 7.29\ kip \cdot ft$

Check:

$\phi Mn > Moment_{bollard} = 1$

$$\frac{Moment_{bollard}}{\phi Mn} = 0.024$$

Flanges Slender/Non Slender:

$bovert := 8.49 < 1.12 \cdot \sqrt{\frac{E}{F_y}} = 31.788 < 1.4 \cdot \sqrt{\frac{E}{F_y}} = 39.735$

therefor the flanges are compact

Walls Slender/Non Slender:

$bovert := 8.49 < 1.4 \cdot \sqrt{\frac{E}{F_y}} = 39.735$

therefor the walls are compact

Because both the flanges and webs are compact Flange Local buckling and Web Local Buckling does not apply

Lateral Torsional Buckling:

if Lb < Lp than LTB does not apply.

$r_y := \frac{Height_{bollard}}{2} = 5\ in$

$L_b := 10\ in$

$A_g := 2 \cdot t_{bollard} \cdot Length_{bollard} = 3\ in^2$

$J := 7.48\ in^4$

$M_p := F_y \cdot Z_y = 8.1\ kip \cdot ft$

Lp: Eq F7-12: $L_p := 0.13 \cdot E \cdot r_y \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 918.664\ in$

$L_b < L_p = 1$

Shear Check: AISC G4

$C_{v2} := 1$

$A_w := 2 \cdot t_{bollard} \cdot Length_{bollard} = 3\ in^2$

$\phi Vn := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 58.32\ kip$

Check: ϕVn > Shear

$\phi Vn > F_{bollard} = 1$

Tension Check: AISC D (uplift)

Yielding:

$\phi P_n := \phi \cdot F_y \cdot A_g = 97.2\ kip$

$\phi P_n > F_{uplift} = 1$

Rupture: $U := 1$ (Table D3.1, case 1) $F_u := 58\ ksi$

$A_e := A_g \cdot U = 3\ in^2$

$\phi P_n := F_u \cdot A_e = 174\ kip$

$\phi P_n > F_{uplift} = 1$

Deflection: L/120

$L_{120} := \frac{Height_{bollard}}{120} = 0.083\ in$

$$Deflection := \frac{F_{bollard} \cdot Height_{bollard}}{3 \cdot E \cdot I_y} = 0.001\ in$$ (deflection of cantilevered beam)

$$L_{120} > Deflection = 1$$

Design weld from bollard to steel plate: forces are from Force on bollards from water and hydrostatic pressure from hollow full of air bollards.

LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22

Goal: The stoplog slot (SL-30) just downstream of the new trash rack will need to be filled to EL. 78.

Design: Design a concrete wall in slot to block flow from EL. 60' (bottom of slot) to EL. 78' (high flow). A 6" LPS water pipe will penetrate the wall at EL 65.

Slot geometry:
Width of slot: 9" (BDF-2-1/4) $t_{slot} := 9\ in$
Length of slot: 3'+10" (BDF-2-1/4) $L_{slot} := 3\ ft + 10\ in$
Height of slot: EL 60 to EL 78. (M-5-16) $H_{slot} := 78\ ft - 60\ ft = 18\ ft$

$f_y := 60\ ksi$ (rebar)
$f'_c := 4000\ psi$ (new conc)
$\gamma_w := 62.4\ pcf$

Pipe geometry: sch 80, outside diameter of 6.625", at EL 65.

Outer diameter of pipe: $diam_{pipe} := 6.625\ in$

Quantities:
Concrete: f'c = min 4000 psi
$Vol_{concrete} := t_{slot} \cdot L_{slot} \cdot H_{slot} = 51.75\ ft^3$ $Vol_{concrete} = 1.917\ yd^3$

Rebar: $D_{\#5} := 0.625\ in$
Horiz: #5 bar every 9", both faces (see calcs below)

Number of bars: $\#_{horiz} := 2 \cdot \frac{H_{slot}}{9\ in} = 48$ (therefore, 48 horizontal bars are required.)

Length: $L_{rebar.h} := \left(L_{slot} - 3\ in\right) \cdot \#_{horiz} = 172\ ft$

Vert: #5 bar every 15", both faces (only tension rebar feels flexure)

Number of bars: $\#_{vert} := 2 \cdot \frac{L_{slot}}{15\ in} = 6.133$ (therefore, 8 bars required because 4 bars each face)

$\#_{vert} := 8$

LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22

Length: $L_{rebar.v} := \left(H_{slot} - 3\ in\right) \cdot \#_{vert} = 142\ ft$

Dowels: #5 spaced every 9" vertically both ends of wall:

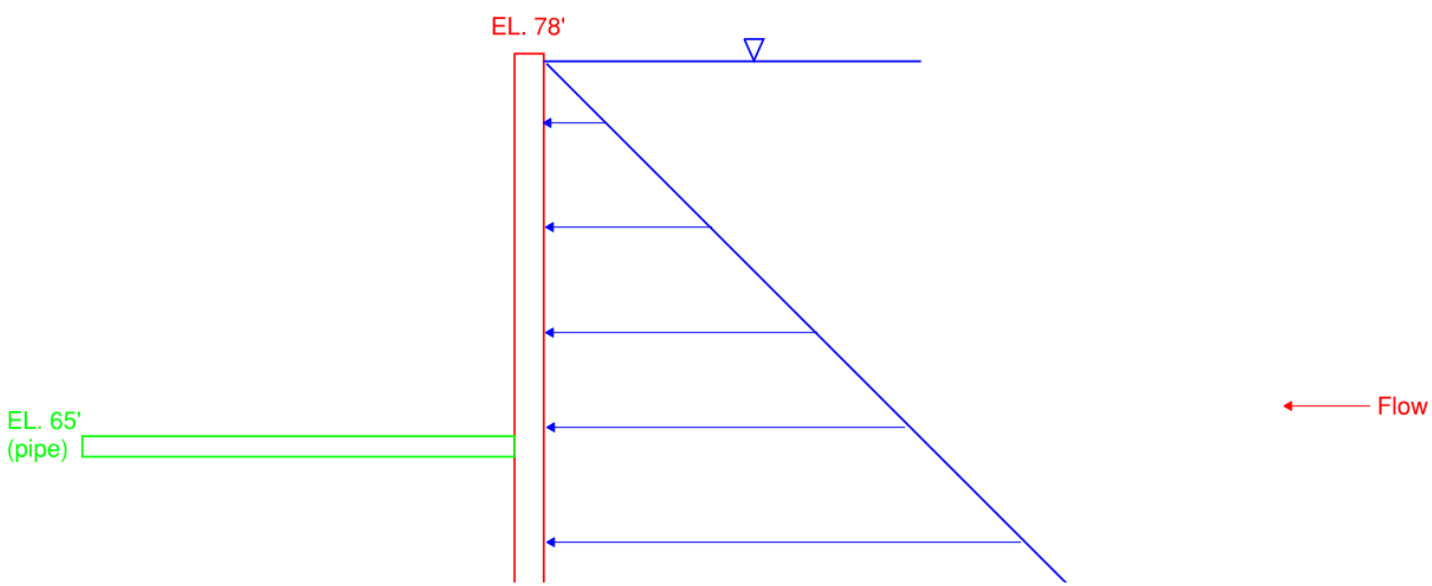
Number of bars: $\#_{dowels} := 2 \cdot \frac{H_{slot}}{9\ in} = 48$ (therefore, 48 dowels (24 each wall) are required.)

Length: $L_{dowels} := 24\ in \cdot \#_{dowels} = 96\ ft$

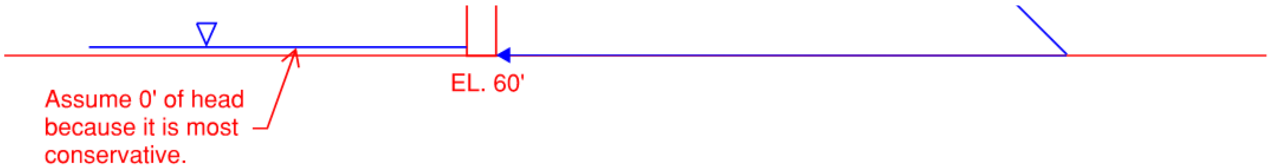
Total length of bar:

$$L_{rebar} := L_{rebar.v} + L_{rebar.h} + L_{dowels} = 410\ ft$$

FBD: SL 30 slot



LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22



Loads, Load Factors:

1. Hydrostatic (assume flow is at top of wall), 1.4
2. Dead load, 1.2
3. Hydrodynamic seismic? westegards

Factored Hydrostatic load:

$$H_s := 1.4 \cdot \frac{1}{2} \cdot \gamma_w \cdot H_{slot} \cdot ft = 786.24 \ \frac{lbf}{ft}$$

(per foot into page)
(max hydrostatic load at sill, 0 psf of hydrostatic load at top of wall)

Max Shear/Moment of cantilevered increasing uniform load on beam:

$$V_u := 7110 \ lbf = 7.11 \ kip$$

$$M_u := 42660 \ lbf \cdot ft = 42.66 \ ft \cdot kip$$

(via, https://skyciv.com/free-beam-calculator/)

Dead Load: weight of wall along height

Weight of concrete: $Vol_{concrete} = 51.75 \ ft^3$ $\quad UnitWeight_{concrete} := 150 \ pcf$

$$Weight_{conc} := Vol_{concrete} \cdot UnitWeight_{concrete} = 7.763 \ kip$$

Weight of steel:

$$Vol_{rebar} := L_{rebar} \cdot \frac{\pi \cdot {D_{\#5}}^2}{4} = 0.874 \ ft^3$$

$$UnitWeight_{steel} := 490 \ pcf$$

$$Weight_{steel} := Vol_{rebar} \cdot UnitWeight_{steel} = 0.428 \ kip$$

Factored DL:

$$DL := 1.2 \cdot \frac{Weight_{conc} + Weight_{steel}}{H_{slot}} = 0.546 \ \frac{kip}{ft}$$

LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22

Treat beam as uniformly loaded cantilevered? Moment would be over capacity with this DL load. The wall is not really cantilevered because its tied into the other walls. What load to use?

Seismic Load: ETL 1110-2-584 3.2.3.6 Westergaard's Eq

Design Wall: Wall design is in accordance with ACI 318, Chapter 11 and 21

Design example is here: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://structurepoint.org/publication/pdf/Reinforced-Concrete-Shear-Wall-Analysis-Design-ACI318-14.pdf

Check horizontal reinforcement:

Assume 1 bar at each face, #5 bar every 12" in all directions: $s_{rebar} := 12\ in$ $A_{v.horiz} := 2 \cdot 0.31\ in^2$

$$\rho_t := \frac{A_{v.horiz}}{s_{rebar} \cdot t_{slot}} = 0.006$$ (ACI 318-14, 2.2)

$\rho_{t.min} := 0.0025$ (ACI 318-14, 11.6.2b)

$\rho_t > \rho_{t.min} = 1$

Spacing:

$$s_{t,\max} = \text{smallest of} \begin{Bmatrix} 3 \times h \\ 18\text{ in.} \\ l_w / 5 \end{Bmatrix}$$

$3 \cdot t_{slot} = 27\ in$

$18\ in$

$\frac{L_{slot}}{5} = 9.2\ in$ (controls)

(ACI 318-14, 11.7.3.1)

LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22

$s_{actual.horiz} := 9\ in$

Determine new ρ_t with 9 in spacing: $A_{v.horiz} := 2 \cdot 0.31\ in^2$ $s_{rebar} := 9\ in$ A_v = area of sh

$$\rho_t := \frac{A_{v.horiz}}{s_{rebar} \cdot t_{slot}} = 0.008$$

Check vertical reinforcement: only one vertical bar can be considered for flexural strength. Bars on both faces are considered for temp and shrinkage

Assume #5 bar, 12" each face:

$A_{v.vertical} := 2 \cdot 0.31\ in^2$

$s_{rebar} := 12\ in$

$$\rho_l := \frac{A_{v.vertical}}{s_{rebar} \cdot t_{slot}} = 0.006$$ (ACI 318-14, 2.2)

(11.6.2a) $$\rho_{l,\min} = \text{greater of} \begin{cases} 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_t - 0.0025) \\ 0.0025 \end{cases}$$

$$0.0025 + 0.5 \cdot \left(2.5 - \frac{H_{slot}}{L_{slot}}\right) \cdot (\rho_t - 0.0025) = -0.003$$

$\rho_{l.min} := 0.0025$ (controls)

$\rho_l > \rho_{l.min} = 1$

Spacing: ACI 11.7.2.1

$$s_{l,\max} = \text{smallest of} \begin{cases} 3 \times h \\ 18 \text{ in.} \\ l_w / 3 \end{cases}$$

$3 \cdot t_{slot} = 27\ in$

$18\ in$

$\frac{L_{slot}}{3} = 15.333\ in$ (controls)

$s_{actual.vertical} := 15\ in$ (can make smaller if needed)

LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22

Determine new ρ_l with 15 in spacing: $A_{v.vertical} := 2 \cdot 0.31\ in^2$ $s_{rebar} := 15\ in$

$$\rho_l := \frac{A_{v.vertical}}{s_{rebar} \cdot t_{slot}} = 0.005$$

$\rho_l > \rho_{l.min} = 1$

Horizontal Reinforcement: #5 bar at each face, 9" o.c.
Vertical Reinforcement: #5 bar at each face, 15" o.c.

Determine Neutral Axis:

$$\beta_1 := 0.85 - \frac{0.05 \cdot (4500 - 4000)}{1000} = 0.825$$

$$\omega := \rho_l \cdot \frac{f_y}{f'_c} = 0.069 \qquad \alpha := \frac{V_u}{t_{slot} \cdot L_{slot} \cdot f'_c} = 0.004$$

$$c := \left(\frac{\alpha + \omega}{(0.85 \cdot \beta_1) + (2 \cdot \omega)}\right) \cdot L_{slot} = 4.012\ in$$

Assume d is approx 0.8Lslot: (11.5.4.2)

$$d := 0.8 \cdot L_{slot} = 36.8\ in$$

$d > c = 1$ (therefore this section is tension controlled)

Moment Capacity Check: use only 1 flexural bar $A_{v.flexural} := 0.31\ in^2$

$$A_{st} := A_{v.flexural} \cdot \frac{L_{slot}}{s_{actual.vertical}} = 0.951\ in^2$$

$$T := A_{st} \cdot f_y \cdot \left(\frac{L_{slot} - c}{L_{slot}}\right) = 52.065\ kip$$

LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22

Incorporate applied axial force and summing force moments about the compression face, C: $\phi := 0.9$

$$\phi M_n := \phi \cdot T \cdot \left(\frac{L_{slot}}{2}\right) = 89.812\ kip \cdot ft$$

$$\phi M_n > M_u = 1$$

Shear Capacity Check: $V_u = 7.11\ kip$

$\frac{H_{slot}}{L_{slot}} = 4.696 < 2$ Therefor use ACI Chapter 11

Determine Vn: Equation 11.5.4.3 $\lambda := 1$ $\phi := 0.75$ $\alpha_c := 2$ $f_{yt} := 60\ ksi$

$$A_{cv} := t_{slot} \cdot L_{slot} = 2.875\ ft^2$$

$$\phi V_n := \phi \cdot \left(\alpha_c \cdot \lambda \cdot \sqrt{4000}\ psi + \rho_t \cdot f_{yt}\right) \cdot A_{cv} = 181.875\ kip$$

$$\phi V_n > V_u = 1$$

Deflection: L/240

$E := 29000\ ksi$ $I := \frac{t_{slot}^{3} \cdot L_{slot}}{6} = \left(5.589 \cdot 10^3\right)\ in^4$

$$\Delta_{allowable} := \frac{H_{slot}}{240} = 0.9\ in$$

$$\Delta_{actual} := \frac{H_s \cdot H_{slot}^{4}}{\ldots} = 0.11\ in$$ (cantilevered, uniformly loaded)

$$8 \cdot E \cdot I$$

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

Check overall wall with penetration:

20.7.4 Reinforcement with an area at least 0.002 times the area of the concrete section shall be provided perpendicular to pipe embedments.

satisfied

20.7.5 Specified concrete cover for pipe embedments with their fittings shall be at least 1-1/2 in. for concrete exposed to earth or weather, and at least 3/4 in. for concrete not exposed to weather, or not in contact with ground.

11.7.5 *Reinforcement around openings*

11.7.5.1 In addition to the minimum reinforcement required by 11.6, at least two No. 5 bars in walls having two layers of reinforcement in both directions and one No. 5 bar in walls having a single layer of reinforcement in both directions shall be provided around window, door, and similarly sized openings. Such bars shall be anchored to develop f_y in tension at the corners of the openings.

satisfied

cover = 1.5" (exposed to weather)

$t_{slot} = 9\ in$ $L_{slot} = 3.833\ ft$ $H_{slot} = 18\ ft$

$D_{pipe} := 6.75\ in$ $clear_{cover} := 1.5\ in$

Penetration: required for 6.75" OD pipe

$$D_{pen} := D_{pipe} + clear_{cover} + clear_{cover} = 9.75\ in$$

Horizontal Reinforcement: #5 bar at each face, 9" o.c.
Vertical Reinforcement: #5 bar at each face, 15" o.c.

Required bars to cut:

Horizontal: 1 bar, due to 9" o.c. rebar spacing and 9.75" diam penetration

Horizontal: bars are only for temp and shrinkage cracking, cutting one bar is not any issue

Vertical: 0 bars. Rebar is spaced 15" o.c. and the penetration is 9.75".
Vertical: zero bars cut, penetration is no issue

Vertical bars spaced every 15" o.c. on both faces (only tension face rebar feels the flexure):

$$\#_{vert.face} := \frac{L_{slot}}{15\ in} = 3.067$$ (therefore, 4 bars each face are required)

$$\#_{vert.total} := 2 \cdot \frac{L_{slot}}{15\ in} = 6.133$$ (therefore, 8 bars required because 4 bars each face)

Horizontal bars/ties spaced every 9" o.c.:

$$\#_{horiz} := 2 \cdot \frac{H_{slot}}{9\ in} = 48$$ (therefore, 24 horizontal bars are required.)

Dowels spaced every 9" vertically:

$$\#_{dowels} := 2 \cdot \frac{H_{slot}}{9\ in} = 48$$ (therefore, 48 dowels (24 each wall) are required.)

Embedment depth into existing slot base and slot walls: ACI 9.7.3.8.4 #5 bar: $d_b := 0.625\ in$

$$Embedment_{depth} := \max\left(d, 12 \cdot d_b, \frac{H_{slot}}{16}\right) = 36.8\ in$$

$$Embedment_{min} := 18\ in$$

LPS Intake, SL-30 Slot
Fill slot with concrete vs steel bulkheads
6/21/22

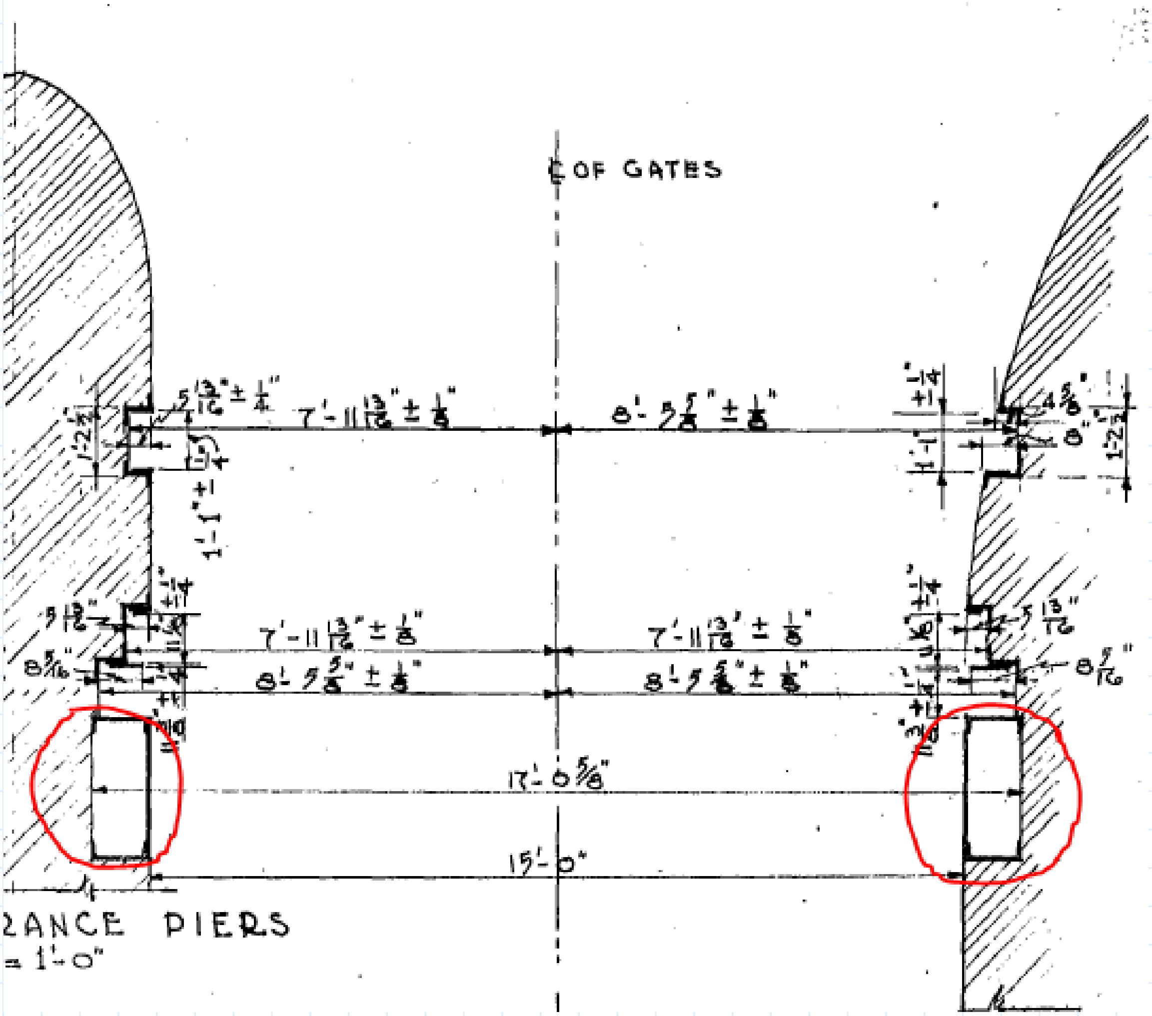
Chose Embedment: $24\ in$

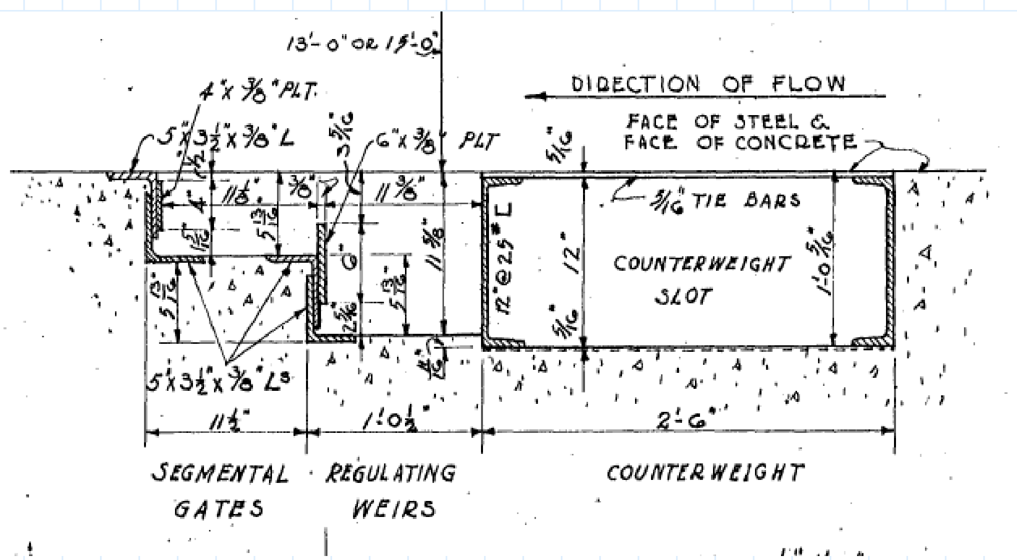
Looking downstream, left, SL-30 slot condition

Looking downstream,Right, SL-30 slot condition

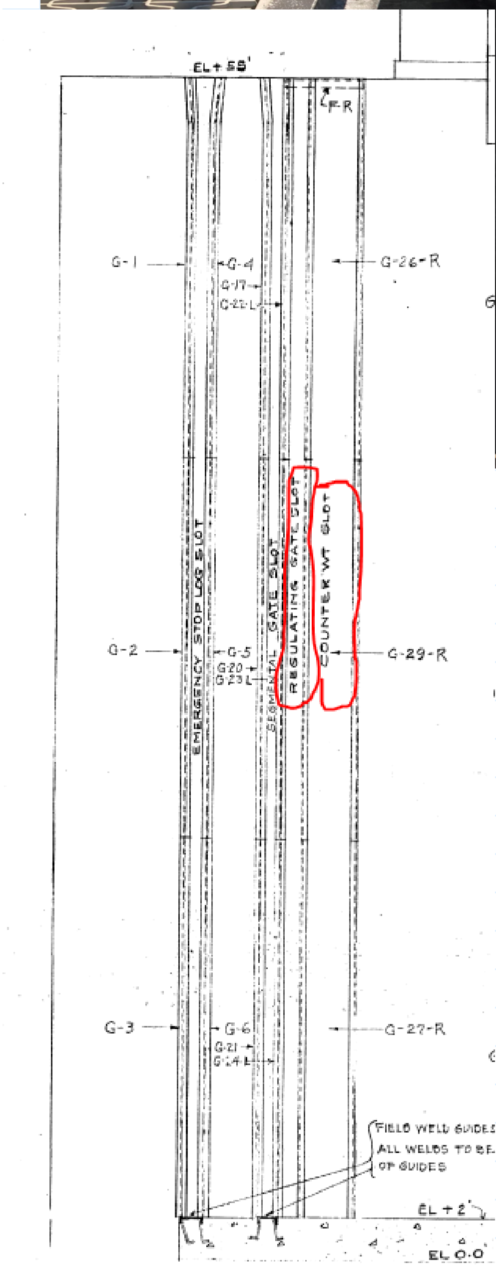
Bonneville FY 19 Lamprey Collection
Counterweight Slot Inserts
Collin Porter

Issue: Counterweight slot must be filled to ease lamprey access in the ladder





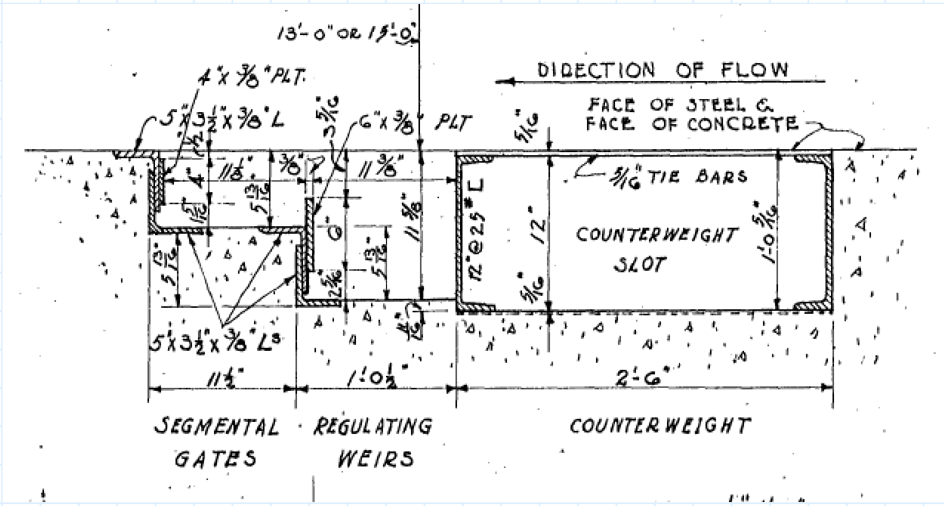
Bonneville FY 19 Lamprey Collection
Counterweight Slot Inserts
Collin Porter



Possible Fixes:

2. Weld, or attach a plate over the opening. The plate could be on the inside of the straps or the outside depending on what the fishery bios say is necessary. The plate should not be watertight and have gaps to allow water in/out, but prevent fish or lamprey from getting in.

Prefered option: #2 use plate and weld to inside of slot. should be the most effective and cheapest.



Dimensions:

Height: slot fillers are 38' high (elev 2' to elev 40'), determine if we want slot fillers to actually go this high

Width counterweight slot: must be less than 2'-6", channels have a .387" web thickness

$$W_{counterweightslot} := 2\ ft + 6\ in$$

$$h_{plate} := 38\ ft$$

Width of plate: leave 1.5" on each end for welding.

$$W_{plate} := W_{counterweightslot} - (1.5\ in \cdot 2) = 2.25\ ft$$

Thickness: wont face much load with openings (not water tight)
= 1/8"

Splices? 38/8 splices = $h_{splice} := 4.75\ ft$

$$weightofsteel := 490\ \frac{lbf}{ft^3}$$

$$t_{plate} := \frac{3}{8}\ in$$

$$Weight_{total} := h_{plate} \cdot W_{plate} \cdot t_{plate} \cdot weightofsteel = 1.309\ kip$$

Weld: Min size: 3/16" fillet weld, both sides all the way up. (AISC J2.4)

Gaps between plates: Place plates 1/4" offset from each other and off the ground to allow flow between channel and inside counterwieght slot.

Loading:

1. Gaps in plating allow flow to pass between slot and channel, leaving zero hydrostatic head on the plate
2. Check for impact load or if someone pushes on plate during construction

Check plate: Assume a point load of 100lb on center of plate when welded to slot $P := 100\ lbf$

Factored Live load (1.4) of 100 lbf: $P_{max} := 1.4 \cdot 100\ lbf = 140\ lbf$

The Plate is 2'-3" wide, the span is: $L_{span} := 2\ ft + 2\ in$

$$M_u := \frac{P \cdot L_{span}}{4} = 0.054\ kip \cdot ft$$

$$V_u := \frac{P}{2} = 50\ lbf$$

$E := 29000\ ksi$

Bending AISC F11: plate bending on minor axis $F_y := 36\ ksi$ $\phi := 0.9$

Yielding: F11-1

$$S := \frac{h_{splice} \cdot t_{plate}^2}{6} = 1.336\ in^3 \qquad Z := \frac{h_{splice} \cdot t_{plate}^2}{4} = 2.004\ in^3$$

$$\phi M_n := \phi \cdot F_y \cdot Z = 5.411\ kip \cdot ft$$

$$\phi M_p := \phi \cdot 1.6 \cdot F_y \cdot S = 5.771\ kip \cdot ft$$

Lateral Torsional Buckling:

$$\frac{0.08 \cdot E}{F_y} = 64.444 \quad < \quad \frac{L_{span} \cdot h_{splice}}{t_{plate}^2} = 10538.667 \quad < \quad \frac{1.9 \cdot E}{F_y} = 1530.556$$

the statement above is untrue, so use EQ F11-3 and F11-4 for LTB

$C_b := 1$
$C_{v2} := 1$

$$F_{cr} := \frac{1.9 \cdot E \cdot C_b}{\frac{L_{span} \cdot h_{splice}}{t_{plate}^2}}$$

$$\phi M_n := \phi \cdot F_{cr} \cdot S = 0.524\ kip \cdot ft$$

Check controlling flexure: $\phi M_n > M_u = 1$

Bonneville FY 19 Lamprey Collection
Counterweight Slot Inserts
Collin Porter

Shear AISC G4-1:

$A_w := h_{splice} \cdot t_{plate} = 21.375\ in^2$

$\phi V_n := \phi \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 415530\ lbf$

$\phi V_n > V_u = 1$

Deflection: L/120:

$I := \frac{h_{splice} \cdot t_{plate}^3}{12} = 0.25\ in^4$

$\Delta_{allowable} := \frac{L_{span}}{120} = 0.217\ in$

$\Delta_{max} := \frac{P_{max} \cdot L_{span}^3}{48 \cdot E \cdot I} = 0.007\ in$

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

APPENDIX B- HYDRAULIC DESIGN CALCULATIONS

Item 1: Bonn1 LPS Flow, Pipe and Valve Size Requirements

Purposes:

- Estimate current and future flow requirements,
- Size pipe for future flow requirements.,
- Size valve for control of initial design flow requirements

Bonneville B Branch LPS Flow Requirements & Supply Pipe Sizing

Determine initial and ultimate water supply requirements

Size Pipe for ultimate, Control valves for initial flow requirements

		Date
Prepared by	SJS	10/19/2021
Checked by	CSM	11/1/2021

References:

Bonneville Power Navigation Project USACE, Portland District (1935). Updated 1955.
Bradford Island Abutment and Fishway Structures As-Builts, M-12 and M-8 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 =	**22**	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 =	7.27	gpm/in	& covers holding tank requirements

Required flumes in Junction Pool Channels:

	Number	width	
Entrance Bay (south):	**1**	**22**	inch
Lower Ladder Channel:	**1**	**22**	inch
Other possible	**1**	**22**	inch
Total LPS widths =		66	inches

Total Ultimate Flow requirement = 480 gpm = 1.07 cfs

Elevations (ft NGVD 29):	Minimum	Normal	Maximum	
Fb = Forebay Elevation:	**70**	**74**	**77**	
Deduct potential screen & intake loss (ft)=	**1**	**0.5**	**0**	
Zh = Supply Elevation Head =	69	73.5	77	
Approx. Elevation at Collection Box	**56**	**55**	**55**	Bradford Is. as-builts M-8, Sheet 23
Yb = Height of collection box (ft) =	**5**	**5**	**5**	
Ha = Available head (ft) =	8	13.5	17	

	Label	Number	K	
Intake	Ki	**1**	**0.5**	
Open valves		**2**	**0.4**	Miller Fig.
Elbows	Kb			
90	Kb	**5**	**0.22**	HDC Chart 228-1
45	Kb	**5**	**0.16**	HDC Chart 228-1
exit	Ke	**1**	**1**	
sum K	Σ K =		4.2	

Length of Pipe ≈	**350**	feet			
Ks = pipe roughness =	**0.001**	feet =	0.012	inches	HDC 224-1
ν = H_2O Kinematic viscosity =	1.41E-05	ft^2/s			

Prefer valve openings between 20 - 70 degrees for control

Kv -Valve loss coefficients

	20 deg.	45 deg.	70 deg.	
Butterfly valve	105	10	1.5	Miller fig. 14.19
Ball Valve	100	10	1.5	Miller fig. 14.17

Butterfly Kv	Butterfly Vo degrees	Miller fig. 14.19 (Valve Opening)
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)

	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)	20.8	12.1	7.7	5.3	3.1	
	ID/Ks	256	336	421	505	665	
	RE	3.8E+05	2.9E+05	2.3E+05	1.9E+05	1.5E+05	
	f	0.028	0.026	0.025	0.023	0.022	HD 224-1/1 Von Karman Prandtl Eqtn.
	fL/ID	0.268	0.189	0.142	0.112	0.079	
	ΣK	4.2	4.2	4.2	4.2	4.2	
Headloss	HL	30.1	10.0	4.0	1.9	0.6	$HL = (fL/D + \Sigma K) * V^2/2g$

VON KARMAN-PRANDTL

$$\frac{1}{\sqrt{f}} = 2 \log \frac{D}{2K_s} + 1.74$$

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

	3	4	5	6	8	
Hva	-22.1	-2.0	4.0	6.1	7.4	Hva = Ha(min) - HL

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

Butterfly valve °	3	4	5	6	8
20	707.5	238.6	96.6	46.3	15.5
45	67.4	22.7	9.2	4.4	1.5
70	10.1	3.4	1.4	0.7	0.2

	3	4	5	6	8	
Required Kv	-3.3	-0.9	4.4	13.8	50.1	Req. Kv = Hva/(V^2/2g)
Est. valve Opening	0	0	56	42	28	Vo = f(Req. Kv) in degrees
Valve % opening	0%	0%	62%	46%	31%	Vo in % opening

USE 6 inch pipe More available pipe size

<u>Check on Valve's operability at Initial Flow for 1 LPS. Use maximum available head:</u>

LPS number = 1

Initial LPS Q = 160 gpm = 0.36 cfs

Neglect headloss in 6" pipe

Maximum available head (Ha(max)) = 17 feet

Nominal Size	3	4	5	6	8	
Velocity (ft/s)	6.9	4.0	2.6	1.8	1.0	
Remaining available head for valve control						
Hva (ft)	17.0	17.0	17.0	17.0	17.0	feet
Required Kv	22.7	67.3	166.3	346.8	1039.8	
Est. valve Opening	36	25	17	13	8	degrees
Valve % opening	40%	27%	19%	15%	9%	

USE 4 inch INITIAL Control Valve