US Army Corps of Engineers®
Portland District

DESIGN DOCUMENTATION REPORT NO. 54

BONNEVILLE DAM SECOND POWERHOUSE
WASHINGTON SHORE FISH LADDER
COLUMBIA RIVER, WASHINGTON

BONNEVILLE WASHINGTON SHORE FISH LADDER CONTROL SECTION MODIFICATIONS FOR IMPROVED FISH PASSAGE

90% Plans and Specifications
October 2023

EXECUTIVE SUMMARY

1. INTRODUCTION

Over twenty years of Pacific Lamprey focused studies have identified the flow control sections at Bonneville Dam as a passage bottleneck for Pacific Lamprey. For some lampreys it causes passage delay, for others, it stops them completely. This DDR describes modifications to the Bonneville Washington shore fish ladder control section that will improve conditions for lamprey passage as well as reduce passage times for adult salmonids.

2. PURPOSE

The purpose of the Bonneville 2nd Powerhouse (PH2) Washington Shore Fish Ladder Control Section modifications is to improve upstream passage success for Pacific Lampreys and reduce passage delay for adult salmonids. The modifications are also likely to reduce stress and passage delay for five adult salmon species, steelhead, and bull trout. The work is being completed as a component of the preferred alternative identified in the Columbia River System Operations (CRSO) Environmental Impact Statement (EIS) and the 2020 Columbia Basin Fish Accords. The EIS specifies that the existing serpentine control section will be replaced with a vertical slot and orifice control section, similar to those in use at Ice Harbor and John Day dams.

3. PROJECT LOCATION

The project is located at the Bonneville Dam PH2 Washington shore fish ladder control section. Bonneville Dam is located at river mile 146 of the Columbia River (146 miles upstream of the Pacific Ocean) and is the downstream-most dam on the Columbia River mainstem.

4. DESCRIPTION OF FACILITY

The Washington shore fish ladder control section has three primary components: the counting station, the control section, and the make-up water supply channel. The control section consists of 17 pools separated by a labyrinth system of baffles and vertical slot openings. Additional flow may be supplied to the top of the ladder via the make-up water supply channel in order to maintain a constant 1-foot head differential. The head differential is the difference in water surface elevation between two consecutive pools in a fish ladder and the National Marine Fisheries Service (NMFS) criteria for anadromous salmonids specify that the head differential be 1 foot or less. Flow may pass between the control section and the make-up water supply channel through a series of five bleed-off and two add-in diffusers. Flow exchange between the two channels is gravity driven (no active control feature or mechanism).

The modifications described in this DDR will replace the existing serpentine control section with a vertical slot and orifice control section. Seventeen of the eighteen existing baffles will be demolished and replaced with nine baffle pairs, each with a vertical slot and two orifices; a large orifice to allow passage by salmon or lamprey and a small orifice that will only allow passage by lampreys. Lamprey refuge boxes will be provided approximately in line with the lamprey orifices. Passive Integrated Transponder (PIT) tag antennas will be installed in the slots and both orifices of four of the baffle pairs. All of the slots and orifices will be flush with the ladder floor and the slot and large orifice edges will be rounded, except in locations that PIT tag antennas are to be installed. The S-curve section that connects the count station to the control section will be modified to reduce the transit length and degree of redirection. A 1-foot-tall steel strip will be added to the bottom of the two add-in diffusers to provide a smooth surface for lamprey on the lower wall of the south side of the control channel, and the orifice plate for the add-in diffuser 1 (the upstream add-in diffuser) will be reduced in size to match the other add-in diffuser.

5. CONSTRUCTION ACCESS

The fish ladder has good access and 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 twenty, a crane, a forklift, and about 4,200 square feet of staging area to accommodate demolished baffles, concrete forms, and reinforcing.

6. CONSTRUCTION SCHEDULE

The construction contract is expected to take 12 months. The contractor will expect to have access to the fish ladder for 82 calendar days from December 6th through February 25th. A potential work schedule calculated that the contractor would need approximately 74 workdays to complete the scope of work. To complete construction within the ladder dewatering period, the contractor will need to work 7x10 hour days per week or work two shifts per day. Weather or schedule delays could easily result in the work extending beyond the standard dewatering period. The scope of work acts as a complete system, and it isn’t feasible to break off any major feature of work to be completed in the next ladder dewatering period. The PDT should continue to discuss the outage period and potentially request an extension to the outage to give the contractor more time for completion of work.

The contractor will need at least three months prior to the ladder dewatering period for submittals and material procurement. Fabrication and preparation on this job is critical to allow for a successful execution during the ladder dewatering period. The project cannot afford delays during the design phase.

8. COST

At the 90% DDR phase (June 2023) the total project cost (design and construction) for is estimated to be $6.95 million. As noted in Section 6.3, BPA is responsible for providing the antennas and all associated electronics; therefore, these costs are excluded from the total project cost estimate. The construction cost and design/management costs for the preferred alternative are estimated to be $4.5 million and $2.45 million respectively. These values include an average 30 percent contingency and an average 6.3 percent escalation.

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APPENDICES

PERTINENT DATA
BONNEVILLE DAM

DRAINAGE AREA, SQUARE MILES	240,000
POOL ELEVATIONS	
Maximum spillway design operating pool	82.5 feet
Maximum regulated pool	77 feet
Normal operating pool range	71.5 feet to 76.5 feet
Minimum pool	70 feet
Normal high tailwater	40 feet
Normal low tailwater	7 feet
FIRST POWERHOUSE	
Type of turbines	Kaplan adj. blade propeller type
Turbine capacity	Two 66,000 hp at 50 feet head
	Eight 74,000 hp at 60 feet head
Total capacity	518.4 MW at 0.9 power factor
SECOND POWERHOUSE	
Length (including erection bay & service bay)	985.5 feet
Width (U/S face of intake to D/S face of draft tube)	221.25 feet
Number of hydro-generating units	
Main units	Eight 70,000 kva
Fish turbine units	Two 13,800 kva
Type of turbines	Kaplan type
Turbine capacity	
Main units	Eight 105,000 hp at 52 feet head
Fish turbine units	Two 20,700 hp at 59 feet head
Total rated capacity	558 MW
Discharge/turbine at rated head and full gate output	
Main units	20,000 cfs
Fish turbine units	3,400 cfs
SPILLWAY	
Type	Concrete gravity, gate controlled
Length (overall)	1,450 feet
Gates	18 – 50-foot-wide sliding, riveted structural steel
Crest elevation	24 feet
Deck elevation	97 feet
Design discharge	1,600,000 cfs

PREVIOUS AND PLANNED REPORTS

Number	Title	Date
1	Design memorandum No. 1 - Miscellaneous Modifications Peaking (Revised)	Sep-71
	Supplement No. 1, Miscellaneous Modifications	Aug-72
	Supplement No. 2, Highways and Railroads	Nov-70
	Supplement No. 3, Protective Works, Upstream	Mar-73
	Supplement No. 4, Little White Salmon Hatchery Modification	Nov-73
	Supplement No. 5, Downstream Bank Protection	Jan-71
	Supplement No. 6, Oregon Shore Slide Study	Jul-71
	Supplement No. 7, Collins Point Slide Study	Aug-71
	Supplement No. 9, In-Lieu Indian Fishing Sites	Jul-73
	Supplement No. 11, Rooster Rock State Park	Dec-72
1B	Design Memorandum No. 1B - Master Plan	Feb-64
	Supplement No. 1, Project Visitor Facilities (Revised 1974)	Oct-77
	Supplement No. 1 to the Master Plan	Dec-69
	Design Memorandum No. 1B, Master Plan (Revised)	Dec-74
2	Design Memorandum No. 2, Second Powerhouse Site Selection and Hydropower Capacity	Dec-68
	Design Memorandum No. 2, Real Estate - Supplement Recreation Lands, Tanner Creek	Apr-66
3	Design Memorandum No. 3, Real Estate - Modification for Peaking	May-70
	Design Memorandum No. 3, Real Estate - Supplement Recreation Lands, Home Valley	May-68
4	Design Memorandum No. 4, General Design, Second Powerhouse	Aug-72
	Supplement No. 1, Recreation Resource Appendix	Aug-72
	Supplement No. 2, North Bonneville Townsite Selection	Aug-74
	Supplement No. 3, Turbine Study	Aug-74
5	Design Memorandum No. 5, Fish Hatchery Future Modifications	
6	Design Memorandum No. 6, Project Development	Aug-73
7	Design Memorandum No. 7, Relocation of Transportation Facilities	Aug-72
	Supplement No. 1, Washington State route No. 14	Aug-75
	Supplement No. 2, Railroad Relocation	Oct-75
	Supplement No. 2, Letter Report No. 1	Oct-77
	Supplement No. 3, Railroad Bridges	Oct-76
	Supplement No. 4, Railroad Tunnel	Oct-76

Number	Title	Date
	Supplement No. 5, Hamilton Creek Bridge	Oct-76
8	Design Memorandum No. 8, Volume I, Relocation of Town of North Bonneville - School Facilities (Two - Volume Set)	Oct-75
	Design Memorandum No. 8, Volume II, Relocation of Town of North	
	Bonneville - School Facilities (Two - Volume Set)	Oct-75
	Supplement No. 1, Detailed Design	Oct-73
	Bonn Project Fish Monitoring Facility	June
9	Design Memorandum No. 9, Fish Facilities 2nd Powerhouse	Apr-74
	Letter Supplement No. 1, Railroad Relocation	Apr-75
	Letter Supplement No. 1, Railroad Relocation (Revised)	Apr-77
	Supplement No. 1, Fish Facilities Details	Apr-75
	Supplement No. 2, Bonneville Second Powerhouse, upstream Migrant Fish Facility, Upstream of Fish Ladder Weir No. 37	Jul-77
	Supplement No. 3, Bonneville Second Powerhouse, upstream Migrant Fish Facility, Upstream of Fish Ladder Weir No. 38	Jul-77
	Supplement No. 4, Bonneville Second Powerhouse, upstream Migrant Fish Facility, Upstream of Fish Ladder Weir No. 39	Jul-77
	Supplement No. 5, Second Powerhouse Fish Facilities	Sep-80
	Supplement No. 6, Downstream Migrant System 2nd Powerhouse	Dec-95
	Supplement No. 7, 2nd Powerhouse Juvenile Bypass Outfall	Apr-96
	Supplement No. 8, 2PH Juvenile Fish Monitoring Facility	Feb-97
10	Design Memorandum No. 10, Real Estate - Second Powerhouse	Dec-73
11	Design Memorandum No. 11, Powerhouse Preliminary Design Report	Dec-73
	Supplement No. 1, Preliminary Design Report No. 11	Dec-73
12	Design Memorandum No. 12, Architectural Design	Sep-77
	Supplement No. 1, Powerhouse Roof Repair	Nov-86
13	Design Memorandum No. 13, Powerhouse Structural	Nov-77
14	Design Memorandum No. 14, Powerhouse Mechanical	Nov-74
15	Design Memorandum No. 15, Cofferdam and Seepage Control	Nov-75
	Supplement No. 2, Cofferdam and Seepage Control	May-76
	Supplement No. 1, Cofferdam and Seepage Control	Jul-76
16	Design Memorandum No. 16, Powerhouse Model Study Report	Jul-75

Number	Title	Date
17	Design Memorandum No. 17, Geology, Excavation and Foundation Treatment	Oct-76
	Supplement No. 1, Geology, Excavation and Foundation Treatment	Jun-77
	Supplement No. 2, Geology, Excavation and Foundation Treatment	Aug-78
	Supplement No. 3, Geology, Excavation and Foundation Treatment	Apr-81
18	Design Memorandum No. 18, Concrete Materials Investigations	Aug-77
	Supplement No. 1, Concrete Temperature Investigations	Aug-77
20	Design Memorandum No. 20, Project Water Sewage	Jun-77
22	Design Memorandum No. 22, Downstream Landscaping and Visitor Facility	Sep-81
23	Design Memorandum No. 23, Buildings and Grounds	Sep-77
	Supplement No. 1, Service Building	Sep-83
	Supplement No. 2, (Unpublished)	Mar-83
25	Design Memorandum No. 25, Ice and Trash Handling System	Apr-76
	Design Memorandum No. 25A, Trash Handling System	Jan-84
26	Design Memorandum No. 26, Intake and Tailrace Channels	Jun-77
27	Design Memorandum No. 27, Home Valley Park	Aug-73
	Design Memorandum No. 27, Home Valley Park (Revised)	Jan-74
	Supplement No. 1	Aug-85
28	Design Memorandum No. 28, Relocation of Public Utility District No. 1 of Skamania County Power Facility	Nov-75
29	Design Memorandum No. 29, Relocation of Telephone Facilities	Dec-75
30	Design Memorandum No. 30, Relocation of Natural Gas Facilities	Sep-75
31	Design Memorandum No. 31, Instrumentation, Inspection, and Evaluation	Jan-78
	Supplement No. 1	Apr-80
32	Design Memorandum No. 32, Water-up Plan	Apr-80
33	Design Memorandum No. 33, Project Interpretive Program	Oct-80
34	Design Memorandum No. 34, Fish Attraction Power Units	Dec-80
35	Design Memorandum No. 35, Upstream Migrant Collection System Justification	Sep-80
36	Design Memorandum No. 36, Units 1 and 2 Upgrading	Nov-81
37	Design Memorandum No. 37, Bonneville First Powerhouse Juvenile Bypass System	Jun-82
	Design Memorandum No. 37, Bonn 1st Powerhouse Juvenile Bypass System Supplement No. 1	Not Distributed

Number	Title	Date
	DDR No. 37, Bonn 1st Powerhouse JBS Improvement Supplement 2	Nov-97
	Supplement 3	
38	Design Memorandum No. 38, Earthquake Fault Study	Oct-82
39	Design Memorandum No. 39, Service Facilities, Letter Supplement No. 1	Aug-83
40	Letter Report No. 40, Intake Gate Hydraulic Cylinder Repair and System Flushing	
41	Design Memorandum No. 41, Steigerwald Lake Wildlife Mitigation Development	Dec-96
42	Design Memorandum No. 42, Fish Guidance Efficiency Improvements	Mar-92
43	Design Memorandum No. 43, Bonneville 2nd PH JBS Fish Monitoring Facility (Draft Only)	Not Distributed
44	Facility-CANCELLED	
45	Bonn 2nd Powerhouse Gatewell Debris Removal System DN (Ron Wridge)	Oct-96
46	Bonneville Spillway Flow Deflectors and Gate Hoists	May-01
47	Bonneville 2PH Corner Collector Suriace Bypass System	Mar-02
48	Second Powerhouse Physical Guidance Device	Aug-98
49	B1 JBS Bridge River Crossing Structure Plans & Specs	Jun-99
50	Bonneville Decision Document Juvenile Fish Passage Recommendation	Dec-02
51	Spillway Rehabilitation Spillway Gate Repair and Storage Pits Design Alternative Analysis Report	Mar-09
52	Bonneville Spillway Gate Repair Pit Rehab (P2#445533)	Oct-14
53	Bonneville Spillway North Viaduct Bridge Repair/Replacement	TBD

ACRONYMS

Acronym	Description
AWS	Auxiliary Water Supply
BMP	Best Management Practice
PH2	Bonneville Second Powerhouse
BPA	Bonneville Power Administration
CFD	Computational Fluid Dynamics
cfs	Cubic Feet per Second
CRFM	Columbia River Fish Mitigation
CRITFIC	Columbia River Intertribal Fish Commission
CRSO	Columbia River System Operations
CSWGP	Construction Stormwater General Permit
CTLWG	Corps-Tribal Lamprey Work Group
DDR	Design Documentation Report
EDF	Energy Dissipation Factor
EDR	Engineering Design Report
EIS	Environmental Impact Statement
EL	Elevation
EM	Engineer Manual
FCRPS	Federal Columbia River Power System
FFDRWG	Fish Facility Design Review Work Group
FRP	Fiber Reinforced Polymer
FY	Fiscal Year
JDAN	John Day North
kcfs	Thousand Cubic Feet per Second
LPS	Lamprey Passage Structure
MOA	Memorandum of Agreement
NMFS	National Marine Fisheries Service
P&S	Plans and Specifications
pcf	Pounds per Cubic Inch
PDT	Product Development Team
PDT	Project Delivery Team
PIT	Passive Integrated Transponder
PLC	Programmable Logic Controller
psf	Pounds per Square Foot
PSMFC	Pacific States Marine Fisheries Commission
RM&E	Research, Monitoring and Evaluation
SWPPP	Stormwater Pollution Prevention Plan
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation

SECTION 1 - PURPOSE AND INTRODUCTION

1.1 PROJECT PURPOSE AND SCOPE

1.1.1 Project Purpose

Pacific Lampreys are culturally and ecologically significant in the Columbia River Basin. Historically, Pacific Lampreys provided an important source of food for the tribes of the Columbia River Basin and were served alongside salmon at tribal feasts and celebrations (CRITFC, 2022). Ecologically, Pacific Lampreys serve as both predator and prey, and as an anadromous species they transport nutrients from the ocean to the freshwater environment (CRITFC, 2022).

The serpentine style control sections present at both Bonneville Dam fishways are known lamprey turn around areas. Improvements to the Washington shore flow control section will increase the number of lampreys that are able to progress further into the Columbia River basin. In a broad study of lamprey passage bottlenecks at Corps dams, Keefer et al. (2014) found that the best way to increase the number of lampreys in the upper watershed was to increase passage efficiency in the upper sections of the fish ladders, specifically the serpentine style flow control sections at Bonneville Dam.

The primary purpose of the Bonneville 2nd Powerhouse (PH2) Washington Shore Fish Ladder Control Section modifications is to improve upstream passage success for Pacific Lampreys. The modifications are also likely to reduce stress and delay for adult salmon, steelhead, and bull trout. Due to problems with salmon passage, the serpentine control sections have already been replaced at John Day Dam's north and south fish ladders.

The work is being completed as a component of the preferred alternative identified in the Columbia River System Operations (CRSO) Environmental Impact Statement (EIS). Section 7.5.2.17 of the EIS describes the measure as follows:

"Bonneville Ladder Serpentine Weir Modifications: …The Corps would modify the serpentine-style flow control sections of Bonneville Dam's Washington shore and Bradford Island fish ladders, converting them to an Ice Harbor-style vertical slot with submerged orifice configurations. This would improve passage conditions for adult lampreys and likely reduce stress and delay for adult salmon, steelhead, and bull trout. This action has the potential to increase adult salmon and steelhead survival by reducing upstream passage time at the dam."

The existing Washington shore control section is prioritized for modifications to improve lamprey passage because past studies have documented that there is considerable fallback at this location (Clabough et al. 2012; Keefer et al. 2013; Keefer et al. 2014; Clabough et al. 2015; Kirk et al. 2017; Clabough et al. 2020). These studies suggest that fallback is likely attributable to the following conditions:

- The extended length that the fish must travel due to the switch-backing nature of the serpentine control section.
- The repeated changes in swimming direction from upstream to downstream.
- The square corners at each baffle which impede attach and burst locomotion which lampreys rely on in difficult situations.
- The high velocity and turbulence associated with the serpentine slots which persist over relatively longer distances than at more traditional vertical slot baffles or orifices.

Over twenty years of Pacific Lamprey focused studies have identified the flow control section at Bonneville Dam as a passage bottleneck. For some lampreys it slows their migration, for others, it stops them completely. A typical lamprey will make five to nine attempts to pass the twisting serpentine section before giving up and falling back out of the fish ladder (Clabough et. al. 2012). Keefer et al. (2013) summarized the migration histories of 2,170 radio tagged lampreys and described the Bonneville flow control section behavior as " …turnarounds in high-elevation segments that often resulted in loss from the upstream population (i.e., no additional attempts)."

Initially, studies using radio-tagged lampreys showed that the count station slot, serpentine baffles, and exit channels of both Bonneville Dam fishways were common turn around points. Later studies increased the monitoring resolution and determined it was the serpentine sections, not the count station area or exit channels, that were the problem. Most recently, Keefer et al., 2014 found, "The highest benefits were for improvements at top-of-fishway segments and at sites where passage routes converged."

In particular, of tagged lampreys that passed the count windows, many turned around and did not pass the serpentine baffles (28-35% at Washington shore and Bradford Island combined). Overall passage efficiency at Bonneville Dam was 43-49% during these evaluations compared to 69-83% at John Day Dam that now uses the flow-control design proposed for Bonneville Dam (Clabough et al. 2015; Clabough et al. 2019; Clabough et al. 2020). These findings guide the decision to make improvements to the control (serpentine) section.

1.1.2 Project Scope

The scope of the work is limited to the Washington shore fish ladder control section and the S-curve section that connects the count station with the control section.

The Washington Shore Fish Ladder Control Section DDR:

- Is a record of design and the technical basis for plans and specifications (P&S).
- Provides the criteria and analytical methods used.
- Documents critical assumptions and key design decisions.
- Summarizes important calculation results and selected example calculations for all critical elements of the design.

A DDR is considered a living document and covers both the pre-construction engineering and design phase, and the construction phase of the project. The DDR will continue to be updated during the P&S phase and will be finalized after the construction phase is complete.

The Washington Shore Fish Ladder Control Section project did not include an Engineering Design Report (EDR) phase, which typically serves to evaluate alternatives and assess feasibility. The EIS specifies the general layout; however, the PDT and regional stakeholders wished to explore a few variations on the EIS-specified arrangement of a vertical slot and submerged orifice control section. In the interest of efficiency, a limited alternatives analysis was performed and is documented in Appendix C of this DDR.

1.2 PROJECT AUTHORIZATION

The Bonneville Project began with the National Recovery Act of 30 September 1933 and was formally authorized by Congress in the River and Harbor Act of 30 August 1935. Authority for completion, maintenance, and operations of Bonneville Dam was provided by Public Law 329, 75th Congress, 20 August 1937. This act provided authority for the construction of additional hydroelectric generation facilities when requested by the Administrator of Bonneville Power Administration (BPA). Letters dated 21 January 1965 and 2 February 1965 from the Administrator developed the need for construction of the PH2. Construction of PH2 started in 1974 and was completed in 1982.

Between 2008 and 2018, USACE addressed many adult, juvenile, and larval lamprey passage issues and Research, Monitoring and Evaluation (RM&E) needs at its Columbia and Snake River dams using Columbia River Fish Mitigation program (CRFM) funding consistent with commitments made through the 2008 Columbia Basin Fish Accords Memorandum of Agreement (MOA) between the three Treaty Tribes and Federal Columbia River Power System (FCRPS) Action Agencies. In 2018, an extension to the Columbia Basin Fish Accords MOA was negotiated and further extended in a 2020 MOA. The 2018/2020 Fish Accords extensions included a commitment by USACE to seek funding to finalize and implement a plan to continue to improve Pacific Lamprey passage conditions at USACE dams.

USACE coordinated with the Treaty Tribes and the Columbia River Intertribal Fish Commission (CRITFC) through the Corps-Tribal Lamprey Work Group (CTLWG) 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 Fish Accords extensions. When Work Plan funding was received in 2020, the prioritized list of actions developed by the CTLWG became the basis for Northwestern Division's Pacific Lamprey Passage Improvements Implementation Plan (Implementation Plan), finalized in May 2021. The Implementation Plan prescribes an action to re-design the control section (serpentine baffles) at the PH2 Washington shore fish ladder and assumes a cost share with non-Fish Accords CRFM funding (at least 50 percent of cost), beginning in either Fiscal Year (FY) 2022 or FY2023 and through construction, as this project is expected to have benefits for Endangered Species Act (ESA)-listed salmon and steelhead, as well as lampreys.

In September 2020, USACE signed a Record of Decision adopting the Preferred Alternative described in the Action Agencies' (BPA, US Bureau of Reclamation (USBR), USACE) Final EIS for the long-term coordinated operation and management of the Columbia River System Project. Several adult and juvenile lamprey passage improvement measures were considered in the EIS and integrated into the EIS's Selected Alternative, including Bonneville Dam fish ladder flow control sections modifications to improve passage conditions for adult lampreys and to reduce stress and delay for adult salmon, steelhead, and bull trout.

1.3 PROJECT DESCRIPTION

1.3.1 Project Datum

The original and proposed fish ladder control section designs are referenced to the Bonneville Dam project datum, which is NGVD 29.

1.3.2 Existing Washington Shore Fish Ladder Overview

The Washington shore fish ladder is located on the north (Washington) shore of the Columbia River, adjacent to PH2. Although the focus of this DDR is the control section, a brief description of the major features of the overall Washington shore fish ladder is provided for context. Figure 1-1 shows a series of aerial photos to illustrate where the control section is located within the larger context of Bonneville Dam and PH2. Figure 1-2 shows the overall fish facilities at Bonneville Dam with the major features labeled. Figure 1-3 and Figure 1-4 show the Washington shore fish facilities in a sketch and on a labeled aerial photo. Figure 1-5 shows the major control section features and adjacent components that are considered in the design of the control section modifications. Narrative descriptions of each major feature are provided in the subsections following these figures.

Figure 1-1. Area of Work

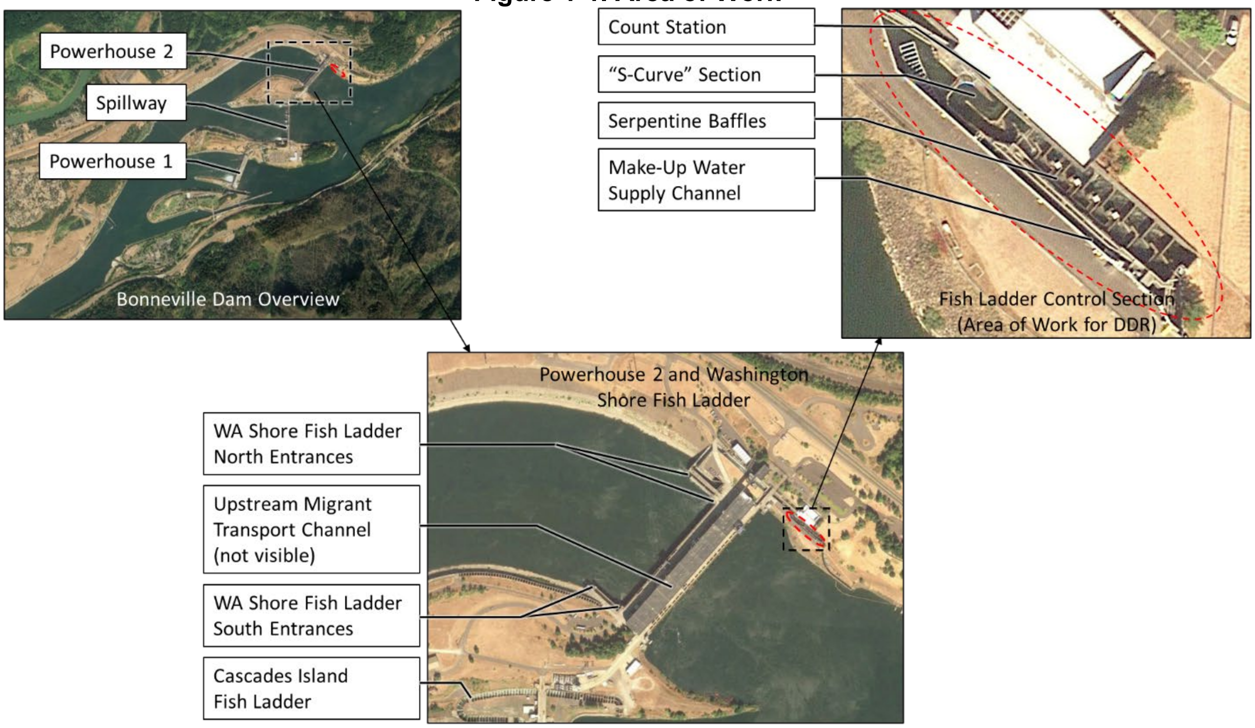
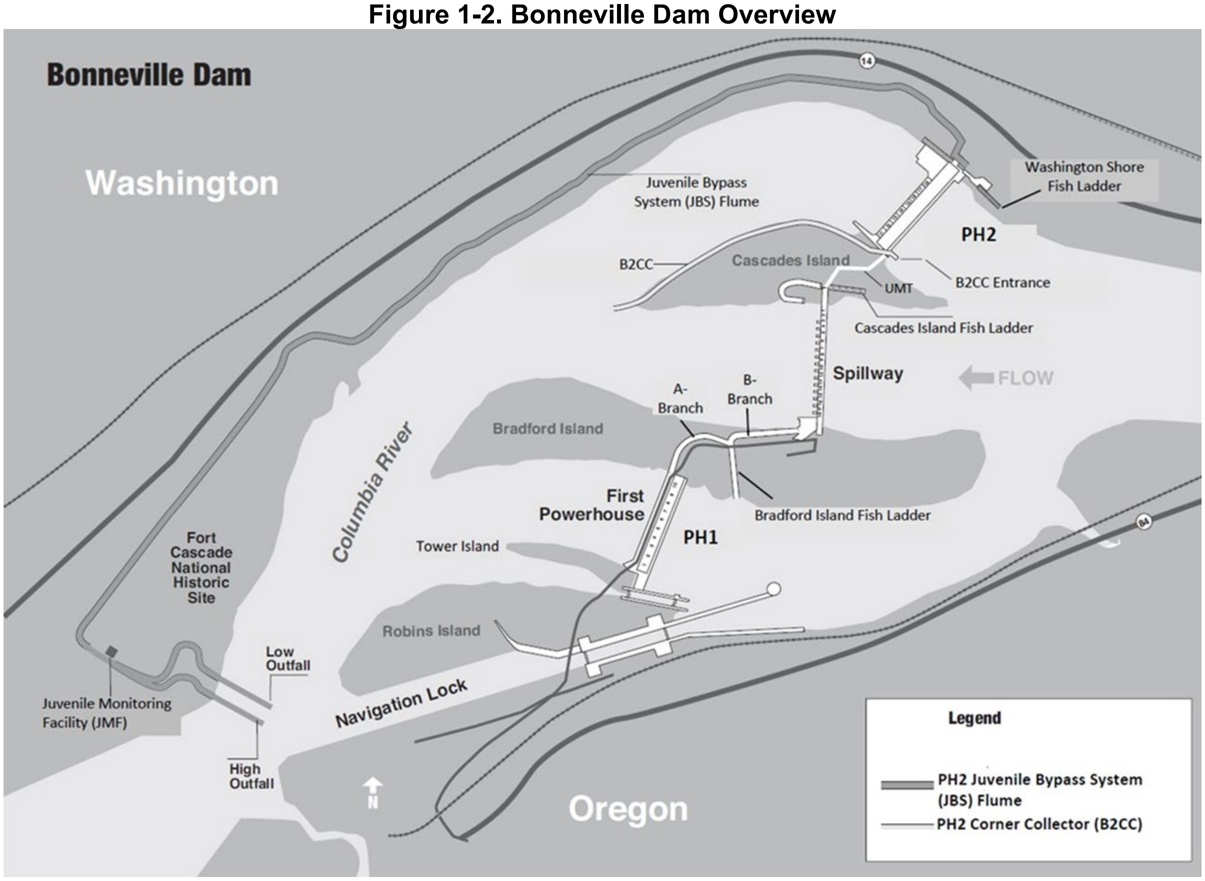


Figure 1-2. Bonneville Dam Overview



Note. Includes Powerhouse 1 (PH1), Powerhouse 2 (PH2), Spillway, Adult Fish Ladders, PH2 Juvenile Bypass System (JBS), Corner Collector (B2CC), Juvenile Monitoring Facility (JMF) and JBS Outfall.

Figure 1-3. Bonneville Dam Powerhouse 2 and Washington Shore Fish Ladder, Plan View

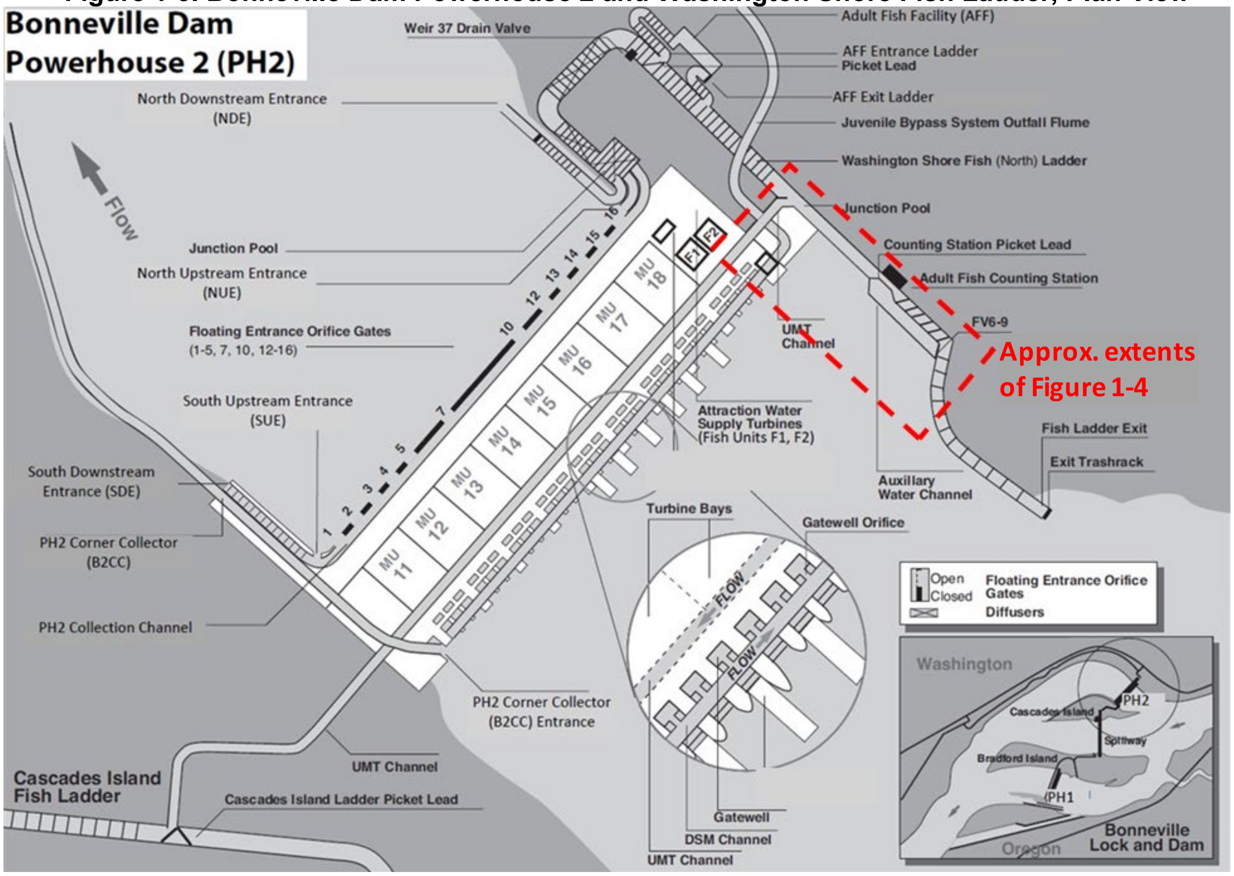


Figure 1-4. Bonneville Dam Powerhouse 2 and Washington Shore Fish Ladder, Aerial Overview

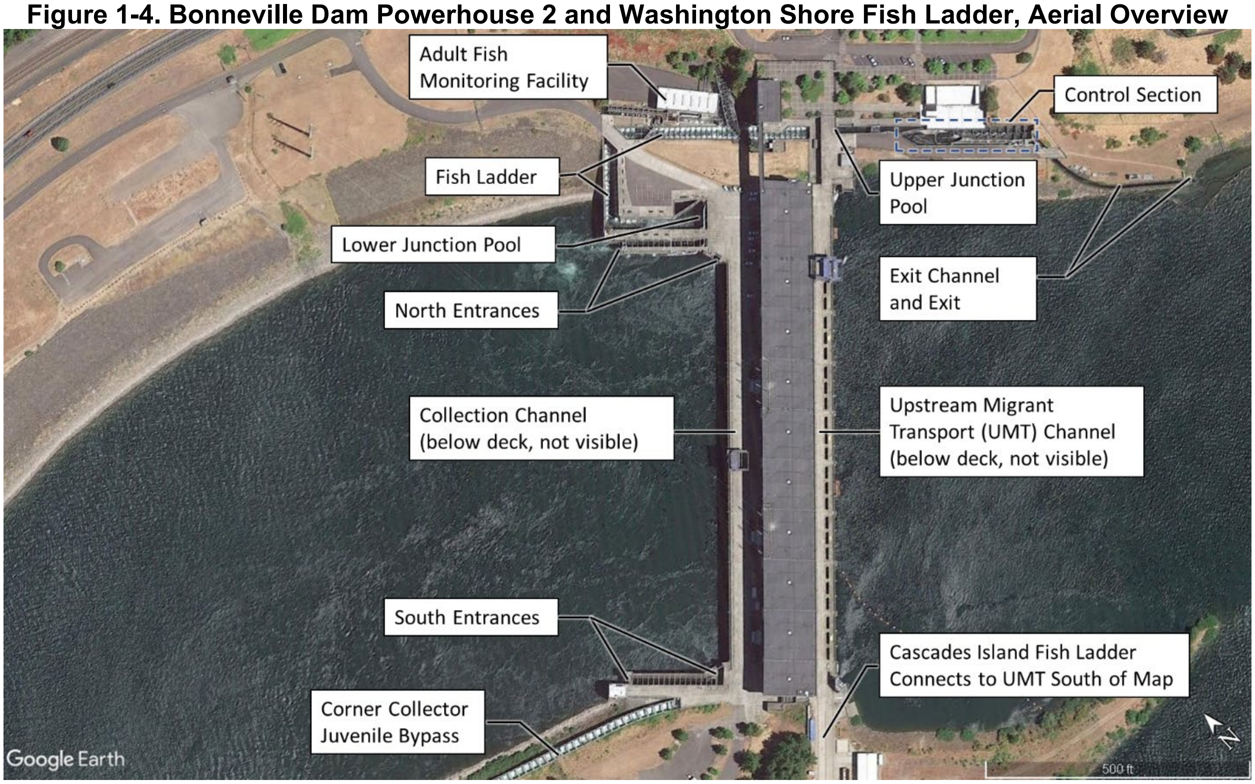
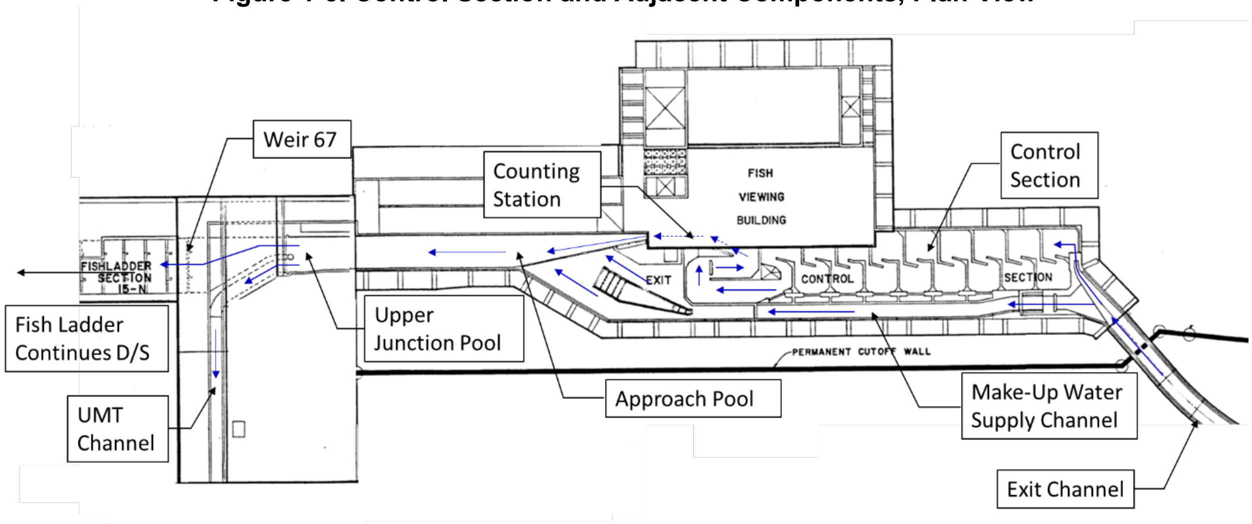


Figure 1-5. Control Section and Adjacent Components, Plan View



1.3.2.1 *Entrances*

The Washington shore fish ladder has four main entrances that provide fish with access to the ladder from the tailrace. There are two entrances on the south side of the powerhouse and two entrances on the north side of the powerhouse. Sea lion exclusion devices are installed in the entrances year-round. A collection channel spans the length of PH2 to connect the two junction pools that receive fish that enter through the main entrances. Floating orifice gates along the collection channel provide additional opportunities for lamprey and other fish to enter the fishway. The entrances connect to the fish ladder near the northwest corner of PH2. There is an additional fish ladder entrance on Cascades Island that connects to the Washington shore control section via an upstream migrant transport (UMT) channel.

1.3.2.2 *Fish Ladder*

The main Washington shore fish ladder is an Ice Harbor-style weir-and-orifice ladder that rises in one-foot increments from the tailrace to the forebay. The ladder is about 1,040 feet long and 24 feet wide, with a slope of 1 on 10. The weirs are numbered according to overflow crest elevation and start from Weir 8 at the bottom and rise to Weir 67 at the top. Each weir has 12 feet of overflow crest, 12 feet of non-overflow crest, and two 18-inch by 18-inch orifices, symmetrically located under the weirs.

The Cascades Island fish ladder is located on the south side of Cascades Island at the north end of the spillway. The Cascades Island fish ladder connects to the Washington shore fish ladder via the UMT and both ladders use the Washington shore exit. The ladder is approximately 1,312 feet long and 30 to 35 feet wide with a slope of 1 on 16. The overflow fish ladder section is made up of a series of overflow ladder weirs with 2-foot square orifices located on opposite sides of each weir. The weir crest elevations drop in one-foot increments from weir 66 to weir 8.

1.3.2.3 *Adult Fish Monitoring Facility*

An adult fish monitoring facility is located on the north side of the ladder between Weir 37 and Weir 50. During the summer research season, a series of picket leads are used to guide fish into the facility according to a timeline spelled out in the Fish Passage Plan (FPP). Upstream of the adult fish monitoring facility the ladder transitions to an approach channel to the control section.

1.3.2.4 *Upstream Migrant Transport Channel*

Upstream of Weir 67, the ladder channel merges with the upstream migrant transport channel (labeled UMT on Figure 1-2 and Figure 1-3) that connects the Cascades Island fishway to the Washington shore upper fish ladder. Both fishway systems share an exit on the north shore.

1.3.2.5 *Upper Junction Pool*

The upper junction pool is located at the top of the fish ladder, upstream of Weir 67 and downstream of the fish counting station and control section, as shown on Figure 1-5. The upstream migrant transport channel and Washington shore fish ladder merge at the upper junction pool. The water inflow from the control section is divided at the upper junction pool. Most of the flow (80 to 120 cfs) is sent down to the Washington shore fish ladder and the remainder (75 to 85 cfs) goes to the upstream migrant transport channel and Cascades Island fish ladder. At the junction pool, the channel to the Washington shore fish ladder is 8 feet wide and the upstream migrant channel is 5-feet, 8-inches wide.

1.3.2.6 *Control Section*

The control section is the combined passage route from the Washington Shore and Cascades Island fish ladders to the forebay. The control section serves to attenuate forebay fluctuations and deliver the necessary flow rate and water surface elevation to Weir 67 so that the fish ladder functions properly over the full forebay range. The control section includes the counting station, the flow control section, and the make-up water supply system. The control section is the primary focus of this DDR and is described in additional detail in Section 1.3.3.

1.3.2.7 *Exit Channel*

Upstream of the control section, a 380-foot-long channel runs eastwardly along the north side of the river to connect to the forebay.

1.3.2.8 *Lamprey Passage System (LPS)*

To improve adult Pacific Lampreys (Entosphenus tridentatus) upstream passage at Bonneville Dam, three alternative Lamprey Passage Systems (LPSs) and three lamprey traps were built to help them avoid dead ends, bypass bottlenecks, and ultimately increase passage. An LPS was installed in the Washington shore control section AWS channel in 2007 to provide an alternate path for lamprey to bypass the serpentine baffles. AWS picket leads are raised 1.5 inches from the fishway floor to allow lamprey passage to the LPS while excluding adult salmonids from the AWS channel. Lampreys exit the LPS into the fishway exit channel. An additional two ramps upstream of the UMT junction and downstream of the count station were added in 2017, connecting to the existing AWS system.

1.3.3 Existing Washington Shore Fish Ladder Exit Control Section

The Washington shore fish ladder exit control section has three primary components: the counting station, the control section, and the make-up water supply channel. Adult fish detection equipment was installed in the control section in 2005 and a lamprey passage structure (LPS) was installed in the make-up water supply channel in 2007. The general layout of the existing control section, including baffle numbering and local stationing for the control section are shown in plan view on Reference Drawings BDF-2-15/121, BDF-2-15/123, and BDF-2-15/125 in Appendix B.

1.3.3.1 *Counting Station*

The fish counting station includes an approach pool with a picket lead, counting slot, exit pool, counting slot bypass, crowder system, and counting room. The approach pool is upstream of Weir 67 and has a picket lead that both guides the fish towards the counting slot and passes make-up water from the make-up water supply channel. The picket lead (called approach pool lead on reference drawing BDF-2-15/144) has 2 inch long by ⅜ inch thick bars angled at 34 degrees and spaced 2½ inches on center. Lamprey are known to enter the make-up water supply channel, which is located upstream of the approach pool, thus the picket lead presumably does not exclude lamprey. A lamprey passage structure is in the make-up water supply channel, see Section 1.3.2.8.

The counting slot is a narrow section that runs adjacent to the counting room with a viewing window. The slot is 20 feet long and 3 feet wide. There is a mechanical crowder that can reduce the slot width to 18 inches to improve viewing when the water is turbid or to change velocities. Design velocities are 2 to 6 feet/second in the counting station slot (USACE, 2005).

Bypass leads are located upstream of the count station and have 3½ inch long by ⅜ inch thick bars angled at 18 degrees and spaced at 4 inches on center. See reference drawing BDF-2-15/144 for the layout and details of the approach pool, counting station and associated leads.

1.3.3.2 *Control Section*

The control section consists of 17 pools separated by a serpentine system of baffles and vertical slot openings as shown on reference drawing BDF-2-15/126. The control section goes from the exit pool (just upstream of the counting slot) to the exit channel to the forebay. The invert of the channel is constant at elevation (EL) 63 feet. The slot widths range from 1.83 feet at the upstream end to 3.75 feet at the downstream end.

The width of the most upstream and final slot is 2.26 feet. The final slot is equipped with an exit gate, which is typically dogged off above the water surface.

1.3.3.3 *Make-Up Water Supply Channel*

The make-up water supply channel augments the flow through the control section so that ladder head criteria are met at Weir 67. The make-up water supply channel runs adjacent to the west wall of the control section channel. A Tainter valve regulates the volume of make-up water that is supplied to maintain ladder head criteria as the forebay changes. The ladder head differential is typically maintained at 1.0 feet; however this is increased to 1.3 feet during the peak of shad passage, see Section 1.6.7 and Section 2.2. The Tainter valve is a 6-foot-wide radial gate with a radius of 5 feet 6 inches.

The fishway programmable logic controller (PLC) automatically adjusts the gate opening based on target ladder head (1.0 to 1.3 feet) and forebay elevation. As the forebay rises, the flow into the exit control section will increase and the Tainter valve must close to reduce flow into the make-up water channel and maintain the balance at Weir 67. For falling forebay levels, the flow into the control section will drop and the Tainter valve will open to maintain the target ladder head at Weir 67. In addition to the flow control Tainter valve, there is an upstream bulkhead that can be used to isolate the channel from the forebay and a downstream Tainter gate that can be used to backflush the make-up water supply channel. The bulkhead and backflush Tainter gate are rarely used.

Project staff have records of routine inspection and maintenance of the flow control Tainter valve and bulkhead, which are regularly used, inspected and maintained. Records are not available for the backflush Tainter valve which has not been used in operational memory and is not proposed for use as part of the control section modifications.

1.3.3.4 *Add-In and Bleed-Off Diffusers*

There are seven rectangular screened orifice openings in the south wall of the control section channel. The purpose of these openings is to exchange water between the control section and the adjacent make-up water channel. The upstream five orifices are “bleed-off” diffusers that typically remove excess water from the exit channel. The downstream two orifices are ‘add-in water’ orifices that allow flow from the make-up water channel to enter the control section. Regardless of the terminology, the diffusers are head-driven, and flow may pass in either direction based on the relative head in the make-up water supply channel and the control section channel.

1.3.3.5 *Lamprey Passage Structure and Lamprey Orifices*

An LPS was constructed during winter maintenance in 2006/2007 to provide a lamprey passage route from the make-up water supply channel to the forebay. The aluminum LPS extends from the make-up water supply channel to the exit channel just upstream of the of the ladder control section. The LPS has two collector ramps where lampreys enter the system, one on each side of the make-up water supply channel. Two pumps located upstream of the make-up water supply Tainter valve provide water to the LPS.

During the winter of 2016/17, the LPS mechanical and electrical systems were upgraded from research grade facilities to permanent facilities, two pumps were added, pump intake screens were added, and the counting system was improved.

During winter maintenance of 2020/21 the north AWS ramp was found damaged. A large hole had formed in the ramp below the waterline, presumably due to impact of high velocity water from Fish Valve 6-9 and faulty aluminum. This was repaired in February of 2021. Two years later, the same north AWS ramp came loose from its attachments and broke in numerous places. An emergency one-day flow reduction in the Washington shore fishway allowed crews to the remove the ramp altogether but leave the south ramp operational. A full rebuild of that ramp was completed over the winter of 2022/23, to include additional bracing and the addition of flow deflectors for both the north and south AWS ramps.

Small orifices (1.5-inches high by 16-inches wide) were cut near the bottom of Baffles 1, 3, and 5 to support lamprey passage prior to the 2018 passage season. After monitoring, orifices were cut in an additional 5 baffles for the 2019 passage season. Lamprey refuge boxes associated with these slots are also installed within the control section to provide a protected resting place and prevent fall back.

1.3.3.6 *Control Section Fish Detection*

PIT tags are small devices that are injected or implanted in fish to track their movement. The tags are passive; they house a radio transponder with a unique code that reacts to a signal emitted from a reader. The readers, which are often installed into antenna arrays, emit an electromagnetic charge and when a PIT tag is in range, the transponder reacts to the charge and transmits the tag's unique code to the reader (Fishbio 2021).

Passive Integrated Transponder (PIT) tag detection equipment was installed in the Washington shore control section in 2005. A portion of eight baffles (baffles 5 through 12) and the underlying concrete floor were demolished and reconstructed to accommodate PIT tag antennas at four of the existing control section slots (slots 5, 7, 9 and 11). The location of the existing PIT tag antennas is shown in Figure 1-6. Transceiver panels with sunshades, access walkways, and power and communications infrastructure were supplied for each antenna. Antennas were provided by BPA. The antennas were replaced in 2021.

1.4 EXISTING FISH LADDER OPERATION

1.4.1 General

Fish enter the lower Washington shore fish ladder from the tailrace via one of four main entrances or through the floating orifice gates along the downstream face of PH2. Fish enter the Cascades Island fish ladder from the north spillway tailrace via one main entrance equipped with a vertical slot weir. Flow is supplied to each of these entrances from the ladder and through Auxiliary Water Supply (AWS) systems. In the lower Washington shore fish ladder, the AWS is supplied from the forebay via two fish turbines and makes up most of the entrance flow. During normal operation, the four entrance weirs are operated simultaneously. The weir settings are adjusted by a Programmable Logic Controller (PLC) and the fish turbine discharge is adjusted to maintain specified entrance head differentials and weir submergence levels. In the Cascades Island fish ladder, the AWS is supplied from forebay Tainter gates with automatic PLC adjustments to maintain differentials. At all entrances, diffusers are adjusted to balance the discharge and prevent excessive differences between the head differentials at the entrance. The work proposed in this DDR will have no effect on the existing operation of any of the fish ladder entrances.

The Washington shore overflow ladder weirs (Weir 8 to Weir 67) extend from the North Junction Pool to the Upper Junction Pool. Flow enters the Upper Junction Pool from the ladder control section and associated make-up water supply. The flow from the Upper Junction Pool is split between the Washington shore ladder and the UMT Channel that conveys fish from the Cascades Island fishway to the Washington shore control section and exit to forebay. The normal discharge in the Washington Shore ladder ranges from 80 to 120 cfs and the discharge in the UMT is about 75 to 85 cfs.

The ladder control section and make-up water supply are operated to provide these flow rates and to maintain around 1 foot head differential at Weir 67 (except when the ladder head is increased to 1.3 feet to move shad through the ladder system). The control section modifications described in this DDR were designed such that there is no change to the head or flow at the upstream end of the UMT and at Weir 67.

1.4.2 Fish Counting Station

The fish counting station is located between Weir 67 and the ladder control section. The counting slot has a mechanical crowder that can reduce the slot width to improve viewing access or change the water velocity in the slot. In addition, a counting slot bypass located in the approach pool adjacent to the counting station has a system of manually adjustable louvers that can be used to regulate the flow through the slot bypass and counting slot. Bonneville staff report that the settings of these louvers are not typically changed. The counting slot design velocity range is 2 to 6 feet/second (USACE, 2005). The control section modifications described in this DDR will be designed so the flow velocity in the counting slot will continue to be in the design range.

1.4.3 Serpentine Ladder Control Section

The serpentine portion of the ladder control section is passive, as it has no operable features to control flow or water level. A gate located at the upstream end can be used to dewater the control section but is not used to regulate flow. There are seven screened orifice openings in the south (river left) sidewall of the control section. These orifices allow exchange of water between the make-up water supply channel (see Section 1.4.4) and the ladder control section.

The upstream five orifices act as bleed-off diffusers that pass flow from the ladder control section into the make-up water supply channel and the downstream two orifices act as add-in diffusers that pass from the make-up water supply channel into the control section. All orifices in the control section can pass flow in either direction to equalize head. Typically, flow passes from the control section to the make-up water supply channel when the forebay is high and flow passes from the make-up water supply channel to the control section when the forebay is low. The diffuser orifice plates have fixed dimensions, and the flow exchange is driven by the head differential between the two channels.

There are four PIT tag antennas located in the ladder control section. Walkways provide access to each PIT tag antenna transceiver enclosure. The antenna housings can be removed and reinstalled if the antennas need to be maintained or replaced.

1.4.4 Make-Up Water Supply

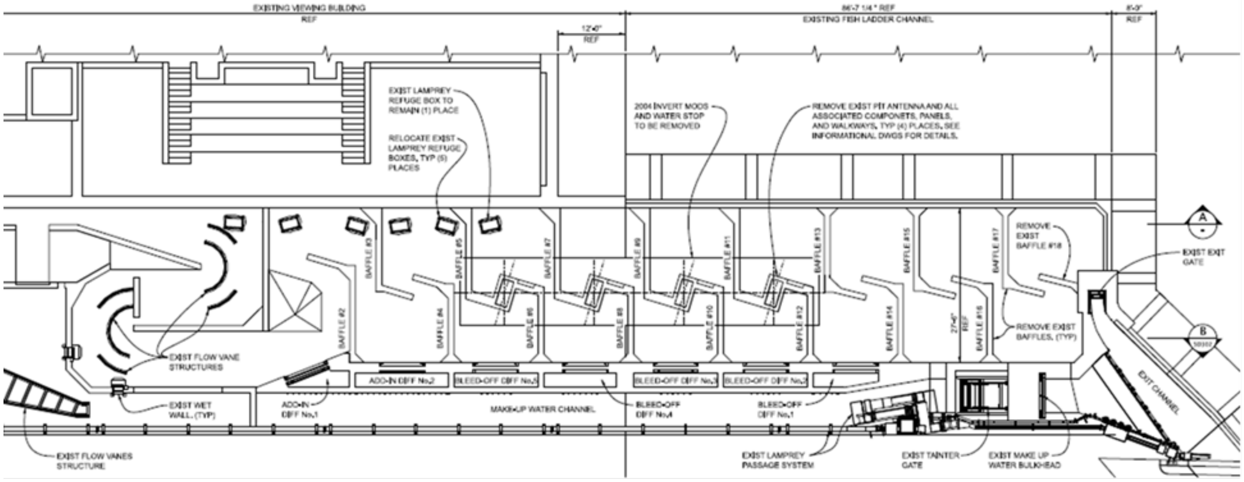
The make-up water supply channel augments the flow through the control section so that ladder head and discharge criteria are met at Weir 67. A Tainter valve at the upstream end of the make-up water supply channel (FV 6-9) regulates the volume of flow so the ladder head criteria are maintained over the full range of forebay elevations. The Tainter valve opening is automatically adjusted by a PLC to achieve a target ladder head of 1.0 to 1.4 feet. There is an additional Tainter gate at the downstream end of the make-up water supply channel that is used for backflushing. This backflush gate is rarely used and is typically fully raised out of the flow path.

1.5 PROPOSED MODIFICATIONS TO THE WASHINGTON SHORE FISH LADDER CONTROL SECTION

The modifications described in this DDR will replace the existing serpentine control section with a vertical slot and orifice control section and will modify the S-curve channel that connects the count station with the control section to have two 90 degree turns instead of two 180 degree turns. The general layout of the vertical slot and orifice control section will be similar to the control sections at Ice Harbor and John Day Dams. Figure 1-6 illustrates the difference between the existing and proposed Washington shore fish ladder control section.

Figure 1-6. Comparison of Existing and Proposed Control Section Layout, Plan View

EXISTING SERPENTINE CONTROL SECTION



PROPOSED VERTICAL SLOT AND ORIFICE CONTROL SECTION

Seventeen of the eighteen existing baffles will be demolished and replaced with nine baffle pairs, each with a vertical slot and two orifices; one orifice will be 18-inches square to allow passage by salmon or lamprey and the other orifice will be 1.5-inches tall and 16-inches wide to exclude salmon and allow passage by lampreys. Lamprey refuge boxes will be provided approximately in line with the lamprey orifices. In addition, one refuge box will be left in place on the north side of the ladder in front of the visitor center viewing windows for the purpose of public education. The slots in the nine new baffle pairs will vary in width from 1.5 feet to 1.7 feet. All the slots and orifices will be flush with the ladder floor. The lamprey orifices will be flush with the south wall of the channel as well as being flush with the floor to provide a continuous attachment surface for lamprey. The slot and large orifice corners will be rounded, except in locations that PIT tag antennas are to be installed. The housing for each PIT tag antenna will be chamfered with angles less than 45 degrees and sanded smooth. The lamprey orifices will have 90-degree edges on the upstream side and radiused edges downstream, as shown on Plate SG508. This configuration was selected to reduce the velocities through the orifices recognizing that one wall and the floor would be completely flush, i.e., only the roof and one wall of the orifice will have a 90 degree upstream edge. The floor of the control section will be provided with a smooth finish (Class A) in the high velocity areas within and adjacent to the orifices and slots. Plate SG101 shows a general plan view of the control section modifications and Plate SG505 shows a typical baffle pair. The plates are provided in Appendix A.

The S-curve channel that connects the count station to the control section will be modified to replace the two 180 degree turns with two 90 degree turns and to shorten the total transit length. Concrete will be used to fill the portion of the S-curve channel that will no longer be used. The concrete fill will also serve as a new access platform to enable manual cleaning of the bypass leads upstream of the count station, see Plates S-003 and SG101. The upstream bypass leads will be cleaned using a hand rake, debris placed in a bucket, then hand carried out of the ladder. The pentagonal concrete structure at the downstream end of the control section will be removed.

The existing control section uses add-in and bleed-off diffusers to convey flow between the control section and the adjacent make-up water supply channel. The add-in and bleed-off diffusers will continue to be used to balance flow and head at Weir 67 after the control section modifications are complete. The two add-in diffusers have trashracks that extend to the floor of the channel; a 1-foot-tall steel strip will be welded to the bottom of the add-in diffuser trashracks to provide additional lamprey passage opportunities. In addition, a flow restrictor plate will be added to the orifice Add-In Diffuser 1 orifice to reduce the open area to the same dimension as the orifice plate on Add-In Diffuser 2.

The fish count data collected at the Washington shore fish ladder is integral to management of ESA-listed Columbia River fish. The existing PIT tag antennas and associated transceiver panels, rain/sun covers, and access stairs and walkways will be removed during demolition. New PIT tag antennas will be placed in the vertical slots and orifices at four consecutive baffle pairs to achieve the same, or better, levels of detection as the existing system. The new antennas will be located within the control section at baffle pairs 3, 4, 5 and 6 as shown on Plate SG101 in Appendix A. Concrete reinforcing in the area of the PIT tag antennas will use fiber reinforced polymer (FRP) to avoid interference that would be caused by standard steel reinforcement. This location is close to where the antennas are currently located. Access, power, and communications infrastructure will be added or replaced as needed for the new PIT tag antennas to function and be maintained. This will include new walkways, transceiver panels, rain/sun covers, and associated conduit and wire. A new uninterrupted power supply (UPS) cabinet will be provided to supply backup power to the antennas in two of the four baffle pairs. A new multimode fiber optic cable (of sufficient fiber count) and fiber optic patch panel will be provided to distribute fiber to each transceiver. Fiber optics will also be provided to the UPS cabinet for UPS monitoring.

No changes are planned for the count station or exit channel.

1.6 PROJECT CONSTRAINTS

1.6.1 Ladder Dewatering Window

The standard shut-down period for ladder maintenance and repairs is December through February. Any work that must be done within the ladder, in the dry, will need to be executed within this 3-month timeframe. The shut-down period coincides with short days and potentially difficult weather, like snow and ice, that may slow down work.

Fishway dewatering for maintenance at Bonneville Dam alternates between the Washington shore fish ladder system and exit and the Bradford Island fish ladder system and exit, so that one fish migration pathway is always open. Recent and upcoming ladder outages are as follows:

- December 2022 through February 2023: Washington shore
- December 2023 through February 2024: Bradford Island
- December 2024 through February 2025: Washington shore

The majority of the control section modifications construction is expected to occur during the 2024/2025 maintenance period. Any delay to schedule that affects the award date is likely to result in a two-year construction delay due to the ladder maintenance periods.

1.6.2 Coordination with Project Maintenance

Preventative maintenance, repairs, and upgrades are performed by USACE employees during the ladder dewatering window. Coordination with Project maintenance crews as they perform maintenance on the surrounding systems will be important to mission success.

1.6.3 Public Outreach

The Bonneville Dam Washington shore visitor center is popular and receives many visitors every year. There is a fish viewing building with windows into the fish ladder control section. The design will consider the potential effect of the modifications on visitor experience and will limit negative effects to the extent possible. The north side of the fish ladder public viewing area may not be available for placing of equipment or staging of materials.

1.6.4 Fish Viewing Windows and Brushes

The Washington shore visitor center accommodates viewing of the fish ladder via glass windows. The glass windows and associated cleaning brushes need to be protected from damage while demolition and construction work is being performed.

1.6.5 Fish Detection

The adult fish detection currently provided by the PIT tag antenna array in the Washington shore control section is very valuable to Columbia River fisheries management. Fish detection efficiency that is comparable to, or better than, the existing system must be provided at the conclusion of the work. PIT tag detection equipment is sensitive to interference from external sources of radio noise such as electric motors, high intensity lights, and field distortion caused by ferrous metals.

1.6.6 Access

Access must be provided to maintain the PIT tag detection equipment, including provisions for future removal and replacement. In addition, the design needs to consider staff access through the ladder for fish removal during dewatering; the minimum slot width will need to be greater than the 1.25-foot minimum dimension specified by the National Marine Fisheries Service (NMFS) anadromous fish passage criteria (NOAA, 2022). The allowable slot width is established by the Project staff that must complete the fish salvage operations and was coordinated for the control section modifications design with the Bonneville Project biologist(s) on the PDT.

1.6.7 Shad Passage

The ladder is operated to increase shad passage when a high number of shad are present in high numbers (>5,000 shad per day at count window). This typically occurs from late-May through mid-July, based on the average daily fish counts from 2012 through 2021. During this time the make-up water supply channel Tainter valve (FV 6-9) is adjusted to supply more water and increase the head drop at the ladder weirs to 1.3 feet. This could change how flow is transmitted through the bleed-off and add-in diffusers. Operations during shad passage season are described in Section 2.2.

1.6.8 Agency Coordination

Design activities are being coordinated with the Lower Columbia River Fish Facility Design Review Work Group (FFDRWG). The FFDRWG meets monthly and provides a forum for ongoing information exchange between USACE and regional stakeholders on the Washington shore fish ladder control section redesign. The FFDRWG is provided with an opportunity to formally review the design at established major milestones.

The PDT is actively coordinating the design efforts with Pacific States Marine Fisheries Commission (PSMFC), which is designing the replacement PIT tag antennas.

SECTION 2 - BIOLOGICAL DESIGN CONSIDERATIONS AND CRITERIA

2.1 PRIMARY SPECIES OF CONCERN

There are nine ESA listed stocks of salmonids that swim through the control sections at Bonneville Dam to spawn in the Columbia Basin. The listed stocks come from several species including spring Chinook, summer Chinook, fall Chinook salmon, as well as Sockeye salmon, and steelhead trout. Another species of concern, Pacific lampreys are ecologically important to the river system and culturally important to several northwest tribes. It was these tribes that reported on the alarming decline of lampreys upstream of Bonneville Dam. Also, tens of thousands of non-ESA listed Coho salmon pass annually. This is the most highly used fish ladder in the Columbia Basin.

Like salmon, Pacific Lampreys are anadromous: adults spawn in rivers, and their larvae rear in fresh water for up to 10 years before migrating to the ocean as juveniles. After several years in the ocean adult lampreys return to fresh water to spawn; yet unlike salmon, lampreys do not home to natal streams (PLTW, 2022).

2.2 OTHER SPECIES

Chum and pink salmon occasionally pass Bonneville Dam, as do other resident species. While there is potential to have ESA listed bull trout use the fish ladders, sightings at Bonneville Dam are extremely rare. For example, no bull trout have passed the counting windows in the last 10 years (USACE Annual Fish Passage Report 2012-2021) In 2012 one PIT tagged bull trout was detected at the upstream PIT tag antennas (Barrows et al., 2016). The annual lamprey run overlaps most significantly with summer Chinook, steelhead, and sockeye (Figure 2-3). Smaller white sturgeon, a few a year, pass through the ladder and are reported in the Annual Fish Passage Report. Other resident species such as northern pikeminnow, smallmouth bass, common carp, and wide varieties of suckers, minnows, sculpins and panfish are entered as comments but not reported in on-line counts.

Atlantic shad were introduced to the Sacramento River in the 1880s and moved up the west coast to the Columbia River. Present day, millions of shad are counted passing Bonneville Dam. At times they outnumber salmonids in the fish ladders and could cause passage delays by physically impeding salmon. Their passage season overlaps that of Pacific Lampreys, as well as Chinook (spring and summer) and sockeye. During shad passage season, when 5,000 or more shad per day pass the count station, water depth over fish ladder weirs is increased to 1.3 feet ±0.1 foot to encourage shad to go over the top of weirs and reduce crowding at the orifice openings to allow salmonids to pass. Outside the shad passage season (less than 5,000 shad per day passing the count station), water depth over fish ladder weirs is maintained at 1.0 foot (±0.1 foot) (USACE, 2021).

2.3 SUMMARY OF RESEARCH TO DATE

Pacific Lamprey passage studies began at Bonneville Dam in the 1990s (Starke and Dalen 1995) and continue today. A synthesis covering several years of passage studies using tagged fish (radio tagged and PIT tagged) was produced by Keefer et. al. (2013). Keefer et. al. used migration histories from thousands of radio tagged lamprey to identify locations of poor passage (bottlenecks) in the fishways at Bonneville Dam.

The serpentine control sections at Bradford Island and Washington shore ladders exhibited high turn-around rates combined with low probability of additional passage attempts, resulting in a high passage failure rate compared to other segments of the ladders. High velocities and turbulence characteristic of serpentine sections are the likely cause of the high turn-around rates in these segments. Remediation for those negative hydraulic conditions should reduce turnarounds and increase overall passage success. More recent passage studies can be found in technical reports from the University of Idaho to USACE (i.e. Clabough et. al. 2020 and earlier) including the work of Kirk et. al. (2017) which details the difficulties lamprey have navigating serpentine-style flow control sections.

2.4 PAST PERFORMANCE OF SIMILAR DESIGNS

The EIS proposes the serpentine-style control section at the Bonneville Dam Washington shore fish ladder be converted to a vertical slot and submerged orifice configuration to improve passage conditions for and reduce stress and delay for adult salmon, steelhead, bull trout, and Pacific Lamprey. The vertical slot and orifice-style of fish ladder control section is in use at Ice Harbor and John Day dams.

Passage delays and jumping behavior of adult salmonids in the fishways of John Day Dam were a problem from initial construction in 1968 until a redesign was implemented. Additionally adult salmon mortalities were found under the ladders after fish jumped out of an elevated section and fell to their death (per comm. Eric Grosvenor, John Day Dam Project Biologist 6/15/22). Netting was installed to keep them in the ladder as seen in Figure 2-1. The flow control section was modified prior to the 2010 fish passage season to replace the serpentine baffles with vertical slot and orifice baffles, Figure 2-2. Figure 2-1 and Figure 2-2 are from Madson and Jonas (2011).

Figure 2-1. John Day North Fish Ladder Serpentine Control Section in 2009 before Modification.

Figure 2-2. John Day North Fish Ladder Slot and Orifice Control Section in 2010, after Rebuild.

The passage problems were nullified when the serpentine style control sections were replaced using the Ice Harbor style vertical slot and orifice design in the south ladder, 2003, and later the north ladder in 2010. A pre-construction evaluation of the north ladder in 2009 recorded 2.28 jumps per observer hour (Madson and Jonas 2011). The post-construction evaluation from the same report recorded no jumping in 2010. Upstream and downstream movement through the count station window, indicative of passage problems, were also greatly reduced, as described in the excerpt below:

"The downstream movement of salmonids through the count station window at the John Day north ladder had been the highest of all count stations on the lower Columbia River. The average percentage of downstream movement for salmonids over five seasons (2005-2009) at the John Day north ladder was 40.1% with Bonneville Bradford Island ladder second highest at 14.8%. In 2010 the percentage of downstream movement by salmonids dropped to 7.7% at the John Day north ladder."

Similarly passage studies using radio tagged spring-summer Chinook adults found they consistently used less time to pass the counting window after the 2010 modifications, when compared to times recorded in 1998 (Jepson et al. 2011).

Lamprey passage was not evaluated in the Jepson et al. 2011 study. However, lamprey passage was evaluated after the pool-and-weir fish ladders at River Mill Dam on the Clackamas River, OR were redesigned for salmon and lamprey. The new ladders were based on the half Ice Harbor-style fishway with additional lamprey friendly features. Two post-modification passage studies were performed using radio and PIT tags. The ladder modifications and results are summarized in the except below:

"*Rounded corners at the fishway entrances, flush-mounted weir gates, chamfered corners on orifices and weir walls, and orifices flush with the floor were all included in the fishway design specifically for Pacific Lampreys. In 2013 and 2015, Pacific Lampreys were radio tagged and PIT-tagged to assess passage success. Dam passage efficiency estimates ranged from 84% to 98%, roughly 10–50% higher than Pacific Lamprey passage efficiency estimates at other dams in the Pacific Northwest.*" (Ackerman et al. 2019)

2.5 BIOLOGICAL CONSIDERATIONS

2.5.1 Winter Maintenance Period

The Bonneville Dam fish ladders are shut down from December through February in alternating years, see Section 1.6.1 for details.

2.5.2 Fish Passage Season

The adult fish passage season is March through November; however, upstream migrants are present throughout the year and adult passage facilities are operated year-round (USACE, 2021). Ten-year average run timing (fish per day) for the species of concern passing Bonneville Dam are shown in Figure 2-3 and more detailed numbers for lamprey by year are shown in Figure 2-4. Note that the vertical scale of "fish per day" is different for lamprey, steelhead, and coho (left axis) versus sockeye and Chinook (right axis) on Figure 2-3.

Figure 2-3. 10-year Average Run Timing at Bonneville Dam

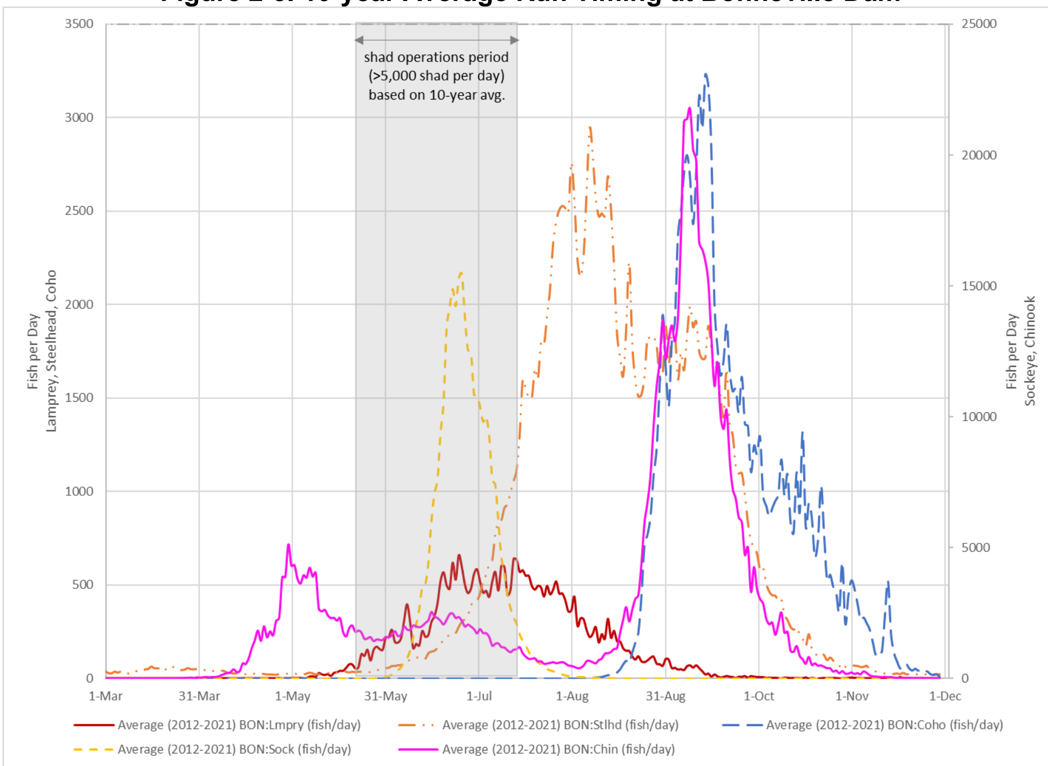
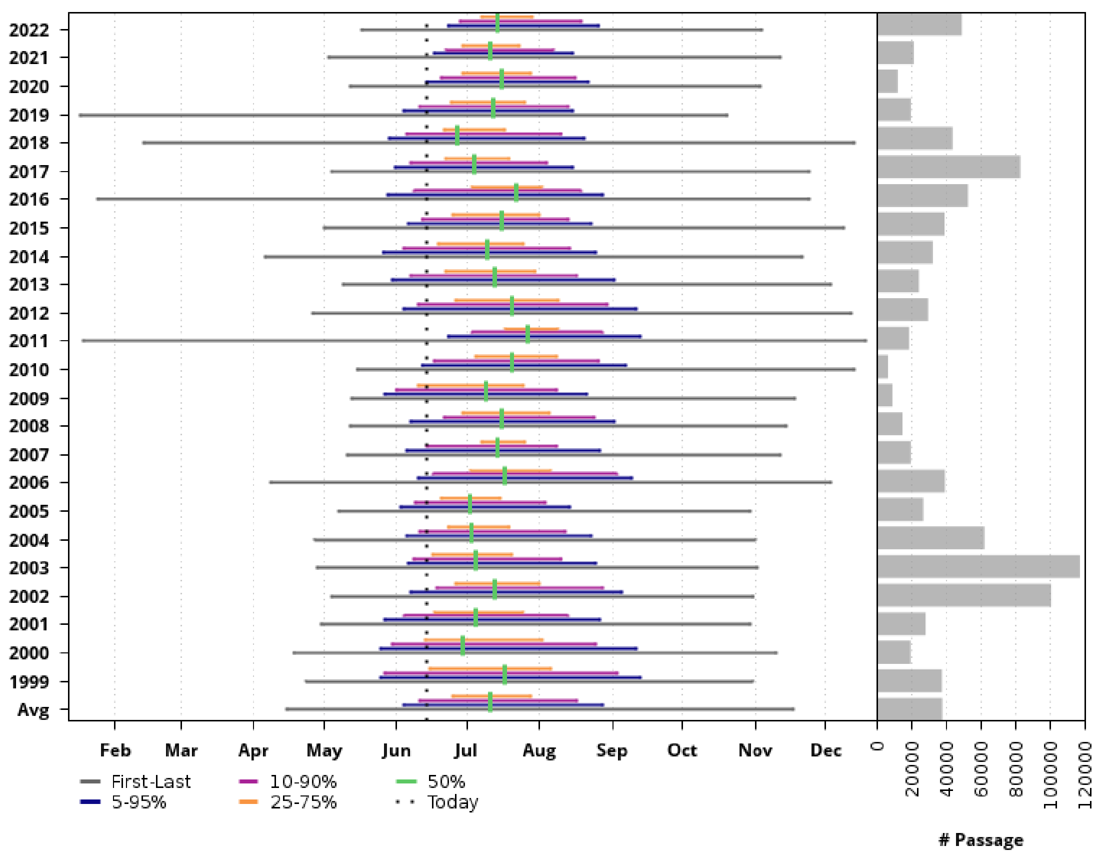


Figure 2-4. Lamprey Historical Run Timing, 1999 – 2022, Adult Visual Counts



2.6 BIOLOGICAL GUIDELINES AND CRITERIA

Design guidelines for lampreys come from Pacific Lamprey Technical Workgroup (PLTW) Practical Guidelines for Incorporating Adult Pacific Lamprey Passage at Fishways, v 2.0 published June 6, 2022. This document will be found online at https://www.pacificlamprey.org/ltwg/.

Design criteria for salmonids comes from the National Marine Fisheries Service (NMFS) Anadromous Salmonid Passage Facility Design published in 2022.

2.6.1 Relevant Lamprey Guidelines

- In areas where velocities exceed 3.3 ft/s:
  - Provide a smooth, continuous, planar attachment surface (continuous floor, ramp or wall); this will allow lampreys to use burst and attach locomotion.
  - Avoid sharp angles, gaps, and uneven surfaces that could prevent or reduce the ability of lampreys to use burst and attach locomotion.
- Round edges of walls with a minimum 3 to 4-inch radius.
- Maintain uniform flow to provide consistent migratory cues, particularly along the floor of the fishway.
- Do not place diffusers on the floor of fishways or along the lower portion of the fishway wall.
- Avoid repeated “passage challenges”, as lampreys have been shown to turn around if exhausted by repetitive challenging passage conditions that are fatiguing (Hanchett, S. A. 2020).

2.6.2 Relevant Salmonid Criteria

- Maximum slot width (salmon): No criteria
- Minimum slot width (large Chinook salmon): 1.25 feet (NMFS, 2022, 5.5.2.1.1)
- Maximum slot velocity (salmon): 12 feet/second (NMFS, 2022, 5.1)
- Minimum slot velocity (salmon): No criteria
- Maximum orifice velocity (salmon): No criteria
- Minimum orifice velocity (salmon): No criteria
- Maximum slot head drop (salmon): 1.0 feet (NMFS, 2022, 5.7.2.1)
- Minimum slot head drop (salmon): 0.25 feet (NMFS, 2022, 5.7.2.1)
- Pool volume / energy dissipation (salmon): Energy dissipation factor ≤4 ft-lbs/s/ft^3 (NMFS, 2022, Section 5.5.3.5)

2.7 POST-CONSTRUCTION EVALUATION

There is potential for two post-construction evaluation studies which will be coordinated through the Anadromous Fish Evaluation Program and vetted by the regional Studies Review Work Group allowing for tribal, state, and federal input. For lamprey, the post-construction evaluation will take advantage of a larger passage study encompassing both Bonneville and The Dalles dams, planned for 2025. If required by NOAA, the salmonid passage study will take advantage the existing PIT tag antenna infrastructure and on-going very large PIT tagging efforts to calculate passage timing through the flow control section. This approach has the potential to provide data on PIT tagged salmon from several species and stocks at a low cost. Alternatively, the salmon study could use the same antennas and receivers deployed for the study of lamprey, placed throughout Bonneville Dam's fishways. This will require buying acoustic or radio tags, tagging and releasing tagged salmonids likely collected at Bonneville's Adult Fish Facility.

Depending on tagging method, several passage metrics and analysis established in previous studies (Keefer et al. 2013) should be used so any changes in these metrics can be compared to previous seasons. Passage metrics should include, but not be limited to:

Metric	Definition
Failure rate	Proportion of turn-around events in each fishway segment that were not followed by additional passage attempt.
Additional attempt rate	Proportion of turn-around events in each fishway segment that were followed by additional passage attempt.
Turn-around rate	Number of turn-around events in each fishway segment per unique fish detected.
Segment passage time	Median length of time between the start and end of each fishway segment, as determined by antenna location.
Route-specific passage efficiency	1) Proportion of unique fish using each route 2) Total attempts at each route
Dam-wide passage efficiency	1) Unique fish; route and event-independent 2) Total attempts; route-independent

In addition, up and down movements past the counting window are indicative of a passage problem. This data may be collected without an active tag study and can be evaluated for each species at several time intervals throughout the year. Fish ladder counts are one of the longest available data sets. Up and down counts should be used to determine the proportion of up and down movement past the counting window for Pacific Lampreys and the salmonid(s) of interest and compared to previous years to see if this metric is improved.

SECTION 3 - HYDROLOGY AND HYDRAULIC DESIGN

3.1 DESIGN STANDARDS AND CRITERIA

- U.S. Army Corps of Engineers (USACE), Waterways Experiment Station. 1986, Hydraulic Design Criteria.
- NMFS (National Marine Fisheries Service). 2022. NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual, NMFS, WCR, Portland, Oregon.
- Pacific Lamprey Technical Workgroup. 2017. Practical guidelines for incorporating adult Pacific Lamprey passage at fishways. June 2017. White Paper. 47 pp + Appendix. Available online: https://www.fws.gov/pacificlamprey/mainpage.cfm

3.2 RESERVOIR ELEVATIONS AND FLOW RATES

Bonneville Dam was originally constructed to accommodate forebay fluctuations between EL 70.0 feet and EL 74.0 feet (USACE, 1971). With the construction of PH2 and modifications for upstream peaking the operating range was changed to:

- Full Pool: EL 77.0 feet (at the dam)
- Normal Operating Range: EL 71.5 feet to EL 76.5 feet (at the dam)
- Minimum Pool: EL 70.0 feet (at the dam)
- Maximum daily fluctuation: 4 feet (at the Stevenson gage)

Additionally, the Water Control Manual (USACE, 2014) states that the Normal Operating Range will be exceeded no more than 5 percent of the days in a year (18 days), the full pool elevation, EL 77.0 feet, is absolute and will not be exceeded except in the case of extreme flood or an approved temporary deviation. Exceedance of the normal operating range requires concurrence with the Bonneville Operations Project Manager.

Analysis of the past 25 years of mean daily data produced the range of water levels and flows shown in Table 3-1. The full year was considered in this analysis because the modifications must consider all periods when salmon or lamprey may be present, which is effectively all year.

Table 3-1. Daily Average Reservoir Elevations and Flow Rates, 1996 to 2021

Percentile	Forebay EL (ft)	Inflow (kcfs)	Outflow (kcfs)
Max	77.5	558	557
5%	76.0	350	352
10%	75.8	300	302
25%	75.3	219	220
50%	74.5	155	157
75%	73.8	125	126
90%	73.1	104	105
95%	72.7	92	92

Percentile	Forebay EL (ft)	Inflow (kcfs)	Outflow (kcfs)
Min	71.2	65	71

The modifications will be designed to operate within NMFS' criteria presented in Section 2.6.2 over the 5 percent to 95 percent pool exceedance range of EL 72.7 feet to EL 76.0 feet. The conditions at full pool (EL 77.0 feet) and minimum pool (EL 70.0) will also be documented for context. This includes flow rates through various parts of the control section and AWS, water surface elevations, and velocities through the slots and orifices.

3.3 DESIGN METHODS

3.3.1 Past Experience

Slot and orifice fish ladder control sections are in use at several dams in the Pacific Northwest. Notable examples that have been used to inform the design of the Washington shore fish ladder control section include John Day and Ice Harbor. In addition to adherence to design criteria and guidelines, design experience was used to support the design components and decisions.

3.3.1.1 *General Layout*

The general layout of the control section baffle pairs is taken from the John Day North (JDAN) fish ladder control section (USACE 2009). The primary change at both facilities is to replace the serpentine baffles with Ice Harbor-style vertical slot and orifices and provide lamprey-specific improvements such as rounding or chamfering edges. The following aspects of the Washington shore control sections are different from the JDAN configuration: the addition of 1.5-inch by 16-inch lamprey orifices, inclusion of PIT tag detection equipment at four of the baffle pairs, removal of the sill gates used at JDAN so that the orifices are flush with the channel invert, and associated reshaping of the baffles. The JDAN control section was developed using a physical hydraulic model (ENSR 2008) and has been in operation since 2010.

Figure 3-1 and Figure 3-2 compare the layout of JDAN to Washington shore, and Table 3-2 summarizes some relevant dimensions for the two control sections. As shown in the table and figures, JDAN is about two-and-a-half times as long as Washington shore and has more than twice as many drops for fish to pass through; the slot jets for JDAN are directed to the north whereas the slot jets for Washington shore are pointed south; and both control sections have some variability in pool length, but the range in pool length is greater at Washington shore.

Figure 3-1. Compare JDAN and Washington Shore Control Sections: Plan View

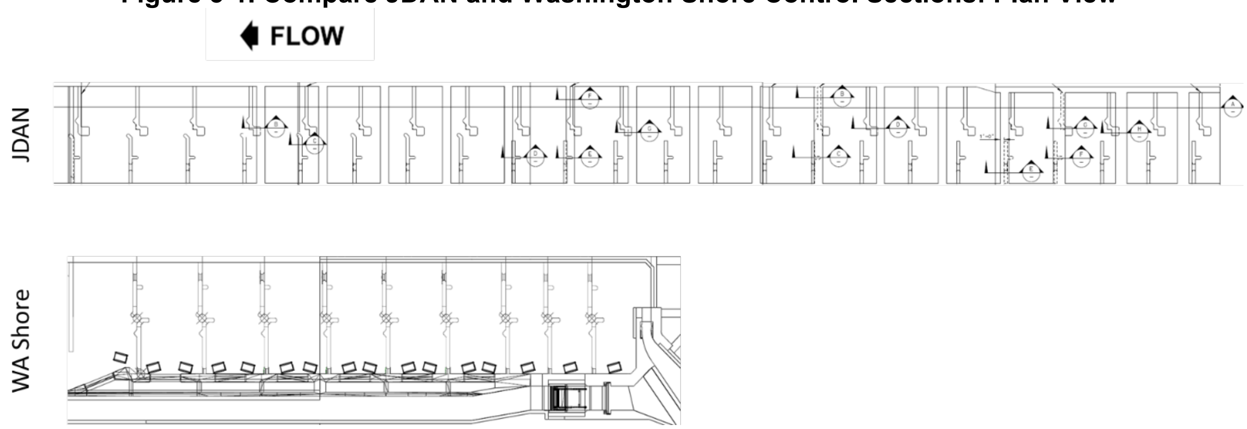


Figure 3-2. JDAN and Washington Shore Control Sections: Elevation View

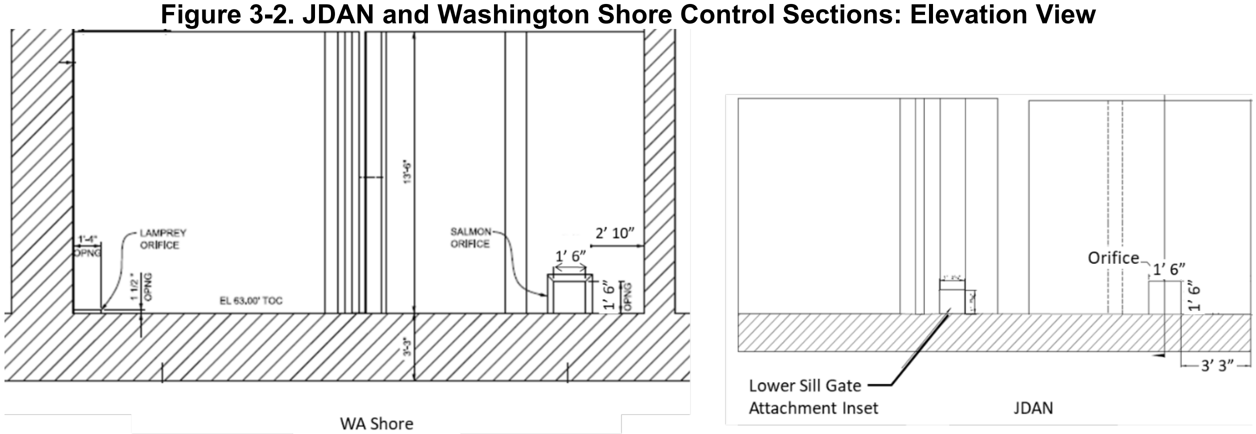


Table 3-2. Compare JDAN and Washington Shore Control Sections

Feature	JDAN	WA Shore
Design Reservoir Range	257 - 268	70 - 77
5% to 95% Forebay Range	263 – 264.9	72.7 - 76
Control Section Total Length (first to last baffle)	~296 feet	~ 117 feet
Number of Baffle Pairs (Slots)	23	9
Slot Width (Range)	1.25 ft – 1.5 ft	1.5 ft – 1.7 ft
Pool Length (Range)	11.75 ft – 15.0 ft	10.83 ft – 16.5 ft

The PDT compared the head drop and velocity calculated by the Washington Shore control section CFD model and the JDAN control section physical hydraulic model. Section 3.3.3 describes the modeling. Table 3-3 presents a comparison of the head drop between pools for each facility at high pool and Table 3-4 provides a comparison of the head drop for each facility at low pool. As part of the Washington Shore control section redesign, the PDT developed a CFD model of the JDAN physical model. Figure

3-3 and Figure 3-4 show a velocity comparison through the slot and orifices for each facility at low pool. Baffle pair 14 for JDAN and baffle pair 5 for BON Washington shore were selected for comparison, as they were both near the middle of their respective control sections and had similar head drops (0.59 ft drop for JDAN, and 0.52 ft drop for Washington shore).

Note that the results are not directly comparable because the JDAN physical hydraulic model was not run for identical conditions to the Washington shore CFD model; for example, the Washington shore design is based on the 5% to 95% exceedance pool range whereas the JDAN physical hydraulic model was run for the Maximum Pool (El. 268), the Minimum Pool (El. 257) and the Minimum Irrigation Pool (El. 262.5). The JDAN CFD model of the physical model domain, for validating the CFD model design approach, was only modeled for a forebay of 262.5 ft. The closest comparable BON WA Shore model would be 72.7 ft forebay run, which would have similar pool exceedance the most similar drop between each control section pool. The tables and figures below compare the closest available scenarios for each site and the results indicate that the hydraulic conditions for the Washington shore control section design are similar to those of the John Day North control section.

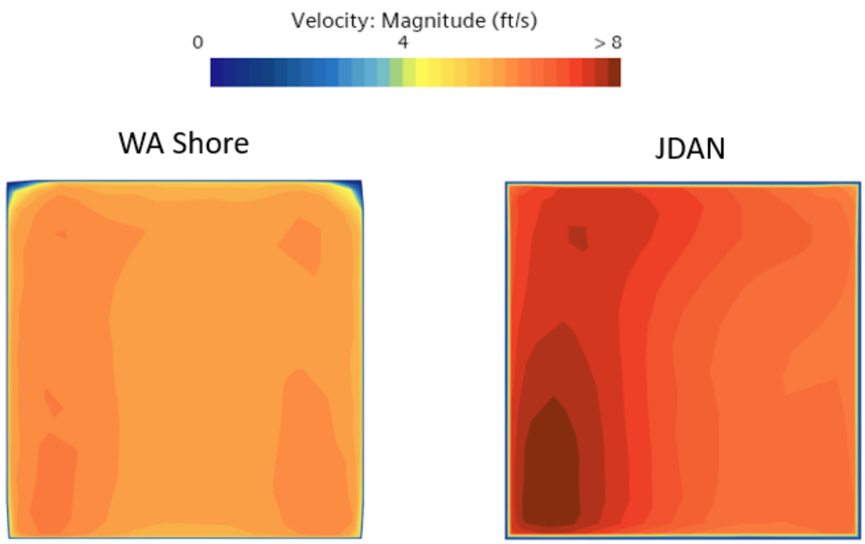
Table 3-3. Compare Washington Shore and John Day North Control Section Head Drop: High Pool

Location	Forebay Elevation	Description	Head Drop (ft)		
			Max	Average	Min
WA Shore	77	Max Pool	1.16	0.88	0.63
	76	Max Design (5% Exceedance)	1.04	0.79	0.55
John Day	268	Max Pool	1.10	0.82	0.56

Table 3-4. Compare Washington Shore and John Day North Control Section Head Drop: Low Pool

Location	Forebay Elevation	Exceedance	Head Drop (ft)		
			Max	Average	Min
WA Shore	72.7	95%	0.52	0.44	0.31
John Day	262.5	98.6%	0.81	0.57	0.28

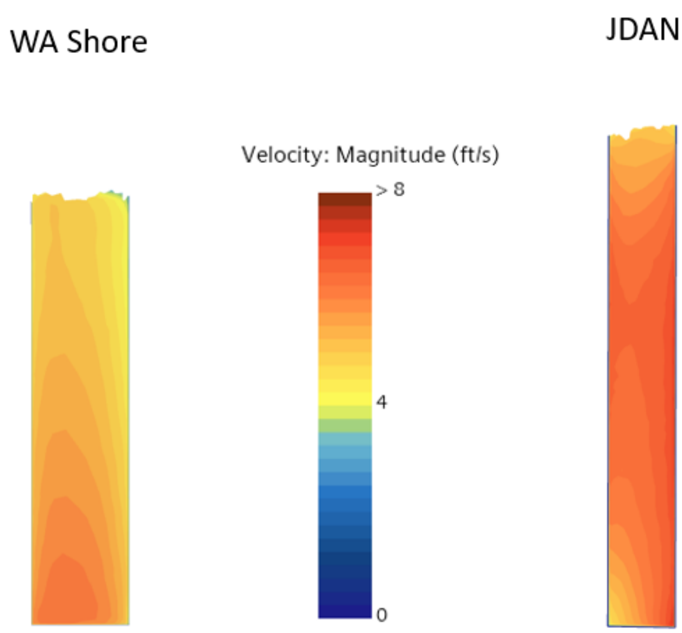
Figure 3-3. Compare Washington Shore and John Day North Control Section Slot Velocities: Low Pool



Baffle 5:	FB 72.7 ft	
Location	Vavg (ft/sec)	Vmax (ft/sec)
Orifice	5.67	6.21

Baffle 14:	FB 262.5 ft	
Location	Vavg (ft/sec)	Vmax (ft/sec)
Orifice	6.88	8.02

Figure 3-4. Compare Washington Shore and John Day North Control Section Orifice Velocities: Low Pool



Baffle 5:	FB 72.7 ft	
Location	Vavg (ft/sec)	Vmax (ft/sec)
Slot	5.23	6.27

Baffle 14:	FB 262.5 ft	
Location	Vavg (ft/sec)	Vmax (ft/sec)
Slot	6.42	7.81

3.3.1.2 *Orifice Placement*

The 18-inch square orifices are proposed to be located flush with the control section floor and offset 3-feet 7-inches from the control section north sidewall. The JDAN ladder uses a 4-foot offset, which was shown to work well hydraulically in the JDAN physical model, and is consistent with the standard Ice Harbor design, which has been proven to be effective for salmon passage. The preliminary design of the new Washington Shore baffles had the large orifice positioned in the same location as the JDAN design, with its centerline 4-feet away from the north ladder wall. While modifying the baffles to account for an increase in baffle thickness from 10-inches to 12-inches, the large orifice was moved to have the centerline be 3-feet 7-inches away from the north wall. All final CFD model runs showed good hydraulic results for flow patterns, head drops, and velocities throughout the ladder. The final geometry will use the 3-feet 7-inches placement.

The JDAN physical model investigated alternative placement locations for the 18-inch square orifices, including flush with the sidewall. The model testing demonstrated that flow through the sidewall orifice was very fast with little energy dissipation between pools. The biologists working with USACE on the JDAN design also reasoned that fish approach the orifice from both sides in the hydraulic shelter behind the wall and that a high velocity jet trained along the sidewall would restrict access from one side. More recently, the USACE Sacramento District investigated orifice placement flush with the sidewall in the adult fish bypass design for the proposed Sacramento Weir Expansion project and the CFD model results showed the same phenomenon: excessively high velocities with insufficient energy dissipation or velocity reduction between orifices (USACE 2021).

3.3.1.3 *Lamprey Orifices*

Lamprey orifices are small (1.5-inch tall by 16-inch wide) openings through the baffles that are flush with the floor. Lamprey orifices have been tested at the Bradford Island fish ladder (USACE, 2019) and the results were promising enough that the PDT, with input from the FFDRWG, determined that these orifices should be included in the Washington shore control section modifications to provide lampreys with an additional passage route. These will be located on the opposite side of the channel from the 18-inch orifices. Based on CFD results and discussions with the FFDRWG, the orifice design was modified from the Bradford Island design by moving them to the south wall of the ladder, shaping the upstream edges as a 90-degree sharp-edge, and maintaining the radiused downstream shaping. Even though past studies (Zobott et. al., 2015; Pacific Lamprey Technical Workgroup, 2017) have found that 90-degree edges are often a challenge to lamprey passage, moving the orifice to the south wall provides two continuous surfaces (the floor of the ladder and the south wall) for lamprey to attach to and move up the ladder. The inclusion of the 90-degree edges on the upstream edge of the top and north sides of the lamprey orifices was included to reduce velocities through the openings and produce a flow separation that should benefit the lamprey passage.

3.3.1.4 *Orifice and Slot Shaping*

The PDT, with input from the FFDRWG, determined that PIT tag detection for lampreys is desired to evaluate passage success after construction. As such, in four of the nine baffle pairs, the two orifices and the vertical slot will be equipped with PIT tag detection antennas. This will provide detection comparable to, or better than, the existing system. Past studies have found that 90-degree edges are often a challenge to lamprey passage. To balance the desire for PIT tag detection with the benefits of reducing 90-degree edges, the slots and orifices without PIT tag antennas will have rounded edges with a minimum radius of 4 inches and the PIT tag antenna enclosures will be flush with concrete faces, chamfered with angles less than or equal to 45 degrees, and any sharp edges sanded smooth.

3.3.2 Screening Analysis

A spreadsheet calculation was used to support a screening analysis of four alternative layouts. A primary objective of the screening analysis was to determine whether the control section could meet NMFS' criteria over the design range of forebay elevations with fixed-elevation, fixed-width slots. This determination was critical to the overall layout, because actuated sill gates such as those used at the JDAN fish ladder, would interfere with PIT tag antenna function. In addition, keeping the base of the slot flush with the control section floor is considered to be better for lamprey passage. The screening analysis confirmed that the control section could function hydraulically without the need to install actuated sill gates.

The spreadsheet calculation balances the calculated flow rate based on the slot characteristics (discharge coefficient, slot width, sill height, and head drop) with a user prescribed flow rate at each slot. The flow rate computations include the flows through the 18-inch orifices, which vary depending on the head differential between pools. Given a desired water surface elevation downstream of the count station, such as at the top-most ladder weir, Weir 67, the user modifies the slot widths and sill heights to achieve the desired forebay water surface.

The discharge coefficients used in the spreadsheet calculation were taken from the 2008 physical hydraulic model of the JDAN fish ladder control section (ENSR, 2008), which has similarly configured vertical slot and orifice baffle pairs.

Based on the JDAN ladder control section physical model, the following discharge coefficients were applied:

- Vertical Slot: 0.87
- Orifice: 0.80

For three of the four alternatives, the count station flows, ladder exit flows, and make-up water supply channel water surface elevations used in the spreadsheet calculation were taken directly, or extrapolated from, a 1973 physical hydraulic model study that was used for the initial design of the control section (USACE, 1973). The model study allowed for validation of the spreadsheet design process for those three alternatives. No validation could be made for one of the alternatives because the physical model study did not contain a comparable scenario.

The results of the screening analysis and rationale for selecting the general layout used as the starting point of the design documented in this report are presented in Appendix D.

3.3.3 Computational Fluid Dynamics (CFD) Model

Star-CCM+ v. 2021.2 was the CFD code chosen for this modeling effort, due to its advanced meshing techniques and ability to capture complex geometry. The polyhedral meshing option in Star-CCM+ is unique in that most CFD codes utilize a trimmer or rectangular mesh, which can cause model instabilities when flows don’t move directly perpendicular to the orientation of the cells. The software also can easily import points for data collection and to select specific surfaces to output scalar data on throughout the model runs. Using the computing power of the High-Performance Computers (HPCs), as part of the Department of Defense (DoD)-funded High Performance Computing Modernization Program (HPCMP) reduced the amount of time to achieve a design.

3.3.3.1 *Verification of Modeling Approach*

The PDT determined that CFD modeling is the most appropriate tool to develop, refine, and verify the hydraulic function of the proposed control section modifications. The last control section redesign completed by the Portland District, at the JDAN ladder, used a physical hydraulic model to support the design development process. Because of advances in CFD modeling code and successful operation of similar designs, the PDT does not believe that physical hydraulic modeling is technically necessary or that the cost and schedule requirements of physical modeling are justified for the Washington shore control section modifications design.

To demonstrate the efficacy of CFD modeling for this application, the PDT replicated the JDAN physical model, which was completed by ENSR in 2008, in CFD. The final geometry from the physical model was created in CAD, at model scale of 1:5, and the boundary conditions in the CFD model were set to mimic the hydraulic conditions from physical model test 11E. These hydraulic conditions include: water levels in the headbox, diffuser flow upstream of the count station, bulkhead knife gate settings, porosity through the trash rack and picket leads, and tailgate setting to produce the 1-foot head drop through the lower ladder sections. An overview of the CFD geometry is shown in Figure 3-5, a cross section through the model showing the mesh is presented in Figure 3-6, and the boundary conditions for both the physical model and CFD model are presented in Table 3-5.

Figure 3-5. JDAN Ladder Physical Model CFD Domain

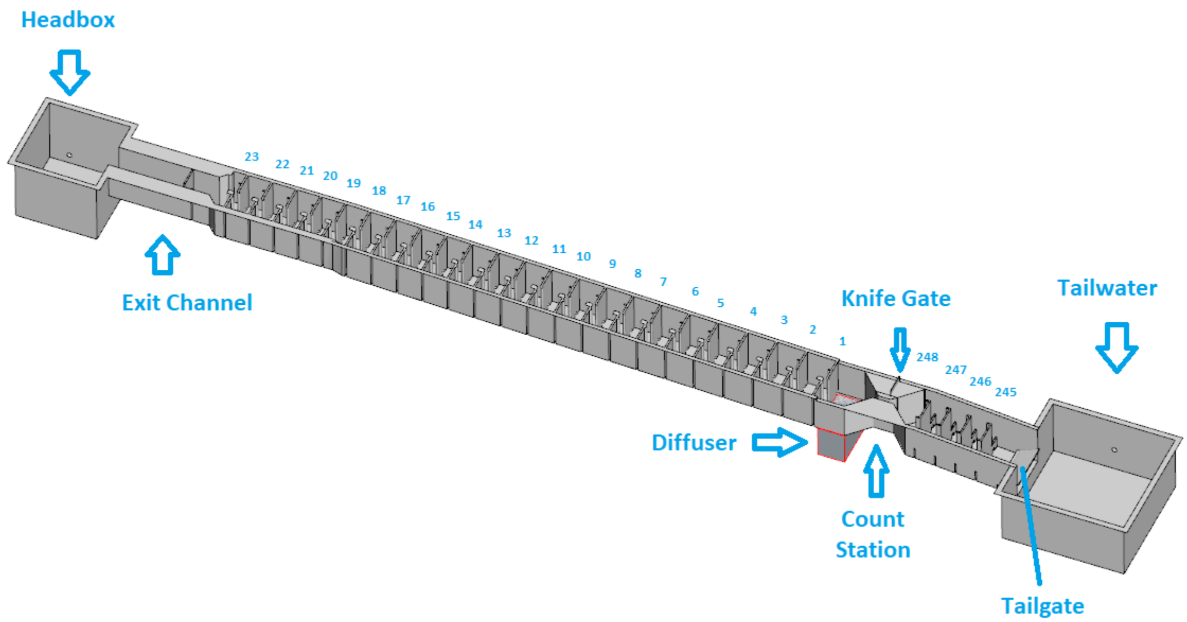


Figure 3-6. JDAN CFD Validation Model Mesh Cross Section

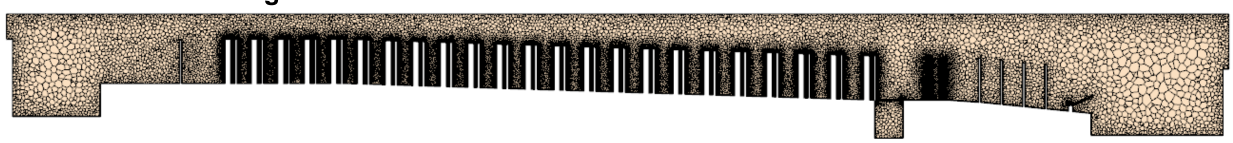


Table 3-5. JDAN Ladder CFD Validation Run: Boundary Conditions (Final Design, No Sills)

Parameter	Scale	Value
Target Forebay EL	Full (feet)	262.5
	Model (inches)	65.55
Head Differential between Pools	Full (feet)	1
	Model (inches)	2.4
Control Section Flow	Full (cfs)	72
	Model (cfs)	1.29
Diffuser Flow	Full (cfs)	13
	Model (cfs)	0.23
Ladder Flow	Full (cfs)	85
	Model (cfs)	1.52

The water levels, head drop between pools, general flow patterns, and discharge were calculated in the CFD model and compared to the same metrics taken from the physical model. Because the exact operations of the physical model weren't specified in the modeling report (including settings of the tailgate, opening of the knife gate, etc.) multiple iterations of the model were tested in an effort to replicate the results from the physical model. Notable iterations include: doubling the mesh size to capture finer flow dynamics, using various turbulence models, and changing the boundary conditions to better approximate the setup of the physical model. These model variations are outlined in Appendix G, CFD Modeling Appendix, and the results for the adopted CFD model are compared to the physical model data in Table 3-6. Note that the data shown in Table 3-6 were converted from prototype elevation to model elevation and shifted vertically to match the datum of the CFD model.

Table 3-6. JDAN Ladder Model Comparison

Physical Model Pressure Tap #	W/S Diff from Forebay (in)	Slot EL (in)	Sill EL (in)	Depth at Pool Center (in)	Headloss (in)	Water Surface EL (in)		
						Physical Model	CFD Model	Difference
Forebay	0.00	N/A	N/A	N/A	0.10	65.55	65.29	-0.26
Exit Channel	0.10	36.75	36.75	28.70	0.55	65.45	65.35	-0.10
23	0.65	36.75	36.75	28.15	0.74	64.90	64.47	-0.43
22	1.37	36.75	36.75	27.43	0.67	64.18	63.81	-0.37
21	2.04	36.75	36.75	26.76	0.77	63.51	62.99	-0.52
20	2.83	36.75	36.75	25.97	0.89	62.72	62.11	-0.61
19	3.70	36.75	36.75	25.10	1.06	61.85	61.2	-0.65
18	4.75	36.15	36.15	24.34	1.49	60.80	60.21	-0.59
17	6.24	35.21	35.21	23.64	1.13	59.31	59.1	-0.21
16	7.37	34.25	34.25	23.45	1.39	58.18	57.93	-0.25
15	8.78	33.32	33.32	22.99	1.20	56.77	56.65	-0.12
14	9.96	32.38	32.38	22.73	1.42	55.59	55.41	-0.18
13	11.38	31.40	31.40	22.30	1.37	54.17	54.03	-0.14
12	12.74	30.41	30.41	21.91	1.37	52.81	52.79	-0.02
11	14.11	29.43	29.43	21.50	1.42	51.44	51.47	0.03
10	15.53	28.42	28.42	21.10	1.54	50.02	50.08	0.06
9	17.09	27.41	27.41	20.57	1.58	48.46	48.7	0.24
8	18.65	26.41	26.41	19.99	1.58	46.90	47.26	0.36
7	20.23	25.37	25.37	19.44	1.68	45.32	45.72	0.40
6	21.94	24.32	24.32	18.768	1.63	43.61	44.21	0.60
5	23.57	23.26	23.26	18.192	1.66	41.98	42.63	0.65
4	25.20	22.18	22.18	17.64	1.94	40.35	40.91	0.56
3	27.14	21.08	21.08	16.80	1.80	38.41	39.12	0.71
2	28.92	19.97	19.97	16.10	1.82	36.63	37.67	1.04
1	30.74	18.85	18.85	15.38	1.49	34.81	36.15	1.34
Count Station	32.23	18.75	18.75	N/A	0.00	33.32	34.38	1.06
248	32.23	16.35	30.75	15.77	2.66	33.32	33.82	0.50
247	34.90	13.95	28.35	15.50	2.26	30.65	31.03	0.38
246	37.15	11.55	25.95	15.65	2.66	28.40	28.54	0.14
245	39.82	9.15	23.55	15.38	N/A	25.73	25.65	-0.08

The CFD model tended to underpredict energy dissipation when compared to the physical model; this is due to the CFD turbulence models averaging the effect of turbulence on the solution and not refining the eddy turbulence losses within each pool. Because of this, the model couldn’t support the prescribed head level in the forebay channel without requiring more flow. The CFD model calculated a flowrate of 1.6 cfs, compared to the 1.29 cfs reported from the physical model, based on the upstream water surface elevation boundary. Even with the flowrate difference, the largest difference between the pool levels when comparing the CFD model to the physical model was in pool 1, with the CFD water surface elevation being 1.34 inches higher. This equates to a prototype difference of near half a foot, which was deemed as within reasonable error when comparing the models. Because the CFD model has higher energy due to the lack of energy dissipation that is present in the prototype, it is also considered a conservative model and should give a conservative estimate of the velocities for the new design of the Washington shore control section. The overestimation of flow in the CFD model also reduces the risk that the new design will increase the approach flow to the count station above existing operations; an increased flow would reportedly overtax the count station and trash rack upstream of the window.

Graphs comparing physical model velocities with the CFD model output at a representative pool and within the count station show a consensus between the flow patterns and velocity magnitudes in the two models. The graphs are included in Appendix G. Overall, the CFD modeling approach was validated for use in the redesign of the Washington shore control section, and a CFD model of the proposed modifications was created.

3.3.3.2 *CFD Modeling of Proposed Modifications*

The CFD model of the Washington shore control section extends from the upstream extent of the fish ladder exit channel to a location directly upstream of Weir 67 where water surface elevations are known. The CFD model includes the exit channel, the full control section and make-up water supply channel including the Tainter valve, add-in and bleed-off diffusers, the count station, attraction pool and picket leads, the upper junction pool, and a portion of the UMT channel, including the weir used to control flow and water surface in the UMT channel. Figure 3-7 highlights the extents of the CFD model, and an isometric of the model looking upstream is shown in Figure 3-8.

Figure 3-7. Washington Shore Ladder Control Section, CFD Model Extents

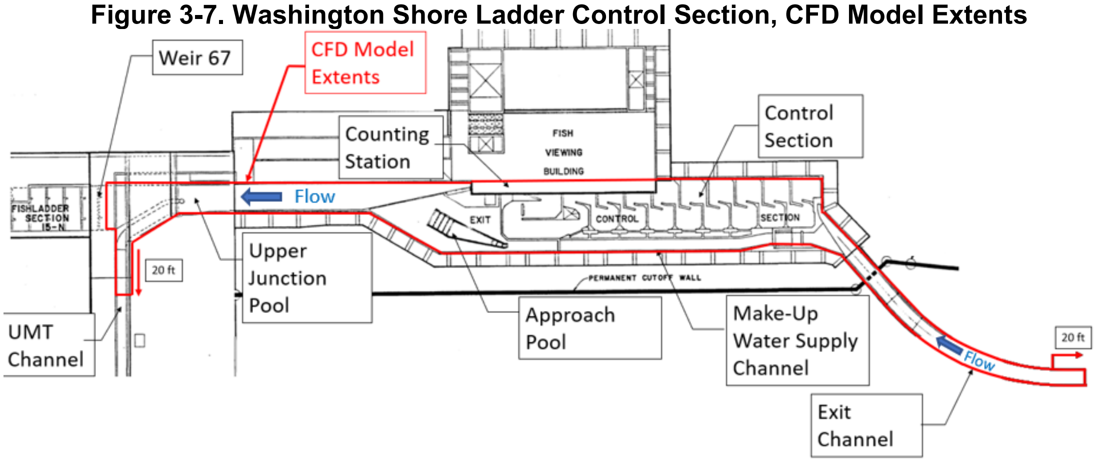
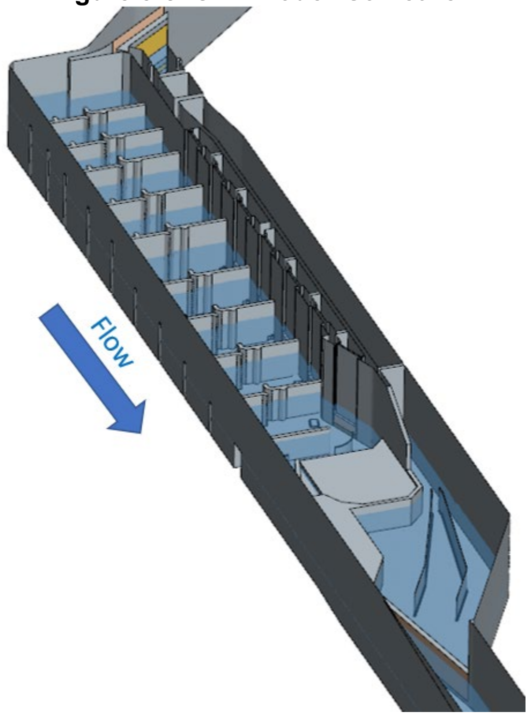


Figure 3-8. CFD Model Isometric



The model of the proposed design was near 4.4 million cells and included a stagnation pressure boundary for forebay elevation as the upstream boundary, a pressure boundary for both the Weir 67 pool and the UMT channel water surface elevations, and operable settings for the upstream Tainter valve and count station for adjustment of flow through the model.

The final documentation runs for the CFD model used the maximum forebay, 5-, 50-, and 95-percent exceedance elevations, and minimum forebay elevations. The model was also used to document the 5-, 50- and 95-percent exceedance elevations with the ladder running in "shad mode", which increased the head level over weir 67 to 1.5 ft[1]. Lastly, to evaluate the effects of turbulence closure models on the design, two runs at the 74.5 ft forebay were completed with both a Large Eddy Simulation (LES) and Detached Eddy Simulation (DES) turbulence model. A table of the different run boundary conditions is shown in Table 3-7.

[1] A communication error resulted in the model being run with 1.5 foot head drop for shad mode. Elsewhere, this is reported as 1.3 foot +/-0.1 foot. The completed runs are deemed sufficient for the purpose of illustrating the approximate effect of the alternative operation.

Table 3-7. Run Summary: CFD Model Boundary Settings, Final Geometry

Run Type	Exceedence	Run	FBL (ft)	FB-to-Channel HL (ft)	AWS WSEL (ft)	Weir 67 WSEL (ft)	UMTC Weir WSEL (ft)	TV Opening (ft)	TV Opening (deg)	Count STA Open (ft)	Turbulence Model
	Max	1	77	0.07	76.93	68	66.5	0.50	5.00	1.5	KE
1 ft diff	5%	2	76	0.06	75.94	68	66.5	0.62	6.15	1.5	KE
	50%	3	74.5	0.05	74.45	68	66.5	0.96	9.62	1.5	KE
	95%	4	72.7	0.04	72.66	68	66.5	1.38	13.77	1.5	KE
	Min	5	70	0.02	69.98	68	66.5	2.00	20.00	1.5	KE
1.5 ft diff	5%	6	76	0.06	75.94	68.5	67	0.62	6.15	1.5	KE
	50%	7	74.5	0.05	74.45	68.5	67	0.96	9.62	1.5	KE
	95%	8	72.7	0.04	72.66	68.5	67	1.38	13.77	1.5	KE
LES/DES Check	50%	9	74.5	0.05	74.45	68	66.5	0.96	9.62	1.5	LES
	50%	10	74.5	0.05	74.45	68	66.5	0.96	9.62	1.5	DES

* FBL = Forebay Level, HL = Headloss, WSEL = Water Surface Elevation, UMTC = Upstream Migrant Transport Channel, TV = Tainter Valve, KE = K Epsilon Turbulence Model, LES = Large Eddy Simulation, DES = Detached Eddy Simulation

The initially proposed modifications included replacing the serpentine baffles with vertical slot and orifice baffles, having both an 18-inch square orifice and a small lamprey orifice.

During design development a wide range of refinements were considered, including: orientation of the slots (north vs. south), location of the lamprey orifices (centered on baffle vs. flush to wall); lamprey orifice shaping, bollards at lamprey orifices, lamprey refuge box positioning, diffuser orifice size, and various S-curve arrangements. Details on the intermediate refinements are provided in Appendix G.

The final design geometry was refined from the initial design to include 1-foot thick baffles (original design was 10-inches), a modified S-curve section which decreased the distance fish would need to travel up the ladder, 1-foot tall plates installed at the bottom of the Add-In Diffuser 1 and 2 grates to provide additional lamprey passage opportunities, a flow restrictor plate on the orifice plate for Add-In Diffuser 1 to make the open area equivalent to the orifice plate on Add-In Diffuser 2, modified lamprey orifice location (moved from mid-baffle to the south wall), shaping the lamprey orifice to have a sharp-edged upstream profile and downstream radius, and refinement of the slot and orifice geometry to include PSMFC's initial shaping for the PIT tag detectors. These changes were made using input from the PDT, FFDRWG, PSMFC, and the Agency Technical Review (ATR) team and the design shown in this DDR provides the hydraulic and physical conditions that are expected to most improve fish passage. The reasoning and evaluation of these changes are documented in Appendix G.

The main objective of the control section modifications is to keep the velocities through the slots and orifices as low as possible for lamprey passage while also meeting the NMFS guideline to maintain head drops between 0.25 and 1.0 feet through the control section for salmonid passage. The focus is to meet the design objectives for the 5-percent to 95-percent exceedance conditions. The model was also used to document the hydraulic conditions for the minimum and maximum pool elevations. The velocity through each slot and orifice for all 10 runs are shown in Table 3-8, and the water surface elevations (WSEs) and associated head drops for each pool are shown in Table 3-9. Note that runs 2, 3, and 4 show the ladder in standard operating mode (1.0 foot head drop) over the design range of forebay elevations.

The new design meets head drop criteria for all the design cases (forebay elevations 72.7 feet to 76 feet), while still maintaining reasonable drops for the minimum and maximum pool elevation. The NMFS criteria document additionally states that flow velocities greater than 12 ft/s over 90 percent of the cross-section constitute a passage impediment for salmonids. For the design forebay range, the average velocities through the large orifices and slots were about 8 ft/sec or less, and the average velocities through the lamprey orifices were 5-7 ft/sec or less.

Table 3-8. CFD Velocity Comparison, Final Geometry

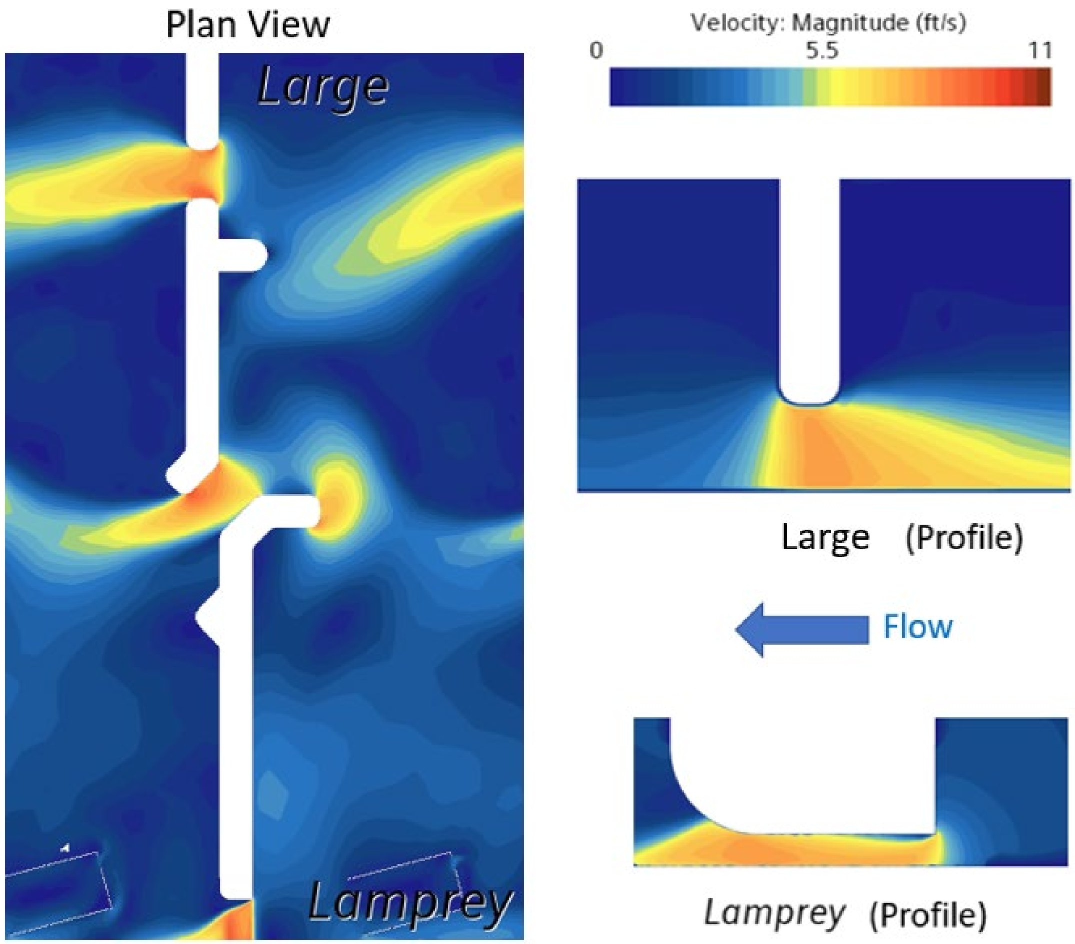
Run	1		2		3		4		5		6		7		8		9		10	
FB El. (ft)	77		76		74.5		72.7		70		76		74.5		72.7		74.5		74.5	
Location	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)
Lamprey_1	6.0	7.9	5.6	7.3	5.1	6.5	4.6	5.8	3.3	4.1	5.1	6.7	4.5	5.7	3.9	4.9	4.2	7.7	4.4	6.1
Lamprey_2	6.2	8.3	5.8	7.8	5.1	6.8	4.4	5.9	3.0	3.8	5.5	7.3	4.8	6.4	4.2	5.5	4.8	7.6	5.4	6.5
Lamprey_3	6.7	8.3	6.2	7.9	5.7	7.4	4.8	6.2	3.0	3.8	6.2	7.9	5.4	6.9	4.5	5.8	5.7	8.4	5.6	7.4
Lamprey_4	7.3	8.8	6.7	8.2	5.9	7.5	5.0	6.5	3.0	3.8	6.6	8.1	5.8	7.3	4.9	6.3	5.8	8.1	6.8	8.0
Lamprey_5	7.4	8.9	6.9	8.3	5.9	7.6	4.9	6.3	3.0	3.7	6.8	8.3	5.8	7.3	4.9	6.2	6.6	9.2	6.2	7.9
Lamprey_6	7.5	9.4	6.9	8.7	6.0	7.7	4.7	6.1	2.9	3.4	7.0	8.6	6.0	7.6	4.6	6.0	6.6	8.5	6.6	8.5
Lamprey_7	7.0	9.3	6.5	8.8	5.8	7.7	4.4	6.0	2.6	3.5	6.5	8.7	5.6	7.6	4.4	5.9	6.4	10.5	5.5	8.0
Lamprey_8	7.3	9.6	6.7	9.1	5.9	8.1	4.4	6.2	2.6	3.5	6.7	9.0	5.8	8.0	4.3	6.2	5.2	8.0	5.7	7.2
Lamprey_9	4.8	6.1	5.2	6.3	4.6	5.7	3.5	4.1	2.3	2.7	5.2	6.3	4.9	5.8	3.5	4.0	3.9	6.0	3.4	4.5
Orifice_1	7.7	9.6	7.1	8.7	6.3	8.1	5.7	7.1	3.9	5.0	6.6	8.2	5.7	7.3	4.8	6.3	4.8	7.7	6.3	7.7
Orifice_2	8.0	8.6	7.5	8.1	6.7	7.2	5.8	6.2	3.5	3.8	7.1	7.6	6.2	6.7	5.4	5.7	6.3	8.2	6.5	7.8
Orifice_3	7.5	10.1	7.0	8.5	6.4	8.0	5.6	6.7	3.3	4.1	7.0	7.9	6.2	8.0	5.3	6.5	5.8	9.3	6.3	8.4
Orifice_4	8.0	9.1	7.6	8.4	6.7	7.7	5.7	6.3	3.3	3.7	7.4	8.3	6.6	7.3	5.5	6.1	6.4	8.3	6.3	8.1
Orifice_5	7.8	9.1	7.6	8.8	6.9	7.8	5.7	6.2	3.2	3.6	7.5	8.8	6.8	7.4	5.5	6.0	6.4	8.5	6.7	7.9
Orifice_6	7.7	8.8	7.6	8.8	6.8	7.7	5.6	6.1	3.0	3.3	7.2	8.5	6.8	7.6	5.6	6.2	7.4	9.9	6.1	7.0
Orifice_7	8.5	10.0	8.1	9.5	7.6	8.8	6.1	6.9	3.5	4.0	8.0	9.5	7.6	8.7	6.0	6.7	7.5	10.1	6.2	7.8
Orifice_8	8.3	9.5	7.9	9.0	7.4	8.3	5.7	6.4	3.6	4.0	7.8	9.0	7.4	8.4	5.7	6.3	7.9	11.9	7.4	9.2
Orifice_9	7.9	10.4	7.7	10.2	7.1	9.2	5.8	7.3	3.6	4.2	7.7	10.1	7.0	8.8	5.8	7.2	7.2	9.5	8.0	10.7
Slot_1	6.1	7.6	5.6	6.9	5.1	6.1	4.7	5.6	3.1	3.9	5.1	6.4	4.4	5.4	3.8	4.6	5.5	7.3	5.4	6.5
Slot_2	6.6	8.0	6.1	7.4	5.4	6.6	4.8	5.6	3.1	3.7	5.8	7.1	5.1	6.1	4.4	5.2	5.7	8.2	5.9	7.1
Slot_3	7.0	8.6	6.5	8.0	5.9	7.1	5.2	6.2	3.2	3.8	6.3	7.7	5.6	6.7	4.9	5.8	6.1	8.6	6.8	7.8
Slot_4	7.4	9.1	6.8	8.4	6.1	7.5	5.2	6.3	3.2	3.8	6.7	8.2	5.9	7.2	5.0	6.0	6.4	8.7	6.9	8.4
Slot_5	7.6	9.2	7.0	8.6	6.3	7.5	5.2	6.3	3.1	3.7	7.0	8.6	6.1	7.4	5.1	6.2	6.3	8.7	6.9	8.3
Slot_6	7.7	9.2	7.2	8.6	6.4	8.0	5.2	6.3	3.0	3.8	7.1	8.6	6.3	7.7	5.1	6.2	6.2	8.6	7.2	9.3
Slot_7	7.6	9.4	7.1	8.6	6.2	7.6	4.8	6.0	2.8	3.5	7.0	8.5	6.2	7.5	4.8	6.0	6.2	9.1	7.3	10.5
Slot_8	7.7	9.3	7.2	8.9	6.4	7.8	5.1	6.4	3.0	3.5	7.2	8.9	6.3	7.8	5.0	6.4	5.8	9.0	7.2	8.9
Slot_9	7.2	8.6	7.1	8.5	6.3	7.7	5.1	6.3	2.9	3.7	7.0	8.4	6.3	7.6	5.0	6.2	6.0	7.7	6.7	8.1

Table 3-9. CFD WSE and Pool Head Drop Summary, Final Geometry

Run	1		2		3		4		5		6		7		8		9		10	
FB El. (ft)	77		76		74.5		72.7		70		76		74.5		72.7		74.5		74.5	
Location	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop
Weir 67	67.9		67.9		67.9		67.9		67.9		68.4		68.3		68.4		67.8		67.9	
UMTC	68.0		68.0		67.9		67.9		67.9		68.4		68.4		68.4		68.0		68.0	
Intake Channel	76.7		75.7		74.2		72.4		69.8		75.7		74.2		72.4		74.3		76.7	
FB	76.6		75.7		74.2		72.3		69.6		75.7		74.1		72.3		74.1		76.6	
Count	68.5		68.4		68.4		68.2		68.1		68.8		68.7		68.6		68.4		68.5	
AWS	68.4		68.3		68.0		67.8		67.6		68.7		68.7		68.3		67.6		68.4	
10	76.5		75.6		74.1		72.4		69.7		75.6		74.1		72.4		74.1		76.5	
9	75.7	0.9	74.7	0.9	73.4	0.7	71.9	0.5	69.5	0.2	74.8	0.8	73.4	0.7	71.9	0.5	73.3	0.8	75.7	0.9
8	74.7	1.0	73.8	0.9	72.7	0.7	71.4	0.4	69.4	0.1	73.9	0.9	72.7	0.7	71.5	0.4	72.6	0.7	74.7	1.0
7	73.8	0.9	73.0	0.8	72.0	0.7	71.0	0.5	69.1	0.2	73.1	0.8	72.1	0.6	71.0	0.5	71.7	0.9	73.8	0.9
6	72.9	0.9	72.3	0.8	71.5	0.5	70.5	0.5	69.0	0.1	72.2	0.9	71.4	0.7	70.5	0.5	71.3	0.4	72.9	0.9
5	71.7	1.2	71.2	1.0	70.6	0.9	70.0	0.5	68.8	0.3	71.3	0.9	70.6	0.8	70.0	0.5	70.4	0.9	71.7	1.2
4	70.9	0.8	70.4	0.8	70.1	0.5	69.5	0.4	68.7	0.1	70.7	0.6	70.1	0.5	69.7	0.4	69.9	0.5	70.9	0.8
3	70.0	0.9	69.7	0.7	69.4	0.7	69.2	0.4	68.5	0.1	69.9	0.8	69.6	0.5	69.3	0.3	69.4	0.5	70.0	0.9
2	69.2	0.8	69.1	0.7	68.9	0.5	68.7	0.5	68.3	0.2	69.3	0.6	69.1	0.5	68.9	0.4	68.8	0.6	69.2	0.8
1	68.6	0.6	68.5	0.6	68.4	0.5	68.4	0.3	68.1	0.2	68.7	0.5	68.7	0.4	68.7	0.2	68.5	0.3	68.6	0.6

Shaping for each of the slots and orifices was intended to provide optimal flow paths for salmonid and lamprey passage up the ladder. Figure 3-9 shows an example of the flow patterns through each passage route for a 76-foot forebay elevation run, which represents the highest design flow. The intent was to have a “free stream” velocity profile through the middle of the large orifice and the baffles, where the higher velocities would be around the edges and the lower velocities would be towards the middle of the openings. The lamprey orifices were too small to produce this flow profile, so a sharp edge was added to provide a flow separation on the north side of the orifice. This provides an ideal approach area for lamprey to attach and burst through as the progress up the ladder and decreased the hydraulic efficiency and associated velocity through the orifice. Additional figures similar to this one are available for other flow conditions in Appendix G.

Figure 3-9. Slot and Orifice Velocity Contours, Forebay El. 76 (5% Exceedance)



The flow characteristics in the model were investigated using horizontal planes cut through the CFD domain at various elevations, and mapping flow contours with velocity magnitude. The three different section cuts through the ladder include: at the centerline of the lamprey orifice (0.85-in above the floor), at the centerline of the large orifice (9.8-in above the floor), and at mid-depth of the pools on a slope that matched the overall slope of the water surface through the ladder pools. Run 3 (50 percent exceedance), with a forebay elevation of 74.5 feet NGVD 29, was selected as a representative flow condition. The mid-depth cross section and lamprey orifice cross section were the most informative and are shown in Figure 3-10. The other cross sections are included in the Appendix G. For visual comparison, the existing conditions model results are shown in Figure 3-11.

Figure 3-10. Modified Control Section, Forebay El. 74.5, Mid-Depth Velocity and Lamprey Orifice Plane Velocity

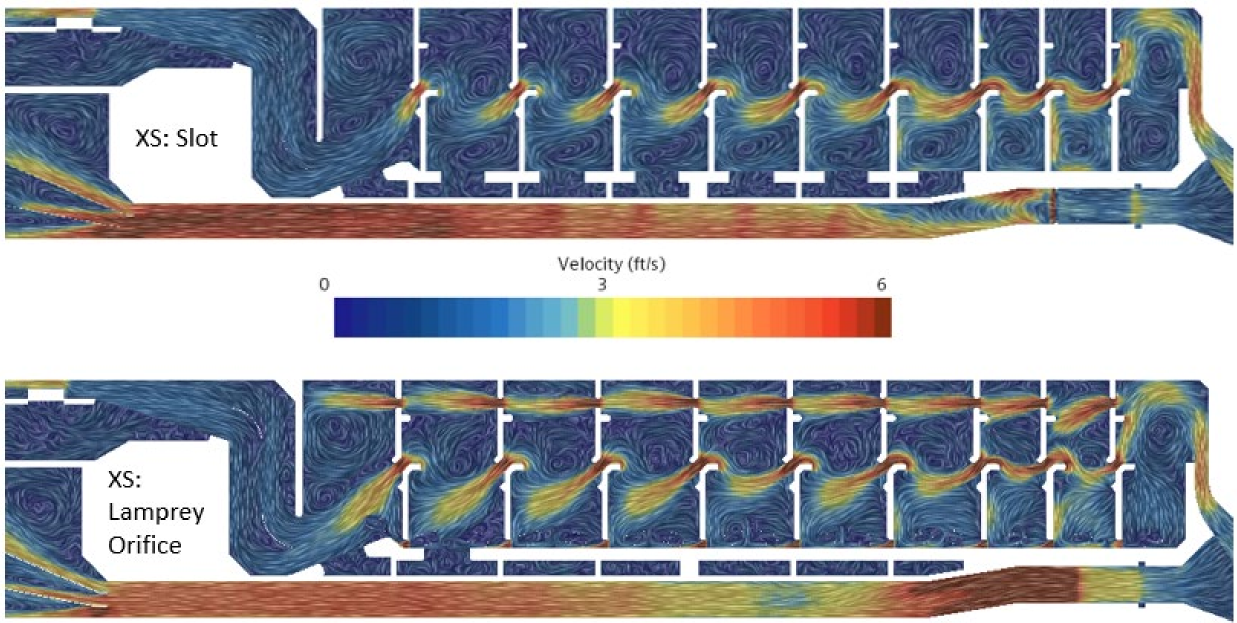
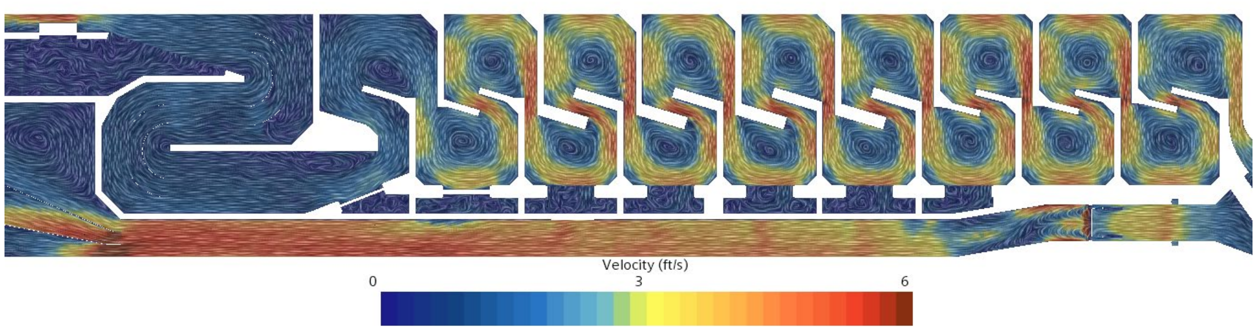


Figure 3-11. Existing Conditions, Forebay El. 74.5, Mid-Depth Velocity



The mid-depth cross section for the modified exit control section geometry shows defined recirculation patterns at the north and south sides of each ladder pool. The cross section through the lamprey orifice shows a well-defined flow path between each large orifice and slot jet. The new S curve area provides a well-distributed, more direct flow path between the count station and the first pool of the exit control section.

In general, the CFD model exhibited a strong alignment with the initial design calculations pertaining to the exit control section redesign, while also offering insights into design features that could be further refined for enhanced performance. The comprehensive evaluation of numerous alternatives and analyses using the CFD model facilitated a reasonably swift and cost-effective means of testing these design features, ultimately contributing to the informed decision-making process that informed the final design. Detailed documentation of all these alternatives can be found in Appendix G.

3.4 HYDRAULIC FEATURES OF THE WORK

The primary hydraulic features of the work include the control section baffles, add-in and bleed-off diffusers and the count station.

3.4.1 Control Section General Layout

The existing serpentine baffles will be fully demolished and replaced. The new control section will include nine new baffle pairs that will form ten pools within the control section. Each baffle pair will have two orifices and one vertical slot to provide passage routes and resting areas for fish and to induce head loss to accommodate fluctuations in the forebay elevation while maintaining around one foot of head and 80 to 120 cfs at the uppermost ladder weir, Weir 67, and 75 to 85 cfs in the UMT. The existing exit channel and exit gate will remain in place, unchanged. The count station will also be unchanged, but the S-curve section upstream of the count station will be shortened and the removed flow area will be filled in. See SG101 in Appendix A for a plan view showing the general layout of the control section.

3.4.2 Control Section Baffles

The control section is 27.5 feet wide with a constant floor elevation at EL 63.0 feet, NGVD 29. The control section baffles are aligned with the existing bleed-off and add-in diffusers and to avoid the visitor center viewing windows, where applicable. This was done to facilitate the structural connection of the new baffles to the existing walls and to avoid interference between the baffles and the diffusers. The baffles are spaced about 15.3 feet adjacent to the bleed-off diffusers. The spacing varies from 11.3 feet to 16.75 feet for all other pools. The energy dissipation factor (EDF) was checked for each pool at the full pool elevation, EL 77.0 feet; the maximum (EDF) is 2.8 ft-lbs/s/ft^3, which is well below the NMFS criterion of less than or equal to 4 ft-lbs/s/ft^3.

The control section baffle pairs each have a vertical slot and two orifices: an 18-inch square orifice and a 1.5-inch-tall by 16-inch-wide lamprey orifice. The slot widths vary from 1 foot-6 inches to 1 foot-8 7/16 inches; the slot widths were established to balance the head drop between pools while also providing sufficient opening to accommodate staff during fish salvage operations. All openings will be flush with the control section floor. The larger orifice will be located 4 feet from the north wall of the control section; this will encourage more salmon to pass close to the visitor center viewing window. The lamprey orifices will be located along the south ladder wall, and the associated refuge boxes will be located in-line with these orifices. The orifice edges will be sharp-edged on the upstream side and rounded on the downstream side, except where PIT tag antennas are to be installed. The PIT tag antenna housings will have chamfered edges with angles less than or equal to 45 degrees and any sharp edges will be sanded smooth. The hydraulic profile, head differential, orifice and slot velocities were computed using the CFD model. CFD model results are provided in Section 3.3.3.2, and the full modeling report is documented in Appendix G.

3.4.3 Add-in and Bleed-Off Diffusers

The add-in and bleed-off diffusers will continue to be used, in conjunction with the make-up water supply channel Tainter valve to balance the flow between the control section and the make-up water supply channel as the forebay elevation changes. The hydraulic conditions with the existing diffusers and orifice sizes were checked using the CFD model, and a restrictor plate was designed for the orifice on Add-In Diffuser 1 to match the open area of the plate for Add-In Diffuser 2. One-foot-tall metal plates will also be installed on the ladder side of the add-in diffusers, starting at the invert of the ladder, to provide another attachment and passage route for lamprey. These plates were not found to affect the flow conditions of the add-in diffusers in the CFD model.

3.4.4 Count Station

No changes are proposed for the count station. A reduced length S-curve section was developed to improve passage conditions between the count station and the control sections. The existing polygonal-shaped concrete mass at the downstream end of the control section will also be removed. See SG101 in Appendix A for a plan view showing the general layout of the control section.

SECTION 4 - STRUCTURAL DESIGN

4.1 DESIGN STANDARDS AND REFERENCES

4.1.1 Standards

The Bonneville Washington shore fish ladder control section modification has structural features that will be constructed using a combination of new and existing concrete, carbon steel, stainless steel, and fiber reinforced polymer (FRP) reinforcement. The work will also include demolishing structural features that are no longer needed.

4.1.1.1 *Concrete*

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

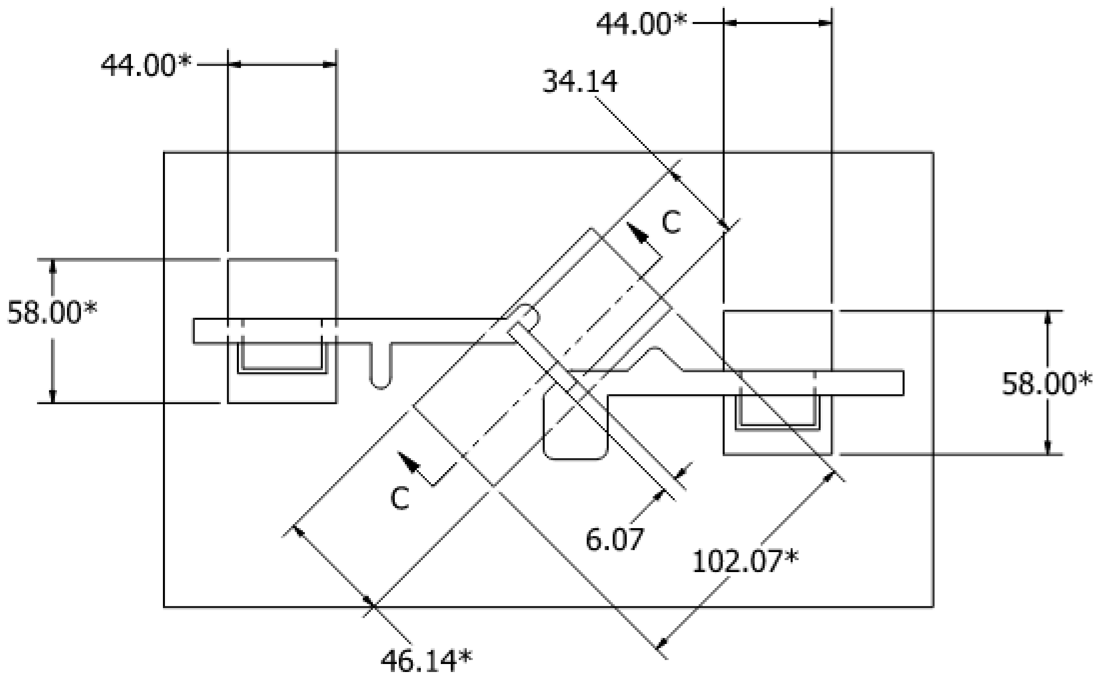
4.1.1.2 *Structural Steel*

The designs for features made of these materials will conform to ETL 1110-2-584 for hydraulic steel structures and to AISC “Specifications for Structural Steel Buildings” for other structural steel features. All welding will conform to the American Welding Society Structural Welding Code, Current Edition, D1.1 for the appropriate material.

4.1.1.3 *Non-Ferrous Metal*

Nonferrous metal must be used adjacent to the PIT tag antennas. Ferrous steel will cause detrimental interference of the field. See Figure 4-1 below from Pacific States showing the required non-ferrous metal region. The vertical boundaries (which aren’t shown below) are 12 inches above and below any PIT antenna openings.

Figure 4-1: Pacific States Diagram for Non-Ferrous Metals near PIT Antennas



note dimensions are in inches

The baffle pairs with PIT antennas will be consist of 100% of FRP rebar. For several reasons (like constructability), the PDT determined that it would be a better design to not mix rebar types in a single baffle (i.e. carbon and FRP bars together).

There are several nonferrous metal features in and around the baffles with PIT tag antennas such as FRP rebar, concrete anchors, antenna hold-downs, rain/sun shields, etc. Type 304 stainless steel will be used for the PIT tag antenna hold-downs and concrete anchors. Type 3003 aluminum will be used for non-load bearing items such as the rain/sun shields.

4.1.1.4 *Fiber Reinforced Polymer Rebar*

Fiber Reinforced Polymer (FRP) bars are required for concrete reinforcement in proximity to the PIT tag antennas, see Section 4.1.1.3. FRP design will follow the ASTM Standard Spec, D7957/D7957M “Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement”.

4.1.1.5 *Fiberglass Composites*

Fiberglass stairs, walkways, and guardrail will be used to access the four baffles with PIT tag antennas. Fiberglass will be used because of the proximity to the antennas. The walkway will be contractor designed. A contractor design was used during the 2007 initial installation of the PIT tag antennas. This approach was selected again because it will save design time, can be easily ordered from commercial suppliers and ENC-DS does not have experience designing complex walkway systems.

Products available from commercial suppliers include stairs, work platforms, gratings, and guardrails.

Fiberglass will provide additional benefit to the project because of its corrosion resistance. The access walkways are in the splash zone of the ladder flow and will experience frequent wetting and drying.

4.1.2 References

- American Association of State Highway Officials (AASHTO) Manual for Bridge Evaluation, 2018
- American Concrete Institute (ACI) 318-19 – Building Code Requirements for Structural Concrete, 2022
- American Institute of Steel Construction (AISC) – AISC 360
- American Society of Civil Engineers (ASCE) 7-16 - Minimum Design Loads for Buildings and Other Structures.
- EM 1110-2-2000 - Standard Practice for Concrete.
- EM 1110-2-2104 - Strength Design for Reinforced Concrete Hydraulic Structures
- ETL 1110-2-584 - Design of Hydraulic Steel Structures
- ER 1110-2-1806 - Earthquake Design and Analysis for Corps of Engineers Projects.
- USACE. ETL 1110-2-584. Design of Hydraulic Steel Structures, 2014
- LRFD Bridge Design Specifications, 9th Edition

4.2 STRUCTURAL CRITERIA AND CONSIDERATIONS

4.2.1 Materials

The material properties for the new and existing structures are:

Concrete/Grout:
- Existing Concrete: f'c = 3,000 pounds per square inch (psi) (Second Powerhouse, Design Memorandum No. 13, Structural Design, February 1977).
- New Concrete: f'c = 4,500 psi (EM 1110-2-2014 and ACI 318-19).
- Grout: f'c = 5,000 psi at 7 days.

Reinforcement:
- Existing Steel Reinforcement: fy = 33,000 psi (AASHTO MBE, prior to 1954).
- New Steel Reinforcement: fy = 60,000 psi (ASTM A615, Grade 60).
- FRP Reinforcement: fy = 80,000 psi (ASTM D7957 and ACI 440.1R-15)

Structural Members:
- Carbon steel structural shapes: fy = 50,000 psi (ASTM A572, Grade 50)

Non-Ferrous Metals:

- 304 Stainless Steel: fy= 30,000 psi (ASTM A240)
- 3003 Aluminum: fy = 40,000 psi (ASTM B221)
- 5052 Aluminum: fy = 28,000 psi (ASTM B209)
- 6061 Aluminum: fy = 40,000 psi (ASTM B308)

4.2.2 Assumptions

- Ferrous Materials: No ferrous features or materials are allowed within 12-inches of the PIT tag antennas, or as specifically identified in Figure 4-1.
- PIT Tag Antenna Access: This design team will provide a conceptual design of the access features (platforms, walkways, etc.) needed for the PIT tag antennas. However, the final design of the access walkway features will be done by the contractor and approved by the government.
- Hydraulic Concrete Structures: hydraulic structures that are permanent, concrete submerged structures (baffles, concrete pyramid).
- Hydraulic Steel Structures: For this work, there are no hydraulic steel structures because there is no risk for life loss.
- Non-hydraulic Structures: Include all temporary structures and features that are not submerged (platforms, walkways, support beam).

4.3 DESIGN METHODS AND LOADS

4.3.1 Risk Category and Importance Factors

All structures as part of this project are designed as Risk Category I, per ASCE 7, Table 1.5-1. Importance factors are selected accordingly.

4.3.2 Live Loads

Maintenance crews will need to access the PIT tag antennas via walkways on the top of the baffles. Pedestrian loading is in accordance with ASCE 7-16, Chapter 4 and will be taken as 60 pounds per square foot (psf) for “Walkways and elevated platforms” (ASCE 7-16, Table 4.3-1).

4.3.3 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 pounds per cubic inch) per AISC manual.

4.3.4 Wind

Wind loads are not considered for this design. The wind loading inside the ladder is greatly reduced because it is below ground level. Additionally, there is minimal freeboard on the baffles.

4.3.5 Hydrostatic/Hydrodynamic

The permanent structural features (new baffles) exposed to flow shall be designed to resist static and hydrodynamic forces due to fish ladder flows associated with the forebay elevation tied to the 100-year event.

4.3.6 Seismic

Seismic loads will be based on requirements of the International Building Code 2018 and ASCE 7-16 documents. (https://www.seismicmaps.org/)

- Site Class: B (Typical for Bonneville)
- Risk Category I
- Design Ground Motion: Ss: 0.61, S1: 0.277, Sds: 0.366, Sd1: 0.147

The inertial dynamic force due to water is determined using Westergaard's equation.

Equation 4-1. Westergaard's Equation

$$p = 0.875W * a_c\sqrt{H * y}$$

Where:

- p = hydrodynamic pressure.
- W = unit weight of water.
- a_c = the maximum base acceleration of the dam (expressed as a fraction of gravitational acceleration).
- H = the reservoir height (to the bottom of the dam).
- y = the depth below the pool surface.

4.4 STRUCTURAL FEATURES OF WORK

The structural features required for this project are:

- Shoring/Demolition Plan
- Standard baffles (steel rebar)
- Baffles with PIT tag antennas (FRP Rebar)
- Access walkways, stairs, and Guardrails
- PIT tag antenna supporting infrastructure (rainshield, electrical panel mounting, hold downs)
- Diffuser lamprey plates and orifice restrictor
- S-curve section modifications (concrete fill, flow vanes, access)
- Electrical conduit support beam

- Lamprey refuge boxes

4.4.1 Shoring/Demolition Plan

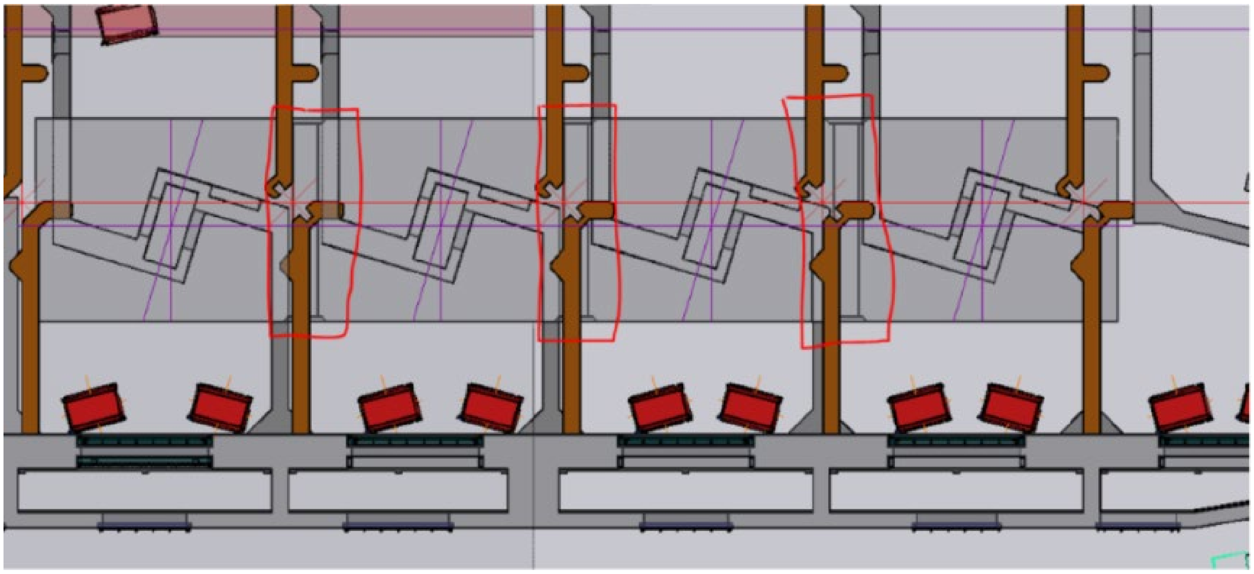
The plan during the DDR phase was to completely remove the invert and place new concrete with non-ferrous rebar in the locations near the 4 PIT antenna baffles. Existing counterforts spaced every 16' on the outside ladder walls would resist ladder wall cave in from soil pressure using 15, #9 bars. The invert would be removed and placed in sequences to prevent cave in in the lower portion of the ladder walls.

However, this was determined to not be a reasonable option for two reasons. The first issue is the steep cost of fully removing the invert. This would require an area of roughly 55' x 26' x 2' to be demolished and replaced with new concrete and non-ferrous rebar. The next issue was the need to construct in sequences during a tight construction window. The contractor will need to complete this work in an accelerated timeline during the winter outage period. This would require two different major concrete pours and heavy machinery within the ladder to make this work.

The new plan post DDR is to demolish the baffles and patch the removed areas. Then the new baffles will be doweled and placed into the existing invert. This will be quite a bit cheaper and easier to construct. However, it will not be as structurally sound due to all patch work on the surface of the invert.

One thing to consider is the existing struts in the invert. They are carbon steel, round HSS members used in the 2004 construction to prevent the invert from caving in during construction. They are almost directly under the new PIT antenna and thus will require complete removal to ensure there are no ferrous metals within the PIT antennas field. These struts can be seen below:

Figure 4-2: Existing Struts in the Invert shown in the red rectangles. Note the location of the new PIT antennas (shown in orange)



4.4.2 Standard Baffles (using Steel Rebar)

The existing control section baffles will be removed and replaced with 12-inch thick (per EM 1110-2-2104), vertical slot and orifice-type baffle pairs like the JDAN and Ice Harbor fish ladder control sections. The north baffles tie into the fish viewing building and ladder wall. The north baffles will incorporate 18-inch by 18-inch fish orifices. The south baffles tie into the fish ladder wall sections between the diffusers and will incorporate 1.5-inch by 16-inch lamprey orifices.

A total of 18 existing serpentine baffles (9 pairs) will be removed and replaced with 9 slot and orifice baffle pairs.

The geometry across the baffles is almost identical. The only geometric differences are the baffle heights and center slot opening distances. Generally, moving from upstream to downstream along the fish ladder the baffles become shorter, and the openings become wider. These differences are required to control flow and head drop in the ladder, see Section 3.4. The tallest baffle is roughly 13.5 feet and the shortest baffle is roughly 6.5 feet. The largest slot opening is 1.7 feet and the smallest opening is 1.5 feet.

The major difference between the nine baffles are the PIT tag antennas in built into Baffles 3 – 6. Baffles 1 and 2 and 7 through 9 are standard hydraulic baffles with no PIT tag antennas. The section below describes the standard baffles. See Section 4.4.3 for a description of the baffles with PIT tag antennas.

For the standard baffles, standard 60 ksi steel rebar with #5 bars will be used. Around the orifices, #5 bars will be used at corners like they're used in concrete buildings at openings.

The baffles will be dowelled into the channel walls and invert of the fish ladder using #5 deformed bars and epoxy. The 12-inch-thick baffles will be anchored using post-installed dowels with 15-inch embedment, spaced every 12-inches vertically (into walls) and horizontally (into invert). Calculations determined a larger concrete flair-out at the attachment point as used in the existing design (see Plate SD101 for an example of a flared connection) is not required for anchoring the baffles to the walls, see Appendix E. The baffles will connect to the ladder walls at 90-degree angles.

Waterstops will be used at the baffle-to-invert joint to prevent water seepage into the concrete at only the non-PIT antenna baffles.

4.4.3 PIT Tag Antenna Baffles (FRP Rebar)

As noted above Baffle pairs 3 through 6 will incorporate PIT tag antennas in the baffle slots and orifices.

The PIT tag antennas are used for tracking fish and are an important part of the new modifications. These antennas are custom fabricated by PSMFC and will be installed in slots and orifices of four baffle pairs. As the fish swim their way up the ladder, they swim through these openings and are tracked via the antennas. All three openings at the PIT tag antenna baffles will have antennas, meaning there is no way tagged lamprey and other fish can swim through the ladder without being tracked.

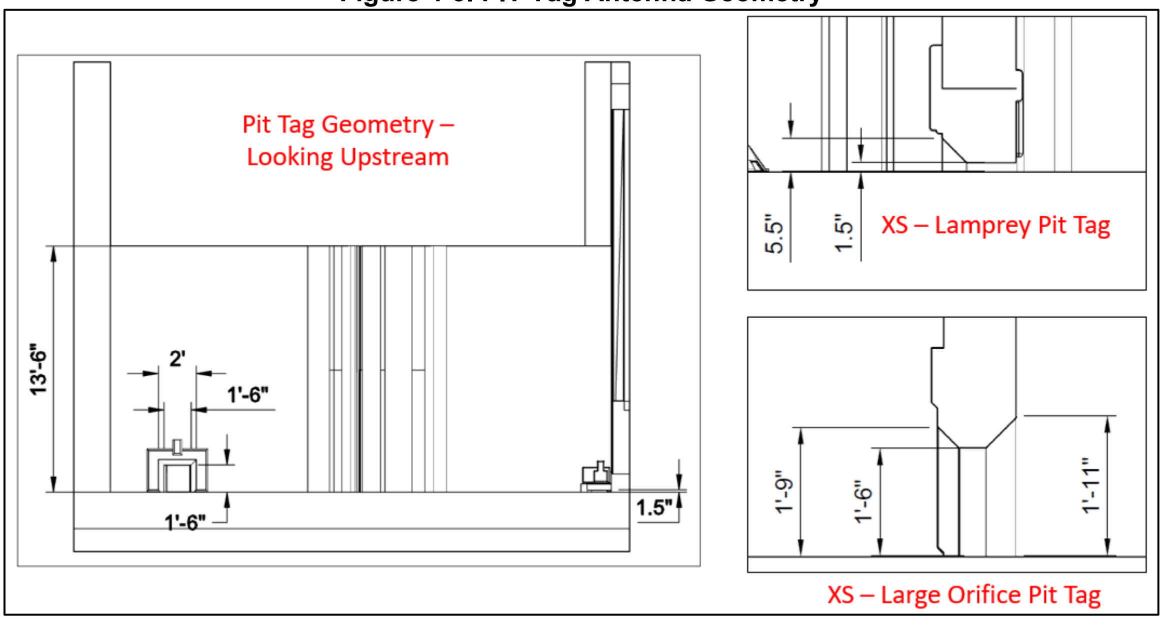
The PDT has been working with PSMFC throughout this project to incorporate the correct geometry needed to accommodate the antennas and provide for their installation and removal, if needed during future maintenance. The center slot PIT tag antennas will be lowered into slots built into the baffles with a crane and secured into place with fasteners. The slot antenna design assumes that 1-1/8-inch clearance will be required in the slots: 1-inch to accommodate ultra-high molecular weight (UHMW) pads that will be permanently installed in the slots, plus 1/8-inch tolerance for installation. The slot antennas can be removed via crane at any time, but typically, they're removed when the ladder is dewatered for routine maintenance. The slot antennas will be secured using stainless steel plates anchored to the top of the baffles. The large orifice antennas are installed via a notch in the floor of the control section, slid into place, and anchored. The lamprey orifice antennas will be installed at the top of the orifice opening. The PIT tag antenna layout is shown in Appendix A, Plates.

All PIT tag antenna baffles require the surrounding rebar to be of the non-ferrous type. The purpose of the antennas is to track radio frequencies from PIT tags attached to the fish. Ferrous rebar does not work near the antennas, as it does not allow them to operate properly. Therefore, GFRP rebar will be used in these baffles. Figure 4-1 shows the areas that will require non-ferrous rebar. Generally, the bigger the antenna, the further away ferrous metals must be. PSMFC has prototype tested the lamprey antenna and has confirmed that the ferrous rebar in the existing control section south wall will not interfere with the antennas.

The height of the PIT tag antenna baffle pairs varies. The furthest downstream PIT tag antenna baffle is underneath the fish building overhang. Therefore, it is 10-feet 6-inches tall, while the three upstream PIT tag antenna baffles are 13 feet 6-inches tall. The PIT tag antenna baffles are all identical except for the height. The ladder control section invert elevation is constant at EL 63 feet.

A schematic of the PIT tag antenna geometry for the slot and two orifices is shown in Figure 4-3. PIT Tag Antenna Geometry.

Figure 4-3. PIT Tag Antenna Geometry



There is no need for water stops at the PIT tag antenna baffle faces. Unlike steel, GFRP rebar does not experience corrosion from water.

As with the standard baffles described in Section 4.4.2, the baffles with antennas will be dowelled into the ladder side walls. However, the dowels will likely be stainless steel and thus will require different detailing than the carbon steel dowels used above.

PSFMC will provide installation instructions for each of the PIT tag antenna types that can be used to develop specifications for the contractor to install the antennas as Government Furnished Equipment (GFE) during the P&S phase.

4.4.4 Access Walkways, Guardrail, and Stairs

Maintenance access to the baffles and their corresponding PIT tag antennas and transceiver enclosures is required for continued operation. The PIT tag antennas and transceiver enclosures will be accessed via non-ferrous walkways (fiberglass) on top of the baffles. Access will only be provided to the PIT antenna baffles, Baffles #3-6. There is no need for staff to access the other baffles because there are no PIT tag antennas or operable equipment.

Access to the staircase into the ladder will be in the same location as existing to utilize the existing entrance/maintenance platform above the ladder, which already have the required safety measures.

Walkways will provide access across the top of Baffle pairs #3 – 6. There will be two walkway layouts because of the fish building overhang. Each set of walkways will be roughly 4-feet 5-inches wide to allow crew access to the transceiver panels. Each electrical panel will have a minimum of 3 feet of clearance from the face of the panel to the adjacent guard rails.

The walkway grating directly above the large center PIT antennas will be removable. This will allow crew easy access (won’t have to reach through and over a guardrail) to the top of the antenna once the grating is removed. This is where the electrical hookup will take place and fed to the electrical panels on top of the baffles. Guardrails and toe kicks will be required wherever walkways are present. The guardrails do not need to be nonferrous, as the vertical distance from the PIT tag antennas to the guardrails is far enough to that metal in the guardrails will not interfere PIT tag antenna operation. Project staff noted that the existing fiberglass guardrails are flaking and both likely polluting the water in the ladder and causing skin irritation for workers that come into contact with them. The guardrails and toe kicks will likely be aluminum and will be finalized during the P&S phase.

The access walkways will be wrapped in plastic construction fencing to prevent fish from jumping onto the platforms. The fencing is currently in use at the project and project staff have confirmed that it works as intended.

The project design team will opt to have the access walkways be contractor-designed. A contractor-designed walkway will save the team several hours of design and drafting time. The walkways for the previous PIT tag antennas were contractor-designed and work as intended. However, this PDT will provide a conceptual walkway layout to ensure the proposed layout is feasible.

One parameter the contractor must follow is to mount the walkway roughly 12-inches above the baffles. The walkway will rest on structural members on top of the baffles. This 12-inch distance will allow plenty of access for the electrical conduit to cross underneath the walkway toward the panels in whichever direction is needed. Another parameter the contractor must follow is a platform with capacity of 60 psf, per ASCE 7-10, “Walkways and Elevated Platforms”. This will allow crew to access and maintain antennas in the field.

Fibergrate is a fiberglass manufacturer that makes structural shapes and grating. This website has been used to size the initial members to determine the proposed walkway is feasible. The contractor will likely purchase the walkway materials from this site.

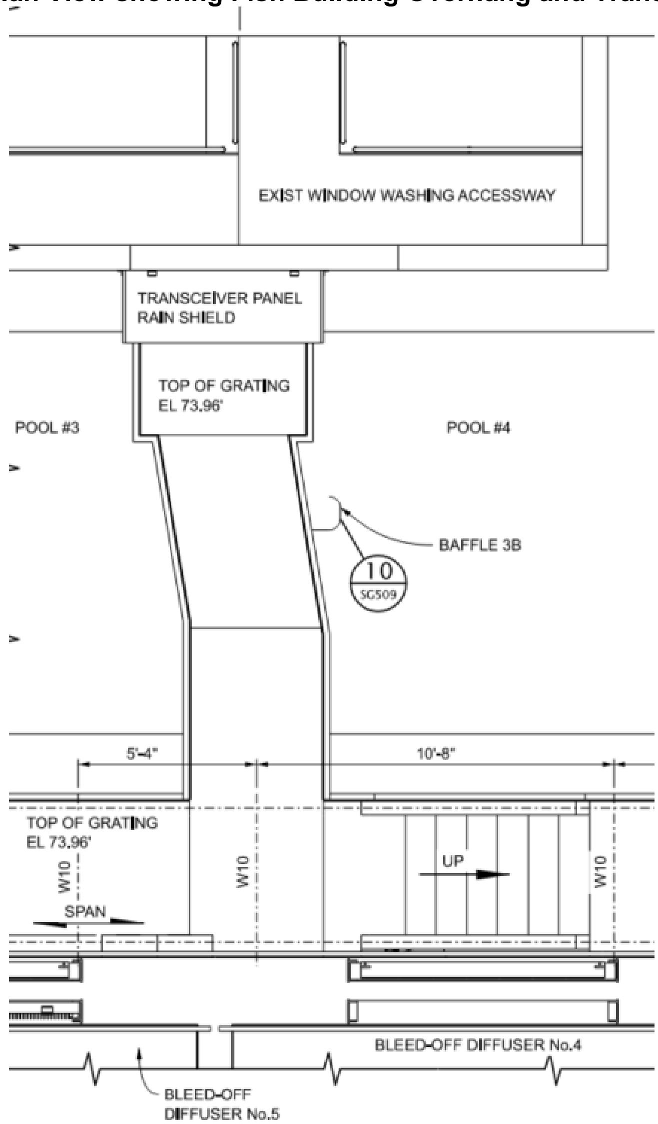
There was a possibility to reuse the existing stairs and walkways. However, due to a different baffle layout and less than ideal condition, this was ruled out.

4.4.5 PIT Tag Antenna Support Infrastructure (Rain Shield, Transceiver Panel Mounting, Antenna Hold-Downs)

The PIT tag antennas require several ancillary items for proper function including rain shields, transceiver panel mounting locations, and hold-downs for the antennas to resist uplift.

Rain shields: Rain shields are required to protect the transceiver panel and maintenance crew from rain. They will completely cover the electrical panel and extend roughly 2-feet outwards to allow a worker access to the panel. Each will be roughly 6-feet 6-inches tall. The standards for work conditions were determined from Architectural Graphic Standards code, Tenth Edition. Four baffle pairs will have PIT tag antennas, with two different designs (as noted above). First, are the most downstream PIT baffle is adjacent to the overhang of the fish viewing building. Because the building takes roughly 8 feet of walkway space away, the transceiver panels and rain shields will be mounted directly to the building face. The wall-mounted rain shield are shown in Figure 4-4:

Figure 4-4. Plan View showing Fish Building Overhang and Transceiver Panel



The other design is for the three upstream PIT tag antenna baffle pairs. The fish viewing overhang does not affect these; therefore, they will be mounted directly to the walkways/top of baffles (up to the contractor) using vertical posts and a baseplate. The design for a post-mounted rain shield can be seen in Figure 4-5:

Figure 4-5. Plan View showing the other Transceiver Panel Layout

PSFMC reports that the existing rain shields work well and would be a good basis for design.

All rain shields will be aluminum. This was used previously, is lightweight, and non-ferrous.

<u>Electrical Panel Mounting:</u> As noted above there will be two different PIT antenna infrastructure configurations; one with the fish viewing overhang and three without. Both configurations will feature the same transceiver panels for the PIT tag antenna equipment. The panels are two, 30-inch x 30-inch x 8-inch panels mounted together that open from the middle. The same panels will be used at all four PIT antennas.

At the building overhang, the panels will be mounted directly to the precast panels. The other three baffles will be mounted to the rain shield, that assembly will be mounted to the baffles and walkways.

<u>PIT Tag Antenna Hold Downs:</u> The large slot antennas in the center of the PIT tag baffles require hold downs due to hydraulic uplift. Unlike the orifice antennas, there is no concrete support above the middle antennas because it is removable, thus 0.5 inch

thick stainless-steel plates will be used on each side to combat uplift pressure. The bottom of the plates will be fitted with UHMW blocks to ensure there is no direct contact between the stainless steel and antenna casing.

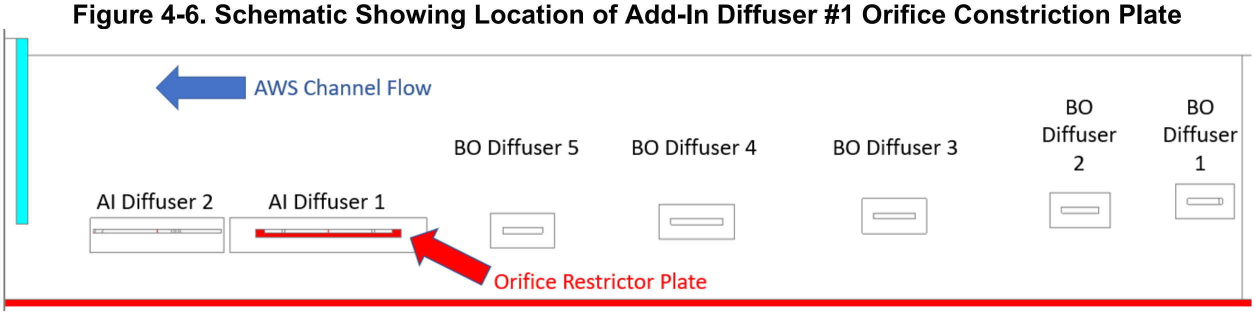
The hold downs will be anchored to the concrete using 4 stainless steel concrete anchors. Each anchor must be removeable in order to access the antennas during needed maintenance. The antennas will be fully removable via crane and will be maintained while they're out of their slots.

4.4.6 Diffuser Lamprey Plates and Orifice Flow Constriction Plate

The two most downstream Diffusers (Add-In #1 and #2) will have a 1-foot-tall strip of ¼-inch thick carbon steel (or Stainless steel) plate welded to the bottom of the diffuser grating on the ladder side. The purpose of the plate is to provide lamprey with a smooth wall surface to attach to.

In addition, a steel plate will be added to Add-In Diffuser #1 to reduce the orifice open area to be equal to the Add-In Diffuser #2 orifice. The purpose of the plate is to improve hydraulic conditions in the control sections. The specific design and installation of the plate will be determined during the P&S stage.

Figure 4-6. Schematic Showing Location of Add-In Diffuser #1 Orifice Constriction Plate



The orifice constrictor plate will be painted with standard vinyl paint, 5-E-Z or 3-A-Z.

There is a possibility that the upstream-most diffuser is too close to the new pit antennas. If so, the cover plates will be changed to stainless steel. This will be determined during the P&S phase.

4.4.7 Modifications to S-Curve Section

To improve fish passage, the S-curve section just downstream of the baffles will undergo major geometric changes. The reason for the change is to replace two full 180 degree turns with two 90 degree turns in the connection channel between the count station and control section. This will provide a shorter and more direct passage route.

There are existing flow vanes and concrete walls in the S-curve section that will be removed to accommodate a more streamlined channel. This will create a large open space in the ladder, which provides no value to passing fish. The open space will be filled with concrete and dowelled into the existing structure at each face. This will become a new working and access platform in the middle of the ladder that will allow staff to clean the bypass leads at the upstream end of the count station. Several options for this area were considered, including leaving it open or creating a hollow space with grating above. Concrete was picked for reasons of lower cost, simpler design, and easier construction.

The boundary of the new platform will include guardrails, toe kicks, and plastic fish netting to keep crew safe and fish out.

4.4.8 Electrical Conduit, Support Beam

At existing Baffles 2 and 3 (new baffle #1), there is a vertical frame supporting a group of electrical conduits, roughly 15 to 20 feet above the ladder invert. The conduits span from the south ladder wall to the north ladder fish viewing building overhang, roughly 20.5 feet. The frame is shown on Figure 4-7 and Figure 4-8 below:

Figure 4-7. Existing Conduit Support Frame Location

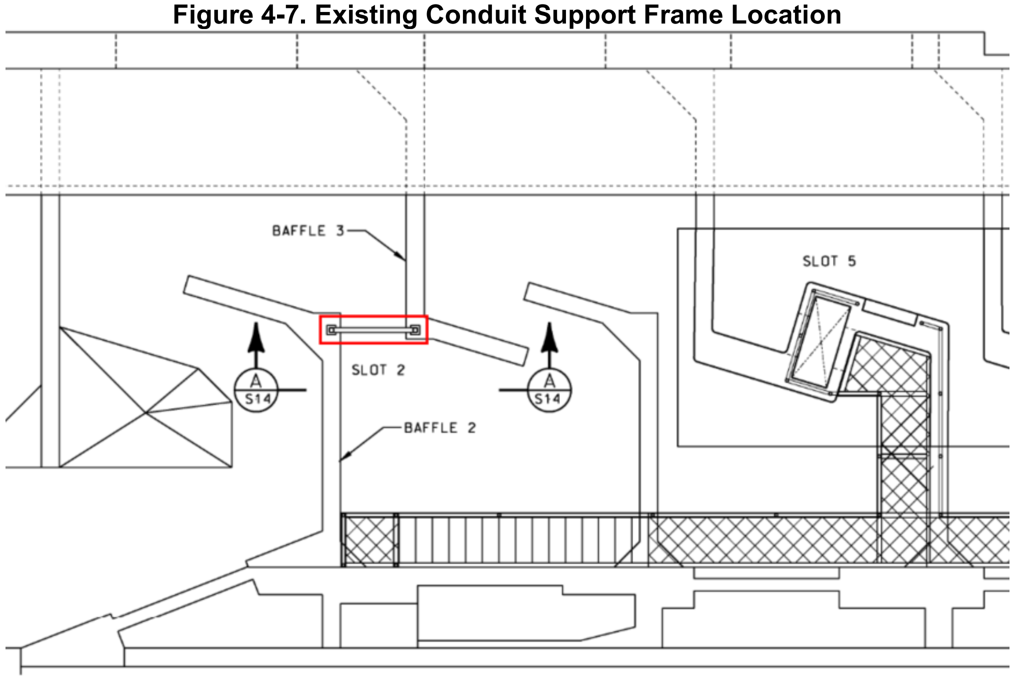
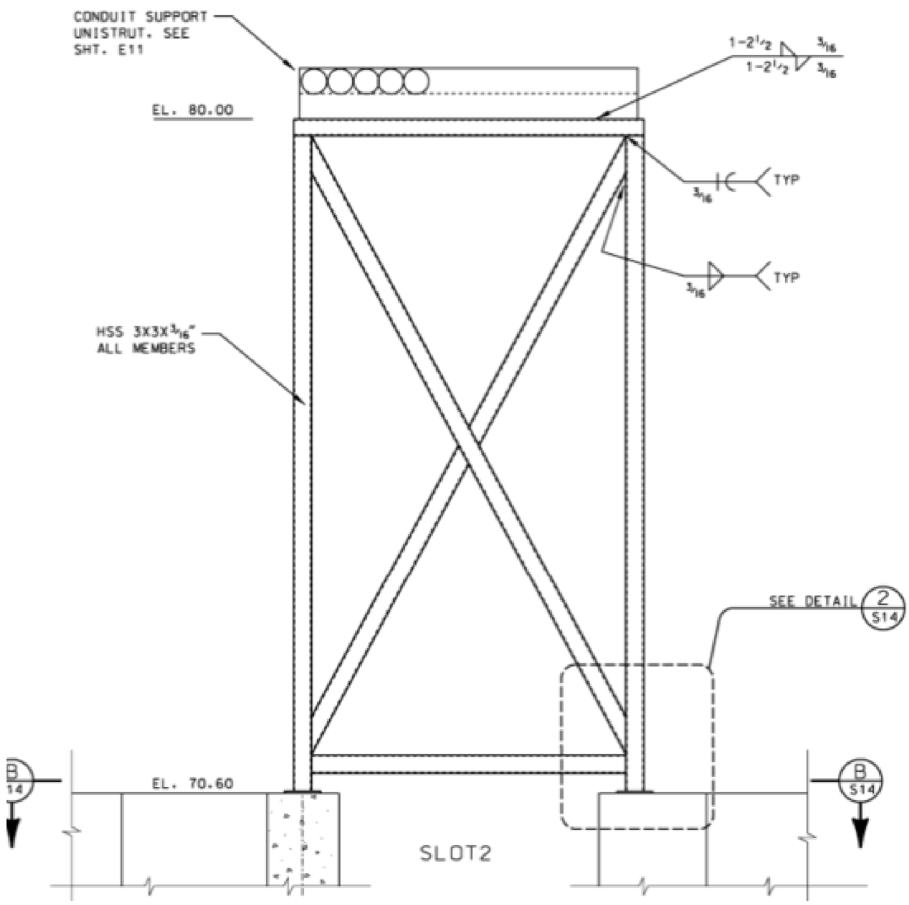


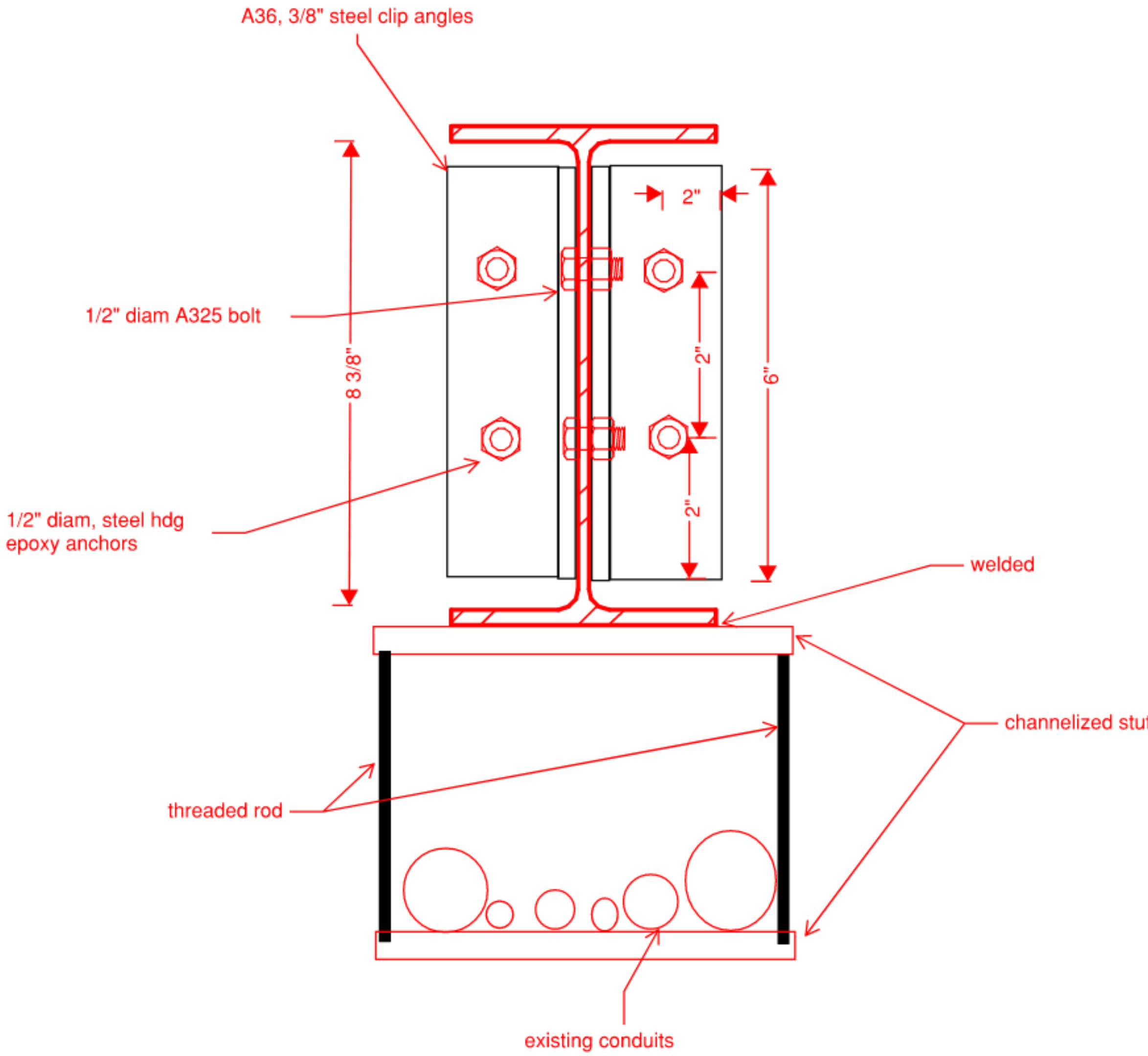
Figure 4-8. Existing Baffle Support Frame, Elevation



Because the vertical slot and orifice baffles will not be in the same location as the existing serpentine baffles, it is not possible to reuse this vertical frame. The distance between the new baffles will be larger due to their new concrete shape and thus the frame would have nothing to bear on. Therefore, this group of conduits will need to be supported in a different manner.

The proposed plan is to span a 20.5-foot-long, W10x19 beam from the south ladder wall to the outer wall of the fish viewing building, built of precast panels. The electrical conduit will hang below the beam, supported by a channelized strut welded to the bottom of the beam. See Figure 4-9 below for a schematic of the beam, anchorage, and conduit. The conduit near the building directs downward, therefore, the beam must be located above the conduit to allow the downward turn.

Figure 4-9. Support Beam Conduit (placeholder)



The beam will be anchored to the existing ladder wall using a welded clip angle and concrete anchors.

The new conduit support structure will not be designed for seismic forces. However, it will provide much more seismic capacity compared to the old, 2-D frame, which had no lateral support in the north and south direction.

4.4.9 Lamprey Refuge Boxes

Based on visual observations made by on-site fish biologists, the existing lamprey refuge boxes (6 total) are working as designed. Therefore, the geometry and material type (aluminum) will remain the same as the Bradford and Cascades Island refuge boxes built in 2017. The one major issue with the current design is the anchors/hold downs. The operations staff wanted the ability to easily remove and secure the rest boxes during the fish ladder outages. The existing design uses anchor sleeves with hand tightening bolts. While a good idea, they did not operate well; debris would fill the anchor sleeves leaving several inches of anchor bolt fully exposed with no real ability to get a snug fit. Additionally, after a few years, it was not easy to remove the refuge boxes only using hands (as originally intended) because of silt, corrosion, and a bad handle design.

The anchors for the new lamprey refuge boxes will be designed during the P&S phase. The main objective is to find a removable concrete anchor, without a sleeve, like a threaded insert anchor. One major issue with these anchor locations is debris fills the holes during each dewatering.

The top of the anchors will be held down using stainless steel acorn nuts. The acorn nuts were picked because of the low-profile design. These nuts will collect the least possible debris.

According to the wants of the fish biologists the refuge box locations will be as follows: along the south wall in pools 1, 6, 7, 8, 9, and 10, plus one box in pool 3 along the north wall for the visitor’s center, for a total of 7 new boxes.

4.4.10 Design Decisions to be Determined

-What are the dowel lengths for all features:
    Standard baffle to invert and side walls
    PIT baffle to invert and side walls
    Concrete pad into invert and sidewalls (dowels to entire half thickness on sidewalls)

-Does the FRP rebar require different concrete than standard rebar (IE do we need two different types of concrete)

-Rest boxes are aluminum and attachments (anchor and acorn nut + washer) are carbon, is this an issue?

Note: supposedly aluminum shouldn't be in contact with concrete… do we need to line the area where the rest boxes are touching? Or just use stainless.

Note: rain shields are aluminum and will be touching concrete.

-Diffuser Plates: what's their condition? Existing appear to be galvanized steel (see drawing BDF-2-15/148)

-Handrails: use stainless or aluminum? Fiberglass is out of the question.

-Electrical panel rainsheild/protection on south wall for new panel:

Brandt would like for the rainsheild to double as impact protection from dropping the diffusers on this panel. However, it is not really that exposed (ie only a small portion is actually infront of the diffuser), and this might require a small rainsheild to be built into quite a large structure to actually protect it.

SECTION 5 - MECHANICAL DESIGN

5.1 GENERAL

The PDT has not identified any mechanical design features that are required to enable the control section to function with a vertical slot and orifice design. A description of mechanical components that have been considered either as integral to the design or as ancillary features, and the decision about whether to include each in the design, are summarized in the following sub-sections.

5.1.1 Actuated Sill Gates in the Vertical Slots

Preliminary hydraulic analysis has demonstrated that actuated sill gates in the vertical slots do not provide any hydraulic benefit to fish passage through the Washington shore control section. Actuated sill gates come with significant additional construction and maintenance costs. The sill gates could cause a physical impediment to lamprey passage by introducing a vertical offset, whereas the selected alternative has openings that are flush with the floor. Additionally, the actuated sill gates interfere with PIT tag detection, limiting the available locations for replacement PIT tag antennas. Actuated sill gates in the vertical slots were therefore removed from consideration.

5.1.2 Slide Gates at the Add-In / Bleed-Off Diffusers

Preliminary hydraulic analysis demonstrated that slide gates at the add-in / bleed-off diffusers are not required for hydraulic performance. Although slide gates could provide future flexibility if the forebay operating range changes or to allow adjustment in the prototype they have not been required to achieve the necessary hydraulic conditions in the existing control section and CFD modeling indicates that they will not be needed in the modified control section. Given that history and analysis, the trade-off between the cost and maintenance requirements of mechanical features that are not strictly required, against added flexibility to adjust the add-in and bleed-off orifice dimensions is not considered to be justified. A permanent flow restrictor plate will be added to Add-In Diffuser 1.

5.1.3 Slot Covers in the Exit Gate Slots

Slot covers have been installed at some fish ladder gates to provide a smooth passage surface for lamprey to aid in upstream migration. The PDT discussed the option to install slot covers at the exit gate at the upstream end of the control section. The bulkhead gate slots are about 3-inches deep and 5-inches wide. The Project needs to be able to close the gate on short notice, at any time of day and without access to a crane; therefore, the Project staff keep the exit gate installed in its slots, dogged off above the water surface. Slot covers need to be removed before the gate can be installed and closed; therefore, it is not possible to use standard slot covers and maintain the ability to quickly deploy the gate without a crane. Fallback at the exit gate has not been studied but is not known to be a problem.

The PDT concluded that the current design effort should focus on making the improvements per the EIS, then monitor passage success. If lampreys are subsequently observed to successfully navigate the ladder control section, but fall back at the gate slot, then a design for a novel mechanism, such as spring-loaded slot covers, or a new flush-mounted gate could be initiated as a stand-alone (or follow-on) product. Slot covers in the exit gate slots are no longer under consideration for this DDR.

5.1.4 Automated Cleaner for Bypass Picketed Lead

The existing picketed lead accumulates debris and is difficult to clean due to poor access. The Project staff report that the increase in velocity through the count station is minimal, even when there is debris on the picketed leads. The Project staff expressed a preference that access for manual cleaning, such as a catwalk, be included in the design, rather than a mechanical cleaner. The access will be provided as described in Section 4.4.7. An automated cleaner for the bypass picketed lead is no longer under consideration for this project.

SECTION 6 - ELECTRICAL DESIGN

6.1 GENERAL

The scope of this project will cover the removal of the existing PIT tag detection system (antennas, transceiver panels, conduit/wire) located in the existing control section. A new PIT tag detection system will be provided in the newly modified control section. New antennas will be provided in selected baffle pairs in the slot and submerged orifices. New transceiver panels will be located on top of the new baffles on the north side. See Sheet E-601 for the existing control section PIT tag detection system.

6.2 DESIGN STANDARDS

- NFPA 70: National Electric Code, 2020
- NFPA 70E: Standard for Electrical Safety in the Workplace, 2018
- EM 385-1-1: Safety and Health Requirements Manual, 2014

6.3 ELECTRICAL CRITERIA AND CONSIDERATIONS

Electrical infrastructure will be provided as indicated in the Memorandum of Understanding (MOU) between BPA and USACE. The USACE responsibility includes transceiver enclosures, transceiver power, and data transmission (fiber optics) including associated wire and conduit. BPA is responsible to provide the antennas and all associated electronics. PSMFC (under contract to BPA) will design the antennas and BPA funding will allow PSMFC to purchase the necessary electronics and construct the antennas.

6.4 DESIGN METHODS

6.4.1 System Configuration

The configuration of the new PIT tag detection system will be closely coordinated with PSMFC. This includes design of the new transceiver and UPS panels, fiber optic cable and power circuits modifications. Preliminary drawings of PSMFC antenna designs are included in the informational drawings.

6.4.2 Calculations

Calculations will be performed for conduit fill and voltage drop (if necessary).

6.5 ELECTRICAL FEATURES OF THE WORK

6.5.1 Demolition

The existing antennas, transceiver panels and associated conduit and wire will be removed from the existing baffles (see Sheets E-402, E-403 and E-601). Disposal of existing equipment will be coordinated with PSMFC. PSMFC may desire to keep the removed equipment. Existing multimode fiber optic cables and power conductors to each transceiver will be removed (see Sheets E-402, E-403 and E-601). The existing multimode fiber optic cables (for data transmission and transceiver monitoring) between the PIT Tag Room and transceiver have an insufficient fiber count to accommodate the new transceivers. These cables will be removed, and the existing conduit will be reused for a new multimode multi-fiber trunk line cable (see Sheets E-102, E-103, E-402, and E-403).

6.5.2 New PIT Tag Antenna Infrastructure

New antennas, transceiver panels and associated conduit and wire will be provided in the selected modified baffle pairs. Antennas and associated electronics will be provided by PSMFC as Government Furnished Equipment (GFE) for contractor installation. USACE will have a contractor provide the remaining electrical infrastructure (conduit, wire, transceiver and UPS panels, etc.) See Sheet E-602. Under a request from PSMFC, a new UPS cabinet (see Sheet E-502) will be provided to supply backup power to the antennas in baffles 3A/B and 4A/B. A new 72-fiber multimode fiber optic cable will be provided between the existing PIT Tag Room and the existing NEMA 4X fiber optic j-box in the control section (see Sheet E-102). A new fiber optic patch panel will be provided in this j-box to distribute fiber to each transceiver (see Sheet E-506). Fiber optics will also be provided to the UPS cabinet for UPS monitoring (See Sheet E-503).

SECTION 7 - PIT TAG ANTENNA DESIGN

The PIT tag antenna design is being completed by PSMFC. BPA is responsible to pay for costs associated with antenna design and procurement. Associated components designed by USACE are detailed in the discipline-specific sections.

PSMFC has provided drawings of the antenna design and required offsets from ferrous materials to the antennas. They do not typically provide design documentation (e.g. design reports, specifications) for their detection systems; however, the PDT and PSMFC are in discussion about what documentation, e.g., product lists, shop drawings, etc. would be appropriate for PSMFC to provide. This discussion will continue into the P&S phase.

SECTION 8 - ENVIRONMENTAL AND PERMITTING

8.1 ENVIRONMENTAL CONSIDERATIONS

All work is expected to occur within the existing footprint of the fish ladder. If the area of disturbance and associated pollutants is minor, as currently expected, then the Contractor will be required to comply with the Project Spill Prevention and Control (SPCC) plan and implement Best Management Practices (BMPs) for stormwater, if a source discharge develops from the site.

All work that requires a dewatered area will be completed during the standard ladder maintenance period of December 01 through February 28. The construction schedule is discussed in Section 10.9.

If access and staging, or changes to the design in subsequent milestones, result in a disturbed area of one or more acres, or will contribute a significant amount of pollutants, then the contractor will need to obtain a Construction Stormwater General Permit (CSWGP) through the Washington State Department of Ecology before work can begin on the project. The CSWGP requires operators of construction sites to develop Stormwater Pollution Prevention Plans (SWPPPs) and implement measures, including Best Management Practices (BMPs), during construction to control erosion, prevent sediment discharges in stormwater, and minimize the potential for hydrocarbon or chemical contamination of site soils and water bodies.

Erosion and sediment control BMPs will be implemented to stabilize exposed areas and contain runoff, such as the installation of silt fencing to ensure that sediment from construction activities is prevented from entering wetlands or the surrounding water bodies, if applicable. Stormwater will be collected, and sediment removed before being released. Disturbed work areas will be mulched, and inactive material stockpiles will be covered during rains that produce runoff. These sediment and erosion control measures will be maintained and replaced as necessary until construction is complete.

Other BMPs that will likely be implemented include containment of equipment fueling areas and locating these areas as far from wetlands or waters as possible to prevent discharges in the event of a spill. Oil absorbing pads, drip pans, or similar devices will be placed beneath equipment when working in waters or staged overnight to catch any leakage. Special construction measures will be required when working above or near water to prevent pollutant discharges, such as the use of Environmentally Acceptable Lubricants on construction equipment and machinery (EPA, 2011). These requirements will be developed during the P&S phase.

Some items identified for further consideration during development of the specifications include:

- Asbestos and lead: asbestos and lead are not known to be present in the work area, but are commonly found in older facilities. The specifications should require that any painted surface to be cut or scraped should be tested for lead. Additionally, the specifications should include language requiring testing and reporting of any asbestos encountered during construction.

- Bradford Island Superfund Site: The design defined at the 90% DDR phase appears unlikely to disturb in-water sediments or the upland unit of the Bradford Island superfund site. Any ground disturbing activities or in-water work within 0.5 miles downstream of the dam requires coordination with the Bradford Island PDT and the Environmental Compliance Coordinator.

Anticipated special conditions related to environmental and permitting for the specifications phase include:

- Special Condition 1: Specifications to identify known potential lead remediation areas and require Contractor to test for lead before removing paint that could contain lead. Require Contractor to file lead abatement plan in accordance with Federal and state laws and Corps Safety Manual EM 385 1-1.
- Special Condition 2: Specifications will require Contractor to abate any asbestos identified during the course of the proposed action in accordance with Federal and state laws.
- Special Condition 3: Any work in the vicinity of the fish ladder performed during fish passage season will be coordinated with FFDRWG. Note: If no work near the Fish Ladder is done during passage season this item can be deleted.
- Special Condition No. 4: All surfaces within the fish passage facilities will be free of sharp edges, burs or protrusions that have the potential to injure fish. All concrete surfaces within the fish passage sections must have a “Class A” finish per ACI 301. Specifications will require Contractor to notify Government when sections are complete and allow reasonable time and access for Government inspection of all surfaces and repair any deficiencies noted prior to the end of the outage window.
- Special Condition 5: Specifications will require BMPs for the prevention of invasive species introduction. All equipment brough onsite will be clean and free of plant matter. Should watercraft be utilized for this proposed action they will be clean and decontaminated prior to arrival per Washington Department of Fish and Wildlife requirements.

8.2 PERMITTING REQUIREMENTS

This section outlines the environmental and cultural resources and permitting requirements as they may apply to Bonneville Washington Shore control section modifications. During plans and specifications, the design will be further refined.

Typically, it is during this phase that environmental clearance documents are prepared to satisfy the various environmental laws and regulations that U.S. Army Corps of Engineers (USACE) must comply with prior to constructing the facilities or modifying operations to improve the facility operation. USACE is required to comply with numerous Federal laws, rules, and regulations, as well as potential additional requirements under state and/or local jurisdictions.

All Federal actions that are funded, constructed, or permitted must comply with the National Environmental Policy Act (NEPA). The NWP District Commander is the USACE NEPA official responsible for compliance with NEPA for actions within District boundaries. Typically, under NEPA, the District will prepare a Categorical Exclusion for O&M activities, or an Environmental Assessment (EA) for larger construction projects. An EA is a brief document that provides sufficient information to the District Commander on potential environmental effects of the proposed action, if appropriate, and its alternatives. The EA review also determines whether an Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI) needs to be prepared. In the case where project impacts are known to be major, USACE may decide to proceed to an EIS without conducting the EA/FONSI.

Consultation with appropriate Federal, State, and tribal agencies regarding potential environmental effects is coordinated by CENWP-PM-E. Compliance and consultation includes all permitting activities associated with the Clean Water Act (CWA) including Sections 401, 402, and 404. Cultural resource clearance will be required for construction sites, other areas disturbed to facilitate construction (access roads, staging areas, etc.), or otherwise affected by operational changes. Endangered Species Act (ESA) compliance will include interagency consultation with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) on all threatened, endangered, and proposed species and/or designated critical habitat, including terrestrial and aquatic plants and animals.

The consultation process may also encompass sections of the Fish and Wildlife Coordination Act; Magnuson-Stevens Act (Essential Fish Habitat); Bald and Golden Eagle Protection Act; several cultural resource laws including the National Historic Preservation Act; Archaeological Resources Protection Act; Native American Grave Protection and Repatriation Act; Antiquities Act; Archaeological and Historic Preservation Act; Executive Order 11988, Flood Plain Management; Executive Order 11990, Protection of Wetlands; Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance; Comprehensive Environmental Response, Compensation, and Liability Act; Resource Conservation and Recovery Act; Toxic Substances Control Act; Federal Insecticide, Fungicide, and Rodenticide Act; and Migratory Bird Treaty Act.

SECTION 9 - OPERATIONS AND MAINTENANCE

The modifications described in this DDR will not result in any change to project operations. Facility start-up, shut-down, normal and emergency operations will remain the same.

Routine maintenance and fish salvage during biannual ladder shut down periods will be similar to existing. The new lamprey refuge box anchors, reduced control section path length and reduction in the number and extent of the vanes in the S-curve region of the modified ladder should make fish salvage easier. The access to the top of the picket leads is intended to make debris management in this location easier.

The replacement PIT tag antennas will be operated and maintained by PSMFC. PSMFC remotely monitors all of the antennas, conduct weekly O&M visits and respond to maintenance needs. Project staff support the O&M only in a limited fashion, e.g., to provide periodic crane support, troubleshoot power sources, and look for sources of ambient or induced noise affecting the proper function of the PIT tag detection system. During the P&S phase, PSMFC will provide a document that will:

- Note past history and/or provide examples of typical Project support
- Identify when and where the project gets involved in PIT tag detection system support
- Specify acceptable power ranges, equipment isolation, needed crane lifts, etc.

SECTION 10 - COST ESTIMATE AND CONSTRUCTION CONSIDERATIONS

10.1 GENERAL

At the 90% DDR phase (June 2023), the total project cost (design and construction) is estimated at $6.95 million. As noted in Section 6.3, BPA is responsible for providing the antennas and all associated electronics; therefore, these costs are excluded from the total project cost estimate. The construction cost and design/management costs for the preferred alternative are estimated to be $4.5 million and $2.45 million respectively. These values include an average 30 percent contingency and an average 6.3 percent escalation. The construction contract is expected to take 12 months, the ladder dewatering period is 3 months, and on-site construction is anticipated to take the entire dewatered period and may have some work spill over outside of the window if allowed. The time for fabrication and preparation on this job is critical to allow for a successful execution during the ladder dewatering period. The project cannot afford delays during the design phase. The total project cost summary sheet for the chosen alternative, risk analysis, and construction schedule are included in the Cost and Construction Appendix. The costs for the alternatives developed at 30% DDR can be found in the Limited Alternatives Evaluation Appendix.

10.2 CRITERIA

ER 1110-2-1302 provides policy, guidance, and procedures for cost engineering for all Civil Works projects within 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.

10.3 BASIS OF THE COST ESTIMATE

The cost estimate is based on engineering calculations from the design team and data presented in the DDR and the DDR plates.

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 June 2023 in MCACES MII and escalated to the midpoint of construction on the total project cost summary sheet.

10.4 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 of design. 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 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 EM 1110-2-1304.

10.5 COSTS OF ALL ALTERNATIVES

The alternatives presented in the Limited Alternatives Evaluation Appendix were estimated at the 30% DDR level. All considered alternatives included replacement of the weirs, platforms for antenna access, and concrete slab replacement to remove metallic reinforcement. The alternatives either included a modification to the count station area or added actuated sill gates. A breakdown of the costs as estimated at the 30% DDR phase can be seen in the Limited Alternatives Evaluation Appendix.

10.6 COST AND SCHEDULE RISK

An abbreviated cost and schedule risk analysis was 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. The project is at the end of the DDR phase. As with all projects in the DDR phase, there is a potential for scope growth. The project will be transitioning to 60% P&S after the 90% DDR completion. Since much of the work is designed beyond a standard DDR, there is a lower likelihood of impact than a standard project in the DDR phase. It is likely that more changes occur with a marginal to moderate cost impact.
- Acquisition Strategy. Sole source is possible but would have significant impact on cost.
- Restricted Work Window. Limited fish ladder closure window may lead to increased cost if contractor runs into delays. Estimate currently assumes contractor will need to work 7x10 most weeks to complete the work within the ladder dewatering period. Additional scope growth or delays could result in multishift work which will greatly impact the cost.
- Limited design for non-ferrous walkway and add-in diffuser modifications. The quantities and design used to estimate this scope could differ from the future design.
- Inflation – A 7.3% escalation to midpoint (2025Q2) was applied in the TPCS on construction costs. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint.

10.7 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 but will take some coordination to complete all the work within the ladder dewatering period. We recommend a competed acquisition strategy, like IFB total small business. We strongly recommend against a sole source acquisition strategy due to the dollar value of the project being close to the $4.5M limit as well as the potential for the bid to be too high leading to the need to readvertise which would likely result in missing the ladder dewatering period. Missing the ladder dewatering period would lead to a two-year delay due to the alternating schedule for ladder outages at Bonneville Dam.

The cost estimate assumes a concrete contractor will act as the prime and the rest of the work, including concrete demolition, will be subcontracted.

The PDT should investigate if the acquisition strategy for JDAN control section modifications was effective. If a best value contract was used, it may be best to also use a best value contract. For a best value contract, good source selection will be very important due to the short period of time that the ladder will be dewatered during construction. A Contractor with a history of concrete work, executing under tight timelines, and a good electrical sub (or in house team) to do the antennas and control work will be critical to success. Additionally, the electrical subconsultant should have experience in working in immersed systems.

10.8 FUNCTIONAL COSTS

10.8.1 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 $1.65 million for the plans and specifications phase.

10.8.2 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 $800,000.

10.8.3 Annual Operations and Maintenance

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

10.9 SCHEDULE

The work will be constructed during the winter ladder maintenance period of 1 December 2024 through 28 February 2025. Bonneville Dam staff dewater the Washington Shore fish ladder every other winter. Staff will begin dewatering 2 December 2024 with a typical dewatering duration of four weekdays. The fish ladder needs to be rewatered by 28 February 2025 with a typical rewatering duration of three weekdays. All work that requires the fish ladder to be dewatered must take place during this dewatering period. The contractor will expect to have access to the fish ladder from

Dec 6 through Feb 25 (82 calendar days.) A potential schedule of work is included in the Cost and Construction Appendix. It is unlikely that this work will be split into multiple dewatering periods. It is likely that the contractor will work overtime to complete the work before the end of the ladder maintenance period. The contractor will need at least three months prior to the ladder dewatering period for submittals and material procurement.

The JDAN control section modifications project had a ladder dewatering period of 17 November to 15 March (118 calendar days,) 36 days more than the current proposed ladder dewatering period. The scope for the JDAN project included similar replacement of serpentine baffles with vertical slot and orifice baffles, however JDAN required construction of 23 new baffle pairs as compared with 9 at Washington Shore, and installation of new sill gates and actuators. The JDAN ladder modifications were constructed shortly after the 2008 market crash, when many contractors didn’t have work and there was heavy competition between sub-contractors. The current market likely won’t have the same level of available labor to finish the job in the same amount of time. The potential work schedule calculated approximately 74 workdays are needed for all the work within the fish ladder. This may be possible within an 82-calendar day outage period, but delays could lead to large issues. It is recommended that the PDT continue to discuss the outage period and potentially request an extension to the outage to give the contractor more time for completion of work.

10.10 SCOPE AND 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 walkways, orifice plate, custom cast-in-place forms, etc. PSMFC fabricates the PIT tag antennas at their own shop; they have indicated that USACE can specify the date on which the antennas need to be on site and available to the contractor and PSFMC will meet that date.

10.10.1 Serpentine Baffle Demolition and Vertical Slot and Orifice Baffle Install

The demolition and construction of the baffles will be constructed like the JDAN fish ladder control section modification project. The fish ladder walls will be braced before the baffles are removed, the baffles will be supported then saw cut and craned out of the channel. After removal, the concrete at the baffle locations will be cleaned and prepared for the new baffle installation. Reinforcing will be installed in place, forms will be erected, and concrete will be pumped to the fish ladder. Due to the limited work window, it is assumed the contractor will have multiple (or larger than average) crews on site and may need to work extended hours.

10.10.2 Pit Tag Antennas

Pit tag antennas will be installed in the modified control section. Ferrous materials interfere with the antennas’ electromagnetic field; therefore, a portion of the concrete floor will be demolished and the concrete and reinforcing near the antennas will be replaced with concrete having non-ferrous reinforcement. The baffles and floor will be designed to accept the antennas. After the baffles have been constructed, a crew will install the antennas in the slots and orifices of four of the nine new baffle pairs.

10.10.3 Walkways and Guardrails

Non-ferrous (fiberglass or aluminum) walkways and guardrails will be required near the PIT tag antennas to prevent interference with the PIT tag antennas. This will be a standard walkway install, though some additional structural supports may be required. This work would likely be completed after the baffle installation and is a good candidate for work that could be completed after the ladder has been watered up.

10.10.4 Bleed-Off and Add-In Diffusers

A one-foot-high metal strip (lamprey plate) will be installed on the two add-in diffusers, which are located at the downstream end of the control section. Also, the orifice plate on one of the add-in diffusers will be replaced. The replacement should be relatively simple when the ladder is dewatered. The PDT originally considered installing gates on all diffusers, but this idea is no longer under consideration.

10.11 OPERATIONS DURING CONSTRUCTION

The work itself is unlikely to cause any significant impacts to operations; however, the contractor will likely need to work extended hours to complete the baffle and concrete slab replacement during the dewatering period. 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.

10.12 CONTRACTOR OPERATIONS

10.12.1 Concurrent Work on the Washington Shore Fish Ladder and Bradford Island Fish Ladder

There is no other major construction anticipated for the Washington Shore fish ladder during this period of work. Biennial fish ladder maintenance will be required during construction. Operations anticipates this work will take about 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.

10.12.2 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 twenty, a crane, a forklift, and about 2,000 square feet of staging area to accommodate demolished baffles, concrete forms, and reinforcing.

10.12.3 Load Restrictions

Load limit and turning radius restrictions on the bridge over the fish ladder must be considered in any plan to deliver equipment and materials to the job site. The PDT should investigate if the contractor would be allowed to access the fish ladder from the eastern field between the southeast corner of the parking lot and the fish ladder. This would allow the use of larger equipment than the bridge would allow potentially increasing productivity.

10.12.4 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.

10.12.5 Material Handling

The contractor must provide their own crane for this work.

10.13 VALUE STUDY

The District Value Officer reviewed the proposed design and total project cost estimate and has determined that a value study is not warranted for this product.

SECTION 11 - CONCLUSIONS

11.1 CONCLUSIONS

The Washington Shore fish ladder control section is a known challenge for the upstream migration of Pacific lamprey. The primary change defined in this DDR would replace the existing control section serpentine baffle arrangement to an Ice Harbor-style vertical slot and orifice arrangement. The Ice Harbor-style vertical slot and orifice configuration has been correlated with substantially higher dam passage efficiency for lamprey and faster transit times for salmonids. Additional improvements are included to streamline the S-curve section to reduce the overall transit distance and reduce the number of direction changes that the fish must make. Minor modifications to improve lamprey passage include adding a 1-foot tall metal strip over the bottom of the add-in diffuser gratings and providing Project staff access to allow more frequent cleaning of the picketed leads at the upstream end of the count station.

Substantial computational modeling was completed to refine the design, answer reviewer questions, and test concepts put forth by reviewers and regional resource agency collaborators. The modeling has demonstrated that the hydraulic conditions comply with NMFS' anadromous fish passage and where applicable, PLWG guidelines. Some of the modifications considered include: orientation of the slots (north vs. south), location of the lamprey orifices (centered on baffle vs. flush to wall); lamprey orifice shaping, bollards at lamprey orifices, lamprey refuge box positioning, diffuser orifice size, and various S-curve arrangements. The design shown in this DDR provides the hydraulic and physical conditions that are expected to most improve fish passage.

The PIT tag detection system that is currently in the ladder will be removed and replaced. The new system will provide levels of detection that are equal to or better than the existing. USACE is coordinating closely with PSMFC to integrate the PIT tag detection system design into the modifications design.

The period for work within the dewatered ladder will be very short. The award date will need to allow for the contractor to procure materials and mobilize in advance of the dewatering so that the time in the dewatered ladder can be maximized. It appears feasible to complete the work in the standard outage period, but there is little room for any delays.

The modifications are expected to be installed during the 2024/2025 ladder shutdown period, with biological monitoring and testing to follow.

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Appendix A

Plates

Note: Plates in this section are from the 90% DDR submittal in June 2023 and do not represent the current contract drawings. These are included in the DDR for reference only to show previous iterations of the design.

US Army Corps
of Engineers
Portland District

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
FY2019 FISH ACCORDS LAMPREY PASSAGE
DESIGN DOCUMENTATION REPORT DRAWINGS - 90% REVIEW

THIS PROJECT WAS DESIGNED BY THE PORTLAND DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS OR SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER 1110-1-8152.

MARK J. SAWKA, P.E.
CHIEF, DESIGN BRANCH

PATRICK L. DUYCK, P.E.
CHIEF, ENGINEERING & CONSTRUCTION DIVISION

MICHAEL D. HELTON, PMP
COLONEL, CORPS OF ENGINEERS
DISTRICT COMMANDER

DATE:

SOLICITATION NUMBER:

GENERAL PLANS

REVISION MARK	FILE NAME	SHEET ID	DRAWING TITLE	SHEET ACTION No.
90% DDR	BDF1.123_G-001XXX.DGN	G-001	DRAWING INDEX SHEET NO.1	2
90% DDR	BDF1.123_G-002XXX.DGN	G-002	DRAWING INDEX SHEET NO.2	2
	BDF1.123_G-003XXX.DGN	G-003	RESERVED	2
90% DDR	BDF1.123_G-004XXX.DGN	G-004	GENERAL NOTES AND SYMBOLS	2
90% DDR	BDF1.123_G-005XXX.DGN	G-005	DISTRICT BOUNDARY, LOCAL VICINITY, PROJECT SITE MAPS AND PROJECT PHOTO	2
90% DDR	BDF1.123_G-006XXX.DGN	G-006	FISH LADDER EXIT CONTROL MODIFICATIONS ISOMETRIC LOOKING	2
90% DDR	BDF1.123_G-007XXX.DGN	G-007	FISH LADDER EXIT CONTROL MODIFICATIONS PLAN	2
	BDF1.123_G-008XXX.DGN	G-008	RESERVED	2

STRUCTURAL PLANS

GENERAL STRUCTURAL ARRANGEMENTS AND NOTES

REVISION MARK	FILE NAME	SHEET ID	DRAWING TITLE	SHEET ACTION No.
90% DDR	BDF1.123_S-001XXX.DGN	S-001	GENERAL STRUCTURAL NOTES	2
90% DDR	BDF1.123_S-002XXX.DGN	S-002	EXIT CONTROL SECTION – ISOMETRICS	2
90% DDR	BDF1.123_S-003XXX.DGN	S-003	EXIT CONTROL BAFFLE ARRANGEMENT ISOMETRIC LOOKING SOUTHEAST	2
	BDF1.123_S-004XXX.DGN	S-004	RESERVED	2

DEMOLITION SHEETS, FEATURE "D", (3) SHEETS

REVISION MARK	FILE NAME	SHEET ID	DRAWING TITLE	SHEET ACTION No.
90% DDR	BDF1.123_SD101XXX.DGN	SD101	EXIT CONTROL SECTION DEMOLITION PLAN	2
90% DDR	BDF1.123_SD302XXX.DGN	SD302	EXIT CONTROL SECTION EXISTING WEIR DEMOLITION SECTIONS AND DETAILS	2
	BDF1.123_SD###XXX.DGN	SD###	RESERVED	2

EXIT CONTROL APPROACH POOL MODIFICATIONS, FEATURE "F"

REVISION MARK	FILE NAME	SHEET ID	DRAWING TITLE	SHEET ACTION No.
	BDF1.123_SF001XXX.DGN	SF001	EXIT CONTROL APPROACH POOL MODIFICATIONS ISOMETRIC ARRANGEMENT	2
	BDF1.123_SF101XXX.DGN	SF101	EXIT CONTROL APPROACH POOL MODIFICATIONS PLAN, SECTIONS, AND DETAILS	2
	BDF1.123_SF301XXX.DGN	SF301	EXIT CONTROL APPROACH POOL MODIFICATIONS SECTIONS AND DETAILS SHT No.1	2
	BDF1.123_SF302XXX.DGN	SF302	EXIT CONTROL APPROACH POOL MODIFICATIONS SECTIONS AND DETAILS SHT No.2	2
	BDF1.123_SF303XXX.DGN	SF303	EXIT CONTROL APPROACH POOL MODIFICATIONS SECTIONS AND DETAILS SHT No.3	2
	BDF1.123_SF304XXX.DGN	SF304	EXIT CONTROL APPROACH POOL MODIFICATIONS SECTIONS AND DETAILS SHT No.3	2
	BDF1.123_SF###XXX.DGN	SF###	RESERVED	2
	BDF1.123_SF###XXX.DGN	SF###	RESERVED	2
	BDF1.123_SF###XXX.DGN	SF###	RESERVED	2

EXIT CONTROL WEIR MODIFICATIONS, FEATURE "G"

REVISION MARK	FILE NAME	SHEET ID	DRAWING TITLE	SHEET ACTION No.
	BDF1.123_SG001XXX.DGN	SG001	EXIT CONTROL WEIR MODIFICATIONS ISOMETRIC ARRANGEMENT	2
90% DDR	BDF1.123_SG101XXX.DGN	SG101	EXIT CONTROL SECTION BAFFLE ARRANGEMENT PLAN AND SECTION	2
	BDF1.123_SG301XXX.DGN	SG301	RESERVED	2
90% DDR	BDF1.123_SG302XXX.DGN	SG302	EXIT CONTROL SECTION BAFFLE ARRANGEMENT SECTIONS AND DETAILS	2
	BDF1.123_SG501XXX.DGN	SG501	RESERVED	2
90% DDR	BDF1.123_SG502XXX.DGN	SG502	EXIT CONTROL SECTION LAMPREY REFUGE BOX PLAN, ELEVATIONS, AND DETAILS	2
90% DDR	BDF1.123_SG503XXX.DGN	SG503	EXIT CONTROL BAFFLE ARRANGEMENT – BAFFLE No.s 1 AND 2 PLAN, ELEVATIONS AND DETAILS	2
90% DDR	BDF1.123_SG504XXX.DGN	SG504	EXIT CONTROL BAFFLE ARRANGEMENT – BAFFLE No.s 4, 5, AND 6 PLAN, ELEVEVATION, AND DETAILS	2
90% DDR	BDF1.123_SG505XXX.DGN	SG505	EXIT CONTROL BAFFLE ARRANGEMENT – BAFFLE No's 7, 8, AND 9 PLAN, ELEVEVATION, AND DETAILS	2
90% DDR	BDF1.123_SG508XXX.DGN	SG508	EXIT CONTROL BAFFLE ARRANGEMENT – BAFFLE DETAILS	2
90% DDR	BDF1.123_SG515XXX.DGN	SG515	EXIT CONTROL BAFFLE ARRANGEMENT – BAFFLE ACCESS WALKWAY PLAN	2
90% DDR	BDF1.123_SG516XXX.DGN	SG516	EXIT CONTROL BAFFLE ARRANGEMENT – BAFFLE ACCESS WALKWAY SECTIONS	2

EXIT CONTROL OUTLET MODIFICATIONS, FEATURE "H"

REVISION MARK	FILE NAME	SHEET ID	DRAWING TITLE	SHEET ACTION No.
	BDF1.123_SH001XXX.DGN	SH001	EXIT CONTROL OUTLET MODIFICATIONS ISOMETRIC ARRANGEMENT	2
	BDF1.123_SH101XXX.DGN	SH101	EXIT CONTROL OUTLET MODIFICATIONS PLAN, SECTIONS, AND DETAILS	2
	BDF1.123_SH301XXX.DGN	SH301	EXIT CONTROL OUTLET MODIFICATIONS SECTIONS AND DETAILS SHT No.1	2
	BDF1.123_SH302XXX.DGN	SH302	EXIT CONTROL OUTLET MODIFICATIONS SECTIONS AND DETAILS SHT No.2	2
	BDF1.123_SH501XXX.DGN	SH303	RESERVED	2
	BDF1.123_SH502XXX.DGN	SH304	RESERVED	2
	BDF1.123_SH001XXX.DGN	SH701	EXIT CONTROL OUTLET MODIFICATIONS REINFORCEMENT SHT No.1	2
	BDF1.123_SH101XXX.DGN	SH702	EXIT CONTROL OUTLET MODIFICATIONS REINFORCEMENT SHT No.2	2
	BDF1.123_SH201XXX.DGN	SH703	RESERVED	2

ELECTRICAL PLANS

REVISION MARK	FILE NAME	SHEET ID	DRAWING TITLE	SHEET ACTION No.
	BDF1.123_E-101.dgn	E-1	ELECTRICAL -- KEY PLAN	2
	BDF1.123_E-103.dgn	E-2	ELECTRICAL -- SITE PLAN	2
	BDF1.123_E-401.dgn	E-3	ELECTRICAL -- ADULT FISH FACILITY -- FIBER OPTIC ROUTING MODIFICATIONS	2
	BDF1.123_E-402.dgn	E-4	ELECTRICAL -- ADULT FISH LADDER -- DEMOLITION PLAN	2
	BDF1.123_E-403.dgn	E-5	ELECTRICAL -- ADULT FISH LADDER -- DEMOLITION SECTION	2
	BDF1.123_E-405.dgn	E-6	ELECTRICAL -- AFF PIT TAG ROOM MODIFICATIONS -- PLAN & SECTIONS	2
	BDF1.123_E-601.dgn	E-7	ELECTRICAL -- TRANSCEIVER BLOCK DIAGRAM -- EXISTING	2
	BDF1.123_E-602.dgn	E-8	ELECTRICAL -- TRANSCEIVER BLOCK DIAGRAM --DEMOLITION	2
	BDF1.123_E-603.dgn	E-9	ELECTRICAL -- TRANSCEIVER BLOCK DIAGRAM -- MODIFIED	2

NOTES:

1. SHEET ACTION NUMBER IDENTIFICATION KEY SHALL BE AS SHOWN BELOW:
   - 1 DENOTES FIO DRAWING IS OBSELETE AT THE COMPLETION OF THIS CONTRACT
   - 2 DENOTES DRAWING SHALL BE UPDATED AT THE COMPLETION OF THIS CONTRACT BY THE CONTRACTOR.
   - 3 DENOTES FIO DRAWING WILL BE SUPERCEDED BY THE FOLLOWING DRAWINGS AT THE COMPLETION OF THIS CONTRACT
   - 4 DENOTES FIO DRAWING WAS REFERENCED BY THE FOLLOWING CONTRACT DRAWINGS
   - 5 DENOTES FIO DRAWING IS FOR REFERENCE ONLY
2. FIO DENOTES "FOR INFORMATION ONLY"
3. ALL SHEETS IN THE PLANS AND SPECIFICATION DRAWING SET ARE INTENDED TO BE PRINTED IN COLOR.

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PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.
	DDR REVIEW 90%		

DATE 07 | DATE 06 | DATE 05 | DATE 04 | DATE 03 | DATE 02 | DATE 01

DESIGNED BY: P.D.T.
DRAWN BY: J.MCMAHON
CHECKED BY: S.DUNLOP
SUBMITTED BY: MATHEW D. HANSON, P.E.
DATE: 01/01/2016
SOLICITATION NO.:
CONTRACT NO.:
DRAWING NUMBER:
PLOT SCALE: 1:1
PLOT DATE:
SIZE: ANSI D
FILE NAME: BDF1.123G-001XXX.dgn

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

DRAWING INDEX SHEET NO.1

SHEET IDENTIFICATION
G-001

INFORMATIONAL PLANS

REVISION MARK	FILE NAME	DRAWING No.	DRAWING TITLE	SHEET ACTION No.
7		BDF-2-15/64	FISH FACILITIES-FISHWAYENTRANCE MONOLITHS NORTH SHORE PIPING	5
5		BDF-2-15/120	FISH FACILITIES EXIT CONTROL KEY PLANS AND SECTIONS	5
4		BDF-2-15/121	FISH FACILITIES EXIT CONTROL CONCRETE OUTLINE I	5
2		BDF-2-15/122	FISH FACILITIES EXIT CONTROL CONCRETE OUTLINE II	5
4		BDF-2-15/123	FISH FACILITIES EXIT CONTROL CONCRETE OUTLINE III	5
3		BDF-2-15/124	FISH FACILITIES EXIT CONTROL CONCRETE OUTLINE IV	5
5		BDF-2-15/125	FISH FACILITIES EXIT CONTROL CONCRETE OUTLINE V	5
1		BDF-2-15/125.1	FISH FACILITIES EXIT CONTROL EXPANSION JOINT DETAILS	5
5		BDF-2-15/126	FISH FACILITIES EXIT CONTROL REINFORCEMENT I	5
1		BDF-2-15/126.1	FISH FACILITIES EXIT CONTROL SLAB REINFORCEMENT I	5
1		BDF-2-15/126.2	FISH FACILITIES EXIT CONTROL SLAB REINFORCEMENT II	5
4		BDF-2-15/127	FISH FACILITIES EXIT CONTROL REINFORCEMENT II	5
1		BDF-2-15/128	FISH FACILITIES EXIT CONTROL REINFORCEMENT III	5
1		BDF-2-15/128.1	FISH FACILITIES EXIT CONTROL REINFORCEMENT IIIa	5
3		BDF-2-15/129	FISH FACILITIES EXIT CONTROL REINFORCEMENT IV	5
4		BDF-2-15/130	FISH FACILITIES EXIT CONTROL REINFORCEMENT V	5
1		BDF-2-15/130.1	FISH FACILITIES EXIT CONTROL REINFORCEMENT Va	5
4		BDF-2-15/131	FISH FACILITIES EXIT CONTROL REINFORCEMENT VI	5
3		BDF-2-15/132	FISH FACILITIES EXIT CONTROL REINFORCEMENT VII	5
4		BDF-2-15/133	FISH FACILITIES EXIT CONTROL REINFORCEMENT VIII	5
5		BDF-2-15/144	FISH FACILITIES EXIT CONTROL APPROACH POOL & BY-PASS LEADS	5
4		BDF-2-15/145	FISH FACILITIES EXIT CONTROL APPROACH POOL AND BY-PASS LEADS DETAILS I	5
2		BDF-2-15/146	FISH FACILITIES EXIT CONTROL APPROACH POOL AND BY-PASS LEADS DETAILS II	5
3		BDF-2-15/147	FISH FACILITIES EXIT CONTROL DISTRIBUTION PANELS & VANES	5
3		BDF-2-15/148	FISH FACILITIES EXIT CONTROL ADD-IN DIFFUSER RACKS & ORIFICE PLATE	5
3		BDF-2-15/149	FISH FACILITIES EXIT CONTROL BLEED-OFF DIFFUSER RACKS	5
2		BDF-2-15/150	FISH FACILITIES EXIT CONTROL MAKE-UP WATER SUPPLY TRASH RACKS	5
1		BDF-2-15/151	FISH FACILITIES EXIT CONTROL MAKE-UP WATER BULKHEAD	5
2		BDF-2-15/152	FISH FACILITIES EXIT CONTROL MAKE-UP WATER BULKHEAD DETAILS	5
1		BDF-2-15/156	FISH FACILITIES EXIT CONTROL DIFFUSER WALKWAYS	5
1		BDF-2-15/158	FISH FACILITIES EXIT CONTROL FISH BARRIER	5
2		BDF-2-15/163	FISH FACILITIES EXIT CONTROL EXIT CHANNEL TRASH RACK	5
3		BDF-2-15/189	D/S MIGRANT FACILITIES EVALUATOR NORTH SHORE FEATURES II	5
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INFORMATIONAL (cont.)

REVISION MARK	FILE NAME	DRAWING No.	DRAWING TITLE	SHEET ACTION No.
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REVISION MARK	FILE NAME	DRAWING No.	DRAWING TITLE	SHEET ACTION No.

NOTES:

1. SEE SHEET G-001 FOR SHEET ACTION NUMBER IDENTIFICATION KEY.

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PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.
	DDR REVIEW 90%	DATE 01	
		DATE 02	
		DATE 03	
		DATE 04	
		DATE 05	
		DATE 06	
		DATE 07	

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

DESIGNED BY: P.D.T.		DATE: 01/01/2016
DRAWN BY: J.MCMAHON	CHECKED BY: S.DUNLOP	SOLICITATION NO.:
SUBMITTED BY: MATTHEW D. HANSON, P.E.		CONTRACT NO.:
PLOT SCALE: 1:1	PLOT DATE:	DRAWING NUMBER:
SIZE: ANSI D	FILE NAME: BDF1.123G-002XXX.dgn	

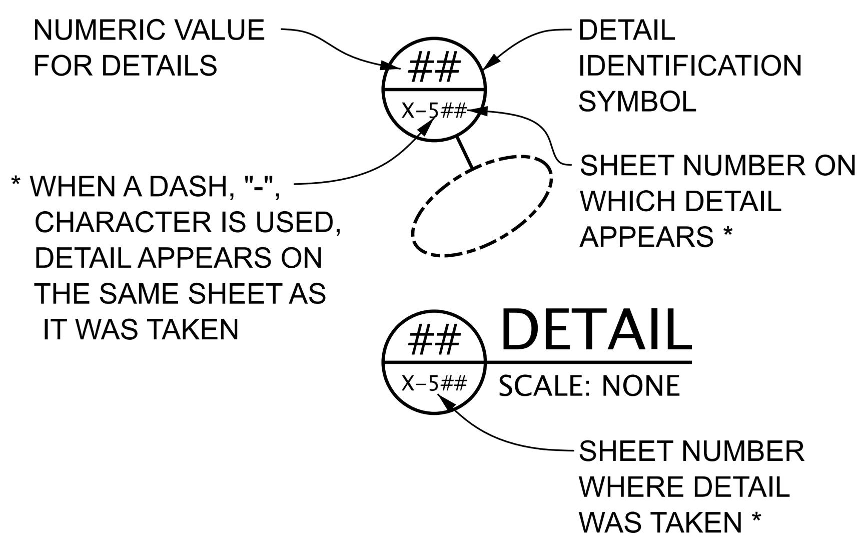
BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

DRAWING INDEX SHEET NO.2

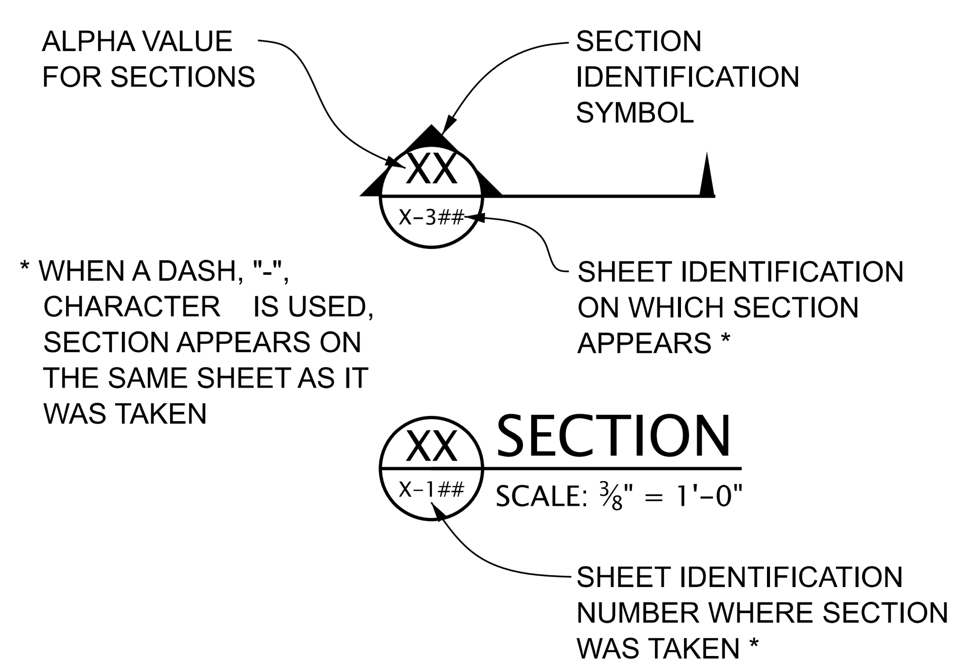
SHEET IDENTIFICATION
G-002

LEGEND:

1. DETAILING CONVENTION SHALL BE INTERPRETED AS SHOWN BELOW:



2. SECTIONING CONVENTION SHALL BE INTERPRETED AS SHOWN BELOW:



3. SHEET IDENTIFICATION CONVENTION SHALL BE INTERPRETED AS SHOWN BELOW, EXCEPT AS NOTED IN LEGEND NOTE 4 ON THIS SHEET:

SE302

- DISCIPLINE (SEE LEGEND NOTE 9)
- AREA FEATURE (SEE LEGEND NOTES 10 THRU 11)
- TYPE DESIGNATOR (SEE LEGEND NOTE 8)
- SEQUENCE NUMBER (00 THRU 99)

4. "MICROSTATION" / "AUTOCAD" SHEET FILE NAME CONVENTION SHALL BE INTERPRETED AS SHOWN BELOW:

BDF1.123G-102XXX.DGN

- PROJECT CODE (BD = BONNEVILLE)
- MAJOR PROJECT FEATURE (F = FISH PASSAGE)
- SERIES CODE (ASSIGNED BY CADD MANAGEMENT)
- "MICROSTATION" FILE EXTENSION (.DGN) "AUTOCAD" FILE EXTENSION (.DWG)
- USE "XXX"
- SEQUENCE NUMBER (00 THRU 99)
- SHEET TYPE (SEE LEGEND NOTE 8)
- AREA FEATURE (SEE LEGEND NOTES 10 THRU 11)
- DISCIPLINE (LEGEND SEE NOTE 9)

5. "MICROSTATION" / "AUTOCAD" MODEL FILE NAME CONVENTION SHALL BE INTERPRETED AS SHOWN BELOW:

BDF1.123zzzzzzzzzzzG-3DXXXX.DGN

- PROJECT CODE (BD = BONNEVILLE)
- MAJOR PROJECT FEATURE (F = FISH PASSAGE)
- SERIES CODE (ASSIGNED BY CADD MANAGEMENT)
- MODEL DESCRIPTION (USER DEFINED) (11) CHARCTERS MAX. OMIT IF NOT USED
- "MICROSTATION" FILE EXTENSION (.DGN) "AUTOCAD" FILE EXTENSION (.DWG)
- USER DEFINED(1 CHARACTER ONLY; USE "X" FOR UNUSED SPACES)
- USE "XXX"
- MODEL FILE TYPE (3D OR 2D)
- DASH SEPARATOR, "-" (REQUIRED)
- DISCIPLINE (SEE LEGEND NOTE 9)

6. "INVENTOR" SHEETS FILE NAME CONVENTION SHALL BE INTERPRETED AS SHOWN BELOW:

BDF1.123G-000XXX.IDW

- PROJECT CODE (BD = BONNEVILLE)
- MAJOR PROJECT FEATURE (F = FISH PASSAGE)
- SERIES CODE (ASSIGNED (BY CADD MANAGEMENT)
- "INVENTOR" SHEETS FILE EXTENSION
- USE "XXX"
- USER DEFINED(3 CHARACTERS ONLY; USE "0" FOR UNUSED SPACES)
- AREA FEATURE (SEE LEGEND NOTES 10 THRU 11)
- DISCIPLINE (SEE LEGEND NOTE 9)

7. "INVENTOR" MODEL FILE NAME CONVENTION SHALL BE INTERPRETED AS SHOWN BELOW:

ME-zzzzzzzzzzz.IPT

- DISCIPLINE (SEE LEGEND NOTE 9)
- AREA FEATURE (SEE LEGEND NOTES 10 THRU 11)
- "INVENTOR" FILE EXTENSION (.IPT, .IAM)
- MODEL DESCRIPTION (USER DEFINED) REQUIRED
- DASH SEPARATOR, "-" (REQUIRED)

8. TYPE DESIGNATOR FOR SHEET IDENTIFICATION SHALL BE AS SHOWN BELOW:

0	DENOTES	GENERAL
1	DENOTES	PLANS
2	DENOTES	ELEVATIONS
3	DENOTES	SECTIONS
4	DENOTES	ENLARGED VIEWS
5	DENOTES	DETAILS
6	DENOTES	SCHEDULES AND SCHEMATICS
7	DENOTES	REINFORCEMENT (USER DEFINED)
8	DENOTES	USER DEFINED

9. ENGINEERING DISCIPLINE DESIGNATOR FOR SHEET IDENTIFICATION SHALL BE AS SHOWN BELOW:

G	DENOTES	GENERAL
S	DENOTES	STRUCTURAL
E	DENOTES	ELECTRICAL

10. STRUCTURAL AREA FEATURE DESIGNATOR FOR "S" SHEETS IDENTIFICATION SHALL BE AS SHOWN BELOW:

-	DENOTES	STRUCTURAL GENERAL FEATURES (OR "ALL SHEETS ARE STRUCTURAL")
D	DENOTES	STRUCTURAL DEMOLITION
F	DENOTES	EXIT CONTROL APPROACH POOL MODIFICATIONS
G	DENOTES	EXIT CONTROL WEIRS MODIFICATIONS

11. ELECTRICAL AREA FEATURE DESIGNATOR FOR "E" SHEETS IDENTIFICATION SHALL BE AS SHOWN BELOW:

-	DENOTES	GENERAL FEATURES (OR "ALL SHEETS ARE ELECTRICAL")

US Army Corps of Engineers®
PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.
	DDR REVIEW 90%	DATE 01	
		DATE 02	
		DATE 03	
		DATE 04	
		DATE 05	
		DATE 06	
		DATE 07	

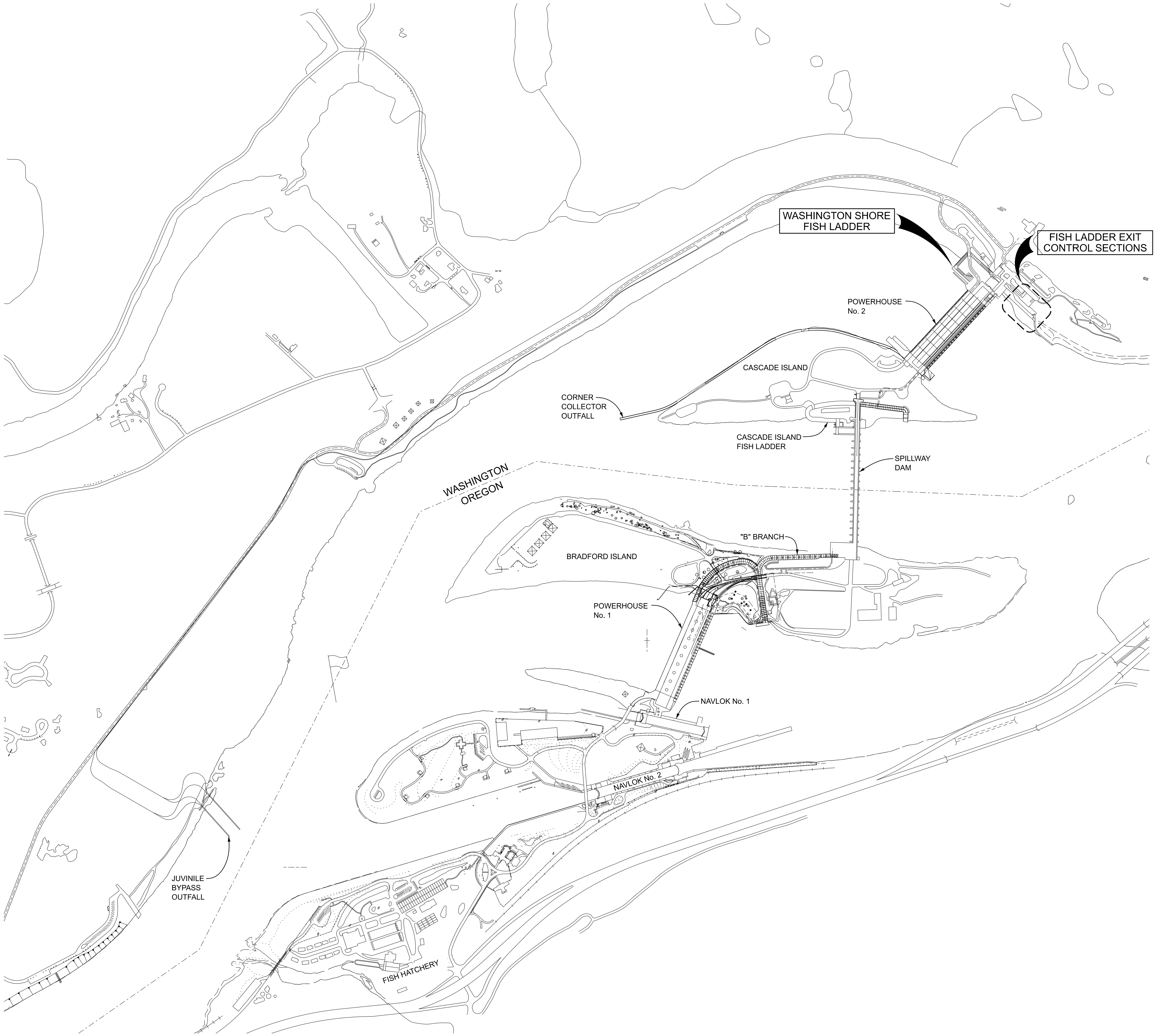
U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

DESIGNED BY: P.D.T. | DATE: 01/01/2016
DRAWN BY: J.MCMAHON | CHECKED BY: S. DUNLOP | SOLICITATION NO.:
SUBMITTED BY: MATTHEW D. HANSON, P.E. | CONTRACT NO.:
PLOT SCALE: 1:1 | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: BDF1.123G-004XXX.dgn

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

GENERAL NOTES AND SYMBOLS

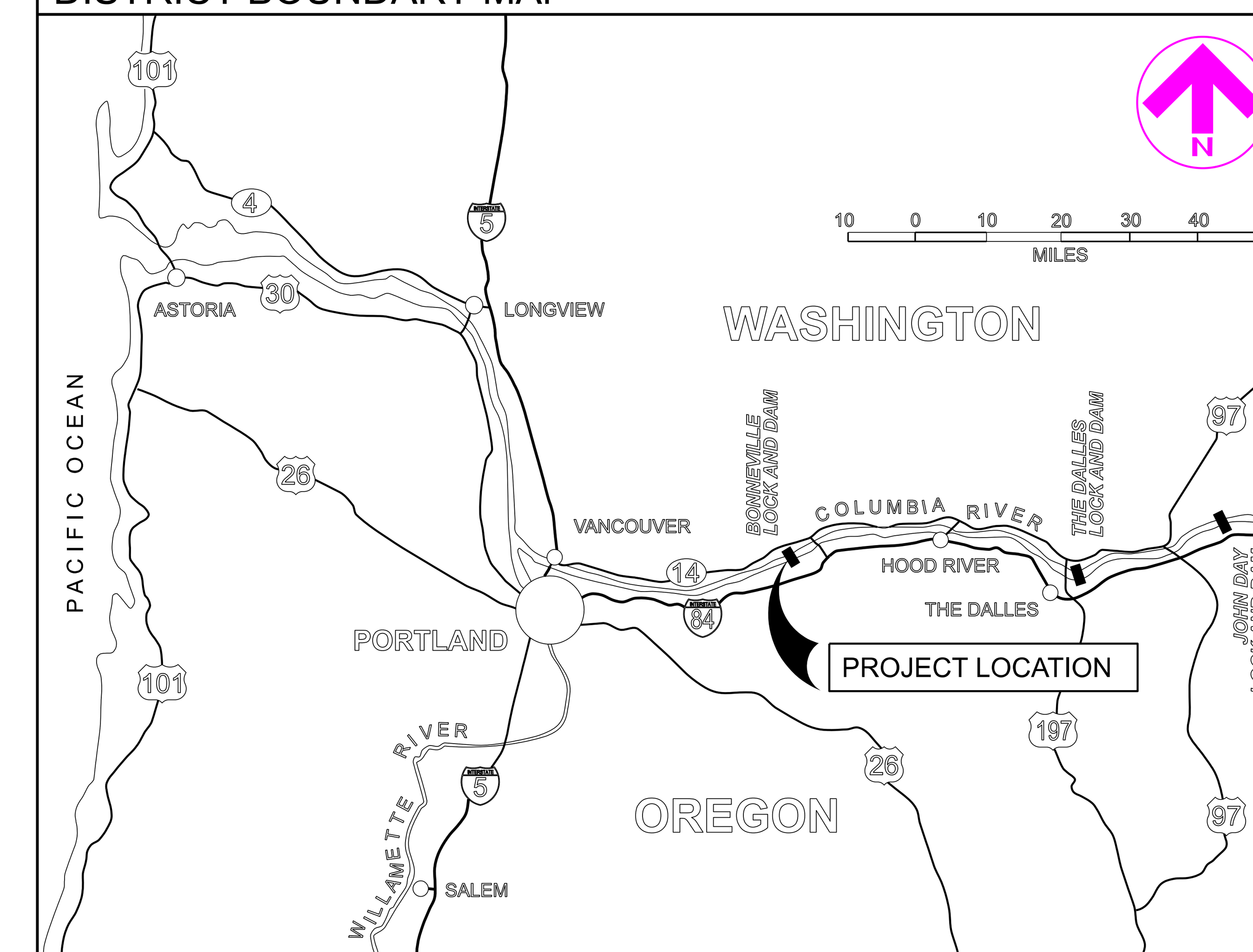
SHEET IDENTIFICATION
G-004



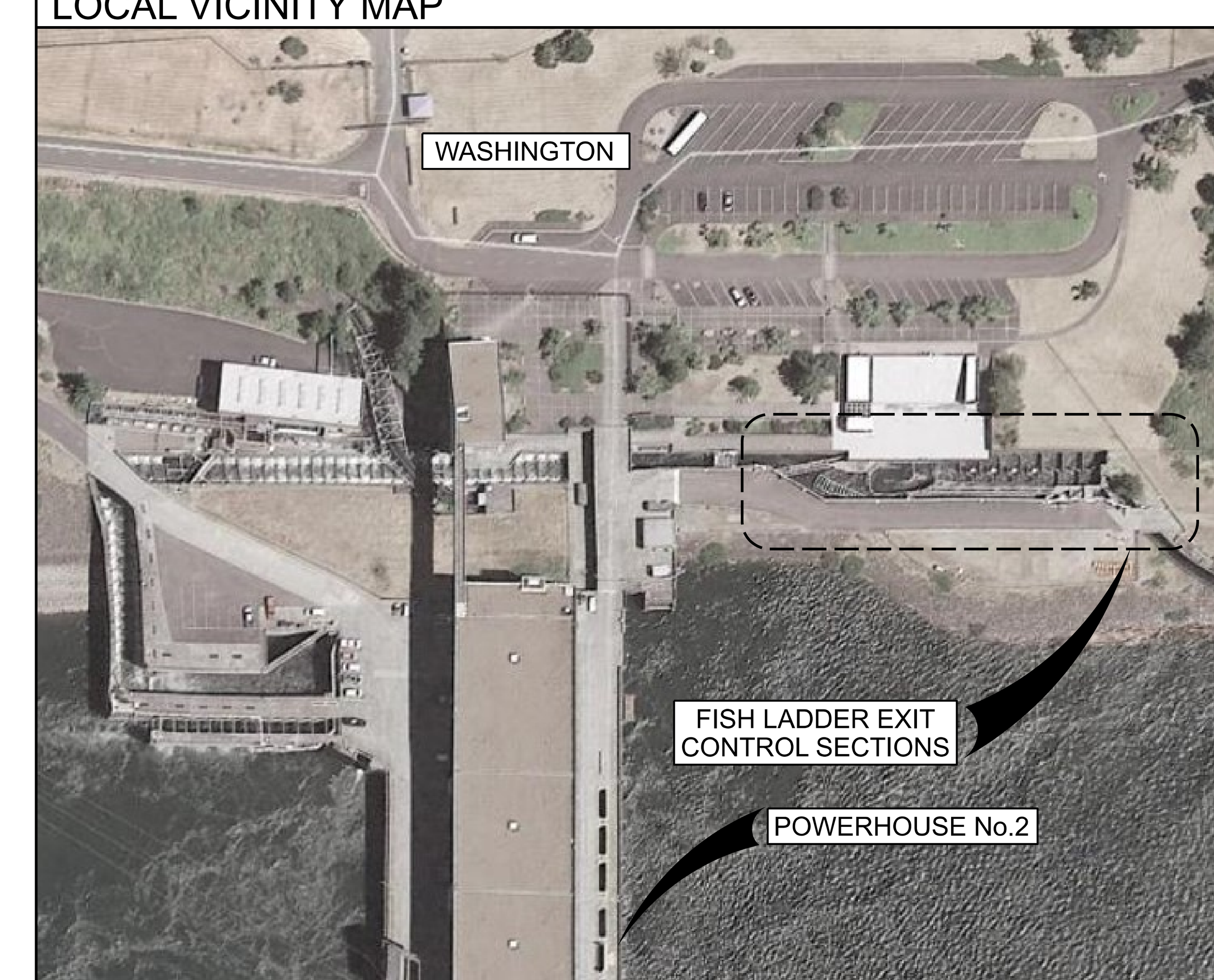
SITE PLAN

SCALE: NONE

DISTRICT BOUNDARY MAP



LOCAL VICINITY MAP



PROJECT PHOTO

US Army Corps of Engineers®
PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.
	DDR REVIEW 90%		

DATE 07 DATE 06 DATE 05 DATE 04 DATE 03 DATE 02 DATE 01

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PORTLAND DISTRICT
PORTLAND, OREGON

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DRAWN BY: J.MCMAHON
CHECKED BY: S. DUNLOP
SUBMITTED BY: MATHEW D. HANSON, P.E.
DATE: 01/01/2016
SOLICITATION NO.:
CONTRACT NO.:
DRAWING NUMBER:
PLOT SCALE: 1:1
PLOT DATE:
SIZE: ANSI D
FILE NAME: BDF1.123G-005XXX.dgn

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

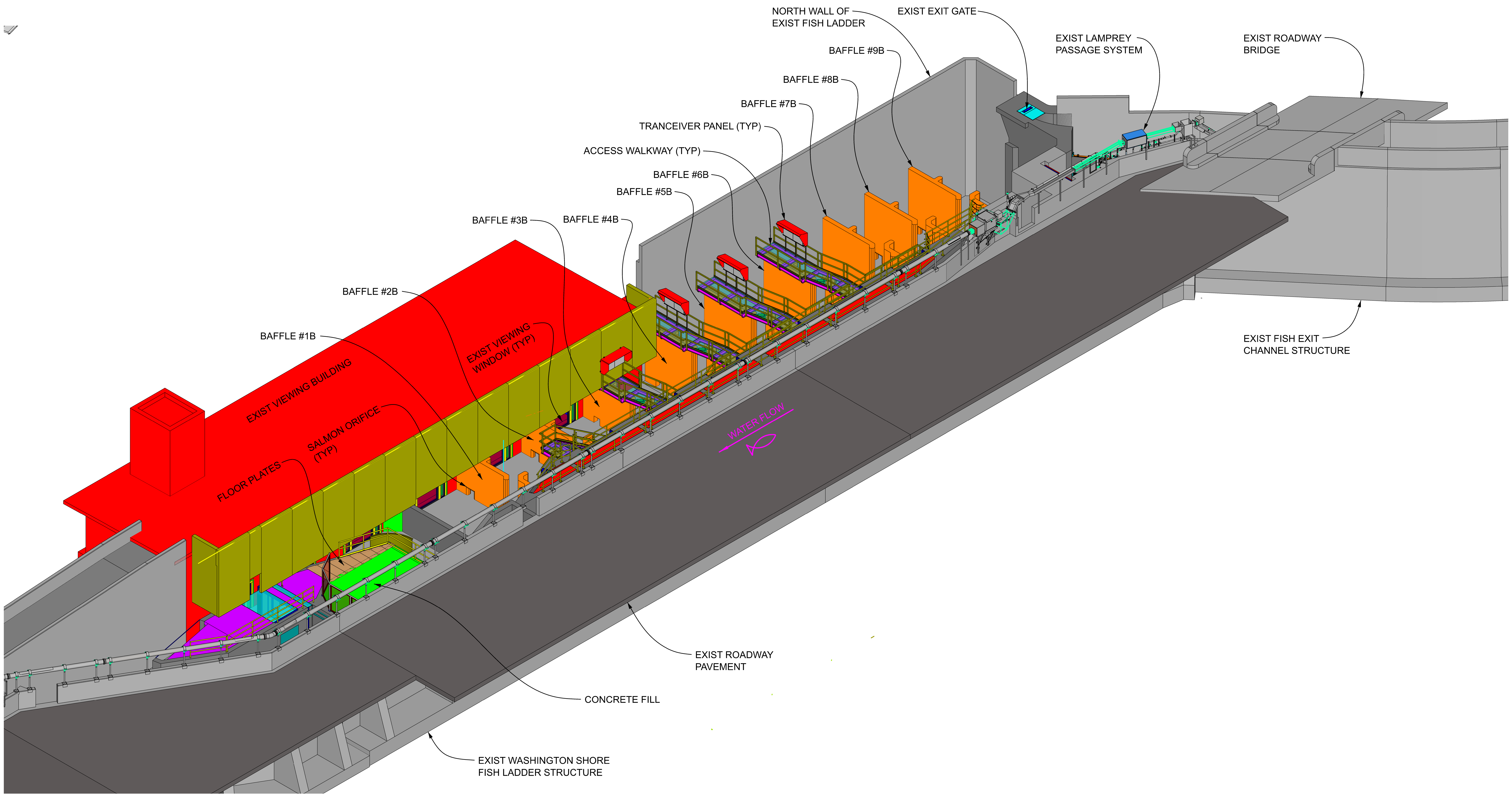
PROJECT SITE MAPS

SHEET IDENTIFICATION
G-005

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS.



ISOMETRIC - FISH LADDER EXIT CONTROL MODIFICATIONS

SCALE: NONE

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BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

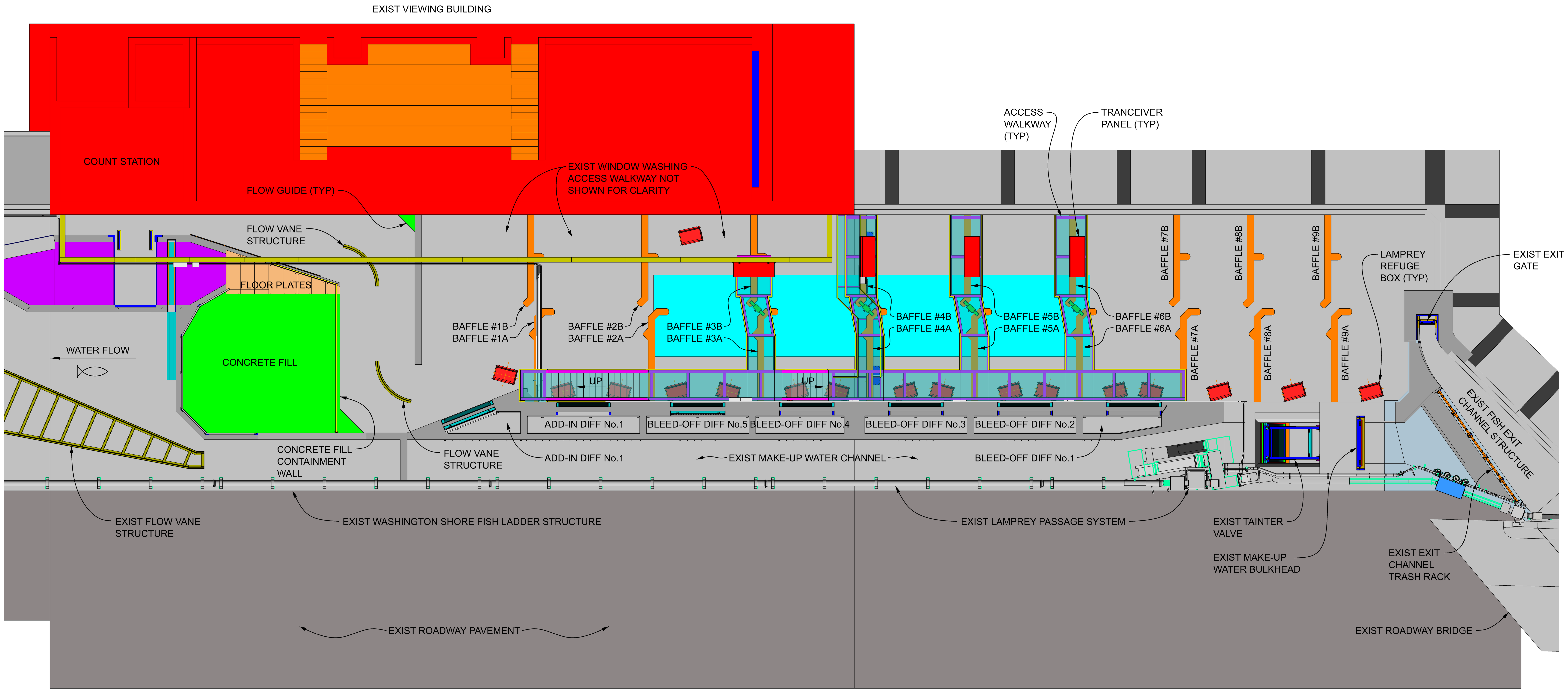
FISH LADDER EXIT CONTROL ARRANGEMENT
ISOMETRIC

SHEET IDENTIFICATION
G-006

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS.



PLAN - FISH LADDER EXIT CONTROL IMPROVEMENTS

SCALE: NONE

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CONTRACT NO.: PYN0XR6YTD
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI E
FILE NAME: BDF1.123G-007XXX.dgn

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

FISH LADDER EXIT CONTROL ARRANGEMENT
PLAN

SHEET IDENTIFICATION
G-007

GENERAL STRUCTURAL NOTES:

1. SCOPE

1.1 THESE GENERAL STRUCTURAL NOTES COVER STRUCTURAL FEATURES OF THE BONNEVILLE WASHINGTON SHORE FISH LADDER MODIFICATIONS FOUND ON THE "S" SERIES DRAWINGS FOR THE FY2019 FISH ACCORDS LAMPREY PASSAGE PRODUCT.

1.2 THESE NOTES ARE TYPICAL UNLESS NOTED OR DETAILED OTHERWISE ON DRAWINGS.

2. CONCRETE

2.1 THERE IS ONE CONCRETE MIX REQUIRED FOR THIS CONTRACT. THE CONTRACTOR SHALL DEVELOP AND SUBMIT THE MIX ACCORDING TO SECTION 03 IN THE SPECIFICATIONS. THE MIX DESIGN IS:

MIX 1 - CAST-IN-PLACE CONCRETE. THE 28 DAY COMPRESSIVE STRENGTH FOR THIS CAST-IN-PLACE CONCRETE (f'c) SHALL BE 4500 PSI.

3. CONCRETE FINISHING

3.1 ALL SURFACES INSIDE THE FISH LADDER, PRE-SORT POOLS AND POST-SORT POOLS, SHALL RECEIVE A CLASS A FINISH. ALL OTHER SURFACES SHALL RECEIVE A CLASS C FINISH.

3.2 ANY DAMAGE TO THE CONCRETE FINISH DURING CONSTRUCTION SHALL BE REPAIRED AS DESCRIBED IN THE SPECIFICATIONS.

4. CONCRETE COVER

4.1 CONCRETE COVER SHALL BE IN ACCORDANCE WITH ACI 318-19. SEE PLANS FOR SPECIFIC COVER DIMENSIONS.

5. STEEL REINFORCEMENT

5.1 PREPARATION FOR PLACING DRAWINGS AND BAR BENDING SCHEDULES SHALL BE IN ACCORDANCE WITH THE MOST RECENT EDITION OF ACI 315,"MANUAL OF STANDARD PRACTICE FOR DETAILING REINFORCED CONCRETE STRUCTURES". REINFORCEMENT PLACEMENT DRAWING SHOWING LENGTH AND LOCATIONS OF ALL SPLICES AND BAR BENDING SCHEDULES NEED TO BE SUBMITTED TO THE GOVERNMENT FOR APPROVAL.

5.2 ALL REINFORCEMENT STEEL SHALL CONFORM TO ASTM A 615, GRADE 60 REQUIREMENTS.

5.3 UNLESS NOTED OTHERWISE, ALL HOOKS SHALL BE STANDARD HOOKS AS DEFINED BY ACI 318-19. BAR SPLICE LOCATIONS WILL BE DESIGNED BY THE CONTRACTOR AND SHOWN ON SUBMITTALS.

5.4 BAR SPACING DIMENSIONS ARE MEASURED TO THE CENTERS OF BARS.

5.5 A SYMBOL SUCH AS STAG. SPL. INDICATES REINFORCING BARS TO BE STAGGER LAP SPLICED (CLASS B) BY ALTERNATING LAP LOCATIONS AS SHOWN, AND PROVIDING THE INDICATED LAP LENGTH.

5.6 A NOTATION SUCH AS 7'-6" 1'-6" FOLLOWING THE BAR SIZE AND SPACING INDICATES A BENT BAR WITH AN OUTSIDE-TO-OUTSIDE DIMENSION (NOT BAR LENGTH) OF 7'-6". A LETTER OR DIMENSION ON THE SHORT LEG INDICATES THE FOLLOWING:

L: EXTEND BAR LAP SPLICE LENGTH BEYOND BEND

E: EXTEND BAR EMBEDMENT LENGTH BEYOND CROSSING BAR

DIMENSION: OUTSIDE-TO-OUTSIDE LENGTH OF SHORT LEG

WHEN NO LETTER OR DIMENSION IS GIVEN, PROVIDE A STANDARD 90° HOOK

5.7 ALL BARS SHALL BE SPACED AS SHOWN ON DRAWINGS.

5.8 REINFORCING BARS SHALL NOT CONTINUE ACROSS AN EXPANSION OR CONTRACTION JOINT UNLESS SHOWN IN THE DRAWINGS. REBAR SHALL CONTINUE ACROSS CONSTRUCTION JOINTS AS DETAILED IN THE DRAWINGS.

5.9 VERTICAL REINFORCEMENT PROJECTING ABOVE THE FORMS SHALL BE SUPPORTED TO PREVENT THE BREAKING OF BOND BETWEEN THE REINFORCING BARS AND FRESHLY PLACED CONCRETE.

5.10 DEVELOPMENT AND SPLICE LENGTHS FOR REINFORCING BARS USED IN THIS CONTRACT SHALL BE AS DESCRIBED IN A.C.I. 318-11 U.N.O., AND ARE SHOWN IN THE TABLES.

5.11 TOP BARS ARE HORIZONTAL REINFORCEMENT SO PLACED THAT MORE THAN 12 INCHES OF FRESH CONCRETE IS CAST IN THE MEMBER BELOW THE DEVELOPMENT LENGTH OR SPLICE.

6 FIBERGLASS REINFORCED PLASTIC REINFORCEMENT

6.1 ALL PIT TAG BAFFLES MUST USE GFRP REBAR.

6.2 ALL REBAR WITHIN 12 INCH VERTICAL BOUNDARY FROM THE PIT ANTENNAS MUST BE GFRP.

6.3 ALL REBAR WITHIN THE HORIZONTAL BOUNDARY MUST BE GFRP. SEE DRAWING xxxxxxxxx FOR THE BOUNDARY DIMENSIONS.

7. STRUCTURAL STEEL

7.1 ALL STRUCTURAL STEEL PLATES AND SHAPES WILL CONFORM TO ASTM A 572 UNLESS OTHERISE NOTED IN THE DRAWINGS.

7.2 STRUCTURAL STEEL PIPE WILL CONFORM TO ASTM A53, GRADE B OR ASTM A500, GRADE B UNLESS NOTED OTHERWISE.

7.3 STRUCTURAL STEEL TUBING WILL CONFORM TO ASTM A500, GRADE B.

7.4 GALVANIZING OF STEEL WILL CONFORM TO ASTM A123, UNLESS OTHERWISE NOTED.

7.5 ALL CARBON STEEL BOLTS, NUTS, AND WASHERS USED FOR STRUCTURAL STEEL CONNECTIONS SHALL BE OF THE MATERIAL, GRADE, TYPE, CLASS, STYLE AND FINISH INDICATED BELOW UNLESS NOTED OTHERWISE:

a. BOLTS - ASTM A325, TYPE 1, GALVANIZED

b. NUTS - ASTM A563, GRADE DH, TYPE 1, GALVANIZED

c. PLAIN WASHERS - ASTM F436, TYPE 1, GALVANIZED

7.6 FIELD WELDING WILL NOT BE PERMITTED UNLESS SHOWN ON THE DRAWINGS OR AUTHORIZED BY THE CONTRACTING OFFICER.

7.7 ALL WELDS SHALL BE CONTINUOUS UNLESS OTHERWISE NOTED. EVERY ACCESSIBLE JOINT NOT HAVING A DESIGNATED TYPE AND SIZE OF WELD SHALL BE SEAL WELDED PER AISC MINIMUM WELD SIZE.

7.8 ALL SHARP EDGES SHALL BE GROUND TO A 1/16" RADIUS MIN. UNO.

7.11 GRIND ALL GROOVE WELDS SMOOTH SUCH THAT THERE ARE NO BURRS, OFFSETS OR ROUGH AREAS. GRIND ALL WELDS ON HANDRAILS SMOOTH SUCH THAT THERE ARE NO BURRS, OFFSETS OR ROUGH AREAS.

7.12 ALL HANDRAIL IS 1½" SCH 40 PIPE. ALL HANDRAIL POSTS SHALL BE 1½" SCH 80 PIPE. ALL HANDRAIL MATERIAL SHALL BE ASTM A53, TYPE S, GRADE B (GALVANIZED).

7.13 WALKWAYS, HANDRAILS, STAIRS, LADDERS AND ALL APPLICABLE CONNECTION DETAILS SHALL BE CONTRACTOR DESIGNED WHERE CALLED OUT ON THE DRAWINGS AND SHALL MEET ALL REQUIRMENTS SET FORTH IN THE LATEST EM 385-1-1 "SAFETY AND HEALTH REQUIREMENTS MANUAL". SUBMIT ALL CALCULATIONS AND DRAWINGS FOR GOVERNMENT APPROVAL AS CALLED OUT IN THE SPECIFICATIONS .

7.14 GALVANIZE ALL WALKWAY STEEL. ALL GRATING TO BE SERRATED ~~OR ANTI-SKID BAR~~ GRATING.

8. EMBEDDED METALS

8.1 CONCRETE ANCHORS SHALL BE AS INDICATED IN THE DRAWINGS.

8.2 UNLESS NOTED OTHERWISE, EMBEDDED PIPES SHALL BE WRAPPED WITH A HYDROPHILIC WATERSTOP SIMILAR TO DE-NEEF CONCHEM BENTORUB.

8.3 POST INSTALLED ANCHORS SHALL MEET ONE OF THE FOLLOWING ESR-1546, ESR-1917, ESR-2302, ESR-2322, AND/OR ESR-3013 EVALUATION REPORTS THAT ARE USING VARIOUS HILTI PRODUCTS. OTHER MANUFACTURES PRODUCTS THAT MEET AN ESR STANDARD COMPARABLE TO THE HILTI STANDARD MAY BE USED UPON APPROVAL. CONCRETE ANCHORS SHALL BE INSTALLED PER MANUFACTURERS PUBLISHED WRITTEN RECOMMENDATIONS.

8.4 ALL EMBEDDED (CAST-IN-PLACE) THREADED ANCHOR RODS (CONCRETE ANCHORS) MUST MEET ASTM F1554, GRADE 36 REQUIREMENTS AND MUST BE GALVANIZED. ANCHOR NUTS MUST MEET ASTM A563, GRADE DH, HEX STYLE (GALVANIZED). WASHERS MUST MEET ASTM F436 (GALVANIZED).

9. MISCELLANEOUS

9.1 GROUT SHALL BE NON SHRINK, NON METALLIC TYPE WITH COMPRESSIVE STRENGTH OF 5000 PSI.

9.2 ALL GROUT USED FOR BASE PLATES SHALL HAVE 100% BEARING AFTER PLACEMENT.

9.3 PLACE GROUT IN ACCORDANCE WITH THE MANUFACTURER'S WRITTEN INSTALLATION INSTRUCTIONS AND RECOMMENDATIONS. DO NOT USE GROUT WHICH HAS BEGUN TO SET OR IF MORE THAN ONE HOUR HAS ELAPSED AFTER INITIAL MIXING. FILL BLIND CAVITIES BY PRESSURE INJECTION UNDER CONTROLLED VENTING.

9.4 PROTECT FRESHLY PLACED GROUT FROM PREMATURE DRYING AND EXCESSIVE COLD OR HOT TEMPERATURES. COMPLY WITH MANUFACTURER'S REQUIREMENTS FOR COLD-WEATHER AND HOT-WEATHER PROTECTION DURING CURING.

STRUCTURAL LEGEND:

1. MATERIAL PATTERNS SHALL BE AS SHOWN BELOW:

DEMOLITION OF CONCRETE

DENOTES EXISTING CONCRETE

DENOTES NEW CONCRETE

DENOTES STEEL AND OTHER METALS

DENOTES GROUT

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CHECKED BY:
SOLICITATION NO.:
SUBMITTED BY: MATTHEW D. HANSON, P.E.
CONTRACT NO.:
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.123S-001XXX.dgn

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
FY2019 FISH ACCORDS LAMPREY PASSAGE

GENERAL STRUCTURAL NOTES AND SPECIFICATIONS

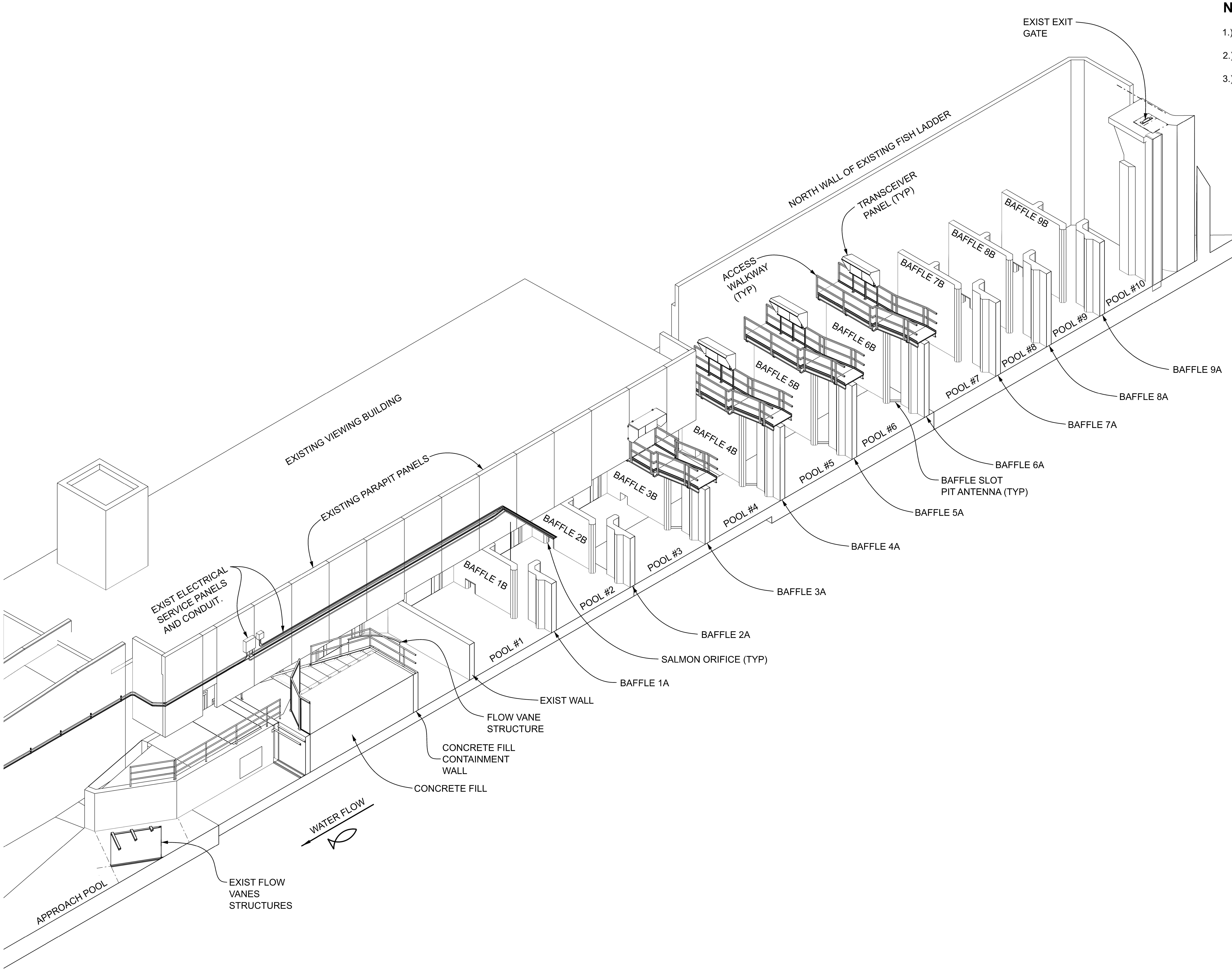
SHEET IDENTIFICATION
S-001

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



ISOMETRIC LOOKING NORTH EAST THRU FISH LADDER EXIT CONTROL BAFFLE ARRANGEMENT

SCALE: NONE

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SIZE: ANSI D	FILE NAME: BDF1.123S-002XXX.dgn	

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
ISOMETRIC LOOKING NORTH EAST

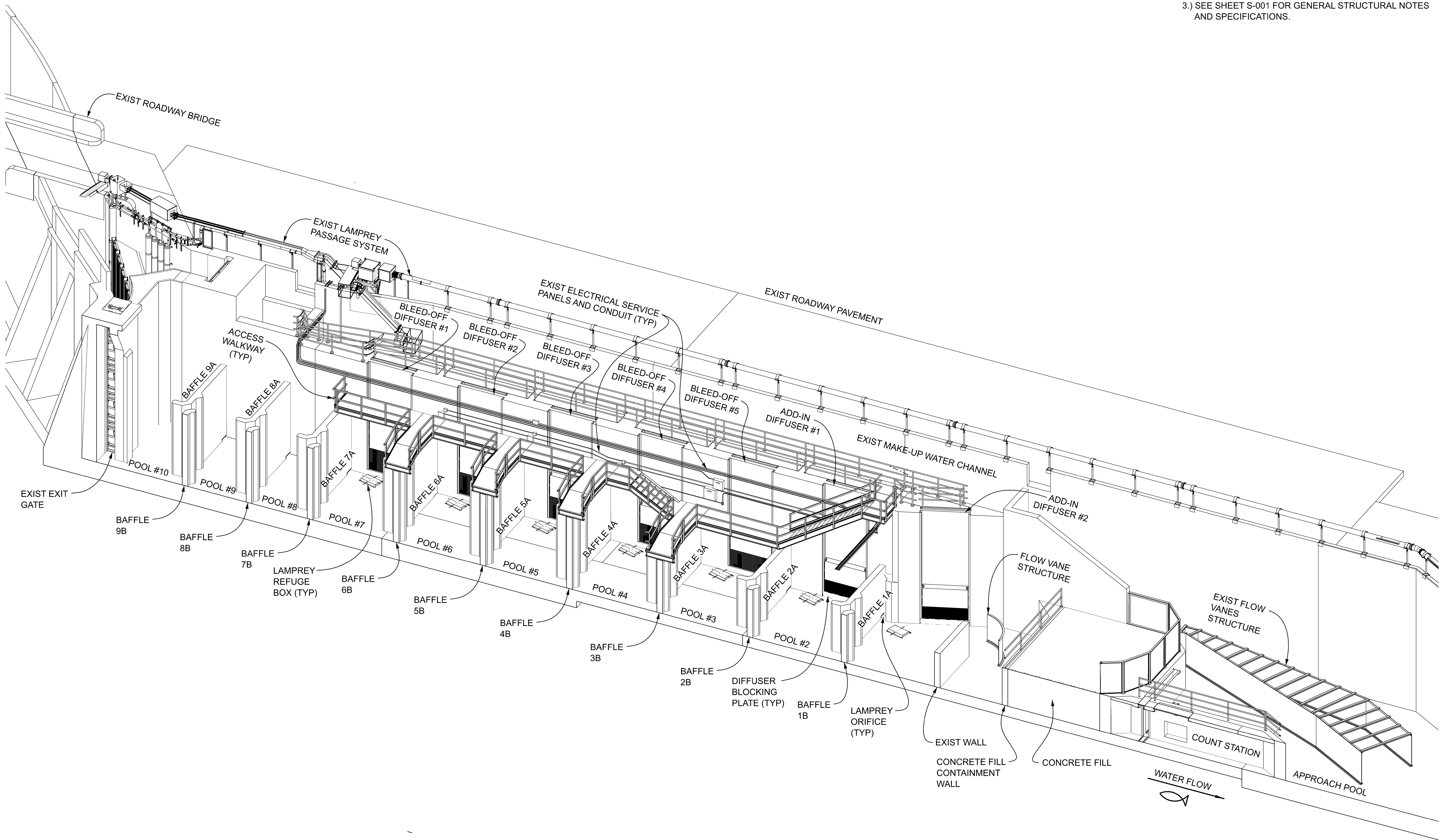
SHEET IDENTIFICATION
S-002

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



ISOMETRIC LOOKING SOUTHEAST THRU FISH LADDER EXIT CONTROL BAFFLE ARRANGEMENT

SCALE: NONE

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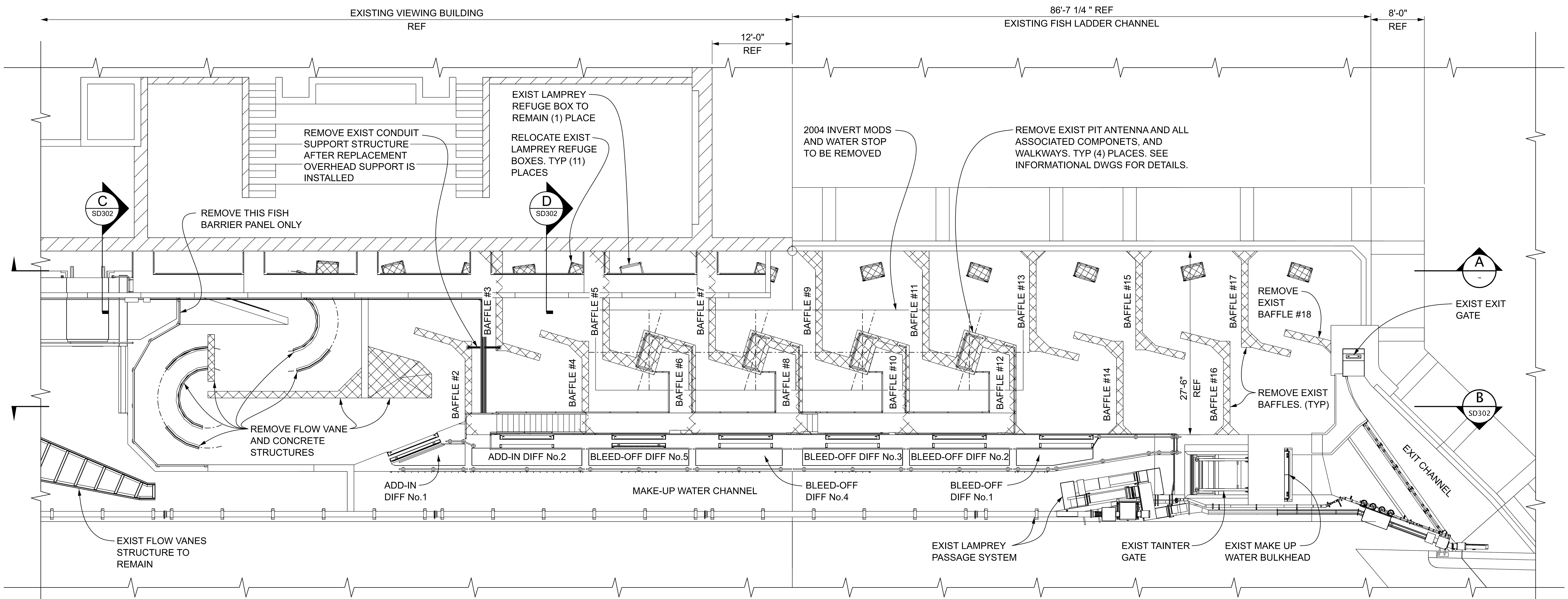
BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

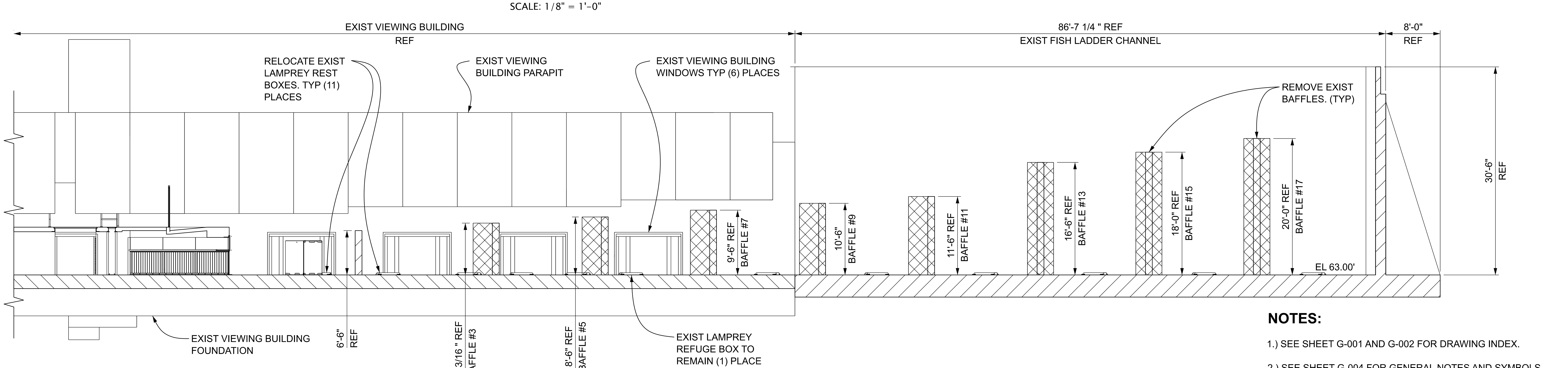
EXIT CONTROL BAFFLE ARRANGEMENT
ISOMETRIC LOOKING SOUTH EAST

SHEET IDENTIFICATION
S-003



PLAN-FISH LADDER EXIT CONTROL DEMOLITION

SCALE: 1/8" = 1'-0"



A SECTION - LOOKING NORTH THRU FISH LADDER CHANNEL

SCALE: 1/8" = 1'-0"

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.

4.) FISH LADDER CHANNEL INVERT DEMOLITION TO BE DETERMINED.

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FILE NAME: BDF1.123SD101XXX.dgn

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BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
FY2019 FISH ACCORDS
LAMPREY PASSAGE

EXIT CONTROL SECTION DEMOLITION
PLAN AND SECTION

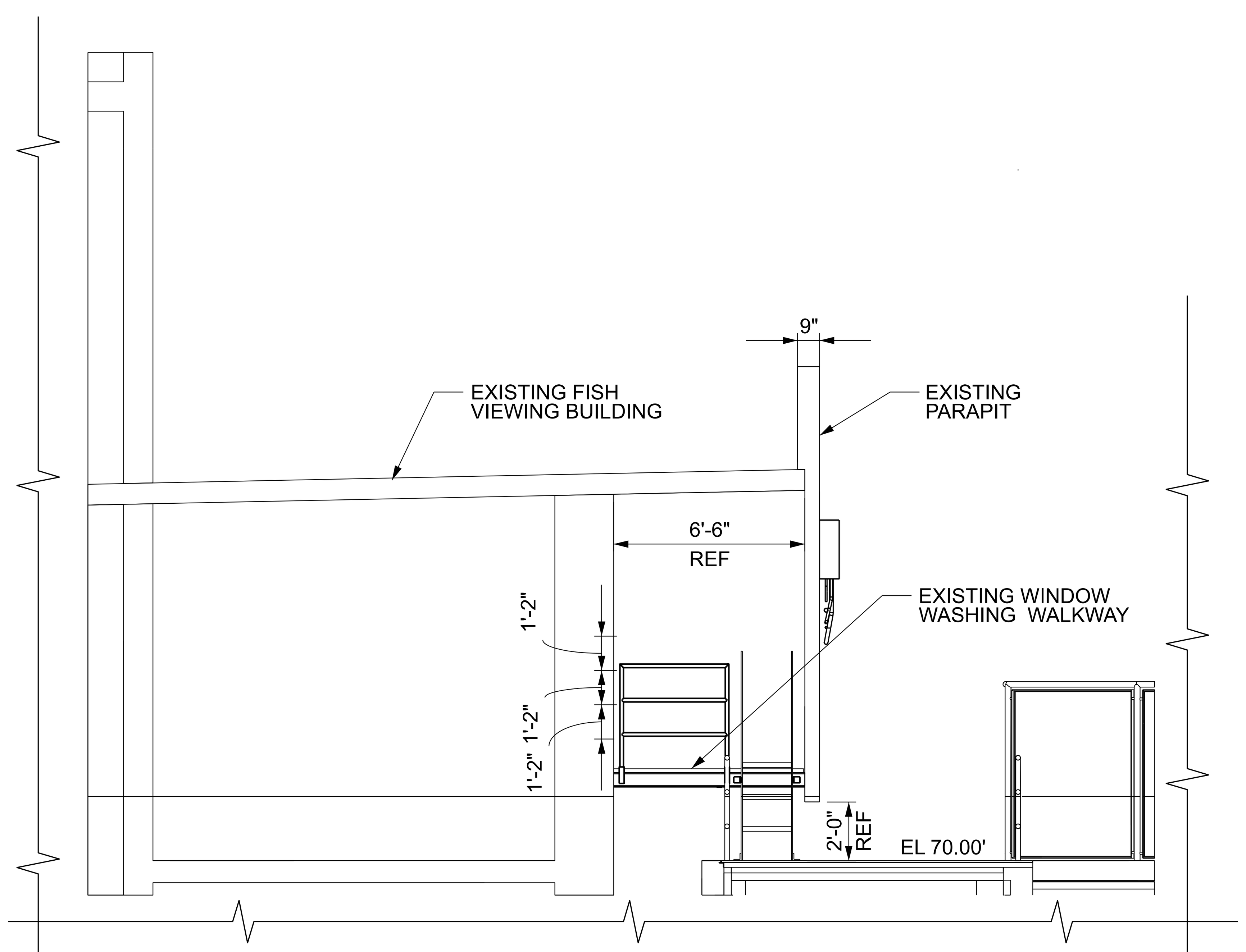
SHEET IDENTIFICATION
SD101

NOTES:

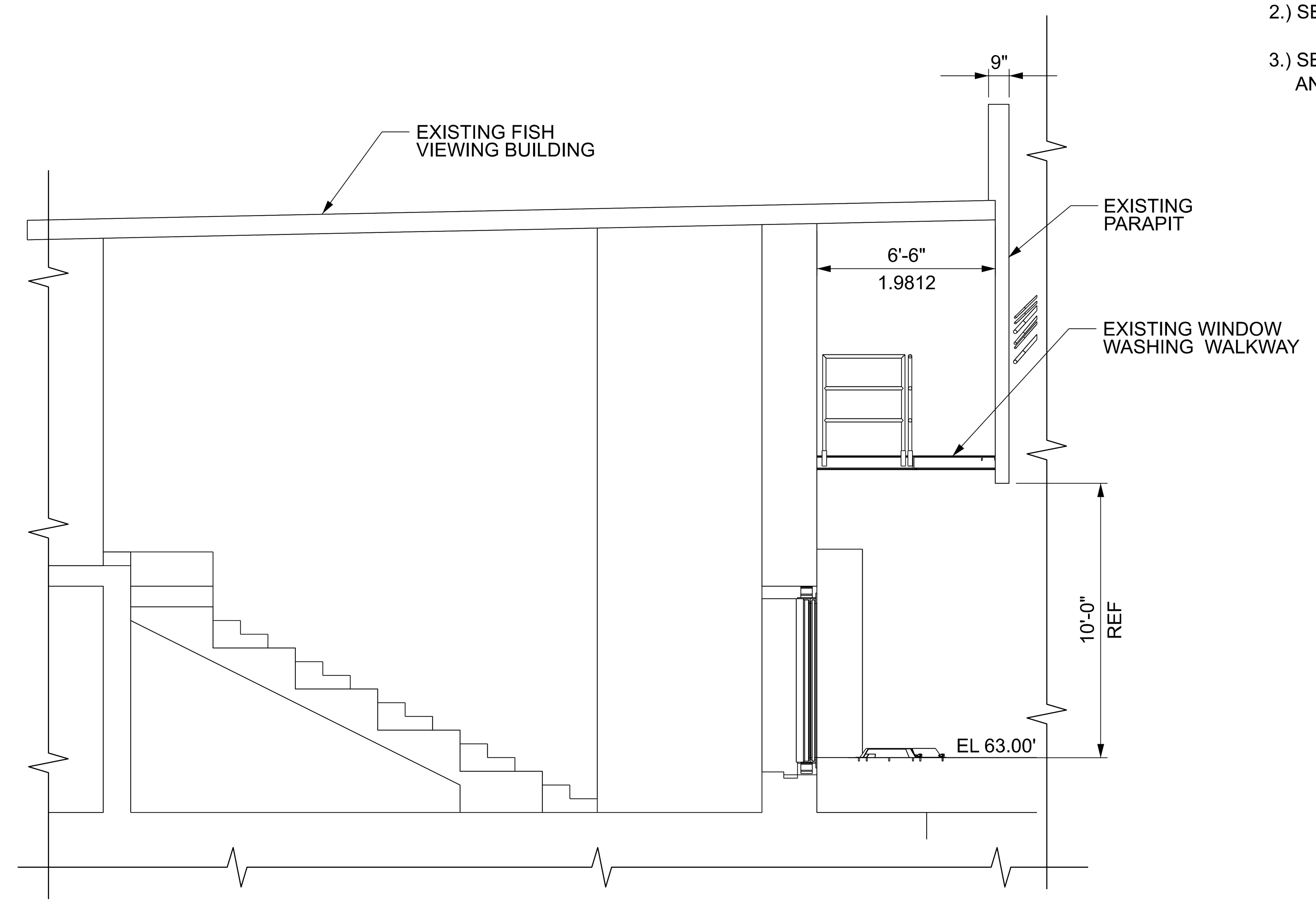
1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

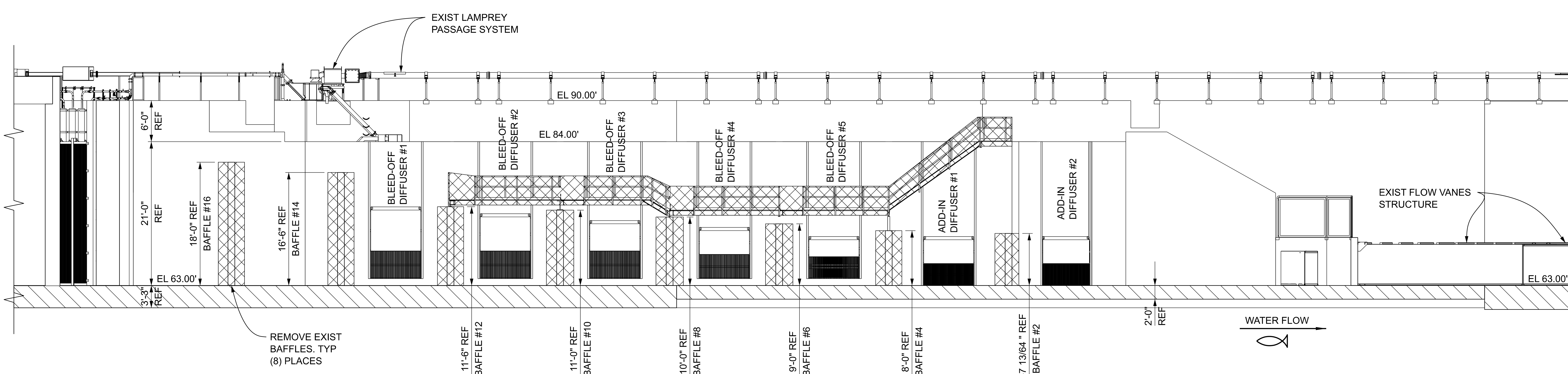
3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



C SD301 SECTION - LOOKING EAST THRU WALKWAY
SCALE: 1/4" = 1'-0"



D SD301 SECTION - LOOKING EAST THRU WALKWAY
SCALE: 1/4" = 1'-0"



B - SECTION - LOOKING SOUTH THRU FISH LADDER CHANNEL
SCALE: 1/8" = 1'-0"

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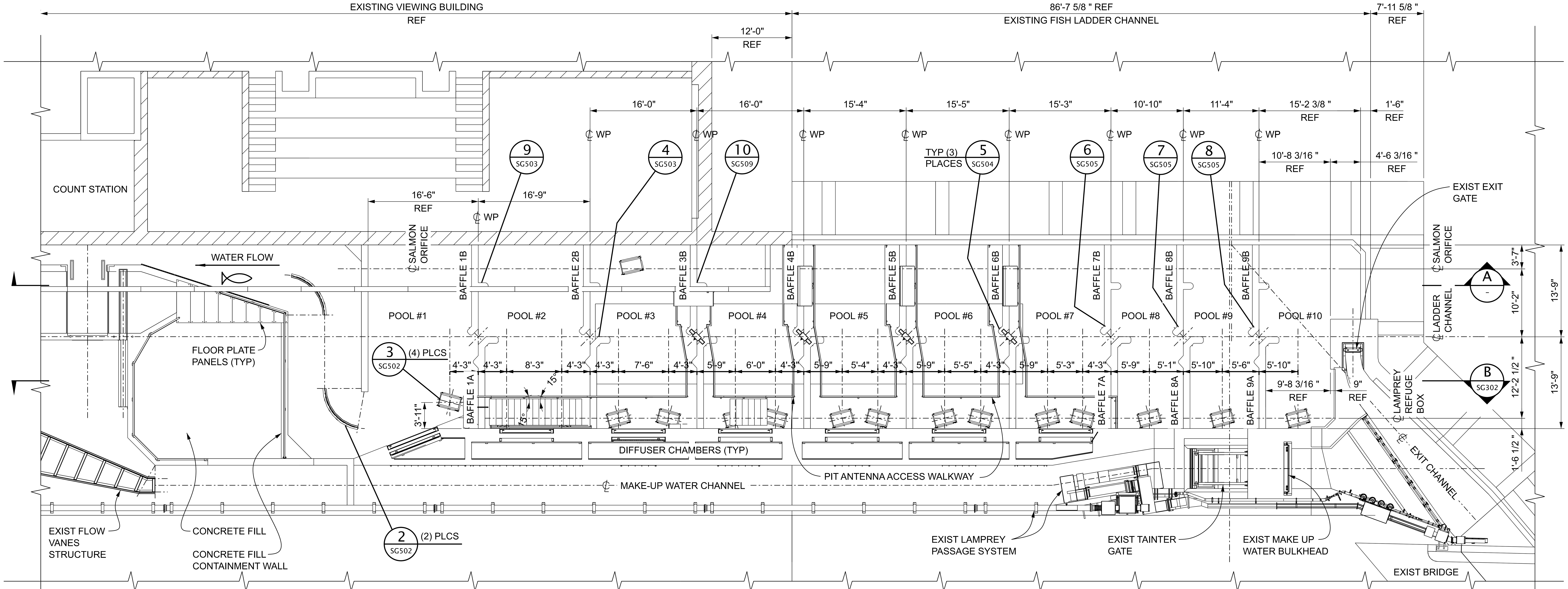
SIZE: ANSI D | FILE NAME: BDF1.123SD302XXX.dgn

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
FY2019 FISH ACCORDS
LAMPREY PASSAGE

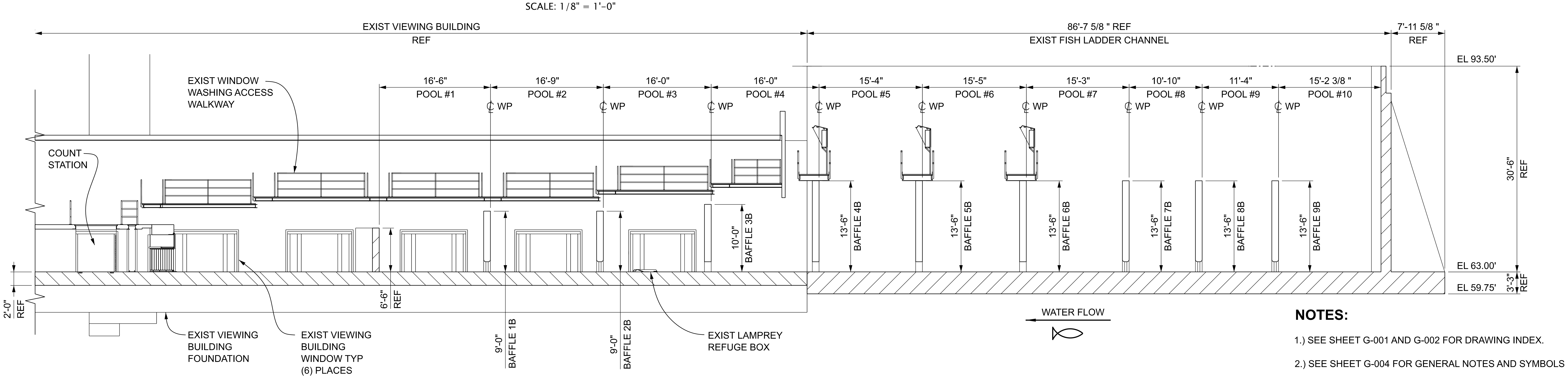
EXIT CONTROL SECTION DEMOLITION
SECTIONS AND DETAILS

SHEET IDENTIFICATION
SD302



PLAN–FISH LADDER EXIT CONTROL BAFFLE ARRANGEMENT

SCALE: 1/8" = 1'-0"



SECTION - LOOKING NORTH THRU FISH LADDER CHANNEL

SCALE: 1/8" = 1'-0"

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.

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BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
PLAN AND SECTION

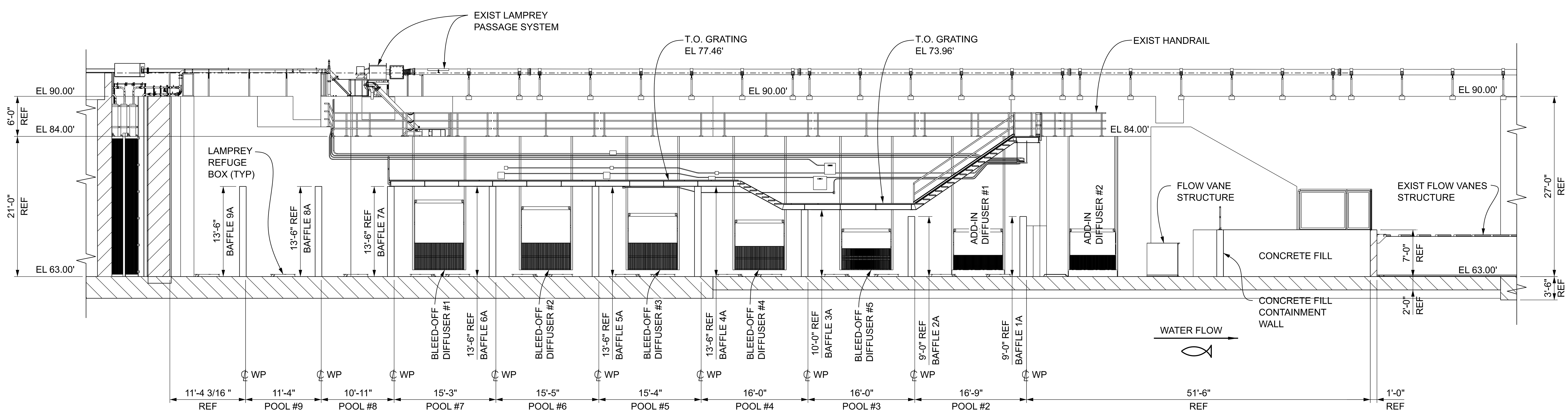
SHEET IDENTIFICATION
SG101

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



B SECTION - LOOKING SOUTH THRU FISH LADDER CHANNEL
SCALE: 1/8" = 1'-0"

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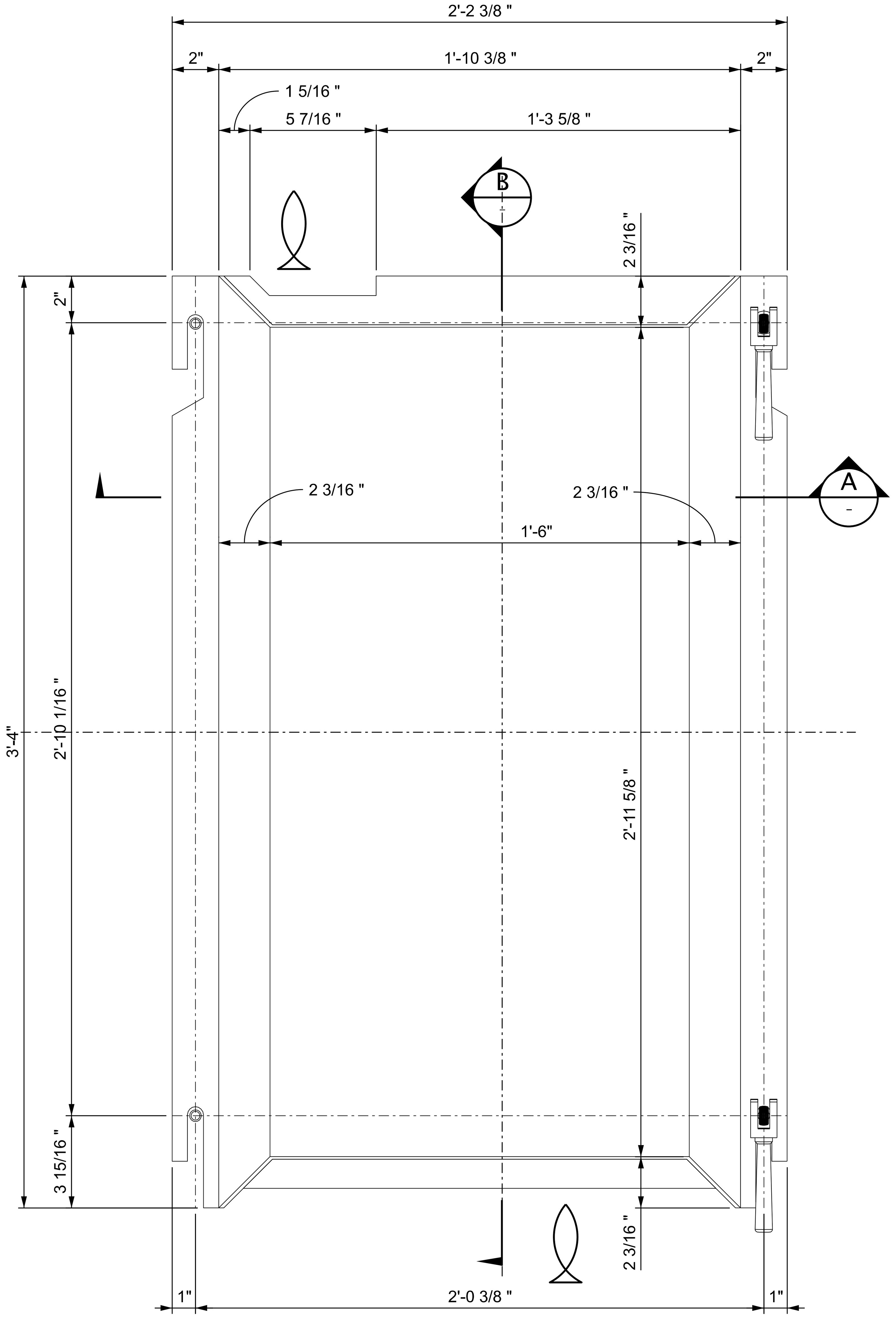
BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
SECTIONS AND DETAILS

SHEET IDENTIFICATION
SG302



DETAIL - LAMPREY REFUGE BOX PLAN

3 / SG101

SCALE: 3" = 1'-0"

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.

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SIZE: ANSI D | FILE NAME: BDF1.123SG502XXX.dgn

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

LAMPREY REFUGE BOX PLAN

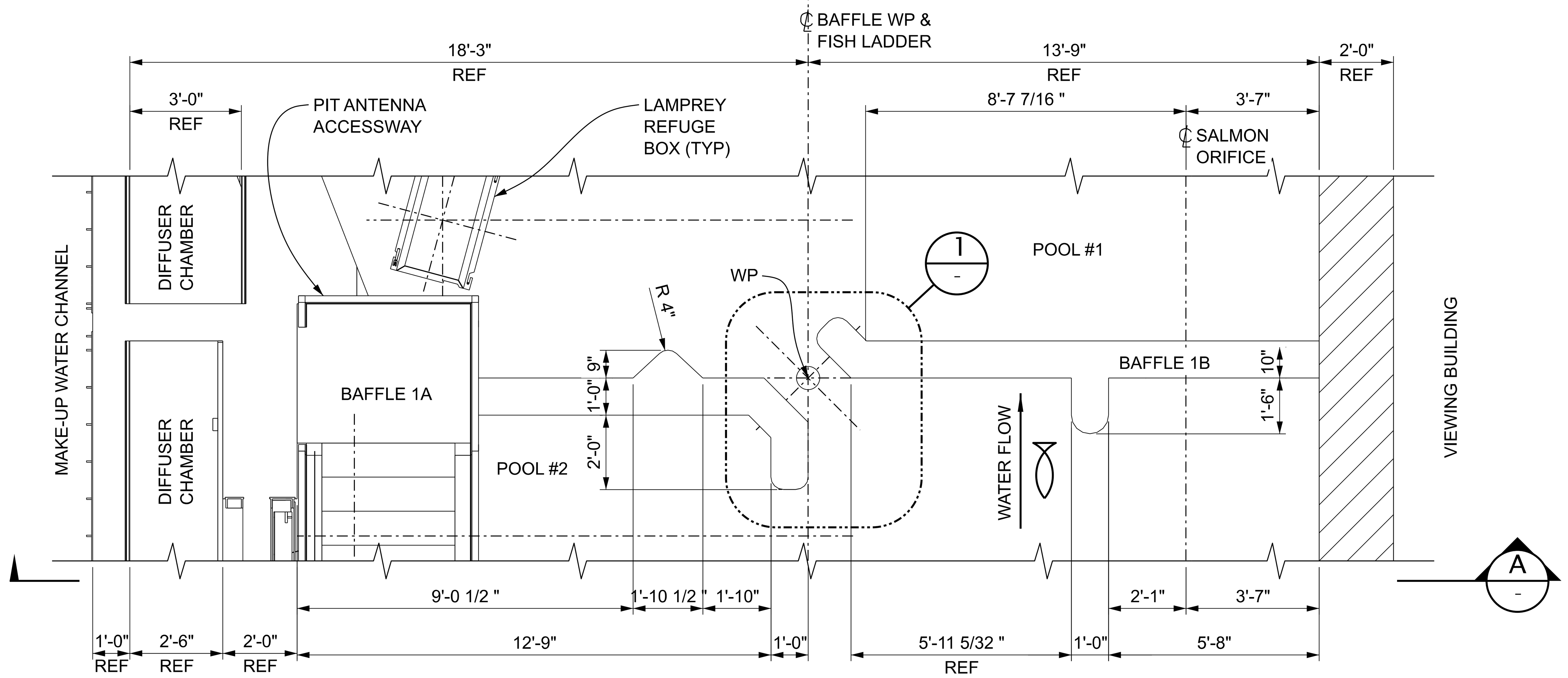
SHEET IDENTIFICATION
SG502

NOTES:

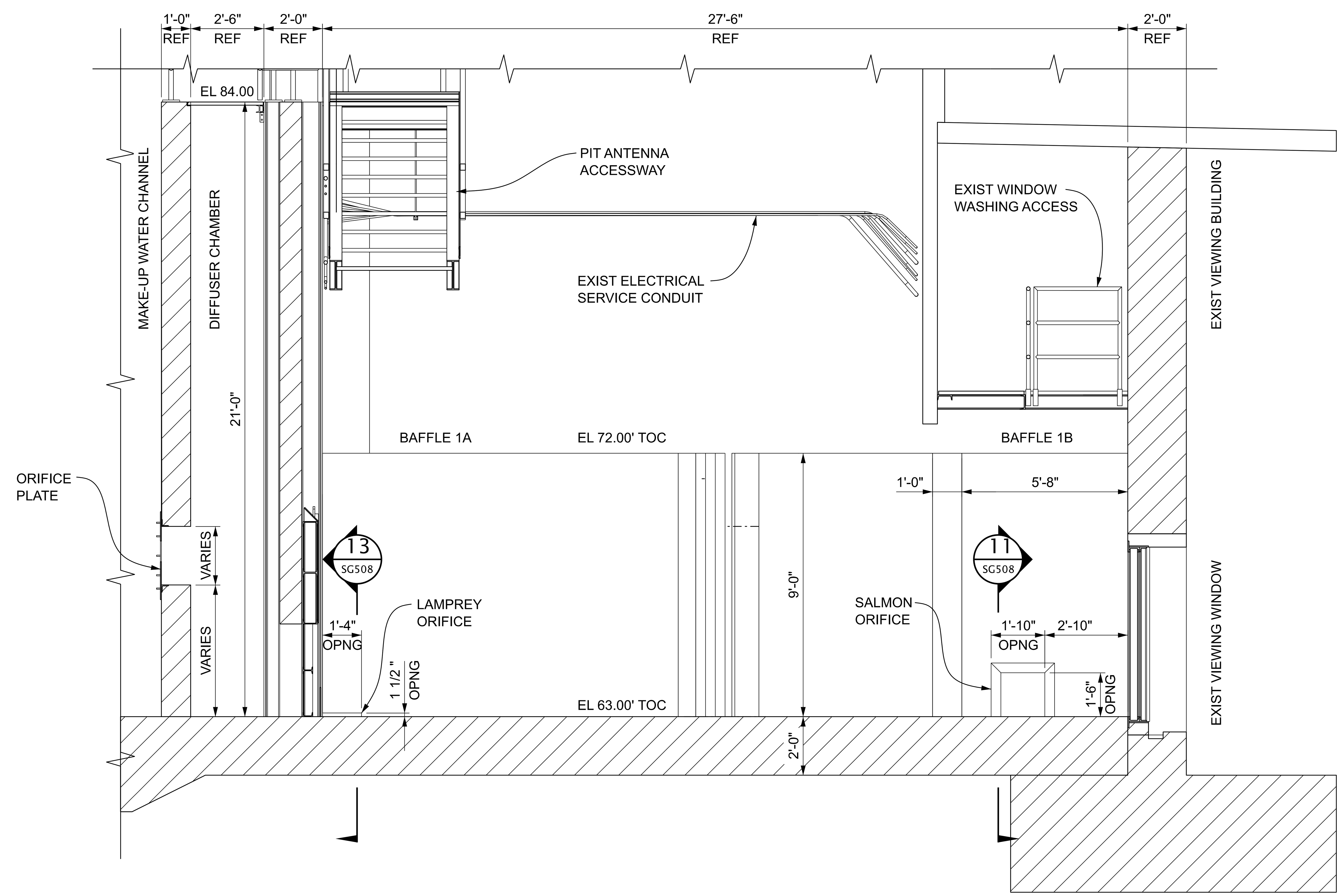
1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

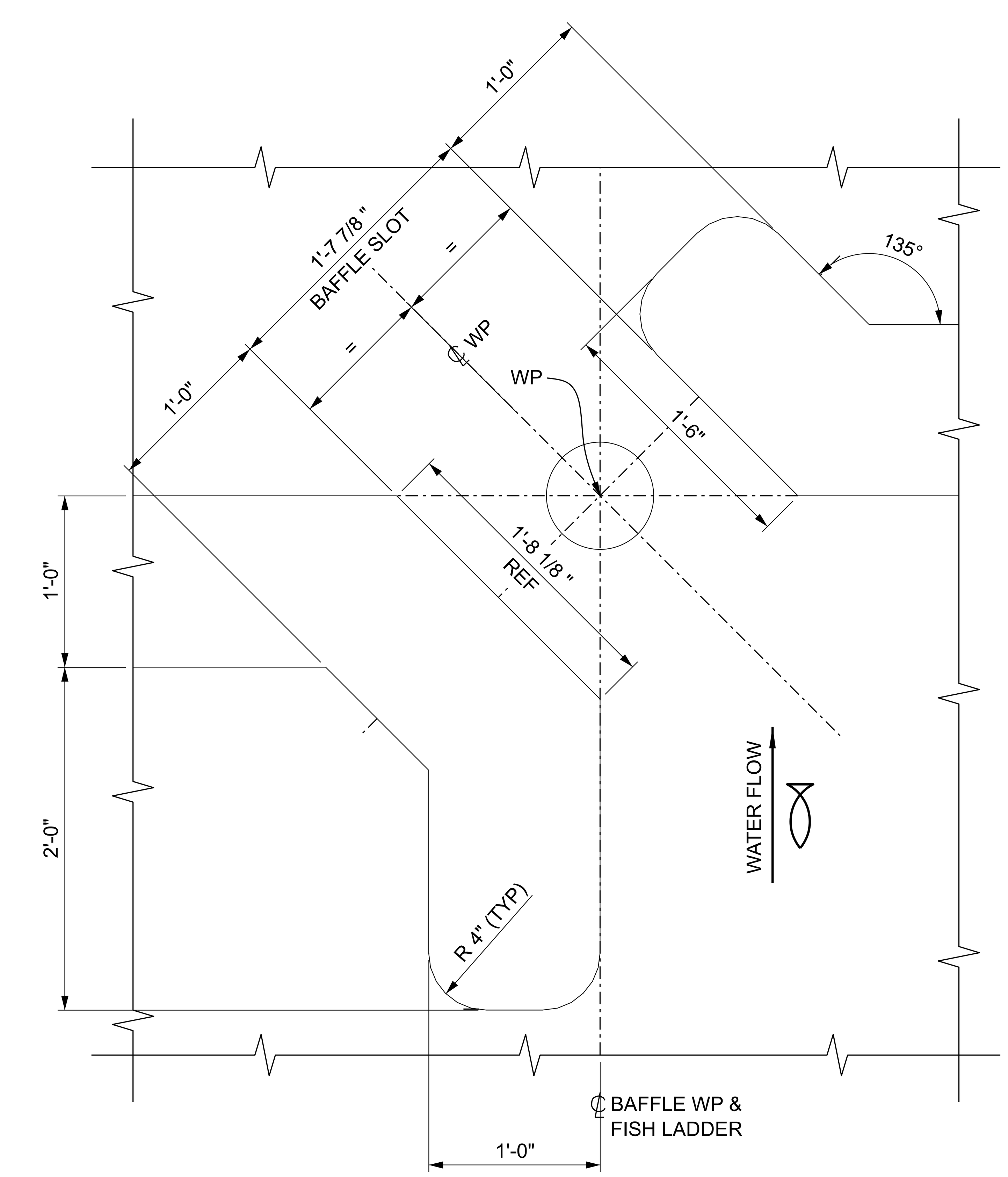
3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



4 ENLARGED PLAN - FISH LADDER BAFFLE No.1
SG101
SCALE: 3/8" = 1'-0"
BAFFLE No. 2 IS SIMILAR



A ELEVATION LOOKING DOWNSTREAM AT BAFFLE No.1
SCALE: 3/8" = 1'-0"
BAFFLE No.2 IS SIMILAR



1 DETAIL - PIT ANTENNA GUIDE SLOT
SCALE: 1 1/2" = 1'-0"

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PLOT SCALE: 1:1 | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: BDF1.123SG503XXX.dgn

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
BAFFLES NO.S 1 AND 2
PLAN, ELEVATION, AND DETAILS

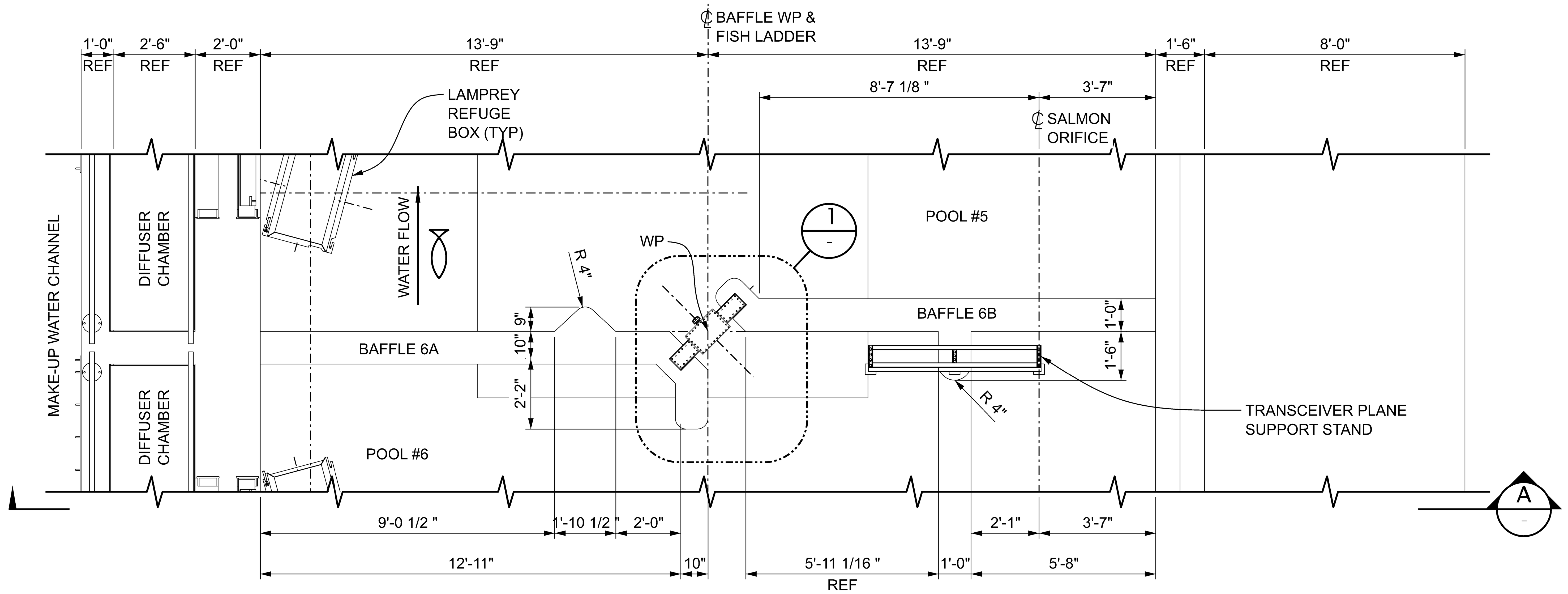
SHEET IDENTIFICATION
SG503

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

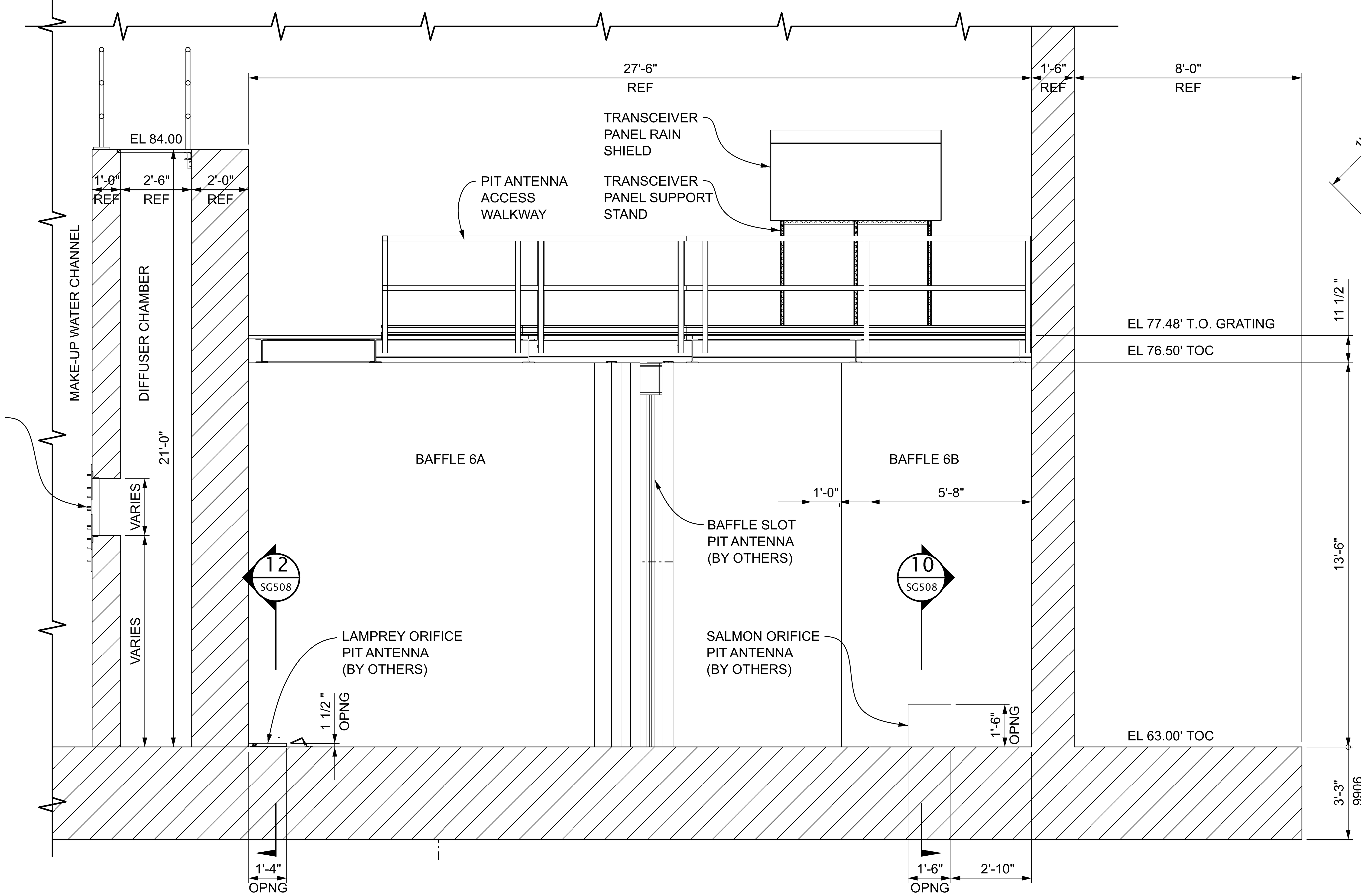
3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



5 SG101 ENLARGED PLAN - FISH LADDER BAFFLE No.6

SCALE: 3/8" = 1'-0"

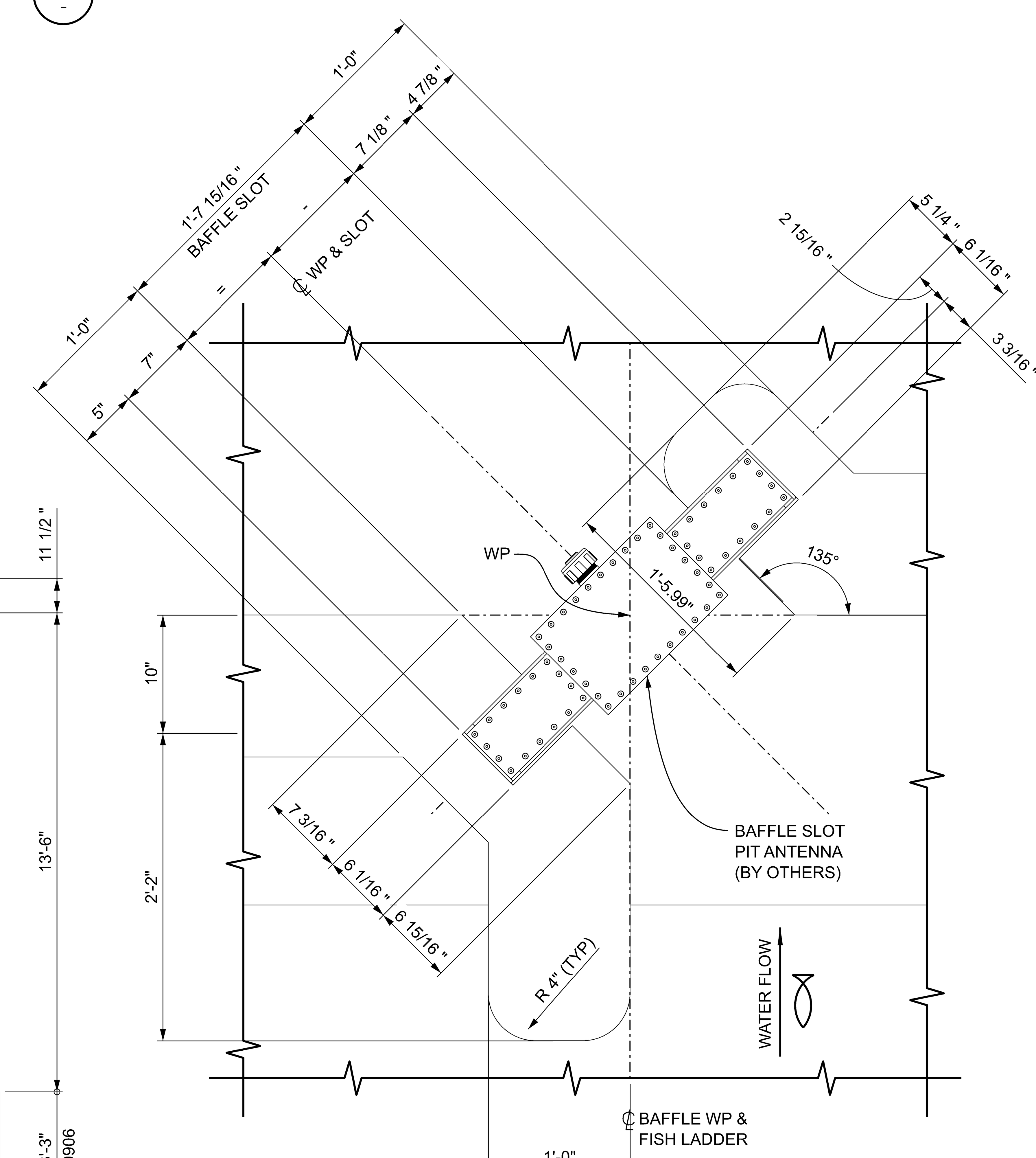
BAFFLE No.s 5, 4, AND 3 ARE SIMILAR



A ELEVATION LOOKING DOWNSTREAM AT BAFFLE No.6

SCALE: 3/8" = 1'-0"

BAFFLE No.s 5, AND 4, ARE SIMILAR



1 DETAIL - PIT ANTENNA GUIDE SLOT

SCALE: 1 1/2" = 1'-0"

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U.S. ARMY CORPS OF ENGINEERS PORTLAND DISTRICT PORTLAND, OREGON

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
BAFFLE NO.S 3, 4, 5, AND 6
PLAN, ELEVATION, AND DETAILS

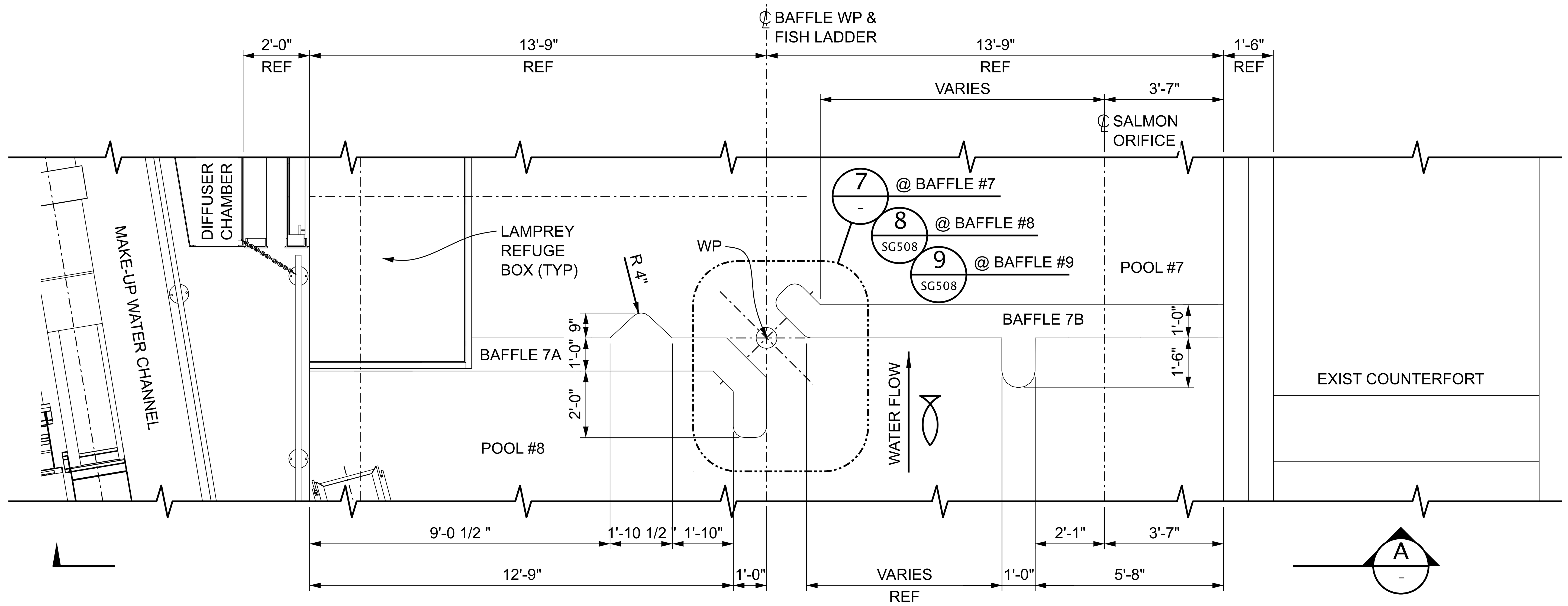
SHEET IDENTIFICATION
SG504

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

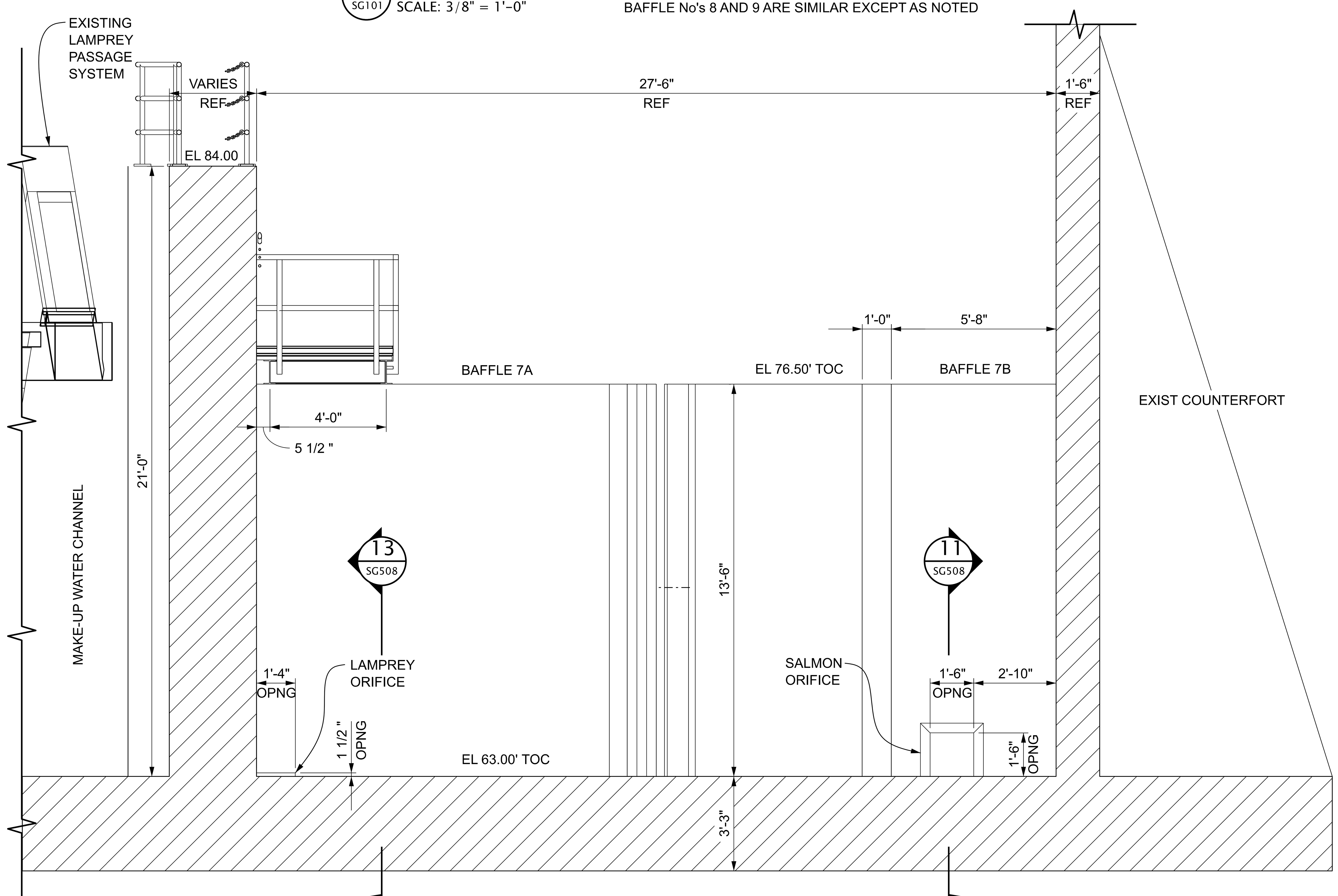
2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



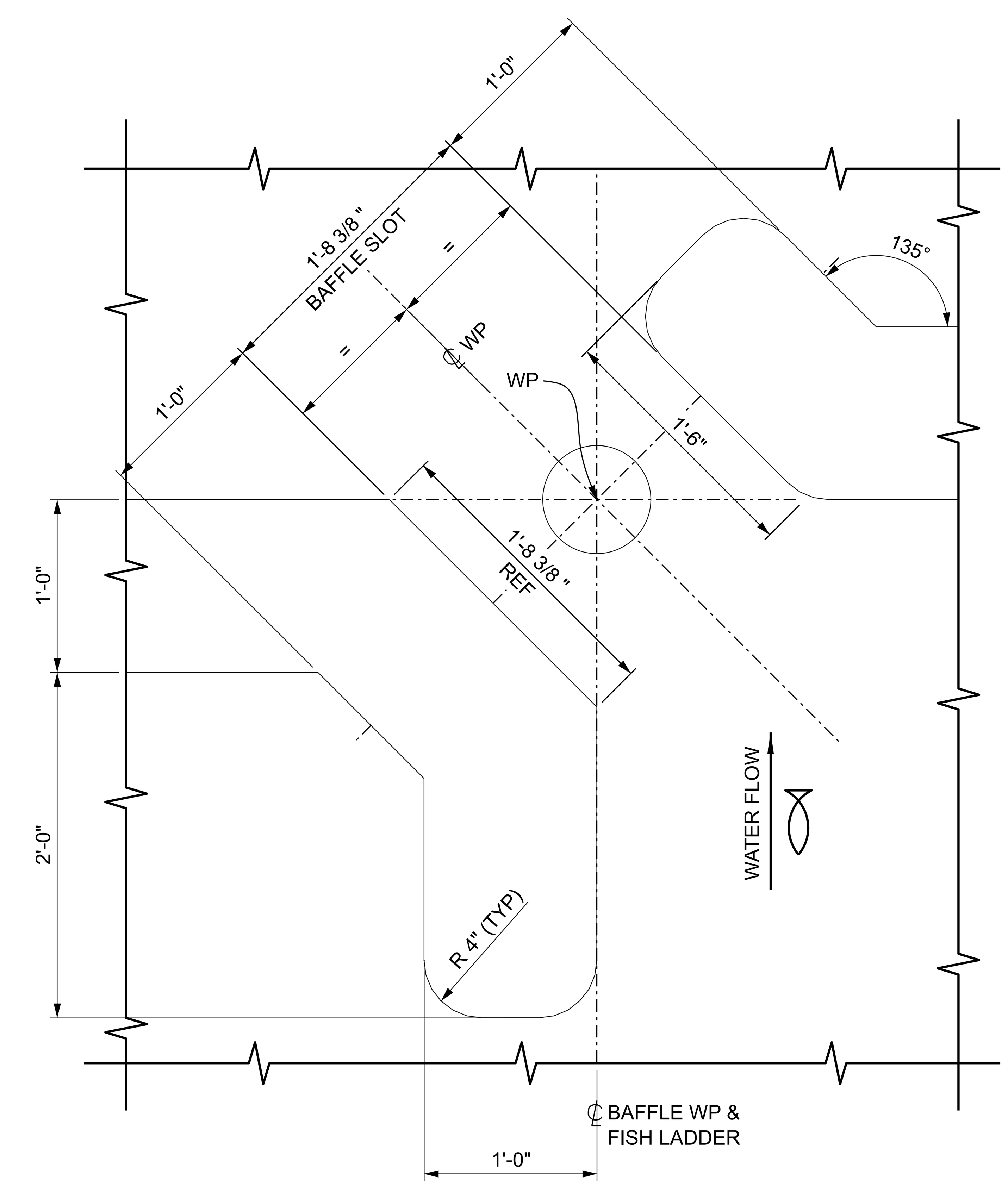
6 SG101 ENLARGED PLAN - FISH LADDER BAFFLE No.7

SCALE: 3/8" = 1'-0" BAFFLE No's 8 AND 9 ARE SIMILAR EXCEPT AS NOTED



A ELEVATION LOOKING DOWNSTREAM AT BAFFLE No.7

SCALE: 3/8" = 1'-0" BAFFLE No's 8 AND 9 ARE SIMILAR EXCEPT AS NOTED



7 DETAIL - BAFFLE No.7 SLOT

SCALE: 1 1/2" = 1'-0"

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CONTRACT NO.:
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.123SG505XXX.dgn

BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
BAFFLE NO.S 7, 8, AND 9
PLAN, ELEVATION, AND DETAILS

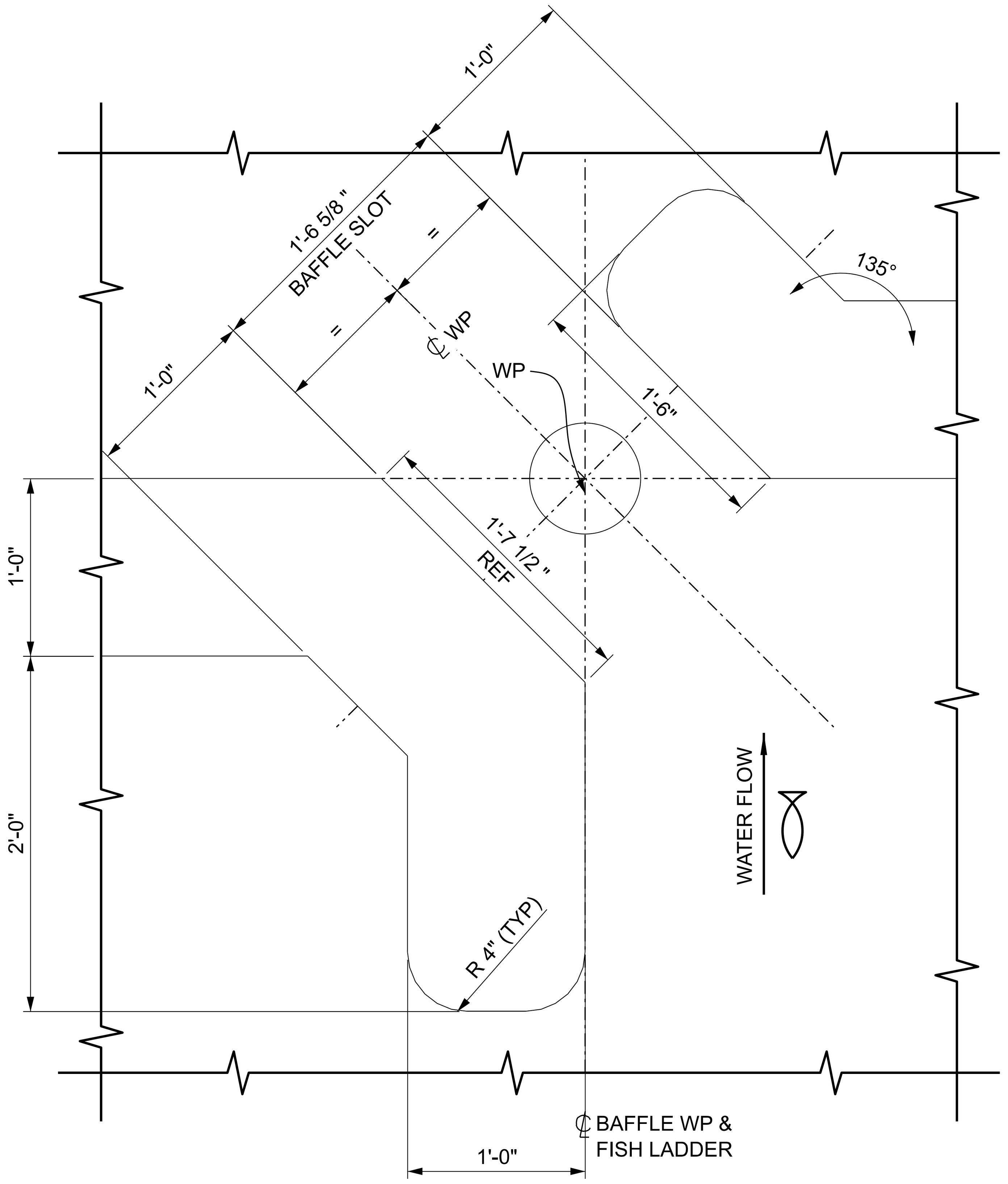
SHEET IDENTIFICATION
SG505

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

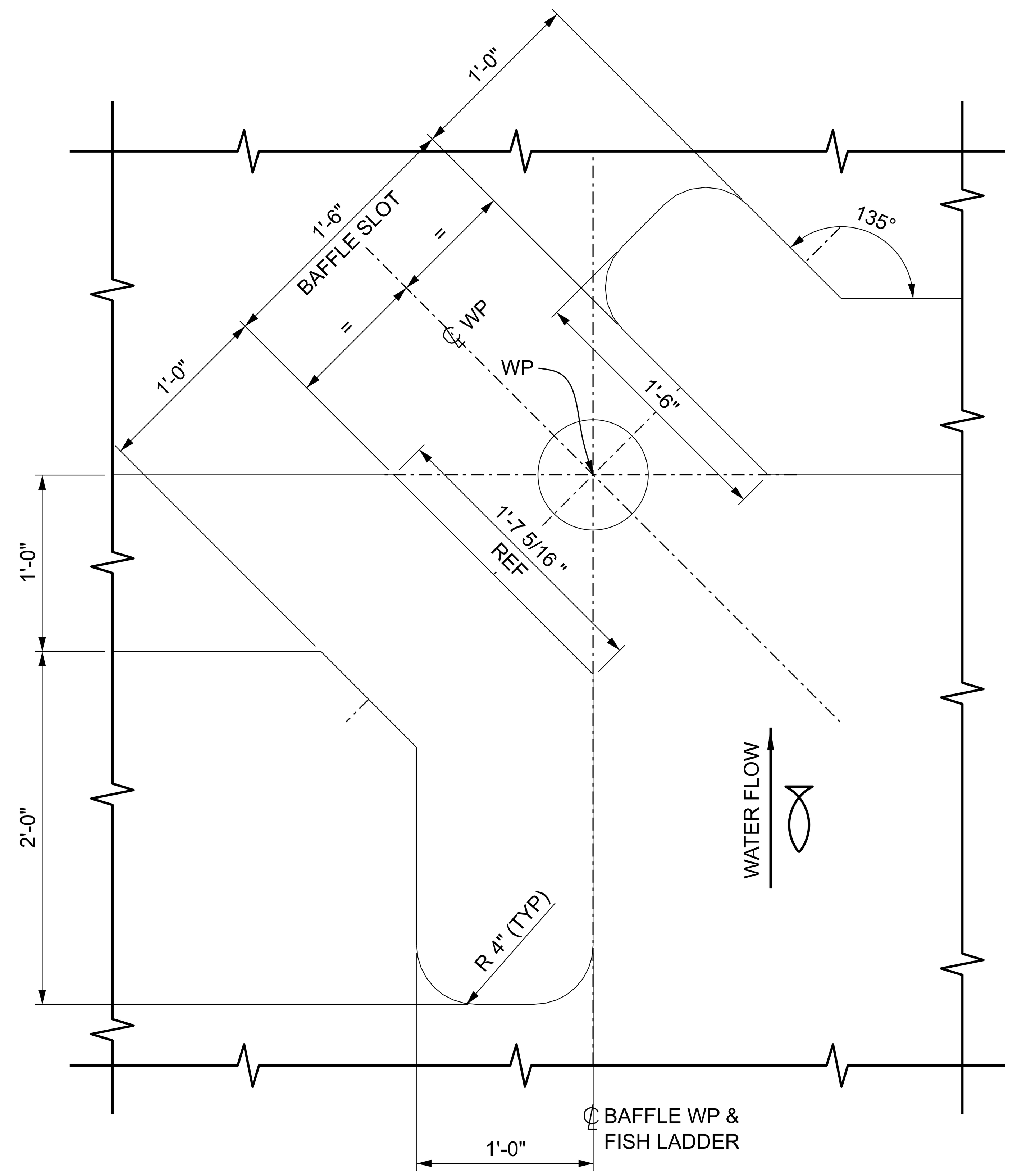
2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.



8 SG505 DETAIL - BAFFLE No.8 SLOT

SCALE: 1 1/2" = 1'-0"



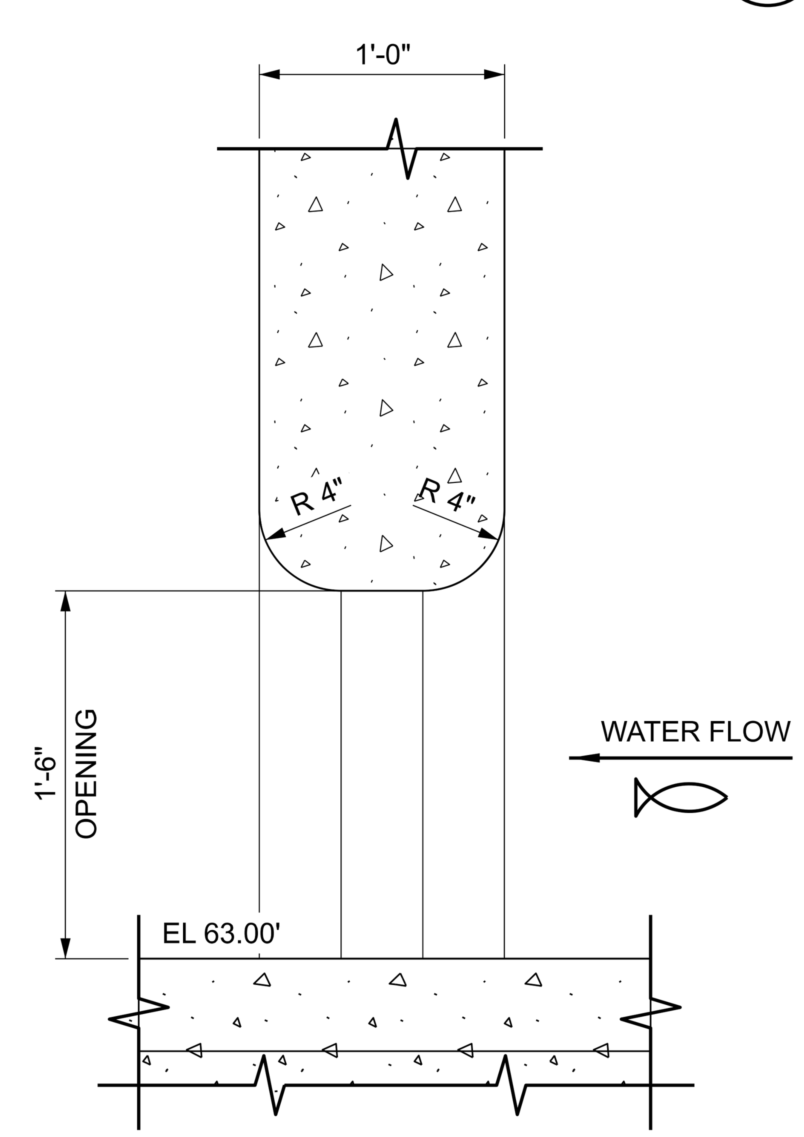
9 SG505 DETAIL - BAFFLE No.9 SLOT

SCALE: 1 1/2" = 1'-0"

TO BE DETERMINED

10 SG504 DETAIL - TYPE 1 SALMON ORIFICE

SCALE: 1 1/2" = 1'-0" TYPICAL @ BAFFLE No's 3, 4, 5, AND 6



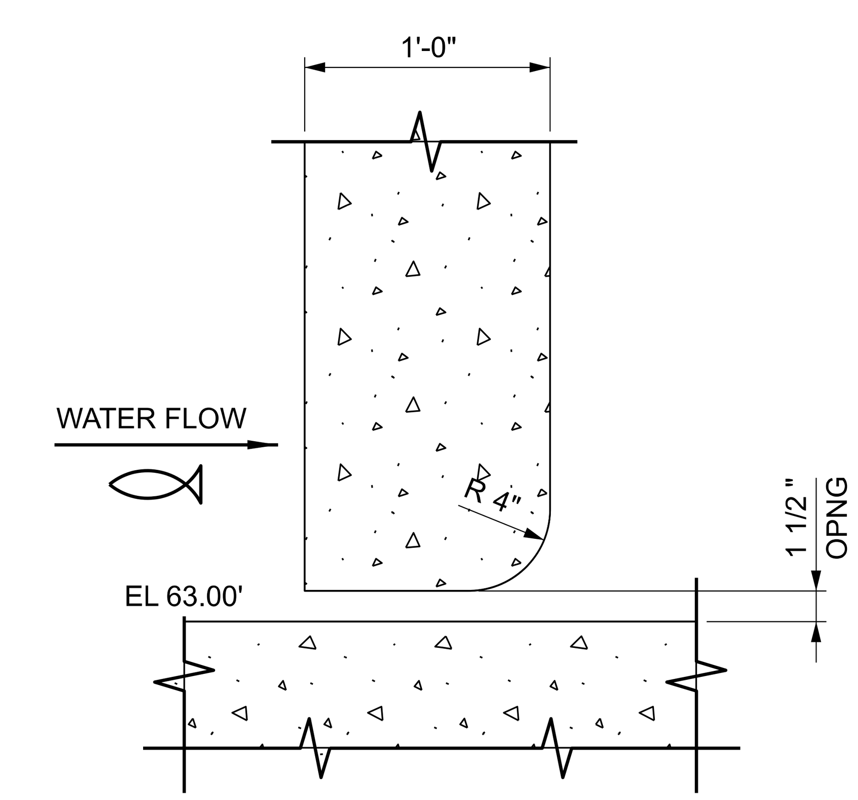
11 SG505 DETAIL - TYPE 2 SALMON ORIFICE

SCALE: 1 1/2" = 1'-0" TYPICAL @ BAFFLE No's 1, 2, 7, 8, AND 9

TO BE DETERMINED

12 SG504 DETAIL - TYPE 1 LAMPREY ORIFICE

SCALE: 1 1/2" = 1'-0" TYPICAL @ BAFFLE No's 3, 4, 5, AND 6



13 SG505 DETAIL - TYPE 2 LAMPREY ORIFICE

SCALE: 1 1/2" = 1'-0" TYPICAL @ BAFFLE No's 1, 2, 7, 8, AND 9

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BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
BAFFLE DETAILS

SHEET IDENTIFICATION
SG508

NOTES:

1.) SEE SHEET G-001 AND G-002 FOR DRAWING INDEX.

2.) SEE SHEET G-004 FOR GENERAL NOTES AND SYMBOLS

3.) SEE SHEET S-001 FOR GENERAL STRUCTURAL NOTES AND SPECIFICATIONS.

4.) MATERIAL FOR WALKWAY ABOVE PIT ANTENNAS MUST BE NON FERROUS (ACCESS STAIRS, WALKWAY, AND HANDRAIL CAN BE FERROUS)

5.) WALKWAY MUST BE ANCHORED TO THE NEW BAFFLES WITH NON FERROUS ANCHORAGE.

6.) WALKWAYS TO BE A MINIMUM OF 3'-0" WIDE.

7.) WALKWAYS AND PLATFORMS MUST HAVE GUARD RAILS AND NON FERROUS TOE KICKS (DESIGNED IN ACCORDANCE WITH USACE SAFETY MANUAL 385-1-1, OREGON OSHA, AND DOD BUILDING CODE).

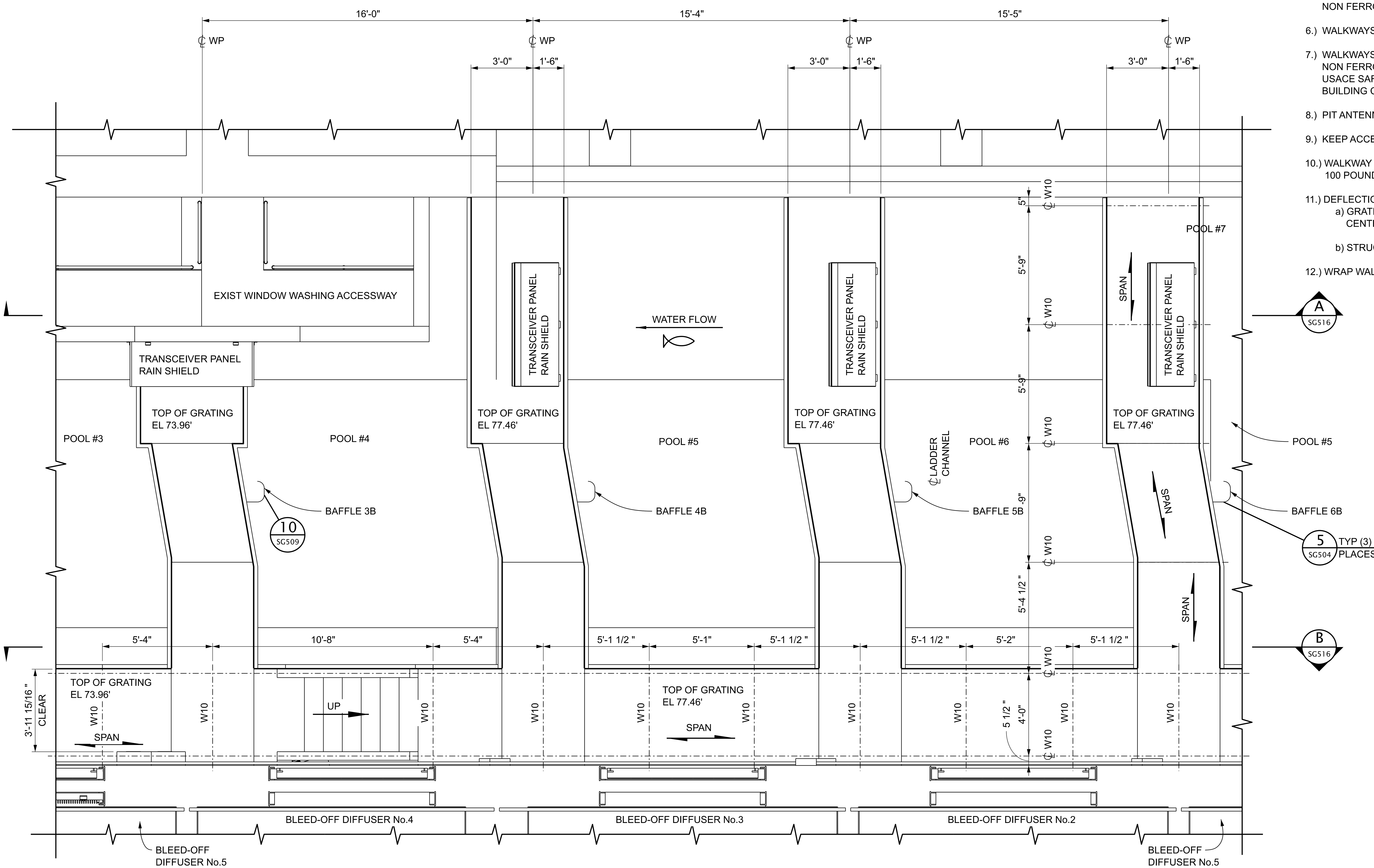
8.) PIT ANTENNAS MUST BE ACCESSIBLE AND REMOVABLE.

9.) KEEP ACCESS TO ALL EXISTING ELECTRICAL BOXES.

10.) WALKWAY LOAD CAPACITY SHALL NOT BE LESS THAN 100 POUNDS PER SQUARE FEET.

11.) DEFLECTION LIMITS:
   a) GRATING AND FLOOR PANEL DEFLECTION AT THE CENTER OF SPAN TO NOT EXCEED 1/4".
   b) STRUCTURAL MEMBERS TO NOT EXCEED L/180.

12.) WRAP WALKWAYS IN PLASTIC CONSTRUCTION FENCING.



SG513 ENLARGE PLAN - PIT ANTENNA ACCESS WALKWAY
SCALE: 3/8" = 1'-0"

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SIZE: ANSI D | FILE NAME: BDF1.123SG515XXX.dgn

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PORTLAND, OREGON

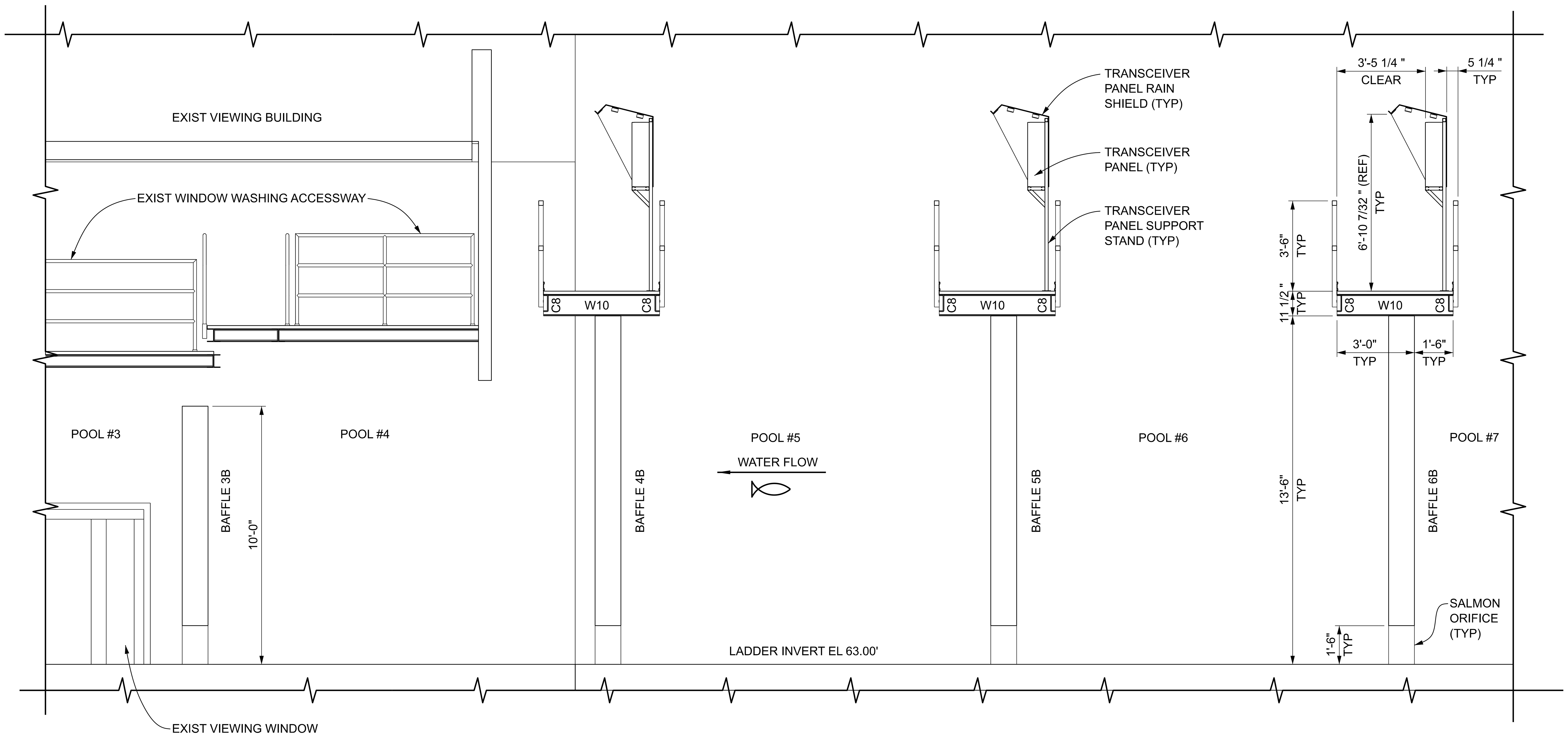
BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
PIT ANTENNA ACCESS WALKWAY
PLAN

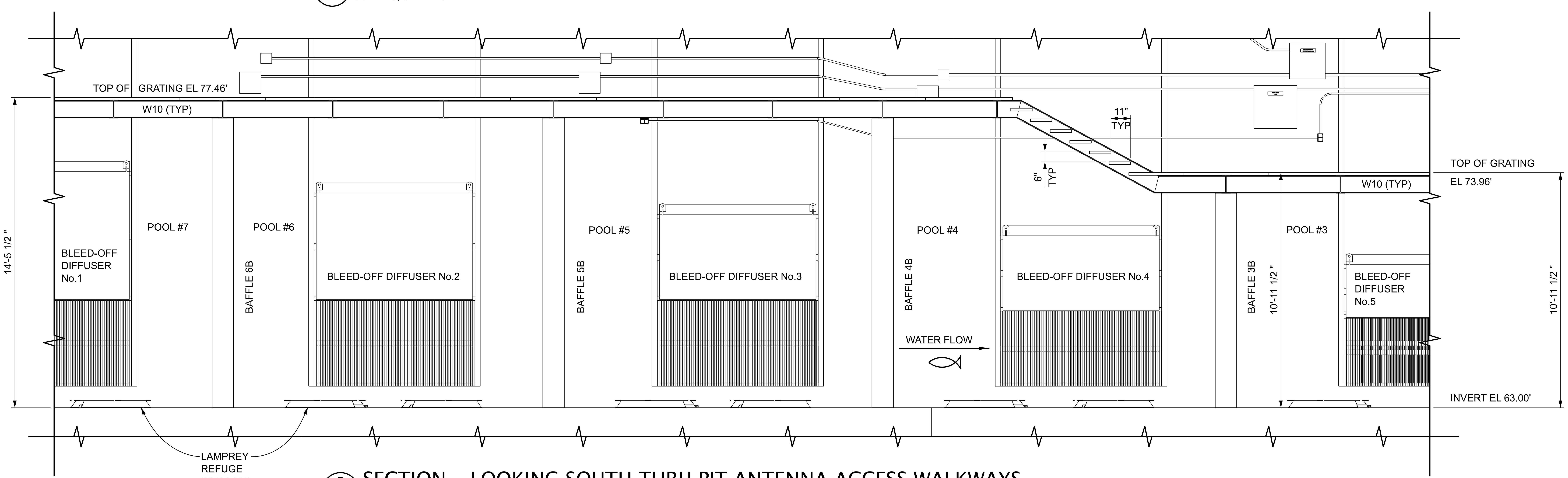
SHEET IDENTIFICATION
SG515

NOTES:

1.) SEE SHEET SG515 ACCESS WALKWAYS GENERAL NOTES.



A SECTION - LOOKING NORTH THRU PIT ANTENNA ACCESS WALKWAYS
SG515 SCALE: 3/8" = 1'-0"



B SECTION - LOOKING SOUTH THRU PIT ANTENNA ACCESS WALKWAYS
SG515 SCALE: 3/8" = 1'-0"

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PLOT DATE:
DRAWING NUMBER:
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FILE NAME: BDF1.123SG516XXX.dgn

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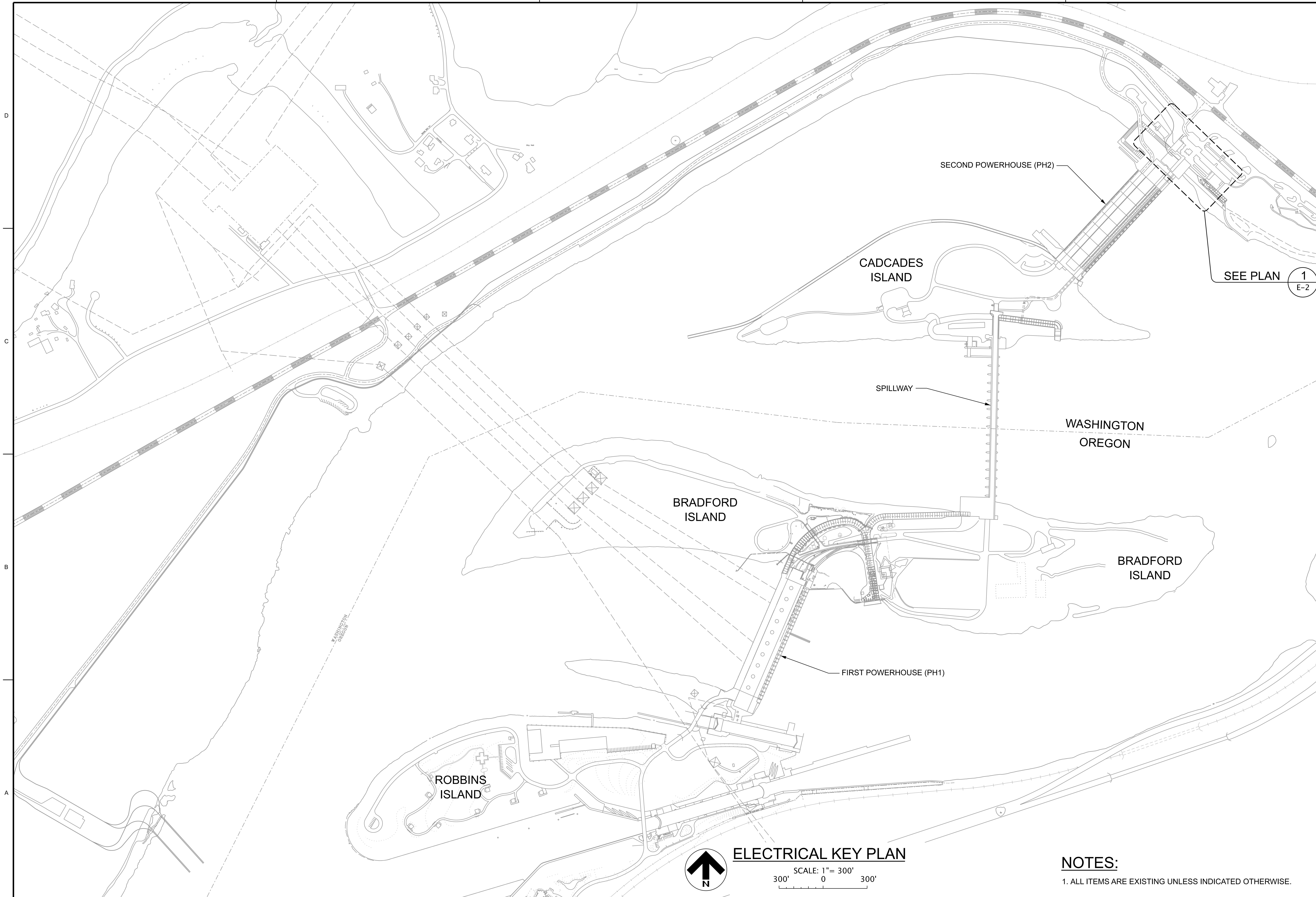
BONNEVILLE LOCK AND DAM
WASHINGTON SHORE FISH LADDER
2019 FISH ACCORDS LAMPREY PASSAGE

EXIT CONTROL BAFFLE ARRANGEMENT
PIT ANTENNA ACCESS WALKWAY
SECTIONS

SHEET IDENTIFICATION
SG516



ELECTRICAL KEY PLAN

SCALE: 1"= 300'
300' 0 300'

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.

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FILE NAME: BDF1.123_E-101.dgn
DATE: 04/06/2023
SOLICITATION NO.:
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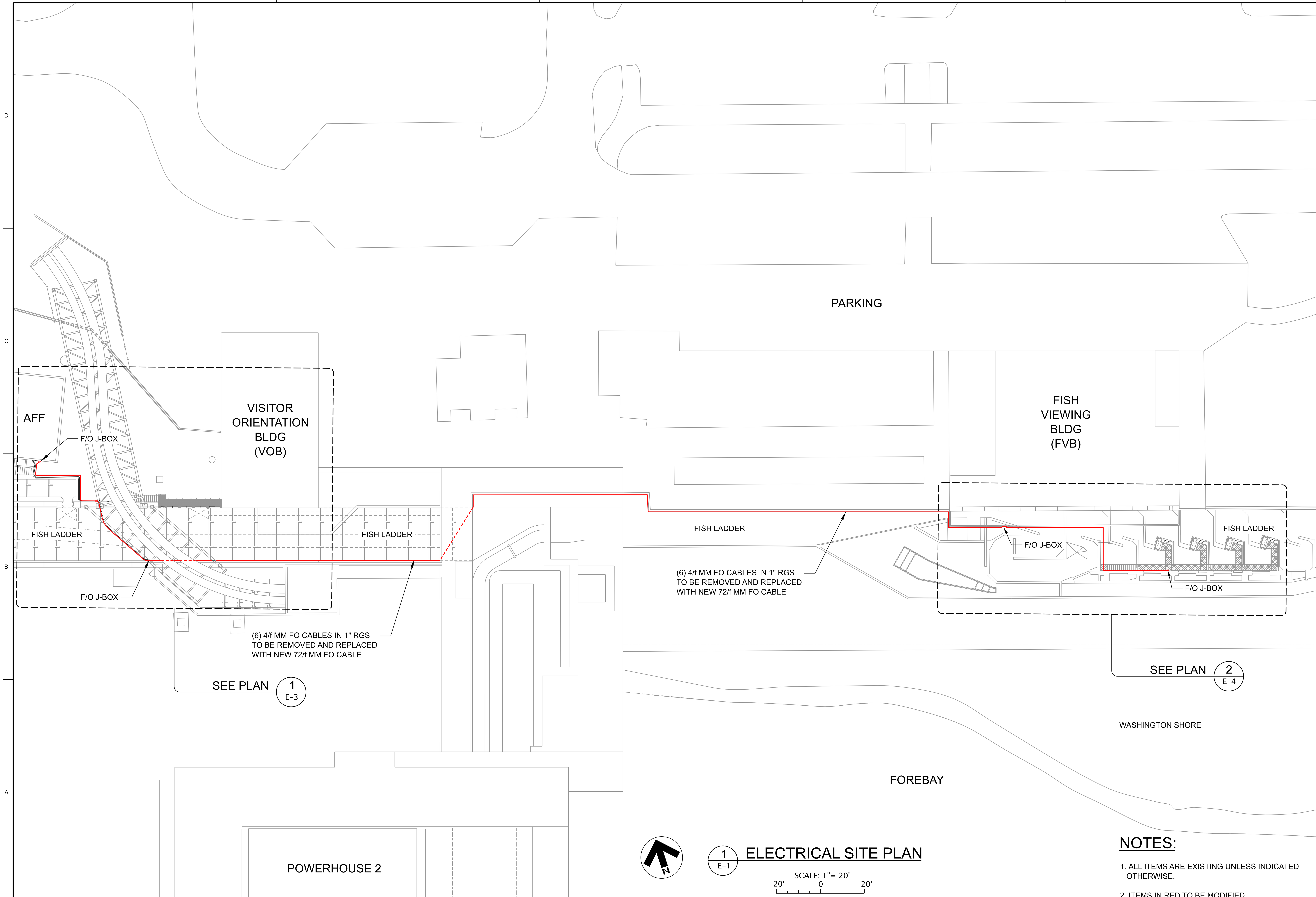
BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
KEY PLAN

PLATE IDENTIFICATION
E-1



1 E-1 ELECTRICAL SITE PLAN

SCALE: 1"= 20'

20' 0 20'

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.
2. ITEMS IN RED TO BE MODIFIED.

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CONTRACT NO.:
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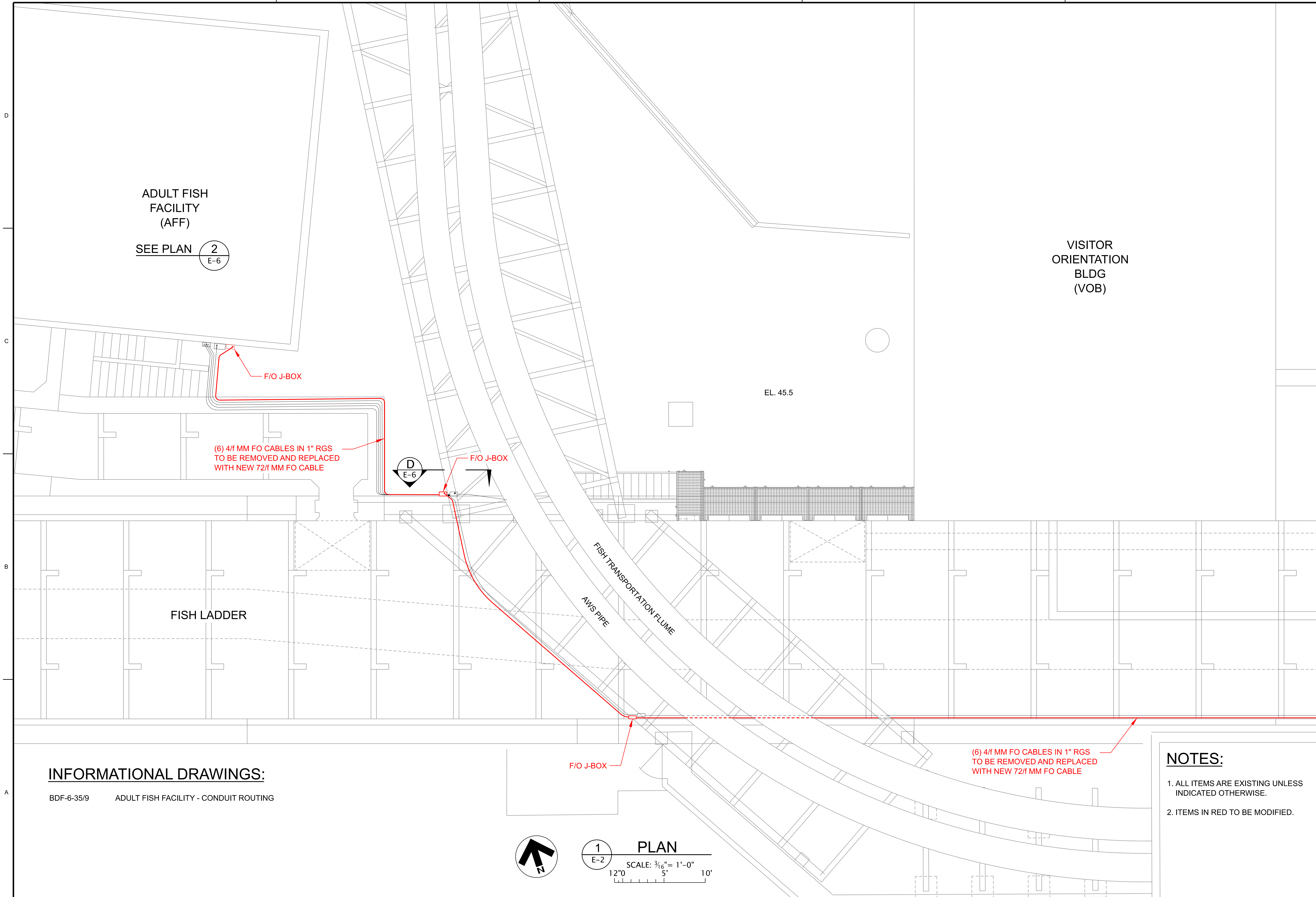
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.123_E-103.dgn

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL SITE PLAN

PLATE IDENTIFICATION
E-2



1 E-2 PLAN

SCALE: 3/16"= 1'-0"

INFORMATIONAL DRAWINGS:

BDF-6-35/9 ADULT FISH FACILITY - CONDUIT ROUTING

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.
2. ITEMS IN RED TO BE MODIFIED.

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SIZE: ANSI D
FILE NAME: BDF1.123_E-401.dgn
DATE: 04/18/2023
SOLICITATION NO.:
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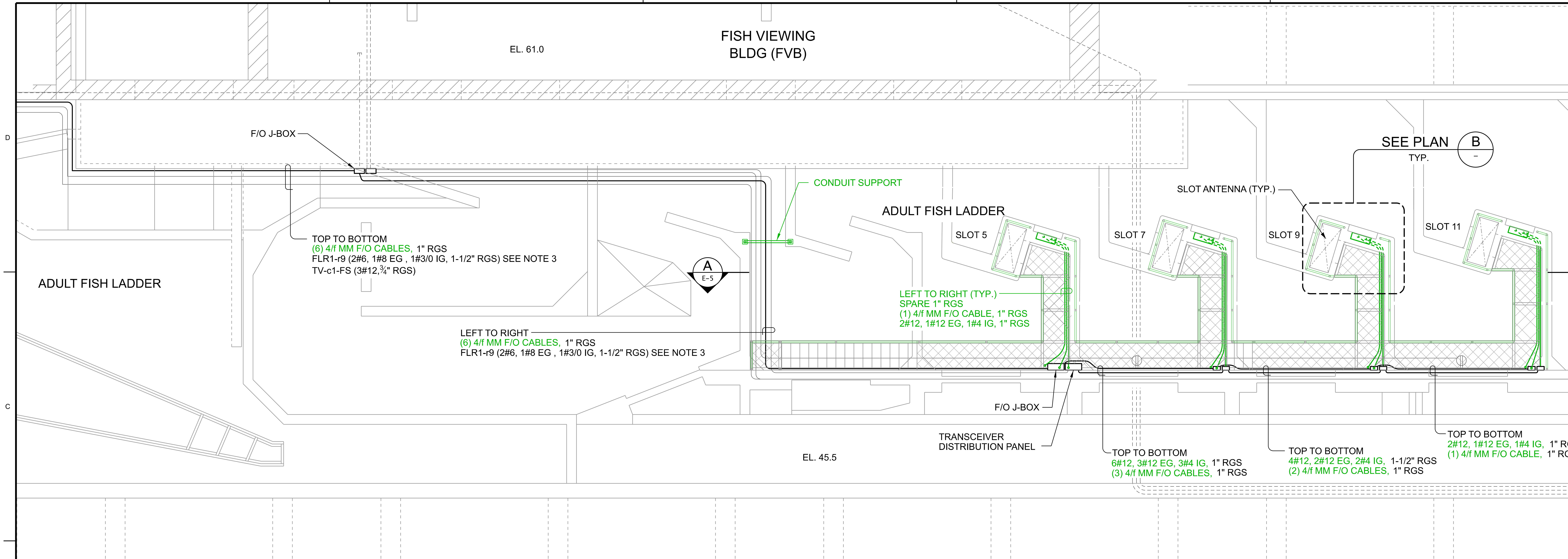
BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
ADULT FISH FACILITY
FIBER OPTICS ROUTING MODIFICATIONS

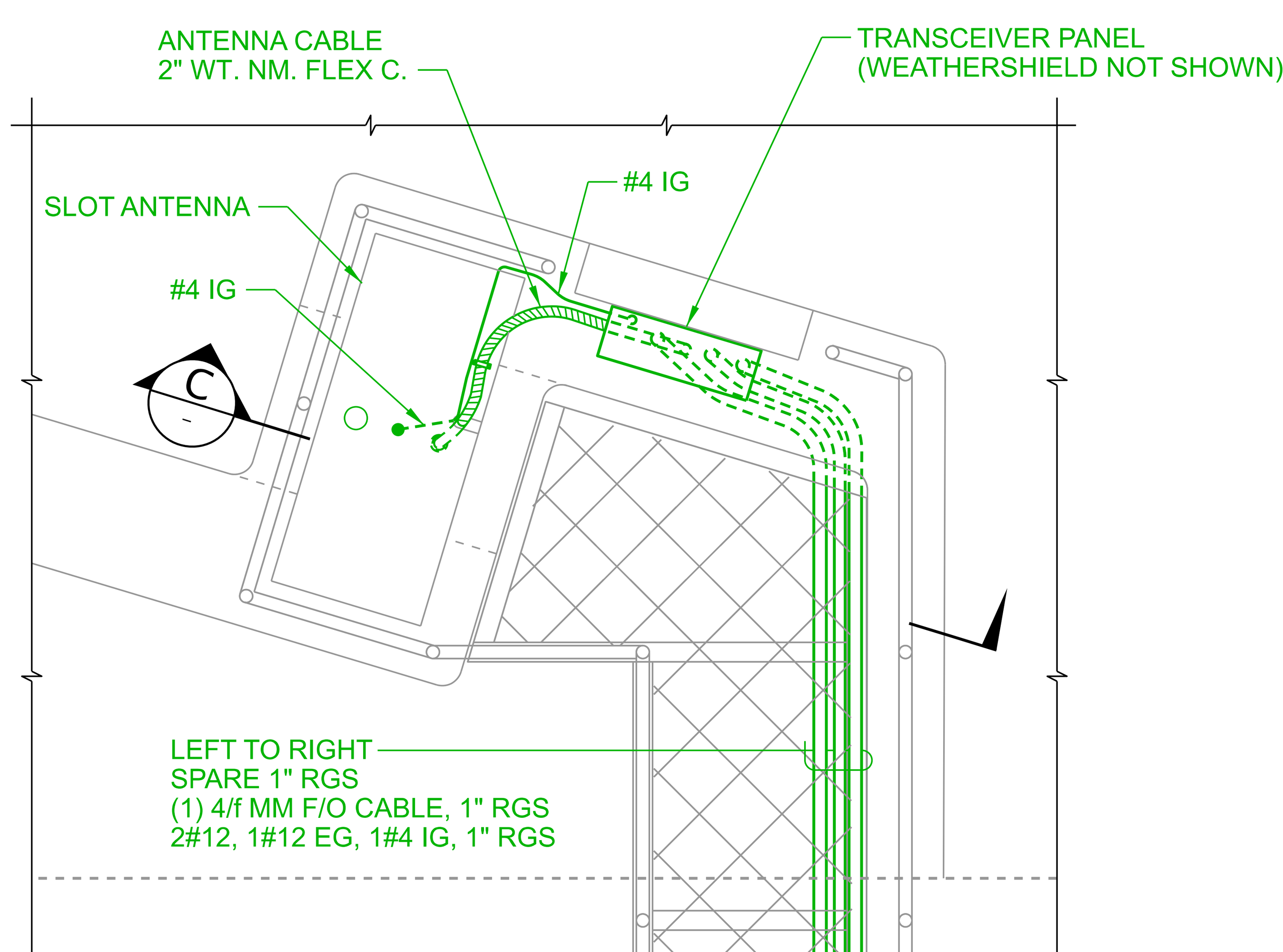
PLATE IDENTIFICATION
E-3



2 E-2 ADULT FISH LADDER DEMOLITION PLAN

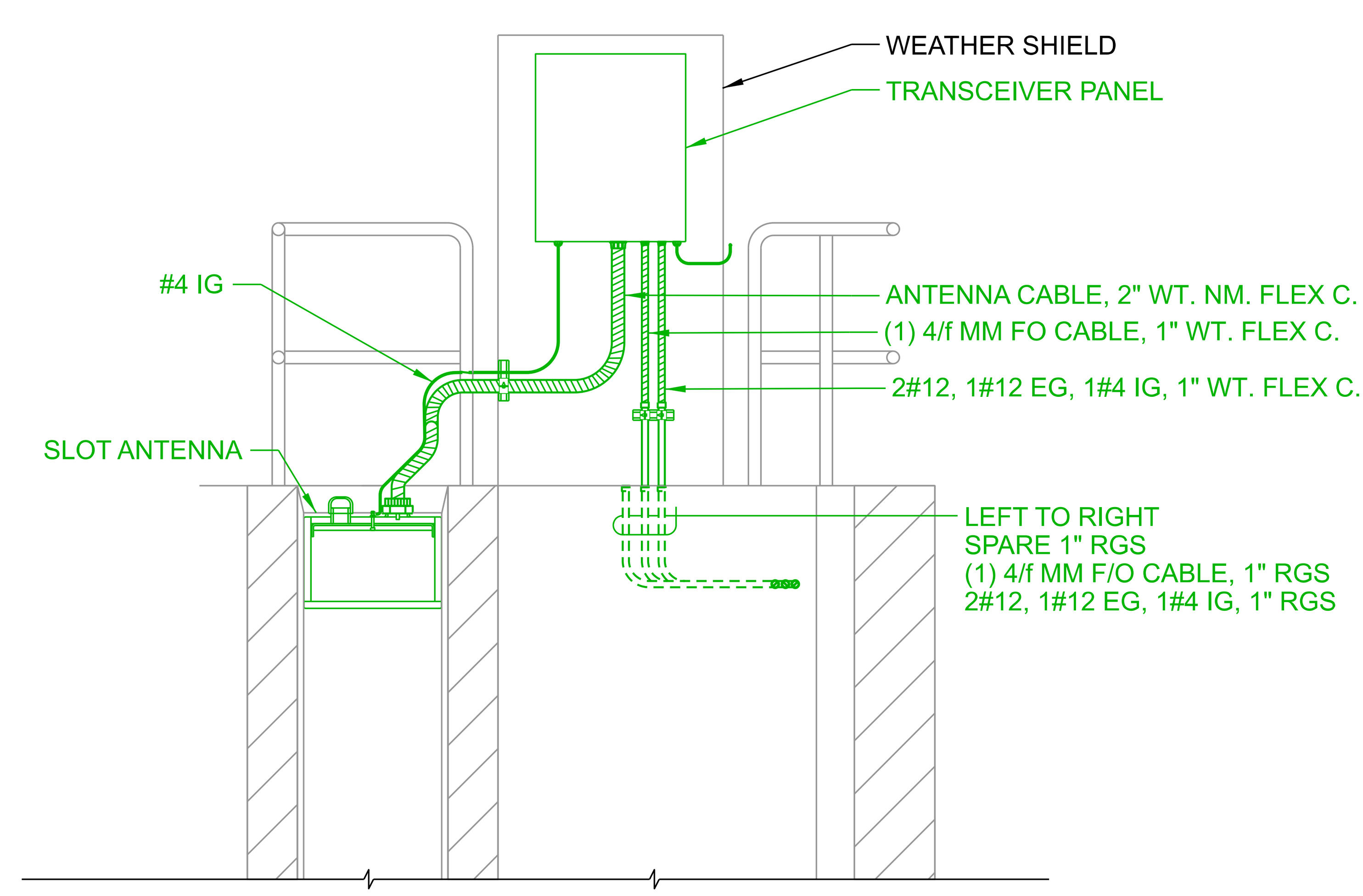
SCALE: $\frac{3}{16}$"= 1'-0"

12" 0 5' 10'



B PLAN

SCALE: ½"= 1'-0"



C SECTION

SCALE: ½"= 1'-0"

SCALE: ½"= 1'-0"

12" 0 1' 2' 3' 4'

INFORMATIONAL DRAWINGS:

BDF-6-35/10	PLAN -ADULT FISH LADDER & FISH VIEWING BLDG
BDF-6-35/12	TYP. PLAN, SECTION & DETAIL - NEW BAFFLE AND ANTENNA

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.
2. ITEMS IN GREEN TO BE REMOVED.
3. POWER CIRCUIT TO BE REUSED.

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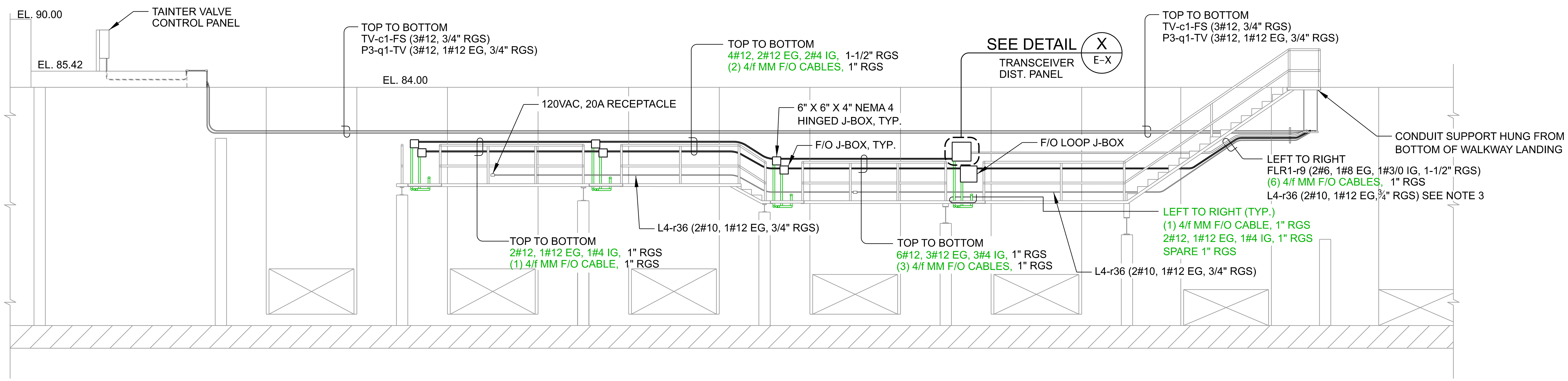
CONTRACT NO.:
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.123_E-402.dgn

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
ADULT FISH LADDER
DEMOLITION PLAN

PLATE IDENTIFICATION
E-4



ADULT FISH LADDER DEMOLITION

A / E-4 **SECTION**

SCALE: 3⁄16"= 1'-0"

INFORMATIONAL DRAWINGS:

BDF-6-35/11 ADULT FISH LADDER - SECTION VIEWS

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.
2. ITEMS IN GREEN TO BE REMOVED.
3. POWER CIRCUIT TO BE REUSED.

SCALE: 3⁄16"= 1'-0"
12"0 5' 10'

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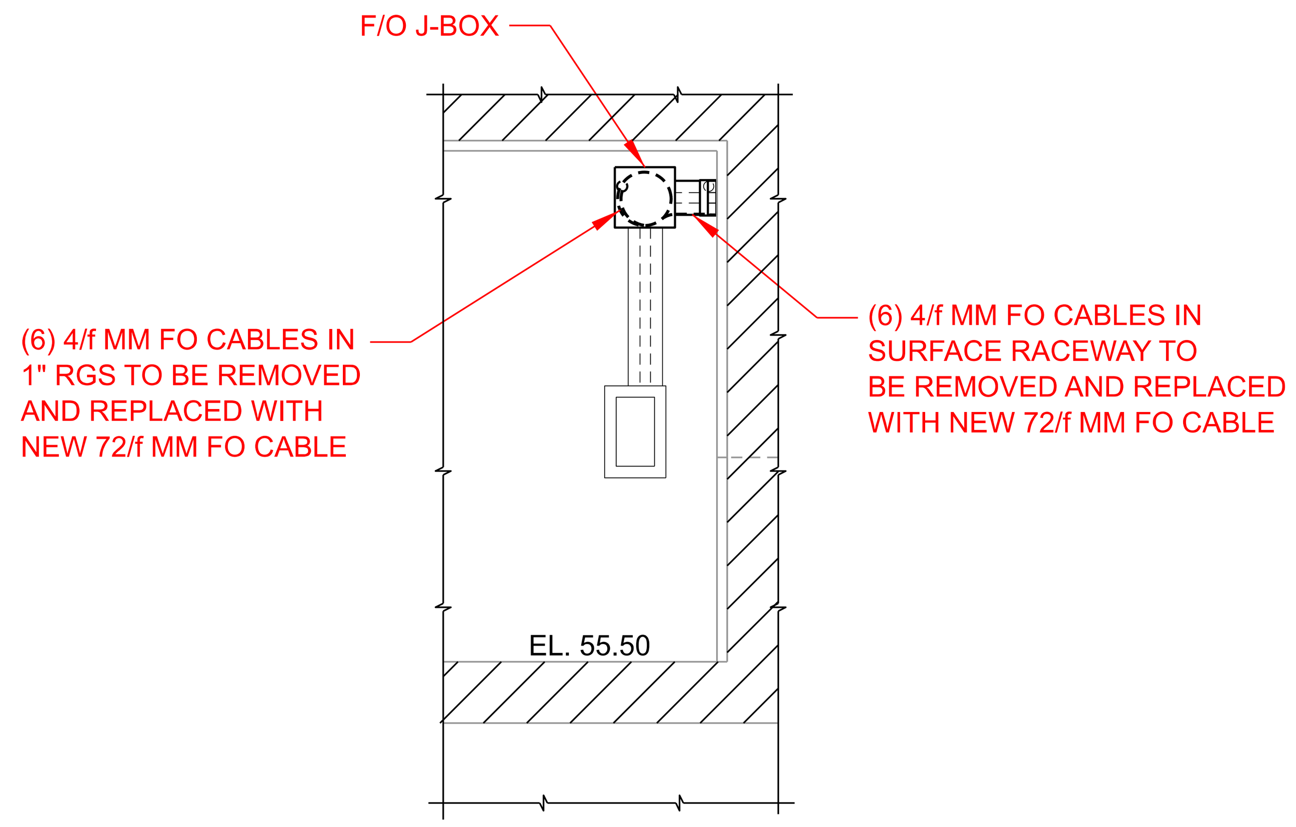
SIZE: ANSI D | FILE NAME: BDF1.123_E-403.dgn

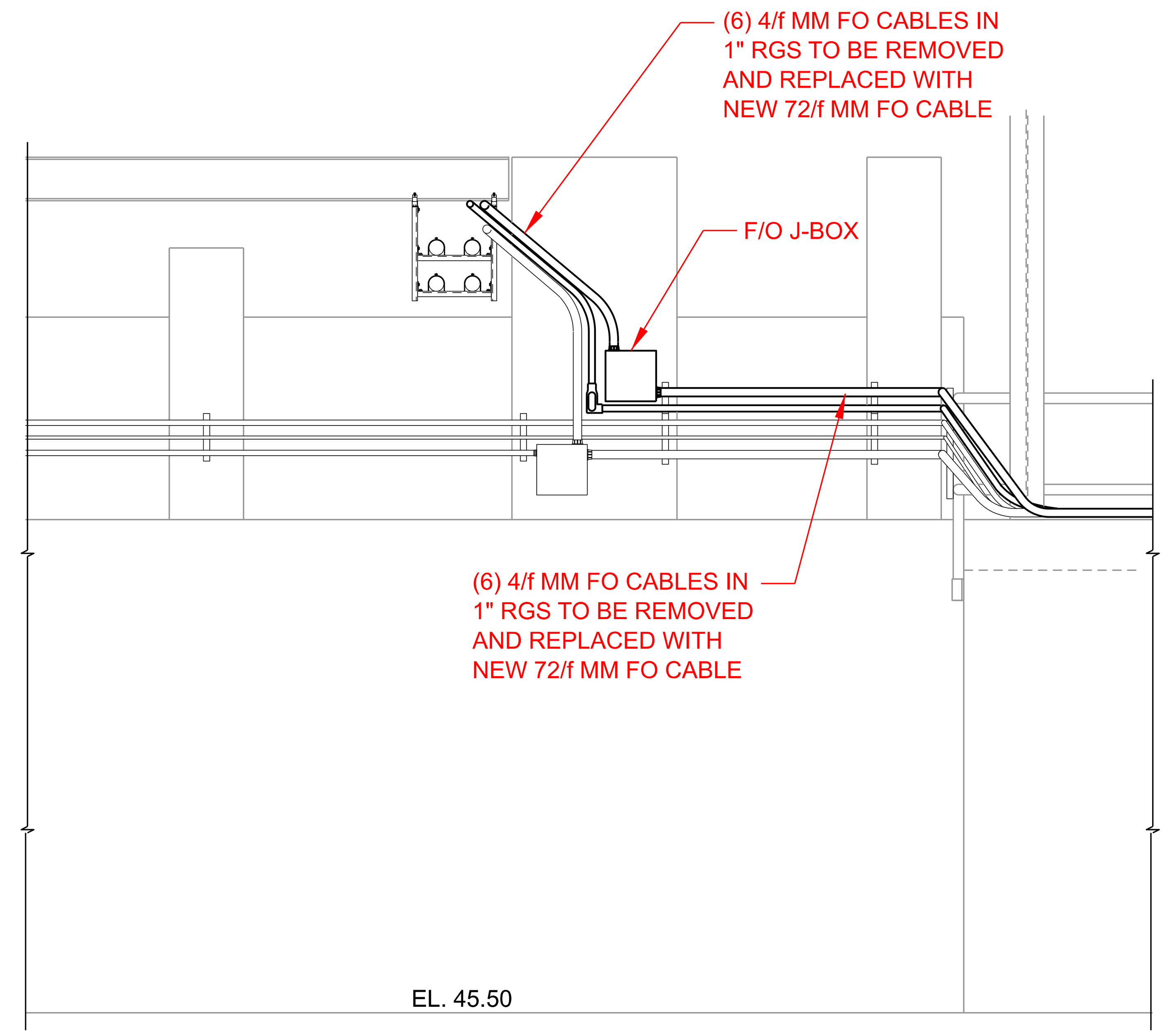
BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
ADULT FISH LADDER
DEMOLITION SECTION

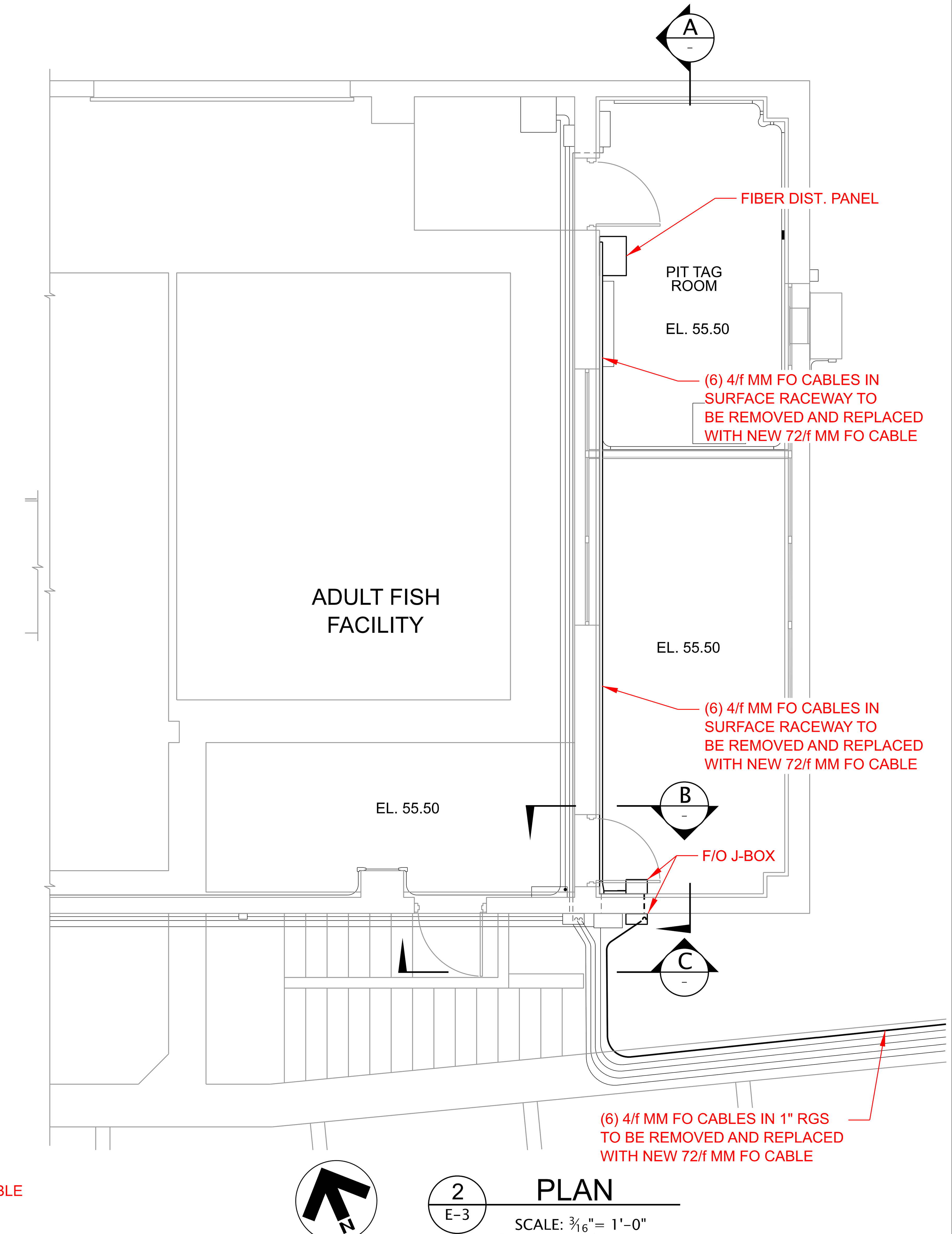
PLATE IDENTIFICATION
E-5



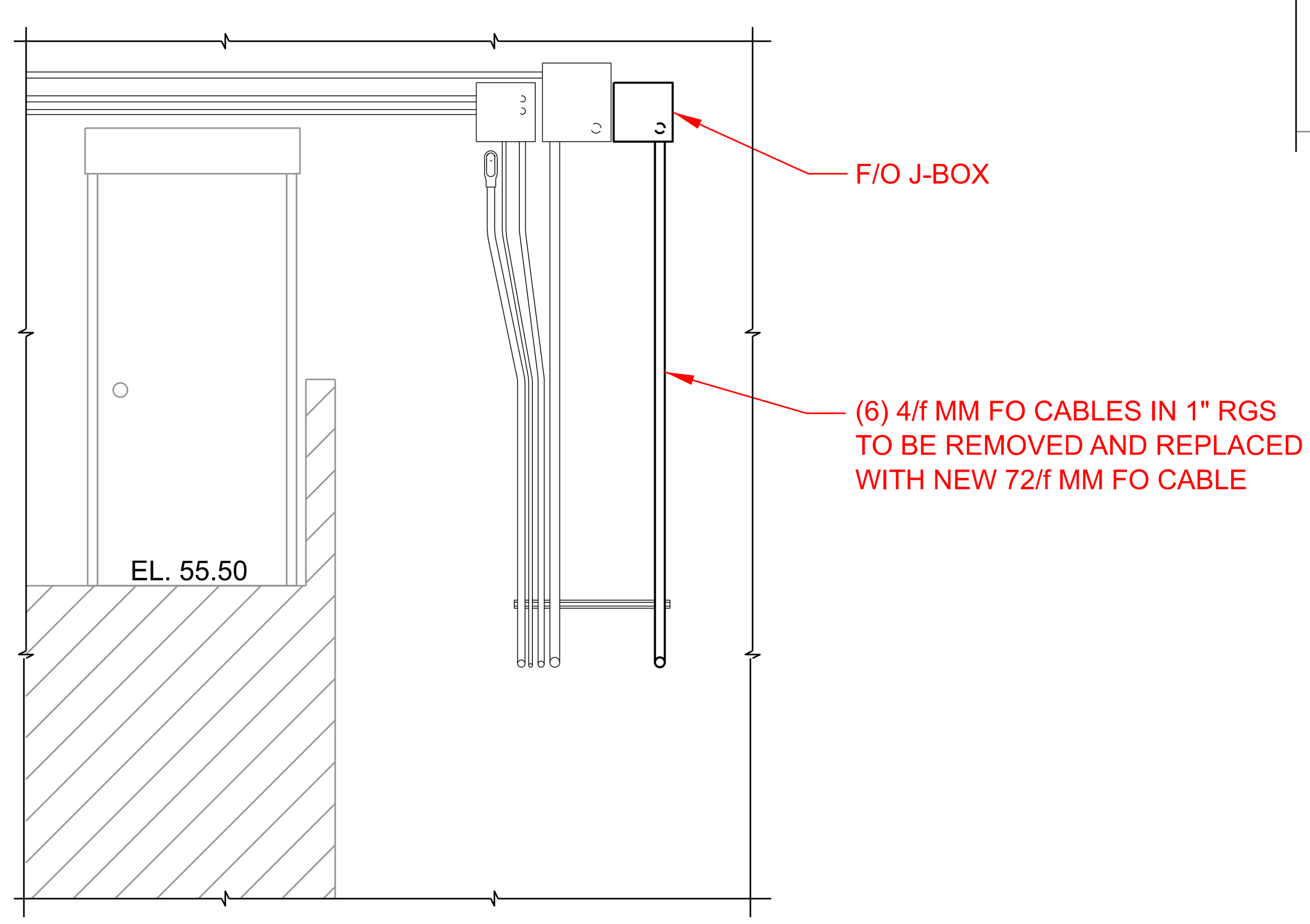
B / – SECTION
SCALE: 3/8"= 1'-0"
12" 0 2' 4' 6'



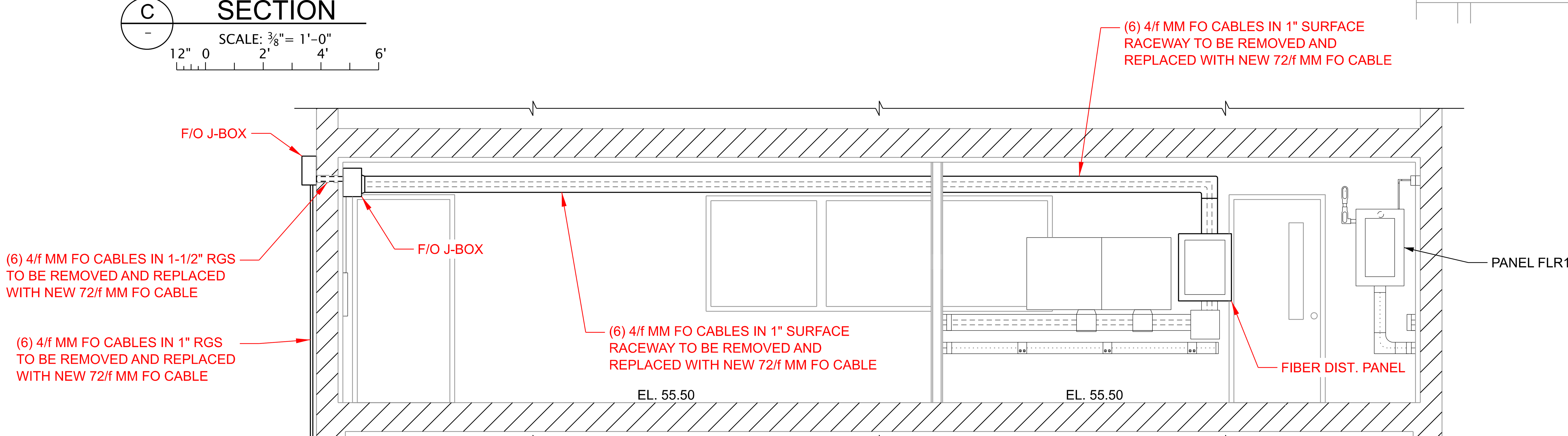
D / E-3 SECTION
SCALE: 3/8"= 1'-0"
12" 0 2' 4' 6'



2 / E-3 PLAN
SCALE: 3/16"= 1'-0"
12"0 5' 10'



C / – SECTION
SCALE: 3/8"= 1'-0"
12" 0 2' 4' 6'



A / – SECTION
SCALE: 3/8"= 1'-0"
12" 0 2' 4' 6'

INFORMATIONAL DRAWINGS:

BDF-6-35/13	AFF PIT TAG ROOM PLAN
BDF-6-35/15	ELEVATIONS
BDF-6-35/16	AFF PIT TAG ROOM - SECTIONS
BDF-6-35/17	MISCELLANEOUS DETAILS

NOTES:

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2. ITEMS IN RED TO BE MODIFIED.

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CONTRACT NO.:
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.123_E-405.dgn

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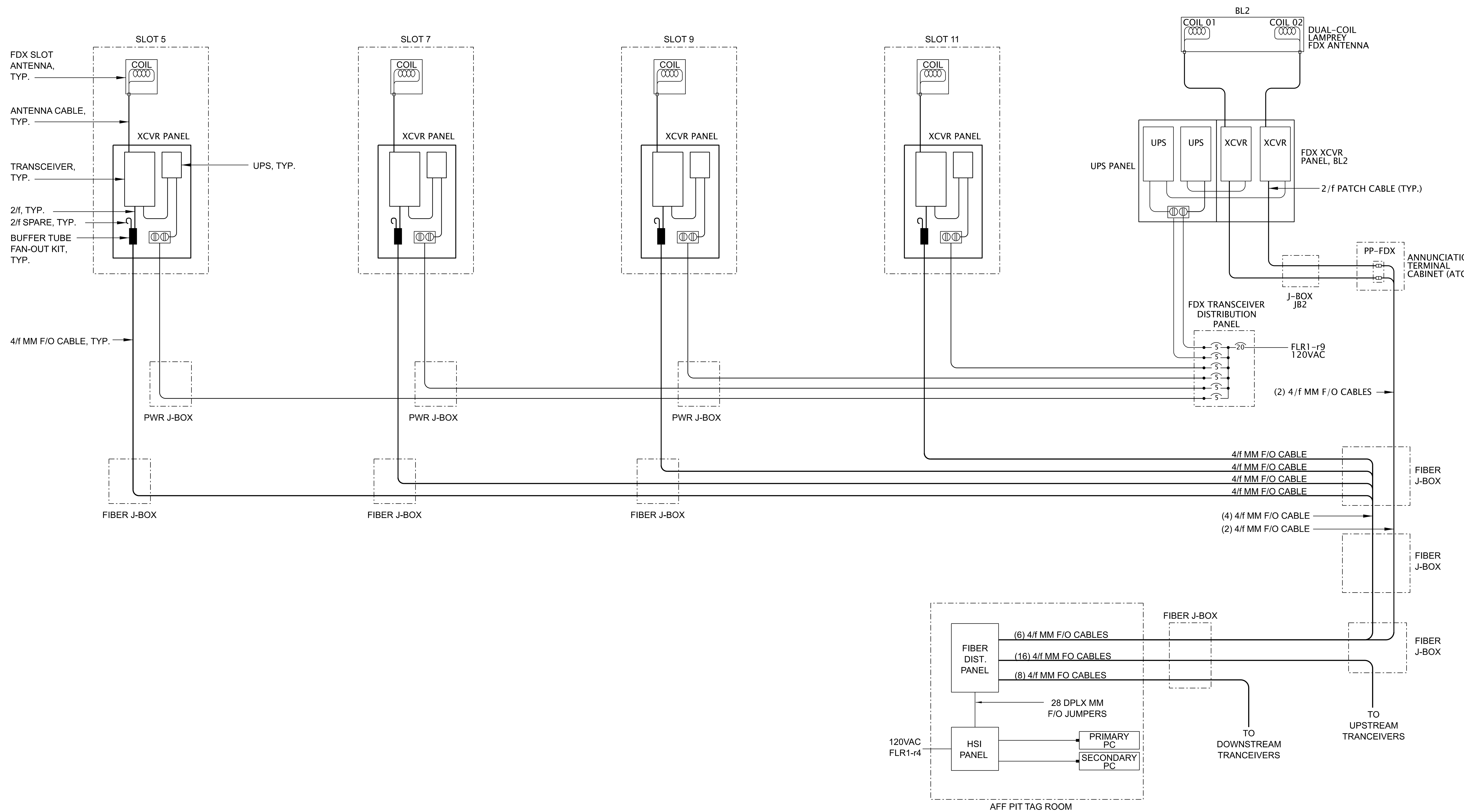
PORTLAND, OREGON

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
AFF PIT TAG ROOM MODIFICATIONS
PLAN & SECTIONS

PLATE IDENTIFICATION
E-6



TRANSCEIVER SYSTEM BLOCK DIAGRAM - EXISTING

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.

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PORTLAND DISTRICT

DDR REVIEW 90%

MARK	DESCRIPTION	DATE	APPR.

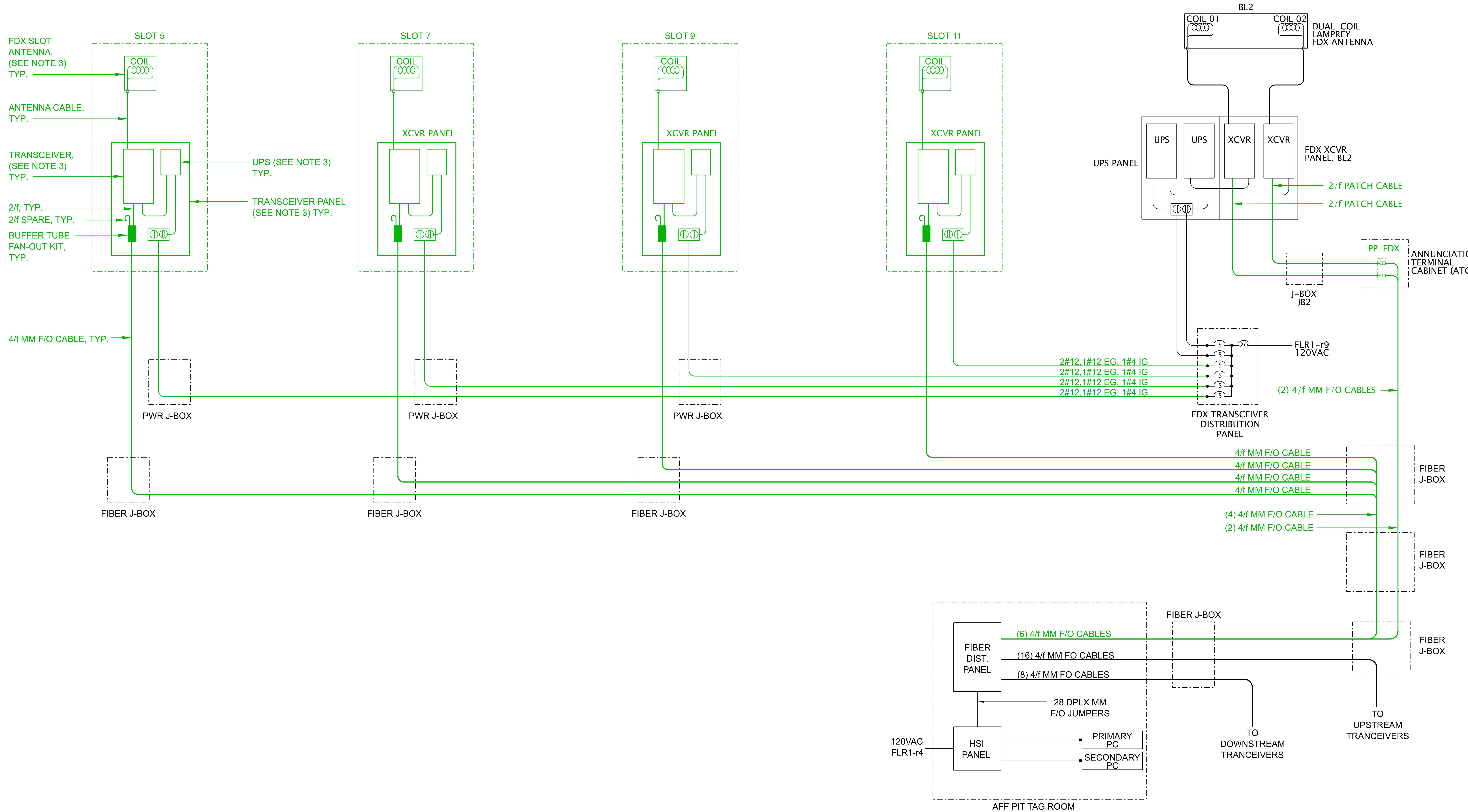
DESIGNED BY: B. BANNISTER
DATE: 04/18/2023
DRAWN BY: G2ENCBDB
CHECKED BY: G2ENCEBR
SOLICITATION NO.:
SUBMITTED BY: BILL FORTUNY, P.E.
CONTRACT NO.:
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.123_E-601.dgn

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
TRANSCEIVER BLOCK DIAGRAM
EXISTING

PLATE IDENTIFICATION
E-7



TRANSCEIVER SYSTEM BLOCK DIAGRAM - DEMO

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.
2. EQUIPMENT SHOWN IN GREEN TO BE REMOVED.
3. EQUIPMENT TO BE TURNED OVER TO PSMFC.

US Army Corps of Engineers®
PORTLAND DISTRICT

DDR REVIEW 90%

MARK	DESCRIPTION	DATE	APPR.

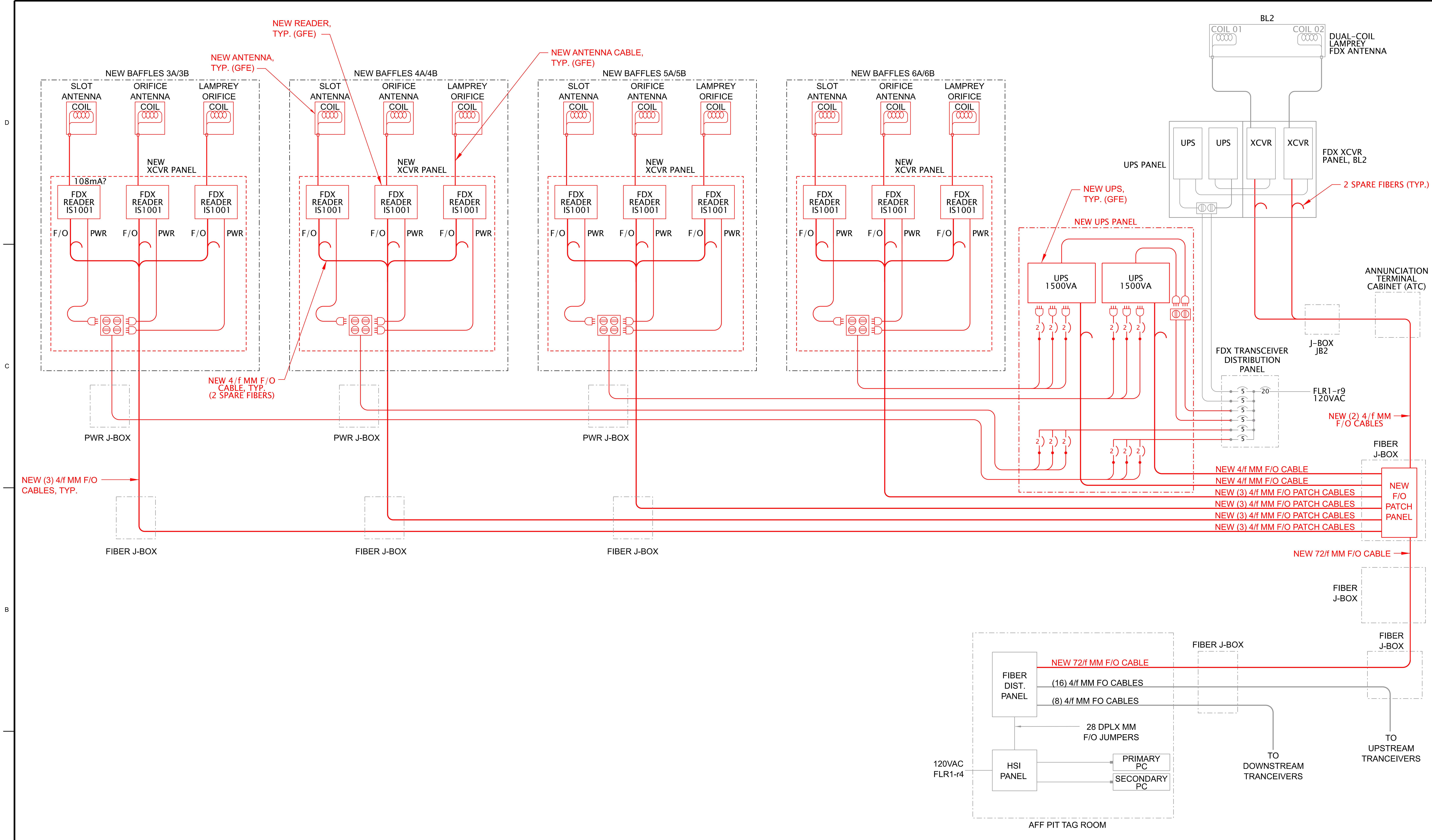
DESIGNED BY: B. BANNISTER
DRAWN BY: G2ENCBOB
CHECKED BY: G2ENCEBR
SUBMITTED BY: BILL FORTUNY, P.E.
DATE: 04/18/2023
SOLICITATION NO.:
CONTRACT NO.:
DRAWING NUMBER:
PLOT SCALE: 1:1
PLOT DATE:
SIZE: ANSI D
FILE NAME: BDF1.123_E-602.dgn

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
TRANSCEIVER BLOCK DIAGRAM
DEMOLITION

PLATE IDENTIFICATION
E-8



TRANSCEIVER SYSTEM BLOCK DIAGRAM - MODIFIED

NOTES:

1. ALL ITEMS ARE EXISTING UNLESS INDICATED OTHERWISE.
2. NEW EQUIPMENT SHOWN IN RED.

US Army Corps of Engineers®
PORTLAND DISTRICT

DDR REVIEW 90%

MARK | DESCRIPTION | DATE | APPR.

DESIGNED BY: B. BANNISTER
DRAWN BY: G2ENCBDB
CHECKED BY: G2ENCEBR
SUBMITTED BY: BILL FORTUNY, P.E.
DATE: 04/18/2023
SOLICITATION NO.:
CONTRACT NO.:
DRAWING NUMBER:
PLOT SCALE: 1:1
PLOT DATE:
SIZE: ANSI D
FILE NAME: BDF1.123_E-603.dgn

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

BONNEVILLE LOCK AND DAM
BON FY19 FISH ACCORDS
LAMPREY BONNEVILLE 2, CRFM

ELECTRICAL
TRANSCEIVER BLOCK DIAGRAM
MODIFIED

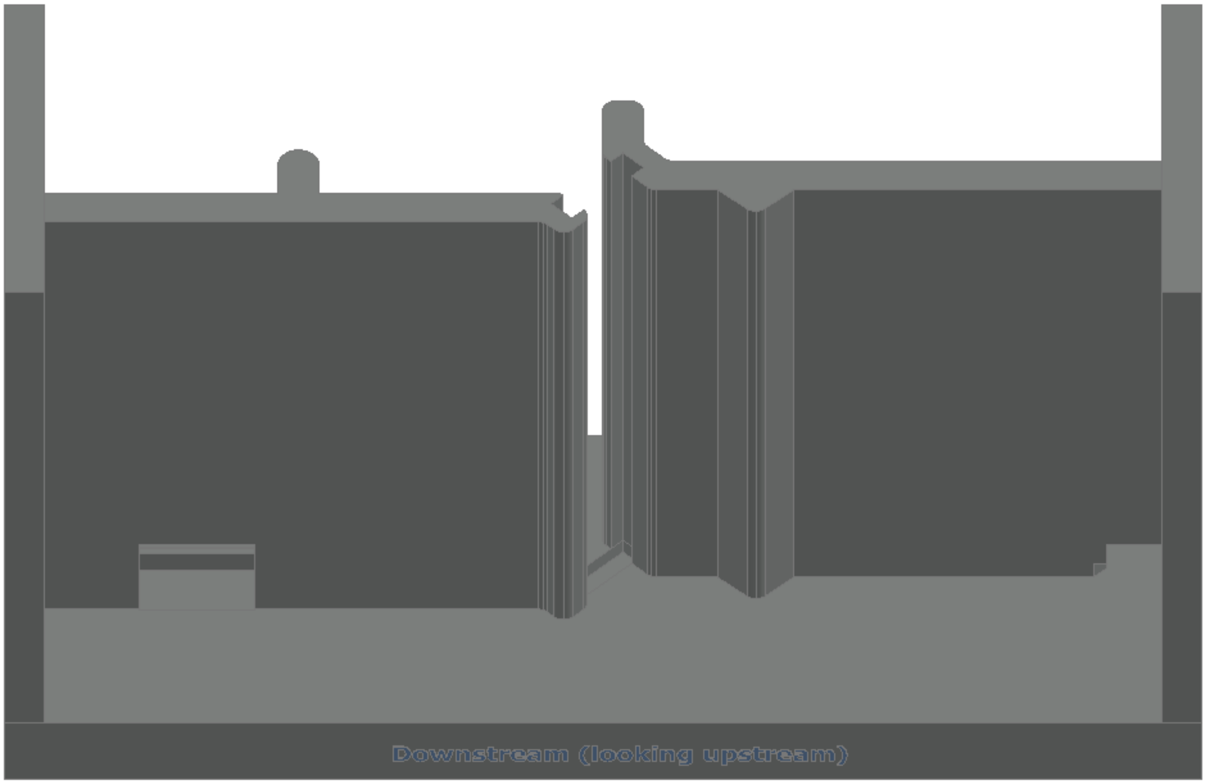
PLATE IDENTIFICATION
E-9

PSMFC – PTAGIS

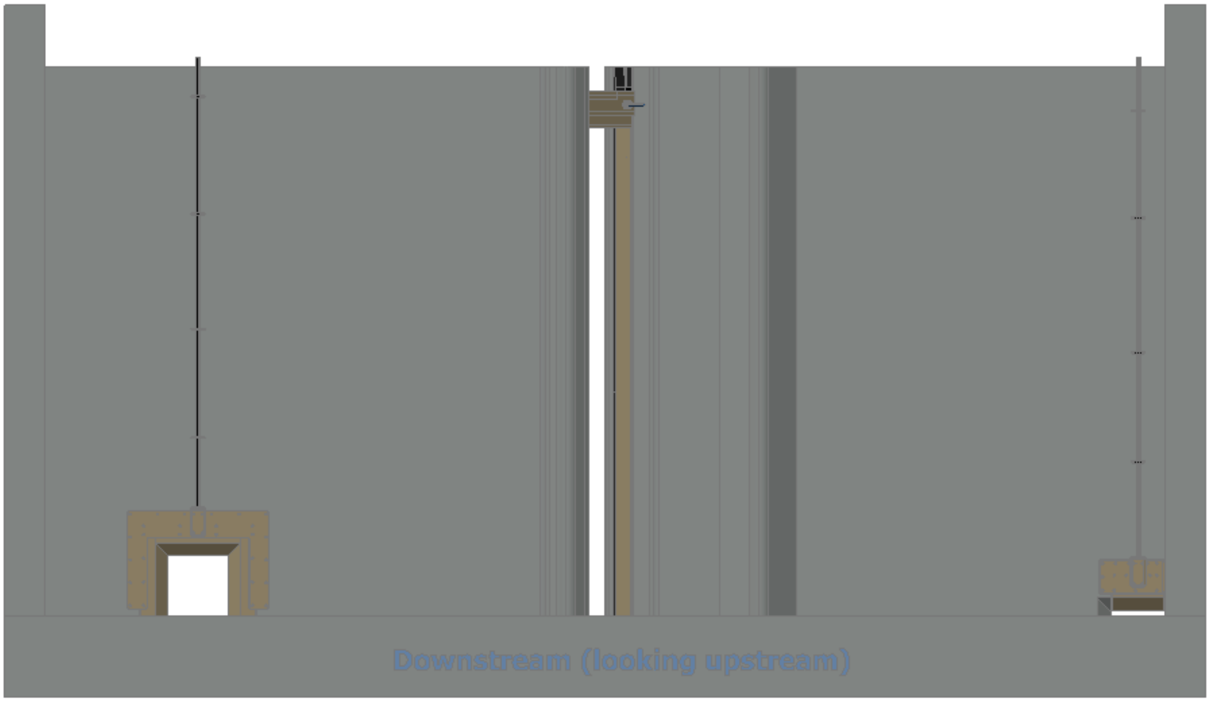
90% Conceptual Drawings – May 5, 2023

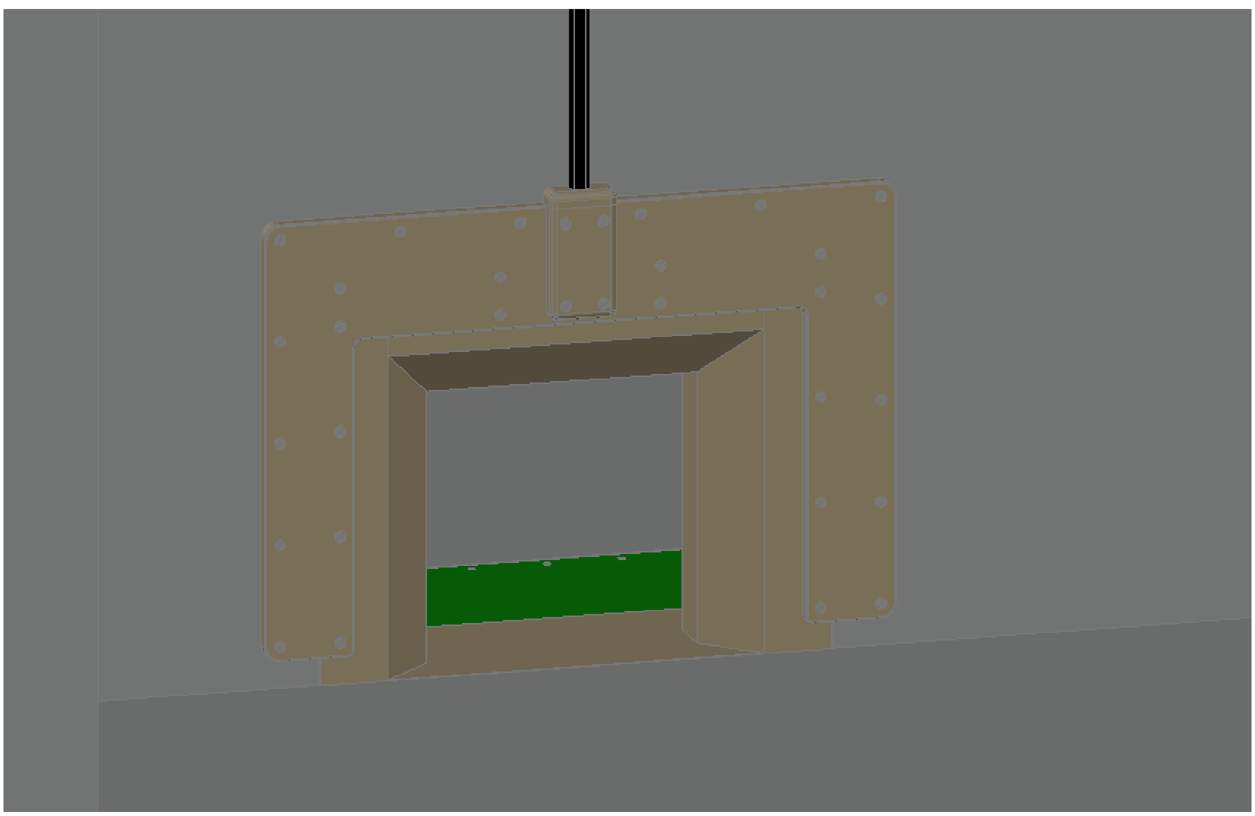
Bonneville Dam WA Fish Ladder

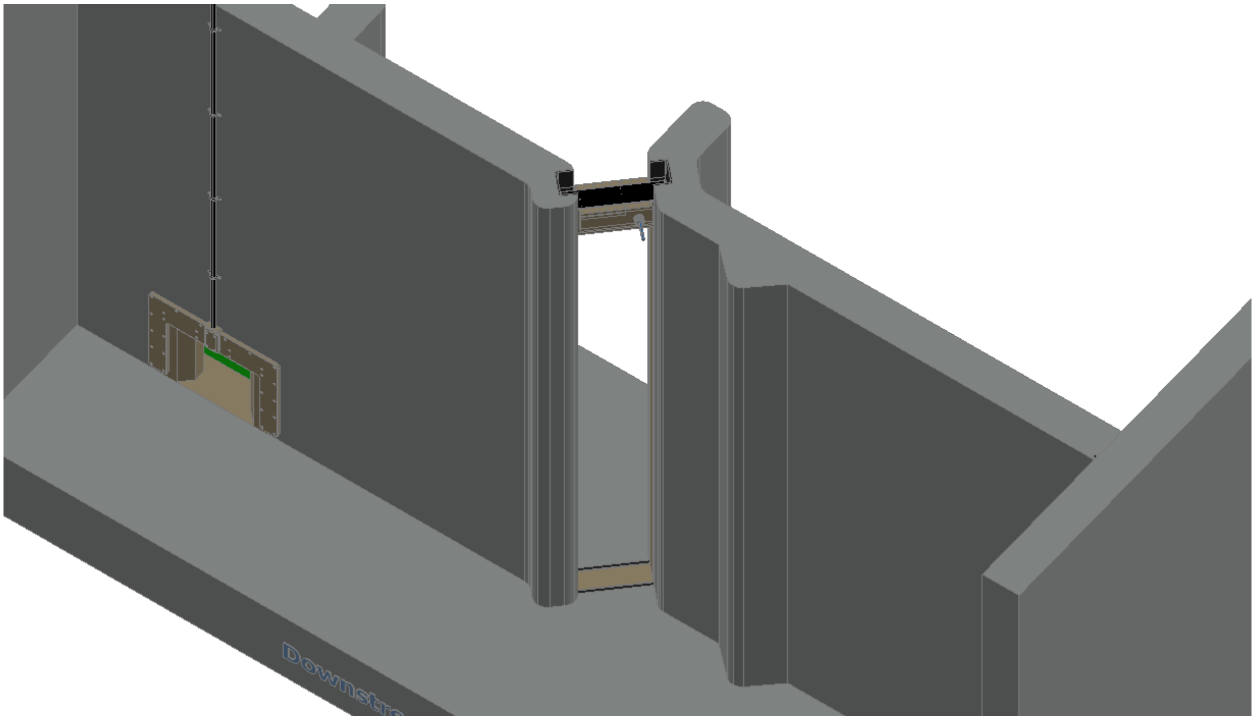
Organized first looking upstream, then looking downstream.

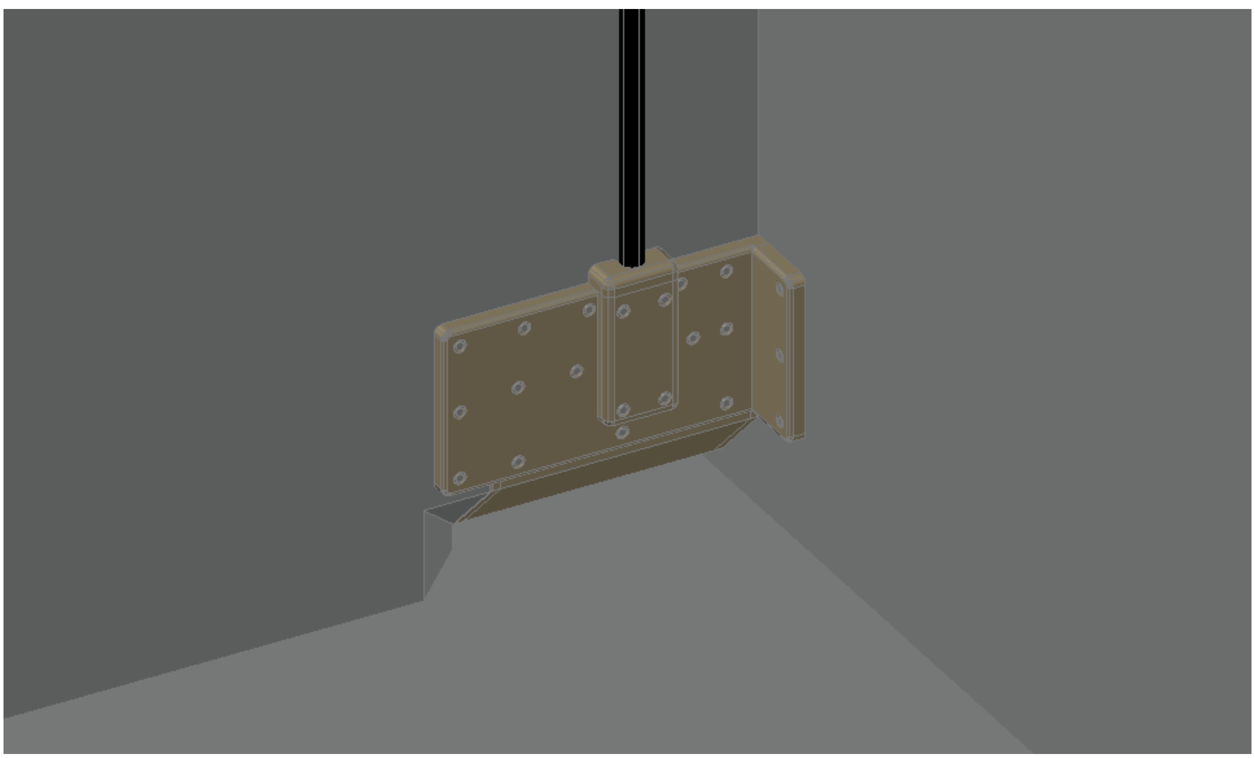

Downstream (looking upstream)

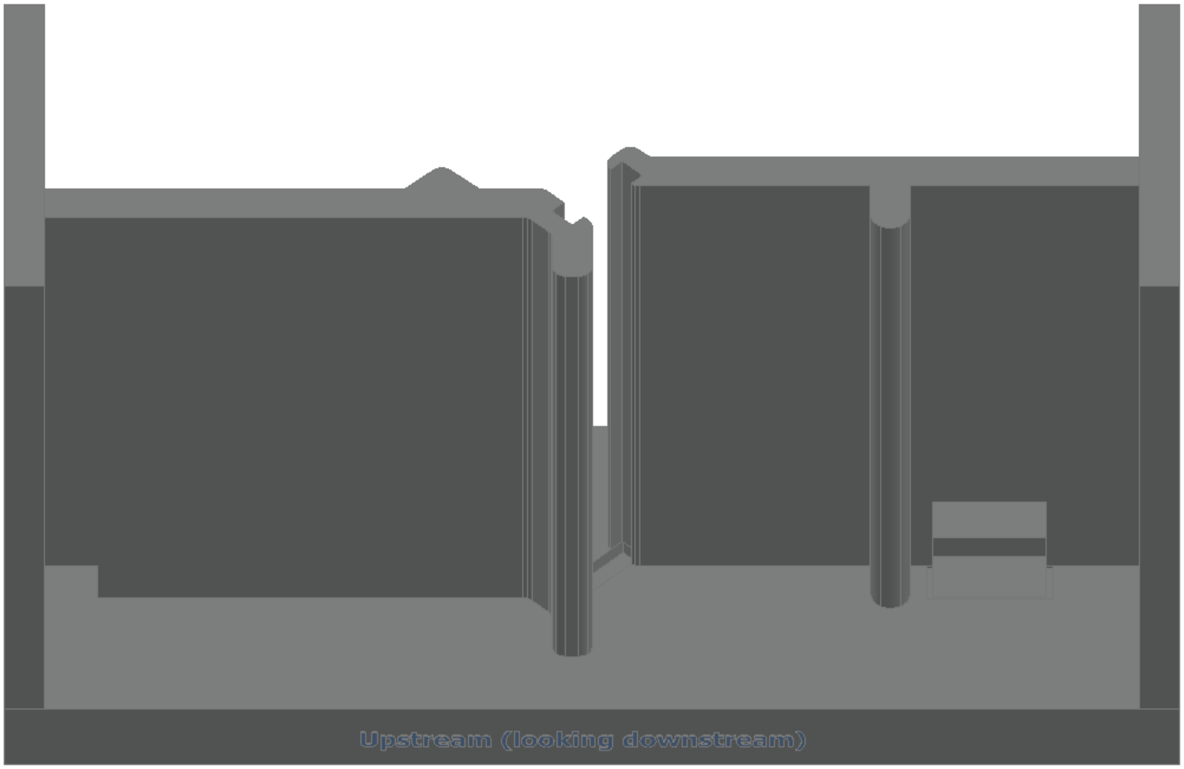

Downstream (looking upstream)

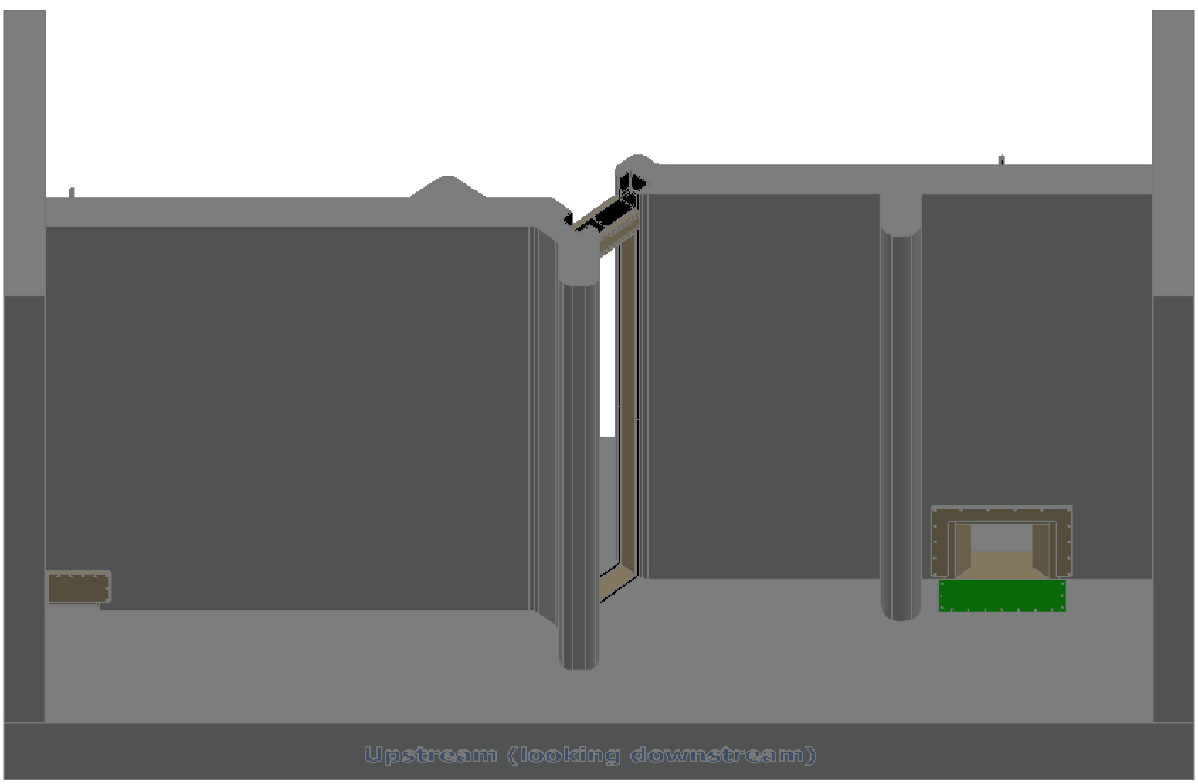

Downstream (looking upstream)

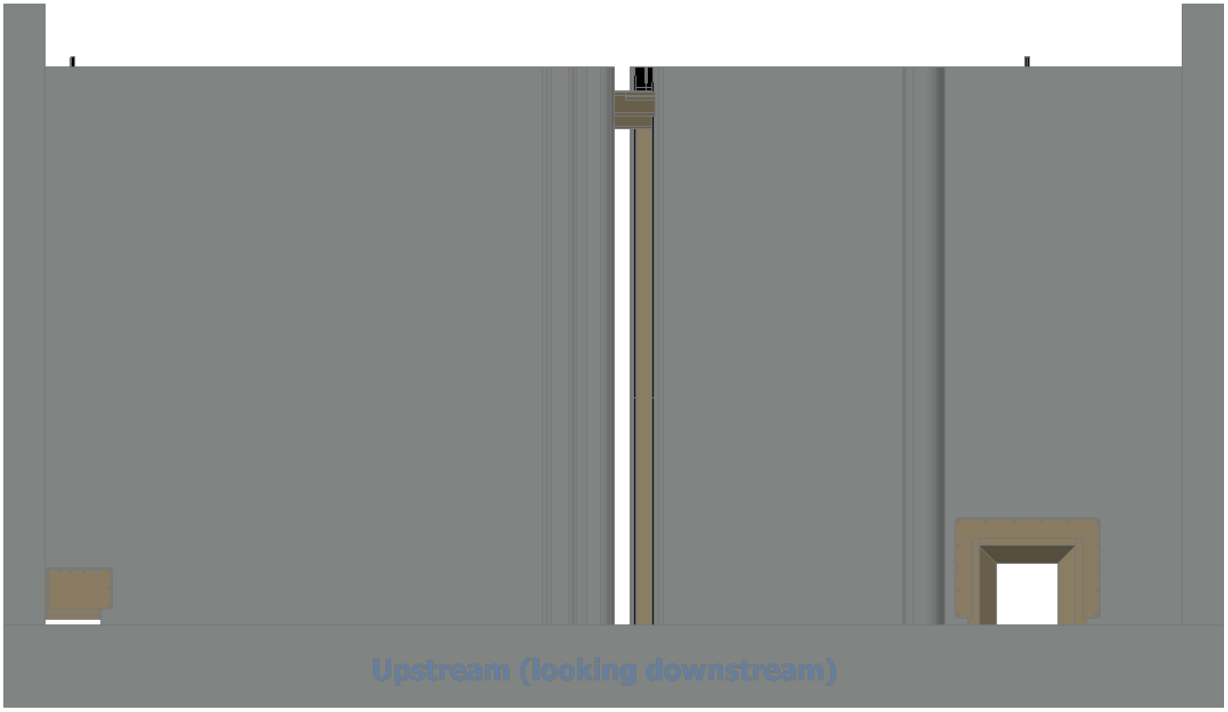


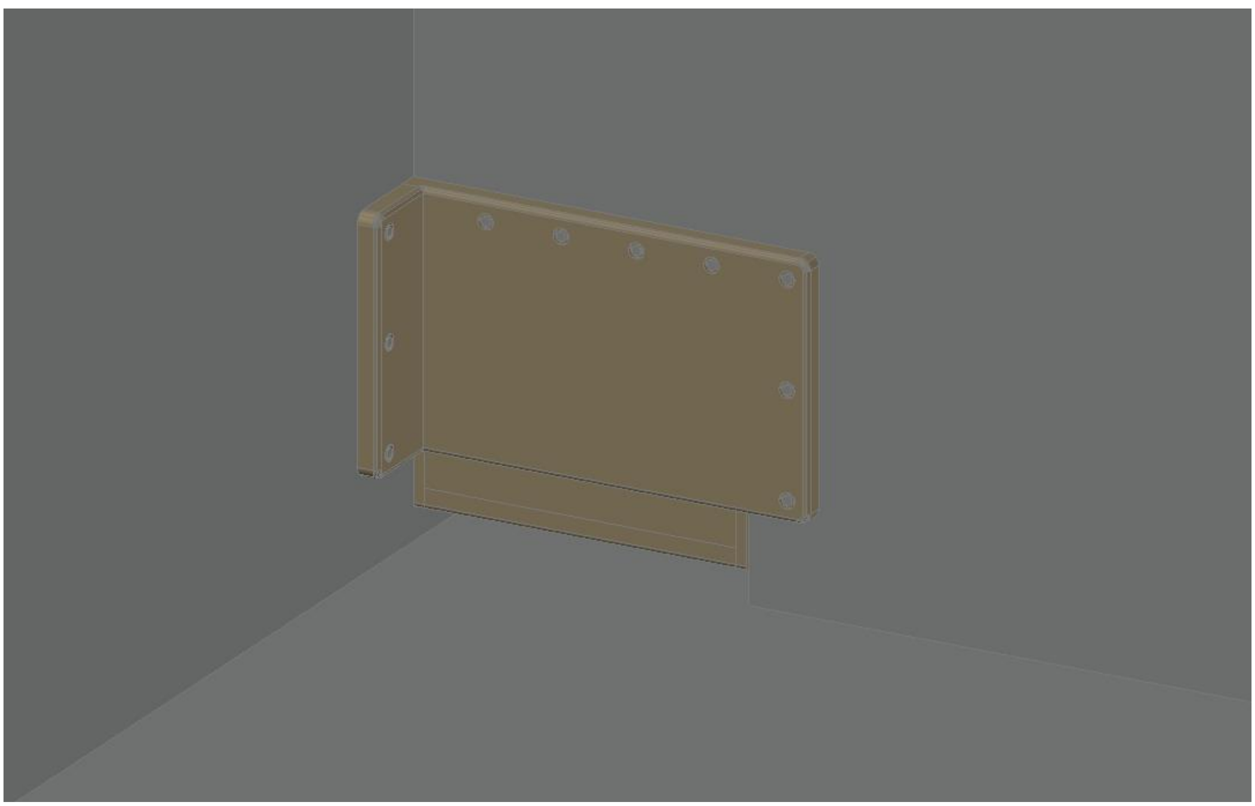


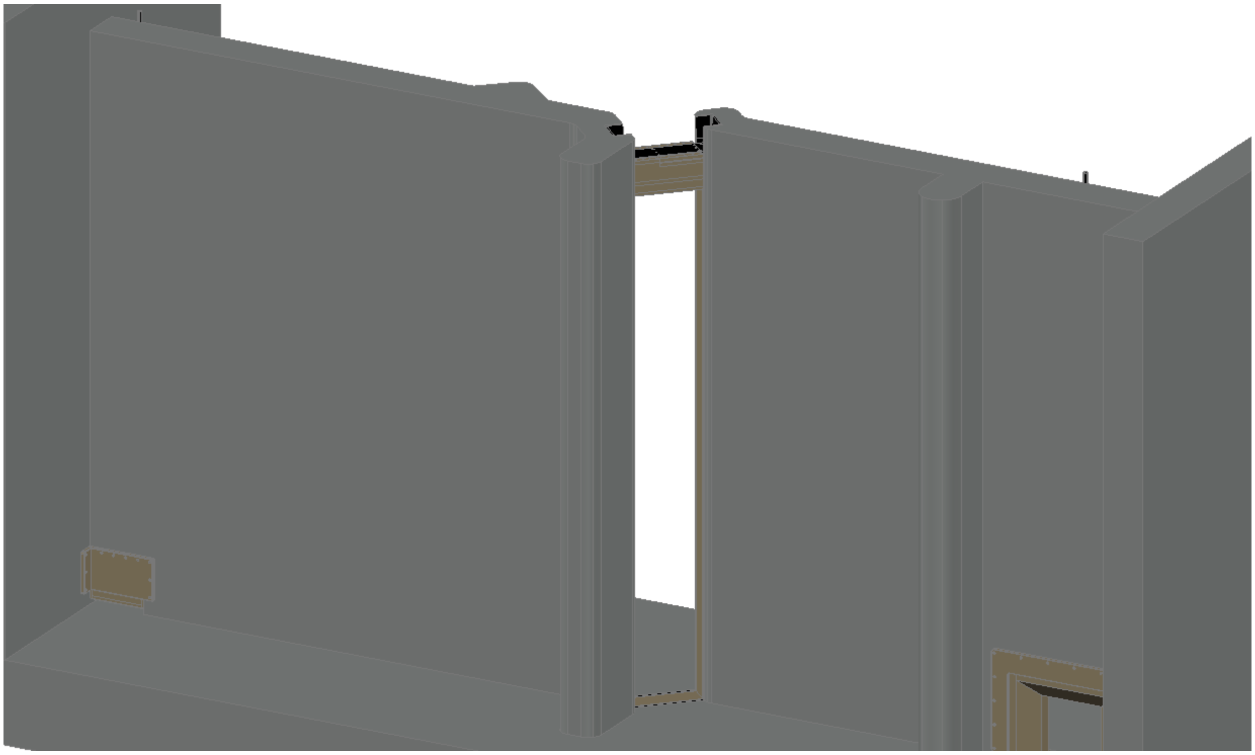


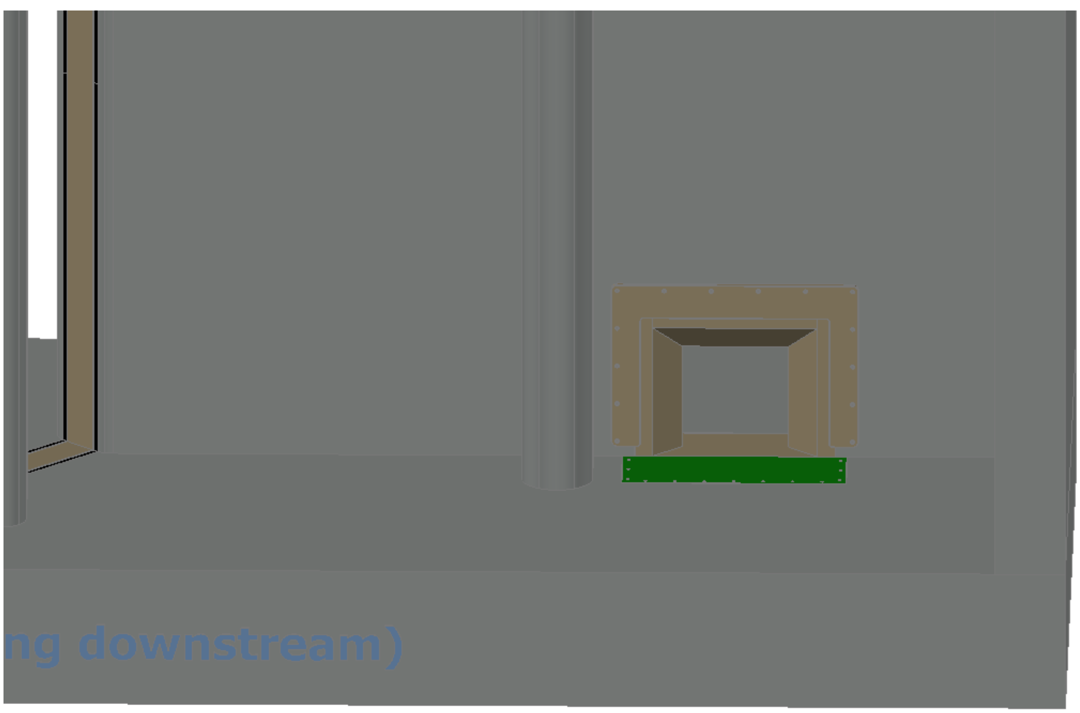

Upstream (looking downstream)


Upstream (looking downstream)


Upstream (looking downstream)

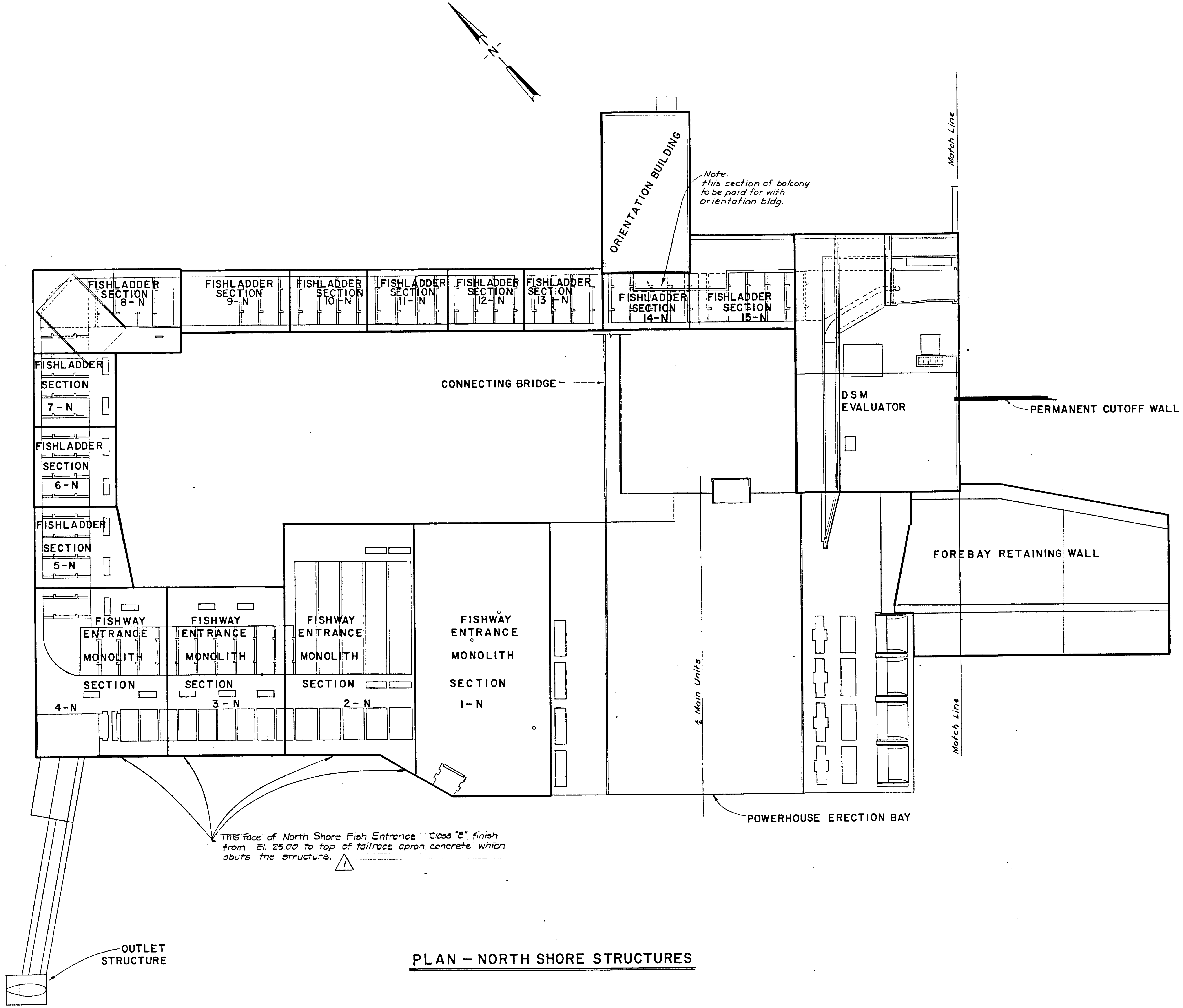




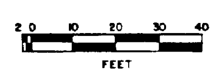

ng downstream)

Appendix B

Reference Drawings



PLAN – NORTH SHORE STRUCTURES



GENERAL CONCRETE & REINFORCEMENT NOTES

1. Chamfer - Unless otherwise shown, all exposed corners and contraction joints shall be chamfered 1½ inches for massive work and ¾ inches for other work. All re-entrant corners shall have 1⅜ inch fillets except at the junction of wall and floor surfaces.

2. Cover - Unless otherwise noted, the clear distance from the face of concrete to the main reinforcement shall not be less than the following:
   - a. Unformed surfaces in contact with foundation 4"
   - b. Formed surfaces exposed to earth, weather, or water 3"
   - c. Formed and screeded surfaces of walls, footings, slabs, beams, and columns 2"

3. Reinforcing Bar Lap Splices - Reinforcing bars are to be spliced at locations indicated on the drawings. Alternate splice locations may be used to suit construction joint locations subject to approval by the contracting officer. Unless otherwise detailed, reinforcing bar splices shall be as follows:

Bar Size	Splice Length Regular Bars	Splice Length Top Bars
#3	24"	24"
#4	24"	24"
#5	24"	24"
#6	24"	25"
#7	24"	34"
#8	32"	44"
#9	40"	56"
#10	51"	71"
#11	63"	88"

Embedments not shown on the drawings and any alternate or additional splices shall be in accordance with ACI 318-71. Bars larger than #11 shall be butt spliced by thermit welding or mechanical splicing.

4. Hooks and Bends - Unless otherwise shown, hooks and bends of reinforcing bars shall be in accordance with ACI 318-71.

5. Vertical reinforcing projecting above forms shall be supported to prevent breaking of bond between reinforcing bars and freshly placed concrete. Unless permitted by the Contracting Officer, reinforcement shall not be bent after embedded in hardened concrete.

6. See sheets 5a & 5b for Precast Beam Details. (Revision 1)

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

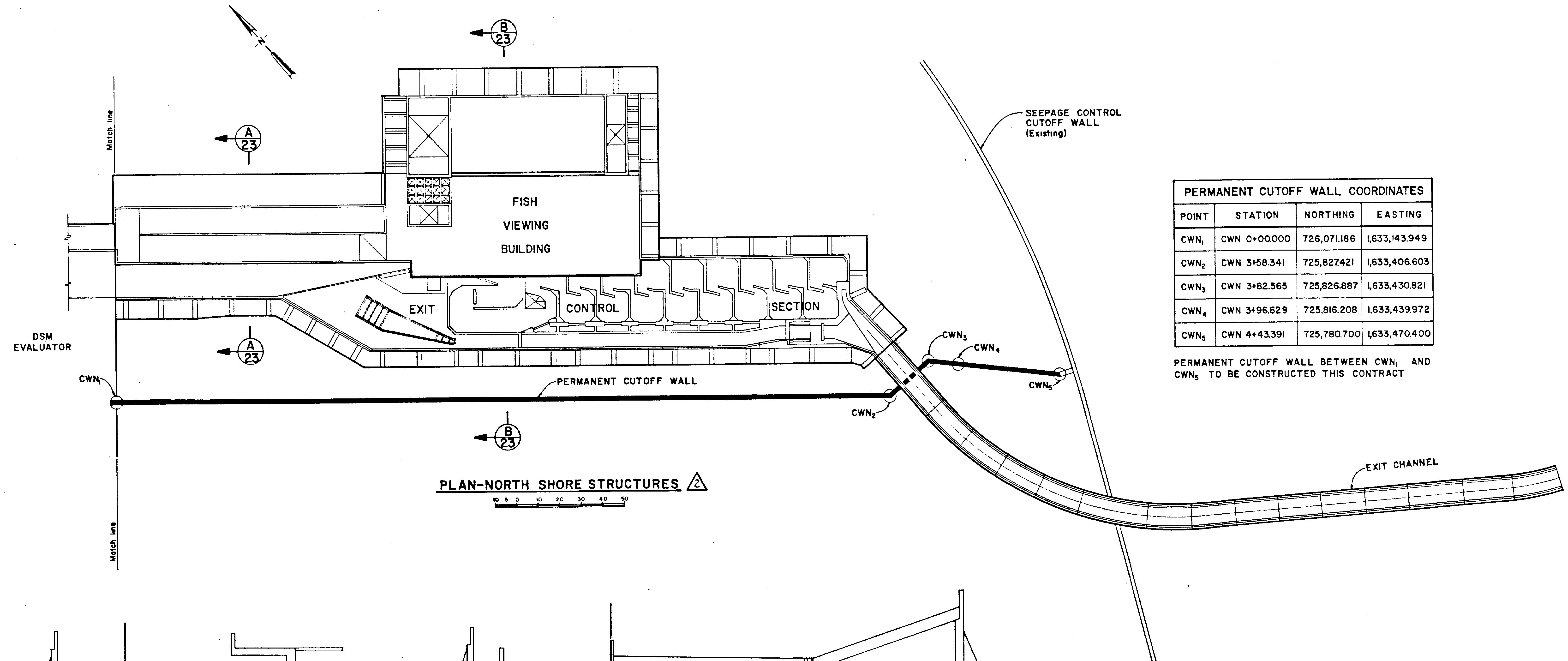
REVISION	DATE	DESCRIPTION	BY
1	8 Sep 23	Revised as constructed	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES – FISHWAY ENTRANCE MONOLITHS
LAYOUT
NORTH SHORE FEATURES I

DESIGNED: R. Strom
DRAWN: A. Binder
CHECKED: D. Illias
PREPARED: Ralph Strom
SUPERVISED: Ronald P. Smith, Chief Structures Section
SUBMITTED: Heber C. Heme, Chief Design Branch — DATE 22 Nov 21

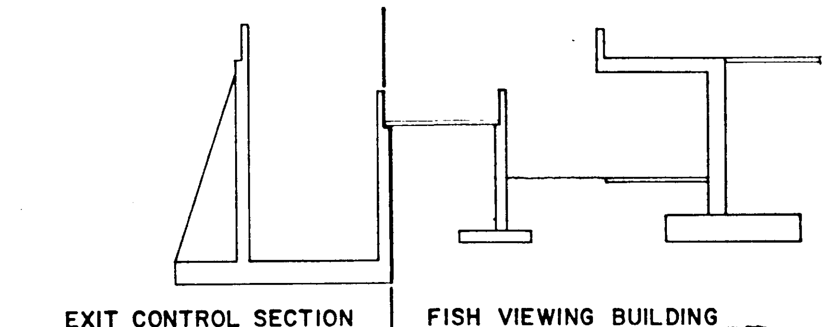
SHEET 22 BDF-2-15/20



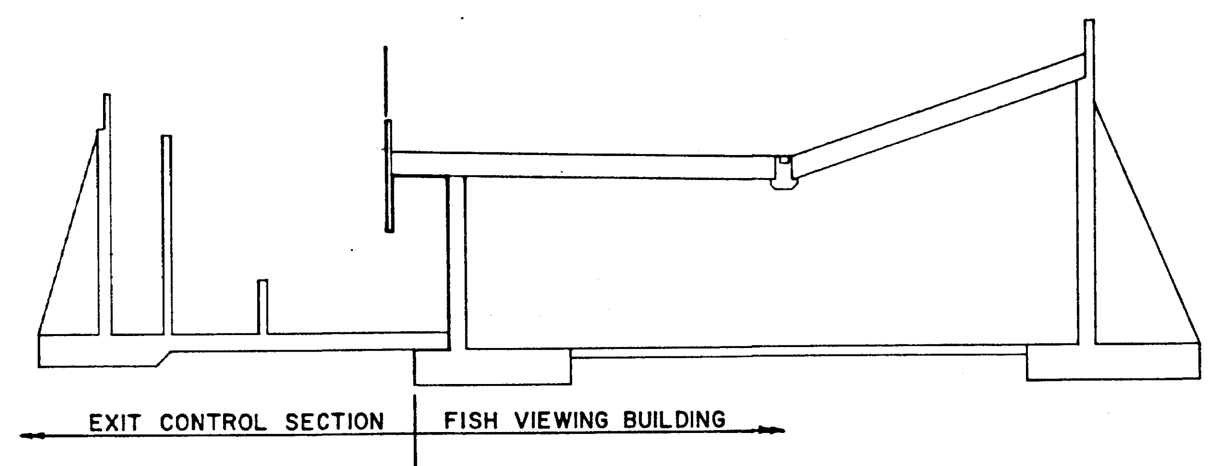
PLAN-NORTH SHORE STRUCTURES 2

PERMANENT CUTOFF WALL COORDINATES			
POINT	STATION	NORTHING	EASTING
CWN_1	CWN 0+00.000	726,071.186	1,633,143.949
CWN_2	CWN 3+58.341	725,827.421	1,633,406.603
CWN_3	CWN 3+82.565	725,826.887	1,633,430.821
CWN_4	CWN 3+96.629	725,816.208	1,633,439.972
CWN_5	CWN 4+43.391	725,780.700	1,633,470.400

PERMANENT CUTOFF WALL BETWEEN CWN_1 AND CWN_5 TO BE CONSTRUCTED THIS CONTRACT



SECTION A 23
3/32"=1'-0"



SECTION B 23
3/32"=1'-0"

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
3	18 Sep 23	As constructed	
2	78 Feb 14	Revised Fish Viewing Bldg., Sheet redrawn	
1	78 Feb 3	Added sections A & B	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

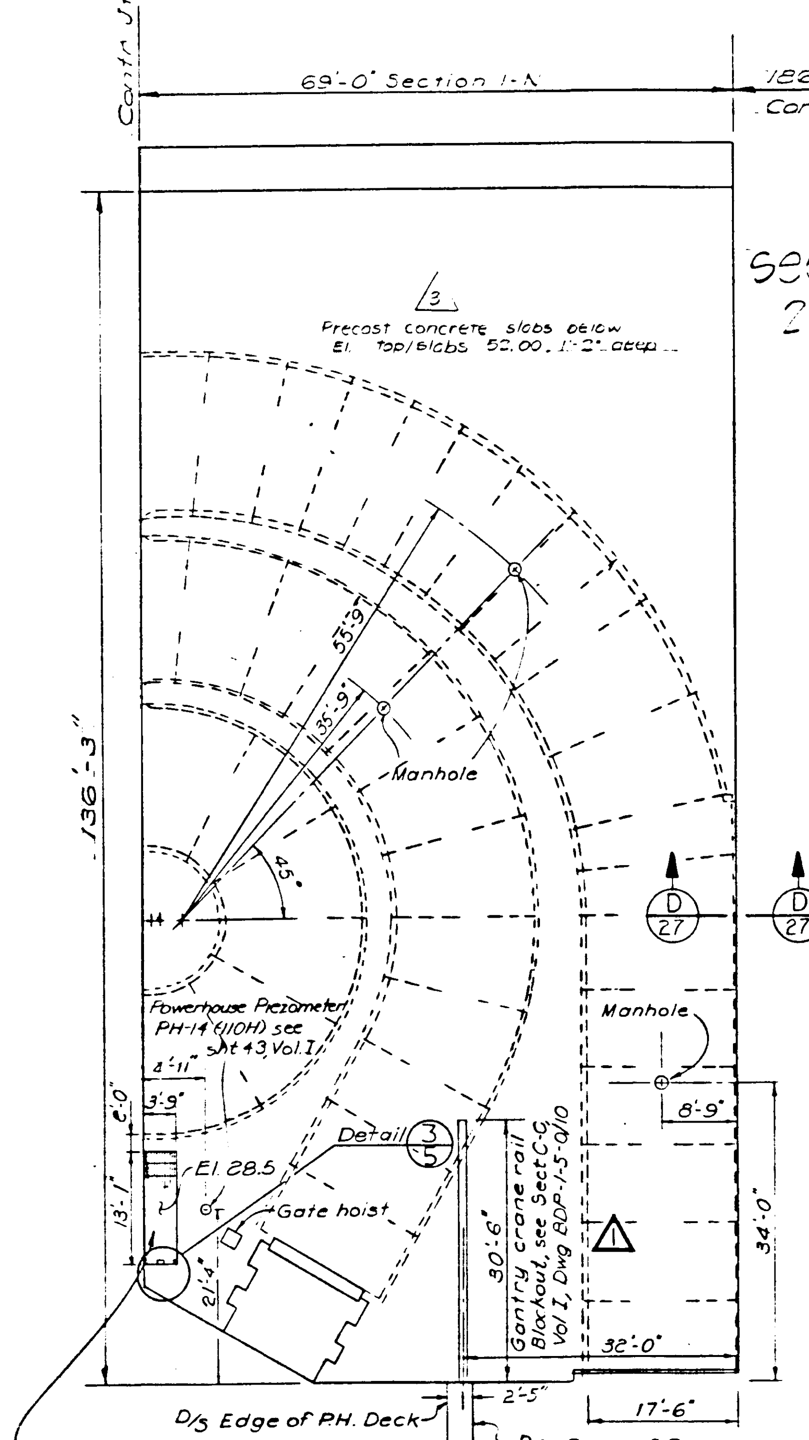
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON - WASHINGTON

FISH FACILITIES – FISHWAY ENTRANCE MONOLITHS

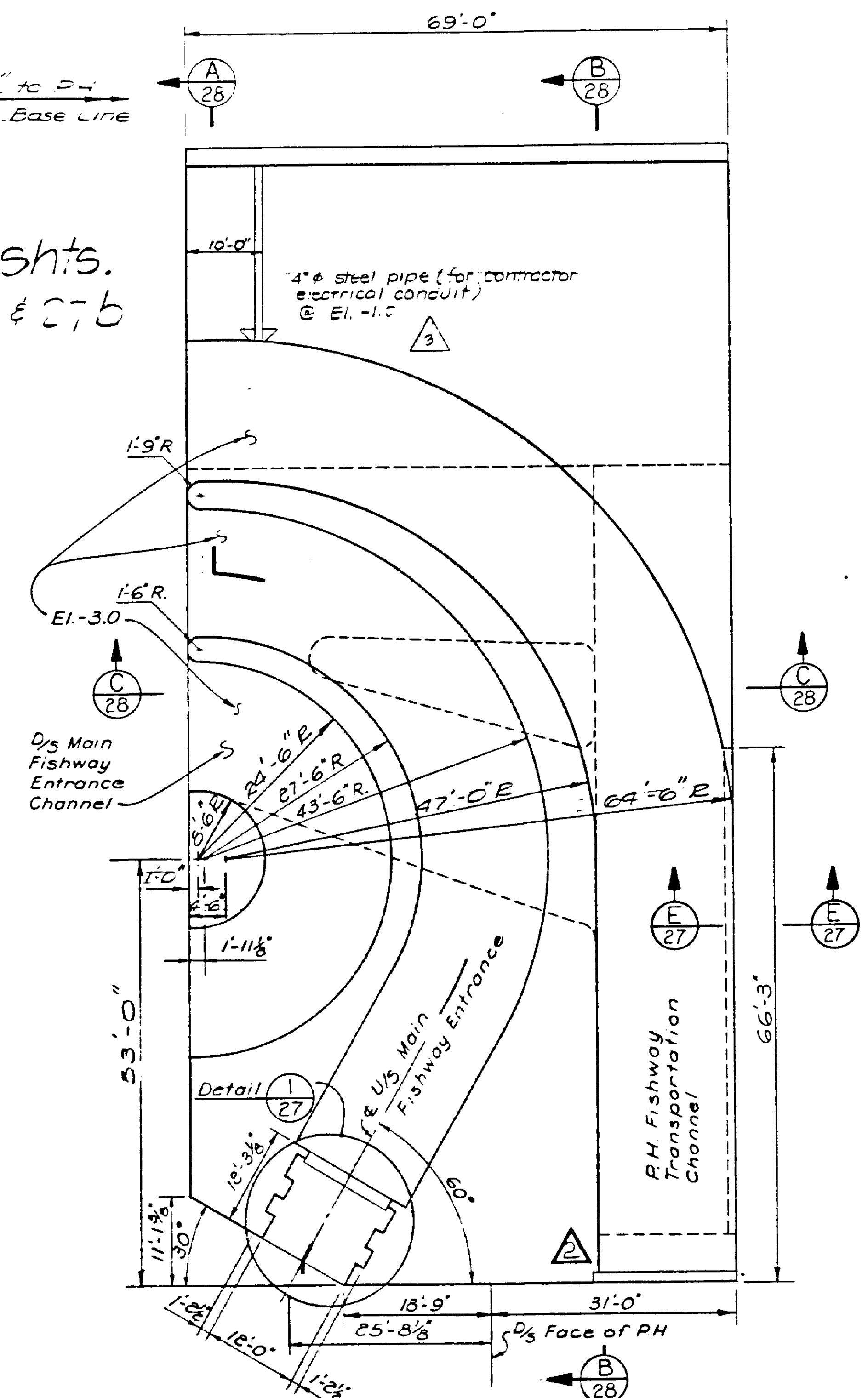
LAYOUT
NORTH SHORE FEATURES II

DESIGNED: R. Strom
DRAWN: A. Binder
CHECKED: D. Illios
PREPARED: Ralph Strom
SUBMITTED: Heber C. Hanna — CHIEF, DESIGN BRANCH — DATE: 22 NOV 21
SUPERVISED: Donald P. Smith — CHIEF, STRUCTURES SECTION

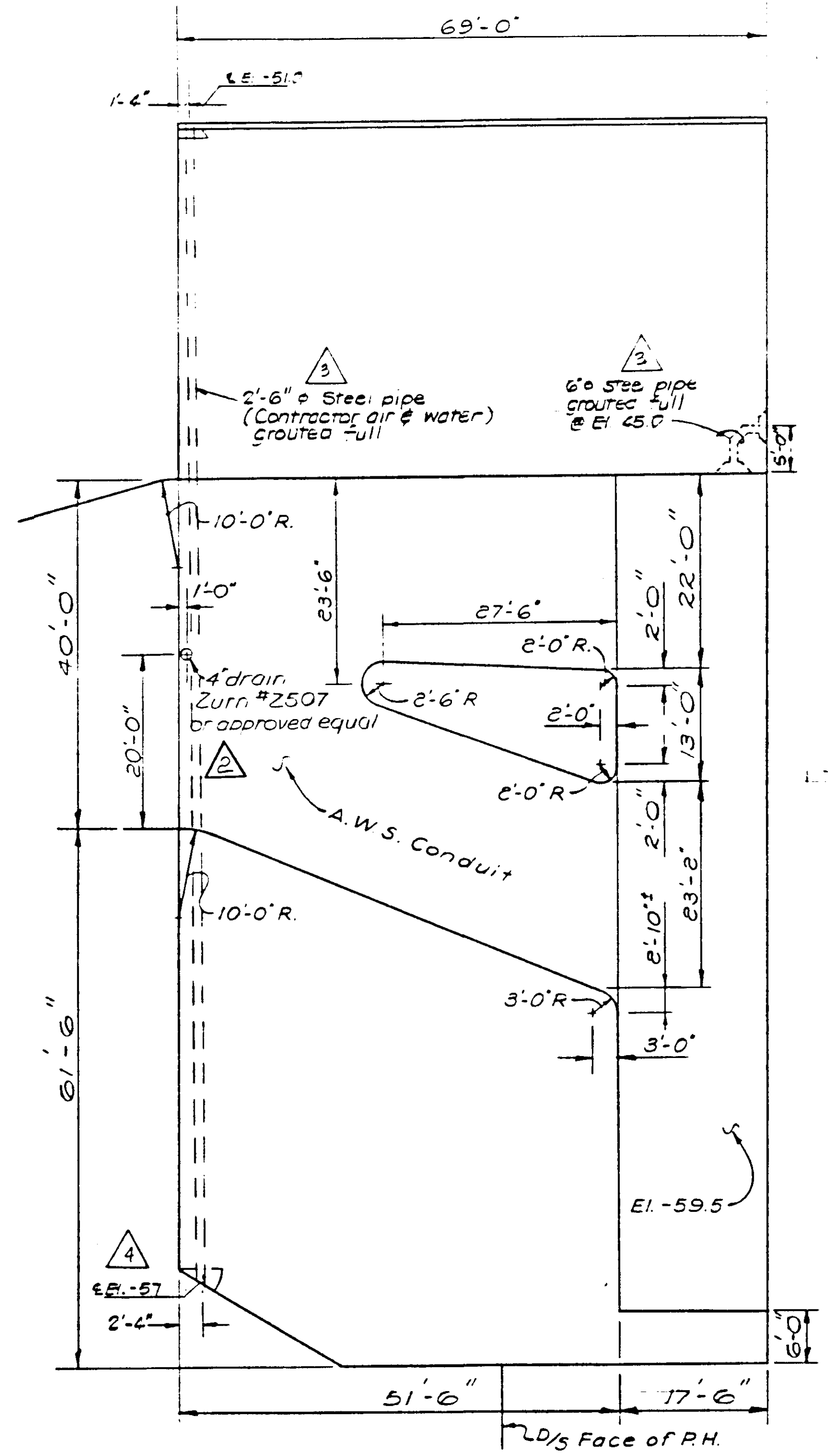
SHEET 23 BDF-2-15/21



PLAN - EL 55.0 (2)
3/32" = 1'-0"

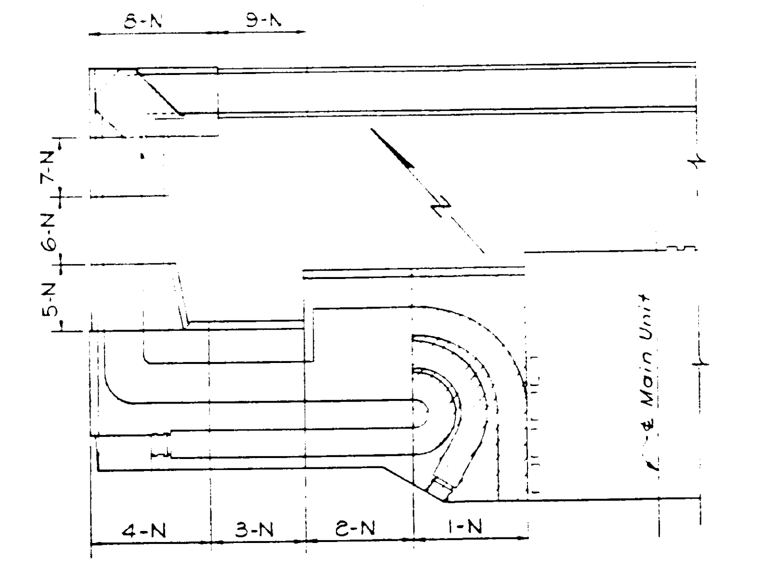


PLAN - EL -3.0
3/32" = 1'-0"

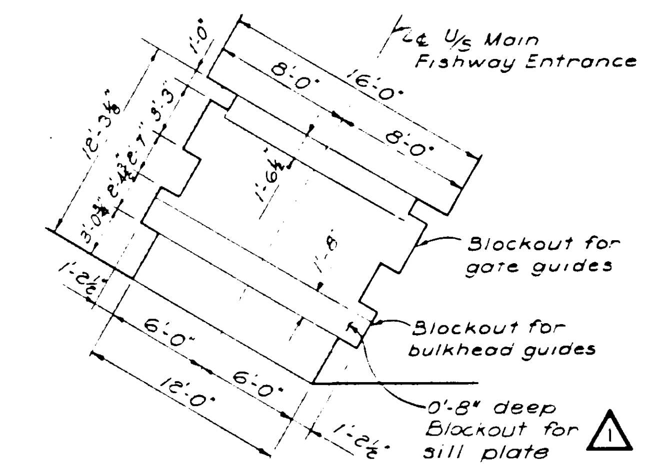


PLAN - EL -41.0
3/32" = 1'-0"

(3) 14 For Precast slabs see shts. 27a & 27b.



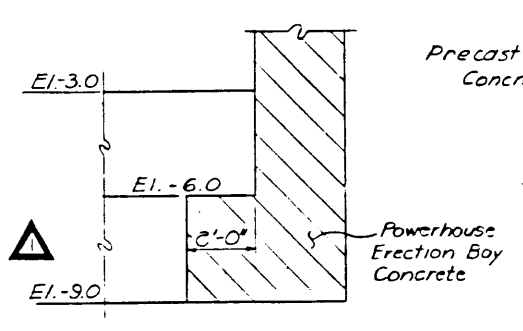
KEY PLAN



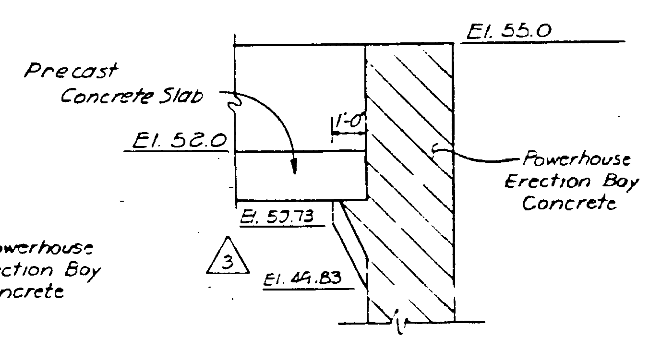
DETAIL (1/27)
3/16" = 1'-0"

NOTES:

1. For General Notes see Sht 22
2. For details of Blockouts for Gate and Bulkhead Guides see Sht 73
3. For handrail details see Sht 63
4. (2) For crane rail details see dwg. BDF-1-5-0/10, Vol. I.
5. For deck drainage see Sht 64
6. For gate hoist see Sht. 93
7. For heavy duty deck grating see Sht. 81.
8. For embedded guides in storage pit see Sht 82.
9. For joint details see Sht. 58
10. For conduit layout see Sht. 25
11. (1) For Manhole detail see Vol. I, Sht. 271, Detail A.
12. For lighting and power layout see Sht. 87.
13. (2) For tailrace transverse bulkhead blockout details see dwg BDP-1-4-2/48 and frame MK 0/15-8, Vol I



SECTION (E/27)
3/8" = 1'-0"



SECTION (D/27)
3/8" = 1'-0"

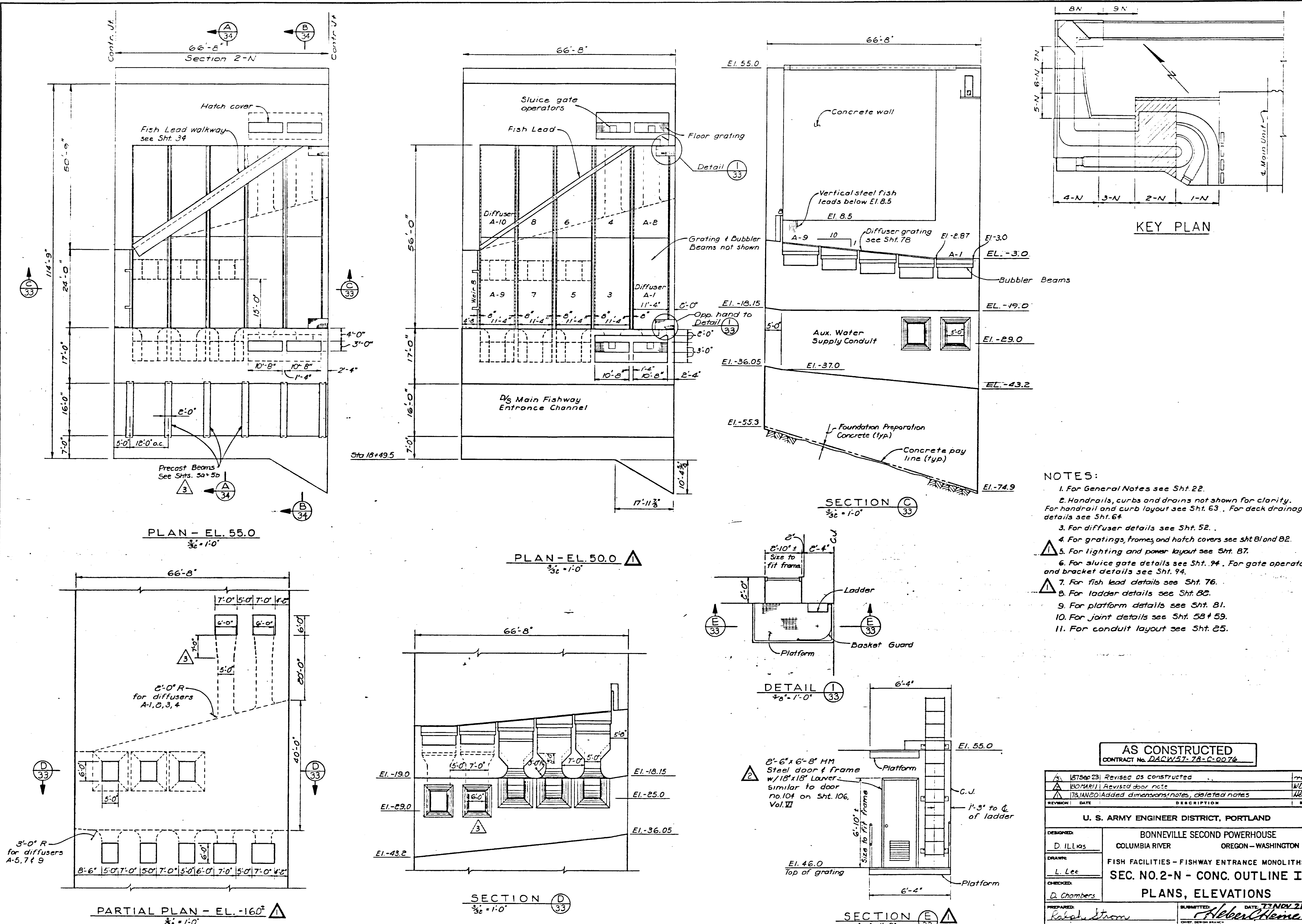
AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
3	81 Sep 21	Revised as constructed	
2	78 Aug 21	Add note, bulkhead blockout & AWS drain.	
1	78 Jan 20	Add Sta. and notes	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON — WASHINGTON
FISH FACILITIES — FISHWAY ENTRANCE MONOLITHS
SEC. NO. 1-N - CONC. OUTLINE I
PLANS, ELEVATIONS

DESIGNED: D. Illias
DRAWN: L. Lee
CHECKED: C. Chambers
SUBMITTED: [signature] DATE: 77 NOV 21
CHIEF, DESIGN BRANCH
SHEET 27 BDF-2-15/25



NOTES:

1. For General Notes see Sht. 22.
2. Handrails, curbs and drains not shown for clarity. For handrail and curb layout see Sht. 63. For deck drainage details see Sht. 64.
3. For diffuser details see Sht. 52.
4. For gratings, frames and hatch covers see sht. 81 and 82.
5. For lighting and power layout see Sht. 87.
6. For sluice gate details see Sht. 94. For gate operator and bracket details see Sht. 94.
7. For fish lead details see Sht. 76.
8. For ladder details see Sht. 88.
9. For platform details see Sht. 81.
10. For joint details see Sht. 58 & 59.
11. For conduit layout see Sht. 25.

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

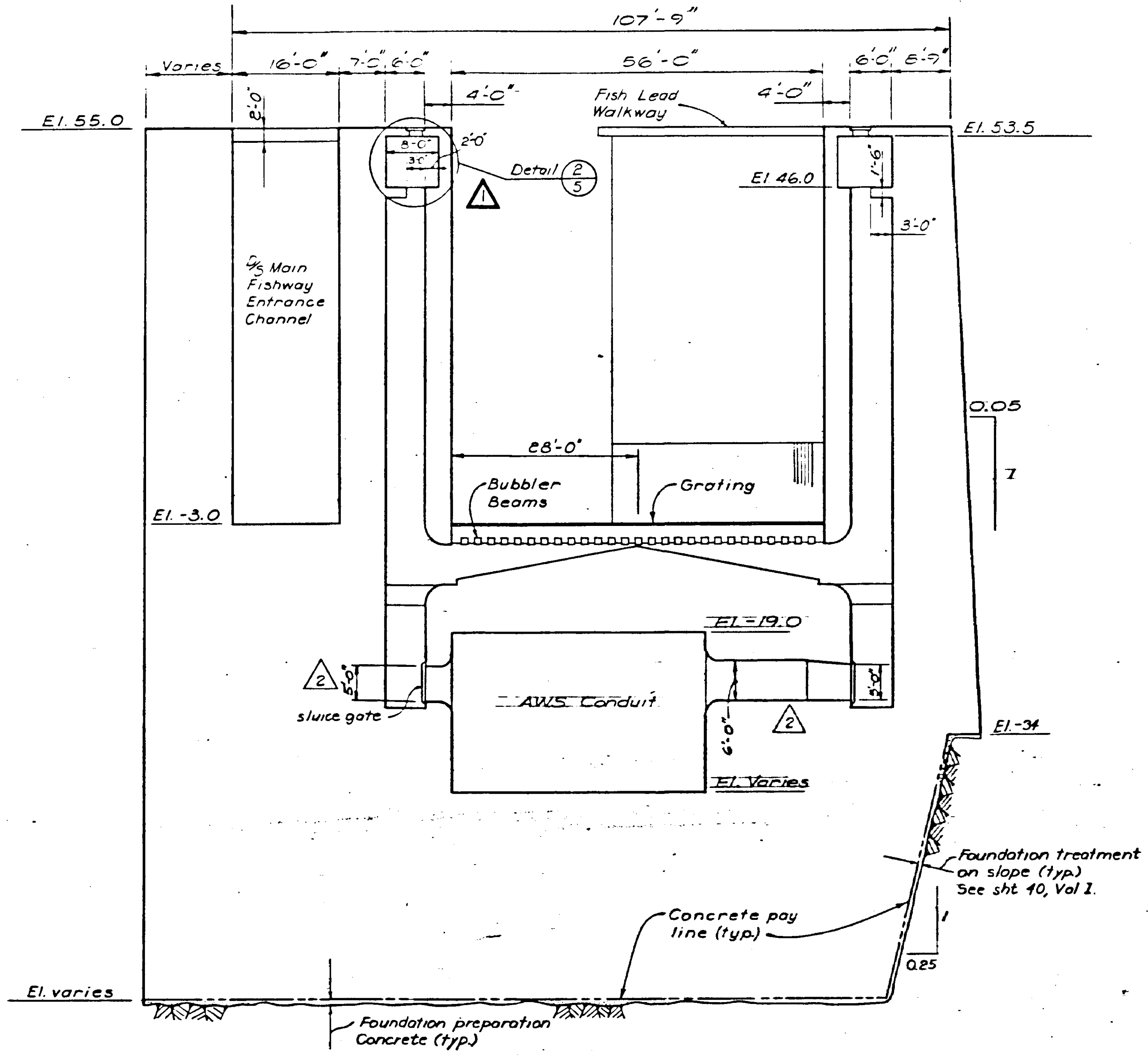
REVISION	DATE	DESCRIPTION	BY
3	18 Sep 23	Revised as constructed	
2	18 MAR 81	Revised door note	
1	17 JAN 80	Added dimensions/notes, deleted notes	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

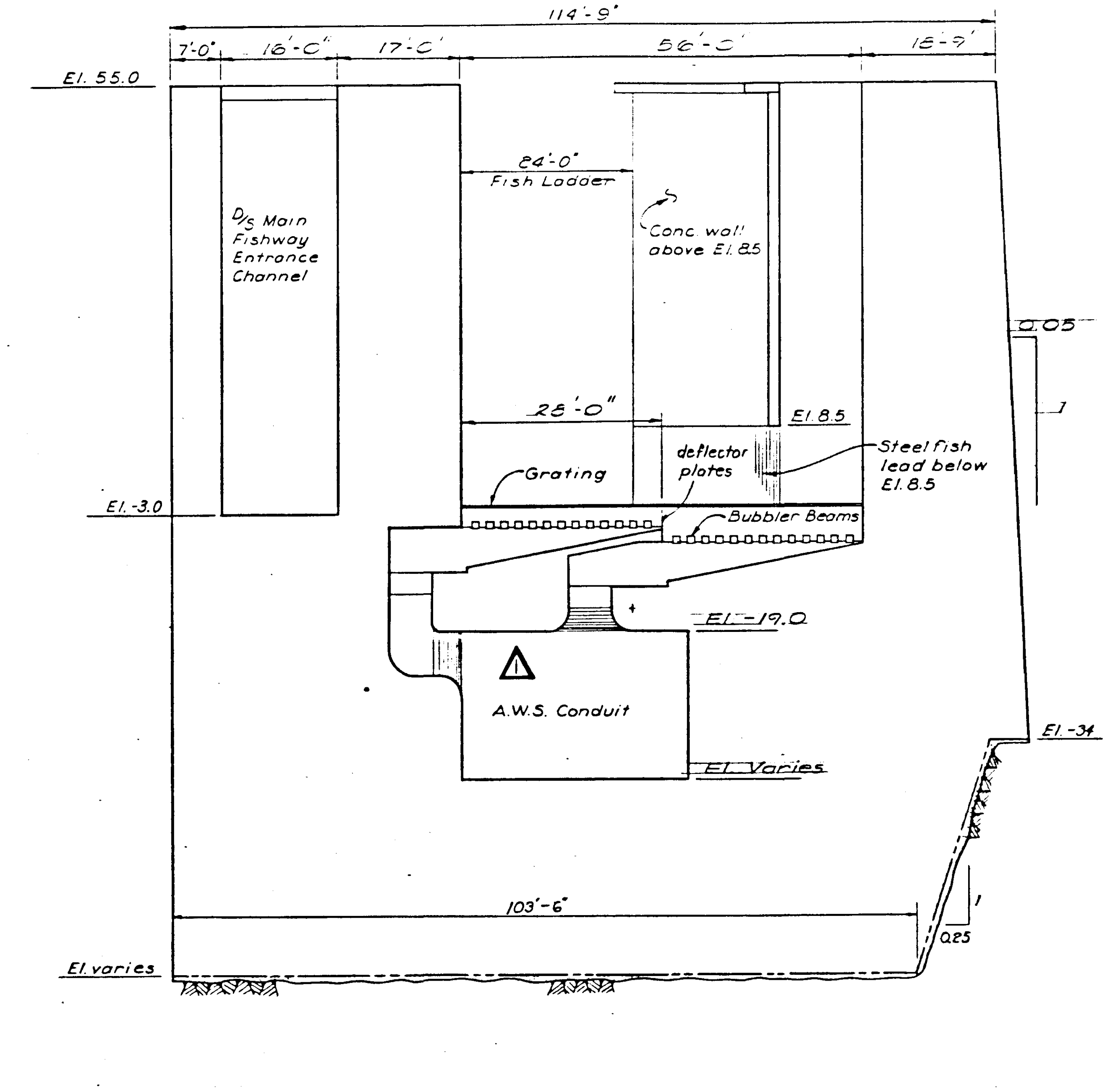
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON - WASHINGTON
FISH FACILITIES - FISHWAY ENTRANCE MONOLITHS
SEC. NO. 2-N - CONC. OUTLINE I
PLANS, ELEVATIONS

DESIGNED: D. Illias
DRAWN: L. Lee
CHECKED: D. Chambers
PREPARED: Ralph Strom
SUBMITTED: Heber Heine, CHIEF, DESIGN BRANCH — DATE: 22 NOV 21
SUPERVISED: CHIEF, STRUCTURES SECTION

SHEET 33 — BDF-2-15/31

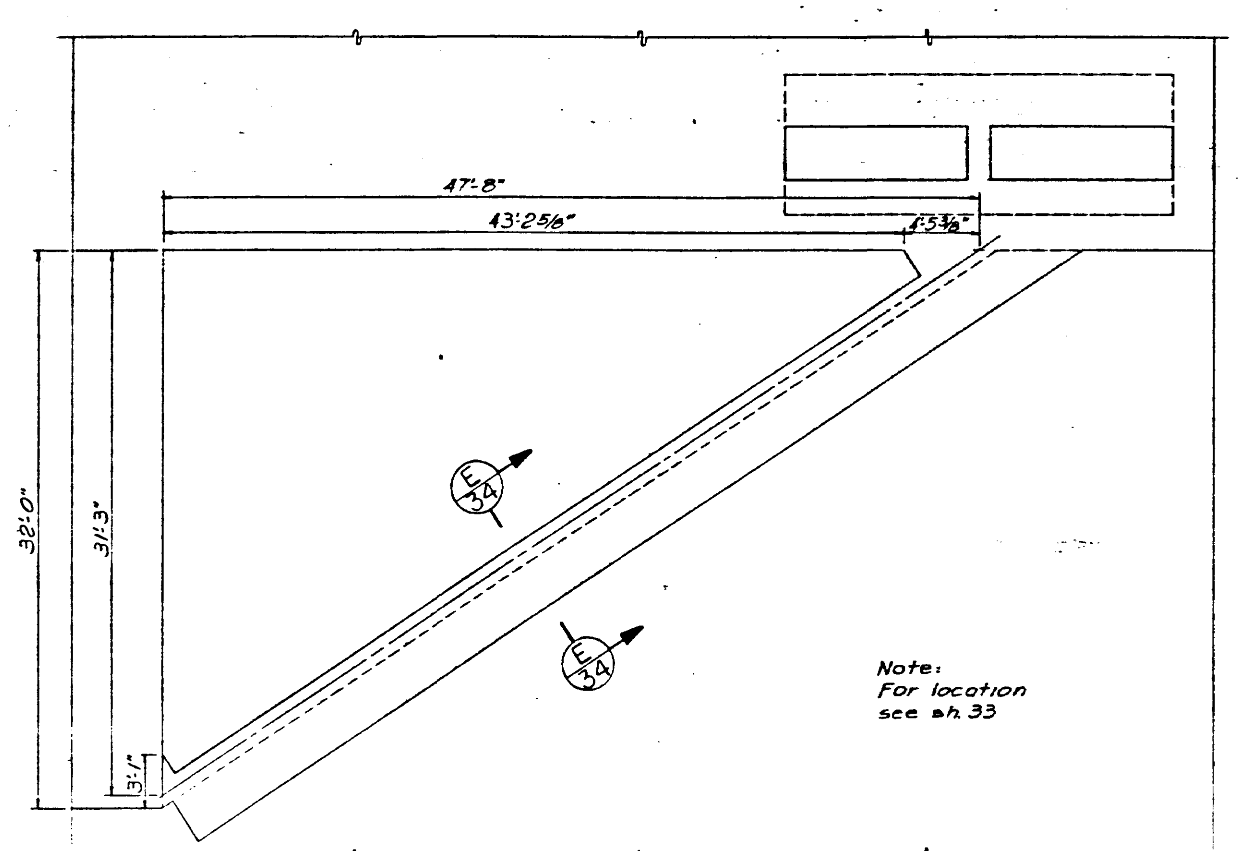


SECTION B/33
3/32" = 1'-0"

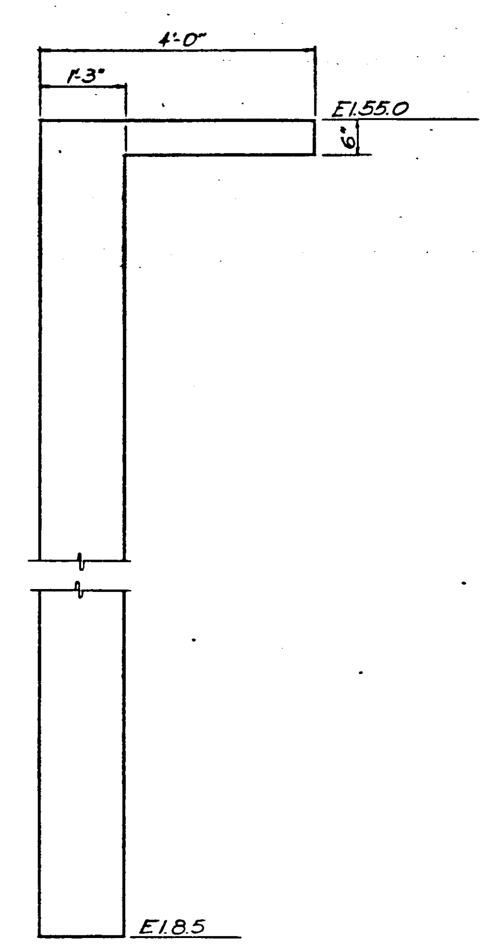


SECTION A/33
3/32" = 1'-0"

NOTES:
1. See Notes on Sht. 33
2. For deflector plates see Sht 78.



FISH LEAD WALKWAY PLAN
3/16" = 1'-0"



SECTION E/34
3/4" = 1'-0"

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
2	87 Sep 23	Revised as constructed	
1	78 Jan 20	Revised dimension and Sect.	

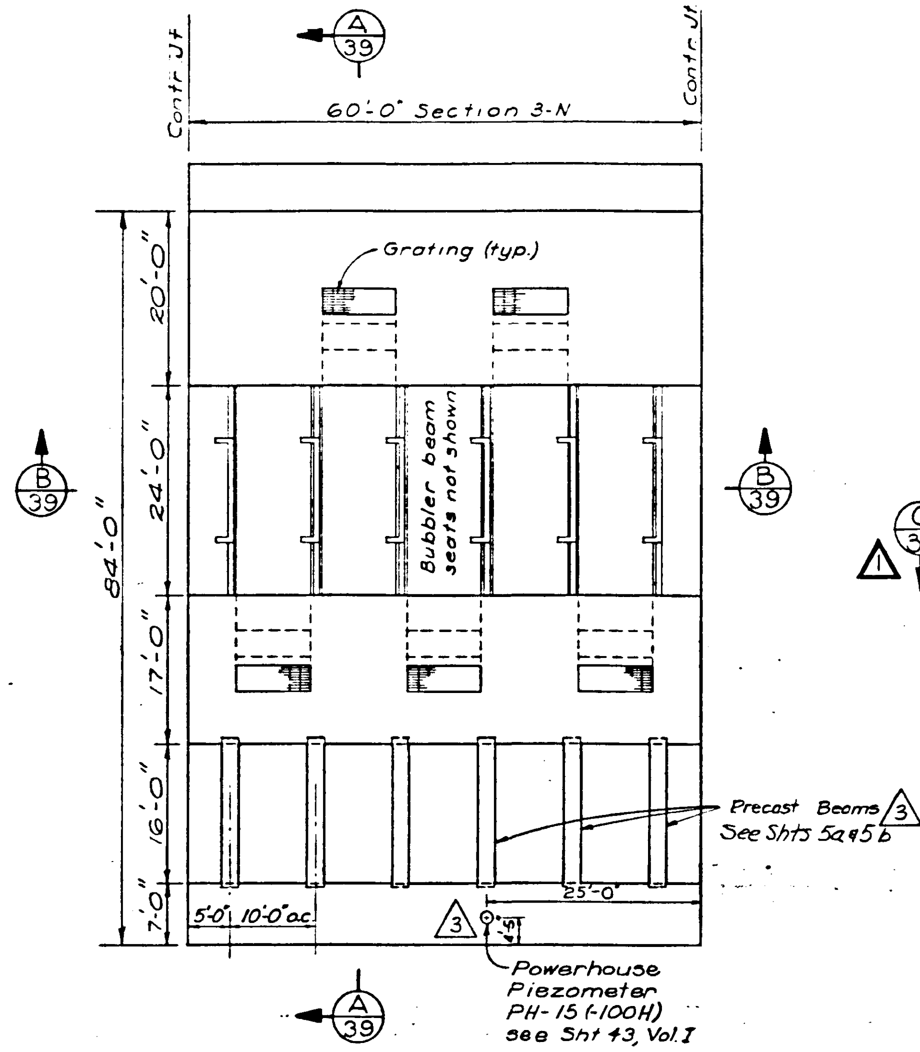
U. S. ARMY ENGINEER DISTRICT, PORTLAND

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON – WASHINGTON

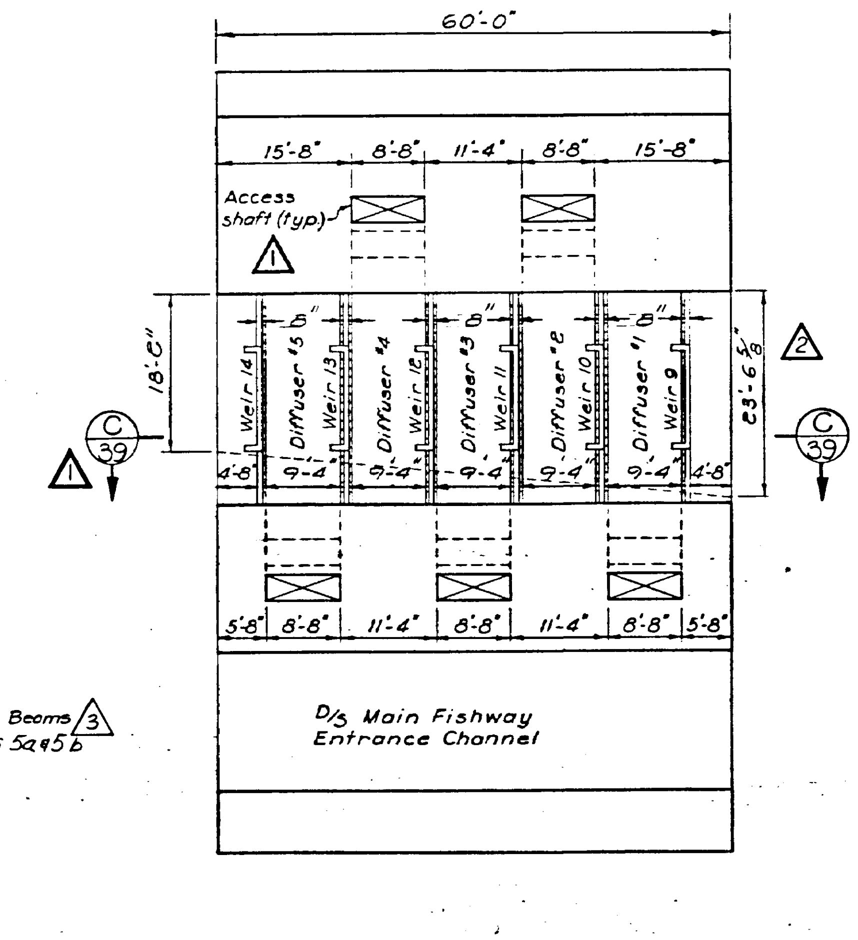
FISH FACILITIES – FISHWAY ENTRANCE MONOLITHS
SEC. NO. 2-N – CONC. OUTLINE II
SECTIONS

DESIGNED: D. ILLias
DRAWN: L. Lee
CHECKED: D. Chambers
PREPARED: Ralph Strom
SUPERVISED: [signature]
CHIEF STRUCTURES SECTION
SUBMITTED: [signature] DATE 77 NOV 21
CHIEF DESIGN BRANCH

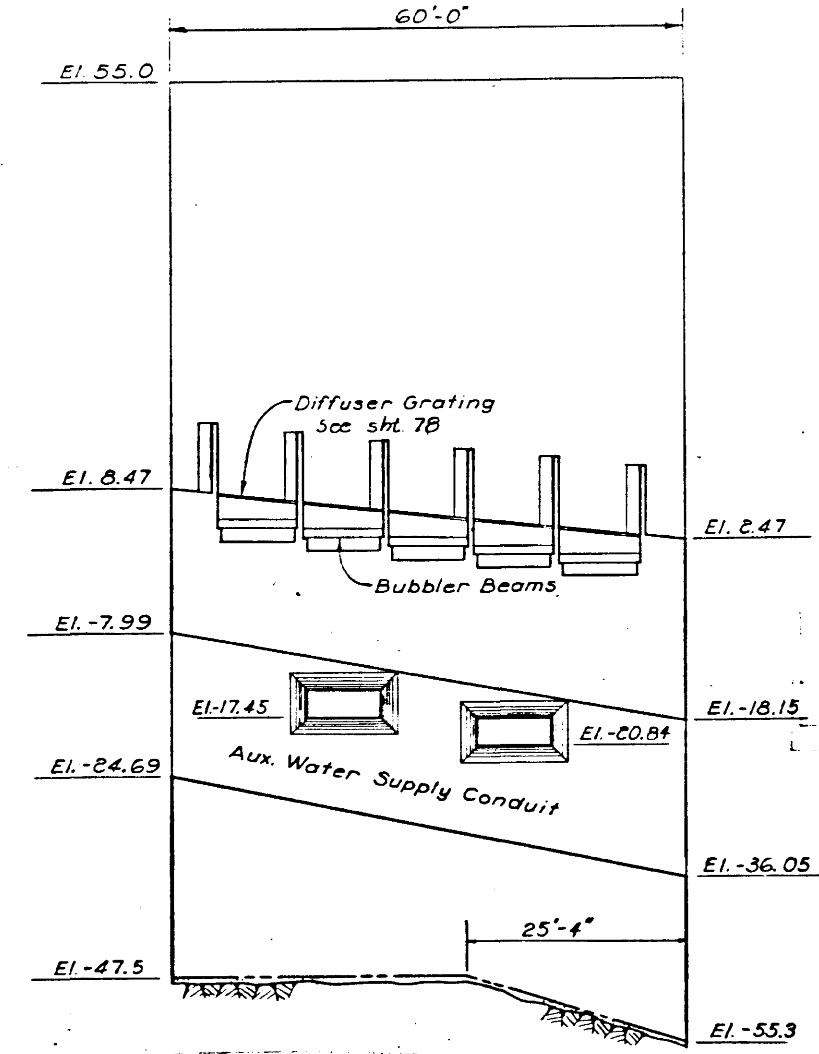
SHEET 34 BDF-2-15/32



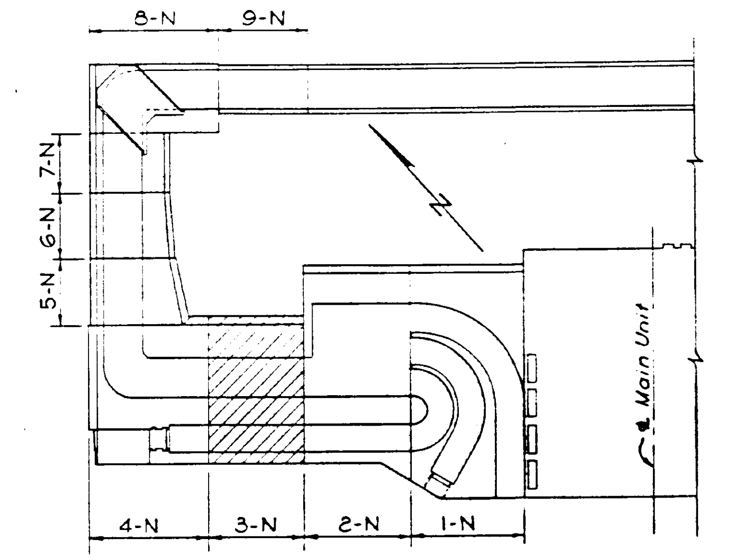
PLAN - EL 55.0
3/32" = 1'-0"



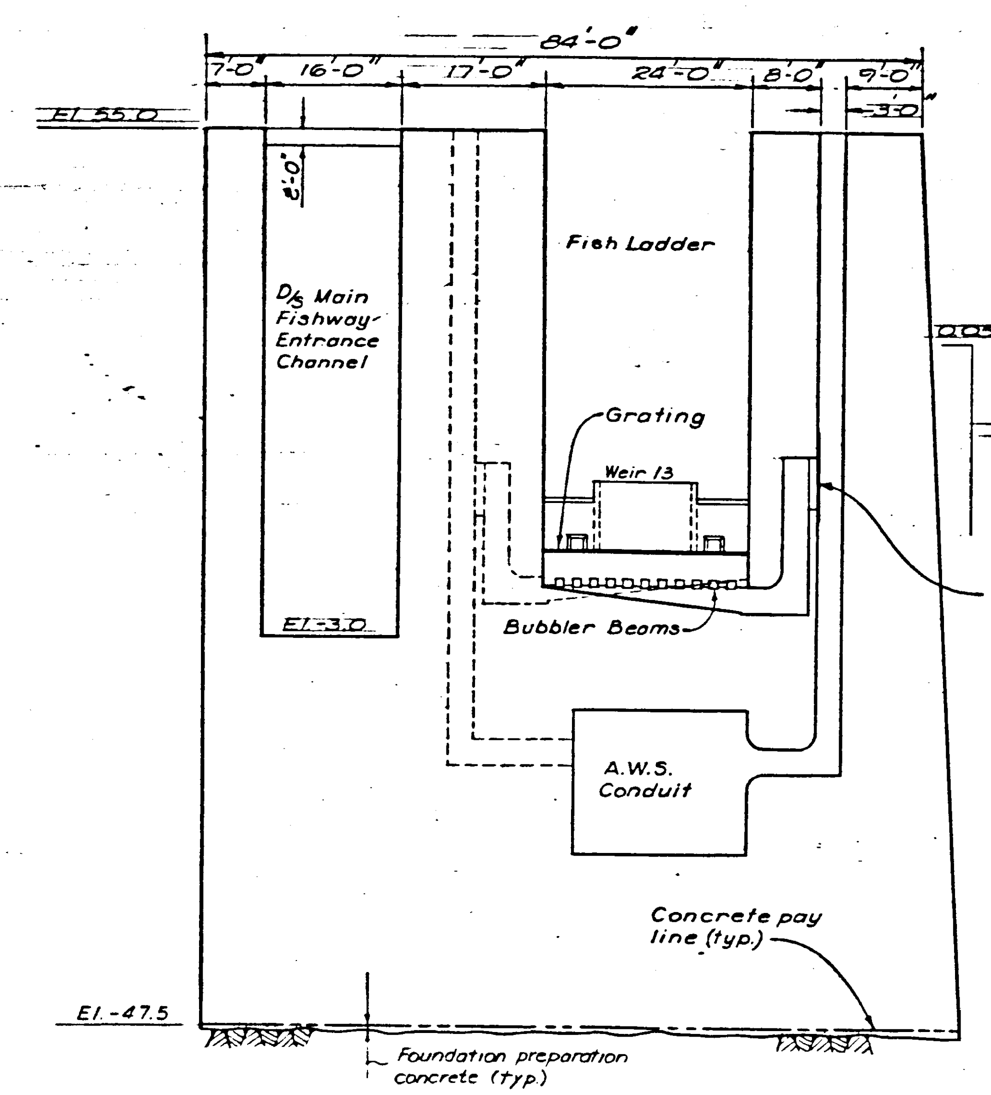
PLAN - EL. 50.0
3/32" = 1'-0"



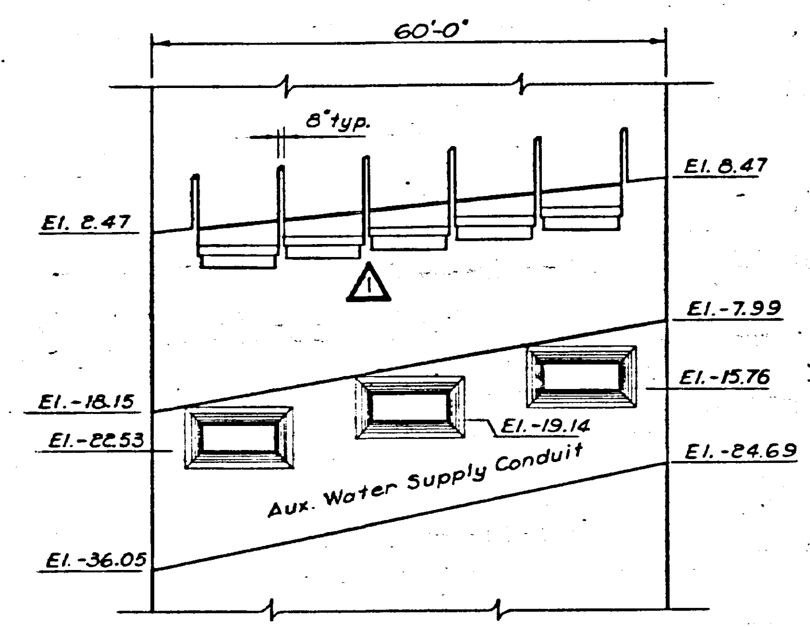
SECTION B/39
3/32" = 1'-0"



KEY PLAN



SECTION A/39
3/32" = 1'-0"



SECTION C/39
3/32" = 1'-0"

NOTES:

1. For General Notes see Sht. 22.
2. Handrails, curbs, and drains not shown for clarity. For handrail and curb layout see Sht 63. For deck drainage details see sht. 64.
3. For diffuser details see Sht. 52.
4. For gratings and frames see Sht. 81 & 82.
5. For lighting and wiring see Sht. 87.
6. For weir details see Sht. 53 & 54.
7. For joint details see Sht. 59.
8. For conduit layout see Sht. 25.
9. For orifice plate see Sht. 79. (revision 1)

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

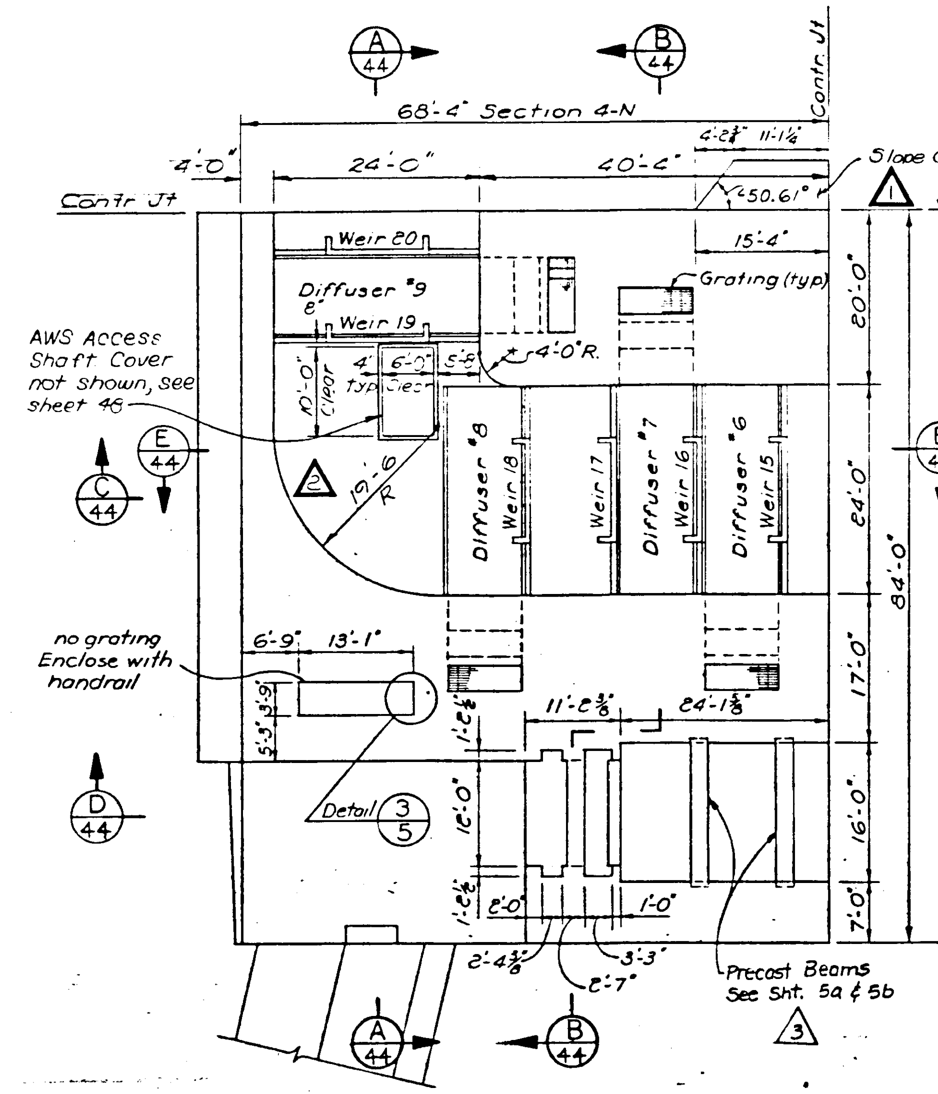
REVISION	DATE	DESCRIPTION	BY
3	15 Sep 83	Revised as constructed	
2	78 Aug 2	Revised dimension	
1	78 Jan 20	Revised section and added note	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

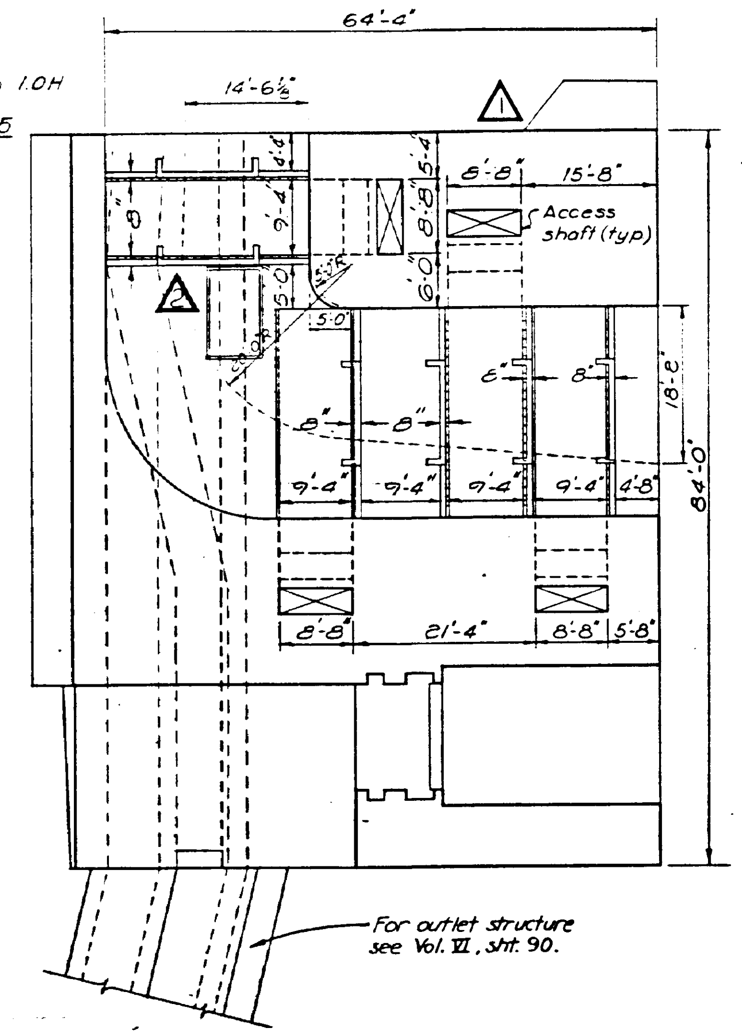
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON—WASHINGTON

FISH FACILITIES - FISHWAY ENTRANCE MONOLITHS
SEC. NO. 3-N — CONC. OUTLINE
PLANS, ELEV., AND SEC.

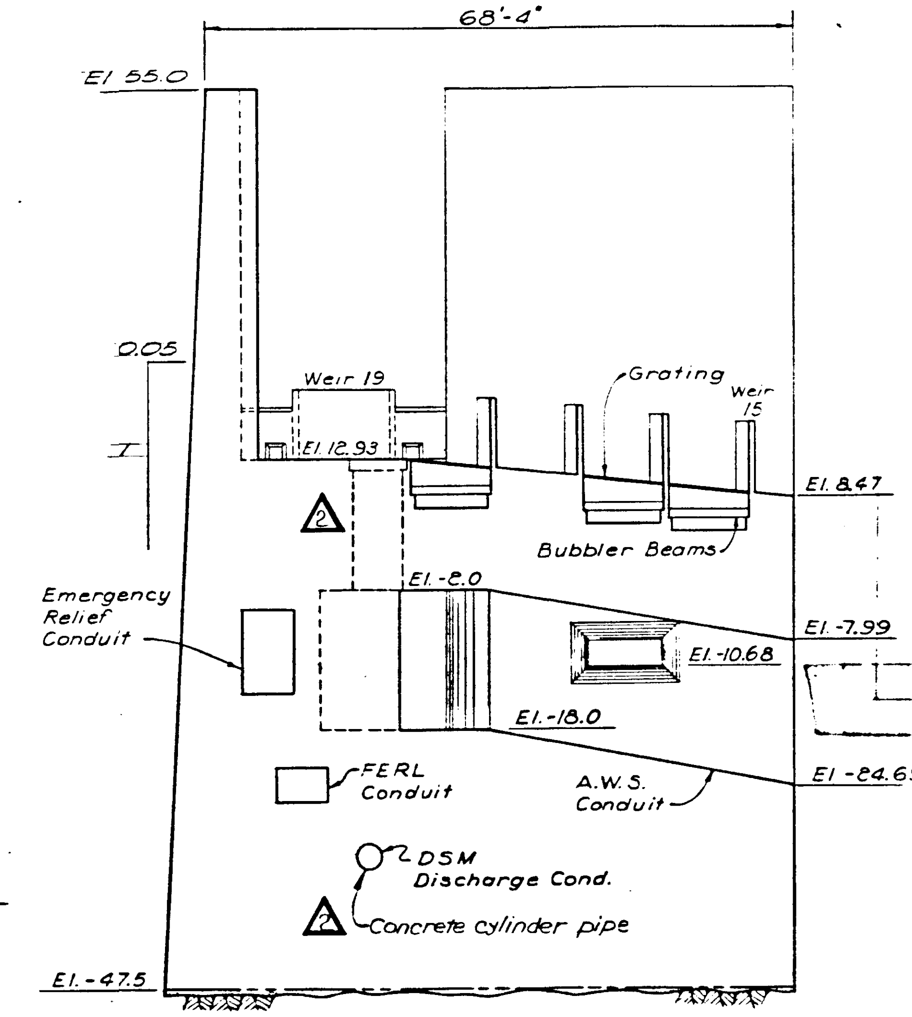
DESIGNED: D. ILLIOS
DRAWN: L. Lee
CHECKED: D. Chambers
PREPARED: Robert Strom
SUPERVISED: [signature] — CHIEF, STRUCTURES SECTION
SUBMITTED: Heber Heine — CHIEF, DESIGN BRANCH — DATE: 77 Nov 21
SHEET 39 BDF-2-15/37



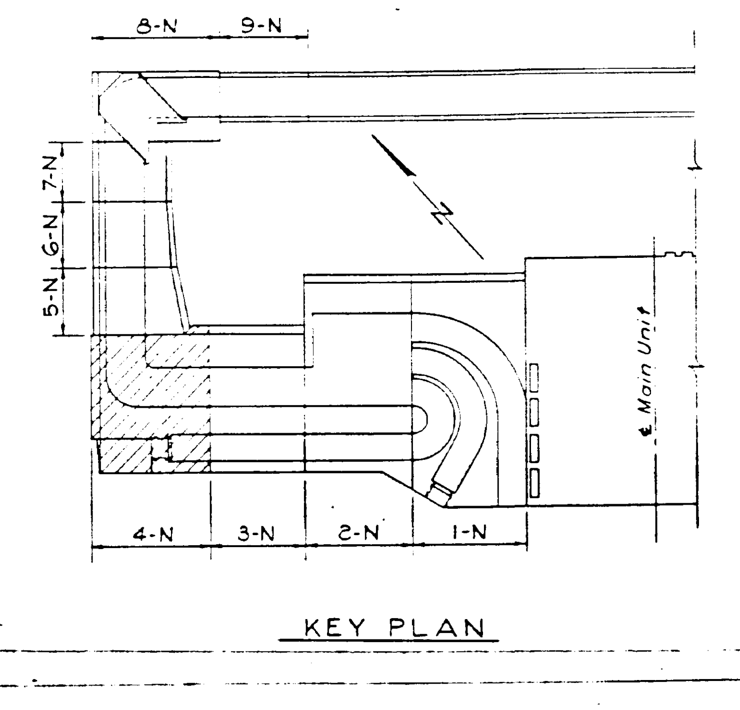
PLAN - EL 55.0
3/32" = 1'-0"



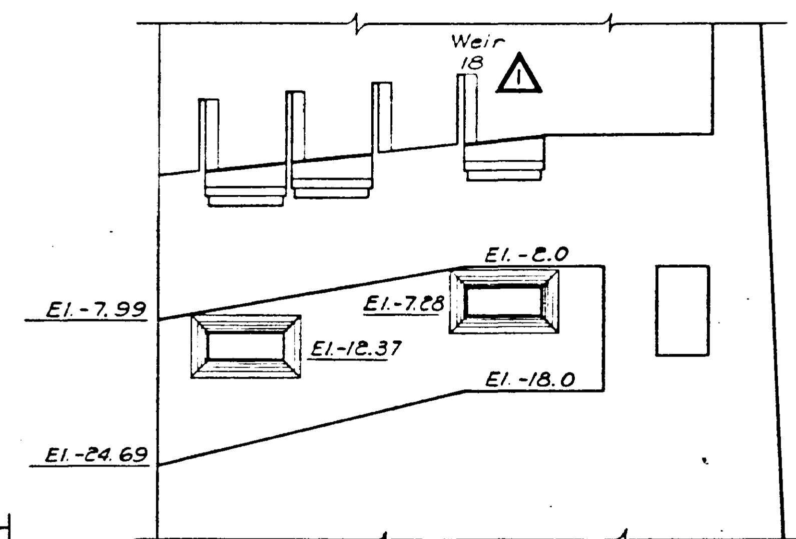
PLAN - EL. 50.0
3/32" = 1'-0"



SECTION C/44
3/32" = 1'-0"



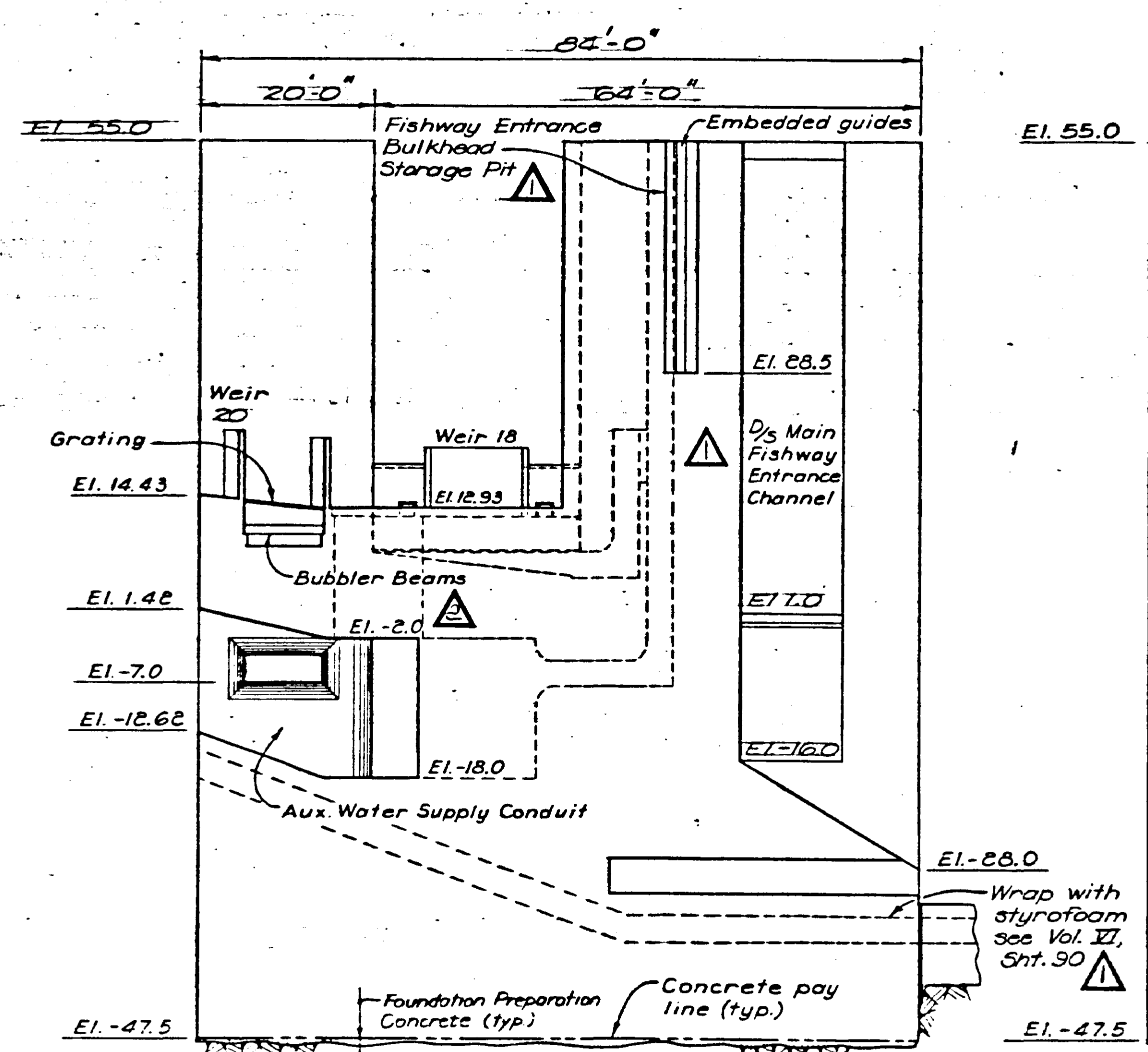
KEY PLAN



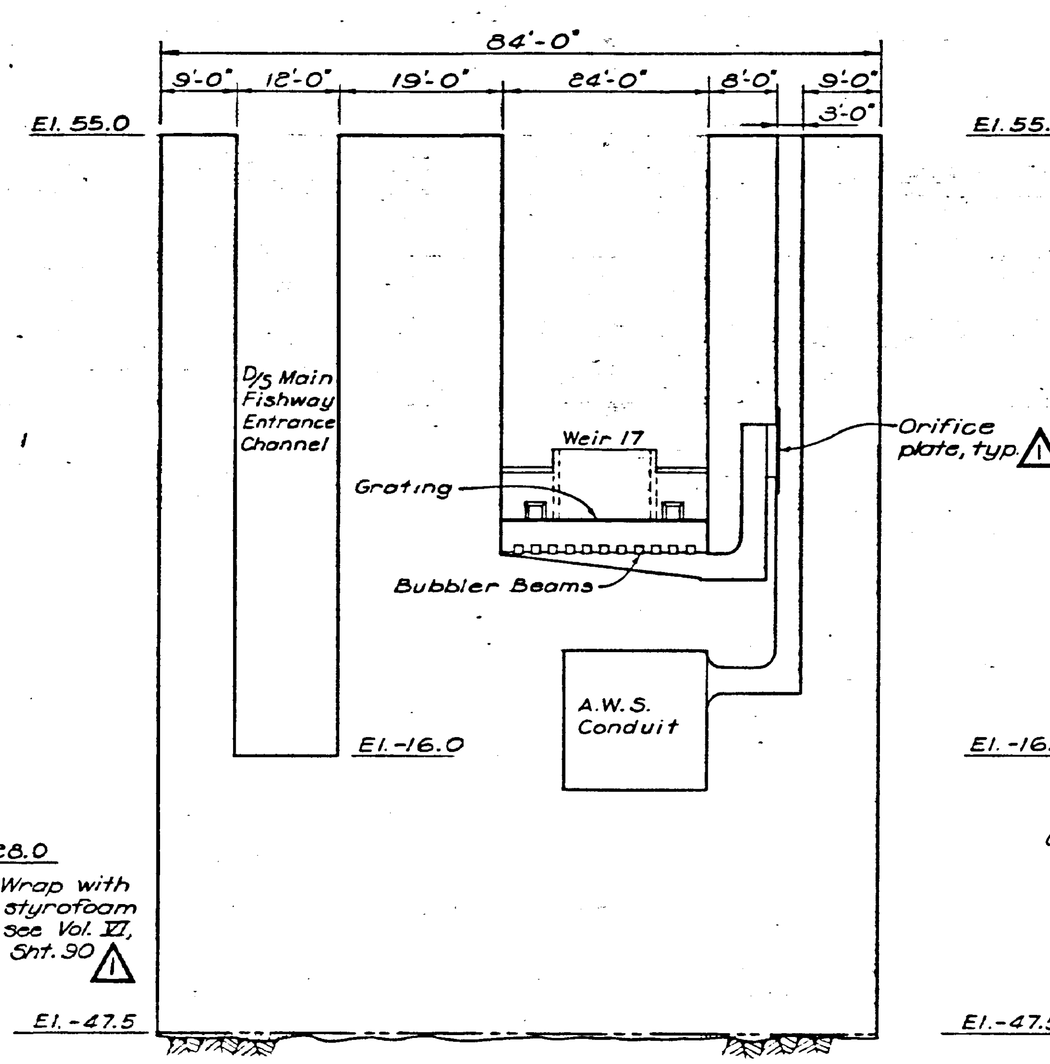
SECTION E/44
3/32" = 1'-0"

NOTES:

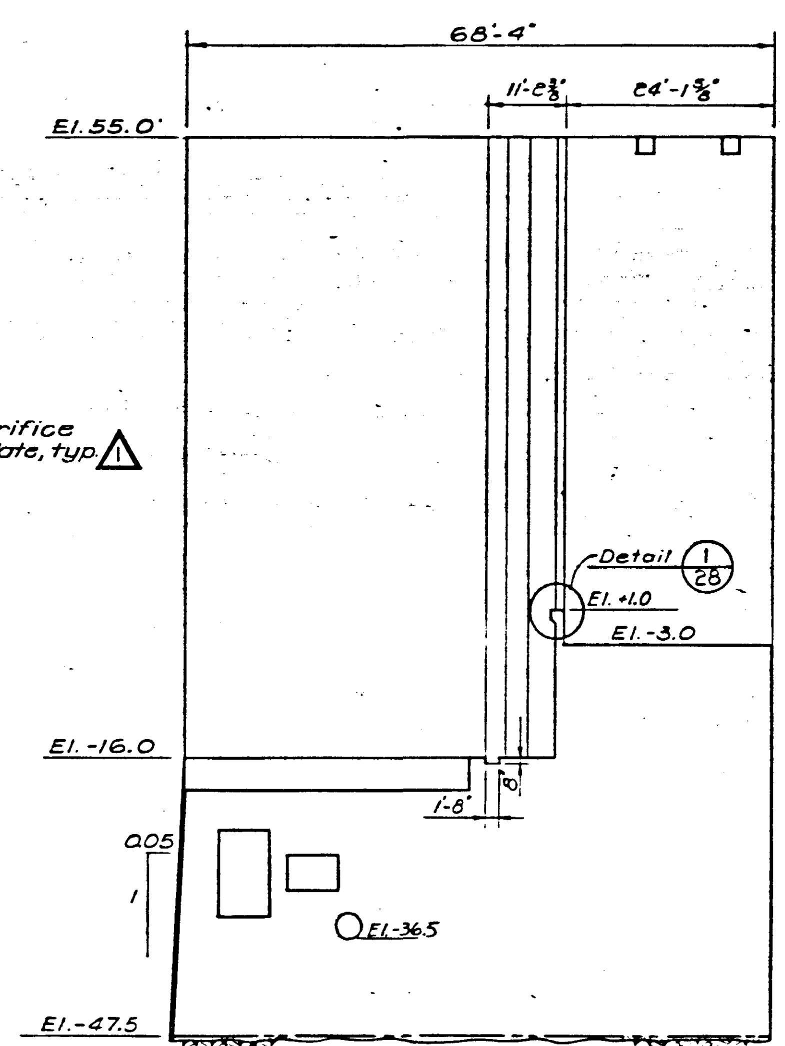
1. For General Notes see Sht. 22.
2. Handrails, curbs, and drains not shown for clarity. For handrail and curb layout see Sht. 63. For deck drainage layout see Sht. 64.
3. For diffuser details see Sht. 52.
4. For gratings and frames see Sht. 81 & 82.
5. For entrance gate and bulkhead guide details see Sht. 73.
6. For entrance gate hoists see Sht. 73.
7. For lighting and wiring layout see Sht. 87
8. For bulkhead storage pit guides see Sht. 82
9. For weir details see Sht. 53 & 54.
10. For joint details see Sht. 59.
11. For conduit layout see Sht. 25 & 26.
12. For orifice plates see Sht. 79. (Rev. 1)
13. For concrete cylinder pipe details see sheet 113
14. For AWS access shaft frame and cover see sheet 48. (Rev. 2)



SECTION A/44
3/32" = 1'-0"



SECTION B/44
3/32" = 1'-0"



SECTION D/44
3/32" = 1'-0"

REVISION	DATE	DESCRIPTION	BY
3	18 Sep 23	Revised as constructed	
2	78 Aug 2	Added notes & AWS access hatch.	
1	78 JAN 20	Added notes	

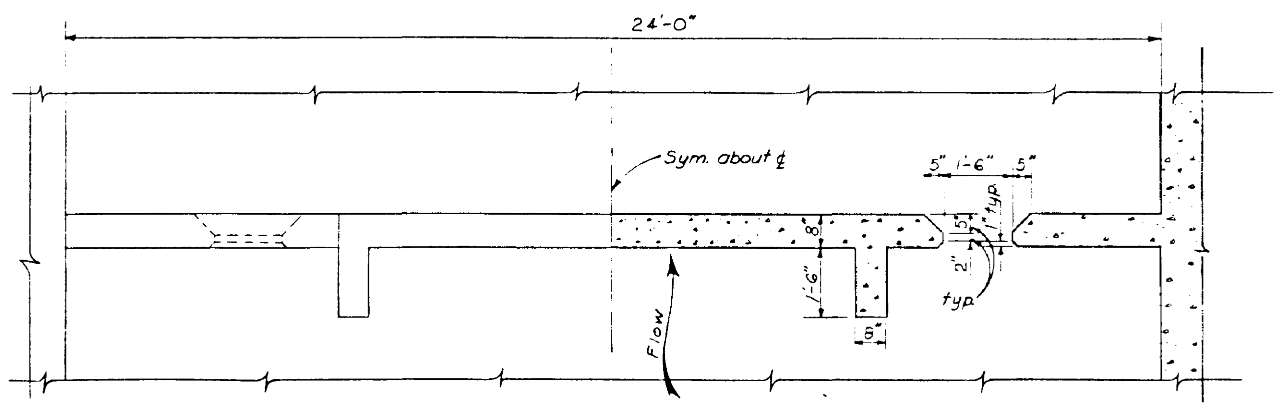
AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

U. S. ARMY ENGINEER DISTRICT, PORTLAND

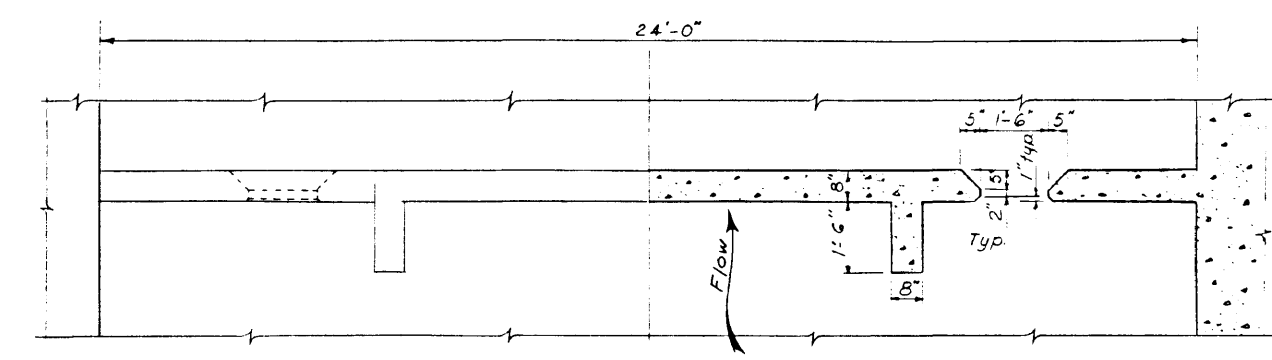
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON – WASHINGTON

FISH FACILITIES - FISHWAY ENTRANCE MONOLITHS
SEC. NO. 4-N — CONC. OUTLINE
PLAN, ELEV. AND SEC.

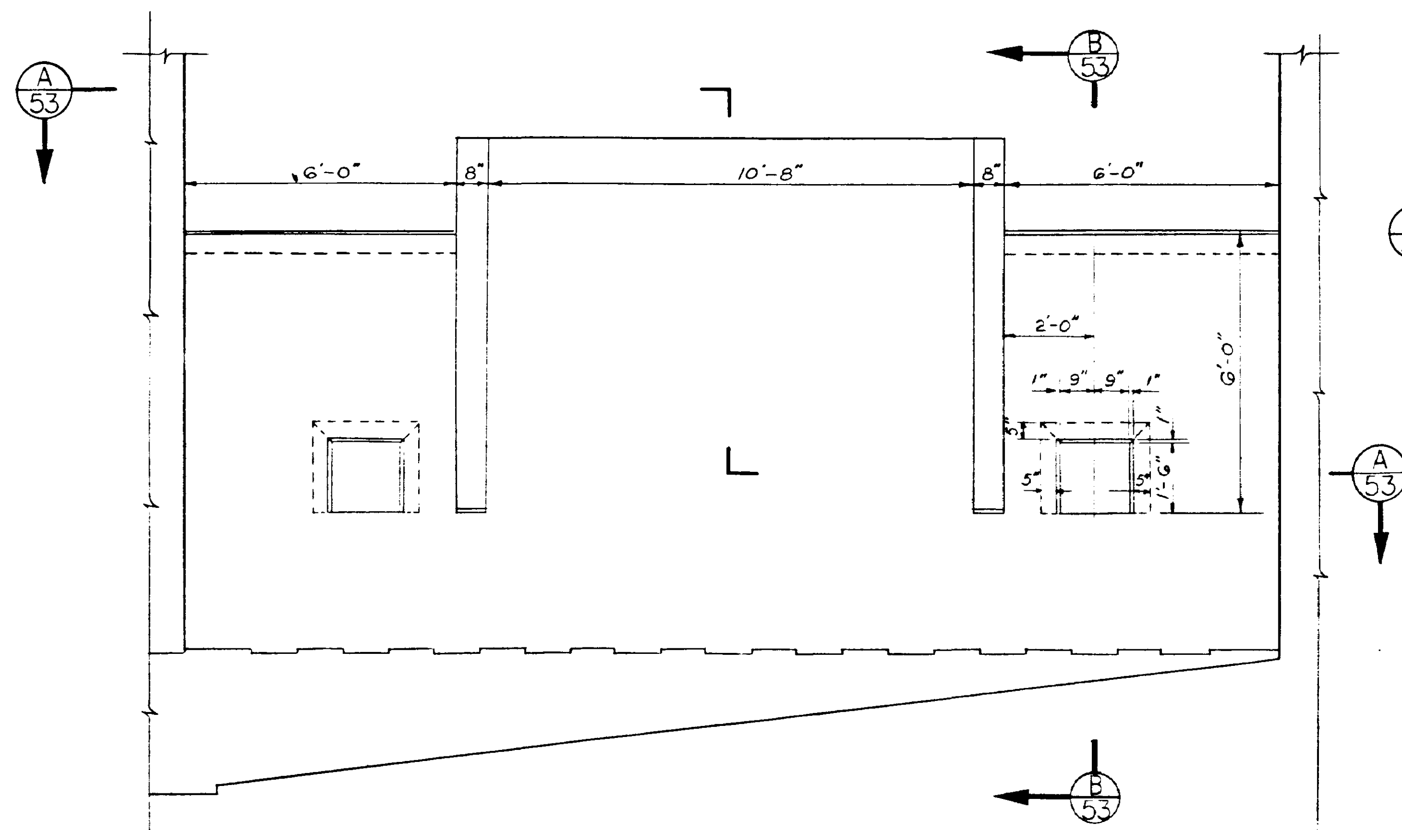
DESIGNED: D. ILLias
DRAWN: L. Lee
CHECKED: D. Chambers
PREPARED: Ralph Strom
SUPERVISED:
SUBMITTED: Heber C Heine
DATE: 77 AUG 21
SHEET 44
BDF-2-15/42



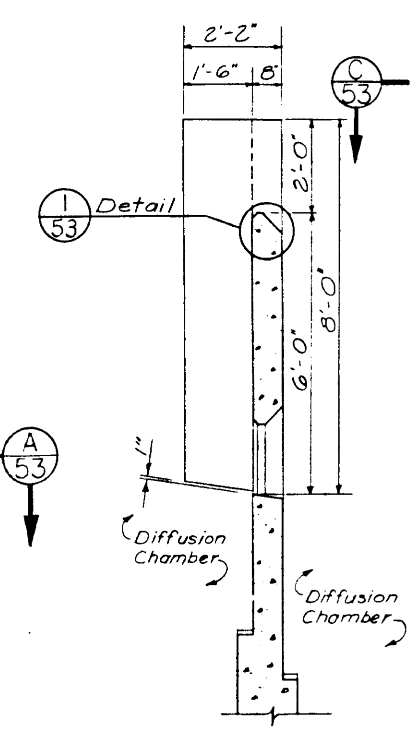
SECTION (A/53)
1/2" = 1'-0"



SECTION (C/53)
1/2" = 1'-0"

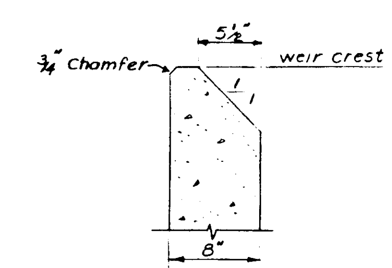


ELEVATION
1/2" = 1'-0"



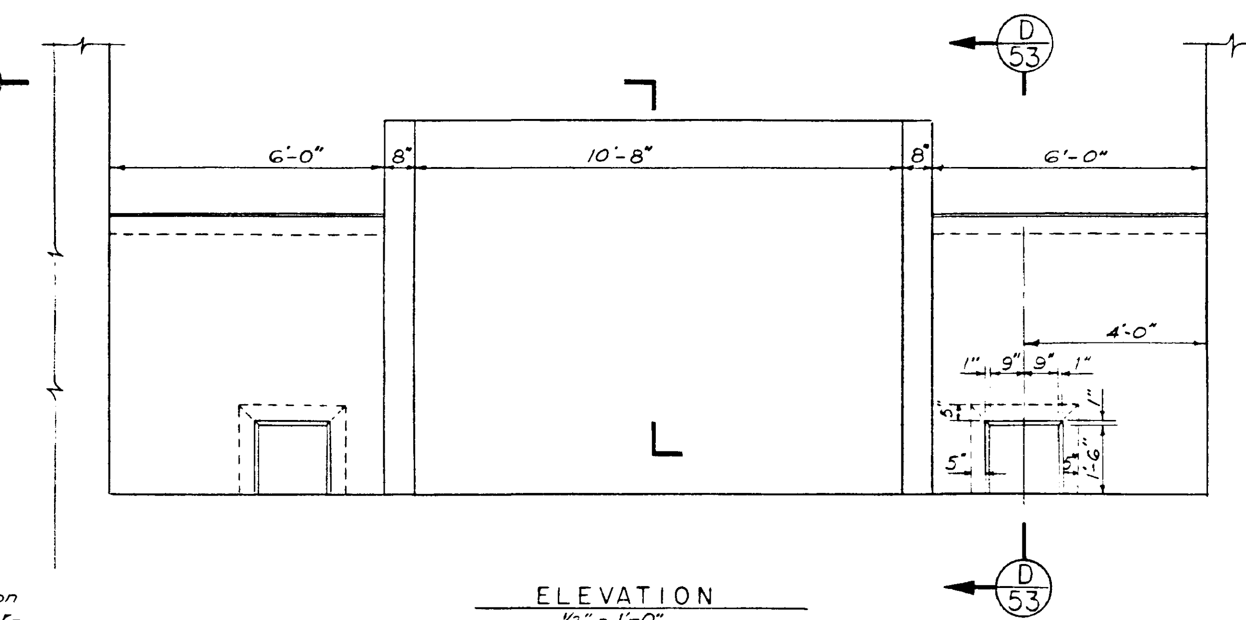
SECTION (B/53)
1/2" = 1'-0"

TYPICAL WEIR DETAILS, WEIRS 10-13, 16

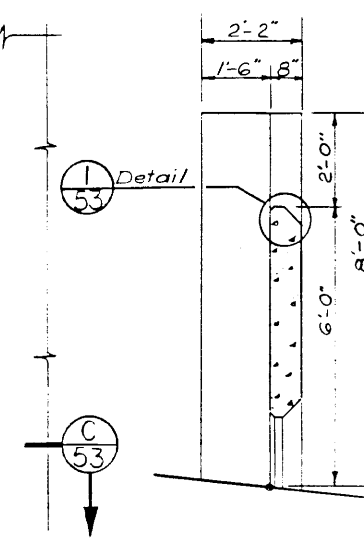


DETAIL (1/53)
1 1/2" = 1'-0"

TYPICAL ALL WEIRS



ELEVATION
1/2" = 1'-0"



SECTION (D/53)
1/2" = 1'-0"

TYPICAL WEIR DETAILS, WEIRS 33, 36-67

NOTES

1. For General Notes see Sht 22
2. The weir number equals the weir crest elevation with the following exceptions: (△1)
   Weir 37 - crest elevation = 36.83
   Weir 67 - crest elevation = 66.83

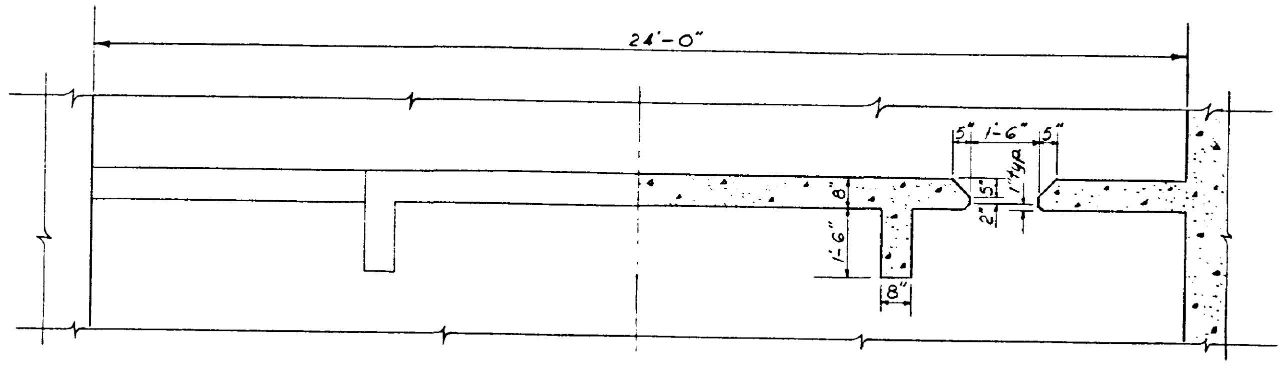
AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
△	37Sep23	As constructed	
△1	79Jul30	Corrected crest elevations of weirs 37 & 67	

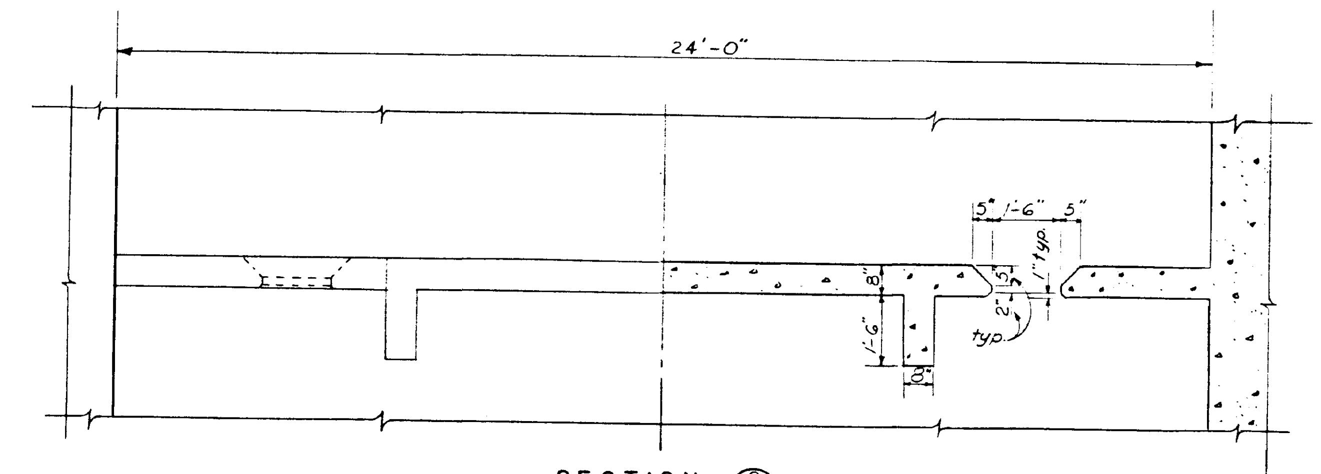
U. S. ARMY ENGINEER DISTRICT, PORTLAND

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON - WASHINGTON
FISH FACILITIES - FISHWAY ENTRANCE MONOLITHS
WEIRS - CONCRETE OUTLINES I

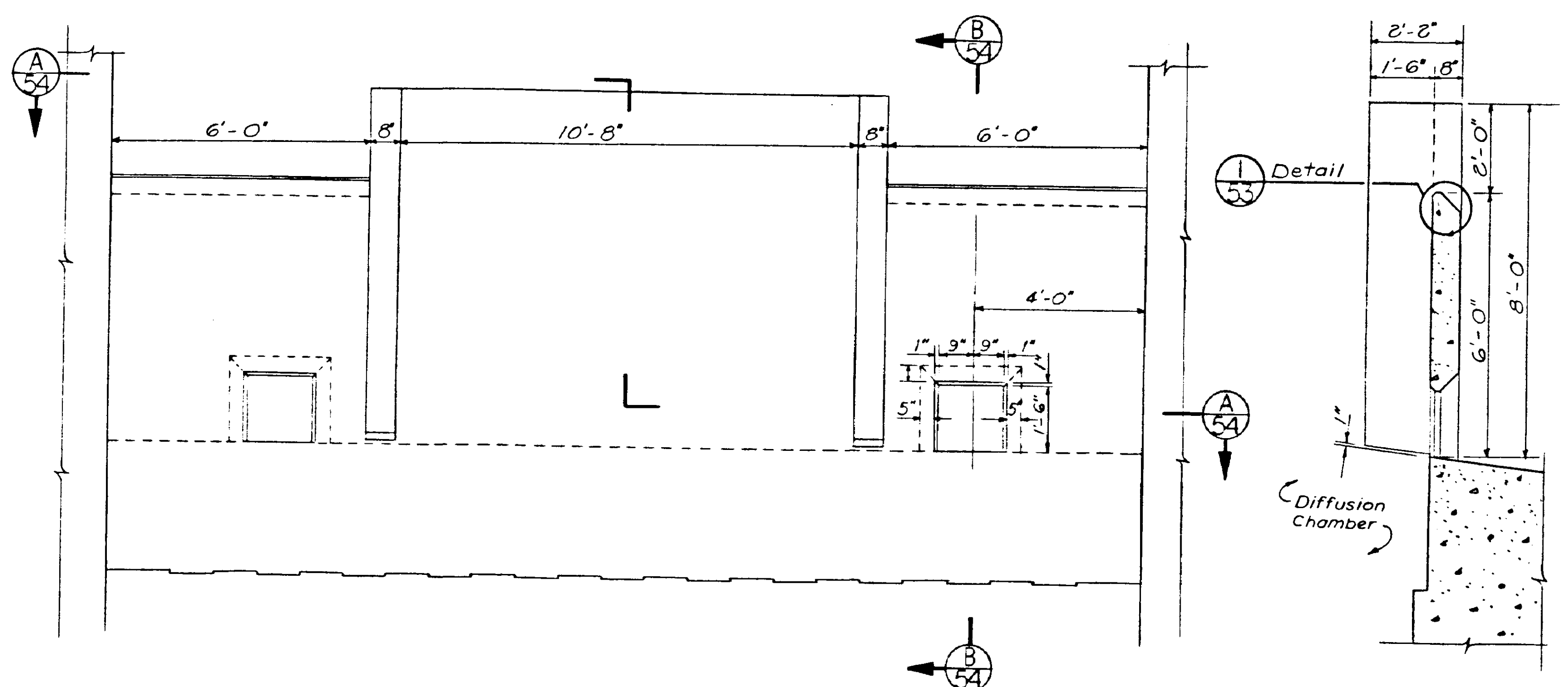
DESIGNED: D. Illios
DRAWN: A. Binder
CHECKED: D. Chambers
PREPARED: [signature]
SUPERVISED: [signature] CHIEF, STRUCTURES SECTION
SUBMITTED: Heber C Heine, CHIEF, DESIGN BRANCH — DATE: 27 Nov 22
SHEET 53 — BDF-2-15/51



SECTION (A/54)
½" = 1'-0"



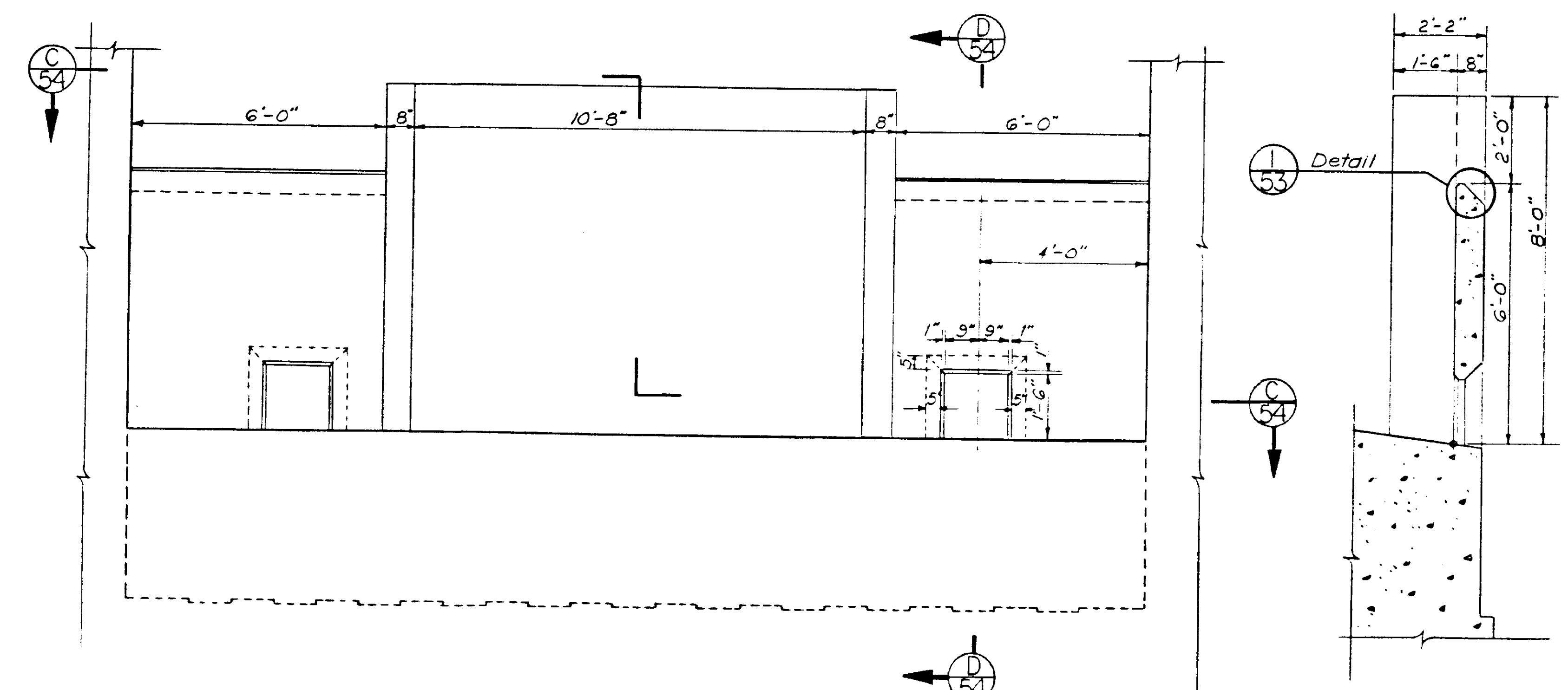
SECTION (C/54)
½" = 1'-0"



ELEVATION
½" = 1'-0"

SECTION (B/54)
½" = 1'-0"

TYPICAL WEIR DETAILS, WEIRS 9, 15, 18, 19, 21, 23, 25, 27, 29, 31, 34



ELEVATION
½" = 1'-0"

SECTION (D/54)
½" = 1'-0

TYPICAL WEIR DETAILS, WEIRS 8, 14, 17, 20, 22, 24, 26, 28, 30, 32, 35

NOTES
1. For General Notes see Sht. 22
2. The weir number equals the weir crest elevation.

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
△	87Sep23	As constructed	

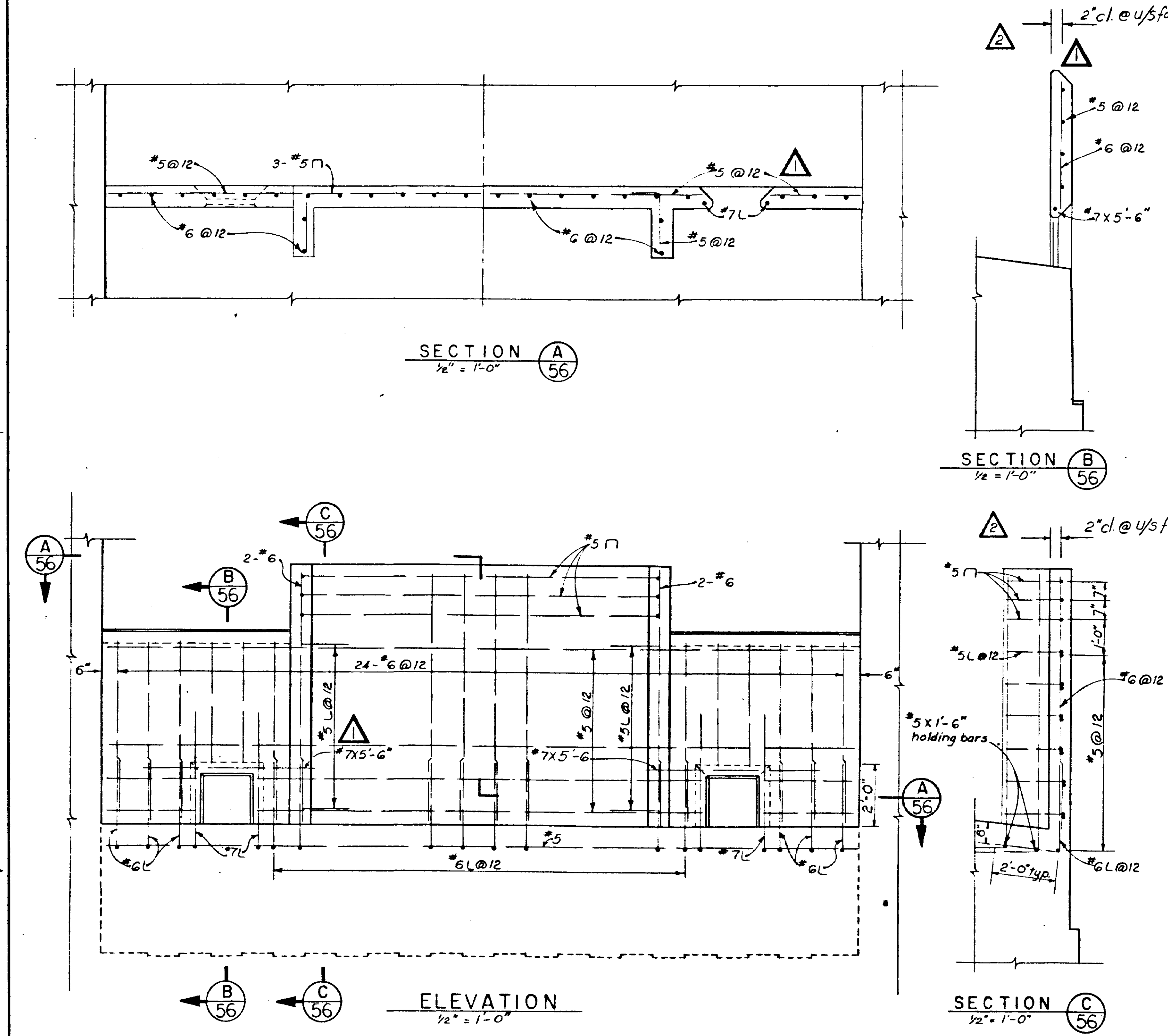
U. S. ARMY ENGINEER DISTRICT, PORTLAND

DESIGNED: D. Illias
DRAWN: A. Binder
CHECKED: D. Chambers

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON - WASHINGTON
FISH FACILITIES - FISHWAY ENTRANCE MONOLITHS
WEIRS - CONCRETE OUTLINES II

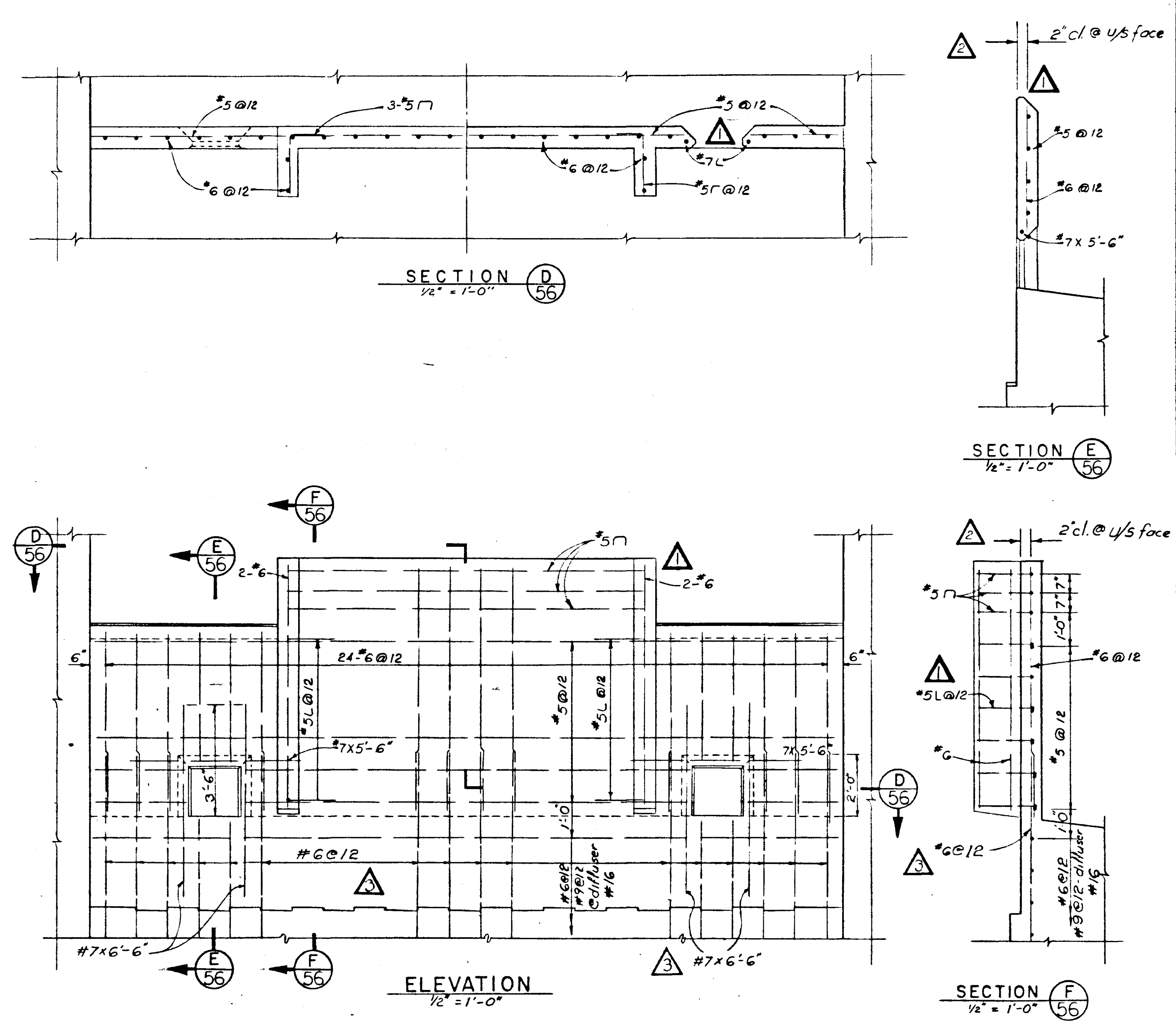
PREPARED: Ralph Strom
SUPERVISED: [signature]
CHIEF, STRUCTURES SECTION
SUBMITTED: Heber C Heime
CHIEF, DESIGN BRANCH
DATE: 77 Nov 22

SHEET 54 BDF-2-15/52



TYPICAL WEIR REINFORCING DETAILS

△3 WEIRS 8, 14, 17, 20, 22, 24, 26, 28, 30, 32, 35



TYPICAL WEIR REINFORCING DETAILS

△3 WEIRS 9, 15, 18, 19, 21, 23, 25, 27, 29, 31, 34

NOTES

1. For General Notes see Sht 22.

△2

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
△4	87Sep23	As constructed	[illegible]
△3	79May22	Revised reinf	[illegible]
△2	78Aug2	Revised reinf location in weir & removed note	[illegible]
△1	78Jan20	Misc. minor corrections	[illegible]

U. S. ARMY ENGINEER DISTRICT, PORTLAND

DESIGNED: D. ILLias
DRAWN: A Binder
CHECKED: D. Chambers

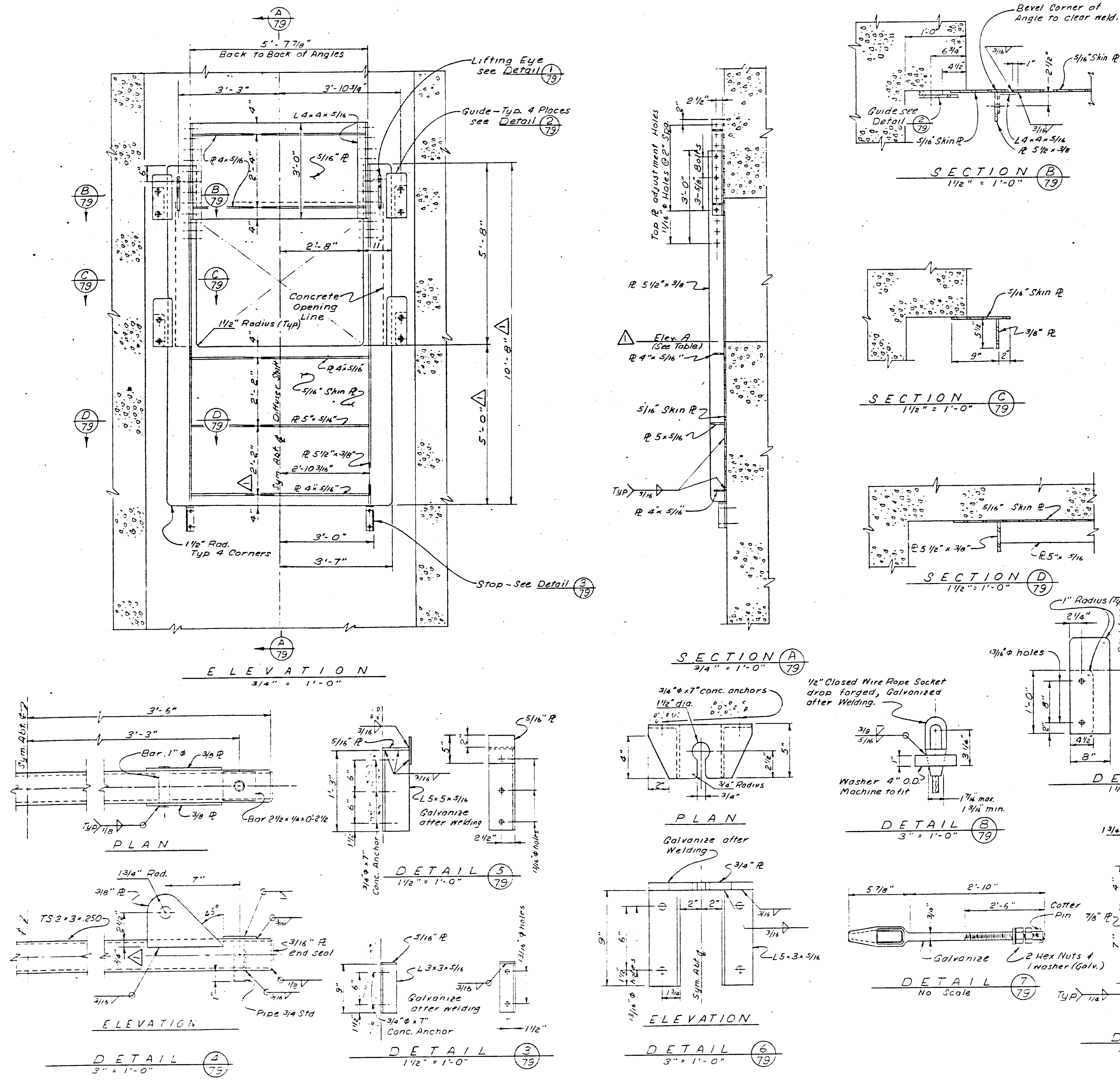
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON - WASHINGTON

FISH FACILITIES - FISHWAY ENTRANCE MONOLITHS

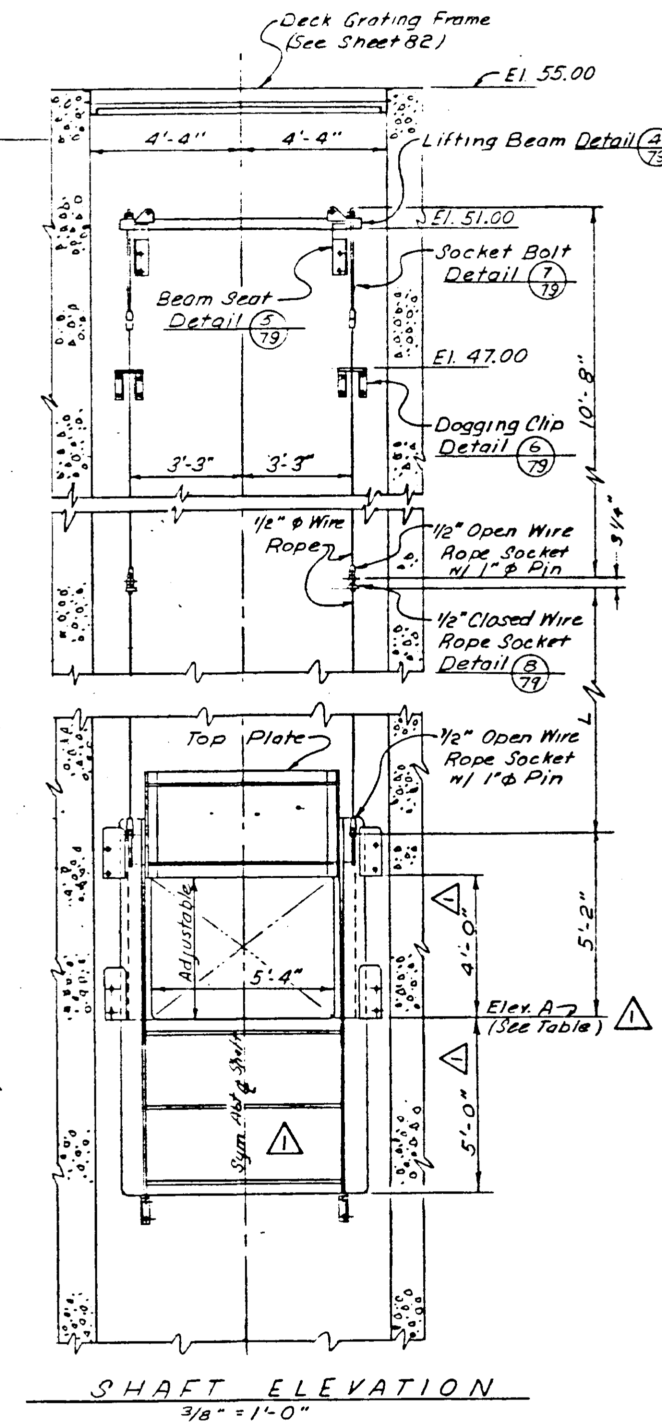
WEIRS – REINFORCEMENT II

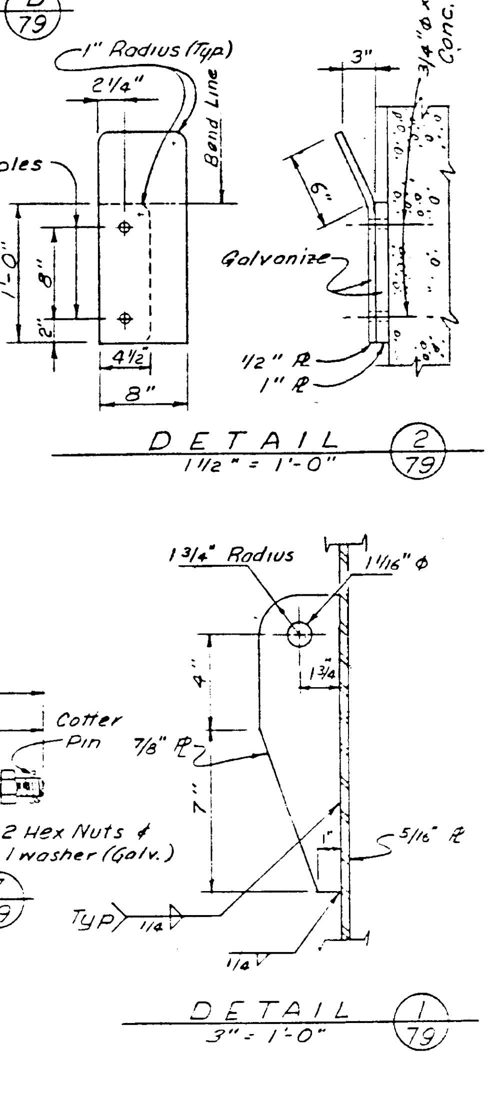
PREPARED: Ralph Strom
SUBMITTED: Heber [illegible] DATE: 77 NOV 22
CHIEF, DESIGN BRANCH
SUPERVISED: [illegible]
CHIEF, STRUCTURES SECTION

SHEET 56 BDF-2-15/54



Diffuser No.	Elev. A	Length L
1	10.50	26'-7"
2	11.50	25'-7"
3	12.50	24'-7"
4	13.50	23'-7"
5	14.50	22'-7"
6	16.50	20'-7"
7	17.50	19'-7"
8	19.50	17'-7"
9	20.50	16'-7"
10	22.50	14'-7"
11	24.50	12'-7"
12	26.50	10'-7"
13	28.50	8'-7"
14	30.50	6'-7"
15	32.50	4'-7"





Notes

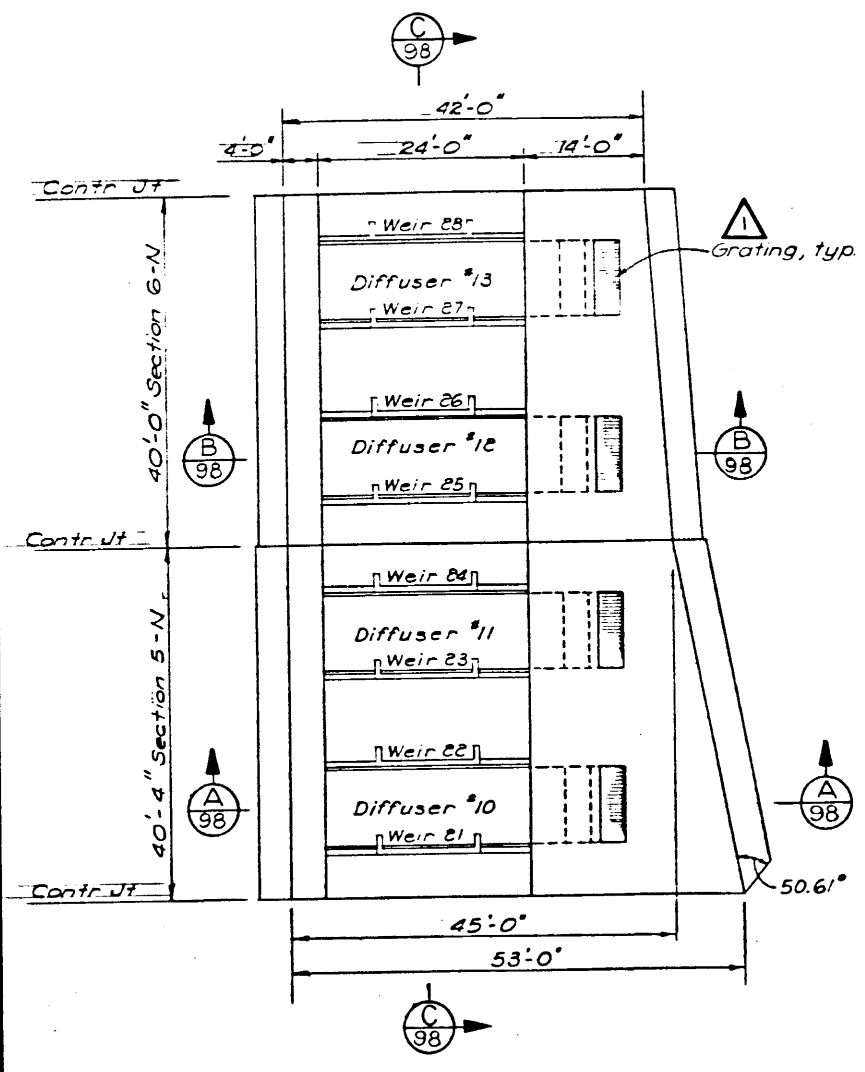
1. Structural Steel shall be ASTM A-36.
2. Painting: use system No. 4 except for items noted for galvanizing. (See Specification).
3. All wire rope fittings shall be galvanized.
4. Wire rope shall be 1/2" dia. Galvanized Bridge Strand with a minimum breaking strength of 15 Tons.
5. Orifice Plate Assemblies for Diffusers #1 thru #9 shall be furnished and installed under Pay Item (T010) and for Diffuseres #10 thru #15 under Pay Item (T020).

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

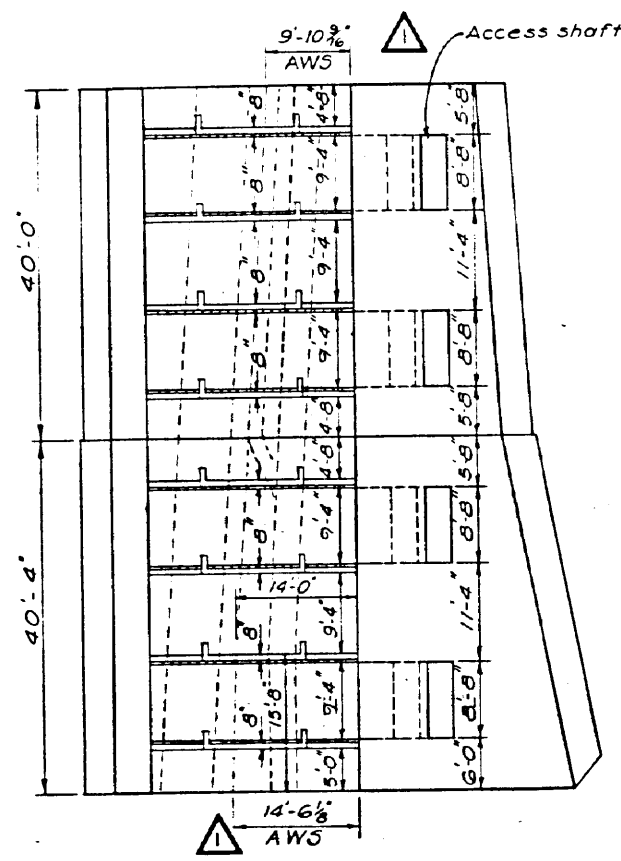
REVISION	DATE	DESCRIPTION	BY
2	87 Sep 23	AS constructed	
1	78 Jan 20	Chng El. "A" & Size of Orifice Pl. Add Dim @ Dtl. 4.	

U. S. ARMY ENGINEER DISTRICT, PORTLAND
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON – WASHINGTON
FISH FACILITIES – FISHWAY ENTRANCE MONOLITHS
WEIR ORIFICE PLATES

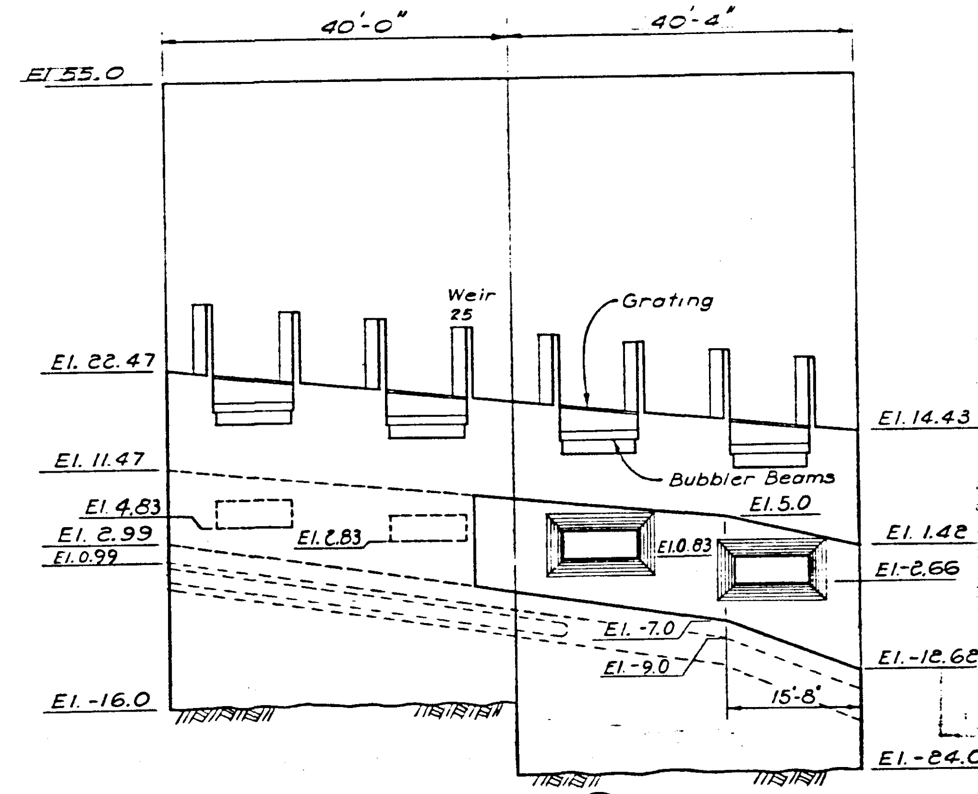
DESIGNED: W. Wheeler
DRAWN: W. Wheeler
CHECKED: R. Davis
PREPARED: [signature]
SUBMITTED: [signature] CHIEF DESIGN BRANCH
DATE: 77 Nov 22
SUPERVISED: [signature]
SHEET 79
BDF-2-15/77



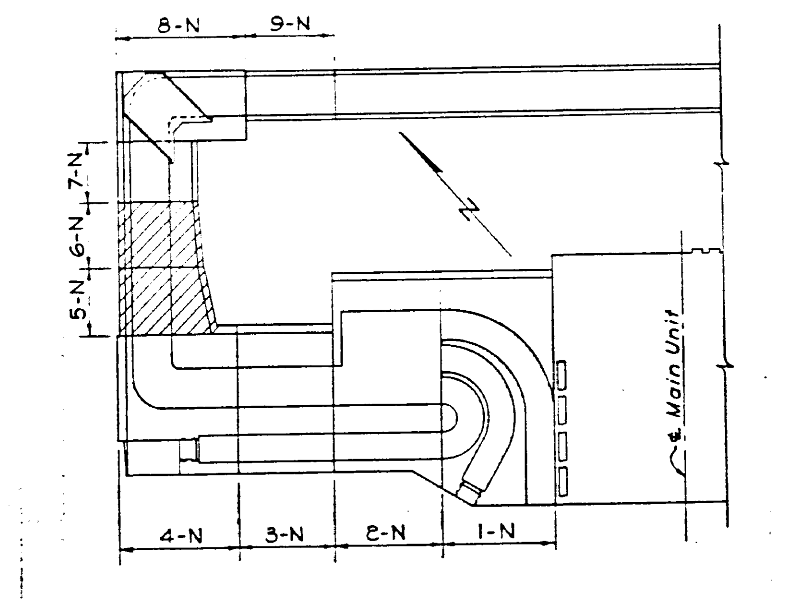
PLAN-EL 55.0
3/32"=1'-0"



PLAN - EL. 50.0
3/32"=1'-0"



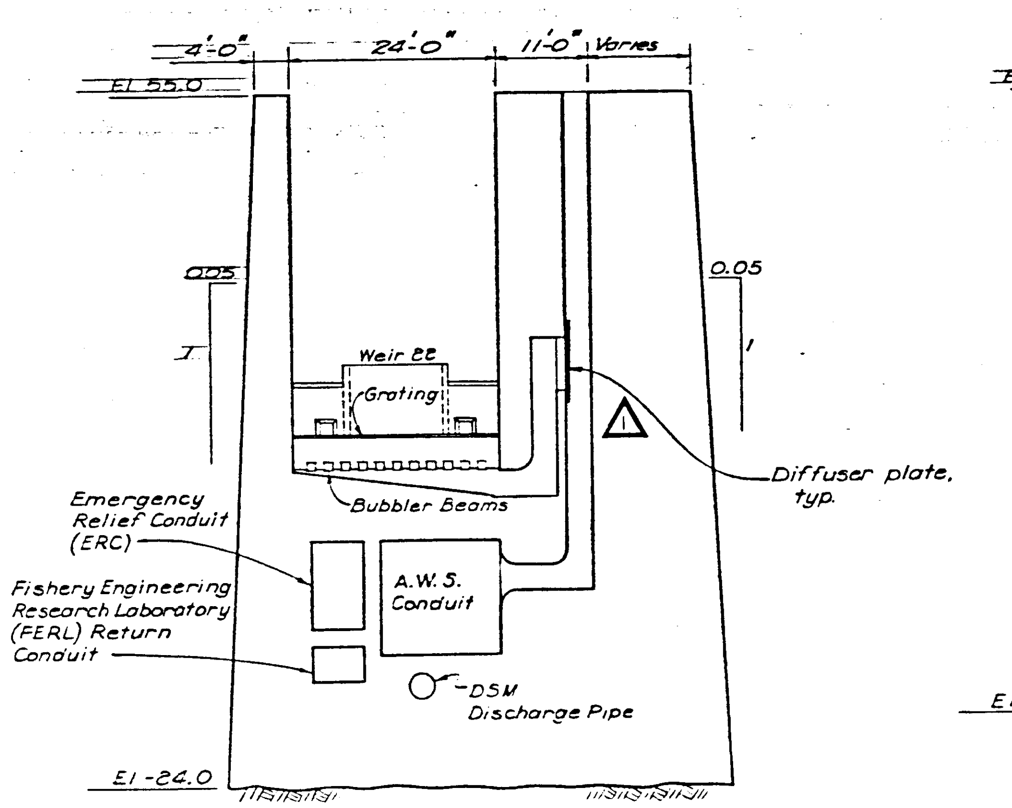
SECTION C/98
3/32"=1'-0"



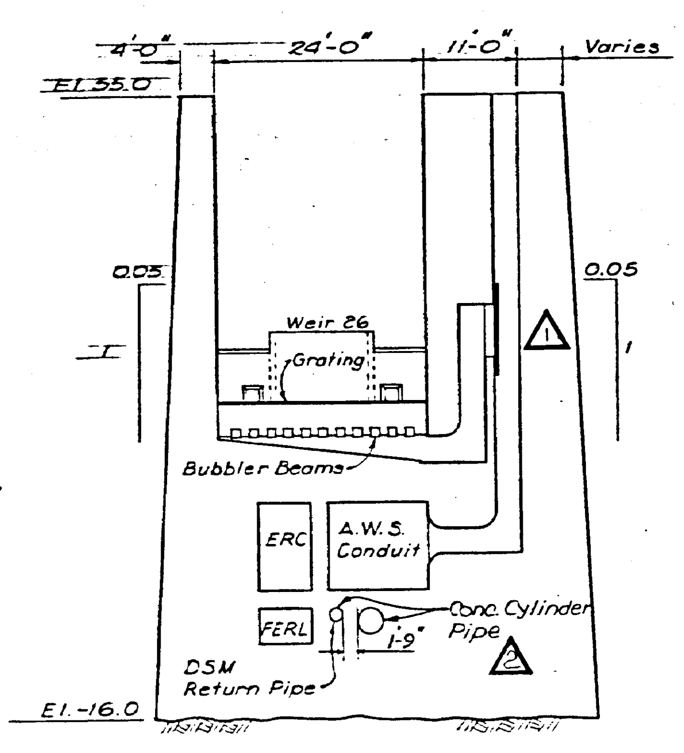
KEY PLAN

NOTES

1. For General Notes see Sht. 22.
2. Handrails, curbs, and drains not shown for clarity. For handrail and curb layout see Sht. 63. For deck drainage layout see Sht. 64.
3. For diffuser details see Sht 52.
4. For gratings and frames see Sht. 81 & 82.
5. For lighting and wiring layout see Sht. 87.
6. For weir details see Sht. 53 & 54.
7. For joint details see sht. 59 & 115. (Rev. 1)
8. For conduit layout see Sht 25 & 26
9. (Rev. 1) For orifice plate see Sht. 79.
10. For concrete cylinder pipe details see sht. 113 (Rev. 2)



SECTION A/98
3/32"=1'-0"



SECTION B/98
3/32"=1'-0"

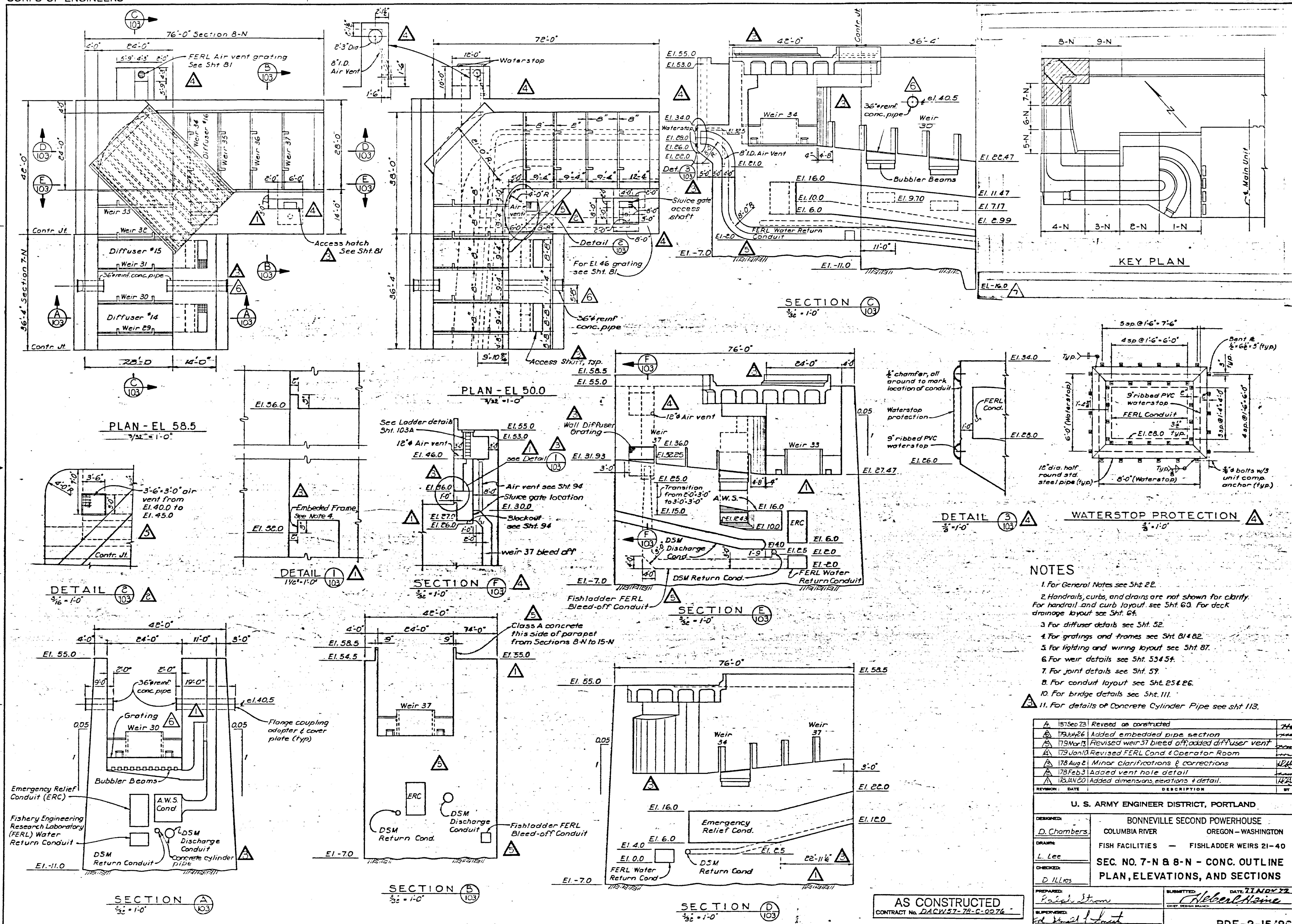
AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
3	18 Sep 23	As constructed	
2	17 Aug 81	Added notes	
1	16 JAN 80	Added grating, diffuser plate dimensions & notes.	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON – WASHINGTON
FISH FACILITIES — FISHLADDER WEIRS 21–40
SEC. NO. 5-N & 6-N - CONC. OUTLINE
PLAN, ELEVATIONS, AND SECTIONS

DESIGNED: D. Chambers
DRAWN: L. Lee
CHECKED: D. Illias
PREPARED: [signature]
SUPERVISED: [signature]
SUBMITTED: [signature] CHIEF DESIGN BRANCH
DATE: 77 NOV 22
SHEET 98
BDF-2-15/81



NOTES

1. For General Notes see Sht 22.
2. Handrails, curbs, and drains are not shown for clarity. For handrail and curb layout see Sht. 63. For deck drainage layout see Sht. 64.
3. For diffuser details see Sht. 52.
4. For gratings and frames see Sht. 81 & 82.
5. For lighting and wiring layout see Sht. 87.
6. For weir details see Sht. 53 & 54.
7. For joint details see Sht. 57.
8. For conduit layout see Sht. 25 & 26.
10. For bridge details see Sht. 111.
11. For details of Concrete Cylinder Pipe see sht 113.

REVISION	DATE	DESCRIPTION	BY
7	1st Sep 23	Revised as constructed	
6	179 July 26	Added embedded pipe section	
5	179 Mar 13	Revised weir 37 bleed off, added diffuser vent	
4	179 Jan 10	Revised FERL Cond & Operator Room	
3	178 Aug 2	Minor clarifications & corrections	
2	178 Feb 3	Added vent hole detail	
1	178 JAN 20	Added dimensions, elevations & detail.	

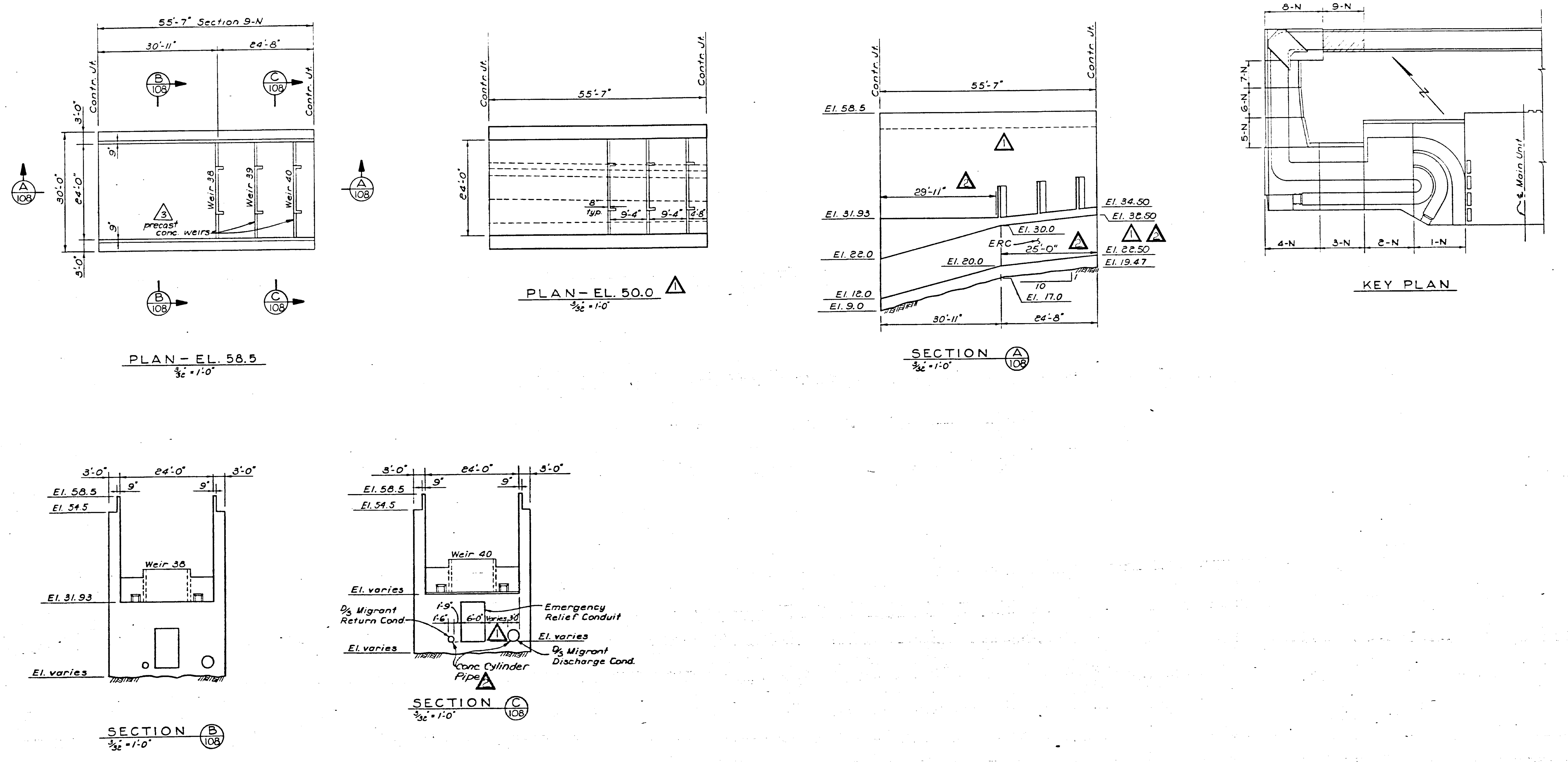
AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

U. S. ARMY ENGINEER DISTRICT, PORTLAND

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES — FISHLADDER WEIRS 21-40
SEC. NO. 7-N & 8-N - CONC. OUTLINE
PLAN, ELEVATIONS, AND SECTIONS

DESIGNED: D. Chambers
DRAWN: L. Lee
CHECKED: D. ILLIOS
DATE: 22 NOV 77

SHEET 103 — BDF-2-15/86



NOTES

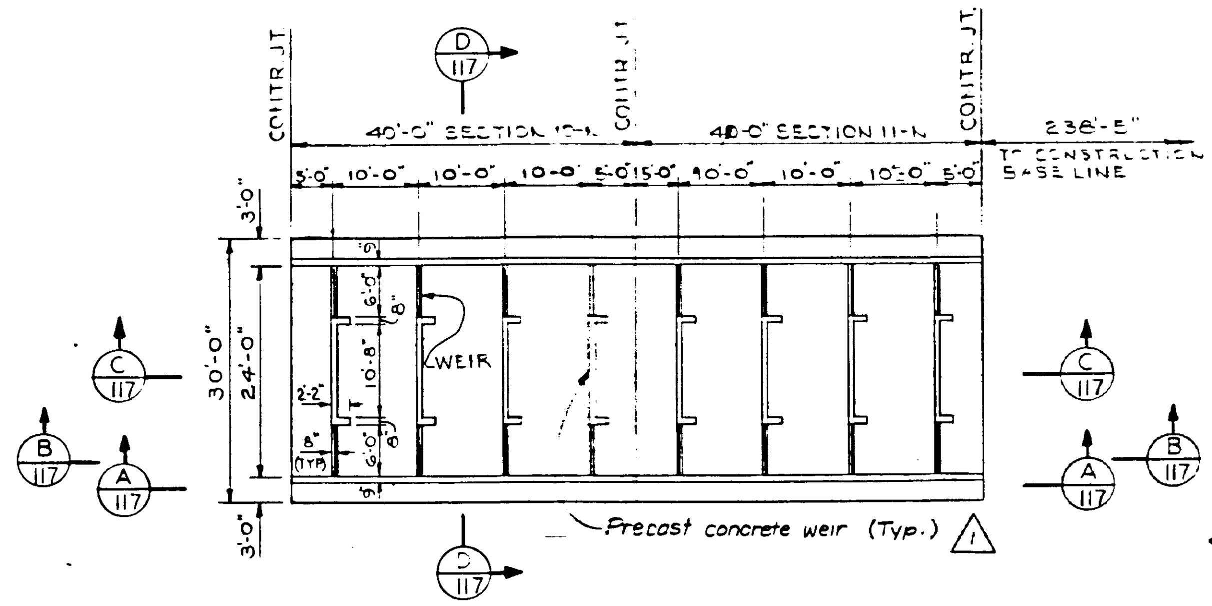
1. For General Notes see Sht 22.
2. For weir details see Sht 53.
3. For joint details see Sht 115 (3)
4. For conduit layout see Sht 26.
5. (2) For details of Concrete Cylinder Pipe see sht. 113.

REVISION	DATE	DESCRIPTION	BY
3	18 Sep 23	Revised as constructed	
2	17 Aug 21	Added notes & dimensions. Corrected elev.	
1	18 JAN 20	revised dimensions, conduits & elevations.	

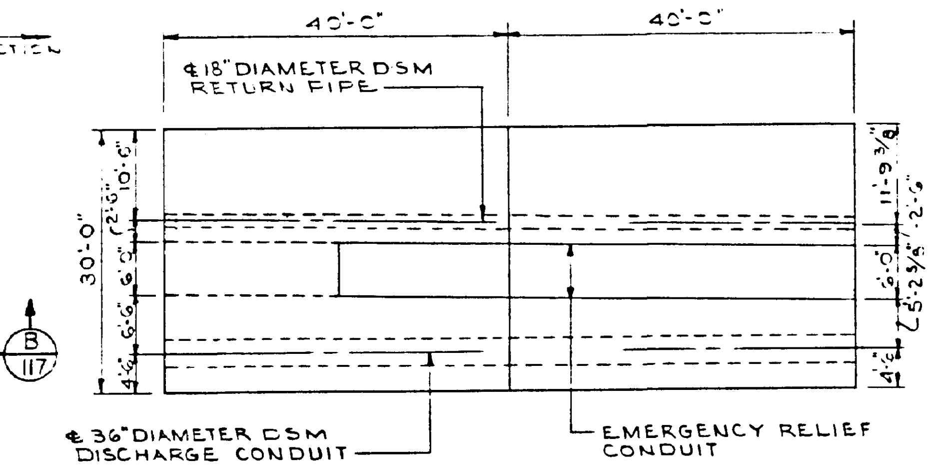
U. S. ARMY ENGINEER DISTRICT, PORTLAND

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES — FISHLADDER WEIRS 21-40
SEC. NO. 9-N — CONC. OUTLINE
PLAN, ELEV. AND SEC.

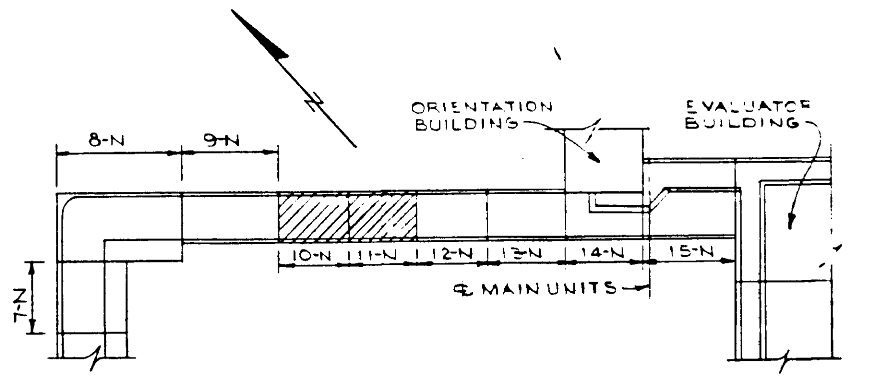
DESIGNED: T. Murphy
DRAWN: L. Lee
CHECKED: D. ILLIAS
PREPARED: Ralph Stone
SUPERVISED:
SUBMITTED: Heber C Heine DATE: 22 Nov 22
SHEET 108 BDF-2-15/91



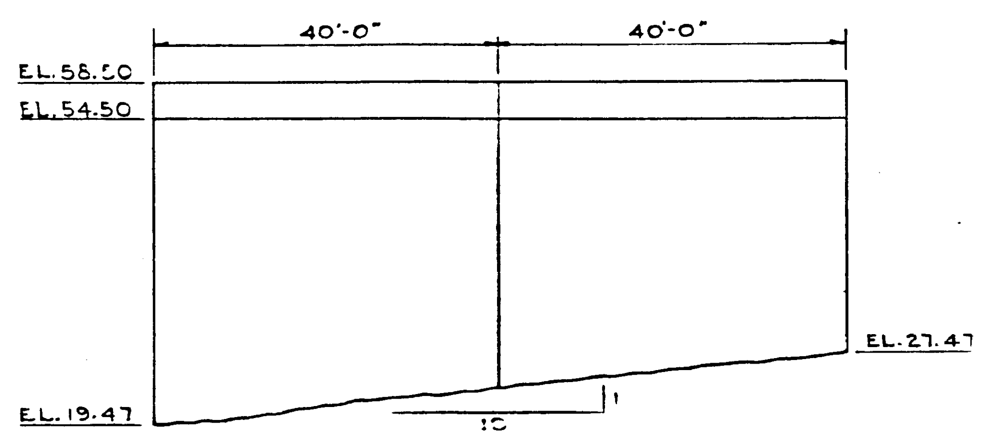
PLAN-EL. 58.5
3/32"=1'-0"



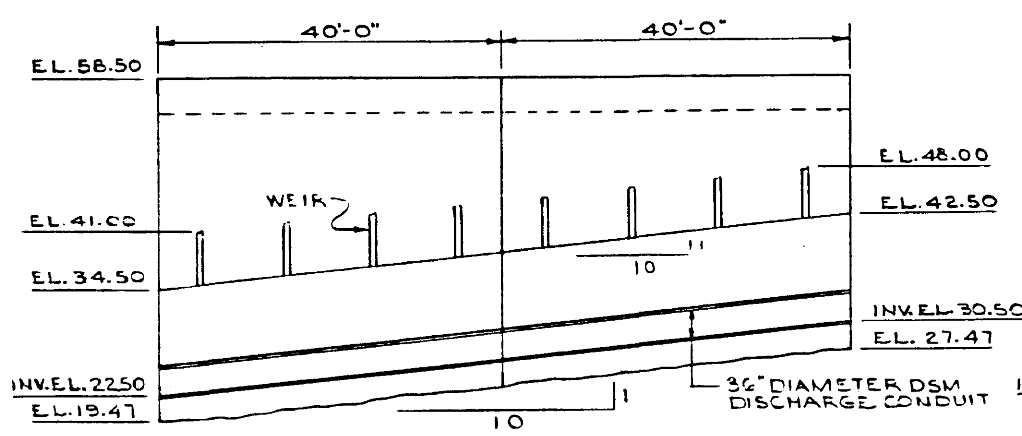
PLAN-EL. 34.50
3/32"=1'-0"



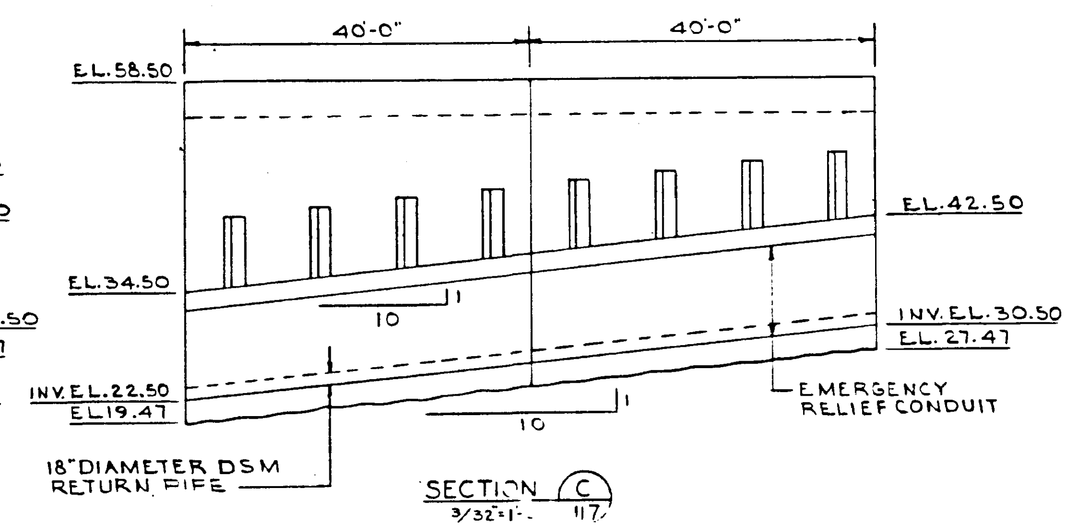
KEY PLAN



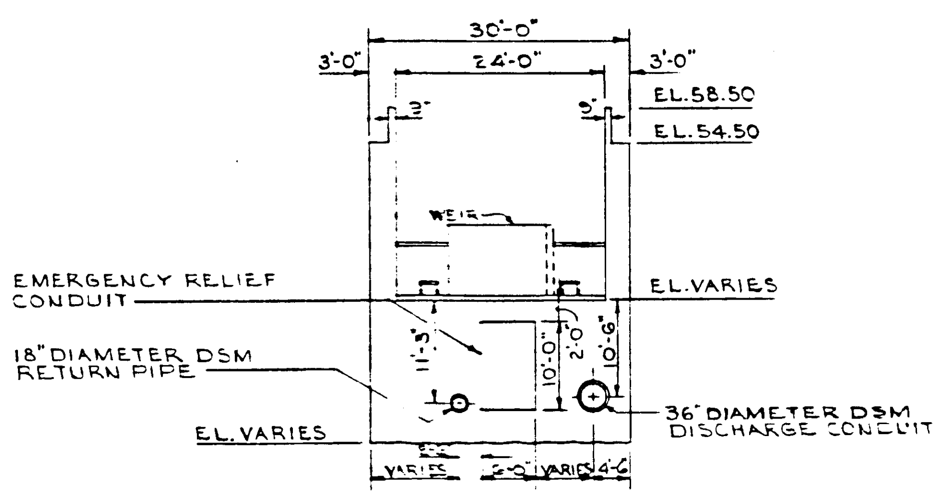
SECTION A/117
3/32"=1'-0"



SECTION B/117
3/32"=1'-0"



SECTION C/117
3/32"=1'-0"



SECTION D/117
3/32"=1'-0"

NOTES

1. FOR GENERAL NOTES, SEE SHEET 22.
2. FOR REINFORCING DETAILS, SEE SHEETS 118 & 119.
3. FOR MONOLITH JOINT DETAILS, SEE SHEET 134 & 115
4. FOR WEIR DETAILS, SEE SHEETS 53 & 54. △1

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

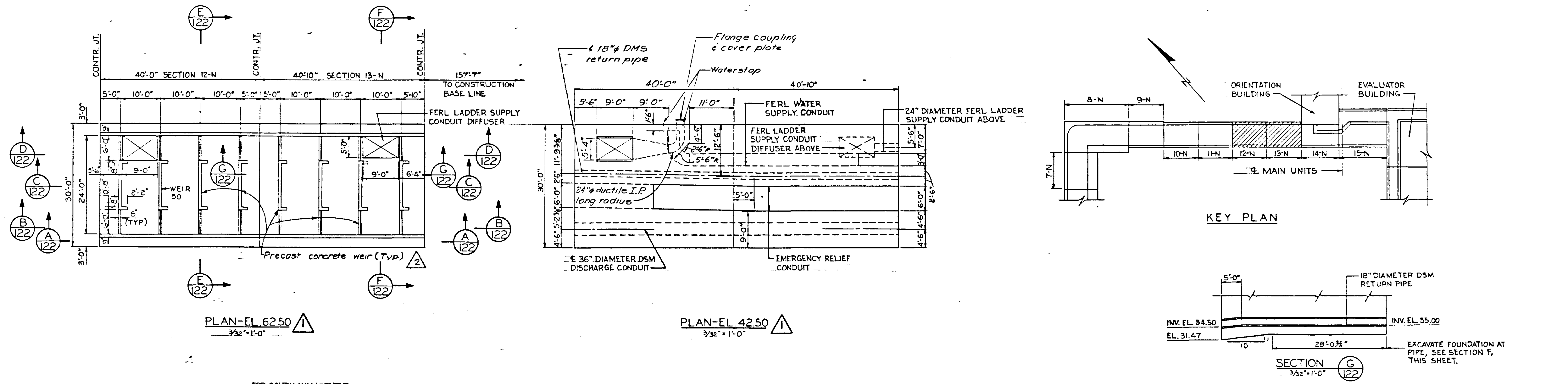
FOR INFORMATION ONLY

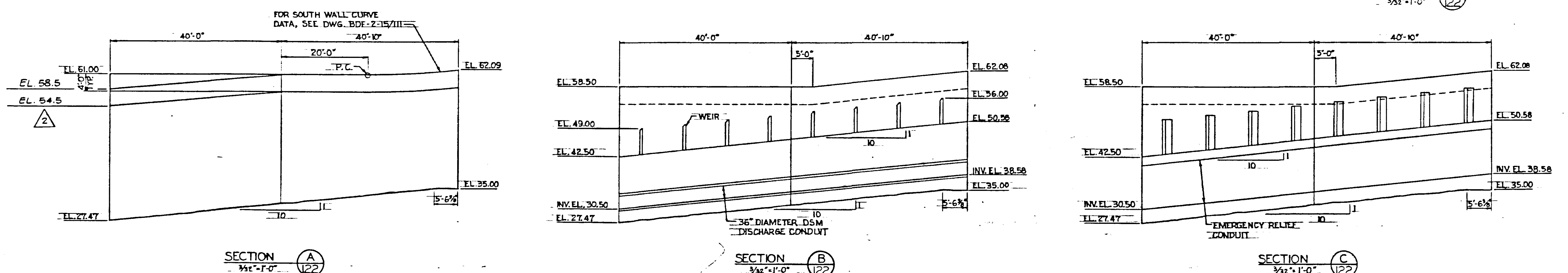
REVISION	DATE	DESCRIPTION	BY
1	18 Sep 23	Revised as constructed	

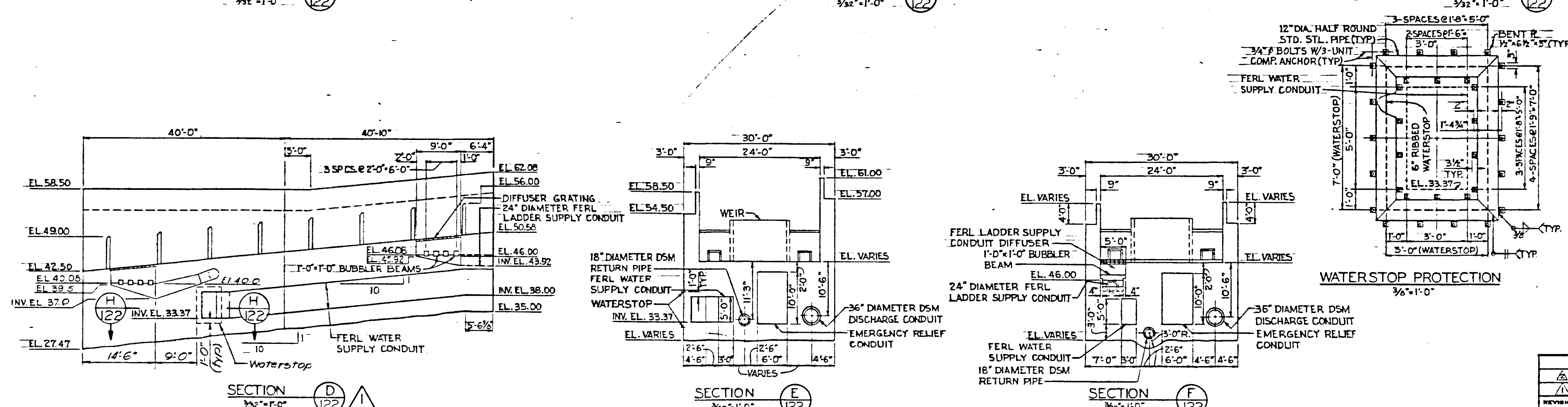
U.S. ARMY ENGINEER DISTRICT, HUNTINGTON, HUNTINGTON, WEST VIRGINIA — U.S. ARMY ENGINEER, DISTRICT PORTLAND, OREGON

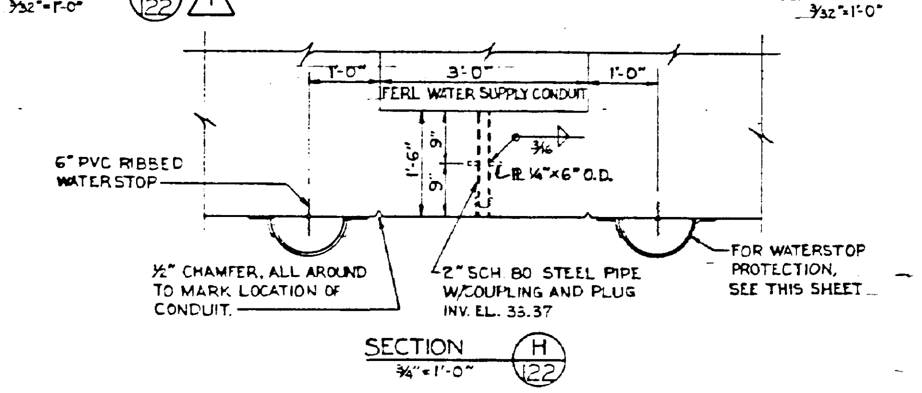
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES - FISHLADDER WEIRS 41-66
SECTIONS 10-N & 11-N - CONC. OUTLINE
PLANS, ELEVATIONS, & SECTION

DESIGNED: WEG-WDB
DRAWN: ELW
CHECKED: KMW-WDB
PREPARED: [signature]
SUPERVISED: [signature]
SUBMITTED: [signature] DATE 77 NOV 21
SHEET 117 BDF-2-15/101









NOTES

1. FOR GENERAL NOTES, SEE SHEET 22.
2. FOR REINFORCING DETAILS, SEE SHEETS 123 AND 125.
3. FOR MONOLITH JOINT DETAILS, SEE SHEET 134.
4. FOR WEIR DETAILS, SEE SHEETS 53 AND 54.
5. FOR DETAILS OF DIFFUSER GRATING, SEE SHEET 78.
6. FOR DETAILS OF BUBBLER BEAMS, SEE SHEET 51.

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
2	18 Sep 81	Revised as constructed	
1	6 Dec 79	Added diffuser & supply line	

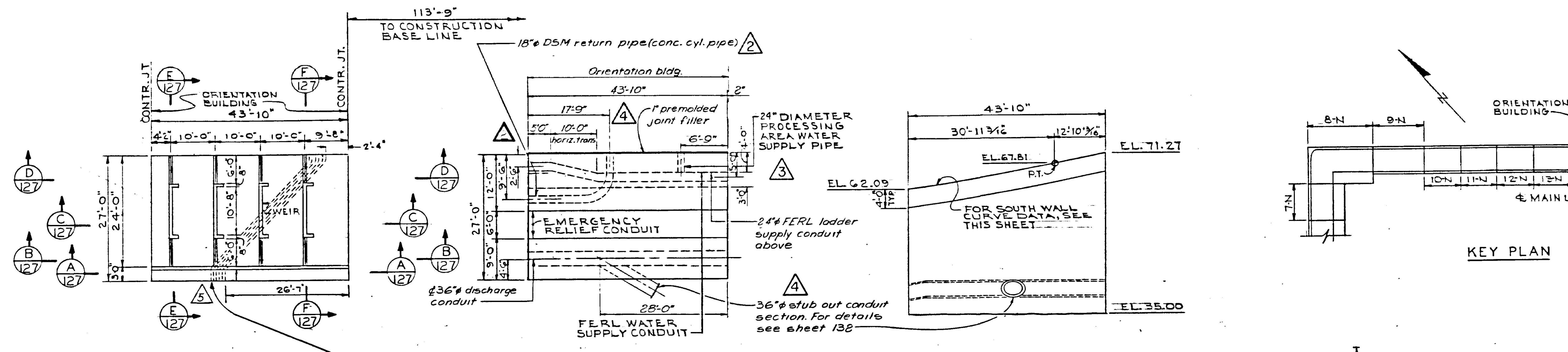
U.S. ARMY ENGINEER DISTRICT, HUNTINGTON
HUNTINGTON, WEST VIRGINIA

U.S. ARMY ENGINEER DISTRICT
PORTLAND, OREGON

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES - FISHLADDER WEIRS 41-66
SECTIONS 12-N & 13-N - CONC. OUTLINE
PLANS, ELEVATIONS, & SECTIONS

DESIGNED: W.D.B.
DRAWN: L.C.B.
CHECKED: K.M.W. - W.D.B.
PREPARED: [signature]
SUPERVISED: [signature]
SUBMITTED: [signature]
DATE: 27 Nov 78

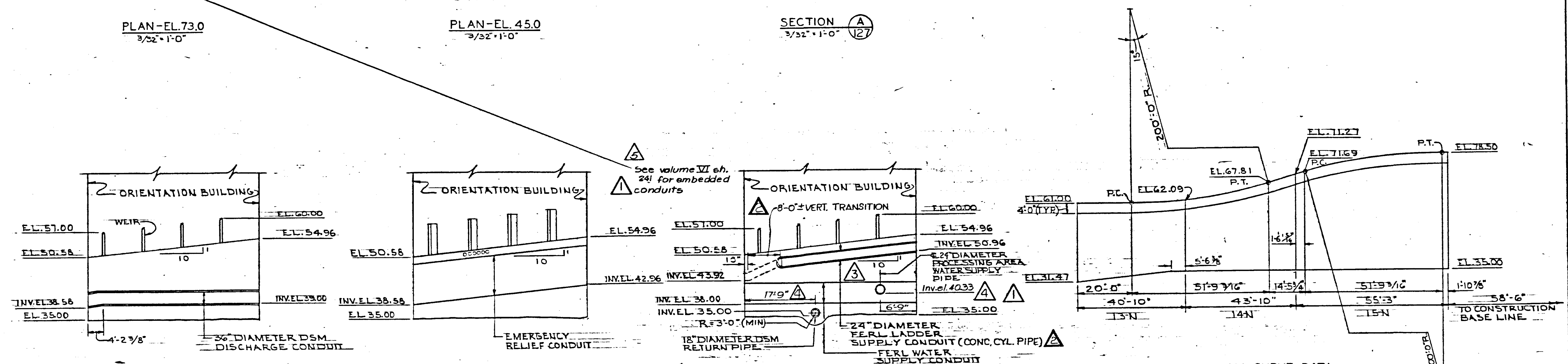
SHEET 122 BDF-2-15/106



PLAN-EL.73.0 3/32" = 1'-0"

PLAN-EL. 45.0 3/32" = 1'-0"

SECTION A/127 3/32" = 1'-0"



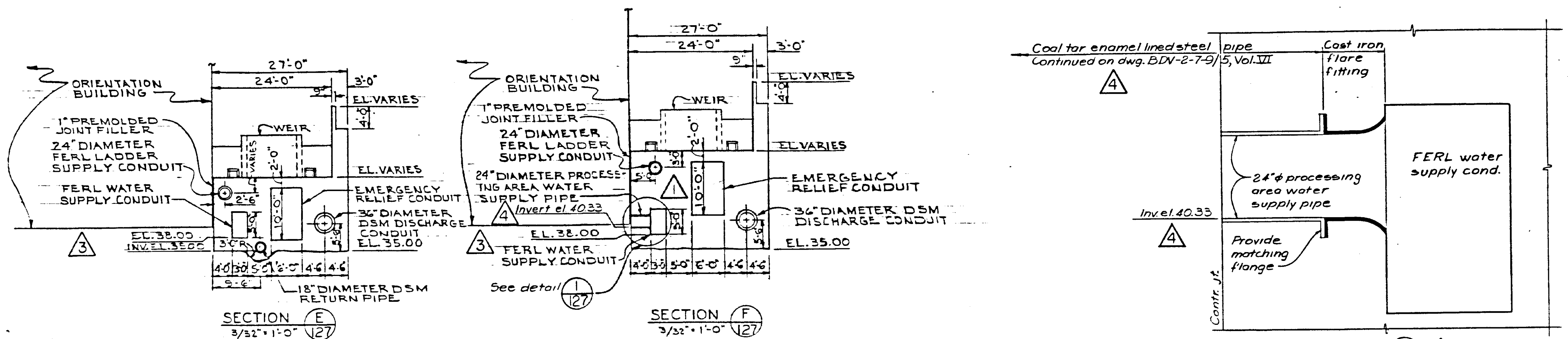
SECTION B/127 3/32" = 1'-0"

SECTION C/127 3/32" = 1'-0"

SECTION D/127 3/32" = 1'-0"

SOUTH WALL CURVE DATA 1/16" = 1'-0"

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076



SECTION E/127 3/32" = 1'-0"

SECTION F/127 3/32" = 1'-0"

DETAIL 1/127 3/4" = 1'-0"

NOTES

1. FOR GENERAL NOTES, SEE SHEET 22.
2. FOR REINFORCING DETAILS, SEE SHEET 128.
3. FOR MONOLITH JOINT DETAILS, SEE SHEET 134.
4. FOR WEIR DETAILS, SEE SHEETS 53 & 54.
5. FOR ORIENTATION BUILDING, SEE VOLUME 6, SHEETS 161 THRU 178.
6. FOR DETAILS OF CONC. PIPE SEE SHEET 113.

REVISION	DATE	DESCRIPTION	BY
5	87 Sep 23	Revised as Constructed	
4	79 Jul 26	Changed pipe locations added 36"ø stub out	
3	79 Jan 30	Changed dimensions	
2	78 Aug 8	Added dimensions and notes	
1	78 Jan 20	Added cond. entrance detail and notes	

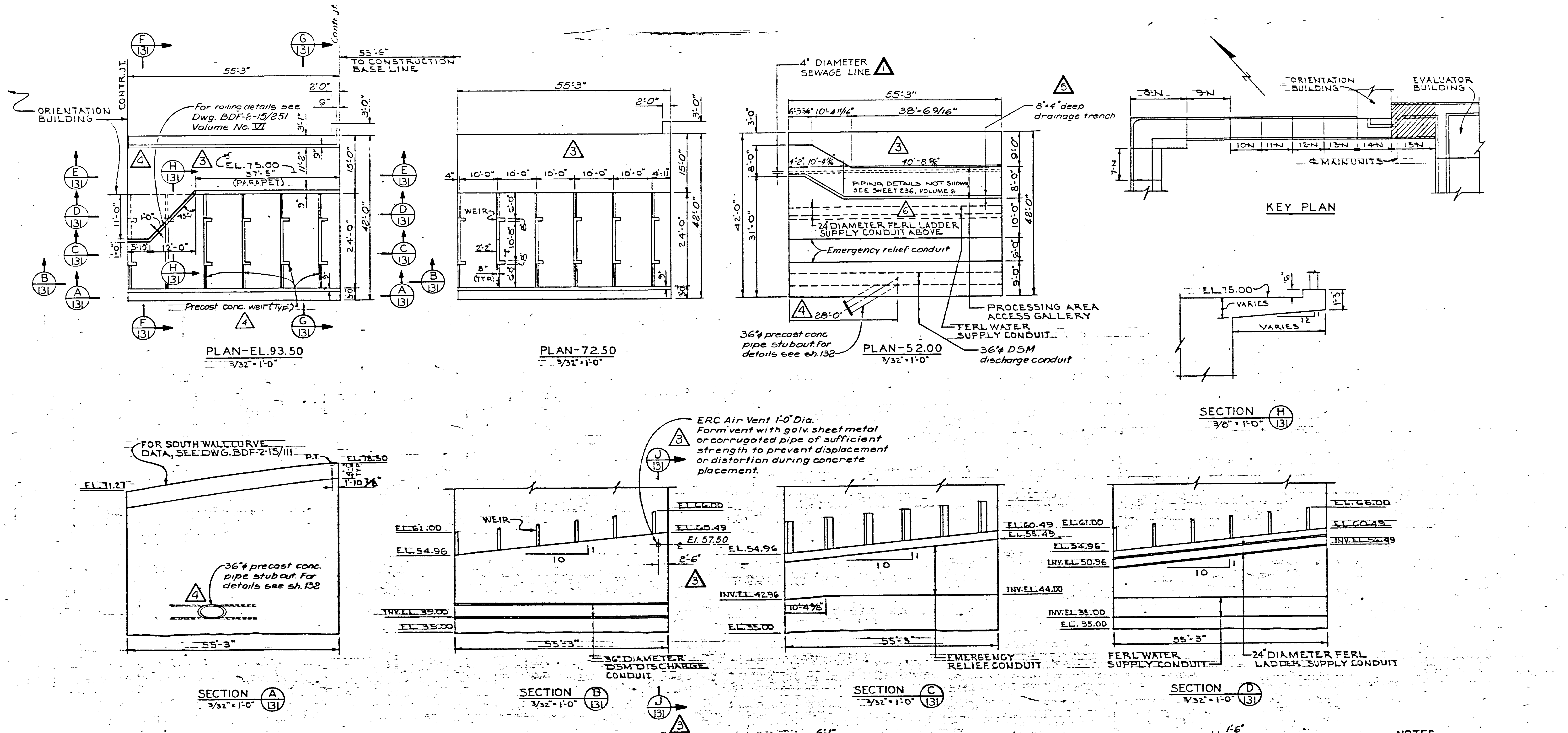
U.S. ARMY ENGINEER DISTRICT, HUNTINGTON
HUNTINGTON, WEST VIRGINIA

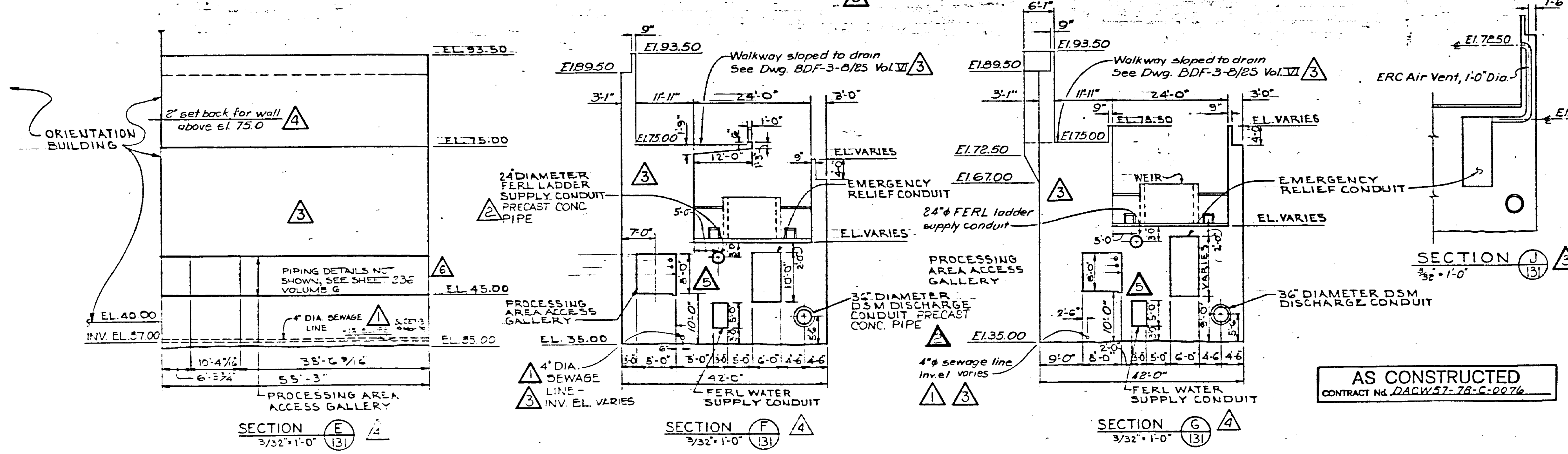
U.S. ARMY ENGINEER, DISTRICT
PORTLAND, OREGON

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES-FISHLADDER WEIRS 41-66
SECTION 14-N – CONC. OUTLINE
PLANS, ELEVATIONS, & SECTIONS

DESIGNED: WDB
DRAWN: ELW
CHECKED: KMW-WDB
PREPARED: (signature)
SUBMITTED: (signature) DATE: 77 NOV 21
SUPERVISED: (signature)

SHEET 127 BDF-2-15/111





NOTES

1. FOR GENERAL NOTES, SEE SHEET 22.
2. FOR REINFORCING DETAILS, SEE SHEETS 132 & 133.
3. FOR MONOLITH JOINT DETAILS, SEE SHEET 134.
4. FOR WEIR DETAILS, SEE SHEETS 53 & 54.
5. FOR ORIENTATION BUILDING, SEE VOLUME 6, SHEETS 161 THRU 178.
6. (2) FOR DETAILS OF PRECAST CONC. PIPE, SEE SHEET 113.
7. (3) For walkway drain details see Dwg. BDF-3-8/25 Vol. VI

REVISION	DATE	DESCRIPTION	BY
4	87 Sep 23	Revised as constructed	
3	79 Jan 30	Added ERC air vent, revised conc. outline	
2	78 Aug 2	Added pipe notes.	
1	78 Feb 14	Added Sewage Line	

6	81 Sep 25 Revised ref numbers, changed piping detail.
5	79 Sep 21 Added drainage trench
4	79 Jul 26 2" wall set back (added 36"⌀ pipe stubout

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

U.S. ARMY ENGINEER DISTRICT, HUNTINGTON
HUNTINGTON, WEST VIRGINIA

U.S. ARMY ENGINEER, DISTRICT
PORTLAND, OREGON

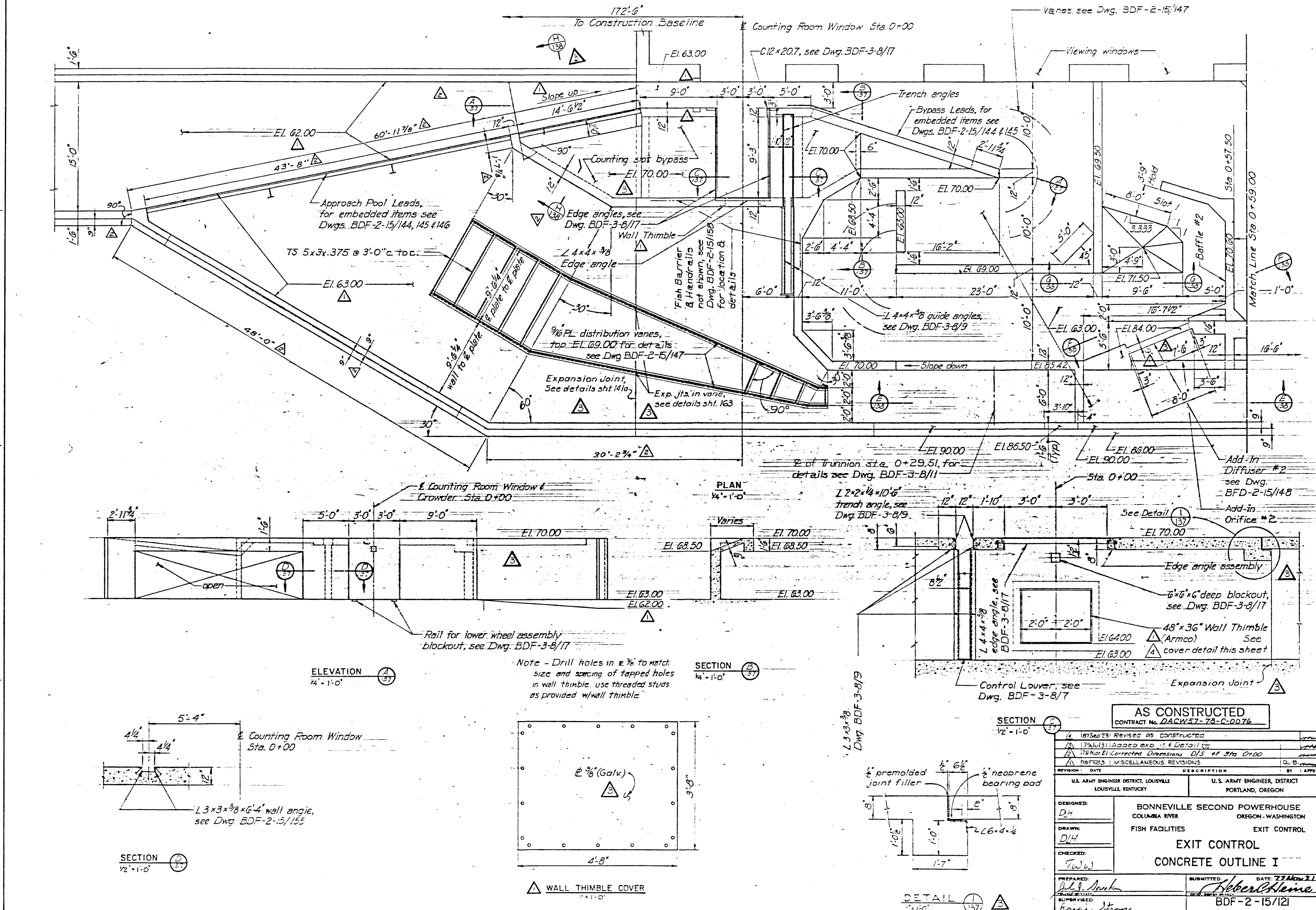
BONNEVILLE SECOND POWERHOUSE

COLUMBIA RIVER — OREGON-WASHINGTON

FISH FACILITIES - FISHLADDER WEIRS 41-66

SECTION 15-N - CONC. OUTLINE PLANS, ELEVATIONS, & SECTIONS

DESIGNED: W.D.B.
DRAWN: E.L.W.
CHECKED: K.MW-W.D.B.
PREPARED: (signature) PROJECT MANAGER
SUPERVISED: Ralph Strom MANAGER FOR DESIGN
SUBMITTED: (signature) CHIEF, DESIGN BRANCH
DATE: 77 Nov 21
SHEET 131
BDF-2-15/115



AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

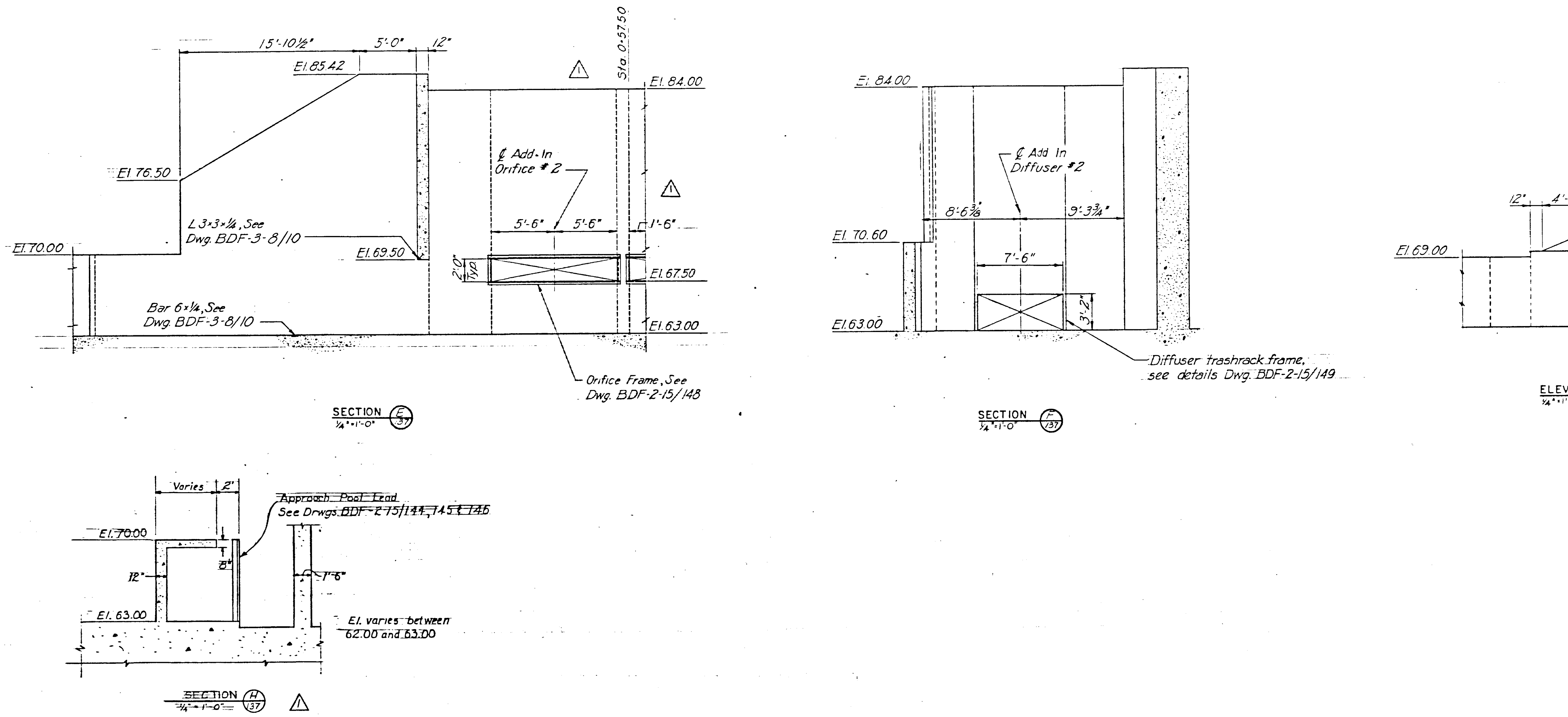
Revision	Date	Description
4	18 Sep 23	Revised as constructed
3	17 Jul 31	Added exp. jt. & Detail
2	17 Nov 81	Corrected Dimensions D/S of Sta 0+00
1	11 Feb 83	MISCELLANEOUS REVISIONS

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER, DISTRICT PORTLAND, OREGON

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON - WASHINGTON
FISH FACILITIES — EXIT CONTROL

EXIT CONTROL
CONCRETE OUTLINE I

DESIGNED: DJH
DRAWN: DJH
CHECKED: TWW
SUBMITTED — DATE: 22 Nov 21
BDF-2-15/121
SHEET 137



AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
2	81 Sep 23	As constructed	
1	79 Jul 31	Added station & Section H corr. dim.	

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
LOUISVILLE, KENTUCKY

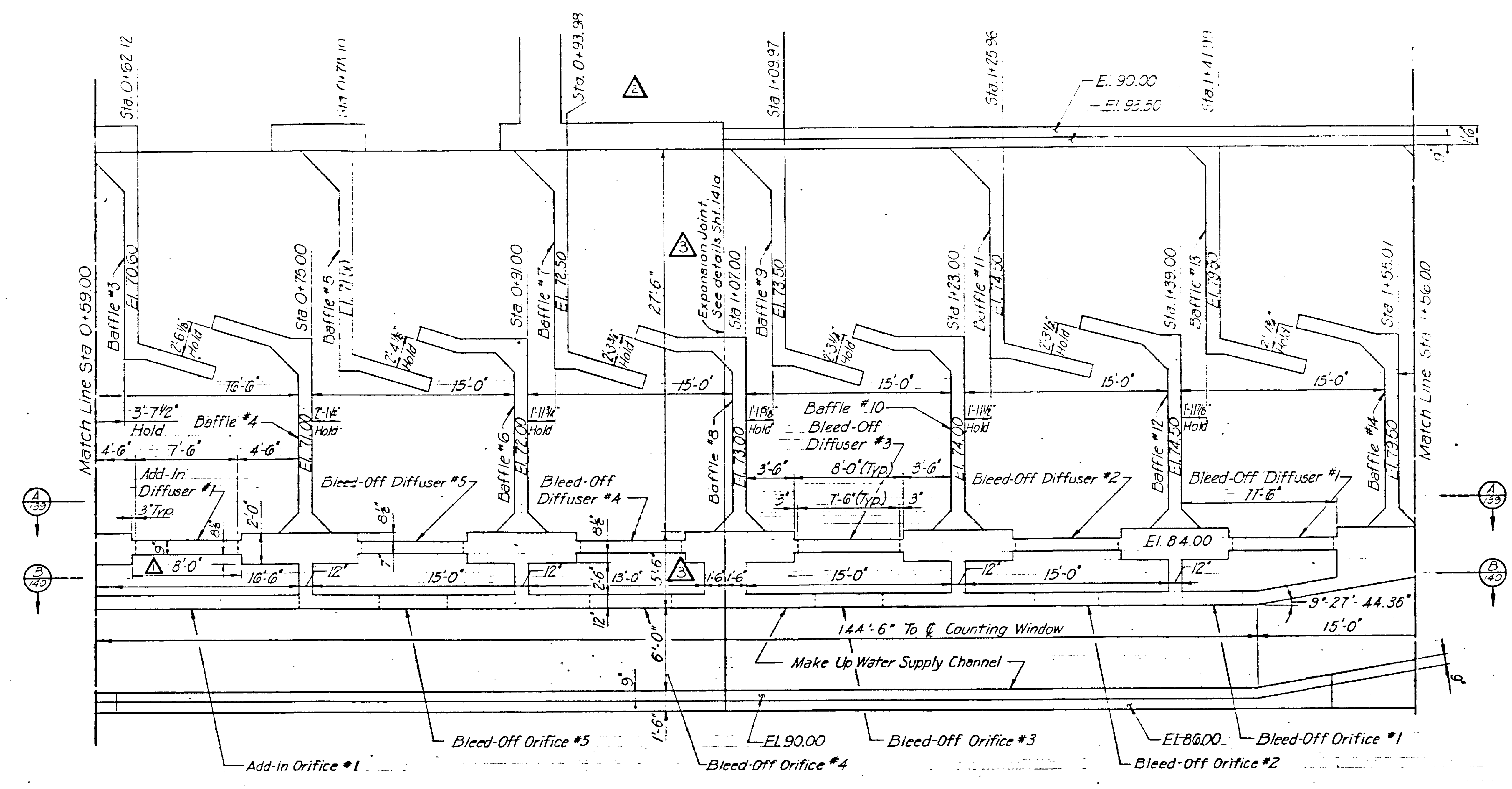
U. S. ARMY ENGINEER, DISTRICT
PORTLAND, OREGON

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES EXIT CONTROL

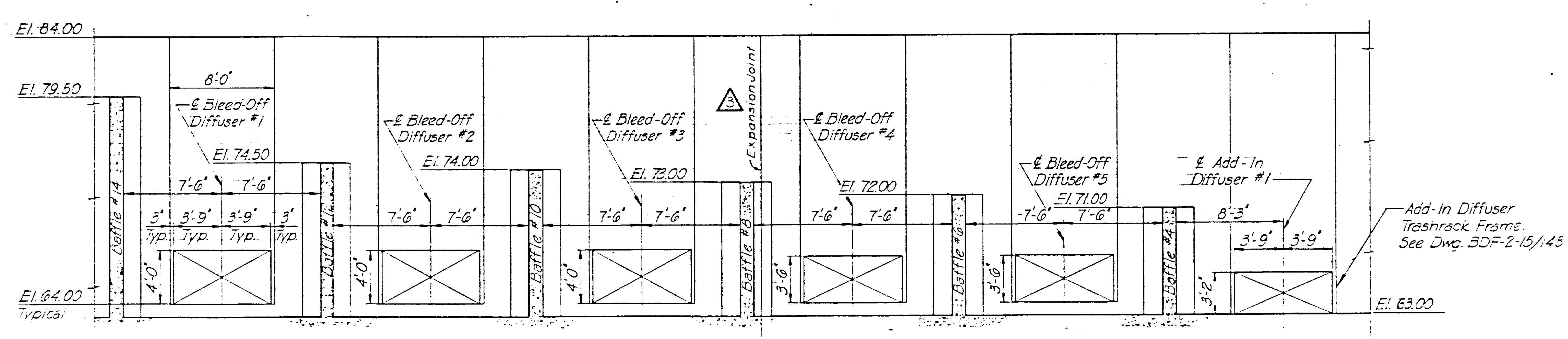
EXIT CONTROL
CONCRETE OUTLINE II

DESIGNED: DH
DRAWN: W.E.S.
CHECKED: TWW
PREPARED:
SUPERVISED:
SUBMITTED:
DATE: 27 NOV 21

BDF-2-15/122
SHEET 135



PLAN
1/4"=1'-0"



SECTION
1/4"=1'-0"

Notes:
1. For Bleed-Off Orifice Plates, See Dwg. BDF-2-15/146
2. For Bleed-Off Diffuser Racks, See Dwg. BDF-2-15/149.
3. For Add-In Diffuser Trashrack, See Dwg. BDF-2-15/148.

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY	APPD
4	18 Sep 23	As Constructed		
	17 Jul 31	Added slab expansion joint, rev. dimen.		
2	17 Feb 14	Revised Plan		
	17 FEB 3	DIMEN CHGD	D.L.B.	

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
LOUISVILLE, KENTUCKY

U.S. ARMY ENGINEER DISTRICT
PORTLAND, OREGON

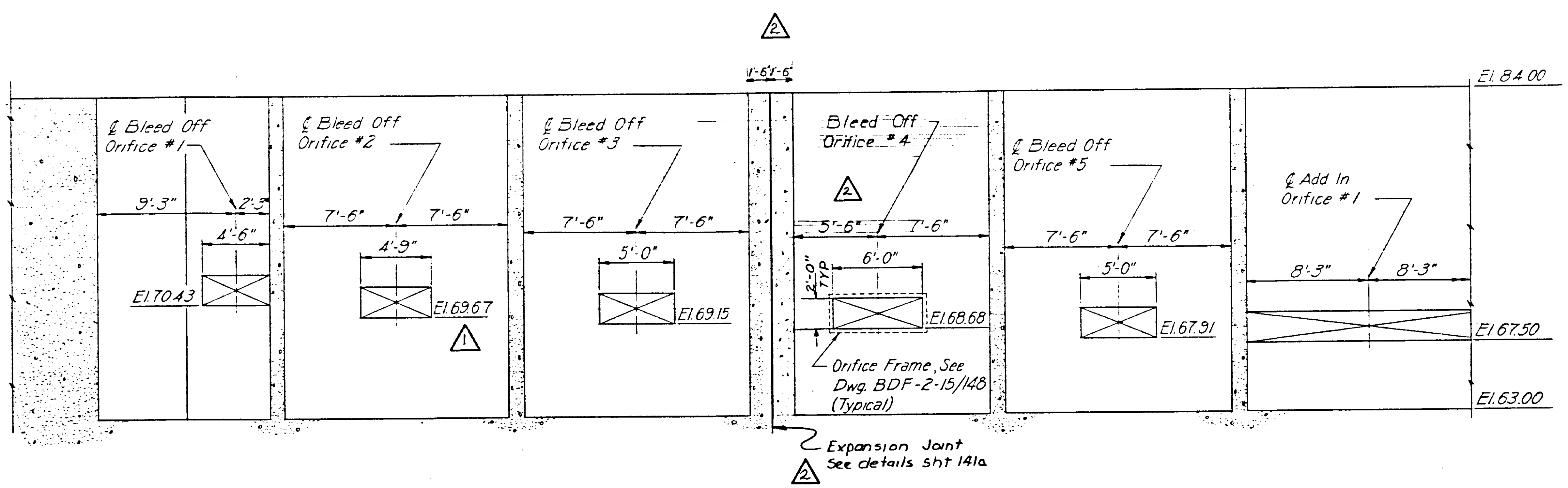
DESIGNED: DH
DRAWN: JWH, WIFS & DH
CHECKED:

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES — EXIT CONTROL

EXIT CONTROL
CONCRETE OUTLINE III

PREPARED: PROJECT MANAGER
SUBMITTED: CHIEF, DESIGN BRANCH — DATE: 77 NOV 21
SUPERVISED: MANAGER FOR DESIGN

BDF-2-15/123
SHEET 139



SECTION B/139
1/4" = 1'-0"

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
3	18 Sep 23	As constructed	
2	19 Jul 31	Added expansion joint	
1	18 Feb 3	Changed elevation	

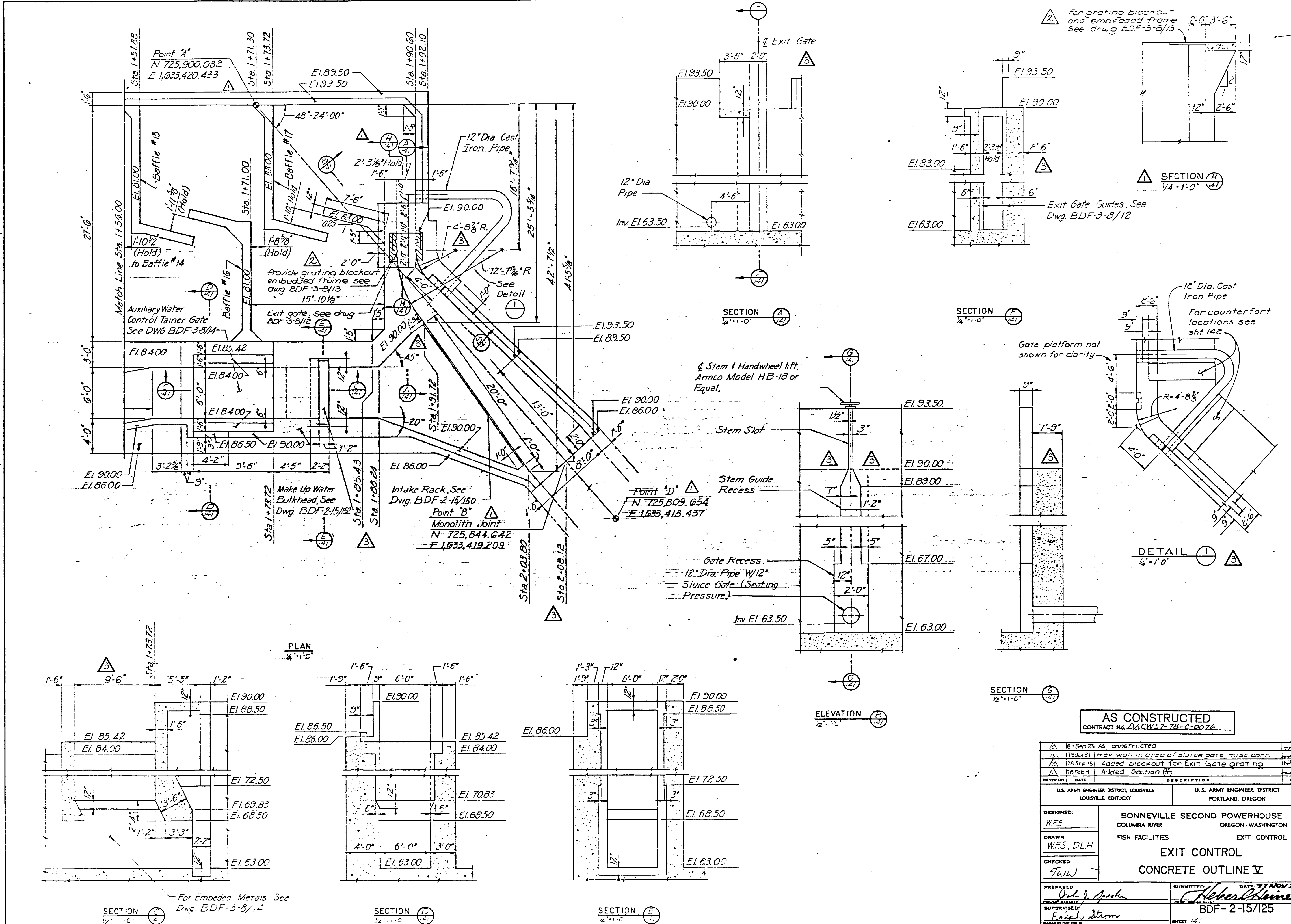
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
LOUISVILLE, KENTUCKY

U.S. ARMY ENGINEER, DISTRICT
PORTLAND, OREGON

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES EXIT CONTROL
EXIT CONTROL
CONCRETE OUTLINE IV

DESIGNED: DH
DRAWN: W.F.S.
CHECKED: TWW
PREPARED: [signature]
SUPERVISED: Ralph Strom
SUBMITTED: Herbert Heine
DATE: 77 Nov 21

BDF-2-15/124
SHEET 142



AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

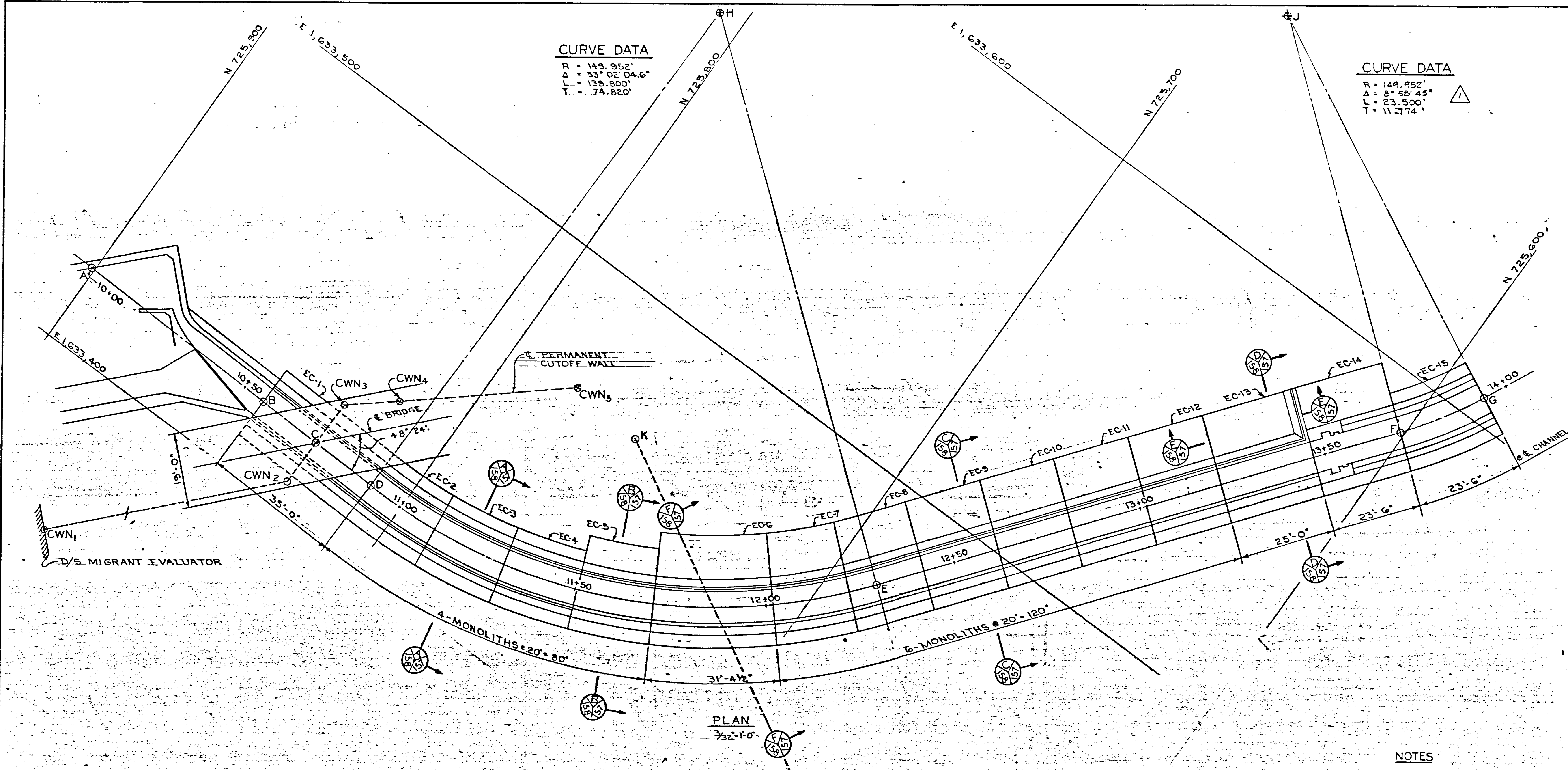
Revision	Date	Description	By
4	87 Sep 23	As constructed	
3	79 Jul 31	Rev wall in area of sluice gate, misc. corr.	
2	78 Sep 15	Added blockout for Exit Gate grating	
1	76 Feb 3	Added Section H	

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, LOUISVILLE, KENTUCKY — U.S. ARMY ENGINEER, DISTRICT PORTLAND, OREGON

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES EXIT CONTROL
EXIT CONTROL
CONCRETE OUTLINE V

Designed: WFS
Drawn: WFS, DLH
Checked: TWW

BDF-2-15/125
Sheet 141



NOTES

1. FOR GENERAL NOTES, SEE SHEET 22.

EXIT CHANNEL COORDINATES		
POINT	N COORD	E COORD
A	725,900.083	1,633,420.433
B	725,844.648	1,633,419.210
C	725,827.152	1,633,418.824
D	725,809.656	1,633,418.438
E	725,688.556	1,633,475.564
F	725,601.261	1,633,586.382
G	725,588.810	1,633,606.259
H	725,588.364	1,633,605.498
J	725,719.724	1,633,678.318
K	725,760.791	1,633,468.722
L	725,636.336	1,633,402.623

PERMANENT CUTOFF WALL COORDINATES			
POINT	STATION	N COORD	E COORD
CWN_1	0+00	726,071.185	1,633,143.949
CWN_2	3+58.341	725,827.421	1,633,406.603
CWN_3	3+82.565	725,826.887	1,633,430.821
CWN_4	3+96.629	725,816.208	1,633,439.972
CWN_5	4+43.391	725,780.700	1,633,470.400

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
1	15 Sep 23	Revised as constructed	

U.S. ARMY ENGINEER DISTRICT, HUNTINGTON
HUNTINGTON, WEST VIRGINIA

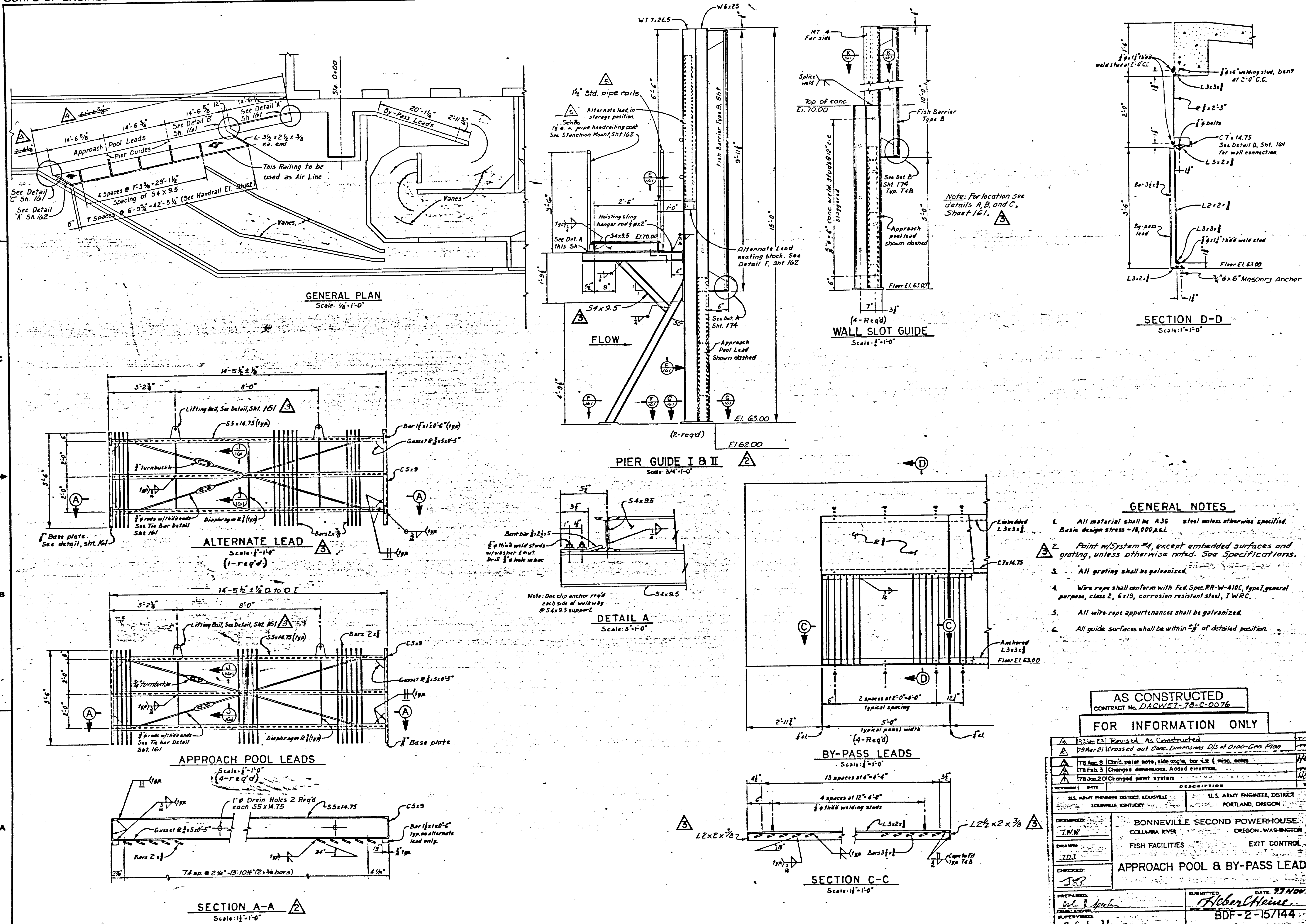
U.S. ARMY ENGINEER, DISTRICT
PORTLAND, OREGON

DESIGNED: W.L.H.-W.D.B.
DRAWN: J.A.V.M.
CHECKED: W.L.H.-W.D.B.

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES – EXIT CONTROL
EXIT CHANNEL
GENERAL PLAN

PREPARED: PROJECT MANAGER
SUBMITTED: DATE: 27 Nov 21 CHIEF, DESIGN BRANCH
SUPERVISED: Ralph Strom MANAGER FOR DESIGN

SHEET 152 BDF-2-15/136



GENERAL NOTES

1. All material shall be A36 steel unless otherwise specified. Basic design stress = 18,000 p.s.i.
2. Paint w/System #4, except embedded surfaces and grating, unless otherwise noted. See Specifications.
3. All grating shall be galvanized.
4. Wire rope shall conform with Fed. Spec. RR-W-410C, type I, general purpose, class 2, 6x19, corrosion resistant steel, I WRC.
5. All wire rope appurtenances shall be galvanized.
6. All guide surfaces shall be within ±1/8" of detailed position.

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

FOR INFORMATION ONLY

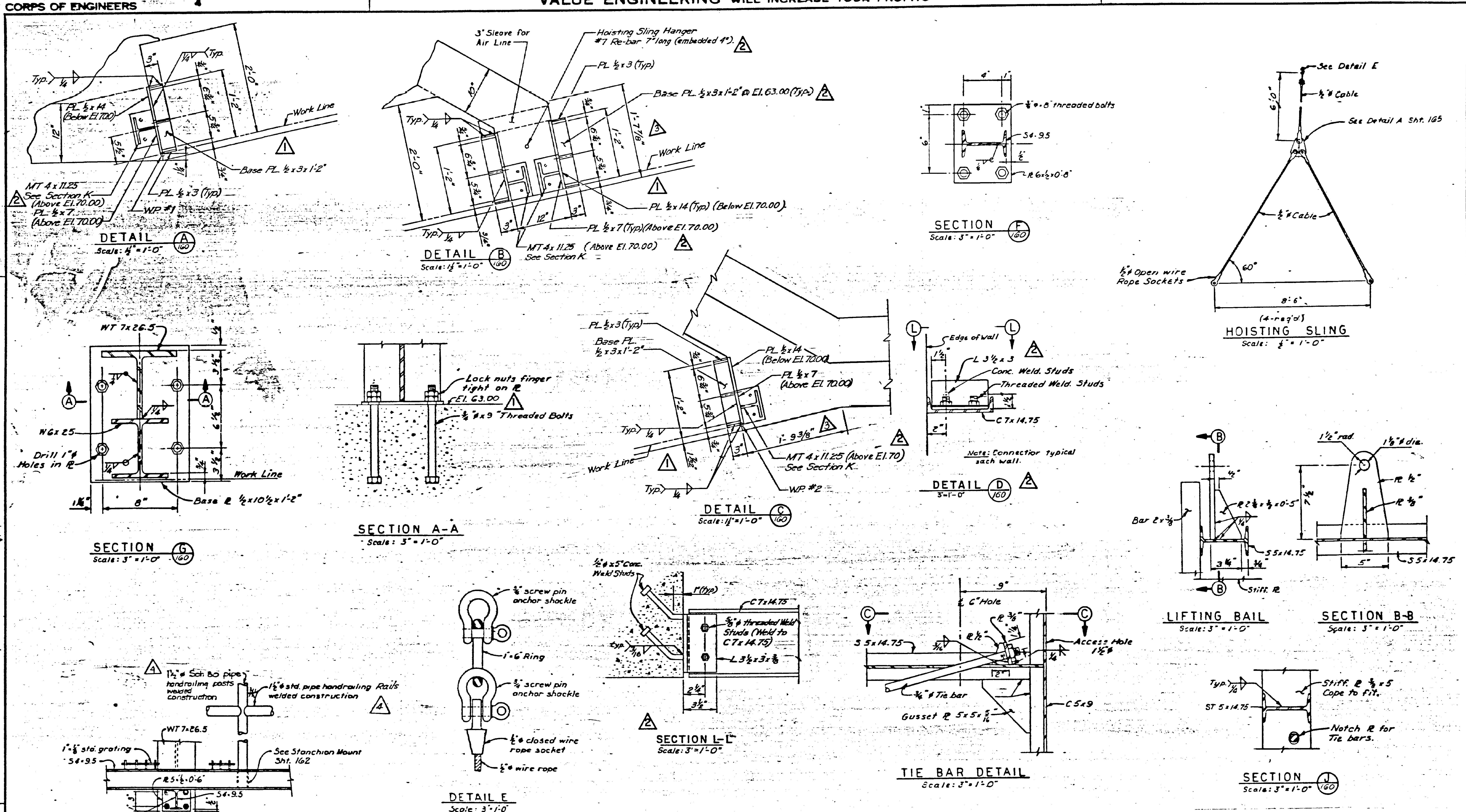
Revision	Date	Description	By
5	83 Sep 23	Revised As Constructed	
4	79 Mar 21	Crossed out Conc. Dimensions D/S of 0+00-Gen Plan	
3	78 Aug 8	Chn'd. paint note, side angle, bar size & misc. notes	
2	78 Feb 3	Changed dimensions. Added elevation.	
1	78 Jan 20	Changed paint system	

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER, DISTRICT PORTLAND, OREGON

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON - WASHINGTON
FISH FACILITIES — EXIT CONTROL

APPROACH POOL & BY-PASS LEADS

DESIGNED: T.W.W.
DRAWN: J.D.J.
CHECKED: J.E.B.
PREPARED: [signature]
SUPERVISED: Ralph [signature]
SUBMITTED: Heber C. Heine
DATE: 77 NOV 21
BDF-2-15/144
SHEET 160



Rev.	Date	Description
4	82 Sep 23	Revised As Constructed
3	79 Mar 21	Changed Conc. Outlines & Dimensions @ Dtl's. B&C.
2	78 Aug 8	Add notes to Dtl A, B, Sect. K; Chng. Weld Studs Sect. L-L.
1	78 Feb 3	Minor revisions

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
LOUISVILLE, KENTUCKY

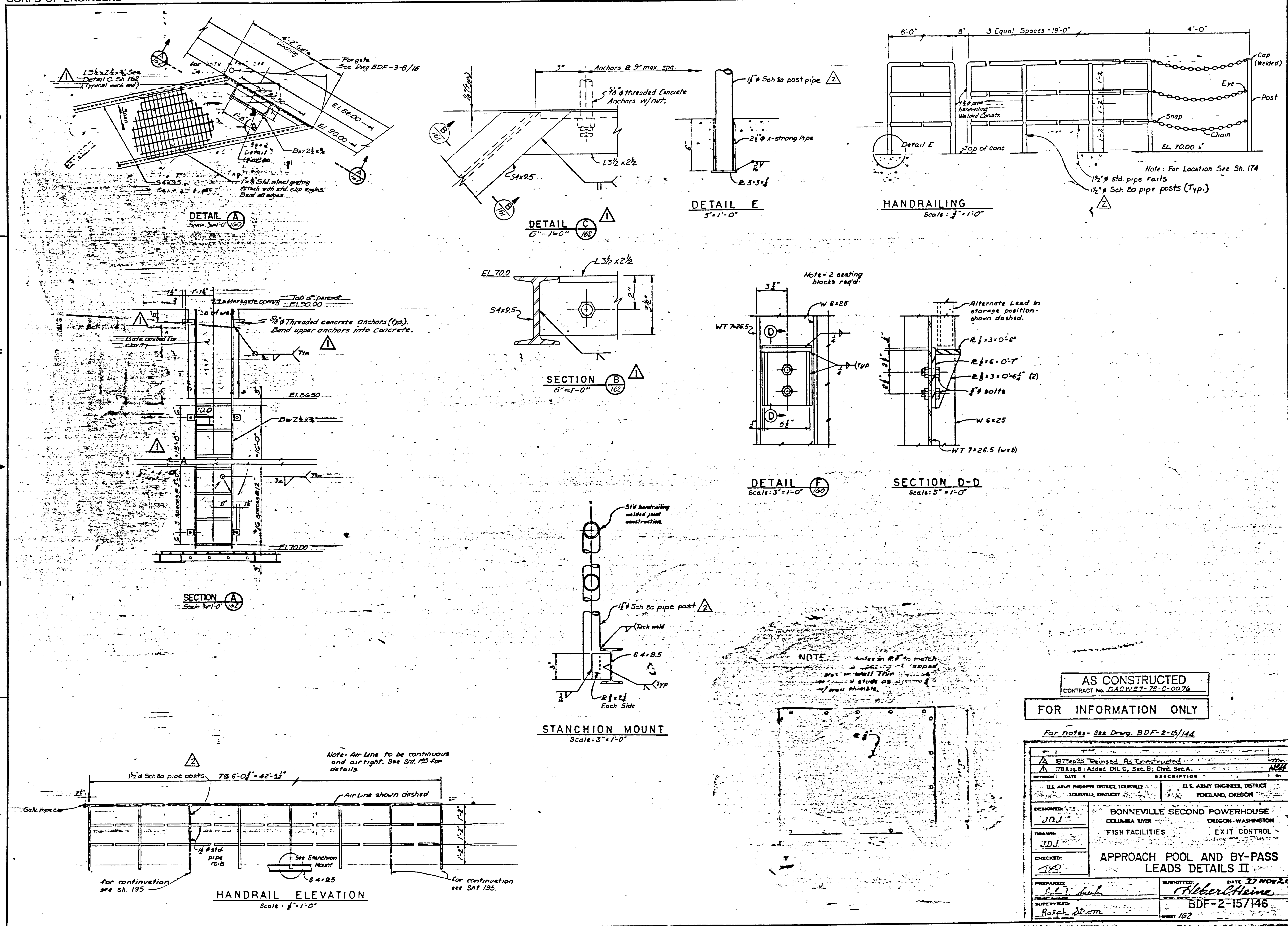
U.S. ARMY ENGINEER DISTRICT
PORTLAND, OREGON

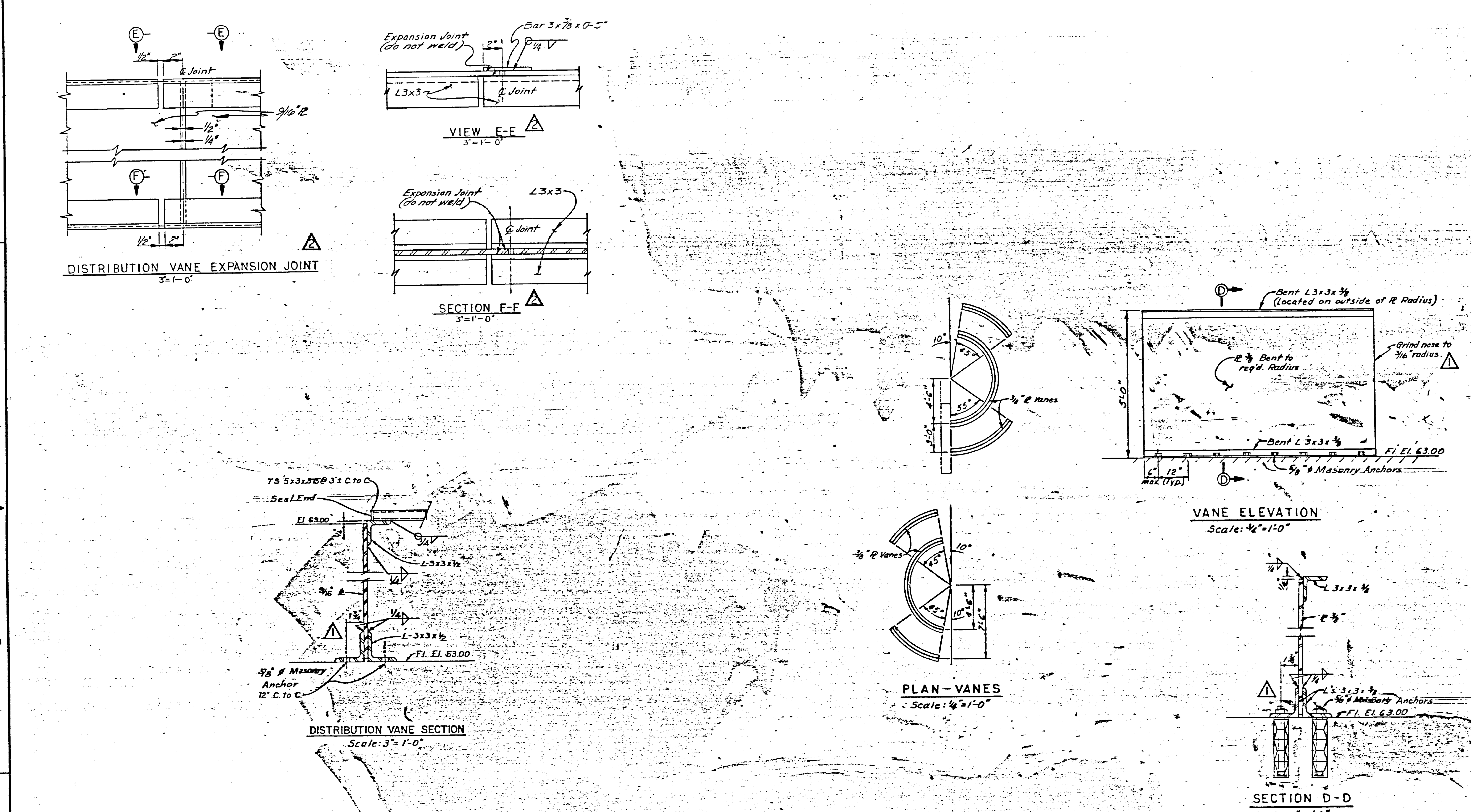
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES — EXIT CONTROL
APPROACH POOL AND BY-PASS LEADS DETAILS I

Designed: JDJ
Drawn: CHD
Checked: JEB
Submitted: Herbert Heine
Date: 77 Nov 21

BDF-2-15/145
Sheet 161

VOL NO. V


DETAIL A
Scale: 3/4"=1'-0"
DETAIL C
6"=1'-0"
DETAIL E
3"=1'-0"
HANDRAILING
Scale: 1/4"=1'-0"
Note: For Location See Sh. 174
1½"φ std. pipe rails
1½"φ Sch 80 pipe posts (Typ.)
Cap (Welded)
Eye
Post
Snap
Chain
EL 70.00
Top of conc.
1½"φ Sch 80 post pipe
2½"φ x-strong Pipe
Anchors @ 9" max. spa.
5/8"φ threaded Concrete Anchors w/nut.
L3½x2½
S4x9.5
SECTION B
6"=1'-0"
EL 70.0
Note - 2 seating blocks req'd.
W 6x25
WT 7x26.5
DETAIL F
Scale: 3"=1'-0"
SECTION D-D
Scale: 3"=1'-0"
Alternate Lead in storage position shown dashed.
3/4"φ bolts
WT 7x26.5 (web)
Top of parapet El. 90.00
5/8"φ Threaded concrete anchors (typ).
Bend upper anchors into concrete.
El. 86.50
Bar 2½x3/8
EL 70.00
SECTION A
Scale: 3/4"=1'-0"
Std handrailing welded joint construction.
1½"φ Sch 80 pipe post
Tack weld
S 4x9.5
Each Side
STANCHION MOUNT
Scale: 3"=1'-0"
Note - Air Line to be continuous and airtight. See Sht. 195 for details.
1½"φ Sch 80 pipe posts
7@6'-0¼"=42'-5¾"
Air Line shown dashed
Galv. pipe cap
1½"φ std. pipe rails
See Stanchion Mount
S 4x9.5
for continuation see sh. 195
for continuation see Sht 195.
HANDRAIL ELEVATION
Scale: 1/4"=1'-0"
AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076
FOR INFORMATION ONLY
For notes - See Drwg. BDF-2-15/144
Revised As Constructed
Added Dtl. C, Sec. B; Chnd. Sec. A.
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER DISTRICT
PORTLAND, OREGON
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER
OREGON-WASHINGTON
FISH FACILITIES
EXIT CONTROL
APPROACH POOL AND BY-PASS
LEADS DETAILS II
JDJ
BDF-2-15/146
162



Note:
1. See Dwg. BDF-2-15/121 For Location of Vanes and expansion Joints. △2
2. For notes See Dwg. BDF-2-15/144. △2

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

For Notes: See BDF-2-15/144

REVISION	DATE	DESCRIPTION	BY
△3	87Sep23	Revised As Constructed	
△2	79 July 9	Added Exp. Jt. & Notes.	
△1	78 Aug. 8	Added note to vane elev.; Added & deleted weld symbols.	

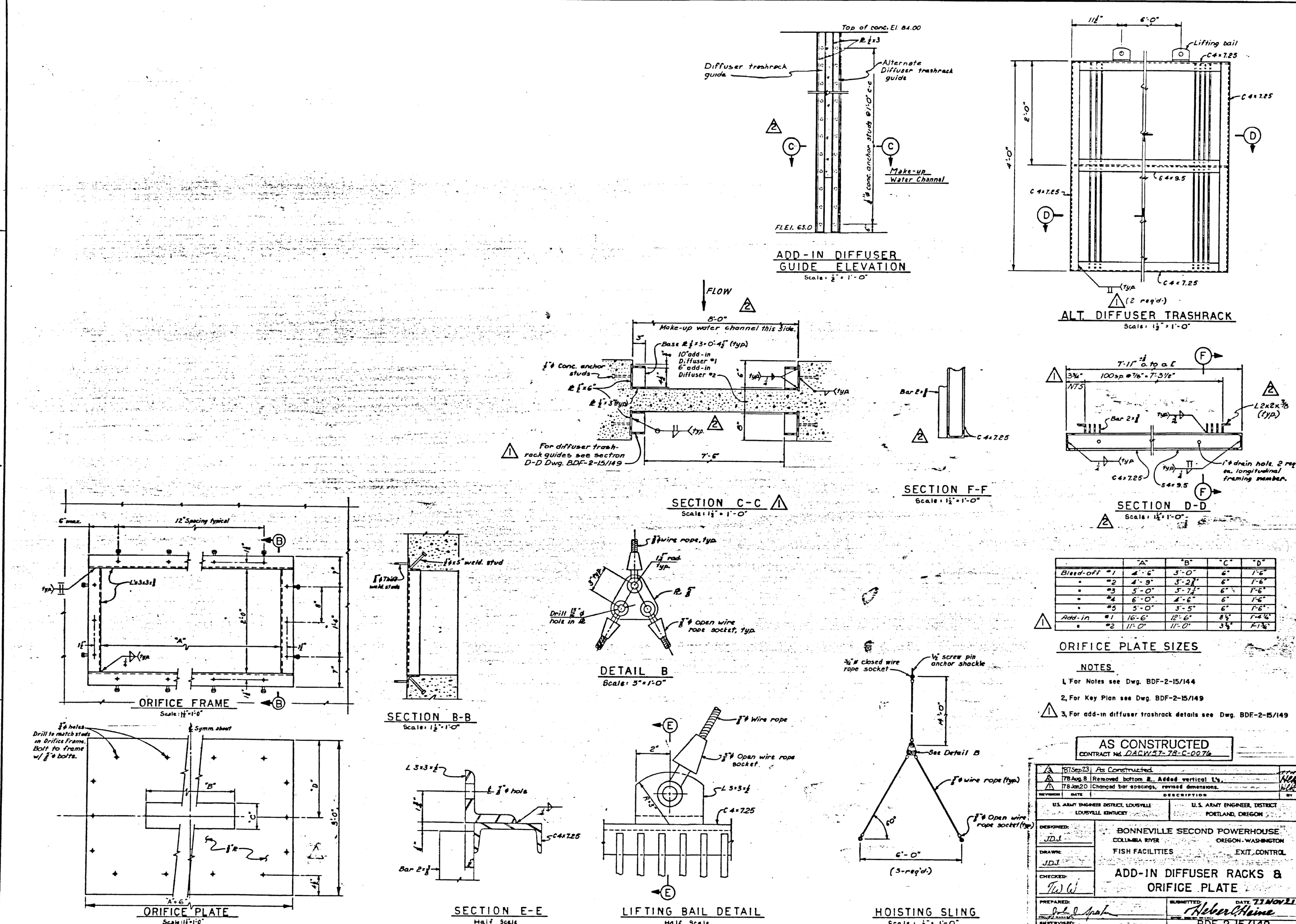
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER DISTRICT, PORTLAND, OREGON

DESIGNED: JXS
DRAWN: DLC
CHECKED: TWW
PREPARED: [signature]
SUPERVISED: Ralph Strom

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES — EXIT CONTROL

DISTRIBUTION PANEL & VANES

SUBMITTED: Heber C. Haine
DATE: 77 NOV 21
BDF-2-15/147
SHEET 163



ORIFICE PLATE SIZES

	"A"	"B"	"C"	"D"
Bleed-off #1	4'-6"	3'-0"	6"	1'-6"
" #2	4'-9"	3'-2⅜"	6"	1'-6"
" #3	5'-0"	3'-7¼"	6"	1'-6"
" #4	6'-0"	4'-6"	6"	1'-6"
" #5	5'-0"	3'-5"	6"	1'-6"
Add-in #1	16'-6"	12'-6"	8½"	1'-4¼"
" #2	11'-0"	11'-0"	3⅝"	1'-1¾"

NOTES

1. For Notes see Dwg. BDF-2-15/144
2. For Key Plan see Dwg. BDF-2-15/149
3. For add-in diffuser trashrack details see Dwg. BDF-2-15/149

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

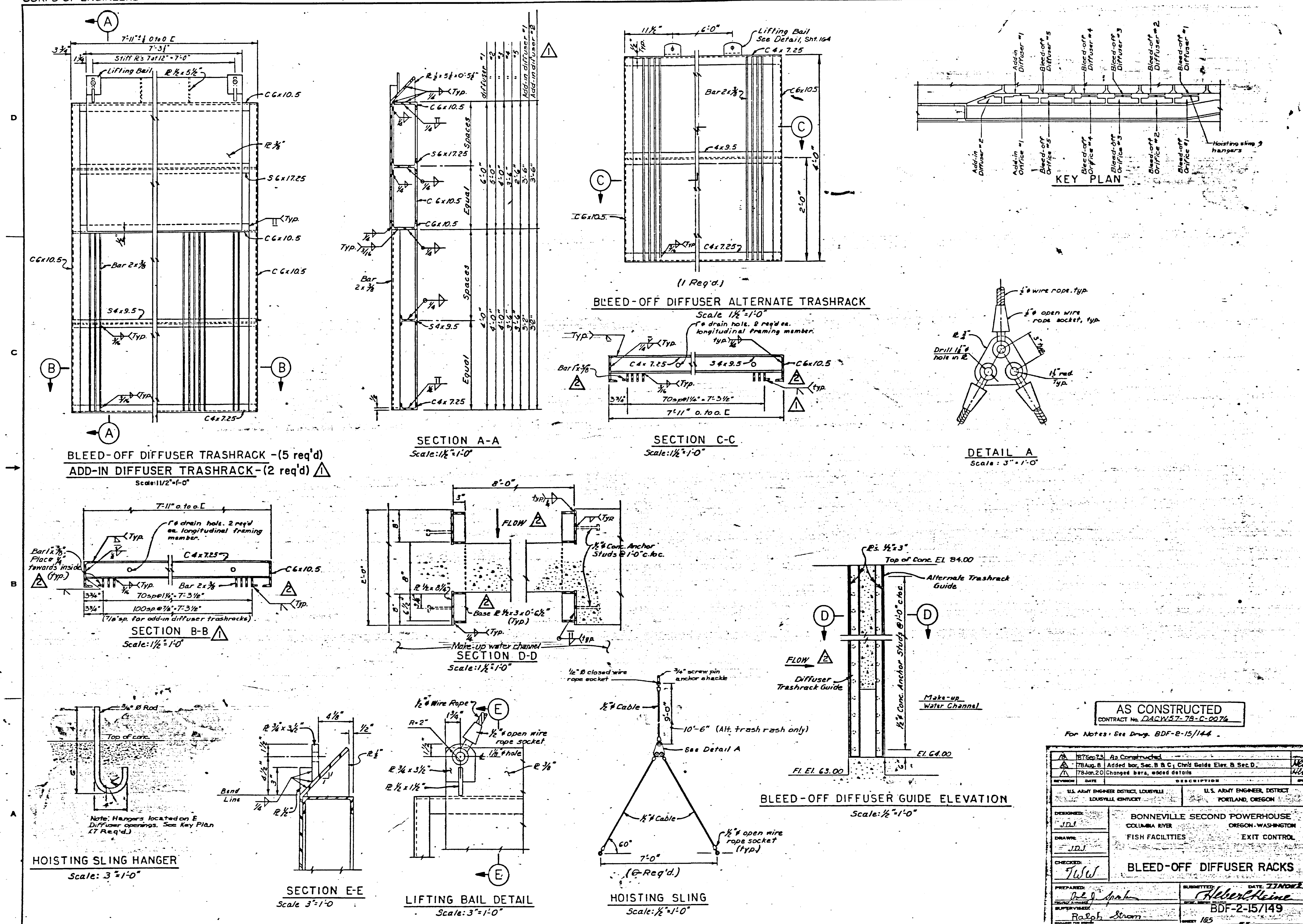
REVISION	DATE	DESCRIPTION	BY
3	87Sep23	As Constructed	
2	78Aug.8	Removed bottom ℞. Added vertical L's.	HCH
1	78Jan20	Changed bar spacings, revised dimensions.	HCH

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER DISTRICT, PORTLAND, OREGON

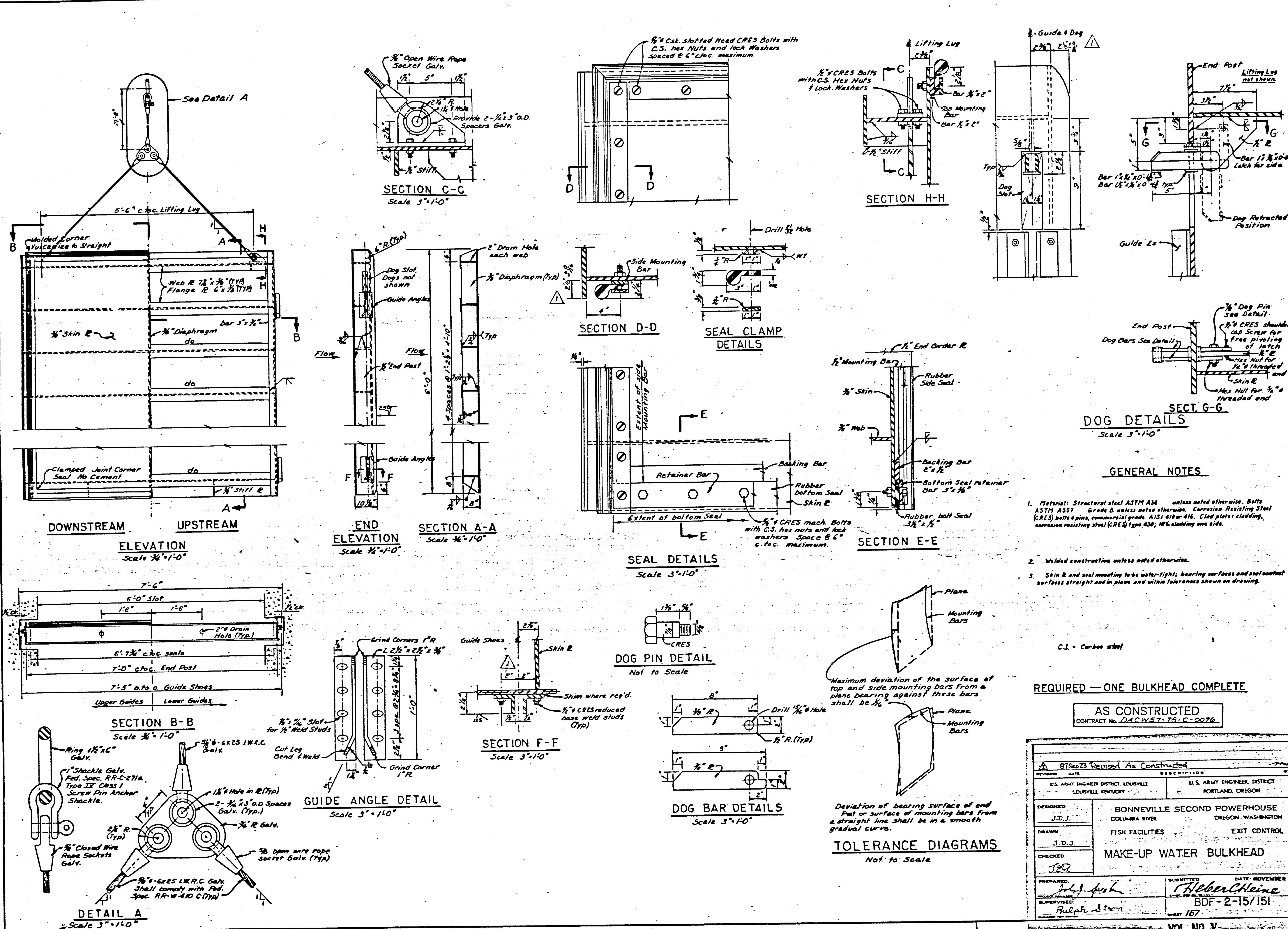
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES — EXIT CONTROL

ADD-IN DIFFUSER RACKS & ORIFICE PLATE

DESIGNED: JDJ
DRAWN: JDJ
CHECKED: TW W
PREPARED: John J. Spahn, PROJECT MANAGER
SUPERVISED: Ralph Strom, MANAGER FOR DESIGN
SUBMITTED: Heber C. Haine, CHIEF, DESIGN BRANCH — DATE 22 NOV 21
BDF-2-15/148
SHEET 164



BLEED-OFF DIFFUSER TRASHRACK -(5 req'd)
ADD-IN DIFFUSER TRASHRACK-(2 req'd)
Scale: 1 1/2"=1'-0"
SECTION A-A
Scale: 1 1/2"=1'-0"
BLEED-OFF DIFFUSER ALTERNATE TRASHRACK
(1 Req'd.)
Scale 1 1/2"=1'-0"
KEY PLAN
SECTION C-C
Scale: 1 1/2"=1'-0"
DETAIL A
Scale: 3"=1'-0"
SECTION B-B
Scale: 1 1/2"=1'-0"
SECTION D-D
Scale: 1 1/2"=1'-0"
BLEED-OFF DIFFUSER GUIDE ELEVATION
Scale: 1/2"=1'-0"
HOISTING SLING HANGER
Scale: 3"=1'-0"
Note: Hangers located on E Diffuser openings. See Key Plan (7 Req'd.)
SECTION E-E
Scale 3"=1'-0"
LIFTING BAIL DETAIL
Scale: 3"=1'-0"
HOISTING SLING
(6 Req'd.)
Scale: 1/2"=1'-0"
AS CONSTRUCTED
CONTRACT No. DACW57-79-C-0076
For Notes: See Drwg. BDF-2-15/144.
78Sep.23 As Constructed
78Aug.8 Added bar, Sec. B & C; Chn'd Guide Elev. & Sec. D.
78Jan.20 Changed bars, added details
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER, DISTRICT PORTLAND, OREGON
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON-WASHINGTON
FISH FACILITIES EXIT CONTROL
BLEED-OFF DIFFUSER RACKS
DESIGNED: JDJ
DRAWN: JDJ
CHECKED: TWW
SUPERVISED: Ralph Strom
BDF-2-15/149
SHEET 165



GENERAL NOTES

1. Material: Structural steel ASTM A36 unless noted otherwise. Bolts ASTM A307 Grade B unless noted otherwise. Corrosion Resisting Steel (CRES) bolts & pins, commercial grade AISI 410 or 416. Clad plate: cladding, corrosion resisting steel (CRES) type 430; 10% cladding one side.

2. Welded construction unless noted otherwise.

3. Skin ℞ and seal mounting to be water-tight; bearing surfaces and seal contact surfaces straight and in plane and within tolerances shown on drawing.

C.S. = Carbon steel

REQUIRED — ONE BULKHEAD COMPLETE

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

REVISION	DATE	DESCRIPTION	BY
1	87Sep23	Revised As Constructed	

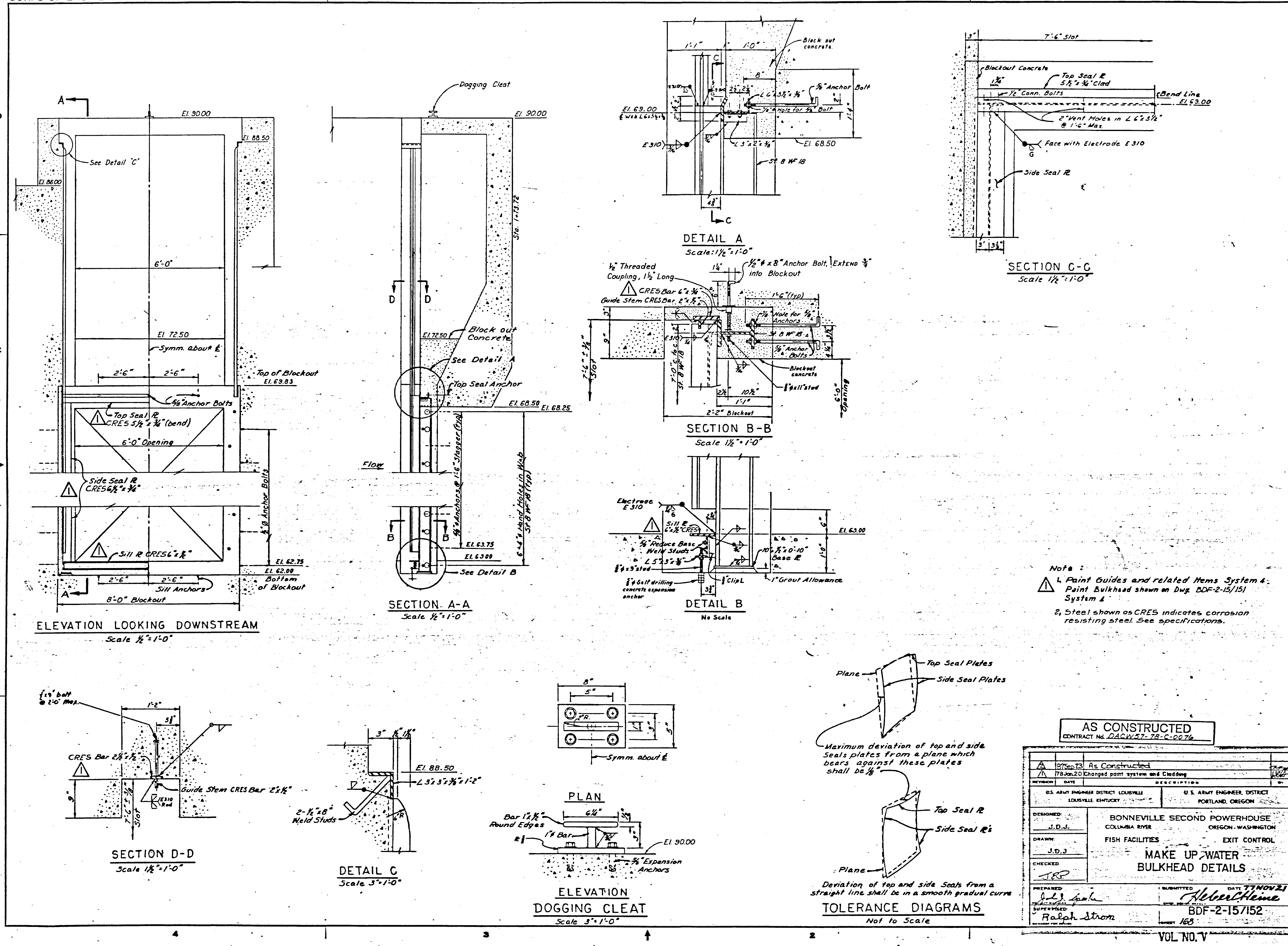
U.S. ARMY ENGINEER DISTRICT LOUISVILLE, LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER DISTRICT, PORTLAND, OREGON

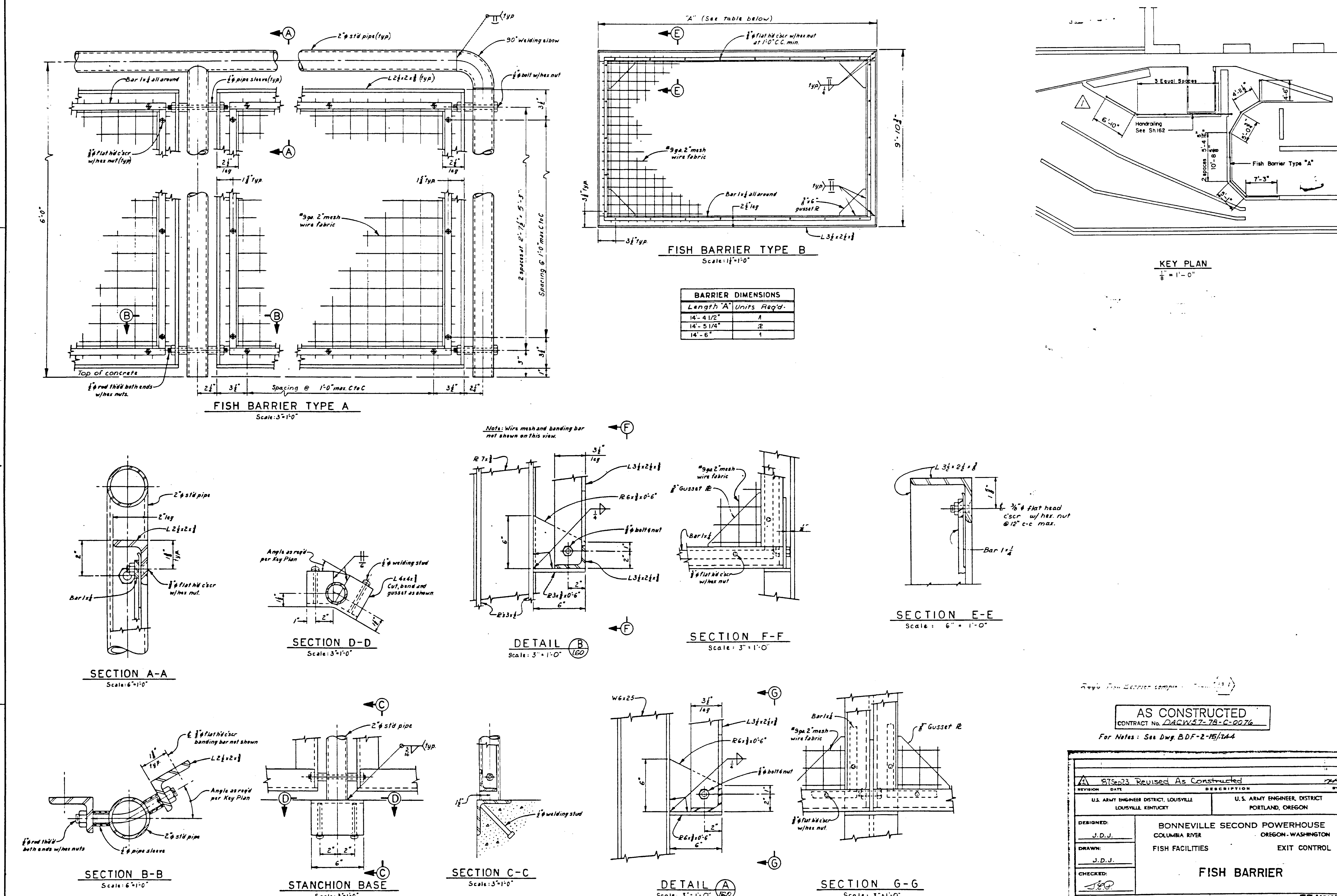
DESIGNED: J.D.J.
DRAWN: J.D.J.
CHECKED: J.B.

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON-WASHINGTON
FISH FACILITIES — EXIT CONTROL
MAKE-UP WATER BULKHEAD

PREPARED: [signature]
SUBMITTED: Heber C Heine
DATE: NOVEMBER
SUPERVISED: Ralph Stron
BDF-2-15/151
SHEET 167

VOL. NO. V


ELEVATION LOOKING DOWNSTREAM
Scale 1/2" = 1'-0"
See Detail "C"
El. 90.00
El. 88.50
El. 86.00
6'-0"
El. 72.50
Symm. about ℄
Top of Blockout El. 69.83
5/8" Anchor Bolts
Top Seal ℞ CRES 5 1/2" x 3/4" (bend)
6'-0" Opening
Side Seal ℞ CRES 6 1/2" x 3/4"
5/8" ⌀ Anchor Bolts
Sill ℞ CRES 6" x 1/2"
El. 62.75
El. 62.00
Bottom of Blockout
Sill Anchors
8'-0" Blockout
SECTION A-A
Scale 1/2" = 1'-0"
Dogging Cleat
Sta. 1+13.72
Block out Concrete
See Detail A
Top Seal Anchor
El. 68.50
El. 68.25
Flow
5/8" Anchors @ 1'-6" Stagger (typ)
6-4" ⌀ Hand Holes in Web St 8 WF 18 (typ)
El. 63.75
El. 63.00
See Detail B
DETAIL A
Scale: 1 1/2" = 1'-0"
Block out concrete
5/8" Anchor Bolt
El. 69.00
El. 68.50
E 310
St 8 WF 18
SECTION B-B
Scale 1 1/2" = 1'-0"
1/2" Threaded Coupling, 1 1/2" Long
1/2" ⌀ x 8" Anchor Bolt, Extend 3/4" into Blockout
CRES Bar 6" x 3/4"
Guide Stem CRES Bar 2" x 1/2"
Blockout concrete
2'-2" Blockout
6'-0" Opening
7'-6" Slot
DETAIL B
No Scale
Electrode E 310
Sill ℞ 6" x 1/2" CRES
5/8" Reduce Base Weld Studs
El. 63.00
1" Grout Allowance
Self drilling concrete expansion anchor
SECTION C-C
Scale 1 1/2" = 1'-0"
7'-6" Slot
Blockout Concrete
Top Seal ℞ 5 1/2" x 3/4" Clad
1/2" Conn. Bolts
Bend Line
El. 69.00
2" Vent Holes in ∠ 6" x 3 1/2" @ 1'-6" Max
Face with Electrode E 310
Side Seal ℞
Note:
1. Paint Guides and related items System 4. Paint Bulkhead shown on Dwg. BDF-2-15/151 System 4.
2. Steel shown as CRES indicates corrosion resisting steel. See specifications.
SECTION D-D
Scale 1 1/2" = 1'-0"
CRES Bar 2 1/2" x 1/2"
Guide Stem CRES Bar 2" x 1/2"
7'-6" Slot
DETAIL C
Scale 3" = 1'-0"
El. 88.50
2-1/2" x 8" Weld Studs
PLAN
ELEVATION
DOGGING CLEAT
Scale 3" = 1'-0"
Symm. about ℄
El. 90.00
5/8" Expansion Anchors
TOLERANCE DIAGRAMS
Not to Scale
Plane
Top Seal Plates
Side Seal Plates
Maximum deviation of top and side Seals plates from a plane which bears against these plates shall be 1/8"
Top Seal ℞
Side Seal ℞'s
Deviation of top and side Seals from a straight line shall be in a smooth gradual curve
AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076
27 Sep 73 As Constructed
17 Jan 20 Changed paint system and Cladding
U.S. ARMY ENGINEER DISTRICT LOUISVILLE, LOUISVILLE, KENTUCKY
U.S. ARMY ENGINEER DISTRICT, PORTLAND, OREGON
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON - WASHINGTON
FISH FACILITIES EXIT CONTROL
MAKE UP WATER BULKHEAD DETAILS
Ralph Strom
BDF-2-15/152
VOL NO. V



BARRIER DIMENSIONS	
Length "A"	Units Req'd.
14'- 4 1/2"	1
14'- 5 1/4"	2
14'- 6"	1

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

For Notes: See Dwg. BDF-2-15/144

REVISION	DATE	DESCRIPTION	BY
1	87Sep23	Revised As Constructed	

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
LOUISVILLE, KENTUCKY

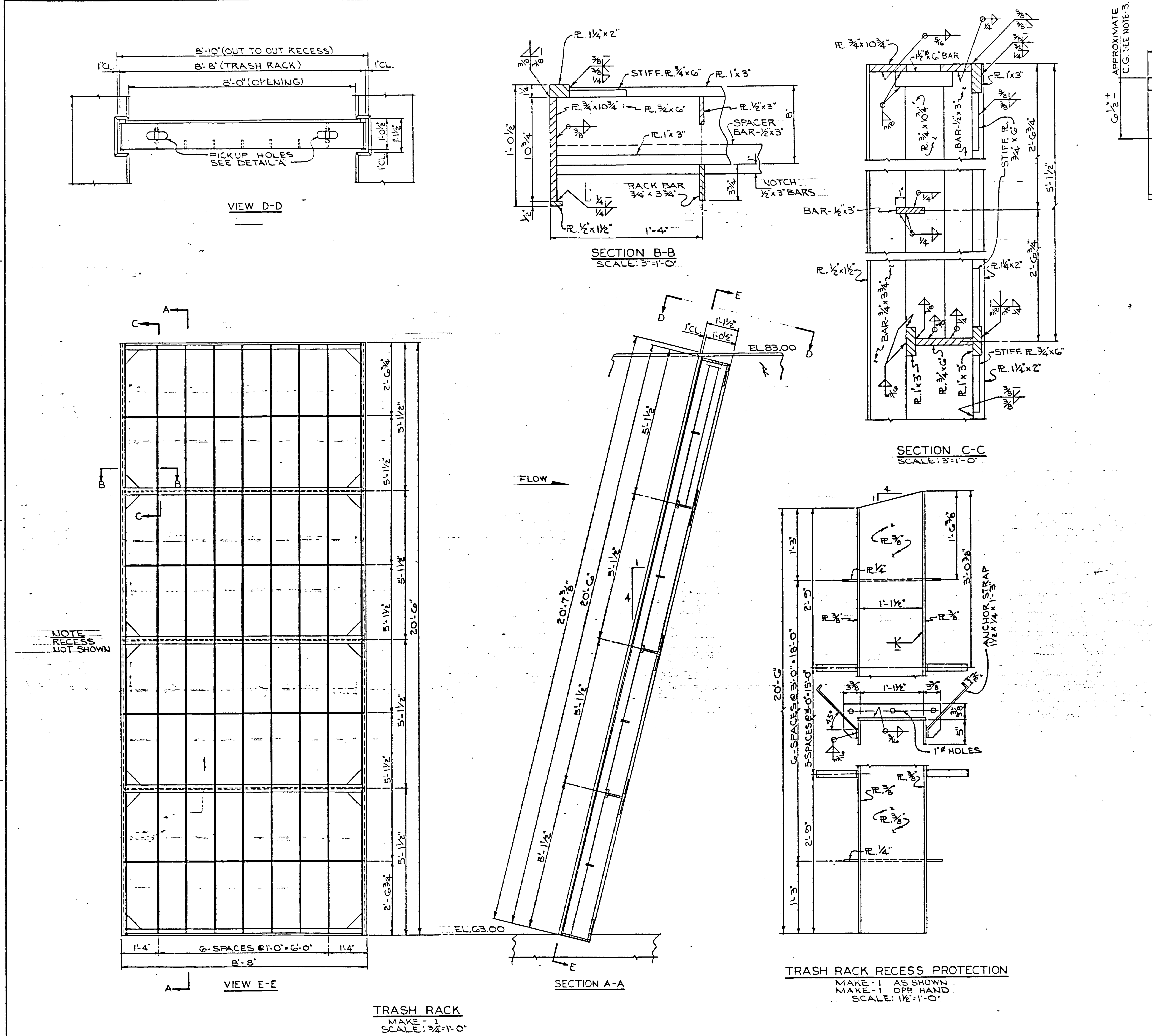
U. S. ARMY ENGINEER, DISTRICT
PORTLAND, OREGON

DESIGNED: J.D.J.
DRAWN: J.D.J.
CHECKED: J.E.P.

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER — OREGON - WASHINGTON
FISH FACILITIES — EXIT CONTROL

FISH BARRIER

PREPARED: PROJECT MANAGER
SUPERVISED: Ralph Strom, MANAGER FOR DESIGN
SUBMITTED: Heber C. Heine — DATE: 27 NOV 21
BDF-2-15/158
SHEET 174



NOTES

1. ALL WELDS TO BE CONTINUOUS.
2. ALL MATERIAL SHALL BE STRUCTURAL STEEL A.S.T.M. A-36 UNLESS OTHERWISE NOTED OR SPECIFIED.
3. LOCATE CENTER OF GRAVITY BY PICK-UP TEST IN SHOP, PRIOR TO CUTTING HOLES.
4. *All trashrack and guide surfaces, except embedded surfaces, shall be painted with system #4 of the specifications.*

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

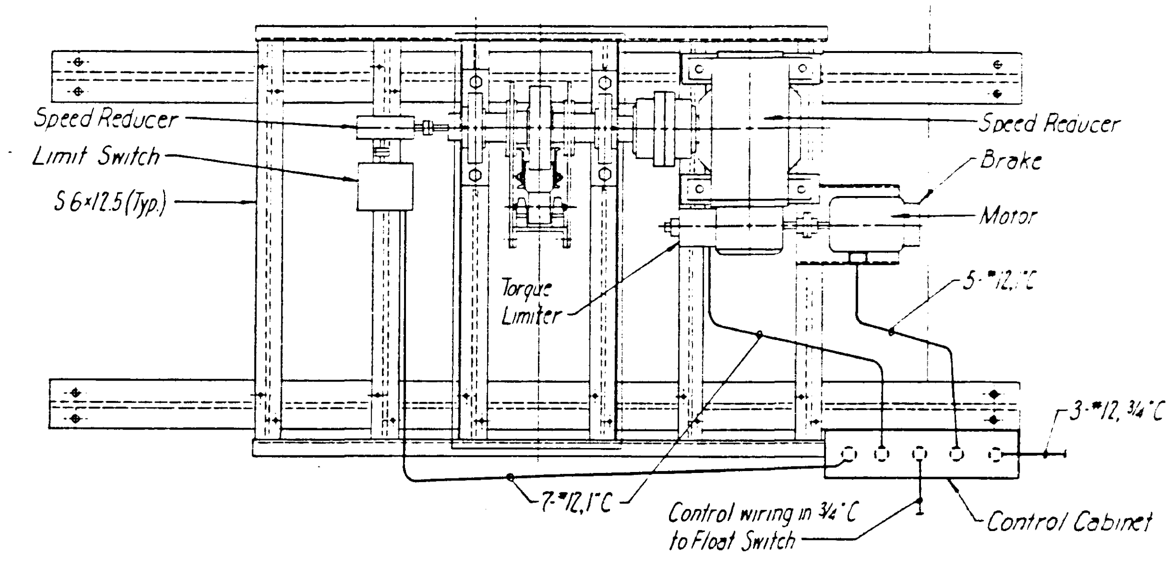
REVISION	DATE	DESCRIPTION	BY
2	87 Sep 23	As Constructed	
1	78 Aug 8	Added General Note No. 4	

U.S. ARMY ENGINEER DISTRICT, HUNTINGTON, HUNTINGTON, WEST VIRGINIA
U. S. ARMY ENGINEER, DISTRICT PORTLAND, OREGON

DESIGNED: J B
DRAWN: D.D.S
CHECKED: J B

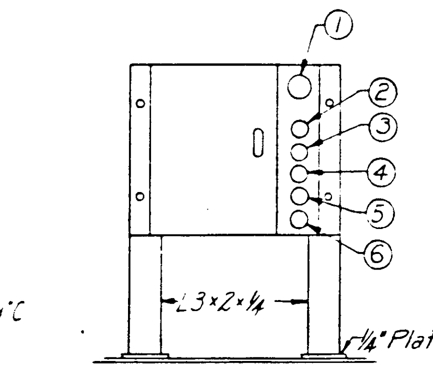
BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON - WASHINGTON
FISH FACILITIES – EXIT CONTROL
EXIT CHANNEL
TRASH RACK

PREPARED: M. D. Berm
SUBMITTED: Helen C. Heine DATE: 77 NOV 21
SUPERVISED: Ralph Strom
SHEET 179
BDF-2-15 / 163



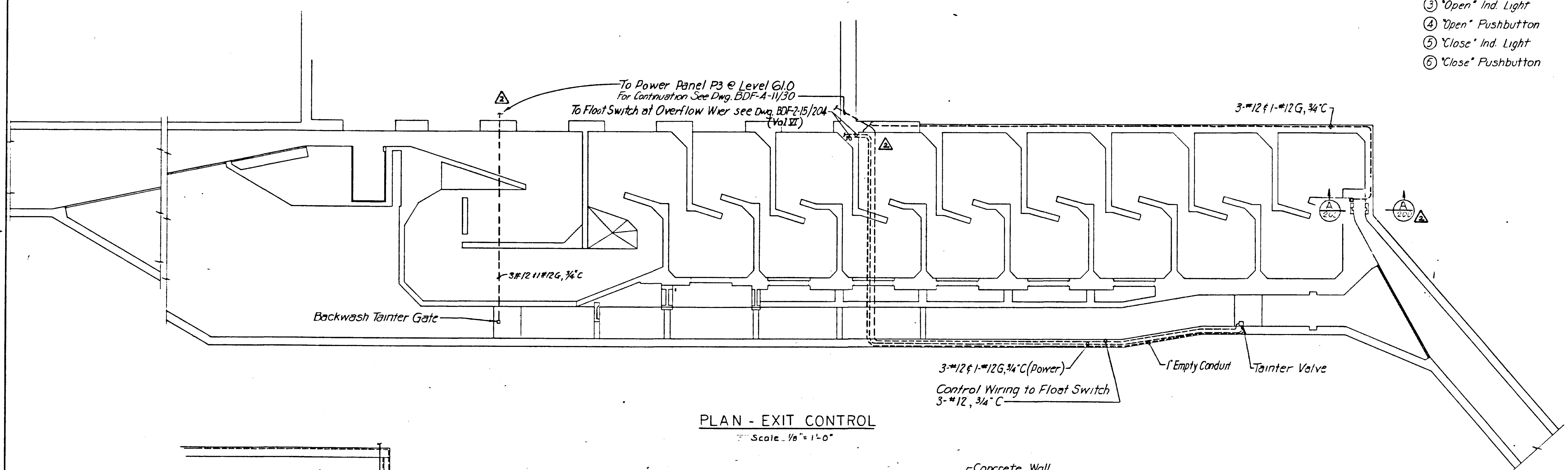
PLAN

TAINTER VALVE
Scale: None

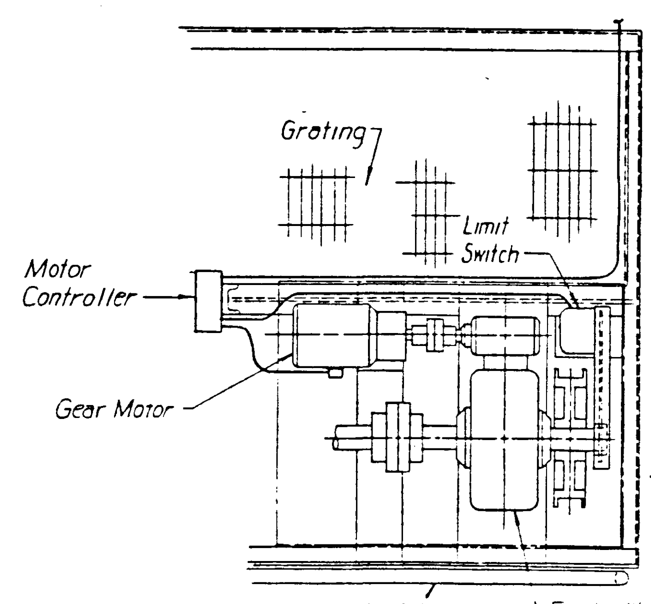


⚠ FRONT VIEW OF CONTROL CABINET

Nameplate Data
① "Power On" Ind. Light
② "On-Off-Auto" Key Operated Switch
③ "Open" Ind. Light
④ "Open" Pushbutton
⑤ "Close" Ind. Light
⑥ "Close" Pushbutton

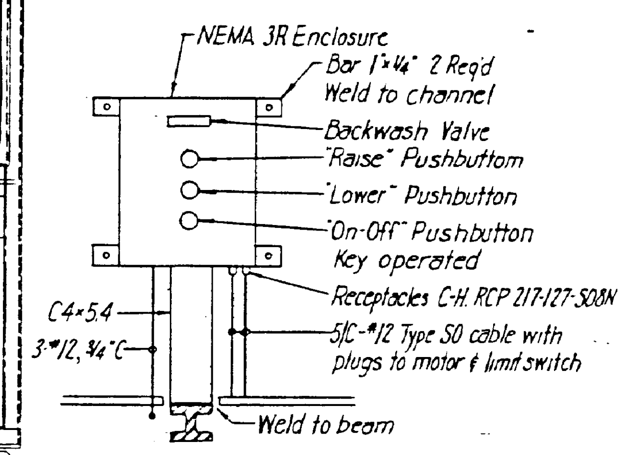


PLAN - EXIT CONTROL
Scale ⅛" = 1'-0"

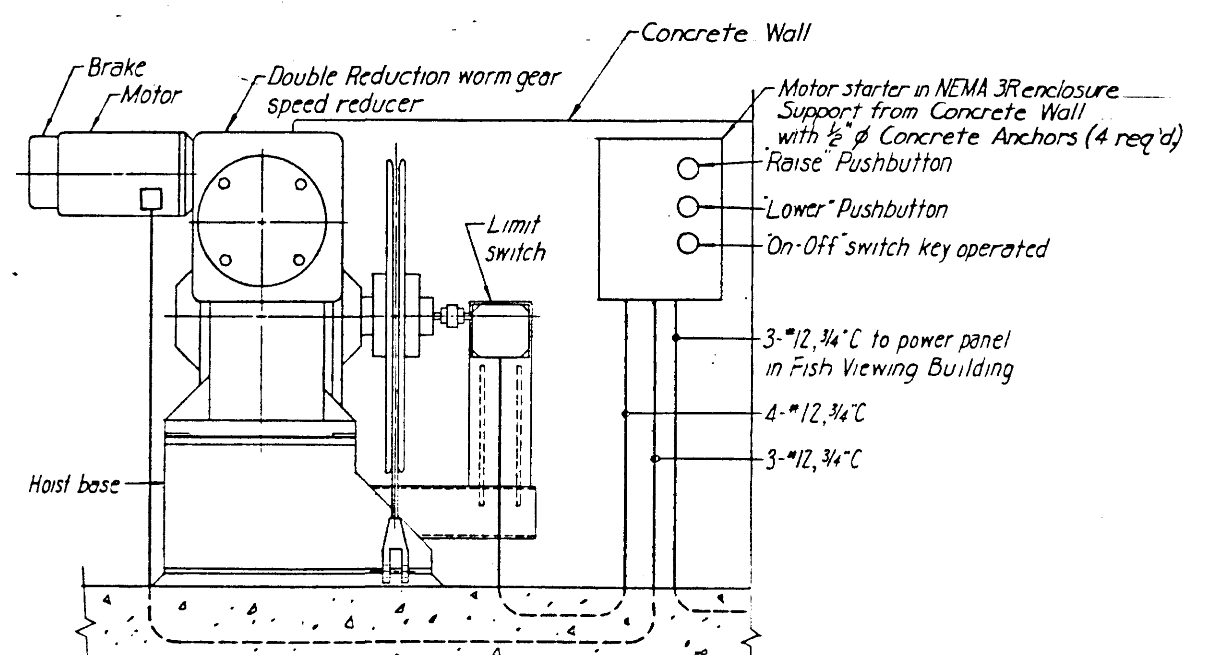


PLAN

BACKWASH TAINTER GATE
Scale: None



MOTOR CONTROLLER



⚠ EXIT GATE HOIST
ELEVATION A-A
Scale: None

⚠ Note:
For Control Diagrams See Sheet 201

AS CONSTRUCTED
CONTRACT No. DACW57-78-C-0076

Revision	Date	Description	By
3	18 Sep 83	As Constructed	
2	17 Mar 78	RELOCATED CONDUIT, MINOR CORRECTIONS	
1	7 FEB 74	GENERAL REVISIONS	S.F.B.

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
LOUISVILLE, KENTUCKY

U.S. ARMY ENGINEER, DISTRICT
PORTLAND, OREGON

DESIGNED: S.F.B.
DRAWN: J.W.H.
CHECKED: W.A.F.
PREPARED:
SUPERVISED:

BONNEVILLE SECOND POWERHOUSE
COLUMBIA RIVER OREGON - WASHINGTON
FISH FACILITIES EXIT CONTROL
LADDER EXIT-PLAN & DETAILS

SUBMITTED: DATE 22 NOV 71
BDF-4-1179
SHEET 200

APPENDIX C

LIMITED ALTERNATIVES EVALUATION

1.0 Description

The CRSO EIS clearly specifies that the overall layout of the modified control section will be an Ice Harbor-style vertical slot with submerged orifice configuration; however, the PDT considered four variations to achieve the required layout. All four alternatives include a series of nine baffle pairs forming ten pools within the existing control section footprint, see Figure 1.

The primary differences between the alternatives are:

- The use of the bleed-off and add-in diffusers.
- Presence or absence of adjustable sills in the vertical slots.
- The location of the PIT tag detection array after modification.

Figure 1 shows an underlay of the existing serpentine exit control section with black lines and the general layout of the slot-and-orifice style baffle pairs (common to all alternatives) sketched with red lines.

Figure 1. General Layout of Baffle Pairs and Orifices (Alternatives 1 through 4), Plan View

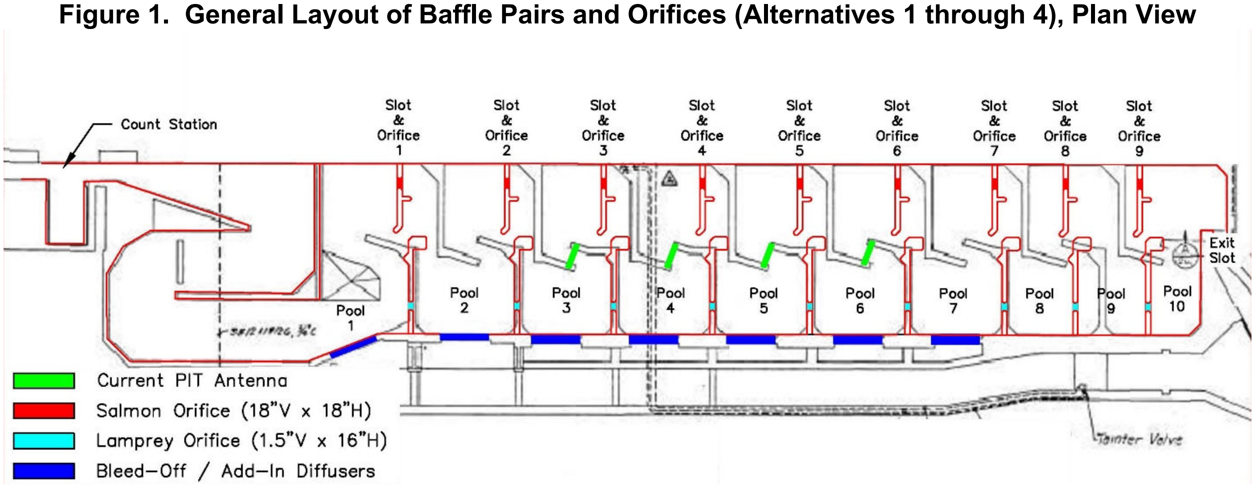
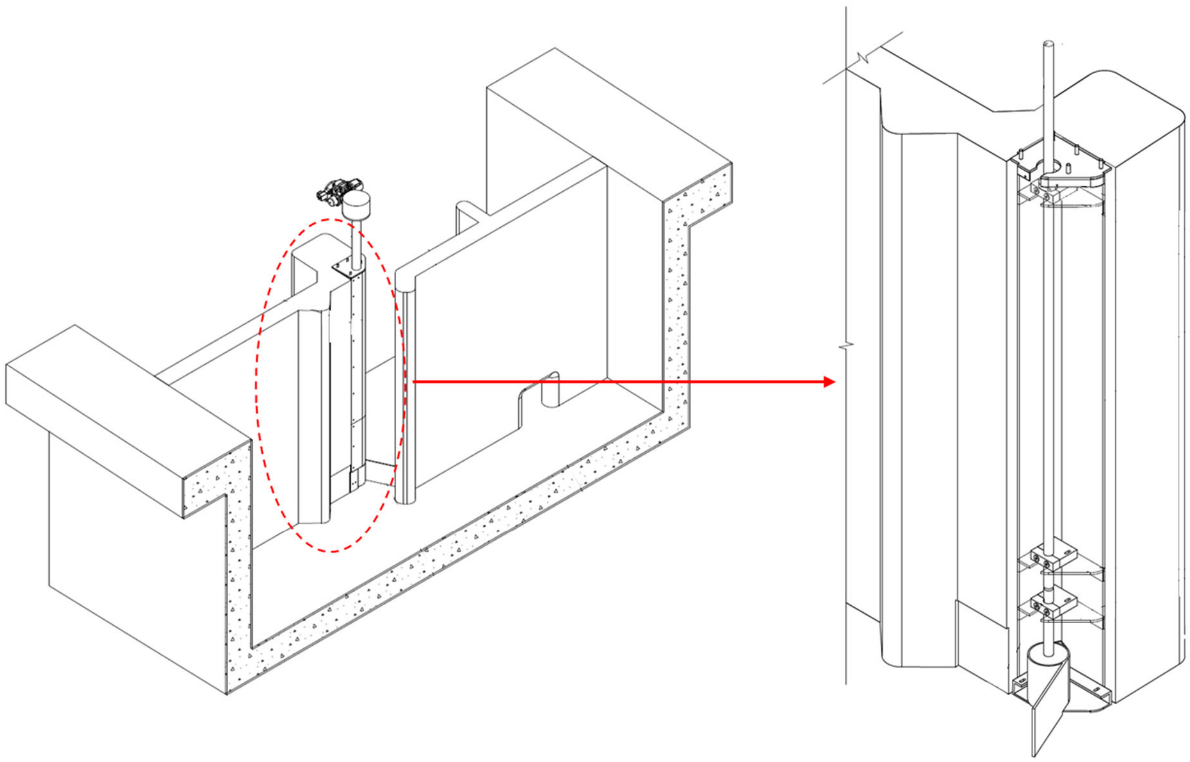


Figure 2 illustrates the concept of the adjustable sill gates using isometric views taken from the JDAN control section modification design.

Figure 2. Isometric View of the JDAN Adjustable Sill Gates

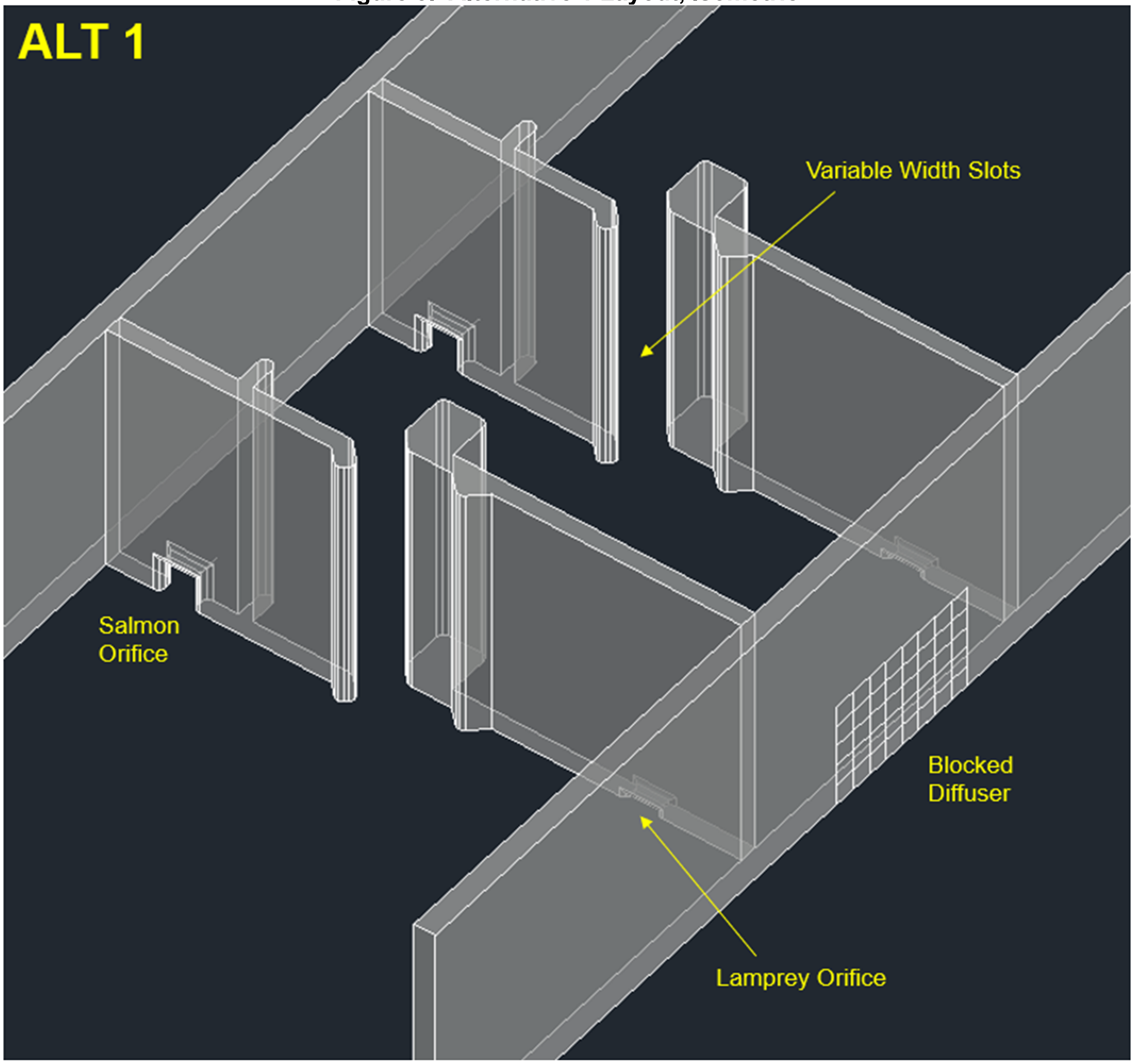


The four alternatives are described in Sections 1.1 through 1.4. A summary of the hydraulic analysis and evaluation of the alternatives is provided in Section 2.0.

1.1 Alternative 1: No Sills, Decommission Bleed-Off and Add-In Diffusers, PIT Tag Detection in Control Section

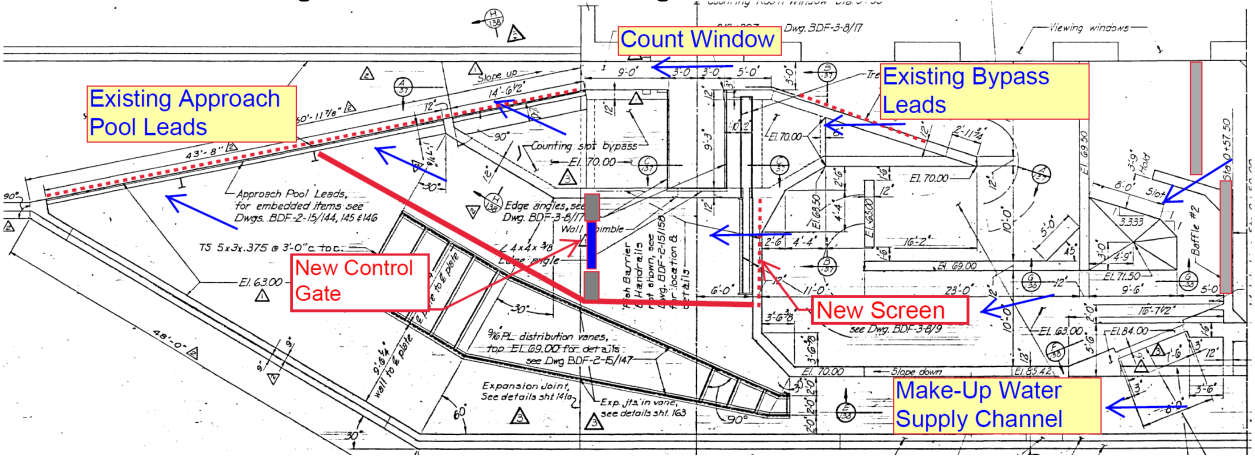
The objective of the first alternative is to simplify the hydraulics of the system and to return PIT tag detection to the control section after modification. The vertical slots would extend the full height of the baffles, with the bottom of the slot flush with the channel invert. No sills would be provided in any of the slots. Slot sills and any associated control mechanisms would interfere with the PIT tag antennas; therefore, a system without sills would allow the PIT tag antennas to be re-installed within the control section. The bleed-off and add-in diffusers would be sealed off to eliminate flow exchange between the control section and the make-up water supply channel. A conceptual rendering of Alternative 1 is shown in Figure 3.

Figure 3. Alternative 1 Layout, Isometric



Removing the bleed-off capability would result in an increased flow rate through the count station slot. With the count station crowder set to the maximum open width of 3 feet, the velocity through the slot would be 6.4 ft/s with the forebay at full pool elevation (EL 77 feet). The count station slot is frequently set to less than 3 feet to improve viewing at the count window. Narrowing the count station slot less than 3 feet would increase the flow velocity through the count station. The count station velocity would be unacceptably high for the Alternative 1 layout, and a new method to remove flow between the end of the control section and the count station would be required. To reduce the flow through the count station to an acceptable level, the pool downstream of the control section and behind the count station crowder would be divided into two chambers and a new screen and control gate would be added, see Figure 4.

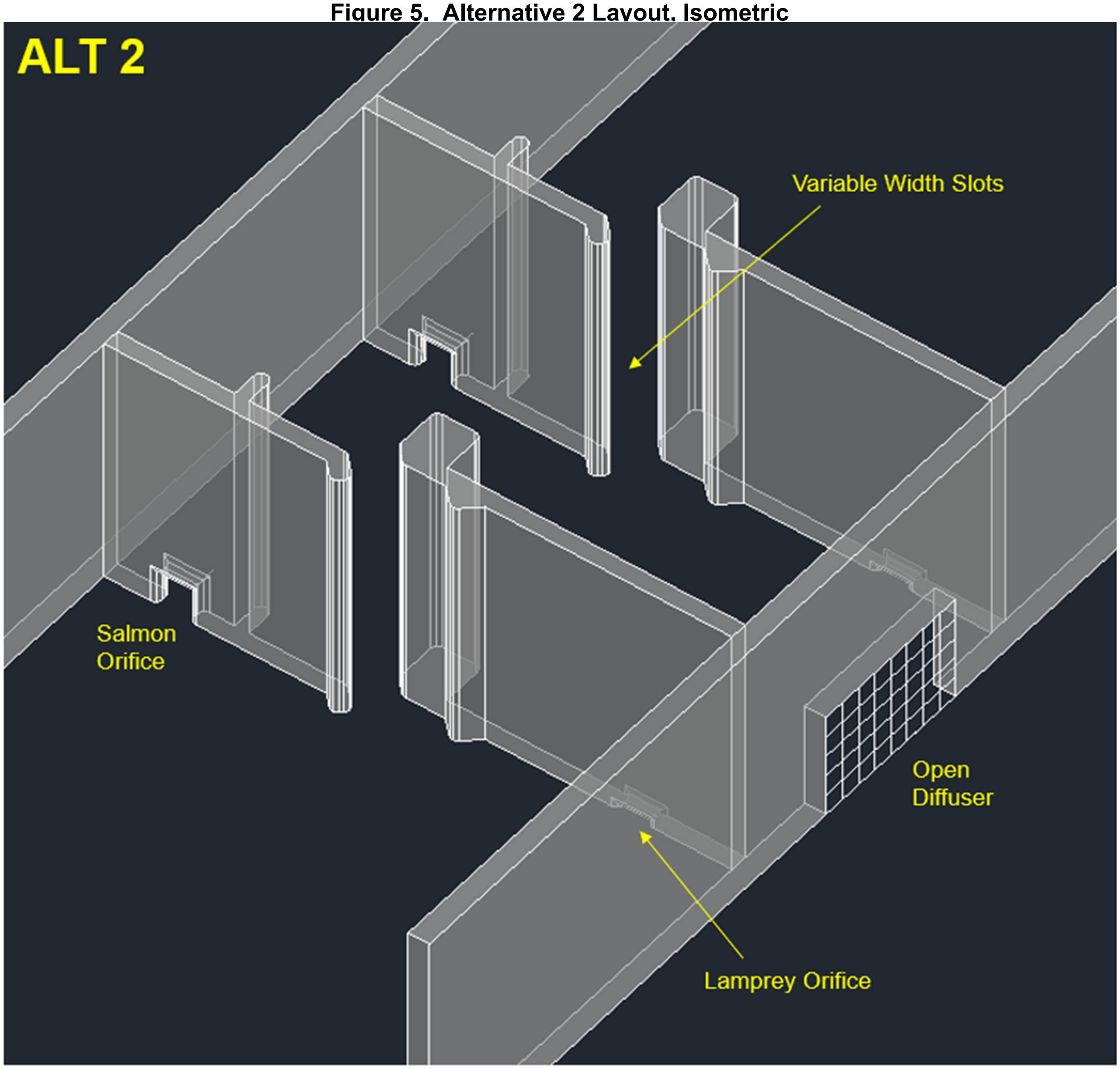
Figure 4. Alternative 1 – Changes to Count Station Area



1.2 Alternative 2: No Sills, Retain Bleed-Off and Add-In Diffusers, PIT Tag Detection in Control Section

The objective of the second alternative is to achieve the required hydraulic conditions in the control section without making modifications to the count station or adjacent pool, and to return PIT tag detection to the control section after modification. The vertical slots would extend the full height of the baffles, with the bottom of the slots flush with the channel invert. No sills would be provided in any of the slots. The PIT tag antennas would be re-installed within the control section. The bleed-off and add-in diffusers would remain open to allow flow exchange between the control section and the make-up water supply channel. A conceptual rendering of Alternative 2 is shown in Figure 5.

Figure 5. Alternative 2 Layout, Isometric



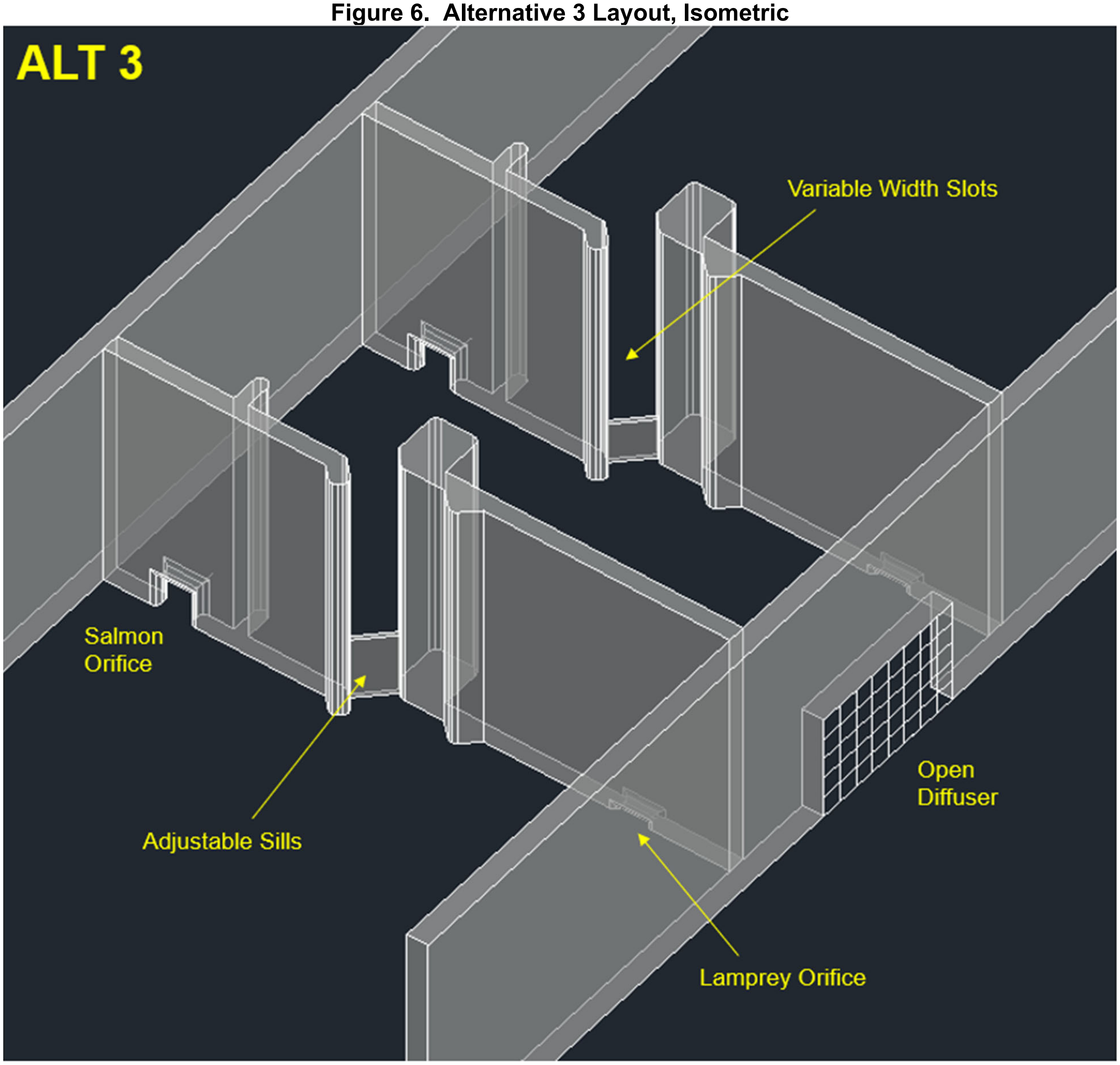
1.3 Alternative 3: Adjustable Sills, Retain Bleed-Off and Add-In Diffusers, PIT Tag Detection in Control Section

The John Day north fish ladder was modified to have a vertical slot and orifice control section, but to help accommodate the forebay fluctuations, particularly at the extremes of the operating range, adjustable sill gates were provided in the vertical slots. The John Day forebay has a larger forebay operating range (11 feet as compared to 7 feet at Bonneville) and the north fish ladder control section does not have add-in and bleed-off diffusers.

The objective of the third alternative is to assess whether the hydraulic conditions that are affecting fish passage success could be improved by adding adjustable sills to some of the slots. Adjustable sills would be provided in five of the nine slots; this would leave four slots without sill and would allow PIT tag antennas to be re-installed within the control section. The sills would range in height from 0.0 feet to 1.75 feet. The bleed-off and add-in diffusers would remain open to allow flow exchange between the control section and the make-up water supply channel.

A conceptual rendering of Alternative 3 is shown in Figure 6.

Figure 6. Alternative 3 Layout, Isometric

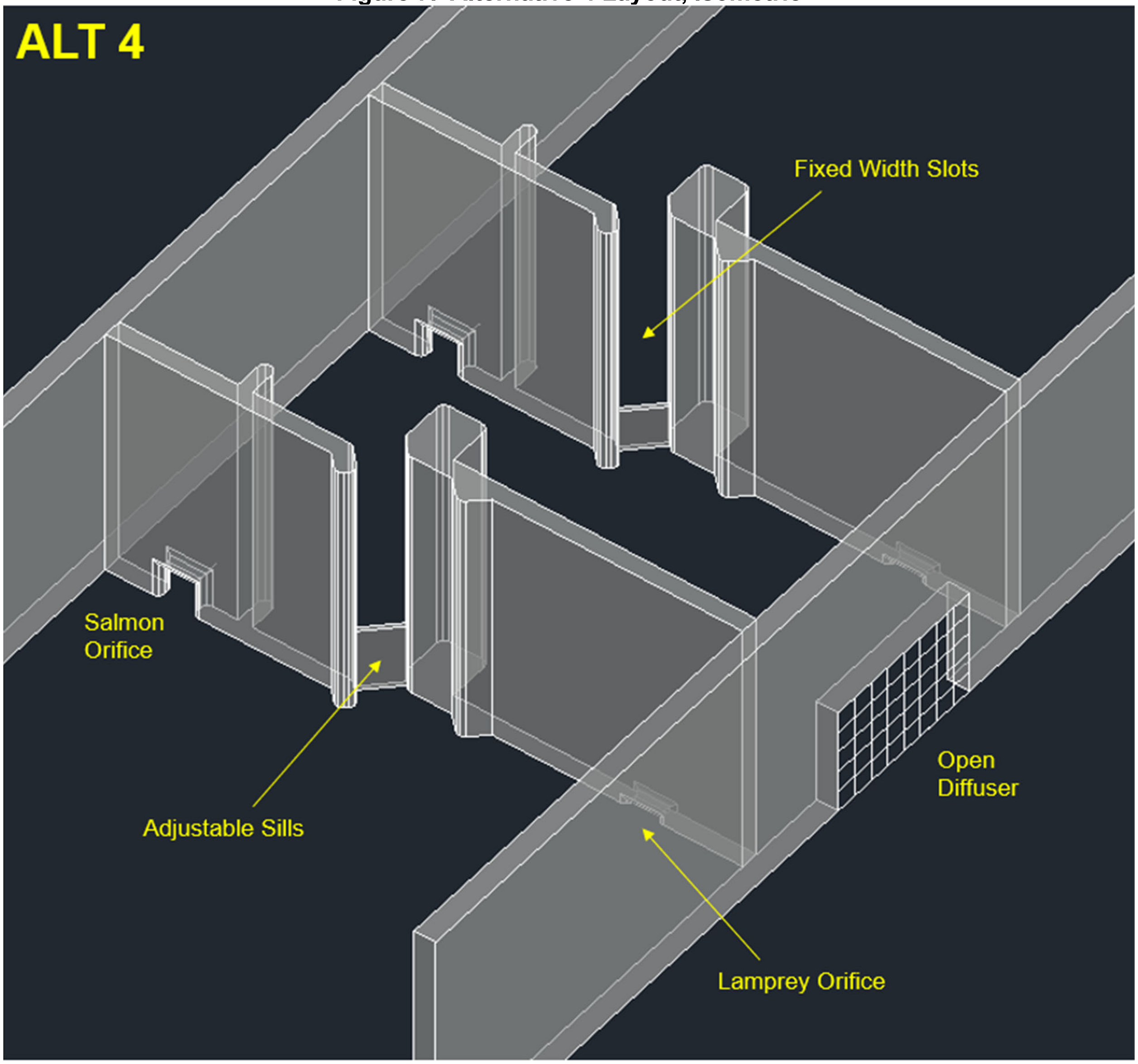


1.4 Alternative 4: Actuated (Adjustable) Slot Sills, Retain Bleed-Off and Add-In Diffusers, Relocate PIT Tag Detection

The objective of the fourth alternative is to assess whether the hydraulic conditions that are affecting fish passage success could be improved by adding adjustable sills to all the slots. The sills would range in height from 0.0 feet to 4.0 feet. The adjustable sills would preclude re-installation of PIT Tag detection within the control section. The most likely place to relocate PIT Tag detection would be in the exit channel, however, the exit channel is considerably wider than the slots covered by the existing antennas. If this alternative is selected as the preferred alternative, some amount of investigation would be required to confirm that detection accuracy comparable to the existing system could be achieved. The bleed-off and add-in diffusers would remain open to allow flow exchange between the control section and the make-up water supply channel. Slot widths would be fixed to allow for ease of construction and installation of adjustable sills.

A conceptual rendering of Alternative 4 is shown in Figure 7.

Figure 7. Alternative 4 Layout, Isometric



2.0 Evaluation

The PDT evaluated the alternatives based on an assessment of the relative improvement of the hydraulic conditions affecting fish passage including operations, maintenance, monitoring requirements, cost, and constructability.

2.1 Fish Passage Improvement

The hydraulic conditions of head differential between pools and velocity through the slots and orifices were calculated for each alternative using a spreadsheet model. The computed values were compared between alternatives to assess relative performance and checked against the criteria and guidelines presented in Section 2.6 of the main DDR. See Section Appendix D for calculation details.

The computed head differentials and slot and orifice velocities for each alternative are compared in Figure 8, Figure 9, and Figure 10 for a range of forebay (FB) elevations (all elevations are in Project datum, NGVD 29). These parameters are used to illustrate the difference in the hydraulic conditions that would affect fish passage. The target range for head drop between pools, per NMFS 2011, is 0.25 ft to 1.0 ft (equivalent velocity = 4 ft/s to 8 ft/s), and lower velocities through the slots and orifices is considered better for lamprey passage than higher velocities. Tabulated results, including a summary of the slot widths, pool lengths, sill heights, flow rates, head drops, and slot and orifice velocities are provided in Appendix D.

More refined analysis is being used to develop the design of the selected alternative, see Section 4.2.3 of the main report.

Figure 8. Comparison of Head Differentials, Alternatives 1 through 4

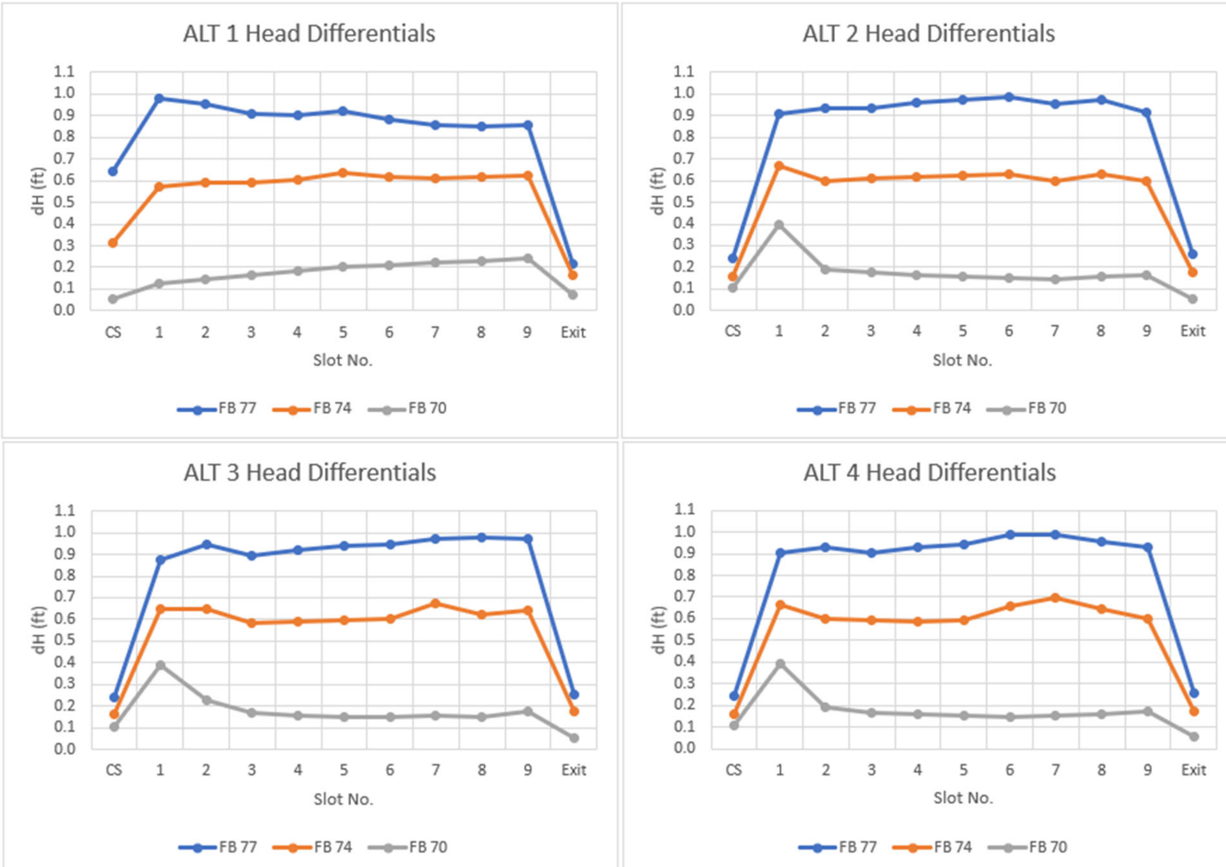


Figure 9. Comparison of Slot Velocities, Alternatives 1 through 4

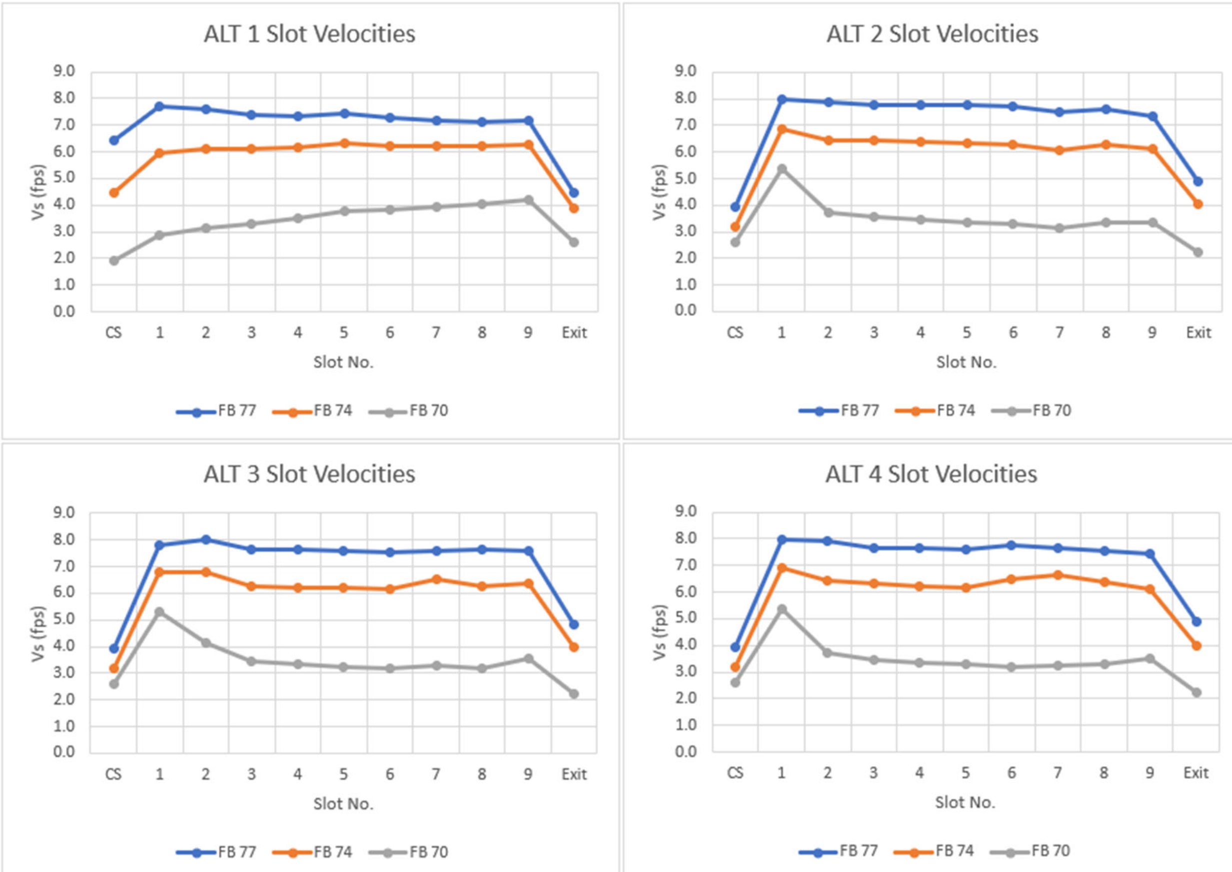
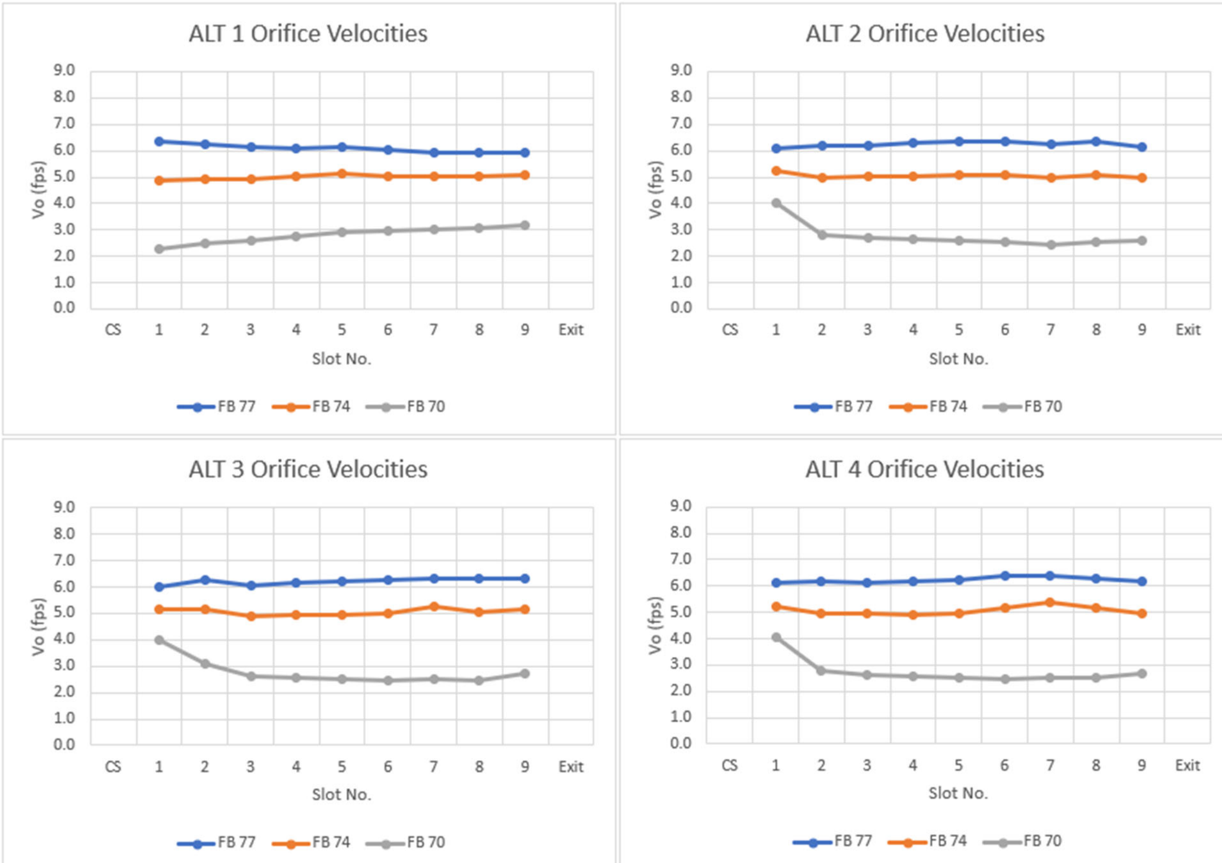


Figure 10. Comparison of Orifice Velocities, Alternatives 1 through 4



The comparisons presented in Figure 8, Figure 9, and Figure 10 demonstrate the following key findings:

- None of the alternatives meet present-day NMFS criteria for minimum head drop (0.25 feet) when the pool is at minimum operating level, EL 70 feet. The existing ladder has similarly low head differentials at low forebay level, and these are not thought to be an impediment to fish passage (USACE, 2005). It is also notable that the pool effectively never operates at EL 70 feet. In the past 25 years, the minimum pool recorded at Bonneville Dam was 71.2 feet and the forebay exceeded EL 72.7 feet ninety-five percent of the time, see Section3.1.1 of the main DDR. With the forebay at EL 71.2 feet, the minimum head drop criteria would be met for Alternatives 2, 3 and 4. At the 95th percentile forebay elevation, the minimum head drop criteria would be met for all alternatives. See AppendixD.
- Alternative 1 has marginally lower average slot velocities than Alternatives 2, 3 or 4. This is attributed to wider slot widths, despite the lack of bleed-off diffusers and a greater volume of flow that is passed through the slots in the lower part of the control section. However, Alternative 1 has increased head drop and high velocity through the count station.
- Alternatives 2, 3 and 4 are hydraulically very similar.

- Alternatives 3 and 4 are not preferred for fish passage; the sill gates degrade one potential passage route for lamprey because the slots are not flush with the floor.

Based on this comparison, Alternative 2 is preferred on the basis of fish passage characteristics.

2.2 Operation and Maintenance

The number and complexity of mechanical systems that are required for each alternative were used as a proxy for evaluating the operation and maintenance. Access to the PIT tag detectors for installation, removal and maintenance as well as access within the ladder for fish salvage are also considerations that would apply to all alternatives. A summary of the major observations about operations and maintenance include:

- Alternative 1 would require a new picketed lead and control gate to allow excess flow to be removed upstream of the count station. The gate would be operated either manually or via PLC and would require periodic maintenance. The new picketed lead would introduce another location for debris accumulation and cleaning; access to the new gate and picketed lead would be required for maintenance.
- The new components proposed for Alternative 2 are fully static and introduce no additional operation or maintenance requirements over the existing control section.
- Alternatives 3 and 4 include actuated sill gates which would be either manually operated or operated via PLC. The associated motors would require periodic maintenance. Access walkways would be required for motor maintenance.
- Alternative 4 requires more gates than Alternative 3 (9 gates versus 5 gates).
- Alternative 4 requires relocation of the PIT tag detection system, which may introduce less desirable access for maintenance.

Based on this comparison, Alternative 2 is preferred on the basis of operation and maintenance, because it requires no new mechanical systems and no new components that would require maintenance in excess of the existing control section. The three other alternatives would require additional operation and maintenance as compared to the existing control section and Alternative 2.

2.3 Cost and Constructability

All alternatives were estimated at a class 5 level. A breakdown of the costs as estimate at the 60% DDR phase can be seen in the table below. These values include varying amounts of contingency determined by the Abbreviated Risk Analysis (ARA) as well as escalation to the midpoint of construction.

Alternative	Alternative Description	Construction Cost	Total Project Cost
1	Static Weirs, Bulkhead for Diffusers, Mod to Count Station, No Actuated Sill Gates	$4.75M	$6.80M
2	Static Weirs, Manual Diffuser Gates, No Mod to Count Station, No Actuated Sill Gates	$3.55M	$5.05M
3	Static Weirs, Manual Diffuser Gates, No Mod to Count Station, 5 Actuated Sill Gates	$4.20M	$1.20M
4	Static Weirs, Manual Diffuser Gates, No Mod to Count Station, 9 Actuated Sill Gates	$4.70M	$6.75M

All four alternatives use the same cost basis for replacing the existing PIT tag antennas (replacement within new slots and orifices in the control section). The cost for replacing PIT tag detection for Alternative 4 is likely to be higher due to the need to relocate the PIT tag antennas to a location other than the control section, however, the PDT did not investigate alternative PIT tag antenna locations such that a more representative cost could be developed because Alternative 4 is hydraulically equivalent to Alternative 2, but the higher cost of Alternative 4 makes it less preferred than Alternative 2.

3.0 Preferred Alternative

Alternative 2 is the preferred alternative that will be developed through the DDR process. Alternative 2 was selected because:

- It uses a proven method to attain the required fish ladder flow and head differential at Weir 67.
- It has similar conditions for fish passage (based on the slot and orifice velocity metrics) as compared to Alternative 1.
- It has equivalent conditions for fish passage (based on the slot and orifice velocity metrics) as compared to Alternatives 3 and 4.
- It has better physical conditions for fish passage as compared to Alternatives 3 and 4 because all the openings are flush with the floor (no sills).
- It has fewer operations and maintenance requirements than any of the other alternatives.
- It is less expensive than any of the other alternatives.

Alternative 2 meets NMFS criteria for salmonid, provides good hydraulic performance, removes more lamprey passage challenges than Alternatives 3 or 4, and is better for operations and maintenance than the other alternatives. Therefore Alternative 2 is selected as the preferred alternative. The recommendation to proceed with Alternative 2 was presented to the FFDRWG on 02 February 2022. FFDRWG is made up of Federal, Tribal, and Sate biologists from USFWS, NMFS, CRITFC, and the States of Washington, Idaho, and Oregon. This advisory group subsequently reviewed this DDR and the responses were either non-objection or concurrence with the proposed direction.

The preferred alternative includes the following major features:

- Demolition of 17 existing serpentine control section baffles.
- Construction of nine vertical slot and orifice baffle pairs.
  - Vertical slot width varies from 1.50 feet to 1.70 feet.
  - 18-inch square orifice location is flush with the control section floor and offset 4-feet from the north sidewall.
  - 1.5-inch-tall by 16-inch-wide lamprey-specific orifice location is flush with the control section floor and offset 4 feet from the south sidewall.
  - The slots and orifice edges are rounded using a minimum radius of 4 inches except where PIT tag antennas are to be installed. The PIT tag antenna housing will have chamfered edges (less than or equal to 45 degrees) and will be sanded smooth.
- Relocation of the refuge boxes currently on the north side of the ladder to the south side of the ladder.
- Installation of new PIT tag antennas in the slots and orifices of four consecutive baffle pairs, and all associated PIT tag detection equipment, access walkways, power, and communications infrastructure.
- Demolition and replacement with non-ferrous reinforced concrete in the proximity of the PIT tag antennas; offset to ferrous reinforcement ranges from about 6 to 60 inches from the antennas, see Plate PSMFC-002 for non-ferrous zones.
- Installation of a new access walkway to provide for manual cleaning of the bypass picketed lead.
- Installation of new orifice plates or gates for the bleed-off and add-in diffusers, if required (hydraulic adequacy of the existing orifice plates will be confirmed through CFD modeling in the 60% DDR).

Plate SG101 shows a general plan view of the modification. Plate SG503 and SG505 show typical baffle pairs without PIT tag antennas and Plate SG504 shows a typical baffle pair with PIT tag antennas. The plates are provided in Appendix A.

APPENDIX D

HYDRAULIC CALCULATIONS

Prepared By: Max Wilson-Fey (ENC-HD), December 2021

Checked By: Steve Schlenker (ENC-HD), January 2022

Glossary of Terms

- A = area
- AWSC = auxiliary water supply channel
- Cd = discharge coefficient
- CdAI = discharge coefficient through add-in orifices
- CdBO = discharge coefficient through bleed-off orifices
- Cdorifice = discharge coefficient through salmon orifice
- CdPL = discharge coefficient through picket lead
- Channel Q -or- Ql = flowrate through the fish ladder
- CL = centerline
- CS = count station
- Cw = discharge coefficient over a weir
- dFBL = forebay level difference between Target FBL and Spreadsheet FBL
- dH -or- Delta H = difference in head across slot
- Diff = difference (between LHS and RHS)
- dQ = flowrate difference between Target Q and Spreadsheet Q
- EDF = energy dissipation factor
- EL = elevation
- FB = forebay
- FBL = forebay level
- FJF = free jet flow
- fps = feet per second
- g = gravitational constant
- hdown = water surface elevation downstream of slot
- HL = head loss, measured in feet
- Hs = sill height
- hup = water surface elevation upstream of slot
- h1 = effective head upstream of slot
- h1/P = [spreadsheet variable artifact, ignore]
- h2 = effective head downstream of slot
- Ke = exit loss coefficient
- Ke, trash = trash rack exit loss coefficient
- LHS = left hand side
- NGVD 29 = National Geodetic Vertical Datum of 1929
- PJF = partial jet flow
- PL = picket lead
- PSOF = partial submerged orifice flow
- Q = flowrate
- Qcs = flowrate at count station
- RHS = right hand side

- Spreadsheet FBL = forebay level calculated by the spreadsheet numerical model
- Spreadsheet Q = flowrate calculated by the spreadsheet numerical model
- sqrt = square root
- Target FBL = forebay level calculated by the physical model
- Target Q = flowrate calculated by the physical model
- v = velocity
- VH = velocity head
- Vo = orifice velocity
- Vs = slot velocity
- w = width
- WF = weir flow
- WL = water level
- WS = water surface
- Modified Q = flowrate exiting or entering the ladder due to the BO/AI orifices and PL

Governing Equations

- h2 = hdown – invert EL – Hs
- h1 = hup – invert EL – Hs
- RHS = Cd*slotwidth*h1*sqrt(2g*dH) + Aorifice*Cdorifice*sqrt(2g*dH)
- Diff = RHS – LHS
- dH = h1-h2
- Vs = LHS/(slotwidth*h1)
- Vo = Cdorifice*sqrt(2g*dH)
- EDF = (density of water)*Q*dHmax/(pool volume) … should be less than 4 ft-lbs/s/cu.ft.
- VH = v^2/2g
- HL = Ke*VH through a slot -or- Manning's Equation through an open channel

Depending on BO/AI orifice geometry and WS EL within ladder and AWSC…

- WF = Weir Flow = WL below orifice bottom on one side, WL between orifice bottom and top on the other side … Q=Cd*w*waterheight^(3/2)
- FJF = Free Jet Flow = WL below orifice bottom on one side, WL above orifice top on the other side … Q=Cd*A*sqrt(2*g*dH)
- PSOF = Partial Submerged Orifice Flow = WL in between orifice top and bottom on both sides … Q=Cd*w*dH*sqrt(2*g*dH)
- PJF = Partial Jet Flow = WL above orifice top on one side, WL between orifice top and bottom on other side … Q = Cd*w*(Orifice Top - WLlow)*sqrt(2*g*(WLhigh-((Orifice Top - WLlow)/2)+WLlow))+Cd*w*(Wllow-Orifice Bottom)*sqrt(2*g*(WLhigh-WLlow))

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ALT 1 SUMMARY

Pool		Slot		FB 77				FB 74			
No.	Length [ft]	No.	Width [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]
CS	-	CS	3.00	0.64	6.44		109.00	0.31	4.49		71.50
1	15.65	1	2.70	0.98	7.72	6.36	138.08	0.57	5.96	4.85	94.76
2	17.50	2	2.40	0.95	7.59	6.27	138.08	0.59	6.10	4.95	94.76
3	16.00	3	2.20	0.91	7.39	6.12	138.08	0.59	6.09	4.94	94.76
4	16.00	4	2.00	0.90	7.35	6.09	138.08	0.61	6.17	5.00	94.76
5	15.29	5	1.80	0.92	7.44	6.16	138.08	0.64	6.33	5.12	94.76
6	15.40	6	1.70	0.88	7.26	6.02	138.08	0.62	6.24	5.05	94.76
7	15.21	7	1.60	0.86	7.16	5.95	138.08	0.61	6.21	5.03	94.76
8	11.18	8	1.50	0.85	7.14	5.93	138.08	0.61	6.22	5.03	94.76
9	11.18	9	1.40	0.86	7.17	5.95	138.08	0.63	6.28	5.08	94.76
10	11.18	Exit Slot	2.26	0.21	4.44		138.08	0.16	3.89		94.76

Pool		Slot		FB 70			
No.	Length [ft]	No.	Width [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]
CS	-	CS	3.00	0.06	1.91		29.00
1	15.65	1	2.70	0.13	2.85	2.28	39.90
2	17.50	2	2.40	0.15	3.12	2.47	39.90
3	16.00	3	2.20	0.16	3.30	2.59	39.90
4	16.00	4	2.00	0.18	3.52	2.73	39.90
5	15.29	5	1.80	0.20	3.77	2.90	39.90
6	15.40	6	1.70	0.21	3.85	2.95	39.90
7	15.21	7	1.60	0.22	3.95	3.02	39.90
8	11.18	8	1.50	0.23	4.07	3.09	39.90
9	11.18	9	1.40	0.24	4.20	3.17	39.90
10	11.18	Exit Slot	2.26	0.07	2.60		39.90

<u>Variables</u>

Qcs =	109.00	cfs
Target Q =	145.50	cfs
Spreadsheet Q =	138.08	cfs
dQ =	-7.42	cfs
Target FBL =	77.00	ft
Spreadsheet FBL =	77.00	ft
dFBL =	0.00	ft
AWSC WS El. =	0.00	ft

<u>Constants</u>

Slope =	0.00	
Invert =	63.00	ft NGVD 29
Wall Elev. =	84.00	ft NGVD 30
Weir 67 Crest =	67.00	ft, NGVD 29
Weir 67 Head =	1.00	ft
Weir 67 WS =	68.00	ft, NGVD 29
CdPL =	0.18	
CdBO =	0.62	
CdAI =	0.61	
Cw =	3.33	
Cdorifice =	0.80	
Orifice Area =	2.25	sq.ft.
Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Picket Lead

0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	4.44	0.70		0.21
Channel	1.39			0.01
Exit to FB	1.39	0.50	0.10	0.02

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	1.05	Yes
Pool 1 (between CS and Slot 1)	2.80	Yes
Pool 2	2.70	Yes
Pool 3	2.58	Yes
Pool 4	2.31	Yes
Pool 5	2.18	Yes
Pool 6	1.97	Yes
Pool 7	1.84	Yes
Pool 8	2.33	Yes
Pool 9	2.17	Yes
Pool 10	2.04	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.64	5.00	5.64	109.00	109.00	0.00	0.64
1.00	63.00	84.00	2.70	0.00	68.64	69.63	5.64	6.63	138.08	138.08	0.00	0.98
2.00	63.00	84.00	2.40	0.00	69.63	70.58	6.63	7.58	138.08	138.08	0.00	0.95
3.00	63.00	84.00	2.20	0.00	70.58	71.49	7.58	8.49	138.08	138.08	0.00	0.91
4.00	63.00	84.00	2.00	0.00	71.49	72.39	8.49	9.39	138.08	138.08	0.00	0.90
5.00	63.00	84.00	1.80	0.00	72.39	73.31	9.39	10.31	138.08	138.08	0.00	0.92
6.00	63.00	84.00	1.70	0.00	73.31	74.19	10.31	11.19	138.08	138.08	0.00	0.88
7.00	63.00	84.00	1.60	0.00	74.19	75.05	11.19	12.05	138.08	138.08	0.00	0.86
8.00	63.00	84.00	1.50	0.00	75.05	75.90	12.05	12.90	138.08	138.08	0.00	0.85
9.00	63.00	84.00	1.40	0.00	75.90	76.76	12.90	13.76	138.08	138.08	0.00	0.86
Exit Slot	63.00	84.00	2.26	0.00	76.76	76.97						0.21
Channel	63.00	84.00	0.00	0.00	76.97	76.98						0.01
Exit to FB	63.00	84.00	0.00	0.00	76.98	77.00						0.02

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	6.44	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	7.72	6.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	NA	orifice	0.87	7.59	6.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	NA	orifice	0.87	7.39	6.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	NA	orifice	0.87	7.35	6.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	NA	orifice	0.87	7.44	6.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	NA	orifice	0.87	7.26	6.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	NA	orifice	0.87	7.16	5.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	7.14	5.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	7.17	5.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.19	-	-	-	-	Bleed Off	-	-	-
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	0.00
CS	-	29.08	29.08	109.00	0.00
1.00	0.00	0.00	0.00	138.08	0.00
2.00	0.00	0.00	0.00	138.08	0.00
3.00	0.00	0.00	0.00	138.08	0.00
4.00	0.00	0.00	0.00	138.08	0.00
5.00	0.00	0.00	0.00	138.08	0.00
6.00	0.00	0.00	0.00	138.08	0.00
7.00	0.00	0.00	0.00	138.08	0.00
8.00	0.00	0.00	0.00	138.08	0.00
9.00	0.00	0.00	0.00	138.08	0.00

ALT 1, FBL = 74 ft

Variables			Constants		
Qcs =	71.50	cfs	Slope =	0.00	
Target Q =	95.30	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	94.76	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	-0.54	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	74.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	74.00	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.00	ft	CdPL =	0.18	
AWSC WS El. =	0.00	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	3.20	ft/s	Cdorifice =	0.80	
VH =	0.16	ft	Orifice Area =	2.25	sq.ft.
HL =	0.12	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.89	0.70		0.16
Channel	1.77			0.02
Exit to FB	1.77	0.50	0.10	0.03

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.69	Yes
Pool 1 (between CS and Slot 1)	1.95	Yes
Pool 2	2.09	Yes
Pool 3	2.07	Yes
Pool 4	1.90	Yes
Pool 5	1.83	Yes
Pool 6	1.68	Yes
Pool 7	1.58	Yes
Pool 8	2.02	Yes
Pool 9	1.89	Yes
Pool 10	1.78	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.31	5.00	5.31	71.50	71.50	0.00	0.31
1.00	63.00	84.00	2.70	0.00	68.31	68.88	5.31	5.88	94.76	94.76	0.00	0.57
2.00	63.00	84.00	2.40	0.00	68.88	69.48	5.88	6.48	94.76	94.76	0.00	0.59
3.00	63.00	84.00	2.20	0.00	69.48	70.07	6.48	7.07	94.76	94.76	0.00	0.59
4.00	63.00	84.00	2.00	0.00	70.07	70.68	7.07	7.68	94.76	94.76	0.00	0.61
5.00	63.00	84.00	1.80	0.00	70.68	71.31	7.68	8.31	94.76	94.76	0.00	0.64
6.00	63.00	84.00	1.70	0.00	71.31	71.93	8.31	8.93	94.76	94.76	0.00	0.62
7.00	63.00	84.00	1.60	0.00	71.93	72.54	8.93	9.54	94.76	94.76	0.00	0.61
8.00	63.00	84.00	1.50	0.00	72.54	73.16	9.54	10.16	94.76	94.76	0.00	0.61
9.00	63.00	84.00	1.40	0.00	73.16	73.78	10.16	10.78	94.76	94.76	0.00	0.63
Exit Slot	63.00	84.00	2.26	0.00	73.78	73.95						0.16
Channel	63.00	84.00	0.00	0.00	73.95	73.97						0.02
Exit to FB	63.00	84.00	0.00	0.00	73.97	74.00						0.03

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	4.49	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.96	4.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	NA	orifice	0.87	6.10	4.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	NA	orifice	0.87	6.09	4.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	NA	orifice	0.87	6.17	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	NA	orifice	0.87	6.33	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	NA	orifice	0.87	6.24	5.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	NA	orifice	0.87	6.21	5.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	6.22	5.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	6.28	5.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.12	-	-	-	-	Bleed Off	-	-	-
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	0.00
CS	-	23.26	23.26	71.50	0.00
1.00	0.00	0.00	0.00	94.76	0.00
2.00	0.00	0.00	0.00	94.76	0.00
3.00	0.00	0.00	0.00	94.76	0.00
4.00	0.00	0.00	0.00	94.76	0.00
5.00	0.00	0.00	0.00	94.76	0.00
6.00	0.00	0.00	0.00	94.76	0.00
7.00	0.00	0.00	0.00	94.76	0.00
8.00	0.00	0.00	0.00	94.76	0.00
9.00	0.00	0.00	0.00	94.76	0.00

ALT 1, FBL = 72.7 ft

Variables			Constants		
Qcs =	60.00	cfs	Slope =	0.00	
Target Q =	70.86	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	75.99	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	5.13	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	72.70	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	72.64	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	-0.06	ft	CdPL =	0.18	
AWSC WS El. =	0.00	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	2.20	ft/s	Cdorifice =	0.80	
VH =	0.08	ft	Orifice Area =	2.25	sq.ft.
HL =	0.06	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.56	0.70		0.14
Channel	2.02			0.03
Exit to FB	2.02	0.50	0.10	0.04

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.58	Yes
Pool 1 (between CS and Slot 1)	1.66	Yes
Pool 2	1.75	Yes
Pool 3	1.78	Yes
Pool 4	1.66	Yes
Pool 5	1.62	Yes
Pool 6	1.50	Yes
Pool 7	1.43	Yes
Pool 8	1.83	Yes
Pool 9	1.73	Yes
Pool 10	1.63	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.23	5.00	5.23	60.00	60.00	0.00	0.23
1.00	63.00	84.00	2.70	0.00	68.23	68.63	5.23	5.63	75.99	75.99	0.00	0.40
2.00	63.00	84.00	2.40	0.00	68.63	69.05	5.63	6.05	75.99	75.99	0.00	0.43
3.00	63.00	84.00	2.20	0.00	69.05	69.50	6.05	6.50	75.99	75.99	0.00	0.44
4.00	63.00	84.00	2.00	0.00	69.50	69.96	6.50	6.96	75.99	75.99	0.00	0.46
5.00	63.00	84.00	1.80	0.00	69.96	70.45	6.96	7.45	75.99	75.99	0.00	0.49
6.00	63.00	84.00	1.70	0.00	70.45	70.94	7.45	7.94	75.99	75.99	0.00	0.49
7.00	63.00	84.00	1.60	0.00	70.94	71.43	7.94	8.43	75.99	75.99	0.00	0.49
8.00	63.00	84.00	1.50	0.00	71.43	71.93	8.43	8.93	75.99	75.99	0.00	0.50
9.00	63.00	84.00	1.40	0.00	71.93	72.44	8.93	9.44	75.99	75.99	0.00	0.51
Exit Slot	63.00	84.00	2.26	0.00	72.44	72.57						0.14
Channel	63.00	84.00	0.00	0.00	72.57	72.60						0.03
Exit to FB	63.00	84.00	0.00	0.00	72.60	72.64						0.04

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers						
						BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.83	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.00	4.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	NA	orifice	0.87	5.23	4.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	NA	orifice	0.87	5.32	4.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	NA	orifice	0.87	5.46	4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	NA	orifice	0.87	5.66	4.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	NA	orifice	0.87	5.63	4.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	NA	orifice	0.87	5.63	4.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	5.67	4.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	5.75	4.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.06	-	-	-	-	Bleed Off	-	-	-
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	0.00
CS	-	15.99	15.99	60.00	0.00
1.00	0.00	0.00	0.00	75.99	0.00
2.00	0.00	0.00	0.00	75.99	0.00
3.00	0.00	0.00	0.00	75.99	0.00
4.00	0.00	0.00	0.00	75.99	0.00
5.00	0.00	0.00	0.00	75.99	0.00
6.00	0.00	0.00	0.00	75.99	0.00
7.00	0.00	0.00	0.00	75.99	0.00
8.00	0.00	0.00	0.00	75.99	0.00
9.00	0.00	0.00	0.00	75.99	0.00

Variables

Qcs =	42.00	cfs
Target Q =	47.50	cfs
Spreadsheet Q =	55.08	cfs
dQ =	7.58	cfs
Target FBL =	71.20	ft
Spreadsheet FBL =	71.09	ft
dFBL =	-0.11	ft
AWSC WS El. =	0.00	ft

Picket Lead

v =	1.80	ft/s
VH =	0.05	ft
HL =	0.04	ft

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.09	0.70		0.10
Channel	2.42			0.05
Exit to FB	2.41	0.50	0.10	0.05

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.41	Yes
Pool 1 (between CS and Slot 1)	1.19	Yes
Pool 2	1.34	Yes
Pool 3	1.39	Yes
Pool 4	1.33	Yes
Pool 5	1.32	Yes
Pool 6	1.25	Yes
Pool 7	1.20	Yes
Pool 8	1.56	Yes
Pool 9	1.49	Yes
Pool 10	1.42	Yes

Constants

Slope =	0.00	
Invert =	63.00	ft NGVD 29
Wall Elev. =	84.00	ft NGVD 30
Weir 67 Crest =	67.00	ft, NGVD 29
Weir 67 Head =	1.00	ft
Weir 67 WS =	68.00	ft, NGVD 29
CdPL =	0.18	
CdBO =	0.62	
CdAI =	0.61	
Cw =	3.33	
Cdorifice =	0.80	
Orifice Area =	2.25	sq.ft.
Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.12	5.00	5.12	42.00	42.00	0.00	0.12
1.00	63.00	84.00	2.70	0.00	68.12	68.34	5.12	5.34	55.08	55.08	0.00	0.23
2.00	63.00	84.00	2.40	0.00	68.34	68.60	5.34	5.60	55.08	55.08	0.00	0.26
3.00	63.00	84.00	2.20	0.00	68.60	68.88	5.60	5.88	55.08	55.08	0.00	0.28
4.00	63.00	84.00	2.00	0.00	68.88	69.18	5.88	6.18	55.08	55.08	0.00	0.30
5.00	63.00	84.00	1.80	0.00	69.18	69.51	6.18	6.51	55.08	55.08	0.00	0.33
6.00	63.00	84.00	1.70	0.00	69.51	69.84	6.51	6.84	55.08	55.08	0.00	0.33
7.00	63.00	84.00	1.60	0.00	69.84	70.18	6.84	7.18	55.08	55.08	0.00	0.34
8.00	63.00	84.00	1.50	0.00	70.18	70.53	7.18	7.53	55.08	55.08	0.00	0.35
9.00	63.00	84.00	1.40	0.00	70.53	70.89	7.53	7.89	55.08	55.08	0.00	0.36
Exit Slot	63.00	84.00	2.26	0.00	70.89	70.99						0.10
Channel	63.00	84.00	0.00	0.00	70.99	71.04						0.05
Exit to FB	63.00	84.00	0.00	0.00	71.04	71.09						0.05

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	2.74	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	3.82	3.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	NA	orifice	0.87	4.10	3.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	NA	orifice	0.87	4.26	3.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	NA	orifice	0.87	4.46	3.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	NA	orifice	0.87	4.70	3.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	NA	orifice	0.87	4.74	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	NA	orifice	0.87	4.80	3.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	4.88	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	4.99	3.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.04	-	-	-	-	Bleed Off	-	-	-
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	0.00
CS	-	13.08	13.08	42.00	0.00
1.00	0.00	0.00	0.00	55.08	0.00
2.00	0.00	0.00	0.00	55.08	0.00
3.00	0.00	0.00	0.00	55.08	0.00
4.00	0.00	0.00	0.00	55.08	0.00
5.00	0.00	0.00	0.00	55.08	0.00
6.00	0.00	0.00	0.00	55.08	0.00
7.00	0.00	0.00	0.00	55.08	0.00
8.00	0.00	0.00	0.00	55.08	0.00
9.00	0.00	0.00	0.00	55.08	0.00

ALT 1, FBL = 70 ft

Variables			Constants		
Qcs =	29.00	cfs	Slope =	0.00	
Target Q =	32.20	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	39.90	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	7.70	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	70.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	70.00	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.00	ft	CdPL =	0.18	
AWSC WS El. =	0.00	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	1.50	ft/s	Cdorifice =	0.80	
VH =	0.03	ft	Orifice Area =	2.25	sq.ft.
HL =	0.03	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	2.60	0.70		0.07
Channel	2.82			0.07
Exit to FB	2.80	0.50	0.10	0.07

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.28	Yes
Pool 1 (between CS and Slot 1)	0.83	Yes
Pool 2	1.00	Yes
Pool 3	1.06	Yes
Pool 4	1.03	Yes
Pool 5	1.04	Yes
Pool 6	1.00	Yes
Pool 7	0.98	Yes
Pool 8	1.28	Yes
Pool 9	1.24	Yes
Pool 10	1.19	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.06	5.00	5.06	29.00	29.00	0.00	0.06
1.00	63.00	84.00	2.70	0.00	68.06	68.18	5.06	5.18	39.90	39.90	0.00	0.13
2.00	63.00	84.00	2.40	0.00	68.18	68.33	5.18	5.33	39.90	39.90	0.00	0.15
3.00	63.00	84.00	2.20	0.00	68.33	68.49	5.33	5.49	39.90	39.90	0.00	0.16
4.00	63.00	84.00	2.00	0.00	68.49	68.68	5.49	5.68	39.90	39.90	0.00	0.18
5.00	63.00	84.00	1.80	0.00	68.68	68.88	5.68	5.88	39.90	39.90	0.00	0.20
6.00	63.00	84.00	1.70	0.00	68.88	69.09	5.88	6.09	39.90	39.90	0.00	0.21
7.00	63.00	84.00	1.60	0.00	69.09	69.31	6.09	6.31	39.90	39.90	0.00	0.22
8.00	63.00	84.00	1.50	0.00	69.31	69.54	6.31	6.54	39.90	39.90	0.00	0.23
9.00	63.00	84.00	1.40	0.00	69.54	69.79	6.54	6.79	39.90	39.90	0.00	0.24
Exit Slot	63.00	84.00	2.26	0.00	69.79	69.86						0.07
Channel	63.00	84.00	0.00	0.00	69.86	69.93						0.07
Exit to FB	63.00	84.00	0.00	0.00	69.93	70.00						0.07

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	1.91	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	2.85	2.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	NA	orifice	0.87	3.12	2.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	NA	orifice	0.87	3.30	2.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	NA	orifice	0.87	3.52	2.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	NA	orifice	0.87	3.77	2.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	NA	orifice	0.87	3.85	2.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	NA	orifice	0.87	3.95	3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	4.07	3.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	4.20	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.03	-	-	-	-	Bleed Off	-	-	-
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	0.00
CS	-	10.90	10.90	29.00	0.00
1.00	0.00	0.00	0.00	39.90	0.00
2.00	0.00	0.00	0.00	39.90	0.00
3.00	0.00	0.00	0.00	39.90	0.00
4.00	0.00	0.00	0.00	39.90	0.00
5.00	0.00	0.00	0.00	39.90	0.00
6.00	0.00	0.00	0.00	39.90	0.00
7.00	0.00	0.00	0.00	39.90	0.00
8.00	0.00	0.00	0.00	39.90	0.00
9.00	0.00	0.00	0.00	39.90	0.00

ALT 2 SUMMARY

Pool		Slot		FB 77				FB 74			
No.	Length [ft]	No.	Width [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]
CS	-	CS	3.00	0.24	3.95	-	62.10	0.16	3.20	-	49.50
1	15.65	1	1.70	0.91	7.96	6.11	83.18	0.67	6.89	5.24	68.21
2	17.50	2	1.70	0.93	7.90	6.20	95.03	0.60	6.41	4.96	70.01
3	16.00	3	1.66	0.93	7.80	6.20	103.71	0.61	6.44	5.03	75.16
4	16.00	4	1.66	0.96	7.79	6.29	116.04	0.61	6.36	5.03	80.77
5	15.29	5	1.66	0.97	7.75	6.34	128.04	0.62	6.34	5.07	87.04
6	15.40	6	1.66	0.98	7.71	6.37	139.95	0.63	6.31	5.09	93.16
7	15.21	7	1.70	0.95	7.51	6.26	151.66	0.60	6.09	4.96	98.23
8	11.18	8	1.55	0.98	7.61	6.34	151.66	0.63	6.26	5.09	98.23
9	11.18	9	1.50	0.91	7.34	6.14	151.66	0.60	6.11	4.98	98.23
10	11.18	Exit Slot	2.26	0.26	4.87	-	151.66	0.18	4.05	-	98.23

Pool		Slot		FB 70			
No.	Length [ft]	No.	Width [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]
CS	-	CS	3	0.10	2.60	-	39.80
1	15.65	1	1.7	0.39	5.36	4.03	50.09
2	17.5	2	1.7	0.19	3.71	2.81	35.85
3	16	3	1.66	0.18	3.54	2.69	34.48
4	16	4	1.66	0.17	3.44	2.62	34.48
5	15.29	5	1.66	0.16	3.35	2.57	34.48
6	15.4	6	1.66	0.15	3.27	2.52	34.48
7	15.21	7	1.7	0.14	3.13	2.42	34.48
8	11.18	8	1.55	0.16	3.35	2.56	34.48
9	11.18	9	1.5	0.16	3.38	2.58	34.48
10	11.18	Exit Slot	2.26	0.05	2.24	-	34.48

ALT 2, FBL = 77 ft

Variables			Constants		
Qcs =	62.10	cfs	Slope =	0.00	
Target Q =	145.46	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	151.66	cfs	Wall Elev. =	84.00	ft NGVD 29
dQ =	6.20	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	77.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	77.06	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.06	ft	CdPL =	0.18	
AWSC WS El. =	68.69	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	2.90	ft/s	Cdorifice =	0.80	
VH =	0.13	ft	Orifice Area =	2.25	sq.ft.
HL =	0.10	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	4.87	0.70		0.26
Channel	1.38			0.01
Exit to FB	1.38	0.50	0.10	0.02

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.60	Yes
Pool 1 (between CS and Slot 1)	1.72	Yes
Pool 2	1.75	Yes
Pool 3	1.90	Yes
Pool 4	1.84	Yes
Pool 5	1.92	Yes
Pool 6	1.90	Yes
Pool 7	1.91	Yes
Pool 8	2.59	Yes
Pool 9	2.39	Yes
Pool 10	2.24	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.24	5.00	5.24	62.10	62.10	0.00	0.24
1.00	63.00	84.00	1.70	0.00	68.24	69.15	5.24	6.15	83.18	83.18	0.00	0.91
2.00	63.00	84.00	1.70	0.00	69.15	70.08	6.15	7.08	95.03	95.03	0.00	0.93
3.00	63.00	84.00	1.66	0.00	70.08	71.01	7.08	8.01	103.71	103.71	0.00	0.93
4.00	63.00	84.00	1.66	0.00	71.01	71.97	8.01	8.97	116.04	116.04	0.00	0.96
5.00	63.00	84.00	1.66	0.00	71.97	72.95	8.97	9.95	128.04	128.04	0.00	0.97
6.00	63.00	84.00	1.66	0.00	72.95	73.93	9.95	10.93	139.95	139.95	0.00	0.98
7.00	63.00	84.00	1.70	0.00	73.93	74.88	10.93	11.88	151.66	151.66	0.00	0.95
8.00	63.00	84.00	1.55	0.00	74.88	75.86	11.88	12.86	151.66	151.66	0.00	0.98
9.00	63.00	84.00	1.50	0.00	75.86	76.77	12.86	13.77	151.66	151.66	0.00	0.91
Exit Slot	63.00	84.00	2.26	0.00	76.77	77.03						0.26
Channel	63.00	84.00	0.00	0.00	77.03	77.04						0.01
Exit to FB	63.00	84.00	0.00	0.00	77.04	77.06						0.02

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.95	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	7.96	6.11	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	7.90	6.20	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	7.80	6.20	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	7.79	6.29	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	7.75	6.34	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	7.71	6.37	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	7.51	6.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	7.61	6.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	7.34	6.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.10	-	-	-	-	Add In	-	-	-
1.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	12.33
4.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.99
5.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.92
6.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.71
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	21.08	21.08	62.10	68.69
1.00	11.85	0.00	11.85	83.18	68.69
2.00	8.68	0.00	8.68	95.03	68.69
3.00	-	0.00	12.33	103.71	68.69
4.00	-	0.00	11.99	116.04	68.69
5.00	-	0.00	11.92	128.04	68.69
6.00	-	0.00	11.71	139.95	68.69
7.00	0.00	0.00	0.00	151.66	68.69
8.00	0.00	0.00	0.00	151.66	68.69
9.00	0.00	0.00	0.00	151.66	68.69

Variables			Constants		
Qcs =	49.50	cfs	Slope =	0.00	
Target Q =	95.30	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	98.23	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	2.93	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	74.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	73.95	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	-0.05	ft	CdPL =	0.18	
AWSC WS El. =	68.73	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	2.60	ft/s	Cdorifice =	0.80	
VH =	0.10	ft	Orifice Area =	2.25	sq.ft.
HL =	0.08	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	4.05	0.70		0.18
Channel	1.78			0.02
Exit to FB	1.77	0.50	0.10	0.03

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.48	Yes
Pool 1 (between CS and Slot 1)	1.39	Yes
Pool 2	1.52	Yes
Pool 3	1.55	Yes
Pool 4	1.52	Yes
Pool 5	1.57	Yes
Pool 6	1.55	Yes
Pool 7	1.56	Yes
Pool 8	2.10	Yes
Pool 9	1.97	Yes
Pool 10	1.86	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.16	5.00	5.16	49.50	49.50	0.00	0.16
1.00	63.00	84.00	1.70	0.00	68.16	68.82	5.16	5.82	68.21	68.21	0.00	0.67
2.00	63.00	84.00	1.70	0.00	68.82	69.42	5.82	6.42	70.01	70.01	0.00	0.60
3.00	63.00	84.00	1.66	0.00	69.42	70.03	6.42	7.03	75.16	75.16	0.00	0.61
4.00	63.00	84.00	1.66	0.00	70.03	70.65	7.03	7.65	80.77	80.77	0.00	0.61
5.00	63.00	84.00	1.66	0.00	70.65	71.27	7.65	8.27	87.04	87.04	0.00	0.62
6.00	63.00	84.00	1.66	0.00	71.27	71.90	8.27	8.90	93.16	93.16	0.00	0.63
7.00	63.00	84.00	1.70	0.00	71.90	72.50	8.90	9.50	98.23	98.23	0.00	0.60
8.00	63.00	84.00	1.55	0.00	72.50	73.12	9.50	10.12	98.23	98.23	0.00	0.63
9.00	63.00	84.00	1.50	0.00	73.12	73.72	10.12	10.72	98.23	98.23	0.00	0.60
Exit Slot	63.00	84.00	2.26	0.00	73.72	73.90						0.18
Channel	63.00	84.00	0.00	0.00	73.90	73.92						0.02
Exit to FB	63.00	84.00	0.00	0.00	73.92	73.95						0.03

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.20	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	6.89	5.24	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	6.41	4.96	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	6.44	5.03	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	6.36	5.03	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	6.34	5.07	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	6.31	5.09	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	6.09	4.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	6.26	5.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	6.11	4.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	Picket Lead PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.08	-	WF	-	-	Add In	-	-0.19	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Bleed Off	1.80	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	5.60
4.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	6.27
5.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	6.12
6.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	5.07
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	18.90	18.71	49.50	68.73
1.00	-	0.00	1.80	68.21	68.73
2.00	5.15	0.00	5.15	70.01	68.73
3.00	-	0.00	5.60	75.16	68.73
4.00	-	0.00	6.27	80.77	68.73
5.00	-	0.00	6.12	87.04	68.73
6.00	-	0.00	5.07	93.16	68.73
7.00	0.00	0.00	0.00	98.23	68.73
8.00	0.00	0.00	0.00	98.23	68.73
9.00	0.00	0.00	0.00	98.23	68.73

ALT 2, FBL = 72.7 ft

Variables

Qcs =	49.01	cfs
Target Q =	70.86	cfs
Spreadsheet Q =	75.52	cfs
dQ =	4.66	cfs
Target FBL =	72.70	ft
Spreadsheet FBL =	72.75	ft
dFBL =	0.05	ft
AWSC WS El. =	68.78	ft

Constants

Slope =	0.00	
Invert =	63.00	ft NGVD 29
Wall Elev. =	84.00	ft NGVD 30
Weir 67 Crest =	67.00	ft, NGVD 29
Weir 67 Head =	1.00	ft
Weir 67 WS =	68.00	ft, NGVD 29
CdPL =	0.18	
CdBO =	0.62	
CdAI =	0.61	
Cw =	3.33	
Cdorifice =	0.80	
Orifice Area =	2.25	sq.ft.
Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Picket Lead

v =	2.20	ft/s
VH =	0.08	ft
HL =	0.06	ft

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.50	0.70		0.13
Channel	2.00			0.03
Exit to FB	1.99	0.50	0.10	0.04

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.47	Yes
Pool 1 (between CS and Slot 1)	1.38	Yes
Pool 2	1.45	Yes
Pool 3	1.45	Yes
Pool 4	1.41	Yes
Pool 5	1.42	Yes
Pool 6	1.38	Yes
Pool 7	1.36	Yes
Pool 8	1.77	Yes
Pool 9	1.68	Yes
Pool 10	1.61	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.16	5.00	5.16	49.01	49.01	0.00	0.16
1.00	63.00	84.00	1.70	0.00	68.16	68.76	5.16	5.76	64.19	64.19	0.00	0.60
2.00	63.00	84.00	1.70	0.00	68.76	69.28	5.76	6.28	64.00	64.00	0.00	0.52
3.00	63.00	84.00	1.66	0.00	69.28	69.80	6.28	6.80	67.77	67.77	0.00	0.53
4.00	63.00	84.00	1.66	0.00	69.80	70.30	6.80	7.30	69.91	69.91	0.00	0.50
5.00	63.00	84.00	1.66	0.00	70.30	70.79	7.30	7.79	72.95	72.95	0.00	0.49
6.00	63.00	84.00	1.66	0.00	70.79	71.25	7.79	8.25	75.32	75.32	0.00	0.47
7.00	63.00	84.00	1.70	0.00	71.25	71.67	8.25	8.67	75.52	75.52	0.00	0.41
8.00	63.00	84.00	1.55	0.00	71.67	72.11	8.67	9.11	75.52	75.52	0.00	0.45
9.00	63.00	84.00	1.50	0.00	72.11	72.55	9.11	9.55	75.52	75.52	0.00	0.44
Exit Slot	63.00	84.00	2.26	0.00	72.55	72.68						0.13
Channel	63.00	84.00	0.00	0.00	72.68	72.71						0.03
Exit to FB	63.00	84.00	0.00	0.00	72.71	72.75						0.04

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers						
						BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.17	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	6.56	4.98	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	6.00	4.62	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	6.00	4.66	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	5.77	4.53	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	5.64	4.47	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	5.50	4.39	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	5.12	4.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	5.35	4.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	5.27	4.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.06	-	WF	-	-	Add In	-	-0.81	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-0.19	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	2.14	-
4.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	3.05	-
5.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	2.37	-
6.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	0.20	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	15.99	15.18	49.01	68.78
1.00	-	0.00	-0.19	64.19	68.78
2.00	3.77	0.00	3.77	64.00	68.78
3.00	-	0.00	2.14	67.77	68.78
4.00	-	0.00	3.05	69.91	68.78
5.00	-	0.00	2.37	72.95	68.78
6.00	-	0.00	0.20	75.32	68.78
7.00	0.00	0.00	0.00	75.52	68.78
8.00	0.00	0.00	0.00	75.52	68.78
9.00	0.00	0.00	0.00	75.52	68.78

ALT 2, FBL = 71.2 ft

<u>Variables</u>

Qcs =	45.17	cfs
Target Q =	47.50	cfs
Spreadsheet Q =	52.51	cfs
dQ =	5.01	cfs
Target FBL =	71.20	ft
Spreadsheet FBL =	71.27	ft
dFBL =	0.07	ft
AWSC WS El. =	68.84	ft

<u>Constants</u>

Slope =	0.00	
Invert =	63.00	ft NGVD 29
Wall Elev. =	84.00	ft NGVD 30
Weir 67 Crest =	67.00	ft, NGVD 29
Weir 67 Head =	1.00	ft
Weir 67 WS =	68.00	ft, NGVD 29
CdPL =	0.18	
CdBO =	0.62	
CdAI =	0.61	
Cw =	3.33	
Cdorifice =	0.80	
Orifice Area =	2.25	sq.ft.
Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Picket Lead

v =	1.90	ft/s
VH =	0.06	ft
HL =	0.04	ft

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	2.88	0.70		0.09
Channel	2.37			0.04
Exit to FB	2.36	0.50	0.10	0.05

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.44	Yes
Pool 1 (between CS and Slot 1)	1.28	Yes
Pool 2	1.32	Yes
Pool 3	1.22	Yes
Pool 4	1.17	Yes
Pool 5	1.17	Yes
Pool 6	1.11	Yes
Pool 7	1.08	Yes
Pool 8	1.42	Yes
Pool 9	1.37	Yes
Pool 10	1.32	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.13	5.00	5.13	45.17	45.17	0.00	0.13
1.00	63.00	84.00	1.70	0.00	68.13	68.63	5.13	5.63	57.16	57.16	0.00	0.49
2.00	63.00	84.00	1.70	0.00	68.63	68.99	5.63	5.99	51.47	51.47	0.00	0.36
3.00	63.00	84.00	1.66	0.00	68.99	69.35	5.99	6.35	52.51	52.51	0.00	0.36
4.00	63.00	84.00	1.66	0.00	69.35	69.67	6.35	6.67	52.51	52.51	0.00	0.33
5.00	63.00	84.00	1.66	0.00	69.67	69.98	6.67	6.98	52.51	52.51	0.00	0.30
6.00	63.00	84.00	1.66	0.00	69.98	70.26	6.98	7.26	52.51	52.51	0.00	0.28
7.00	63.00	84.00	1.70	0.00	70.26	70.52	7.26	7.52	52.51	52.51	0.00	0.26
8.00	63.00	84.00	1.55	0.00	70.52	70.80	7.52	7.80	52.51	52.51	0.00	0.28
9.00	63.00	84.00	1.50	0.00	70.80	71.08	7.80	8.08	52.51	52.51	0.00	0.28
Exit Slot	63.00	84.00	2.26	0.00	71.08	71.17						0.09
Channel	63.00	84.00	0.00	0.00	71.17	71.21						0.04
Exit to FB	63.00	84.00	0.00	0.00	71.21	71.27						0.05

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	2.93	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.97	4.52	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	5.05	3.86	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	4.98	3.83	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	4.74	3.67	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	4.53	3.54	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	4.36	3.42	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	4.11	3.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	4.34	3.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	4.33	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.04	-	WF	-	-	Add In	-	-1.82	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-5.69	-	-
2.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Bleed Off	1.04	-	-
3.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
4.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
5.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
6.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	13.81	11.99	45.17	68.84
1.00	-	0.00	-5.69	57.16	68.84
2.00	-	0.00	1.04	51.47	68.84
3.00	-	0.00	0.00	52.51	68.84
4.00	-	0.00	0.00	52.51	68.84
5.00	-	0.00	0.00	52.51	68.84
6.00	-	0.00	0.00	52.51	68.84
7.00	0.00	0.00	0.00	52.51	68.84
8.00	0.00	0.00	0.00	52.51	68.84
9.00	0.00	0.00	0.00	52.51	68.84

ALT 2, FBL = 70 ft

Variables			Constants		
Qcs =	39.80	cfs	Slope =	0.00	
Target Q =	32.20	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	34.48	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	2.28	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	70.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	70.00	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.00	ft	CdPL =	0.18	
AWSC WS El. =	68.88	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	1.80	ft/s	Cdorifice =	0.80	
VH =	0.05	ft	Orifice Area =	2.25	sq.ft.
HL =	0.04	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	2.24	0.70		0.05
Channel	2.82			0.07
Exit to FB	2.80	0.50	0.10	0.07

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.38	Yes
Pool 1 (between CS and Slot 1)	1.13	Yes
Pool 2	1.18	Yes
Pool 3	0.89	Yes
Pool 4	0.83	Yes
Pool 5	0.85	Yes
Pool 6	0.82	Yes
Pool 7	0.81	Yes
Pool 8	1.08	Yes
Pool 9	1.05	Yes
Pool 10	1.03	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.10	5.00	5.10	39.80	39.80	0.00	0.10
1.00	63.00	84.00	1.70	0.00	68.10	68.50	5.10	5.50	50.09	50.09	0.00	0.39
2.00	63.00	84.00	1.70	0.00	68.50	68.69	5.50	5.69	35.85	35.85	0.00	0.19
3.00	63.00	84.00	1.66	0.00	68.69	68.87	5.69	5.87	34.48	34.48	0.00	0.18
4.00	63.00	84.00	1.66	0.00	68.87	69.03	5.87	6.03	34.48	34.48	0.00	0.17
5.00	63.00	84.00	1.66	0.00	69.03	69.19	6.03	6.19	34.48	34.48	0.00	0.16
6.00	63.00	84.00	1.66	0.00	69.19	69.35	6.19	6.35	34.48	34.48	0.00	0.15
7.00	63.00	84.00	1.70	0.00	69.35	69.49	6.35	6.49	34.48	34.48	0.00	0.14
8.00	63.00	84.00	1.55	0.00	69.49	69.65	6.49	6.65	34.48	34.48	0.00	0.16
9.00	63.00	84.00	1.50	0.00	69.65	69.81	6.65	6.81	34.48	34.48	0.00	0.16
Exit Slot	63.00	84.00	2.26	0.00	69.81	69.86						0.05
Channel	63.00	84.00	0.00	0.00	69.86	69.93						0.07
Exit to FB	63.00	84.00	0.00	0.00	69.93	70.00						0.07

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers						
						BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	2.60	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.36	4.03	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	3.71	2.81	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	3.54	2.69	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	3.44	2.62	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	3.35	2.57	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	3.27	2.52	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	3.13	2.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	3.35	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	3.38	2.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.04	-	WF	-	-	Add In	-	-2.80	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-14.24	-	-
2.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-1.37	-	-
3.00	0.00	0.00	0.00	0.00	-	-	-	-	Add In	-	-	-
4.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
5.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
6.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	13.08	10.29	39.80	68.88
1.00	-	0.00	-14.24	50.09	68.88
2.00	-	0.00	-1.37	35.85	68.88
3.00	-	0.00	0.00	34.48	68.88
4.00	-	0.00	0.00	34.48	68.88
5.00	-	0.00	0.00	34.48	68.88
6.00	-	0.00	0.00	34.48	68.88
7.00	0.00	0.00	0.00	34.48	68.88
8.00	0.00	0.00	0.00	34.48	68.88
9.00	0.00	0.00	0.00	34.48	68.88

ALT 3 SUMMARY

Pool		Slot		FB 77					
No.	Length [ft]	No.	Width [ft]	Hs [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]	Hs [ft]
CS	-	CS	3.00	-	0.24	3.95	-	62.10	-
1	15.65	1	1.90	0.50	0.87	7.79	6.00	83.18	0.50
2	17.50	2	1.80	0.50	0.95	7.99	6.25	94.42	0.75
3	16.00	3	1.70	0.00	0.89	7.61	6.07	103.04	0.00
4	16.00	4	1.70	0.00	0.92	7.62	6.16	115.11	0.00
5	15.29	5	1.70	0.00	0.94	7.60	6.21	126.80	0.00
6	15.40	6	1.70	0.00	0.95	7.56	6.25	138.38	0.00
7	15.21	7	1.75	0.50	0.97	7.61	6.33	149.69	1.00
8	11.18	8	1.75	1.50	0.98	7.63	6.34	149.69	1.25
9	11.18	9	1.65	1.75	0.97	7.60	6.32	149.69	1.50
10	11.18	Exit Slot	2.26	-	0.25	4.84	-	149.69	-

FB 74				FB 70				
dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]	Hs [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]
0.16	3.20	-	49.50	-	0.10	2.60	-	39.80
0.65	6.77	5.16	68.21	0.50	0.39	5.28	3.99	50.09
0.65	6.77	5.18	69.49	1.00	0.23	4.16	3.08	35.34
0.58	6.25	4.90	74.82	0.00	0.17	3.43	2.61	34.28
0.59	6.21	4.92	80.48	0.00	0.16	3.34	2.55	34.28
0.60	6.19	4.96	86.61	0.00	0.15	3.25	2.50	34.28
0.60	6.16	4.98	92.49	0.00	0.15	3.18	2.45	34.28
0.67	6.53	5.27	97.15	0.50	0.15	3.27	2.51	34.28
0.62	6.25	5.08	97.15	0.50	0.15	3.19	2.46	34.28
0.64	6.35	5.15	97.15	1.00	0.18	3.57	2.70	34.28
0.17	3.99	-	97.15	-	0.05	2.22	-	34.28

ALT 3, FBL = 77 ft

Variables			Constants		
Qcs =	62.10	cfs	Slope =	0.00	
Target Q =	145.46	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	149.69	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	4.23	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	77.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	76.97	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	-0.03	ft	CdPL =	0.18	
AWSC WS El. =	68.69	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	2.90	ft/s	Cdorifice =	0.80	
VH =	0.13	ft	Orifice Area =	2.25	sq.ft.
HL =	0.10	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	4.84	0.70		0.25
Channel	1.39			0.01
Exit to FB	1.39	0.50	0.10	0.02

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.60	Yes
Pool 1 (between CS and Slot 1)	1.72	Yes
Pool 2	1.76	Yes
Pool 3	1.90	Yes
Pool 4	1.84	Yes
Pool 5	1.92	Yes
Pool 6	1.90	Yes
Pool 7	1.92	Yes
Pool 8	2.59	Yes
Pool 9	2.39	Yes
Pool 10	2.22	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.24	5.00	5.24	62.10	62.10	0.00	0.24
1.00	63.00	84.00	1.90	0.50	68.24	69.12	4.74	5.62	83.18	83.18	0.00	0.87
2.00	63.00	84.00	1.80	0.50	69.12	70.07	5.62	6.57	94.42	94.42	0.00	0.95
3.00	63.00	84.00	1.70	0.00	70.07	70.96	7.07	7.96	103.04	103.04	0.00	0.89
4.00	63.00	84.00	1.70	0.00	70.96	71.88	7.96	8.88	115.11	115.11	0.00	0.92
5.00	63.00	84.00	1.70	0.00	71.88	72.82	8.88	9.82	126.80	126.80	0.00	0.94
6.00	63.00	84.00	1.70	0.00	72.82	73.77	9.82	10.77	138.38	138.38	0.00	0.95
7.00	63.00	84.00	1.75	0.50	73.77	74.74	10.27	11.24	149.69	149.69	0.00	0.97
8.00	63.00	84.00	1.75	1.50	74.74	75.72	10.24	11.22	149.69	149.69	0.00	0.98
9.00	63.00	84.00	1.65	1.75	75.72	76.69	10.97	11.94	149.69	149.69	0.00	0.97
Exit Slot	63.00	84.00	2.26	0.00	76.69	76.94						0.25
Channel	63.00	84.00	0.00	0.00	76.94	76.95						0.01
Exit to FB	63.00	84.00	0.00	0.00	76.95	76.97						0.02

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.95	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	7.79	6.00	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	7.99	6.25	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	7.61	6.07	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	7.62	6.16	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	7.60	6.21	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	7.56	6.25	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	7.61	6.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	7.63	6.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	7.60	6.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.10	-	-	-	-	Add In	-	-	-
1.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	12.06
4.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.69
5.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.58
6.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.31
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	21.08	21.08	62.10	68.69
1.00	11.24	0.00	11.24	83.18	68.69
2.00	8.62	0.00	8.62	94.42	68.69
3.00	-	0.00	12.06	103.04	68.69
4.00	-	0.00	11.69	115.11	68.69
5.00	-	0.00	11.58	126.80	68.69
6.00	-	0.00	11.31	138.38	68.69
7.00	0.00	0.00	0.00	149.69	68.69
8.00	0.00	0.00	0.00	149.69	68.69
9.00	0.00	0.00	0.00	149.69	68.69

ALT 3, FBL = 74 ft

Variables			Constants		
Qcs =	49.50	cfs	Slope =	0.00	
Target Q =	95.30	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	97.15	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	1.85	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	74.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	73.99	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	-0.01	ft	CdPL =	0.18	
AWSC WS El. =	68.73	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	2.60	ft/s	Cdorifice =	0.80	
VH =	0.10	ft	Orifice Area =	2.25	sq.ft.
HL =	0.08	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.99	0.70		0.17
Channel	1.77			0.02
Exit to FB	1.77	0.50	0.10	0.03

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.48	Yes
Pool 1 (between CS and Slot 1)	1.39	Yes
Pool 2	1.52	Yes
Pool 3	1.53	Yes
Pool 4	1.51	Yes
Pool 5	1.57	Yes
Pool 6	1.55	Yes
Pool 7	1.56	Yes
Pool 8	2.08	Yes
Pool 9	1.95	Yes
Pool 10	1.83	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.16	5.00	5.16	49.50	49.50	0.00	0.16
1.00	63.00	84.00	1.90	0.50	68.16	68.81	4.66	5.31	68.21	68.21	0.00	0.65
2.00	63.00	84.00	1.80	0.75	68.81	69.46	5.06	5.71	69.49	69.49	0.00	0.65
3.00	63.00	84.00	1.70	0.00	69.46	70.04	6.46	7.04	74.82	74.82	0.00	0.58
4.00	63.00	84.00	1.70	0.00	70.04	70.63	7.04	7.63	80.48	80.48	0.00	0.59
5.00	63.00	84.00	1.70	0.00	70.63	71.22	7.63	8.22	86.61	86.61	0.00	0.60
6.00	63.00	84.00	1.70	0.00	71.22	71.83	8.22	8.83	92.49	92.49	0.00	0.60
7.00	63.00	84.00	1.75	1.00	71.83	72.50	7.83	8.50	97.15	97.15	0.00	0.67
8.00	63.00	84.00	1.75	1.25	72.50	73.13	8.25	8.88	97.15	97.15	0.00	0.62
9.00	63.00	84.00	1.65	1.50	73.13	73.77	8.63	9.27	97.15	97.15	0.00	0.64
Exit Slot	63.00	84.00	2.26	0.00	73.77	73.94						0.17
Channel	63.00	84.00	0.00	0.00	73.94	73.96						0.02
Exit to FB	63.00	84.00	0.00	0.00	73.96	73.99						0.03

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.20	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	6.77	5.16	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	6.77	5.18	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	6.25	4.90	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	6.21	4.92	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	6.19	4.96	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	6.16	4.98	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	6.53	5.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	6.25	5.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	6.35	5.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.08	-	WF	-	-	Add In	-	-0.19	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Bleed Off	1.28	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	5.65
4.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	6.13
5.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	5.88
6.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	4.66
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	18.90	18.71	49.50	68.73
1.00	-	0.00	1.28	68.21	68.73
2.00	5.34	0.00	5.34	69.49	68.73
3.00	-	0.00	5.65	74.82	68.73
4.00	-	0.00	6.13	80.48	68.73
5.00	-	0.00	5.88	86.61	68.73
6.00	-	0.00	4.66	92.49	68.73
7.00	0.00	0.00	0.00	97.15	68.73
8.00	0.00	0.00	0.00	97.15	68.73
9.00	0.00	0.00	0.00	97.15	68.73

ALT 3, FBL = 72.7 ft

Variables			Constants		
Qcs =	49.01	cfs	Slope =	0.00	
Target Q =	70.86	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	77.10	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	6.24	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	72.70	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	72.81	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.11	ft	CdPL =	0.18	
AWSC WS El. =	68.78	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	2.20	ft/s	Cdorifice =	0.80	
VH =	0.08	ft	Orifice Area =	2.25	sq.ft.
HL =	0.06	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.55	0.70		0.14
Channel	1.99			0.03
Exit to FB	1.98	0.50	0.10	0.04

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.47	Yes
Pool 1 (between CS and Slot 1)	1.38	Yes
Pool 2	1.45	Yes
Pool 3	1.42	Yes
Pool 4	1.41	Yes
Pool 5	1.43	Yes
Pool 6	1.40	Yes
Pool 7	1.38	Yes
Pool 8	1.79	Yes
Pool 9	1.71	Yes
Pool 10	1.63	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.16	5.00	5.16	49.01	49.01	0.00	0.16
1.00	63.00	84.00	1.90	0.50	68.16	68.74	4.66	5.24	64.19	64.19	0.00	0.58
2.00	63.00	84.00	1.80	1.00	68.74	69.35	4.74	5.35	63.74	63.74	0.00	0.61
3.00	63.00	84.00	1.70	0.00	69.35	69.85	6.35	6.85	67.93	67.93	0.00	0.50
4.00	63.00	84.00	1.70	0.00	69.85	70.34	6.85	7.34	70.68	70.68	0.00	0.48
5.00	63.00	84.00	1.70	0.00	70.34	70.82	7.34	7.82	74.14	74.14	0.00	0.48
6.00	63.00	84.00	1.70	0.00	70.82	71.28	7.82	8.28	76.79	76.79	0.00	0.46
7.00	63.00	84.00	1.75	0.50	71.28	71.73	7.78	8.23	77.10	77.10	0.00	0.45
8.00	63.00	84.00	1.75	0.50	71.73	72.14	8.23	8.64	77.10	77.10	0.00	0.41
9.00	63.00	84.00	1.65	1.00	72.14	72.60	8.14	8.60	77.10	77.10	0.00	0.46
Exit Slot	63.00	84.00	2.26	0.00	72.60	72.74						0.14
Channel	63.00	84.00	0.00	0.00	72.74	72.77						0.03
Exit to FB	63.00	84.00	0.00	0.00	72.77	72.81						0.04

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.17	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	6.45	4.91	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	6.62	5.01	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	5.83	4.55	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	5.67	4.47	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	5.58	4.44	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	5.46	4.37	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	5.35	4.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	5.10	4.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	5.43	4.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	Picket Lead PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.06	-	WF	-	-	Add In	-	-0.81	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-0.45	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	2.75	-
4.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	3.46	-
5.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	2.65	-
6.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	0.31	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	15.99	15.18	49.01	68.78
1.00	-	0.00	-0.45	64.19	68.78
2.00	4.19	0.00	4.19	63.74	68.78
3.00	-	0.00	2.75	67.93	68.78
4.00	-	0.00	3.46	70.68	68.78
5.00	-	0.00	2.65	74.14	68.78
6.00	-	0.00	0.31	76.79	68.78
7.00	0.00	0.00	0.00	77.10	68.78
8.00	0.00	0.00	0.00	77.10	68.78
9.00	0.00	0.00	0.00	77.10	68.78

Variables			Constants		
Qcs =	45.17	cfs	Slope =	0.00	
Target Q =	47.50	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	52.56	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	5.06	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	71.20	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	71.28	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.08	ft	CdPL =	0.18	
AWSC WS El. =	68.84	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	1.90	ft/s	Cdorifice =	0.80	
VH =	0.06	ft	Orifice Area =	2.25	sq.ft.
HL =	0.04	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	2.87	0.70		0.09
Channel	2.37			0.04
Exit to FB	2.36	0.50	0.10	0.05

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.44	Yes
Pool 1 (between CS and Slot 1)	1.28	Yes
Pool 2	1.32	Yes
Pool 3	1.20	Yes
Pool 4	1.17	Yes
Pool 5	1.16	Yes
Pool 6	1.11	Yes
Pool 7	1.08	Yes
Pool 8	1.42	Yes
Pool 9	1.37	Yes
Pool 10	1.32	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.13	5.00	5.13	45.17	45.17	0.00	0.13
1.00	63.00	84.00	1.90	0.50	68.13	68.62	4.63	5.12	57.16	57.16	0.00	0.48
2.00	63.00	84.00	1.80	1.00	68.62	69.04	4.62	5.04	50.94	50.94	0.00	0.43
3.00	63.00	84.00	1.70	0.00	69.04	69.38	6.04	6.38	52.56	52.56	0.00	0.34
4.00	63.00	84.00	1.70	0.00	69.38	69.70	6.38	6.70	52.56	52.56	0.00	0.31
5.00	63.00	84.00	1.70	0.00	69.70	69.99	6.70	6.99	52.56	52.56	0.00	0.29
6.00	63.00	84.00	1.70	0.00	69.99	70.26	6.99	7.26	52.56	52.56	0.00	0.27
7.00	63.00	84.00	1.75	0.50	70.26	70.53	6.76	7.03	52.56	52.56	0.00	0.27
8.00	63.00	84.00	1.75	0.50	70.53	70.79	7.03	7.29	52.56	52.56	0.00	0.26
9.00	63.00	84.00	1.65	1.00	70.79	71.09	6.79	7.09	52.56	52.56	0.00	0.30
Exit Slot	63.00	84.00	2.26	0.00	71.09	71.18						0.09
Channel	63.00	84.00	0.00	0.00	71.18	71.22						0.04
Exit to FB	63.00	84.00	0.00	0.00	71.22	71.28						0.05

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	2.93	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.88	4.46	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	5.61	4.20	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	4.84	3.74	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	4.62	3.59	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	4.42	3.46	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	4.26	3.35	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	4.27	3.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	4.12	3.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	4.49	3.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.04	-	WF	-	-	Add In	-	-1.82	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-6.22	-	-
2.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Bleed Off	1.62	-	-
3.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
4.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
5.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
6.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	13.81	11.99	45.17	68.84
1.00	-	0.00	-6.22	57.16	68.84
2.00	-	0.00	1.62	50.94	68.84
3.00	-	0.00	0.00	52.56	68.84
4.00	-	0.00	0.00	52.56	68.84
5.00	-	0.00	0.00	52.56	68.84
6.00	-	0.00	0.00	52.56	68.84
7.00	0.00	0.00	0.00	52.56	68.84
8.00	0.00	0.00	0.00	52.56	68.84
9.00	0.00	0.00	0.00	52.56	68.84

ALT 3, FBL = 70 ft

Variables			Constants		
Qcs =	39.80	cfs	Slope =	0.00	
Target Q =	32.20	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	34.28	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	2.08	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	70.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	70.01	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.01	ft	CdPL =	0.18	
AWSC WS El. =	68.88	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	1.80	ft/s	Cdorifice =	0.80	
VH =	0.05	ft	Orifice Area =	2.25	sq.ft.
HL =	0.04	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	2.22	0.70		0.05
Channel	2.82			0.07
Exit to FB	2.79	0.50	0.10	0.07

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.38	Yes
Pool 1 (between CS and Slot 1)	1.13	Yes
Pool 2	1.18	Yes
Pool 3	0.88	Yes
Pool 4	0.83	Yes
Pool 5	0.84	Yes
Pool 6	0.82	Yes
Pool 7	0.81	Yes
Pool 8	1.07	Yes
Pool 9	1.05	Yes
Pool 10	1.02	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.10	5.00	5.10	39.80	39.80	0.00	0.10
1.00	63.00	84.00	1.90	0.50	68.10	68.49	4.60	4.99	50.09	50.09	0.00	0.39
2.00	63.00	84.00	1.80	1.00	68.49	68.72	4.49	4.72	35.34	35.34	0.00	0.23
3.00	63.00	84.00	1.70	0.00	68.72	68.89	5.72	5.89	34.28	34.28	0.00	0.17
4.00	63.00	84.00	1.70	0.00	68.89	69.04	5.89	6.04	34.28	34.28	0.00	0.16
5.00	63.00	84.00	1.70	0.00	69.04	69.20	6.04	6.20	34.28	34.28	0.00	0.15
6.00	63.00	84.00	1.70	0.00	69.20	69.34	6.20	6.34	34.28	34.28	0.00	0.15
7.00	63.00	84.00	1.75	0.50	69.34	69.49	5.84	5.99	34.28	34.28	0.00	0.15
8.00	63.00	84.00	1.75	0.50	69.49	69.64	5.99	6.14	34.28	34.28	0.00	0.15
9.00	63.00	84.00	1.65	1.00	69.64	69.82	5.64	5.82	34.28	34.28	0.00	0.18
Exit Slot	63.00	84.00	2.26	0.00	69.82	69.87						0.05
Channel	63.00	84.00	0.00	0.00	69.87	69.94						0.07
Exit to FB	63.00	84.00	0.00	0.00	69.94	70.01						0.07

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	2.60	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.28	3.99	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	4.72	orifice	0.87	4.16	3.08	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	3.43	2.61	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	3.34	2.55	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	3.25	2.50	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	3.18	2.45	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	3.27	2.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	3.19	2.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	3.57	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.04	-	WF	-	-	Add In	-	-2.80	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-14.75	-	-
2.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-1.06	-	-
3.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
4.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
5.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
6.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	13.08	10.29	39.80	68.88
1.00	-	0.00	-14.75	50.09	68.88
2.00	-	0.00	-1.06	35.34	68.88
3.00	-	0.00	0.00	34.28	68.88
4.00	-	0.00	0.00	34.28	68.88
5.00	-	0.00	0.00	34.28	68.88
6.00	-	0.00	0.00	34.28	68.88
7.00	0.00	0.00	0.00	34.28	68.88
8.00	0.00	0.00	0.00	34.28	68.88
9.00	0.00	0.00	0.00	34.28	68.88

ALT 4 SUMMARY

Pool		Slot		FB 77					
No.	Length [ft]	No.	Width [ft]	Hs [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]	Hs [ft]
CS	-	CS	3.00	-	0.24	3.95	-	62.10	-
1	15.65	1	1.70	0.00	0.91	7.96	6.11	83.18	0.00
2	17.50	2	1.70	0.00	0.93	7.90	6.20	95.03	0.00
3	16.00	3	1.70	0.00	0.90	7.64	6.10	103.71	0.00
4	16.00	4	1.70	0.00	0.93	7.65	6.19	115.88	0.00
5	15.29	5	1.70	0.00	0.94	7.62	6.24	127.67	0.00
6	15.40	6	1.70	0.25	0.99	7.74	6.38	139.34	0.50
7	15.21	7	1.70	0.25	0.99	7.66	6.38	150.84	1.00
8	11.18	8	1.70	1.00	0.96	7.53	6.28	150.84	1.25
9	11.18	9	1.70	1.75	0.93	7.42	6.19	150.84	1.50
10	11.18	Exit Slot	2.26	-	0.26	4.87	-	150.84	-

FB 74				FB 70				
dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]	Hs [ft]	dH [ft]	Vs [fps]	Vo [fps]	Ql [cfs]
0.16	3.20	-	49.50	-	0.10	2.60	-	39.80
0.67	6.89	5.24	68.21	0.00	0.39	5.36	4.03	50.09
0.60	6.41	4.96	70.01	0.00	0.19	3.71	2.81	35.85
0.59	6.30	4.94	75.16	0.00	0.17	3.46	2.64	34.48
0.59	6.21	4.92	80.20	0.00	0.16	3.37	2.58	34.48
0.59	6.18	4.95	86.16	0.00	0.15	3.28	2.52	34.48
0.65	6.47	5.19	91.88	0.00	0.15	3.21	2.47	34.48
0.70	6.65	5.36	96.68	0.25	0.15	3.26	2.51	34.48
0.64	6.36	5.15	96.68	0.50	0.16	3.31	2.54	34.48
0.60	6.12	4.98	96.68	1.00	0.17	3.50	2.66	34.48
0.17	3.96	-	96.68	-	0.05	2.24	-	34.48

Variables			Constants		
Qcs =	62.10	cfs	Slope =	0.00	
Target Q =	145.46	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	150.84	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	5.38	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	77.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	77.00	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.00	ft	CdPL =	0.18	
AWSC WS El. =	68.69	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	2.90	ft/s	Cdorifice =	0.80	
VH =	0.13	ft	Orifice Area =	2.25	sq.ft.
HL =	0.10	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	4.87	0.70		0.26
Channel	1.39			0.01
Exit to FB	1.39	0.50	0.10	0.02

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.60	Yes
Pool 1 (between CS and Slot 1)	1.72	Yes
Pool 2	1.75	Yes
Pool 3	1.90	Yes
Pool 4	1.84	Yes
Pool 5	1.93	Yes
Pool 6	1.91	Yes
Pool 7	1.92	Yes
Pool 8	2.59	Yes
Pool 9	2.39	Yes
Pool 10	2.23	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.24	5.00	5.24	62.10	62.10	0.00	0.24
1.00	63.00	84.00	1.70	0.00	68.24	69.15	5.24	6.15	83.18	83.18	0.00	0.91
2.00	63.00	84.00	1.70	0.00	69.15	70.08	6.15	7.08	95.03	95.03	0.00	0.93
3.00	63.00	84.00	1.70	0.00	70.08	70.98	7.08	7.98	103.71	103.71	0.00	0.90
4.00	63.00	84.00	1.70	0.00	70.98	71.91	7.98	8.91	115.88	115.88	0.00	0.93
5.00	63.00	84.00	1.70	0.00	71.91	72.85	8.91	9.85	127.67	127.67	0.00	0.94
6.00	63.00	84.00	1.70	0.25	72.85	73.84	9.60	10.59	139.34	139.34	0.00	0.99
7.00	63.00	84.00	1.70	0.25	73.84	74.83	10.59	11.58	150.84	150.84	0.00	0.99
8.00	63.00	84.00	1.70	1.00	74.83	75.78	10.83	11.78	150.84	150.84	0.00	0.96
9.00	63.00	84.00	1.70	1.75	75.78	76.71	11.03	11.96	150.84	150.84	0.00	0.93
Exit Slot	63.00	84.00	2.26	0.00	76.71	76.97						0.26
Channel	63.00	84.00	0.00	0.00	76.97	76.98						0.01
Exit to FB	63.00	84.00	0.00	0.00	76.98	77.00						0.02

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.95	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	7.96	6.11	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	7.90	6.20	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	7.64	6.10	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	7.65	6.19	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	7.62	6.24	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	7.74	6.38	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	7.66	6.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	7.53	6.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	7.42	6.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.10	-	-	-	-	Add In	-	-	-
1.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	12.17
4.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.79
5.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.67
6.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	11.50
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	21.08	21.08	62.10	68.69
1.00	11.85	0.00	11.85	83.18	68.69
2.00	8.68	0.00	8.68	95.03	68.69
3.00	-	0.00	12.17	103.71	68.69
4.00	-	0.00	11.79	115.88	68.69
5.00	-	0.00	11.67	127.67	68.69
6.00	-	0.00	11.50	139.34	68.69
7.00	0.00	0.00	0.00	150.84	68.69
8.00	0.00	0.00	0.00	150.84	68.69
9.00	0.00	0.00	0.00	150.84	68.69

Variables

Qcs =	49.50	cfs
Target Q =	95.30	cfs
Spreadsheet Q =	96.68	cfs
dQ =	1.38	cfs
Target FBL =	74.00	ft
Spreadsheet FBL =	74.01	ft
dFBL =	0.01	ft
AWSC WS El. =	68.73	ft

Picket Lead

v =	2.60	ft/s
VH =	0.10	ft
HL =	0.08	ft

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.96	0.70		0.17
Channel	1.77			0.02
Exit to FB	1.76	0.50	0.10	0.03

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.48	Yes
Pool 1 (between CS and Slot 1)	1.39	Yes
Pool 2	1.52	Yes
Pool 3	1.55	Yes
Pool 4	1.52	Yes
Pool 5	1.57	Yes
Pool 6	1.55	Yes
Pool 7	1.55	Yes
Pool 8	2.06	Yes
Pool 9	1.93	Yes
Pool 10	1.82	Yes

Constants

Slope =	0.00	
Invert =	63.00	ft NGVD 29
Wall Elev. =	84.00	ft NGVD 30
Weir 67 Crest =	67.00	ft, NGVD 29
Weir 67 Head =	1.00	ft
Weir 67 WS =	68.00	ft, NGVD 29
CdPL =	0.18	
CdBO =	0.62	
CdAI =	0.61	
Cw =	3.33	
Cdorifice =	0.80	
Orifice Area =	2.25	sq.ft.
Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1 LHS	RHS	Diff	Delta h
CS	63.00	84.00	3.00	0.00	68.00	68.16	5.00	5.16	49.50	49.50	0.00	0.16
1.00	63.00	84.00	1.70	0.00	68.16	68.82	5.16	5.82	68.21	68.21	0.00	0.67
2.00	63.00	84.00	1.70	0.00	68.82	69.42	5.82	6.42	70.01	70.01	0.00	0.60
3.00	63.00	84.00	1.70	0.00	69.42	70.01	6.42	7.01	75.16	75.16	0.00	0.59
4.00	63.00	84.00	1.70	0.00	70.01	70.60	7.01	7.60	80.20	80.20	0.00	0.59
5.00	63.00	84.00	1.70	0.00	70.60	71.20	7.60	8.20	86.16	86.16	0.00	0.59
6.00	63.00	84.00	1.70	0.50	71.20	71.85	7.70	8.35	91.88	91.88	0.00	0.65
7.00	63.00	84.00	1.70	1.00	71.85	72.55	7.85	8.55	96.68	96.68	0.00	0.70
8.00	63.00	84.00	1.70	1.25	72.55	73.19	8.30	8.94	96.68	96.68	0.00	0.64
9.00	63.00	84.00	1.70	1.50	73.19	73.79	8.69	9.29	96.68	96.68	0.00	0.60
Exit Slot	63.00	84.00	2.26	0.00	73.79	73.96						0.17
Channel	63.00	84.00	0.00	0.00	73.96	73.98						0.02
Exit to FB	63.00	84.00	0.00	0.00	73.98	74.01						0.03

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.20	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	6.89	5.24	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	6.41	4.96	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	6.30	4.94	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	6.21	4.92	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	6.18	4.95	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	6.47	5.19	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	6.65	5.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	6.36	5.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	6.12	4.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.08	-	WF	-	-	Add In	-	-0.19	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Bleed Off	1.80	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	5.03	-
4.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	5.96
5.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	5.72
6.00	0.00	0.00	0.00	0.00	-	-	FJF	-	Bleed Off	-	-	4.80
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	18.90	18.71	49.50	68.73
1.00	-	0.00	1.80	68.21	68.73
2.00	5.15	0.00	5.15	70.01	68.73
3.00	-	0.00	5.03	75.16	68.73
4.00	-	0.00	5.96	80.20	68.73
5.00	-	0.00	5.72	86.16	68.73
6.00	-	0.00	4.80	91.88	68.73
7.00	0.00	0.00	0.00	96.68	68.73
8.00	0.00	0.00	0.00	96.68	68.73
9.00	0.00	0.00	0.00	96.68	68.73

ALT 4, FBL = 72.7 ft

Variables

Qcs =	49.01	cfs
Target Q =	70.86	cfs
Spreadsheet Q =	74.15	cfs
dQ =	3.29	cfs
Target FBL =	72.70	ft
Spreadsheet FBL =	72.63	ft
dFBL =	-0.07	ft
AWSC WS El. =	68.78	ft

Constants

Slope =	0.00	
Invert =	63.00	ft NGVD 29
Wall Elev. =	84.00	ft NGVD 30
Weir 67 Crest =	67.00	ft, NGVD 29
Weir 67 Head =	1.00	ft
Weir 67 WS =	68.00	ft, NGVD 29
CdPL =	0.18	
CdBO =	0.62	
CdAI =	0.61	
Cw =	3.33	
Cdorifice =	0.80	
Orifice Area =	2.25	sq.ft.
Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Picket Lead

v =	2.20	ft/s
VH =	0.08	ft
HL =	0.06	ft

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	3.48	0.70		0.13
Channel	2.03			0.03
Exit to FB	2.02	0.50	0.10	0.04

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.47	Yes
Pool 1 (between CS and Slot 1)	1.38	Yes
Pool 2	1.45	Yes
Pool 3	1.45	Yes
Pool 4	1.42	Yes
Pool 5	1.42	Yes
Pool 6	1.38	Yes
Pool 7	1.35	Yes
Pool 8	1.75	Yes
Pool 9	1.67	Yes
Pool 10	1.60	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.16	5.00	5.16	49.01	49.01	0.00	0.16
1.00	63.00	84.00	1.70	0.00	68.16	68.76	5.16	5.76	64.19	64.19	0.00	0.60
2.00	63.00	84.00	1.70	0.00	68.76	69.28	5.76	6.28	64.00	64.00	0.00	0.52
3.00	63.00	84.00	1.70	0.00	69.28	69.78	6.28	6.78	67.77	67.77	0.00	0.51
4.00	63.00	84.00	1.70	0.00	69.78	70.26	6.78	7.26	69.70	69.70	0.00	0.48
5.00	63.00	84.00	1.70	0.00	70.26	70.73	7.26	7.73	72.33	72.33	0.00	0.46
6.00	63.00	84.00	1.70	0.00	70.73	71.17	7.73	8.17	74.15	74.15	0.00	0.44
7.00	63.00	84.00	1.70	0.25	71.17	71.60	7.92	8.35	74.15	74.15	0.00	0.43
8.00	63.00	84.00	1.70	0.50	71.60	72.01	8.10	8.51	74.15	74.15	0.00	0.41
9.00	63.00	84.00	1.70	1.00	72.01	72.43	8.01	8.43	74.15	74.15	0.00	0.42
Exit Slot	63.00	84.00	2.26	0.00	72.43	72.56						0.13
Channel	63.00	84.00	0.00	0.00	72.56	72.59						0.03
Exit to FB	63.00	84.00	0.00	0.00	72.59	72.63						0.04

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	3.17	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	6.56	4.98	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	6.00	4.62	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	5.88	4.58	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	5.64	4.45	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	5.51	4.37	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	5.34	4.27	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	5.23	4.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	5.13	4.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	5.17	4.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.06	-	WF	-	-	Add In	-	-0.81	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-0.19	-	-
2.00	0.00	0.00	0.00	0.00	-	-	-	PJF	Bleed Off	-	-	-
3.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	1.92	-
4.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	2.63	-
5.00	0.00	0.00	0.00	0.00	-	WF	-	-	Bleed Off	-	1.82	-
6.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	15.99	15.18	49.01	68.78
1.00	-	0.00	-0.19	64.19	68.78
2.00	3.77	0.00	3.77	64.00	68.78
3.00	-	0.00	1.92	67.77	68.78
4.00	-	0.00	2.63	69.70	68.78
5.00	-	0.00	1.82	72.33	68.78
6.00	-	0.00	0.00	74.15	68.78
7.00	0.00	0.00	0.00	74.15	68.78
8.00	0.00	0.00	0.00	74.15	68.78
9.00	0.00	0.00	0.00	74.15	68.78

ALT 4, FBL = 71.2 ft

Variables			Constants		
Qcs =	45.17	cfs	Slope =	0.00	
Target Q =	47.50	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	52.51	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	5.01	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	71.20	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	71.24	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.04	ft	CdPL =	0.18	
AWSC WS El. =	68.84	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	1.90	ft/s	Cdorifice =	0.80	
VH =	0.06	ft	Orifice Area =	2.25	sq.ft.
HL =	0.04	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	2.89	0.70		0.09
Channel	2.38			0.04
Exit to FB	2.37	0.50	0.10	0.05

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.44	Yes
Pool 1 (between CS and Slot 1)	1.28	Yes
Pool 2	1.32	Yes
Pool 3	1.22	Yes
Pool 4	1.18	Yes
Pool 5	1.17	Yes
Pool 6	1.11	Yes
Pool 7	1.09	Yes
Pool 8	1.42	Yes
Pool 9	1.37	Yes
Pool 10	1.32	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.13	5.00	5.13	45.17	45.17	0.00	0.13
1.00	63.00	84.00	1.70	0.00	68.13	68.63	5.13	5.63	57.16	57.16	0.00	0.49
2.00	63.00	84.00	1.70	0.00	68.63	68.99	5.63	5.99	51.47	51.47	0.00	0.36
3.00	63.00	84.00	1.70	0.00	68.99	69.33	5.99	6.33	52.51	52.51	0.00	0.34
4.00	63.00	84.00	1.70	0.00	69.33	69.65	6.33	6.65	52.51	52.51	0.00	0.32
5.00	63.00	84.00	1.70	0.00	69.65	69.94	6.65	6.94	52.51	52.51	0.00	0.29
6.00	63.00	84.00	1.70	0.00	69.94	70.22	6.94	7.22	52.51	52.51	0.00	0.28
7.00	63.00	84.00	1.70	0.25	70.22	70.49	6.97	7.24	52.51	52.51	0.00	0.27
8.00	63.00	84.00	1.70	0.50	70.49	70.76	6.99	7.26	52.51	52.51	0.00	0.27
9.00	63.00	84.00	1.70	1.00	70.76	71.05	6.76	7.05	52.51	52.51	0.00	0.29
Exit Slot	63.00	84.00	2.26	0.00	71.05	71.14						0.09
Channel	63.00	84.00	0.00	0.00	71.14	71.19						0.04
Exit to FB	63.00	84.00	0.00	0.00	71.19	71.24						0.05

Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	Bleed-Off / Add-In Diffusers						
						BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	2.93	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.97	4.52	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	5.05	3.86	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	4.88	3.76	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	4.64	3.61	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	4.45	3.48	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	4.28	3.37	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	4.26	3.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	4.25	3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	4.38	3.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.04	-	WF	-	-	Add In	-	-1.82	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-5.69	-	-
2.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Bleed Off	1.04	-	-
3.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
4.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
5.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
6.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	13.81	11.99	45.17	68.84
1.00	-	0.00	-5.69	57.16	68.84
2.00	-	0.00	1.04	51.47	68.84
3.00	-	0.00	0.00	52.51	68.84
4.00	-	0.00	0.00	52.51	68.84
5.00	-	0.00	0.00	52.51	68.84
6.00	-	0.00	0.00	52.51	68.84
7.00	0.00	0.00	0.00	52.51	68.84
8.00	0.00	0.00	0.00	52.51	68.84
9.00	0.00	0.00	0.00	52.51	68.84

ALT 4, FBL = 70 ft

Variables			Constants		
Qcs =	39.80	cfs	Slope =	0.00	
Target Q =	32.20	cfs	Invert =	63.00	ft NGVD 29
Spreadsheet Q =	34.48	cfs	Wall Elev. =	84.00	ft NGVD 30
dQ =	2.28	cfs	Weir 67 Crest =	67.00	ft, NGVD 29
Target FBL =	70.00	ft	Weir 67 Head =	1.00	ft
Spreadsheet FBL =	70.00	ft	Weir 67 WS =	68.00	ft, NGVD 29
dFBL =	0.00	ft	CdPL =	0.18	
AWSC WS El. =	68.88	ft	CdBO =	0.62	
			CdAI =	0.61	
Picket Lead			Cw =	3.33	
v =	1.80	ft/s	Cdorifice =	0.80	
VH =	0.05	ft	Orifice Area =	2.25	sq.ft.
HL =	0.04	ft	Maximum EDF =	4.00	ft-lbs/s/cu.ft.

Exit Losses

	Velocity	Ke	Ke, trash	HL
Exit Slot	2.24	0.70		0.05
Channel	2.83			0.07
Exit to FB	2.80	0.50	0.10	0.07

EDF Analysis

Pool Number	EDF	EDF OK?
Pool 0 (between Weir 67 and CS)	0.38	Yes
Pool 1 (between CS and Slot 1)	1.13	Yes
Pool 2	1.18	Yes
Pool 3	0.89	Yes
Pool 4	0.83	Yes
Pool 5	0.85	Yes
Pool 6	0.82	Yes
Pool 7	0.81	Yes
Pool 8	1.08	Yes
Pool 9	1.06	Yes
Pool 10	1.03	Yes

Output Copy

Slot & Orifice	Invert Elev.	Wall Elev.	Slot Width	Sill Height	hdown	hup	h2	h1	Slot Q Solving for H1			Delta h
									LHS	RHS	Diff	
CS	63.00	84.00	3.00	0.00	68.00	68.10	5.00	5.10	39.80	39.80	0.00	0.10
1.00	63.00	84.00	1.70	0.00	68.10	68.50	5.10	5.50	50.09	50.09	0.00	0.39
2.00	63.00	84.00	1.70	0.00	68.50	68.69	5.50	5.69	35.85	35.85	0.00	0.19
3.00	63.00	84.00	1.70	0.00	68.69	68.86	5.69	5.86	34.48	34.48	0.00	0.17
4.00	63.00	84.00	1.70	0.00	68.86	69.02	5.86	6.02	34.48	34.48	0.00	0.16
5.00	63.00	84.00	1.70	0.00	69.02	69.17	6.02	6.17	34.48	34.48	0.00	0.15
6.00	63.00	84.00	1.70	0.00	69.17	69.32	6.17	6.32	34.48	34.48	0.00	0.15
7.00	63.00	84.00	1.70	0.25	69.32	69.48	6.07	6.23	34.48	34.48	0.00	0.15
8.00	63.00	84.00	1.70	0.50	69.48	69.63	5.98	6.13	34.48	34.48	0.00	0.16
9.00	63.00	84.00	1.70	1.00	69.63	69.80	5.63	5.80	34.48	34.48	0.00	0.17
Exit Slot	63.00	84.00	2.26	0.00	69.80	69.86						0.05
Channel	63.00	84.00	0.00	0.00	69.86	69.92						0.07
Exit to FB	63.00	84.00	0.00	0.00	69.92	70.00						0.07

						Bleed-Off / Add-In Diffusers						
Slot & Orifice	h1/P	Equation	Discharge Coeff.	Vs (fps)	Vo (fps)	BO/AI No.	BO/AI Height	BO/AI Width	BO/AI Area	BO/AI Top EL	BO/AI Bot. EL	BO/AI CL EL
CS	NA	orifice	1.00	2.60	-	AI2 + PL	0.30	11.00	3.30	69.00	68.70	68.85
1.00	NA	orifice	0.87	5.36	4.03	AI1	0.71	12.50	8.88	69.01	68.30	68.66
2.00	NA	orifice	0.87	3.71	2.81	BO5	0.50	3.42	1.71	69.16	68.66	68.91
3.00	NA	orifice	0.87	3.46	2.64	BO4	0.50	4.50	2.25	70.03	69.53	69.78
4.00	NA	orifice	0.87	3.37	2.58	BO3	0.50	3.60	1.80	70.40	69.90	70.15
5.00	NA	orifice	0.87	3.28	2.52	BO2	0.50	3.20	1.60	70.92	70.42	70.67
6.00	NA	orifice	0.87	3.21	2.47	BO1	0.50	3.00	1.50	71.68	71.18	71.43
7.00	NA	orifice	0.87	3.26	2.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	NA	orifice	0.87	3.31	2.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	NA	orifice	0.87	3.50	2.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Picket Lead											
Slot & Orifice	PL Height	PL Width	PL Area	dH, PL	Par Sub Ori Flow?	Weir Flow?	Free Jet Flow?	Partial Jet Flow?	AI or BO Flow?	PSOF (cfs)	WF (cfs)	FJF (cfs)
CS	3.50	20.01	47.16	0.04	-	WF	-	-	Add In	-	-2.80	-
1.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-14.24	-	-
2.00	0.00	0.00	0.00	0.00	PSOF	-	-	-	Add In	-1.37	-	-
3.00	0.00	0.00	0.00	0.00	-	-	-	-	Add In	-	-	-
4.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
5.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
6.00	0.00	0.00	0.00	0.00	-	-	-	-	Bleed Off	-	-	-
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Slot & Orifice	PJF (cfs)	PL Flow (cfs)	Modified Q (cfs)	Channel Q (cfs)	AWSC WS EL
CS	-	13.08	10.29	39.80	68.88
1.00	-	0.00	-14.24	50.09	68.88
2.00	-	0.00	-1.37	35.85	68.88
3.00	-	0.00	0.00	34.48	68.88
4.00	-	0.00	0.00	34.48	68.88
5.00	-	0.00	0.00	34.48	68.88
6.00	-	0.00	0.00	34.48	68.88
7.00	0.00	0.00	0.00	34.48	68.88
8.00	0.00	0.00	0.00	34.48	68.88
9.00	0.00	0.00	0.00	34.48	68.88

APPENDIX E

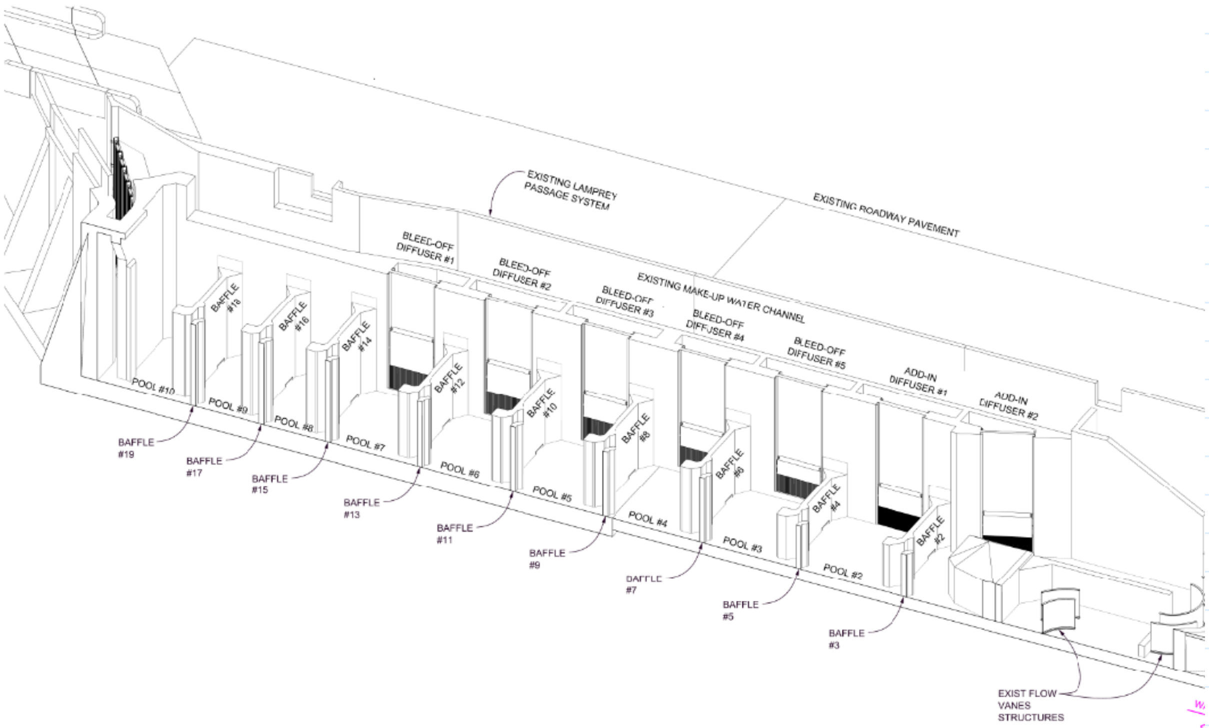
STRUCTURAL CALCULATIONS

Standard Baffle Design
Bonn Washington Shore Fish Ladder Work
DS Calcs

Collin Porter
8/6/21

Scope: Demolish control section weirs, replace them with vertical slot and orifice baffles. 4 baffle locations will require PIT tags. PIT tags will require FRP rebar.

DESIGN examples: https://structurepoint.org/publication/pdf/Reinforced-Concrete-Cantilever-Beam-Analysis-and-Design-(ACI-318-14).pdf
https://structurepoint.org/publication/pdf/Reinforced-Concrete-Precast-Wall-Panel-Analysis-Design-ACI318-11.pdf



Summary:
1. Constants
2. Loads/Load Combos
3. FBD
4. Assumptions
5. Hydrostatic Load
6. Vertical Live Load/Wall design
7. Seismic Loading
8. Wall Design
9. Temp and Shrinkage
10. Misc detailing
15. Platform Design
PIT Tag Baffle Design:
16. Geometry
17. PIT Tag Loads
18. FRP Rebar Constants
19. Flexure
20. Serviceability
21. Shear
22. Misc Detailing

on the 24 inch dowels:
how much is embedded and how much is exposed? and what size bars are these? are they deformed or smooth? are they epoxy installed and is cracked concrete the assumed condition for design? is there a need for waterstops on the new baffles

Design: Two different baffles will be designed in the report. One design will incorporate the PIT tags and FRP rebar. The other design will be a standard baffle with steel rebar.

1. Constants:

$Width_{controlsection} := 27\ ft + 6\ in$

$Heightwater_{controlsection} := varies$

$H_{pooldif} := 2.5\ ft$

$fc' := 4500\ psi$

$E_c := 57000 \cdot 67.1\ psi = 3824.7\ ksi$

$Heightwater_{diffuser} := 70\ ft - 63\ ft = 7\ ft$

$clear_{cover} := 2\ in$

$L_w := 1\ ft$

$b := 1\ ft$

$t_{baffle} := 12\ in$ (EM 1110-2-2104, 3

$\gamma_{fill} := 100\ pcf$

$\gamma_{conc} := 150\ pcf$

$sqrt4500psi := \sqrt{4500} \cdot psi = 67.082\ psi$

Standard Baffles:

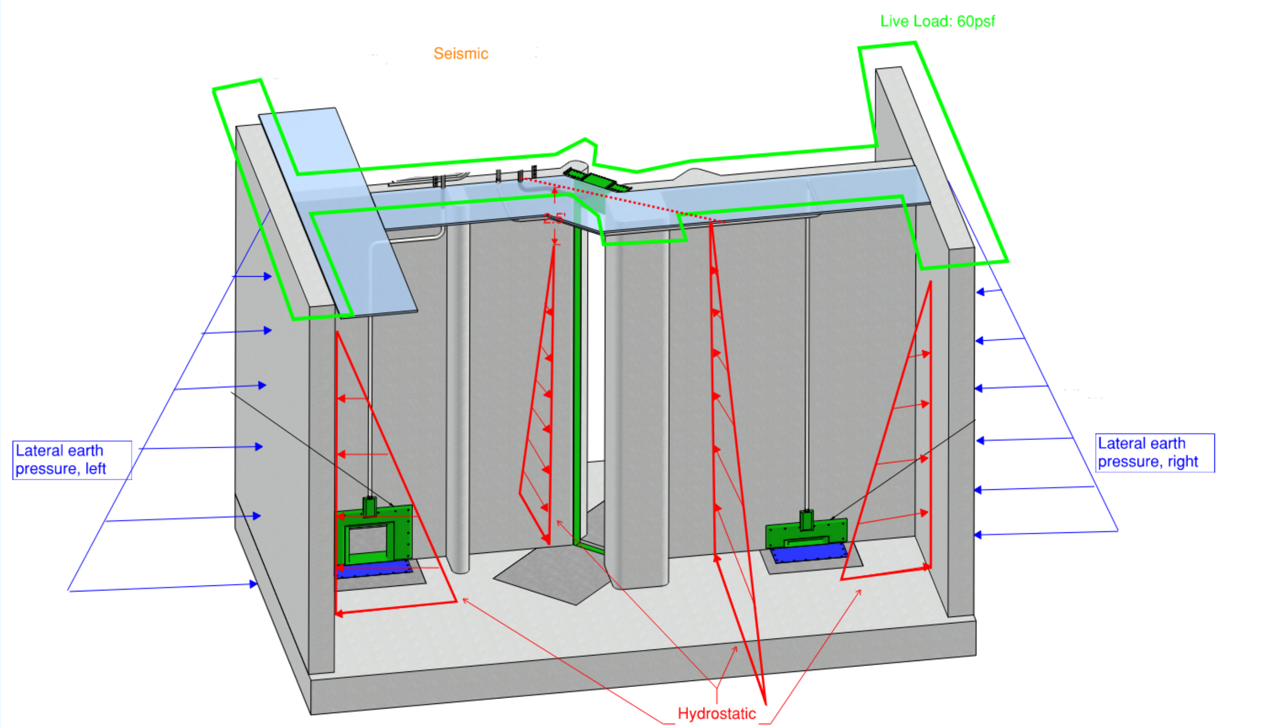
$H_{standard} := 13\ ft + 5\ in$ $E_s := 29000\ ksi$ $f_y := 60\ ksi$ $\phi_s := 0.75$ $\phi_f := 0.9$

2. Loads (Load Factors): EM 1110-2-2104 Table 3-1, Use all "unusual" factors (hydraulic engineer)
1. Dead load (self wt)(2.2)
2. Lateral earth (2.2)
3. Hydrostatic (1.6) (from hydraulic engineer: I would assume an ACE of 9E-04 for pool 82 feet NGVD 29)
4. Live Loading (60 psf, "Walkways and elevated platforms" (ASCE 7-16, Table 4.3-1))(2.2)
6. Seismic

Table
cast-

Conc

3. FBD:



4. Assumptions:

1. Max water level in control section channel assumed to be top of baffle
2. Hydraulic force was treated as uniform to be most conservative
3. Baffles are treated as cantilevered beam anchored at control section floor
4.

5. Hydrostatic load: Loading provided by Hydraulic Engineer

Load from Hydraulic engineer: (see document titled "B2 WA Shore Hydrodynamic Force" and snip its shown below)

Load Factor: 1.6 (EM 1110-2-2104, unusual)

Uniform load given: $F_{hydrostatic.unfactored} := 118.2\ \frac{lbf}{ft^2}$ (lbf per ft, per ft into page)

Factored Hydrostatic load: $F_{hydrostatic} := 1.6 \cdot 118.2\ \frac{lbf}{ft} = 189.12\ \frac{lbf}{ft}$ (lbf per ft into page)

Shear/Moment/Deflection: of a cantilevered beam, uniformly loaded

$E_s := 29000\ ksi$ $\quad I_{baffle} := \frac{b \cdot t_{baffle}^{\ 3}}{12} = 1728\ in^4$ $\quad b := 1\ ft$

$$V_u := F_{hydrostatic} \cdot H_{standard} = 2.537\ kip$$

$$M_u := \frac{F_{hydrostatic} \cdot H_{standard}^{\ 2}}{2} = 17.021\ kip \cdot ft$$

$$\Delta_{baffle} := \frac{F_{hydrostatic.unfactored} \cdot H_{standard}^{\ 4} \cdot in}{8 \cdot E_s \cdot I_{baffle}} = 0.001\ in$$

6. Vertical Live Load + Hydrostatic load: Combined Wall Loads

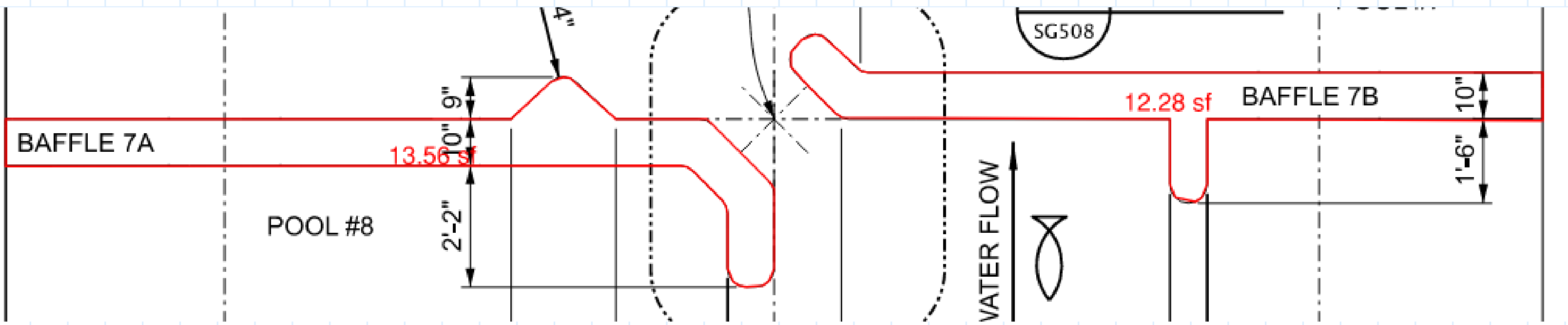
https://structurepoint.org/publication/pdf/Reinforced-Concrete-Precast-Wall-Panel-Analysis-Design-ACI318-11.pdf

Live Load: 60 psf on top of baffles for maintenance and walkways (ASCE 7-16, Table 4.3-1)

Factored live load: $L_L := 1.6 \cdot 60\ psf = 96\ \frac{lbf}{ft^2}$

Live load area:
Left side: 13.56 sf
Right side: 12.28 sf

$A_{liveload} := 13.56\ ft^2 + 12.28\ ft^2 = 25.84\ ft^2$

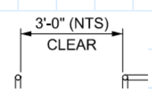


Design the right side baffle because it has slightly less concrete and both have a orifice antenna. Right side antenna is roughly 18" wide.

ACI Chapter 11 Loading: bending (force of water), Live load (on top of baffles), and self weight

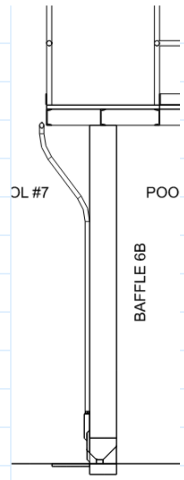
Determine Pu (vertical load)for a 1' wide strip and 10" baffle: $L_w := 1\ ft$

$$P_{u1} := L_L \cdot L_w \cdot t_{baffle} = 0.096\ kip$$



Standard Baffle Design
Bonn Washington Shore Fish Ladder Work
DS Calcs

Collin Porter
8/6/21



Eccentricity of Pu1: (assume half of walkway span)

$$e_1 := \frac{3\ ft}{2} = 18\ in$$

Determine self weight Pu2, factored:

$$P_{u2} := 1.6 \cdot \gamma_{conc} \cdot t_{baffle} \cdot L_w \cdot H_{standard} = 3.22\ kip$$

$$P_u := P_{u1} + \frac{P_{u2}}{2} = 1.706\ kip$$

Mua: max moment with 3 loads

$$M_{ua} := \frac{F_{hydrostatic} \cdot H_{standard}^{\ 2}}{2} + \frac{P_u \cdot e_1}{2} = 18.301\ kip \cdot ft$$

(Mua is the mx factored moment at midheight of wall due to lateral and eccentric vertical loads, not including Pdelta effects.)

7. Seismic Design: Same for Standard baffles and PIT baffles

Risk category: 1   (IBC Table 1604.5) (low hazard to human life in the event of a failure)

Seismic design category: Table 1613.2.5

OBE = Unusual Load
MDE = MCE = Extreme Load

TABLE 1613.2.5(1)
SEISMIC DESIGN CATEGORY BASED ON SHORT-PERIOD (0.2 second) RESPONSE ACCELERATION

VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
S_{DS} < 0.167g	A	A	A

$$S_{DS} := 0.367$$ (seismic maps .org)

SDC from table: C

0.167g ≤ S_{DS} < 0.33g	B	B	C
0.33g ≤ S_{DS} < 0.50g	C	C	D
0.50g ≤ S_{DS}	D	D	D

TABLE 1613.2.5(2)

SEISMIC DESIGN CATEGORY BASED ON 1-SECOND PERIOD RESPONSE ACCELERATION

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
S_{D1} < 0.067g	A	A	A
0.067g ≤ S_{D1} < 0.133g	B	B	C
0.133g ≤ S_{D1} < 0.20g	C	C	D
0.20g ≤ S_{D1}	D	D	D

$S_{D1} := 0.148$ (seismic maps .org)

SDC from table: C

From ACI 319-19, structures assigned to SDC C shall satisfy sections 18.2.2, 18.2.3, and 18.13:

18.2.2: Analysis and proportioning of structural members: yes
18.2.3: Anchoring to Concrete:
-Post installed anchors shall be in accordance with ACI 355.2 or ACI 355.4
-Steel strength needs to be 1.2 times the nominal strength of anchor. (steel is fy = 60 ksi, anchor needs to be 50ksi or less)
18.13: Foundations: However, this work will not deal with any foundations and will not extend past channel floor.

Westergaards Equation: ETL 1110-2-584, EQ 3-2

Distance below water surface: $y := \frac{H_{standard}}{2}$

ac: $a_{c.OBE} := 0.09\ g$ $a_{c.MCE} := 0.24\ g$ (Bon Seismic Eval Report Phase 1b)

$\gamma_w := 62.4\ \frac{lb}{ft^3}$

$$p_{.OBE} := \frac{7}{8} \cdot \gamma_w \cdot a_{c.OBE} \cdot \sqrt{H_{standard} \cdot y} \cdot ft = 46.619\ \frac{lbf}{ft}$$ (converted to per ft per ft)

$$p_{.MCE} := \frac{7}{8} \cdot \gamma_w \cdot a_{c.MCE} \cdot \sqrt{H_{standard} \cdot y} \cdot ft = 124.318\ \frac{lbf}{ft}$$ (converted to per ft per ft)

Factored, site specific OBE with all other loads: EM 2104

3.3.3.3.1. For standard and site specific OBE ground motion analysis:

$$U = 1.5\ (\Sigma\ Lp + Lt_U + EQ) \quad (3\text{-}7)$$

$$M_{ua.OBE} := M_{ua} + 1.5 \cdot \left(\frac{p_{.OBE} \cdot H_{standard}^{\ 2}}{2} \right) = 24.595 \ kip \cdot ft$$

(Mua has already been factored, 1.6)

Therefore this load controls

Factored, site specific MCE with all other loads: EM 2104

3.3.3.3.5. For site specific MCE ground motion analysis Critical RCHS:

U = 1.0 Σ Lp + 1.0 Lt_U + 1.0 EQ (3-11)

$$M_{ua.MCE} := \frac{M_{ua}}{1.6} + \left(\frac{p_{.MCE} \cdot H_{standard}^{\ 2}}{2} \right) = 22.627 \ kip \cdot ft$$

(Mua was unfactored, from 1.6 to 1)

8. Design Baffle as Wall: Using ACI chapter 11 wall design with a vertical load on top of wall and lateral load pushing on the wall

https://structurepoint.org/publication/pdf/Reinforced-Concrete-Precast-Wall-Panel-Analysis-Design-ACI318-11.pdf

Wall Combined Flexural and Axial load, 11.8.3: Factored Moment

$L_w = 12 \ in$

$clear_{cover} = 2 \ in$

$fc' := 4500 \ psi$

$d_{stirrups} := 0.5 \ in$

$d_{longitudinal} := 0.5 \ in$

$E_c := 57000 \cdot sqrt4500psi = 3823.676 \ ksi \quad E_s := 29000 \ ksi$

$f_y := 60 \ ksi$

$k := 0.8$ (Table 11.5.3.2)

$$d := t_{baffle} - clear_{cover} - d_{stirrups} - \frac{d_{longitudinal}}{2} = 9.25 \ in$$

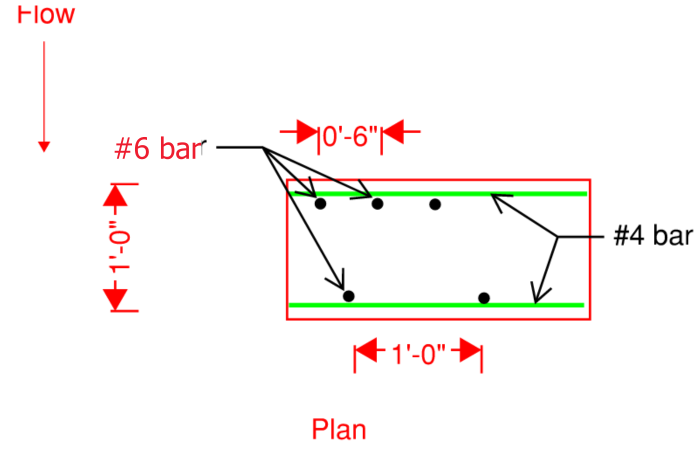
$A_g := L_w \cdot t_{baffle} = 144 \ in^2$

Phi, ϕ:

$\varepsilon_{ty} := 0.002$

$\varepsilon_t := 0.005$ (tension controlled limit) $\phi := 0.9$

$\varepsilon_t \geq \varepsilon_{ty} + 0.003 = 1$ (Table 21.2.2)



$r := 0.289 \cdot t_{baffle}$

Check slenderness: ACI 6.2.5

$$\frac{k \cdot H_{standard}}{r} = 37.14$$

$$\frac{k \cdot H_{standard}}{r} < 22 = 0$$

Therefore wall is slender

Vertical Reinforcement: two #6 bars at 6 in o.c. (As = 0.44 in^2)

$A_{s.vertical} := 0.44\ in^2 \cdot 2 = 0.88\ in^2$ (cross sectional area per foot)

Loading: from above seismic controls

$M_{ua.OBE} = 24.595\ kip \cdot ft$ (combined) $P_u = 1.706\ kip$ (axial load)

Axial load and out of plane flexure, Axial capacity: 11.5.3.1 and 22.4

$$\phi P_n := \phi \cdot 0.55 \cdot fc' \cdot A_g \cdot \left(1 - \left(\frac{k \cdot L_w}{32 \cdot t_{baffle}}\right)\right) = 312.741\ kip \qquad (11.5.3.1)$$

$$\phi P_o := \phi \cdot 0.85 \cdot fc' \cdot (A_g - A_{s.vertical}) + f_y \cdot A_{s.vertical} = 545.491\ kip \qquad (22.4)$$

Axial load and out of plane flexure, flexural capacity: 11.5.3.1 and 22.4

11.5.2 *Axial load and in-plane or out-of-plane flexure*

11.5.2.1 For bearing walls, P_n and M_n (in-plane or out-of-plane) shall be calculated in accordance with 22.4. Alternatively, axial load and out-of-plane flexure shall be permitted to be considered in accordance with 11.5.3.

11.5.2.2 For nonbearing walls, M_n shall be calculated in accordance with 22.3.

11.5.3 *Axial load and out-of-plane flexure – simplified design method*

11.5.3.1 If the resultant of all factored loads is located within the middle third of the thickness of a solid wall with a rectangular cross section, P_n shall be permitted to be calculated by:

$$P_n = 0.55 f'_c A_g \left[1 - \left(\frac{k\ell_c}{32h}\right)^2\right] \quad (11.5.3.1)$$

See below

Wall Cracking Moment Capacity, Modulus of rupture: ACI 19.2.3

$\lambda := 1$

$f_r := 7.5 \cdot \lambda \cdot sqrt4500psi = 503.115\ psi$ (aci EQ 19.2.3.1)

$I_{baffle} = 1728\ in^4$

$y_t := \frac{t_{baffle}}{2} = 6\ in$

$$M_{cr} := \frac{f_r \cdot I_{baffle}}{y_t} = 12.075\ kip \cdot ft$$ (aci EQ 24.2.3.5)

Wall Flexural Moment capacity: 22.4

$$a := \frac{A_{s.vertical} \cdot f_y}{0.85 \cdot fc' \cdot L_w} = 1.15\ in$$

$$\phi_f M_n := \phi_f \cdot A_{s.vertical} \cdot f_y \cdot \left(d - \frac{a}{2}\right) = 34.352\ kip \cdot ft$$

Check:

$\phi_f M_n > M_{ua} = 1$ $M_{cr} > M_{ua} = 0$ (meaning temp and shrinkage bars are required)

Wall Vertical Stress Check:

$$\frac{P_u}{A_g} < 0.06 \cdot fc' = 1$$ (therefore wall is ok)

$$I_{baffle} = \left(1.728 \cdot 10^3\right)\ in^4$$

Deflection: ACI EQ 11.8.4.3a

$$\Delta_{allowable} := \frac{H_{standard}}{240} = 0.671\ in$$

$$\Delta_u := \frac{5 \cdot M_{ua} \cdot H_{standard}^{\ 2}}{0.75 \cdot 48 \cdot E_c \cdot I_{baffle}} = 0.12\ in$$

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

$allowable \cdot \quad u$

Check, In Plane Shear: EQ 11.5.4.3

$\frac{H_{standard}}{14\ ft} = 0.958$ Hw/Lw therefor, $\alpha_c := 1.5$

$A_v := 0.2\ in^2 = 0.2\ in^2$ (1 legs of #4 bar every 12", see shear design below)

$\rho_t := \frac{A_v}{L_w \cdot t_{baffle}} = 0.001$

$A_{cv} := L_w \cdot t_{baffle}$

$$\phi V_n := \left(\alpha_c \cdot \lambda \cdot sqrt4500psi + \rho_t \cdot f_y\right) \cdot A_{cv} = 26.49\ kip$$

$$\phi V_n > V_u = 1$$

Check, Out of plane shear: ACI 22.5.1.1

$\phi V_n := \phi \cdot \left(V_c + V_s\right)$ (see below)

Vc: 22.5.5

Determine if Av > Avmin

$A_v = 0.2\ in^2$ (1 legs of #4 bar, per foot)

$s := 12\ in$
(because on on each face?)

Av min, 10.6.2.2: max of eq's below

$s := 12\ in$

is this vertical or US/DS?
(spacing, assumed)

$A_{v\_min1} := 0.75 \cdot sqrt4500psi \cdot \frac{L_w \cdot s}{\ } = 0.121\ in^2$

$$f_y$$

$$A_{v.min2} := 50 \cdot \frac{L_w \cdot s}{f_y} \cdot psi = 0.12\ in^2$$

$$A_v > A_{v.min1} = 1$$

Therefore use Table 22.5.5.1, (a)

$$V_c := \left(2 \cdot \lambda \cdot sqrt4500psi + \frac{P_u}{6 \cdot A_g}\right) L_w \cdot d = 15.111\ kip$$

Vs: 22.5.8.5.3

$$V_s := \frac{A_v \cdot f_y \cdot d}{s} = 9.25\ kip$$

Shear check:

$$\phi V_n := \phi \cdot \left(V_c + V_s\right) = 21.925\ kip$$

$$V_u = 2.537\ kip$$

$$\phi V_n > V_u = 1$$

Check Shear, strength of just concrete:

$$\phi_s := 0.75$$

$$\phi_s V_c := \phi_s \cdot 2 \cdot L_w \cdot d \cdot sqrt4500psi = 11.169\ kip$$

$$\frac{\phi_s V_c}{} = 5.585\ kip \quad > \quad V_u = 2.537\ kip$$

2

$$\frac{\phi_s V_c}{2} > V_u = 1$$

therefor shear reinforcement is not required. (however will still use shear bars)

Max Spacing, ACI 11.7.3.1: shall not exceed the lesser of 3h (h=wall thickness) and 18":

$$s_{max} := min\left(3 \cdot t_{baffle}, 18\ in\right) = 18\ in$$

Try 12" o.c. spacing. $s := 12\ in$

$$\#_{stirrups} := \frac{H_{standard}}{s} = 13.417$$

9. Temp and Shrinkage Bars: ACI 24.4 and EM 2100-2-2104

Ratio of deformed shrinkage and temp reinforcement area to gross concrete area shall be greater than 0.0018 and 0.003:

$$A_v = 0.2\ in^2$$

Check upstream side: (has flexural bars)

$$A_{st} := A_{s.vertical} + A_v = 1.08\ in^2$$

(two #6 bars vertically every 12" and 1 #4 bars horizontally every 12")

$$A_g = 144\ in^2$$

$$\rho := \frac{A_{st}}{A_g} = 0.008$$

$$\rho > 0.003 = 1$$

Check downstream side: (does not have flexural bars)

$$A_{st} := A_v = 0.2\ in^2$$

$$A_g = 144\ in^2$$

$$\rho := \frac{A_{st}}{A_g} = 0.001$$

$\rho > 0.003 = 0$ Therefore, the downstream face needs temp and shrinkage bars.

Try 1 vertical #6 bar every 12":

$$A_{st} := \frac{A_{s.vertical}}{2} + A_v = 0.64\ in^2$$

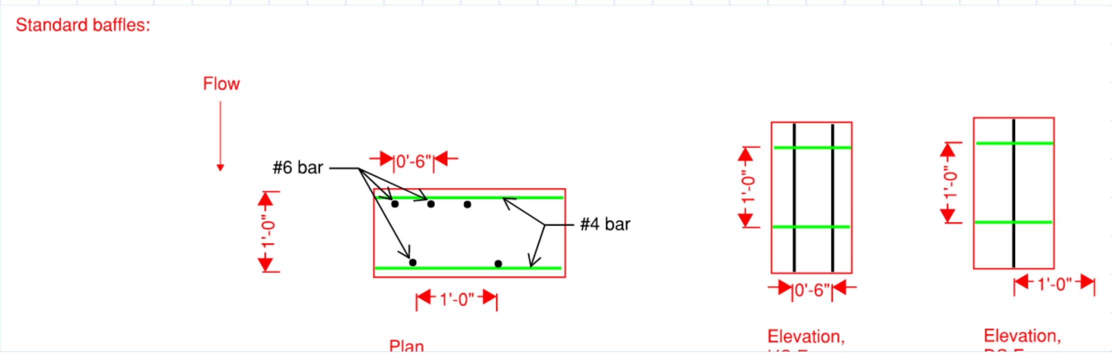
$$\rho := \frac{A_{st}}{A_g} = 0.004$$

$\rho > 0.003 = 1$ Therefore, the downstream face needs one #6 bar every 12"

Max temp and shrinkage bar spacing: min (5h, 18in) $h := 10\ in$

Max spacing: 18" (assumed spacing was 12" max)

Sketch:



US Face DS Face

10. Misc Detailing: ACI

Concrete cover: Table 20.5.1.3.1

No. 5 bars and less: 1.5 in all around

No. 6-18 sized bars: 2 in all around

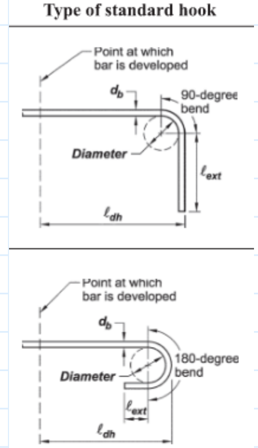
Hooks/Inside Bend Diameters: Section 25.3

Bend diam, Table 25.3.1:

90 degree hook: bend diam = 6*db = 3 inches (for #4 bars) and 4.5 inches (for #6 bars)

180 degree hook: identical

Type of standard hook



Length of extension, Ldh, Table 25.3.1:

90 degree hook: 12db = 6" or 9"

180 degree hook: 2.5"

Developmental Length: Section 25.4

For deformed bars or deformed wires, Ld, EQ 25.4.2.4a

$\lambda := 1$ $K_{tr} := 0$ (25.4.2.4b, 0 can be used as a design simplification)

$\psi_t := 1$ (less than 12" of fresh conc under horizontal reinforcement)

$\psi_e := 1$ (uncoated or galvanized rebar)

$\psi_s := 0.8$ (No. 6 bars or smaller)

Cb: lesser of: a. distance from center of a bar to nearest concrete surface or b. 1/2 c.c. of bars developed

a. $clear_{cover} + \frac{0.75\ in}{2} = 2.375\ in$

b. $10\ in$

$\psi_g := 1$ (Reinforcement grade 60) $c_b := 2.375\ in$ $d_{flexure} := 0.75\ in$

$$l_d := \left(\frac{3 \cdot f_y \cdot \psi_t \cdot \psi_e \cdot \psi_s \cdot \psi_g}{40 \cdot \lambda \cdot sqrt4500psi \cdot \left(\frac{c_b + K_{tr}}{d_{flexure}} \right)} \right) \cdot d_{flexure} = 12.71\ in$$

(call it 14")

Splice Lengths for flexural bars: Section 25.5, table 25.5.2.1

$l_{st} := 12\ in$

(splice length for bars in compression is the larger of 12" or 0.0005*fy*db. The flexural bars are tension and compression)

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.

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15. Maintenance Platform/Walkways: (see plans for more info)

-to be contractor designed

-Requirements for design:

- -Material for entire walkway system must be non ferrous (alumninum, fiberglass seem to be most popular)
- -Walkway must be anchored into new baffles (non ferrous anchorage required)
- -Walkways to be a minimum 2 ft wide
- -Walkways and platforms must have guard rails and toe kicks (designed in accordance with USACE Safety Manual 385-1-1)
- -PIT antennas must be easily accessible and removable, meaning grating cannot cover the PIT Antennas
- -Walkway must keep access/allow access to all electrical boxes

-Loading: shall not be less than 100 pounds per square feet (unless noted on the drawings)

-Deflection Limits:

- -Grating and floor panel deflection at center of span to not exceed 1/4"
- -Structural members: L/180

Post installed anchors shall be in accordance with ACI 355.2 or ACI 355.4

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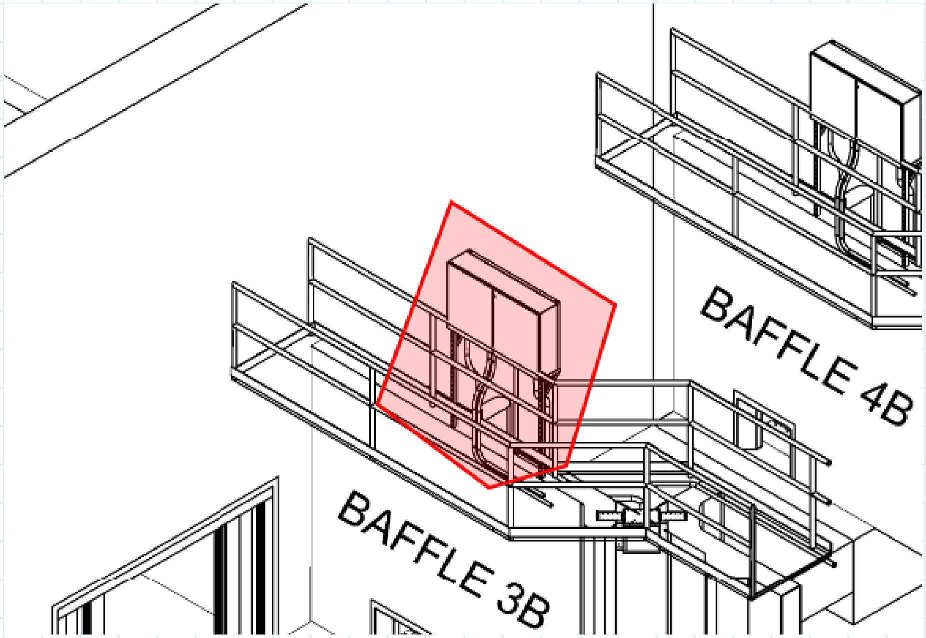
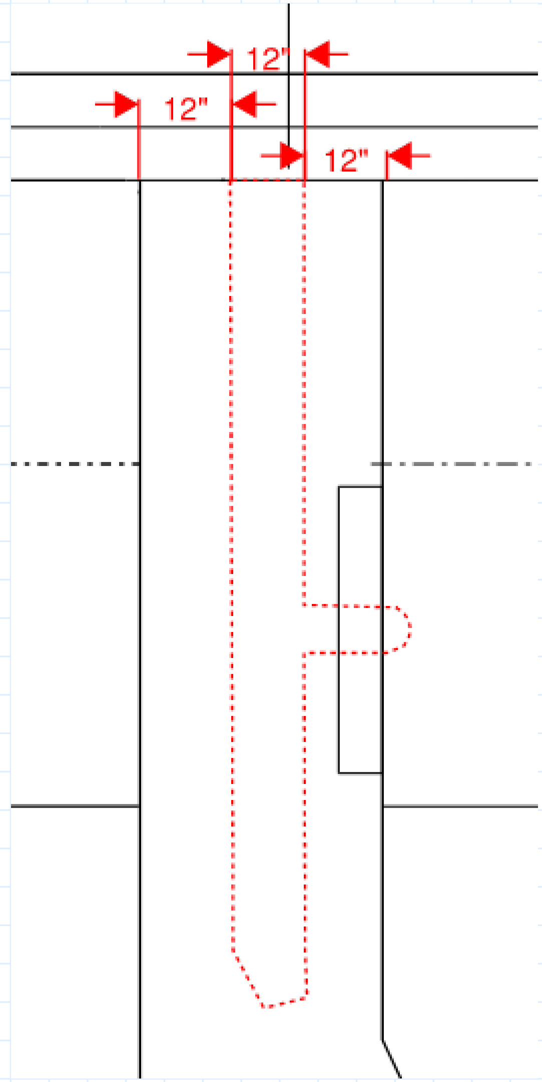
Electrical Panel/Rain Shield Design/Attachment:





Note: maintenance platform to straddle baffle "3b" vs cantilvered (as shown).

Standard Baffle Design
Bonn Washington Shore Fish Ladder Work
DS Calcs

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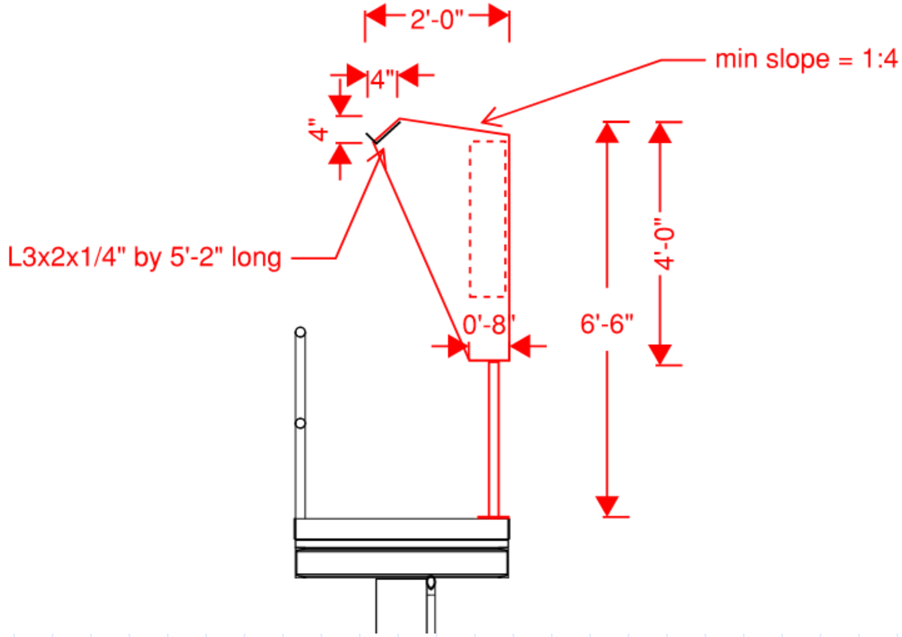

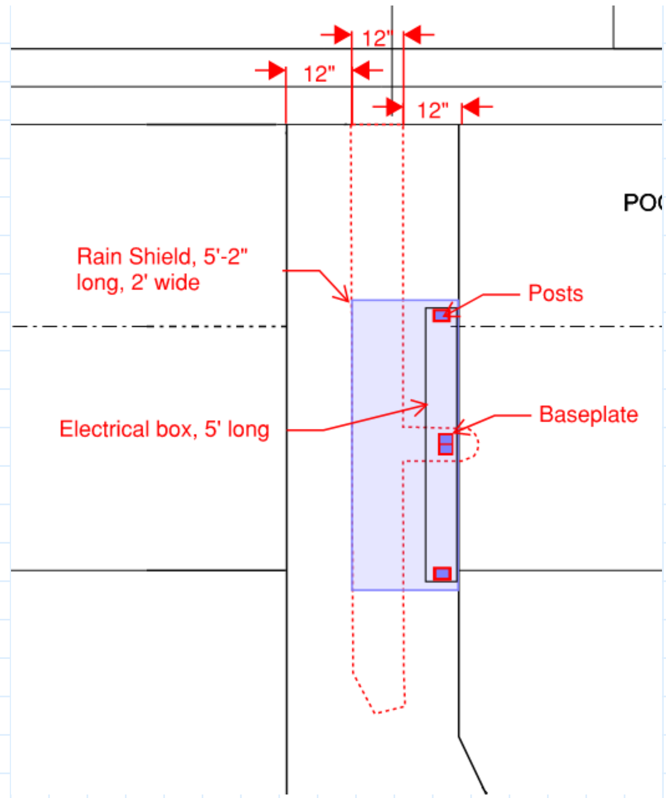

Height of shield:

- previous rain shields top at 6'-6"
- easily fit a 6'-3" person with hard hat

Width of shield:

- one inch wider than electrical panel on each side

Depth of shield:

- 18" from eyes to control panel (Normal control panel distance)

$$w_{aluminum} := 169 \frac{lbf}{ft^3}$$

Weight of shield:

- 4, 6'-2" tall aluminum posts (3x2x1/4")

$$weight_{posts} := \left(\left(\left(3\ in \cdot \frac{1}{4}\ in \cdot 2\right) + \left(2\ in \cdot \frac{1}{4}\ in \cdot 2\right)\right) \cdot 6.167\ ft\right) \cdot 4 \cdot w_{aluminum} = 72.377\ lbf$$

- Sides (from drawings)

$$weight_{sides} := \left(5.762\ ft^2 \cdot \frac{1}{4}\ in\right) \cdot 2 \cdot w_{aluminum} = 40.574\ lbf$$

- Top (footprint is 2' wide by 5'-2" long)

$$weight_{top} := 2\ ft \cdot 5.167\ ft \cdot \frac{1}{4}\ in \cdot w_{aluminum} = 36.384\ lbf$$

- Back (4' by 5'-2")

$$weight_{back} := 4\ ft \cdot 5.167\ ft \cdot \frac{1}{4}\ in \cdot w_{aluminum} = 72.769\ lbf$$

- Baseplates (4, 4x3x1/4)

$$weight_{baseplates} := 4 \cdot \left(4\ in \cdot 3\ in \cdot \frac{1}{4}\ in \cdot w_{aluminum}\right) = 1.174\ lbf$$

Rain Shield Weight: Factored (1.2*D) and 5% misc weight

$$Weight_{rainshield} := \left(1.2 \cdot \left(weight_{posts} + weight_{sides} + weight_{top} + weight_{back} + weight_{baseplates}\right)\right) \cdot 1.05 = 281.329\ lbf$$

Electrical box weight: Factored, 1.2D (from electrical engineer)

$$Weight_{electricalbox} := 1.2 \cdot 200\ lbf = 240\ lbf$$

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Combined added weight:

$$Weight_{total} := Weight_{rainshield} + Weight_{electricalbox} = 521.329\ lbf$$

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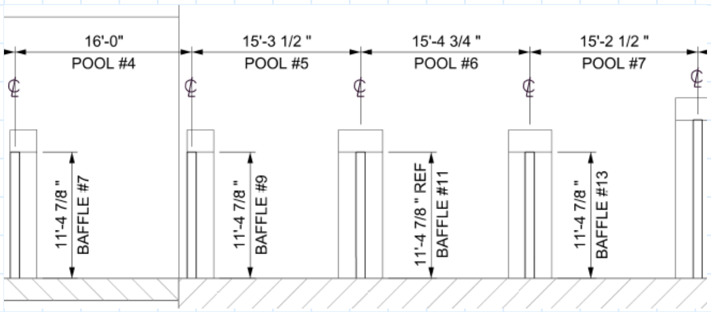
PIT Tag Baffle's (Slots 3-6) Must be GFRP (glass), to be non conductive

Design: The baffles are designed in accordance with ACI 318-19, ACI 440, and EM 1110-2-2104

Geometry: The PIT tag baffles will be approximately 3' shorter than the controlling non PIT tag baffles. All other geometry is identical.

PIT Tag Baffle: (Slots 3-6)

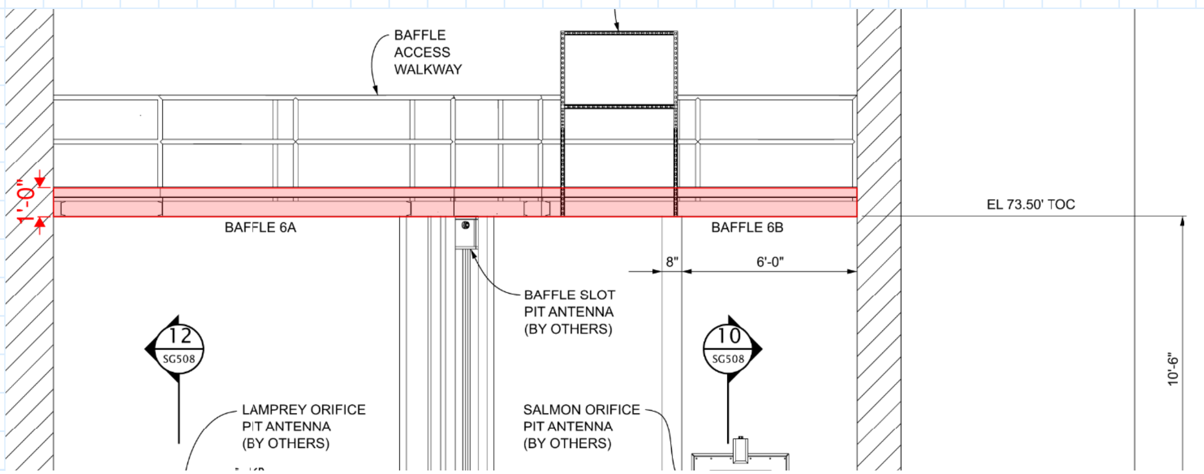


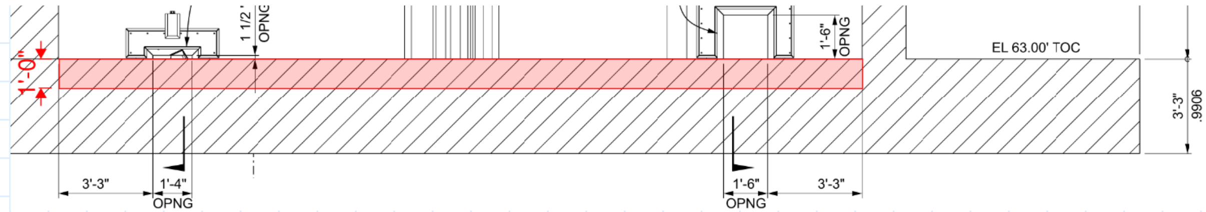
$H_{PIT} := 10\ ft + 6\ in$

$t_{baffle} := 12\ in$

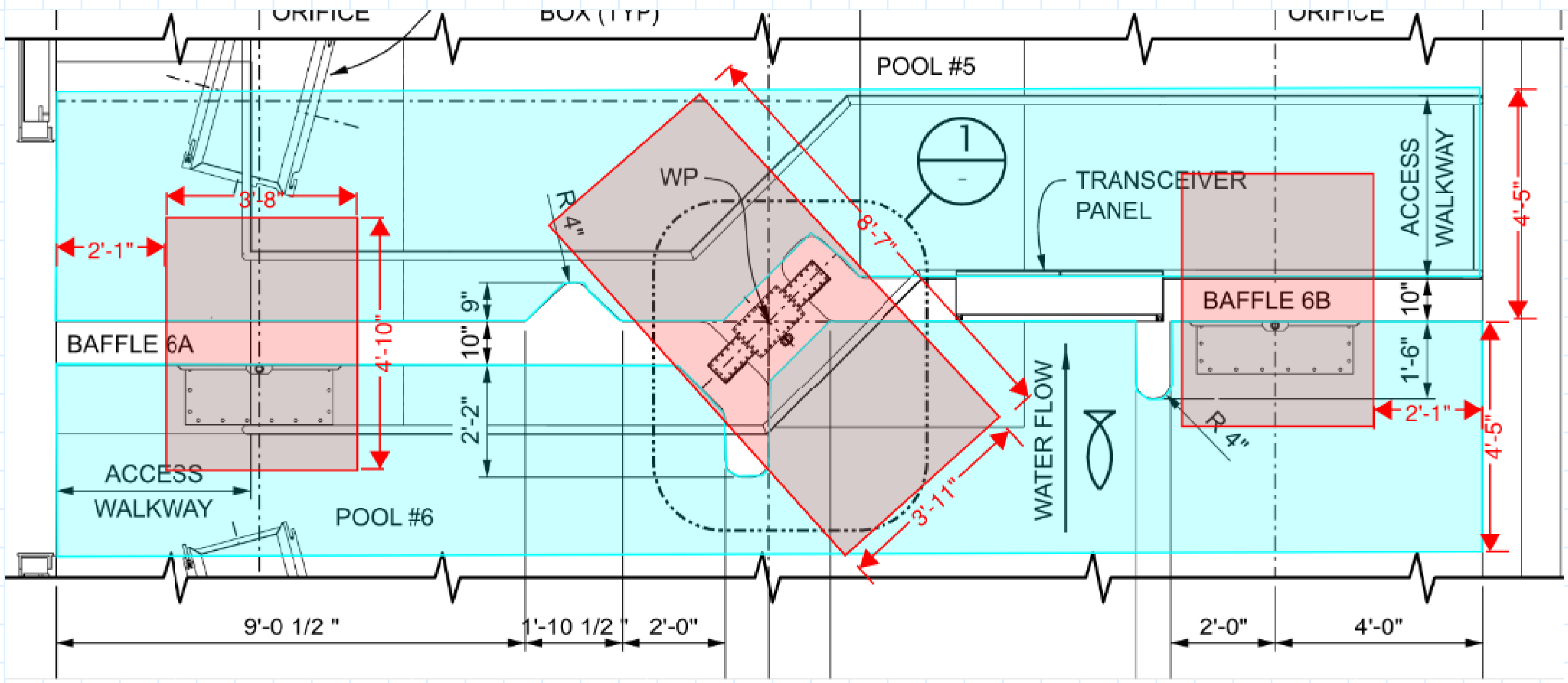
Non ferrous region: Distances from Pacific States, shown in the 30% drawing package

Vertical: 12" from each antenna





Horizontal: The non ferrous region will need to be 4'-5" from the centerline of the main antenna



PIT Tag Loads: See page 5 for more detailed loading diagrams.

Hydrostatic load: Loading provided by Hydraulic Engineer

Load from Hydraulic engineer: (see document titled "B2 WA Shore Hydrodynamic Force" and snip its shown below)

Load Factor: 1.6 (EM 1110-2-2104, unusual)

Uniform load given: $F_{hydrostatic.unfactored} := 118.2 \frac{lbf}{ft^2}$ (lbf per ft, per ft into page)

Factored Hydrostatic load: $F_{hydrostatic} := 1.6 \cdot 118.2 \frac{lbf}{ft} = 189.12 \frac{lbf}{ft}$ (lbf per ft into page)

Shear/Moment/Deflection: of a cantilevered beam, uniformly loaded

$b := 1\ ft$

$E_s := 29000\ ksi$

$I_{baffle} := \frac{b \cdot t_{baffle}^3}{12} = 1728\ in^4$

$$V_u := F_{hydrostatic} \cdot H_{PIT} = 1.986\ kip$$

$$M_u := \frac{F_{hydrostatic} \cdot H_{PIT}^2}{2} = 10.425\ kip \cdot ft$$

$$\Delta_{baffle} := \frac{F_{hydrostatic.unfactored} \cdot H_{PIT}^4 \cdot in}{8 \cdot E_s \cdot I_{baffle}} = 0.001\ in$$

Vertical Live Load + Hydrostatic load: Combined Wall Loads

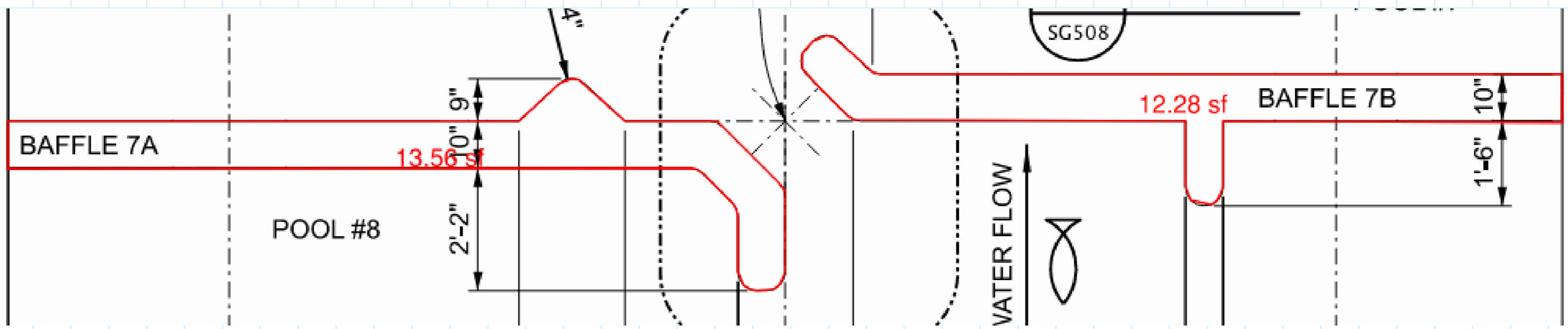
https://structurepoint.org/publication/pdf/Reinforced-Concrete-Precast-Wall-Panel-Analysis-Design-ACI318-11.pdf

Live Load: 60 psf on top of baffles for maintenance and walkways (ASCE 7-16, Table 4.3-1)

Factored live load: $L_L := 1.6 \cdot 60\ psf = 96\ \frac{lbf}{ft^2}$

Live load area:
Left side: 13.56 sf
Right side: 12.28 sf

$A_{liveload} := 13.56\ ft^2 + 12.28\ ft^2 = 25.84\ ft^2$

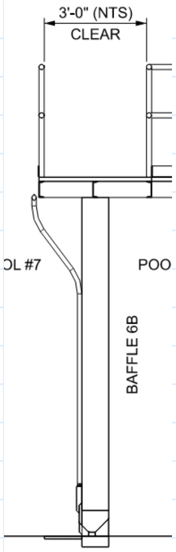


Design the right side baffle because it has slightly less concrete and both have a orifice antenna. Right side antenna is roughly 18" wide.

ACI Chapter 11 Loading: bending (force of water), Live load (on top of baffles), and self weight

Determine Pu (vertical load)for a 1' wide strip and 10" baffle: $L_w := 1\ ft$

$P_{u1} := L_L \cdot L_w \cdot t_{baffle} = 0.096\ kip$



Eccentricity of Pu1: (assume half of walkway span)

$$e_1 := \frac{3\ ft}{2} = 18\ in$$

$$\gamma_{conc} := 150\ \frac{lbf}{ft^3}$$

Determine self weight Pu2, factored:

$$P_{u2} := 1.6 \cdot \gamma_{conc} \cdot t_{baffle} \cdot L_w \cdot H_{PIT} = 2.52\ kip$$

$$P_u := P_{u1} + \frac{P_{u2}}{2} = 1.356\ kip$$

Mua: max moment with 3 loads

$$M_{ua} := \frac{F_{hydrostatic} \cdot H_{PIT}^{2}}{2} + \frac{P_u \cdot e_1}{2} = 11.442\ kip \cdot ft$$

(Mua is the mx factored moment at midheight of wall due to lateral and eccentric vertical loads, not including Pdelta effects.)

Seismic Design: Same for Standard baffles and PIT baffles

Risk category: 1 (IBC Table 1604.5) (low hazard to human life in the event of a failure)

Seismic design category: Table 1613.2.5

OBE = Unusual Load
MDE = MCE = Extreme Load

TABLE 1613.2.5(1)

SEISMIC DESIGN CATEGORY BASED ON SHORT-PERIOD (0.2 second) RESPONSE ACCELERATION

RISK CATEGORY

$$S_{DS} := 0.367$$ (seismic maps .org)

VALUE OF S_{DS}	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D

SDC from table: C

TABLE 1613.2.5(2)

SEISMIC DESIGN CATEGORY BASED ON 1-SECOND PERIOD RESPONSE ACCELERATION

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D	D	D

$S_{D1} := 0.148$ (seismic maps .org)

SDC from table: C

From ACI 319-19, structures assigned to SDC C shall satisfy sections 18.2.2, 18.2.3, and 18.13:

18.2.2: Analysis and proportioning of structural members: yes
18.2.3: Anchoring to Concrete:
-Post installed anchors shall be in accordance with ACI 355.2 or ACI 355.4
-Steel strength needs to be 1.2 times the nominal strength of anchor. (steel is fy = 60 ksi, anchor needs to be 50ksi or less)
18.13: Foundations: However, this work will not deal with any foundations and will not extend past channel floor.

Westergaards Equation: ETL 1110-2-584, EQ 3-2

Distance below water surface: $y := \frac{H_{PIT}}{2}$

ac: $a_{c.OBE} := 0.09\ g$ $a_{c.MCE} := 0.24\ g$ (Bon Seismic Eval Report Phase 1b)

$\gamma_w := 62.4\ \frac{lb}{ft^3}$

$$p_{.OBE} := \frac{7}{8} \cdot \gamma_w \cdot a_{c.OBE} \cdot \sqrt{H_{PIT} \cdot y} \cdot ft = 36.485\ \frac{lbf}{ft}$$

(converted to per ft per ft)

$$p_{.MCE} := \frac{7}{8} \cdot \gamma_w \cdot a_{c.MCE} \cdot \sqrt{H_{PIT} \cdot y} \cdot ft = 97.292\ \frac{lbf}{ft}$$

(converted to per ft per ft)

Factored, site specific OBE with all other loads: EM 2104

3.3.3.3.1. For standard and site specific OBE ground motion analysis:

$$U = 1.5\ (\Sigma\ Lp + Lt_U + EQ) \qquad (3\text{-}7)$$

$$M_{ua.OBE} := M_{ua} + 1.5 \cdot \left(\frac{p_{.OBE} \cdot H_{PIT}^{\ 2}}{2} \right) = 14.459\ kip \cdot ft$$

(Mua has already been factored, 1.6)

Therefore this load controls

Factored, site specific MCE with all other loads: EM 2104

3.3.3.3.5. For site specific MCE ground motion analysis Critical RCHS:

$$U = 1.0\ \Sigma\ Lp + 1.0\ Lt_U + 1.0\ EQ \qquad (3\text{-}11)$$

$$M_{ua.MCE} := \frac{M_{ua}}{1.6} + \left(\frac{p_{.MCE} \cdot H_{PIT}^{\ 2}}{2} \right) = 12.515\ kip \cdot ft$$

(Mua was unfactored, from 1.6 to 1)

FRP Rebar Constants: ACI 440
ASTM D7957 (Lower Granite example page 190)

FRP rebar spec: ACI 440.5-08 (2008)

Density of FRP rebar (ranges from 78-131 lb/ft^3) $\rho_{FRP} := 78 \frac{lb}{ft^3}$

Table 4.2.1—Typical tensile properties of reinforcing bars*

	Steel	GFRP	CFRP	AFRP
f_y Nominal yield stress, ksi (MPa)	40 to 75 (276 to 517)	NA	NA	NA
σ Tensile strength, ksi (MPa)	70 to 100 (483 to 1600)	70 to 230 (483 to 690)	87 to 535 (600 to 3690)	250 to 368 (1720 to 2540)
ε Elastic modulus, × 10³ ksi (GPa)	29.0 (200.0)	5.1 to 7.4 (35.0 to 51.0)	15.9 to 84.0 (120.0 to 580.0)	6.0 to 18.2 (41.0 to 125.0)
Yield strain, percent	0.14 to 0.25	NA	NA	NA
Rupture strain, percent	6.0 to 12.0	1.2 to 3.1	0.5 to 1.7	1.9 to 4.4

*Typical values for fiber volume fraction ranging from 0.5 to 0.7.

$\varepsilon_{FRP} := 5.1\ ksi$

$\phi_{FRP} := 0.55$ (ACI 440 7.1.1 Tension controlled GFRP)

Table 7.2.1—Typical values for balanced reinforcement ratio for a rectangular section with $f_c' = 5000$ psi (34.5 MPa)

Bar type	Yield strength f_y or tensile strength f_{fu}, ksi (MPa)	Modulus of elasticity, ksi (GPa)	ρ_b or ρ_{fb}
Steel	60 (414)	29,000 (200)	0.0335
GFRP	80 (552)	6000 (41.4)	0.0078
AFRP	170 (1172)	12,000 (82.7)	0.0035
CFRP	300 (2070)	22,000 (152)	0.0020

$E_f := 6000\ ksi$

3.4. Design Strength of Reinforcement.

3.4.1. Design should normally be based on 60,000 psi, the yield strength of ASTM Grade 60 reinforcement. Other grades may be used, subject to the provisions of Paragraphs 2.2 and 3.4.2. The yield strength used in the design shall be indicated on the drawings.

3.4.2. Reinforcement with yield strength in excess of 60,000 psi shall not be used unless a detailed investigation of ductility and serviceability requirements is conducted in consultation

????

with and approved by CECW-CE.

Environmental Reduction Factor: ACI 440 Table 6.2: $C_E := 0.7$ (apply to all tensile strength)

FRP Flexure: ACI 440 Chapter 7

$clear_{cover} := 2\ in$

$d_{flexure} := 0.75\ in$

$$d := t_{baffle} - clear_{cover} - \left(\frac{d_{flexure}}{2}\right) = 9.625\ in$$

Steel per ft: $A_f := 2 \cdot 0.44\ in^2 + \left(\frac{2}{5}\right) \cdot 0.44\ in^2 = 1.056\ in^2$ (#6 bars @ 5in o.c.) (should work with 6" o.c.)

Design tensile strength: $C_E := 0.7$

$$f_{fu.star} := 80\ ksi$$

$$f_{fu} := C_E \cdot f_{fu.star} = 56\ ksi$$

Design Rupture Strain: (8.2.1 FRP limit)

$$\varepsilon_{fu.star} := 0.002$$

$$\varepsilon_{fu} := C_E \cdot \varepsilon_{fu.star} = 0.001$$

$f_c' := 4500\ psi$ $\varepsilon_{cu} := 0.003$ $E_f := 6000\ ksi$

$\beta_1 := 0.825$ (GRFP assumes concrete strength of 4500 psi)

Reinforcement Ratios:

$$\rho_f := \frac{A_f}{b \cdot d} = 0.009$$

$$\rho_{fb} := 0.85 \cdot \beta_1 \cdot \frac{f_c{}'}{f_{fu}} \cdot \frac{E_f \cdot \varepsilon_{cu}}{E_f \cdot \varepsilon_{cu} + f_{fu}} = 0.014$$

$$\frac{\rho_f}{\rho_{fb}} = 0.667$$ when pf < pfb use EQ 7.2.2f and Phi = 0.55

$$c := \left(\frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{fu}}\right) \cdot d = 6.563 \; in$$

Flexural Capacity: EQ 7.2.2f

$$\phi M_n := \phi_{FRP} \cdot A_f \cdot f_{fu} \cdot \left(d - \frac{\beta_1 \cdot c}{2}\right) = 18.75 \; kip \cdot ft$$

$$\phi M_n > M_{ua.OBE} = 1$$

$$sqrt4500psi := \sqrt{4500} \; psi = 67.082 \; psi$$

Minimum reinforcement: 440 EQ 7.2.4

$$A_{fmin} := \frac{4.9 \cdot sqrt4500psi}{f_{fu}} \cdot b \cdot d = 0.678 \; in^2$$

▯>▯

$$A_{fmin1} := \frac{330 \; psi}{f_{fu}} \cdot b \cdot d = 0.681 \; in^2$$

$$A_f > A_{fmin} = 1$$

FRP Serviceability: ACI 440 Chapter 7/9

$\rho_f := \frac{A_f}{b \cdot d}$

$E_s := 29000\ ksi \quad E_f := 5100\ ksi$

Stress in Tensile Reinf: Eq 7.2.2d

$$f_f := \sqrt{\frac{(E_f \cdot \varepsilon_{cu})^2}{4} + \frac{0.85\ \beta_1 \cdot f_c'}{\rho_f} E_f \cdot \varepsilon_{cu}} - 0.5 \cdot E_f \cdot \varepsilon_{cu} = 65.42\ ksi \quad ■<■ \quad f_{fu} = 56\ ksi$$

$$f_f := f_{fu} = 56\ ksi$$

Moment at Cracking: Eq 7.3.2.2d

$y_t := \frac{t_{baffle}}{2} = 6\ in \qquad I_{baffle} = 1728\ in^4$

$\lambda := 1$ (not lightweight concrete)

$$M_{cr} := \frac{7.5 \cdot \lambda \cdot sqrt4500psi \cdot I_{baffle}}{y_t} = 12.075\ kip \cdot ft$$

$M_{ua.OBE} > M_{cr} = 1$ (therefor, cracking does need to be considered because cracking moment will control)

Crack Control:

$E_c := 57000 \cdot sqrt4500psi = 3823.676\ ksi$ (modulus of elasticity of concrete)

$$n_f := \frac{E_f}{E_c} = 1.33379$$

$$k := \sqrt{2 \cdot \rho_f \cdot n_f + (\rho_f \cdot n_f)^2} - \rho_f \cdot n_f = 0.144 \quad (7.3.2.2b)$$

$$I_{cr} := \frac{b \cdot d^3}{3} \cdot k^3 + n_f \cdot A_f \cdot d^2 \cdot (1-k)^2 = 106.259\ in^4$$

Max bar spacing:

Max Crack Width: $w := 0.039\ in$ (1 millimeter) $k_b := 1.4$ $f_{fs.sus} := 0.2 \cdot f_{fu} = 11.2\ ksi$

$$s_{max} := 1.15 \cdot \frac{E_f \cdot w}{f_{fs.sus} \cdot k_b} - 2.5\ clear_{cover} = 9.588\ in < 0.92 \cdot \frac{E_f \cdot w}{f_{fs.sus} \cdot k_b} = 11.67\ in$$ (7.3.1a)

Creep Control: 7.4.1 $M_{s.sus} := \frac{M_{ua}}{1.6}$ (unfactored load)

$$f_{fs.sus} := M_{s.sus} \cdot \frac{n_f \cdot d \cdot (1-k)}{I_{cr}} = \left(8.87 \cdot 10^3\right)\ psi$$

Table 7.4.1 $f_{fs.sus} := 0.2 \cdot f_{fu} = 11.2\ ksi$

$$M_{s.sus} := \frac{f_{fs.sus}}{\frac{n_f \cdot d \cdot (1-k)}{I_{cr}}} = 9.03\ kip \cdot ft$$

$$\phi M_n > M_{s.sus} = 1$$

Meaning if bars are spaced less than 9.5" inches apart cracking control is satisfied.

Minimum FRP reinforcement ratio: ACI 440 9.1

$$\rho_{f.ts} := 0.0018 \cdot \frac{60000}{f_{fu}} \cdot psi \cdot \frac{E_s}{E_f} = 0.011$$

$$\rho_{f.ts} > 0.003 = 1$$

Therefor the minimum reinforcement ratio is satisfied

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FRP Weak axis Shear: ACI 440 Chapter 8

$\phi_s := 0.75$ $b = 12\ in$ $s_{actual} := 12\ in$ $d = 9.625\ in$

Actual Shear steel: (1 #4 stirrups per 12") OR is this considered two bars cause US/DS faces??

$$A_v := 0.2\ in^2 = 0.2\ in^2$$

Minimum shear steel:

$$f_{fv} := min\left(\left(0.004 \cdot E_f\right), f_{fu}\right) = 20.4\ ksi$$

$$A_{fvmin} := \frac{50 \cdot b \cdot s_{actual}}{f_{fv}} \cdot psi = 0.353\ in^2$$ (8.2.2)

$$A_v > A_{fvmin} = 0$$

Try more steel: (1, #6 stirrups per 12")

$s_{actual} := 12\ in$

$$A_v := 0.44\ in^2 = 0.44\ in^2$$

$$A_v > A_{fvmin} = 1$$

Determine Concrete Shear Strength: ACI 440 8.2b

$k = 0.144$

$$\phi V_c := \phi_s \cdot \frac{5}{2} \cdot k \cdot 2 \cdot sqrt4500psi \cdot b \cdot d = 4.197\ kip$$ (8.2b)

$$\phi V_c > V_u = 1$$

(therefore shear reinforcement is not required but will still use anyways)

Determine Steel strength: ACI 440

$$\phi V_f := \phi_s \cdot \frac{A_v \cdot f_{fv} \cdot d}{s_{actual}} = 5.4\ kip$$

$$\phi V_f > V_u = 1$$

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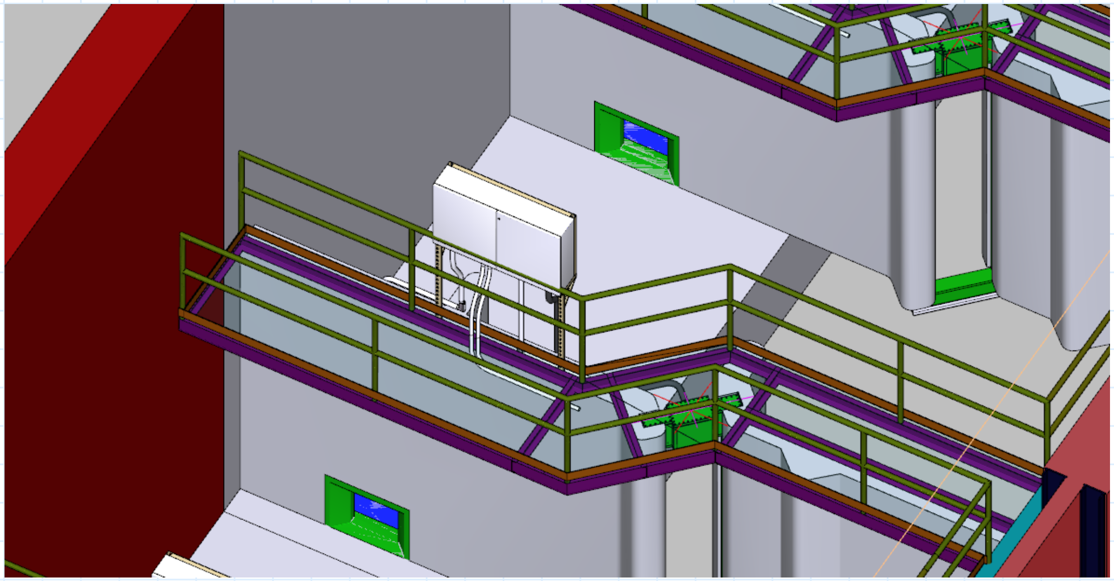
Transceiver Panel Attachment: See 2017 WA Shore Plans

Sun shade:



Panel: 4' wide by 2'-6" tall by 10" wide.

Weight of panel = 200 lb (from DE)

$$\gamma_{aluminum} := 170 \ \frac{lbf}{ft^3}$$

Weight of Sunshade:

$$weight := \underbrace{\left(6\ ft \cdot 3.5\ ft \cdot \frac{1}{4}\ in \cdot \gamma_{aluminum}\right)}_{\text{(back)}} + \underbrace{\left(1.5\ ft \cdot 6\ ft \cdot \frac{1}{4}\ in \cdot \gamma_{aluminum}\right)}_{\text{(top)}} + 2 \cdot 0.5 \cdot \underbrace{\left(1.5\ ft \cdot 3.5\ ft \cdot \frac{1}{4}\ in \cdot \gamma_{aluminum}\right)}_{\text{(sides)}} + \underbrace{\left(2.65\ \frac{lbf}{ft} \cdot 3.5\ ft \cdot 4\right)}_{\text{(posts)}} = 161.944\ lbf$$

Weight of Transceiver Panel:

22. Misc Detailing:

Bar Spacing: (EM 1110-2-2104 2.6.1)
Flexural bars
Upstream face = 1 #6 bar every 6"
Downstream face = 1 #6 bar every 12"
Shear bars = 1 #6 bars parallel, spaced vertically every 12".

Rebar Cover: (EM 1110-2-2104 Table 2-1)
Min: ACI 318 for baffles less than or equal to 12" thick
2" is good

Temp and Shrinkage: (EM 1110-2-2104 2.9.1)

Required on DS face see sketch. (EM says use #4 at 12" o.c shall i use that instead of #6 to match US face?)

Rebar Detailing at Joints: (EM 1110-2-2104 2.11.1)

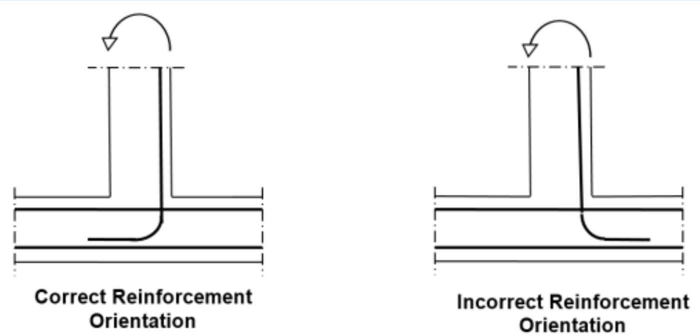
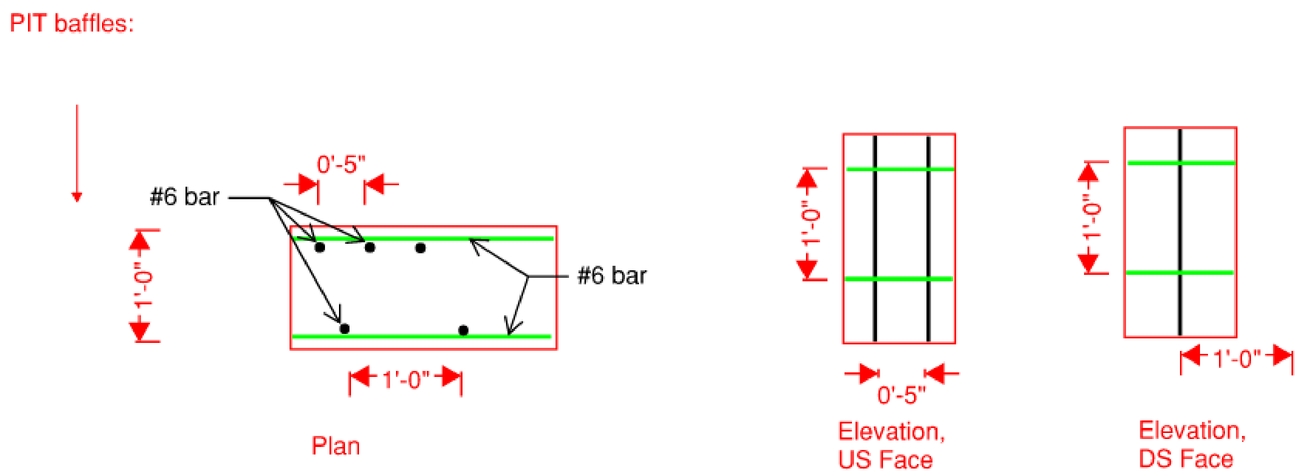


Figure 2-1. Reinforcement Detailing at Moment Connections.

Rebar Sketch:



Developmental Length of 90 degree hooked bar: ACI 440 10.2a

$K_4 := 1820$ (ffu less than 75ksi)

$d_b := 0.75\ in$

For #6 bars: $l_{bhf} := K_4 \cdot \frac{d_b \cdot psi}{sqrt4500psi} = 20.348\ in$

Developmental Length of straight bars: ACI 440 10.3a

$\alpha := 1$

$C := clear_{cover} + \frac{d_b}{2} = 2.375\ in$

For #6 bars: $l_d := \frac{\alpha \cdot \frac{f_{fu}}{sqrt4500psi} - 340}{13.6 + \frac{C}{d_b}} \cdot d_b = 22.133\ in$

Tension Lap Splice: ACI 440 10.4

$l_{splice} := 1.3 \cdot l_d = 28.773\ in$ (assumed Class B splice)

APPENDIX F

ELECTRICAL CALCULATIONS

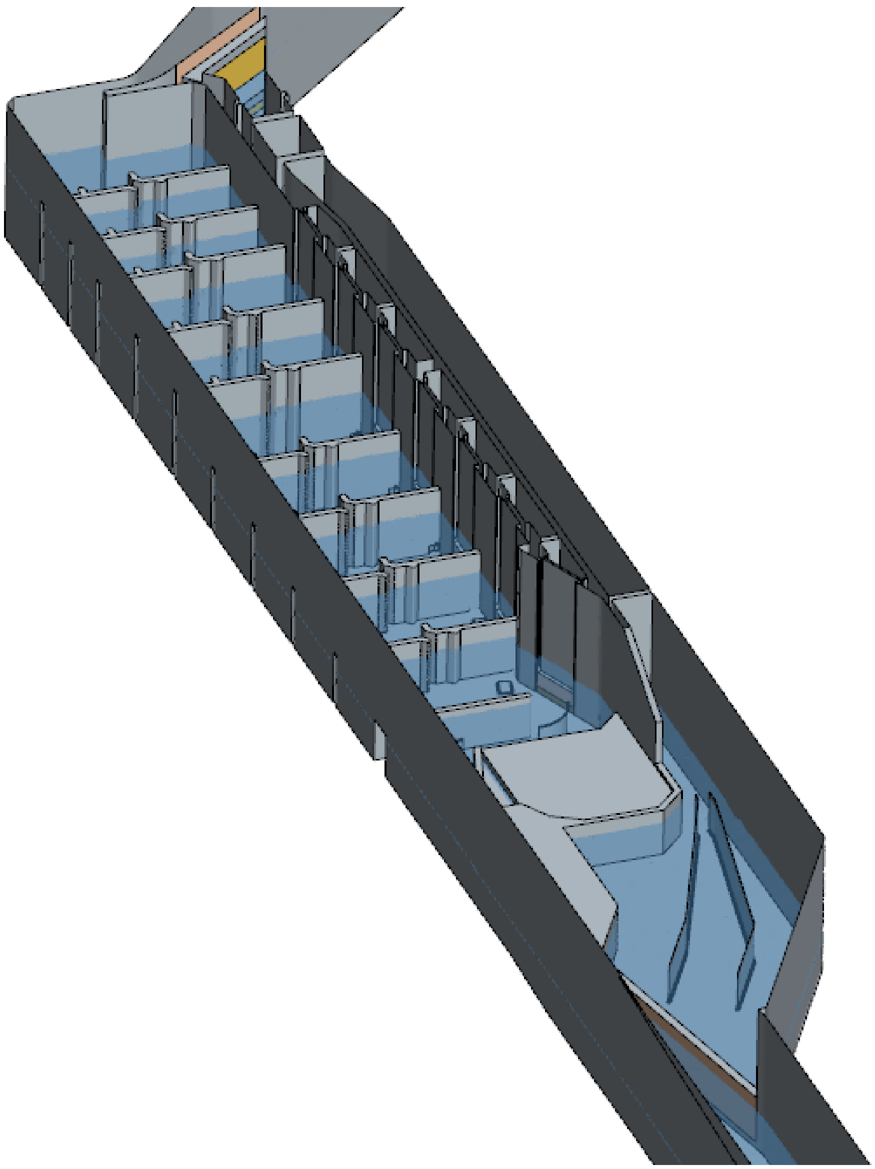
(none at 90% DDR)

APPENDIX G

CFD MODELING REPORT

CFD Modeling Report

CFD Modeling for Bonneville Washington Shore Fish Ladder Modifications



April 2023

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CFD Modeling Overview

Background:

The purpose of the Bonneville (BON) 2nd Powerhouse (PH2) Washington Shore Fish Ladder Control Section modifications is to improve upstream passage success for Pacific Lamprey (pictures and plans of the existing Exit Control Section can be found in the main DDR). The modifications are also likely to reduce stress and delay for adult salmon, steelhead, and bull trout. The preferred alternative is to convert the serpentine-style flow control sections of Bonneville Dam's Washington Shore fish ladder, to an Ice Harbor-style vertical slot with submerged orifice configurations.

A similar redesign of the exit control section has been accomplished for several other fish ladders on the Columbia River, traditionally with the aid of a physical hydraulic model to test and refine the modifications. With the progression of Computational Fluid Dynamic (CFD) modeling codes and computing power, it was decided that a numerical model would be used for redesign of the Bonneville Washington Shore Fish Ladder Control Section, in lieu of a physical model. Using a CFD model will save time and money compared to using a physical model. To verify the validity of the CFD modelling approach and solutions, a validation effort was undertaken to compare results from a previous physical model to that of the CFD code.

ENSR completed a physical model study for Portland District USACE (CENWP) in 2008, for the redesign of the exit control section of the John Day (JDA) North fish ladder. The model was a 1:5 scale model and included a forebay head tank, the redesigned fish ladder section, AWS floor diffuser, count station and bypass channel, and four of the standard Ice Harbor fish ladder weirs. Because of the extensive data available from this model, it was selected as a good validation test case to verify the validity of using CFD to design the Bonneville Washington Shore Lamprey modifications. Once the modeling approach was validated, a CFD model of the redesigned exit control section for the Bonneville Washington Shore Fish Ladder was created and checked against the design calculations.

Star-CCM+ was the CFD code chosen for this modeling effort, due to its advanced meshing techniques and ability to capture complex geometry. The polyhedral meshing option in Star-CCM+ is unique in that most CFD codes utilize a trimmer or rectangular mesh, which can cause model instabilities when flows don't move directly perpendicular to the orientation of the cells. The software also has the ability to easily import points for data collection and to select specific surfaces to output scalar data on throughout the model runs. Utilizing the computing power of the High-Performance Computers (HPCs), as part of the Department of Defense (DoD)-funded High Performance Computing Modernization Program (HPCMP) reduced the amount of time to achieve a design.

This report has been structured to trace the development of the proposed design as it progressed. The initial segment delves into the validation modeling which was based on the physical modeling conducted for the John Day North Ladder Exit Control Section Modification project. Subsequently, the second section encompasses the preliminary analysis of the proposed design for the Exit Control Section at the Bonneville Washington Shore Fish Ladder. Owing to a substantial number of design alterations and alternative analyses that were undertaken following the 60% submittal, the 90% DDR Submittal was documented as an independent endeavor in the final section.

Model 1: John Day North Fish Ladder Exit Control Section

Model Overview

The physical model study performed by ENSR in 2008 was a 1:5 scale model of the John Day North fish ladder exit control section and included multiple iterations of the design to find the best option for improving lamprey passage. This included variable spacing for slot weirs, variable floor inverts and sill gates within the slot inverts, and differing floor geometries for the count station. The final geometry that was chosen was Alternative 11, which included no sill gates. This geometry was used for the CFD validation effort. Flow patterns, pool elevations throughout the model, and velocity measurements from the physical model study were used to compare with the CFD model results.

The physical model domain included a headbox, which was supplied via a pump and utilized porosity plates to normalize the flow patterns on the upstream end of the model. It then transitioned into the exit channel, and down to the 23 redesigned slot weirs in the main exit control section. Downstream of the final slot weir, a floor diffuser was supplied via the main pump, and flow patterns normalized with porosity plates. The flow then either went through the count station or passed through screens into the bypass section that was controlled with a knife gate. The flow recombined downstream of the count station, and moved past four Ice Harbor-style ladder weirs. A tailgate at the downstream extent of the model controlled head levels, and flow that spilled over the tailgate and into the tailwater tank was removed and recycled back upstream via the pump. A plan view of the model is shown in Figure 1.

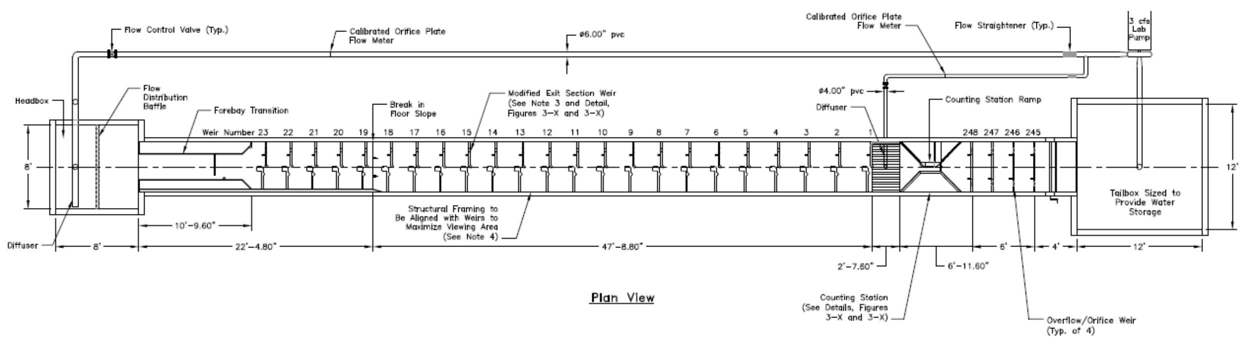


Figure 1 - JDA Physical Model Plan View

The CFD model was constructed at scale (1:5) to mimic the geometry of the physical model as closely as possible. It included the same components but relied on upstream and downstream boundary conditions to initiate and remove flow. These boundary conditions will be described in more detail later in the appendix. An isometric view of the CFD model domain is shown in Figure 2.

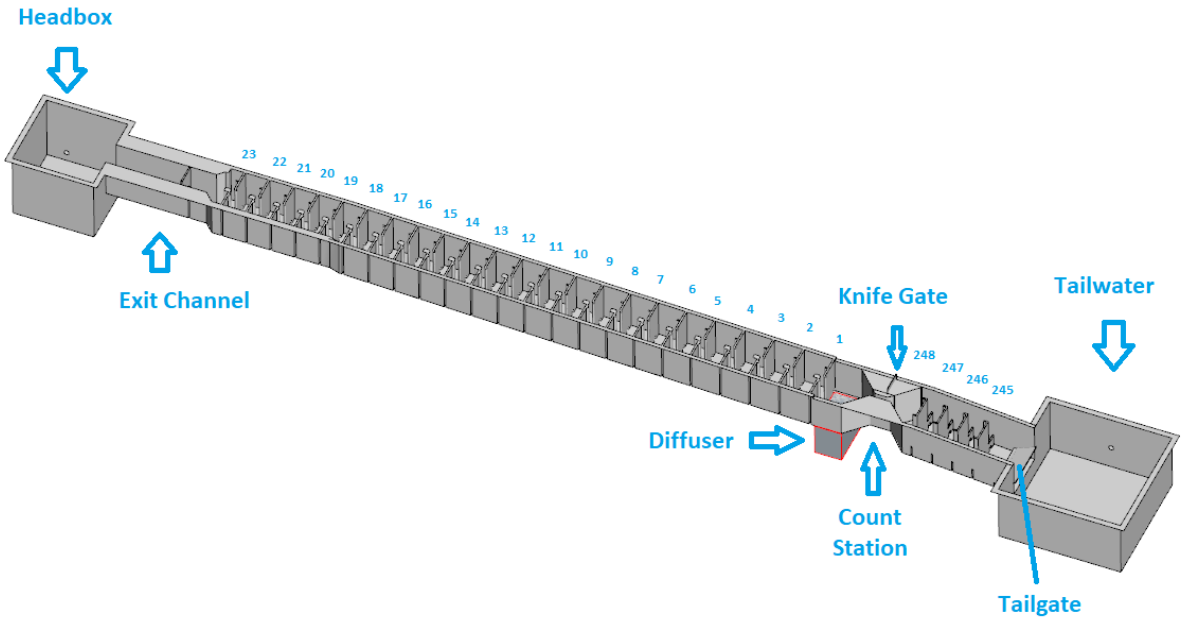


Figure 2 - JDA CFD Model Domain

Grid Development

The grid for the CFD model runs was created in Star-CCM+ version 16.04. The development of the model grid parameters to be used for CFD model runs was an iterative process that involved testing and adjusting grid development strategies. Due to the sloped channel and multiple pool levels, a water surface refinement wasn't utilized for this model.

A final computational grid was developed, using Polyhedral cell meshing. This included remeshing the surface, and developing the volume mesh based on the following parameters:

- Base grid: 2 inch cell size, minimum 0.2 inch cell size, maximum of 200 inch cell size

The resultant mesh consisted of 3.9 million cells, which included multiple regions in the model. An example of the mesh in the ladder section is shown in Figure 3.

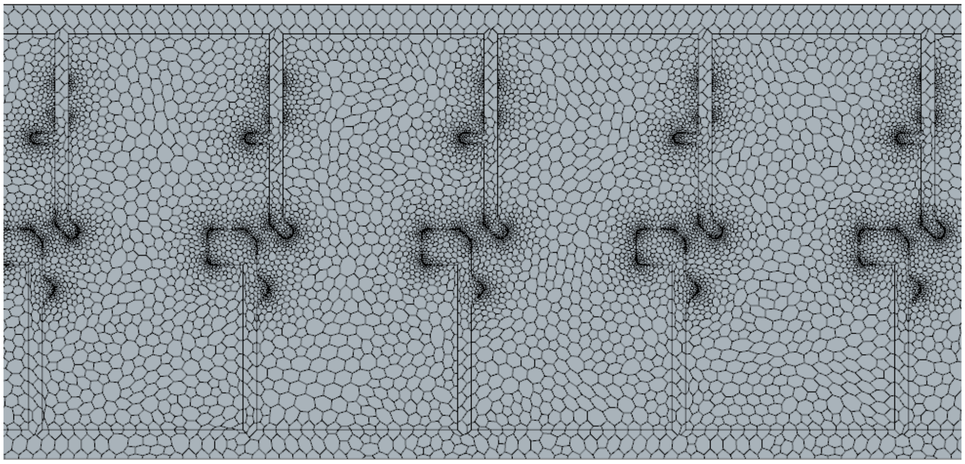


Figure 3 - JDA Ladder Mesh Example

Multiple regions were created, to enable the use of porous baffle interfaces in the model to replicate diffusers and porosity plates that were used in the physical model. This includes a floor diffuser upstream of the count station, and the trash rack and picket lead in the count station bypass corridor.

Boundary Conditions

The boundary conditions for the model included:

- A stagnation inlet boundary with static hydraulic pressure set at the intended elevation in the forebay (varied by run).
- A velocity inlet, defined as the intended flowrate through the diffuser dispersed over the area of the diffuser inlet (V = Q/A) for the diffuser upstream of the count station
- A porous baffle interface between the diffuser chamber and the ladder, set using a porosity.
- A porous baffle interface between the downstream end of the final pool before count station and the bypass channel, which mimicked the trash rack.
    - A porosity of 70.5% was used, which corresponded to a porous inertial resistance value of 0.155.
- A porous baffle interface between the downstream end of the bypass channel and the first Ice Harbor pool downstream of the count station, which mimicked the picket lead.
    - A porosity of 80.0% was used, which corresponded to a porous inertial resistance value of 0.140.
- A pressure outlet in the tailwater box, set below the anticipated crest elevation of the tailgate weir so that the weir flow was unsubmerged. This guaranteed that the weir had full control over the head in the model.

All other region boundaries were set as default wall boundaries, including all concrete structures and gate structures. Other components of the model that could be adjusted include:

- The knife gate controlling flow around the gate station bypass. This was set to encourage a 50/50 flow split between the count station and bypass channel.
- The tailgate was rotated around its main axis, to try and maintain a 1 ft prototype head drop over the furthest downstream Ice Harbor weir, replicating conditions in the physical model. As there was no indication as to how this was set in the physical model, an iterative process was used to set the tailgate to the correct level.

Through iteratively adjusting the tailgate and the knife gate opening, a 16.8-degree rotation from the shop drawings was used as the tailgate setting and a model scale 3 inch opening was used for the knife gate.

Table 1 shows the physical model settings for test 11E, used to validate the CFD model.

Table 1 - JDA Model Run Settings

Config. No.	Test	Model	Sills	Proto Target Forebay Elev. (ft)	Model Target Forebay Elev. (in)	Proto Weir Head (ft)	Model Weir Head (in)	Proto Exit Section Flow (cfs)	Model Exit Section Flow (cfs)	Proto Diffuser Flow (cfs)	Model Diffuser Flow (cfs)	Phys Ladder Flow (cfs)	Model Ladder Flow (cfs)
11	E	Physical Model	No Sills	262.5	65.55	1	2.4	72	1.29	13	0.23	85	1.52

Model Validation

Multiple iterations of the CFD model were created, due to the uncertainty with the setup conditions of the physical model (tailgate and knife gate settings), as well as to try and match the properties of the physical model with the boundary conditions available in Star-CCM+. A good example of this is the use of a porosity plate in the forebay of the physical model, to even out the flow as it is pumped into the upstream end of the model. Because there was no information on the porosity of that plate, a modification to the CFD model was implemented that cut out the extents upstream of that plate and used the plate face as the new inlet for the model. This was to try and provide even flow into the CFD model in the same location as the physical model. As mentioned in the Boundary Conditions section, a similar modification was implemented in the diffuser chamber, since multiple porosity plates were used below the floor grating in the physical model to provide uniform flow. The diffuser chamber was eventually removed, and the velocity inlet was moved to the location of the grating, flush with the ladder floor.

The other changes to the model were exploring upstream boundary conditions to see if any of the options compared better to the physical model results, as well as varying turbulence models to try and model the complex hydraulics within the ladder. The various upstream boundary conditions included a stagnation pressure boundary set to the intended water surface elevation, a pressure outlet boundary with a similar setting, a velocity boundary set to the correct head level and anticipate flow rate, and a similarly set mass flow inlet. The flowrates for the velocity and mass flow boundaries matched perfectly with the physical model, as the rates were prescribed in the boundary condition, but both types of pressure boundaries estimated more flow in the ladder under the given forebay elevation. The pressure run flowrates compared to the physical model flow rates are shown in Table 2. An excess of 0.31 cfs model scale flow was introduced on the upstream end of the model in the CFD compared to the physical model.

Table 2 - JDA CFD vs. Physical Model Flows for U/S Pressure Boundaries

Config. No.	Test	Model	Sills	Proto Target Forebay Elev. (ft)	Model Target Forebay Elev. (in)	Proto Weir Head (ft)	Model Weir Head (in)	Proto Exit Section Flow (cfs)	Model Exit Section Flow (cfs)	Model Diffuser Flow (cfs)
11	E	Physical Model	No Sills	262.5	65.55	1	2.4	72	1.29	0.23
Run	Pressure	CFD Model	No Sills	262.5	65.55	1.12	2.69	89	1.60	0.23

The head levels in each pool for each boundary condition were also checked against the head levels in the physical model. This was done by probing the isosurface in the model, set to a Volume of Fluid (VoF) for water of 0.5. Comparisons for the different boundary conditions are presented in Table 3.

Table 3 - JDA U/S Boundary Condition Pool Elevation Comparisons

		u/s BC: Stagnation Pressure		u/s BC: Pressure		u/s BC: Velocity		u/s BC: Mass Flow	
Tap #	WSEL	CFD Elev	(CFD - Physical Model) Elev. Diff.	CFD Elev	(CFD - Physical Model) Elev. Diff.	CFD Elev	(CFD - Physical Model) Elev. Diff.	CFD Elev	(CFD - Physical Model) Elev. Diff.
	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)
Forebay	65.55	65.45	-0.10	65.58	0.03	60.82	-4.73	52.40	-13.15
Exit Channel	65.45	65.43	-0.02	65.51	0.06	60.72	-4.73	52.45	-13.00
23	64.90	64.58	-0.32	64.69	-0.21	60.02	-4.88	52.14	-12.76
22	64.18	64.39	0.21	64.24	0.06	59.80	-4.38	51.80	-12.38
21	63.51	63.57	0.06	63.48	-0.03	58.91	-4.60	51.39	-12.12
20	62.72	62.69	-0.03	62.63	-0.09	58.21	-4.51	50.72	-12.00
19	61.85	61.74	-0.11	61.88	0.03	57.38	-4.47	50.05	-11.80
18	60.80	60.64	-0.16	60.74	-0.06	56.44	-4.36	49.43	-11.37
17	59.31	59.64	0.33	59.69	0.38	55.51	-3.80	48.57	-10.74
16	58.18	58.48	0.30	58.57	0.39	54.44	-3.74	47.76	-10.42
15	56.77	57.19	0.42	57.28	0.51	53.20	-3.57	46.85	-9.92
14	55.59	55.84	0.25	55.96	0.37	52.03	-3.56	45.93	-9.66
13	54.17	54.56	0.39	54.69	0.52	50.89	-3.28	45.09	-9.08
12	52.81	53.28	0.47	53.45	0.64	49.67	-3.14	44.11	-8.70
11	51.44	52.05	0.61	52.03	0.59	48.55	-2.89	43.15	-8.29
10	50.02	50.63	0.61	50.72	0.70	47.41	-2.61	42.25	-7.77
9	48.46	49.36	0.90	49.32	0.86	46.14	-2.32	41.34	-7.12
8	46.90	47.81	0.91	47.91	1.01	44.81	-2.09	40.42	-6.48
7	45.32	46.23	0.91	46.36	1.04	43.72	-1.60	39.57	-5.75
6	43.61	44.61	1.00	44.93	1.32	42.28	-1.33	38.61	-5.00
5	41.98	43.02	1.04	43.45	1.47	40.95	-1.03	37.44	-4.54
4	40.35	41.45	1.10	41.64	1.29	39.50	-0.85	36.57	-3.78
3	38.41	39.7	1.29	39.94	1.53	38.03	-0.38	35.60	-2.81
2	36.63	38.21	1.58	38.38	1.75	36.71	0.08	34.70	-1.93
1	34.81	36.31	1.50	36.75	1.94	35.58	0.77	33.84	-0.97
Count Station	33.32	33.82	0.50	33.35	0.03	33.12	-0.20	32.56	-0.76
248	33.32	33.8	0.48	33.90	0.58	33.30	-0.02	32.55	-0.77
247	30.65	31.03	0.38	31.16	0.51	30.62	-0.03	29.89	-0.76
246	28.40	28.52	0.12	28.66	0.26	28.06	-0.34	27.39	-1.01
245	25.73	25.72	-0.01	25.63	-0.10	25.21	-0.52	24.63	-1.10

Both pressure models seemed to be close in pool elevation higher in the ladder, and overpredict the ladder pool elevations further downstream. The mass and velocity boundary conditions, even though they had the correct flowrates, all had an immediate head drop into the forebay pool from the upstream boundary condition. This low pool elevation carried through the extents of the CFD model.

Having a higher flowrate with a pressure boundary and set head level, and lower head levels for a set outflow, points to the CFD model geometry not being able to physically support the specified head level with the specified flow rate. This could be due to less friction in the CFD model compared to the physical model, causing less backwater of the pools, and more efficient passing of the flow. To try and match the pool levels in the physical model, the stagnation pressure boundary was selected as the preferred upstream boundary condition.

Even with the higher flowrate, the model seemed to have lower head levels in the upstream end, and transition to higher levels at the downstream end. Due to the averaged nature of the k-epsilon turbulence model, there was concern that the circulating flow and associated energy loss wasn't being captured adequately within the CFD model. A sensitivity analysis was conducted by changing the turbulence models, as well as over meshing the upstream portion of the ladder to better capture minute flow characteristics, to see if a different model would bring the CFD results into better alignment with the physical model results. Detached Eddy Simulation (DES) and Large Eddy Simulation (LES) turbulence models were investigated, as well as a denser 0.25 inch cell size mesh that covered the upper four pools. A comparison of the original mesh to the dense mesh is shown in Figure 4.

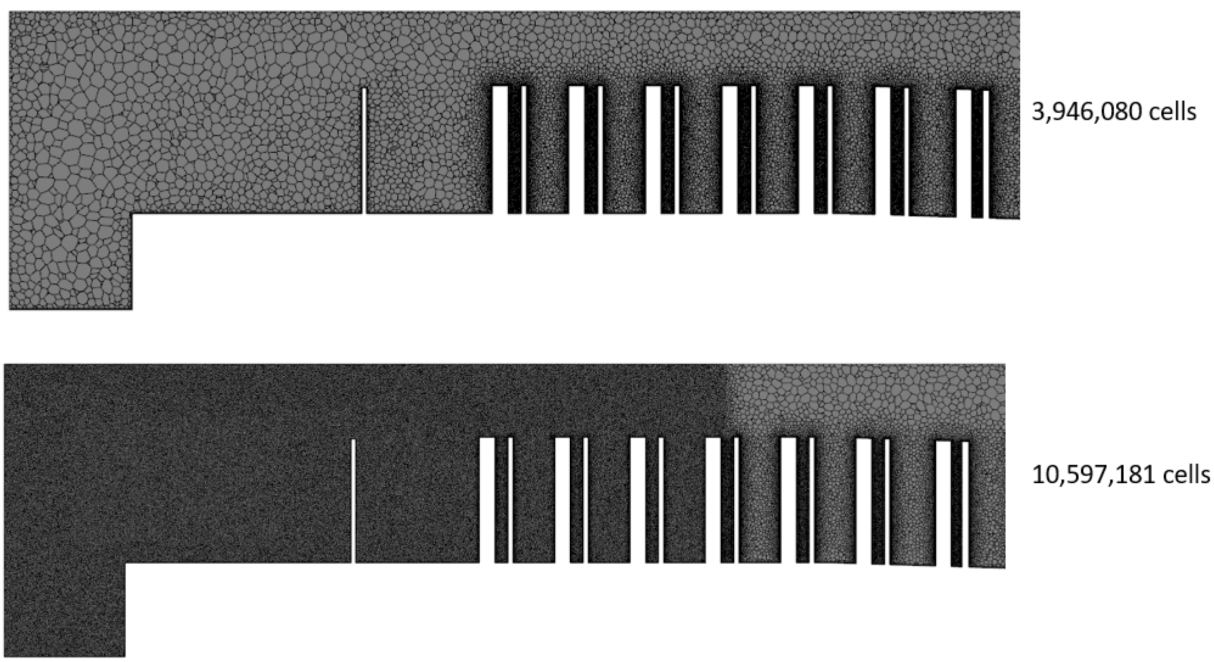


Figure 4 - JDA CFD Mesh Comparison. Top: Original Mesh, Bottom: Dense Mesh

When checking the head levels of the turbulence and mesh sensitivity runs, a more accurate water surface estimate for each pool was taken using probe points in the CFD models. The pressures near the invert of the ladder were exported for each pool, and then converted to a depth by multiplying by the unit weight of water (62.4 lbs/ft^3). This depth was added to the invert of the ladder to get an estimate of water surface. Comparisons for the pool levels to the physical model are shown in Table 4.

Table 4 - JDA CFD Turbulence and Mesh Sensitivity

Tap #	Phys. Model	Press. Model		Des		LES		Mesh	
	WSEL	WSEL	Diff	WSEL	Diff	WSEL	Diff	WSEL	Diff
	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)
Forebay	65.55	65.29	-0.26	65.28	-0.27	65.26	-0.29	65.30	-0.25
Exit Channel	65.45	65.35	-0.10	65.36	-0.10	65.38	-0.07	65.34	-0.11
23	64.90	64.47	-0.43	64.33	-0.57	64.21	-0.69	64.55	-0.35
22	64.18	63.81	-0.37	63.69	-0.49	63.93	-0.25	63.95	-0.23
21	63.51	62.99	-0.52	62.85	-0.66	62.92	-0.59	63.14	-0.37
20	62.72	62.11	-0.61	61.95	-0.77	61.86	-0.86	62.32	-0.40
19	61.85	61.20	-0.65	61.10	-0.75	61.33	-0.52	61.40	-0.46
18	60.80	60.21	-0.59	59.70	-1.10	60.19	-0.60	60.42	-0.38
17	59.31	59.10	-0.21	59.03	-0.28	58.76	-0.55	59.45	0.14
16	58.18	57.93	-0.25	57.75	-0.43	58.00	-0.18	58.23	0.05
15	56.77	56.65	-0.12	56.45	-0.31	56.02	-0.74	56.98	0.22
14	55.59	55.41	-0.18	55.13	-0.46	55.17	-0.42	55.75	0.16
13	54.17	54.03	-0.14	53.63	-0.55	53.81	-0.36	54.47	0.30
12	52.81	52.79	-0.02	52.55	-0.25	52.45	-0.35	53.15	0.35
11	51.44	51.47	0.03	51.20	-0.24	50.91	-0.53	51.81	0.37
10	50.02	50.08	0.06	49.85	-0.18	49.77	-0.25	50.46	0.43
9	48.46	48.70	0.24	48.59	0.12	48.44	-0.02	49.02	0.56
8	46.90	47.26	0.36	46.97	0.07	47.07	0.17	47.56	0.65
7	45.32	45.72	0.40	45.61	0.29	45.38	0.06	46.02	0.70
6	43.61	44.21	0.60	44.15	0.54	44.07	0.46	44.45	0.83
5	41.98	42.63	0.65	42.69	0.71	42.47	0.49	42.82	0.83
4	40.35	40.91	0.56	41.11	0.76	41.07	0.72	41.11	0.76
3	38.41	39.12	0.71	39.27	0.86	39.38	0.97	39.27	0.87
2	36.63	37.67	1.04	37.79	1.16	38.07	1.44	37.70	1.07
1	34.81	36.15	1.34	36.37	1.56	36.47	1.67	36.04	1.23
Count Station	33.32	34.38	1.06	34.73	1.42	34.87	1.55	34.31	0.99
248	33.32	33.82	0.50	33.92	0.61	34.08	0.77	33.82	0.50
247	30.65	31.03	0.38	31.03	0.38	31.18	0.53	31.04	0.39
246	28.40	28.54	0.14	28.42	0.03	28.44	0.04	28.51	0.11
245	25.73	25.65	-0.08	25.57	-0.16	25.51	-0.23	25.59	-0.14

Of the three different turbulence models and the dense mesh runs, the k-epsilon model (called pressure run in the results table) still provided the closest comparison with regards to matching the physical model pool elevations. Because of this, the final JDA ladder CFD model was evaluated with a k-epsilon turbulence model, along with a stagnation pressure upstream boundary.

Each iteration of the CFD model was ran to quasi-steady state, to allow the inflow to remain constant. This condition was met once the inflow stopped changing, and the residuals from the model had levelled off at a low value.

Results

The CFD model results were compared to the physical model results with three different methods. The first method was the same that was used for validation and sensitivity, by comparing pool levels. The second method was comparing flow characteristics in Pool 8 and upstream of the Count Station, both of which were hand-drawn from the physical model. The final comparison was utilizing point velocity vector measurements taken in Pool 8 and upstream of the count station. There were ten point measurements taken for each location.

The pool level comparison between the CFD and physical model is the same as the turbulence and mesh sensitivity comparisons. This table is reproduced in Table 5.

Table 5 - JDA Models Comparison - Pool Levels

Tap #	Phys. Model WSEL (in)	CFD Model WSEL (in)	CFD Model Diff (in)
Forebay	65.55	65.29	-0.26
Exit Channel	65.45	65.35	-0.10
23	64.90	64.47	-0.43
22	64.18	63.81	-0.37
21	63.51	62.99	-0.52
20	62.72	62.11	-0.61
19	61.85	61.20	-0.65
18	60.80	60.21	-0.59
17	59.31	59.10	-0.21
16	58.18	57.93	-0.25
15	56.77	56.65	-0.12
14	55.59	55.41	-0.18
13	54.17	54.03	-0.14
12	52.81	52.79	-0.02
11	51.44	51.47	0.03

Tap #	Phys. Model WSEL (in)	CFD Model WSEL (in)	CFD Model Diff (in)
10	50.02	50.08	0.06
9	48.46	48.70	0.24
8	46.90	47.26	0.36
7	45.32	45.72	0.40
6	43.61	44.21	0.60
5	41.98	42.63	0.65
4	40.35	40.91	0.56
3	38.41	39.12	0.71
2	36.63	37.67	1.04
1	34.81	36.15	1.34
Count Station	33.32	34.38	1.06
248	33.32	33.82	0.50
247	30.65	31.03	0.38
246	28.40	28.54	0.14
245	25.73	25.65	-0.08

The largest difference between the pool levels when comparing the CFD model to the physical model was in pool 1, with the CFD water surface elevation being 1.34 inches higher. This equates to a prototype difference of approximately half a foot.

Hand-drawn flow pattern plates were included in the physical model report, which provided a good comparison for the overall characteristics of flow through the model. The velocity magnitude from the CFD model was mapped onto a horizontal cross section cut through mid-depth of each location of interest, and velocity vector arrows were included. The hand-drawn plates were then overlayed on top of the CFD images. The comparison for Pool 8 is shown in Figure 5 and the comparison for the Count Station is shown in Figure 6. The flow characteristic matched well, showing a consensus between the hydrodynamics in the CFD and physical models.

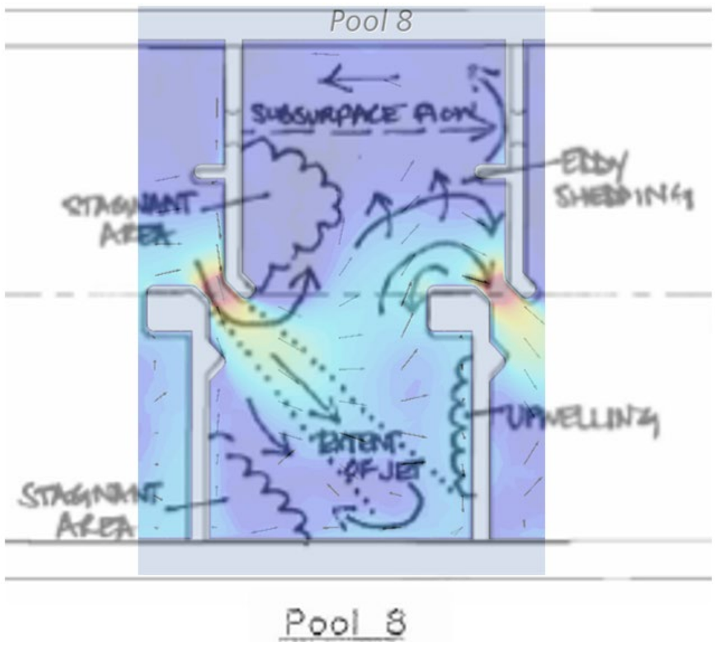


Figure 5 - JDA Pool 8 Flow Pattern Comparison

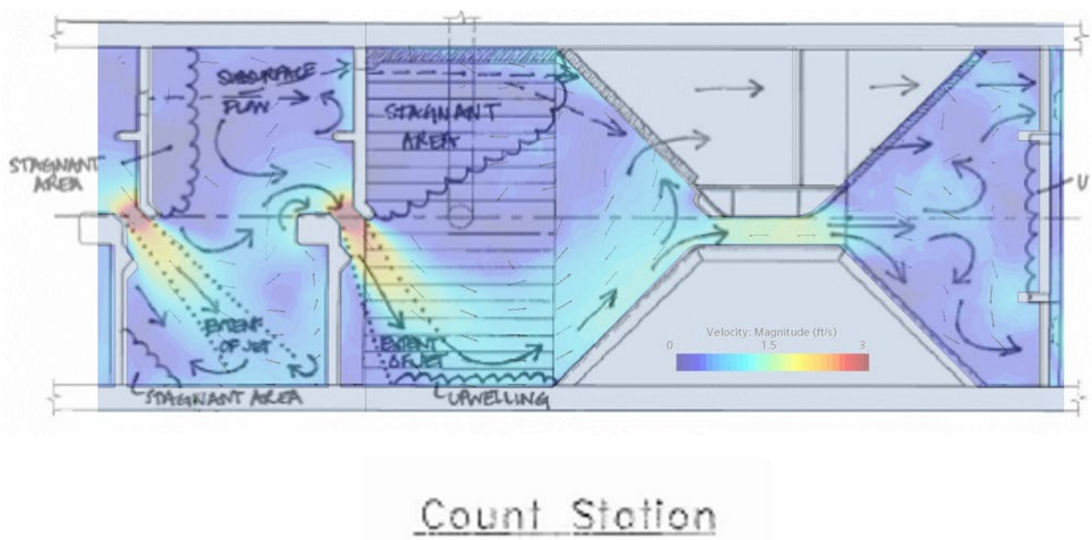


Figure 6 - JDA Count Station Flow Pattern Comparison

The final comparison between the two models was at 10 points in both Pool 8 and the Count Station, where three-dimensional velocity was measured in the physical model using an acoustic Doppler velocimeter (ADV). The points were replicated in the CFD model, and velocity vectors were extracted. The comparison includes three levels at each point: 0.2, 0.6, and 0.8 of the depth in each pool. Point maps for each location are shown in Figure 7.

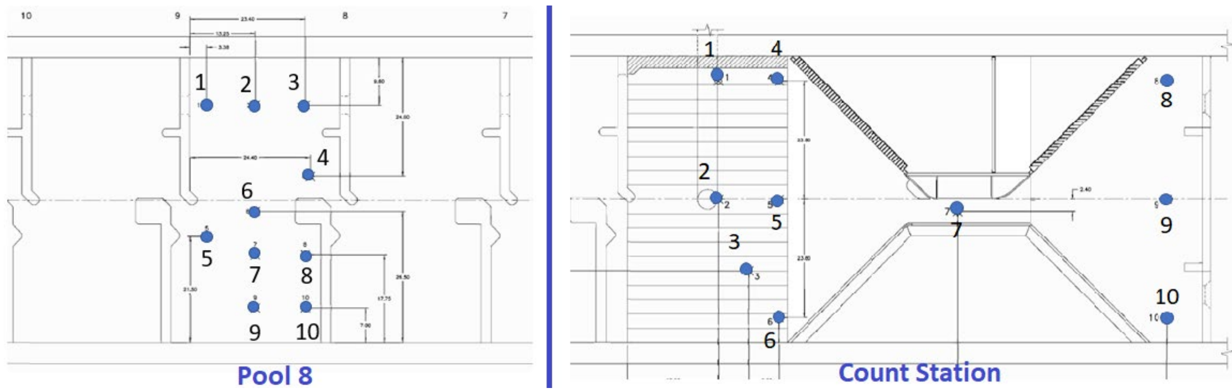


Figure 7 - JDA Point Velocity Locations Map

The magnitude of the velocity at each point was graphed for both models. The physical model measurements were made over a three-minute period and averaged. To mimic the physical model, the CFD model output was ran to steady state, then output every second for near 6 minutes of model time. The velocity vectors were time averaged over the 6 minutes for comparison. Comparison plots for Pool 8 and the Count Station are shown in Figure 8 and Figure 9, respectively.

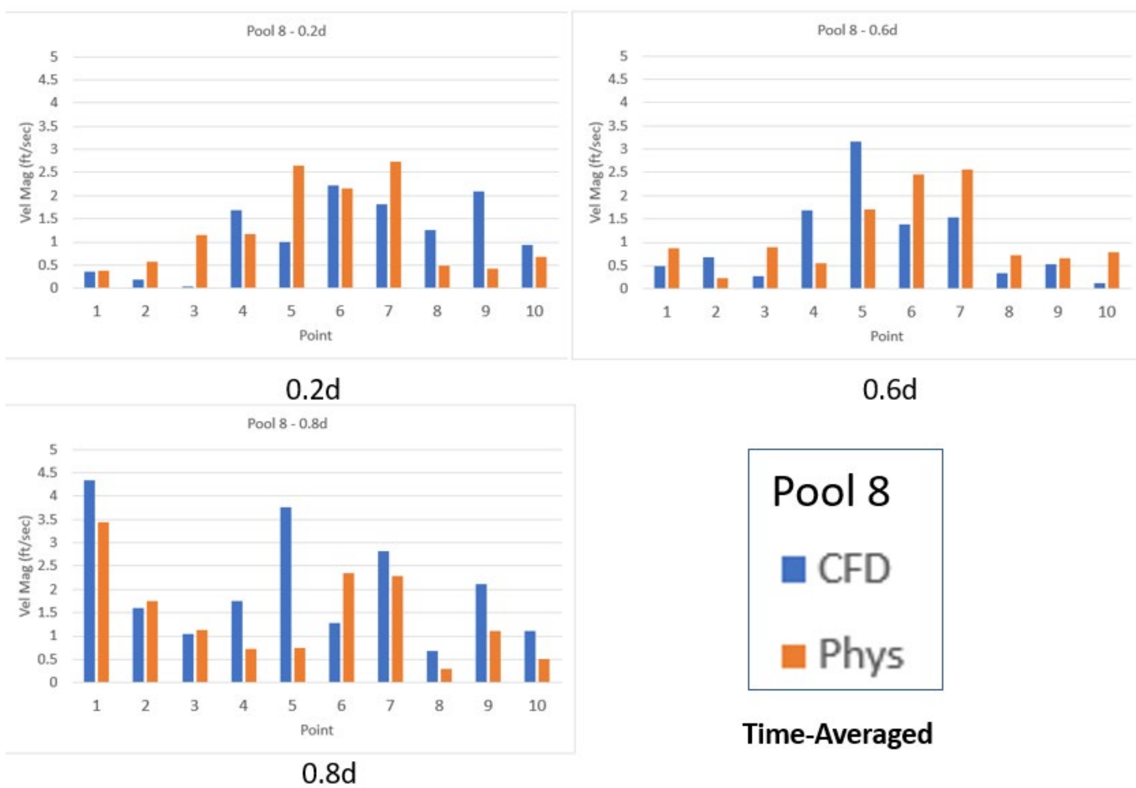


Figure 8 - JDA Pool 8 Velocity Magnitude Comparison

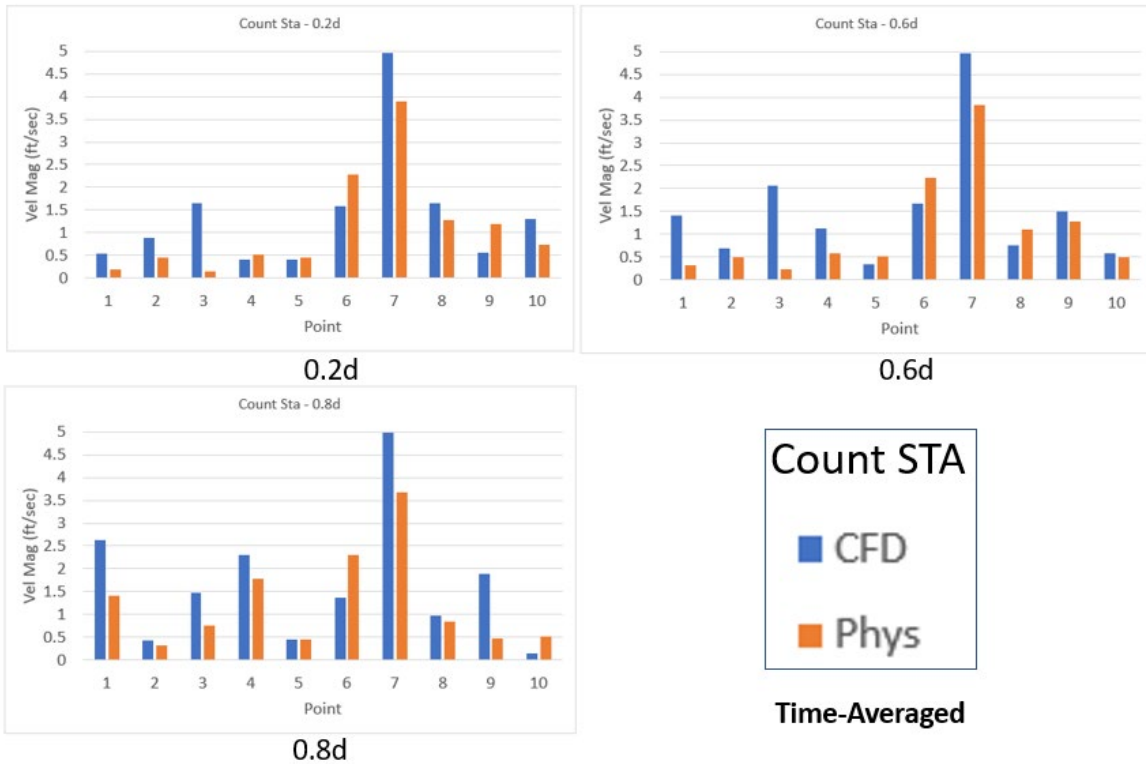


Figure 9 - JDA Count Station Velocity Magnitude Comparison

The velocity magnitudes are in general agreement with each other. The main differences in Pool 8 were at point 5, which was in line with the upstream weir slot. The CFD model was predicting lower velocities higher in the water column, and higher velocities lower in the water column when compared to the physical model. While this is a strange phenomenon, it could be due to how the depth locations were taken in the physical model versus the CFD model, either from the water surface down or from the ladder invert up. This was not specified in the physical model report. The CFD model velocities at point 5 still cover the full range of velocities from the physical model over the depth, which would still give an upper and lower range velocities for design of the new weirs at Bonneville. The velocity magnitudes in the Count Station were also in general agreement, with the CFD model tending to overpredict the magnitudes. This would make the CFD model conservative for design when analyzing the design for velocity criteria.

The time-averaged velocity vectors for each depth were mapped on top of the ADV vector maps from the physical model report. Because the raw data from the original vector maps wasn’t available, all three depth velocity vectors from the physical model are present in the underlain image. The velocity vectors from the CFD model were mapped at each depth separately for comparison. These comparison plots are presented in Figure 10 and Figure 11.

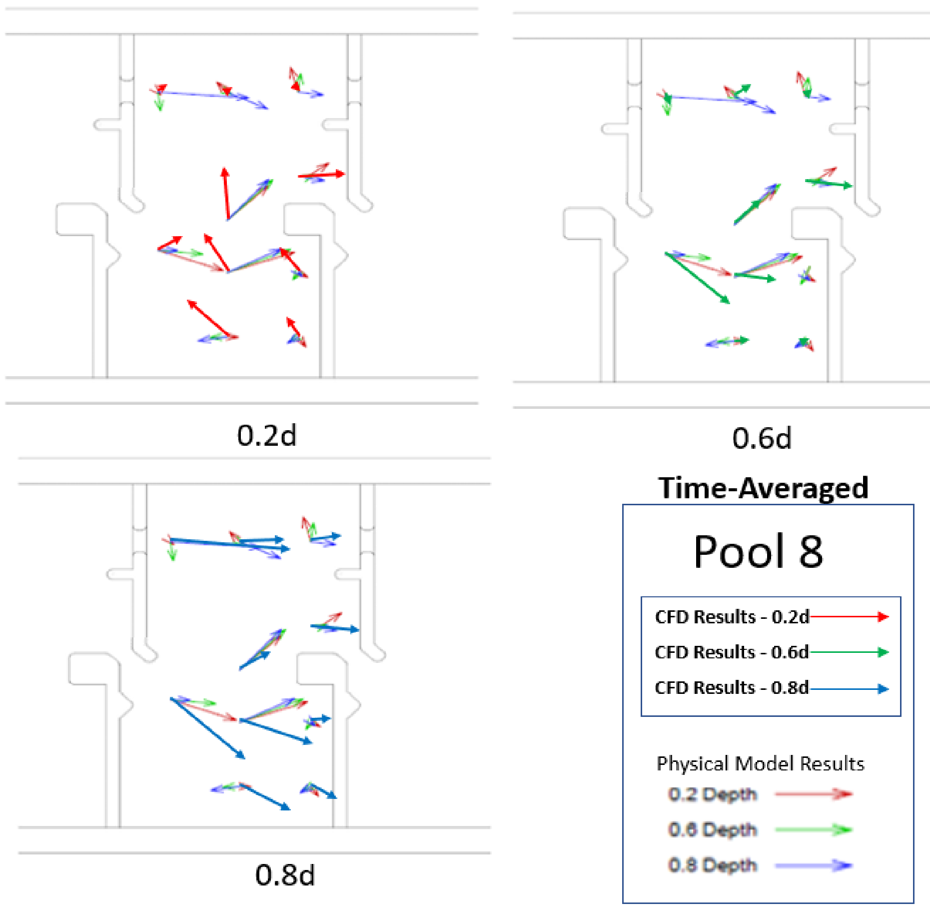


Figure 10 - JDA Pool 8 Velocity Vector Comparison

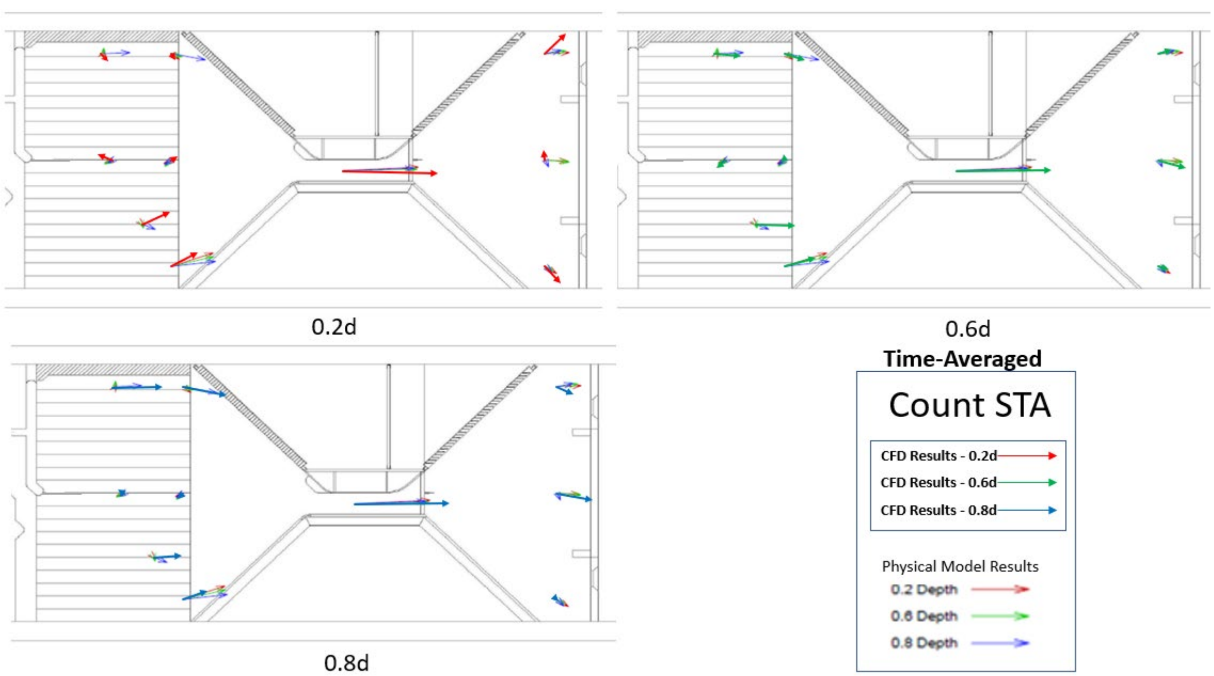


Figure 11 - JDA Count Station Velocity Vector Comparison

The vector length (magnitudes) showed the same comparisons between the physical model and CFD model as the previous magnitude bar graphs. For Pool 8, the direction of the velocity vectors agreed between both models, with the main differences being near the top of the water column at 0.2d at the southern half of the pool. Because there is heavy recirculation in this area, both horizontally and vertically, it could just be due to slight differences in measurement locations. The directions of the velocity vectors in the count station were all mostly in agreement, with a general trend of slow moving from upstream to downstream and accelerating through the count station slot.

Discussion

The physical model of the JDA north fish ladder exit control section was modeled in CFD to test the validity of using a numerical model to design the new exit control section for BON Washington shore fish ladder. The numerical model was created at the same scale as the physical model, 1:5, and multiple boundary conditions and physics models were tested to try and replicate the results from the 2008 physical model study. The most accurate depiction of the model numerically involved truncating the head tank where a porosity plate was in the physical model, simplifying the inlet for the diffuser water supply, using a stagnation pressure boundary as the inlet to the model, and utilizing the k-epsilon turbulence model as a means of closure for the Reynolds-averaged Navier-Stokes equations.

The CFD model was compared to the physical model results using three different outputs from the model: water surface elevations in each ladder pool, flow characteristics in Pool 8 and the Count Station, and velocity magnitude and vectors taken at ten points also in Pool 8 and the Count Station. The CFD model tended to underpredict energy dissipation when compared to the physical model; this is due to the CFD turbulence models averaging the effect of turbulence on the solution and not refining the eddy turbulence losses within each pool. Because of this, the model couldn’t support the prescribed head level in the forebay channel without requiring more flow. The CFD model calculated a flowrate of 1.6 cfs, compared to the 1.29 cfs reported from the physical model, based on the upstream water surface elevation boundary. Even with the flowrate difference, the largest difference between the pool levels when comparing the CFD model to the physical model was in pool 1, with the CFD water surface elevation being 1.34 model inches higher. This equates to a prototype difference of near half a foot, which was deemed as within reasonable error when comparing the models. Because the CFD model has higher energy due to the lack of energy dissipation that is present in the prototype, it is also considered a conservative model and should give a conservative estimate of the velocities for the new design of the control section at BON.

The flow characteristics in Pool 8 and the Count Station matched well between the CFD model and physical model, showing the same overall trends in circulating flow and flow direction. The velocity magnitudes compared relatively well, with some exceptions at the upstream slot in Pool 8. Even though there were some differences, the CFD model captured the full range of velocity magnitudes through the water column as the results taken from the physical model, which is one of the main criteria for the design of the new BON ladder weirs. The velocity vectors also compared relatively well, with the exception of a few points near the water surface in Pool 8.

Overall, given the unknowns on setup for the physical model and ability of the CFD model to mimic boundary conditions in the physical model, the two models compared well to each other. Where there wasn’t full agreement, the CFD model tended to be conservative for design, and as such it was decided that a CFD model would be an adequate design tool for the new exit control section at BON.

Model 2: Bonneville Washington Shore Fish Ladder 60% Design

Model Overview

The Bonneville Washington Shore Fish Ladder is located on the north side of the dam, and currently utilizes a serpentine weir design at the exit control section to pass fish into the forebay. From previous studies and prototype applications, a slot weir design was found to be more advantageous for passing lamprey successfully through the ladder exit control section, while reducing stress and delay for adult salmon, steelhead, and bull trout. The only changes to the prototype structure are replacing the serpentine weirs with nine new vertical slot-style weirs.

The proposed weirs were design based on required energy dissipation through each pool, while staying under the design velocity criteria of 8 ft/s between the 5% and 95% exceedance pool elevations at BON of 76 ft and 72.7 ft NGVD 29, respectively. The weirs include a salmonid orifice on the north side at the invert of the ladder, a slot that extends from the floor of the ladder to above the water surface in the model, and a smaller lamprey orifice on the south side at the invert of the ladder. A CFD model of the area was constructed for the new design, to evaluate the initial design calculations and check against the design criteria for the ladder, listed in the main DDR text. The CFD model includes the flume section leading into the forebay, the exit control section with the new slot weirs, the Auxiliary Water Supply (AWS) channel with upstream Tainter valve control, the orifices and bleed-off/add-in diffuser, adjustable count station wall with flow bypass and louver flow control, picket leave, main channel upstream of weir 67, and the Upstream Migrant Transport (UMT) Channel. A plan view showing the extents of the model is shown in Figure 12.

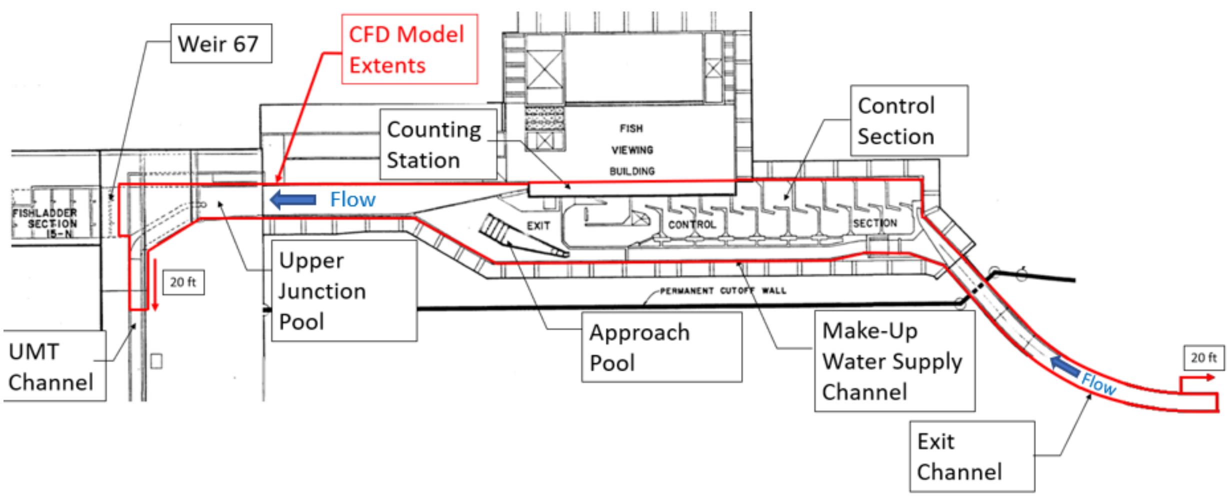


Figure 12 - BON WA Shore CFD Model Extents

The CFD model used for validation at the JDA North Shore ladder was completed at the scale of the physical model (1:5), whereas the model for the exit control section improvements at Bonneville WA Shore was done at prototype scale (1:1). Because the CFD models were scaled to the intended comparison metrics for each case, the physical model for JDA and the 1-D calculations for BON, there shouldn't be any scale effects present between the comparisons of each model.

Grid Development

The grid for the CFD model runs was created in Star-CCM+ version 16.04. The development of the model grid parameters to be used for CFD model runs was an iterative process that involved testing and adjusting grid development strategies. Similar to the JDA ladder model, a water surface refinement wasn't utilized for this model.

A final computational grid was developed, using Polyhedral cell meshing. This included remeshing the surface, and developing the volume mesh based on the following parameters:

- Base grid: 0.75 ft cell size, minimum 0.075 ft cell size, maximum of 3.75 ft cell size

The resultant mesh consisted of 2.5 million cells, which included multiple regions in the model. An example of the mesh in the ladder section is shown in Figure 13.

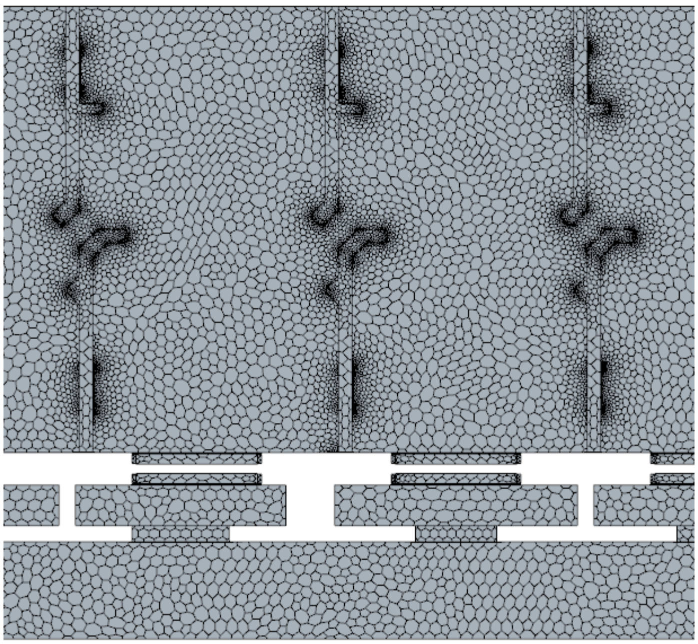


Figure 13 - BON Ladder Mesh Example

Multiple regions were created, to enable the use of porous baffle interfaces in the model to replicate diffusers and trash racks that exist in the prototype. This includes a trash rack upstream of the AWS inlet, diffuser grates on all of the seven bleed-off/add-in diffusers, trash racks on the upstream and downstream end of the count station bypass channel, a porous baffle replicating the louvers that adjust flow through the count station bypass, and the picket lead.

Boundary Conditions

The boundary conditions for the model include:

- A stagnation inlet boundary with static hydraulic pressure set at the intended elevation in the forebay (varied by run).
- A porous baffle interface between the exit section and AWS intake channel

- A porous baffle interface between each of the bleed-off/add-in diffuser pools and the ladder section
    - There are two slots for diffuser racks at each diffuser. All seven racks were included on the ladder side of the model, and two additional racks were included on the AWS side of the diffuser for bleed-off diffusers four and five.
- A porous baffle interface between the upstream section of the count station channel and the count station bypass channel.
- A porous baffle interface between the downstream section of the count station channel and the count station bypass channel.
- A porous baffle interface bisecting the count station bypass channel.
    - This baffle was meant to mimic the louver gates that control flow through the count station bypass channel. It was iteratively set to try and achieve a 50/50 flow split between the count station and the bypass.
- A porous baffle interface for the picket lead, between the approach pool and the channel leading to the upper junction pool.
- A pressure outlet directly upstream of weir 67, set to the 1 ft head differential specified for adult salmonid passage through the ladder. This was a constant 68 ft NGVD 29 elevation for all models. A higher head level of 1.3 ft will also be examined, to mimic shad ladder flows.
- A pressure outlet 20 ft downstream of the turn in the UMT, set to an estimated head level of 66.5 ft NGVD 29.

A diagram of all the porous baffle regions is shown in Figure 14, and the porosities, loss values (K), and Porous Inertial Resistance (alpha) specified in the CFD model are listed in Table 6. The porosities were calculated from as-builts of the ladder, K values were determined using D.S Miller's *Internal Flow Systems* (1978), and the alpha values were determined to be half of the loss values based on previous CFD efforts.

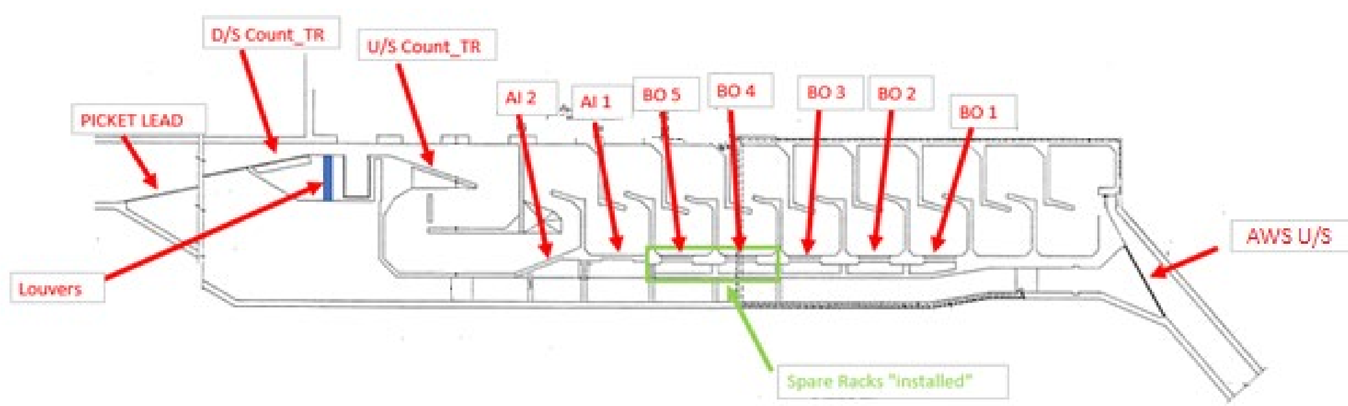


Figure 14 - BON Porous Baffle Locations

Table 6 - BON Porosity Settings

Baffle	Porosity	K	alpha
AWS Upstream	0.6	0.45	0.225
B.O. 1	0.598	0.45	0.225
B.O. 2	0.598	0.45	0.225
B.O. 3	0.598	0.45	0.225
B.O. 4*	0.589	0.45	0.225
B.O. 5*	0.589	0.45	0.225
A.I. 1	0.477	0.8	0.4
A.I. 2	0.477	0.8	0.4
Count Upstream	0.673	0.3	0.15
Count Downstream	0.673	0.3	0.15
Louvre	0.160	30	15.0
Picket lead	0.696	0.25	0.125

*spare racks installed here

All other region boundaries were set as default wall boundaries, including all concrete structures and gate structures. Other components of the model that could be adjusted include:

- The Tainter valve, know to the Project as FV6-9, which was set to an opening between one to two feet based on Project guidance. Setting this valve was an iterative process, as the prototype valve is adjusted in real time using a PLC, to maintain a head level of 68 ft NGVD 29 at weir 67.
- The count station moving wall, which is adjustable in the prototype between 1.5 to 3 ft open, depending on flow through the ladder. This was set to a constant 1.5 ft open for all CFD runs.

The maximum forebay, 5%, 50%, 95% exceedance elevations, and minimum pool levels were evaluated in the model, along with a forebay elevation of 74 ft NGVD29 to align with the initial hydraulic calculations. A table of the different run boundary conditions are shown in Table 7.

Table 7 - BON Model Run Settings

	Run	FBL (ft)	FB-to-Channel HL (ft)	AWS WSEL (ft)	Weir 67 WSEL	UMTC Weir WSEL (ft)	TV Opening (ft)	TV Opening (deg)	Count STA Open (ft)	Exit Channel Flow (cfs)
Max	1	77	0.07	76.93	68	66.5	1	10	1.5	152
5%	2	76	0.06	75.94	68	66.5	1.21	12.1	1.5	145
50%	3	74.5	0.05	74.45	68	66.5	1.42	14.2	1.5	115
Calcs	3a	74	0.03	68.73	68	66.5	1.61	16.1	1.5	105
95%	4	72.7	0.04	72.66	68	66.5	1.67	16.7	1.5	81
Min	5	70	0.02	69.98	68	66.5	2	20	1.5	34

Each separate case in the CFD model was ran to quasi-steady state, to allow the inflow to remain constant. This condition was met once the inflow stopped changing, and the residuals from the model had levelled off at a low value.

Results

Runs 1, 3a, 4, and 5 were analyzed in both the CFD model and the spreadsheet calculations, and the water surface levels in the new control section baffle pools were compared as a check on the reasonableness of the CFD model results. Points were created in the model near the north wall of the ladder, at the center of each pool, and pressures were extracted and converted to overall water surface elevation for comparison. The table of comparisons is shown in Table 8. Note that the pool numbering increases from downstream to upstream, i.e., Pool 1 is at the downstream end of the control section and Pool 9 is at the upstream end of the control section. A summary of the head drop in each pool, including the maximum and minimum drop for each run, is shown in Table 9.

Table 8 - BON WSE Comparison

Location	FB 77			FB 74			FB 72.7			FB 70		
	WSE (ft)		Difference	WSE (ft)		Difference	WSE (ft)		Difference	WSE (ft)		Difference
	Calcs	CFD	(ft)	Calcs	CFD	(ft)	Calcs	CFD	(ft)	Calcs	CFD	(ft)
1	69.15	70.1	-0.95	68.8	68.8	0.01	68.76	69.14	-0.39	68.50	68.68	-0.18
2	70.08	70.4	-0.32	69.4	69.4	0.07	69.28	69.48	-0.20	68.69	68.81	-0.11
3	71.01	71.2	-0.19	70.0	69.9	0.09	69.80	69.90	-0.10	68.87	68.97	-0.10
4	71.97	72.1	-0.16	70.6	70.6	0.05	70.30	70.35	-0.05	69.03	69.13	-0.10
5	72.95	73.0	-0.10	71.3	71.2	0.02	70.79	70.82	-0.04	69.19	69.29	-0.10
6	73.93	73.8	0.10	71.9	71.9	0.01	71.25	71.27	-0.01	69.35	69.42	-0.08
7	74.88	74.7	0.15	72.5	72.5	0.03	71.67	71.64	0.03	69.49	69.53	-0.05
8	75.86	75.8	0.11	73.1	73.1	0.02	72.11	72.07	0.04	69.65	69.67	-0.02
9	76.77	76.6	0.17	73.7	73.8	-0.04	72.55	72.53	0.02	69.81	69.83	-0.02
AWS	68.69	76.2	-7.51	68.7	68.5	0.23	68.78	68.60	0.18	68.88	68.00	0.88
Exit to FB	77.04	76.8	0.22	74.0	73.8	0.11	72.75	72.55	0.20	69.93	69.86	0.07

Table 9 - BON Pool Drop Summary

Downstream

U/S Pool	D/S Pool	Drop (ft)			
		FB 77 ft	FB 74 ft	FB 72.7 ft	FB 70 ft
9	8	0.85	0.66	0.46	0.16
8	7	1.02	0.64	0.43	0.14
7	6	0.90	0.58	0.38	0.11
6	5	0.79	0.64	0.44	0.13
5	4	0.92	0.65	0.47	0.16
4	3	0.93	0.65	0.45	0.16
3	2	0.81	0.59	0.42	0.16
2	1	0.30	0.54	0.33	0.13
	Maximum:	1.02	0.66	0.47	0.16
	Minimum:	0.30	0.54	0.33	0.11

The CFD-predicted pool elevations compared well to the spreadsheet calculations for runs at forebay elevations of 74 feet, 72.7 ft, and 70 ft. At these forebay elevations the differences between the two methods of analysis were near or less than 0.1 feet, with some slightly higher differences near Pool 1.

There is a notable difference in the pool elevations calculated by the spreadsheet calculations and the CFD model at a forebay El. 77. A review of the model results for forebay El. 77 shows that:

- the pool elevations in the lower control section (Pools 1 to 2) were substantially higher in the CFD model as compared to the spreadsheet calculations; and
- the AWS channel elevations for a forebay elevation of 77 was much higher than what was originally assumed

These observations prompted another evaluation of the CFD model at higher forebay elevations, to see what was causing the higher elevation in the make-up water supply channel.

There is a Tainter gate at the downstream end of the make-up water supply channel that can be used to backflush the diffusers. There is a wall immediately upstream of the Tainter gate that provides a sealing surface for the gate. The upstream wall has a bottom elevation of 69.5 ft and the channel floor elevation is at elevation 63 feet, leaving a 6.5 ft opening for flow to pass underneath the wall. The backflush Tainter gate is normally left in its full open position and doesn't affect the flow in the channel at typical forebay elevations. However, Runs 1 and 2, with forebay elevations of 77 feet and 76 feet respectively, showed a flow constriction in the make-up water supply channel caused by the upstream sealing surface of the backflush Tainter gate. An image showing this flow control is shown in Figure 15 .

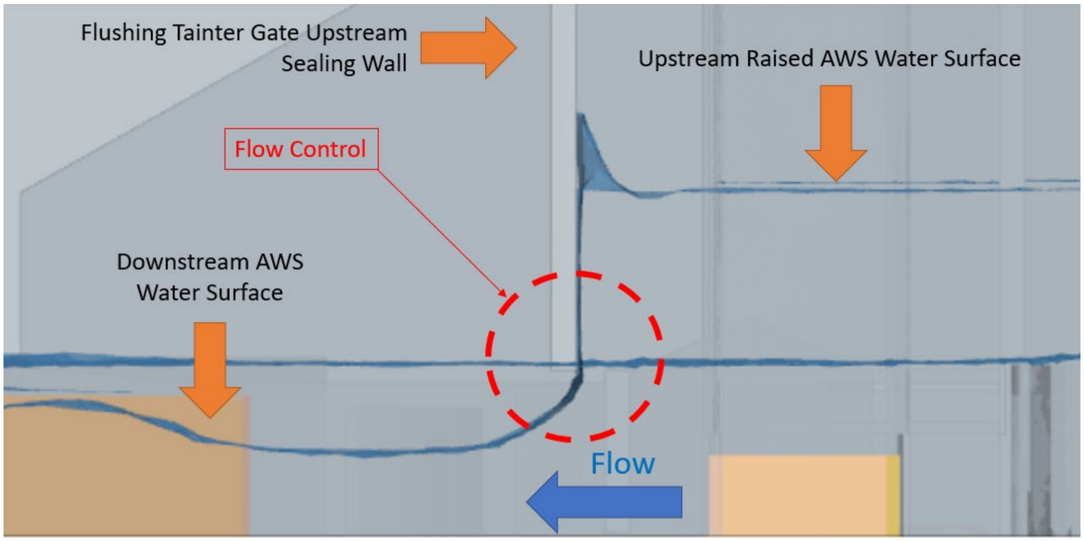


Figure 15 - Backflush Tainter Gate Seal Wall and Associated Flow Control

The same flow control/orifice flow conditions were looked at in Run 3 with a 74.5 ft forebay elevation; in this case there was enough drawdown in the make-up water supply channel to keep the water surface below the bottom of the wall, so that the constriction wasn't controlling flow through the channel. The CFD model is showing that the wall becomes the flow control at an undetermined forebay elevation between 74.5 ft (no constriction) and 76 ft (observed constriction).

A prototype test was conducted to verify the validity of the orifice control seen in the model. The ladder and AWS channel were observed at forebay elevations of 76.2 ft and 76.5 ft, and the AWS channel flow wasn't interacting with the bottom of the flushing Tainter valve sealing wall. When observing the Project, it was noted that the upstream Tainter valve that controls flow into the AWS was set to an opening between 0.75 ft and 0.25 ft, based on the staff gage located on the gate operating equipment. This was lower than the previously understood operation of that valve, which was believed to be open from one to two feet over the entire operation of the ladder. Having this valve open more in the CFD model than in the prototype, which would allow more flow to pass into the AWS channel, is what is believed to have caused the orifice-control condition in the CFD model. The CFD models at the higher forebay elevations were repeated with lower valve openings and documented in this report for the 90% design submittal.

One objective of the control section modifications is to keep the velocities through the slots and orifices as low as possible for lamprey passage while also meeting the NMFS guideline to maintain head drops between 0.25 and 1.0 feet through the control section for salmonid passage. The NMFS criteria document additionally states that flow velocities greater than 12 ft/s over 90 percent of the cross-section constitute a passage impediment for salmonids. The average velocity associated with 1.0 feet of head drop is 8 ft/s.

The new control section was designed to meet flow and head drop requirements between exceedance forebay elevations of 5% and 95%, corresponding to elevations 76 ft and 72.7 ft respectively. As the higher forebay elevation will provide more head to the ladder and cause higher velocities through each opening, Run 2 was selected to check the upper bounds of the design. Because energy is dissipated as flow moves through the control section, the uppermost baffle pair (Baffles 9a and 9b) will have the highest energy and the conditions at this baffle pair were analyzed for velocity magnitude. Figure 16 shows a map of these velocities through each outlet. A more average water surface elevation, at 74.5 ft, was also evaluated to show typical conditions, and the velocities are presented in Figure 17.

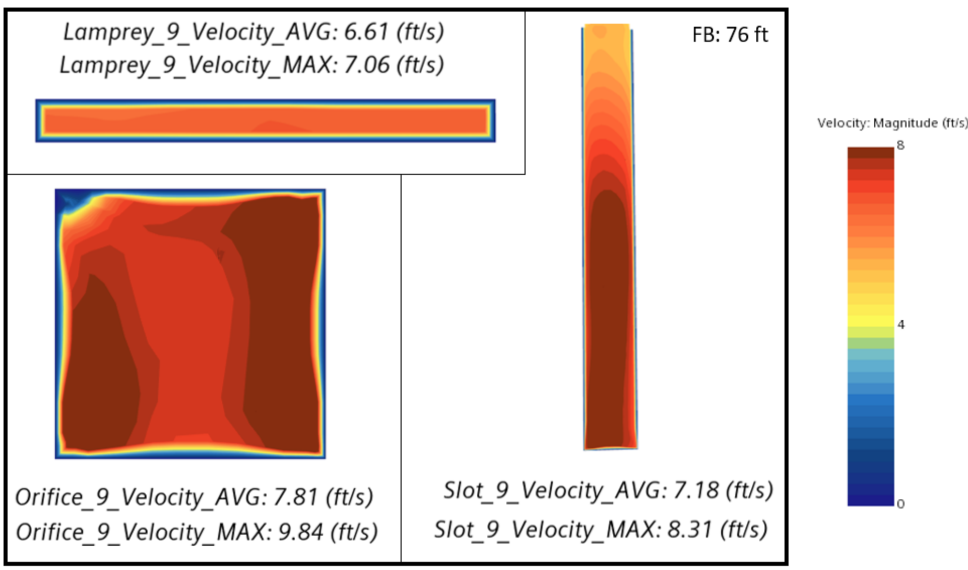


Figure 16 - Slot and Orifice Velocity Contours at Baffle Pair 9, Forebay El. 76 (5% Exceedance)

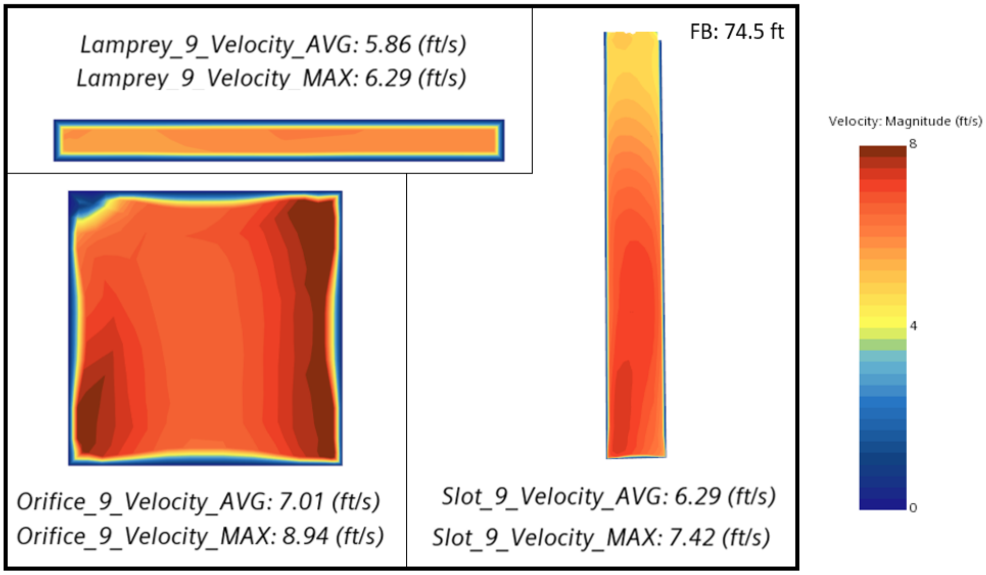


Figure 17 - Slot and Orifice Velocity Contours at Baffle Pair 9, Forebay El. 74.5 (50% Exceedance)

The average velocities for the 5 percent exceedance forebay elevation (El. 76) are within the 8 ft/s range (1 foot head drop), but localized maximum velocities are above 9 ft/s. The flow control at the backflush Tainter gate and elevated water surface in the make-up water supply channel, which appears to be driving additional flow into the control section via the bleed-off diffusers could be contributing to higher than necessary velocities in the control section. The average velocities for the 50 percent exceedance forebay elevation (El. 74.5 ft), show lower average velocities through the slot and orifices, closer to 6 to 7 ft/s. The salmonid orifice has a maximum velocity above 8 ft/s, but the highest velocity occurs near the corners and the main jet core is closer to 7 ft/s.

The final check on the design was looking at flow patterns within the new ladder section, to see if there were any areas of concern or potential for optimization. A horizontal plane was cut at three different elevations through the ladder section: at the centerline of the lamprey orifice (0.85-in above the floor), at the centerline of the salmonid orifice (9.8-in above the floor) , and at mid-depth of the pools on a slope that matched the overall slope of the water surface through the ladder pools. Run 3 (50% exceedance), with a forebay elevation of 74.5ft NGVD 29, was selected as the representative flow condition. These flow characteristic plots are shown in Figure 18, Figure 19, and Figure 20.

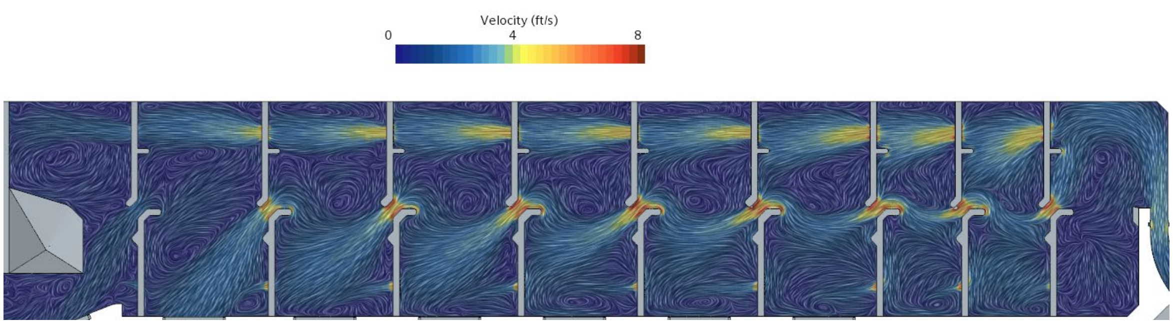


Figure 18 - FB 74.5 ft Lamprey Orifice Horizontal Plane Velocity

The cross section cut at the centerline of the lamprey orifice shows a good flow signature coming from the lamprey orifices on the south side, that blends into the diagonal flow from the slots. There is an acceleration of flow around the slot weir sides, shown by the higher velocities with a lower velocity in the middle of the jet. The salmonid orifices flow signature seems to extend from the outlet of the upstream orifice into the downstream orifice. There is a stagnant flow area upstream of the first lamprey orifice, on the south side of the ladder. A small recirculation occurs on the far south wall of all the pools, and another recirculation occurs directly to the north of the jet from the slots. The last pool, including the pyramid-shaped concrete form, has a relatively large recirculation in the north side and the jet from the final weir appears to interact with the pyramid form.

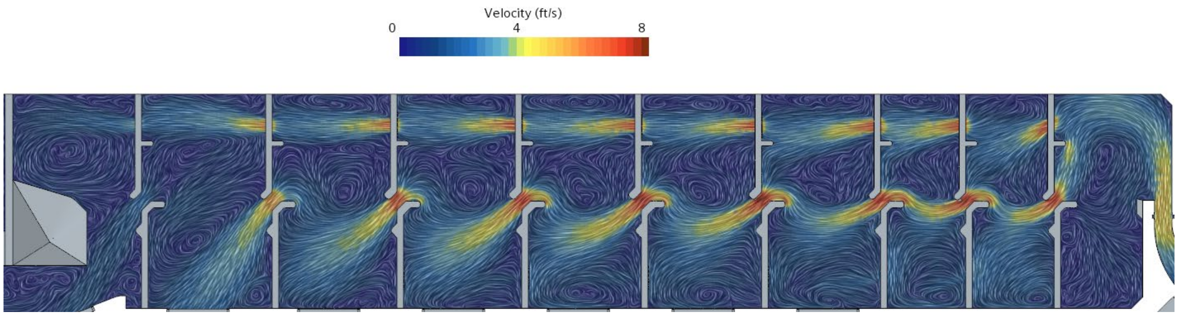


Figure 19 - FB 74.5 ft Salmonid Orifice Horizontal Plane Velocity

The cross section at the centerline of the salmonid orifice shows similar characteristics as the lower cross section. The flow entering the ladder on the upstream end seems to interact with the north wall and cause the jet projecting from the salmonid orifice to bend slightly to the south as it passes into the next pool downstream. A more defined recirculation occurs in the south portion of each ladder pool, and the final downstream slot jet still is interacting with the pyramid form.

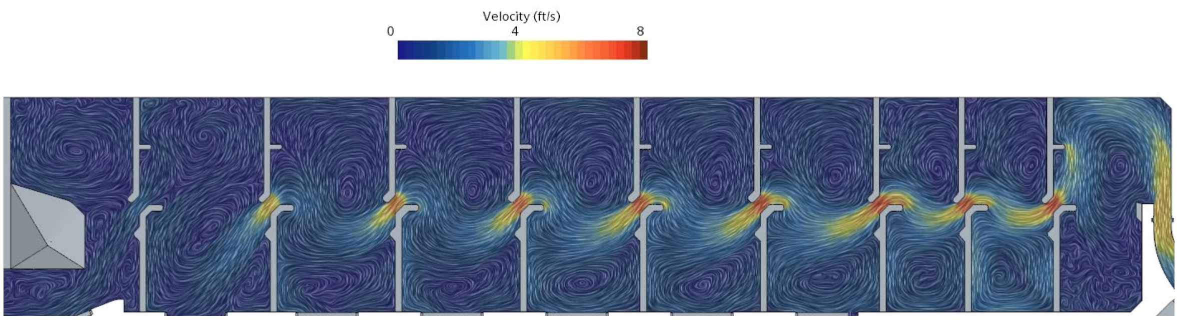


Figure 20 - FB 74.5 ft Mid Depth Plane Velocity

The mid-depth cross section shows very defined recirculations at the north and south sides of each ladder pool. There is still a stagnant area in the first upstream pool on the south side, and the jet from the furthest downstream slot still interacts with the pyramid form.

Based on these cross sections and flow characteristics, areas of interest for changes could be in the first pool upstream, and the final pool downstream. In the most upstream pool, a slight deflector on the downstream side of the salmonid orifice could help to straighten the flow towards the next orifice downstream. A discussion of the effects of a stagnant pool on the south side of the upstream pool should also occur between ENC-HD and Fish Biologists. Lastly, the pyramid form in the final pool downstream could either be modified or removed to facilitate a cleaner approach to the slot for fish.

Discussion/Continuing Effort

Overall, the CFD model seemed to agree well with the initial design calculations for the control section redesign. An unforeseen flow control at the existing flushing Tainter gate sealing wall was found, which forced orifice control in the make-up water supply channel for higher forebay elevations. This appears to cause flow to be added to the control section via the bleed-off diffusers during high pool events, which was not anticipated nor intended. Based on field testing, this was found to be a result of operating the AWS flow control Tainter valve at a larger opening in the CFD model than in the prototype. The CFD model was updated to reflect the prototype operations and documented in this report, labeled at the 90% design.

The next steps for the hydraulic modeling and design refinements include:

- Rerun the CFD model with more refined TV openings based on the prototype operations, and update the CFD Appendix and DDR accordingly.
- Determine options to reduce the velocity through the slots and orifices and quantify the potential benefits for lamprey and salmon passage through the control section. Potential changes that could be investigated include modifying the slot widths to achieve more equal head drops across each baffle pair.
- Investigate potential modifications in the furthest upstream and downstream ladder pools, per recommendations from the flow characteristics check.

Opportunities may be available to reduce the flow velocities in the upper portion of the control section, through the slots and orifices, for the forebay El. 76 operation. The flow velocities are notably lower for the more typical forebay El. 74.5 ft, with average velocities of less than 6 ft/s to 7 ft/s range, with localized areas above 8 ft/s in the corners of the salmon orifice.

Once the hydraulic conditions for fish passage have been optimized to the extent possible, the model will be rerun to document the conditions during shad passage season, during which the head drop at Weir 67 would be increased to 1.3 feet. This is meant to be a check on hydraulic conditions within the ladder at another flow regime. It will also be determined if it is feasible to add a 1-foot-high solid strip at the bottom of the two add-in diffusers to provide a smooth surface on the lower portion of the left wall for the full extent of the control section.

Model 2: Bonneville Washington Shore Fish Ladder 90% Design

Model Overview

The continuing effort from the 60% DDR submittal included validating the prototype data that was collected of the AWS Tainter valve settings, which included running an existing condition serpentine weir CFD model. This model was not only used to update the rating curve for all the remaining CFD models but was used as a comparison to the new baffle design.

Multiple ATR comments also required that adjustments and alternatives were evaluated in the CFD model. These included:

- Evaluating slot flow interaction with AI/BO diffuser
- Possible issues with wrong direction recirculation in the most upstream portion of ladder
- Eliminating or modifying the S curve
- Eliminating upstream radii on orifices
- Ladder flow reversal

Evaluating slot jet interaction with the diffusers led to the discovery of a high inflow case from the AWS channel into the ladder during high forebay elevations for Add-In (AI) Diffuser 1. This discovery is discussed in the results section. The possible recirculation issue with flow entering from the exit channel into the most upstream ladder pool was evaluated by varying the turbulence closure model for two example CFD runs. Both a Large Eddy Simulation (LES) and Detached Eddy Simulation (DES) turbulence model were utilized to evaluate potential transient hydraulic flows in the upper reach of the ladder. Removing the S curve wouldn't have been possible with the slot jets directed from north to south, so a simplification to the S curve was modeled by replacing the 180 degree turns with two 90 degree turns and effectively halving the distance of the curve. The radii on the upstream and downstream of the larger orifice were maintained because they didn't seem to negatively impact velocity profiles through the orifices, but when evaluating the models for velocity through the lamprey orifices it was noted that the velocities were much higher than anticipated. Due to this, a much more extensive alternatives analysis was conducted to try and reduce these velocities, which will be discussed below. The last ATR comment that was evaluated in the CFD model was mirroring the baffles to project the slot jet from south to north. This would also effectively remove the S curve and project the most downstream slot jet directly into the count station.

Once all the alternatives and ATR comments models were run and evaluated, a final geometry was selected for the design. This included the final location and shape of the lamprey orifice in each baffle, a reduced S curve length, 1 ft tall plates at the inverts of AI Diffusers 1 and 2 to facilitate lamprey passage, a flow constriction orifice plate for AI Diffuser 1, and preliminary geometry for pit tag detectors in baffles 3 through 6. This geometry was run for the full range of forebay head conditions, both regular and "shad mode" head levels, as well as with two additional turbulence models. Results include head levels in each pool, average and maximum velocities through all slots and orifices, and general hydrodynamic characteristics.

Grid and Geometry Development

The grid used for the 90% design runs has the same sizes and setup as the mesh setup for the 60% design runs. Once the high velocities in the lamprey orifices were discovered, a mesh sensitivity was performed for flow through the lamprey orifices by doubling the number of cells and rerunning, but it didn't show any appreciable difference in velocity or flow pattern.

The existing conditions models entailed placing the current serpentine weirs back into the model. This included the baffles formed for the current pit tag detectors and the existing lamprey orifices. A model overview for the existing condition is shown in Figure 21.

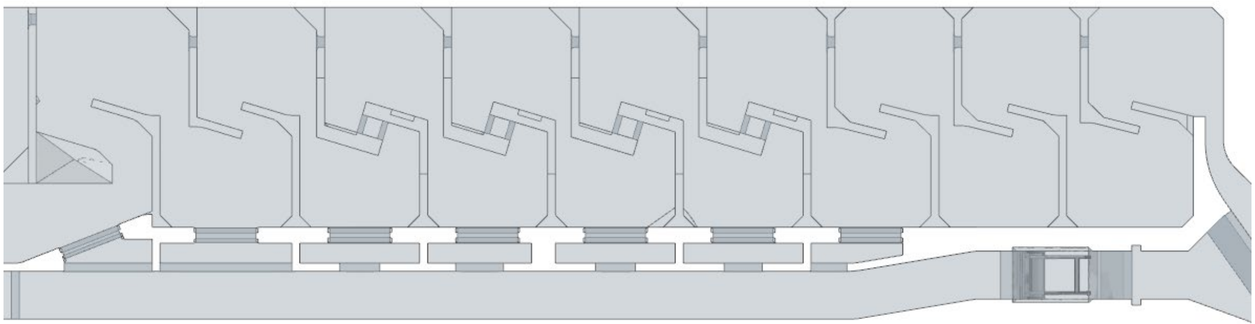


Figure 21 - Existing Conditions Geometry

The geometry for investigating the slot jet interaction with the diffuser panels was not any different than the previous 60% design geometry, but a restrictor plate was added to the orifice plate for AI Diffuser 1 to prevent too much flow from transferring from the ladder into the AWS channel from pool 2. This plate leaves that same open flow area as the AI Diffuser 2 orifice. A schematic showing the orifice plates and new restrictor plate is shown in Figure 22.

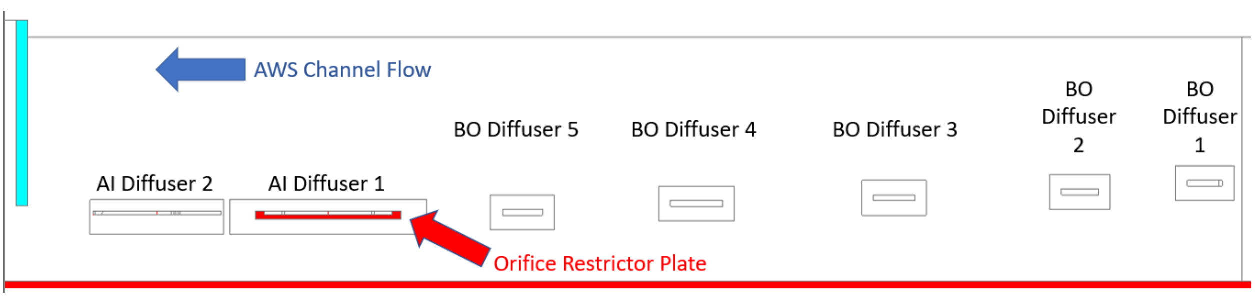


Figure 22 - Diffuser Orifice Plates with New AI1 Restrictor Plate

The S curve changes were made to shorten the length that fish need to travel in that lower portion of the ladder. This was accomplished by removing the 180 degree turns and shortening to 90 degree turns. With this modification, some sort of filler or structure needs to fill in the existing S curve section that was removed from the flow path. A comparison of the existing and proposed S curve sections is shown in Figure 23.

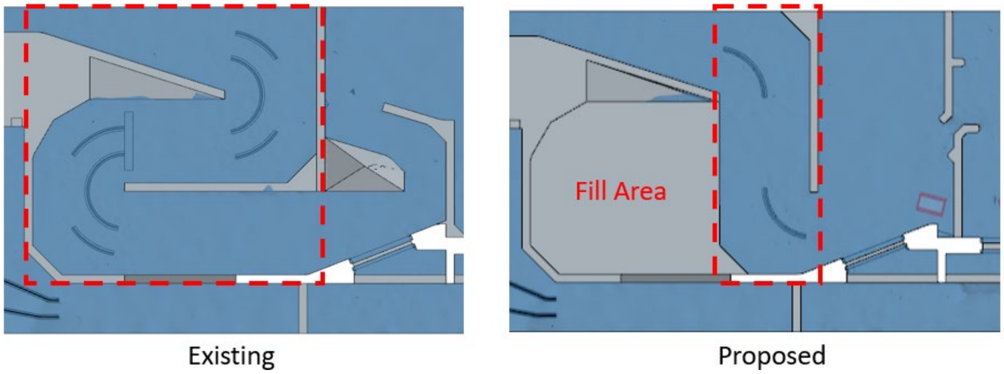


Figure 23 - Existing vs. Proposed S Curve Plan

Evaluating a south-to-north slot jet required mirroring the baffles. This included moving the larger orifices to the south side of the ladder, and the lamprey orifices to the north side. Because the jet was now facing into the count station, no S curve area was required, and a simplified geometry was included that still allowed access to AI Diffuser 2. A plan view of the mirrored design is shown in Figure 24.

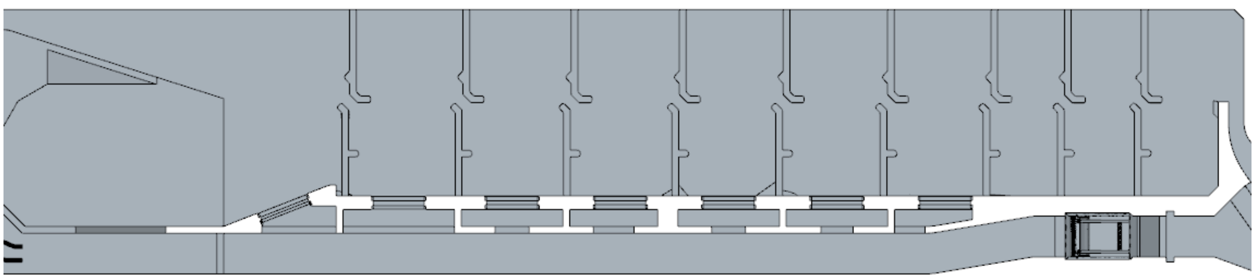


Figure 24 - Mirrored Baffle Design

The alternatives analysis for the lamprey orifice design involved both moving the orifice location in the baffles, changing the shape of the upstream lip of the orifice, adding in bollards, and attaching a lamprey rest box to the downstream opening of the lamprey orifice. The location changes are shown in Figure 25, the various upstream shaping is shown in Figure 26, the bollards are shown in Figure 27, and the attached lamprey box is shown in Figure 28.

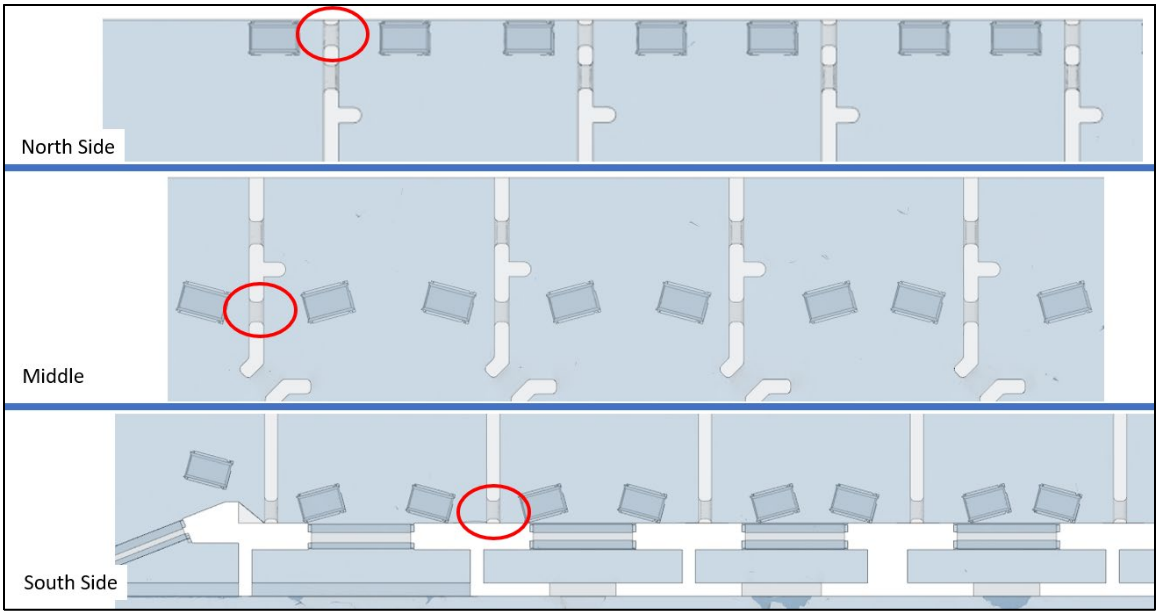


Figure 25 - Lamprey Orifice Alternative Locations

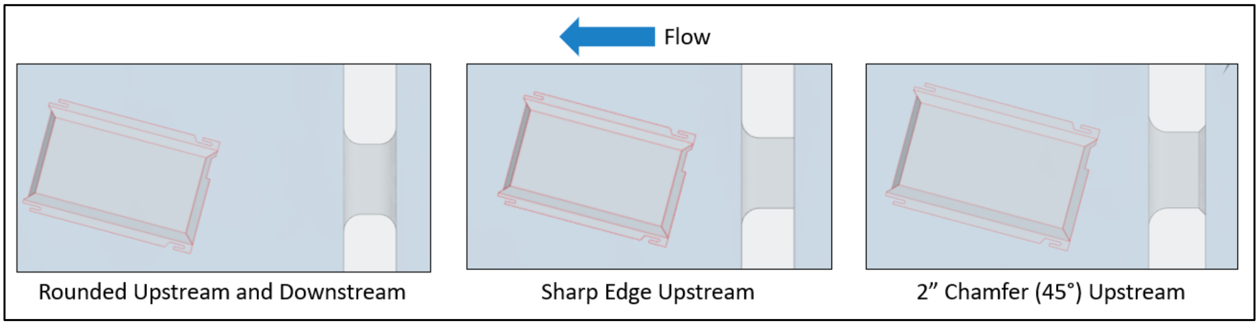


Figure 26 - Lamprey Orifice Shaping

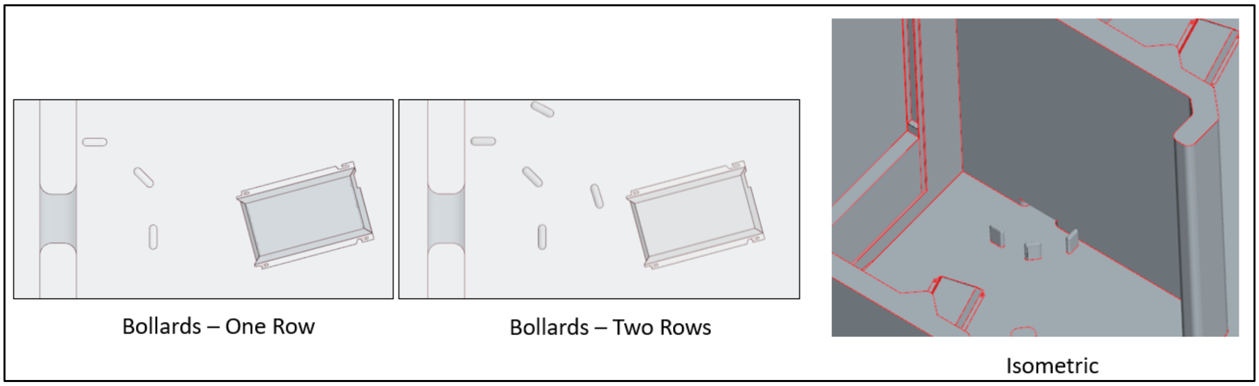


Figure 27 - Lamprey Orifice Bollards

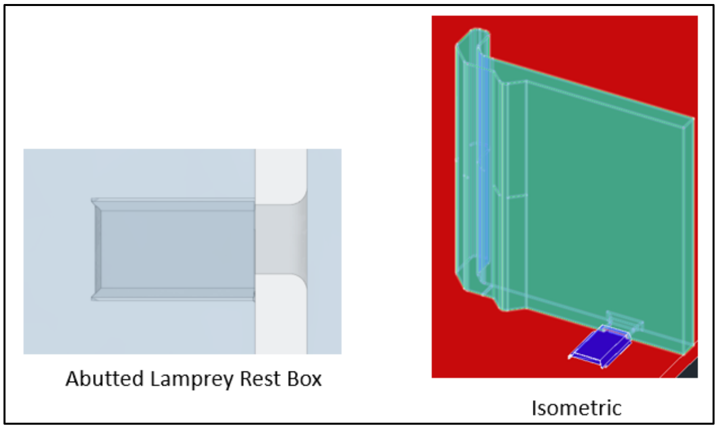


Figure 28 - Attached Lamprey Box

The final geometry was created based on the lessons learned from the previous modeling work, along with inputs from the PDT and the FFDRWG members. Anticipated shapes for pit tag detectors were also included. A plan view of the final geometry is shown in Figure 29, and preliminary pit tag detector geometry for the large orifice and lamprey orifice are shown in Figure 30.

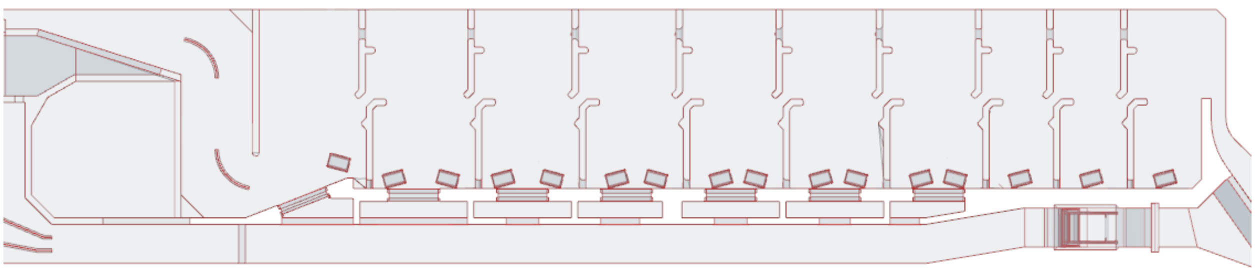


Figure 29 - Final Geometry Plan View

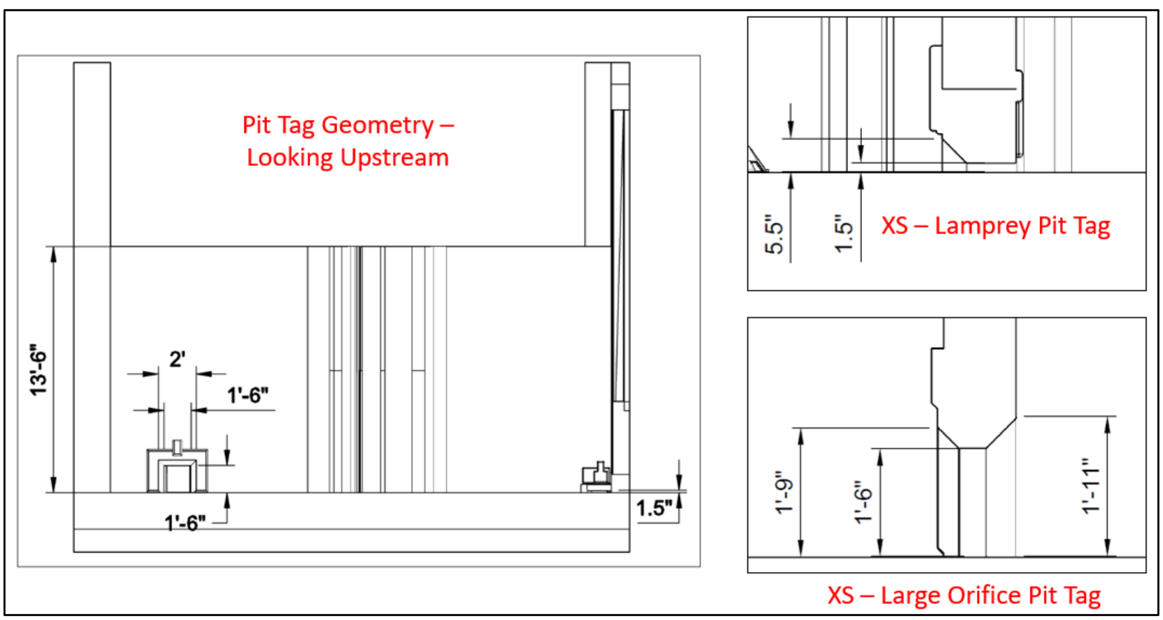


Figure 30 - Pit Tag Detector Geometry

Boundary Conditions

The boundary conditions for the 90% design runs were the same as the 60% design runs, which includes pressure boundaries on the upstream and downstream boundaries (forebay, weir 67 and the UMTC channel), porous baffle treatment for diffuser screens, picket leads and trash racks, and wall treatment for all concrete and valve surfaces. The count station opening was held at 1.5 ft for all runs.

Based on the field validation work completing in July 2022, the rating curve for the AWS Tainter valve was updated for the 90% design runs. The updated rating curve is shown in Table 10.

Table 10 - 90% Design AWS Tainter Valve Rating Curve

FB Elev. (ft)	Opening (degrees)	Opening (ft)
76.5	5.00	0.50
76	6.15	0.62
74.5	9.62	0.96
72.7	13.77	1.38
70	20.00	2.00

The validation runs were set up to reflect field data collected during two site visits in July. The first run, based on the 13July2023 site visit data, was set up to mimic the ladder flowing in "shad mode" with 1.5 ft of head over the lower ladder weirs. This increased the head level at the downstream boundaries by 0.5 ft (weir 67 set to a hydrostatic pressure at elevation 68.5 ft, and the UMTC channel set to a hydrostatic pressure at elevation 67 ft), and the forebay elevation was set to 76.1 ft. The AWS Tainter valve was set to 0.5 ft open based on the staff gage at the Project, and the count station opening was set to 1.8 ft open. For the 22July2022 validation run the model was set back to the regular 1 ft weir head setup, with a forebay elevation of 76.5 ft and an AWS Tainter valve opening of 0.16 ft. The count station was also set to 1.8 ft open for this run.

The lamprey orifice alternatives modeling was all done with a forebay of 76 ft and the associated boundary conditions, as it should be the worst-case scenario for high velocities within the design criteria (95% non-exceedance).

The final model geometry was run for 10 different flow scenarios to fully document the design. The run conditions are show in Table 11.

Table 11 - Final Design Run Settings

Run Type	Exceedence	Run	FBL (ft)	FB-to-Channel HL (ft)	AWS WSEL (ft)	Weir 67 WSEL (ft)	UMTC Weir WSEL (ft)	TV Opening (ft)	TV Opening (deg)	Count STA Open (ft)	Turbulence Model
1 ft diff	Max	1	77	0.07	76.93	68	66.5	0.50	5.00	1.5	KE
	5%	2	76	0.06	75.94	68	66.5	0.62	6.15	1.5	KE
	50%	3	74.5	0.05	74.45	68	66.5	0.96	9.62	1.5	KE
	95%	4	72.7	0.04	72.66	68	66.5	1.38	13.77	1.5	KE
	Min	5	70	0.02	69.98	68	66.5	2.00	20.00	1.5	KE
1.5 ft diff	5%	6	76	0.06	75.94	68.5	67	0.62	6.15	1.5	KE
	50%	7	74.5	0.05	74.45	68.5	67	0.96	9.62	1.5	KE
	95%	8	72.7	0.04	72.66	68.5	67	1.38	13.77	1.5	KE
LES/DES Check	50%	9	74.5	0.05	74.45	68	66.5	0.96	9.62	1.5	LES
	50%	10	74.5	0.05	74.45	68	66.5	0.96	9.62	1.5	DES

Validation

The validation of the AWS Tainter Valve rating curve involved modeling two field-measured conditions, which were observed on the 13th and 22nd of July 2022. The original intent of the testing was due to a submerged orifice condition at high forebay elevations in the AWS channel, where the AWS flow would interact with the downstream flushing gate top sealing wall, causing the water level in the channel to drastically increase. This water level increase would submerge all the diffuser orifices, leading to additional water being introduced to the exit control section of the fish ladder. This is the opposite effect than is intended for this AWS system, where flow is supposed to be bled off under higher forebay conditions.

A special operations request (SOR) was submitted, in conjunction with the Reservoir Control Center (RCC), to raise the Bonneville Dam forebay to a higher level than it is normally operated to in July. The maximum forebay on the 13th was recorded at 76.1 ft, which was increased to 76.5 ft for the site visit on the 22nd. Three water level measurements were taken for both site visits, and the staff gage reading on top of the AWS Tainter valve was recorded. A diagram of where the water level measurements were taken is shown in Figure 31.

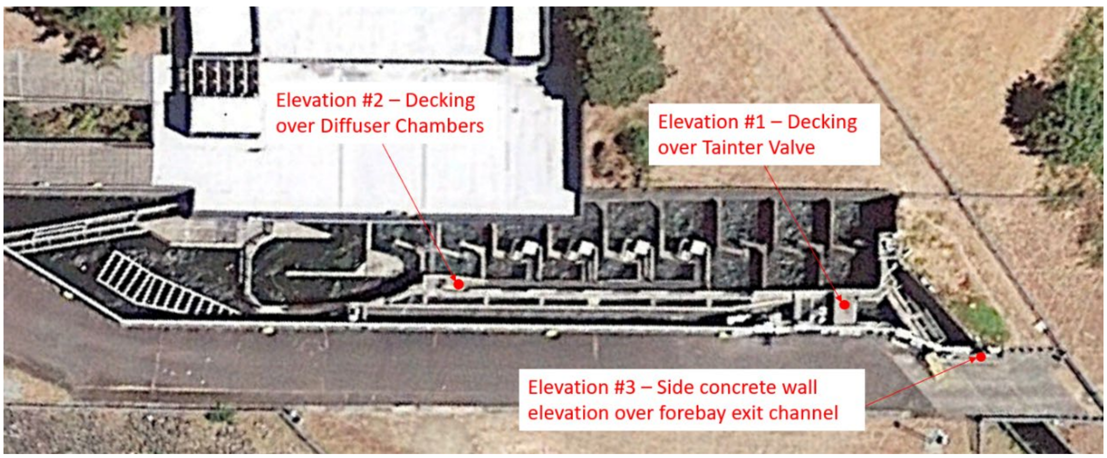


Figure 31 - Prototype Validation Water Level Measurement Locations

On the 13th, the ladder was operating in "shad mode", which raised the water level over the weirs in the lower ladders to 1.5 ft (compared to the normal 1 ft of head). The count station crowder was open to 1.8 ft, and the staff gage for the AWS Tainter Valve was recorded as open 0.5 ft. The existing CFD model was set to reflect these conditions and probed in the same location that the water surface elevations were taken. Table 12 shows the comparisons between the prototype and the CFD model.

Table 12 - 13July2023 WSE Comparisons

Measurement Locations	Elevation (ft)	Measured Distance (ft)	Water Level (ft)	CFD Model
(1) Decking over Tainter Valve	85.42	9.65	75.77	76.25
(2) Decking over Diffuser Chambers	84	15.25	68.75	68.83
(3) Side concrete wall over forebay exit	90	14.1	75.9	75.98

On the 22nd, the ladder was operating with its normal head conditions, with 1 ft of head over the weirs in the lower ladder. The count station crowder was open to 1.8 ft, and the staff gage for the AWS

Tainter Valve was recorded as open 0.16 ft. shows the comparisons between the prototype and the CFD model.

Table 13 - 22July2023 WSE Comparisons

Measurement Locations	Elevation (ft)	Measured Distance (ft)	Water Level (ft)	CFD Model
(1) Decking over Tainter Valve	8.95	85.42	76.47	76.2
(2) Decking over Diffuser Chambers	15.5	84	68.5	68.3
(3) Side concrete wall over Forebay exit	13.5	90	76.5	76.0

Overall, the CFD model compared well to the prototype measurements, and the absence of the submerged flow conditions at higher forebays was validated. Based on the measured valve openings, a new AWS Tainter valve rating curve was calculated and used for the 90% Runs.

Because an existing conditions CFD model was built, it was also used as a tool to evaluate the hydraulic differences between the serpentine design and the proposed slot baffle design. An overview image of the tortuous flow pattern through the serpentine section is shown in Figure 32, and more comparisons between the designs will be discussed in the Results section.

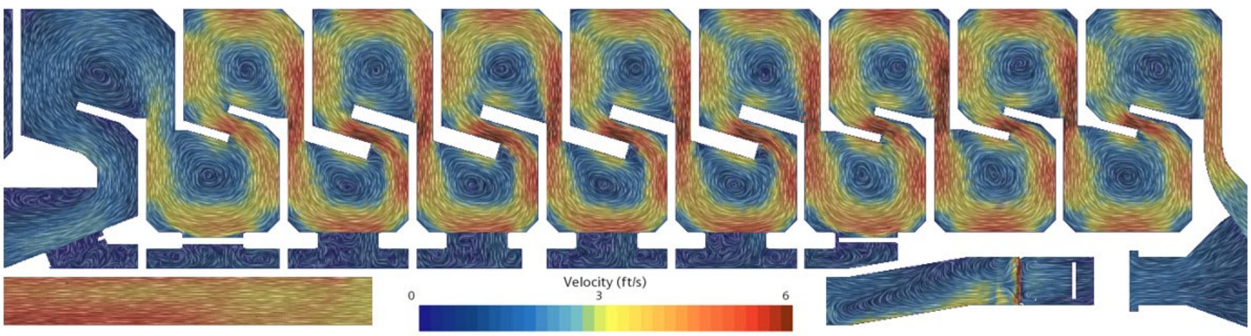


Figure 32 - Serpentine Section Flow Pattern

Results

After the Tainter valve rating curve was updated, the 60% design CFD model was rerun with the new valve opening to try and answer the questions from the ATR review. The first evaluation was based on potential for the slot jets to impinge fish on the diffuser gratings. There is no NMFS criteria for impinging adult fish on screens; the criteria is either to minimize through-screen velocities to prevent false attraction for adults, or to reduce through-screen velocities to 0.2-0.4 ft/sec to prevent juvenile fish impingement. The models were evaluated for any potential negative interaction and to respond to the comment.

Figure 33 shows the velocities of flow moving through the diffuser screens, from the perspective of the ladder side, for the 60% design. Most diffuser screens had relatively low through-screen velocities, with a slight hotspot on the downstream portion of each screen. The screen for AI Diffuser 1 showed the highest velocities, close to 1.5 ft/sec, distributed over most of the screen.

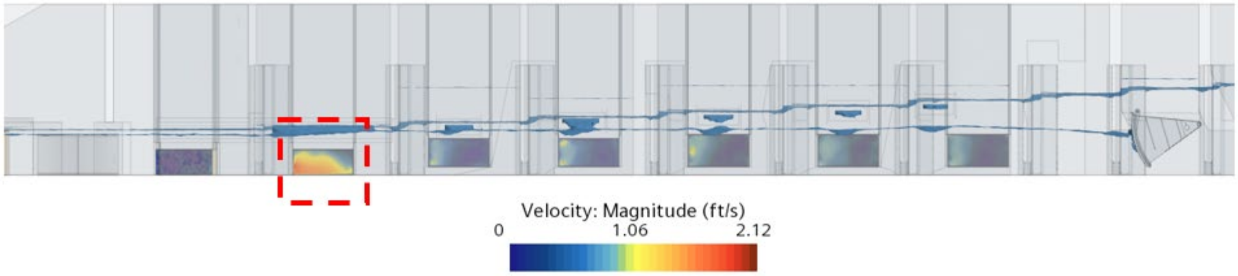


Figure 33 - 60% Design Diffuser Screen Velocities

The cause for the higher velocity and associated flow moving through the AI Diffuser 1 screen was a larger orifice plate opening on the AWS channel side. Based on reports from the physical model that was used to design the original serpentine ladder, the orifice plates were continually switched out in the model until an ideal flow distribution was achieved; there were no accompanying calculations to justify the differences in orifice plate sizing. To restrict the flow out of AI Diffuser 1, an additional orifice restriction plate was created in the CFD model. This plate has the same open area as AI Diffuser two, including the same orifice invert elevation. Figure 34 shows the diffuser velocities with the restrictor plate installed, which lowered the maximum velocities and redistributed the through-screen flow similar to that of the upstream diffusers. Note the difference in velocity scale magnitudes. No other negative interactions of the slot jets with the diffusers were noted.

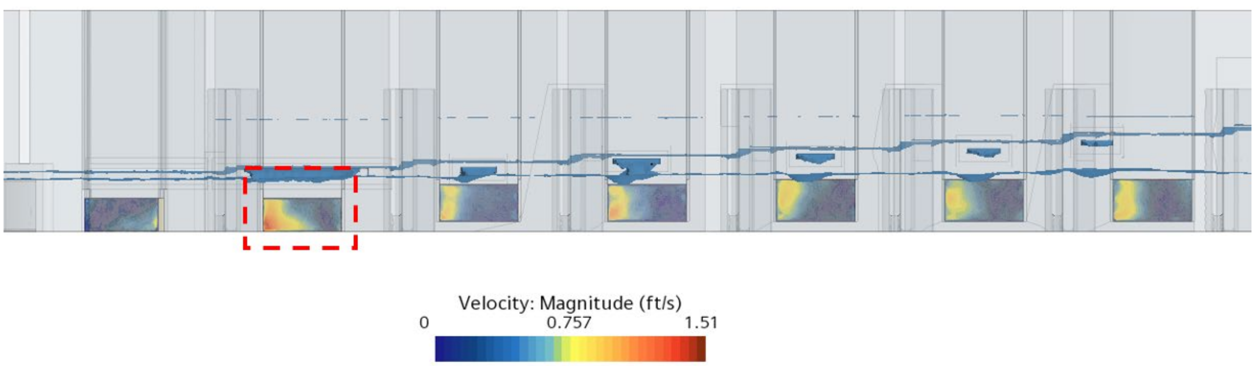


Figure 34 - 60% Design Diffuser Screen Velocities with Orifice Restrictor Plate

Changes to the S curve section were the next feature evaluated in the CFD model, per the ATR comments. With the proposed design of the slot baffles directing flow from north to south, it was not possible to fully remove the s curve as the most downstream slot still needed a flow path from the south side of the ladder to the count station exit on the north side. To minimize this distance, the S curve was shortened to having two 90 degree turns, instead of two 180 degree turns. Figure 35 shows flow patterns and velocities for the new S curve design at a forebay of 74.5 ft.

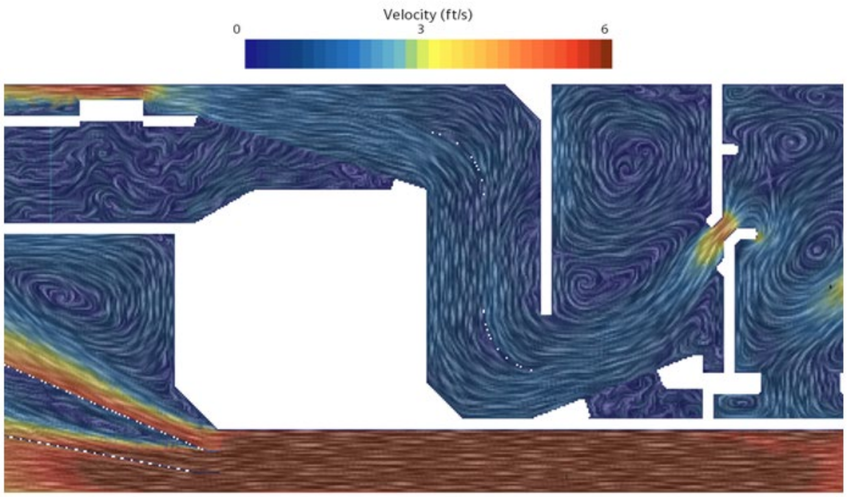


Figure 35 - New S curve Run, 74.5 ft FB Elevation

Shortening the curve and providing simplified flow vanes helped to evenly distribute the flow, while still maintaining some energy dissipation before the flow gets to the count station exit. Chamfered corners were also included on the exterior bends of the new S curve design to help reduce stagnation areas within the curve.

Another way to remove the S curve would be to mirror the ladder baffles, so that the jet from the final slot would project straight into the count station exit. Another possible benefit of this mirrored design would be to face the slot jets away from the diffusers, and it was thought it may have a positive impact on the recirculation in the furthest upstream pool. Figure 36 shows a plan view image of the velocities for the mirrored baffle design, cut horizontally through the slot baffles mid-depth, for a forebay of 74.5 ft.

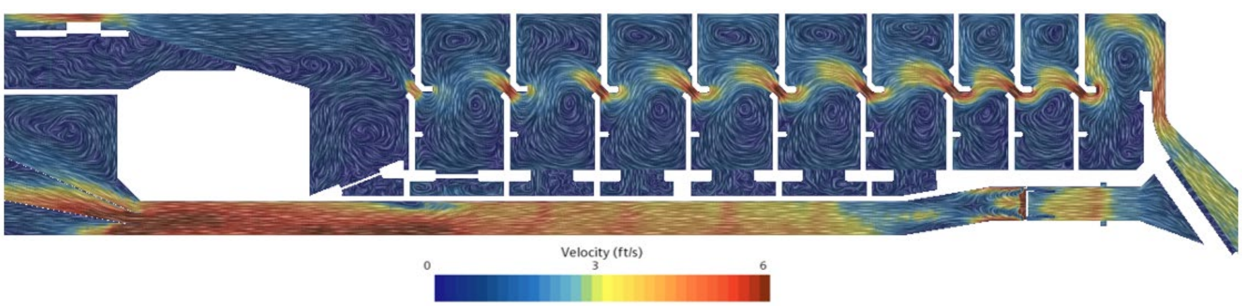


Figure 36 - Mirrored Baffle Velocities, 74.5 ft FB Elevation

The first area of focus was on the upstream pool. With the mirrored design, the flow still has to curl from the channel exit towards the first slot, but now also has to bend around the protruding baffle block. This causes a more tortuous path for the flow, and potentially higher velocities around the baffle section protruding upstream. This wasn't considered an improvement on the proposed design. The next focus area was the downstream slot flow projecting into the count station exit. This design removed the S curve completely, but also projected a high velocity jet straight towards the count station with little room for energy dissipation. This also created a large ineffective pool area in the south portion of the ladder, which was still required for hydraulic connection to AI Diffuser 2. Due to the high velocities entering the count station and the ineffective flow in the south portion of the ladder, this was also not deemed an improvement over the proposed design. These deficiencies are highlighted in Figure 37. As the interaction of the slot jets with the diffusers was not found to be an issue with the proposed design, it was not evaluated with the mirrored design.

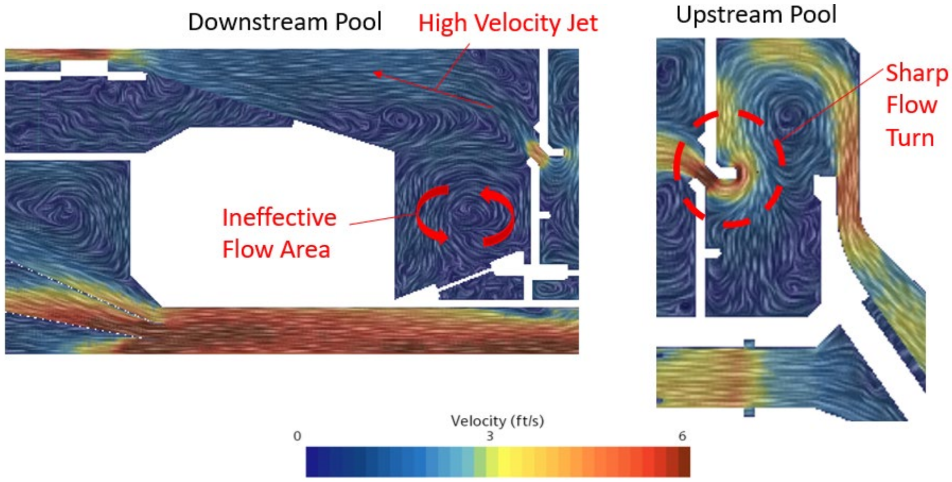


Figure 37 - Mirrored Baffle Deficiencies

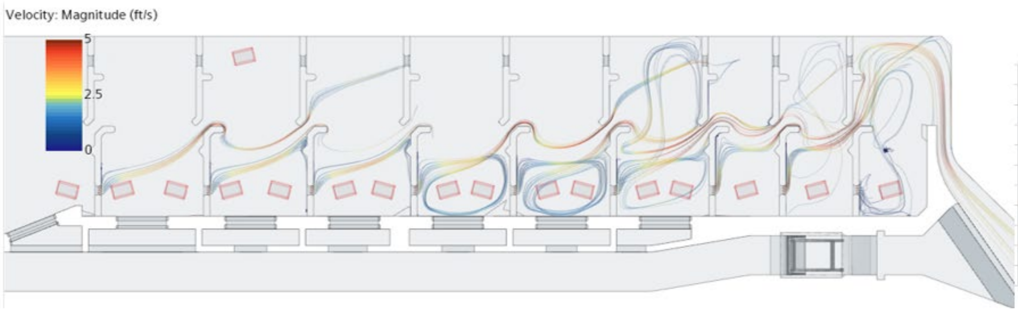
As a final comparison, the water surface elevations and associated head drops were checked for both proposed and mirrored designs. Table 14 shows the comparison in water surface elevations and pool head drops. The largest difference in head drop was less than 0.1 ft, which isn't considered to be significant. Overall, the mirrored design was not shown to be an improvement on the proposed design, and the proposed design was carried forward.

Table 14 - Proposed Vs. Mirrored WSE

Location	Proposed		Mirrored	
	WSE (ft)	Diff (ft)	WSE (ft)	Diff (ft)
FB	74.36		74.37	
Channel	74.31		74.32	
Pool 9	74.22		74.25	
Pool 8	73.56	0.66	73.54	0.70
Pool 7	72.83	0.73	72.90	0.64
Pool 6	72.20	0.63	72.26	0.64
Pool 5	71.51	0.69	71.59	0.67
Pool 4	70.81	0.70	70.92	0.67
Pool 3	70.13	0.68	70.27	0.65
Pool 2	69.50	0.63	69.67	0.60
Pool 1	68.93	0.57	69.07	0.59
Pool 0	68.61	0.32	68.66	0.41
CS	68.62		68.64	
AWS	68.47		68.33	
UMC	68.12		68.12	
Weir 67	67.99		67.99	

While testing the mirrored design against the proposed, higher velocities in the lamprey orifice were noted. These values were much higher than anticipated, and above the suggested guidance of 8 ft/sec average. Based on this observation, along with an ATR comment regarding the shaping of the orifices, an alternatives evaluation was conducted to try and reduce the velocities through the lamprey orifices.

To try and understand the cause of the high lamprey orifice velocities, streamlines were inserted into the high design forebay case of 76 ft, projected backwards from the lamprey orifices.



Part	Max Vel (ft/s)	Average Vel (ft/s)
Lamprey_9	6.75	6.44
Lamprey_8	11.05	10.38
Lamprey_7	10.98	10.44
Lamprey_6	10.49	9.98
Lamprey_5	10.44	9.76
Lamprey_4	10.25	9.65
Lamprey_3	10.12	9.52
Lamprey_2	9.57	8.93
Lamprey_1	10.07	9.46

Figure 38 - Lamprey Orifice Streamlines and Velocity Table – 76ft FB Elevation

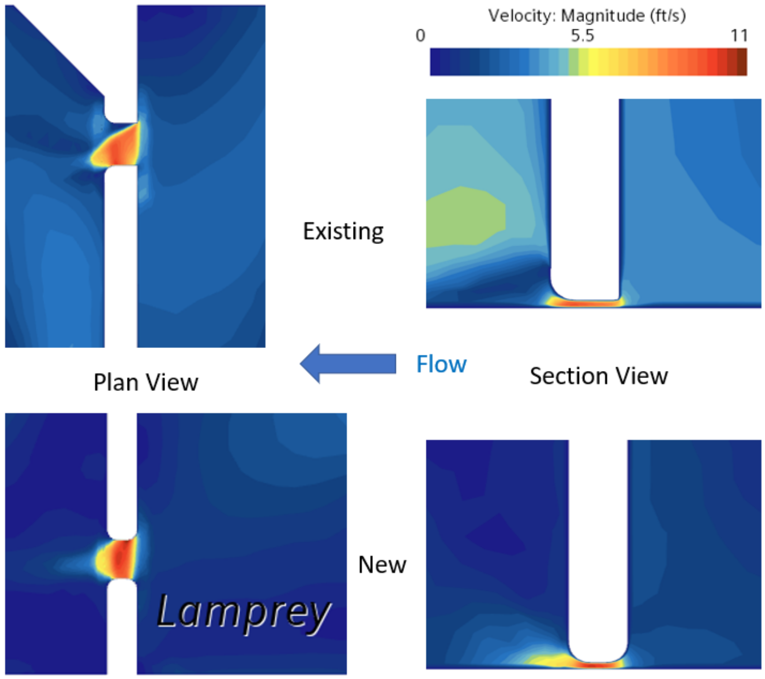
It showed that most of the flow through the lamprey orifices was being fed from the slot jets, at a lower elevation in the water column. To test if a different location for the orifice would result in lower velocities, the location of the lamprey orifice was moved to three new locations in the ladder: to the north of the large orifice, between the large orifice and the slots (middle), and to the south wall of the ladder. Average and maximum velocities were recorded for each lamprey orifice, on a plane bisecting the 1 ft weirs. Table 15 shows the results for each location, for a 76 ft forebay. Moving the lamprey orifice did not have the intended effect of lowering the velocities.

Table 15 - Lamprey Location Alternative Velocities

Upstream

Part	Proposed Location		South		North		Middle	
	Average Vel (ft/s)	Max Vel (ft/s)	Average Vel (ft/s)	Max Vel (ft/s)	Average Vel (ft/s)	Max Vel (ft/s)	Average Vel (ft/s)	Max Vel (ft/s)
Lamprey_1	9.46	10.07	9.22	9.72	8.52	9.00	8.16	8.68
Lamprey_2	8.93	9.57	9.86	10.32	8.63	9.08	9.11	9.52
Lamprey_3	9.52	10.12	9.62	10.26	9.01	9.42	10.25	10.91
Lamprey_4	9.65	10.25	10.62	11.22	9.30	9.93	10.32	10.98
Lamprey_5	9.76	10.44	10.52	11.13	10.35	10.86	11.17	11.77
Lamprey_6	9.98	10.49	11.28	12.13	10.42	10.90	11.10	11.57
Lamprey_7	10.44	10.98	11.37	11.91	9.50	9.98	10.95	12.33
Lamprey_8	10.38	11.05	10.32	10.91	10.65	11.13	11.46	12.23
Lamprey_9	6.44	6.75	6.34	6.86	10.89	11.54	8.72	9.48

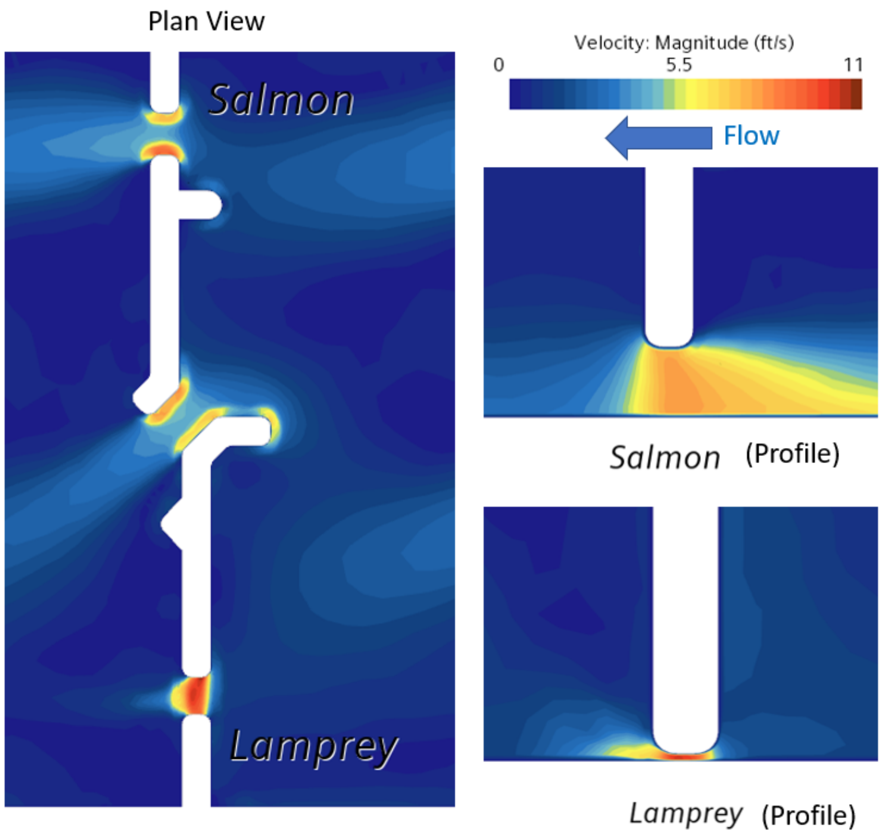
Reexamining the streamline results, it was noted that even though the slots were feeding the lamprey orifices, the flow into the orifices seemed to decelerate upstream before being entrained into the orifice. The acceleration to the higher velocity was localized to directly upstream of the orifice, which would be more related to the shaping of the orifice itself. To check the difference between the new design and the existing serpentine lamprey weirs, cross sections were cut through both models to look at flow patterns through the lamprey orifices, and average and maximum velocities were compared (Figure 39). A similar cut was done for all three passage routes for the proposed design (slot, large orifice, and lamprey orifice) to look for any differences between the routes, shown in Figure 40.



Location	Existing			
	Avg (ft/sec)	Max (ft/sec)	Drop (ft)	V est (ft/sec)
1	3.32	3.81	0.02	1.09
2	3.96	5.87	0.14	3.02
3	6.64	8.64	0.92	7.69
4	6.82	8.82	0.88	7.53
5	6.74	8.74	0.86	7.46
6	7.10	9.07	0.97	7.90
7	6.25	8.28	0.80	7.19
8	6.65	8.75	0.97	7.92
9	7.67	9.44	1.20	8.78

Location	New			
	Avg (ft/sec)	Max (ft/sec)	Drop (ft)	V est (ft/sec)
1	9.46	10.07	0.76	7.00
2	8.93	9.57	0.87	7.49
3	9.52	10.12	0.76	7.00
4	9.65	10.25	0.83	7.31
5	9.76	10.44	0.81	7.22
6	9.98	10.49	0.76	7.00
7	10.44	10.98	0.68	6.62
8	10.38	11.05	0.58	6.11
9	6.44	6.75	0.71	6.76

Figure 39 - Existing vs. Proposed Lamprey Velocities, 76 ft FB Elevation



Part	Average Vel (ft/s)	Max Vel (ft/s)
Lamprey_1	9.46	10.07
Lamprey_2	8.93	9.57
Lamprey_3	9.52	10.12
Lamprey_4	9.65	10.25
Lamprey_5	9.76	10.44
Lamprey_6	9.98	10.49
Lamprey_7	10.44	10.98
Lamprey_8	10.38	11.05
Lamprey_9	6.44	6.75
Orifice_1	7.77	9.92
Orifice_2	7.20	8.52
Orifice_3	7.63	8.94
Orifice_4	7.89	9.17
Orifice_5	8.21	9.64
Orifice_6	8.25	9.48
Orifice_7	8.37	9.90
Orifice_8	8.36	9.56
Orifice_9	7.43	9.79
Slot_1	6.42	7.78
Slot_2	5.75	7.01
Slot_3	6.23	7.65
Slot_4	6.73	8.49
Slot_5	6.96	8.61
Slot_6	7.11	8.76
Slot_7	7.09	8.51
Slot_8	7.19	8.79
Slot_9	7.20	8.80

Figure 40 - Proposed Slot and Orifice Velocities, 76 ft FB Elevation

Comparing the existing lamprey orifices to the proposed, even though there is a slight radius on the upstream shape it appears to be acting more like a sharp-edged design. Because of the circulation pattern with the serpentine baffles, it causes a flow separation on the north side of the orifice, which could be a good flow path for lamprey to move up through the orifice. The sharp-edged shaping would also be less efficient that the dual-radiused proposed shape, leading to lower flows and overall lower velocities. Comparing the proposed shaping for all three flow paths, even though the large orifice and the slots have a more flow-efficient shape, there appears to be large enough openings that a “free-stream” velocity profile occurs, with a lower velocity in the middle of the openings and an acceleration around the edges. To try and take advantage of these observations, multiple upstream orifice shapes for the lamprey orifices were evaluated in the CFD model: the initially proposed rounded shape, a 2-inch chamfer, and a sharp-edged design. Other geometries that were tested included installing one or two rows of bollards on the upstream side of the orifices and attaching a lamprey rest box to the downstream side of the orifice to act as flow control. These alternatives were all evaluated at the 95% non-exceedance design forebay elevation of 76 ft. The orifice shapes were evaluated in the original design case, as well as moved down to the south wall of the ladder. By moving to the south wall, this provides the lamprey a flat surface to move up.

Figure 41 shows the flow patterns and velocity profiles through each alternative shape, and Table 16 lists the average and maximum velocities.

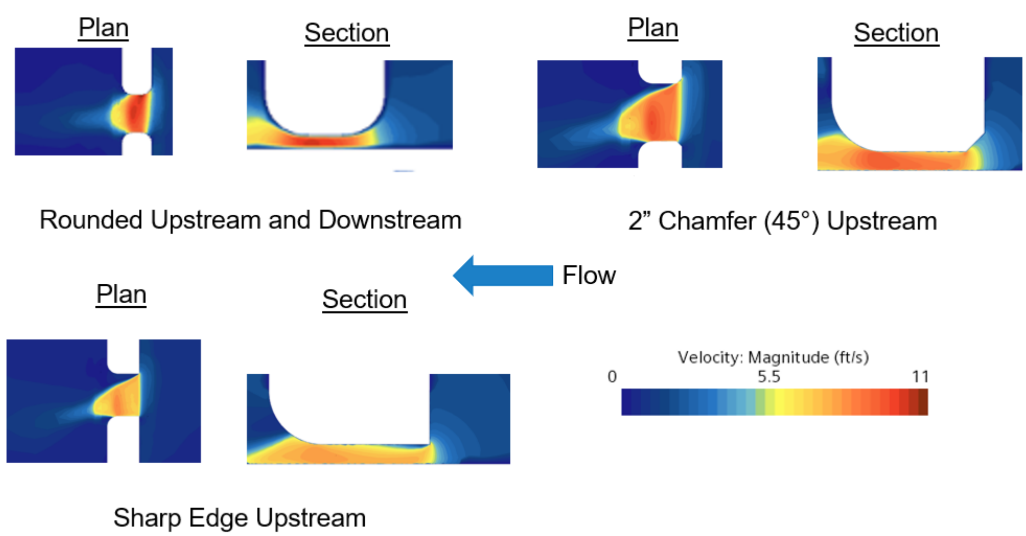


Figure 41 - Lamprey Shaping Velocity Scalar Cross Sections, 76 ft FB Elevation

Table 16 - Lamprey Shaping Velocities, 76 ft FB Elevation

Location:	Rounded (original)		Sharp Edge		Chamfer	
	Avg. Vel (ft/sec)	Max Vel (ft/sec)	Avg. Vel (ft/sec)	Max Vel (ft/sec)	Avg. Vel (ft/sec)	Max Vel (ft/sec)
Lamprey_1	9.46	10.07	5.61	6.95	5.83	6.72
Lamprey_2	8.93	9.57	5.60	7.64	7.75	9.06
Lamprey_3	9.52	10.12	5.87	8.08	7.55	9.15
Lamprey_4	9.65	10.25	5.85	8.80	7.47	8.90
Lamprey_5	9.76	10.44	5.92	7.86	7.61	8.85
Lamprey_6	9.98	10.49	5.98	8.21	7.76	9.09
Lamprey_7	10.44	10.98	5.80	9.28	7.56	9.37
Lamprey_8	10.38	11.05	5.63	9.28	7.34	9.37
Lamprey_9	6.44	6.75	4.08	5.02	4.91	5.52

Both the sharp-edged and chamfered shaping alternatives showed the desired flow separation on the upstream side of the orifice, which was reflected in the velocity values. It was more effective for the sharp-edged profile, which brought the average velocities down to near 5.8 ft/sec, whereas the chamfer design only reduced the average velocities to near 7.7 ft/sec. Both were noticeable improvements over the radiused design, which had average velocities between 9 and 10 ft/sec.

Moving the orifices to the south wall showed similar improvements, with slightly more efficient orifice flow due to lack of flow separation on the south wall side. Geometries from the south wall lamprey shaping runs are shown in Figure 42, and measured velocities are presented in Table 17.

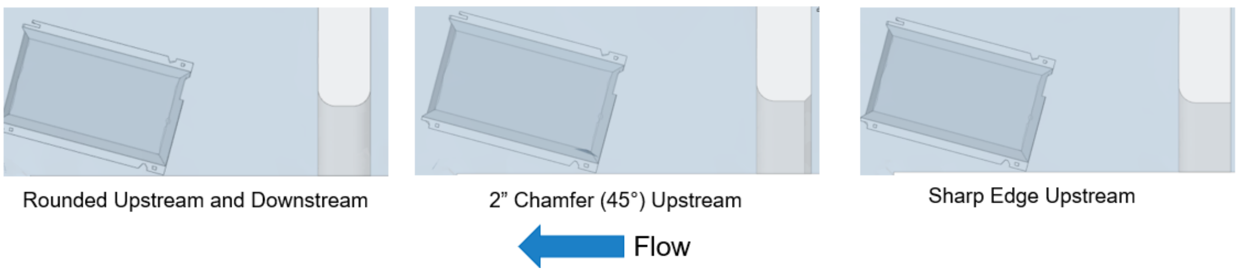


Figure 42 - South Wall Lamprey Orifice Shapes

Table 17 - South Wall Lamprey Orifice Velocities

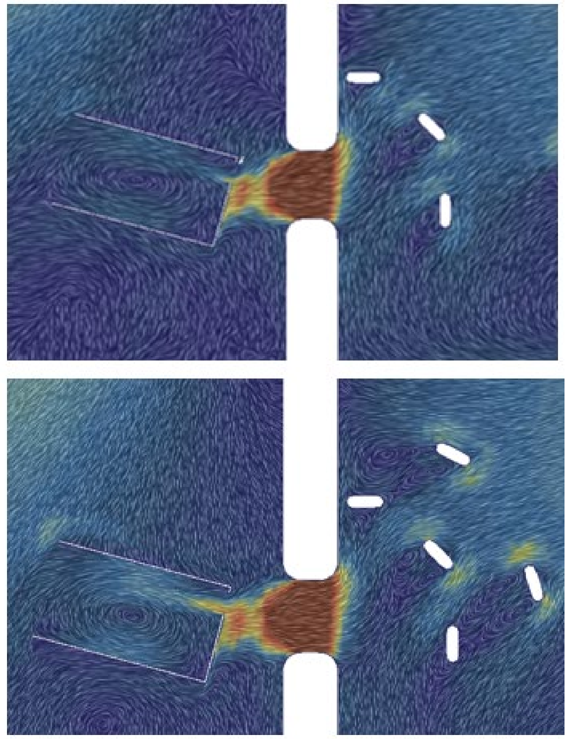
Location:	Rounded Edge - South		Sharp Edge - South		Chamfered Edge - South	
	Avg. Vel (ft/sec)	Max Vel (ft/sec)	Avg. Vel (ft/sec)	Max Vel (ft/sec)	Avg. Vel (ft/sec)	Max Vel (ft/sec)
Lamprey_1	8.78	9.35	5.48	7.00	7.20	8.36
Lamprey_2	9.89	10.52	5.61	7.43	7.33	8.78
Lamprey_3	10.04	10.72	5.88	7.88	7.69	9.27
Lamprey_4	10.45	11.10	6.14	8.20	8.02	9.69
Lamprey_5	10.80	11.46	6.30	8.29	8.20	9.80
Lamprey_6	10.97	11.62	6.66	8.64	8.29	9.96
Lamprey_7	11.18	11.88	6.55	8.71	8.51	10.22
Lamprey_8	10.89	11.68	6.42	8.66	8.42	10.27
Lamprey_9	6.98	7.49	4.45	5.38	5.83	6.78

After discussing the results with the FFDRWG at a meeting on 5Jan2023, the group came to the consensus that the sharp-edged orifice placed along the south wall was the alternative that should be carried forward. This was due to the reduction in velocities compared to the previous design, but also with the added benefit of potential passage along the south wall. It should be noted that some of the maximum velocities for this alternative were above the 8 ft/sec guidance, but the average velocities through the orifice were much lower (near 5-6 ft/sec). This alternative was carried forward to the final design.

The one and two rows of bollards, along with the attached lamprey rest box, were also evaluated in the CFD model. Horizontal velocity profiles and velocity measurements for the bollards are shown in Figure 43. The bollards influence the flow field upstream of the lamprey orifice, but because the higher velocities don't start until relatively close to the upstream opening, they didn't help to reduce velocities through the orifices.

One Row

Part	Avg (ft/sec)	Max (ft/sec)
Lamprey_1	8.72	9.17
Lamprey_2	9.39	9.83
Lamprey_3	9.70	10.34
Lamprey_4	9.93	10.50
Lamprey_5	10.00	10.46
Lamprey_6	9.98	10.54
Lamprey_7	10.07	10.57
Lamprey_8	9.97	10.45
Lamprey_9	6.21	6.47



Two Rows

Part	Avg (ft/sec)	Max (ft/sec)
Lamprey_1	8.58	8.94
Lamprey_2	9.16	9.70
Lamprey_3	9.67	10.26
Lamprey_4	9.88	10.41
Lamprey_5	9.89	10.41
Lamprey_6	9.94	10.58
Lamprey_7	10.07	10.56
Lamprey_8	9.89	10.41
Lamprey_9	6.23	6.47

Figure 43 - Bollard Alternative Velocities, 76 ft FB Elevation

The attached lamprey box output, with the velocity scalar and measured velocities, is shown in Figure 44. The velocities for this alternative were measured through the smaller upstream rest box opening. Even though this rest box effectively reduced the velocity and flow through the lamprey orifices, it induced a high shear flow pattern within the lamprey rest box. As this is different than the current rest box hydrodynamics, which appear to work well, changing the flow conditions within the rest boxed was not preferred and this alternative was not carried forward.

Location:	Rest Boxes	
	Avg. Vel (ft/sec)	Max Vel (ft/sec)
Lamprey_1	5.56	6.58
Lamprey_2	6.05	7.16
Lamprey_3	6.35	7.56
Lamprey_4	6.29	7.65
Lamprey_5	6.37	7.59
Lamprey_6	6.52	7.67
Lamprey_7	6.83	8.25
Lamprey_8	6.76	8.19
Lamprey_9	4.26	4.97

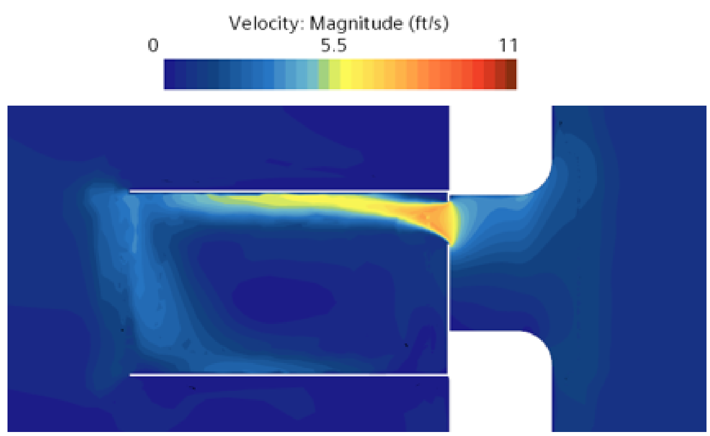


Figure 44 - Attached Lamprey Box Velocities

With the final selection of the lamprey orifice shape and location, the geometry was ready to be finalized and documented for the full range of forebay elevations and flow conditions. With the finalized geometry, the planned geometry for the 4 baffles containing the pit tag detectors was included. These shapes were originally provided by Pacific States, who is responsible for the final design of the pit tag detectors, but the finalized geometry wasn't ready to be included in the CFD model. The geometry that was included in the modeling was reviewed by Pacific States and deemed to be close to the final geometry. Velocity scalar scenes comparing the finalized orifice shapes to the pit tag detector shapes are shown in Figure 45 and Figure 46 for the lamprey orifice and large orifice, respectively. The pit tag detector shapes did not have a negative effect on the flow field or velocities and were carried forward for the final documentation runs.

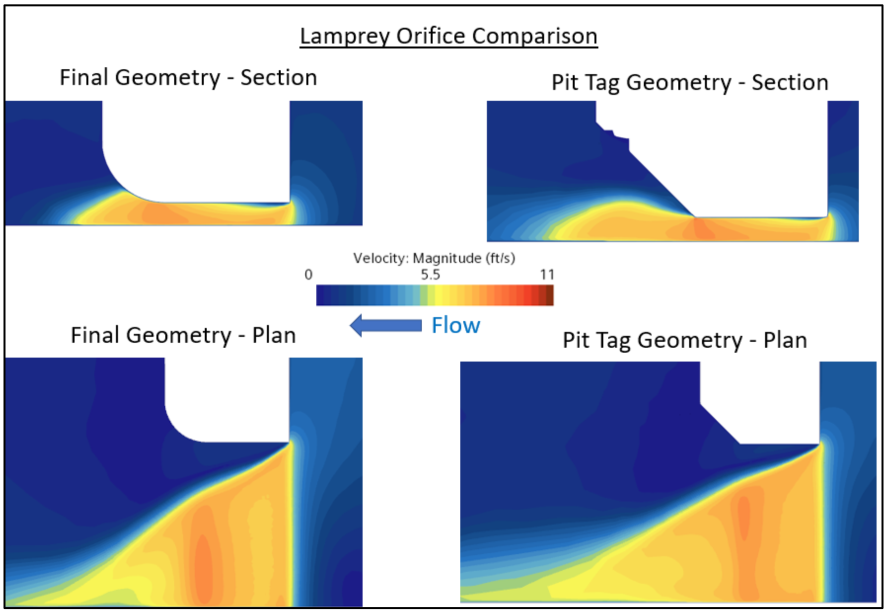


Figure 45 - Lamprey Pit Tag Comparison, 76 ft FB Elevation

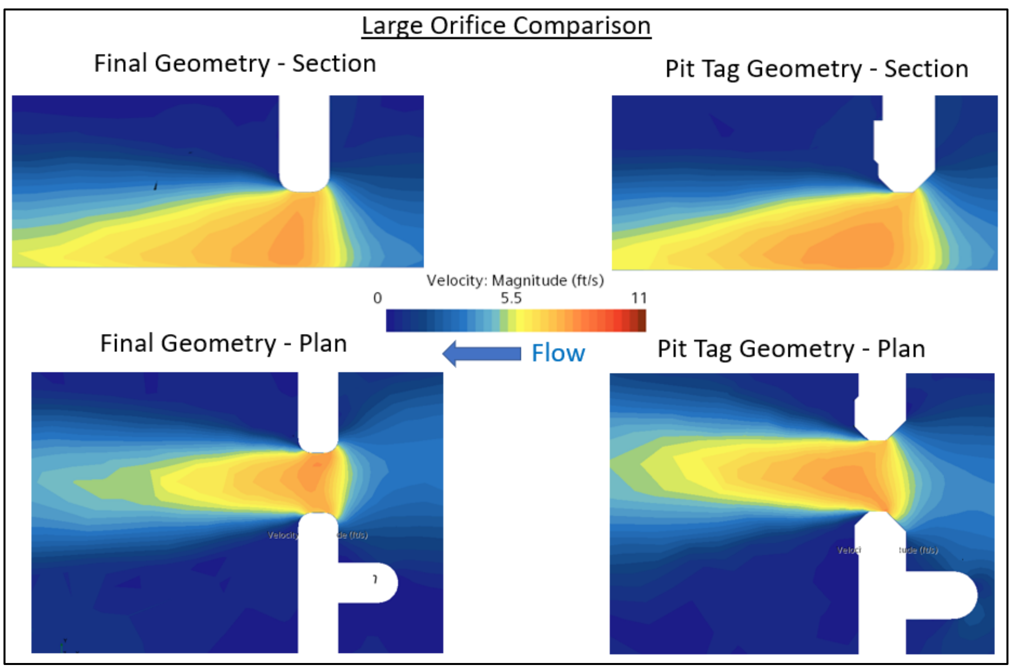


Figure 46 - Large Orifice Pit Tag Comparison, 76 ft FB Elevation

The main goal of the finalized documentation runs was to evaluate the final design under five flow conditions with the model running regularly (maximum, 95%, 50%, and 5% non-exceedance, and minimum forebay elevations), three flow conditions with the model in “shad mode” (95%, 50%, and 5% non-exceedance), and two additional runs looking at varying the turbulence closure model to verify that there are no unexpected hydraulic transient conditions within the ladder.

Representative cross sections through the slots and the lamprey orifice are shown for the 74.5 ft forebay in Figure 47. The main output from the ten final runs was the average and maximum velocities through each orifice and slot, the WSE’s and head drops for each pool within the exit control section and the flow rates at various places throughout the ladder. Tables with this output are presented in Table 18, Table 19, and Table 20 respectively. Average velocities for the design forebay elevations (76 ft to 72.7ft) are all within the design guidance of 8 ft/sec, except for the large orifice in baffle number 7 for Run 2 with a 76 ft forebay elevation. The average velocity through that orifice was 8.1 ft/sec, which is barely over the recommended guidance. Because of the “free-stream” velocity field through these orifices, it is not believed that this would be a hinderance to adult fish migrating upstream. All the head drops were within the 1 ft criteria except for the drop across baffle 5 (between pools 6 and 5) for Run 2, which was recorded as 1.04 ft. The flowrates were all consistent between equivalent forebay elevations, and this table is included in the results as more of an informational piece for operations if needed.

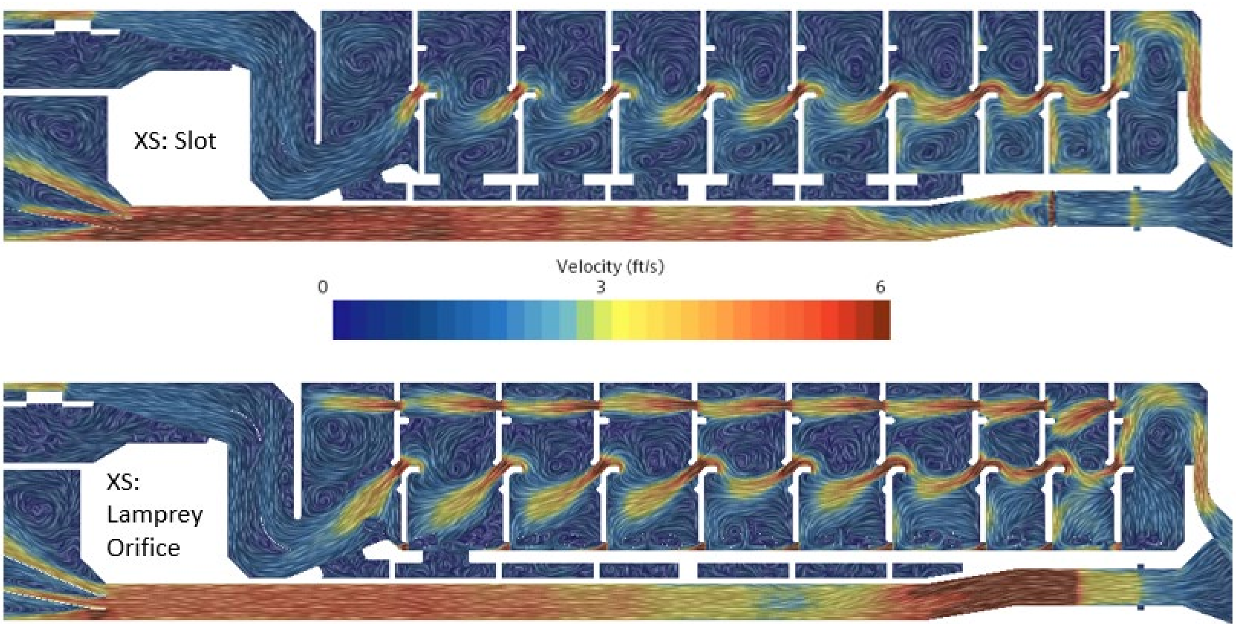


Figure 47 - Final Design Representative Cross Sections, 74.5 ft FB Elevation

Table 18 - Final Geometry Opening Velocities

Run	1		2		3		4		5		6		7		8		9		10	
FB El. (ft)	**77**		**76**		**74.5**		**72.7**		**70**		**76**		**74.5**		**72.7**		**74.5**		**74.5**	
Location	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)	Avg (fps)	Max (fps)
Lamprey_1	6.0	7.9	5.6	7.3	5.1	6.5	4.6	5.8	3.3	4.1	5.1	6.7	4.5	5.7	3.9	4.9	4.2	7.7	4.4	6.1
Lamprey_2	6.2	8.3	5.8	7.8	5.1	6.8	4.4	5.9	3.0	3.8	5.5	7.3	4.8	6.4	4.2	5.5	4.8	7.6	5.4	6.5
Lamprey_3	6.7	8.3	6.2	7.9	5.7	7.4	4.8	6.2	3.0	3.8	6.2	7.9	5.4	6.9	4.5	5.8	5.7	8.4	5.6	7.4
Lamprey_4	7.3	8.8	6.7	8.2	5.9	7.5	5.0	6.5	3.0	3.8	6.6	8.1	5.8	7.3	4.9	6.3	5.8	8.1	6.8	8.0
Lamprey_5	7.4	8.9	6.9	8.3	5.9	7.6	4.9	6.3	3.0	3.7	6.8	8.3	5.8	7.3	4.9	6.2	6.6	9.2	6.2	7.9
Lamprey_6	7.5	9.4	6.9	8.7	6.0	7.7	4.7	6.1	2.9	3.4	7.0	8.6	6.0	7.6	4.6	6.0	6.6	8.5	6.6	8.5
Lamprey_7	7.0	9.3	6.5	8.8	5.8	7.7	4.4	6.0	2.6	3.5	6.5	8.7	5.6	7.6	4.4	5.9	6.4	10.5	5.5	8.0
Lamprey_8	7.3	9.6	6.7	9.1	5.9	8.1	4.4	6.2	2.6	3.5	6.7	9.0	5.8	8.0	4.3	6.2	5.2	8.0	5.7	7.2
Lamprey_9	4.8	6.1	5.2	6.3	4.6	5.7	3.5	4.1	2.3	2.7	5.2	6.3	4.9	5.8	3.5	4.0	3.9	6.0	3.4	4.5
Orifice_1	7.7	9.6	7.1	8.7	6.3	8.1	5.7	7.1	3.9	5.0	6.6	8.2	5.7	7.3	4.8	6.3	4.8	7.7	6.3	7.7
Orifice_2	8.0	8.6	7.5	8.1	6.7	7.2	5.8	6.2	3.5	3.8	7.1	7.6	6.2	6.7	5.4	5.7	6.3	8.2	6.5	7.8
Orifice_3	7.5	10.1	7.0	8.5	6.4	8.0	5.6	6.7	3.3	4.1	7.0	7.9	6.2	8.0	5.3	6.5	5.8	9.3	6.3	8.4
Orifice_4	8.0	9.1	7.6	8.4	6.7	7.7	5.7	6.3	3.3	3.7	7.4	8.3	6.6	7.3	5.5	6.1	6.4	8.3	6.3	8.1
Orifice_5	7.8	9.1	7.6	8.8	6.9	7.8	5.7	6.2	3.2	3.6	7.5	8.8	6.8	7.4	5.5	6.0	6.4	8.5	6.7	7.9
Orifice_6	7.7	8.8	7.6	8.8	6.8	7.7	5.6	6.1	3.0	3.3	7.2	8.5	6.8	7.6	5.6	6.2	7.4	9.9	6.1	7.0
Orifice_7	8.5	10.0	8.1	9.5	7.6	8.8	6.1	6.9	3.5	4.0	8.0	9.5	7.6	8.7	6.0	6.7	7.5	10.1	6.2	7.8
Orifice_8	8.3	9.5	7.9	9.0	7.4	8.3	5.7	6.4	3.6	4.0	7.8	9.0	7.4	8.4	5.7	6.3	7.9	11.9	7.4	9.2
Orifice_9	7.9	10.4	7.7	10.2	7.1	9.2	5.8	7.3	3.6	4.2	7.7	10.1	7.0	8.8	5.8	7.2	7.2	9.5	8.0	10.7
Slot_1	6.1	7.6	5.6	6.9	5.1	6.1	4.7	5.6	3.1	3.9	5.1	6.4	4.4	5.4	3.8	4.6	5.5	7.3	5.4	6.5
Slot_2	6.6	8.0	6.1	7.4	5.4	6.6	4.8	5.6	3.1	3.7	5.8	7.1	5.1	6.1	4.4	5.2	5.7	8.2	5.9	7.1
Slot_3	7.0	8.6	6.5	8.0	5.9	7.1	5.2	6.2	3.2	3.8	6.3	7.7	5.6	6.7	4.9	5.8	6.1	8.6	6.8	7.8
Slot_4	7.4	9.1	6.8	8.4	6.1	7.5	5.2	6.3	3.2	3.8	6.7	8.2	5.9	7.2	5.0	6.0	6.4	8.7	6.9	8.4
Slot_5	7.6	9.2	7.0	8.6	6.3	7.5	5.2	6.3	3.1	3.7	7.0	8.6	6.1	7.4	5.1	6.2	6.3	8.7	6.9	8.3
Slot_6	7.7	9.2	7.2	8.6	6.4	8.0	5.2	6.3	3.0	3.8	7.1	8.6	6.3	7.7	5.1	6.2	6.2	8.6	7.2	9.3
Slot_7	7.6	9.4	7.1	8.6	6.2	7.6	4.8	6.0	2.8	3.5	7.0	8.5	6.2	7.5	4.8	6.0	6.2	9.1	7.3	10.5
Slot_8	7.7	9.3	7.2	8.9	6.4	7.8	5.1	6.4	3.0	3.5	7.2	8.9	6.3	7.8	5.0	6.4	5.8	9.0	7.2	8.9
Slot_9	7.2	8.6	7.1	8.5	6.3	7.7	5.1	6.3	2.9	3.7	7.0	8.4	6.3	7.6	5.0	6.2	6.0	7.7	6.7	8.1

Table 19 - Final Geometry WSE's and Pool Drops

Run	1		2		3		4		5		6		7		8		9		10	
FB El. (ft)	**77**		**76**		**74.5**		**72.7**		**70**		**76**		**74.5**		**72.7**		**74.5**		**74.5**	
Location	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop	WSE	Drop
Weir 67	67.86		67.88		67.85		67.85		67.90		68.40		68.32		68.35		67.84		67.86	
UMTC	67.99		67.96		67.95		67.93		67.90		68.39		68.39		68.37		68.04		67.99	
Intake Channel	76.74		75.74		74.24		72.43		69.76		75.75		74.24		72.44		74.26		76.74	
FB	76.61		75.74		74.19		72.30		69.63		75.74		74.11		72.31		74.10		76.61	
Count	68.49		68.40		68.40		68.24		68.06		68.81		68.74		68.59		68.41		68.49	
AWS	68.40		68.27		68.04		67.78		67.64		68.70		68.71		68.31		67.62		68.40	
10	76.54		75.60		74.14		72.38		69.65		75.58		74.14		72.39		74.11		76.54	
9	75.68	0.85	74.71	0.89	73.40	0.74	71.87	0.51	69.46	0.20	74.81	0.77	73.40	0.74	71.88	0.51	73.27	0.84	75.68	0.85
8	74.70	0.98	73.84	0.87	72.70	0.70	71.44	0.43	69.35	0.11	73.87	0.93	72.70	0.71	71.46	0.42	72.61	0.66	74.70	0.98
7	73.81	0.90	73.04	0.80	71.99	0.71	70.96	0.48	69.13	0.23	73.09	0.79	72.08	0.62	70.99	0.47	71.74	0.87	73.81	0.90
6	72.88	0.93	72.25	0.79	71.48	0.51	70.50	0.46	69.04	0.09	72.17	0.92	71.41	0.67	70.53	0.46	71.29	0.44	72.88	0.93
5	71.72	1.16	71.21	1.04	70.57	0.91	69.97	0.52	68.77	0.27	71.28	0.89	70.64	0.77	70.04	0.49	70.44	0.86	71.72	1.16
4	70.94	0.78	70.43	0.78	70.11	0.46	69.54	0.43	68.68	0.09	70.65	0.63	70.10	0.54	69.65	0.39	69.95	0.49	70.94	0.78
3	70.02	0.92	69.74	0.69	69.36	0.75	69.16	0.39	68.54	0.14	69.89	0.76	69.60	0.51	69.32	0.33	69.41	0.53	70.02	0.92
2	69.23	0.79	69.07	0.67	68.86	0.50	68.69	0.46	68.32	0.22	69.27	0.62	69.08	0.52	68.92	0.40	68.82	0.59	69.23	0.79
1	68.60	0.63	68.51	0.55	68.41	0.45	68.39	0.31	68.08	0.24	68.74	0.53	68.69	0.40	68.74	0.18	68.52	0.31	68.60	0.63

Table 20 - Final Geometry Flowrates

Run Type	Run	FB El. (ft)	Inflow (cfs)	Weir 67 Flow (cfs)	UMTC Flow (cfs)	Control Section Flow (cfs)	Count Sta flow (cfs)	Bypass Flow (cfs)	AWS Inflow (cfs)	AWS BleedOff (cfs)
1 ft drop	1	77	246.8	195.9	50.8	165.1	38.6	37.7	81.7	88.9
	2	76	232.7	182.6	50.5	145.6	35.2	33.8	87.1	76.6
	3	74.5	225.1	175.7	50.3	116.7	31.1	30.5	108.4	55.1
	4	72.7	203.7	154.0	49.1	81.1	28.2	27.2	122.6	25.8
	5	70	167.9	121.3	47.1	37.1	18.3	16.5	130.8	2.3
1.5 ft drop	6	76	230.4	161.9	67.2	145.0	30.4	30.4	85.4	84.3
	7	74.5	220.3	153.1	67.4	115.7	26.1	24.7	104.6	64.9
	8	72.7	196.7	129.6	66.7	80.3	22.7	22.7	116.4	34.9
Turbulence	9	74.5	218.3	160.2	58.6	111.3	30.4	21.2	107.0	59.7
	10	74.5	229.1	176.2	62.3	123.2	34.2	30.6	105.9	58.5

When evaluating the results for the simulations utilizing the LES and DES turbulence models, which were originally run to check for hydraulic surging or transient phenomena per an ATR comment, it was noted that the velocities and flow patterns did change with time. Figure 48 shows velocities projected on a horizontal cross section halfway through the depth of the ladder flow 50 seconds apart in run time. Note the slight change in direction of the flow from the slots. This didn't appear to be any major transient phenomena, but more like what would be expected in the prototype where slight time-varied flow patterns would materialize. These time-varied flow patterns did not materialize in the DES model, only in the LES model. Figure 49 shows the same velocity scalar scene for the DES run that doesn't change between time steps.

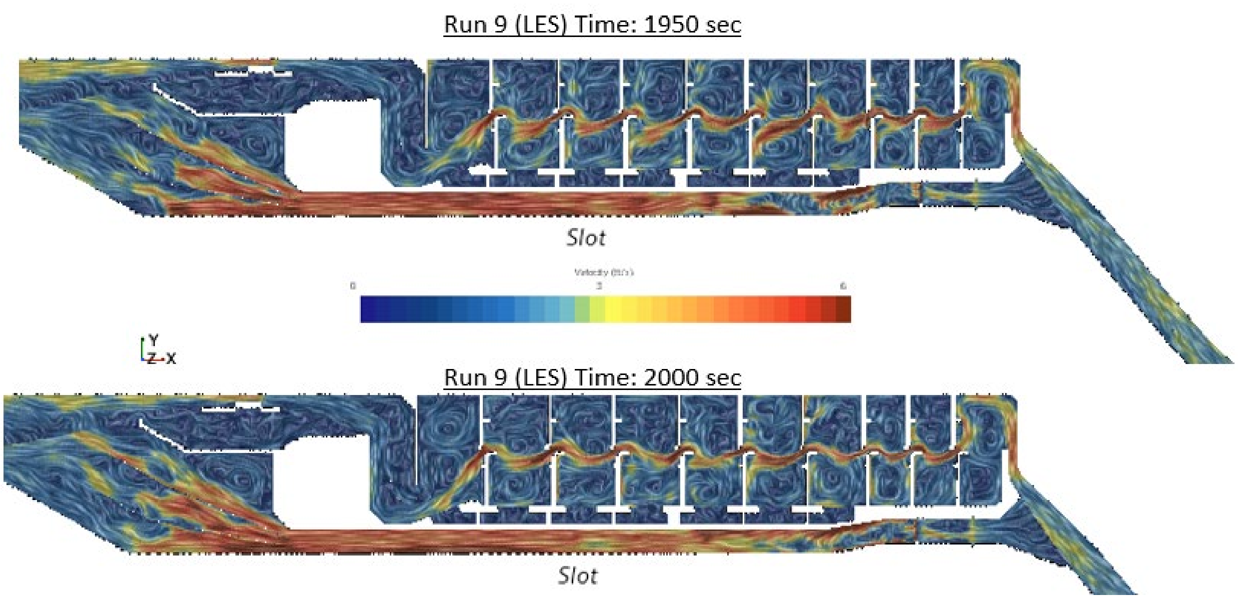


Figure 48 - Run 9 LES Velocity Scalar Scene

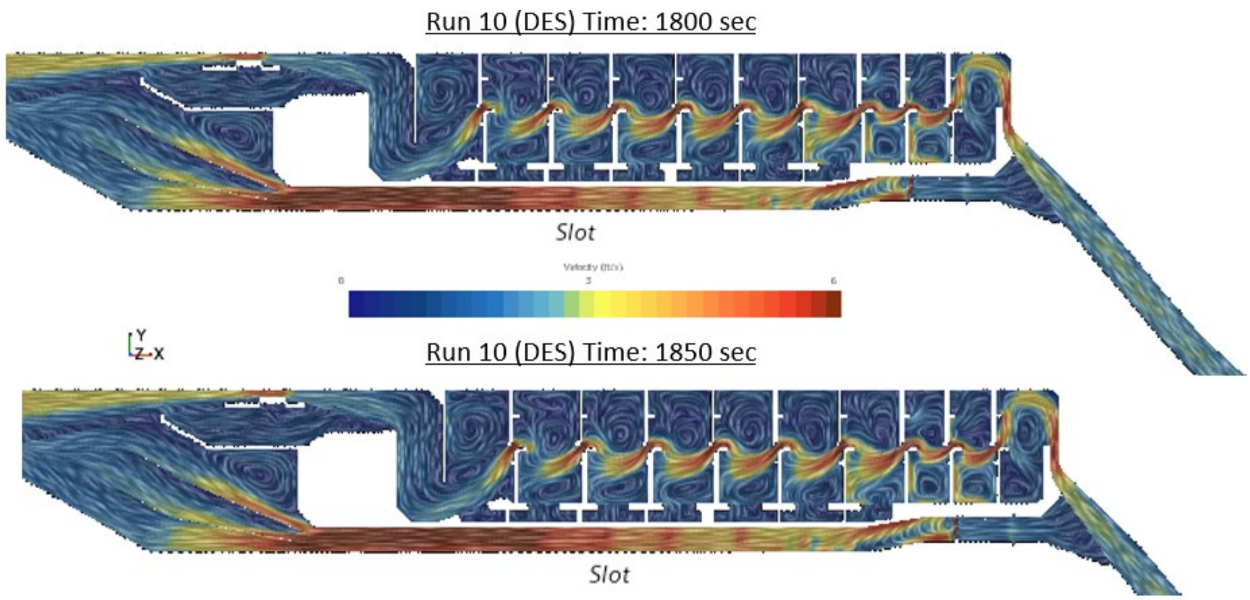


Figure 49 - Run 10 DES Velocity Scalar Scene

To check and make sure that these phenomena from the LES model weren't due to large water level surges, the water level in each pool was statistically analyzed over the duration of the run. The water level was checked every 50 seconds for the 2000 sec run, but the first 500 seconds of data wasn't analyzed as the solution hadn't run to a quasi-steady state until that point. A graph of the water levels in each pool over time is shown in Figure 50, and the statistical summary is presented in Table 21.

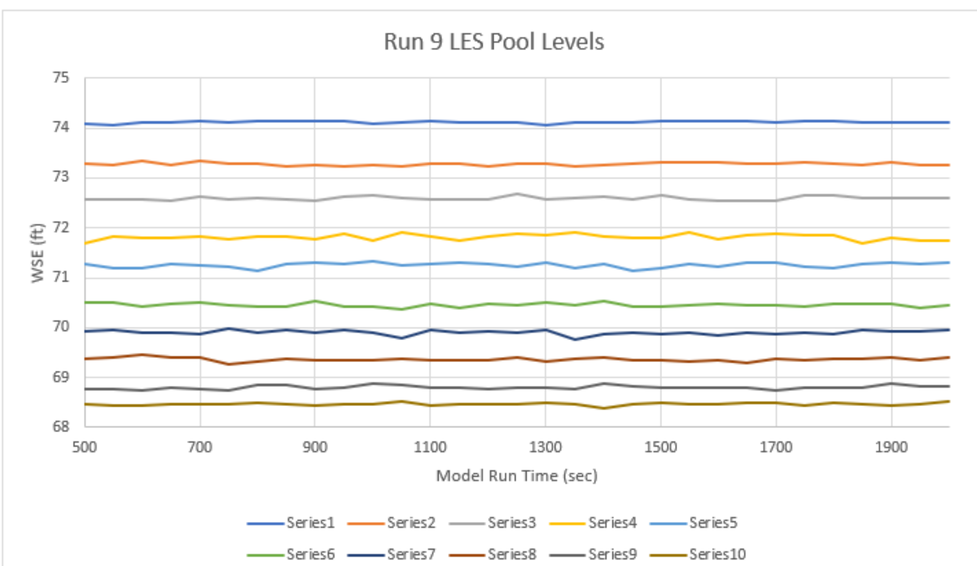


Figure 50 - Run 9 WSE Over Run Time

Table 21 - Run 9 WSE Statistics

Location	Min (ft)	Avg (ft)	Max (ft)	St Dev (ft)
Weir 67	67.80	67.84	67.89	0.02
UMTC	68.04	68.07	68.13	0.02
Intake Channel	74.23	74.26	74.29	0.01
FB	74.10	74.10	74.11	0.00
Count	68.38	68.42	68.46	0.02
AWS	67.38	67.68	68.02	0.16
10	74.07	74.12	74.16	0.02
9	73.24	73.28	73.35	0.03
8	72.54	72.60	72.68	0.04
7	71.68	71.81	71.91	0.06
6	71.13	71.25	71.32	0.05
5	70.36	70.45	70.54	0.04
4	69.75	69.90	69.99	0.05
3	69.25	69.36	69.45	0.04
2	68.73	68.80	68.88	0.04
1	68.39	68.47	68.52	0.03

As can be seen from the statistics, the WSE for each pool didn't vary much over the duration of the run. This helps to show that there isn't any major surging in the pools. As a final check on the LES model results, the existing serpentine section model was run with the LES turbulence model utilized. The same scalar scene of pool velocities was output and compared for the model, shown in Figure 51. A graph of the pool WSE over time is shown in Figure 52, and the statistical summary is shown in Table 22.

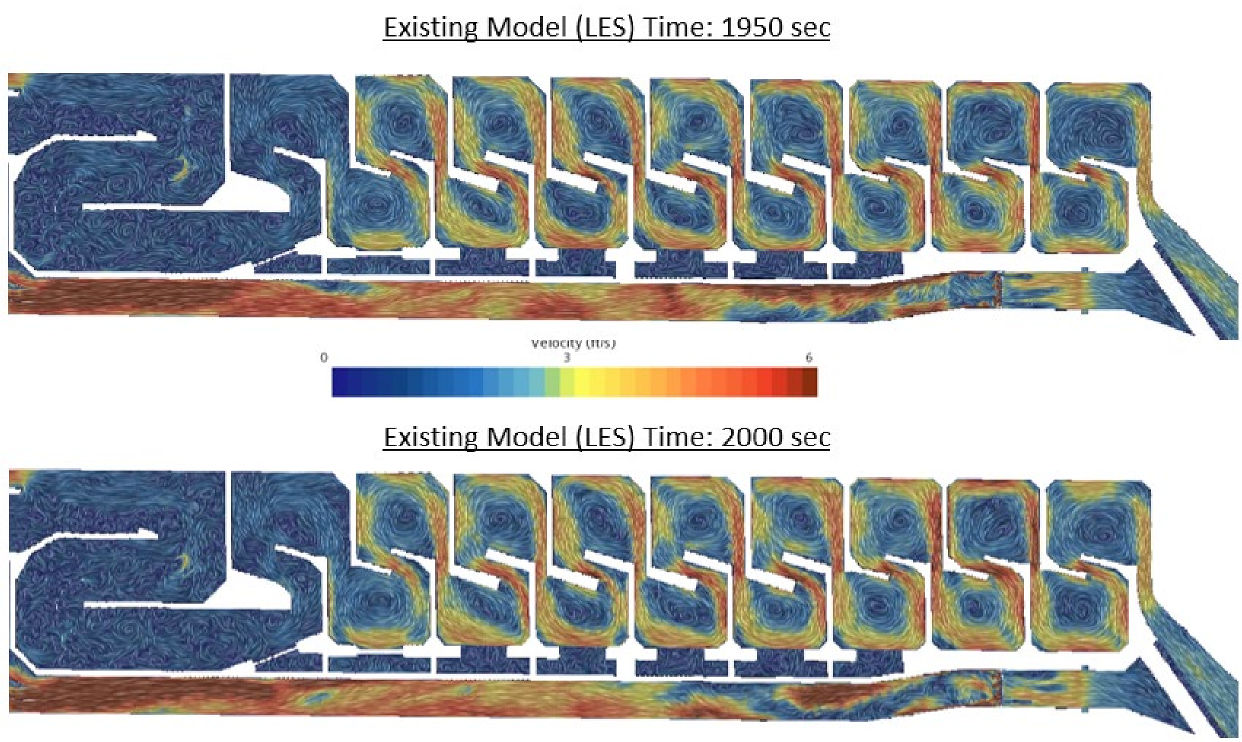


Figure 51 - Existing Model LES Velocity Scalar Scene

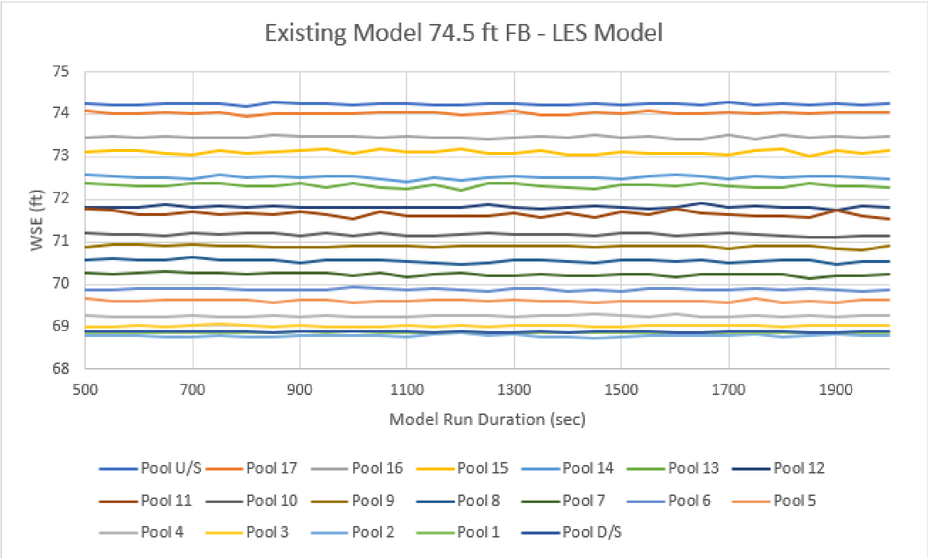


Figure 52 - Existing Model LES WSE Over Time

Table 22 - Existing LES Model WSE Statistics

Location	Min (ft)	Avg (ft)	Max (ft)	Std Dev (ft)
Pool U/S	74.19	74.23	74.27	0.02
Pool 17	73.96	74.02	74.08	0.03
Pool 16	73.40	73.46	73.51	0.03
Pool 15	73.00	73.11	73.18	0.05
Pool 14	72.40	72.51	72.57	0.04
Pool 13	72.21	72.32	72.39	0.05
Pool 12	71.74	71.82	71.92	0.03
Pool 11	71.54	71.65	71.78	0.06
Pool 10	71.11	71.17	71.22	0.03
Pool 9	70.80	70.89	70.95	0.03
Pool 8	70.48	70.55	70.62	0.03
Pool 7	70.12	70.23	70.29	0.04
Pool 6	69.83	69.88	69.93	0.02
Pool 5	69.56	69.61	69.66	0.03
Pool 4	69.22	69.25	69.29	0.02
Pool 3	69.00	69.02	69.06	0.02
Pool 2	68.74	68.79	68.86	0.03
Pool 1	68.85	68.87	68.89	0.01
Pool D/S	68.86	68.89	68.90	0.01

The existing serpentine section model with the LES Turbulence model showed a very similar time-varied velocity profile as that of Run 9, and the WSE elevations varied near the same magnitude as the Run 9 results. This helps to give confidence in the proposed slot baffle design not producing surging or transient hydraulic flow characteristics, and that the LES Turbulence model just produces more time-varied results than the K Epsilon Turbulence model. The final design geometry proved to meet the design criteria and will be carried forward to Plans and Specifications. Finalized velocity scalar scenes for the final geometry cut on horizontal cross sections through the lamprey orifice, the large orifice, and halfway down the depth of flow will be provided at the end of this report for documentation.

Conclusions

The 90% design for the Washington Shore Exist Control Section project built on the 60% design by validating prototype operations of the AWS Tainter valve under two flow conditions, evaluating interactions of the slot jets with the diffuser gratings, modifying the AI Diffuser 1 orifice plate to restrict flow similar to AI Diffuser 2, modifying the S curve section to minimize the travel distance for fish, conducting an extensive alternatives analysis of the shaping and location of the lamprey orifices to minimize velocities, checking a mirrored baffle design for any improvements to fish passage hydraulics, and checking the turbulence model of the CFD runs by running both a LES and DES model of the final geometry.

The prototype testing of the AWS Tainter valve resulted in an updated rating curve for the valve; the previous understand of the valve operations had it limited to a minimum of 1 ft open. By measuring the opening of the valve in the prototype under high forebay conditions, it was found that the valve closes much more when a lower WSE is required in the AWS channel. All runs for the 90% design were completed with the updated valve rating curve, and the existing conditions model was used as a comparison to the proposed design output.

There were no negative impacts of the slot jets interacting with the diffuser gratings, but a high flow from the ladder to the AWS channel was noted for AI Diffuser 1. This was found to be due to the large orifice opening on the AWS channel side of the diffuser, which resulted in more flow leaving the ladder in this location. To redistribute the flow, a restrictor plate was evaluated in the CFD model that was the same open area as the orifice for AI Diffuser 2, and this restrictor plate was added to the final design. 1 ft tall plates were also added to the inverts of both add-in diffusers, to provide additional lamprey passage areas.

The S curve was changed from two full 180-degree bends to a simpler design utilizing two 90-degree turns. This produced a much cleaner flow profile through the curve area and minimized the passage distance for fish. This new design also requires new curved flow vanes, two additional chamfers at the exterior corners of the bend and filling in of the removed S curve area. This design was added to the final design.

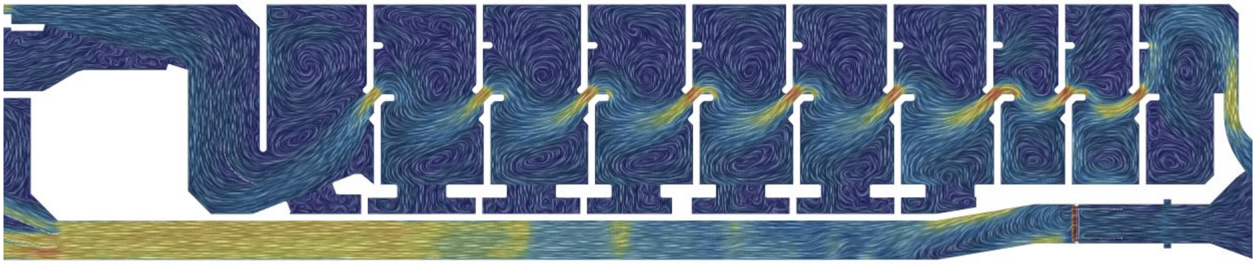
When evaluating the results from the 60% design, high velocities in the lamprey orifices were noted. To try and reduce these velocities, an extensive alternatives analysis was completed that involved changing the shape and size of the lamprey orifice within the ladder. The final path forward was a sharp-edged upstream orifice while maintaining the curved downstream shaping from the previous design, and it was moved to the south wall of the fish ladder. Preliminary pit tag detector shaping for the large and lamprey orifices was also included in the final geometry and found to conform to the design criteria.

To test for any positive flow effects of mirroring the baffles and projecting the slot jets from south to north, multiple runs were completed with this configuration. It was determined that this design would lead to less ideal hydraulics within the furthest upstream pool, while also projecting a higher velocity jet into the count station and leaving an ineffective pool area in the most downstream pool. The mirrored design was not carried forward.

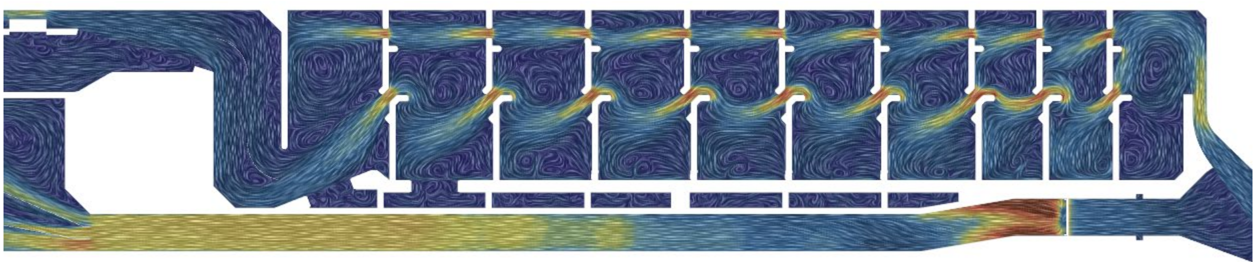
The final design, including all the changes outlined above, was documented for the full range of forebay conditions, both regular and “shad mode” flow settings, and tested using both LES and DES turbulence models. The final geometry met the design guidance and criteria for its intended design heads, but some changing in flow patterns were noted for the LES turbulence run. To check and make sure this wasn't due to surging, water levels were analyzed over the duration of the CFD run to show that there wasn't much change in water level. The existing serpentine CFD model was also run with the LES turbulence model, which showed similar time-varied flow changes and water level fluctuations, which gave confidence in the results for the proposed design. Overall, the final geometry met the necessary requirements and is being progressed to the Plans and Specifications phase.

Sub-Appendix – Final Geometry Velocity Scalar Scenes

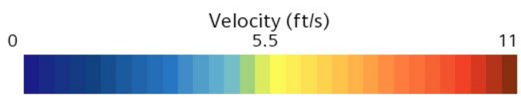
Run 1: Fb 77 ft, 1 ft head drop @ weir 67

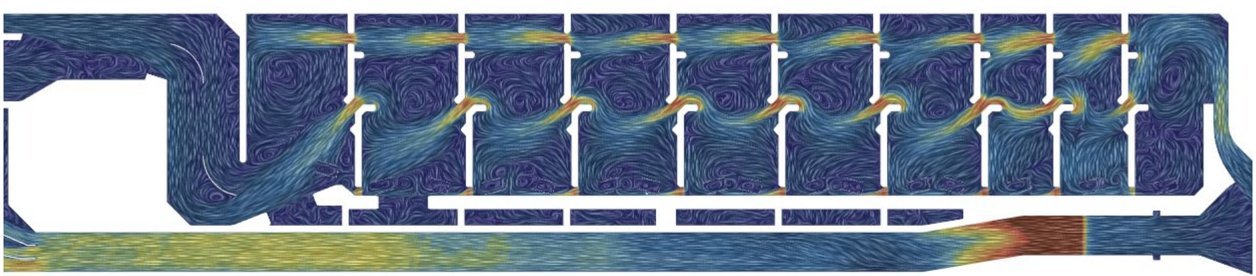


Slot

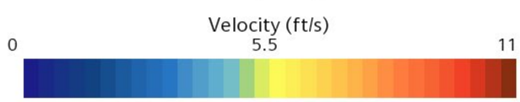


Salmon

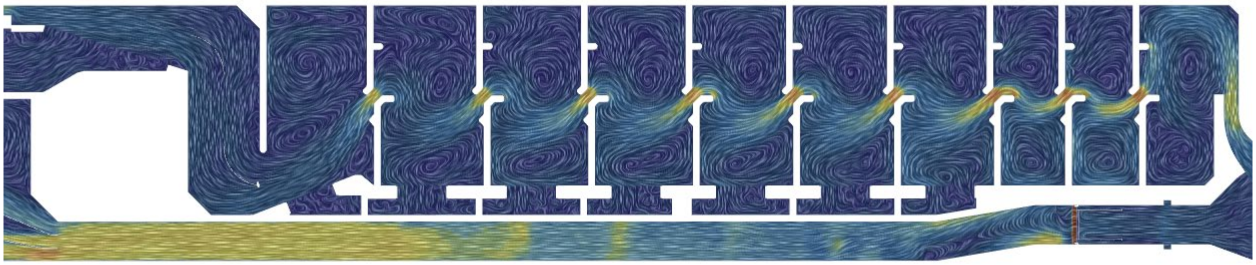




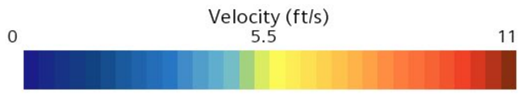
Lamprey

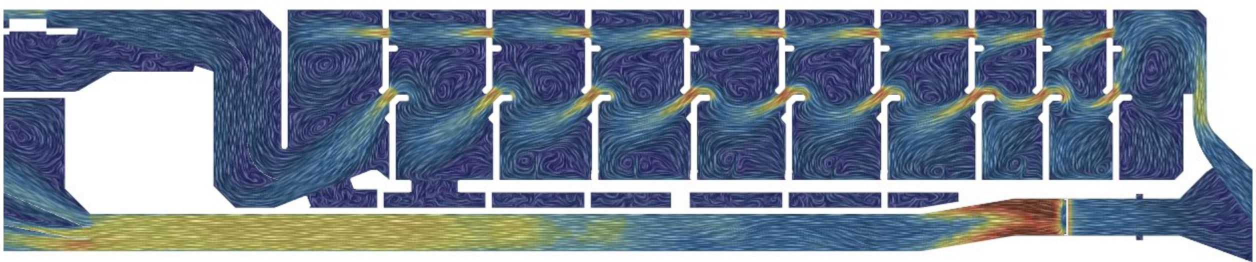


Run 2: Fb 76 ft, 1 ft head drop @ weir 67

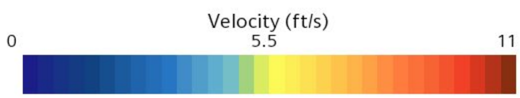


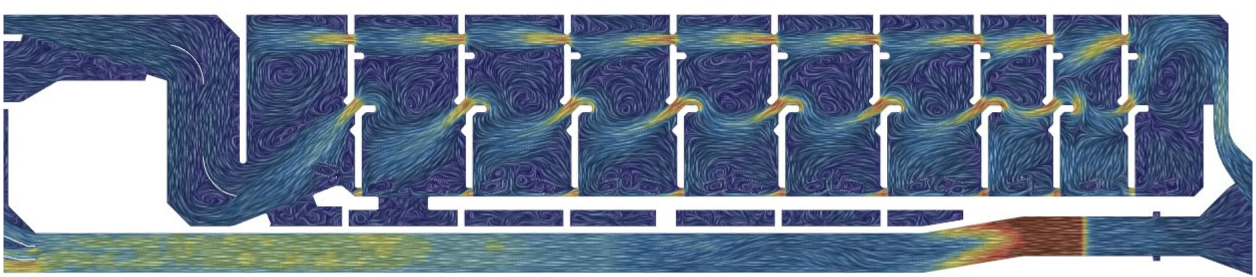
Slot



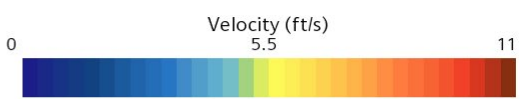


Salmon

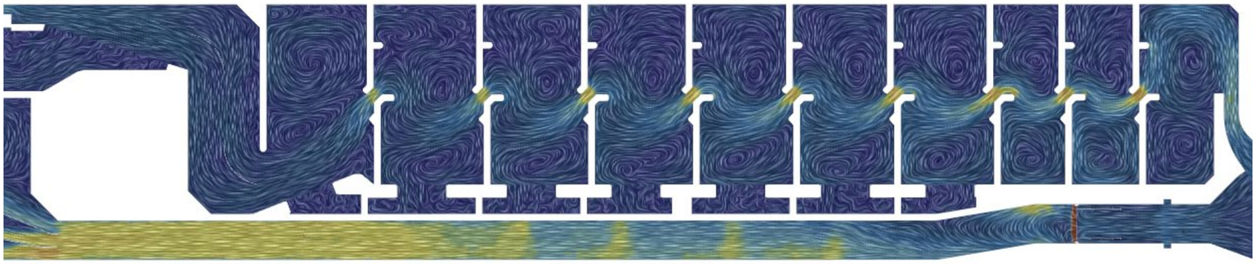




Lamprey



Run 3: Fb 74.5 ft, 1 ft head drop @ weir 67



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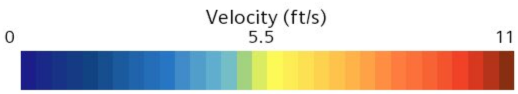
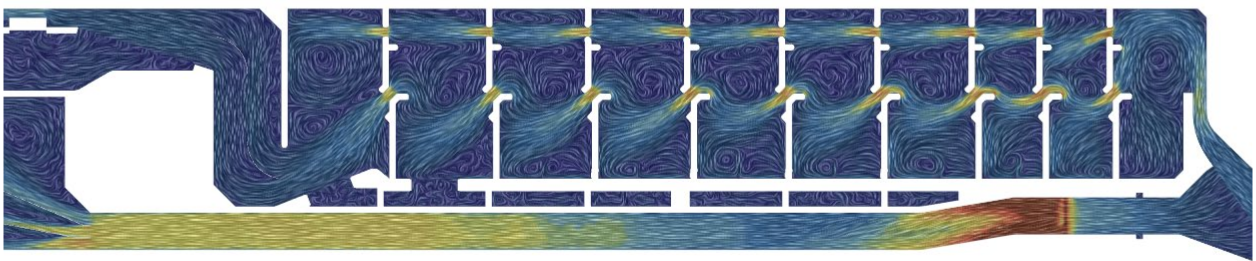
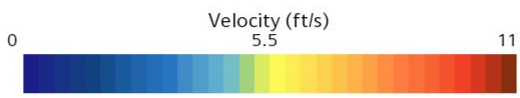
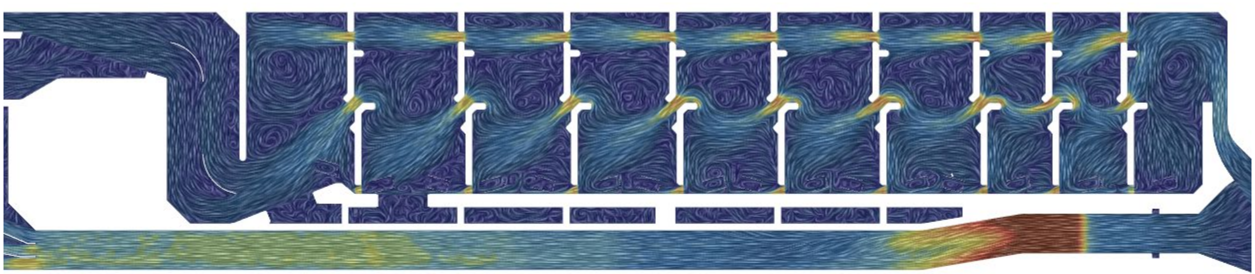


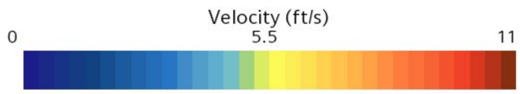


Salmon

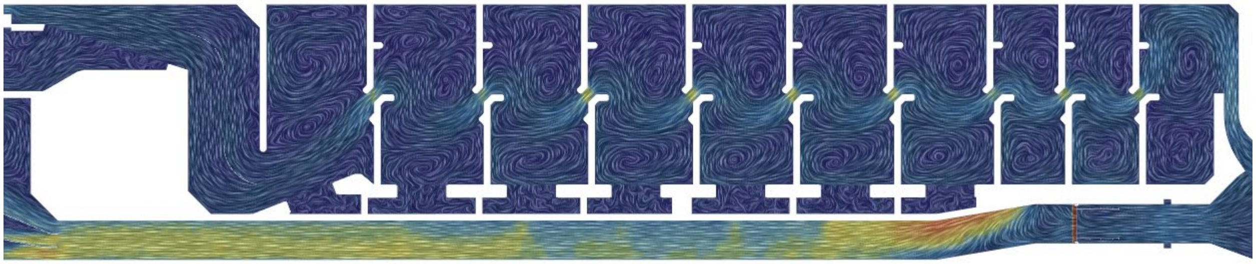




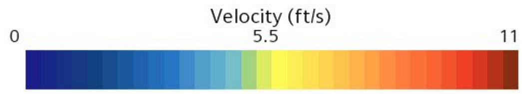
Lamprey

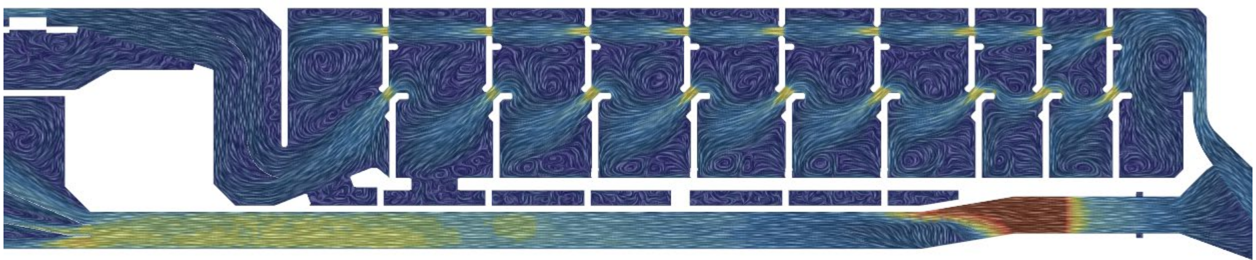


Run 4: Fb 72.7 ft, 1 ft head drop @ weir 67

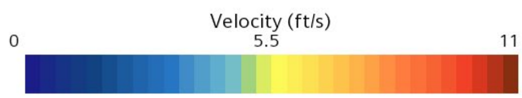


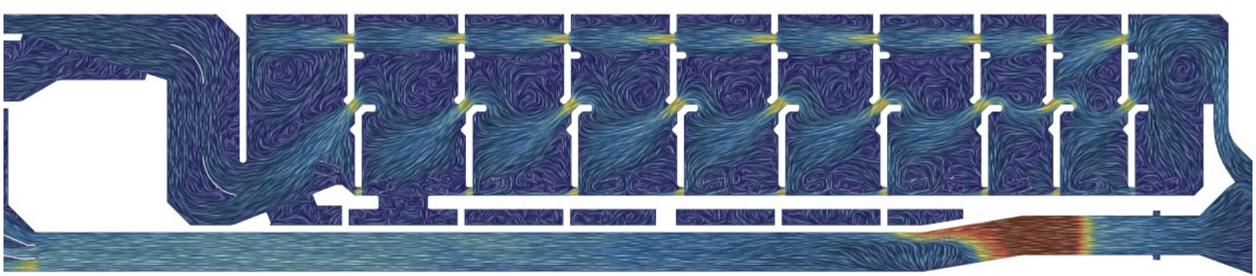
Slot



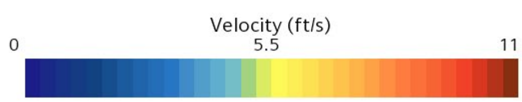


Salmon

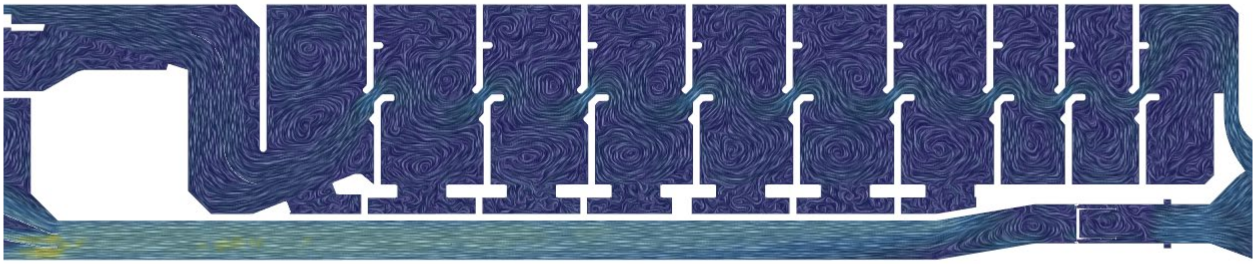




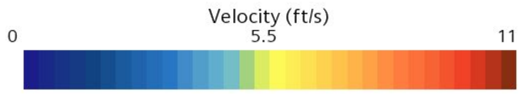
Lamprey

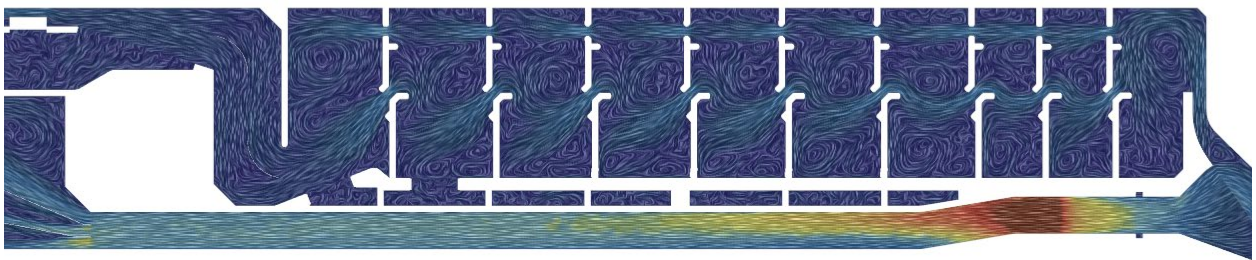


Run 5: Fb 70 ft, 1 ft head drop @ weir 67

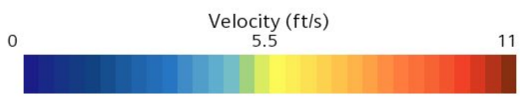


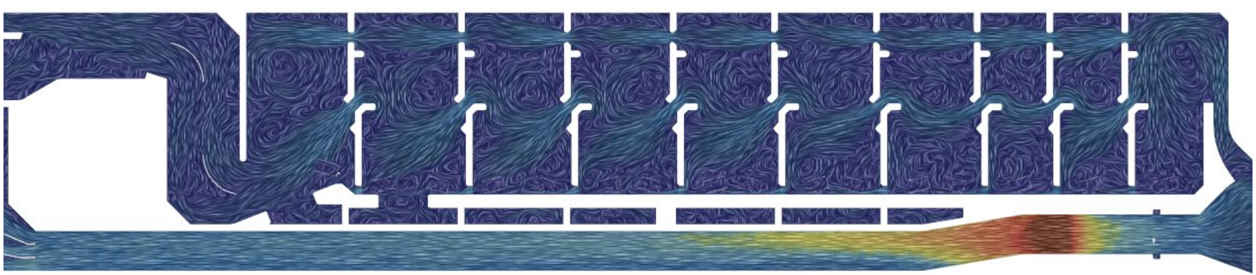
Slot



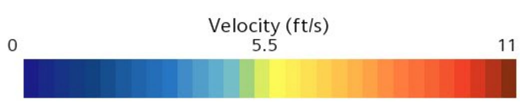


Salmon

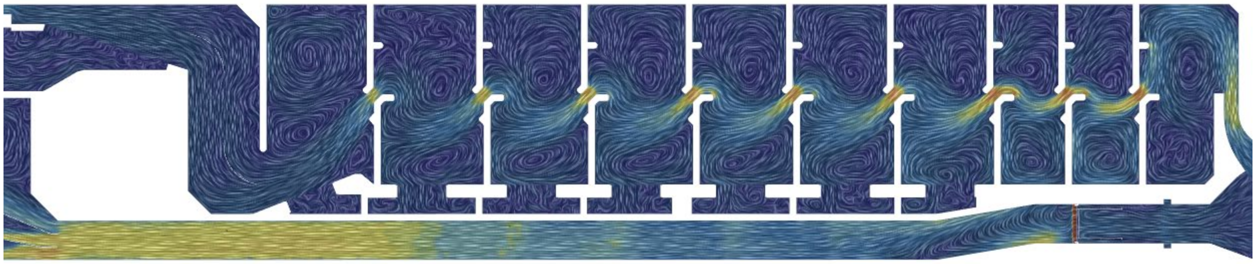




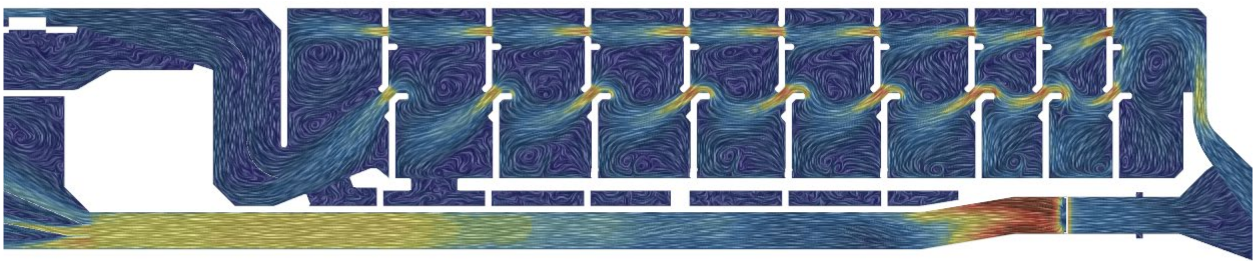
Lamprey



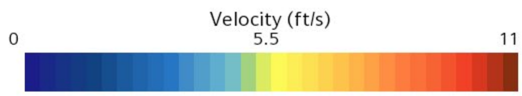
Run 6: Fb 76 ft, 1.5 ft head drop @ weir 67

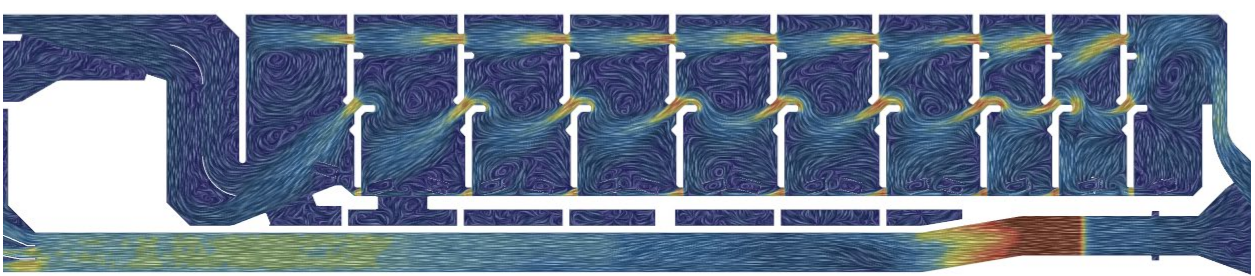


Slot

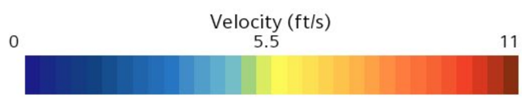


Salmon

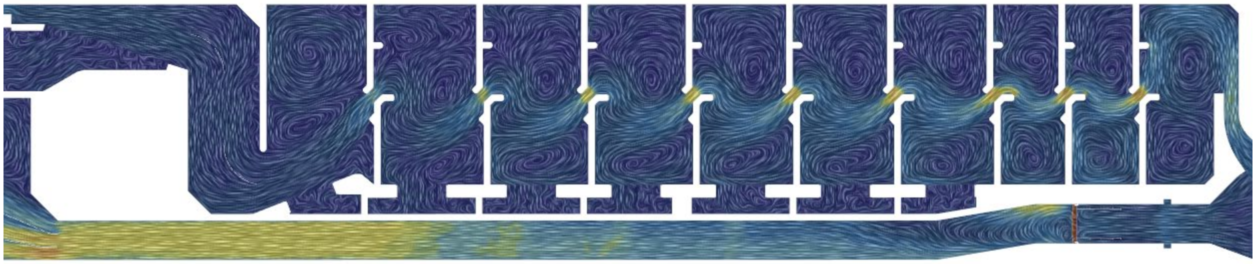




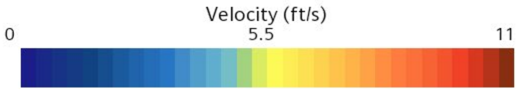
Lamprey

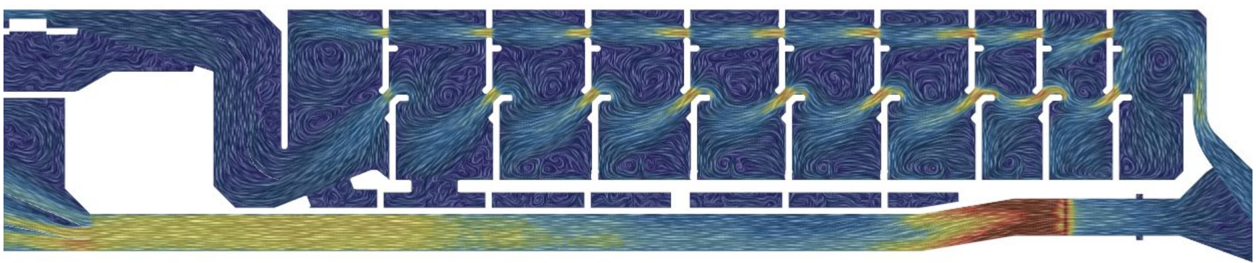


Run 7: Fb 74.5 ft, 1.5 ft head drop @ weir 67

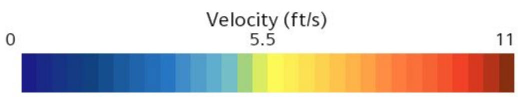


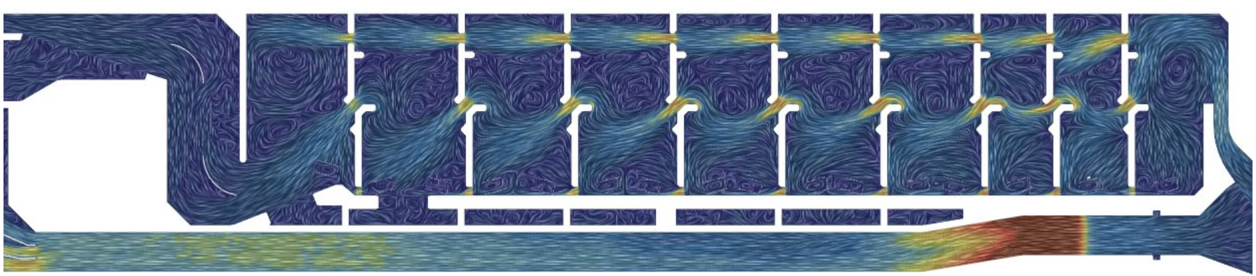
Slot





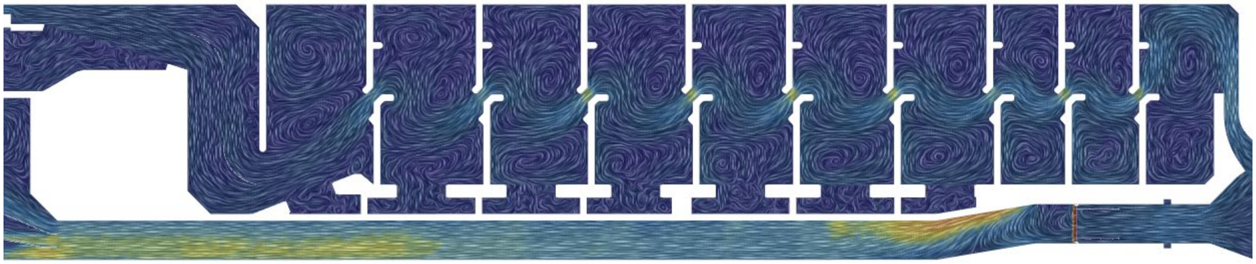
Salmon





Lamprey

Run 8: Fb 72.7 ft, 1.5 ft head drop @ weir 67



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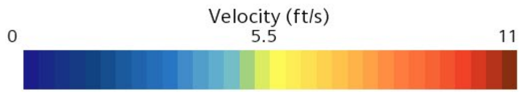

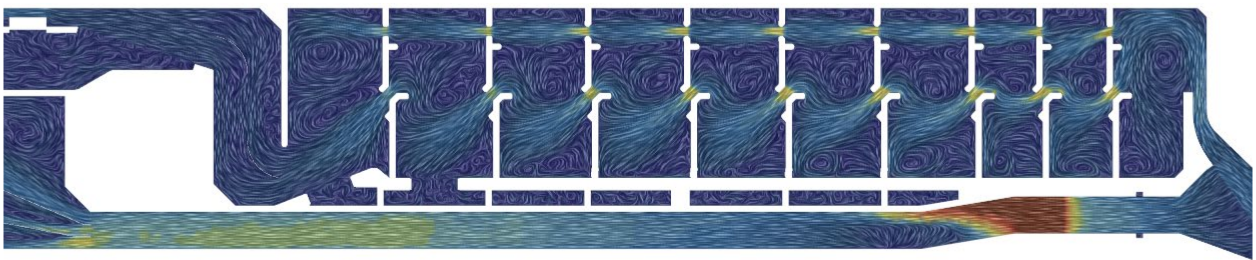

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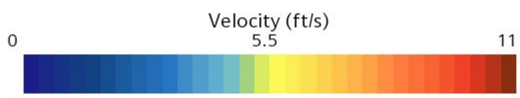
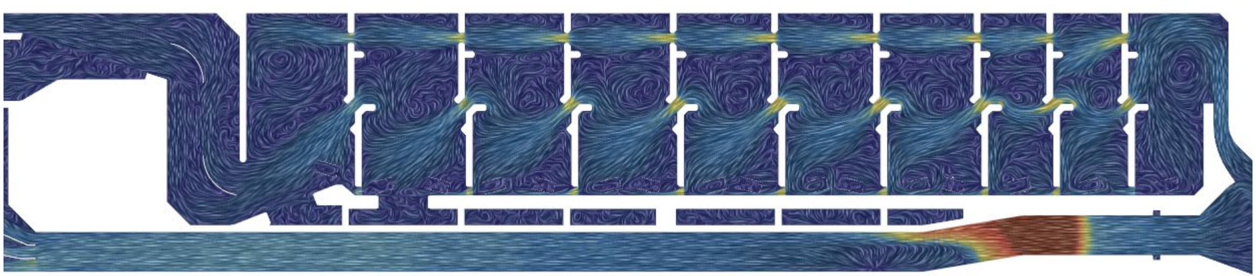
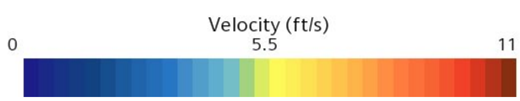
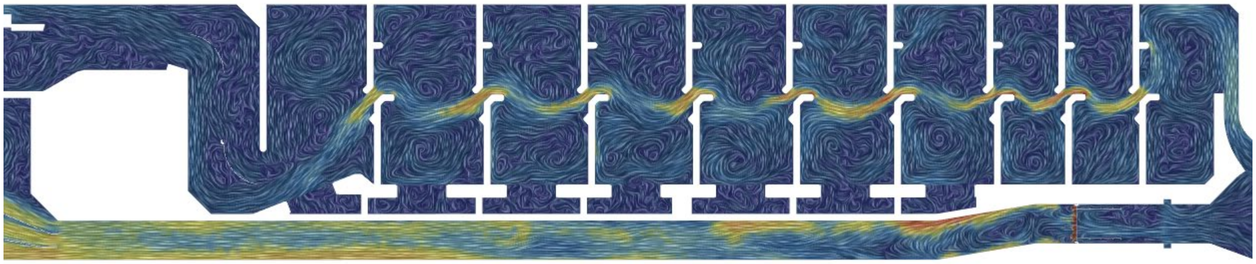




Lamprey



Run 9: Fb 74.5 ft, 1 ft head drop @ weir 67, LES Turbulence Model



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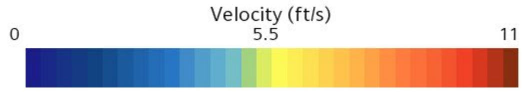

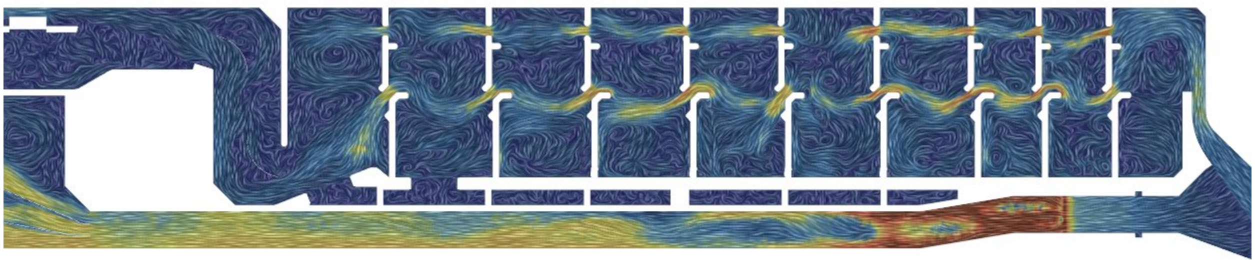

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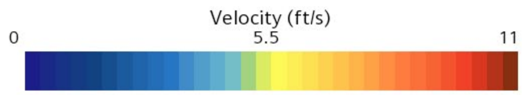
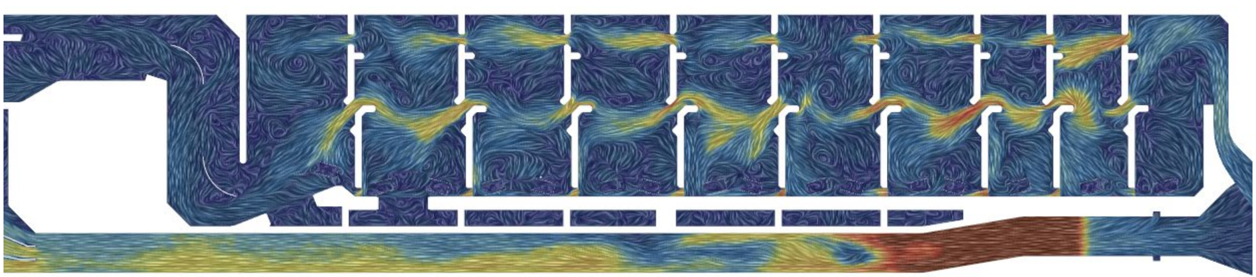
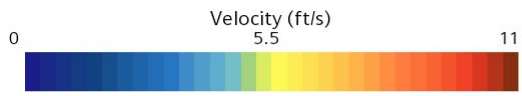
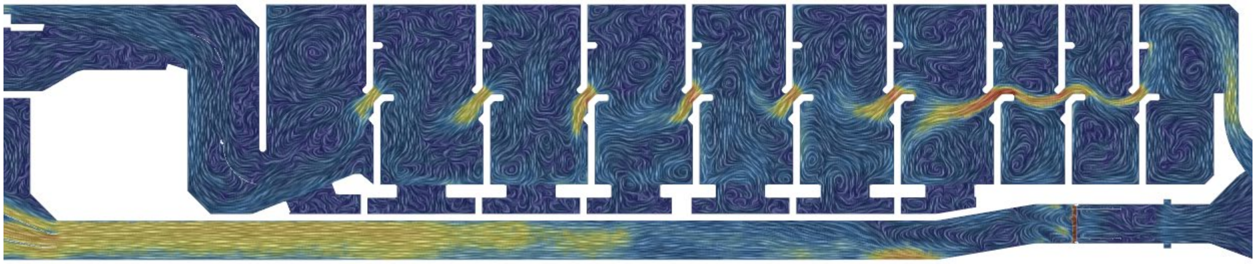




Lamprey



Run 10: Fb 74.5 ft, 1 ft head drop @ weir 67, DES Turbulence Model



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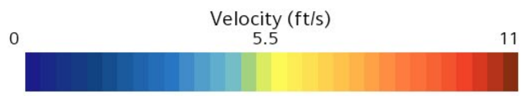

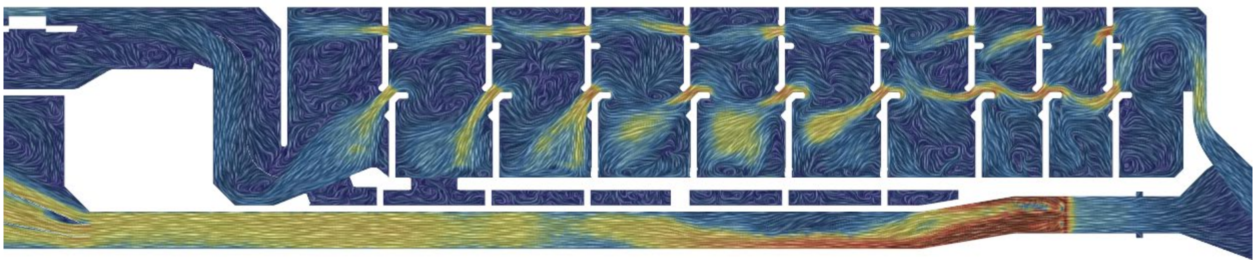

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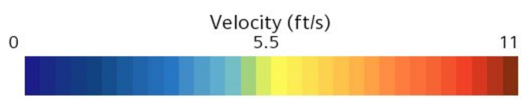
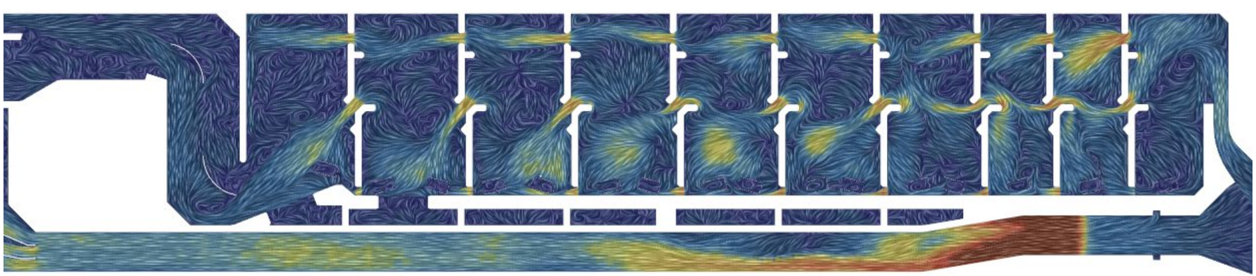
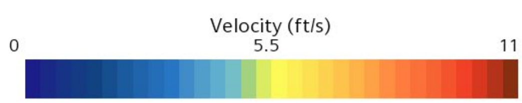




Lamprey



APPENDIX H

COST ESTIMATE AND SCHEDULE

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: **BON2 Fish Accords Lamprey 2019**
PROJECT NO: P2 492401
LOCATION: Bonneville Dam, OR

DISTRICT: Portland District **PREPARED: 6/13/2023**
POC: CHIEF, COST ENGINEERING, Eileen Rodriguez

This Estimate reflects the scope and schedule in report; DDR 90%

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2023 Effective Price Level Date: 1 OCT 22									
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	**TOTAL ($K)** *J*	Spent Thru: **1-Oct-22** ($K)	**TOTAL FIRST COST** ($K) *K*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
04	DAMS	$3,100	$1,103	35.6%	$4,203	0.0%	$3,100	$1,103	$4,203	$0	$4,203	7.3%	$3,327	$1,184	$4,511
	CONSTRUCTION ESTIMATE TOTALS:	$3,100	$1,103		$4,203	0.0%	$3,100	$1,103	$4,203	$0	$4,203	7.3%	$3,327	$1,184	$4,511
01	LANDS AND DAMAGES	$0	$0 -		$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$946	$193	20.4%	$1,139	0.0%	$946	$193	$1,139	$0	$1,139	4.0%	$983	$201	$1,184
31	CONSTRUCTION MANAGEMENT	$605	$149	24.6%	$753	0.0%	$605	$149	$753	$0	$753	5.7%	$639	$157	$796
	PROJECT COST TOTALS:	$4,650	$1,445	31.1%	$6,095		$4,650	$1,445	**$6,095**	$0	**$6,095**	6.5%	$4,948	$1,542	$6,490

ESTIMATED TOTAL PROJECT COST: **$6,490**

______________________ **CHIEF, COST ENGINEERING, Eileen Rodriguez**

______________________ **PROJECT MANAGER, Erin Kovalchuk**

______________________ **CHIEF, REAL ESTATE, Amanda Deth**

______________________ **CHIEF, PLANNING, Valarie Ringold**

______________________ **CHIEF, ENGINEERING, Patrick Duyck**

______________________ **CHIEF, OPERATIONS, Kymberly Anderson**

______________________ **CHIEF, CONSTRUCTION, Martha Brandl**

______________________ **CHIEF, CONTRACTING, Mitch Johnson**

______________________ **CHIEF, PM-PB, Eric Stricklin**

______________________ **CHIEF, DPM, Elizabeth Wells**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: BON2 Fish Accords Lamprey 2019
LOCATION: Bonneville Dam, OR
This Estimate reflects the scope and schedule in report; DDR 90%

DISTRICT: Portland District
POC: CHIEF, COST ENGINEERING, Eileen Rodriguez
PREPARED: 6/13/2023

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 13-Jun-23 Effective Price Level: 1-Oct-22		RISK BASED		Program Year (Budget EC): 2023 Effective Price Level Date: 1 OCT 22								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 1 or CONTRACT 1													
04	DAMS	$3,100	$1,103	35.6%	$4,203	0.0%	$3,100	$1,103	$4,203	2025Q2	7.3%	$3,327	$1,184	$4,511
	CONSTRUCTION ESTIMATE TOTALS:	$3,100	$1,103	35.6%	**$4,203**		$3,100	$1,103	$4,203			$3,327	$1,184	$4,511
01	LANDS AND DAMAGES	$0	$0	0.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$78	$16	20.4%	$93	0.0%	$78	$16	$93	2024Q2	3.4%	$80	$16	$96
1.0%	Planning & Environmental Compliance	$31	$6	20.4%	$37	0.0%	$31	$6	$37	2024Q2	3.4%	$32	$7	$39
15.0%	Engineering & Design	$465	$95	20.4%	$560	0.0%	$465	$95	$560	2024Q2	3.4%	$481	$98	$579
1.0%	Reviews, ATRs, IEPRs, VE	$31	$6	20.4%	$37	0.0%	$31	$6	$37	2024Q2	3.4%	$32	$7	$39
1.0%	Life Cycle Updates (cost, schedule, risks)	$31	$6	20.4%	$37	0.0%	$31	$6	$37	2024Q2	3.4%	$32	$7	$39
1.0%	Contracting & Reprographics	$31	$6	20.4%	$37	0.0%	$31	$6	$37	2024Q2	3.4%	$32	$7	$39
3.0%	Engineering During Construction	$93	$19	20.4%	$112	0.0%	$93	$19	$112	2025Q2	5.7%	$98	$20	$118
2.0%	Planning During Construction	$62	$13	20.4%	$75	0.0%	$62	$13	$75	2025Q2	5.7%	$66	$13	$79
3.0%	Adaptive Management & Monitoring	$93	$19	20.4%	$112	0.0%	$93	$19	$112	2025Q2	5.7%	$98	$20	$118
1.0%	Project Operations	$31	$6	20.4%	$37	0.0%	$31	$6	$37	2024Q2	3.4%	$32	$7	$39
31	CONSTRUCTION MANAGEMENT													
15.0%	Construction Management	$465	$114	24.6%	$579	0.0%	$465	$114	$579	2025Q2	5.7%	$491	$121	$612
2.0%	Project Operation:	$62	$15	24.6%	$77	0.0%	$62	$15	$77	2025Q2	5.7%	$66	$16	$82
2.5%	Project Management	$78	$19	24.6%	$97	0.0%	$78	$19	$97	2025Q2	5.7%	$82	$20	$102
	CONTRACT COST TOTALS:	$4,650	$1,445		$6,095		$4,650	$1,445	**$6,095**			$4,948	$1,542	**$6,490**

Abbreviated Risk Analysis

Project (less than $40M): **BON1 Fish Accords Lamprey FY 2019**

Alternative: **Chosen Alternative**

Project Development Stage/Alternative: **Feasibility (Recommended Plan)**

Risk Category: **Moderate Risk: Typical Project Construction Type**

Meeting Date: **6/13/2023**

Total Estimated Construction Contract Cost = **$ 3,100,000**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		0.00%	$ -	$ -
1	06 01 FISH FACILITIES AT DAMS	Mob/Demob	$ 265,000		26.61%	$ 70,511	$ 335,511
2	06 01 FISH FACILITIES AT DAMS	Replace Weirs	$ 1,220,000		30.33%	$ 369,998	$ 1,589,998
3	06 01 FISH FACILITIES AT DAMS	Fish Count Area Work	$ 205,000		35.76%	$ 73,304	$ 278,304
4	06 01 FISH FACILITIES AT DAMS	Pit Antenna Concrete Work	$ 460,000		43.35%	$ 199,416	$ 659,416
5	06 01 FISH FACILITIES AT DAMS	Pit Antennas	$ 360,000		52.20%	$ 187,931	$ 547,931
6	06 01 FISH FACILITIES AT DAMS	Walkways	$ 555,000		33.88%	$ 188,055	$ 743,055
7	06 01 FISH FACILITIES AT DAMS	Bleed-off / Add-in Diffusers	$ 35,000		39.96%	$ 13,987	$ 48,987.42
8					0.00%	$ -	$ -
9					0.00%	$ -	$ -
10					0.00%	$ -	$ -
11					0.00%	$ -	$ -
12	All Other	Remaining Construction Items	$ -	0.0%	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$ 946,000		20.43%	$ 193,245	$ 1,139,245
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$ 605,000		24.61%	$ 148,911	$ 753,911
XX	FIXED DOLLAR RISK ADD (EQUALLY DISPERSED TO ALL, MUST INCLUDE JUSTIFICATION SEE BELOW)					$ -	

Totals				
Real Estate	$ -	0.00%	$ -	$ -
Total Construction Estimate	$ 3,100,000	35.59%	$ 1,103,203	$ 4,203,203
Total Planning, Engineering & Design	$ 946,000	20.43%	$ 193,245	$ 1,139,245
Total Construction Management	$ 605,000	24.61%	$ 148,911	$ 753,911
Total Excluding Real Estate	**$ 4,651,000**	**31.08%**	**$ 1,445,359**	**$ 6,096,359**

	Base	50%	80%
Confidence Level Range Estimate ($000's)	$4,651k	$5,518k	$6,096k

* 50% based on base is at 5% CL.

Fixed Dollar Risk Add: (Allows for additional risk to be added to the risk analsyis. Must include justification. Does not allocate to Real Estate.	

BON1 Fish Accords Lamprey FY 2019 Chose

Feasibility (Recommended Plan)

Abbreviated Risk Analysis

Meeting Da 13-Jun-23

Risk Level

	Negligible	Marginal	Moderate	Significant	Critical
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Register

Risk Element	Feature of Work	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Impact	Likelihood	Risk Level
Project Management & Scope Growth				**Maximum Project Growth**		**75%**
PS-1	Mob/Demob	The scope of work is not fully developed.	Additional scope requirements could result in higher equipment and crew mob.demob costs. Assume a moderate impact is likely.	Moderate	Likely	3
PS-2	Replace Weirs	The scope of work is not fully developed.	Major features of the scope have been defined. It is likely that scope is altered, but unlikely that more scope is added on this CLIN since there isnt any more weirs to replace. Assume it is likely that marginal impact will occur.	Marginal	Likely	2
PS-3	Fish Count Area Work	The scope of work is not fully developed.	Major features of the scope have been defined, it is likely that more changes occur with a moderate impact.	Moderate	Likely	3
PS-4	Pit Antenna Concrete Work	The scope of work is not fully developed.	Major features of the scope have been defined, it is likely that more changes occur with a moderate impact.	Moderate	Likely	3
PS-5	Pit Antennas	The scope of work is not fully developed.	Major features of the scope have been defined, it is likely that more changes occur with a moderate impact.	Moderate	Likely	3
PS-6	Walkways	The scope of work is not fully developed.	Major features of the scope have been defined, it is likely that more changes occur with a moderate impact.	Moderate	Likely	3
PS-7	Bleed-off / Add-in Diffusers	The scope of work is not fully developed.	Major features of the scope have been defined, it is likely that more changes occur with a moderate impact.	Moderate	Likely	3
PS-13	Planning, Engineering, & Design	The scope of work is not fully developed.	Major features of the scope have been defined, it is likely that more changes occur with a moderate impact.	Moderate	Likely	3
PS-14	Construction Management	The scope of work is not fully developed.	Major features of the scope have been defined, it is likely that more changes occur with a moderate impact.	Moderate	Likely	3
Acquisition Strategy				**Maximum Project Growth**		**30%**
AS-1	Mob/Demob	Acquisition strategy change from small business BVTO to Sole Source	Sole Source is possible. The contractor would likely subcontract out all work except oversite. Assume this would have a moderate impact on mob/demob	Moderate	Possible	2

AS-2	Replace Weirs	Acquisition strategy change from small business BVTO to Sole Source	Sole Source is possible. The contractor would likely subcontract out all work except oversite. Currently, 65% of the CLIN is concrete install assumed to be done by the prime contractor. If we went SS, that scope would likely increase in cost by 25% (overall CLIN impact of 16.25%). Assume a Significant impact.	Significant	Possible	3
AS-3	Fish Count Area Work	Acquisition strategy change from small business BVTO to Sole Source	Sole Source is possible. The contractor would likely subcontract out all work except oversite. Currently, 65% of the CLIN is concrete install assumed to be done by the prime contractor. If we went SS, that scope would likely increase in cost by 25% (overall CLIN impact of 16.25%). Assume a Significant impact.	Significant	Possible	3
AS-4	Pit Antenna Concrete Work	Acquisition strategy change from small business BVTO to Sole Source	Sole Source is possible. The contractor would likely subcontract out all work except oversite. Currently, 65% of the CLIN is concrete install assumed to be done by the prime contractor. If we went SS, that scope would likely increase in cost by 25% (overall CLIN impact of 16.25%). Assume a Significant impact.	Significant	Possible	3
AS-5	Pit Antennas	Acquisition strategy change from small business BVTO to Sole Source	Sole Source is possible. The contractor would likely subcontract out all work except oversite. The estimate already assumes this work is subcontracted. Sole Source contractors also tend to not get competitive subcontractor pricing. Assume a moderate impact.	Moderate	Possible	2
AS-6	Walkways	Acquisition strategy change from small business BVTO to Sole Source	Sole Source is possible. The contractor would likely subcontract out all work except oversite. The estimate already assumes this work is subcontracted. Sole Source contractors also tend to not get competitive subcontractor pricing. Assume a moderate impact.	Moderate	Possible	2
AS-7	Bleed-off / Add-in Diffusers	Acquisition strategy change from small business BVTO to Sole Source	Sole Source is possible. The contractor would likely subcontract out all work except oversite. The estimate already assumes this work is subcontracted. Sole Source contractors also tend to not get competitive subcontractor pricing. Assume a moderate impact.	Moderate	Possible	2
AS-13	Planning, Engineering, & Design	Acquisition strategy change from small business BVTO to Sole Source	The acquisition strategy is unlikey to have a meaningful impact on PED.	Negligible	Unlikely	0
AS-14	Construction Management	Acquisition strategy change from small business BVTO to Sole Source	The acquisition strategy is unlikey to have a meaningful impact on CM.	Marginal	Unlikely	0
Construction Elements				**Maximum Project Growth**		**25%**
CON-1	Mob/Demob	Typical construction elements for NWP	NA	Negligible	Unlikely	0
CE-2	Replace Weirs	Restricted work windows apply	Estimate includes OT on all items to account for 3 month work window. If the contractor runs behind, they may need to extend to shift work to complete by the end of the IWW period. Assume further cost increases are possible with a moderate impact	Moderate	Possible	2

CE-3	Fish Count Area Work	Restricted work windows apply	Estimate includes OT on all items to account for 3 month work window. If the contractor runs behind, they may need to extend to shift work to complete by the end of the IWW period. Assume further cost increases are possible with a moderate impact	Moderate	Possible	2
CE-4	Pit Antenna Concrete Work	Restricted work windows apply	Estimate includes OT on all items to account for 3 month work window. If the contractor runs behind, they may need to extend to shift work to complete by the end of the IWW period. Assume further cost increases are possible with a moderate impact	Moderate	Possible	2
CE-5	Pit Antennas	Restricted work windows apply	Estimate includes OT on all items to account for 3 month work window. If the contractor runs behind, they may need to extend to shift work to complete by the end of the IWW period. Assume further cost increases are possible with a moderate impact	Moderate	Possible	2
CE-6	Walkways	Restricted work windows apply	Estimate includes OT on all items to account for 3 month work window. If the contractor runs behind, they may need to extend to shift work to complete by the end of the IWW period. Assume further cost increases are possible with a moderate impact	Moderate	Possible	2
CE-7	Bleed-off / Add-in Diffusers	Restricted work windows apply	Estimate includes OT on all items to account for 3 month work window. If the contractor runs behind, they may need to extend to shift work to complete by the end of the IWW period. Assume further cost increases are possible with a moderate impact	Moderate	Possible	2
CE-13	Planning, Engineering, & Design	Restricted work windows apply	No impact to PED.	Negligible	Unlikely	0
CE-14	Construction Management	Restricted work windows apply	Additional oversight may be required if some of the work is pushed toward the end of the fish ladder closure.	Marginal	Possible	1
Specialty Construction or Fabrication					**Maximum Project Growth**	**65%**
SC-1	Mob/Demob	NA beyond IWW from Construction risk	NA	Negligible	Unlikely	0
SC-2	Replace Weirs	NA beyond IWW from Construction risk	NA	Negligible	Unlikely	0
SC-3	Fish Count Area Work	NA beyond IWW from Construction risk	NA	Negligible	Unlikely	0
SC-4	Pit Antenna Concrete Work	Non-Ferrous reinforcing may be harder to procure.	Non-Ferrous reinforcing may be harder to procure. Assume a delay that causes a Moderate cost impact is possible.	Moderate	Possible	2
SC-5	Pit Antennas	Non standard electrical work for Pit Antennas	The contractor will mainly be connecting the GFCI antennas to the GFCI panels. The contractor may not be familiar with antennas and any special requirements they may have during installation. Assume a moderate impact is likely.	Moderate	Likely	3
SC-6	Walkways	NA beyond IWW from Construction risk	NA	Negligible	Unlikely	0
SC-7	Bleed-off / Add-in Diffusers	NA beyond IWW from Construction risk	NA	Negligible	Unlikely	0
SC-13	Planning, Engineering, & Design	NA beyond IWW from Construction risk	NA	Negligible	Unlikely	0
SC-14	Construction Management	NA beyond IWW from Construction risk	NA	Negligible	Unlikely	0

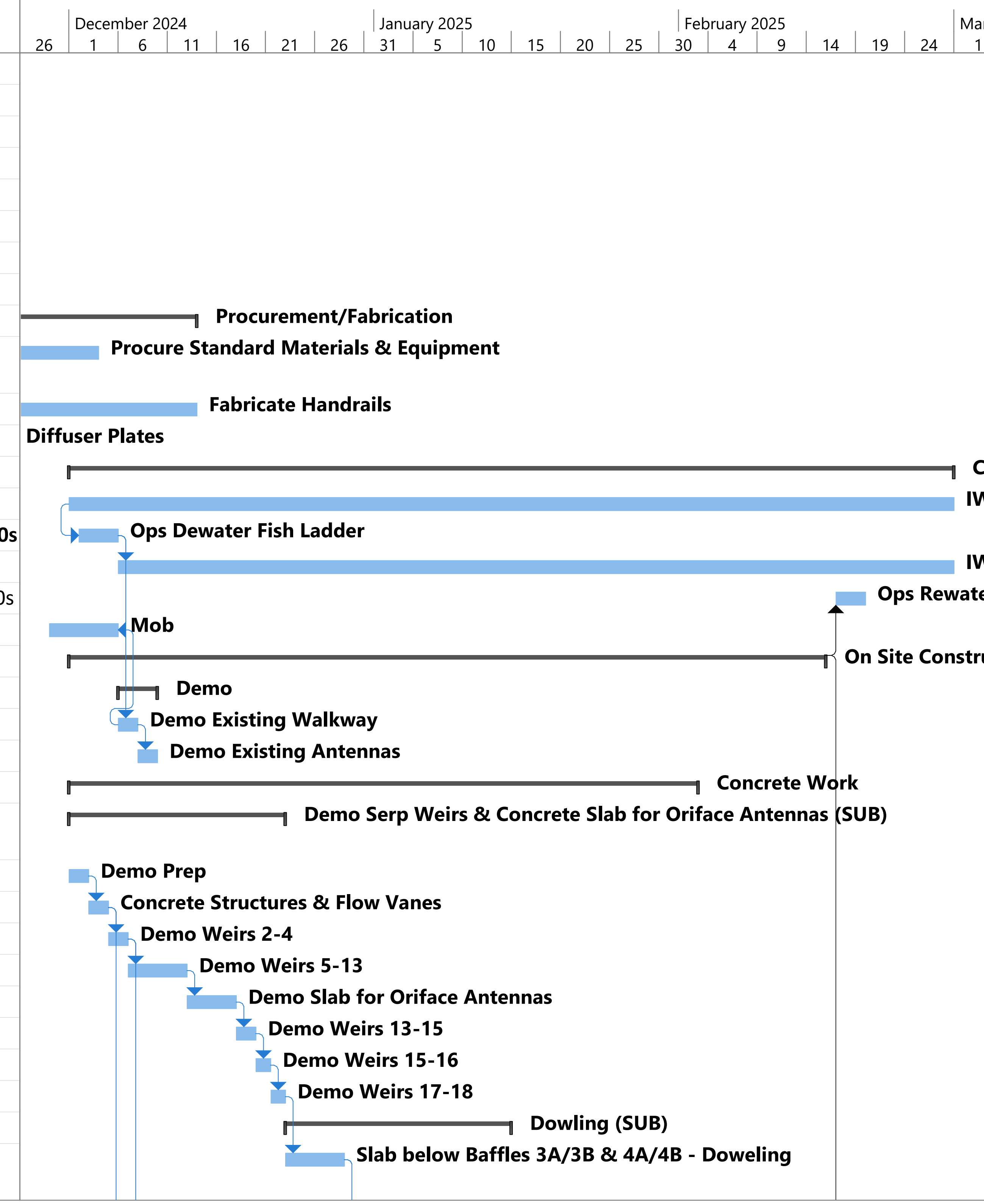
Technical Design & Quantities					Maximum Project Growth	30%
T-1	Mob/Demob	Minimal design supplied in DDR plates	Unlikely to be impacted by design changes	Negligible	Unlikely	0
T-2	Replace Weirs	Minimal design supplied in DDR plates	Design is relatively far along for a 90% DDR. Some items are still missing including the rebar layout. Assume a marginal impact is possible.	Marginal	Possible	1
T-3	Fish Count Area Work	Minimal design supplied in DDR plates	Design is relatively far along for a 90% DDR. Some items are still missing including the rebar layout. Assume a marginal impact is possible.	Marginal	Possible	1
T-4	Pit Antenna Concrete Work	Minimal design supplied in DDR plates	Design is relatively far along for a 90% DDR. Some items are still missing including the rebar layout. Assume a marginal impact is possible.	Marginal	Possible	1
T-5	Pit Antennas	Minimal design supplied in DDR plates	Quantities used in estimate are based off of DDR plates which contained very little walkway information. Assume a Moderate impact is likely	Moderate	Likely	3
T-6	Walkways	Minimal design supplied in DDR plates	Design is relatively far along for a 90% DDR. Some items are still missing including the fiberglass walkway details. Assume a moderate impact is possible.	Moderate	Possible	2
T-7	Bleed-off / Add-in Diffusers	Minimal design supplied in DDR plates	No design shown for diffusers. Requirements were detailed in the DDR and estimated based off of the described scope. Assume a moderate impact is likely.	Moderate	Likely	3
T-13	Planning, Engineering, & Design	Minimal design supplied in DDR plates	No impact to PED.	Negligible	Unlikely	0
T-14	Construction Management	Minimal design supplied in DDR plates	No impact to CM.	Negligible	Unlikely	0

Cost Estimate Assumptions					Maximum Project Growth	35%
EST-1	Mob/Demob	Typical Mob Demob	No impact.	Negligible	Unlikely	0
EST-2	Replace Weirs	Estimate may not have enough detail	Estimate used info from the JD North Fish ladder for demo production rates and crew makeup. Concrete install uses cost book items for their production rates and major scope material costs are from quotes. Assume it is possible that there is still a marginal impact to cost based off of the estimate.	Marginal	Possible	1
EST-3	Fish Count Area Work	Estimate may not have enough detail	Estimate used info from the JD North Fish ladder for demo production rates and crew makeup. Concrete install uses cost book items for their production rates and major scope material costs are from quotes. Assume it is possible that there is still a marginal impact to cost based off of the estimate.	Marginal	Possible	1
EST-4	Pit Antenna Concrete Work	Estimate may not have enough detail	Estimate used info from the JD North Fish ladder for demo production rates and crew makeup. Concrete install uses cost book items for their production rates and major scope material costs are from quotes. Assume it is possible that there is still a marginal impact to cost based off of the estimate.	Marginal	Possible	1
EST-5	Pit Antennas	Estimate may not have enough detail	Approximately half of the materials are GFCI. Labor based on past projects. Assume marginal impact is possible.	Marginal	Possible	1

EST-6	Walkways	Estimate may not have enough detail	Estimate uses custom fabrication cost takeoff for steel and fiberglass walkways and cost book items for stairs and railing. Custom railing pricing was modeled previously for another project which found the cost book item to still be accurate. Assume it is possible that there is still a marginal impact to cost based off of the estimate.	Marginal	Possible	1
EST-7	Bleed-off / Add-in Diffusers	The assumptions in the cost estimate may not have enough backup/data to validate costs	The scope for this section is small. Plate sizes were set by DDR and discussion with designer. Estimate assumes plates will be fabricated offsite and installed by a standard welding crew. Assume it is possible that there is still a marginal impact to the cost based off of the estimate.	Marginal	Possible	1
EST-13	Planning, Engineering, & Design	Estimate may not have enough detail	No impact to PED.	Negligible	Unlikely	0
EST-14	Construction Management	Estimate may not have enough detail	No impact to CM.	Negligible	Unlikely	0
External Project Risks				**Maximum Project Growth**		**40%**
EX-1	Mob/Demob	Inflation could worsen prior to solicitation	Escalation to midpoint (2025Q2) is 7.3%. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint. This CLIN is approximately 55% labor costs. Assume moderate impact is possible.	Moderate	Possible	2
EX-2	Replace Weirs	Inflation could worsen prior to solicitation	Escalation to midpoint (2025Q2) is 7.3%. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint. This CLIN is approximately 60% labor costs. Assume moderate impact is possible.	Moderate	Possible	2
EX-3	Fish Count Area Work	Inflation could worsen prior to solicitation	Escalation to midpoint (2025Q2) is 7.3%. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint. This CLIN is approximately 45% labor costs. Assume moderate impact is possible.	Marginal	Possible	1
EX-4	Pit Antenna Concrete Work	Inflation could worsen prior to solicitation	Escalation to midpoint (2025Q2) is 7.3%. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint. This CLIN is approximately 60% labor costs. Assume moderate impact is possible.	Moderate	Possible	2
EX-5	Pit Antennas	Inflation could worsen prior to solicitation	Escalation to midpoint (2025Q2) is 7.3%. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint. This CLIN is approximately 70% labor costs. Assume moderate impact is possible.	Moderate	Possible	2

EX-6	Walkways	Inflation could worsen prior to solicitation	Escalation to midpoint (2025Q2) is 7.3%. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint. This CLIN is approximately 20% labor costs. Assume marginal impact is possible.	Marginal	Possible	**1**
EX-7	Bleed-off / Add-in Diffusers	Inflation could worsen prior to solicitation	Escalation to midpoint (2025Q2) is 7.3%. Material inflation has seemed to level back off to ~2-3% per year depending on the item. Labor rates seem to still be catching up with past inflation and could exceed the escalation to midpoint. This CLIN is approximately 65% labor costs. Assume moderate impact is possible.	Moderate	Possible	**2**
EX-13	Planning, Engineering, & Design	Inflation could worsen prior to solicitation	Government labor rates could increase during design but the affect would be marginal at most.	Marginal	Possible	**1**
EX-14	Construction Management	Inflation could worsen prior to solicitation	Government labor rates could increase during construction but the affect would be moderate at most.	Moderate	Possible	**2**

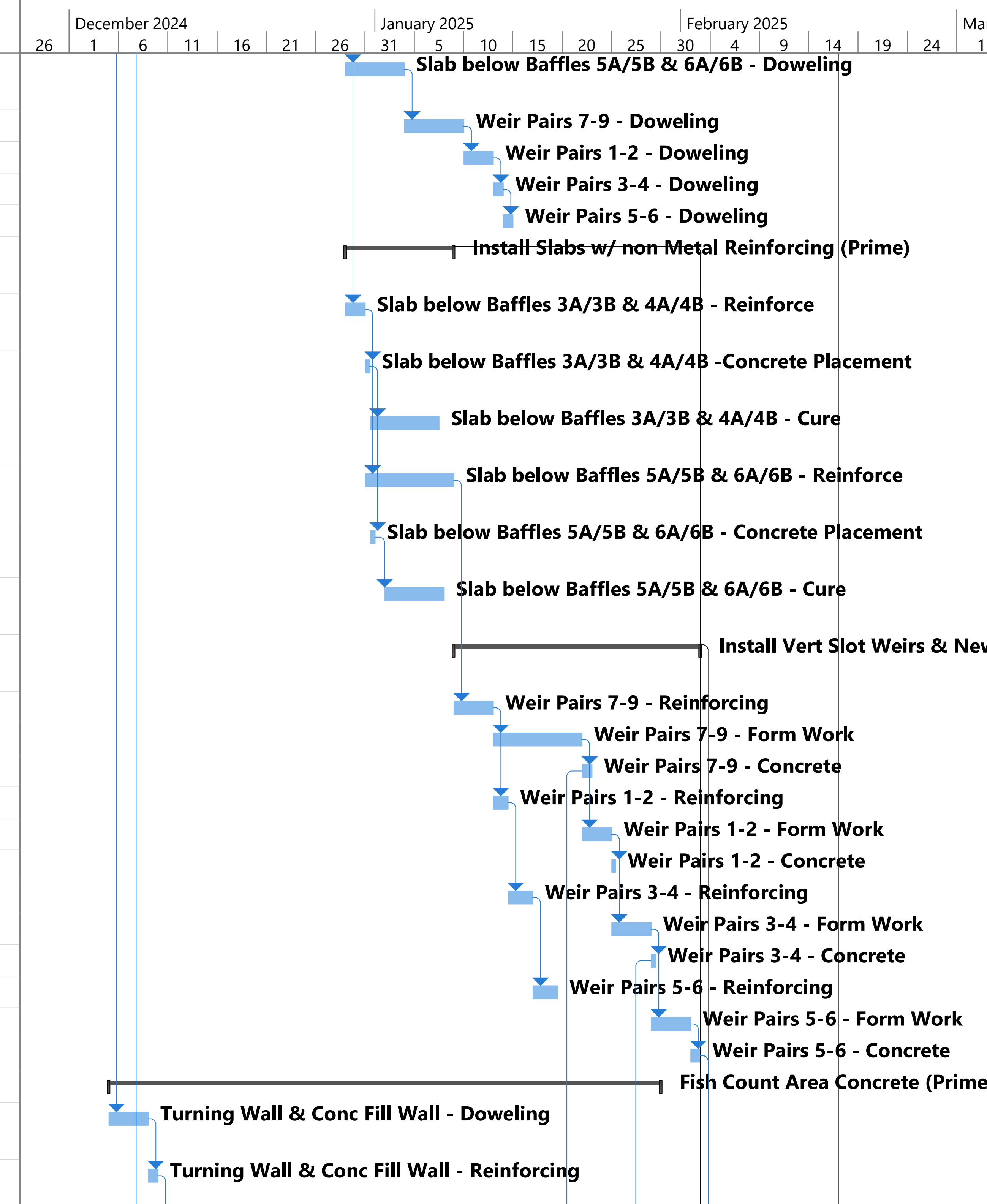
ID	Task Name	Duration	Start	Finish	Prede	Man Hours	Crew Size	Crew Hour	Task Calendar
1	**Design**	**0 days**	**Mon 7/15/24**	**Mon 7/15/24**					**Standard**
2	P&S Complete	0 days	Mon 7/15/24	Mon 7/15/24					Standard
3	**Solicitation**	**30 days**	**Mon 7/15/24**	**Mon 8/26/24**					**Standard**
4	Advertisement	35 edays	Mon 7/15/24	Mon 8/19/24	2				None
5	Bids Due	0 days	Mon 8/19/24	Mon 8/19/24	4				Standard
6	NTP	7 edays	Mon 8/19/24	Mon 8/26/24	5				None
7	**Preconstruction**	**40 days**	**Mon 8/26/24**	**Fri 10/18/24**					**Standard**
8	Preconstruction submittals	40 days	Mon 8/26/24	Fri 10/18/24	6				Standard
9	**Procurement/Fabrication**	**40 days**	**Mon 10/21/24**	**Fri 12/13/24**					**Standard**
10	Procure Standard Materials & Equipment	32 days	Mon 10/21/24	Tue 12/3/24	8				Standard
11	Fabricate Handrails	40 days	Mon 10/21/24	Fri 12/13/24	8				Standard
12	Fabricate Diffuser Plates	20 days	Mon 10/21/24	Fri 11/15/24	8				Standard
13	**Critical Dates**	**86 days**	**Sun 12/1/24**	**Fri 2/28/25**					**IWW, 7 day/wk**
14	IWW period	86 days	Sun 12/1/24	Fri 2/28/25					**IWW, 7 day/wk**
15	Ops Dewater Fish Ladder	4 days	Mon 12/2/24	Thu 12/5/24	14SS				**Ops Schedule, 4x10s**
16	IWW period Contractor Access	81 days	Fri 12/6/24	Fri 2/28/25	15				IWW, 7 day/wk
17	Ops Rewater Fish Ladder	3 days	Mon 2/17/25	Wed 2/19/25	19				Ops Schedule, 4x10s
18	Mob	5 days	Fri 11/29/24	Fri 12/6/24	21SF				Standard
19	**On Site Construction**	**74 days**	**Sun 12/1/24**	**Sat 2/15/25**					**IWW, 7 day/wk**
20	**Demo**	**4 days**	**Fri 12/6/24**	**Mon 12/9/24**					**IWW, 7 day/wk**
21	Demo Existing Walkway	2 days	Fri 12/6/24	Sat 12/7/24	15	125	6	20	IWW, 7 day/wk
22	Demo Existing Antennas	2 days	Sun 12/8/24	Mon 12/9/24	21	60	3	20	IWW, 7 day/wk
23	**Concrete Work**	**61 days**	**Sun 12/1/24**	**Sun 2/2/25**					**IWW, 7 day/wk**
24	**Demo Serp Weirs & Concrete Slab for Oriface Antennas (SUB)**	**22 days**	**Sun 12/1/24**	**Sun 12/22/24**					**IWW, 7 day/wk**
25	Demo Prep	2 days	Sun 12/1/24	Mon 12/2/24					IWW, 7 day/wk
26	Concrete Structures & Flow Vanes	2 days	Tue 12/3/24	Wed 12/4/24	25				IWW, 7 day/wk
27	Demo Weirs 2-4	2 days	Thu 12/5/24	Fri 12/6/24	26				IWW, 7 day/wk
28	Demo Weirs 5-13	6 days	Sat 12/7/24	Thu 12/12/24	27				IWW, 7 day/wk
29	Demo Slab for Oriface Antennas	5 days	Fri 12/13/24	Tue 12/17/24	28				IWW, 7 day/wk
30	Demo Weirs 13-15	2 days	Wed 12/18/24	Thu 12/19/24	29				IWW, 7 day/wk
31	Demo Weirs 15-16	1.5 days	Fri 12/20/24	Sat 12/21/24	30				IWW, 7 day/wk
32	Demo Weirs 17-18	1.5 days	Sat 12/21/24	Sun 12/22/24	31				IWW, 7 day/wk
33	**Dowling (SUB)**	**21 days**	**Mon 12/23/24**	**Tue 1/14/25**					**IWW, 7 day/wk**
34	Slab below Baffles 3A/3B & 4A/4B - Doweling	5 days	Mon 12/23/24	Sat 12/28/24	32	844*0.50=422	8	53	IWW, 7 day/wk



Project: B2 Fish Ladder Improve
Date: Wed 6/21/23

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

ID	Task Name	Duration	Start	Finish	Prede	Man Hours	Crew Size	Crew Hour	Task Calendar
35	Slab below Baffles 5A/5B & 6A/6B - Doweling	5 days	Sun 12/29/24	Fri 1/3/25	34	844*0.50=422	8	53	IWW, 7 day/wk
36	Weir Pairs 7-9 - Doweling	6 days	Sat 1/4/25	Thu 1/9/25	35	834*0.52=434	8	54	IWW, 7 day/wk
37	Weir Pairs 1-2 - Doweling	3 days	Fri 1/10/25	Sun 1/12/25	36	834*0.27=225	8	28	IWW, 7 day/wk
38	Weir Pairs 3-4 - Doweling	1 day	Mon 1/13/25	Mon 1/13/25	37	834*0.105=88	8	11	IWW, 7 day/wk
39	Weir Pairs 5-6 - Doweling	1 day	Tue 1/14/25	Tue 1/14/25	38	834*0.105=88	8	11	IWW, 7 day/wk
40	**Install Slabs w/ non Metal Reinforcing (Prime)**	**10 days**	**Sun 12/29/24**	**Wed 1/8/25**					**IWW, 7 day/wk**
41	Slab below Baffles 3A/3B & 4A/4B - Reinforce	2 days	Sun 12/29/24	Mon 12/30/24	34	125*0.50=63	3	21	IWW, 7 day/wk
42	Slab below Baffles 3A/3B & 4A/4B -Concrete Placement	0.5 days	Tue 12/31/24	Tue 12/31/24	41	48/2=24	8	3	IWW, 7 day/wk
43	Slab below Baffles 3A/3B & 4A/4B - Cure	6 days	Tue 12/31/24	Tue 1/7/25	42				IWW, 7 day/wk
44	Slab below Baffles 5A/5B & 6A/6B - Reinforce	8 days	Tue 12/31/24	Wed 1/8/25	41	125*0.50=63	3	21	IWW, 7 day/wk
45	Slab below Baffles 5A/5B & 6A/6B - Concrete Placement	0.5 days	Tue 12/31/24	Tue 12/31/24	42	48/2=24	8	3	IWW, 7 day/wk
46	Slab below Baffles 5A/5B & 6A/6B - Cure	6 days	Thu 1/2/25	Tue 1/7/25	45				IWW, 7 day/wk
47	**Install Vert Slot Weirs & New Slab w/ non Metal Reinforcing (Prime)**	**24 days**	**Thu 1/9/25**	**Sun 2/2/25**					**IWW, 7 day/wk**
48	Weir Pairs 7-9 - Reinforcing	4 days	Thu 1/9/25	Sun 1/12/25	44	293*0.43=126	3	42	IWW, 7 day/wk
49	Weir Pairs 7-9 - Form Work	8 days	Mon 1/13/25	Tue 1/21/25	48	1467*0.42=616	8	77	IWW, 7 day/wk
50	Weir Pairs 7-9 - Concrete	1 day	Wed 1/22/25	Wed 1/22/25	49	88*0.42=37	5	8	IWW, 7 day/wk
51	Weir Pairs 1-2 - Reinforcing	1.5 days	Mon 1/13/25	Tue 1/14/25	48	293*0.13=38	3	13	IWW, 7 day/wk
52	Weir Pairs 1-2 - Form Work	3 days	Wed 1/22/25	Fri 1/24/25	49	1467*0.14=206	8	26	IWW, 7 day/wk
53	Weir Pairs 1-2 - Concrete	0.2 days	Sat 1/25/25	Sat 1/25/25	52	88*0.14=12	5	2.5	IWW, 7 day/wk
54	Weir Pairs 3-4 - Reinforcing	2.5 days	Tue 1/14/25	Thu 1/16/25	51	293*0.22=65	3	22	IWW, 7 day/wk
55	Weir Pairs 3-4 - Form Work	4 days	Sat 1/25/25	Tue 1/28/25	52	1467*0.22=323	8	40	IWW, 7 day/wk
56	Weir Pairs 3-4 - Concrete	0.4 days	Wed 1/29/25	Wed 1/29/25	55	88*0.22=20	5	4	IWW, 7 day/wk
57	Weir Pairs 5-6 - Reinforcing	2.5 days	Fri 1/17/25	Sun 1/19/25	54	293*0.22=65	3	22	IWW, 7 day/wk
58	Weir Pairs 5-6 - Form Work	4 days	Wed 1/29/25	Sat 2/1/25	55	1467*0.22=323	8	40	IWW, 7 day/wk
59	Weir Pairs 5-6 - Concrete	1 day	Sun 2/2/25	Sun 2/2/25	58	88*0.22=20	5	4	IWW, 7 day/wk
60	**Fish Count Area Concrete (Prime)**	**53 days**	**Thu 12/5/24**	**Wed 1/29/25**					**IWW, 7 day/wk**
61	Turning Wall & Conc Fill Wall - Doweling	4 days	Thu 12/5/24	Sun 12/8/24	26	130	4	33	IWW, 7 day/wk
62	Turning Wall & Conc Fill Wall - Reinforcing	1 day	Mon 12/9/24	Mon 12/9/24	61	22.5	3	7.5	IWW, 7 day/wk



Project: B2 Fish Ladder Improve
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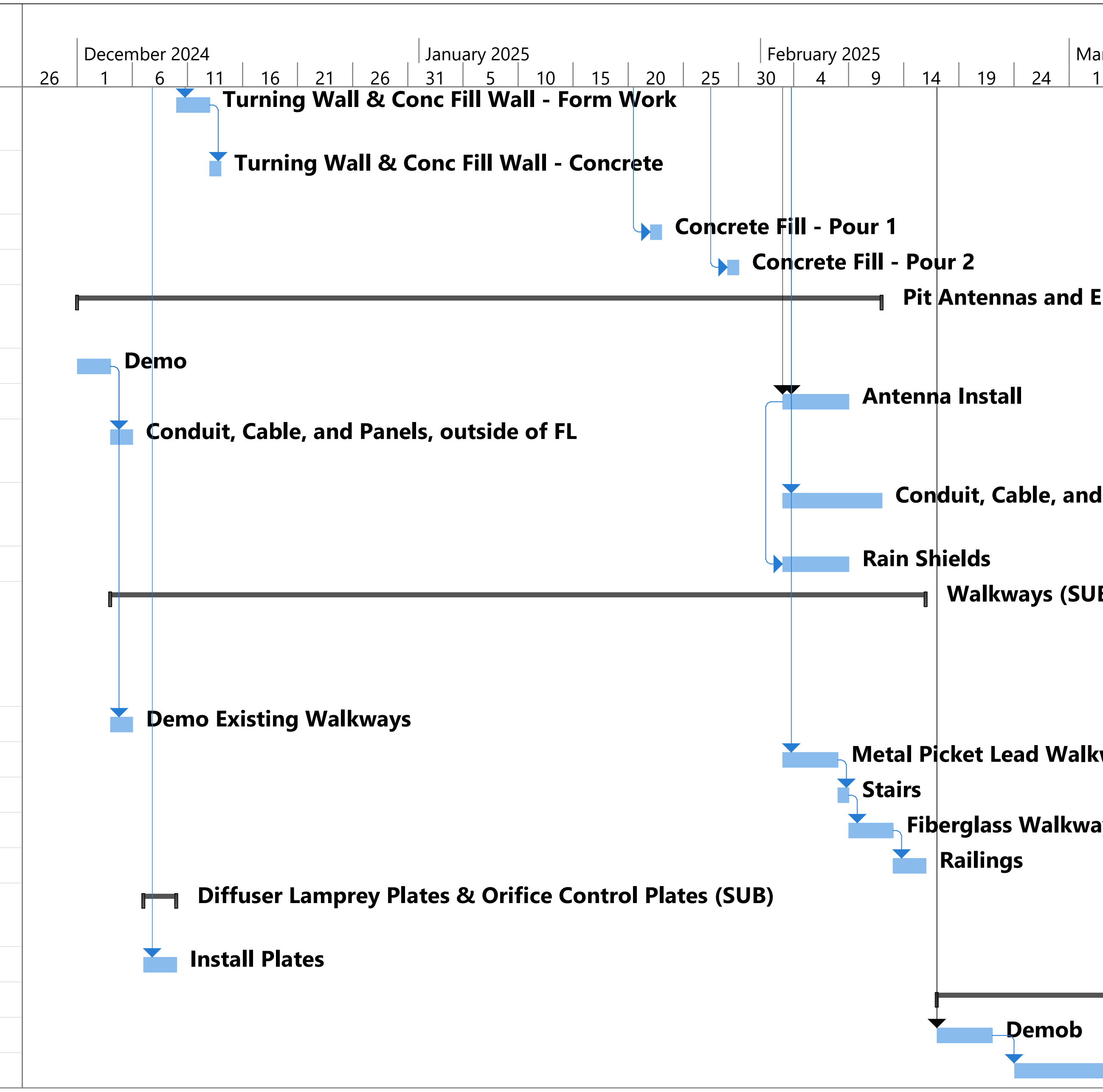
Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

ID	Task Name	Duration	Start	Finish	Prede	Man Hours	Crew Size	Crew Hour	Task Calendar
63	Turning Wall & Conc Fill Wall - Form Work	3 days	Tue 12/10/24	Thu 12/12/24	62	115	4	29	IWW, 7 day/wk
64	Turning Wall & Conc Fill Wall - Concrete	1 day	Fri 12/13/24	Fri 12/13/24	63	7.5	5	1.5	IWW, 7 day/wk
65	Concrete Fill - Pour 1	1 day	Wed 1/22/25	Wed 1/22/25	50SS				IWW, 7 day/wk
66	Concrete Fill - Pour 2	1 day	Wed 1/29/25	Wed 1/29/25	56SS				IWW, 7 day/wk
67	**Pit Antennas and Electrical Work (SUB)**	**70 days**	**Sun 12/1/24**	**Tue 2/11/25**					**IWW, 7 day/wk**
68	Demo	3 days	Sun 12/1/24	Tue 12/3/24					IWW, 7 day/wk
69	Antenna Install	6 days	Mon 2/3/25	Sat 2/8/25	47,4	180	3	60	IWW, 7 day/wk
70	Conduit, Cable, and Panels, outside of FL	2 days	Wed 12/4/24	Thu 12/5/24	68	333*0.2=67	3	22	IWW, 7 day/wk
71	Conduit, Cable, and Panels, outside of FL, Post Weir install	9 days	Mon 2/3/25	Tue 2/11/25	59	333*0.8=267	3	89	IWW, 7 day/wk
72	Rain Shields	6 days	Mon 2/3/25	Sat 2/8/25	69SS	180	3	60	IWW, 7 day/wk
73	**Walkways (SUB) (work will likely qualify to continue past the IWW period since it is out of the fish ladder.)**	**71 days**	**Wed 12/4/24**	**Sat 2/15/25**					**IWW, 7 day/wk**
74	Demo Existing Walkways	2 days	Wed 12/4/24	Thu 12/5/24	68				IWW, 7 day/wk
75	Metal Picket Lead Walkway	5 days	Mon 2/3/25	Fri 2/7/25	59	139	3	46	IWW, 7 day/wk
76	Stairs	1 day	Sat 2/8/25	Sat 2/8/25	75	30	3	10	IWW, 7 day/wk
77	Fiberglass Walkway	4 days	Sun 2/9/25	Wed 2/12/25	76	160	4	40	IWW, 7 day/wk
78	Railings	3 days	Thu 2/13/25	Sat 2/15/25	77	88	3	30	IWW, 7 day/wk
79	**Diffuser Lamprey Plates & Orifice Control Plates (SUB)**	**3 days**	**Sat 12/7/24**	**Mon 12/9/24**					**IWW, 7 day/wk**
80	Install Plates	3 days	Sat 12/7/24	Mon 12/9/24	27	90	3	30	IWW, 7 day/wk
81	**Post Construction**	**10 days**	**Mon 2/17/25**	**Fri 6/13/25**					**None**
82	Demob	5 days	Mon 2/17/25	Fri 2/21/25	19				Standard
83	Post Con Submittals	80 days	Mon 2/24/25	Fri 6/13/25	82				Standard



Project: B2 Fish Ladder Improve
Date: Wed 6/21/23

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress