US Army Corps of Engineers®
Portland District

Design Documentation Report

Foster Dam Downstream Fish Passage

Foster Dam

March 2017

100% Report

ABBREVIATIONS AND ACRONYMS

BiOp	Biological Opinion
cfs	cubic feet per second
COP	Configuration/Operation Plan
Corps	U.S. Army Corps of Engineers
DDR	Design Documentation Report
ER	Engineering Regulation
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
ft/s	Feet per second
MW	Megawatt(s)
NAVD88	North American Vertical Datum of 1988*
NGVD29	National Geodetic Vertical Datum of 1929*
NMFS	National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
O&M	Operations and Maintenance
PDT	Project (or Product) Delivery Team
RM	river mile(s)
RM&E	Research, Monitoring, and Evaluation
RO	Regulating outlet
RPA	Reasonable and Prudent Alternative
TDG	total dissolved gas
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Society
WATER	Willamette Action Team for Ecosystem Restoration
WVP	Willamette Valley Project

English to Metric Conversion Factors

To Convert From	To	Multiply by
feet (ft)	meters	0.3048
Miles	kilometers (km)	1.6093
Acres	hectares (ha)	0.4047
Acres	square meters (m^2)	4047
square miles (mi^2)	square kilometers (km^2)	2.590
acre-feet	hectare-meters	0.1234
acre-feet	cubic meters (m^3)	1234
cubic feet (ft^3)	cubic meters (m^3)	0.02832
feet/mile	meters/kilometer (m/km)	0.1894
cubic feet/second (cfs or ft^3/s)	cubic meters/second (m^3/s)	0.02832
degrees fahrenheit (°F)	degrees celsius (°C)	(Deg F - 32) x (5/9)

* Elevations in this report are presented in National Geodetic Vertical Datum of 1929 (NGVD29) unless otherwise shown. NGVD29 is 3.43 ft above the North American Vertical Datum of 1988 (NAVD88).

To convert NGVD29 to NAVD88 at Foster: [Elev ft NAVD88]=[Elev ft NGVD29 +3.43 ft]

EXECUTIVE SUMMARY

This Foster Dam Downstream Fish Passage Design Documentation Report (DDR) is in response to the National Marine Fisheries Service (NMFS) Biological Opinion (BiOp), which requires evaluation and improvements to downstream fish passage at Foster Dam (NMFS 2008). Results from research, monitoring, and evaluation (RM&E) activities, the Comprehensive and Operations Plan (COP) analysis of sub-basin priorities, and other BiOp-related studies were used along with the results of the Foster Dam Downstream Fish Passage Alternatives Engineering Documentation Report (EDR) to inform the Action Agencies and the Willamette Action Team for Ecosystem Restoration (WATER) and select an alternative for addressing the objectives of the Reasonable and Prudent Alternative (RPA) measures of the BiOp.

The selected alternative from the Foster Dam Downstream Fish Passage Alternatives EDR is a new fish weir capable of operating within a range of flows from 300 cfs to 860 cfs to allow the flexibility of operating at higher flows than the existing fish weir. The weir will primarily be operated with a flow of 530 cfs. The designed range of flows from 300 cfs to 860 cfs allows the flexibility of operating at 300 cfs during periods of dry years when river flows are low and at 860 cfs when flows are high. Based on Res Sim results, it is anticipated that the fish weir will be operated at 300 cfs less than five percent of the time. The Foster pool elevation will vary 1 to 1.5 feet daily because of power generation at Green Peter Dam. The fish weir will likely release more flow during these fluctuations. The new stoplogs and stoplog placements will allow up to 985cfs if needed. Post construction studies: research, monitoring and evaluation will provide information that may be used to optimize the fish weir operations and any additional operational measures for safe and effective downstream fish passage at Foster Dam. Design and fabrication of the new weir is estimated to cost $1,250,000 and must be installed no later than March 1st 2018. This DDR documents the 100% design and supporting information for the new fish weir.

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SECTION 1

PURPOSE AND INTRODUCTION

1.1 SCOPE AND PURPOSE

a. General. This Design Documentation Report (DDR) presents the technical details of the proposed improvements to the existing downstream passage at Foster Dam.

b. Main Features. The main features of the proposed Foster Downstream Passage improvements will be comprised of a new and an improved fish weir and additional stop logs.

c. Purpose. The purpose of the proposed project is to improve downstream fish passage at Foster Dam. The current fish weir has structural and hydraulic limitations on flows and hydraulic head. The Foster Dam Downstream Passage Alternatives Engineering Documentation Report (EDR) recommends a new fish weir to operate with flows ranging from 300 to 860 cfs between approximately October 1 and June 15 annually. This alternative is expected to effectively improve attraction, passage, and survival of downstream migrating, surface oriented, juvenile Chinook salmon and steelhead compared to baseline conditions, while minimizing impacts to other missions of Foster Dam (flood risk reduction, hydropower, and recreation). The higher flow capacity and longer seasonal operation of the new weir will provide passage opportunity during a period when most juvenile Chinook salmon and steelhead are migrating downstream. Additionally, this alternative will benefit downstream migrating steelhead kelts (adult steelhead returning to the ocean) because these fish are surface oriented and out-migrate during the spring.

1.2 PROJECT AUTHORIZATION

The existing authorized purposes for Foster Dam include flood risk management, hydropower generation, recreation, fish and wildlife, irrigation, water quality, and navigation. There are no non-Federal sponsor Operation and Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) responsibilities. Foster Dam is part of the general comprehensive plan for flood control and other purposes in the Willamette River Basin. Foster Project was authorized by the Flood Control Act of 1960 (Public Law 645, 86th Congress, H.R. 7634).

1.3 GENERAL PROJECT DESCRIPTION

a. Willamette River Basin Location. The Willamette River Basin, composed of 11 sub-basins, is located in northwestern Oregon, and is approximately 150 miles long and 75 miles wide. It covers 12 percent of the state, contains extensive, rich agricultural land and forests, and is home to approximately 70 percent of the state's residents. The Willamette River flows north and is a major tributary to the Columbia River. The Willamette River Basin supports two ESA listed anadromous fish species (Upper Willamette River (UWR) Chinook salmon and UWR winter steelhead) above Willamette Falls. Additionally, the Willamette River supports three ESA listed fish species (Lower Columbia River Chinook salmon, coho salmon, and steelhead) below Willamette Falls. These fish species have historical, economic, and cultural significance. Historically, the South Santiam sub-basin was a significant contributor to the UWR Chinook salmon and steelhead stocks; however, population declines for both species have been noted in recent years.

b. Foster Dam Location. Foster Dam is located at river mile 37.9 on the South Santiam River at Foster, Oregon; 38.5 miles above the confluence of the North and South Santiam Rivers and approximately 25 miles southeast of Albany, Oregon (Figure 1-1). Foster provides regulation of river flows for Green Peter project, located 8 miles upstream on the Middle Santiam River. Features of Foster Dam include the main embankment dam, a concrete gravity spillway section south of the main dam, and an embankment wing dam south of the spillway. The Foster Spillway consists of four 50 feet wide spill bays. The powerhouse, with two turbine units, is located at the downstream base of the dam.

c. History. During the last 50 years, 13 dams have been constructed and operated by the Corps in the Willamette River basin for a variety of purposes, including flood risk management, power generation, and supply of water for irrigation, navigation, improved water quality, recreation opportunities, and improved habitat conditions for fish and wildlife. Authorized individually, these 13 dams are collectively referred to as the Willamette System. Foster Dam was completed in 1968 and serves as a re-regulating dam for the upstream Green Peter Dam.

1.4 COORDINATION WITH OTHERS

Design and construction activities will be fully coordinated with NOAA Fisheries, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, U.S Forest Service, Oregon Department of Environmental Quality, and with other agencies as appropriate.

Figure 1.1 – The Willamette River Basin.

SECTION 2

BIOLOGICAL DESIGN CONSIDERATIONS AND CRITERIA

2.1 GENERAL

This Section describes the biological design considerations and criteria used to develop and evaluate the design of the weir. It identifies biological and behavioral characteristics of the target fish species important to consider in weir design and function.

Target Fish Species.

The targeted fish species for this project are UWR Spring Chinook salmon and UWR Winter steelhead.

Spring Chinook salmon and winter steelhead are present in the South Santiam sub-basin. Upstream passage is provided above Foster Dam for natural origin (unmarked) adult spring Chinook salmon and winter steelhead through a trap and haul facility located downstream of Foster Dam, on the South Santiam River. Juvenile and adult downstream passage typically occurs, from February to July, at the spillway, through an existing fish weir or a regular spill bay, and the turbines of the dam.

2.2 BIOLOGICAL DESIGN CRITERIA

The new fish weir will be designed in accordance with the NMFS fish passage design criteria (NMFS 2011) and the USACE Fisheries Handbook of Engineering Requirements and Biological Criteria (Bell 1991).

1. Target Species Swimming Speed Criteria and Considerations.

The assumed design criteria for juvenile salmonid swimming speeds (*Bell, 1991, Jones et al 1974, Webb 1971)* are shown in Table 2-1.

Table 2-1. Juvenile Fish Swimming Speeds (Bell, 1991, Jones et al 1974, Webb 1971)

Species	**Speed (fps), Sustained**
Chinook salmon (2”)	0.5-1.2
Chinook salmon (>2”)	1.0-2.1
Steelhead	2.1-2.9

Three aspects of swimming speed are considered in the design criteria for fish passage facilities:

- Cruising – a speed that can be maintained for long periods of time (hours).
- Sustained – a speed that can be maintained for minutes.
- Darting – a single effort burst of speed that is not sustainable.

2. <u>Generalized Downstream Passage Considerations</u>

- The design or operation of the fish passage device needs to accommodate all juvenile life stages of spring Chinook salmon and winter steelhead, and adult winter steelhead (kelts).
- The flownet created by the entrances should be of sufficient intensity to attract juveniles toward them, particularly in the absence of guidance nets or structures (NMFS 2011).
- Location: The entrance must be located so that it may easily be located by downstream migrating target fish species (NMFS 2011).
- Location: The fish passage device must permit passage of out-migrating salmonids with minimal injury or delay (NMFS 2011).
- Lighting: Ambient lighting conditions must be included upstream of the entrance and should extend to the flow control device. Where lighting transitions cannot be avoided, they should be gradual, or should occur at a point in the system where fish cannot escape the device (NFMS, 2011).

2.3 REFERENCES

Bell, M. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria.

Jones, DR, JW Kiceniuk and OS Bamford. 1974. Evaluation of the swimming performance of several fish species from the Mackenzie River. Journal of the Fisheries Research Board of Canada, 31(10): 1641–1647.

NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility.

Oregon Revised Statute (ORS) 509.585-.910

Oregon Administrative Rule (OAR) 635-412-0005 through 0040.

Webb, PW. 1971. The Swimming Energetics of Trout. Thrust and power output at cruising speed. J. Exp. Biol. 55:489-520.

SECTION 3

HYDRAULIC DESIGN

3.1 GENERAL

This Section describes the hydraulic design of the new fish weir. The weir is comprised of a shaped spillway fish weir centered within a stoplog that sets upon multiple stoplogs and utilized in Spill Bay 4. The weir is designed to operate as a surface outlet for downstream fish passage generally at two forebay elevations: the maximum conservation pool elevation of 637 ft. and minimum flood pool of EL 613 ft. (the two forebay elevations specified in the Water Control Manual). The depth of flow (or head) over the fish weir defines the discharge with higher head resulting in more flow. To modify the head over the fish weir for a given pool elevation, the weir must be seated on a set number of stoplogs such that the difference between the forebay elevation and the top of the weir (the head) provides the desired flow. To change the flow given the same forebay elevation, the stoplogs must be (added or subtracted) to create the head over the weir for the desired flow. To maintain the same flow for a different forebay elevation, the stoplog combinations will need to be adjusted to provide the same head for that particular flow. It is assumed that throughout the fish weir operation (from several months to year round as determined through field testing) the elevation of the fish weir will only have to be re-positioned vertically (by changing stoplogs) twice a year coinciding with the two prescribed changes in forebay elevation listed above.

The capacity of the new weir has been designed to be flexible to work for a range of discharges of approximately 300 cfs to 860 cfs. During the EDR study phase it was determined that the existing fish weir of 22 feet width used for research could be improved by reducing the width and increasing the head allowing more flow for attraction, increased depth of flow on the ogee, reduced sensitivity to common daily forebay fluctuations and provide a greater range of flow possibilities from 300 to 860 cfs. The new fish weir design utilizes a 14 ft. wide weir centered in the top stop log. During the DDR phase CFD modeling provided vital information regarding attraction flownets in the forebay, jet trajectory, depth of flow on the ogee and allowed a more accurate estimate of the rating curve for the fish weir.

Based on CFD modeling the new 14 ft. wide weir would allow approximately 860 cfs flow with a vertical depth over the weir (forebay EL – weir EL) of approximately 6.5 feet, 530 cfs with 4.8 feet and 300 cfs with 3.5 feet of head (Table 3-1). This will require additional stoplog components to be built to create the appropriate weir flow depth and is presented in Table 3-1 as well as Section 4 Structural Design and Analysis (4.6 Features). As the 530 cfs flow rate is anticipated to be the primary flow operation it was determined that the 860 cfs flow could be met through raising the pool elevation slightly (~1.7 feet) without requiring an additional stoplog to be built and placed under the new weir to achieve the required head over the weir.

Table 3-1 Weir Head and Pool Elevation to Obtain Desired Fish Weir Flow Rate and New Stoplogs Required

Desired Flow (cfs)	Pool Elev (ft)	Bottom of Weir Elev (ft)	Top of Weir Elev (ft)	Head Over Weir (ft)	Actual Flow (cfs)	Number of 2.33ft Stoplogs	Number of 5ft Stoplogs	Number of 4ft Stoplogs
860	*638.67	629.8	632.17	6.5	860	0	1	7
860	*614.67	605.8	608.17	6.5	860	0	1	1
530	637	629.8	632.17	4.83	529	0	1	7
530	613	605.8	608.17	4.83	529	0	1	1
300	637	631.13	633.5	3.50	297	1	0	8
300	613	607.13	609.5	3.50	297	1	0	2

* Indicates a pool elevation outside of current standard project operations.

Operation of the spillway gate for the new fish weir will follow the same operations as used for the previous ~200 cfs fish weir use. When the fish weir is in use the tainter gate will be opened fully out of the water. When the fish weir is not in use the tainter gate will be closed. No additional risks related to filling and emptying the space between the stoplogs and the tainter gate during the opening and closing sequence are anticipated based on years of similar use operating the initial fish weir.

3.2 COMPUTATIONAL FLUID DYNAMICS MODELING

Computational Fluid Dynamics (CFD) modeling was utilized to inform design and analyze the hydraulic characteristics of the new fish weir. Both 2D and 3D modeling were used to analyze acceleration characteristics in the forebay, provide a rating table for the new weir, provide depth of flow on the ogee surface, and compare the existing weir to the proposed weir.

The shape of the weir was modeled in 2D to ensure that the weir provided appropriate and safe attraction, acceleration, capture velocity and downstream trajectory. A scaled down representation of the John Day Spillway Fish Weir, which has been proven to be an effective downstream passage route, was the first design explored in the Foster 2D model. The intent was to capitalize on the flow signature in the forebay of the John Day weir, which provided gradual acceleration of flow as it approached the weir crest. This acceleration is small enough that it doesn’t deter fish from approaching until they pass into capture velocity. Once entrained in capture velocity, the acceleration can increase without the ability of the fish to abandon their passage downstream.

The John Day shape could not be directly translated to Foster due to physical design constraints, but it was scaled down to meet the width of the Foster stoplog slots (see Figure 3-1), along with another shape that was developed using engineering judgement. The weir shape for the alternative was a quarter ellipse with a major radius of three feet and a minor radius of two feet.

The very downstream end of the weir tapered to a horizontal line of seven inches to help shape the jet (see Figure 3-2).

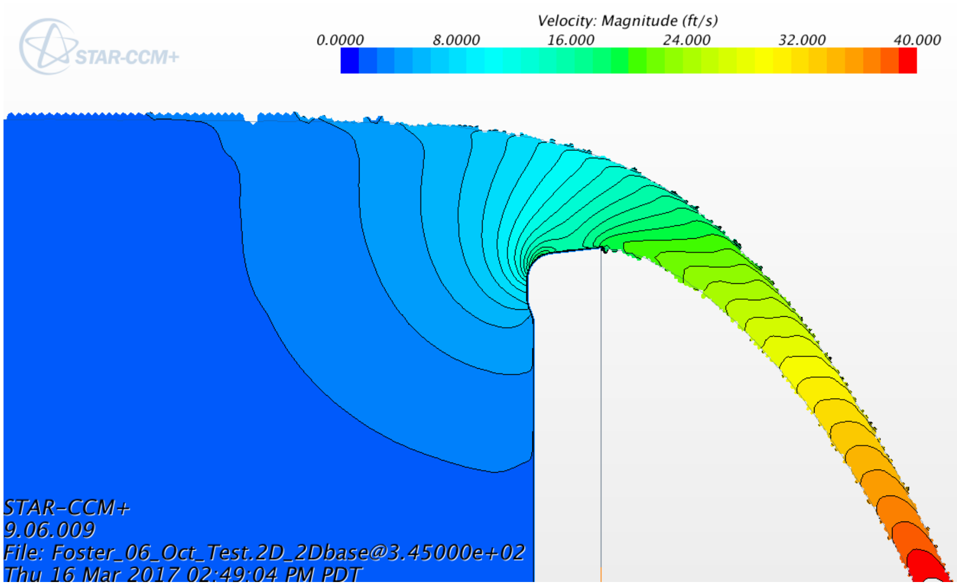


Figure 3-1: John Day Spillway Fish Weir Shape Scaled for Foster

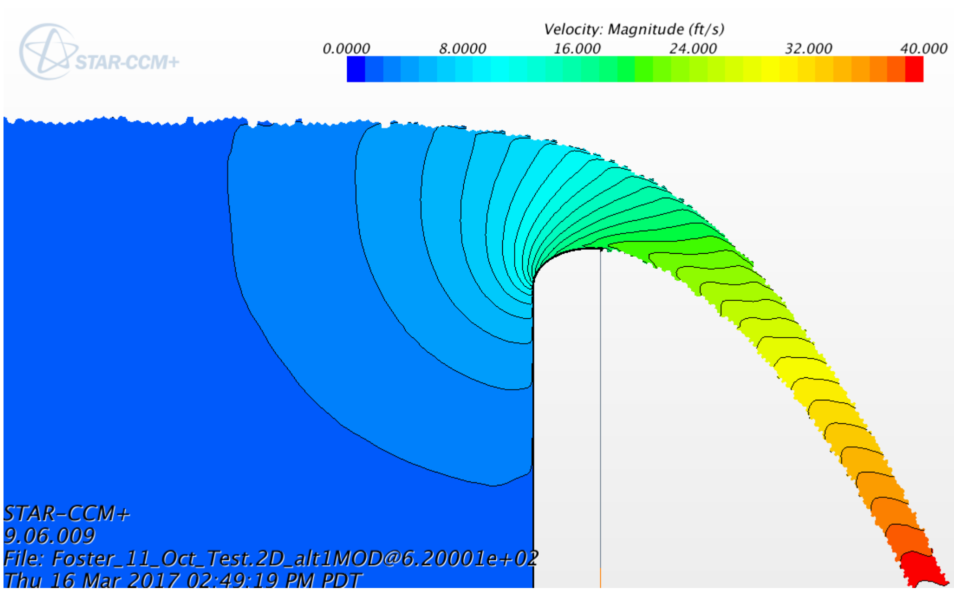


Figure 3-2: Alternative Fish Weir Shape

The alternative shape was chosen over the scaled-down John Day weir shape based on its smooth flow transitions near the surface of the forebay and across the weir. The John Day shape showed a pocket of higher velocity around the upstream lip of the weir crest, and an increased velocity profile along the surface of the forebay. Another issue with the John Day shape is the upstream lip that extends into the forebay, which could lead to unnecessary uplift forces on the weir. The proposed alternative showed a velocity profile on the water surface that matches the gradual velocity profile farther down in the water column, with a steady transition over the weir crest and no higher velocity pockets.

Further modeling and investigation was undertaken (using a 3D model) to assist in the shaping of the weir sides, providing a more accurate flow volume and potential insight to the jet expansion as it flows down the ogee face. The 3D model was created as a half-bay model, to decrease run time while still informing design (see Figure 3-4). The model was then mirrored over the symmetry boundary, to give the appearance of the full weir.

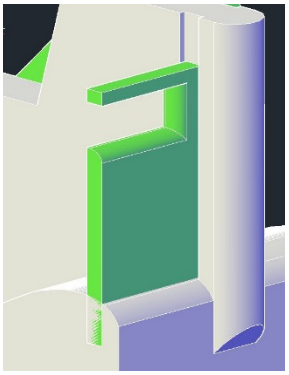


Figure 3-3 – Half Bay 3D Model

Since the model is only a half bay, all flow outputs on the following images will be half of what would be seen in the prototype. The weir was modeled as the proposed 14 ft weir, with side shaping that matched the shaping on the crest. There were four main concerns with the weir that were investigated using a 3D CFD model:

1. Uplift Pressure on new weir
2. A rating curve for the new weir
3. The flow depth where the jet of the weir flow impacts on the ogee surface
4. The acceleration field leading into the weir, compared to the existing weir

The existing weir was also modeled in 3D CFD, to compare to the proposed weir (see Figure 3-5). A standard operation for the existing weir was modeled, with an invert set to 614.3 ft and the forebay being held at 616.6 ft. The width of the existing weir is 22 feet compared to the new design of 14 feet. The prototype was designed for a flow around 200 cfs, which the model compliments well with 190 cfs. See Figure 3-5 for the existing weir CFD model run.

The uplift pressure on their weir was a design parameter requested by Structural Design, to make sure that the high velocity flow over the weir crest wasn't creating an uplift force on the weir face. Pressure was mapped onto the surfaces of the weir that come into contact with water, either hydrostatic or hydrodynamic. From the mapped pressures, it is apparent that there will be no uplift on the weir face due to flow, and a mostly hydrostatic pressure on the upstream face. See the Structural Design Section for in-depth analysis.

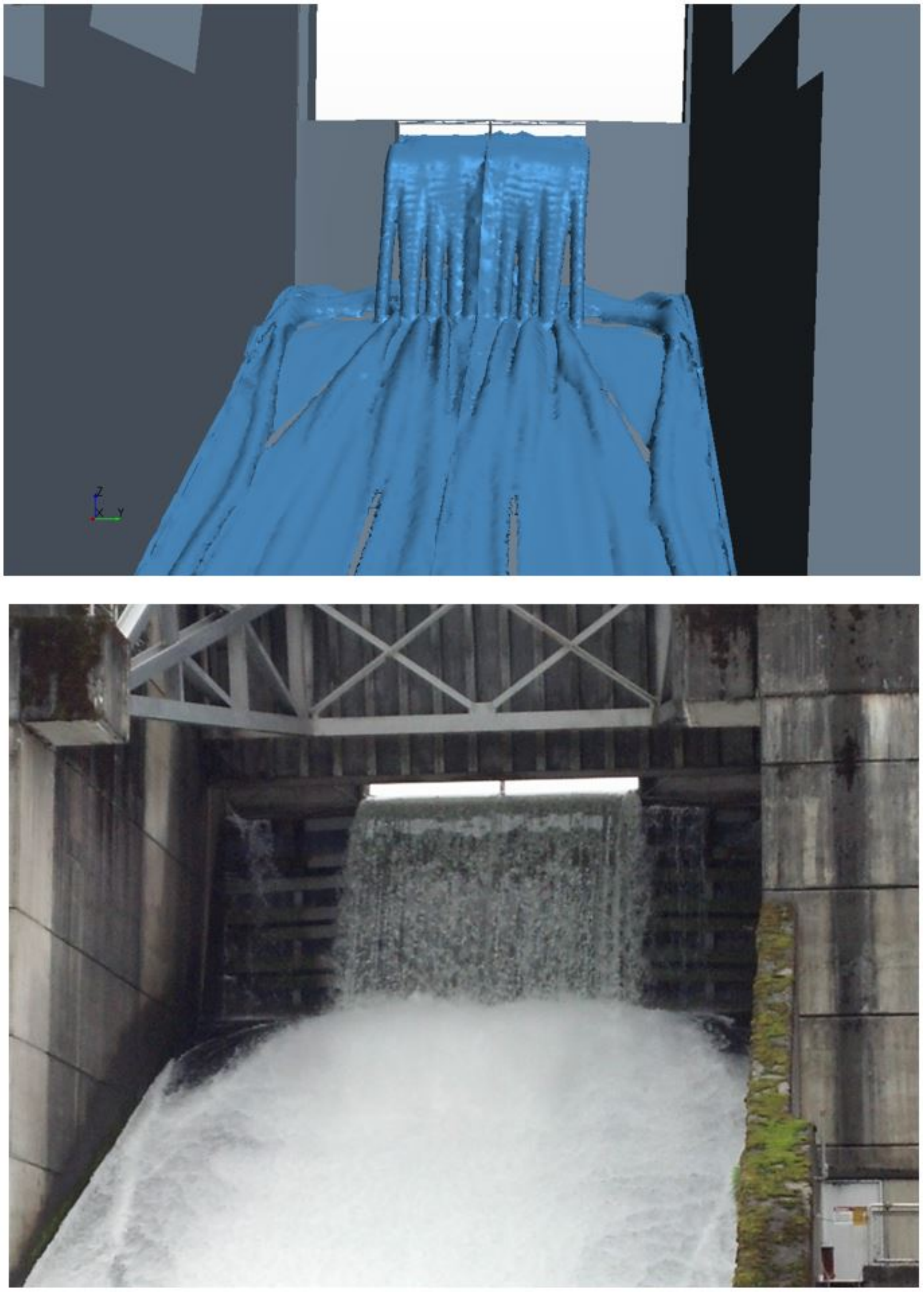


Figure 3-4 – Top**:** CFD of Existing Weir at Approximately 200 cfs;   Bottom: Existing Weir at Approximately 200 cfs

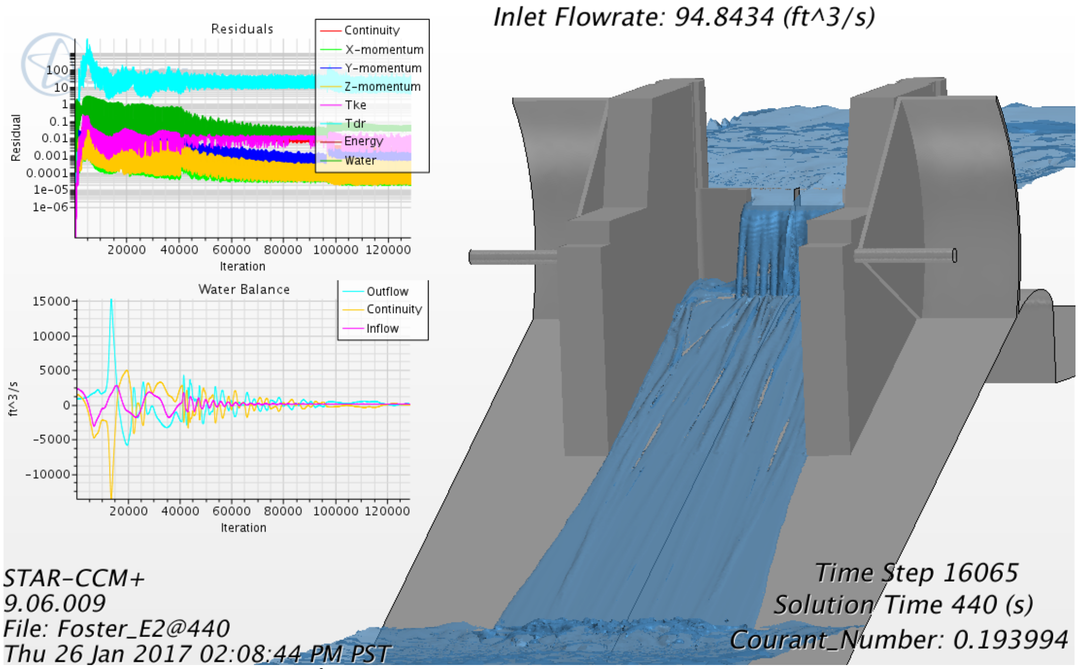


Figure 3-5 – Existing Weir CFD Run

The proposed new weir was modeled with CFD at heads of one, three, five, and seven feet to get a rating curve for the new weir and is shown in Table 3-2.

Head (ft)	Width (ft)	C	Q (cfs)
0	14	0	0
0.5	14	3	15
1	14	3	42
1.5	14	3	77
2	14	3	119
2.5	14	3.04	168
3	14	3.13	228
3.5	14	3.24	297
4	14	3.36	376
4.5	14	3.48	465
5	14	3.60	563
5.5	14	3.70	668
6	14	3.77	776
6.5	14	3.81	883
7	14	3.80	985

Table 3-2 – Proposed New Weir Rating Curve

The water depth (head) on the ogee surface at jet impact were investigated using the three, five, and seven foot of head CFD runs. They were then compared to the existing weir run at 200 cfs. All of the flow depths were taken at the same cross-section in the model, shown in Figure 3-6.

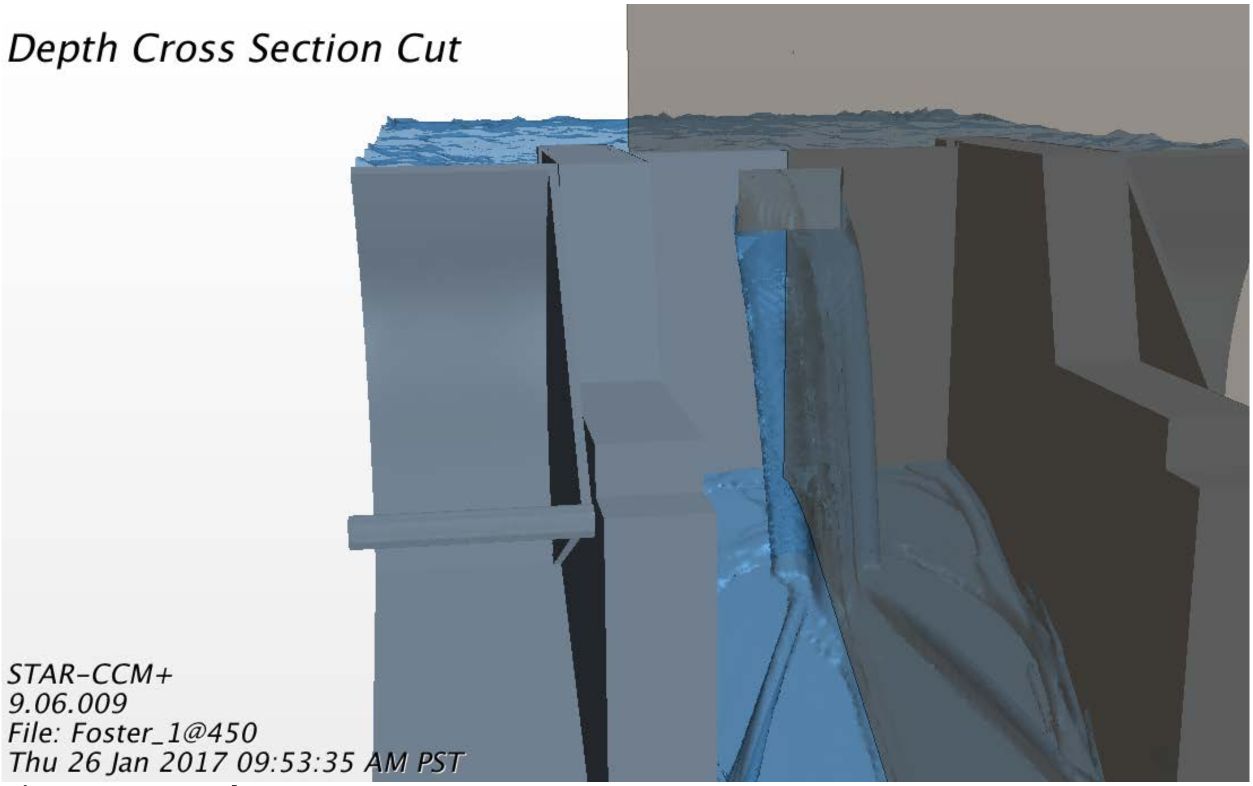


Figure 3-6 – Depth Cross Section Cut

As can be seen in Figure 3-7 below, the existing weir does not have much flow depth at jet impact, almost immediately spreading out as it flows down the ogee with nearly one foot of depth (Upper Left). The three foot of head CFD run mimics this closely, with a flowrate only 30 cfs higher than the existing run (Upper Right). Both of the five foot and seven foot of head runs have more depth as the jet disperses on the ogee, with around four feet and six feet of depth respectively (Lower Left and Lower Right). With the goal of operating the weir in the 500 to 800 cfs range consistently, the modeling shows that there should be more flow depth for juveniles as they pass downstream over the weir. The table below provides the operations shown.

Figure 3-8 Location	Weir Length (ft)	Water Depth Over Weir (ft)	Discharge (cfs)	Approximate Water Depth on Ogee Surface (ft)
Upper Left	22	~2.3	~200	~1.0
Upper Right	14	~3.0	~228	~1.0
Lower Left	14	~5.0	~563	~4.0
Lower Right	14	~7.0	~985	~6.0

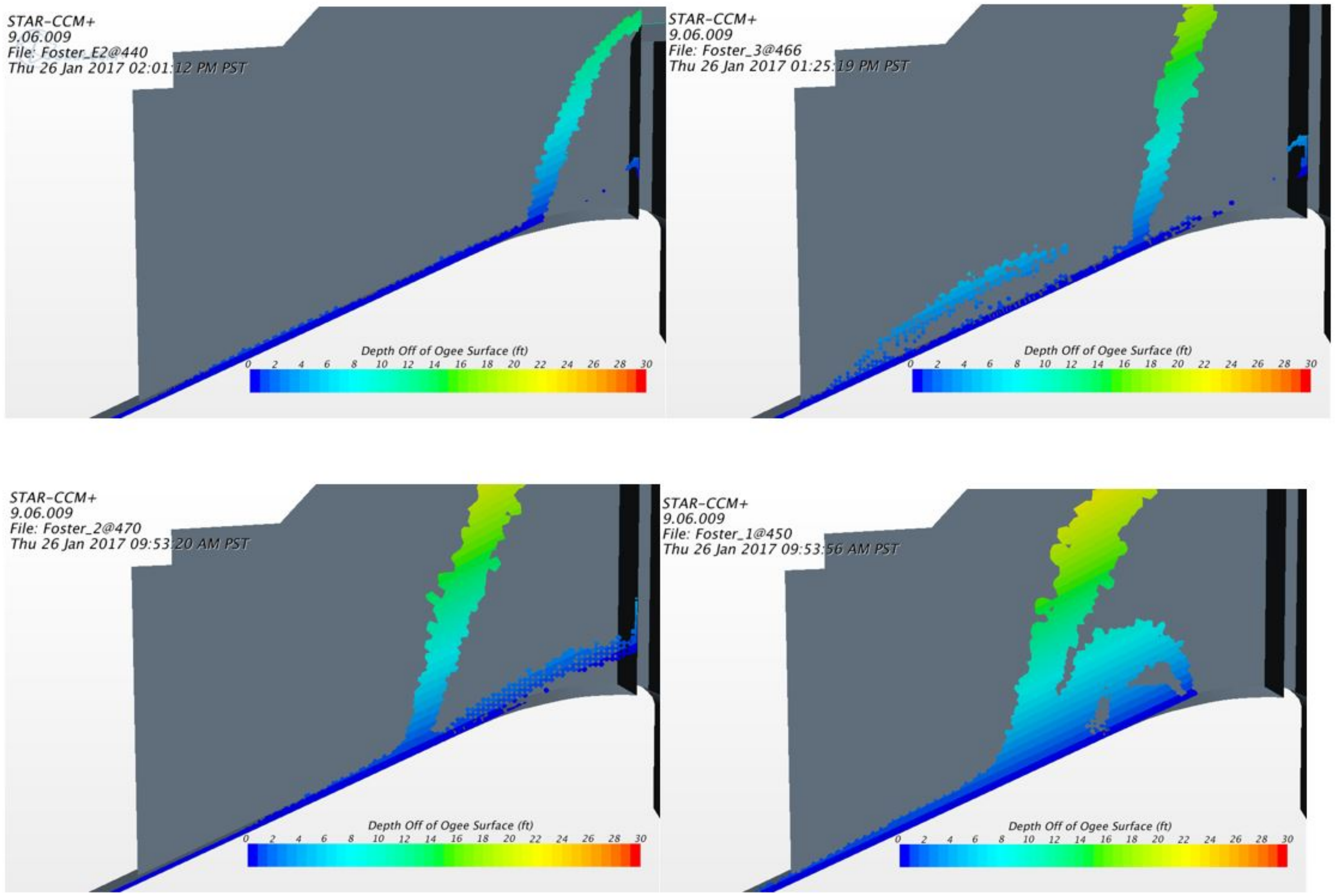


Figure 3-7 – Depth Cross Section Cut: Top left – Existing weir, 200cfs; Top right – Proposed Weir, 228 cfs; Bottom left – Proposed Weir, 563 cfs; Bottom right – Proposed Weir, 985 cfs

The acceleration of the water passing over the proposed weir, compared to that of the existing weir, was examined using particle tracking. For a qualitative analysis, 21 streamlines were placed starting in the middle of the weir crest at various depths in the flow column, and projected backwards in the model displaying velocity magnitude (by color) along those streamlines. Because acceleration is the change in velocity over a specified distance, a general comparison can be made between the images in Figure 3-9. This analysis was conducted for the existing weir passing 200 cfs (top screenshot), the proposed weir with three feet of head passing 228 cfs (middle screenshot), and the proposed weir with five feet of head passing 562 cfs (lower screenshot).

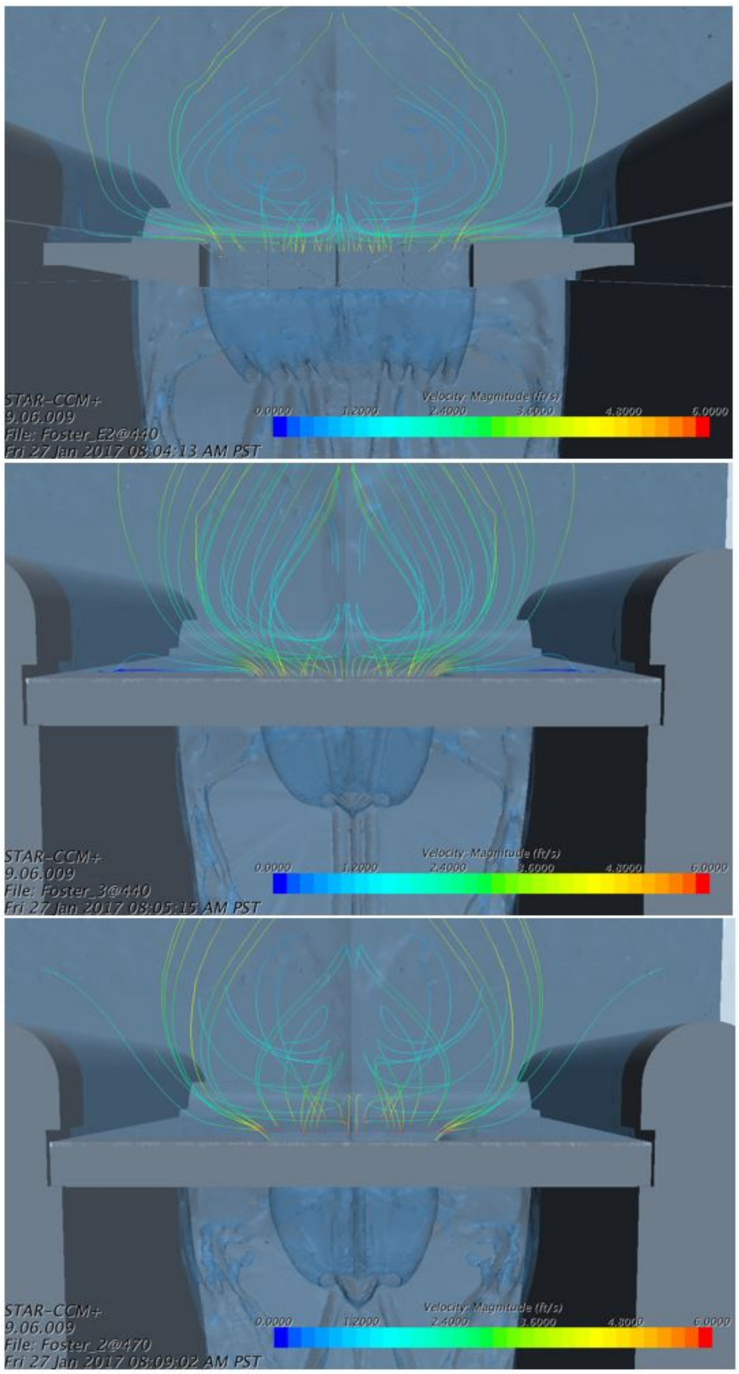


Figure 3-9 – Particle Tracking Analysis. (Top: Existing weir – 200 cfs, Middle: Proposed Weir – 228 cfs, Bottom: Proposed Weir – 562 cfs)

Due to the shaping of the sides of the proposed weirs, the flow path near the outer edges of the weir are less efficient than the existing sharp-edged weir. This results in better accelerations closer to the weir entrance as water moves around the sides. This could be beneficial as the juveniles have already been attracted by the velocity of the water moving towards the weir.

For a quantitative analysis, four streamlines were placed one foot above the weir crest for both the existing and proposed models, at set intervals away from the centerline of the weir. The graphs in Figure 3-10 are labeled as distance from the centerline of the weir, and include both velocity and acceleration information. The goal of shaping the new weir (on both the bottom and the sides) was to have better attraction velocity, while not accelerating too quickly into the weir flow to prevent juveniles from not using the passage route. The graphs show the existing weir in blue, the proposed weir with three feet of head in orange, and the proposed weir with five feet of head in green. Velocities and accelerations are graphed on the same axis due to the similarity in the magnitude of their values, with velocity data graphed above the acceleration data.

The main trends that are apparent in the graphs are that the proposed weir has higher velocities at the same distance upstream as the existing weir, while maintaining lower accelerations until getting closer to the weir. At one foot offset from the centerline of the weir (and one foot above the crest, as in all of the graphs) the velocity accelerated from 3.5 ft/sec to 5 ft/sec over a distance of 1.5 ft from upstream to downstream. With three feet of head over the proposed weir, the velocity starts out at 4.2 ft/sec in the same location and increases to 5.5 ft/sec at the crest. Looking at the accelerations for these locations, the existing weir accelerates near or above 1 ft/sec/ft in this entire range, yet the proposed weir never exceeds the 1 ft/sec/ft line before reaching the crest. As the tracking was moved away from the weir centerline, the acceleration of the proposed weir with three feet of head was larger at the weir crest than the existing weir, but higher velocities were reached further away from the weir. This would hopefully attract fish before they were able to sense the higher accelerations.

For the five foot of head run, velocity and acceleration data is shown farther away from the weir, as it reaches similar velocities to the other runs upstream of the weir because of higher flows. Near the centerline of the weir, the proposed weir with 5 feet of head accelerates near the same as the existing weir with less flow, in the same velocity vicinity. As the particle tracking was moved from the centerline of the weir towards the edge, the acceleration was less for the proposed weir than for the existing, in the same velocity range. This would suggest that juveniles would see high enough velocities for capture farther away from the proposed weir than the existing, while experiencing less acceleration in that area. More velocity cross-sections, both horizontal and vertical, have been included in Appendix A.

Overall, compared to the existing fish weir the 3D CFD modeling showed that if the proposed weir is operated in the 500 to 800 cfs flow range, it should provide more depth at impact with the ogee, as well as higher velocities in the forebay with less acceleration until it is closer to the weir crest. These features are an improvement over the existing weir, and should improve fish passage of juveniles migrating downstream.

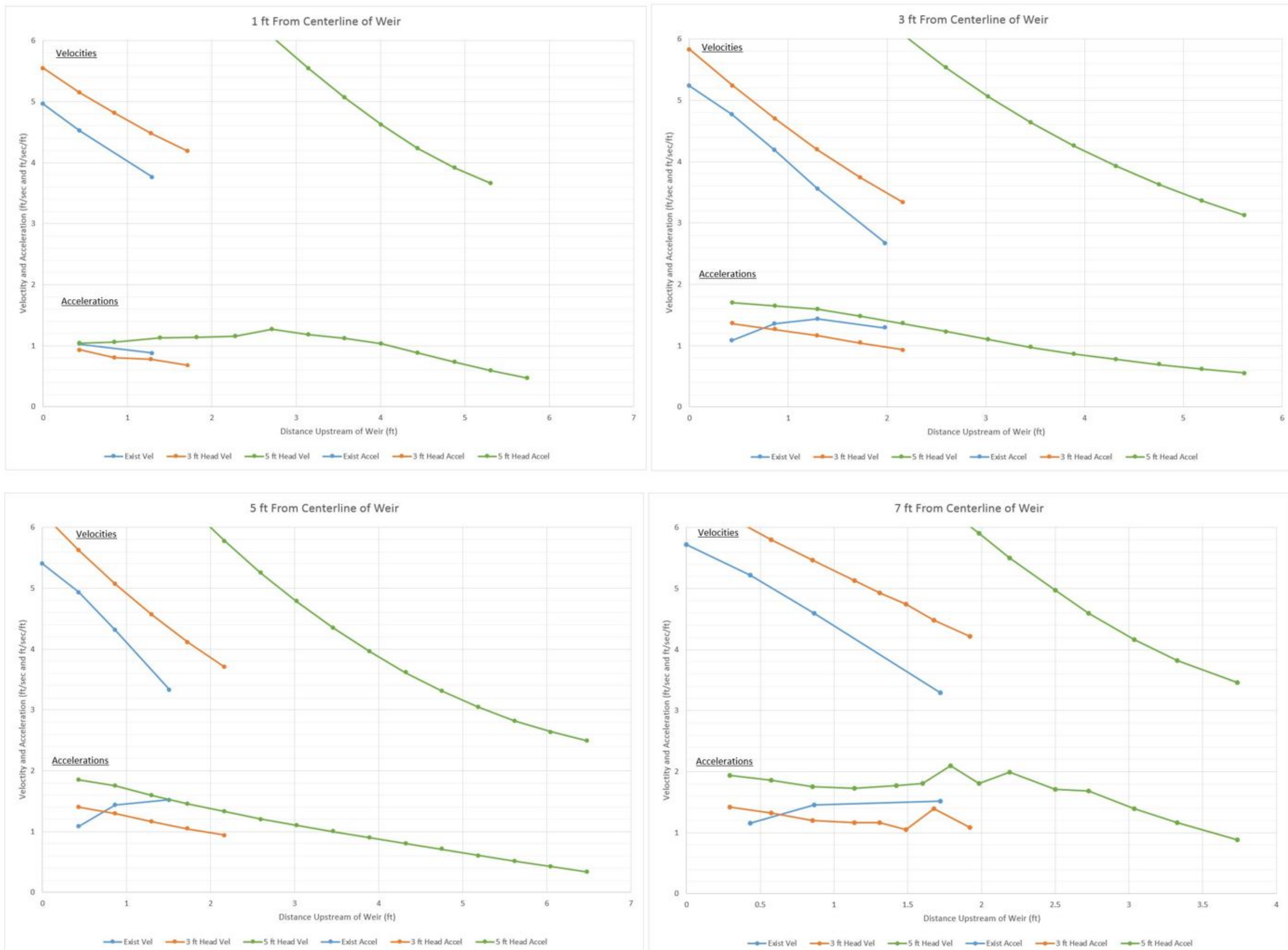


Figure 3-10 – Particle Tracking for Acceleration and Velocities at Set Locations from Weir Centerline, all One Foot above Weir Crest

3.3 REFERENCES

3. Hydraulic Criteria and Considerations Design References

The following references were used to establish hydraulic criteria and considerations and perform design calculations to analyze the alternatives.

- NMFS (National Marine Fisheries Service), 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.
- U.S. Army Corps of Engineers (USACE)/Bell, Milo C., 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria.
- USACE EM 1110-2-1602 Hydraulic Design of Reservoir Outlet Works. 1980. October.
- Corps of Engineers Hydraulic Design Criteria. 1987. November.
- USACE Portland District. 1968. Water Control Manual for Foster Lake. December.
- Federal Emergency Management Agency (FEMA). 1986. Flood Study, Linn County, Oregon Community Number 410136. September.

4. General Criteria and Considerations

The following general hydraulic considerations were applied to evaluation of the final alternatives considered and the more pertinent criteria are underlined below:

- Civil Works: The civil works of the passage facilities must be designed in a manner that prevents undesirable hydraulic effects (such as eddies and stagnant flow zones) that may delay or injure fish or provide predator habitat or predator access (NMFS 2011 Section 11.8.1.3)
- Evaluation: bypass facilities may be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved (NMFS 2011 Section 11.10.1.6).
- The bypass entrance and all components of the bypass system must be of sufficient size and hydraulic capacity to minimize the potential for debris blockage (NMFS 2011 Section 11.9.1.1).
- Bypass channel velocity: To ensure that fish move quickly through the bypass channel (i.e. the conveyance from the terminus of the screen to the bypass pipe), the rate of increase in velocity between any two points in the bypass channel should not decrease and should not exceed 0.2 ft/s per foot of travel (NMFS 2011 Section 11.9.1.8).
- Minimum velocity: The minimum bypass entrance flow velocity should be greater than 110% of the maximum channel velocity upstream of the bypass entrance. At no point must flow decelerate along the screen face or in the bypass channel. (NMFS 2011 Section 11.9.2.2).
- Weirs: For diversions greater than 25 cfs, weirs used in bypass systems should maintain a weir depth of at least 1 foot throughout the smolt out-migration period (NMFS 2011 Section 11.9.2.5).
- Design bypass flow: Design bypass flow should be about 5% of the total diverted flow amount, unless otherwise approved by NMFS (NMFS 2011 Section 11.9.3.7).
- Impact velocity: Maximum bypass outfall impact velocity, including vertical and horizontal velocity components, should be less than 25.0 ft/s (NMFS 2011 Section 11.9.4.2).

- Discharge and attraction of adult fish: The bypass outfall discharge into the receiving water must be designed to avoid attraction of adult fish thereby reducing the potential for jumping injuries and false attraction (NMFS 2011 Section 11.9.4.3).
- Water quality: The outfall flow should not cause the total dissolved gas (TDG) at the project to exceed accepted standards (110% saturation).

SECTION 4

STRUCTURAL DESIGN

4.1 GENERAL

This section discusses the structural design of a new fish weir, two 4 ft. tall stoplogs and one 2ft-4in tall stoplog. The weir will be installed in stoplog slots in Spill Bay 4, stacked on new and existing stoplogs. Fish passage and hydraulic requirements provided by the fish biologist and hydraulic engineer were the driving design criteria for the size and shape of the weir. The new stoplogs were sized to be stacked with existing stoplogs beneath the new weir in various configurations to set the weir at desired elevations for target flowrates and pool elevations.

The fish weir and stoplogs features are constructed of coated steel. This section covers references, basic data, loads, and structural design/analysis considerations for each feature.

4.2 EXISTING WEIR

Foster Dam has an existing spillway fish weir, shown in Figure 4-1, which was constructed in 1994 and intended to be temporary, but is still in use as of 2017. It is installed in the Spill Bay 4 stoplog slots, passing water from the forebay onto the spillway through a 22 ft. wide by 4 ft. tall opening with a vertical stiffener plate at midspan. The weir is roughly 47ft long by 4.5 ft. tall by 3.5 ft. wide. The new weir will be a permanent structure to replace the existing weir with improved fish attraction and survivability characteristics.

Figure 4-1: Existing Foster Dam spillway passage fish weir during operation.

4.3 BASIC DATA AND CONSTRAINTS

Hydraulic data and flow criteria detailed in SECTION 3 - HYDRAULIC DESIGN of this DDR are the basis for the new weir design, shape and size.

The new weir and stoplogs are dimensioned such that they can be deployed through the openings in the spillway bridge deck using a mobile crane. The weight of each separate structure is limited by the capacity of a mobile truck crane on the spillway bridge deck. According to the Willamette Valley Project, the maximum weight is 22,000 lb.

4.4 TERMINOLOGY

Figure 4-2 and Figure 4-3 are 3D renderings of the weir structural analysis model. They are labeled to show the various components that will be referenced later in this section.

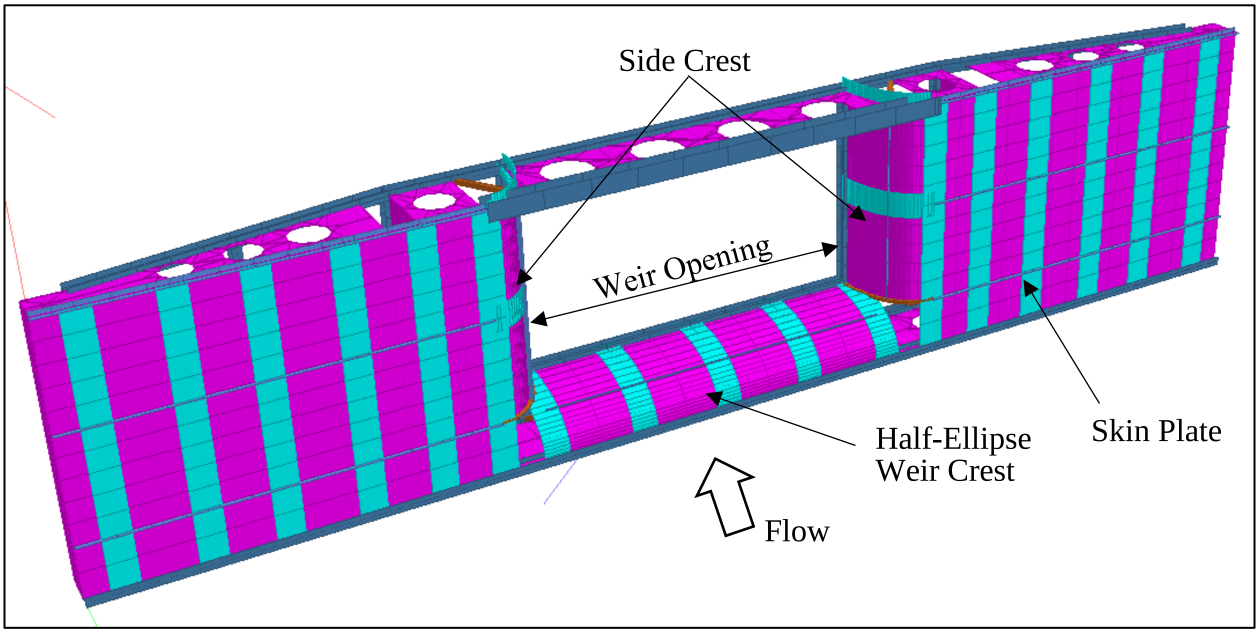


Figure 4-2: New fish weir front isometric of STAAD model rendering

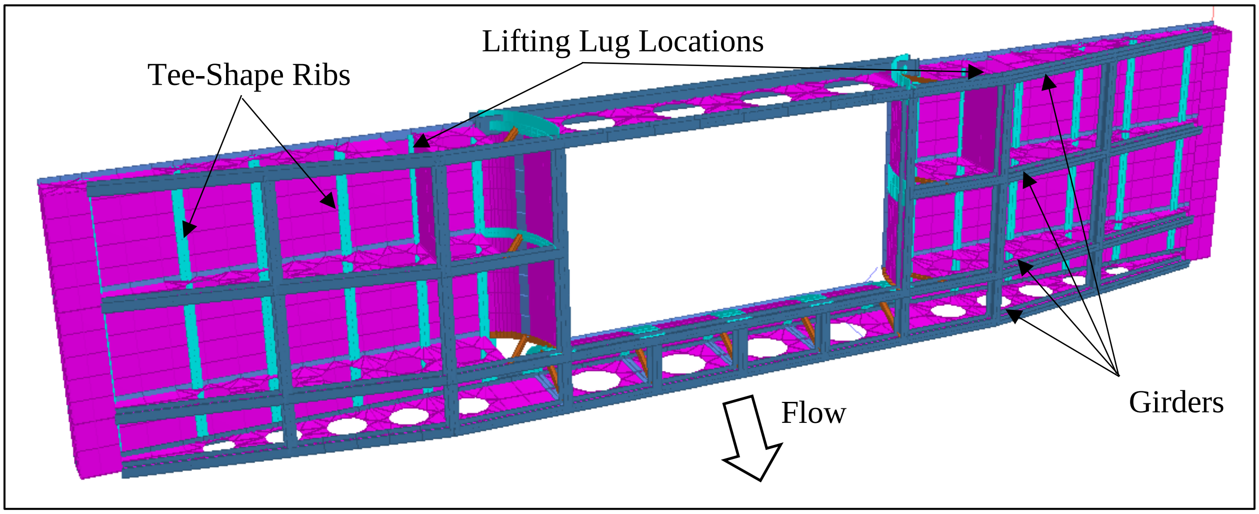


Figure 4-3: New fish weir rear isometric of STAAD model rendering

4.5 ENGINEERING PROPERITIES OF CONSTRUCTION MATERIALS

The engineering properties of construction materials are shown in Table 4-1.

Structural Carbon Steel and Structural Stainless Steel: Areas of use shown on drawings		
ASTM A709, Gr. 50, Zone 2	Structural Steel	fy=50,000 psi
ASTM A593, Type 316	Bolts	
ASTM A594, Type 316	Nuts	

Table 4-1 : Engineering Properties of Construction Materials

4.6 DESIGN LOADS

a. Dead Loads, D. Dead loads consist of the weight of metal, and fixed equipment. Steel unit weight of 490 lb/ft^3 (pcf) is based upon AISC values for structural plates and shapes.

b. Gravity Loads, G. Gravity loads including weight from mud and silt (M), ice weight (C) and snow load (S) are determined on a site-specific basis. Snow and ice loads will be negligible compared to hydraulic loads and will not be considered. Per 3.2.2 of ETL 1110-2-584, all features were designed for a 1 in. thick silt load with a density of 90-pcf.

b. Hydrostatic Loads, H_{S1}, H_{S2}. The hydrostatic loads against the structure include internal and external pressures for all design load conditions. The unit weight of water is assumed 62.4 lb /ft^3. With the spillway gate is closed there is balanced head against the weir and stoplogs. Opening the spillway gate creates unbalanced head. The hydrostatic load, H_{S1}, is the maximum net hydrostatic load that will ever occur. H_{S1} is an extreme overtopping event that occurs when there is 11 ft of unbalanced head against the weir. The weir should never be overtopped. The hydrostatic load, H_{S2}, is the design hydrostatic load during normal operation with 7 ft. of head over the weir crest. This is the upper end of normal operating range. Equivalent hydrostatic pressures at the bottom of the weir are as follows. H_{S1} is 0.686 ksf. H_{S2} is 0.562 ksf.

The design hydrostatic pressure for the 2ft-4in stoplog is the equivalent of 18 ft. of static head at the bottom edge. The 2ft-4in stoplog should always be deployed directly below the fish weir. However, designing for 18 ft. of head conservatively assumes a 5 ft. stoplog is incorrectly stacked between the 2ft-4in stoplog and the weir.

c. Buoyancy, F_B. Conservatively assuming full submersion of the weir, a buoyant force of 2.8 kips was used to design the structure. Seals are located on the upstream face of the weir; therefore, water should never submerge the weir except when the spillway gate is in the closed position. This eliminates the potential for buoyancy during operation.

d. Hydrodynamic Loads, H_d. Per CENWP-EC-HD, hydrodynamic loads are negligible for the design flowrates. Figure 4-4 shows pressure data collected from a Computational Fluid Dynamics (CFD) model for 7 ft. head over the weir crest. This figure shows total positive pressure against the upstream face of the weir is equal to hydrostatic pressure, implying there are no hydrodynamic load effects. Figure 4-5 shows uplift pressure for 7 ft. head over the weir crest. The uplift pressure occurs in finite areas and is negligible in magnitude. For these reasons, hydrodynamic loads were not considered in this design.

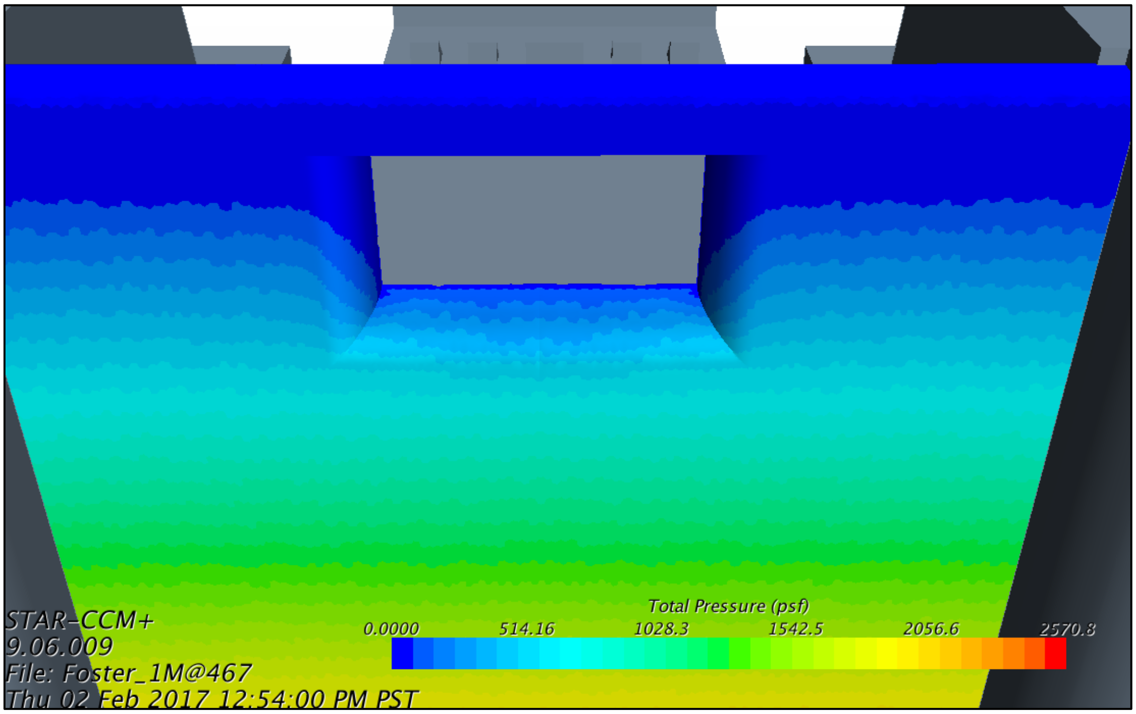


Figure 4-4: Positive hydraulic pressure distribution on the upstream face of the weir with 7ft of head over the weir crest (provided by EC-HD)

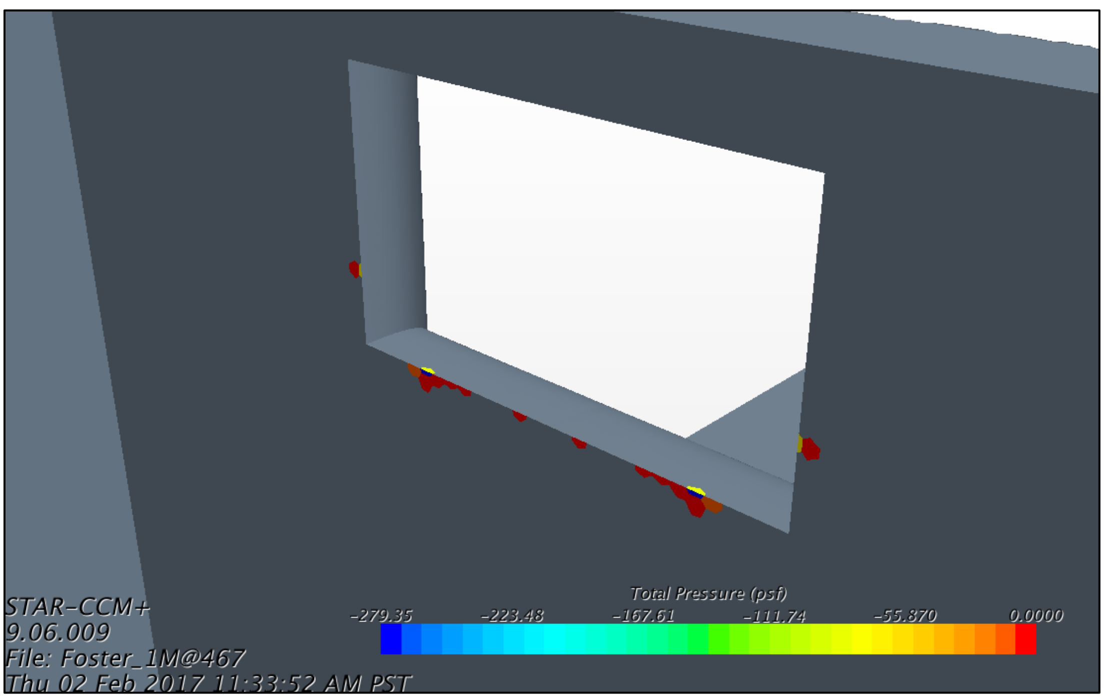


Figure 4-5: Negative (uplift) pressure distribution on weir viewed from downstream side (provided by EC-HD)

e. Wave Loads, W_a. Wave loads are calculated from a wave plus or minus two feet from the mean water surface (4 ft. total amplitude). Wave loading is taken as 2 ft. of extra hydrostatic head applied over the entire skin plate. This equates to 124 psf. wave pressure.

f. Uplift, U. Uplift could occur if an air bubble formed under the weir crest after the spillway gate closed and water rapidly filled between the gate and the stoplogs. An air bubble is not expected to form because the back and sides of the weir are open which allows air to escape.

As shown in Figure 4-5, uplift resulting from high water velocity over the weir is not significant and was not used in the design.

g. Debris Load, D_b. The debris load accounts for a floating debris mat impacting the structure. Portland District Hydraulic Design has determined a worst-case impact at Foster Reservoir from a floating debris mat 10 ft. deep moving at 7 feet per second (ft/s). The water velocity at the face of the weir is roughly 7 ft/s, so this is applicable to the weir as well. The load is applied to the skin plate at pool elevation as a 0.9 kip per linear foot (klf) distributed load.

Section 3.2.3.5 of ETL 1110-2-584 states that a load of 5 klf should be applied uniformly over a depth of 2 ft. depth across the HSS member exposed to ice. In this case the load will be reduced to 0.9 klf. because ice formation is not a concern at Foster Reservoir and Portland District has found this to be a more accurate load for Foster Reservoir. A debris load of 0.9 klf. has been used for tainter gate analysis throughout the Willamette Valley and is considered a reasonable debris load.

h. Glancing Impact, I. A glancing impact could occur from a log hitting the vertical skin plate or the weir crest plate as it passes through the opening.

The impact load was calculated per the procedure in C5.4.5: Impact Loads of ASCE 7-10. A 4000 lb log was used with an impact duration of 0.03s as recommended by ASCE. The log velocity was taken as half that of the water flowing over the weir to account for the log accelerating less quickly than the water.

The impact is considered glancing because a direct hit to the flat vertical portion of the skin plate is unlikely since debris will be swept toward the opening. A direct hit to the weir crest and side plates is unlikely since there will be 5 ft. to 7 ft. of head. Additionally, the half-ellipse shape will deflect direct contact.

The impact load is applied to critical members. The first location is the skin plate between ribs where it is unsupported. This load controlled the thickness of the skin plate. The other location is the girder spanning over the opening. This girder is exposed to passing debris and does not have bracing out-of-plane. The girder could take a horizontal hit from a log that would cause flexure about the strong-axis or it could take a vertical hit causing flexure about the girder's weak axis. This vertical hit would occur from a log passing through the weir and "see-sawing" through the weir, as shown in Figure 4-6. The back end of the log would tilt up and hit the girder from below. A vertical hit to the compression chord would cause out-of-plane bending moment and increase susceptibility to buckling. Impact load was applied at mid-span of the compression chord over opening.

Figure 4-5: Existing weir during operation with logs "see-sawing" through the opening and making contact with top truss.

i. Wind, W. Wind is an environmental load. Wind loads are small compared to hydrostatic loads. A blanket wind loading of 50 psf was used in this design. Wind load was only applied for the lifting/removal load cases since the weir will be otherwise submerged in water.

j. Seismic Loads, E. Seismic loads were specified based on the Operational Basis Earthquake (OBE). For structural design, the direction of seismic acceleration was assumed perpendicular to the axis of the dam. Seismic forces include mass inertial forces of the structure as well as inertial dynamic forces due to water. Per ETL 1110-2-584, Section 3.2.3.6, when a hydraulic steel structure (HSS) is submerged, the mass inertial forces due to structural weight, ice, and mud are insignificant when compared with earthquake-induced hydrodynamic loads and can be ignored. The new fish weir and stoplogs will be mostly submerged; therefore, the mass inertial forces were ignored. Inertial dynamic effects due to water were estimated using the Westergaard Equation (See ETL 1110-2-584, Eqn. 3-2).

k. Side Seal Friction, F_s. This frictional force results from contact between side seals and stoplog slots. It is a function of the coefficient of friction, which is assumed 0.5, the amount of hydrostatic force on the seal, and the amount of preset deflection that is set in the seal. Equation 3-2 from EM 1110-2-2702, Design of Spillway Tainter gates, is used to estimate side seal friction (Eqn. 4-1). However, side seal friction is not expected to exist since the weir will only be installed and removed under balanced head when the spillway gate is closed. For these reasons, side seal friction was not used in the design.

$$F_S = \mu_S Sl + \mu_s \gamma_w \frac{D}{2}\left(l_1 \frac{h}{2} + hl_2\right) \quad (4\text{-}1)$$

l. Fatigue Loads. Fatigue loads and limit state were considered, but not included in design since the new weir and stoplog will not be subject to cyclic loading. It is assumed that the weir will be operated continuously from October 1 through December 31 and again from February 1 through June 15 with a one-week break in April. The weir will experience a stress cycle when the spillway gate is operated. Opening and closing is considered one cycle, which would happen only three times per year. Therefore, per 4.1.4 of ETL 1110-2-584, the number of loading cycles based on the design life is n_{sr}, where:

n_{sr} = # of operations per year * years of design life

Therefore, n_{sr} = 3 cycles/year * 100 years = 300 cycles

Fatigue design is not required for less than 20,000 cycles of stress. Therefore, fatigue was not considered for the design of the weir and stoplog. If the gate were opened every day for 100 years during the period of operation the number of cycles would be:

n_{sr} = 220 cycles/year * 100 years = 22,000 cycles

This scenario exceeds 20,000 cycles by 9%. Since it is already unlikely that the spillway gate will be opened and closed each day of operation, fatigue will be neglected.

Stress cycling could also result from vibrations caused by turbulent flow through the weir. The hydraulic engineer stated that turbulent flow and vibrations are only likely at low flow rates (less than 300 cfs.) or during strong wind events when flowrate becomes variable. Both of these are rare load cases. At 300 cfs., the hydraulic loads would be low and the stress range would be low indicating fatigue is not a significant concern. Flow will be smooth at higher flow rates and vibration is not expected. Variable flow during high winds would also cause a very low stress range. For these reasons, fatigue due to vibrations was not considered in design.

Even though fatigue was not a design consideration, good fatigue detailing was incorporated into the design where possible. This generally entailed detailing to fatigue category C' or better per AISC 360-10, Appendix 3.

4.7 STRUCTURAL DESIGN AND ANALYSIS

All features of the Foster Downstream Fish Passage Project were designed to meet the strength, stability, and serviceability requirements outlined in applicable design references listed in Section 4.10 REFERENCES.

a. Hydraulic Steel Structures. All hydraulic steel structures are evaluated with the appropriate load factors as defined in ETL 1110-2-584 and the AISC Steel Construction Manual. These structures include the following:

- Fish Weir
- 2ft-4in Tall Stoplog
- 4 ft. Tall Sloplogs (2 Total)

b. ASD Design Basis.

The 2ft-4in stoplog was designed using ASD, per ETL 1110-2-584 Section 3.4, since LRFD load cases have not yet been developed for stoplogs.

ASD is a method of proportioning structures such that allowable stresses are not exceeded when the structure is subjected to specified working loads. An elastically computed stress is compared to an allowable stress as represented by:

$$f(\Sigma Q_i) \le R_n/\alpha\Omega \quad (4\text{-}2)$$

where:

$f(\Sigma Q_i)$ = elastically computed stress arising from the appropriately combined nominal loads

α = allowable stress modifier per ETL 1110-2-584

Ω = safety factor specified in AISC

R_n = nominal resistance

The allowable stress modifier, α, was taken equal to 0.9 because the new stoplog will be a Type C structure per 3.4.3.2.3 of ETL 1110-2-584. The stoplog will be a temporary structure not used for emergency closure and will be easily accessed for maintenance and inspection.

c. LRFD Design Basis.

The new fish weir was designed using Load Resistance Factor Design (LRFD).

LRFD is a method of proportioning structures such that no applicable limit state is exceeded when the structure is subjected to all appropriate design load combinations. The expression $\Sigma\gamma_i Q_{ni}$ is the *required strength* and the product $\alpha\phi R_n$ is the *design strength.* Load factors and load combinations for structural steel design are based on limit states of steel structures. All HSS members and connections shall satisfy the equation below for each limit state, unless otherwise specified. The basic safety check in LRFD may be expressed mathematically as:

$$\Sigma\gamma_i Q_{ni} \le \alpha\phi R_n \tag{4-3}$$

where:

γ_i = load factors that account for variability in loads to which they are assigned

Q_{ni} = nominal (code-specified) load effects

α = performance factor per ETL 1110-2-584

ϕ = resistance factor that reflects the uncertainty in the resistance for the particular limit state and, in a relative sense, the consequence of attaining the limit state

R_n = nominal resistance

The LRFD performance factor, α, was taken equal to 0.9 per 3.1.1 of ETL 1110-2-584. The weir will be easily removed for maintenance and inspection without causing disruption to larger projects and it will not be placed in salt/brackish water.

d. Structure Classification.

The fish weir is classified as a Hydraulic Steel Structure (HSS) with fracture critical members (FCM), per ER 1110-2-8157. All tension chords are fracture critical since their failure would result in partial or total collapse of the structure. All welds to the tension chords are also fracture critical. Web/diaphragm plates between chords are considered fracture critical because they are attached to an FCM with an attachment dimension greater than 4in in a direction parallel to the tensile stress in the tension chords (ER 1110-2-8157, 7.b.1).

In accordance with ER 1110-2-8157, the 2ft-4in stoplog is classified as a Hydraulic Steel Structure with FCMs. The tension flange is an FCM because its failure would result in total or partial collapse of the structure. The web and the weld attaching the web to the tension flange are also considered FCMs because they are attached to the tension flange with an attachment dimension exceeding 4 in. in a direction parallel to the tensile stress in the tension flange (ER 1110-2-8157, 7.b.1).

FCMs are designed and fabricated in accordance with ETL 1110-2-584, Ch. 4.

e. Design Life. In accordance with 2.1.5 of ETL 1110-2-584, the new fish weir, 2ft-4in tall stoplog, and 4 ft. tall stoplogs have a design life of 100 years.

f. Seismic Analysis. Earthquake loads are based on the Operational Basis Earthquake (OBE) per ETL 1110-2-584, Section 3.2.3.6. The OBE is an earthquake that can reasonably be expected to occur within the service life of the project, that is, with a 50% probability of exceedance during the service life. (This corresponds to a return period of 144 years for a project with a service life of 100 years.) The associated performance requirement is that the project functions with little or no damage, and without interruption of function. The OBE peak ground acceleration (PGA) is site specific and was determined from the Regional Seismic Hazard Assessment, Table 4-2.

	50% PE in 100 years 144 year return (OBE)	**2% PE in 50 years 2475 year return (MCE based on IBC 2006)**
PGA	0.0298g	0.2702g

Table 4-2: Foster Dam, Probabilistic Ground Motion

PE = Probability of Exceedance
PGA = Peak Ground Acceleration
OBE = Operational Basis Earthquake
MCE = Maximum Credible Earthquake

The new fish weir and stoplogs were designed for the OBE rather than the maximum credible earthquake (MCE). For critical structures, it is conservative and recommended to design for the MCE. However, for hydraulic steel structures, ETL 1110-2-584 recommends design for the OBE. The weir will be designed for the OBE since it is not considered a critical HSS.

A brief analysis was performed for the MCE, however, it significantly increased the size of structural members and the allowable weight of the weir was exceeded. For these reasons, it was decided to take the less conservative approach and design for the OBE rather than the MCE.

The inertial dynamic forces due to water are estimated by the Westergaard equation and the PGA for the OBE. Westergaard's equation calculates an equivalent pressure distribution on the face of the dam due to inertial hydrodynamic forces. The Westergaard equation is shown below.

$$p = \frac{7}{8}\gamma_w a_c \sqrt{Hy} \qquad (4\text{-}4)$$

Where:

P = hydrodynamic pressure at depth y, from the water surface in psf

a_c = horizontal ground acceleration in units of g.

γ_w = unit weight of water.

H = depth of forebay against dam.

Y = depth from water surface

PGA values are developed for rigid structures set directly on the ground. Whereas the new fish weir will be installed at the top of relatively flexible spillway piers, which will amplify accelerations. For this reason, a dynamic amplification factor was applied to the PGA per EM 1110-2-6053, Section 7-2. The DAF is based on the natural period of the structure. To be conservative the maximum DAF, 2.5, was used for design of the fish weir.

g. Serviceability. Deflections under service load conditions must not impair the serviceability or operability of the weir or stoplogs. The primary serviceability concerns are that bulb seals maintain their seal and that the weir can be deployed/removed without binding. Deflection of key elements shall be limited to those set forth in Table 4-3. Dead, hydrostatic and hydrodynamic loads were applied at service level for the serviceability load case. These criteria are severe but ensure rigidity of the structure.

Element	**Max Allowable Deflection**
Frame members for weir trusses and main girders for stoplog	L/600
Skin Plate (ETL 1110-2-584, F4.3.1)	0.4 * Plate thickness

Table 4-3: Deflection Criteria

h. Flotation. The weir and stoplogs were designed to not exceed a factor of safety of 2.0 against flotation due to buoyant forces.

i. Finite Element Computer Analysis. Structural members and components were evaluated using STAAD.Pro V8i, a finite element analysis computer software. The structural geometry of the new Foster Downstream Fish Passage Weir is shown in Figure 4-2 and Figure 4-3.

Structural calculations, STAAD models and member data can be found in the appendix of this DDR.

4.8 FEATURES

Load combinations, criteria, and other design information for each of the structural features are described below.

a. Fish Weir. The new fish weir will be installed in existing spillway stoplog slots and will pass water onto the spillway through a 14 ft. x 8 ft. opening. The new weir is similar in design to the existing weir except it is taller and the opening is narrower. Existing 4 ft. and 5 ft. stoplogs along with new 2ft.-4in. and 4 ft. stoplogs will be deployed below the fish weir to set it at elevations required to pass desired flowrates during high and low pool.

The structural system consists of four horizontal girders composed of W-sections, WT-sections and plate. The girders are spaced tighter near the bottom of the weir where hydraulic forces are greatest. The 3/8 in. skin plate is braced horizontally and vertically by tee-shaped ribs. The stem of the tee members are welded to the skin plate, which will act as an effective flange. The total structural weight of the new design is roughly 22 kips. Diaphragm plates were used between chords of the girder. A truss system would require large gussets in tight spaces and complicated welding. To save weight, the diaphragm plates were castellated in the middle portion of the weir, away from the high-shear areas at the end-supports.

The weir crest and side crest plates, described by Eqn. 4-5 are shaped in a half-ellipse to achieve desired flow pattern, velocity and fish attraction characteristics. The opening is 8 ft. tall to accommodate an upper operating head of 7 ft. over the weir crest with 1 ft. of freeboard.

$$\frac{X^2}{9\,\text{ft}}+\frac{Y^2}{4\,\text{ft}}=1 \qquad (4\text{-}5)$$

The weir is similar in function and load scenarios to a bulkhead. ETL 1110-2-584, Appendix G advises that bulkheads be designed similar to vertical lift gates. The new weir design utilized load cases similar to a vertical lift gate. Load Case 3 for vertical lift gates accounts for loads when the gate is full open, and does not apply to the new weir. Load Case 4 accounts for jamming of the gate during opening/closing. This load case was not evaluated since the weir and stoplog will be removed/installed by a project crane, which is a manned operation.

(1) Material Design. The entire weir is constructed of painted steel conforming to ASTM A709, Gr. 50, Zone 2. Bulb and crush seals are rubber. Seal keeper bolts and nuts are Type 316 stainless steel.

(2) Hydraulic Criteria. Under normal conditions, the weir will pass roughly 530-cfs. Hydrostatic head should reach no higher than 7 ft. from the top of the weir crest, which corresponds to 985 cfs. flow. Low pool elevation is 613.0 ft. and high pool elevation is 637.0 ft. Stoplogs will be stacked in various configurations below the new fish weir to achieve desired head over the weir at both low and high pool elevations.

(3) Fit-Up Requirements. The bottom of the new weir is dimensioned to fit-up with the top of new and existing stoplogs to ensure proper transfer of gravity loads and to minimize flow-induced vibrations. Lifting points on the weir are dimensioned to match stoplog as-built drawings so as to fit-up with the existing lifting beam.

It was noted that the bottom seal at the ends of the existing fish weir is notched to fit-up with the 8 in. x ¾ in. ogee sill plates (reference Detail B on as-built drawing FSD-2-112). An identical plate was bolted to the top of existing 5 ft. stoplog #10. Because of this notch, the existing fish weir can only fit-up with stoplog #10 and the ogee. The new fish weir will never be installed directly on the ogee, so the bottom seal will not be notched for the sill plate. The bolted faux sill plate on stoplog #10 should be removed.

(4) Seals. Seals will be arranged to match the existing weir. Rubber bulb seals running vertically will be used to seal the weir to downstream face of the stoplog guide slots. A rubber crush seal will be installed on the upstream bottom edge of the weir to fit-up with the stoplog seal plate below. Seals will be fastened to the weir using painted steel keeper plates and stainless steel countersunk flat head bolts conforming to ASTM A593, Type 316. Nuts will conform to ASTM A594, Type 316. The crush seal will not be notched to fit the faux sill plate, as discussed in item (3) above.

(5) Center of Gravity. The center of gravity of the weir is downstream of the lifting points such that when the weir is stacked on the stoplogs, it will land on its downstream side first and then roll forward onto the crush seal. This ensures that the faces of the weir and stoplogs are in a common plane and seal properly. The distance from the center of gravity to the lifting points in the horizontal direction was matched to that of existing 4 ft. stoplogs.

(6) Weight Limitations. The weight of the new fish weir is limited by the lifting capacity of the truck-crane on the spillway bridge deck overhead. The weir is designed to weigh less than 22,000 lb., the weight of existing 4 ft. stoplogs. This load is within the limits of the truck crane and the existing lifting beam.

(7) Coating System. The coating system for the weir considers the guidelines of EM 1110-2-3400. The primary considerations for the weir painting system are as follows:

a. Immersion. Coating should exhibit low moisture vapor permeability (MVP) and water absorption rates. Industry practice generally has found that, the lower the moisture vapor transfer rate, the better corrosion protection the coating provides.

b. Wet/dry cycling. Strong adhesion, low moisture vapor transfer rate, and good corrosion and undercutting resistance.

c. Thermal Cycling. Coating should have the ability to expand and contract with the structure due to normal atmospheric weathering.

d. Ultraviolet Exposure. Coating must endure daily ultraviolet (UV) exposure without losing film, chalking, losing gloss, fading or becoming brittle. Acrylic aliphatic polyurethanes tend to remain stable with UV light exposure while two-component epoxy systems do not.

e. Impact/Abrasion. Coatings subjected to abrasion must have adequate hardness; formulations of epoxies and polyurethane coatings provide good abrasion resistance.

The coating system follows the coating requirements outlined in Unified Facilities Guide Specification (UFGS) Section 09 97 02: Painting Hydraulic Structures. Recommended painting systems for immersed structures that experience moderate to high velocity flow and some atmospheric exposure include System No. 5-D, 5-C-Z, and 5-E-Z from Specification Section 09 97 02. These vinyl-coating systems are highly resistant to abrasion from debris, ice and suspended particulates in water. System 5-E-Z will be used for the fish weir and new stoplogs.

The paint color will be gray to match existing stoplogs and promote fish attraction and passage.

(8) Dimensional Limitations. Stoplog openings in the bridge deck are 4.5 ft. wide and require a 2 in. minimum clearance on each side of the weir for ease of installation. The weir is designed to fit through existing bridge deck openings.

Transportation was considered when designing height of the weir. When transporting the weir to and from the boneyard, the truck must pass under an overhead crane structure on the spillway bridge deck. Total clearance is limited to 14 ft. The current truck bed is 5 ft. high. The existing truck would not be able to pass under the crane with the 10.5ft weir. The concrete crane structure was part of the original fish passage system but is no longer used by the project. The crane will be demolished through a separate contract so that the weir can be transported to and from the boneyard on a standard truck.

(9) Load Cases. The weir structure was designed to resist the most severe of the load conditions listed below. It is assumed that the weir will experience similar loading conditions to a spillway lift gate. The following load cases were developed and adapted using ETL 1110-2-584, Appendix E: Spillway Crest Lift Gates:

Load Case 1: Normal operating condition where the weir has maximum normal operating head of 7 ft. over the weir crest. Hydrodynamic, wave, debris, and buoyancy load effects are considered for this scenario. This condition applies to both high and low pool elevations.

$1.2D + 1.4H_{S2} + 1.4F_B + 1.6D_B + 1.6I$ (Usual)

$1.2D + 1.4H_{S2} + 1.4F_B + 1.6W_A$ (Usual)

Load Case 2: Lifting/removal load case. The spillway gate is closed, with no flow and 7 ft. of head. The weir will not be deployed or removed under differential head, and therefore side seal friction is neglected. The load from the lifting beam is applied at lifting points. Weight of weir and gravity/silt loads oppose the lifting force. The buoyant force is factored down to be conservative. The second equation occurs once the weir has been lifted above the water surface and is exposed to wind pressure. This load case occurs a few times per year when adjusting stoplogs to transition from low to high pool and vice versa.

$1.2D + 1.6G + 0.9F_B$ (Usual)

$1.2D + 1.6G + 1.3W + 0.9F_B$ (Usual)

Load Case 3: Seismic load case where a hydrodynamic pressure force is applied normal to the face of the weir from seismic inertial dynamic forces due to water. In this case, it is assumed that the weir has maximum normal operating head of 7 ft. since it is unlikely the upper limit of the normal operating head would be exceeded at the time of the design earthquake. Earthquake loads are based on the OBE.

$1.2D + 1.4H_{S2} + 1.4F_B + 1.0E$ (Extreme)

Load Case 4: Overtopping load case where the weir is operated with head exceeding height of weir and water is spilling over the top of the entire weir. This load case is extreme since operations personnel should not operate the weir outside of its designed operating range.

$1.2D + 1.4H_{S1} + 1.4F_B$ (Extreme)

Serviceability: Normal operating condition used to check deflection and flotation criteria. Loads will be applied at service level.

$D + H_{S2} + F_B$ (Usual)

(10) STAAD Model. An image of the weir STAAD model is shown in Figure 4-7 and 3D renderings of the model in Figure 4-2 and Figure 4-3. The weir was modelled as a combination of beams and plates.

For Load Cases 1, 3, 4, and serviceability (the horizontal load cases) the weir was assumed simply supported horizontally between the spillway piers on either end. Compression-only springs were created at each node along the bottom upstream edge to simulate the weir resting on top of the stack of stoplogs. For Load Case 2 (the lifting load case), the weir was modelled as simply supported between spillway piers. To simulate lifting, the weir was pinned at lifting lugs and vertical loads were applied.

Connections between members are assumed pinned. Tee-sections were used as ribs along the skin plate. To model the effective flange action of the skin plate in STAAD, the tee-sections were modelled as singly symmetric I-sections. The density of the skin plate was scaled down to account for the added flanges on the tee-sections.

To simplify the STAAD modelling process, plates were not added around the intersection between the side and bottom weir crests since it would involve forming a 3D ellipse. While this does not exactly model the behavior of weir, it is a close approximation. Framing members were selected conservatively to compensate.

Loads were combined and applied to the model using a repeat load, which applies loads concurrently rather than one at a time and summing the resultants. An LRFD steel code check was applied to all beams according to AISC 360-10. Unity checks were used to select members sufficient for the design loads. Plate stress was checked against the maximum allowable for 50-ksi plate. Skin plate thickness is governed by a glancing impact from a floating log.

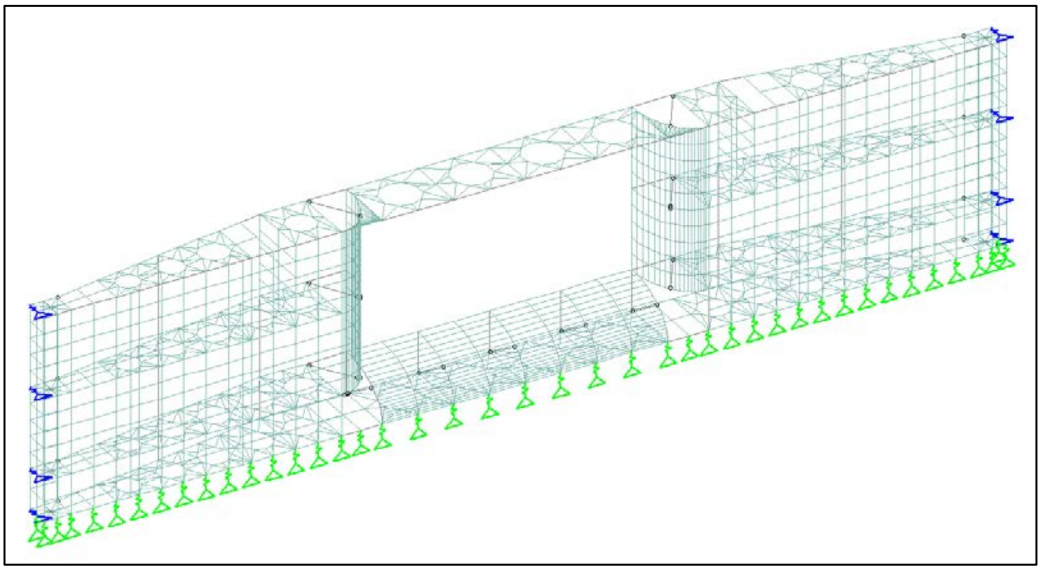


Figure 4-6: Isometric showing STAAD model of the weir for Load Cases 1, 3, and 4

b. 2ft-4in Tall Stoplog. A new 2ft-4in tall stop log was designed for use in the spillway stoplog slots above an existing 5 ft. stoplog or 4 ft. stoplog. In accordance with ETL 1110-2-584, Appendix G, the stoplog was designed using ASD methods because LRFD load cases have not yet been developed for stoplogs and bulkheads.

The new 2ft-4in stoplog was assumed to act as a simply supported beam spanning between spillway piers. It has a single girder with a ¾ in. thick skin plate acting as an effective flange, ½ in. thick web plate and 1in. thick tension flange. Similar to existing 4 ft. stoplogs, the 2ft-4in stoplog is deeper at midspan to account for higher bending moment. The stoplog tapers back to a depth that fits into the stoplog slot. The section at midspan was designed for maximum flexural loads. The section at the supports was designed for maximum shear.

Transverse stiffeners spaced along the length of the stoplog on both sides of the web provide greater shear capacity and brace the skin plate and web out-of-plane. A cross section at mid-span of the stoplog is shown in Figure 4-8. An isometric view is shown in Figure 4-9.

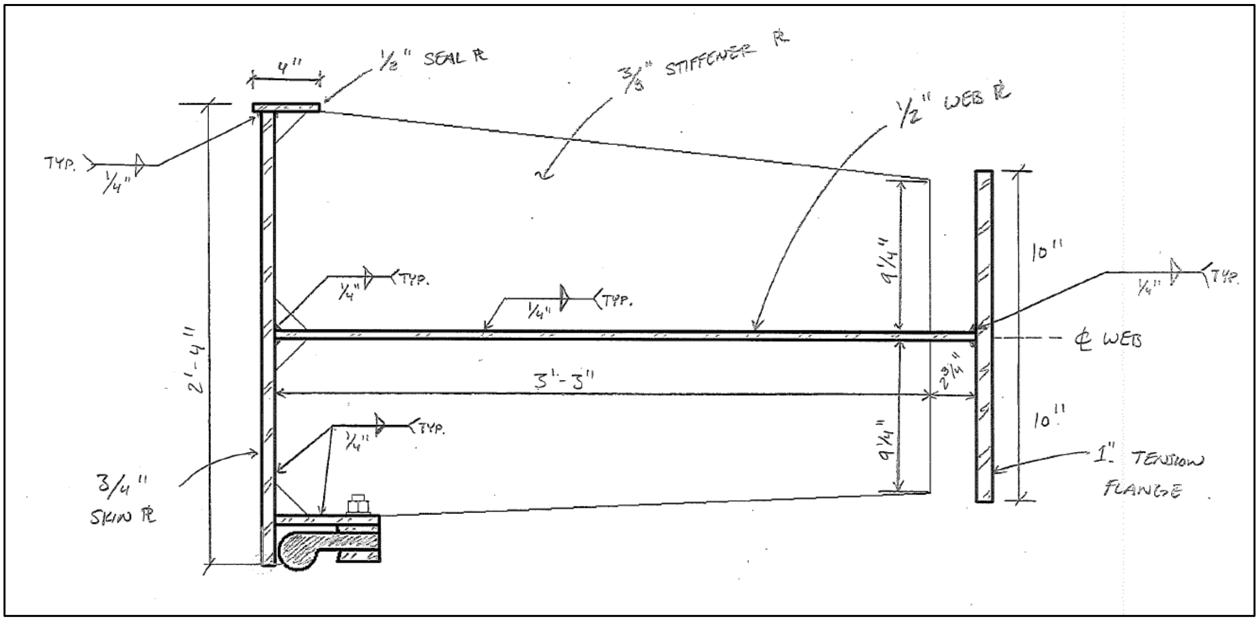


Figure 4-7: Cross-section of the 2ft-4in stoplog at midspan

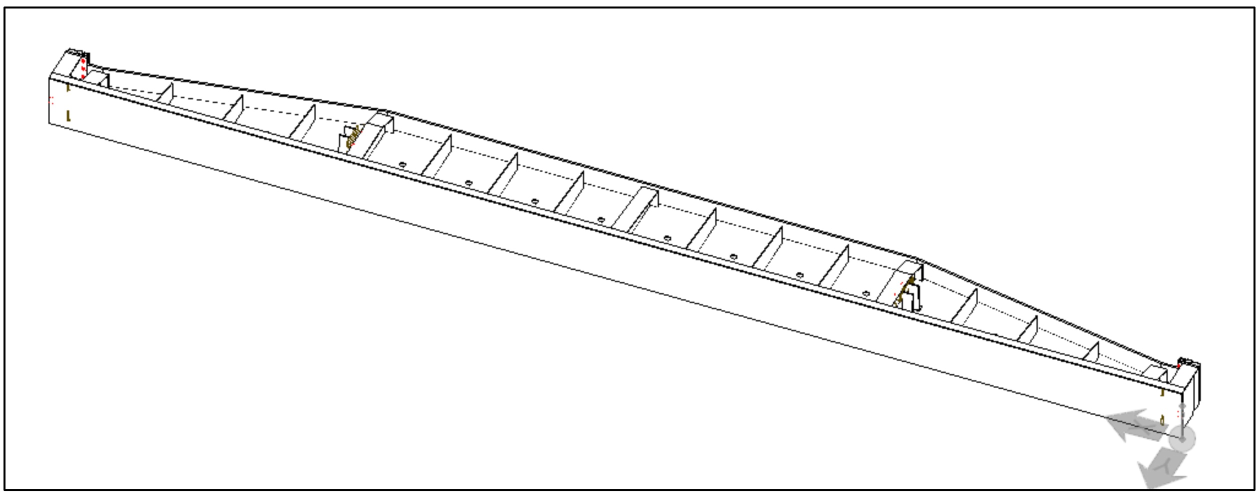


Figure 4-9: Isometric of the new 2ft-4in stoplog.

(1) Material Design. The entirety of the new stoplog is constructed of painted steel, conforming to ASTM A709, Gr. 50, Zone 2. Bulb seals are rubber. Seal keeper bolts and nuts are Type 316 stainless steel.

(2) Hydraulic Criteria. The new stoplog will be installed above existing 5ft and 4ft stoplogs to provide 4.83 ft. of head over the new fish weir for 530 cfs. flow or 3.5 ft. head for 300cfs flow per hydraulic design requirements.

(3) Fit-Up Requirements. The new stoplog was dimensioned to fit-up with the top of existing 4 ft. and 5 ft. stoplogs to ensure proper transfer of loads. The lifting lug system shown in as-built drawings for existing 4 ft. stoplogs were matched on the new 2ft-4in stoplog to ensure fit-up with the existing lifting beam. The stoplog was sized to fit through the 4.5 ft. wide openings in the bridge deck intended for stoplog deployment.

(4) Seals. Seals are arranged to match existing stoplogs. A bulb seal runs along the upstream bottom edge, sealing to the stoplog below. A seal plate is provided on the upstream top edge to seal against the weir seal above. A bulb seal runs vertically along the downstream face of the end plate to seal against the downstream face of the guide slot. Seals are affixed to the stoplog with painted steel keeper plates and stainless steel flathead countersunk bolts. Bolts conform to ASTM A593, Type 316 and nuts conform to ASTM A594, Type 316.

(5) Center of Gravity. The stoplog is designed such that the center of gravity is downstream of the lifting points so that when the stoplog is stacked on top of other stoplogs, its downstream side lands first and the log will roll forward onto its seal. This ensures that all stoplogs are in the same plane and seal properly. The distance from the center of gravity to the lifting points in the horizontal direction was matched to that of existing 4 ft. stoplogs.

(6) Weight Limitations. Total weight of the new stoplog is limited by the lifting capacity of the truck-crane on the bridge deck overhead and must not exceed 22,000 lb, the weight of existing stoplogs.

(7) Coating System. The new coating system for the stoplogs will follow the guidelines of EM 1110-2-3400. The stoplog will use 5-E-Z painting system to match the weir.

(8) Load Cases (ASD).

Stoplog Installed Load Cases. These are load cases where the stoplog is installed in spillway guide slots under the new weir during operation. These load cases were mostly significant to the flexural and shear design in the direction normal to the axis of the dam.

Load Case 1:

$D + H_S + M + D_B + F_B$ (Usual)

Load Case 2:

$D + H_s + G + D_B + W_A + F_B$ (Usual)

Load Case 3:

$D + H_s + G + D_B + I + F_B$ (Unusual)

Load Case 4:

$D + H_s + G + D_B + E + F_B$ (Extreme)

Lifting Load Cases. These are load cases where the stoplog is being installed or removed from the spillway guide slots using a mobile crane from the spillway bridge deck. This manned operation will always be performed under balanced head. Jamming in the slots and side seal friction are unlikely.

Load Case 5:

$D + F_B + D_{BV}$ (Usual)

c. <u>4ft Tall Stoplogs.</u> Two new 4 ft. stoplogs are needed to achieve target flows through the weir. In 2009 4 ft. stoplogs were supplied to Foster Dam as part of contract W9127-09-C-0008. The same design will be used for the new 4 ft. stoplogs. Figure 4-10 and Figure 4-11 show an isometric and section at midspan of new 4 ft. stoplogs.

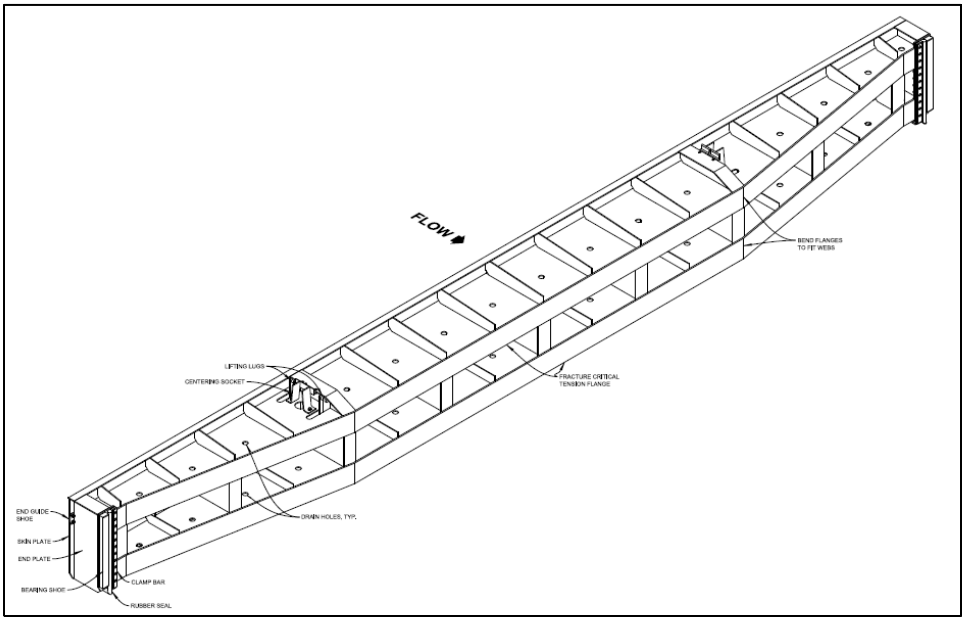


Figure 4-10: 4 ft. stoplog isometric.

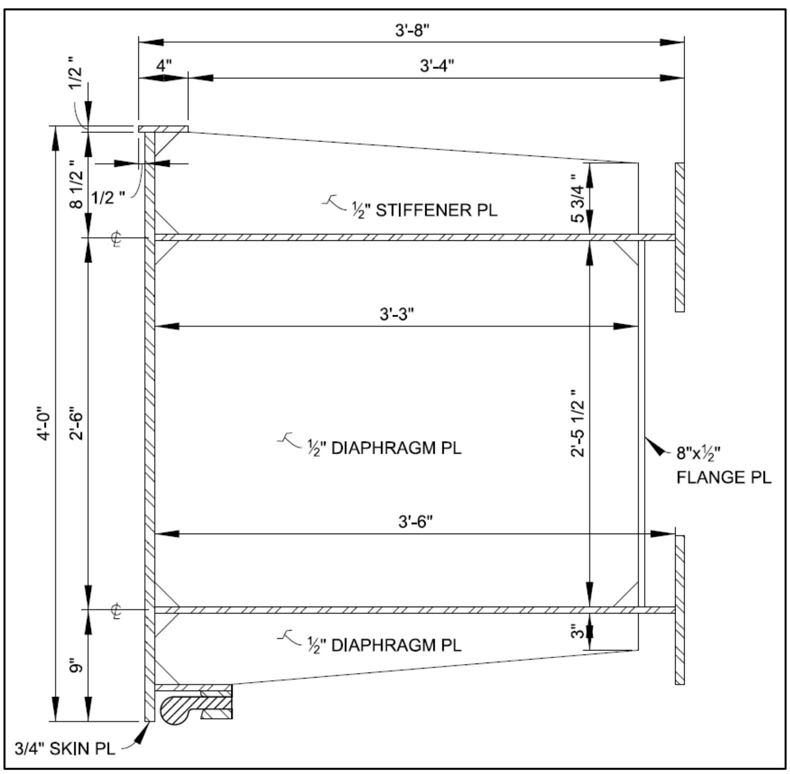


Figure 4-11: 4 ft. stoplog cross-section at midspan.

d. Lifting Beam. The existing lifting beam was recently evaluated in a “Below the Hook” assessment and was found to be acceptable and no modifications are required. The lifting beam will not need to be redesigned and will be compatible with the new stoplogs and weir. The lifting beam is shown on as-built drawing FSD-3-9. It was noted that the as-built drawing shows a total of eight picking hooks, four sets of two hooks. However, during inspection it was found that the four inner most hooks have been removed or were never fabricated. For this reason, the new fish weir and stoplogs were designed with four total pick points to correspond with the four outer-most hooks on the lifting beam.

4.9 STOPLOG STACKING CONFIGURATIONS

a. General Configuration Considerations. Foster dam currently has six 4 ft. stoplogs and four 5 ft. stoplogs for the spillway. The ogee is at 596.8 ft.

The existing 5 ft. stoplogs have less capacity than new and existing 4 ft. logs and must be placed at the top of the stack to ensure their capacity is not exceeded. Hydraulic head on the 5 ft. stoplogs must not exceed 20 ft. Stoplog #1, an existing 4 ft. log should always be installed on the bottom of the stack against the ogee. The bottom seal is configured to fit up with the sill plate on the ogee. When the 2ft-4in stoplog is used, it must be directly below the weir since it is designed for less head than the 4 ft. and 5 ft. stoplogs.

According to Reservoir Regulation, the pool can fluctuate ±2 ft. from target elevation. The weir is designed to pass up to a maximum of 985 cfs, corresponding to 7 ft. head over the crest. The weir is intended to operate at 530 cfs with a cushion up to 985 cfs to account for fluctuation of the forebay elevation. For this reason, there is not a specific stoplog configuration to pass 985 cfs. The spillway gate should be closed if head over the weir crest exceeds 7 ft. The weir should never be overtopped.

b. Normal Pool Elevation Configuration. The normal high pool elevation is 637.0 ft. and normal low pool is 615.0 ft.

The proposed stoplog configuration is as follows. To achieve 530 cfs. at pool elevation 637.0 ft., one 5 ft. stoplog will be stacked on seven 4 ft. stoplogs to put the top of the weir crest at 632.13 ft., with 4.87 ft. head over the crest. To achieve 300 cfs. at 637.0 ft. pool, the 2ft-4in stoplog will be placed on eight 4 ft. stoplogs, putting top of weir crest at 633.46 ft., achieving 3.54 ft. head over the crest. To achieve 530 cfs. at 615.0 ft. pool, the 2ft-4in stoplog will be stacked on top of one 5 ft. and one 4 ft. log, which puts top of weir crest at 610.46 ft. with 4.54 ft. head over the crest. To achieve 300 cfs. at 615.0 ft. pool, the weir will be stacked on three 4 ft. logs, putting the top of weir crest at 611.13 ft. with 3.87 ft. head over the crest. Table 4-4 details stoplog configurations for normal pool elevations.

The weir is designed to pass up to a maximum of 985 cfs, corresponding to 7 ft. head over the crest. There is not a specific stoplog configuration to pass 985 cfs. The weir is intended to operate at 530 cfs. with a cushion up to 985 cfs. to account for fluctuation of the forebay elevation. The spillway gate should be closed if head over the weir crest exceeds 7 ft.

Desired Flow Rate (cfs)	Pool Elev (ft)	Number of 2.33ft Stoplogs	Number of 5ft Stoplogs	Number of 4ft Stoplogs	T.O. Weir Crest Elev. (ft)	Head Over Weir (ft)
530	637	0	1	7	632.13	4.87
530	615	1	1	1	610.46	4.54
300	637	1	0	8	633.46	3.54
300	615	0	0	3	611.13	3.87

Table 4-4: Stoplog configuration and flow rate data for normal pool elevations

c. Dry Year Alternative Configuration. According to Reservoir Regulation, the pool is maintained at alternative lower elevations during a dry year. The dry year high pool is 635.0 ft. and alternative low pool is 613.0 ft. A schematic showing stoplog configuration guidance for the alternative pool elevation configurations is included in the Appendix.

The proposed stoplog configuration is as follows. To achieve 530 cfs. at a pool elevation of 635.0 ft., the 2ft-4in stoplog will be stacked on one 5 ft. and six 4 ft. stoplogs which puts the top of weir crest at 630.46 ft., with 4.54 ft. head over the crest. To achieve 300 cfs. at 635.0 ft. pool, the weir will be placed on top of eight 4 ft. stoplogs, which puts top of weir crest at 631.13 ft., with 3.87 ft. head over the crest. To achieve 530 cfs. at 613.0 ft. pool, the weir will be stacked on one 5 ft. log and one 4 ft. log, which puts top of weir crest at 608.13 ft. with 4.87 ft. head over the crest. To achieve 300 cfs. at 613.0 ft. pool, the weir will be stacked on the 2ft-4in log and two 4 ft. logs, putting top of weir crest at 609.46 ft. with 3.54 ft. head over the crest. Table 4-5 details stoplog configurations.

Desired Flow Rate (cfs)	Pool Elev (ft)	Number of 2.33ft Stoplogs	Number of 5ft Stoplogs	Number of 4ft Stoplogs	T.O. Weir Crest Elev. (ft)	Head Over Weir (ft)
530	635	1	1	6	630.46	4.54
530	613	0	1	1	608.13	4.87
300	635	0	0	8	631.13	3.87
300	613	1	0	2	609.46	3.54

Table 4-5: Stoplog configuration and flow rate data for dry year pool elevations

4.10 REFERENCES

The structural design will conform to the following Engineering Circulars (ECs), Engineering Manuals (EMs), Engineering Regulations (ERs), Engineering Technical Letters (ETLs), Technical Manuals (TMs), and Industry Codes:

a. ETL 1110-2-584 Design of Hydraulic Steel Structures.

b. EM 1110-2-2702 Design of Spillway Tainter Gates.

c. ER 1110-2-1806 Earthquake Design & Evaluation for Civil Works Projects.

d. ER 1110-2-8157 Responsibility for Hydraulic Steel Structures

e. American Society of Civil Engineers (ASCE), ASCE 07-10, Minimum Design Loads for Buildings and Other Structures.

f. American Association of State and Highway Transportation Officials (AASHTO), Bridge Design Manual (latest version).

g. American Institute of Steel Construction (AISC), 14th Edition Steel Construction Manual (LFRD and ASD).

h. American Welding Society (AWS), Structural Welding Codes for Steel and Aluminum.

i. International Building Code 2015.

j. U.S. Geological Survey (USGS) 2008 National Seismic Hazard Maps.

k. Structural Engineering Association of Oregon, Snow Load Analysis for Oregon.

l. State of Oregon Revised Statute (ORS) 509.585 through 509.910.

m. State of Oregon Administrative Rule (OAR) 635-412-0005 through 00400.

SECTION 5

MECHANICAL DESIGN

5.1 GENERAL

This Section describes the mechanical portions of the Foster Downstream Passage. The Facility includes one shaped spillway fish weir for operation in the Spill Bay 4 at low and high pool.

5.2 MECHANICAL FEATURES

a. Lifting Beam

The existing lifting beam will be used to handle new stoplogs and weirs. All stoplogs and weirs are to be installed under balanced head conditions.

b. Stoplogs

i. Existing Stoplogs

Existing stoplogs will be utilized to form the basis of the weir. Stoplog #1 is shaped on the bottom to fit the curvature of the ogee. Stoplog #1 must always be placed on the bottom.

ii. New Stoplogs

A new fish weir will be designed and installed. The new weir will be 14 feet wide and designed for 7 feet deep flow through the weir. This will provide up to 860 cfs through the weir.

A Two foot tall weir is required to provide the correct elevation of the bottom of the weir at elevation 637. In order to get 7 foot of head through the new weir, 4 foot tall stoplogs #1, #2, #3, #4, as well as 5 foot tall stoplogs #7, #8, and #10 must be installed. This leaves the weir too low and requires a short stoplog to be installed.

iii. Reducing flow

The weir flow can be adjusted from 860 cfs at 7 feet of opening to 520 cfs at 5 feet of opening.

At low pool the fish weir is lifted by installing the new 2 foot weir between Stoplogs #1 and #10. This will reduce the weir depth to 5 feet deep and reduce flow to 520 cfs.

At elevation 637 the 2 foot stoplog must be removed and 4-foot stoplog #5 is installed.

5.3 REFERENCES

a. South Willamette Valley Fish Facilities Improvements, Conceptual Design Report, McMillen Engineering, November 2005.

b. Fisheries Handbook of Engineering Requirements and Biological Criteria, US Army Corps of Engineers/Bell, Milo C., 1991.

c. Anadromous Salmonid Passage Facility Guidelines and Criteria, National Marine Fisheries Service, February 2011.

d. EM 1110-2-2610, Mechanical and Electrical Design of Lock and Dam Operating and Control Systems.

SECTION 6

ELECTRICAL DESIGN

6.1 GENERAL

No electrical design is anticipated for construction of the new fish weir. A Passive Integrated Transponder (PIT) Detection System was considered in the EDR, but was not carried forward in the design phase. The PDT and Corps recognize there are many excellent examples of PIT Detection System throughout the region and over the years the significant improvements in the technology and installation requirements. In the case of the Foster fish weir the PDT has determined not to design and/or install PIT technology at this time. This conclusion was reached because the design effort to incorporate PIT technology has challenges with this weir and would likely result in a delay in implementing the new weir. Another important consideration is it is believed the necessary post implementation assessments will be conducted with other approaches, specifically active tag evaluations, which will provide route-specific fish passage information that PIT technology would not provide. The Corps recognizes additional costs may incur to install a PIT detection system if it is determined in the future that long term monitoring with PIT technology is required, than if the PIT detection system is implemented during the construction of the new fish weir.

6.2 SEISMIC CONSIDERATIONS FOR ELECTRICAL EQUIPMENT

Typical seismic restraints for floor-mounted equipment criteria are in SECTION 4 – STRUCTURAL DESIGN.

6.3 ELECTRIC DISTRIBUTION & EQUIPMENT

a. Distribution: Facility power is distributed in a simple radial configuration at 480V to various panelboards. A lighting transformer will transition the 480V to 120V.

b. Grounding and Bonding: The electrical system is solidly grounded and the installation complies with article 250 of the NEC.

c. Raceways: Rigid galvanized steel conduit (RGS) is provided for all exposed work, except in the storage/office building. Schedule 40 PVC rigid conduits are installed in all underground concrete-encased duct banks.

6.4 REFERENCES

If it is determined electrical engineering is required during the design and construction of the new fish weir, the electrical design will follow Engineering Manuals (EMs), Engineering Regulations (ERs), Engineering Technical Letters (ETLs), Technical Manuals (TMs), Unified Facilities Criteria (UFC) documents, and Industry Codes listed below where applicable.

a. American Society of Civil Engineers (ASCE), ASCE 07-10, Minimum Design Loads for Buildings and Other Structures

b. American Association of State and Highway Transportation Officials (AASHTO), Bridge Design Manual (latest version).

c. American Institute of Steel Construction (AISC), 14th Edition Steel Construction Manual (LFRD and ASD).

d. International Building Code 2006.

e. EM 1110-2-3105, Mechanical and Electrical Design of Pumping Stations.

f. National Fire Protection Association NFPA 70, National Electrical Code, 2010 Edition

g. The IESNA Lighting Handbook – 10^{th} Edition

SECTION 7

COST ESTIMATES

7.1 General

This section presents the cost estimate for Foster Downstream Passage, as presented in this report. Fabrication of the weir and stop log will require approximately 6 months to complete and is estimated to cost $530,000 including a 15% contingency. The crane demolition will require approximately 1 month to complete and is estimated to cost $75,000 including a 10% contingency. The Total Project Cost (design and construction) is estimated at $1,250,000.

7.2 Criteria

ER 1110-2-1302, Engineering and Design Civil Works Cost Engineering, provides policy, guidance, and procedures for cost engineering for all Civil Works projects in the US Army Corps of Engineers. 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.

7.3 Basis of Cost Estimate

The cost estimate is based on historical data for metal fabrication. The estimate is calculated with MCACES MII Version 4.3, using labor and equipment crews, quantities, production rates, and material prices. Prices are updated for 2017, and escalated to the Midpoint of construction.

7.4 Construction Schedule

Fish weir and stoplog fabrication is anticipated to begin in October 2017 with a completion date no later than March 2018. Crane demolition is anticipated to occur during the month of October 2017.

7.5 Acquisition Plan

A supply contract will be used to purchase the fish weir. The source selection strategy is Invitation for Bid and competition is restricted to small businesses. A service contract will be used to demolish the crane. The source selection strategy is Invitation for Bid and competition is restricted to small businesses.

7.6 Project Construction

The weir will be fabricated offsite and delivered to Foster Dam. The crane will be demolished by cutting the four concrete legs flush and disposing of the concrete and metal at an approved disposal site.

SECTION 8

OPERATIONAL CONSIDERATIONS

8.1 GENERAL

The PDT recommends the selected alternative from the EDR process; a new fish weir capable of operating with flows of 500 cfs between October 1 and June 15 annually to improve downstream fish passage at Foster Dam. The new weir will effectively improve attraction, passage, and survival of downstream migrating, surface oriented, juvenile Chinook salmon and steelhead and adult steelhead (kelts), as well as limiting impacts to other missions of Foster Dam (e.g. flood risk reduction, hydropower, and recreation). However, given the inherent uncertainty of climate forecasting and minimum flow requirements, operational flexibility is required to manage real time hydrologic conditions.

The Water Control Manual for Foster Lake prescribes a minimum downstream flows of 800 cfs from February 1 through March 15. Foster Dam generally passes flow through the turbines and spillway, with some flow directed to the adult fish facility. The turbines operate with a minimum required flow of 525 cfs (El. 613) and 565 cfs (El. 637). The fish facility is gravity fed and uses roughly 70 cfs. This leaves the Project with 175cfs to operate the new fish weir, which is less than the discharge over the current weir.

To maintain the minimum downstream flows of 800 cfs during February through March 15, the PDT recommends operating the weir at 530 cfs, operating the fish ladder for the Adult Fish Facility (70 cfs), and operating the turbine for station service (200 cfs). Operating the new weir with less than 300 cfs is not desirable because it will likely cause injury and mortality to fish. Studies indicate most of the injuries observed for fish passing over the current weir were attributed to the shallow depth of the weir jet and the angle the jet contacted the spillway ogee. In order to provide reservoir regulation with more flexibility, the new fish weir must have the capability of operating from 300 to 860 cfs.

During drought years, when Foster is restricted to passing minimum flow (roughly 25% of the time from October through June 15), the PDT recommends prioritizing passing flow through the spillway, instead of the weir, for fish passage when the forebay is at minimum flood control pool (El.613). If flows are too low to operate the spillway and turbines, then the recommendation is to prioritize using the spillway and shutting off the turbines until flows are high enough to operate the spillway and turbines or fish weir and turbines during fish migration periods. Operating the new fish weir at 300 cfs is not desirable but will allow the weir to pass fish when 500 cfs is not achievable.

The new fish weir would be the primary means of passing water through Spill Bay 4 when installed. The tainter gate must be dogged fully open. The changes in the forebay elevation between flood control season (low pool) and summer (high pool) require the operations staff to remove the fish weir and either add or remove stoplogs to operate the fish weir at the correct elevation related to the reservoir. This alternative would pursue the construction of a new fish weir (with flows of approximately 500 cfs) to be operated during peak fish passage timing, or year round, as the primary passage route. If high flows are expected that require use of Spill Bay 4, the Project would be required to remove the fish weir to return the tainter gate and bay to normal flow control. The concept is to construct a new fish weir with the ability to accommodate multiple reservoir elevations. The following describes the general operational considerations pertinent to the design of the fish weir.

8.2 RESERVIOR REGULATION

Foster Reservoir draws down to elevation 613 ft by October 1st and tries to maintain this elevation until May 15th (Figure 8-1). The fish wier is operated with a constant release, of 530 cfs, from October 1st through May 15th. After May 15th, the reservoir is refilled to elevation 637 ft. Any required outflow over 500 cfs is released through the powerhouse, if minimum powerhouse flows can be met. If the minimum flows cannot be met, the extra outflow above 860 cfs is released with the other spill bays. If additional water besides the fish weir and powerhouse is required to be released, Spill Bays 1, 2, or 3 shall be used. Figure 8-1 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the Fish Benefit Workbook model.

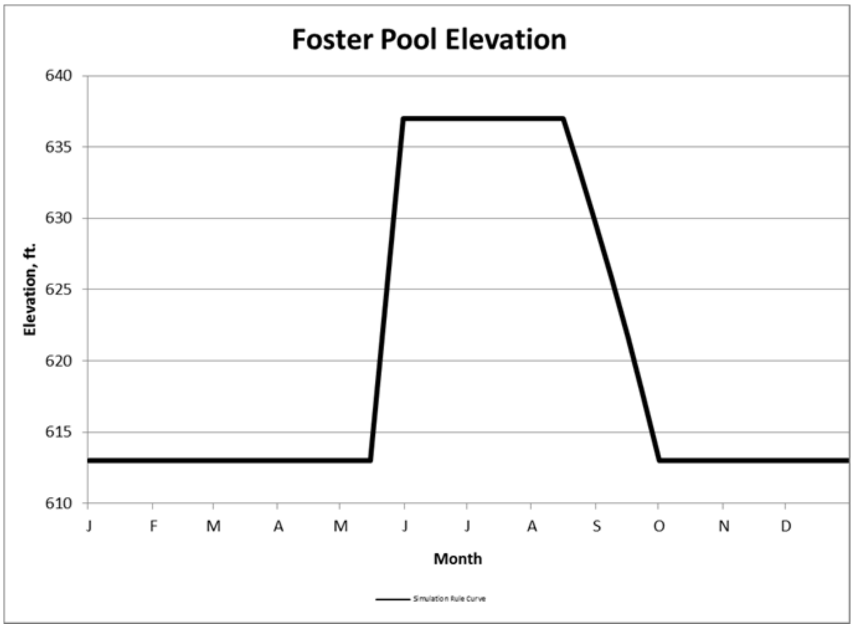


Figure 8-1. Rule Curve for Operation of New Weir at Foster Dam

Date Range	Minimum Required Downstream Flow
February 1st through March 15th	800 cfs
March 16th through May 15th	1500 cfs
May 16th through June 30th	1100 cfs
July 1st through August 31st	800 cfs
September 1st through October 15th	1500 cfs
October 16th through January 31st	1100 cfs

Table 8-1. BiOp minimum required downstream flow.

8.3 LOCATION, HANDLING, AND STORAGE OF THE FISH WEIR

The fish weir will be installed in bay 4 of the spillway during use at Foster Dam. When removed for inspection every 5 years according to ER 1110-2-8157, the weir will be removed and placed on the spillway deck with the spillway gantry crane. The new fish weir's lifting eyes have been designed to utilize Foster's stoplog lifting beam to allow lifting of the weir by the spillway gantry crane. The weight of the new weir is approximately 20,000 lbs. The Project's current stop logs weigh roughly 22,000lbs. The new weir would has been designed such that it could be used with the current stoplogs and lifting beam. The Project crane maximum lift capacity for the weir and stoplogs is 22,000 lbs.

8.4 STOPLOG CONFIGURATION AND WEIR INSTALLATION

Installation of the fish weir and stop logs take a day or less (6-8 hours) and requires a crane to hoist and install it in Spill Bay 4. The weir is lowered through the road deck gatewell slot, and rests on top of existing stoplogs in the spillway bay. The stoplogs are installed in the spill bay such that the surface of the top stoplog is at elevation 607 ft prior to installing the weir. The weir sits on top of the stoplogs. This installation work requires a complete closure of the Foster Dam road deck for one day because the crane and trucks block the road deck. Because Foster Dam road deck is generally open to the public, a road closure announcement is required to be released to the public prior to the road closure. After the fish weir is installed, the tainter gate (spill bay gate) is raised to the full open position and water flows over the surface of the weir and falls on the downstream side of the spillway. To allow inspection of the stoplogs every 5 years, per ER 1110-2-8157, the weir will be removed and the stoplogs will then be removed for inspection with a lifting beam specially designed for that purpose.

The fish weir and associated stoplogs will have to be reconfigured twice a year for the low (winter) and full (summer) reservoir elevations; 1) during the last week of September the weir will be lowered to the low reservoir elevation (613 ft), 2) during the last week of April the weir will be raised to the summer reservoir elevation (635 ft). Each weir changeover takes a day or less (6-8 hours) to complete.

8.5 DEMOLITION OF FISHLADDER GANTRY CRANE

The fish ladder gantry crane is a concrete structure crossing the entire roadway 35 feet above the deck. The crane is permanently mounted in 5 places to the dam structure adjacent to the spillway. The concrete structure of the fish ladder Gantry crane limits access to the spillway from the south side. The crane has various lights and mechanical equipment that hang down over the road. The gearbox for the hoisting equipment has been drained, but there is residual oil in the gearbox and grease on various components.

Demolition and removal of the crane will allow proper positioning of the crane when lifting the weir, moving trucks supplying stoplogs and movement of materials to the weir worksite. Demolition involves removing all equipment from the crane including all lights, hoists, gearboxes, drums, conduit, etc. The concrete structure is to be removed down to guardrail height on both the upstream and downstream sides of the roadway.

8.6 ReS-Sim ANALYSIS

5. a. Preferred Alternative from EDR.

The Willamette River Basin Res Sim model simulates the operations of the 13 USACE Willamette River Basin dams. The inputs to this model comes from a dataset of unregulated daily discharges from WY 1936 to 2009. The model computes various outputs on a daily time step. A statistical analysis was done on these daily outputs and is presented below. See Appendix B for more details on the results.

Figure 8-2 shows the Res Sim results of the new fish weir operating from October 1st through May 15th at 500 cfs with use of the powerhouse. This operation only has a minor impact to the pool elevation.

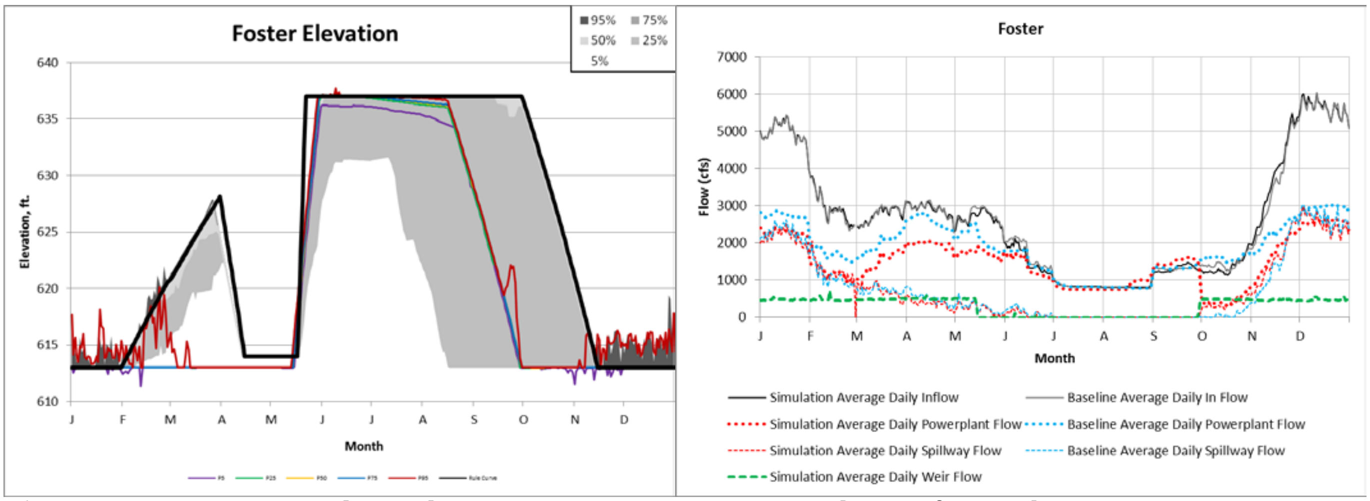


Figure 8-2. Res-Sim Results, Fish Weir 500 01 Oct - 15 May with use of Powerhouse.

6. b. Fish Weir 500 01 Oct – 15 Jun with use of powerhouse.

During the 90% review of the EDR, a comment was received suggesting operating the fish weir through 15 June. This is based on some new research indicating that fish passage occurs through the middle of June. This suggestion was modeled using Res Sim and the results are shown below in Figure 8-3. This simulation, named Fish Weir 500 01 Oct – 15 Jun with use of powerhouse, was the same as the preferred alternative from the EDR (described above) except the fish weir is operated through 15 June. As can be seen in the left graph, the average summer pool elevation from the 73 years of record was less than 625 feet (NGVD29). The summer pool elevation reached the desired elevation of 637 approximatley 5% of the time. This impacted the usable boat ramps in Foster Reservoir which would have an impact to recreation at the reservoir.

As can be seen in the discharge graph on the right, the discharge from the powerhouse has decreased, similar to the prefered alternative except for a month longer.

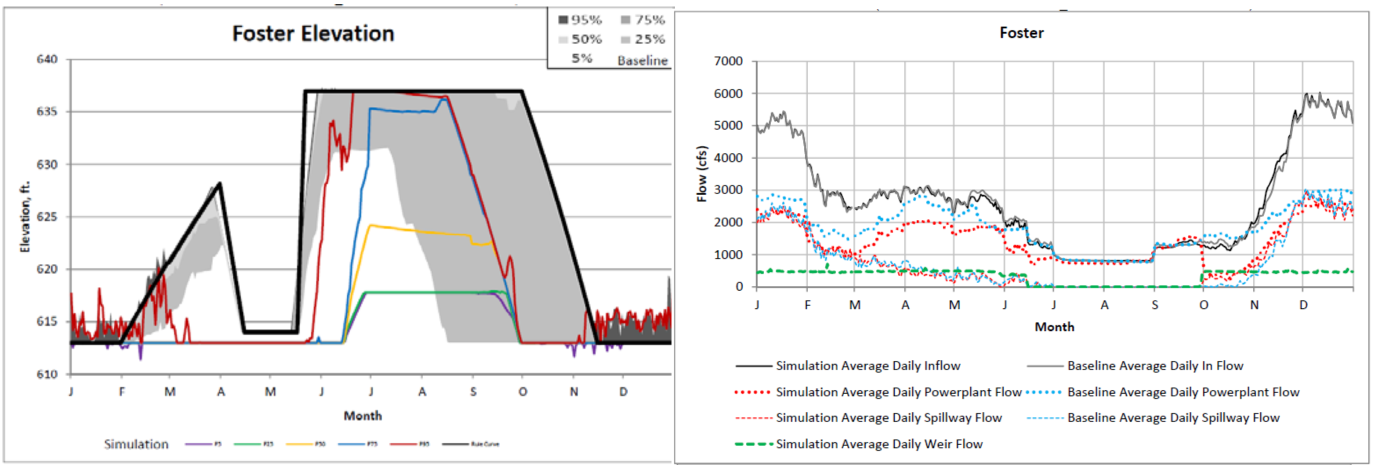


Figure 8-3. Res-Sim Results, Fish Weir 500 01 Oct - 15 June with use of Powerhouse.

7. c. Fish Weir 500 01 Oct – 15 Jun with use of powerhouse, keeping FOS full.

The Res Sim results from the Fish Weir 500 01 Oct – 15 Jun with use of powerhouse simulation was discussed with the Willamette Fish Facility Design Group. They suggested using water from Green Peter Reservoir to maintain Foster Reservoir at elevation 637 feet (NGVD29). Three different scenarios were modeled with Res Sim: operating the fish weir through 15 June while trying to maintain Foster Reservoir at elevation 367 feet (NGVD29, operating the fish weir through 07 June while trying to maintain Foster Reservoir at elevation 367 feet (NGVD29, and operating the fish weir through 01 June while trying to maintain Foster Reservoir at elevation 367 feet (NGVD29. The results from the first scenario, named Fish Weir 500 01 Oct – 15 Jun with use of powerhouse, keeping FOS full, are shown below in Figure 8-4. This simulation was the same as the preferred alternative from the EDR (described above) except the fish weir is operated through 15 June and water is used from Green Peter Reservoir to try to maintain Foster Reservoir at an elevation of 637 feet (NGVD29). As can be seen in the left graph, the summer pool elevation was usually maintained at or near elevation 637 feet (NGVD29). There was a slight decrease in the summer pool elevation at Green Peter Reservoir, shown in Figure 8-5. This decrease pool elevation did not have an impact to the boat ramps in Green Peter Reservoir when compared to the baseline. As can be seen in the discharge graph on the right of Figure 3-4, the discharge from the powerhouse has decreased, similar to the prefered alternative except for a month longer. There is an increase in the powerhouse flow in late June while Foster Reservoir is being refilled.

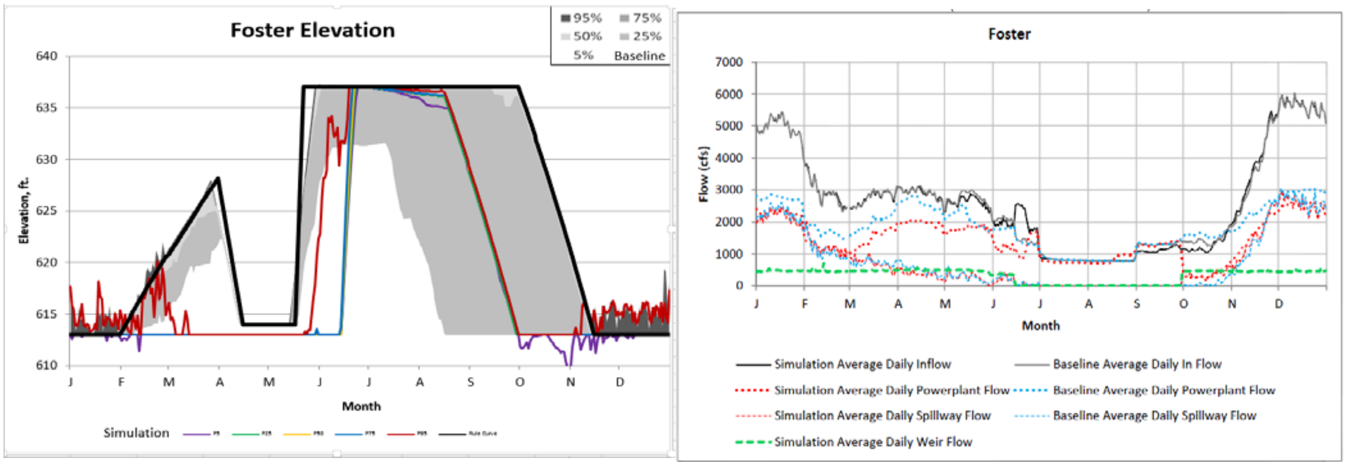


Figure 8-4. Fish Weir 500 01 Oct – 15 Jun with use of powerhouse, keeping FOS full.

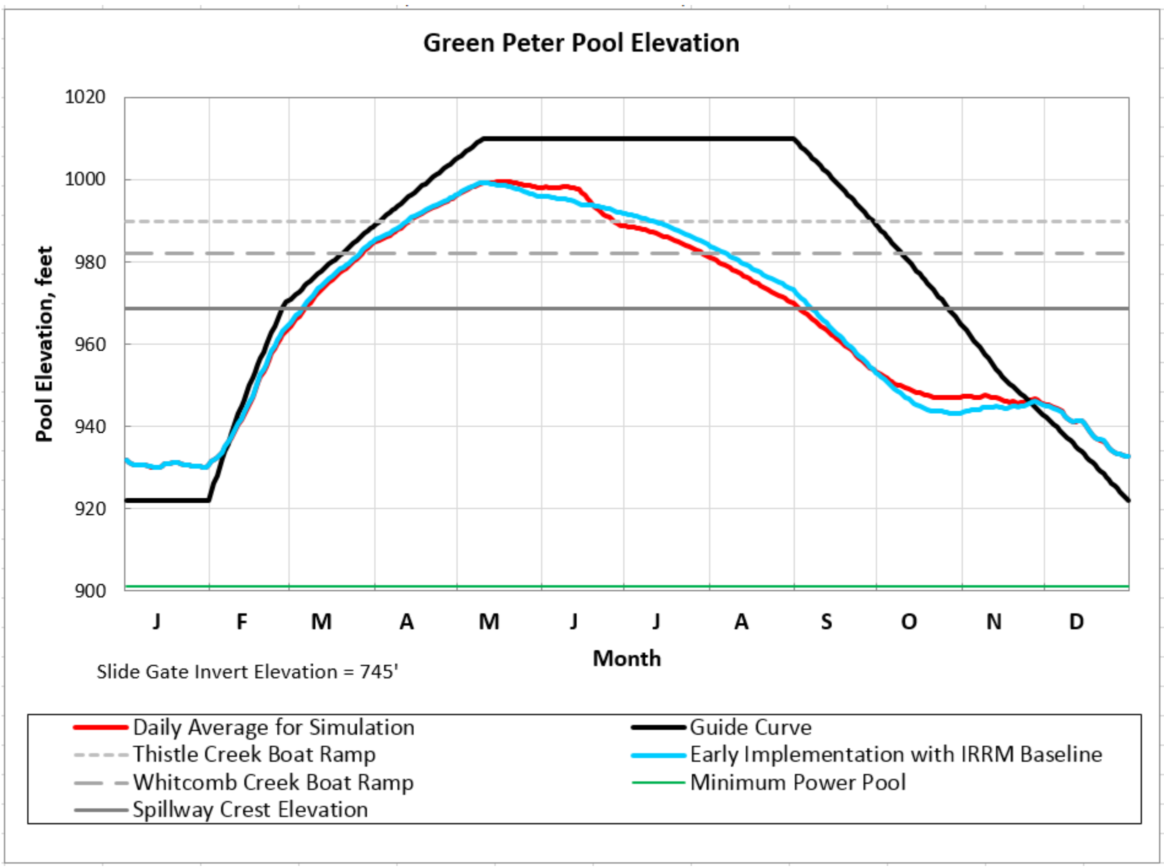


Figure 8-5. Green Peter Reservoir Average Pool Elevations, Fish Weir 500 01 Oct – 15 Jun with use of powerhouse, keeping FOS full compared to the Baseline.

d. Fish Weir 500 01 Oct – 07 Jun with use of powerhouse, keeping FOS full.

The results from the second scenario, named Fish Weir 500 01 Oct – 07 Jun with use of powerhouse, keeping FOS full, are shown below in Figure 8-6. This simulation was the same as the preferred alternative from the EDR (described above) except the fish weir is operated through 07 June and water is used from Green Peter Reservoir to try to maintain Foster Reservoir at an elevation of 637 feet (NGVD29). As can be seen in the left graph, the summer pool elevation was usually maintained at or near elevation 637 feet (NGVD29). There was a slight decrease in the summer pool elevation at Green Peter Reservoir, shown in Figure 8-7. This decrease pool elevation did not have an impact to the boat ramps in Green Peter Reservoir when compared to the baseline. As can be seen in the discharge graph on the right of Figure 8-6, the discharge from the powerhouse has decreased, similar to the prefered alternative. There is an increase in the powerhouse flow in late June while Foster Reservoir is being refilled.

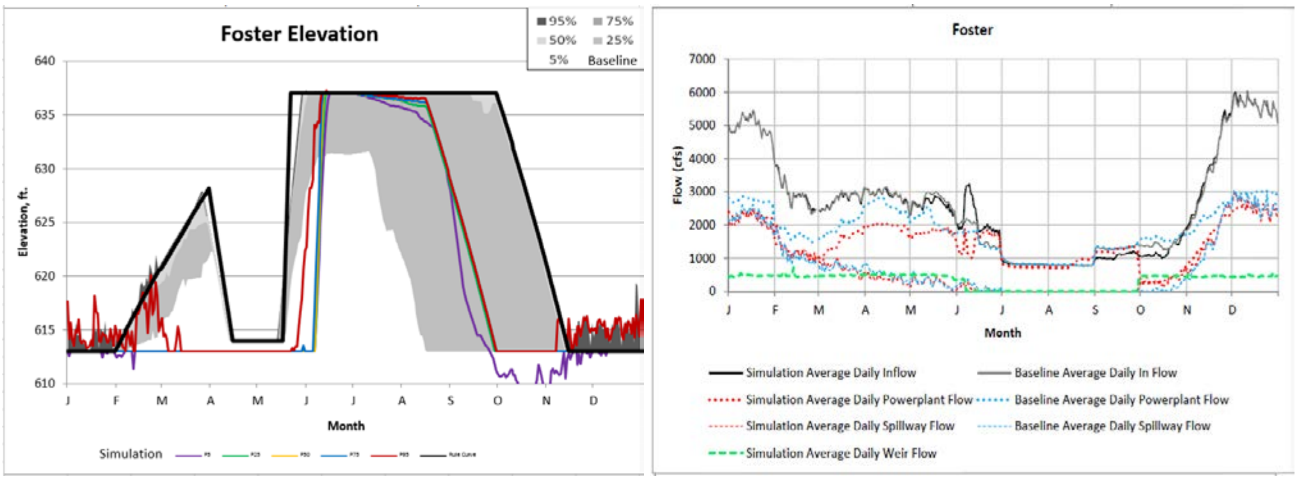


Figure 8-6. Fish Weir 500 01 Oct – 07 Jun with use of powerhouse, keeping FOS full.

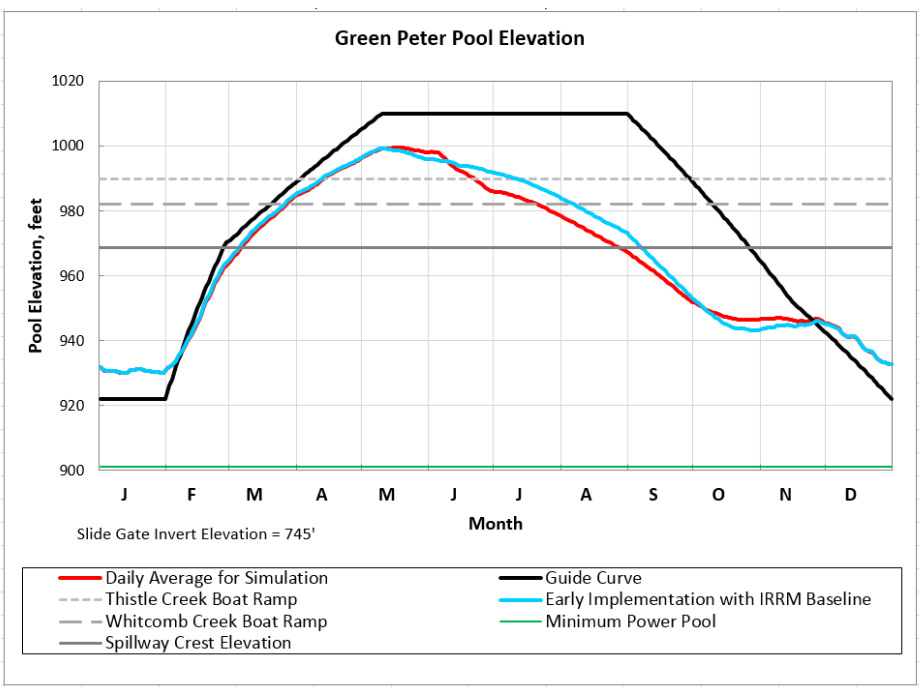


Figure 8-7. Green Peter Reservoir Average Pool Elevations, Fish Weir 500 01 Oct – 07 Jun with use of powerhouse, keeping FOS full compared to the Baseline.

e. Fish Weir 500 01 Oct – 01 Jun with use of powerhouse, keeping FOS full.

The results from the third scenario, named Fish Weir 500 01 Oct – 01 Jun with use of powerhouse, keeping FOS full, are shown below in Figure 8-8. This simulation was the same as the preferred alternative from the EDR (described above) except the fish weir is operated through 01 June and water is used from Green Peter Reservoir to try to maintain Foster Reservoir at an elevation of 637 feet (NGVD29). As can be seen in the left graph, the summer pool elevation was usually maintained at or near elevation 637 feet (NGVD29). There was very little chnage in the summer pool elevation at Green Peter Reservoir, shown in Figure 8-9. The slight changes to the pool elevation did not have an impact to the boat ramps in Green Peter Reservoir when compared to the baseline. As can be seen in the discharge graph on the right of Figure 8-8, the discharge from the powerhouse has decreased, similar to the prefered alternative.

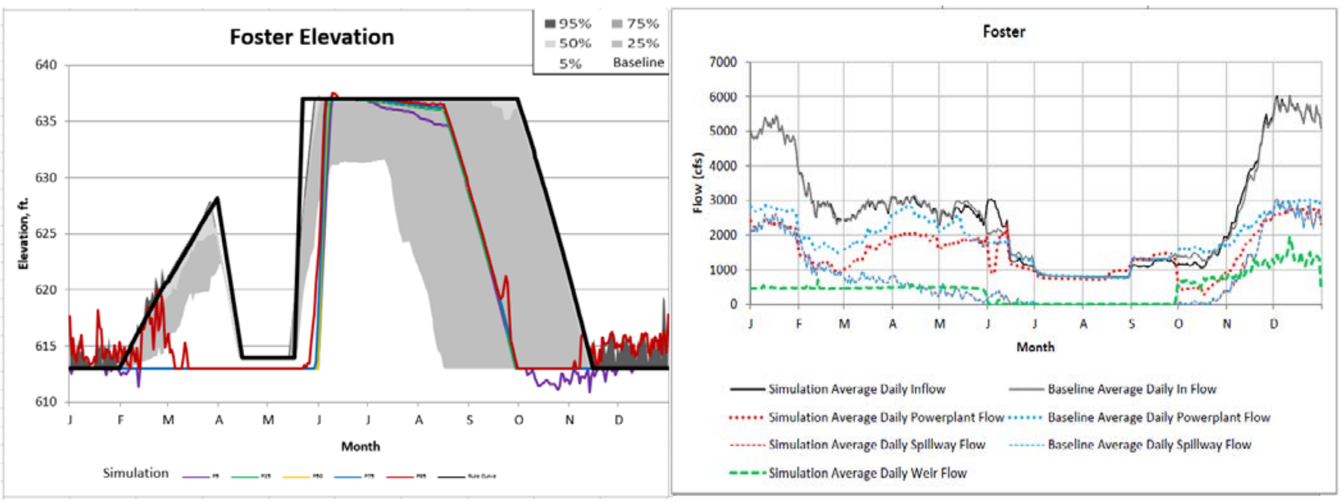


Figure 8-8. Fish Weir 500 01 Oct – 01 Jun with use of powerhouse, keeping FOS full.

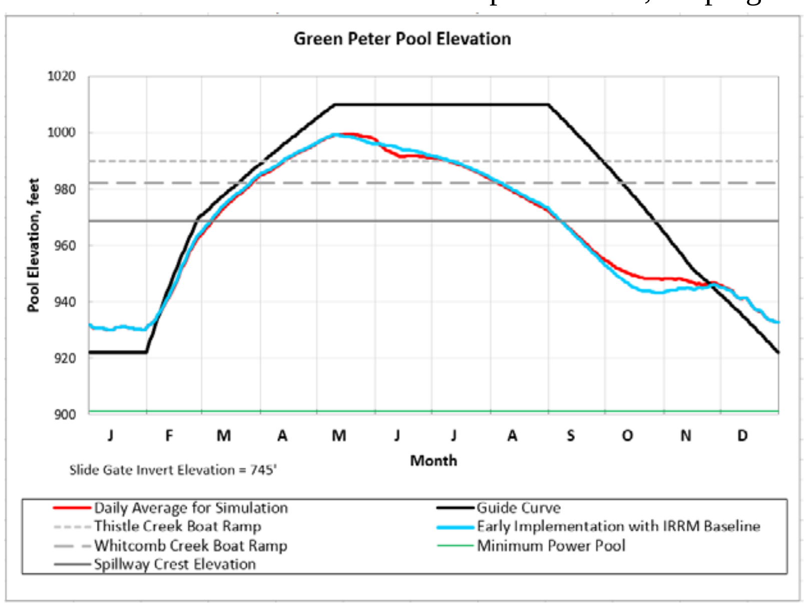


Figure 8-9. Green Peter Reservoir Average Pool Elevations, Fish Weir 500 01 Oct – 01 Jun with use of powerhouse, keeping FOS full compared to the Baseline.

f. Fish Weir 500 01 Oct – 15 Jun, actual minimum downstream flows, keeping FOS full.

The USACE Willamette regulator was asked to review the review the current design and operations. She pointed out that with a minimum discharge of 500 cfs from the fish weir, the downstream flow target of 800 cfs (01 Feb – 15 Mar) cannot be meet. See Table 8-1 for the minimum discharge through each opening in the dam at the elevations the fish weir will be operated at.

Minimum Downstream Flow of 800 cfs				
Outlet	**Foster Pool Elevation (ft NVDG29)**			
	613	**615**	**635**	**637**
Fish Ladder	70	70	70	70
Station Service	200	220	300	320
Turbine	0	0	0	0
Fish Weir	500	860	500	860
1 Spillway	0	0	0	0
Total Flow	**770**	**1150**	**870**	**1250**

Table 8-1. Minimum Discharges Through Foster Outlets.

From 01 Feb through 15 Mar the downstream minimum flow is 800 cfs. During this time period the Foster Reservoir pool elevation will vary between 613 ft to 615 ft. In order to meet the downstream minimum flow, the turbine would need to be changed from station service to the minimum power generation. The discharge through the minimum turbine at a pool elevation of 613 ft is 540 cfs. This would bring the total minimum discharge under these conditions to 1,110 cfs.

In order to determine the impacts of the increased minimum discharges, a new scenario was modeled with Res Sim, named FOS-Weir_500-01Oct-15Jun_Refill_FOS_Mod_Min_Flows. This simulation was the same as Fish Weir 500 01 Oct – 15 Jun with use of powerhouse, keeping FOS full (described above) except the minimum downstream flow target from 01 Feb – 15 Mar was increased to 1,100 cfs. Green Peter Reservoir was still used to maintain the pool elevation in Foster Reservoir. The results are shown below in Figures 8-10 and 8-11. As can be seen in the left graph, the summer pool elevation was usually maintained at or near elevation 637 feet (NGVD29). There was very little chnage in the summer pool elevation at Green Peter Reservoir, shown in Figure 8-9. The slight changes to the pool elevation did not have an impact to the boat ramps in Green Peter

Reservoir when compared to the baseline. As can be seen in the discharge graph on the right of Figure 8-8, the discharge from the powerhouse has decreased, similar to the prefered alternative.

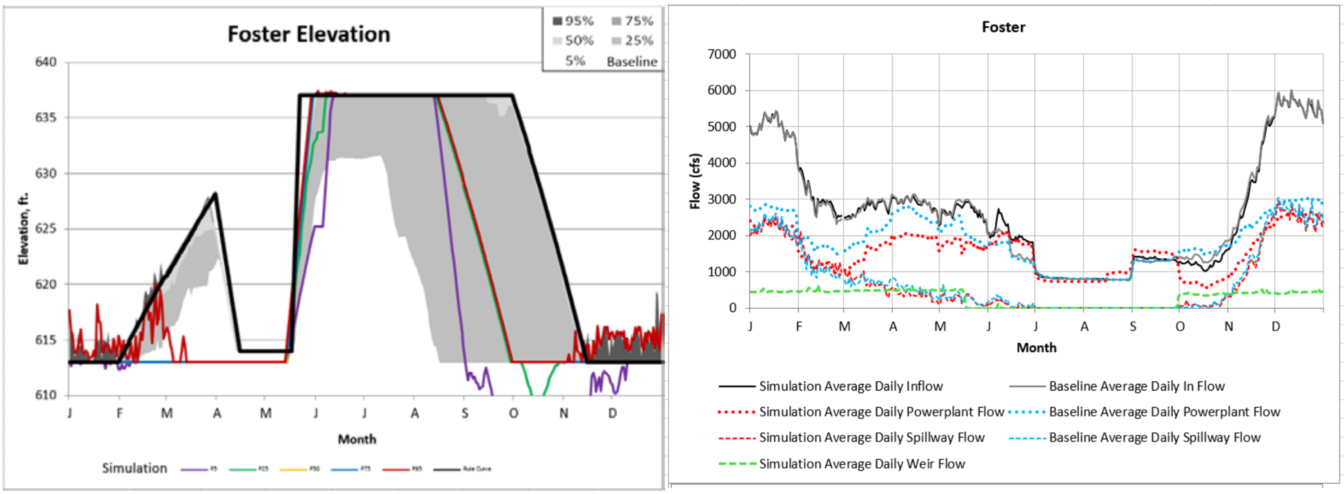


Figure 8-10. Fish Weir 500 01 Oct – 15 Jun, actual minimum downstream flows, keeping FOS full.

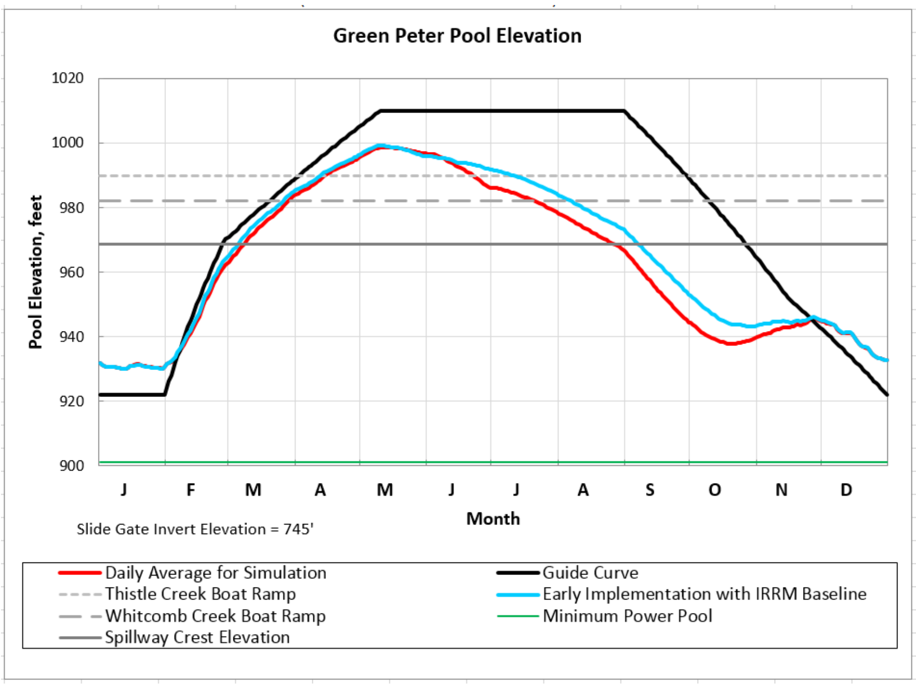


Figure 8-11. Green Peter Reservoir Average Pool Elevations, Fish Weir 500 01 Oct – 15 Jun, actual minimum downstream flows, keeping FOS full compared to the Baseline.

8.7 POST INSTALLATION OF FISH WEIR

Fish passage and survival studies will be conducted to evaluate the effectiveness of the new fish weir and improvements to downstream passage.

If downstream fish passage does not improve from the baseline, then operational measures, identified in the EDR, will be implemented to improve downstream passage (Table 8-1). Operational measures include operating one or more spill bays in conjunction with the weir or no turbine operation during all or parts of a day and operating one or more spill bays to improve passage. Studies to evaluate operational measures will be developed with input from the WATER RM&E Team. Measures will be implemented in a phased approach (that is, not all measures will be implemented simultaneously), with studies to assess the success of the alternative and measure(s) before implementing any additional measures. Additional cost and risk analysis may be required before implementation of additional measures due to associated impacts to other project missions (for example, flood risk reduction, hydropower, downstream flow augmentation, and recreation). This approach provides important phased prototyping steps to help lower risks and improve chances of reaching biological goals of improving downstream fish passage. The list of adaptive operational measures are listed in Table 8-1.

Operational Measures
Use spill bays 2 and 3 at low and high pool, with the fish weir in bay 4
Shut off turbines during peak run timing and operate spill bays and weir; e.g. turn off the turbines at night when most fish are passing the dam
Provide flushing flow from Green Peter Dam to aid in moving fish out of the Foster reservoir
Remove fish weir and use spill bay 4 at low and high pool

Table 8-1. Operational Measures to improve downstream fish passage. These measures were identified in the EDR and are listed in the table in no particular order.

8.8 WATER TEMPERATURE INFORMATION

The water temperature of the Foster reservoir will be modeled to better understand the temperature profile of the reservoir and any effects the water from Green Peter Dam, which generally discharges cold water, have on fish outmigration from the reservoir and impacts to downstream water temperatures.

Assessing different operations and impacts on temperature will be a part of the post implementation process. Results of the Foster reservoir temperature model will be included in a future draft of the DDR.

SECTION 9

REFERENCES

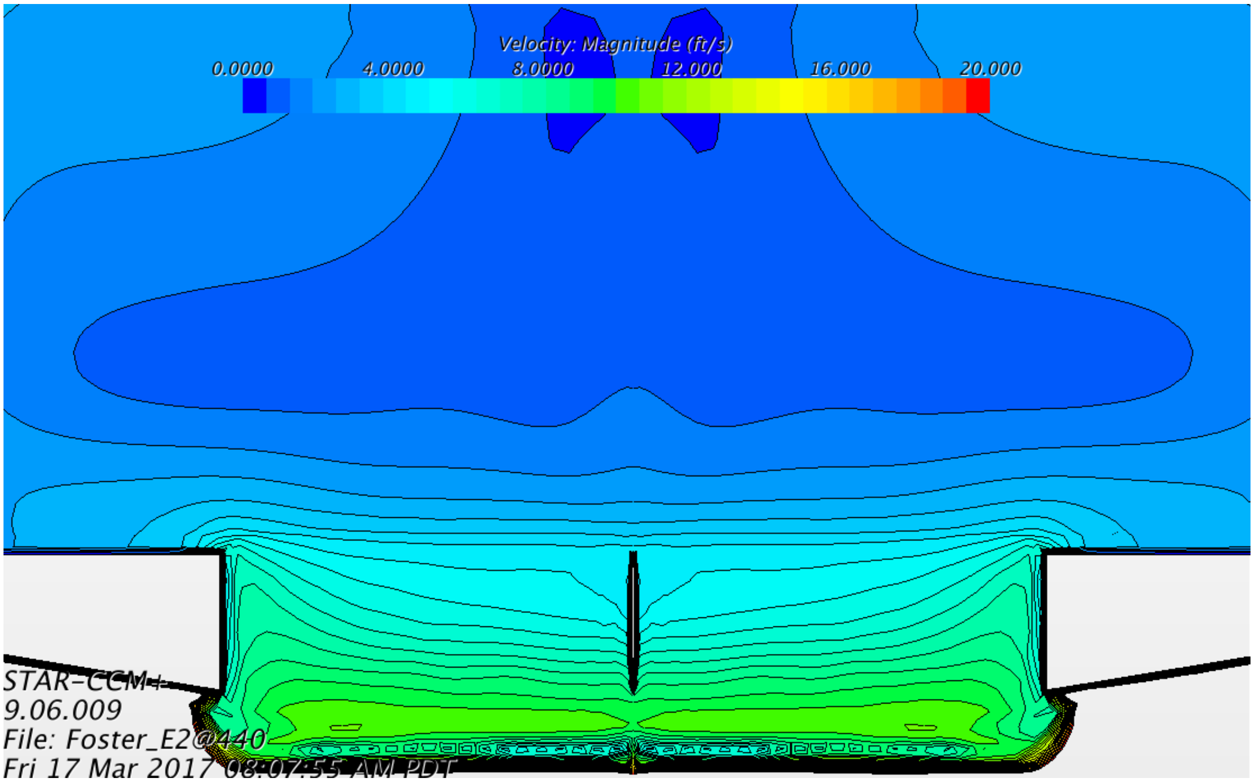
Each section above contains references for that section.   Additional references for this will be included in the 100% DDR.

APPENDIX

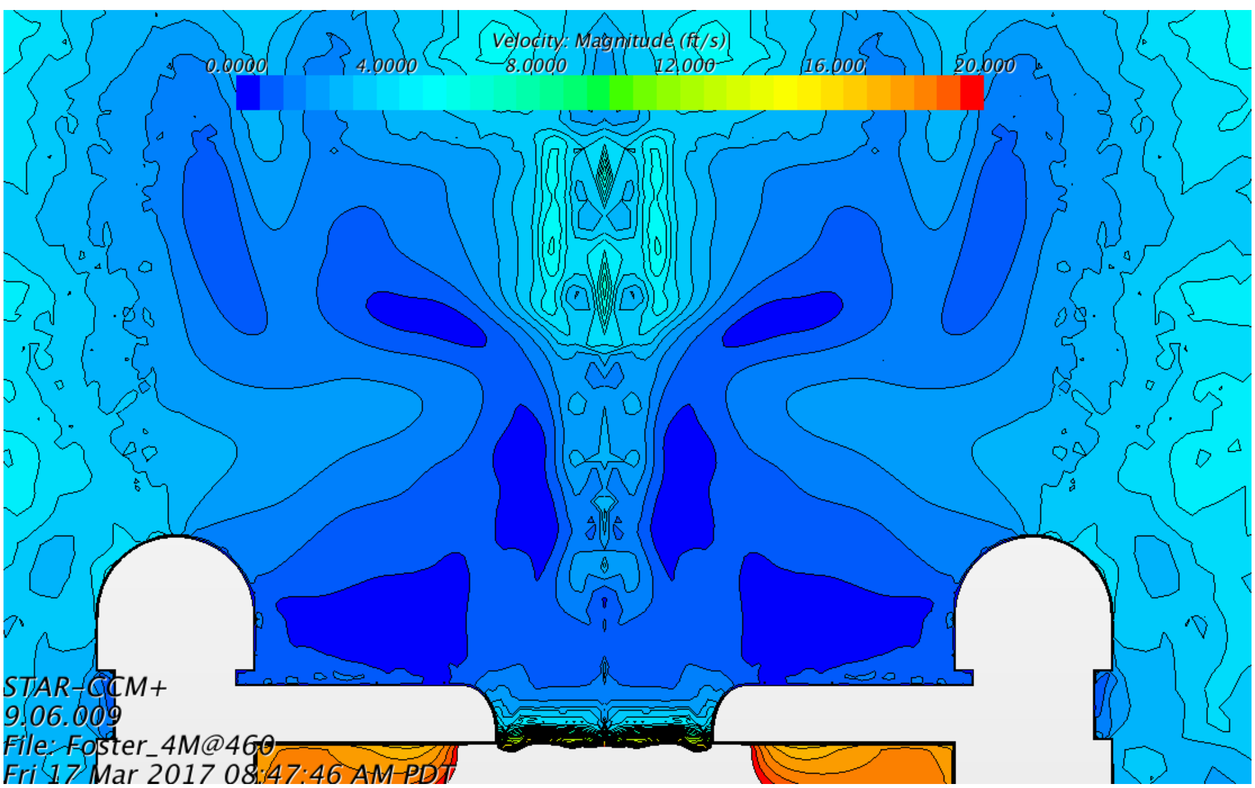
Appendix A – CFD Modeling Results

Horizontal Velocity Cross-Sections in Forebay

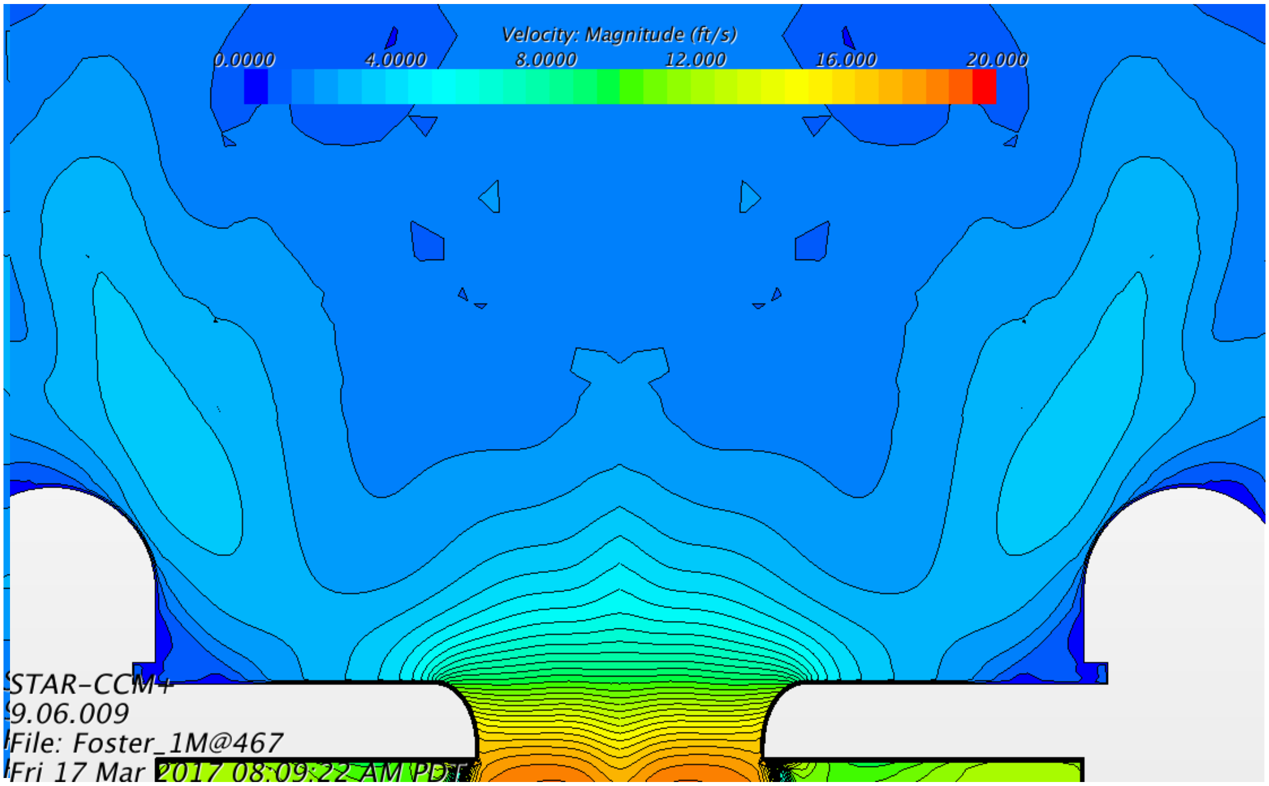
Existing Weir, 200 cfs



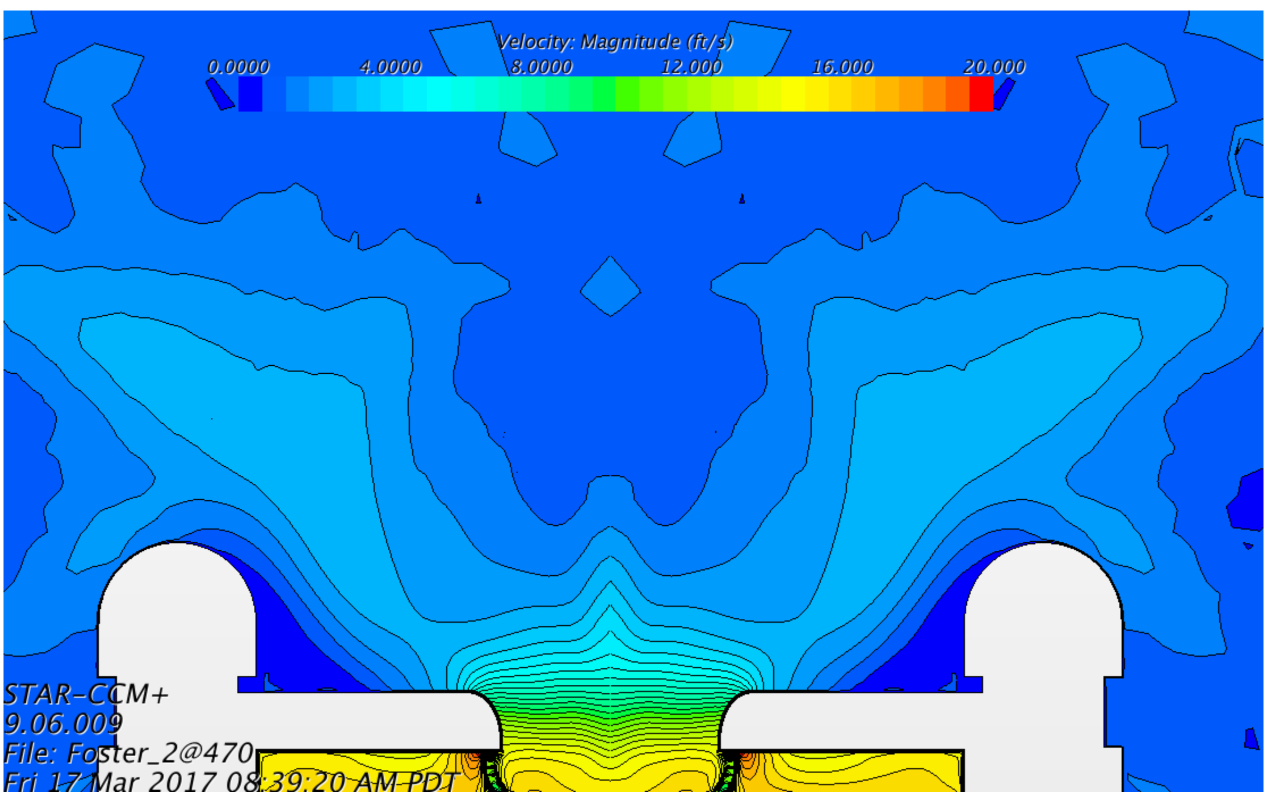
Proposed Weir, 42 cfs



Proposed We 85 cfs

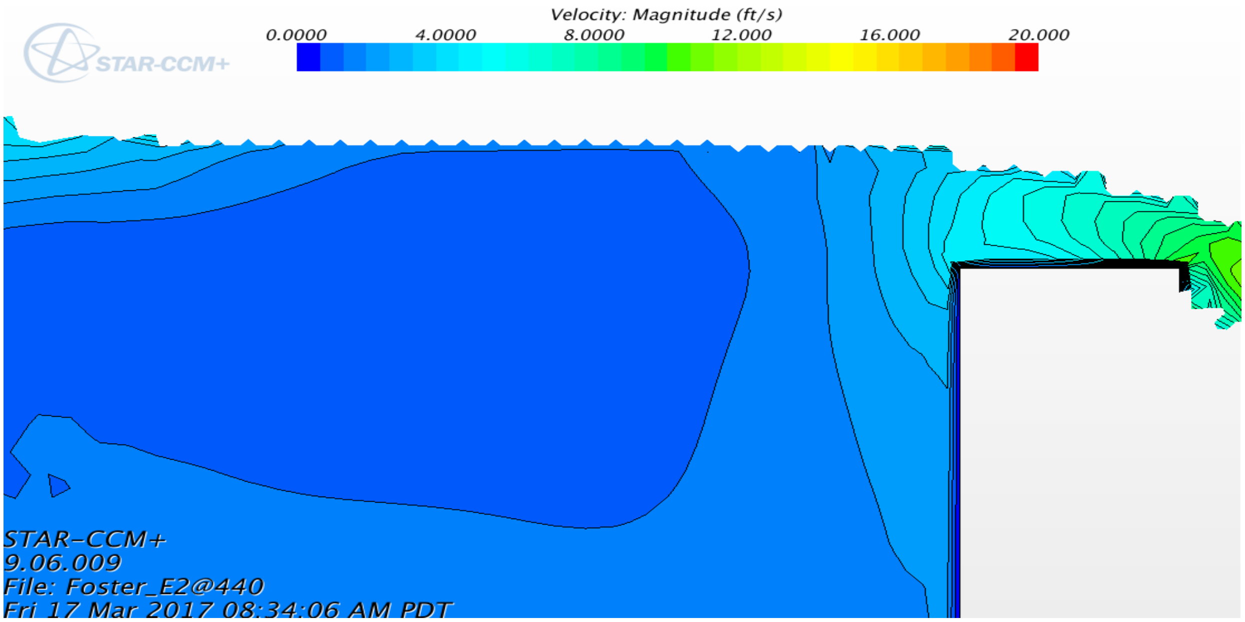


Proposed We 63 cfs

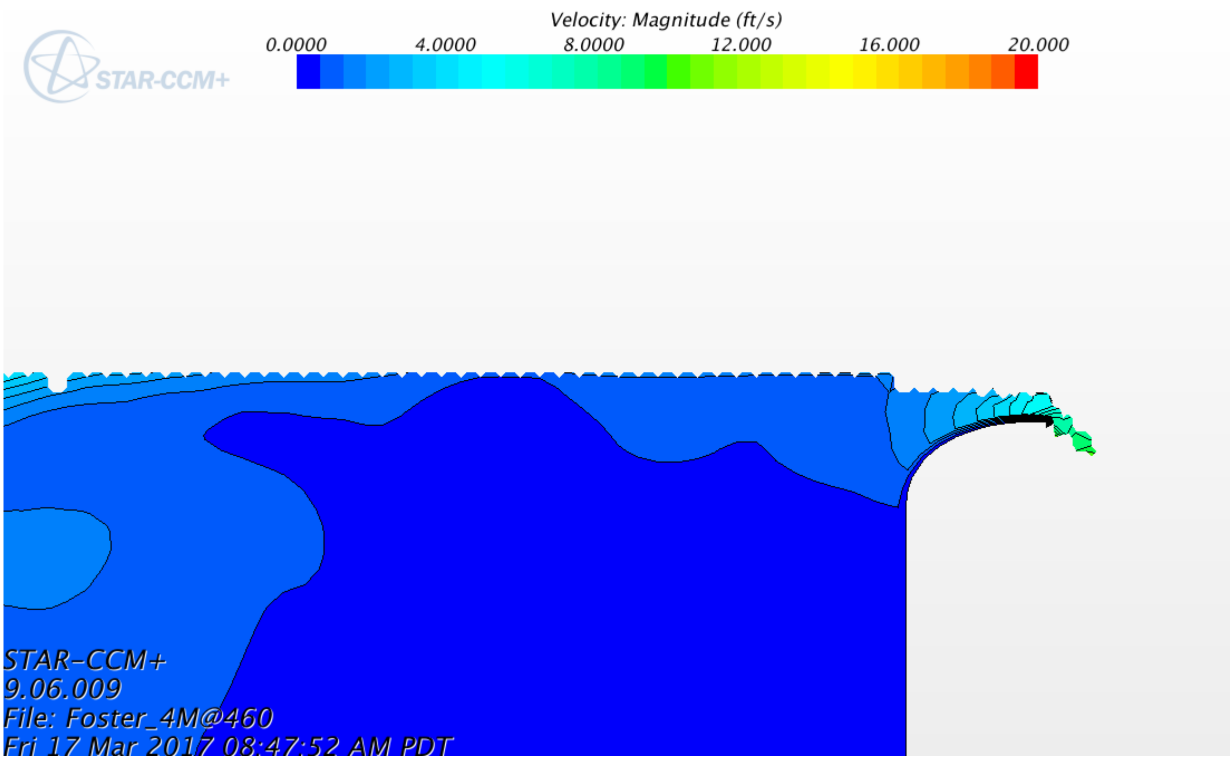


Vertical Velocity Cross-Sections in Forebay

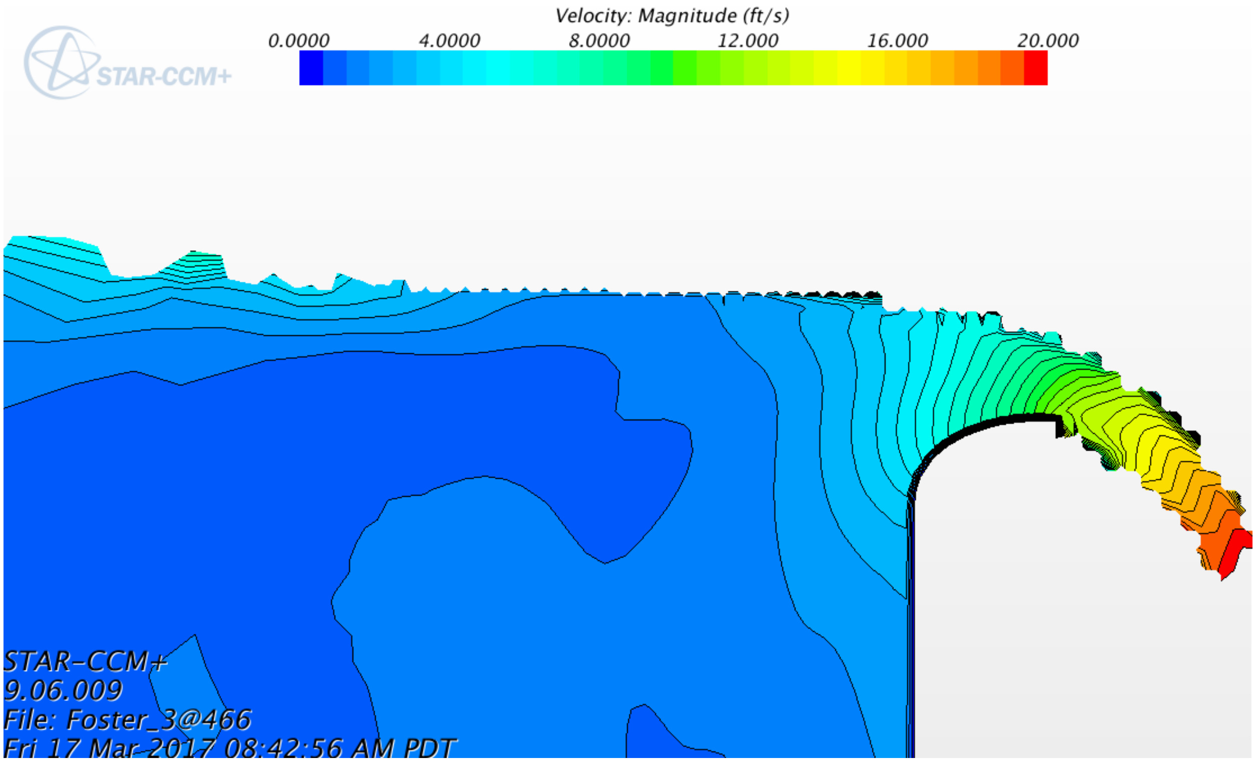
Existing Wei 500 00 cfs



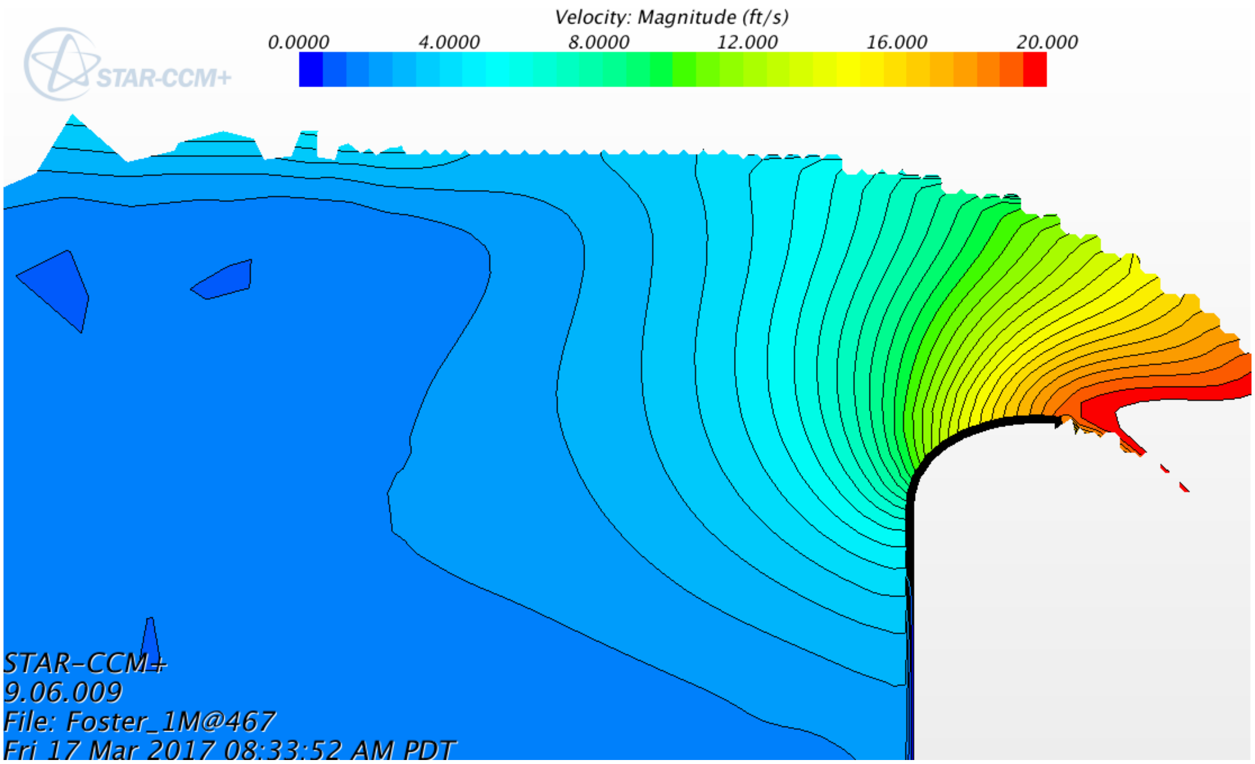
Proposed We 500 49 cfs



Proposed We[illegible]228 cfs



Proposed W[illegible]85 cfs



Proposed W[illegible]62 cfs