Bonneville Dam Adult Fish Facility Improvements
Fish Passage and Sample Equipment Improvements**,** 2011-2015

U.S. Army Corps of Engineers
Portland District
September 2015

1. **General Facility Description**

   Bonneville Dam on the Columbia River (RM 146.1) consists of two Powerhouses, a navigation lock, and a spillway for reservoir control. The first powerhouse, old navigation lock, and the spillway were completed in 1938. The second powerhouse was completed in 1982. Fish ladders exist at these structures with the exception of the navigation lock. Construction of the north shore adult fish ladder along the WA shore at the second powerhouse consists of a trapping facility that can be configured in an active sample mode or bypass when not in use. Entry into the Adult Fish Facility (AFF) is located on the north fish ladder wall between weirs 37 and 38. Picket leads operated electrically with mechanical hoists can be lowered into the ladder to direct fish into the sampling laboratory. Fish gain elevation into the laboratory holding pool through a half Ice Harbor Dam style ladder. False weirs can be manually operated at the holding pool to encourage fish to migrate into two distribution flumes that operate in bypass until personnel manually operate a switch gate to divert fish to a sample flume allowing entry into an anesthetic tank. Once anesthetized, fish can be handled, biological data collected, tagged, and released to a brail pool for recovery from anesthetic. The brail pool can be raised and lowered to encourage fish to find the exit to continue migration through another half Ice Harbor style ladder back to the WA shore main ladder at weir 50. Trap and haul capabilities include moving a fish transport tank in and out of the lab by way of the laboratory 10 ton bridge crane.

2. **Federal Columbia River Power System Biological Opinion (FCRPS BiOp) Requirements, Columbia Basin Fish Accords, and Facility Use**

   The 2008 National Marine Fisheries Service (NMFS) BiOp requires passage and survival analyses to be conducted when assessing the effects of activities affecting listed fish such as dam modifications and operational changes. This results in utilization of the Bonneville Dam AFF to capture adult salmonids for Radio Telemetry (RT) and Passive Integrated Transponder (PIT) studies, primarily conducted by the University of Idaho (U of I) in recent years.

   Under the 2008 Columbia Basin Fish Accords, the Action Agencies and Tribes are partnering to implement a lamprey improvement program to halt decline and avoid ESA listing. Active and PIT-tag evaluations for adult lamprey passage through the FCRPS rely heavily on the AFF ladder for collection; lamprey traps are located in the AFF half Ice Harbor ladder sections leading into and out of the facility. The AFF facility has been plumbed and modified to hold and tag lamprey for these evaluations. Tagged lamprey are hauled to locations downstream or upstream of the dam for release.

Adult salmonid post-construction evaluations may continue to evaluate FCRPS salmon and lamprey modifications. Collection of fish to meet ESA mandated requirements for harvest management of fishery related impacts to listed species as a result of US vs. Oregon occurs at the AFF. Other regional adult salmonid and lamprey research, such as the recent years WDFW/OFDW alternative gear study, may continue with the handling of ESA listed fish.

Chapter 13.6 of the BiOp outlines Conservation Recommendations for Bonneville Dam Adult Trap Modifications and states –

> "The Corps should modify the Bonneville Dam adult trap to provide greater and more efficient adult collection capability, and to reduce handling stress of adult salmonids during collections."

The FCRPS BiOp references the Fish Passage Plan (FPP) and calls for safe collection and handling protocols. Lab operation protocols are included as Appendix G of the FPP. The Fish Passage Operations and Maintenance Team (FPOM) have worked for years to develop safe fish handling and collection operations. These protocols are reviewed annually and changes have been mostly operations related with some relatively cost effective and easy structural modifications to address fish safety issues. The most recent structural modifications were made to the picket leads and tested in 2009 in an attempt to reduce the number of fish that enter the trap loop and impacted by the facility while maintaining a representative sample of Bonneville Dam fish passage. These structural modifications were discontinued after the 2009 season due to evidence of sample bias reported by the Columbia River Inter-Tribal Fish Commission (CRITFC) through the FPOM forum. Many of benefits to fish handling and safety that have been developed through the FPOM workgroup have reduced time the lab is in operation. Immediate fish impacts appear more significant during elevated water temperatures and FPOM has adjusted operation of the lab to the cooler periods of the day. Members of the US v. Oregon Technical Advisory Committee (TAC) have advocated for increased use of the lab thus reducing the FPOM developed protective measures in the FPP, especially during elevated water temperatures. CRITFC and the technical committees that use the data have expressed concern with not being able to achieve their monitoring goals. More detail can be found in a CRITFC Memorandum submitted and discussed at the August 11, 2011 FPOM.

The AFF's use as a research and monitoring tool has increased over the years and is expected to continue. In recent years, there have been higher incidences of adult salmonid and lamprey mortalities observed within the AFF system compared to other passage routes on the project. Primary concerns were delay, stress, and injury as fish encounter and migrate through the facility. Areas where mortalities occurred appeared to be variable consisting of bypass impacts while in sample operation, diversion to anesthetizing and handling, recovery from anesthetization and exit, as well as possible exhaustion due to hydraulic conditions both in sample and lab bypass operation between sample periods.

3. Regional Coordination

A subgroup of the FPOM team met at Bonneville Dam on November 21, 2011 to discuss improvements to the AFF. A NOAA File Memorandum dated December 7, 2011 details areas of specific concern in the AFF trapping system.

The team agreed that there were probably three levels of implementation for improvement to address the major areas of specific concerns. They included:

A. Short-term projects:
    a) Modify the anesthetic tank to eliminate the internal ledge.
    b) Modify the crowder net in the anesthetic tank to eliminate net folds.
    c) Re-pipe bleed-off water from the anesthetic flume to outside of the recovery pool to eliminate confusing flows in the pool.

B. Near-term projects:
    a) Install a new floor in the recovery pool area to hold up a new two stage recovery tank. Extend the exit section of this new tank well upstream of the drain grizzly.
    b) Evaluate potential to improve drain grizzly hydraulics to even out flow distribution.
    c) Extend the return to ladder flume pipes out of the existing building (perhaps with another 90 degree bend around corner of the building).

C. Long-term projects:
    a) Develop a capture and hold system that allows selective capture from a short side ladder. This would require rebuilding of the current access ladder/holding pool system. This would also require some type of selective capture gate system that would allow water to water transfer of selected fish. This system will require much more design thought and time.

4. Modifications 2012-2013

The short term projects were addressed by CRITFC and the USACE so no further action was necessary.

The USACE Portland District organized a Columbia River Fish Mitigation program (CRFM) funded Product Delivery Team (PDT) to work with the FPOM subcommittee and Fish Facility Design Review Work Group (FFDRWG) to focus on the near term projects with general objectives to improve fish handling safety and adult fish survival for those that are captured and pass through the AFF. Lab modifications and construction activity was scheduled during the 2012/2013 winter maintenance period. An AFF Memorandum for the Files from the PDT dated December 27, 2012 detailed the current lab operation, configuration, dimensions, measurements, missing data, and recommendations. Additional AFF memos, meeting minutes, and documents referenced throughout this report can be found at the following FPOM link:

http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/Task%20Groups/Task%20Group%20BON%20AFF/

The overall focus of modifications was to improve the hydraulic conditions in the return pool area, where both bypassed and sampled fish re-enter the AFF ladder system, and to improve the AFF transport and recovery equipment to provide an environment that is easier on fish. Mortalities discovered in the AFF are predominantly recovered from the valve 15 trashrack. The valve 15 drain, the valve 15 trashrack, and the return pool area were the focal point of the AFF improvement efforts. The hydraulic goals were to bring the velocities just upstream of the valve 15 trashrack down from 1.7 ft/s to an average of about 1 ft/s, with an emphasis on reducing the excessively high surface velocities and making it more uniform throughout the water column. The brail pool exit is located near the surface in close proximity to the trashrack. Goals for fish passage in the return pool and shallow exit section included a reduction of the high velocity conditions at the surface for fish exiting the brail pool as well as the fish exiting the bypass flumes that are immediately exposed to swift flow upon entry.

Hydraulic measurements and field testing continued and after extensive study to determine the most effective ways to increase survival, improvements were made during winter 2013.

A. Modifications to the drain valve 15 weir occurred to improve hydraulic flow distribution. Replaced 4.5 feet opening width of stoplog weirs (out of 12.5 feet total) with low porosity (3-inch holes at 20% porosity) perforation plate to distribute hydraulic flow along the entire water column (Figure 1). Replaced existing stoplog weirs with new members and added ultra high molecular weight polyethylene (UHMW) plate to minimize leakage. A new stoplog guide was added to divide the remaining 4.5 feet open section of the south weir and new 1.5-foot open section of porosity plate. The remaining sum open weir length is 7.5 feet, accounting for the guide. The remaining weir crests were raised 4 inches to reduce outflow.

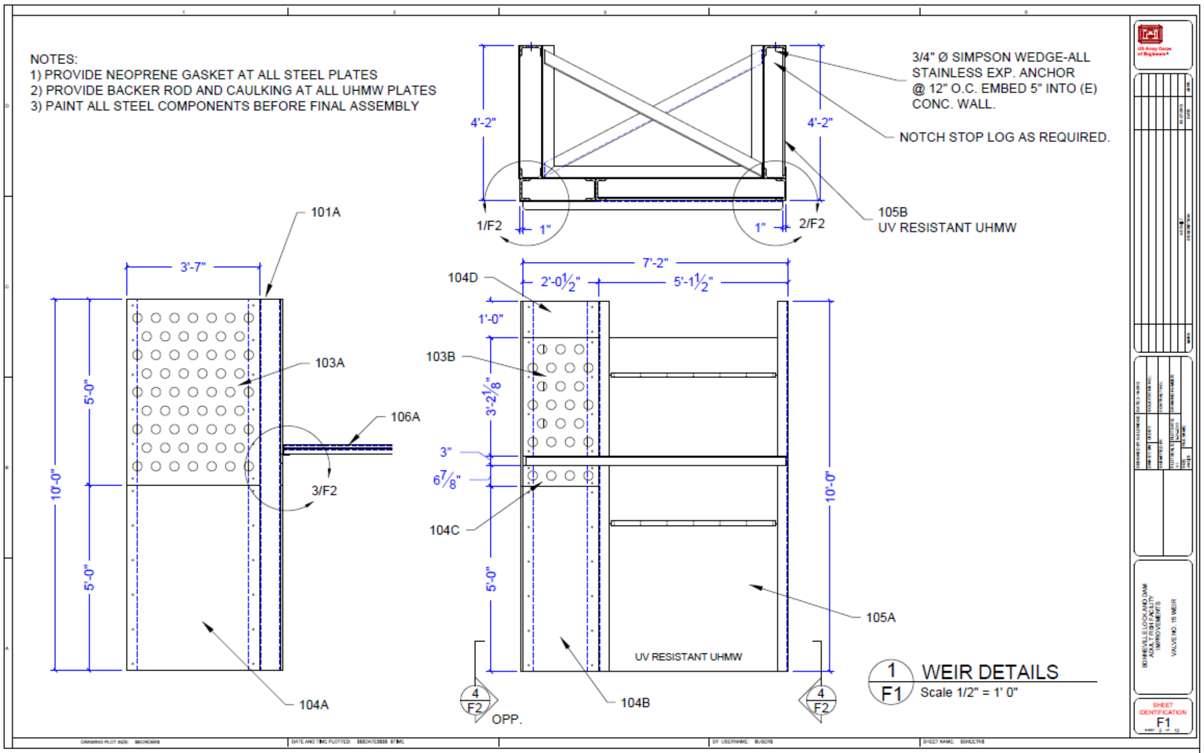

Figure 1: Valve 15 weir details.

Hydraulic testing following installation showed insignificant reduction in velocities upstream of the valve 15 trashrack. The momentum of the high velocity jet, ~4.5 ft/s, coming off the 2-foot deep channel ledge was too strong to be influenced by the porosity plates. After conference with FFDRWG and FPOM subcommittee members, a new hydraulic improvement was developed. A prototype baffle was designed to be positioned in the surface flow and UHMW floor plates installed in the return pool.

The baffle was secured across the channel perpendicular to flow and located above the recessed area outside the brail pool upstream of the brail pool exit. UHMW floor plating was installed at the bottom of the return pool to determine the best configuration to keep the velocities low in the return pool at the brail exit and reduce velocities in the upper water column at the trashrack (Figures 2 and 3). The baffle was set to 18 inches into the water (at nominal 5 feet flow depth) in 2013.

Figure 2: Baffle constructed in the AFF return pool looking upstream from the valve 15 trashrack.

Figure 3: UHMW floor plating fastened to the return pool floor grating

After installation of the baffle and floor plating, velocity measurements upstream of the valve 15 trashrack showed improvement to the flow distribution through the water column. The average velocity just upstream from the valve 15 trashrack was reduced from 1.7 ft/s to 1.1 ft/s. Prior to the modifications, the velocity averaged of 2.8 ft/s at the surface and 0.7 ft/s at the bottom (range of velocities within 2.1 ft/s). With the 18-

inch deep baffle, the velocity distribution was reversed with an average of 0.5 ft/s in the top 1.5 feet of flow and an average 2.2 ft/s near the bottom (range reduced slightly to 1.7 ft/s).

The baffle successfully reduced surface velocities. However, the velocities near the floor were considered excessive suggesting that the UHMW plating on the grating floor of the return pool needed to be modified and the baffle depth might need to be reduced. During the following winter, prior to the 2014 season, roughly one-third of the plating was removed and the baffle depth was investigated to help mitigate the high bottom velocities.

B. Two "hands on" recovery tanks were constructed to hold up to four fish for duration of 20-30 minutes as a transition for sample fish between the anesthesia tank and the brail pool (Figure 4). This allows fish greater recovery time from anesthesia, lest fish that struggle to do so become more susceptible to impingement on the valve 15 trash rack. Researchers also have the opportunity and ease to physically help a recovering fish if needed as the ability to recapture them, without the use of a cumbersome and potentially damaging net, was unavailable with direct release to the brail pool. Only one tank was installed along the south wall due to space limitations (Figure 5). The other tank is being stored onsite.

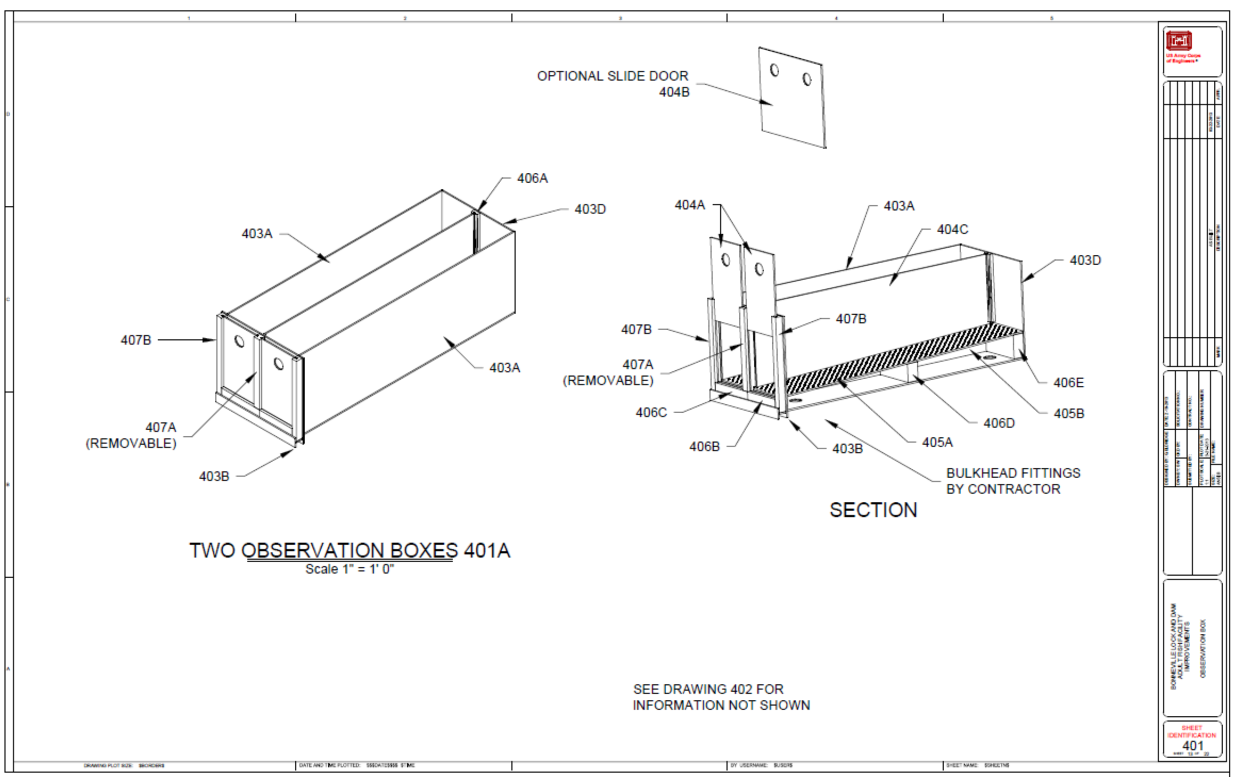

Figure 4: Observation and recovery tank detail.

Figure 5: Observation and recovery tank with exit chute to brail pool.

CRITFC researchers reported the addition of anesthetic recovery tank worked well and continued to be used with no plans for significant modifications other than replacing the center divider with stiffer aluminum in 2014.

C. The existing 14” diameter bypass pipes were extended approximately 30 feet at 10% slope with a bend around the corner in the exit channel to increase the distance between the point of fish entry and the valve 15 trashrack allowing the fish more time to orient in swift flow (Figure 6 and 7). The drop between invert and water level in exit channel was reduced to about six inches.

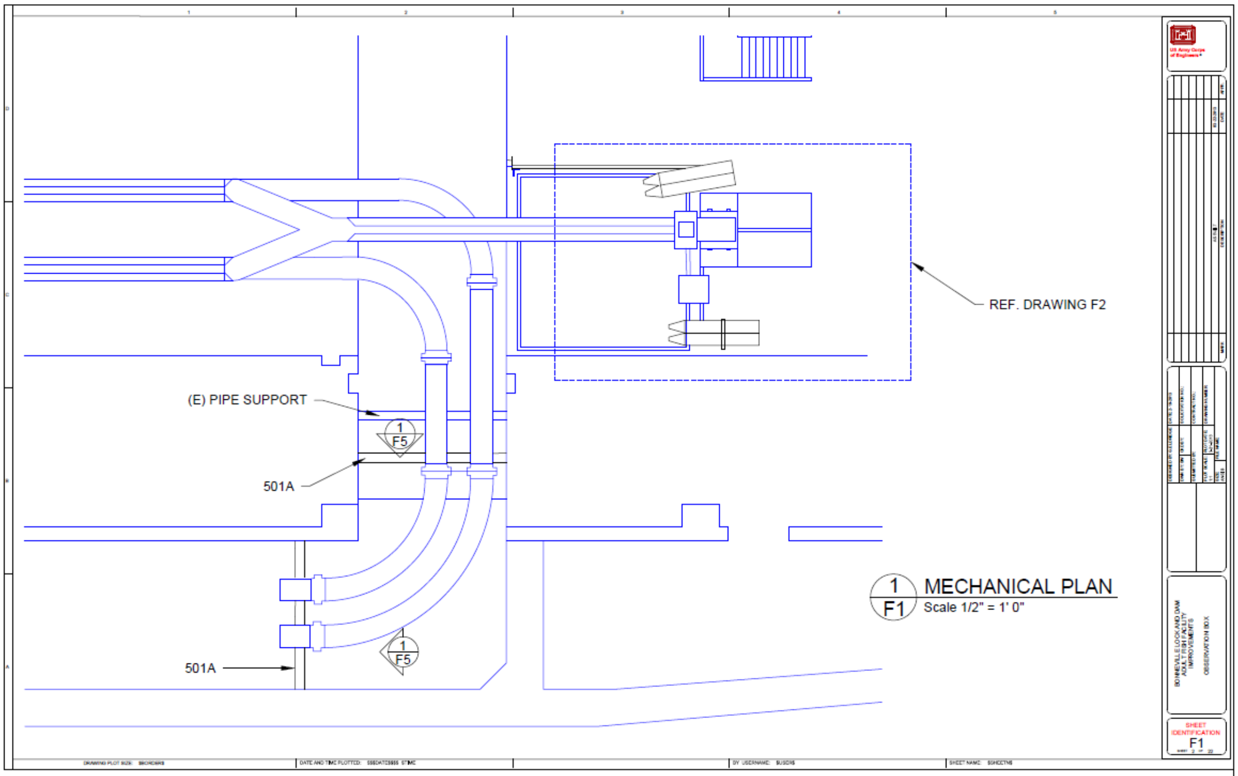

Figure 6: Plan view bypass flume modifications.

Figure 7: Extended bypass pipes outside the lab following installation.

CRITFC researchers and Bonneville Dam (BON) project biologists reported during the spring of 2013 that the newly installed bypass pipes invert elevation was at the water line and fish were not exiting as intended resulting in holding, thrashing, and potential injury near the end of the bypass pipe. Mortalities continued to be retrieved from the valve 15 trashrack. The decision was made to remove the bypass pipe extensions in-season on June 17, 2013 and return the exit location inside of the lab. Reconnecting the pipe extensions was discussed at the end of the 2013 season but were not modified and installed for the following reasons:

a) It would be physically difficult due to limitations with space, complexity, and passage criteria to re-route outside the lab to increase the slope and keep the invert elevation of the pipe above the water line.
b) During the 2013 season, large numbers of shad built up against the trash rack occluding flow and raising the water level resulting in additional investigation to remedy this situation.
c) The mortality that was occurring in the bypass configuration following lab operation during the sample period appeared to be a significant factor in overall AFF mortality and other alternatives were prioritized for implementation.

As agreed upon at the February 5, 2015 FFDRWG meeting, the bypass pipes will remain removed but will be stored onsite should future evaluations deem them necessary.

D. Water was added to both bypass flumes at the switch gate to improve fish egress.

An assessment of the biological benefit of the added water supply was difficult to make; however they are of minimal impact to researchers and to the operation and maintenance of the facility, and so they were left in place.

E. Replaced and reshaped neoprene at the transition to the anesthetic tank where minijacks were being impeded.

After the addition of neoprene at the transition from the sample flume to anesthetic tank, mortalities of minijacks recovered from either the sample flume or brail pool was reduced from four in 2013 to zero in 2014. No further actions were taken.

F. Added a neoprene panel to upper brail pool fencing to minimize fish injury should they jump (Figure 8).

Figure 8: Brail pool fencing with new neoprene panel.

The neoprene added to the upper brail pool fencing to minimize fish injury was a preventative measure with no reporting of problems by researchers. The modification remains in place.

The AFF mortality summary for 2013-2014 is provided in Section 7. Despite some improvement, mortality during the 2013 research season continued to be excessive and consisted primarily of bypassed fish as documented in Bonneville Dam Fisheries AFF Memorandum for the Records (MFRs) provided to FPOM and available at the FPOM website –

http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/

In addition, during the 2013 season large numbers of shad built up against the trashrack occluding flow and raising the water level. BON biologists reported that approximately 2000 shad mortalities were removed during the dewatering to remove the bypass pipes, highlighting the large numbers that frequent this area. Shad accumulation on the trashrack was problematic. Researchers reported one hour was spent raking shad prior to sampling and one hour raking following the sample period. Raking was strenuous due to the need to pull trash and fish completely out onto the walkway grating with an abrupt transition where the top of the trashrack met the bottom of the floor grating. There were safety concerns due to inadequate tools, access, and fall protection equipment.

Adult salmonid and lamprey mortality reports continued to be sent to FPOM over the season. Follow-on modifications were required to address these problems.

5. Modifications 2014-2015

Continued evaluation of alternatives for improvement lead to additional modifications in 2014:

G. Operational modifications to reduce flow into the lab in the afterhours bypass condition in an attempt to reduce the impingement of potentially sick, injured, exhausted, or weak-swimming fish (both salmon and lamprey) on the valve 15 trashrack.

Operations during lab bypass configuration (i.e. during non-sample periods) were modified to reduce the water velocity into the lab and through the trashrack in an attempt to create zero velocity flow conditions to discourage salmon, shad, and lamprey from congregating in the return pool and accumulating on the trashrack. Observations made with the AFF exit bulkhead partially lowered into the water at weir 50 and valve 15 closed appeared promising. However, partially closing the AFF exit bulkhead was determined to be undesirable due to fish egress concerns. Closing valve 15 then became the primary objective. Closing the valve completely to 0% open raised the water level too high and triggered the water alarms in the lab that signal flooding. Through trial and error, a 20% opening for valve 15 was deemed the optimal setting for the 2014 sample season until more operational investigation could occur with upgraded monitoring equipment that would allow an increase in the high water elevation threshold. New water alarms were installed and thresholds repositioned in early 2015 to accommodate higher water elevation while protecting personnel and equipment.

The average velocity just upstream from the valve 15 trashrack was raised slightly from 1.1 ft/s to 1.2 ft/s in the adjustments from 2013 to 2014 and 2015. More importantly, the flow was made more uniform with bottom velocities lowered from 2.2 ft/s in 2013 to 1.4 - 1.5 ft/s in 2015. Surface velocities rose from 0.5 ft/s in 2013 to 0.9 ft/s in 2015, which was considered an acceptable compromise with the flow becoming much more uniform throughout the water column (range dropped from 1.7 ft/s to 0.6 ft/s). Section 6 provides detail and the hydraulic testing summary.

H. Trash raking conditions were improved to allow researchers to safely and efficiently reach mortalities through the water column to the bottom of the valve 15 trashrack.

   a) Better access was provided by enlarging the access hatch in the floor grating and removal of the splash shield on the lamprey test flume.
   b) Provided longer-handled, user-friendly rake.
   c) Installed staff gauge indicator next to trashracks to measure water level in response to debris loading.
   d) Improved transition from trashrack to walkway grating to make fish removal easier and more efficient (Figure 9); the added plating also

prevents fish from accessing the area behind the valve 15 trash rack at elevated water levels.

Figure 9: Improved raking transition from trashrack to walkway grating.

The enlarged access, new rake, and plating placed above the valve 15 trashrack grating improved raking conditions and the researchers are successfully cleaning the valve 15 trashrack. In addition, closing down the valve 15 drain increases the water levels in the facility; the plating prevents fish from swimming over the trashrack and becoming trapped in the area behind the trashrack. The modifications for cleaning are safer and more efficient so no further changes are deemed necessary.

I. A large water supply increase was added to the north bypass pipe in an attempt to reduce the ability of fish to swim upstream if the pipes were re-connected and routed outside the lab (Figure 10).

Figure 10: Additional water supply to north bypass flume (larger left pipe).

The water supply was increased to the north bypass flume at the switch gate. It has been difficult to quantify how much benefit the additional water has been for improved passage through the pipe with the pipe exit location inside the lab. It was determined that reconnecting the pipes would not occur in 2014 due to the results from 2013 and reasons identified in Section 4.C.

The evaluation of fish egress in the pipes was necessarily observational and conducted by USACE personnel and researchers already present in the AFF. No change to fish behavior was noted compared to previous years with the pipes exit location inside the lab. A concern was raised with the increased pipe flow and the potential for larger bodied fish entering the shallow section to make contact with the shallow bottom. An underwater GoPro video camera was used to view fish exiting the high flow and lower flow pipes during July 2015. The increased water in the north flume did not appear to cause fish to enter the water and continue deeper compared to the south flume with unchanged flow. The usefulness of the added water supply was deemed neither beneficial nor detrimental. Currently, this additional water supply remains in place and is at the discretion of AFF researchers to utilize as they see fit.

A summary of the hydraulic testing can be found in the following Section 6. Based on the difference in two flow measurements in 2015, Test 10 (the flumes were off) and Test 11 (with the flumes and false weirs on), the sum flume flow + false weir flow may be up to 7 cfs. However, these flow measurements are imprecise due to the fact that the direction of the surface velocity vectors are not perpendicular, and often variable, with respect to the measurement transect located just upstream of the sloping valve 15 trashrack.

J. Replaced the center divider in the observation box with stiffer aluminum to improve utility for researchers.

The divider in the observation box was switched from UHMW to stiffer aluminum. Researchers continue to use the box and this modification is considered successful and concluded.

K. Continued improvement of velocity distribution in the return pool upstream of the trashrack for permanent configuration:

a) The baffle was raised from 18-inches to 10 inches deep (nominal flow depth = 5 feet) to reduce the velocities on the bottom and improve uniformity of velocities throughout the water column.
b) Replace the prototype wooden baffle with a permanent fixture.
c) Due to the still-elevated velocities at the bottom of the valve 15 trashrack, a portion of floor plating to improve hydraulics in the return pool was to be removed. The combination of the baffle and new floor plating scheme was predicted to lower the velocity upstream of the valve 15 trashrack in the lower depths.

The PDT modified the lab to run in various configurations of baffle and plating to determine which provided the best velocities prior to taking action for the 2014 sampling season. Testing results determined a 10" baffle and 67% floor plating were optimal for:

a) Reduced velocities at the brail pool exit compared to the original condition.
b) Hydraulic relief if the trash rack became occluded.
c) Less velocity near the bottom compared to the previous year’s configuration.
d) Potential for less of an impact on surface oriented fish and better egress conditions.

These modifications resulted in a permanent wooden baffle being installed in early 2015. Purpleheart was selected due to its longevity in wet environments, ease of construction, and O&M costs. The hydraulic results of this final configuration are presented in the next section.

6. Hydraulic Testing Summary

Velocity data was collected in the exit channel during multiple tests in 2012 (original or baseline condition), 2013 (Tests 1 – 5), 2014 (Tests 6- 9), and 2015 (Tests 10 and 11) to evaluate different configurations and operations. Measurements were always taken just upstream of the sloping valve 15 trashrack in a grid pattern consisting of 5 lateral locations across the 8-foot channel width and 5 depths below water surfaces between 0.5 feet to 4.2 - 4.4 feet (channel depth varied between 4.9 feet and 5.2 feet). The operational settings for all 11 hydraulic tests as well as the original (baseline) operation are shown in Table 1. A summary of the results for Tests 5 -11 with the percent reductions in velocity compared to the original operation is shown in Table 2.

Table 1 – Date and AFF operational settings for 11 hydraulic tests and the original (baseline) operation.

Bonneville AFF Test Operation Settings										
Ladder Head =		1	ft							
TEST No.	Date	Operation represnted	Percent Open Valve 2	Valve 15	Flow Depth (ft)	Baffle (inches into water)	Plating Percent	Flume Flushing on?	False Weirs On?	Other Adjustments
Baseline	10/31/12	2012 ≤	50%	75%	4.9			no	probably	
1	3/1/13		50%	78%	5.0			no	probably	
2	3/21/13		50%	72%	5.0			no	unkown	Valve 14 open to 20%
3	4/11/13		50%	85%	5.0			no	unlikely	
4	4/11/13		50%	84%	5.1			no	unlikely	
5	4/16/13	2013	50%	84%	5.0	18"	100%	no	unlikely	
6	1/21/14		50%	78%	5.0	18"	67%	unlikely	unlikely	
7	1/27/14		46%	70%	5.0	out	67%	unlikely	unlikely	
8	2/3/14	2014	48%	70%	5.0	10"	67%	unlikely	unlikely	
9	3/27/14		48%	70%	5.3	10"	67%	unlikely	unlikely	U/S Bulkhead Partially Closed
10	4/13/15		34%	68%	5.1	10"	67%	no	no	
11	5/26/15	2015	35%	75%	5.0	10"	67%	YES	YES	

Table 2 – Summary results of pertinent velocity tests with comparison to original operation. Units of velocity are in feet per second (ft/s).

	Test Number and Date							
Depth below WS (ft)	ORIGINAL Baseline 10/31/2012	2013 OP TEST 5 4/16/2013	Test 6 1/21/2014	Test 7 1/27/2014	2014 OP TEST 8 2/3/2014	Test 9 3/27/2014	2015 TEST 10 4/13/2015	2015 OP TEST 11 5/26/2015
	baseline	18" baffle & 100% plates	18" baffle & 67% plates	No baffle & 67% plating	10" baffle 67% Plates	# 8 with BH part closed	10" baffle, FINAL DESIGN	Full Sampling Operation ***
0.5	2.8	0.5	0.4	1.8	0.4	0.4	0.4	0.9
1.5	2.4	0.5	0.4	1.5	1.0	0.6	0.7	0.9
2.5	1.6	1.0	0.9	1.5	1.3	1.0	0.9	1.3
3.5	0.9	1.5	1.4	1.3	1.6	1.2	1.2	1.5
4.4	0.7	2.2	1.9	0.8	1.2	1.4	1.4	1.4
Average	1.69	1.08	0.96	1.33	1.02	0.88	0.87	1.19
% reduction *		36%	43%	21%	39%	48%	48%	29%
Discharge**	66	*43*	*38*	*53*	*41*	*37*	*36*	*46*
% reduction		35%	42%	19%	38%	43%	46%	31%
** % reduction compared to ORIGINAL Oct 2012 test*								
*** Discharge rates in Test 5 -10 are uncertain due to variable angles of flow*								
**** TEST 11 is likely only full sampling operation since original test*								

The following represent the operations for the respected fish passage season:

Original – 2012 (and prior years) operations
Test 5 – 2013 Operation (Flume flow not included)
Test 8 – 2014 Operation (Flume flow not included)
Test 11 – 2015 Operation (Flume flow included—full sampling operation),

Table 3 provides additional velocity data for the above listed four operations representing the different fish passage seasons. It should be noted that the tests representing the 2013 (Test 5) and 2014 (Test 8) operations did not likely include the flume and false weir discharges. Whereas Test 11 (2015 operations) was conducted following a CRITFC sampling operation that included all the required sampling discharges.

Table 3 – Summary of velocity data for different year operations in feet per second (ft/sec).

Depth below WS (ft)	ORIGINAL OPERATION: Baseline Test Data on 10/31/12			2013 Operation (Test 5 Data on 4/16/13) Test Number: 5 18" Baffle with 100% floor plates		
	Average	Max	Min	Average	Max	Min
0.5	2.81	3.4	2.1	0.48	1.0	-0.5
1.5	2.44	3.2	1.8	0.47	1.2	-0.5
2.5	1.57	2.0	1.0	1.02	1.6	0.7
3.5	0.91	1.4	0.6	1.46	1.6	1.2
4.4	0.65	0.9	0.5	2.23	2.4	2.1

Depth below WS (ft)	2014 Operation (Test 8 on 02/03/14) Test Number: 8 10" Baffle with 67% floor plates			2015 FINAL DESIGN (Test 11 on 05/26/15) Test Number: 11 FULL SAMPLING OPEARATION		
	Average	Max	Min	Average	Max	Min
0.5	0.35	0.9	-0.6	0.86	1.1	0.6
1.5	1.04	1.3	0.9	0.89	1.1	0.7
2.5	1.33	1.7	1.1	1.26	1.5	1.0
3.5	1.56	2.1	1.0	1.53	2.1	1.3
4.4	1.23	2.0	0.8	1.43	2.3	0.8

A comparative graph showing the velocity versus depth in the deep section of the Exit Channel is shown in Figure 11. The comparison is between the original operation (Table 3 - brown) and final design full sampling operation (Table 3 – blue, Test 11). The heavy lines in Figure 11 represent average velocities. Maximum and minimums are shown in the dashed lines. Aside from a reduction in average velocity from 1.7 to 1.2 ft/s, the salient result is that the location of maximum velocity has been shifted from top to bottom.

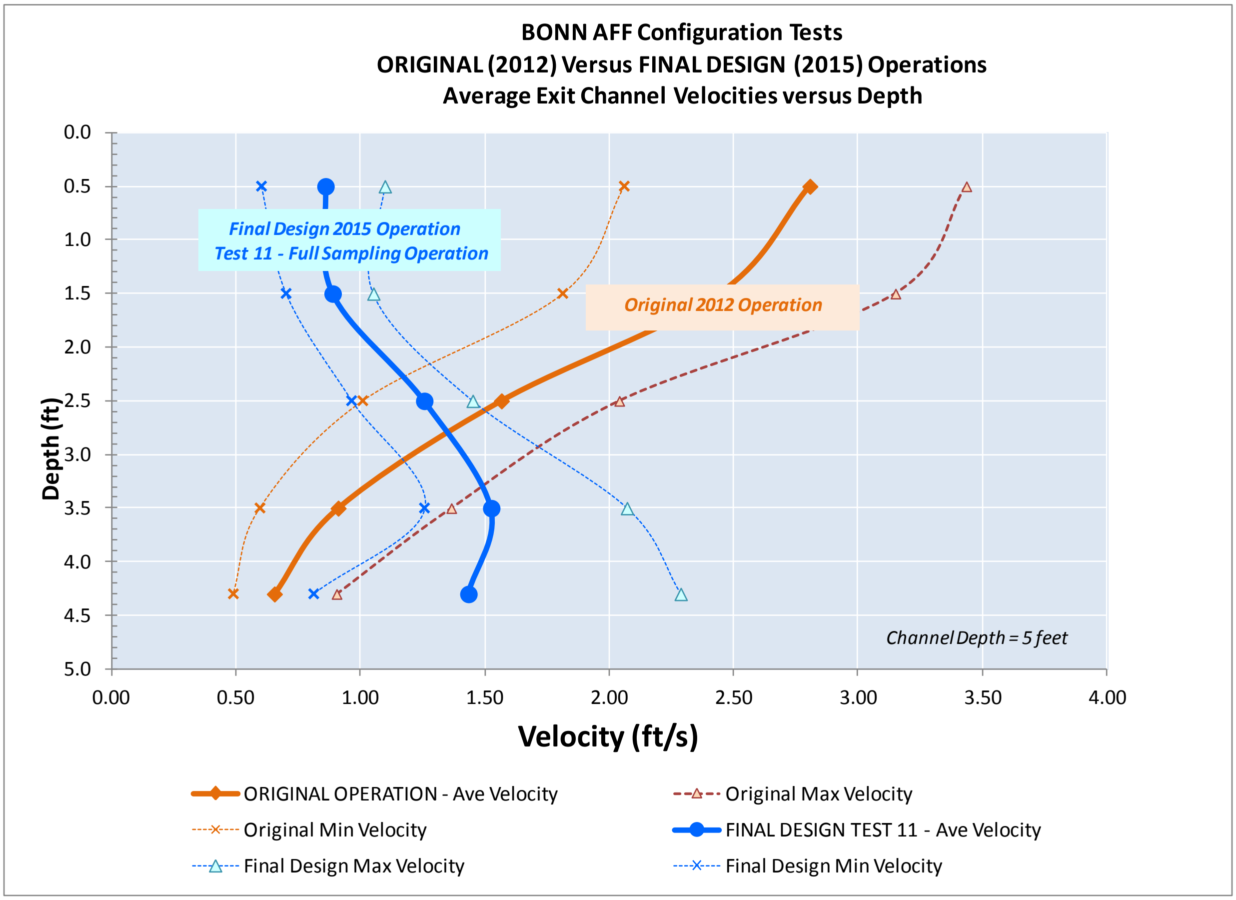

Figure 11 – Comparison of Velocities versus Depth in Final Design (Test 11) and Original Operations

A bypass operation was tested (Test 10-b) with valve 15 set at 20% open. The flow depth was 5.6 feet or 5 feet 7 inches with a discharge rate of 8 cfs. The overall average velocity was 0.17 ft/s and the maximum average velocity occurred near the invert between 0.3 – 0.4 ft/s.   The water depth was also measured at 5 feet 11 inches with valve 15 set to 10%. When valve 15 was closed the water began rising above the top of the walkway grating and flooding the concrete area under the flumes. The valve was reopened to terminate the test.

The velocities were also measured routinely from the upper level walkway that crosses over the exit channel. Measurements were taken across the shallow (~2 feet deep) section of the exit channel near the location of the ledge that shifts to the 5-foot depth return pool. These were rough measurements being in rapid flow including an eddy on the left side (looking downstream).   Four to five measurements were taken across the channel, all at 1-foot depth below the water surface. Table 4 provides data (velocities, estimated discharge, and depth) from multiple tests. The test numbers in Table 4 correspond to the operations applied to the primary test number for the deep exit channel measurements near the valve 15 trashrack, with the 'a' signifying the shallow depth location. Highlighted tests 5a, 8a, and 11a represent fish passage season operations for 2013, 2014 and 2015, respectively (However, the 2013 and 2014 measurements likely did not include flume flows). The maximum velocities typically occurred in the middle right side of the channel (2.8 feet from right edge).

Table 4 – Summary of the 2-foot Depth Exit Channel Measurements. Velocity units are in ft/s, discharge is cfs.

	Test 1a 3/20/13	Test 2a 3/21/13	Test 5a 4/16/13	Test 6a 1/21/14	Test 7a 1/27/14	Test 8a 2/3/14	Test 9a 3/27/14	Test 11a 5/26/15
Max Velocity	4.4	4.3	4.3	4.1	4.1	3.8	3.3	4.4
Ave Velocity	2.9	2.7	3.0	2.6	2.5	2.3	2.0	3.0
Discharge****	47	43	47	42	41	39	37	48
Depth (ft)	2	2	2	2	2	2	2.3	2
**** Discharge rates are uncertain due to excessive movement of price meter and west side eddy								

Additional hydraulic data from the testing is provided in Attachment A.

7. Monitoring and Results

Prior to 2013, sample mortalities were well documented; however, it was discovered through discussion with the researchers that not all mortalities retrieved from the valve 15 trashrack were reported to project biologists. This was due to the state of decomposition, ability to access and retrieve morts, and focus on mortality of sampled fish retrieved from the anesthetic tank and brail pool. In addition, it was not standard procedure to check for tags in mortalities retrieved from the valve 15 trashrack. Therefore, AFF lab mortality records prior to 2013 are incomplete and should be considered an underestimate of total mortality observed in the lab. All mortalities encountered in the lab have been reported since 2013 and a much larger proportion retrieved from the valve 15 trashrack have been checked for tags.

Table 5 summarizes total mortality in 2013 and 2014 as reported in the BON Memorandum for the Records (MFRs). For each species, the table describes the total number of mortalities that were removed from the AFF facility, how many of those fish were sample mortalities, and how many of the total number of AFF mortalities were recovered from the valve 15 trashrack. Less frequent mortalities occurred in other areas of the lab such as the anesthetic tank, sample flumes, transport tanks, etc… The total number of fish passing the Washington shore count station is included as well as the ratio of total AFF mortalities to this number as a percent. 2013 and 2014 are the only years where there is certainty that all mortalities discovered in the lab were reported.

Table 5 - AFF mortalities in 2013 (top) and 2014 (bottom) as recorded in the official Memorandum for the Records (MFRs).

2013					
Species	Total no. of AFF morts	No. of sampled morts (included in total)	Morts taken from trashrack	WA shore passage	No. of AFF morts/WA shore passage (%)
Chinook	99	5	80	913485	0.011%
Steelhead	1	0	1	131537	0.001%
Sockeye	10	3	6	122192	0.008%
Coho	11	1	10	46751	0.024%
Lamprey	45	2	42	14067	0.320%
Total	*166*	*11*	*139*		
2014					
Species	Total no. of AFF morts	No. of sampled morts (included in total)	Morts taken from trashrack	WA shore passage	No. of AFF morts/WA shore passage (%)
Chinook	21	3	15	851609	0.002%
Steelhead	2	0	1	193231	0.001%
Sockeye	11	4	8	439048	0.003%
Coho	1	0	1	163785	0.001%
Lamprey	31	3	26	18196	0.170%
Total	*66*	*10*	*51*		

From 2013 to 2014, the total number of AFF mortalities decreased 60%. The number of AFF mortalities relative to the total number of fish passing the Washington shore ladder decreased significantly for all species with the exception of Steelhead, of which AFF mortalities remained at 0.001% of total Washington shore passage.

The AFF was in operation from April 22 – October 15, 2013 and from April 6 – October 17, 2014. Pauses in sampling during 2014 occurred from August 13 – September 2 due to high temperatures and from September 9 - 15 when sampling was halted due to high fish passage numbers at Washington shore.

The level of effort to collect fish varied somewhat between 2013 and 2014 in the fall with WDFW and ODFW objectives but the numbers of sample mortalities for salmon and lamprey were low and very similar. No changes were made to FPP lab criteria during sampling by any group. Effort and targeted numbers are reported in the following text.

- CRITFC PIT tagged and collected biological data up to five days per week each year. All Fish were released to the brail pool for recovery and return to the WA shore ladder.

- U of I RT and PIT tagged 600 chinook, 300 jack Chinook, 400 sockeye, 400 early steelhead, and 400 late steelhead each year. Fish were tagged in proportion to the run. Adults were transported downstream for release.

- During 2013, WDFW collected fish from August to October for a sample target up to 1000 steelhead, 1000 coho, 2000 tule and bright Chinook. This effort included weekend work. Adults were transported downstream for release.

- During 2014, ODFW collected fish from late September to mid October for a sample target of 600 Coho only. Sampling occurred five days per week. Adults were transported downstream for release.

- U of I lamprey collection occurred both years. Lamprey were collected at the AFF and powerhouse 2 auxiliary water supply. All tagged lamprey were released upstream and downstream of BON.

    - 2013 - 1000 HD-PIT and 400 JSATS-PIT tagged.
    - 2014 - 600 HD-PIT and RT.

The number of sampled fish mortalities did not decrease in 2014, indicating that sampling mortality between 2013 and 2014 may be independent of changes made to improve overall AFF operations.

AFF sample mortalities reported during 2009 - 2012 were similar to 2013 and 2014 for salmon with annual numbers in the single digits. CRITFC sampled in the lab 2009 - 2012. U of I sampled salmon from 2009 - 2011 and lamprey from 2009 - 2012. WDFW sampled salmon in the fall of 2011 and 2012. The 2009 - 2012 numbers of sampled mortalities as recorded in MFRs are listed in Table 6. (*It is possible that sample mortalities during these years are underrepresented for reasons described at the beginning of Section 7*)

Table 6 - Total numbers and composition of sampled fish mortalities in the AFF.

Year	Total no. of sampled morts	Composition of morts
2009	3	3 CHK
2010	8	1 STH, 7 CHK
2011	8	2 SOC, 6 CHK
2012	2	2 CHK

The percent of AFF mortalities taken from the valve 15 trashrack relative to the total number of mortalities taken from the facility as a whole were 84% in 2013 and 77% in 2014. The remainder of non-sample mortalities were due to a variety of reasons, including mini-jack Chinook getting caught in the sample flume (3 in 2013 and 1 in 2014) or in the anesthetic tank (1 in 2013), fish jumping out of transport tanks (1 adult Coho and 1 adult Chinook in Oct 2013), non-sampled fish deaths in the brail pool (1 Sockeye in 2013 and 2014 each, 5 adult Chinook in 2013, 1 Chinook mini-jack in 2014, 2 lamprey in 2014), fish caught in the AFF lamprey traps (1 Sockeye in 2013 and 1 Chinook mini-jack in 2014), and mortality in other AFF areas (e.g. 1 adult Chinook and 1 adult Steelhead in the collection pool in 2013 and 2014, respectively).

Following the September 12, 2013 FPOM, the USACE requested U of I and CRITFC mark and release dead fish into the upper WA shore ladder. The objective was to better understand the downstream movement of dead fish if present in WA shore ladder upstream of the AFF exit at weir 50. One question was whether it was possible that the large number of untagged fish ending up in the facility, and specifically on the valve 15 trashrack, were originating from the main ladder outside the AFF. A total of 29 dead adult Chinook, Coho, and a single steelhead were recovered from the valve 15 trashrack in the AFF and PIT-tagged. Colored tape was attached for ease of visual identification. These fish were released from Sept. 13 – 19 just downstream of the WA count station window and above weir 67 on the north side. Fish were in varying condition including fish with estimated mortality within past two days and severely decayed. U of I noted that the fresher fish did not float and fish that were severely decayed prior to release were more buoyant. None of the fish were re-collected on the valve 15 trashrack. The facility was in bypass mode during all releases. (Please see MFR 13BON85 for more detail)

Eight salmonid mortalities from the AFF were saved and collected in June and July, 2014 as part of the National Wild Fish Health Survey by the U.S. Fish and Wildlife Service (USFWS). Of the four Chinook salmon collected, two Chinook had Furunculosis (*Aeromonas salmonicida*) and one was too decomposed to test. Of the four sockeye collected, one was reported having unspecified bacterial growth and three sockeye appeared normal. 19 Pacific Lamprey mortalities from the AFF were collected from late May until early August by USFWS for examination as well. Furunculosis was detected on 10 of 19 lamprey, though due to the decomposed state of some of the collected fish, the bacteria may have been present on others but not able to be isolated. Enteric Redmouth (*Yersinia ruckeri),* Coldwater Disease (*Flavobacterium psychrophilum)*, and Columnaris (*Flavobacterium columnare)* were not detected on any lamprey. Results were discussed at FPOM and can be found at the following November 13, 2014 FPOM meeting files link:

http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/2014_FPOM_MEET/2014_NOV/

Underwater observations of fish behavior in the return pool area upstream of the valve 15 trashrack were made using a GoPro video camera. It was noted that when CRITFC researchers released groups of adult salmonids from the brail pool, they held at the bottom of the return pool in close proximity to the valve 15 trash rack. Fish did not immediately swim upstream toward the exit outside the lab. A recording was also made in the same location prior to the first daily sample fish release. There were already salmonids present at the same location, suggesting that during sample operation at least, the return pool may be a holding area for both sampled and bypassed fish.

Lamprey trapping in the AFF occurs in traps located in the half Ice Harbor style weirs in both the entrance and exit sections. Trapped lamprey are released upstream or downstream of the dam depending on the objectives for collection. Lamprey sample mortalities are few (Table 5) and those recovered from the valve 15 trashrack are in-river fish. Lamprey do not pass through the false weirs and flumes like salmonids while the lab is in sample operation. They are able to pass through the lab when the lab is in bypass and the collection pool bulkhead is raised. Three sources of potential bottlenecks were identified by a member of the lamprey work group during a site visit that may affect lamprey passage and behavior in the AFF:

1. The bulkhead guide slot on the first overflow weir immediately downstream of the AFF exit.
2. The irregularly shaped framework located in the guide slot downstream and next to the exit bulkhead.
3. The lamprey traps and positioning.

Figure 12 shows the bulkhead guide slot and the irregular shaped framework at the water surface. These locations are located in swift flow and present challenging attachment surfaces during upstream movement such as sharp angles and narrow edges.

Figure 12 – Bulkhead guide slot (left) and irregular shaped frame (right).

8. Conclusion and Recommendation

The data collected from 2013 and 2014 suggest salmonid mortality has been reduced. Not as many salmonid morts are being retrieved from the valve 15 trashrack during the sample day. Structural modifications and operations have been adjusted in the lab to provide optimal conditions in sample and bypass configuration given the constraints with space, flow, and biological criteria.

Effort and access for raking was made easier with the modifications. Salmonids and non salmonids (especially shad) are easier to retrieve. This should result in improved ability to maintain water elevation and design flow, personnel safety, as well as reporting and a more accurate count of fish mortality.

CRITFC researchers report that the recovery box with the new center divider continues to work well. The second observation box remains stored onsite at the AFF. It is recommended that the second observation box be kept as a backup or used in the future if needed for efforts to fulfill other regional objectives.

The bypass pipe extensions remain stored onsite at Bonneville Dam.

During sample operation, fish that exit the brail pool near the surface immediately upstream of the trashrack are now exposed to flow with a significant reduction in velocity with the baffle and plating in place. Average velocity through the return pool has also been reduced. These modifications met the objective to improve velocity distribution and egress conditions.

While the dead fish "test" did not result in any marked fish observed on the valve 15 trashrack following release and provided some useful information, it should be recognized that the evaluation lacked scientific rigor and had a small sample size. There is little evidence to suggest significant numbers of fish are dying in the main WA shore ladder and the following should be considered:

1. The lack of reporting by fish counters regarding downstream movement of dead fish at the count station window.
2. Rare observations of dead fish in the WA shore main ladder system by project biologists during inspections as well as other USACE personnel and researchers.
3. Dead fish are rarely observed on the AFF picket leads during sampling or when leads are raised following sampling operation, however, they may be difficult to observe if not at the surface.

If there is a future desire to gain a better understanding of upstream and downstream movement in the WA shore ladder and AFF, it is recommended that other tools and methods be considered, such as analysis of PIT or RT data. This could occur retrospectively and/or if a problem is identified. In April 2015, CRITFC installed a new PIT detector located in the shallow exit section from the return pool outside the lab.

Sick, injured, and moribund fish are present in the AFF ladder system as reported through the BON MFRs and USFWS fish health survey reporting. These types of physical conditions tend to result in weak swimming behavior with the potential for reduced ability to migrate. Fish could potentially be moving downstream and/or seeking a location of reduced flow to hold. The AFF and return pool exit section are unique and differ from the other areas of the main ladder in configuration and hydraulics and to fish, may appear to be a sanctuary. Fish that found this area attractive or moved into the exit section for any reason while the lab was in bypass, prior to the PDT modifications, may have become exhausted in the swift bypass flow and unable to exit, ultimately ending up on the trashrack. Water temperature will be variable among years and elevated temperatures can exacerbate this situation. Structural modifications and minimizing flow through valve 15, to the extent possible during the bypass operation, is expected to continue to be beneficial by reducing exhaustion and aiding weaker swimming fish. However, it is difficult to exclude fish from this area in day-to-day operations without potentially trapping some and delaying migration. If fish find sanctuary in this area and are sick, injured, or moribund they may succumb and continue to be discovered on the trashrack. This location is one the most thoroughly monitored and easily observed locations in the Bonneville Dam ladder system due to configuration and researcher personnel presence.

Lamprey passage and condition may be improved by modifying the structures identified in Section 7 to aid ease of migration. The Lamprey Minor Mods PDT has included these locations in their draft scope. Upstream movement during the bypass operation, downstream movement as a result of impediments to passage, or milling behavior may result in fish continuing to enter the return pool area. Mortality may continue to be observed at this location for the same reasons as salmon. Lamprey mortality will be evaluated following any additional AFF modifications in the future.

No further PDT action is planned at this time. If excessive mortality were to occur in the future, the FPOM subcommittee should reconvene and take a close look at the remaining possible mechanisms for mortality and determine if pursuing additional measures, including the long term projects identified in Section 3, would be worthwhile. Monitoring efforts will continue through fishway inspections, feedback from researchers, MFRs, and FPOM reporting.