US Army Corps
of Engineers®
Portland District

Design Documentation Report

Bonneville Second Powerhouse
Fish Guidance Efficiency (FGE) Program
Post-construction

November 2015

90% Draft Report

EXECUTIVE SUMMARY

There have been several modifications made over the years to the gatewells at the Bonneville Dam, second powerhouse. Most of the improvements have been intended to increase flow into the gatewells in an attempt to increase fish guidance. However, testing in 2008 and 2009 suggested that, while fish guidance has improved, gatewell modifications have also resulted in undesirable flow conditions that are contributing to elevated mortality and descaling for juvenile salmon (Gilbreath et al., 2012). As a result, several alternatives were considered to improve the hydraulic conditions within the gatewells, resulting in a recommendation to further study the use of flow control plates, mounted to the +31 msl elev. gatewell beam behind the vertical barrier screen (VBS) to reduce the flow into the gatewells (USACE 2013, 2015). It was also recommended that a design be developed for modifications to the porosity plates on the upper panels of the vertical barrier screens (VBSs) to reduce the areas of high through-screen velocity.

As part of this study, a computational fluid dynamics (CFD) model was used to help develop the designs for the flow control plates and VBS modifications. Based on the modeling and velocity data that was collected in 2014 (Harbor and Alden, 2014), the proposed improvements include a flow control plate that blocks approximately 50% (reduced hydraulic volume) of the opening between the +31 msl elev. gatewell beam and the intake gate in bay A; a flow control plate the blocks approximately 25% (reduced hydraulic volume) of the opening in bay B, and no flow control plate in bay C. The proposed improvements also include modifying the porosity plates on the upper two rows of panels on the VBSs. The proposed design includes reducing the open areas for those panels by about 50%.

A prototype of the proposed improvements was constructed in Unit 15 in February 2015 for biological and hydraulic testing during the spring of 2015. The testing was used to evaluate the effectiveness of the prototype at improving hydraulic conditions and reducing juvenile salmon mortality within the gatewells.

Evaluations conducted of the modified unit confirm that implementing the changes (flow control plates in slots A and B and VBS modifications) will allow turbine units to operate in the upper 1% peak efficiency range. Full implementation will restore full project operational flexibility.

The construction cost for this design is estimated to be approximately $597,472.00.

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PERTINENT PROJECT DATA – BONNEVILLE DAM

PROJECT DESCRIPTION

Stream	Columbia River (River Mile 146.1)
Location	Bonneville, Oregon
Owner	U.S. Army Corps of Engineers
Project Authorization	Rivers and Harbors Act of 1935
Authorized Purposes	Power, Navigation
Other Uses	Fisheries, Recreation

LAKE/RIVER ELEVATIONS (elevation above sea level in feet)

Maximum Controlled Flood Pool	90.0
Maximum Spillway Design Operating Pool	82.5
Maximum Regulated Pool	77.0
Minimum Pool	69.5
Normal Operating Range	71.5 - 76.5
Maximum 24-Hour Fluctuation at Stevenson Gage	4.0
Maximum Flood Tailwater (spillway design flood)	51.5
Maximum Operating Tailwater	33.1
Standard Project Flood Tailwater	48.9
Minimum Tailwater	7.0
Base (100-year) Flood Elev. (at project site tailwater)	39.8

POWERHOUSES

First Powerhouse (Oregon)	
Length	1,027 feet
Number of Main Units	10
Nameplate Capacity (2 @ 43 MW, 8 @ 54 MW)	518 MW
Overload Capacity (2 @ 47 MW, 8 @ 60 MW)	574 MW
Station Service Units (1 @ 4 MW)	4 MW
Hydraulic Capacity	136,000 ft^3/s
Second Powerhouse (Washington)	
Length (including service bay & erection bay)	985.5
feet Number of Main Units	
	8
Nameplate Capacity (8 @ 66.5 MW)	532 MW
Overload Capacity (8 @ 76.5 MW)	612 MW
Fish Water Units (2 @ 13.1 MW)	26.2 MW
Hydraulic Capacity	152,000 ft^3/s

SPILLWAY

Capacity at Pool Elevation (Elev. 87.5)	1,600,000 ft^3/s

FISH PASSAGE FACILITIES

Fish Ladders
- Washington Shore
- Cascades Island
- Bradford Island

Juvenile Bypass System – First Powerhouse
Downstream Migrant System – Second Powerhouse
Upstream Migrant System

ACRONYMS AND ABBREVIATIONS

ADV	acoustic Doppler velocimeter
BiOp	Biological Opinion
BIT	Biological Index Testing
BPA	Bonneville Power Administration
CFD	computational fluid dynamics
CRFM	Columbia River Fish Mitigation Program
DDR	Design Documentation Report
DSM	downstream migrant transportation
EDR	Engineering Documentation Report
FCRPS	Federal Columbia River Power System
FFDRWG	Fish Facility Design Review Work Group
FGE	fish guidance efficiency
FPP	Fish Passage Plan
ft/s	feet (foot) per second
ft^3/s	cubic feet per second
ft^2/s^2	feet squared per second squared
GCD	gap closure device
HDC	Hydroelectric Design Center
JBS	juvenile bypass system
JFMF	Juvenile Fish Monitoring Facility
KCFS	Thousands of Cubic Feet Per Second
LCC	life cycle costs
LDV	laser Doppler velocimeter
mm	millimeter(s)
MW	megawatt(s)
MWh	megawatt hour(s)
MSL	Mean Sea Level
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
O&M	operation and maintenance
PSMFC	Pacific States Marine Fisheries Commission
PDT	Product Development Team
PH1	first powerhouse
PH2	second powerhouse
PIT	passive integrated transponder
RM	river mile(s)
SCNFH	Spring Creek National Fish Hatchery
SP	super-peak (hours)
STS	submerged traveling screen
SWRG	USACE Northwestern Division Anadromous Fish Evaluation Program Studies Review Work Group
TEAM	Turbine Energy Analysis Model
TDG	total dissolved gas
TIE	turbine intake extension
TRD	turbulence reduction device
TSP	Turbine Survival Program
UMT	upstream migrant transportation
USACE	U.S. Army Corps of Engineers

VBS	vertical barrier screen

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this report is to document the development of the design for a concept to reduce the mortality and descaling of juvenile salmonids in the gatewells at the Bonneville Dam second powerhouse (PH2). The *Supplement to the Engineering Documentation Report Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program Post Construction* (USACE January 2015), referred to herein as the Supplement to the EDR, recommended static flow control plates on the gatewell beams as the primary method of improving conditions in the gatewells. An additional recommendation was to modify the vertical barrier screens (VBSs) to reduce areas of high approach velocity on the upper panels.

The scope of this project is to develop the design for flow control plates and VBS modifications to reduce hydraulic volume in the gatewells. The design will be developed using the existing sectional computational fluid dynamics (CFD) model that was developed as part of the Supplement to the EDR. The CFD model will be used to help determine the appropriate sizes for the plates for each of the three intake bays of a single turbine unit, as well as to help design the modifications to the VBSs. Once designed, these modifications will be implemented in a single turbine unit at PH2 as a prototype and will be evaluated with field hydraulic and field biological testing.

1.2 AUTHORIZATION

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

Actions to improve juvenile salmonid survival were identified by NOAA Fisheries at Bonneville PH2 in the Federal Columbia River Power System (FCRPS) 2008 Biological Opinion (BiOp). This project is Columbia River Fish Mitigation Program (CRFM) funded in response to Reasonable and Prudent Alternative (RPA) 18.

1.3 PROJECT DESCRIPTION

Bonneville Lock and Dam is located on the Columbia River, 145 river miles from its mouth and approximately 40 miles east of Portland, Oregon. It is the first dam on the Columbia River upstream of the Pacific Ocean. The facility consists of several components, including a new

navigation lock, the original navigation lock, the original powerhouse (PH1), the spillway, and the second powerhouse (PH2), as shown in Figure 1.

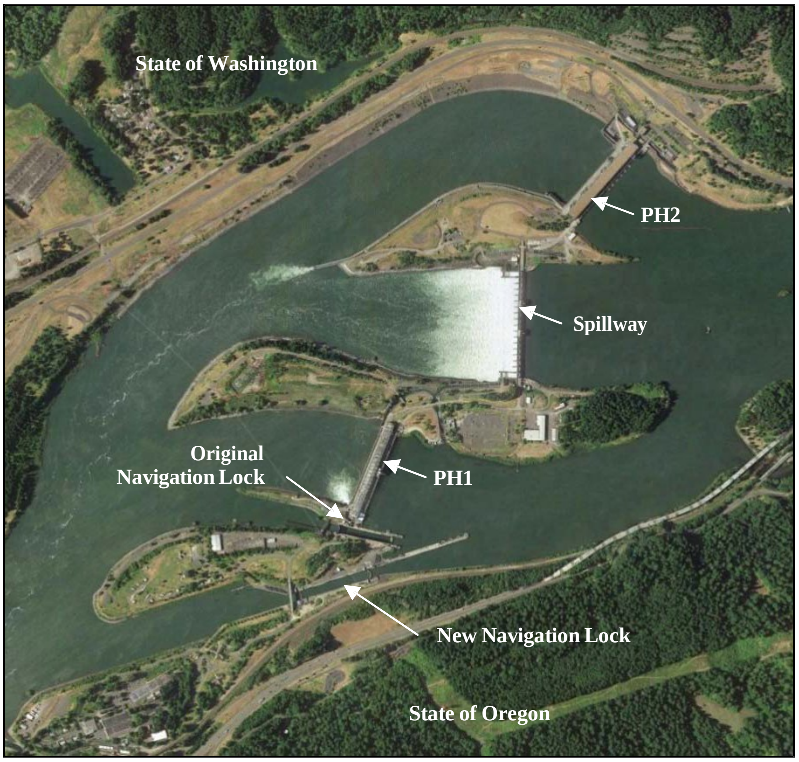

Figure 1 - Overview of Bonneville Dam

Image Source: Google Earth Pro V 7.1.1.188. Imagery Date 7/18/2010. Accessed 9/5/2014.

This report is focused on improvements at PH2. PH2 was completed in 1982 and is located between the spillway and the Washington shore. It has eight main generating turbines (numbered 11-18 from south to north), two fish turbines, and a sluiceway located at the south end of the powerhouse. Each intake for each of the main turbines is divided into three intake bays (or "slots"), designated "A", "B", and "C" from south to north. Figure 2 shows the PH2 arrangement.

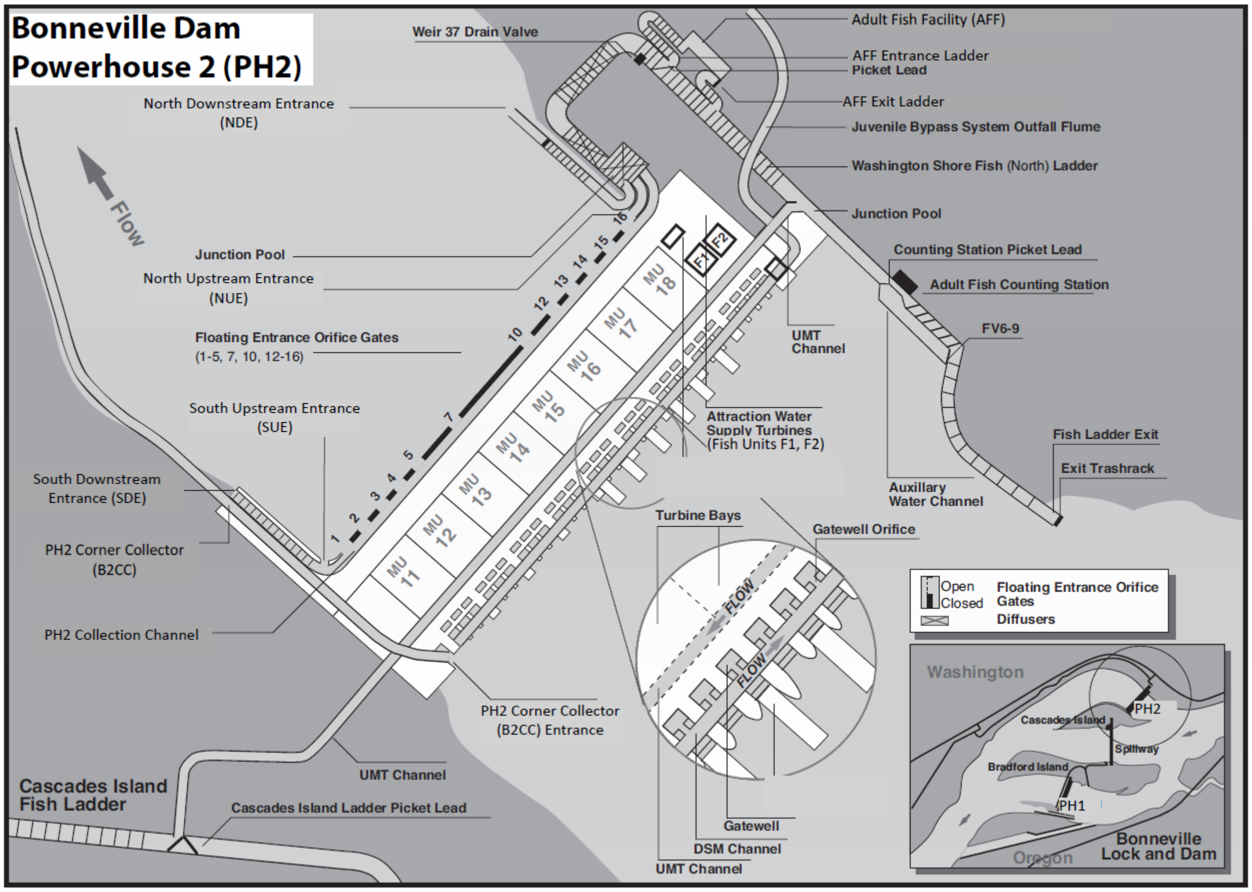

Figure 2 - Bonneville Dam Powerhouse 2 (PH2). (USACE 2015)

1.4 AGENCY COORDINATION

This report and all supporting studies were coordinated through the Fish Facility Design Review Work Group (FFDRWG), Northwestern Division Anadromous Fish Evaluation Program Studies Review Work Group (SRWG), and Fish Passage Operations and Maintenance (FPOM) regional work group. Members include representatives from Action Agencies (NOAA, BPA, and USACE), Federal and State fisheries managers, and Columbia River Inter-Tribal Fish Commission (CRITFC). Agency review occurred at 90 percent DDR. See Appendix B.

2. BACKGROUND

The construction of the Bonneville Dam second powerhouse (PH2) was completed in 1982. The powerhouse was designed with a juvenile bypass system (JBS) to guide out-migrating juvenile salmonids away from the hydroelectric turbines and around of the dam. The main components of the original JBS were submerged traveling screens (STS) to guide fish into the gatewells, vertical barrier screens (VBS) to prevent fish from returning to the turbine intakes from the gatewells, orifices to allow fish to pass from the gatewells into the downstream migrant transportation (DSM) channel, and an outfall that discharged into the powerhouse tailrace. USACE contracted with the National Marine Fisheries Service (NMFS) to oversee and monitor the initial operation of the JBS. Evaluations conducted by NFMS in 1983 showed unacceptably low fish guidance efficiency (FGE). Since those initial evaluations, there has been an ongoing effort to improve FGE at PH2.

Between 1983 and 1989, several short-duration tests were conducted on a wide range of structural modifications intended to improve FGE in the JBS, and a summary of the research is presented in Monk et al. April 1999. That research resulted in modifications that were fully implemented at PH2 in 1993 and included the installation of structures called turbine intake extensions (TIEs), lowering the STSs by extending their frames, and installing turbine intake trash racks with more streamlined members (USACE March 1992). Subsequent biological testing demonstrated lower than expected FGE with these improvements, and the regional goal for FGE was not achieved (Monk et al. April 1999).

In 1999, regional fisheries agencies agreed to pursue a phased approach to improve fish guidance and survival at PH2 by maximizing flow up the turbine intake gatewells, a guideline that has been used on similar programs to improve FGE. Typical juvenile fish bypass systems at lower Columbia River dams consist of submerged traveling screens, gatewell orifice passage, and turbine intake vertical barrier screens (VBS; Figure 3). The modifications at PH2 were completed in 2008 and included an increase in VBS flow area by removing portions of the gatewell beams, installation of turning vanes to facilitate flow up the gatewells, addition of a gap closure devices (GCD) to reduce fish loss between the STSs and gatewell beams, and allowances for the installation of an interchangeable VBS to allow for screen removal and cleaning without outages or intrusive gatewell dipping (Figure 4).

Prototype testing of improvements consisting of larger VBS's, GCD, and turning vanes was introduced in Main Unit 15B and 15C gatewells in 2001 with favorable results following biological testing for improved FGE, orifice passage efficiency (OPE), and fish condition. The 15A gatewell had a turning vane and larger VBS but the gap closure device was not installed. Results from spring testing showed an average FGE of 71% for yearling chinook and over 80% for steelhead and coho. These were the highest FGE values measured at B2 since testing began in the early 1980's (Monk et al 2002). Orifice passage efficiency tests were conducted during the same period with no significant differences between the modified gatewell 15B and unmodified 16B. Descaling rates averaged 2-3% for all species during the spring testing and 2% or less for subyearling chinook during summer tests. There were no significant differences between modified and unmodified units during both test periods (Monk et al. 2002). Treatments

to determine if the turbine operation had an effect on FGE were set up to test the upper 1% best efficiency operation for a given head and the standard operating automatic governor control (AGC) mode. They were used on alternating nights during both migration periods. Average spring unit discharge in the upper 1% was 15.8 kcfs with AGC mode averaging 13.6 kcfs. Summer discharge levels averaged 15.6 kcfs in the upper 1% with AGC mode averaging 13.8 kcfs.

Forebay hydraulics differ between the middle of the powerhouse near units 14 and 15 with more direct flow entering the units compared to the ends of the powerhouse where flow tends to show more lateral direction toward the north and south. Lateral flow and eddies in the forebay were thought to reduce FGE. Turbine unit 17 was modified with the same three intake modifications as unit 15B and 15C and tested in 2002 to determine if improvement could be achieved at the end units. Turbine Intake Extensions (TIEs) were installed in 17A and 17C and no TIE in 17B. FGE was highest in 17B. Monk et al. 2004 reported differences were significant for yearling chinook salmon among all three gatewells. FGE values were higher than what was observed in unit 17 in 1994, however, they were not as high as unit 15 in 2001. Descaling and injury rates for all species were examined during FGE and OPE tests. Results were promising with descaling and injury rates low for all species and no significant differences between the modified and unmodified units (Monk et al. 2004). Fry sized coho were also released to gatewell 15B during the last two weeks in March with a video camera set up in the gatewell to observe potential impingement on the VBS. Results showed minimal impingement or descaling. All FGE testing in Unit 17 during 2002 was conducted with unit 17 operating on AGG since no significant difference in FGE was detected between the two operating modes from 2001 testing. Discharge levels ranged from 12.0-16.7 kcfs and averaged 13.9 kcfs. Discharge during summer testing ranged from 12.2 to 16.3 kcfs and averaged 14.9 kcfs.

Elevated mortality and descaling rates were recorded at the PH2 Juvenile Fish Monitoring Facility (JFMF) following Spring Creek National Fish Hatchery sub-yearling Chinook salmon releases in 2007 (Gilbreath et al., 2012). Physical inspections of bypass facilities at PH2 resulted in little evidence to indicate that a mechanical system was the causative mechanism. Testing in 2008 and 2009 suggested undesirable flow conditions in the gatewell created as a result of bypass system modifications (i.e. turning vanes, larger VBS, and gap closure devices) were the causative mechanism for elevated mortality and descaling (Gilbreath et al., 2012). Starting in 2008, PH2 units were operated at the lower end of the 1% peak efficiency range during Spring Creek NFH releases to mitigate mortality and descaling. Since March 2011, PH2 units have been operated at the middle to lower end of the 1% peak efficiency range during regionally coordinated special operations to minimize PH2 descaling and mortality. Confining operation to the middle to lower end of the 1% range at PH2 reduces the operational flexibility and configuration that may maximize benefits to juvenile and adult salmonid passage at this priority powerhouse and through the project. A detailed description of the lower, middle, and upper 1% turbine operating efficiency range can be found in the U.S. Army Corps of Engineers (USACE) Turbine Survival Program (TSP) Phase I and II Biological Index Testing (BIT) reports, as well as the current Fish Passage Plan (FPP).

The challenge for the USACE and Fish Managers was to optimize FGE while keeping mortality and descaling to a minimum without compromising power generating efficiency. In response to the results of the 2008 biological testing, the USACE developed preliminary alternatives for potentially reducing flow into the gatewells, and presented them to the regional fisheries agencies. The regional fisheries agencies agreed with the USACE analysis and approved the study to investigate and evaluate flow control and operational alternatives to increase juvenile salmon survival within the gatewells. The effort and results of that study are documented in *Engineering Documentation Report Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program Post Construction* (USACE October 2013), which is referred to herein as the EDR.

The EDR evaluated both operational and structural alternatives for increasing juvenile survival in the gatewells. The hypothesis was that turbulence and poor hydraulic quality in the gatewells contributed to mortality and descaling by increasing gatewell residence time for fish. It was reasoned that high turbulence and high residence time in the gatewells fatigued fish that could not find egress orifices. One structural alternative was considered that was not intended to reduce flow into the gatewell, but was intended to modify the flow pattern within the gatewell, resulting in a hydraulic environment that is less detrimental to juvenile salmon. This alternative, called a “gate slot filler” or “turbulence reduction device” (TRD), consists of solid members that are installed in the guide slots above the STS side frame to eliminate the sudden expansions that occur there. CFD modeling conducted as part of the EDR indicated that the sudden expansions above the STS side frame cause areas of flow circulation and high turbulence. The CFD modeling conducted also showed a reduction in flow circulation and turbulence with the gate slot filler in place. It was hypothesized that the gate slot filler could improve juvenile salmon survival by improving the hydraulic environment within the gatewell by modifying flow patterns and reducing turbulence. Additional benefits of this alternative were that the operating range of the turbines would not be affected and that the existing fish guidance flow into the gatewells could be maintained.

The EDR recommended that a gate slot filler prototype be constructed and tested, both hydraulically and biologically. The EDR also recommended that the other alternatives in the report be reconsidered if the prototype did not result in satisfactory improvements in juvenile salmon survival within the gatewell.

A gate slot filler prototype was constructed and tested for hydraulic and biological performance (Harbor and Alden 2013; Gilbreath et al. 2014) during the spring of 2013. The results of the testing indicated that the prototype did not lead to adequate improvements in subyearling Chinook salmon survival within the gatewell (Gilbreath et al. 2014). In addition, the results of the hydraulic testing demonstrated hydraulic conditions within the gatewell that were previously unknown and not predicted with the CFD model that was used to evaluate alternatives as part of the EDR. The unsatisfactory performance of the gate slot filler, along with the new hydraulic data, prompted the need for further study, which resulted in the effort documented in *Supplement to the Engineering Documentation Report Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program Post Construction* (USACE November 2014), which is referred to herein as the Supplement to the EDR.

The Supplement to the EDR reconsidered the alternatives that were developed as part of the EDR for improving juvenile salmon survival in the gatewells at PH2. As part of the process, a criterion was developed to help evaluate the design alternatives. The criterion that was established based on coordination with NMFS and states that the flow through any VBS at any unit flow cannot exceed the flow though the bay A VBS at a unit flow of 15,000 cfs. This criterion is based on the determination that juvenile salmon gatewell survival is acceptable in the bay A VBS at a unit flow of 15,000 cfs, and the assumption that juvenile salmon gatewell survival directly correlates with flow through the VBS.

As part of the Supplement to the EDR, CFD models were developed for the alternatives and for the baseline conditions. The results from the modeling were used to evaluate the performance of the alternatives compared to the baseline conditions. Of the five alternatives modeled, only the following three met the design criterion for flow through the VBS.

- Install Static Flow Control Plate on Gatewell Beam
- Remove Gap Closure Device
- Remove Submerged Traveling Screen and Turning Vane

Of the three alternatives that met the design criterion, the alternative to install a static flow control plate demonstrated a hydraulic environment within the gatewell that most closely resembled the target design condition (baseline bay A with unit flow of 15 kcfs). The other two alternatives produced hydraulic conditions in the area of the STS and in the gatewells which could have negative impacts on FGE and fish survival.

Field velocity data was also collected as part of the effort for the Supplement to the EDR (Harbor and Alden 2014). Velocity data was collected under several scenarios, including various bays, various unit flows, and with some modifications to the gatewells. The gatewell modifications included installing a flow control plate on the gatewell beam in Unit 15A that blocked 50% of the opening between the downstream side of the beam at +31 mean sea level (msl) elevation and the intake gate. The velocity data supported the results of the CFD modeling, and indicated that the flow control plate reduced the flow up the gatewell, reduced the approach velocity for the VBS, and potentially reduced turbulence in the gatewell, all of which are expected to improve survival in the gatewells.

Based on the results of the CFD modeling and field velocity data, the recommendation in the Supplement to the EDR was to further study a static flow control plate installed on the gatewell beam as part of a DDR to reduce the mortality and descaling in the gatewells at PH2. Field velocity data collected in 2013 and 2014 demonstrated areas of high approach velocity on the upper panels of the VBS (Harbor and Alden, 2013 and 2014). An additional recommendation in the Supplement to the EDR was to study modifying the porosity plates on the upper two rows of panels on the VBS to conform to the approach velocity criteria (NMFS 2011) for the entire turbine operation range. Thus the overall intent was to reduce mortality and descaling without compromising FGE and power generation efficiency. The proposed alternative, therefore, should facilitate operating main units within the upper 1% efficiency, streamlining hydraulic flow through the gatewells, to reduce turbulence.

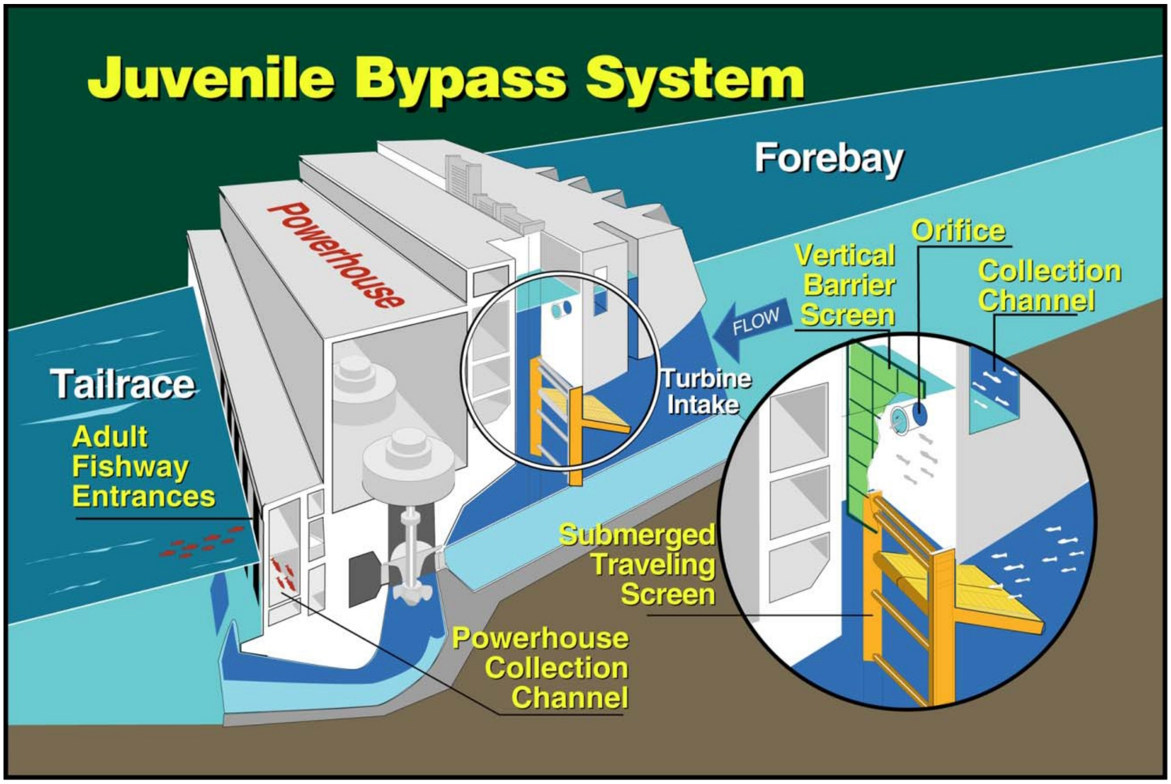

Figure 3 - Typical Juvenile Bypass System with STS, VBS and Orifice

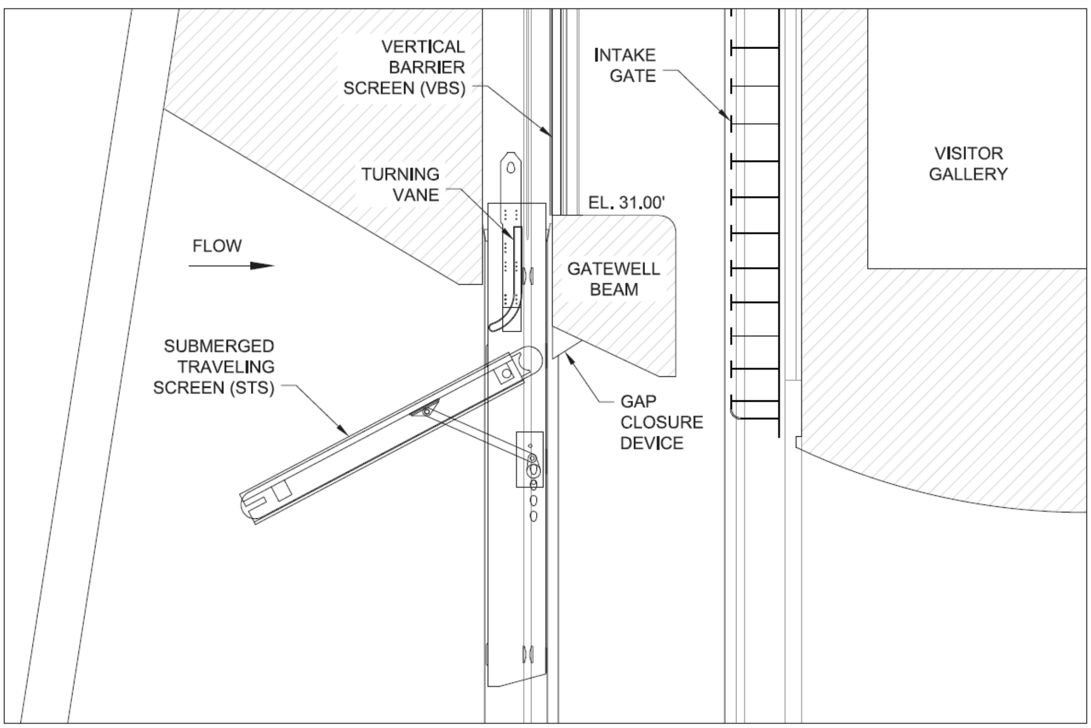

Figure 4 - Gatewell Entrance

3. BIOLOGICAL DESIGN CONSIDERATIONS AND CRITERIA

3.1 GENERAL

The 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) lists Reasonable and Prudent Alternatives (RPAs) that NOAA Fisheries concluded were sufficient to avoid jeopardy of ESA-listed salmon and steelhead. RPA #18 states –

"Configuration and Operational Plan for Bonneville Project
The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for the Bonneville Project (2008). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

…Bonneville Powerhouse II
Screened bypass system modification to improve fish guidance efficiency (FGE) and reduce gatewell residence time."…

The FGE Program Post Construction evaluations and regional coordination through; FFDRWG for structural modifications, FPOM for interim operations prior to completion of construction, and SRWG during study design have all had an influence in the development of DDR biological criteria. The primary source of general criteria for adult and juvenile salmon passage is taken from the *Anadromous Salmonid Passage Facility Design* Report (NMFS, 2011). Passage criteria specific to Bonneville Dam and the PH2 juvenile bypass system is provided in the 2015 *Fish Passage Plan* (USACE, 2015).

Regionally reviewed design and construction procedures in the FGE program in previous years have been sound and will continue to be coordinated through the FFDRWG and FPOM regional forums through construction. Please see 2013 EDR, 2014 EDR supplement, and DDR Appendix B for agency coordination.

3.2 REGIONAL COORDINATION

Regional coordination through FFDRWG resulted in agency representatives recognizing the potential for reduced FGE with the EDR Supplement flow control alternatives. The potential benefits of these alternatives were prioritized by FFDRWG, including increased survival in the gatewell and the ability to maintain the full operation range of the PH2 main turbine units. (Please see EDR and EDR Supplement for additional biological benefits, FFDRWG minutes, and relevant correspondence)

A design criterion was developed for the EDR study to help evaluate the design alternatives. The criterion that was established was based on coordination with FFDRWG and states that the flow through any VBS at any unit flow cannot exceed the flow though the Bay A VBS at a unit flow of 15.0 kcfs. This criterion is based on the determination that river run juvenile salmon gatewell survival is acceptable through Bay A at a unit flow of 15.0 kcfs, and the assumption that juvenile salmon gatewell survival directly correlates with flow through the VBS. FPOM coordinated interim operations have consisted of limiting the PH2 main unit operation to flows not exceeding15.0 kcfs. Survival measured at the Bonneville Dam Juvenile Fish Monitoring Facility has been acceptable with this operation.

The USACE presented the alternatives evaluation and DDR recommended alternative at the 13 August 2014 FFDRWG. FFDRWG members were supportive in moving forward with further investigation and a prototype design was developed for testing.

3.3 BIOLOGICAL TESTING OF PROTOYPE

Biological testing of the modified Unit 15 A and C gatewells was coordinated through the USACE Northwestern Division Anadromous Fish Evaluation Program Studies Review Work Group (SRWG) during FY 2014/2015. The evaluation addressed study code BPS-P-15-1. USACE contracted the National Marine Fisheries Service (NMFS) to conduct the biological evaluation during the spring of 2015. For more detail, please see the NMFS FY15 research proposal *"B2 FGE Improvements, and Post Construction Gatewell Improvement Testing."*

The generator limit at 54 feet of head with STS installed is 19.536 kcfs (Figure 6). This is the maximum discharge in the normal operation range during fish passage season. Physical modeling, Computational Fluid Dynamics (CFD) modeling, and direct measurements in the gatewell has confirmed that the "A" gatewell receives more flow than the "B" gatewell and the "B" gatewell receives more flow that the "C", primarily influenced by the asymmetrical main unit scroll case geometry.

Test ranges needed to be developed for the modified main unit in the upper 1% peak efficiency at a flow that was a high enough level to represent the most problematic hydraulic conditions yet could be operationally achieved with regularity through the test period of April and May. Review of operations data resulted in the 18.0-18.5 kcfs range identified as the optimal test range representing the upper 1% peak efficiency for the modified unit. Flows targeted in the 14.3-14.8 kcfs range would represent the middle 1% in the unmodified unit.

A complete prototype of the proposed gatewell improvements was constructed in Unit 15 in February 2015 for biological and hydraulic testing. The primary purpose of the biological testing was to evaluate the effect of the prototype on fish survival and gatewell residence time. AFEP research summary BPS-P-15-1 was designed to test the hypothesis that reducing flow into a PH2 modified A and C gatewell will improve gatewell flow conditions thereby reducing mortality at the upper 1% peak efficiency turbine operation range. Evaluation of gatewell residence times and fish condition (mortality and injury) compared treatments at the upper and middle 1%. Specific biological objectives included:

1. Investigate hydraulic impacts and gatewell dynamics resulting from the installation of flow control plates.
2. Investigate through-screen-velocities optimization by adjusting porosity plate density.

3. Estimate Spring Creek NFH juvenile subyearling Chinook salmon mortality and gatewell residence time at the upper and middle 1% peak efficiency range under the following gatewell configurations in 15A and 14A.

    a. Modified Gatewell 15A at upper 1% operation.
    b. Unmodified Gatewell 14A at middle 1% operation.

4. Estimate Spring Creek NFH juvenile subyearling Chinook salmon mortality and gatewell residence time at the upper and middle 1% peak efficiency range of Gatewell Slots 14A and 15C.

    a. Unmodified Gatewell Slot 15C at upper 1% operation.
    b. Unmodified Gatewell Slot 14A at middle 1% operation.

5. Compare treatment A against treatment B for Objective 1 and 2 releases (sample sizes shall be calculated to detect a difference in fish condition of 3% at $\alpha = 0.05$).

    i. Fish Condition (FC): $H_0 = FC_{upper15A} = FC_{mid14A}$;
    $H_A = FC_{upper15A} \neq FC_{mid14A}$

    ii. Gatewell Residence Time (GRT): $H_0 = GRT_{upper15A} = GRT_{mid14A}$;
    $H_A = GRT_{upper15A} \neq GRT_{mid14A}$

    iii. Fish Condition (FC): $H_0 = FC_{upper15C} = FC_{mid14A}$;
    $H_A = FC_{upper15C} \neq FC_{mid14A}$

    iv. Gatewell Residence Time (GRT): $H_0 = GRT_{upper15C} = GRT_{mid14A}$;
    $H_A = GRT_{upper15C} \neq GRT_{mid14A}$

Test species were subyearling Chinook salmon obtained directly from Spring Creek National Fish Hatchery (SCNFH). Fish were transported to the JFMF for PIT tagging and held for approximately 24 hours prior to tagging. After tagging, fish were held again for 24 hours to detect mortality and loose tags prior to release. Releases of PIT tagged test fish were made at the +90 deck through a flexible release hose inserted into a PVC and steel pipe mounted guide on the trashracks (used in 2008-2009 and 2013 tests) into Second Powerhouse Turbine Intakes 14A, 15A, and 15C (Figure 5). Since only one trashrack release mechanism was used in previous years, a duplicate trashrack release mechanism was constructed to evaluate a modified and unmodified gatewell at the same time. Three groups of reference fish were released to the bypass system transport channel near the unit 14 and 15 orifices for each evaluation to quantify baseline timing, tag loss, and mortality not associated with the gatewell environment. Passage effects were estimated, including mortality proportions and median passage times from turbine intake release to recapture at the Second Powerhouse Juvenile Fish Monitoring Facility (JFMF). Test fish were recaptured at the JFMF using programmable separation-by-code (SbyC), anesthetized, examined for injury and mortality, and returned to the river. Early season smaller bodied SCNFH subyearling Chinook have been determined to be good test fish for measuring gatewell survival. Previous testing in 2008-2009 resulted in river run fish being better test fish for descaling impacts. SRWG concluded that SCNFH subyearlings were preferred given what is known through previous years B2 FGE evaluations, river run fish testing impacts, test complexity and schedule constraints, as well as the prioritization of the mortality data.

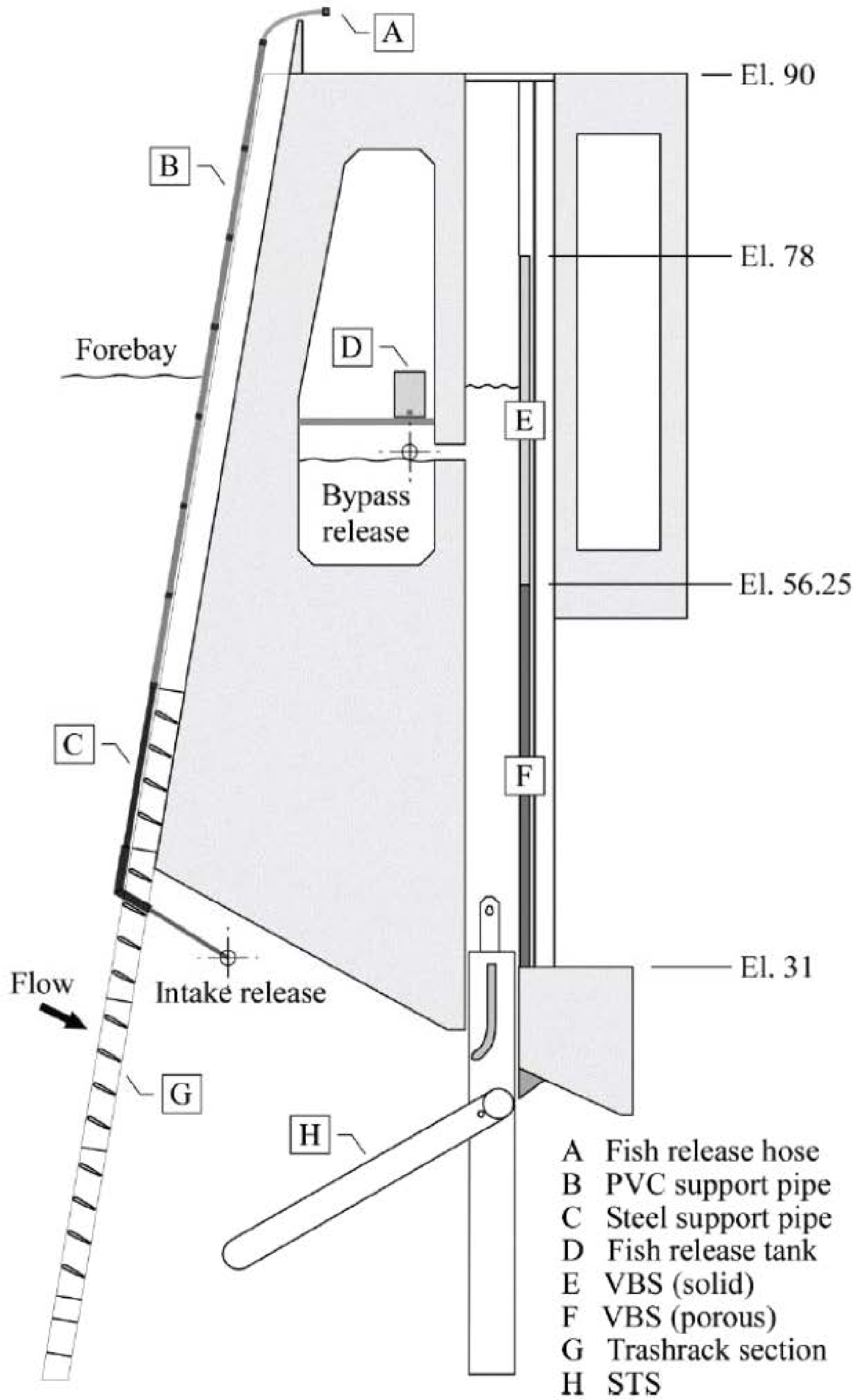

Figure 5 - Partial transverse section through a turbine intake and gatewell at Bonneville Dam Second Powerhouse.

Standard fish guidance structures and release locations used by NOAA Fisheries in 2015 are labeled. Elevations are in feet msl. Crosshair symbols denote release locations. Abbreviations: VBS, vertical barrier screen; SIS, submersible traveling screen.

3.4 NMFS PRELIMINARY RESULTS OF TESTING

NMFS researchers have provided preliminary results to the USACE. Please see Appendix H for the complete set of preliminary results and 2015 AFEP abstract including figures of the results reported in Tables 1 through 3 as well as box plots for gatewell residence times i.e., test fish passage time comparisons.

An AFEP presentation of preliminary results is scheduled for Dec. 8 - 10, 2015 in Walla Walla, WA. A draft report will be available Dec. 2015 and USACE will send it to FFDRWG for review and comment. A final report will be submitted to the USACE and distributed to FFDRWG following NMFS researcher's response to review comments, no later than March 2016.

Preliminary Data Provided by NMFS on Sept. 8, 2015:

Subyearling Chinook salmon were PIT-tagged and released between 1 April and 29 May 2015 into gatewell slots 14A, 15A, and 15C. A portion of the tagged fish were detected at the Second Powerhouse Juvenile Fish Monitoring Facility (JFMF) and a portion were diverted into sample tanks using the Sort-by-Code system. Diverted fish were examined for injury (rare) and mortality. Date and time of first detection at the JFMF was noted for detected fish. Useful metrics were defined and calculated as follows:

ObsProp = Observed proportion of each release that were subsequently detected somewhere in the PIT-tag system of the JFMF
RecapProp = Observed proportion of JFMF-detections that were recaptured in sample tanks and examined for injury/mortality. [*USACE NOTE: NMFS reported bare tags recovered from the JFMF sump are included in this group*]
ObsMortProp = Proportion of ObsMort to Total in recapture sample
MaxMortProp = Estimated mortality proportion of released fish =
ObsMort + NonRecapObs*ObsMortProp + NonObs,
Where ObsMort = Observed mortalities in recapture sample,
NonRecapObs = Observed JFMF detections that were not in recapture sample
And NonObs = Fish released but not observed anywhere in the JFMF

Gatewell Residence Time (GRT) = Median time from release to first detection in the JFMJ for each cohort of daily-released PIT-tagged fish into each gatewell

Consider the following possible assumptions:

A1 – Mortality was related only to gatewell treatment or passage to the JFMF, and not as a result of being sampled by the Sort-by-Code system. Therefore, all mortality was expressed fairly quickly after the mechanism that caused it, and fish not sampled by the Sort-by-Code system had the same mortality probability as those sampled.

A2a – Fish not detected by the JFMF were mortalities that prevented the PIT tag from reaching the facility. This means the JFMF detection probability was assumed to be 100% and tagged fish did not have an opportunity to exit the dam without passing through the JFMF.

A2b – Fish not detected by the JFMF passed another route that prevented the PIT tag from being detected. This means the JFMF detection probability was assumed to be 0% and these fish would have had the same mortality probability as the JFMF-detected fish if they had used the same passage route.

ObsMortProp is an appropriate estimate of the true treatment mortality under A1 and A2b. MaxMortProp is an appropriate estimate of the true treatment mortality under A1 and A2a. We made assumption A1 for this study. We also assumed that neither assumptions A2a or A2b were probably completely correct, but rather an unknown proportion of fish "fit" under each of them. Unfortunately we have no way of estimating that proportion. Therefore, accurate estimates of treatment mortality in this study lie between these two estimates. When the proportion of undetected fish was small, ObsMortProp was assumed to be a reasonably accurate estimate of the particular treatment mortality.

Summary data results are as follows:

Table 1- Series 1, Unit 14A. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
4/1	100	0.930	0.978	0.187	0.244	0.106
4/2	94	0.872	1.000	0.122	0.234	0.057
4/3	101	0.960	0.990	0.292	0.320	0.263
4/4	100	0.920	0.978	0.256	0.315	0.038
4/5	100	0.920	0.957	0.443	0.488	0.347
4/6	102	0.951	0.969	0.340	0.373	0.463
4/7	100	0.930	0.968	0.322	0.370	0.251
4/8	99	0.960	0.916	0.184	0.217	0.044
4/9	101	0.970	0.949	0.323	0.343	0.289
4/21	116	0.879	0.961	0.122	0.228	0.506
4/23	250	0.912	0.890	0.059	0.142	0.487
5/5	125	0.992	0.952	0.034	0.042	0.544
5/7	233	0.966	0.942	0.038	0.071	0.495
	Mean	0.936	0.958	0.209	0.260	0.299
	SE	0.010	0.008	0.036	0.035	0.053

Table 2 - Series 1, Unit 15A. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
4/1	100	0.950	1.000	0.000	0.050	0.095
4/2	99	0.914	0.975	0.026	0.105	0.035
4/3	102	0.882	1.000	0.000	0.118	0.054
4/4	100	0.910	1.000	0.044	0.130	0.040
4/5	100	0.890	0.989	0.000	0.110	0.057
4/6	100	0.840	1.000	0.000	0.160	0.175
4/7	101	0.634	0.984	0.032	0.386	0.106
4/8	100	0.620	0.952	0.051	0.412	0.076
4/9	100	0.580	0.983	0.018	0.430	0.068
4/21	115	0.443	0.922	0.085	0.594	0.075
4/23	240	0.783	0.963	0.006	0.221	0.522
5/5	125	0.800	0.980	0.010	0.208	0.537
5/7	247	0.834	0.971	0.000	0.166	0.543
	Mean	0.775	0.978	0.021	0.238	0.183
	SE	0.043	0.006	0.007	0.046	0.056

Table 3 - Series 2, Unit 14A. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
5/12	131	0.985	0.938	0.017	0.032	0.532
5/13	129	0.984	0.937	0.000	0.016	0.044
5/14	123	0.984	0.942	0.018	0.034	0.392
5/15	130	0.954	0.976	0.025	0.070	0.548
5/18	130	0.977	0.969	0.016	0.039	0.545
5/19	130	0.985	0.953	0.041	0.056	0.527
5/20	129	0.984	0.984	0.016	0.031	0.393
5/21	130	0.954	0.960	0.076	0.118	0.288
5/22	140	0.986				0.407
5/27	130	0.992	0.953	0.000	0.008	0.369
5/28	130	0.946	0.935	0.017	0.070	0.548
5/29	135	0.993	0.978	0.008	0.015	0.568
	Mean	0.977	0.957	0.021	0.044	0.430
	SE	0.005	0.005	0.006	0.010	0.044

Table 4 - Series 2, Unit 15C. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
5/12	131	0.954	0.984	0.000	0.046	0.345
5/13	131	0.962	1.000	0.008	0.046	0.368
5/14	118	0.983	0.948	0.000	0.017	0.337
5/15	134	0.985	0.962	0.016	0.030	0.511
5/18	130	0.969	0.968	0.016	0.047	0.497
5/19	130	0.915	0.958	0.018	0.101	0.633
5/20	130	0.815	0.962	0.000	0.185	0.296
5/21	130	0.962	0.992	0.008	0.046	0.545
5/22	142	0.944				0.567
5/27	130	0.954	0.847	0.000	0.046	0.518
5/28	130	0.962	0.920	0.000	0.038	0.545
5/29	134	0.993	0.955	0.000	0.007	0.475
	Mean	0.950	0.954	0.006	0.055	0.470
	SE	0.014	0.013	0.002	0.015	0.031

The above metrics were used to provide estimates for objectives 3 and 4 (Note means and se's in Tables 1, 2, 3, and 4) and to make comparisons for objective 5 using paired t-tests. Results are in Tables 3 and 4 and visually represented in Figures 6-8 of Appendix H. These preliminary results suggest that mortality for comparison "i." above was significantly higher in Unit 14A than in Unit 15A using the observed sample mortality ($P < 0.001$) but using the maximum estimated mortality it was undetermined since the first 6 groups had higher mortality in Unit 14A but the last 6 groups had lower for a non-significant difference overall (P=0.705). For the latter metric, dividing the data into the "obvious" groupings, the early part (releases on 1-6 April showed significantly higher mortality in Unit 14A (P = 0.003) and for 7 April-7 May showed significantly lower mortality in Unit 14A (P =0.021) For comparison "iii." above, there was a significant difference in mortality using either the observed metric (Unit 14A > Unit 15C by 1.5%, P = 0.029) but not significant using the maximum estimated mortality metric (Unit 14A < Unit 15C by 1.1%, P = 0.549). For comparison "ii." above, Gatewell Residence Time was around three hours significantly longer than for Unit 15A (P = 0.021) but not different at all for Unit 15C (P = 0.402). Further, perhaps more complex, analysis will be explored to examine these patterns.

Boxplots of Gatewell Residence Time distributions are in Appendix H. Fish that were observed as mortalities at the JFMF Sort-by-Code sample had somewhat longer times than live fish (Figure A1 of Appendix H). This difference needs to be discussed. There were not generally large differences in median Gatewell Residence Time as noted in Table 5 and 6, but there were some observed differences in the shape of the distributions (Figures A2 and A3).

[*USACE NOTE: Figures A1, A2, A3 can be found in BON2Gatewell Study 2015 Preliminary Results located in DDR Appendix H*]

Table 5 Paired differences for metrics comparing conditions in Unit 14A and 15A gatewells in 2015 at Bonneville Dam 2nd Powerhouse.

Release Date	ObsProp Difference	RecapProp Difference	ObsMortProp Difference	MaxMortProp Difference	Median Gatewell Residence Time (d) Difference	MaxMortProp Difference	
						4/1 -4/6	4/7 - 5/7
4/1	-0.020	-0.022	0.187	0.194	0.011	0.194	
4/2	-0.042	0.025	0.096	0.129	0.022	0.129	
4/3	0.078	-0.010	0.292	0.202	0.209	0.202	
4/4	0.010	-0.022	0.212	0.185	-0.002	0.185	
4/5	0.030	-0.032	0.443	0.378	0.290	0.378	
4/6	0.111	-0.031	0.340	0.213	0.288	0.213	
4/7	0.296	-0.017	0.290	-0.017	0.146		-0.017
4/8	0.340	-0.036	0.133	-0.195	-0.032		-0.195
4/9	0.390	-0.034	0.305	-0.087	0.222		-0.087
4/21	0.436	0.039	0.037	-0.366	0.431		-0.366
4/23	0.129	-0.072	0.054	-0.079	-0.035		-0.079
5/5	0.192	-0.028	0.024	-0.167	0.007		-0.167
5/7	0.132	-0.029	0.038	-0.095	-0.048		-0.095
	0.160	-0.021	0.189	0.023	0.116	0.217	-0.144
	0.044	0.008	0.038	0.058	0.044	0.034	0.043
t	3.625	-2.681	4.958	0.388	2.664	6.320	-3.328
df	12	12	12	11	12	4	5
P-value	0.003	0.020	0.000	0.705	0.021	0.003	0.021
95% CI Lower	0.064	-0.037	0.106	-0.106	0.021	0.122	-0.255
95% CI Upper	0.256	-0.004	0.271	0.151	0.211	0.312	-0.033

Table 6- Paired differences for metrics comparing conditions in Unit 14A and 15C gatewells in 2015 at Bonneville Dam 2nd Powerhouse.

Release Date	ObsProp Difference	RecapProp Difference	ObsMortProp Difference	MaxMortProp Difference	Median Gatewell Residence Time (d) Difference
5/12	0.031	-0.046	0.017	-0.014	0.187
5/13	0.023	-0.063	-0.008	-0.030	-0.324
5/14	0.001	-0.006	0.018	0.017	0.056
5/15	-0.031	0.014	0.009	0.039	0.037
5/18	0.008	0.000	0.000	-0.008	0.049
5/19	0.069	-0.005	0.023	-0.045	-0.106
5/20	0.169	0.022	0.016	-0.153	0.098
5/21	-0.008	-0.032	0.068	0.072	-0.258
5/22	0.042				-0.160
5/27	0.038	0.107	0.000	-0.038	-0.149
5/28	-0.015	0.015	0.017	0.032	0.003
5/29	0.000	0.023	0.008	0.008	0.093
	0.027	0.003	0.015	-0.011	-0.040
	0.015	0.013	0.006	0.018	0.045
t	1.787	0.189	2.545	-0.620	-0.872
df	11	10	10	10	11
P-value	0.102	0.854	0.029	0.549	0.402
95% CI Lower	-0.006	-0.027	0.002	-0.051	-0.139
95% CI Upper	0.061	0.033	0.028	0.029	0.060

Preliminary Data Provided by NMFS on Nov. 9, 2015:

All test fish were obtained from the Spring Creek National Fish Hatchery. Fish were typically held for 24 hours before being PIT tagged. After tagging, fish were again held for 24 hours to detect mortality and loose tags before being released. Of the 6,626 total fish tagged for the study we had 4 mortalities and 0 loose tags prior to release. On study days, releases occurred in the morning, and were made into the turbine intakes of both gateslots. Fish were released into each turbine intake through a 4" flex hose from the intake deck. Fish were recaptured at the Juvenile Fish Monitoring Facility (JFMF) using the PIT-tag separation-by-code (SbyC) system.

For the first series (14A v 15A), a total of 3,250 fish in thirteen replicates were released from 1 April through 7 May 2015. Test fish averaged 70 mm fork length (range 52 to 103 mm) increasing from 65 mm to 75mm over the study period

The overall observed mortality proportion during the evaluation of 15A v 14A was 0.021 and 0.209 for 15A and 14A, respectively, which was a significant difference. This was the proportion of fish that were mortalities either when recaptured in the SbyC system or recovered as bare tags in the sump located just upstream of the primary dewatering structure at the JFMF. The observed mortality varied over the course of the evaluation. During the first six replicates, observed mortality was significantly higher in 14A, while it was significantly lower over the last replicates. The overall proportion of test fish recaptured from 15A releases was lower for the last six replicates which may have affected the results.

Under the assumption fish not detected after release are mortalities, the maximum possible mortality proportion was 0.260 and 0.238 for 14A and 15A, respectively, which was not significantly different.

The percentage of tagged fish that were recaptured by the SbyC system of those that were detected by the full flow detectors were both high at 0.958 and 0.978 in 14A and 15A, respectively.

For the second series (14A v 15C), a total of 3,137 fish in twelve replicates were released from 12 – 29 May 2015. Test fish averaged 79 mm fork length (range 57 to 112 mm) and increased from 75 mm to 81mm over the study period

The overall observed proportion was relatively high for both groups (0.977 and 0.950 for 14A and 15C, respectively). As in the first evaluation, the recapture proportion was over 0.95 for both groups.

The observed mortality proportion for both groups was low (0.021 and 0.006, for 14A and 15C respectively) and not significantly different.

As was observed in the first evaluation, the percentage of test fish that were recaptured with the SbyC system was just over 0.95 for both release groups.

We also released three groups of fish into the bypass system collection channel during each evaluation series (total of 239 fish) to quantify baseline timing, tag loss, and mortality not associated with the gatewell environment. We recaptured 229 of these fish and none were observed with any injury or mortality. The ten fish not recaptured were all detected on the full flow detectors. Nine of them were "missed" by the SbyC system, and the other fish was detected in the smolt monitoring sample. The overall median passage time was just over 38 minutes from time of release to first detection at the full flow detectors.

3.5 DISCUSSION OF PRELIMINARY RESULTS

Low river flows in 2015 resulted in close coordination between PM-E, RCC, BPA and the BON to ensure operations targets could be met through the test period since high unit head can result in the inability to pass the upper 1% target test flow due to generator limitations. Additionally, having enough river flow was a concern for the number of units operating, including both test units simultaneously. More detail regarding test unit operations and adjacent units will be forthcoming in the draft report. Preliminary NMFS review of the BON 5-minute operations data provided by BON confirmed that operations targets for each main unit were met through the study period (Absolon pers. comm. and Appendix H).

Preliminary review of PSMFC Smolt Monitoring Program weekly reports for river run fish through the test period did not identify higher than expected mortality during testing for this time of year with a FPP ≤ mid 1% unit operation at PH2 (Ballinger and Absolon pers. comm.). There were periods during testing when one priority unit and unit 14 were operating ≤ mid 1%, unit 15 at upper 1%, while all other PH2 units were in standby. Nearly all JBS passed fish would have likely passed through these three units during these periods.

The VBS seals were inspected prior to testing and in good condition. They remained this way with no change through the test period. The structural crew reported that during the test period of April and May 2015, debris loading in the gatewells and on the VBSs in unit 14 and 15 were lower than normal. The VBSs and gatewells were free of large accumulations of debris and mortalities on the VBS or in the gatewells were not evident as in previous years (Jackson pers. comm.). Debris accumulation and mortalities were more concentrated on the upper two VBS panels in previous years but there was little difference in the vertical distribution of VBS debris in the modified unit high flow gatewells 15A and 15C during the test period. However, no distinct differences in debris volume were noted between unit 15 and 14. VBS cleaning occurred on Mondays and Thursdays during the test period. Debris loading was not likely a significant contributor to mortality for either modified unit 15 or unmodified unit 14.

Units 11-14 have regulating orifices and units 15-18 have a single orifice. The unit 14 regulating orifice was closed and not operated as a flow regulating orifice during test periods. The unit 14 and 15 single orifices operated normal as in 2008-2009 and 2013 testing, i.e., with the auto cycling flush enabled and orifice lights functioning.

Test releases of PIT-tagged Spring Creek NFH subyearling Chinook salmon in 2008-09 provided consistent evidence that passage mortality in this stock increases in a stepwise manner as Second Powerhouse turbine operation is raised to higher levels within the 1% peak efficiency range (Gilbreath et al. 2012). Results from biological testing in 2013 showed increasing turbine operation from the lower to the upper 1% had higher rates of observed mortality and lower rates of recapture (Gilbreath et al. 2014). Similar trends in recapture occurred in 2008 in comparison of the lower, middle, and upper 1% with SCNFH stock. These trends were observed again in 2009. Fish released at the middle 1% had higher mortality and lower recapture than those released at the lower-middle 1% (13.5 kcfs). The overall ObsProp rate in 2015 was lower for the higher flow unit during comparison of 14A and 15A, following trends from previous years testing. Mortality proportions using both metrics, ObsMortProp and MaxMortProp, did not follow that same mortality pattern as previous years indicating improvement in test unit 15. Mean Mortality using the MaxMortProp estimate in 14A and 15A had a non significant difference overall (P = 0.705). Since the ObsProp difference between 14A and 15A were much more pronounced during the latter half of testing from April 7 to May 7, NMFS divided the early and late groups for the MaxMortProp mortality estimates. The early group from April 1 to 6 showed significantly higher mortality in Unit 14A ($P = 0.003$) and for April 7 to May 7 showed significantly lower mortality in Unit 14A ($P = 0.021$). The assumption that missing fish are all mortalities drives the mortality estimate up for the latter group in 15A. Both estimates should be considered but it is unknown what happened to the missing fish and the real mortality rate may lie somewhere between.

Gatewell Residence Time was around three hours significantly longer in Unit 14A (7.2 hrs) compared to 15A (4.4 hrs) (P = 0.021) but not different at all for 14A and 15C (P = 0.402). Longer gatewell residence times were linked with higher mortality as unit flow increased in previous years 2008-09 gatewell studies. This is a strong contributing factor for higher or similar mortality observed in 14A at mid 1% if gatewell hydraulic conditions are better or similar in 15A and 15C at upper 1%.

The preliminary data from biological testing suggests that the objectives have been met for improved survival in modified unit 15A and 15C gatewells at upper 1% operation compared to unmodified unit 14A operated at mid 1%.

3.6 BIOLOGICAL DESIGN CRITERIA

The DDR biological criteria are based primarily upon modifications to the configuration of the gatewells in the PH2 screened bypass system and benefits to juvenile salmonids (genus *Oncorhynchus*). However, this passage route is available for downstream adult salmonid passage, Pacific lamprey (*Entosphenus tridentatus)*, white sturgeon *(Acipenser transmontanus)*, and bull trout (Salvelinus confluentus). Structural modifications and impacts to these fish have also been considered and any improvements made for juvenile salmonids are expected to benefit passage conditions for these species.

Anadromous Salmonid Passage Facility Design (NMFS 2011) criteria for this project include through screen velocities for vertical barrier screens (VBS) and states: "*Average VBS through screen velocity must be a maximum of 1.0ft/s, unless field testing is conducted to prove sufficiently low fish descaling/injury rates at a specific site*."

Biological design criteria are focused on improving gatewell survival during PH2 main unit operations in the upper 1% peak efficiency range as a result of reducing flow into the gatewell and reducing excessive through screen velocities on the VBS. Turbine discharge ranges for each foot of head at PH2 can be found in Bon Table 16 of 2015 Fish Passage Plan and displayed in Figure 6.

Table BON-15. Bonneville Dam Powerhouse Two Turbine Units 11–18 Power (MW) and Flow (cfs) at Lower, Mid-Range and Upper Limits of the ±1% Peak Efficiency Operating Range. [1]

	Powerhouse Two (Units 11-18)											
	With STS						No STS					
Project	1% Lower Limit		1% Mid-Range		1% Upper Limit		1% Lower Limit		1% Mid-Range		1% Upper Limit	
Head			13kcfs	15kcfs					13kcfs	15kcfs		
(ft)	(MW)	(cfs)	(MW)	(MW)	(MW)	(cfs)	(MW)	(cfs)	(MW)	(MW)	(MW)	(cfs)
35	27.6	11,259	31.9	36.8	44.3	18,068	28.2	11,444	32.1	37.0	45.1	18,277
36	28.5	11,271	32.9	37.9	45.8	18,097	29.2	11,455	33.1	38.2	46.6	18,306
37	29.4	11,279	33.9	39.1	47.3	18,121	30.1	11,464	34.1	39.4	48.1	18,331
38	30.3	11,284	34.9	40.3	48.8	18,139	31.0	11,470	35.2	40.6	49.7	18,350
39	31.3	11,287	36.0	41.6	50.3	18,153	32.0	11,473	36.3	41.8	51.2	18,364
40	32.2	11,288	37.1	42.8	51.8	18,162	32.9	11,474	37.3	43.0	52.7	18,374
41	33.0	11,259	38.1	44.0	53.3	18,197	33.7	11,445	38.3	44.2	54.3	18,409
42	33.8	11,230	39.1	45.2	54.9	18,228	34.6	11,415	39.4	45.4	55.8	18,441
43	34.6	11,201	40.2	46.3	56.4	18,255	35.4	11,386	40.4	46.6	57.4	18,468
44	35.4	11,172	41.2	47.5	57.9	18,278	36.2	11,357	41.4	47.8	58.9	18,493
45	36.2	11,144	42.2	48.7	59.4	18,299	37.0	11,328	42.5	49.0	60.5	18,514
46	37.0	11,139	43.2	49.8	61.0	18,366	37.9	11,324	43.5	50.2	62.1	18,581
47	37.8	11,135	44.2	51.0	61.9	18,200	38.7	11,319	44.5	51.3	63.0	18,415
48	38.7	11,129	45.2	52.1	62.7	18,040	39.6	11,314	45.5	52.5	63.8	18,255
49	39.5	11,124	46.2	53.3	63.5	17,887	40.4	11,308	46.5	53.6	64.7	18,101
50	40.3	11,118	47.2	54.4	67.5	18,598	41.3	11,303	47.5	54.8	68.7	18,817
51	41.3	11,154	48.1	55.5	69.8	18,850	42.2	11,339	48.4	55.9	71.1	19,072
52	42.3	11,187	49.1	56.7	72.1	19,091	43.2	11,373	49.4	57.0	73.4	19,316
53	43.2	11,219	50.1	57.8	74.5	19,323	44.2	11,405	50.4	58.1	75.8	19,551
54	44.2	11,249	51.0	58.8	76.5	19,536	45.2	11,436	51.3	59.2	76.5	19,431
55	45.2	11,278	52.1	60.1	76.5	19,115	46.2	11,466	52.4	60.5	76.5	18,975
56	46.4	11,343	53.2	61.3	76.5	18,718	47.4	11,531	53.5	61.7	76.5	18,581
57	47.6	11,404	54.2	62.6	76.5	18,336	48.6	11,593	54.6	63.0	76.5	18,202
58	48.8	11,461	55.4	63.9	76.5	17,967	49.9	11,652	55.7	64.3	76.5	17,836
59	50.0	11,515	56.5	65.1	76.5	17,611	51.1	11,707	56.8	65.6	76.5	17,483
60	51.2	11,567	57.6	66.4	76.5	17,267	52.3	11,760	57.9	66.8	76.5	17,142
61	51.8	11,532	58.5	67.5	76.5	16,978	53.0	11,724	58.9	67.9	76.5	16,857
62	52.5	11,498	59.5	68.6	76.5	16,699	53.7	11,690	59.8	69.1	76.5	16,582
63	53.1	11,466	60.4	69.7	76.5	16,428	54.3	11,657	60.8	70.1	76.5	16,315
64	53.7	11,434	61.3	70.7	76.5	16,166	55.0	11,625	61.7	71.2	76.5	16,056
65	54.4	11,405	62.3	71.8	76.5	15,912	55.6	11,595	62.6	72.3	76.5	15,806
66	55.4	11,448	63.2	72.9	76.5	15,671	56.7	11,639	63.6	73.4	76.5	15,570
67	56.5	11,490	64.2	74.0	76.5	15,437	57.8	11,682	64.6	74.5	76.5	15,341
68	57.5	11,532	65.1	75.1	76.5	15,210	58.9	11,724	65.5	75.6	76.5	15,119
69	58.6	11,571	66.1	76.3	76.5	14,990	59.9	11,764	66.5	76.5	76.5	14,903
70	59.6	11,610	67.0	77.3	76.5	14,775	61.0	11,803	67.5	76.5	76.5	14,693

1. Table based on January 2001 data (HDC). Updated 2006. Added "Mid-Range" 2014.

Figure 6 - 2015 FPP PH2 operation range.

3.7 ANADROMOUS FISH PASSAGE STRUCTURE MATERIALS

All structural modifications of the gatewell will occur in fish free water downstream of the VBS stainless steel face. No structural changes will be made to the STS guidance system components or the gatewell dimensions. Materials to be used for the construction of the flow control plates attached to the gatewell beam at elevation +31 and VBS porosity modifications will be nontoxic stainless and carbon steel. This material will have no negative effect on adult salmonid and lamprey attraction and passage.

3.8 IN- WATER WORK WINDOW

The FPP in-water work window (IWW) for annual maintenance of fish facilities is scheduled for December 1 through Feb 28 or 29. Work during this period minimizes impacts on both upstream and downstream migrating salmonids. During the in-water work period, one fish ladder (Bradford Island or WA Shore) is always operational. Juvenile fish passage facilities operate from March 1 through November 30; however, STSs remain in place through December 15 to prevent adult salmonids from falling back through turbine units. Beginning December 16, all STSs may be removed. STS re-installation is normally scheduled during the last two weeks of February.

During the 2016/2017 IWW period, WA shore adult fish ladder will be dewatered Dec. 1 – Feb. 28. The Bradford Is. adult ladder will be in operation and PH1 as priority.

Construction impacts will be coordinated through FPOM. Units 18 and 11 are less flexible in terms of outage dates and are priority for scheduling and minimization of fish impacts.

The B2 FGE PDT met with BON project representatives at BON on Oct. 5 and Nov. 17, 2015 to discuss construction schedule and project support. The construction sequence for installing plates in A and B gatewells at el. +31 requires the main units to be dewatered to tailwater. STSs need to be removed from the gatewell and bulkheads installed to dewater the A and B gatewell. The C gatewell will not have a plate installed therefore the hydraulic head gate can be deployed for the unit dewatering. A schedule was developed based on fish passage impacts, unit outages, the number of bulkheads available (one solid, two segmented), significance of crane work, competing winter maintenance priorities and project crew availability, navlock work in March, etc… The following schedule (also in section 7.2) represents the preferred timing, given our current constraints and ability to complete the modifications.

Outage schedule -

a. Unit 16, 17 & 18 - during the T12 outage: Sept. 7 thru Nov. 23, 2016.
b. Unit 11, 12, 13, 14 – targeting winter maintenance period: Dec. 1, 2016 thru Feb. 17, 2017. (*PH2 STS installation last week of Feb.)*
c. Unit 13 & 14 – Flexibility if necessary until March 31, 2017.

4. HYDRAULIC DESIGN

4.1 GENERAL

There have been several modifications made over the years to the gatewells at the second powerhouse, as discussed in Section 2. Most of the improvements have been intended to increase flow into the gatewells in an attempt to increase fish guidance. However, testing in 2008 and 2009 suggested that gatewell modifications have resulted in undesirable flow conditions that are contributing to elevated mortality and descaling within the gatewells (Gilbreath et al., 2012). As a result, several alternatives were considered to improve the hydraulic conditions within the gatewells, resulting in a recommendation to further study using flow control plates to reduce the flow into the gatewells (USACE 2013, 2014). It was also recommended that a design be developed for modifications to the porosity plates on the upper panels of the VBSs to reduce the areas of high through-screen velocity observed there.

As part of this study, a computational fluid dynamics (CFD) model was selected to be the primary tool to help develop the designs for the flow control plates and VBS modifications. The intent of the CFD model is to provide insight to the impacts that proposed improvements might have on the hydraulics within the gatewells relative to the baseline, or existing, configuration. A detailed documentation of the modeling effort is in provided in Appendix D, *Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Computational Fluid Dynamics Modeling Report for DDR, November 2014.*

A prototype of the proposed improvements was constructed in Unit 15 in February 2015 for biological and hydraulic testing. The hydraulic testing was used to evaluate the hydraulic performance of the prototype.

4.2 HYDRAULIC CRITERIA

A hydraulic design criterion was established as part of the development of the Supplement to the EDR to help evaluate the design alternatives. The criterion was based on coordination with NOAA and states that the flow through any VBS at any unit flow cannot exceed the flow though the bay A VBS at a unit flow of 15,000 cfs. This criterion is based on the determination that juvenile salmon gatewell survival is acceptable in the bay A VBS at a unit flow of 15,000 cfs, and the assumption that juvenile salmon gatewell survival directly correlates with flow through the VBS.

4.3 HYDRAULIC FEATURES

4.3.1. Vertical Barrier Screens

Per NMFS criteria, the average through-screen velocity for a vertical barrier screen cannot exceed 1.0 ft/s (NMFS 2011). Hydraulic data collected in the gatewells of units 14 and 15 (Harbor and Alden 2013, 2014) demonstrated areas of approach velocity normal to the screen above 1 ft/s through the upper portions of the VBS panels, mostly at the second row of panels, but also at the upper row of panels. One of the objectives of this study is to develop a design recommendation for modifying the porosity plates on the upper two rows of panels on the VBS to better conform to the approach velocity criteria for the entire turbine operation range.

The existing configuration for the VBS panels includes no porosity plates on the upper row of panels and porosity plates with 45.6% opening on the second row of panels. Velocities up to 1.8 ft/s were measured in this region, so it was determined that the initial design should be to reduce the open areas by about 50% to reduce the velocities by about the same. It was also determined that it would be beneficial to use the same design as the existing porosity plates if possible. As a result, the proposed design for the porosity plates on the top row of panels is an open area of 45.6% and the proposed design for the porosity plates on the second row of panels is an open area of 21.3%, as shown in Table 7.

Table 7 - VBS Porosity Plate Porosities

Row	Existing Porosity	Proposed Porosity
1 (top)	1.000	*0.456*
2	0.456	*0.213*
3	0.213	0.213
4	0.213	0.213
5	0.213	0.213
6	0.185	0.185
7	0.185	0.185
8	0.276	0.276
9	0.627	0.627

4.3.2. Flow Control Plates

Flow control plates were selected as the preferred alternative for improving hydraulic conditions within the gatewells. These plates will be installed on the tops of the gatewell beams and will restrict the openings between the gatewell beams and the intake gates that the return flows from the gatewells to the turbines pass through as shown in Figure 7. The intent of these plates is to reduce the flow into the gatewells with the goal of reducing the intensity of the turbulence there and improving the overall hydraulic conditions within the gatewells with respect to fish condition and mortality.

Based on the modeling that was conducted as part of the Supplement to the EDR, and the velocity data that was collected in 2014 (Harbor and Alden, 2014), the proposed improvements include a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate the blocks approximately 25% of the opening in bay B, and no flow control plate in bay C.

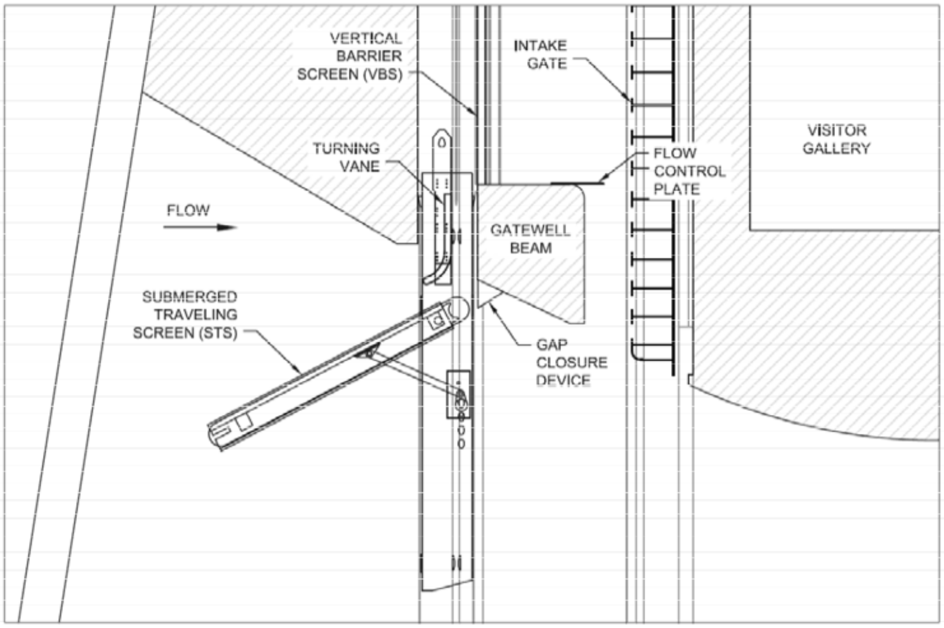

Figure 7 - Flow Control Plate Location

4.4 COMPUTATIONAL FLUID DYNAMICS MODELING

A computational fluid dynamics (CFD) model was selected to be the primary tool to help develop the designs for the flow control plates and VBS modifications. The CFD model used for this study is a sectional model of a single powerhouse unit and is the same model that was used to evaluate alternatives as part of the Supplement to the EDR. More information on the CFD model development and results can be found in Appendix D *Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Computational Fluid Dynamics Modeling Report for the DDR, November 2014*.

The modeled scenarios for this study included the baseline conditions and proposed conditions at three different turbine operations representing the lower, middle, and upper operation ranges. The calculated flows through the VBS panels for each of those scenarios are show in Table 8 below. Based on the modeling, the maximum allowable flow through a VBS panel is 232 cfs (Baseline, bay A, Unit Flow = 15,000 cfs). The modeling indicates that the proposed improvements will result in flows through the VBSs that meet the specified VBS flow criterion for the entire turbine operating range. The modeling also shows a reduction in the intensity of turbulence in the bay A and B gatewells compared to the baseline condition. In addition, the modeling indicates that the proposed improvements will greatly reduces the areas of high approach velocity normal to the screen on the upper portions of the VBSs.

Table 8 - VBS Flow Summary from CFD Modeling

Turbine Operation	Unit Flow (cfs)	Bay A VBS Flow (cfs)	Bay B VBS Flow (cfs)	Bay C VBS Flow (cfs)
Baseline Conditions				
Lower Range	12,000	176	168	139
Middle Range	15,000	232	211	173
Upper Range	18,000	279	253	209
With Flow Control Plates and Modified VBS Panels				
Lower Range	12,000	131	141	135
Middle Range	15,000	164	176	169
Upper Range	18,000	202	212	204

4.5 VELOCITY DATA COLLECTION

Hydraulically the modifications being recommended are to provide gatewell hydraulics that are as good as the hydraulic conditions in slot A at a mid-range flow conditions ~15,000 cfs. In 2013 prototype data was collected in unit 15 at 15,100 cfs, Figure 8 shows the results. The proposed modifications (flow plates in slots A and B and VBS modifications) were installed in unit 15 and velocity data was collected in the modified unit and unmodified units, see Appendix I. Figure 9 shows the hydraulic conditions in the modified unit (Unit 15) Slot A under a high flow condition (18,300 cfs). When Figure 8 is compared to Figure 9 the hydraulic conditions in Figure 9 (modified unit at high flow) are generally more uniform and slower than the target. In particular the hotspots around elevation 53 to 54 are significantly reduced if not eliminated. Figure 10 compares high flow conditions in a modified unit 15A and a non- modified unit 14A. This figure clearly illustrates the improvements in the hydraulic conditions (slower and more uniform flow conditions) with the modifications.

Modifications were different depending on the slot. All three slots (A, B and C) were modified with new VBS panels – with porosity plates described in Table 7. Slot A passes the most flow and has a flow control plate that blocks 50% of the flow area. Slot B passes less flow than A and has a flow control plate that blocks 25% of the flow area. Slot C passes the least flow and had no flow control plate. Data was collected in all three bays in the modified unit (15) to verify that acceptable flow conditions were achieved in all three bays. Additional data can be found in Appendix I but Figure 11 shows the hydraulic conditions for all three slots for the high flow condition. Hydraulic conditions at the high range flow in the modified unit (15) look good and hydraulically should be implemented across the second powerhouse at Bonneville.

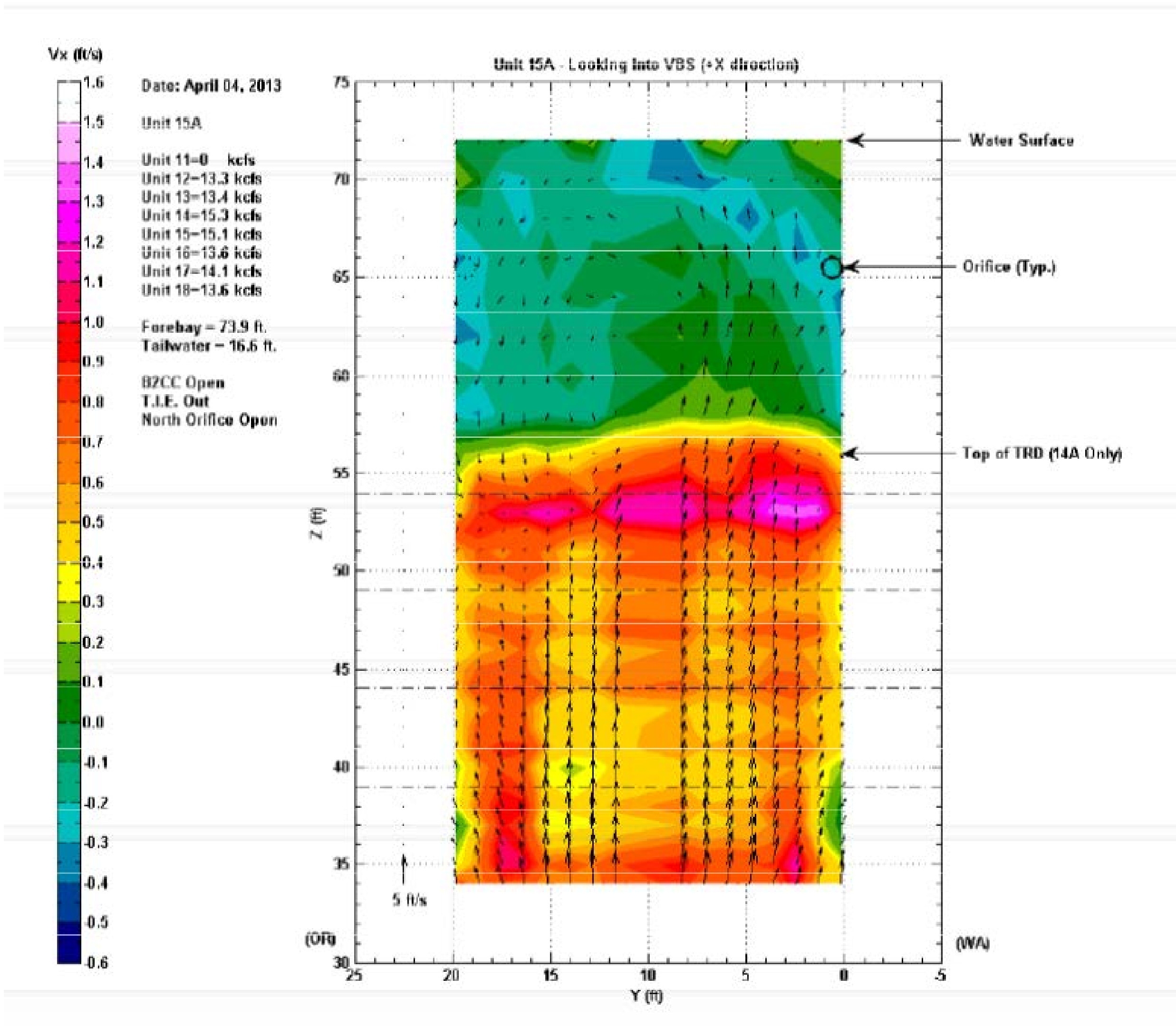

Figure 8 - No Modification Unit 15 Slot A - Mid-Range Flow

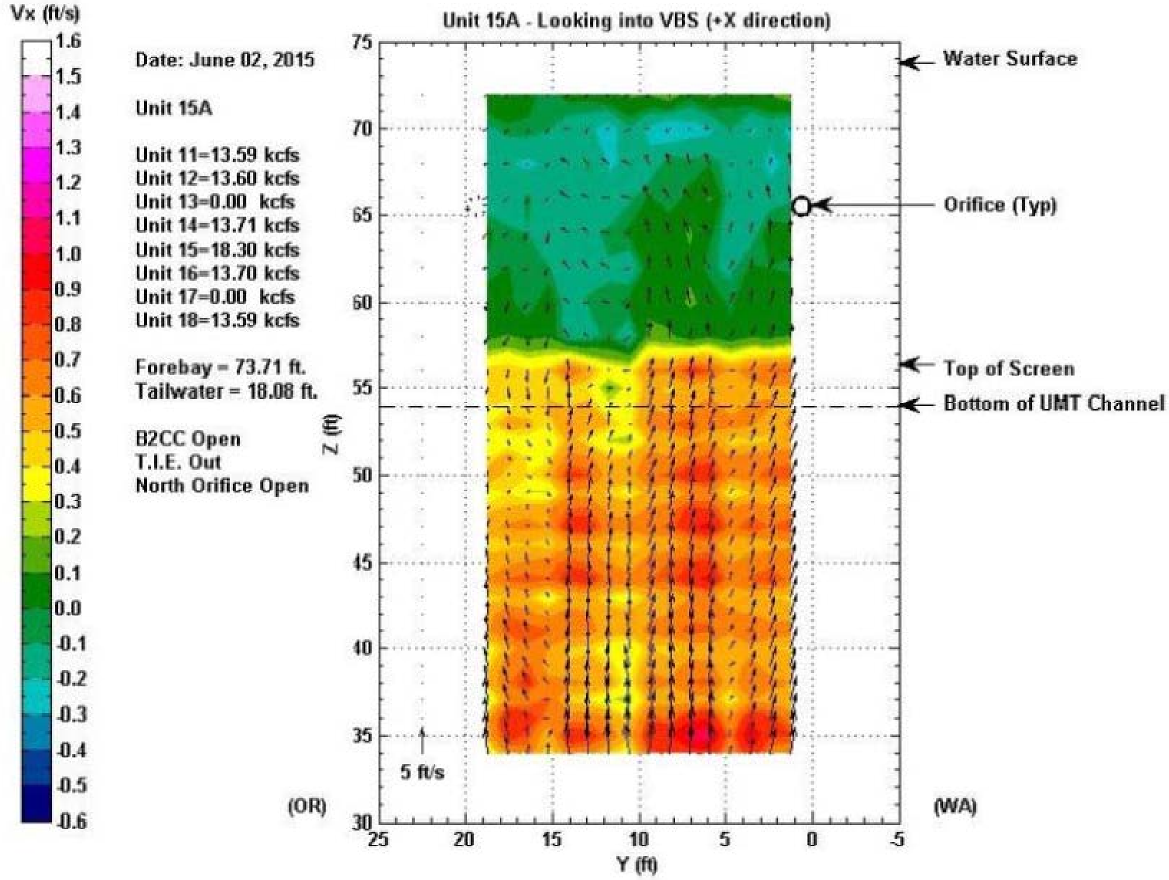

Figure 9 - Modified Unit 15 Slot A - High-Range Flow

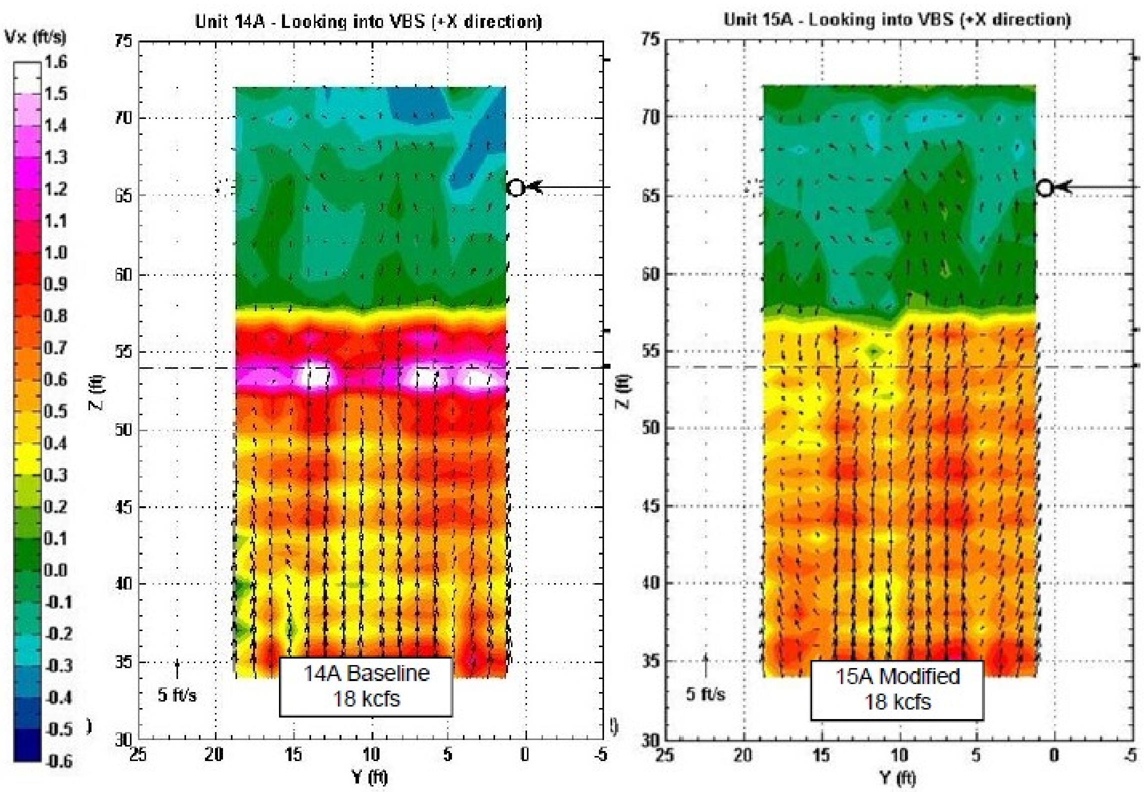

Figure 10 - Comparison High Flow Slot A - No Modifications and Full Modifications

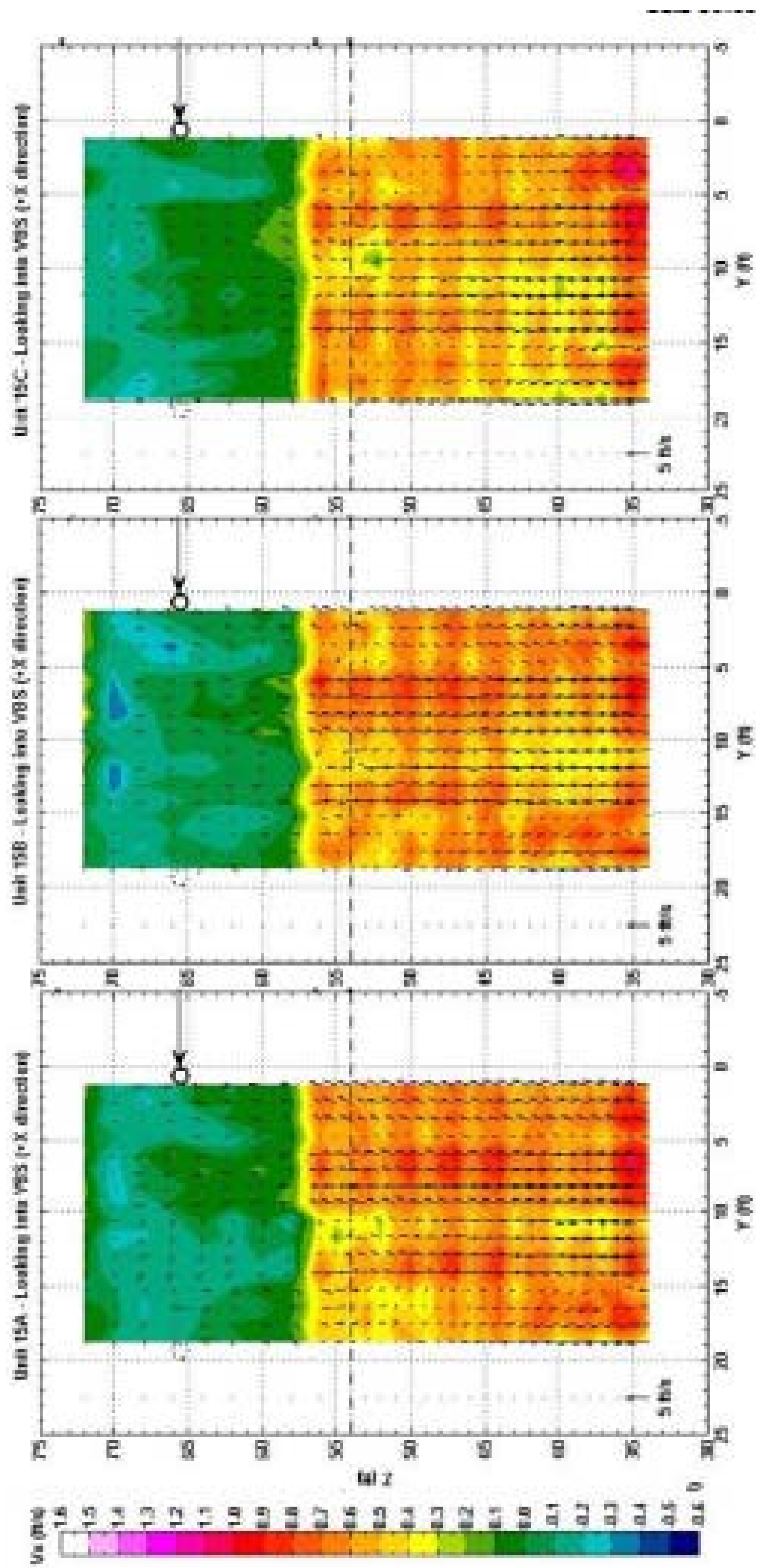

Figure 11 - Modified Unit 15 High-Range Flow

5. STRUCTURAL DESIGN

5.1 GENERAL

The structural features of the proposed gatewell improvements are described in this section. The new structural features will be constructed of concrete, steel, stainless steel and will be designed as described in the following paragraphs. This section covers references, basic data, design loads, and structural design/analysis considerations for each component of the modifications.

5.2 BASIC GEOTECHNICAL DATA

No Geotechnical information is needed for this project.

5.3 ENGINEERING PROPERTIES OF CONSTRUCTION MATERIALS

The engineering properties of construction materials are:

Concrete: All Cast-in-Place Structures

Existing concrete f'c=4,000 psi
Modulus of elasticity (E) 3,600,000
psi Poisson's ratio 0.2

Steel Reinforcement: All Structures

Existing: ASTM A15 (replaced by A615) Grade 40 fy=40,000 psi

Structural carbon steel and structural stainless steel: Areas of use shown on drawings

ASTM A36 (carbon steel) fy=36,000 psi
ASTM A240 (stainless steel) fy=30,000
psi
ASTM A276 (stainless steel) fy =30,000 psi to 45,000 psi depending on Type selected

ASTM = American Society for Testing
Materials f'c = Specified compressive
strength of concrete fy = Specified yield
strength

5.4 DESIGN LOADS

5.4.1. Dead Loads

Dead loads consist of the weight of concrete, metal, and fixed equipment. Concrete unit weight is assumed to be 150 pounds per cubic foot (lbs/ft^3). Steel unit weight of 0.283 pound per cubic inch (lb/in^3) is based upon AISC values for structural plates and shapes. Aluminum unit weight of 0.098 lb/in^3 is based on AA values for structural shapes and plates.

5.4.2. Live Loads

The load rejection forces applied to the flow control plates will be considered as live loads.

5.4.3. Hydrostatic Loads

The hydrostatic loads against the structure include internal and external pressures for all design load conditions. The unit weight of water is assumed to be 62.4 lbs/ft^3.

5.5 STRUCTURAL ANALYSIS

5.5.1. Design References

The structural design will conform to the following reports, criteria, Engineering Technical Letters (ETLs), and industry codes.

- U.S. Army Corps of Engineers (USACE) /Bell, Milo C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria.
- National Marine Fisheries Service, 2008. Anadromous Salmonid Passage Facility Design.
- USACE. 2014. ETL 1110-2-584, Design of Hydraulic Steel Structures.
- American Concrete Institute (ACI).ACI 318-11, Building Code Requirements for Structural Concrete.
- ACI. ACI 350-06, Code Requirements for Environmental Engineering Concrete Structures.
- American Institute of Steel Construction (AISC). Steel Construction Manual (LRFD and ASD), 14th Edition.
- American Society of Civil Engineers (ASCE). ASCE 07-10, Minimum Design Loads for Buildings and Other Structures.
- American Welding Society (AWS). 2011. Structural Welding Codes for Steel and Aluminum.
- International Building Code (IBC). 2012, as supplemented by the 2007 Oregon Structural Specialty Code, Chapter 16, “Wind and Snow Load Analysis.”

5.6 STRUCTURAL FEATURES

Several alternatives were considered to improve the hydraulic conditions within the gatewells, resulting in a recommendation to further study using flow control plates to reduce the flow into the gatewells (USACE 2013, 2015). It was also recommended that a design be developed for modifications to the porosity plates on the upper panels of the vertical barrier screens (VBSs) to reduce the areas of high through-screen velocity.

5.6.1. Vertical Barrier Screens

As part of this study, a computational fluid dynamics (CFD) model was used to help develop the designs for the flow control plates and VBS modifications. The proposed improvements include modifying the porosity plates on the upper two rows of panels on the VBSs. The proposed design includes reducing the open areas for those panels by about 50%.

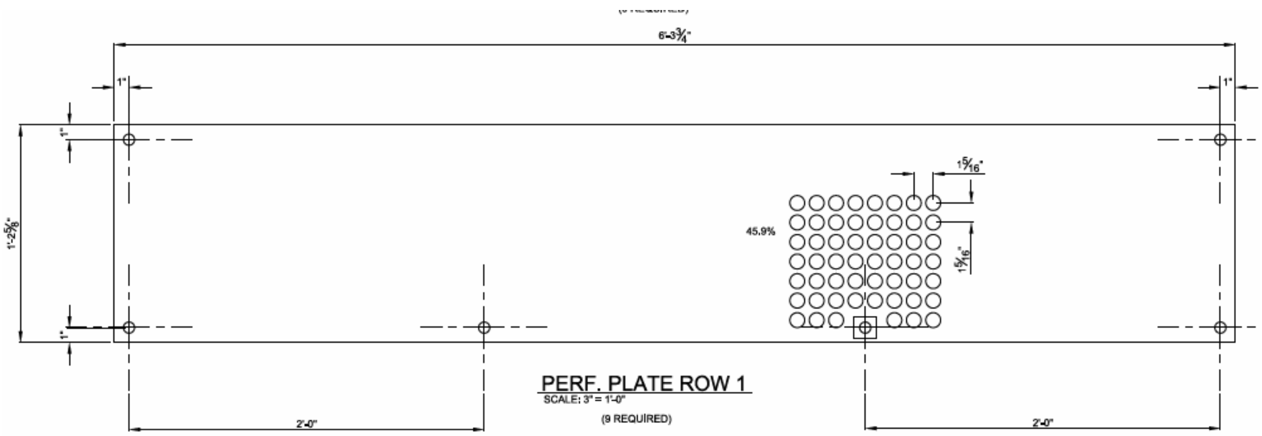

Figure 12 - VBS Modification, Row 1 on upper panels

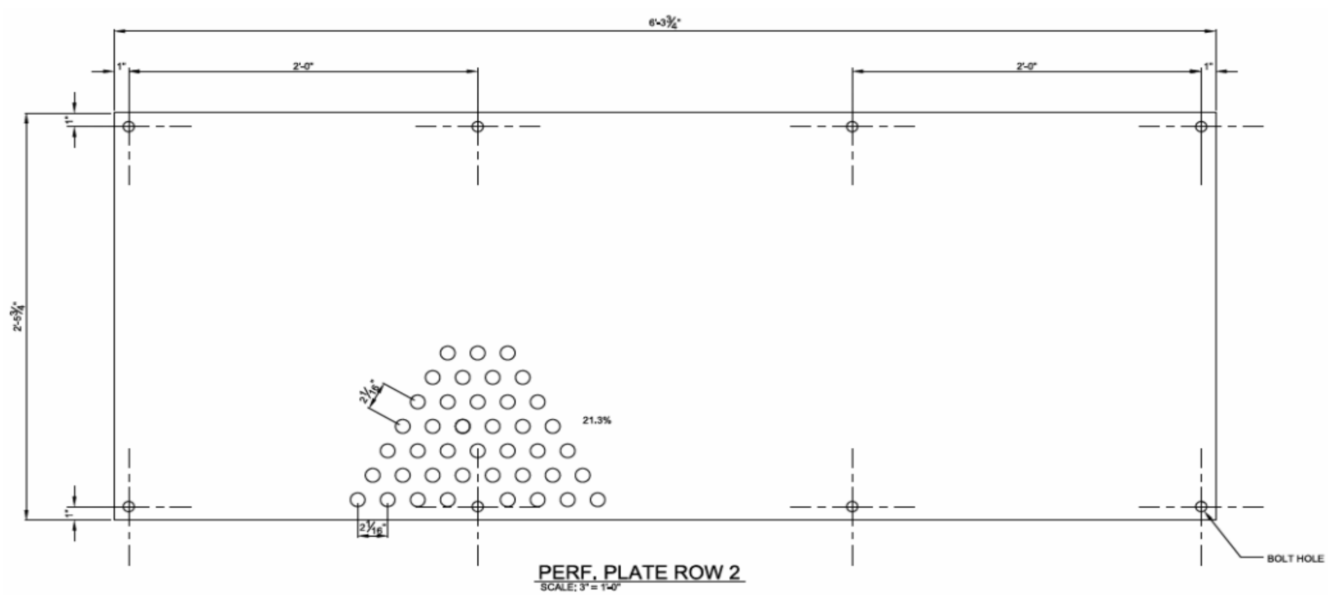

Figure 13 - VBS Modification, Row 2 on upper panels

5.6.2. Flow Control Plates

As part of this study, a computational fluid dynamics (CFD) model was used to help develop the designs for the flow control plates and VBS modifications. Based on the modeling and velocity data that was collected in 2014 (Harbor and Alden, 2014), the proposed improvements include a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate the blocks approximately 25% of the opening in bay B, and no flow control plate in bay C.

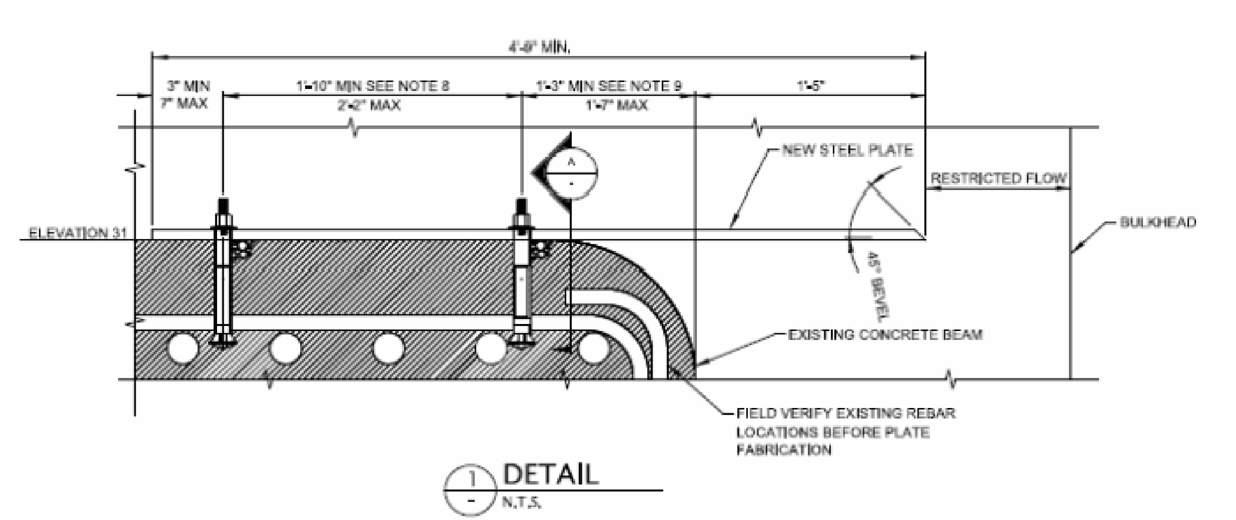

Figure 14 - Flow Control Plate in A Slot

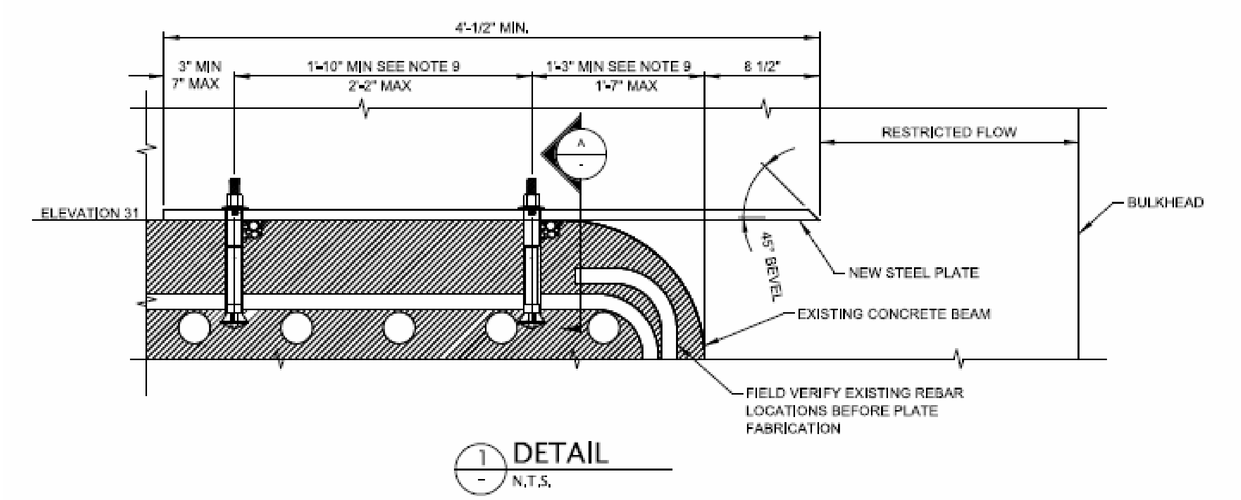

Figure 15 - Flow Control Plate in B Slot

6. ENVIRONMENTAL AND CULTURAL RESOURCES

6.1 GENERAL

Contract execution of the flow control plate installation is contingent on compliance with the National Environmental Policy Act and related applicable environmental laws, such as the National Historic Preservation Act (NHPA) and Endangered Species Act (ESA).

6.2 ENVIRONMENTAL RESOURCES

The following Environmental Acts are given consideration for the flow control plate installation:

National Environmental Policy Act (NEPA): This action falls under the Categorical Exclusions outlined in 33 CFR 230.9(b) because it is an activity at a completed Corps project and the Corps' review ensures the authorized project purposes will be carried out. At this design stage, there have been no extraordinary circumstances identified that would require the preparation of an Environmental Assessment or Environmental Impact Statement.

Clean Water Act (CWA): No point source discharge or non-point discharge would result from the activity; therefore a Section 402 National Pollutant Discharge Elimination System (NPDES) is *not* required.

Endangered Species Act (ESA): The Columbia River in the project area is designated critical habitat for eleven Evolutionarily Significant Units or Distinct Population Segments of listed Pacific salmonids. Pacific eulachon and green sturgeon are listed in the Columbia River to Bonneville Dam, although the project area does not include critical habitat for green sturgeon.
http://www.westcoast.fisheries.noaa.gov/maps_data/endangered_species_act_critical_habitat.html.

The Columbia River in the project area is designated critical habitat for bull trout. Information on the listing can be found at: http://ecos.fws.gov/species_profile/bull trout Consultation with NOAA Fisheries for the above described project has been addressed through the non-routine maintenance provisions in the FCRPS Biological Opinion (BiOp). The FCRPS BiOp states that "non-routine maintenance" of fish passage facilities may be conducted "as needed" but that any fish passage criteria that have to be changed (such as de-watering of the fish ladder outside of the usual routine outage schedule) must be coordinated with Fish Passage Operations and Maintenance (FPOM) Coordination Team. The proposed improvements described above will occur during the previously scheduled T-12 outage and normal winter maintenance period within the in-water work window. Construction impacts are anticipated to be minimal and will be coordinated through FPOM. The Corps participates in a Fish Facilities Design and Research Working Group (FFDRWG) which includes representatives from NOAA Fisheries, USFWS, CRITFC, as well as states of OR, WA, ID. The Corps has presented an overview of the proposed improvements to FFDRWG. Final review and approval by FFDRWG will come at the final design.

Scheduled in-water work periods:

1. Unit 16, 17 and 18: 7 September through 23 November 2016, during the T12 outage.
2. Unit 11, 12, 13, and 14: 01 December 2016 through 28 February 2017, during winter maintenance.
3. Unit 13-14: Flexibility if necessary during March. Contract completion will be 31 March 2017.

Columbia River Gorge National Scenic Area Act (CRGNSA): This Act created a National Scenic Area in the Columbia River Gorge to protect and enhance the scenic, natural, cultural and recreational resources of the Columbia River Gorge; and to protect and support the economy of the area by encouraging growth to occur in urban areas and allowing future economic development consistent with resource protection. The operation, maintenance, and improvement of navigation facilities at Bonneville Dam except for the offsite disposal of excavation material, is exempt from regulation under the Management Plan or land use ordinances adopted by counties or the Gorge Commission under the Scenic Area Act (see 16 U.S.C.§ 5440 Sec. 17 and the 2004 Management Plan Part II Chapter 7 General Policies and Guidelines amended in 2011). The contractor will be responsible for locating an approved (commercial) facility for the collection of the construction waste ensuring that all applicable environmental laws and regulations will be followed when disposing of construction waste.

6.3 CULTURAL RESOURCES

The Bonneville second powerhouse was built in 1982 making it 32 years old. Since the building is less than 50 years old and is located outside the existing Bonneville historic district, the proposed project will have no potential to cause effects to a historic property per 36 CFR 800.3(a)(1). Therefore, in accordance with 36 CFR 800.3(a)(1), the proposed project *does not* have the potential to cause effects.

7. CONSTRUCTION

7.1 GENERAL

The recommended path forward to implement the fabrication and installation of the preferred alternatives are described in this section. The preferred alternatives based on hydraulic and biological data results are to modify the upper VBS panels across the gate wells in powerhouse two at Bonneville Dam in addition to fabricating and installing the flow control plates in slots A and B through Main Units 11-14 and 16-18.

The construction methods are based on the execution of contracts W9127N-14-P-0044 and W9127N-15-0004. These contracts were executed by the USACE Portland District Small Projects Team to install the Main Unit 15 prototype flow control plates in slots A and B.

7.2 SCHEDULE

The schedule for implementing the flow control plates and the VBS modifications corresponds to the scheduled outages of the units for 2016-2017. This will minimize the impact to the Bonneville Project Staff and their resources to support the installation effort.

The current outage schedule and assumptions that the work is operating under are as follows:

A. Units 16, 17, and 18: Out during the T12 outage. September 7, 2016 – November 23, 2016.
B. Units 11, 12, 13, and 14: Out one unit at a time during the winter maintenance period. December 1, 2016 – February 28, 2017.
C. All work must be completed prior to November 1, 2017 in order to not impact the scheduled Bradford Island Fish Ladder outage and PH2 winter operation.
D. Units 11 and 18 are priority units for modifications in order to maintain Fish Passage Plan unit priority when Bradford Island and WA shore fish ladders are in service.
E. Units 13 and 14 are more flexible to have an additional outage outside of the winter maintenance period, after February 28, 2017 but before March 31, 2017.

7.3 CONTRACTOR & BONNEVILLE PROJECT STAFF OPERATIONS

Bonneville Project Staff will support the installation of the modified VBS plates and it was agreed upon that having the Project staff install the modified VBS plates would provide the most flexibility in meeting the outage schedule. This alternative requires removing existing VBS panels, which the Project staff has more handling experience compared

to a contractor. The modified plates will be delivered onsite at the Bonneville Dam via a supply contract that will solicit bids from metal fabrication shops.

Installation of the flow control plates in the gate well slots and reinforcement bar survey will be contracted out via a construction contract, similarly to the construction contract executed for the initial test flow control plate of W9127N-15-C-0004. The Contractor would be allowed access in a dewatered unit to complete the reinforcement bar survey and the installation of the plates.

7.4 QUALITY ASSURANCE AND CONTRACTOR QUALITY CONTROL

Quality Assurance will be provided by the Bonneville Construction Resident Office or Small Projects Team personnel in accordance with a written Quality Assurance Supplement Plan. The QA staff will ensure the Quality Control System, prepared by the contractor, follows the construction contract. The Contractor's Quality Control is comprised of a Quality Management Plan prepared by the Contractor and implemented by the Contractor's Quality Control Manager. The plan will be submitted and approved by the Government prior to work starting.

8. OPERATIONS AND MAINTENANCE

8.1 GENERAL

Installing the flow control plates throughout slots A and B of the remaining gatewells will not require operation by project staff and maintenance will be minimized since they are permanent fixtures. This applies to the modified VBS plates installation as well. Operations staff will facilitate the installation of the modified VBS plates and remove and dispose of the old VBS plates.

8.2 FEATURES

8.2.1. Flow Control Plates

Based on the prototype installed in February 2015, no maintenance was required to keep the plates in functioning condition. Fabricating the flow control plates out of stainless steel mitigated the need for maintenance as it minimized corrosion. This was not the case in the prototype installation of February 2014 where the flow control plate installed in slot A was fabricated out of carbon steel. Upon removal to switch with the stainless plate in February 2015, the carbon steel plate displayed significant rust signs after one year, which would only continue over time.

8.2.2. Vertical Barrier Screens

The current VBS plates require periodic cleaning as debris and would apply to the modified VBS plates as well. No additional maintenance would be required.

8.3 MAINTENANCE

To confirm the premise that the installations of the flow control plates do not require maintenance, the Bonneville Operations will deploy a Remote Operated Vehicle (ROV) into slots A and B of Main Unit 15 to inspect the condition of the plates.

The ROV inspection will occur during the routinely scheduled outage.

8.4 SAFETY

Bonneville Operations staff and Contractor staff are expected to follow the EM-385-1-1, The U.S. Corps of Engineers Safety and Health Requirements, 30 November 2014, in addition to the Occupational Safety and Health Administration Regulations. Critical safety aspects of the installation of the flow control plates include lowering personnel into each gatewell, as demonstrated by the contractor during the February 2014 and 2015 installations. This is a critical lift and requires an approved plan prior to the start of work.

8.5 DOCUMENTATION

As-built records are required contractually from the contractor to show the final hole pattern of the flow control plates. The hole pattern is determined by the initial reinforcement bar survey of the gatewell platform. All gatewell reinforcement bar surveys would be provided in electronic and hard copy format to the Bonneville Operations staff to be kept for their records. Final shop drawings of the VBS plates and the flow control plates would also be provided upon final installation.

9. COST ESTIMATE

9.1 GENERAL

The current cost estimate for the construction contract for Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program is $597,472. The total project cost is $981,000 which includes 14.5% for contingency, construction, engineering and design, along with supervision and administration. This estimate is based on the construction schedule and cost estimate from the Flow Control PL_A3 IGE estimate dated 21-Feb-2014.

The basis of design was the study and implantation of the flow control plates installed in one unit in 2014. This project consists of the installation of flow control plates in 7 more units. The flow control plates will reduce the flow up the gatewell, reduce the approach velocity for the VBS, and reduce the intensity of turbulence in the gatewell. This is expected to improve juvenile fish survival in the gatewells.

To meet the VBS flow design criteria, a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate will be required in bay A. Also, a flow control plate that blocks approximately 25% of the opening will be required in bay B. It is anticipated that a flow control plate will not be necessary in bay C, as it appears to meet the VBS flow criteria without a plate at a unit flow of 18 kcfs.

The cost estimate for this project is developed by using information provided by the design team, including plans and quantities. The estimate is a detailed MCACES MII Version 4.2, using labor, equipment, crews, quantities, production rates, and material price quotes. The general layout of the estimate is the use of standard cost library tasks along with modifications to suit the project where quotes and local conditions are known or user defined.

9.2 Criteria / Project Description

There are 8 Main Units, each have 3 sets of slots (A, B, & C). Of the 8 units 7 units are scheduled to receive the flow control plates. One unit (Unit 15) received flow control plates in March of 2015.

The project is to bolt a stainless steel plate on the concrete "beam" at the bottom of the opening between the upstream and downstream gate slots for the intakes to the turbines. The steel plate projects horizontally downstream into the area of the downstream gate slot. This restricts the area through which the return flow from the gatewells to the turbine units can pass.

Slot "A" of each unit would have "50% plates" which have a width of 4'-9" min and 1" thick. Slot "B" of each unit would have "25% plates" which have a width of 4'-1/2" min and 1 -1/2" thick.

Slot "C" of each unit would NOT have a plate.

There are two Fish Units which have 2 slots each. It is assumed that NO flow control plates need to be added. Assume the top 2 rows of the "Perf Plates" on the VBS are replaced with new Perf plates with 1" dia perforations with varying porosities (20-50%). Assume Type 304 stainless steel for the material, 3/16" thickness. The VBS Panels on the main units will be changed for a total of 24 slots. No change for the VBS panels at the Fish Units.

9.3 BASIS OF COST ESTIMATE

The following assumptions were made for the cost estimate.

a. **Basis of Design**

Design is based on the successful results from B2 FGE Slots for one set of plates for one gate.

b. **Basis of Estimate**

The estimate for this project was developed using information provided by the PDT, and information in the report, along with the previous IGE estimate. Experience from the installation for testing of the prototype Flow reduction plate and associated costs are used. The estimate is a MCACES MII Version 4.2

c. **Assumptions for the Cost Estimate**

The work by the contractor includes Steel Plate installation. Each plate is assumed to be from 1" to 1 -1/2" thick by 19'-10" long. 50% plates are 4'-9" wide and 25% plates are 4'-1/2" wide. Plates are installed in the downstream intake slot from the intake deck. The plates will be attached to the existing concrete piece above the turbine intake. This concrete surface is the bottom of the opening where the VBS is located and is about 40 or so feet below the Intake deck. The contractor is to identify the location of the existing rebar and place the new anchor bolts to miss the existing rebar.
Changes to the VBS will happen on the intake deck. The VBSs are removable. The estimate assumes minimal handling of the VBSs by raising them to the intake deck so the top 2 rows of the perf plates can be accessed from the deck. A crane is assumed in the estimate, (or temporary jig) is needed to hold the VBS while changing out the Perf Plates, since the dogging been is at the level of the top row of plates. Assume Operations Project Staff will install, contractor will fabricate and deliver plates

9.4 COST ITEMS

The Cost estimate incorporates the following assumptions:

1. Contractor’s shop is 100 miles or less from the site.
2. Workmen will access the work location for the flow plate installation and work from a man basket on a crane on the intake deck.
3. A separate crane is used for material handling due to safety requirement that personnel cannot be supported by the same crane supporting the working load.
4. Government forces will dewater the slot.
5. Rule of thumb markups were used for HOOH & JOOH on the high end of the typical ranges. This is typical of contractor’s.
6. The estimate includes Mobilization and Demob to account for the costs to initiate and end the project, coordination activities, initial set up and customization of equipment, field offices, jigs, storage sheds, etc.

9.5 CONSTRUCTION SCHEDULE

Assume unit outages can be scheduled to average 1 per month so work can progress at a controlled pace. Total construction duration to be 12 months, with three interim pauses in work flow due to Main Unit dewatered availability constraints

Typical work durations for schedule (assume 5 day work weeks.) 1 week to dewater a unit (5 days)

1 day to setup at a slot

3 days to map rebar, report & mark drill locations (VBS installation is independent of flow plate installation, this work can be done while awaiting report)

1 day to install plates in slots (includes adjusting plates to match rebar markings, drilling, bolting down)

1 day to move & set up at next slot 4 days to map & install

5 days to move, map, install @ 3rd slot. 2 days to clean up & water up unit.

Typical total 22 work days (1 month) per unit. The contract could work concurrently in 3 slots completing a unit in 2 weeks, but unit availability assumes a12 month duration.

Due to complexities of coordinating Main Unit outages the units will need to be scheduled within the following time frame.

Unit 16, 17 & 18 - during the T12 outage, 09/07/16 thru 11/23/2016 (11 weeks) Unit 11, 12, 13, 14 - during winter maintenance, 12/1/16 thru 2/28/17 (9 weeks)

Unit 13 & 14 – installation time is flexible and can be continued after winter maintenance

during 03/01/17 thru 03/31/17 (4 weeks)

Units will be worked on one at a time. For the full powerhouse assume 3 interim pauses in the work flow.

(NOTE – Current suggested schedule will be 29 days short from the previous project)

a. Overtime

Overtime is not assumed for this project.

b. Construction Windows

Project can have one unit down and dewatered and still operate. Assume first priority units would be available during IWWP via control scheduling of outages. Units 10 and 11 need to work within the outage schedule.

9.6 ACQUISITION STRATEGY

Assume the acquisition strategy is a sole source set-aside to an 8a contractor.

9.7 SUBCONTRACTING PLAN

This cost estimate assumes the prime contractor be experience in heavy construction and provides cranes for access and material handling, and uses own crews for installation.

Subcontract for rebar location work.

9.8 PROJECT CONSTRUCTION

a. Site Access

Bonneville Powerhouse Two: The Contractor's vehicles and construction equipment will enter into the project via the Washington State side via Highway 14. Minor staging areas and minor storage can be located at the work on the north shore.

b. Contingencies by Feature or Sub-Feature

See Abbreviated risk analysis.

9.9 FUNCTION COSTS

Functional costs for Engineering and Design and Construction Management associated with this work were assumed typical default values as follows:

a. 01 Account - Lands and Damages

N/A all work will be on existing project and in the type of regular operations and maintenance.

b. 30 Account - Planning, Engineering and Design

This account covers Planning, Engineering and Design.

Program Management:	2.5%
Planning & Environmental Compliance:	1%
Engineering & Design:	15%
Reviews, ATRs, IEPRs, VE:	1%
Life Cycle Updates (cost, schedule, risks):	1%
Contracting & Reprographics:	1%
Engineering During Construction:	3%
Planning During Construction:	2%
Project Operation:	1%
TOTAL:	27.5%

c. 31 Account - Construction Management(31 Account)

This account covers construction management of the project.

Supervision & Assurance:	10%
Project Operation	2%
Program Management	2.5%
TOTAL:	14.5%

10. CONCLUSIONS AND RECOMMENDATIONS

To improve operational flexibility that encompasses the upper 1% efficiency to the second powerhouse at Bonneville Dam, the modifications implemented in Unit 15 prior to the 2015 juvenile fish passage season should be implemented across the powerhouse:

- Modify all VBS screens to include porosity plates in the upper 1 and ½ panels.
- Install a 50% flow control plate in Slot A.
- Install a 25% flow control plate in Slot B.

Biological testing and velocity measurements acquired on non-modified and modified units in 2013, 2014 and 2015 support this recommendation.

No specific biological post construction evaluation is warranted except through regular monitoring at the Bonneville Dam Juvenile Fish Monitoring Facility.

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APPENDIX A

Technical Review Documentation

APPENDIX B

Agency Coordination

CENWP-PM-E 05 February 2015

MEMORANDUM FOR THE RECORD

Subject: Final minutes for the 05 February 2015 FFDRWG meeting.

The meeting was held in NWP RDP 3rd Floor Meeting Room, Portland OR. In attendance:

Last	First	Agency	Office/Mobile	Email
Baus	Doug	RCC		Douglas.m.baus@usace.army.mil
Bettin	Scott	BPA		swbettin@bpa.gov
Bissell	Brian	NWP-BON		
Chase	Darren	PITAGIS		
Conder	Trevor	NOAA		
Cordie	Bob	NWP-TDA		
Derugin	Andrew	NWP-BON		
Doumbia	Julie	BPA		
Duyck	Pat	NWP		
Ebner	Laurie	NWP		Laurie.l.ebner@usace.army.mil
Eppard	Brad	NWP		Matthew.b.eppard@usace.army.mil
Fredricks	Gary	NOAA Fisheries	503-231-6855	Gary.fredricks@noaa.gov
Grosvenor	Eric	NWP-JDA		
Hevlin	Bill	NOAA		
Kiefer	Russ	IDFG		
Livingston	Scott	PITAGIS		
Lorz	Tom	CRITFC		lort@critfc.org
Mackey	Tammy	NWP	503-961-5733	Tammy.m.mackey@usace.army.mil
Medina	George	NWP	503-808-4753	George.J.Medina@usace.army.mil
Meyer	Ed	NOAA Fisheries		Ed.meyer@noaa.gov
Petersen	Christine	BPA		
Rerecich	Jon	NWP	503-808-4779	Jonathan.g.rerecich@usace.army.mil
Richards	Natalie	NWP		
Roshani	Mehdi	NWP		
Royer	Ida	NWP-BON		Ida.m.royer@usace.army.mil
Saldana	Gail	NWP		
Schlenker	Steve	NWP		
Skalicky	Joe	USFWS		
Stevens	Seth	NWP		
van Dyke	Erick	ODFW		Erick.s.vandyke@state.or.us
Warf	Don	PITAGIS		
Wright	Lisa	RCC		Lisa.s.wright@usace.army.mil
Zyndol	Miro	NWP-JDA		

Hevlin, Kiefer, Richards, Skalisky, and Warf called in.

All documents may be found at http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/FFDRWG/FFDRWG.html

1. Final Actions or recommendations from the 05 February 2015 NWP FFDRWG.

1.1. JDA-S overflow weirs. FFDRWG was supportive of removing the weirs. Both lamprey and salmon may benefit from this change.

1.2. BON FGE. If the plates and balanced VBSs work, then Unit 15 will be complete. Stevens pointed out that biological data is available only for A and C slots. B slot data will need to be inferred. FFDRWG agreed with that. Fredricks and Lorz suggested we could move forward with modifications to other units as long as the data are supportive. Full unit operation would be possible as well.

1.3. B2CC. FFDRWG stressed that BON will now have to conduct a rigorous monitoring and maintenance program for the B2CC. Mackey noted that she did check with BON prior to Operations agreeing to take over the B2CC.

2. Action Items from the 5 February 2015 FFDRWG Meeting.

2.1. Lamprey LPS prioritization discussion. **ACTION:** Tackley will schedule a meeting with FFDRWG in March.

2.2. JDA overflow PIT tag detection. **ACTION:** Eppard will have a hydraulic and structural engineer look at the design. Feedback will be provided back to the Region.

2.3. BON performance standards meeting. **ACTION:** PM-E will schedule a meeting to discuss BON performance standards, likely late March.

3. Outstanding Action Items from Last FFDRWG Meeting (27 Oct, 2014):

3.1. BON survival. NWP will put together some meetings to focus on the path forward for BON. The meeting will likely be in the March/April timeframe. Fredricks requested this be a COP discussion. ***STATUS: Fredricks asked about the schedule. Tackley and Rerecich deferred to Eppard. Eppard will return to PM-E soon. Fredricks stressed the need to have a meeting sooner rather than later. PM-E will set up a meeting in September 2014. Discussed later in the agenda.***

3.2. <u>BON FGE alternatives</u>. FFDRWG gave concurrence to move forward with further investigations in the alternatives but they want the data and details to look at more in-depth. ***STATUS: Special FFDRWG occurred on Oct. 27 to discuss the FFDRWG review of the 90% EDR supplement and path forward.***

3.3. <u>BON AFF Mods</u>. FFDRWG agreed that the mods made over the winter appear to have helped with mortality. Right now the question is whether or not the release pipes should be reattached. Rerecich needs to have a decision by early fall. Fredricks said he wouldn't worry about putting them back on right away. He said don't throw them away but no need to rush to re-attach. FFDRWG would like to see the rest of the data before making that decision. ***STATUS: Moving forward to finalize the AFF modifications for Bon project without reinstallation of bypass pipes.***

3.4. <u>Lamprey Minor Fishway Modifications</u>. FFDRWG expressed concern with the loss of entrance weir depth. The weir caps cannot affect the ability for the entrances to meet FPP depth criteria. ***STATUS: Discussed later in the agenda.***

3.5. <u>Lamprey. WS LFS AWS</u>. Tackley will ask a hydraulic engineer to attend the next NWP FFDRWG to go through the conditions in the area. ***STATUS: Discussed later in the agenda.***

3.6. <u>JSATS.</u> Eppard will send an email with the information for accessing the website. ***STATUS: Complete***

3.7. <u>TDA AWS</u>. Rerecich will send the DDR out again. ***STATUS: Complete***

4. PNNL BON report. Eppard reported that Weiland is about a week away from sending the report to their editor. Once NWP gets a copy, it will be sent out for Regional review.

5. **Bonneville Spillway - Stilling Basin Erosion and Bon Major Rehab (Cutts/ Lee/ Ebner)**.
   - **5.1.** Ebner reported that the repairs made have held. She clarified t hat rock movement is flow driven. NWP will survey when a flow trigger is met. We have not yet met that trigger. Ebner said we continue to monitor rock movement and she would like a survey in 2015, after spill ends.
   - **5.2.** Cutts reported on BON Major Rehab. The Probable Mode of Failure Analysis (PMFA) will start on 9 February. A Major Rehab report will follow. The analysis considers the flow the spillway needs to pass, dam safety, fish survival, etc. Fredricks asked if outside agencies will have a chance to review the report. Cutts said this is the first major rehab project he has worked on so he isn't sure what level of outside review is normal. He will report back to FFDRWG as the process progresses. Ebner said outside input would be a benefit when it comes to authorized purposes and meeting those obligations. Eppard clarified that major maintenance would occur before major rehab. Cutts confirmed that. Maintenance would be prioritized based on need and included in budget submissions. As those items are developed, they will be brought back to FFDRWG for review. Ebner suggested summer would be a good time to look at authorized purposes and how maintenance can help us meet those purposes.

6. **Lamprey Passage Projects. PDT updates are available on the website.**
   - **6.1.** Lamprey Minor Fishway Modifications (Saldaña/Wilcox/Tackley). Tackley reported that the goal is to make small scale mods which will lead to incremental improvements in lamprey passage.
   - **6.2.** Lamprey Passage Structure (LPS) Development (Saldaña/Stevens/Tackley). Stevens discussed the plan for future LPSs at Bon and JDA. Designs are at 30%. Stevens said we now need to prioritize tasks.
   - **6.3. Bonneville WA Shore Lamprey Flume System – Entrained Air**
     - **6.3.1.** Bettin asked if the LFS fix will be completed anytime soon. Stevens said plans are still being developed. He suggested work may need to be completed in October from a barge but there likely won't be any construction in FY15. Tackley said a range of alternatives will be looked at and a decision matrix will be developed. Bettin said there will be transformer work going on in upcoming years so depending on which units need to be out of service, it may be worthwhile to try to sync up the LFS schedule with the transformer schedule.
     - **6.3.2.** Schlenker described the problem of backwater in the flume. There is a section of the flume with super critical flow. There may need to be a divider between flume flow and AWS flow. Venting may be improved as well. There may be an opportunity to do the work without divers depending on the time of year. Bettin suggested turning the system off after August. This could make the fix a little easier if the tailrace range is a narrower band. Alternatives are still being developed.
     - **6.3.3.** Tackley noted that FFU will be operating the system to enumerate the number of fish in the trap. Fredricks asked about analysis of the bubble curtain created by the entrained air. Fredricks said he would like to see an ad hoc discussion about AWS valve operational limits.
     - **6.3.4.** Tackley would like to schedule a special FFDRWG in March to discuss potential alternatives and priorities. **ACTION:** Tackley will schedule a meeting with FFDRWG in March. 26 March was recommended as a good day.

7. **The Dalles East Adult Fish Ladder AWS Backup System (Duyck/Rerecich).** Duyck provided a presentation (available on the website). He explained that the schedule is still being shuffled. He would like to hear concerns about specific activities so they may be

scheduled at the best possible time. Work will extend beyond the in-water work window. Duyck walked through the diagrams for the proposed back up AWS. Surveys have shown no large rock or woody debris in the location of the upstream boring area. The substrate appears to be sandy and about three feet thick. The tremmie slab will be poured in the first in-water work window. Pre-fabbed concrete slabs will be constructed off-site and placed during the in-water work window. The bulkhead would be removed and stored for future use and a bar screen trashrack would be installed, using the same slots. Butterfly valves will be used to operate the system and help control flow during water up. Duyck pointed out that the fishladder will be about 25' above the AWS pipe. Duyck suggested early November might need to be the start date for boring. He noted that Dorena Dam had boring within three feet of galleries with no cracking; he is pretty confident, with ten feet between the pipe and any gallery, there should be minimal issues at TDA.

7.1. Currently at 90% Plans and Specs review. 100% P&S review is expected by the end of March. During the first winter would include the tremmie slab and the lower pipe work under the parking lot. The second winter would include the coffer dam and the final boring connecting with the lower pipe.

7.2. Bettin asked about the pipe material. Duyck said it would be steel penstock pipe; probably coated in vinyl paint.

7.3. Bettin asked about flow restrictions when the slab is poured. Duyck thought maybe January and there may need to be a reduction in flow, but those would be short term.

7.4. It was determined that Fredricks could not retire until the AWS is completed.

8. **TDA/ WASCO PUD north ladder engineering evaluation.** Rerecich explained this came from FPOM. Fredricks said he heard Wasco PUD was going to do the geotechnical evaluation of the rock channel. He said efforts to stabilize that channel occurred in the 1990's. Wasco PUD would like to use that channel if they conduct testing. Fredricks wanted to make sure TDA was on top of the issues and review the reports from Wasco PUD. Cordie confirmed TDA will review the reports and make sure their results seem reasonable. Fredricks said Wasco PUD wants to use the channel for several months. He told Wasco PUD that NOAA approval for that study would be contingent on there being no effect on the channel stability. Cordie said the Project Engineers will be looking at the study.

8.1. Eppard asked if Fredricks has seen the study. Fredricks has seen it. Bettin said the Action Agencies are going to review the study before it goes to SRWG. Fredricks said increasing counts would be a benefit. Duyck said he didn't want to forward a study without thorough review. Fredricks stressed that the Wasco PUD study should be evaluated on their study design, not on USACE study design. Eppard said NWP wants to make sure the study will result in useful information.

9. **John Day North Ladder AWS pumps (Richards).** Richards reported that pump #4 is still in re-design. There are four pumps running. Vibration issues are still being addressed. Lorz asked when testing will be completed. Richards said there isn't so much in the way of testing as it is a re-design. The 50%-60% will be available in April. The re-design may affect the other five pumps as well. Richards said it depends on the re-design for pump #4. Fredricks asked if the failures across the pumps are related. Richards said those details are not yet known. Lorz asked if misalignment is the problem, should we expect pumps to misalign over time? Richards said no because the pumps are supposed to be bolted in place so they won't misalign. Fredricks asked if this is a CRFM burden for years. Richards said no. She believes this will be a legal issue as it is the belief of NWP that the contractor did not meet the terms of the contract. FFDRWG wanted to make sure NWP has not accepted ownership of the pumps. Richards said NWP does not want to take ownership until the pumps are functional. Late 2016 is expected to be the earliest the contract might be complete. Richards

said the monitoring by JDA has been really good. Zyndol said he only cares that there are enough pumps available. This is a project that leaves no one feeling overly comfortable but NWP is working to get everything sorted out.

10. **B2 Fish Unit Trash Rake (Stricklin/Filan/Royer/Rerecich).** Rerecich reported that the 1 March date hasn't slipped yet. Stricklin is working with BON to try to stay on schedule. Rerecich said an ROV inspection will need to occur after the trashrake is returned to service.

11. **JDA PIT feasibility (Fredricks/Axel/ Warf).** Chase and Livingston walked through the presentation (available on the website) describing the feasibility study conducted last year. Livingston went through the background of the project. They propose bolt on systems for the overflow and the orifices in the weir. Two weirs would be outfitted to ensure redundancy. The antenna would raise the weir notch by two inches – would that be a concern? Another option would be to shave the weir down two inches so there is no change in height. The detectors are built off-site, bolted in, and have about 100% efficiencies. The antennas are made from aluminum, ferrite tiles, and have a smooth plastic outer shell. Lamprey ramps are included with installation. Fredricks would like to know what the hydraulic footprint might be in the ladder. Chase noted that the ever increasing thinness of the detector means cutting into the weir is not always required and if it is, it's shallow. Lorz suggested sinking the overflow by two inches so the head remains constant. Fredricks asked if modeling would be needed. Eppard asked if two weirs would be needed or could two antennas be used on one weir. Chase said there isn't enough room to put two antennas on one weir. He said two weirs give directional movement and redundancy. Lorz asked if the weirs need to be consecutive or if we could skip a weir. Conder asked about the pass through design. Chase said there are concerns about debris and supporting structures for the pass through design. Fredricks would like some feedback from NWP regarding hydraulic impacts from these designs. **ACTION:** Eppard will have a hydraulic and structural engineer look at the design. Feedback will be provided back to the Region. Cost estimates have been updated to reflect potential BPA cost-sharing. Total cost for one ladder would be $136K, this does not include any costs for NWP engineering evaluations though. Concrete removal (two inches for two weirs in each ladder) has been estimated at $20K.
    11.1. Conder asked if lamprey could also be detected. Chase and Livingston said the capability is there if it's turned on but there may be an impact on the salmon detection.

12. **Overflow weir removal at JD south fishway (Zyndol).** Zyndol provided a handout. He said HELCRABS recommended removing the JDA-S lower weirs. Removal had been on the CRFM list but scheduling and work load didn't allow for it to occur during previous construction periods. Zyndol stressed that removal would not have a negative impact on fish passage. He likened the weirs to impacted wisdom teeth – they never come up so why not remove them. Zyndol is asking for NWP FFDRWG support for removal and potentially funding through CRFM. Cordie asked if the RT results for JDA-N were looked at after the lower weirs were removed. Zyndol and Rerecich suggested studies showed improved passage times after weir removal. Lorz was supportive but asked if it could be funded under CRFM. Tackley said JDA has traditionally had the longest passage times so this could help. Zyndol said the cost would be about $100K. **FFDRWG was supportive of removing the weirs. Lamprey and salmon would likely both benefit from this change.** Tackley noted that he has the weir removal included in the lamprey minor mods program.

13. **B2-FGE (Medina/Stevens/Rerecich)** Medina reported that this is a follow up to the October 2014 FFDRWG meeting. Rerecich said biological testing data sets will be collected throughout the season with a draft report in November and a final by January 2016. Medina

said he feels confident we are headed in a good direction with viable solutions. Fredricks asked about the final implementation schedule. Medina said the plates are easy to install but the schedule has not been worked out yet. Stevens explained there is a pre-construction meeting with the contractor on 9 February. BON will work on the VBS mods. Biological testing starts in April. Bettin asked if the installation is a "final" installation. Stevens said technically it's a prototype but the plate is stainless steel and could remain in place. Medina said the PDT believes the two plates and a balanced VBS will work. **If this works, then Unit 15 will be complete. Stevens pointed out that biological data is available only for A and C slots. B slot data will need to be inferred. FFDRWG agreed with that.** Medina asked if FFDRWG would be willing to commit to going forward with full implementation if the data shows these mods are the answer. He would like to have FFDRWG commitment upfront so coordination with BON could start early. This would be part of the effort to get all units modified by 2018. Bettin asked how soon until we know this works. Stevens said we could see data by July. Bettin said BPA is interested in running the unit at the upper end of 1% if possible. Medina said the intent of the mods is to return units to full range operation. Eppard suggested the conservative approach would be to not make changes until FY17. There is a performance test coming up. Fredricks suggested BON may need these modifications to meet performance standards. FFDRWG believes data will be back very quickly so decisions about unit operation could be made as early as June/July. Fredricks suggested that once units start coming down, plates could go in (as soon as funding and contracting were in order). Medina said there are elements to the planning process that still need to be looked at. Questions such as do we order all of the plates and the Project installs them as units come down, or do we hire a contractor, etc still need to be answered. Hydraulic testing will occur right after the biological testing. Stevens stressed that the critical data is the biological data but the hydraulic data should be available about a month later. **FFDRWG believed we could move forward as long as the data are supportive. Full unit operation would be possible as well.**

14. **B2 Orifices (Medina/Kuhn/Rerecich) No handout.** Medina said there is an EDR that still needs to be finalized. The PDT will be meeting later in February. An ad hoc meeting can be scheduled between FFDRWG meetings.

15. **B2CC (Medina).** Medina reported that the B2CC has been turned over to Operations. Spalling is considered wear and tear. Lorz asked about the problems with the joints. Medina said there is movement and the only real fix is to redo the entire channel. **FFDRWG stressed that BON will now have to conduct a rigorous monitoring and maintenance program for the B2CC. Mackey noted that she did check with BON prior to Operations agreeing to take over the B2CC.**

16. **Turbine Survival Program (Medina/Rerecich).** Medina said the TSP group will pick up the pace for the bead analysis. Fredricks said he heard final reports won't be available until September. There is a TSP meeting on 10 February. Medina invited Lorz to call in. Fredricks explained that the call is to discuss the bead analysis for both powerhouses but primarily PH2. Medina went the blunt route and said the models were set up with erroneous curves. The curves have been corrected so this call is to discuss this.

17. **The Dalles Spillwall erosion update (Ament).** The rock seems stable now however there are erosion holes (best described as slivers) up near the spillway. Contract issued last summer to repair those holes. When the contractor filled the holes, the concrete between the slivers fell away and the two slivers became one. The bad concrete was removed and new grout pumped in. The PDT is closing the contract and finishing this project. Ament said

there is no erosion on the south side of the wall but there is an erosion hole near the apron. That erosion appears to be a result of an eddy caused by not spilling out of bays 9-11. This area is routinely monitored by Dam Safety.

18. **Bonneville Adult Fish Facility Mods (Ament/Sipe/Royer).** Ament gave a brief history. There are still some mods the PDT would like to do. The wood baffle was going to be replaced with steel but instead the PDT went with purple heart (life expectancy of about 50 years) and painted the steel brackets. The level sensor will be repaired. Rerecich showed a picture of the purple heart. If these mods work, the extensions won't necessarily be needed. Lorz and Fredricks discussed the extensions. Rerecich commented that he agreed with Ed Meyer in that if it isn't needed don't mess with it. The extensions will be saved in the event they are needed in the future but at this time the plan is to leave them off.

19. **BON FY16 Performance Standard Evaluation planning (Eppard)** Eppard said there is a need to resurrect discussion of the summer ops. Fredricks would like to know where NWP believes standards have been met.
    - **19.1.** Route specific information is needed for both years for JDA. NOAA believes there does need to be a change at JDA, possibly an operation change. FFDRWG discussed whether or not the problem is spill. Van Dyke asked why route specific data hasn't been included in the initial contracting since it's been consistently asked for by SRWG members.
    - **19.2.** A meeting will be set up to discuss BON. Fredricks said a meeting won't help until NWP lays out what they believe to be valid results. Fredricks suggested Weiland could provide his report and we could discuss what more, if anything, is needed prior to final performance testing. **ACTION:** PM-E will schedule a meeting to discuss BON performance standards, likely late March.

20. **Next NWP FFDRWG Meeting: 2 April 2015**

USACE Portland District (NWP) FFDRWG Update Form
5 February 2015

PROJECT INFORMATION

Project Title	Bonneville Second Powerhouse Fish Guidance Efficiency
SCT Reference Number	
Project Manager (PM)	George Medina (NWP, 503-808-4753)
Technical Lead (TL)	Seth Stevens (NWP, 503-808-4849)
Biologist/Coordination	Jon Rerecich (NWP, 503-808-4779)

PROJECT DESCRIPTION

This project consists of improving juvenile salmon survival in the gatewells at the Bonneville Dam second powerhouse. Biological testing in 2008 and 2009 showed elevated mortality for juvenile salmon in the gatewells when the units are operating at the upper end of the peak efficiency range (>15 kcfs). It was suggested that undesirable flow conditions develop within the gatewells at the high unit flows and are causing the increase in mortality.

CURRENT SCHEDULE

- Constructing prototype of proposed gatewell improvements in unit 15, including flow control plates in A and B slots, and modified VBS panels in all three slots: FEB-MAR 2015
- Developing second set of modified trash racks for biological testing: MAR 2015
- NOAA to conduct biological testing to evaluate effectiveness of unit 15 modifications: APR-MAY 2015 (Draft Report NOV 2015, Final Report MAR 2016)
- Conduct hydraulic testing to evaluate performance of unit 15 modifications: JUN 2015
- Complete DDR after field evaluations
- Prepare Plans & Specs if testing shows successful results
- Full Implementation (tentatively 2016-18)

PROGRESS AND KEY ISSUES (List)

1. Final Supplement to the EDR issued JAN 2015.
    a. Based on field data and CFD modeling, recommends flow control plates attached to the gatewell beams downstream of the VBSs to reduce the flow into the gatewells.

   b. Also recommends that a design be developed for modifications to the porosity plates on the upper panels of the vertical barrier screens (VBSs) to reduce the areas of high through-screen velocity.
2. 30% DDR complete.
   a. Design refined to include a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate the blocks approximately 25% of the opening in bay B, and no flow control plate in bay C.
   b. The proposed design also includes reducing the open areas for the porosity plates on the upper two rows of panels on the VBSs by about 50%.
   c. Unit 15 prototype based on these design recommendations.
3. Biological testing to evaluate survival in 15A and 15C at high unit flow (~18 kcfs) and compare to survival in unit 14A at mid-range flow (~15 kcfs). Comparison of hydraulic testing/modeling in unit 15A, B, C will be used to infer expected survival in 15B.

FFDRWG REVIEW NEEDED AT MEETING? (If YES, list discussion topics below)

- Looking for concurrence for moving forward

CENWP-PM-E 23 April 2015

MEMORANDUM FOR THE RECORD

Subject: Final minutes for the 23 April 2015 FFDRWG meeting.

The meeting was held in NWD Columbia Room, Portland OR. In attendance:

Last	First	Agency	Office/Mobile	Email
Baus	Doug	RCC		Douglas.m.baus@usace.army.mil
Bissell	Brian	NWP-BON		Brian.m.bissell@usace.army.mil
Brower	Alan	PSMFC		abrower@psmfc.org
Chase	Darren	PSMFC		dchase@psmfc.org
Conder	Trevor	NOAA		Trevor.conder@noaa.gov
Cordie	Bob	NWP-TDA		Robert.p.cordie@usace.army.mil
Eppard	Brad	NWP		Matthew.b.eppard@usace.army.mil
Fredricks	Gary	NOAA	503-231-6855	Gary.fredricks@noaa.gov
Hevlin	Bill	NOAA		Bill.Hevlin@noaa.gov
Kiefer	Russ	IDFG		Russ.kiefer@idfg.idaho.gov
Livingston	Scott	PSMFC		slivingston@psmfc.org
Lopez-Johnston	Siena	BPA		smlopez@bpa.gov
Lorz	Tom	CRITFC		lort@critfc.org
Lut	Agnes	BPA		axlut@bpa.gov
Mackey	Tammy	NWP	503-961-5733	Tammy.m.mackey@usace.army.mil
Medina	George	NWP	503-808-4753	George.J.Medina@usace.army.mil
Meyer	Ed	NOAA		Ed.meyer@noaa.gov
Rerecich	Jon	NWP	503-808-4779	Jonathan.g.rerecich@usace.army.mil
Richards	Natalie	NWP		Natalie.a.richards@usace.army.mil
Royer	Ida	NWP-BON		Ida.m.royer@usace.army.mil
Schlenker	Steve	NWP		Stephen.j.schlenker@usace.army.mil
Skalicky	Joe	USFWS		Joe_Skalicky@fws.gov
Stevens	Seth	NWP		Seth.t.stevens@usace.army.mil
van Dyke	Erick	ODFW		Erick.s.vandyke@state.or.us
Warf	Don	PSMFC		dwarf@psmfc.org
Wright	Lisa	RCC		Lisa.s.wright@usace.army.mil
Zorich	Nathan	NWP-FFU		Nathan.a.zorich@usace.army.mil
Zyndol	Miro	NWP-JDA		Miroslaw.a.zyndol@usace.army.mil

Kiefer, Medina, Richards, Schlenker, and called in.

All documents may be found at http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/FFDRWG/FFDRWG.html

1. Final Actions or recommendations from the 23 April 2015 NWP FFDRWG.

1.1. BON Cascade Island, FGE and pinniped issues. We have attraction flow at CI entrance and are just below criteria. FGE test will be delayed a couple of weeks. We will continue to monitor pinniped predation.

1.2. Rerecich had to step out to work on FGE. FFDRWG was diverted to a discussion about MFR 15TDA03 and the need to take both fish units out of service for five hours each on 7 May. The Region recognized the need to have the brushes inspected and repaired and expressed not much concern about the work.

1.3. The fish managers are all on board with the JDA adult ladder PIT detectors. The Action Agencies need a bit more time to consider this project. NWP plans to have a clearer path forward by the June FFDRWG.

2. Action Items from the 23 April 2015 FFDRWG Meeting.

2.1. TDA Back up AWS. **ACTION:** Rerecich will draft a MOC, including the proposed schedule and schedule a special FFDRWG or FPOM to further discuss the construction plan.

2.2. JDA-S lower weirs. Fredricks said we may see more focus on JDA-S in the future, especially given the dry, potentially warm water year we are looking at for 2015. Fredricks mentioned a letter report from Matt Kiefer (UI). **ACTION:** Rerecich will send that letter report to NWP FFDRWG. NWP needs to figure out the path forward since there is no team assigned to investigating this issue further.

2.3. Tackley talked through the first v second tier LPS tasks and priorities, based on special FFDRWG meeting and other considerations. **ACTION:** Tackley will distribute a summary table (with notes from FFDRWG and current project status) to FFDRWG.

2.4. Next meeting was scheduled to be 4 June but there is a conflict with SRWG. **ACTION:** Tackley will initiate a Doodle poll to identify possible June/early July FFDRWG dates.

3. Outstanding Action Items from Last FFDRWG Meeting (5 February 2015):

3.1. Lamprey LPS prioritization discussion. ACTION: Tackley will schedule a meeting with FFDRWG in March. ***STATUS: Complete.*** *Meeting was held on April 1.*

3.2. JDA overflow PIT tag detection. ACTION: Eppard will have a hydraulic and structural engineer look at the design. Feedback will be provided back to the Region. ***STATUS:*** *Design has not been reviewed.*

3.3. BON performance standards meeting. ACTION: PM-E will schedule a meeting to discuss BON performance standards, likely late March. ***STATUS:*** *Meeting has not been scheduled. Scott Fielding is new POC on planning BON performance standard studies and will work on scheduling this meeting through SRWG. Fredricks said pre-proposals should not go out until the performance standards meeting occurs. Eppard explained that Fielding will be working on this but his workload is pretty full right now so there hasn't been time to prepare for this meeting. Fredricks stressed that this discussion needs to occur and there should likely be more than one meeting. Definitely need to have this discussion prior to the prioritization meeting on 4 June. This discussion needs to center around the acceptance of the tests and whether additional testing is needed. Conder asked if the FGE mods will be ready for the 2016 performance test.*

4. Added items on the agenda.

4.1. BON Cascades Island FV5-4 failure. **See MFR 15BON03 for more details.** Royer reported that the valve pit was re-watered on Wednesday so FV5-3 is operating in manual. The entrance differential is just below 1.0' and with some adjustments, the plan is to get the entrance up to 1.0'. **We have attraction flow at CI entrance and are just below criteria.**

4.2. Many FFDRWG reps commented that FFU reported higher sea lion predation on Tuesday and Wednesday as well as a corresponding decrease in fish passage. The bulk of river flow is passing through the BON spillway so attraction to the powerhouses has been decreased. **We will continue to monitor pinniped predation.**

4.3. Rerecich said he has requested NOAA not tag fish until after Spring Creek releases. **FGE test will be delayed a couple of weeks.**

5. Bonneville Spillway - Stilling Basin Erosion and Bon Major Rehab. The team is working on a Major Rehab report.

6. Lamprey Passage Projects. (powerpoint presentation)

6.1. Tackley talked through his powerpoint explaining potential mods to the BI serpentine section. This includes wetted walls (*not* included in the scope of this project), refuge boxes, and lamprey orifices. The serpentine section is particularly difficult for lamprey due to the constant changing of direction and high velocities/turbulence. The proposal would potentially create a straight path through the serpentine section.

6.1.1. Efforts to minimize impacts to salmon are always ongoing. Conder expressed some concern about the sockeye interactions with the lamprey orifices in the Snake River projects. Fredricks noted that sockeye at BON behave differently than upriver; they get everywhere we don't want them to go. Zorich and Conder thought that the 2" opening had been agreed to. Another option was to make the orifices big enough for salmon to go through but then the hydraulics will be disrupted in the ladder. Tackley asked Conder for thoughts on the orifices at the BON serpentine section. NWP FFDRWG discussed some other options to attract fish out of the ladder and into a LPS. Meyer suggested starting lower than the serpentine system, near the count window. There was concern about the accuracy of the lamprey counts. The wetted wall will be installed upstream of the count station so video will be taken to try to make corrections. Lorz suggested it might be worth taking a little risk for sockeye to help lamprey. Conder said we are already walking a fine line between risks to salmon and benefits to lamprey as it is. Conder asked if it is possible to hold the forebay within a foot for the lamprey season. Wright asked if he meant for the entire season – May to September. More discussion about forebay restrictions and fluctuations occurred.

6.1.2. In general, FFDRWG thought we could settle on an orifice height and width. Right now this project is still in the conceptual stage; further discussions will take place and the Region is encouraged to provide input. Stevens said he is trying to get a draft plan out in the next couple of months. Tackley said there are two approaches to consider – 1. Start small and monitor for two years or 2. Use one winter maintenance season and make the mods in one year for the whole ladder. Zorich said the concerns from O&M would be monitoring and maintenance of the refuge boxes. Van Dyke asked about creating a continuous channel instead.

6.2. Lamprey Passage Structure (LPS) Development and Improvements. This is a phased project – with initial focus on BON WA Shore and Cascades Island (2016-17 IWW), then Bradford Island and JDA North (2017-18 IWW). Stevens said the current focus is on design and installation of an LPS downstream of the Washington Shore count station picket leads. The team is still exploring a fix for the LFS AWS air entrainment. Stevens expects to have LPS Plans and Specs available early in 2016 for construction in winter 16/17. The LFS Plans and Specs should be completed early and mods to the AWS could happen outside the in-water work (IWW) period. Lut asked if operation constraints would be needed. Stevens said possibly. Lorz asked about costs of the LFS fix. He said Brian McIlraith may be concerned about growing costs and changing priorities.

6.2.1. Zorich added that FFU will be operating the LFS this year. The plan is to have it on intermittently throughout the season and test a variety of operational settings.

6.2.2. Tackley talked through the first v second tier LPS tasks and priorities, based on special FFDRWG meeting and other considerations. **ACTION:** Tackley will distribute a summary table (with notes from FFDRWG and current project status) to FFDRWG.

7. The Dalles East Adult Fish Ladder AWS Backup System. Rerecich reported that comments are due back on 24 April (tomorrow). He said he has received verbal comments from Fredricks but no other comments. Rerecich said the team has asked for TDA-E to be dewatered for the entire IWW period. This may result in pushing TDA-N dewatering into November or have a dual ladder outage. The construction schedule has the forebay work completed during the IWW period but there may be some protrusions and bedrock clean-up in March. There would be about 10 days total (3 days/ 30 foot section) when this work would occur. Rerecich needs to have these days defined so they can be included in the contract. Van Dyke asked why this work couldn't wait until next winter. Rerecich explained that this work needs to be completed prior to the next IWW period. NWP FFDRWG expressed concern about having TDA-E out for two full seasons. **ACTION:** Rerecich will draft a MOC, including the proposed schedule and schedule a special FFDRWG to further discuss the construction plan. NOAA and CRITFC had questions about the need to have TDA-E OOS for the entire second winter season.

Rerecich had to step out to work on FGE. FFDRWG was diverted to a discussion about MFR 15TDA03 and the need to take both fish units out of service for five hours each on 7 May. The Region recognized the need to have the brushes inspected and repaired and expressed not much concern about the work.

8. John Day North Ladder AWS pumps. Richards said the pumps are currently working, except for #4, which will be re-designed. Zyndol said we have 70% fish passage through JDA-N right now. Richards said the re-design of pump #4 will have implications for the other pumps as well. Lorz asked about cost-sharing between NWP and the contractor. Richards said the failure analysis found that the problem was a design flaw. She was unsure how Office of Legal Counsel will proceed with pushing the contractor to bear the full cost of the re-design.

9. Overflow weir removal at John Day South Ladder. Tackley said this is on the lamprey minor mods spreadsheet. Tackley said he talked with Langeslay and Langeslay thought some of the weirs might be structural support. There currently is no PDT for this so it may need to go to SCT. Fredricks said we may see more focus on JDA-S in the future, especially given the year we are looking at for 2015. Fredricks mentioned a letter report from Matt Kiefer (UI). **ACTION:** Rerecich will send the letter report to NWP FFDRWG. Fredricks would like to look at passage and water quality at JDA-S to make sure there are no fish passage issues here. He stated that the north ladder often passes a greater percentage of fish that at other similarly configured dams. NWP needs to figure out the path forward since there is no team assigned to investigating this issue further. Cordie said FFU had some reports on JDA-S. Fredricks suggested there were reports that are not out though and those are the ones he is concerned about. Basically, it is a good time to take a look at the ladder again.

10. BON FY16 Performance Standard Evaluation planning. Scott Fielding is new POC on planning BON performance standard studies and will work on scheduling this meeting through SRWG. Fredricks said pre-proposals should not go out until the performance standards meeting occurs. Eppard explained that Fielding will be working on this but his workload is pretty full right now so there hasn't been time to prepare for this meeting. Fredricks stressed that this discussion needs to occur and there should likely be more than one meeting. Definitely need to have this discussion prior to the prioritization meeting on 4 June. This discussion needs to center around the acceptance of the tests and whether additional testing is needed. Conder asked if the FGE mods will be ready for the 2016 performance test.

11. Bonneville Adult Fish Facility Mods. Royer reported the AFF is watered up and working. The After Action Report (requested by FPOM) is in progress.

12. John Day North Ladder PIT feasibility. PSMFC provided a powerpoint presentation. Livingston talked through the proposed design. The new design requires the top six inches of the weir notch be removed and replaced with the antenna. The only change to the weir will be the chamfer, otherwise the orifice and weir notch dimensions would remain as they are. FFDRWG asked questions about the confidence with only two weirs outfitted. Warf said TDA has the highest detection efficiency and there are only two weirs there. The magic lies in the ferrite tiles. Warf said each antenna would have its own transceiver. These are paid for by BPA. There would be eight transceivers per ladder. Installation of the antennas would take about 3 days however, the entire process would take a minimum of 4 weeks per ladder. The first step (3 to 4 days) would be to remove the concrete and take exact measurements of each location. The second step (2 weeks) would be to fabricate the antennas to the exact weir wall dimensions. The third step (3 days) would be installing the antennas. The final step (2 days) would be installing the antenna cable conduits. Installation could be done during the IWW period. If rebar is hit during concrete removal, the rebar could be cut out and not impact the detector. FFDRWG expressed some concern about removing rebar. The engineers in the room suggested it may not be a problem if it doesn't impact the structural support of the weir and the weir (or ladder floor) doesn't crack; NWP structural engineers will still need to sign off. PSMFC gave many examples of where they have cut into weirs and penetrated weirs with conduit.

12.1. FFDRWG expressed concern about the chamfer dimension change. The chamfer will be thicker and may impact the hydraulics. Fredricks asked about having an unmodified weir between the detectors. Brower suggested below the count station has good flow; maybe there is another location that has similar flow conditions. Chase said there wouldn't be a problem having the detectors further apart. Fredricks said there is a greater chance that fish could turn around between antennas if they are too far apart as opposed to on weirs that are next to each other.

12.2. Livingston said the detectors are bolt in place structures that come pre-assembled. The cost per ladder is about $174K. Both ladders could be completed within one normal IWW period. This includes the concrete cutting and more complex nature of JDA weirs. This cost does NOT include NWP engineering costs.

12.3. Fredricks asked about location. PSMFC said near the count window, where there are catwalks that access the weirs. Skalicky suggested one at the entrance and one at the exit so lamprey delay could be tracked. Fredricks said that is a different issue. The point of this system is to provide redundancy but he understood the desire to have lamprey detection as well. Lorz suggested one weir on each side of the JDA-S count window. The north ladder doesn't have overflow weirs upstream of the JDA-N count window. Fredricks suggested PSMFC come back with recommendations for the best locations.

12.4. Tackley went around the room asking the agencies where they stood on JDA detection. BPA is not yet 100% on board with detectors at JDA. Fredricks said this is on the FY16 spreadsheet for ranking this summer so a decision needs to be made soon. Eppard said this project could probably be kicked off with FY15 funds. This would include deciding if this is a new project or part of an existing one and there is a process to follow. NWD still needs to approve. Eppard plans to talk to I. Chane (NWP CRFM PM) about moving this forward. Van Dyke said this sounds like a project that could provide a lot of information and ODFW would like to see it go forward. **The fish managers are all on board with the detectors. The Action Agencies need a bit more time to consider this project. NWP plans to have a clearer path forward by the June FFDRWG.**

12.5. Brower showed a 3D picture of the weir notch detector. He noted the screw heads were at an 82 degree pitch and will be completely countersunk. His fancy drawings included the threads on the screws. FFDRWG was suitably impressed with the graphics. Meyer would prefer the side plate extend above the water elevation. The aluminum plate is ¼" and could impact the plunging flow of the water.

13. B2-FGE. Rerecich reported that a trigger has been developed that will result in canceling testing due to pinniped predation and low flows. If three units cannot be operated, then the study will cease until May.

14. NEW: Bonneville B1 Ice and Trash Sluiceway (ITS) PIT detection to improve precision of reach survival estimates. Fredricks said detectors in the ITS would help bolster reach survival studies. He said this seems like low hanging fruit. There are five entrances into the ITS, three move and two are fixed at sill level. Tackley used Google Earth to determine that the slots are about 20' wide. Whatever goes in the ITS needs to be durable due to debris loads. FFDRWG agreed that something is probably better than nothing. PSMFC said they had been contacted by BPA about this project. They are scheduling a site visit with B. Hausmann. Chase asked if the BON ITS channel can be dewatered. He noted TDA ITS cannot be dewatered. Bissell said the ITS can be dewatered and it will be dewatered later this summer when the end gate is replaced. More discussion about the location and next steps occurred by several different groups of people at the same time. The bottom line being that PSMFC would develop some independent ideas for implementation (as they have for the JDA adult PIT detectors).

15. Bonneville B2 Fish Unit Trash Rake. Rerecich noted that there are pictures in the update form (available on the website). BON is finishing up welds on the perf plate and it should be ready on 23 April (today). Neither BON biologist could tell us if it was truly ready for use though. It was noted that Lorz is now able to retire since his Tom Lorz Memorial Trash Rake is complete. Lorz said we need a test rake first. FPOM will be watching to see how often units are floated once the new rake is commissioned. Lorz asked if dredging is going to occur in front of the fish units. Mackey noted that the dredging should be included in the budget proposal every year; how the Project prioritizes dredging is something we can discuss in FPOM. The FPP recommends soundings taken in one FY and dredging occurring during the following winter during the appropriate year for the ladder outages.

16. B2 Orifices. No update at this time.

17. Turbine Survival Program. Fredricks reported that ERDC folks are now shifting to a full bead assessment of the BON Second Powerhouse turbine model with a data review meeting scheduled for some time in September. The team is also evaluating data to make sure the model is accurately reflecting what is actually occurring at the Project.

18. Next meeting was scheduled to be 4 June but there is a conflict with SRWG. **ACTION:** Tackley will initiate a Doodle poll to identify possible June/early July FFDRWG dates.

USACE Portland District (NWP) FFDRWG Update Form
23 April 2015

PROJECT INFORMATION

Project Title	Bonneville Second Powerhouse Fish Guidance Efficiency
SCT Reference Number	
Project Manager (PM)	George Medina (NWP, 503-808-4753)
Technical Lead (TL)	Seth Stevens (NWP, 503-808-4849)
Biologist/Coordination	Jon Rerecich (NWP, 503-808-4779)

PROJECT DESCRIPTION

This project consists of improving juvenile salmon survival in the gatewells at the Bonneville Dam second powerhouse. Biological testing in 2008 and 2009 showed elevated mortality for juvenile salmon in the gatewells when the units are operating at the upper end of the peak efficiency range (>15 kcfs). It was suggested that undesirable flow conditions develop within the gatewells at the high unit flows and are causing the increase in mortality.

CURRENT SCHEDULE

- NOAA to conduct biological testing to evaluate effectiveness of unit 15 modifications: APR-MAY 2015 (Draft Report NOV 2015, Final Report MAR 2016)
- Conduct hydraulic testing to evaluate performance of unit 15 modifications: JUN 2015
- Complete DDR after field evaluations
- Prepare Plans & Specs if testing shows successful results
- Full Implementation (tentatively 2016-18)

PROGRESS AND KEY ISSUES (List)

1. Final Supplement to the EDR issued JAN 2015.
    a. Based on field data and CFD modeling, recommends flow control plates attached to the gatewell beams downstream of the VBSs to reduce the flow into the gatewells.
    b. Also recommends that a design be developed for modifications to the porosity plates on the upper panels of the vertical barrier screens (VBSs) to reduce the areas of high through-screen velocity.
2. 30% DDR complete.

a. Design refined to include a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate that blocks approximately 25% of the opening in bay B, and no flow control plate in bay C.
b. The proposed design also includes reducing the open areas for the porosity plates on the upper two rows of panels on the VBSs by about 50%.
c. Unit 15 prototype based on these design recommendations.

3. Unit 15 prototype construction completed in MAR 2015. Modifications included flow control plates in A and B slots, and modified VBS panels in all three slots.
4. Second set of modified trash racks installed for biological testing on MAR 17, 2015
5. NOAA began biological testing APR 1, 2015 and is scheduled to go through MAY, 2015. Testing will evaluate survival in 15A and 15C at high unit flow (~18 kcfs) and compare to survival in unit 14A at mid-range flow (~15 kcfs). Comparison of hydraulic testing/modeling in unit 15A, B, C will be used to infer expected survival in 15B.

FFDRWG REVIEW NEEDED AT MEETING? (If YES, list discussion topics below)

- No review needed, this is just an update.

Participants: Ricardo Walker, Sean Tackley, Scott Fielding, Christine Petersen.
Phone: Shane Scott
CENWP-PM-E 18 June 2015

MEMORANDUM FOR THE RECORD

Subject: DRAFT minutes for the 23 April 2015 FFDRWG meeting.

The meeting was held in CRITFC Lloyd 700 Building Portland OR. In attendance:

Last	First	Agency	Office/Mobile	Email
Baus	Doug	RCC		Douglas.m.baus@usace.army.mil
Bissell	Brian	NWP-BON		Brian.m.bissell@usace.army.mil
Brower	Alan	PSMFC		abrower@psmfc.org
Conder	Trevor	NOAA		Trevor.conder@noaa.gov
Fredricks	Gary	NOAA	503-231-6855	Gary.fredricks@noaa.gov
Graham	Jen	Warm Springs		
Kiefer	Russ	IDFG		Russ.kiefer@idfg.idaho.gov
Lopez-Johnston	Siena	BPA		smlopez@bpa.gov
Lorz	Tom	CRITFC		lort@critfc.org
Meyer	Ed	NOAA		Ed.meyer@noaa.gov
Rerecich	Jon	NWP	503-808-4779	Jonathan.g.rerecich@usace.army.mil
Royer	Ida	NWP-BON		Ida.m.royer@usace.army.mil
Skalicky	Joe	USFWS		Joe_Skalicky@fws.gov
Warf	Don	PSMFC		dwarf@psmfc.org
Wright	Lisa	RCC		Lisa.s.wright@usace.army.mil

Kiefer, Meyer, Scott, Skalicky, Wright called in.

All documents may be found at http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/FFDRWG/FFDRWG.html

1. Final Actions or recommendations from the 23 April 2015 NWP FFDRWG.

1.1. BON Cascade Island, FGE and pinniped issues. We have attraction flow at CI entrance and are just below criteria. FGE test will be delayed a couple of weeks. We will continue to monitor pinniped predation.

1.2. Rerecich had to step out to work on FGE. FFDRWG was diverted to a discussion about MFR 15TDA03 and the need to take both fish units out of service for five hours each on 7 May. The Region recognized the need to have the brushes inspected and repaired and expressed not much concern about the work.

1.3. The fish managers are all on board with the JDA adult ladder PIT detectors. The Action Agencies need a bit more time to consider this project. NWP plans to have a clearer path forward by the June FFDRWG.

2. Outstanding action items from previous FFDRWG meetings:

2.1. TDA Back up AWS. **ACTION:** Rerecich will draft a MOC, including the proposed schedule and schedule a special FFDRWG or FPOM to further discuss the construction plan. ***STATUS: A special FPOM meeting was held on 2 June to coordinate this and other projects.***

2.2. JDA-S lower weirs. Fredricks said we may see more focus on JDA-S in the future, especially given the dry, potentially warm water year we are looking at for 2015. Fredricks mentioned a letter report from Matt Keefer (UI). **ACTION:** Rerecich will send that letter report to NWP FFDRWG. NWP needs to figure out the path forward since there is no team assigned to investigating this issue further. ***STATUS: Rerecich distributed the letter report to FFDRWG on 23 April. NWP has not discussed this issue further, though it may fit within the scope of the lamprey minor fishway modifications project.*** Group discussed potential weir removal. Not likely a high priority task for salmon. Need to look at potential reduction in operational flexibility in the event that The Dalles pool elevation is dropped.

2.3. Tackley talked through the first vs. second tier LPS tasks and priorities, based on special FFDRWG meeting and other considerations. **ACTION:** Tackley will distribute a summary table (with notes from FFDRWG and current project status) to FFDRWG. ***STATUS: Tackley will distribute the summary table NLT 19 June.***

2.4. Next meeting was scheduled to be 4 June but there is a conflict with SRWG. **ACTION:** Tackley will initiate a Doodle poll to identify possible June/early July FFDRWG dates. ***STATUS: Tackley scheduled the 18 June NWP FFDRWG meeting based on Doodle poll results.***

2.5. JDA overflow weir PIT tag detection. **ACTION:** Eppard will have a hydraulic and structural engineer look at the design. Feedback will be provided back to the Region. ***STATUS: This will require further discussion between the Corps and BPA prior to committing funds and resources to design review/support. Based on 23 April FFDRWG meeting, PSMFC will identify proposed locations for the PIT arrays at the 18 June FFDRWG.***

2.5.1. NOAA requests schedule outline for decisions, path forward.

2.5.2. Conder: NWW had a contractor complete hydraulic analysis. Report is already completed – pretty straight forward.

2.5.3. Bettin: Need to have more discussion about objectives, cost of maintenance, etc.

2.6. BON performance standards meeting. ACTION: PM-E will schedule a meeting to discuss BON performance standards, likely late March. ***STATUS: Fielding will schedule a meeting (likely for July) to discuss BON performance standard metrics. A Doodle poll will be sent to FFDRWG/SRWG NLT 19 June.***

2.6.1. Fielding: Looking at last week in July.

2.6.2. Fredricks recommends including first week in August as well.

2.6.3. Lorz and Fredricks: Also need to discuss path forward on JDA performance testing, given the miss. Gary also wants to follow up on the Weiland report comments. Need route specific info on MCN and JDA. ACTION: Fielding will follow up with Weiland on status of route-specific passage analysis for JDA. Need a schedule.

3. Bonneville Spillway - Stilling Basin Erosion and Bon Major Rehab (Cutts/Lee/Ebner)

3.1. Finishing up Phase 1 this summer, which is our delineation of which items (outside of powerhouse) we will study further in the Major Rehab Report, and which items we will pursue Major Maintenance (kick off in FY16).
3.2. Done with fishways and bridges; working on results for spillway and navlock.
3.3. How much Q do we have to pass is one of the questions. Has to stay within authorized purpose of the project. H&H (Ebner) recommendation is 1.6M cfs; which BON can't currently sustain. Any changes that would affect routes of passage for juvenile or adult fish would be coordinated with FFDRWG.
3.4. NOAA and CRITFC want the schedule and plan for FFDRWG engagement. ACTION: Rerecich will work with Cutts on providing clarification on schedule and how/when FFDRWG will be engaged in this process.

4. Lamprey Passage Projects (Turaski/Stevens/Tackley)
4.1. Lamprey Minor Fishway Modifications
4.1.1. Scheduled to complete 90% design for Bradford Island serpentine mods by 15 June (overdue).
4.1.2. Working with FFU (Zorich/Wertheimer) on outlining video evaluation of refuge boxes and lamprey orifices. This will determine exact configuration that will require FFDRWG review.
4.1.3. Tackley will seek FFDRWG review of 90% package (with caveats) ASAP.
4.1.4. Lorz recommends looking at velocities at top of serpentine section.

4.2. Lamprey Passage Structure (LPS) Development and Improvements
4.2.1. PDT is working on 60% DDR (due 30 June). Should be ready for regional review in July.
4.2.2. Distributing prioritization spreadsheet to FFDRWG NLT 19 June.
4.2.3. Tackley will be sending FPOM an MOC for BON WA Shore LFS testing on/around July 29-30. Plan to test in conjunction with WAShore ROV (July 29) to minimize any potential impacts. Targeting off-peak (mid-day) passage hours for higher flow LFS treatments.

5. The Dalles East Adult Fish Ladder AWS Backup System (Duyck/Rerecich)
5.1. Contract is out for advertisement (16 June) and is schedule to award mid August. Onsite work likely to begin in Oct/Nov.
5.2. Last month we held special FPOM to coordinate The Dalles work. It was agreed that we could take TDA NFL down early for normal maintenance so the AWS contractor could use the full IWW on TDA EFL.
5.3. Construction will span two IWW windows and once a contractor is selected we will work with them on all schedule and any possible items that may need to be coordinated with FFDRWG or FPOM.

6. John Day North Ladder AWS pumps (Richards)
6.1. Zyndol: All is well with the JD North AWS pumps at this time. Typically only three pumps have been necessary and are in service this time of year. Bottom line, we have sufficient AWS capacity with two spares as well.

6.2. Bettin: Low flows this year. Do we have sufficient number AWS pumps available? Lorz: Lower tailwater means fewer pumps required.

6.3. NOAA requests schedule on fixing this issue. ACTION: Tackley will request that Richards and Boag provide schedule update to FFDRWG.

7. Bonneville B2 Fish Unit Trash Rake (Stricklin/Filan/Royer/Rerecich)

7.1. All the perforated plate has been installed including stiffeners for the top perforated plate. All carbon steel impacted by the modifications has been painted (touch up).

7.2. The only thing left to do is make adjustments of the UHMW scraper blocks. Our plan is to install a few more trash racks into a trashrack slot above the existing trashracks. This will provide us racks out of the water so that we can make the adjustments on the scraper blocks when we put the rake down the trash rack rake guides. Riggers will use camera to inspect.

7.3. Bottom-line is the work is done and the big test will be during the next milfoil (summer) die-off.

7.4. Lorz: Requests update on video inspections to see how it is working. Milfoil and large woody debris will present different challenges. Also, need to verify that trash isn't being floated. ACTION: Rerecich will update group as information comes in.

8. B2-FGE (Medina/Stevens/Rerecich)

8.1. Unit 15 prototype construction completed in MAR 2015. Modifications included flow control plates in A and B slots, and modified VBS panels in all three slots.

8.2. NOAA began biological testing APR 1, 2015. Testing was completed MAY, 2015. Purpose for testing: evaluate survival in 15A and 15C at high unit flow (~18 kcfs) and compare to survival in unit 14A at mid-range flow (~15 kcfs). Comparison of hydraulic testing/modeling in unit 15A, B, C will be used to infer expected survival in 15B. (Draft Report NOV 2015, Final Report MAR 2016). SHOULD HAVE PRELIMINARY DATA BEFORE NOVEMBER TO FACILITATE DISCUSSION ABOUT OPERATIONS.

8.3. Second set of modified trash racks installed for biological testing on MAR 17, 2015.

8.4. Harbor Engineering successfully conducted field hydraulic testing to evaluate performance of unit 15 modifications.

8.5. 30% DDR complete.

8.5.1. Design refined to include a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate that blocks approximately 25% of the opening in bay B, and no flow control plate in bay C.

8.5.2. Proposed design includes reducing the open areas for the porosity plates on the upper two rows of panels on the VBSs by about 50%.

8.6. Path forward: anticipating positive results from bio testing and field velocity measurements, the intent is to accelerate the completion of the DDR and move into formal P&S with the intent of awarding contract in Summer 2016.

9. B2 Orifices (Medina/Kuhn/Rerecich)

9.1. EDR still close to completion, pending EDR comment backcheck.

9.2. At this time there is no intention to further pursue the B2 orifice work beyond the EDR phase.

9.3. Fredricks: Still considers this a problem; would prefer that this continued moving forward.

10. Turbine Survival Program (Medina/Rerecich)

10.1. No update. Waiting for final B1/B2 report from ERDC. Report is scheduled for completion in December 2015.

10.2. Model trip currently scheduled for third week in September (week of 21 September). **ACTION: Rerecich will follow up with Medina on trip particulars.**

11. John Day North Ladder PIT feasibility (PSMFC presentation)

11.1. Corps has budgeted for Corps tasks in FY16, but this also requires commitments from BPA. Corps and BPA need to discuss further and plan/budget/resource accordingly.

11.2. Brower presentation: JDAS – May need to core drill for power and fiber optic cable to transceivers to prevent trip hazard. Similar to what was done for JDAS count station jib crane.

11.3. Brower presentation: JDAN – Preferred location is on roadway deck adjacent to visitor center. Alternative location is at tailrace deck level, but this would require providing internet, poorer access, etc.

11.4. Conder: At Lower Granite, hydraulic analysis indicated relatively neutral impacts on hydraulics. May increase velocity through orifices by 0.5 fps. Not sure how analogous this is to JDA.

11.5. Meyer: Adding 2 inches to overflow height would increase count station pool elevation, which will affect head. Recommend trying to have zero effect on hydraulics.

11.6. Bettin: What is estimated annual maintenance cost? Warf: No net increase in maintenance cost, since PSMFC staff already have to maintain juvenile PIT array. Already have transceivers.

12. Bonneville B1 Ice and Trash Sluiceway (ITS) PIT detection (PSMFC presentation)

12.1. Quad Antenna Scheme: 4 antennas with 4 transceivers ("Quad Antenna") to cover 21 ft span. Use thin body design. Each antenna would have unique identifier to reduce changes of tag collisions across the gate. No detection redundancy in this design.

12.2. If redundancy is required, antenna could be inserted into trash rack guides. Due to physical size of this antenna, Biomark FS-3001 transceiver would be required to have adequate detection field. No concrete cutting required.

12.3. Chain Gate Antenna Scheme – Bays 1A and 1B. Changing forebay levels mean that a pass-through antenna would be required. Antenna height could

be reduced with the addition of debris deflector, if acceptable to BON (O&M clearance).

12.4. Group discussed advantages and disadvantages of the different options. Pass through antennas would get better detection efficiency, but may require more O&M review. Quad Antenna concept is less expensive (transceiver and antenna both cheaper), but may require redundancy, depending on detection efficiency and goals. All antennas would be constructed of durable, solid plastic material (needs to withstand direct hits from large woody debris).

12.5. Are gates set on sill (68 ft)? Fredricks: Should be flush/on sill. ACTION: Corps (Royer?) will verify elevation of the gate crest.

12.6. Warf: Could test prototype(s) in slot. Would need Corps PDT to support mechanical, structural, O&M, electrical, etc.

12.7. Same concept could potentially be applied to the TDA ITS.

12.8. Group discussed need for cost estimates (PSMFC and Corps) and further discussion regarding particular goals, given trade-offs. Bettin: It would be good to be able to achieve detection targets without relying on having screens in at B2.

Next NWP FFDRWG Meeting: TBD (June 2015)

CENWP-PM-E 1 October 2015

MEMORANDUM FOR THE RECORD

Subject: DRAFT minutes for the 1 October 2015 FFDRWG meeting.

The meeting was held at the Columbia Room CRITFC, Portland OR. In attendance:

Last	First	Agency	Email
Absolon	Randy	NOAA	Randy.absolon@noaa.gov
Bettin	Scott	BPA	swbettin@bpa.gov
Bissell	Brian	NWP	Brian.m.bissell@usace.army.mil
Conder	Trevor	NOAA	Trevor.conder@noaa.gov
Donahue	Scott	BPA	scdonahue@bpa.gov
Ebner	Laurie	NWP	Laurie.l.ebner@usace.army.mil
Eppard	Brad	NWP	Matthew.b.eppard@usace.army.mil
Fielding	Scott	NWP	Scott.d.fielding@usace.army.mil
Fredericks	Gary	NOAA	Gary.fredericks@noaa.gov
Gibbons	Karrie	NWP	Karrie.m.gibbons@usace.army.mil
Knowles	Sarah	NWP	Sarah.l.knowles@usace.army.mil
Kuhn	Karen	NWP	Karen.a.kuhn@usace.army.mil
Lopez-Johnson	Siena	BPA	smlopez@bpa.gov
Lorz	Tom	CRITFC	lort@critfc.org
Mackey	Tammy	NWP	Tammy.m.mackey@usace.army.mil
McIlraith	Brian	CRITFC	MCIB@critfc.org
Medina	George	NWP	George.j.medina@usace.army.mil
Meyer	Ed	NOAA	Ed.meyer@noaa.gov
Petersen	Christine	BPA	chpetersen@bpa.gov
Piaskowski	Richard	NWP	Richard.m.piaskowski@usace.army.mil
Popescu	Corina	NWP	Corina.popescu@usace.army.mil
Rerecich	Jon	NWP	Jonathan.g.rerecich@usace.army.mil
Richards	Natalie	NWP	Natalie.a.richards@usace.army.mil
Tackley	Sean	NWP	Sean.c.tackley@usace.army.mil
Turaski	Mike	NWP	Michael.r.turaski@usace.army.mil
van Dyke	Erick	ODFW	Erick.s.vandyke@state.or.us
Welton	Brent	USACE	Brent.c.welton@usace.army.mil
Zyndol	Miro	NWP-JDA	Miroslaw.a.zyndol@usace.army.mil

Meyer, Piaskowski, Richards called in.

USACE Fish Facility Design Review Work Group

Portland District

Outstanding action items from previous FFDRWG meetings:

1. BON B2 Fish Unit Trash Rake (Stricklin/Filan/Royer/Rerecich). CRITFC (Lorz) requests update on inspections to see how it is working. Milfoil and large woody debris will present different

challenges. Also, need to verify that trash isn't being floated. **ACTION:** Corps will update group as information comes in. ***STATUS: Trash rake is operational and has been working. Project operators had to float debris on the weekends on two occasions, as no maintenance personnel are available on weekends to operate the rake. Future updates can be provided through FPOM, as needed. UPATE:*** Trash rake is still functioning. It is functioning well and they have only had to shut the units down twice while operating. BON Fisheries will update FPOM as needed. Lorz asked if there would be video provided. Rerecich said an ROV inspection was recommended to be done at the same time as the WA fishway collection channel ROV. More information will be provided by BON project when available.

2. Bonneville B1 Ice and Trash Sluiceway (ITS) PIT detection. Are gates set on sill (68 ft)? Fredricks: Should be flush/on sill. **ACTION:** Corps (Royer?) will verify elevation of the gate crest. ***STATUS: The ITS manual gates were both lowered to 68 msl per NOAA's request over a month ago, which caused the ITS to flood at high forebay elevations and reduced water flow at the north end of the channel. After conferring with NOAA (G. Fredricks), BON currently has the southern-most gate (1A) on sill at 68 msl and the other (1B) at 70 msl. The channel is still flooded somewhat at high forebay but FPOM will need to determine whether or not the lessened water flows at the north end of the channel are enough of a concern to raise both gates back to 70 msl. UPDATE:*** Fredericks said the elevation of gate crest 1A is 68 and 1B is 70. The question was, will this capacity of the sluiceway gates accept flow? Yes, it has so far.

3. BON performance standards meeting. **ACTION:** PM-E will schedule a meeting to discuss BON performance standards, likely late March. ***STATUS: Fielding hosted a BON performance standard meeting on 29 July; a follow-up meeting was held on 16 September. UPDATE:*** SRWG discussion

Link to FFDRWG folder:
http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/FFDRWG/FFDRWG.html

1. B2 FGE (Medina/Popescu/Rerecich)

1.1. The COE hydraulically and biologically tested prototype gatewell modifications in the field to improve flow conditions and survival at the upper 1% peak efficiency unit operation.. This provided a better understanding of gatewell dynamics and fish condition. Planning is underway to award a construction contract mid August 2016. The COE is moving ahead and should be completed end of 2017. The goal is to improve the gatewell environment and open up operation range to upper 1% peak efficiency. Optimize project passage conditions for juveniles and adults by pulling more flow to B2. The hydraulic results showed improvement. Biological testing showed improvement as well. In April, COE modified unit 15A to the upper 1% and compared it to unmodified unit 14A and mid 1%. Bio testing in May evaluated 15C operated at upper 1% compared to unmodified unit 14A and mid 1%. Hydraulic measurements were taken, modifications include 50% blockage behind A slot VBS at elevation +31, 25% in B slot, C slot did not have a plate. Ebner said the recommendation was to test the plates in A and B slots with the assumption that we did not need a plate in slot C. The assumption when starting the test is 15k mid flow is acceptable and 18k high flow is unacceptable. CFD modeling was done to show hydraulic velocities to achieve the correct flow representations. The hydraulic recommendation is based on the field measurements for Unit 15 to have 50% plate in slot A, 25% plate in slot B, no plate in slot C, and modified VBS. Bettin asked what does it take to modify a VBS? The VBS would need to be pulled and backing would need to come off for the new porosity plates to be installed in addition to configuring new holes. Bettin asked how long does it take to convert a unit?

1.1.1. Schedule. The unit will need to be dewatered and a map of the rebar will need to be done. COE will meet with BON project staff next week to discuss how long it will take and if they can do the work. Medina said they could provide a soft schedule by the next FFDRWG meeting. Popescu said the challenges will be the time to fabricate the plates and to map the rebar, but the installation of the plates will not take as long. The fabrication of the plates will take about two weeks and the unit will need to be down during that time. If the schedule moves forward as planned, the work should be complete in one year. Units 16, 17, and 18 will be completed in 2017 during the scheduled outage and 11, 12 and 13 during the winter maintenance period.

1.2. Biological Results. In April, Spring Creek subyearling Chinook salmon with PIT-tags were released in gatewells 14A, 15A, and 15C. Tables 1and 2 show the metrics for the PIT-tag fish at B2. The comparison between 14A and 15A of the observed proportions of detections at the JMF showed the overall mean for 14A was 93.6% and 15A was 77.5%, however, it is noteworthy that within the first six days of testing the high detections are in the 80-90% range. The next seven days decreased detections at the JMF, but it was expected based on the work that was done in 2008, 2009 and 2013. All releases occurred in the morning, between 8-9am. Looking at the Observed Mortality Proportion metric, there is significant mortality occurring in 14A than 15A. The Max Mortality Proportion metric had a non-significant difference overall. We should consider both estimates, but recognize that we don't know what happened to the missing fish. Fredericks asked do you have hydraulic information about the release location and how it leads into the screened system? Rerecich referenced a diagram in the packet of the release pipe set up. Fredericks said the key is the velocity of the area of release and the velocity of what is going into the screen. He thought the velocity is about four feet per second at the intake, the fish could swim out of there. What was the vitality of the fish as the test progressed? Absolon said they were healthy fish, tagged down to 55mm, and all were held for 24 hours prior to release. There were only four fish mortalities after 24 hours. Eppard asked, when the fish come out of the release pipe where are they going? One fish was detected in the Corner Collector (CC) 10 days after it was released. Conder stated the other issue is if the fish are not going through the unit, there is potential we are losing FGE at the upper end of 1%, we could lose more if we go to the mid range of 1%. Rerecich said one noteworthy thing he heard from the rigging crew, they reported all of the seals were good on the VBS and they did not see mortalities on the VBS or in the gatewells. Fredericks asked if Ballinger had seen any evidence of problems developing during the study at the JMF? Ballinger's weekly reports were sent to Absolon, they could not see any correlation. Absolon said they found about 60 tags in the sump, which is less than previous years. Conder asked if there is a higher likelihood the tags were from 15A? Absolon has not had a chance to look at that data yet. Absolon looked at the 5 minute OPS data to make sure operations was running correctly. Fredericks stated concerns as the physiology of the fish changes and performance goes up, throughout the season there could be decreases in FGE. Fredericks would like 2008-2009 data included in the report for comparison. Van dyke asked for clarification for the condition in the gatewell between 14A, 15A, B and C. The 15A slot receives higher flow, so it has a larger blockage area to reduce the hydraulic efficiency of the slot and provide better conditions and in tandem with 15B slot. The 15C slot appeared to be meeting the hydraulic criteria without adding a plate and just needed to modify the VBS. Fredericks said the two questions are, can you operate at 18k without killing fish in the high flow slot (15B) and how far do you need to go with the blockages? The answer to the first question is if no, then everything is off the table. The answer to the second question is a comparison for A to A slots to determine how much of a blockage is needed. Van Dyke said regardless of the date tested, can fish pass through each slot as well as A or is it just one slot? It is always all slots. Van Dyke asked for clarification for demonstrating the difference between 15A and 15C. In 2008-2009, the median residency time increased with a little higher mortality. Residence time of 3-4 hours is typical and increases as it gets darker and shadows hit the gatewells. Van Dyke asked, are we considering trying to improve gatewell residence times? No, trying to reduce harsher flow and increase survival, reduce turbulence and reduce mortality. Conder said he is concerned small fish were tested in the A slot and larger fish were tested in the C slot. Lorz said, as the season went on, fish loss increased in the higher flow unit, early in the season the fish are being guided into the unit, but later in the season it's the opposite, why don't you see this earlier in the season? Fredericks thinks the fish are able to swim out or are going under the screens. Ebner said it could be the forebay hydraulics because of the low flow year, water was not always available for the adjacent unit to 14. Lorz is concerned about the fish that are swimming out or possibly being swept under the screens.

1.2.1. Moving Forward. COE will continue working on the DDR. Fredericks said it is your decision to move forward. Bettin said he expects the Corps to be moving forward. Absolon will be presenting at AFEP and the draft report will be out around then. Medina will ask for a show of hands at the next FFDRWG meeting, 3 Dec. The advertisement for the contract would go out in February, a decision will need to be made by January, and the anticipated award date is June/July. ***Action: Special FFDRWG conference call on 12 January at 1:30pm, Rerecich to schedule.***

2. **B2 Orifices (Medina/Kuhn/Rerecich)**

2.1. The project originally tied in with B2 FGE and using light as an attraction mechanism. Currently looking at using different light sources but do not have a plan to move forward. Fredericks said closing out with a report is not enough, something needs to be done to make the orifices easier to monitor and would like to discuss some closeout ideas. Fredericks has some inexpensive ideas that greatly facilitate the lighting of the orifices. The idea is to enclose the lights to keep spiders out and lessen the build up on lens. ***Action: Schedule PDT meeting and brief at next FFDRWG***

3. **Turbine Survival Program (Medina/Ebner/Rerecich)**

3.1. Davidson will produce a report late fall. TSP is moving forward with support from BPA for JDA turbine replacement program. Fredericks asked about MCN, it should be before JDA. TSP from NWW is more directly involved with MCN. Focus here is NWP. Conder asked, currently there is a line item for the CRFM budget for TSP, it is that correct? Yes, however, it currently states it will end in 2018, but it will likely be reduced significantly. In 2018, if funding for TSP is still available it will likely be distributed elsewhere. Conder asked, the results of the study indicate a substantial difference in hydraulics between the lower and upper end of 1% for IHR, is that true? BON survival data suggests there is not a difference in survival while TSP data shows there is a difference, how will you incorporate these two differences? Ebner clarified the discussion is regarding BON. BON is unique from the other projects and the survival characteristics are different. Fredericks stated looking at the flow in each unit to judge whether it is a good or bad condition. If you look at the BON model, the flow looks bad, but looking at the data it doesn't appear to be as bad. Fredericks suggested having a discussion in the future. Two points came up regarding the BON model from ERDC, at the lower end of 1% it looks bad, and as flow increases it looks better. Weiland's Steelhead data does show lower survival at the lower end of 1%. Ebner said there is sensor fish data from BON and JDA that show the differences. Fredericks stated there are pressure issues at B2, there is a very deep runner relative to tailwater, and the tailrace is manufactured instead of natural which makes it difficult to see the turbine boils at B2, which allows fish to get out better. .

4. **Lamprey Minor Fishway Modifications (Turaski/Knowles/Tackley)**

4.1. Turaski discussed the general scope of the project. The PDT's focus is now shifting to BON WA Shore design, for 2016-17 IWW period construction. This includes minor improvements at the BON adult fish facility (AFF) and count station, in addition to serpentine weir mods and diffuser plating. Smaller tasks will be done by BON project staff.

4.2. **Lamprey orifices.** Corps currently plans to cut 2 (approx. 1.5" x 16") orifices in serpentine weirs at BON WA Shore Ladder during the 2016-17 IWW period. The serpentine section modifications are new to the Lower Columbia, so we will use video to evaluate before cutting a full array of orifices at Bradford Island (2017-18 IWW period) and remaining orifices at WA Shore (schedule TBD).

4.2.1. The PDT recently discussed, in light of missing the opportunity to install at BI this winter and resulting impacts on the schedule, cutting *all* orifices at WA Shore this winter but temporarily blocking all but 2 for evaluation. This would also be less expensive than re-mobilizing a contractor, even if we decided to fill in the orifices later. The group discussed possible solutions. **DECISION:** Consensus from the group to move forward with the plan to cut all orifices at WA Shore and block all but 2 during the post-construction evaluation phase. The PDT will devise a solution for blocking orifices.

4.3. **Refuge boxes.** Proposed BON WA Shore serpentine modifications include pilot installation of refuge boxes, which would be mounted to the floor of the fishway and provide a place for lamprey to rest. We plan to build about 6-8 boxes and monitor with video from a fisheries perspective as well as an O&M perspective.

4.4. **Wetted wall.** Tackley noted that just like the Bradford Island serpentine weir mods, testing of a prototype wetted wall (design/construction by NOAA researchers/Kinsey Frick) upstream of the count station was pulled from 2016 actions. The plan now is to test the wetted wall at BON WA Shore in 2017 (2016-17 IWW period install). Fredericks is concerned about changing the wetted wall from BI to WA Shore because of the volume of fish and all the other new lamprey projects (LPS, serpentine weirs, etc) at this location. Fredericks is okay with installing it at BI. Tackley said this structure will be monitored by video and if we see any issues we could shut the water off. Lorz suggested mapping out all of the proposed lamprey structures and mods. Tackley and Lorz are concerned the wetted wall will be pushed out another year and lamprey funding runs out in 2018, precluding testing at WA Shore (post-2018) after initial testing at BI (2017-18 IWW period install). Lorz would like to see a work plan for all the projects; Tackley agreed. Fredericks is not saying no, but feels like it's a shot-gun approach. **ACTION:** Tackley will follow-up with a memo describing all proposed actions in the vicinity of serpentine weirs at BI and WA Shore, including drawings/photos for reference. *NOTE (Tackley): The prototype wetted wall design and testing is not part of the scope of the Minor Fishway Modifications Project. Development and testing of this structure is currently included in the Corps' lamprey studies project; NOAA Fisheries (Kinsey Frick) prepared a research proposal for Bradford Island wetted wall construction and testing in 2016. This study was removed from the FY16 lamprey program due to budget constraints and prioritization decisions.*

4.5. **Additional discussion of lamprey actions at BON WA Shore.** Tackley said we have a four-pronged approach to address poor lamprey passage in the serpentine weirs: (1) new LPS downstream of the count station; (2) installation of the line of orifices for better directionality; (3) refuge boxes to retain them in that section (provision of cover), and; (4) the wetted wall to guide additional lamprey out of the serpentine weir area and toward an LPS. Fredericks is concerned with all of the project proposals for one ladder, WA shore, and in one year. If something goes wrong, the uncertainty of the cause is too much of a risk. Fredericks hasn't seen any information regarding any of these concepts working prior to its implementation. Fredericks is not saying no to the LPS ramps, orifices or other entrance work, but the wetted wall is a little over the top for now. Lorz said the only concept that has not been tested is the wetted wall. Conder suggested the LPS walkway and the orifice construction to be installed in WA shore, and install the wetted wall in BI. Fredericks agreed. Turaski: We plan to award the LPS/Minor Modifications contract in July, there will be opportunities to review over the next few months. **ACTION:** See 5.4 (Wetted Wall) follow-on action.

5. **Lamprey Passage Structure (LPS) Development and Improvements (Turaski/Kuhn/Tackley)**

5.1. Current focus (Phase 1) is on BON WA Shore, including a new LPS upstream of the UMT junction, upgrades to existing LPS, and fixes to the Lamprey Flume System (LFS) in the tailrace area.

5.2. **LFS improvements.** LFS fixes include installing an air manifold to address the entrained air issue, installing plates within the flume to address the velocity barrier in the climbing section, and an access ladder/platform (over tailrace). This work will be done over the tailrace during the in water work window in October 2016 during low tailwater to facilitate access to the climbing section of the flume.

5.3. **LPS upstream of UMT junction.** Tackley sent preliminary drawings to FFDRWG previously. Includes 2 new ramps, rest boxes, access platform for lower rest box inspection, and a traversing flume to connect to existing make-up water supply (MUWS) channel LPS. Design elements include staggering the ramps, the platform will be grating, shaping on upstream side of the ramps so it's not 90 degrees to the flow. Schlenker and Welton said we will use 10-12" aluminum irrigation piping for traversing flume to save cost and simplify installation, since parts are off the shelf and assembly is relatively simple. The climbing sections, above deck level, are still rectangular except the submerged section will have a flow control surface on the upstream side to allow it to be more hydro dynamic.

5.3.1. **Water supply.** Welton: A new addition to the upwelling box will be combining a head box to it, with a control weir and drain on one side and a notched weir on the other side. The notched weir will show how much flow is going into the LPS and will be easier to adjust the flow. There is interest in staying with the 3 hp well pumps (fully screened), at the same location as current pumps - between the trash racks and the MUWS channel, and including redundancy in the system. In total, 4 pumps needed to run 2 existing ramps and 2 new ramps and maintain redundancy.

5.3.2. **Fykes.** The existing system tends to be centered with the upstream side, if a lamprey falls back, there is a greater likelihood it will fall back through the fyke. The idea is to move the fyke to the side for less chance to accidentally fall back. The ends of the fykes will also be able to be adjusted to the flow of water.

5.3.3. **LPS Rest box platform.** In order to provide access and meet safety requirements, it will need to be approx. 13 ft x15 ft platform structure over the ladder. Tackley said FFU is checking the LPS rest boxes every two days but to expect someone checking them once and during dewaterings. Bettin asked what material? Steel walkway, open grating. The location of platform is about half way up the water surface to the elevation of the traversing flume/parapet wall. Fredericks will send his comments and would like to see more finished drawings. McIlraith asked if the walkway is necessary. Tackley: It is necessary to access the rest boxes for inspections. Meyer said he is concerned there is too much access at the ladder and is not comfortable with this. Tackely asked Bissell if he thought this would be an issue or if signage would be enough. Bissell didn't think it would be an issue with signage and place it on a BON Fisheries padlock. Lorz asked would a solid walkway or a platform be better? Fredericks said to just limit the access.

5.3.4. **Schedule.** Wrapping up the 90% DDR this week and should be ready for agency review shortly after. Moving ahead to get through 90% Plans and Specs (P&S) by mid December, final P&S toward the end of March, and awarding the contract in July to allow fabrication time. Construction to begin in October 2016 (LFS). Once the contract has been awarded, the team will begin working on the DDR for the improvements at BON and JDA north, as well as some O&M upgrades at the Cascades Island (CI) LPS.

5.3.5. **LFS Modifications Construction.** Bettin asked if there was any impact to passage when working in October? Turaski said the PDT is working through construction approaches; this will be coordinated with the FPOM group as a design comes together. The LFS is located on the monolith, just downstream of the North Upstream Entrance (NUE). Some ideas for construction include a man basket over the wall, roped climbers, a safety boat, and possibly some operational changes to achieve tailrace elevation. Trying to minimize impacts on normal operations. Bettin asked can you work at night when tailwater is lower and fish do not pass? Working at night for the roped climbers is unlikely. Fredericks said this (use of climbers, man basket, etc during day) is not a problem. October would be optimal time for low flows. A small jib crane mounted to the deck would be needed for the work.

5.3.6. **LFS access hatch repair**. One of the LFS access hatch lids has come off and will need to be replaced. We are currently working on temporary cover ideas. Bettin said 4 turbines will be off on the north side of B2 next year. **ACTION:** Tackley and BON Fisheries will coordinate with FPOM on any activities near the fishway. ***STATUS: After further coordination with BON staff regarding potential temporary solutions, it is unlikely that this will be addressed until the October 2016 construction of other LFS modifications. The Corps will continue to work on a temporary fix and will schedule an ROV to ensure that this is the only damaged hatch lid.***

6. The Dalles East Adult Fish Ladder AWS Backup System (Duyck/Roshani/Rerecich)

6.1. The COE made an award to Kiewit Construction for 22.6 million. One of the unsuccessful offers has filed a Government Accountability Office (GAO) protest. Due to protest the district has suspended work of Kiewit pending resolution of the protest. The Schedule will need to be adjusted. There are many unknowns but we are likely to miss part of the first IWW window and may have to utilize the following two IWW windows. More updates will be provided as the COE works through this.

7. Bonneville Spillway - Stilling Basin Erosion and BON Major Rehab (Cutts/Lee/Ebner)

7.1. **ACTION:** Rerecich will work with Cutts on providing clarification on schedule and how/when FFDRWG will be engaged in this process. ***STATUS: No facility design or design decisions to be made at this point. The PDT is identifying those items that fall under a Major Rehab, Major Maintenance and Regular O&M. The document that describes those decisions should be available before the end of the calendar year (2015). Key messages should be available sometime in November 2015. Item 7 of agenda***

7.2. BON has a project dealing with the major rehab/maintenance. The group has gone through and identified the features that fall into the major rehab or major maintenance categories. The reports should be out within the next couple of weeks. The Corps has identified the major maintenance categories are: 2 years of construction or less, or there is a dollar limit. Cascades Island (CI) fishway has been elevated instead of waiting for major maintenance reports, due to the sinkhole and will begin digging next week. The rest of the ladders have been classified under major maintenance, including mitor gates at the New Nav-Lock, valves, and the Old Nav-Lock swing bridge. The spillway is classified as major rehab. The stumbling block for the spillway is, what cue does it need to pass, or, what is the design flow? Currently, the spillway can pass about one million cfs without splitting gates. It is authorized to pass 1.6 million cfs, because BON was built prior to the Probable Maximum Floods (PMF). The Columbia River PMF was last updated in 1969. The Dalles design flow is 2.1 million cfs, and we are unable to pass that at BON. What cue do we design it for? The spillway is categorized as major rehab, but until we know what the cue is, we don't know which direction to go.

7.2.1. In addition to the work we are doing, the Risk Management Center is doing an IES (Issues Evaluation Study). The Risk Management Center (Dam Safety) has initiated a study that will begin in FY'16 at BON. They always look at a PMF and are more interested in life lost, associated if we put a PMF by BON. This is the first project the Risk Management Center will incorporate the economic impacts associated with a large flood event. If you lose BON, you lose power generation at BON, and TDA will come offline as well. In addition, there will be a loss in fish passage at TDA. There is uncertainty as to what the recommendation will be from the Risk Management Center. If we could split the gates at BON, we can only pass 1.4 million cfs. Ebner asked, where are we going to put 0.8 million cfs? If we are going to have to build a new spillway, do we build a new spillway that meets our environmental obligation in a much more efficient way than it does now? The major rehab study will kick off a concept of what would we have to do to pass one million cfs, 1.6 million cfs or 2.1 million cfs. What does it look like and does the 1.6 and 2.1 marry together? If they do, the major rehab will continue for BON as the IES states. The reports and summaries should be available in about a month. Will the reports be made available to FFDRWG? Yes. The path forward will be summarized around the first of December. Van Dyke asked, how close are we to the limit that BON has passed (what are the record flows)? In 1948, BON passed 1.48 million cfs. In 1957, BON passed 827 million cfs. In 1958, BON passed 727 million cfs. In 1974, BON passed 780 million cfs. In 1996/1997, BON passed 680 million cfs, but it was mostly Willamette based flooding. Conder asked, does the treaty impact the maximum number for flow or is it based on how much water is available? Ebner said, most dam safety studies don't consider regulated for the design flood, regulated is what happens because of the other dams on the system, and BON will not likely fall out that way. The issue is, to get to a new PMF for BON, you do not get it without doing the entire Columbia River Basin. Typically when a new PMF comes out, we see an increase by about 10%, and we anticipate the PMF will be close to what it is currently.

8. **John Day North Ladder AWS pumps (Richards)**

8.1. NOAA requests update on schedule for this effort. **ACTION:** Tackley will request updated schedule from Richards and Boag and will send to FFDRWG. ***STATUS: Corps has directed contractor to redesign certain aspects of the pumps to address reliability concerns. Tentative schedule is to have design complete by 12/31/15, first pump in service June 2016, last pump in service approx 12/31/16.***

8.2. The Corps does not have 100% design complete, but they are expecting to have it by December. The goal is to have pump 4 fixed by the freshet, then we would have pumps 3 and 4 fixed allowing them to be available. The work will begin July 2016, but we do not have it in writing yet.

9. **John Day Fish Ladders PIT detection (Tackley)**

9.1. **ACTION:** Eppard will have a hydraulic and structural engineer look at the design. Feedback will be provided back to the Region. ***STATUS: The President's Budget for FY16 includes funding for moving forward on evaluating the completion of an adult PIT detection system at John Day Dam. The Portland District is currently chartering a Product Design Team (PDT) to initiate this work in FY16. A schedule will be worked out once we have a PDT, but we expect to move forward with installation if feasible (design work completed, sufficient funds to support construction, etc).***

9.2. It is in the budget for 2016. Currently the Corps does not have a PDT yet. Tackley said he will work to keep the scope of the PDT as limited as possible, mainly limited to (PSMFC) design review and providing electrical, etc. The PDT will meet in the first quarter. Eppard said the charter has been approved but he hasn't heard if the PM has been assigned. BPA needs to know when the project will be implemented for funding. ***ACTION:*** Fredericks would like a meeting with the region when the PDT begins scoping.

Next NWP FFDRWG Meeting: 3 December 2015

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Subject: B2 VBS Velocity Profiles - Final 2015 Data Collection Report (UNCLASSIFIED)
Date: Thursday, September 17, 2015 8:02:00 AM
Attachments: 2015_B2 VBS_FINAL.pdf

Classification: UNCLASSIFIED
Caveats: NONE

Hello FFDRWG,

Please find attached the 2015 Final Data Collection Report for B2 VBS Velocity Profiles at Bonneville Dam, Second Powerhouse. Measurements were taken in the B2 gatewells in early June 2015 to further our understanding of the hydraulic conditions between modified and unmodified gatewells as it relates to unit operation.

Thank you,

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Classification: UNCLASSIFIED
Caveats: NONE

APPENDIX C

Value Engineering Studies

Appendix C – Value Engineering Studies

Per ER 11-1-321, for Civil Works projects under the $2 Million threshold, it is optional for construction projects to undergo a Value Engineering study. The Product Development Team has requested documentation verifying the construction portion of installing the flow control plates has a "Low Opportunity for Value Engineering."

APPENDIX D

Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Computational Fluid Dynamics Modeling Report for the DDR, November 2014

US Army Corps of Engineers ®
Portland District

Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Computational Fluid Dynamics (CFD) Modeling Report for the DDR

Bonneville Lock and Dam

November 2014 Draft Report

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APPENDICES

ABBREVIATIONS AND ACRONYMS

3D	three-dimensional
B2CC	Bonneville second powerhouse corner collector
CAD	computer-aided design
CFD	computational fluid dynamics
cfs	cubic feet per second
DSM	downstream migrant transportation
EDR	Engineering Documentation Report
FGE	fish guidance efficiency
ft/s	feet per second
ft^2/s^2	square feet per second squared
JBS	juvenile bypass system
kg/s	kilograms per second
NOAA	National Oceanic and Atmospheric Administration
PNNL	Pacific Northwest National Laboratory
STS	submerged traveling screen
TIE	turbine intake extension
TRD	turbulence reduction device
UMT	upstream migrant transportation
USACE	U.S. Army Corps of Engineers
VBS	vertical barrier screen

1. INTRODUCTION

1.1. BACKGROUND

The construction of the Bonneville Dam second powerhouse (PH2) was completed in 1982. The powerhouse was designed with a juvenile bypass system (JBS) to guide out-migrating juvenile salmonids away from the hydroelectric turbines and around of the dam. The main components of the original JBS were submerged traveling screens (STS) to guide fish into the gatewells, vertical barrier screens (VBS) to prevent fish from returning to the turbine intakes from the gatewells, orifices to allow fish to pass from the gatewells into the downstream migrant transportation (DSM) channel, and an outfall that discharged into the powerhouse tailrace. USACE contracted with the National Marine Fisheries Service (NMFS) to oversee and monitor the initial operation of the JBS. Evaluations conducted by NFMS in 1983 showed unacceptably low fish guidance efficiency (FGE). Since those initial evaluations, there has been an ongoing effort to improve FGE at PH2.

Between 1983 and 1989, several short-duration tests were conducted on a wide range of structural modifications intended to improve FGE in the JBS, and a summary of the research is presented in Monk et al. April 1999. That research resulted in modifications that were fully implemented at PH2 in 1993 and included the installation of structures called turbine intake extensions (TIEs), lowering the STSs by extending their frames, and installing turbine intake trash racks with more streamlined members (USACE March 1992). Subsequent biological testing demonstrated lower than expected FGE with these improvements, and the regional goal for FGE was not achieved (Monk et al. April 1999).

In 1999, regional fisheries agencies agreed to pursue a phased approach to improve fish guidance and survival at PH2 by maximizing flow up the turbine intake gatewells, a guideline that has been used on similar programs to improve FGE. Typical juvenile fish bypass systems at lower Columbia River dams consist of submerged traveling screens, gatewell orifice passage, and turbine intake vertical barrier screens (VBS; Figure 1and Figure 2). The modifications at PH2 were completed in 2008 and included an increase in VBS flow area by removing portions of the gatewell beams, installation of turning vanes to facilitate flow up the gatewells, addition of a gap closure devices (GCD) to reduce fish loss between the STSs and gatewell beams, and allowances for the installation of an interchangeable VBS to allow for screen removal and cleaning without outages or intrusive gatewell dipping (Figure 3). Results of biological studies showed an increase in FGE by 21% for yearling Chinook and 31% for subyearling Chinook. Test fish conditions showed no problems with descaling and gatewell retention time (including fry) in a newly modified unit.

Elevated mortality and poor fish condition was recorded the PH2 Smolt Monitoring Facility following Spring Creek National Fish Hatchery sub-yearling Chinook salmon releases in 2007. Physical inspections of bypass facilities at PH2 resulted in little evidence to indicate that a mechanical system was the causative mechanism. Testing in 2008 and 2009 suggested undesirable flow conditions in the gatewell created as a result of bypass system modifications (i.e. turning vanes, larger VBS, and gap closure devices) were the causative mechanism (Gilbreath et al., 2012). Starting in 2008, PH2 units were operated at the lower end of the 1% peak efficiency range during Spring Creek NFH releases. Since March 2011, PH2 units have been operated at the middle to lower end of the 1% efficiency range during regionally coordinated special operations to minimize PH2 screened bypass descaling and mortality. Confining operation to the lower end of the 1% efficiency range at PH2 reduces the operational flexibility and configuration that may maximize benefits to juvenile salmonid passage at this priority powerhouse and through the project. A detailed description of the lower, middle, and upper 1% turbine operating efficiency range can be found in the U.S. Army Corps of Engineers (USACE) Turbine Survival Program (TSP) Phase I and II Biological Index Testing (BIT) reports, as well as the current Fish Passage Plan (FPP).

In response to the results of the 2008 biological testing, the USACE developed preliminary alternatives for potentially reducing flow into the gatewells, and presented them to the regional fisheries agencies. The regional fisheries agencies agreed with the USACE analysis and approved the study to investigate and evaluate flow control and operational alternatives to increase juvenile salmon survival within the gatewells. The effort and results of that study are documented in *Engineering Documentation Report Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program Post Construction* (USACE October 2013), which is referred to herein as the EDR.

The EDR evaluated both operational and structural alternatives for increasing juvenile survival in the gatewells. One other structural alternative was considered that was not intended to reduce flow into the gatewell, but was intended to modify the flow pattern within the gatewell, resulting in a hydraulic environment that is less detrimental to juvenile salmon. This alternative, called a "gate slot filler" or "turbulence reduction device" (TRD), consists of solid members that are installed in the guide slots above the STS side frame to eliminate the sudden expansions that occur there. CFD modeling conducted as part of the EDR indicated that the sudden expansions above the STS side frame cause areas of flow circulation and high turbulence. The CFD modeling conducted also showed a reduction in flow circulation and turbulence with the gate slot filler in place. It was hypothesized that the gate slot filler could improve juvenile salmon survival by improving the hydraulic environment within the gatewell by modifying flow patterns and reducing turbulence. Additional benefits of this alternative were that the operating range of the turbines would not be affected and that the existing fish guidance flow into the gatewells could be maintained.

The EDR recommended that a gate slot filler prototype be constructed and tested, both hydraulically and biologically. The EDR also recommended that the other alternatives in the report be reconsidered if the prototype did not result in satisfactory improvements in juvenile salmon survival within the gatewell.

A gate slot filler prototype was constructed and tested for hydraulic and biological performance (Harbor and Alden 2013; Gilbreath et al. 2014) during the spring of 2013. The results of the testing indicated that the prototype did not lead to adequate improvements in subyearling Chinook salmon survival within the gatewell (Gilbreath et al. 2014). In addition, the results of the hydraulic testing demonstrated hydraulic conditions within the gatewell that were previously unknown and not predicted with the CFD model that was used to evaluate alternatives as part of the EDR. The unsatisfactory performance of the gate slot filler, along with the new hydraulic data, prompted the need for further study, which resulted in the effort documented in *Supplement to the Engineering Documentation Report Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program Post Construction* (USACE November 2014), which is referred to herein as the Supplement to the EDR.

The Supplement to the EDR reconsidered the alternatives that were developed as part of the EDR for improving juvenile salmon survival in the gatewells at PH2. As part of the process, a criterion was developed to help evaluate the design alternatives. The criterion that was established based on coordination with FFDRWG and states that the flow through any VBS at any unit flow cannot exceed the flow though the bay A VBS at a unit flow of 15,000 cfs. This criterion is based on the determination that juvenile salmon gatewell survival is acceptable in the Bay A VBS at a unit flow of 15,000 cfs, and the assumption that juvenile salmon gatewell survival directly correlates with flow through the VBS.

CFD models were developed for the alternatives and for the baseline conditions. The results from the modeling were used to evaluate the performance of the alternatives compared to the baseline conditions. Of the five alternatives modeled, only the following three met the design criterion for flow through the VBS.

- Install Static Flow Control Plate on Gatewell Beam
- Remove Gap Closure Device
- Remove Submerged Traveling Screen and Turning Vane

Of the three alternatives that met the design criterion, the alternative to install a static flow control plate demonstrated a hydraulic environment within the gatewell that most closely resembled the target design condition (baseline bay A with unit flow of 15 kcfs). The other two alternatives produced hydraulic conditions in the area of the STS and in the gatewells which could have negative impacts on FGE and fish survival.

Field velocity data was also collected as part of the effort for the Supplement to the EDR (Harbor and Alden 2014). Velocity data was collected under several scenarios, including various bays, various unit flows, and with some modifications to the gatewells. The gatewell modifications included installing a flow control plate on the gatewell beam in Unit 15A that blocked 50% of the opening between the downstream side of the beam and the intake gate. The velocity data supported the results of the CFD modeling, and indicated that the flow control plate reduced the flow up the gatewell, reduced the approach velocity for the VBS, and potentially reduced turbulence in the gatewell, all of which are expected to improve survival in the gatewells.

Based on the results of the CFD modeling and field velocity data, the recommendation in the Supplement to the EDR was to further study a static flow control plate installed on the gatewell beam as part of a DDR to reduce the mortality and descaling in the gatewells at PH2. As a starting point for the additional study, the Supplement to the EDR recommended a configuration that included a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate the blocks approximately 25% of the opening in bay B, and no flow control plate in bay C.

An additional recommendation in the Supplement to the EDR was to study modifying the porosity plates on the upper two rows of panels on the VBS to conform to the approach velocity criteria for the entire turbine operation range. Field velocity data collected in 2013 and 2014 demonstrated areas of high approach velocity on the upper panels of the VBS (Harbor and Alden, 2013 and 2014).

1.2. OBJECTIVES

The USACE Portland District Hydraulic and Coastal Design Section carried out a modeling study to meet the following objectives:

1. Confirm or refine the sizes and configuration for the flow control plates recommended in the Supplement to the EDR, which included a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate the blocks approximately 25% of the opening in bay B, and no flow control plate in bay C.

2. Develop a design recommendation for modifying the porosity plates on the upper two rows of panels on the VBS to conform to the approach velocity criteria for the entire turbine operation range.

2. CFD MODELING OVERVIEW

2.1. MODEL DEVELOPMENT

The CFD model used for this study is a sectional model of a single powerhouse unit and is the same model that was used to evaluate alternatives as part of the Supplement to the EDR. The CFD model was constructed with the intent of providing relative comparisons of gatewell hydraulic conditions between modeled proposed improvements and modeled baseline conditions, and not with the intent to provide highly accurate representations of actual existing or future gatewell hydraulic conditions. The model geometry was developed using record drawings and field measurements. As part of the Supplement to the EDR, the computation volume mesh was evaluated for sensitivity to refinement, and was refined where it was deemed appropriate to do so. The resulting volume mesh is shown in Figure 4 and Figure 5.

In the model, the STS and VBS panels are represented by porous baffles that have two parameters (porosity coefficients α and β) which affect the flow through the panels. As part of the Supplement to the EDR, the CFD model was calibrated by adjusting these parameters associated such that the flow through the VBS panels in the model was in acceptable agreement with field data. It turned out that calculated theoretical porosity coefficients provided acceptable agreement between the model results and the field data that was used for calibration. The resulting porosity coefficients used for the existing VBS panels and STSs are shown in Table 2-1 and Table 2-2.

More detail on the development of the CFD model can be found in the CFD report that is an appendix to the Supplement to the EDR.

Table 2-1. Porosity Coefficients for Existing (Baseline) VBS Panels

Panel	Porosity	α	β
1 (top)	1.000	11.00	0.01
2	0.456	13.90	0.01
3	0.213	34.00	0.01
4	0.213	34.00	0.01
5	0.213	34.00	0.01
6	0.185	41.00	0.01
7	0.185	41.00	0.01
8	0.276	22.00	0.01
9 (bottom)	0.627	11.65	0.01

Table 2-2. Porosity Coefficients for an Existing (Baseline) STS

α	β
4.90	0.01

The model used for the baseline conditions for this study used the existing gatewell geometry and the porosity coefficients in Table 2-1 and Table 2-2. The geometry modifications for the model for the proposed conditions in this study included a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A and a flow control plate the blocks approximately 25% of the opening in bay B. The volume meshes for the models for baseline conditions and proposed improvements were exactly the same, only the cells that represented the flow control plates were removed from the fluid domain for the proposed improvements model.

One other change for the model for the proposed conditions was to the porosity coefficients for the VBS panels. An objective of this study is to develop a design recommendation for modifying the porosity plates on the upper two rows of panels on the VBS to conform to the approach velocity criteria for the entire turbine operation range. As a starting point, it was decided that the porosities of the flow control plates on the upper two rows of panels would be reduced by approximately 50%. The resulting porosity coefficients used for the model for the proposed improvements are shown in Table 2-3.

Table 2-3. Porosity Coefficients for Proposed VBS Panels

Panel	Porosity	α	β
1 (top)	0.456	13.9	0.01
2	0.213	34.00	0.01
3	0.213	34.00	0.01
4	0.213	34.00	0.01
5	0.213	34.00	0.01
6	0.185	41.00	0.01
7	0.185	41.00	0.01
8	0.276	22.00	0.01
9 (bottom)	0.627	11.65	0.01

2.2. BOUNDARY CONDITIONS

The model was setup as a steady-state model with constant flow and boundary conditions. For all scenarios, the model was run with prescribed uniformly distributed outflow velocities at the downstream boundaries for bays A, B, and C corresponding to the flows in Table 2-4. The flow distribution in Table 2-4 is based on …. The upstream boundary condition in the forebay was prescribed uniformly distributed inflow velocities corresponding to the flows in Table 2-4 plus an additional 33 cfs, which discharges into the downstream migrant transportation (DSM) channel through orifices in each of the three gatewells. In all runs, the north fish orifice was in operation in bays A and B with an outflow of 11 cfs. A pressure boundary at the bay C north fish orifice was specified to allow the flow to equalize in the model domain, resulting in an outflow of approximately 11 cfs at that location.

Table 2-4. Model Outflow Conditions

Unit Flow	Bay A Flow	Bay B Flow	Bay C Flow
Flow Distribution			
100%	37.8%	34.2%	28.0%
Flow (cfs)			
12,000	4,536	4,104	3,360
15,000	5,670	5,130	4,200
18,000	6,804	6,156	5,040

The 18,000 cfs unit flow provided a baseline for hydraulic conditions to represent the upper turbine operation range, the 15,000 cfs unit flow provided a baseline to represent the middle turbine operation range, and the 12,000 cfs provided a baseline to represent lower turbine operation range.

The forebay water surface was set at a constant elevation of 72.0' and was modeled as a symmetry plane (no friction at the boundary). Similarly, the water surfaces in the gatewells and intake gate slots were set at a constant elevation of 72.0'. All of the surfaces for the structures were set as "wall" boundaries with a no-slip (friction) condition at the surface.

2.3. AVERAGING OF MODEL RESULTS

The hydraulic conditions within the gatewells are dynamic, even for steady-state flow conditions. The flow patterns within the gatewells and velocity distributions on the VBS panels vary considerably over time with a constant unit flow. The dynamic nature of the flow within the gatewells has been observed with field data (Harbor and Alden 2013; Harbor and Alden 2014), and also with the CFD model. While the CFD model used for this study is not transient, the hydraulic conditions within the gatewells vary with model iterations, even after the model residuals have stabilized. The hydraulic conditions within the gatewells appear to by cyclical within the model, with the same general flow patterns continuing to develop and oscillate with model iterations.

In order to account for the dynamic conditions within the gatewells, it was decided that hydraulic data that was averaged over several flow pattern oscillations would be most representative for comparisons between model runs. Prior to averaging hydraulic data, the models used for this study were all run for 3,000 iterations so that the model residuals were stabilized. The next step was to determine the appropriate number of iterations that should be used to develop a representative average for the data. The model for the proposed improvements (flow control plates in bay A and bay B, and modified VBS panels) was used to do this. This model was run from iteration 3,000 to iteration 15,000 and images showing the magnitudes of the average normal velocities for all three VBS panels were exported every 10 iterations. These images were visually inspected to determine when there was no longer a noticeable change in the distribution of the magnitudes of the average normal velocities. It appeared that the average normal velocities stabilized within about four thousand iterations (at iteration 7,000), so it was determined that adequate averages for the hydraulic data for subsequent model runs (except the baseline 18 kcfs run, which was also averaged from iteration 3,000 to 15,000) would be achieved by averaging over 7,000 iterations (from iteration 3,000 to iteration 10,000). The hydraulic data from the CFD modeling that are presented in this report are from these average data values unless otherwise noted.

2.4. POST-PROCESSING MODEL RESULTS

The CFD model results for all runs were post-processed using FieldView, a CFD model post-processing software program, and the results are discussed in the following sections. Similar figures were generated for each model run and include plots that show: (1) velocity magnitudes at the center lines of each bay through the entire model domain; (2) the velocity magnitudes and directions at the center lines of each bay in the vicinities of each gatewell; (3) the magnitude of the normal velocities and sweeping velocity vectors at a section 0.65 ft upstream of the VBSs; and (4) an isosurface of turbulent kinetic energy (TKE).

Turbulence results from instability in a fluid, and the motions associated with it are mostly random in nature, so it can be difficult to accurately represent in a numerical model and also difficult to display in graphical form, such as in a figure. In this report, we chose to represent with the turbulent kinetic energy, which is the mean kinetic energy associated with eddies in turbulent flow. The TKE isosurface plots show 3-D surfaces where the turbulent kinetic energy is at 1.0 ft^2/s^2; the volume inside the isosurface has higher turbulent kinetic energy, and the volume outside the surface has lower turbulent kinetic energy than the isosurface.

3. CFD Modeling of Baseline Conditions

CFD model runs were conducted with the existing gatewell geometry to establish a hydraulic baseline for evaluation of the proposed improvements. The model was run for unit flow conditions representing the lower, middle, and upper unit operation range. The CFD model-predicted VBS flows for each baseline flow condition considered are summarized in Table 3-1. The VBS flow for each bay was calculated from the CFD model results by converting the average panel velocity across the VBS baffles to flow (cfs) by multiplying it by the surfaced area of the panel.

Table 3-1. Baseline Conditions VBS Flow Summary

Unit Flow (cfs)	Bay A VBS Flow (cfs)	Bay B VBS Flow (cfs)	Bay C VBS Flow (cfs)
12,000	176	168	139
15,000	232	211	173
18,000	279	253	209

The velocities are highest through bay A and lowest through bay C as a result of the flow distribution for the bays shown in Table 2-4. For the baseline conditions, a higher flow through a bay results in more flow up the gatewell for that bay, so bay A has the highest gatewell flow and bay C has the lowest for a given unit flow.

The majority of the gatewell flow enters on the upstream side of the turning vane, and the remainder enters downstream of the turning vane along the gatewell beam. The flow that passes along the upstream side of the turning vane demonstrates flow separation downstream of the intake roof, as shown by the areas of low velocity there in the figures. Similarly, the flow that enters the gatewell along the gatewell beam demonstrates flow separation downstream of the lower end of the turning vane, as shown by the area of low velocity on the downstream side of the turning vane. The result is an uneven distribution of flow into the gatewell, which induces turbulence and irregular flow patterns.

As the flow passes above the turning vane, the gate slot width increases abruptly above the turning vane and STS side frame and the flow can not immediately expand to fill the volume. This sudden expansion induces turbulence and irregular flow patterns within the gatewell. An opposing circulation of flow upward and then downward on either side of each bay results as the flow expands downstream of the abrupt gate slot transition.

3.1. Low Unit Flow Conditions – 12,000 cfs

The CFD model results for the baseline low unit flow condition (12,000 cfs) are summarized in Figure 6 through Figure 13. Figure 6 through Figure 8 show velocity magnitudes at the center lines of each bay through the entire model domain. Figure 9 through Figure 11 show the velocity magnitudes and directions at the center lines of each bay in the vicinities of each gatewell.

Figure 12 shows the magnitude of the normal velocities and sweeping velocity vectors just upstream of the VBSs. The normal velocity magnitudes appear to be less than the 1 ft/s criteria. Sweeping velocities at the VBSs are generally positive (positive upward) along the center of the screen, but negative in the circulation on the sides of the VBSs.

An isosurface of turbulent kinetic energy (TKE) at 1.0 ft^2/s^2 is shown in Figure 13. The gatewell volume with TKE above 1.0 ft^2/s^2 is low for this unit flow. It is almost non-existent in the bay C gatewell, and only exists in small areas in the lower portions of the bay A and B gatewells.

3.2. MEDIUM UNIT FLOW CONDITIONS – 15,000 CFS

The CFD model results for the baseline medium unit flow condition (15,000 cfs) are summarized in Figure 14 through Figure 21. Figure 14 through Figure 16 show velocity magnitudes at the center lines of each bay through the entire model domain. Figure 17 through Figure 19 show the velocity magnitudes and directions at the center lines of each bay in the vicinities of each gatewell.

Figure 20 shows the magnitude of the normal velocities and sweeping velocity vectors just upstream of the VBSs. The normal velocity magnitudes appear to be mostly less than the 1 ft/s criteria, but there are areas of high normal velocity on the upper portions of the VBSs in bay A and bay B. In particular, there is a significant portion of the VBS in bay A where the normal velocities are above 1 ft/s. Sweeping velocities at the VBSs are generally positive (positive upward) along the center of the screen, but negative in the circulation on the sides of the VBSs.

An isosurface of turbulent kinetic energy (TKE) at 1.0 ft^2/s^2 is shown in Figure 21. The gatewell volume with TKE above 1.0 ft^2/s^2 is significantly higher in bay A and bay B compared to the low unit flow condition. The regions within the TKE isosurface include the areas downstream of the intake roof, on the upstream face of the turning vane, along the upstream side of the gatewell beam, and extending along either side of the VBS at the gate slot expansion above the STS side supports.

3.3. HIGH UNIT FLOW CONDITIONS – 18,000 CFS

The CFD model results for the baseline high unit flow condition (18,000 cfs) are summarized in Figure 22 through Figure 29. The gatewell flow patterns for the 18,000 unit flow condition are generally similar to those for the medium unit flow condition, but the velocity magnitudes and intensity of the turbulence in the gatewells are greater. Figure 22 through Figure 24 show velocity magnitudes at the center lines of each bay through the entire model domain. Figure 25 through Figure 27 show the velocity magnitudes and directions at the center lines of each bay in the vicinities of each gatewell.

Figure 28 shows the magnitude of the normal velocities and sweeping velocity vectors just upstream of the VBSs. The areas of high normal velocity on the upper portions of the VBSs in bay A and bay B are larger compared to the medium unit flow condition. There are significant portions of the VBSs in bay A and bay B where the normal velocities are above 1 ft/s. Sweeping velocities at the VBSs are generally positive (positive upward) along the center of the screen, but negative in the circulation on the sides of the VBSs.

An isosurface of turbulent kinetic energy (TKE) at 1.0 ft^2/s^2 is shown in Figure 29. The gatewell volume with TKE above 1.0 ft^2/s^2 is higher in all bays compared to the medium unit flow condition. The regions within the TKE isosurface include the areas downstream of the intake roof, on the upstream face of the turning vane, along the upstream side of the gatewell beam, and extending along either side of the VBS at the gate slot expansion above the STS side supports.

4. CFD MODELING OF PROPOSED IMPROVEMENTS

CFD model runs were conducted with the proposed gatewell improvements to compare to the baseline runs. The model was run for unit flow conditions representing the lower, middle, and upper unit operation range. The CFD model-predicted VBS flows for each baseline flow condition considered are summarized in Table 4-1. The VBS flow for each bay was calculated from the CFD model results by converting the average panel velocity across the VBS baffles to flow (cfs) by multiplying it by the surfaced area of the panel.

Table 4-1. Proposed Improvements VBS Flow Summary

Gatewell Condition	Unit Flow (cfs)	Bay A VBS Flow (cfs)	Bay B VBS Flow (cfs)	Bay C VBS Flow (cfs)
Design Target	All	Max. 232	Max. 232	Max. 232
Proposed Improvements	12,000	131	141	135
Proposed Improvements	15,000	164	176	169
Proposed Improvements	18,000	202	212	204

The design criterion that has been set for this study is that the flow through any VBS at any given flow cannot exceed the flow through the bay A VBS for the baseline conditions at a unit flow of 15,000 cfs. Based on the CFD modeling, the bay A VBS flow for the baseline conditions at a unit flow of 15,000 cfs was calculated to be 232 cfs, as shown in Table 3-1, so that is the maximum allowable VBS flow for the proposed improvements for any bay and any unit flow. Table 4-1 shows that the CFD modeling indicates that the VBS flows for the proposed improvements will meet the design criteria.

For the proposed improvements, the flow distribution for the bays is still that shown in Table 2-4, however, because of the flow control plates in bays A and B, a higher flow through a bay does not necessarily result in more flow up the gatewell for that bay. The modeling indicates that the gatewell flows are nearly equal among the bays for all three unit flow conditions, with the bay B gatewell flow being slightly higher than for bays A and C.

4.1. LOW UNIT FLOW CONDITIONS – 12,000 CFS

The CFD model results for the proposed improvements low unit flow condition (12,000 cfs) are summarized in Figure 30 through Figure 37. Figure 30 through Figure 32 show velocity magnitudes at the center lines of each bay through the entire model domain. Figure 33 through Figure 35 show the velocity magnitudes and directions at the center lines of each bay in the vicinities of each gatewell. Compared to the baseline low flow condition, the velocities in the bays A and B gatewells appear to be slightly lower, and the velocities in the bay C gatewell appear to be very similar.

Figure 36 shows the magnitude of the normal velocities and sweeping velocity vectors just upstream of the VBSs. Compared to the baseline low flow condition, the normal velocities in bays A and B are generally lower through the majority of the VBSs, but areas of higher velocity are developed on the lower corners of the VBSs. The normal velocities in bay C are very similar to the baseline low flow condition. For all three bays, the sweeping velocities at the VBSs appear to be similar to the baseline low flow condition, with generally positive (positive upward) along the center of the screen, but negative in the circulation on the sides of the VBSs.

An isosurface of turbulent kinetic energy (TKE) at 1.0 ft^2/s^2 is shown in Figure 37. The gatewell volume with TKE above 1.0 ft^2/s^2 is lower in bays A and B, and similar in bay C compared to the baseline low flow condition.

4.2. Medium Unit Flow Conditions – 15,000 cfs

The CFD model results for the proposed improvements medium unit flow condition (15,000 cfs) are summarized in Figure 38 through Figure 45. Figure 38 through Figure 40 show velocity magnitudes at the center lines of each bay through the entire model domain. Figure 41 through Figure 43 show the velocity magnitudes and directions at the center lines of each bay in the vicinities of each gatewell. Compared to the baseline medium flow condition, the velocities in the bays A and B gatewells appear to be slightly lower, and the velocities in the bay C gatewell appear to be very similar.

Figure 44 shows the magnitude of the normal velocities and sweeping velocity vectors just upstream of the VBSs. Compared to the baseline medium flow condition, the normal velocities in bays A and B are generally lower through the majority of the VBSs, and appear to be better distributed on the screens. The areas of high normal velocity on the upper portions of the VBSs seen in the baseline condition for bays A and B are not present, but there are areas of higher velocity that have formed on the lower corners of those VBSs. The normal velocities in bay C are very similar to the baseline medium flow condition. For all three bays, the sweeping velocities at the VBSs appear to be similar to the baseline medium flow condition, with generally positive (positive upward) along the center of the screen, but negative in the circulation on the sides of the VBSs.

An isosurface of turbulent kinetic energy (TKE) at 1.0 ft^2/s^2 is shown in Figure 45. The gatewell volume with TKE above 1.0 ft^2/s^2 is significantly reduced in bays A and B, and similar in bay C compared to the baseline medium flow condition.

4.3. High Unit Flow Conditions – 18,000 cfs

The CFD model results for the proposed improvements high unit flow condition (18,000 cfs) are summarized in Figure 46 through Figure 53. Figure 46 through Figure 48 show velocity magnitudes at the center lines of each bay through the entire model domain. Figure 49 through Figure 51 show the velocity magnitudes and directions at the center lines of each bay in the vicinities of each gatewell. Compared to the baseline high flow condition, the velocities in the bays A and B gatewells appear to be slightly lower, and the velocities in the bay C gatewell appear to be very similar.

Figure 52 shows the magnitude of the normal velocities and sweeping velocity vectors just upstream of the VBSs. Compared to the baseline high flow condition, the normal velocities in bays A and B are generally lower through the majority of the VBSs, and appear to be better distributed on the screens. The areas of high normal velocity on the upper portions of the VBSs seen in the baseline condition for bays A and B are not present, but there are areas of higher velocity that have formed on the lower corners of those VBSs. Compared to the baseline medium flow condition, the normal velocities in bays A and B are generally lower through the majority of the VBSs. The normal velocities in bay C are very similar to the baseline high flow condition.

For bays B and C, the sweeping velocities at the VBSs appear to be similar to the baseline high flow condition, with generally positive (positive upward) along the center of the screen, but negative in the circulation on the sides of the VBSs. The sweeping velocities at the VBS in bay A are moderately different that the baseline high flow condition. The circulation areas are not symmetrical like the baseline condition; the circulation on the Oregon side of the gatewell is larger.

An isosurface of turbulent kinetic energy (TKE) at 1.0 ft^2/s^2 is shown in Figure 53. The gatewell volume with TKE above 1.0 ft^2/s^2 is significantly reduced in bays A and B, and similar in bay C compared to the baseline high flow condition. The volumes of the isosurfaces in bays A and B are comparable, and also similar in volume to the bay A baseline medium flow condition.

5. CONCLUSIONS AND RECOMMENDATIONS

The proposed improvements to the gatewells include a flow control plate that blocks approximately 50% of the opening between the gatewell beam and the intake gate in bay A, a flow control plate the blocks approximately 25% of the opening in bay B, installing porosity plates with approximately 46% open area on the top row of panels of the VBSs, and installing porosity plates with approximately 21% open area on the second row of panels of the VBSs. The modeling conducted indicates that these modifications will result in flow through the VBSs that meet the specified criterion for the entire turbine operating range, and will reduce turbulence intensity in the bay A and B gatewells. In addition, the modeling indicates that the proposed improvements will greatly reduce the areas of high approach (normal) velocity on the upper portions of the VBSs.

6. REFERENCES

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7. FIGURES

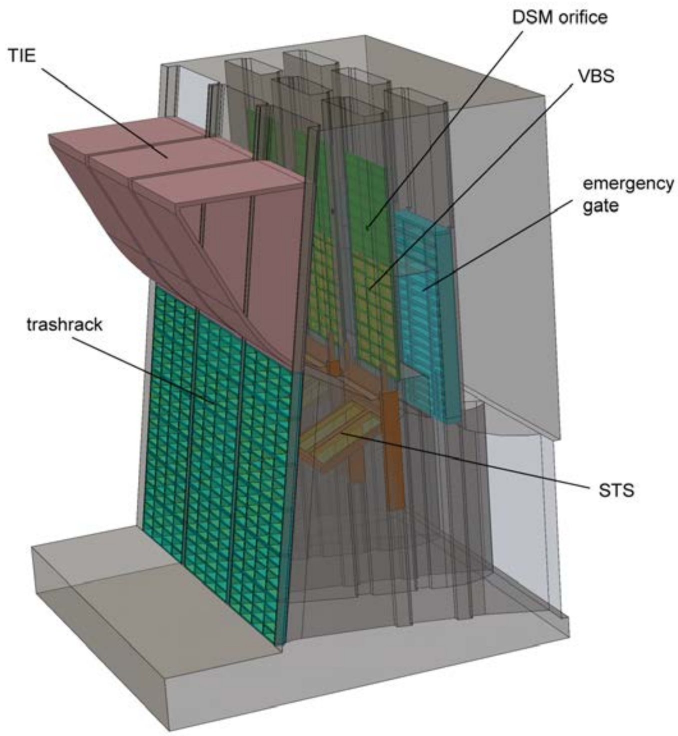


Figure 1. Isometric View of Turbine Unit

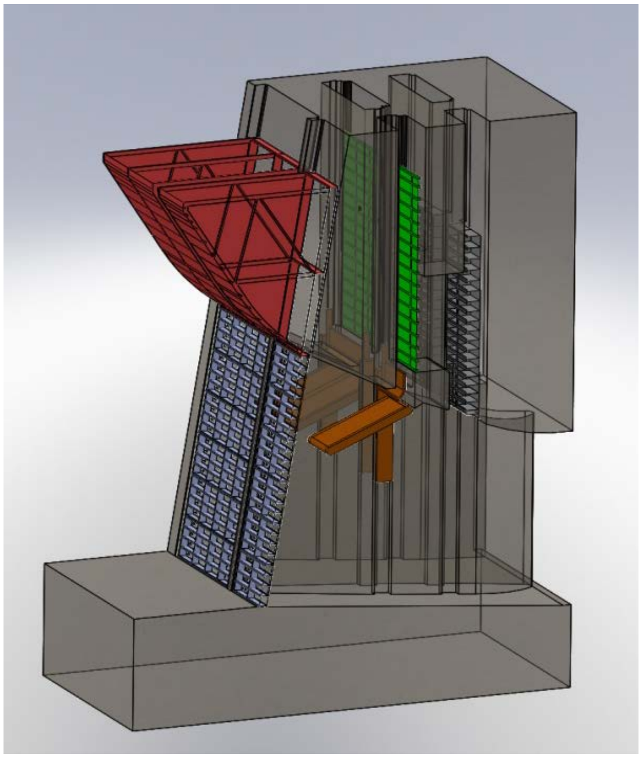


Figure 2. Section View of Turbine Unit

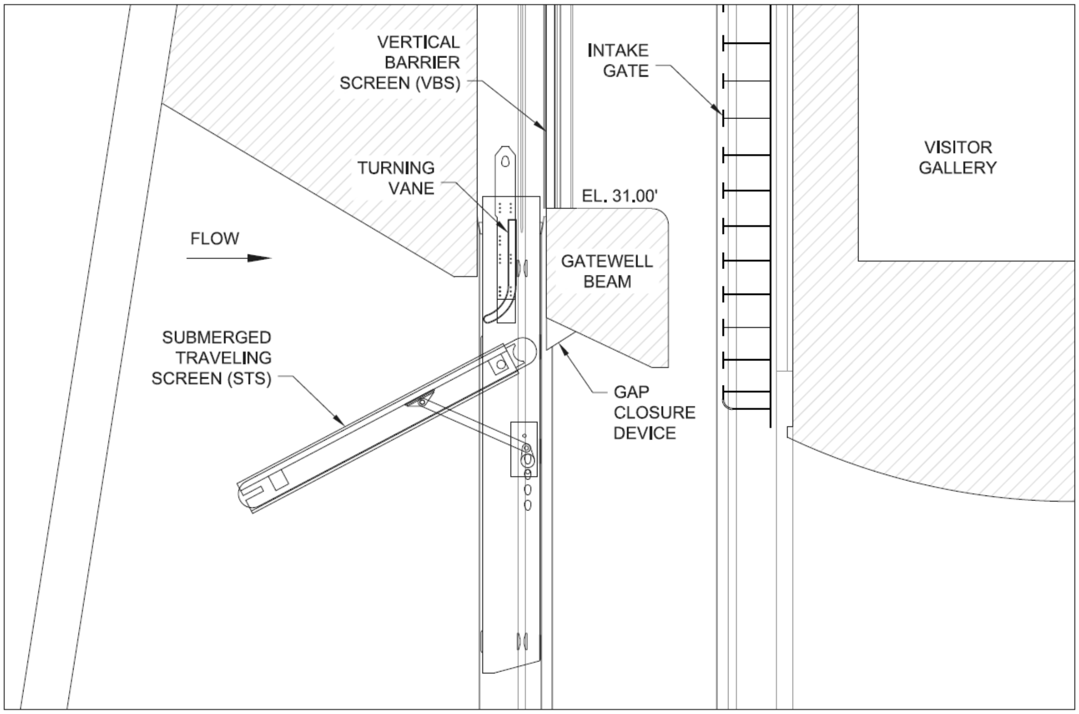


Figure 3. Gatewell Entrance

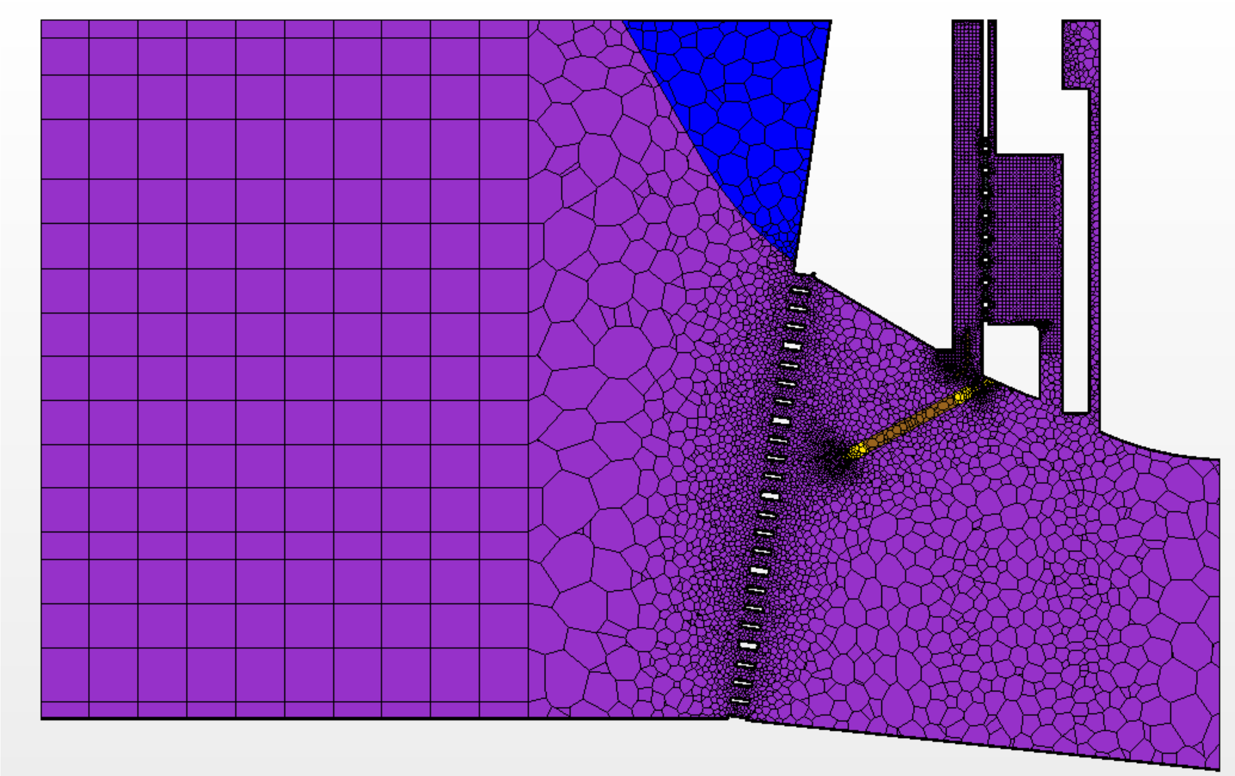


Figure 4. CFD Volume Mesh – Section View

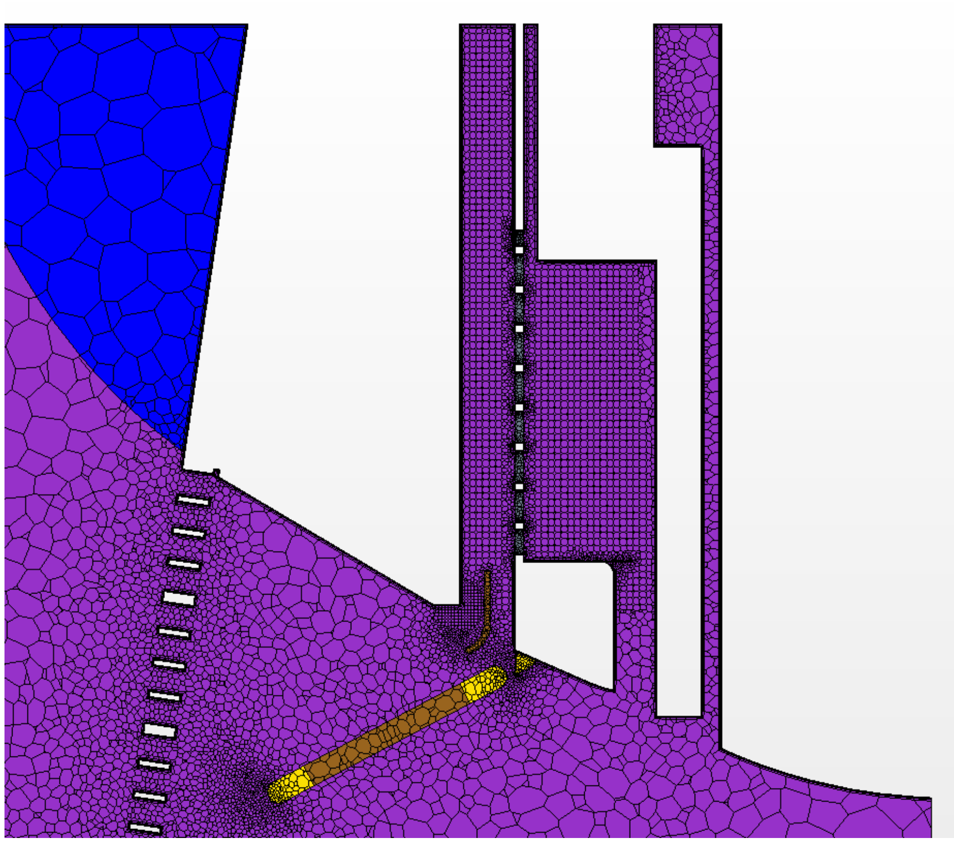


Figure 5. CFD Volume Mesh – Zoomed Sectional View

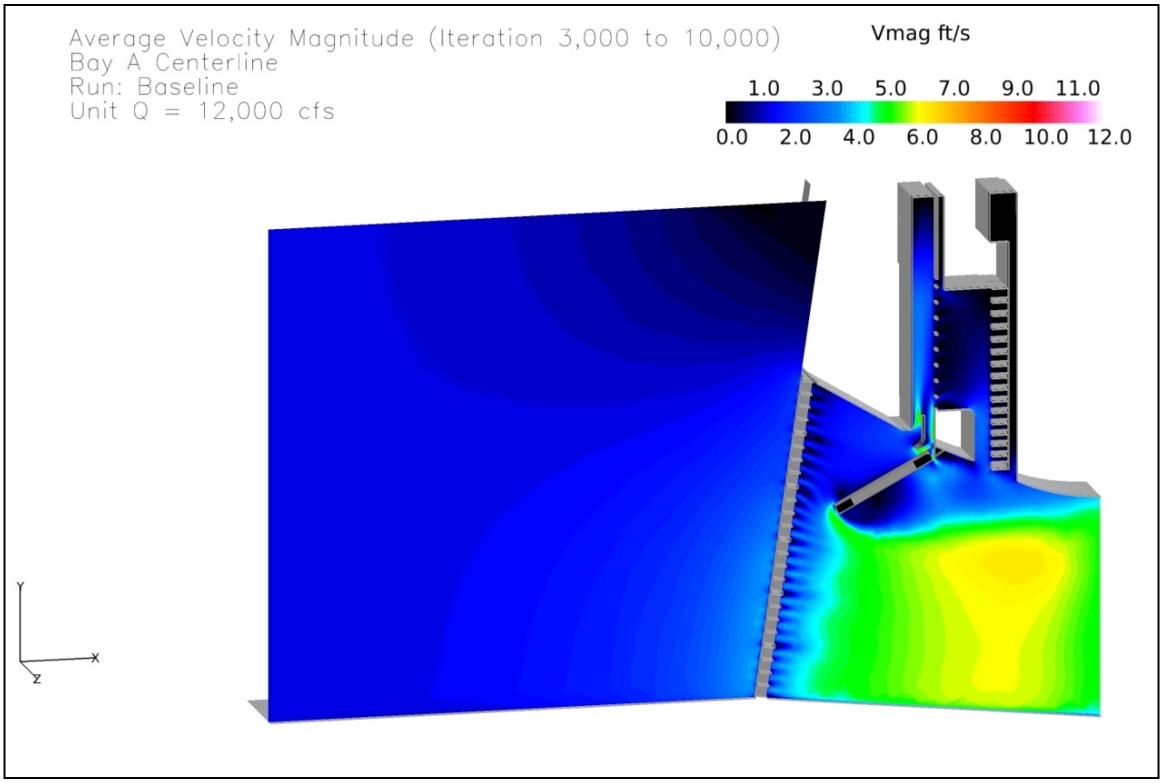


Figure 6. Baseline Conditions, Unit Q=12 kcfs, Bay A Centerline Velocity Magnitude

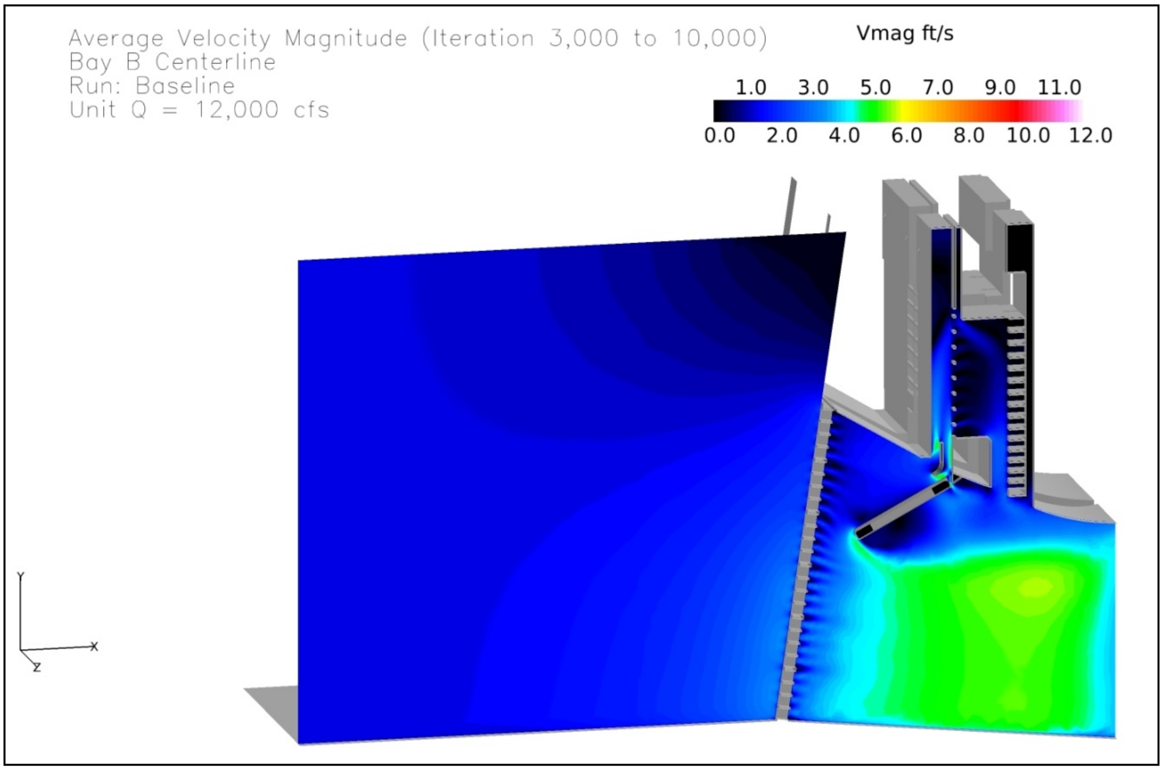


Figure 7. Baseline Conditions, Unit Q=12 kcfs, Bay B Centerline Velocity Magnitude

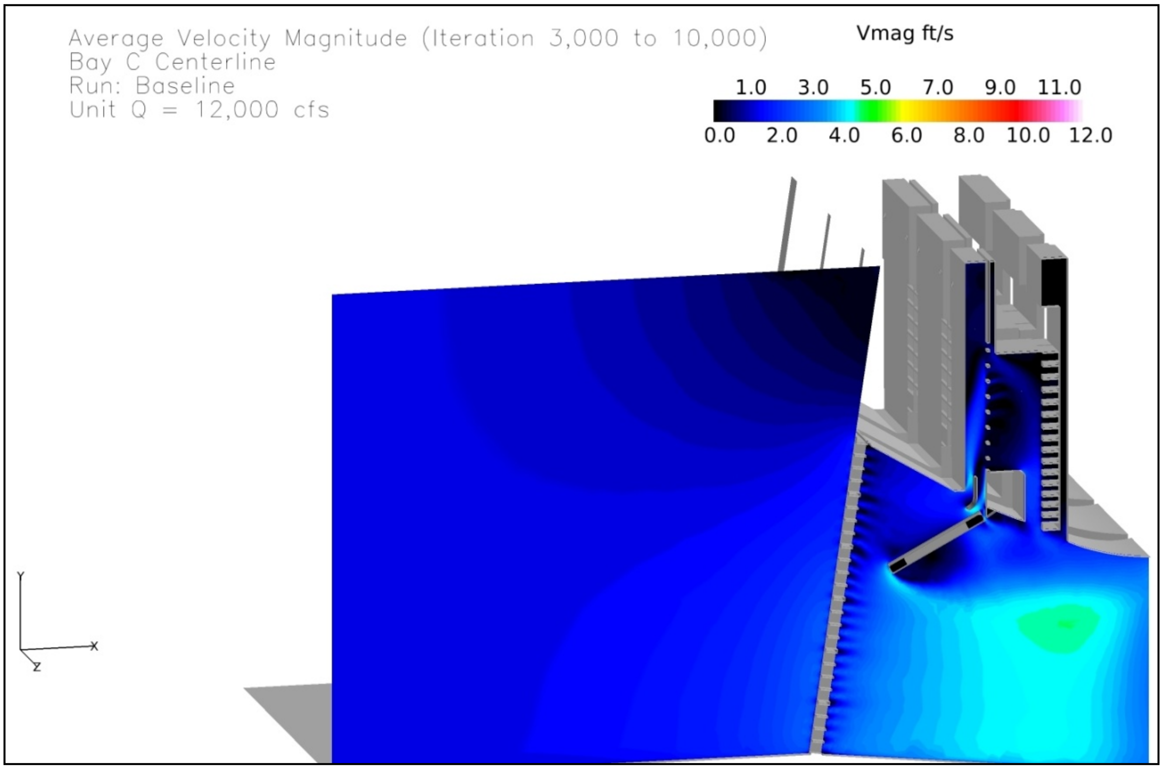


Figure 8. Baseline Conditions, Unit Q=12 kcfs, Bay C Centerline Velocity Magnitude

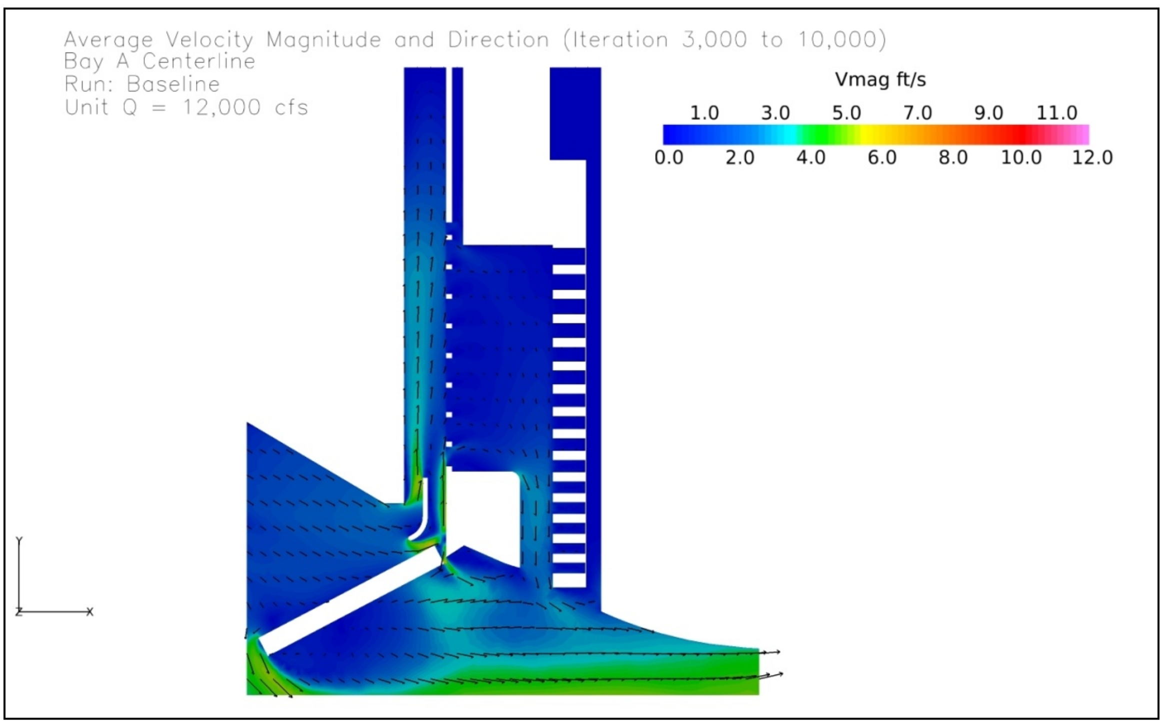


Figure 9. Baseline Conditions, Unit Q=12 kcfs, Bay A Centerline Velocity Magnitude and Flow Patterns

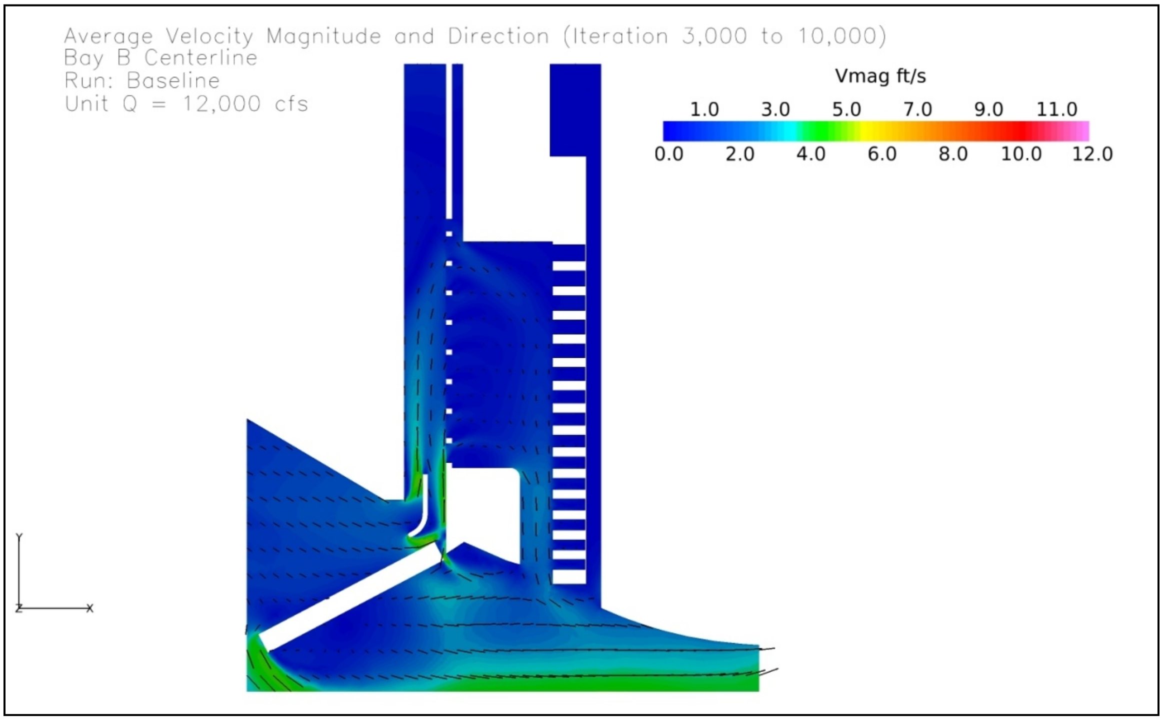


Figure 10. Baseline Conditions, Unit Q=12 kcfs, Bay B Centerline Velocity Magnitude and Flow Patterns

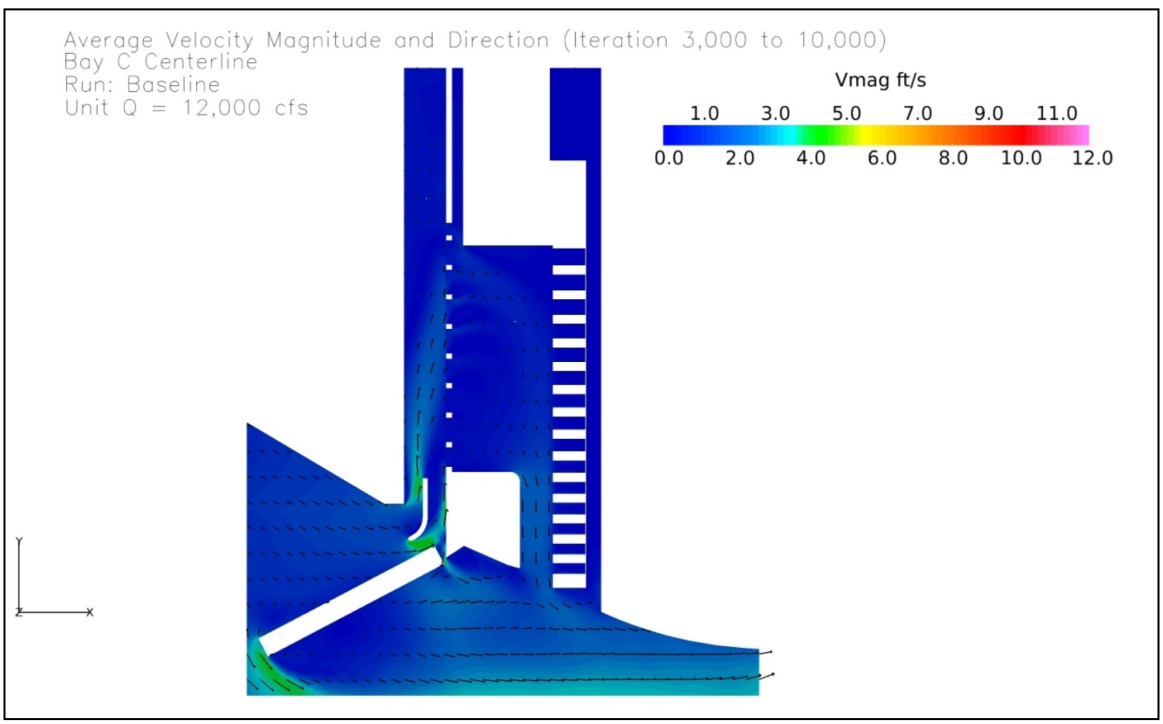


Figure 11. Baseline Conditions, Unit Q=12 kcfs, Bay C Centerline Velocity Magnitude and Flow Patterns

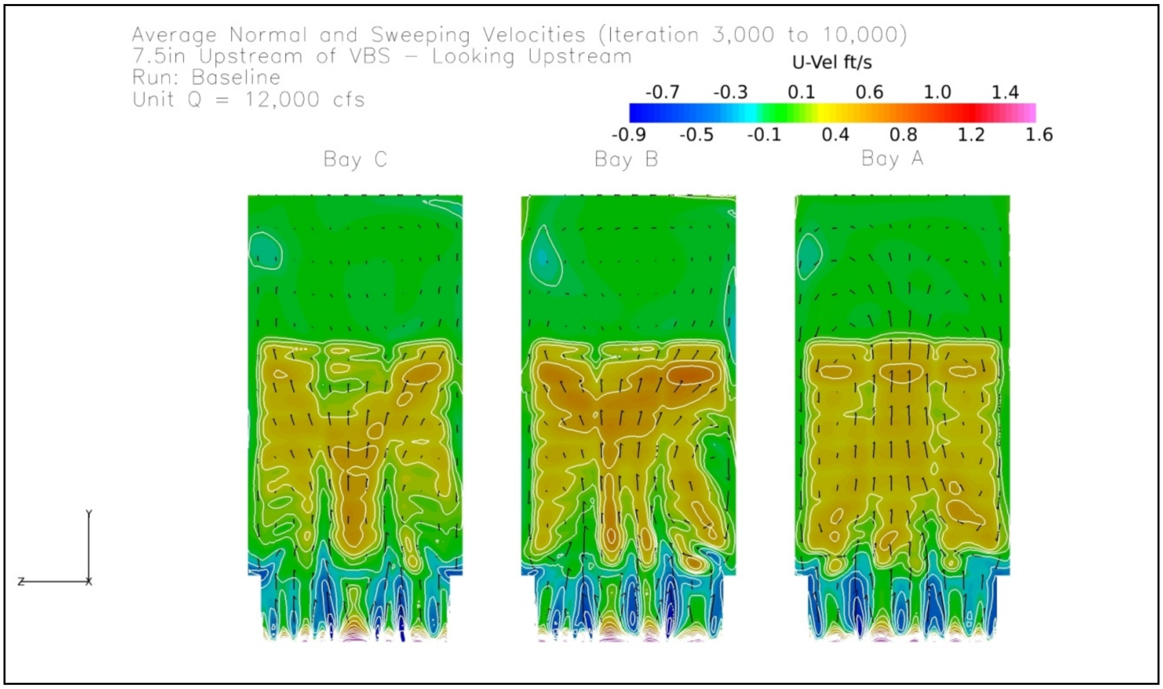


Figure 12. Baseline Conditions, Unit Q=12 kcfs, VBS Normal Velocities and Flow Patterns

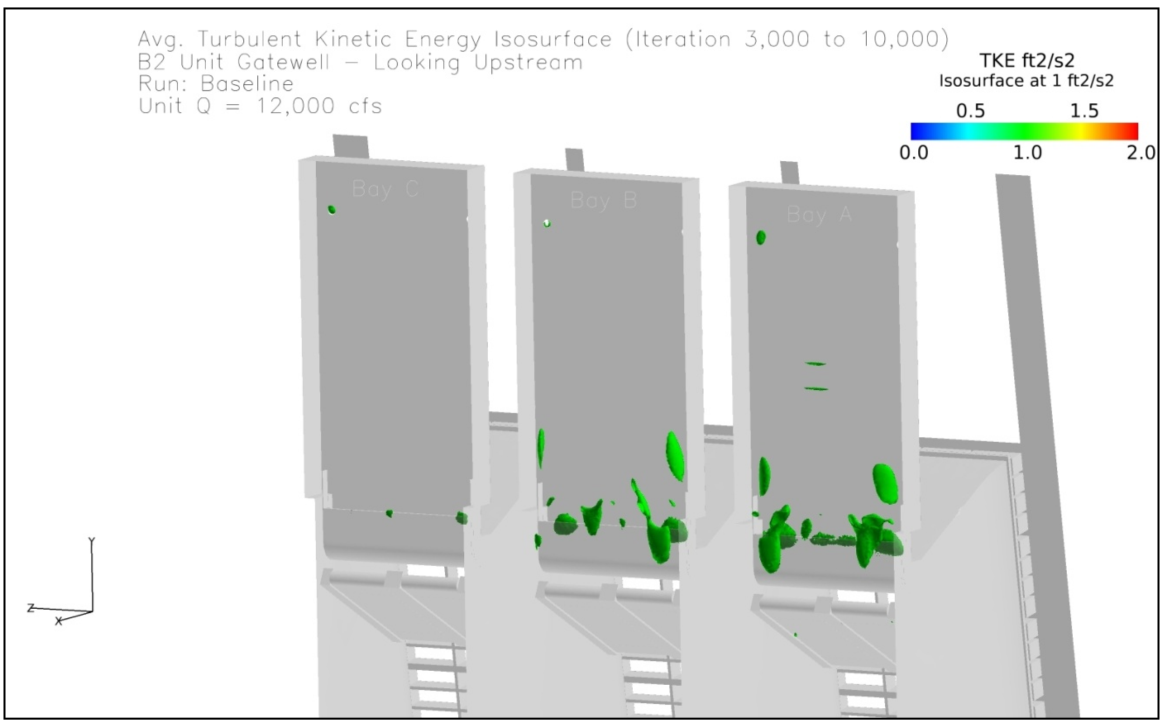


Figure 13. Baseline Conditions, Unit Q=12 kcfs, Turbulent Kinetic Energy Isosurface (1 ft^2/s^2)

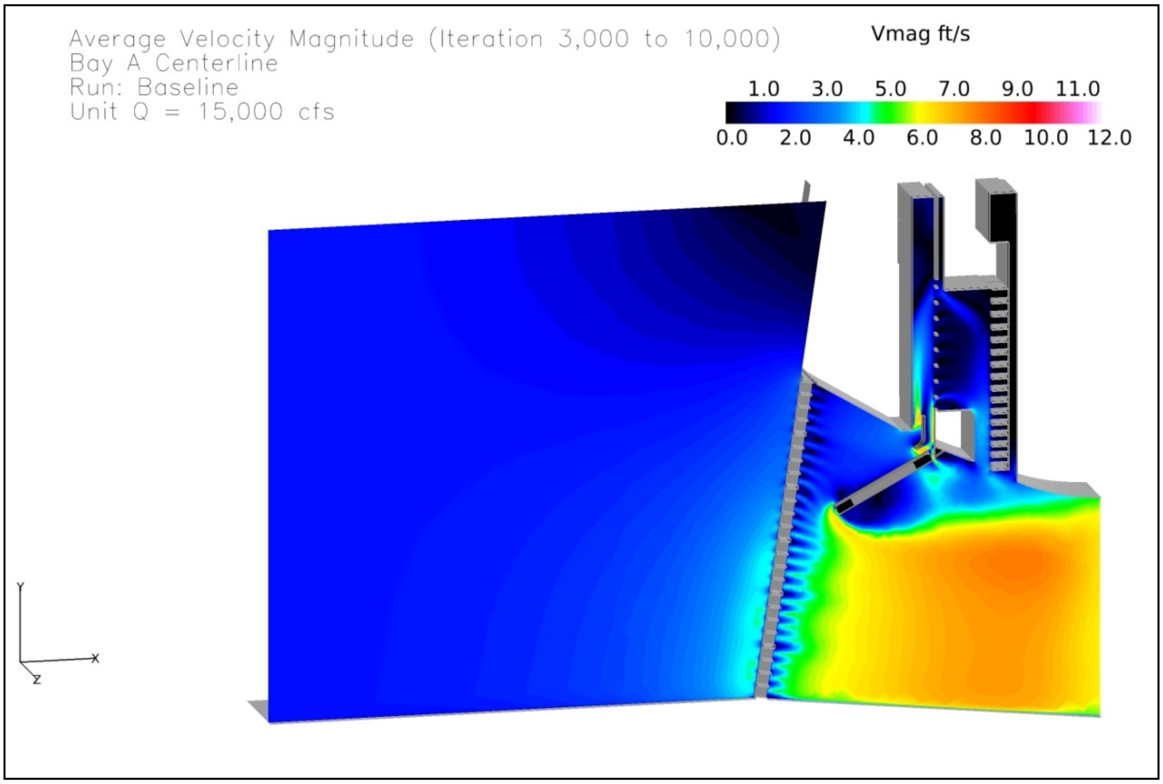


Figure 14. Baseline Conditions, Unit Q=15 kcfs, Bay A Centerline Velocity Magnitude

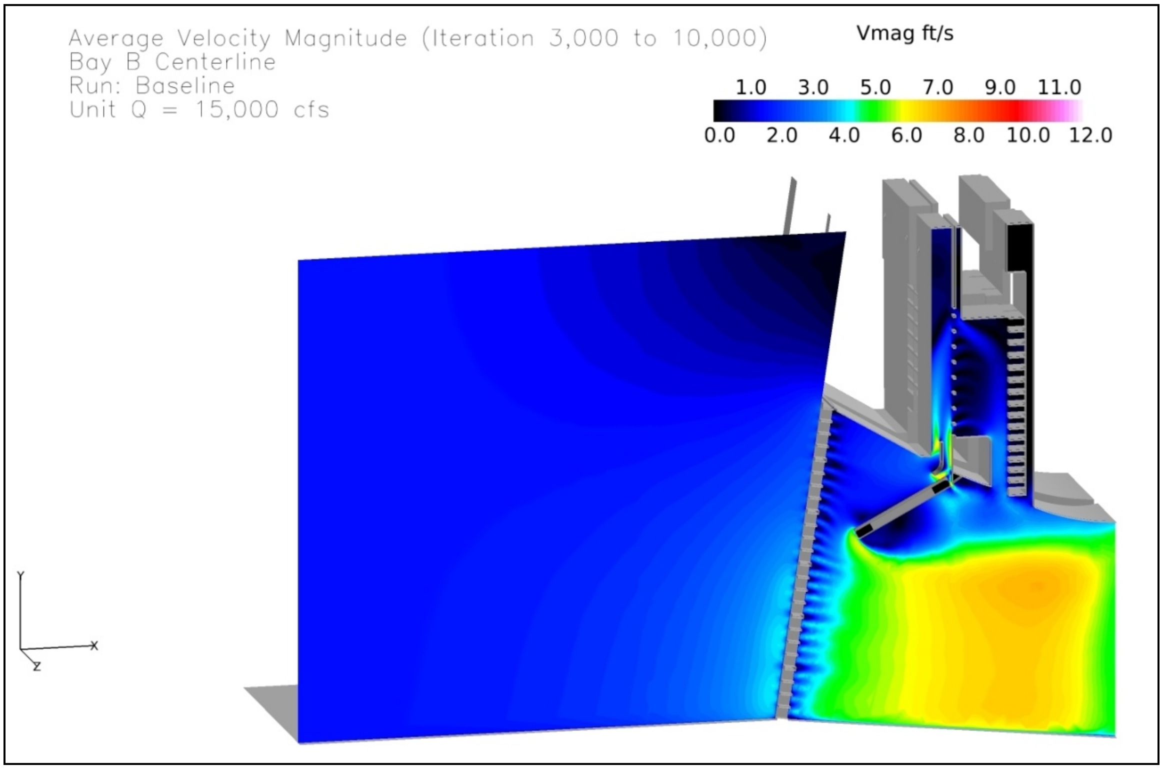


Figure 15. Baseline Conditions, Unit Q=15 kcfs, Bay B Centerline Velocity Magnitude

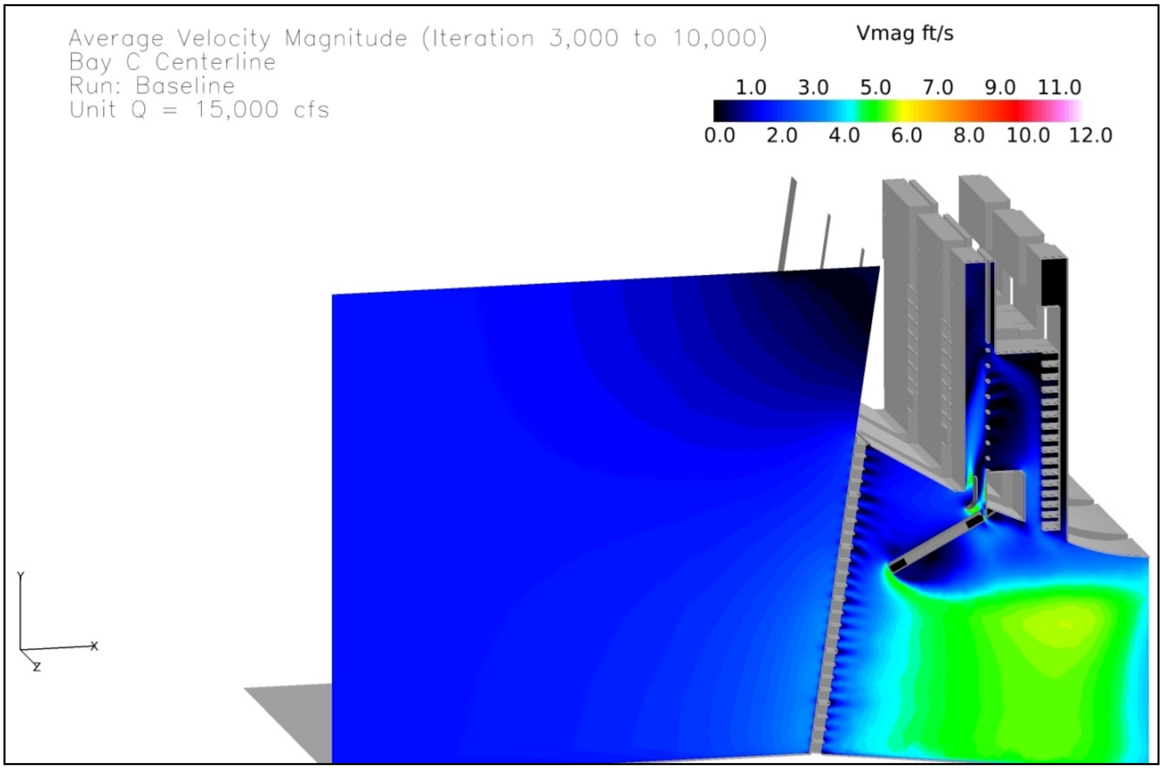


Figure 16. Baseline Conditions, Unit Q=15 kcfs, Bay C Centerline Velocity Magnitude

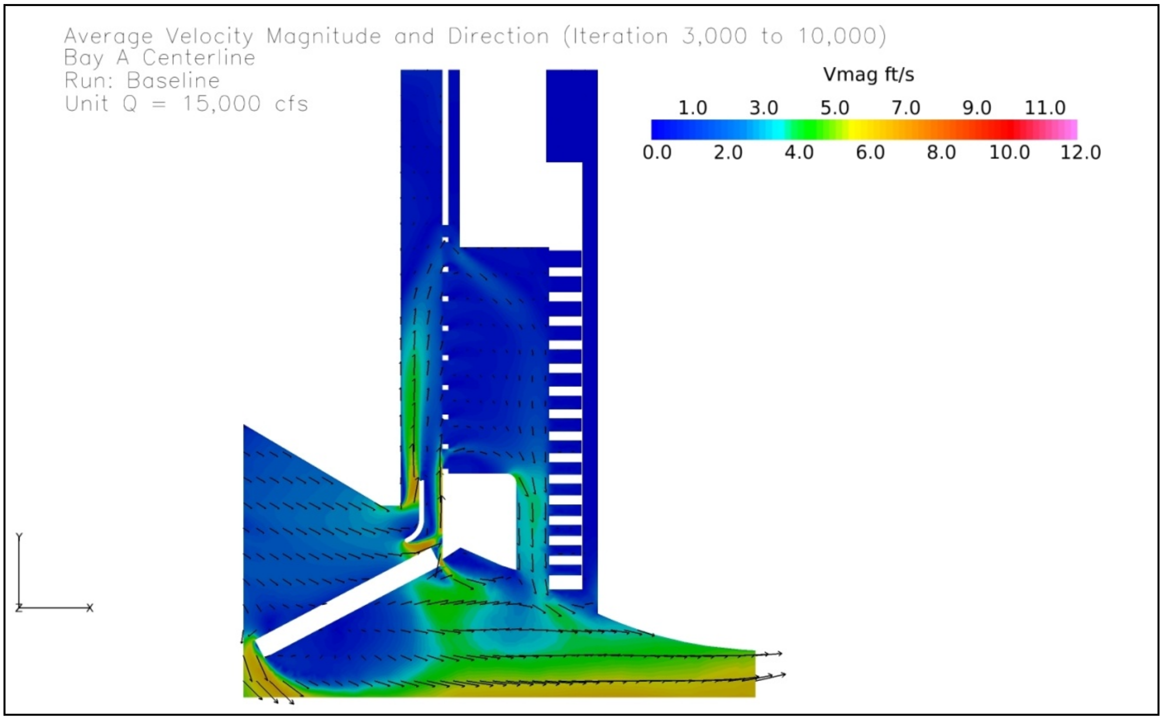


Figure 17. Baseline Conditions, Unit Q=15 kcfs, Bay A Centerline Velocity Magnitude and Flow Patterns

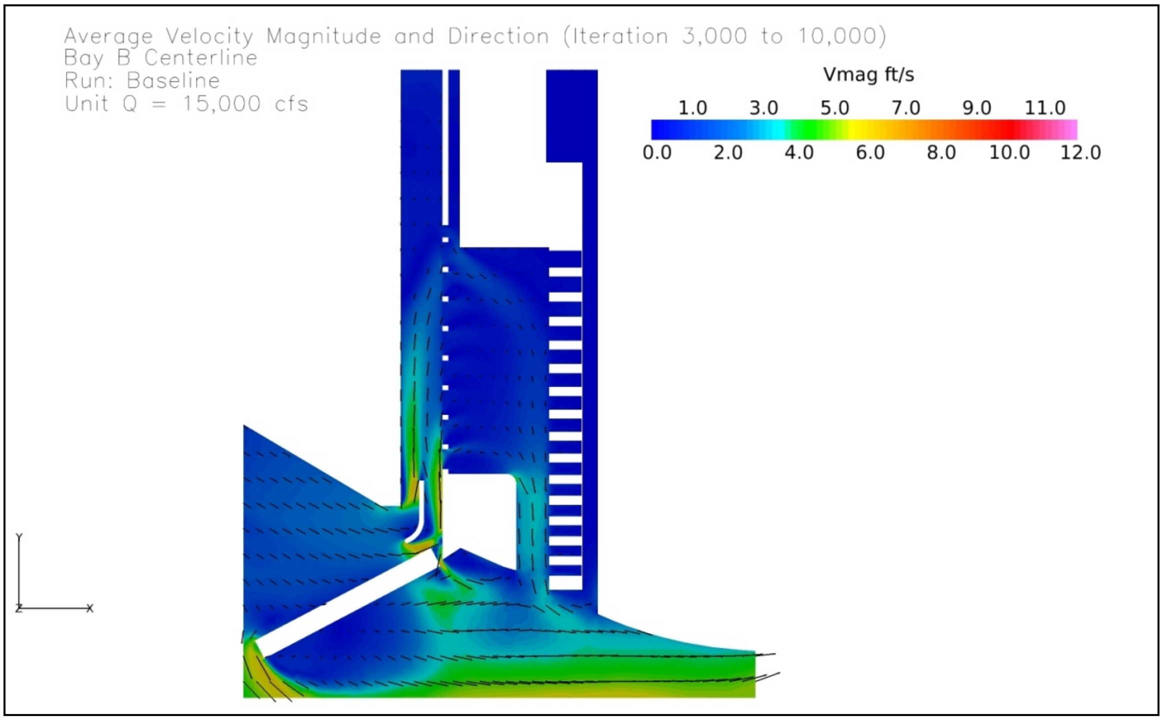


Figure 18. Baseline Conditions, Unit Q=15 kcfs, Bay B Centerline Velocity Magnitude and Flow Patterns

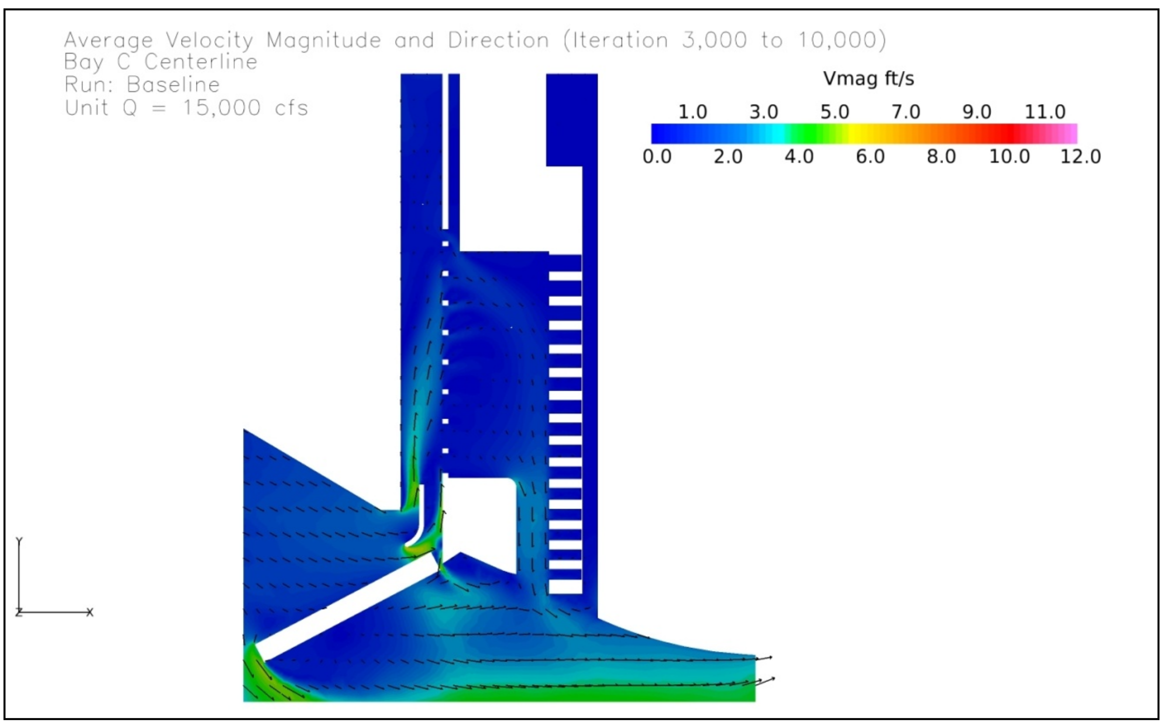


Figure 19. Baseline Conditions, Unit Q=15 kcfs, Bay C Centerline Velocity Magnitude and Flow Patterns

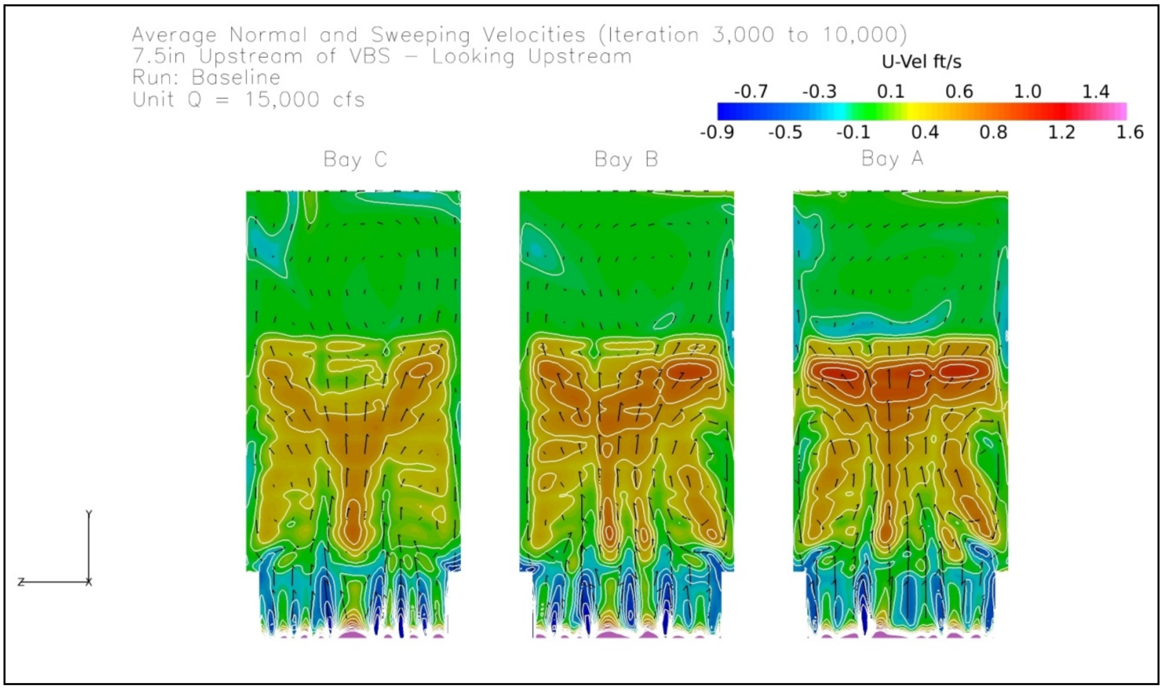


Figure 20. Baseline Conditions, Unit Q=15 kcfs, VBS Normal Velocities and Flow Patterns

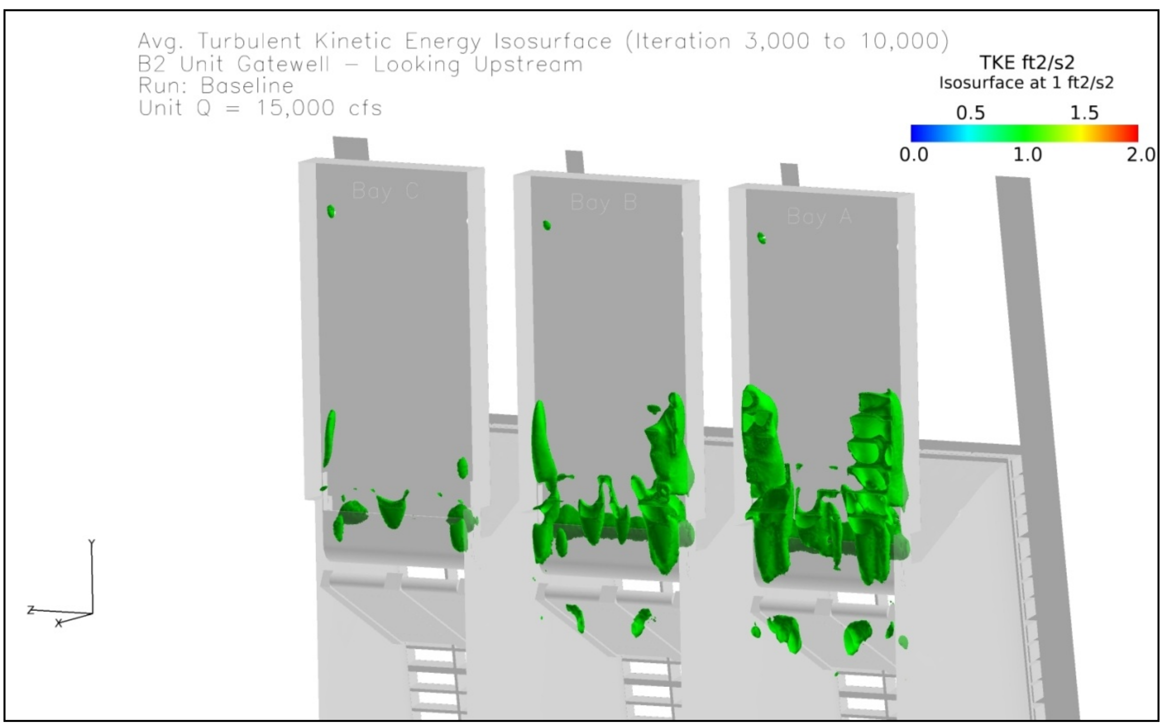


Figure 21. Baseline Conditions, Unit Q=15 kcfs, Turbulent Kinetic Energy Isosurface (1 ft^2/s^2)

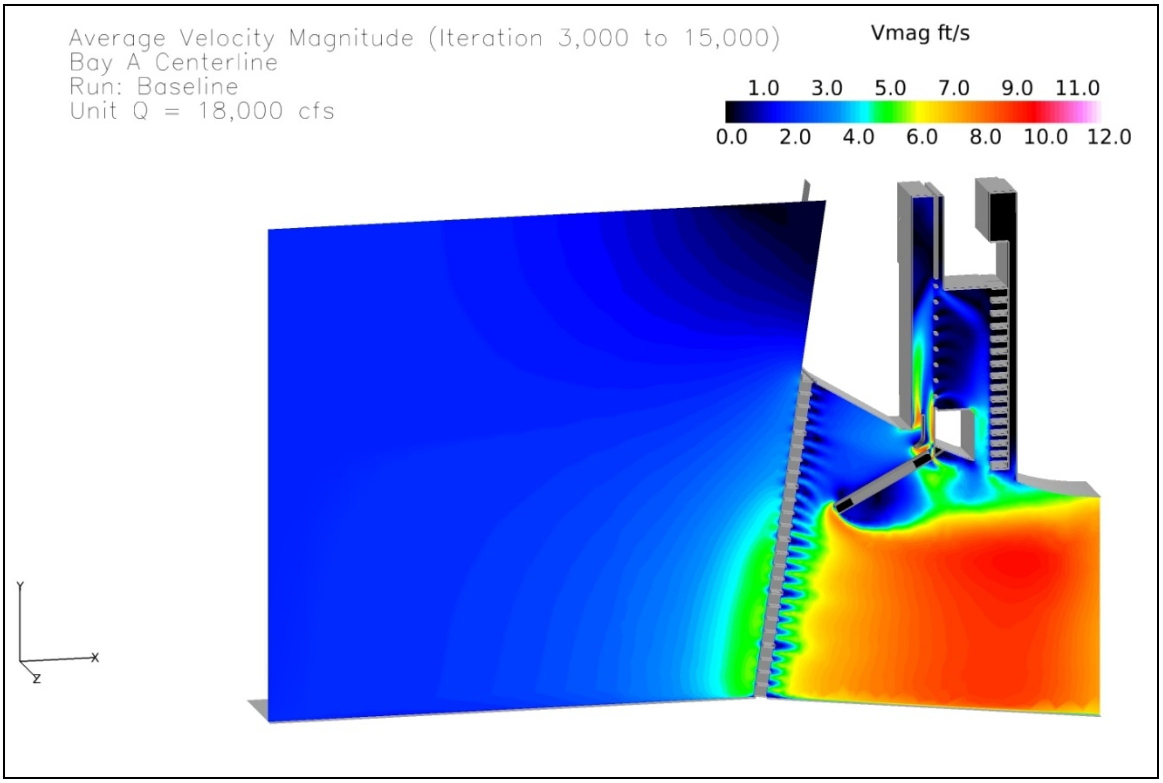


Figure 22. Baseline Conditions, Unit Q=18 kcfs, Bay A Centerline Velocity Magnitude

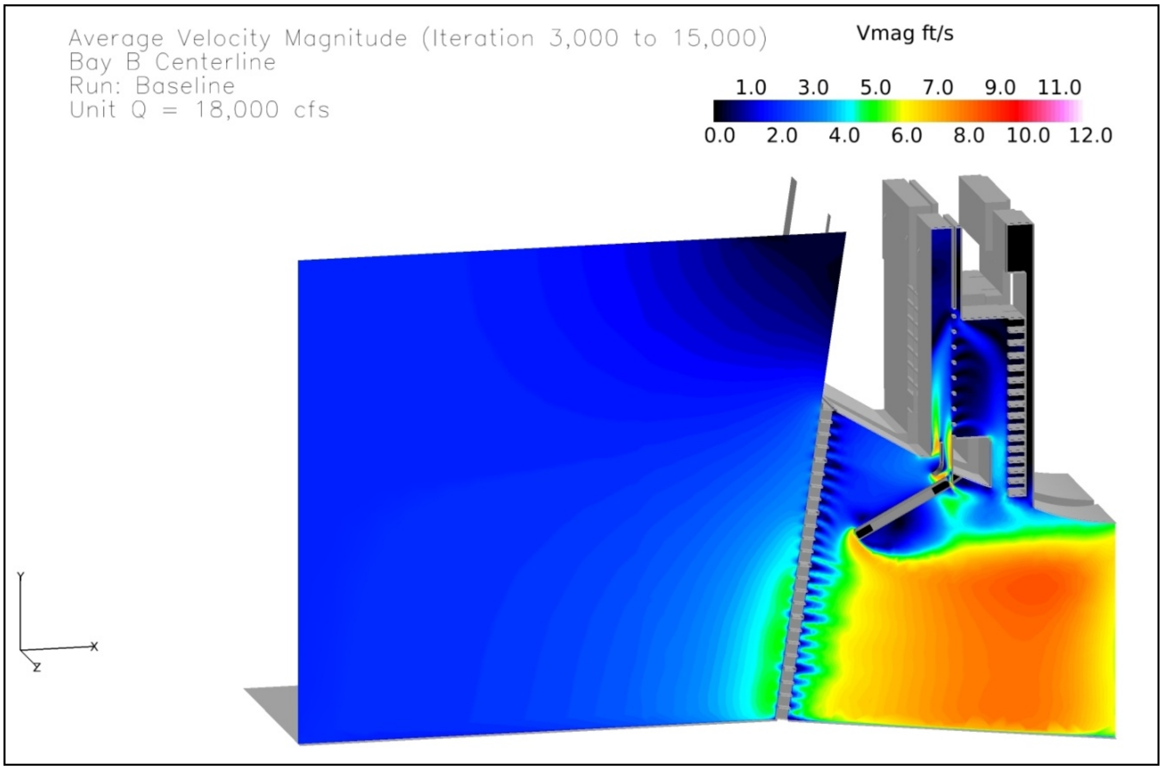


Figure 23. Baseline Conditions, Unit Q=18 kcfs, Bay B Centerline Velocity Magnitude

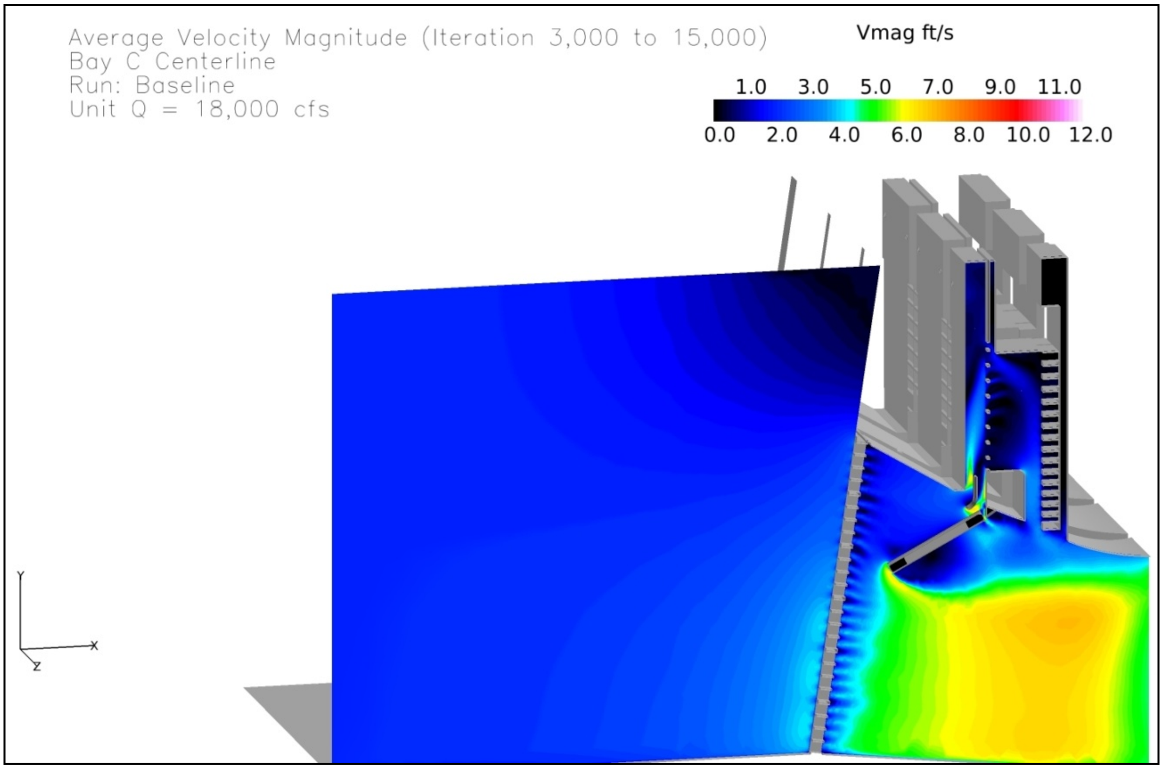


Figure 24. Baseline Conditions, Unit Q=18 kcfs, Bay C Centerline Velocity Magnitude

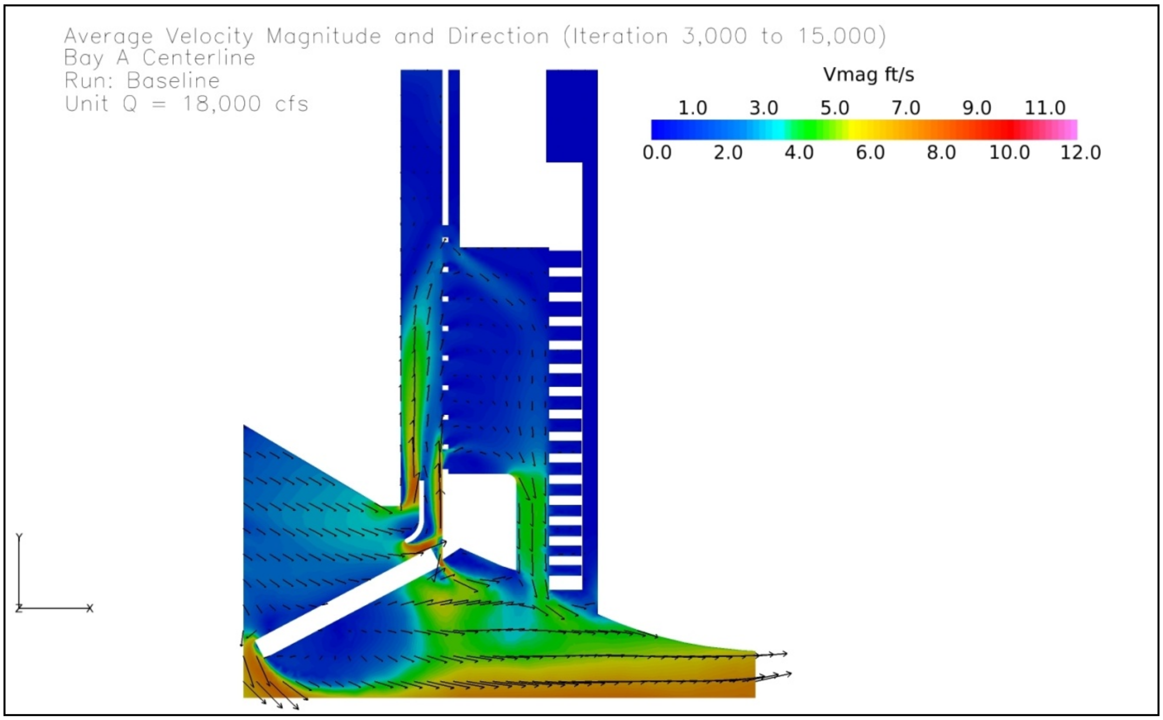


Figure 25. Baseline Conditions, Unit Q=18 kcfs, Bay A Centerline Velocity Magnitude and Flow Patterns

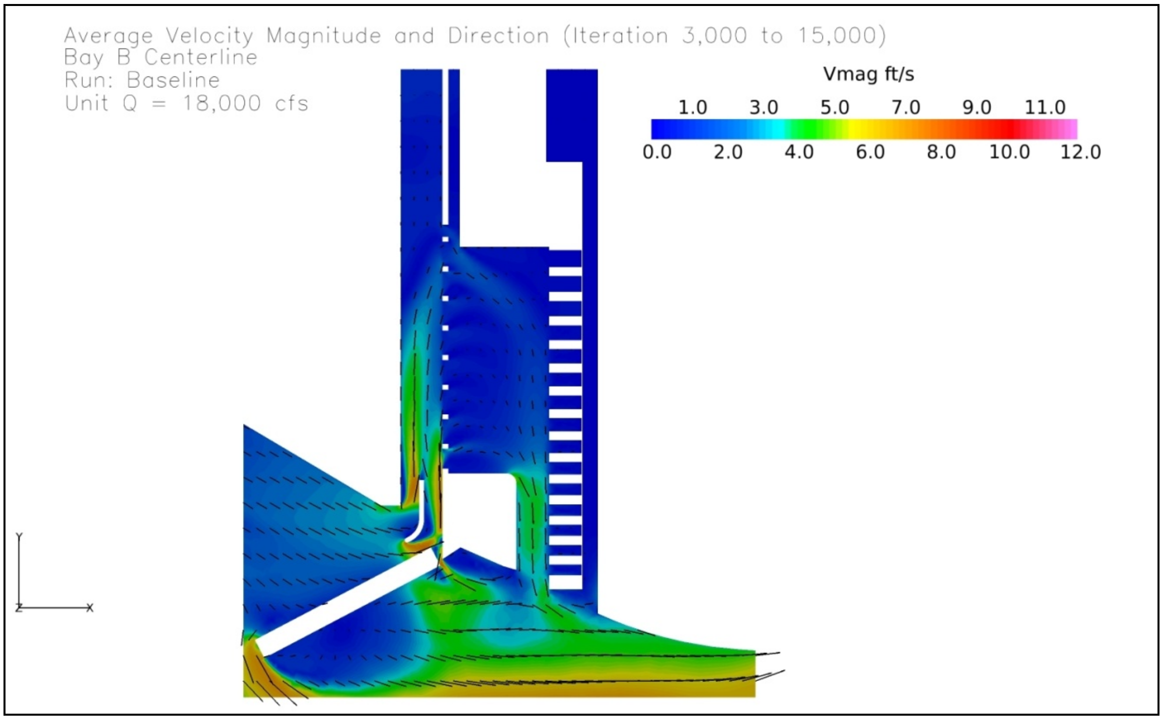


Figure 26. Baseline Conditions, Unit Q=18 kcfs, Bay B Centerline Velocity Magnitude and Flow Patterns

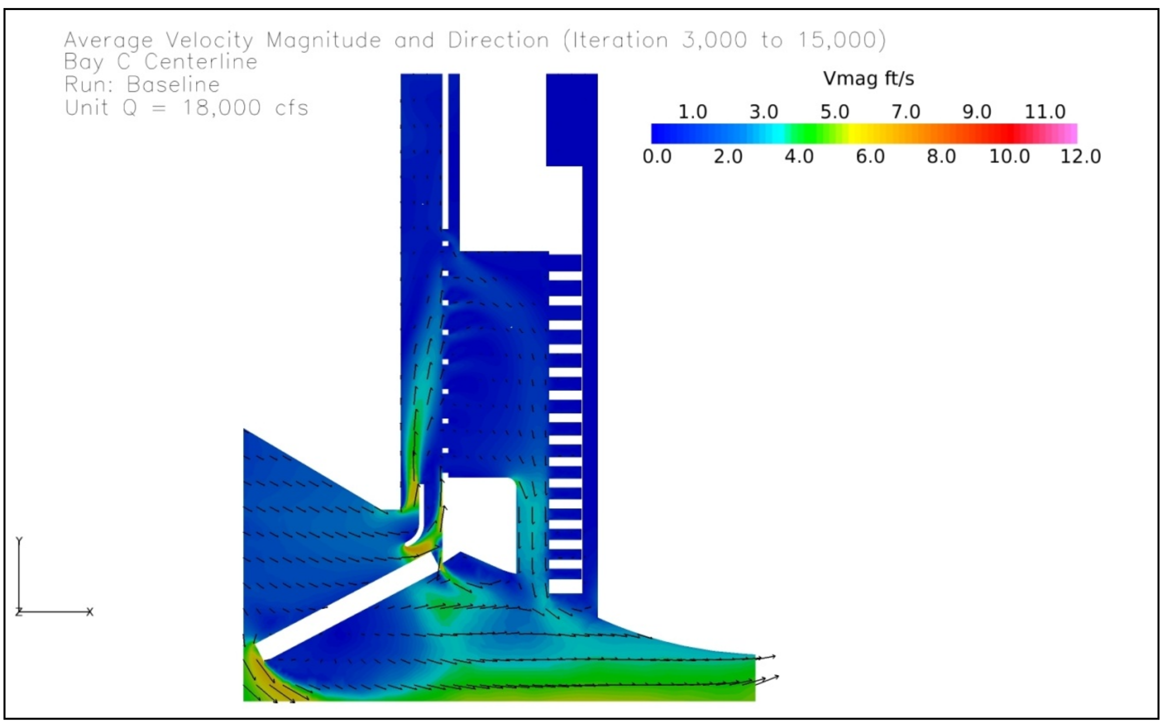


Figure 27. Baseline Conditions, Unit Q=18 kcfs, Bay C Centerline Velocity Magnitude and Flow Patterns

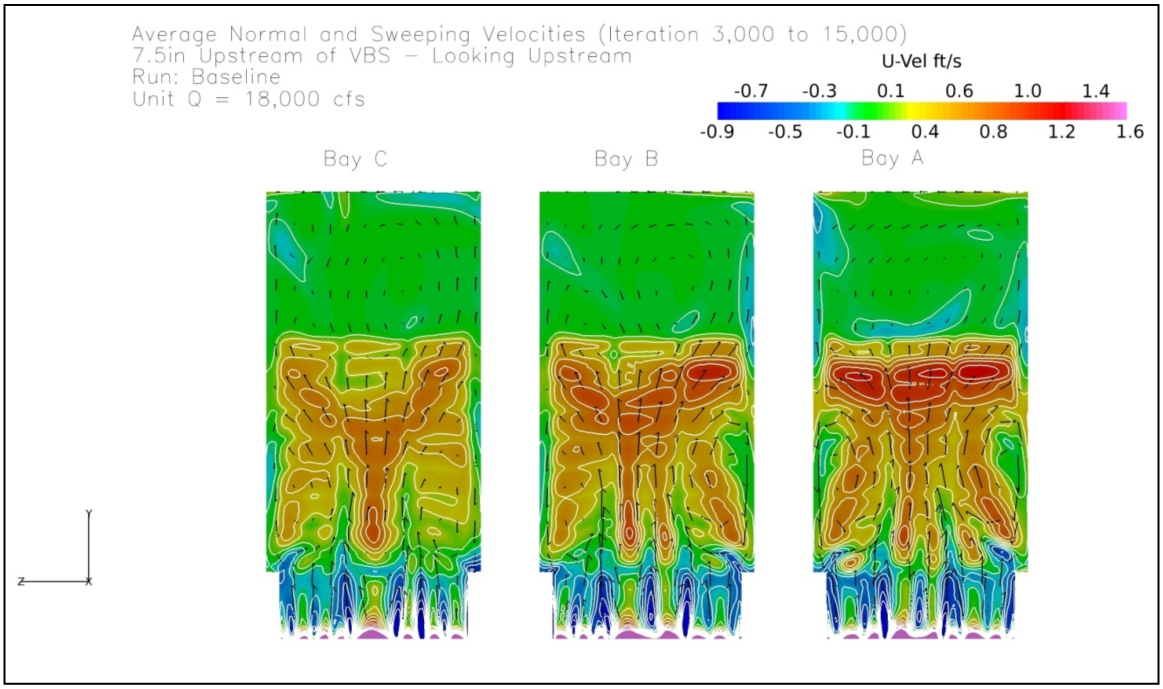


Figure 28. Baseline Conditions, Unit Q=18 kcfs, VBS Normal Velocities and Flow Patterns

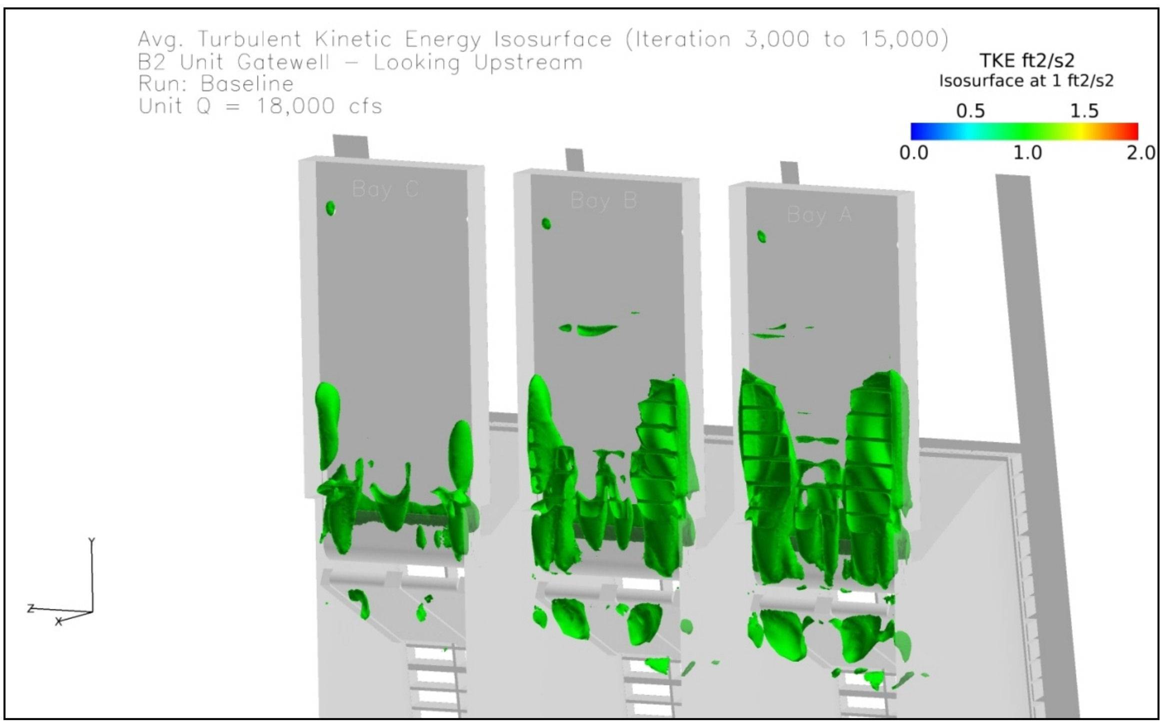


Figure 29. Baseline Conditions, Unit Q=18 kcfs, Turbulent Kinetic Energy Isosurface (1 ft^2/s^2)

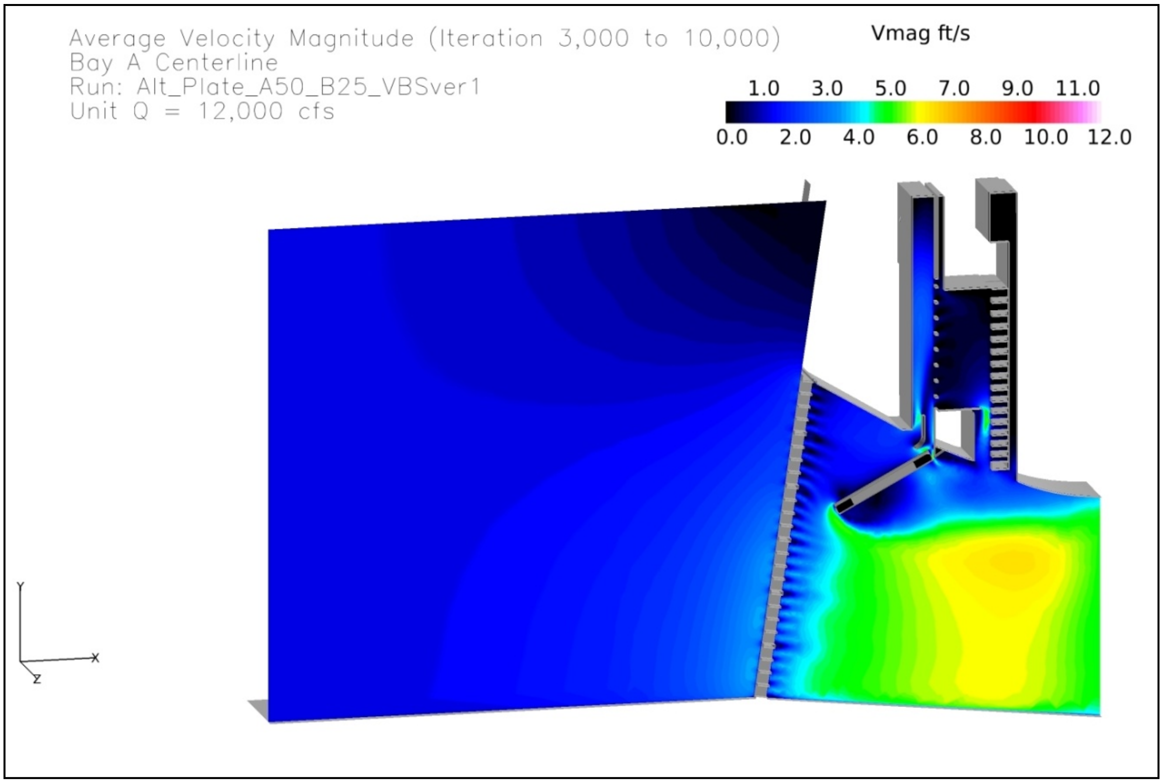


Figure 30. Proposed Improvements, Unit Q=12 kcfs, Bay A Centerline Velocity Magnitude

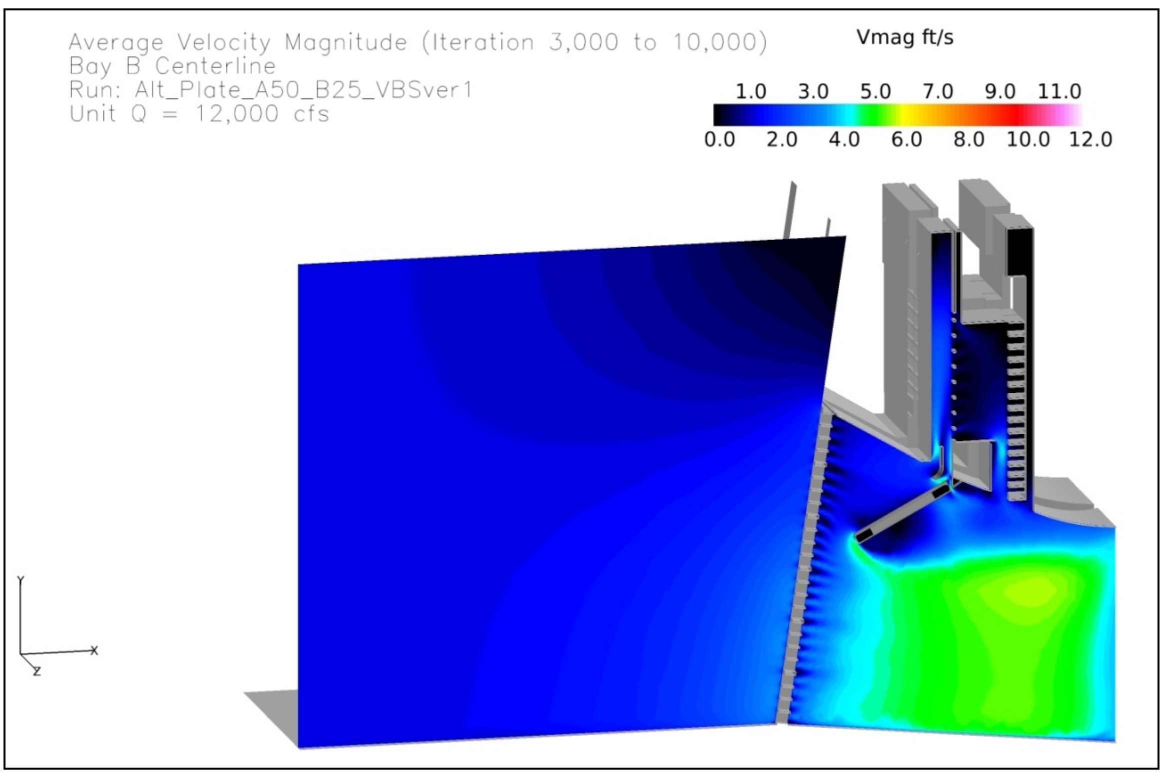


Figure 31. Proposed Improvements, Unit Q=12 kcfs, Bay B Centerline Velocity Magnitude

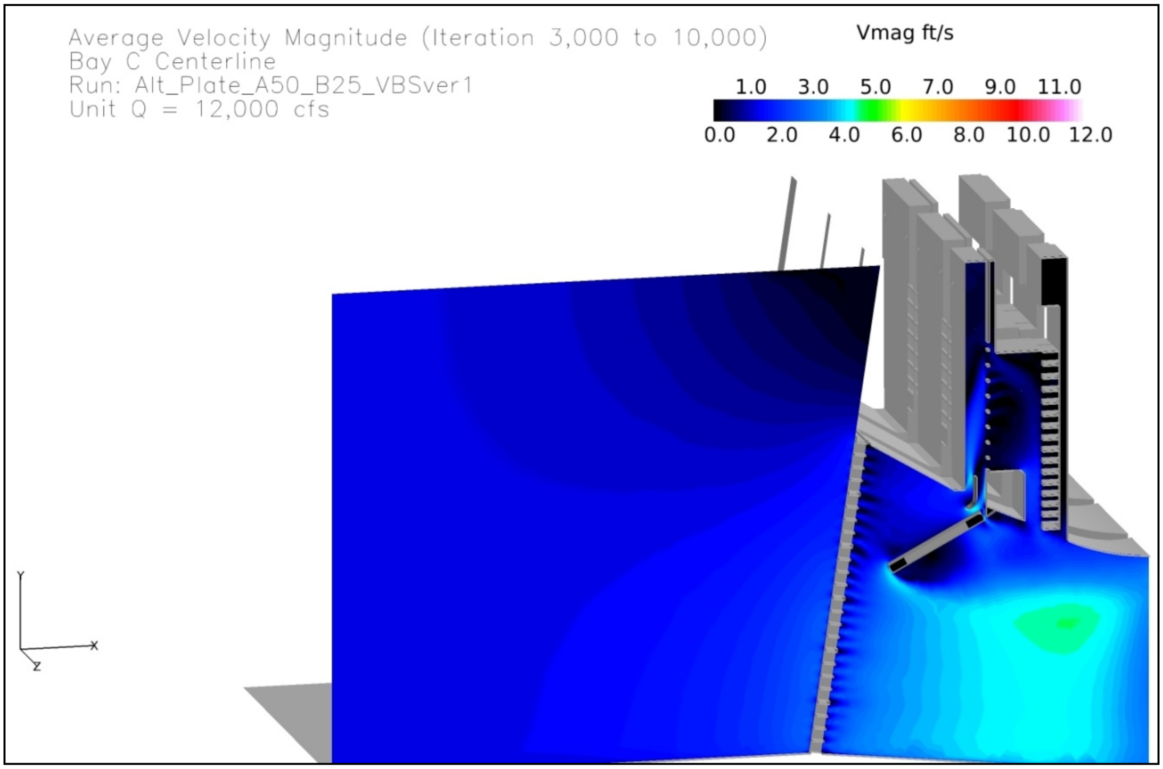


Figure 32. Proposed Improvements, Unit Q=12 kcfs, Bay C Centerline Velocity Magnitude

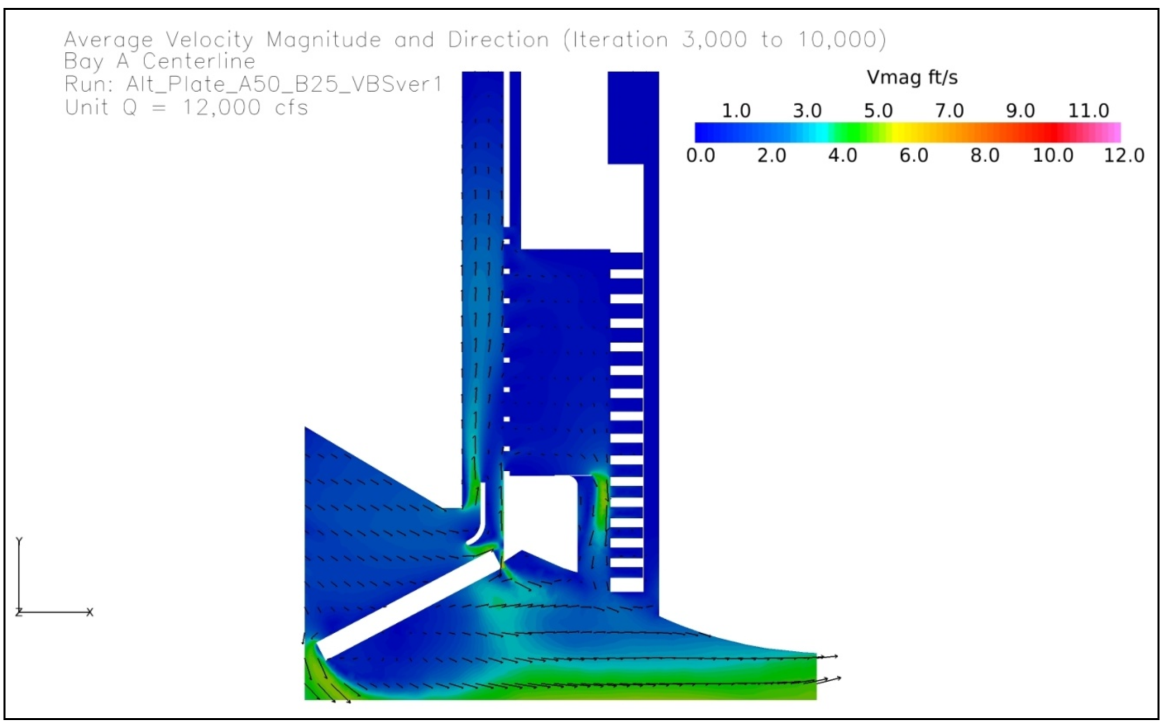


Figure 33. Proposed Improvements, Unit Q=12 kcfs, Bay A Centerline Velocity Magnitude and Flow Patterns

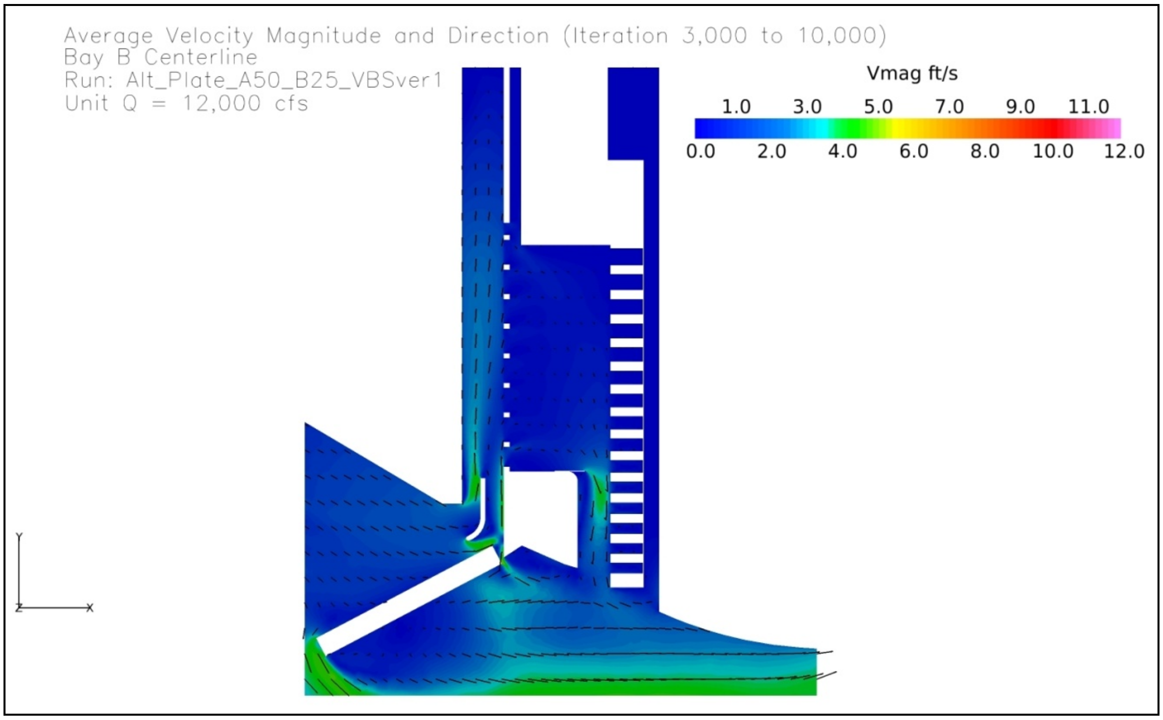


Figure 34. Proposed Improvements, Unit Q=12 kcfs, Bay B Centerline Velocity Magnitude and Flow Patterns

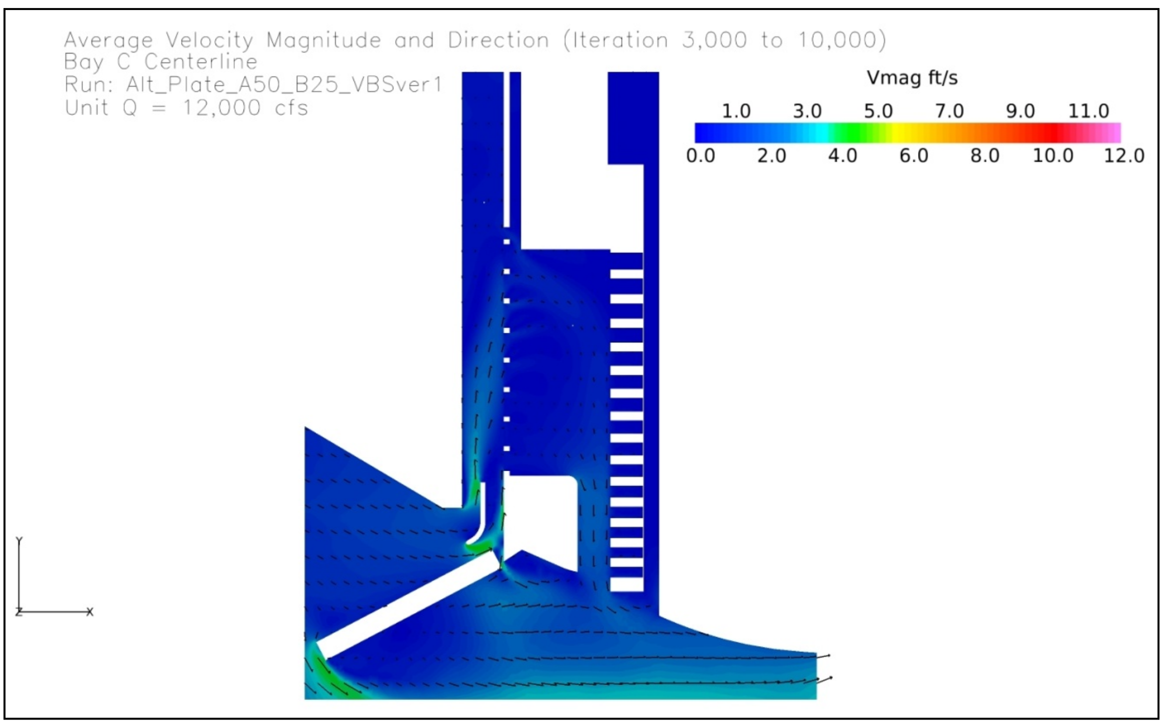


Figure 35. Proposed Improvements, Unit Q=12 kcfs, Bay C Centerline Velocity Magnitude and Flow Patterns

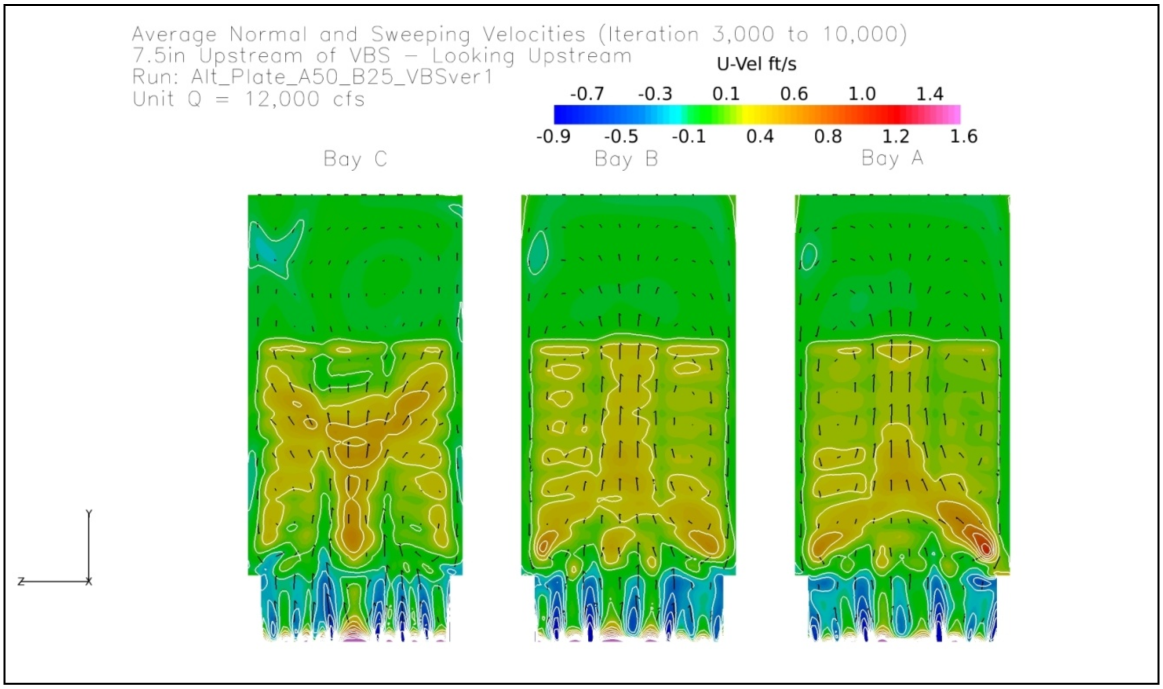


Figure 36. Proposed Improvements, Unit Q=12 kcfs, VBS Normal Velocities and Flow Patterns

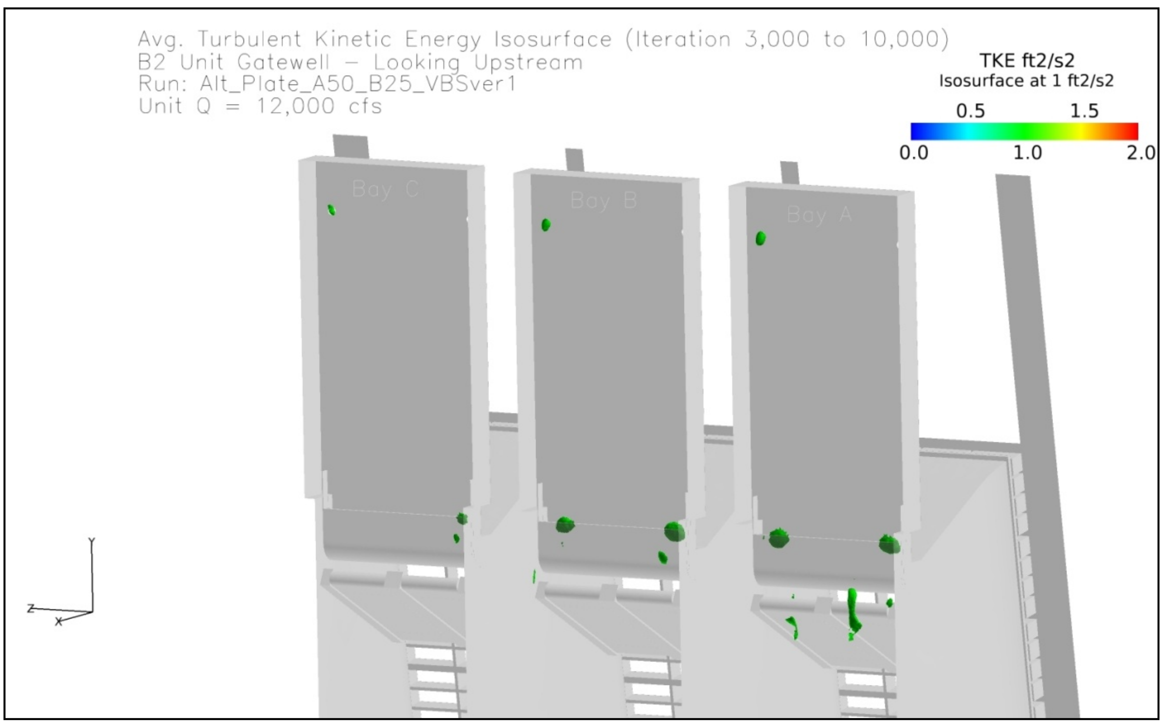


Figure 37. Proposed Improvements, Unit Q=12 kcfs, Turbulent Kinetic Energy Isosurface (1 ft^2/s^2)

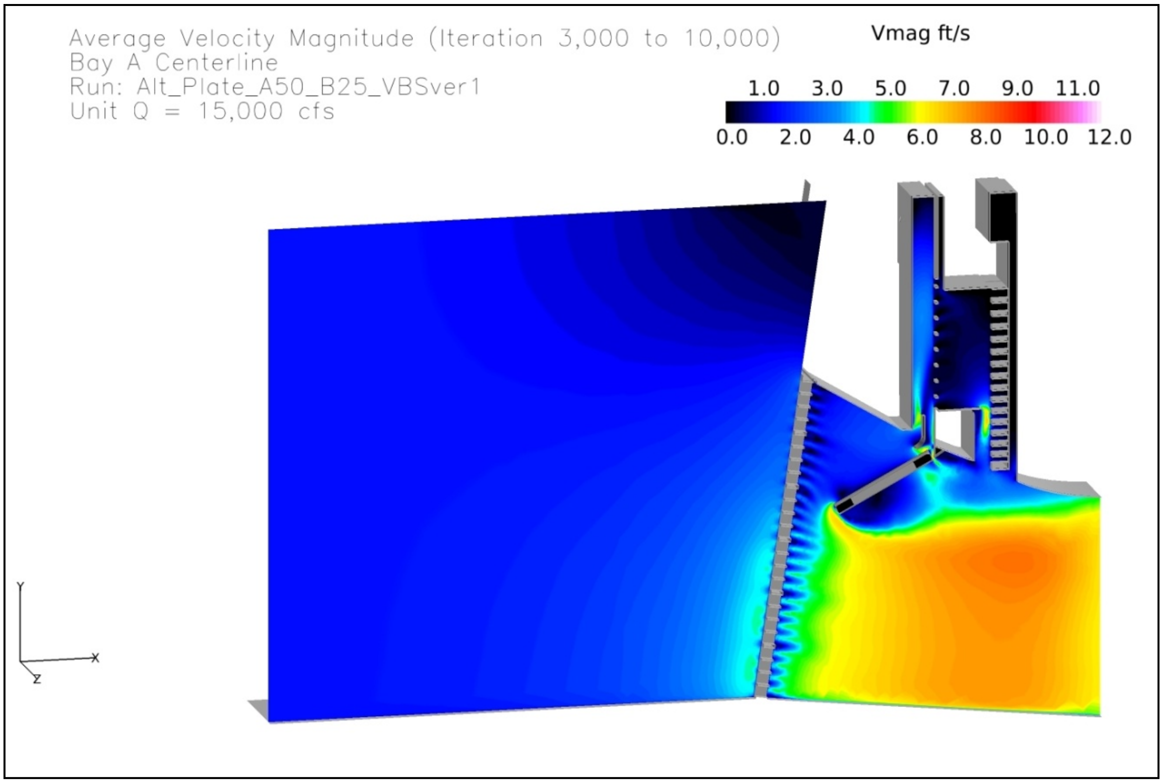


Figure 38. Proposed Improvements, Unit Q=15 kcfs, Bay A Centerline Velocity Magnitude

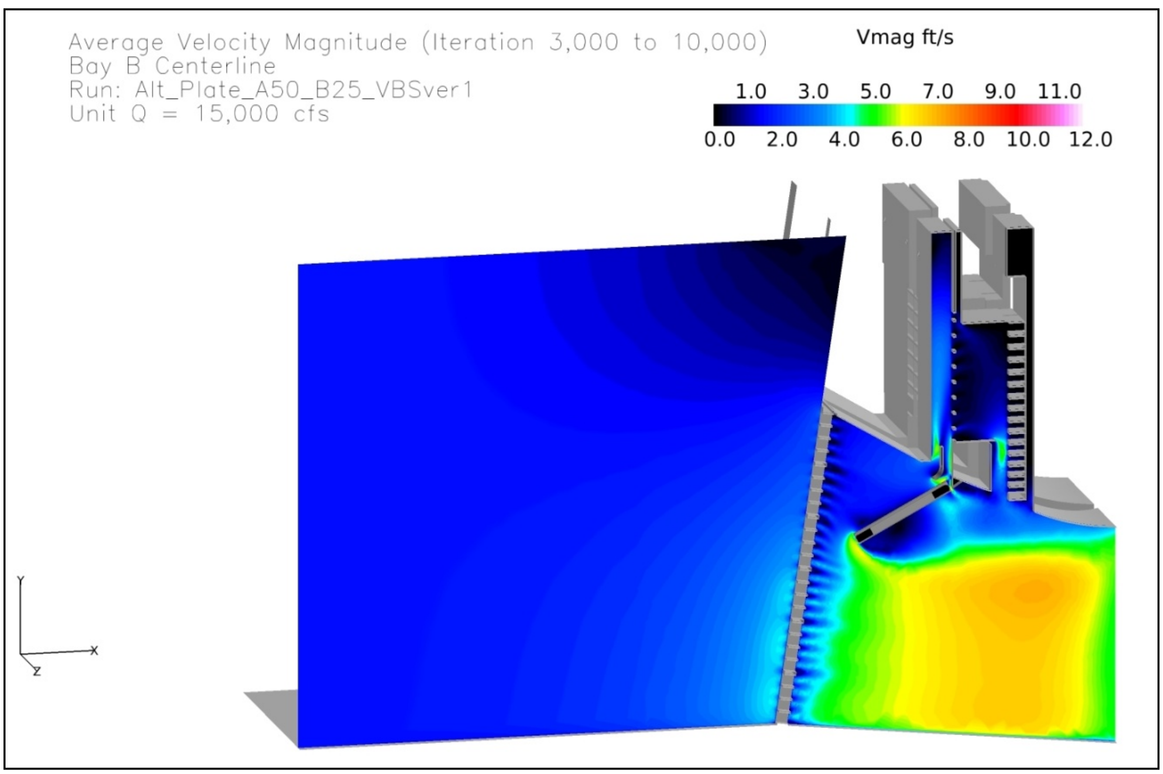


Figure 39. Proposed Improvements, Unit Q=15 kcfs, Bay B Centerline Velocity Magnitude

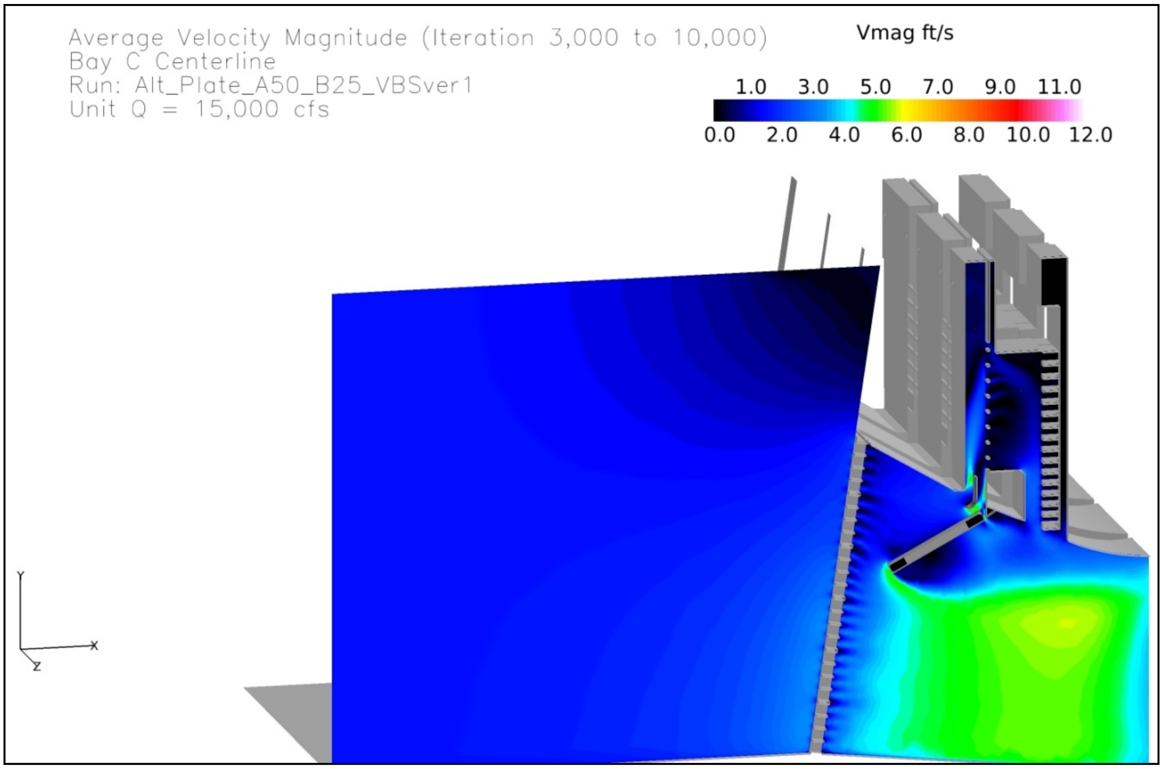


Figure 40. Proposed Improvements, Unit Q=15 kcfs, Bay C Centerline Velocity Magnitude

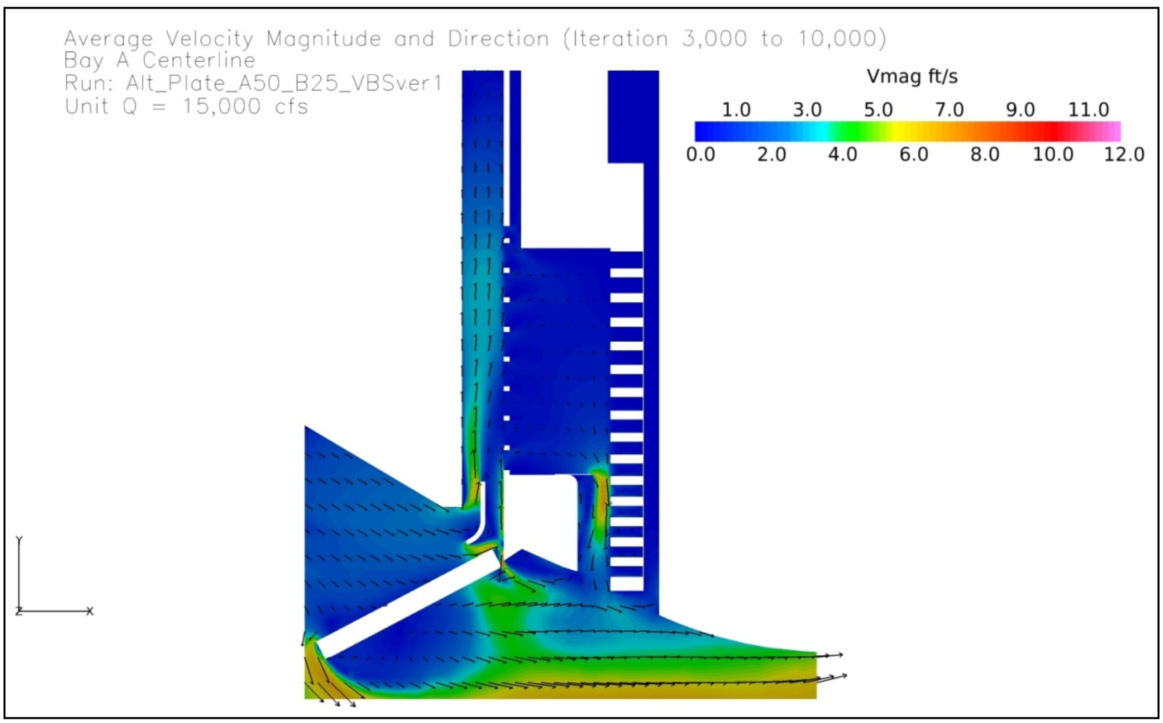


Figure 41. Proposed Improvements, Unit Q=15 kcfs, Bay A Centerline Velocity Magnitude and Flow Patterns

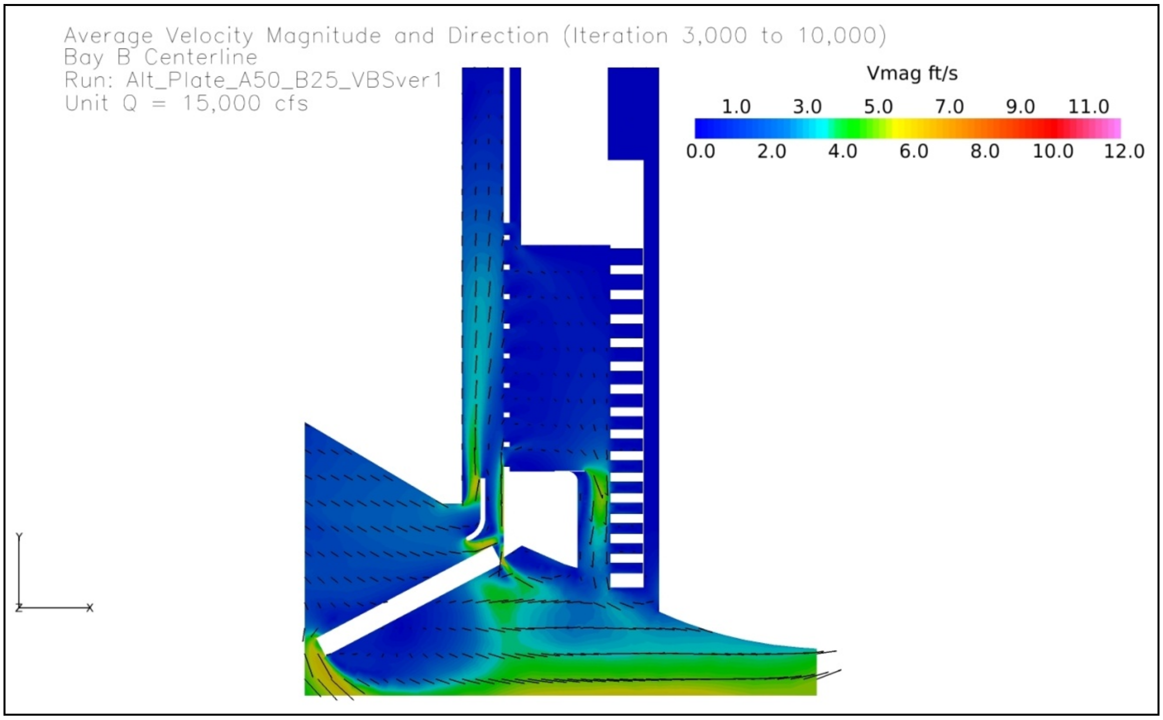


Figure 42. Proposed Improvements, Unit Q=15 kcfs, Bay B Centerline Velocity Magnitude and Flow Patterns

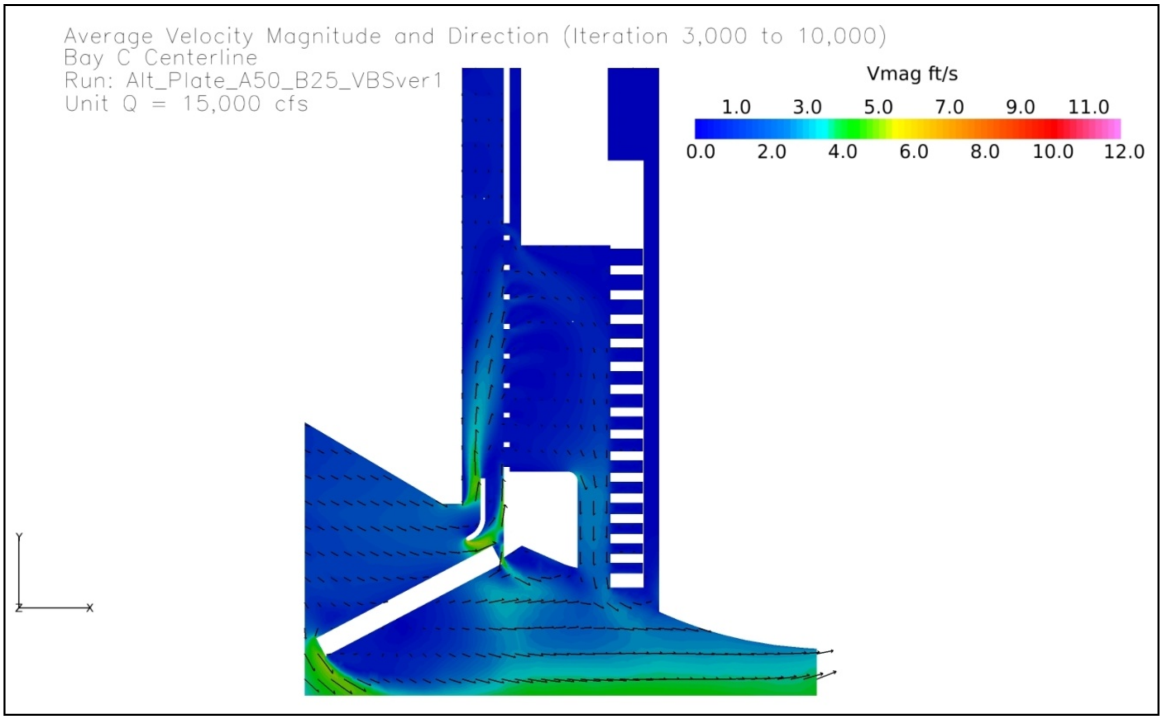


Figure 43. Proposed Improvements, Unit Q=15 kcfs, Bay C Centerline Velocity Magnitude and Flow Patterns

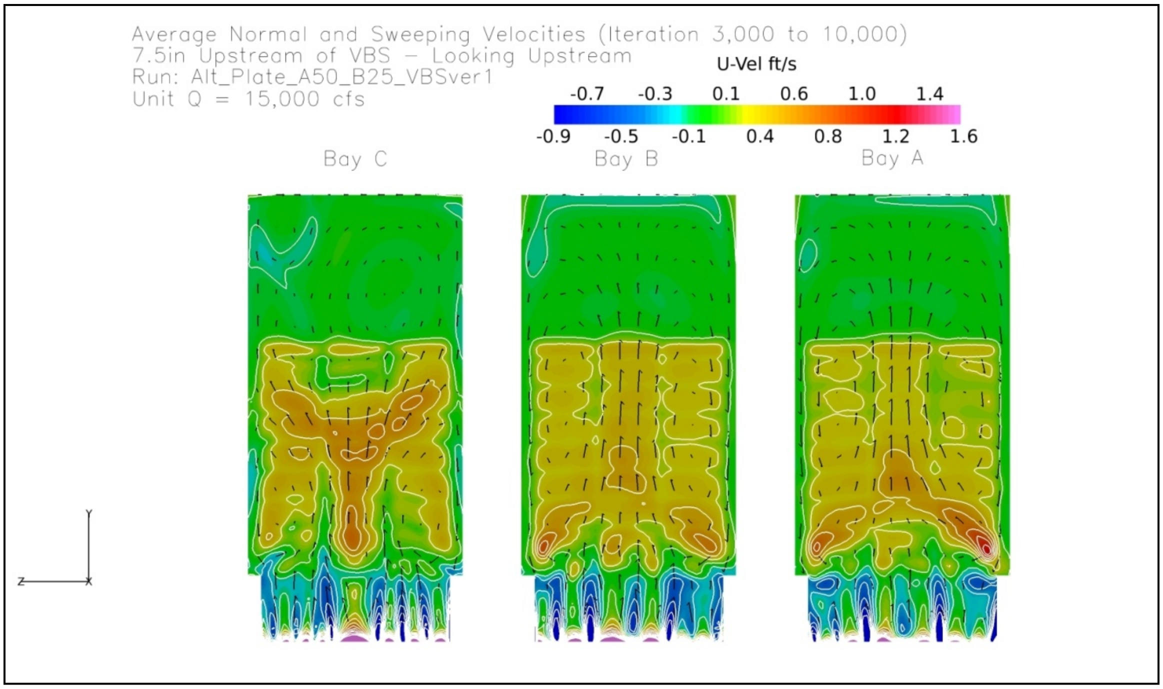


Figure 44. Proposed Improvements, Unit Q=15 kcfs, VBS Normal Velocities and Flow Patterns

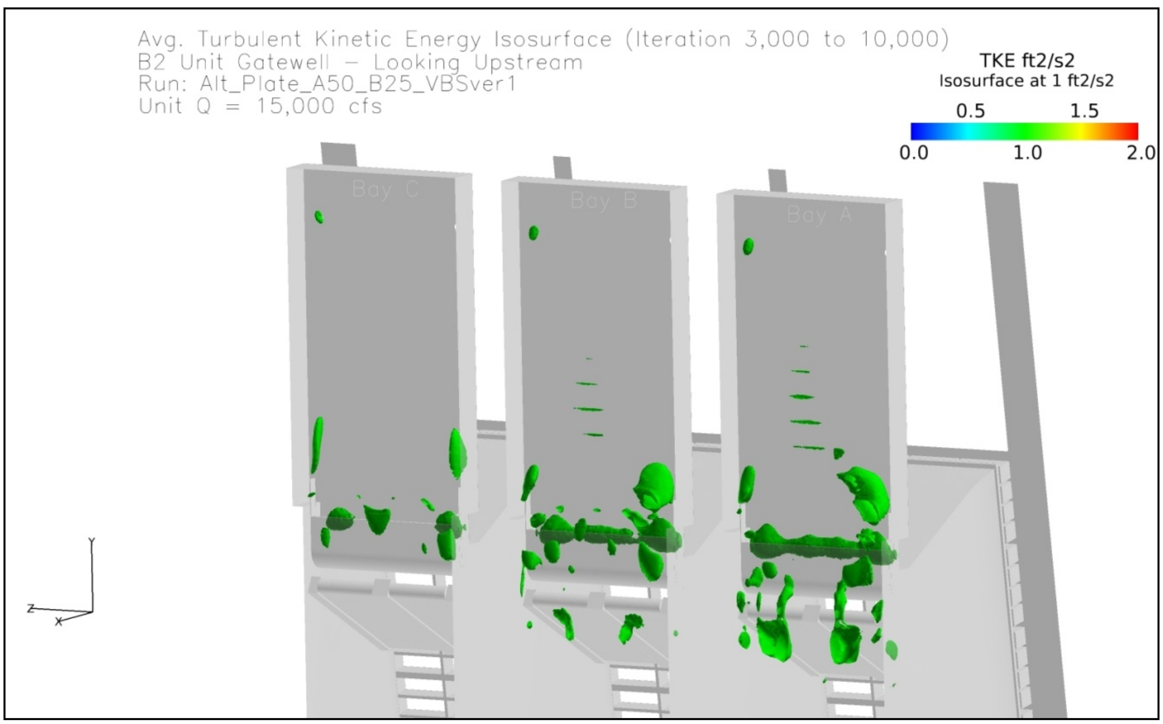


Figure 45. Proposed Improvements, Unit Q=15 kcfs, Turbulent Kinetic Energy Isosurface (1 ft^2/s^2)

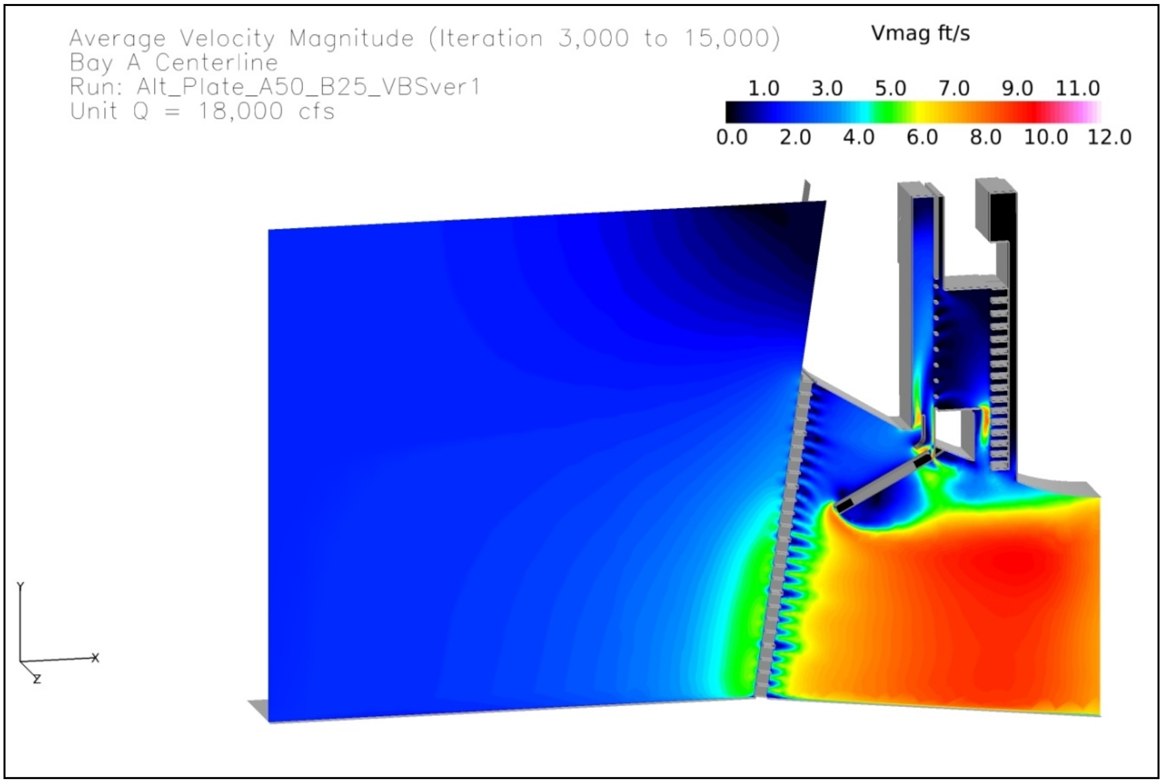


Figure 46. Proposed Improvements, Unit Q=18 kcfs, Bay A Centerline Velocity Magnitude

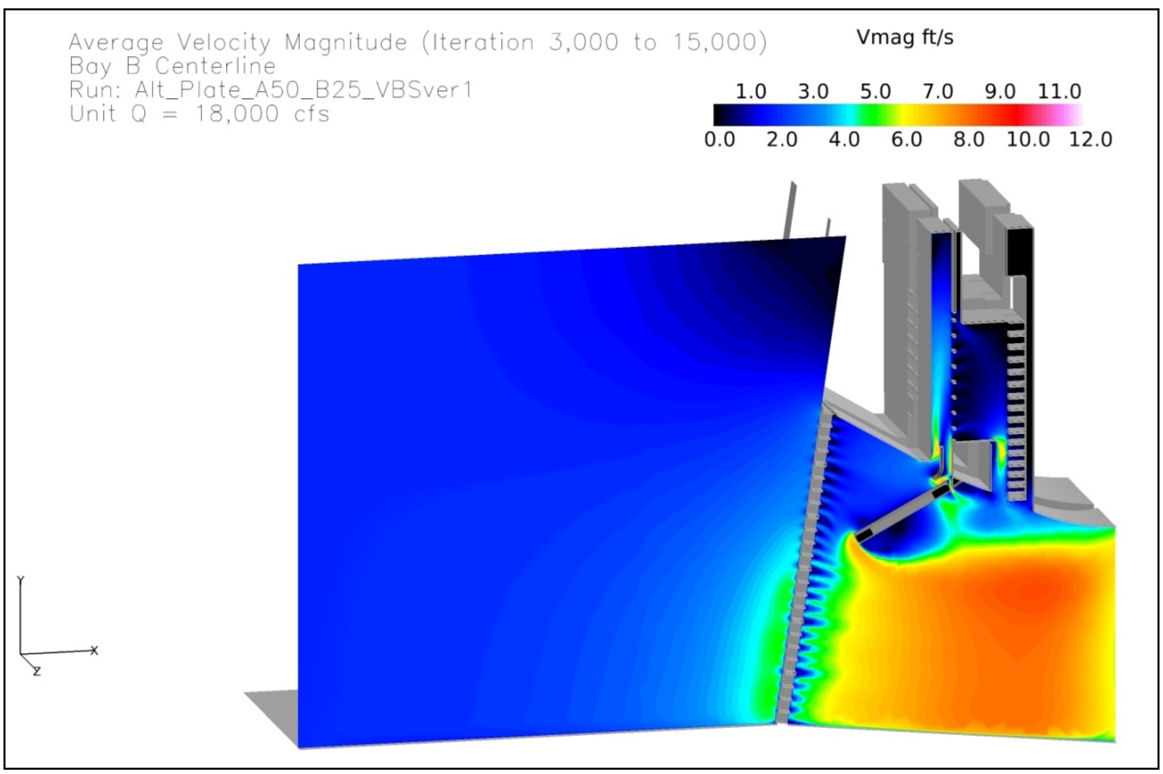


Figure 47. Proposed Improvements, Unit Q=18 kcfs, Bay B Centerline Velocity Magnitude

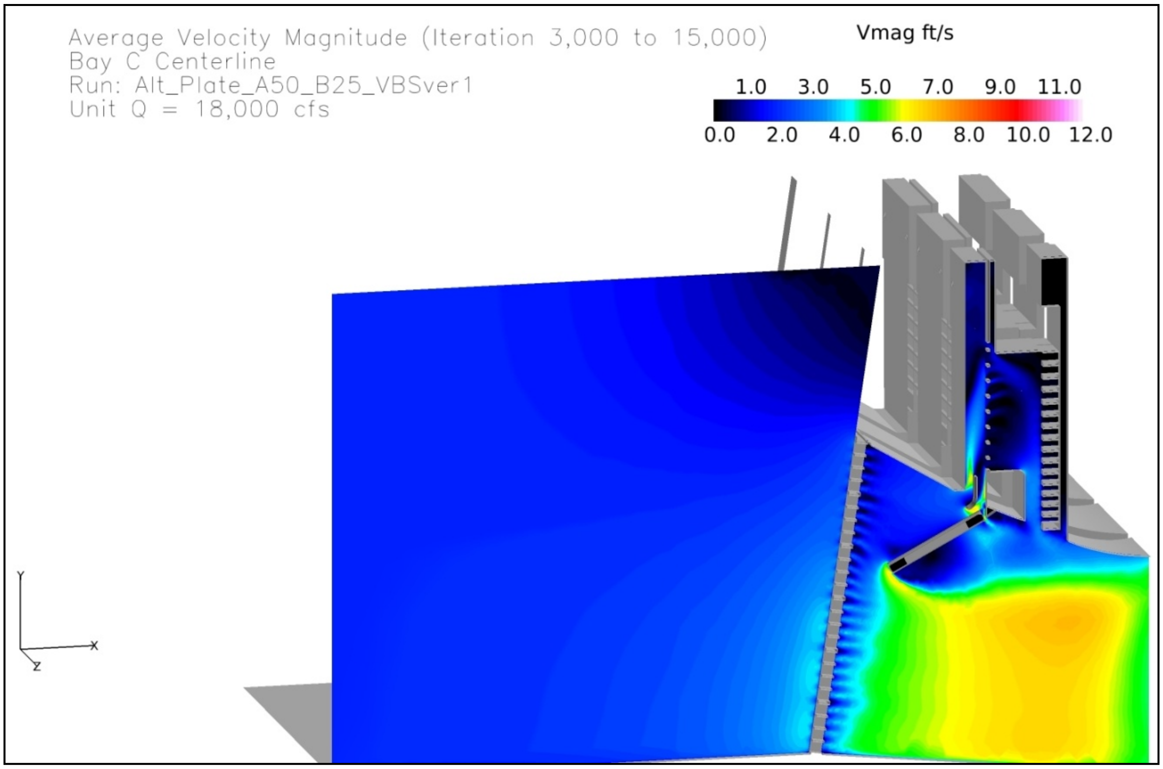


Figure 48. Proposed Improvements, Unit Q=18 kcfs, Bay C Centerline Velocity Magnitude

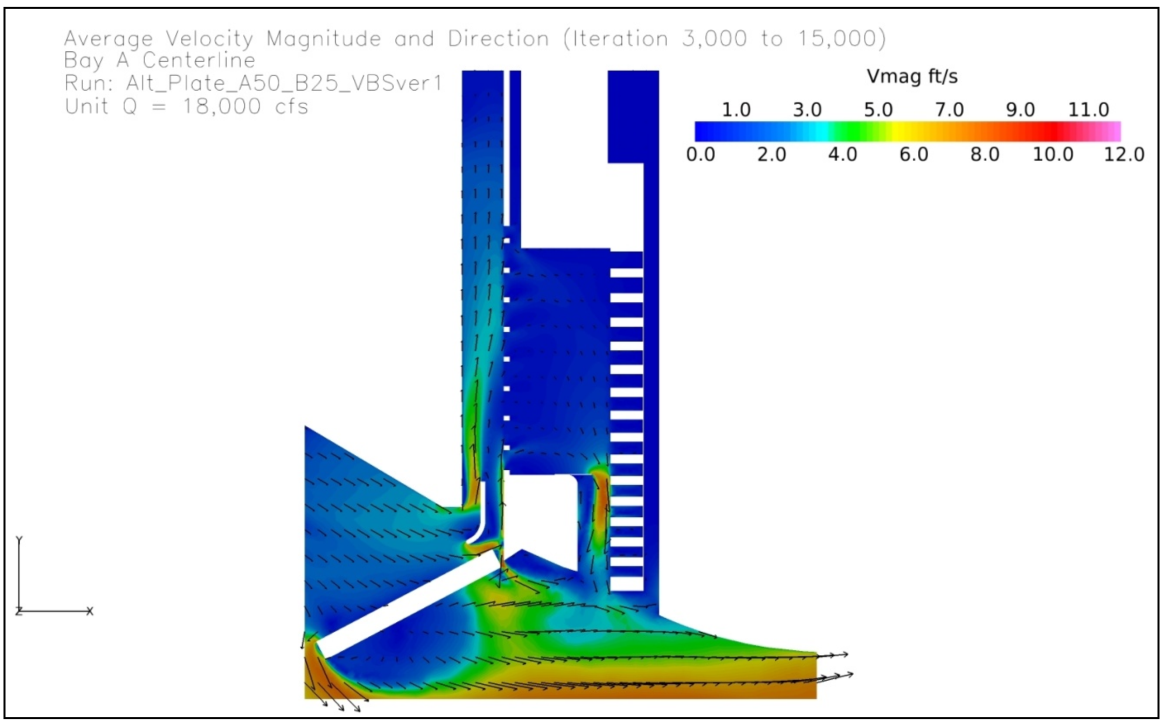


Figure 49. Proposed Improvements, Unit Q=18 kcfs, Bay A Centerline Velocity Magnitude and Flow Patterns

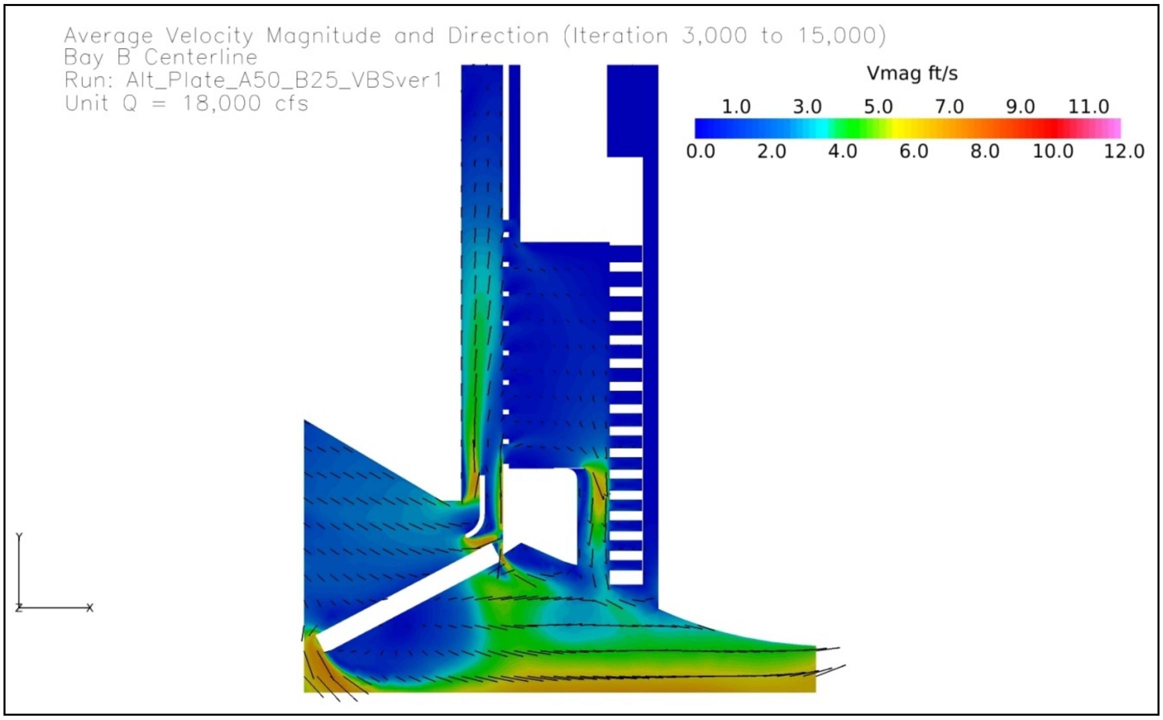


Figure 50. Proposed Improvements, Unit Q=18 kcfs, Bay B Centerline Velocity Magnitude and Flow Patterns

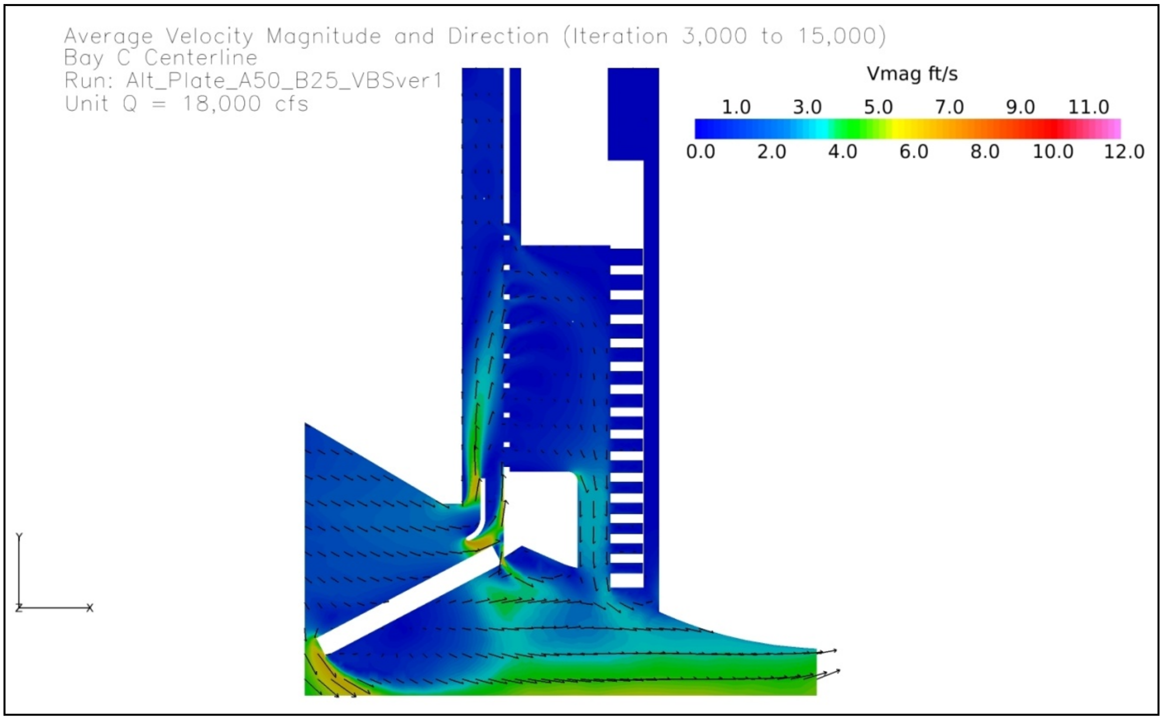


Figure 51. Proposed Improvements, Unit Q=18 kcfs, Bay C Centerline Velocity Magnitude and Flow Patterns

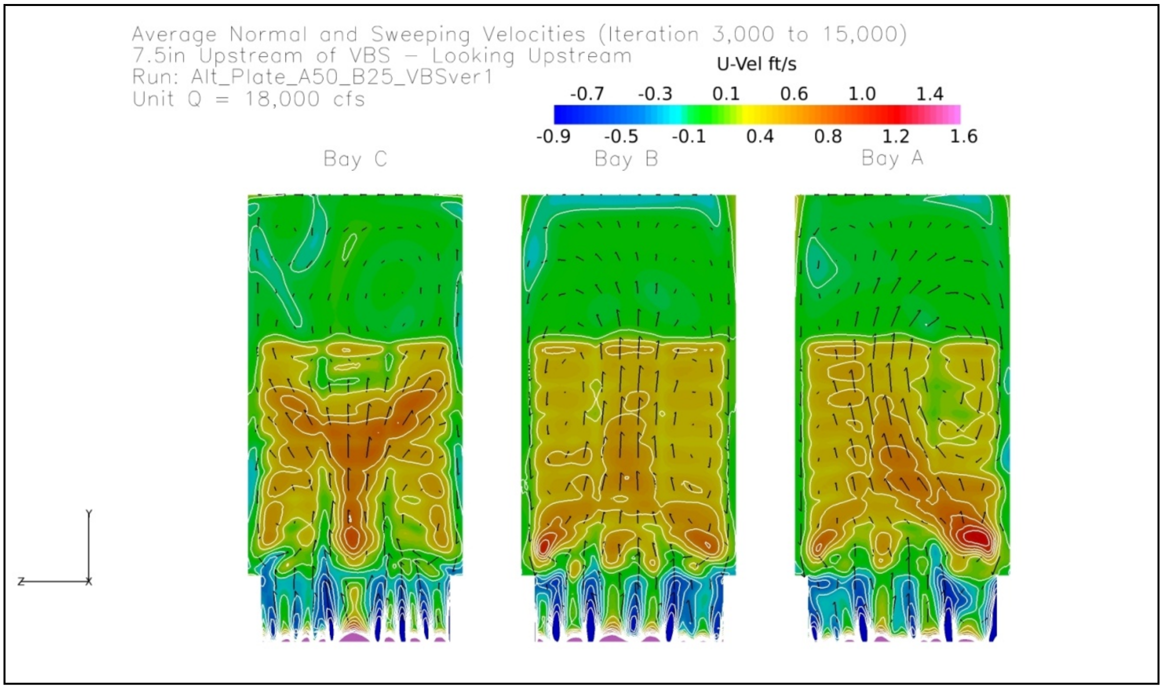


Figure 52. Proposed Improvements, Unit Q=18 kcfs, VBS Normal Velocities and Flow Patterns

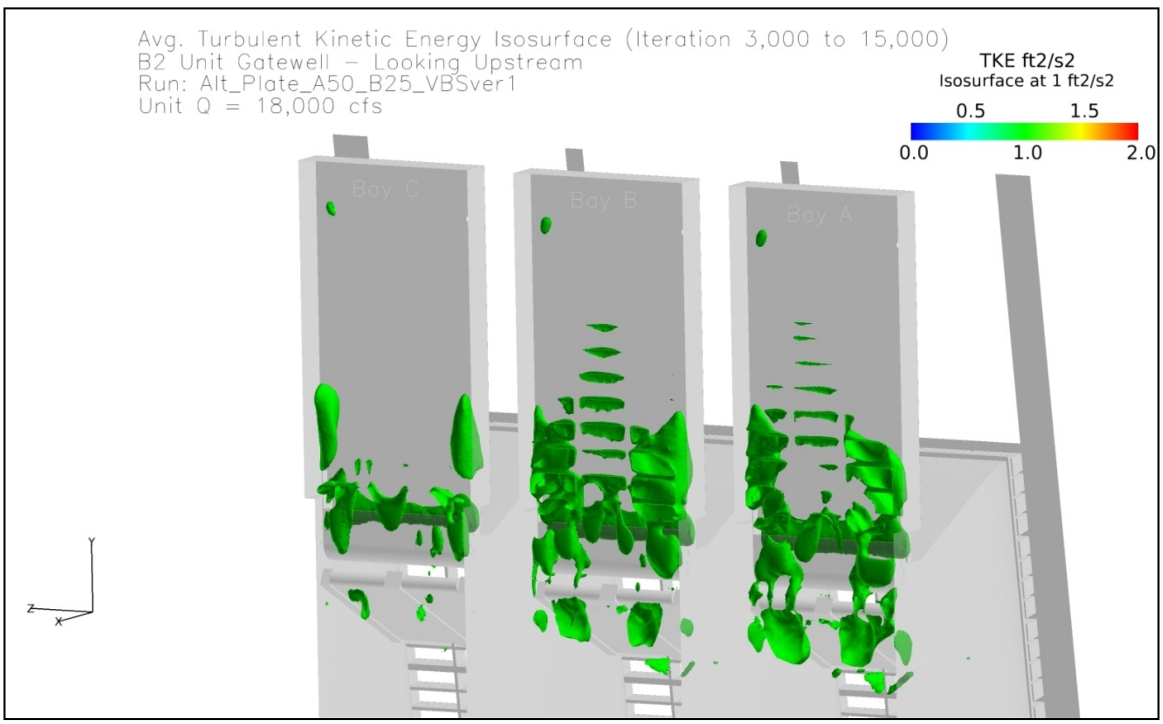


Figure 53. Proposed Improvements, Unit Q=18 kcfs, Turbulent Kinetic Energy Isosurface (1 ft^2/s^2)

APPENDIX E

Flow Control Plate Design Calculations and Drawings

PROJECT:	COMPUTED BY:	DATE:
Bonneville Second Powerhouse Fish Guidance Efficiency	STS	11/14/2014
SUBJECT:	**CHECKED BY:**	**SHT. OF**
Hydraulic Load Calculations for Bay A Flow Control Plate	LLE 11/17/2014	1 5
		PART:

CALCULATION COVER SHEET

These calculations are for the expected hydraulic loads on a proposed flow control plate to be installed in Bay A of Unit 15 at Bonneville Second Powerhouse. These calculations account for a load from flow past the plate during a load rejection, as well as a load from a pressure wave induced from a load rejection. The calculations also include natural frequency and forcing frequency calculations to estimate the potential for induced vibration in the plate. The exact bolt placement will be determined at the time of construction based on a field rebar locate; for that reason, the natural frequency calculations were performed for two possible bolt placement scenarios.

Results:

Based on field data and CFD modeling, a flow of 500 cfs past the plate was determined to be an appropriate design case. This load case, along with a load rejection, produces a load of about 3.17 kips/ft along the center of the exposed area of the bottom of the plate. In addition, the natural frequency of the plate was calculated to be much greater than the forcing frequency produced by the flow and load rejection pressure wave, so hydraulic induced vibration is not expected to be a concern for the proposed plate.

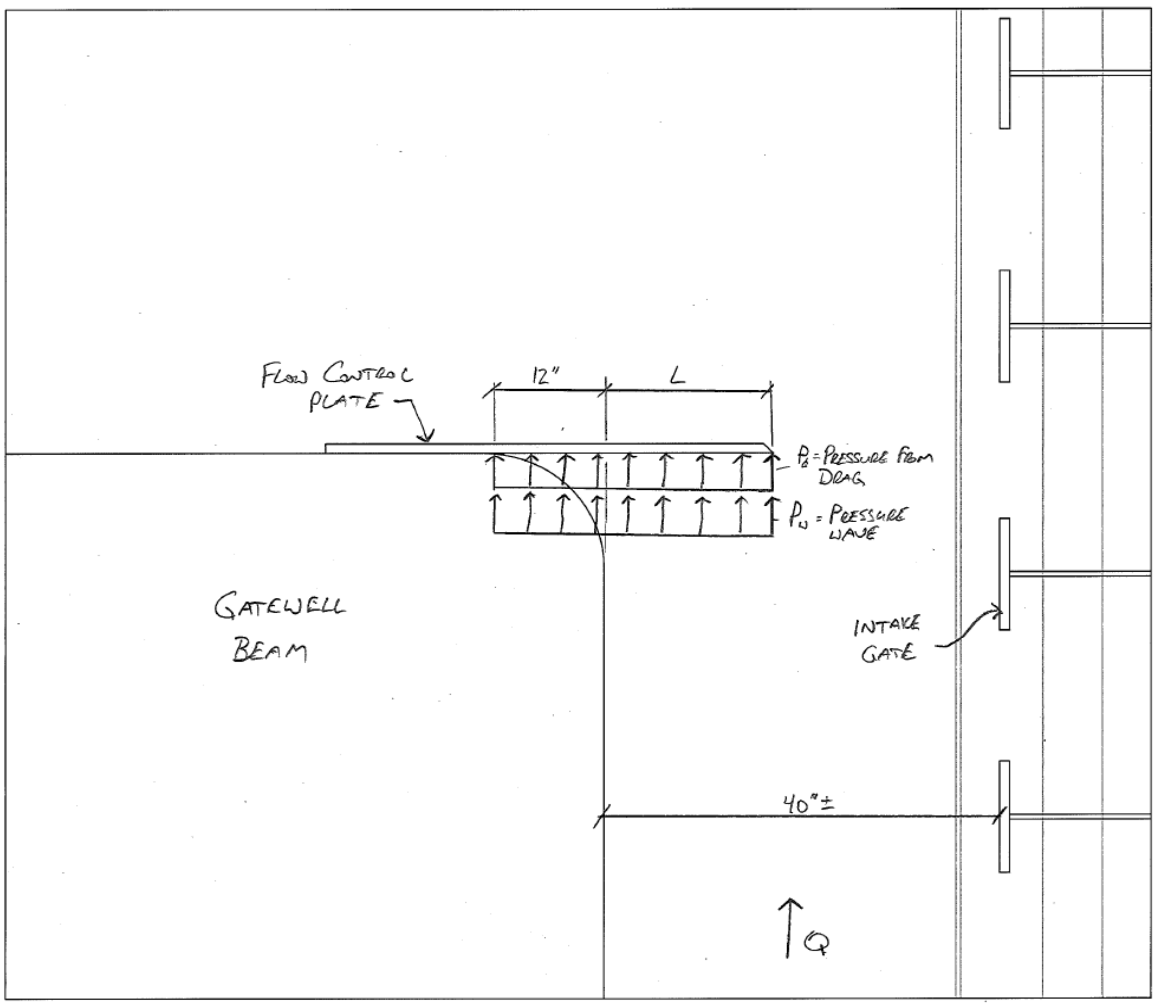
Review Comments:

Revision History:

Revision	Date:	Purpose	Checked By	Date
Original				10/9/2014
rev 1				
rev 2				
rev 3				

Load Rejection Load Calculations

A load rejection will apply two pressure loads to the plate: (1) Pd - pressure from the drag force from flow moving past the plate and (2) Pw - a pressure wave induced from a load rejection. These loads are calculated per foot of plate width.



<u>Drag Force Load</u>

The pressure from a drag force on the plate is calculated with the following equation:

$$P_d = C_d \frac{1}{2} \rho V^2$$ (from Fox and McDonald)

where

P_d, Pressure from Drag Force

C_d, Drag Coefficient: 1.18 (Flat Plate Normal to Flow, from Fox and McDonald)

ρ_w, Density of Water: 1.94 slugs/ft^3

V, Velocity of Water

Pressure Wave Load

The pressure wave (Pw) magnitude on the plate is based observations of water reaching the 90' deck during a load rejection. The normal water surface elevation in the gatewell is approximately 74', so the pressure wave adds about 16' of head to the system. For these calculations, 20' of head will be the assumed magnitude of the pressure wave. The pressure wave was caculated with the following equation:

$$P_w = H\gamma$$

where

P_w, pressure wave

H, head: 20 ft

γ, specific weight of water: 62.4 lbs/ft^3

Load Calculations

Intake Gate Chamber Opening Dimensions:

Width:	20.00	ft
Length:	3.33	ft
Beam Radius:	12.00	in
Plate Length, L:	17.00	in (from edge of gatewell beam)

Q (cfs)	V (ft/s)	P_d (psf)	P_w (psf)	Total Pressure (psf)	Total Force (lbs/ft)	
100	1.50	3	1248	1,251	3,022	
200	3.00	10	1248	1,258	3,041	
300	4.50	23	1248	1,271	3,072	
400	6.00	41	1248	1,289	3,116	
500	7.50	64	1248	1,312	3,172	<Design
600	9.00	93	1248	1,341	3,240	Case
700	10.50	126	1248	1,374	3,321	
800	12.00	165	1248	1,413	3,414	
900	13.50	209	1248	1,457	3,520	
1000	15.00	258	1248	1,506	3,638	

Natural Frequecy Calculations

The natural frequency of a plate is calculated with the following equation:

$$fn = \frac{\lambda^2}{2\pi L^2}\sqrt{\frac{EI}{m}}$$ (Blevins and Au-Yang page 2-23)

where

fn , natural frequency of the plate

λ , a non-dimensional parameter that varies with the boundary condition of the member

L , length of plate

E , modulus of elasticity: 4,320,000,000 psf

I , area moment of inertia $I = \frac{ba^3}{12}$ (Blevins and Au-Yang page 2-18)

m , mass per unit length of plate

Plate Parameters - 32 in Plate

Length, *L* :	32	in (min. distance from end of plate to first bolt)
Width, *b* :	1	ft
Thickness, *a* :	1.25	in
Volume, *vol* :	0.278	ft^3
Density Steel, ρ_s :	15.2	slugs/ft^3
Mass of Steel, m_s :	4.22	slugs
Mass of Water, m_w :	0.54	slugs
I :	9.42E-05	ft^4

Plate Parameters - 36 in Plate

Length, *L* :	36	in (min. distance from end of plate to first bolt)
Width, *b* :	1	ft
Thickness, *a* :	1.25	in
Volume, *vol* :	0.313	ft^3
Density Steel, ρ_s :	15.2	slugs/ft^3
Mass of Steel, m_s :	4.75	slugs
Mass of Water, m_w :	0.61	slugs
I :	9.42E-05	ft^4

		fn (hz)	
Mode	λ	L=32 in	L=36 in
1	1.87510407	23	17
2	4.69409113	144	107
3	7.85475744	404	301
4	10.99554073	791	589

λ reference: Blevins and Au-Yang page 2-23

Forcing Frequecy Calculations

The forcing frequency for a plate is calculated with the following equation:

$$fs = \frac{SV}{D}$$ (Blevins 1990 page 47)

where

fs , forcing frequency

S , Strouhal number, dimensionless constant: 0.2 (Blevins 1990 Fig 3-7)

V , flow velocity approaching plate

D , plate length

		L=32 in, Mode 1			L=36 in, Mode 1		
Q (cfs)	V (ft/s)	fs	fn/fs	Vred (V/fn/d)	fs	fn/fs	Vred (V/fn/d)
100	1.50	0.11	204.49	0.02	0.10	171.37	0.03
200	3.00	0.23	102.24	0.05	0.20	85.69	0.06
300	4.50	0.34	68.16	0.07	0.30	57.12	0.09
400	6.00	0.45	51.12	0.10	0.40	42.84	0.12
500	7.50	0.56	40.90	0.12	0.50	34.27	0.15
600	9.00	0.68	34.08	0.15	0.60	28.56	0.18
700	10.50	0.79	29.21	0.17	0.70	24.48	0.20
800	12.00	0.90	25.56	0.20	0.80	21.42	0.23
900	13.50	1.01	22.72	0.22	0.90	19.04	0.26
1000	15.00	1.13	20.45	0.24	1.00	17.14	0.29

To avoid resonance or lock-in, criteria must be met below:

fn/fs > 5 OK for all cases

Vred < 1 OK for all cases

References

1. Fox, R.W. and McDonald, A.T. 1998. Introduction to Fluid Mechanics, Fifth Edition. John Wiley & Sons, Inc. New York, NY.

2. Saha, A.K. 2013. Direct numerical simulation of two-dimensional flow past a normal flat plate. J. Eng. Mech. 139: 1894-1901.

3. Blevins, R.D. 1990. Flow-Induced Vibration, 2nd Ed. Krieger Publishing Company. Malabar, FL.

4. Blevins, R.D. and Au-Yang, M.K. 2009. Flow-Induced Vibration with Failure Analysis Considerations. Course Manual. ASME Continuing Education Institute.

PROJECT:	COMPUTED BY:	DATE:
Bonneville Second Powerhouse Fish Guidance Efficiency	STS	10/9/2014
SUBJECT: Hydraulic Load Calculations for Bay B Flow Control Plate	CHECKED BY: LLE 10/10/2014	SHT. 1 OF 5 PART:

CALCULATION COVER SHEET

These calculations are for the expected hydraulic loads on a proposed flow control plate to be installed in Bay B of Unit 15 at Bonneville Second Powerhouse. These calculations account for a load from flow past the plate during a load rejection, as well as a load from a pressure wave induced from a load rejection. The calculations also include natural frequency and forcing frequency calculations to estimate the potential for induced vibration in the plate. The exact bolt placement will be determined at the time of construction based on a field rebar locate; for that reason, the natural frequency calculations were performed for two possible bolt placement scenarios.

Results:

Based on field data and CFD modeling, a flow of 500 cfs past the plate was determined to be an appropriate design case. This load case, along with a load rejection, produces a load of about 2.24 kips/ft along the center of the exposed area of the bottom of the plate. In addition, the natural frequency of the plate was calculated to be much greater than the forcing frequency produced by the flow and load rejection pressure wave, so hydraulic induced vibration is not expected to be a concern for the proposed plate.

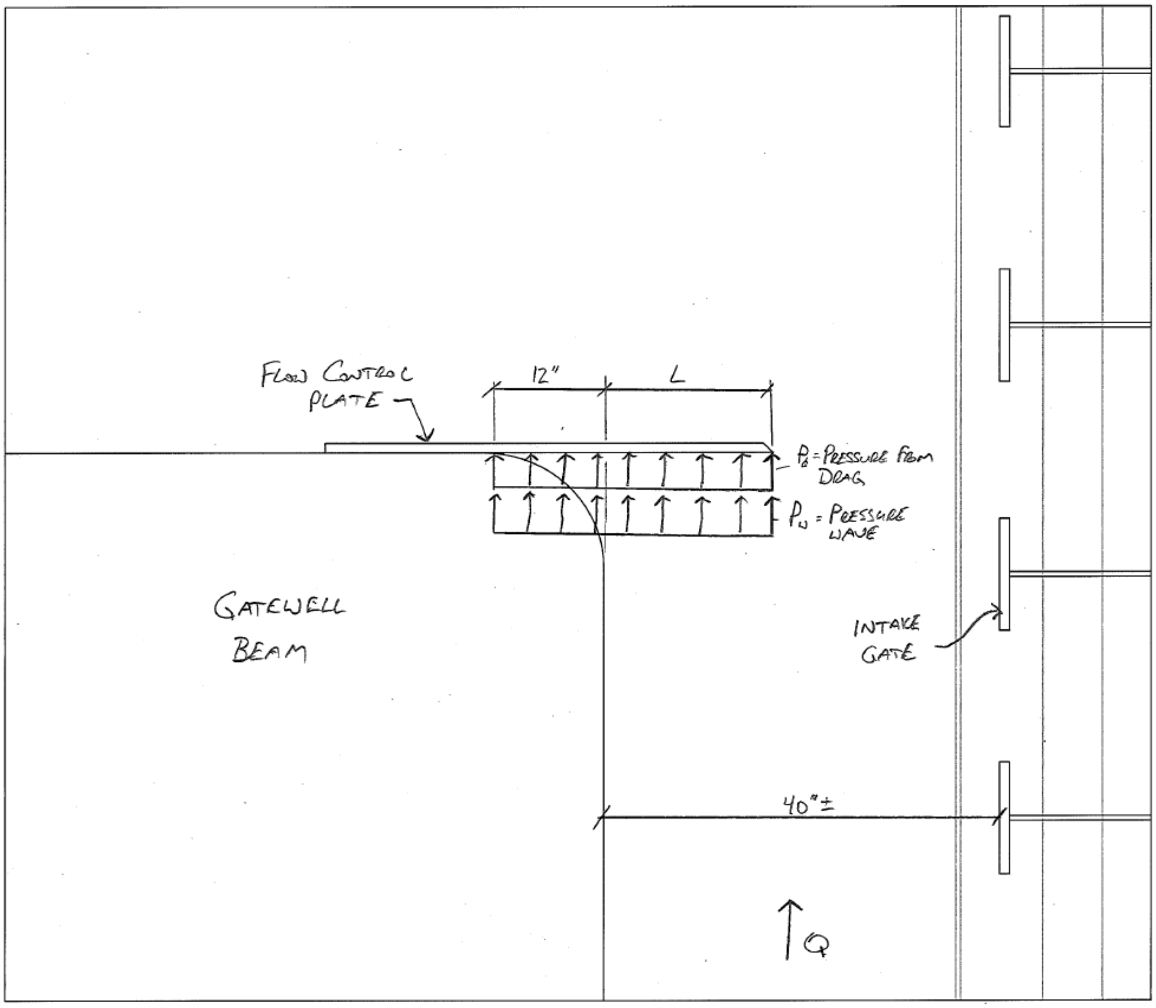
Review Comments:

Revision History:

Revision	Date:	Purpose	Checked By	Date
Original				10/9/2014
rev 1				
rev 2				
rev 3				

Load Rejection Load Calculations

A load rejection will apply two pressure loads to the plate: (1) Pd - pressure from the drag force from flow moving past the plate and (2) Pw - a pressure wave induced from a load rejection. These loads are calculated per foot of plate width.



Drag Force Load

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where

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C_d, Drag Coefficient: 1.18 (Flat Plate Normal to Flow, from Fox and McDonald)

ρ_w, Density of Water: 1.94 slugs/ft^3

V, Velocity of Water

Pressure Wave Load

The pressure wave (Pw) magnitude on the plate is based observations of water reaching the 90' deck during a load rejection. The normal water surface elevation in the gatewell is approximately 74', so the pressure wave adds about 16' of head to the system. For these calculations, 20' of head will be the assumed magnitude of the pressure wave. The pressure wave was caculated with the following equation:

$$P_w = H\gamma$$

where

P_w, pressure wave

H, head: 20 ft

γ, specific weight of water: 62.4 lbs/ft^3

Load Calculations

Intake Gate Chamber Opening Dimensions:

Width: 20.00 ft

Length: 3.33 ft

Beam Radius: 12.00 in

Plate Length, L : 8.50 in (from edge of gatewell beam)

Q (cfs)	V (ft/s)	P_d (psf)	P_w (psf)	Total Pressure (psf)	Total Force (lbs/ft)	
100	1.50	3	1248	1,251	2,136	
200	3.00	10	1248	1,258	2,150	
300	4.50	23	1248	1,271	2,172	
400	6.00	41	1248	1,289	2,202	
500	7.50	64	1248	1,312	2,242	<Design
600	9.00	93	1248	1,341	2,290	Case
700	10.50	126	1248	1,374	2,348	
800	12.00	165	1248	1,413	2,414	
900	13.50	209	1248	1,457	2,488	
1000	15.00	258	1248	1,506	2,572	

Natural Frequecy Calculations

The natural frequency of a plate is calculated with the following equation:

$$fn = \frac{\lambda^2}{2\pi L^2}\sqrt{\frac{EI}{m}}$$ (Blevins and Au-Yang page 2-23)

where

fn , natural frequency of the plate

λ , a non-dimensional parameter that varies with the boundary condition of the member

L , length of plate

E , modulus of elasticity: 4,320,000,000 psf

I , area moment of inertia $I = \frac{ba^3}{12}$ (Blevins and Au-Yang page 2-18)

m , mass per unit length of plate

Plate Parameters - 23.5 in Plate

Length, *L* :	23.5	in (min. distance from end of plate to first bolt)
Width, *b* :	1	ft
Thickness, *a* :	1	in
Volume, *vol* :	0.163	ft^3
Density Steel, ρ_s :	15.2	slugs/ft^3
Mass of Steel, m_s :	2.48	slugs
Mass of Water, m_w :	0.32	slugs
I :	4.82E-05	ft^4

Plate Parameters - 27.5 in Plate

Length, *L* :	27.5	in (min. distance from end of plate to first bolt)
Width, *b* :	1	ft
Thickness, *a* :	1	in
Volume, *vol* :	0.191	ft^3
Density Steel, ρ_s :	15.2	slugs/ft^3
Mass of Steel, m_s :	2.90	slugs
Mass of Water, m_w :	0.37	slugs
I :	4.82E-05	ft^4

		fn (hz)	
Mode	λ	L=32 in	L=36 in
1	1.87510407	40	27
2	4.69409113	250	168
3	7.85475744	699	472
4	10.99554073	1,369	924

λ reference: Blevins and Au-Yang page 2-23

Forcing Frequecy Calculations

The forcing frequency for a plate is calculated with the following equation:

$$fs = \frac{SV}{D}$$ (Blevins 1990 page 47)

where

fs , forcing frequency

S , Strouhal number, dimensionless constant: 0.2 (Blevins 1990 Fig 3-7)

V , flow velocity approaching plate

D , plate length

		L=32 in, Mode 1			L=36 in, Mode 1		
Q (cfs)	V (ft/s)	fs	fn/fs	Vred (V/fn/d)	fs	fn/fs	Vred (V/fn/d)
100	1.50	0.15	259.95	0.02	0.13	205.35	0.02
200	3.00	0.31	129.97	0.04	0.26	102.67	0.05
300	4.50	0.46	86.65	0.06	0.39	68.45	0.07
400	6.00	0.61	64.99	0.08	0.52	51.34	0.10
500	7.50	0.77	51.99	0.10	0.65	41.07	0.12
600	9.00	0.92	43.32	0.12	0.79	34.22	0.15
700	10.50	1.07	37.14	0.13	0.92	29.34	0.17
800	12.00	1.23	32.49	0.15	1.05	25.67	0.19
900	13.50	1.38	28.88	0.17	1.18	22.82	0.22
1000	15.00	1.53	25.99	0.19	1.31	20.53	0.24

To avoid resonance or lock-in, criteria must be met below:

fn/fs > 5 OK for all cases

Vred < 1 OK for all cases

References

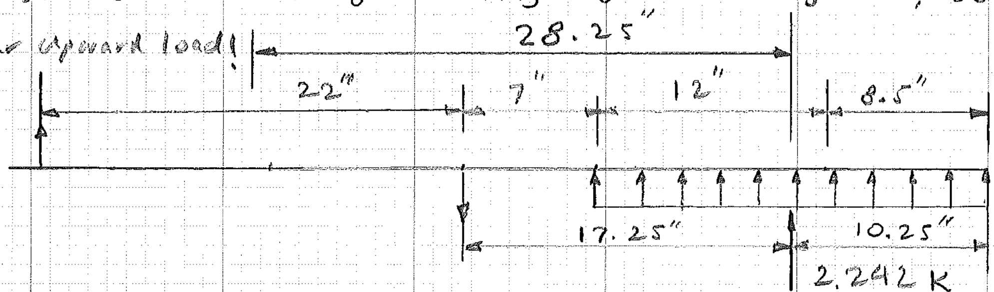
1. Fox, R.W. and McDonald, A.T. 1998. Introduction to Fluid Mechanics, Fifth Edition. John Wiley & Sons, Inc. New York, NY.
2. Saha, A.K. 2013. Direct numerical simulation of two-dimensional flow past a normal flat plate. J. Eng. Mech. 139: 1894-1901.
3. Blevins, R.D. 1990. Flow-Induced Vibration, 2nd Ed. Krieger Publishing Company. Malabar, FL.
4. Blevins, R.D. and Au-Yang, M.K. 2009. Flow-Induced Vibration with Failure Analysis Considerations. Course Manual. ASME Continuing Education Institute.

U.S. ARMY CORPS OF ENGINEERS OFFICE SYMBOL:

PROJECT:	COMPUTED BY:	DATE:
Bonneville Powerhouse II FGE	Mehdi Roshani	10/21/14
SUBJECT: Flow control plate (stainless steel)	CHECKED BY: MMA 10/23/14	SHT. 2 OF 6 PART:

Stainless plate Design for 8.5" Opening: 1" plate

Pressure wave load is significantly larger than drag load, so only consider upward load!



ASCE 7-05 2.3.2 & ETL 1110-2-584 Table E-1

$\gamma_{Hd} = 1.6$

$M_u = 1.6 \times 2.242 \times 17.25 = 61.88$ K-in

$M_n = F_y Z$ AISC F11-1

$$Z = \frac{bt^2}{4} = \frac{12 \times 1^2}{4} = 3 \ in^3$$

$\phi M_n = .9 \times 30 \times 3 = 81$ K-in $> M_u = 61.88$ K-in O.K.
(ASTM A240)

Anchor bolts:

$$T = 1.6 \times \frac{28.25}{22} \times 2.242 = 4.61 \text{ Kips}$$

Use stainless steel Hilti HDA-TR 30 M16x190/40 or approved equal. Anchor every 1 ft

Allowable nonseismic Tension per anchor for $f'_c = 4000$ psi is:

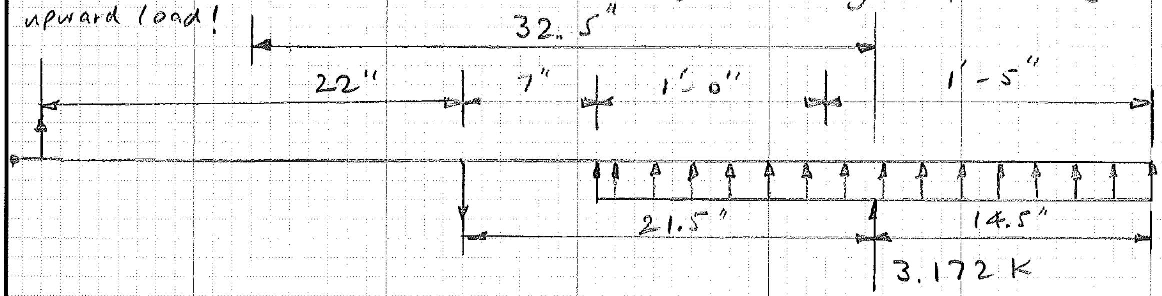
7.51 Kips > 4.61 Kips O.K.

U.S. ARMY CORPS OF ENGINEERS   OFFICE SYMBOL:

PROJECT:	COMPUTED BY:	DATE:
Bonneville Powerhouse II FGE	Mehdi Roshani	10/21/14
SUBJECT:	CHECKED BY:	SHT. 3 OF 6
Flow Control Plate (Stainless steel)	MDM 10/30/14	PART:

Stainless plate design for 1'-5" opening; 1 1/4" plate

Pressure wave load is significantly larger than drag load, so only consider upward load!



ASCE 7-05 2.3.2 & ETL 1110-2-584 Table E-1

$\gamma_{LLd} = 1.6$

$M_u = 1.6 \times 3.172 \times 21.5 = 109.12$ K-in

$M_n = F_y Z$ AISC F11-1

$Z = \frac{bt^2}{4} = \frac{12 \times 1.25^2}{4} = 4.69 \text{ in}^3$

$\phi M_n = .9 \times 30 \times 4.69 = 126.56$ K-in $>$ $M_u = 109.12$ K-in O.K.

(ASTM A240)

Anchor bolts:

$T = 1.6 \times \frac{32.5''}{22} \times 3.172 = 7.50$ Kips

Use Stainless Steel Hilti HDA-TR 30 M16x190/40 or approved equal.

Anchor every 1 ft

Allowable nonseismic Tension per anchor for $f'_c = 4000$ psi is:

7.51 Kips > 7.50 Kips OK

U.S. ARMY CORPS OF ENGINEERS OFFICE SYMBOL:

PROJECT:	COMPUTED BY:	DATE:
Bonneville Powerhouse II FGE	Mehdi Roshani	10/24/14
SUBJECT:	CHECKED BY:	SHT. 4 OF 6
Flow Control Plate Anchor Design	MDA 10/30/14	PART:

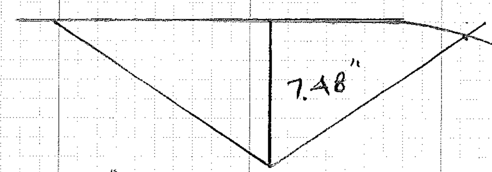
Concrete Breakout strength for installed plate:

Anchor : HDA-TR-30 M16 x 190 x 40

(ACI 318-11)

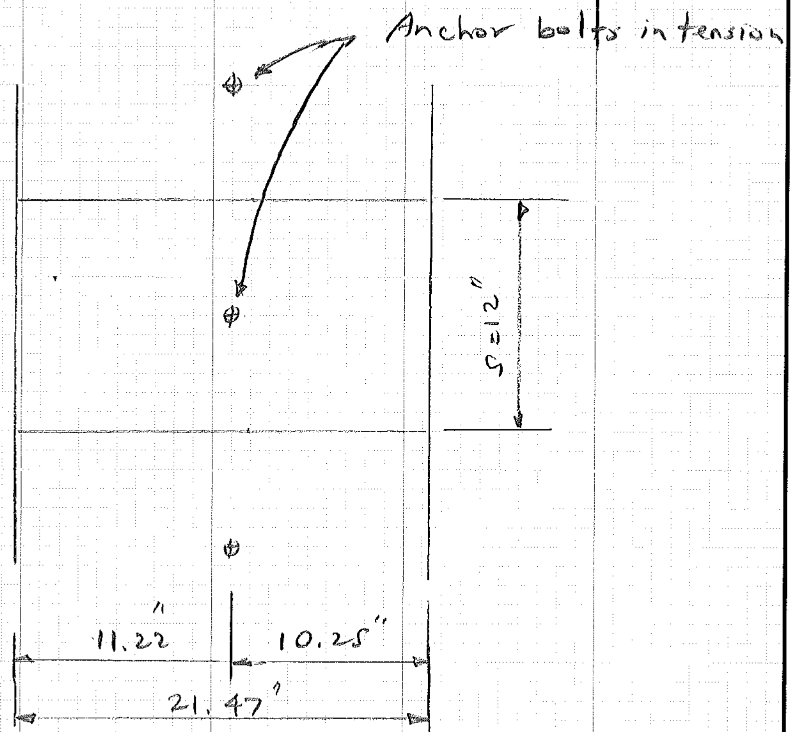
$\phi N_{cbg} = \phi \frac{A_{nc}}{A_{nco}} \Psi_{ec,N} \times \Psi_{ed,N} \times \Psi_{c,N} \Psi_{cp,N} N_b$ (D-4)

$1.5 h_{ef} = 1.5 \times 7.48 = 11.22$



$A_{Nco} = 9 h_{ef}^2 = 9 \times 7.48^2 = 503.55''$

$A_{nc} = 12 \times 21.47 = 257.64$



$N_b = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5}$

$k_c = 24$ per manufactures Table 2-HDA (D.5.2.2)

$\lambda_a = 1$ Undercut anchors (D.3.6)

PROJECT: Bonneville Powerhouse II FGE	COMPUTED BY: Mehdi Roshani	DATE: 10/24/14
SUBJECT: Flow Control Plate Anchor Design	CHECKED BY: MDA 10/30/14	SHT. 5 OF 6 PART:

$N_b = 24 \times 1 \sqrt{4000} \times 7.48^{1.5} = 31.052$ Kips

$\psi_{ec,N} = 1$ No eccentricity

$\psi_{ed,N} = 0.7 + .3 \frac{C_{a,min}}{1.5 h_{ef}}$ (D-10)

$= .7 + .3 \frac{10.25}{11.22} = .97$

$\psi_{c,N} = 1.25$ per manufacturer Table 2 - HDA

$\phi = .65$ (Medium sensitivity to installation and Medium reliability) (D.4.4.)

$C_{ac} = 2.5 h_{ef} = 2.5 \times 7.48 = 18.7''$ (D.8.6)

$\psi_{cp,N} = \frac{C_{a,min}}{C_{ac}} = \frac{10.25}{18.7} = .55$ (D.12) or

$= \frac{1.5 h_{ef}}{C_{ac}} = \frac{11.22}{18.7} = .6 \leftarrow$ (D.5.2.7)

$\phi N_{cbg} = .65 \times \frac{257.64}{503.55} \times 1 \times .97 \times 1.25 \times .6 \times 31.052$

$= 7.51$ Kips

PROJECT: Bonneville Powerhouse II FGE	COMPUTED BY: Mehdi Roshani	DATE: 10/24/14
SUBJECT: Flow Control Plate Anchor Design	CHECKED BY: MAH 10/30/14	SHT. 6 OF 6
		PART:

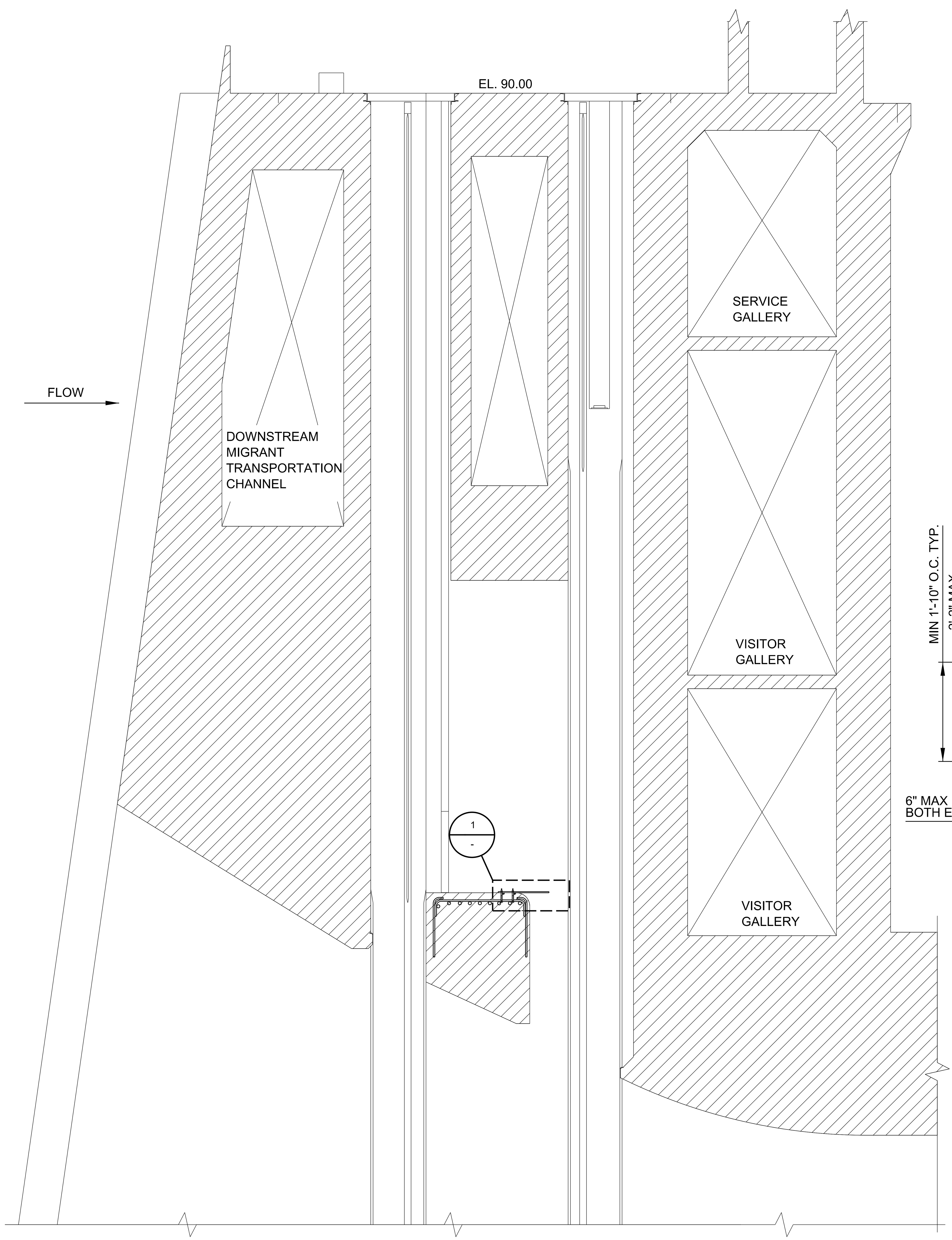
Pullout strength of Anchor bolts:

$N_{pn} = \psi_{c,p} N_p$ (D-13)

$\psi_{c,p} = 1.0$ cracking @ service load (conservative) (D.5.3.6)

$N_p = 22.481$ Kips Table 2 - HDA

$\phi N_{pn} = .65 \times 1 \times 22.48 = 14.61$ Kips



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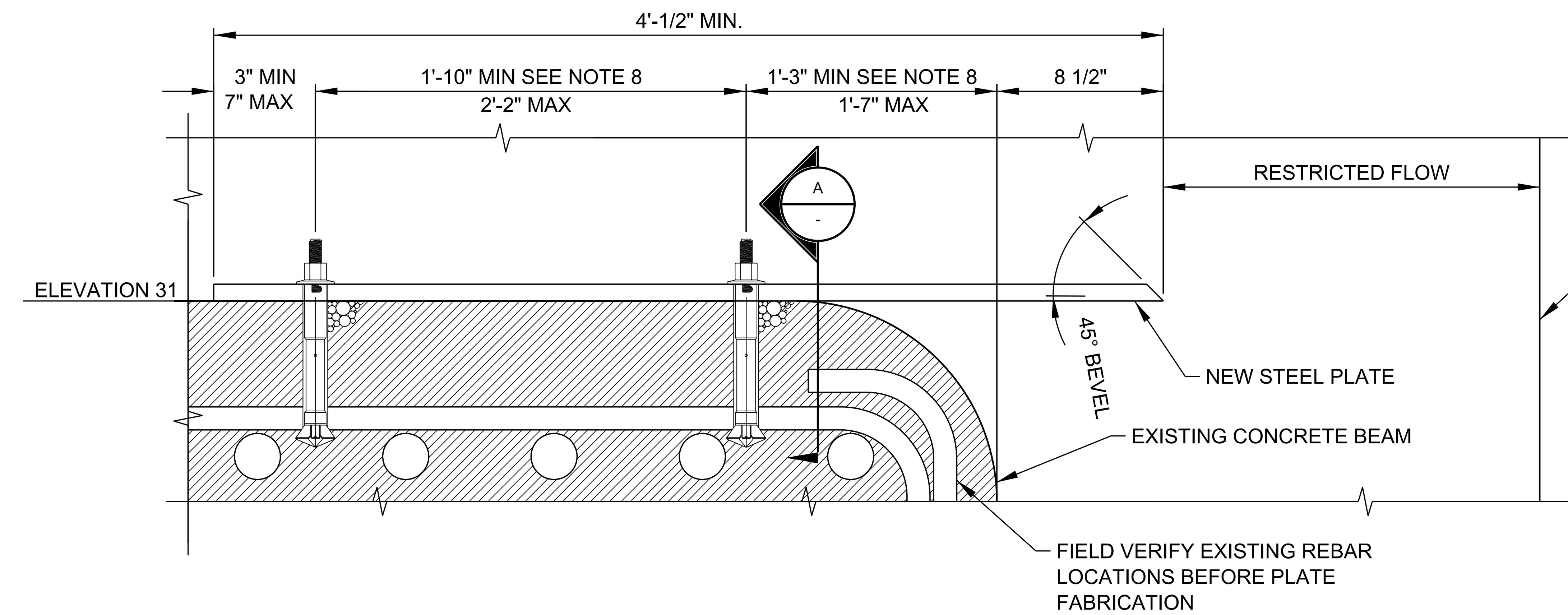
N.T.S.



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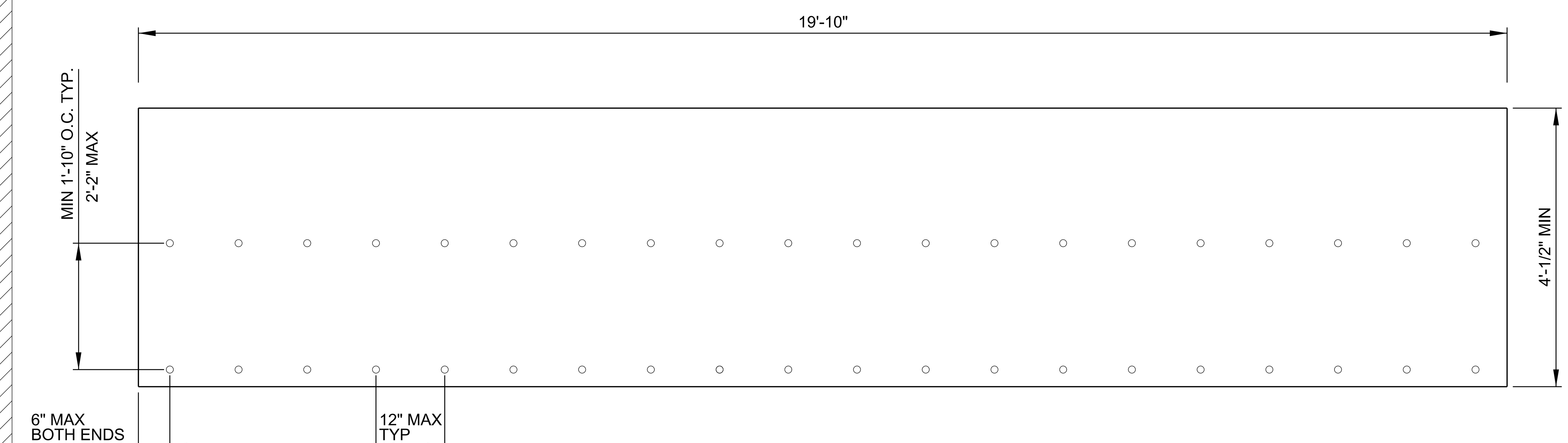
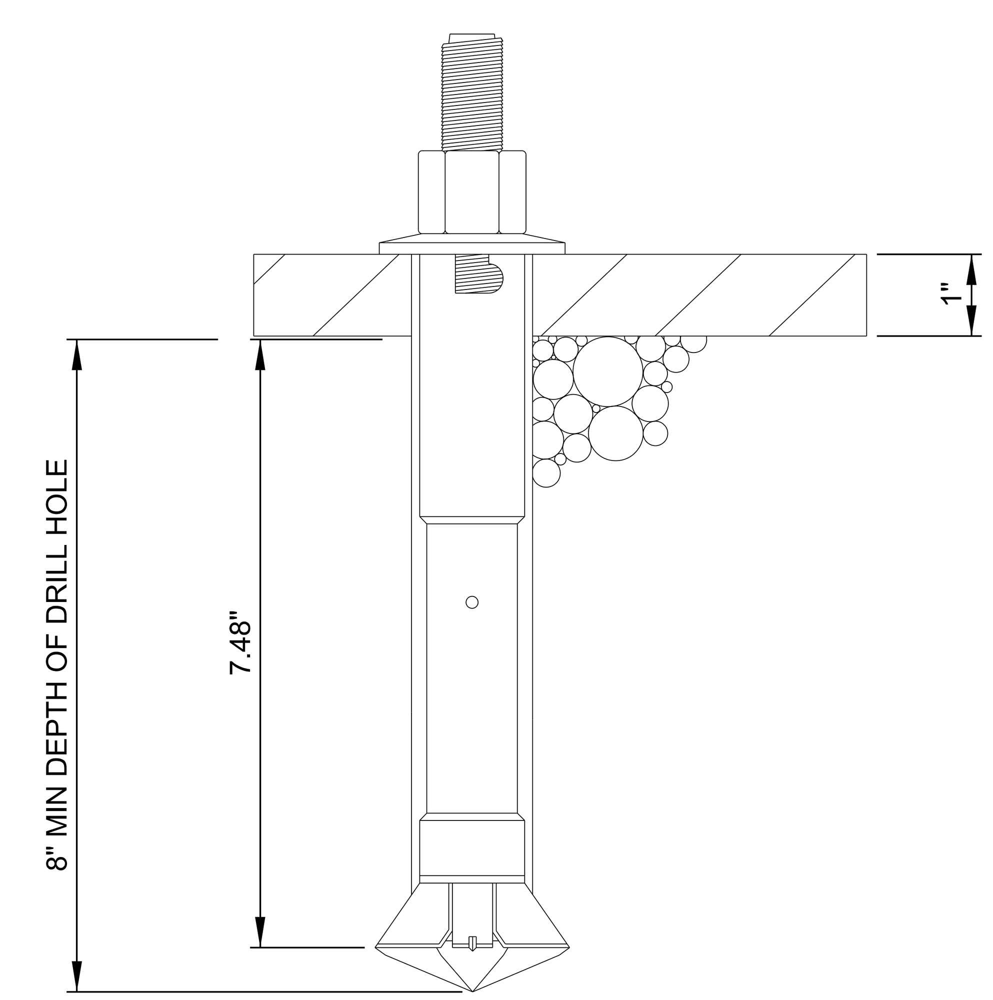
N.T.S.



PLAN VIEW
N.T.S.



A - SECTION
N.T.S.

NOTES:
1. FIELD VERIFY DIMENSIONS BEFORE PLATE FABRICATION
2. ALL PLATES SHALL BE STAINLESS STEEL AND CONFORM TO ASTM A240, TYPE 304.
3. ALL ANCHOR BOLTS SHALL BE STAINLESS STEEL HILTI HDA-TR 30 M16X190/40 OR APPROVED EQUAL.
4. ANCHOR BOLTS SHALL BE INSPECTED, TESTED, AND INSTALLED PER MANUFACTURER'S RECOMMENDATIONS.
5. NOMINAL PLATE HOLE DIMENSIONS FOR EACH ANCHOR BOLT SHALL BE 1 1/4" INCH +$\frac{1}{16}$ -0.0
6. REFFERENCE EXISTING REBAR ON DWG BDF-2-60/04 SEE INFORMATIONAL DRAWING (FIO)
7. ANCHOR BOLTS MINIMUM EMBEDMAENT DEPTH IS 7.48 INCHES.
8. THE CONTRACTOR SHALL MAP EXISTING EMBEDED REBAR LOCATIONS AT PLATE INSTALLATION AND SUBMIT A REPORT TO THE CONSTRUCTION OFFICE BEFORE FABRICATION AND INSTALLATION OF PLATE AND ANCHOR BOLTS.
9. THE CONTRACTOR SHALL LOCATE THE EXISTING REBAR AND ADJUST PLATE HOLES AND ANCHOR BOLT LOCATIONS TO AVOID EXISTING REBAR BEFORE PLATE FABRICATION AND DRILLING FOR THE ANCHOR BOLTS.
10. THE CONTRACTOR SHALL HAVE THE OPTION OF FABRICATING THE 19'-10"LONG PLATE IN SMALLER SECTIONS AND FIELD BUTT THE SECTIONS FOR A TOTAL DIMENSION AT 19'-10".
11. THE CONTRACTOR SHALL DESIGN AND INSTALL PERMANENT LIFTING EYES FOR THE PLATE SECTIONS.
12. THE CONTRACTOR SHALL USE ROTARY IMPACT HAMMER DRILLS FOR THE ANCHOR BOLTS.
13. TOTAL PLATE WEIGHT IS APPROXIMATELY 3,300 LBS.

US Army Corps of Engineers®
PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

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

DESIGNED BY: JEFFREY HICKS
DATE: 01/31/2014
DWN BY: G2ECDACW
CKD BY: G2ECDMR9
SOLICITATION NO.: W9127N-14-R-0026
SUBMITTED BY: MATTHEW D. HANSON, P.E.
CONTRACT NO.: W9127N-14-P-0044
PLOT SCALE: 1:1
PLOT DATE: 10/27/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.111_S-502XXX.dgn

BONNEVILLE LOCK AND DAM
SECOND POWERHOUSE
FISH GUIDANCE EFFICIENCY

TURBINE INTAKE
FLOW CONTROL PLATE
B SLOT

SHEET IDENTIFICATION
S-502
SHEET 0 OF 0

DESIGN FILE: \\nwd\nwp\ETDS\CADD-Workspaces\NWP\WorkSpace\projects\Local Resource\

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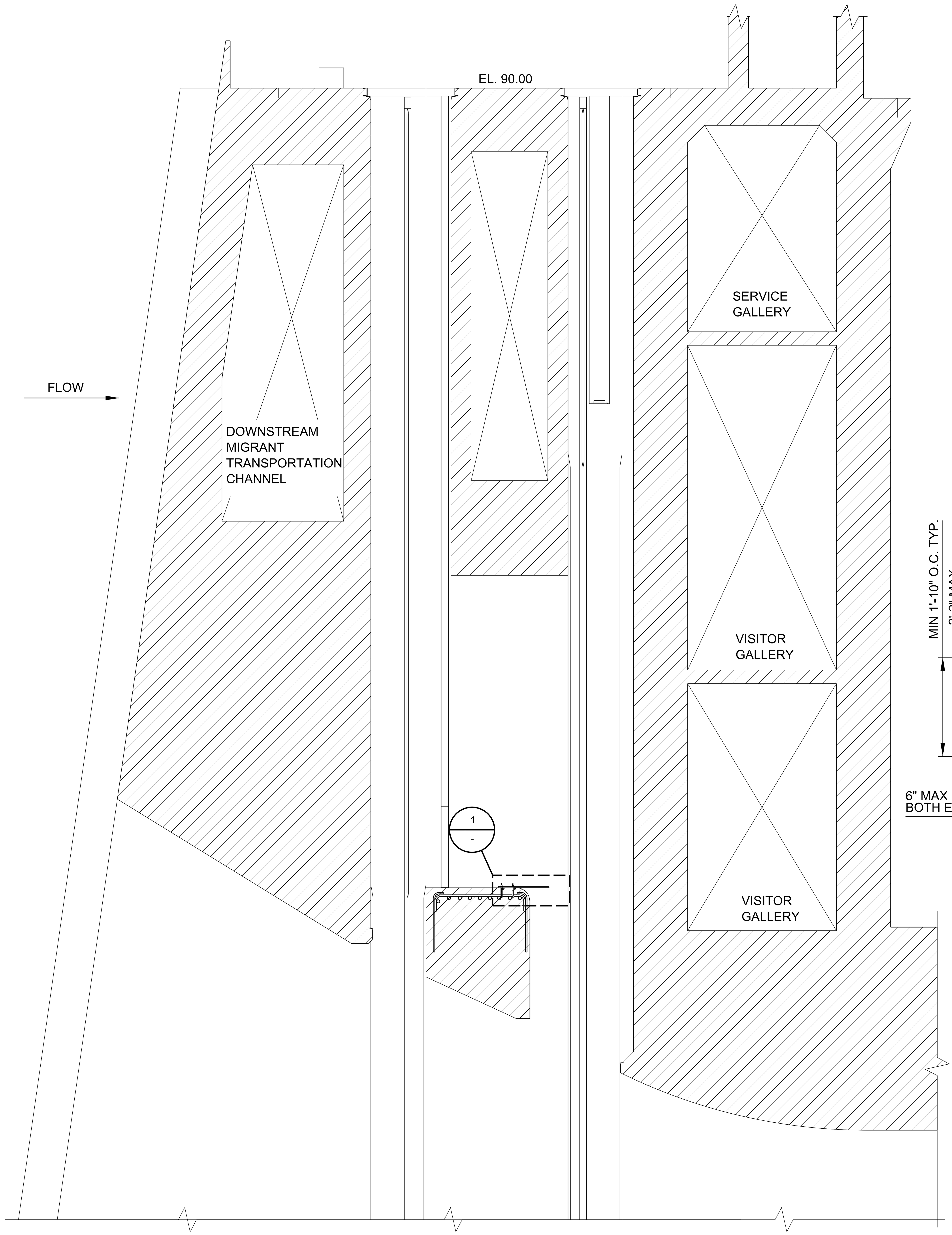
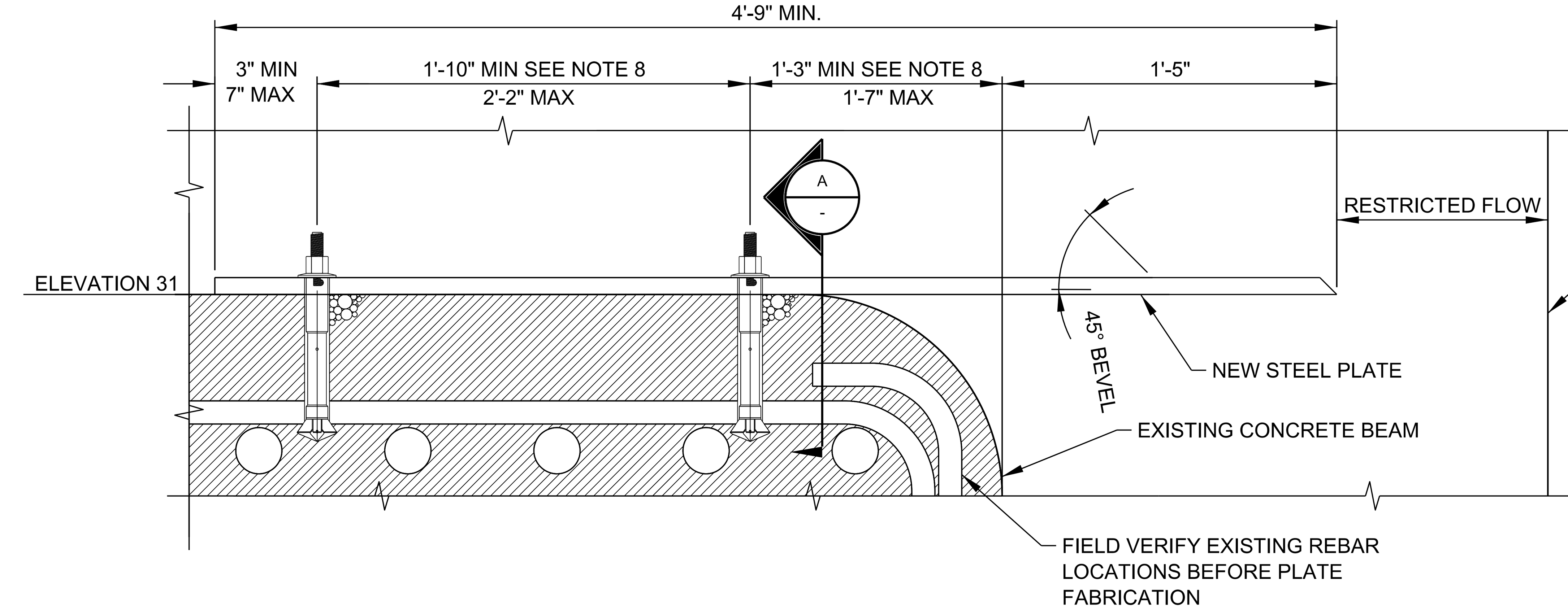
DATE AND TIME PLOTTED: 10/27/2014 1:30:05 PM
BY USERNAME: G2ECDACW
SHEET NAME: Untitled Sheet



A SLOT, UNIT 15
N.T.S.



1 DETAIL
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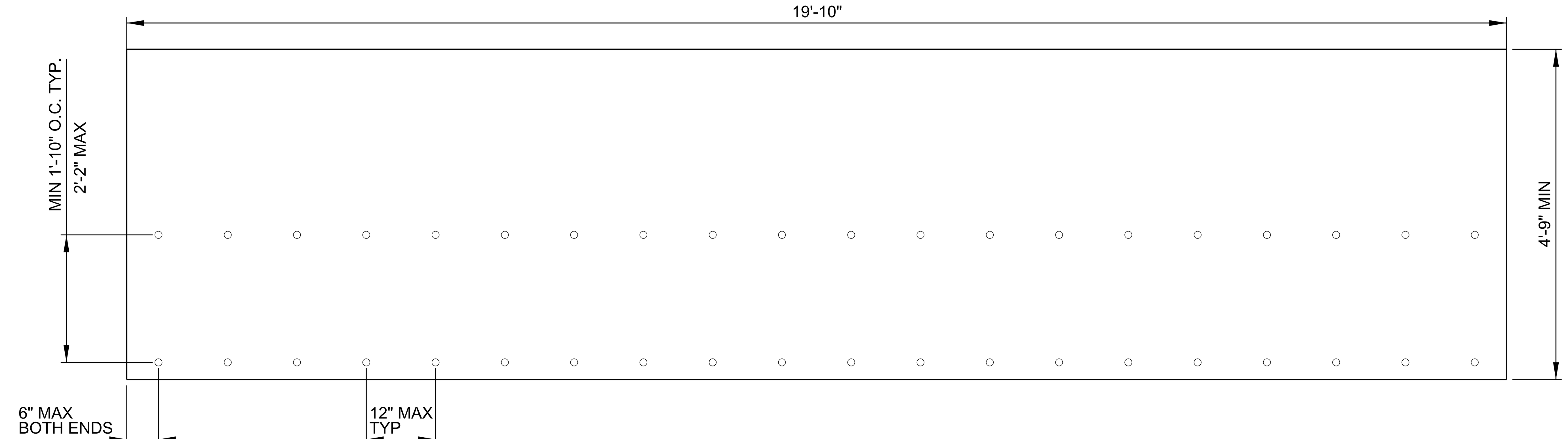
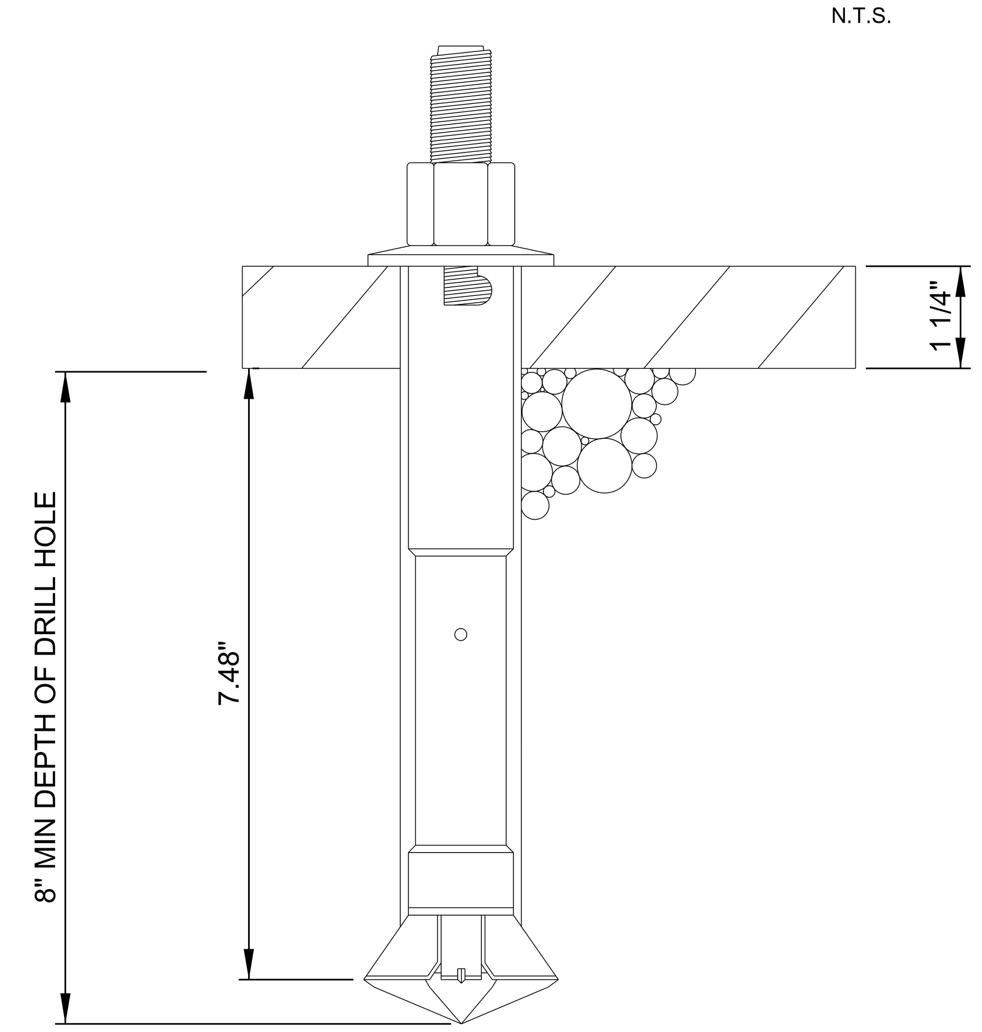


PLAN VIEW
N.T.S.



A SECTION
N.T.S.

NOTES:
1. FIELD VERIFY DIMENSIONS BEFORE PLATE FABRICATION
2. ALL PLATES SHALL BE STAINLESS STEEL AND CONFORM TO ASTM A240, TYPE 304.
3. ALL ANCHOR BOLTS SHALL BE STAINLESS STEEL HILTI HDA-TR 30 M16X190/40 OR APPROVED EQUAL.
4. ANCHOR BOLTS SHALL BE INSPECTED, TESTED, AND INSTALLED PER MANUFACTURER'S RECOMMENDATIONS.
5. NOMINAL PLATE HOLE DIMENSIONS FOR EACH ANCHOR BOLT SHALL BE 1 1/4" INCH +1/16 -0.0
6. REFFERENCE EXISTING REBAR ON DWG BDF-2-60/04 SEE INFORMATIONAL DRAWING (FIO)
7. ANCHOR BOLTS MINIMUM EMBEDMAENT DEPTH IS 7.48 INCHES.
8. THE CONTRACTOR SHALL MAP EXISTING EMBEDED REBAR LOCATIONS AT PLATE INSTALLATION AND SUBMIT A REPORT TO THE CONSTRUCTION OFFICE BEFORE FABRICATION AND INSTALLATION OF PLATE AND ANCHOR BOLTS.
9. THE CONTRACTOR SHALL LOCATE THE EXISTING REBAR AND ADJUST PLATE HOLES AND ANCHOR BOLT LOCATIONS TO AVOID EXISTING REBAR BEFORE PLATE FABRICATION AND DRILLING FOR THE ANCHOR BOLTS.
10. THE CONTRACTOR SHALL HAVE THE OPTION OF FABRICATING THE 19'-10"LONG PLATE IN SMALLER SECTIONS AND FIELD BUTT THE SECTIONS FOR A TOTAL DIMENSION AT 19'-10".
11. THE CONTRACTOR SHALL DESIGN AND INSTALL PERMANENT LIFTING EYES FOR THE PLATE SECTIONS.
12. THE CONTRACTOR SHALL USE ROTARY IMPACT HAMMER DRILLS FOR THE ANCHOR BOLTS.
13. TOTAL PLATE WEIGHT IS APPROXIMATELY 4,850 LBS.

US Army Corps of Engineers®
PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

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

DESIGNED BY: JEFFREY HICKS
DATE: 01/31/2014
DWN BY: G2ECDACW
CKD BY: G2ECDMR9
SOLICITATION NO.: W9127N-14-R-0026
SUBMITTED BY: MATTHEW D. HANSON, P.E.
CONTRACT NO.: W9127N-14-R-0044
PLOT SCALE: 1:1
PLOT DATE: 10/28/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF1.111_S-503XXX.dgn

BONNEVILLE LOCK AND DAM
SECOND POWERHOUSE
FISH GUIDANCE EFFICIENCY

TURBINE INTAKE
FLOW CONTROL PLATE
A SLOT

SHEET IDENTIFICATION
S-503
SHEET 0 OF 0

DESIGN FILE: \\nwd\nwp\ETDS\CADD-Workspaces\NWP\WorkSpace\projects\Local Resource\

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DATE AND TIME PLOTTED: 10/28/2014 8:03:35 AM
BY USERNAME: G2ECDACW
SHEET NAME: Untitled Sheet

APPENDIX F

Vertical Barrier Screen Modifications Design Calculations and Drawings

U.S. ARMY CORPS OF ENGINEERS OFFICE SYMBOL:

PROJECT:	COMPUTED BY:	DATE:
Bonneville Powerhouse II FGE	Mehdi Roshani	10/27/14
SUBJECT:	**CHECKED BY:**	**SHT.** 1 **OF** 1
VBS plate connection (Top plate)	MRA 10/30/14	**PART:**

$1\frac{1}{2}'' \sim \frac{1}{4}''$ filet weld :

$.3 \times 70 \times .707 \times .25 = 3.712$ kips / in length

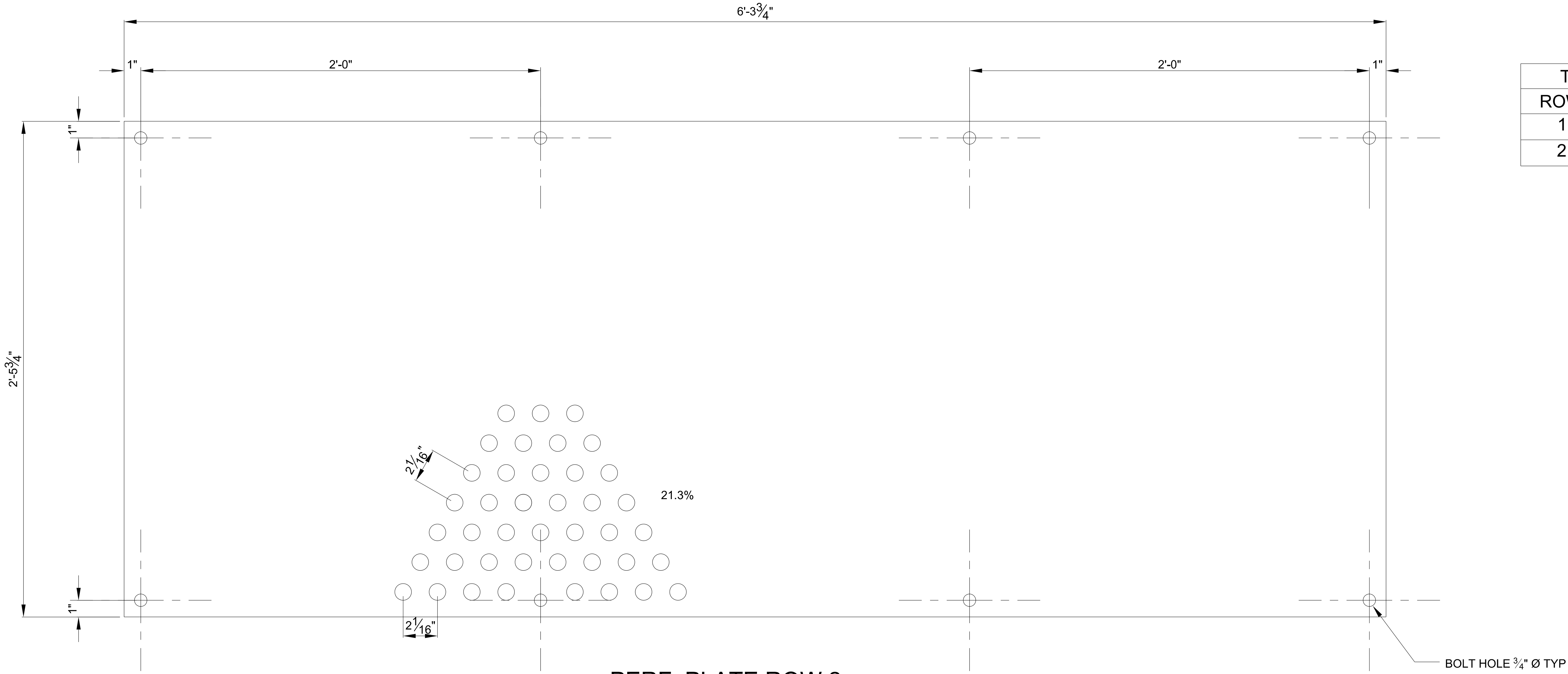
$1.5 \times 3.712 = 5.57$ kips

The area applied Load for each connection

$25\frac{3}{4} \times 14\frac{5}{8} = 377 \text{ in}^2 = 2.615 \text{ ft}^2$

$\frac{5.57 \times 1000}{2.615} = 2130$ PSF

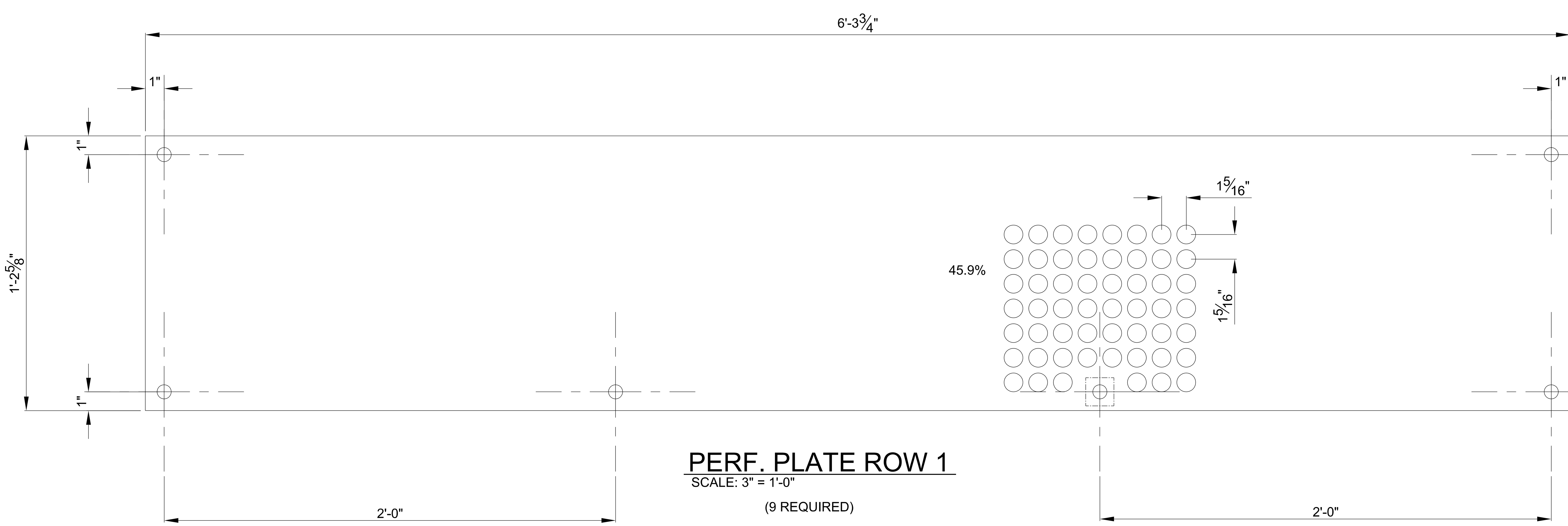
$\frac{2130}{62.4} = 34$ ft of head



PERF. PLATE ROW 2

SCALE: 3" = 1'-0"

(9 REQUIRED)

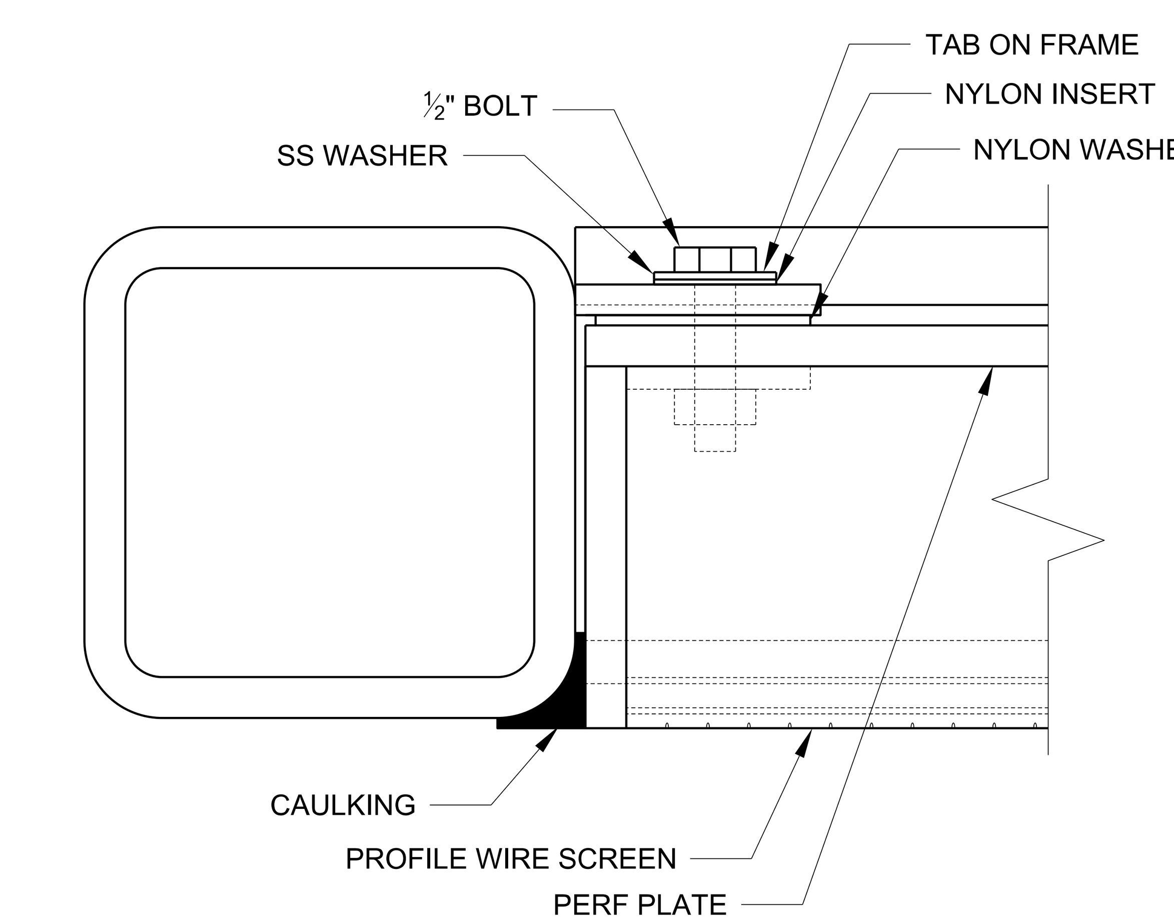


PERF. PLATE ROW 1

SCALE: 3" = 1'-0"

(9 REQUIRED)

TABLE 1: HOLE PATTERN DIMENSIONS				
ROW	% OPEN	DIA.	C-C	ANGLE
1	45.9%	1	1 5/16	90
2	21.3%	1	2 1/16	60



PROFILE WIRE/PERF. PLATE DETAIL

NOT TO SCALE

NOTES:

1. PERF PLATES SHALL BE 3/16" THICK STAINLESS STEEL AND CONFORM TO ASTM A240 TYPE 304.

2. INSTALL BOLTS FOR PERF PLATE AND PROFILE WIRE WITH NYLON BOLT INSULATORS.

3. HOLES TO BE UNIFORMLY SPREAD OVER ENTIRE PLATE. A 1" MARGIN WITHOUT POROSITY HOLES SHALL BE MAINTAINED AROUND THE PERIMETER OF ALL PERF PLATES, ALONG WITH A 1-1/2 SQUARE AT EACH BOLT HOLE.

US Army Corps of Engineers®
PORTLAND DISTRICT

MARK | DATE | DESCRIPTION | APPR.

DESIGNED BY: JEFFREY HICKS
DATE: 01/31/2014
DRAWN BY: G2ECUNS
CHECKED BY: G2ECDMR9
SOLICITATION NO.: W9127N-14-R-0026
SUBMITTED BY: MATTHEW D. HANSON, P.E.
CONTRACT NO.: W9127N-14-P-0044
PLOT SCALE: 1:1
PLOT DATE: 11/21/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: BDF-1.111_S-504XXX.dwg

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

AE / CONTRACTOR NAME
AE / CONTRACTOR ADDRESS
AE / CONTRACTOR (CITY, STATE)
AE / CONTRACTOR ID

BONNEVILLE LOCK AND DAM
SECOND POWERHOUSE
FISH GUIDANCE EFFICIENCY

VBS PERF PLATES

SHEET IDENTIFICATION
S-504
SHEET 0 OF 0

APPENDIX G

Construction Cost Estimate

Table of Contents

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: **B2 Fish Guidance Efficiency**
PROJECT NO: 0
LOCATION: Bonneville 2

DISTRICT: NWP District **PREPARED: 11/4/2015**
POC: CHIEF, COST ENGINEERING, Eileen Horiuchi

This Estimate reflects the scope and schedule in report; B2 Fish Guidance Efficiency DDR

Project First Cost (Constant Dollar Basis): Program Year (Budget EC): 2016; Effective Price Level Date: 1 OCT 15

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	**TOTAL ($K) J**	Spent Thru: **10/1/2013** ($K)	**TOTAL FIRST COST** ($K) K	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
06	FISH & WILDLIFE FACILITIES	$597	$87	14.5%	$684	0.4%	$600	$87	$687	$0	$687	2.2%	$613	$89	$702
	CONSTRUCTION ESTIMATE TOTALS:	$597	$87		$684	0.4%	$600	$87	$687	$0	$687	2.2%	$613	$89	$702
01	LANDS AND DAMAGES	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$165	$8	5.0%	$173	2.3%	$169	$8	$177	$0	$177	2.1%	$172	$9	$181
31	CONSTRUCTION MANAGEMENT	$87	$8	8.8%	$95	1.6%	$88	$8	$96	$0	$96	2.3%	$90	$8	$98
	PROJECT COST TOTALS:	$849	$102	12.1%	$951		$857	$103	**$960**	$0	**$960**	2.2%	$876	$105	$981

______________________ **CHIEF, COST ENGINEERING, Eileen Horiuchi**

______________________ **PROJECT MANAGER, George Medina**

______________________ **CHIEF, REAL ESTATE, Amanda Det**

______________________ **CHIEF, PLANNING, Joyce Casey**

______________________ **CHIEF, ENGINEERING, Lance Helwig**

______________________ **CHIEF, OPERATIONS, Dwayne Watsek**

______________________ **CHIEF, CONSTRUCTION, Karen Garmire**

______________________ **CHIEF, CONTRACTING, Tracy Wickham**

______________________ **CHIEF, PM-PB, Don Erickson**

______________________ **CHIEF, DPM, Laura Hicks**

ESTIMATED FEDERAL COST:	**100%**	**$981**
ESTIMATED NON-FEDERAL COST:	**0%**	**$0**
ESTIMATED TOTAL PROJECT COST:		**$981**

Filename: TPCS B2 FGE 2015 11-04.xlsx
TPCS

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: B2 Fish Guidance Efficiency
LOCATION: Bonneville 2
This Estimate reflects the scope and schedule in report; B2 Fish Guidance Efficiency DDR

DISTRICT: NWP District
POC: CHIEF, COST ENGINEERING, Eileen Horiuchi
PREPARED: 11/4/2015

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared:			**5-Sep-15**	Program Year (Budget EC):			2016					
		Effective Price Level:			1-Oct-14	Effective Price Level Date:			1 OCT 15					
				RISK BASED										
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***P***	***L***	***M***	***N***	***O***
	PHASE 1 or CONTRACT 1													
06	FISH & WILDLIFE FACILITIES	$597	$87	14.5%	$684	0.4%	$600	$87	$687	2017Q2	2.2%	$613	$89	$702
	CONSTRUCTION ESTIMATE TOTALS:	$597	$87	14.5%	**$684**		$600	$87	$687			$613	$89	$702
01	LANDS AND DAMAGES	$0	$0	0.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$15	$1	5.0%	$16	2.3%	$15	$1	$16	2016Q3	1.6%	$16	$1	$16
1.0%	Planning & Environmental Compliance	$6	$0	5.0%	$6	2.3%	$6	$0	$6	2016Q3	1.6%	$6	$0	$7
15.0%	Engineering & Design	$90	$5	5.0%	$95	2.3%	$92	$5	$97	2016Q3	1.6%	$94	$5	$98
1.0%	Reviews, ATRs, IEPRs, VE	$6	$0	5.0%	$6	2.3%	$6	$0	$6	2016Q3	1.6%	$6	$0	$7
1.0%	risks)	$6	$0	5.0%	$6	2.3%	$6	$0	$6	2016Q3	1.6%	$6	$0	$7
1.0%	Contracting & Reprographics	$6	$0	5.0%	$6	2.3%	$6	$0	$6	2016Q3	1.6%	$6	$0	$7
3.0%	Engineering During Construction	$18	$1	5.0%	$19	2.3%	$18	$1	$19	2017Q2	4.6%	$19	$1	$20
2.0%	Planning During Construction	$12	$1	5.0%	$13	2.3%	$12	$1	$13	2017Q2	4.6%	$13	$1	$13
1.0%	Project Operations	$6	$0	5.0%	$6	2.3%	$6	$0	$6	2016Q3	1.6%	$6	$0	$7
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$60	$5	8.8%	$65	1.6%	$61	$5	$66	2017Q2	2.3%	$62	$5	$68
2.0%	Project Operation:	$12	$1	8.8%	$13	1.6%	$12	$1	$13	2017Q2	2.3%	$12	$1	$14
2.5%	Project Management	$15	$1	8.8%	$16	1.6%	$15	$1	$17	2017Q2	2.3%	$16	$1	$17
	CONTRACT COST TOTALS:	$849	$102		$951		$857	$103	$960			$876	$105	$981

Filename: TPCS B2 FGE 2015 11-04.xlsx
TPCS

Abbreviated Risk Analysis

B2 FGE Flow Plates
Feasibility (Recommended Plan)

Meeting Date: 20-Oct-15

PDT Members
Note: PDT involvement is commensurate with project size and involvement.

Project Management:	George Medina
Planner:	
Technical Lead:	Corina Popescu
Contracting:	Mike Grasso
Real Estate:	
Relocations:	
Environmental:	Jon Rerecich
Engineering & Design:	
Technical Lead:	
Geotech:	
Hydrology:	Laurie Ebner
Civil:	
Structural:	Mehdi Roshani
Mechanical:	James Schroeder
Electrical:	
Cost Engineering:	Pat Noland
Construction:	
Operations:	Roger James
Public Affairs	
OTHER:	
OTHER:	
OTHER:	
OTHER:	
OTHER:	
OTHER:	
OTHER:	

Abbreviated Risk Analysis

Project (less than $40M): **B2 FGE Flow Plates**
Project Development Stage: **Feasibility (Recommended Plan)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 597,472**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		0.00%	$ -	$ -
1	04 DAMS	Mob Install Steel Plate	$ 145,162		18.92%	$ 27,461	$ 172,623.31
2	04 DAMS	Furnish and Install Steel Plate	$ 284,065		11.17%	$ 31,720	$ 315,784.71
12		Remaining Construction Items	$ 168,245	*39.2%*	16.28%	$ 27,397	$ 195,642.26
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$ 716,966		5.00%	$ 35,848	$ 752,814.72
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$ 657,219		8.88%	$ 58,348	$ 715,567.15

Totals				
Real Estate	$ -	0.00%	$ -	$ -
Total Construction Estimate	$ 597,472	14.49%	$ 86,578	$ 684,050
Total Planning, Engineering & Design	$ 716,966	5.00%	$ 35,848	$ 752,815
Total Construction Management	$ 657,219	8.88%	$ 58,348	$ 715,567
Total	$ 1,971,658		$ 180,775	$ 2,152,432

B2 FGE Flow Plates
Feasibility (Recommended Plan)
Abbreviated Risk Analysis

Meeting Date: 20-Oct-15

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	75%
PS-1	Mob Install Steel Plate	• Design confidence?	• number of wells need plates	• Due to outage schedule the contractor will be limited to (2) gate wells at a time.	Unlikely	Marginal	0
PS-2	Furnish and Install Steel Plate	• Potential for scope growth, added features and quantities?	• increased number of wells needing plates	• potential to impact quaunties	Unlikely	Marginal	0
PS-12	Remaining Construction Items	• Potential for scope growth, added features and quantities?	• Rebar Location	• Where it is located, hitting it, damaged it	Unlikely	Significant	1
PS-13	Planning, Engineering, & Design	• Potential for scope growth, added features and quantities?	• Additional design needed	• unusal rebar pattern	Unlikely	Marginal	0
PS-14	Construction Management	• Potential for scope growth, added features and quantities?	• Additional scope could lead to added S&A.	• scope growth could lead to a longer construction schedule	Unlikely	Marginal	0
Acquisition Strategy							
						Max Potential Cost Growth	30%
AS-1	Mob Install Steel Plate	• Contracting plan firmly established?	• Unqualified Contractors working in extreme weather environment.	• Contractor has completed same project 2 years in a row successfully	Unlikely	Significant	1
AS-2	Furnish and Install Steel Plate	• Contracting plan firmly established?	• Unqualified Contractors working in extreme weather environment.	• Contractor has completed same project 2 years in a row successfully	Unlikely	Significant	1

AS-12	Remaining Construction Items	• Contracting plan firmly established?	• Unqualified Contractors working in extreme weather environment.	• Contractor has completed same project 2 years in a row successfully	Unlikely	Significant	1
AS-13	Planning, Engineering, & Design	• Contracting plan firmly established?	• Unqualified Contractors working in extreme weather environment.	•Not a concern for PED	Unlikely	Marginal	0
AS-14	Construction Management	• Contracting plan firmly established?	• Unqualified Contractors working in extreme weather environment.	• S&A increase due to delays related to contractor failures or weather	Possible	Marginal	1
Construction Elements							
						Max Potential Cost Growth	**25%**
CE-1	Mob Install Steel Plate	• High risk or complex construction elements, site access, in-water?	• Unusual equipment needed to mobilize • Extreme weather in the Gorge	• Accelerated schedule due to harsh weather and in-water flows	Possible	Significant	2
CE-2	Furnish and Install Steel Plate	• Unique construction methods?	• potential for material availabitlity	Would increase cost of the material	Unlikely	Marginal	0
CE-12	Remaining Construction Items	• Accelerated schedule or harsh weather schedule?	Extreme weather conditions , would cause issues with the crane usage	Would delay the schdule	Possible	Significant	2
CE-14	Construction Management	• Accelerated schedule or harsh weather schedule?	• Accelerated schedule could cause for more S&A oversight	• Increase amount of shifts or OT needed for QA over site.	Possible	Marginal	1
Quantities for Current Scope							
						Max Potential Cost Growth	**20%**
Q-1	Mob Install Steel Plate	• Level of confidence based on design and assumptions?	• Quantities could change the amount of equipment needed for mob/demob	• More or less equipment may be need to get to the site	Possible	Marginal	1
Q-2	Furnish and Install Steel Plate	• Level of confidence based on design and assumptions?	• Design is not complete	• Quantities change will affect equipment and labor as well as material cost, cuurently the design is complete	Unlikely	Significant	1
Q-12	Remaining Construction Items	• Level of confidence based on design and assumptions?	Possible ground penetrating radar could inaccurate	Possible hit rebar when installing the plate	Unlikely	Critical	2

Q-13	Planning, Engineering, & Design	• Level of confidence based on design and assumptions?	• Quantities increase as design gets more detailed	• Increase in OT needed by design team	Unlikely	Marginal	0
Q-14	Construction Management	• Level of confidence based on design and assumptions?	• Quality control check applied? • Possibility for increased quantities due to loss, waste, or subsidence?	• Could lead to additional QA and project Engineer time.	Unlikely	Negligible	0
Specialty Fabrication or Equipment							
						Max Potential Cost Growth	75%
FE-1	Mob Install Steel Plate	• Unusual parts, material or equipment manufactured or installed?	• Unusual equipment needed to mobilize • Equipment not available	• Equipment should be available for this type of work	Unlikely	Significant	1
FE-2	Furnish and Install Steel Plate	• Unusual parts, material or equipment manufactured or installed?	• Large crane may not be available	• Should be able to find adequate equipment, otherwise would impact schedule	Unlikely	Significant	1
Cost Estimate Assumptions							
						Max Potential Cost Growth	35%
CT-1	Mob Install Steel Plate	• Site accessibility, transport delays, congestion?	• Assume highway could be in accessable	• Should the weather turn bad could limit highway access	Unlikely	Significant	1
CT-2	Furnish and Install Steel Plate	• Assumptions related to prime and subcontractor markups/assignments?	• Prime contractor could use a sub not familiar project.	• Could increase contingency cost from the sub	Unlikely	Marginal	0
External Project Risks							
						Max Potential Cost Growth	40%
EX-1	Mob Install Steel Plate	• Political influences, lack of support, obstacles?	• Outage schedule is affect by either BPA or the Bonneville project staff	• BPA could change the outage schedule	Unlikely	Significant	1
EX-2	Furnish and Install Steel Plate	• Unanticipated inflations in fuel, key materials?	• Outage schedule is affect by either BPA or the Bonneville project staff	• Material is not volitile at this time	Unlikely	Marginal	0
EX-12	Remaining Construction Items	• Political influences, lack of support, obstacles?	• Outage schedule is affect by either BPA or the Bonneville project staff	BPA could change the outage schedule	Unlikely	Marginal	0
EX-13	Planning, Engineering, & Design	• Political influences, lack of support, obstacles?	• Outage schedule is affect by either BPA or the Bonneville project staff	• BPA could change the outage schedule	Unlikely	Marginal	0
EX-14	Construction Management	• Political influences, lack of support, obstacles?	• Outage schedule is affect by either BPA or the Bonneville project staff	• BPA could change the outage schedule	Unlikely	Marginal	0

B2 FGE Flow Plates
Feasibility (Recommended Plan)
Abbreviated Risk Analysis

Typical Risk Elements	Potential Risk Areas								
	Mob Install Steel Plate	Furnish and Install Steel Plate	0	0	0	0	Remaining Construction Items	Planning, Engineering, & Design	Construction Management
Project Scope Growth	-	-	-	-	-	-	1	-	-
Acquisition Strategy	1	1	-	-	-	-	1	-	1
Construction Elements	2	-	-	-	-	-	2	-	1
Quantities for Current Scope	1	1	-	-	-	-	2	-	-
Specialty Fabrication or Equipment	1	1	-	-	-	-	-	-	-
Cost Estimate Assumptions	1	-	-	-	-	-	-	-	-
External Project Risks	1	-	-	-	-	-	-	-	-

APPENDIX H

Biological Testing Results

EVALUATION OF SURVIVAL AND GATEWELL RESIDENCE TIME FOR TULE STOCK SUBYEARLING CHINOOK SALMON IN A MODIFIED GATEWELL AT THE BONNEVILLE DAM SECOND POWERHOUSE

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ABSTRACT

Smolt monitoring observations in 2007 and tests conducted by NOAA Fisheries in 2008-09 confirmed that tule stock subyearling Chinook salmon *Oncorhynchus tshawytscha* passing through Second Powerhouse gatewells were subject to higher mortality rates during turbine operation at the upper end of the 1% peak efficiency range than at lower operational levels within the range. In 2013, Turbulence Reduction Devices were evaluated and determined to not be effective in reducing mortality at higher flows. This year, we evaluated a prototype flow control plate in combination with modified vertical barrier screens intended to reduce the flow up the gatewell and improve survival. All three gate slots of Turbine Unit 15 had the same modified vertical barrier screens installed. In addition, the "A" slot had 50% flow control plates, the "B" slot had 25% plates and the "C" slot had no flow control plates installed. The difference in control plates was designed to allow for the differences in flow that occur across each gatewell of the turbine units. Slot 14A was unmodified and served as the control.

We conducted two evaluations. The first compared an unmodified gatewell (14A) at the middle 1% operation (approximately 15.0 kcfs) with a modified gatewell (15A) at the upper 1% operation (18.0 kcfs). The second evaluation compared the same unmodified gatewell 14A at the middle 1% operation against a gatewell (15C) at the upper 1% operation. Sample sizes were set to detect a 3% additive mortality difference at α=0.05.

All test fish were obtained from the Spring Creek National Fish Hatchery. Fish were typically held for 24 hours before being PIT tagged. After tagging, fish were again held for 24 hours to detect mortality and loose tags before being released. Of the 6,626 total fish tagged for the study we had 4 mortalities and 0 loose tags prior to release. On study days, releases occurred in the morning, and were made into the turbine intakes of both gateslots. Fish were released into each turbine intake through a 4" flex hose from the intake deck. Fish were recaptured at the Juvenile Fish Monitoring Facility (JFMF) using the PIT-tag separation-by-code (SbyC) system.

For the first series (14A v 15A), a total of 3,250 fish in thirteen replicates were released from 1 April through 7 May 2015. Test fish averaged 70 mm fork length (range 52 to 103 mm) increasing from 65 mm to 75mm over the study period

The overall observed mortality proportion during the evaluation of 15A v 14A was 0.021 and 0.209 for 15A and 14A, respectively, which was a significant difference. This was the proportion of fish that were mortalities either when recaptured in the SbyC system or recovered as bare tags in the sump located just upstream of the primary dewatering structure at the JFMF. The observed mortality varied over the course of the evaluation. During the first six replicates, observed mortality was significantly higher in 14A, while it was significantly lower over the last replicates.

The overall proportion of test fish recaptured from 15A releases was lower for the last six replicates which may have affected the results.

Under the assumption fish not detected after release are mortalities, the maximum possible mortality proportion was 0.260 and 0.238 for 14A and 15A, respectively, which was not significantly different.

The percentage of tagged fish that were recaptured by the SbyC system of those that were detected by the full flow detectors were both high at 0.958 and 0.978 in 14A and 15A, respectively.

For the second series (14A v 15C), a total of 3,137 fish in twelve replicates were released from 12 – 29 May 2015. Test fish averaged 79 mm fork length (range 57 to 112 mm) and increased from 75 mm to 81mm over the study period

The overall observed proportion was relatively high for both groups (0.977 and 0.950 for 14A and 15C, respectively). As in the first evaluation, the recapture proportion was over 0.95 for both groups.

The observed mortality proportion for both groups was low (0.021 and 0.006, for 14A and 15C respectively) and not significantly different.

As was observed in the first evaluation, the percentage of test fish that were recaptured with the SbyC system was just over 0.95 for both release groups.

We also released three groups of fish into the bypass system collection channel during each evaluation series (total of 239 fish) to quantify baseline timing, tag loss, and mortality not associated with the gatewell environment. We recaptured 229 of these fish and none were observed with any injury or mortality. The ten fish not recaptured were all detected on the full flow detectors. Nine of them were "missed" by the SbyC system, and the other fish was detected in the smolt monitoring sample. The overall median passage time was just over 38 minutes from time of release to first detection at the full flow detectors.

We note that test results were achieved using what is generally acknowledged to be one of the most sensitive stocks of fish passing Bonneville Dam. Therefore, results may not be applicable to other stocks and may not accurately represent the overall passage mortality at the Second Powerhouse for tule stock subyearling Chinook salmon. These and other study aspects, including gatewell residence times, will be discussed during our presentation.

	4/1	4/2	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
Turbine Unit 13	on	on	off 0600 - 0940 off for 3:40	on	on	on	on	on	on	off 0210-0905
Turbine Unit 14										
min (kcfs)	13.9	14.1	14	14.1	14.2	13.6	14	13.9	13.9	13.6
max (kcfs)	15	15.1	15.1	15	15.2	15	15.3	15	15.2	15.3
Turbine Unit 15										
min (kcfs)	17.3	17.6	17	17.2	17.8	17.7	17.9	17.8	17.2	16.7
max (kcfs)	18.7	18.9	18.7	18.7	18.9	18.6	18.9	18.7	18.4	18.1
Turbine Unit 16	on	on	on	on	on	on	on	on	on	off 0015-2400 off for 23:45

dates of releases in yellow

	4/11	4/12	4/13	4/14	4/15
Turbine Unit 13	off 0405-0850, 1710-2400	off	off 0000-0545, 2300-2400	off 0000-0450, 2250-2400	off 0000-0605, 0625-2400
Turbine Unit 14					
min (kcfs)					
max (kcfs)					
Turbine Unit 15					
min (kcfs)					
max (kcfs)					
Turbine Unit 16	off	off	off	off	off

	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23
Turbine Unit 13	off 0000-1100,1625-2400	off	off	off	off 0000-0905	off 0305-2400	off	off 0000-0730, 1340-2400
						off for 20:55		off for 10:50
Turbine Unit 14								
min (kcfs)						13.9	10.5	13.9
max (kcfs)						15.3	14.9	15.6
Turbine Unit 15						17.7	17.1	16.7
min (kcfs)						18.9	18.6	18.6
max (kcfs)								
Turbine Unit 16	off 0000-1145, 1225-2400	off	off	off	off	off	off	off

0:00
13:40
10:20

	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1
Turbine Unit 13	off	off	off	off 0000-0510	off 0205-1710	off 0205-1555, 2200-2400	off	off 0000-1705, 1755-2400
Turbine Unit 14								
min (kcfs)	14.2							
max (kcfs)	15.5							
Turbine Unit 15								
min (kcfs)								
max (kcfs)								
Turbine Unit 16	off	off	off	off	off	off	off	off

	5/2	5/3	5/4	5/5	5/6	5/7	5/8	5/9	5/10	5/11
Turbine Unit 13	off 0000-1155	on	off 0100-0605, 2105-2400	off	off	off	off	off	off	off
Turbine Unit 14										
min (kcfs)				14.1	14.1	14	14.1			
max (kcfs)				15	14.9	14.9	14.7			
Turbine Unit 15				17.8	17.8	17.7	17.8			
min (kcfs)				18.8	18.8	18.7	18.4			
max (kcfs)										
Turbine Unit 16	off	off	off	off	off	off	off	off	off	off
						16:55				
						6:50				
						10:05				
						10:55				
						21:00				

	5/12	5/13	5/14	5/15	5/16	5/17	5/18	5/19
Turbine Unit 13	off 0000-1055, 1505-2400	off	off	off	off	off 0000-1955	off 0650-1655	off 0305-2400
	off for 19:50						off for 10:05	off for 20:55
Turbine Unit 14								
min (kcfs)	13.5	14	14	13.9	13.8		14.3	14.2
max (kcfs)	15	14.9	15.1	15.2	14.5		15.1	14.9
Turbine Unit 15	17.4	17.8	17.9	17.7	17.6		17.9	17.8
min (kcfs)	18.8	18.8	18.8	18.8	18.6		18.9	18.7
max (kcfs)								
Turbine Unit 16	off 0000-1200, 1340-2400	off	off	off	off	off	off 0000-1800	off 0205-2400
	off for 22:20						off for 18:00	off for 21:55

	5/20	5/21	5/22	5/23	5/24	5/25
Turbine Unit 13	off 0000-1700, 2300-2400	off 0000-0600, 2110-2400	off	off 0000-0750	off 0120-0800	on
	off for 18:00	off for 16:55				
Turbine Unit 14						
min (kcfs)	14	13.9	14	14		
max (kcfs)	15	14.8	15	14.6		
Turbine Unit 15	17.8	17.5	17.7	17.8		
min (kcfs)	18.6	18.8	18.9	18.4		
max (kcfs)						
Turbine Unit 16	off	off	off	off	off 0000-1155	off 0905-2400
			0:00			
			13:40			
			10:20			
			14:35			
			0:55			

	5/26	5/27	5/28	5/29	5/30	5/31
Turbine Unit 13	on	off 0640-1420, 2300-2400	off 0000-0900, 2325-2400	off 0000-1605, 2300-2400	off	off 0000-1100
		off for 8:40	off for 9:35	off for 17:05		
Turbine Unit 14						
min (kcfs)		13.9	14	14	14	
max (kcfs)		14.9	15.6	15	15.4	
Turbine Unit 15		17.5	17.8	17.6	18.1	
min (kcfs)		18.9	18.8	18.7	19	
max (kcfs)						
Turbine Unit 16	off 0000-1500	off 0000-1435, 1705-2400	off	off	off	off
		off for 21:30				

To: Randy Absolon
From: Benjamin Sandford
Date: 13 August, 2015
Subject: Preliminary analyses for project: B2 FGE Improvements, Post Construction Gatewell Improvement Testing (update from 23 and 30 July and 3 August due to travel time update, adding mortality proportion of observed sample, and some name changes

Data

Subyearling Chinook salmon were PIT-tagged and released between 1 April and 29 May 2015 into gatewell slots 14A , 15A, and 15C. A portion of the tagged fish were detected at the Second Powerhouse Juvenile Fish Monitoring Facility (JFMF) and a portion were diverted into sample tanks using the Sort-by-Code system. Diverted fish were examined for injury (rare) and mortality. Date and time of first detection at the JFMF was noted for detected fish. Useful metrics were defined and calculated as follows:

ObsProp = Observed proportion of each release that were subsequently detected somewhere in the PIT-tag system of the JFMF

RecapProp = Observed proportion of JFMF-detections that were recaptured in sample tanks and examined for injury/mortality

ObsMortProp = Proportion of ObsMort to Total in recapture sample

MaxMortProp = Estimated mortality proportion of released fish =
ObsMort + NonRecapObs*ObsMortProp + NonObs,
Where ObsMort = Observed mortalities in recapture sample,
NonRecapObs = Observed JFMF detections that were not in recapture sample
And NonObs = Fish released but not observed anywhere in the JFMF

Gatewell Residence Time (GRT) = Median time from release to first detection in the JFMJ for each cohort of daily-released PIT-tagged fish into each gatewell

Consider the following possible assumptions:

A1 – Mortality was related only to gatewell treatment or passage to the JFMF, and not as a result of being sampled by the Sort-by-Code system. Therefore, all mortality was expressed fairly quickly after the mechanism that caused it, and fish not sampled by the Sort-by-Code system had the same mortality probability as those sampled.

A2a – Fish not detected by the JFMF were mortalities that prevented the PIT tag from reaching the facility. This means the JFMF detection probability was assumed to be 100% and tagged fish did not have an opportunity to exit the dam without passing through the JFMF.

A2b – Fish not detected by the JFMF passed another route that prevented the PIT tag from being detected. This means the JFMF detection probability was assumed to be 0% and these fish would have had the same mortality probability as the JFMF-detected fish if they had used the same passage route.

ObsMortProp is an appropriate estimate of the true treatment mortality under A1 and A2b. MaxMortProp is an appropriate estimate of the true treatment mortality under A1 and A2a. We made assumption A1 for this study. We also assumed that neither assumptions A2a or A2b were probably completely correct, but rather an unknown proportion of fish "fit" under each of them. Unfortunately we have no way of estimating that proportion. Therefore, accurate estimates of treatment mortality in this study lie between these two estimates. When the proportion of undetected fish was small, ObsMortProp was assumed to be a reasonably accurate estimate of the particular treatment mortality.

Summary data results are as follows:

Table 1a. Series 1, Unit 14A. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
4/1	100	0.930	0.978	0.187	0.244	0.106
4/2	94	0.872	1.000	0.122	0.234	0.057
4/3	101	0.960	0.990	0.292	0.320	0.263
4/4	100	0.920	0.978	0.256	0.315	0.038
4/5	100	0.920	0.957	0.443	0.488	0.347
4/6	102	0.951	0.969	0.340	0.373	0.463
4/7	100	0.930	0.968	0.322	0.370	0.251
4/8	99	0.960	0.916	0.184	0.217	0.044
4/9	101	0.970	0.949	0.323	0.343	0.289
4/21	116	0.879	0.961	0.122	0.228	0.506
4/23	250	0.912	0.890	0.059	0.142	0.487
5/5	125	0.992	0.952	0.034	0.042	0.544
5/7	233	0.966	0.942	0.038	0.071	0.495
	Mean	0.936	0.958	0.209	0.260	0.299
	SE	0.010	0.008	0.036	0.035	0.053

Table 1b. Series 1, Unit 15A. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
4/1	100	0.950	1.000	0.000	0.050	0.095
4/2	99	0.914	0.975	0.026	0.105	0.035
4/3	102	0.882	1.000	0.000	0.118	0.054
4/4	100	0.910	1.000	0.044	0.130	0.040
4/5	100	0.890	0.989	0.000	0.110	0.057
4/6	100	0.840	1.000	0.000	0.160	0.175
4/7	101	0.634	0.984	0.032	0.386	0.106
4/8	100	0.620	0.952	0.051	0.412	0.076
4/9	100	0.580	0.983	0.018	0.430	0.068
4/21	115	0.443	0.922	0.085	0.594	0.075
4/23	240	0.783	0.963	0.006	0.221	0.522
5/5	125	0.800	0.980	0.010	0.208	0.537
5/7	247	0.834	0.971	0.000	0.166	0.543
	Mean	0.775	0.978	0.021	0.238	0.183
	SE	0.043	0.006	0.007	0.046	0.056

Table 2a. Series 2, Unit 14A. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
5/12	131	0.985	0.938	0.017	0.032	0.532
5/13	129	0.984	0.937	0.000	0.016	0.044
5/14	123	0.984	0.942	0.018	0.034	0.392
5/15	130	0.954	0.976	0.025	0.070	0.548
5/18	130	0.977	0.969	0.016	0.039	0.545
5/19	130	0.985	0.953	0.041	0.056	0.527
5/20	129	0.984	0.984	0.016	0.031	0.393
5/21	130	0.954	0.960	0.076	0.118	0.288
5/22	140	0.986				0.407
5/27	130	0.992	0.953	0.000	0.008	0.369
5/28	130	0.946	0.935	0.017	0.070	0.548
5/29	135	0.993	0.978	0.008	0.015	0.568
	Mean	0.977	0.957	0.021	0.044	0.430
	SE	0.005	0.005	0.006	0.010	0.044

Table 2b. Series 2, Unit 15C. Metrics for PIT-tag released subyearling Chinook salmon at Bonneville Dam 2nd Powerhouse in 2015.

Release Date	Release Number	ObsProp	RecapProp	ObsMortProp	MaxMortProp	Median Gatewell Residence Time (d)
5/12	131	0.954	0.984	0.000	0.046	0.345
5/13	131	0.962	1.000	0.008	0.046	0.368
5/14	118	0.983	0.948	0.000	0.017	0.337
5/15	134	0.985	0.962	0.016	0.030	0.511
5/18	130	0.969	0.968	0.016	0.047	0.497
5/19	130	0.915	0.958	0.018	0.101	0.633
5/20	130	0.815	0.962	0.000	0.185	0.296
5/21	130	0.962	0.992	0.008	0.046	0.545
5/22	142	0.944				0.567
5/27	130	0.954	0.847	0.000	0.046	0.518
5/28	130	0.962	0.920	0.000	0.038	0.545
5/29	134	0.993	0.955	0.000	0.007	0.475
	Mean	0.950	0.954	0.006	0.055	0.470
	SE	0.014	0.013	0.002	0.015	0.031

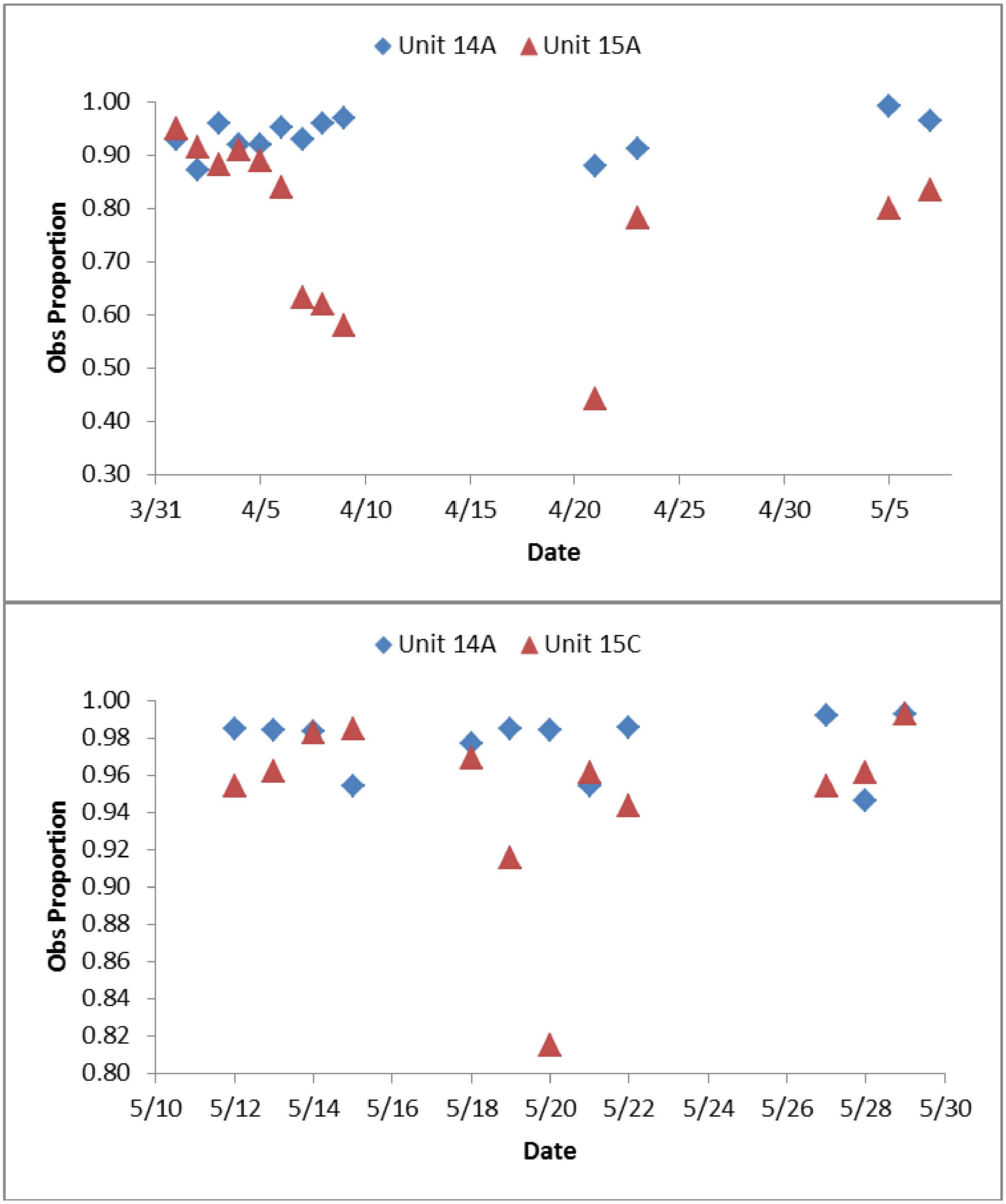

Figure 1. Observed proportion of fish detected on the JFMF in 2015.

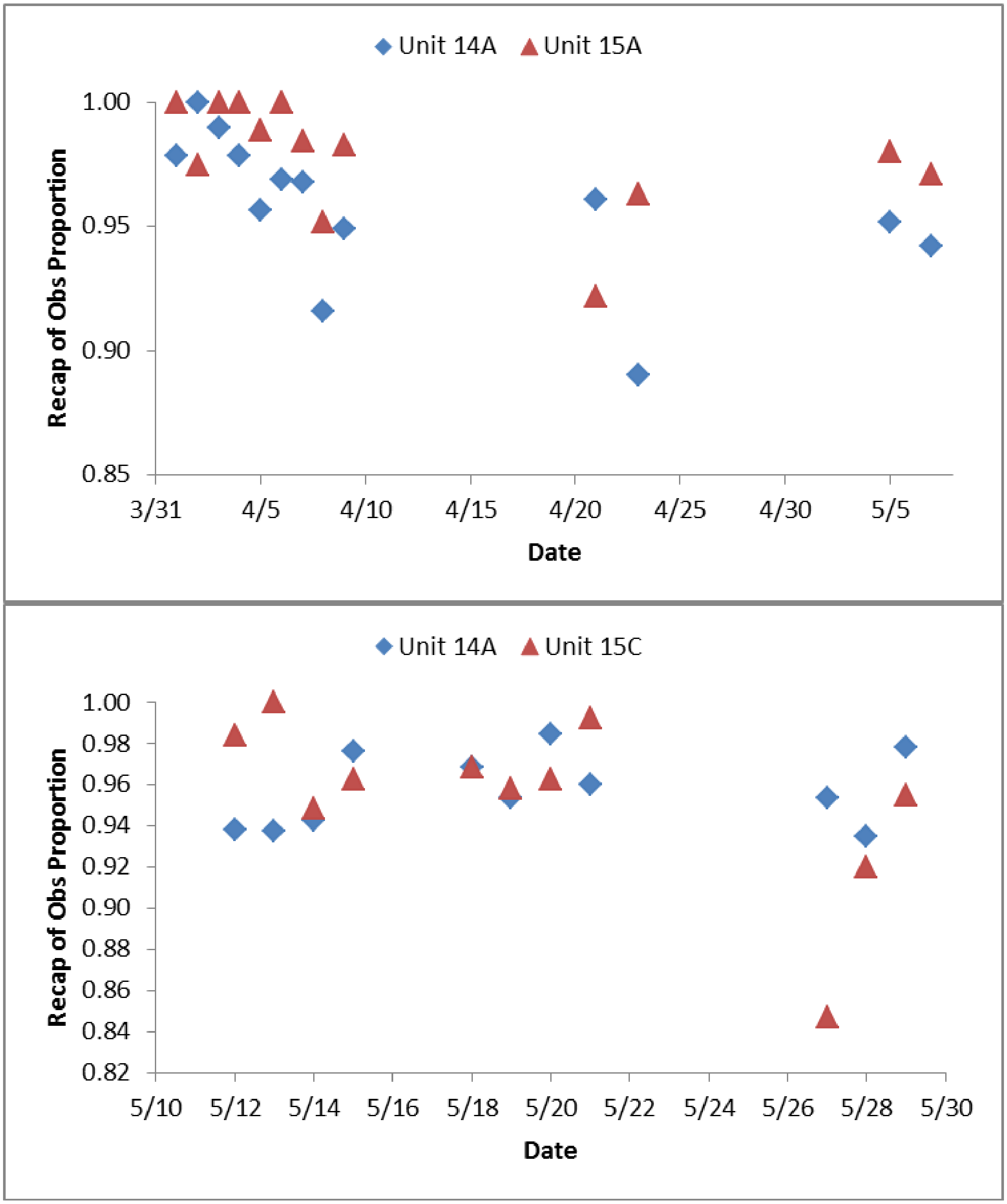

Figure 2. Recapture proportion of JFMF-detected fish in 2015.

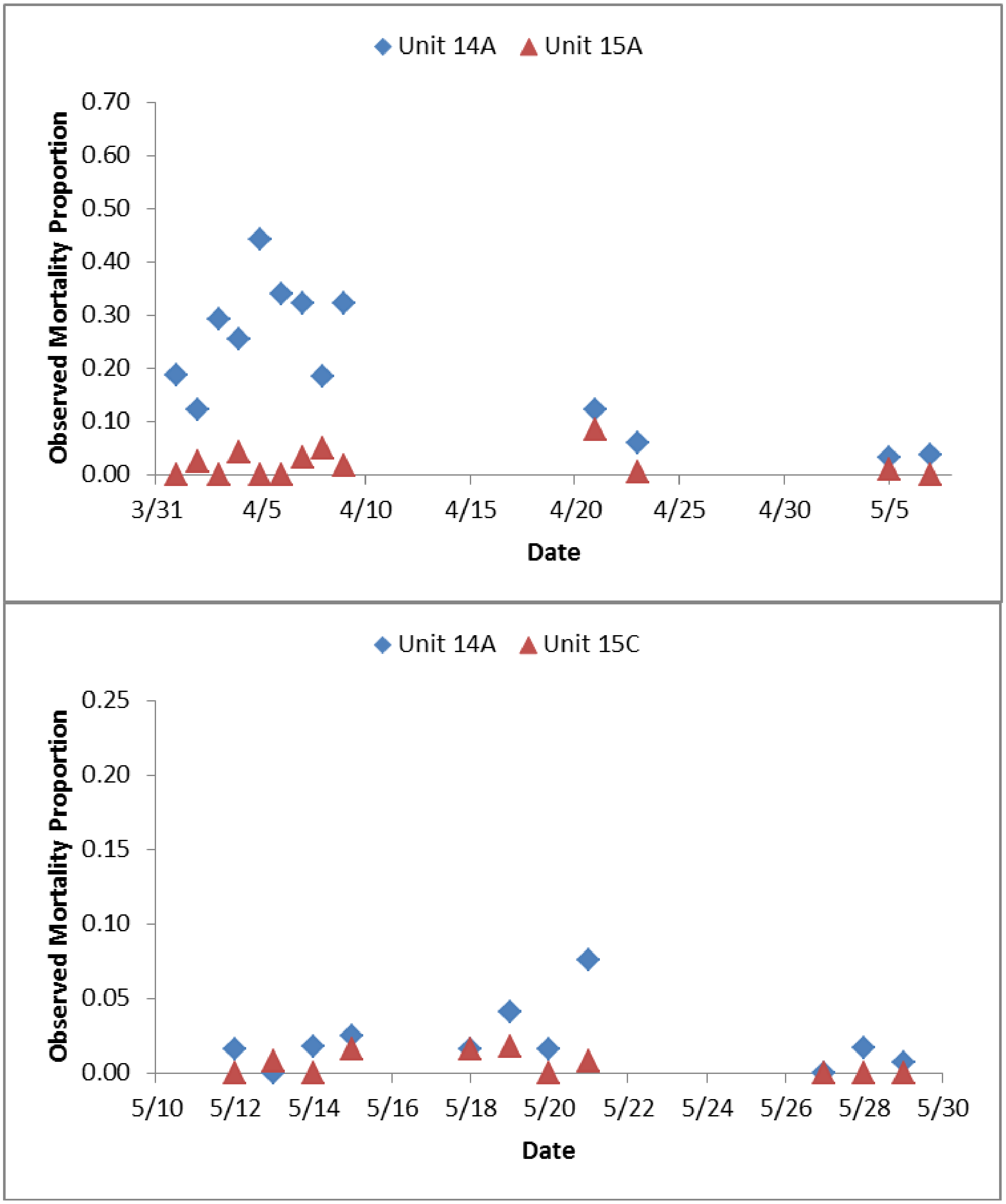

Figure 3. Observed mortality for fish observed in the recapture sample in 2015.

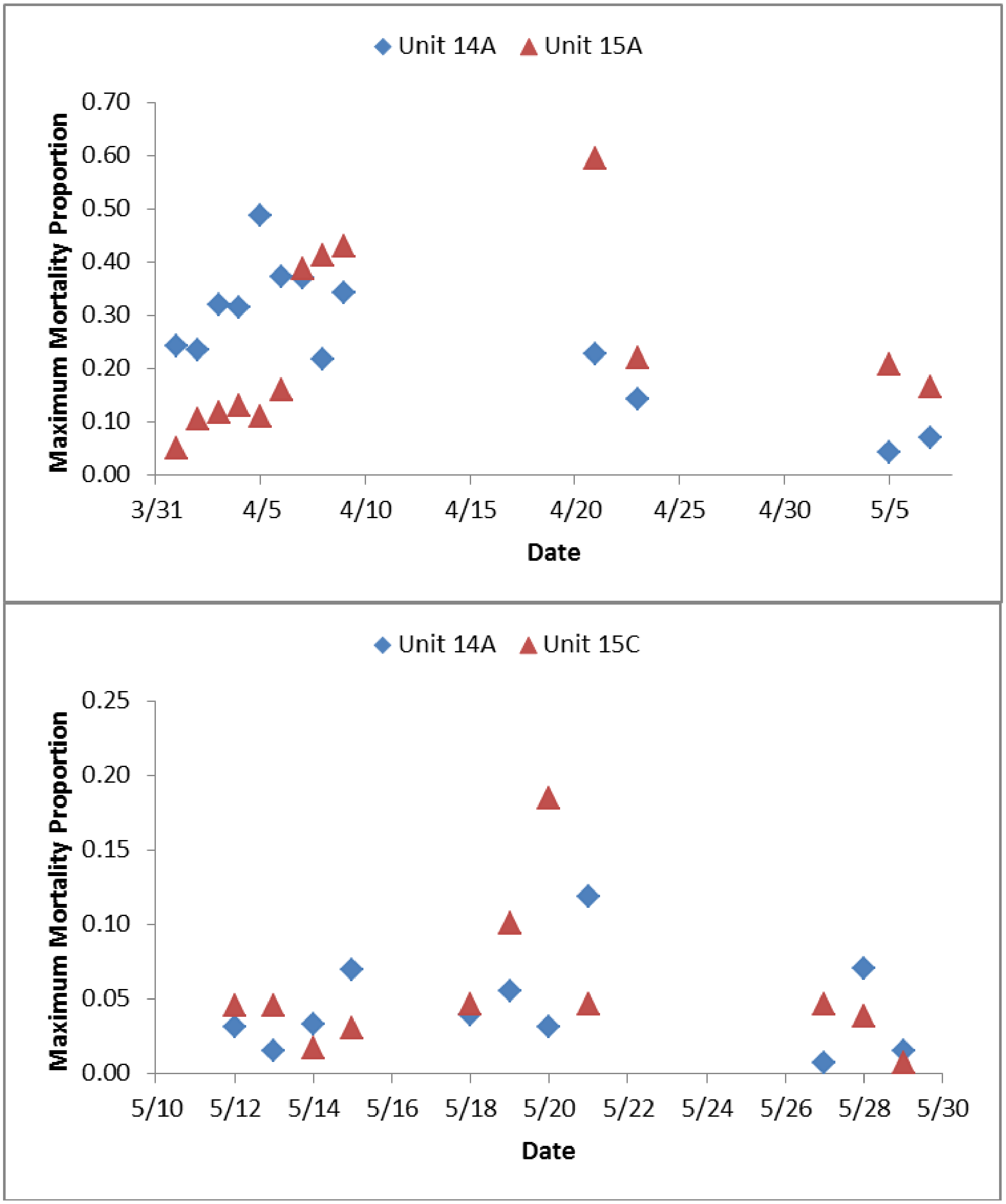

Figure 4. Maximum estimated mortality for fish observed in the recapture sample, estimated for fish in the JFMF but not recaptured, and assumed for non-detected fish in 2015

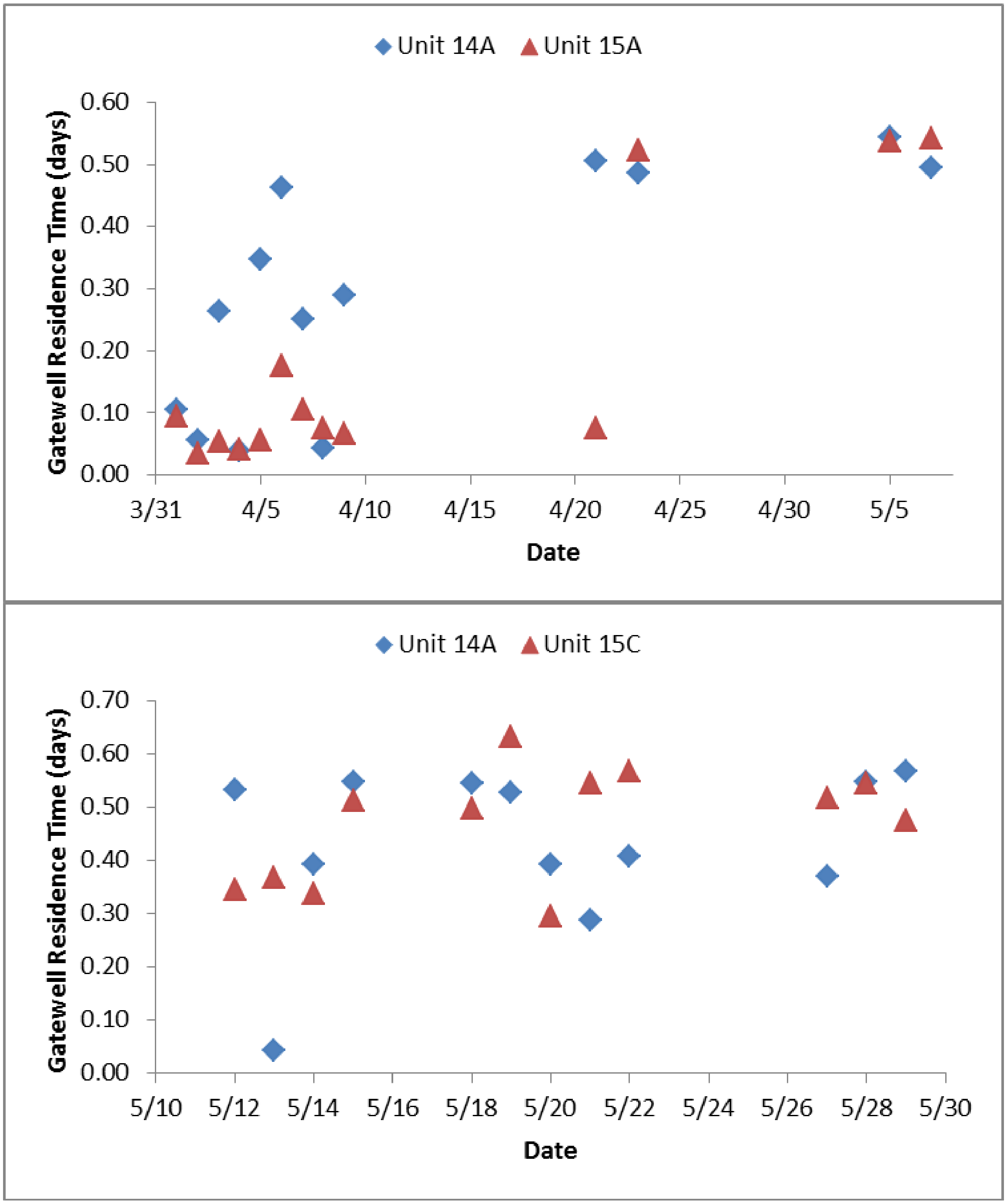

Figure 5. Median Gatewell Residence time from Gatewells 14A, 15A, or 15C to first detection in the JFMF in 2015.

Comparisons

From the proposal for this study, the objectives were:

1 & 2. Hydraulic testing (not included).

3. Estimate Spring Creek NFH juvenile subyearling Chinook salmon mortality and gatewell residence time at the upper and middle 1% peak efficiency range under the following gatewell configurations in 15A and 14A.

   A. Modified Gatewell 15A at upper 1% operation.
   B. Unmodified Gatewell 14A at middle 1% operation.

4. Estimate Spring Creek NFH juvenile subyearling Chinook salmon mortality and gatewell residence time at the upper and middle 1% peak efficiency range of Gatewell Slots 14A and 15C.

   A. Unmodified Gatewell Slot 15C at upper 1% operation.
   B. Unmodified Gatewell Slot 14A at middle 1% operation.

5. Compare treatment A against treatment B for Objective 3 and 4 releases (sample sizes shall be calculated to detect a difference in fish condition of 3% at $\alpha = 0.05$).

   i. Fish Condition (FC): $H_0 = FC_{upper15A} = FC_{mid14A}$;
   $H_A = FC_{upper15A} \neq FC_{mid14A}$

   ii. Gatewell Residence Time (GRT): $H_0 = GRT_{upper15A} = GRT_{mid14A}$;
   $H_A = GRT_{upper15A} \neq GRT_{mid14A}$

   iii. Fish Condition (FC): $H_0 = FC_{upper15C} = FC_{mid14A}$;
   $H_A = FC_{upper15C} \neq FC_{mid14A}$

   iv. Gatewell Residence Time (GRT): $H_0 = GRT_{upper15C} = GRT_{mid14A}$;
   $H_A = GRT_{upper15C} \neq GRT_{mid14A}$

The above metrics were used to provide estimates for objectives 3 and 4 (Note means and se's in Tables 1a, 1b, 2a, and 2b) and to make comparisons for objective 5 using paired t-tests. Results are in Tables 2a and 2b and visually represented in Figures 6-8. These preliminary results suggest that mortality for comparison "i." above was significantly higher in Unit 14A than in Unit 15A using the observed sample mortality ($P < 0.001$) but using the maximum estimated mortality it was undetermined since the first 6 groups had higher mortality in Unit 14A but the last 6 groups had lower for a non-significant difference overall (*P*=0.705). For the latter metric, dividing the data into the "obvious" groupings, the early part (releases on 1-6 April showed significantly higher mortality in Unit 14A (*P* = 0.003) and for 7 April-7 May showed significantly lower mortality in Unit 14A (*P* =0.021) For comparison "iii." above, there was a significant difference in mortality using either the observed metric (Unit 14A > Unit 15C by 1.5%, *P* = 0.029) but not significant using the maximum estimated mortality metric (Unit 14A < Unit 15C by 1.1%, *P* = 0.549). For comparison "ii." above, Gatewell Residence Time was around three hours significantly longer than for Unit 15A (*P* = 0.021) but not different at all for Unit 15C (*P* = 0.402). Further, perhaps more complex, analysis will be explored to examine these patterns.

Boxplots of Gatewell Residence Time distributions are in the Appendix. Fish that were observed as mortalities at the JFMF Sort-by-Code sample had somewhat longer times than live fish (Figure A1). This difference needs to be discussed. There were not generally large differences in median Gatewell Residence Time as noted in Table 3a and 3b, but there were some observed differences in the shape of the distributions (Figures A2 and A3).

Table 3a. Paired differences for metrics comparing conditions in Unit 14A and 15A gatewells in 2015 at Bonneville Dam 2nd Powerhouse.

Release Date	ObsProp Difference	RecapProp Difference	ObsMortProp Difference	MaxMortProp Difference	Median Gatewell Residence Time (d) Difference	MaxMortProp Difference 4/1 - 4/6	MaxMortProp Difference 4/7 - 5/7
4/1	-0.020	-0.022	0.187	0.194	0.011	0.194	
4/2	-0.042	0.025	0.096	0.129	0.022	0.129	
4/3	0.078	-0.010	0.292	0.202	0.209	0.202	
4/4	0.010	-0.022	0.212	0.185	-0.002	0.185	
4/5	0.030	-0.032	0.443	0.378	0.290	0.378	
4/6	0.111	-0.031	0.340	0.213	0.288	0.213	
4/7	0.296	-0.017	0.290	-0.017	0.146		-0.017
4/8	0.340	-0.036	0.133	-0.195	-0.032		-0.195
4/9	0.390	-0.034	0.305	-0.087	0.222		-0.087
4/21	0.436	0.039	0.037	-0.366	0.431		-0.366
4/23	0.129	-0.072	0.054	-0.079	-0.035		-0.079
5/5	0.192	-0.028	0.024	-0.167	0.007		-0.167
5/7	0.132	-0.029	0.038	-0.095	-0.048		-0.095
	0.160	-0.021	0.189	0.023	0.116	0.217	-0.144
	0.044	0.008	0.038	0.058	0.044	0.034	0.043
t	3.625	-2.681	4.958	0.388	2.664	6.320	-3.328
df	12	12	12	11	12	4	5
P-value	0.003	0.020	0.000	0.705	0.021	0.003	0.021
95% CI Lower	0.064	-0.037	0.106	-0.106	0.021	0.122	-0.255

95% CI Upper	0.256	-0.004	0.271	0.151	0.211	0.312	-0.033

Table 3b. Paired differences for metrics comparing conditions in Unit 14A and 15C gatewells in 2015 at Bonneville Dam 2nd Powerhouse.

Release Date	ObsProp Difference	RecapProp Difference	ObsMortProp Difference	MaxMortProp Difference	Median Gatewell Residence Time (d) Difference
5/12	0.031	-0.046	0.017	-0.014	0.187
5/13	0.023	-0.063	-0.008	-0.030	-0.324
5/14	0.001	-0.006	0.018	0.017	0.056
5/15	-0.031	0.014	0.009	0.039	0.037
5/18	0.008	0.000	0.000	-0.008	0.049
5/19	0.069	-0.005	0.023	-0.045	-0.106
5/20	0.169	0.022	0.016	-0.153	0.098
5/21	-0.008	-0.032	0.068	0.072	-0.258
5/22	0.042				-0.160
5/27	0.038	0.107	0.000	-0.038	-0.149
5/28	-0.015	0.015	0.017	0.032	0.003
5/29	0.000	0.023	0.008	0.008	0.093
	0.027	0.003	0.015	-0.011	-0.040
	0.015	0.013	0.006	0.018	0.045
t	1.787	0.189	2.545	-0.620	-0.872
df	11	10	10	10	11
P-value	0.102	0.854	0.029	0.549	0.402
95% CI Lower	-0.006	-0.027	0.002	-0.051	-0.139
95% CI Upper	0.061	0.033	0.028	0.029	0.060

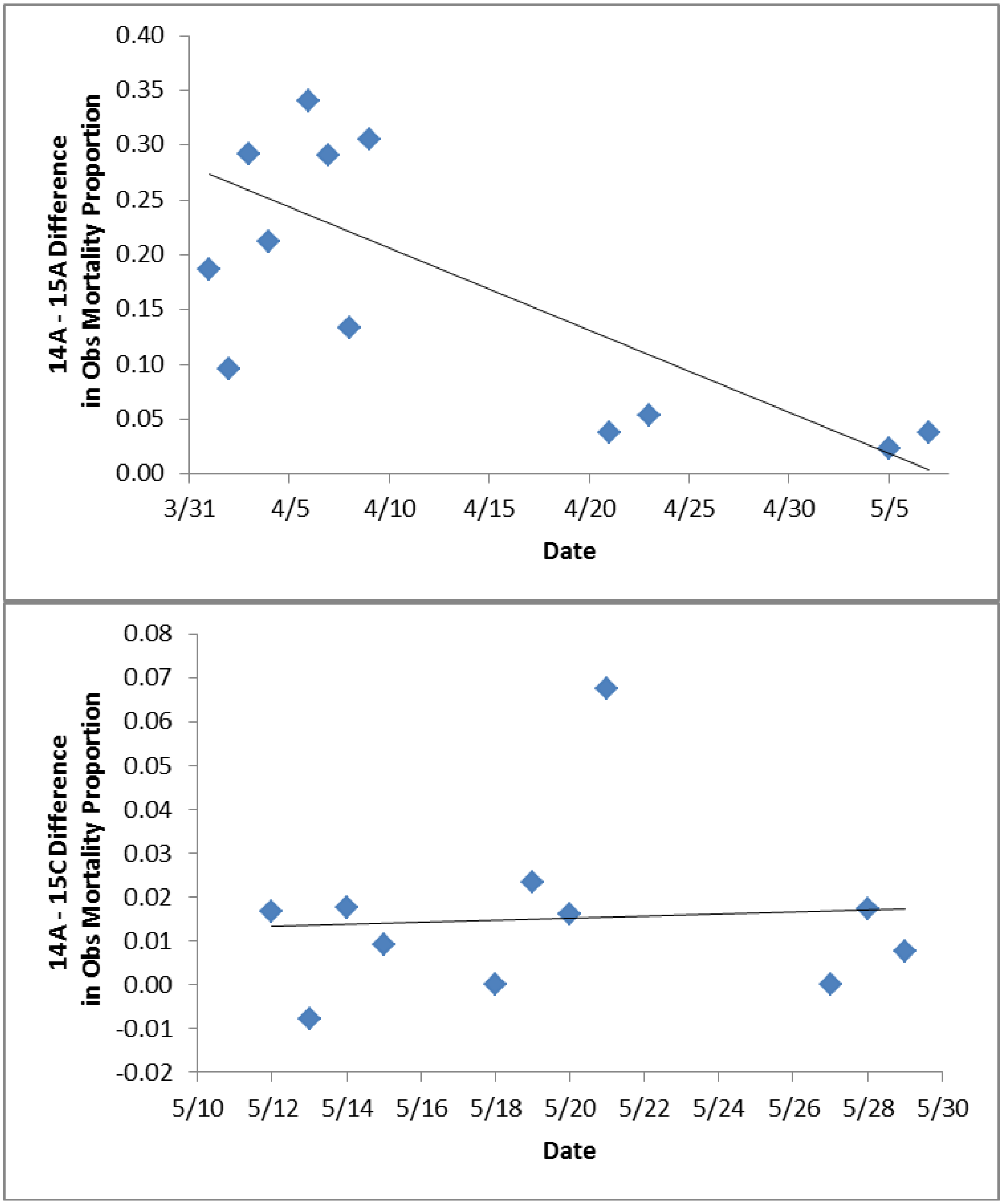

Figure 6. Paired comparison of observed mortality for different gatewell treatments in 2015. The line represents a standard linear regression curve.

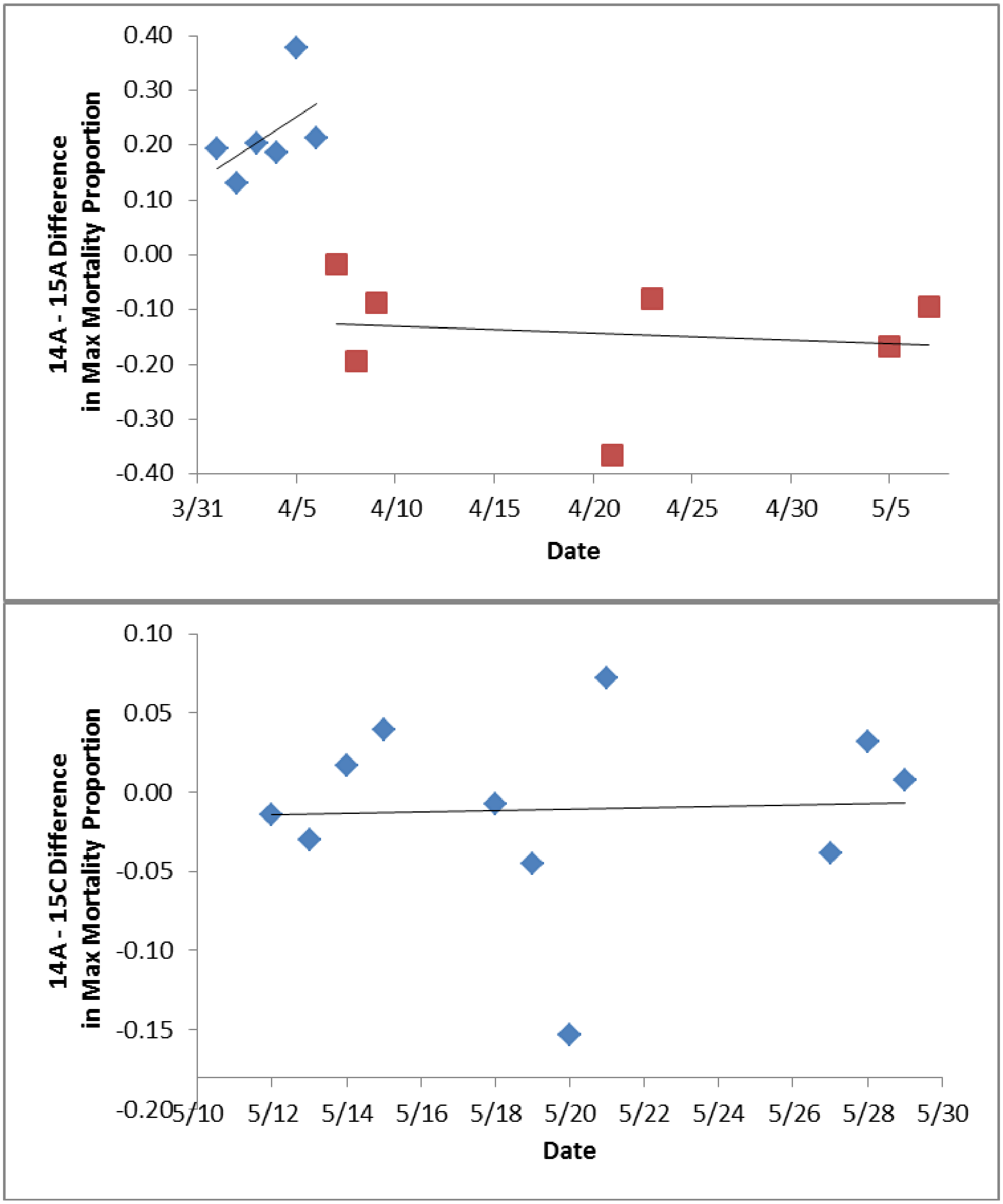

Figure 7. Paired comparison of maximum estimated mortality for different gatewell treatments in 2015. The line represents a standard linear regression curve. The dataset for the first series was, for visual purposes, split into early and late periods that indicated opposite results.

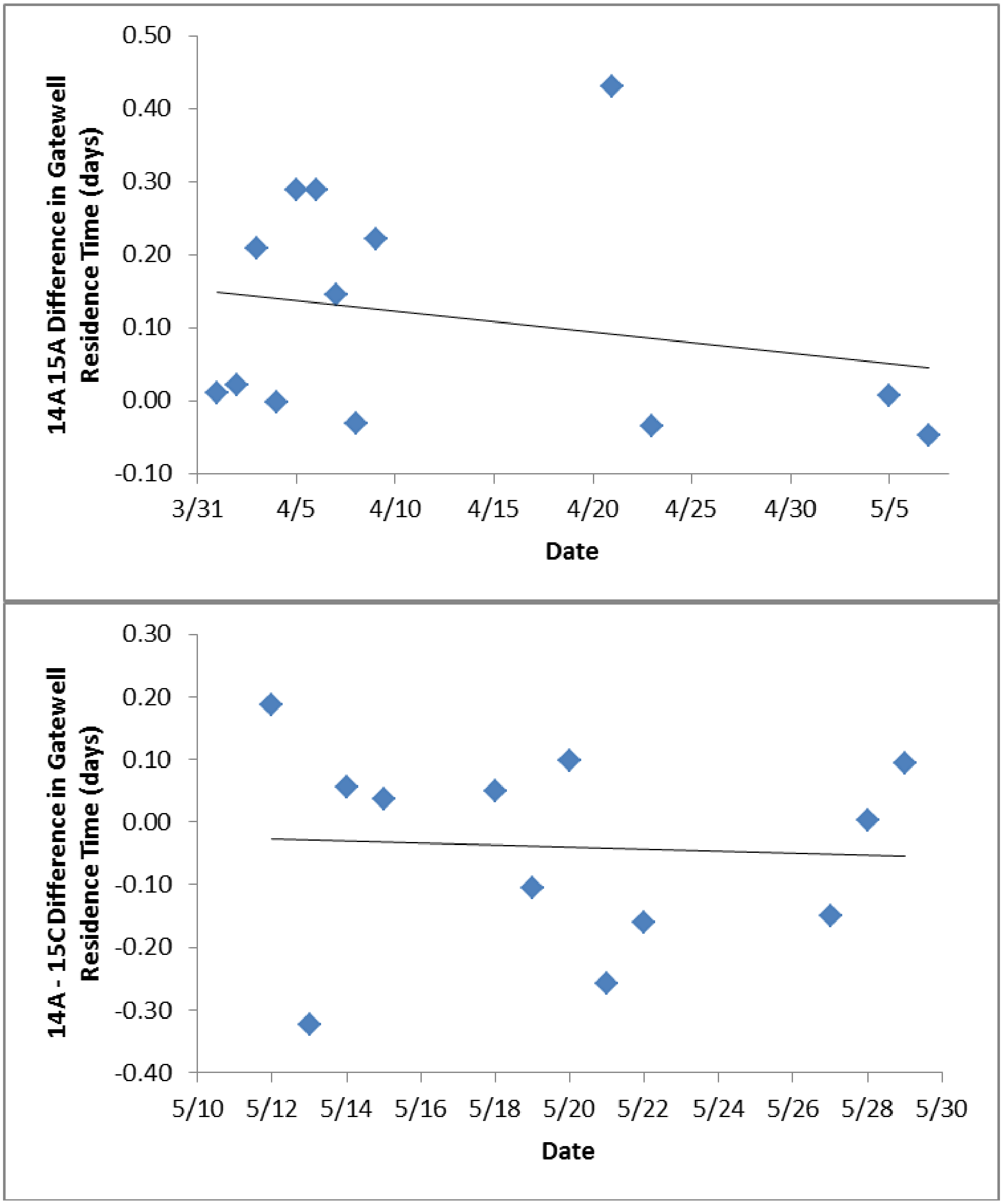

Figure 8. Paired comparison of Gatewell Residence Time for different gatewell treatments in 2015. The line represents a standard linear regression curve.

Appendix

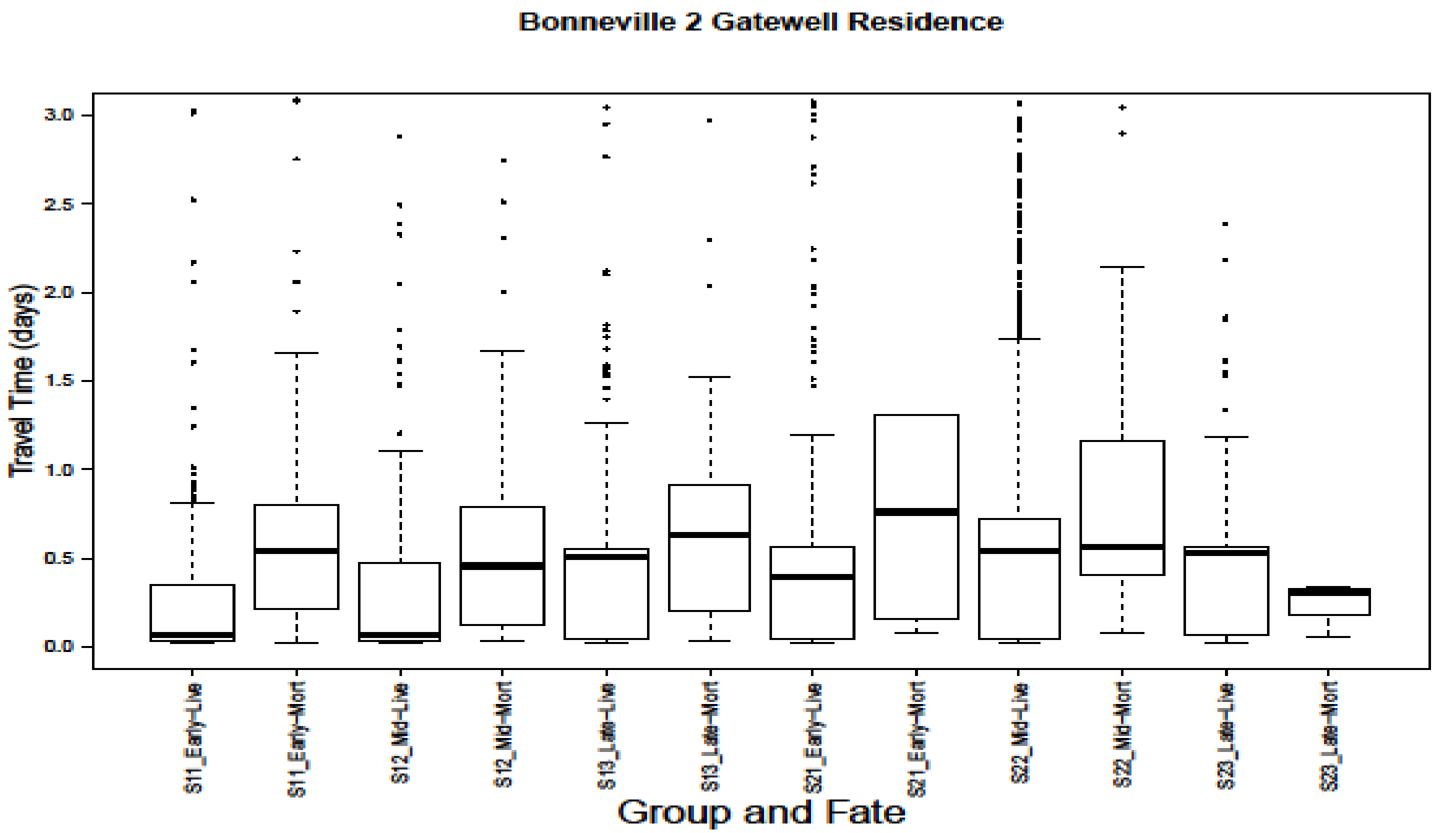

Figure A1. Gatewell Residence Time Distributions for various release day groupings for Series 1 (Unit 14A vs Unit 15A) and Series 2 (Unit 14A vs Unit 15C) further divided into fish observed at JFMF as Live vs Mortalities for Bonneville Dam 2nd Powerhouse in 2015.

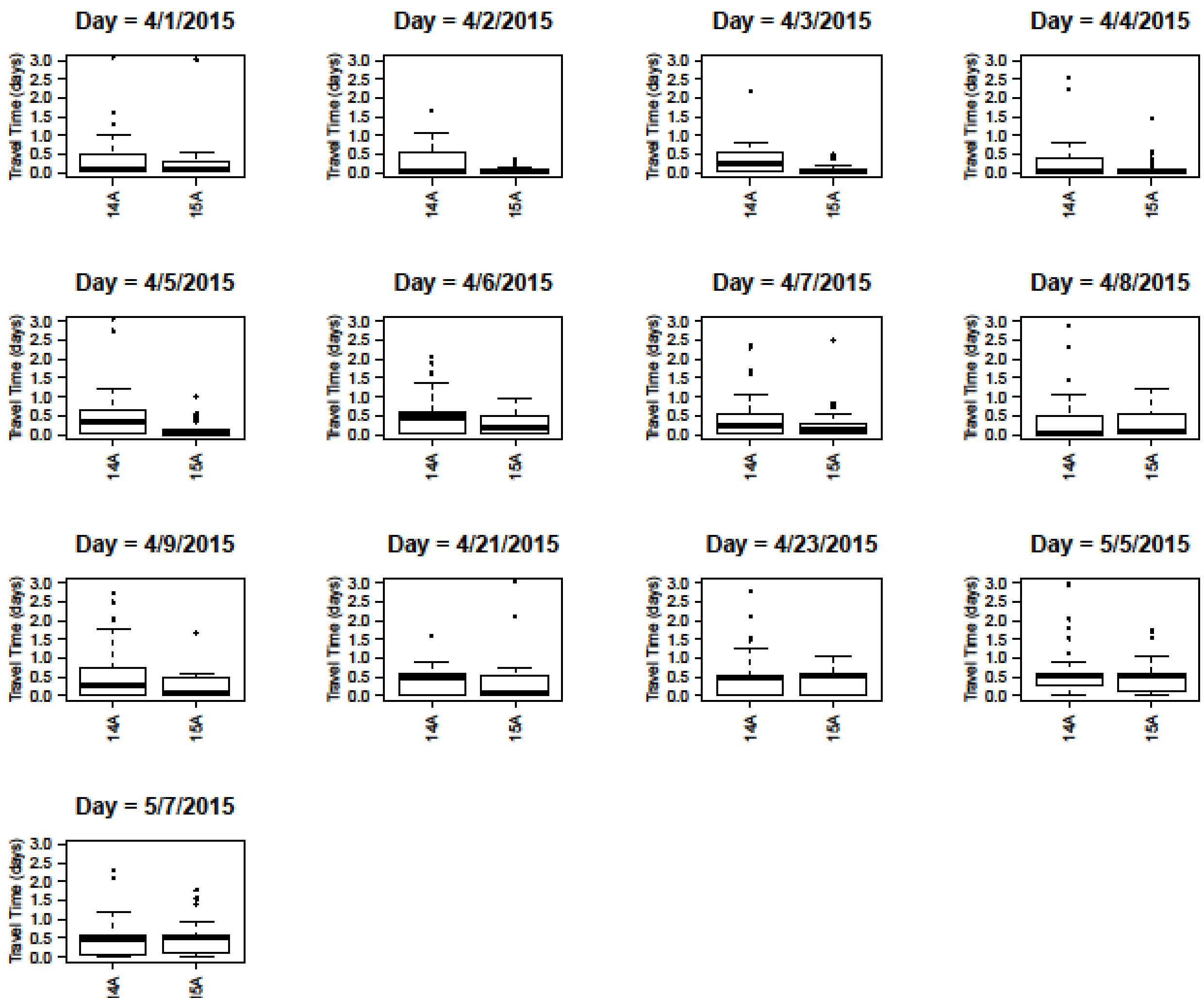

Figure A2. Gatewell Residence Time Distributions by Release Day Replicate for Series 1 comparing Unit 14A and Unit 15A at Bonneville Dam 2nd Powerhouse in 2015.

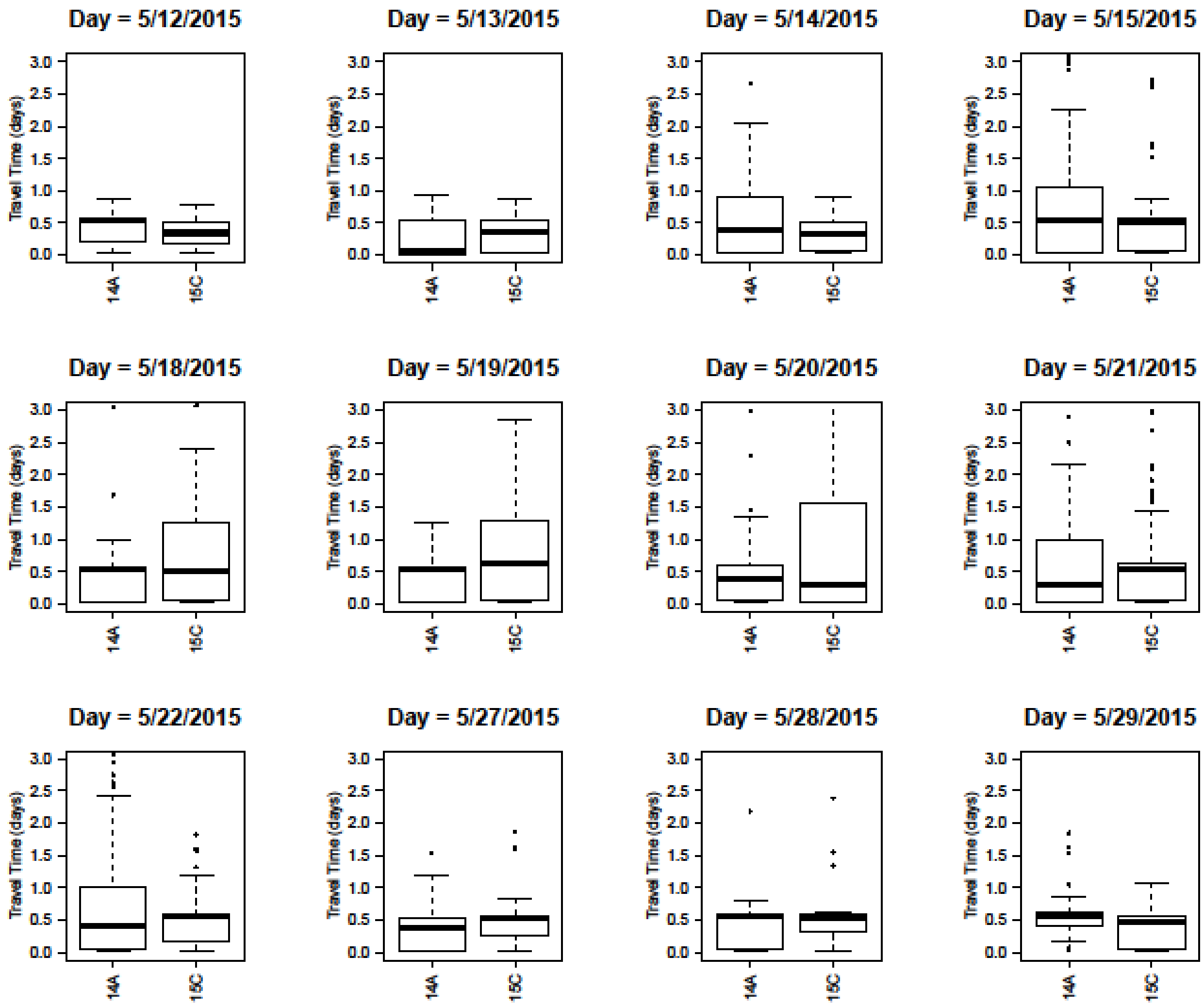

Figure A3. Gatewell Residence Time Distributions by Release Day Replicate for Series 2 comparing Unit 14A and Unit 15C at Bonneville Dam 2nd Powerhouse in 2015.

PIT tags recovered from sump at the JFMF primary dewatering structure 6/23/15

	Number	Percent
from 14A rel (14Av15A)	47	70.1
from 14A rel (14Av15C)	9	13.4
from 15A	4	6.0
from 15C	2	3.0
Other researcher	5	7.5
	67	100

Release date	14A	15A
4/1	7	0
4/2	1	0
4/3	1	0
4/4	4	1
4/5	3	0
4/6	6	0
4/7	5	1
4/8	1	0
4/9	9	1
4/21	2	1
4/23	1	0
4/23	0	0
5/5	3	0
5/7	4	0
5/7	0	0
	47	4

Release date	14A	15C
5/12	2	0
5/13	0	0
5/14	1	0
5/15	1	0
5/18	1	0
5/19	0	1
5/20	0	0
5/21	3	1
5/22	0	0
5/27	0	0
5/28	0	0
5/29	1	0
	9	2

APPENDIX I

Hydraulic Testing Results

US Army Corps
of Engineers
Portland District

Data Collection Report

B2 VBS Velocity Profiles
Bonneville Dam, Second Powerhouse

Prepared for:

U.S. Army Corps of Engineers
Portland District

August 21, 2015

ALDEN

US Army Corps of Engineers
Portland District

Data Collection Report

B2 VBS Velocity Profiles

Bonneville Dam, Second Powerhouse

Contract No.
W9127N-12-D-0001, Task Order No. 0005

Prepared for:

U.S. Army Corps of Engineers
Portland District

Prepared by:

Harbor Consulting Engineers, Inc.

Alden Research Laboratory, Inc.

August 21, 2015

ALDEN

Executive Summary

The purpose of the study was to collect water velocity data sufficient to map flow patterns within gatewell slots at Bonneville Dam's Second Powerhouse with modified Vertical Barrier Screen (VBS) baffling, and with a flow control Baffle Plate installed downstream of the VBS at elevation 31 ft. Both modifications address flow control through the VBS; with the former restricting flow at the screen and the latter restricting flow into the VBS screened flow return slot. The results of the study will be used to investigate the effectiveness of the combined alternative at improving gatewell flow conditions with respect to fish passage survival.

The objective of the field study was to collect water velocity data sufficient to map flow patterns within gatewell slots 15A, 15B, and 15C. Data was collected in slot 15A and 15B at high flows (18+ kcfs) with modified VBS baffling as well as a flow control baffle plate installed. Data was collected in slot 15C at high flows but gatewell modifications only included modified VBS baffling.

Velocity data was collected from June 2st through June 4th with a single gatewell condition measured each day. Measurements were taken 0.65 feet off the upstream face of the vertical barrier screens for all test conditions. Three dimensional water velocity data was collected using four Nortek Vectrino Acoustic Doppler Velocimeters (ADVs) deployed from a traversing beam assembly lowered into the gatewell slot. Velocities were measured at 16 equally spaced locations at each traversing beam deployment elevation. The traversing beam was deployed at one foot intervals between elevations[1] 34 and 56 and at two foot intervals between elevations 56 and 72.

Data was post-processed to remove outliers that are an artifact of multiple variables. Results are presented graphically in the body of the report, and tabulated data is included in appendices.

The general flow patterns among all gatewell slots were similar. Higher sweeping flows at the bottom of the gatewell corresponded with higher levels of turbulence than elsewhere in the gatewell. Vertical sweeping flow is concentrated near the center of the gatewell where turbulence levels are lower. Overall, there is a strong preference for flow at the center of the gatewell as identified by the total velocity magnitude plots. A narrow low velocity band bounds the high velocity central zone on each side for all test conditions. A steep total velocity magnitude gradient exists between the high velocity central zone and bounding low velocity bands.

Historically, screen approach velocities were generally higher at the edges (i.e. along the northern and southern screen panels), as opposed to at the center of the VBS. However, this trend is less apparent when reviewing the current data. Screen approach velocities continue to be consistently higher near the bottom screen panels.

The reduction of flow through the top two screen panels in the modified VBS appears to have resulted in an overall decrease in approach velocities between elevations 50 and 58. The inclusion of the baffle plate appears to have resulted in an overall decrease in approach velocity magnitude. The combined effect of the modifications appears to result in a well distributed VBS approach flow.

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[1] All elevations refer to mean sea level (MSL) datum.

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Acronyms

ADV	Acoustic Doppler Velocimeter
CENWD	Corps of Engineers, Northwest Division
CENWP	Corps of Engineers, Northwest, Portland District
CFD	Computational Fluid Dynamics
DSM	Downstream Migrant
JBS	Juvenile Bypass System
KCFS	Thousand Cubic Feet per Second
POC	Point of Contact
STS	Submerged Traveling Screen
TRD	Turbulence Reduction Device (Slot Fillers)
USACE	U.S. Army Corps of Engineers
UMT	Upstream Migrant Transportation
VBS	Vertical Barrier Screen

1.0 Introduction

The data collection program discussed in the following report is authorized by CENWP Contract Number W9127N-12-D-0001, Task Order Number 0005, B2 VBS Velocity Profiles at Bonneville Dam, Second Powerhouse.

The following Data Collection Report is organized to provide a thorough account of the means and methods applied to the data collection field program, data processing and data reporting. Data collection findings are summarized for each test condition in the Results section. A brief discussion of observations derived from the data and a corresponding qualitative analysis is included in the Discussion section. This is intended to be a cursory discussion to facilitate deeper evaluation conducted by CENWP.

1.1 Site Description

Bonneville Dam is located on the Columbia River, at River Mile 146, between Oregon & Washington State. The dam was originally constructed in 1938 and is currently operated by the U.S. Army Corps of Engineers (USACE), Portland District.

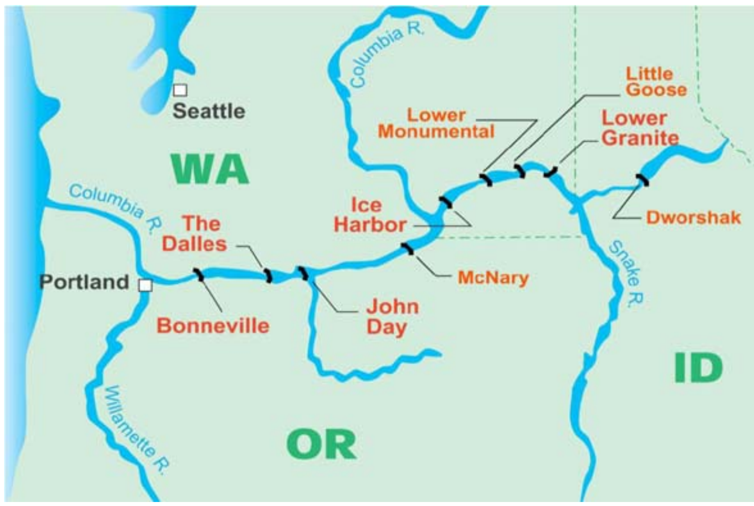

Figure 1-1 Vicinity Map (from USACE)

The dam is a run-of-river project spanning across the Columbia River between Robins Island, Bradford Island, and Cascades Island. Bonneville Dam consists of two powerhouses (B1 & B2), a spillway, and a navigation lock. Refer to Figure 1-1 Vicinity Map and Figure 1-2 Location Map, Bonneville Dam for project location and configuration of the dam. Figure 1-3 provides a detailed configuration of Powerhouse 2.

The project focused on the vertical barrier screens (VBS) at the Second Powerhouse located between Cascades Island and the Washington shore. The Second Powerhouse consists of turbine unit numbers 11 through 18. Each turbine unit includes three gatewell slots, A, B, and C. Vertical barrier screen locations are described in this report by unit number and slot designation. For example, gatewell 14A describes the A-slot of Unit 14.

Velocity data was collected in gatewells 15A, 15B, and 15C during a single field deployment. Data collection occurred from June 2nd through June 4th. No interruptions in data collection were experienced.

Figure 1-2 Location Map, Bonneville Dam

1.2 Background

Significant effort has been put into providing safe passage for downstream outmigrant salmonids at hydroelectric dams throughout the northwest. At Bonneville Dam, a juvenile bypass system (JBS) has been installed that collects a portion of juvenile outmigrants in the upper portions of the water column that would otherwise be passed through the powerhouse turbine intakes. The juvenile bypass system operates by diverting flow upwards into a vertical gatewell at each intake unit. A majority of the diverted flow is routed through vertical barrier screens (VBS) designed to exclude juvenile fish while the remainder is routed into the downstream migrant (DSM) channel. The screened flow returns to the powerhouse intake while excluded juvenile fish are transported through a submerged orifice into the DSM channel contained within the dam structure and released downstream. Refer to Figure 1-4 and Figure 1-5 below. Efforts to improve the juvenile collection and passage efficiency of the Bonneville juvenile bypass system have resulted in the addition of a submerged traveling screen (STS) extending below each gatewell and a turning vane designed to maximize flow up the gatewell.

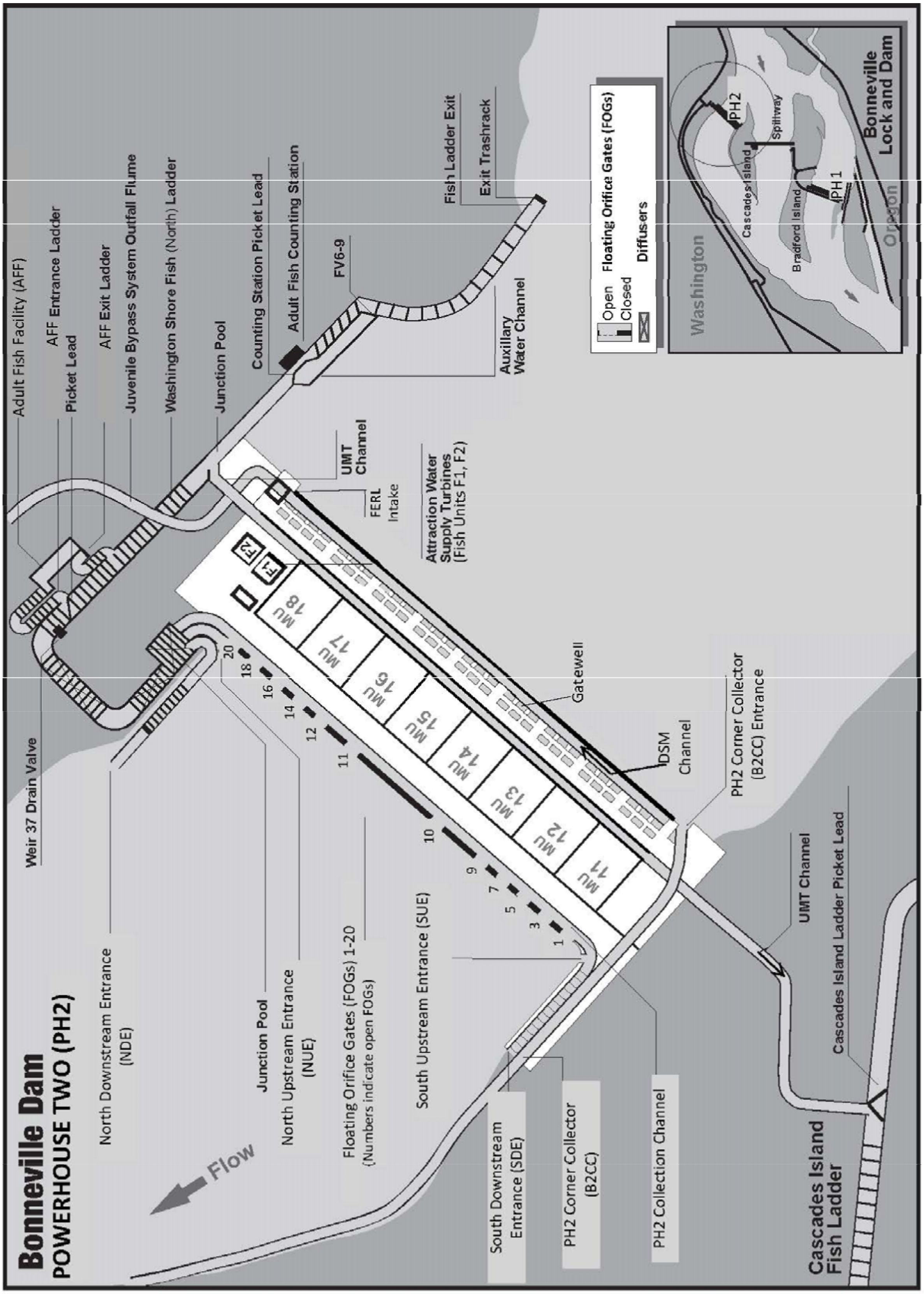

Figure 1-3 Bonneville Dam Powerhouse Two (from USACE)

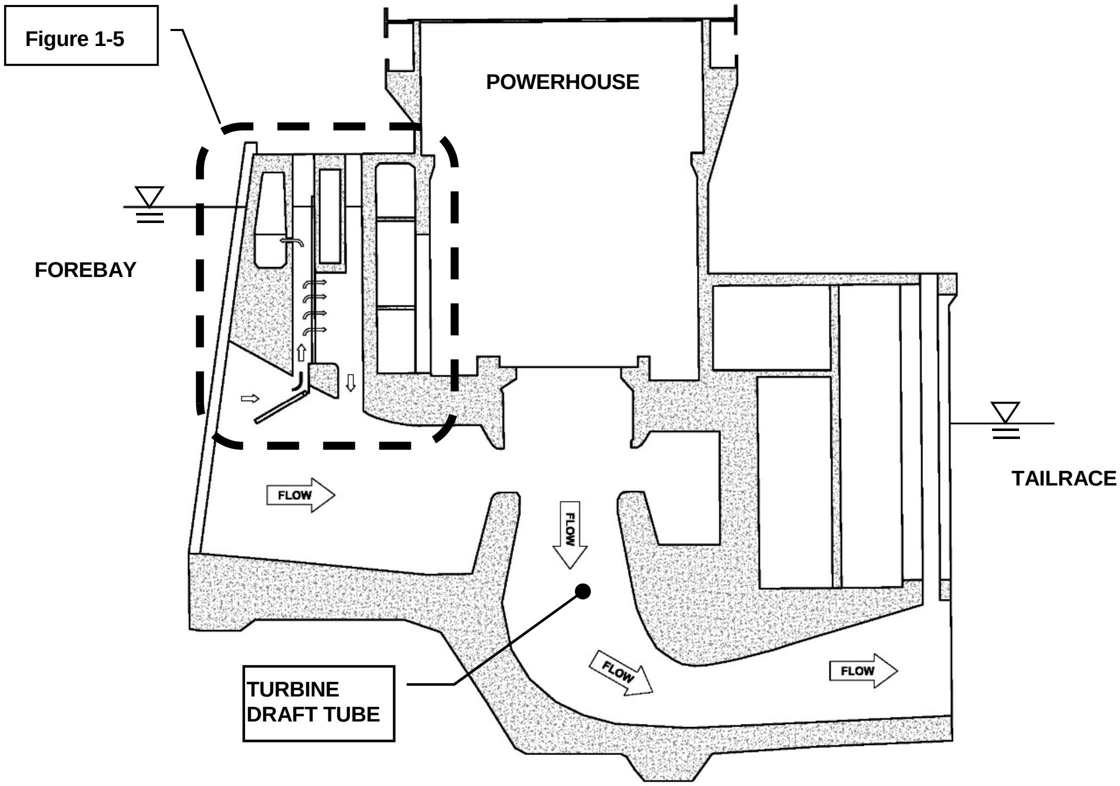

Figure 1-4 Cross Section of Bonneville Dam Second Powerhouse

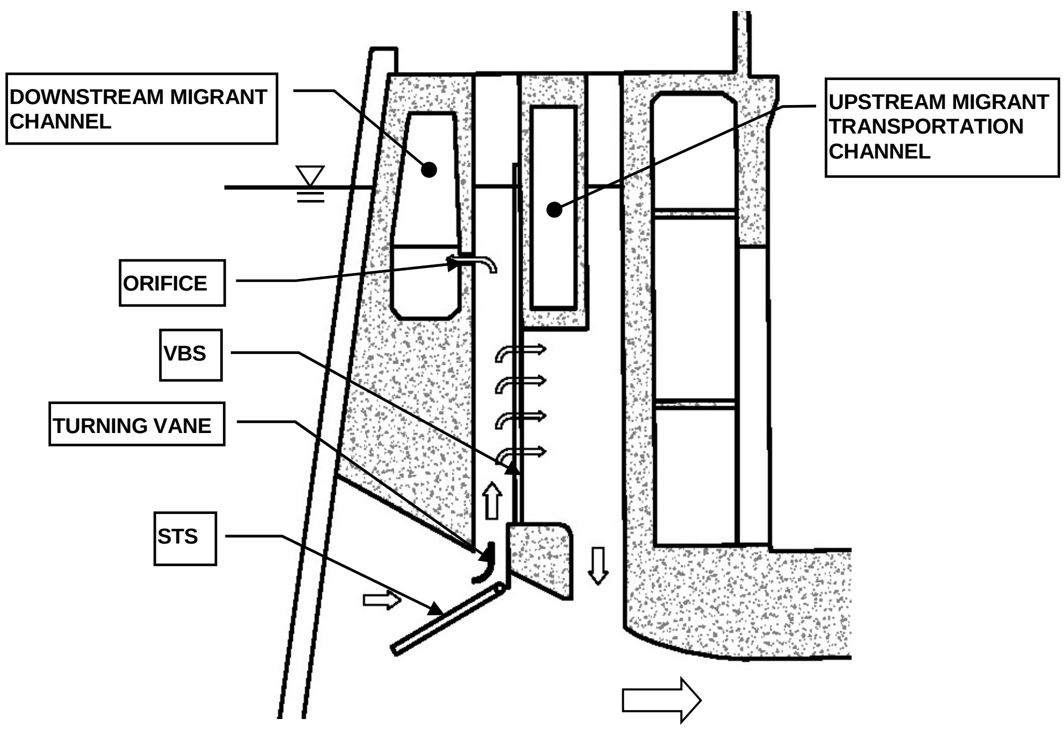

Figure 1-5 Detail Section of Gatewell and Flow Path

The purpose of the juvenile bypass system is to provide safe, unimpaired transport to juvenile fish past the dam. An even distribution of flow through the vertical barrier screen at a low approach velocity is required to prevent impingement of juvenile fish on the screens prior to entering the DSM channel. Additionally, the sweeping velocity parallel the screen face must be high enough to transport fish past the screen quickly without delay. A uniform, non-turbulent, flow pattern is critical to preventing injury to fish at the screens. Juvenile fish screen criteria have been developed by NOAA's National Marine Fisheries Service (NMFS) (NMFS, 2011) for guidance when designing and evaluating fish screening structures.

In 2008, a high mortality and descaling rate of hatchery Chinook salmon within the Bonneville JBS was observed at the Bonneville Dam juvenile monitoring facility. This high rate of injury has spurred questions relating to flow conditions that salmonids encounter at the VBS.

A 3-D velocity profile study was performed by Pacific Northwest National Laboratory (PNNL) in 2011 at vertical barrier screens in Units 12 and 14 (PNNL, 2011). This study indicated that localized screen approach velocity "hot spots" and turbulent sweeping velocities were characteristic in the study gatewells for the entire study flow regime.

Following the PNNL study in 2011, turbulence reduction devices (TRDs) were conceptualized for installation in the gatewell bulkhead slots to address the turbulent flow patterns identified in the PNNL study. Computational Fluid Dynamics (CFD) modeling performed by USACE suggested that a more uniform flow distribution can be achieved along the VBS with TRDs installed. Proof of concept TRDs which extended from approximately Elevation 31 to Elevation 56 ft. were designed, constructed, and installed in gatewell 14A for further performance evaluation.

Gatewell velocity data was collected by Harbor Consulting Engineers and Alden Research Laboratory with and without proof-of-concept TRDs installed (Harbor/Alden, 2013) to determine the effectiveness of the TRDs at improving gatewell flow conditions. Additionally, biological testing was conducted in spring of 2013 to correlate measured gatewell conditions to fish survival. The velocity data collected indicated that screen approach velocities through the second row of VBS screen panels from the top are higher than those for much of the rest of the VBS.

Following the Harbor/Alden study in 2013, additional alternatives for improving fish guidance efficiency (FGE) including modifications to VBS porosity and installation of a flow control plate on the backside of the VBS support beam at elevation 31 (see Figure 1-6) were considered. Both alternatives address flow control through the VBS; with the former restricting flow at the screen and the latter restricting flow into the VBS screened flow return slot. During early 2014 the top two panels of the spare VBS were modified with steel plates to eliminate flow through these panels. Additionally, a prototype version of the flow control plate concept discussed above was installed in gatewell 15A for performance evaluation.

The 2015 data collection program focused on full prototype testing of improvements installed in Unit 15. Improvements included flow control plates installed in Gatewells 15A and 15B and modified VBS panels in all three gatewells. VBS modifications include porosity adjustments to the top two screen panels (see Figure 1-7).

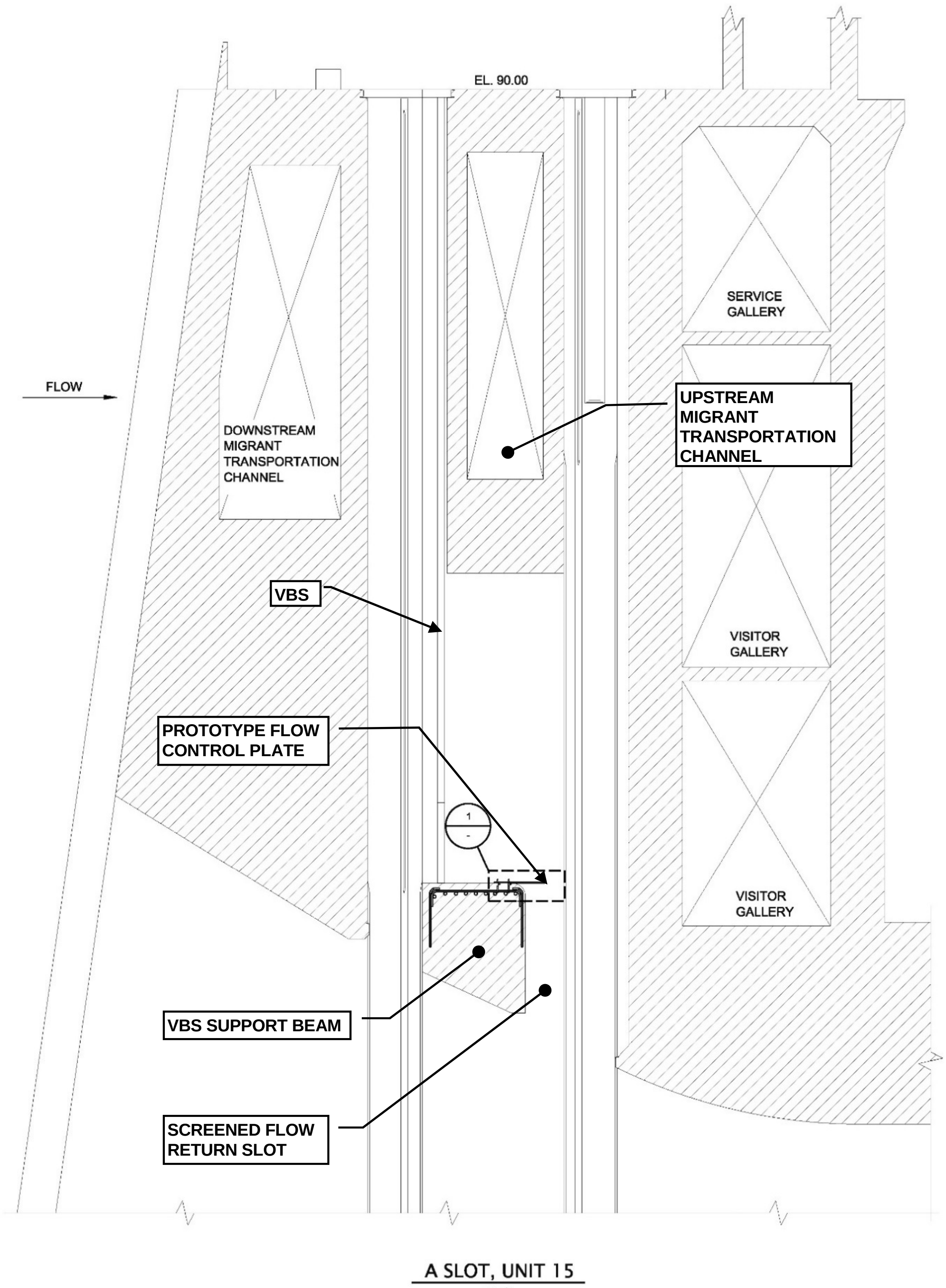

Figure 1-6 Prototype Flow Control Plate Installation

Figure 1-7 Vertical Barrier Screen Modified for 2015 Data Collection.

2.0 Methods

2.1 Collection Equipment

Water velocity measurements were collected in the gatewell using four Nortek Vectrino Acoustic Doppler Velocimeters (ADVs). The ADVs consist of a single acoustic transmitter and four acoustic receivers, along with a signal conditioning module. Photo 2-1 shows a Nortek ADV attached to one of the traversing beam's stanchions.

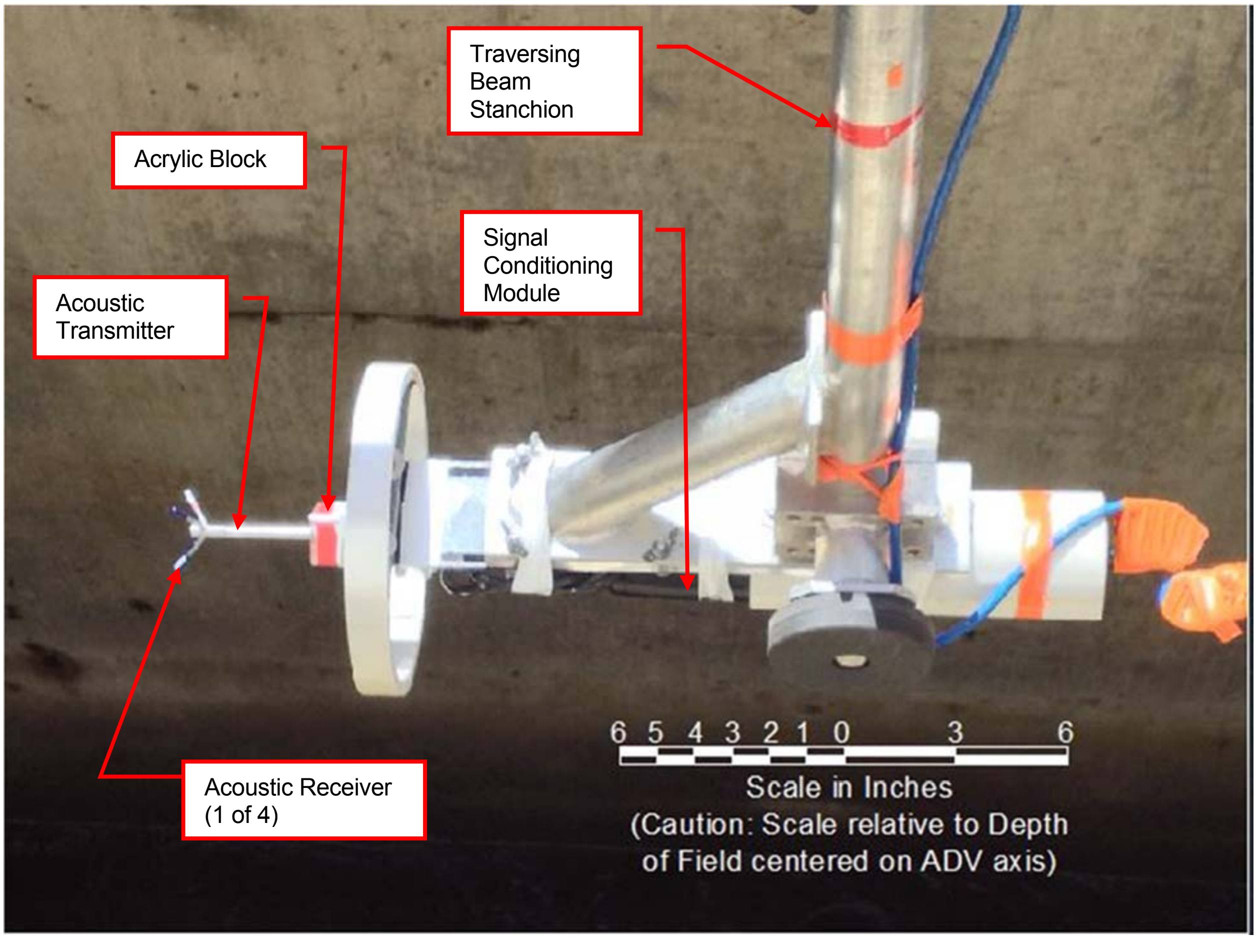

Photo 2-1 Nortek Vectrino ADV

ADVs operate by emitting a sound wave at a known frequency (10 MHz) from the transmitter and receiving a reflected sound wave off particles suspended in the fluid. As the particles pass the stationary probe, the reflected sound waves are shifted in frequency, and the direction and magnitude of the fluid's velocity is calculated using the relationship in Equation (2.1) below.

$$\Delta f = \frac{\Delta v}{c} f_o \qquad (2.1)$$

where:

Δf = change in frequency (Hz)
Δv= change in velocity (m/s or ft/s)
c= speed of sound *(1497 m/s at 25 degrees-Celsius)*
f_o = transmitted frequency.

When ADVs are in close proximity to each other, the transmitted wave from one ADV may interfere with the others. This problem is avoided by operating the ADVs using a common hub and computer software (proprietary to each manufacturer) for timing the sequence of transmitted and received acoustical waves so the interference is avoided.

An example of this interference is presented in Figure 2 1, where the correlation percentage (which should be greater than 60-percent for reliable data) is presented with and without interference. In a controlled laboratory flume, one ADV was placed into water (at time = 18 sec) and brought within proximity of another submerged sampling ADV (t=18) and was then slowly withdrawn until the two probes where no longer interfering with each other (t=40), where the correlation percentage is above 90. It was observed that only when the two probes transmitting/receiving signals interfered with each other, that the correlation percentage indicated a poor data sampling signal. The described close-proximity interference did not occur with the field deployment setup as the probes data positions were 14-inches apart at their closest.

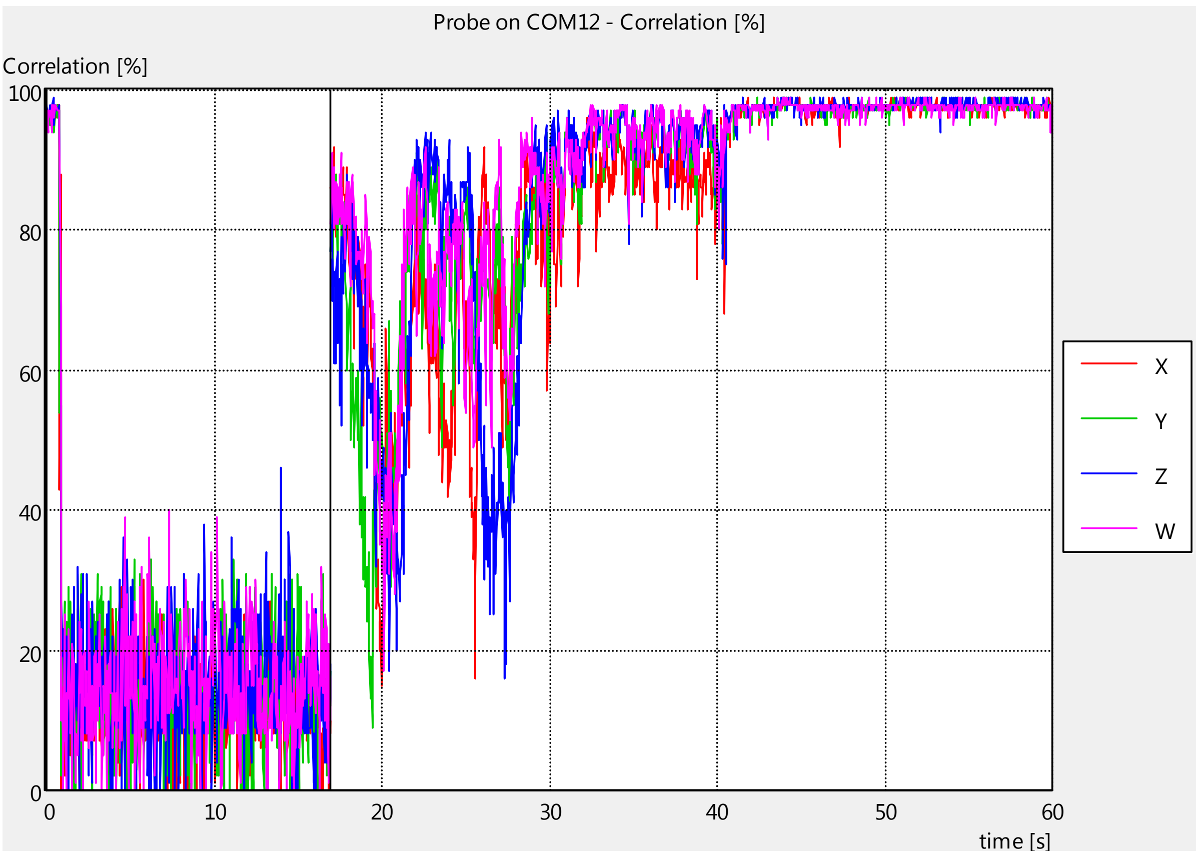

Figure 2-1 ADV Correlation with and without Acoustical Interference.

The ADV must also measure the water temperature to accurately adjust for the change in speed of sound with temperature (salinity is assumed to be nil in the gatewells at Bonneville Dam). In order to assure the ADV was using an accurate recording of the water temperature, the instrument was not initiated until it was fully submerged for several minutes. Typical recorded water temperatures during the period of operation were between 17.25 and 17.75-degrees Celsius during the June deployment.

Measurements were collected over a sampling volume with a pre-determined focal length (center of the sampling volume) based on the geometry of the probes. The accuracy of the ADV can be within 1 percent of the actual velocity, depending on water quality, velocity range, probe orientation, electronic noise, and mechanical noise (such as vibration). It is not possible to control the water quality, but it is possible to clean the velocity barrier screens such that accumulated debris does not affect the results. As such, the VBS in each gatewell associated with testing was cleaned prior to data collection.

Probe orientation was controlled by means of its physical attachment to the traversing beam. The probes were affixed to the traversing beam using a steel angle which connected to a square acrylic block containing the probe. The relative orientation of the four receivers was positioned relative to the flat side of the square acrylic block to within ±1-degree of rotation. A measure of this relative angle was determined through the measurement of the resultant velocity vector in Alden's calibration tank. Photo 2-2 shows probe number ARL-03 (OR-1) in the acrylic block housing.

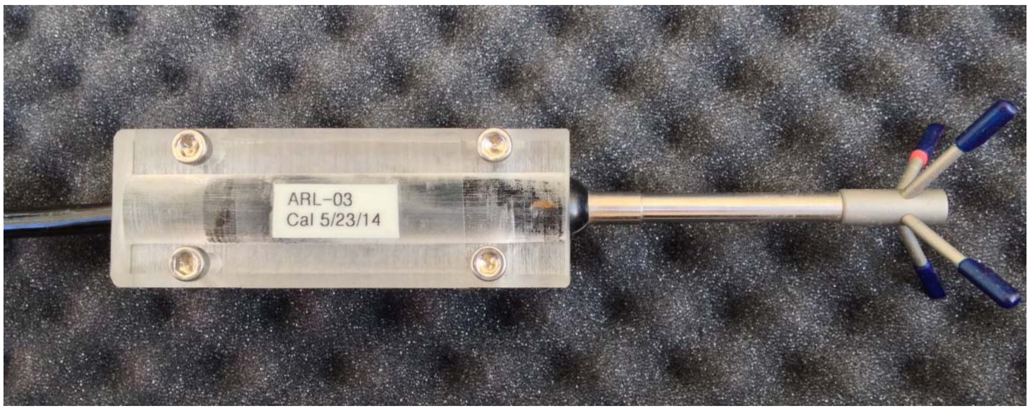

Photo 2-2 ADV in Calibrated Acrylic Block Housing

Electrical noise interferences will be avoided by ensuring all power sources were properly grounded and locating power source cables away from the transmitting end of the ADV probes.

The ADVs have a default X-direction which is oriented along the axis of one of the probe's receivers marked with a red ring. The ADVs were oriented such that the X-direction is into the VBS, sensing the approach velocity (Vx). The probe's Y-direction was pointed towards the vertical orientation (up or down) sensing the vertical component of the sweeping velocity (Vy), see Figure 2-2. The probe's Z-direction is defined as the vector towards the probe's transmitter, sensing the lateral sweeping velocity (Vz). To facilitate comparison with existing data sets, a coordinate transformation will be used to convert velocity components from the Vectrino software to a standardized coordinate system. The data was post-processed to describe the velocity components as follows:

Vx_USACE: Screen Approach Velocity, with positive X-direction into the screen

Vy_USACE: Positive Y-direction towards Oregon (South)

Vz_USACE: Positive Z-direction towards El. 90 ft. deck

Vtot_USACE: The resultant velocity

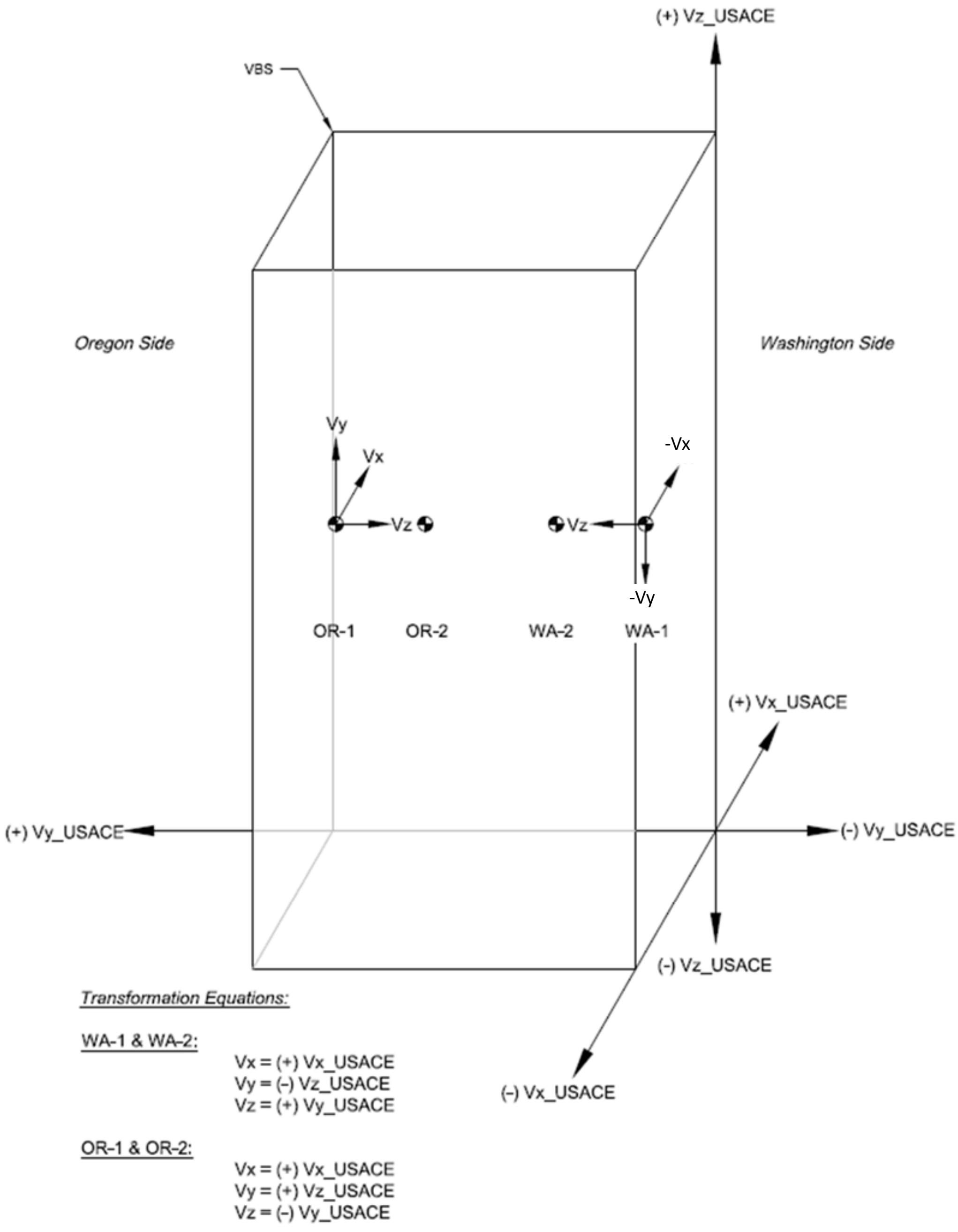

Figure 2-2 ADV Coordinate Transformation Illustration

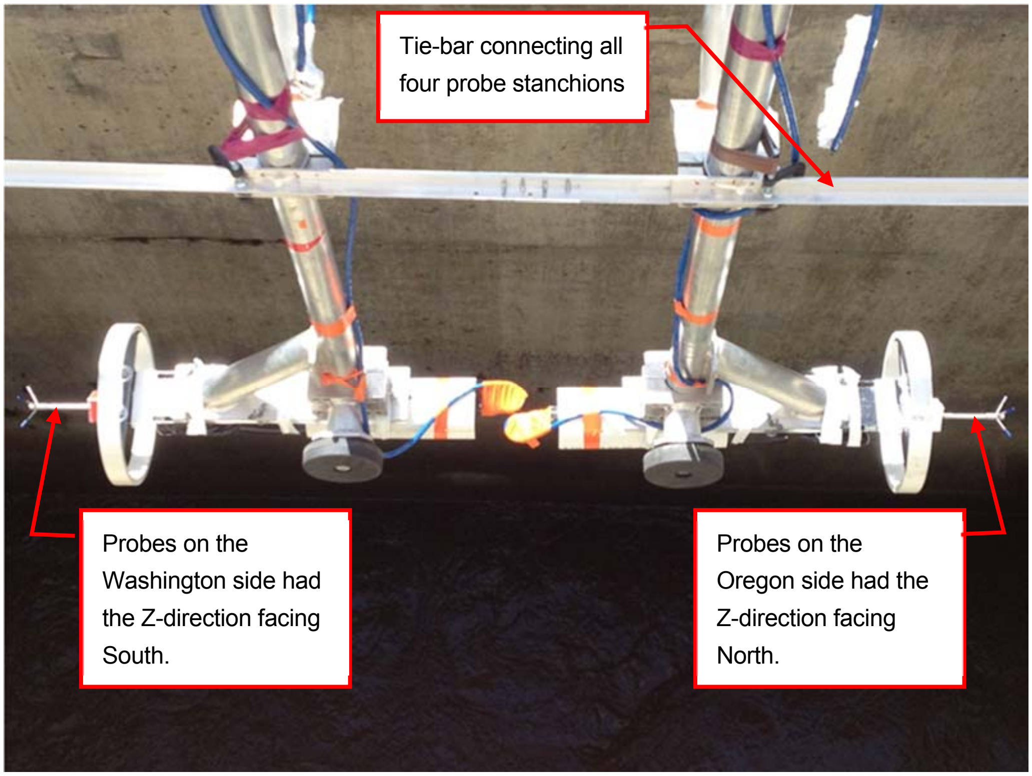

Photo 2-3 Probe Orientation within Gatewell (Looking East)

In order to address vibrations that might be initiated by the turbulent nature of the flow surrounding the probes, the four stanchions which hold the probes off the traversing beam were connected with a common tie-bar made from aluminum angle. Connecting all four stanchions together helped to stiffen the overall measurement apparatus and control any oscillations such that all four probes experience the same relative motion.

In addition to the velocity in the gatewell, the water surface on both sides of the VBS was monitored using an electronic depth probe (see Photo 2-4). The depth probe tape is graduated in increments of 0.01 ft. and produces a sound when the tip of the deployed probe contacts the water surface.

Photo 2-4 Electronic Depth Probe

2.2 Traversing Beam Equipment

The equipment used to deploy the ADVs was originally designed and built by Pacific Northwest National Laboratory for field deployments in 2011. The equipment was modified by the Harbor-Alden team for deploying four (as opposed to two) ADVs in 2013, and was further modified for the 2014 deployment operations, including:

- a newly designed and fabricated deployment frame;
- larger winches with a new fair lead design;
- refurbishment of the Empire Magnetics stepper motor (Model WP-U42-42P:10-OFP)[2]
- the traversing beam support tube was replaced with larger hoist arms;
- the spring-loaded wheel assemblies were removed to increase the allowable traverse distance;
- hoisting cable lengths were adjusted to re-balance the center of gravity;
- set screws were installed to lock the rotation of the ADV deployment arms;
- the ADV mounting plate was altered to accommodate a new data spacing;
- approximately 350 lbf of steel [3] was added to the interior of the support tube; and
- the linear actuator was rebuilt including replacement of the following components:
    - the timing belt;
    - idler pulley;
    - drive assembly; and
    - bearing cart wheels.

The modifications to the existing equipment are graphically shown in Figure 2-3.

The control center equipment remained unchanged from the 2013 deployment operation. The control center (shown in Photo 2-5) includes:

- Parker Hannifin Corporation 6K8 Motion Controller;
- Parker Hannifin ZETA microstepping driver; and
- Laptop computers running motion control and data collection software.

The ADV cables required a specific range of motion to traverse between all five positions, thus creating a catenary that could sometimes become snagged over the ADV deployment arm (as experienced during the

[2] The motor's bearings, seals, pressure compensator, cable, sealing compounds, and all other elastomeric items were replaced along with re-wiring the motor such that the power supply cable's shielding was grounded to the motor case to avoid power leakage.

[3] The approximate weight was determined by assuming the beam was neutrally buoyant at 17 kcfs and that a 13% increase in the average velocity would occur for a 19 kcfs flow near the bottom of the VBS. Trending of the 2013 field data substantiates a 13% increase in bottom sweeping velocities. An additional 50 lbf was then added to the weight.

2014 data collection year). In order to avoid such snagging issues during 2015, cable deflectors were installed on the deployment arms to guard against the catenary from looping over the head of the deployment arm, as depicted in Photo 2-6.

During the 2014 deployment year, the winch cables experienced an unweighting due to the traversing beam getting caught on an STS cable. In order to prevent “bird-caging” of the winch cables, the 2015 deployment equipment incorporated a spring-tensioned roller, which pressed against the winch cable, to prevent the spool of the winch from unraveling, as shown in Photo 2-7.

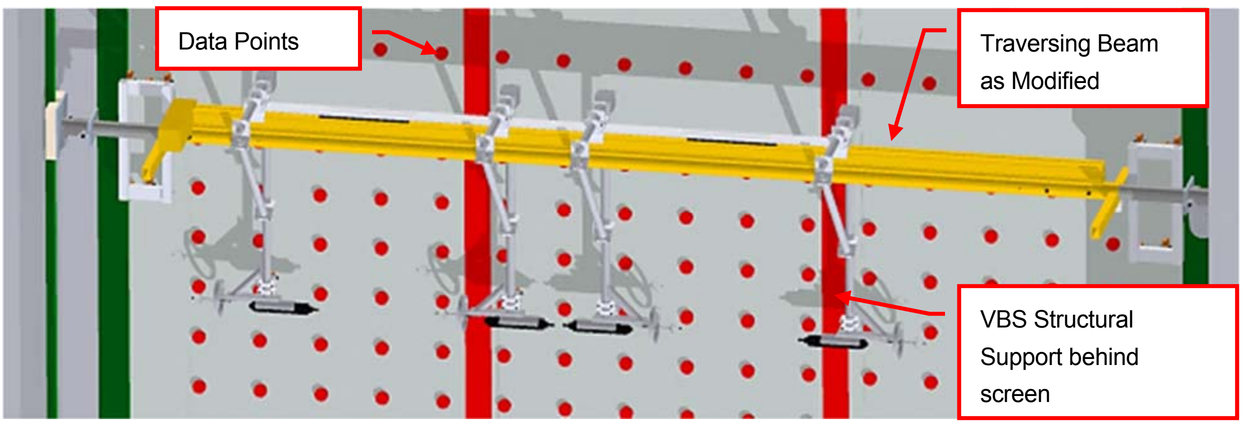

Figure 2-3 Traversing Beam Inside Gatewell with 2015 Data Spacing

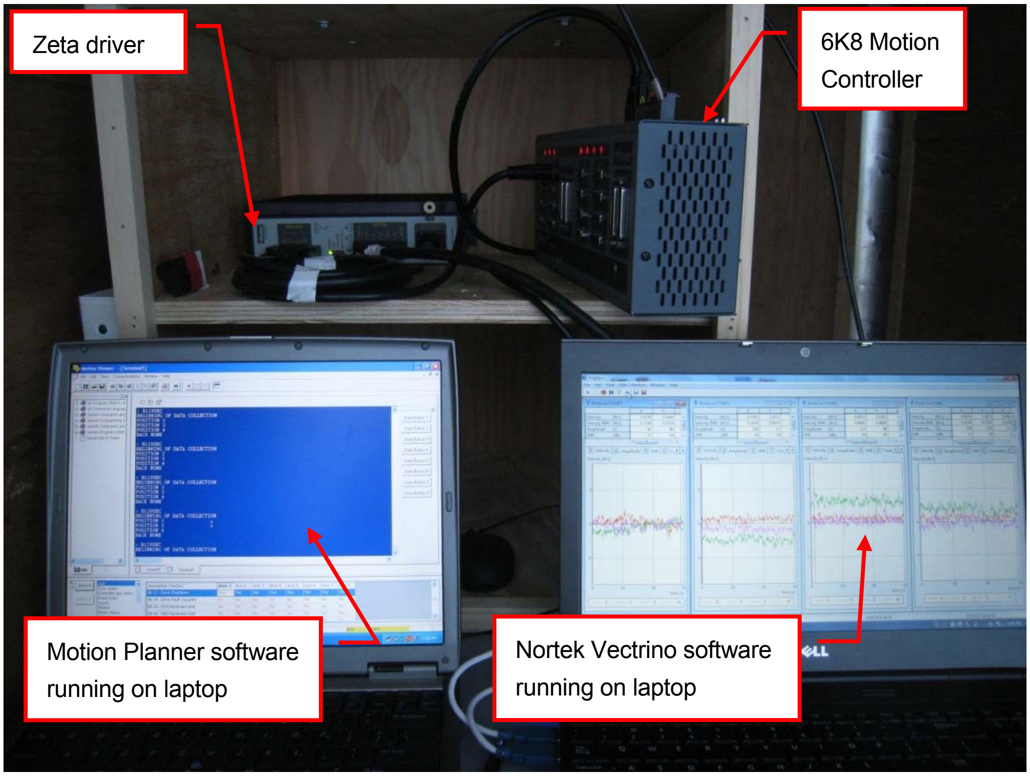

Photo 2-5 Traversing Beam Control Center

The beam was lowered by a set of cable hoists which is suspended by the traversing beam from two support fames. The elevation of the beam was determined by a graduated tape that is fixed to the winch cable as it was lowered into position. The beam was held in place in the gatewell by engaging a cam with a rope that extended plates on either side of the beam and created a compressive clamping force into the sides of the gatewell. Upon releasing the cam, the plates retract by tension springs and the beam will be allowed to move vertically with the hoist cables.

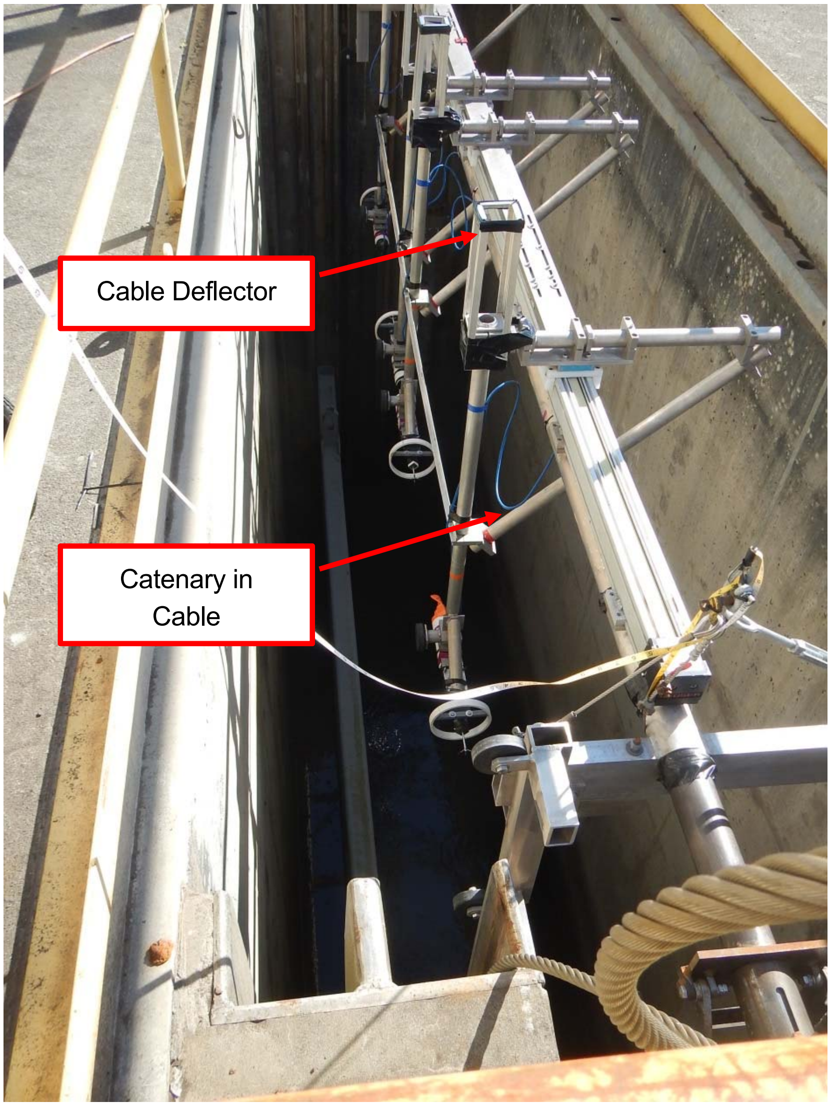

Photo 2-6 Cable Deflectors and Cable Catenary

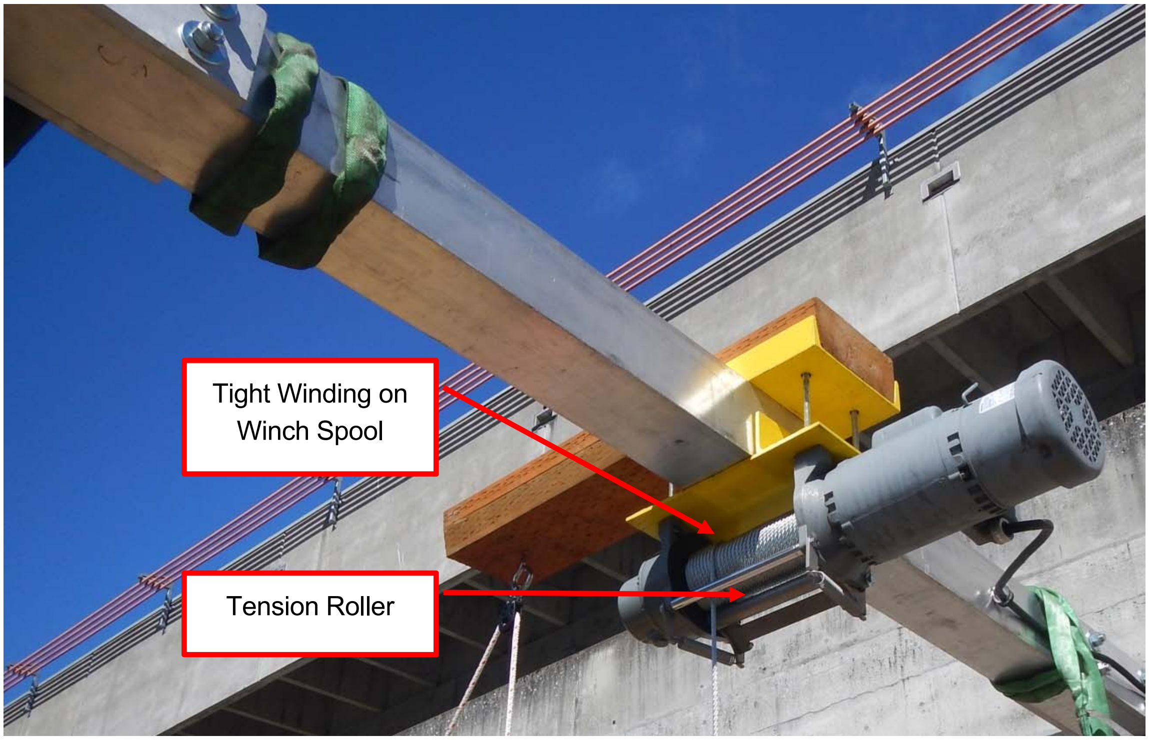

Photo 2-7 Winch Cable Tension Roller

2.3 Field Operations

A covered cargo trailer, approximately 7 feet wide by 10 feet long, was utilized as a field office and temporary storage facility for data collection field operations. All data collection activities were performed from this location. The trailer was located between the gatewells where data collection occurred and was positioned such that gantry crane and normal vehicle travel on the dam were not obstructed (see Photo 2-8).

The traversing beam was deployed in each gatewell during data collection via two electric cable hoists mounted on individual hoist frames. The hoist frames spanned the gatewell near each end of the traversing beam with gatewell handrails in place to maintain a safe working environment. Beam elevation was controlled by simultaneously operating the two positioning hoists.

The traversing beam support frames were redesigned and new cable hoists installed prior to the 2014 field program. Updates were made to accommodate increased beam weight and improve the safety of field operations based on lessons learned during the spring, 2013 deployment. For the 2015 field program, the winches were modified to include a tension-roller assembly to keep wire rope tightly wound on the winch drum.

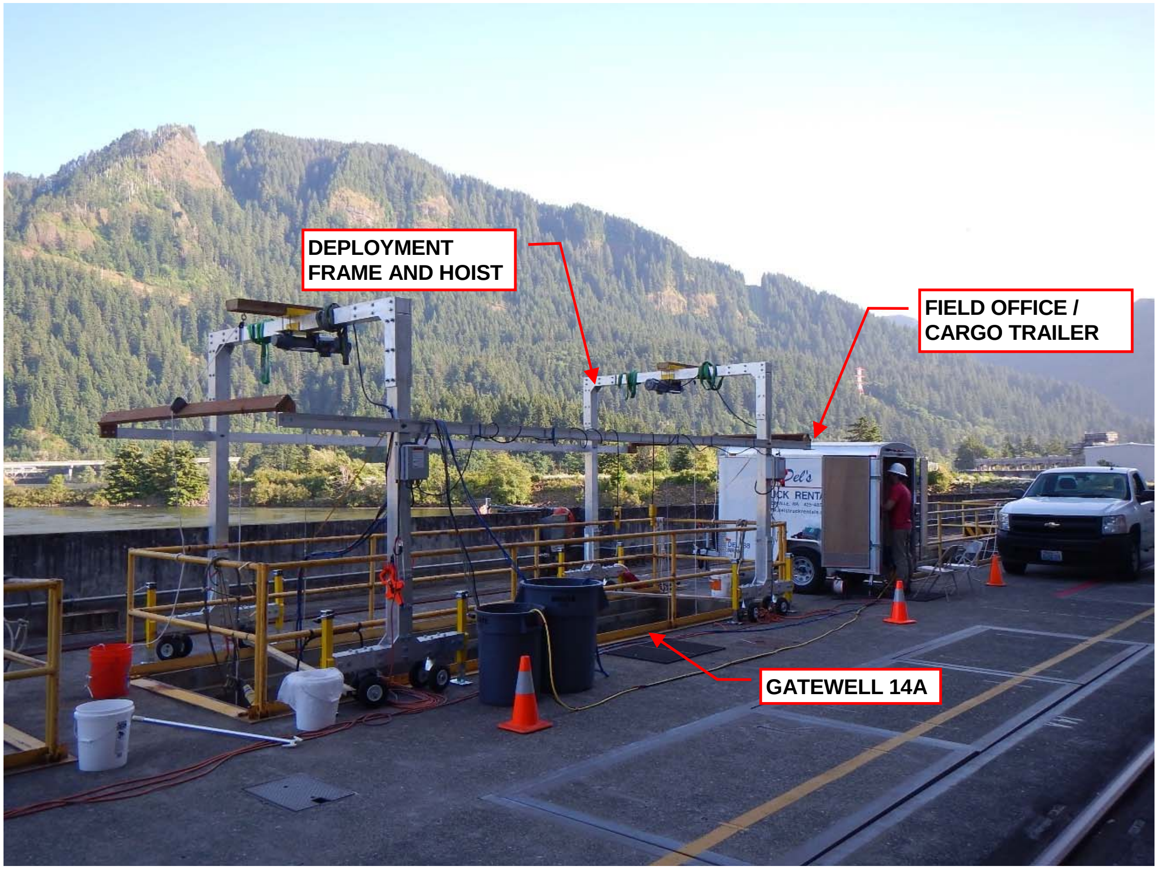

Photo 2-8 Field Operations Setup

Approximate power requirements for equipment utilized during data collection are included below in Table 2-1. Allowances have been included for computer and monitor equipment. Power for field operations supplied by USACE via a 480 VAC circuit hookup at gatewell 14C and a load center dedicated to field data collection operations.

Table 2-1 Field Operation Power Requirements

Equipment Description	Max Current @ 120VAC
Empire Magnetics Stepper Motor (Model WP-U42-42P:10-OFP)	25 amp
(2) Positioning hoists	12 amp each
Data collection equipment allowance (ADVs, computer, monitor)	5 amp
Lights	2 amp

2.4 Deployment

2.4.1 Mobilization & Demobilization

Initial mobilization of data collection equipment from PNNL to Bonneville Dam occurred on May 19, 2015. A coordination meeting with key project personnel from USACE, Harbor and Alden was held in the morning of

May 20th to go over project schedule, safety procedures and ensure all lines of communication have been established.

A wet test of the beam and frame equipment was performed on May 21, 2015. This wet test served as a shake down for the equipment and as an opportunity to practice deployment methods and review personnel tasks prior to commencing data collection. No significant issues were encountered.

2.4.2 Data Collection Deployments

Data collection occurred from Tuesday, June 2nd through Thursday, June 4th with a total of three test conditions conducted. Following data collection, all equipment was demobilized to PNNLs North Bonneville office. Table 2-2 provides a summary of data collection sequence, conditions and test outcomes. Daily data collection logs are included in Appendix A.

Table 2-2 Anticipated Equipment Setup and Data Collection Sequence

Day No.	Date	Gatewell	Condition	Target Flow Rate	Actual Flow Rate*	Test Outcome
1	6/1/15	N/A	N/A	N/A	N/A	Mobilization and ADV setup.
2	6/2/15	15A	Prototype FCP/VBS	18.5 kcfs	18.3 kcfs	Completed
3	6/3/15	15B	Prototype FCP/VBS	18.5 kcfs	18.3 kcfs	Completed
4	6/4/15	15C	Prototype VBS	18.5 kcfs	18.0 kcfs	Completed
5	6/5/15	N/A	N/A	N/A	N/A	Demobilization of equipment to PNNL

* Average unit flow rate for duration of data collection.

Crane support was required to initially position the equipment over Gatewell 15A to commence data collection and to remove the equipment from the 90 deck for demobilization. Additionally, the presence of a DSM channel access hatch and curb at Gatewell 15B required crane support to place and remove the equipment at gatewell 15B.

CENWP hydraulic design personnel provided instruction to dam operations personnel and the field data collection team for target flow rates in the unit being tested and adjacent unit operations. Flow rates were determined by CENWP personnel based on river stage and discharge conditions at the time of data collection and dam operational requirements.

Vertical barrier screens were cleaned each morning by CENWP project personnel in the unit where measurements were taken prior to deployment of data collection equipment. This assured consistent screen conditions at the beginning of each data collection condition and provided a baseline for evaluation of screen blockage. The differential head across the screen was monitored throughout data collection. Any change in differential was noted to asses if additional screen cleaning was required or if results may be influenced by screen blockage.

Screen condition was observed each morning during cleaning and typically presented limited debris accumulation. Debris accumulation was noted as occurring primarily at the top and bottom two panels of the screen.

2.5 Data Collection

The local Cartesian coordinate origin (0,0,0) is located at Elevation 0 feet above sea level on the face of the VBS screen at the northern edge (*i.e.* Washington side) of each gatewell. Data was collected in two grids. The Fine Resolution Grid consists of 16 horizontal measurements taken at one foot vertical spacing between Elevations 34[4] and 56. The Coarse Resolution Grid consists of 16 horizontal measurements taken at two foot vertical spacing between Elevations 58 and 76 (or the water surface elevation). Data was collected approximately 15-inches from the VBS's lateral extents and 14-inches on center for sixteen (16) equally spaced data points. All data points were located 0.65 ft. from the face of the VBS. This measurement layout permitted three (3) duplicate measurements and one (1) extraneous measurement 1-inch from the edge of the VBS with an extra traverse. Duplicate data was collected at elevations 38, 43, 53, 55, 60, and 66 ft. The total number of measurement locations contained in the Fine and Coarse Resolution Grids was 544, with 18 additional points at the 'duplicate' locations. The equal lateral spacing between measurement points allowed for a consistent integration of flow patterns between data points. No data was taken directly in front of the support channels located behind the VBS. See Figure 2-4 and Figure 2-5 for a graphical illustration of the data measurement points.

[4] Due to STS interferences discovered during the 2013 Field Program, the lowest targeted elevation was Elevation 34 ft.

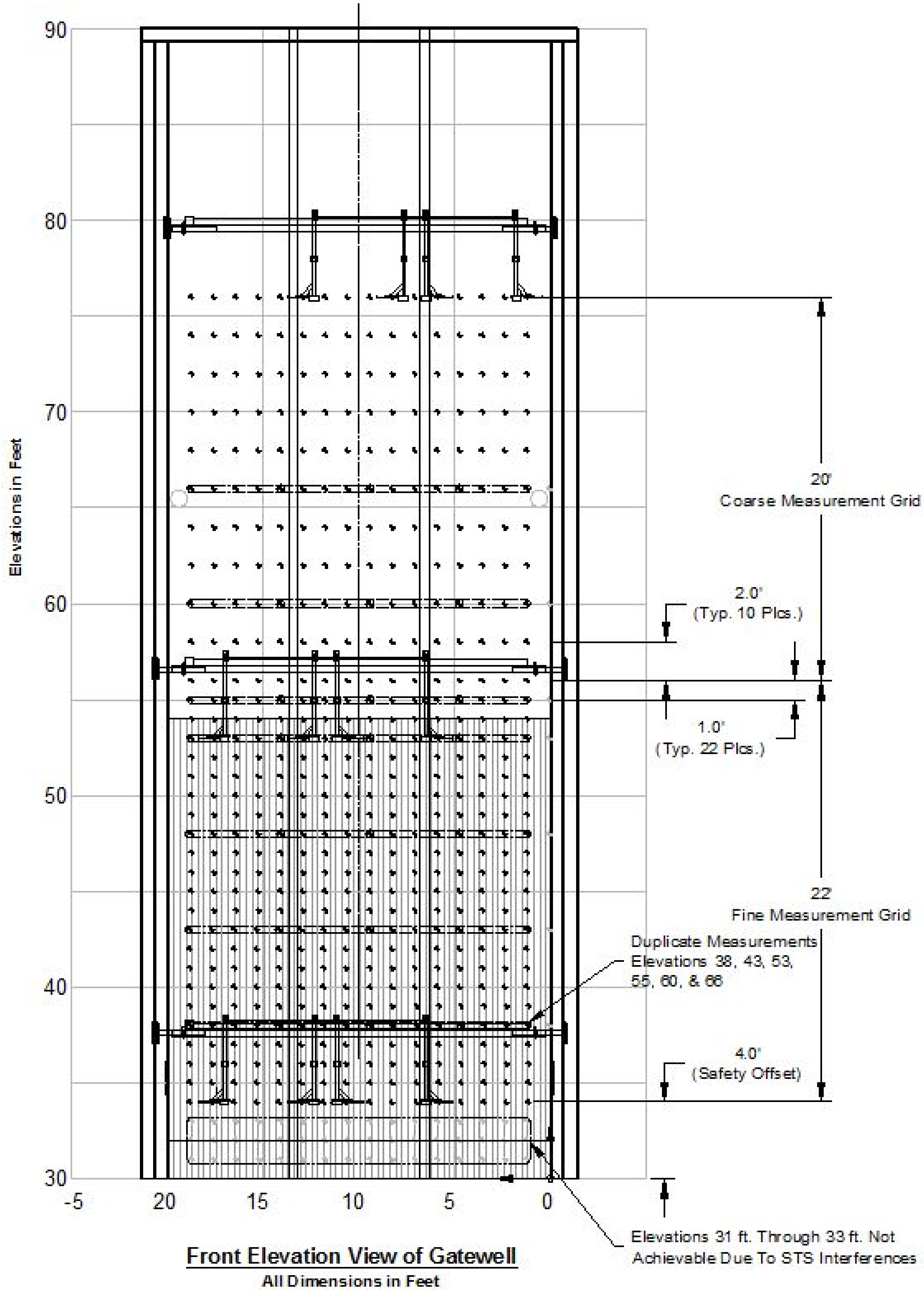

Figure 2-4 Measurement Locations

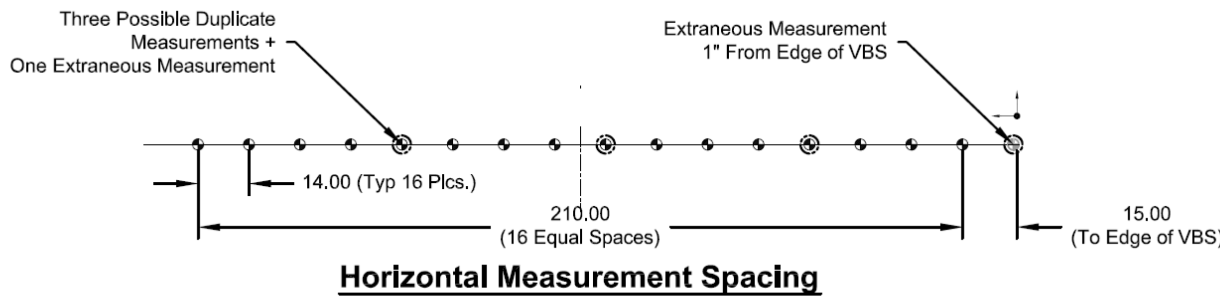

Figure 2-5 Horizontal Measurement Spacing

(Units provided in inches)

Data collection began at the initiation of the traversing beam's program, and was stopped when the traversing beam returned to a "home" position. A continuous time series of velocity data was recorded for each meter for each elevation. A Matlab script was used to parse out the time at which the ADVs were sampling while the traversing beam was at rest at each measurement location.

Data was collected at a sampling frequency of 200 Hz for a minimum of 120 seconds (24,000 data points) at each measurement location. The traversing beam program was written such that the resting period, which correlates with a measurement location, would not begin until the traversing beam completed the traverse between positions. The time for the traversing beam to move between positions was recorded and used for parsing the time series.

In addition to velocity data, the following information was collected each day of field operations:

- Date and time
- The locations where measurements were taken
- Total river flow (cfs)
- Spillway flow (cfs)
- Second Powerhouse flow (kcfs)
- Forebay pool elevation (ft)
- Tailrace pool elevation (ft)
- Water surface elevation in the gatewell upstream and downstream of the VBS (ft)
- B2 corner collector (B2CC) status (on or off)
- Turbine intake extension (TIE) status (in or out)
- Number of orifices in test gatewell that are open (1 or 2) (and which orifice, if only one is open)

2.6 Data Processing

A data file was created for each elevation per test condition. The data files were converted from binary files to text files using the Nortek Vectrino file conversion toolbox. All post-processing and figure creation was conducted in Matlab software. A brief description of the overall scripted process is below.

2.6.1 Data Set Reduction

Data files were read into Matlab and sorted into structured[5] data sets per the associated probe numbers. The naming convention utilized for the probes is as follows:

WA-1: The northern most probe.

WA-2: The second most northern probe.

OR-2: The second most southern probe.

OR-1: The southernmost probe.

The data will then be split further into the x, y, and z component velocities and simultaneously transformed into the USACE Cartesian coordinate system depicted in Figure 2-2. The data was then further parsed into each of the four (4) positions.

Positional parsing was accomplished by defining the beginning and ending of each of the following time segments and multiplying the relative time by the sampling frequency (200 Hz).For example:

Position 1: Zero to 120 seconds

Traverse 1: Translation between Position 1 and Position 2

Position 2: End of Traverse 1 plus 120 seconds

Traverse 2: Translation between Position 2 and Position 3

Position 3: End of Traverse 2 plus 120 seconds

Traverse 3: Translation between Position 3 and Position 4

Position 4: End of Traverse 3 plus 120 seconds

---

[5] A “structure” in Matlab is an array with specified fields and values. It is organizationally similar to using nested folders for organization, except the variables within the structure are called using the structure name, a dot, and then the variable. Ex. EL_34.WA1 is the variable WA1 under the structure EL_34.

An example of the resulting variables for WA-1's x-component of velocity at Elevation 34 was as follows:

EL_34.WA1x1 – Elevation 34, WA-1 probe, x-component, 1st position

EL_34.WA1x2 – Elevation 34, WA-1 probe, x-component, 2nd position

EL_34.WA1x3 – Elevation 34, WA-1 probe, x-component, 3rd position

EL_34.WA1x4 – Elevation 34, WA-1 probe, x-component, 4th position

Once the data have been parsed into their respective velocity components per elevation per position, the data was post-processed for removal of spurious data points.

2.6.2 Outlier Testing and Post-Processing

ADV data may be adversely affected by the combined effects of:

- Signal aliasing
- Velocity fluctuations
- Poor water quality
- Deployment hardware vibrations
- Close proximity to a physical boundary
- Close proximity to other acoustic sources (such as other ADVs)
- Electrical noise
- Large debris passing through the measurement volume.

These influences may result in a velocity signal that exhibits *noise* in the form of velocity spikes (see Photo 2-9). The Signal-to-Noise (SNR) ratio should be above 10 decibels and the correlation percentage should be above 60% at a minimum.

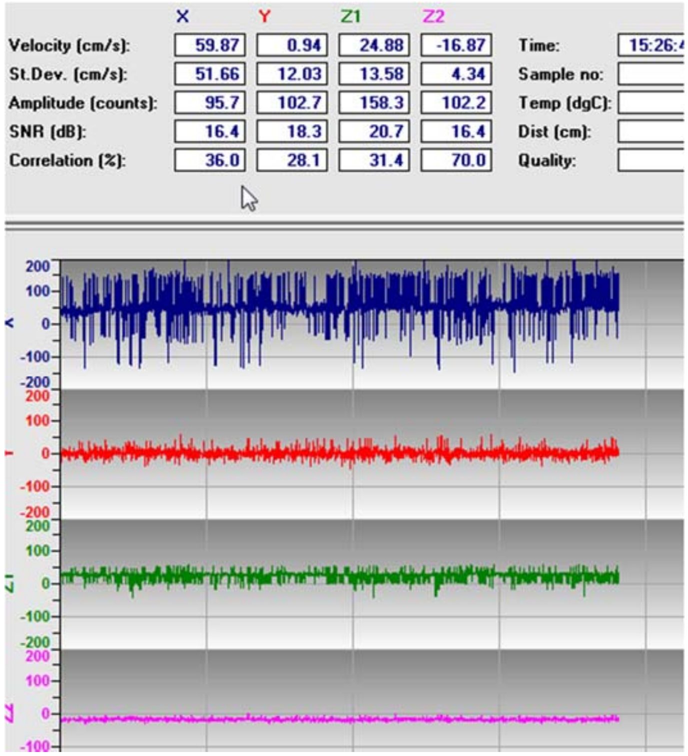

Photo 2-9 Example of Noisy Data

The velocity data was collected using settings which permit the highest SNR and correlation percentage as possible. However, even when collecting very *clean* data, post-processing helps to reduce unwanted influences of noise. To remove spikes from the time series, a kernel-density filter method will be employed. The kernel density method uses a bivariate kernel density function (Duong and Hazelton, 2003) to automatically select a cutoff threshold and to calculate the major and minor axes of the phase-space ellipse used for spike detection and elimination (Islam, 2013). The method does not require iteration, but does require replacement of the removed data through interpolation techniques. The method is more computationally efficient than the phase-space method, and according to the author of the technique, it can be a more robust method for filtering data which are 40% or more contaminated by spurious points.

The kernel density method identifies the “good” data as that which is the most dense (has the largest kernel density), as illustrated in Figure 2-6.

The process for this method is as follows:

Calculate the forward (Eq. 2.12) and backward (Eq. 2.13) differences of the 1st derivative, Δu. Select the method which provides the smallest absolute value.

$$\Delta u_i = (u_{i+1} - u_i) \tag{2.12}$$

$$\Delta u_i = (u_i - u_{i-1}) \tag{2.13}$$

Then, calculate the rotation angle of the principle axes using the least-squares approximation.

$$\theta = tan^{-1}\left(\frac{N\sum_{i=1}^{N} u_i \Delta u_i - \sum_{i=1}^{N} u_i \sum_{i=1}^{N} \Delta u_i}{N\sum_{i=1}^{N} u_i^2 - \left(\sum_{i=1}^{N} u_i\right)^2}\right) \tag{2.14}$$

Next, transform the data using the following formula:

$$u_t = ucos\theta + \Delta usin\theta \; ; \; \Delta u_t = -usin\theta + \Delta ucos\theta \tag{2.15}$$

Rescale the data to range between 0 and 1 by using the below equations where the subscript, s, refers to the component being scaled:

$$u_s = \frac{u - \min(u)}{\max(u) - \min(u)} \; ; \; \Delta u = \frac{\Delta u - \min(\Delta u)}{\max(\Delta u) - \min(\Delta u)} \tag{2.16}$$

Once the data has been rescaled, the kernel density estimation may be obtained using Eq. 2.17. Here, h_u and $h_{\Delta u}$ are the bandwidths along the two axes about the identified peak, and are defined as a percentage of the grid size used to divide the *u and* Δ*u axes*. Figure 2-6 illustrates the kernel density for the 2013 field data correlating with gatewell 14A, El. 34 ft., WA-1, position 1.

$$\hat{f}(u, \Delta u) = \frac{1}{2\pi N h_u h_{\Delta u}} \sum_{i}^{N} exp\left[-\frac{(u-u_i)^2}{(2h_u^2)} - \frac{(\Delta u - \Delta u_i)^2}{(2h_{\Delta u}^2)}\right] \tag{2.17}$$

After the peak has been identified, an ellipse may be defined surrounding the peak. The size of the ellipse is determined as the extent where the slope of the peak falls off below 0.4, while moving outward from the central peak, as defined in Eq. 2.18. Here n_u *and* $n_{\Delta u}$ denote the size of the grid used to calculate the kernel density (e.g. 256 x 256), and the subscript, *p*, denotes the peak. Data that lay outside of the ellipse is defined as spurious data, and are removed from the original time series and replaced with linearly interpolated values.

$$S_u = \frac{n_u |\Delta \hat{f}(u_{i+1} - u, \Delta u_p)|}{\hat{f}(u_p, \Delta u_p)} \leq 0.4 \; ; \; S_{\Delta u} = \frac{n_{\Delta u} |\Delta \hat{f}(u_p, \Delta u_{i+1} - \Delta u)|}{\hat{f}(u_p, \Delta u_p)} \leq 0.4 \tag{2.18}$$

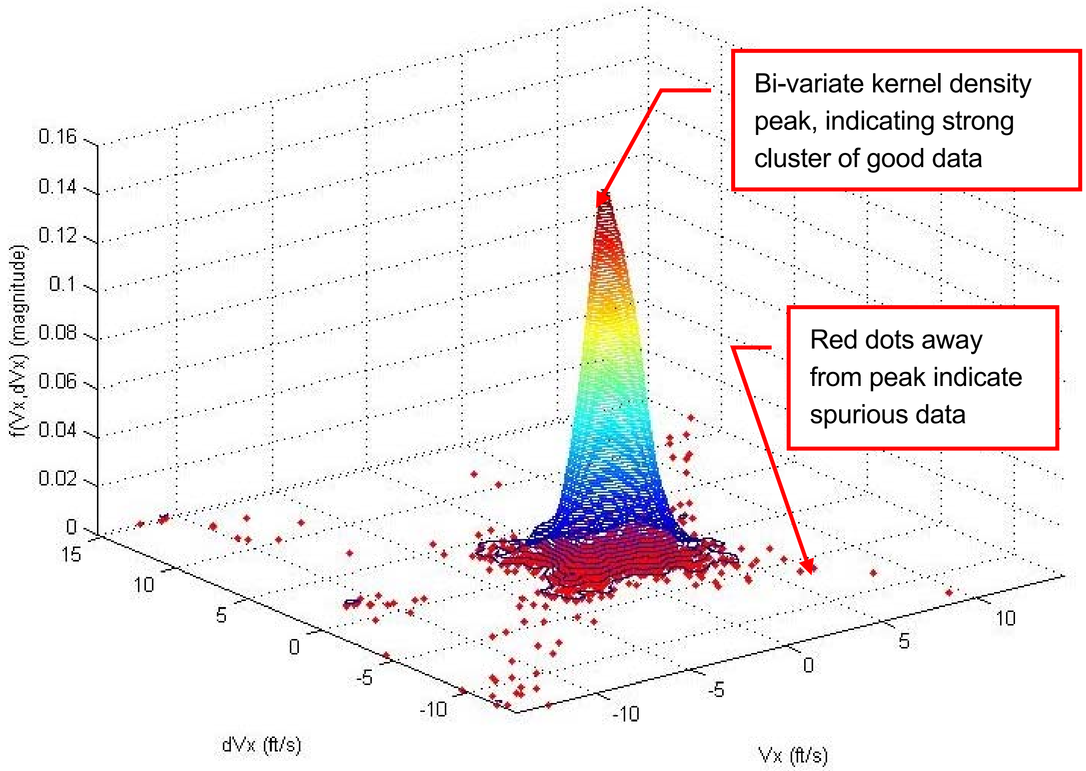

Figure 2-6 Kernel Density Estimation of (14A High Flow, El 34, WA-1, pos 1)

2.6.3 Statistical Analysis

After despiking, the mean velocity components and turbulence were computed. The root mean square (RMS) of the velocity fluctuations about the mean (mathematically equal to the standard deviation about the mean of the samples) was calculated as an indicator of turbulence.

$$RMS_i = \sqrt{\frac{\Sigma\left(v_{i,n} - \bar{v}_i\right)^2}{N}} \qquad (2.12)$$

$$RMS = \sqrt{{RMS_x}^2 + {RMS_y}^2 + {RMS_z}^2} \qquad (2.13)$$

2.6.4 Fail Testing Post-Processed data

Post-processing with a despiking filter may still provide questionable results if the initial time series collected were bad. As noted in Section 2.6.2, potential causes for bad readings from an ADV include:

- Signal aliasing

- Velocity fluctuations
- Poor water quality
- Deployment hardware vibrations
- Close proximity to a physical boundary
- Close proximity to other acoustic sources (such as other ADVs)
- Electrical noise
- Large debris passing through the measurement volume.

Extreme velocity fluctuations, poor water quality (such as aerated water), and deployment hardware vibrations are the most difficult to avoid once deployed. Even after despiking the original data, it is possible to simply have started with bad data. A good indication of this is if the RMS of velocity fluctuation is greater than 2 times the mean of the resultant or if the mean of the velocity is zero but contains a large velocity fluctuation. The following equation describes the use of the fail test.

$$If\ \frac{RMS}{V_{tot}} > 2, then\ Fail \qquad (2.14)$$

3.0 Results

Post-processed data for Tests 1 through 3 is presented below, sequentially. Detailed results from all tests are presented in Appendix B.

3.1 Gatewell Slot 15A – Test 1

The through-screen velocity (Vx – see Figure 3-1) ranged from 0.21 to 1.11 ft/s between elevations 34 ft. and 56 ft., with an average of 0.62 ft/s ± 0.15 ft/s. Sweeping velocity (Vyz) ranged from 0.38 to 5.92 ft/s, with an average of 3.01 ft/s ±1.28 ft/s. Total RMS values (Figure 3-2) ranged between 0.65 and 2.30 ft/s, with an average of 1.23 ft/s ± 0.30 between elevations 34 ft. and 56 ft.

Twenty-five (25) data points (of 544) did not pass the fail test.

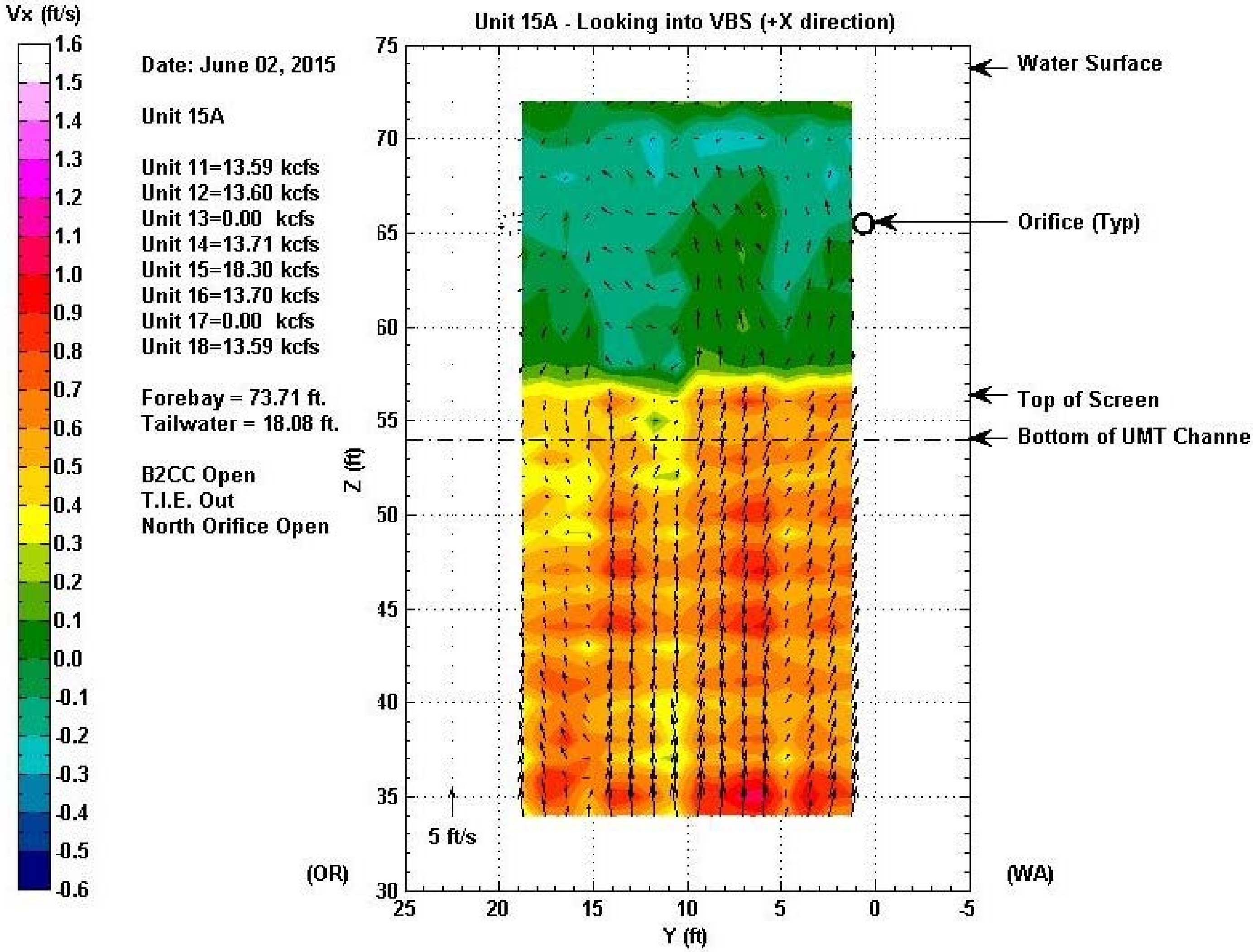

Figure 3-1 X-direction velocity contour at Unit 15A (Modified VBS) with Y-Z directional velocity, High Flow

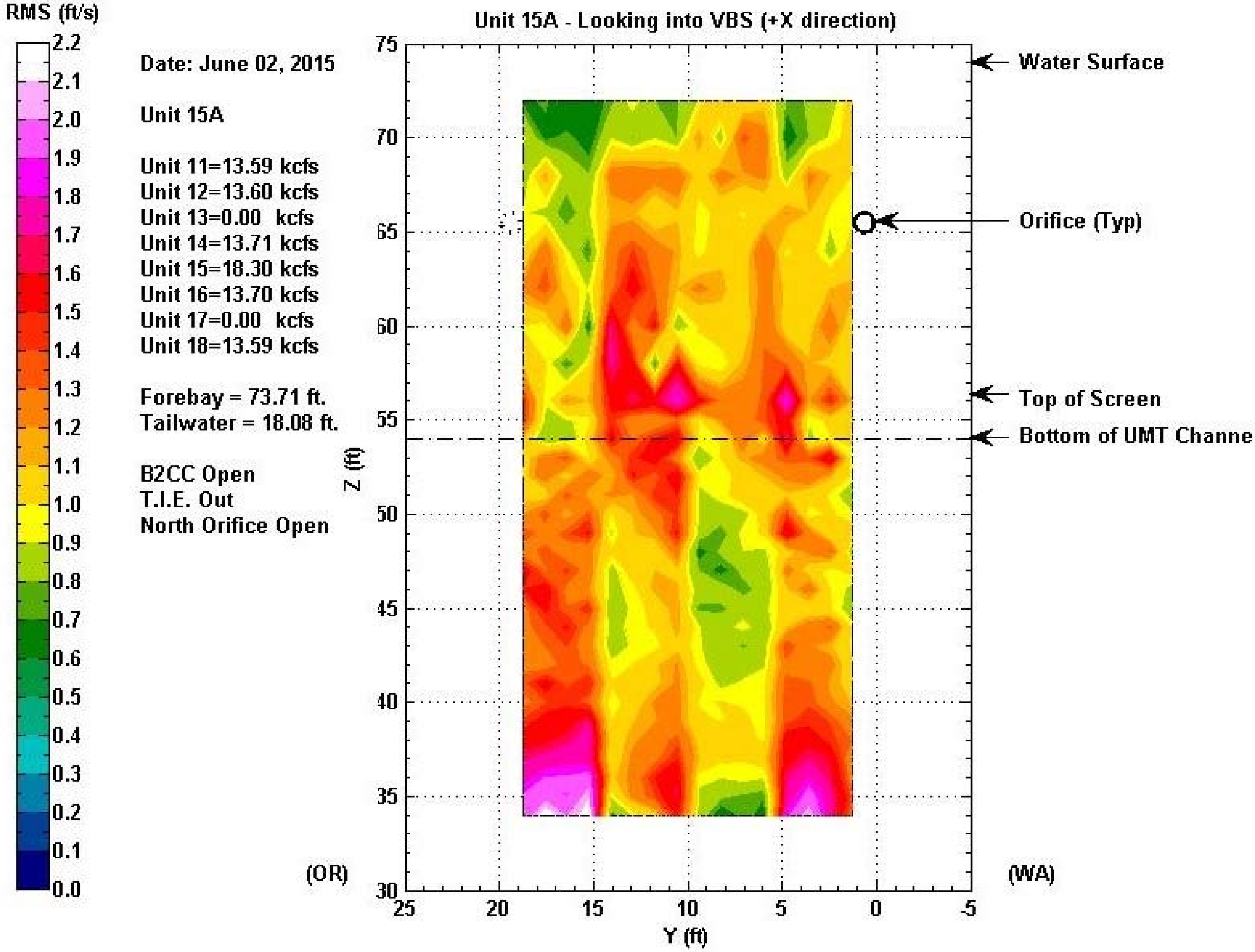

Figure 3-2 Root mean square velocity fluctuation at Unit 15A (Modified VBS), High Flow

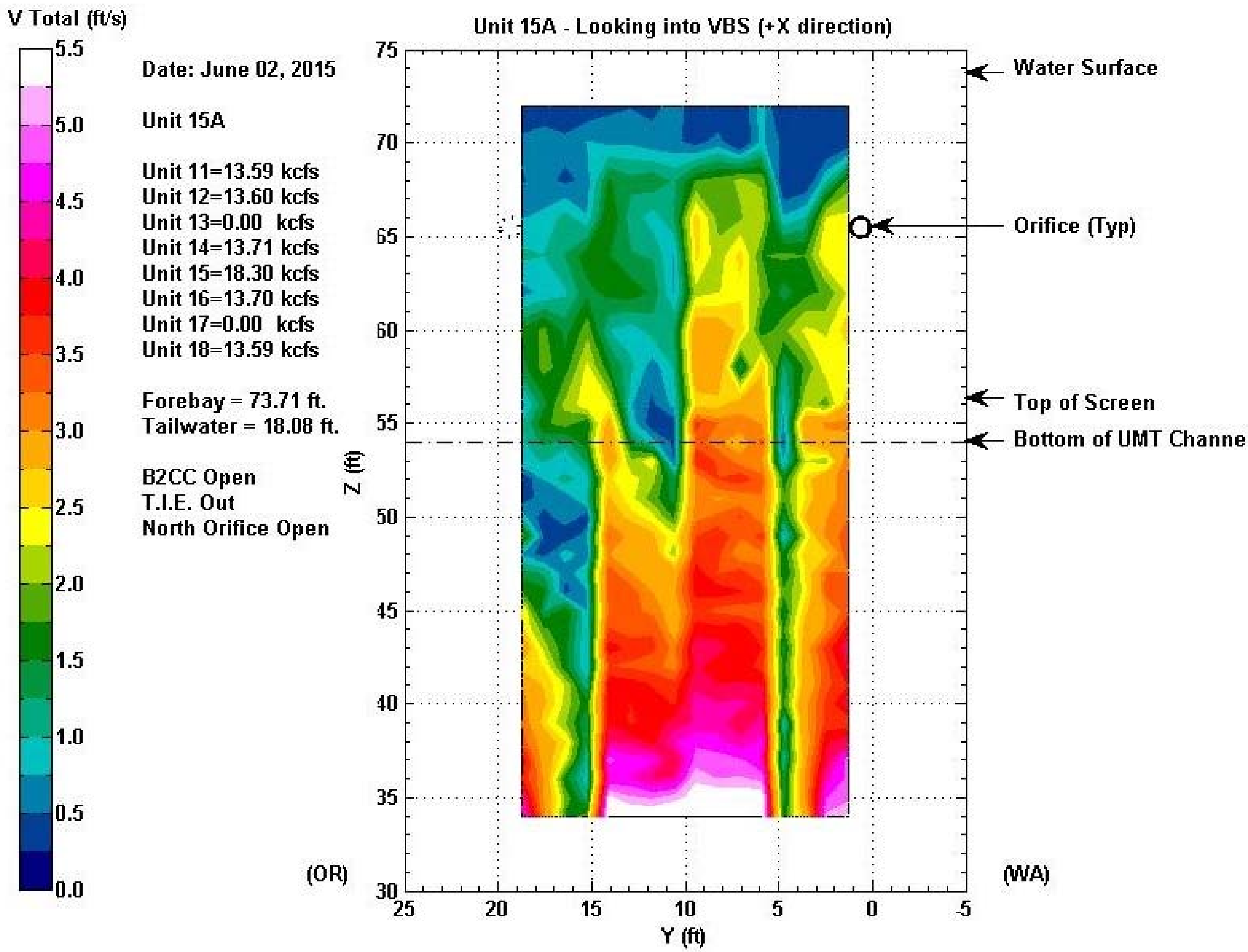

Figure 3-3 Total Velocity Magnitude at Unit 15A (Modified VBS), High Flow

3.2 Gatewell Slot 15B – Test 2

The through-screen velocity (Vx – see Figure 3-4) ranged from 0.25 to 1.04 ft/s between elevations 34 ft. and 56 ft., with an average of 0.61 ft/s ± 0.14 ft/s. Sweeping velocity (Vyz) ranged from 0.23 to 6.16 ft/s, with an average of 3.19 ft/s ±1.37 ft/s. Total RMS values (Figure 3-5) ranged between 0.65 and 2.22 ft/s, with an average of 1.32 ft/s ± 0.31 between elevations 34 ft. and 56 ft.

Forty-seven (47) data points (of 544) did not pass the fail test.

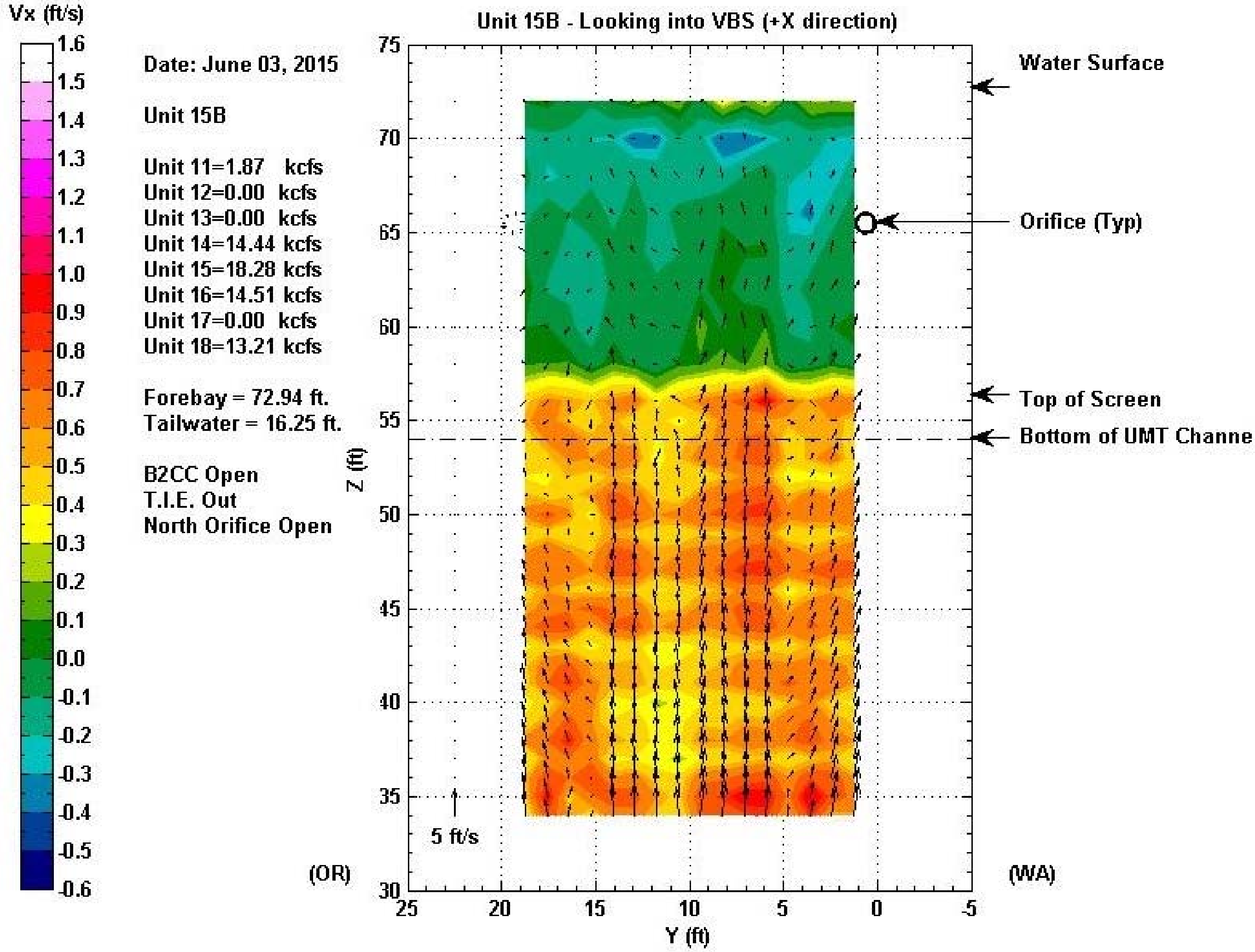

Figure 3-4 **X-direction velocity contour at Unit 15B (Modified VBS) with Y-Z directional velocity, High Flow**

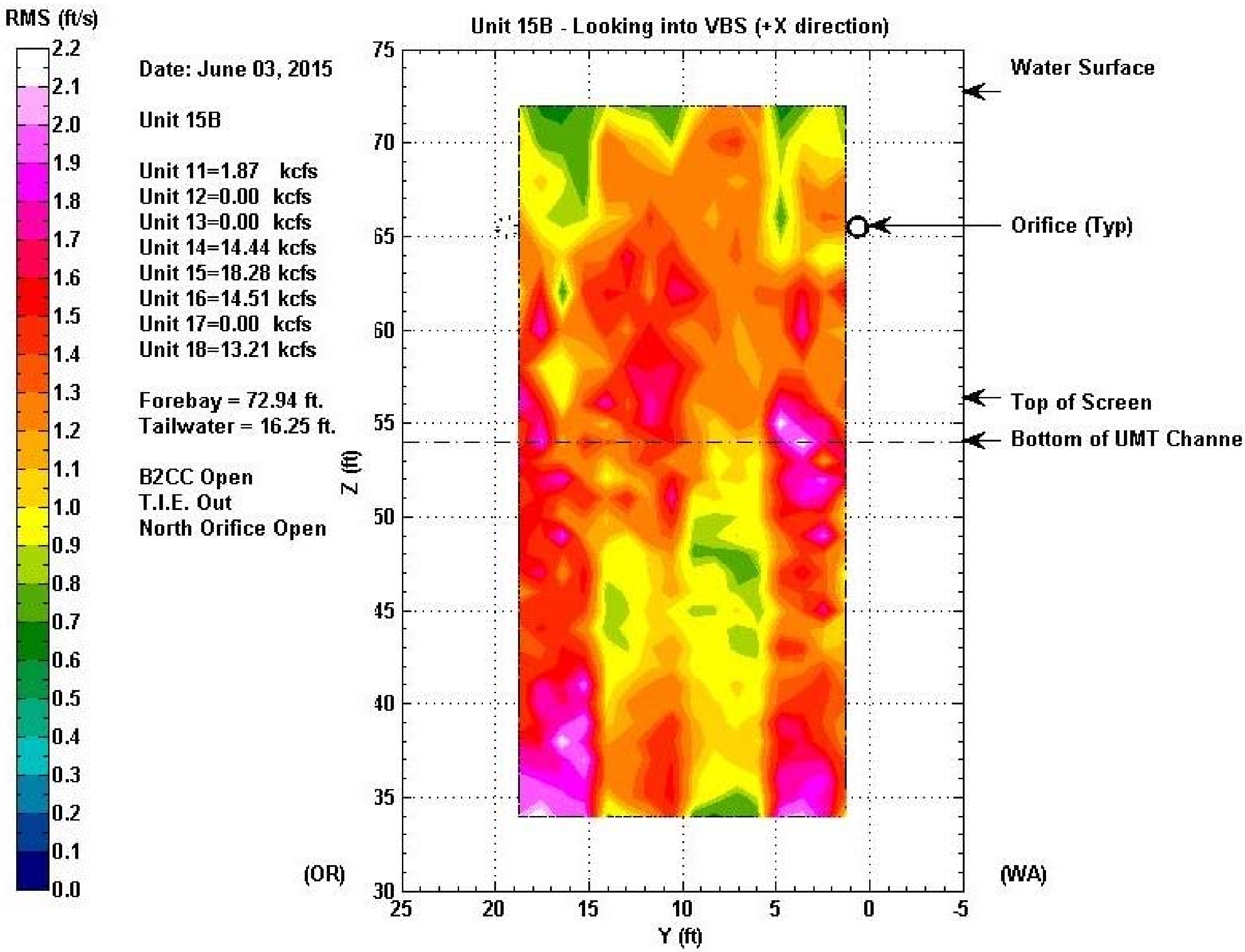

Figure 3-5 Root mean square velocity fluctuation at Unit 15B (Modified VBS), High Flow

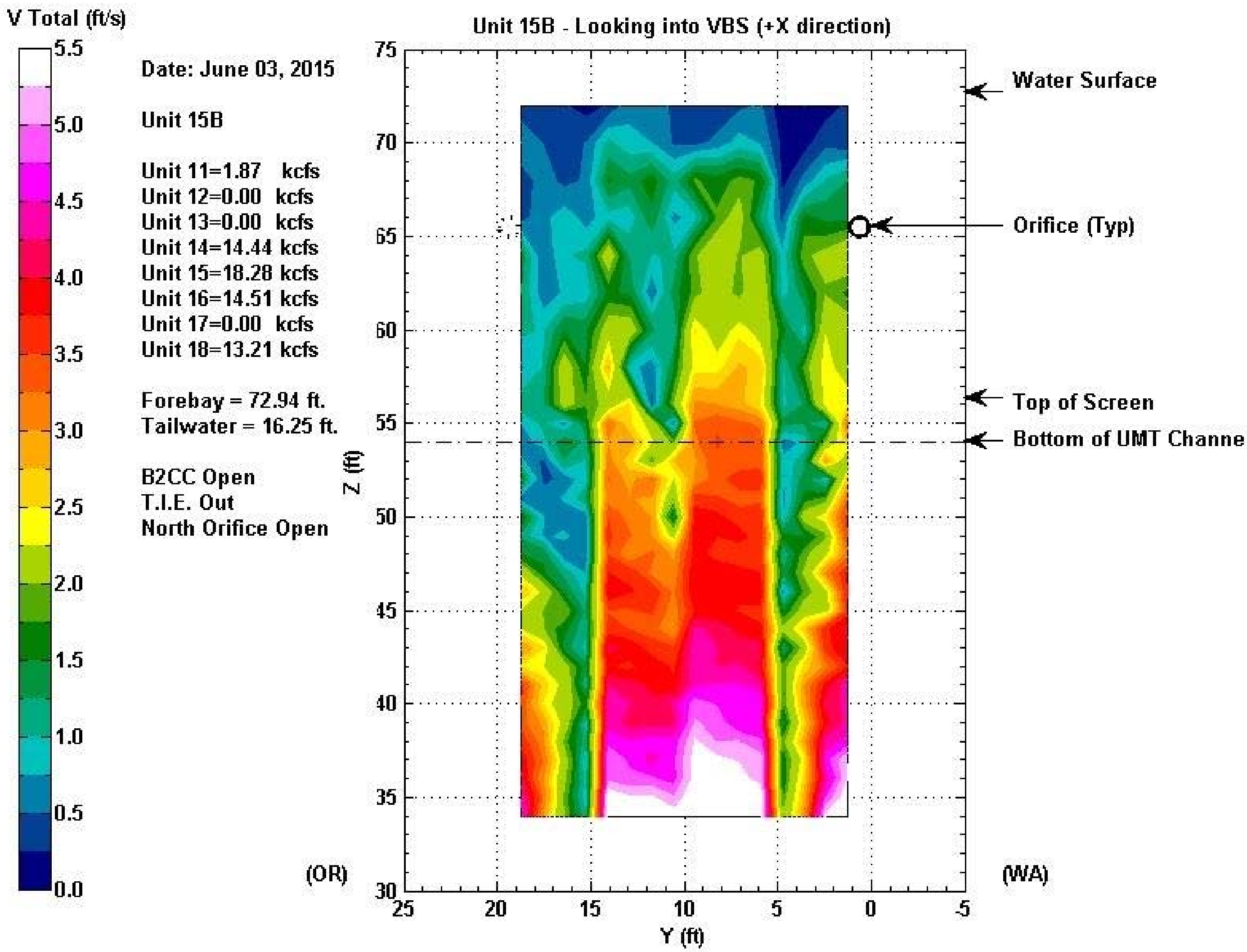

Figure 3-6 Total Velocity Magnitude at Unit 15B (Modified VBS), High Flow

3.3 Gatewell Slot 15C – Test 3

The through-screen velocity (Vx – see Figure 3-7) ranged from 0.20 to 1.22 ft/s between elevations 34 ft. and 56 ft., with an average of 0.58 ft/s ± 0.16 ft/s. Sweeping velocity (Vyz) ranged from 0.18 to 5.89 ft/s, with an average of 2.71 ft/s ±1.41 ft/s. Total RMS values (Figure 3-8) ranged between 0.38 and 1.95 ft/s, with an average of 0.97 ft/s ± 0.29 between elevations 34 ft. and 56 ft.

Seventeen (17) data points (of 544) did not pass the fail test.

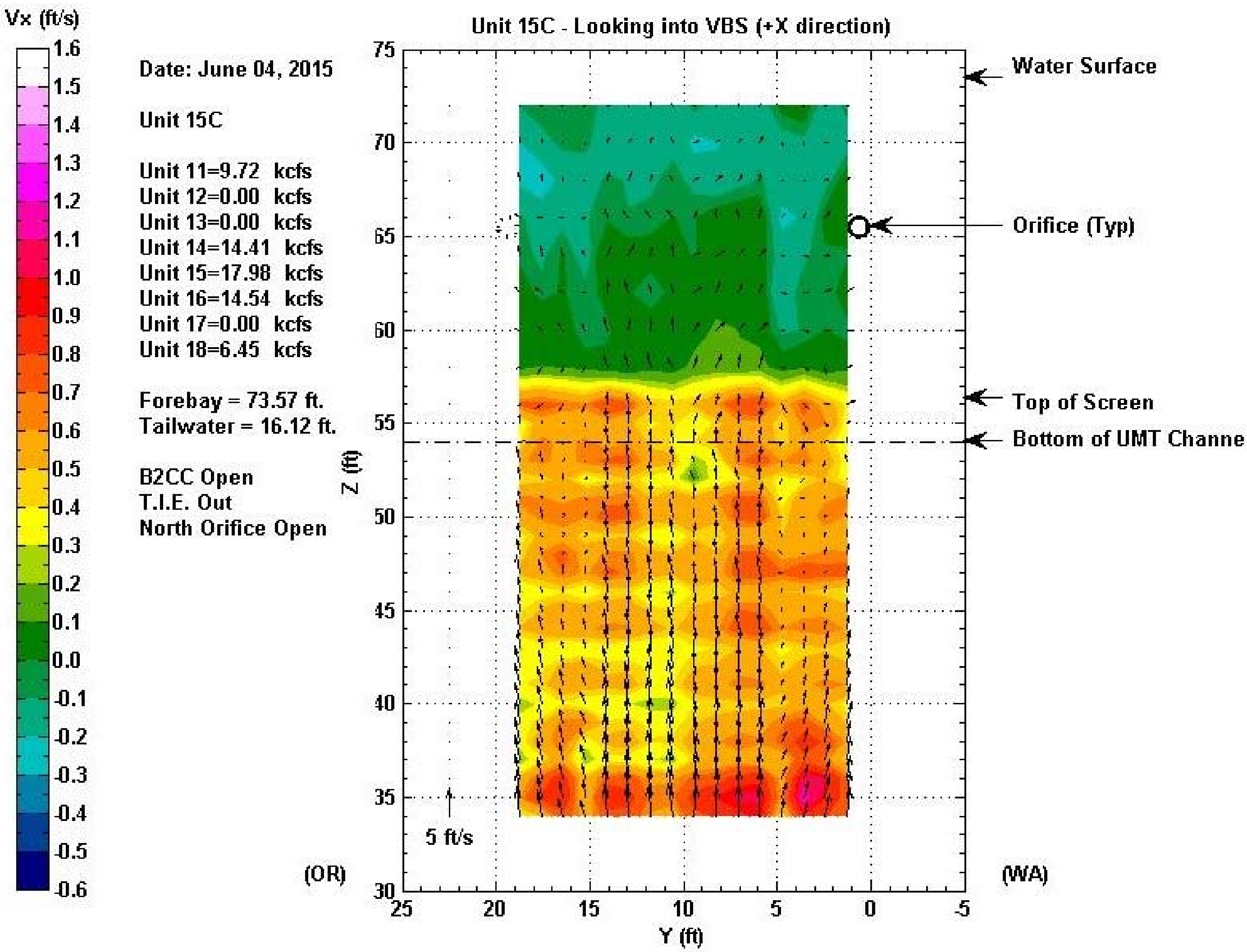

Figure 3-7 X-direction velocity contour at Unit 15C (Modified VBS) with Y-Z directional velocity, High Flow

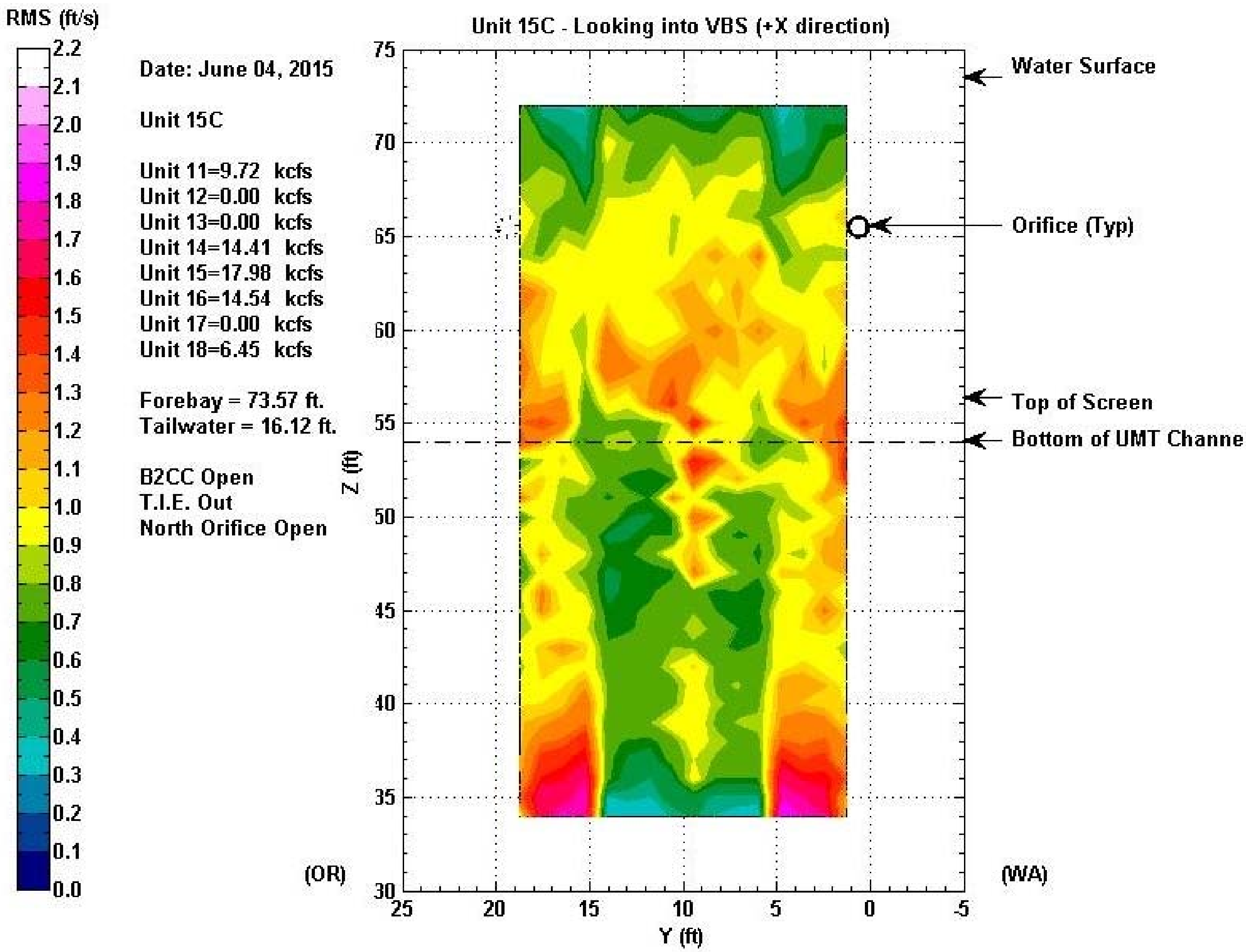

Figure 3-8 Root mean square velocity fluctuation at Unit 15C (Modified VBS), High Flow

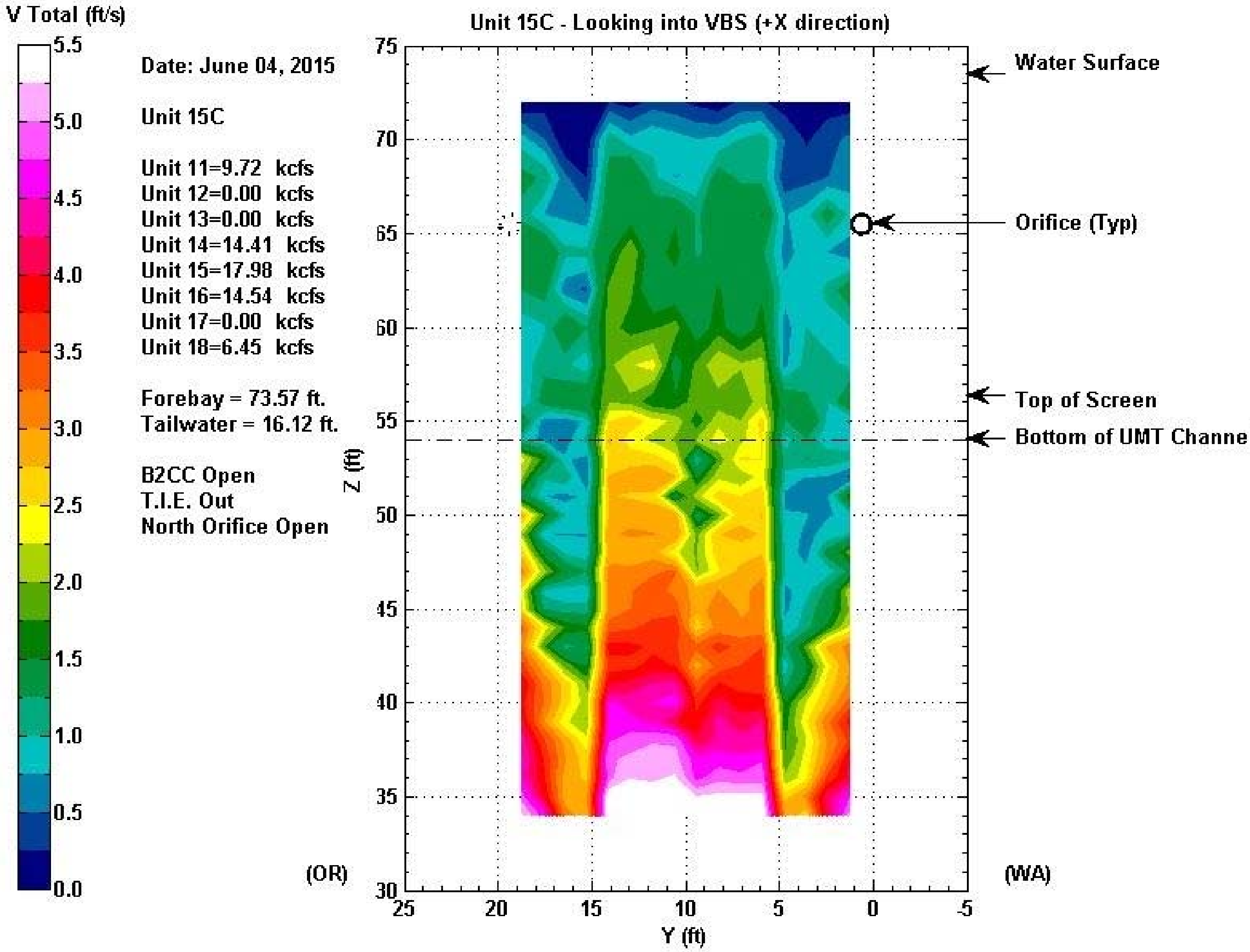

Figure 3-9 Total Velocity Magnitude at Unit 15C (Modified VBS), High Flow

3.4 Summary of Complete Test Data

A summary of all tests are provided in Table 3-1 for data collected between elevations 34 ft. and 56 ft. (the common elevations in front of the vertical barrier screen for all tests).

Table 3-1 Summary of Test Results from Gatewell Slots 15A, 15B, and 15C

Velocity Component (ft/s)	Flow Condition	15A				15B				15C			
		Min.	Max.	Avg.	σ	Min.	Max.	Avg.	σ	Min.	Max.	Avg.	σ
Vx (VBS Approach Velocity) (ft/s)	18 KCFS	0.23	1.11	0.62	0.15	0.25	1.04	0.61	0.14	0.20	1.22	0.58	0.16
Vyz(VBS Sweeping Velocity) (ft/s)	18 KCFS	0.38	5.92	3.01	1.28	0.23	6.16	3.19	1.37	0.18	5.89	2.71	1.41
Vtot (Total Velocity) (ft/s)	18 KCFS	0.67	5.98	3.09	1.25	0.67	6.20	3.27	1.33	0.56	5.92	2.80	1.35
Total RMS (ft/s)	18 KCFS	0.65	2.30	1.23	0.30	0.65	2.22	1.32	0.31	0.38	1.95	0.97	0.29

Note: Data Compiled from common elevations 34-56 ft excluding spurious data points identified with the "Fail Test".

3.5 Duplicate Data

During the 2013 Field Data Collection, there was a question as to whether, in general, a probe's data recording could be repeated with another probe. The traversing beam and measurement locations were modified for the 2014 data collection program to gain insight into this question. The 2015 data collection program repeated the data duplication scheme from the 2014 collection program. This extra data provides a test-by-test validity check on the results with respect to the probes (not the variability due to flow conditions). Since there are four probes, only three of the probes are checked against an adjacent probe as outlined below:

- WA-1, position 1 is repeated by WA-2, position 5 at Y-position 4.57 ft.
- WA-2, position 1 is repeated by OR-1, position 5 at Y-position 9.24 ft.
- OR-1, position 1 is repeated by OR-2, position 5 at Y-position 13.90 ft.

See also, Figure 2-5 for an illustration of the data points.

Duplicate Data tables are presented in Appendix B along with the rest of the tabular data. Summary tables for duplicate data are presented on the following pages in Tables 3-2 through 3-4.

In general, the duplicate data served to confirm that the data collected by one probe *could* be repeated with another probe. However, the duplicate data was not always an exact or close match to the original data. Typically the difference between original and duplicate data falls within or near the RMS recorded at the measurement location. Vz data at Y-position 4.57 is an exception, often falling outside the RMS range. This is possibly due to probe shadowing effects resulting from changes in probe orientation between the original and duplicate data probes.

Table 3-2 Duplicate Data Comparison – 15A

	Gatewell 15A – Vx (ft/s)											
	OR				Y-POSITION							WA
	13.9				9.24				4.57			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	(0.13)	(0.11)	(0.02)	1.22	(0.13)	(0.14)	0.01	0.92	(0.11)	(0.09)	(0.02)	1.24
58	(0.14)	(0.03)	(0.10)	4.15	0.18	0.05	0.13	3.78	0.04	0.22	(0.18)	0.16
53	0.65	0.41	0.24	1.59	0.65	0.67	(0.02)	0.97	0.67	0.73	(0.06)	0.92
48	0.75	0.43	0.32	1.75	0.63	0.71	(0.08)	0.89	0.66	0.72	(0.06)	0.92
43	0.52	0.30	0.22	1.73	0.51	0.57	(0.06)	0.89	0.51	0.49	0.02	1.03
38	0.66	0.30	0.35	2.16	0.71	0.66	0.05	1.07	0.55	0.70	(0.15)	0.78
AVE			0.17	2.10			0.00	1.42			(0.08)	0.84

	Gatewell 15A– Vy (ft/s)											
	OR				Y-POSITION							WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	1.30	0.84	0.46	1.54	0.68	1.31	(0.64)	0.52	(0.15)	0.55	(0.71)	(0.28)
58	0.80	1.13	(0.33)	0.71	(0.19)	0.69	(0.88)	(0.28)	(0.58)	(0.82)	0.24	0.71
53	(0.60)	(0.12)	(0.48)	4.95	(0.82)	(0.36)	(0.46)	2.27	(0.31)	(1.04)	0.73	0.30
48	(0.63)	(0.24)	(0.39)	2.58	(1.06)	(0.43)	(0.63)	2.47	(0.31)	(1.02)	0.71	0.30
43	0.09	0.08	0.00	1.05	(0.76)	(0.21)	(0.55)	3.64	(0.44)	(1.01)	0.57	0.43
38	0.20	0.39	(0.19)	0.52	(0.96)	0.05	(1.00)	(20.96)	(0.69)	(1.04)	0.35	0.66
AVE			(0.15)	1.89			(0.69)	(2.06)			0.32	0.35

	Gatewell 15A – Vz (ft/s)											
	OR				Y-POSITION							WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	1.01	(0.01)	1.02	(102.30)	1.72	1.11	0.62	1.56	(0.34)	1.54	(1.88)	(0.22)
58	1.45	0.36	1.09	4.08	3.02	2.94	0.08	1.03	1.20	1.91	(0.72)	0.63
53	2.92	0.60	2.33	4.88	3.72	2.82	0.90	1.32	0.52	3.02	(2.49)	0.17
48	3.09	2.03	1.06	1.52	3.58	3.20	0.39	1.12	1.46	3.43	(1.98)	0.42
43	4.01	3.37	0.64	1.19	4.17	3.79	0.37	1.10	1.29	3.98	(2.69)	0.32
38	4.30	3.90	0.40	1.10	4.63	4.50	0.13	1.03	1.03	4.37	(3.34)	0.24
AVE			1.09	(14.92)			0.41	1.19			(2.18)	0.26

V_o = Original velocity measurement (ft/s)
V_d = Duplicate velocity measurement (ft/s)

Table 3-3 Duplicate Data Comparison – 15B

	Gatewell 15B – Vx (ft/s)											
	OR					Y-POSITION						WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	(0.10)	(0.27)	0.16	0.38	(0.17)	(0.26)	0.09	0.65	(0.18)	(0.24)	0.06	0.75
58	0.12	0.05	0.07	2.26	0.10	0.05	0.05	1.93	(0.05)	0.04	(0.09)	(1.49)
53	0.69	0.34	0.35	2.04	0.65	0.77	(0.12)	0.84	0.49	0.74	(0.25)	0.66
48	0.79	0.41	0.38	1.93	0.64	0.74	(0.10)	0.87	0.67	0.75	(0.07)	0.90
43	0.46	0.30	0.16	1.54	0.43	0.42	0.01	1.03	0.47	0.47	(0.00)	1.00
38	0.59	0.28	0.31	2.10	0.63	0.51	0.12	1.23	0.69	0.59	0.09	1.15
AVE			0.24	1.71			0.01	1.09			(0.04)	0.50

	Gatewell 15B– Vy (ft/s)											
	OR					Y-POSITION						WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	0.35	0.49	(0.14)	0.71	(0.55)	0.78	(1.33)	(0.71)	(0.11)	(0.03)	(0.08)	3.64
58	0.22	0.39	(0.17)	0.56	(1.14)	0.18	(1.31)	(6.39)	(0.81)	(1.21)	0.39	0.67
53	(0.13)	0.06	(0.20)	(2.11)	(0.89)	(0.16)	(0.72)	5.44	(0.73)	(1.10)	0.38	0.66
48	(0.30)	0.15	(0.45)	(2.07)	(0.80)	(0.10)	(0.69)	7.71	(0.12)	(0.73)	0.60	0.17
43	0.07	0.35	(0.28)	0.21	(0.58)	0.09	(0.67)	(6.72)	(0.20)	(0.67)	0.47	0.30
38	0.04	0.45	(0.41)	0.09	(0.91)	0.15	(1.06)	(6.15)	(1.14)	(0.93)	(0.21)	1.22
AVE			(0.28)	(0.44)			(0.97)	(1.14)			0.26	1.11

	Gatewell 15B – Vz (ft/s)											
	OR					Y-POSITION						WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	1.52	0.10	1.42	14.77	1.70	1.32	0.38	1.29	(0.20)	1.22	(1.41)	(0.16)
58	2.95	0.34	2.61	8.77	2.32	2.57	(0.25)	0.90	(0.60)	2.28	(2.88)	(0.26)
53	3.19	1.56	1.63	2.04	2.92	2.91	0.01	1.00	0.08	2.78	(2.70)	0.03
48	3.51	2.79	0.72	1.26	3.85	3.56	0.29	1.08	0.82	3.36	(2.54)	0.24
43	4.15	3.50	0.66	1.19	4.39	4.06	0.34	1.08	1.08	4.01	(2.93)	0.27
38	4.66	4.51	0.15	1.03	5.19	4.94	0.25	1.05	1.21	4.84	(3.63)	0.25
AVE			1.20	4.84			0.17	1.07			(2.68)	0.06

V_o = Original velocity measurement (ft/s)
V_d = Duplicate velocity measurement (ft/s)

Table 3-4 Duplicate Data Comparison – 15C

	Gatewell 15C – Vx (ft/s)											
	OR					Y-POSITION						WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	-0.04	(0.24)	0.20	0.17	-0.1	(0.15)	0.05	0.68	-0.12	(0.14)	0.02	0.83
58	0.03	0.08	(0.05)	0.40	0.18	0.16	0.02	1.15	0.06	0.20	(0.14)	0.31
53	0.73	0.46	0.27	1.57	0.27	0.71	(0.44)	0.38	0.64	0.42	0.22	1.52
48	0.66	0.36	0.30	1.81	0.59	0.67	(0.08)	0.89	0.61	0.65	(0.04)	0.95
43	0.37	0.21	0.16	1.79	0.42	0.39	0.03	1.08	0.41	0.42	(0.01)	0.97
38	0.55	0.30	0.25	1.84	0.57	0.54	0.03	1.05	0.72	0.64	0.08	1.13
AVE			0.19	1.26			(0.06)	0.87			0.02	0.95

	Gatewell 15C – Vy (ft/s)											
	OR					Y-POSITION						WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	-0.51	(0.50)	(0.01)	1.02	-0.66	(0.89)	0.23	0.75	-0.28	(0.64)	0.36	0.44
58	0.44	0.43	0.00	1.01	-0.59	(0.59)	0.00	0.99	-0.67	(1.06)	0.39	0.63
53	0.23	0.36	(0.13)	0.64	0.37	0.20	0.17	1.84	0.12	0.18	(0.06)	0.65
48	0.41	0.68	(0.27)	0.61	0.09	0.81	(0.72)	0.11	0.51	0.01	0.50	48.35
43	0.28	0.52	(0.24)	0.54	-0.24	0.47	(0.71)	-0.50	-0.27	(0.07)	(0.20)	3.78
38	0.47	0.74	(0.27)	0.64	-0.31	0.50	(0.81)	-0.63	-0.72	(0.44)	(0.28)	1.64
AVE			(0.15)	0.74			(0.31)	0.43			0.12	9.25

	Gatewell 15C – Vz (ft/s)											
	OR					Y-POSITION						WA
	13.9 ft				9.24 ft				4.57 ft			
EL (ft)	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d	V_o	V_d	V_o-V_d	V_o/V_d
68	1.26	1.35	(0.09)	0.94	0.47	0.85	(0.38)	0.55	-0.23	(0.10)	(0.13)	2.24
58	2.08	2.24	(0.16)	0.93	1.90	1.83	0.07	1.04	-0.06	(0.52)	0.46	0.12
53	2.64	2.84	(0.20)	0.93	0.81	2.80	(1.99)	0.29	-0.86	(0.32)	(0.53)	2.66
48	2.83	3.22	(0.38)	0.88	2.06	2.83	(0.78)	0.73	0.52	0.49	0.03	1.07
43	3.89	3.83	0.07	1.02	3.42	3.56	(0.14)	0.96	0.99	2.74	(1.75)	0.36
38	4.70	4.71	(0.02)	1.00	4.08	4.43	(0.35)	0.92	1.56	3.46	(1.90)	0.45
AVE			(0.13)	0.95			(0.59)	0.75			(0.64)	1.15

V_o = Original velocity measurement (ft/s)
V_d = Duplicate velocity measurement (ft/s)

4.0 Discussion

A brief qualitative discussion is provided below as it relates to general flow patterns and observations. Further detailed analysis and discussion of data results is beyond the scope of this report and will be accomplished CENWP.

4.1 General Flow Patterns

Data was collected in gatewells 15A, 15B, and 15C. The A and B slot improvements included modified VBS porosity and a prototype flow control plate installed on the downstream side of the VBS support beam at elevation 31. This flow control pate restricts the flow area of the VBS screened flow return slot. Gatewell 15C improvements included only modified VBS porosity. Tests were conducted at high (18 – 18.5 kcfs) target unit flow rates.

The general flow patterns among all gatewell slots were similar. Higher sweeping flows at the bottom of the gatewell corresponded with higher levels of turbulence than elsewhere in the gatewell. Vertical sweeping flow is concentrated near the center of the gatewell where turbulence levels are lower than elsewhere in the gatewell. Evidence of this flow pattern was observed at the water surface where large boils of water would surface near the center of the gatewell. Obstructions near the edges of the gatewell such as the STS hoist arms, sudden contractions and expansions and increased boundary layer effects likely contribute in part to the significantly higher turbulence and reduced sweeping velocities near the edges.

A large counterclockwise sweeping velocity circulation cell was consistently present above the screened portion of the VBS on the Oregon side in all gatwells tested. This flow condition was similarly noted in the 2013 and 2014 data collection report (Harbor/Alden 2013 & Harbor/Alden 2014), however the intensity of the circulation appears to be less than in previous years. The flow circulation results in downward flow (negative Vz) at the upper Oregon corner of the screened portion of the VBS. The observed circulation corresponds to the side of the gatewell that does not have an open DSM channel orifice; conversely, flow on the Washington side predominately swept upward (positive Vz) and towards the open DSM channel orifice. Instances of downward flow were less common on the Washington side for all test conditions. In gatewell 15C instances of downward flow on the Washington side were more pronounced.

Historically, screen approach velocities were noted as being higher at the edges (i.e. along the northern and southern screen panels), as opposed to at the center of the VBS. This phenomenon appears to have subsided with the current gatewell improvements. Approach velocities appeared predominately uniform laterally across the screen. A small zone of reduced velocity is, however, still apparent at the center of the VBS. Screen approach velocities are consistently higher near the bottom screen panels as was observed during previous testing. The addition of modified porosity plates on the top screen panels appears to have mitigated the “hot-spots” that had previously been noted. Refer to Table 4-1 for VBS porosity control plate schedule of open area as tested.

Table 4-1 Baseline VBS Porosity Control Plate Schedule

SCREEN ROW	% OPEN AREA	APPROX. ELEVATION (FT)	
		BOTTOM	TOP
1	45.9%	55.0	56.25
2	21.3%	52.0	54.5
3	21.3%	49.0	51.5
4	21.3%	46.0	48.5
5	21.3%	43.0	45.5
6	18.0%	40.0	42.5
7	18.0%	37.0	39.5
8	28.0%	34.0	36.5
9	63.0%	31.5	33.5

4.2 Comparison of Tests

The results of the 2015 data collection presented in this report were compared to high flow baseline results for 14A and 13C from 2014. A high flow baseline comparison for a 15B was not available. During 2014 data collection a baseline test in 14B was conducted, however a flow rate of only 16 kcfs was achieved.

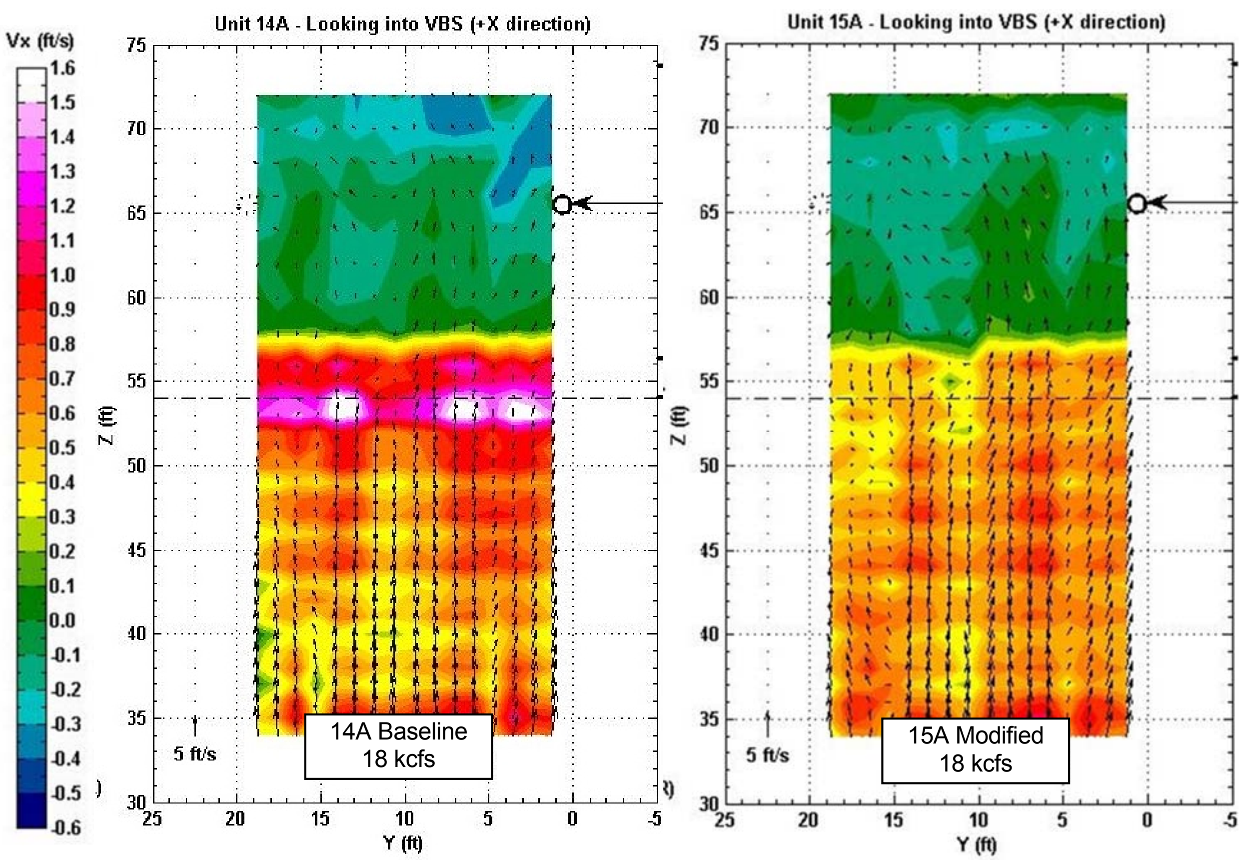

Figure 4-1 14A Baseline and 15A Modified Velocity Profile Comparison at 18 kcfs Flow Rate

Figure 4-1 compares the hydraulic conditions in gatewell 15A after the 2015 improvements to a 2014 baseline condition as measured in gatewell 14A. It is apparent that overall approach velocities are decreased and localized hot-spots are reduced. The counterclockwise flow rotation on the Oregon side of the gatewell near elevation 55 appears to remain.

Figure 4-2 compares a high flow baseline condition in gatewell 13C measured in 2014 to conditions measured in gatewell 15C. In general, localized approach velocity hot-spots appear to have been reduced. The counterclockwise flow rotation on the Oregon side of the gatewell near elevation 55 appears to remain, however in a weaker state.

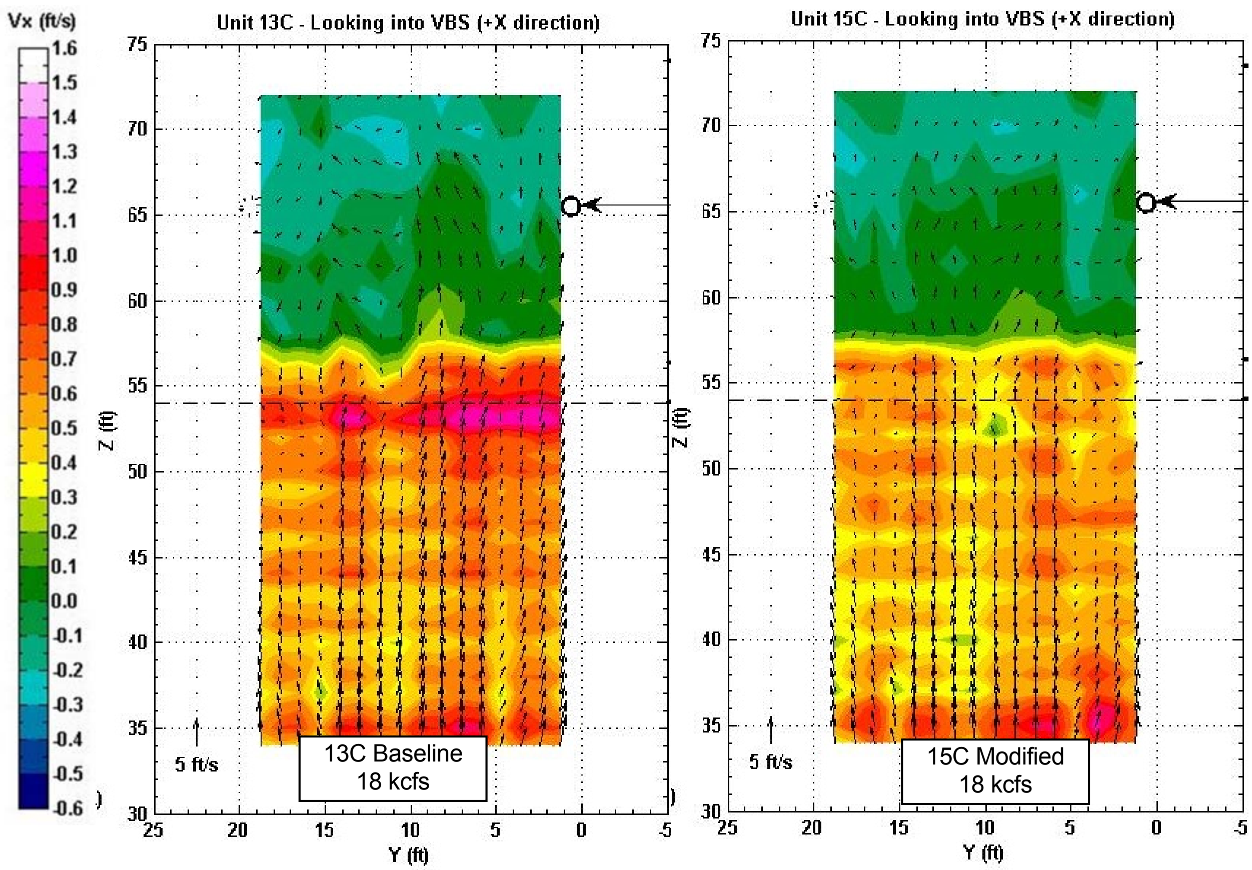

Figure 4-2 13C Baseline and 15C Modified Velocity Profile Comparison at 18 kcfs Flow Rate

Figure 4-3 presents all three velocity profile plots from the 2015 data collection side by side for comparison between gatewells.

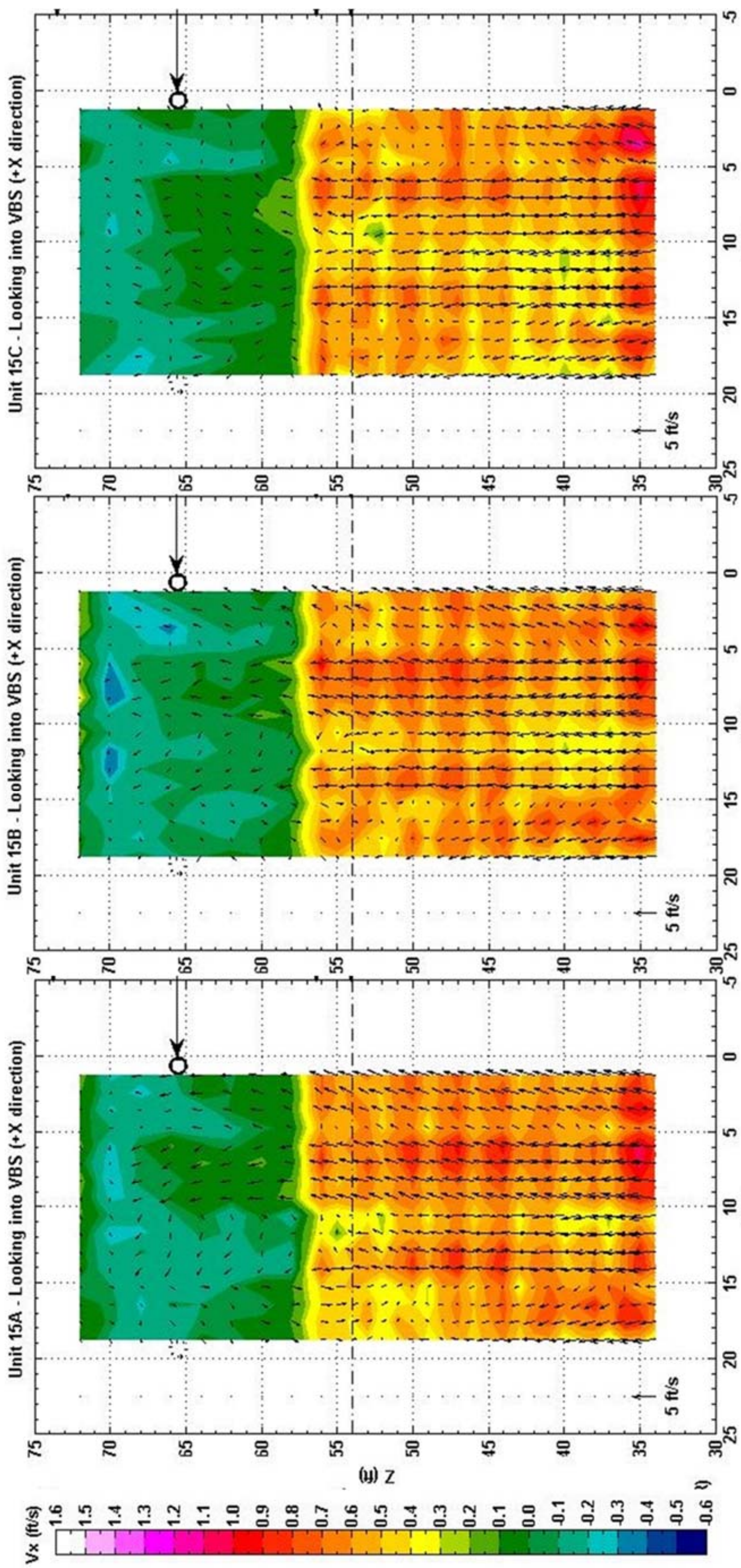

Figure 4-3 Comparison of All 2015 Test Gatewells

5.0 Conclusions

The objective of the field study was to collect water velocity data sufficient to map flow patterns within gatewell slots 15A, 15B, and 15C. Data was collected at high (18+ kcfs) flows for all test conditions. This objective was met upon the completion of June field deployment.

All post-processed data presented in this report is an accurate and valid representation of the actual flow conditions in the gatewell at the time of data collection. Data was post-processed to remove outliers that are an artifact of multiple variables. Tabulated data in Appendix B highlights areas where data may have been overly influenced by noise as identified by the fail test, by shading the suspect data with the color grey. Analysis of the presented data should be carefully undertaken with the utilization of all presentation methods provided, and should include variances with the powerhouse operation of adjacent gatewells.

Ultimately, the results of this study will be evaluated by CENWP for indications of the effectiveness of the modified VBS or the baffle plate at improving flow conditions within the gatewell with respect to fish passage.

6.0 References

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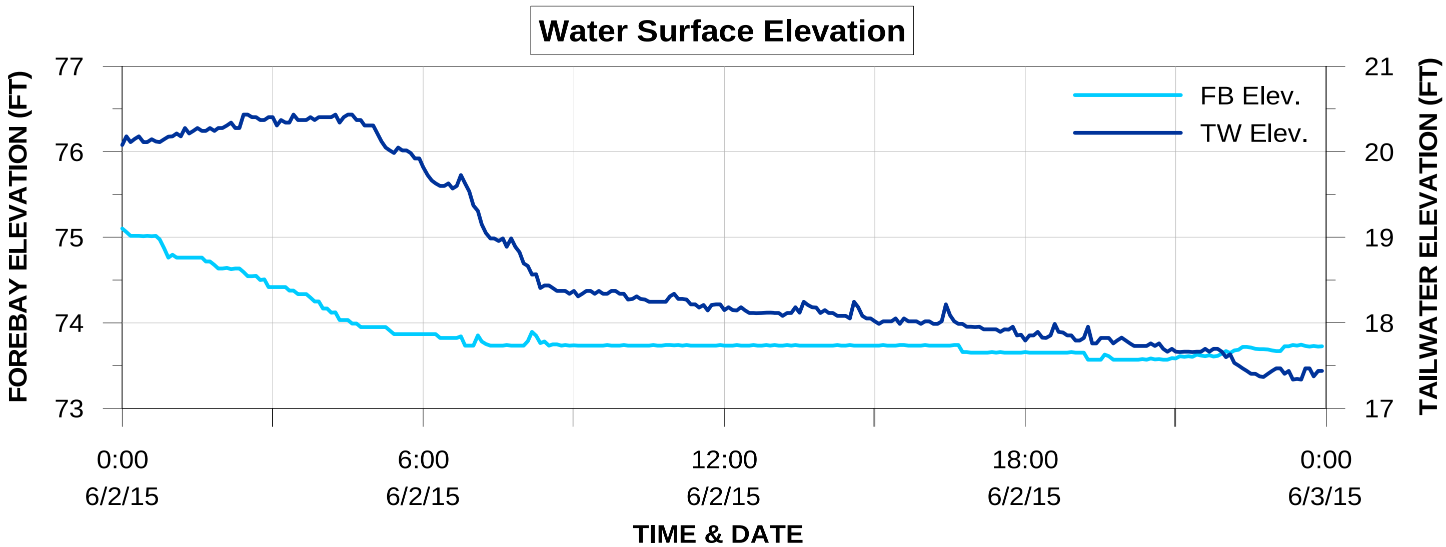
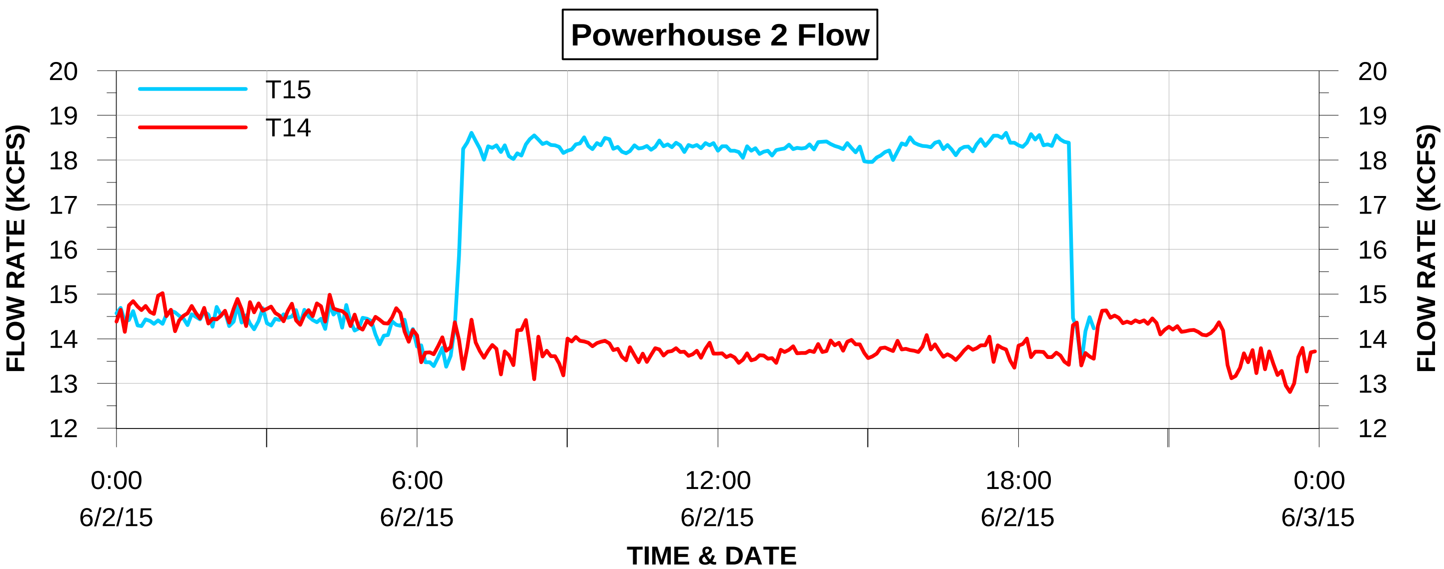
Appendix A

Data Collection Conditions

Data Collection Unit	15A	Flow Condition	18 KCFS
DATE	June 2, 2015	DIFFERENTIAL HEAD ACROSS VBS	
BEGIN DATA COLLECTION	10:00 HRS	@ 11:30 HRS	0.4 ft
END DATA COLLECTION	19:00 HRS	@ 18:30 HRS	0.4 ft





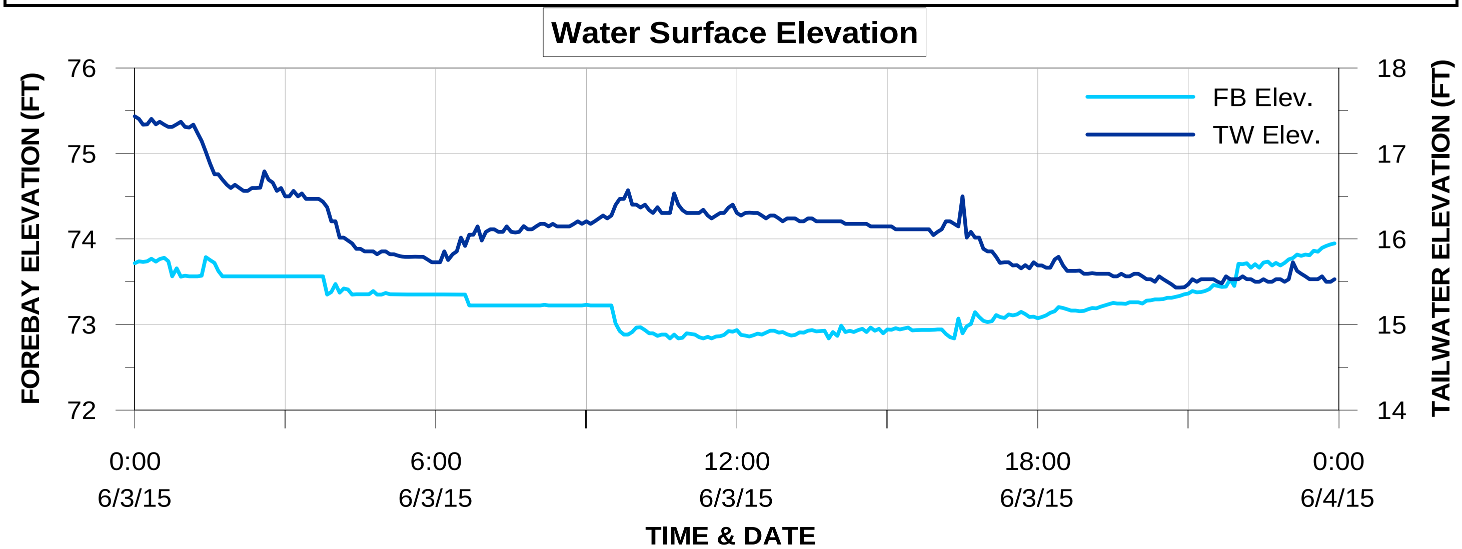
HYDRAULIICS & HYDROLOGY SUMMARY FOR PERIOD OF DATA COLLECTION								
AVERAGE TOTAL FLOW			190.63		AVERAGE SPILLWAY FLOW			98.90
B2 AVERAGE FLOW			91.73		FISH 1	2.76	FISH 2	2.48
FLOW	UNIT 11	UNIT 12	UNIT 13	UNIT 14	UNIT 15	UNIT 16	UNIT 17	UNIT 18
AVERAGE	13.59	13.60	0	13.71	18.30	13.70	0	13.59
MAX	14.26	13.92	0	14.08	18.61	14.00	0	14.03
MIN	12.98	13.24	0	13.36	17.96	13.13	0	13.09
STDEV	0.28	0.13	0	0.14	0.13	0.18	0	0.15
AVERAGE FOREBAY W/S ELEVATION			73.71 FT		AVERAGE TAILWATER W/S ELEVATION			18.08 FT
B2CC	OPEN		T.I.E.	OUT		ORIFICE OPEN		NORTH

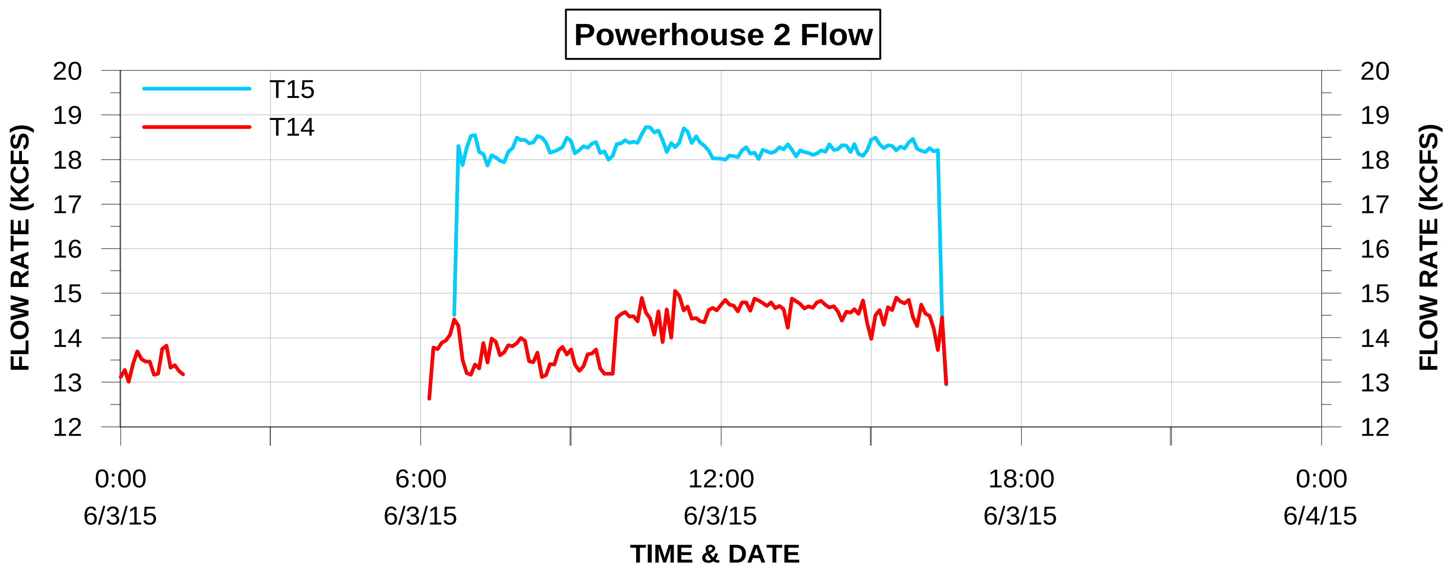
Note: Flows in KCFS

Daily Conditions Summary

Bonneville Dam 2nd Powerhouse

Data Collection Unit	15B	Flow Condition	18 KCFS
DATE	June 3, 2015	DIFFERENTIAL HEAD ACROSS VBS	
BEGIN DATA COLLECTION	09:00 HRS	@ 10:00 HRS	0.4 ft
END DATA COLLECTION	16:00 HRS	@ 14:30 HRS	0.4 ft

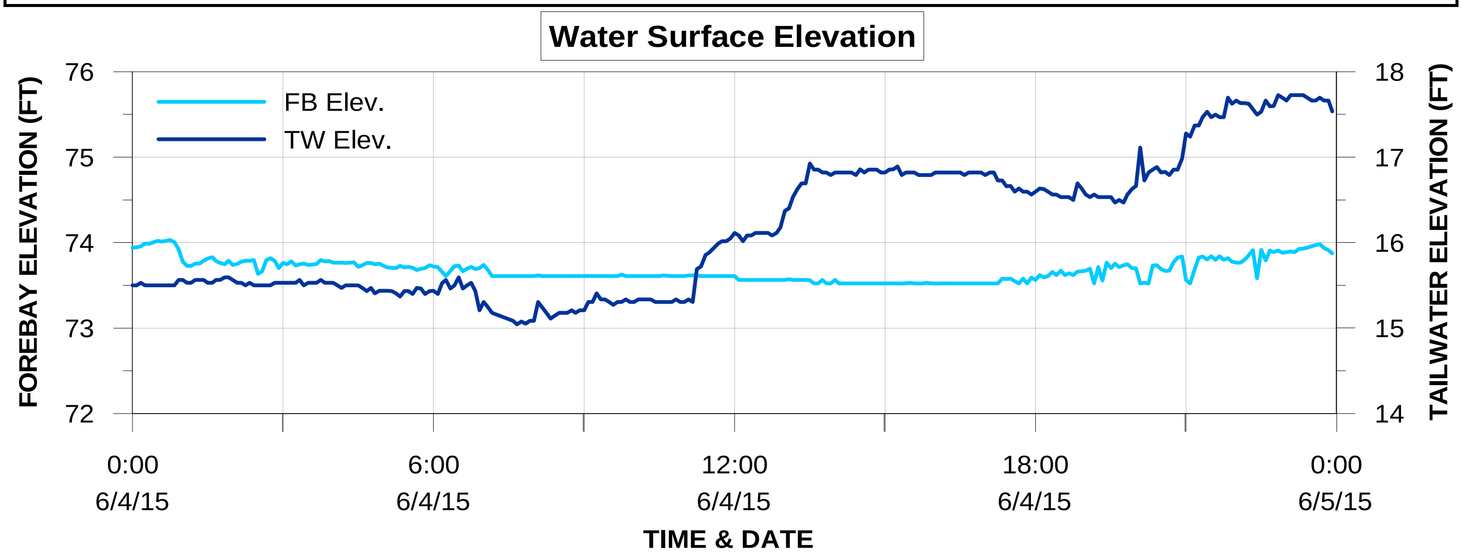


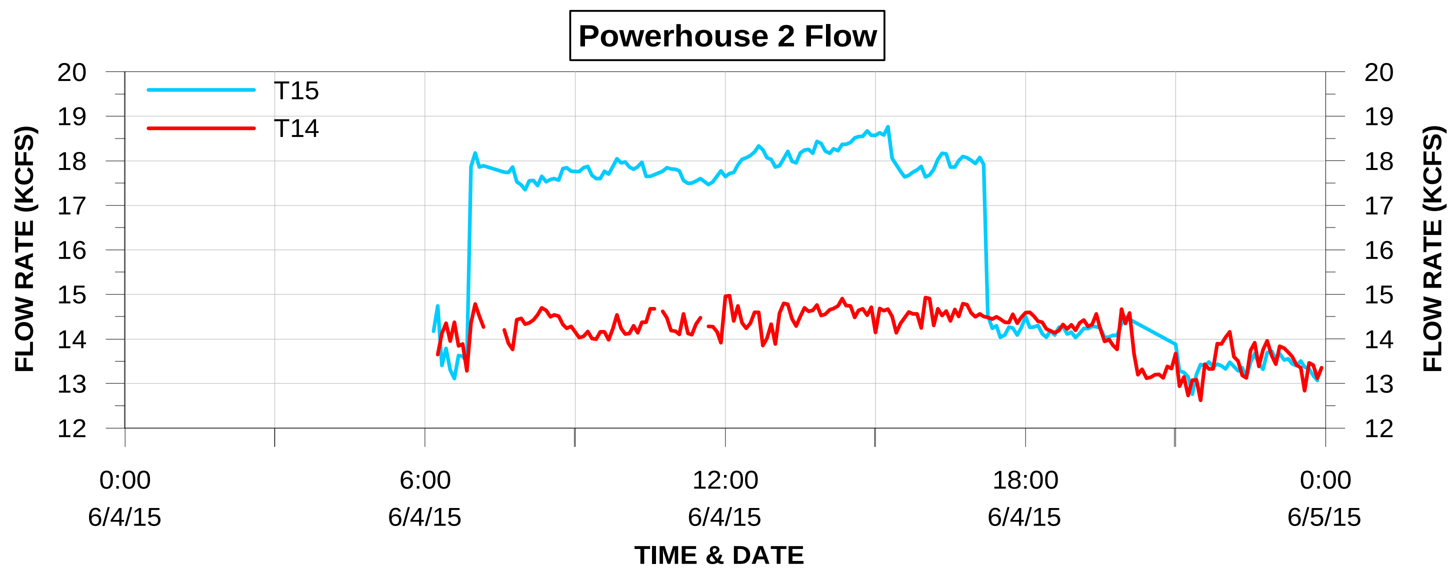


HYDRAULIICS & HYDROLOGY SUMMARY FOR PERIOD OF DATA COLLECTION								
AVERAGE TOTAL FLOW			167.28		AVERAGE SPILLWAY FLOW			99.84
B2 AVERAGE FLOW			67.44		FISH 1	2.67	FISH 2	2.46
FLOW	UNIT 11	UNIT 12	UNIT 13	UNIT 14	UNIT 15	UNIT 16	UNIT 17	UNIT 18
AVERAGE	1.87	0	0	14.44	18.28	14.51	0	13.21
MAX	13.79	0	0	15.05	18.73	15.02	0	15.05
MIN	0.00	0	0	13.19	17.99	12.84	0	0.00
STDEV	4.65	0	0	0.47	0.17	0.48	0	4.31
AVERAGE FOREBAY W/S ELEVATION			72.94 FT		AVERAGE TAILWATER W/S ELEVATION			16.25 FT
B2CC	OPEN		T.I.E.	OUT		ORIFICE OPEN		NORTH

Note: Flows in KCFS

Data Collection Unit	15C	Flow Condition	18 KCFS
DATE	June 4, 2015	DIFFERENTIAL HEAD ACROSS VBS	
BEGIN DATA COLLECTION	09:00 HRS	@ 16:00 HRS	0.4 ft
END DATA COLLECTION	16:00 HRS		





HYDRAULIICS & HYDROLOGY SUMMARY FOR PERIOD OF DATA COLLECTION								
AVERAGE TOTAL FLOW			167.64		AVERAGE SPILLWAY FLOW			99.32
B2 AVERAGE FLOW			68.32		FISH 1	2.72	FISH 2	2.50
FLOW	UNIT 11	UNIT 12	UNIT 13	UNIT 14	UNIT 15	UNIT 16	UNIT 17	UNIT 18
AVERAGE	9.72	0	0	14.41	17.98	14.54	0	6.45
MAX	14.73	0	0	14.97	18.76	14.99	0	14.91
MIN	0.00	0	0	13.85	17.47	13.36	0	0.00
STDEV	6.79	0	0	0.27	0.32	0.29	0	7.27
AVERAGE FOREBAY W/S ELEVATION			73.57 FT		AVERAGE TAILWATER W/S ELEVATION			16.12 FT
B2CC	OPEN		T.I.E.	OUT		ORIFICE OPEN		NORTH

Note: Flows in KCFS

Appendix B

Tabulated Data

List of Tables

Table B-1 Unit 15A, High Flow (Modified VBS), Vx (ft/s), Test 1

EL (ft)	OR							Y-Positions (ft)								WA
	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.11	0.15	0.06	(0.04)	0.06	0.05	0.12	0.15	0.13	0.21	0.05	0.17	0.05	0.10	0.13	0.21
70	(0.07)	(0.02)	(0.01)	(0.04)	(0.13)	(0.13)	(0.26)	(0.07)	(0.21)	(0.29)	(0.23)	(0.21)	(0.05)	(0.20)	(0.12)	(0.20)
68	(0.11)	(0.16)	(0.20)	(0.15)	(0.13)	(0.04)	(0.18)	(0.16)	(0.13)	0.01	(0.02)	0.01	(0.11)	(0.09)	(0.21)	(0.13)
66	(0.13)	(0.11)	(0.03)	(0.14)	(0.07)	(0.08)	(0.15)	(0.07)	0.02	(0.03)	0.04	0.15	(0.10)	(0.06)	(0.12)	(0.06)
64	0.04	(0.03)	(0.05)	(0.10)	(0.11)	(0.09)	(0.03)	0.03	0.11	0.06	0.15	0.03	(0.12)	(0.11)	0.07	0.04
62	(0.01)	0.01	(0.01)	(0.04)	(0.09)	(0.07)	(0.06)	(0.14)	0.04	0.02	0.11	(0.03)	(0.07)	0.02	0.01	0.00
60	0.04	0.05	(0.05)	0.08	(0.11)	(0.04)	(0.03)	0.04	0.08	0.07	0.16	0.10	(0.01)	0.09	0.09	0.07
58	0.08	0.14	0.09	0.12	(0.14)	(0.10)	(0.01)	(0.16)	0.18	0.15	0.02	0.11	0.04	0.11	0.06	0.12
56	0.48	0.51	0.44	0.48	0.74	0.57	0.39	0.37	0.65	0.64	0.85	0.79	0.59	0.70	0.75	0.76
55	0.47	0.47	0.49	0.48	0.47	0.42	0.21	0.35	0.54	0.46	0.54	0.51	0.54	0.57	0.60	0.57
54	0.44	0.43	0.45	0.52	0.50	0.54	0.35	0.36	0.61	0.56	0.57	0.74	0.54	0.64	0.64	0.58
53	0.43	0.56	0.53	0.42	0.65	0.54	0.50	0.40	0.65	0.72	0.82	0.63	0.67	0.65	0.52	0.67
52	0.34	0.34	0.39	0.31	0.53	0.43	0.30	0.26	0.50	0.51	0.60	0.61	0.44	0.46	0.49	0.55
51	0.42	0.55	0.43	0.43	0.67	0.65	0.50	0.50	0.68	0.64	0.73	0.77	0.64	0.67	0.68	0.71
50	0.60	0.46	0.44	0.53	0.84	0.80	0.56	0.57	0.72	0.77	0.88	0.89	0.65	0.72	0.78	0.79
49	0.36	0.44	0.30	0.30	0.59	0.56	0.47	0.39	0.56	0.51	0.64	0.66	0.37	0.48	0.56	0.52
48	0.48	0.51	0.58	0.60	0.75	0.76	0.58	0.58	0.63	0.70	0.83	0.81	0.66	0.69	0.65	0.66
47	0.58	0.64	0.66	0.62	0.90	0.87	0.68	0.66	0.73	0.76	0.90	0.98	0.69	0.81	0.74	0.81
46	0.42	0.47	0.49	0.43	0.57	0.59	0.50	0.43	0.53	0.51	0.65	0.66	0.52	0.53	0.56	0.59
45	0.55	0.58	0.64	0.68	0.79	0.73	0.62	0.55	0.68	0.75	0.81	0.82	0.62	0.70	0.71	0.71
44	0.64	0.75	0.78	0.75	0.84	0.87	0.70	0.67	0.74	0.78	0.88	0.97	0.69	0.75	0.81	0.71
43	0.46	0.50	0.49	0.34	0.52	0.53	0.42	0.37	0.51	0.50	0.62	0.63	0.51	0.54	0.50	0.46
42	0.54	0.74	0.66	0.59	0.67	0.63	0.57	0.52	0.59	0.62	0.72	0.73	0.67	0.61	0.58	0.59
41	0.59	0.80	0.80	0.75	0.69	0.67	0.56	0.53	0.67	0.71	0.77	0.76	0.64	0.77	0.69	0.66
40	0.37	0.54	0.71	0.61	0.48	0.46	0.37	0.32	0.49	0.43	0.54	0.54	0.50	0.56	0.51	0.47
39	0.45	0.71	0.75	0.58	0.51	0.59	0.46	0.38	0.58	0.56	0.67	0.65	0.51	0.68	0.56	0.60
38	0.51	0.72	0.86	0.64	0.66	0.62	0.56	0.38	0.71	0.63	0.76	0.77	0.55	0.74	0.67	0.62
37	0.25	0.63	0.66	0.76	0.45	0.41	0.32	0.29	0.53	0.53	0.55	0.58	0.37	0.62	0.57	0.47
36	0.57	0.92	0.88	0.69	0.70	0.70	0.61	0.44	0.77	0.75	0.89	0.91	0.63	0.90	0.84	0.70
35	0.56	0.86	0.78	0.5[illegible]	0.89	0.86	0.72	0.51	0.91	0.93	1.09	1.11	0.71	1.04	0.83	0.81
34	0.23	0.63	0.72	0.38	0.69	0.66	0.50	0.35	0.78	0.82	0.85	0.88	0.65	0.87	0.69	0.61

Box indicates position where duplicate data measured

DUPLICATE DATA

EL (ft)	OR							Y-Positions (ft)								WA
	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					(0.11)				(0.14)				(0.09)			
58					(0.03)				0.05				0.22			
53					0.41				0.67				0.73			
48					0.43				0.71				0.72			
43					0.30				0.57				0.49			
38					0.30				0.66				0.70			

Shading indicates position where $RMS_{Total} / V_{Total} > 2$ (*i.e.* does not pass the "fail test")

Table B-2 Unit 15A, High Flow (Modified VBS), Vx RMS (ft/s), Test 1

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.45	0.47	0.38	0.43	0.44	0.55	0.45	0.48	0.50	0.62	0.62	0.56	0.43	0.45	0.51	0.52
70	0.43	0.39	0.42	0.39	0.42	0.39	0.40	0.35	0.53	0.49	0.52	0.50	0.37	0.37	0.39	0.50
68	0.41	0.59	0.40	0.35	0.50	0.53	0.54	0.57	0.43	0.56	0.55	0.56	0.36	0.53	0.43	0.50
66	0.51	0.43	0.35	0.42	0.58	0.53	0.49	0.58	0.47	0.44	0.44	0.52	0.53	0.52	0.37	0.50
64	0.50	0.50	0.54	0.37	0.57	0.50	0.59	0.46	0.40	0.45	0.44	0.46	0.42	0.38	0.43	0.45
62	0.49	0.59	0.56	0.34	0.48	0.50	0.56	0.55	0.47	0.49	0.47	0.47	0.45	0.46	0.50	0.45
60	0.42	0.43	0.55	0.33	0.51	0.53	0.55	0.38	0.43	0.43	0.40	0.48	0.49	0.49	0.50	0.42
58	0.52	0.48	0.28	0.49	0.53	0.61	0.32	0.56	0.45	0.42	0.48	0.47	0.56	0.54	0.43	0.46
56	0.58	0.40	0.48	0.46	0.52	0.42	0.50	0.53	0.51	0.47	0.45	0.48	0.54	0.47	0.59	0.43
55	0.61	0.42	0.41	0.36	0.53	0.40	0.50	0.46	0.39	0.46	0.53	0.50	0.63	0.42	0.46	0.43
54	0.54	0.38	0.36	0.44	0.50	0.47	0.42	0.52	0.40	0.44	0.47	0.42	0.59	0.42	0.43	0.44
53	0.51	0.48	0.53	0.44	0.47	0.51	0.50	0.47	0.36	0.39	0.40	0.56	0.56	0.54	0.61	0.38
52	0.46	0.51	0.51	0.51	0.44	0.55	0.50	0.56	0.40	0.45	0.42	0.49	0.57	0.52	0.46	0.43
51	0.49	0.45	0.55	0.44	0.47	0.42	0.54	0.59	0.38	0.42	0.48	0.46	0.52	0.44	0.41	0.37
50	0.46	0.53	0.49	0.55	0.43	0.50	0.52	0.56	0.43	0.43	0.39	0.48	0.56	0.45	0.43	0.41
49	0.57	0.56	0.48	0.56	0.40	0.51	0.46	0.55	0.42	0.35	0.40	0.45	0.69	0.57	0.46	0.46
48	0.53	0.61	0.45	0.51	0.46	0.48	0.45	0.55	0.37	0.37	0.43	0.45	0.48	0.52	0.50	0.39
47	0.54	0.53	0.61	0.54	0.42	0.47	0.54	0.51	0.42	0.36	0.40	0.40	0.52	0.52	0.45	0.47
46	0.55	0.59	0.51	0.57	0.45	0.44	0.54	0.54	0.44	0.42	0.40	0.43	0.59	0.64	0.50	0.47
45	0.57	0.60	0.55	0.57	0.43	0.46	0.50	0.53	0.44	0.41	0.45	0.43	0.53	0.52	0.51	0.41
44	0.62	0.61	0.68	0.52	0.45	0.47	0.49	0.56	0.46	0.44	0.46	0.46	0.53	0.58	0.60	0.48
43	0.67	0.66	0.63	0.53	0.46	0.50	0.54	0.57	0.48	0.45	0.41	0.48	0.71	0.66	0.58	0.51
42	0.65	0.70	0.68	0.59	0.48	0.53	0.55	0.63	0.49	0.46	0.46	0.48	0.64	0.65	0.63	0.51
41	0.74	0.83	0.73	0.72	0.50	0.54	0.57	0.62	0.53	0.47	0.48	0.48	0.69	0.74	0.62	0.54
40	0.73	0.76	0.81	0.74	0.50	0.55	0.64	0.65	0.52	0.49	0.49	0.51	0.76	0.76	0.65	0.58
39	0.75	0.84	0.86	0.88	0.51	0.57	0.60	0.65	0.52	0.48	0.51	0.49	0.80	0.76	0.71	0.63
38	0.85	0.87	0.96	1.03	0.51	0.63	0.66	0.73	0.55	0.48	0.48	0.50	0.80	0.85	0.77	0.67
37	0.86	1.00	0.97	1.11	0.48	0.64	0.64	0.79	0.53	0.51	0.47	0.51	0.86	0.90	0.86	0.64
36	0.96	1.07	1.03	1.05	0.53	0.59	0.75	0.79	0.48	0.49	0.47	0.46	0.85	0.97	0.92	0.64
35	1.03	1.09	0.95	0.95	0.44	0.62	0.71	0.77	0.46	0.41	0.40	0.37	0.88	1.04	0.93	0.71
34	0.98	1.20	1.17	1.06	0.38	0.46	0.53	0.69	0.45	0.36	0.40	0.35	0.99	1.16	0.94	0.65

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					0.48				0.48				0.47			
58					0.68				0.42				0.56			
53					0.54				0.45				0.40			
48					0.56				0.41				0.36			
43					0.62				0.45				0.45			
38					0.81				0.50				0.60			

Table B-3 Unit 15A, High Flow (Modified VBS), Vy (ft/s), Test 1

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.44	0.39	0.32	0.35	0.60	0.57	0.56	0.71	0.37	(0.12)	0.30	0.91	(0.07)	(0.41)	(0.33)	0.16
70	0.70	0.39	0.15	0.18	0.88	0.73	0.69	0.64	0.54	0.64	0.29	0.96	0.15	0.25	(0.01)	0.37
68	0.62	0.80	0.42	0.23	1.30	1.02	1.22	1.22	0.68	0.46	0.59	0.97	(0.15)	(0.00)	(0.08)	0.27
66	0.87	0.64	0.41	0.45	1.50	1.20	1.04	1.31	0.92	1.04	1.21	1.18	0.12	0.33	0.61	0.24
64	0.75	0.82	0.73	0.32	1.40	1.21	1.35	0.70	0.64	0.67	1.19	1.24	(0.24)	(0.22)	0.13	0.13
62	0.81	0.92	0.90	0.51	1.01	1.14	1.31	0.78	0.05	0.37	0.48	1.10	(0.67)	(0.42)	(0.50)	0.07
60	0.38	0.56	0.74	0.22	0.84	1.00	1.26	0.36	(0.04)	0.72	0.58	0.76	(0.77)	(0.21)	(0.59)	(0.14)
58	0.46	0.69	(0.01)	0.48	0.80	1.09	(0.06)	0.88	(0.19)	0.07	(0.27)	0.54	(0.58)	(0.85)	(0.65)	(0.33)
56	0.00	0.03	0.15	0.56	0.13	(0.26)	(0.11)	0.95	(0.75)	(0.69)	(0.65)	(0.04)	(0.80)	(0.99)	(1.12)	(0.78)
55	0.30	(0.33)	(0.13)	(0.06)	0.30	(0.64)	(0.49)	0.21	(0.86)	(0.76)	(0.61)	(0.54)	(0.31)	(1.01)	(1.09)	(1.01)
54	(0.19)	(0.43)	(0.35)	(0.03)	(0.21)	(0.59)	(0.63)	(0.13)	(0.67)	(0.86)	(0.88)	(0.59)	(0.20)	(0.93)	(1.18)	(0.72)
53	(0.58)	(0.37)	(0.21)	(0.44)	(0.60)	(0.62)	(0.12)	(0.38)	(0.82)	(0.59)	(0.53)	(0.92)	(0.31)	(0.77)	(0.89)	(0.95)
52	(0.32)	(0.39)	(0.46)	(0.39)	(0.61)	(0.72)	(0.76)	(0.35)	(1.17)	(0.81)	(0.72)	(0.71)	(0.78)	(0.90)	(0.75)	(1.03)
51	(0.33)	(0.57)	(0.55)	(0.55)	(0.70)	(0.71)	(0.67)	(0.41)	(1.12)	(0.77)	(0.98)	(0.93)	(0.79)	(0.97)	(0.98)	(1.04)
50	(0.11)	(0.32)	(0.57)	(0.22)	(0.43)	(0.71)	(0.66)	(0.13)	(1.26)	(0.79)	(0.92)	(0.88)	(0.80)	(0.87)	(0.84)	(1.14)
49	0.02	(0.32)	(0.22)	(0.43)	(0.18)	(0.62)	(0.33)	(0.19)	(0.91)	(0.74)	(0.80)	(0.68)	(0.50)	(0.63)	(1.06)	(0.80)
48	(0.24)	(0.29)	0.16	(0.15)	(0.63)	(0.58)	(0.22)	(0.09)	(1.06)	(0.63)	(0.58)	(0.91)	(0.31)	(0.76)	(0.97)	(0.95)
47	(0.22)	0.18	(0.15)	0.26	(0.51)	(0.45)	(0.53)	0.21	(1.00)	(0.68)	(0.89)	(0.59)	(0.24)	(0.57)	(0.76)	(0.78)
46	0.02	0.10	0.01	0.35	(0.46)	(0.28)	(0.46)	(0.00)	(1.09)	(0.61)	(0.85)	(0.68)	(0.47)	(0.85)	(0.83)	(0.69)
45	0.18	0.22	0.43	0.24	(0.28)	(0.26)	(0.05)	0.09	(1.02)	(0.64)	(0.54)	(0.68)	(0.37)	(0.67)	(0.90)	(0.88)
44	0.10	0.12	0.26	0.22	(0.23)	(0.29)	(0.10)	0.06	(0.96)	(0.63)	(0.41)	(0.95)	(0.32)	(0.71)	(0.64)	(1.09)
43	0.29	0.01	0.41	0.23	0.09	(0.15)	(0.16)	0.10	(0.76)	(0.65)	(0.63)	(0.78)	(0.44)	(0.85)	(0.86)	(1.10)
42	0.03	0.53	0.29	0.31	(0.17)	0.06	(0.08)	(0.03)	(0.96)	(0.59)	(0.58)	(0.74)	(0.49)	(0.87)	(0.85)	(1.08)
41	0.36	0.60	0.54	0.32	0.15	0.27	0.06	0.38	(0.95)	(0.54)	(0.55)	(0.49)	(0.61)	(0.87)	(1.01)	(0.93)
40	0.34	0.44	0.63	0.48	0.15	0.07	0.20	0.30	(0.97)	(0.70)	(0.51)	(0.56)	(0.83)	(1.04)	(1.05)	(1.13)
39	0.48	0.33	0.81	0.82	0.20	(0.00)	0.36	0.72	(0.90)	(0.63)	(0.46)	(0.25)	(0.69)	(1.07)	(0.97)	(0.82)
38	0.43	0.68	0.93	0.78	0.20	0.36	0.34	0.76	(0.96)	(0.53)	(0.56)	(0.15)	(0.69)	(1.02)	(1.07)	(0.88)
37	0.62	0.62	0.96	0.82	0.39	0.35	0.45	0.54	(0.84)	(0.54)	(0.45)	(0.52)	(0.60)	(0.96)	(1.04)	(1.18)
36	0.59	0.49	0.69	0.77	0.19	0.40	0.25	0.55	(0.97)	(0.45)	(0.54)	(0.42)	(0.34)	(0.92)	(1.00)	(1.09)
35	0.54	0.43	0.20	(0.57)	0.39	0.32	0.27	0.57	(0.89)	(0.50)	(0.53)	(0.31)	0.01	(0.78)	(0.90)	(0.90)
34	0.56	0.32	(0.19)	(0.04)	0.42	0.29	0.40	0.69	(0.78)	(0.55)	(0.41)	(0.31)	(0.23)	(0.63)	(1.05)	(0.86)

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					0.84				1.31				0.55			
58					1.13				0.69				(0.82)			
53					(0.12)				(0.36)				(1.04)			
48					(0.24)				(0.43)				(1.02)			
43					0.08				(0.21)				(1.01)			
38					0.39				0.05				(1.04)			

Table B-4 Unit 15A, High Flow (Modified VBS), Vy RMS (ft/s), Test 1

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.30	0.40	0.29	0.29	0.33	0.52	0.36	0.35	0.62	0.55	0.53	0.62	0.46	0.45	0.40	0.60
70	0.41	0.36	0.42	0.36	0.42	0.35	0.44	0.38	0.64	0.40	0.68	0.56	0.33	0.36	0.57	0.47
68	0.40	0.56	0.42	0.43	0.51	0.51	0.54	0.58	0.47	0.64	0.55	0.54	0.43	0.60	0.62	0.45
66	0.42	0.42	0.38	0.35	0.49	0.56	0.48	0.57	0.48	0.46	0.53	0.48	0.46	0.55	0.52	0.45
64	0.46	0.60	0.45	0.35	0.68	0.65	0.59	0.50	0.51	0.60	0.58	0.54	0.53	0.45	0.45	0.58
62	0.54	0.65	0.42	0.37	0.51	0.69	0.59	0.48	0.65	0.57	0.56	0.76	0.59	0.63	0.58	0.60
60	0.61	0.44	0.64	0.32	1.01	0.64	0.64	0.49	0.64	0.63	0.66	0.81	0.57	0.54	0.64	0.49
58	0.63	0.54	0.32	0.53	1.04	0.71	0.40	0.76	0.49	0.53	0.50	0.74	0.68	0.66	0.42	0.66
56	0.60	0.50	0.42	0.57	0.89	0.44	0.46	0.88	0.87	0.67	0.77	0.79	0.69	0.68	0.72	0.64
55	0.76	0.47	0.43	0.34	0.77	0.54	0.62	0.69	0.63	0.71	0.72	0.76	0.87	0.61	0.63	0.53
54	0.55	0.42	0.43	0.51	1.14	0.56	0.55	0.91	0.62	0.62	0.65	0.60	0.79	0.55	0.60	0.69
53	0.60	0.58	0.73	0.47	0.72	0.78	0.79	0.73	0.48	0.51	0.79	0.68	0.81	0.85	0.74	0.54
52	0.43	0.79	0.54	0.75	0.56	0.79	0.67	0.85	0.48	0.57	0.56	0.71	0.65	0.86	0.71	0.63
51	0.57	0.71	0.75	0.64	0.68	0.62	0.74	0.72	0.44	0.54	0.62	0.60	0.64	0.62	0.53	0.48
50	0.67	0.72	0.70	0.80	0.53	0.62	0.68	0.73	0.47	0.49	0.49	0.58	0.69	0.54	0.66	0.58
49	0.77	0.69	0.83	0.71	0.46	0.58	0.54	0.83	0.47	0.41	0.49	0.60	0.92	0.71	0.60	0.63
48	0.62	0.84	0.63	0.78	0.56	0.47	0.50	0.68	0.32	0.49	0.55	0.49	0.57	0.69	0.65	0.50
47	0.80	0.82	0.87	0.70	0.51	0.57	0.62	0.54	0.41	0.31	0.46	0.46	0.71	0.64	0.54	0.64
46	0.58	0.78	0.63	0.66	0.52	0.52	0.57	0.67	0.48	0.47	0.42	0.47	0.64	0.79	0.60	0.52
45	0.62	0.67	0.79	0.74	0.41	0.51	0.55	0.62	0.41	0.37	0.47	0.51	0.62	0.63	0.63	0.49
44	0.69	0.68	0.73	0.63	0.48	0.51	0.57	0.62	0.49	0.43	0.56	0.47	0.54	0.70	0.72	0.52
43	0.69	0.73	0.75	0.72	0.42	0.53	0.45	0.57	0.47	0.41	0.38	0.48	0.80	0.69	0.63	0.52
42	0.71	0.69	0.80	0.64	0.51	0.51	0.63	0.69	0.48	0.44	0.47	0.48	0.72	0.71	0.73	0.56
41	0.71	0.78	0.71	0.86	0.50	0.54	0.53	0.62	0.49	0.43	0.49	0.50	0.74	0.75	0.66	0.61
40	0.65	0.73	0.72	0.79	0.52	0.55	0.67	0.70	0.49	0.50	0.49	0.52	0.75	0.77	0.67	0.61
39	0.77	0.84	0.84	0.82	0.47	0.55	0.57	0.63	0.45	0.50	0.47	0.47	0.69	0.79	0.80	0.65
38	0.84	0.84	0.88	0.82	0.51	0.51	0.69	0.70	0.52	0.49	0.49	0.50	0.84	0.85	0.83	0.71
37	0.93	0.94	0.91	0.83	0.50	0.61	0.69	0.72	0.52	0.50	0.46	0.48	0.84	0.93	0.86	0.64
36	0.97	1.07	0.93	0.90	0.52	0.59	0.74	0.83	0.44	0.43	0.45	0.47	1.02	1.01	0.88	0.62
35	0.96	0.98	1.15	1.02	0.40	0.60	0.70	0.85	0.42	0.39	0.36	0.37	0.98	1.07	0.96	0.69
34	0.92	1.18	1.11	1.14	0.40	0.47	0.50	0.68	0.43	0.33	0.37	0.35	1.08	1.10	0.82	0.68

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					0.50				0.57				0.44			
58					0.96				0.72				0.63			
53					0.80				0.74				0.55			
48					0.71				0.49				0.43			
43					0.64				0.43				0.45			
38					0.80				0.51				0.58			

Table B-5 Unit 15A, High Flow (Modified VBS), Vz (ft/s), Test 1

	OR							Y-Positions (ft)							WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	(0.24)	(0.32)	(0.23)	(0.43)	(0.27)	(0.39)	(0.33)	(0.35)	(0.44)	(0.32)	(0.35)	(0.51)	(0.26)	(0.39)	(0.15)	(0.15)
70	(0.33)	(0.79)	(0.81)	(0.94)	0.01	(0.54)	(0.34)	(0.46)	0.15	(0.46)	(0.07)	0.17	(0.63)	(0.52)	(0.35)	0.18
68	(0.29)	(0.04)	(0.46)	(0.76)	1.01	1.07	0.95	0.59	1.72	1.88	2.05	1.78	(0.34)	0.46	1.12	1.90
66	(0.31)	(0.74)	(1.19)	(0.85)	1.06	0.48	0.09	0.40	2.46	1.72	1.66	1.94	0.97	1.13	2.23	2.37
64	(0.97)	(0.84)	(1.21)	(1.73)	0.85	0.75	0.26	(0.56)	2.53	2.04	2.31	1.37	1.88	1.84	2.52	2.37
62	(0.28)	(0.39)	(0.68)	(1.47)	1.38	1.35	0.86	(0.38)	2.21	2.25	2.45	1.72	1.35	1.73	1.83	2.34
60	(1.59)	(1.82)	(1.35)	(1.97)	0.81	(0.27)	0.16	(1.33)	3.04	2.89	2.63	1.48	1.88	2.35	2.20	2.70
58	(1.47)	(1.81)	(1.73)	(2.32)	1.45	0.59	(0.80)	(0.79)	3.02	3.15	1.36	2.67	1.20	1.70	2.35	2.27
56	(0.68)	(1.43)	(2.08)	(2.36)	2.22	0.73	0.54	0.08	2.42	2.43	2.82	2.77	0.08	1.88	1.43	2.60
55	(0.97)	(1.70)	(1.90)	(1.59)	2.88	0.70	(0.07)	(0.43)	3.60	3.33	3.31	3.12	0.40	2.83	3.03	3.07
54	(1.02)	(1.34)	(1.18)	(1.67)	3.11	1.34	0.75	0.54	3.45	3.13	2.81	3.37	0.17	2.57	2.80	3.02
53	(0.84)	(0.98)	(0.69)	(1.29)	2.92	1.93	2.41	(0.18)	3.72	3.53	3.18	3.01	0.52	2.03	1.86	3.32
52	0.16	(0.80)	(1.14)	(0.87)	2.44	2.25	2.01	1.39	2.99	3.55	3.68	3.42	1.38	2.42	2.96	3.18
51	(0.09)	(0.32)	(0.28)	(0.98)	2.62	2.17	1.75	1.38	3.01	3.01	3.03	3.19	1.52	2.25	2.85	3.15
50	0.86	0.13	(0.49)	0.16	2.93	2.43	2.21	1.68	3.06	3.32	3.47	3.05	1.04	2.54	3.00	3.16
49	1.96	0.38	0.35	(0.66)	3.41	3.02	2.76	2.30	3.50	3.76	3.33	3.64	0.62	2.12	3.08	3.42
48	0.72	0.05	0.89	(0.47)	3.09	2.69	2.96	2.01	3.58	3.61	3.09	3.17	1.46	2.43	2.37	3.49
47	1.37	1.18	0.34	0.99	3.42	3.08	2.85	2.89	3.84	3.51	3.53	3.31	1.37	2.30	3.31	3.25
46	1.81	1.61	0.42	0.74	3.55	3.50	3.14	3.08	3.79	3.96	3.77	3.68	1.72	2.19	3.40	3.47
45	2.48	1.22	1.63	0.60	3.35	3.43	3.32	2.96	3.53	3.46	3.39	3.40	1.38	2.52	3.01	3.41
44	2.52	1.73	1.52	0.49	3.57	3.44	3.58	2.91	3.81	3.86	3.91	3.47	1.60	2.67	3.09	3.82
43	3.05	2.12	1.53	0.80	4.01	3.76	3.70	3.34	4.17	4.15	3.89	3.78	1.29	2.86	3.65	4.11
42	2.57	2.36	1.52	0.63	3.60	3.56	3.52	3.27	4.03	3.86	3.90	3.68	1.42	2.79	3.47	3.95
41	3.13	2.54	2.05	0.90	4.04	3.97	3.84	3.73	4.13	4.05	4.05	4.06	1.28	2.72	3.38	3.72
40	3.30	2.74	2.00	1.44	4.03	3.86	4.11	3.82	4.37	4.29	4.37	4.15	1.43	2.89	3.54	4.10
39	3.41	2.48	1.77	1.00	4.06	3.82	3.97	4.13	4.26	4.39	4.10	4.41	0.53	2.88	3.59	3.56
38	3.46	2.94	2.19	0.92	4.30	4.22	3.97	4.47	4.63	4.60	4.32	4.59	1.03	2.64	3.89	4.11
37	4.01	2.90	2.04	0.17	4.84	4.63	4.62	4.06	4.80	4.83	4.78	4.50	0.79	2.88	4.00	4.76
36	3.81	3.02	1.24	(0.06)	4.55	4.51	4.26	4.32	5.08	4.96	4.97	4.85	1.22	2.90	4.31	4.72
35	4.36	3.01	1.83	0.99	5.21	5.02	4.93	5.13	5.24	5.43	5.49	5.54	1.21	2.87	4.66	4.78
34	4.70	3.24	1.64	1.87	5.68	5.58	5.63	5.52	5.81	5.90	5.56	5.66	1.44	2.73	4.92	5.20

DUPLICATE DATA

	OR							Y-Positions (ft)							WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					(0.01)				1.11				1.54			
58					0.36				2.94				1.91			
53					0.60				2.82				3.02			
48					2.03				3.20				3.43			
43					3.37				3.79				3.98			
38					3.90				4.50				4.37			

Table B-6 Unit 15A, High Flow (Modified VBS), Vz RMS (ft/s), Test 1

	OR							Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.47	0.44	0.37	0.36	0.56	0.66	0.58	0.53	0.53	0.83	0.64	0.71	0.44	0.52	0.60	0.75
70	0.76	0.47	0.49	0.42	0.73	0.61	0.73	0.62	0.89	0.57	1.10	1.05	0.45	0.63	0.68	0.83
68	0.63	0.88	0.64	0.59	1.08	1.15	1.04	1.06	0.86	0.97	0.92	0.98	0.66	0.97	0.89	0.74
66	0.69	0.66	0.53	0.75	0.89	0.90	0.76	0.81	0.73	0.83	0.74	0.77	1.02	0.87	0.76	0.71
64	0.77	1.07	0.65	0.52	0.98	1.18	1.00	1.00	0.71	0.86	0.79	1.17	0.73	0.90	0.63	0.81
62	1.02	1.12	0.83	0.81	1.12	1.34	1.07	0.90	0.97	0.91	0.82	0.91	0.85	0.84	0.87	0.91
60	0.69	0.75	1.04	0.49	1.31	0.95	1.28	0.55	0.68	0.82	0.73	0.96	0.76	0.82	1.05	0.76
58	0.77	0.72	0.57	0.71	1.28	1.21	0.50	1.24	0.71	0.66	0.94	1.07	1.04	0.80	0.94	0.81
56	1.24	0.72	1.06	0.88	1.14	1.57	1.44	1.59	1.20	1.05	0.95	1.02	1.67	0.88	1.18	0.85
55	1.10	0.67	0.72	0.86	1.16	1.02	0.95	1.06	0.68	0.89	0.93	1.09	1.17	0.59	0.72	0.74
54	0.85	0.59	0.64	0.83	0.91	1.13	1.35	1.26	0.66	0.69	1.03	0.73	1.42	0.62	0.68	0.76
53	0.74	1.07	1.09	0.77	0.96	1.14	1.29	0.91	0.55	0.79	0.80	0.96	1.02	0.94	1.37	0.62
52	0.89	0.91	0.76	0.99	0.89	1.17	1.08	1.26	0.76	0.68	0.77	0.77	0.91	0.84	0.81	0.62
51	0.81	0.65	1.08	0.88	0.94	0.95	1.15	1.18	0.71	0.69	0.79	0.78	0.78	0.77	0.74	0.60
50	0.93	1.11	0.76	1.01	0.74	0.84	1.01	1.12	0.70	0.62	0.64	0.79	1.13	0.66	0.67	0.65
49	1.07	0.95	1.04	1.22	0.70	0.85	0.97	1.14	0.62	0.50	0.76	0.70	1.16	0.92	0.70	0.75
48	1.00	0.95	1.03	0.85	0.75	0.89	0.80	0.95	0.48	0.57	0.64	0.66	0.78	0.90	1.09	0.55
47	1.26	0.94	0.99	0.95	0.60	0.80	0.81	0.86	0.56	0.50	0.58	0.55	0.93	0.72	0.67	0.70
46	1.27	1.23	1.05	0.89	0.61	0.71	0.89	0.79	0.59	0.61	0.51	0.57	0.72	0.83	0.66	0.58
45	1.00	1.24	0.98	1.16	0.58	0.68	0.76	0.90	0.50	0.55	0.60	0.62	0.72	0.67	0.64	0.59
44	0.95	1.09	1.15	1.03	0.61	0.71	0.71	0.85	0.68	0.61	0.67	0.56	0.85	0.94	1.01	0.68
43	0.84	0.95	1.04	0.91	0.62	0.64	0.68	0.79	0.69	0.66	0.55	0.58	0.97	0.80	0.80	0.67
42	0.93	0.84	0.95	1.03	0.67	0.71	0.77	0.81	0.71	0.63	0.64	0.65	0.91	0.83	0.84	0.70
41	0.95	1.09	0.97	1.00	0.75	0.70	0.81	0.89	0.77	0.65	0.68	0.71	0.96	0.89	0.78	0.74
40	0.89	0.96	1.02	0.86	0.64	0.77	0.82	0.86	0.73	0.75	0.74	0.71	0.94	0.93	0.82	0.77
39	0.96	1.01	1.01	1.22	0.75	0.83	0.89	0.90	0.77	0.74	0.77	0.73	0.95	0.98	0.95	0.86
38	1.05	1.06	1.07	1.22	0.77	0.89	0.88	0.97	0.80	0.87	0.79	0.72	1.09	1.05	0.93	0.94
37	1.12	1.09	1.20	1.11	0.76	0.89	0.93	1.04	0.86	0.75	0.79	0.83	1.02	1.12	1.08	0.80
36	1.15	1.19	1.35	1.42	0.85	0.94	1.07	1.17	0.72	0.70	0.74	0.70	1.04	1.21	1.08	0.93
35	1.32	1.37	1.20	1.59	0.72	0.91	1.03	1.19	0.69	0.60	0.57	0.52	1.13	1.32	1.13	0.97
34	1.41	1.57	1.26	1.59	0.51	0.69	0.80	1.18	0.66	0.42	0.54	0.51	1.18	1.39	1.20	0.96

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					0.65				1.04				1.09			
58					1.07				0.83				1.10			
53					1.27				0.86				0.62			
48					0.99				0.66				0.51			
43					0.84				0.53				0.62			
38					1.07				0.86				0.91			

Table B-7 Unit 15A, High Flow (Modified VBS), Vyz (ft/s), Test 1

	OR						Y-Positions (ft)									WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.50	0.51	0.39	0.55	0.66	0.70	0.65	0.79	0.57	0.35	0.46	1.04	0.26	0.57	0.36	0.22
70	0.78	0.88	0.82	0.96	0.88	0.91	0.76	0.78	0.56	0.79	0.30	0.98	0.65	0.58	0.35	0.41
68	0.69	0.80	0.62	0.79	1.65	1.47	1.55	1.36	1.85	1.94	2.13	2.03	0.38	0.46	1.12	1.92
66	0.93	0.98	1.26	0.96	1.84	1.29	1.05	1.37	2.62	2.01	2.05	2.28	0.97	1.18	2.32	2.38
64	1.23	1.17	1.41	1.76	1.64	1.42	1.38	0.90	2.61	2.15	2.60	1.85	1.89	1.86	2.52	2.37
62	0.85	1.00	1.13	1.56	1.71	1.77	1.57	0.87	2.21	2.28	2.49	2.04	1.51	1.78	1.90	2.34
60	1.64	1.90	1.54	1.98	1.16	1.04	1.27	1.38	3.04	2.98	2.69	1.66	2.03	2.36	2.28	2.71
58	1.54	1.94	1.73	2.37	1.65	1.24	0.80	1.18	3.02	3.15	1.39	2.73	1.33	1.90	2.44	2.30
56	0.68	1.43	2.09	2.42	2.23	0.77	0.55	0.95	2.53	2.53	2.90	2.77	0.81	2.12	1.82	2.72
55	1.02	1.73	1.90	1.59	2.90	0.95	0.49	0.48	3.70	3.42	3.36	3.16	0.51	3.01	3.22	3.23
54	1.04	1.40	1.23	1.67	3.12	1.46	0.98	0.56	3.51	3.24	2.95	3.42	0.26	2.74	3.04	3.10
53	1.02	1.05	0.72	1.37	2.99	2.03	2.41	0.42	3.81	3.57	3.22	3.15	0.61	2.17	2.07	3.45
52	0.36	0.89	1.23	0.95	2.52	2.36	2.14	1.44	3.21	3.64	3.75	3.50	1.59	2.58	3.05	3.34
51	0.34	0.65	0.61	1.12	2.71	2.28	1.87	1.44	3.21	3.10	3.19	3.32	1.71	2.46	3.01	3.32
50	0.87	0.35	0.75	0.28	2.96	2.53	2.31	1.68	3.31	3.41	3.59	3.17	1.31	2.69	3.12	3.35
49	1.96	0.50	0.41	0.79	3.42	3.08	2.78	2.31	3.62	3.83	3.43	3.70	0.80	2.21	3.26	3.52
48	0.76	0.30	0.90	0.49	3.16	2.75	2.97	2.01	3.74	3.66	3.14	3.30	1.49	2.55	2.56	3.62
47	1.38	1.20	0.38	1.02	3.46	3.12	2.90	2.89	3.96	3.57	3.64	3.36	1.39	2.37	3.39	3.34
46	1.81	1.61	0.42	0.82	3.58	3.51	3.17	3.08	3.94	4.01	3.87	3.75	1.78	2.35	3.50	3.54
45	2.49	1.25	1.69	0.65	3.36	3.44	3.32	2.96	3.67	3.52	3.44	3.47	1.43	2.61	3.15	3.52
44	2.52	1.74	1.54	0.54	3.58	3.45	3.58	2.91	3.93	3.91	3.93	3.60	1.63	2.76	3.16	3.97
43	3.07	2.12	1.59	0.83	4.01	3.77	3.70	3.34	4.23	4.20	3.94	3.86	1.36	2.98	3.75	4.26
42	2.57	2.42	1.54	0.70	3.61	3.56	3.52	3.27	4.14	3.90	3.94	3.75	1.50	2.92	3.57	4.09
41	3.15	2.61	2.12	0.96	4.04	3.98	3.84	3.74	4.24	4.08	4.08	4.09	1.42	2.86	3.53	3.84
40	3.32	2.78	2.10	1.51	4.04	3.86	4.11	3.83	4.47	4.35	4.40	4.19	1.66	3.07	3.69	4.25
39	3.44	2.50	1.95	1.29	4.06	3.82	3.98	4.19	4.36	4.43	4.13	4.41	0.87	3.07	3.72	3.65
38	3.48	3.02	2.38	1.20	4.31	4.23	3.98	4.53	4.73	4.63	4.36	4.59	1.24	2.83	4.04	4.20
37	4.05	2.97	2.25	0.84	4.86	4.64	4.64	4.09	4.87	4.86	4.80	4.53	0.99	3.04	4.13	4.90
36	3.86	3.06	1.41	0.78	4.55	4.53	4.26	4.35	5.17	4.98	4.99	4.87	1.27	3.04	4.42	4.84
35	4.40	3.05	1.85	1.14	5.23	5.03	4.93	5.16	5.31	5.45	5.51	5.54	1.21	2.98	4.75	4.87
34	4.73	3.25	1.65	1.87	5.69	5.58	5.64	5.56	5.86	5.92	5.58	5.67	1.46	2.81	5.03	5.27

Table B-8 Unit 15A, High Flow (Modified VBS), V Total (ft/s), Test 1

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.51	0.53	0.40	0.56	0.66	0.70	0.66	0.80	0.59	0.41	0.46	1.05	0.27	0.58	0.39	0.30
70	0.78	0.88	0.82	0.96	0.89	0.92	0.81	0.79	0.60	0.84	0.37	1.00	0.65	0.62	0.37	0.46
68	0.69	0.82	0.65	0.81	1.65	1.48	1.56	1.37	1.85	1.94	2.13	2.03	0.39	0.47	1.14	1.93
66	0.94	0.99	1.26	0.97	1.84	1.29	1.06	1.37	2.62	2.01	2.05	2.28	0.98	1.18	2.32	2.38
64	1.23	1.18	1.41	1.76	1.64	1.42	1.38	0.90	2.61	2.15	2.60	1.85	1.89	1.86	2.52	2.37
62	0.85	1.00	1.13	1.56	1.71	1.77	1.57	0.88	2.21	2.28	2.50	2.04	1.51	1.78	1.90	2.34
60	1.64	1.90	1.54	1.99	1.17	1.04	1.27	1.38	3.04	2.98	2.69	1.66	2.03	2.36	2.28	2.71
58	1.55	1.94	1.73	2.37	1.66	1.24	0.80	1.19	3.03	3.16	1.39	2.73	1.33	1.90	2.44	2.30
56	0.84	1.51	2.13	2.47	2.35	0.96	0.67	1.02	2.61	2.61	3.02	2.88	1.00	2.24	1.97	2.82
55	1.12	1.80	1.97	1.66	2.94	1.03	0.53	0.60	3.74	3.45	3.41	3.20	0.74	3.06	3.27	3.28
54	1.13	1.46	1.31	1.75	3.15	1.56	1.04	0.66	3.56	3.29	3.00	3.50	0.60	2.81	3.11	3.15
53	1.11	1.19	0.90	1.43	3.06	2.10	2.46	0.58	3.86	3.65	3.32	3.21	0.91	2.27	2.13	3.52
52	0.49	0.95	1.29	1.00	2.58	2.40	2.17	1.46	3.25	3.68	3.80	3.55	1.65	2.62	3.09	3.39
51	0.54	0.86	0.75	1.20	2.79	2.37	1.94	1.52	3.28	3.17	3.27	3.41	1.82	2.55	3.09	3.40
50	1.05	0.57	0.87	0.60	3.07	2.65	2.37	1.78	3.38	3.50	3.69	3.30	1.47	2.78	3.21	3.45
49	1.99	0.67	0.51	0.84	3.47	3.13	2.82	2.34	3.66	3.87	3.49	3.76	0.88	2.26	3.31	3.56
48	0.90	0.59	1.07	0.77	3.25	2.85	3.02	2.09	3.79	3.73	3.25	3.39	1.63	2.64	2.64	3.68
47	1.50	1.36	0.76	1.19	3.57	3.24	2.98	2.97	4.03	3.65	3.75	3.50	1.55	2.50	3.47	3.44
46	1.86	1.68	0.64	0.93	3.62	3.56	3.21	3.11	3.98	4.04	3.92	3.81	1.86	2.41	3.55	3.59
45	2.55	1.37	1.81	0.94	3.45	3.52	3.38	3.01	3.74	3.60	3.53	3.56	1.55	2.71	3.22	3.59
44	2.60	1.89	1.73	0.92	3.68	3.56	3.65	2.99	4.00	3.99	4.03	3.73	1.77	2.86	3.26	4.03
43	3.10	2.18	1.66	0.90	4.04	3.80	3.72	3.36	4.26	4.23	3.99	3.91	1.45	3.03	3.78	4.28
42	2.62	2.53	1.68	0.91	3.67	3.62	3.57	3.31	4.18	3.95	4.01	3.82	1.64	2.98	3.62	4.14
41	3.21	2.73	2.27	1.21	4.10	4.04	3.88	3.78	4.29	4.14	4.16	4.16	1.56	2.96	3.59	3.90
40	3.34	2.83	2.21	1.63	4.06	3.89	4.13	3.84	4.50	4.37	4.43	4.23	1.73	3.12	3.72	4.28
39	3.47	2.60	2.09	1.42	4.09	3.87	4.01	4.21	4.39	4.47	4.18	4.46	1.01	3.15	3.76	3.70
38	3.52	3.10	2.53	1.36	4.36	4.28	4.02	4.55	4.78	4.67	4.42	4.65	1.35	2.93	4.09	4.25
37	4.06	3.03	2.34	1.13	4.88	4.66	4.65	4.10	4.90	4.89	4.83	4.57	1.06	3.10	4.17	4.92
36	3.90	3.20	1.67	1.04	4.60	4.58	4.31	4.37	5.23	5.04	5.07	4.96	1.42	3.17	4.50	4.89
35	4.43	3.16	2.00	1.26	5.30	5.10	4.99	5.18	5.39	5.53	5.62	5.65	1.40	3.15	4.82	4.93
34	4.73	3.31	1.80	1.91	5.74	5.62	5.66	5.57	5.92	5.98	5.64	5.74	1.60	2.94	5.08	5.30

Table B-9 Unit 15A, High Flow (Modified VBS), Total RMS (ft/s), Test 1

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.71	0.76	0.60	0.63	0.78	1.00	0.81	0.79	0.96	1.17	1.04	1.10	0.77	0.82	0.88	1.09
70	0.97	0.71	0.77	0.67	0.94	0.80	0.94	0.81	1.22	0.85	1.40	1.29	0.66	0.81	0.97	1.08
68	0.85	1.20	0.87	0.81	1.29	1.37	1.29	1.34	1.07	1.29	1.21	1.25	0.87	1.26	1.16	1.00
66	0.96	0.89	0.74	0.93	1.17	1.18	1.03	1.14	0.99	1.05	1.01	1.05	1.24	1.16	0.99	0.98
64	1.03	1.32	0.96	0.73	1.32	1.44	1.30	1.21	0.96	1.14	1.07	1.37	1.00	1.07	0.89	1.09
62	1.25	1.42	1.09	0.95	1.32	1.59	1.34	1.16	1.26	1.18	1.10	1.28	1.13	1.15	1.16	1.18
60	1.01	0.97	1.34	0.67	1.73	1.26	1.53	0.83	1.03	1.12	1.06	1.34	1.07	1.10	1.33	1.00
58	1.12	1.02	0.71	1.02	1.73	1.53	0.72	1.56	0.98	0.94	1.17	1.38	1.37	1.17	1.12	1.14
56	1.49	0.96	1.24	1.14	1.54	1.69	1.59	1.89	1.57	1.33	1.31	1.38	1.89	1.21	1.50	1.15
55	1.48	0.92	0.93	0.99	1.49	1.23	1.24	1.35	1.00	1.23	1.29	1.42	1.59	0.95	1.06	1.01
54	1.15	0.81	0.85	1.06	1.54	1.35	1.51	1.64	0.99	1.02	1.30	1.04	1.72	0.93	1.00	1.12
53	1.08	1.30	1.42	1.01	1.29	1.47	1.59	1.26	0.81	1.02	1.20	1.30	1.42	1.38	1.67	0.91
52	1.09	1.31	1.07	1.35	1.14	1.52	1.37	1.62	0.98	1.00	1.04	1.16	1.26	1.31	1.16	0.99
51	1.11	1.06	1.43	1.18	1.25	1.21	1.48	1.50	0.92	0.98	1.11	1.09	1.14	1.09	1.00	0.85
50	1.23	1.42	1.14	1.40	1.01	1.16	1.32	1.45	0.95	0.90	0.89	1.09	1.44	0.96	1.04	0.96
49	1.44	1.30	1.41	1.52	0.93	1.15	1.20	1.52	0.88	0.74	0.99	1.03	1.63	1.29	1.03	1.08
48	1.29	1.40	1.29	1.26	1.04	1.11	1.04	1.30	0.69	0.83	0.95	0.94	1.08	1.25	1.37	0.84
47	1.58	1.35	1.45	1.29	0.89	1.09	1.16	1.14	0.81	0.69	0.84	0.82	1.28	1.10	0.97	1.06
46	1.50	1.57	1.33	1.24	0.91	0.98	1.19	1.17	0.88	0.88	0.77	0.86	1.13	1.31	1.02	0.91
45	1.31	1.53	1.38	1.49	0.83	0.97	1.06	1.22	0.78	0.78	0.88	0.91	1.09	1.05	1.03	0.87
44	1.33	1.42	1.52	1.32	0.90	0.99	1.03	1.19	0.96	0.87	0.99	0.87	1.14	1.30	1.38	0.98
43	1.28	1.37	1.43	1.28	0.88	0.97	0.98	1.13	0.96	0.90	0.79	0.90	1.44	1.24	1.17	0.99
42	1.34	1.29	1.42	1.35	0.97	1.02	1.14	1.24	0.98	0.89	0.92	0.94	1.33	1.27	1.28	1.03
41	1.40	1.58	1.41	1.50	1.03	1.03	1.12	1.25	1.06	0.91	0.96	0.99	1.40	1.38	1.20	1.10
40	1.32	1.43	1.49	1.38	0.97	1.09	1.24	1.28	1.02	1.02	1.01	1.02	1.42	1.42	1.25	1.14
39	1.45	1.55	1.57	1.71	1.02	1.15	1.22	1.28	1.03	1.02	1.04	0.99	1.42	1.47	1.43	1.25
38	1.59	1.61	1.68	1.80	1.06	1.20	1.30	1.40	1.10	1.11	1.05	1.01	1.59	1.59	1.46	1.36
37	1.69	1.76	1.79	1.78	1.03	1.26	1.32	1.49	1.14	1.04	1.03	1.09	1.58	1.71	1.63	1.21
36	1.79	1.93	1.94	1.98	1.13	1.25	1.50	1.64	0.97	0.95	0.98	0.96	1.69	1.85	1.66	1.29
35	1.93	2.01	1.92	2.11	0.93	1.25	1.43	1.65	0.93	0.82	0.79	0.74	1.74	1.99	1.75	1.38
34	1.95	2.30	2.05	2.23	0.75	0.95	1.08	1.53	0.90	0.65	0.77	0.71	1.88	2.12	1.74	1.34

Table B-10 Unit 15B, High Flow (Modified VBS) Vx (ft/s), Test 2

	OR							Y-Positions (ft)							WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.06	0.10	(0.01)	(0.04)	0.05	0.15	0.09	0.18	0.01	0.38	0.17	0.31	0.02	0.25	0.24	0.25
70	(0.12)	(0.10)	(0.09)	(0.20)	(0.20)	(0.33)	(0.31)	(0.08)	(0.16)	(0.37)	(0.35)	(0.26)	(0.16)	(0.15)	(0.20)	(0.24)
68	(0.01)	(0.24)	(0.14)	(0.12)	(0.10)	(0.07)	(0.10)	(0.20)	(0.17)	(0.16)	(0.06)	0.02	(0.18)	(0.20)	(0.26)	(0.11)
66	(0.14)	0.04	(0.06)	0.04	(0.12)	0.03	(0.13)	(0.02)	(0.00)	0.04	0.02	0.02	(0.21)	(0.29)	(0.13)	0.01
64	0.04	(0.04)	(0.10)	(0.13)	(0.01)	(0.02)	(0.14)	(0.07)	(0.02)	0.09	0.06	0.07	(0.17)	(0.12)	(0.01)	0.02
62	0.12	(0.08)	(0.08)	(0.16)	(0.04)	(0.05)	(0.02)	0.02	0.05	0.08	0.02	0.00	(0.12)	(0.03)	(0.06)	(0.03)
60	0.06	0.06	(0.04)	(0.13)	0.01	0.04	0.01	(0.02)	0.15	0.04	0.10	0.11	(0.07)	(0.10)	0.05	0.10
58	0.09	0.12	0.12	(0.03)	0.12	0.02	(0.04)	0.07	0.10	0.16	0.11	0.20	(0.05)	(0.02)	0.06	0.01
56	0.50	0.65	0.59	0.53	0.65	0.74	0.38	0.56	0.64	0.69	0.79	1.00	0.66	0.58	0.71	0.68
55	0.59	0.66	0.54	0.52	0.57	0.43	0.46	0.37	0.47	0.64	0.60	0.59	0.59	0.58	0.61	0.50
54	0.46	0.63	0.70	0.56	0.58	0.58	0.39	0.52	0.59	0.63	0.76	0.78	0.42	0.59	0.55	0.54
53	0.54	0.52	0.62	0.61	0.69	0.67	0.33	0.54	0.65	0.68	0.77	0.83	0.49	0.57	0.72	0.43
52	0.41	0.39	0.55	0.51	0.56	0.52	0.43	0.43	0.42	0.54	0.61	0.62	0.34	0.37	0.35	0.51
51	0.57	0.46	0.53	0.58	0.78	0.67	0.52	0.46	0.64	0.70	0.80	0.83	0.55	0.67	0.59	0.68
50	0.64	0.79	0.63	0.34	0.81	0.76	0.60	0.67	0.72	0.75	0.90	0.89	0.66	0.68	0.67	0.72
49	0.42	0.49	0.43	0.53	0.56	0.52	0.50	0.45	0.53	0.53	0.58	0.64	0.46	0.49	0.49	0.55
48	0.62	0.74	0.62	0.53	0.79	0.73	0.57	0.61	0.64	0.66	0.79	0.80	0.67	0.58	0.63	0.67
47	0.73	0.71	0.70	0.61	0.80	0.79	0.60	0.72	0.64	0.79	0.90	0.92	0.71	0.75	0.83	0.81
46	0.47	0.60	0.51	0.50	0.54	0.53	0.40	0.44	0.52	0.55	0.64	0.64	0.32	0.50	0.59	0.51
45	0.56	0.67	0.71	0.76	0.72	0.70	0.54	0.53	0.64	0.65	0.81	0.75	0.57	0.71	0.72	0.63
44	0.68	0.80	0.82	0.54	0.74	0.80	0.58	0.68	0.60	0.63	0.76	0.79	0.67	0.75	0.70	0.67
43	0.37	0.52	0.47	0.38	0.46	0.45	0.37	0.34	0.43	0.51	0.51	0.53	0.47	0.56	0.42	0.51
42	0.53	0.67	0.78	0.58	0.55	0.58	0.40	0.44	0.49	0.57	0.64	0.63	0.62	0.65	0.64	0.59
41	0.49	0.72	0.90	0.63	0.57	0.62	0.48	0.46	0.58	0.59	0.68	0.69	0.76	0.69	0.72	0.59
40	0.38	0.49	0.65	0.67	0.32	0.40	0.27	0.32	0.40	0.43	0.45	0.48	0.54	0.63	0.49	0.38
39	0.46	0.61	0.77	0.61	0.45	0.49	0.36	0.38	0.51	0.51	0.58	0.56	0.71	0.75	0.60	0.53
38	0.63	0.74	0.93	0.62	0.59	0.52	0.39	0.41	0.63	0.61	0.68	0.66	0.69	0.84	0.66	0.61
37	0.37	0.63	0.73	0.70	0.38	0.41	0.35	0.25	0.40	0.45	0.52	0.52	0.45	0.52	0.55	0.38
36	0.55	0.83	0.72	0.84	0.63	0.66	0.49	0.45	0.69	0.71	0.77	0.81	0.62	0.85	0.83	0.58
35	0.53	0.96	0.50	0.71	0.81	0.78	0.61	0.50	0.80	0.87	0.98	0.97	0.70	1.04	0.82	0.68
34	0.36	0.82	0.59	0.46	0.68	0.69	0.51	0.44	0.74	0.80	0.83	0.87	0.58	0.88	0.56	0.59

DUPLICATE DATA

	OR							Y-Positions (ft)							WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					(0.27)				(0.26)				(0.24)			
58					0.05				0.05				0.04			
53					0.34				0.77				0.74			
48					0.41				0.74				0.75			
43					0.30				0.42				0.47			
38					0.28				0.51				0.59			

Table B-11 Unit 15B, High Flow (Modified VBS) Vx RMS (ft/s), Test 2

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.51	0.41	0.41	0.58	0.52	0.50	0.45	0.44	0.54	0.63	0.61	0.53	0.31	0.49	0.48	0.54
70	0.54	0.44	0.39	0.42	0.58	0.47	0.48	0.43	0.54	0.60	0.55	0.53	0.41	0.47	0.44	0.44
68	0.44	0.50	0.48	0.34	0.54	0.57	0.57	0.56	0.55	0.49	0.58	0.58	0.42	0.42	0.49	0.53
66	0.45	0.39	0.34	0.44	0.48	0.46	0.58	0.47	0.47	0.47	0.52	0.54	0.39	0.48	0.48	0.54
64	0.68	0.57	0.44	0.49	0.57	0.51	0.51	0.49	0.55	0.52	0.51	0.48	0.48	0.50	0.46	0.44
62	0.55	0.51	0.41	0.54	0.52	0.56	0.43	0.54	0.54	0.49	0.51	0.49	0.41	0.50	0.58	0.55
60	0.58	0.62	0.57	0.46	0.56	0.51	0.61	0.55	0.47	0.49	0.55	0.52	0.52	0.48	0.47	0.45
58	0.64	0.43	0.43	0.56	0.46	0.49	0.55	0.63	0.58	0.48	0.47	0.48	0.62	0.67	0.51	0.56
56	0.62	0.70	0.44	0.61	0.52	0.48	0.58	0.68	0.49	0.48	0.44	0.47	0.57	0.65	0.48	0.54
55	0.56	0.68	0.57	0.44	0.46	0.54	0.47	0.62	0.50	0.43	0.51	0.49	0.73	0.64	0.64	0.47
54	0.51	0.61	0.57	0.56	0.49	0.47	0.54	0.58	0.48	0.45	0.40	0.42	0.62	0.67	0.58	0.57
53	0.62	0.55	0.52	0.51	0.45	0.45	0.58	0.53	0.47	0.40	0.42	0.42	0.62	0.58	0.47	0.62
52	0.59	0.57	0.68	0.54	0.39	0.49	0.51	0.56	0.55	0.41	0.46	0.40	0.62	0.66	0.64	0.62
51	0.57	0.62	0.52	0.53	0.49	0.49	0.50	0.64	0.44	0.46	0.40	0.42	0.71	0.58	0.60	0.45
50	0.67	0.61	0.49	0.57	0.47	0.54	0.52	0.63	0.41	0.41	0.39	0.47	0.62	0.58	0.63	0.47
49	0.69	0.54	0.63	0.60	0.46	0.44	0.50	0.58	0.43	0.42	0.46	0.43	0.61	0.64	0.58	0.50
48	0.67	0.62	0.57	0.56	0.47	0.46	0.47	0.57	0.42	0.39	0.36	0.39	0.49	0.63	0.57	0.53
47	0.65	0.64	0.56	0.61	0.42	0.45	0.52	0.58	0.48	0.47	0.40	0.44	0.54	0.70	0.58	0.48
46	0.63	0.65	0.67	0.69	0.44	0.46	0.50	0.61	0.50	0.50	0.41	0.46	0.64	0.63	0.58	0.51
45	0.66	0.64	0.68	0.60	0.46	0.46	0.50	0.53	0.48	0.44	0.50	0.42	0.53	0.61	0.66	0.56
44	0.63	0.65	0.72	0.56	0.46	0.51	0.56	0.59	0.53	0.49	0.43	0.46	0.59	0.60	0.58	0.56
43	0.63	0.71	0.69	0.72	0.49	0.49	0.60	0.61	0.56	0.51	0.46	0.47	0.70	0.68	0.57	0.60
42	0.74	0.79	0.87	0.88	0.54	0.55	0.59	0.64	0.53	0.49	0.50	0.49	0.66	0.69	0.71	0.62
41	0.80	0.85	0.85	0.93	0.53	0.60	0.66	0.70	0.59	0.52	0.54	0.54	0.73	0.75	0.75	0.69
40	0.82	0.90	0.94	1.02	0.55	0.64	0.65	0.71	0.57	0.55	0.56	0.51	0.82	0.85	0.77	0.73
39	0.82	0.88	0.94	1.14	0.56	0.62	0.68	0.82	0.64	0.55	0.54	0.59	0.93	0.83	0.78	0.70
38	0.93	0.96	1.11	1.01	0.60	0.67	0.78	0.78	0.63	0.54	0.56	0.54	0.90	0.92	0.80	0.73
37	0.98	1.00	1.09	1.19	0.64	0.64	0.75	0.85	0.65	0.51	0.55	0.58	0.93	0.95	0.93	0.76
36	1.06	1.05	0.99	1.03	0.67	0.67	0.74	0.85	0.58	0.51	0.49	0.54	0.96	1.01	1.01	0.73
35	1.04	1.19	1.08	0.87	0.54	0.67	0.72	0.83	0.56	0.51	0.43	0.49	0.92	1.06	0.96	0.70
34	1.04	1.23	1.08	1.08	0.44	0.54	0.59	0.73	0.45	0.41	0.44	0.42	1.05	1.19	0.98	0.52

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					0.52				0.50				0.50			
58					0.59				0.47				0.58			
53					0.65				0.41				0.46			
48					0.58				0.38				0.48			
43					0.58				0.45				0.57			
38					0.85				0.53				0.71			

Table B-12 Unit 15B, High Flow (Modified VBS) Vy (ft/s), Test 2

	OR							Y-Positions (ft)							WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.40	0.43	0.39	0.19	0.38	0.74	0.78	0.50	(0.38)	0.12	0.51	0.53	(0.09)	(0.18)	0.09	(0.30)
70	0.81	0.43	0.18	(0.03)	0.81	0.83	0.71	0.56	0.24	0.45	0.17	0.76	0.05	(0.08)	(0.43)	0.32
68	0.42	0.60	0.50	(0.04)	0.35	1.08	0.94	0.84	(0.55)	0.45	0.17	0.53	(0.11)	(0.04)	(0.43)	(0.32)
66	0.43	0.48	0.49	0.43	0.57	0.71	1.07	0.63	(0.20)	0.40	0.46	0.17	(0.43)	(0.30)	(0.24)	(0.44)
64	1.25	0.45	0.60	0.64	0.77	0.73	0.99	1.03	(0.60)	(0.20)	1.02	1.01	(0.78)	(0.74)	(0.04)	0.05
62	0.78	0.59	0.32	0.70	0.48	0.83	0.44	0.62	(0.25)	(0.02)	(0.39)	(0.51)	(0.60)	(0.73)	(1.04)	(0.93)
60	0.83	0.99	0.81	0.64	1.33	0.61	1.30	1.08	(0.09)	(0.68)	0.61	0.74	(0.99)	(0.86)	(0.59)	(0.44)
58	0.62	0.43	0.33	0.75	0.22	0.31	0.67	1.21	(1.14)	(0.63)	0.09	(0.09)	(0.81)	(1.35)	(0.73)	(1.20)
56	0.85	0.66	(0.12)	0.84	0.32	0.23	0.19	1.52	(0.79)	(0.71)	(0.56)	(0.02)	(0.75)	(0.88)	(1.15)	(1.45)
55	0.52	0.64	(0.10)	0.06	(0.08)	0.35	(0.10)	0.02	(1.34)	(0.58)	(0.72)	(0.56)	(1.09)	(0.70)	(0.83)	(1.17)
54	0.43	0.70	0.26	0.44	0.29	0.27	0.16	0.65	(0.65)	(0.50)	(0.30)	(0.30)	(0.30)	(0.65)	(0.81)	(0.95)
53	(0.05)	(0.10)	(0.25)	(0.25)	(0.13)	(0.05)	(0.57)	0.11	(0.89)	(0.56)	(0.62)	(0.44)	(0.73)	(0.52)	(1.08)	0.42
52	0.20	(0.09)	0.39	(0.16)	(0.07)	(0.15)	0.41	0.29	(0.77)	(0.56)	(0.16)	(0.48)	(0.20)	(0.67)	0.09	(0.97)
51	(0.36)	0.34	(0.39)	(0.26)	(0.51)	0.02	(0.00)	0.16	(0.92)	(0.34)	(0.30)	(0.42)	(0.30)	(0.70)	(0.35)	(0.73)
50	0.56	(0.08)	(0.10)	(0.61)	(0.04)	(0.53)	(0.27)	(0.18)	(0.82)	(0.57)	(0.52)	(0.93)	(0.15)	(0.26)	(0.49)	(0.88)
49	0.03	(0.13)	0.14	(0.42)	(0.25)	(0.24)	0.08	0.06	(0.83)	(0.47)	(0.22)	(0.74)	(0.39)	(0.36)	(0.24)	(0.92)
48	0.16	0.48	0.17	0.25	(0.30)	(0.24)	(0.05)	0.27	(0.80)	(0.44)	(0.23)	(0.36)	(0.12)	(0.51)	(0.28)	(0.55)
47	0.41	0.22	0.38	0.38	0.03	(0.01)	(0.13)	0.24	(0.57)	(0.30)	(0.54)	(0.62)	(0.11)	(0.52)	(0.73)	(0.87)
46	0.43	0.46	0.23	0.63	0.28	0.20	0.19	0.41	(0.38)	(0.17)	0.01	(0.49)	(0.10)	(0.45)	(0.36)	(0.71)
45	0.41	0.57	0.48	0.49	(0.12)	(0.03)	0.49	0.17	(0.89)	(0.32)	0.09	(0.50)	(0.37)	(0.65)	(0.72)	(1.02)
44	0.16	0.44	0.79	0.37	(0.30)	(0.22)	(0.16)	(0.09)	(1.10)	(0.70)	(0.77)	(0.81)	(0.86)	(0.85)	(0.94)	(1.09)
43	0.30	0.41	0.83	0.52	0.07	0.28	(0.00)	0.34	(0.58)	(0.20)	(0.61)	(0.41)	(0.20)	(0.68)	(0.87)	(0.76)
42	0.16	0.52	0.64	0.84	(0.18)	(0.04)	0.30	0.57	(0.90)	(0.56)	(0.29)	(0.31)	(0.59)	(0.70)	(0.76)	(0.72)
41	0.67	0.64	0.61	0.62	0.34	0.07	0.11	0.45	(0.59)	(0.55)	(0.50)	(0.44)	(0.78)	(1.00)	(0.97)	(0.98)
40	0.58	0.63	0.74	1.00	0.09	0.14	0.19	0.69	(0.81)	(0.52)	(0.58)	(0.31)	(0.88)	(1.06)	(1.01)	(0.83)
39	0.52	0.49	1.00	0.65	0.08	0.15	0.21	0.50	(0.74)	(0.51)	(0.49)	(0.38)	(0.89)	(1.18)	(1.16)	(0.95)
38	0.50	0.64	0.53	0.71	0.04	0.15	0.10	0.63	(0.91)	(0.50)	(0.51)	(0.16)	(1.14)	(1.15)	(1.20)	(1.05)
37	0.42	0.71	0.67	0.37	0.12	0.32	0.20	0.49	(0.79)	(0.47)	(0.58)	(0.52)	(1.04)	(0.93)	(1.16)	(1.04)
36	0.30	0.34	0.35	0.02	(0.01)	0.04	0.21	0.44	(0.84)	(0.44)	(0.42)	(0.47)	(0.84)	(0.76)	(0.85)	(0.99)
35	0.46	0.42	(0.49)	(0.35)	0.11	0.07	0.15	0.34	(0.75)	(0.43)	(0.45)	(0.54)	(0.10)	(0.54)	(0.93)	(0.91)
34	0.31	0.31	(0.18)	(0.47)	0.15	0.13	0.13	0.42	(0.70)	(0.45)	(0.49)	(0.51)	(0.05)	(0.57)	(0.87)	(0.85)

DUPLICATE DATA

	OR							Y-Positions (ft)							WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					0.49				0.78				(0.03)			
58					0.39				0.18				(1.21)			
53					0.06				(0.16)				(1.10)			
48					0.15				(0.10)				(0.73)			
43					0.35				0.09				(0.67)			
38					0.45				0.15				(0.93)			

Table B-13 Unit 15B, High Flow (Modified VBS) Vy RMS (ft/s), Test 2

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.60	0.33	0.30	0.33	0.49	0.40	0.41	0.37	0.51	0.82	0.82	1.03	0.36	0.42	0.73	0.31
70	0.49	0.37	0.35	0.42	0.47	0.57	0.44	0.39	0.71	0.69	0.81	0.63	0.51	0.54	0.56	0.57
68	0.46	0.46	0.50	0.48	0.72	0.57	0.54	0.54	0.68	0.54	0.56	0.62	0.46	0.42	0.60	0.67
66	0.57	0.33	0.38	0.38	0.45	0.36	0.62	0.68	0.57	0.62	0.81	0.50	0.41	0.46	0.57	0.51
64	0.62	0.43	0.53	0.48	0.60	0.62	0.75	0.60	0.70	0.57	0.67	0.64	0.49	0.63	0.42	0.50
62	0.61	0.64	0.36	0.63	0.66	0.62	0.54	0.70	0.72	0.63	0.59	0.92	0.50	0.48	0.71	0.57
60	0.51	0.75	0.59	0.47	0.65	0.63	0.78	0.66	0.58	0.65	0.63	0.65	0.62	0.66	0.60	0.59
58	0.76	0.55	0.42	0.54	0.78	0.93	0.74	0.74	0.76	0.69	0.62	0.73	0.59	0.58	0.68	0.66
56	0.90	0.87	0.42	0.68	1.07	0.77	0.97	0.63	0.66	0.87	0.74	0.75	0.71	0.78	0.74	0.69
55	0.99	0.77	0.61	0.52	0.72	0.92	0.68	0.79	0.71	0.77	0.87	0.62	0.71	0.88	1.03	0.62
54	0.84	0.96	0.61	0.71	0.86	0.90	0.71	0.83	0.62	0.70	0.78	0.65	0.80	1.00	0.98	0.98
53	0.92	0.61	0.62	0.50	0.64	0.74	0.92	0.61	0.70	0.63	0.53	0.64	0.78	1.25	0.75	0.72
52	0.74	0.82	1.10	0.69	0.61	0.52	0.84	0.92	0.77	0.62	0.65	0.73	0.84	1.08	1.07	0.99
51	0.71	0.91	0.74	0.68	0.71	0.89	0.59	0.93	0.62	0.74	0.61	0.55	0.98	1.02	1.11	0.74
50	0.60	0.97	0.54	0.75	0.67	0.67	0.67	0.68	0.64	0.50	0.51	0.55	0.84	0.95	0.89	0.60
49	0.78	0.85	0.88	0.63	0.61	0.60	0.73	0.65	0.54	0.51	0.71	0.52	0.81	0.86	0.92	0.62
48	0.79	0.77	0.84	0.62	0.51	0.54	0.54	0.65	0.47	0.46	0.45	0.53	0.73	0.72	0.80	0.71
47	0.83	0.74	0.75	0.77	0.53	0.59	0.56	0.69	0.50	0.48	0.45	0.41	0.85	0.89	0.66	0.59
46	0.68	0.69	0.71	0.89	0.47	0.53	0.57	0.67	0.49	0.55	0.45	0.48	0.82	0.77	0.70	0.59
45	0.75	0.79	0.70	0.62	0.51	0.51	0.65	0.52	0.47	0.51	0.69	0.43	0.65	0.67	0.75	0.68
44	0.64	0.85	0.85	0.69	0.43	0.52	0.55	0.57	0.54	0.53	0.46	0.51	0.76	0.71	0.67	0.65
43	0.79	0.74	0.74	0.79	0.57	0.42	0.57	0.66	0.53	0.52	0.43	0.45	0.95	0.82	0.62	0.66
42	0.83	0.71	0.86	0.88	0.58	0.53	0.56	0.56	0.53	0.48	0.45	0.49	0.71	0.74	0.82	0.68
41	0.77	0.85	0.81	0.92	0.52	0.60	0.65	0.66	0.57	0.50	0.56	0.47	0.75	0.74	0.79	0.73
40	0.78	0.85	0.89	0.83	0.48	0.67	0.59	0.67	0.51	0.50	0.56	0.50	0.73	0.78	0.77	0.73
39	0.72	0.94	0.85	0.98	0.55	0.60	0.67	0.73	0.56	0.49	0.52	0.56	0.79	0.78	0.73	0.66
38	0.90	0.78	1.08	0.76	0.55	0.53	0.75	0.73	0.59	0.51	0.53	0.44	0.76	0.84	0.81	0.57
37	0.99	0.92	0.94	0.91	0.65	0.55	0.67	0.76	0.54	0.49	0.53	0.57	0.76	0.91	0.88	0.71
36	1.04	1.01	0.98	0.97	0.54	0.57	0.68	0.80	0.52	0.45	0.48	0.48	0.91	1.02	1.02	0.68
35	0.88	1.00	1.00	1.03	0.50	0.49	0.63	0.73	0.48	0.43	0.38	0.43	0.80	1.08	0.94	0.65
34	0.87	1.13	1.05	1.03	0.41	0.44	0.52	0.73	0.36	0.32	0.39	0.38	1.21	1.05	0.76	0.56

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					0.43				0.48				0.64			
58					0.94				0.75				0.79			
53					0.91				0.60				0.64			
48					0.72				0.48				0.64			
43					0.57				0.45				0.58			
38					0.80				0.47				0.64			

Table B-14 Unit 15B, High Flow (Modified VBS) Vz (ft/s), Test 2

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.06	(0.07)	(0.08)	(0.18)	0.11	0.05	0.04	(0.11)	0.06	(0.17)	(0.08)	(0.17)	(0.10)	(0.21)	(0.08)	(0.12)
70	0.20	(0.40)	(0.33)	(0.58)	0.76	0.19	0.29	(0.01)	0.45	0.30	0.84	0.11	(0.26)	(0.22)	(0.19)	(0.00)
68	0.06	(0.32)	(0.08)	(0.62)	1.52	0.86	1.35	0.76	1.70	1.58	1.83	1.65	(0.20)	0.65	0.96	1.27
66	0.16	(0.55)	(0.85)	(0.59)	0.78	0.59	0.98	0.43	0.93	1.76	2.13	1.24	0.16	1.54	1.43	1.41
64	0.76	(0.43)	(0.83)	(0.91)	2.16	0.99	0.34	0.34	1.85	2.34	1.67	1.95	0.34	1.79	2.09	2.35
62	(1.04)	(0.30)	(0.80)	(0.53)	1.51	1.22	0.41	1.22	1.84	2.31	1.82	2.32	0.68	1.27	1.67	1.40
60	(0.76)	0.27	(1.27)	(1.32)	1.78	2.17	0.39	0.02	2.71	2.11	2.55	2.13	1.30	0.27	2.37	2.23
58	0.47	(0.97)	(2.25)	(1.33)	2.95	0.88	(0.05)	0.83	2.32	2.51	2.96	2.85	(0.60)	1.20	2.48	1.89
56	(0.71)	(0.80)	(2.09)	(1.49)	2.02	2.60	0.28	1.18	3.03	3.00	2.87	2.50	0.17	(0.78)	2.22	2.12
55	(0.26)	(0.64)	(0.38)	(1.40)	3.32	2.66	2.27	(0.27)	3.10	3.51	3.31	3.26	(0.58)	0.94	(0.03)	3.21
54	(0.22)	(0.16)	(1.36)	(0.97)	3.08	3.05	2.45	1.69	3.22	3.56	3.44	3.37	(0.38)	(0.29)	1.72	2.67
53	0.70	(0.06)	(1.08)	(0.76)	3.19	2.68	1.65	2.88	2.92	3.51	3.31	3.44	0.08	0.93	2.87	1.85
52	1.52	0.34	(0.04)	(0.78)	3.37	3.03	3.36	2.34	3.07	3.44	3.72	3.63	(0.71)	1.18	0.74	2.63
51	0.23	0.43	(0.56)	(1.07)	3.14	3.10	3.09	1.96	3.56	3.56	3.42	3.45	0.34	1.28	1.65	3.24
50	1.54	0.29	(0.20)	(0.08)	3.53	3.17	3.08	1.09	3.84	3.83	3.60	3.51	0.24	2.07	2.50	3.53
49	1.17	0.63	0.75	0.02	3.62	3.37	3.12	2.27	3.91	3.80	3.89	3.64	1.43	1.41	1.85	3.49
48	1.40	1.17	0.15	(0.27)	3.51	3.04	3.40	3.04	3.85	3.65	3.68	3.56	0.82	1.71	2.25	3.18
47	2.21	1.39	0.92	0.33	3.78	3.76	3.28	3.11	3.99	3.99	3.77	3.70	1.11	1.84	3.00	3.72
46	2.89	2.22	1.37	0.55	4.00	3.84	3.79	3.28	3.98	3.96	3.85	3.92	0.59	1.68	2.22	3.83
45	2.32	1.78	1.80	0.79	3.54	3.52	3.59	3.21	3.73	3.87	3.76	3.71	1.32	1.99	1.97	3.57
44	2.31	1.79	1.10	0.89	3.65	3.51	3.47	3.05	4.19	4.14	3.88	3.73	1.75	2.65	3.60	3.96
43	3.17	2.62	1.05	0.75	4.15	4.00	3.72	3.60	4.39	4.30	4.12	4.16	1.08	1.97	3.65	3.94
42	2.63	2.34	1.93	0.91	3.85	3.74	4.04	3.75	4.41	4.24	4.31	3.98	1.56	2.63	3.11	3.74
41	3.61	2.69	2.05	0.60	4.27	4.14	4.01	3.83	4.42	4.51	4.49	4.35	1.38	2.90	3.77	4.38
40	3.58	2.54	1.96	1.08	4.44	4.33	4.14	4.31	4.85	4.72	4.64	4.73	1.38	2.82	4.03	4.30
39	3.43	3.00	1.90	0.06	4.44	4.19	4.19	4.18	4.97	4.89	4.50	4.54	0.75	2.43	3.77	4.32
38	3.70	3.12	1.56	0.65	4.66	4.55	4.66	4.59	5.19	4.95	4.97	4.78	1.21	2.73	4.17	4.48
37	3.96	3.26	1.99	(0.15)	5.00	4.71	4.44	4.69	5.32	5.28	5.18	5.10	1.10	2.38	4.50	5.14
36	4.11	3.05	1.90	(0.32)	4.89	4.82	4.79	4.65	5.29	5.36	5.29	5.06	1.11	2.55	4.21	5.16
35	4.50	3.21	1.73	0.24	5.48	5.23	5.27	5.03	5.61	5.67	5.71	5.44	1.53	2.76	4.61	5.48
34	4.71	3.00	1.85	0.87	6.01	5.72	5.55	5.36	6.12	6.06	6.04	5.69	1.91	2.93	5.26	5.97

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					0.10				1.32				1.22			
58					0.34				2.57				2.28			
53					1.56				2.91				2.78			
48					2.79				3.56				3.36			
43					3.50				4.06				4.01			
38					4.51				4.94				4.84			

Table B-15 Unit 15B, High Flow (Modified VBS) Vz RMS (ft/s), Test 2

	OR							Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.51	0.42	0.36	0.36	0.59	0.55	0.48	0.42	0.62	0.66	0.63	0.54	0.32	0.45	0.51	0.50
70	0.85	0.56	0.60	0.40	1.10	0.92	0.89	0.63	0.91	1.05	1.09	0.84	0.56	0.79	0.76	0.52
68	0.70	0.90	0.68	0.42	1.00	1.05	0.97	0.96	1.02	1.01	0.84	0.90	0.68	1.07	0.81	0.96
66	0.96	0.79	0.69	0.66	0.90	0.97	1.18	0.97	0.99	0.89	0.92	0.96	0.49	0.97	1.18	1.11
64	0.96	0.99	0.84	1.13	1.01	1.46	1.00	1.33	0.90	1.00	1.11	0.85	0.71	0.81	0.69	0.69
62	0.57	1.38	0.40	1.20	1.34	1.32	1.06	1.44	1.38	1.07	0.98	0.91	1.22	1.47	0.98	1.44
60	1.04	1.58	0.94	1.03	1.22	0.98	1.30	1.03	0.97	1.18	0.80	0.97	1.03	1.62	0.94	0.86
58	1.17	0.75	0.71	0.90	0.75	1.26	1.31	1.37	1.13	0.91	0.94	0.80	1.01	0.99	0.99	1.01
56	1.53	1.10	0.75	1.10	1.37	0.99	1.37	1.27	0.85	0.77	0.96	0.84	1.52	1.30	0.96	1.09
55	0.86	1.39	0.90	1.04	0.71	1.06	1.50	1.18	0.89	0.62	0.79	0.89	1.94	1.32	1.30	0.98
54	0.99	1.58	0.80	1.17	0.94	0.88	1.11	1.22	1.03	0.69	0.69	0.78	1.47	1.88	1.29	1.03
53	1.33	1.09	1.05	1.15	0.79	1.02	1.04	0.85	1.00	0.63	0.86	0.65	1.12	1.11	0.69	1.38
52	1.16	1.34	1.35	0.99	0.71	0.89	0.77	1.19	0.90	0.76	0.76	0.61	1.31	1.31	1.52	1.11
51	1.09	1.17	1.04	1.29	1.01	1.12	0.89	1.34	0.61	0.68	0.66	0.80	0.92	1.48	1.26	0.72
50	1.34	1.08	1.02	0.99	0.75	0.99	0.87	1.25	0.55	0.57	0.66	0.76	1.17	0.88	1.00	0.68
49	1.25	1.11	1.60	0.84	0.85	0.74	0.98	1.06	0.54	0.64	0.67	0.67	0.80	1.17	1.67	0.90
48	1.22	1.11	1.00	1.18	0.70	0.63	0.82	0.83	0.54	0.56	0.49	0.65	0.87	1.07	0.95	0.73
47	1.12	1.41	0.78	1.28	0.68	0.73	0.75	0.74	0.67	0.77	0.54	0.59	1.03	1.20	1.08	0.63
46	0.81	1.06	1.10	1.11	0.58	0.64	0.73	0.79	0.78	0.67	0.63	0.61	0.95	1.02	1.06	0.68
45	1.12	1.07	1.19	1.14	0.61	0.58	0.77	0.73	0.56	0.60	0.71	0.60	0.75	1.05	1.47	0.66
44	1.01	1.19	0.95	0.89	0.59	0.63	0.72	0.75	0.68	0.69	0.57	0.64	0.82	0.81	0.72	0.72
43	0.97	0.90	1.19	1.00	0.64	0.61	0.77	0.81	0.71	0.69	0.63	0.60	0.97	0.99	0.73	0.73
42	1.10	0.98	1.03	1.07	0.69	0.68	0.76	0.78	0.73	0.65	0.72	0.65	0.81	0.85	0.90	0.77
41	0.92	1.27	1.11	1.51	0.70	0.73	0.79	0.89	0.74	0.74	0.75	0.75	0.88	0.92	0.96	0.86
40	0.88	1.29	1.07	1.15	0.76	0.79	0.85	0.82	0.80	0.77	0.70	0.70	0.88	0.93	0.93	0.89
39	0.91	1.01	1.28	1.41	0.80	0.79	0.87	1.06	0.78	0.81	0.74	0.79	1.19	1.14	0.90	0.86
38	1.03	1.03	1.53	1.30	0.86	0.94	0.97	0.98	0.81	0.81	0.79	0.80	1.08	1.06	0.93	0.87
37	1.13	1.14	1.13	1.45	0.89	0.91	0.98	1.06	0.81	0.75	0.80	0.80	1.09	1.06	1.07	0.89
36	1.29	1.20	1.22	1.28	0.95	0.96	1.06	1.08	0.77	0.69	0.72	0.78	1.22	1.12	1.23	0.93
35	1.38	1.29	1.27	1.26	0.79	1.01	1.11	1.15	0.80	0.64	0.52	0.67	1.15	1.14	1.23	0.94
34	1.56	1.46	1.31	1.36	0.61	0.77	0.87	1.07	0.49	0.38	0.55	0.54	1.27	1.38	1.33	0.63

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					0.81				1.10				0.90			
58					1.46				1.04				0.95			
53					1.23				0.86				0.85			
48					0.97				0.57				0.66			
43					0.70				0.54				0.71			
38					0.99				0.77				0.92			

Table B-16 Unit 15B, High Flow (Modified VBS) Vyz (ft/s), Test 2

	OR						Y-Positions (ft)									WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.40	0.44	0.40	0.26	0.39	0.74	0.78	0.52	0.38	0.20	0.52	0.55	0.13	0.27	0.12	0.33
70	0.83	0.58	0.37	0.58	1.11	0.85	0.77	0.56	0.51	0.54	0.86	0.77	0.26	0.23	0.47	0.32
68	0.43	0.68	0.50	0.62	1.56	1.38	1.65	1.14	1.79	1.64	1.84	1.73	0.23	0.65	1.05	1.31
66	0.46	0.74	0.98	0.73	0.97	0.92	1.45	0.76	0.95	1.80	2.18	1.25	0.46	1.57	1.45	1.48
64	1.46	0.62	1.02	1.11	2.29	1.23	1.04	1.09	1.95	2.34	1.95	2.19	0.85	1.94	2.09	2.35
62	1.30	0.66	0.86	0.88	1.59	1.48	0.60	1.37	1.85	2.31	1.86	2.38	0.91	1.47	1.97	1.68
60	1.13	1.02	1.51	1.47	2.22	2.25	1.35	1.08	2.71	2.21	2.62	2.26	1.63	0.90	2.44	2.27
58	0.78	1.06	2.27	1.53	2.96	0.94	0.68	1.47	2.58	2.59	2.97	2.85	1.01	1.81	2.59	2.23
56	1.11	1.04	2.09	1.71	2.04	2.61	0.34	1.92	3.13	3.09	2.92	2.50	0.77	1.18	2.50	2.57
55	0.58	0.91	0.40	1.40	3.32	2.69	2.28	0.27	3.38	3.56	3.39	3.31	1.23	1.17	0.83	3.42
54	0.49	0.72	1.39	1.07	3.09	3.07	2.45	1.81	3.28	3.59	3.45	3.39	0.49	0.71	1.90	2.83
53	0.70	0.11	1.11	0.80	3.19	2.68	1.75	2.88	3.05	3.55	3.36	3.46	0.73	1.07	3.06	1.90
52	1.53	0.36	0.40	0.79	3.37	3.03	3.39	2.36	3.17	3.48	3.72	3.66	0.74	1.36	0.74	2.80
51	0.42	0.55	0.68	1.10	3.18	3.10	3.09	1.97	3.68	3.58	3.43	3.48	0.46	1.46	1.69	3.33
50	1.64	0.30	0.23	0.62	3.53	3.22	3.09	1.10	3.93	3.87	3.63	3.63	0.28	2.09	2.55	3.64
49	1.17	0.64	0.76	0.42	3.63	3.38	3.12	2.27	4.00	3.83	3.89	3.72	1.48	1.45	1.86	3.61
48	1.41	1.27	0.23	0.37	3.52	3.05	3.40	3.05	3.93	3.68	3.69	3.57	0.83	1.78	2.27	3.23
47	2.25	1.41	1.00	0.51	3.78	3.76	3.28	3.12	4.03	4.00	3.81	3.76	1.12	1.91	3.08	3.82
46	2.92	2.26	1.39	0.84	4.01	3.84	3.80	3.30	4.00	3.96	3.85	3.96	0.60	1.74	2.25	3.89
45	2.36	1.87	1.87	0.93	3.54	3.52	3.63	3.22	3.84	3.88	3.76	3.74	1.37	2.10	2.10	3.71
44	2.32	1.84	1.35	0.96	3.66	3.52	3.48	3.05	4.33	4.20	3.96	3.81	1.95	2.78	3.72	4.11
43	3.19	2.65	1.33	0.91	4.16	4.01	3.72	3.62	4.43	4.30	4.17	4.18	1.10	2.08	3.75	4.01
42	2.64	2.40	2.03	1.24	3.86	3.74	4.05	3.80	4.50	4.28	4.32	3.99	1.67	2.72	3.20	3.80
41	3.67	2.76	2.13	0.86	4.29	4.14	4.01	3.86	4.46	4.55	4.52	4.37	1.58	3.07	3.89	4.49
40	3.63	2.61	2.09	1.47	4.44	4.33	4.15	4.37	4.92	4.75	4.68	4.74	1.64	3.02	4.16	4.38
39	3.47	3.04	2.15	0.65	4.44	4.19	4.20	4.21	5.03	4.92	4.52	4.56	1.16	2.70	3.95	4.43
38	3.73	3.18	1.65	0.96	4.66	4.55	4.66	4.64	5.27	4.98	5.00	4.79	1.66	2.96	4.34	4.60
37	3.98	3.33	2.10	0.40	5.00	4.72	4.45	4.72	5.38	5.30	5.21	5.13	1.52	2.56	4.65	5.25
36	4.12	3.07	1.93	0.33	4.89	4.82	4.80	4.67	5.36	5.37	5.30	5.08	1.39	2.67	4.29	5.26
35	4.52	3.24	1.80	0.43	5.49	5.23	5.28	5.04	5.66	5.69	5.73	5.47	1.53	2.81	4.71	5.55
34	4.72	3.02	1.86	0.99	6.01	5.72	5.55	5.37	6.16	6.07	6.06	5.71	1.91	2.99	5.33	6.03

Table B-17 Unit 15B, High Flow (Modified VBS) V Total (ft/s), Test 2

	OR						Y-Positions (ft)									WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.41	0.45	0.40	0.27	0.40	0.76	0.78	0.55	0.38	0.43	0.54	0.63	0.14	0.37	0.27	0.41
70	0.84	0.59	0.39	0.61	1.13	0.91	0.83	0.57	0.53	0.66	0.93	0.81	0.31	0.27	0.51	0.40
68	0.43	0.72	0.52	0.63	1.57	1.38	1.65	1.15	1.80	1.65	1.84	1.73	0.29	0.68	1.09	1.31
66	0.48	0.74	0.98	0.73	0.97	0.92	1.46	0.76	0.95	1.80	2.18	1.25	0.51	1.59	1.46	1.48
64	1.46	0.62	1.03	1.12	2.29	1.23	1.05	1.09	1.95	2.35	1.95	2.19	0.87	1.94	2.09	2.35
62	1.31	0.67	0.86	0.89	1.59	1.48	0.60	1.37	1.85	2.31	1.86	2.38	0.91	1.47	1.97	1.68
60	1.13	1.03	1.51	1.48	2.22	2.25	1.35	1.08	2.71	2.21	2.62	2.26	1.63	0.91	2.45	2.27
58	0.79	1.07	2.28	1.53	2.96	0.94	0.68	1.47	2.58	2.60	2.97	2.86	1.01	1.81	2.59	2.23
56	1.22	1.23	2.17	1.79	2.15	2.71	0.51	2.00	3.20	3.16	3.02	2.69	1.01	1.31	2.60	2.65
55	0.83	1.12	0.67	1.50	3.37	2.72	2.32	0.46	3.41	3.62	3.44	3.36	1.37	1.31	1.03	3.45
54	0.67	0.95	1.55	1.20	3.15	3.12	2.48	1.88	3.33	3.65	3.54	3.47	0.64	0.92	1.98	2.89
53	0.88	0.53	1.27	1.01	3.27	2.76	1.78	2.93	3.12	3.62	3.45	3.56	0.88	1.21	3.14	1.95
52	1.59	0.53	0.68	0.94	3.41	3.07	3.42	2.39	3.19	3.52	3.77	3.71	0.81	1.41	0.82	2.85
51	0.71	0.72	0.87	1.24	3.27	3.17	3.13	2.02	3.73	3.65	3.52	3.58	0.71	1.60	1.79	3.40
50	1.76	0.85	0.67	0.71	3.63	3.31	3.15	1.29	3.99	3.95	3.74	3.74	0.72	2.20	2.64	3.71
49	1.24	0.80	0.88	0.68	3.67	3.42	3.16	2.31	4.03	3.86	3.93	3.77	1.55	1.53	1.93	3.65
48	1.54	1.47	0.66	0.65	3.61	3.13	3.45	3.11	3.98	3.74	3.77	3.66	1.07	1.87	2.35	3.30
47	2.36	1.58	1.22	0.79	3.86	3.84	3.33	3.20	4.08	4.08	3.92	3.87	1.32	2.05	3.19	3.91
46	2.96	2.34	1.48	0.98	4.04	3.88	3.82	3.33	4.03	4.00	3.91	4.01	0.68	1.81	2.32	3.93
45	2.42	1.99	2.00	1.20	3.61	3.59	3.67	3.26	3.89	3.93	3.85	3.81	1.49	2.21	2.22	3.76
44	2.42	2.01	1.58	1.10	3.73	3.61	3.52	3.13	4.38	4.24	4.03	3.90	2.06	2.88	3.79	4.16
43	3.21	2.70	1.41	0.98	4.18	4.04	3.74	3.63	4.45	4.33	4.20	4.21	1.19	2.15	3.78	4.05
42	2.69	2.49	2.18	1.37	3.90	3.78	4.07	3.82	4.52	4.32	4.36	4.04	1.79	2.80	3.27	3.85
41	3.70	2.86	2.32	1.07	4.32	4.19	4.04	3.89	4.49	4.58	4.57	4.42	1.75	3.15	3.96	4.53
40	3.65	2.66	2.19	1.61	4.46	4.35	4.16	4.38	4.93	4.77	4.70	4.76	1.72	3.08	4.19	4.40
39	3.50	3.10	2.28	0.89	4.47	4.22	4.21	4.23	5.05	4.95	4.56	4.59	1.36	2.80	3.99	4.46
38	3.79	3.27	1.89	1.14	4.69	4.58	4.68	4.66	5.31	5.01	5.05	4.83	1.80	3.07	4.39	4.64
37	4.00	3.39	2.22	0.81	5.02	4.74	4.46	4.73	5.40	5.32	5.24	5.16	1.58	2.61	4.68	5.26
36	4.16	3.18	2.06	0.90	4.93	4.86	4.82	4.69	5.40	5.42	5.36	5.15	1.53	2.80	4.37	5.29
35	4.55	3.38	1.87	0.83	5.54	5.29	5.31	5.06	5.72	5.76	5.81	5.55	1.68	3.00	4.78	5.59
34	4.73	3.13	1.95	1.09	6.05	5.76	5.58	5.39	6.20	6.13	6.12	5.78	2.00	3.11	5.36	6.06

Table B-18 Unit 15B, High Flow (Modified VBS) RMS Total (ft/s), Test 2

	OR						Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.94	0.67	0.63	0.76	0.93	0.84	0.78	0.71	0.96	1.23	1.20	1.28	0.57	0.79	1.02	0.80
70	1.12	0.80	0.80	0.72	1.33	1.18	1.10	0.86	1.28	1.39	1.46	1.17	0.86	1.07	1.04	0.89
68	0.95	1.12	0.97	0.73	1.34	1.32	1.25	1.23	1.34	1.24	1.17	1.24	0.92	1.22	1.12	1.28
66	1.21	0.94	0.86	0.88	1.12	1.13	1.45	1.27	1.24	1.18	1.34	1.21	0.74	1.17	1.39	1.34
64	1.33	1.22	1.09	1.32	1.30	1.67	1.35	1.53	1.27	1.26	1.39	1.17	0.98	1.15	0.92	0.96
62	1.00	1.61	0.68	1.46	1.58	1.56	1.26	1.69	1.65	1.34	1.25	1.39	1.38	1.63	1.35	1.64
60	1.30	1.85	1.25	1.22	1.49	1.28	1.63	1.34	1.23	1.43	1.16	1.28	1.31	1.81	1.21	1.14
58	1.54	1.03	0.93	1.19	1.18	1.64	1.60	1.68	1.48	1.24	1.22	1.19	1.32	1.33	1.30	1.33
56	1.88	1.57	0.96	1.43	1.81	1.35	1.77	1.57	1.18	1.26	1.29	1.22	1.77	1.65	1.30	1.40
55	1.42	1.73	1.23	1.24	1.11	1.51	1.71	1.55	1.24	1.08	1.28	1.19	2.19	1.71	1.77	1.25
54	1.40	1.94	1.16	1.47	1.37	1.35	1.43	1.58	1.29	1.08	1.11	1.10	1.79	2.23	1.72	1.53
53	1.73	1.37	1.33	1.35	1.11	1.34	1.51	1.17	1.30	0.97	1.09	1.01	1.50	1.77	1.12	1.68
52	1.49	1.67	1.87	1.32	1.02	1.14	1.25	1.61	1.31	1.06	1.10	1.03	1.67	1.82	1.96	1.61
51	1.42	1.61	1.38	1.55	1.33	1.51	1.18	1.75	0.97	1.10	0.98	1.06	1.52	1.89	1.78	1.12
50	1.62	1.58	1.26	1.37	1.11	1.32	1.22	1.55	0.94	0.86	0.92	1.05	1.57	1.42	1.48	1.02
49	1.62	1.50	1.93	1.21	1.14	1.05	1.32	1.37	0.87	0.92	1.07	0.95	1.29	1.59	1.99	1.20
48	1.60	1.48	1.42	1.44	0.98	0.95	1.09	1.20	0.83	0.82	0.76	0.92	1.23	1.43	1.37	1.15
47	1.53	1.72	1.22	1.62	0.96	1.04	1.07	1.16	0.96	1.02	0.81	0.85	1.44	1.65	1.39	0.98
46	1.23	1.42	1.47	1.58	0.86	0.95	1.05	1.20	1.05	1.00	0.87	0.90	1.41	1.43	1.40	1.03
45	1.50	1.48	1.53	1.43	0.92	0.90	1.12	1.04	0.88	0.90	1.11	0.85	1.13	1.39	1.78	1.10
44	1.35	1.60	1.47	1.26	0.86	0.96	1.06	1.10	1.01	1.00	0.85	0.94	1.27	1.23	1.14	1.12
43	1.40	1.37	1.57	1.46	0.98	0.89	1.13	1.21	1.05	1.00	0.89	0.88	1.53	1.45	1.11	1.15
42	1.57	1.45	1.61	1.65	1.05	1.02	1.12	1.16	1.04	0.95	0.99	0.95	1.26	1.32	1.41	1.20
41	1.44	1.75	1.62	1.99	1.02	1.12	1.22	1.31	1.10	1.04	1.09	1.03	1.37	1.40	1.46	1.32
40	1.43	1.79	1.68	1.75	1.05	1.22	1.23	1.27	1.11	1.07	1.06	1.00	1.41	1.48	1.43	1.36
39	1.42	1.64	1.80	2.06	1.12	1.17	1.29	1.53	1.16	1.09	1.05	1.13	1.70	1.62	1.39	1.29
38	1.65	1.61	2.18	1.81	1.18	1.27	1.45	1.45	1.18	1.09	1.10	1.06	1.59	1.64	1.47	1.27
37	1.80	1.77	1.83	2.08	1.28	1.24	1.40	1.56	1.17	1.03	1.10	1.14	1.62	1.69	1.67	1.37
36	1.97	1.88	1.85	1.91	1.28	1.29	1.46	1.59	1.10	0.97	1.00	1.06	1.80	1.82	1.89	1.36
35	1.94	2.02	1.94	1.85	1.08	1.30	1.46	1.60	1.09	0.93	0.78	0.93	1.68	1.90	1.82	1.34
34	2.07	2.22	2.00	2.03	0.85	1.04	1.17	1.49	0.76	0.65	0.81	0.78	2.04	2.10	1.82	0.99

Table B-19 Unit 15C, High Flow (Modified VBS) Vx (ft/s), Test 3

	OR							Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	(0.06)	(0.01)	(0.05)	(0.04)	(0.07)	(0.10)	(0.16)	(0.15)	(0.03)	(0.09)	(0.10)	(0.15)	0.04	0.07	(0.14)	(0.03)
70	(0.20)	(0.10)	(0.04)	(0.03)	(0.18)	(0.15)	(0.13)	(0.09)	(0.23)	(0.20)	(0.17)	(0.08)	(0.12)	(0.09)	(0.15)	(0.11)
68	(0.22)	(0.25)	(0.16)	(0.14)	(0.04)	(0.07)	(0.08)	(0.02)	(0.10)	(0.16)	(0.11)	(0.05)	(0.12)	(0.18)	(0.10)	0.06
66	(0.05)	(0.13)	(0.10)	(0.07)	(0.02)	(0.06)	(0.03)	0.00	(0.00)	0.06	0.09	0.09	(0.23)	(0.17)	0.02	0.07
64	(0.01)	(0.09)	0.02	(0.13)	0.12	0.05	0.04	0.05	(0.00)	0.08	0.02	0.04	(0.12)	(0.08)	(0.01)	(0.01)
62	0.04	(0.02)	0.01	(0.04)	0.04	0.01	(0.04)	0.02	0.11	0.07	0.01	0.07	(0.19)	(0.00)	(0.07)	0.08
60	0.02	0.07	0.07	(0.07)	(0.02)	0.11	0.06	0.06	0.07	0.15	0.13	0.09	(0.08)	(0.05)	0.00	(0.03)
58	0.09	0.13	0.11	0.07	0.03	0.01	0.08	0.05	0.18	0.18	0.14	0.17	0.06	0.11	0.05	0.08
56	0.74	0.75	0.71	0.66	0.83	0.76	0.52	0.49	0.52	0.63	0.82	0.82	0.57	0.75	0.58	0.43
55	0.37	0.58	0.49	0.59	0.59	0.53	0.44	0.47	0.31	0.48	0.60	0.60	0.44	0.67	0.66	0.39
54	0.42	0.67	0.62	0.66	0.59	0.63	0.48	0.44	0.45	0.52	0.65	0.64	0.46	0.62	0.51	0.35
53	0.62	0.67	0.60	0.67	0.73	0.74	0.57	0.55	0.27	0.37	0.69	0.77	0.64	0.69	0.57	0.39
52	0.43	0.47	0.54	0.37	0.44	0.49	0.40	0.37	0.20	0.37	0.44	0.51	0.42	0.43	0.51	0.39
51	0.67	0.65	0.61	0.65	0.67	0.69	0.51	0.59	0.56	0.63	0.73	0.72	0.38	0.61	0.62	0.65
50	0.57	0.66	0.70	0.65	0.76	0.73	0.56	0.57	0.58	0.54	0.74	0.77	0.48	0.58	0.68	0.63
49	0.41	0.55	0.59	0.45	0.48	0.49	0.39	0.34	0.50	0.44	0.56	0.54	0.51	0.57	0.60	0.51
48	0.46	0.65	0.74	0.59	0.66	0.66	0.54	0.51	0.59	0.52	0.72	0.73	0.61	0.62	0.66	0.66
47	0.53	0.57	0.70	0.62	0.73	0.68	0.55	0.54	0.63	0.57	0.76	0.76	0.72	0.78	0.75	0.75
46	0.29	0.41	0.44	0.33	0.45	0.46	0.35	0.28	0.46	0.45	0.55	0.56	0.51	0.51	0.48	0.42
45	0.44	0.53	0.57	0.61	0.59	0.63	0.48	0.47	0.53	0.58	0.70	0.70	0.59	0.62	0.62	0.56
44	0.52	0.57	0.63	0.63	0.66	0.65	0.54	0.50	0.55	0.63	0.76	0.80	0.64	0.67	0.69	0.63
43	0.30	0.40	0.33	0.35	0.37	0.36	0.35	0.34	0.42	0.45	0.51	0.51	0.41	0.48	0.49	0.44
42	0.40	0.43	0.54	0.56	0.48	0.49	0.42	0.41	0.50	0.53	0.60	0.57	0.49	0.54	0.59	0.52
41	0.43	0.49	0.60	0.55	0.55	0.56	0.45	0.45	0.59	0.60	0.68	0.67	0.55	0.62	0.67	0.64
40	0.26	0.33	0.43	0.38	0.31	0.33	0.25	0.26	0.44	0.47	0.47	0.48	0.46	0.58	0.52	0.41
39	0.37	0.50	0.68	0.69	0.46	0.49	0.43	0.41	0.50	0.55	0.58	0.58	0.69	0.76	0.62	0.49
38	0.39	0.58	0.71	0.36	0.55	0.57	0.45	0.47	0.57	0.62	0.70	0.65	0.72	0.92	0.81	0.61
37	0.22	0.43	0.60	0.24	0.41	0.41	0.32	0.26	0.50	0.53	0.58	0.54	0.54	0.79	0.67	0.46
36	0.53	0.74	0.93	0.51	0.73	0.77	0.61	0.62	0.74	0.78	0.89	0.93	0.59	1.10	1.03	0.71
35	0.63	0.87	0.96	0.48	0.96	0.90	0.68	0.69	0.88	0.96	1.05	1.04	0.62	1.22	0.96	0.76
34	0.41	0.51	0.78	0.58	0.76	0.78	0.63	0.55	0.80	0.84	0.92	1.00	0.41	0.95	0.84	0.71

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					(0.24)				(0.15)				(0.14)			
58					0.08				0.16				0.20			
53					0.46				0.71				0.42			
48					0.36				0.67				0.65			
43					0.21				0.39				0.42			
38					0.30				0.54				0.64			

Table B-20 Unit 15C, High Flow (Modified VBS) Vx RMS (ft/s), Test 3

	OR						Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.36	0.26	0.23	0.23	0.41	0.23	0.36	0.30	0.29	0.27	0.35	0.33	0.22	0.25	0.28	0.25
70	0.34	0.34	0.27	0.24	0.41	0.37	0.39	0.39	0.39	0.39	0.45	0.49	0.28	0.21	0.38	0.41
68	0.43	0.43	0.39	0.32	0.44	0.45	0.42	0.45	0.47	0.53	0.51	0.50	0.32	0.34	0.43	0.50
66	0.53	0.45	0.47	0.42	0.46	0.45	0.49	0.45	0.48	0.50	0.49	0.45	0.44	0.51	0.53	0.55
64	0.42	0.45	0.49	0.47	0.45	0.42	0.40	0.45	0.57	0.62	0.53	0.48	0.47	0.53	0.48	0.38
62	0.61	0.55	0.45	0.40	0.47	0.43	0.41	0.51	0.60	0.48	0.48	0.47	0.51	0.51	0.55	0.57
60	0.49	0.46	0.50	0.45	0.45	0.39	0.45	0.43	0.48	0.61	0.56	0.58	0.48	0.58	0.54	0.53
58	0.51	0.55	0.52	0.45	0.46	0.45	0.46	0.49	0.45	0.45	0.43	0.38	0.51	0.65	0.46	0.56
56	0.51	0.53	0.54	0.41	0.39	0.37	0.45	0.46	0.44	0.39	0.36	0.33	0.53	0.57	0.55	0.61
55	0.54	0.46	0.43	0.33	0.33	0.33	0.36	0.39	0.52	0.44	0.43	0.34	0.44	0.57	0.52	0.53
54	0.52	0.43	0.43	0.34	0.35	0.36	0.35	0.44	0.45	0.38	0.33	0.34	0.45	0.43	0.53	0.49
53	0.40	0.39	0.41	0.33	0.35	0.33	0.33	0.41	0.55	0.51	0.41	0.34	0.38	0.41	0.39	0.49
52	0.41	0.48	0.43	0.37	0.34	0.32	0.33	0.35	0.58	0.44	0.45	0.41	0.42	0.42	0.40	0.54
51	0.47	0.45	0.35	0.37	0.29	0.32	0.35	0.42	0.43	0.36	0.36	0.32	0.36	0.41	0.45	0.41
50	0.33	0.46	0.38	0.36	0.37	0.32	0.30	0.34	0.48	0.53	0.37	0.35	0.41	0.37	0.41	0.49
49	0.46	0.48	0.41	0.39	0.31	0.31	0.35	0.35	0.44	0.37	0.34	0.34	0.44	0.44	0.50	0.48
48	0.39	0.47	0.43	0.41	0.33	0.35	0.37	0.42	0.47	0.44	0.36	0.33	0.40	0.43	0.45	0.44
47	0.34	0.45	0.38	0.35	0.33	0.34	0.33	0.37	0.51	0.46	0.41	0.36	0.47	0.46	0.47	0.51
46	0.45	0.53	0.44	0.42	0.33	0.34	0.35	0.39	0.40	0.35	0.36	0.34	0.38	0.43	0.54	0.47
45	0.43	0.48	0.44	0.44	0.35	0.35	0.36	0.41	0.42	0.38	0.38	0.37	0.44	0.47	0.52	0.47
44	0.44	0.47	0.46	0.46	0.36	0.37	0.38	0.40	0.46	0.43	0.38	0.36	0.47	0.46	0.48	0.49
43	0.48	0.53	0.51	0.51	0.39	0.38	0.44	0.44	0.42	0.40	0.37	0.39	0.47	0.50	0.50	0.44
42	0.44	0.52	0.54	0.54	0.39	0.39	0.41	0.46	0.51	0.42	0.42	0.39	0.48	0.50	0.50	0.49
41	0.49	0.54	0.57	0.59	0.42	0.43	0.39	0.43	0.54	0.48	0.46	0.42	0.53	0.58	0.59	0.54
40	0.55	0.57	0.62	0.69	0.41	0.40	0.40	0.42	0.53	0.49	0.46	0.43	0.65	0.64	0.59	0.57
39	0.58	0.65	0.69	0.71	0.40	0.40	0.43	0.54	0.55	0.45	0.46	0.44	0.69	0.75	0.67	0.59
38	0.58	0.70	0.76	0.77	0.39	0.38	0.40	0.42	0.51	0.49	0.46	0.44	0.76	0.81	0.77	0.67
37	0.60	0.79	0.87	0.82	0.38	0.34	0.33	0.40	0.47	0.44	0.43	0.38	0.87	0.84	0.80	0.61
36	0.61	0.84	0.91	0.87	0.39	0.32	0.31	0.32	0.51	0.36	0.39	0.39	0.88	0.93	0.90	0.69
35	0.72	0.94	0.98	0.91	0.26	0.32	0.29	0.32	0.33	0.29	0.30	0.27	0.92	1.04	0.87	0.59
34	0.50	0.92	1.05	1.00	0.23	0.25	0.24	0.26	0.31	0.27	0.26	0.24	1.05	1.07	0.98	0.59

DUPLICATE DATA

	OR						Y-Positions (ft)								WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					0.41				0.41				0.42			
58					0.43				0.44				0.58			
53					0.38				0.36				0.56			
48					0.34				0.40				0.49			
43					0.41				0.37				0.50			
38					0.41				0.41				0.64			

Table B-21 Unit 15C, High Flow (Modified VBS) Vy (ft/s), Test 3

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.02	0.11	0.21	0.22	(0.29)	0.17	0.11	0.18	(0.21)	(0.04)	(0.15)	(0.11)	0.01	0.15	(0.08)	(0.16)
70	(0.04)	(0.17)	0.07	0.07	(0.51)	(0.39)	(0.22)	0.21	(0.66)	(0.65)	(0.68)	(0.45)	(0.11)	(0.03)	(0.43)	(0.45)
68	0.10	(0.05)	0.04	0.24	(0.51)	(0.53)	(0.21)	0.40	(0.66)	(1.07)	(0.73)	(0.14)	(0.28)	(0.35)	(0.52)	(0.46)
66	0.90	0.75	0.70	0.57	0.30	0.97	0.89	0.98	(0.37)	0.14	0.10	(0.16)	(0.49)	(0.43)	(0.83)	(0.68)
64	0.24	0.12	0.45	0.59	(0.61)	(0.87)	(0.25)	0.03	(1.06)	(1.29)	(1.06)	(0.89)	(0.61)	(0.83)	(0.77)	(0.61)
62	0.72	1.14	0.53	0.48	(0.25)	0.67	0.17	0.29	(1.25)	(0.64)	(0.61)	(0.48)	(0.80)	(0.78)	(0.95)	(1.13)
60	0.83	0.59	0.92	0.61	0.42	(0.18)	(0.05)	0.00	(0.79)	(1.39)	(1.10)	(1.23)	(0.62)	(0.92)	(0.91)	(0.93)
58	0.67	0.62	0.40	0.44	0.44	0.69	0.62	0.76	(0.59)	(0.90)	(0.26)	(0.48)	(0.67)	(0.88)	(0.29)	(0.94)
56	0.13	0.89	0.76	0.40	(0.06)	0.41	0.67	0.25	(1.04)	(0.40)	(0.20)	(0.41)	(0.73)	(0.79)	(0.79)	(1.35)
55	0.02	(0.12)	(0.27)	(0.14)	0.15	0.01	0.13	0.41	(0.36)	(0.82)	(0.18)	(0.29)	0.13	(0.71)	(0.37)	(0.51)
54	(0.83)	0.06	0.17	0.03	0.25	0.02	0.07	0.09	0.07	(0.06)	(0.24)	(0.14)	0.40	0.20	(0.55)	0.03
53	0.44	0.28	(0.35)	(0.13)	0.23	0.28	0.13	0.30	0.37	0.67	0.16	(0.22)	0.12	0.06	0.53	0.28
52	0.25	0.06	0.06	(0.27)	0.18	0.17	0.39	0.58	0.57	0.15	0.53	0.17	0.43	0.46	0.28	0.19
51	0.20	(0.03)	(0.24)	(0.37)	0.19	0.01	(0.02)	(0.06)	0.00	0.03	0.02	(0.35)	0.58	0.41	0.11	(0.25)
50	0.56	0.17	(0.11)	(0.20)	0.65	0.42	0.20	0.53	0.13	0.44	0.27	0.12	0.63	0.52	(0.03)	0.34
49	0.31	0.24	(0.17)	(0.23)	0.23	0.12	0.06	0.44	(0.10)	0.04	0.11	0.11	0.39	(0.06)	0.03	0.04
48	0.40	0.10	(0.30)	(0.23)	0.41	0.32	(0.06)	0.15	0.09	0.41	0.02	(0.30)	0.51	0.23	(0.14)	(0.29)
47	0.63	0.30	0.05	0.01	0.69	0.52	0.50	0.68	0.17	0.33	0.44	0.29	0.60	(0.01)	(0.07)	(0.18)
46	0.18	0.15	0.13	0.06	0.21	0.06	0.18	0.35	(0.19)	(0.08)	0.03	(0.05)	(0.02)	(0.14)	(0.06)	(0.12)
45	0.22	0.09	0.07	0.09	0.31	0.11	0.25	0.51	(0.07)	(0.02)	0.13	(0.04)	0.01	(0.19)	(0.06)	(0.08)
44	0.58	0.31	0.27	0.21	0.56	0.50	0.47	0.75	0.02	0.14	0.17	0.14	(0.20)	(0.09)	(0.09)	(0.15)
43	0.34	0.24	0.27	0.19	0.28	0.13	0.02	0.30	(0.24)	(0.27)	(0.41)	(0.28)	(0.27)	(0.21)	(0.40)	(0.40)
42	0.80	0.50	0.34	0.49	0.63	0.50	0.26	0.52	0.06	0.08	(0.07)	(0.13)	(0.22)	(0.23)	(0.27)	(0.34)
41	0.81	0.66	0.62	0.51	0.67	0.58	0.59	0.86	(0.06)	0.07	0.03	0.01	(0.26)	(0.26)	(0.30)	(0.29)
40	0.68	0.70	0.65	0.76	0.46	0.52	0.54	0.79	(0.22)	(0.07)	(0.06)	(0.05)	(0.43)	(0.36)	(0.37)	(0.41)
39	0.65	0.51	0.51	0.75	0.46	0.27	0.16	0.34	(0.26)	(0.20)	(0.33)	(0.42)	(0.48)	(0.55)	(0.58)	(0.74)
38	0.75	0.76	0.76	0.93	0.47	0.49	0.38	0.77	(0.31)	(0.04)	(0.17)	(0.04)	(0.72)	(0.59)	(0.55)	(0.46)
37	0.75	0.77	0.76	0.84	0.44	0.48	0.42	0.70	(0.45)	(0.11)	(0.06)	(0.07)	(0.76)	(0.64)	(0.66)	(0.66)
36	0.73	0.81	0.73	0.63	0.40	0.48	0.33	0.83	(0.37)	0.02	(0.08)	0.02	(0.79)	(0.72)	(0.78)	(0.54)
35	0.57	0.79	0.69	0.39	0.40	0.37	0.28	0.71	(0.53)	(0.18)	(0.22)	(0.18)	(0.78)	(0.85)	(0.76)	(0.64)
34	0.61	0.64	0.81	0.74	0.46	0.47	0.39	0.85	(0.41)	(0.11)	(0.13)	(0.01)	(0.39)	(0.74)	(0.85)	(0.46)

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					(0.50)				(0.89)				(0.64)			
58					0.43				(0.59)				(1.06)			
53					0.36				0.20				0.18			
48					0.68				0.81				0.01			
43					0.52				0.47				(0.07)			
38					0.74				0.50				(0.44)			

Table B-22 Unit 15C, High Flow (Modified VBS) Vy RMS (ft/s), Test 3

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.54	0.24	0.23	0.21	0.45	0.36	0.36	0.29	0.26	0.20	0.33	0.28	0.19	0.27	0.40	0.24
70	0.38	0.32	0.30	0.28	0.40	0.41	0.39	0.35	0.38	0.33	0.41	0.41	0.24	0.33	0.31	0.39
68	0.37	0.42	0.44	0.18	0.39	0.39	0.41	0.49	0.39	0.40	0.37	0.50	0.30	0.35	0.36	0.47
66	0.46	0.41	0.30	0.36	0.43	0.41	0.44	0.39	0.49	0.39	0.44	0.38	0.30	0.41	0.43	0.57
64	0.49	0.44	0.45	0.45	0.44	0.45	0.38	0.48	0.48	0.50	0.49	0.45	0.36	0.40	0.36	0.38
62	0.56	0.53	0.45	0.49	0.43	0.56	0.53	0.62	0.52	0.55	0.68	0.41	0.34	0.38	0.38	0.55
60	0.63	0.54	0.44	0.44	0.60	0.46	0.55	0.44	0.58	0.52	0.49	0.62	0.30	0.45	0.42	0.43
58	0.57	0.58	0.54	0.45	0.91	0.72	0.74	0.83	0.54	0.58	0.68	0.61	0.43	0.47	0.50	0.47
56	0.72	0.48	0.51	0.43	0.62	0.51	0.69	0.87	0.55	0.50	0.57	0.47	0.50	0.60	0.66	0.55
55	0.81	0.62	0.51	0.37	0.47	0.45	0.44	0.52	0.95	0.62	0.63	0.53	0.44	0.69	0.63	0.78
54	0.59	0.61	0.52	0.28	0.50	0.44	0.45	0.68	0.58	0.53	0.52	0.38	0.40	0.60	0.73	0.96
53	0.37	0.58	0.65	0.39	0.39	0.44	0.33	0.50	0.85	0.59	0.54	0.44	0.47	0.48	0.47	0.86
52	0.49	0.70	0.58	0.56	0.42	0.34	0.35	0.36	0.68	0.50	0.62	0.49	0.54	0.49	0.58	0.74
51	0.66	0.56	0.53	0.40	0.37	0.43	0.35	0.60	0.56	0.42	0.43	0.41	0.47	0.54	0.75	0.50
50	0.40	0.57	0.54	0.48	0.45	0.37	0.35	0.39	0.58	0.61	0.46	0.36	0.41	0.43	0.55	0.71
49	0.51	0.58	0.52	0.50	0.37	0.37	0.37	0.40	0.47	0.40	0.38	0.35	0.55	0.62	0.52	0.60
48	0.48	0.59	0.55	0.58	0.36	0.36	0.42	0.50	0.53	0.41	0.43	0.36	0.48	0.53	0.56	0.49
47	0.39	0.57	0.48	0.46	0.30	0.34	0.34	0.27	0.49	0.49	0.48	0.39	0.41	0.66	0.57	0.52
46	0.52	0.57	0.54	0.52	0.32	0.36	0.39	0.45	0.40	0.34	0.37	0.34	0.47	0.55	0.48	0.44
45	0.41	0.56	0.55	0.48	0.35	0.37	0.40	0.40	0.43	0.31	0.37	0.38	0.57	0.56	0.62	0.57
44	0.50	0.51	0.47	0.47	0.36	0.38	0.40	0.44	0.46	0.44	0.35	0.35	0.63	0.52	0.50	0.53
43	0.44	0.59	0.64	0.55	0.37	0.38	0.41	0.41	0.43	0.36	0.35	0.36	0.54	0.46	0.53	0.49
42	0.44	0.58	0.52	0.45	0.43	0.41	0.38	0.49	0.55	0.42	0.40	0.36	0.57	0.58	0.54	0.43
41	0.52	0.58	0.55	0.63	0.43	0.44	0.38	0.40	0.50	0.37	0.43	0.36	0.58	0.63	0.62	0.51
40	0.55	0.58	0.60	0.71	0.42	0.41	0.38	0.41	0.51	0.41	0.42	0.40	0.58	0.50	0.51	0.51
39	0.61	0.57	0.68	0.68	0.38	0.37	0.37	0.47	0.50	0.37	0.42	0.42	0.60	0.66	0.66	0.51
38	0.56	0.73	0.75	0.89	0.36	0.32	0.29	0.38	0.48	0.40	0.37	0.40	0.69	0.62	0.71	0.61
37	0.60	0.74	0.84	0.93	0.35	0.30	0.27	0.30	0.42	0.33	0.32	0.36	0.81	0.75	0.75	0.54
36	0.56	0.82	0.87	1.04	0.32	0.25	0.24	0.28	0.44	0.27	0.29	0.30	0.89	0.83	0.87	0.68
35	0.65	0.82	0.95	1.05	0.22	0.22	0.20	0.27	0.26	0.21	0.20	0.21	0.92	0.94	0.82	0.56
34	0.47	0.83	0.98	0.91	0.20	0.19	0.19	0.24	0.24	0.21	0.18	0.20	1.04	0.95	0.71	0.50

DUPLICATE DATA

	OR							Y-Positions (ft)								WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
68					0.39				0.34				0.27			
58					0.53				0.58				0.45			
53					0.41				0.50				0.75			
48					0.35				0.48				0.55			
43					0.46				0.40				0.56			
38					0.36				0.38				0.55			

Table B-23 Unit 15C, High Flow (Modified VBS) Vz (ft/s), Test 3

EL (ft)	OR							Y-Positions (ft)								WA
	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.04	(0.17)	0.02	(0.00)	(0.00)	0.02	0.38	0.27	(0.07)	0.04	0.34	0.28	(0.19)	(0.08)	0.05	(0.04)
70	0.86	0.51	(0.02)	(0.13)	1.02	0.74	0.92	0.83	0.35	0.45	0.75	1.09	(0.51)	(0.25)	0.02	0.38
68	1.32	1.18	0.55	(0.03)	1.26	1.62	1.04	0.65	0.47	0.90	0.94	1.13	(0.23)	(0.20)	0.12	0.44
66	0.72	0.09	0.13	(0.25)	1.44	1.18	1.16	1.31	1.15	1.43	1.50	1.72	0.52	0.76	1.12	0.66
64	1.64	1.71	0.96	0.88	1.55	1.99	1.44	1.86	0.53	0.70	0.95	0.93	(0.26)	(0.30)	(0.04)	(0.18)
62	1.01	0.78	0.32	(0.05)	2.00	1.90	1.33	1.44	0.85	1.61	1.50	1.58	(0.19)	0.07	0.48	0.89
60	0.24	0.76	1.35	1.05	2.04	1.82	1.92	2.04	1.31	1.18	1.00	1.36	(0.17)	(0.41)	(0.16)	(0.28)
58	(0.41)	(1.03)	(0.97)	(0.75)	2.08	2.30	2.44	1.37	1.90	2.21	2.20	2.22	(0.06)	(0.66)	(1.03)	0.17
56	(0.22)	(0.65)	(1.10)	(1.40)	2.01	1.93	1.53	1.65	1.74	1.91	1.83	2.11	(1.22)	(0.72)	0.22	0.76
55	1.62	0.21	0.08	(0.63)	2.63	2.80	2.48	2.28	1.71	2.16	2.11	2.68	(1.10)	(1.32)	(0.58)	0.35
54	0.30	(0.17)	(0.24)	(0.85)	2.86	2.41	2.30	2.09	2.15	2.47	2.21	2.59	(0.67)	(1.05)	0.33	0.91
53	2.36	1.70	0.39	(0.12)	2.64	2.73	2.72	2.46	0.81	1.84	2.60	2.55	(0.86)	(1.05)	(0.94)	0.93
52	2.17	0.93	1.04	0.33	2.89	2.93	3.05	2.84	1.55	2.33	2.12	2.48	(0.76)	(0.41)	(0.43)	0.17
51	1.29	0.38	0.20	(0.33)	2.82	2.79	2.77	1.30	2.23	2.72	2.55	2.69	(0.15)	(0.10)	0.28	1.74
50	2.91	1.75	0.67	0.76	2.72	2.96	2.98	3.00	1.27	1.94	2.69	2.80	(0.11)	(0.06)	0.33	0.49
49	2.20	0.47	0.46	0.57	3.07	3.12	3.12	3.08	2.05	2.86	2.91	2.83	0.63	0.45	0.59	0.89
48	2.74	1.37	0.43	0.60	2.83	2.94	2.95	2.42	2.06	2.71	2.70	2.76	0.52	0.10	1.17	1.94
47	3.13	2.19	1.37	1.07	3.07	3.06	3.27	3.28	2.02	2.54	2.82	2.98	0.08	0.21	0.43	1.09
46	2.55	0.84	0.71	0.83	3.22	3.33	3.44	3.29	2.98	3.10	3.03	3.16	0.46	0.76	1.22	2.35
45	2.69	1.01	0.92	0.87	3.14	3.30	3.49	3.39	2.92	3.28	3.02	3.11	0.34	0.84	1.38	2.15
44	3.35	2.45	1.79	1.65	3.40	3.48	3.61	3.73	2.70	3.18	3.07	3.11	0.58	0.85	1.64	2.38
43	3.22	1.91	1.03	1.30	3.89	3.90	3.75	3.61	3.42	3.65	3.47	3.55	0.99	1.97	2.88	3.17
42	3.56	2.88	1.96	1.50	3.67	3.68	3.92	3.76	2.98	3.45	3.56	3.68	0.69	1.51	2.48	3.09
41	3.97	3.20	2.66	1.95	3.94	4.04	4.27	4.31	3.38	3.81	3.63	3.69	0.90	1.76	2.65	3.11
40	3.81	3.25	2.67	2.07	4.55	4.46	4.52	4.59	3.75	4.13	3.99	3.90	1.58	2.33	2.83	3.40
39	4.00	3.05	2.31	1.93	4.58	4.55	4.49	4.03	3.83	4.38	4.07	4.27	1.60	2.41	3.19	3.81
38	4.34	3.52	2.87	2.26	4.70	4.88	4.93	4.91	4.08	4.33	4.35	4.31	1.56	2.13	2.98	3.56
37	4.52	3.70	2.96	2.61	4.96	5.03	5.19	5.04	4.58	4.66	4.55	4.72	1.70	2.30	3.08	4.03
36	4.43	3.69	2.73	2.75	4.88	5.16	5.15	5.19	4.63	4.85	4.77	4.81	1.96	2.22	3.41	4.03
35	4.80	3.83	2.77	2.99	5.41	5.39	5.48	5.41	5.17	5.23	5.25	5.22	2.57	2.84	4.06	4.65
34	5.22	4.61	3.07	2.82	5.53	5.68	5.63	5.83	5.43	5.34	5.43	5.60	3.11	2.40	4.01	5.01

DUPLICATE DATA

EL (ft)	OR							Y-Positions (ft)								WA
	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					1.35				0.85				(0.10)			
58					2.24				1.83				(0.52)			
53					2.84				2.80				(0.32)			
48					3.22				2.83				0.49			
43					3.83				3.56				2.74			
38					4.71				4.43				3.46			

Table B-24 Unit 15C, High Flow (Modified VBS) Vz RMS (ft/s), Test 3

	OR						Y-Positions (ft)									WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.41	0.21	0.29	0.30	0.44	0.29	0.47	0.48	0.34	0.44	0.48	0.48	0.24	0.35	0.34	0.35
70	0.68	0.58	0.41	0.32	0.78	0.67	0.64	0.67	0.61	0.58	0.65	0.62	0.31	0.30	0.50	0.57
68	0.60	0.71	0.66	0.43	0.67	0.60	0.63	0.80	0.63	0.67	0.69	0.66	0.35	0.50	0.55	0.54
66	0.81	0.59	0.60	0.54	0.74	0.81	0.83	0.69	0.67	0.69	0.64	0.58	0.72	0.83	0.75	0.83
64	0.62	0.55	0.73	0.67	0.69	0.75	0.83	0.64	0.76	0.87	0.76	1.05	0.53	0.61	0.66	0.68
62	0.99	0.89	0.79	0.76	0.76	0.62	0.82	0.80	0.85	0.65	0.83	0.73	0.74	0.65	0.84	0.83
60	0.84	0.84	0.67	0.59	0.98	0.80	0.68	0.80	0.88	0.94	0.83	0.88	0.95	0.77	0.65	0.81
58	1.14	0.64	0.73	0.64	0.86	0.94	0.76	0.87	1.06	0.79	0.81	0.75	0.74	0.93	0.54	1.12
56	0.79	0.97	1.01	0.43	0.72	0.71	0.94	1.05	0.77	0.69	0.78	0.62	1.01	0.82	0.96	1.01
55	0.90	1.18	1.13	0.57	0.59	0.62	0.53	0.65	1.09	0.76	0.72	0.59	0.79	1.09	0.85	1.16
54	1.17	0.92	0.70	0.55	0.63	0.69	0.55	0.64	0.67	0.57	0.71	0.54	0.53	0.57	0.88	0.87
53	0.58	0.56	0.79	0.70	0.63	0.60	0.59	0.62	1.18	1.10	0.65	0.58	0.74	0.65	0.78	1.16
52	0.65	0.71	0.50	0.70	0.53	0.48	0.46	0.52	1.00	0.69	0.86	0.75	0.63	0.79	0.69	1.17
51	0.96	0.74	0.59	0.60	0.52	0.54	0.50	1.00	0.65	0.56	0.50	0.55	0.66	0.71	0.80	0.71
50	0.44	0.65	0.55	0.58	0.58	0.43	0.44	0.51	1.04	0.85	0.49	0.62	0.76	0.67	0.69	0.79
49	0.72	0.69	0.64	0.57	0.40	0.42	0.51	0.45	0.89	0.52	0.48	0.54	0.62	0.69	0.85	0.87
48	0.54	0.87	0.66	0.60	0.48	0.47	0.58	0.77	0.88	0.60	0.56	0.48	0.70	0.53	0.94	0.92
47	0.43	0.68	0.70	0.59	0.44	0.46	0.45	0.46	1.01	0.77	0.58	0.50	0.92	0.72	0.80	0.90
46	0.56	0.95	0.69	0.60	0.41	0.46	0.45	0.61	0.58	0.44	0.50	0.45	0.69	0.73	0.84	0.70
45	0.62	0.95	0.76	0.80	0.45	0.48	0.52	0.55	0.60	0.53	0.47	0.47	0.74	0.77	0.93	0.77
44	0.56	0.68	0.66	0.69	0.49	0.48	0.49	0.54	0.64	0.55	0.49	0.41	0.71	0.81	0.87	0.72
43	0.71	0.77	0.89	0.80	0.49	0.51	0.54	0.61	0.57	0.52	0.47	0.53	0.74	0.69	0.66	0.56
42	0.58	0.77	0.75	0.77	0.55	0.54	0.52	0.65	0.79	0.57	0.54	0.56	0.69	0.80	0.69	0.69
41	0.64	0.70	0.70	0.79	0.59	0.58	0.57	0.54	0.65	0.58	0.59	0.56	0.91	0.82	0.75	0.69
40	0.72	0.68	0.69	0.86	0.59	0.56	0.56	0.55	0.73	0.60	0.56	0.61	0.79	0.77	0.78	0.74
39	0.75	0.79	0.79	0.88	0.54	0.56	0.62	0.72	0.69	0.60	0.60	0.63	0.79	0.85	0.82	0.71
38	0.74	0.85	0.83	0.95	0.52	0.51	0.47	0.56	0.71	0.63	0.58	0.61	0.87	0.84	0.86	0.80
37	0.74	0.97	0.89	1.02	0.55	0.44	0.42	0.58	0.68	0.64	0.57	0.55	1.02	0.84	0.93	0.79
36	0.79	1.03	0.97	1.11	0.57	0.40	0.32	0.43	0.75	0.54	0.53	0.53	1.19	0.98	1.00	0.95
35	0.91	1.17	0.98	1.18	0.27	0.26	0.27	0.40	0.39	0.32	0.32	0.33	1.23	1.04	1.11	0.77
34	0.67	1.15	1.15	1.18	0.23	0.22	0.23	0.29	0.35	0.28	0.27	0.24	1.28	1.08	1.27	0.77

DUPLICATE DATA

	OR						Y-Positions (ft)									WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
68					0.61				0.65				0.58			
58					0.77				0.84				0.90			
53					0.52				0.61				1.04			
48					0.45				0.68				0.99			
43					0.58				0.51				0.85			
38					0.52				0.59				0.80			

Table B-25 Unit 15C, High Flow (Modified VBS) Vyz (ft/s), Test 3

	OR						Y-Positions (ft)									WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.04	0.20	0.21	0.22	0.29	0.17	0.39	0.32	0.22	0.05	0.37	0.30	0.19	0.17	0.09	0.16
70	0.86	0.53	0.07	0.14	1.14	0.84	0.95	0.86	0.75	0.79	1.01	1.18	0.52	0.25	0.43	0.59
68	1.33	1.18	0.55	0.24	1.36	1.71	1.06	0.77	0.81	1.40	1.19	1.14	0.36	0.41	0.53	0.64
66	1.15	0.75	0.71	0.62	1.47	1.53	1.46	1.63	1.21	1.43	1.50	1.73	0.72	0.87	1.39	0.95
64	1.65	1.72	1.07	1.06	1.67	2.17	1.46	1.86	1.18	1.47	1.42	1.29	0.67	0.88	0.77	0.63
62	1.24	1.38	0.62	0.48	2.01	2.02	1.34	1.47	1.51	1.73	1.62	1.65	0.82	0.79	1.06	1.44
60	0.86	0.96	1.63	1.22	2.08	1.83	1.92	2.04	1.53	1.82	1.49	1.83	0.64	1.01	0.92	0.98
58	0.78	1.20	1.05	0.87	2.12	2.40	2.52	1.57	1.99	2.39	2.21	2.27	0.67	1.10	1.07	0.96
56	0.25	1.10	1.34	1.45	2.01	1.97	1.67	1.67	2.02	1.95	1.84	2.15	1.42	1.07	0.82	1.55
55	1.62	0.24	0.28	0.65	2.63	2.80	2.48	2.32	1.75	2.31	2.12	2.69	1.11	1.50	0.69	0.61
54	0.88	0.18	0.29	0.85	2.87	2.41	2.30	2.09	2.15	2.47	2.23	2.60	0.78	1.07	0.64	0.91
53	2.40	1.72	0.52	0.18	2.65	2.75	2.72	2.47	0.89	1.96	2.61	2.55	0.86	1.05	1.08	0.97
52	2.19	0.93	1.04	0.42	2.90	2.94	3.07	2.90	1.65	2.33	2.18	2.49	0.88	0.62	0.51	0.25
51	1.30	0.38	0.31	0.49	2.83	2.79	2.77	1.30	2.23	2.72	2.55	2.72	0.60	0.42	0.31	1.75
50	2.96	1.76	0.68	0.78	2.80	2.99	2.99	3.05	1.28	1.99	2.70	2.80	0.64	0.52	0.33	0.60
49	2.22	0.53	0.49	0.61	3.08	3.12	3.12	3.11	2.05	2.86	2.91	2.83	0.74	0.46	0.59	0.89
48	2.77	1.37	0.52	0.64	2.86	2.95	2.95	2.43	2.06	2.74	2.70	2.78	0.73	0.25	1.18	1.96
47	3.19	2.21	1.37	1.07	3.15	3.10	3.31	3.35	2.03	2.56	2.86	2.99	0.60	0.21	0.43	1.11
46	2.55	0.86	0.72	0.83	3.22	3.33	3.44	3.30	2.99	3.10	3.03	3.16	0.46	0.77	1.22	2.35
45	2.70	1.02	0.93	0.88	3.16	3.30	3.50	3.42	2.92	3.28	3.02	3.11	0.34	0.86	1.38	2.15
44	3.40	2.47	1.81	1.66	3.44	3.51	3.64	3.80	2.70	3.18	3.08	3.11	0.62	0.85	1.64	2.38
43	3.24	1.93	1.07	1.31	3.90	3.90	3.75	3.62	3.43	3.66	3.49	3.56	1.03	1.98	2.91	3.20
42	3.65	2.92	1.99	1.57	3.72	3.71	3.92	3.80	2.98	3.45	3.56	3.68	0.72	1.52	2.50	3.11
41	4.05	3.27	2.73	2.02	4.00	4.08	4.31	4.39	3.38	3.81	3.63	3.69	0.93	1.77	2.67	3.13
40	3.87	3.33	2.74	2.20	4.57	4.49	4.55	4.66	3.75	4.13	3.99	3.90	1.64	2.35	2.86	3.43
39	4.06	3.09	2.36	2.07	4.60	4.56	4.49	4.05	3.84	4.38	4.08	4.29	1.67	2.47	3.24	3.88
38	4.40	3.60	2.97	2.44	4.72	4.90	4.95	4.97	4.09	4.33	4.35	4.31	1.72	2.21	3.03	3.59
37	4.58	3.78	3.06	2.75	4.97	5.05	5.21	5.09	4.61	4.66	4.55	4.72	1.86	2.39	3.15	4.08
36	4.49	3.78	2.83	2.82	4.89	5.18	5.16	5.26	4.65	4.85	4.77	4.81	2.11	2.33	3.50	4.07
35	4.84	3.91	2.85	3.01	5.42	5.40	5.48	5.46	5.20	5.23	5.26	5.22	2.69	2.97	4.13	4.69
34	5.26	4.66	3.18	2.91	5.55	5.70	5.64	5.89	5.44	5.34	5.43	5.60	3.14	2.51	4.10	5.03

Table B-26 Unit 15C, High Flow (Modified VBS) V Total (ft/s), Test 3

	OR						Y-Positions (ft)									WA
EL (ft)	**18.57**	**17.40**	**16.24**	**15.07**	**13.90**	**12.74**	**11.57**	**10.40**	**9.24**	**8.07**	**6.90**	**5.74**	**4.57**	**3.40**	**2.24**	**1.07**
72	0.07	0.20	0.22	0.23	0.30	0.20	0.43	0.36	0.22	0.11	0.39	0.33	0.19	0.19	0.17	0.17
70	0.88	0.54	0.08	0.15	1.15	0.85	0.96	0.87	0.78	0.82	1.02	1.18	0.54	0.27	0.45	0.60
68	1.34	1.21	0.57	0.28	1.36	1.71	1.07	0.77	0.82	1.41	1.20	1.14	0.38	0.44	0.54	0.64
66	1.15	0.76	0.72	0.62	1.47	1.53	1.46	1.63	1.21	1.43	1.50	1.73	0.75	0.89	1.39	0.95
64	1.65	1.72	1.07	1.07	1.67	2.17	1.46	1.86	1.18	1.47	1.42	1.29	0.68	0.88	0.77	0.63
62	1.24	1.38	0.62	0.48	2.02	2.02	1.34	1.47	1.51	1.73	1.62	1.66	0.84	0.79	1.06	1.44
60	0.86	0.96	1.63	1.22	2.08	1.83	1.92	2.04	1.53	1.83	1.49	1.83	0.65	1.01	0.92	0.98
58	0.79	1.21	1.05	0.87	2.12	2.40	2.52	1.57	2.00	2.40	2.22	2.27	0.68	1.11	1.07	0.96
56	0.78	1.34	1.51	1.60	2.17	2.11	1.75	1.74	2.09	2.05	2.02	2.30	1.53	1.30	1.00	1.61
55	1.66	0.63	0.57	0.87	2.70	2.85	2.52	2.37	1.78	2.36	2.20	2.76	1.19	1.64	0.95	0.73
54	0.98	0.69	0.68	1.07	2.93	2.49	2.35	2.14	2.20	2.53	2.32	2.68	0.90	1.24	0.82	0.97
53	2.48	1.85	0.80	0.69	2.75	2.85	2.78	2.53	0.93	1.99	2.69	2.67	1.07	1.25	1.22	1.04
52	2.23	1.05	1.17	0.56	2.93	2.98	3.10	2.92	1.66	2.36	2.23	2.54	0.97	0.76	0.73	0.46
51	1.47	0.76	0.69	0.82	2.91	2.87	2.82	1.43	2.30	2.79	2.66	2.81	0.71	0.74	0.69	1.87
50	3.02	1.88	0.97	1.02	2.90	3.08	3.04	3.10	1.41	2.07	2.80	2.91	0.80	0.78	0.76	0.86
49	2.26	0.76	0.76	0.76	3.12	3.16	3.14	3.13	2.11	2.89	2.97	2.88	0.90	0.73	0.84	1.03
48	2.81	1.52	0.91	0.87	2.94	3.03	3.00	2.48	2.14	2.79	2.80	2.87	0.95	0.67	1.35	2.07
47	3.23	2.28	1.54	1.23	3.23	3.18	3.35	3.39	2.12	2.63	2.96	3.09	0.94	0.81	0.87	1.34
46	2.57	0.95	0.85	0.89	3.25	3.36	3.46	3.32	3.02	3.13	3.08	3.21	0.69	0.93	1.31	2.39
45	2.74	1.15	1.09	1.07	3.21	3.36	3.53	3.46	2.97	3.33	3.10	3.19	0.68	1.06	1.51	2.22
44	3.44	2.53	1.92	1.78	3.51	3.57	3.68	3.83	2.76	3.25	3.17	3.21	0.89	1.09	1.78	2.47
43	3.25	1.97	1.12	1.36	3.92	3.92	3.77	3.64	3.46	3.69	3.53	3.60	1.10	2.03	2.95	3.23
42	3.67	2.96	2.06	1.67	3.75	3.74	3.95	3.82	3.02	3.49	3.61	3.72	0.87	1.62	2.56	3.15
41	4.07	3.30	2.80	2.10	4.04	4.12	4.34	4.41	3.43	3.86	3.70	3.75	1.09	1.88	2.75	3.19
40	3.88	3.35	2.78	2.23	4.58	4.51	4.56	4.67	3.78	4.16	4.02	3.93	1.70	2.43	2.91	3.45
39	4.07	3.13	2.46	2.18	4.62	4.59	4.51	4.07	3.88	4.42	4.13	4.33	1.81	2.59	3.30	3.91
38	4.42	3.65	3.05	2.47	4.75	4.94	4.97	5.00	4.13	4.38	4.41	4.36	1.87	2.40	3.13	3.64
37	4.59	3.81	3.12	2.76	4.99	5.07	5.22	5.09	4.63	4.69	4.59	4.75	1.94	2.51	3.22	4.11
36	4.53	3.85	2.98	2.87	4.95	5.24	5.20	5.30	4.71	4.91	4.86	4.90	2.19	2.58	3.65	4.13
35	4.88	4.00	3.01	3.05	5.51	5.48	5.53	5.50	5.27	5.32	5.36	5.32	2.76	3.21	4.24	4.75
34	5.28	4.69	3.27	2.97	5.60	5.76	5.68	5.92	5.50	5.41	5.51	5.69	3.16	2.68	4.19	5.08

Table B-27   Unit 15C, High Flow (Modified VBS) Total RMS (ft/s), Test 3

	OR						Y-Positions (ft)									WA
EL (ft)	18.57	17.40	16.24	15.07	13.90	12.74	11.57	10.40	9.24	8.07	6.90	5.74	4.57	3.40	2.24	1.07
72	0.77	0.41	0.43	0.43	0.75	0.52	0.69	0.63	0.52	0.56	0.68	0.64	0.38	0.51	0.60	0.49
70	0.85	0.75	0.57	0.49	0.97	0.86	0.84	0.86	0.82	0.77	0.89	0.89	0.48	0.49	0.70	0.81
68	0.82	0.93	0.89	0.56	0.89	0.84	0.86	1.04	0.88	0.94	0.93	0.97	0.57	0.70	0.79	0.87
66	1.07	0.85	0.82	0.78	0.97	1.02	1.06	0.91	0.96	0.93	0.92	0.83	0.90	1.05	1.01	1.15
64	0.89	0.84	0.98	0.94	0.93	0.97	1.00	0.91	1.07	1.18	1.05	1.24	0.79	0.91	0.89	0.87
62	1.29	1.18	1.01	0.99	0.99	0.94	1.05	1.14	1.16	0.98	1.18	0.96	0.96	0.91	1.07	1.15
60	1.16	1.09	0.95	0.86	1.23	1.01	0.98	1.01	1.16	1.24	1.12	1.22	1.10	1.06	0.95	1.06
58	1.37	1.02	1.05	0.91	1.33	1.26	1.15	1.30	1.27	1.08	1.14	1.03	1.00	1.23	0.87	1.34
56	1.19	1.21	1.25	0.73	1.03	0.95	1.25	1.44	1.05	0.94	1.03	0.85	1.24	1.16	1.29	1.30
55	1.32	1.41	1.31	0.75	0.83	0.83	0.78	0.92	1.54	1.08	1.04	0.86	1.01	1.41	1.18	1.50
54	1.41	1.19	0.97	0.71	0.88	0.89	0.79	1.04	1.00	0.87	0.95	0.74	0.80	0.93	1.26	1.39
53	0.79	0.90	1.11	0.86	0.82	0.82	0.75	0.89	1.55	1.35	0.94	0.81	0.95	0.90	0.99	1.53
52	0.91	1.11	0.88	0.97	0.76	0.67	0.67	0.72	1.34	0.96	1.16	0.98	0.93	1.02	0.99	1.48
51	1.26	1.03	0.87	0.81	0.70	0.76	0.71	1.23	0.97	0.79	0.75	0.76	0.89	0.98	1.19	0.96
50	0.69	0.98	0.86	0.83	0.82	0.65	0.64	0.72	1.28	1.17	0.77	0.80	0.95	0.88	0.98	1.17
49	1.00	1.02	0.92	0.85	0.62	0.64	0.72	0.70	1.10	0.76	0.70	0.73	0.93	1.03	1.12	1.16
48	0.81	1.15	0.96	0.93	0.69	0.69	0.80	1.01	1.13	0.85	0.79	0.69	0.94	0.86	1.19	1.13
47	0.67	1.00	0.93	0.82	0.63	0.66	0.65	0.65	1.23	1.02	0.86	0.73	1.11	1.08	1.08	1.16
46	0.89	1.23	0.98	0.90	0.62	0.67	0.69	0.86	0.81	0.65	0.72	0.66	0.92	1.01	1.10	0.95
45	0.86	1.21	1.03	1.03	0.66	0.70	0.75	0.80	0.84	0.72	0.71	0.71	1.03	1.06	1.23	1.06
44	0.87	0.97	0.93	0.95	0.70	0.72	0.74	0.80	0.91	0.82	0.72	0.65	1.06	1.07	1.11	1.02
43	0.96	1.10	1.21	1.10	0.73	0.74	0.80	0.86	0.83	0.75	0.69	0.75	1.02	0.97	0.98	0.86
42	0.85	1.09	1.06	1.04	0.80	0.78	0.77	0.94	1.09	0.83	0.80	0.77	1.02	1.10	1.01	0.95
41	0.96	1.06	1.06	1.17	0.84	0.84	0.79	0.80	0.98	0.84	0.87	0.79	1.20	1.19	1.14	1.01
40	1.06	1.06	1.10	1.31	0.84	0.80	0.78	0.81	1.04	0.88	0.83	0.85	1.18	1.12	1.10	1.06
39	1.12	1.17	1.25	1.32	0.77	0.78	0.84	1.02	1.01	0.83	0.86	0.87	1.21	1.31	1.25	1.06
38	1.09	1.32	1.35	1.51	0.74	0.71	0.68	0.80	1.00	0.89	0.83	0.85	1.35	1.32	1.36	1.21
37	1.12	1.45	1.51	1.61	0.76	0.63	0.59	0.77	0.93	0.84	0.78	0.76	1.56	1.40	1.44	1.14
36	1.14	1.56	1.59	1.75	0.76	0.58	0.51	0.60	1.00	0.71	0.72	0.72	1.73	1.58	1.60	1.36
35	1.33	1.71	1.68	1.82	0.44	0.47	0.44	0.58	0.58	0.48	0.48	0.48	1.79	1.74	1.63	1.12
34	0.96	1.69	1.84	1.80	0.38	0.38	0.38	0.46	0.53	0.44	0.42	0.39	1.95	1.79	1.75	1.09

APPENDIX J

Operations Coordination

Agenda

Project: Bonneville Powerhouse II Fish Guidance Efficiency
Purpose: Scheduling discussion for implementation
Date: 10/5/15, 11:00 am
Location: Bonneville Dam Training Room

Conference Call Information
Phone Number: (877) 336-1831
Access Code: 4949747
Host Password: 8798
Security Code: 1111

Attendees:

☒ George Medina	☒ Ray Guajardo	☒ Roger James
☐ Laurie Ebner	☒ Jon Rerecich	☐ James Schroeder
☐ Mehdi Roshani	☐ Ben Hausmann	☒ Pat Noland
☐ Cyril Stokman	☒ Corina Popescu	☒ Brian Smith
☒ Scott Mac Kinnon	☒ Mike Adams	☒ Ricky Jackson

1. Introductions

2. Work to be done in FY16/17
   a. Flow Control Plates to be installed.
   b. Install flow control plates in slots A and B for each unit. Unit 15 is complete (from previous contract). Involves:
      i. Rebar locate in each slot.
      ii. Plate fabrication.
      iii. Plate installation. Plates were installed in 4 pieces in each slot (from previous contract.)
   c. Fabricate and Install VBS modifications.

3. Overview of results of the flow control plate and VBS install
   a. Inspection of plates in MU15 during construction? – Yes, Project staff confirmed availability to support this effort.
   b. From last year’s install (15-C-0004):
      i. Contractor mobilized: 2/23/15
      ii. Rebar survey: 2/23/15 (1 day total to install fall protection anchors, crane load test, and survey 1 slot.)
      iii. Contractor installed plate: 3/11/15.
      iv. Total: 13 working days.

4. Outage schedule
   a. Unit 16, 17 & 18 - during the T12 outage, 9/7 thru 11/23/2016.
   b. Unit 11, 12, 13 & 14 - during winter maintenance, 12/1/16 thru 2/28/17.
   c. Fish Ladder outage - All this work must be completed prior to November 2017.

5. VBS plates implementation
   a. Bonneville Structural Crew confirmed available to support installation of plates.
   b. Complete supply contract for fabrication of VBS plates. Delivery onsite by 9/7/2016.
   c. OD-B to install during scheduled outages.
   d. Last year, had some shortage of materials including:
      i. Sealant

ii. Plastic sleeves in between metal.
iii. Ricky Jackson to send material shortage to Roger.

6. Flow control plate implementation
    a. Possible use of pattern burner. Cost of burner = $167,000. Currently, OD-B is in the process of procuring. In Contracting.
    b. Contractor to conduct rebar survey, fabricate, and install flow control plates in remaining gatewells. Complete Construction contract for this effort.
    c. One unit will be accessible at a time (rebar survey, fabricate, install). About 13 work days from rebar survey to installation. This includes plate lead time.
    d. Work period would be during scheduled outages. Units 13 & 14 are more flexible outside of the above outage schedule.
    e. Contract completion date: May 2017.
    f. Work hours: Monday – Thursday, project hours.
    g. Require language that states coordination needed for gatewell access outside of the scheduled outage. (Coordination will be required in general.)
    h. Require construction staff to support crane inspection.

7. Other
    a. BPA coordination (Ray Guajardo)
    b. Units 18 and 11 are less flexible in terms of outage dates. List as priority.
    c. BCOES review for month of February.
    d. DDR to be complete by 20 November 2015.

Action Items:

1. **Ask Contracting about possibility of supply/install contract with use of Gov't supporting hole punching with burner. (Corina)**
2. **Follow up on who in Contracting is supporting current purchase of Burner and send to team. (Brian Smith)**
3. **Send reports of biological and hydraulic data reports. (Corina) (Completed)**
4. **Initiate and engage contracting for purchase of VBS plates. (Corina)**
5. **Ensure implementation of items from this discussion into contract. (Corina/PDT)**

Meeting Minutes

Project: Bonneville Powerhouse II Fish Guidance Efficiency
Purpose: Scheduling discussion for implementation
Date: 11/17/15, 10:00 am
Location: Bonneville Dam Training Room

Conference Call Information
Phone Number: (877) 336-1831
Access Code: 4949747
Host Password: 8798
Security Code: 1111

Attendees:

☐ George Medina	☐ Ray Guajardo	☒ Roger James
☐ Laurie Ebner	☒ Jon Rerecich	☐ James Schroeder
☐ Mehdi Roshani	☐ Ben Hausmann	☐ Pat Noland
☐ Cyril Stokman	☒ Corina Popescu	☒ Brian Smith
☐ Scott Mac Kinnon	☐ Mike Adams	☐ Ricky Jackson

1. Outage schedule updated
   a. Unit 16, 17 & 18 - during the T12 outage, 9/7 thru 11/23/2016.
   b. Unit 11, 12, 13 & 14 - during winter maintenance and can go into unit 11 earlier, 11/28 thru 2/28/17.
   c. Units 13-15: Flexibility if necessary during Feb/March. Contract completion will be 31 March 2017.
   d. Fish Ladder outage - All this work must be completed prior to November 2017.

2. Key dates/times:
   a. 11/28/16 – Switch PH priority for fish passage. PH1 becomes priority.
   b. 11/24/16 – Thanksgiving
   c. 11/10/16 – 11/11/16 – Operations will be out for Veterans Day.
   d. Typical work durations for operations support – Monday thru Thursday, 0700 – 1630.
   e. 10/31/16 – 11/3/16 - Operations will support ROV inspection during MU15 scheduled outage

3. Draft schedule for Units 11 – 14 (Subject to change, to ensure schedule feasibility only)
   a. Based on 3 work weeks to conduct rebar survey, fab plates, and install plates in 1 gatewell
   b. MU11: 11/28/16 – 12/16/16
   c. MU12: 12/9/16 – 1/6/17
   d. MU13: 1/9/17 – 1/27/17
   e. MU14: 1/30/17 – 2/17/17
   f. Give approximately 1.5 weeks of float for project staff to conduct misc maintenance on other items.

4. Other
   a. Per fish passage plan, need to operate screen bypass system. During the outages, STSs will need to come out and go somewhere. Operations confirmed that STSs can be placed in empty gatewell and have one set out in their yard. The movement of STSs would be alternated into empty gatewells.
   b. Ensure contract includes contractor access from the WA side.

Action Items:

1. **Check with Ray Guajardo that these outage dates are good. (Roger)**
2. **Check which fish ladder will be operating during proposed construction dates. (Roger) (Completed 11/18/15)**