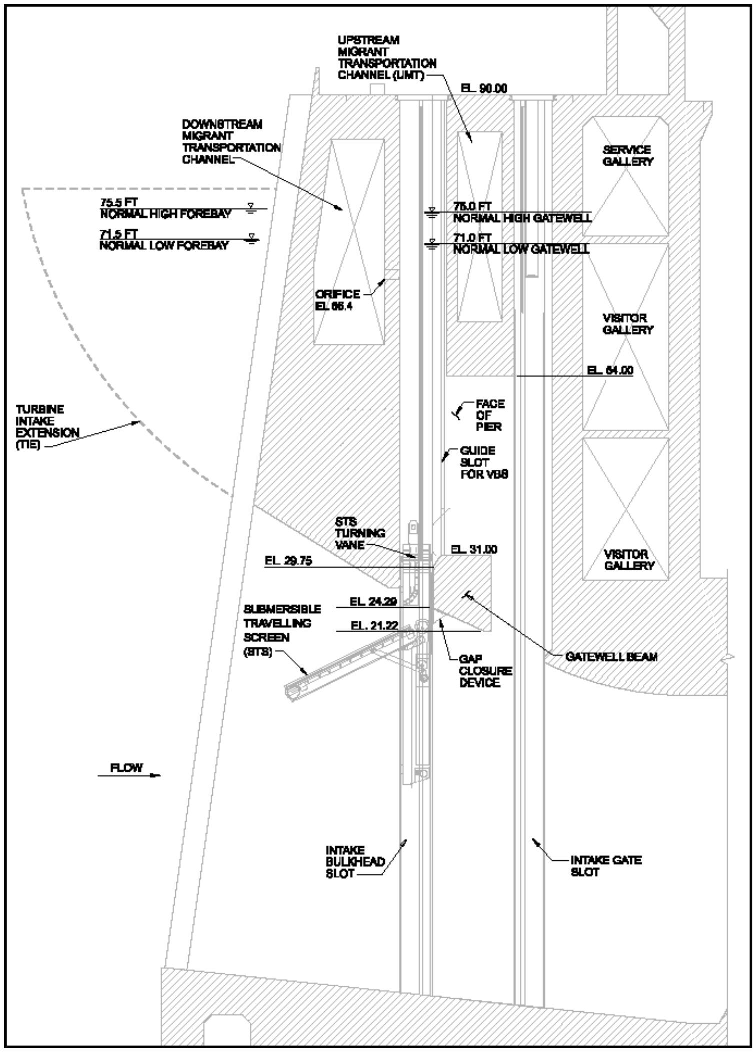
US Army Corps of Engineers®

Portland District

Alternatives Report

Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program Post Construction



November 2011

60% Review

EXECUTIVE SUMMARY

This report documents the investigation and development of alternatives to improve fish guidance efficiency (FGE) for subyearling and juvenile fish survival at the Bonneville second powerhouse. Alternatives to investigate were identified and chosen via collaborative discussions with regional state and federal agencies. The initial suggested premise was that high subyearling mortality in the second powerhouse gatewells was directly attributed to high flow conditions feeding into the gatewells. It was reasoned that if flow conditions were reduced or adjusted, subyearling mortality would similarly drop. Three types of operational and structural alternatives were recommended for investigation: flow control alternatives, operational alternatives, and a flow pattern change alternative. Flow control alternatives included:

- Construction of a device to control the flow up the gatewell. The device would be placed downstream of the vertical barrier screen (VBS). Similar devices have been used at the John Day and McNary dams.
- Modify the existing VBS perforated plates, which results in a reduction of gatewell flow.
- Modify the turning vane and gap closure device.

Operational alternatives included:

- Operating main turbine units at the lower to mid 1% peak operating range during juvenile fish release.
- Open the second downstream migrant system gatewell orifice to decrease fish retention time in the gatewell.
- Construction of a horizontal slot in place of the existing orifices or additional orifices to decrease fish retention time in the gatewell.

Once the investigation and study got underway, a third set of alternatives came to light. Using computational fluid dynamics modeling of the gatewell environment, it became apparent that flow conditions in the gatewell were far from streamline and optimum. In fact, the modeling exercise revealed notable levels of turbulence that increased relative to flow volume and pattern. The Product Development Team reasoned that perhaps there was a correlation between the levels of turbulence and subyearling mortality. It was further reasoned that the origin of the gatewell turbulence stemmed from hydraulic expansion into the VBS slots. Thus, the team introduced the flow pattern-change alternative. The pattern-change alternative will focus on means and methods for filling the VBS slots to reduce turbulence of flow up the gatewell.

A phased approach is being recommended for the development and implementation of the FGE improvements at the Bonneville second powerhouse. Phase I will represent development of a prototype design. A prototype will allow a check for errors, adjustments and modifications to a target velocity. Phase I may extend one to two seasons based on performance and cost. Phase II will follow and may extend from one to three seasons. The time duration will depend on complexity of design, costs, and operational requirements.

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PERTINENT PROJECT DATA

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

BiOp	Biological Opinion
BPA	Bonneville Power Administration
CFD	computational fluid dynamics
CRFM	Columbia River Fish Mitigation Program
DSM	downstream migrant system
ERC	emergency relief conduit
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
GCD	gap closure device
JBS	juvenile bypass system
LCC	life cycle costs
mm	millimeter(s)
MW	megawatt(s)
NOAA	National Oceanic and Atmospheric Administration
O&M	operation and maintenance
OPE	orifice passage efficiency
PDT	Product Development Team
PH1	Bonneville first powerhouse
PH2	Bonneville second powerhouse
PNNL	Pacific Northwest National Laboratory
PSMFC	Pacific States Marine Fisheries Commission
RM	river mile(s)
SCNFH	Spring Creek National Fish Hatchery
SIMPAS	New Spreadsheet Model for Fish Passage Survival Estimates
STS	submerged traveling screen
TEAM	Turbine Energy Analysis Model
TDG	total dissolved gas
TIE	turbine intake extension
UHMW	ultra-high molecular weight
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VBS	vertical barrier screen

1. INTRODUCTION

1.1. PURPOSE

The purpose of this report is to document the evaluation of alternatives developed and to provide a recommended alternative that will help eliminate or reduce subyearling fish mortality in the Bonneville second powerhouse (PH2) gatewell environment. Three types of operational and structural alternatives were considered: flow control alternatives, operational alternatives, and a flow pattern change alternative.

1.2. PROJECT OBJECTIVE

With the recent discovery of poor survival of Spring Creek National Fish Hatchery (SCNFH) subyearling fish, the biological objective and goal is to improve hydraulic conditions in the gatewell without compromising the existing fish guidance efficiency (FGE) capability.

1.3. BACKGROUND

In 1999, regional fisheries agencies agreed to pursue a phased approach and focus on improving fish guidance and survival at Bonneville PH2 by maximizing flow up the turbine intake gatewells, a guideline that has been used on similar programs to improve FGE. These modifications, completed in 2008, included an increase in vertical barrier screen (VBS) flow area, installation of turning vanes to increase flow up the gatewell, addition of a gap closure device (GCD) to eliminate fish loss at submerged traveling screen (STS), and installation of interchangeable VBS to allow for screen removal and cleaning without outages or intrusive gatewell dipping. Results from biological studies showed an increase in FGE by 21% for yearling Chinook salmon (*Oncorhynchus tshawytscha)* and 31% for subyearling Chinook. Test fish conditions showed no problems with descaling and gatewell retention time (including fry) in a newly modified unit.

During the 2008 juvenile fish passage season, the SCNFH released hatchery subyearlings in early spring 2008 over a 3-month period (March, April, May). Biological testing conducted by National Oceanic and Atmospheric Administration (NOAA) suggests that SCNFH subyearlings are incurring high mortality and de-scaling when the newly modified units are being operated at the upper 1% range. Evidence suggests a relationship may exist between the operation of the powerhouse units (lower, mid, and upper 1%) and survival of the SCNFH subyearlings. A logical assumption would be that operating turbine units at the upper 1% puts more water up the gatewell, thus producing poor hydraulic conditions within the gatewell.

Biologic test data was evaluated by USACE and preliminary alternatives were suggested that could potentially regulate and throttle hydraulic conditions in the gatewell. This data and preliminarily proposed alternatives were presented to the region and discussed. The region agreed with the initial assessment and approved the study to investigate and evaluate flow control and operational alternatives: flow control devices to regulate the volume and direction of flow and operational alternatives that use turbine operation as a means to throttle and control flow volume going into the gatewell.

1.4. PROJECT SCOPE

The project scope comprises a comprehensive investigation of the gatewell environment to better understand the hydraulic dynamics as they impact subyearling mortality, and assessment and evaluation of alternatives that improve passage and survival of subyearlings through the gatewell environment.

Development of a computational fluid dynamics (CFD) model will facilitate the investigation of the gatewell hydraulic environment and will be used to assess and evaluate alternatives. The alternatives evaluated in this study and report include flow control device alternatives, operational alternatives, and a flow pattern change alternative. The alternatives were collaboratively developed and approved by the regional federal and state agencies (see Appendix A, Gatewell Fish Condition Test Results Meeting on October 3, 2008). Flow control alternatives included:

- Construction of a device to control the flow up the gatewell. The device would be placed downstream of the VBS. Similar devices have been used at the John Day and McNary dams.
- Modify the existing VBS perforated plates, which results in a reduction of gatewell flow.
- Modify the turning vane and GCD.

Operational alternatives included:

- Operating main turbine units at the lower to mid 1% peak operating range during juvenile fish release.
- Open the second downstream migrant system gatewell orifice to decrease fish retention time in the gatewell.
- Construction of a horizontal slot in place of the existing orifices or additional orifices to decrease fish retention time in the gatewell.

The flow pattern change alternative was developed after modeling data suggested that relative to hydraulic volume and flow, eddy currents were developed at the top of the gatewell that could potentially have negative effects on subyearlings. It is hypothesized that filling the VBS gate slots will change the flow patterns in the gatewell, reduce turbulent flow, and improve subyearling passage and survival.

1.5. PROJECT 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 (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 PH2. Construction started in 1974 and was completed in 1982.

1.6. PROJECT COORDINATION

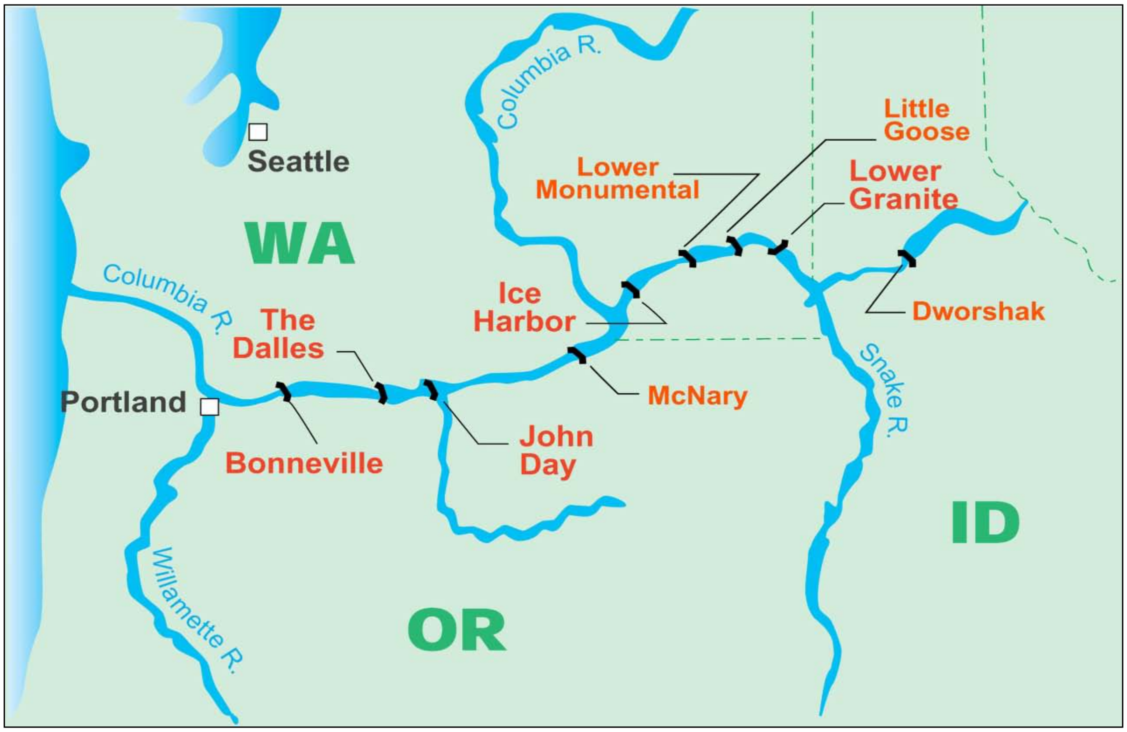
This report was coordinated with the regional fisheries agencies and tribes through the Fish Facility Design Review Work Group (FFDRWG).

2. EXISTING PROJECT FEATURES

2.1. PROJECT LOCATION AND FEATURES

The Bonneville Project is located on the Columbia River approximately 42 miles east of Portland, Oregon at river mile (RM) 146. (Figure 2-1). The second powerhouse (PH2) is located between Cascades Island and the river's north shore in the State of Washington (Figure 2-2). Bonneville's PH2 consists of eight 66 megawatt (MW) Kaplan turbine main units and two 13.1 MW turbine units that supply water to the adult fish passage facilities.

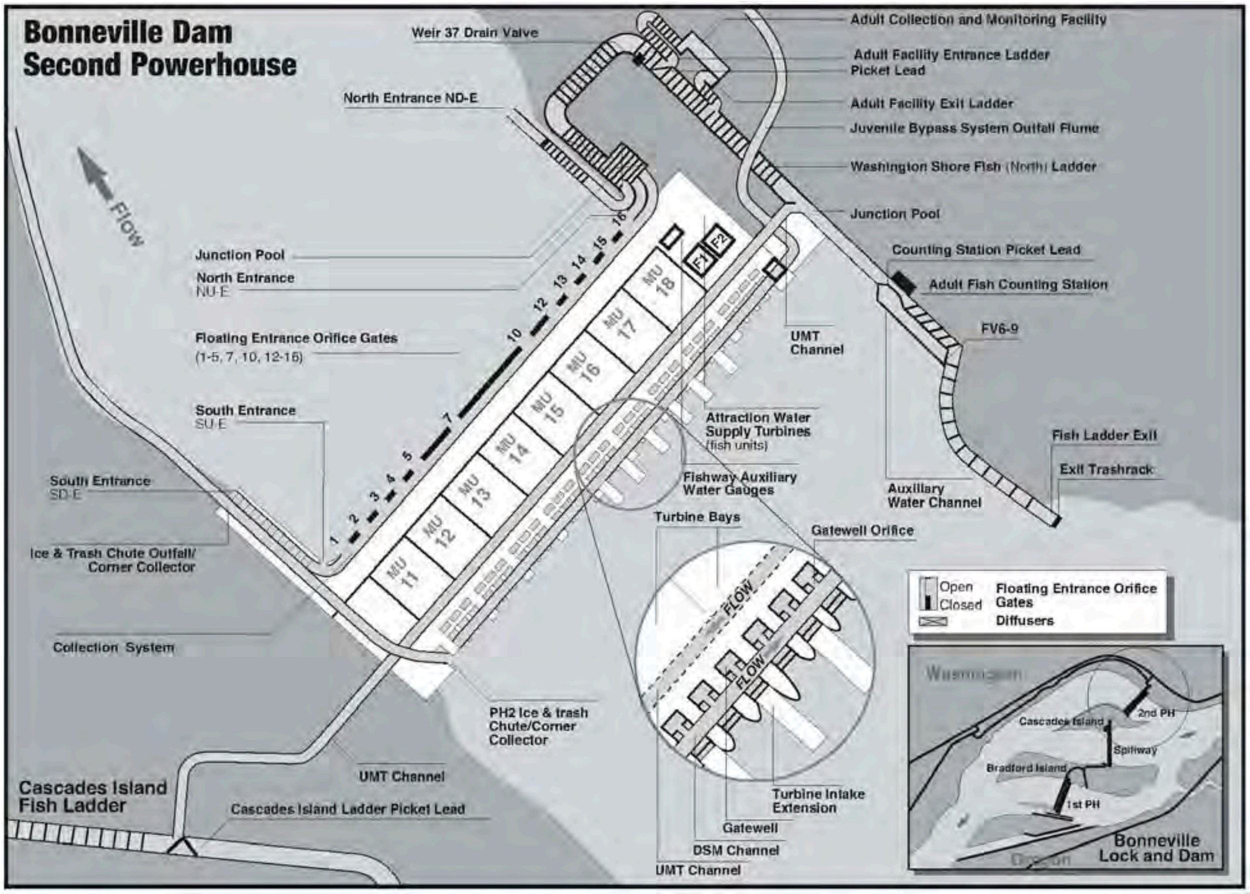
Figure 2-1. Bonneville Project Location



2.2. GATEWELL CONDITION ISSUES POST-FGE IMPROVEMENTS

In 2006 and 2007, SCNFH subyearling Chinook passing the PH2 juvenile bypass system (JBS) showed increased mortalities and descaling. Physical inspections of the bypass facilities rendered little evidence to indicate that a mechanical system was causing this increased poor condition of fish. Regional fish managers along with USACE believed that gatewell modifications that focused more water up the gatewell area (thus improving FGE) was the cause for the increase numbers of damaged fish. In 2008, increased mortality of SCNFH fish were again noticed during the first releases in early March. Regional fish managers asked USACE to reduce MW loads (reduced flow up the gatewell slot) on the FGE modified units to the lower end of their 1% operating ranges during both of the spring releases to see if this would reduce mortalities. The reduced load operations were seen to lessen the amount of descaling and mortalities in the daily samples.

Figure 2-2. Bonneville Dam Second Powerhouse



2.2.1. Target Species

The focus of the proposed improvements has been mainly on hatchery reared subyearling Chinook salmon from Spring Creek National Fish Hatchery (SCNFH) and run-of-river spring migrants such as yearling Chinook and steelhead (*Oncorhynchus mykiss).* Previous research has lead the USACE to focus on subyearling migrants because of the higher mortality documented by smolt monitoring at the Bonneville PH2 juvenile monitoring facility. Researchers and the USACE Product Development Team (PDT) believe that the more naïve the fish is to the river system, the higher probability that these fish will be impacted by the current PH2 gatewell environment at turbine loads at the upper end of their 1% operating range (15-17+MW).

2.2.2. Gatewell Orifice Passage Efficiency Testing 2008-2009

In response to the suspected gatewell issues that were indentified in 2006-2007, the USACE developed research through the Columbia River Fish Mitigation Program (CRFM) with the assistance of NOAA to test the orifice passage efficiency (OPE) effects of varying turbine loads along with opening additional gatewell orifices. Test fish were collected, PIT-tagged, and released via a release hose into the top of the turbine intake. Fish then volitionally entered the intake and were directed up the gatewell via the submerged traveling screens. Test fish entered the gatewell environment and then exited the gatewell via orifices. Fish were then detected at PIT-tag readers the downstream smolt monitoring facility and timing and passage data collected and compared for varying loads and numbers of orifices open. Research from the 2008 study indicated that SCNFH subyearling test fish were being impacted significantly at turbine operations above 13,900 cubic feet per second (ft^3/s) and were highly impacted at the upper operating ranges (Table 2-1).

Table 2-1. 2008 Recapture Rates and Mortality of Juvenile SCNFH Fish Released in Bypass System Collection Channel or Gatewell 12A

Juvenile SCNFH Chinook salmon released in the bypass system collection channel or gatewell 12A on March 3 and 4, 2008, at Bonneville PH2. Average fork length of fin-clipped test fish was 63 millimeters (mm).

Parameter	Collection Channel	Gatewell 12A Lower 1% 11,600-11,800 ft^3/s	Gatewell 12A Middle 1% 13,900-14,000 ft^3/s	Gatewell 12A Upper 1% 16,800-16,900 ft^3/s
Test blocks (no.)	2	2	2	2
Test duration (h)	4	4	4	4
Fish released (no.)	1,801	799	854	799
Recaptured (%)	98.3	82.7	81.3	66.6
Mortality (%)	0.3	1.9	14.2	32.3
T-test results for comparisons of recapture and mortality percentages: $P<0.01$ for all comparisons except for recapture of lower and middle 1% gatewell releases where $P=0.44$.				

In addition, run-of-river yearling Chinook were also evaluated in late spring and early summer and the same outcome was noted for their test releases. Under higher turbine operations starting at 13,900 ft^3/s, researchers noted that mortality rose sharply as turbine operations increased (Table 2-2).

Table 2-2. 2009 Data for Yearling Fish from Bonneville Smolt Monitoring Program Released into PH2 Turbine 14A Intake

Recapture rates, observed mortality, passage timing, and descaling data for yearling Chinook salmon from Bonneville Smolt Monitoring Program, PIT-tagged and released into the PH2 Turbine 14A intake in 2009. Descaling is expressed as the percentage of recaptured fish that were descaled ≥20% on at least one side.

Parameter	Collection Channel	Intake 14A Middle 1%, 14,700 ft^3/s	Intake 14A Upper 1%, 17,800 ft^3/s	P[a]
Test blocks (no.)	8	8	8	
Test duration (h)	24	24	24	
Fish released (no.)	389	3,229	3,153	
Recaptured (%)	97.7	98.4	97.4	0.05
Mortality (%)	0.3	0.5	4.4	<0.01
Timing (median, h)	0.6	1.7	2.7	<0.01
Descaling (%)	0.3	1.0	11.5	<0.01
[a] ANOVA. P values are for load comparisons.				

Once again in 2009, the USACE conducted research at Bonneville's PH2. Fish were released in the same fashion as in the 2008 study and once again the trends were identified as the same (Table 2-3). At higher turbine operations (17,800 ft^3/s), test fish showed greater mortality rates than fish that were released at a turbine mid-range operation at 14,700 ft^3/s (Table 2-3).

Table 2-3. 2009 Data for Subyearling Fish from Bonneville Smolt Monitoring Program Released into PH2 Turbine 14A Intake, One Open Gatewell Orifice

Recapture rates, observed mortality, passage timing, and descaling data for subyearling Chinook salmon obtained from the Bonneville Smolt Monitoring Program, PIT-tagged, and released into the Bonneville PH2 Turbine 14A intake in 2009. Descaling is expressed as the percentage of recaptured fish descaled ≥20% on at least one side. Tests conducted with one open gatewell orifice.

Parameter	Collection Channel	Intake 14A Middle 1%, 14,700 ft^3/s	Intake 14A Upper 1%, 17,800 ft^3/s	P[a]
Test blocks (no.)	8	8	5	
Test duration (h)	24	24	24	
Fish released (no.)	400	3,167	2,058	
Recaptured (%)	96.7	97.2	96.5	0.13
Mortality (%)	0.3	2.6	4.5	0.01
Timing (median, h)	0.6	2.6	6.1	0.03
Descaling (%)	0.3	0.5	2.6	<0.01

[a] ANOVA. P values are for load comparisons, one open gatewell orifice.

The USACE also undertook a 2009 gatewell testing protocol that opened an additional gatewell orifice during specific releases to see if this additional open orifice had any impact on OPE or mortality. Test results indicated that OPE increased from a median time of 6.1 hours with one orifice open to 2.9 hours with two open (Table 2-4). Also descaling dropped from 2.6% to 1.2%. Indications are that providing and additional open orifice had a significant impact on reducing the gatewell retention time as well as descaling associated with these higher OPE times.

Table 2-4. 2009 Data for Subyearling Fish from Bonneville Smolt Monitoring Program Released in PH2 Turbine 14A Intake, One or Two Open Gatewell Orifices

Recapture rates, observed mortality, passage timing, and descaling data for subyearling Chinook salmon obtained from the Bonneville Smolt Monitoring Program, PIT-tagged, and released into the Bonneville PH2 Turbine 14A intake in 2009. Descaling is expressed as the percentage of recaptured fish descaled ≥20% on at least one side. Tests conducted with one or two open gatewell orifices.

Parameter	Collection Channel	Intake 14A Upper 1%, One Orifice	Intake 14A Upper 1%, Two Orifices	P[a]
Test blocks (no.)	8	5	4	
Test duration (h)	24	24	24	
Fish released (no.)	400	2,058	1,641	
Recaptured (%)	96.7	96.5	95.9	0.08
Mortality (%)	0.3	4.5	2.4	0.04
Timing (median, h)	0.6	6.1	2.9	0.06
Descaling (%)	0.3	2.6	1.2	0.10

[a] ANOVA. P values are for load comparisons of one or two open gatewell orifices.

2.3. HYDRAULIC FEATURES

A computational fluid dynamics (CFD) model of the existing features of the Bonneville PH2 was developed to investigate the existing hydraulic conditions and support alternative development for FGE improvement as described in the report, *Bonneville Second Powerhouse Fish Guidance Efficiency Computational Fluid Dynamics Modeling* dated September 2011 (Appendix C). The following sections summarize the model selection, development, and application to existing conditions. Additional detailed information is provided in Appendix C.

2.3.1. Hydraulic Model Selection

An existing forebay CFD model was developed by PNNL (2009) using the Star CD software. The forebay CFD model was applied to investigate the relative impacts of forebay configuration on hydraulic conditions approaching and in the intake gatewells. However, this model does not include the current details of improvements to the gatewell geometry, and an updated model was needed to support the alternatives analysis for this study.

During earlier phases of this study, the thought was to build a physical sectional model to investigate FGE improvement alternatives. After reviewing the physical and numerical models developed to date, it was determined that the gatewell hydraulics could be impacted by the physical configuration of the PH2 forebay. Therefore, using a CFD model to analyze FGE alternatives would allow for investigation of alternatives in a sectional CFD model with secondary confirmation of selected alternatives over a range of forebay configurations and operations in the full forebay CFD model. A summary of the advantages and limitations of the selected CFD model are summarized below.

Advantages

- The CFD model can be linked to the forebay model to investigate the impacts of forebay configuration and powerhouse operations on gatewell hydraulics. This capability will be important in confirming the performance of FGE improvement alternatives over a range of forebay configurations and powerhouse operations.
- Relevant geometric features in the powerhouse unit that affect gatewell hydraulics can be readily included in the CFD model. These features are described in Section 2.3.2, CFD Model Development.
- Model results can be queried at any location in the model domain for velocity, pressure, turbulence. Particles seeded into the model results can provide quantifiable information on gatewell residence time and flow patterns.
- Alternatives (operational or functional changes) can be included in the CFD model relatively efficiently.
- CFD models can be maintained on a computer system in backup files. If the model is compatible with future software versions, it can be used for many years with little maintenance.

Limitations

- Significant changes to VBS velocities that require rebalancing of VBS screen porosities will result in the need for a physical model. The CFD model cannot be used to directly identify updated porosity plate configurations for screen balancing as configured. The CFD model represents the VBS as a porous baffle and uses two porosity parameters to represent the pressure change across the screen panels rather than direct porosity.

- The sectional CFD model calibration is adequate to investigate the relative change in gatewell flow between existing conditions and FGE alternatives. If the CFD model is to be used to develop detailed gatewell flow rating curves, additional prototype velocity data is recommended to minimize uncertainty in the rating curves.
- The CFD model is a steady-state representation of hydraulic conditions and the influence of transient conditions needs to be considered when interpreting the results.
- Real time viewing of results in a CFD model is limited to available computing resources.

2.3.2. CFD Model Development

An updated sectional CFD model of a PH2 turbine unit was developed to support alternative development and analysis for FGE improvements. The updated sectional CFD model was developed of a single PH2 turbine unit to include the following geometric features in sufficient detail to capture the hydraulic influence of the features:

- TIEs;
- Trash rack including main horizontal and vertical support members;
- STS including structural members and a with a zero-thickness porous baffle representing the STS screen for each bay;
- Gap closure device;
- Turning vane;
- Gate slots including overall width and depth of gate slots;
- Modified gatewell beam;
- VBS including structural members and zero-thickness porous baffles representing the nine VBS screen panels in each bay;
- Fish orifice; and
- Emergency gate including horizontal structural members on upstream face of gate.

The updated sectional CFD model was developed by creating a solid geometry of the turbine unit (Figures 2-3 and 2-4) in SolidWorks, a 3-dimensional rendering software. The sectional CFD model domain extends from the upstream boundary approximately 100 feet upstream of the trashrack to just upstream of the ends of the piers separating the A, B, and C bays prior to the scroll case.

The computational grid for the model domain was developed using the grid generation program in the Star CCM+ modeling software and consists of approximately 2.4 million polyhedral (or many-sided) cells, as shown in Figures 2-5 and 2-6. The sectional CFD model is of sufficient detail for analyzing relative impacts of FGE improvement alternatives on gatewell hydraulic conditions and flow. The sectional CFD model calibration and validation using VBS normal and sweeping velocity data from previous physical modeling and field studies is described in detail in Appendix C. A grid sensitivity analysis was conducted as described in Appendix C to ensure that the baseline model results are not dependent on the grid resolution.

Figure 2-3. Isometric View of Turbine Unit

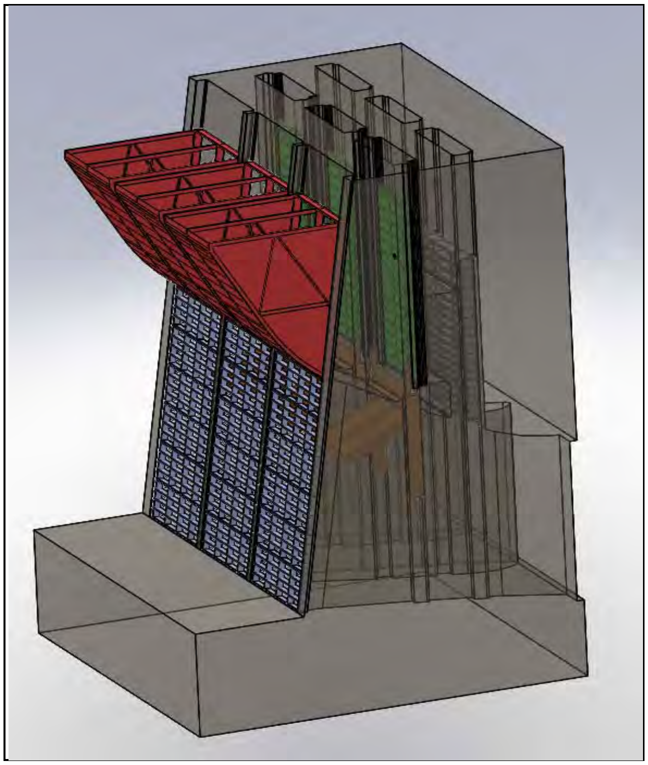


Figure 2-4. Section View of Turbine Unit

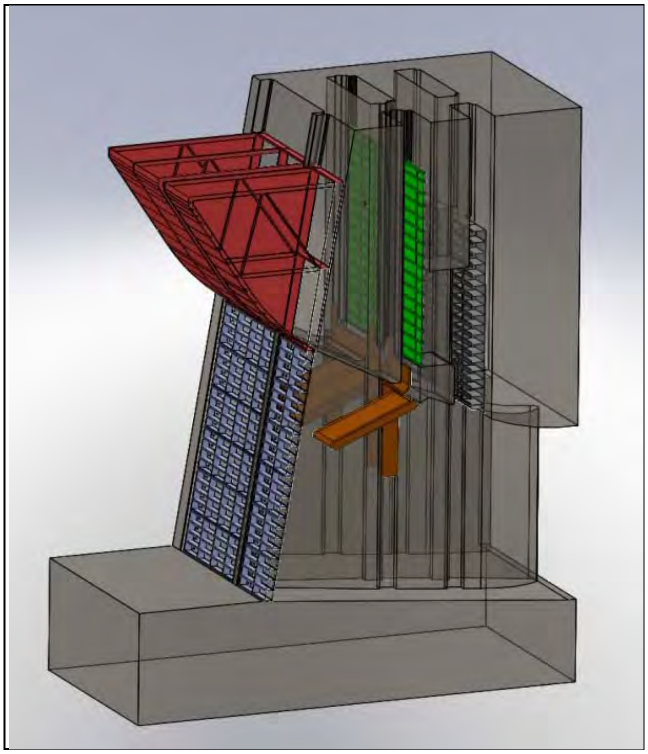


Figure 2-5. CFD Model Grid – Section View

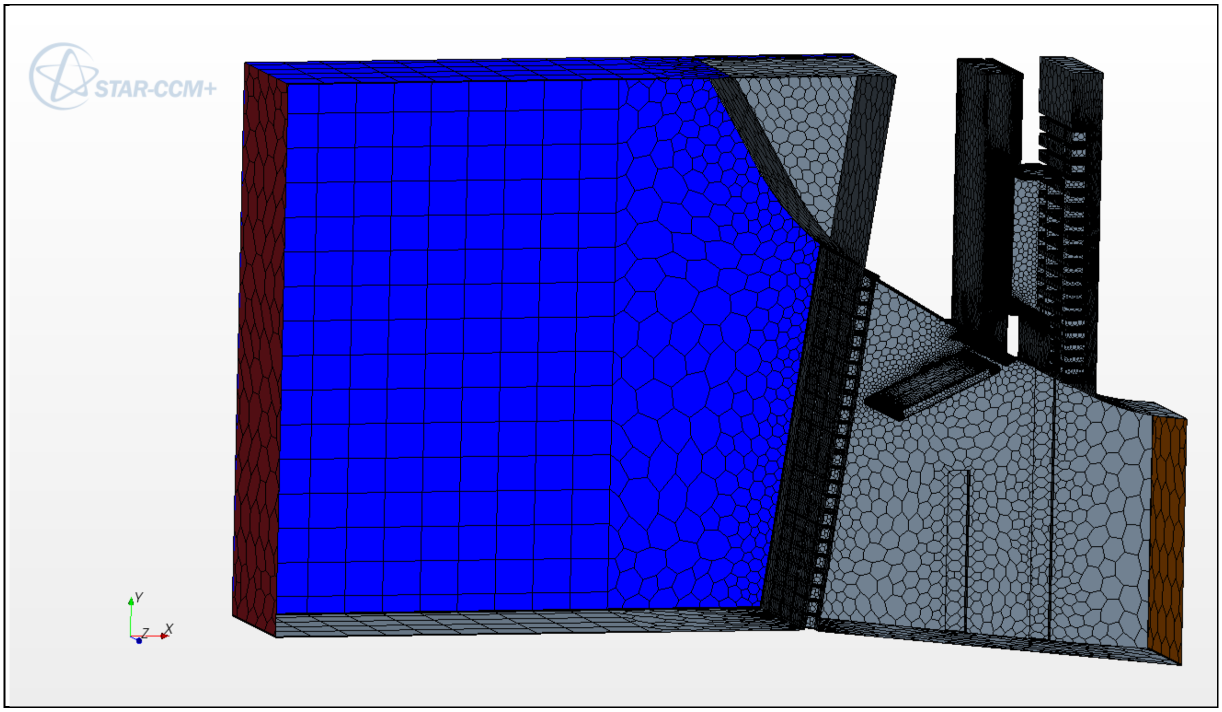
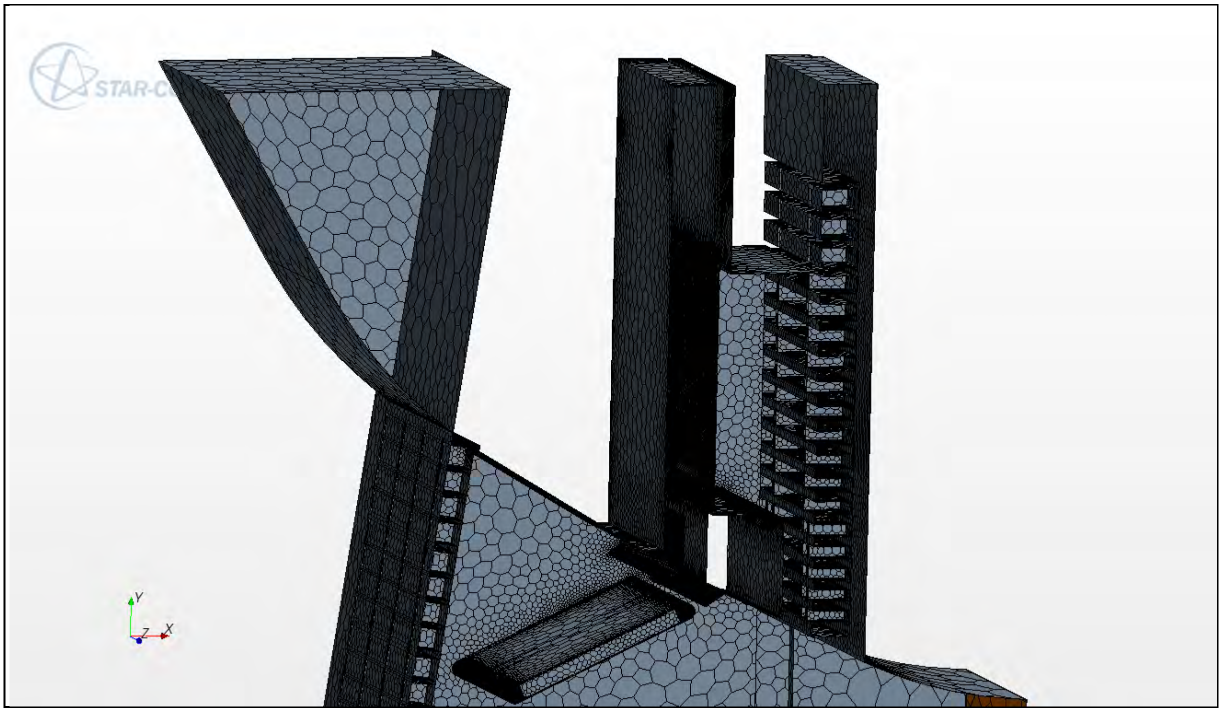


Figure 2-6. CFD Model Grid – Zoomed View



2.3.1. CFD Modeling for Baseline Conditions

Following calibration and validation, the CFD Model was run for unit flow conditions representing the low, medium, and high 1% efficiency unit operation as shown in Table 2-5. The runs were conducted with existing gatewell geometry to establish a hydraulic baseline for evaluation of alternatives.

Table 2-5. Baseline Run Outflow Conditions

Unit Flow (ft^3/s)	**Bay A Flow (ft^3/s)**	**Bay B Flow (ft^3/s)**	**Bay C Flow (ft^3/s)**
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 ft^3/s unit flow provided a baseline for hydraulic conditions assumed to represent unfavorable flow conditions for fish passage at the high 1% efficiency range, while the 15,000 ft^3/s unit flow provided a baseline for assumed minimally favorable hydraulic conditions for fish passage at the medium 1% efficiency range. The 12,000 ft^3/s provided a low flow baseline for assumed favorable hydraulic conditions for fish passage at the low 1% efficiency range. Additional details of the sectional CFD model boundary conditions are provided in Appendix C.

2.3.1.1. Low Unit Flow Conditions – 12,000 ft^3/s

With the existing gatewell geometry in place and a unit flow of 12,000 ft^3/s, the CFD model-predicted Bay A VBS flows are summarized in Table 2-10. Bay A has the highest flow of the three bays in each unit, and therefore the highest VBS and gatewell flow. The VBS flow for each bay was calculated from the CFD model results by converting the mass flux (kg/s) across the VBS baffle to flow (ft^3/s). The VBS flows for the baseline CFD model runs in Table 2-6 shows increasing VBS flow with increasing unit flow, as expected.

Table 2-6. Baseline Run VBS Flow Summary

Unit Flow (ft^3/s)	**Bay A VBS Flow (ft^3/s)**
12,000	219
15,000	272
18,000	328

The CFD model results for the low unit flow condition are summarized in Figure 2-7 through Figure 2-12 show flow passing through the trashrack, with a portion of the flow passing up the STS to the gatewell, and the remainder passing into the intake. Flow up the STS accelerates to up to 5-6 ft/s, with a portion of the flow returning to the intake between the GCD and the STS (Figure 2-7 through Figure 2-9). The gatewell flow passes along the turning vane, with some separation downstream of the upstream intake roof and the turning vane, as shown by the low velocity areas in Figure 2-8. As the flow passes above the turning vane, the gate slot width increases abruptly above the turning vane and STS side supports and the flow can not immediately expand to fill the volume. An opposing recirculation of flow upward and then downward on either side of each bay results as the flow expands downstream of the abrupt gate slot transition (Figure 2-10). The CFD model results show that the recirculation is more intense on one side (generally the left side, looking upstream), likely as a result of slightly asymmetrical approach conditions generated by the different bay flows for Bays A, B, and C.

Figure 2-7. Baseline, Unit Q = 12,000 ft^3/s, Bay A Centerline Velocities

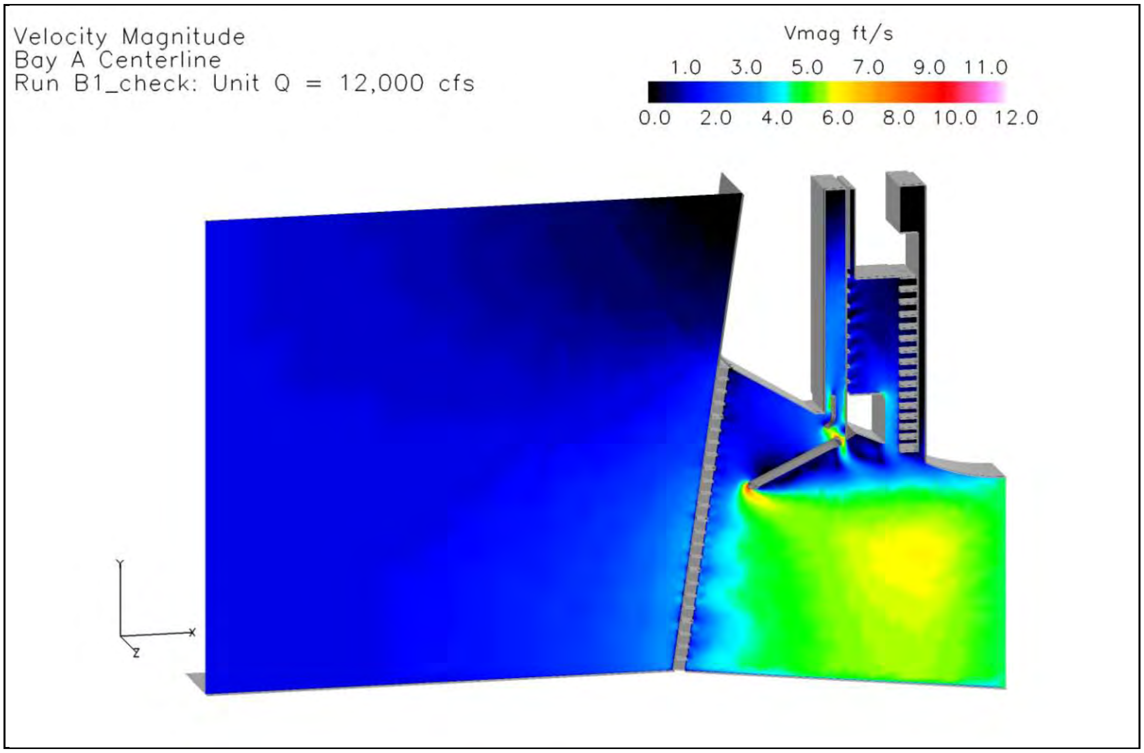


Figure 2-8. Baseline, Unit Q = 12,000 ft^3/s, Bay A Centerline Velocities (zoomed)

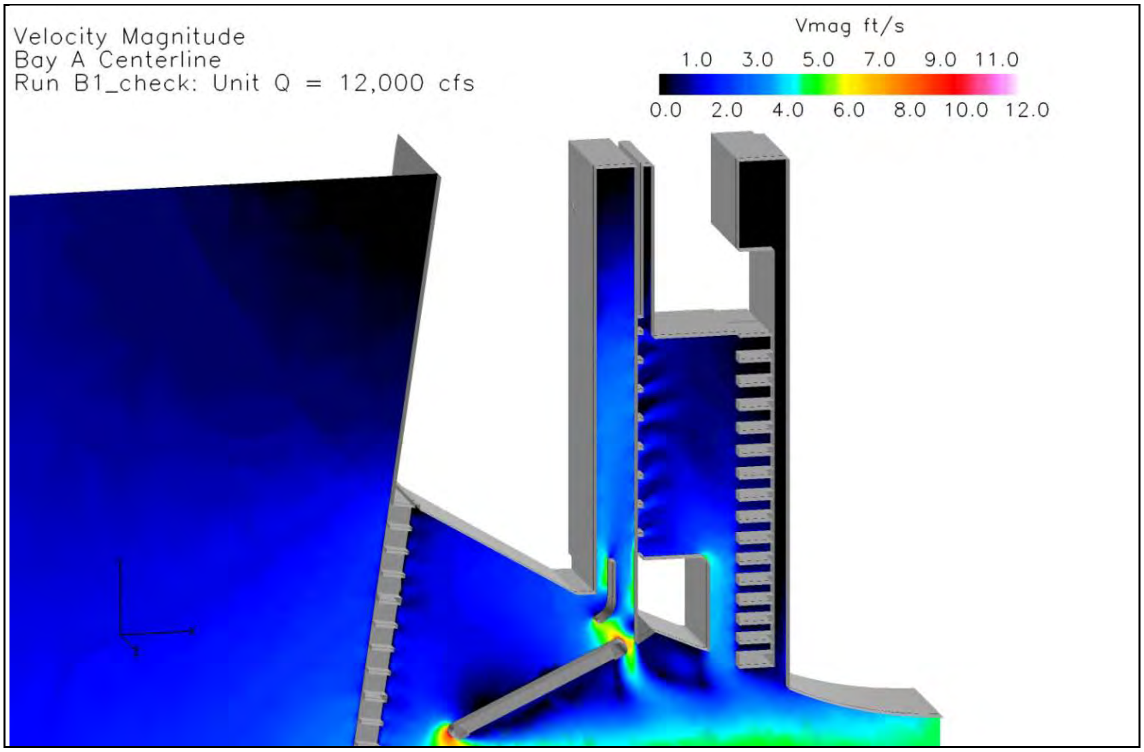


Figure 2-9. Baseline, Unit Q = 12,000 ft^3/s, Bay A Fish Orifice Centerline Velocities

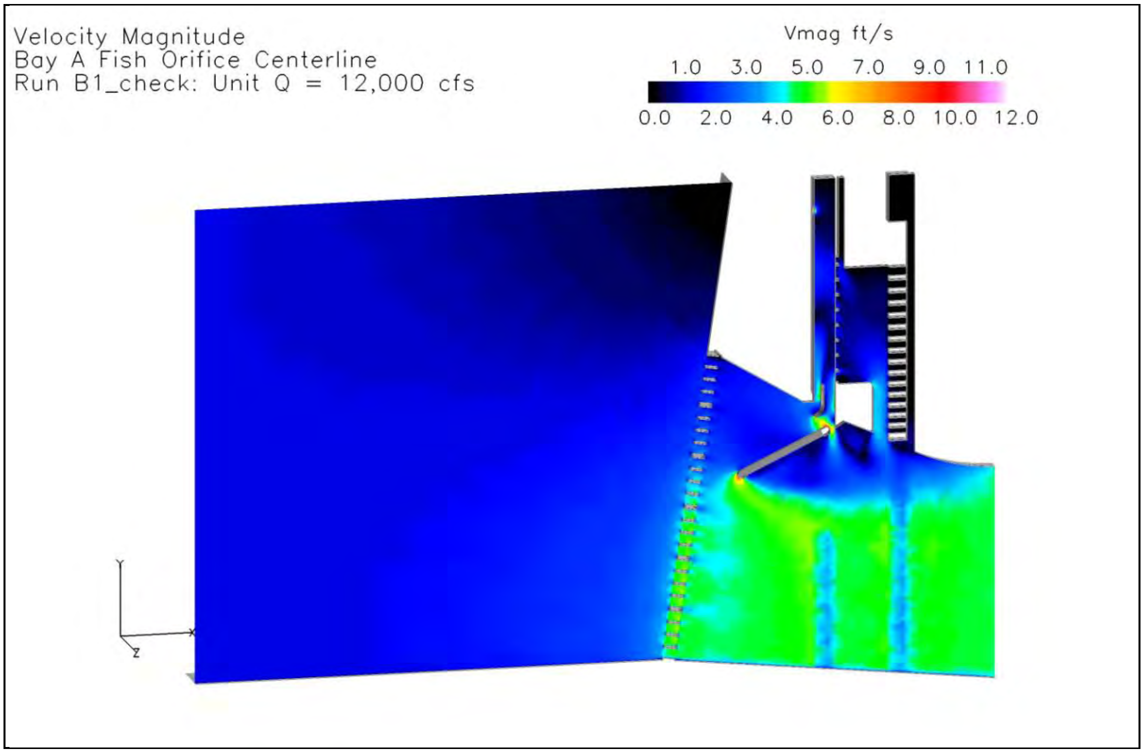


Figure 2-10. Baseline, Unit Q = 12,000 ft^3/s, VBS Normal Velocities and Flow Patterns

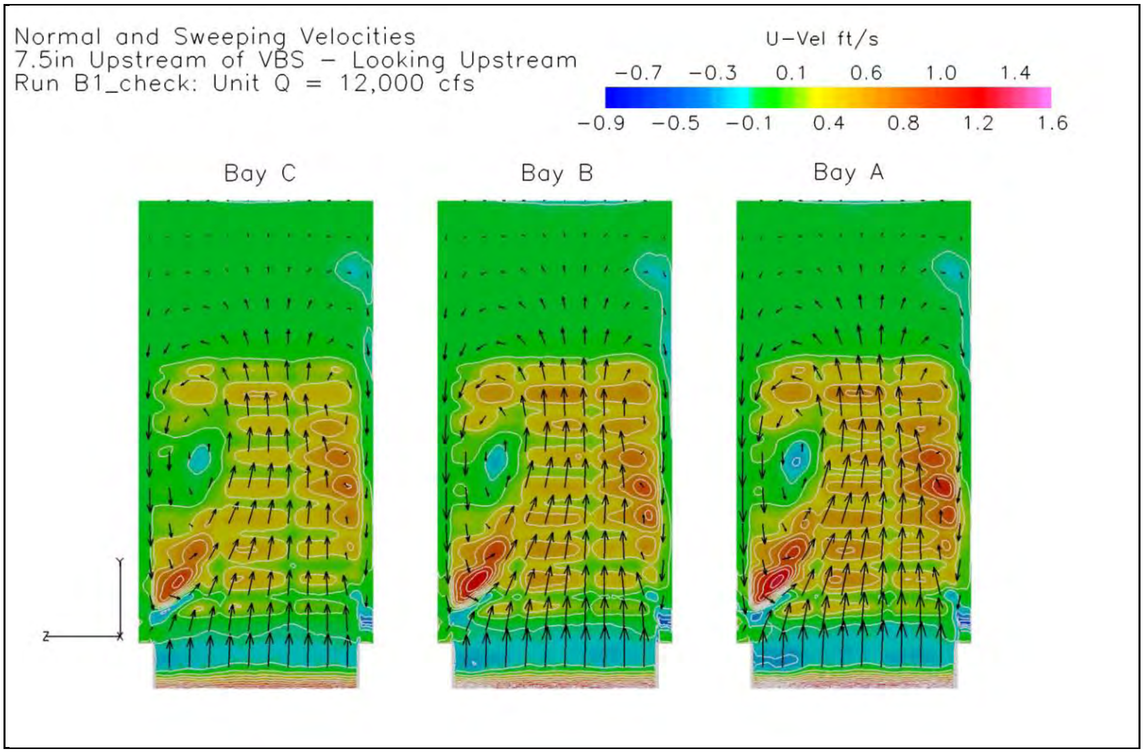


Figure 2-11. Baseline, Unit Q = 12,000 ft^3/s, Turbulent Kinetic Energy Isosurface (0.25 ft^2/s^2)

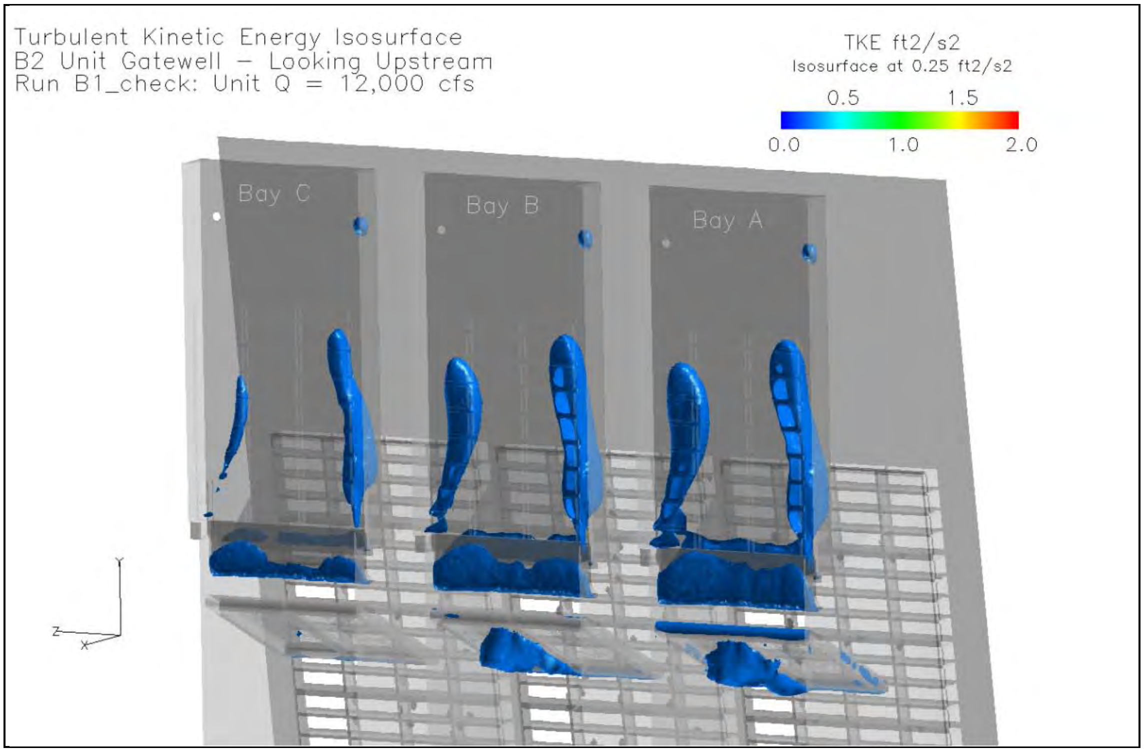
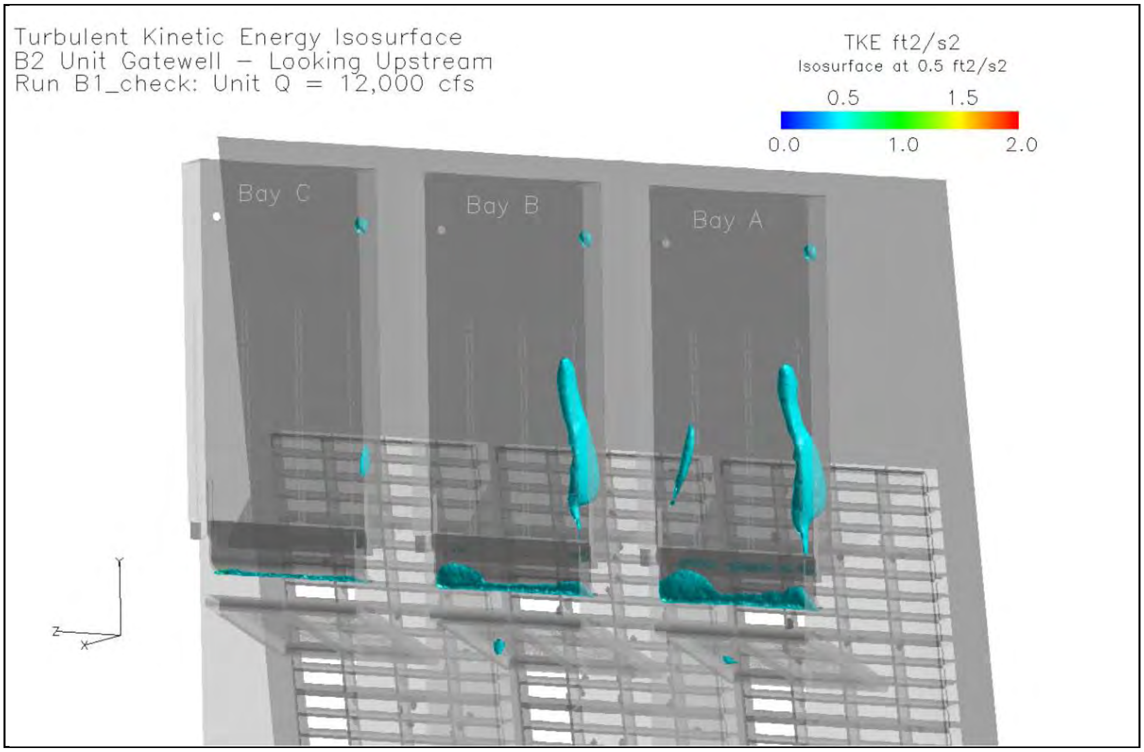


Figure 2-12. Baseline, Unit Q = 12,000 ft^3/s, Turbulent Kinetic Energy Isosurface (0.5 ft^2/s^2)



Normal velocities just upstream of the VBS are generally less than the 1ft/s criteria, with some velocities approaching 1 ft/s in the recirculation areas on either side of the VBS (Figure 2-10). Sweeping velocities up the VBS are generally positive (positive upward), but negative in the recirculation on either side of the VBS. The general level of turbulence in the gatewell is characterized by the turbulent kinetic energy isosurface plots in Figures 2-11 and 2-12. In the isosurface plots, regions with a specified level of turbulent kinetic energy (0.25 ft^2/s^2 and 0.5 ft^2/s^2 in Figures 2-11 and 2-12, respectively) are plotted as a 3-dimensional surface to indicate location. For low flow conditions, regions of turbulence are present downstream of the intake roof, on the downstream face of the turning vane, and extending along either side of the VBS downstream of the gate slot expansion above the STS side supports.

2.3.1.2. Medium Unit Flow Conditions – 15,000 ft^3/s

The CFD model results for the medium unit flow condition are summarized in Figures 2-13 through 2-16, with additional plots provided in Appendix C. The VBS flow for the medium unit flow condition (15,000 ft^3/s) is approximately 270 ft^3/s (Table 2-6). The gatewell flow patterns for the 15,000 ft^3/s unit flow condition are generally similar to those for the low unit flow condition, but the velocity magnitudes and intensity of the turbulence in the gatewell are increased. As flow passes up the STS to the GCD and turning vane, velocities reach 7-8 ft/s (Figure 2-14) as compared to 5-6 ft/s for the low unit flow condition. The plots of VBS normal velocity show increased intensity of the recirculation regions downstream of the gate slot expansion, and VBS normal velocities as high as 1.3-1.5 ft/s in the “hot spots” inside the left and right recirculation zones in Bay A (Figure 2-15). The positive sweeping velocities are concentrated to the center portion of the VBS, with negative sweeping velocities on the outer left and right portions of the VBS (Figure 2-15). Turbulent kinetic energy increased in the gatewell with increased unit flow as shown by the larger volume isosurfaces in Figure 2-16.

Figure 2-13. Baseline, Unit Q = 15,000 ft^3/s, Bay A Centerline Velocities

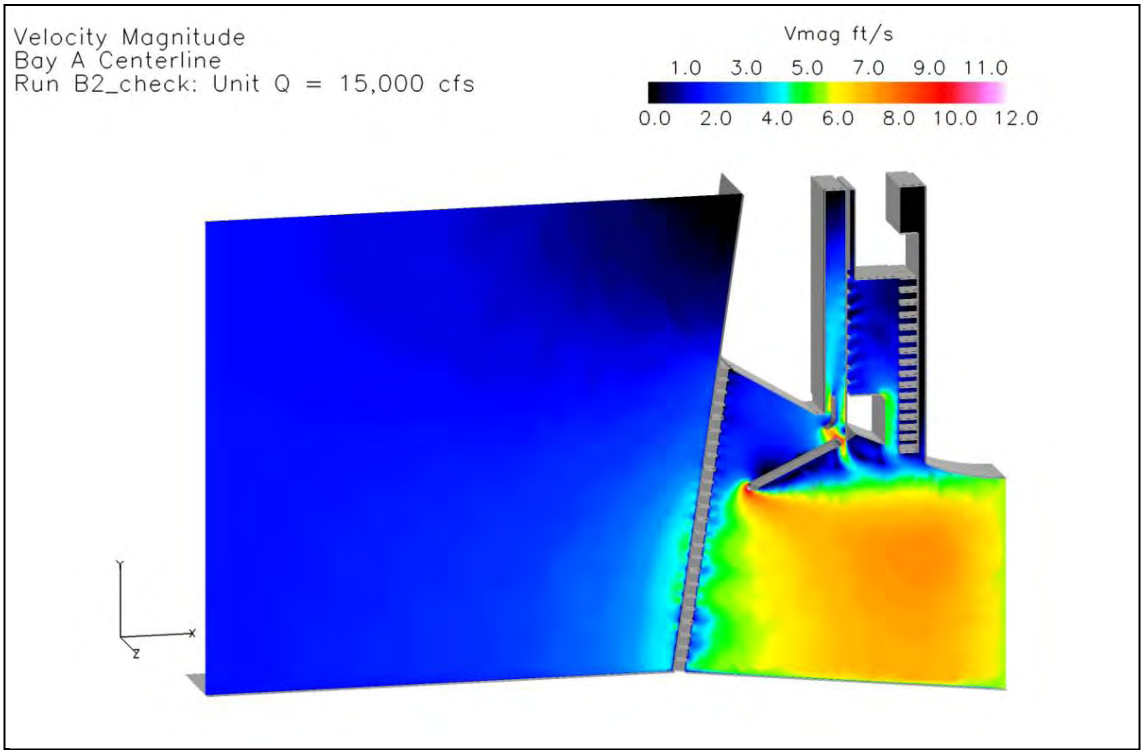


Figure 2-14. Baseline, Unit Q = 15,000 ft^3/s, Bay A Centerline Velocities (zoomed)

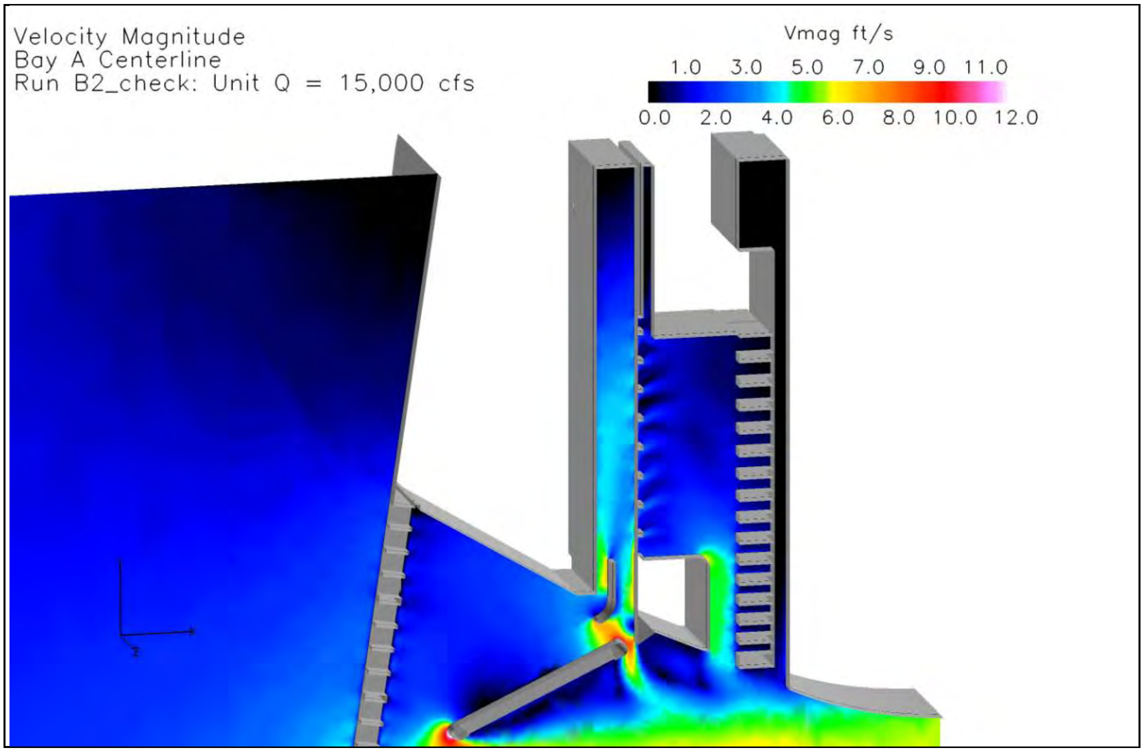


Figure 2-15. Baseline, Unit Q = 15,000 ft^3/s, VBS Normal Velocities and Flow Patterns

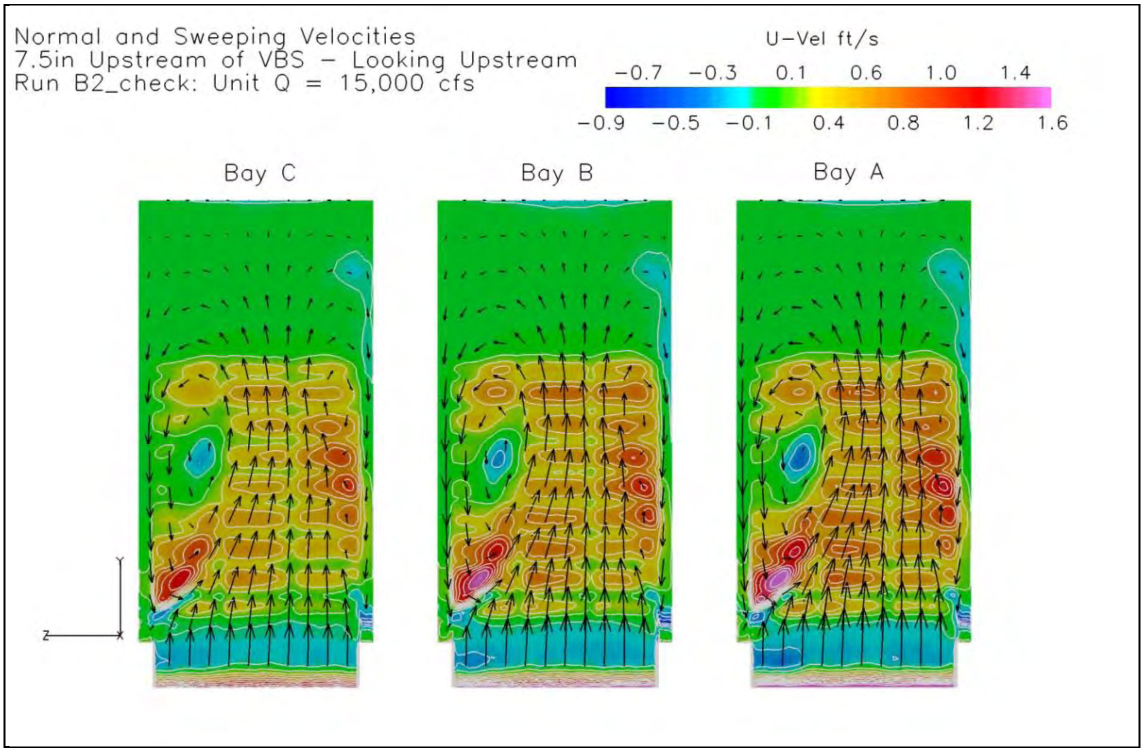
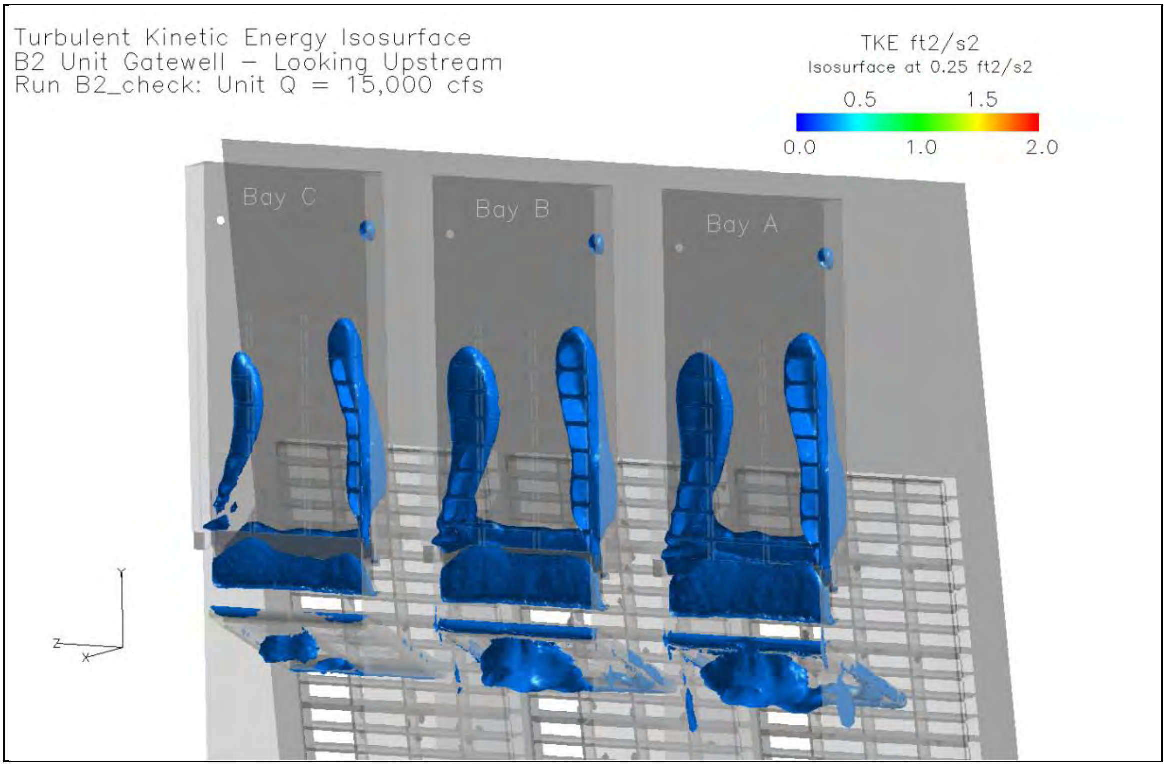


Figure 2-16. Baseline, Unit Q = 15,000 ft^3/s, Turbulent Kinetic Energy Isosurface (0.25 ft^2/s^2)



2.3.1.3. High Unit Flow Conditions – 18,000 ft^3/s

The CFD model results for the high unit flow condition are summarized in Figure 2-17 through Figure 2-20. The VBS flow for the high unit flow condition (18,000 ft^3/s) is approximately 330 ft^3/s (see Table 2-6). The gatewell flow patterns for the 18,000 ft^3/s unit flow condition are generally similar to those for the low and medium unit flow condition, but the velocity magnitudes and intensity of the turbulence in the gatewell are further increased. As flow passes up the STS to the GCD and turning vane, velocities reach 9-10 ft/s (Figure 2-18) as compared to 5-6 ft/s for the low unit flow condition. The plots of VBS normal velocity show increased intensity of the recirculation regions downstream of the gate slot expansion, and VBS normal velocities as high as 1.4-1.6 ft/s in the “hot spots” inside the left and right recirculation zones in Bay A (Figure 2-19). The positive sweeping velocities are concentrated to the center portion of the VBS, with negative sweeping velocities on the outer left and right portions of the VBS (Figure 2-19). Turbulent kinetic energy increased in the gatewell with increased unit flow as shown by the larger volume isosurfaces in Figure 2-20.

It is unknown whether there is a specific threshold for tolerance of turbulence by juveniles, but the increased turbulent kinetic energy coincident with higher recirculation and normal velocities on the VBS may be a significant factor in exhaustion and subsequent injury for juveniles. Therefore, alternatives for improving FGE will consider streamlining the sweeping velocities along the VBS, reducing turbulence in the gatewell, minimizing gatewell residence time, and reducing and evenly distributing normal velocities on the VBS.

Figure 2-17. Baseline, Unit Q = 18,000 ft³/s, Bay A Centerline Velocities

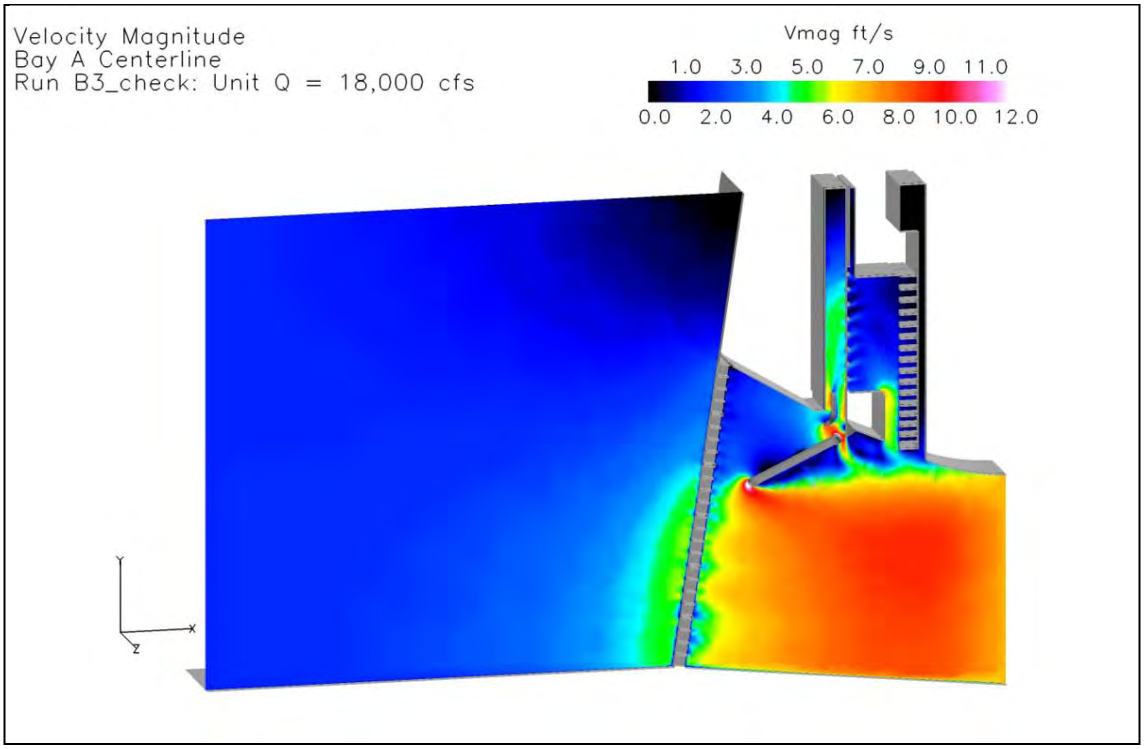


Figure 2-18. Baseline, Unit Q = 18,000 ft³/s, Bay A Centerline Velocities (zoomed)

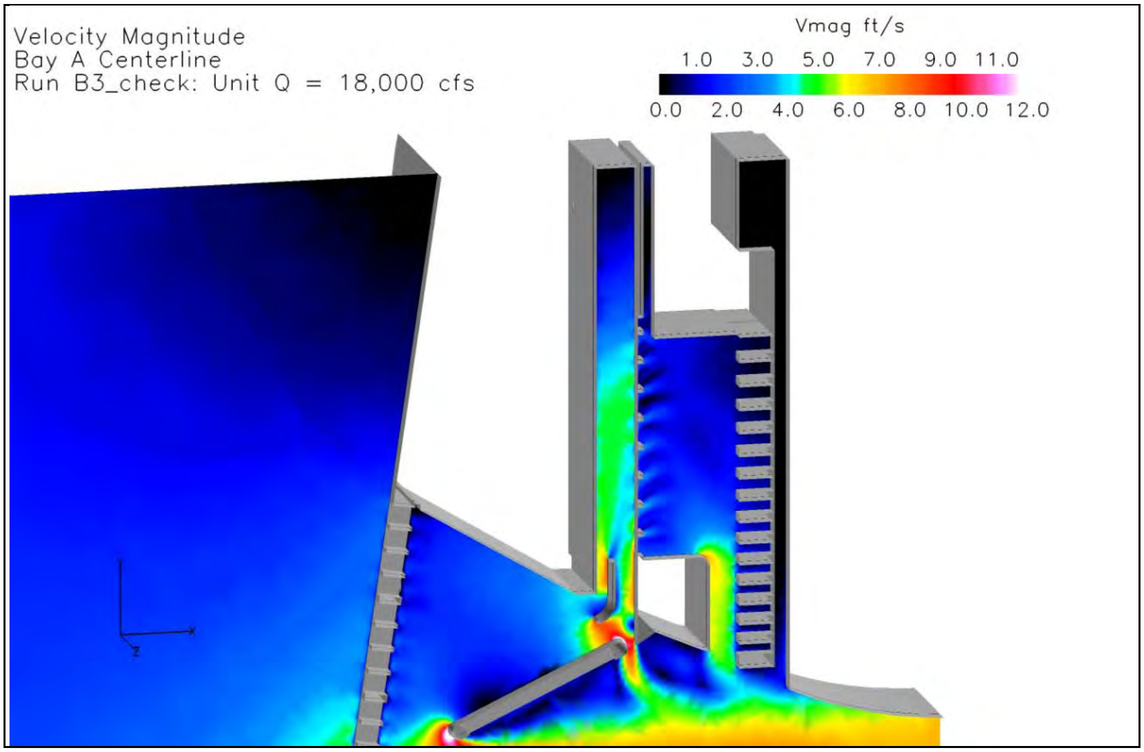


Figure 2-19. Baseline, Unit Q = 18,000 ft^3/s, VBS Normal Velocities and Flow Patterns

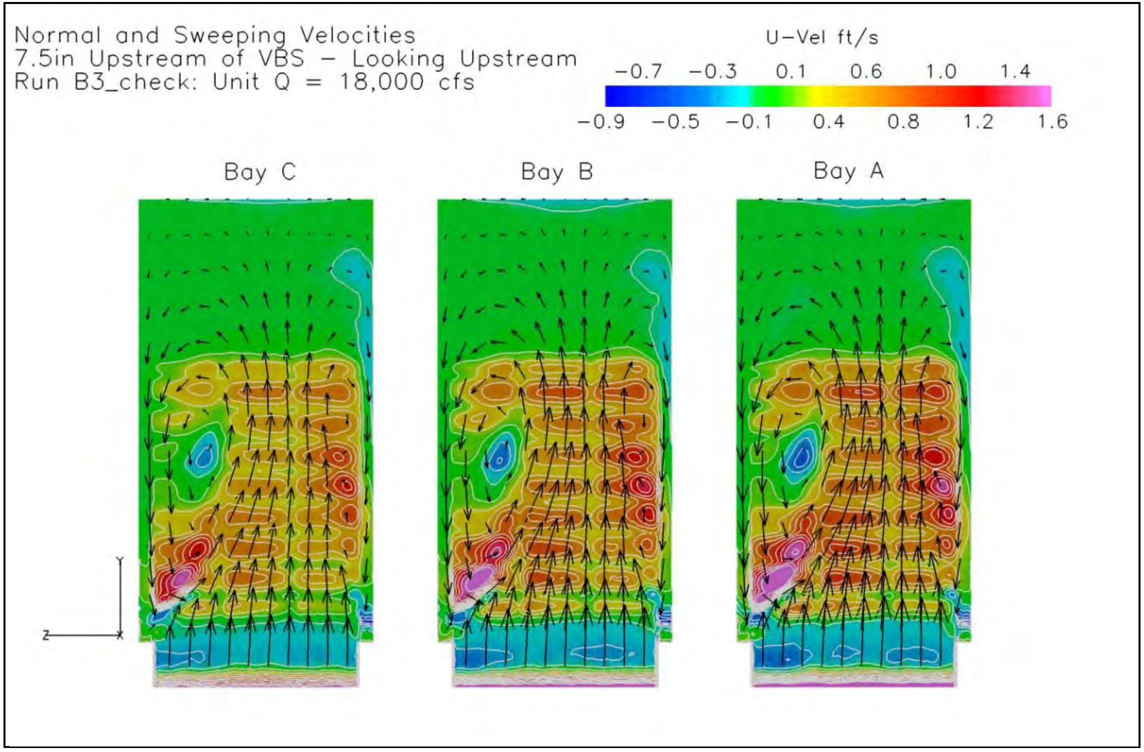
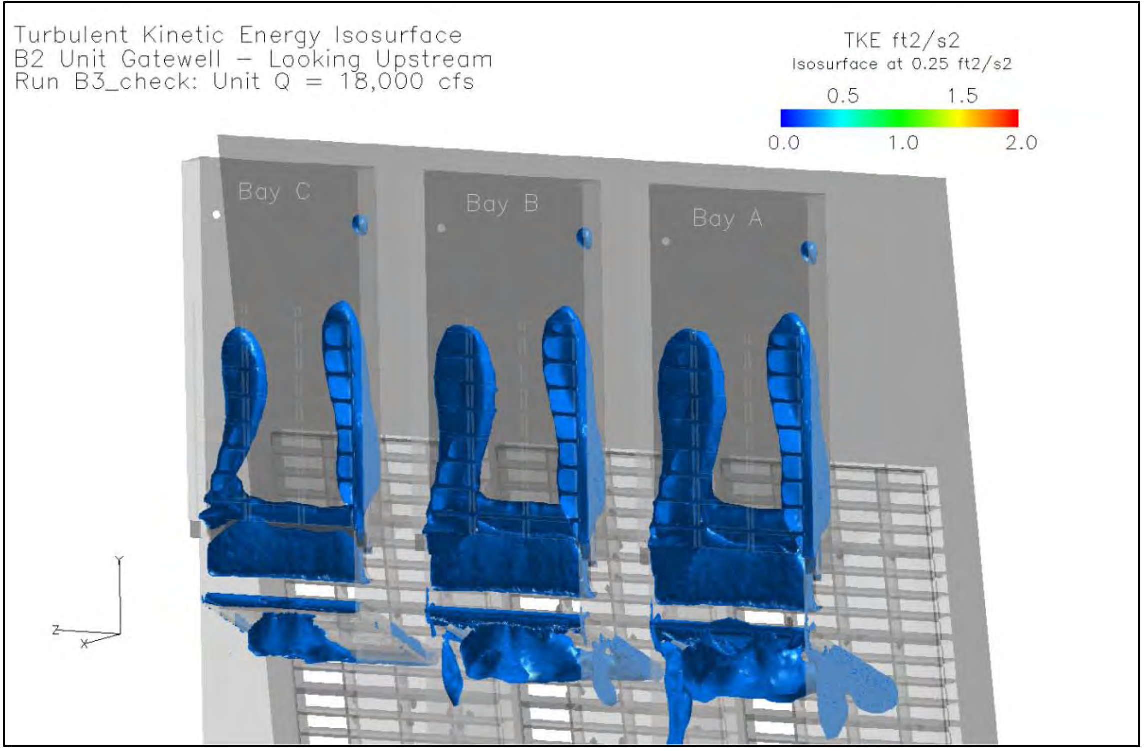


Figure 2-20. Baseline, Unit Q = 18,000 ft^3/s, Turbulent Kinetic Energy Isosurface (0.25 ft^2/s^2)



3. CONSIDERATIONS AND ASSUMPTIONS

3.1. GENERAL

Issues have been identified that have to be considered during investigation of alternatives.

1. The vertical inlet opening that may require flow control is 25 feet, 3 inches tall by 21 feet, 3 inches wide. This represents an area of 539 square feet in which a flow control device may have to be installed and operate.
2. The horizontal inlet opening that may require flow control is 21 feet, 3 inches long by 7 feet, 8 inches wide. This represents an area of 163 square feet in which a flow control device may have to be installed and operated. This does not include any adjustment for the configuration of the downstream bulkhead guides.
3. The horizontal or normal downstream flow varies from 0.2 feet per second (ft/s) at the top intake elevation of 54.00 feet to a maximum of 0.6 ft/s at the bottom sill elevation 31.00 feet.
4. The vertical flow velocity varies from 1.5 ft/s at the top intake elevation to a maximum of 6.3 ft/s at the bottom sill elevation (note that this is based on the 1:12 physical model results as a source).
5. The VBS frames must be pulled and cleaned of heavy drift wood debris throughout the year. During peak months of October thru December, they are pulled and cleaned two times a week.

3.2. BIOLOGICAL

The BiOp for Bonneville Dam juvenile survival goal is 93% subyearling Chinook and 96% yearling Chinook and steelhead. Second powerhouse FGE improvements made to the turbine environment originally showed benefits with a 0.1% to 0.3% overall FGE improvement for yearling Chinook, subyearling Chinook, and steelhead during regular spill (April-August). A 0.7% FGE improvement was found after spill termination on September 1.

With the recent discovery of poor survival of SCNFH fish, the biological goal is to improve conditions for these fish while maintaining (or improving) the FGE and survival improvements of the original Bonneville PH2 FGE design. These are the current assumptions that are the driving factor for this report.

3.2.1. Assumptions

Current assumptions as to what is happening within the gatewell post-FGE improvements are as follows:

- After FGE modifications, juvenile migrants, especially SCNFH subyearling Chinook, are being impacted and mortality is higher due to higher gatewell turbulence at turbine loads at the current upper 1% operating range, which is making it more difficult for fish to exit.
- Higher turbine loads (mid to upper 1%) result in more flow up the slot increasing turbulence.
- Increased turbulence is causing fish housed within the gatewell to take more time to find the orifice that is their exit to the downstream migrant system (DSM) channel.
- Dead fish that are being collected at the PH2 smolt monitoring facility are showing little or no signs of injury. It is speculated that these fish are spending greater time within the gatewell trying to exit. Under these more turbulent conditions, fish are expending excessive energy trying to exit the gatewell and are dying of exhaustion before being able to exit.

- Reducing turbine loads on the FGE-modified units to mid to lower turbine operational ranges have shown to bring fish passage mortality back to acceptable ranges (>1%).
- Opening an additional available orifice within the gatewell during loads at mid and upper 1% allows OPE to remain high and mortality/descaling is kept at acceptable historical levels (>1%).
- Taking actions that reduce turbulence either through operations or modifications to the gatewell environment will improve OPE, condition and fish survival through the PH2 DSM system.

After improvements or operational changes are made to the system, the USACE will able to be able to measure and identify quantifiable improvements that have been achieved by comparing pre- and post-implementation success via historical smolt passage date that will determine what constitutes success.

3.3. HYDRAULIC

3.3.1. Assumptions and Evaluation Criteria

In general, the following working assumptions were used in developing and evaluating alternatives:

- Based on available biological information, at 12,000 ft^3/s unit flow, hydraulic conditions in the gatewell are favorable for fish passage. Conditions at 15,000 ft^3/s unit flow may be acceptable for fish passage, but available data is limited.
- Based on available biological information, at 18,000 ft^3/s unit flow, hydraulic conditions are unfavorable for fish passage.
- Based on the baseline CFD model results described in Section 2, alternatives for improving FGE will focus on the following to improve hydraulic conditions for fish passage:
  - Streamlining the sweeping velocities along the VBS,
  - reducing turbulence in the gatewell,
  - minimizing gatewell residence time, and
  - reducing and evenly distributing normal velocities on the VBS.
- The improvements listed above may be achieved by reducing gatewell flow through structural or operational means. Because FGE will likely decrease with decreased gatewell flow, flow control alternatives must be carefully balanced to achieve an overall improvement in FGE.
- Alternatives that streamline the gatewell geometry to reduce turbulence, change flow patterns, or reduce fish residence time while maintaining gatewell flow may improve hydraulic conditions for fish passage while maintaining FGE. These alternatives may be feasible as stand-alone alternatives or in combination with flow control alternatives.
- Structural alternatives will be included in the CFD model to a level of detail to capture hydraulic influence of structures (i.e., overall shape and dimensions as available, but not fasteners or minor structural details).

The CFD model results for alternatives will be compared to baseline results using the following metrics:

- Turbulent kinetic energy
- Gatewell residence time
- Gatewell flow patterns (normal and sweeping velocities)

3.3.2. Turbine Intake Screens and Vertical Barrier Screens

Turbine intake screen and VBS at mainstem Columbia and Snake River hydroelectric dams are exception to design criteria for conventional screens. Turbine intake screens are considered partial screens, because they do not screen the entire turbine discharge. They are high-velocity screens, meaning approach velocities are much higher than allowed for conventional screens. Turbine intake screens were retrofitted at many mainstem Columbia and Snake River powerhouses (which cannot be feasibly screened using conventional screen criteria) to protect juvenile fish from turbine entrainment to the extent possible. Vertical barrier screens pass nearly all flow entering the gatewell from the intake screen and intake ceiling apex zone. Fish pass upward along the VBS and then accumulate in the upper gatewell, near an orifice that is designed to pass them safely into the downstream migrant system (DSM).

Alternatives should be designed to operate within the design forebay level range (elevation 71.5 to 76.5 feet). Forebay levels remain within this range 97.3% of time (1974-1981 forebay data).

3.3.2.1. Turbine Intake Screens – Specific Criteria

Maximum Approach Velocity: Maximum approach velocity (normal to the screen face) for turbine intake screens must be 2.75 ft/s.

Stagnation Point: The stagnation point (point where the component of velocity along the turbine intake screen face is 0 ft/s) must be at a location where the submerged screen intercepts 40% to 43% of turbine intake flow, and must be within 5 feet of the leading edge of the screen.

3.3.2.2. Vertical Barrier Screens – Specific Criteria

Through-Screen Velocity: Average VBS through-screen velocity must be a maximum of 1.0 ft/s, unless field testing is conducted to prove sufficiently low fish descaling injury rates at a specific site. The VBS must be designed to achieve uniform velocity distribution and minimize turbulence in upper gatewell. If a flow vane is used at gatewell entrance to increase flow up the gatewell, VBS should be constructed of stainless steel bar screens with bars oriented horizontally and 1.75 mm maximum clearance between bars.

3.3.3. Downstream Migrant System – Specific Criteria

The hydraulic design of the DSM is driven by hydraulic criteria for safe passage of downstream migrating juvenile salmon. The primary objective of these criteria is to minimize injury or delay to the fish. Criteria for the forebay range, orifices, collection channel, dewatering structure, and exit section, provided by NOAA Fisheries, are listed below.

Design Forebay Operating Ranges

- Design forebay elevation for DSM constant flow operation: 71.5 to 76.5 feet (normal operating range).

Orifices

- Plate velocity $\geq$ 10 ft/s.
- Orifice discharge $\geq 11\ \text{ft}^3/\text{s}$.
- Centerline trajectory of the orifice jets should enter the collection channel water surface at least 4 feet from the opposite wall.

Collection Channel

- Channel velocity ≥ 2 ft/s (acceptable for unit 11 per NOAA discussion).
- Channel velocity between 3 to 5 ft/s at downstream end.
- Channel water depth ≥ 4 feet.

Dewatering Facility

- Channel velocity between 3 to 5 ft/s.
- Average gross velocity entering dewatering screens ≤ 0.4 ft/s.
- Bypass outflow rate = 30 ft^3/s.
- Channel water depth ≥ 2 feet.

Exit Section

- Flow rate 30 ft^3/s.
- Ratio of bend radius to pipe diameter (R/D) ≥ 5.
- Velocities should not increase or decrease at rates greater than 0.1 ft/s per unit foot of conduit length.

3.4. STRUCTURAL

(is this section needed?- RL)

3.5. MECHANICAL/ELECTRICAL

Mechanical and electrical features and criteria will be developed for each alternative to a conceptual level. The upstream gate slot is where the STSs are deployed and where the inspection camera descends to inspect the STS while it is travelling. In addition, the VBSs are in this slot at the downstream face, dividing the upstream and downstream gate slots. The downstream gate slot is where the hydraulic head gates are permanently mounted, in a ready-to-deploy configuration. The deck area around both slots will need to be kept clear, so that equipment and weight handing devices can be used to service the turbine intakes. Alternatives that are developed in this study will need to accommodate existing equipment and work activities.

If electrical power is needed, cabling can be routed through existing conduits from the Elevation 70 Gallery into the downstream head gate slot. The instrumentation for the VBS, the power supply, and instrumentation cabling for the STSs are in existing conduits; any new cabling will need to be routed around these existing features.

3.6. COST ENGINEERING

3.6.1. Total Project Costs

Total project costs will be generated for the alternatives. These costs are applicable to structural alternatives which require design and construction to modify the VBS or installation of additional equipment. These costs include design, construction, escalation to the mid-point of construction, supervision and inspection, engineering during construction, and contingency costs. ETL 1110-2-573, *Construction Cost Estimating Guide for Civil Works*, provides the criteria for developing these costs, which is to estimate a fair and reasonable cost for the alternative.

3.6.2. Life Cycle Costs

Life cycle costs (LCC) will be generated for the alternatives. LCC are used to compare alternatives with high initial costs and low operational costs, with other alternatives with low initial costs and high maintenance costs, or in this case, lost power costs. LCC will include ALL costs involved in the alternative during its project life, such as design, construction, operation, and lost power costs as applicable. For comparison purposes, all these costs will be calculated as the present worth, using appropriate discount rates for future costs and assuming a nominal 50-year project service life. They will also be presented as an average annual cost. ER 1110-2-8159, *Life Cycle Design and Performance*, defines the policies for long-term performance and life cycle costs.

3.7. HYDROPOWER ECONOMIC ANALYSIS

Alternative B1 consists of operating Bonneville PH2 main units off the 1% peak range during the juvenile fish passage season (March-August). The estimated impacts of this alternative, in terms of foregone project generation and foregone hydropower benefits, are summarized in Section 4.6.7. Details regarding the procedures and methodology used to develop these estimates are presented in Appendix G. The main inputs and assumptions associated with the hydropower impacts analysis are summarized below.

3.7.1. Alternatives Defined for the Hydropower Impacts Analysis

The hydropower impacts of Alternative B1 were developed by estimating Bonneville generation output and hydropower benefits under each of two alternatives:

- **Base Case: PH2 Units Operate to Upper 1% Operating Point.** This alternative assumes that all PH1 and PH2 main units operate between the peak efficiency operating point and the upper 1% operating point during the juvenile fish passage season.
- **Alternative Case: PH2 Units Operate at Peak Efficiency Operating Point.** This alternative assumes that all PH1 main units operate between the peak efficiency operating point and the upper 1% operating point during the juvenile fish passage season, while all PH2 main units operate at the peak efficiency operating point during this time period.

3.7.2. Turbine Energy Analysis Model Inputs and Assumptions

The Turbine Energy Analysis Model (TEAM) was used to estimate the energy generation output of Bonneville under the Base Case and Alternative Case. Model inputs and assumptions are listed below.

- **Monthly Flow Releases and Forebay Elevations.** Bonneville monthly total flow releases and forebay elevations for a 50-year period served as input to TEAM. This monthly data was obtained as output from the USACE Hydro System Seasonal Regulation (HYSSR) model. HYSSR is used to simulate the operation of the Columbia River Basin system of projects over the hydrologic period of record from August 1928 through July 1978.
- **Tailwater Rating Table.** The Bonneville tailwater rating table obtained from HYSSR served as input to TEAM. TEAM used this table to estimate the tailwater elevation corresponding to each

monthly total flow release. The model then used monthly forebay and tailwater elevations to estimate generating head for each month in 50-year period of record.

- **Monthly Non-Power Discharges/Flow Losses.** TEAM allows for the input of a year of monthly non-power discharges / flow losses which represent flows not available for power generation. Included in this category are lockages, flows through fish ladders, juvenile bypass systems, ice and trash sluiceways, the PH2 corner collector, and auxiliary water supply for fishways. Not included are spill for fish requirements, which are entered into TEAM separately. The year of monthly non-power discharges / flow losses were obtained from the annual COE Data Submittal and were subtracted from each of the 50 years of project monthly total flow releases.
- **PH1 and PH2 Unit Performance Equations.** In order to estimate Bonneville monthly generation output under the Base Case and Alternative Case, TEAM required as input equations representing the combined performance of the unit turbine and generator. The Hydroelectric Design Center (HDC) developed performance equations for PH1 and PH2 units, expressing unit output (MW) and unit efficiency as a function of generating head. HDC developed separate equations for unit performance at the peak efficiency operating point and for unit performance at the upper 1% operating point.
- Since the interest of this study is unit operation during juvenile fish passage season, the unit performance equations assumed unit operation with STS fish screens in place. In addition, since PH1 major rehabilitation has been completed, the performance equations for PH1 units assume unit operation with turbine runner replacement and generator rewind for all 10 units.
- **Unit Loading Order.** A single unit loading order was assumed in TEAM for the juvenile fish passage season. Consistent with the predominant unit loading order listed in the annual FPP, PH2 units were loaded ahead of PH1 units.
- **Unit Outage Order.** TEAM allows for the input of one or more unit outage orders, indicating which units are to taken out of service during a given month. Based on an analysis of Bonneville historical unit outage data (planned and forced outages) for a recent 10-year period, from two to four units were assumed to be out of service during a given month. Units from PH1 and PH2 were assumed to be placed on outage in the reverse of unit loading order. To the extent possible, units placed on outage were evenly split between PH1 and PH2.
- **Spill for Juvenile Fish.** Monthly spill for fish requirements for the April-August spill season were obtained from the annual FPP and the annual USACE Data Submittal and were entered into TEAM using two parameters: (1) percent of project flow spilled for fish; and (2) upper limit (in thousand cfs) on project flow spilled for fish (i.e., spill cap). Since TEAM uses a monthly time step, it was not possible to model separate daytime and nighttime spill caps for each month of the spill season. TEAM assumed a weighted spill cap for each month, with the daytime and nighttime spill caps for any given month being weighted according to the number of hours per day that each spill cap applied.

Additional information to be developed in during the 60%-90% phase

4. ALTERNATIVES

This section describes the configuration and components of the alternatives. The technical analyses used in the alternatives analysis and design are also described. The sectional CFD model grid was modified to include geometric features of select alternatives, as described in Section 4.3.

4.1. DESCRIPTION OF ALTERNATIVES

Alternatives are categorized into modifications for flow control, operations, and flow pattern change, as described below.

Flow control alternatives include:

- A1 – Adjustable Louver Flow Control Device: Construct a device to control the flow up the gatewell. The device would be placed downstream of the VBS. Similar devices have been used at John Day and McNary dams.
- A2 – Sliding Plate Flow Control Device: Construct a sliding plate flow control device attached to the top of the gatewell beam.
- A3 – Modify VBS Perforated Plates.
- A4 – Modify Turning Vane and/or Gap Closure Device.

Operational alternatives include:

- B1 – Operate Main Units Off 1% Peak Range: Operate the main turbine units at the lower to mid 1% peak operating range during the SCNFH juvenile fish release.
- B2 – Open Second DSM Orifices: Open the second DSM gatewell orifice to decrease fish retention time in the gatewell.
- B3 – Horizontal Slot for DSM: Construct a horizontal slot in place of the existing orifices to decrease fish retention time in the gatewell.

Flow pattern change alternative:

- C1 – Install Gate Slot Fillers: Install gate slot fillers in the slots above the turning vane and STS supports to reduce turbulence in the gatewell and streamline sweeping velocities up the VBS.

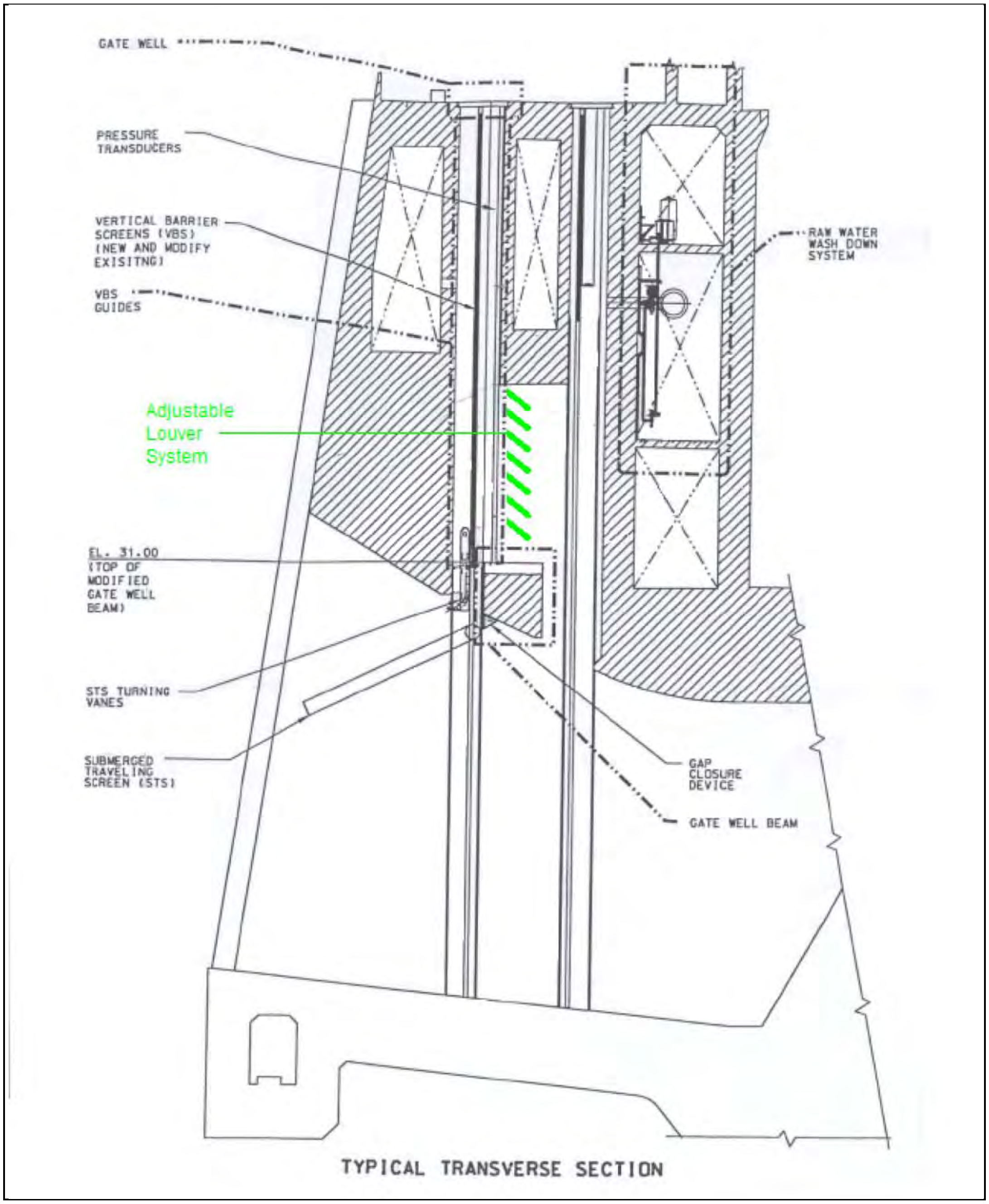
Each of the alternatives will require some degree of real time monitoring for flow velocity. This will be required to determine baseline flow conditions, compare prototype performance, and fine tune operations to meet the target requirements.

4.2. ALTERNATIVE A1 – ADJUSTABLE LOUVER FLOW CONTROL DEVICE

4.2.1. Description

Alternative A1 involves installation of a series of adjustable plates (louvers) in the opening downstream of the VBS (Figure 4-1). The louvers would be adjusted accordingly to meet the target flow in the gatewell. This system can be constructed of stainless or carbon steel and can be designed to vary the opening width at top and bottom. For a permanent design, opening and closing adjustments may be made from a separate device lowered into the downstream VBS slot, through a conduit cored through the existing concrete or by remote control.

Figure 4-1. Alternative A1 – Adjustable Louver Flow Control Device



4.2.2. Hydraulic Design

4.2.2.1. Hydraulic Modeling

Alternative A1 has not been evaluated using the CFD model to date. If the team prioritizes this alternative for further evaluation, the CFD model will be modified to include a hydraulic representation of the louvers downstream of the VBS. The alternative would be evaluated at high flow conditions (18,000 ft^3/s unit flow) to determine the impact on VBS velocities and flow patterns. Additional documentation runs at low and medium unit flows (12,000 and 15,000 ft^3/s, respectively) would confirm the performance of the alternative over a range of unit flows.

4.2.2.2. CFD Model Results

Alternative A1 was not prioritized for simulation in the CFD model as it is similar in principle to Alternative A2 – Sliding Plate Flow Control Device.

4.2.3. Structural Design

Alternative A1 would consist of aluminum plates making up the louver system. Aluminum is light weight, rigid and corrosion resistant. This material would aid in the easy of control of the louvers by reducing the lifting capacity of the hoist system or the manual lift requirement.

The louvers could be anchored individually to the concrete or as a system. The system allows for a variety of pivot designs and control of the friction points. Either design would allow for individual replacement of the louvers. However the system would allow the installation of the louvers as a system and removal as a system. The louvers anchored individually must be removed individually.

The inspection period would ideally be on a 5-year period after the prototype was built or the first year in service. Inspection would be during the unit outage and inspected from a man basket.

4.2.4. Mechanical/Electrical Design

A louver system is suggested because the downstream gate slot is partially obstructed by the head gates, and there is concern that a flow control device in the slot would need to be designed around both the movement and the geometry of the head gate. It is unknown at this time if a head gate might be removed for servicing at the same time as the flow control device is needed. There is a risk that the flow control device in the downstream gate slot might interfere with deploying the headgate in an emergency. These two factors are the motivation that initiated consideration of an adjustable flow control device that is not located in the downstream gate slot, and the louver-type device is the outgrowth of that consideration.

The louver-type device would be installed in the space immediately downstream of the VBS, in the rectangular opening between the upstream and downstream gate slots. In the existing arrangement, flow goes upward from the turbine intake tunnel into the upstream gate slot, passes through the VBS, through the rectangular opening into the downstream gate slot, and then flows back down into the turbine intake tunnel. Flow is currently modulated by panels of perforated (perf) plate that are integral to the VBS screen structure.

A louver-type device would be modeled after a flow control damper that is used to modulate flow in HVAC ducting. Similar devices do not exist for water, or other liquid systems, except in very rare instances such as flow modulation devices that also control turbulence in flow-testing tunnels, and these are always custom designs. The same approach would be employed in this case. The louver in the full open position will generate a small but significant amount of obstruction, causing increased resistance to flow. It is possible that the existing perf plates will need to be modified to increase their porosity to compensate for the increase in resistance from the louver device. The increased resistance caused by the louver device will need to be distributed in a relatively uniform way across the surface of the VBS screen upstream face. Unless it is found to be helpful, the flow leaving the louver device should not have a dominant velocity vector direction which could tend to reduce the total energy loss through the louver. To accommodate and/or mitigate these concerns, the HVAC damper design is suggested as a suitable concept. The louver design is much like a Venetian blind, except that every other blade turns the opposite direction. By varying the angle of the blades, the occluded flow area varies, which causes variation in the overall flow rate.

Some means of control and operating power is needed to vary the position of the louver blades. The operating equipment will need to be located in a place that allows removal for servicing, possibly located in a recess created by core-drilling into the concrete intake deck. The louvers themselves will be very difficult to remove and service, so ultra-low maintenance design and materials should be employed.

4.2.5. Fisheries Considerations

Similar devices have been tried at both John Day and McNary dams to control the flow of water entering the gatewell. High velocities and turbulent flow result in poor fish conditions within the gatewell that reduces OPE, which is the measure of how effectively fish vacate and utilize the gatewell orifice to move into the juvenile bypass collection channel. This type of flow reduction device has shown to be effective at reducing flows up into the slot but not without reductions to FGE, increasing juvenile passage through the gap at the top of the screen and the turbine intake ceiling and also being problematic from an operational stand point due to having an obstacle in the permanent downstream head gate slot.

4.2.6. Operation and Maintenance (O&M)

Other operational issues may also be incurred due to the need to regularly adjust the louvered system from the intake deck by the rigging crew. Any additional manpower needs to fish bypass equipment also come with labor and O&M cost increases that will have to be absorbed into the currently tight O&M budgets.

4.2.7. Cost

To be developed in during the 60%-90% phase

4.3. ALTERNATIVE A2 – SLIDING PLATE FLOW CONTROL DEVICE

4.3.1. Description

Alternative A2 involves a system of two sliding plates attached to the top of the gatewell beam (Figures 4-2 and 4-3). Gatewell flow could be controlled by one plate sliding over the other to adjust the opening depending on the required velocity. Both plates can be made of carbon steel or stainless steel (with a Teflon coating to reduce friction) or aluminum. Similar to Alternative A1, a permanent design may be operated from a separate device lowered into the downstream VBS slot, through a conduit cored through the existing concrete or by remote control.

Figure 4-2. Alternative A2 – Sliding Plate Flow Control Device

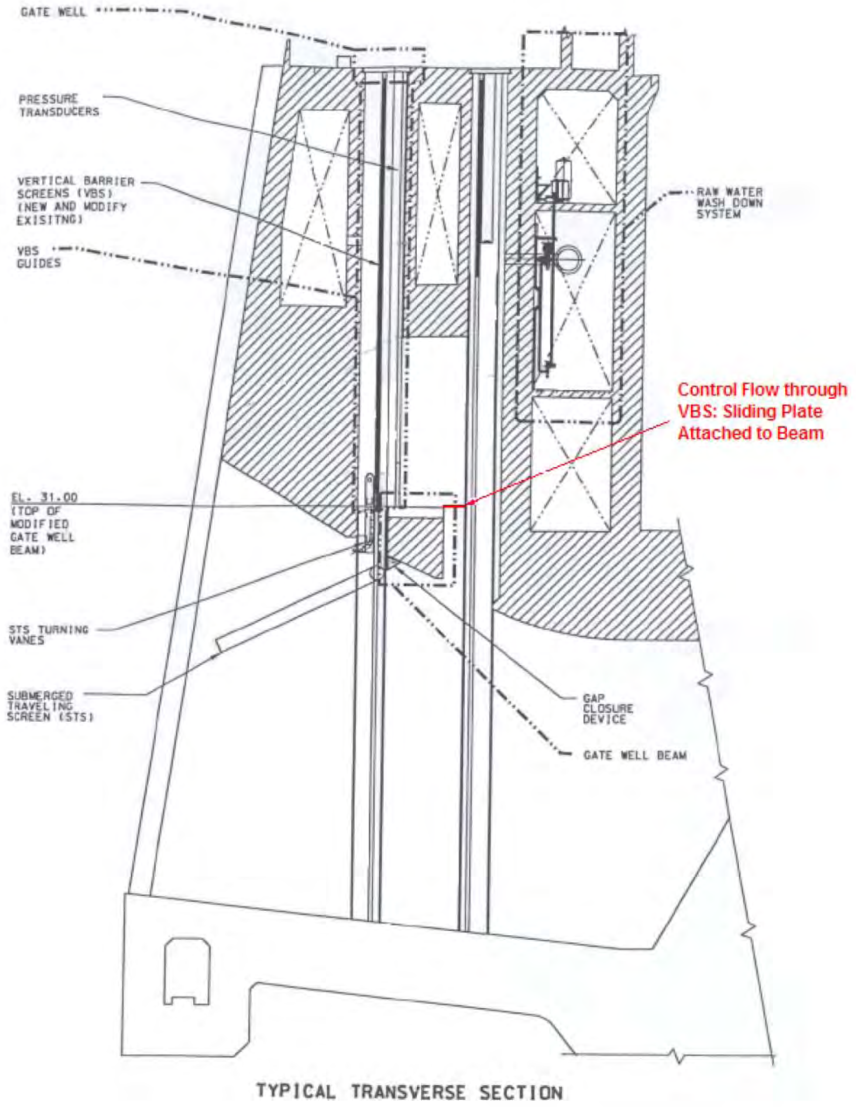
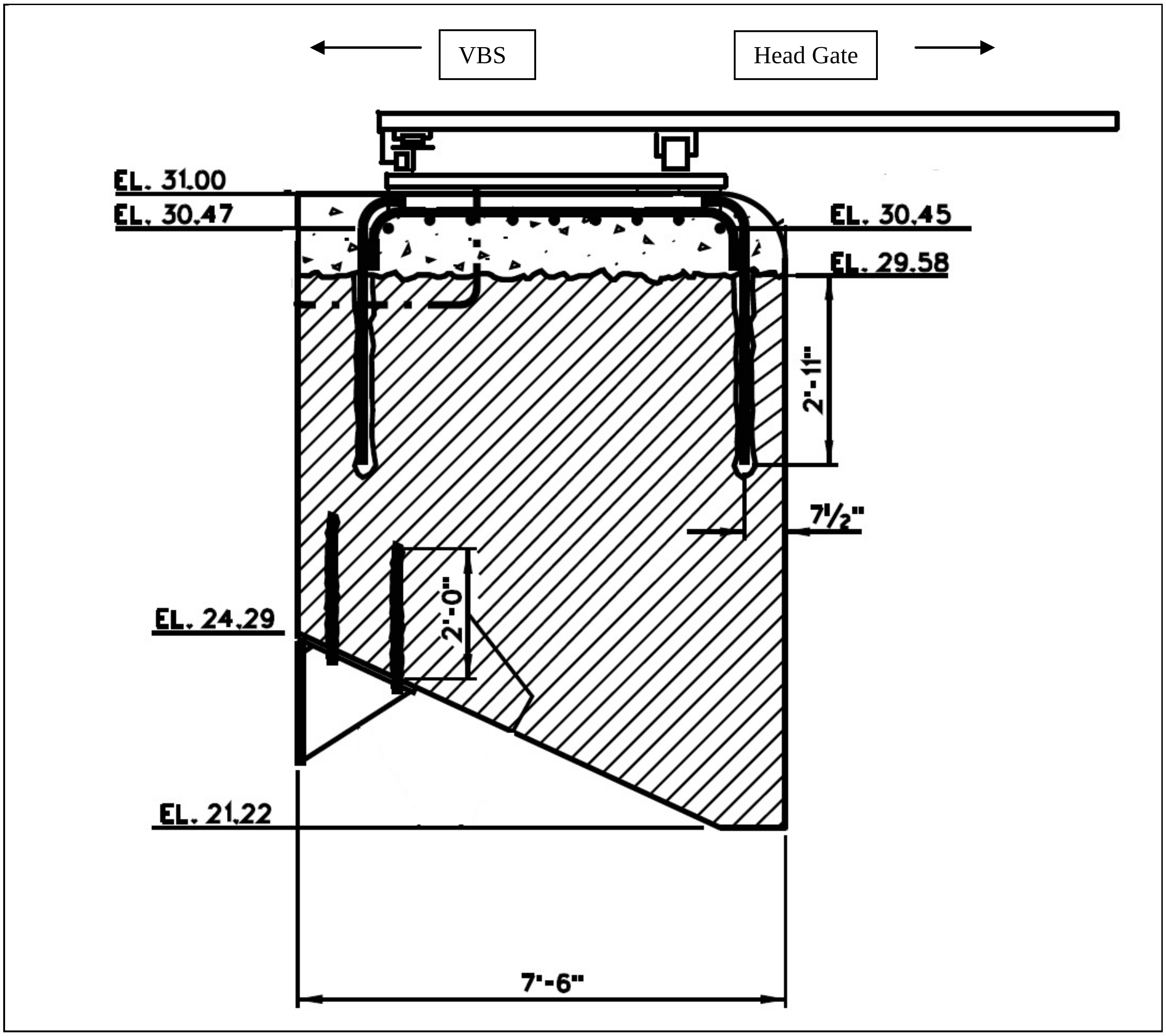


Figure 4-3. Alternative A2 – Sliding Plate Flow Control Device Detail

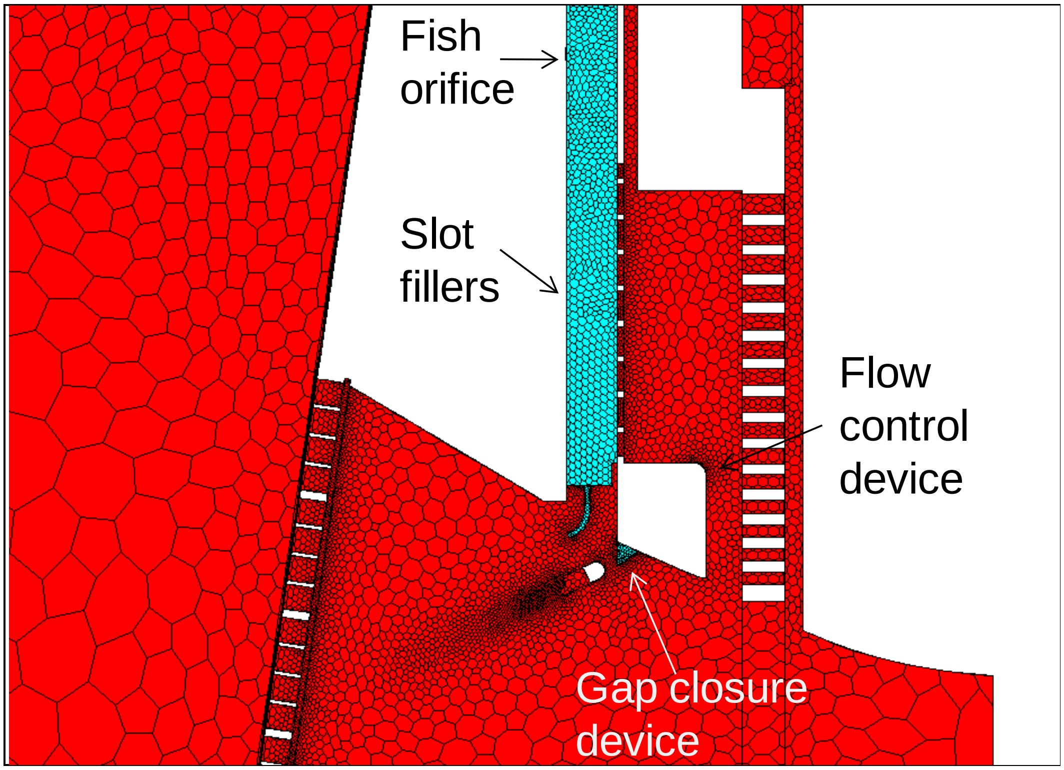


4.3.2. Hydraulic Design

4.3.2.1. Hydraulic Modeling

The sectional CFD model grid was modified to include the approximate geometric features of the sliding plate flow control device as described in Appendix C. The flow control device was modeled as a 6-inch thick plate, extending across the full width of each bay and with varied lengths in the downstream direction. The flow control device was included in the model grid in three segments representing occlusion of 25%, 50%, and 75% of the cross-sectional flow area between the gatewell beam and emergency gate as shown in Figure 4-4. Three CFD model runs were conducted at a unit flow of 18,000 ft^3/s to investigate the relative change in VBS flow with the flow control device occluding 25%, 50%, and 75% of the return flow area. All other geometric conditions in the model were representative of baseline conditions.

Figure 4-4. Alternative A2 – Sliding Plate Flow Control Device CFD Model Grid



4.3.2.2. CFD Model Results

The VBS flows with the sliding plate flow control device occluding 25%, 50%, and 75% of the return flow area are summarized in Table 4-1. The 25% sliding plate setting results in a Bay A VBS flow (272 ft^3/s) that is comparable to the VBS flow for the Baseline conditions with 15,000 ft^3/s unit flow. The 50% sliding plate setting results in a Bay A VBS flow (219 ft^3/s) that is comparable to the Bay A VBS flow for the baseline conditions for 12,000 ft^3/s unit flow. For brevity, the results of the 25% sliding plate setting sectional CFD model run are described below.

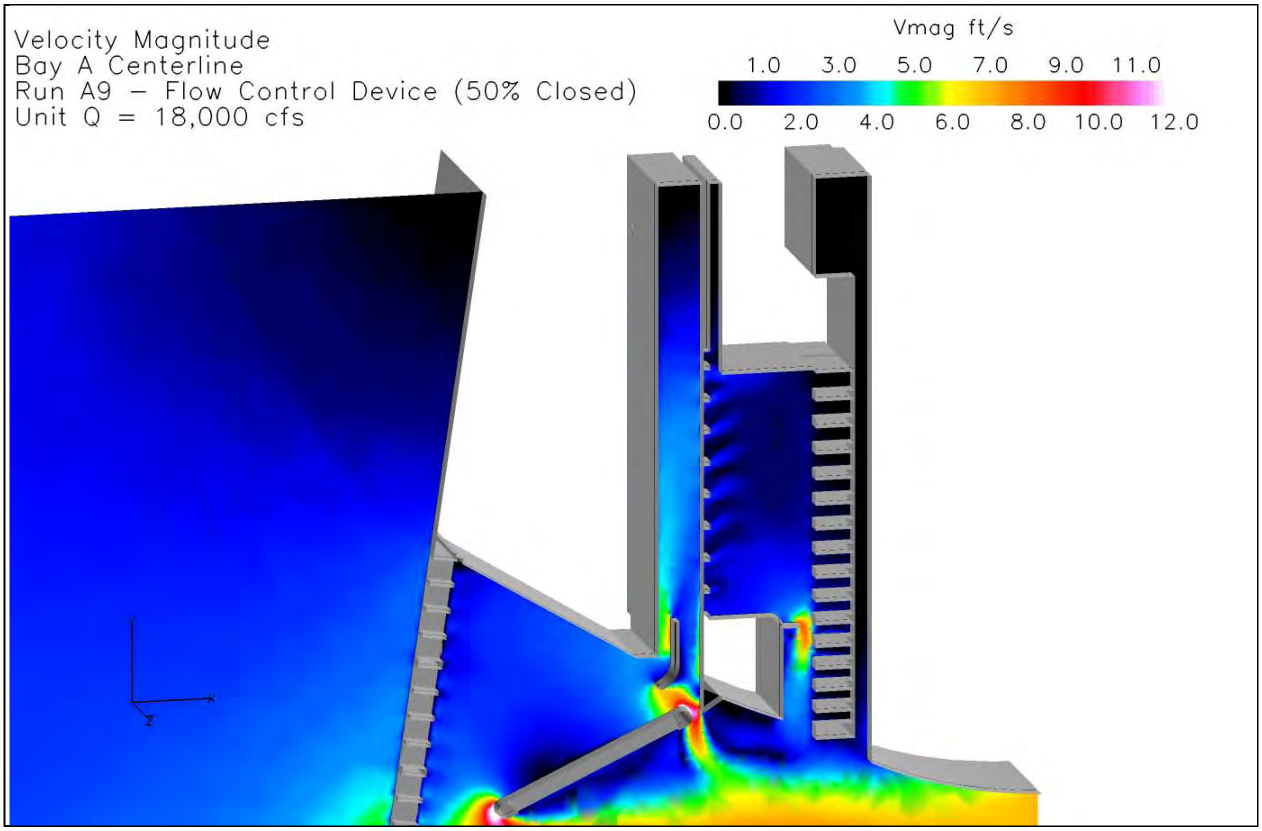
Table 4-1. VBS Flow Control with Sliding Plate Flow Control Device

Unit Flow (ft^3/s)	**Sliding Plate Setting**	**Bay A VBS Flow (ft^3/s)**
18,000	25%	276
18,000	50%	216
18,000	75%	116

The sectional CFD model results for the sliding plate flow control device occluding 25% of the return flow area are summarized in Figure 4-5 through Figure 4-7. The velocity magnitudes approaching the STS and gatewell look similar with the 25% sliding plate installed (Figure 4-5) to those for the baseline 18,000 ft^3/s unit flow case (Figure 2-17), as expected, since the unit flows are the same. As the flow enters the gatewell, the influence of the flow control device can be seen in the lower gatewell velocities in Figure 4-5 that are more comparable to the baseline 15,000 ft^3/s unit flow case (Figure 2-13). The 25%

sliding plate alternative appears to have slightly more flow up the upstream side of the turning vane and less up the downstream side of the turning vane than in the baseline 15,000 ft^3/s unit flow case for an equivalent gatewell flow.

Figure 4-5. Alternative A2 – Bay A Centerline Velocity Magnitude



Normal velocities and flow patterns on the VBS are similar for the 25% sliding plate alternative and the baseline 15,000 ft^3/s unit flow case (Figure 4-6 and Figure 2-14), as expected for comparable VBS flows. Turbulent kinetic energy in the gatewell for the 25% sliding plate alternative (Figure 4-7) is slightly reduced from the baseline 18,000 ft^3/s unit flow case (Figure 2-19), but not quite to the level seen in the baseline 15,000 ft^3/s unit flow case (Figure 2-15). This may be due to the difference in velocities and flow patterns approaching the gatewell along the turning vane described above.

Figure 4-6. Alternative A2 – VBS Normal Velocities and Flow Patterns

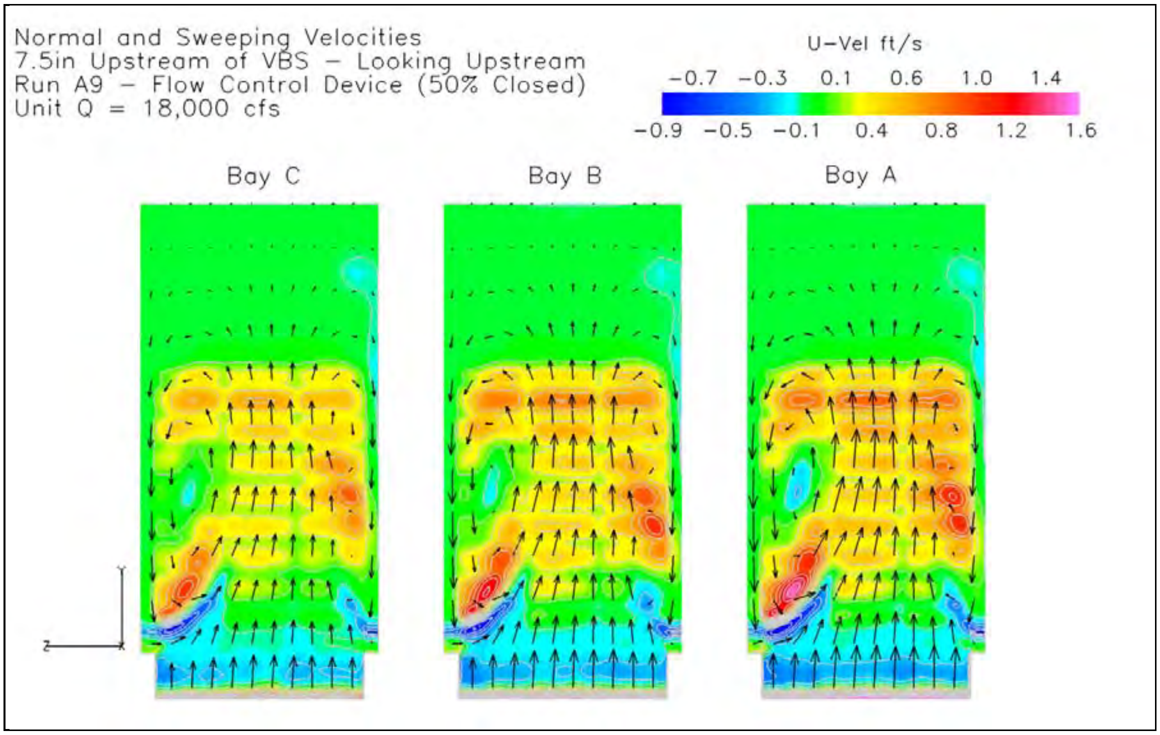
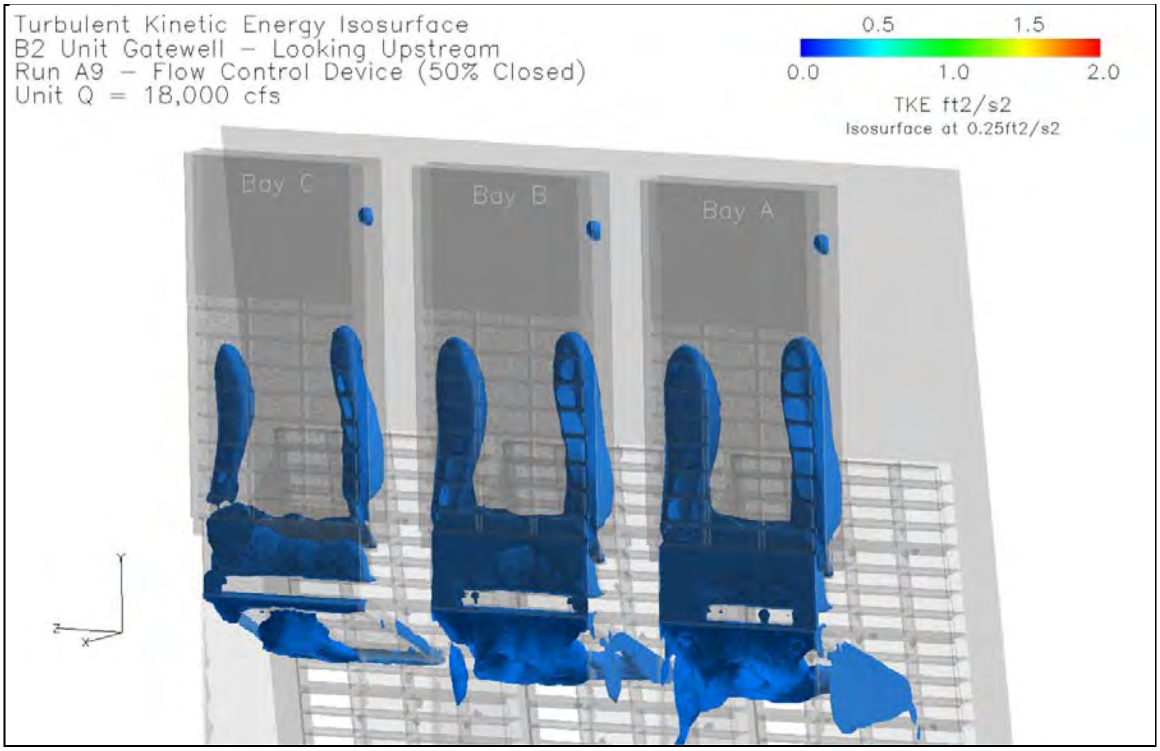


Figure 4-7. Alternative A2 – Turbulent Kinetic Energy Isosurface



4.3.3. Structural Design

Alternative A2 could be designed using a combination of materials; aluminum, steel, and ultra-high molecular weight (UHMW) plastic. While UHMW plastic, aluminum. or steel could be used for the sliding plate, UHMW plastic would be necessary for the sliding surface. The plate would run along in groves, tracks, or rails made of angle or UHMW plastic. The anchorage points would be mainly from the sliding surface to the concrete and the opposing sliding surface to the plate (see Figure 4-3).

The inspection period would ideally be on a 5-year period after the prototype was built or the first year in service. Inspection would be during the unit outage and inspected from a man basket.

4.3.4. Mechanical/Electrical Design

The sliding plate concept is suggested because the downstream gate well and head gate configuration provides a location where flow can be throttled by a plate that slides horizontally outward from the bottom of the rectangular opening between gate slots. The plate would move out in the downstream direction and partially close off the flow passing down into the turbine intake tunnel.

Two key issues for consideration include not allowing the plate to be capable of failing in a manner that allows the plate device to interfere with deployment of the head gates, and determining if there is ever a time when the plate device would be needed when the head gate has been removed from the slot for servicing.

The plate will be carrying the hydraulic load in a partially cantilevered mode, so it will likely need gusseting and reinforcing ribs. In addition the trailing edge where flow is cleaving away will need to be streamlined to resist vibration. The supports and operating machinery will need to be streamlined, since there is a risk that the VBS and the STS may be pulled out of the slots in high-debris situations, and juvenile fish will be carried past the equipment by the flow.

Instrumentation and operating machinery will likely need to be underwater, although the electric or hydraulic motors could be located remotely with power transmission shafting extending down to the location of the operating equipment. This equipment will be very difficult to service, so ultra-low maintenance materials and components should be selected.

4.3.5. Fisheries Considerations

As with Alternative A1, this alternative does provide for a controlled gatewell flow and may provide acceptable conditions that allow the implementation of the full turbine unit operational range but with reduced FGE outcomes.

4.3.6. Operation and Maintenance

This option also has a sizeable O&M component but also is retained in the downstream headgate slot that is problematic for emergency headgate deployment.

4.3.7. Cost

To be developed during the 60%-90% phase.

4.4. ALTERNATIVE A3 – MODIFY VBS PERFORATED PLATES

4.4.1. Description

Alternative A3 involves modifying the existing VBS perforated plates resulting in a reduction of gatewell flow. A separate, modified perforated plate would be attached to the existing perforated plate and be allowed to slide to constrict flow to meet a target flow velocity. This perforated plate can be constructed of carbon steel with a Teflon coating to reduce friction during operation. A prototype could be built that would be adjustable and locked in place by hand. A permanent design may be attached to the existing perforated plate and mechanically or remotely controlled.

4.4.2. Hydraulic Design

This alternative has not been evaluated using hydraulic modeling because it is considered similar in principle to Alternative A2. If the team prioritizes this alternative for further evaluation, physical hydraulic modeling investigations will be needed. Preliminary investigation can be conducted using the CFD model to gain an initial understanding of the relative change in VBS flow from changes to the screen perforated plates. A physical hydraulic model would need to be constructed to evaluate actual required changes to prototype perforated plate porosities to maintain balanced normal velocities within criteria.

4.4.3. Structural, Mechanical and Electrical Design

This alternative involves a concept wherein two identical perforated plates are stacked (or layered) face to face on the back of the VBS (Figure 4-8). Flow of water passing through the VBS is regulated by an existing perforated plate, and the layered perforated plate concept would be accomplished by adding a second perforated plate to the backside of the VBS.

Figure 4-8. Alternative A3 – Modify VBS Perforated Plates

The initial position of the two perforated plates would have all the holes in both perforated plates concentrically aligned and open. To reduce the volume of water flowing through the VBS, the outer perforated plate would slide with respect to the inner perforated plate, so that the outer plate holes are not perfectly concentric with the holes in the inner plate anymore, but are now partially occluding each other. Further movement increases the amount of occlusion, and increases restriction in flow.

The existing perforated plate and fish screen assembly is not readily adaptable to the sliding perforated plate concept. The existing perforated plates are roughly 2 feet by 6 feet, and are separated by the VBS structural frame made out of 6-inch by 6-inch square structural tubing. The perforated plates are inset about 5/8 inch into rectangular openings in the back of the VBS, and are not flush with the back surface of the framing. The perforated plates are carbon steel with an epoxy coating system. Furthermore, bolting tabs that hold the existing perforated plates and fish screens in place in the VBS frame are on the back of the perforated plates. There is a limited amount of space between the downstream side of the VBS and the concrete gate slot wall, which constrains the thickness of any sort of machinery or mechanism that extends downstream beyond the VBS structural framing to about one inch. The design for the sliding perforated plate concept would need to include replacement of the existing perforated plates and also take into account all of the issues presented here. This is a formidable design challenge.

4.4.4. Fisheries Considerations

This alternative could present significant operational challenges when adjustments are needed. Any mechanical adjustments will need to be made while the screens are in the dogged position and up out of the water. This requires the unit to be shut down and out of service while adjustments are being made. Also, this concept may include many moving parts that have historically been problematic from an operations and maintenance perspective when operated in a debris-rich environment.

4.4.5. Operation and Maintenance

To be developed in during the 60%-90% phase

4.4.6. Cost

To be developed during the 60%-90% phase

4.5. ALTERNATIVE A4 – MODIFY TURNING VANE AND GAP CLOSURE DEVICE

4.5.1. Description

Alternative A4 involves modifying the existing turning vane and/or gap closure device (GCD) to reduce the discharge flowing into the gatewell. Turning vanes direct the flow up the gate slot and are installed just above the top of the STS. The GCD is mounted on the intake roof just downstream of the STS to prevent fish from travelling through the turbine, as well as divert more flow up the gatewell.

4.5.2. Hydraulic Design

4.5.2.1. Hydraulic Modeling

The sectional CFD model grid was modified to model the removal of the GCD to reduce gatewell flow in all three bays. The grid cells representing the gap closure device in the sectional CFD model (see Figure 4-4) were defined as fluid cells rather than solid cells to allow flow freely through the region previously occupied by the GCD. One CFD model run was conducted at a unit flow of 18,000 ft^3/s to investigate the relative change in VBS flow with the GCD removed. All other geometric conditions in the model were representative of baseline conditions.

4.5.2.2. CFD Model Results

The sectional CFD model results for Alternative A4 are summarized in Figures 4-9 through 4-11. With the GCD removed, more flow passes through the gap between the STS and the gatewell beam, resulting in lower VBS flow (approximately 110 ft^3/s). Velocity magnitude through the gap is increased over that for the baseline condition as shown in Figure 4-9. The higher velocities at the upper end of the STS and through the gap result in an altered flow pattern at the base of the VBS with flow actually recirculating and passing upstream through the lower VBS panels as shown in Figure 4-10. It is important to note that the VBS porosity settings for this alternative were set the same as the baseline condition and no attempt was made to compensate for the backflow through the VBS in this particular model run. Turbulent kinetic energy in the gatewell is similar to baseline conditions, though some effect of the backflow through the lower VBS is apparent in the turbulence plots in Figure 4-11.

4.5.3. Structural Design

The modifications to the STS and the GCD would be similar in style and material as the current design. The existing anchor system for the GCD would likely not be able to be put back in service once the GCD is removed for modification. A new anchoring schema would need to be designed, likely to be similar to the original design only located the appropriate distance adjacent to the existing anchors. The STS turning vane would be modified on the STS to meet the shape required to meet the ideal shape developed for the CFD model.

4.5.4. Mechanical/Electrical Design

No significant mechanical or electrical involvement, unless designers discover that some modifications to existing STS electrical or mechanical equipment are necessary.

Figure 4-9. Alternative A4 – Bay A Centerline Velocity Magnitude

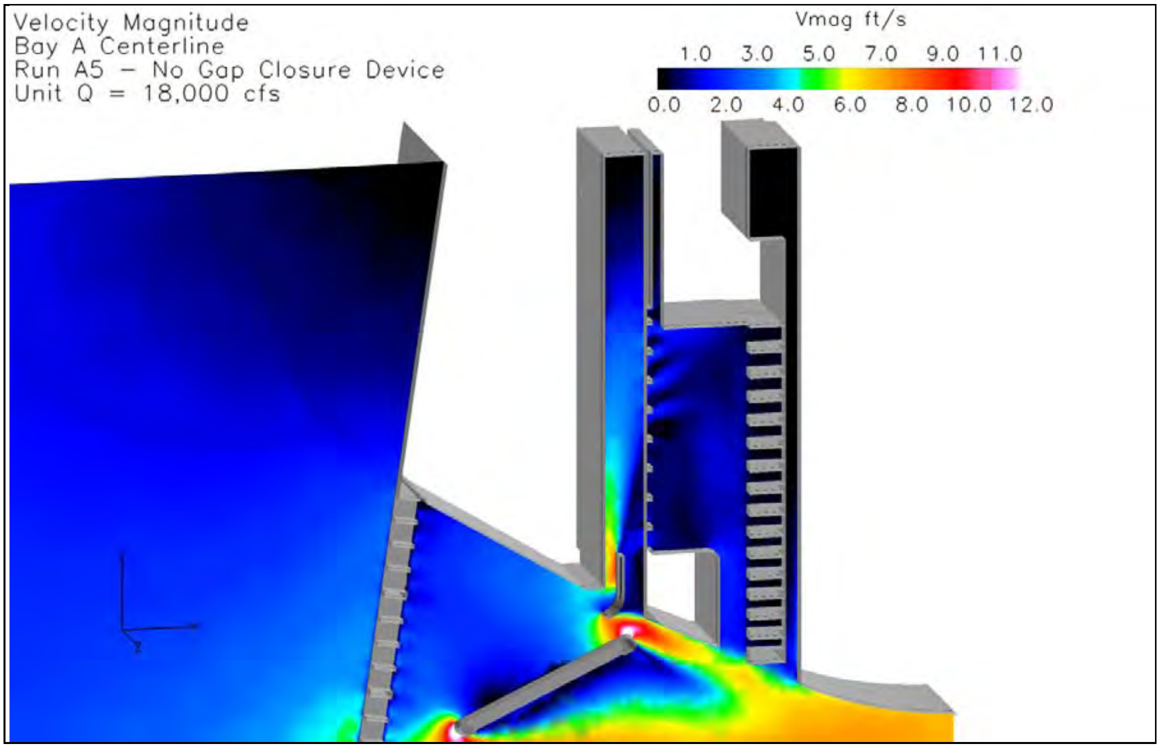


Figure 4-10. Alternative A4 – VBS Normal Velocities and Flow Patterns

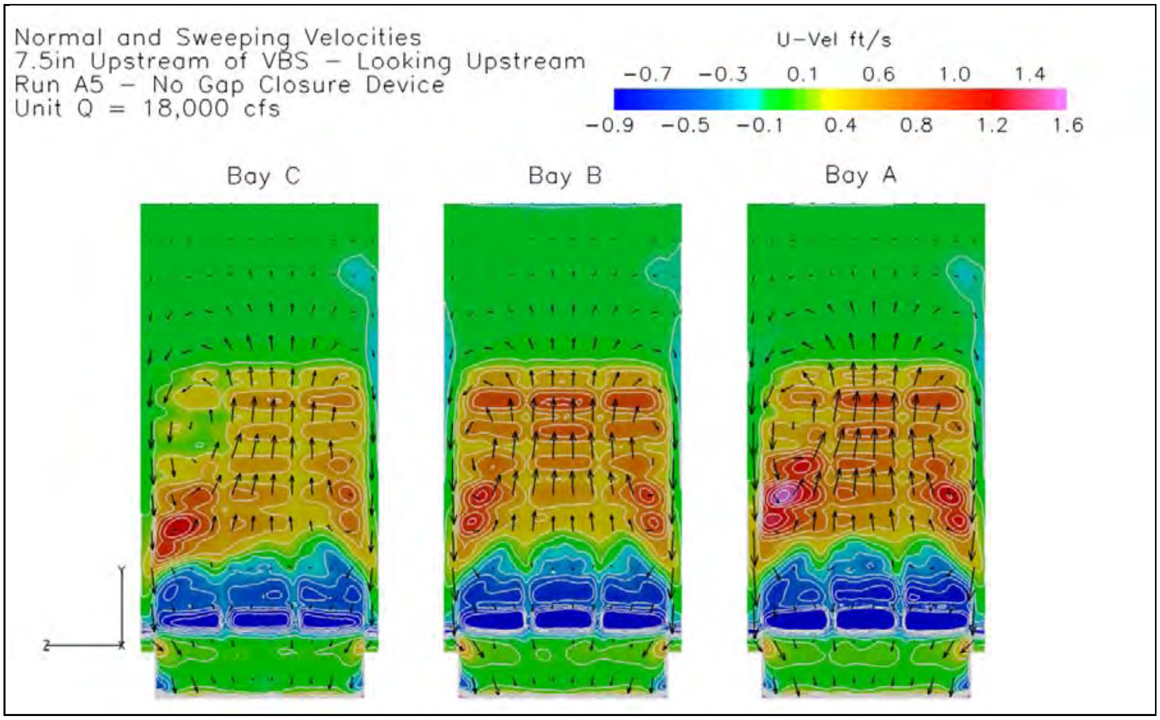
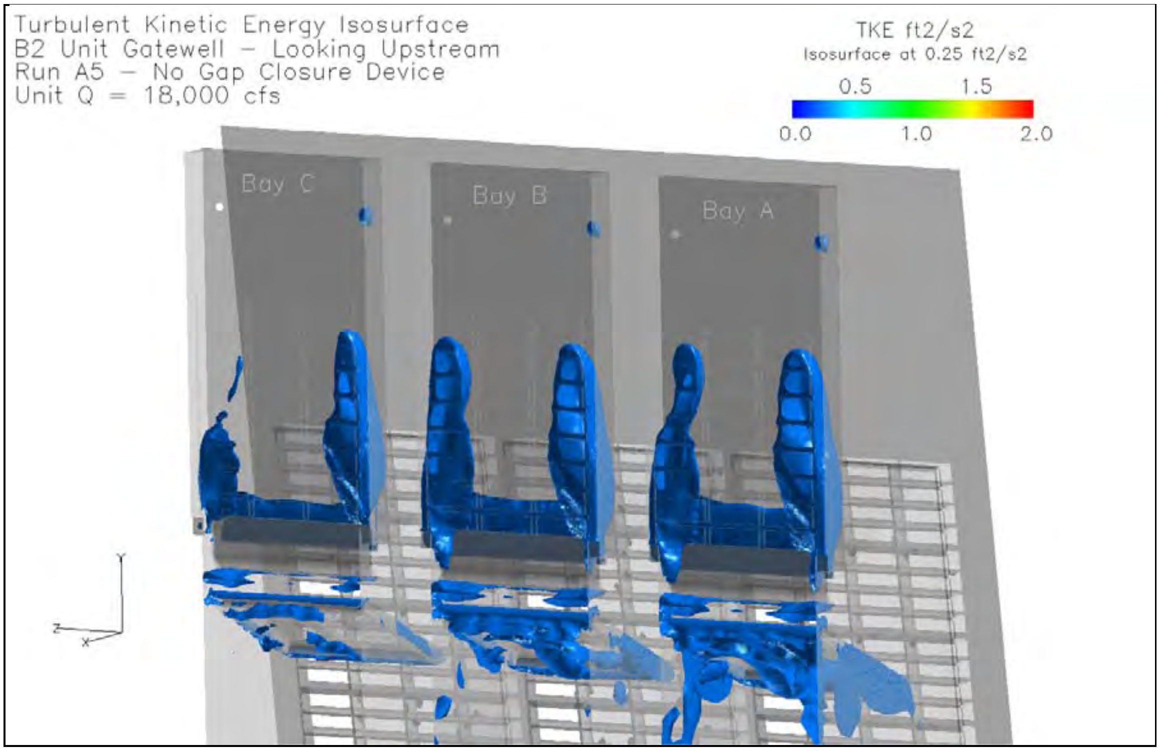


Figure 4-11. Alternative A4 – Turbulent Kinetic Energy Isosurface



4.5.5. Fisheries Considerations

Hydraulic CFD analysis has indentified problematic areas with this design. The removal of the GCD would allow fish normally directed upward and into the gatewell to now be directed through the top gap thus reducing FGE. Hydraulics also identified a problematic reverse backflow that was problematic as well and no real reduction to the turbulent kinetic energy that is what we have determined that is most critical to remove in a system modification. Modifications to the turning vane design will also have an effect of reduced FGE by reducing the amount of water shunted up the gatewell. The goal of this alternatives phase is to reduce gatewell turbulence but also maintain the full range of turbine operations and FGE guidance. This option reduces FGE and may even increase the amount of fish that would normally be diverted through the gap by removing it and its effectiveness.

4.5.6. Operation and Maintenance

Operation and maintenance requirements will be similar to the current system.

4.5.7. Cost

To be developed during the 60%-90% phase

4.6. ALTERNATIVE B1 – OPERATE MAIN UNITS OFF 1% PEAK RANGE

4.6.1. Description

Alternative B1 involves reducing the gatewell flow by operating PH2 main units off the 1% peak operating range (lower to mid 1% or 12,000 to 15,000 ft^3/s, respectively) to improve fish survival. In spring during the 2008 juvenile fish passage season, SCNFH released hatchery subyearlings over a period of 3 months (March, April, May). Biological testing conducted by NOAA (spring 2008) suggests that SCNFH subyearlings are incurring high mortality and descaling when turbine units are being operated at the upper 1% range, so the reduced unit flows are expected to improve hydraulic conditions for fish passage. Typical unit flow for this operation would be approximately 12,000 to 15,000 ft^3/s.

4.6.2. Hydraulic Design

4.6.2.1. Hydraulic Modeling

This operational alternative does not involve any changes to the baseline geometry of the unit, gatewell, or screens. Therefore, the results of the baseline sectional CFD model runs at lower unit flows (12,000 and 15,000 ft^3/s) are indicative of the hydraulic conditions in the gatewell with the unit operating in the lower and mid 1% range.

4.6.2.2. CFD Model Results

The hydraulic conditions expected during unit operations in the lower and mid 1% range are described in the 12,000 and 15,000 ft^3/s baseline results, respectively (Section 2 and Figures 2-6 through 2-19).

4.6.3. Structural Design

Structural engineering is not required for this alternative.

4.6.4. Mechanical/Electrical Design

Mechanical/electrical engineering is not required for this alternative.

4.6.5. Fisheries Considerations

This unit operational constraint has been used during times of SCNFH fall Chinook releases to reduce the turbulence associated with higher turbine operations. It has been the alternative design team’s goal to maintain FGE but reduce turbulence. This reduction in turbine discharge is problematic due to several operational issues. First, the reduced turbine discharge equates to a reduction in anticipated FGE through PH2. Gatewell turbulence and the associated byproducts such as increased passage descaling and mortality are reduced and brought back into normal parameters with this curtailed unit operation but at the sake of reduced FGE. Second, with these restricted turbine discharge operations comes an issue throughout the spring and even summer outmigration that may increase total dissolved gas (TDG) effects by having to spill above the 120% TDG limits. If unit operations are curtailed, any water that is not bypassed through PH2 turbines has to be either be spilled or picked up as generation at PH1.

During a majority of the outmigration season (April-June), the project is at or is exceeding its hydraulic capacity to pass water through the powerhouses and maintain our court mandated spill cap of 100,000 ft^3/s. As spill is increased, so does the TDG produced by this forced spill. Clean Water Act regulations, as well as Oregon and Washington state water quality standards, indicate that USACE is to manage TDG generated through spill at its projects below the 120% guidelines over a 24-hour period. If turbine operations are restricted, the USACE may be forced to exceed these standards that affect a much larger amount of juvenile and adult fish that would not be as affected if units were operated at their normal upper end of 1% range. Reduced unit operational alternatives should be used sparingly and other methods should be investigated as to head off this as a final option.

4.6.6. Operation and Maintenance

To be developed in during the 60%-90% phase

4.6.7. Cost

An analysis to estimate the impact to project generation and corresponding hydropower benefits was conducted by the Hydroelectric Design Center's Hydropower Analysis Center. Details regarding the procedures and methodology used for the analysis are provided in Appendix G. Analysis of the hydropower impacts of restricting PH2 units to peak efficiency operation during the juvenile fish passage season (March through August) involves estimating project generation output and corresponding hydropower benefits under each of two alternatives, which are briefly described below.

1. **Base Case: PH2 Units Operate to Upper 1% Operating Point.** This alternative assumes that all PH1 and PH2 units operate between the peak efficiency operating point and the upper 1% operating point during the juvenile fish passage season. The project is assumed to conform to the operating requirements summarized in April 2009 FPP and USACE 2009-2010 Data Submittal.

2. **Alternative Case: PH2 Units Operate at the Peak Efficiency Operating Point.** This alternative assumes that all PH1 units operate between the peak efficiency operating point and the upper 1% operating point during the juvenile fish passage season, while all PH2 units operate at peak efficiency operating point during this time period. The project is assumed to conform to the operating requirements summarized in April 2009 FPP and USACE 2009-2010 Data Submittal.

The Turbine Energy Analysis Model (TEAM) was used to estimate the energy production output of Bonneville under the base case and alternative case. Table 4-2 shows the monthly average energy generation for the base case and alternative case.

The BPA has developed and provided to USACE the projected hourly market-clearing prices based on the 50 years of hydrologic data used in estimating energy production. These projections were developed using an electric energy market model called AURORA, which is owned and licensed by EPIS Incorporated.

To determine the energy benefits associated with the Bonneville base case and alternative case, an Excel spreadsheet called COMPARE was developed that utilized as input TEAM output for each case, along with the weekly energy values. The results of this process are summarized in Table 4-3. The energy benefits estimates summarized in the table are consistent with the energy generation estimates summarized in Table 4-2. The last column of each table shows losses during the months March through July and gains during the month of August.

Table 4-2. Bonneville 1929-1978 Monthly Average Energy Generation

Month	Generation (MWh)		
	Base Case	Alternative Case	BC - AC
MAR	482,580	474,690	7,890
APR	411,610	393,860	17,750
MAY	447,770	414,730	33,040
JUN	441,620	413,250	28,370
JUL	329,410	326,770	2,640
AUG	218,360	219,000	-640
Total	2,331,350	2,242,300	89,050

Table 4-3. Bonneville 1929-1978 Monthly Average Energy Benefits

Month	Benefits ($1,000)		
	Base Case	Alternative Case	BC - AC
MAR	19,670	19,390	280
APR	14,670	14,090	580
MAY	12,760	11,950	810
JUN	11,170	10,650	520
JUL	12,490	12,430	60
AUG	10,770	10,800	-30
Total	81,530	79,310	2,220

4.7. ALTERNATIVE B2 – OPEN SECOND DSM ORIFICES

4.7.1. Description

The DSM has two fish passage orifices in the gatewell slots of units 11-14. Under present operating conditions, one orifice in each gatewell is typically used. This alternative involves opening the second gatewell orifice to decrease fish retention time in the gatewell.

4.7.2. Hydraulic Design

Opening the second orifice could require modification of the DSM to meet system flow and operating criteria. Addressing potential modifications to the DSM is outside the scope of this project. However, a brief discussion of the general considerations for the DSM follows:

Considerations

- Per criteria and hydraulic design standards, this system is at maximum capacity.
- The orifices open or close to maintain a constant DSM water level (between collection channel and dewatering) at 64.3 feet.
- Do not want to increase this level (64.3 feet), as the discharge to the flume is a function of this level and we are already at or near dewatering capacity at the smolt monitoring facility.

Collection Channel

- Maintain a constant water level at 64.3 feet to deliver the right amount of flow down the flume.
- To maintain a constant water level, flexibility is needed to open/close the second orifices as the forebay changes (elevation 71.5 to 76.5 feet).
- Given the need for a constant water level at 64.3 feet, the increased flow would force a higher backwater and begin to incrementally reduce the flow from upstream units (unit 11, 12...).
- Channel widening at the upstream end could partially alleviate the height of the backwater, but the trade off is channel velocity (meets NOAA Fisheries criteria well at this time).
- The above impacts and options cannot be quantified without analytical tools.

Dewatering System

- In order to increase the dewatering rate, there are two options:
  - Violate screen velocity criteria by some amount. Drainage is limited on several of the larger screens, so some concrete would be excavated to improve drainage to emergency relief conduit (ERC).
  - Add a second dewatering system outside the building (this option was biologically rejected in design memorandum phase.) Also, the existing dewatering would have to be redesigned.
- Modify the existing dewatering so there is a longer converging section so that screens can be added on upstream end. This requires excavation of concrete in order to provide drainage to the ERC. Given the previous difficulties found in the retrofit design, this is easier said than done.

4.7.2.1. Hydraulic Modeling

The operation of two fish passage orifices was incorporated into the sectional CFD model by applying a velocity boundary condition to both fish passage orifices in each bay, corresponding to 11 ft^3/s through each fish orifice. No changes to the sectional CFD model grid were made. All other model boundary conditions were representative of baseline conditions. One CFD model run was conducted at a unit flow of 18,000 ft^3/s to investigate the relative change in gatewell hydraulics with the second fish orifice operating. If this requires further evaluation, an existing numerical spreadsheet model may be used to analyze the hydraulics in the downstream migrant system due to opening two orifices per gatewell.

4.7.2.2. CFD Model Results

The sectional CFD model results for Alternative B2 are summarized in Figures 4-11 through Figure 4-13. Velocity magnitudes along the STS, past the turning vane and up the gatewell are similar for two orifice operation (Figure 4-11) and baseline conditions with one orifice operating (Figure 2-17). The VBS normal velocities are similar in magnitude with two orifices operating (Figure 4-12) and one orifice operating (Figure 2-18), but the recirculation to either side on the VBS is intensified slightly with two orifices operating. In addition, the side with the larger recirculation zone flips in bays A and B from the left side, looking upstream, during single orifice operation (Figure 2-18) to the right side, looking upstream, during the double operation (Figure 4-12). The change in the asymmetry from bay to bay is apparent in the prototype VBS data as well may indicate that the recirculation patterns in the gatewell is a relatively stable, yet transient condition that flips from side to side. Turbulent kinetic energy is slightly higher with the second orifice operating (Figure 4-13) as compared to baseline (Figure 2-19). Overall, the flow patterns on the VBS are not more uniform with the second orifice operating, but the second orifice may provide fish a second opportunity for exit from the upper portion of the gate slot.

4.7.3. Structural Design

Structural engineering is not required for this alternative.

4.7.4. Mechanical/Electrical Design

Mechanical/electrical engineering is not required for this alternative.

4.7.5. Fisheries Considerations

PIT-tagged fish released and collected in the spring and summer at PH2 DSM in 2009 by NOAA researchers indicated that fish passage, descaling and survival through the DSM system and through the orifice could be maintained at normal levels while running PH2 units at the upper 1% range. Researchers measured the effects of a single orifice operation compared to a double orifice open and measured a significant reduction in OPE and descaling as compared to a single orifice open at these high turbine ranges. The action of opening two orifices also brought mortality and descaling within historical smolt monitoring facility percentages (>1%). It is recommended that this alternative be investigated and implemented in conjunction with any improvements adopted.

4.7.6. Operation and Maintenance

Operational issues may also be incurred due to the need to adjust the existing DSM to manage the increase in flow from opening a second orifice. Additional funding requirements for labor and/or O&M cost increases will have to be absorbed into the currently tight O&M budgets.

4.7.7. Cost

To be developed during the 60%-90% phase

Figure 4-12. Alternative B2 – Bay A Centerline Velocity Magnitude

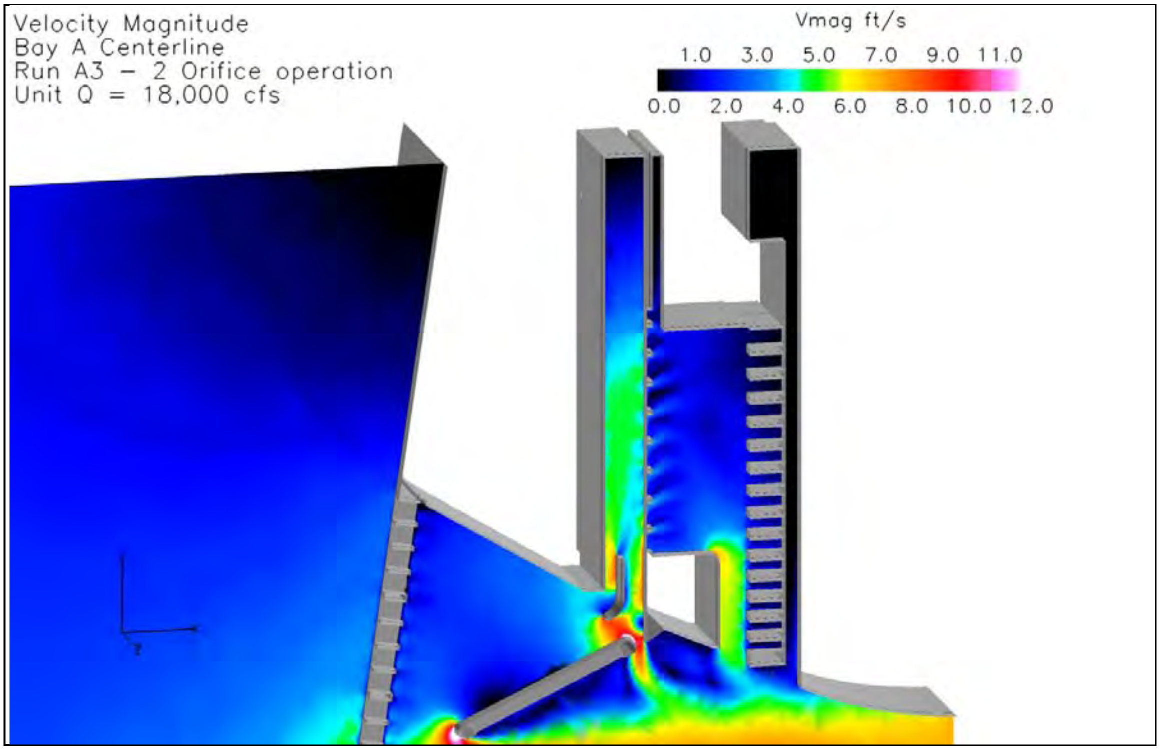


Figure 4-13. Alternative B2 – VBS Normal Velocities and Flow Patterns

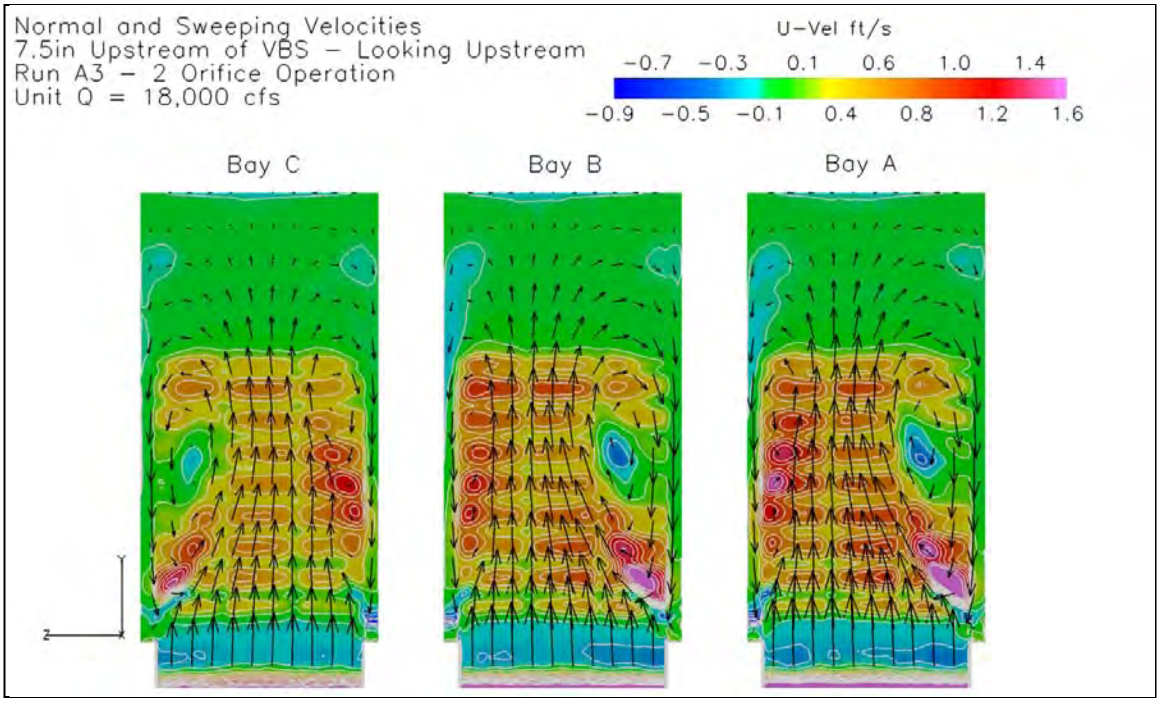
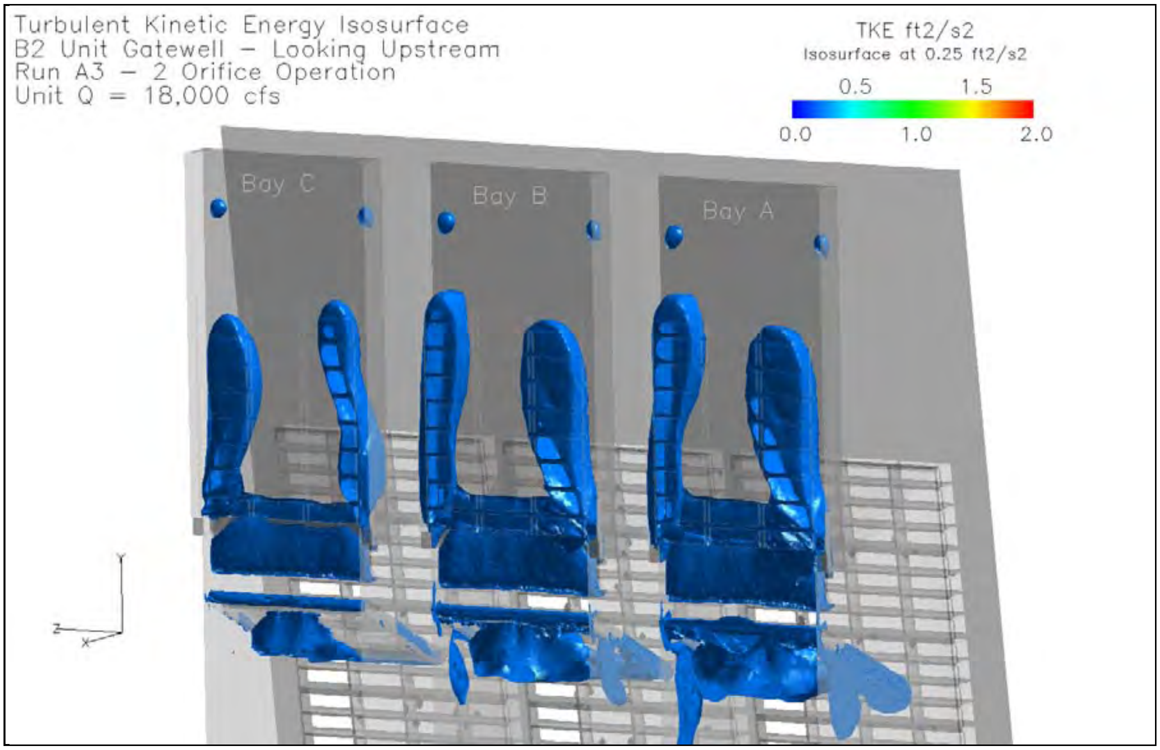


Figure 4-14. Alternative B2 – Turbulent Kinetic Energy Isosurface



4.8. ALTERNATIVE B3 – HORIZONTAL SLOT FOR DSM

4.8.1. Description

This alternative involves constructing slot to help facilitate faster movement of juveniles through the orifices and decrease fish retention time in the gatewell.

4.8.2. Hydraulic Design

4.8.2.1. Hydraulic Modeling

To be developed during the 60%-90% phase.

4.8.2.2. CFD Model Results

To be developed during the 60%-90% phase.

4.8.3. Structural Design

To be developed during the 60%-90% phase.

4.8.4. Mechanical/Electrical Design

To be developed during the 60%-90% phase.

4.8.5. Fisheries Considerations

To be developed during the 60%-90% phase

4.8.6. Operation and Maintenance

To be developed during the 60%-90% phase

4.8.7. Cost

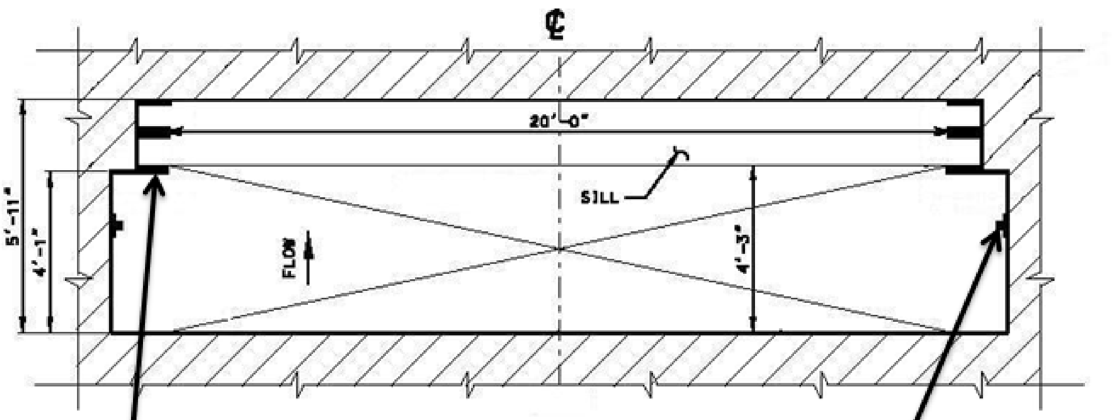
To be developed during the 60%-90% phase

4.9. ALTERNATIVE C1 – INSTALL GATE SLOT FILLERS

4.9.1. Description

In the existing configuration, the STS and turning vane side supports occupy the 4’-1” x 1’-4” gate slot on either side of each bay. Above the STS side supports, the gate slot expands abruptly and is open to flow up the gatewell. At the abrupt expansion to the gatewell slot above the STS side supports, baseline CFD model results have shown that flow can not immediately expand into the slot and an area of recirculation and higher turbulence results. Gate slot fillers are considered to eliminate the abrupt expansion into the gate slot, reduce turbulence, and streamline sweeping velocities up the VBS. The slot fillers would be installed on each side of each of the three bays and would be dogged off to extend from the top of the STS side supports to above the gatewell water surface (Figures 4-15 to 4-17).

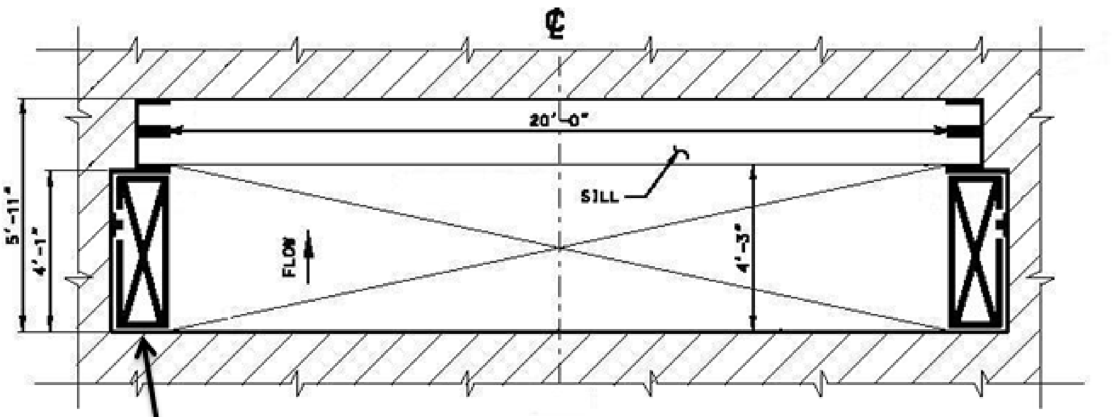
Figure 4-15. Alternative C1 – Slot Fillers (Plan View)



Plan View-Existing

VBS Guide Slots (Typ)

STS Turning Vane Guide (Typ)



Plan View-Proposed

4′-1″ x 1′-4″ Slot Fill Assembly (Typ)

Figure 4-16. Alternative C1 – Slot Fillers (Section View)

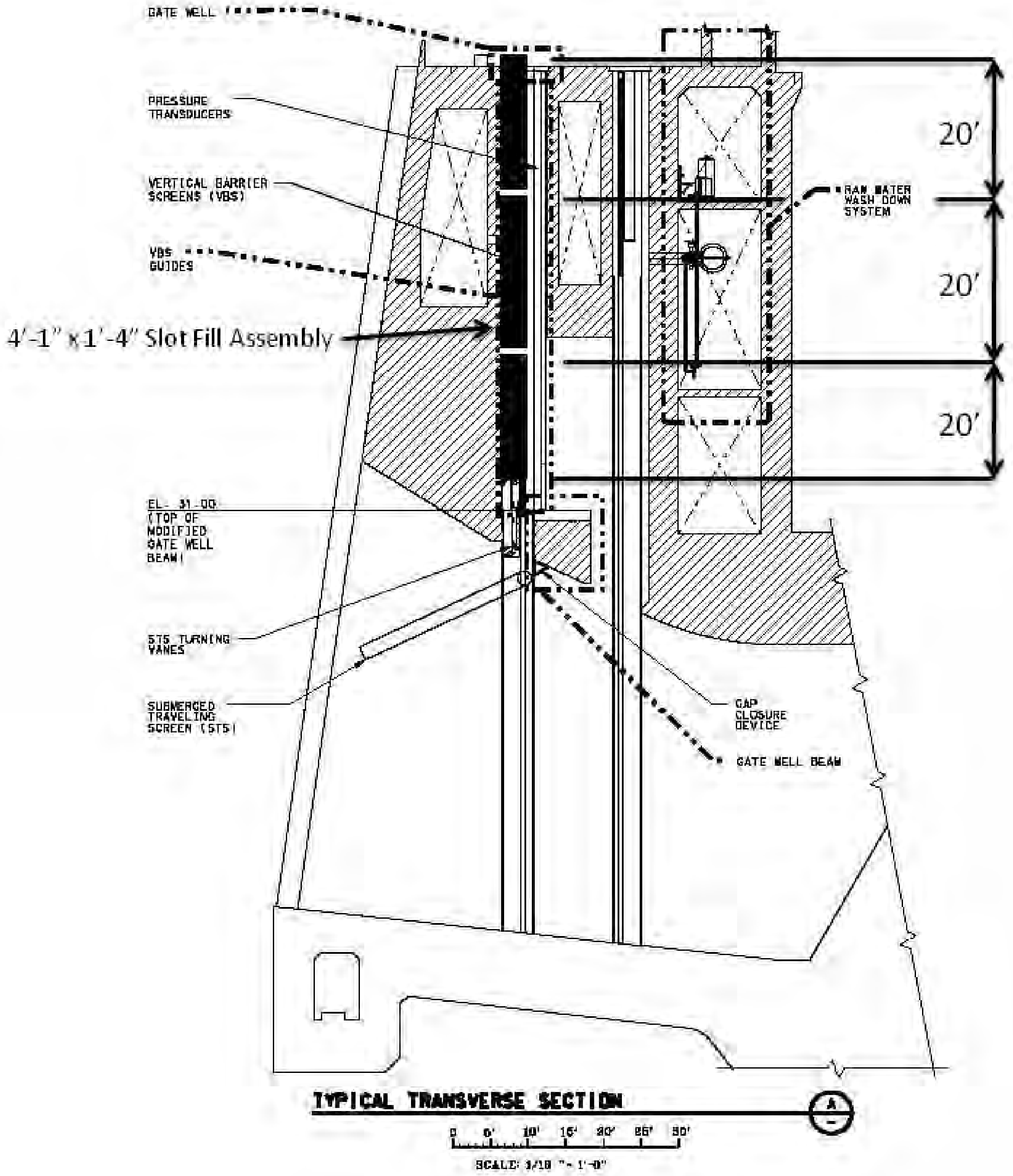
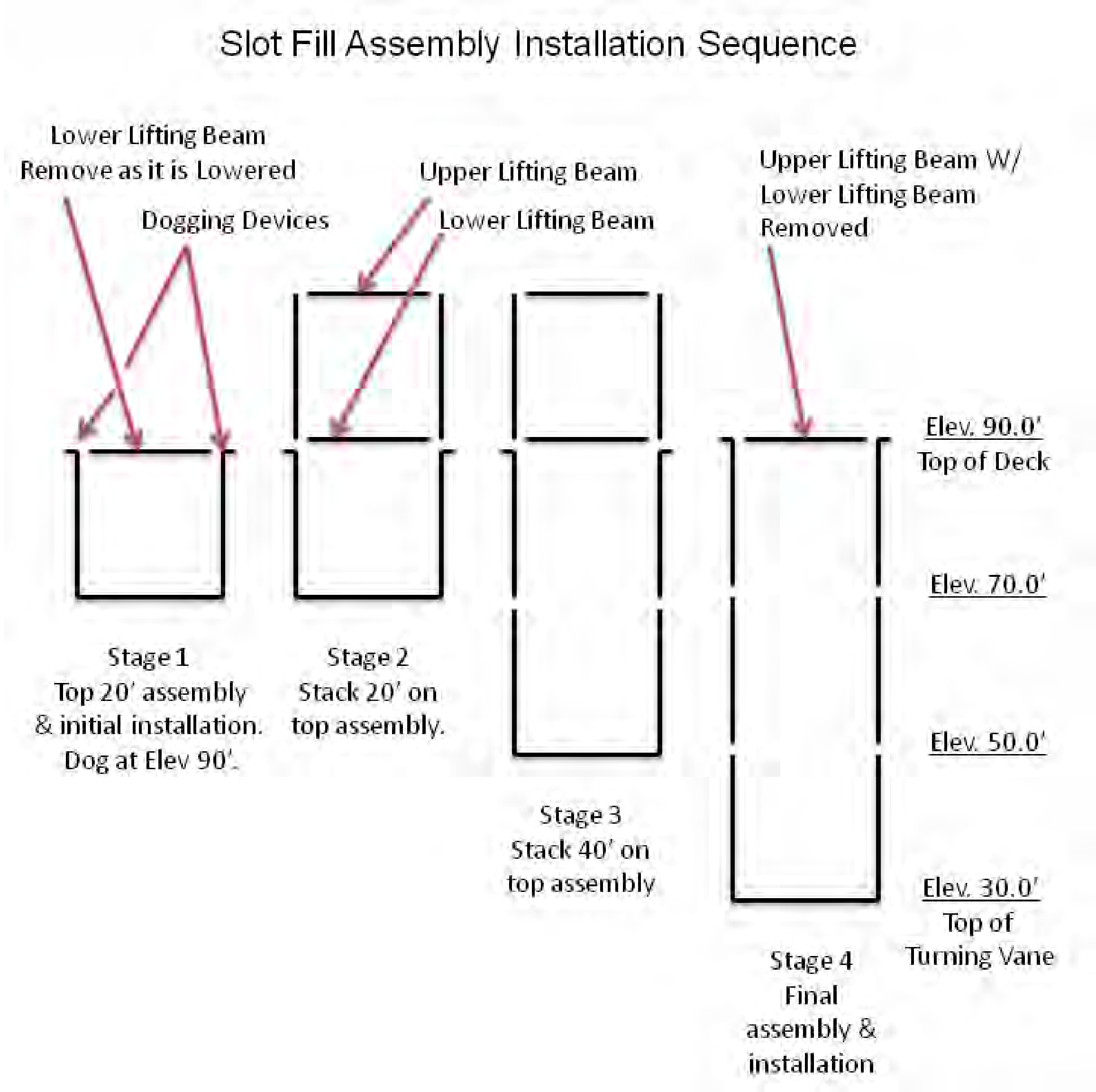


Figure 4-17. Alternative C1 – Slot Fillers (Front View)



4.9.2. Hydraulic Design

4.9.2.1. Hydraulic Modeling

The sectional CFD model grid was modified to model the gate slot fillers above the STS side supports in all three bays (Figure 4-4). The sectional CFD model grid cells inside the gate slots were isolated and defined as solid cells rather than fluid cells to simulate the presence of the slot fillers. The solid cells representing the slot fillers extended from the top of the STS side supports to the top of the model domain. One CFD model run was conducted at a unit flow of 18,000 ft^3/s to investigate the relative change in gatewell hydraulic conditions with the slot fillers installed. All other geometric conditions in the model were representative of baseline conditions.

4.9.2.2. CFD Model Results

The sectional CFD model results for Alternative C1 are summarized in Figures 4-18 through 4-20. Based on the CFD model results, bay A VBS flow increased to 366 ft^3/s with the gate slot fillers in place due to more streamlined flow and reduced turbulent energy loss in the gatewell. This is approximately an 11% increase in VBS flow. In general, the velocity magnitude approaching the STS and turning vane with the gate slot fillers in place (Figure 4-15) is very similar to the baseline 18,000 ft^3/s unit flow case (see Figure 2-17), as expected. The influence of the gate slot fillers can be seen in the gatewell where the centerline velocity magnitude actually decreases with the gate slot fillers in place. This is due to a more even distribution of the flow up the slot, reducing the centerline sweeping velocities. The effect of the gate slot fillers can be seen in Figure 4-19 with the more uniform upward flow pattern and the more even distribution of normal velocities over the VBS panels. The regions of recirculation present in the baseline due to the abrupt slot expansion are significantly reduced to a small region of less intense recirculation in the upper portion of the VBS on either side (Figure 4-19). The turbulent kinetic energy in the gatewell is significantly reduced with the gate slot fillers in place as shown in Figure 4-20 by the elimination of the turbulent regions on the VBS.

4.9.3. Structural Design

The slot fill assembly is assembled with a lower 4’-1” x 1’-4” U-frame, upper and lower lifting beams and a series of (4)- 4’-1” x 1’-4” tubes that stack and interlock on top of each other to create a simple, rigid frame to cover the STS traveling screen and turning vane slot (see Figures 4-1 and 4-2). The bottom U-frame can be rigid or be designed as a bolted moment frame. The two lifting beams are designed to raise or lower the frame assembly in pieces. The subassemblies lock together in stages and can be dogged off at the necessary elevations. Each subassembly is 20 feet tall with a total assembled height of 60 feet. All of the subassemblies are made of aluminum to reduce weight and eliminate the need for painting.

4.9.4. Mechanical/Electrical Design

Alternative C1 involves streamlining the upstream gate slots with a fixed flow guiding surface that would be located in the recesses for the gate guides at the right and left ends of the upstream gate slot. The slot filler would be designed to replicate the surfaces in the CFD model that streamlined the gatewell flow and produced a reduction in turbulence energy.

At the design stage, an important aspect of this alternative that needs to be considered is the potential for conflict with the existing operating equipment. The STSs are in this slot, and the operating cables used to extend or retract the STS rotating screen are currently anchored in the guide slots. The video inspection camera uses this slot for inspection of the STS traveling screen and the VBS screen surfaces. Work on the intake deck uses the space around the gate slot opening, so any equipment that extends into this area will need to be carefully coordinated. The mechanical aspects of this concept could involve designing how the slot fillers stack onto the STS, and various mechanisms to anchor the gate slot fillers in the gate guides.

Figure 4-18. Alternative C1 – Bay A Centerline Velocity Magnitude

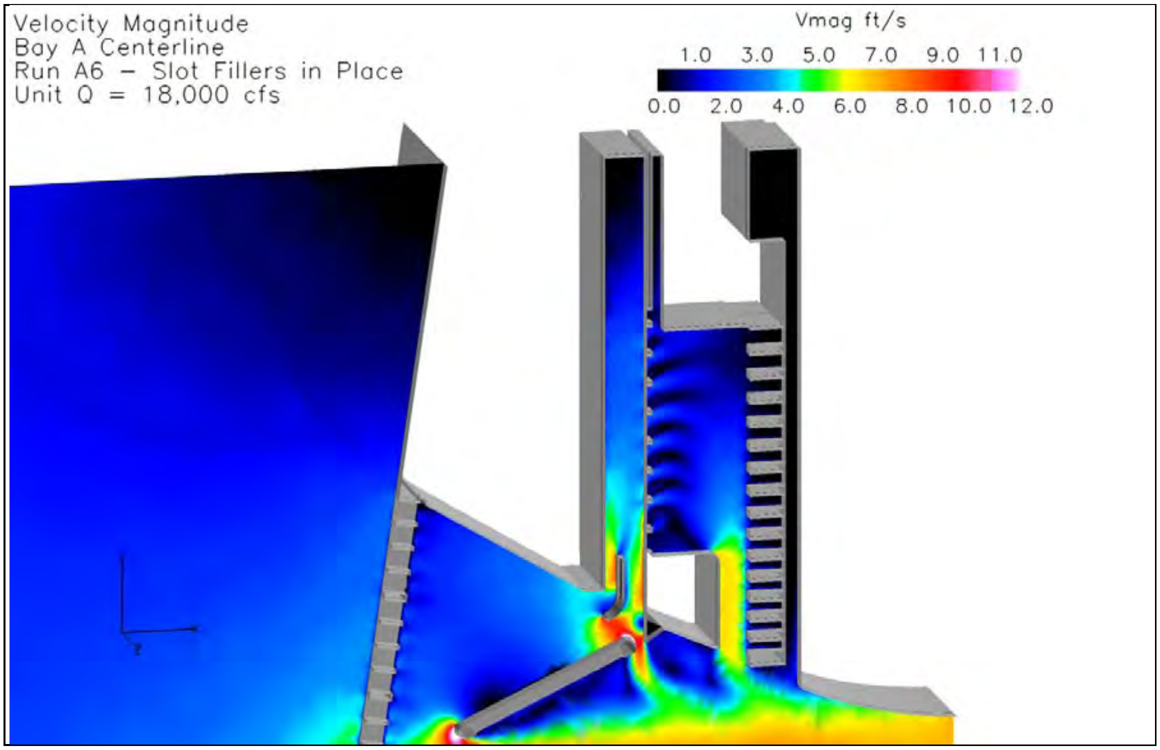


Figure 4-19. Alternative C1 – VBS Normal Velocities and Flow Patterns

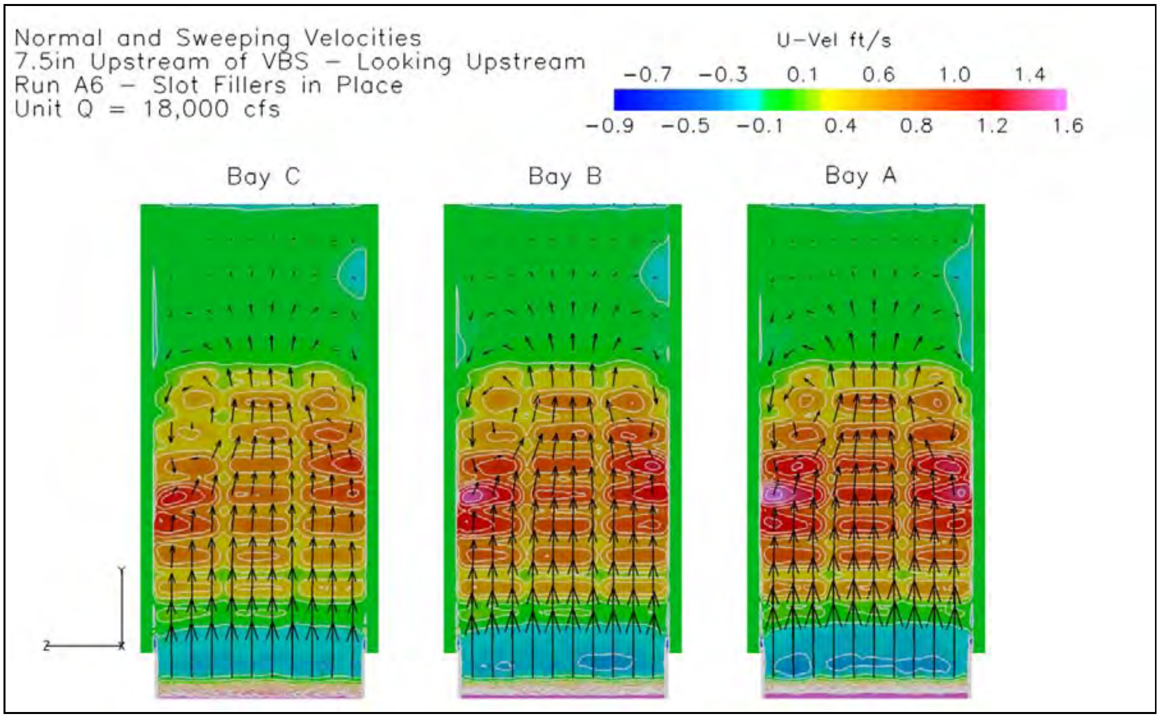
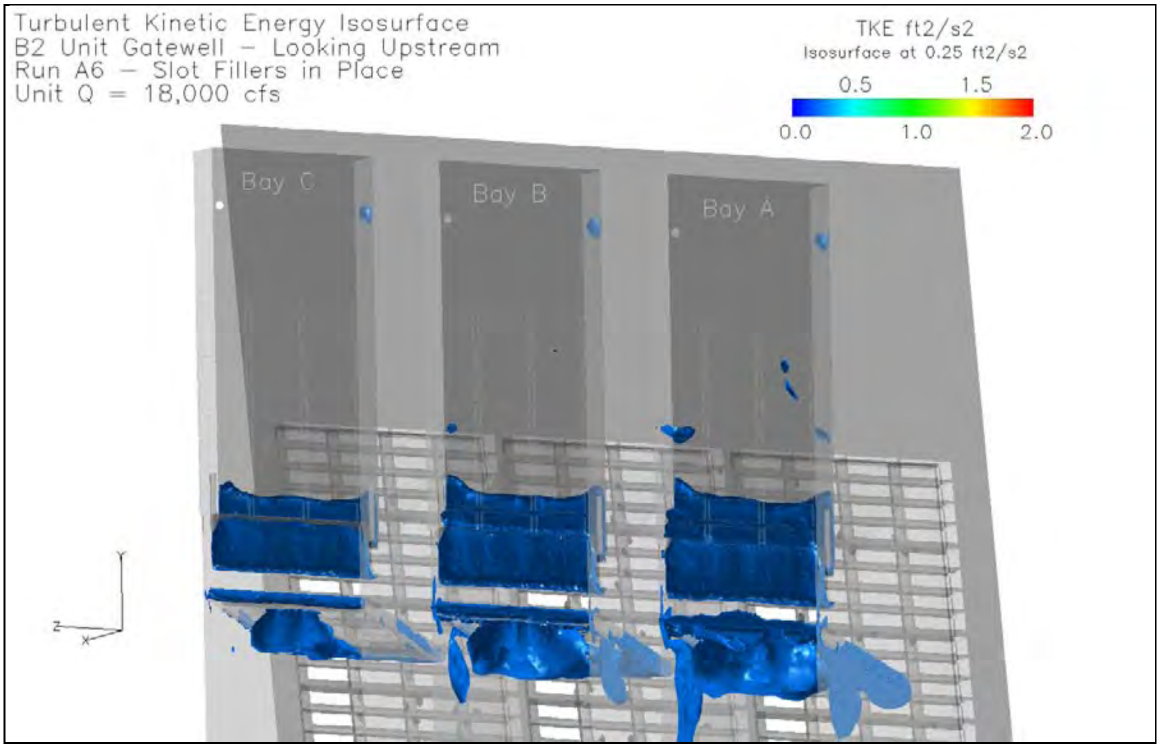


Figure 4-20. Alternative C1 – Turbulent Kinetic Energy Isosurface



4.9.5. Fisheries Considerations

CFD modeling of the current slot filler design has shown great promise in streamlining the flow up the gatewell, reducing turbulence, and more evenly distributing VBS normal velocities, even under high unit operations. This slot filler alternative may improve hydraulic conditions for passage, while also allowing the USACE to maintain the current unit operational range and without impacting FGE. These slot fillers are also capable of being designed, built and testing in a timely manner and if accepted can be easily outfitted throughout the entire powerhouse in one in-water-work season.

4.9.6. Operation and Maintenance

The bottom U-frame is lowered 20 feet into the gate slot with the lower lifting beam and dogged off (see Figure 4-?, Stage 1). Two 20-foot tall filler tubes are stacked on top of the bottom U frame and locked together. The upper lifting beam is then attached to the top, the lower lifting beam is removed, the dogs retracted and the frame is lowered an additional 20 feet to a total of 40 feet (see Figure 4-?, stage 2). The process is repeated and the frame is lowered another 20 feet to reach the intended elevation at the bottom (see Figure 4-?, stages 3 and 4). The lower U-frame serves a stiffened structural element, while the upper lifting beam serves both to move the frame assembly and provide required structural support at the top.

At the operational stage, an important aspect of this alternative that needs to be considered is the potential for conflict with the existing operating equipment. The STSs are in this slot, and the operating cables used to extend or retract the STS rotating screen are currently anchored in the guide slots. The video inspection camera uses this slot for inspection of the STS traveling screen and the VBS screen surfaces. Additional labor will be required to work the gate slot fillers in with current operations at the gate slot.

4.9.7. Cost

To be developed during the 60%-90% phase.

4.9.8. Advantages and Disadvantages

Advantages

- Easy to assemble. The Stage 1 assembly is a U-frame with a lower lifting beam. The subsequence stages are stacked together and locked as they are lowered in place while removal follows the opposite of the installation sequence.
- Easy to handle. All of the sections are designed to be no more than 20 feet long. The frame assembly can be deployed with a 15 ton crane, Tie crane, or gantry crane.
- Portable. The entire assembly can be designed to comprise seven components, four of which stack and lock together. An entire disassembled slot fill unit can be stored in a 20’ x 20’ x 6’-6” space.
- Lightweight. The entire assembly can be made out of aluminum.
- Corrosion proof. No painting will be required with the aluminum. All fasteners will be stainless steel.

Disadvantages

To be developed during the 60%-90% phase.

5. EVALUATION OF ALTERNATIVES

5.1. INTRODUCTION

Note: Evaluation of alternatives will be conducted in the 60%-90% phase

Each alternative will be evaluated using a point based matrix approach. The framework for matrix is shown in Figure 5-1. The matrix includes the following evaluation factors: biological benefits, construction costs, construction time, operating and maintenance cost, operational effectiveness, reliability, impacts to power revenues, and environmental factors. Numerical scoring for construction cost, operations and maintenance cost, and impacts to power revenue range from 0 to 4, with 0 being a highly unfavorable score and 4 being a highly favorable score. The numerical scoring for the remainder of the evaluation factors range from 1 to 4, with 1 being a highly unfavorable score and 4 being a highly favorable score.

5.2. EVALUATION FACTORS

This section describes the evaluation factors that were used to score the alternatives under consideration.

- Biological benefits evaluation factors were based on the ability of the alternative to meet the fish passage goals.
- Construction costs are considered in the evaluation of each alternative.
- Construction time is the overall difficulty or ease of constructing the alternative.
- Operation and maintenance cost considers the overall maintenance and cost of the alternative. For example, if a component needs to be inspected weekly, it will receive a low ranking score. If an alternative that has yearly maintenance or components that require less frequent inspections, it will receive a higher ranking score.
- Reliability evaluation factors are based on the overall ease to operate the alternative. For example, if the alternative had complicated steps required to operate or needed to be monitored on a continuous basis, it will receive a low score. If the alternative required few steps, less frequent monitoring, or required little or no adjustments to operate, it will receive a higher score.
- Impacts to power revenues were considered in the evaluation of each alternative.
- Environmental factors are based on the alternatives overall effect on water quality (total dissolved gas) in the river. Alternatives that increase the level of total dissolved gas from current estimated levels without the alternative will receive lower scores.

5.3. SUMMARY OF EVALUATION

Figure 5-1. Alternatives Evaluation Matrix

Alternative	**Biological Benefits**	a. Overall FGE	b. OPE	**Construction Costs**	**Construction Time**	**O & M Cost**	**Reliability**	**Impacts to Power Revenue**	**Environmental Factors**	**Comments**	**Total**
BASELINE											
Baseline Condition											
Flow Control Alternatives											
1. A1 - Flow Control Device, Adj. Louvers	🟩										
2. A2 - Flow Control Device, Sliding Plate											
3. A3 - Modify Vertical Barrier Screen Plates											
4. A4 - Modify Turning Vane and/or Gap Device											
Operational Alternatives											
5. B1 - Oper. Main Unit Off 1% Peak	🟩										
6. B2 - Open Second DSM Orifice											
7. B3 - Horizontal or Additional Orifices											
Flow Pattern Change Alternative											
8. C - Gate Slot Fillers	🟩										

General Scoring
Poor = 1
Fair = 2
Good = 3
Excellent = 4

Cost Scoring
High = 0
Medium-High = 1
Medium = 2
Low-Medium = 3
Low = 4

6. RECOMMENDATION

7. REFERENCES

ENSR. August 2004. Bonneville Second Powerhouse Fish Guidance Efficiency Program Interchangeable VBS Investigation, Contract No. DACW57-02-D-0004, Task Order No. 1, Modification Nos. 4 through 7, Final Submittal, Document No. 09000-309(2).

PNNL (Pacific Northwest National Laboratory). 2009. Bonneville Powerhouse 2, 3-D CFD for the Behavioral Guidance System, Draft Report. Richland, WA.

PNNL. November 2010. Water Velocity Measurements on a Vertical Barrier Screen at the Bonneville Dam Second Powerhouse, Draft Final Report. Richland, WA.