US Army Corps
of Engineers ®
Portland District

Bonneville Second Powerhouse FGE Velocity Data Collection Plan

Spring 2014

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Abbreviations and Acronyms

ADV	Acoustic Doppler Velocimeters
CFD	Computational Fluid Dynamics
EDR	Engineering Design Report
FGE	Fish Guidance Efficiency
ft/s	feet per second
kcfs	thousand cubic feet per second
PH2	Second Powerhouse
STS	Submerged Traveling Screen
VBS	Vertical Barrier Screen

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1. BACKGROUND

In 1999, regional fisheries agencies agreed to pursue a phased approach to improve 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 fish guidance efficiency (FGE). A typical juvenile fish bypass system at the lower Columbia River dams consist of submersible traveling screen (STS), gatewell orifice passage and turbine intake vertical barrier screens. The modifications at PH2 were completed in 2008 and 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 the STS, and installation of interchangeable VBS to allow for screen removal and cleaning without outages or intrusive gatewell dipping. Results of biological studies showed an increase in FGE by 21% for yearling Chinook and 31% for sub-yearling 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 Spring Creek National Fish Hatchery (SCNFH) released hatchery sub-yearling chinook in early spring over a 3-month period (March, April, May). The Bonneville Dam Pacific States Marine Fisheries Commission Smolt Monitoring Program recorded above average mortality. Facility inspections did not identify anything concerning. Biological testing conducted by National Oceanic and Atmospheric Administration (NOAA) suggested that SCNFH sub-yearlings and run of river juvenile chinook were incurring high mortality and de-scaling when the newly modified units were being operated at the upper 1% range. Evidence suggested a relationship may exist between the operation of the powerhouse units (lower, mid, and upper 1%) and survival of juvenile salmonids. 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. A detailed description of the lower, middle, and upper 1% turbine operating efficiency range can be found in the U.S. Army Corps of Engineers (USACE) Turbine Survival Program (TSP) Phase I and II Biological Index Testing (BIT) reports, as well as the current Fish Passage Plan (FPP).

Biological test data were evaluated by the USACE and preliminary alternatives were suggested to the region that could potentially regulate and throttle hydraulic conditions in the gatewell. The region agreed with the initial assessment and approved the study to investigate alternatives.

An Engineering Design Report (EDR) was started in 2010 and completed in September 2013. The EDR evaluated several potential alternatives based on the assumption and hypothesis that sub-yearling mortality is attributed, in great part, to acute turbulence in the gatewells that makes it difficult for fish to find the egress through the orifice. Fish not able to find the orifice get caught in turbulent eddies, fatigue, and eventually die from exhaustion. Integral to the EDR study, field velocity gatewell measurements were taken in the spring of 2013 that identified "hot-spots" on the VBS where velocities normal to the screen were in excess of one foot per second, strongly suggesting that the gatewells are being operated outside of design criteria. Findings were shared with regional fish managers and it was agreed that reducing juvenile salmonid mortality is the still the primary objective. It was agreed that understanding the hydraulic conditions and dynamics in the gatewell is essential prior to design.

2. OBJECTIVES

The USACE Portland District plans to collect water velocity data at PH2 in the spring of 2014 to help achieve the following objectives:

1. Evaluate the Performance of a Flow Control Plate – one of the flow control devices considered as part of the EDR is a flow control plate mounted downstream of the VBS on the gatewell beam that would potentially reduce flow up the gatewell. The region has indicated strong support for this alternative, so the USACE would like to construct a prototype and gather velocity data to evaluate its performance as part of the spring 2014 data collection effort. The data collected can be used to evaluate the effect of the flow control plate on the hydraulic conditions within the gatewell, and potentially for the design of a permanent flow control plate if it is decided that it is the preferred alternative for a long-term solution.

2. Calibration of Computational Fluid Dynamics (CFD) Model – an existing CFD model of a single unit at PH2 is the current tool, outside of an actual prototype, used for evaluating design alternatives to improve hydraulics within the gatewell. This model was calibrated using data collected from a 1:12 physical model, which has since shown to be inconsistent with data collected in the field. The field data collected in the spring of 2013 is currently being used to attempt to recalibrate the model, but that data was not collected during high unit flows (>18 kcfs) when fish survival in the gatewell is greatly diminished. The data that is planned to be collected in the spring of 2014 will serve two purposes with respect to the calibration of the CFD model:
    a. This data can be used to validate the data collected in the spring of 2013.
    b. This data will potentially be collected at higher unit flows so that an attempt can be made to calibrate the model for a larger range of unit flows, specifically at the higher unit flows that are a particular concern for fish survival.

3. Obtain Better Understanding of the Hydraulic Characteristics in Gatewell at High Flows – there has never been any velocity data collected in a gatewell at PH2 during unit flows greater than about 17 kcfs. However, the units are regularly operated above those flows, and biological testing indicates a large increase in fish mortality in the gatewells at those higher flows. Obtaining velocity data during high unit flows (>18 kcfs) will help provide a better understanding of the hydraulic conditions within the gatewells at those flows, and potentially help to clarify the cause of the higher fish mortality rates at those flows.

4. Evaluate the Effect of Modifying Upper Panels of VBS – field velocity data taken in the spring of 2013 identified “hot-spots” on the VBS in where velocities normal to the screen were in excess of one foot per second, which is outside of the design criteria. USACE is planning on modifying some of the porosity plates on a spare VBS and collecting velocity data with the modified VBS in place to see how the modifications might affect velocities elsewhere on the VBS. This data could potentially be used to develop a design to minimize areas of high velocity on the screen.

3. Data Collection

3.1. Execution

The water velocity data collection will be conducted by USACE consultant Harbor Consulting Engineers and Alden Research Laboratory, a sub-consultant to Harbor. USACE will oversee the data collection. The same team conducted the velocity data collection at PH2 in the spring of 2013.

3.2. Methods

The velocity data will be collected using a method that is very similar to that used for the data collection in the spring of 2013. The data will be collected using four acoustic Doppler velocimeters (ADVs), see Figure 1, which provide instantaneous velocity magnitude and direction at a given point. The ADVs will be mounted onto a traversing beam (Figure 2) that will be lowered into the gatewell by a set of cable hoists that connect to a support frame located on the deck. Data will be collected in a grid pattern approximately 8-inches upstream of the VBS, as shown in Figure 3. The traversing beam will be raised and lowered within the gatewell to adjust the elevation at which data is collected, and the ADVs will traverse laterally, parallel to the VBS, to collect data at several points at a given elevation.

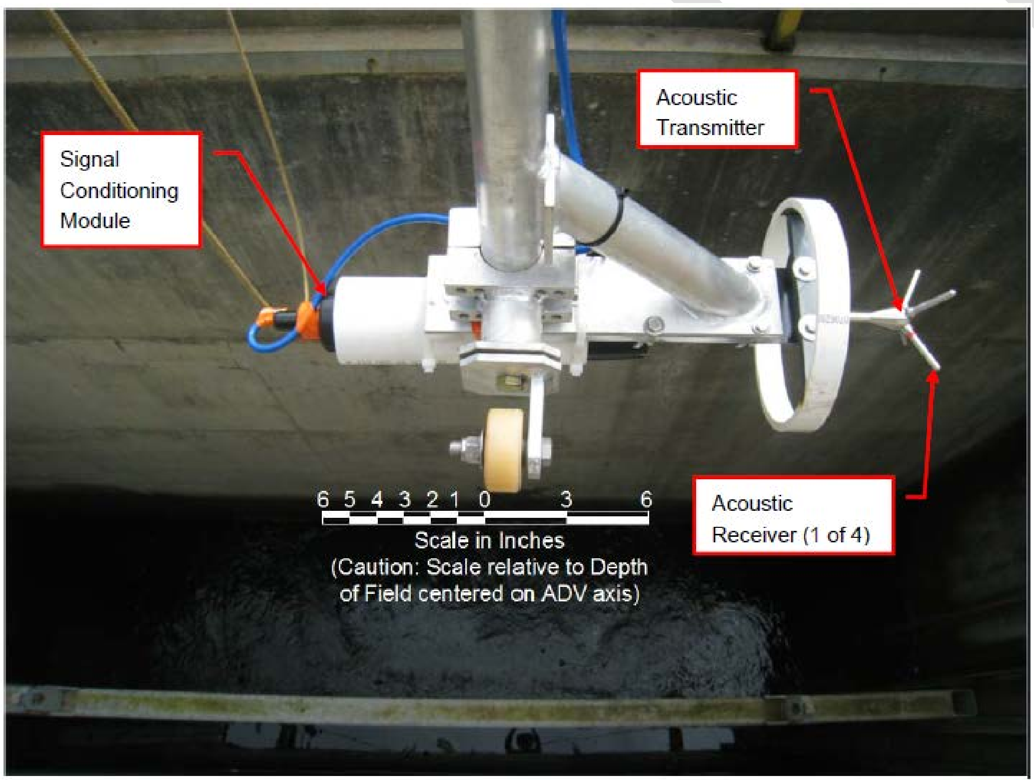


Figure 1: Nortek Vectrino ADV

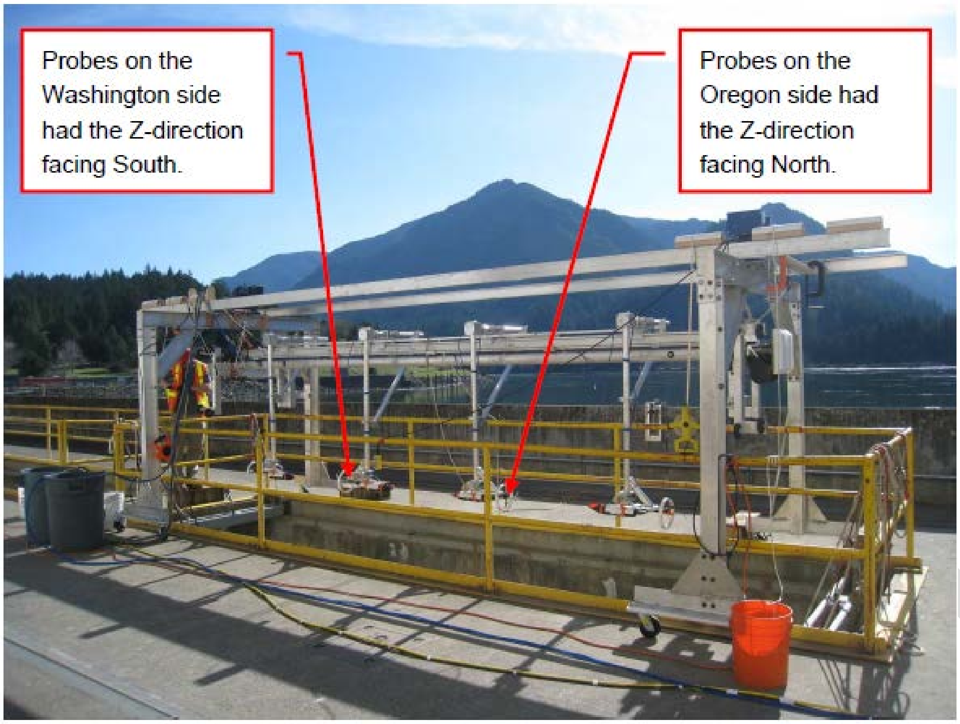


Figure 2: Probe Orientation within Gatewell (Looking East)

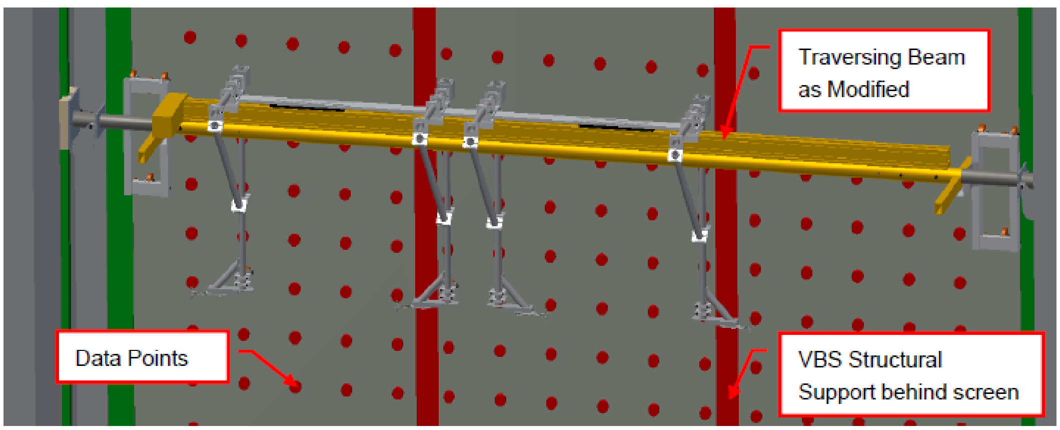


Figure 3: Traversing Beam Inside of Gatewell

3.3. Configurations

Data are planned to be collected with three gatewell configurations – with a flow control plate installed, existing conditions, and with a modified VBS. An important configuration to evaluate is a flow control plate installed downstream of the VBS on the gatewell beam. The intent of this configuration is to evaluate the effect of the flow control plate on the hydraulic conditions within the gatewell, since the flow control plate is a potential long-term solution for improving the hydraulics within the gatewell. The data collected with the existing conditions configuration will provide a baseline to compare the other configurations to, as well as provide for comparison of previously collected data, and potentially provide velocity data at higher unit flows than has previously been collected. There is an existing spare VBS that is sometimes deployed in a unit when that unit's VBS is being cleaned. This spare VBS will be modified such that the porosity plates on the upper two panels are completely blocked. The intent of this configuration is to see how modifying the porosity plates in the areas where high normal velocities were observed will affect the other screen panels.

The flow control plate will need to be installed prior to data collection, and will remain in-place until a scheduled unit shut-down, which is likely to occur in the fall of 2014. The flow control plate is planned to be installed in the A slot of Unit 15, or possibly in the A slot of Unit 13, depending on the scheduled unit outages and when the work can be contracted out. Unit 15 has a scheduled outage for digital governor installation beginning Feb. 4^{th} and needs to be back in service by April 4. The contractor will need to be done working in the Unit one week prior to the return to service date. A short outage is scheduled for Unit 15 in Sept. which could provide an opportunity for plate removal. Unit 13 has a scheduled outage from April 7 to May 16 for digital governor installation. There is a Unit 13 T11 outage currently scheduled for July 21 to August 29 which could be a window for plate removal. Velocity data will be collected at low and high unit flows.

The other two configurations to be tested, existing conditions and with a modified VBS, are planned to occur in Unit 14. For the existing conditions, velocity will be collected in the A and C slots. The purpose of collecting data in the C slot is to confirm the flow distribution between the A and C slots. Velocity will be collected in the A slot only for the configuration of the modified VBS. Velocity data is planned to be collected at low and high unit flows for both configurations in the A slot, and only at high unit flow for the existing conditions configuration in the C slot.

A total of eight scenarios are planned for data collection. A summary of the scenarios is shown in Table 1 below.

Table 1: Scenarios for Data Collection

Configuration	Location	Flow
Existing Conditions	14A	Low and High
Existing Conditions	14C	High
Modified VBS	14A	Low and High
Flow Control Plate	15A or 13A	Low and High
To Be Determined	*15A or 13A*	*High*

3.4. RIVER AND UNIT OPERATIONS

The following table from the 2013 Fish Passage Plan shows that 57 feet of head or less is required to be able to pass >18,000 cfs through the unit with STS installed, typical of our most problematic flows for fish passage through gatewells in the screened bypass system. A 74-75 ft forebay operation would require at least a 210 – 225 KCFS river flow to achieve that head.

Table 2: Bonneville Dam Powerhouse Two Turbine Units 11-18 (with and without STSs) Output (MW) and Discharge (cfs) at the Upper and Lower Limits of the 1% of Peak Efficiency Operating Range.

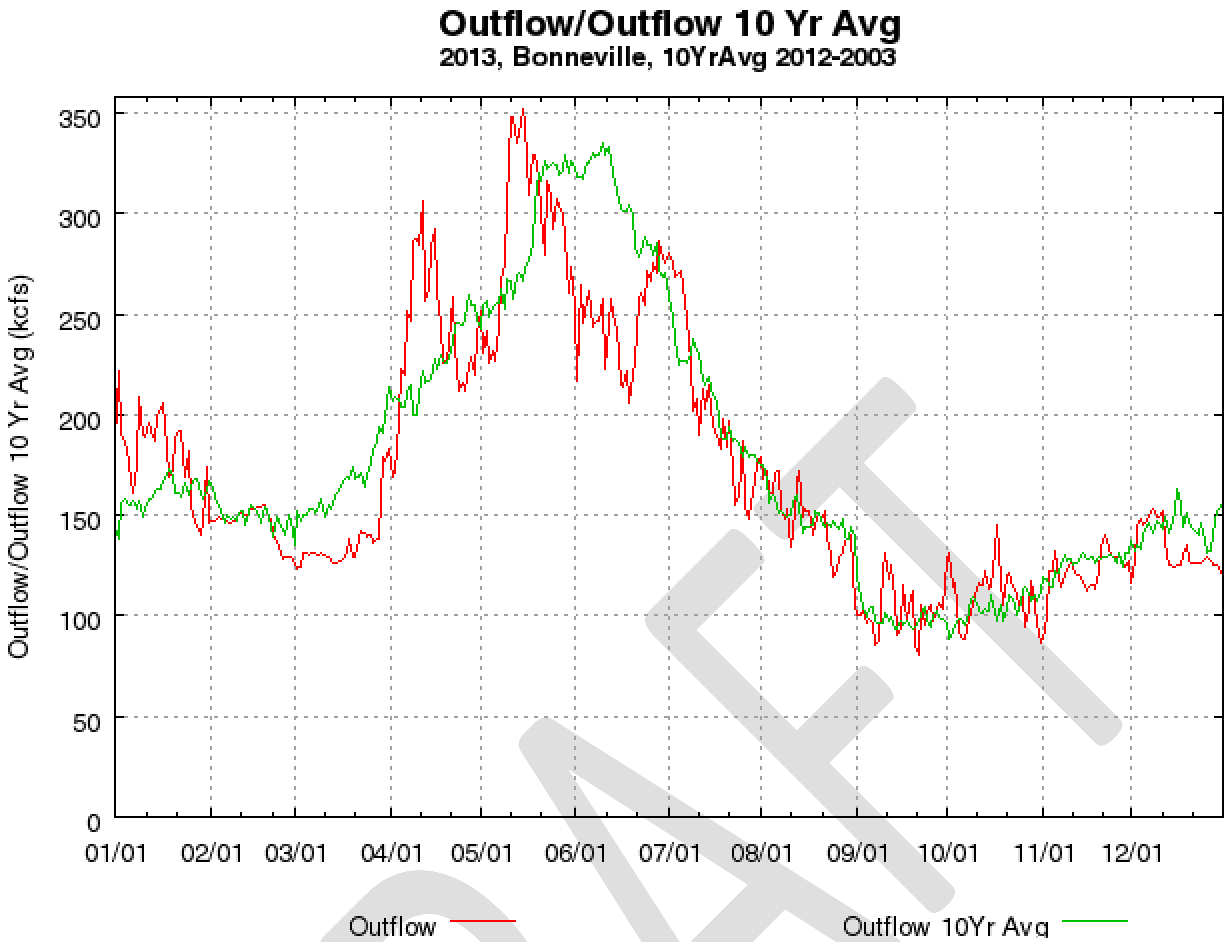
Head (feet)	Powerhouse Two (units 11-18)							
	With STS				Without STS			
	Lower 1% Limit		Upper 1% Limit		Lower 1% Limit		Upper 1% Limit	
	(MW)	(cfs)	(MW)	(cfs)	(MW)	(cfs)	(MW)	(cfs)
35	27.6	11,259	44.3	18,068	28.2	11,444	45.1	18,277
36	28.5	11,271	45.8	18,097	29.2	11,455	46.6	18,306
37	29.4	11,279	47.3	18,121	30.1	11,464	48.1	18,331
38	30.3	11,284	48.8	18,139	31.0	11,470	49.7	18,350
39	31.3	11,287	50.3	18,153	32.0	11,473	51.2	18,364
40	32.2	11,288	51.8	18,162	32.9	11,474	52.7	18,374
41	33.0	11,259	53.3	18,197	33.7	11,445	54.3	18,409
42	33.8	11,230	54.9	18,228	34.6	11,415	55.8	18,441

43	34.6	11,201	56.4	18,255	35.4	11,386	57.4	18,468
44	35.4	11,172	57.9	18,278	36.2	11,357	58.9	18,493
45	36.2	11,144	59.4	18,299	37.0	11,328	60.5	18,514
46	37.0	11,139	61.0	18,366	37.9	11,324	62.1	18,581
47	37.8	11,135	61.9	18,200	38.7	11,319	63.0	18,415
48	38.7	11,129	62.7	18,040	39.6	11,314	63.8	18,255
49	39.5	11,124	63.5	17,887	40.4	11,308	64.7	18,101
50	40.3	11,118	67.5	18,598	41.3	11,303	68.7	18,817
51	41.3	11,154	69.8	18,850	42.2	11,339	71.1	19,072
52	42.3	11,187	72.1	19,091	43.2	11,373	73.4	19,316
53	43.2	11,219	74.5	19,323	44.2	11,405	75.8	19,551
54	44.2	11,249	76.5	19,536	45.2	11,436	76.5	19,431
55	45.2	11,278	76.5	19,115	46.2	11,466	76.5	18,975
56	46.4	11,343	76.5	18,718	47.4	11,531	76.5	18,581
57	47.6	11,404	76.5	18,336	48.6	11,593	76.5	18,202
58	48.8	11,461	76.5	17,967	49.9	11,652	76.5	17,836
59	50.0	11,515	76.5	17,611	51.1	11,707	76.5	17,483
60	51.2	11,567	76.5	17,267	52.3	11,760	76.5	17,142
61	51.8	11,532	76.5	16,978	53.0	11,724	76.5	16,857
62	52.5	11,498	76.5	16,699	53.7	11,690	76.5	16,582
63	53.1	11,466	76.5	16,428	54.3	11,657	76.5	16,315
64	53.7	11,434	76.5	16,166	55.0	11,625	76.5	16,056
65	54.4	11,405	76.5	15,912	55.6	11,595	76.5	15,806
66	55.4	11,448	76.5	15,671	56.7	11,639	76.5	15,570
67	56.5	11,490	76.5	15,437	57.8	11,682	76.5	15,341
68	57.5	11,532	76.5	15,210	58.9	11,724	76.5	15,119
69	58.6	11,571	76.5	14,990	59.9	11,764	76.5	14,903
70	59.6	11,610	76.5	14,775	61.0	11,803	76.5	14,693

* Table based on data provided by HDC, January 2001 (Table BON-16 revised 2006)

Lower River flows that result in head at the unit higher than 57 ft has limited the FGE programs ability to collect information in the gatewell during biological testing in 2001, and hydraulic testing in 2010 and 2013. It is imperative that the unit flows representing the most problematic conditions for fish passage through the gatewells be measured during testing in 2014. Biological testing in 2001 was limited to an upper 1% efficiency representation of 15.8K due to a low flow year. Testing in 2010 was also limited 15.8K at upper 1% and 2013 test conditions allowed 17K. 2010 and 2013 testing occurred prior to spill when the river Q was too low to achieve the high end 1% range test goal. This may not always be the case for that time of year but it is essential to minimize risk of inferior data collection and complications with scheduling contractors.

To achieve the FGE program goals for the long term, it would be prudent to test in the gatewell in latter half of May or early June and minimize risk of not being able to achieve 18+K through the unit and resulting flows into the gatewell. The following graph from DART shows the 10 year average outflow at Bonneville Dam (green) and outflow from 2013 (red) for comparison.



Columbia River DART, Columbia Basin Research, University of Washington. (2014). Available from http://www.cbr.washington.edu/dart/query/smolt_graph_text

The typical March timeframe normally scheduled for testing to minimize fish impacts is problematic for the desired upper end 1% efficiency flow conditions. Additionally, there may not be enough time to execute a contract as well as have the contractor fabricate and install equipment in Unit 15 during the March timeframe.

3.5. SCHEDULE

The primary goal underlying all of the objectives noted above is to obtain velocity data during high unit flows. For that reason, the data collection is planned to be conducted in late May and early June 2014 when the chances of achieving the desired flows are highest while minimizing fish impacts. During the first week, there will be an initial set-up and deployment of the equipment for wet-testing prior to the data collection. The equipment will be set up and lowered into the gatewell to check for performance and interferences. No data will be collected during the equipment set-up and wet-testing.

Data collection for each scenario described above is anticipated to take approximately 10 hours, or one work day. Accordingly, it is expected that the data collection equipment will be deployed in a gatewell for a total of eight work days for data collection, one work day for sensitivity testing, and a total of one day for wet-tests prior to data collection. There is only one set of data collection equipment, so there will only be equipment in one gatewell at any given time. Taking into account the mobilization of the data collection equipment, the mobilization of the personnel performing the data collection, and the weekends, it is anticipated that the data collection will take approximately three-and-a-half weeks. Table 3 below shows the preliminary schedule for data collection.

Table 3: Preliminary Schedule

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
May 18 Mobilization to site	**19** Equipment Setup (No ADVs)	**20** Wet Test	**21** Equipment Setup (With ADVs)/ Wet Test	**22** Low-Flow Test #1	**23** Partial Demobilization	**24**
25	**26** Memorial Day Mobilization to site	**27** Low-Flow Test #2	**28** Low-Flow Test #3	**29** Sensitivity Testing	**30** Partial Demobilization	**31**
June 1 Mobilization to site	**2** High-Flow Test #1	**3** High-Flow Test #2	**4** High-Flow Test #3	**5** High-Flow Test #4	**6** Equipment Demobilization	**7**
8 Mobilization to site	**9** High-Flow Test #5	**10** [Reserve testing day]	**11** Equipment Demobilization	**12**	**13**	14