FISH PASSAGE CENTER

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MEMORANDUM

TO: Dave Statler, NPT
Dave Wills, USFWS
Charles Morrill, WDFW

FROM: Michele DeHart

DATE: June 7, 2012

RE: Juvenile Fish Mortality Estimates for Bonneville Second Powerhouse Bypass

In response to your request we have used the smolt monitoring information collected at the Bonneville PH2 bypass system to calculate the total mortality and descaling that has occurred in the juvenile salmon population passing through this bypass system thus far this year. The estimates were developed for the time period from March 2, 2012 to May 30, 2012 for the real-time project operations.

- A total of 52,496 juvenile salmonid mortalities occurred during the operation of the Bonneville PH2 juvenile bypass system through May 30, 2012. The passage through the PH2 juvenile bypass system represents a subset of the total mortality of juvenile salmonids that died as a result of passing Bonneville Dam.
- An additional total of 73,299 juvenile salmonids were descaled during the operation of the Bonneville PH2 juvenile bypass system through May 30, 2012. The expected mortality on these fish could be as high as 75%, converting to a loss of an additional 54,974 juvenile salmon.
- Based on average Bonneville to Bonneville smolt to adult returns collected since 2000, the juvenile mortalities at Bonneville PH2 convert to an expected loss of 1,106 adults

and up to an additional 1,169 adults from the descaled juveniles using the 75% loss conversion estimate.

- To provide a relative perspective, this represents an equivalent percentage of the adult population passing through May 30th that was estimated to be removed by sea lions below Bonneville Dam in 2012.
- Although the action agencies routinely exceeded the FOP TDG criteria for the purpose of involuntary spill (lack of market or excess hydraulic capacity), the Action Agencies would not agree to additional voluntary spill to avoid powerhouse passage (to improve fish survival) during the Spring Creek National Fish Hatchery releases, or during passage of juvenile sockeye.
- Adopting a strategy of provision of additional spill for fish passage and decreasing the operation of the turbines at the powerhouse to the mid to low end of the 1% efficiency, could have improved juvenile survival, and adult return, by reducing the number of fish passing through the Bonneville PH2.

Background

Some level of mortality and descaling occurs at every hydro-electric project bypass system. However, over the past years the mortality and decaling rates have been elevated at Bonneville PH2. The high juvenile mortality and descaling rates were first noted in 2008 after changes were made to the juvenile bypass system at PH2 to improve the proportion of fish passing through the system. A study conducted by Hughes et al. (2011) obtained information on velocity measurements near the screens. The study revealed approach velocities exceeding recommended criteria intended to improve fish passage conditions. The authors concluded that the turbulence in the gate well region in proximity to the VBS when PH2 was operated at the upper 1% efficiency range could be expected to result in suboptimal fish passage conditions. The high velocities and turbulent conditions could cause impingement, impact, or descaling of juvenile salmonids before they exit through the orifice into the juvenile fish bypass channel. In addition, the powerhouse turbine unit discharge rate directly affected the velocity distribution as well as the turbulence conditions in the gate well. Both the velocity and the turbulence increase as the operation within the 1% efficiency range increases. Results of this COE funded study revealed that the approach velocities in the gate wells exceeded criteria intended to improve fish passage conditions recommended by National Marine Fisheries Service and the Washington State Department of Fish and Wildlife.

Based on what is known about the hydraulic turbulence in the bypass of Bonneville PH2, the best condition for fish passage survival would be to operate PH2 at the low end of the 1% operating range. In 2012, the fishery agencies and tribes recognized the high flows this year and addressed the potential for mortality at Bonneville PH2, which increases as operation includes the upper range of the 1% efficiency, by requesting that the Action Agencies cap PH2 at the mid-point of the 1% best efficiency range. The Action Agencies would not implement the request because the operation would result in additional voluntary spill in excess of the involuntary spill that was already exceeding the gas cap. The Action Agencies implemented the following flow neutral operations that at times resulted in operation near the midpoint of

the 1% efficiency, but also included operating above the 50% range of the 1% and operating PH1 above the 1% efficiency range:

1. Bonneville (BON) PH2 units will be operated at the 25% of the 1% operating range;
2. To pass additional flows, operate powerhouse 1 (PH1) units up to the 100% (full capacity) of the 1% operating range;
3. To pass additional flows after PH1 is fully loaded, increase PH2 units one at a time in the order of priority within 25-50% of the 1% operating range;
4. To pass additional flow after PH1 is fully loaded and all available PH2 units are operating at 50%, increase operation of PH1 units up to best geometry;
5. To pass additional flow after all available PH1 units are operating at best geometry; increase PH2 units one at a time in the order of priority within 50-75% of the 1% operating range;
6. To pass additional flow after all available PH2 units are operating at 75%, decrease PH1 unit operation to 100% of the 1% operating range and increase PH2 units one at a time in the order of priority within 75-100% of the 1% operating range.

Juvenile Mortality and Descaling

The mortality and descaling measurements described in this memo were obtained during the implementation of the Action Agencies recommended flow neutral operation of Bonneville Dam. The daily mortality estimates have ranged from 0% to 33%, and the descaling estimates have ranged from 0% to 25%.

Condition sampling occurs daily as part of the SMP sampling. The primary role of the condition monitoring is to identify the proportion of each species of migrant juvenile salmon that are descaled or have significant injuries indicative of problems in fish passage at dams such as debris in the fish bypass apparatus or mechanical issues. In the condition monitoring, a distinction is made between fish that are descaled and fish that are descaled with concurrent injuries or predator marks. While a fish that is descaled while passing through the bypass system can also display injuries or predation marks that are independent of its descaling, the distinction is made in the SMP condition monitoring to be conservative. In addition, effort is made to assure that only recent injury and descaling data are reported to eliminate descaling or injuries that were likely not to have occurred at the dam where the fish are being examined.

In order to determine the mortality that occurred by species for fish passing through the Bonneville PH2 bypass system, the daily sample was expanded by the daily sample rate to obtain a daily collection (number of fish passing Bonneville PH2 bypass). The daily collection was then multiplied by the daily sample mortality rate and the estimates were summed over the time period. (Daily collection, mortality and descaling data are available at www.fpc.org). Table 1 displays the total mortalities in the Bonneville Powerhouse 2 bypass collection when mortality rate from the sample was expanded to the total collection on a daily basis.

Table 1. Expanded juvenile fish mortalities at Bonneville Dam PH2 bypass in 2012.

Species	Average Percent Mortality	PH 2 Bypass Mortalities
Chinook subyearling	2.4%	18,221
Chinook yearling	1.9%	14,958
Coho	0.7%	1,028
Sockeye	7.2%	17,976
Steelhead	0.4%	313

A total of 52,496 juvenile salmon mortalities occurred in the Bonneville PH2 juvenile bypass system thus far in 2012.

Table 2 displays the total number of descaled fish that were estimated passing through the PH2 bypass system after the daily estimates were summed over the time period in the same way that mortalities were estimated. It is difficult to assess the impact of descaling on the future survival of juvenile salmonids. However, there is considerable evidence stating that descaling injuries have serious implications to stress related indicators and osmoregulatory ability (Congleton et al., 1998; Zydlewski et al., 2010). Evidence suggests that impairing the osmoregulatory performance during smolting compromises the long-term survival of descaled smolts subsequently entering seawater.

Bouck and Smith (1979) concluded that the loss of scales during or immediately before a saltwater challenge is a very real threat to the life of a salmonid smolt. Removal of slime and scales from 25% of the body area of coho smolts caused no deaths in fresh water, but 75% mortality within 10 days in seawater. Since smolts at Bonneville will generally enter seawater within a few days of leaving the project, this 75% mortality estimate could be used to describe the potential mortality associated with this descaled population from Bonneville PH2 bypass system.

Table 2. Expanded juvenile fish descaled at Bonneville Dam PH2 bypass in 2012.

Species	Average Percent Descaled	PH 2 Bypass Descaled
Chinook subyearling	0.1%	686
Chinook yearling	4.3%	30,729
Coho	2.3%	2,053
Sockeye	15.2%	38,042
Steelhead	2.8%	1,789

Therefore, using the 75% mortality estimate and applying it to the total number of descaled fish yields the possibility that an estimated 54,974 additional juvenile salmonid mortalities could be attributed to the passage through the Bonneville PH2 bypass.

Conversion to Adult Equivalents

The Bonneville to Bonneville smolt to adult return estimates were calculated for PIT tagged spring Chinook and steelhead smolts arriving at Bonneville dam for seven years between 2000 and 2009; with the exception of 2001, 2004 and 2005. These years were not included because: 1) there were relatively few detections of fish at BON in those years and, 2) the smolt hydrosystem experiences (i.e., number of bypass events) was higher in those years due to the elimination of spill. In these analyses, adult returns are all adults, including jacks. The SARs for wild and hatchery combined spring Chinook ranged from 1 to 4.1%, with an average of 2.1% and, for wild and hatchery combined steelhead the SARs ranged from 1.4 to 6.0%, with an average of 3.2%. (Table 3 and 4, Steve Haeseker, USFWS, personal communication).

Table 3. Estimated smolt to adult return rates for PIT tagged juvenile wild and hatchery Chinook detected at Bonneville Dam.

Wild and hatchery Chinook			
Year	Smolts	Adults	SAR
2000	10436	382	0.037
2002	15363	231	0.015
2003	15551	123	0.008
2006	8385	113	0.013
2007	17373	222	0.013
2008	8135	336	0.041
2009	15971	274	0.017
		Average	0.021

Table 4. Estimated smolt to adult return rates for PIT tagged juvenile wild and hatchery Chinook detected at Bonneville Dam.

Wild and hatchery steelhead			
Year	Smolts	Adults	SAR
2000	2957	115	0.039
2002	3335	87	0.026
2003	3801	52	0.014
2006	1201	30	0.025
2007	2170	68	0.031
2008	11491	687	0.060
2009	16232	473	0.029
		Average	0.032

For this analysis the average Chinook SAR was applied to yearling Chinook, subyearling Chinook, coho and sockeye and the combined steelhead SAR was applied to the juvenile population of steelhead. Table 5 shows the loss of fish in terms of adult equivalents that would be expected based on the juvenile mortality estimates at Bonneville PH2.

Table 5. Expanded juvenile fish mortalities to adult equivalents at Bonneville Dam PH2 bypass in 2012.

Species	Juvenile Mortalities	Adult Equivalents
Subyearling Chinook	18,221	383
Yearling Chinook	14,958	314
Coho	1,028	22
Sockeye	17,976	377
Steelhead	313	10
Total		**1,106**

A total of 1106 adult equivalents could be lost from the returning adult population to Bonneville Dam of spring/summer and fall Chinook, coho, sockeye and steelhead combined based on the juvenile mortalities at this project through May 30, 2012. The impact of juvenile passage at Bonneville PH2 bypass system will have the greatest impact on the returning adult populations of Chinook and sockeye.

Table 6 shows the loss of fish in terms of adult equivalents that would be expected based on the juvenile descaling estimates at Bonneville PH2 bypass system, with a conversion rate of 75% mortalities based on Bouck and Smith (1979). The same average smolt to adult conversion rates were then applied to the juvenile mortalities to yields the adult equivalents.

Table 6. The number juvenile fish descaled expanded to adult equivalents at Bonneville Dam PH2 bypass in 2012, using a 75% conversion of descaling to mortality.

Species	Juvenile Mortalities	Adult Equivalents
Subyearling Chinook	686	11
Yearling Chinook	30,729	484
Coho	2,053	32
Sockeye	38,042	599
Steelhead	1,789	43
Total		**1,169**

A total of 1,169 adult equivalents could be lost from the returning adult population to Bonneville Dam of spring/summer and fall Chinook, coho, sockeye and steelhead combined based on the juvenile descaling rates and projected mortalities at this project through May 30, 2012. The impact of juvenile passage at Bonneville PH2 bypass system will have the greatest impact on the returning adult populations of spring/summer Chinook and sockeye due to the high decaling rates on these populations.

To put the number of adult equivalents that will not return to Bonneville Dam based on the juvenile mortality data in 2012 from PH2 bypass system passage, we used the percentage of adult salmonids consumed by sea lions below Bonneville Dam in 2012. Although the data are still preliminary the *Columbia Basin Bulletin (June 1, 2012)*, reports that it appears the overall predation expanded estimate will be about 1.3 percent of the January 1 through May 31 salmonid run. The expected final adjusted estimate (for unidentified prey and night time predation) will be slightly higher. While the juvenile salmon represents more species, if we were for illustrative purposes to take the total number of adult equivalents from both mortalities and descaling (2,275) at the Bonneville PH2 juvenile bypass system and divide it to the total number of

salmonid adults that have passed Bonneville Dam through May 30th (169,219) it would also equal 1.3% of the 2012 adult salmon run to May 30, 2012.

Total Dissolved Gas Effects

You also requested that we attempt to quantify what the change in total dissolved gas levels would have been if the COE did not reject the recommendation based on the need to provide a flow neutral implementation of operations. You also asked if we could translate those effects into estimated juvenile mortalities that might have occurred from such an operation of increased spill levels. It is difficult to estimate the exact change in flow that would have had to be added to spill in order to operate PH2 at the middle and lower end of the 1% efficiency range, since it is dependent on the project head (the difference in elevation between the forebay and tailwater). A lower head characterizes the condition when there is high flow through the project and at a lower head; it requires that less water be spilled. We chose to do the analysis based on the information shared by the COE at the Technical Management Team call on May 30th, operating at the mid-point of the 50% range requires a reduction in flow of 25 Kcfs, while operating to the 25% of the 1% operating range reduces flow through the powerhouse by 36 Kcfs. These data are for a lower flow than occurred in late April to mid-May, but should mean that the analysis is very conservative.

The analysis used the Cascade Island tailrace gage to measure water quality compliance. We recognize that the COE uses both the Camas/Washougal and Cascade Island tailrace gage to measure compliance, however, neither the State of Oregon nor the State of Washington require the use of the Camas/Washougal gage. The use of the Camas/Washougal gage as mimicking the next downstream forebay is recognized as being problematic because other factors, such as temperature and biological processes that produce oxygen, affect the concentration of TDG at this gage. While reductions of spill upstream will decrease the TDG at this gage, the spill itself is not responsible for the excursions beyond 115%.

Using the data from 2012 through May 31st was developed an exponential regression model to predict the Cascade Island gage TDG from spill at Bonneville Dam. The Cascade gage has not been operational for most of the time period considered this year, but the COE is providing estimated modeled TDG. Using the COE data we developed the following equation (R^2= 0.65):

$$TDG = 112.71e^{(0.0005*BonSpill)},$$

The actual and predicted TDG under the various operations are shown in Table 7. As can be observed in Table 7 and in Figure 1 the majority of time spill at Bonneville was already in excess of the BIOP spill levels for most of the time period considered. The increases in spill of 25 and 36 Kcfs did cause the tailrace TDG to exceed the 120% level on more days in the 61 day period, but rarely did the TDG levels exceed the 125%. Again, these are conservative estimates and are based on the reductions stated by the COE on the May 30th TMT conference call. On average, the TDG increase was 1.4% at 25 Kcfs additional spill to 2.2% with an additional 36 Kcfs spill.

Table 7. Actual versus estimated spill and TDG for conditions that might have occurred if the Bonneville PH2 was operated at the mid or lower end of the 1% efficiency range.

Operation	Spill	TDG	Number of Days Cascade Island Gage Exceeded out of 61 Days:		
			120%	125%	130%
Actual	130.4 Kcfs Range: 74.6-229.1 Kcfs	122.3% Range: 117.1-131.2%	42	10	3
+ 25 Kcfs Spill	155.4 Kcfs Range: 99.6-254.1 Kcfs	123.8% Range: 119.7-131.3%	60	12	3
+36 Kcfs Spill	166.4 Kcfs Range: 110.6-265.1 Kcfs	124.6% Range: 120.4-132.1%	61	16	4

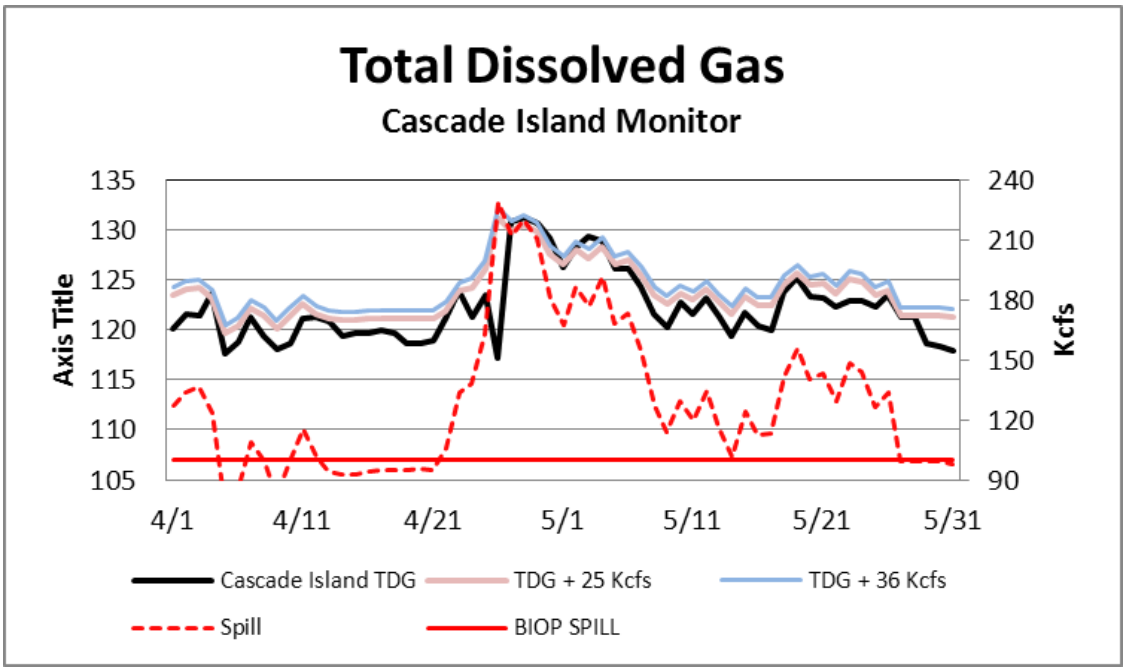

Figure 1. Actual spill compared to the Biological Opinion level of 100 Kcfs, and actual total dissolved gas concentrations compared to the modeled concentrations for two increased levels of spill.

The increased spill from the operation of Bonneville PH2 to the 25% or 50% of the 1% efficiency range would likely have caused no additional mortality to the juvenile fish population passing Bonneville Dam from gas bubble trauma. The gas bubble trauma monitoring program has demonstrated that few fish are observed with signs of GBT until TDG levels approach and are sustained for a period of time at levels above 130%. The operation as described above would

only have resulted in one additional day when the TDG at Cascade Island would have been above the 130% level, and we are most likely over-estimating the change in TDG because at these already high flows the additional spill would have been considerably less than the 25 or 36 Kcfs we modeled.

In summary, the operation of Bonneville PH2 as occurred in 2012 through May 30th imposed considerable mortality on juvenile fish passing through this bypass. It is likely that fish operations requested for operating this project at the low end of the 1% operating range would have reduced both the direct mortalities that occurred and the descaling levels, while likely imposing little or no additional mortality due to the levels of total dissolved gas that were predicted to occur with increased spill levels.

References:

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DATA REQUEST FORM

Request Taken By: M. Filardo **Date:** 5/30/12

Data Requested By:
Name: Dave Statler **Phone:**
Address: NPT **Fax:**
Charlie Morrill, WDFW **Email:**
Dave Wills, USFWS

Data Requested:
Estimate the number of juveniles ~~that~~ mortalities at BVL PH II Dam thus far this year by species. If possible, convert to adult returns.

Also, make a comparison based on existing GBT data of the additional mortality that would have been imposed if TDG were to exceed the 115/120% by a few percent

Data Format: **Hardcopy** [1] **Text** [ ] **Excel** [ ]

Delivery: **Mail** [ ] **Email** [ ] **Fax** [✓] **Phone** [ ]

Comments:

Data Compiled By: FPC Staff **Date:** 06/07/12

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