FISH PASSAGE CENTER

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Ms. Agnes Lut
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Oregon Department of Environmental Quality
Water Quality Division, Watershed Management
811 SW 6th Ave
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Mr. Andrew Kolosseus
Water Quality Program
Washington State Dept. of Ecology
PO Box 47600
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Dear Ms. Lut and Mr. Kolosseus,

At your request the Fish Passage Center developed a presentation for the December meeting of the Adaptive Management Team providing estimates of spill volume changes that might be expected if the 115% TDG forebay monitoring sites were no longer used for management purposes. Further request was made to develop a short description of the analyses conducted for the presentation and this document responds to that request.

The analysis suggested that the volume of spill that was limited by the 115% TDG forebay management could be significant with the largest changes expected Little Goose, Lower Monumental and the Lower Columbia projects. The analysis then translated the changes in spill to changes in fish passage at a project. As you can see from the tables the additional proportion of fish passing a project if forebay monitoring sites were no longer used for management varies among projects and water years, however, the present operation of limiting spill on the basis of forebay monitoring criteria has resulted in reducing the numbers of fish that could pass a project via the spillway.

Sincerely,

Michele DeHart

Michele DeHart
Fish Passage Center Manager

Spill Volume Changes with Use of Tailrace Monitors

Fish Passage Center
January 2008

When the TDG criteria were initially developed in 1995 as part of the management of dissolved gas, it was not anticipated that the 115% TDG criteria in the forebay would limit the implementation of the Biological Opinion spill program at upstream projects to the extent that has been observed since that time. This analysis was undertaken at the request of the Adaptive Management Team to show the difference in the amount of spill under the implementation of the Biological Opinion spill program that would have occurred if spill had not been managed using the forebay criteria. The approach employed in the analysis was to use empirical data for each year and estimate changes in spill volumes without restrictions in spill operations based on forebay monitors. Actual spill levels (Base Case) were estimated for 4 years including three low to moderate water years (2003, 2005, and 2007) and a high water year (2006). The Base Case levels were then compared to three alternate operational scenarios. The scenarios considered in the analysis were:

- Base Case,
- Spill (**FB restricted**) that would have occurred if all projects spilled to the 120% cap on days when spill was restricted by the 115% downstream forebay (but not the 120% tailrace),
- Spill (**120% Limited**) that would have occurred in that year if all projects spilled to the 120% cap (limited by planned operations); and,
- Spill (**120%**) that would have occurred in that year if all projects spilled to the 120% cap (not limited by planned operations).

The three scenarios allowed the estimation of a range of possible volume changes and, therefore, the estimation of a magnitude of change. There were some difficulties encountered using empirical data, such as: the changing of planned project spill operations among years at many projects for research studies, and changing spill patterns that affected gas production. Since the years' used in the analysis included both moderate and high flow years, spill in the analysis was both voluntary and involuntary. However, developing curves to depict spill vs TDG was hampered by the lack of range of TDG data in some years' since spill was limited in order to manage to 115/120% TDG criteria.

The analysis concluded with estimating the numbers of fish passing through spill for the four scenarios in each water year based on the spill volumes estimated for each scenario.

Spill Volumes

The TDG Management Plans and/or Water Management Plans were used for each of the modeled years to determine the planned operations for each project. Table 1 provides a brief overview of the operations that occurred each year. There were several years of research that required different spill volumes over 2-4 day blocks at various projects. The TDG Management Plans was used as a guide for these scheduled changes, but empirical data were employed to determine exactly when different treatments began and ended. Hourly flow and spill data were used for all the modeled scenarios. Below is a detailed explanation of the assumptions used in each of the four modeled scenarios.

Table1. Planned Operations for each project (2003, 2005-2007), according to the TDG and Water Management Plans for these years.

Project	Year	Spring Spill	Summer Spill
LGR	2003	0/GC vs. 18.5-20.5 Kcfs (24hrs)	No Spill
	2005	No Spill	GC/GC
	2006	20 Kcfs/20 Kcfs	18 Kcfs/18 Kcfs
	2007	20 Kcfs/20 Kcfs	18 Kcfs/18 Kcfs
LGS	2003	0/GC	No Spill
	2005	No Spill	GC/GC (6/20-6/28); 50%/GC (6/29-6/30); 30%/GC (7/1-8/31)
	2006	30%/30%	30%/30%
	2007	30%/30% Additional 14 nights GC (Apr 29- May 12)	30%/30%
LMN	2003	50%/50% (flows <75 Kcfs, >100 Kcfs); 45%/45% (flows 75-100 Kcfs); 12K/12K (flows <24 Kcfs)	No Spill
	2005	No Spill	GC/GC
	2006	40 Kcfs/40 Kcfs	17 Kcfs/17 Kcfs
	2007	GC/GC	17 Kcfs/17 Kcfs
IHR	2003	45 Kcfs/100 Kcfs; 50%/50%	45 Kcfs/100 Kcfs; 50%/50%; 0/0; GC/GC
	2005	45 Kcfs/GC; GC/GC; 35%/35%	45 Kcfs/GC; GC/GC; 35%/35%
	2006	45 Kcfs/GC; 30%/30%	45 Kcfs/GC; 30%/30%
	2007	45 Kcfs/GC; 30%/30%	45 Kcfs/GC; 30%/30%
MCN	2003	0/GC (Until flows <200 Kcfs)	No Summer Spill
	2005	0/GC	GC/GC (all flows above 50 Kcfs)
	2006	40%/40%; 0/GC	40%/40%; 60%/60%
	2007	40%/40%	40%/40%; 60%/60%
JDA	2003	0/60%; 0/45%	0/60%; 30%/30%
	2005	0/60%; 40%/60% (5/22-5/30)	30%/30%
	2006	0/60%	30%/30%
	2007	0/60%	30%/30%
TDA	2003	40%/40%	40%/40%
	2005	40%/40%	40%/40%
	2006	40%/40%	40%/40%
	2007	40%/40%	40%/40%
BON	2003	75 Kcfs/GC; GC/GC	75 Kcfs/GC
	2005	75 Kcfs/GC	75 Kcfs/GC
	2006	100 Kcfs/100 Kcfs	75 Kcfs/GC
	2007	100 Kcfs/100 Kcfs	85 Kcfs/GC (June 21-July 15); 75 Kcfs/GC (July 16-Aug 31)

Base Case: Actual Spill

In the base case any involuntary spill was removed from the hourly spill volume. Involuntary spill was considered to be any volume of spill over the planned spill operation for that project and year (Table 1). If the operations called for spill to the gas cap, then the gas cap was assumed according to the TDG Management Plan (Table 2, Column A). Since it is difficult to model involuntary spill in the three scenarios, removing involuntary spill from what actually happened was necessary for comparison among the four different scenarios. If the planned operation called for 12 hours of spill but the project spilled in excess of 12 hours, these additional hours of spill were not removed, unless the spill volume was over the 120% spill cap (Table 2, Column A) since we were comparing relative changes among the modeled scenarios. Total spill volume (KAF) was then calculated for the entire spill season (April 3-August 31 for Snake Projects, April 10-August 31 for Lower Columbia Projects).

Table2. Estimated spill caps from TDG Management Plans for each project (A) (2003, 2005-2007) and FPC estimates (B) of spill cap from September 21, 2006 memo.

Project	Year	120% Spill Cap from TDG Management Plan (Kcfs) A	120% Spill Cap from 2006 FPC Memo (Kcfs) B
LGR	2003	60	54.1
	2005	60	54.1
	2006	42	54.1
	2007	42	54.1
LGS	2003	50	50.7
	2005	50	50.7
	2006	32	50.7
	2007	32	50.7
LMN	2003	45	39
	2005	45	39
	2006	40	39
	2007	40	39
IHR	2003	85	100[A]
	2005	85	76.2
	2006	105	76.2
	2007	105	76.2
MCN	2003	170	179.2
	2005	170	179.2
	2006	155	179.2
	2007	155	179.2
JDA	2003	160	160[B]
	2005	160	160[B]
	2006	95	160[B]
	2007	95	160[B]
TDA	2003	200	147
	2005	200	147
	2006	91	147
	2007	91	147
BON	2003	170	155.2[C]
	2005	170	116[D]
	2006	100	116[D]
	2007	100	116[D]

[A] – 2006 estimate was based on bulk pattern, which was not used in 2003.
[B] – 120% spill cap was estimated as 160 Kcfs, per the 2000 BiOp
[C] – Estimated spill cap based on regression of Average 12-hour high TDG at Warrendale in 2003 and corresponding 12 hours of spill.
[D] – Estimated spill cap based on regression of average 12-hour high TDG at Cascade Island and corresponding 12 hours of spill. This value is based on 2005, 2006, and 2007 data, collectively.

FB Restricted - Spill managed to 120% when forebay exceeded 115%, but tailrace <120%

Under this scenario, the volume of spill provided at each project was estimated if spill were managed to the 120% spill cap on days where the 115% in the downstream forebay was limiting spill. This scenario allowed for an estimate of the lower portion of the range of possible spill volume increases. Extra spill was estimated only for days where the TDG was >115.1% in the downstream forebay but <120.1% in the tailrace. On days where this was not the case, Base Case Volumes (accounting for excess spill) were reported. For this scenario, the estimated spill caps from FPC's September 21, 2006 memo (Table 2, Column B; see Appendix B for details) were used.

If the planned operation called for a set volume of spill, that volume was provided and if the planned operation called for a percent of the total flow, than that percent of the flow was provided. In this case, if the necessary percent flow was greater than the estimated spill cap (Table 2, Column B), spill during these times was capped at the spill cap. Finally, if the planned operation called for gas cap spill, than spill to the estimated spill cap (Table 2, Column B) was provided. Minimum generation requirements were considered.

This scenario is the most conservative of the three, since it does not increase spill to the 120% on days when the tailrace is below 120% and the downstream forebay is below the 115%.

120% Limited - Spill if managed to 120% at all Times (Under Planned Operations)

The volume of spill provided at each project was estimated if spill were managed to the 120% spill cap whenever possible, but limited to planned operations if the planned spill volume was less than the 120% volume. The spill caps at each project was assumed to be the estimated spill caps from FPC's September 21, 2006 memo (Table 2, Column B) and the planned operations and schedules were as outlined in the TDG Management Plans for each project and year (Table 1). Minimum generation requirements at each project were taken into account.

In a few cases where planned operations called for no spill during daytime hours but spill occurred for other reasons (e.g., MCN 2006, JDA 2006, JDA 2005, etc.) the Base Case volumes were assumed during the no spill hours. It is important to note that this would not equate to additional spill under this scenario compared to the Base Case scenario. This was done in order to prevent this scenario from underestimating additional spill compared to the Base Scenario given that planned operations were not always followed in the Base Scenario.

120% - Spill if managed to 120% at all Times (Not Limited by Planned Operations)

The volume of spill provided at each project was estimated as if spill were managed to the 120% spill cap whenever possible, but <u>was not limited to planned operations</u> if the planned spill volume was less than the 120% volume. However, this scenario did limit spill to only the planned spill hours, so projects that called for nighttime spill, only implemented voluntary spill during these hours. The estimated spill caps from FPC's September 21, 2006 memo (Table 2, Column B) were used. As with the 120% Limited scenario, there were a few cases where planned operations called for "no spill" during daytime hours but spill was actually provided during these times (e.g., MCN 2006, JDA 2006, JDA 2005, etc.). For the same reasons stated above, the Base Case volumes were included for those hours. Minimum generation requirements were considered. This scenario allowed for an estimate of the upper portion of the range of possible spill volume under the spill program in place for that year.

Fish Numbers Passing Through Spill

To estimate the proportion of the juvenile population passing through spill an estimate of the total fish population at each project for each water year was determined. Daily fish collections from the Smolt Monitoring Program (SMP), daily average spill, and estimates of Spill Passage Efficiency (SPE) from NOAA's COMPASS Model were used to obtain daily population estimates of yearling Chinook, steelhead, and subyearling Chinook at all projects. Currently, the COMPASS model does not include SPE estimates for subyearling Chinook because of insufficient data. However, for this exercise the SPE estimates for yearling Chinook were assumed for subyearling Chinook in order to have some comparison of the change in fish passage with different levels of spill. Daily population estimates were summed over the entire spill season (April 3-August 31 at Snake River projects, April 10-August 31 at Lower Columbia projects) for an estimate of total population.

In the spring and early summer, McNary Dam collects juvenile salmonids every other day. Also, there are times when Bonneville and John Day dams stop daily collections due to high temperatures in the juvenile facilities, particularly in the late summer. Therefore, daily collections during these events were estimated as the average of the adjacent days.

Daily average spill was then estimated for the Base Case (accounting for involuntary spill) and each of the three modeled scenarios. The daily average spill volumes were applied to the daily population estimates to determine the daily population of fish passing through spill under each scenario. As with the estimates of total population, a total population of fish passing through spill was calculated for the entire spill season. Finally, the proportion of the population passing through spill was calculated as the spill population divided by the total population.

Results:

Spill Volumes:

As mentioned above, the three modeled scenarios allowed for the estimation of a range of possible volume changes if the 115% TDG criteria were to be eliminated, with the FB Restricted scenario providing an estimate of the lower portion of that range and the 120% scenario providing an estimate of the upper portion of that range. The additional spill volume under FB Restricted, compared to the Base Case (accounting for excess spill), ranged from 0.5 to 2.8 MAF, depending on the water year (Table 3). This scenario only allows for additional spill on days when the 115% criteria is exceeded in the downstream forebay, while the tailrace TDG is not exceeding 120%. This is important to note, given that the lowest estimate of additional spill came from water year 2005, which had no spring spill at Snake River Projects. It is likely that this estimate of additional spill would have been higher if spring spill had been implemented in 2005, given that many of the Snake River projects are limited by the 115% criteria in the spring and not so much in the summer.

The 120% Limited is the scenario that comes closest to what would have occurred if the 115% forebay criteria was not used in the years modeled. Under 120% Limited, the additional spill volume ranged from 5.98 MAF in 2007 to 13.01 MAF in 2003 (Table 3). Finally, 120% scenario provided estimates of spill that would be at the higher end of the range of possibilities. Under this scenario, additional spill ranges from 41.6 to 58.1 MAF (Table 3). Appendix A (Table A-1) provides a more detailed breakdown of the additional volumes provided under each scenario, at each project.

Table 3. Additional spill volumes (MAF) under the three modeled scenarios, compared to the Base Case volume (involuntary spill removed)

Water Year	FB Restricted	120% Limited	120%
2003	2.27	13.01	41.57
2005	0.52	11.06	43.06
2006	2.80	9.56	52.53
2007	1.45	5.98	58.07

Proportion of Fish Passing Through Spill:

The proportion of the fish population passing through spill is dependent on the proportion of the total flow that passes over the spill way. Therefore, just as the three modeled scenarios allowed for a range of possible additional volumes, they also allowed for a range of possible increases in the proportion of fish passing through spill. As with additional spill volume, FB Restricted generally resulted in the least increase in proportion passing through spill, while 120% resulted in the highest increase in proportion passing through spill. Table 4 provides an estimate of the proportion of each species passing through spill, under each of the different modeled scenarios. Furthermore, Appendix A (Table A-2) provides a more detailed breakdown of the actual population sizes (number of fish) that would pass through spill, along with estimates of percent increase under each of the modeled scenarios, compared to the Base Case.

Table 4. Total spill season population (A) and proportion of the population passing through spill under Base Case (excess spill removed, B), FB Restricted (C), 120% Limited (D), and 120% (E) for yearling Chinook, steelhead, and subyearling Chinook at LGR, LGS, LMN, MCN, JDA, and BON. Estimates are not possible for IHR and TDA due to no SMP sampling at these sites.

Project	Migration Year	Species	Spill Season Population A	Base Case (Excess spill removed) B	FB Restricted C	120% Limited D	120% E
LGR	2003	Yearling Chinook	6,036,250	0.47	0.47	0.64	0.70
		Steelhead	8,461,179	0.66	0.66	0.78	0.83
		Subyearling Chinook	2,114,153	0.29	0.29	0.34	0.34
	2005	Yearling Chinook	7,232,368	0.00	0.00	0.00	0.00
		Steelhead	7,753,635	0.00	0.00	0.00	0.00
		Subyearling Chinook	2,456,171	0.10	0.10	0.11	0.11
	2006	Yearling Chinook	6,589,315	0.30	0.30	0.30	0.63
		Steelhead	13,067,516	0.43	0.43	0.43	0.78
		Subyearling Chinook	1,341,378	0.39	0.39	0.39	0.72
	2007	Yearling Chinook	3,825,176	0.49	0.49	0.50	0.83
		Steelhead	4,165,641	0.65	0.65	0.65	0.93
		Subyearling Chinook	618,213	0.62	0.62	0.63	0.86
LGS	2003	Yearling Chinook	2,852,429	0.26	0.26	0.33	0.33
		Steelhead	2,713,159	0.25	0.26	0.29	0.29
		Subyearling Chinook	773,527	0.12	0.14	0.14	0.14
	2005	Yearling Chinook	2,833,956	0.00	0.00	0.00	0.00
		Steelhead	3,034,701	0.00	0.00	0.00	0.00
		Subyearling Chinook	1,487,652	0.08	0.08	0.09	0.11
	2006	Yearling Chinook	4,818,186	0.24	0.29	0.30	0.40
		Steelhead	4,585,326	0.25	0.29	0.31	0.39
		Subyearling Chinook	1,309,600	0.27	0.28	0.30	0.52
	2007	Yearling Chinook	731,724	0.29	0.35	0.36	0.60
		Steelhead	1,927,495	0.30	0.35	0.36	0.62
		Subyearling Chinook	500,930	0.30	0.30	0.31	0.72
LMN	2003	Yearling Chinook	2,901,598	0.80	0.80	0.82	0.85
		Steelhead	6,136,216	0.74	0.75	0.77	0.79
		Subyearling Chinook	728,541	0.51	0.55	0.59	0.59
	2005	Yearling Chinook	1,070,344	0.01	0.01	0.01	0.01
		Steelhead	1,171,631	0.00	0.00	0.00	0.00
		Subyearling Chinook	426,086	0.46	0.46	0.49	0.49
	2006	Yearling Chinook	3,835,310	0.61	0.66	0.71	0.71
		Steelhead	3,543,760	0.61	0.64	0.69	0.69
		Subyearling Chinook	1,088,640	0.65	0.67	0.74	0.77
	2007	Yearling Chinook	888,394	0.62	0.66	0.82	0.82
		Steelhead	1,866,186	0.62	0.67	0.82	0.82
		Subyearling Chinook	304,248	0.83	0.84	0.90	0.92

Table 4 cont'd. Total spill season population (A) and proportion of the population passing through spill under Base Case (excess spill removed, B), FB Restricted (C), 120% Limited (D), and 120% (E) for yearling Chinook, steelhead, and subyearling Chinook at LGR, LGS, LMN, MCN, JDA, and BON. Estimates are not possible for IHR and TDA due to no SMP sampling at these sites.

Project	Migration Year	Species	Spill Season Population A	Base Case (Excess spill removed) B	FB Restricted C	120% Limited D	120% E
MCN	2003	Yearling Chinook	4,127,868	0.33	0.34	0.42	0.42
		Steelhead	560,236	0.35	0.37	0.44	0.44
		Subyearling Chinook	14,106,761	0.11	0.12	0.25	0.25
	2005	Yearling Chinook	3,072,828	0.38	0.39	0.48	0.48
		Steelhead	441,780	0.37	0.37	0.47	0.47
		Subyearling Chinook	12,398,115	0.36	0.36	0.49	0.49
	2006	Yearling Chinook	3,951,504	0.40	0.40	0.43	0.50
		Steelhead	1,011,783	0.40	0.40	0.44	0.48
		Subyearling Chinook	7,654,912	0.43	0.43	0.46	0.64
	2007	Yearling Chinook	5,670,257	0.38	0.38	0.38	0.65
		Steelhead	870,511	0.38	0.38	0.38	0.65
		Subyearling Chinook	11,979,553	0.47	0.47	0.47	0.70
JDA	2003	Yearling Chinook	4,478,492	0.46	0.47	0.49	0.55
		Steelhead	872,619	0.37	0.39	0.40	0.44
		Subyearling Chinook	6,014,941	0.47	0.48	0.50	0.59
	2005	Yearling Chinook	3,019,504	0.47	0.48	0.54	0.59
		Steelhead	859,934	0.41	0.42	0.48	0.53
		Subyearling Chinook	5,295,212	0.52	0.52	0.53	0.80
	2006	Yearling Chinook	5,643,002	0.62	0.62	0.66	0.66
		Steelhead	2,992,014	0.56	0.56	0.59	0.59
		Subyearling Chinook	6,924,436	0.54	0.55	0.57	0.75
	2007	Yearling Chinook	9,359,967	0.48	0.49	0.53	0.55
		Steelhead	1,550,601	0.40	0.41	0.45	0.47
		Subyearling Chinook	8,403,341	0.51	0.51	0.52	0.78
BON	2003	Yearling Chinook	7,639,411	0.49	0.50	0.53	0.64
		Steelhead	2,056,743	0.43	0.45	0.47	0.58
		Subyearling Chinook	16,177,566	0.53	0.54	0.56	0.76
	2005	Yearling Chinook	4,199,374	0.39	0.40	0.45	0.57
		Steelhead	344,853	0.34	0.35	0.38	0.50
		Subyearling Chinook	7,316,785	0.47	0.48	0.52	0.65
	2006	Yearling Chinook	4,026,733	0.31	0.32	0.34	0.39
		Steelhead	321,665	0.29	0.30	0.31	0.36
		Subyearling Chinook	6,777,882	0.37	0.38	0.41	0.50
	2007	Yearling Chinook	3,210,439	0.40	0.40	0.42	0.47
		Steelhead	316,688	0.39	0.39	0.40	0.46
		Subyearling Chinook	15,075,542	0.47	0.48	0.50	0.60

Appendix A

Detailed summary of spill volumes and fish numbers from modeled scenarios

Table A-1. Total spill volume under each of the modeled scenarios, compared to the "Actual Volume (accounting for excess spill). All volumes are in KAF.

Project	Migration Year	Base Case (Excess Spill Removed) A	Estimated Spill Volume (FB Restricted) B	Difference in Spill Volume (B-A)	Estimated Spill Volume (120% Limited) C	Difference in Spill Volume (C-A)	Estimated Spill Volume (120%) D	Difference in Spill Volume (D-A)
LGR	2003	3,865.7	3,907.2	41.5	5,386.4	1,520.7	6,122.9	2,257.2
	2005	2,788.4	2,788.4	0.0	3,212.3	423.9	3,212.3	423.9
	2006	5,528.5	5,528.7	0.2	5,538.9	10.4	12,170.4	6,641.9
	2007	5,263.3	5,263.3	0.0	5,319.4	56.1	9,280.0	4,016.6
LGS	2003	3,322.9	3,518.5	195.6	4,147.6	824.7	4,147.6	824.7
	2005	2,249.4	2,274.0	24.5	2,651.4	402.0	3,272.5	1,023.1
	2006	6,515.6	6,997.0	481.4	7,353.0	837.4	11,523.1	5,007.5
	2007	4,016.7	4,321.4	304.7	4,369.3	352.6	8,896.2	4,879.5
LMN	2003	4,499.2	4,800.3	301.1	5,447.8	948.6	6,020.9	1,521.7
	2005	2,437.2	2,493.3	56.1	2,971.9	534.7	2,971.9	534.7
	2006	6,534.1	7,166.9	632.8	8,338.3	1,804.1	9,401.3	2,867.1
	2007	5,446.2	6,228.1	781.9	7,593.0	2,146.8	7,932.9	2,486.7
IHR	2003	9,869.2	9,940.1	71.0	11,334.1	1,464.9	15,479.4	5,610.2
	2005	8,805.2	8,815.7	10.4	9,927.8	1,122.6	12,756.8	3,951.6
	2006	11,570.6	11,597.1	26.5	11,713.1	142.5	15,832.5	4,261.9
	2007	7,903.9	7,950.1	46.2	8,147.0	243.0	10,624.3	2,720.3
MCN	2003	12,239.0	12,870.9	631.9	16,296.5	4,057.5	16,299.6	4,060.5
	2005	24,851.0	24,999.9	148.9	29,106.1	4,255.1	29,106.1	4,255.1
	2006	32,784.9	32,848.5	63.6	34,632.3	1,847.4	41,359.8	8,574.9
	2007	25,897.2	25,897.2	0.0	26,036.0	138.8	41,328.9	15,431.7
JDA	2003	13,077.0	13,313.7	236.8	14,411.9	1,334.9	17,941.0	4,864.0
	2005	14,342.4	14,419.0	76.5	15,857.8	1,515.3	25,527.5	11,185.1
	2006	26,136.1	26,429.0	293.0	27,834.9	1,698.9	34,747.3	8,611.2
	2007	15,273.2	15,398.5	125.3	16,958.2	1,685.0	24,793.7	9,520.5
TDA	2003	19,895.1	20,114.3	219.2	20,971.8	1,076.7	31,826.5	11,931.4
	2005	17,609.8	17,747.1	137.3	19,722.7	2,112.9	31,580.6	13,970.9
	2006	26,203.1	27,204.3	1,001.2	27,892.5	1,689.4	35,817.0	9,613.9
	2007	21,889.6	21,906.5	16.9	22,068.9	179.3	34,417.0	12,527.4
BON	2003	29,120.9	29,691.6	570.7	30,901.6	1,780.7	39,620.7	10,499.8
	2005	23,093.6	23,156.9	63.4	23,785.0	691.4	30,813.7	7,720.2
	2006	25,398.2	25,696.4	298.2	26,931.6	1,533.5	32,350.1	6,951.9
	2007	25,798.1	25,975.3	177.2	26,979.8	1181.7	32,281.2	6,483.1

Table A-2. Total population (A) and populations passing in spill under Base Case (B), FB Restricted (C), 120% Limited (D), and 120% (E) for LGR, LGS, LMN, MCN, JDA, and BON. Estimates of population are not possible at IHR and TDA due to no SMP sampling at these sites.

Project	Migration Year	Species	Spill Season Population A	Base Case (Excess spill removed) B	FB Restricted C	Percent Increase ((C-B)/B)*100	120% Limited D	Percent Increase ((D-B)/B)*100	120% E	Percent Increase ((E-B)/B)*100
LGR	2003	Yearling Chinook	6,036,250	2,848,732	2,849,012	0.01	3,845,126	34.98	4,238,697	48.79
		Steelhead	8,461,179	5,575,645	5,578,463	0.05	6,615,228	18.65	6,993,404	25.43
		Subyearling Chinook	2,114,153	610,371	615,593	0.86	710,781	16.45	715,566	17.23
	2005	Yearling Chinook	7,232,368	7,889	7,889	0.00	8,813	11.72	8,813	11.72
		Steelhead	7,753,635	31,812	31,812	0.00	33,227	4.45	33,227	4.45
		Subyearling Chinook	2,456,171	241,429	241,429	0.00	269,720	11.72	269,720	11.72
	2006	Yearling Chinook	6,589,315	1,997,244	1,997,244	0.00	1,997,443	0.01	4,125,483	106.56
		Steelhead	13,067,516	5,627,142	5,627,143	0.00	5,628,364	0.02	10,247,526	82.11
		Subyearling Chinook	1,341,378	522,832	522,873	0.01	523,550	0.14	961,113	83.83
	2007	Yearling Chinook	3,825,176	1,891,841	1,891,841	0.00	1,898,408	0.35	3,165,146	67.31
		Steelhead	4,165,641	2,698,348	2,698,348	0.00	2,708,428	0.37	3,877,512	43.70
		Subyearling Chinook	618,213	384,759	384,759	0.00	386,423	0.43	532,764	38.47
LGS	2003	Yearling Chinook	2,852,429	733,733	747,353	1.86	941,032	28.25	941,032	28.25
		Steelhead	2,713,159	673,407	696,519	3.43	780,951	15.97	780,951	15.97
		Subyearling Chinook	773,527	95,847	107,664	12.33	111,352	16.18	111,352	16.18
	2005	Yearling Chinook	2,833,956	2,325	2,328	0.15	2,675	15.05	3,151	35.52
		Steelhead	3,034,701	3,087	3,128	1.32	3,483	12.84	3,721	20.56
		Subyearling Chinook	1,487,652	117,591	119,628	1.73	138,793	18.03	163,415	38.97
	2006	Yearling Chinook	4,818,186	1,173,913	1,385,475	18.02	1,459,352	24.32	1,920,396	63.59
		Steelhead	4,585,326	1,153,965	1,348,953	16.90	1,399,273	21.26	1,785,939	54.77
		Subyearling Chinook	1,309,600	359,701	371,208	3.20	397,275	10.45	686,128	90.75
	2007	Yearling Chinook	731,724	214,643	257,178	19.82	265,374	23.64	438,636	104.36
		Steelhead	1,927,495	572,567	668,644	16.78	691,722	20.81	1,187,080	107.33
		Subyearling Chinook	500,930	151,878	152,198	0.21	153,180	0.86	359,335	136.59

Table A-2 cont'd. Total population (A) and populations passing in spill under Base Case (B), FB Restricted (C), 120% Limited (D), and 120% (E) for LGR, LGS, LMN, MCN, JDA, and BON. Estimates of population are not possible at IHR and TDA due to no SMP sampling at these sites.

Project	Migration Year	Species	Spill Season Population A	Base Case (Excess spill removed) B	FB Restricted C	Percent Increase ((C-B)/B)*100	120% Limited D	Percent Increase ((D-B)/B)*100	120% E	Percent Increase ((E-B)/B)*100
LMN	2003	Yearling Chinook	2,901,598	2,319,046	2,333,618	0.63	2,383,730	2.79	2,472,512	6.62
		Steelhead	6,136,216	4,549,718	4,617,500	1.49	4,750,050	4.40	4,869,962	7.04
		Subyearling Chinook	728,541	371,816	397,267	6.84	426,929	14.82	430,825	15.87
	2005	Yearling Chinook	1,070,344	7,613	7,630	0.22	8,073	6.05	8,073	6.05
		Steelhead	1,171,631	4,604	4,669	1.41	5,203	12.99	5,203	12.99
		Subyearling Chinook	426,086	195,069	196,271	0.62	210,465	7.89	210,465	7.89
	2006	Yearling Chinook	3,835,310	2,346,766	2,513,773	7.12	2,734,909	16.54	2,735,096	16.55
		Steelhead	3,543,760	2,159,695	2,281,903	5.66	2,437,915	12.88	2,438,153	12.89
		Subyearling Chinook	1,088,640	702,512	731,731	4.16	806,660	14.83	833,746	18.68
	2007	Yearling Chinook	888,394	546,688	590,101	7.94	730,918	33.70	730,934	33.70
		Steelhead	1,866,186	1,163,224	1,249,998	7.46	1,537,445	32.17	1,537,928	32.21
		Subyearling Chinook	304,248	251,918	255,003	1.22	275,029	9.17	280,441	11.32
MCN	2003	Yearling Chinook	4,127,868	1,362,573	1,398,249	2.62	1,717,177	26.02	1,717,719	26.06
		Steelhead	560,236	196,327	208,456	6.18	244,513	24.54	244,568	24.57
		Subyearling Chinook	14,106,761	1,582,841	1,639,330	3.57	3,523,967	122.64	3,524,014	122.64
	2005	Yearling Chinook	3,072,828	1,161,677	1,183,896	1.91	1,475,631	27.03	1,475,631	27.03
		Steelhead	441,780	162,599	164,686	1.28	208,919	28.49	208,919	28.49
		Subyearling Chinook	12,398,115	4,424,942	4,427,385	0.06	6,019,361	36.03	6,019,361	36.03
	2006	Yearling Chinook	3,951,504	1,575,811	1,578,186	0.15	1,691,983	7.37	1,975,132	25.34
		Steelhead	1,011,783	406,855	407,621	0.19	440,188	8.19	489,801	20.39
		Subyearling Chinook	7,654,912	3,318,563	3,321,130	0.08	3,521,570	6.12	4,888,831	47.32
	2007	Yearling Chinook	5,670,257	2,152,581	2,152,581	0.00	2,157,769	0.24	3,662,393	70.14
		Steelhead	870,511	331,253	331,253	0.00	332,083	0.25	565,751	70.79
		Subyearling Chinook	11,979,553	5,618,875	5,618,875	0.00	5,677,291	1.04	8,391,691	49.35

Table A-2 cont'd. Total population (A) and populations passing in spill under Base Case (B), FB Restricted (C), 120% Limited (D), and 120% (E) for LGR, LGS, LMN, MCN, JDA, and BON. Estimates of population are not possible at IHR and TDA due to no SMP sampling at these sites.

Project	Migration Year	Species	Spill Season Population A	Base Case (Excess spill removed) B	FB Restricted C	Percent Increase ((C-B)/B)*100	120% Limited D	Percent Increase ((D-B)/B)*100	120% E	Percent Increase ((E-B)/B)*100
JDA	2003	Yearling Chinook	4,478,492	2,051,048	2,091,733	1.98	2,183,129	6.44	2,471,087	20.48
		Steelhead	872,619	323,057	338,259	4.71	345,874	7.06	387,132	19.83
		Subyearling Chinook	6,014,941	2,842,077	2,872,023	1.05	3,024,370	6.41	3,563,474	25.38
	2005	Yearling Chinook	3,019,504	1,430,415	1,450,432	1.40	1,641,995	14.79	1,773,387	23.98
		Steelhead	859,934	355,009	360,316	1.49	416,531	17.33	459,981	29.57
		Subyearling Chinook	5,295,212	2,741,744	2,741,906	0.01	2,803,340	2.25	4,217,255	53.82
	2006	Yearling Chinook	5,643,002	3,501,640	3,511,695	0.29	3,710,701	5.97	3,721,011	6.26
		Steelhead	2,992,014	1,676,903	1,683,325	0.38	1,750,521	4.39	1,754,453	4.62
		Subyearling Chinook	6,924,436	3,747,412	3,777,769	0.81	3,937,836	5.08	5,198,276	38.72
	2007	Yearling Chinook	9,359,967	4,452,687	4,559,408	2.40	4,961,438	11.43	5,158,493	15.85
		Steelhead	1,550,601	616,472	636,142	3.19	701,447	13.78	732,457	18.81
		Subyearling Chinook	8,403,341	4,303,374	4,304,012	0.01	4,379,174	1.76	6,565,477	52.57
BON	2003	Yearling Chinook	7,639,411	3,741,194	3,842,466	2.71	4,046,919	8.17	4,899,484	30.96
		Steelhead	2,056,743	881,334	926,352	5.11	966,222	9.63	1,184,202	34.36
		Subyearling Chinook	16,177,566	8,602,558	8,688,296	1.00	9,033,075	5.00	12,259,870	42.51
	2005	Yearling Chinook	4,199,374	1,643,951	1,682,216	2.33	1,906,220	15.95	2,411,008	46.66
		Steelhead	344,853	118,534	122,140	3.04	132,693	11.95	172,719	45.71
		Subyearling Chinook	7,316,785	3,470,525	3,489,486	0.55	3,774,029	8.75	4,763,809	37.26
	2006	Yearling Chinook	4,026,733	1,263,335	1,291,358	2.22	1,358,963	7.57	1,566,680	24.01
		Steelhead	321,665	94,803	95,950	1.21	99,499	4.95	115,416	21.74
		Subyearling Chinook	6,777,882	2,510,468	2,579,622	2.75	2,787,229	11.02	3,390,901	35.07
	2007	Yearling Chinook	3,210,439	1,280,183	1,284,203	0.31	1,358,963	6.15	1,518,055	18.58
		Steelhead	316,688	122,115	122,859	0.61	126,515	3.60	147,023	20.40
		Subyearling Chinook	15,075,542	7,156,590	7,198,077	0.58	7,549,888	3.50	9,078,550	26.86

Appendix B

FPC September 29, 2006 Memo regarding Spring Spill in 2006

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MEMORANDUM

TO: FPAC

FROM: Michele DeHart

DATE: September 29, 2006

RE: Spring Spill 2006

The Fish Passage Advisory Committee requested that the Fish Passage Center conduct an evaluation of the spill that occurred this past spring in the Federal Columbia River Power System (FCRPS). The FCRPS spring spill program was provided in response to the 9th Circuit Court's Order for spill and, therefore, the analysis conducted was in the context of the Court Order. In general, the Court's Order was implemented appropriately, but conservatively, within the present guidelines for total dissolved gas (TDG) management. The question arises as to whether the original criteria established in 1995 for total dissolved gas management remain appropriate given the additional knowledge gained since that time.

There were several key points that came from this analysis:

1. The actual spill that occurred (when excess hydraulic capacity and spill in excess of market capacity, or spill due to turbine unit outages, were removed) was considerably less than what could have occurred under the Court's Order (about 4.1 MAF) if TDG were managed to the tailrace monitor.
2. The amount of spill varied from project to project; with a few key projects having the greatest limitation on spill (Lower Monumental, The Dalles, Bonneville and Little Goose) based on the downstream forebay monitor readings.
3. The reason why the spill was significantly less at some projects lies partly due to the real time management of spill to total dissolved gas measurements at the tailrace, but is most significantly related to the management of spill to downstream forebay TDG levels.

4. The use of downstream forebay monitors for measuring dissolved gas relative to spill needs to be addressed. Downstream forebay monitors, as presently configured, are not indicative of the readings in a well-mixed water column due to the local influence of temperature, barometric pressure and biological processes.
5. In season management of total dissolved gas during periods of overgeneration spill must be managed with consideration of biological objectives, rather than to dissolved gas objectives alone.

Assessment of Spill for Spring 2006

Appendix A contains graphic representations of the actual spill that occurred in the spring of 2006 relative to the Court's Order. From the graphs it can be seen that spill occurred in three distinct time periods, first when flows were manageable, second when flows exceeded hydraulic capacity of the projects and third, when flows were manageable at most project's but spill was high due to a lack of market for the electricity. When flows were less than powerhouse capacity, spill was managed to the waiver requirements of 120% total dissolved gas in the tailrace and 115% total dissolved gas in the next downstream forebay monitor. At some projects spill exceeded the Court Order due to project limitations e.g. Lower Granite had a limited hydraulic capacity throughout the season due to a turbine unit outage and spill exceeded the Court Order most of the time. In the later part of May, flows peaked in the Snake River and all the projects exceeded the Court Order. Subsequent to this period, extremely high volumes of spill occurred during nighttime hours due to excess market capacity spill and management actions that limited spill during daytime hours to meet water quality waivers.

In order to develop an assessment of spill relative to the Court order the volume of spill was calculated in several ways. The first was to determine the maximum amount of spill that could have occurred if the Court Order were fully implemented without any total dissolved gas restrictions, or in the case of projects that are to spill to the gas caps, spill was calculated to the tailrace value of 120%(a). Then the actual volume of spill that occurred was calculated (b). This volume did not include any involuntary spill, or spill that was in excess of the court order. This excess spill occurred due to project capacity limits (flow in excess of hydraulic capacity or limited hydraulic capacity due to unit outages) or due to overgeneration or lack of market spill. The difference between what actually occurred and what could have occurred under the Court's order without gas restrictions was determined (c). The next calculations considered what could have been spilled if the Court ordered spill program were only managed to the tailrace 120%, rather than to both the tailrace and the downstream forebay monitors (d). The difference between the Court Ordered spill and what could have occurred if tailrace monitors were used is calculated as the potential difference (e). John Day Dam was excluded from the analysis this year. The T1 line outage at John Day Dam reduced hydraulic capacity resulting in tailrace egress conditions that were not particularly good for fish passage. To address this line outage, the Salmon Managers requested that John Day Dam operate as close to 40% spill around the clock, as possible, to address fish passage concerns. Consequently, it is impossible to evaluate the spill that occurred relative to the Court's Order.

From the following table it is estimated that spring spill during 2006 was approximately 4.4 MAF less that what was expected under the Court's Order if TDG was not a constraint. This was primarily a result of in-season management to the downstream forebay total dissolved gas monitors. This was an appropriate management of the system under the present dissolved gas waiver criteria established by the States' water quality agencies. However, from the second part of this exercise it can be observed that if the tailrace monitor were used for in-season management (rather than both the forebay and tailrace) then the volume of spill (4.1 MAF) would have been substantially greater than would have occurred under the present management due to higher gas cap spill levels (Table 2). This would have provided additional survival benefits to migrating salmonids by increasing the number of fish that passed a project via spill. Biological monitoring when TDG is managed to 120% in the tailrace continues to show little impact to populations at this TDG concentration. Consequently, since the forebay monitors are limiting the fish mitigation measure, then it must be explored if the present TDG management criteria are appropriate.

Site	Volume Court Order Spill (Kaf) (a)	Volume Actual 2006 Spill (not including involuntary spill- or spill greater than court order) (Kaf) (b)	Difference (c)	Volume Spill at 120% TDG @TW Limited by 2006 Court Order (d)	Potential difference if managed to 120% TR (Kaf) (e)
Lower Granite	3134	3134	**0**	3134	**0**
Little Goose	5810	5141	**669**	5774	**36**
Lower Monumental	6268	4687	**1581**	6111	**157**
Ice Harbor	8165	8012	**153**	8165	**0**
McNary	15661	15374	**287**	15632	**29**
John Day**	18341	17993			
The Dalles	18016	16965	**1051**	17936	**80**
Bonneville	14281	13585	**696**	14281	**0**
Total			**4437**		**302**

**** John Day not included in total Kaf calculation.**

Table 1. Volume calculation for spill in 2006 that would have occurred if the Court Order were fully implemented (i.e. no TDG restriction) (a), that volume that did occur voluntarily (b), and the volume that could have occurred if the Court order were managed using tailrace monitors only (d).

Project	Spill (Kcfs) if Gas Cap Managed to Project Tailrace Monitor (120%)	Spill (Kcfs) if Gas Cap Managed to Downstream Forebay Monitor (115%)
Lower Granite	54.1	53.1
Little Goose	50.7	30.2
Lower Monumental	39.0	29.5
Ice Harbor	76.2	63.5
McNary	179.2	161.1
John Day	133.5	131.0
The Dalles	147.0	122.2
Bonneville	101.3	113.3

Table 2. Gas cap estimates generated based on regressions between spill volumes and tailrace TDG or in the next downstream forebay for the Spring 2006 data.

Spill, TDG Supersaturation, and Monitoring

Supersaturation occurs when a solution contains more of the dissolved material than could be dissolved by the solvent under normal circumstances. Dissolved gas supersaturation in the Columbia and Snake rivers routinely occurs during the spring and summer freshet as a result of water spilling over dams. Total Dissolved Gas (TDG) is the measure of the sum total of all gas partial pressures (including water vapor) in water. TDG can be reported as an absolute overall dissolved gas pressure or relative to atmospheric pressure. Gas bubbles can form in the blood and tissues of aquatic organisms when water becomes supersaturated with gas. This results in "Gas Bubble Disease" in the affected organisms. Gas Bubble Disease can, in turn, cause rapid acute mortality as well as increase long-term mortality in aquatic organisms.

The original waiver criteria for TDG were established in 1994. This was the first time a waiver had been requested from the water quality agencies for variation from the national standard with the intent of providing survival benefits to migrating juvenile salmonids through additional spill passage. A literature review of past experiments (Spill and 1995 Risk Management) had suggested that 125% TDG levels might still have provided the benefits of spill, but to err on the conservative side a target of 115% in the mixed waters of the forebay and 120% total dissolved gas in the tailrace was adopted. These criteria have been in-place since 1994 along with a biological monitoring program to assess the impacts of the controlled spill program.

For all spills, the highest TDG levels, and therefore the area most likely to exceed standards, are directly below the spillway. In this area, the plunging and air entrainment of the spill (aerated zone) generates high levels of TDG, but then quickly degasses while the water remains turbulent and full of bubbles. However, as this water moves from the stilling basin into the tailrace, degassing slows and the TDG levels stabilize. In the pools, gas exchange rates increase as wind speeds rise, which produces degassing, particularly if breaking waves result. At the next downstream project water should be well mixed and TDG levels much reduced.

However, if wind speeds are still and TDG concentrations are not being increased because of spill, the percent saturation of TDG can increase if the water temperature increases or barometric pressure drops, or if primary productivity (periods of algal growth) occurs. It is important to note that the gas added to the water column by primary productivity is oxygen, and while it contributes to the overall TDG concentration, it is not regarded as a problem for aquatic organisms since oxygen can be removed from tissues via metabolic activity.

Efficacy of forebay monitoring

The goal of the spill program is to provide benefits to migrating juvenile salmonids, while not imposing harm from exposure to dissolved gas that outweighs the benefits of spill. The project forebay TDG monitors were originally intended to represent a mixed cross section in the river just upstream of the dam. The tailwater instruments are located nearer the projects, often in spillway releases downstream of aerated flow, and prior to complete mixing with powerhouse releases. The ability to adequately monitor TDG is extremely important and the question of whether, or not, the forebay monitors reflect the actual picture of the potential harm that could occur from TDG has been a question from the beginning of the monitoring program. While the tailwater instruments are also affected to some degree during periods of non-spill by the same processes that cause the forebay monitors to measure TDG levels above 100%, the physical process of spilling water sufficiently mixes the water column such that the tailwater monitors adequately represent the mixed water column measurement of TDG due to spill.

In 2000 NOAA Fisheries addressed the concern regarding forebay monitors and included in their Biological Opinion a reasonable and prudent alternative (RPA 132), which states "The Action Agencies shall develop a plan to conduct a systematic review and evaluation of the TDG fixed monitoring stations in the forebays of all the mainstem Columbia and Snake river dams (including the Camas/Washougal monitor)…The Action Agencies shall conduct the evaluation and make changes to the location of the fixed monitoring sites, as warranted, and in coordination with the Water Quality Team." All of the project forebay FMS stations were problematic in that each experienced thermally induced TDG pressure spikes during the test periods indicating down welling of warm surface waters, resulting in non-representative spiking of TDG (Carroll, 2004).

In October 2004 the COE presented the results of the RPA 132 study (Carroll 2004) conducted relative to the forebay monitors and the recommendation for relocating these monitors. In RPA 132 the COE used temperature to define surface water and the potential for monitors to measure surface rather than mixed water. Routine spikes in daily water temperature were strongly associated with the daily spikes in TDG. The COE recommended the relocation of several monitors to address the daily spike in temperature. The monitors were relocated upstream of the dam face and the transducers were placed deeper in the water column where daily spikes in temperature were minimized (Appendix B).

Did the COE's Relocation Lead to More Accurate Monitoring?

In order to assess whether the relocation of TDG monitors addressed the problem associated with forebay monitoring identified in RPA 132, an analysis of the data collected before and after relocation was developed. The analysis addressed the variation in TDG due to processes other than spill (i.e. primary productivity, barometric pressure and temperature). The data used for the analysis were the TDG measurements that were taken during periods when spill was not occurring in the hydrosystem. In these data the variation in TDG observed would be a function of daily variations in temperature, barometric pressure and in biological processes. To investigate the variation in total dissolved gas (TDG) levels when no spill occurred, the corresponding TDG, flow, and spill data were collected for each of the following forebay monitors: Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, Bonneville, and Camas/Washougal. To minimize the effects of any spill that might have occurred, the analysis focused on three time relatively spill free periods and removed any TDG data that could have potentially been affected by spill. The data were evaluated for removal from the data set based on the lag time (water transit time) between projects and review of the potential for any data point being affected by spill at upstream projects, as well as TDG monitor malfunctions.

The first no-spill time period was during the weeks prior to the implementation of voluntary spill in 2001-2006. The target dates for the Lower Snake projects were generally March 1 – April 2. However, TDG data at Little Goose and Lower Monumental were not logged until after March 1. In this case, the first date for each year that data were available at these sites was used. Voluntary spring spill at the Lower Columbia projects begins in April. Therefore, the dates used for the Lower Columbia projects were the first date for which data was available prior to the initiation of spill. This analysis allowed for the evaluation of whether relocating forebay monitors in 2004 (at John Day) and 2005 (at Little Goose, Lower Monumental, Ice Harbor, and McNary) had an effect on TDG variation, as it was intended.

Beginning in 2003, Bonneville began spilling water to facilitate adult passage (training spill) at this project. This training spill was initiated prior to the implementation of voluntary spring spill and involved spilling a small amount of water (less than 5 kcfs) for a period of approximately 12 hours during the daytime. To investigate the effect of this spill level on TDG at Camas/Washougal, a regression analysis on spill at Bonneville and TDG at Camas/Washougal was conducted. This regression indicated that 5 kcfs might increase the TDG levels at Camas/Washougal by approximately 1%. Therefore, in order to compensate for increased TDG at Camas/Washougal due to training spill, the measured TDG levels were reduced by 1% for use in the analyses.

Second, the 2001 spring and summer voluntary spill seasons (April 3 – August 31, 2001 for both Lower Snake Projects and Lower Columbia Projects) were studied. In 2001, voluntary spill did not occur at the Snake River projects and only occurred for a few days in the Lower Columbia due to extremely low water levels and flows. This analysis addressed variation in TDG throughout an entire spill season, over the range of possible temperatures, when no spill was occurring upstream of the monitors. (Spill at Priest Rapids Dam was accounted for in the analysis and the days when spill at Priest could have affected the forebay reading at McNary were removed).

Finally, the 2005 spring spill season for the Lower Snake Projects (April 3 – June 20, 2005) was reviewed. In the spring of 2005, voluntary spill did not occur at most of the Lower Snake projects due to low water levels and flows. This analysis allowed the investigation in the variation in TDG levels in the spring when no spill was occurring. Adjustments were made to account for the time periods during which spill did occur at the lower Snake projects to remove these data from the data sets.

For each of the forebay monitors listed above, the following data were used in these analyses: 1) hourly measures of TDG, 2) hourly measures of flow, and 3) hourly measures of spill. Spill data were taken from the project directly upstream of the monitor of interest. For each forebay monitor, the mean, minimum, and maximum TDG levels for time periods when spill was not occurring at the project(s) above the monitor was estimated. The hourly spill data were used to corroborate that no spill was occurring above each forebay monitor. In instances where spill was occurring above the forebay monitor, hourly flow data were used to estimate water travel times for each spill event through the use of regression. An average water travel time was estimated for each spill event. Total dissolved gas measures that were recorded after a period of spill, based on the average water travel time for that spill event, were eliminated from the analysis. This enabled the elimination of any TDG levels that may have been influenced by spill occurring above the monitor of interest from each of the analyses. Furthermore, the TDG measurements considered were between 95% and 130%.

1. Pre-Spill Season (2001-2006)

The TDG levels prior to the beginning of the spill season were assessed at all projects using available data (Table 3). The table lists the mean TDG value over the period as well as the minimum and maximum values. From the table it can be seen that TDG averaged above 100% with maximum hourly values well in excess of 100%. These data show that all forebay monitors in the system are affected to some degree by processes other than spill, e.g. temperature and primary productivity.

Additionally, the table shows that at projects where forebay monitors were relocated to address RPA 132 (see bold line in table), there was no discernable response to the relocation of the monitor. At all locations, after monitor relocation, the effect of local processes on forebay TDG readings appeared about the same as before relocation.

Pre Spill Season							
Forebay Monitor		**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Lower Granite	**Mean TDG**	**102.9**	**101.1**	**101.4**	***101.6***	***103.5***	***102.3***
	Min. TDG	99.6	98.1	98.3	*98.5*	*98.9*	*98.7*
	Max TDG	105.9	103.6	105.8	*104.8*	*108.8*	*104.9*
Little Goose	**Mean TDG**	***104.2***	***101.4***	**101.1**	***102.2***	***102.7***	***103.3***
	Min. TDG	*102.3*	*100.5*	99.2	*99.5*	*99.5*	*100.8*
	Max TDG	*108.1*	*103.6*	103.3	*106.4*	*105.2*	*105.3*
Lower Monumental	**Mean TDG**	***104.4***	**101.7**	**100.9**	**102.9**	**102.2**	***103.4***
	Min. TDG	*102.3*	100.4	98.5	100.7	100.2	*102.1*
	Max TDG	*108.5*	103.5	103.4	107.3	105.8	*105.1*
Ice Harbor	**Mean TDG**	***103.2***	**101.8**	**101.4**	**103.0**	**104.9**	***101.8***
	Min. TDG	*100.7*	99.2	98.7	100.4	99.4	*99.7*
	Max TDG	*107.8*	104.4	104.8	106.9	109.7	*105.1*
McNary Oregon	**Mean TDG**	***104.3***	***102.1***	***101.8***	***104.2***	***104.6***	***103.0***
	Min. TDG	*101.1*	*99.1*	*98.1*	*100.1*	*101.0*	*99.9*
	Max TDG	*110.5*	*110.1*	*110.1*	*111.9*	*110.0*	*108.4*
McNary Washington	**Mean TDG**	***103.9***	***102.2***	***102.2***	***104.1***	***104.3***	***102.9***
	Min. TDG	*101.2*	*99.0*	*99.2*	*100.0*	*101.1*	*100.0*
	Max TDG	*109.9*	*107.5*	*105.8*	*108.4*	*108.7*	*106.8*
John Day	**Mean TDG**	**103.3**	***103.5***	***102.9***	***105.1***	***104.4***	***103.9***
	Min. TDG	100.8	*100.7*	*100.3*	*102.5*	*101.7*	*100.9*
	Max TDG	106.50	*107.2*	*107.8*	*109.5*	*106.9*	*107.1*
The Dalles	**Mean TDG**	**102.6**	***103.2***	***102.3***	***103.8***	***104.0***	***103.8***
	Min. TDG	100.3	*100.8*	*100.1*	*100.8*	*101.6*	*101.2*
	Max TDG	105.5	*110.9*	*104.9*	*108.1*	*108.2*	*107.0*
Bonneville	**Mean TDG**	**103.7**	***102.8***	***102.0***	***103.7***	***104.5***	***103.2***
	Min. TDG	100.8	*100.5*	*99.7*	*101.2*	*101.3*	*100.7*
	Max TDG	106.1	*106.0*	*106.2*	*106.7*	*107.2*	*107.7*
Camas/ Washougal	**Mean TDG**	***104.1***	***103.0***	***101.5***	***103.4***	***104.3***	***102.9***
	Min. TDG	*100.3*	*100.0*	*99.0*	*99.5*	*100.6*	*100.3*
	Max TDG	*107.5*	*108.5*	*105.0*	*107.9*	*108.6*	*108.0*

Table 3. Mean, minimum and maximum TDG values estimated for each project based on hourly TDG data available for the season prior to the initiation of spill. Italicized data indicate the years where some above-project spill occurred and some TDG measures were eliminated when estimating mean, min, and max TDG. An estimated water travel time was used to determine which TDG measurements to eliminate from the estimation of mean, min, and max TDG at each project.

2. 2001 Spill Season

The 2001 drought year presented a data set where most of the time spill did not affect the forebay monitors. During the 2001 spill season (April 3 to August 31, 2001), all projects had a mean TDG above 100% after removal of any data from the data set that may have been affected by spill (spill did occur in the Mid Columbia). The mean TDG level ranged from 101.3% at John Day to 104.1% at McNary dam (Oregon side) (Table 4). The lowest minimum TDG was 95% at the John Day monitor. Finally, the highest maximum TDG was 111% at the Lower Granite monitor.

2001 In Season TDG Levels (April 3 – August 31)			
Forebay Monitor	**Mean Seasonal TDG**	**Min Hourly TDG**	**Max Hourly TDG**
Lower Granite	*102.9*	*97.7*	*111.0*
Little Goose	*101.2*	*95.8*	*110.2*
Lower Monumental	*102.4*	*97.1*	*110.6*
Ice Harbor	*101.9*	*95.4*	*110.1*
McNary - Oregon	*104.1*	*101.7*	*110.1*
McNary - Washington	*103.1*	*99.0*	*105.7*
John Day	*101.3*	*95.0*	*107.3*
The Dalles	*101.2*	*95.1*	*107.2*
Bonneville	*102.1*	*97.9*	*107.1*
Camas/Washougal	*103.4*	*97.9*	*110.4*

Table 4. Mean, minimum and maximum TDG values estimated for each project based on hourly TDG data available for 2001. Italicized data indicate the years where some above-project spill occurred and some TDG measures were eliminated when estimating mean, min, and max TDG. An estimated water travel time was used to determine which TDG measurements to eliminate from the estimation of mean, min, and max TDG at each project.

3. 2005 Spring Spill Season

Planned spill did not occur in the Snake River above Ice Harbor Dam during the spring. During the 2005 spring spill season (April 3 to June 20, 2005), all Lower Snake River projects had a mean TDG above 100% (Table 5). The mean TDG for the Lower Snake River projects ranged from 102.8% at the Lower Granite forebay monitor to 103.5% at the Ice Harbor forebay monitor. The lowest minimum TDG was 98.9% at the Lower Granite monitor. The highest maximum TDG was 108.8% at the Lower Monumental monitor.

2005 Spring Spill Season TDG Levels (April 3 – June 20)			
Forebay Monitor	**Mean TDG**	**Min TDG**	**Max TDG**
Lower Granite	*102.8*	*98.9*	*108.3*
Little Goose	*103.0*	*99.7*	*106.7*
Lower Monumental	*103.0*	*100.0*	*108.8*
Ice Harbor	*103.4*	*101.3*	*106.4*

Table 5. Mean, minimum and maximum TDG values estimated for each project based on hourly TDG data available for 2005. Italicized data indicate the years where some above-project spill occurred and some TDG measures were eliminated when estimating mean, min, and max TDG. An estimated water travel time was used to determine which TDG measurements to eliminate from the estimation of mean, min, and max TDG at each project.

Based on the three separate analyses that were conducted, it is safe to say that, in conclusion, forebay monitors do not accurately reflect the TDG of mixed waters and continue to be impacted by localized processes. Measures (relocation) taken under RPA 132 to assure that the forebay monitors were representative of mixed water at several of the projects did not achieve that objective.

Oxygen relationship

While the role of dissolved oxygen from primary productivity is acknowledged in affecting the overall TDG concentration, in RPA 132 the COE did not specifically address the impact of primary productivity on the total dissolved gas levels. Primary productivity can increase dissolved oxygen levels, which would result in a higher TDG percent saturation reading. It is possible that the forebay monitors are often affected by oxygen production due to primary productivity as well as diel temperature variations. Dissolved oxygen readings are not routinely collected, therefore, limited dissolved oxygen data exists in the record to assess the impact of dissolved oxygen on the overall total dissolved gas readings for the time period used in the previous analysis. However, there are some periods where simultaneous hourly data are available for total dissolved gas, dissolved oxygen and temperature at the dam forebay monitors. These data were available for certain periods prior to the initiation of the spill program at the lower Snake River projects for 2001 to 2004. Those limited data were analyzed to determine the potential relation between dissolved oxygen, total dissolved gas and temperature (Table 6).

A series of correlation coefficients were estimated for the available data. From the table it can be seen that about half of the correlation coefficients showed a stronger relation between dissolved oxygen and total dissolved gas, than for temperature and total dissolved gas. While the studies conducted under RPA 132 only addressed temperature, the data here suggest that at times dissolved oxygen may be as important in affecting the forebay monitor reading as temperature. The impact of dissolved oxygen from primary productivity may explain why the monitor relocation in response to RPA 132 did not achieve its objective.

Project		**2001**	**2002**	**2003**	**2004**
LGR	**TEMP**	-0.34	-0.11	0.06	0.33
	DO	**0.48**	**0.11**	-0.02	**0.62**
LGO	**TEMP**	-0.31	-0.02	0.71	-0.05
	DO	**0.83**	**0.21**	0.20	0.11
LMN	**TEMP**	0.53	0.28	0.06	Data not useable
	DO	0.18	0.19	**0.12**	
IHR	**TEMP**	-0.41	-0.02	0.49	Data not useable
	DO	**0.85**	**0.19**	-0.57	

Table 6. Correlation coefficients (r^2) between hourly temperature readings (TEMP) and TDG and between hourly dissolved oxygen (DO) readings and TDG at the Snake River projects.

While these data are limited, they do suggest a mechanism that may be contributing to the continued inability of forebay monitors to adequately represent the TDG of the mixed water column in the forebay of a dam.

Biological Monitoring

Since 1995, the biological monitoring program has recorded annually the effects of the FCRPS biological opinion spill program. The data observed over the years through the biological monitoring has consistently shown very low incidence of GBT when gas levels are at the 120%

tailrace criteria. When fish are exposed to gas levels greater than 120%, there is an increasing trend in incidence and severity of these signs (Figure 1). For all fish examined through the Smolt Monitoring Program for signs of GBT when tailrace TDG levels were 120% or less the incidence of any fin signs observed in that population was 0.5%. This demonstrates the minimal effect of biological opinion spill levels with TDG levels managed to 120% in the project tailrace. That percentage of fish affected with GBT begins to increase above 120% and then dramatically increases above 125%.

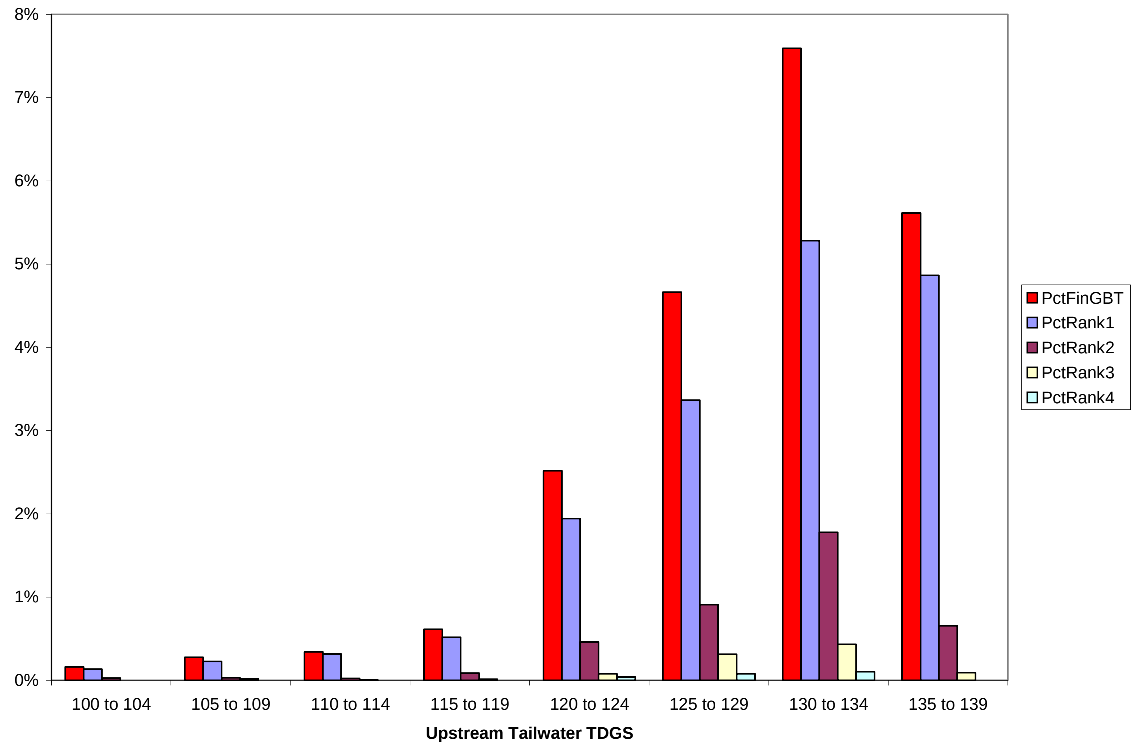

Figure 1. Percentage of all Fish Examined for GBT at Little Goose, Lower Monumental, McNary and Bonneville dams from 1995 to 2005 that showed fin any GBT as well as the percent by TDG category based on upstream tailwater monitor and fish travel time from that site. Fin ranks are: rank 1 – less than 5% fin area covered with bubbles, rank 2 – 5 to 25%, rank 3 – 26 to 50% and rank 4 – greater than 50%.

2006 Spill

An issue surfaced during the 2006 spring spill season with regard to the management of spill solely to physical TDG criteria. During the spring freshet the TDG levels exceeded the water quality standards and the incidence of GBT in fish exceeded the criteria at some projects (Appendix C). However, since this was uncontrolled spill, no recourse was possible. However, later in the season the incidence of GBT again increased at the Snake River projects as a result of project operations for the management of excess market spill after the spring peak flows had occurred. This occurred during mid-June of 2006. At the time the Action Agencies' management of spill attempted to meet water quality standards during daytime hours, which resulted in spill levels well in excess of the Court's order during nighttime hours. The management resulted in periods when TDG levels may have been significantly higher that if attempts were made to manage spill to a lower overall daily average. A more logical management approach would have been to attempt as best as possible to evenly distribute spill over the 24-hour period. While the instantaneous gas would have exceeded the waiver criteria, the daily average TDG would have been lower for the day. The overall lower TDG values may have had less impact on fish. This type of management should be implemented in future years.

Conclusions

Spill in 2006 was implemented according to the Court's Order and the current dissolved gas waiver criteria. However, it appears that there is sufficient information to conclude that changes should be considered to the waiver criteria regarding the use of forebay monitors as a point of compliance for dissolved gas. These monitors do not represent the measurements of TDG in mixed waters as was originally intended. Further, it appears that efforts to relocate monitors have not addressed the impacts to measurements caused by localized variations in temperature, barometric pressure and primary productivity.

Consequently, spill that occurred in the spring of 2006 offered less mitigation to migrating salmonids (4.1 MAF) than what could have occurred if spill only met the 120% TDG tailrace objective, after excess hydraulic capacity and excess market spill were removed from the equation. The bias towards a higher TDG reading at the forebay monitors results in an unnecessary limitation of protection measures for fish passage. The alternative of using the tailrace monitor allows for better implementation of the intent of the Court's Order.

Biological monitoring conducted over several years' supports the minimal impact to migrating salmonids of total dissolved gas levels at 120% or less. So few fish have been detected over 12 years of monitoring when spill is 120% at the tailrace location of an upstream project that it is safe to assume minimal impact. Management to the 120% tailrace criteria assures the safety of fish in a planned spill program, while at the same time better allowing for the achievement of the biological objectives of the program.

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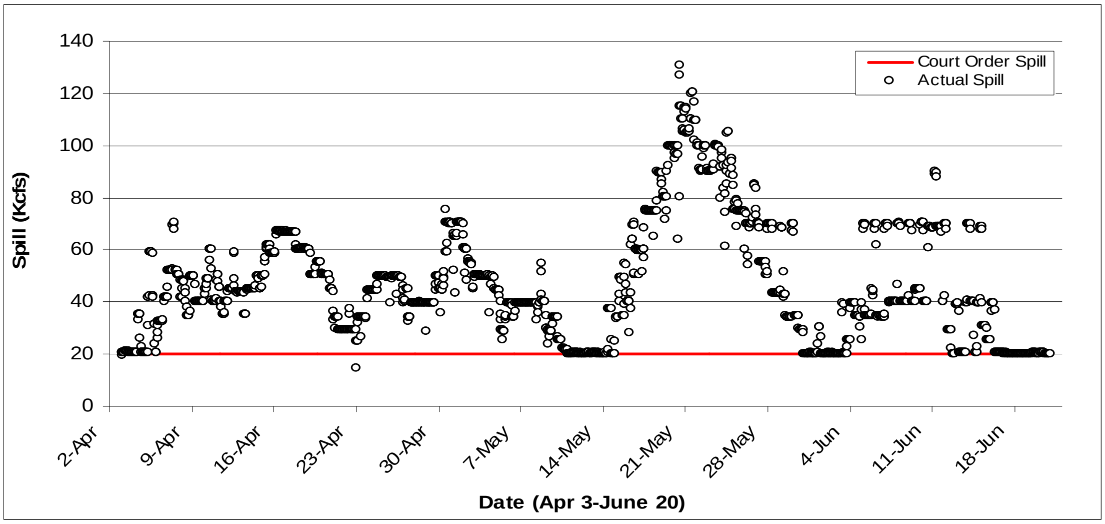
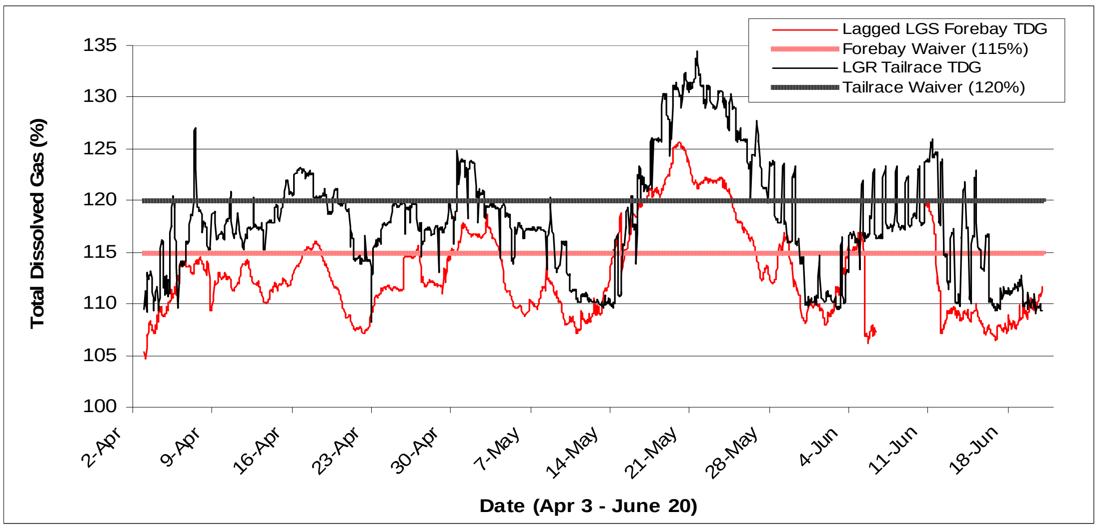
Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, and Columbia River Inter-Tribal Fish Commission. 1995. Spill and 1995 Risk Management.

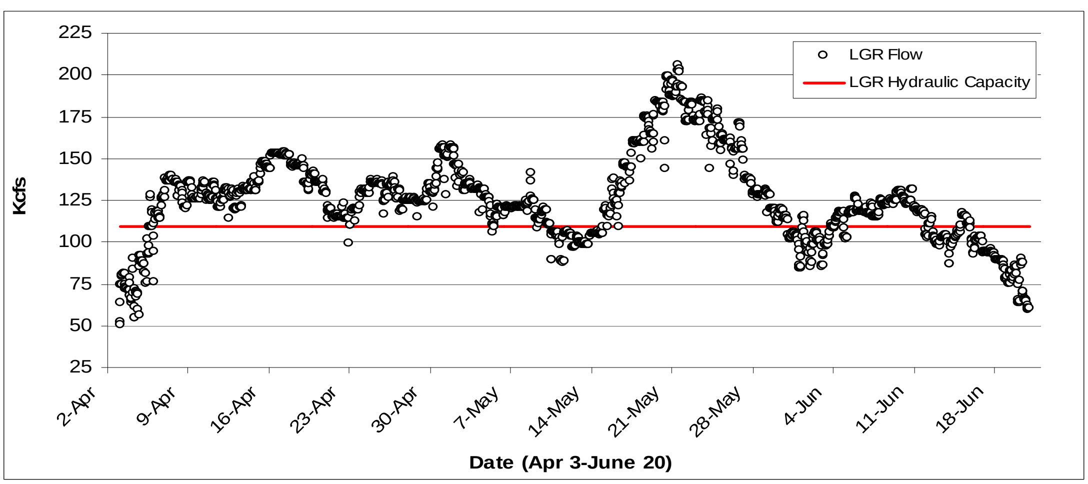
Appendix A



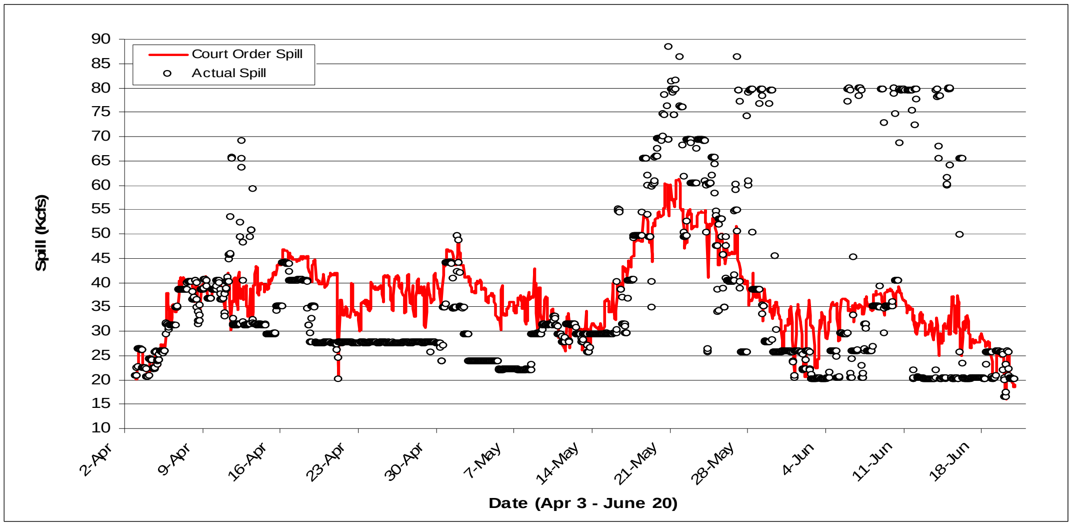
Lower Granite (Spill vs. Court Order)



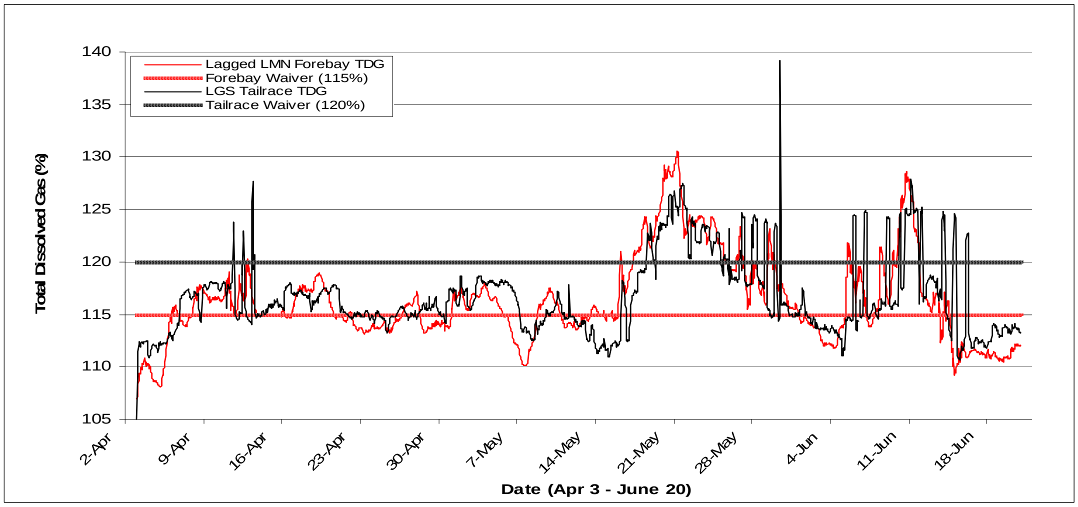
Lower Granite (Forebay and Tailrace TDG)



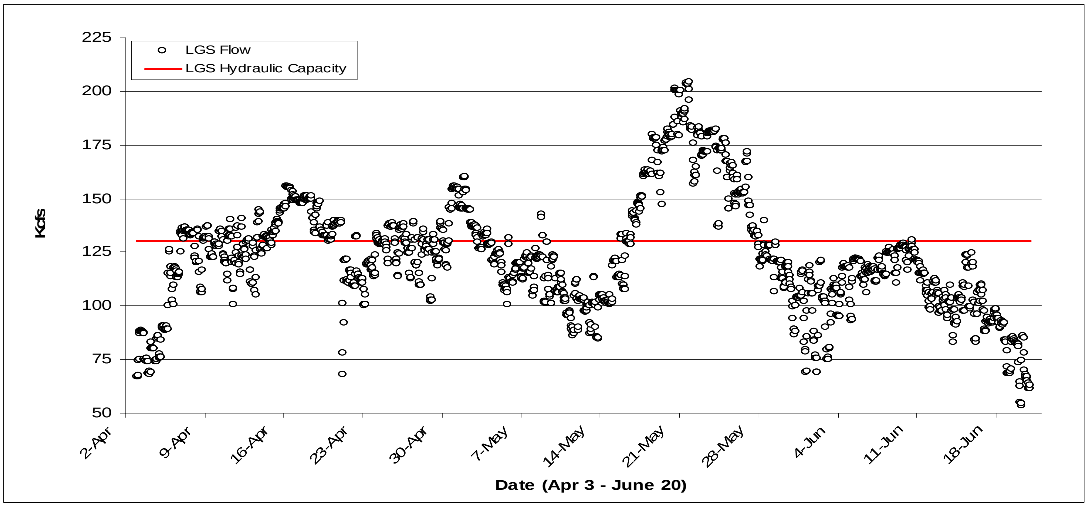
Lower Granite (Flow vs. Hydraulic Capacity)



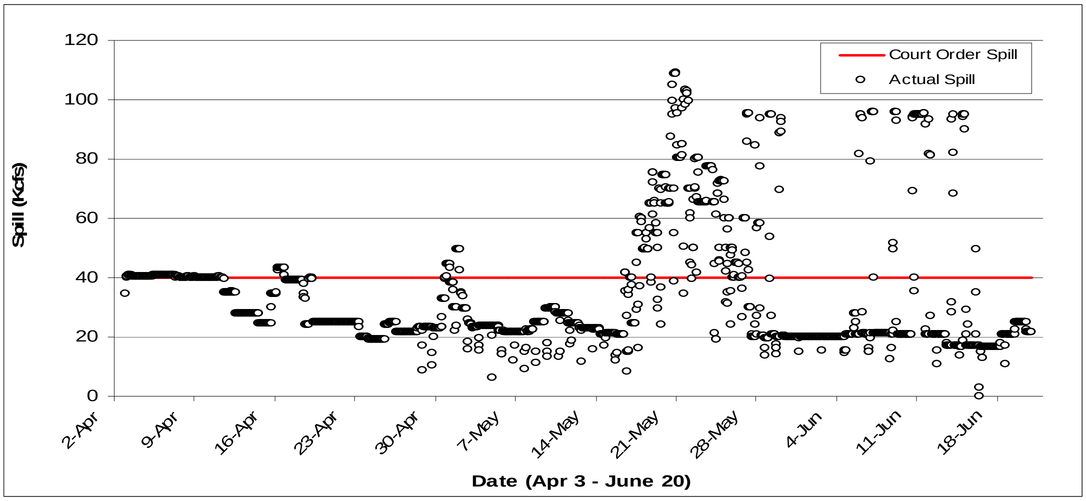
Little Goose (Spill vs. Court Order)



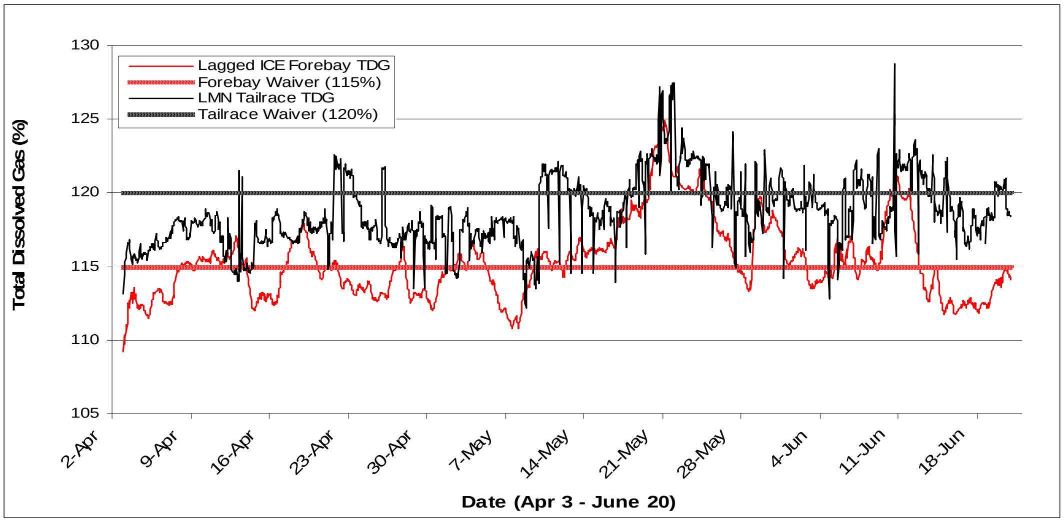
Little Goose (Forebay and Tailrace TDG)



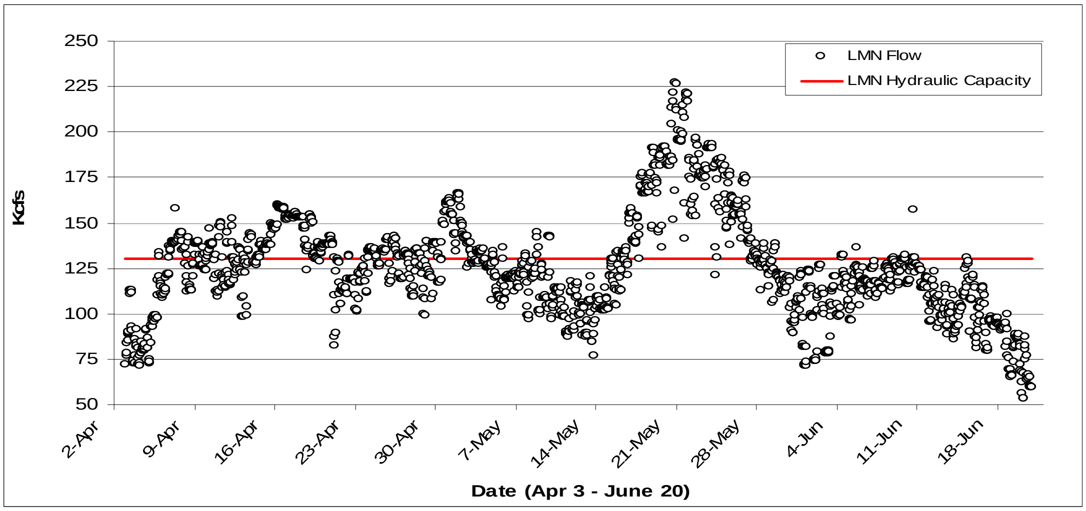
Little Goose (Flow vs. Hydraulic Capacity)



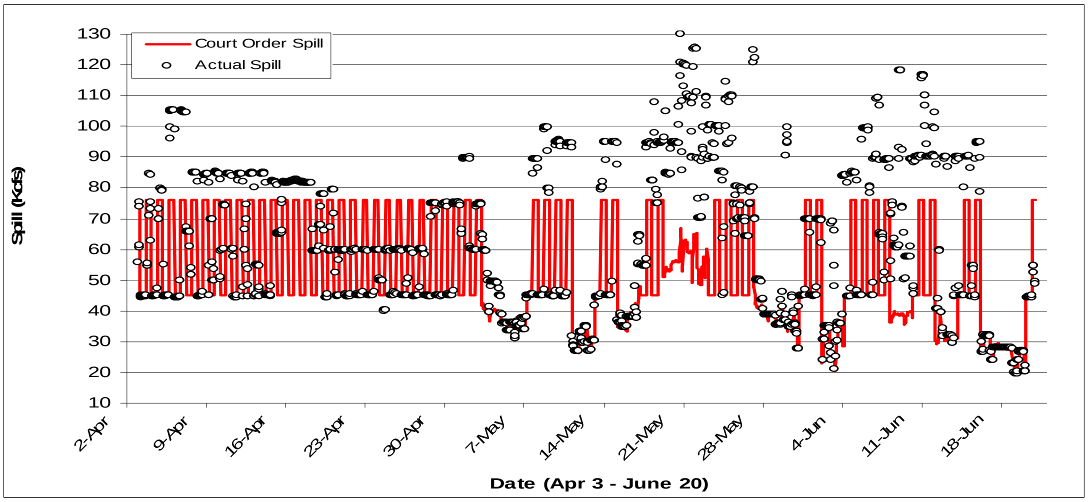
Lower Monumental (Spill vs. Court Order)



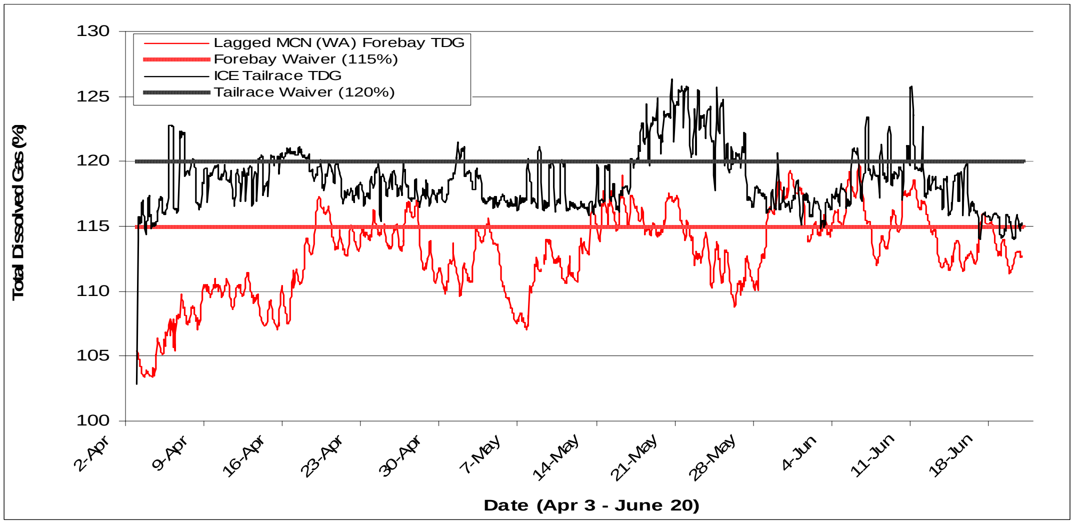
Lower Monumental (Forebay and Tailrace TDG)



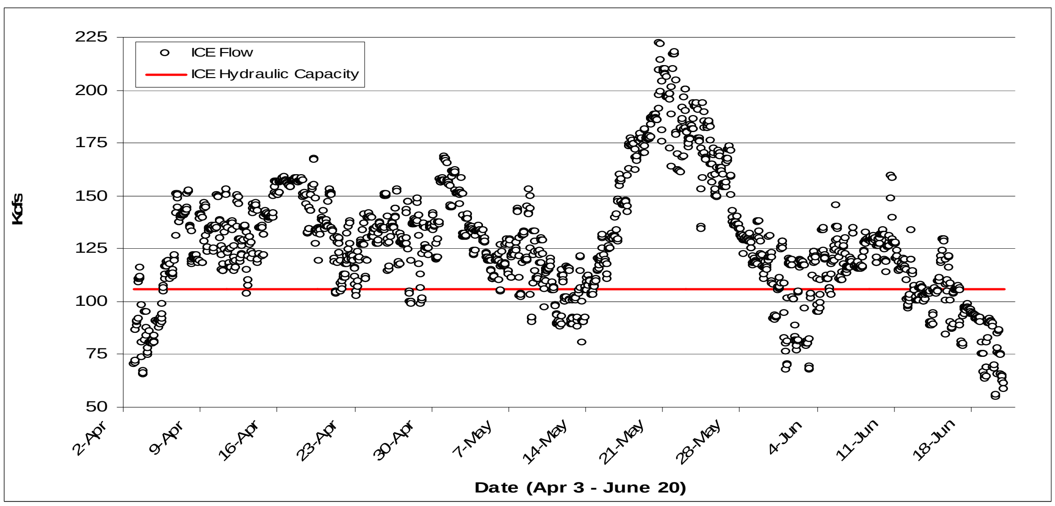
Lower Monumental (Flow vs. Hydraulic Capacity)



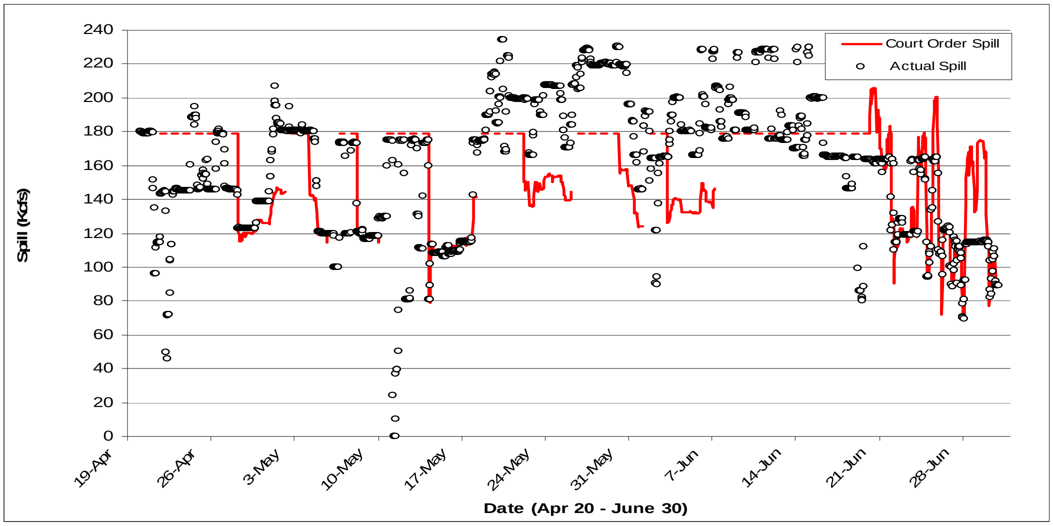
Ice Harbor (Spill vs. Court Order)



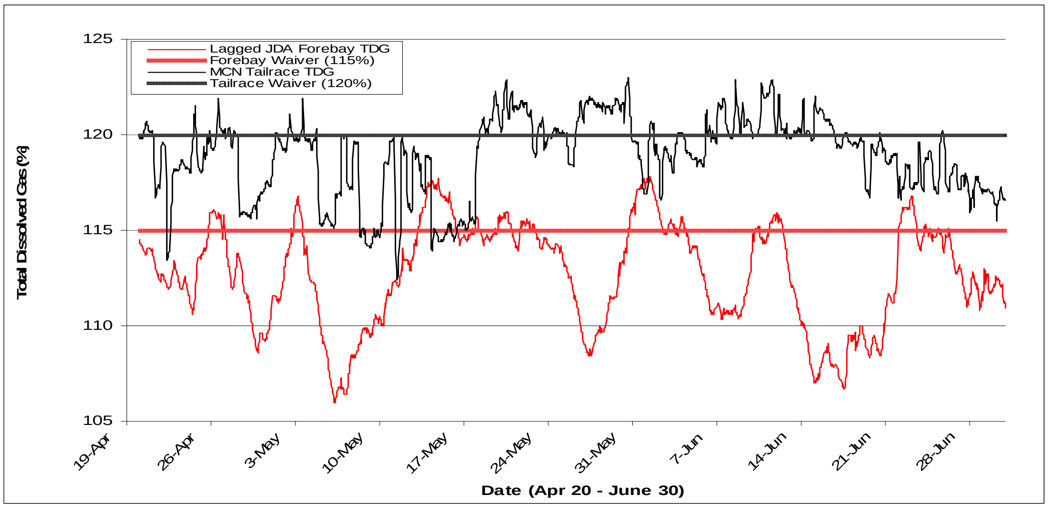
Ice Harbor (Forebay and Tailrace TDG)



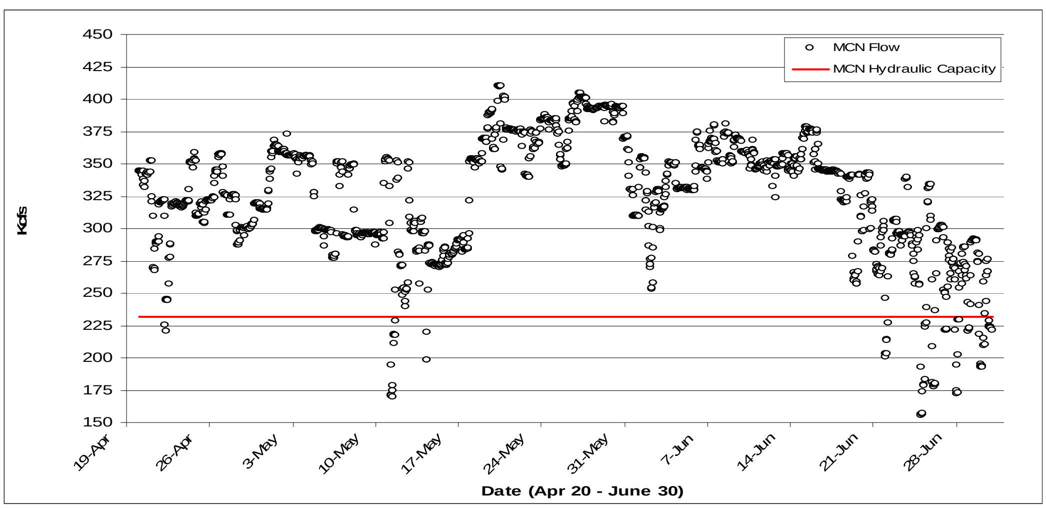
Ice Harbor (Flow vs. Hydraulic Capacity)



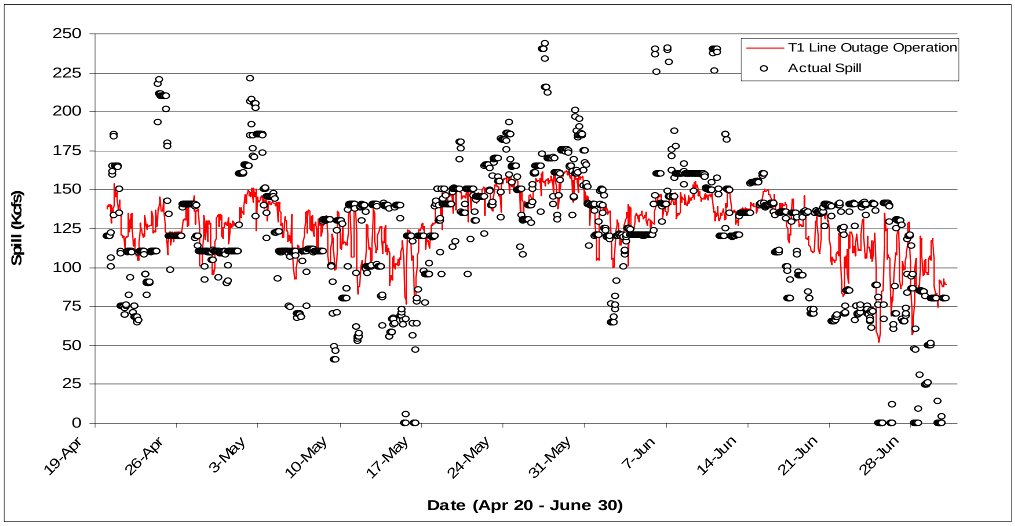
McNary (Spill vs. Court Order)



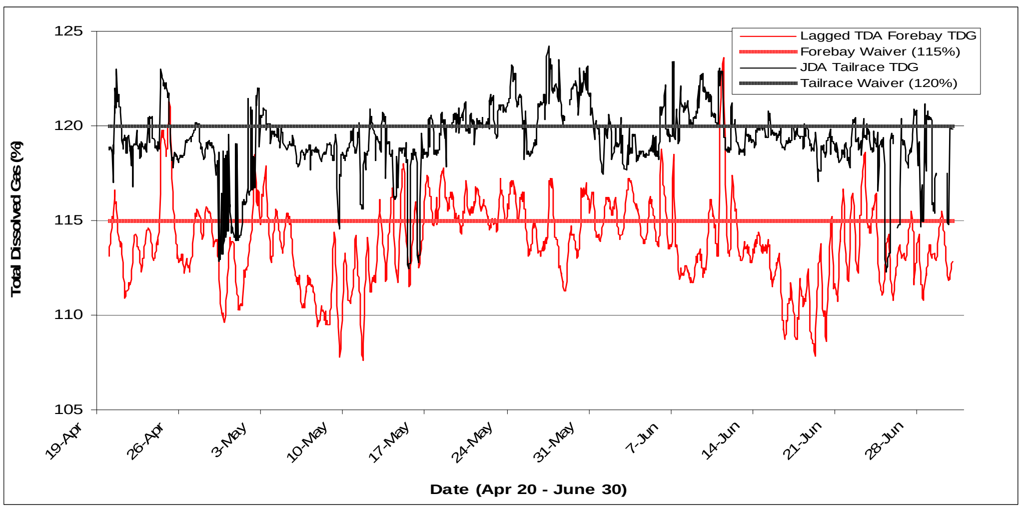
McNary (Forebay and Tailrace TDG)



McNary (Flow vs. Hydraulic Capacity)



John Day (Spill vs. Court Order)



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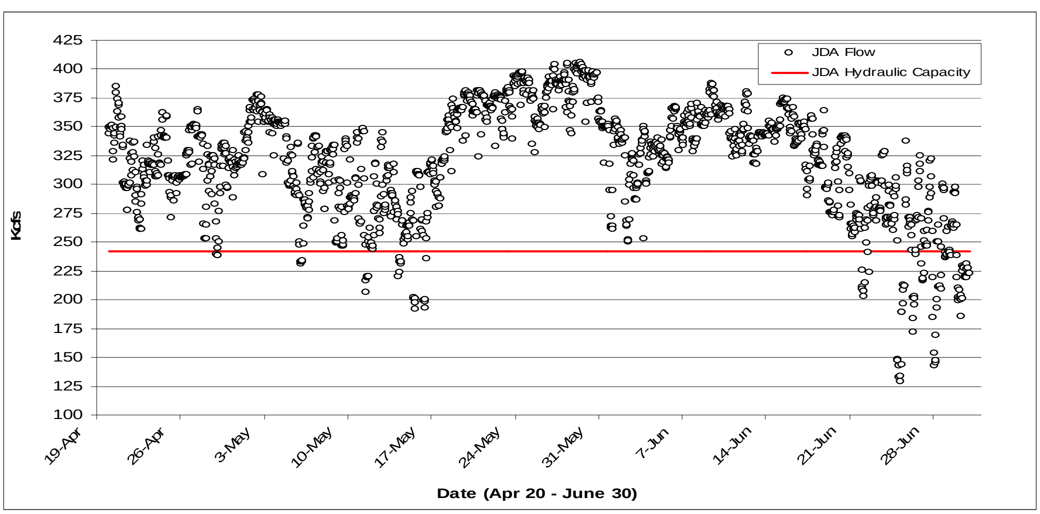
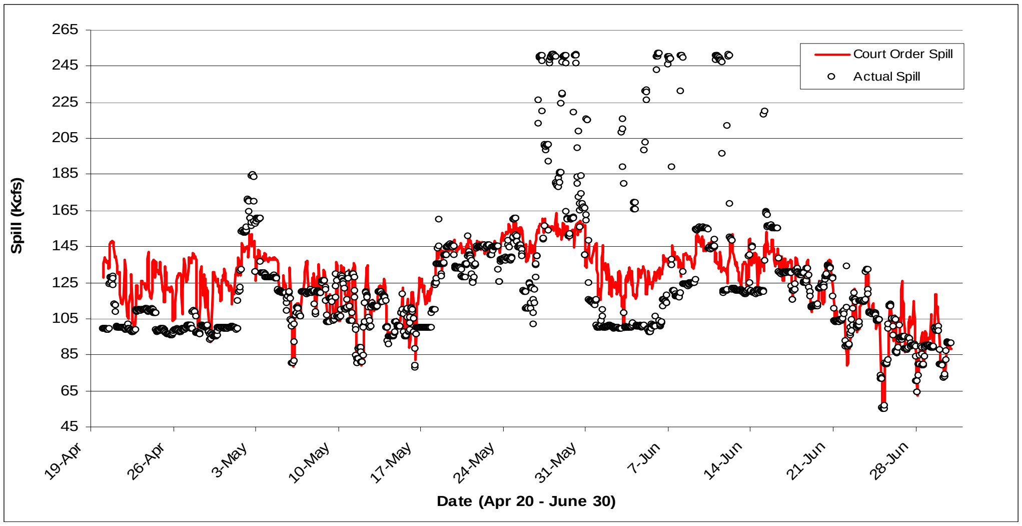
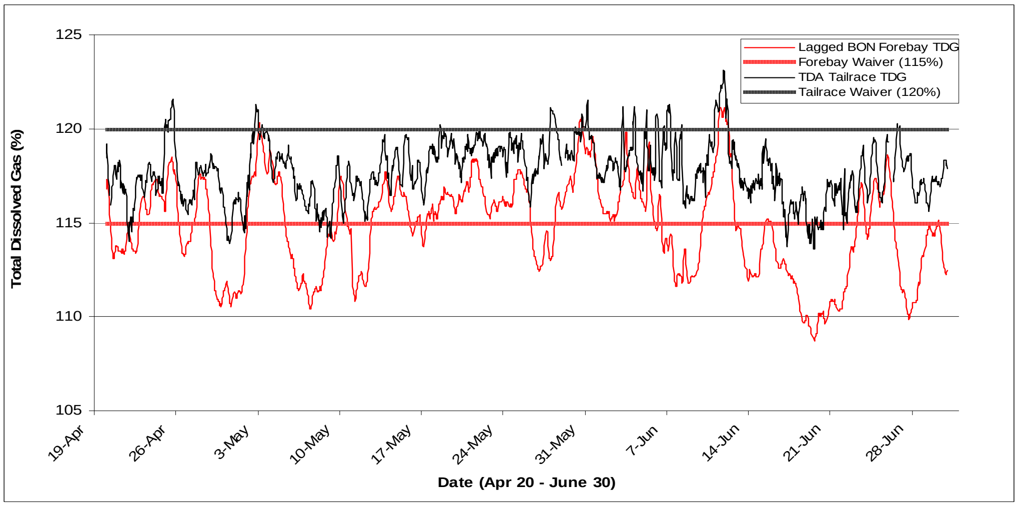


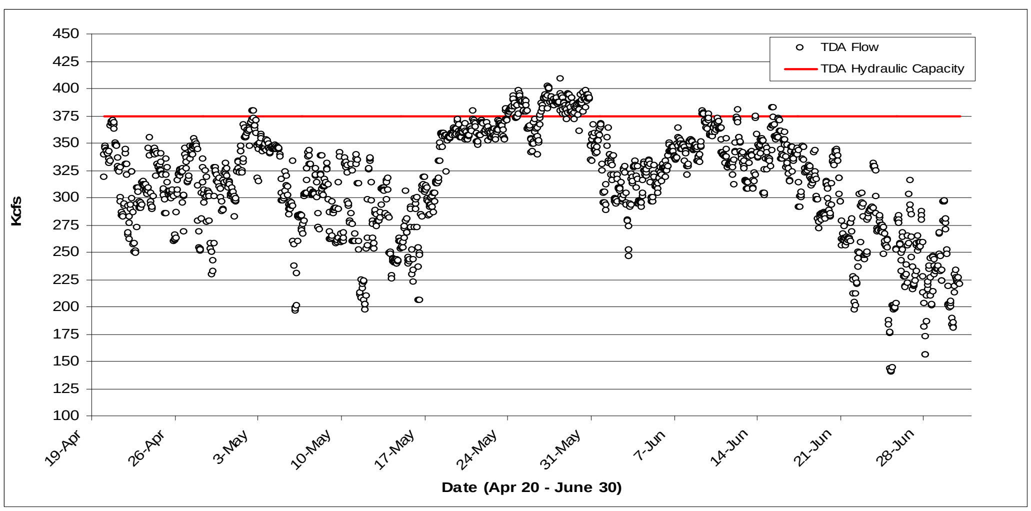
John Day (Flow vs. Hydraulic Capacity)



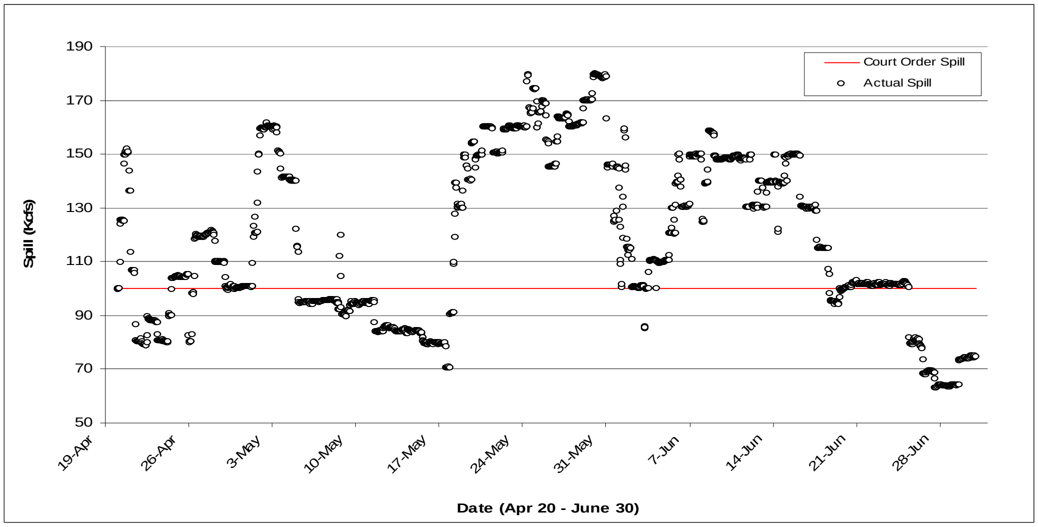
The Dalles (Spill vs. Court Order)



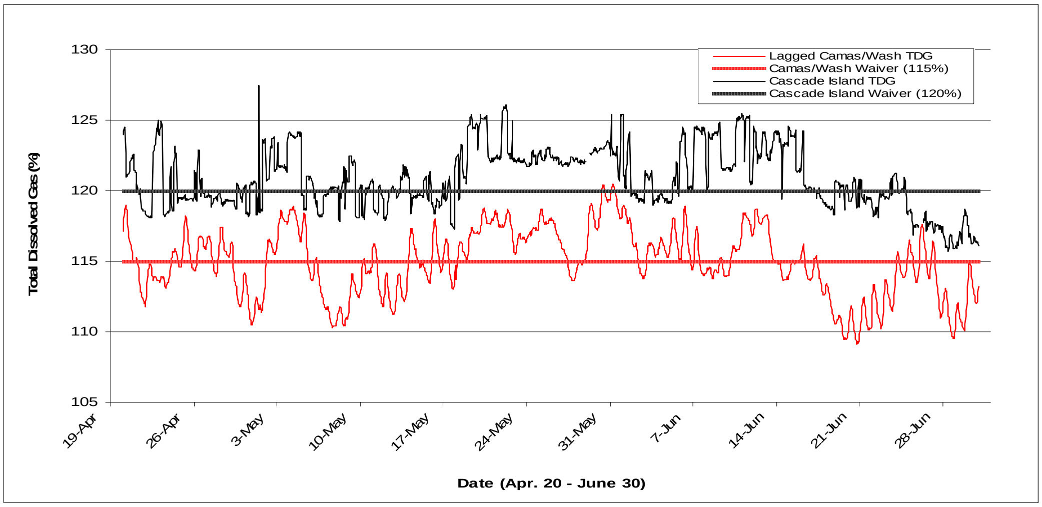
The Dalles (Forebay and Tailrace TDG)



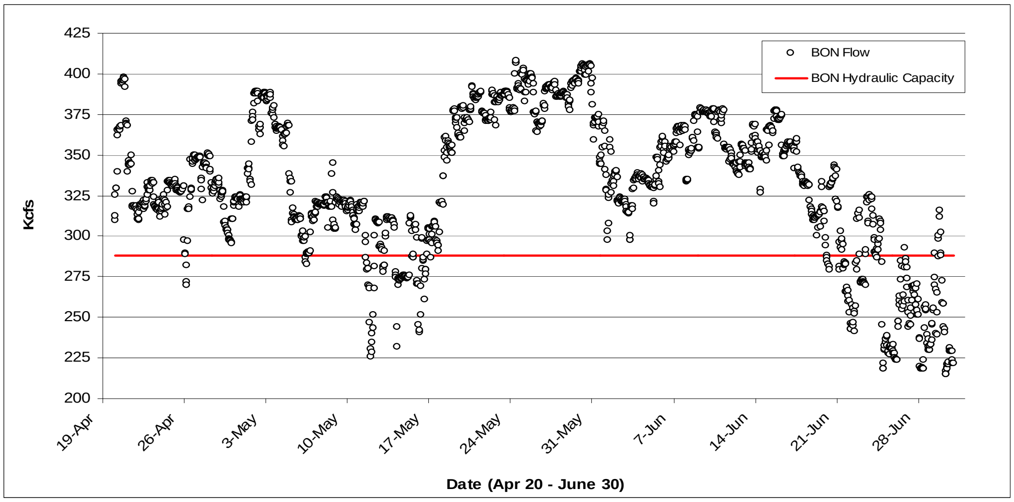
The Dalles (Flow vs. Hydraulic Capacity)



Bonneville (Spill vs. Court Order)



Bonneville (Forebay and Tailrace TDG)



Bonneville (Flow vs. Hydraulic Capacity)

APPENDIX B

Columbia River TDG Fixed Monitoring System History
Draft, 7/5/06

Fixed Monitoring System Station Codes – See attached table.

Year	Status or Action
2000	- All stations remain as they were in 1999
	- JDAW – a second, redundant monitor added
2001	- All stations remain as they were in 1999
	- Walla Walla District installed temperature monitor in DWQ pool
	- Pasco & Anatone kept as winter monitors
	-Portland District added a 2nd Camas gauge
2002	- WQT recommended Camas remain, add a new station at Corbett
	- SKAW terminated in favor of new Corbett station
	- WRNO remained in service
	-Added data logger at west end of TDA powerhouse, east end station remained official mgmt gauge
	-Added JDA scroll case temperature monitor. JDA forebay remained as mgmt gauge
	-WQT agreed to evaluate all FMS for performance at the end of 2002
2003	-Continued exploratory monitoring at Corbett
	-WRNO & TDDO declared inconsistent with other tailrace monitors
	- A monitor in the BON tailrace replaced WRNO
	- No change in BON forebay monitor
	- Relocation of forebay monitors under consideration for TDA, JDA, MCQW & MCQO
	- FB monitor relocation reviewed for IHR, LMN, LGS, & LGR. A multi-year plan to review and analyze includes review and analysis of existing data from the forebay fixed monitors for representativeness and anomalies in total dissolved gas and temperature.
2004	- CMWM remained a spill mgmt site
	- no change
	- BON tailrace monitor installed on Bradford Island
	Page 2
	- No Change - WRNO, BON (forebay), TDA, TDDO, JDAW, MCN, Pasco, IDSW, LMNW, LGSW, LGNW
	TDDO is inconsistent with other tailwater sites. Continue use of site to manage spill. Recommend additional investigations of more suitable location
	- JDA relocates to upstream end of nav. lock, 15 m deep.

2004 continued	- MCNW and MCNO – transition year. Evaluate alternate sites, include
	Re-locate to upstream end of Washington nav lock guide wall, 15 m deep, & at the Oregon BRZ (Oregon side)
	- Transition year for IHR, LMN, LGS, LGW. Evaluate & locate Monitors were set at 5 m
2005	- No Change CWMW, BON, TDA, TDDO, JDA-2, JDAW, MCPW, Pasco, IDSW, LMNW, LGSW, LGNW
	- Winter only (TDG and Temp) - WRNO
	- BON tailrace moved to CCIW. Use CCIW data to manage BON spill
	- MCPO, MCPW- Washington side monitor moved to end of nav lock guide wall, 15 m deep. MCPO no change, add a monitor on a float at the BRZ
	- Redeploy monitor to depth of 15 m. at IHR-2, LMN-2, LGS-2, LGR-2
2006	-No Change CMWM, TDA, JDA-2, MCPW-2, IDSW, LMN-2, LGS-2, LGNW
	-WRNO installed 3/1/06, removed at end of May 2006 after chum emergence
	- Site became year-round tailrace TDG monitor – CCIW, TDDO, IDSW, LMNW, LGSW
	- Site monitoring discontinued during fall and winter – BON, MCQW-2, IHR-2, LGW-2. Operational during spill season
	- MCQO permanently retired

Note: See page 3 for fixed monitoring system station code and name

Summary Notes:

2003 - BON tailrace monitor added at Turtle Rock
- Multi-year plan to relocate Snake River forebay monitors developed

2004 – forebay monitor relocations to JDA, MCN, IHR, LMN, & LGR. Moved monitors to 5 m depth on nav lock walls

2005 – Redeployed MCPW, IHR-2, LMN-2, LGS-2, LGR-2 to 15 m depth on nav lock wall
- BON tailrace moved to CCIW
-WRNO used during the chum incubation and emergence period (March- May)

2005 Dissolved Gas Monitoring Network

Station Code and Name

STATION CODE	STATION NAME
CIBW	US/Can Boundary
HGHW	Below Hungry Horse
FDRW	Grand Coulee Forebay
GCGW	Grand Coulee Tailwater
ALFI	Albeni Falls Forebay
ALFW	Albeni Falls Tailwater
LBQM	Libby Tailwater
CHJ	Chief Joseph Forebay
CHQW	Chief Joseph Tailwater
WEL	Wells Forebay
WELW	Wells Tailwater
RRH	Rocky Reach Forebay
RRDW	Rock Reach Tailwater
RIS	Rock Island Forebay
RIGW	Rock Island Tailwater
WAN	Wanapum Forebay
WANW	Wanapum Tailwater
PRD	Priest Rapids Forebay
PRXW	Priest Rapids Tailwater
PAQW	Columb. R. Above Snake
DWQI	Dworshak Tailwater
PEKI	Peck/Clearwater
LEWI	Lewiston/Clearwater
ANQW	Upper Snake at Anatone
LWG-2	Lower Granite Forebay
LGNW	Lower Granite Tailwater
LGS-2	Little Goose Forebay
LGSW	Little Goose Tailwater
LMN-2	Lower Monum. Forebay
LMNW	Lower Monum. Tailwater
IHR-2	Ice Harbor Forebay
IDSW	Ice Harbor Tailwater
MCQW-2	McNary Forebay – WA
MCQO	McNary Forebay – OR
MCPW	McNary Tailwater
JDA-2	John Day Forebay
JHAW	John Day Tailwater
TDA	The Dalles Forebay
TDDO	The Dalles Tailwater
BON	Bonneville Forebay
CCIW	Bonneville Tailwater
WRNO	Warrendale
CWMW	Camas/Washougal

APPENDIX C

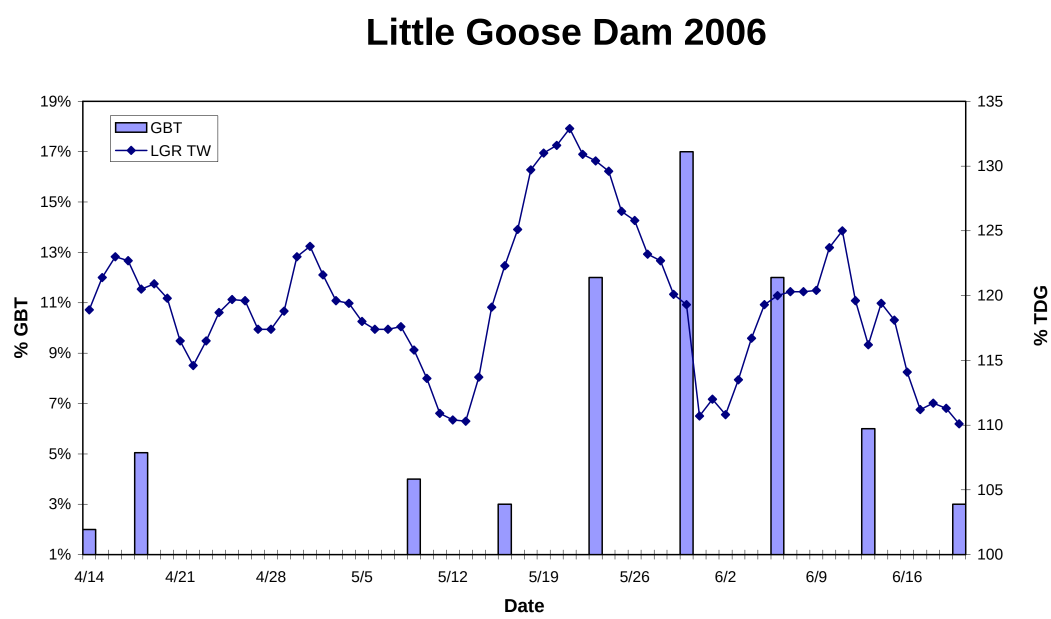


Figure 1. Percent signs of GBT observed in samples of juvenile salmon at Little Goose Dam and the upstream tailwater reading of total dissolved gas.

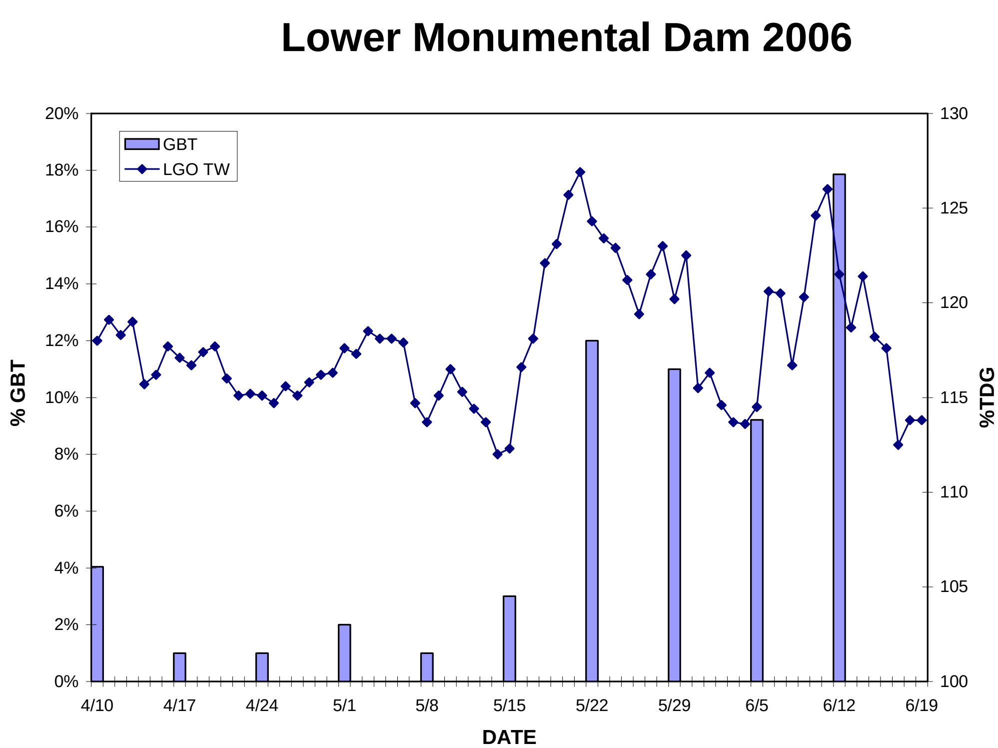


Figure 2. Percent signs of GBT observed in samples of juvenile salmon at Lower Monumental Dam and the upstream tailwater reading of total dissolved gas.

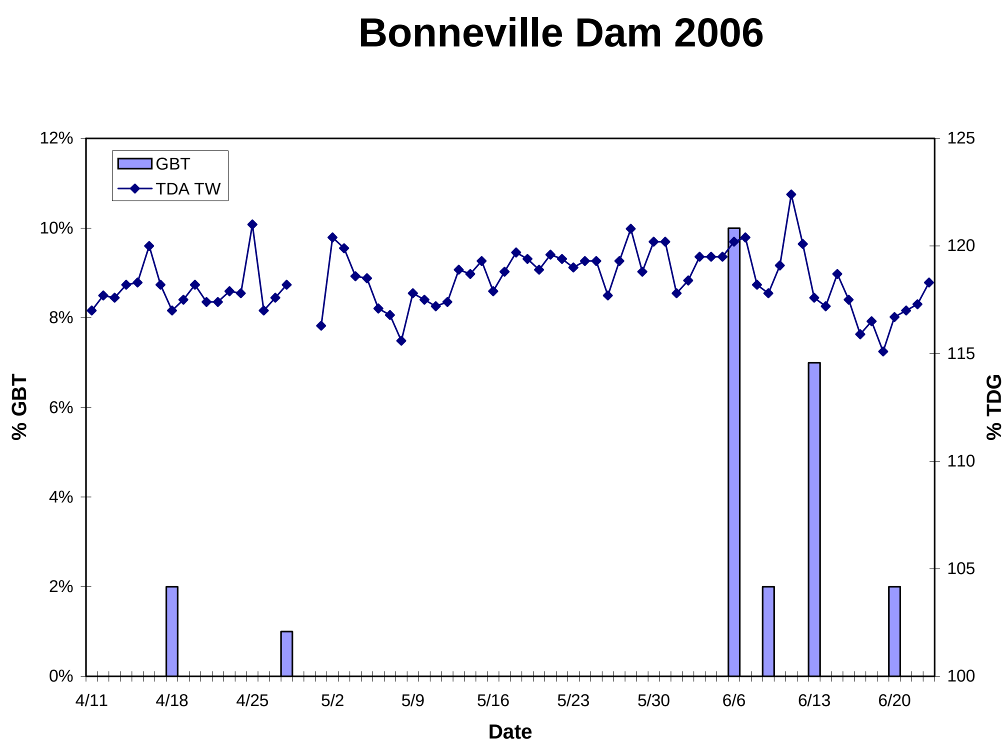


Figure 3. Percent signs of GBT observed in samples of juvenile salmon at Bonneville Dam and the upstream tailwater reading of total dissolved gas.