For RFAC Meeting April 7, 2011

Responses to the Queries of Glenn Erikson, President, Wild Trout Flyrodders

Peter Kolesar and James Serio

Part I. Dr. Erikson of Wild Trout Flyrodders (WTF) asks two interrelated questions:

> ***1)*** *Per the figures that have been made available to us, it appears that for each of the past three normal water years, all under FFMP flows, the East Branch of the Delaware River received less total annual water than it did under Revision 7, and for distinct and consistent periods of time it received less than under the drought program of Revision 7.*
> ***Can you confirm whether or not each of these two conditions will continue under your present model?***
>
> ***2)*** *In the event either of these two conditions on the East Branch continues:* ***How does the reduction of total annual water releases on the East Branch compare to the reduction or increase of annual releases on the West Branch and the Neversink?***

The WTF communication goes on to explain that his questions are largely motivated by concerns about thermal stress to trout from low flows on the East Branch during hot weather, and it then augments the queries as follows:

> *A) Can your model incorporate the above thermal stress day data to increase flows during the summer months, at least to those experienced on average during Revision 7 years?*
>
> *B) Can your model include substantially higher flows than 100 cps during the first two weeks of September?*

Response for Part I:

We will respond to the common concern in these several questions as a whole. The questions are complex, and we are limited by the data available and the technical capabilities of the models that we work with, as well as by the existing scientific knowledge relating reservoir releases, stream flows and ambient temperatures to river water temperatures at locations downstream of the reservoir discharge.

Some Background: The design of release policy involves balancing a set of objectives which are sometimes in conflict. Our own design reflects sometimes difficult choices. From a theoretical mathematical perspective alone, it is not possible to simultaneously maximize more than one objective, and so we follow the common practice of maximizing one objective while treating others as constraints. The most obvious and critical of the interrelated and conflicting issues on the Delaware are a release policy's impacts on trout habitat versus reliability of water supply, versus flood mitigation. Even within the domain of trout habitat, there are choices to be made regarding the priority to be given to different species, reaches of the river and seasons of the year. Various members of the fishing environmental community will make those trade-offs differently depending on personal preferences motivated perchance by their own relative emphasis on wild versus stocked fish, or on an emphasis for a favorite reach of the River, etc.

Our approach to release policy design is as follows: First, prompted by DRBC and decree party policy, we treat drought days, the key measure of reliability of water supply, as the dominant constraint. Given that constraint, we seek policies that use released water as efficiently as possible from an overall trout habitat perspective. We also tend to place a higher emphasis on wild versus stocked fish. While attentive to habitat throughout the year, we focus to a large extent on adult trout in the summer. Our research has shown that releases from the Cannonsville reservoir are the most efficient in maximizing total adult trout summer habitat. For example, an increase of one cfs in the L2 summer release from Cannonsville produces 1.6 times more habitat per drought day than does a 1 cfs release from Pepacton. Moreover, given that Cannonsville refills faster than the other reservoirs, and given the NYC-DEP preference for high water quality diversions from Pepacton and Neversink, our policies tend to emphasize Cannonsville releases.

However, our goal is to treat the East Branch and the Neversink equitably. That is, to generally keep them 'whole' with respect to the releases that would have occurred under previous release regimes. We are aware that others in the fishing/environmental community disagree with some of our design choices, and we have been prompted by the WTF's questions to reassess the performance of the 'Enhanced Joint Fisheries Program' release proposal that we offered at the March 8 RFAC meeting.

Technical Limitations in Conducting a Re-assessment: Dr. Erikson's questions are specific to the last three years during which the River has been managed according to the FFMP and are specific to conditions that might have been experienced during those years under Revision 7. Unfortunately, the OASIS database does not cover the years from 2007 to 2010. The DRBC version of OASIS that we work with only runs to September 30, 2006. (We understand that the New York City version of OASIS runs to 2008.) Thus, we cannot make direct evaluations for the years highlighted in the WTF questions. Instead, we have conducted an analysis for years that share some of the characteristics alluded to in the question -- specifically years with basically adequate water supply (runoff into the reservoirs), and also some years with short water supply.

Moreover, we do not have available a model of Revision 7 running in the current version of OASIS. As a surrogate, we relied on our own archived OASIS runs that were completed in January 2007 -- during our research on the development of the original FFMP. Thus, the time frame of our model of Revision 7 only runs to September 30, 2000, and the most appropriate diversion level available in our archive was a constant 500 MGD. To create a comparable data set we ran simulations of our Enhanced Joint Fishery

White Paper program also at 500 MGD constant diversions and we truncated the output data set at September 30, 2000. We have conducted most of the comparisons on the output of these runs for the 1990s. So, both the time frame and the diversion levels of the simulations and analyses were dictated by what was available and archived.

We do not have available scientific models that permit a projection of East Branch river temperatures at points downstream of the reservoir from reservoir discharges – particularly during periods of thermal stress such as alluded to in the question. (There might be a way of getting inside the DSS code to approximate this, but it was not doable in the time available before this meeting.) Thus, our analysis is on the magnitude of river flows, especially on the lower tail of the flow duration distribution. We focus on the Harvard gage on the East Branch which is approximately 10 miles downstream from the Pepacton dam. Our hypothesis is that bigger releases from the reservoir will generally result in bigger minimum flows -- and in lower river temperatures in reaches of the river not too far downstream of the reservoir.

Principle Results:

A Reminder: Analysis of summer flows at Harvard on the East Branch, as well as the other key gage sites: Callicoon on the Main Stem; Hale Eddy on the West Branch; and Bridgeville on the Neversink under our recommended policy as compared to both the FFMP and Revision 1 indicate that all reaches of the River would fare substantially better during summers under our recommendation than under the alternatives (Table 1). These comparisons were made at 550 MGD variable diversions over 1928 to 2006.

Location	Policy	0%	25%	50%	75%
Bridgeville	Enh JFish	42	107	123	155
	FFMP	45	91	108	144
	Rev1	29	61	81	117
Callicoon	Enh JFish	406	1,115	1,318	1,753
	FFMP	438	897	1,109	1,460
	Rev1	314	896	1,122	1,446
Hale Eddy	Enh JFish	120	672	709	791
	FFMP	120	330	408	704
	Rev1	23	379	516	806
Harvard	Enh JFish	80	215	241	297
	FFMP	93	166	191	262
	Rev1	47	100	122	175

Table 1. Flow Statistics Summers 1928 to 2006 @ 550 Variable Diversions

However, as the WTF questions imply, summer is not the whole story. Table 2 contains comparative summary flow statistics at Harvard by month for the 1990s for our Enhanced Joint Fishery program and Revision 7 as simulated in OASIS at a constant 500 MGD diversion. The table confirms the WTF concern that in the fall of the year flows at Harvard under our recommendation would fall below what they would have been under Revision 7. The autumn shortfalls, indicated in red, while real, are modest as compared to the flow gains in other months.

	Minimum				Q1 (25th Percentile)				Median (50th Percentile)			
Month	En JFish	Rev 7	Diff	Pct	En J Fish	Rev 7	Diff	Pct	En JFish	Rev 7	Diff	Pct
Jan	127	62	65	105	208	175	33	19	305	183	122	66
Feb	140	55	85	155	198	175	23	13	293	175	118	67
Mar	120	61	59	97	302	207	95	46	522	389	133	34
Apr	199	105	94	90	317	317	0	0	612	565	47	8
May	151	71	80	113	203	175	28	16	263	234	29	12
Jun	150	71	79	112	232	175	57	33	249	175	74	42
Jul	140	64	76	119	200	175	25	14	219	175	44	25
Aug	140	86	54	63	200	175	25	14	209	175	34	19
Sep	100	175	-75	-43	158	175	-17	-10	170	175	-6	-3
Oct	100	90	11	12	122	175	-53	-30	171	175	-4	-2
Nov	100	80	20	25	168	175	-7	-4	247	182	65	36
Dec	134	74	60	81	189	175	14	8	242	178	64	36

Table 2. Monthly Flow Statistics at Harvard: 1990s @ 500 Constant Diversions

As to the WTF question regarding comparative flow statistics across the several reaches of the upper Delaware, see Table 3. The percentage improvement in the median summer flow due to our recommendation versus Revision 1 are 52%, 17%, 37% and 97% at Bridgeville, Callicoon, Hale Eddy and Harvard , respectively. Harvard on the East Branch comes out the winner.

Stimulated by the WTF inquiry regarding low autumn flows on the East Branch, we conducted a similar investigation on the Neversink. (Table 4.) The Neversink shortfalls relative to Revision 7, indicated in red, are in both the summer and autumn.

Flow Statistics at Key Gages Summers 1928 to 2006 @ 550 Variable Diversions

Location	Policy	0%	10%	25%	50%	75%	90%	100%
Bridgeville	Enh JFish	42	98	107	123	155	235	5,020
	FFMP	45	82	91	108	144	240	5,007
	JFish	43	96	105	120	151	237	5,020
	OST-100	33	88	97	115	151	235	5,012
	Rev1	29	50	61	81	117	212	4,982
Callicoon	Enh JFish	406	972	1,115	1,318	1,753	2,725	119,156
	FFMP	438	771	897	1,109	1,460	2,495	124,326
	JFish	411	922	1,039	1,225	1,608	2,588	121,745
	OST-100	323	928	1,036	1,234	1,667	2,674	120,581
	Rev1	314	737	896	1,122	1,446	2,422	124,541
Hale Eddy	Enh JFish	120	551	672	709	791	956	36,267
	FFMP	120	299	330	408	704	1,033	34,627
	JFish	120	543	566	611	743	1,004	35,704
	OST-100	104	550	573	634	768	1,007	36,087
	Rev1	23	209	379	516	806	1,138	34,602
Harvard	Enh JFish	80	176	215	241	297	455	23,522
	FFMP	93	154	166	191	262	421	23,792
	JFish	85	153	165	188	247	393	23,712
	OST-100	65	154	166	189	246	456	23,656
	Rev1	47	87	100	122	175	335	23,804
Montague	Enh JFish	874	1,771	2,035	2,707	3,989	6,489	191,160
	FFMP	872	1,760	1,905	2,319	3,613	6,273	195,756
	JFish	874	1,801	1,984	2,552	3,835	6,373	193,582
	OST-100	1,124	1,747	1,960	2,582	3,903	6,474	192,526
	Rev1	822	1,718	1,857	2,232	3,497	6,148	195,728
Trenton	Enh JFish	1,983	2,967	3,703	5,377	8,364	14,086	281,726
	FFMP	1,982	2,975	3,545	5,005	8,009	13,962	286,853
	JFish	1,982	3,000	3,646	5,238	8,222	14,002	284,362
	OST-100	2,292	2,958	3,623	5,280	8,268	14,035	283,162
	Rev1	2,021	2,944	3,520	4,931	7,924	13,763	286,576

Table 3. Summer Flow Statistics at Key Gage Sites: 1928 to 2006 @ 550 Variable Diversions.

	Minimum				Q1 (25th Percentile)				Median (50th Percentile)			
Month	En JFish	Rev 7	Diff	Pct	En JFish	Rev 7	Diff	Pct	En JFish	Rev 7	Diff	Pct
Jan	82	49	32	66	111	113	-1	-1	142	136	6	4
Feb	92	53	39	74	111	111	-1	-1	129	117	12	10
Mar	84	45	39	86	139	118	21	18	180	186	-7	-4
Apr	120	105	15	14	163	153	10	6	246	224	21	10
May	116	71	46	65	136	115	21	18	173	154	19	12
Jun	97	49	48	97	114	114	1	1	125	115	11	9
Jul	94	57	37	65	102	114	-11	-10	114	115	0	0
Aug	93	56	37	66	98	113	-15	-13	111	115	-4	-3
Sep	70	95	-25	-26	98	113	-15	-13	111	115	-3	-3
Oct	70	75	-6	-7	88	113	-25	-22	109	115	-6	-5
Nov	77	48	30	63	109	112	-3	-3	142	116	26	22
Dec	88	58	30	53	114	112	2	2	133	115	18	16

Table 4. Monthly Flow Statistics at Bridgeville 1990s @ 500 Constant Diversions

Amelioration:

We carried out a series of OASIS and DSS experiments with varying autumn releases in order to identify modifications to our Enhanced Joint Fishery release recommendation that alleviate key elements of these shortfalls – but without incurring an excessive drought day penalty. Avoidance of increased drought days is important since being in a drought condition has stronger negative consequences for the fishery than for New York City – or, indeed, for any of the decree parties. Our modified release schedule is given in Table 5. Changes from our original proposal are highlighted in yellow.

Table 6 shows the resulting amelioration of the flow shortfalls on both the East Branch (Harvard), and the Neversink (Bridgeville.) The table shows that Harvard flows in September achieve the 100 cfs suggested by the WTF question. In order to make apple to apple comparisons with Revision 7, we again focus on the 1990s, and with a diversion regime at 500 MGD constant.

In addition to resolving the key concern raised by the WTF, and the summer shortfalls we observed on the Neversink, the modified release proposal increases summer adult trout habitat at a very modest increase in drought days. Other benefits include a modest additional increase in September voids, and decrease in spilling. Table 7 is an overall statistical summary of performance over the years 1928 to 2006 under a regime of 550 MGD variable diversions. Figure 1 charts habitat versus Drought Days.

	Winter			Spring		Summer			Fall		
Cannonsville Storage Zone	**Dec 1 to Mar 31**	**Apr 1 to Apr 15**	**Apr 16 to Apr 30**	**May 1 to May 20**	**May 21 to May 31**	**Jun 1 to Jun 15**	**Jun 16 to Jun 30**	**Jul 1 to Aug 31**	**Sep 1 to Sep 15**	**Sep 16 to Sep 30**	**Oct 1 to Nov 30**
L1-a	1500	1500	1500	*	*	*	1500	1500	1500	1500	1500
L1-b	700	700	700	525	525	650	650	700	700	700	700
L1-c	225	475	475	525	525	650	650	650	400	375	225
L2 High	150	400	400	525	525	650	650	650	400	300	150
L2 Low	150	400	400	400	450	500	525	525	400	300	150
L3	55	55	55	85	85	135	135	135	85	85	55
L4	50	50	50	60	60	120	120	120	50	50	50
L5	50	50	50	50	50	120	120	120	50	50	50
	Winter			**Spring**		**Summer**			**Fall**		
Pepacton Storage Zone	**Dec 1 to Mar 31**	**Apr 1 to Apr 15**	**Apr 16 to Apr 30**	**May 1 to May 20**	**May 21 to May 31**	**Jun 1 to Jun 15**	**Jun 16 to Jun 30**	**Jul 1 to Aug 31**	**Sep 1 to Sep 15**	**Sep 16 to Sep 30**	**Oct 1 to Nov 30**
L1-a	700	700	700	*	*	400	700	700	700	700	700
L1-b	400	400	400	*	*	400	400	400	400	400	400
L1-c	150	150	150	150	150	200	200	200	**175/150**	**175/150**	150
L2 High	100	100	100	100	150	200	200	200	**175/150**	**175/150**	100
L2 Low	100	100	100	100	**140/100**	**175/140**	**175/140**	**175/140**	**175/100**	**175/100**	100
L3	45	45	45	50	50	80	80	80	45	45	45
L4	40	40	40	50	50	80	80	80	40	40	40
L5	40	40	40	40	40	80	80	80	30	30	30
	Winter			**Spring**		**Summer**			**Fall**		
Neversink Storage Zone	**Dec 1 to Mar 31**	**Apr 1 to Apr 15**	**Apr 16 to Apr 30**	**May 1 to May 20**	**May 21 to May 31**	**Jun 1 to Jun 15**	**Jun 16 to Jun 30**	**Jul 1 to Aug 31**	**Sep 1 to Sep 15**	**Sep 16 to Sep 30**	**Oct 1 to Nov 30**
L1-a	190	190	190	*	*	*	190	190	190	190	190
L1-b	125	110	110	*	*	*	*	150	150	150	125
L1-c	90	90	90	125	125	140	140	140	130	130	90
L2 High	90	90	90	125	125	130	130	130	130	130	90
L2 Low	90	90	90	90	110	**130/125**	**130/125**	**130/125**	**130/90**	**130/90**	90
L3	30	30	30	40	40	55	55	55	30	30	30
L4	30	30	30	30	30	55	55	55	25	25	25
L5	30	30	30	30	30	55	55	55	25	25	25

Table 5. Modified Release Matrix: Kolesar & Serio

Flow Comparisons Enhanced J Fishery and Revision 7 Release Policies: 1990s

Harvard Gage on the East Branch OASIS Simulations @ 500 MGD Constant Diversions

	Minimum					Q1 (25th Percentile)					Median (50th Percentile)				
Month	Rev 7	En JFish	PKJS	Diff	Pct	Rev 7	En J Fish	PKJS	Diff	Pct	En JFish	Rev 7	PKJS	Diff	Pct
Jan	62	127	127	65	105	175	208	208	33	19	305	183	305	0	0
Feb	55	140	140	85	155	175	198	198	23	13	293	175	293	0	0
Mar	61	120	120	59	97	207	302	302	95	46	522	389	521	-1	0
Apr	105	199	199	94	90	317	317	317	0	0	612	565	612	0	0
May	71	151	151	80	113	175	203	203	28	16	263	234	263	0	0
Jun	71	150	184	113	159	175	232	232	57	33	249	175	249	0	0
Jul	64	140	175	111	173	175	200	210	35	20	219	175	224	5	2
Aug	86	140	175	89	103	175	200	201	26	15	209	175	211	2	1
Sep	175	100	175	0	0	175	158	185	10	6	170	175	196	26	15
Oct	90	100	100	11	12	175	122	122	-53	-30	171	175	171	0	0
Nov	80	100	100	20	25	175	168	168	-7	-4	247	182	247	-1	0
Dec	74	134	134	60	81	175	189	189	14	8	242	178	242	0	0

Bridgeville Gage on theNeversink OASIS Simulations @ 500 MGD Constant Diversions

	Minimum					Q1 (25th Percentile)					Median (50th Percentile)				
Month	Rev 7	En JFish	PKJS	Diff	Pct	Rev 7	En JFish	PKJS	Diff	Pct	Rev 7	En JFish	PKJS	Diff	Pct
Jan	49	82	82	32	66	113	111	111	-1	-1	136	142	142	6	4
Feb	53	92	92	39	74	111	111	111	-1	-1	117	129	129	12	10
Mar	45	84	84	39	86	118	139	139	21	18	186	180	180	-7	-4
Apr	105	120	120	15	14	153	163	163	9	6	224	246	246	21	10
May	71	116	116	46	65	115	136	136	21	18	154	173	173	19	12
Jun	49	97	97	48	97	114	114	115	2	1	115	125	125	11	9
Jul	57	94	94	37	65	114	102	103	-11	-9	115	114	115	1	1
Aug	56	93	94	37	67	113	98	99	-15	-13	115	111	111	-3	-3
Sep	95	70	94	-2	-2	113	98	99	-14	-12	115	111	114	-1	-1
Oct	75	70	70	-6	-7	113	88	89	-24	-21	115	109	109	-6	-5
Nov	48	77	77	30	63	112	109	109	-3	-3	116	142	142	26	22
Dec	58	88	88	30	53	112	114	114	2	2	115	133	133	18	16

Table 6. Neversink Flow Comparisons 1990s Modified PKJS Proposal @ 500 MGD Constant Diversions

Policy	Rev 1	FFMP	J Fishery	OST Table F	Original K &S	Modified K &S
Storage Mean	223,186	217,477	208,398	213,117	203,673	203,214
Storage Min	13,515	8,746	7,168	45,036	7,215	7,111
Storage Jun 1	261,554	259,173	255,871	261,120	254,115	254,018
Reservoir Void Sep 1	62,185	53,523	62,602	74,599	85,392	85,759
NYC Diversions Mean	549	548	547	535	547	547
NJ Diversions Mean	97.0	99.0	98.4	98.7	98.3	98
Spills Mean	401	286	239	220	198	196
Upper Drought Watch	458	692	952	910	909	854
Upper Drought Warning	568	672	1,175	1,159	1,272	1,342
Upper Drought Emergency	1,389	1,480	1,757	864	1,761	1,772
Upper Drought Total	2,415	2,844	3,884	2,933	3,942	3,968
Lower Drought Total	1,364	1,216	1,156	1,266	1,333	1,325
Reservoir Refill Years	64	61	55	57	55	55
95% Reservoir Refill Years	70	66	66	67	65	65
West Branch	53,482	64,586	88,795	95,230	93,068	92,588
East Branch	75,721	89,261	85,468	84,991	92,353	99,706
Neversink	39,939	50,252	50,661	51,726	56,265	57,123
Main Stem	28,267	26,249	70,447	89,543	104,285	128,043
Total Habitat	197,409	230,348	295,371	321,489	345,970	377,461

Table 7. OASIS and DSS Statistical Summary: 1928 to 2006 at 550 Variable Diversions

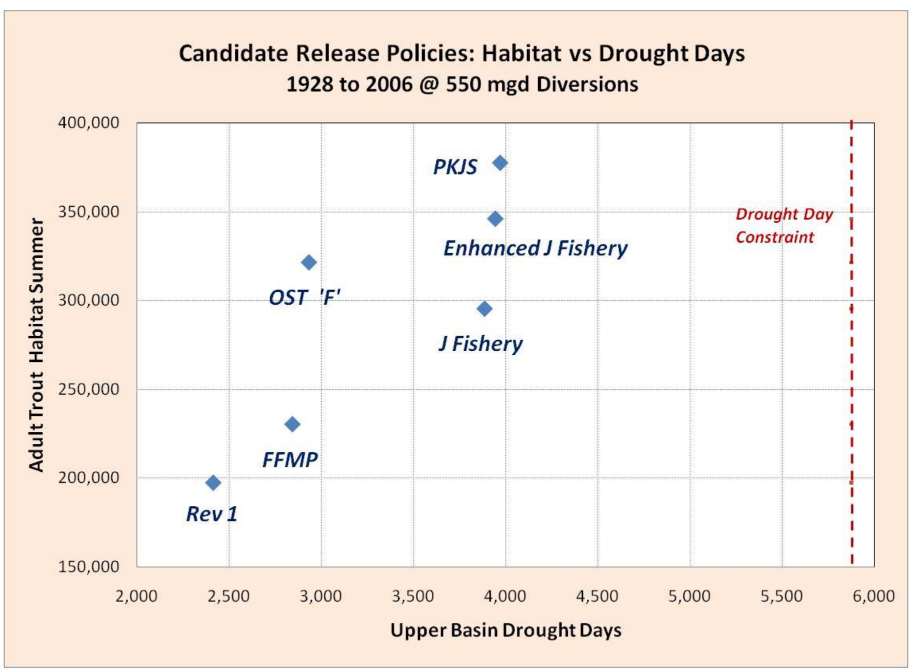

Figure 1. Habitat vs. Drought Days: Candidate Policies Including the PKJS Modification

Part II: Three Related Winter Flow Issues

*4) **Frazil Ice:** Maintaining a constant release during the coldest periods of the winter has been shown to reduce the damaging impacts of frazil ice in tailwaters. What can [your] model do to minimize potential mortality to trout from frazil ice due to fluctuating winter releases?*

*5) **Anchor Ice**:*

We understand that maintaining a sufficient minimum winter release to keep water temperatures high enough to combat anchor ice, and also constant enough to minimize frazil ice will minimize anchor ice formation. What can each [your] model do to minimize anchor ice formation during the coldest period of the winter?

*6) **[Brown Trout Spawning]***

The increased constant release of the JFWP of 100 cps, if maintained on a constant basis would minimize this potential mortality. Please direct your answer to maintaining this constant release. What can [your] each model do to minimize potential mortality to brown trout spawning beds in the gravel beds of each of the tailwaters below the reservoirs?

The flow statistics in Table 6 indicate that minimum winter flows (December, January, and February) at Bridgeville and Harvard are expected to be generally higher under our proposal than under Revision 7. This is also true at Hale Eddy on the West Branch and Callicoon on the Main Stem (Callicoon and Hale Eddy data not shown here.) However, we do not know whether these differences are enough to ameliorate the formation of frazil ice or anchor ice.

We do not know whether these differences in minimum winter flows are enough to ameliorate disruption to trout spawning beds. (Median winter flows are nearly equal for both polices.)

Part III: Two High Flow/Spilling Issues

7) Do you have access to figures detailing year by year the amount of spillage that you can share with us? and B) What can each model do to further minimize reservoir spillage?

We have actual NYC-DEP data on spilling by reservoir by day from 1982 to 2010, and OASIS simulated spills by day from 1928 to 2006.

Table 8 below gives this actual spill data aggregated by year by reservoir. For perspective we include in the table annual reservoir inflows (runoff) and NYC diversions. Total annual spills are highly correlated with inflows (r = 0.81). Figure 2 plotting the total annual spills illustrates the extreme volatility.

Table 9 below gives simulated spills by policy by year. For reference we include actual spills. Note that direct comparison of actual to simulated spills is complicated by the fact that the actual diversions over this 25 year time frame were 616 MGD, while our OASIS simulations were run at 550 MGD. However the correlations from year to year are very strong – over 90%. The synchronicity of annual spills by candidate release policy is illustrated in Figure 3. The impact of annual inflow is illustrated in Appendix Figure 1r

In response to the WTF query about spill reduction please observe that our modified policy here denoted by 'PKJS' reduces spills by a half relative to Revision 1 and by a third relative to the FFMP. Our proposal also reduces overall spilling considerably throughout the year relative to Revision 7. We do not know whether this reduction in spilling is enough to ameliorate disruption to trout spawning beds.

Year	Neversink Spill	Pepacton Spill	Cannonsville Spill	Total Spill	Percent Spill	Total Inflow	Total Divisions	Percent Diversion
1982	1,386	5,368	35,280	42,034	12.3	340,680	212,687	62.4
1983	4,155	27,937	68,036	100,128	22.1	452,974	198,537	43.8
1984	5,470	32,871	78,258	116,599	27.4	424,805	219,461	51.7
1985	0	0	0	0	0.0	311,866	216,863	69.5
1986	1,765	16,475	95,887	114,127	25.2	452,951	231,557	51.1
1987	8,277	13,222	65,307	86,806	21.6	402,199	258,289	64.2
1988	0	331	40,676	41,007	13.2	310,055	257,733	83.1
1989	1,475	114	8,922	10,511	2.7	391,521	220,660	56.4
1990	4,424	23,673	119,678	147,775	29.5	500,530	260,891	52.1
1991	0	3,272	64,401	67,673	21.3	318,035	255,526	80.3
1992	0	0	0	0	0.0	362,500	251,309	69.3
1993	9,786	44,518	95,613	149,917	33.6	446,255	243,102	54.5
1994	4,270	18,192	40,796	63,258	14.6	432,029	252,196	58.4
1995	0	0	28,515	28,515	8.5	334,900	243,975	72.9
1996	7,659	116,496	182,963	307,118	43.2	710,189	237,819	33.5
1997	348	39,493	85,678	125,519	38.4	327,234	244,360	74.7
1998	8,253	57,695	114,691	180,639	38.8	465,214	196,218	42.2
1999	0	0	0	0	0.0	380,425	203,596	53.5
2000	5,295	32,649	125,567	163,511	33.5	487,964	214,267	43.9
2001	10,368	3,863	50,025	64,256	25.1	255,701	241,028	94.3
2002	0	0	0	0	0.0	403,649	181,903	45.1
2003	26,955	134,992	208,677	370,624	57.8	641,512	164,175	25.6
2004	9,100	38,777	142,479	190,356	39.5	481,637	197,844	41.1
2005	28,869	51,420	117,177	197,466	40.2	490,610	196,948	40.1
2006	18,796	95,197	197,894	311,887	49.7	627,979	144,048	22.9
2007	10,632	32,808	55,954	99,394	19.6	507,562	206,264	40.6
2008	13,240	52,791	50,051	116,082	21.1	550,765	151,507	27.5
2009	6,104	12,884	21,307	40,295	8.9	451,998	176,589	39.1
2010	9,414	29,917	16,204	55,535	11.5	484,584	209,469	43.2
Average	6,760	30,516	72,760	110,036	25.0	439,597	216,856	49.3

Table 8. Annual Spills from NYC Delaware Dams 1082 to 2010: Data source NYC-DEP

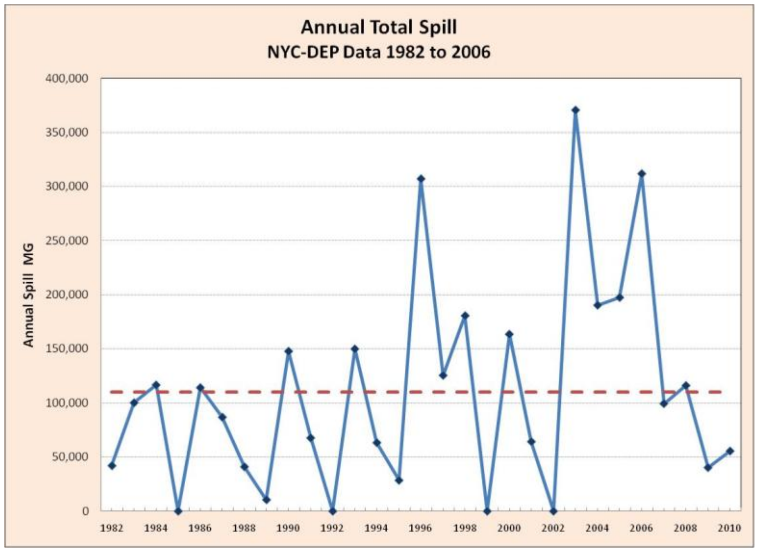

Figure 2 Historical Annual Spills: 1982 to 2006

Year	OST F	J Fish	FFMP	Rev 1	PKJS	Actual
1982	40,722	14,652	63,882	93,859	15,225	42,034
1983	83,377	80,692	95,098	102,143	75,454	100,128
1984	115,577	108,412	131,031	140,210	105,119	116,599
1985	-	-	-	-	-	-
1986	95,453	100,948	119,338	141,848	81,977	114,127
1987	73,859	82,331	99,195	142,605	68,903	86,806
1988	43,590	58,118	74,237	122,473	30,742	41,007
1989	17,533	11,212	35,754	48,247	3,107	10,511
1990	96,263	126,972	139,590	230,572	93,271	147,775
1991	28,396	69,192	75,572	124,864	28,074	67,673
1992	-	-	1,820	7,549	-	-
1993	156,294	142,911	177,398	215,821	141,391	149,917
1994	84,339	74,818	101,094	121,250	75,923	63,258
1995	-	10,500	39,280	80,659	-	28,515
1996	236,168	288,344	334,198	420,875	226,995	307,118
1997	74,124	114,815	117,834	165,256	74,769	125,519
1998	130,476	139,362	165,747	192,668	124,364	180,639
1999	-	-	1,191	2,911	-	-
2000	137,048	138,479	188,444	219,244	121,549	163,511
2001	37,796	42,884	68,794	98,008	29,770	64,256
2002	24,072	-	-	-	-	-
2003	208,941	187,152	222,230	358,070	181,230	370,624
2004	81,754	120,666	139,132	277,017	78,460	190,356
2005	141,396	155,173	158,727	220,958	142,382	197,466
Average	79,466	86,151	106,233	146,963	70,779	106,993

Table 9. Simulated Spills 1982 to 2006 for Candidate Policies @ 550 Variable Diversions

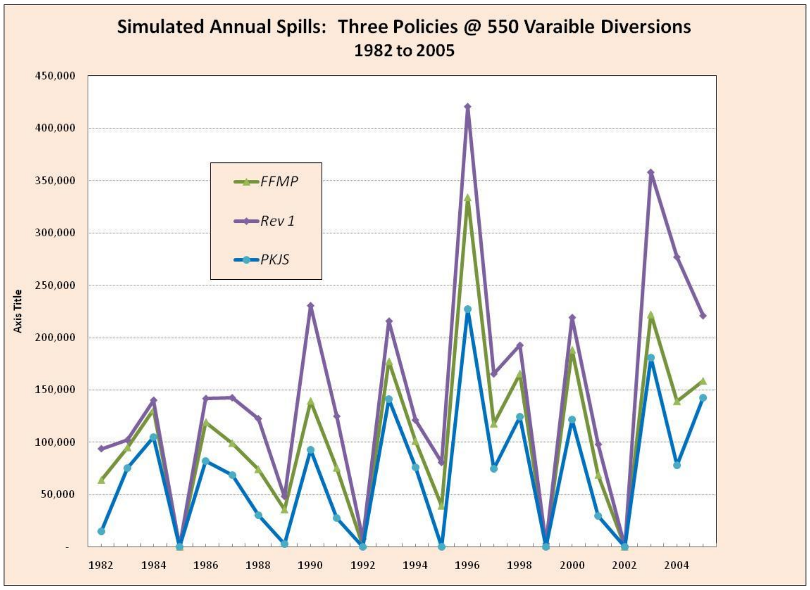

Figure 3. Simulated Spills 1982 to 2005

8) What can your model do to insure a late spring 3,500 cps flood of short duration to minimize both the damage to habitat from Didymo as well as its potential spread?

Response:

We have not considered micro-management of the type implied by this question in our design. To a large extent the theme of our release policy design has been, from its outset in January 2006, to maximize trout habitat within the water supply reliability and other constraints of the decree parties, but to let 'the River be the River.' It was in that spirit that we recommended back in 2006 ceasing to rely on 'habitat banks.' But that being said, we observe that early spring spilling is consistent with full reservoirs on June 1.

Our recommended policy, PKJS, despite its overall lower level of spilling , would under 550 variable diversions have spilled in April, May or June in 20 out of the 25 years from 1982 to 2006. By comparison Revision 1 would have spilled in 23 of the 25 years – but at a cost of twice as much spilling overall.

APPENDIX

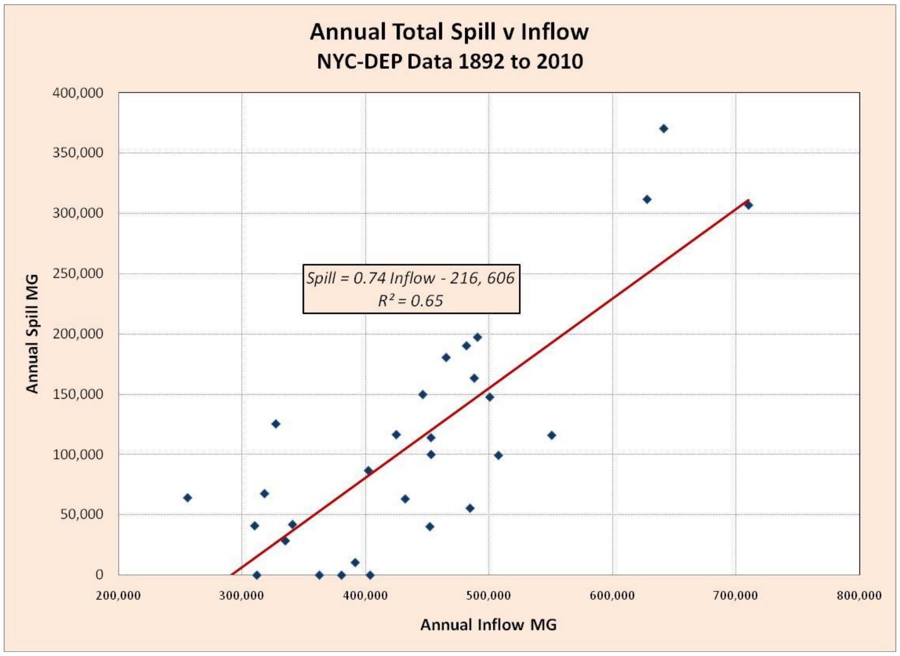

Figure 3. Correlation of Spills with Inflows