APPENDIX 3

Model Results and Evaluation of Alternatives

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Model Results and Evaluation of Alternatives

There were several activities comprising the detailed review of model runs and results, and the eventual selection of preferred and final alternatives. This appendix describes the process and displays sample output and results, but does not include an exhaustive summary of all model runs and detailed results that were viewed by the Workgroup. The full inventory of output is available in the data files of the Commission.

The process for evaluating alternatives that was undertaken by the Workgroup consisted of several steps:

- Development of Performance Measures – The selection of output parameters used to evaluate the success or failure of a particular alternative.
- Identification of Preliminary Operational Alternatives – The compilation by the Workgroup of the initial set of alternatives to be evaluated.
- Computer-Aided Negotiations (CAN) – Interactive Workgroup sessions involving the critique of operational alternatives.
- Evaluation of Results – The review of results for selected operational alternatives, displayed in the form of performance measures.
- Selection of Preferred Operational Alternatives – The selection of a smaller set of promising alternatives for closer analysis.
- Refinement of Alternatives and Final Evaluation – The fine-tuning of alternatives based on review of preliminary results.
- Selection of Recommended Alternative – The final selection of the preferred alternative and the use of position analysis.

These steps are described in further detail in the remainder of this appendix.

A. Development of Performance Measures

Performance measures are simply displays based on the results of an evaluation of an alternative. Each performance measure shows how well the alternative does with regard to one or more management objectives, such as maintaining minimum pond releases or providing adequate cooling water. Each performance measure is designed to allow one or more stakeholder to determine whether one alternative is better than another with respect to the objective that is important to them. There are numerous objectives for management of the Conowingo pond, so many performance measures were developed.

Initially, 26 performance measures were proposed by Workgroup members for consideration. They are listed below.

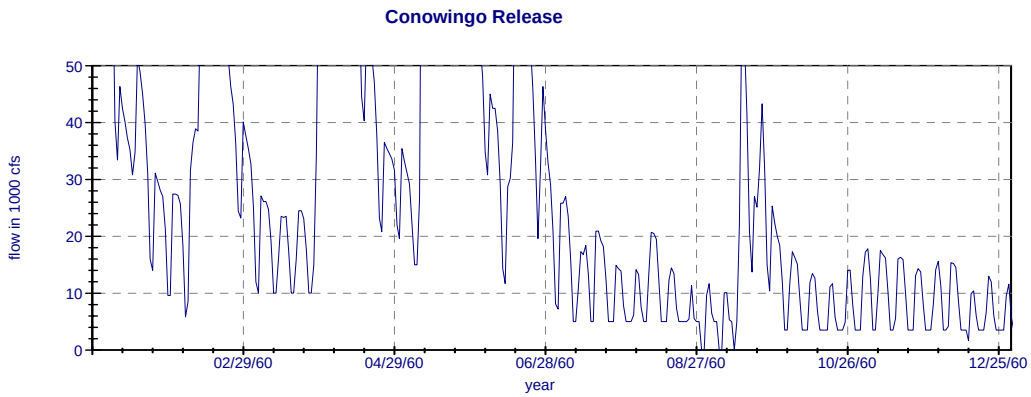
- Days of reduced withdrawals – based on rules.
- Years of inadequate fish flows.
- Days of potential turbidity problems.

- Sodium levels at intakes downstream of dam.
- Occurrence of discharge restrictions from dam (because Marietta flow <Q-FERC).
- Total flow from the dam (including leakage).
- Days total flow from dam is less than seasonal criteria.
- Minimum Baltimore system storage.
- Average turbidity at Deer Creek pumping station (City of Baltimore intake).
- Daily Baltimore pumpage.
- Minimum York Water Co. system storage.
- Minimum Octoraro Reservoir storage.
- Nutrient levels at Chester Water Authority intake/reservoir.
- Minimum Lancaster supply.
- Days Baltimore pumpage <250 mgd.
- Days Commission releases from upstream storage.
- Difference between Commission releases and Q-FERC restrictions.
- Energy – days under 5,000 cfs at Conowingo.
- Energy – pumped storage water available per week.
- Days pool level below 104.5 feet at Conowingo.
- Days of reduced pumped storage operations.
- Recreation pool requirement violations (especially on weekends).
- Fish spawning.
- Upstream lake levels (not Raystown – perhaps in lakes with Commission storage).
- Days of upstream restrictions.
- Number of trigger flow days over period of record.

All performance measures fall into one of the following five categories. To illustrate the potential use of the performance measures, mock displays are presented for each category.

1. **Basic Time Series Output Measures** – Basic time series outputs for flows, water deliveries, and reservoir levels were made available in the form of both plots and tables. Displays showed these time series individually or side-by-side for comparison of values from a single model run or across runs for different alternatives.

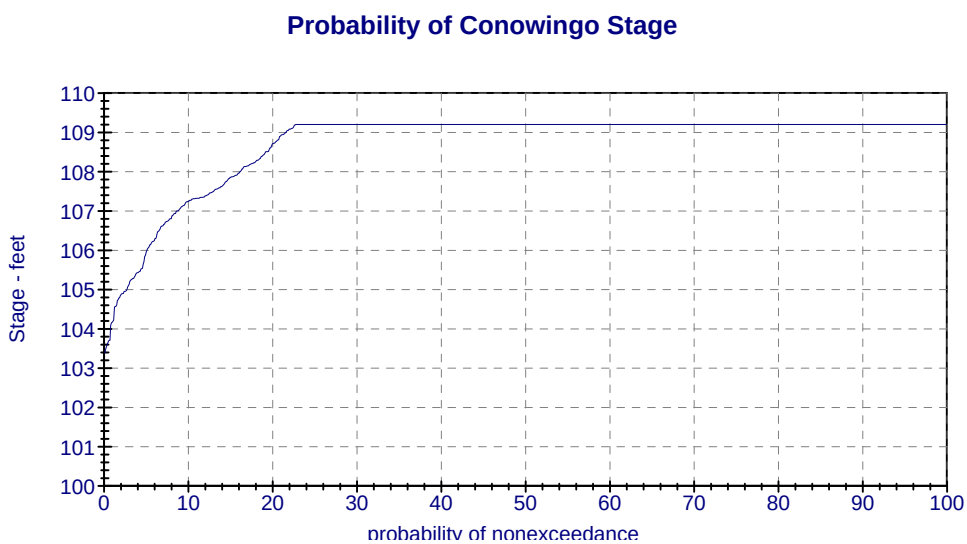
   The mock-up example below shows a time series trace of the flow released from the Conowingo dam. The plot is useful because it demonstrates the range of releases that might be expected over the course of a year and, in particular, shows the potential for extreme conditions during the drier summer months.



2. **Conowingo Pond Level-Based Performance Measures**

   a. Probability of Pond Level: Plotting the probability that the pond falls below a given level allowed stakeholders to ascertain rapidly how often various facilities could be impacted by low pond levels.

   In the mock-up below, stakeholders can determine that the pond level is at a level below the maximum approximately 23 percent of the time. Further, if the level 106 is critical, stakeholders can learn that the pond falls below that level about 5 percent of the time.



   b. Number of Days and Events Below Threshold Levels and Number of Years with Events: This was a tabular output for comparing alternatives. There was one row per alternative and several groups of three columns (days, events, and years with events) for each threshold of interest. Displayed below is a mock-up sample set of

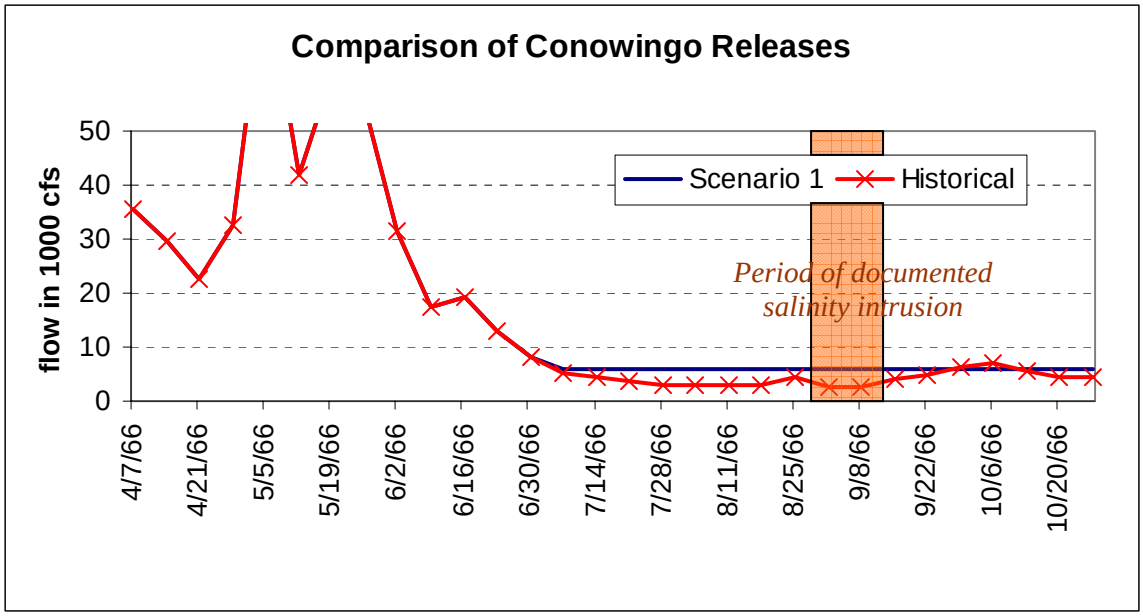
output data for the number of days when water demand falls below a given threshold. For example, the table shows that scenario No. 2 results in 45 days below the threshold of 12 mgd, while there are 50 days below with scenario No. 1. However, when the threshold is increased to 15 mgd, both scenarios result in the same number of days below (80 days).

Scenario	Demand Threshold (mgd)	Days Below Threshold	Demand Threshold (mgd)	Days Below Threshold	Demand Threshold (mgd)	Days Below Threshold
1	10	40	12	50	15	80
2	10	30	12	45	15	80

3. **Displays Related to Conditions Below Conowingo Pond** – In addition to time traces of releases from Conowingo pond, there was interest in salinity intrusion in the reach below the dam. There is also substantial interest in maintaining adequate flow for fish habitat and to support fish migration.

   Flows During Periods of High Salinity in the Upper Chesapeake Bay: It was outside the scope of this study to develop flow/salinity relationships for this reach of the river. As a surrogate, modeled flows for historical periods of high salinity were graphed alongside historical flows for the same period. The graphs were annotated with available information as to historical salinity in the reach if such information was available.

   In the sample display below, a historical flow trace during a period of documented salinity intrusion is plotted alongside the results from a model scenario (scenario No. 1). Although the display gives no specific information about salinity levels, the selected scenario results in flows sustained at a higher level than those documented during the period of salinity intrusion. Consequently, stakeholders may deduce that salinity conditions may be more favorable under scenario No. 1 than under historic conditions.



4. **Water Supply Related Performance Measures** – In the lower Susquehanna basin, water use restrictions are based on two flow indices: the Q7-10 and the FERC minimum flow at Marietta. The frequency of these flows may be influenced by releases from upstream reservoirs and/or the growth of water demands upstream. In addition, stakeholders may need to impose water use restrictions based on levels in local storage reservoirs.

   Number of Days Under Water Use Restrictions, Number of Water Use Restriction Events, Number of Years with Water Use Restrictions, and Total Water Not Delivered: Displays of this type were tabular outputs for comparing alternatives. There was one row per alternative and several groups of three columns (days, events, and years with events). Examples of parameters displayed include Conowingo releases below the FERC seasonal values, and water withdrawal restrictions for the City of Baltimore.

   The table below demonstrates a general sample of the type of display for this category.

Scenario	Number of Days in Water Restriction	Number of Years with Water Restrictions	Volume of Water Not Delivered (million gallons)
1	10	1	25
2	16	3	30
3	5	5	5
4	25	3	140
5	30	6	130
6	18	2	65

5. **Hydropower Related Performance Measures** – Hydropower generation on the lower Susquehanna River is a peaking operation, and water can be held in both the Conowingo and Muddy Run ponds overnight and over weekends. Low flow requirements can force releases from Conowingo dam which do not optimize power generation because less water is available for power generation at Muddy Run.

   Reduction of Water Available for Pumping to Muddy Run: This was a tabular output for comparing alternatives. It consisted of one row for each scenario, and two columns – one identifying the scenario and the other displaying the volume of water unavailable for hydropower generation at Muddy Run.

Scenario	Reduction in Water Available for Pumping to Muddy Run Pond (acre-feet)
1	1,000
2	1,240
3	320
4	320
5	800
6	900

   In a year with ample flow, operators would have enough water in Conowingo pond to start each generation cycle with a full pond at Muddy Run. However, in years with low flow conditions, some cycles will begin with less storage available. The accumulated storage deficit over the year or period of record is an indication of how well a scenario performs with respect to optimizing hydro generation. In the sample table above, the conditions of scenario Nos. 3 and 4 provide the most water for generation at Muddy Run, with a reduction of only 320 acre-feet over the period, while the conditions of scenario No. 2 result in the most amount of water reduction, 1,240 acre-feet.

   After further consideration, the Workgroup identified a smaller set of performance measures to be used for evaluation of alternatives. These measurements are listed below.

   - Conowingo releases less than FERC seasonal flows.
   - Conowingo stages lower than recreation levels.
   - Conowingo releases less than surrogate flows for salinity intrusion.
   - Probability of Conowingo stage levels.
   - Time series of Conowingo stage.
   - Time series of Conowingo release.
   - Average and minimum Conowingo releases during drought periods.
   - Water available for pumped storage power generation.

B. Identification of Preliminary Operational Alternatives

The Workgroup initially identified 32 alternative operational plans for consideration at the Conowingo pond. Initially, all alternatives were given equal consideration. Key variable parameters were established to distinguish differences in the alternatives. The parameters used and alternative plans are discussed below. A summary table displaying the 32 alternatives and parameters follows the discussion.

1. **Parameters Used**:

   a. Q-FERC Requirements Met: Does the alternative meet (Yes) or not meet (No) the minimum downstream flow releases required by the 1988 settlement agreement (see Section IV-B)?

   b. Credit for Leakage Allowed: Is a credit for gate leakage at Conowingo dam allowed toward meeting the minimum flow requirements notwithstanding the prohibition against this in the settlement agreement?

   c. Baltimore Withdrawal, Maximum/Low Flow: Defines the maximum water supply withdrawal allowed under normal and low flows into the Conowingo pond, respectively. Currently, Baltimore has an approved maximum withdrawal of 250 mgd, a maximum output of 137 mgd, and a reduced 30-day withdrawal rate of 64 mgd during low flow periods.

   d. Chester Water Authority Withdrawal: Defines the maximum water supply withdrawal allowed from the Conowingo pond by Chester Water Authority. Currently, Chester Water Authority has an approved maximum withdrawal of 30 mgd.

   e. Consumptive Use in the Basin: The amount of consumptive water use in the Susquehanna River Basin, upstream of the Conowingo pond, based on estimates of daily averages for peak monthly use in 2000 and a similar projection for 2025, and an assumed increase of 30 percent in the 2025 daily averages as an estimate for the maximum peak daily use. These consumptive uses are 456, 640, and 830 mgd, respectively.

   f. Commission Reservoir Storage Trigger: The Commission-owned water supply storage at Cowanesque and Curwensville Lakes in the upper basin is used to augment low flows when trigger levels are reached at one of several key stream gages. Under current rules, the trigger level is Q7-10, which is defined as the consecutive 7-day low flow values having a frequency of occurrence of 10 percent in a given year (commonly referred to as once in 10 years). An alternative trigger value considered for the purpose of this analysis is Q-FERC. This is defined as the comparable flow at key upstream gages that correspond to the minimum flow release requirements at the Conowingo pond as established in the 1988 settlement agreement (see Section IV-B).

2. **Alternative Operational Plans**:

   a. **"_SimBase" Options** (five options): Represents baseline conditions with existing operations in place and four other modified baseline options as defined by varying parameters for leakage credit, Baltimore's maximum water withdrawal, and consumptive water use in the basin. If a credit for leakage was included, its implementation was triggered on the condition of the pond declining below the critical elevation of 104.5 feet, at which continued operation of Muddy Run is threatened. At that time, a credit of 800 cfs for gate leakage was allowed.

   b. **"AutoWaiver" Options** (seven options): Includes an automatic credit allowance for gate leakage toward the required minimum flow releases. The time period for the credit is either year-round, from July–March or June 16–March 31. Other parameters are changed for several alternatives, including Baltimore's and Chester's maximum water withdrawals, consumptive water use in the basin, and the low flow trigger for releasing water from Commission-owned storage in two upstream federal reservoirs.

   c. **"Stepped_Waiver" Options** (two options): Includes an automatic flow credit for gate leakage, but the credit is allowed in increments of 250, 500, and 750 cfs, as needed, to maintain a stable Conowingo pond level. A second option increases Baltimore's maximum water withdrawal.

   d. **"Level_Storage" Options** (five options): This set of alternatives includes a minimum operability level in the pond of 104.5 feet to maintain both Muddy Run storage transfers into/from the Conowingo pond and reliable Peach Bottom operations. Minimum flow releases from Conowingo dam, Baltimore's maximum water withdrawal, and consumptive water use in the basin were varied to distinguish options.

   e. **Other Alternatives**: Thirteen other initial alternatives were considered by varying the parameters in different combinations.

Conowingo Pond Management Plan
Alternative Operational Plans Considered

Plan Number	Alternative Plan	Q-FERC Requirements Met	Credit for Leakage Allowed	Baltimore Withdrawal Max/Low Flow (mgd)	Chester Withdrawal (mgd)	Consumptive Use in Basin			Commission Reservoir Storage Trigger	
						2000	2025	Max. Peak	Q7-10	Q-FERC
	A. "_SimBase" Options									
1.	A1. **_SimBase** = baseline conditions	Yes	No[1] (unless waived)	137/64	30	X			X	
2.	A2. **_SimBase** with no emergency waiver for leakage credit	Yes	No	137/64	30	X			X	
3.	A3. **Future_Baseline** = **_SimBase** with 2025 CU levels	Yes	No[1] (unless waived)	137/64	30		X		X	
4.	A4. **_SimBase_Plus** = Auto **Waiver** plus Baltimore low flow withdrawal to 100 mgd	Yes	Yes	137/100	30	X			X	
5.	A5. **Future_Plus** = **_SimBase_Plus** with 2025 CU	Yes	Yes	137/100	30		X		X	
	B. "AutoWaiver" Options									
6.	B1. **AutoWaiver** = year-round leakage credit	Yes	Yes	137/64	30	X			X	

Plan Number	Alternative Plan	Q-FERC Requirements Met	Credit for Leakage Allowed	Baltimore Withdrawal Max/Low Flow (mgd)	Chester Withdrawal (mgd)	Consumptive Use in Basin			Commission Reservoir Storage Trigger	
						2000	2025	Max. Peak	Q7-10	Q-FERC
7.	B2. **Future_Max** = **AutoWaiver** plus Baltimore and Chester max withdrawals of 250 and 40 mgd	Yes	Yes	250/100	40		X		X	
8.	B3. **AutoWaiver** with Commission reservoir storage trigger of Q-FERC	Yes	Yes	137/64	30	X				X
	B4. **AutoWaiver** with no leakage credit from April 1 to June 30:									
9.	a. With Commission reservoir storage trigger at Q7-10	Yes	Yes (July-March)	137/64	30	X			X	
10.	b. With Commission reservoir storage trigger at Q-FERC	Yes	Yes (July-March)	137/64	30	X				X
	B5. **AutoWaiver** with no leakage credit from April 1 to June 15:									
11.	a. With Commission reservoir storage trigger of Q7-10	Yes	Yes (June 16 to-March)	137/64	30	X			X	
12.	b. With Commission reservoir storage trigger of Q-FERC	Yes	Yes (June 16 to-March)	137/64	30	X				X

Plan Number	Alternative Plan	Q-FERC Requirements Met	Credit for Leakage Allowed	Baltimore Withdrawal Max/Low Flow (mgd)	Chester Withdrawal (mgd)	Consumptive Use in Basin			Commission Reservoir Storage Trigger	
						2000	2025	Max. Peak	Q7-10	Q-FERC
	C. "Stepped_Waiver" Options									
13.	C1. **Stepped_Waiver** = leakage a credit in steps of 250,500 and 750 cfs	Yes	Yes	137/64	30	X			X	
14.	C2. **Stepped_Waiver** plus Baltimore withdrawal of 100 mgd	Yes	Yes	137/100	30	X			X	
	D. "Level_Storage" Options									
15.	D1. **Level_Storage** = maintain storage so Muddy Run is full and Conowingo pond is at least 104.5 elev. Provide minimum release of 3,250 cfs.	No	Yes	137/64	30	X			X	
16.	D2. **Level_ Storage** with 2025 CU levels	No	Yes	137/64	30		X		X	
17.	D3. **Level Storage** plus Baltimore withdrawal of 100 mgd	No	No	137/100	30	X			X	
18.	D4. **Level_ Storage** with Q-FERC requirements and with leakage credit	Yes	Yes	137/64	30	X			X	
19.	D5. **Level_ Storage** with Q-FERC requirements and without leakage credit	Yes	No[1] (unless waived)	137/64	30	X			X	

Plan Number	Alternative Plan	Q-FERC Requirements Met	Credit for Leakage Allowed	Baltimore Withdrawal Max/Low Flow (mgd)	Chester Withdrawal (mgd)	Consumptive Use in Basin			Commission Reservoir Storage Trigger	
						2000	2025	Max. Peak	Q7-10	Q-FERC
	E. Other Options									
20.	E1. Max current withdrawals plus max CU	Yes	No[1] (unless waived)	250/64	30			X	X	
21.	E2. **E1** with Chester at 40 mgd and year 2000 CU	Yes	No[1] (unless waived)	250/64	40	X			X	
22.	E3. **E2** with max CU	Yes	No[1] (unless waived)	250/64	40			X	X	
23.	E4. **Balt-84** = **_SimBase** with 84 mgd lowflow withdrawal	Yes	No[1] (unless waived)	137/84	30	X			X	
24.	E5.**SRBC_FERC_Trig**	Yes	No[1] (unless waived)	137/64	30	X				X
25.	E6. Upstream reservoir storage offset CU below Marietta	Yes	No[1] (unless waived)	137/64	30	X				X
26.	E7. **E9** with Chester at 40 mgd	Yes	No[1] (unless waived)	137/64	40	X			X	
27.	E8. **Fictional_Lake** = use new reservoir for low flow augmentation	Yes	No[1] (unless waived)	137/64	30	X			X	
28.	E9. **FERC_Passthru**	Yes[2]	No[1] (unless waived)	137/64	30	X			X	

Plan Number	Alternative Plan	Q-FERC Requirements Met	Credit for Leakage Allowed	Baltimore Withdrawal Max/Low Flow (mgd)	Chester Withdrawal (mgd)	Consumptive Use in Basin			Commission Reservoir Storage Trigger	
						2000	2025	Max. Peak	Q7-10	Q-FERC
29.	E10. **Storage_Waiver** = leakage credit when Conowingo pond and Muddy Run storage is 10,000 ac-ft or more below normal	Yes	Yes	137/64	30	X			X	
30.	E11. **Salinity4500** = minimum release flows only when 30-day avg. release decreases to 4,500 cfs or less	No	Yes	137/64	30	X			X	
31.	E12. Compare release flow to downstream dissolved oxygen	Yes	No[1] (unless waived)	137/64	30	X			X	
32.	E13. Compare release flows to downstream temperature	Yes	No[1] (unless waived)	137/64	30	X			X	

[1] Temporary emergency waivers to allow leakage credit have been approved by FERC in 1995, 1999, 2001, and 2002 when the Conowingo pond was at, or near, elevation 104.5 feet. Alternatives were modeled assuming a waiver was in place for pond elevations of 104.5 feet or less.

[2] Minimum release from Conowingo is Q-FERC less the difference between inflow downstream of Marietta and leakage estimate when inflow is less than leakage.

3. **Results of Analysis of Alternatives –** These initial 32 alternatives were the starting point for evaluation of management options at the Conowingo pond. The Workgroup analyzed the alternatives by reviewing the key performance measures identified earlier to determine which options warranted further consideration. After careful consideration of the alternatives, it was determined that 14 of them had sufficient merit to be carried forward for further analysis. Conversely, 18 alternatives failed to produce positive results and were dropped from further consideration.

   The 14 remaining alternatives are shown in the table below, with details on the parameters defining each alternative included.

Alternative Operational Plans Evaluated During Computer-Aided Negotiations

Plan No.	Alternative Plan	Threshold for Leakage Credit	Upstream Consumptive Use Level	Commission Reservoir Storage Release Trigger	Baltimore Maximum Withdrawal	Chester Maximum Withdrawal	Other Pond Consumptive Use
1	**_SimBase**	Pond < 104.5'	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000
3	**Future_Baseline**	Pond < 104.5'	Year 2025	Q7-10	137/64 mgd	30 mgd	Year 2025
4	**SimBase_Plus**	Always	Year 2000	Q7-10	137/100 mgd	30 mgd	Year 2000
5	**Future_Plus**	Always	Year 2025	Q7-10	137/100 mgd	30 mgd	Year 2025
6	**AutoWaiver**	Always	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000
7	**FutureMax_AW**	Always	Year 2025	Q7-10	250/100 mgd	40 mgd	Year 2025
13	**Stepped_Waiver**	**(1)**	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000
15	**Level_Storage**	Always **(2)**	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000
23	**Balt-84mgd**	Pond < 104.5'	Year 2000	Q7-10	137/84 mgd	30 mgd	Year 2000
24	**SRBC_FERC_trig**	Pond < 104.5'	Year 2000	Q-FERC	137/64 mgd	30 mgd	Year 2000
27	**Fictional_Lake**	Pond < 104.5'	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000
28	**FERC_Passthru**	Local inflow **(3)**	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000
29	**Storage_Waiver**	**(4)**	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000
30	**Salinity4500**	Always **(5)**	Year 2000	Q7-10	137/64 mgd	30 mgd	Year 2000

(1) The credit for leakage increases from 250 cfs to 500 cfs to 750 cfs as conditions worsen in the pond.
(2) Total release must exceed 3,000 cfs.
(3) Conowingo dam must pass the lesser of the leakage estimate (800 cfs) or the incremental inflow between the Marietta gage and the Conowingo pond (estimated by drainage area relationships).
(4) The credit for leakage is dependent on storage deficit in Muddy Run and the Conowingo pond.
(5) Leakage is credited at all times, unless the 30-day average outflow decreases to 4,500 cfs or below.

C. Computer-Aided Negotiations

After the full set of possible operational alternatives was initially evaluated, the next step involved the use of computer-aided negotiations (CAN) on the remaining alternatives. Computer modeled results of operations and facility scenarios were prepared in advance and distributed at the beginning of the meetings. Stakeholders reviewed results of the alternatives and critiqued both the positive aspects and the problems presented by the alternatives. The Workgroup then identified alternatives to be dropped from consideration, modifications to alternatives, and new alternatives to mitigate any problems identified from the results.

Sample results of the evaluation of alternatives during the CAN sessions are shown in the following tables and plots.

Display of Conowingo Dam Releases Less Than FERC Seasonal Flows: A very important result of any credit to Conowingo for leakage is that the resulting total flows out of the dam have the potential to be lower than the flows established by FERC in the 1988 settlement agreement. While not necessarily an adverse result, it is nevertheless an important piece of information. The table below displays the frequency ("number of events") and duration (in terms of days) of releases less than the FERC values for the remaining 14 alternatives. It also shows the occurrence of such releases during the critical spawning season of April, May and June. The various alternatives did not show a great deal more events than the existing conditions ("Simbase"), but the results did demonstrate that it might be necessary to impose restrictions on the leakage credit during the spawning period.

	Conowingo Flows Less than FERC Flows, June - Nov.						April & May Events*	April - June Events*
	Years (out of 73) with Number of Days Specified					Max Number of Days		
	0 Days	1-15 Days	16-30 Days	31-60 Days	Over 60 Days			
_SimBase	36	17	5	10	5	104	0	0
Future_Baseline	34	13	10	11	5	111	0	0
SimBase_Plus	24	18	13	12	6	128	0	3
Future_Plus	21	21	11	14	6	132	0	3
AutoWaiver	24	19	12	13	5	123	0	3
FutureMax_AW	21	21	11	13	7	132	0	3
Stepped_Waiver	33	16	10	11	3	113	0	0
Level_Storage	24	18	11	13	7	129	0	3
Balt-84	36	17	5	10	5	104	0	0
SRBC_FERC_trig	37	16	7	10	3	104	0	0
Fictional_Lake	36	17	7	10	3	102	0	0
FERC_Passthru	32	15	10	11	5	108	0	1
Storage_Waiver	24	19	12	13	5	124	0	3
Salinity4500	0	11	19	39	4	89	17	39

* Number of years with one or more occurrence.

Display of Conowingo Pond Stages Lower Than Seasonal Recreation Levels: During extreme low flow conditions, various competing requirements for water may render Conowingo

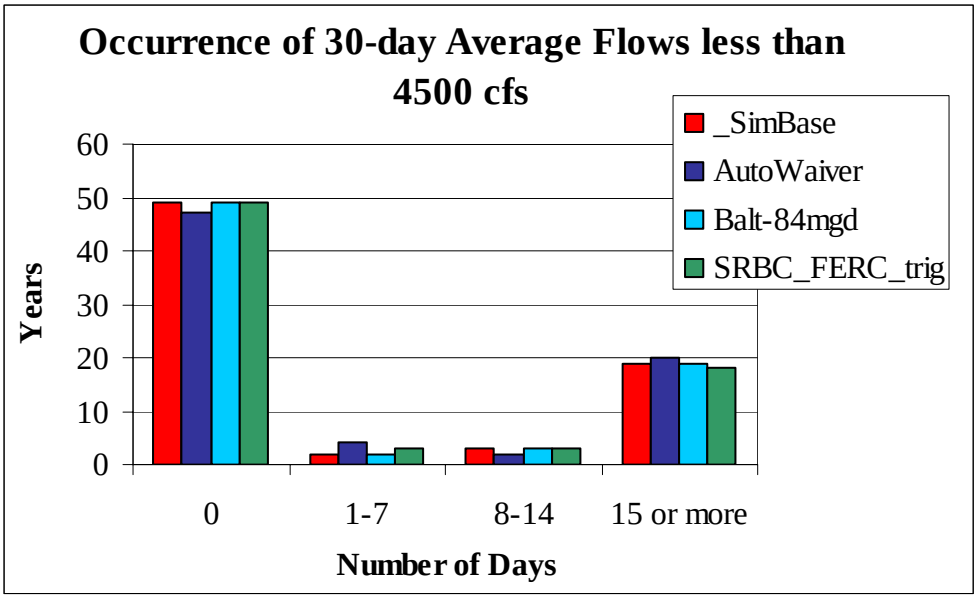
unable to maintain seasonal recreation levels. It may be that varied operating requirements or upstream conditions can alleviate the adverse impacts of low flows on recreation. The table below offers a comparison for the remaining 14 alternatives by displaying the frequency and duration of pond elevations below the seasonal recreation level. As might be expected, options that liberally apply a leakage credit to help conserve storage, such as "AutoWaiver," and options that add water to the system, such as "Fictional_lake," show a reduction in the frequency and duration of pond levels below recreation thresholds.

	Unmet Recreation Levels, May - September						
	Years (out of 73) with Number of Days Specified					Max Number	Total No.
	0 Days	1-7 Days	8-15 Days	16-30 Days	Over 30 Days	of Days	of Days
_SimBase	24	26	12	10	1	37	439
Future_Baseline	22	25	13	12	1	38	526
SimBase_Plus	27	40	4	2	0	21	202
Future_Plus	23	40	4	6	0	28	296
AutoWaiver	40	29	4	0	0	10	120
FutureMax_AW	22	41	4	6	0	30	312
Stepped_Waiver	25	31	10	6	1	34	366
Level_Storage	3	29	29	12	0	23	667
Balt-84	24	26	12	10	1	37	439
SRBC_FERC_trig	32	25	9	7	0	25	292
Fictional_Lake	24	28	13	7	1	35	410
FERC_Passthru	24	35	7	6	1	33	333
Storage_Waiver	38	31	4	0	0	10	123
Salinity4500	61	3	5	4	0	22	126

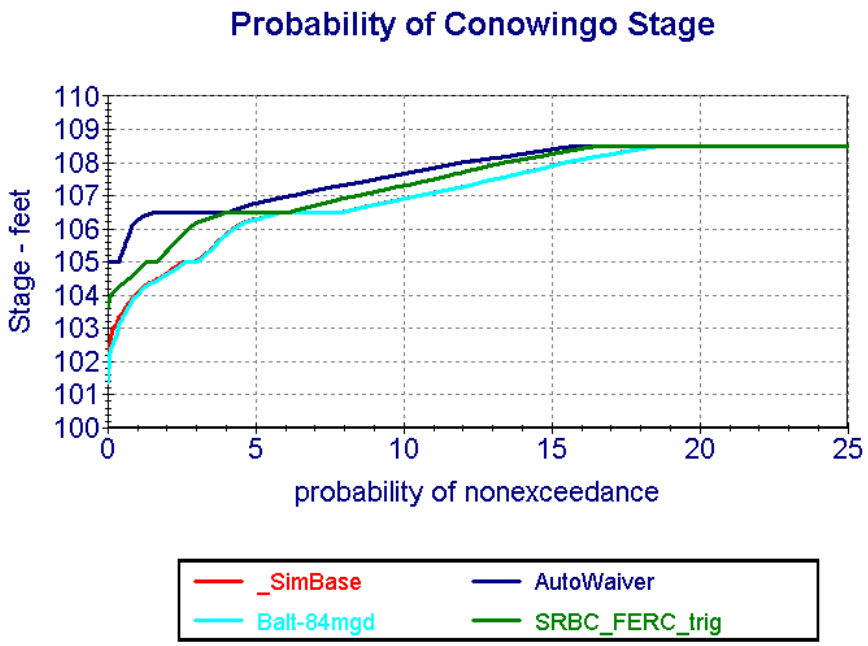
Display of Conowingo Dam Releases Less Than Surrogate Flows for Salinity Intrusion: While it was beyond the scope of this study to model salinity levels downstream of the Conowingo dam, the Workgroup did establish that a 30-day average flow rate from Conowingo of 4,500 cfs or less correlated well with the historic occurrences of salinity problems at the water intake at Havre de Grace. It was, therefore, useful to display the frequency and duration of events in which Conowingo releases meet that threshold, as shown in the table below. Although there is some variation in the occurrence of the salinity threshold among the different alternatives, the results suggest that natural conditions are more important than operating protocols in driving salinity presence. If the favorable combination of the tidal cycle, wind direction and strength, and flows out of Deer Creek all converge, salinity intrusion poses a threat regardless of slight fluctuations of releases from Conowingo dam.

	Salinity Indicator (30-day average flow < 4,500 cfs)		
	Number of Occurences (years)	Maximum Consecutive Days	Average Duration (days)
_SimBase	23	134	40
Future_Baseline	26	136	41
SimBase_Plus	26	134	36
Future_Plus	26	138	43
AutoWaiver	26	124	36
FutureMax_AW	26	138	43
Stepped_Waiver	23	131	40
Level_Storage	26	134	39
Balt-84	23	134	40
SRBC_FERC_trig	24	128	38
Fictional_Lake	22	132	39
FERC_Passthru	24	136	39
Storage_Waiver	26	124	36
Salinity4500	27	107	36

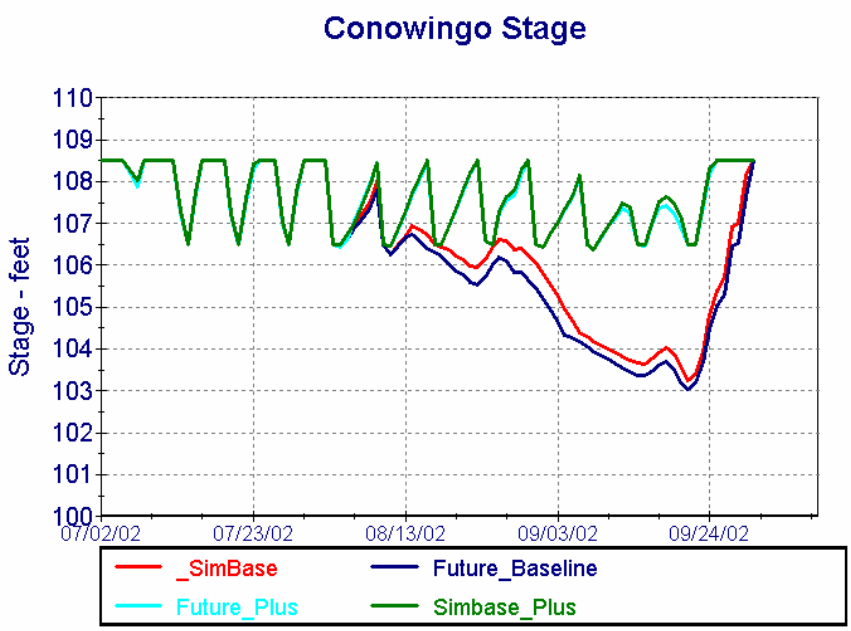
The bar chart below shows the same information in a different format, with more details about the duration of occurrences. As in the table above, there are not significant differences between the alternatives shown with regard to occurrence of the surrogate flows for salinity intrusion. The relatively infrequent occurrence of the surrogate for a period of 1 to 2 weeks, and the more frequent occurrence of duration over 15 days, also serves to demonstrate that the occurrence of salinity intrusion is the result of severe low flow conditions when several factors combine favorably. The phenomenon is not readily influenced by the day-to-day operations of the Conowingo facility.



Probability of Conowingo Stage Level: Because there are important considerations associated with various levels of the Conowingo pond (such as the recreation level of 106.5 feet and the concern for Peach Bottom's cooling intake below elevation 104.5 feet), it was useful to display the likelihood of Conowingo pond at various elevations. The probability plot shown below allowed the Workgroup to compare the frequency of occurrence of pond levels for the remaining scenarios. The most difference was realized at the extreme infrequent occurrences, where the credit provided by the AutoWaiver option allowed the pond to remain above recreation levels more often than the other alternatives, and also preserved the pond at a higher minimum level than the other scenarios (105.0 feet).



Time Series of Conowingo Stage: In addition to the probability of certain stages at Conowingo being observed over the period of record, it was useful to display daily results during known drought years to observe the pond behavior on a real-time basis. The plot below demonstrates that the two alternatives with an automatic waiver ("Future_Plus" and "Simbase_Plus") perform more favorably with regard to maintaining stage in the pond during the drought of 2002.



D. Evaluation of Results

The results of the CAN sessions served to demonstrate positive and negative aspects of the various scenarios, and allowed the Workgroup to eliminate operating parameters that do not offer desirable outcomes. Evaluation of results also allowed the Workgroup to focus on operating parameters that meet the objectives of the planning effort. Because many of the alternatives involved variations in other aspects of the system, such as water demands or storage releases, examination of the results provided a sensitivity analysis for the system; the Workgroup was, thus, able to discern those parameters that deserved the most scrutiny during selection of the final alternative.

1. **Water Demand** – The Workgroup felt it was important to evaluate the impact of water withdrawals and upstream consumptive water uses on the ability of the Conowingo pond to remain viable during droughts. In addition to running the scenarios with estimates of current water demands in the Susquehanna River Basin, scenarios were run using demands increased to 2025 levels, and 2025 demands with a peaking factor to estimate maximum short-term water use. Various levels of water use were also investigated for specific water users such as Chester Water Authority and the City of Baltimore. Also, new anticipated water uses were incorporated into the total demands. The results showed that, although water demand from the pond and the upstream basin was projected to increase by as much as 59 percent, the impact of varying water demands on the resource (pond stage and minimum dam releases) was not significant. Dam releases were generally not affected and pond stages were diminished by less than one foot. Although still deemed important to incorporate accurate estimates of future water demand, it was not anticipated to have

significant impacts on the pond resource and, thus, the Workgroup's efforts were focused more on other aspects of planning.

The Workgroup also considered the role water conservation might play in mitigating low flow conditions on the Conowingo pond. Estimates were made about potential reductions obtainable through conservation. Even using optimistic reductions of 10 to 20 percent basinwide, maximum water savings are relatively small compared to river flows, and would offer limited drought relief. Therefore, while conservation measures are to be encouraged and are a vital component of sound drought management, they do not offer the mitigation needed to sustain the Conowingo pond.

2. **Water Releases to Augment Low Flows** – The water storage owned by the Commission at two federal reservoirs in the upper basin is currently dedicated to offsetting specific consumptive uses during droughts in the vicinity of Wilkes Barre and Harrisburg, Pennsylvania. Certainly, it can be argued that any water released will eventually supplement flows into the Conowingo pond. However, that storage has not been a factor in pond management during recent droughts because none of the storage was used to offset the identified consumptive uses during that time. Under the contractual agreement between the Commission and the USACE, release of the storage is predicated on flow conditions of Q7-10 at either the Harrisburg or Wilkes Barre stream gages. That condition was not met in recent low flow years.

   To gain an understanding of the potential for large storage projects to mitigate drought conditions at the Conowingo pond, different operating conditions were investigated. For example, because much of the operations at Conowingo dam are dictated by flow conditions at the Marietta gage relative to the Q-FERC values, model runs were performed using Q-FERC values as the criterion for the release of augmenting flow from Commission-owned storage. Results showed that excess inflow can be demonstrated at the pond, but the benefit is not significant, particularly when compared to the leakage flow of 800 cfs from Conowingo dam. The ability of the storage to improve conditions at the pond is limited due to the relative size of the storage with respect to the daily fluctuations typically observed in the pond. The Commission owns 30,000 acre-feet of storage collectively at the two projects, which is equivalent to roughly 4 feet of water in the pond.

   Releasing a quantity of storage that is of significant use to the pond would deplete the Commission's storage in a matter of days; conversely, releasing the storage at a rate sustainable over a summer-long drought (75 – 125 cfs) would contribute minimal extra inflow to the pond on a daily basis. While further study may demonstrate unrealized potential for drought mitigation from Commission storage, the Workgroup decided it is beyond the scope of this effort, and it was not pursued as a management objective.

3. **Implementation of Leakage Credit** – The single variable that most directly and measurably impacted the pond is the credit for including leakage in meeting minimum flows. The quantity of credit and the timing of its use proved to be very

influential in the ability of the pond to remain viable for multipurpose use during low flows. As such, much of the Workgroup's subsequent effort was focused on evaluating implementation strategies for the credit, discussing the need for restrictions on use of the credit, and assessing the potential for the credit to offer benefits and impart adverse impacts to the pond and the river downstream of the dam.

Following completion of the CAN sessions and evaluation of the model results as described above, the Workgroup selected a set of preferred operation alternatives for closer analysis and final evaluation.

E. Selection of Preferred Operational Alternatives

The final set of preferred operating alternatives differ mainly in operating rules for release requirements from Conowingo dam during times of low flow. Parameters such as demand for water supply and water withdrawal operations were kept consistent in the scenarios to best allow for direct comparison between them. Consumptive use in the Susquehanna basin and withdrawal demands from the Conowingo pond were set at projected levels for 2025, as agreed upon by the Workgroup.

1. Description of Preferred Alternatives

a. Baseline: The model was configured to represent as closely as possible the existing operations in the Conowingo pond, using the previous "SimBase" model as a basis. In contrast to the "SimBase" alternatives, in which the credit for leakage was conditioned solely on the pond level declining below 104.5 feet, Exelon personnel assisted Commission staff in crafting a rule for implementation of ad hoc leakage credits that served as a reasonable approximation of the historic occurrences of such a waiver by FERC. The rule based the implementation of a credit for leakage on the storage in the pond and the time of year. Otherwise, the release requirements contained in the FERC license, which do not include a consideration for leakage estimates, were followed. For example, if the matching release is 4,000 cfs, the volume of the pond was reduced by 4,000 cfs plus an additional 800 cfs that is estimated to be leaking through the gates.

   Similarly, all other operations (e.g., control of Commission-owned storage in upstream reservoirs and operation of other water supply reservoirs and flood control dams) were modeled to reflect, as closely as possible, currently existing rules or requirements. Results of this scenario represented the "baseline" for comparison and served to demonstrate to the Workgroup the long-term conditions that can be expected in the pond if no action is taken to modify existing protocols.

b. Automatic Credit: Under this scenario, the full 800 cfs leakage was recognized and credited towards satisfying minimum dam releases at all times, regardless of flow conditions at Marietta. Although minimum flow releases made from Conowingo dam were still dependent on flow conditions at the Marietta gage, as required by the existing FERC settlement agreement, their magnitude was

automatically reduced by 800 cfs to account for leakage. This outcome was true whether the flow at Marietta was greater or less than the FERC-identified flow (i.e., Q-FERC) for a particular day.

For example, during June, the dam is required under the settlement agreement to release 5,000 cfs if Marietta flow is at least that much. Including the 800 cfs leakage, a total of 5,800 cfs actually passes downstream. Under the Automatic Credit scenario, 800 cfs for leakage is discounted from the required release of 5,000 cfs, leaving a release of 4,200 cfs. That release, combined with the 800 cfs leakage, totals a quantity passing the dam of 5,000 cfs.

On the other hand, if the flow at Marietta is below the threshold of 5,000 cfs in June, the settlement agreement stipulates that the dam match the Marietta flow. Under the settlement agreement, if 4,000 cfs is measured at Marietta, the dam must release 4,000 cfs in addition to the 800 cfs that leaks through, for a total of 4,800 cfs passing the dam. Under the Automatic Credit scenario, 800 cfs is credited toward the required matching release (4,000 cfs in this example), and only 3,200 cfs is released from the dam. Combined with the 800 cfs leakage, a total of 4,000 cfs passes the dam.

The only exception to the full-time inclusion of the leakage credit in meeting release requirements arose out of concern for passage of spawning anadromous species; the credit for leakage was never available in April, May, or June.

c. Critical Level: The full credit of 800 cfs for uncontrolled leakage was allowed under this scenario, but only when the elevation of the Conowingo pond dropped below a pre-defined critical stage (104.5 feet, Conowingo datum) due to extreme low flow conditions. That stage was selected because it is a reasonable indication of conditions at which continued operations at Peach Bottom and Muddy Run lose sustainability. Above that stage, no consideration was given for estimated leakage. Below that stage, the dam could count all 800 cfs of estimated leakage toward meeting the FERC-required minimum release. As in scenario No. 2, the credit for leakage was never available in April, May, or June, regardless of the pond elevation, out of concern for fish migration.

d. System Deficit: Rather than linking a credit for leakage to the flow past Marietta as in scenario No. 2, or to a critical stage of the Conowingo pond as in scenario No. 3, the rules of this alternative defined a minimum operability level for the combined pond and Muddy Run system, and allowed a leakage credit (up to 800 cfs, as needed) to maintain that minimum operability level. In other words, the scenario was structured such that enough water would always be held in the combined ponds of the Conowingo pond and the Muddy Run facility, such that when Muddy Run is full, the Conowingo pond would not be below an identified threshold. After some deliberation, the Workgroup established a threshold of 106.5 feet (Conowingo datum) for the pond.

Under typical operating conditions, there is sufficient water so that both Muddy Run and the pond can be held full; however, during low flow conditions, the total combined storage between the two can begin to trend downward when the operators act according to license requirements. The threshold of 106.5 feet was chosen because it represents a condition in which some of the operational capacity of Muddy Run has been lost, but operations at Peach Bottom are still fully sustainable.

An example of the application of the System Deficit alternative follows: if flows into the pond are sufficiently low so that the designated amount of storage can be maintained only through the allowance of a credit for 300 cfs of the leakage, then a credit of 300 cfs is allowed. Unlike scenario Nos. 2 and 3, the operators are prohibited from taking a credit for the remaining 500 cfs in leakage for the purpose of maintaining pond level above 106.5 feet. Only when river flows naturally provide sufficient water can the pond level be restored to 108.5 feet. As in the above scenarios, the credit for leakage was never available in April, May, or June, regardless of the situation in the pond.

e. Stepped Waiver: The introduction of a leakage credit was applied incrementally in this alternative, based on conditions in and around the Conowingo pond. There were two basic criteria: (1) the flow at Marietta dropping below the specified threshold levels (5,000 or 3,500 cfs, seasonally); and (2) the estimated local inflow (downstream of Marietta) into the pond being less than the estimated 2025 combined public water supply (for Baltimore and Chester withdrawals) and thermal power generation consumptive water use (for Peach Bottom and new Conectiv project) from the pond. If either of the two basic criteria was met, a credit for up to 250 cfs of the estimated leakage was granted. Intermediately, if both criteria were met, the credit was additive and granted up to 500 cfs. If the pond continued to trend downward in spite of the credit for leakage and reached a pre-defined critical stage (104.5 feet, Conowingo datum), the maximum credit of the full 800 cfs was allowed. As in the above scenarios, the credit for leakage was never available in April, May, or June, regardless of conditions in and around the pond.

f. Minimum Flow: Under this scenario, the flow thresholds established by Conowingo's FERC license (5,000 and 3,500 cfs, seasonally) were adopted as absolute minimum release criteria, even during times when Marietta flows were below these thresholds. In consideration of the dam striving to meet those minimum releases at all times, the estimated leakage of 800 cfs was always fully counted toward that goal. From the perspective of having the credit available under any conditions, this scenario resembles No. 2, Automatic Waiver. However, the mandated minimum release of 3,500 or 5,000 cfs was unique to this alternative. The only circumstance under which no credit for leakage was given was during the months of April, May, and June, as in the above scenarios.

2. **Evaluation of Preferred Alternatives** – Based on an evaluation of results for the six preferred alternatives, the Workgroup was able to identify positive and negative aspects of each option. The Workgroup was able to eliminate certain options from consideration because they were unable to meet various objectives for the plan, the most important being sustained viability of the Conowingo pond.

   a. Baseline: The Baseline alternative was developed only with the intent to serve as being representative of existing conditions for comparison purposes, and not as a proposal for recommended operations. Instead, the goal of the Workgroup was to modify existing conditions, as warranted, for improved management of the pond.

   b. Automatic Credit: The Automatic Credit option was very successful at protecting the level of the pond during droughts, and was deemed worthy of further evaluation. However, the Workgroup was concerned about allowing the variance for leakage even during times when the dam can be operated at full capacity without the credit. The intent behind formalizing the credit for leakage was to ensure reliability of the pond during droughts, and not to enhance operations of the hydroelectric facility. The results of the Automatic Credit option indicated that there are times during moderately low flows where usage of a leakage credit could noticeably alter the dam's outflow as a result of intra-day peaking. Implementing a permanent, full-time credit for leakage runs counter to the settlement agreement negotiated in 1988 to protect downstream habitat, and affords more flexibility to the dam at the expense of downstream flows than is warranted. Nevertheless, the Automatic Credit option consistently provided reliability to the storage in the Conowingo pond, and the Workgroup recognized the potential benefits.

   c. Critical Level: The Critical Level option quickly proved to be inadequate in ensuring sustainability of the pond. By restricting the leakage credit until the pond was at a level of 104.5 feet, the opportunity to maintain flexibility necessary to withstand droughts was generally lost. In other words, the variance simply came too late. Further, by tying the variance to the pond level, which is a parameter entirely within the control of the dam operators, the Workgroup expressed concern that the public would perceive the potential for a conflict of interest.

   d. System Deficit: Although the results for the System Deficit option were very favorable in terms of timing of the variance and success in sustaining pond operations, concern was expressed that the implementation of the variance was overly complicated and potentially restrictive of operational flexibility at the dam. It is not the intent of the plan to dictate operations to Exelon. Also, the variance relied on conditions in the pond that are not always readily available to the public, or even to members of the Workgroup, and might under certain circumstances be considered proprietary and confidential by Exelon. Nevertheless, the alternative was viewed favorably overall, as it was successful at providing the credit for leakage when it was truly needed, and allowed the pond to remain viable. At the

same time, the conditions required for the credit ensured that the waiver does not benefit hydroelectric operations at the expense of downstream habitat. As such, the System Deficit alternative was recommended for further consideration and possible selection as the final recommended alternative.

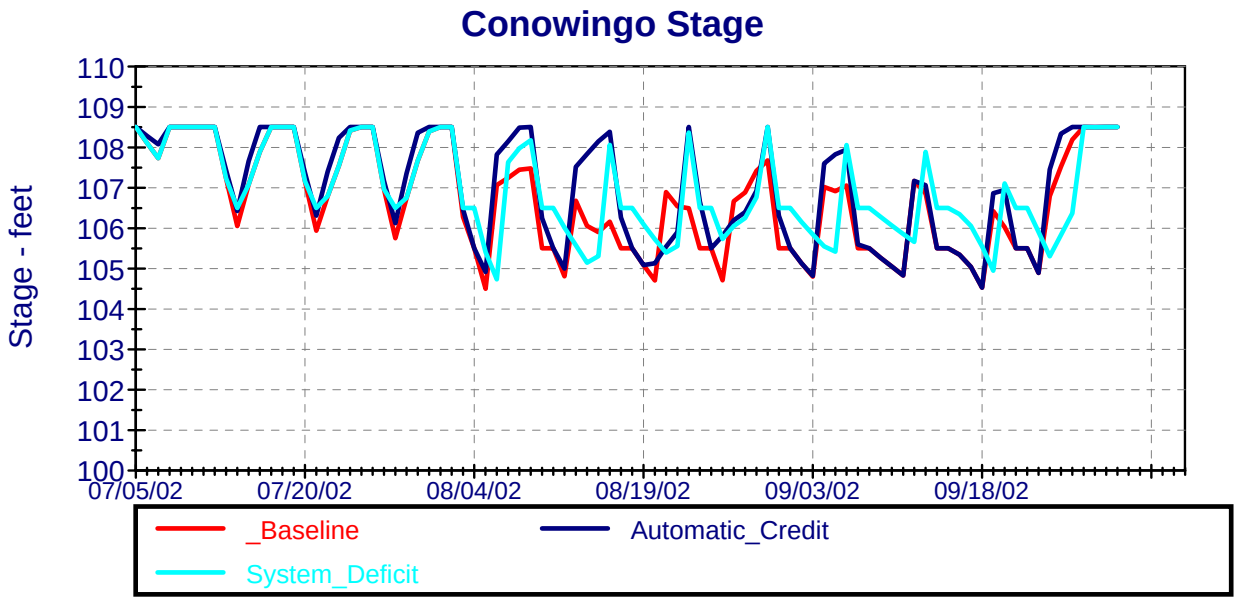
e. Stepped Waiver: In contrast to the criteria associated with System Deficit, the criteria under the Stepped Waiver option are readily available to the public and members of the Workgroup. However, daily assessment of withdrawals, pond level, and inflow estimates was deemed overly complicated and in opposition to the goal of a more direct and straightforward protocol for implementing the leakage credit. Further, despite several overlapping criteria for the variance, the option was not able to, in all cases, ensure pond viability during drought conditions.

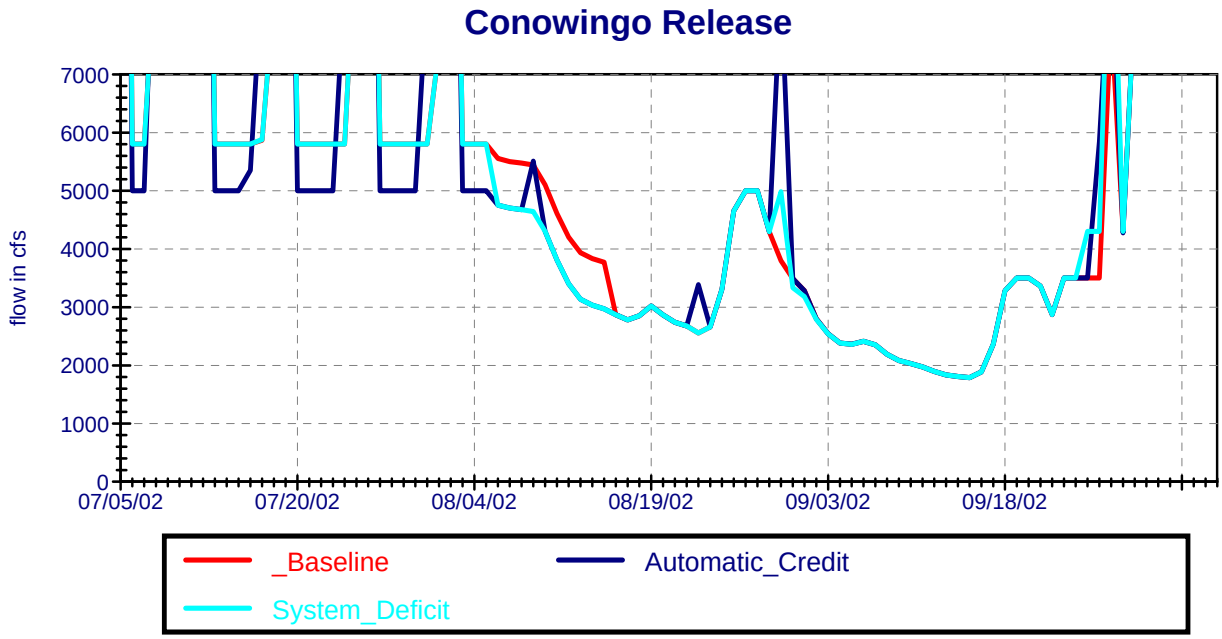
f. Minimum Flow: Finally, the Minimum Flow alternative demonstrated that the pond is simply unable to meet sustained releases of 5,000 and 3,500 cfs under drought conditions, even with the advantage of a full-time credit for leakage. The results reinforced the rationale implicit in the 1988 settlement agreement, tying required releases to the conditions at the Marietta stream gage. Adoption of the Minimum Flow alternative would have run contrary to that negotiated agreement, and would not have met the goals of the Conowingo Pond Management Plan.

The table and samples of the plots used to evaluate the six preferred alternatives are shown below.

Alternative Plan	1. Baseline	2. Automatic Credit	3. Critical Level	4. System Deficit	5. Stepped Waiver	6. Minimum Flow
Conowingo Releases						
Probability less than Q-FERC	6.1%	15%	5.3%	6.4%	4.8%	
Maximum days below Q-FERC	132	132	120	131	124	
Max consecutive days less than Q-FERC	65	65	62	51	65	
Events with flows < Q-FERC :						
For 1-7 days	6	13	6	13	8	*This alternative*
8-15 days	5	9	5	9	11	*was eliminated*
16-30 days	11	11	12	10	8	
31-60 days	12	15	10	15	11	
Over 60 days	6	6	6	7	6	
Events below salinity threshold	27	27	27	28	27	
Max days below salinity threshold	131	131	136	136	136	
Conowingo Stage						
Probability stage < 108.5 ft	18.9%	16.8%	19.3%	19.3%	19.2%	*This alternative*
Probability stage < 106.5 ft	4.2%	2.0%	6.4%	4.6%	5.8%	*was eliminated*
Probability stage <104.5 ft	0.6%	0%	2.2%	0.1%	1.9%	
Probability stage <103 ft	0.04%	0%	0.2%	0%	0.1%	
Minimum Stage (ft)	102.6	104.8	101.9	103.4	102.1	
Drought Comparisons						
Average release during August 1964	4061 cfs	4164	4262	4157	4290	
Minimum release during August 1964	2588	2588	2588	2588	2588	
Average release during September 1964	2195	2195	2195	2195	2195	
Minimum release during September 1964	1806	1806	1806	1806	1807	
Average stage during summer 1964	107.1 ft	107.1	105.1	106.6	105.6	*This alternative*
Minimum stage during summer 1964	106.2	106.3	102.7	104.8	103.0	*was eliminated*
Average release during August 2002	4553	4604	4985	4405	4687	
Minimum release during August 2002	2555	2659	3355	2495	3040	
Average release during September 2002	3502	3502	2924	3630	3303	
Minimum release during September 2002	1786	1786	1786	1786	1786	
Average stage during summer 2002	107.5	107.7	106.3	107.4	107.0	
Minimum stage during summer 2002	106.3	106.4	103.2	104.9	104.1	

Alternative Plan	1. Baseline	2. Automatic Credit	3. Critical Level	4. System Deficit	5. Stepped Waiver	6. Minimum Flow
Conowingo Recreation Violations						
0-7 days	33	36	25	26	29	
8-15 days	14	3	14	17	11	*This alternative*
16-30 days	4	1	11	25	9	*was eliminated*
Over 30 days	0	0	1	3	2	
Max days	29	17	36	34	37	
Average days	4.5	2.3	7.0	12.9	6.2	
Muddy Run Generation						
Avg. storage (1,000 ac-ft) available, Jul-Sep	1529	1658	1449	1625	1474	*This alternative*
Average storage NOT available, Jul-Sep	644	515	724	548	699	*was eliminated*
Minimum storage available, Jul-Sep	330	488	42	297	11	
Percent generation capacity lost, Jul-Sep	29.6%	23.7%	33.3%	25.2%	32.2%	


Conowingo Stage
Stage - feet
110
109
108
107
106
105
104
103
102
101
100
07/05/02
07/20/02
08/04/02
08/19/02
09/03/02
09/18/02
_Baseline
Automatic_Credit
System_Deficit


Conowingo Release
flow in cfs
7000
6000
5000
4000
3000
2000
1000
0
07/05/02
07/20/02
08/04/02
08/19/02
09/03/02
09/18/02
_Baseline
Automatic_Credit
System_Deficit

F. Refinement of Alternatives and Final Evaluation

Having evaluated the six preferred alternatives, the Workgroup was able to drop two from consideration, carry one forward for the final evaluation, and suggest modifications to an alternative, leaving four final alternatives for final evaluation. The four final alternatives were No Action, Baseline, Automatic Q-FERC + 1,000, and System Deficit. A full description of the alternatives, including the development of the Automatic Q-FERC + 1,000 alternative, is included in the main body of the report, as is a discussion of the results (see Section V-C).

As with previous evaluations, the Workgroup considered parameters such as minimum pond elevation, average flows from the dam, frequency of the pond being unable to meet required recreation levels, and impact to hydroelectric generating capacity. A detailed discussion of how the four alternatives performed with respect to these parameters is presented below. Following that, the tables and sample plots of results used in the final evaluation are also shown.

Minimum Pond Elevation: The table shows the minimum daily pond elevation reached in the Conowingo pond for each alternative through the entire 73-year period of record. The timely usage of leakage credit under the Automatic Q-FERC + 1,000 scenario allowed the pond the most reliability in terms of maintaining adequate levels. The results clearly show that the Automatic Q-FERC + 1,000 alternative provides the most reliability; two of the other three options declined below 102 feet, and the third remaining alternative allowed the pond to decline to the minimum allowable level specified in the FERC license, several feet below optimum minimum conditions.

During the drought of 2002, each of the options – Baseline, Automatic Q-FERC + 1,000, and System Deficit – maintained a minimum pond level of 104.5 feet by implementing a credit for leakage in different ways. The No Action option, however, not only was unable to maintain 104.5 feet in the pond, but also demonstrated that the pond level would have declined to the extreme minimum of 100.5 feet without the benefit of a credit for leakage. That result serves to reinforce the importance of the credit in keeping the Conowingo pond at reliable levels during droughts.

When looking at the level of the Conowingo pond over the entire 73-year record, a period of 26,663 days, on only 53 days (0.2 percent) did the pond level decline below 104.5 feet under the selected alternative. The No Action, Baseline, and System Deficit alternatives demonstrated pond levels below 104.5 on 1,200 days (4.5 percent), 267 days (1 percent), and 106 days (0.4 percent), respectively.

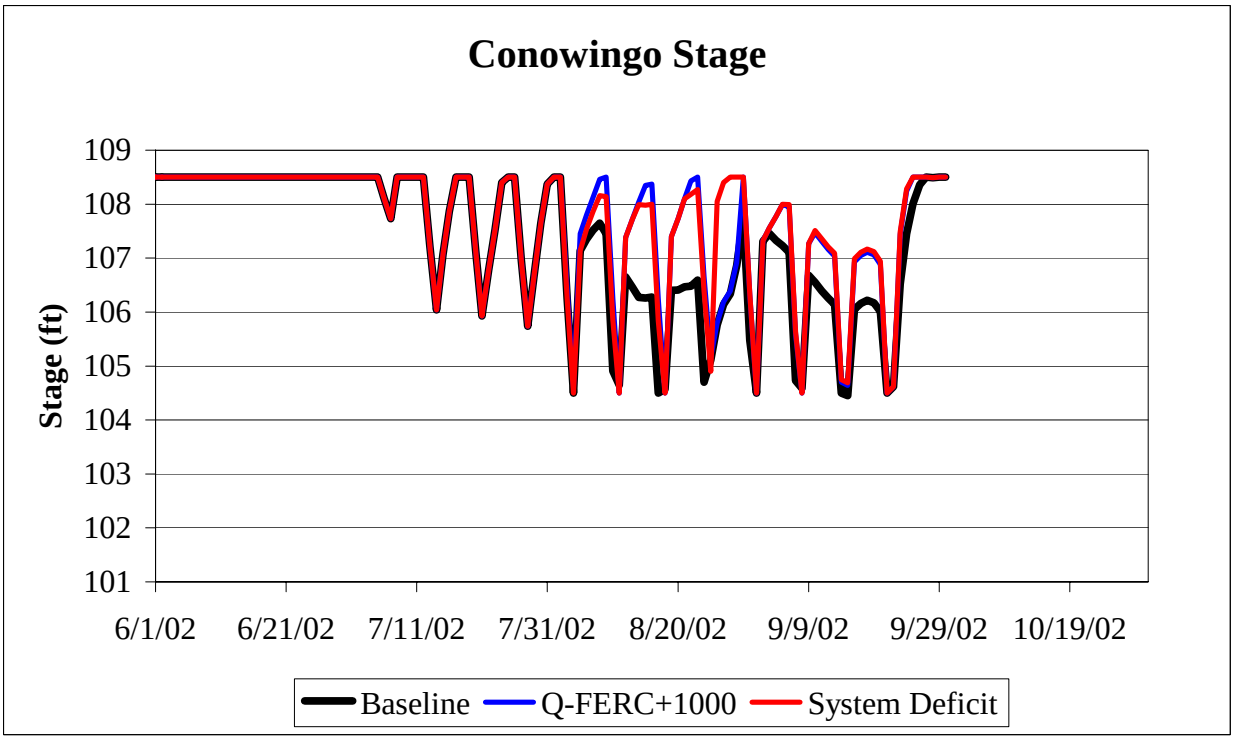
Average Release: The Workgroup looked at simulated releases from Conowingo during several droughts, including 2002. The differences in results of the four alternatives are attributable to the implementation (both timing and quantity) of the leakage credit. Any credit taken will reduce by that same quantity the water that is released downstream. On average during September 2002, the dam released about 3,630 cfs under the Automatic Q-FERC + 1,000 and System Deficit scenarios, while releasing 3,516 cfs under the Baseline scenario and 3,359 cfs under the No Action alternative. It seems counterintuitive that higher releases are shown by the alternatives that apply the leakage credit more liberally, but their ability to do so is

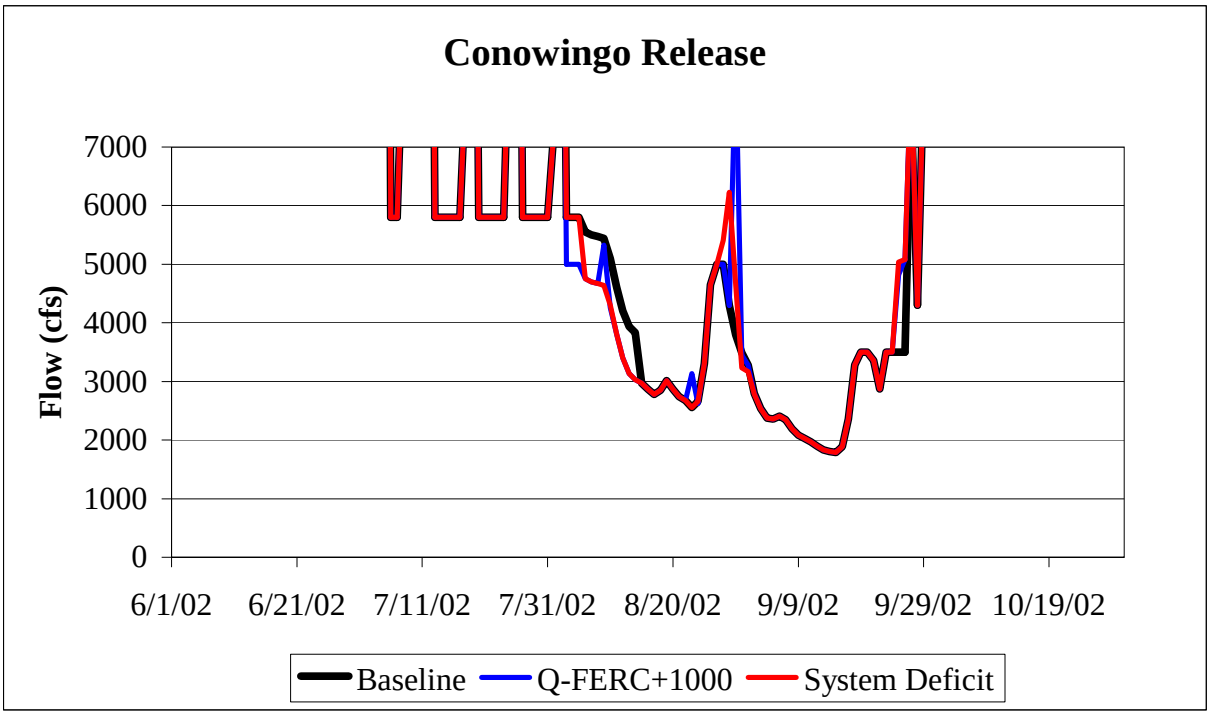
ensured by the higher stages of the pond. When the drought conditions eased in mid-September 2002, the dam was able to return to normal conditions more quickly under those alternatives, while it needed to retain more flow for refilling under No Action and Baseline conditions.

For comparison purposes, it is useful to also consider average releases during August 2002, before flows increased above drought conditions. During that month, the dam released the least water (4,479 cfs) under the System Deficit scenario, followed closely by 4,495 cfs under the Automatic Q-FERC + 1,000 scenario. The Baseline and No Action alternatives allowed releases of 4,616 cfs and 5,055 cfs, respectively. While there is significant difference in those results, the higher releases under the No Action scenario came at the expense of lower pond levels, as described above. Although providing less flow downstream during the month of August 2002, the Workgroup is satisfied that, based on available information, the releases under the Automatic Q-FERC + 1,000 and System Deficit alternatives are no more harmful to aquatic habitat than the releases under the No Action and Baseline scenarios.

Unmet Recreation Days: It is expected that allowing a credit for leakage will increase the reliability of the Conowingo pond to provide adequate levels for recreation. Because the FERC license stipulates maintenance of a recreational pond level of 106.5 feet only on weekends between Memorial Day weekend and the end of September, recreation usage is concentrated during that time, which is roughly 55 to 60 days spread over 18 to 20 weekends. Results show that, over the 73-year record, there are fewer days of unmet recreation levels (on an average annual basis) under the Automatic Q-FERC + 1,000 and System Deficit scenarios, at 12.2 and 12.7 days, respectively. Conversely, an average of 13.5 days (Baseline) and 15 days (No Action) fail to meet recreation needs under the other alternatives. In terms of the total days available for recreation (up to 60), the range of unmet days ranges from about 20 to 25 percent. The results, therefore, show that Automatic Q-FERC + 1,000 and System Deficit operations provided the equivalent of one additional weekend of optimum recreational opportunities (pond level at 106.5 feet) in an average summer. The results also suggest that when impacts do occur to recreation, they are less severe and of shorter duration under the chosen alternative.

Generating Capacity: Although the purpose of establishing management objectives for the Conowingo pond is not to provide the means for sustained or increased hydroelectric generation, reliable power generation is nevertheless a vital multipurpose use of the Conowingo pond. Thus, the generating capacity retained through drought periods is a useful indicator of whether or not the alternatives have provided more sustainable and reliable operations. Results show that the water available for generation at Muddy Run during the July through September timeframe can support about 92 percent of capacity under the Baseline, Automatic Q-FERC + 1,000, and System Deficit alternatives. However, the No Action option can sustain only about 81.5 percent of capacity. The period July through September is particularly useful for evaluation because it is the juxtaposition of the time that low flows are most likely to occur and the typical occurrence of peaks in power demand.


Conowingo Stage
Stage (ft)
109
108
107
106
105
104
103
102
101
6/1/02
6/21/02
7/11/02
7/31/02
8/20/02
9/9/02
9/29/02
10/19/02
Baseline
Q-FERC+1000
System Deficit


Conowingo Release
Flow (cfs)
7000
6000
5000
4000
3000
2000
1000
0
6/1/02
6/21/02
7/11/02
7/31/02
8/20/02
9/9/02
9/29/02
10/19/02
Baseline
Q-FERC+1000
System Deficit

Alternative Plan	1. No Waiver	2. Baseline	3. Q-FERC + 1000	4. System Deficit
Conowingo Releases				
Probability less than Q-FERC	4.2%	6.7%	10.1%	7.6%
Maximum days below Q-FERC	117	132	132	133
Max consecutive days less than Q-FERC	45	65	65	65
Events with flows < Q-FERC :				
For 1-7 days	9	6	16	14
8-15 days	6	5	6	7
16-30 days	11	11	11	11
31-60 days	9	12	14	15
Over 60 days	4	6	7	7
Events below salinity threshold	26	27	28	27
Average days below salinity threshold	44	46	44	46
Max days below salinity threshold	134	134	134	135
Conowingo Stage				
Probability stage < 108.5 ft	20.6%	20.0%	19.1%	19.6%
Probability stage < 106.5 ft	10.0%	7.7%	6.2%	6.8%
Probability stage <104.5 ft	4.5%	1.0%	0.2%	0.4%
Probability stage <103 ft	3.2%	0.1%	0%	0.05%
Minimum Stage (ft)	100.5	101.8	103.1	101.8
Drought Comparisons				
Average release during August 1964	4546 cfs	3968 cfs	4071 cfs	4050 cfs
Minimum release during August 1964	3388	2588	2588	2588
Average release during September 1964	2052	2195	2195	2195
Minimum release during September 1964	1561	1806	1806	1806
Average stage during summer 1964	103.7 ft	106.5 ft	106.6 ft	106.4 ft
Minimum stage during summer 1964	100.5	104.4	104.4	104.4
Average release during August 2002	5055 cfs	4616 cfs	4495 cfs	4479 cfs
Minimum release during August 2002	3355	2555	2620	2555
Average release during September 2002	3359	3516	3633	3636
Minimum release during September 2002	1350	1786	1786	1786
Average stage during summer 2002	105.3 ft	106.9 ft	107.3 ft	107.4 ft
Minimum stage during summer 2002	100.5	104.5	104.5	104.5

Alternative Plan	1. No Waiver	2. Baseline	3. Q-FERC + 1000	4. System Deficit
Conowingo Recreation Violations				
1-7 days	26	26	26	26
8-15 days	15	16	21	18
16-30 days	19	25	21	24
Over 30 days	11	4	3	3
Max days	42	36	33	36
Average days	15.0	13.5	12.2	12.7
Muddy Run Generation	***(max of 1564 thousand acre-feet are available July – September)***			
Avg. storage (1000 acft) available, Jul-Sep	1274	1432	1448	1439
Average storage NOT available, Jul-Sep	290	133	116	125
Minimum storage available, Jul-Sep	171	1173	1172	1172
Percent generation capacity lost, Jul-Sep	18.5%	8.5%	7.4%	8.0%

G. Selection of Recommended Alternative

The evaluation of preferred alternatives showed that Automatic Q-FERC + 1,000 provided the best overall results for key parameters, including minimum pond elevation, minimum and average flows from the dam, frequency of the pond being unable to meet required recreation levels, and impact to hydroelectric generating capacity. Thus, Automatic Q-FERC + 1,000 was carried forward as the best alternative, and was evaluated with respect to the important issues defined by the Workgroup at the outset of the study. A discussion of that evaluation is available in the full body of the main report (see Section VI).

Finally, a position analysis of the alternative was performed for the purpose of predicting the consequences of the application of the recommended operations, in comparison to existing conditions.

Position Analysis for Occurrences of Q-FERC + 1,000 at Marietta

The entire available period of record (October 1, 1931 through September 30, 2005) at the Marietta, Pennsylvania, gage was analyzed to assess the frequency of flows equivalent to Q-FERC + 1,000 cfs and the likelihood that Q-FERC conditions will then follow later that year. Results are shown in the table below.

The second column in the table below shows the number of years in which the gage at Marietta recorded flows less than Q-FERC + 1,000 cfs. Q-FERC is 5,000 cfs from June 1 through September 14, and 3,500 cfs from September 15 through November 30; no instances of flows less than Q-FERC + 1,000 cfs occurred before June 1 or after November 30. The data are separated into 2-week periods, denoting the FIRST occurrence of flows less than Q-FERC + 1,000 cfs in a particular year.

The table's third column shows the number of the years in which the flow at Marietta eventually dropped below Q-FERC. The data show that early occurrences of flows less than Q-FERC + 1,000 are very reliable indicators of eventual flows less than Q-FERC. The later in the year the first occurrence of Q-FERC + 1,000, the less likely the river at Marietta is to eventually decrease below Q-FERC.

Close evaluation of the position analysis yields the following conclusions:

1. Q-FERC + 1,000 events beginning in July or August are highly indicative of subsequent Q-FERC flows.

    a. Forty-two of the 56 Q-FERC + 1,000 events, or 75 percent, began in July and August and 36 of these events, or 86 percent, were followed by Q-FERC flows.

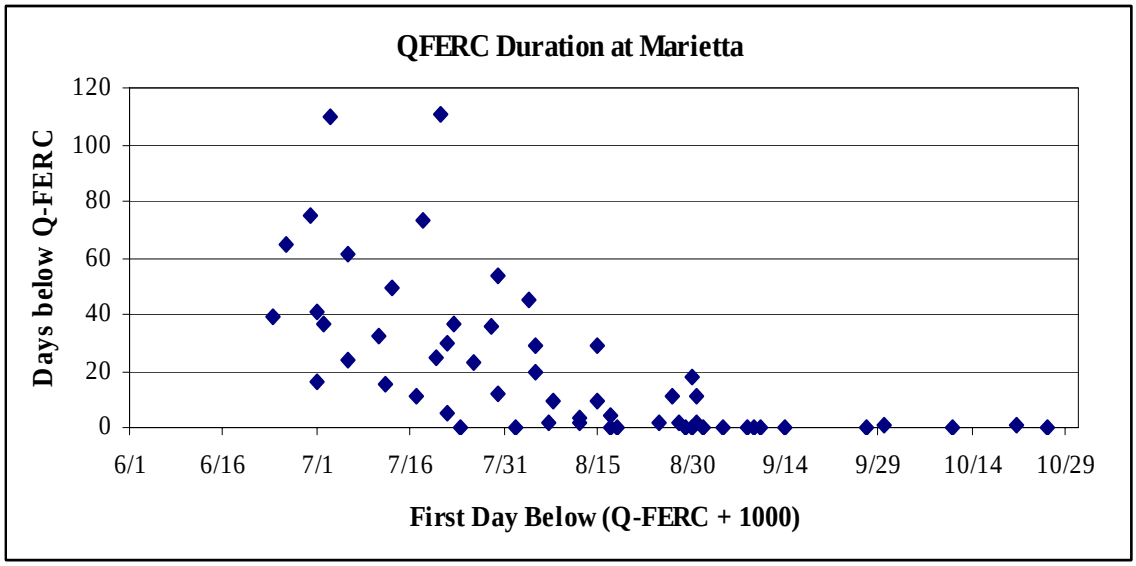
2. Q-FERC + 1,000 events beginning in September and October are not as indicative of the infrequent Q-FERC flows that have occurred in this time period.

a. Eleven of the 56 Q-FERC + 1,000 events, or 20 percent, occurred in September and October, but only 2 of these events, or 18 percent, were followed by Q-FERC flows.

Time Period of First Q-FERC + 1,000 Occurrence	Number of Years Measuring Q-FERC + 1,000	Number of those Years Measuring Q-FERC	Reliability (percent)
June 1 – June 14	0	0	--
June 15 – June 30	3	3	100
July 1 – July 15	9	9	100
July 16 – July 31	12	11	92
August 1 – August 15	10	9	90
August 16 – August 31	11	7	64
September 1 – September 14	6	0	0
September 15 – September 30	2	1	50
October 1 – October 15	1	0	0
October 16 – October 31	2	1	50

3. Q-FERC + 1,000 events beginning in July and August indicate potentially significant durations of subsequent flow periods below Q-FERC.

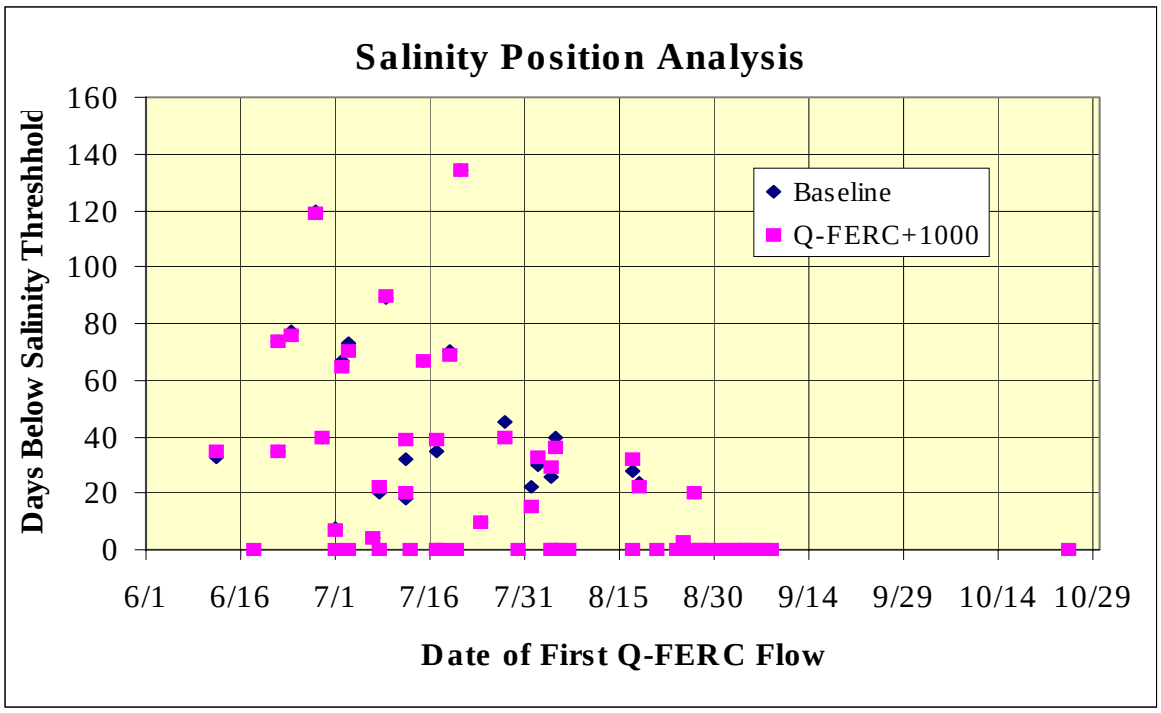
   a. Twenty of the 42 Q-FERC + 1,000 events beginning in July and August, or 48 percent, were followed by Q-FERC durations of 20 days or longer.
   b. Eleven of the 42 Q-FERC + 1,000 events beginning in July and August, or 26 percent, were followed by Q-FERC durations of a few days up to 20 days.
   c. The plot below shows that years with the most days measured below Q-FERC tend to first experience flows lower than Q-FERC + 1,000 prior to the end of August.



Position Analysis for Occurrences of Salinity Threshold Downstream of Conowingo

The Workgroup concluded during the CAN sessions that the various operating alternatives did not have significant impacts on the occurrence of the surrogate salinity threshold downstream of the Conowingo dam. Nevertheless, once an alternative is selected for recommendation to the Commission, it is useful to perform a position analysis to verify that the implementation of the alternative does not cause significantly more frequent occurrences of the salinity threshold.

The plot below shows, for existing conditions (Baseline) and the proposed operations, the number of days below the salinity threshold that can be expected to occur based on the date of the first flow that is below Q-FERC at the Marietta gage.



First, the plot clearly shows that, regardless of operations, years with extended number of days below the salinity threshold (greater than 60 days), are all indicated by an initial occurrence of Q-FERC prior to August 1. Likewise, for both operating modes, the salinity threshold does not occur at all if the first instance of Q-FERC happens after the end of August.

Finally, the position analysis results show that there is not expected to be a significant increase in the number of days below the salinity threshold as a result of implementation of the Q-FERC + 1,000 operations. In fact, it appears that some low flow events actually suffer fewer days below the salinity threshold under the proposed operations. The reason is likely because the proposed operations, by virtue of the credit for leakage, allows the conservation of storage early in a drought, which in turn allows for potentially higher releases towards the drought's end. Higher releases could provide a countermeasure to increased salinity levels downstream of the dam.