U.S. DEPARTMENT OF ENERGY

PNNL-23306, Rev. 1

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Evaluation of Hydrologic Alterations Associated with Consumptive Water Use for Bell Bend Nuclear Power Plant Operation

PD Meyer

Revision 1
February 2016

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Operation of Bell Bend Nuclear Power Plant (BBNPP) will require consumptive use of water from the North Branch Susquehanna River (NBSR) at an estimated rate of 43 cubic feet per second (cfs). The Susquehanna River Basin Commission (SRBC) has the regulatory authority to approve this use and to impose consumptive-use mitigation and passby flow requirements. SRBC has stated that consumptive-use mitigation and passby low-flow protection will be required in the form of compensating releases from upstream sources. As stated in the applicant's primary plan for BBNPP consumptive-use mitigation, water would be released from Cowanesque Lake into the Cowanesque River and from Rushton Mine into Moshannon Creek during low-flow periods as required by SRBC. Hydrologic alterations to these water bodies from the consumptive use of NBSR water by the proposed BBNPP are estimated in this report along with the evaluation of hydrologic alterations to the NBSR at the point-of-use.

SRBC has specified passby flows that will trigger releases for BBNPP low-flow protection. These passby flows will be measured by the observed discharge at the U.S. Geological Survey Wilkes-Barre gage on the NBSR. The existing discharge record at this gage was used to evaluate the occurrence of flow conditions requiring releases for consumptive use mitigation and BBNPP passby flow requirements. The frequency and distribution in time of the occurrence of conditions requiring releases for BBNPP operations were compared to the occurrence of conditions requiring consumptive use mitigation releases for the existing Susquehanna Steam Electric Station (SSES) and the Montour and Three Mile Island (TMI) power plants. Mitigation triggers based on annual 7Q10 flow values and monthly P95 flow values (flows that are exceeded 95 percent of the time) were evaluated. The SRBC passby flow values specified for BBNPP resulted in significantly more frequent and lengthy periods of upstream releases, particularly in June and July.

Using the occurrence of conditions requiring upstream releases, as determined from the existing discharge record at the Wilkes-Barre gage (and the Harrisburg gage for TMI), and the projected changes in consumptive-use mitigation releases if the applicant's primary plan were approved, changes in flows to the NBSR mainstem, the Cownesque River below the dam, and Moshannon Creek near the point of Rushton Mine discharge were evaluated. In addition, changes to the elevation of Cowanesque Lake were estimated. The greatest apparent hydrologic alterations are the changes in Cowanesque Lake elevation and changes in Cowanesque River flows immediately below the dam.

The estimated hydrologic alterations are dependent on the passby flows for BBNPP set by SRBC. Because an actual consumptive-use mitigation plan for BBNPP has not been approved, the analysis presented here was based on reasonable assumptions about the implementation of the applicant's primary plan while attempting to produce alteration estimates that were also bounding. The primary bounding assumption of the analysis was the use of the passby flow values specified by SRBC. The SRBC has indicated that these values may be changed (lowered) in the future because of planned modifications to the operations plan for Cowanesque Dam, namely, a switch from 7Q10 to P95 flow triggers for consumptive use mitigation for the existing SSES, Montour, and TMI plants.

Acronyms and Abbreviations

BBNPP	Bell Bend Nuclear Power Plant
cfs	Cubic feet per second
CU	Consumptive Use
ft	Feet
IHA	Indicators of Hydrologic Alteration (code)
NBSR	North Branch Susquehanna River
PPL	PPL Bell Bend
P95	Flow with a 95-percent probability of being exceeded
RVA	Range of Variability Approach
SRBC	Susquehanna River Basin Commission
SSES	Susquehanna Steam Electric Station
TMI	Three Mile Island
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WY	Water Year
7Q10	7-day average flow occurring on average once every 10 years

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1.0 Introduction

Operation of Bell Bend Nuclear Power Plant (BBNPP) will require consumptive use of water from the North Branch Susquehanna River (NBSR) at an estimated rate of 43 cfs. The Susquehanna River Basin Commission (SRBC) has the regulatory authority to approve this use and to impose consumptive-use mitigation (SRBC 2008) and passby flow requirements (SRBC 2012b). Although SRBC has declined to grant conditional approval prior to receipt of a final application, in a December 28, 2012 letter to PPL Bell Bend (PPL), SRBC described general conditions that would be required for a future application to be approved. In this letter, SRBC stated that consumptive-use mitigation and passby flow requirements will be used to avoid significant adverse impacts from BBNPP consumptive use during low-flow conditions by requiring compensating releases from upstream sources. The consumptive use at BBNPP and the upstream releases will alter stream flows in the Susquehanna River watershed. Quantitative measures of these flow alterations are evaluated in this report and compared to flow alterations that have occurred following construction of major dams in the watershed. Measures of flow alterations evaluated here are similar to those recommended previously by The Nature Conservatory (TNC 2010). These measures are based on the occurrence and magnitude of high and low flows and on flow-duration curves. Flow-duration curves show the cumulative distribution of measured flow, displayed as the probability of exceeding given flow values. (The flow exceeded 95% of the time is referred to as the P95 flow value.) Examples of measures of flow alteration based on flow-duration curves include the following (from the recommendations of The Nature Conservatory [2010]).

- Less than 10 percent change to the P10 flow value
- Median flows (P50) fall between the 45^{th} and 55^{th} percentiles of flow prior to alteration
- No change in the P75 and P95 flow values (i.e., the flows with probabilities of exceedance of 0.75 and 0.95).

In addition to the alteration measures based on flow-duration curves, other indicators of flow alteration were computed using The Nature Conservancy's Indicators of Hydrologic Alteration (IHA) code (version 7.1.0.10) (TNC 2009).

In its December 28, 2012, letter to PPL, SRBC stated that mitigation releases for BBNPP consumptive use will be triggered when discharge measurements at the U.S. Geological Survey (USGS) Wilkes-Barre stream gage (01536500, Susquehanna River at Wilkes-Barre, Pennsylvania) reach monthly P95 flow values, plus the consumptive use in the vicinity of the gage, which the SRBC subsequently stated includes the combined consumptive use of BBNPP and the permitted Susquehanna Steam Electric Station (SSES) use. Consumptive use mitigation is required when the low-flow triggers are reached during the months of July through November.

In its December 28, 2012 letter to PPL, SRBC also provided passby flow requirements that would be applicable at the BBNPP point-of-use. Passby flows at the point-of-use were adjusted by the SRBC to the Wilkes-Barre gage location using the ratio of drainage areas at the point of use and at the gage. The SRBC stated that upstream releases would be required for low flow protection when flows at the Wilkes-Barre gage reach the adjusted passby flow values plus the combined consumptive use of BBNPP and

SSES (see Appendix A). The SRBC set passby flow requirements for the months of May to October, with no passby flow requirements during the remainder of the year.

In the October 21, 2013, response to Request for Additional Information ENV-19, PPL proposed a primary plan for consumptive-use mitigation that would release water from Cowanesque Lake to compensate for BBNPP water use. This plan would involve the purchase of rights to Cowanesque Lake water supply storage currently allocated to mitigate consumptive use of a power plant downstream of BBNPP, and the transfer of water supply storage currently used to mitigate consumptive use of PPL's Montour power plant on the West Branch Susquehanna River. PPL proposed that water from the Rushton Mine could be released to Moshannon Creek, a tributary of the West Branch Susquehanna River, to satisfy the Montour consumptive-use mitigation needs. This primary plan for consumptive-use mitigation at BBNPP would alter river flows downstream of Cowanesque Dam and downstream of the Rushton Mine discharge. This report evaluates the occurrence of upstream releases to satisfy BBNPP consumptive-use mitigation and passby flow requirements based on the existing discharge data measured at the Wilkes-Barre gage. In addition, the resulting changes in discharge below Cowanesque Dam and on Moshannon Creek are assessed.

2.0 Occurrence of BBNPP Consumptive-Use Mitigation Conditions

River discharge conditions at the USGS Wilkes-Barre gage (01536500, Susquehanna River at Wilkes-Barre, Pennsylvania) would trigger consumptive-use mitigation and passby flow releases for BBNPP. Daily discharge data from this gage covering the period from 1899 to 2013 were used to evaluate the occurrence of conditions that would trigger releases. Three of the four lakes with the largest storage capacity upstream of BBNPP in the NBSR watershed were completed in 1980; these lakes are Cowanesque Lake and Tioga-Hammond Lakes. The fourth lake, Whitney Point Lake, was completed in 1942. Because the dams that created these lakes have affected flows at the Wilkes-Barre gage, the data were divided into two periods for this analysis, 1899 to 1980 and 1981 to present. Characteristics of flow in the two periods are described below.

Median daily discharge by month at the Wilkes-Barre gage is shown in Figure 2.1 for the two periods considered. The reduction in median March and April discharge suggests that the dams may impact the peak flows at Wilkes-Barre. For most months, however, median discharge during 1981 to 2013 was higher than during 1899 to 1980. Generally wetter conditions in the post-dam period than over the period of record are reflected in the annual mean discharge, shown in Figure 2.2.

The dams could also be expected to increase low flows during the summer months. The occurrence of low flows during the two periods is shown by the annual flow-duration curves (i.e., the flow-duration curve constructed from daily discharge data over the entire year) in Figure 2.3. Some changes to exceedance probabilities between the two periods are provided in Table 2.1. While there was little change to the occurrence of high flows (i.e., the P10 value was reduced by less than 1 percent), the median and low flows were significantly larger during the post-dam period. The median (P50) flow in the

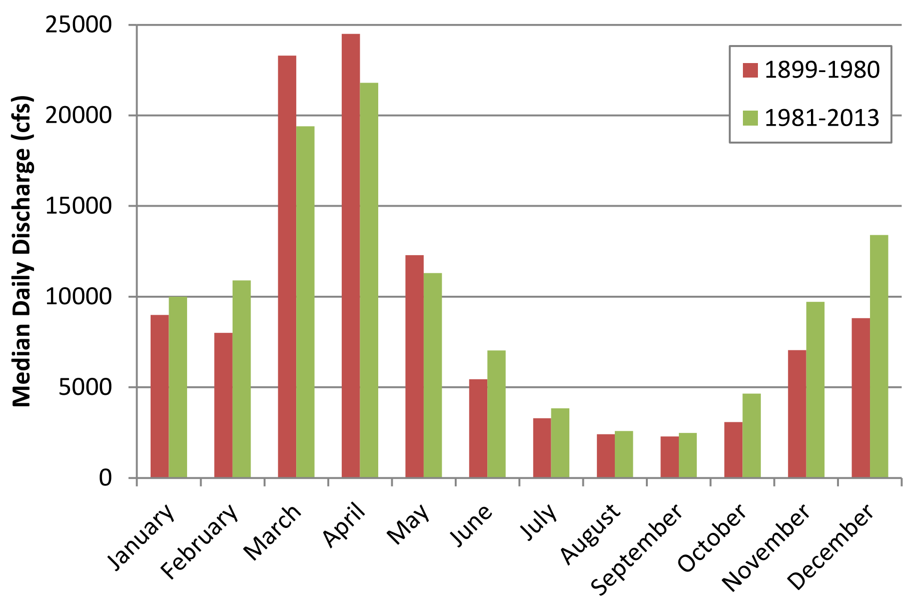


Figure 2.1. Median Daily Discharge by Month at the Wilkes-Barre Gage (USGS 2014)

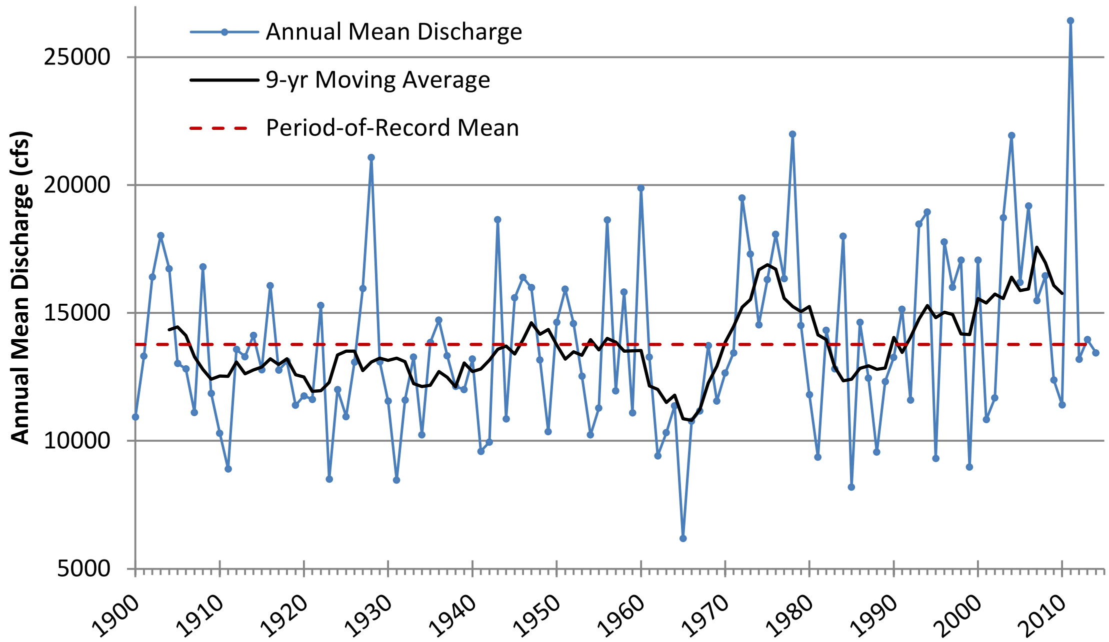


Figure 2.2. Annual Mean Discharge at the Wilkes-Barre Gage, the 9-Year Moving Average, and the Average Annual Mean Discharge Over the Period of Record

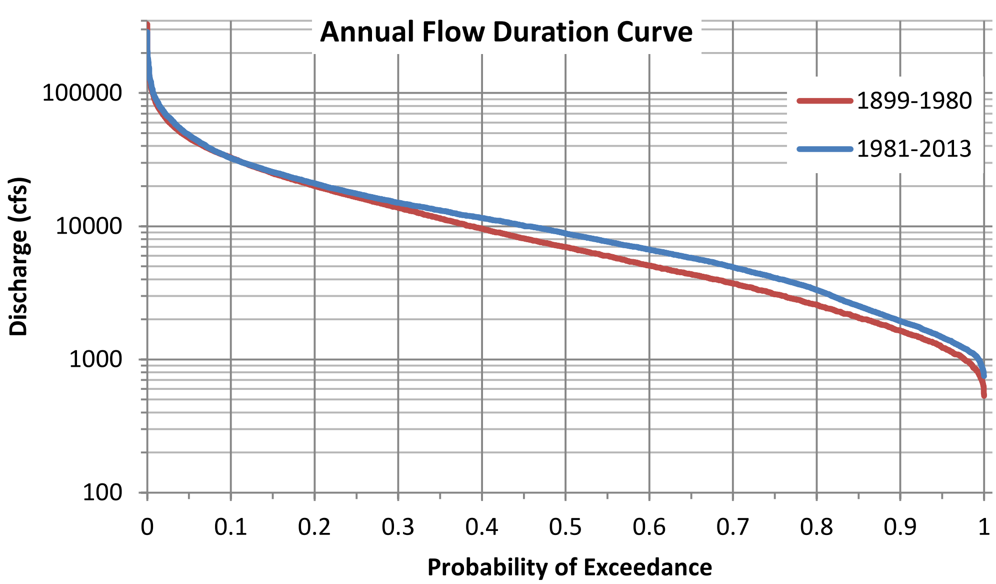


Figure 2.3. Annual Flow-Duration Curve (constructed from daily discharge data over the entire year) for Discharges at the Wilkes-Barre Gage. (Pre-dam [1899 to 1980] and post-dam [1981 to 2013])

Table 2.1. Pre-Dam and Post-Dam Flows (cfs) at the Wilkes-Barre Gage for Specific Exceedance Probabilities

	1899-1980	1981-2013
P10	32,600	32,400
P45	8,110	10,100
P50	6,970	8,825
P55	5,990	7,660
P75	3,080	4,100
P95	1,230	1,460

post-dam period falls above the pre-dam P45 to P55 range. The P75 and P95 values were increased in the post-dam period by 33 and 19 percent, respectively. However, this effect may be due to the generally wetter conditions during the post-dam period.

The SRBC proposes to use measured discharge at the Wilkes-Barre gage as the basis for triggering consumptive-use mitigation and passby flow releases for BBNPP. Currently, consumptive-use mitigation releases are made from Cowanesque Lake when the discharge at the Wilkes-Barre gage falls below the yearly 7Q10 value of 826 cfs plus 72 cfs. The U.S. Army Corps of Engineers (USACE) identifies 72 cfs as the average water-supply needs for the combined consumptive use by the Susquehanna and Montour plants (USACE 2013). A mitigation release from Cowanesque Lake is made for the Three Mile Island (TMI) plant when the discharge at the Harrisburg gage falls below the 7Q10 value of 2,631 cfs plus consumptive use at TMI of 22 cfs (USACE 2013). Since 1990 when Cowanesque Lake was first used for consumptive-use mitigation, releases based on the 7Q10 triggers have occurred in 1991 and 1995 (USACE 2013).

The impacts of changing the triggers for consumptive-use mitigation releases from Cowanesque Lake were evaluated in USACE (2013). The preferred alternative was to base the triggers on monthly P95 flow values, which would provide a greater degree of mitigation without significantly impacting other project objectives. Using data from 1930-2007, USACE (2013) evaluated the P95 values at the Wilkes-Barre gage for the months of August to October. The P95 values are listed in Table 2.2. The flows for July and November were set equal to August and October, respectively. Cowanesque Dam operations will implement the preferred alternative in the near future (likely in 2015 according to USACE staff in a teleconference held on January 14, 2014).

The passby flow requirements specified by SRBC at the BBNPP location and adjusted to the Wilkes-Barre gage location are shown in Table 2.2. SRBC policy generally recommends monthly P95 values for passby flows, but the SRBC considered other factors in setting the BBNPP passby flow values.

- SRBC considered the special aquatic studies provided by PPL in their application to SRBC.
- SRBC used the P90 value as the August passby flow value.
- Consumptive use at SSES and the two thermal discharges from the SSES and BBNPP power plants were factored into the passby flow values. The SRBC staff have indicated they assumed the SSES consumptive use and the operation of Cowanesque Lake as a source of mitigation

releases for that use would continue under current conditions. Evaluation of impacts in the river and determination of passby flows for BBNPP incorporated this use. The effect of this assumption was to increase passby flows for BBNPP (i.e., make them more restrictive). The SRBC indicated that if the trigger for mitigation of SSES consumptive use changed in the future, passby flows for BBNPP would be adjusted.

Passby flow releases for BBNPP would be triggered when the flow at the Wilkes-Barre gage is below the adjusted passby flow values plus 117 cfs, which is the combined consumptive use at SSES (74 cfs) and BBNPP (43 cfs).

The monthly P95 values (P90 for August) for the Wilkes-Barre gage data were calculated with the IHA code for the pre-dam period of 1899 to 1980 and the post-dam period of 1981 to 2013. These values also are listed in Table 2.2. A comparison between these P95 values, SRBC-designated passby flow values at the Wilkes-Barre gage, and the USACE (2013) preferred alternative P95-based values is shown in Figure 2.4. Two observations can be made. The P95/P90 values generally increased after dam construction, potentially reflecting the effect of the dams on reducing the occurrence of very low flows. For the period from May to October, the increase in P95/P90 values ranged from 1 percent (May) to 27 percent (October). For all months except May, the difference in P95/P90 values between the two periods was greater than the BBNPP maximum consumptive use (43 cfs). Likewise, differences between the IHA results and the SRBC/USACE values were generally on the order of the consumptive use (or larger). It is apparent that the calculated P95 values depend on the length of the record and the particular period of the record used in the analysis. As a result, the occurrence of mitigation releases also will depend on the particular period of record used to determine the triggering P95 values.

The SRBC passby flow values are not entirely consistent with the IHA-calculated P95/P90 values. This is due to the other factors considered by the SRBC in setting the passby flows (see discussion above). For May and June, SRBC passby flow values are less than the IHA-calculated P95/P90 values for the pre-dam and post-dam periods. Relative to use of the IHA values, this would reduce the occurrence of mitigation releases. In July, the SRBC passby flow value is greater than the IHA-calculated P95/P90 values. Relative to use of the IHA values, this would increase the occurrence of mitigation releases. For the period from August to October, the SRBC passby flow values are between the pre-dam and post-dam IHA-calculated values.

Passby flow requirements are complementary to consumptive use mitigation (SRBC 2012b), so that releases satisfying one would also satisfy the other. For the months of May to October, the SRBC passby flows at the Wilkes-Barre gage are equal to or greater than the 7Q10 and the USACE P95 flows. As a result, the passby flow requirements will trigger releases during these months prior to the triggering of consumptive use mitigation releases. Consumptive use mitigation requirements could trigger releases during November since the SRBC did not set a passby flow requirement for that month.

Table 2.2. SRBC Passby Flow Values for BBNPP and Some Comparative Values (cfs)

Month	SRBC Passby Flows at BBNPP	SRBC Passby Flows at Wilkes-Barre Gage[a]	Annual 7Q10 Flow at Wilkes-Barre Gage[b]	USACE (2013) P95 Flows[c] (1930-2007)	P95 Values Calculated by IHA Code (P90 for August)	
					1899-1980	1981-2013
January	0	0	826		2,170	3,342
February	0	0	826		2,600	3,980
March	0	0	826		4,748	5,605
April	0	0	826		8,854	6,886
May	1,750	1,700	826		4,162	4,182
June	1,750	1,700	826		2,170	2,341
July	1,750	1,700	826	970	1,220	1,397
August	1,200	1,100	826	970	1,090	1,270
September	890	860	826	860	828	997
October	1,010	980	826	970	936	1,187
November	0	0	826	970	1,350	1,840
December	0	0	826		1,700	3,300

[a] Releases triggered by passby flows plus 117 cfs, the combined consumptive use permitted at SSES (74 cfs) and applied for at BBNPP (43 cfs) (see Appendix A).
[b] Mitigation releases currently triggered by 7Q10 flow plus 72 cfs, the combined consumptive use at SSES and Montour (USACE 2013).
[c] Mitigation releases triggered by P95 flows plus 72 cfs, the combined consumptive use at SSES and Montour (USACE 2013). July and November values set equal to August and October values, respectively.

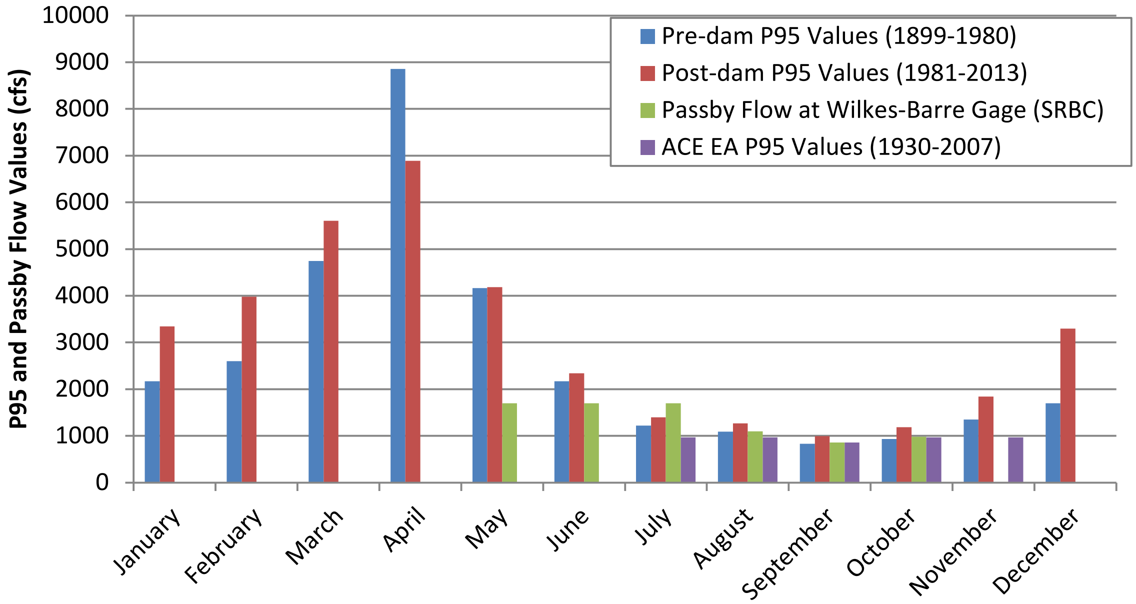


Figure 2.4. P95 values (P90 for August) Calculated for Two Periods using IHA, SRBC Passby Flow Values, and P95 Values Reported in the USACE Cowanesque Environmental Assessment

Using the Wilkes-Barre gage data, the number of days that consumptive-use mitigation or passby flow releases would be required was evaluated. The occurrence of release conditions was evaluated for release triggers based on the annual 7Q10 flow, the USACE monthly P95 flows for July to November, and the SRBC passby flows at the Wilkes-Barre gage for May to October plus the P95 flow for November. These three cases represent the historical triggers, the USACE's preferred alternative for current consumptive use mitigation releases from Cowanesque Lake, and the SRBC's requirements for the BBNPP. Releases were assumed to be required when the daily flow at the Wilkes-Barre gage was less than the triggering flow for that day plus the relevant consumptive use. For current policy and the preferred alternative from USACE (2013), the consumptive use is 72 cfs (identified in USACE [2013] as the combined use at SSES and Montour). For the case of BBNPP operation with SRBC passby flows triggering mitigation, the consumptive use is 117 cfs, which is the combined use of SSES (74 cfs) and BBNPP (43 cfs) as stated by the SRBC (see Appendix A). Consistent with USACE (2013), releases were assumed to stop when flow is greater than the triggering flow plus the relevant consumptive use for three consecutive days, or is more than twice the triggering flow plus the relevant consumptive use on any day.

Results shown in Figure 2.5 are the number of days each year that releases would be required under the three triggering cases described above. The figure illustrates that the number of release days increases as the triggering flow values increase. For the case with triggering flows based on the SRBC requirements for BBNPP, the number of release days is significantly larger than the USACE P95 case because the passby flows are larger than the P95 flows, there are passby flow requirements in May and June when consumptive use mitigation is not required, and the relevant consumptive use added to the passby flows is larger (117 cfs) than that added to the P95 flows for the USACE preferred alternative case (72 cfs).

Table 2.3 contains statistics for the pre-dam (1899-1980) and post-dam (1981-2013) periods for the case with triggering flows based on the SRBC requirements for BBNPP operation. There is a significant difference in the occurrence of releases during the two periods, a result that may be due to the presence of the dams. By reducing the occurrence of the lowest flows, the dams would reduce the number of years in which releases are required, and also reduce the average and maximum number of days requiring releases for those years when it is required.

With the SRBC requirements for BBNPP operation, consumptive use mitigation and/or passby flow releases occurred from June to November (i.e., no releases occurred in May). Figure 2.6 shows the average number of release days, by month, for those months in which releases occurred. During the pre-dam period (1899 to 1980), the average number of release days from July to November is relatively constant (i.e., between 14 and 16 days). During the post-dam period (1981 to 2013), the average number of release days is somewhat more variable, peaking in July at approximately 14 days. No consumptive use mitigation releases occurred in November during the post-dam period. Overall, the average number of mitigation days were fewer during the post-dam period in all months except in June.

The results presented to this point suggest a possible impact on river flows at the Wilkes-Barre gage from the construction of upstream dams. Because the evaluation of potential impacts from consumptive-use mitigation at BBNPP presented in this report is based on observed river discharges (and not on modeling such as that carried out for USACE [2013]), that evaluation will be completed using observations from the post-dam period. However, because conditions were generally wetter during the post-dam period (see Figure 2.2), the entire period of record was also used in certain portions of the evaluation for comparison.

Figure 2.5 shows that, in the post-dam period (1981 to 2013), the occurrence of releases for consumptive-use mitigation or passby flows depends strongly on the flows used to trigger the releases. Additional characterization of the occurrence of releases for the post-dam period is shown in Figure 2.7. While the move from 7Q10 flows to P95 flows results in an increase in the number of years with releases and in the total number of release days, both the number of years in which releases occur and the total number of days with releases are significantly larger for the case of BBNPP operation with SRBC passby flows triggering releases. The SRBC passby flows are the only trigger values that result in the releases in June and July, and July is the month with the largest number of days of releases. The bottom chart in Figure 2.7 shows that, for months when releases do occur, the average number of days of releases is fairly similar for the three types of triggering values.

The differences seen in Figure 2.5 and Figure 2.7 are due not only to the values of the flows triggering mitigation, but also to the differences in consumptive-use values because mitigation occurs when the flow falls below the trigger value plus the consumptive use (see discussion above for Table 2.2 and its footnotes). SRBC passby flows are nearly the same as the USACE P95 flows in September and October. For these two months, differences in the occurrence of releases for these two cases result from the difference in consumptive use in determining when releases are required. During July and August, however, differences in the occurrence of releases is primarily because the SRBC passby flows are larger than the USACE P95 flow values (see Table 2.2).

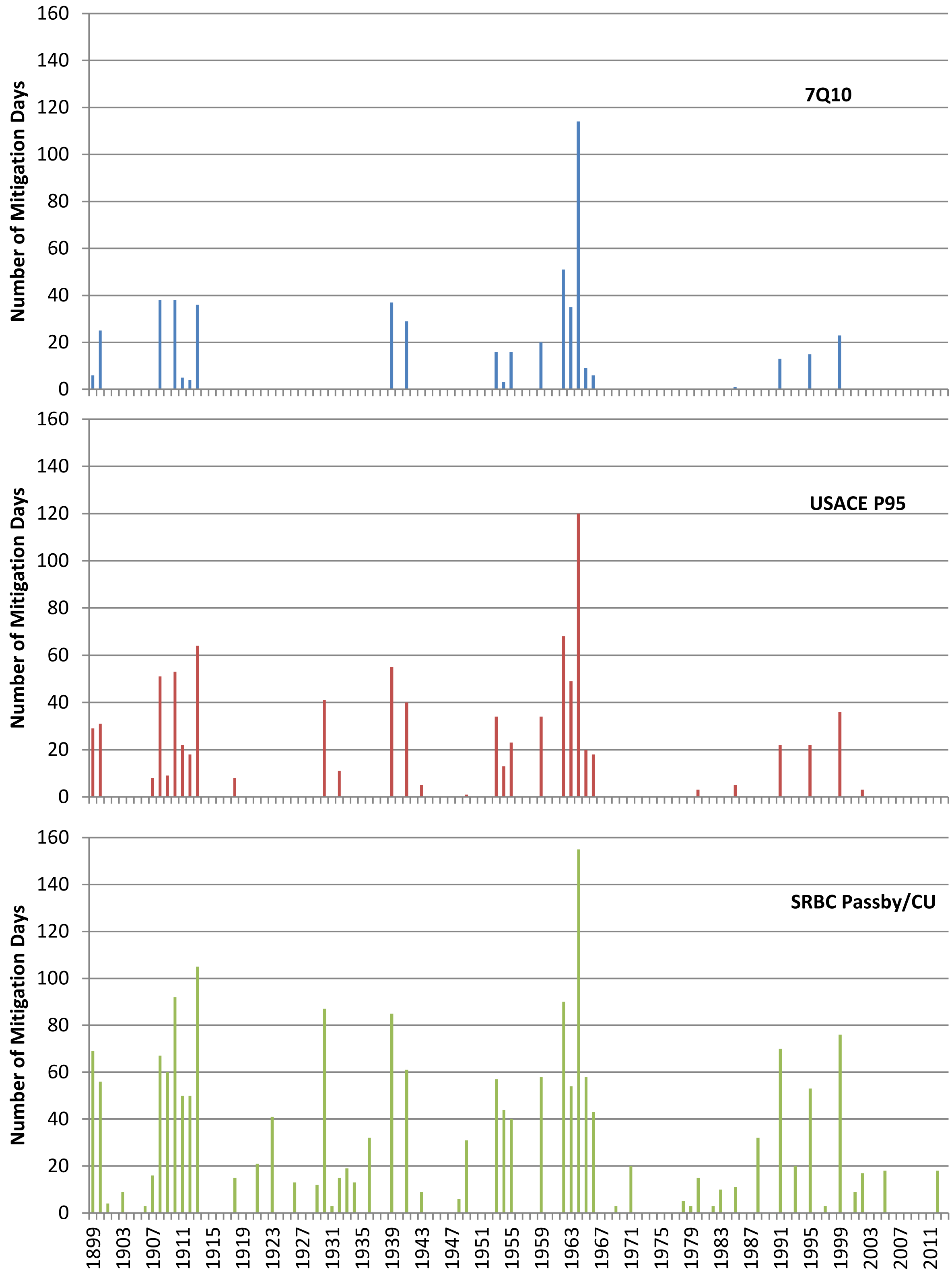


Figure 2.5. Number of Days Releases Would Be Required by Year for the (top) Current Policy, (middle) Preferred Alternative from USACE (2013), and (bottom) BBNPP Operation with SRBC Passby Flow and Consumptive Use Mitigation Requirements.

Table 2.3. Comparison of Pre-Dam and Post-Dam Occurrence of Conditions at the Wilkes-Barre Gage Requiring Releases with Triggering Flows Based on the SRBC Requirements for BBNPP

		1899-1980	1981-2013
Percent Years Releases Required		51%	42%
For Years in which Releases are Required	Average Number of Release Days	40	25
	Maximum Number of Release Days	155	76

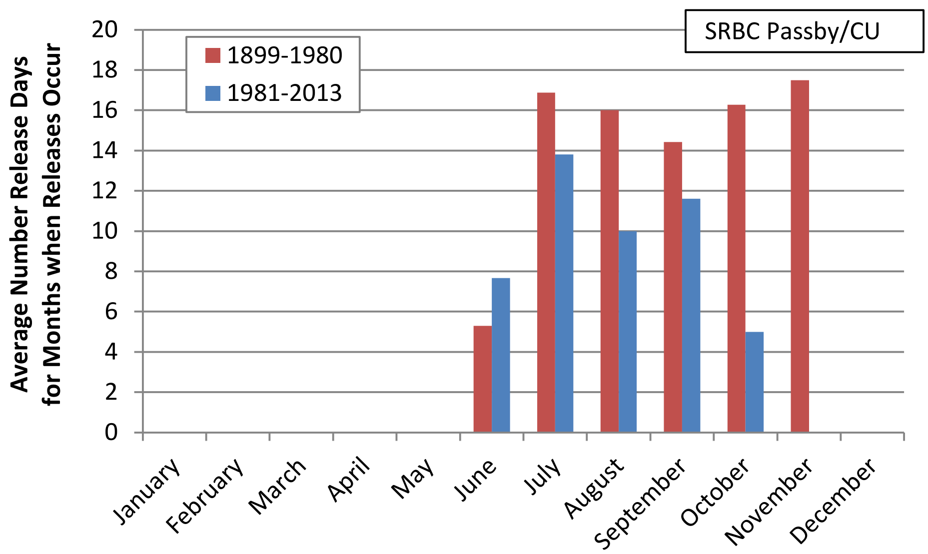


Figure 2.6. Average Number of Release Days for Months in which Conditions Triggering Releases Occurred

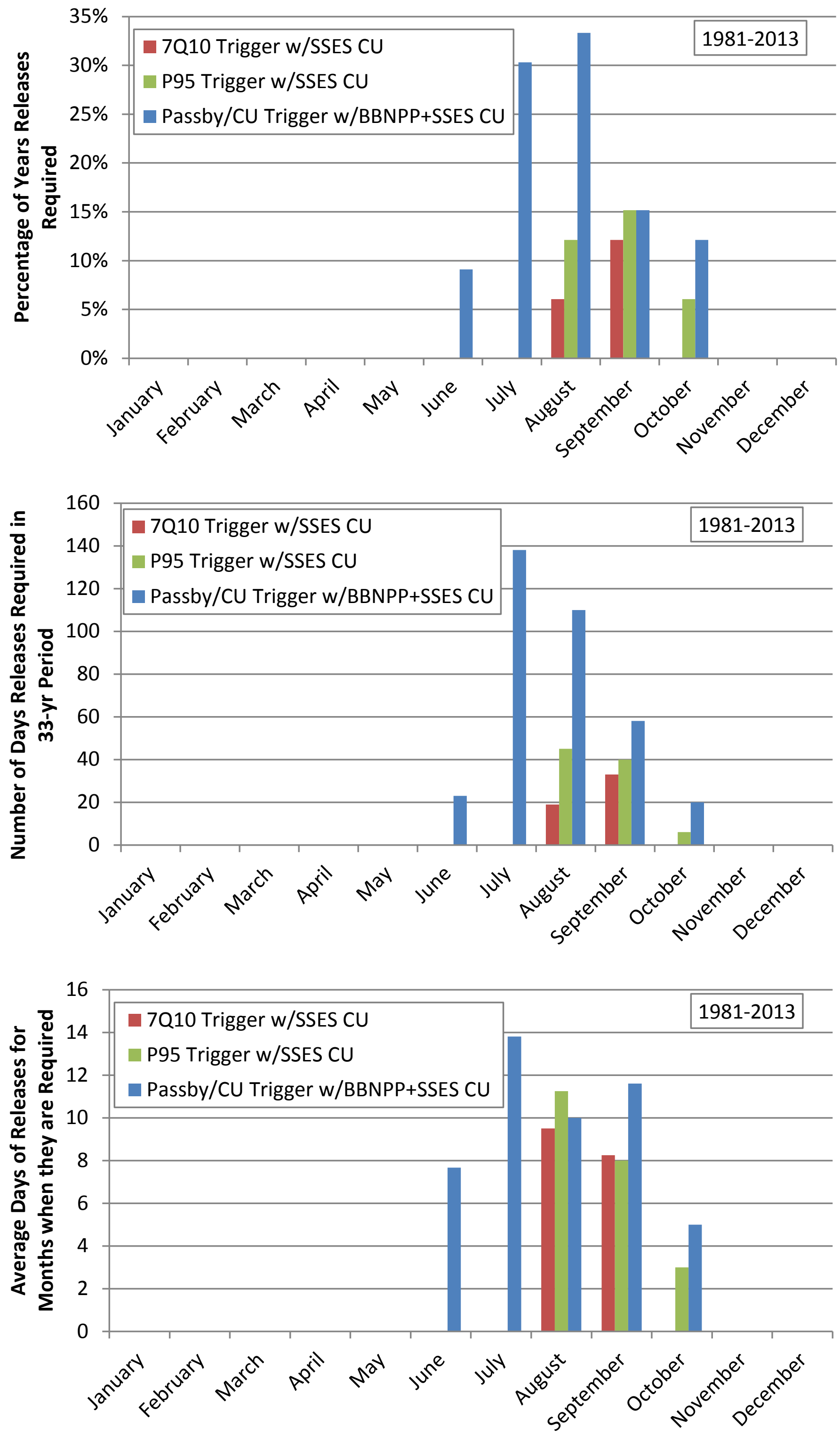
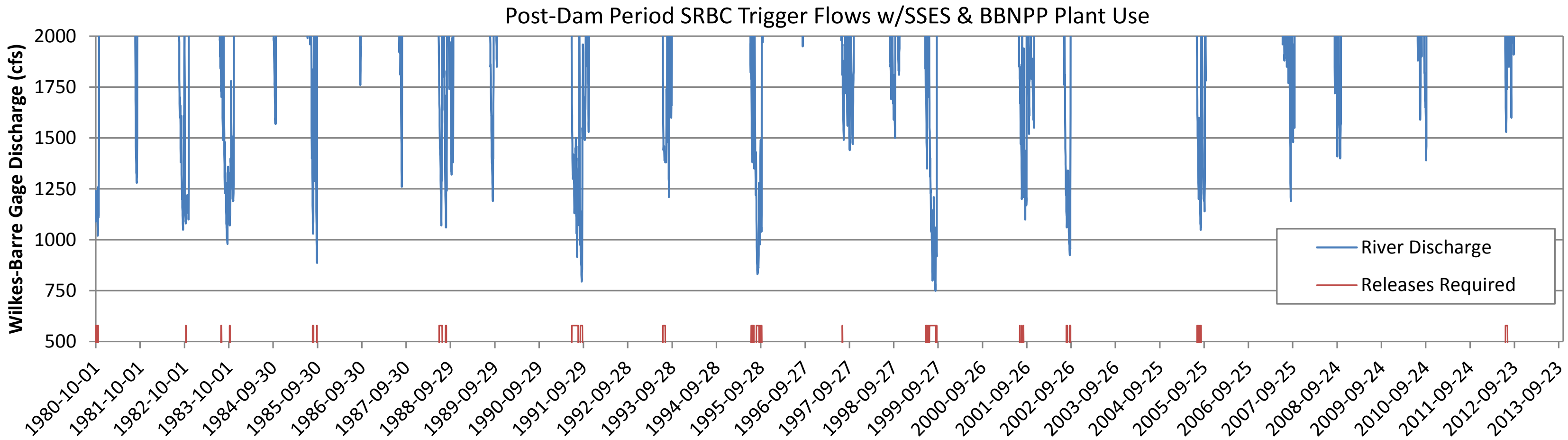


Figure 2.7. Occurrence of Consumptive-Use Mitigation and Passby Flow Releases in the Post-Dam Period for Three Different Triggering Flows: (Top) Number of Years in Which Releases Occurred, (Middle) Total Number of Days with Releases, and (Bottom) Average Number of Release Days for Months When Releases Occurred

Figure 2.8 shows the occurrence of conditions requiring consumptive-use mitigation or passby flow releases for the post-dam period (1981 to 2013) with the SRBC passby flow values plus SSES and BBNPP consumptive use as the release triggers. As noted in Table 2.3, releases occurred in 42 percent of the years (14 out of 33 years). Figure 2.8 also shows detail during the period from May to October 1999, illustrating the occurrence of conditions requiring releases during a year in which those conditions were relatively frequent. The overall period requiring releases in 1999 was approximately 13 weeks, with the longest continuous period of releases being approximately 7.5 weeks.



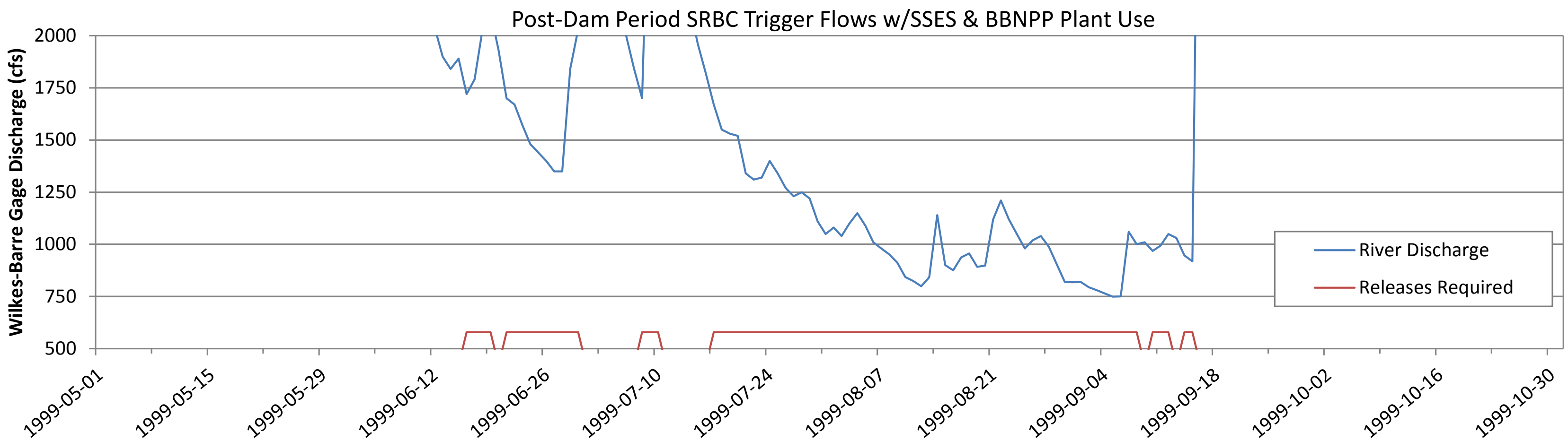


Figure 2.8. Daily Discharge at the Wilkes-Barre Gage and the Occurrence of Conditions Requiring Consumptive-Use Mitigation or Passby Flow Releases with SRBC Triggering Values for BBNPP: (Top) Post-dam Period (1981 to 2013), (Bottom) Detail from 1999

3.0 Indicators of Hydrologic Alteration at the Wilkes-Barre Gage

Hydrologic alteration indicators for the pre-dam (1899 to 1980) and post-dam (1981 to 2013) periods were computed using the IHA code. For this analysis, the Wilkes-Barre gage discharge data were used without consideration of consumptive use or its mitigation. These results provide a reference of alterations that have already occurred in the watershed. These reference values are subsequently compared to the same alteration indicators evaluated prior to and after consumptive use of NBSR water by BBNPP. For that analysis, the pre-alteration conditions were represented by the existing discharge record for the post-dam period. The altered conditions were represented by subtracting BBNPP consumptive use (43 cfs) from the existing discharge record, with no mitigation releases stemming from this use. This approach will maximize the effect of BBNPP consumptive use on the alteration indicators.

Indicators of alteration between two sets of data were computed with IHA using a nonparametric analysis with the Range of Variability Approach (RVA) categories at 0 to 33 percent (Low), 34 to 67 percent (Middle), and 68 to 100 percent (High). RVA measures of the alteration indicators were computed by the IHA code as

$$(\%\text{values in category} - \%\text{values expected in category})/\%\text{values expected in category}$$

with the percent expected based on the pre-dam (1899 to 1980) data when evaluating alterations in the post-dam period. (In a subsequent discussion evaluating alterations due to BBNPP operation, the percent expected was based on the gage data without the BBNPP consumptive use.)

3.1 Hydrologic Alteration Resulting from Dam Construction

Indicator values for alterations in flow from the pre-dam period to the post-dam period are shown in Figure 3.1. An alteration of 0.5 represents a 50 percent increase in the hydrologic indicator (e.g., for the 1981 to 2013 November median flows, 50 percent more values fell in the high category than would have been expected based on the 1899 to 1980 data). Figure 3.1 suggests a significant impact on all characteristics of flow at the Wilkes-Barre gage between the two periods. A few of these characteristics are highlighted in Figure 3.2 to Figure 3.12, and are briefly discussed below. Consistent with the discussion above, the presence of the dams may be only partially responsible for the observed alterations; generally wetter conditions during the post-dam period will affect some of the alteration measures.

Flow alterations during the post-dam period resulted in higher median flows in 7 months, particularly during October, November, and December (Figure 3.2), and lower median flows in the high-flow months of March and April (Figure 3.3). The low-flow month of August (Figure 3.4) had median flows shifted to higher values with small changes to the prevalence of lower median flows (the median and the 25th percentile of the median flow was unchanged). Seven-day minimum flows shifted upward (Figure 3.5), while 3-day maximum flows were little affected (Figure 3.6). Characteristics of extreme low flows (defined as flows that are initially lower than the 10th percentile of all daily flows for the period) were evaluated as these are of particular concern. The peak (Figure 3.7), duration (Figure 3.8), and timing (Figure 3.9) of the extreme low flows were little changed. The frequency of extreme low flows (Figure 3.10) was noticeably reduced in the post-dam period. For the months when passby flow requirements would be applicable (May to October), the monthly flow-duration curves were relatively unchanged in the post-dam period (e.g., August [Figure 3.11], with the greatest alteration during these months occurring in October [Figure 3.12]). In general, alterations to the flow-duration curves consisted of increases in the exceedance probabilities of flows, particularly the low flows, consistent with the presence of the dams reducing the occurrence of low flows.

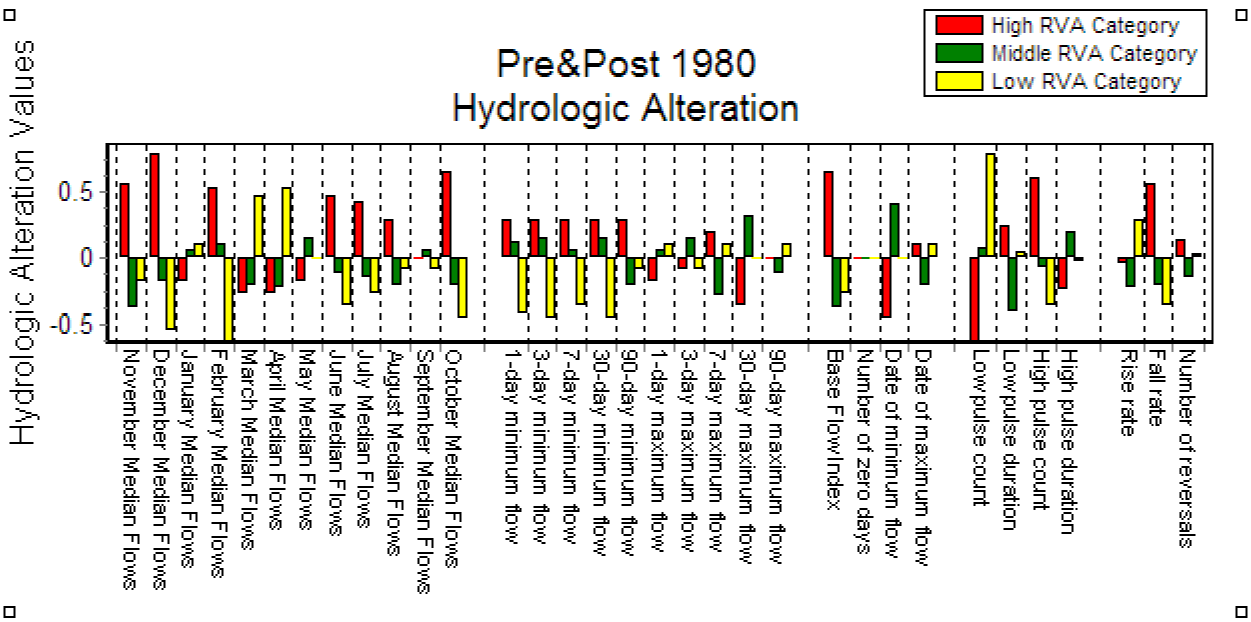


Figure 3.1. Hydrologic Alteration Measures at the Wilkes-Barre Gage Computed by the IHA Code for Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

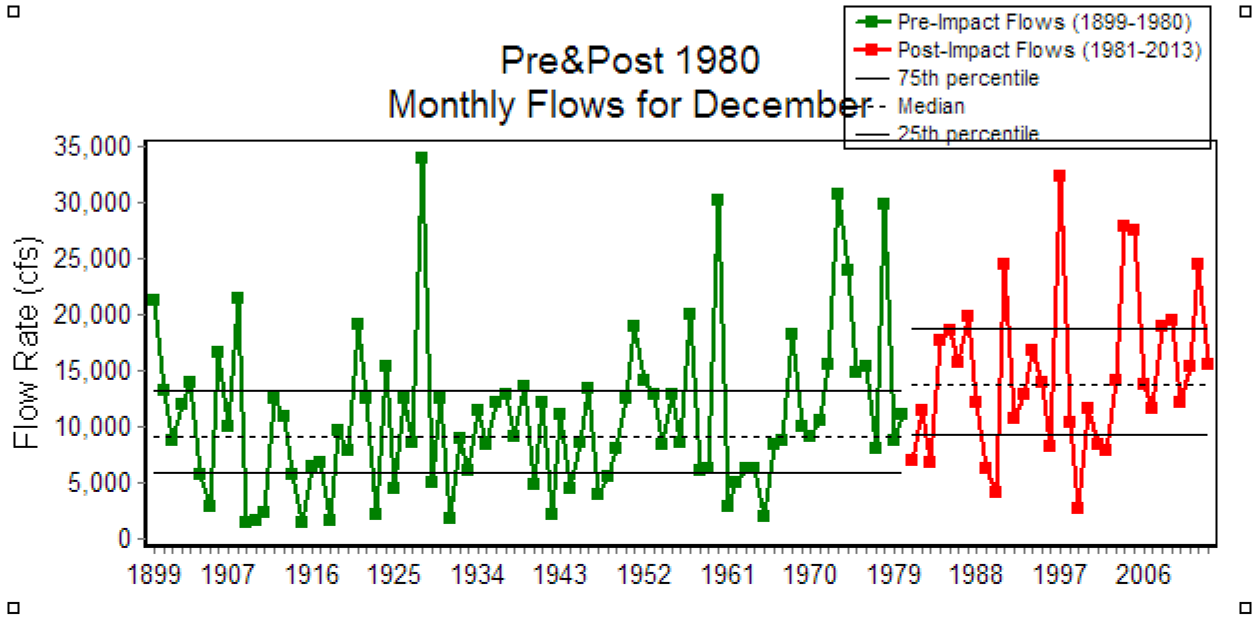


Figure 3.2. Monthly Flow in December at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

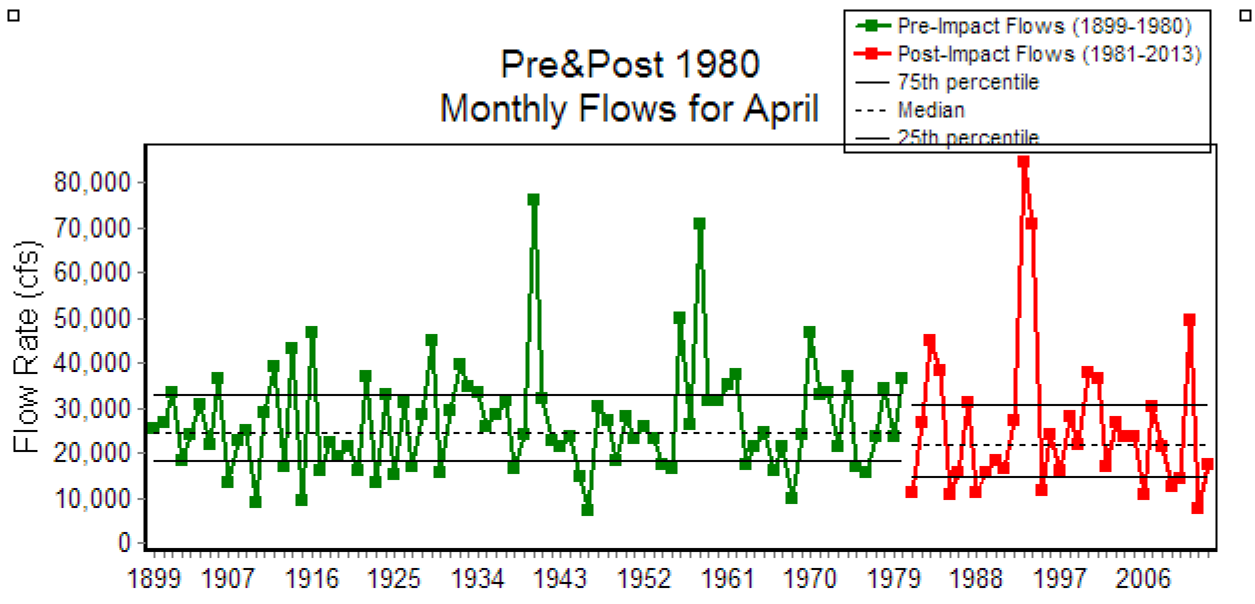


Figure 3.3. Monthly Flow in April at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

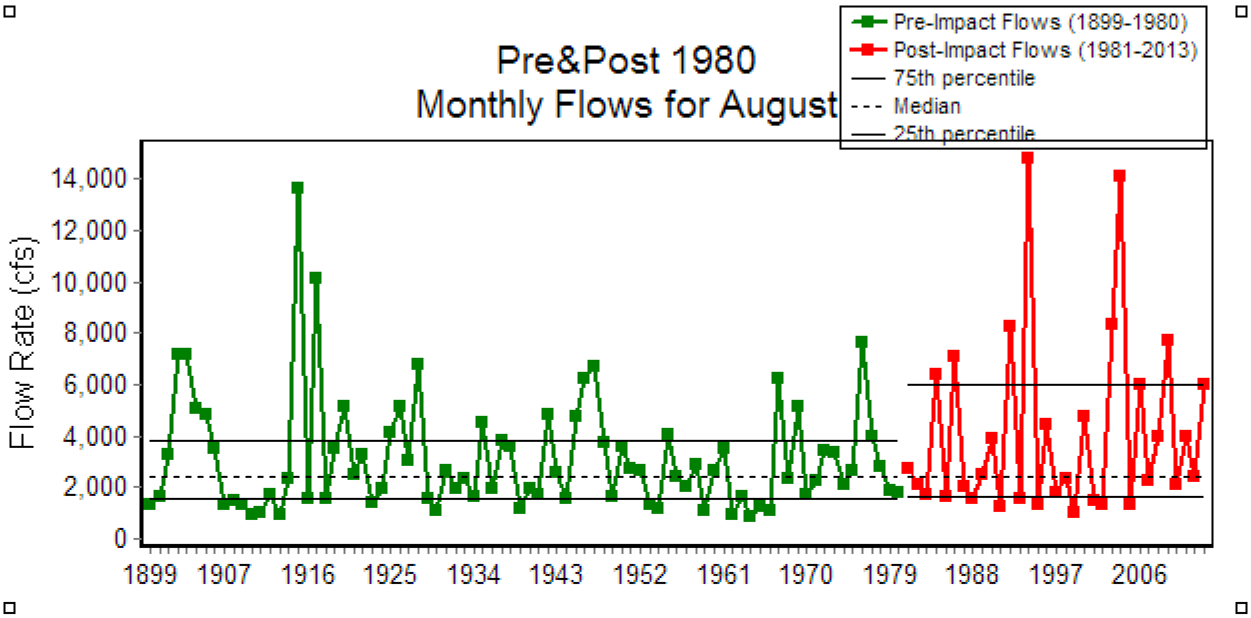


Figure 3.4. Monthly Flow in August at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013).

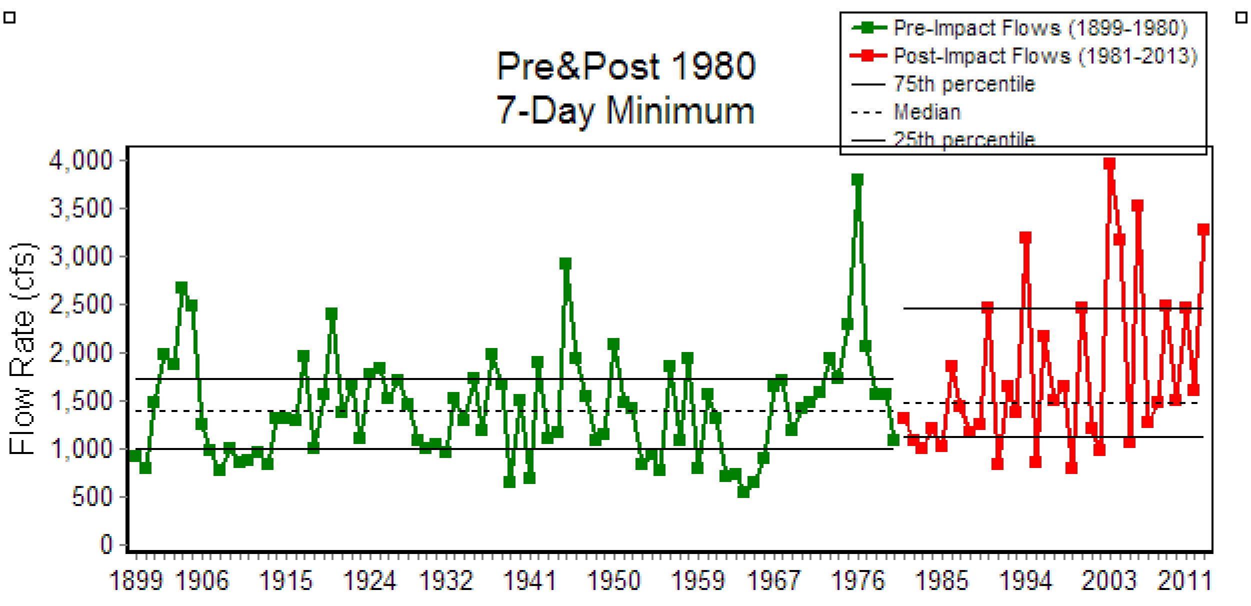


Figure 3.5. Seven-Day Minimum Flow at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

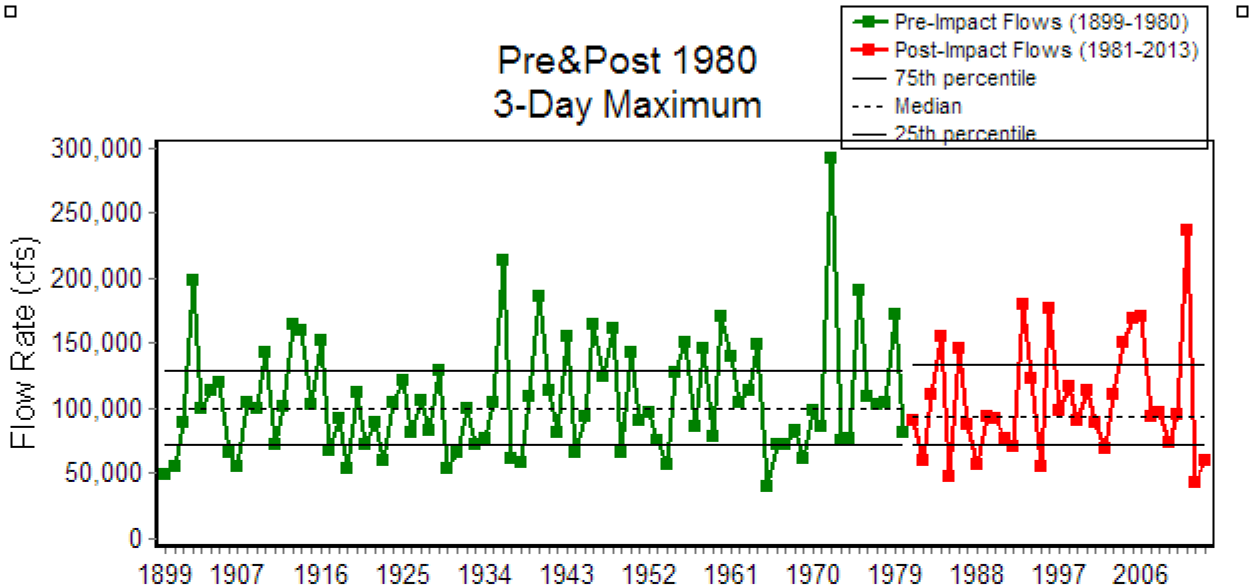


Figure 3.6. Three-Day Maximum Flow at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

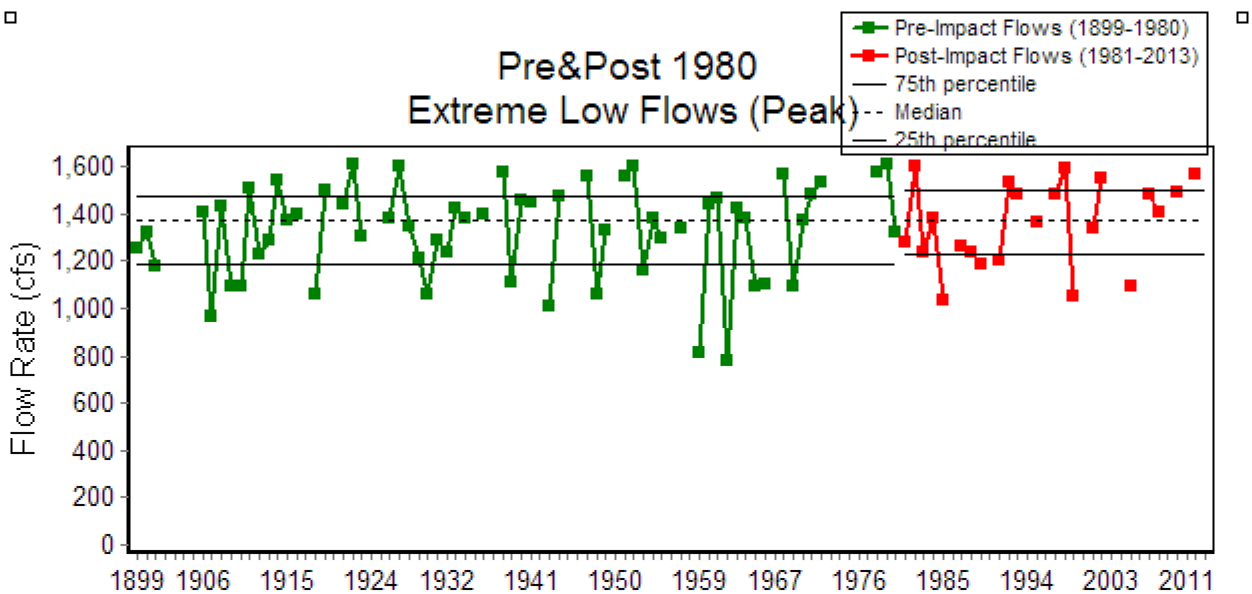


Figure 3.7. Peak of Extreme Low Flows at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

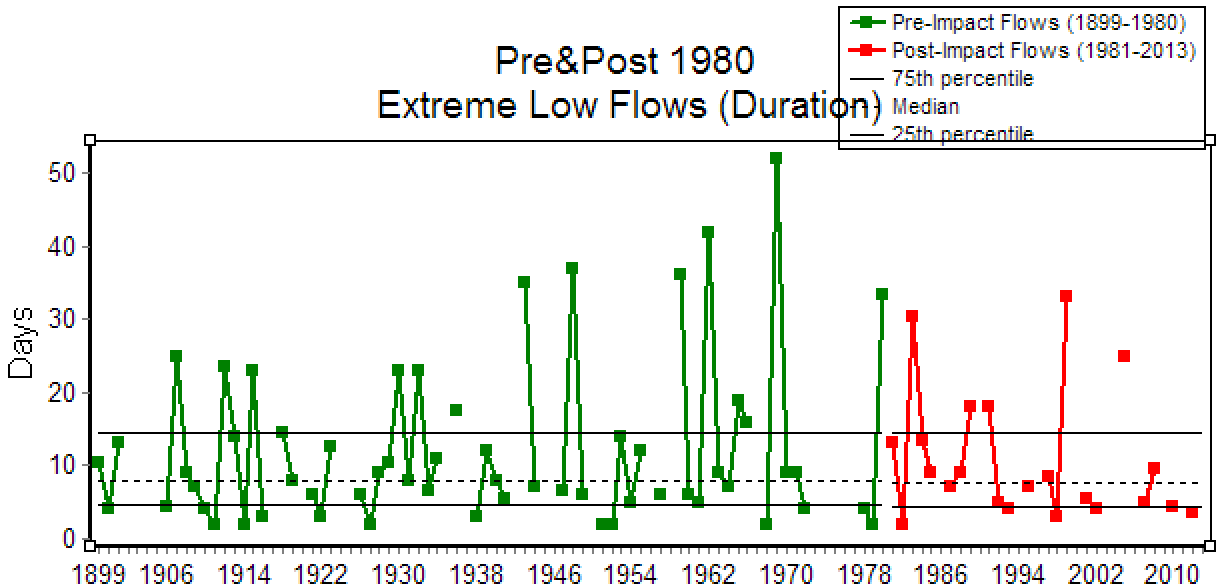


Figure 3.8. Duration of Extreme Low Flows at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

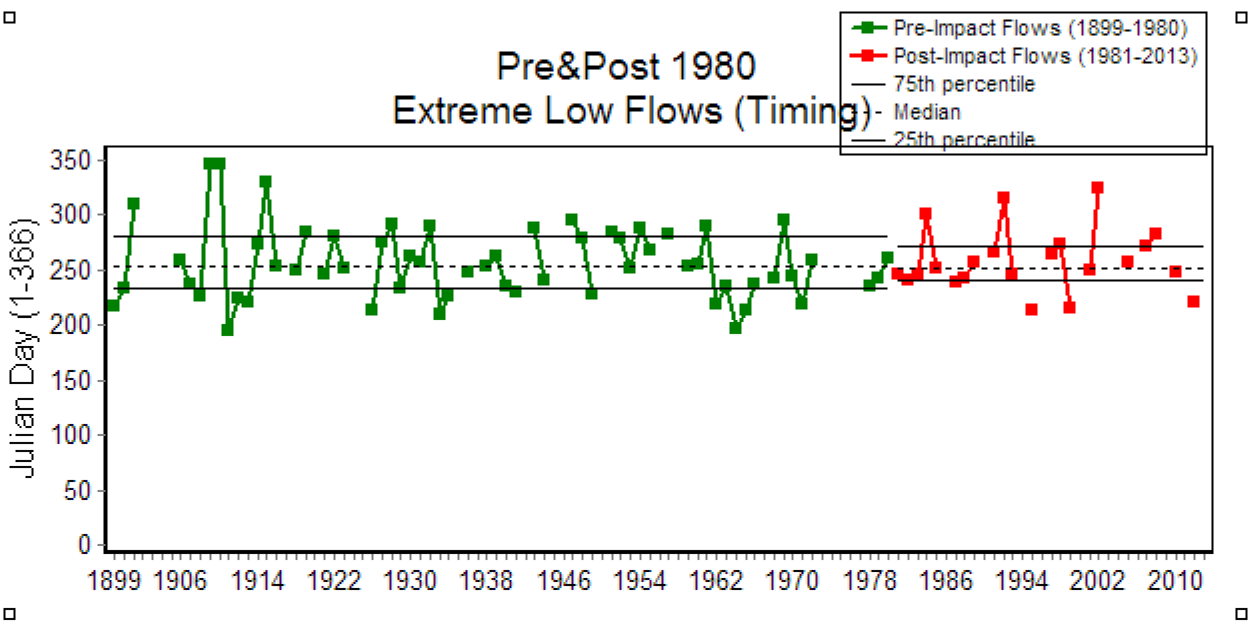


Figure 3.9. Timing (day of year) of Extreme Low Flows at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

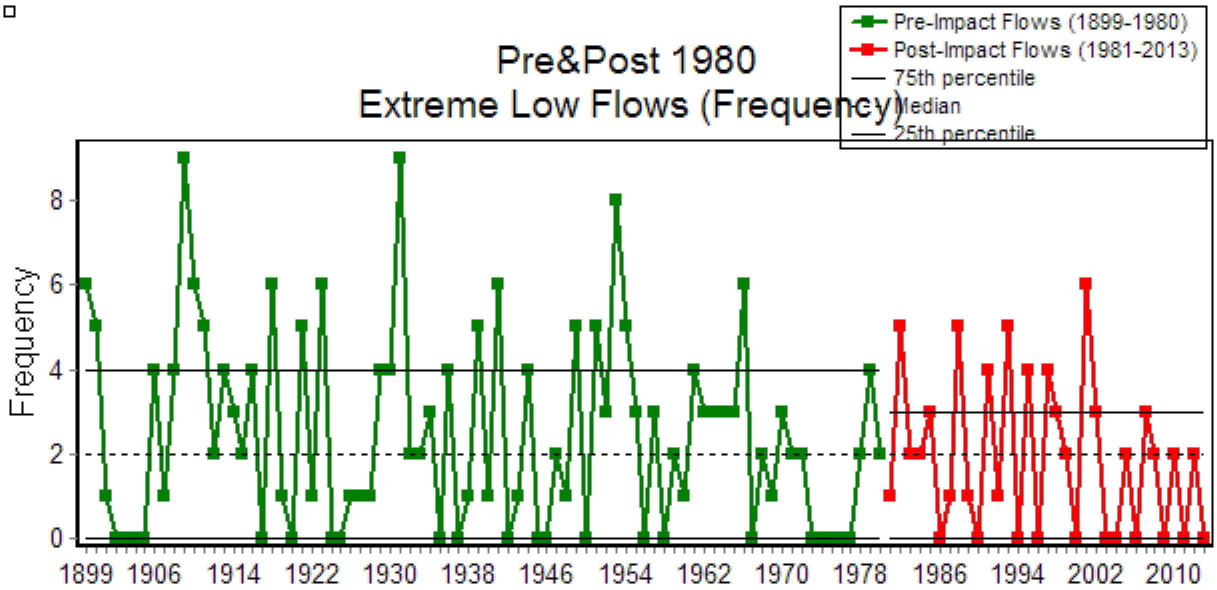


Figure 3.10. Frequency of Extreme Low Flows at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

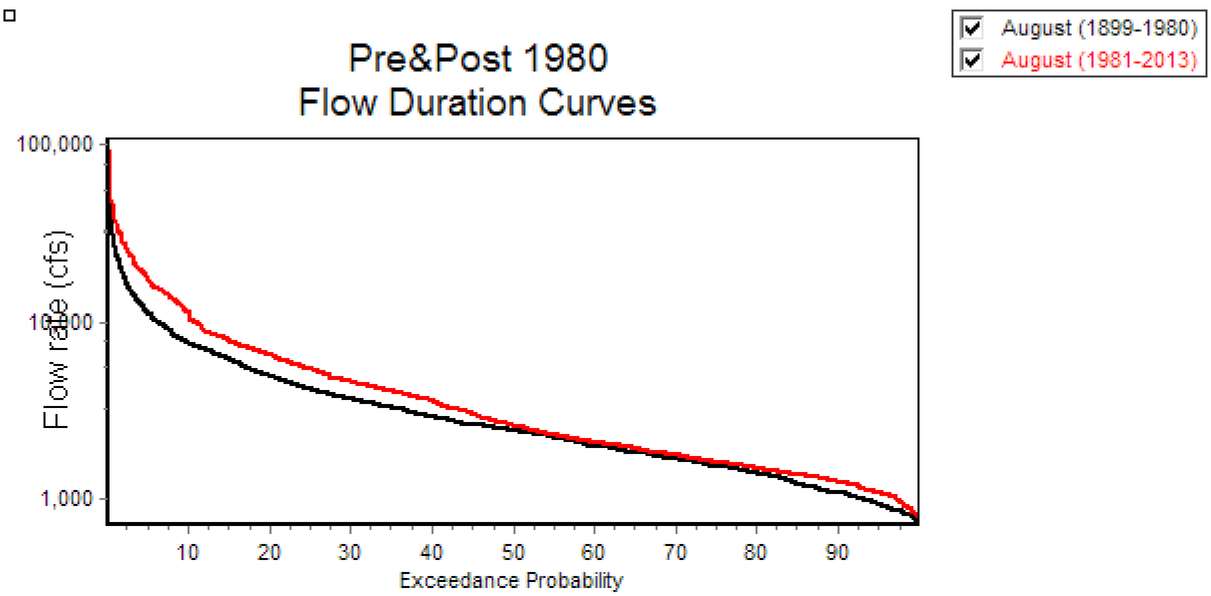


Figure 3.11. August Flow-Duration Curve at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows From the Pre-Dam Period (1899 to 1980) to the Post-Dam Period (1981 to 2013)

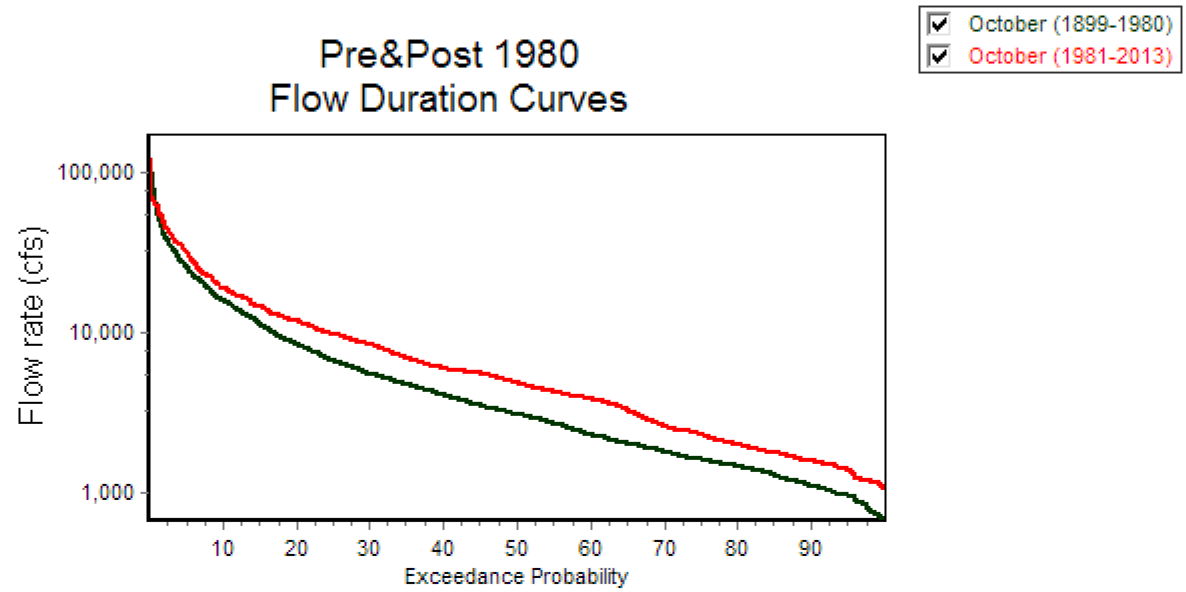


Figure 3.12. October Flow-Duration Curve at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows From the Pre-Dam period (1899 to 1980) to the Post-Dam period (1981 to 2013)

3.2 Hydrologic Alteration Resulting from BBNPP Consumptive Use

The IHA code also was used to evaluate changes to the hydrologic indicators that would result from the consumptive use, without mitigation, of 43 cfs by the BBNPP. The discharge data for the period 1981 to 2013 were used in this analysis. Figure 3.13 shows the minimal impact the BBNPP consumptive water use is projected to have on the indicators at the Wilkes-Barre gage (compare to Figure 3.1). Even for the only significant alterations (to the 1- and 3-day minimum flows), differences in the flows are essentially indiscernible (e.g., Figure 3.14).

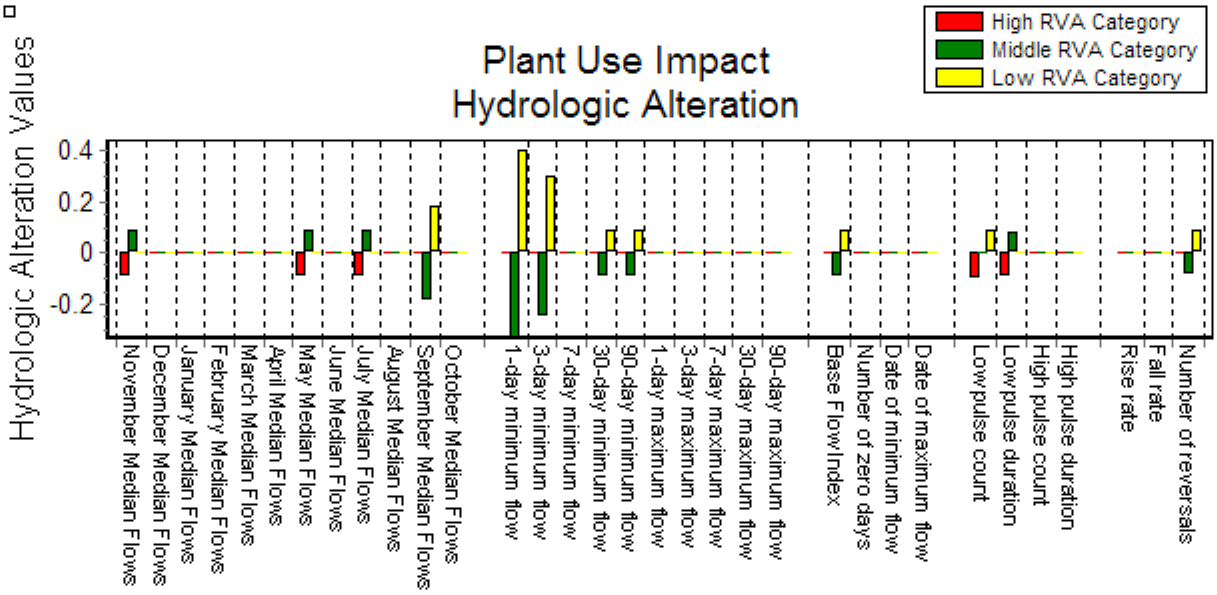


Figure 3.13. Hydrologic Alteration Measures at the Wilkes-Barre Gage Computed by the IHA Code for Changes Occurring in Flows from BBNPP Consumptive Use with No Mitigation, Post-Dam Period (1981 to 2013)

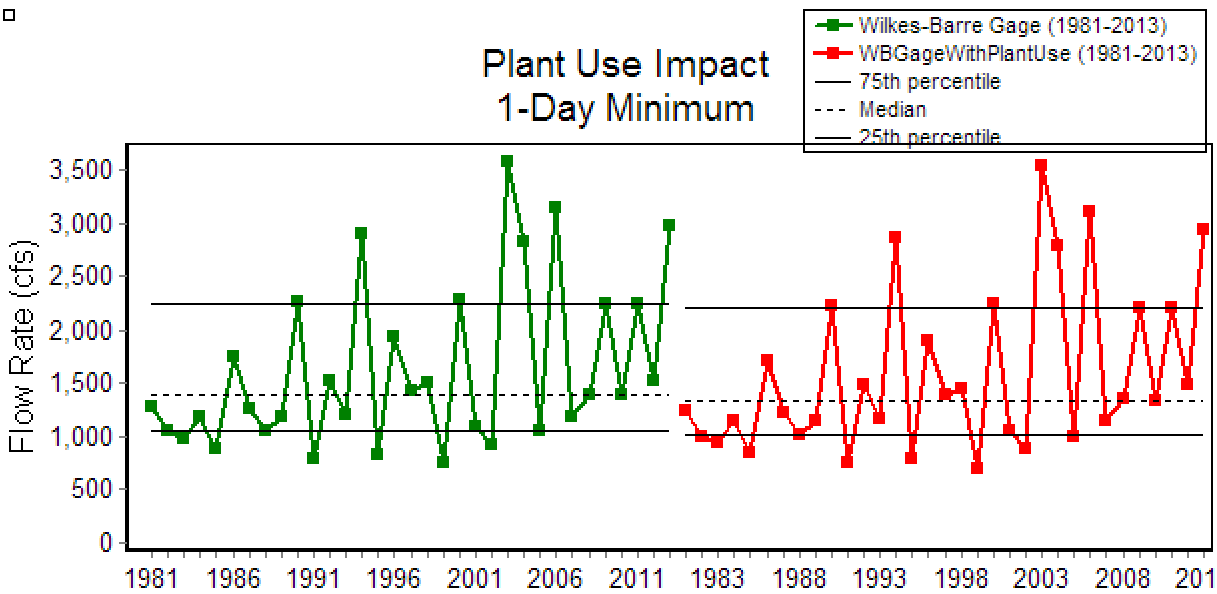


Figure 3.14. One-Day Minimum Flow at the Wilkes-Barre Gage Computed by the IHA Code Showing Changes Occurring in Flows from BBNPP Consumptive Use with No Mitigation, Post-Dam Period (1981 to 2013)

4.0 Indicators of Hydrologic Alterations on Cowanesque Lake and River

Potential impacts from releases of water for mitigation of BBNPP consumptive use are likely to be greatest near the source of those releases. The primary plan for BBNPP mitigation involves releases from Cowanesque Lake into the Cowanesque River below the dam. This section evaluates hydrologic alterations to these water bodies.

4.1 Hydrologic Alterations on Cowanesque River

A flow analysis based on data from the USGS Cowanesque gage (01520000 Cowanesque River near Lawrenceville, Pennsylvania) was completed to evaluate the impact of BBNPP consumptive-use mitigation and passby flow releases on the Cowanesque River below the dam. Daily discharge and the median monthly discharge at the gage are shown in Figure 4.1. Cowanesque Lake began filling in December 1979. For the purposes of this analysis, the post-impact (post-dam) period is from October 1, 1980, to September 1, 2013 (Water Years [WY] 1981 to 2013, 33 years). The dam reduced peak flows significantly and increased median flows over much of the year, including the summer months. A minimum flow of 15 cfs is currently targeted for releases from the dam (USACE 2013).

Hydrologic alteration indicators for the WY period 1981 to 2013 were computed using IHA with a nonparametric analysis with RVA categories at 0 to 33 percent (Low), 34 to 67 percent (Middle), and 68 to 100 percent (High), as was done above. To provide a reference for changes in flows, the indicators were evaluated for alterations resulting from the operation of the dam. This evaluation compared flows in the pre-dam period (WY 1952 to 1980) with flows in the post-dam period (WY 1981 to 2013). Consumptive-use mitigation and passby flow releases for BBNPP were not included, but the post-dam flows include mitigation releases for SSES that occurred in 1991 and 1995. Alteration indicator results are shown in Figure 4.2. An alteration of 1.0 represents a 100 percent increase in the hydrologic indicator (e.g., for the May median flows, the number of post-dam flows in the Low category doubled [compared to what would have been expected based on the WY 1952 to 1980 data]). An alteration of −1.0 indicates the absence of observed values in the RVA category. For example, for August and September median flows, there were no post-dam flows observed in the Low category. Figure 4.2 indicates that the dam has had a significant impact on all characteristics of flow at the Cowanesque gage. A few of these flow characteristics are highlighted in the subsequent figures: monthly median flows for May and August in Figure 4.3 and Figure 4.4, 3-day minimum and 1-day maximum flows in Figure 4.5 and Figure 4.6, and September flow-duration curves in Figure 4.7. These figures illustrate the main effect of the dam in reducing the occurrence of the largest and smallest flows.

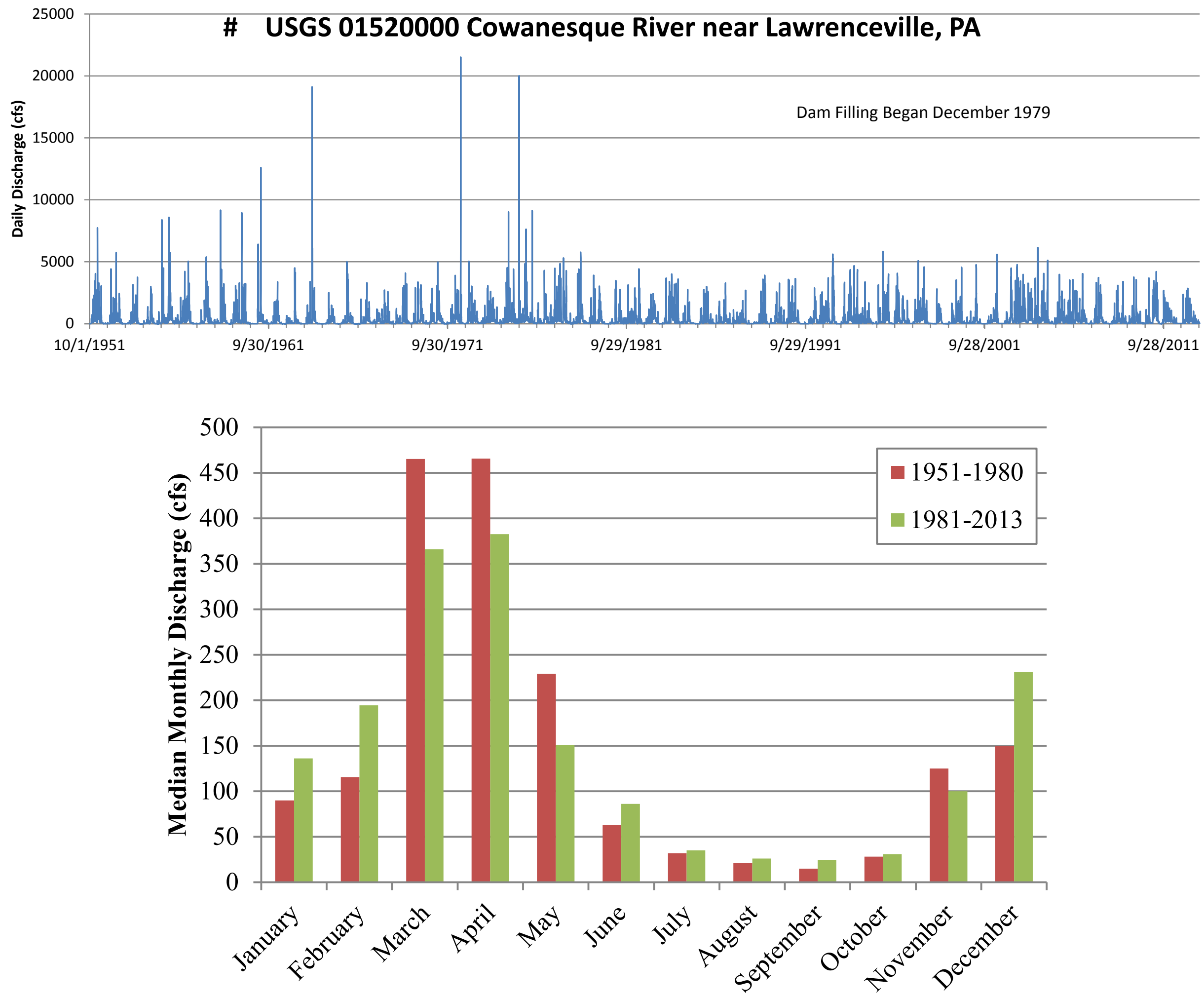


Figure 4.1. Daily Discharge (top) Below Cowanesque Dam for the Period of Record, and Median Monthly Discharge (bottom) for the Pre-Dam Period (1951 to 1980) and Post-Dam Period (1981 to 2013) (USGS 2014)

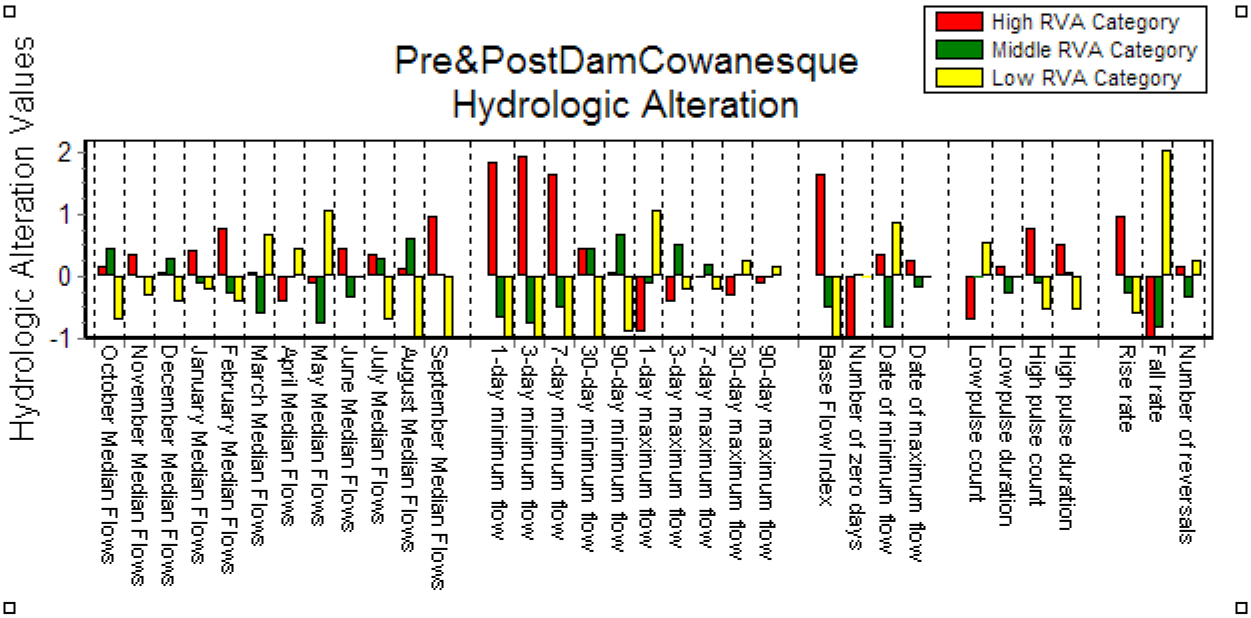


Figure 4.2. Hydrologic Alteration Measures at the Cowanesque Gage Computed by the IHA Code for Changes Occurring in Flows from the Pre-Dam Period (1952 to 1980) and Post-Dam Period (1981 to 2013)

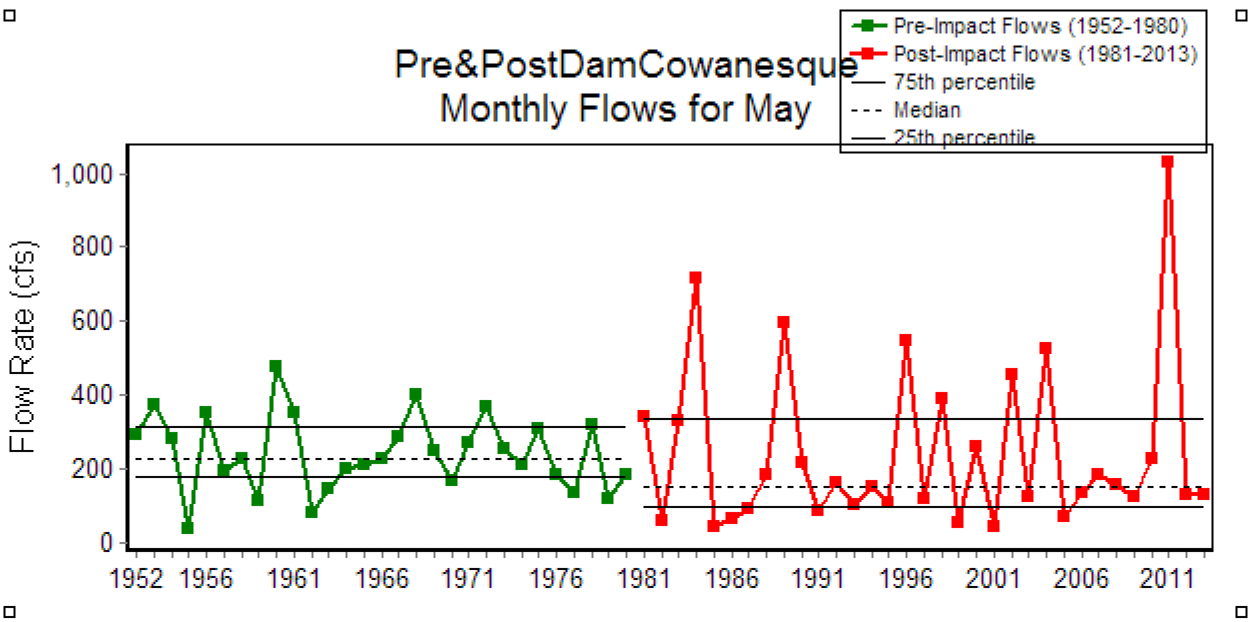


Figure 4.3. Median Monthly Flow in May at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1952 to 1980) to the Post-Dam Period (1981 to 2013)

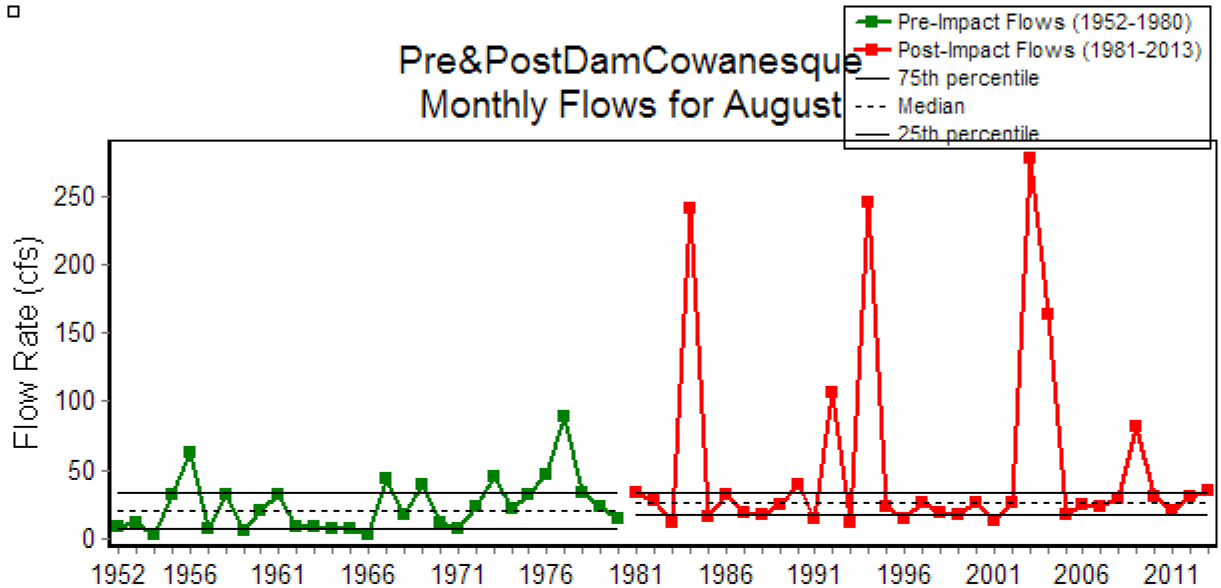


Figure 4.4. Median Monthly Flow in August at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1952 to 1980) to the Post-Dam Period (1981 to 2013)

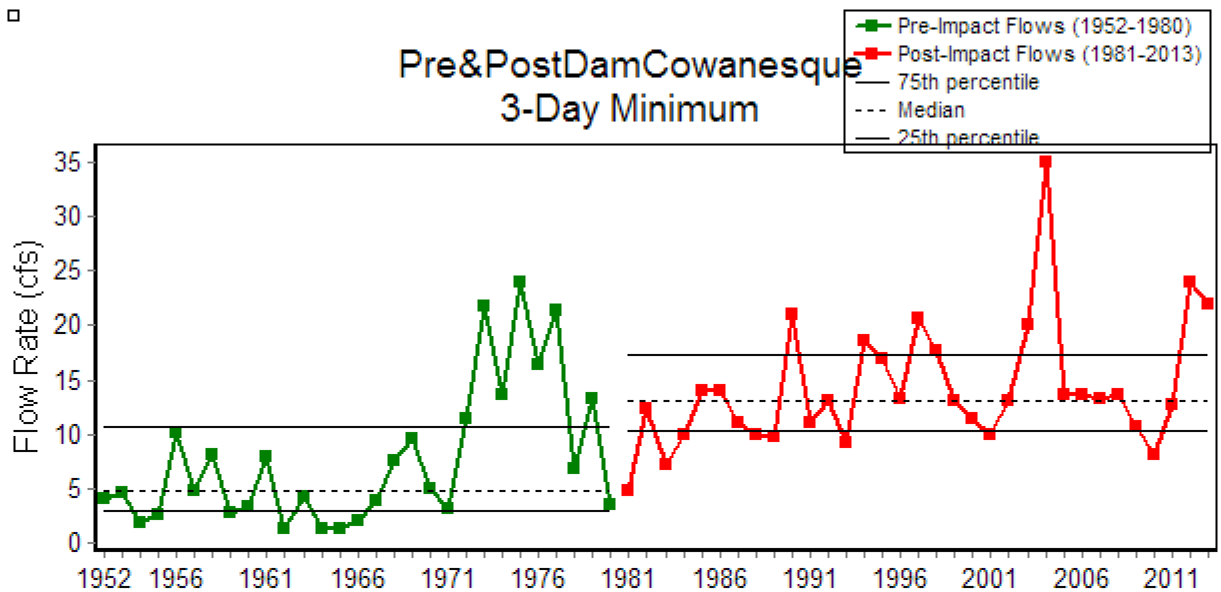


Figure 4.5. Three-Day Minimum Flow at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1952 to 1980) to the Post-Dam Period (1981 to 2013)

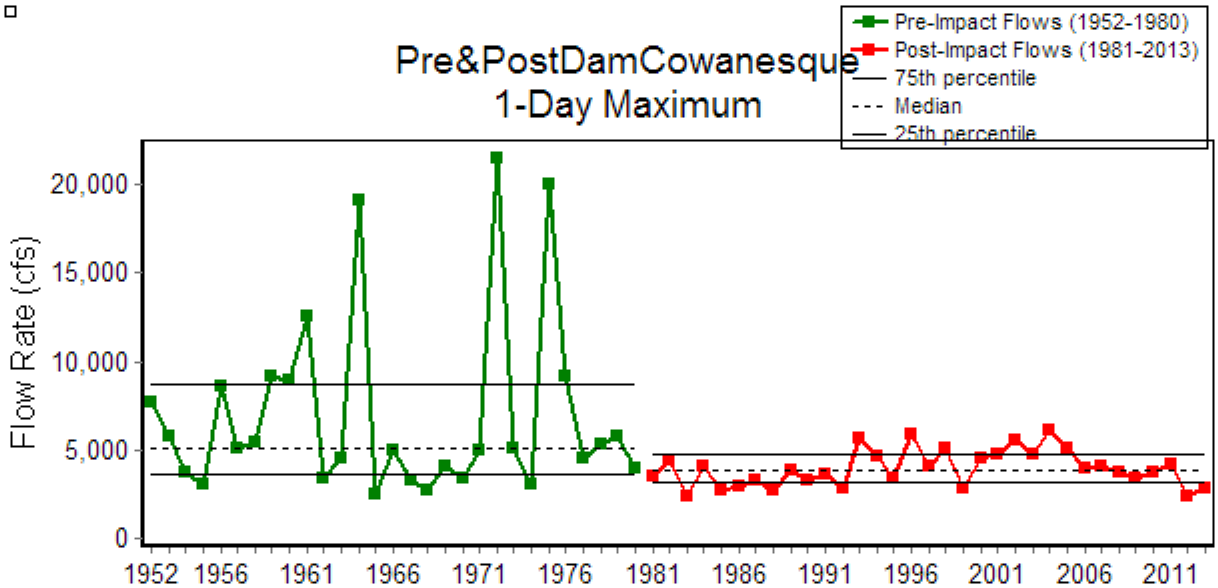


Figure 4.6. One-Day Maximum Flow at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1952 to 1980) to the Post-Dam Period (1981 to 2013)

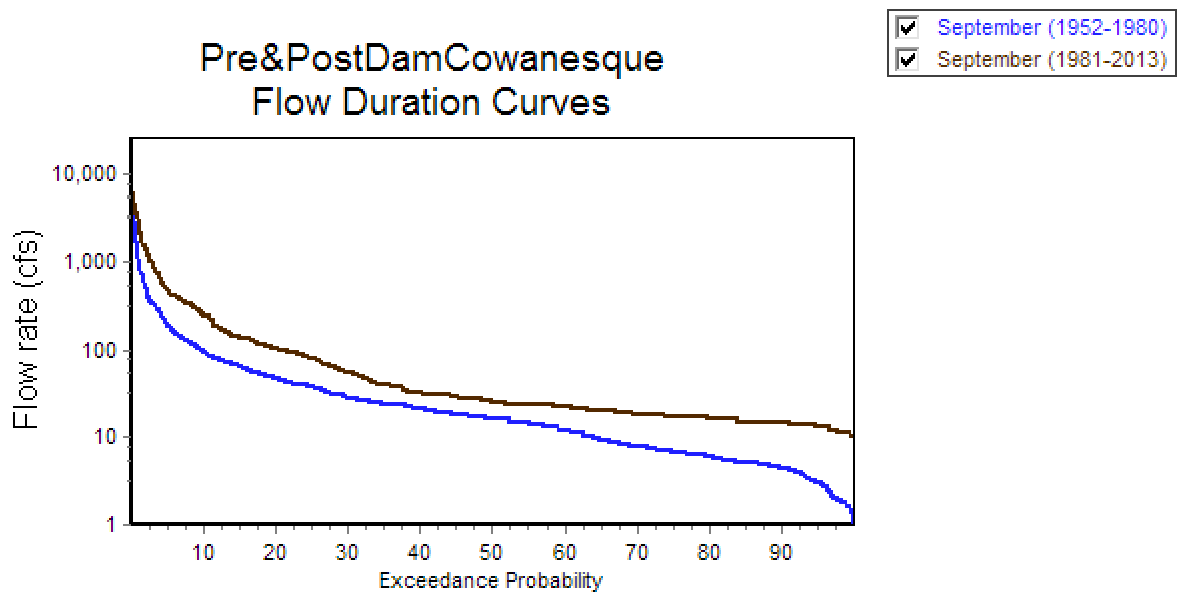


Figure 4.7. September Flow-Duration Curve at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows from the Pre-Dam Period (1952 to 1980) to the Post-Dam Period (1981 to 2013)

Because the dam has had a large effect on Cowanesque River flows, the impact of BBNPP mitigation releases was evaluated in the post-dam period. The IHA code was used to evaluate changes to the hydrologic indicators if the post-dam flows were altered by release of 43 cfs from Cowanesque Lake, with those releases triggered based on the SRBC-specified consumptive use mitigation and passby flow requirements at the Wilkes-Barre gage. Because the trigger for consumptive use mitigation releases will change from 7Q10 to P95 flows prior to construction of BBNPP, the baseline flows at the gage in the post-dam period were adjusted to reflect the dam operations described in USACE (2013). That is, the baseline flow in the post-dam period was the measured discharge at the Cowanesque gage, but increased by 72 cfs on days when consumptive-use mitigation for SSES and Montour would be triggered by low flows at the Wilkes-Barre gage as described by USACE for the preferred alternative (USACE 2013). Consumptive use mitigation releases from Cowanesque Lake for TMI were not considered in this analysis. The altered flows were set as the measured discharge at the Cowanesque gage, but increased by 117 cfs (the combined consumptive use at SSES, Montour, and BBNPP) when consumptive-use mitigation or passby flow releases would be triggered by the proposed SRBC requirements (see Table 2.2 and Appendix A). This approach likely overestimates the flow alteration for several reasons. Actual releases would be less than 117 cfs if the mitigation for the Montour plant is shifted to the Rushton Mine as proposed by PPL. In addition, SRBC would likely maintain separate triggering flows for SSES (i.e., the P95 flow values of the USACE preferred alternative) and BBNPP. Finally, the BBNPP passby flows are likely to be adjusted downward when the flow triggers for SSES mitigation move to the P95 values.

Results for the hydrologic alteration indicators computed by IHA are shown in Figure 4.8. These are alterations from the baseline conditions, SSES mitigation releases triggered by USACE P95 flows, to the conditions with combined BBNPP and SSES mitigation releases triggered by the SRBC passby flows. The magnitudes of the alterations are much smaller than those resulting from the presence of the dam. The most significant impacts from the mitigation releases are on the July median flows and the low pulse count and duration. A low-flow pulse is a day with flow less than the 25th percentile, or 36 cfs for the Cowanesque gage under baseline conditions. A mitigation release increases the low-flow pulse count when the flow goes from a low value (15 cfs), to a higher value (15+72=87 cfs), and back to a low value (15 cfs). A mitigation release reduces the duration of a low-flow (15 cfs) period by ending it at the point the mitigation release begins. July median flows are shown in Figure 4.9, with low pulse count and duration shown in Figure 4.10 and Figure 4.11, respectively.

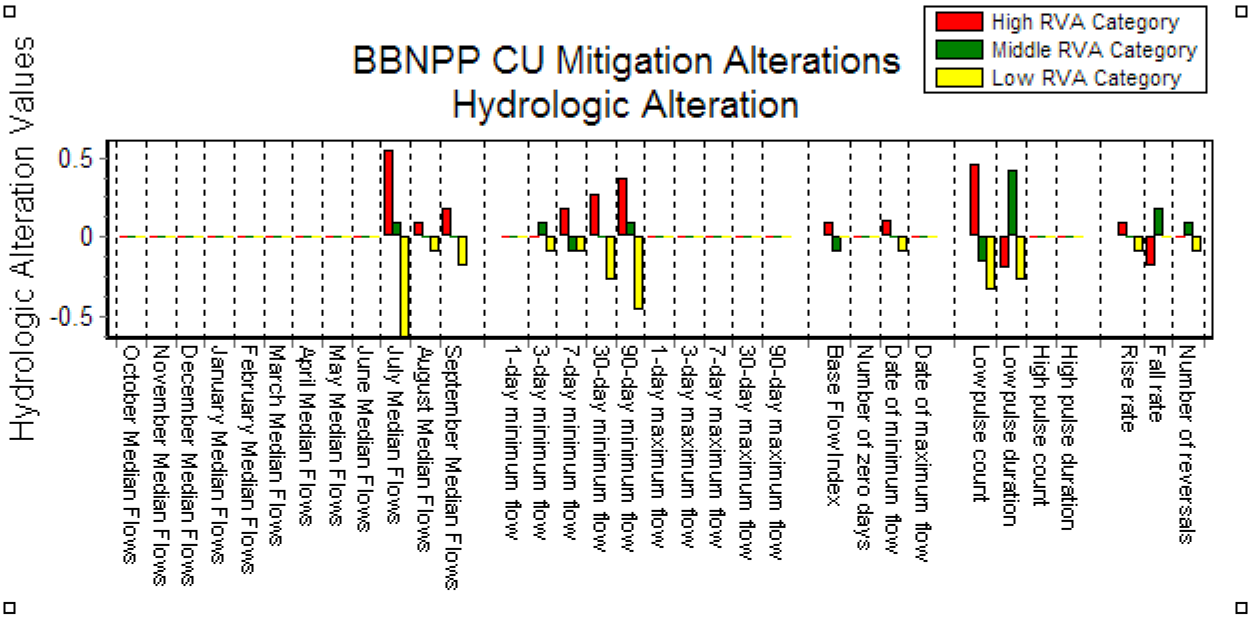


Figure 4.8. Hydrologic Alteration Measures in the Post-Dam period (1981 to 2013) at the Cowanesque Gage Computed by the IHA Code for Changes Occurring in Flows between the Baseline Conditions (SSES mitigation releases triggered by USACE [2013] P95 flows) and the BBNPP Primary Plan Conditions (combined BBNPP and SSES releases triggered by SRBC consumptive use mitigation and passby flow requirements)

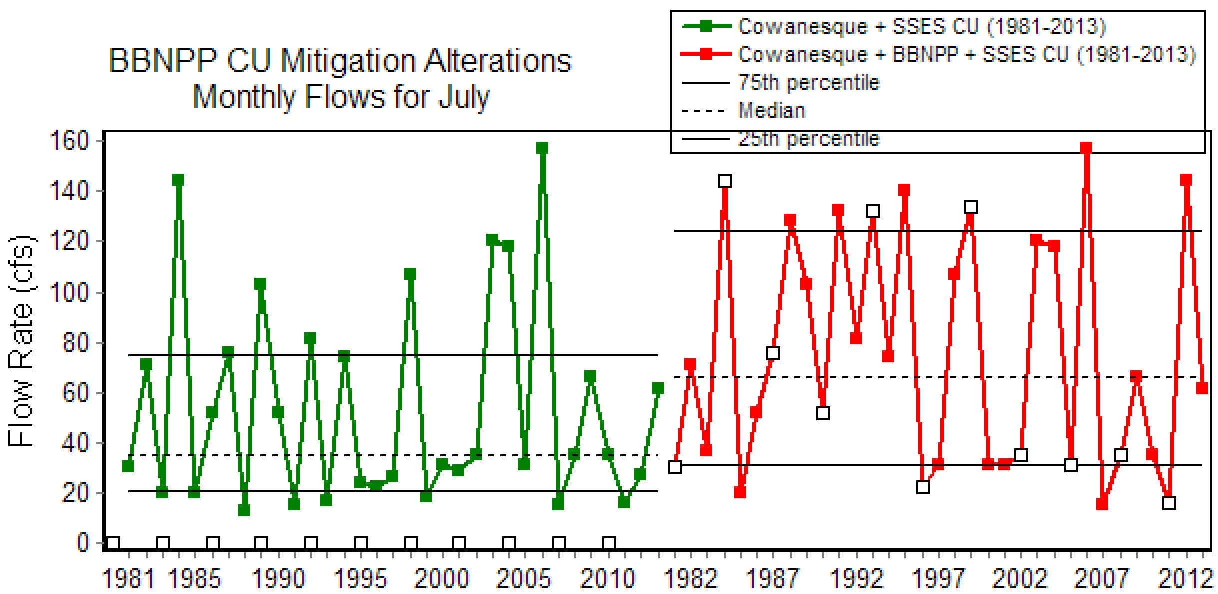


Figure 4.9. July Median Flow in the Post-Dam Period (1981 to 2013) at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows between the Baseline Conditions (SSES mitigation releases triggered by USACE [2013] P95 flows) and the BBNPP Primary Plan Conditions (combined BBNPP and SSES releases triggered by SRBC consumptive use mitigation and passby flow requirements)

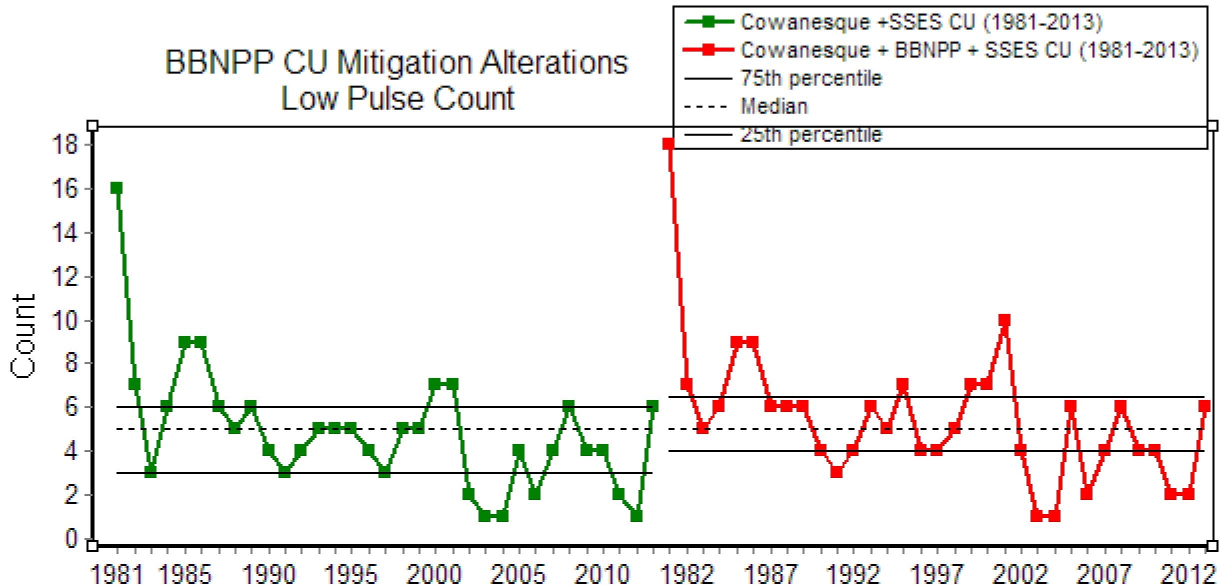


Figure 4.10. Low Pulse Count in the Post-Dam Period (1981 to 2013) at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows between the Baseline Conditions (SSES mitigation releases triggered by USACE [2013] P95 flows) and the BBNPP Primary Plan Conditions (combined BBNPP and SSES releases triggered by SRBC consumptive use mitigation and passby flow requirements)

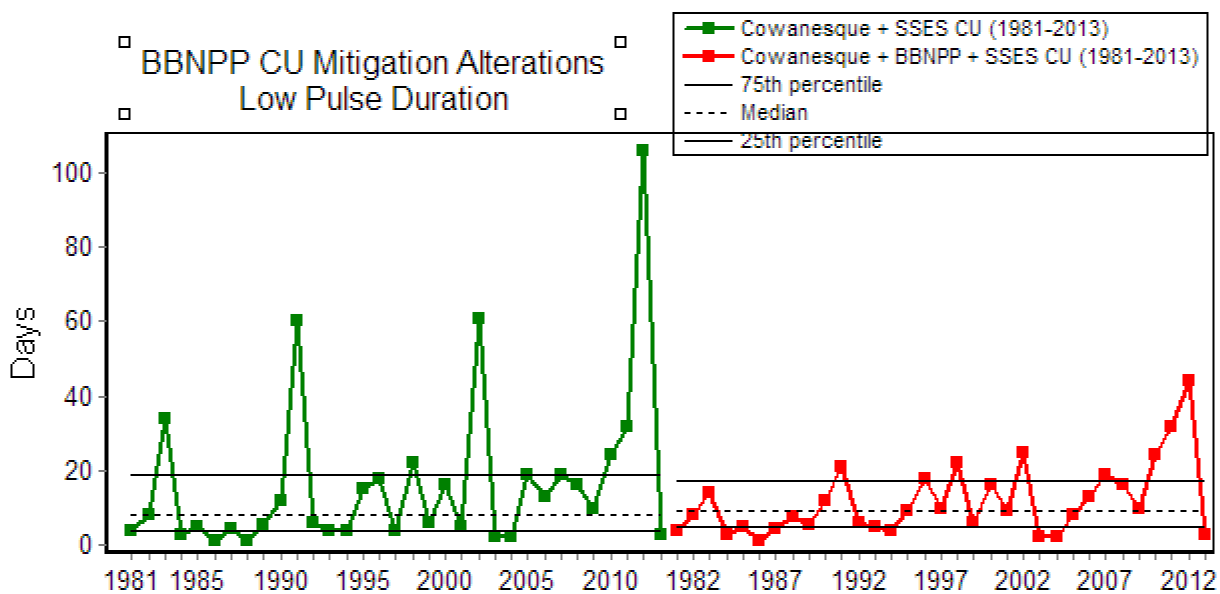
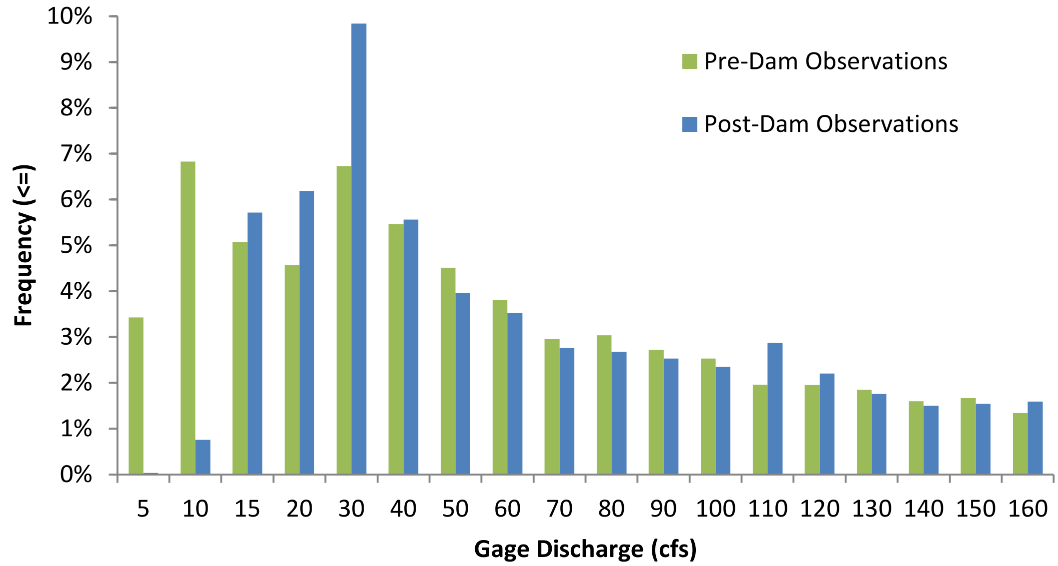


Figure 4.11. Low Pulse Duration in the Post-Dam Period (1981 to 2013) at the Cowanesque Gage Computed by the IHA Code Showing Changes Occurring in Flows between the Baseline Conditions (SSES mitigation releases triggered by USACE [2013] P95 flows) and the BBNPP Primary Plan Conditions (combined BBNPP and SSES releases triggered by SRBC consumptive use mitigation and passby flow requirements)

While the actual consumptive-use mitigation and passby flow release triggers and the future operation of Cowanesque Dam releases are unknown, a reasonable expectation if PPL's primary plan were to be implemented is for SSES mitigation to continue as currently implemented, but with releases reduced because Montour consumptive use would not be included. In other words, SSES mitigation releases of 62 cfs would be triggered by the P95 flows of the USACE preferred alternative. BBNPP releases of 43 cfs would be triggered by P95 flows and by passby flows no greater than those specified by SRBC (Appendix A). These conditions comprise the projected future scenario for evaluating the impacts of BBNPP operations on Cowanesque Lake and the river below the dam.

To provide some perspective on the expected changes in flows below the Cowanesque Dam, histograms of low flows at the Cowanesque gage are shown in Figure 4.12. Releases during 1991 and 1995 for SSES consumptive use mitigation were subtracted from the gage observations for this analysis. As shown in Figure 34, low-flow conditions during the pre-dam period (1952 to 1980) are conspicuous for the relatively frequent occurrence of extremely low flows; 10 percent of daily flows were less than 10 cfs. During the post-dam period (1981 to 2013), these extremely low flows were nearly eliminated, while flows between 15 and 30 cfs became more common. The bottom chart of Figure 4.12 compares baseline conditions to those with BBNPP operating. The baseline conditions for this analysis are the observations at the Cowanesque gage for the full period of record (1952-2013) supplemented with consumptive use mitigation releases for SSES, Montour, and TMI triggered by flows at the Wilkes-Barre and Harrisburg gages, respectively. Conditions with BBNPP operating include BBNPP releases (43 cfs) triggered by SRBC consumptive use mitigation and passby flow requirements, and the SSES consumptive-use mitigation releases (62 cfs) triggered by the USACE P95 flows. Compared to the baseline conditions, operating BBNPP results in a reduction of daily flows less than 40 cfs (and from 90 to 100 cfs) and an increase in the occurrence of flows in the range of 40 to 70 cfs, which corresponds to BBNPP mitigation releases alone, and in the range of 110 to 130 cfs, which primarily corresponds to the combined SSES/BBNPP mitigation releases.



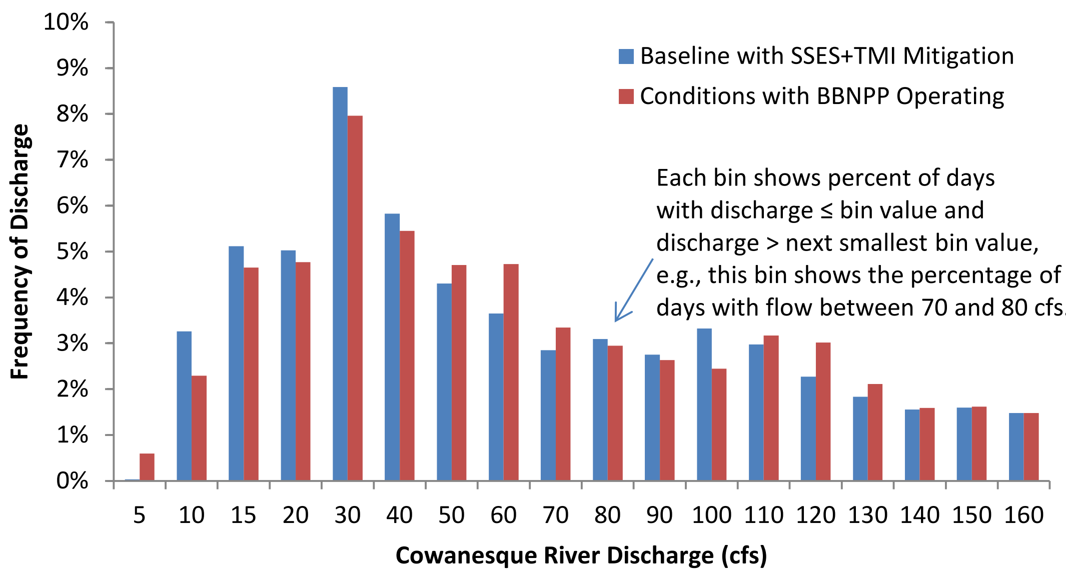
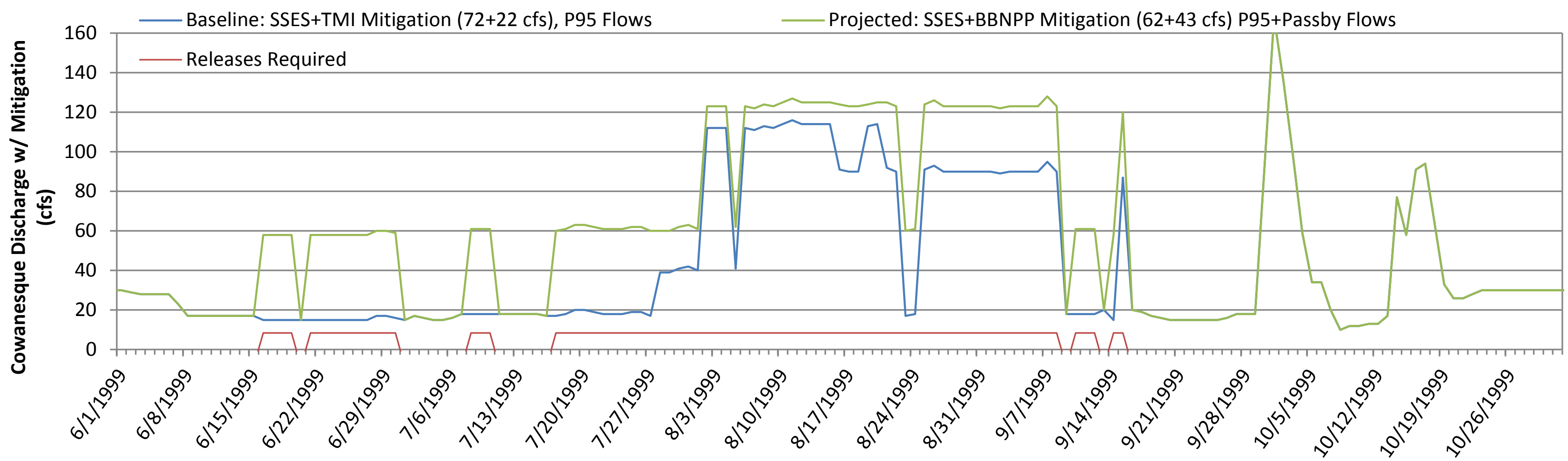


Figure 4.12. Histogram of Daily Flows at the Cowanesque Gage: (Top) Pre-Dam and Post-Dam Observations; (Bottom) Full Record Observations (1952-2013) Supplemented with SSES/Montour (72 cfs) and TMI (22 cfs) Releases Triggered by USACE P95 Flows at the Wilkes-Barre Gage, and SSES (62 cfs) and BBNPP (43 cfs) Releases Triggered by USACE P95 Flows and (for BBNPP) SRBC Passby Flows. The approximately 40 percent of daily flows greater than 160 cfs are not shown.

Discharge at the Cowanesque gage under the baseline conditions and under projected conditions with BBNPP operating are shown in Figure 4.13 for the summer of 1999. The baseline conditions include SSES and TMI consumptive-use mitigation releases of 72 and 22 cfs, respectively, triggered by USACE P95 flows at the Wilkes-Barre and Harrisburg gages, respectively. The projected BBNPP operating conditions include passby flow and consumptive use mitigation releases for BBNPP (43 cfs) and consumptive use mitigation releases for SSES (62 cfs) initiated by their respective triggering flows at the

Wilkes-Barre gage (SRBC passby flows for BBNPP and USACE P95 flows for BBNPP and SSES consumptive use mitigation). Days with flows at the Wilkes-Barre gage triggering releases for BBNPP are shown in red in Figure 4.13. Releases are triggered more frequently under the projected BBNPP operating conditions because the SRBC passby flows are larger than the P95 flows, and release rates are higher for those periods of time when the combined consumptive use of BBNPP and SSES is required to be released. Note that termination of the releases for both cases follows USACE procedures (USACE 2013) and that the effect of releases on flow at the Wilkes-Barre gage is not considered. The variable flows in late September and October of 1999 are unrelated to consumptive-use mitigation releases. Rapid and significant changes in discharge at the gage occur regularly, including when the discharge is at or near the minimum release from the dam but no consumptive use mitigation or passby flow releases are required. Such excursions can occur in the fall months, as seen in the 1999 data, or during the summer, as seen in the discharge data for 2000, also shown in Figure 4.13.



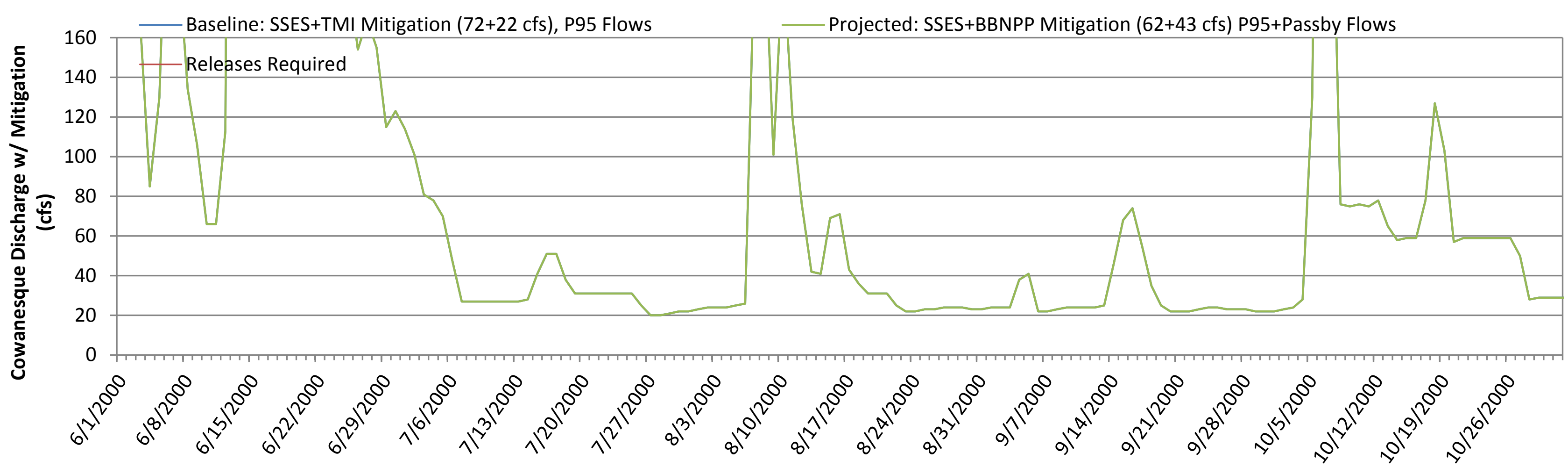


Figure 4.13. Discharge at the Cowanesque Gage with (blue) SSES (72 cfs) and TMI (22 cfs) Consumptive-Use Mitigation Releases Triggered by USACE P95 flows, and (green) BBNPP (43 cfs) and SSES (62 cfs) Releases Triggered by SRBC Passby Flows and USACE P95 Flows, Respectively. Days with flows at the Wilkes-Barre gage triggering BBNPP releases are shown in red for 1999; no releases would be required in 2000.

4.2 Hydrologic Alterations on Cowanesque Lake

For evaluating the effect of consumptive-use mitigation and passby flow releases on Cowanesque Lake, estimates of annual cumulative releases from Cowanesque Lake were calculated for the baseline conditions and under the projected conditions with BBNPP operating. Cumulative releases were calculated from May through November for each year based on the respective triggering flows at the Wilkes-Barre and Harrisburg gages. For the baseline conditions, releases of 72 cfs for SSES and 22 cfs for TMI were triggered based on the USACE P95 flows for July to November. For the projected conditions with BBNPP operating, releases of 43 cfs for BBNPP were triggered based on the SRBC passby flows for May to October and the USACE P95 flow for November; releases of 62 cfs for SSES were triggered by P95 flows for July to November. Changes in lake elevation resulting from the releases were calculated using area-elevation-capacity curves for Cowanesque Lake[1]. For this calculation it was assumed that the lake starts each summer at normal pool (1,080 ft) and receives no excess inflow (i.e., inflow is exactly balanced by evaporation and non-water-supply releases from the dam) until December 1, at which point the lake refills to normal pool.

Cumulative releases and lake elevation changes over the post-dam period (1981-2013) are shown in Figure 4.14 for TMI (22 cfs) and SSES (72 cfs) releases based on P95 triggering flows at the gages, and for the BBNPP releases (43 cfs). Projected releases for TMI are relatively small in comparison to the projected releases for SSES and BBNPP. Releases for BBNPP are projected to be more frequent and larger than releases for SSES. For comparison, USACE (2013) states that the actual water-supply releases from Cowanesque, triggered by the 7Q10 flows, were 1,280 ac-ft and 2,630 ac-ft in 1991 and 1995, respectively, with corresponding lake elevation drops of 1.5 and 1.8 ft attributed to these water-supply releases. No actual releases were made in 1999, although the flows at the Wilkes-Barre and Harrisburg gages were less than the 7Q10 flows plus the average consumptive use values used here. Over the period of 1981 to 2013 shown in Figure 4.14, the maximum cumulative releases occur in 1999. Note that, in 1991 and 1995, the actual lake elevations were lower than what could be attributed solely to water-supply releases (SRBC 2012a, Figures B3-3 and B3-6), suggesting that excess inflow to the lake was negative during the summers of those two years.

Cumulative releases and lake elevation changes over the post-dam period are shown in Figure 4.15 for the baseline conditions (combined TMI and SSES releases based on P95 triggering flows) and for conditions with BBNPP operating (combined BBNPP and SSES releases). Drawdown in the lake elevation projected to result from the combined operations of SSES and BBNPP is typically less than 2 ft for the period from 1981 to 2013. Significant drawdown is projected to occur in 1991, 1995, and 1999, with a maximum drawdown of approximately 12 ft. The drawdown in 1999 results from a cumulative release of approximately 10,900 ac-ft, approximately 46 percent of the water-supply storage volume in the lake, consisting of 4,400 ac-ft for SSES mitigation and 6,500 ac-ft for BBNPP mitigation. Drawdowns in lake elevation during 1991, 1995, and 1999 are 4 to 6 ft larger with the combined releases for BBNPP and SSES than for the baseline conditions.

As discussed in Section 2.0 and shown in Figure 2.2, annual average discharge at the Wilkes-Barre gage was somewhat less during the period of record prior to 1981 than from 1981-2013. In addition,

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[1] J.W. Haines, USACE, personal communication, March 10, 2014.

there were significant drought period in the Susquehanna River basin prior to 1981, including the drought of record in the 1960s. Annual cumulative releases from Cowanesque Lake and the corresponding drawdowns in lake elevation were calculated using the Wilkes-Barre and Harrisburg gage data for the period 1899 to 2013. Cumulative releases and lake elevation changes for the baseline conditions and for conditions with BBNPP operating are shown in Figure 4.17. For conditions with BBNPP operating, cumulative releases exceeded 12,000 ac-ft during seven years (out of 115). During the drought of record (1964), projected cumulative releases were 22,000 ac-ft under the baseline (SSES and TMI releases) and 28,000 ac-ft with BBNPP operating (SSES and BBNPP releases). The latter volume exceeds the SRBC-owned water supply storage in Cowanesque Lake.

The frequency of daily lake drawdown, based on the results presented in Figure 4.16, is shown in the upper chart Figure 4.17. Results in this figure should be used with caution because they are based on the assumption that any drawdown that occurs persists until December 1st. This assumption would tend to increase the drawdown frequencies. Based on results presented in Appendix B1 of SRBC (2012a), however, it does seem that normal pool is often not reestablished until the November time frame (or later) for the larger drawdowns of the driest years. Operating BBNPP increases the frequency of days with a given drawdown, compared to the baseline. For example, the frequency of days with lake elevation 1075 ft or lower increases from 3.5 percent for the baseline to 8.4 percent with BBNPP operating.

Drawdown of Cowanesque Lake begins to affect recreational facilities at the lake when the elevation reaches 1077 ft and affects all recreational facilities at the lake when the elevation reaches 1070 ft. (USACE 2013). The frequency of daily lake drawdown during the recreation season, May 20 to September 14, is shown in the lower chart of Figure 4.17. The frequency of days during the recreation season with lake elevation 1077 ft or lower is projected to increase from 2.2 percent for the baseline to 5.1 percent with BBNPP operating. For lake elevation of 1070 ft or lower, the frequency increases from 0.0 to 0.5 percent of days.

In addition to the frequency of daily drawdown in the elevation of Cowanesque Lake shown in Figure 4.17, the frequency of the annual maximum drawdown was evaluated. Table 4.1 shows the frequency of annual maximum lake drawdown under baseline conditions and with BBNPP operating for various drawdown values. Results are provided for the entire period of potential releases (May 1st to November 30th) and for the recreational season (May 20th to September 14th). Maximum drawdown during the entire release period was less than 1 ft in 75 percent of years under the baseline conditions; with BBNPP operating, maximum drawdown was less than 1 ft in about 63 percent of years. During the recreation season, maximum drawdown exceeded 3 ft in 11 percent of years for the baseline and in about 16 percent of years with BBNPP operating. Maximum drawdown exceeded 15 ft in 4.4 percent of years (5 out of 115) with BBNPP operating. However, a significant portion of the drawdown was due to releases that occurred after the end of the recreation season. With BBNPP operating, the largest drawdown during the recreation season occurred in 1962 and was slightly smaller than 15 ft.

Drawdown frequency based on simulations from 1930 to 2007 were presented in Annex B of USACE (2013) for the recreation period of May to mid-September. Because of the different bases for the two figures (e.g., results presented in this report do not include the effect of natural conditions on lake elevation), a direct comparison of frequencies in Figures B1 and B2 of USACE (2013) and Figure 4.17 is not warranted. However, qualitatively comparing USACE (2013) to the results of Figure 4.17 suggests that the impact on Cowanesque Lake elevations of moving from 7Q10 to P95 flows for triggering consumptive use mitigation will be smaller than the impact of moving from the baseline considered in this report to the scenario with BBNPP operating. The difference between the annual maximum drawdown with BBNPP operating and under the baseline conditions provides a measure of the marginal impact of the BBNPP that is independent of the effect of natural conditions on the lake elevation. Figure 4.18 shows the frequency of occurrence for differences from zero to six feet, for the entire release period and for the recreation season. In about 69 percent of years there was less than 1 ft difference in the annual maximum drawdown with BBNPP operating and under the baseline conditions. The largest differences during the recreation season were between 5 and 6 ft, occurring in less than 2 percent of years. Differences larger than 6 ft occurred in less than 3 percent of years when the entire release period was considered.

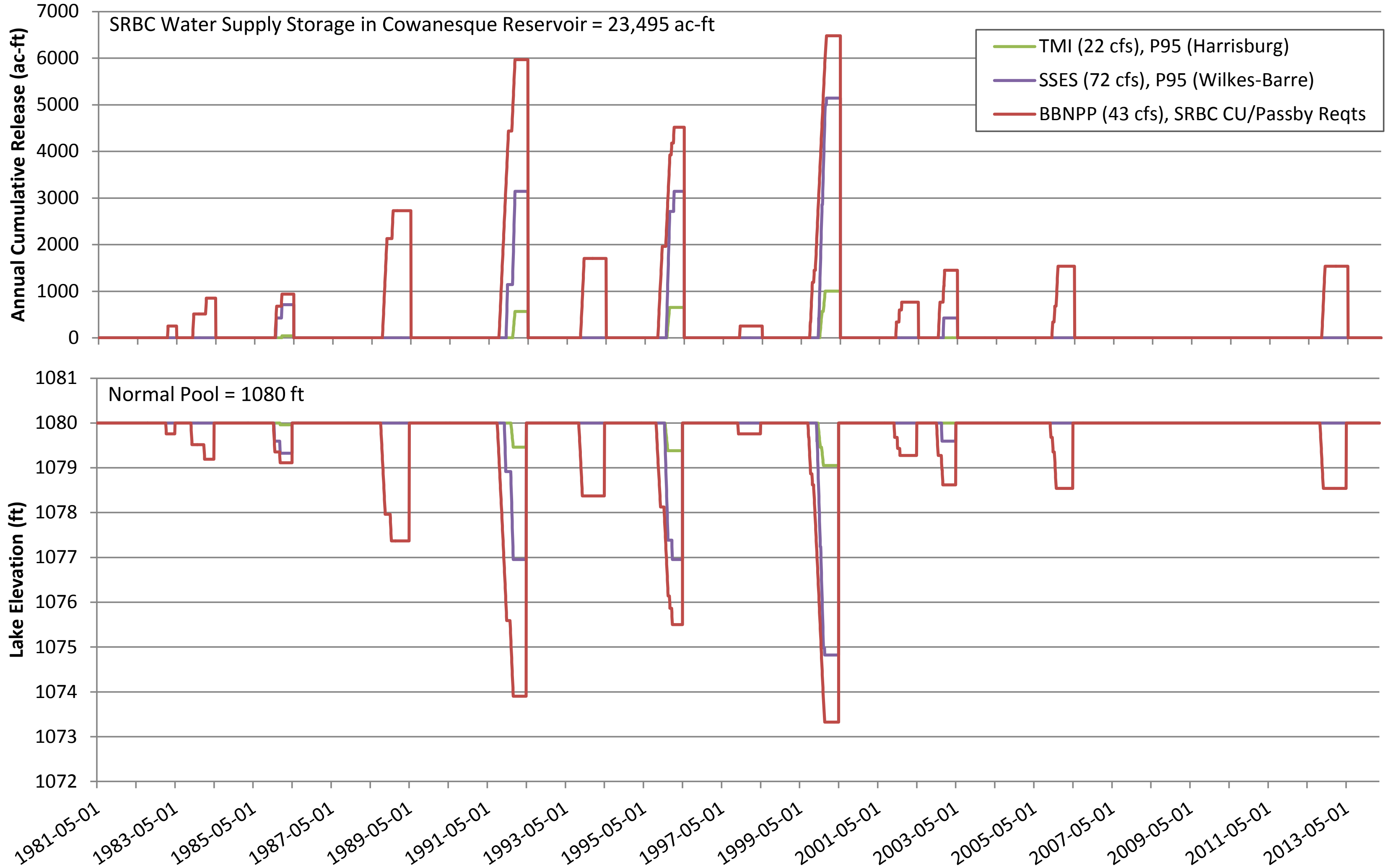


Figure 4.14. Estimated Annual Cumulative Mitigation Releases from Cowanesque Lake and Corresponding Lake Elevations for TMI and SSES Releases Triggered by P95 Flows at the Harrisburg and Wilkes-Barre Gages, Respectively, and for BBNPP Releases Triggered by SRBC Consumptive Use Mitigation and Passby Flow Requirements

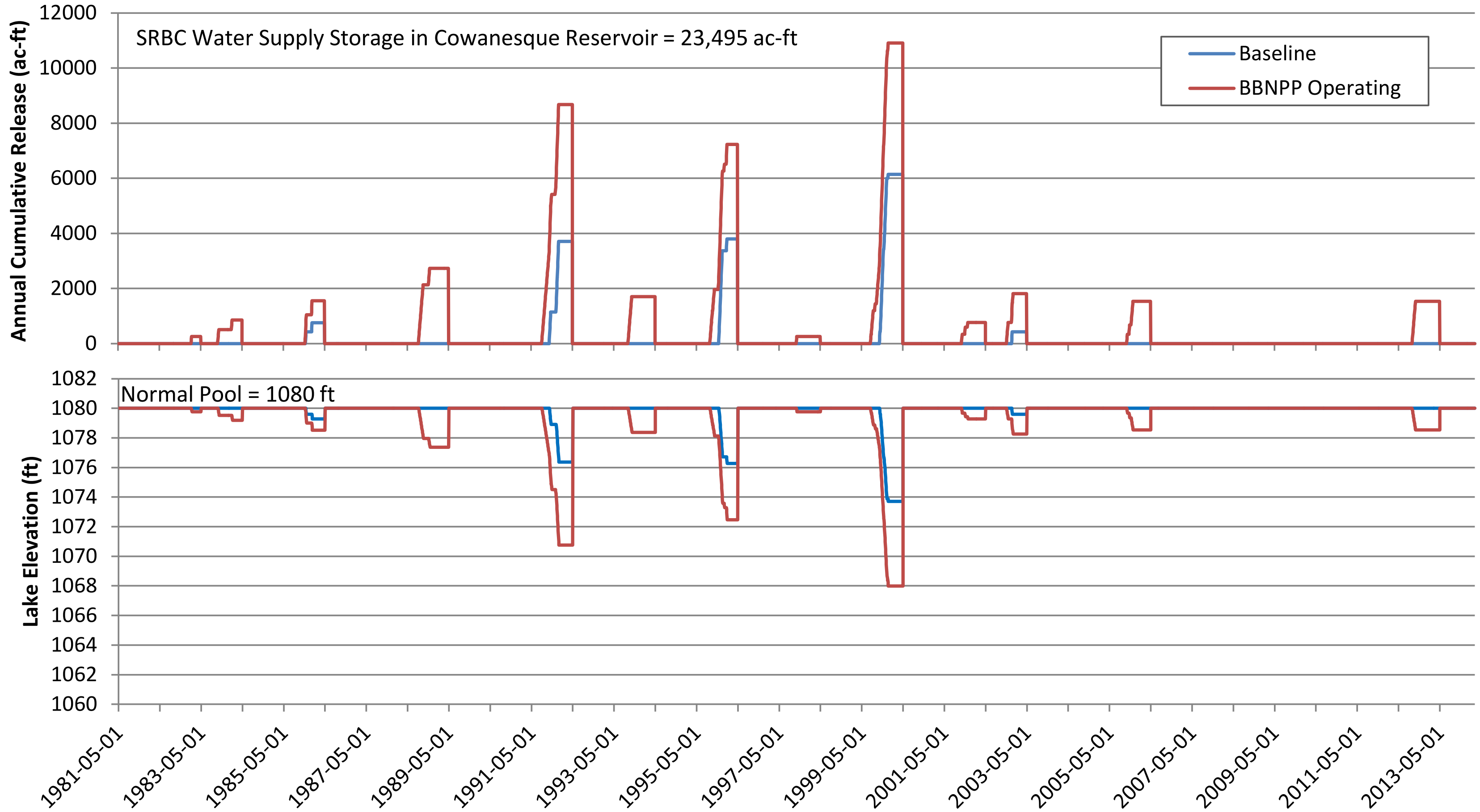


Figure 4.15. Estimated Annual Cumulative Mitigation Releases from Cowanesque Lake and Corresponding Lake Elevations for Baseline Conditions (SSES Releases of 72 cfs plus TMI Releases of 22 cfs Triggered by P95 flows) and for Conditions with BBNPP Operating (SSES Releases of 62 cfs Triggered by P95 flows plus BBNPP Releases of 43 cfs Triggered by SRBC Passby Flow and Consumptive Use Mitigation Requirements), May to November, 1981 to 2013

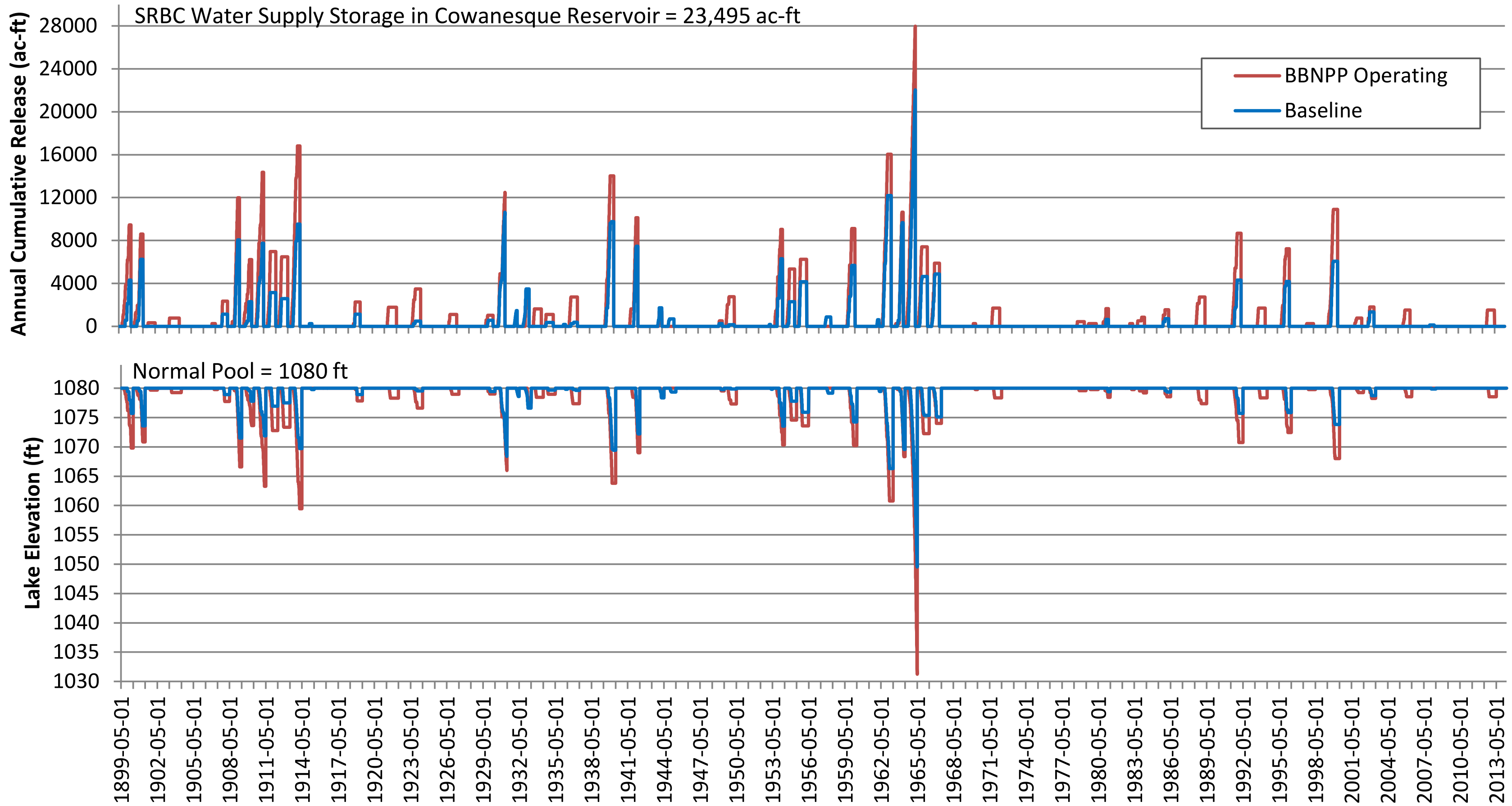
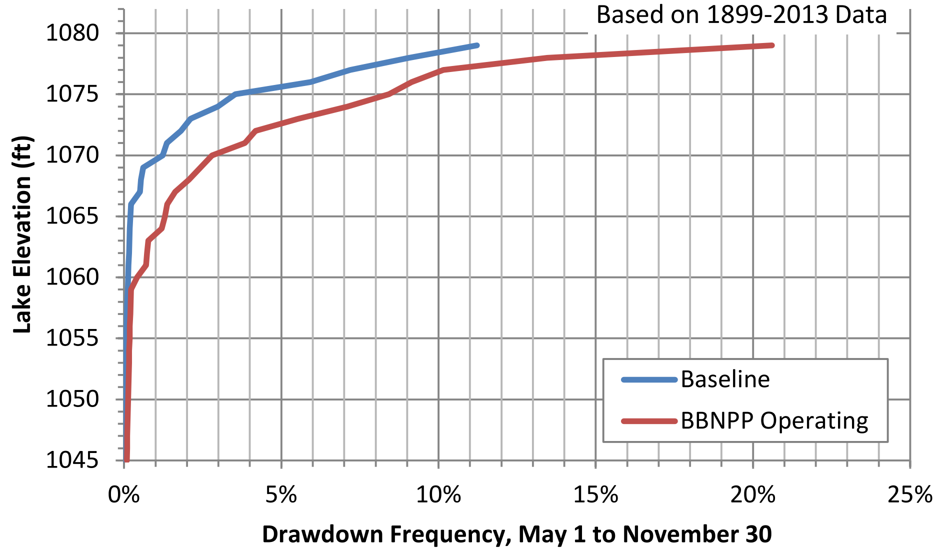


Figure 4.16. Estimated Annual Cumulative Mitigation Releases from Cowanesque Lake and Corresponding Lake Elevations for Baseline Conditions (SSES Releases of 72 cfs plus TMI Releases of 22 cfs Triggered by P95 flows) and for Conditions with BBNPP Operating (SSES Releases of 62 cfs Triggered by P95 flows plus BBNPP Releases of 43 cfs Triggered by SRBC Passby Flow and Consumptive Use Mitigation Requirements), May to November, 1899 to 2013



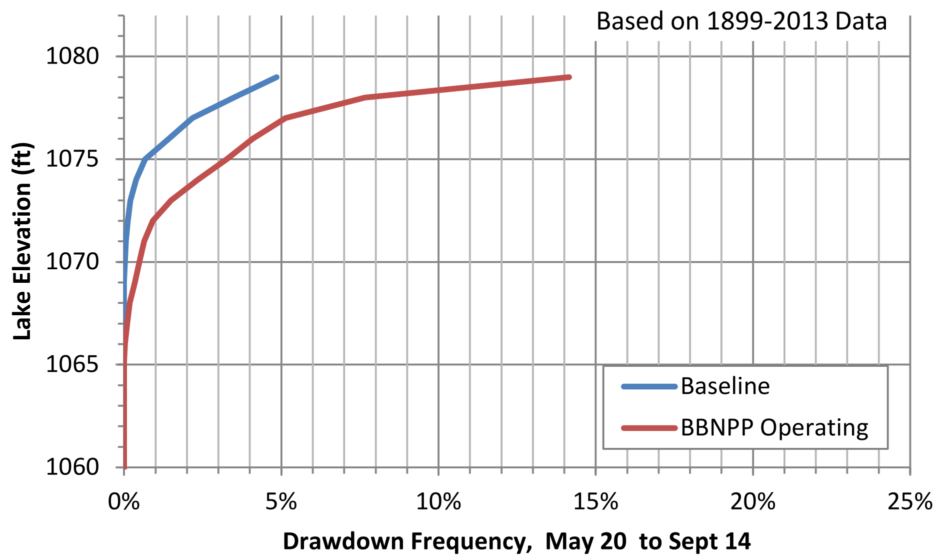


Figure 4.17. Frequency of Daily Cowanesque Lake Drawdown, 1899 to 2013: (Top) May 1st to November 30th, (Bottom) May 20th to September 14th

Table 4.1. Frequency of Annual Maximum Cowanesque Lake Drawdown Under Baseline Conditions and with BBNPP Operating, During May 1st to November 30th and During the Recreational Season (May 20th to September 14th)

	May 1 – November 30		May 20 – September 14	
Drawdown (ft)	**Baseline[(a)]**	**BBNPP Operating[(b)]**	**Baseline[(a)]**	**BBNPP Operating[(b)]**
< 1	74.8%	63.5%	82.6%	67.8%
≥ 1	25.2	36.5	17.4	32.2
≥ 2	20.9	26.1	14.8	22.6
≥ 3	18.3	20.9	11.3	16.5
≥ 4	16.5	20.0	7.0	14.8
≥ 5	11.3	20.0	4.4	13.0
≥ 6	10.4	18.3	4.4	10.4
≥ 7	7.8	15.6	1.7	7.8
> 10	5.2	9.6	0.9	4.4
≥ 15	0.9	4.4	0.0	0.0

(a) Consumptive-use mitigation releases of 72 cfs for SSES and MSES and 22 cfs for TMI triggered by P95 flows at the Wilkes-Barre and Harrisburg gages, respectively.
(b) Consumptive-use mitigation releases of 62 cfs for SSES triggered by P95 flows at Wilkes-Barre; releases of 43 cfs for BBNPP triggered by P95 or SRBC-specified passby flows at Wilkes-Barre.

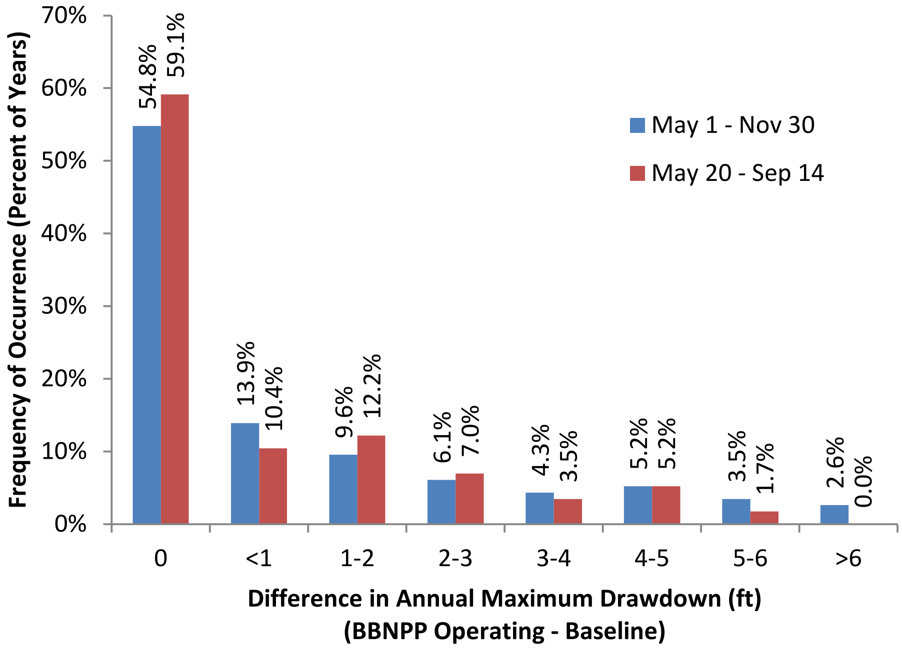


Figure 4.18. Difference in Annual Maximum Cowanesque Lake Drawdown between BBNPP Operating and Baseline Conditions, Frequency of Occurrence

5.0 Indicators of Hydrologic Alteration on Moshannon Creek Near Rushton Mine

Under PPL's primary plan for consumptive-use mitigation for BBNPP, the portion of consumptive use for Montour that is currently mitigated with releases from Cowanesque Lake would be mitigated instead using releases from Rushton Mine. These releases would flow into Moshannon Creek approximately 2 miles downriver from an inactive USGS gage, (01542000, Moshannon Creek at Osceola Mills, Pennsylvania), with a daily discharge record from 1940 to 1993. Potential alterations in Moshannon Creek flow resulting from these releases are briefly evaluated in this chapter. Daily discharges and the median monthly discharge at the Moshannon Creek gage are shown in Figure 5.1. Median monthly flow exceeds 200 cfs in the spring and falls to 36 cfs in September. Peak recorded flow at the gage was approximately 4,500 cfs. No major alterations in flow are apparent in the daily discharge data. Annual flow-duration curves shown in Figure 5.2 illustrate that there are some small differences in the occurrence of flows before and after 1980, with very low flows being less common after 1980.

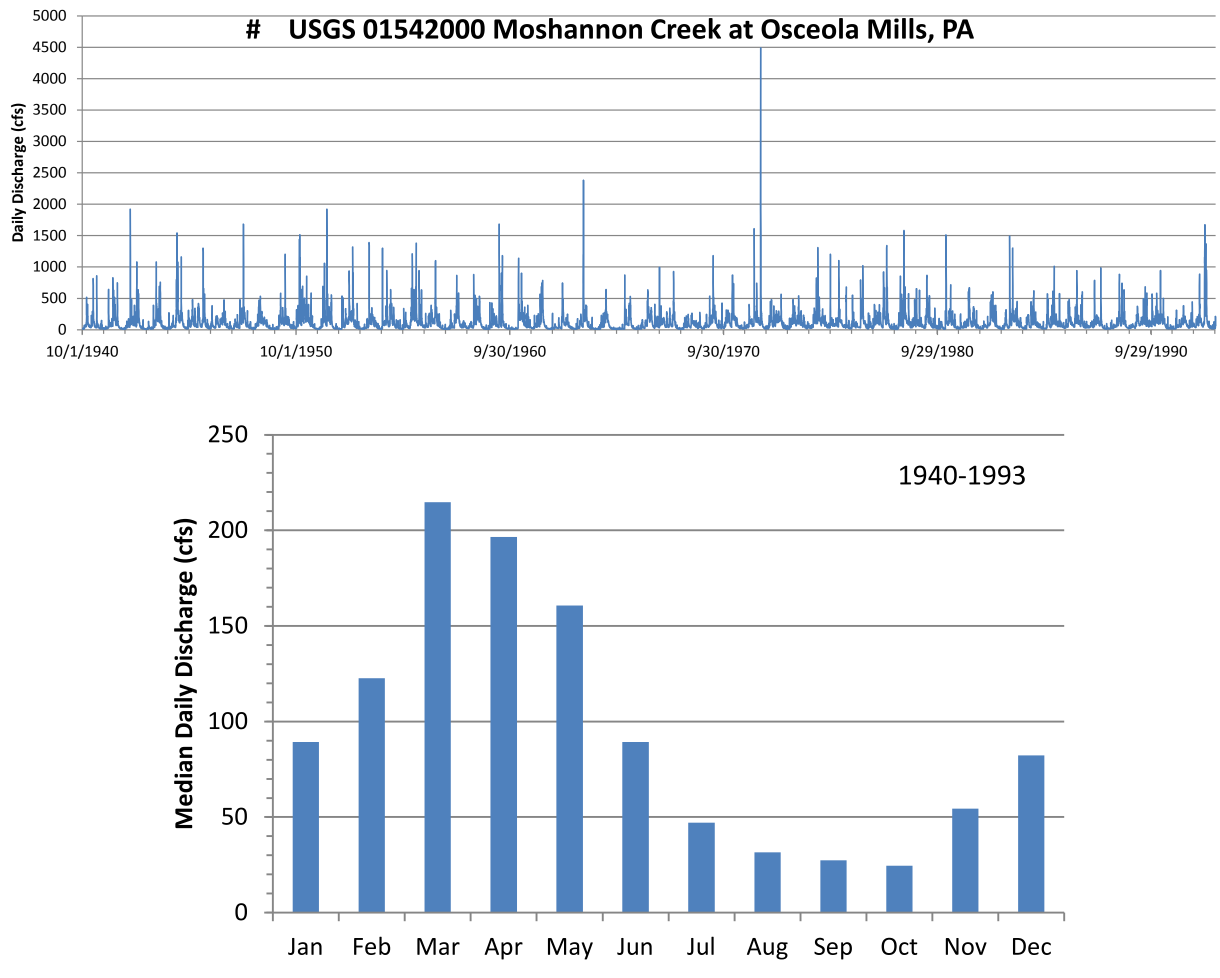


Figure 5.1. Daily Discharge (top) and Median Daily Discharge by Month (bottom) in Moshannon Creek for the Period of Record (1940 to 1993) (USGS 2014)

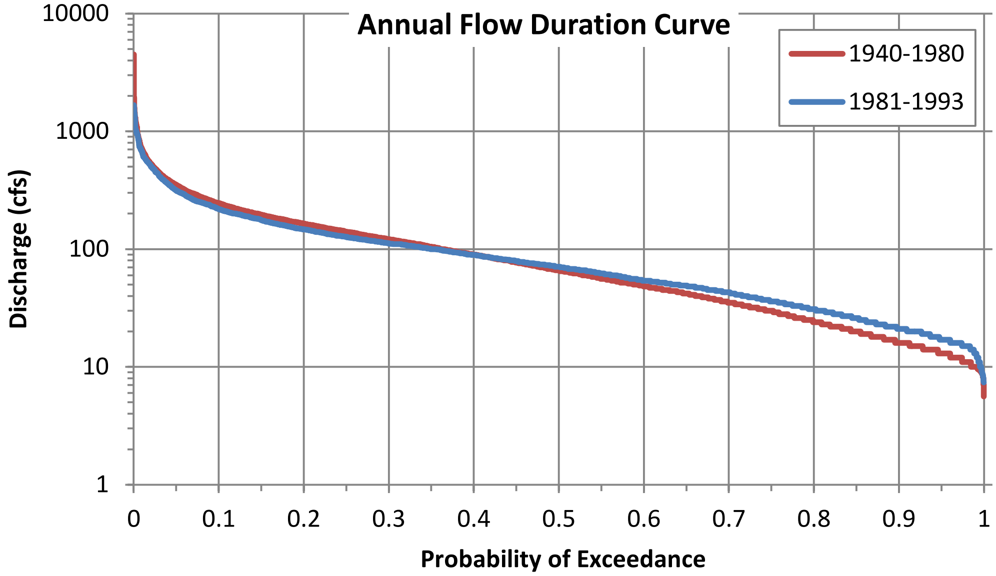


Figure 5.2. Annual Flow-Duration Curve (constructed from daily discharge data over the entire year) for Discharge at the Moshannon Creek Gage (1940 to 1980 and 1981 to 1993 periods)

While the actual consumptive-use mitigation triggers and future releases from Rushton Mine are unknown, a reasonable expectation if PPL's primary plan were to be implemented is for Montour mitigation to occur consistent with the current mitigation releases from Cowanesque Lake. It was assumed here that Montour mitigation releases of 12 cfs would be triggered by P95 flows at the Wilkes-Barre gage (plus 72 cfs, the combined consumptive use of SSES and Montour). SRBC might choose to move the triggering gage to the West Branch Susquehanna River, but that possibility was not evaluated here. Histograms of low flows at the Moshannon Creek gage are shown in Figure 5.3 for observations during the period of 1940 to 1993 (baseline conditions). For the conditions with BBNPP operating, the observed flows are augmented with 12 cfs mitigation releases. These releases have the effect of increasing the frequency of flows in the range of 20 to 50 cfs and decreasing the frequency of flows in the range of 5 to 20 cfs.

Moshannon Creek gage discharge observations supplemented with mitigation releases of 12 cfs for Montour are shown in Figure 5.4 for the period from June to October 1991. The mitigation releases are added to the discharge when consumptive-use mitigation is required, as determined by P95 flow values at the Wilkes-Barre gage and as indicated in red in Figure 5.4. Addition of the 12-cfs releases significantly increases the flow in Moshannon Creek, but the impact is masked somewhat by the large variability of flow in this uncontrolled stream.

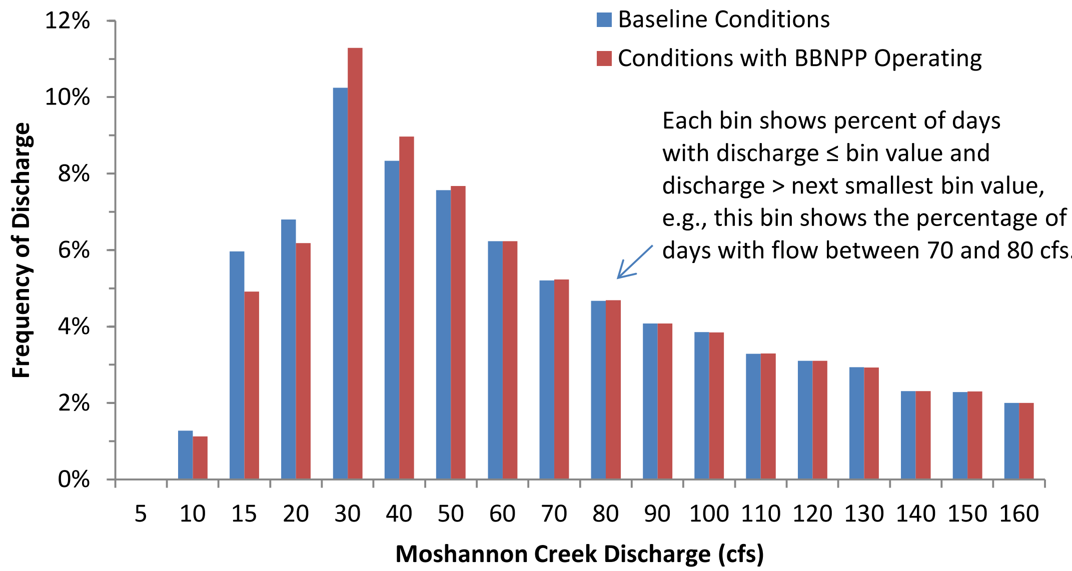


Figure 5.3. Histogram of Daily Flows at the Moshannon Creek Gage, 1940-1993, for Baseline Conditions (Observed Flows at the Gage) and for Conditions with BBNPP Operating (Observations Supplemented with Montour Consumptive-Use Mitigation Releases of 12 cfs Triggered by P95 Flows at the Wilkes-Barre Gage). The approximately 20 percent of daily flows greater than 160 cfs are not shown.

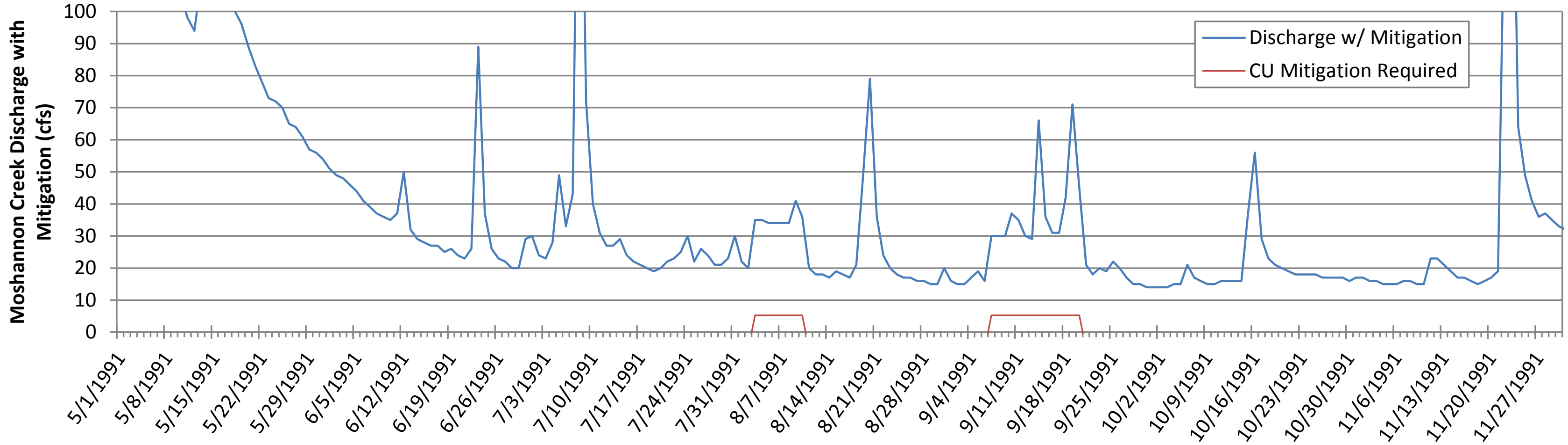


Figure 5.4. Daily Discharge During 1991 at the Moshannon Creek Gage with Montour Consumptive-Use Mitigation Releases (12 cfs) Included When Mitigation Is Required (as determined by P95 flow values at the Wilkes-Barre gage)

6.0 Conclusion

Hydrologic alterations resulting from the consumptive use of NBSR water by the proposed BBNPP were evaluated. Because SRBC would require upstream releases of water as mitigation for the consumptive use at BBNPP and to satisfy passby flow requirements, the alterations occur well beyond the immediate vicinity of the consumptive use. Under PPL's primary plan, water for BBNPP consumptive-use mitigation would be released from Cowanesque Lake into the Cowanesque River and from Rushton Mine into Moshannon Creek. Hydrologic alterations to these water bodies were estimated along with the evaluation of alterations to the NBSR at the point-of-use. The greatest apparent alterations are changes in the surface elevation of Cowanesque Lake and changes in Cowanesque River flows immediately below the dam. The estimated alterations are dependent on the passby flow requirements for BBNPP set by SRBC. Because an actual consumptive-use mitigation plan for BBNPP has not been approved, the analysis presented here made reasonable assumptions about the implementation of PPL's primary plan while attempting to produce alteration estimates that also were bounding. The primary bounding assumption of the analysis was the use of the passby flow values specified by SRBC. SRBC has indicated that these values may be changed (i.e., lowered) in the future because of planned modifications to the operations plan for Cowanesque Dam in switching from 7Q10 to P95 flow triggers for consumptive use mitigation for the existing SSES plant.

7.0 References

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Appendix A

Susquehanna River Basin Commission Recommended Passby Flows for Bell Bend Nuclear Power Plant

Appendix A

Susquehanna River Basin Commission Recommended Passby Flows for Bell Bend Nuclear Power Plant

The following information was provided by Susquehanna River Basin Commission staff following a January 8, 2014, teleconference with staff from the U.S. Nuclear Regulatory Commission and Pacific Northwest National Laboratory.

In general, Susquehanna River Basin Commission Policy No. 2012-01 recommends standard monthly passby flows equal to the calculated P95 monthly percent exceedance values for withdrawals from rivers in Aquatic Resource Class 6. In consideration of the site-specific special aquatic studies, Commission staff recommends imposition of the passby flows identified in Table A.1. Note that flows listed in the table are adjusted to the project site location and show corresponding compliance flows for the Wilkes-Barre gage.

Table A.1. Recommended Passby Flows for Bell Bend Nuclear Power Plant (BBNPP)

Month	Passby Flow at BBNPP (cfs)	Passby Flow at Wilkes-Barre Gage (cfs)	Monthly Px[a]
January	None	NA	NA
February	None	NA	NA
March	None	NA	NA
April	None	NA	NA
May	1,750	1,700 + cu[b] = 1,817	Approximately P99
June	1,750	1,700 + cu = 1,817	P99
July	1,750	1,700 + cu = 1,817	P85
August	1,200	1,100 + cu = 1,217	P90
September	890	860 + cu = 977	P95
October	1,010	980 + cu = 1,097	P95
November	None	NA	NA
December	None	NA	NA

[a] Flow with a x-percent probability of being exceeded.

[b] cu is equal to 117 cfs, the combined total of consumptive use at SSES (74 cfs) plus the proposed consumptive use for BBNPP (43 cfs)

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