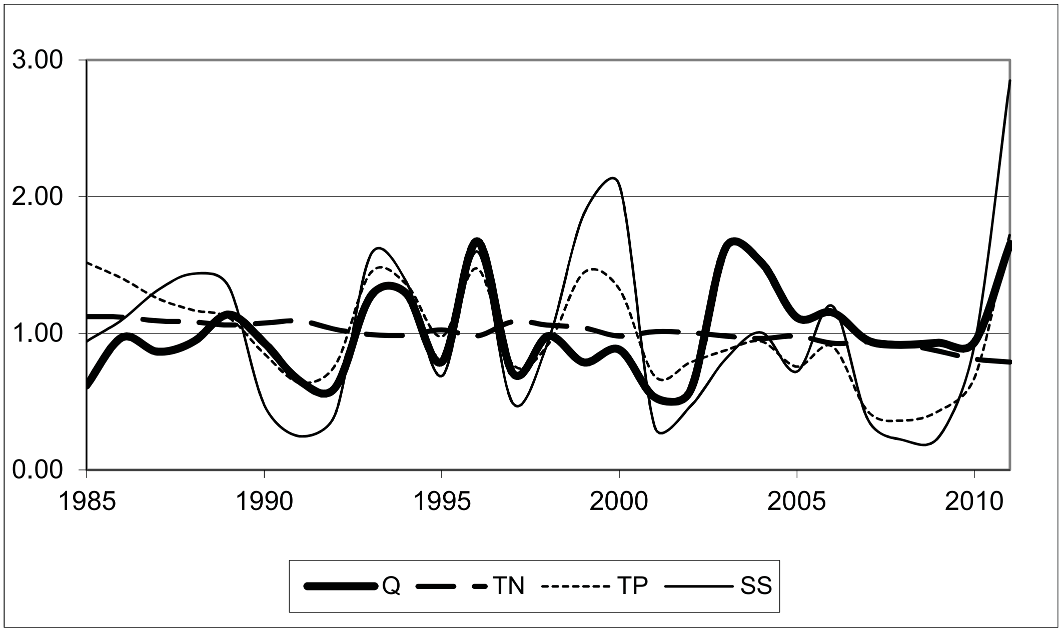

Figure 14. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

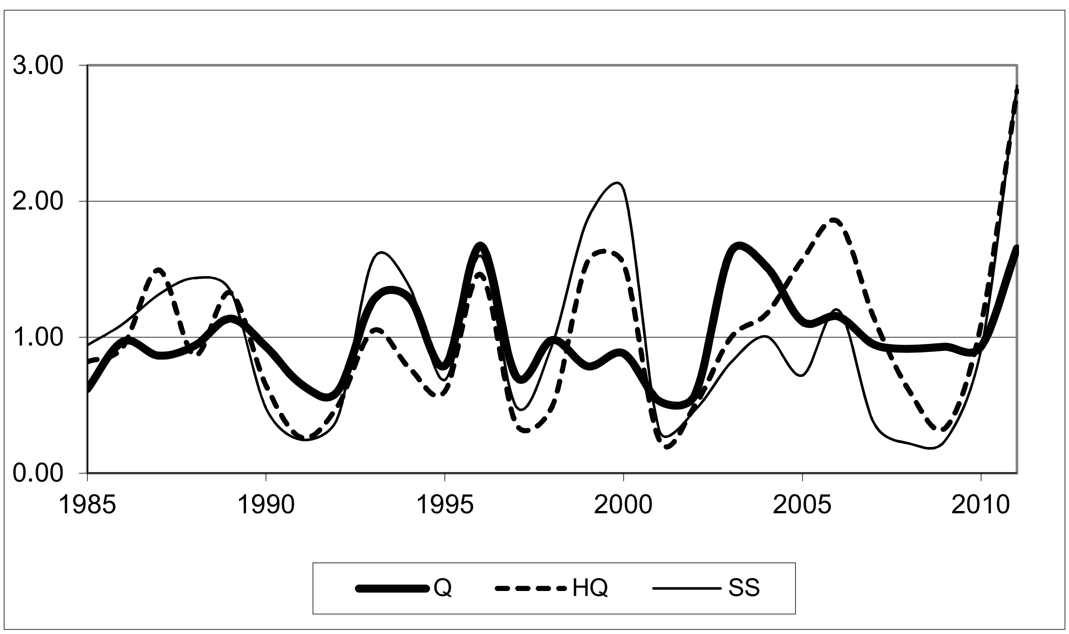

Figure 15. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

2011 KEY FINDINGS

2011 brought several high flow events spread throughout the year with the largest occurring in August and September. Hurricane Irene and T.S. Lee brought intense rainfall and extreme nutrient and suspended sediment loads. Whereas Hurricane Irene affected the eastern portion of the basin, T.S. Lee affected the entire basin. However, each subbasin within the watershed was affected differently. The Conestoga Watershed was dramatically affected by both Irene and Lee resulting in a September high daily average discharge that was 330 percent of the closest daily high that occurred in March. In comparison, high daily average discharge at Lewisburg was 140 percent of the March high and the average daily high flow for September at Newport was 91 percent of the March high.

Annual rainfall ranged from 11 inches above the LTM at Towanda to 22.33 inches above the LTM at Lewisburg. Although the two major events brought the most significant amounts of precipitation, the spring events collectively produced 1.5 inches less. The rainfall was spread through a few months during the spring and concentrated during a short period of time during August and September.

T.S. Lee peak flow at Conestoga occurred on September 8 reaching 6.3 feet over major flood stage, second only to Hurricane Agnes in 1972. Peak flows at Towanda and Danville were historically second highest as well. September peak flow at Marietta was historically fourth, 11th at Lewisburg, and outside the top 15 at Newport.

Although T.S. Lee affected the entire basin, lower peak flows at Lewisburg and Newport led to dramatically lower yields of TP and SS as compared to the other four sites. This led to less impact, including lower SS yields at Marietta, as compared to Danville and Towanda. However, TP yields were higher at Marietta than at Danville and Towanda. Comparison of loads from Lewisburg, Danville, and Newport, to Marietta suggests that 49 percent, 61 percent, and 23 percent of the TN, TP, and SS loads at Marietta, respectively, was transported by the lower basin above Marietta. Within the lower basin, Swatara recorded peak flows over 10 feet above the closest historical peak flow and 12.8 feet over major flood stage.

September at Conestoga had the highest yield values for TN, TP, and SS. Due to the size of the Conestoga Watershed and the loads delivered, this occurred most previous years. September 2011 was unique in that not only was the September TP load at Conestoga larger than the September loads at Lewisburg and Newport, it was larger than the entire annual loads at Lewisburg and Newport. The SS load at Conestoga was above the annual load at Newport and was 78 percent of the annual load at Lewisburg. For comparison, September average flow was 22,459 cfs at Lewisburg, 11,873 cfs at Newport, and 3,034 cfs at Conestoga. September TN load at Conestoga was 8 and 9 percent of Lewisburg and Newport's annual load, respectively.

Summary statistics for all sites showed all four West Branch sites having the lowest mean TP concentrations and the Lower Susquehanna Subbasin having the top five when all sites were compared. Three of the top five were below Marietta and did not affect the load there while Swatara and the West Conewago were above it. Comparing the summary statistics based on location, West Branch Susquehanna Sites had lower mean TN and TP values, Juniata sites had higher mean TN and lower TP values, mainstem Susquehanna sites had lower mean TN and higher mean TP values, and lower Susquehanna sites had higher mean TN and TP values. The Chemung site had values similar to the mainstem while Unadilla, Cohocton, Penns, and Bald Eagle had lower mean TN and TP values.

When the TN, TP, and SS load was broken down into tributary contribution, Danville accounted for 38, 39, and 64 percent, respectively, of the Marietta load. Lewisburg and Newport combined accounted for 28, 12, and 8 percent of the respective loads. Subtracting this from the Marietta loads suggests that the Lower Susquehanna above Marietta accounted for 34, 50, and 28 percent of the TN, TP, and SS load, respectively. Discharge contributions were 43, 36, and 21 percent of Marietta's annual flow from Danville, Lewisburg plus Newport, and the lower subbasin tributaries, respectively.

Comparison of 2011 trends between Marietta and Danville, Lewisburg, and Newport suggest that the Lower Susquehanna's tributaries may be reducing the downward trends. Although all nitrogen species had downward trends at Danville and Marietta, the magnitude of these trends was less at Marietta. This included TON, TNH_3, and TNO_{23}. Six of the eight monitored tributaries to the Lower Susquehanna had the highest TNO_{23} average concentrations over all other sites. TNO_{23} trend magnitudes were lower for Lewisburg and there was no trend for Newport, playing an additional role in lowering the magnitude of the Marietta TNO_{23} trend as compared to Danville. The same was found for DNO_{23} while TNO_{23} and DNO_{23} constituted the majority of the TN load. Whereas Danville and Towanda showed larger magnitudes of improving nitrogen trends, both showed less improvement in phosphorus species. This included no trend for TP, an upward trend for DOP at Towanda, and no trend for DP at Danville. There were large magnitude trends for TP at all three tributary sites as well as large downward trends in DP at Newport and Conestoga.

SS trends were similar to TN trends in that Marietta had a much lower magnitude trend than Danville. Both Lewisburg and Newport trend magnitudes were similar to Marietta's.

Conestoga, the highest yield watershed in the basin for TN, TP, and SS, showed some of the highest magnitude reductions in trends. This included 73–81 percent reduction in TNH_3 and DNH_3, 70–80 percent SS, 54–64 percent TP, and the only downward trend for DOP of all six sites. Conestoga and Newport continue to have no trends for TNO_{23} and DNO_{23}, which constitutes the majority of TN and DN loads.

The data in Table 3 show that the high flow events drove the loads for many constituents including TP and SS during 2011. The three highest flow months of 2011 accounted for between 60–82 percent and 73–94 percent of the TP and SS load while TN loads accounted for 40–57 percent of that annual load. September alone accounted for 75 and 89 percent of the annual TP and SS load, respectively, at Conestoga. Considering the total flow and load of TN, TP, and SS transported from Marietta between 1987 and 2011, March, April, and September accounted for 3.7 percent of the flow, 3.03 percent of the TN, 7.92 percent of the TP, and 17.2 percent of the SS. September alone accounted for 1.12, 0.94, 4.71, and 12.36 percent of the total 24 year flow and load of TN, TP, and SS, respectively. The SS load that was transported past Marietta during September was equivalent to the entire load transported through Danville for 2011. This volume would be enough dry sand to reproduce the largest pyramid in Egypt two and a half times.

2011 showed that TN, TP, and SS react differently to individual high flow events. TN follows downward tendencies regardless of flow, whereas TP and SS show variable tendencies depending on presence of high flow events. A possible reason for this is management action that has occurred in the watershed. With increases in impervious surfaces and channeling of water into rivers, it is possible that storm flows are reaching their peaks faster and higher and subsequently having greater ability to erode streambanks and scour streambeds.

Another potential reason for the large increase in TP and SS load during a major event could be related to the watershed Best Management Practice (BMPs) design capacities. Since many BMPs are designed for 10 to 25-year storms, they cannot function properly during the extreme events that have hit the basin over the recent past including the major events of 2011 (Baldwin, 2007). Thus, while we find continued reductions in loads when we experience flows within their design capacity, massive transport of TP and SS occurred when flows surpassed the BMPs' functional design capacity.

Table 3. March, April, and September Total Precipitation, Flow, and Nutrient Loads as Percentage of Annual Totals and the Percent of LTM for Flow

Site	Time Period	Mean Q	High Daily Mean Q	Flow	TN	TP	SS
Towanda	March	47,732	106,000	20	23	18	8
	April	45,037	110,000	19	20	19	12
	September	36,785	220,000	15	14	40	73
	3-mo Total			54	57	77	94
Danville	March	69,235	167,000	18	22	17	9
	April	64,007	164,000	17	18	17	11
	September	64,923	301,000	17	15	39	72
	3-mo Total			52	55	73	91
Lewisburg	March	45,226	109,000	20	22	23	23
	April	44,343	99,500	20	19	25	25
	September	22,459	153,000	10	9	16	26
	3-mo Total			50	49	63	75
Newport	March	17,765	59,000	19	19	19	21
	April	15,755	40,600	17	16	15	16
	September	11,873	53,900	13	13	26	32
	3-mo Total			48	47	60	70
Marietta	March	162,713	423,000	18	19	16	12
	April	148,010	363,000	17	16	15	12
	September	137,867	616,000	16	16	44	63
	3-mo Total			51	51	75	88
Conestoga	March	1,651	7,960	12	13	4	3
	April	1,480	3,860	11	11	3	2
	September	3,034	25,400	22	17	75	89
	3-mo Total			45	40	82	93

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