2013 NUTRIENTS AND SUSPENDED SEDIMENT IN THE SUSQUEHANNA RIVER BASIN

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SUSQUEHANNA RIVER BASIN COMMISSION

The Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact* among the states of Maryland and New York, the Commonwealth of Pennsylvania, and the federal government. In creating the Commission, the Congress and state legislatures formally recognized the water resources of the Susquehanna River Basin as a regional asset vested with local, state, and national interests for which all the parties share responsibility. As the single federal-interstate water resources agency with basinwide authority, the Commission's goal is to coordinate the planning, conservation, management, utilization, development, and control of basin water resources among the public and private sectors.

**Statutory Citations: Federal - Pub. L. 91-575, 84 Stat. 1509 (December 1970); Maryland - Natural Resources Sec. 8-301 (Michie 1974); New York - ECL Sec. 21-1301 (McKinney 1973); and Pennsylvania - 32 P.S. 820.1 (Supp. 1976).*

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ABSTRACT

In the 1970s and early 1980s, scientists recognized that nutrients and suspended sediments entering the Chesapeake Bay (Bay) from its tributaries contributed to water quality problems in the Bay. At the time, the Lower Susquehanna River Basin, with its abundant farmland and urban settings, was considered the origin for much of the nutrient and sediment pollution that entered the Bay.

In 1985, the Susquehanna River Basin Commission (SRBC) along with partners consisting of the United States Geological Survey (USGS), Pennsylvania Department of Environmental Protection (PADEP), and United States Environmental Protection Agency (USEPA) began an intensive study of nutrient and sediment transport in the Susquehanna River Basin. Funding for the program was provided by grants from PADEP and the USEPA's Chesapeake Bay Program Office. The project was established to quantify amounts of the nutrients nitrogen (N) and phosphorus (P) as well as suspended sediment (SS) transported in the basin. Subsequently, the project was modified resulting in the current network of 26 sites throughout the Susquehanna River Basin. The monitoring network stations vary in watershed size and land use.

The project objectives currently include the following: (1) to measure and assess the actual nutrient and sediment concentration and load reductions in tributary strategy basins across the watershed; (2) to improve calibration and verification of the Bay partners' watershed models; and, (3) to assess factors affecting nutrient and sediment distributions and trends. This report summarizes the project's activities and findings based on sampling carried out through 2013.

In 2013, water samples were collected monthly regardless of flow status and eight additional samples were collected during four storm events that were spread throughout the year. An extra sample was collected each month at six long-term monitoring sites identified as Towanda, Danville, Lewisburg, Newport, Marietta, and Conestoga.

Sample collection was conducted using approved USGS methods including vertical and horizontal integration across the water column to ensure collection of a representative sample. Samples were analyzed for various nitrogen and phosphorus forms, total organic carbon (TOC), total suspended solids (TSS), and SS.

Data were used to calculate nutrient and sediment loads and trends using the USGS minimum variance unbiased estimator (MVUE) model (Cohn et al., 1989). Results for annual, seasonal, and monthly loads also were compared to long-term mean (LTM) to identify changes through time. A subset of cases were analyzed according to the ratio of discharge to rainfall (Q/P, the runoff ratio) as another means to discern trends and facilitate a more thorough understanding of processes that influence nutrient and sediment transport in the basin.

In 2013, precipitation across the basin was within approximately 10 percent of the LTM. Two basin-wide storm events occurred: one in January and another in November. Regional high rainfall events occurred in June in the northern part of the basin and in October in the southern part of the basin. These regional storms resulted in Conestoga having annual precipitation and flow slightly above LTM during 2013 and Towanda having Annual precipitation above annual LTM and flow slightly below LTM; all other stations were below LTM for precipitation and flow. High flows during winter months were exacerbated by melting snow.

Annual nutrient and sediment loads were below respective LTM at all sites, despite

monthly flows during February, June, and July that exceeded LTM for all sites. The 2013 yields for total nitrogen (TN), total phosphorus (TP), and SS were below baseline comparisons, but specific forms of N as well as TOC, were above at least one baseline condition at Towanda (DNO_x), Marietta (TOC), and Conestoga (TNO_x and DNO_x). Since the Bay monitoring project began, TN has expressed the most consistent and distinct downward trend throughout the basin.

Of the six long-term monitoring stations, Conestoga exhibited the highest yields (i.e., area-adjusted pollutant input) for TN, TP, and SS in 2013. Conestoga has the highest proportion of area given to urban development and agriculture and the lowest proportion of forest. The Marietta station provided the highest overall loading (i.e., total pollutant mass) for TN, TP, and SS in 2013. Newport and Lewisburg accounted for the lowest pollutant yields and loads.

In 2013, most individual forms of N and P as well as TN, TP, and SS adhered to trends of improvement, meaning that flow adjusted concentrations declined with respect to prior years. New downward trends, not apparent in 2012, were found for TNO_x at Newport and for dissolved ammonia (DNH_3) at Marietta. Mainstem Susquehanna River sites Towanda, Danville, and Marietta showed downward trends for all parameters except DNH_3 and dissolved orthophosphate (DOP). Trends with respect to DNH_3 at Towanda and Danville and DOP at Danville and Marietta could not be assessed because more than 20 percent of sample results were below method detection limit (BMDL). DOP showed an upward trend at Towanda. Conestoga had downward trends for all parameters except TNO_x and DNO_x, which constituted the majority of TN and dissolved nitrogen (DN) at the station. Newport had no trends in DNO_x, total ammonia (TNH_3), and DNH_3 and an upward trend in DOP; all others were downward. Lewisburg had downward trends in all nitrogen species except TNH3 and DNH_3 and no trends in phosphorus or TOC. There were no trends in flow at any site.

BACKGROUND

Nutrients and SS entering the Chesapeake Bay from all of its tributaries contribute to nutrient enrichment problems in the Bay; the Susquehanna River Basin is the largest single freshwater source to the Bay; contributing approximately 60 percent of freshwater stream flow. Although the largest non-tidal source of water to the Bay, 2009 modeled estimates for the Susquehanna River accounted for 46 percent of TN, 26 percent of TP, and 33 percent of the SS loads to the Bay (USEPA, 2010).

Efforts have been underway to improve water quality in the Bay since the 1970s. Emphasis has been placed on nutrient-reduction strategies that include:

- regulated limits and phase-out of certain P-containing detergents;
- more stringent effluent limits on N and P point-source discharges;
- adoption of agriculture Best Management Practices (BMPs) that seek to optimize fertilizer application rates and timing to better coincide with site-specific soil conditions and seasonal crop demand; and,
- promotion of stormwater BMPs that seek to reduce N and P associated with non point-sources.

Begun in 1985, the initial Bay monitoring network consisted of two mainstem sites on the Susquehanna River and 10 tributary sites. The original project goal was to develop baseline nutrient loading data. Since 1989, several modifications to the network have occurred as follows:

- 1990, the number of stations was reduced to five;
- 1994, one station was added;
- 2004, 13 stations were added;
- 2005, four stations were added;
- 2012, four stations were added; and,
- 2013, one site was dropped in 2013.

The current network consists of six sites on the mainstem of the Susquehanna River and 20 tributary sites. The 26 site network contains five sites in New York, 20 in Pennsylvania, and one in Maryland. Table 1 lists the individual sites grouped as long-term sites (Group A) and enhanced sites (Group B) along with subbasin, drainage area, USGS gage number, and land use. Actual locations of current sites are shown in Figure 1.

All site additions from 2004 onward were added as part of the Chesapeake Bay Program's Non-tidal Water Quality Monitoring Workgroup's effort to develop a non-tidal monitoring network uniform in site selection criteria, parameters analyzed, and collection and analysis methodology. Objectives for the network included the following: to measure and assess the actual nutrient and sediment concentration and load reductions in the tributary strategy basins across the watershed; to improve calibration and verification of the partners' watershed models; and to help assess the factors affecting nutrient and sediment distributions and trends. Specific site selection criteria included location at outlets of major streams draining the tributary strategy basins, location in areas within the tributary strategy basins that have the highest nutrient delivery to the Bay, and to ensure the various conditions in the Bay watershed among land use type, physiographic/geologic setting, and watershed size were adequately represented.

This project involves monitoring efforts conducted by all six Bay state jurisdictions, the District of Columbia, USEPA, USGS, and SRBC. The purpose of this report is to present basic information on annual and seasonal loads and yields of nutrients and SS measured during calendar year 2013 at the six SRBC-monitored long-term sites, and present summary statistics for the additional 20 enhanced sites, and to determine whether changes in water quality have occurred.

DESCRIPTION OF THE SUSQUEHANNA RIVER BASIN

The Susquehanna River drains an area of 27,510 square miles (Susquehanna River Basin Study Coordination Committee, 1970), and is the largest tributary to the Chesapeake Bay. The Susquehanna River originates in the Appalachian Plateau of southcentral New York, flows into the Valley and Ridge and Piedmont Provinces of Pennsylvania and Maryland, and joins the Bay at Havre de Grace, Md. The climate in the Susquehanna River Basin varies considerably from the low lands adjacent to the Bay in Maryland to the high elevations, above 2,000 feet, of the northern headwaters in central New York State. The annual mean temperature ranges from 53^{o} F (degrees Fahrenheit) near the Pennsylvania-Maryland border to 45^{o} F in the northern part of the basin. Annual precipitation in the basin averages 40 inches and is fairly well distributed throughout the year.

Land use in the Susquehanna River Basin, shown in Table 1, is predominantly rural with woodland accounting for 69 percent; agriculture, 21 percent; and urban, 7 percent. Woodland occupies the higher elevations of the northern and western parts of the basin and much of the mountain and ridge land in the Juniata and Lower Susquehanna Subbasins. Woods and grasslands occupy areas in the lower part of the basin that are unsuitable for cultivation because the slopes are too steep, the soils are too stony, or the soils are poorly drained. The Lower Susquehanna Subbasin contains the highest density of agriculture operations within the watershed. However, extensive areas are cultivated along the river valleys in southern New York and along the West Branch Susquehanna River from Northumberland, Pa., to Lock Haven, Pa., including the Bald Eagle Creek Valley.

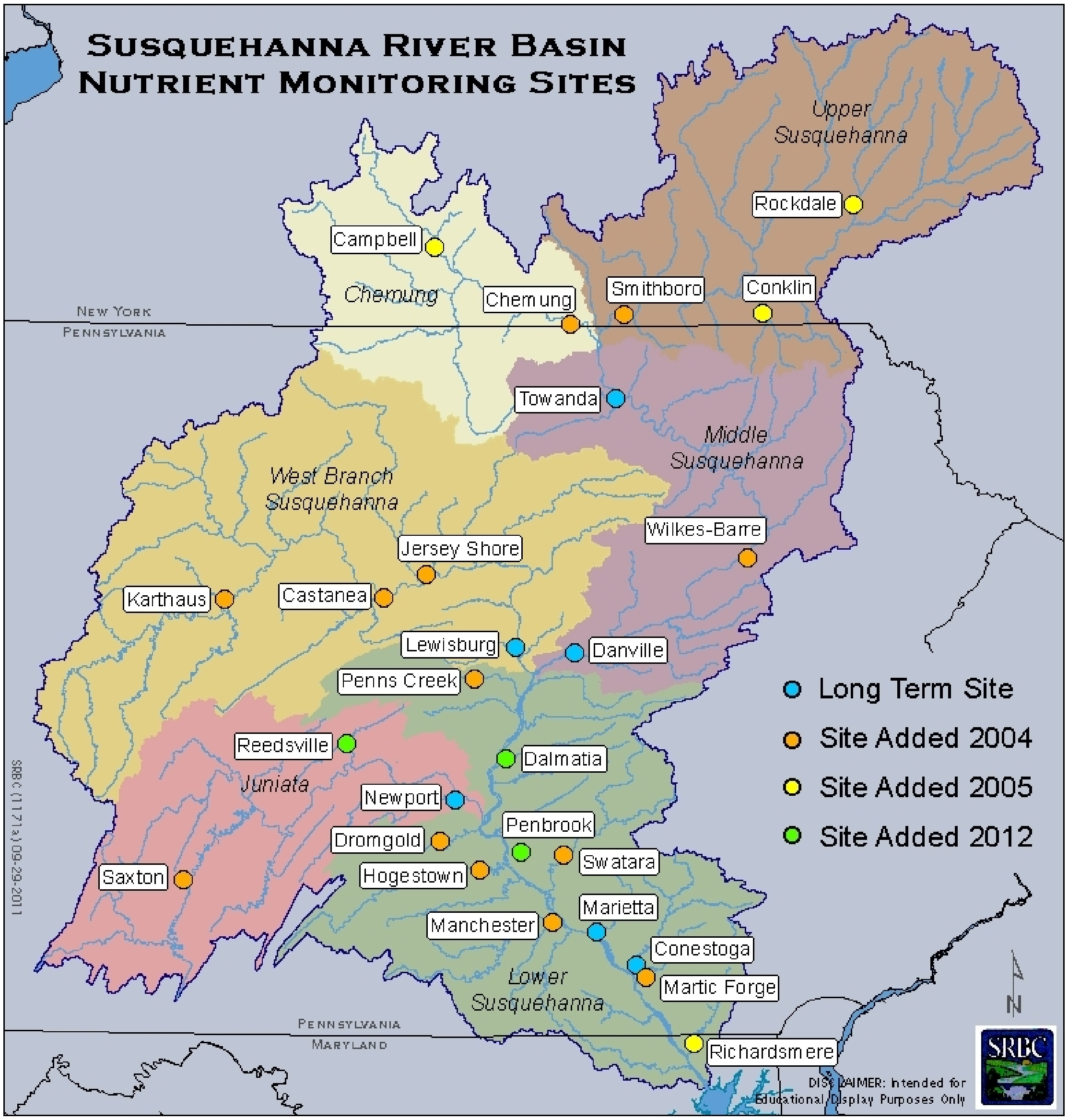

Figure 1. ***Locations of Sampling Sites Within the Susquehanna River Basin***

Table 1. Data Collection Sites and Their Drainage Areas and 2000 Land Use Percentages

Site Location	USGS Site ID	Subbasin	Waterbody	Drainage Area (Sq. Mi.)	Water/ Wetland	Urban	Agricultural			Forest	Other
							Row Crops	Pasture Hay	Total		
Group A: Long-term Sites											
Towanda	01531500	Middle Susquehanna	Susquehanna	7,797	2	5	17	5	22	71	0
Danville	01540500	Middle Susquehanna	Susquehanna	11,220	2	6	16	5	21	70	1
Lewisburg	01553500	W Branch Susquehanna	W Branch Susquehanna	6,847	1	5	8	2	10	84	0
Newport	01567000	Juniata	Juniata	3,354	1	6	14	4	18	74	1
Marietta	01576000	Lower Susquehanna	Susquehanna	25,990	2	7	14	5	19	72	0
Conestoga	01576754	Lower Susquehanna	Conestoga	470	1	24	12	36	48	26	1
Group B: Enhanced Sites											
Rockdale	01502500	Upper Susquehanna	Unadilla	520	3	2	22	6	28	66	1
Conklin	01503000	Upper Susquehanna	Susquehanna	2,232	3	3	18	4	22	71	1
Itaska	01511500	Upper Susquehanna	Tioughnioga	730	2	4	22	5	27	66	1
Smithboro	01515000	Upper Susquehanna	Susquehanna	4,631	3	5	17	5	22	70	0
Campbell	01529500	Chemung	Cohocton	470	3	4	13	6	19	74	0
Chemung	01531000	Chemung	Chemung	2,506	2	5	15	5	20	73	0
Wilkes-Barre	01536500	Middle Susquehanna	Susquehanna	9,960	2	6	16	5	21	71	0
Karthaus	01542500	W Branch Susquehanna	W Branch Susquehanna	1,462	1	6	11	1	12	80	1
Castanea	01548085	W Branch Susquehanna	Bald Eagle	420	1	8	11	3	14	76	1
Jersey Shore	01549760	W Branch Susquehanna	W Branch Susquehanna	5,225	1	4	6	1	7	87	1
Saxton	01562000	Juniata	Raystown Branch Juniata	756	< 0.5	6	18	5	23	71	0
Reedsville	01565000	Juniata	Kishacoquillas	164	<0.5	5	20	6	26	67	2
Dalmatia	01555500	Lower Susquehanna	East Mahantango	162	1	6	20	6	26	66	1
Penbrook	01571000	Lower Susquehanna	Paxton	11	<0.5	50	9	11	20	29	1
Penns Creek	01555000	Lower Susquehanna	Penns	301	1	3	16	4	20	75	1
Dromgold	01568000	Lower Susquehanna	Shermans	200	1	4	15	6	21	74	0
Hogestown	01570000	Lower Susquehanna	Conodoguinet	470	1	11	38	6	44	43	1
Hershey	01573560	Lower Susquehanna	Swatara	483	2	14	18	10	28	56	0
Manchester	01574000	Lower Susquehanna	West Conewago	510	2	13	12	36	48	36	1
Martic Forge	01576787	Lower Susquehanna	Pequea	155	1	12	12	48	60	25	2
Richardsmere	01578475	Lower Susquehanna	Octoraro	177	1	10	16	47	63	24	2
			Entire Susquehanna River Basin	27,510	2	7	14	7	21	69	1

Major urban areas in the basin, many of which are located along river valleys, include: Binghamton, N.Y., in the Upper Susquehanna Subbasin; Corning and Elmira, N.Y., in the Chemung Subbasin; Scranton and Wilkes-Barre, Pa., in the Middle Susquehanna Subbasin; Clearfield, Lock Haven, and Williamsport, Pa., in the West Branch Subbasin; Altoona and Lewisburg, Pa., in the Juniata Subbasin; and Harrisburg, Lancaster, Sunbury, and York, Pa., in the Lower Susquehanna Subbasin.

SAMPLE COLLECTION

2013 sampling efforts at the six long-term (Group A) sites included sampling during monthly base flow conditions, monthly flow-independent conditions, and seasonal storm conditions. This resulted in two samples collected per month: one with a set date near the twelfth of each month independent of flow and one based on targeting monthly base flow conditions. The mid-monthly samples were intended to be flow independent with the intention that the data would help to quantify long-term trends. Additionally, due to the linkage of high flow and nutrient and sediment loads, it was necessary to target storm events for additional sampling to adequately quantify loads. Long-term site sampling goals included targeting one storm per season with a second storm collected during the spring season. Spring storms were planned to collect samples before and after agricultural crops had been planted.

All storm samples were collected during the rising and falling limbs of the hydrograph with goals of three samples on each side and one sample as close to the peak as possible. The enhanced sites (Group B) targeted a mid-monthly flow independent sample and two storm samples per season. Storm samples were planned to have one sample on the rising limb and one on the falling limb of the hydrograph with the goal that one of the two be as close to the peak as possible. Due to the quick nature of the hydrograph on several of the smaller streams, sometimes the two storm samples per season were taken from two different storms with the goal of having samples as close to the peak of each storm as possible.

The goal of sample collection was to collect a sample representative of the entire water column. Due to variations in stream width and depth and subsequent lack of natural mixture of the stream, it was necessary to composite several individual samples across the water column into one representative sample. The number of individual verticals at each site varied from three to ten dependent upon the stream width. Based on USGS depth integrated sampling methodology at each vertical location, the sampler was lowered at a consistent rate from the top of the water surface to the stream bottom and back to insure water from the entire vertical column was represented (Myers, 2006). Instream water quality readings were taken at each vertical to insure accurate dissolved oxygen and temperature values.

All samples were processed onsite and included whole water samples analyzed for nitrogen and phosphorus species, TOC, TSS, and SS. For Group B sites, SS samples were only collected during storm events. Additionally, filtered samples were processed onsite to analyze for DN and DP species. Several sites included additional parameters pertinent to the natural gas industry.

SAMPLE ANALYSIS

Samples were either hand-delivered or shipped directly to the appropriate laboratory for analysis on the day following collection. When storm events occurred over the weekend, samples collected were analyzed on the following Monday. Samples collected in Pennsylvania and at the Octoraro Creek site near Richardsmere, Md., were delivered to PADEP's Bureau of Laboratories in Harrisburg, Pa. Samples collected at New York sites were shipped to ALS Environmental Laboratory in Rochester, N.Y. Parameters for all samples at all sites included various nitrogen and phosphorus species, TOC, and TSS. Specific parameters, methodology, and detection limits are listed in Table 2.

Due to the high influence of stormflow on sediment concentrations, SS samples were collected during storm events at all sites with the goal of two samples for each event and one event per quarter. Of the two samples per storm, the more sediment-laden sample was analyzed for both sediment concentration and sand/fine particle percentage. The additional sample was submitted for sediment concentration only. Sediment samples were shipped to the USGS sediment laboratory in Louisville, Ky., for analysis. Additional SS samples also were collected at all Group A sites as part of each sampling round. These samples were analyzed at the SRBC laboratory for sediment concentration alone.

Table 2. Water Quality Parameters, Laboratory Methods, and Detection Limits

Parameter	Storet	Laboratory	Methodology	Detection Limit (mg/l)	References
Total Ammonia (TNH_3)	610	PADEP	Colorimetry	0.020	USEPA 350.1
		CAS*	Colorimetry	0.010	USEPA 350.1R
Dissolved Ammonia (DNH_3)	608	PADEP	Block Digest, Colorimetry	0.020	USEPA 350.1
		CAS*	Block Digest, Colorimetry	0.010	USEPA 350.1R
Total Nitrogen (TN)	600	PADEP	Persulfate Digestion for TN	0.040	Standard Methods #4500-N_{org}-D
Dissolved Nitrogen (DN)	602	PADEP	Persulfate Digestion	0.040	Standard Methods #4500-N_{org}-D
Total Organic Nitrogen (TON)	605	N/A	TN minus TNH_3 and TNO_x	N/A	N/A
Dissolved Organic Nitrogen (DON)	607	N/A	DN minus DNH_3 and DNO_x	N/A	N/A
Total Kjeldahl Nitrogen (TKN)	625	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Dissolved Kjeldahl Nitrogen (DKN)	623	CAS*	Block Digest, Flow Injection	0.050	USEPA 351.2
Total Nitrite plus Nitrate (TNO_x)	630	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
		CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Nitrite plus Nitrate (DNO_x)	631	PADEP	Cd-reduction, Colorimetry	0.010	USEPA 353.2
		CAS*	Colorimetric by LACHAT	0.002	USEPA 353.2
Dissolved Orthophosphate (DOP)	671	PADEP	Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Dissolved Phosphorus (DP)	666	PADEP	Block Digest, Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Phosphorus (TP)	665	PADEP	Persulfate Digest, Colorimetry	0.010	USEPA 365.1
		CAS*	Colorimetric Determination	0.002	USEPA 365.1
Total Organic Carbon (TOC)	680	PADEP	Combustion/Oxidation	0.50	SM 5310D
		CAS*	Chemical Oxidation	0.05	GEN 415.1/9060
Total Suspended Solids (TSS)	530	PADEP	Gravimetric	5.0	USGS I-3765
		CAS*	Residue, non-filterable	1.1	SM2540D
Suspended Sediment Fines	70331	USGS	**		
Suspended Sediment (SS)	80154	SRBC	**		
		USGS	**		

* Columbia Analytical Services, Rochester, N.Y. (New York sites only)
** TWRI Book 3, Chapter C2 and Book 5, Chapter C1, Laboratory Theory and Methods for Sediment Analysis (Guy and others, 1969)

PRECIPITATION AND DISCHARGE

Precipitation data were obtained from long-term monitoring stations operated by the U.S. Department of Commerce. The data are published as Climatological Data–Pennsylvania, and as Climatological Data–New York by the National Oceanic and Atmospheric Administration at the National Climatic Data Center in Asheville, N.C. Monthly data from these online sources were compiled across the subbasins of the Susquehanna River Basin. Discharge values were obtained from the USGS gaging network system. All sites were collocated with USGS gages so that discharge amounts could be matched with each sample. Average daily discharge values for each site were used as input to the estimator model used to estimate nutrient and sediment loads and trends. Average monthly flow values were used to check for trends in flow.

DATA ANALYSIS

Sample results were compiled into an existing comprehensive database that included all years of the program. These data were then listed on SRBC's web site as well as submitted to various partners for use with models and individual analyses. Specific analyses completed by SRBC staff include load and trend estimation, yields, LTM comparisons, and runoff ratio comparisons.

Loads and Yields

Load and yield represents two methods for describing nutrient and SS amounts. Load refers to the actual mass of the constituent being transported in the water column past a given point over a specific duration of time and is expressed in units of mass/time. Yield compares the transported load with the watershed land area and is expressed in units of mass/area. Yield allows for comparison regardless of watershed size differences. This project reports loads and yields for the constituents listed in Table 2 as computed by the Minimum Variance Unbiased Estimator (MVUE) described by Cohn and others (1989). MVUE relates the constituent concentration to water discharge rate, seasonal effects, and long-term trends, and computes the best-fit regression equation. Daily loads of the constituents were then calculated from the daily mean water discharge records. The loads were reported along with the estimates of accuracy. Average concentrations were determined by dividing the total load by the total flow during the time period and were reported in mg/L. 2013 yield, load, and calculated concentration data are listed in Appendix A.

Summary statistics are listed in Appendix B and include minimum, maximum, median, mean, and standard deviation values taken from the 2013 dataset.

Discerning Trends

Nutrient and sediment transport processes largely are governed by precipitation and stream flow, as well as seasonal cycles of plant communities, and the timing of fertilizer applications. A substantial challenge to understanding pollutant trends is whether management outcome effects can be separated from the plethora of factors that influence nutrient and sediment dynamics. Although the relationship is not always linear, high flow generally increases constituent loads in streams (Ott and others, 1991; Takita, 1996, 1998).

The following subsections describe several techniques that were employed in a weight-of-evidence approach to assess whether nutrient and sediment-reduction strategies have had a positive effect in the Susquehanna River Basin. Long-term mean (LTM) ratio and flow-adjusted concentration (FAC) approaches were applied to all of the long-term monitoring stations and each of the pollutant forms; whereas, runoff ratio techniques were used on subsets of cases (stations and pollutant forms) as a means to introduce a novel trend-discerning approach in a future reporting phase.

Long-Term Mean Ratio

In an attempt to determine annual changes from previous years, 2013 nutrient and SS loads, yields, and concentrations were compared to

LTMs. LTM load and discharge ratios were calculated for a variety of time frames, including annual, seasonal, and monthly, by dividing the 2013 value by the LTM for the same time frame and reported as a percentage or ratio. It was thought that identifying sites where the percentage of LTM for a constituent, termed the load ratio, was different than the corresponding percentage of LTM for discharge, termed the water-discharge ratio or discharge ratio, would suggest areas where improvements or degradations may have occurred for that particular constituent. Specifically, 2013 annual discharge ratio at Conestoga was 107 percent while annual TN, TP, and SS ratios were 96, 67, and 28 percent, respectively. At odds with the conclusion is that individual high flow events tend to produce higher loads, especially for TP and SS, than would be predicted by a simple comparison with the LTM. This was seen for October at Conestoga where the discharge ratio was 203 percent and the TN, TP, and SS ratios were 166, 276, and 188 percent, respectively. Thus, apparent changes in water quality based on LTM comparison may be masked by the presence or absence of significant storm events.

Baseline Comparisons

As a means to determine whether the annual fluctuations of nutrient and SS loads were due to water discharge, Ott and others (1991) used the relationship between annual loads and annual water discharge. This was accomplished by plotting the annual yields against the water-discharge ratio for a given year to calculate a baseline regression line. Data from the initial five-year study (1985-89) were used to provide a best-fit linear regression trend line to be used as the baseline relationship between annual yields and water discharge. It was hypothesized that as future yields and water-discharge ratios were plotted against the baseline, any significant deviation from the baseline would indicate that some change in the annual yield had occurred, and that further evaluations to determine the reason for the change were warranted.

Due to the size of the current dataset, the opportunity exists for there to be non-linear changes in the yield versus water discharge plot as more years are added. Therefore, this report included comparisons to baselines created from different time frames including the initial five-year period of the dataset for each station, the first half of the entire dataset, the second half of the entire dataset, and the entire dataset. Although the tendency was for increasing loads to be associated with increasing flows, this relationship was not strictly linear, especially regarding TP and SS.

All comparisons include an associated R^2 value representing the strength of the correlation between the two parameters in the regression. The closer the R^2 is to a value of one, the better the regression line is for accurately using one variable (flow) to predict the other. An R^2 of one indicates that there is perfect correlation between the two variables. For example, R^2 values for TN tend to be close to one as the relationship between TN and flow is very strong and consistent through various ranges of flows. R^2 values for TP and SS tend to vary more, especially towards higher flows. Thus, when regression graphs include high flow events, the resulting correlation tends to be weaker as indicated by a low R^2 value. This is an indication that single high flow events, and not necessarily a high flow year, are the highest contributors to loads in TP and SS and that these contributions do not necessarily follow a strictly linear increase.

Figure 2 shows the baseline regression line developed for TN at Marietta using the first half of the dataset where each hollow circle represents an individual year during that time period. Each was plotted using an individual year's yield and discharge ratio. The discharge ratio was calculated by dividing the year's annual flow by the average flow for the baseline years used. A regression line was plotted through these data points and the equation of the regression line was used to calculate a baseline prediction for the 2013 yield given the 2013 discharge ratio. The baseline prediction for 2013 TN yield is shown as a black X at 6.98 lbs/ac. The actual 2013 yield at the same discharge ratio, 4.98 lbs/ac, is shown as the black diamond (Figure 2). Since the actual 2013 yield was lower than the prediction made by the first 13 years of data, the comparison suggests that improvements have occurred.

Figure 3 shows the baseline regression lines that were developed using the initial five years at Marietta, the first 13 years at Marietta, and the most recent 13 years at Marietta. Using multiple regression lines developed from different time periods within that dataset also can show whether changes occurred. (For example, at a discharge ratio of 0.84, the initial 13-year baseline predicts the 2013 yield to be 6.98 lbs/ac, while the actual 2013 yield was 4.98 lbs/ac.) Comparison to the regression from the most recent 13 years, which predicted the 2013 TN yield to be 5.97 lbs/ac, implies that yields during the first half of the dataset were higher than the second half of the dataset. Additional support for improvements can be seen when comparing regression lines to each other. As more recent years were added to the baseline, the slope of the regression line decreased. This suggested that the more recent 13-year dataset included lower yield values as compared to the initial 13-year dataset. Thus, a regression line that predicts lower yields for the same water discharge ratio directly implies improved water quality between the two timeframes.

Due to the different behavior of TP and SS with regard to flow, the baseline comparison between time frames showed different results. Figures 4 and 5 show that baselines from more recent data have a steeper slope suggesting improvements from the original baselines at low flows and degradations at high flows. Figure 5 shows a baseline for the most recent half of the dataset and the same baseline with the effects of Tropical Storm Lee in 2011 removed. The slope of the baseline is greatly reduced but still suggests that high flows have been producing higher loads of SS in recent years when compared to the early years of the program. 2013 baseline data is listed in Appendix A.

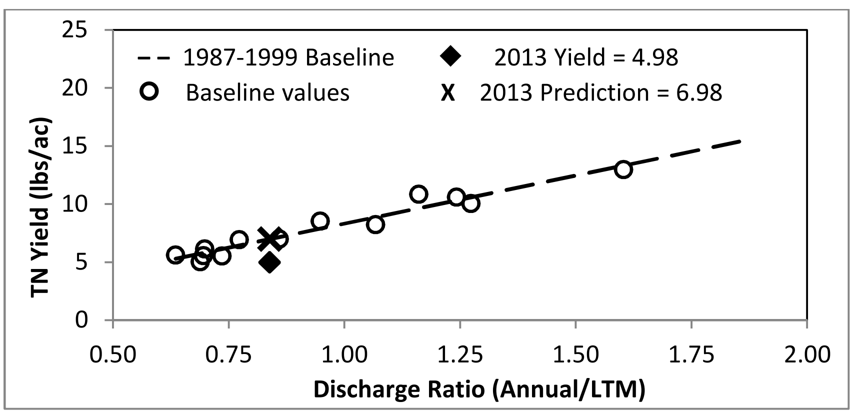

Figure 2. First Half Baseline Regression Line, 2013 TN Yield Prediction, and Actual 2013 Yield for TN at Marietta

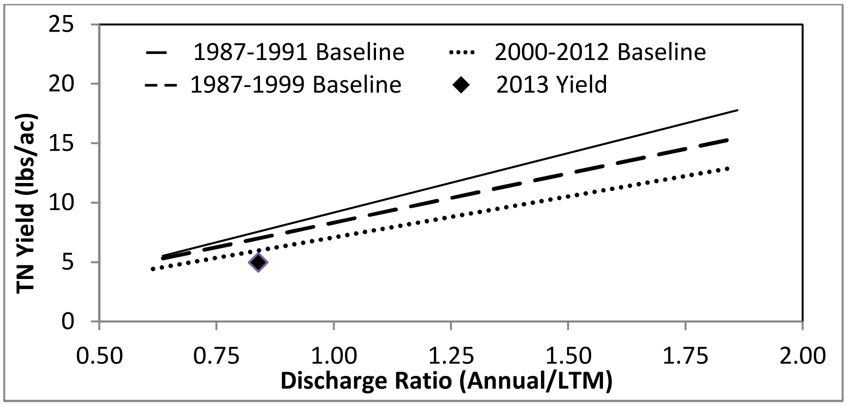

Figure 3. Initial, First Half, and Second Half Baseline Regression Lines, Yield Predictions, and Actual 2013 Yields for TN at Marietta

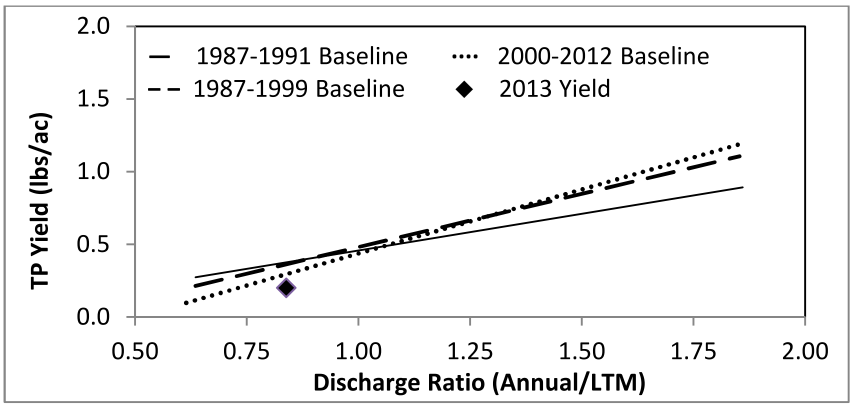

Figure 4. Initial, First Half, and Second Half Baseline Regression Lines, Yield Predictions, and Actual 2013 Yields for TP at Marietta

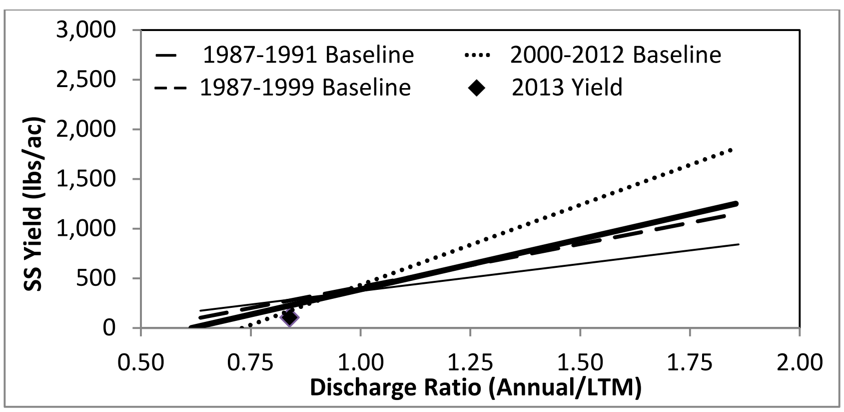

Figure 5. Initial, First Half, and Second Half Baseline Regression Lines, Yield Predictions, and Actual 2013 Yields for SS at Marietta

Flow-Adjusted Trends

Flow-Adjusted Concentration (FAC) trend analyses of water quality and flow data collected at Danville, Lewisburg, Newport, and Conestoga were completed for the period January 1984 through December 2013. Sample collection at Marietta and Towanda began later and their respective trend periods are 1986-2013 and 1988-2013. Trends were estimated based on the USGS water year, October 1 to September 30, using the USGS 7-parameter, log-linear regression model (MVUE) developed by Cohn and others (1989) and described in Langland and others (1999). MVUE relates the constituent concentration to water discharge, seasonal effects, and long-term trends, and computes the best-fit regression equation. These tests were used to estimate the direction and magnitude of trends for SS, TOC, and several forms of nitrogen and phosphorus. Trend slope, p-value, and sigma (error) values are taken directly from ESTIMATOR output. These values are then used to calculate flow-adjusted trends using the following equations:

Trend =
100*(exp(Slope *(end yr – begin yr)) – 1)

Trend minimum =
100*(exp((Slope – (1.96*sigma)) *(end yr – begin yr)) – 1)

Trend maximum =
100*(exp((Slope + (1.96*sigma)) *(end yr – begin yr)) – 1)

The USGS program ESTREND was used to conduct Seasonal Kendall trend analysis on flows (Schertz and others, 1991). Trend results were reported for monthly mean discharge (FLOW) and individual parameter FACs. Trends in discharge indicate any natural changes in hydrology. Changes in flow and the cumulative sources of flow (base flow and overland runoff) affect the observed concentrations and the estimated loads of nutrients and SS. The FAC is the concentration after the effects of flow are removed from the concentration time series. Trends in FAC indicate that changes have occurred in the processes that deliver constituents to the stream system. After the effects of flow are removed, this is the concentration that relates to the effects of nutrient-reduction activities and other actions taking place in the watershed. A description of the methodology is included in Langland and others (1999).

INDIVIDUAL SITES

The following discussion of individual long-term Group A sites includes comparison to LTMs, baseline regression lines, and short- and long-term trends. LTM comparisons were intended to identify variations between discharge and individual parameters. Differences between the discharge ratio (2013 flow divided by the LTM) and the parameter LTM ratio imply changes from the historical means. Additional historical comparisons include baseline data predictions. Plotting yields versus discharge ratios for different periods allows a view of the current year from the context of previous historical periods. It also allows different time periods to be compared. Baselines from the initial five years of data at a site, the first half of the dataset, the second half of the dataset, and the full dataset have been used.

Towanda

2013 annual precipitation above Towanda was 2.79 inches above the LTM with high rainfall during June. Resultant annual flows were 97 percent of the LTM. High flow events were fairly distributed throughout the year including events with greater than 1 inch of precipitation during January, May, June, July, August, September, and November. The most significant rainfall event occurred June 28 in the Upper Susquehanna where 2.05 and 3.48 inches of rain were recorded at Cooperstown and Norwich, N.Y., respectively.

2013 flow at Towanda included eight peak flows over 30,000 cfs; four of which were over 50,000 cfs. Highest flow occurred during February followed by July, December, and March. High flows in February and July were driven by rainfall that occurred during the end of the previous month. Additionally, snowmelt was a factor contributing to high flows during January, February, March, and December.

Annual loads at Towanda for all parameters were below LTMs with phosphorus species and SS, the parameters most affected by stream flow, deviating farthest. TP was 55 percent, DP was 51 percent, DOP was 52 percent, and SS was 37 percent of their respective LTMs. Flows during June, July, and August were well above LTMs resulting in TN and TP being above LTMs for all three while SS was only above LTMs during July. Peak flow during June and August was above 30,000 cfs while the July peak flow topped 50,000 cfs. SS was only above LTM during July due to the excessive rainfall in the northern basin on June 28 and additional rainfall in early July. Similar peaks, driven by snowmelt during March and December, produced higher TN loads and lower TP and SS loads than July.

2013 yields for all parameters were below baseline predictions except for DNO_x when compared to the most recent half of the dataset and DOP when compared to the early baselines. Comparison to initial five-year baselines showed the biggest reductions in TNH_3 and DP. TOC, TNO_x, and DNO_x had the lowest reductions while DOP showed increases. The majority of nitrogen reductions were found in the NO_x and organic fractions. FAC trends were in agreement with baseline comparisons although reductions with TP and DP showed smaller. FAC trends for all parameters were downward except for DOP which was upward. Trend analysis could not be conducted on DNH_3 due to greater than 20 percent of the values being BMDL. There were no trends in flow.

Danville

2013 annual precipitation above Danville was 0.62 inches below the LTM with low rainfall during winter followed by high spring rainfall. Winter, Spring, and Fall flows were below LTMs while summer was 160 percent of the LTM due to high July flows. Annual flow was 90 percent of the LTM. Highest flow, above 85,000 cfs, occurred during January and February, driven by moderate rainfall coupled with snowmelt. 2013 had six instances where the flow was above 50,000 cfs including January, February, March, April, June, and December.

All 2013 annual nutrient and SS loads were below their respective LTMs. Monthly loads were above LTMs during June and August for TN, February for SS, and July for TN, TP, and SS. February's high sediment load was a result of modest rainfall coupled with snowmelt. Average flow for July was fifth highest for the year while the peak flow was second highest behind February's peak. July represented the largest deviation above the LTMs for flow, TN, TP, and SS.

All 2013 yields were below baseline predictions except for DOP, which was above both the initial five-year baseline and the baseline from the first half of the dataset. Initial five-year baseline comparisons were similar to those found at Towanda for TNO_x and DNO_x at 26 percent and 25 percent, respectively. All other forms of nitrogen showed larger reductions as did TP, TOC, and SS while DOP showed a 10 percent increase. Largest reductions suggested by the comparison were for TNH_3, DNH_3, TON, DON, TP, and DP. All parameters continue to have downward trends during the time frame except DHN_3 and DOP, which were unable to be analyzed due to BMDL. There were no flow trends at Danville.

Marietta

2013 annual precipitation was 2.11 inches below LTM resulting in annual flow being 84 percent of LTM. Summer was the only season with flows above LTM due to high rainfall in the northern basin and West Brach of the Susquehanna during June, July, and August. The most significant storm event of 2013 in the lower portion of the basin occurred during October 10-12 with between 5-10 inches of rain falling in Adams, York, Lancaster, Cumberland, Dauphin, Franklin, Lebanon, and Perry counties. While most rainfall was in the Juniata, Lower Susquehanna, and Conestoga subbasins, the West Branch of the Susquehanna received between 1 and 2 inches on October 11. The result was a spike in flow above 100,000 cfs at Marietta, which did not occur at Towanda or Danville.

2013 was a relatively dry year that included six events that were over 100,000 cfs and one that was over 200,000 cfs in January/February. For comparison, 2011 contained five events over 200,000 cfs, three over 300,000 cfs, and one over 600,000 cfs. 2013 spent the equivalent of 11 days over 100,000 cfs, while 2011 spent the equivalent of 90 days over 100,000 cfs.

2013 annual loads for all nutrients and SS were below LTMs at Marietta. Winter had the highest loads for all parameters except DOP, which was highest in fall. February and July had the highest departure from LTMs for TN, TP, and SS. Combined load for the two months was 22 percent, 30 percent, and 39 percent of the annual TN, TP, and SS load, respectively.

All 2013 baseline comparisons suggested improvements for all parameters. Initial five-year baseline showed largest improvements in SS, TON, and TP. This baseline showed lowest improvements for TOC, TNO_x, and DNO_x. Improvements in TNO_x and DNO_x at Marietta were lower than those shown at Danville and Towanda. FAC trends results were similar to baseline comparisons for most parameters. Biggest differences between trend reductions and baseline reductions were shown for THN_3, DNH_3, DOP, and SS. Trends for all parameters, except DOP, were downward including a new downward trend in DNH_3, which was not found previously due to BMDL. Largest reductions were in TON, DON, DP, and SS. There were no flow trends.

Lewisburg

Lewisburg received the least amount of precipitation of all sites during 2013. Annual precipitation was 4.69 inches below the LTM with large shortfalls during winter and summer. Significant storms in the West Branch of the Susquehanna occurred in January, June, October, and November. The largest single event occurred on June 28 when 3.38 inches were recorded at State College, Pa. 2013 annual flow was 81 percent of the LTM with highest flows during February and December due to rainfall coupled with snowmelt. Flow crossed 30,000 cfs at Lewisburg five times during 2013 including an annual peak flow of 76,400 cfs on February 1.

Annual loads at Lewisburg were below LTMs for all parameters. Seasonal loads of all parameters were highest during winter followed by fall. 2013 monthly loads were above LTMs during July for TN, TP, and SS and February for SS. Flow during July was well above LTM at 202 percent. This resulted in the largest monthly departures from the LTMs in TN, TP, and SS with 142 percent, 128 percent, and 225 percent of their LTMs, respectively. Monthly TN and SS loads were highest during February, driven by modest rainfall coupled with snowmelt.

All 2013 yields were below baseline predictions. Largest reductions in nitrogen species by percent were for TON and DON, which were 63 and 66 percent lower than the five-year baseline prediction. 2013 TNO_x and DNO_x yields were 24 and 23 percent lower than the five-year baselines. FAC trends magnitudes showed similar reductions for the four constituents. Trends analyses could not be conducted for TNH_3, DNH_3, DP, and DOP due to BMDL and there were no trends for TOC. All other parameters had downward trends. There were no trends in flow.

Newport

2013 annual precipitation in the Juniata subbasin was 2.79 inches below the LTM with winter and summer having the largest departures below the LTM. Annual discharge was 79 percent of the LTM with one large event occurring during the end of January into the beginning of February that peaked at 34,800 cfs. Two other events, one earlier in January and one in December, had flows above 10,000. All three events were the results of modest rainfall coupled with snowmelt.

The largest 2013 precipitation event occurred on October 11 with above 2 inches of rainfall. Although this was by far the largest rain event, the resulting peak flow was the ninth highest for the year. Two other events, June 28 and November 26-27 were the next largest storm events. June’s event led to the fourth highest peak for 2013 while November's event results in a peak just short of the October event.

2013 annual loads for all parameters were below their respective LTMs. Winter produced the highest loads for all parameters. TNO_x and DNO_x during January and February and SS during February were the only parameters that were above monthly LTMs while monthly flows for January, February, and July were above LTMs.

2013 yields were below all baseline predictions. Comparison to initial five-year baselines suggested modest reductions in TNO_x and DNO_x of 8 percent and 5 percent, respectively. Reductions suggested by baselines were largest for TON, DON, TNH_3, and DNH_3 with 57 percent reductions in both TON and TNH_3, and 54 percent reductions in DON and DNH_3. FAC trend results were in relative agreement with baseline findings for TON and DON but showed lower reductions in TNH_3 and DNH_3. Initial five-year baseline comparisons suggested 70 percent reduction in TP and DP, 40 percent reduction in DOP, 36 percent reduction in TOC, and 74 percent reduction in SS. TP, DP, TOC, and SS reductions predictions were larger than their associated FAC trends predictions.

2013 trends results at Newport included no trend in DNO_x, no trends in TNH_3 and DNH_3 due to BMDL, and an upward trend in DOP. All other trends were downward. The majority of the reductions in TN and DN suggested by trends analyses occurred in TON and DON, which accounted for approximately 20 percent of the TN and DN load. TNO_x was a new downward trend, not found in 2012. There were no trends in flow.

Conestoga

2013 annual precipitation at Conestoga was 3.09 inches above the LTM due to two significant flooding events in January and October. Both events produced more than 3 inches of rain per day including two day totals between five and ten inches during October. Both events resulted in peak flows over 13,000 cfs although the January event occurred at the end of the month with the majority of the flow occurring in February. Other significant events, with greater than 2 inches per day, occurred during June, July, August, and November. Although two of those events occurred during summer, the season total was 2.34 inches below the seasonal LTM.

TN loads were highest during December, February, January, and October, respectively. Loads during these months were above LTMs with October having the largest deviation above the LTM due to the large two-day storm event. TP and SS were highest during October followed by January. Although the January and October events were very similar, the nutrient load was split between January and February. The majority of the SS load was delivered during the rise and peak of the hydrograph on January 31 and was captured in the January load. The October storm occurred mid-month such that all loading from the storm was contained in the same month. January and October accounted for 24 percent of the TN load, 48 percent of the TP load, and 70 percent of the 2013 SS load.

2013 yields were below all baseline predictions for all parameters except TNO_x, DNO_x, and DOP. The initial five-year baseline prediction suggested that reductions in TN and DN were driven by reductions in organic and ammonia nitrogen. 2013 yields as a percent of the initial five-year baseline predictions suggest reductions of 63 percent in TON, 75 percent in TNH_3, 51 percent in DON, and 75 percent in DNH_3. FAC trends show similar results with reductions of 67 percent in TON, 79 percent in TNH_3, 40 percent in DON, and 78 percent DNH_3.

Although reductions in organic and ammonia nitrogen have been quite large, they have been tempered by minimal reductions in TNO_x and DNO_x for which there were no trends at Conestoga for 2013 and baseline reductions of 1.1 percent to 1.5 percent of DNO_x and TNO_x, respectively. Since TNO_x and DNO_x account for the largest portion of nitrogen, TN and DN trends were much smaller with 24 percent for

TN and 9 percent for DN. There were no trends in flow for the time period.

Runoff Ratio Approach

The runoff ratio (RR) represents the unit area-adjusted proportion of discharge observed at a basin outlet to the precipitation amount delivered to the basin for a specified duration. The RR regime reflects key aspects of the basin water balance and is a direct measure of water availability (Renner and Bernhofer, 2011); as such, RR may provide a useful normalizing context when comparing flow-dependent factors across time or different hydrological conditions.

RR is calculated as the ratio of discharge (Q) to Precipitation (Precip) and normalized to drainage area and time period. For temperate regions, RR adheres to a distinct seasonal (i.e., sinusoidal) pattern across a year due mostly to the evapotranspiration cycle.

To test the utility of discerning pollutant trends in long-term Susquehanna River monitoring data, RR was calculated for Towanda, Marietta, and Conestoga for consecutive five-year spans divided at quarter-year intervals (i.e., five years equates to 20 quarters). As with the regression approach summarized above, the five-year spans compared conditions early in the Bay monitoring project (1989-1993) to the most recent (2009-2013) period. At Towanda, an intermediate period (1999-2003) also was assessed.

For the specified five-year periods of interest, cumulative precipitation and one or more pollutant loads among TN, TP, and SS were superimposed to RR charts (refer to Figures 6 – 8). Visual inspection of the charts shows the following general consistencies:

- RR adheres to distinct sinusoidal pattern as expected with highest magnitude during the quarter that corresponds to January–March and lowest magnitude occurring during the July–August quarter.
- When comparing the early and recent five-year time periods, the cumulative precipitation and RR curves were highly correlated during the initial approximately 10 quarters (2 ½ years) of both periods.
- A separation of cumulative precipitation coincided with above-normal rainfall throughout the basin that occurred in 2011 – with dramatic impact caused by Tropical Storm Lee in early September 2011.

Figure 6 depicts cumulative precipitation and TN load as well as RR at Marietta. The cumulative TN load at the end of the most recent five-year period was 21 percent lower than the corresponding period 20 years earlier. Of note, through the initial 9 quarters of both time periods (shown by the vertical gray bar), RR and cumulative precipitation trends were nearly identical. However, during the initial 9 quarters of both time spans, the TN loads exhibited distinctly different trajectories – cumulative TN load was 37 percent higher during the earlier period as compared with the latter period, which suggests that N-reduction strategies have been effective at lowering TN loads.

After the ninth quarter, the RR and precipitation trends separated as more precipitation occurred in the recent period and a consequent higher RR pulse persisted through the 13th quarter. The Marietta station is located low in the Susquehanna River Basin, meaning observations at the Marietta station aggregate effects across a vast portion of the basin. The 10th and 11th quarters of the most recent time span corresponded to the spring and summer of 2011 (April through September) which also corresponded to the wettest two consecutive quarters for all long-term stations in the entire period of record (total precipitation during those six months ranged from 31.5 to 39 inches at the upstream stations).

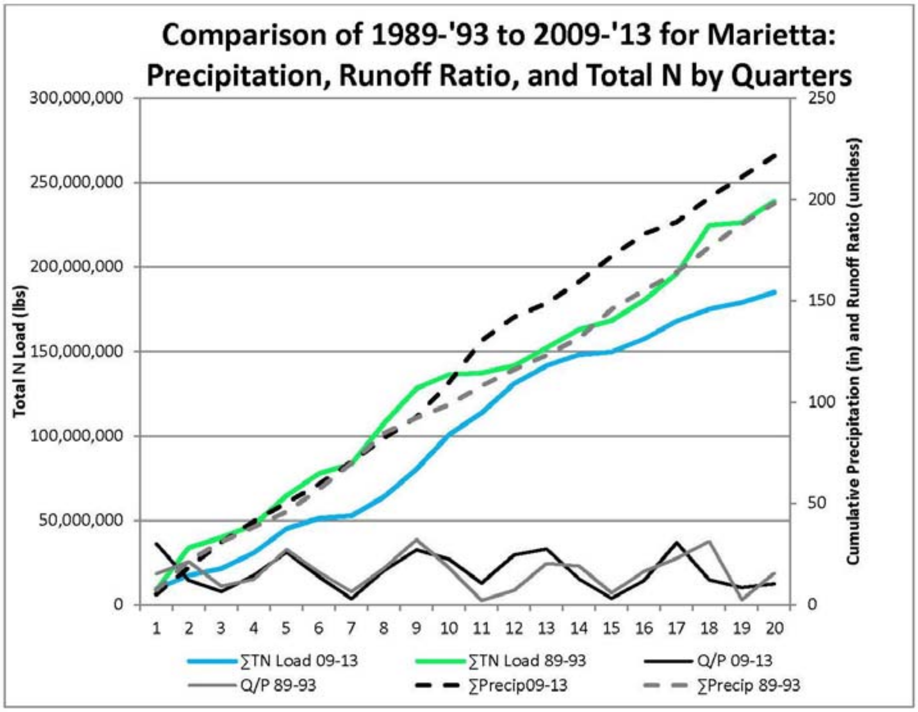

Figure 6. ***TN Trend Analysis using Runoff Ratio for Marietta Station and Comparison of 5-year Spans Beginning in 1989 and 2009 as Means to Infer Effectiveness of Pollutant-reduction Strategies (The sine wave patterns represent RR (Q/P) estimated based on quarter-year time steps. Cumulative precipitation and TN load also are depicted for the periods of interest. The gray vertical bar indicates the approximate position where cumulative precipitation and RR departed. The overall outcome shows that the 5-year cumulative TN load was lower during the most recent period, an indication that TN-reduction strategies were effective.)***

Further support that long-term TN load has reduced due to N-reduction strategies is shown at Towanda; the uppermost long-term monitoring station in the basin. Figure 7 examines RR, cumulative precipitation, and cumulative TN load for three five-year periods and illustrates the progression of cumulative TN load reduction from 20 years in the past to 10 years in the past to the recent period.

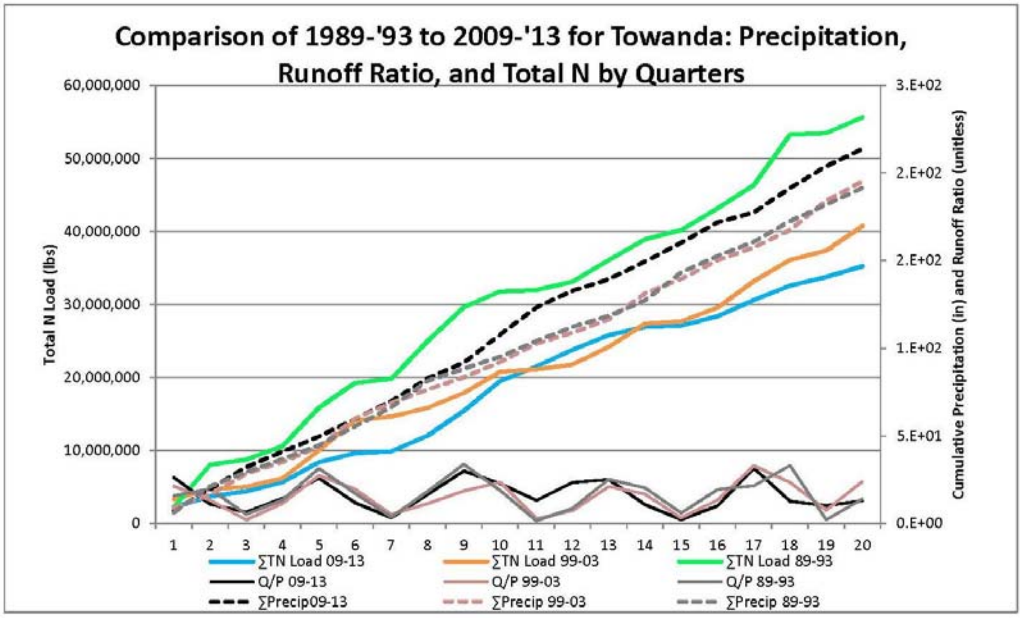

Figure 7. TN Trend Analysis using Runoff Ratio for Towanda Station and Comparison of 5-year Spans Beginning in 1989, 1999, and 2009

As was evident at Marietta, the TN load trends iteratively declined through each of the five-year time periods including especially the earliest and most recent 9-10 quarters when precipitation and RR conditions were most similar.

For Conestoga, RR charts were developed for the initial and recent 5-year spans for TN, TP, and SS loads, respectively. Plots for TP and SS are depicted in Figure 8. The Conestoga station tracks conditions in a small, agriculture-dominated portion of the basin. Conestoga consistently exhibits the highest nutrient and SS yields of any station in the long-term monitoring network.

The TP and SS loads for Conestoga depict both a similarity to one another and a distinct difference to the TN pattern. Again, comparison of the initial 10 quarters when precipitation and RR were comparable, suggests dramatic improvement through time with respect to both TP and SS load at Conestoga. However, the 11th quarter abruptly erased the gains realized through the prior 2 ½ years. By the 12th quarter, TP and SS loads, respectively, both returned to the trajectories exhibited during the initial 10 quarters of the recent period.

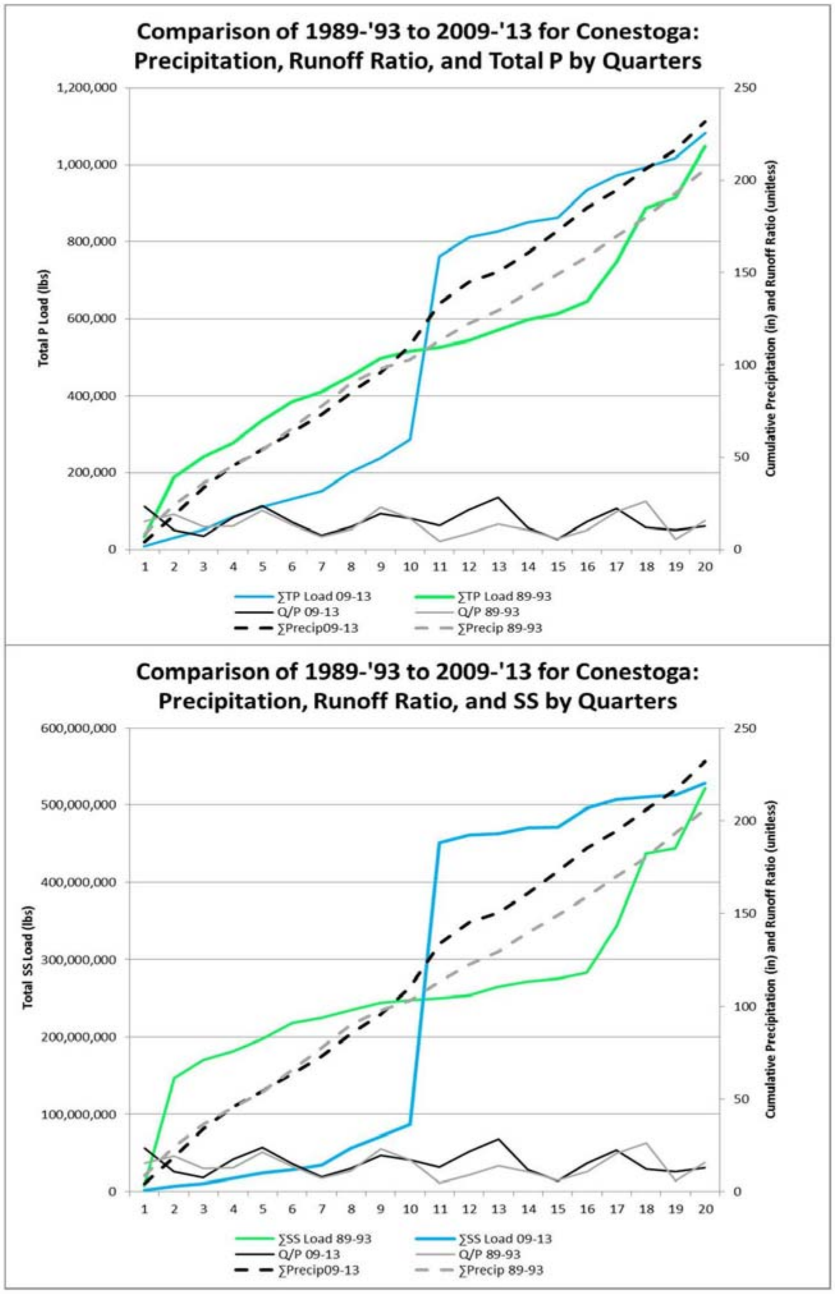

Figure 8. TP (above) and SS (below) Trend Analysis using Runoff Ratio for Conestoga Station and Comparison of 5-year Spans Beginning in 1989 and 2009 (The RR approach illustrates the similarity of response for TP and SS and shows dramatic pollutant load increase from 10^{th} to 11^{th} quarters which coincided with Tropical Storm Lee in September 2011.)

Source Contributions within the Susquehanna River Basin

The long-term nutrient and sediment monitoring network demonstrates that variations in pollutant load and yield contribution exist within the basin. Marietta is the lowermost station situated on a mainstem river and as such, Marietta aggregates contributions from the entire drainage area upstream. Despite factoring for the cumulative increase in watershed area attributed to upstream stations, Marietta still accounts for nearly half of the total land area in the long-term monitoring network and Marietta is more than twice as large as the next largest station (Danville). TN and TP loads from Marietta account for approximately half the loads in the basin monitoring network.

Conestoga is the smallest drainage area in the network, yet the TN, TP, and SS yields are consistently the highest as shown on the chart below (Figure 9). Conestoga lies in the highly fertile Lancaster County region and this station monitors both the highest proportion of agriculture and developed land among the long-term stations.

The pollutant yields that emanate from the Conestoga drainage area are disproportionately large as exemplified by comparison of the TN and TP loading rates for Conestoga with those of the two next smallest stations; Newport and Lewisburg. At more than 3,300 mi^2, the Newport drainage area is seven times larger than Conestoga and the Lewisburg station is nearly 15 times larger (6,800 mi^2). Despite their vastly larger land areas, Newport accounts for 8 percent and 4 percent of the TN and TP load, respectively, and Lewisburg accounts for 9 percent and 6 percent. Whereas, Conestoga accounts for 5 percent of the overall TN load and 9 percent of the TP load in the monitoring network.

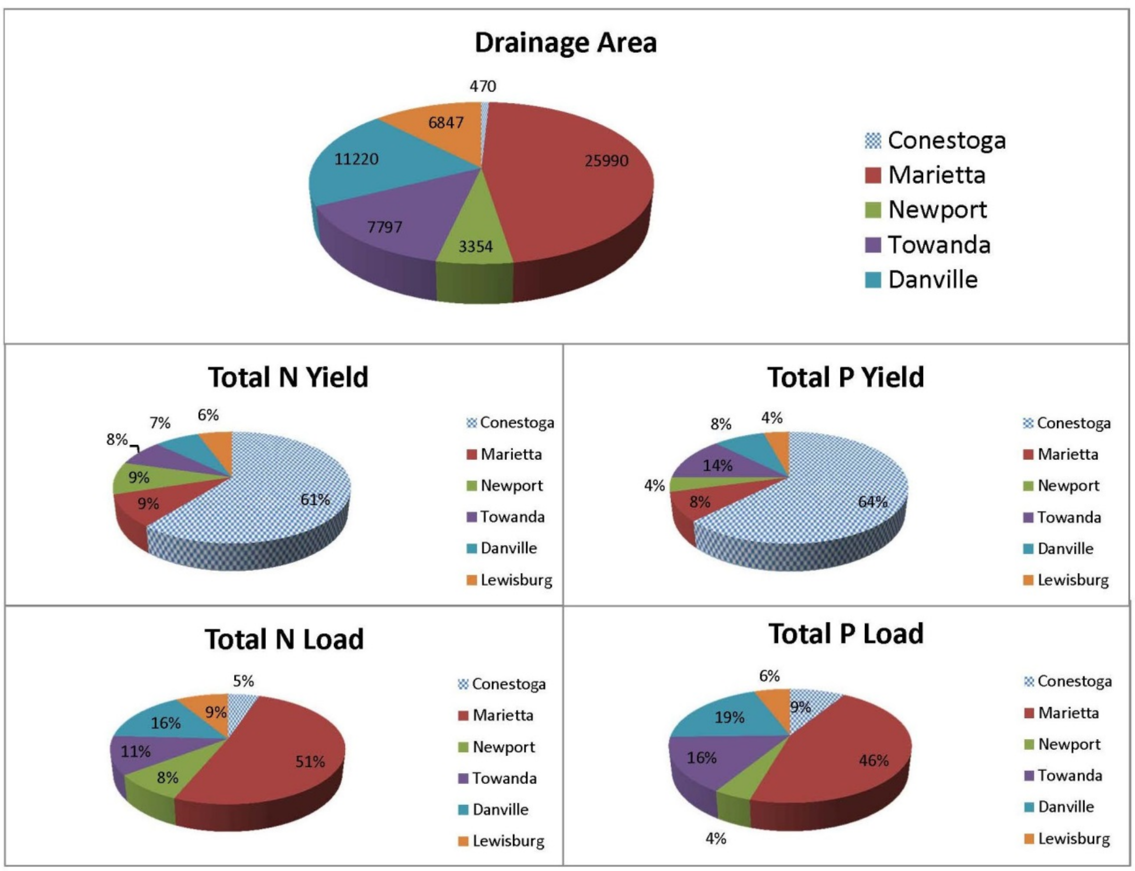

Figure 9. ***Pie Chart Series Showing Relative Differences in Drainage Area, N and P Yield, and N and P Load for the Long-term Monitoring Station Network in the Susquehanna River Basin***

CONCLUSION

2013 was a relatively dry year with fairly well distributed rainfall. The first basin-wide event of significance occurred in late January. During this event, the Upper Susquehanna received the least amount of rainfall with less than 1 inch and Lancaster County received the most with over 3 inches. The rest of the basin received between 1 and 2 inches. Rainfall plus snowmelt resulted in high flow at all sites. Two other significant, but more isolated, events occurred in June where over 3 inches fell in the Upper Susquehanna and West Branch of the Susquehanna and during October when between 5 and 10 inches fell in the lower Susquehanna and Conestoga basins. The West Branch Susquehanna and Juniata subbasins also received above 1 inch of rain in October. A late significant basin-wide event occurred at the end of November when between 1 and 2 inches fell throughout the basin.

Several observations were found comparing initial five-year baseline results between sites regarding TNO_x and DNO_x, the largest contributors to TN and DN loads. Newport and Conestoga showed the lowest reductions in TNO_x and DNO_x, of between 1 percent and 8 percent. Lewisburg, Towanda, Danville, and Marietta all showed larger reductions between 21 percent and 28 percent with highest reductions at Towanda and lowest reductions at Marietta. Trend analyses agreed with this result at Marietta but showed larger reductions, greater than 40 percent, in TNO_x and DNO_x at Towanda and Danville. Lower reductions at Marietta appear, in part, to be due to the low reductions of TNO_x and DNO_x at Newport.

Comparison of base flow and trend analyses between sites showed mixed results. Conestoga had some of the largest reductions for TON, TNH_3, DNH_3, TOC, and SS. Newport had some of the largest reductions for TP, DP, TOC, and SS. Lewisburg had some of the largest reductions for TON, DON, TP, and DP. Lewisburg also had some of the lowest reductions in DNH_3 and SS. Towanda had some of the lowest reductions for TON, DON, TP, and SS. Danville had some of the largest reductions for TNH_3, DNH_3, and TOC. Marietta had some of the lowest reductions for TP and TOC.

Initial five-year baseline analyses also suggest that changes in nutrient loads have led to changes in the percent contribution of individual nitrogen species to total nitrogen. The largest changes were found at Lewisburg, Newport, and Conestoga, which subsequently provoked similar results at Marietta. During the first five years of monitoring at Lewisburg, the TN load consisted of 57 percent TNO_x, 38 percent TON, and 4.6 percent TNH_3. During the most recent five years, the TN load consisted of 75 percent TNO_x, 24 percent TON, and 4.6 percent TNH_3. Similar changes occurred for all sites with the changes at Towanda and Danville being the least pronounced. Initial five-year values at Conestoga were similar to current values at Lewisburg with TN being composed of 75 percent TNO_x, 22 percent TON, and 3.3 percent TNH_3. The most recent five-year yields at Conestoga show TN to be composed of 89 percent TNO_x, 11 percent TON, and 1.4 percent TNH_3. Trends in individual species of TN and DN, show smallest reductions for TNO_x and DNO_x, which constitute the largest fraction of TN and DN and appear to constitute a larger percentage as time passes.

Comparison of recent yields to historical yields has shown varied results for TN, TP, and SS. The regression line from the first half of the dataset compared to the regression line of the second half of the dataset at Marietta, suggests that TN reductions were found at all flows. The same comparison suggests that TP and SS had varied responses dependent upon flow with reductions apparent at lower flows while increases were indicated at higher flows. Notwithstanding this observation, 2013 trends in SS continue to be downward at all sites. This discrepancy could be due to the effectiveness of management actions at low- to mid-level flows and the infrequent occurrence of high sediment transporting events.

The finding of varied SS responses at different flows at Marietta, located above the dams in the Southern Basin, suggests that processes similar to deposition and scour at the dams may be occurring for sediment reduction strategies throughout the watershed. Sediment retained during low to moderate flows would be available for transport during subsequent high flow events. Thus, management practices would redistribute SS load from low to high flows with a possible jump in loads as design capacities are exceeded. Aquatic organisms may have difficulty adapting to continued exposure to such abrupt changes in SS loads.

The application of the runoff ratio technique as a method to reduce noisy data signals associated with climatic and hydrologic factors demonstrated intriguing results for the subset of conditions examined herein and SRBC plans to expand use of this approach in the future. The runoff ratio approach helps clarify mechanisms that govern pollutant transport in the basin. Moreover, the RR approach emphasized the impact that single outlier events such as Tropical Storm Lee in 2011 exert on TP and SS loadings, even across a multi-year span of observation.

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APPENDIX A

Individual Long-Term Site Data

INDIVIDUAL SITES: TOWANDA

Table A1. 2013 Annual and Seasonal Precipitation and Discharge at Towanda

Season	Precipitation (inches)			Discharge (cfs)		
	2013	LTM	LTM Departure	2013	LTM	% LTM
January-March (Winter)	5.64	7.54	-1.90	13,788	16,443	0.84
April-June (Spring)	13.98	10.88	3.10	13,440	15,326	0.88
July-September (Summer)	12.47	11.36	1.11	9,398	5,018	1.87
October-December (Fall)	9.87	9.38	0.49	9,445	10,892	0.87
Annual Total	41.95	39.16	2.79	11,500	11,889	0.97

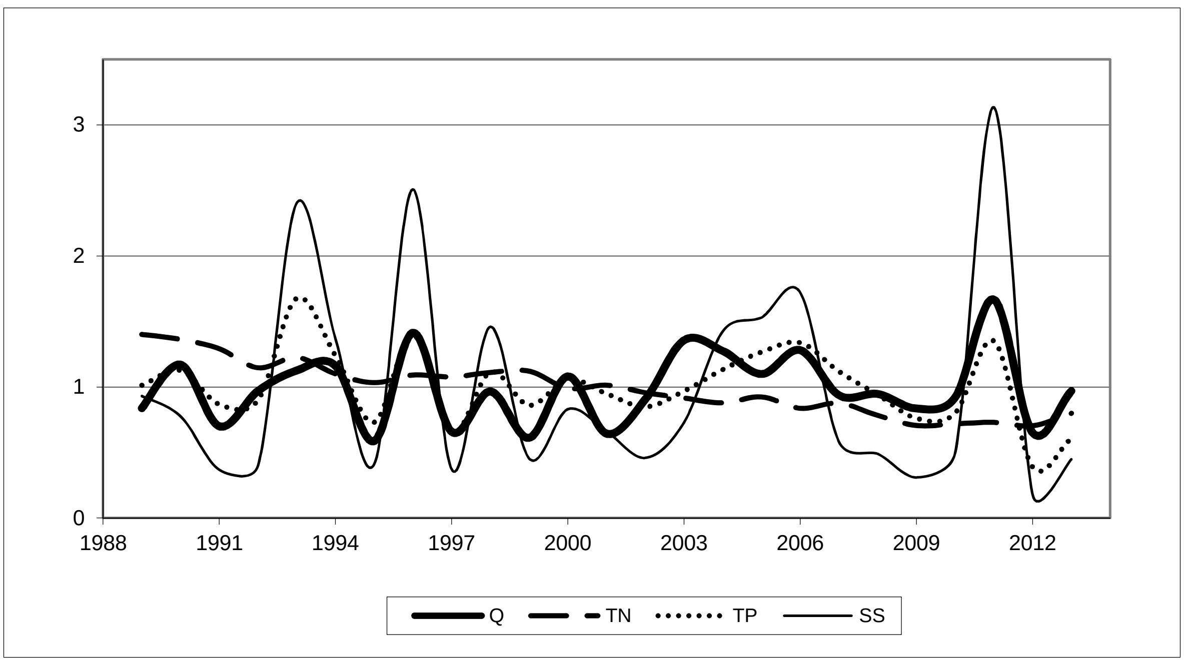

Figure A1. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

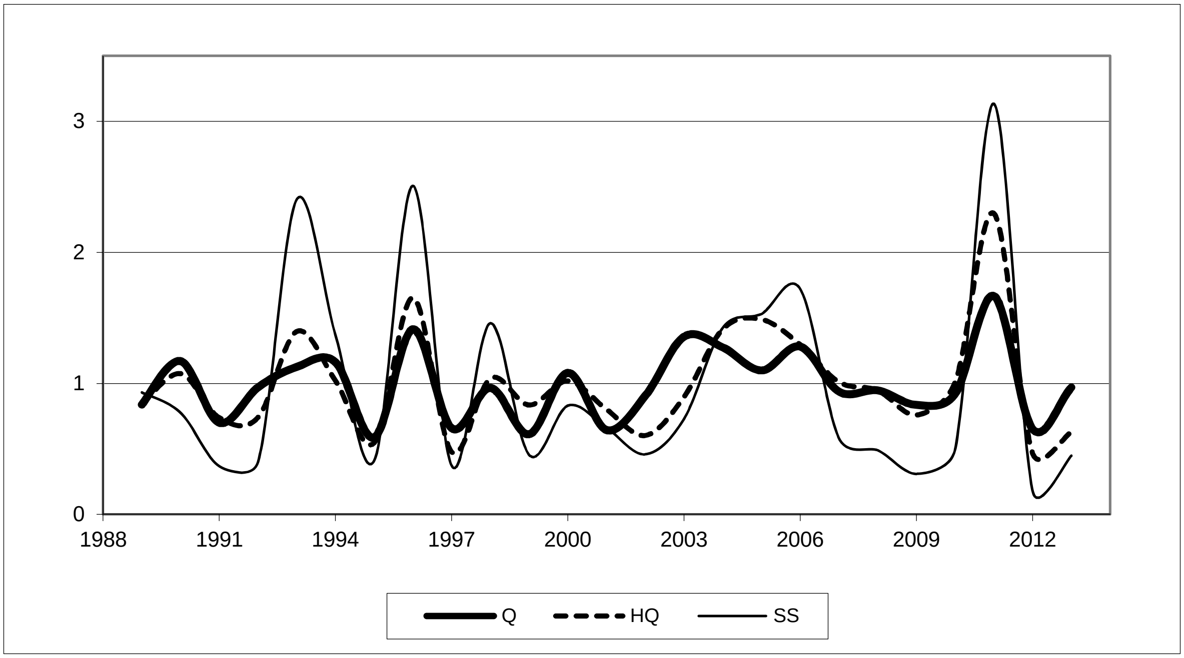

Figure A2. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

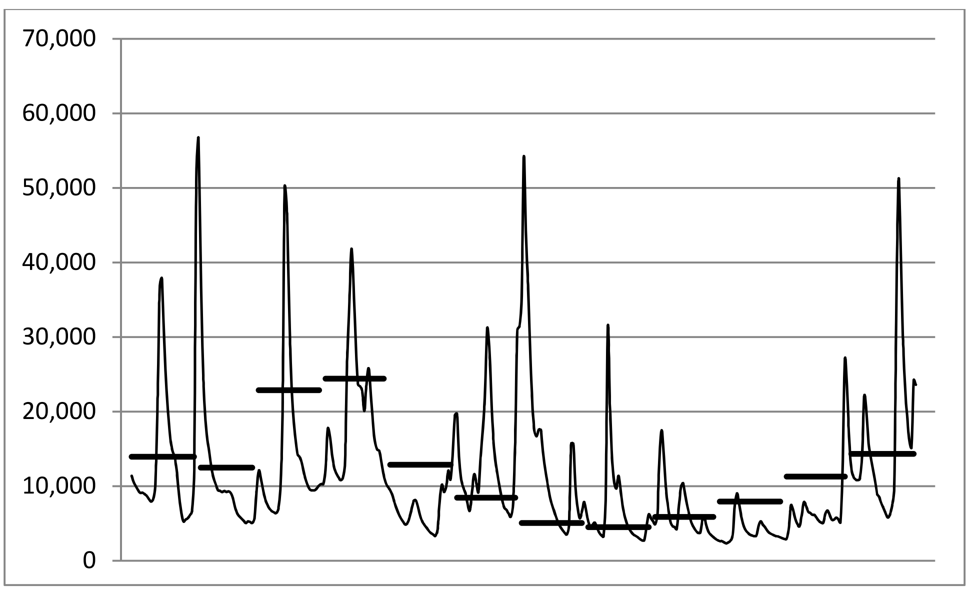

Figure A3. 2013 Daily Average Flow and Monthly LTM at Towanda

Table A2. 2013 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Towanda

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	20,530	77%	3%	4.11	5.33	0.91	80%
TNO_x	13,794	86%	6%	2.76	3.21	0.61	89%
TON	7,097	72%	7%	1.42	1.97	0.31	75%
TNH_3	816	63%	10%	0.16	0.26	0.04	65%
DN	18,714	80%	4%	3.75	4.67	0.83	83%
DNO_x	14,032	89%	6%	2.81	3.15	0.62	92%
DON	4,819	71%	8%	0.97	1.37	0.21	73%
DNH_3	782	76%	10%	0.16	0.21	0.03	78%
TP	1,270	55%	8%	0.25	0.46	0.06	57%
DP	394	51%	9%	0.08	0.16	0.02	53%
DOP	236	52%	11%	0.05	0.09	0.01	54%
TOC	70,535	85%	4%	14.13	16.53	3.12	88%
SS	1,164,108	37%	13%	233.28	629.48	51.42	38%

Table A3. 2013 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Towanda

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	6,666	1.34	5,869	1.18	3,638	0.73	4,357	0.87
TNO_x	5,248	1.05	3,581	0.72	1,747	0.35	3,218	0.64
TON	1,669	0.33	2,244	0.45	1,965	0.39	1,219	0.24
TNH_3	255	0.05	229	0.05	158	0.03	174	0.03
DN	6,401	1.28	5,186	1.04	3,017	0.60	4,110	0.82
DNO_x	5,336	1.07	3,654	0.73	1,770	0.35	3,272	0.66
DON	1,278	0.26	1,440	0.29	1,167	0.23	934	0.19
DNH_3	246	0.05	217	0.04	148	0.03	170	0.03
TP	317	0.06	391	0.08	354	0.07	208	0.04
DP	103	0.02	120	0.02	102	0.02	70	0.01
DOP	85	0.02	94	0.02	81	0.02	60	0.01
TOC	16,725	3.35	20,750	4.16	19,476	3.90	13,583	2.72
SS	249,264	49.95	360,432	72.23	423,816	84.93	130,596	26.17

Table A4. 2013 Monthly Average Precipitation (in), High Daily Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Towanda

Month	Precip		Flow		TN			TP			SS		
	Ave	Max	2013	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	1.91	0.85	14,362	103%	2,375	0.48	81%	112	0.022	49%	76,620	15.4	22%
February	2.17	0.57	12,466	102%	1,894	0.38	80%	87	0.017	68%	68,559	13.7	76%
March	1.55	0.32	14,407	63%	2,398	0.48	52%	118	0.024	32%	104,085	20.9	24%
April	3.43	0.50	19,020	77%	2,937	0.59	61%	173	0.035	38%	162,421	32.5	23%
May	4.10	0.99	7,402	58%	1,055	0.21	46%	57	0.011	33%	28,889	5.8	14%
June	6.45	1.13	14,099	161%	1,877	0.38	136%	161	0.032	110%	169,122	33.9	71%
July	5.30	1.07	14,667	281%	1,965	0.39	251%	223	0.045	267%	341,865	68.5	383%
August	3.80	1.09	6,958	163%	877	0.18	139%	76	0.015	109%	56,623	11.3	95%
September	3.36	0.89	6,475	116%	796	0.16	100%	56	0.011	34%	25,328	5.1	5%
October	2.82	0.57	4,034	54%	534	0.11	43%	27	0.005	21%	6,199	1.2	5%
November	3.54	0.97	7,677	70%	1,098	0.22	56%	49	0.010	30%	20,976	4.2	14%
December	3.51	0.48	16,567	116%	2,725	0.55	99%	131	0.026	66%	103,421	20.7	65%

Table A5.   2013 Annual Comparison to Baselines at Towanda

Parameter	2013	Q ratio	Period	Y'	R^2	Parameter	2013	Y'	R^2
TN	4.11	0.97	89-93	6.666	0.86	DN	3.75	5.583	0.86
			89-00	6.043	0.86			5.204	0.90
			01-12	4.427	0.89			4.007	0.87
			89-12	5.212	0.61			4.585	0.64
TNO_{23}	2.764	0.97	89-93	3.816	0.85	DNO_{23}	2.812	3.807	0.81
			89-00	3.471	0.82			3.429	0.78
			01-12	2.840	0.83			2.768	0.69
			89-12	3.145	0.81			3.088	0.57
TON	1.42	0.97	89-93	2.542	0.69	DON	0.97	1.597	0.88
			89-00	2.313	0.82			1.606	0.88
			01-12	1.528	0.87			1.102	0.81
			89-12	1.917	0.61			1.344	0.53
TNH_3	0.164	0.97	89-93	0.332	0.83	DNH_3	0.157	0.268	0.73
			89-00	0.311	0.84			0.235	0.72
			01-12	0.202	0.89			0.171	0.89
			89-12	0.254	0.56			0.203	0.61
TP	0.250	0.97	89-93	0.480	0.70	DP	0.079	0.175	0.84
			89-00	0.472	0.88			0.155	0.76
			01-12	0.406	0.89			0.152	0.74
			89-12	0.436	0.85			0.153	0.75
SS	233	0.97	89-93	396	0.54*	DIP	0.064	0.041	0.22
			89-00	430	0.81*			0.053	0.04
			01-12	313	0.82*			0.120	0.72
			89-12	366	079*			0.088	0.29
TOC	14.1	0.97	89-93	16.283	0.84				
			89-00	16.331	0.96				
			01-12	15.352	0.98				
			89-12	15.894	0.96				

Q = discharge ratio
R^2 = correlation coefficient
* indicates where an exponential regression was used as it yields a better fit to the data

Table A6. Trend Statistics for the Susquehanna River at Towanda, Pa., October 1988 Through September 2013

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.420	-	-	-	-	NS
TN	600	FAC	-0.024	<0.0001	-48	-45	-42	42-48	Down
TNOx	630	FAC	-0.024	<0.0001	-50	-46	-40	40-50	Down
TON	605	FAC	-0.026	<0.0001	-54	-48	-41	41-54	Down
TNH_3	610	FAC	-0.026	<0.0001	-55	-47	-38	38-55	Down
TKN	625	FAC	-0.026	<0.0001	-54	-48	-42	42-54	Down
DN	602	FAC	-0.022	<0.0001	-45	-42	-39	39-45	Down
DNOx	631	FAC	-0.023	<0.0001	-49	-44	-39	39-49	Down
DON	607	FAC	-0.022	<0.0001	-50	-43	-35	35-50	Down
DNH_3	608	FAC	-0.016	<0.0001	-43	-33	-20	N/A	BMDL
DKN	623	FAC	-0.022	<0.0001	-48	-42	-36	36-48	Down
TP	665	FAC	-0.008	0.0035	-28	-18	-6	6-28	Down
DP	666	FAC	-0.014	<0.0001	-39	-29	-18	18-39	Down
DOP	671	FAC	0.066	<0.0001	314	416	544	314-544	Up
TOC	680	FAC	-0.006	<0.0001	-18	-13	-8	8-18	Down
SS	80154	FAC	-0.014	0.0009	-44	-30	-13	13-44	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: DANVILLE

Table A7. 2013 Annual and Seasonal Precipitation and Discharge at Danville

Season	Precipitation (inches)			Discharge (cfs)		
	2013	LTM	LTM Departure	2013	LTM	% LTM
January-March (Winter)	5.44	7.68	-2.24	19,680	22,828	0.86
April-June (Spring)	13.04	10.97	2.07	17,394	21,235	0.82
July-September (Summer)	11.17	11.53	-0.36	11,790	7,372	1.60
October-December (Fall)	9.36	9.45	-0.09	11,752	15,832	0.74
Annual Total	39.01	39.63	-0.62	15,123	16,775	0.901

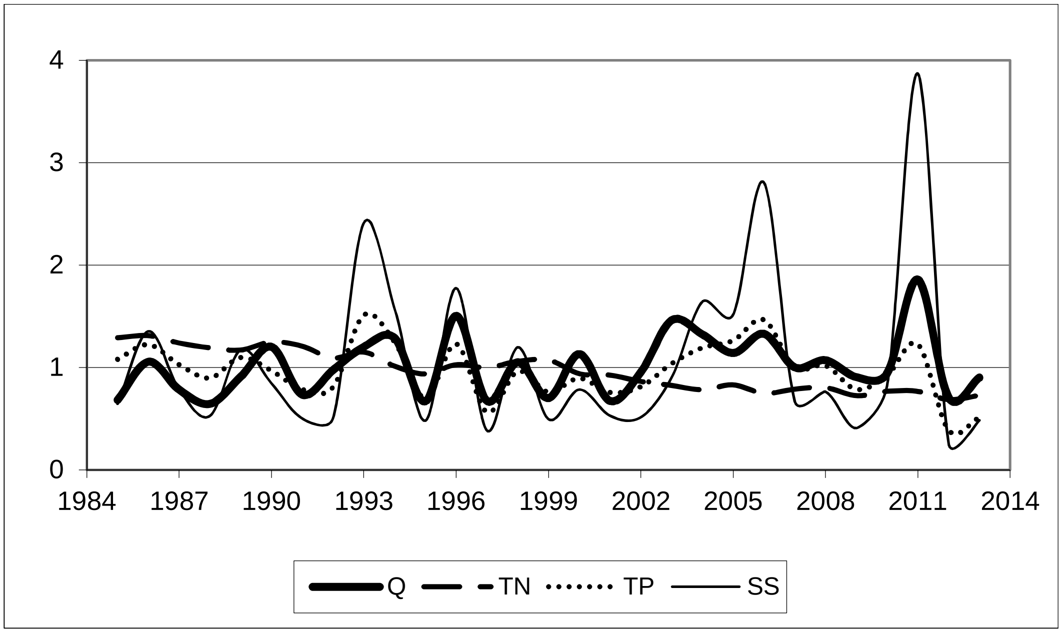

Figure A4. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

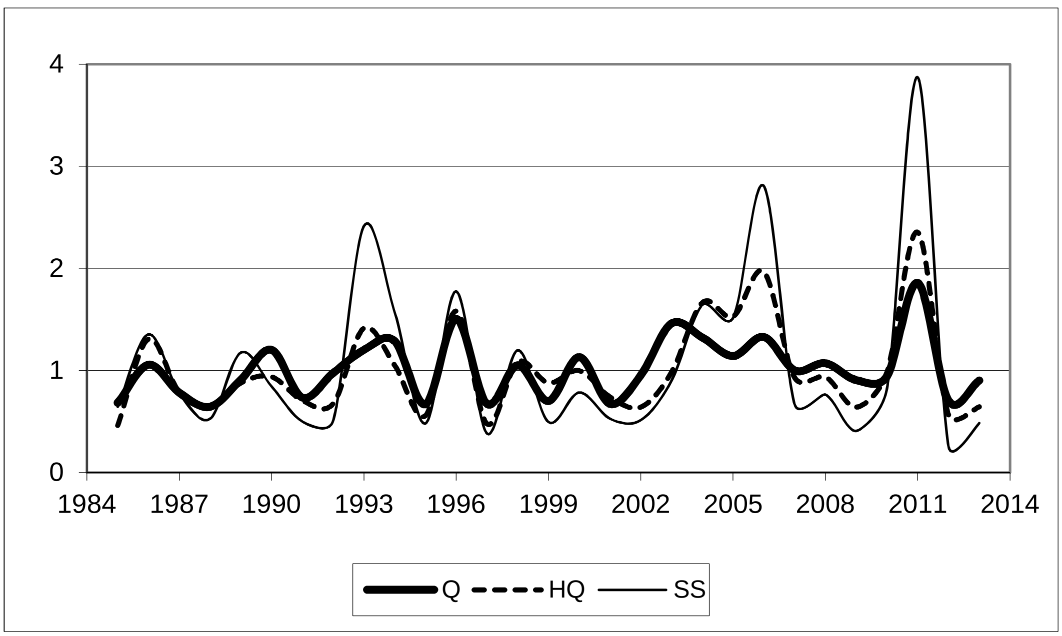

Figure A5. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

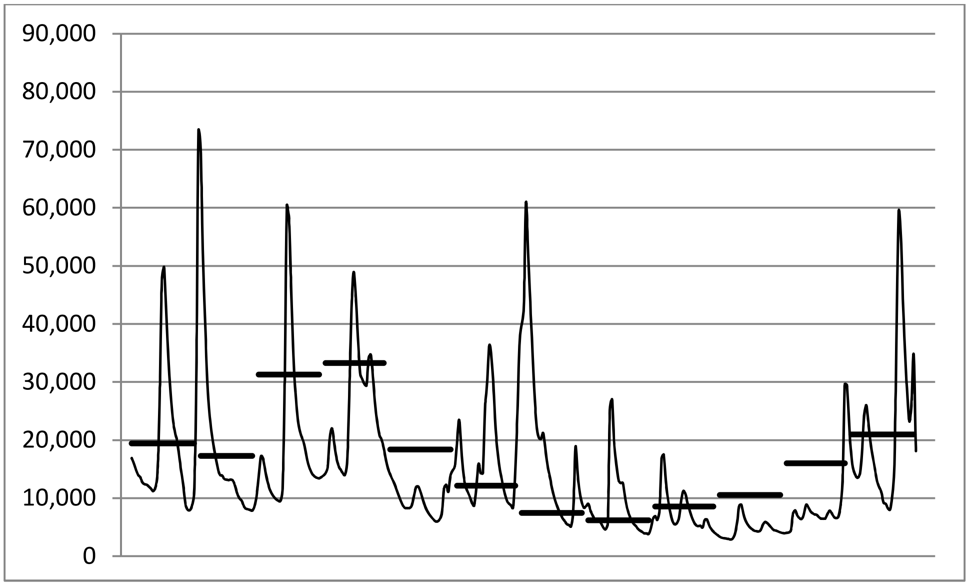

Figure A6. 2013 Daily Average Flow and Monthly LTM at Danville

Table A8. 2013 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Danville

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	27,749	66%	4%	3.86	5.85	0.93	73%
TNO_x	19,049	76%	6%	2.65	3.47	0.64	85%
TON	8,997	58%	7%	1.25	2.18	0.30	64%
TNH_3	1,021	49%	11%	0.14	0.29	0.03	55%
DN	25,133	70%	4%	3.50	4.98	0.84	78%
DNO_x	19,265	78%	6%	2.68	3.45	0.65	86%
DON	6,189	64%	9%	0.86	1.35	0.21	71%
DNH_3	954	52%	12%	0.13	0.25	0.03	58%
TP	1,557	43%	9%	0.22	0.50	0.05	48%
DP	445	43%	11%	0.06	0.14	0.01	48%
DOP	248	42%	14%	0.03	0.08	0.01	46%
TOC	84,078	72%	4%	11.71	16.18	2.82	80%
SS	1,365,201	36%	13%	190.12	526.66	45.85	40%

Table A9. 2013 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Danville

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	9,911	1.38	7,763	1.08	4,622	0.64	5,454	0.76
TNO_x	7,614	1.06	4,684	0.65	2,435	0.34	4,316	0.60
TON	2,420	0.34	2,904	0.40	2,292	0.32	1,380	0.19
TNH_3	374	0.05	288	0.04	169	0.02	189	0.03
DN	9,350	1.30	6,662	0.93	3,831	0.53	5,291	0.74
DNO_x	7,716	1.07	4,732	0.66	2,446	0.34	4,372	0.61
DON	1,820	0.25	1,854	0.26	1,392	0.19	1,122	0.16
DNH_3	365	0.05	257	0.04	146	0.02	185	0.03
TP	453	0.06	463	0.06	399	0.06	243	0.03
DP	126	0.02	131	0.02	113	0.02	75	0.01
DOP	90	0.01	94	0.01	86	0.01	57	0.01
TOC	22,441	3.13	24,573	3.42	22,032	3.07	15,033	2.09
SS	385,012	53.62	386,986	53.89	416,752	58.04	176,451	24.57

Table A10. 2013 Monthly Average Precipitation (in), High Daily Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Danville

MONTH	Precip		Flow		TN			TP			SS		
	Ave	Max	2013	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	2.06	0.73	18,948	98%	3,259	0.45	71%	139	0.019	40%	92,040	12.8	31%
February	1.98	0.50	20,087	116%	3,213	0.45	87%	156	0.022	77%	154,798	21.6	137%
March	1.40	0.41	20,045	64%	3,440	0.48	48%	158	0.022	27%	138,175	19.2	24%
April	2.88	0.50	24,867	75%	3,951	0.55	55%	218	0.030	33%	197,703	27.5	25%
May	3.59	0.76	10,034	55%	1,434	0.20	40%	66	0.009	23%	28,206	3.9	11%
June	5.29	0.92	17,527	144%	2,378	0.33	117%	180	0.025	77%	161,077	22.4	45%
July	4.61	0.89	18,987	255%	2,609	0.36	218%	264	0.037	211%	346,507	48.3	329%
August	3.52	0.86	8,648	140%	1,087	0.15	108%	80	0.011	77%	47,883	6.7	78%
September	3.16	0.64	7,600	89%	926	0.13	67%	56	0.008	21%	22,362	3.1	3%
October	2.40	0.45	4,732	45%	606	0.08	30%	26	0.004	13%	5,587	0.8	4%
November	3.29	0.86	8,498	53%	1,198	0.17	36%	48	0.007	17%	21,738	3.0	13%
December	3.49	0.53	21,921	105%	3,650	0.51	78%	169	0.024	48%	149,127	20.8	69%

Table A11. 2013 Annual Comparison to Baselines at Danville

Parameter	2013	Q ratio	Period	Y'	R^2	Parameter	2013	Y'	R^2
TN	3.86	0.90	85-89	6.957	0.95	DN	3.50	5.732	0.87
			85-98	6.306	0.87			5.265	0.87
			99-12	4.605	0.90			4.112	0.79
			85-12	5.482	0.59			4.697	0.57
TNO_{23}	2.653	0.90	85-89	3.601	0.93	DNO_{23}	2.683	3.578	0.93
			85-98	3.597	0.97			3.567	0.96
			99-12	2.909	0.82			2.894	0.83
			85-12	3.254	0.67			3.234	0.68
TON	1.25	0.90	85-89	3.102	0.95	DON	0.86	1.852	0.70
			85-98	2.427	0.63			1.457	0.58
			99-12	1.510	0.86			1.082	0.63
			85-12	1.999	0.50			1.275	0.40
TNH_3	0.142	0.90	85-89	0.425	0.32	DNH_3	0.133	0.403	0.28
			85-98	0.329	0.43			0.283	0.12
			99-12	0.209	0.86			0.194	0.88
			85-12	0.272	0.31			0.243	0.22
TP	0.220	0.90	85-89	0.502	0.97	DP	0.062	0.145	0.96
			85-98	0.453	0.86			0.122	0.69
			99-12	0.398	0.90			0.139	0.67
			85-12	0.428	0.88			0.131	0.67
SS	190	0.90	85-89	396	0.98*	DIP	0.046	0.042	0.45
			85-98	295	0.83*			0.033	0.12
			99-12	229	0.86*			0.111	0.56
			85-12	263	0.83*			0.072	0.31
TOC	11.7	0.90	85-89	17.978	0.90				
			85-98	15.034	0.82				
			99-12	13.211	0.97				
			85-12	14.307	0.90				

Q = discharge ratio
R^2 = correlation coefficient
* indicates where an exponential regression was used as it yields a better fit to the data

Table A12. Trend Statistics for the Susquehanna River at Danville, Pa., October 1984 Through September 2013

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.197	-	-	-	-	NS
TN	600	FAC	-0.023	<0.0001	-52	-49	-46	46-52	Down
TNOx	630	FAC	-0.019	<0.0001	-47	-43	-38	38-47	Down
TON	605	FAC	-0.030	<0.0001	-63	-59	-53	53-63	Down
TNH_3	610	FAC	-0.026	<0.0001	-61	-53	-45	45-61	Down
TKN	625	FAC	-0.029	<0.0001	-62	-58	-53	53-62	Down
DN	602	FAC	-0.020	<0.0001	-47	-44	-40	40-47	Down
DNOx	631	FAC	-0.019	<0.0001	-47	-42	-37	37-47	Down
DON	607	FAC	-0.026	<0.0001	-59	-53	-47	47-59	Down
DNH_3	608	FAC	-0.021	<0.0001	-55	-46	-36	36-55	BMDL
DKN	623	FAC	-0.024	<0.0001	-56	-51	-45	45-56	Down
TP	665	FAC	-0.016	<0.0001	-46	-38	-29	29-46	Down
DP	666	FAC	-0.011	0.0001	-39	-28	-16	16-39	Down
DOP	671	FAC	0.062	<0.0001	342	475	646	N/A	BMDL
TOC	680	FAC	-0.009	<0.0001	-28	-24	-20	20-28	Down
SS	80154	FAC	-0.024	<0.0001	-59	-51	-41	41-59	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: MARIETTA

Table A13. 2013 Annual and Seasonal Precipitation and Discharge at Marietta

Season	Precipitation (inches)			Discharge (cfs)		
	2013	LTM	LTM Departure	2013	LTM	% LTM
January-March (Winter)	6.07	8.09	-2.02	48,130	54,859	0.88
April-June (Spring)	12.05	11.02	1.03	37,436	49,622	0.75
July-September (Summer)	10.04	11.83	-1.80	21,163	18,473	1.15
October-December (Fall)	10.39	9.72	0.68	26,630	36,070	0.74
Annual Total	38.56	40.66	-2.11	33,248	39,657	0.838

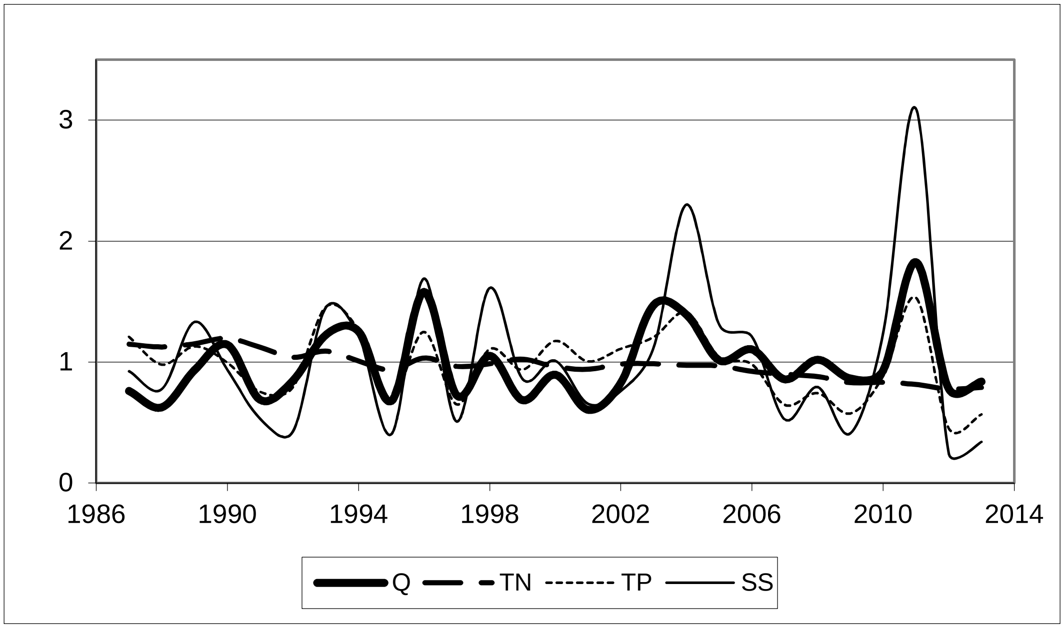

Figure A7. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

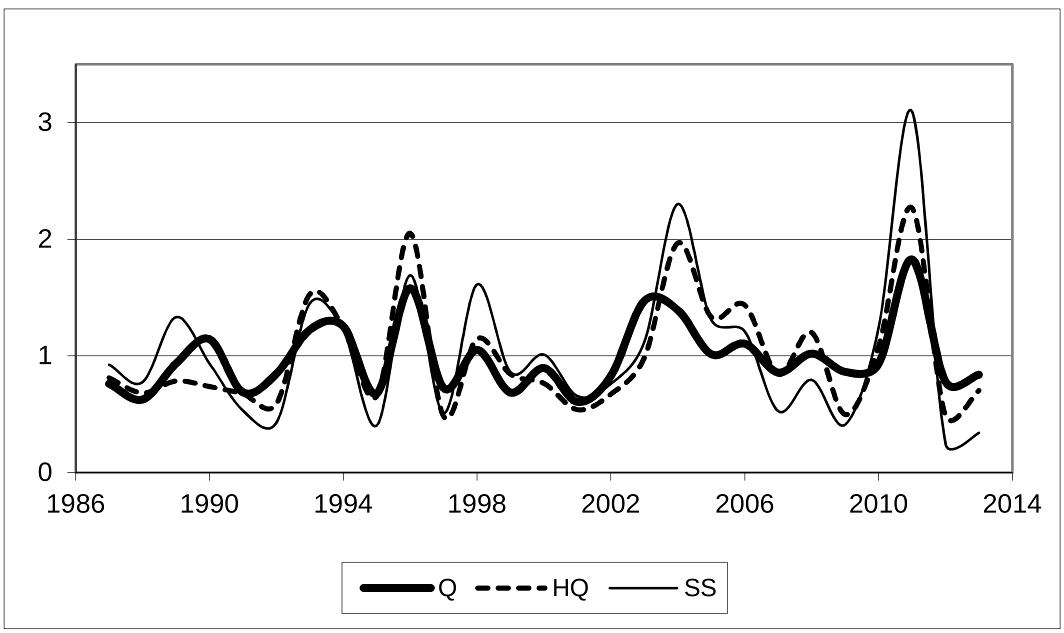

Figure A8. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

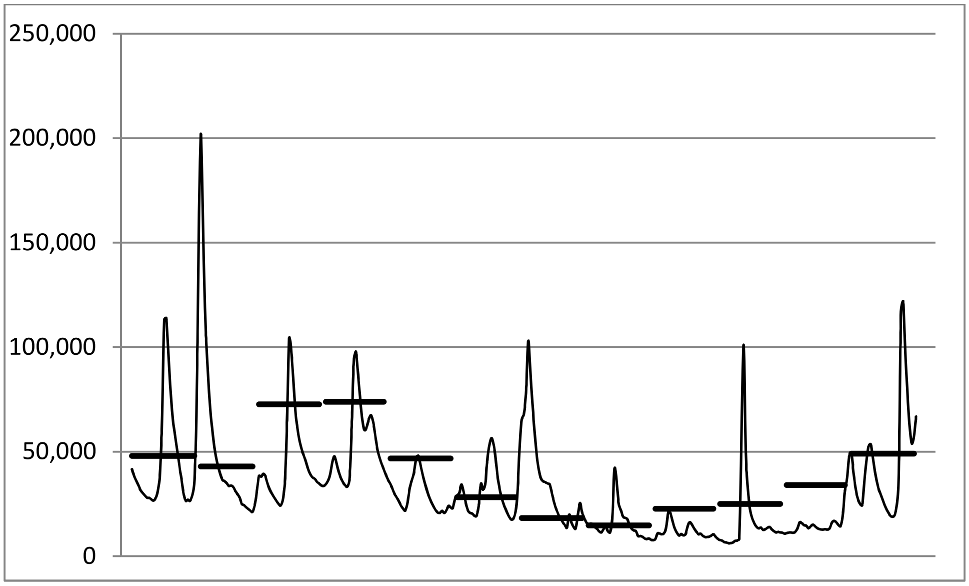

Figure A9. 2013 Daily Average Flow and Monthly LTM at Marietta

Table A14. 2013 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Marietta

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	82,833	66%	4%	4.98	7.58	1.27	78%
TNO_x	61,552	69%	5%	3.70	5.36	0.94	82%
TON	19,306	57%	9%	1.16	2.05	0.29	67%
TNH_3	2,307	52%	10%	0.14	0.27	0.04	62%
DN	74,565	68%	4%	4.48	6.60	1.14	81%
DNO_x	61,787	70%	5%	3.71	5.33	0.94	83%
DON	11,050	59%	11%	0.66	1.12	0.17	71%
DNH_3	2,304	60%	9%	0.14	0.23	0.04	71%
TP	3,394	43%	8%	0.20	0.47	0.05	52%
DP	1,232	56%	9%	0.07	0.13	0.02	67%
DOP	828	66%	11%	0.05	0.08	0.01	79%
TOC	207,720	84%	5%	12.49	14.82	3.17	101%
SS	1,738,512	24%	11%	104.52	438.87	26.56	28%

Table A15. 2013 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Marietta

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	31,676	1.90	21,046	1.27	11,914	0.72	18,197	1.09
TNO_x	24,890	1.50	14,987	0.90	7,737	0.47	13,938	0.84
TON	5,907	0.36	5,536	0.33	4,198	0.25	3,665	0.22
TNH_3	914	0.05	564	0.03	321	0.02	509	0.03
DN	29,054	1.75	18,215	1.10	10,130	0.61	17,166	1.03
DNO_x	24,995	1.50	15,020	0.90	7,755	0.47	14,017	0.84
DON	3,445	0.21	2,742	0.16	2,218	0.13	2,645	0.16
DNH_3	896	0.05	553	0.03	322	0.02	533	0.03
TP	1,101	0.07	897	0.05	736	0.04	660	0.04
DP	362	0.02	275	0.02	262	0.02	333	0.02
DOP	280	0.02	210	0.01	222	0.01	301	0.02
TOC	61,310	3.69	58,758	3.53	45,244	2.72	42,407	2.55
SS	630,114	37.88	432,756	26.02	385,636	23.18	290,005	17.43

Table A16. 2013 Monthly Average Precipitation (in), High Daily Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Marietta

Month	Precip		Flow		TN			TP			SS		
	Ave	Max	2013	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	2.59	**1.12**	45,600	95%	10,762	0.65	74%	321	0.019	44%	151,055	9.1	22%
February	1.83	0.64	54,829	128%	11,534	0.69	104%	493	0.030	118%	341,725	20.5	133%
March	1.57	0.33	44,610	61%	9,379	0.56	48%	287	0.017	24%	137,333	8.3	13%
April	2.98	0.47	52,573	71%	10,207	0.61	54%	420	0.025	32%	228,375	13.7	19%
May	3.25	0.64	29,100	62%	5,345	0.32	47%	195	0.012	28%	74,951	4.5	12%
June	4.88	0.88	30,913	109%	5,494	0.33	89%	283	0.017	65%	129,430	7.8	33%
July	4.31	0.66	36,277	199%	6,947	0.42	172%	526	0.032	213%	329,902	19.8	218%
August	2.90	0.54	15,033	103%	2,777	0.17	83%	130	0.008	61%	39,202	2.4	30%
September	2.51	0.55	11,880	52%	2,190	0.13	39%	79	0.005	9%	16,531	1.0	1%
October	3.72	1.28	17,492	70%	3,779	0.23	54%	185	0.011	43%	88,246	5.3	29%
November	3.12	1.18	16,493	48%	3,472	0.21	35%	85	0.005	17%	19,797	1.2	6%
December	3.57	0.49	45,577	93%	10,946	0.66	74%	390	0.023	53%	181,962	10.9	36%

Table A17. 2013 Annual Comparison to Baselines at Marietta

Parameter	2013	Q ratio	Period	Y’	R^2	Parameter	2013	Y’	R^2
TN	4.98	0.84	87-91	7.566	1.00	DN	4.48	6.267	0.99
			87-99	6.984	0.95			6.030	0.98
			00-12	5.968	0.92			5.298	0.84
			87-12	6.512	0.86			5.686	0.85
TNO_{23}	3.700	0.84	87-91	4.761	0.95	DNO_{23}	3.715	4.730	0.95
			87-99	4.723	0.98			4.703	0.98
			00-12	4.389	0.82			4.360	0.84
			87-12	4.563	0.87			4.538	0.87
TON	1.16	0.84	87-91	2.470	0.91	DON	0.66	1.264	0.95
			87-99	2.017	0.59			1.131	0.62
			00-12	1.328	0.81			0.873	0.49
			87-12	1.709	0.61			1.012	0.41
TNH_3	0.139	0.84	87-91	0.258	0.88	DNH_3	0.139	0.241	0.65
			87-99	0.247	0.94			0.218	0.85
			00-12	0.195	0.84			0.176	0.83
			87-12	0.223	0.77			0.199	0.77
TP	0.200	0.84	87-91	0.376	0.79	DP	0.074	0.131	0.74
			87-99	0.363	0.91			0.123	0.75
			00-12	0.295	0.90			0.105	0.50
			87-12	0.334	0.89			0.115	0.54
SS	105	0.84	87-91	257	0.69*	DIP	0.061	0.025	0.97
			87-99	226	0.78*			0.042	0.03
			00-12	200	0.79*			0.009	0.34
			87-12	214	0.79*			0.063	0.20
TOC	12.5	0.84	87-91	13.237	0.84				
			87-99	12.304	0.93				
			00-12	10.928	0.93				
			89-12	11.728	0.91				

Q = discharge ratio
R^2 = correlation coefficient
* indicates where an exponential regression was used as it yields a better fit to the data

Table A18. Trend Statistics for the Susquehanna River at Marietta, Pa., October 1986 Through September 2013

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.846	-	-	-	-	NS
TN	600	FAC	-0.016	<0.0001	-38	-35	-31	31-38	Down
TNOx	630	FAC	-0.011	<0.0001	-30	-25	-20	20-30	Down
TON	605	FAC	-0.026	<0.0001	-57	-51	-44	44-57	Down
TNH_3	610	FAC	-0.015	<0.0001	-43	-33	-22	22-43	Down
TKN	625	FAC	-0.025	<0.0001	-55	-49	-42	42-55	Down
DN	602	FAC	-0.014	<0.0001	-35	-31	-27	27-35	Down
DNOx	631	FAC	-0.010	<0.0001	-29	-24	-19	19-29	Down
DON	607	FAC	-0.029	<0.0001	-62	-55	-48	48-62	Down
DNH_3	608	FAC	-0.012	<0.0001	-38	-28	-16	16-38	Down
DKN	623	FAC	-0.027	<0.0001	-58	-53	-46	46-58	Down
TP	665	FAC	-0.018	<0.0001	-45	-38	-30	30-45	Down
DP	666	FAC	-0.025	<0.0001	-56	-50	-43	43-56	Down
DOP	671	FAC	0.063	<0.0001	312	421	557	N/A	BMDL
TOC	680	FAC	-0.004	0.0008	-16	-10	-4	4-16	Down
SS	80154	FAC	-0.022	<0.0001	-55	-46	-35	35-55	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: LEWISBURG

Table A19. 2013 Annual and Seasonal Precipitation and Discharge at Lewisburg

Season	Precipitation (inches)			Discharge (cfs)		
	2013	LTM	LTM Departure	2013	LTM	% LTM
January-March (Winter)	6.29	8.30	-2.02	13,499	15,366	0.88
April-June (Spring)	11.84	11.26	0.58	10,945	13,026	0.84
July-September (Summer)	9.08	12.66	-3.58	4,667	5,041	0.93
October-December (Fall)	10.29	9.96	0.33	6,314	10,232	0.62
Annual Total	37.49	42.18	-4.69	8,825	10,889	0.810

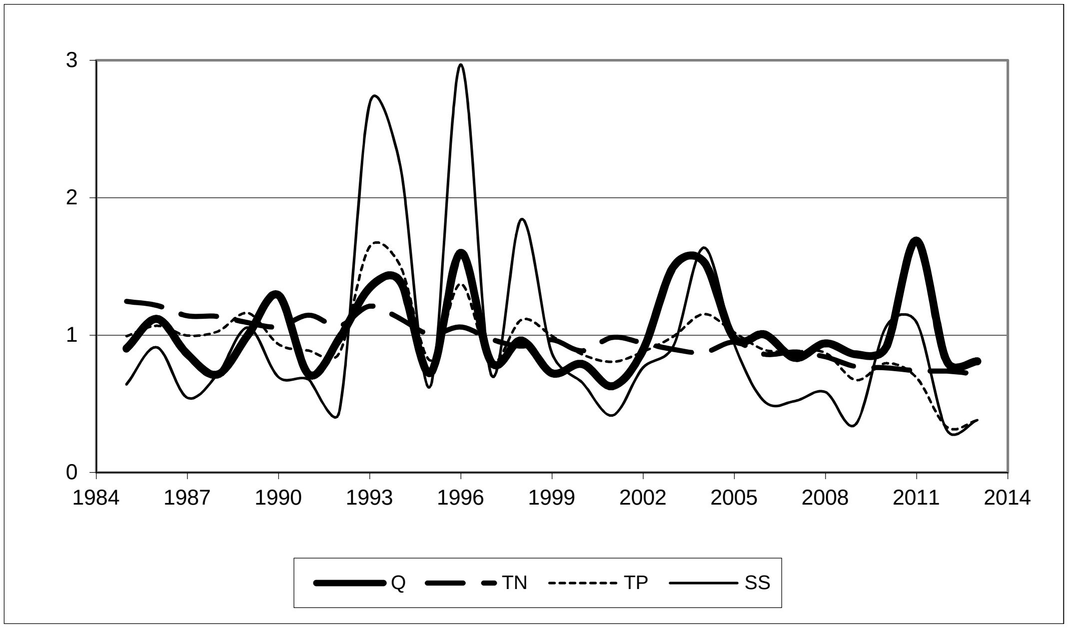

Figure A10. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

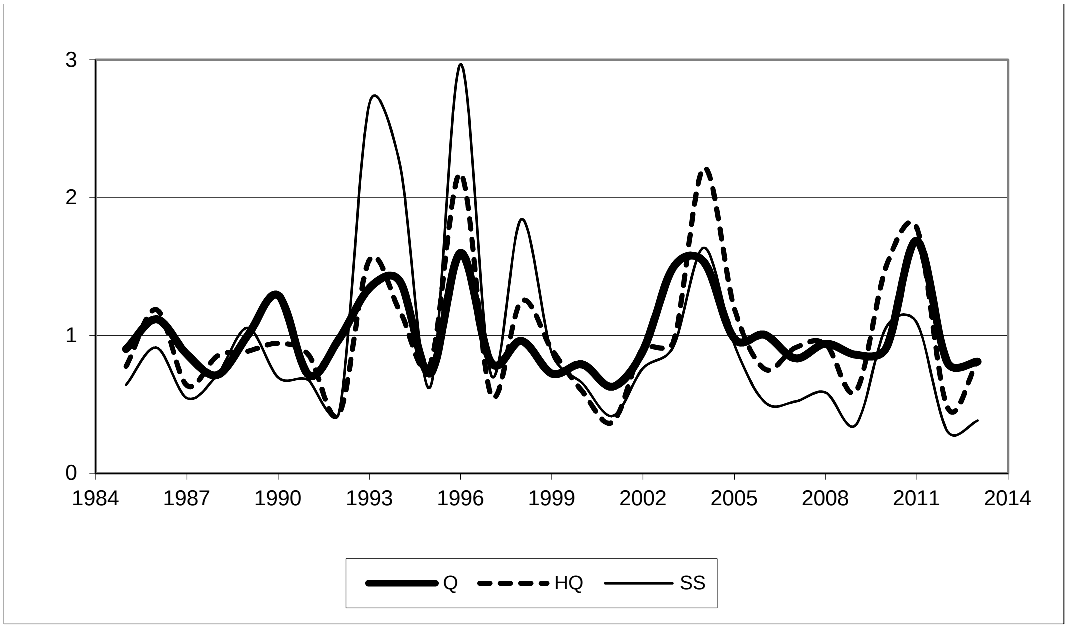

Figure A11. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

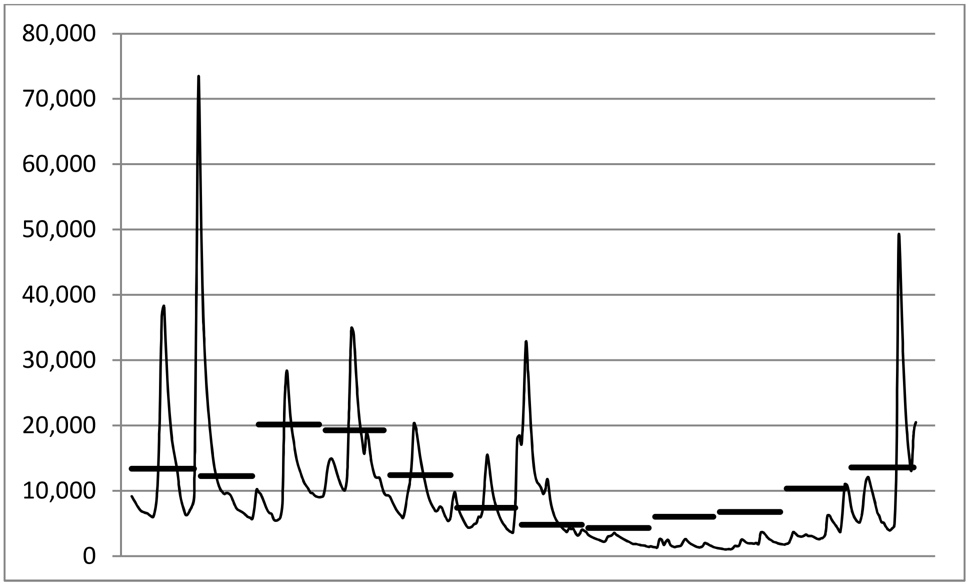

Figure A12. 2013 Daily Average Flow and Monthly LTM at Lewisburg

Table A20. 2013 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Lewisburg

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	12,929	58%	5%	2.95	5.12	0.74	71%
TNO_x	9,436	64%	5%	2.15	3.34	0.54	80%
TON	3,094	44%	12%	0.71	1.60	0.18	54%
TNH_3	607	60%	9%	0.14	0.23	0.03	73%
DN	11,962	60%	5%	2.73	4.54	0.69	74%
DNO_x	9,498	65%	5%	2.17	3.32	0.55	81%
DON	1,850	39%	12%	0.42	1.07	0.11	49%
DNH_3	595	67%	9%	0.14	0.20	0.03	82%
TP	347	29%	10%	0.08	0.27	0.02	36%
DP	104	23%	14%	0.02	0.10	0.01	29%
DOP	71	31%	17%	0.02	0.05	0.00	39%
TOC	29,060	64%	5%	6.63	10.38	1.67	79%
SS	298,029	27%	15%	68.01	253.13	17.15	33%

Table A21. 2013 Seasonal Loads (1000's lbs) and Yields (lbs/acres) at Lewisburg

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	5,215	1.19	3,716	0.85	1,546	0.35	2,453	0.56
TNO_x	3,942	0.90	2,642	0.60	1,017	0.23	1,836	0.42
TON	1,104	0.25	930	0.21	515	0.12	545	0.12
TNH_3	244	0.06	186	0.04	70	0.02	107	0.02
DN	4,882	1.11	3,435	0.78	1,379	0.31	2,266	0.52
DNO_x	3,973	0.91	2,654	0.61	1,019	0.23	1,852	0.42
DON	691	0.16	566	0.13	280	0.06	314	0.07
DNH_3	243	0.06	180	0.04	66	0.02	107	0.02
TP	124	0.03	114	0.03	60	0.01	49	0.01
DP	32	0.01	40	0.01	20	0.00	12	0.00
DOP	33	0.01	39	0.01	19	0.00	13	0.00
TOC	9,994	2.28	8,723	1.99	5,101	1.16	5,242	1.20
SS	132,467	30.23	78,357	17.88	40,742	9.30	46,462	10.60

Table A22. 2013 Monthly Average Precipitation (in), High Daily Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Lewisburg

Monthly	Precip		Flow		TN			TP			SS		
	Prec	Max	2013	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	2.67	0.95	13,435	100%	1,828	0.42	70%	41	0.009	30%	38,495	8.8	22%
February	1.80	0.83	15,859	129%	1,923	0.44	91%	52	0.012	62%	72,696	16.6	126%
March	1.41	0.45	11,431	57%	1,463	0.33	40%	31	0.007	16%	21,276	4.9	11%
April	3.24	0.87	15,869	82%	1,832	0.42	56%	54	0.012	28%	44,981	10.3	20%
May	3.01	0.62	9,515	77%	1,086	0.25	56%	32	0.007	31%	18,370	4.2	22%
June	3.51	1.38	7,499	101%	798	0.18	74%	28	0.006	49%	15,006	3.4	52%
July	3.58	0.90	9,748	202%	1,040	0.24	142%	49	0.011	128%	38,267	8.7	225%
August	1.54	0.48	2,385	55%	285	0.07	43%	7	0.002	17%	1,616	0.4	6%
September	1.91	0.71	1,774	29%	221	0.05	25%	4	0.001	6%	860	0.2	1%
October	3.37	0.85	1,989	29%	268	0.06	24%	4	0.001	7%	951	0.2	2%
November	3.23	1.09	4,322	42%	553	0.13	30%	9	0.002	9%	3,547	0.8	5%
December	3.31	0.52	12,565	92%	1,632	0.37	65%	36	0.008	31%	41,964	9.6	50%

Table A23. 2013 Annual Comparison to Baselines at Lewisburg

Parameter	2013	Q ratio	Period	Y'	R^2	Parameter	2013	Y'	R^2
TN	2.95	0.81	85-89	4.955	0.91	DN	2.73	4.300	0.87
			85-98	4.685	0.92			4.160	0.94
			99-12	3.754	0.90			3.490	0.87
			85-12	4.247	0.74			3.847	0.76
TNO_{23}	2.153	0.81	85-89	2.830	0.98	DNO_{23}	2.168	2.821	0.96
			85-98	2.868	0.92			2.851	0.93
			99-12	2.641	0.84			2.628	0.84
			85-12	2.767	0.84			2.752	0.84
TON	0.71	0.81	85-89	1.897	0.84	DON	0.42	1.236	0.82
			85-98	1.606	0.65			1.110	0.61
			99-12	1.014	0.74			0.783	0.42
			85-12	1.321	0.44			0.954	0.32
TNH_3	0.139	0.81	85-89	0.227	0.36	DNH_3	0.136	0.205	0.38
			85-98	0.226	0.62			0.198	0.53
			99-12	0.170	0.80			0.156	0.87
			85-12	0.199	0.52			0.177	0.56
TP	0.080	0.81	85-89	0.228	0.92	DP	0.024	0.116	0.76
			85-98	0.207	0.87			0.098	0.47
			99-12	0.183	0.71			0.083	0.35
			85-12	0.199	0.69			0.091	0.38
SS	68	0.81	85-89	128	0.71*	DIP	0.024	0.025	0.31
			85-98	130	0.76*			0.025	0.04
			99-12	108	0.72*			0.070	0.29
			85-12	120	0.69*			0.047	0.06
TOC	6.6	0.81	85-89	8.653	0.88				
			85-98	7.925	0.94				
			99-12	7.837	0.98				
			85-12	7.855	0.96				

Q = discharge ratio
R^2 = correlation coefficient
* indicates where an exponential regression was used as it yields a better fit to the data

Table A24. Trend Statistics for the West Branch Susquehanna River at Lewisburg, Pa., October 1984 Through September 2013

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.901	-	-	-	-	NS
TN	600	FAC	-0.018	<0.0001	-45	-41	-36	36-45	Down
TNOx	630	FAC	-0.010	<0.0001	-29	-25	-20	20-29	Down
TON	605	FAC	-0.037	<0.0001	-72	-67	-61	61-72	Down
TNH_3	610	FAC	-0.015	<0.0001	-46	-36	-25	N/A	BMDL
TKN	625	FAC	-0.031	<0.0001	-66	-60	-54	54-66	Down
DN	602	FAC	-0.016	<0.0001	-41	-37	-33	33-41	Down
DNOx	631	FAC	-0.010	<0.0001	-29	-25	-20	20-29	Down
DON	607	FAC	-0.034	<0.0001	-68	-63	-57	57-68	Down
DNH_3	608	FAC	-0.010	<0.0001	-36	-24	-11	N/A	BMDL
DKN	623	FAC	-0.032	<0.0001	-66	-61	-56	56-66	Down
TP	665	FAC	-0.026	<0.0001	-60	-53	-44	44-60	Down
DP	666	FAC	-0.041	<0.0001	-76	-70	-64	N/A	BMDL
DOP	671	FAC	0.039	<0.0001	124	205	314	N/A	BMDL
TOC	680	FAC	0.000	0.7136	-8	-1	6	N/A	NS
SS	80154	FAC	-0.018	<0.0001	-53	-41	-27	27-53	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant tren

INDIVIDUAL SITES: NEWPORT

Table A25. 2013 Annual and Seasonal Precipitation and Discharge at Newport

Season	Precipitation (inches)			Discharge (cfs)		
	2013	LTM	LTM Departure	2013	LTM	% LTM
January-March (Winter)	6.24	7.61	-1.37	6,147	6,501	0.95
April-June (Spring)	10.33	10.12	0.21	4,156	5,528	0.75
July-September (Summer)	7.94	10.35	-2.41	1,222	1,993	0.61
October-December (Fall)	10.07	9.28	0.78	2,571	3,815	0.67
Annual Total	34.58	37.37	-2.79	3,508	4,446	0.789

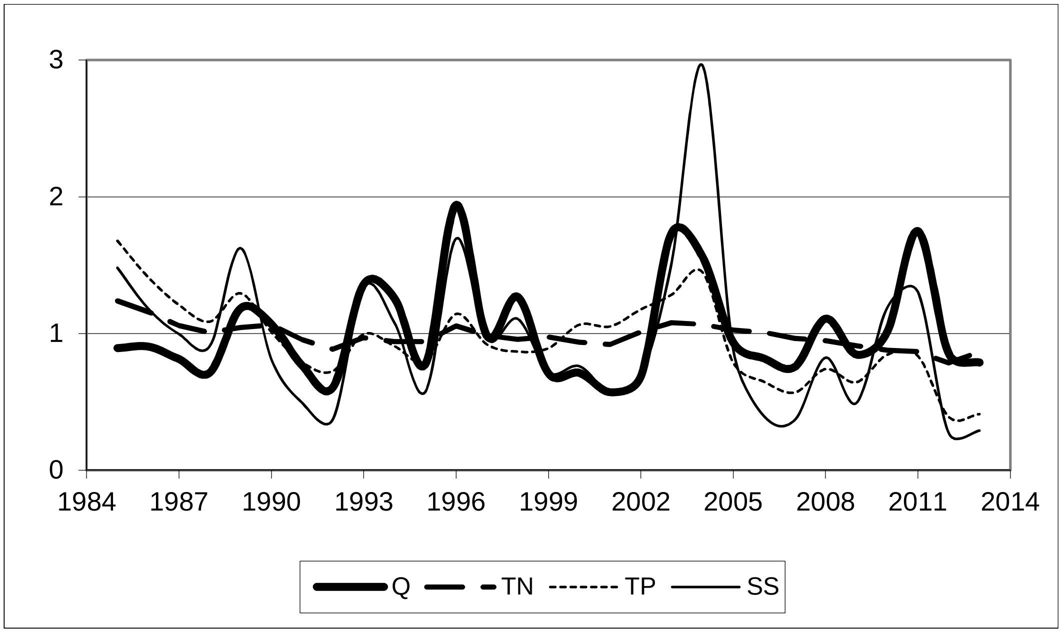

Figure A13. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

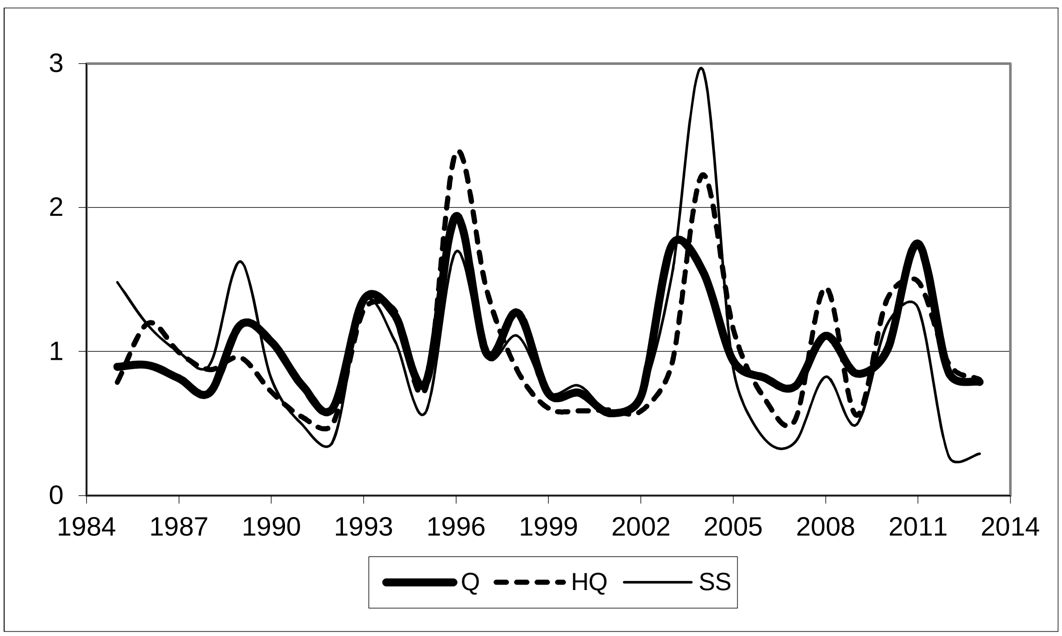

Figure A14. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

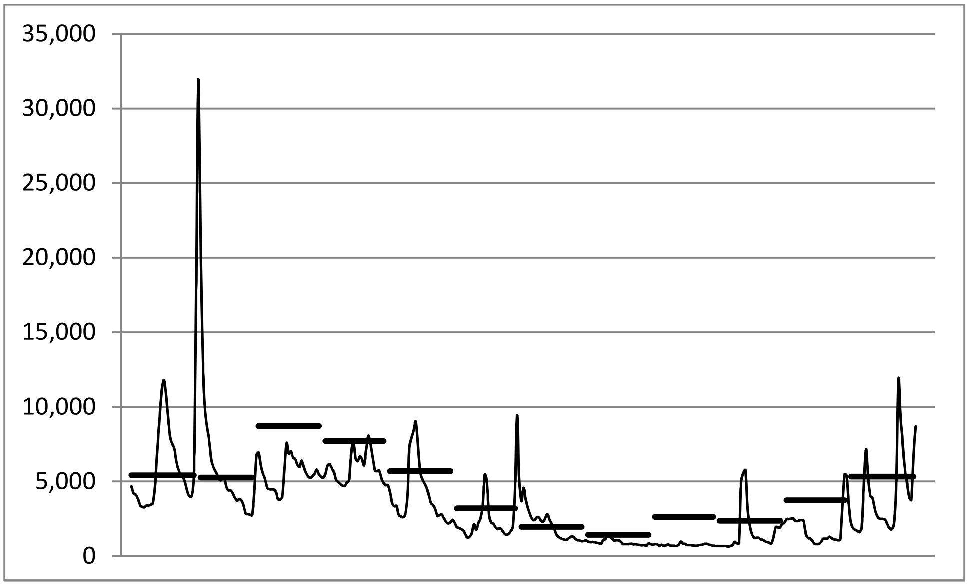

Figure A15. 2013 Daily Average Flow and Monthly LTM at Newport

Table A26. 2013 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Newport

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	10,751	67%	3%	5.01	7.45	1.56	85%
TNO_x	8,950	75%	3%	4.17	5.57	1.30	95%
TON	1,820	47%	11%	0.85	1.80	0.26	60%
TNH_3	190	51%	10%	0.09	0.17	0.03	65%
DN	10,188	70%	3%	4.75	6.74	1.48	89%
DNO_x	8,949	75%	3%	4.17	5.53	1.30	96%
DON	1,195	50%	11%	0.56	1.12	0.17	63%
DNH_3	181	56%	10%	0.08	0.15	0.03	71%
TP	231	31%	9%	0.11	0.35	0.03	39%
DP	119	34%	10%	0.06	0.16	0.02	43%
DOP	76	36%	11%	0.04	0.10	0.01	46%
TOC	17,223	61%	5%	8.02	13.17	2.49	77%
SS	98,231	20%	14%	45.76	234.01	14.22	25%

Table A27. 2013 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Newport

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	4,936	2.30	2,988	1.39	757	0.35	2,071	0.96
TNO_x	4,186	1.95	2,408	1.12	574	0.27	1,782	0.83
TON	735	0.34	590	0.27	198	0.09	298	0.14
TNH_3	70	0.03	65	0.03	23	0.01	32	0.02
DN	4,644	2.16	2,800	1.30	725	0.34	2,019	0.94
DNO_x	4,189	1.95	2,410	1.12	572	0.27	1,778	0.83
DON	445	0.21	360	0.17	154	0.07	236	0.11
DNH_3	64	0.03	61	0.03	23	0.01	32	0.01
TP	92	0.04	75	0.03	26	0.01	39	0.02
DP	40	0.02	36	0.02	17	0.01	24	0.01
DOP	34	0.02	31	0.01	15	0.01	23	0.01
TOC	7,009	3.27	5,198	2.42	1,798	0.84	3,219	1.50
SS	49,335	22.98	32,008	14.91	4,984	2.32	11,904	5.55

Table A28. 2013 Monthly Average Precipitation (in), High Daily Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Newport

Month	Precip		Flow		TN			TP			SS		
	Ave	Max	2013	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	2.62	**1.40**	6,118	113%	1,759	0.82	99%	30	0.014	49%	14,121	6.6	38%
February	1.57	0.74	6,864	130%	1,725	0.80	115%	38	0.018	76%	25,542	11.9	109%
March	1.72	0.38	5,527	63%	1,452	0.68	56%	23	0.011	20%	9,672	4.5	12%
April	3.00	0.71	5,874	76%	1,448	0.67	67%	30	0.014	29%	13,921	6.5	19%
May	2.64	0.61	4,052	71%	977	0.46	62%	26	0.012	31%	11,008	5.1	21%
June	4.42	1.44	2,546	80%	563	0.26	68%	19	0.009	39%	7,079	3.3	26%
July	3.68	0.62	2,004	102%	447	0.21	85%	16	0.007	49%	3,978	1.9	21%
August	2.77	1.43	905	64%	174	0.08	47%	6	0.003	30%	657	0.3	11%
September	1.82	0.60	740	28%	136	0.06	17%	4	0.002	6%	349	0.2	<1%
October	4.31	2.41	1,655	70%	413	0.19	55%	11	0.005	29%	2,711	1.3	14%
November	2.64	1.51	1,929	52%	482	0.22	38%	9	0.004	15%	1,919	0.9	6%
December	3.73	0.85	4,109	77%	1,175	0.55	64%	19	0.009	27%	7,274	3.4	20%

Table A29. 2013 Annual Comparison to Baselines at Newport

Parameter	2013	Q ratio	Period	Y'	R^2	Parameter	2013	Y'	R^2
TN	5.01	0.79	85-89	6.596	0.84	DN	4.75	5.800	0.87
			85-98	6.055	0.95			5.460	0.96
			99-12	5.64	0.94			5.190	0.93
			85-12	5.845	0.94			5.325	0.94
TNO_{23}	4.169	0.79	85-89	4.535	0.92	DNO_{23}	4.169	4.386	0.95
			85-98	4.363	0.97			4.289	0.98
			99-12	4.358	0.92			4.344	0.92
			85-12	4.352	0.93			4.310	0.94
TON	0.85	0.79	85-89	1.979	0.61	DON	0.56	1.209	0.58
			85-98	1.621	0.76			1.046	0.80
			99-12	1.221	0.85			0.816	0.62
			85-12	1.422	0.73			0.937	0.60
TNH_3	0.088	0.79	85-89	0.206	0.37	DNH_3	0.084	0.182	0.36
			85-98	0.158	0.55			0.139	0.47
			99-12	0.114	0.93			0.098	0.94
			85-12	0.135	0.72			0.117	0.69
TP	0.110	0.79	85-89	0.367	0.68	DP	0.055	0.184	0.49
			85-98	0.291	0.72			0.152	0.62
			99-12	0.227	0.75			0.115	0.59
			85-12	0.257	0.73			0.133	0.58
SS	46	0.79	85-89	177	0.91*	DIP	0.048	0.080	0.03
			85-98	130	0.75*			0.061	0.30
			99-12	98	0.78*			0.095	0.55
			85-12	112	0.75*			0.077	0.36
TOC	8.0	0.79	85-89	12.535	0.71				
			85-98	10.801	0.85				
			99-12	9.634	0.98				
			85-12	10.169	0.93				

Q = discharge ratio
R^2 = correlation coefficient
* indicates where an exponential regression was used as it yields a better fit to the data

Table A30. Trend Statistics for the Juniata River at Newport, Pa., October 1984 Through September 2013

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.451	-	-	-	-	NS
TN	600	FAC	-0.008	<0.0001	-25	-21	-17	17-25	Down
TNOx	630	FAC	-0.002	0.0062	-11	-7	-2	2-11	Down
TON	605	FAC	-0.030	<0.0001	-65	-59	-52	52-65	Down
TNH_3	610	FAC	-0.017	<0.0001	-49	-39	-27	N/A	BMDL
TKN	625	FAC	-0.027	<0.0001	-61	-55	-48	48-61	Down
DN	602	FAC	-0.006	<0.0001	-20	-16	-12	12-20	Down
DNOx	631	FAC	-0.001	0.0796	-9	-4	1	N/A	NS
DON	607	FAC	-0.030	<0.0001	-65	-59	-52	52-65	Down
DNH_3	608	FAC	-0.016	<0.0001	-48	-37	-25	N/A	BMDL
DKN	623	FAC	-0.029	<0.0001	-63	-58	-51	51-63	Down
TP	665	FAC	-0.028	<0.0001	-62	-56	-49	49-62	Down
DP	666	FAC	-0.031	<0.0001	-65	-60	-54	54-65	Down
DOP	671	FAC	0.023	<0.0001	52	94	148	52-148	Up
TOC	680	FAC	-0.011	<0.0001	-34	-28	-21	21-34	Down
SS	80154	FAC	-0.026	<0.0001	-63	-54	-42	42-63	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

INDIVIDUAL SITES: CONESTOGA

Table A31. 2013 Annual and Seasonal Precipitation and Discharge at Conestoga

Season	Precipitation (inches)			Discharge (cfs)		
	2013	LTM	LTM Departure	2013	LTM	% LTM
January-March (Winter)	9.23	8.69	0.54	960	893	1.08
April-June (Spring)	11.62	10.96	0.66	641	726	0.88
July-September (Summer)	10.50	12.84	-2.34	503	485	1.04
October-December (Fall)	15.18	10.94	4.23	854	663	1.29
Annual Total	46.53	43.44	3.09	739	691	1.07

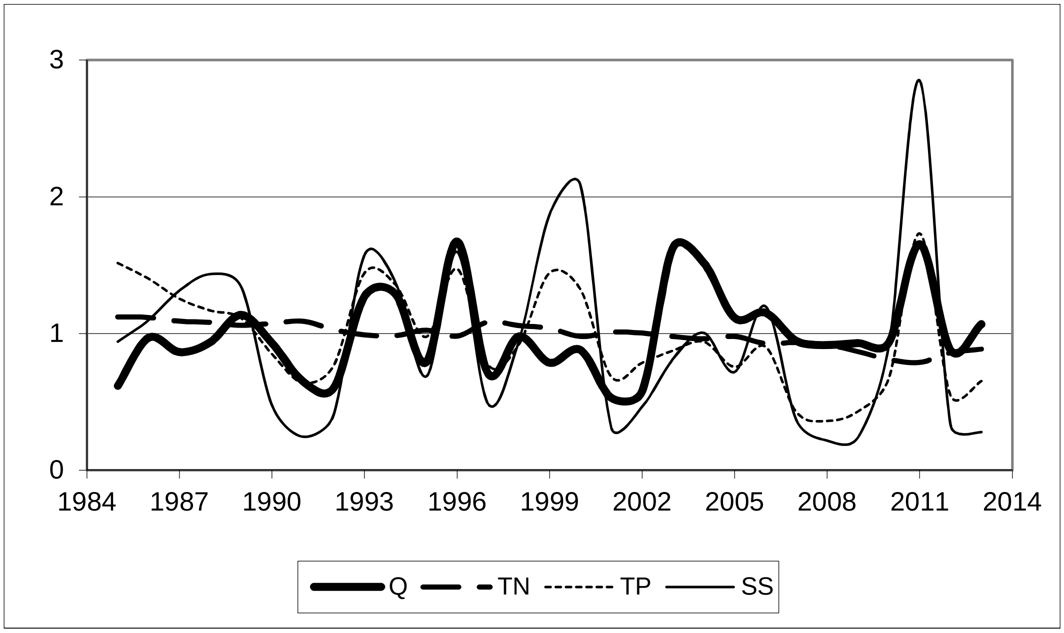

Figure A16. Annual Discharge and Calculated Annual TN, TP, and SS Concentrations Expressed as LTM Ratio

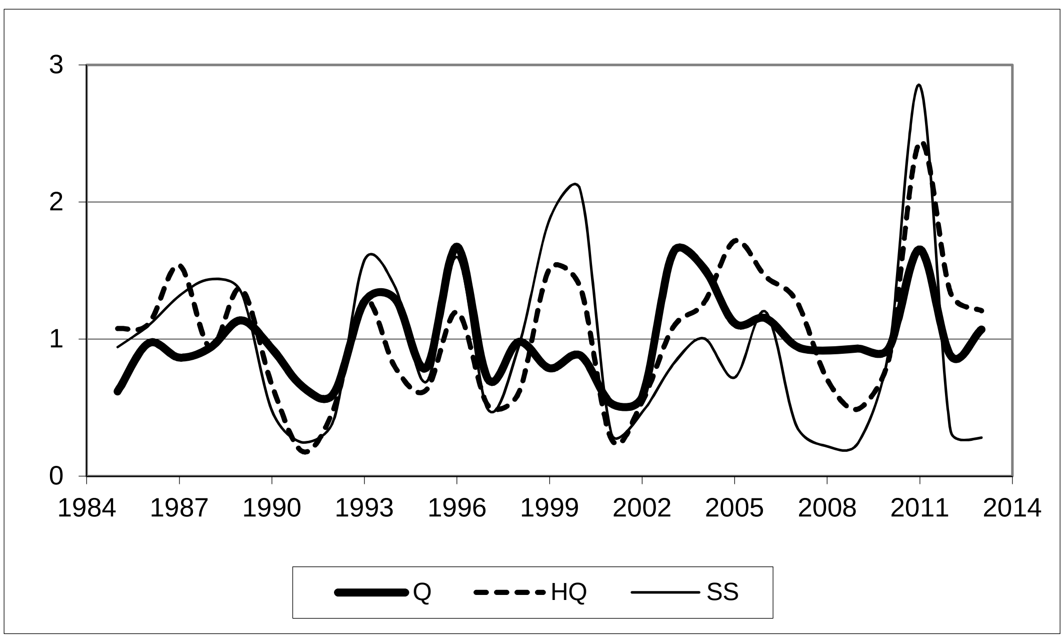

Figure A17. Annual Discharge and Annual Daily Mean High Discharge and Calculated Annual SS Concentration Expressed as LTM Ratio

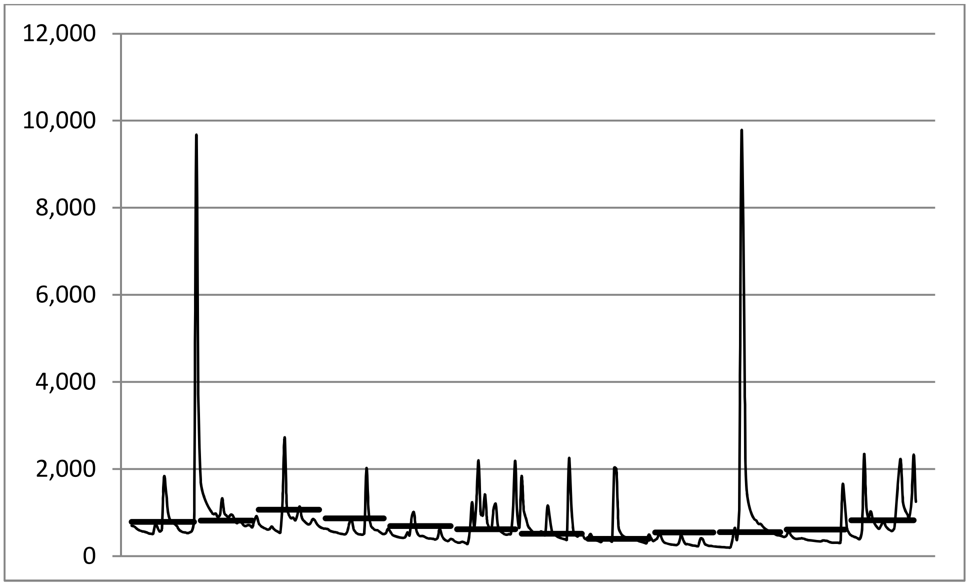

Figure A18. 2013 Daily Average Flow and Monthly LTM at Conestoga

Table A32. 2013 Annual Loads (1000's lbs), Yields (lbs/acre), and Concentrations (mg/L) at Conestoga

Parameter	Load	Load % of LTM	Error %	Yield	LTM Yield	Ave. Conc.	Conc. % of LTM
TN	9,782	96%	3%	32.52	34.01	6.74	90%
TNO_x	8,890	106%	4%	29.56	27.91	6.13	99%
TON	979	55%	14%	3.26	5.88	0.68	52%
TNH_3	98	41%	14%	0.33	0.79	0.07	39%
DN	9,410	99%	3%	31.28	31.51	6.49	93%
DNO_x	8,907	108%	4%	29.61	27.44	6.14	101%
DON	551	51%	13%	1.83	3.61	0.38	48%
DNH_3	93	43%	14%	0.31	0.72	0.06	40%
TP	443	67%	11%	1.47	2.21	0.31	62%
DP	244	93%	9%	0.81	0.88	0.17	87%
DOP	195	88%	10%	0.65	0.74	0.13	83%
TOC	5,177	70%	6%	17.21	24.72	3.57	65%
SS	97,297	28%	22%	323.46	1,170	67.08	26%

Table A33. 2013 Seasonal Loads (1000's lbs) and Yields (lbs/acre) at Conestoga

Parameter	Winter		Spring		Summer		Fall	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
TN	3,251	10.81	2,092	6.95	1,611	5.35	2,829	9.41
TNO_x	2,973	9.89	1,911	6.35	1,464	4.87	2,542	8.45
TON	281	0.93	182	0.61	162	0.54	355	1.18
TNH_3	38	0.13	19	0.06	12	0.04	29	0.10
DN	3,111	10.34	2,046	6.80	1,577	5.24	2,677	8.90
DNO_x	2,970	9.87	1,909	6.35	1,469	4.88	2,559	8.51
DON	166	0.55	130	0.43	104	0.35	151	0.50
DNH_3	34	0.11	18	0.06	12	0.04	28	0.09
TP	111	0.37	69	0.23	70	0.23	193	0.64
DP	54	0.18	42	0.14	50	0.17	97	0.32
DOP	48	0.16	38	0.13	48	0.16	96	0.32
TOC	1,572	5.22	990	3.29	855	2.84	1,760	5.85
SS	34,089	113.33	9,538	31.71	7,321	24.34	46,348	154.08

Table A34. 2013 Monthly Average Precipitation (in), High Daily Precipitation During Month (in), Flow (cfs), Loads (1000's lbs), and Yields (lbs/acre) at Conestoga

Month	Precip		Flow		TN			TP			SS		
	Ave	Max	2013	% LTM	Load	Yield	% LTM	Load	Yield	% LTM	Load	Yield	% LTM
January	5.20	**2.49**	991	125%	1,098	3.65	102%	62	0.206	117%	25,861	86.0	112%
February	1.61	0.35	1,059	130%	1,146	3.81	112%	27	0.090	61%	4,726	15.7	28%
March	2.61	1.34	840	79%	1,007	3.35	73%	22	0.073	26%	3,503	11.6	6%
April	2.77	1.56	644	74%	733	2.44	67%	17	0.056	33%	2,306	7.7	9%
May	2.57	0.96	480	69%	555	1.84	62%	14	0.046	29%	1,323	4.4	5%
June	7.19	2.03	806	131%	804	2.67	116%	38	0.126	72%	5,909	19.6	18%
July	4.57	1.37	689	133%	716	2.38	118%	35	0.116	76%	4,367	14.5	15%
August	3.41	2.03	510	129%	547	1.82	119%	25	0.084	83%	2,562	8.5	25%
September	2.45	1.04	304	56%	347	1.16	61%	10	0.034	10%	393	1.3	1%
October	5.88	2.58	1,121	203%	1,059	3.52	166%	151	0.501	276%	42,422	141.0	188%
November	2.34	1.15	461	75%	572	1.90	76%	12	0.041	29%	732	2.4	5%
December	5.08	1.57	968	118%	1,198	3.98	114%	30	0.101	51%	3,193	10.6	13%

Table A35. 2013 Annual Comparison to Baselines at Conestoga

Parameter	2013	Q ratio	Period	Y'	R^2	Parameter	2013	Y'	R^2
TN	32.52	1.07	85-89	40.241	0.99	DN	31.28	34.886	0.87
			85-98	38.596	0.98			34.401	0.97
			99-12	34.427	0.93			32.427	0.90
			85-12	36.413	0.91			33.422	0.91
TNO_{23}	29.556	1.07	85-89	29.997	0.97	DNO_{23}	29.610	29.297	0.93
			85-98	29.973	0.99			29.237	0.97
			99-12	29.028	0.92			28.600	0.93
			85-12	29.541	0.94			28.994	0.93
TON	3.26	1.07	85-89	8.732	0.97	DON	1.83	3.751	0.95
			85-98	7.917	0.89			4.255	0.71
			99-12	5.242	0.58			3.707	0.45
			85-12	6.457	0.57			3.938	0.54
TNH_3	0.327	1.07	85-89	1.327	0.29	DNH_3	0.310	1.258	0.24
			85-98	1.190	0.09			1.069	0.07
			99-12	0.522	0.92			0.484	0.92
			85-12	0.846	0.08			0.769	0.08
TP	1.470	1.07	85-89	2.770	0.67	DP	0.810	1.153	0.56
			85-98	2.885	0.89			0.987	0.66
			99-12	2.146	0.60			0.902	0.69
			85-12	2.491	0.66			0.950	0.65
SS	324	1.07	85-89	1,724	0.87*	DIP	0.765	0.926	0.61
			85-98	1,224	0.73*			0.732	0.43
			99-12	871	0.49*			0.830	0.63
			85-12	1,021	0.56*			0.794	0.54
TOC	17.2	1.07	85-89	37.020	0.11				
			85-98	30.106	0.43				
			99-12	23.354	0.89				
			85-12	26.786	0.56				

Q = discharge ratio
R^2 = correlation coefficient
* indicates where an exponential regression was used as it yields a better fit to the data

Table A36. Trend Statistics for the Conestoga River at Conestoga, Pa., October 1984 Through September 2013

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend % Change	Trend Direction
					Min	Trend	Max		
FLOW	60	SK	-	0.190	-	-	-	-	NS
TN	600	FAC	-0.010	<0.0001	-28	-24	-21	21-28	Down
TNOx	630	FAC	-0.001	0.5526	-7	-2	4	N/A	NS
TON	605	FAC	-0.037	<0.0001	-71	-67	-62	62-71	Down
TNH_3	610	FAC	-0.052	<0.0001	-82	-79	-75	75-82	Down
TKN	625	FAC	-0.043	<0.0001	-76	-72	-68	68-76	Down
DN	602	FAC	-0.003	0.0001	-13	-9	-5	5-13	Down
DNOx	631	FAC	0.000	0.9093	-5	0	6	N/A	NS
DON	607	FAC	-0.017	<0.0001	-47	-40	-31	31-47	Down
DNH_3	608	FAC	-0.051	<0.0001	-81	-78	-74	74-81	Down
DKN	623	FAC	-0.025	<0.0001	-58	-52	-46	46-58	Down
TP	665	FAC	-0.033	<0.0001	-66	-62	-57	57-66	Down
DP	666	FAC	-0.024	<0.0001	-55	-51	-47	47-55	Down
DOP	671	FAC	-0.010	<0.0001	-36	-26	-15	15-36	Down
TOC	680	FAC	-0.026	<0.0001	-57	-53	-49	49-57	Down
SS	80154	FAC	-0.056	<0.0001	-85	-81	-77	77-85	Down

Down = downward/improving trend
Up = Upward/degrading trend
BMDL = Greater than 20% of values were Below Method Detection Limit
NS = No significant trend

APPENDIX B

Summary Statistics

Table B1. Temperature, Dissolved Oxygen, Conductivity, and pH Summary Statistics of Samples Collected During 2013

Station	N	Temperature (C°)					Dissolved Oxygen (mg/L)					Conductivity (umhos/cm)					pH (S.U.)				
		Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	23	0.36	24.98	9.20	10.75	8.21	8.34	16.21	11.90	11.38	2.20	29	470	270	261	126	7.06	8.98	7.67	7.81	0.55
Cohocton	19	0.13	29.56	5.45	10.38	9.42	6.91	15.62	12.08	11.57	2.57	23	532	225	275	162	7.04	8.82	7.87	7.90	0.47
Conklin	19	0.06	24.51	8.02	10.18	8.36	8.55	13.97	11.30	11.39	1.96	38	261	150	150	57	7.1	8.2	7.7	7.69	0.35
Smithboro	24	0.22	21.67	11.38	10.95	7.39	7.90	15.61	11.26	11.18	2.11	106	249	180	181	41	5.55	8.9	7.61	7.62	0.71
Itaska	12	0.09	18.80	3.20	6.36	6.41	9.33	14.82	12.47	12.32	1.76	41	310	160	174	77	7.08	8.01	7.72	7.62	0.35
Unadilla	19	0.29	21.78	6.10	9.07	7.68	8.43	14.25	11.54	11.34	2.03	30	323	183	180	78	7.02	8.56	7.8	7.76	0.39
Castanea	18	1.72	21.78	11.03	10.69	6.75	6.11	14.45	10.93	11.21	2.30	131	433	294	300	90	7.14	8.36	7.74	7.82	0.33
Conestoga	32	2.97	25.88	14.59	13.75	6.86	7.45	18.41	11.32	11.46	2.62	213	813	582	546	153	7.07	8.86	8.04	7.99	0.40
Dalmatia	20	0.00	24.00	12.08	10.59	7.02	8.52	14.56	9.97	10.92	2.07	114	226	172	172	26	6.64	8.07	7.31	7.3	0.31
Danville	33	0.00	25.98	9.77	11.00	8.49	7.66	15.33	11.56	11.60	2.27	170	329	253	251	41	7.16	8.85	7.6	7.74	0.45
Dromgold	20	0.80	25.07	13.50	12.36	8.18	8.76	14.83	10.50	11.20	1.99	110	260	155	163	40	7.05	8.6	8.03	8.01	0.35
Hershey	20	1.19	24.99	13.70	11.91	7.43	7.01	12.88	9.53	10.02	2.08	173	394	286	276	59	7.06	8.01	7.5	7.55	0.28
Hogestown	20	3.30	26.65	14.16	13.68	8.14	6.88	14.79	10.85	10.82	1.99	216	539	351	362	97	7.37	8.91	7.98	8.02	0.37
Jersey Shore	17	2.18	25.07	10.13	10.82	7.41	8.83	14.46	11.80	11.82	1.98	101	340	180	197	72	7.05	8.23	7.84	7.72	0.40
Karthaus	17	1.30	21.81	10.41	9.75	6.84	8.64	14.25	10.89	11.50	1.93	203	589	316	355	122	6.51	8.64	7.68	7.65	0.63
Lewisburg	30	0.23	26.57	10.06	11.43	8.49	7.35	14.63	11.47	11.44	2.30	110	338	191	206	65	6.76	8.54	7.6	7.64	0.45
Manchester	19	0.44	28.24	14.81	13.27	8.61	5.25	16.75	9.64	10.20	3.00	28	364	233	232	86	6.11	8.25	7.44	7.37	0.50
Marietta	30	0.10	29.10	14.48	13.30	9.20	7.67	14.39	10.58	11.05	2.24	135	327	229	230	44	7.14	8.8	7.96	7.94	0.43
Martic Forge	20	2.10	25.13	14.02	12.78	6.78	8.49	13.99	10.96	11.00	1.87	153	624	469	421	130	6.9	8.43	7.93	7.86	0.39
Newport	33	1.40	27.51	12.77	13.17	8.87	7.40	14.92	10.30	10.71	2.12	167	366	252	255	47	7.01	8.83	8.07	8.05	0.35
Paxton	19	1.40	21.58	14.15	11.72	6.45	6.71	12.70	9.39	9.85	1.89	163	832	582	524	177	6.87	8.02	7.56	7.58	0.30
Penns Creek	19	1.76	25.39	13.36	12.85	7.78	7.73	14.96	11.00	11.45	2.11	151	258	205	209	34	7.29	8.7	8.06	8.04	0.42
Reedsville	19	3.00	19.65	10.42	10.93	5.67	6.71	14.09	10.44	11.14	1.89	187	425	326	311	79	7.41	8.47	8.07	8.01	0.26
Saxton	18	0.78	23.60	13.16	11.92	8.38	7.80	14.66	10.37	10.60	2.10	140	411	305	290	80	6.88	8.64	7.95	7.92	0.41
Towanda	30	0.14	25.74	6.98	10.11	8.30	4.20	14.56	11.47	11.19	2.36	145	313	233	234	52	7.11	8.63	7.85	7.89	0.32
Wilkes-Barre	19	0.00	25.76	6.00	9.15	8.00	7.73	14.45	12.40	11.55	2.20	160	284	225	227	43	7.18	8.62	7.53	7.58	0.37
Richardsmere	18	0.36	24.98	9.20	10.75	8.21	8.34	16.21	11.90	11.38	2.20	29	470	270	261	126	7.06	8.98	7.67	7.81	0.55

Table B2.   Total Nitrogen Species Summary Statistics of Samples Collected During 2013, in mg/L

Station	N	Total Nitrogen					Total Ammonium					Total Nitrate plus Nitrite					Total Organic Nitrogen				
		Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	23	0.53	1.69	0.94	0.99	0.28	0.01	0.10	0.03	0.03	0.02	0.31	1.29	0.55	0.58	0.20	0.07	1.18	0.34	0.38	0.22
Cohocton	19	0.78	2.14	1.65	1.63	0.40	0.01	0.09	0.03	0.03	0.02	0.42	1.68	1.12	1.13	0.40	0.17	1.02	0.41	0.47	0.24
Conklin	19	0.53	1.14	0.74	0.79	0.17	0.01	0.06	0.03	0.03	0.01	0.27	0.80	0.42	0.46	0.14	0.04	0.57	0.29	0.30	0.14
Smithboro	24	0.67	1.48	0.88	0.93	0.22	0.01	0.08	0.04	0.04	0.02	0.31	0.82	0.49	0.50	0.13	0.15	0.96	0.32	0.39	0.24
Itaska	12	0.70	1.71	1.11	1.17	0.31	0.01	0.03	0.03	0.02	0.01	0.41	1.38	0.89	0.83	0.25	0.15	0.75	0.27	0.32	0.16
Unadilla	19	0.68	2.06	1.03	1.10	0.32	0.00	0.06	0.03	0.03	0.01	0.29	1.62	0.60	0.68	0.31	0.17	0.96	0.33	0.39	0.20
Castanea	18	0.94	2.06	1.48	1.44	0.29	0.01	0.08	0.02	0.03	0.02	0.66	1.62	1.21	1.18	0.28	0.05	0.94	0.19	0.23	0.19
Conestoga	32	3.09	8.30	6.70	6.30	1.36	0.01	0.25	0.04	0.07	0.07	0.40	8.20	6.30	5.55	1.97	0.08	4.23	0.51	0.73	0.79
Dalmatia	20	1.15	11.81	4.70	4.70	2.48	0.01	0.23	0.02	0.05	0.06	0.97	9.92	3.79	4.23	2.17	0.09	1.66	0.33	0.52	0.49
Danville	33	0.44	1.45	0.88	0.88	0.25	0.01	0.08	0.02	0.03	0.02	0.14	1.08	0.51	0.58	0.24	0.11	0.52	0.26	0.28	0.12
Dromgold	20	0.83	3.06	1.88	1.80	0.62	0.01	0.17	0.03	0.03	0.03	0.63	2.14	1.54	1.47	0.48	0.04	1.24	0.19	0.29	0.28
Hershey	20	2.27	4.75	3.24	3.21	0.61	0.01	0.21	0.05	0.06	0.05	1.42	4.29	2.52	2.79	0.76	0.01	1.32	0.30	0.39	0.33
Hogestown	20	2.49	5.14	3.60	3.58	0.62	0.01	0.10	0.04	0.05	0.03	1.83	4.51	3.19	3.16	0.67	0.06	0.77	0.40	0.40	0.21
Jersey Shore	17	0.36	1.60	0.63	0.66	0.29	0.01	0.08	0.03	0.03	0.02	0.25	0.57	0.44	0.44	0.11	0.04	1.03	0.14	0.19	0.23
Karthaus	17	0.27	1.13	0.56	0.62	0.27	0.01	0.10	0.04	0.04	0.02	0.15	0.76	0.39	0.41	0.18	0.04	0.53	0.14	0.16	0.12
Lewisburg	30	0.35	1.22	0.64	0.69	0.22	0.01	0.06	0.02	0.03	0.02	0.04	0.95	0.46	0.49	0.19	0.00	0.59	0.14	0.17	0.15
Manchester	19	0.21	4.25	2.31	2.25	0.94	0.01	0.22	0.04	0.06	0.06	0.68	3.19	1.53	1.71	0.74	0.09	1.25	0.43	0.53	0.36
Marietta	30	0.55	2.26	1.05	1.22	0.45	0.01	0.14	0.03	0.03	0.03	0.38	1.85	0.78	0.89	0.38	0.09	0.91	0.29	0.31	0.17
Martic Forge	20	3.27	8.70	7.26	6.86	1.40	0.01	0.52	0.07	0.11	0.12	1.79	8.62	6.57	5.94	2.13	0.31	3.17	0.64	0.94	0.84
Newport	33	0.88	2.68	1.48	1.53	0.43	0.01	0.08	0.03	0.03	0.02	0.62	1.77	1.16	1.19	0.34	0.03	0.98	0.25	0.30	0.17
Paxton	19	0.77	2.90	1.56	1.57	0.53	0.01	0.06	0.02	0.03	0.02	0.72	2.45	1.08	1.27	0.51	0.00	0.74	0.21	0.28	0.23
Penns Creek	19	0.91	2.27	1.48	1.52	0.44	0.01	0.08	0.03	0.04	0.02	0.72	1.67	1.18	1.18	0.29	0.03	1.06	0.22	0.30	0.26
Reedsville	19	1.65	3.98	3.03	2.98	0.61	0.01	0.07	0.03	0.03	0.02	1.45	4.47	2.86	2.77	0.80	0.04	1.34	0.20	0.30	0.30
Saxton	18	1.25	3.14	1.90	1.93	0.42	0.01	0.06	0.03	0.03	0.01	0.97	2.83	1.55	1.56	0.44	0.09	0.98	0.23	0.34	0.25
Towanda	30	0.62	1.57	0.83	0.90	0.24	0.01	0.08	0.03	0.03	0.02	0.14	1.15	0.52	0.58	0.21	0.08	0.87	0.24	0.28	0.15
Wilkes-Barre	19	0.58	1.55	0.88	0.95	0.26	0.01	0.10	0.04	0.04	0.03	0.22	1.07	0.57	0.59	0.20	0.04	0.76	0.30	0.32	0.15
Richardsmere	18	4.50	8.28	6.58	6.52	1.09	0.01	0.17	0.05	0.06	0.05	3.93	7.75	6.06	5.90	1.30	0.14	1.98	0.56	0.61	0.42

Table B3. Dissolved Nitrogen Species Summary Statistics of Samples Collected During 2013, in mg/L

Station	N	Dissolved Nitrogen					Dissolved Ammonium					Dissolved Nitrate plus Nitrite					Dissolved Organic Nitrogen				
		Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	23	0.60	1.70	0.97	0.95	0.27	0.01	0.10	0.03	0.03	0.02	0.34	1.30	0.65	0.66	0.24	0.08	0.48	0.23	0.25	0.13
Cohocton	19	0.74	2.82	1.50	1.58	0.57	0.01	0.10	0.04	0.04	0.02	0.42	1.85	1.11	1.16	0.44	0.05	0.89	0.30	0.38	0.24
Conklin	19	0.46	1.11	0.73	0.71	0.16	0.01	0.07	0.03	0.03	0.02	0.27	0.91	0.43	0.47	0.15	0.06	0.45	0.18	0.21	0.12
Smithboro	24	0.68	1.38	0.79	0.87	0.19	0.01	0.10	0.04	0.04	0.02	0.37	0.87	0.50	0.54	0.13	0.08	0.71	0.25	0.29	0.18
Itaska	12	0.60	1.70	1.09	1.14	0.36	0.00	0.07	0.03	0.03	0.02	0.42	1.41	0.90	0.85	0.26	0.08	0.63	0.17	0.26	0.19
Unadilla	19	0.59	2.00	0.89	0.98	0.38	0.01	0.06	0.02	0.03	0.01	0.30	1.78	0.61	0.70	0.33	0.04	0.88	0.19	0.26	0.23
Castanea	18	0.84	2.00	1.40	1.36	0.31	0.01	0.06	0.03	0.03	0.01	0.66	1.78	1.22	1.19	0.30	0.03	0.33	0.14	0.14	0.08
Conestoga	32	2.17	8.37	6.69	6.08	1.64	0.01	0.24	0.04	0.07	0.07	0.39	8.19	6.28	5.54	1.97	0.01	3.72	0.38	0.49	0.64
Dalmatia	20	1.19	11.05	4.13	4.50	2.33	0.01	0.22	0.02	0.05	0.06	0.97	9.93	3.75	4.18	2.16	0.02	0.90	0.25	0.29	0.20
Danville	33	0.33	1.38	0.74	0.79	0.26	0.01	0.08	0.02	0.03	0.02	0.14	1.22	0.51	0.59	0.25	0.04	0.42	0.19	0.18	0.07
Dromgold	20	0.86	2.58	1.73	1.72	0.55	0.01	0.16	0.03	0.03	0.03	0.64	2.12	1.53	1.48	0.49	0.03	0.64	0.18	0.22	0.14
Hershey	20	1.98	4.81	2.93	3.07	0.71	0.01	0.21	0.05	0.06	0.05	1.40	4.23	2.49	2.78	0.75	0.07	0.60	0.23	0.27	0.15
Hogestown	20	2.38	5.08	3.47	3.49	0.66	0.01	0.10	0.05	0.05	0.03	1.83	4.52	3.18	3.17	0.68	0.10	0.69	0.33	0.34	0.16
Jersey Shore	17	0.31	0.81	0.59	0.57	0.13	0.01	0.06	0.03	0.03	0.01	0.25	0.57	0.43	0.44	0.11	0.05	0.27	0.10	0.11	0.05
Karthaus	17	0.23	0.95	0.50	0.53	0.22	0.01	0.07	0.03	0.04	0.02	0.16	0.76	0.39	0.41	0.18	0.00	0.16	0.09	0.09	0.04
Lewisburg	30	0.34	1.09	0.59	0.63	0.19	0.01	0.06	0.02	0.03	0.02	0.04	0.94	0.46	0.50	0.19	0.00	0.57	0.10	0.11	0.10
Manchester	19	1.01	3.75	2.12	2.15	0.73	0.01	0.21	0.04	0.06	0.05	0.68	3.18	1.53	1.71	0.74	0.06	0.78	0.42	0.38	0.17
Marietta	30	0.51	2.21	0.96	1.08	0.40	0.01	0.12	0.04	0.03	0.03	0.38	1.83	0.79	0.89	0.37	0.03	0.37	0.15	0.16	0.09
Martic Forge	20	2.47	8.72	7.02	6.45	1.91	0.01	0.50	0.07	0.10	0.12	1.76	8.54	6.55	5.89	2.09	0.10	1.27	0.59	0.55	0.29
Newport	33	0.84	2.16	1.34	1.42	0.37	0.01	0.10	0.03	0.03	0.02	0.62	1.76	1.14	1.19	0.34	0.01	0.44	0.19	0.19	0.09
Paxton	19	0.79	2.38	1.34	1.39	0.42	0.01	0.06	0.02	0.02	0.02	0.72	2.46	1.08	1.21	0.45	0.02	0.34	0.18	0.19	0.10
Penns Creek	19	0.89	2.01	1.42	1.41	0.34	0.01	0.08	0.03	0.03	0.02	0.71	1.67	1.20	1.18	0.28	0.03	0.43	0.16	0.19	0.11
Reedsville	19	1.57	3.95	2.88	2.85	0.66	0.01	0.07	0.03	0.03	0.02	1.46	3.68	2.82	2.66	0.69	0.03	0.40	0.17	0.19	0.12
Saxton	18	1.17	3.07	1.75	1.78	0.44	0.01	0.05	0.03	0.03	0.01	0.96	2.85	1.54	1.56	0.44	0.05	0.42	0.18	0.20	0.09
Towanda	30	0.43	1.25	0.75	0.79	0.20	0.01	0.07	0.02	0.03	0.02	0.15	1.07	0.52	0.59	0.20	0.06	0.29	0.18	0.17	0.05
Wilkes-Barre	19	0.36	1.27	0.76	0.81	0.24	0.01	0.09	0.03	0.04	0.02	0.23	1.05	0.58	0.59	0.19	0.03	0.40	0.18	0.18	0.08
Richardsmere	18	4.26	7.90	6.40	6.26	1.18	0.01	0.18	0.05	0.06	0.05	3.93	7.81	6.03	5.88	1.29	0.13	0.78	0.34	0.38	0.18

Table B4. Phosphorus Species and Total Suspended Solids Summary Statistics of Samples Collected During 2013, in mg/L

Station	N	Total Phosphorus					Dissolved Phosphorus					Orthophosphorus					Total Suspended Solids				
		Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	23	0.027	0.292	0.063	0.079	0.066	0.011	0.087	0.021	0.028	0.018	0.005	0.078	0.019	0.022	0.018	1.30	288	10.5	41.9	67.4
Cohocton	19	0.015	0.144	0.049	0.053	0.032	0.007	0.034	0.022	0.021	0.007	0.005	0.027	0.012	0.012	0.006	2.00	112	18.5	24.8	27.4
Conklin	19	0.014	0.220	0.044	0.064	0.065	0.005	0.024	0.014	0.013	0.005	0.005	0.015	0.006	0.007	0.003	1.80	219	17.9	48.6	66.5
Smithboro	24	0.014	0.277	0.051	0.075	0.076	0.006	0.036	0.014	0.015	0.007	0.003	0.028	0.007	0.010	0.007	2.00	252	29.3	57.7	76.2
Itaska	12	0.015	0.136	0.038	0.046	0.032	0.005	0.030	0.013	0.014	0.006	0.005	0.018	0.007	0.008	0.003	2.70	63	22.5	25.2	18.0
Unadilla	19	0.009	0.253	0.056	0.072	0.068	0.005	0.029	0.012	0.013	0.007	0.004	0.017	0.008	0.008	0.004	1.70	214	33.7	54.8	59.8
Castanea	18	0.016	0.243	0.031	0.042	0.050	0.005	0.033	0.012	0.016	0.008	0.007	0.027	0.012	0.014	0.007	2.50	208	8.0	28.2	59.5
Conestoga	32	0.042	2.720	0.209	0.368	0.492	0.023	0.471	0.172	0.186	0.103	0.018	0.431	0.161	0.172	0.094	<5.0	2,086	8.0	129.5	386.3
Dalmatia	20	0.013	0.384	0.059	0.108	0.122	0.004	0.155	0.047	0.052	0.039	0.006	0.142	0.042	0.046	0.035	<5.0	282	5.0	47.3	87.7
Danville	33	0.010	0.158	0.043	0.051	0.035	0.006	0.033	0.012	0.015	0.007	0.002	0.050	0.009	0.012	0.010	<5.0	108	12.0	22.6	24.3
Dromgold	20	0.009	0.261	0.039	0.071	0.076	0.007	0.165	0.029	0.050	0.050	0.003	0.138	0.025	0.042	0.042	<5.0	152	5.5	20.3	36.2
Hershey	20	0.023	0.570	0.065	0.115	0.135	0.016	0.202	0.051	0.060	0.047	0.014	0.185	0.044	0.052	0.043	<5.0	284	9.0	41.9	81.1
Hogestown	20	0.014	0.187	0.040	0.063	0.054	0.010	0.108	0.031	0.037	0.027	0.005	0.082	0.024	0.029	0.022	<5.0	140	8.0	27.2	36.6
Jersey Shore	17	0.007	0.337	0.015	0.039	0.079	0.003	0.012	0.005	0.005	0.002	0.003	0.009	0.006	0.006	0.002	<5.0	332	6.0	32.8	79.0
Karthaus	17	0.003	0.097	0.015	0.026	0.027	0.003	0.008	0.004	0.004	0.002	0.002	0.010	0.005	0.005	0.002	<5.0	110	10.0	27.1	33.2
Lewisburg	30	0.008	0.160	0.014	0.027	0.036	0.003	0.018	0.006	0.007	0.004	0.003	0.015	0.006	0.006	0.003	<5.0	174	6.0	22.5	45.0
Manchester	19	0.028	0.557	0.183	0.232	0.176	0.022	0.364	0.134	0.152	0.103	0.020	0.329	0.126	0.135	0.093	<5.0	384	14.0	60.3	92.4
Marietta	30	0.011	0.413	0.045	0.071	0.090	0.004	0.223	0.020	0.033	0.049	0.002	0.193	0.013	0.027	0.043	<5.0	228	14.0	29.2	47.3
Martic Forge	20	0.029	2.559	0.255	0.607	0.771	0.014	0.829	0.149	0.273	0.269	0.009	0.769	0.131	0.247	0.244	<5.0	1,260	19.0	148.0	310.7
Newport	33	0.008	0.195	0.041	0.056	0.046	0.003	0.099	0.032	0.031	0.022	0.002	0.083	0.023	0.026	0.019	<5.0	170	10.0	22.3	34.2
Paxton	19	0.005	0.196	0.026	0.058	0.064	0.003	0.076	0.021	0.023	0.019	0.004	0.070	0.018	0.021	0.017	<5.0	184	6.0	32.3	50.5
Penns Creek	19	0.006	0.316	0.035	0.067	0.083	0.004	0.153	0.024	0.033	0.034	0.004	0.141	0.020	0.028	0.031	<5.0	146	8.0	22.7	39.0
Reedsville	19	0.022	0.265	0.068	0.084	0.060	0.015	0.101	0.059	0.057	0.027	0.014	0.089	0.059	0.049	0.023	<5.0	380	10.0	41.7	92.2
Saxton	18	0.004	0.170	0.044	0.054	0.046	0.004	0.075	0.029	0.027	0.016	0.001	0.063	0.021	0.022	0.015	<5.0	186	14.0	35.1	57.4
Towanda	30	0.014	0.476	0.046	0.068	0.086	0.008	0.031	0.018	0.018	0.007	0.004	0.028	0.014	0.015	0.007	<5.0	562	13.0	44.5	103.6
Wilkes-Barre	19	0.014	0.421	0.058	0.086	0.092	0.005	0.031	0.015	0.016	0.008	0.003	0.027	0.010	0.012	0.007	<5.0	396	26.0	57.9	91.6
Richardsmere	18	0.046	0.901	0.147	0.208	0.209	0.017	0.367	0.104	0.117	0.099	0.011	0.320	0.091	0.101	0.088	<5.0	242	9.0	26.3	55.1

Table B5. ***Flow, Total Organic Carbon, Total Kjeldahl, and Dissolved Kjeldahl Summary Statistics of Samples Collected During 2013, in mg/L***

Station	N	Flow (cfs)					Total Organic Carbon					Total Kjeldahl Nitrogen					Dissolved Kjeldahl Nitrogen				
		Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD	Min	Max	Med	Mn	SD
Chemung	23	276	17,300	2,115	5,383	5,796	2.30	5.70	3.40	3.62	0.99	0.10	1.22	0.38	0.41	0.23	0.09	0.52	0.26	0.29	0.14
Cohocton	19	58	2,630	473	968	965	2.80	5.70	4.10	4.05	0.84	0.18	1.08	0.43	0.50	0.24	0.10	0.97	0.35	0.42	0.25
Conklin	19	1,280	17,800	7,315	7,596	5,609	1.80	4.30	2.70	2.84	0.70	0.06	0.62	0.33	0.33	0.14	0.09	0.47	0.20	0.24	0.12
Smithboro	24	2,500	42,200	11,430	15,975	12,906	1.80	6.30	3.20	3.48	1.08	0.17	1.01	0.36	0.43	0.24	0.12	0.74	0.30	0.33	0.17
Itaska	12						2.10	4.50	3.05	3.07	0.69	0.18	0.77	0.30	0.34	0.16	0.10	0.69	0.20	0.29	0.21
Unadilla	19	310	6,760	2,035	2,598	2,250	1.60	5.20	3.20	3.34	1.02	0.17	1.02	0.36	0.42	0.21	0.10	0.90	0.21	0.29	0.23
Castanea	18	278	5,287	1,088	1,768	1,724	1.34	8.48	1.95	2.41	1.56	0.08	1.29	0.22	0.31	0.31	0.04	0.39	0.16	0.17	0.08
Conestoga	32	249	10,100	613	1,658	2,592	1.58	11.62	2.70	4.26	2.77	0.01	4.45	0.48	0.78	0.84	0.02	3.92	0.47	0.56	0.67
Dalmatia	20	27	2,180	285	519	642	1.04	8.67	2.62	3.33	2.34	0.03	1.89	0.27	0.51	0.53	0.03	1.12	0.25	0.32	0.25
Danville	33	3,910	71,900	11,000	18,949	17,180	1.68	4.14	2.71	2.85	0.67	0.12	0.55	0.28	0.31	0.13	0.07	0.48	0.21	0.21	0.07
Dromgold	20	28	4,070	359	654	904	1.07	11.12	2.58	3.61	2.53	0.06	1.29	0.21	0.33	0.29	0.05	0.69	0.22	0.25	0.16
Hershey	20	154	8,420	684	1,902	2,596	1.47	11.50	2.85	3.88	2.69	0.06	1.38	0.36	0.45	0.35	0.00	0.65	0.27	0.31	0.17
Hogestown	20	115	7,190	805	1,344	1,685	1.34	8.32	3.73	3.70	1.85	0.08	0.82	0.47	0.45	0.22	0.01	0.70	0.36	0.37	0.18
Jersey Shore	17	2,580	8,040	6,700	5,773	2,846	0.98	7.96	1.68	2.12	1.61	0.06	1.11	0.17	0.22	0.24	0.02	0.33	0.13	0.13	0.07
Karthaus	17	343	13,000	2,630	4,083	3,968	1.22	5.14	1.89	2.20	1.10	0.05	0.60	0.18	0.21	0.13	0.01	0.22	0.13	0.12	0.05
Lewisburg	30	1,230	75,400	7,945	13,871	16,336	0.87	5.33	1.63	1.88	0.94	0.03	0.64	0.15	0.20	0.15	0.02	0.58	0.13	0.14	0.10
Manchester	19	68	25,200	733	4,095	7,528	2.05	13.35	5.59	6.56	3.19	0.10	1.47	0.48	0.61	0.39	0.07	0.84	0.49	0.44	0.20
Marietta	30	8,700	139,000	34,400	40,265	31,777	1.51	43.04	3.45	5.78	7.58	0.12	0.98	0.31	0.34	0.18	0.04	0.41	0.18	0.19	0.10
Martic Forge	20	90	3,140	186	546	854	1.32	19.11	2.77	5.40	5.05	0.35	3.38	0.66	1.05	0.93	0.23	1.28	0.68	0.66	0.32
Newport	33	732	34,200	4,585	5,494	6,454	1.65	8.90	2.80	3.40	1.51	0.05	1.02	0.30	0.33	0.18	0.03	0.48	0.22	0.23	0.10
Paxton	19	3	4,710	17	305	1,074	1.58	8.65	2.45	3.62	2.21	0.01	0.80	0.21	0.31	0.24	0.03	0.37	0.19	0.21	0.10
Penns Creek	19	62	3,970	460	706	936	1.07	8.41	2.66	3.49	2.04	0.04	1.11	0.25	0.34	0.27	0.04	0.50	0.18	0.23	0.13
Reedsville	19	34	1,680	144	323	421	0.90	10.33	2.29	3.13	2.34	0.03	1.39	0.21	0.31	0.31	0.06	0.45	0.23	0.22	0.12
Saxton	18	119	8,400	678	1,718	2,383	1.42	6.65	3.12	3.27	1.24	0.11	1.01	0.25	0.37	0.25	0.07	0.47	0.21	0.23	0.09
Towanda	30	2,700	62,100	8,415	17,465	17,087	1.65	7.53	2.95	3.19	1.20	0.14	0.95	0.28	0.31	0.16	0.09	0.36	0.21	0.20	0.06
Wilkes-Barre	19	4,730	80,200	18,800	25,757	21,152	2.07	4.75	3.23	3.27	0.79	0.10	0.86	0.33	0.36	0.17	0.07	0.48	0.20	0.22	0.10
Richardsmere	18	100	4,800	311	698	1,175	2.28	12.37	3.68	4.24	2.29	0.24	2.05	0.58	0.68	0.42	0.15	0.79	0.39	0.44	0.18