DISCHARGE, NUTRIENT, AND SUSPENDED-SEDIMENT TRENDS

Trend analyses of water quality and flow data collected at the six Group A monitoring sites were completed for the period January 1985 through December 2004. FAC trends were estimated using the USGS 7-parameter, log-linear regression model (ESTIMATOR) developed by Cohn and others (1989) and described in Langland and others (1999). This estimator 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 discharge, SS, TOC, and several forms of nitrogen and phosphorus. Trends in FAC are directly taken from ESTIMATOR output. Trends in flow are calculated using S-Plus with the USGS ESTREND library addition (Shertz and others, 1991). Results were reported for monthly mean discharge (FLOW) and FAC.

Trends in FLOW indicate the natural changes in hydrology. Changes in flow and the cumulative sources of flow (base flow and over land 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).

Trend results for each monitoring site are presented in Tables 30 through 35. Each table lists the results for flow, the various nitrogen and phosphorus species, TOC, and SS. The level of significance was set by the p-value of 0.05 for FAC (Langland and others, 1999). The magnitude of the slope incorporates a confidence interval and was reported as a range (minimum and maximum). The slope direction was reported as not significant (NS) or, when significant, as improving or degrading. When a time series had greater than 20 percent of its observations below the method detection level (BMDL), a trend analysis could not be completed.

Table 30. Trend Statistics for the Susquehanna River at Towanda, Pa., January 1989 Through December 2004

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	FLOW	66.209	0.5812	-	-	-	NS
TN	600	FAC	-0.0248	0.0000	-37	-33	-29	IMPROVING
DN	602	FAC	-0.0173	0.0000	-29	-24	-20	IMPROVING
TON	605	FAC	-0.0291	0.0000	-45	-37	-29	IMPROVING
DON	607	FAC	-0.0135	0.0014	-29	-19	-8	IMPROVING
DNH_3	608	FAC	-0.0129	0.0175	-32	-19	-3	IMPROVING
TNH_3	610	FAC	-0.0374	0.0000	-54	-45	-34	IMPROVING
DKN	623	FAC	-0.0231	0.0000	-40	-31	-20	IMPROVING
TKN	625	FAC	-0.0313	0.0000	-47	-39	-31	IMPROVING
TNOx	630	FAC	-0.0172	0.0000	-29	-24	-19	IMPROVING
DNOx	631	FAC	-0.0166	0.0000	-28	-23	-18	IMPROVING
TP	665	FAC	-0.0135	0.0053	-31	-19	-6	IMPROVING
DP	666	FAC	-0.0226	0.0000	-40	-30	-19	IMPROVING
DOP	671	FAC	0.1024	0.0000	304	414	554	DEGRADING
TOC	680	FAC	-0.0066	0.0003	-15	-10	-5	IMPROVING
SS	80154	FAC	-0.0264	0.0006	-49	-34	-16	IMPROVING

Table 31. Trend Statistics for the Susquehanna River at Danville, Pa., January 1985 Through December 2004

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	FLOW	151.34	0.2695	-	-	-	NS
TN	600	FAC	-0.0243	0.0000	-42	-38	-34	IMPROVING
DN	602	FAC	-0.0173	0.0000	-34	-29	-25	IMPROVING
TON	605	FAC	-0.0345	0.0000	-56	-50	-43	IMPROVING
DON	607	FAC	-0.0192	0.0000	-40	-32	-22	IMPROVING
DNH_3	608	FAC	-0.0275	0.0000	-51	-42	-31	IMPROVING
TNH_3	610	FAC	-0.0428	0.0000	-65	-57	-49	IMPROVING
DKN	623	FAC	-0.0278	0.0000	-50	-43	-34	IMPROVING
TKN	625	FAC	-0.0344	0.0000	-55	-50	-43	IMPROVING
TNOx	630	FAC	-0.0124	0.0000	-27	-22	-17	IMPROVING
DNOx	631	FAC	-0.0125	0.0000	-27	-22	-17	IMPROVING
TP	665	FAC	-0.0249	0.0000	-48	-39	-29	IMPROVING
DP	666	FAC	-0.0235	0.0000	-46	-37	-27	IMPROVING
DOP	671	FAC	0.0848	0.0000	329	445	592	DEGRADING
TOC	680	FAC	-0.0125	0.0000	-27	-22	-17	IMPROVING
SS	80154	FAC	-0.0450	0.0000	-67	-59	-50	IMPROVING

Table 32. Trend Statistics for the West Branch Susquehanna River at Lewisburg, Pa., January 1985 Through December 2004

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	FLOW	25.15	0.7625	-	-	-	NS
TN	600	FAC	-0.0150	0.0000	-31	-26	-20	IMPROVING
DN	602	FAC	-0.0115	0.0000	-25	-21	-15	IMPROVING
TON	605	FAC	-0.0300	0.0000	-54	-45	-35	IMPROVING
DON	607	FAC	-0.0249	0.0000	-47	-39	-30	IMPROVING
DNH_3	608	FAC	-0.0067	0.1150	-26	-13	4	NS
TNH_3	610	FAC	-0.0258	0.0000	-51	-40	-27	BMDL
DKN	623	FAC	-0.0300	0.0000	-54	-45	-35	BMDL
TKN	625	FAC	-0.0254	0.0000	-49	-40	-29	IMPROVING
TNOx	630	FAC	-0.0051	0.0048	-16	-10	-3	IMPROVING
DNOx	631	FAC	-0.0050	0.0056	-16	-10	-3	IMPROVING
TP	665	FAC	-0.0231	0.0000	-48	-37	-24	IMPROVING
DP	666	FAC	-0.0374	0.0000	-60	-53	-44	IMPROVING
DOP	671	FAC	0.0736	0.0000	230	335	475	BMDL
TOC	680	FAC	0.0007	0.7373	-7	1	10	NS
SS	80154	FAC	-0.0520	0.0000	-74	-65	-53	IMPROVING

Table 33. Trend Statistics for the Juniata River at Newport, Pa., January 1989 Through December 2004

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	FLOW	31.56	0.3726	-	-	-	NS
TN	600	FAC	-0.0059	0.0000	-16	-11	-6	IMPROVING
DN	602	FAC	-0.0026	0.0277	-9	-5	0	IMPROVING
TON	605	FAC	-0.0253	0.0000	-48	-40	-29	IMPROVING
DON	607	FAC	-0.0184	0.0000	-40	-31	-21	IMPROVING
DNH_3	608	FAC	-0.0179	0.0000	-41	-30	-17	IMPROVING
TNH_3	610	FAC	-0.0334	0.0000	-58	-49	-38	BMDL
DKN	623	FAC	-0.0279	0.0000	-51	-43	-33	BMDL
TKN	625	FAC	-0.0228	0.0000	-45	-37	-27	IMPROVING
TNOx	630	FAC	0.0006	0.6322	-4	1	6	NS
DNOx	631	FAC	0.0017	0.2059	-2	3	9	NS
TP	665	FAC	-0.0131	0.0006	-34	-23	-11	IMPROVING
DP	666	FAC	-0.0092	0.0139	-28	-17	-3	IMPROVING
DOP	671	FAC	0.0710	0.0000	219	313	435	DEGRADING
TOC	680	FAC	-0.0144	0.0000	-31	-25	-18	IMPROVING
SS	80154	FAC	-0.0166	0.0058	-43	-28	-9	IMPROVING

Table 34. Trend Statistics for the Susquehanna River at Marietta, Pa., January 1987 Through December 2004

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	FLOW	-102.3	0.6849	-	-	-	NS
TN	600	FAC	-0.0149	0.0000	-28	-24	-19	IMPROVING
DN	602	FAC	-0.0082	0.0000	-19	-14	-8	IMPROVING
TON	605	FAC	-0.0202	0.0000	-41	-30	-18	IMPROVING
DON	607	FAC	0.0041	0.4713	-12	8	32	NS
DNH_3	608	FAC	-0.0122	0.0072	-32	-20	-6	IMPROVING
TNH_3	610	FAC	-0.0260	0.0000	-48	-37	-25	IMPROVING
DKN	623	FAC	-0.0191	0.0000	-39	-29	-18	IMPROVING
TKN	625	FAC	-0.0267	0.0000	-46	-38	-29	IMPROVING
TNOx	630	FAC	-0.0054	0.0065	-15	-9	-3	IMPROVING
DNOx	631	FAC	-0.0052	0.0091	-15	-9	-2	IMPROVING
TP	665	FAC	-0.0027	0.4998	-17	-5	10	NS
DP	666	FAC	0.0003	0.9347	-12	1	15	NS
DOP	671	FAC	0.1448	0.0000	953	1253	1638	DEGRADING
TOC	680	FAC	-0.0076	0.0000	-18	-13	-7	IMPROVING
SS	80154	FAC	-0.0194	0.0015	-43	-29	-13	IMPROVING

Table 35. Trend Statistics for the Conestoga River at Conestoga, Pa., January 1985 Through December 2004

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	FLOW	3.571	0.6145	-	-	-	NS
TN	600	FAC	-0.0089	0.0000	-20	-16	-13	IMPROVING
DN	602	FAC	0.0000	0.9722	-5	0	5	NS
TON	605	FAC	-0.0267	0.0000	-48	-41	-33	IMPROVING
DON	607	FAC	0.0007	0.8278	-11	1	15	NS
DNH_3	608	FAC	-0.0645	0.0000	-76	-72	-68	IMPROVING
TNH_3	610	FAC	-0.0700	0.0000	-79	-75	-71	IMPROVING
DKN	623	FAC	-0.0171	0.0000	-37	-29	-20	IMPROVING
TKN	625	FAC	-0.0333	0.0000	-54	-49	-42	IMPROVING
TNOx	630	FAC	0.0020	0.1808	-2	4	10	NS
DNOx	631	FAC	0.0029	0.0543	0	6	12	NS
TP	665	FAC	-0.0219	0.0000	-43	-35	-27	IMPROVING
DP	666	FAC	-0.0215	0.0000	-40	-35	-29	IMPROVING
DOP	671	FAC	-0.0072	0.0173	-23	-13	-3	IMPROVING
TOC	680	FAC	-0.0300	0.0000	-49	-45	-40	IMPROVING
SS	80154	FAC	-0.0423	0.0000	-65	-57	-48	IMPROVING

DISCUSSION

2004 was a significant year for loads in the Susquehanna River Basin. Unusually high flows during the summer months, specifically from Tropical Storm Ivan, led to high TP and SS values for the season. September flows ranged from 247 percent of the LTM at Conestoga to 608 percent of the LTM at Towanda. Annual flows ranged from 127.7 percent of the LTM at Danville to 157.9 percent of the LTM at Conestoga due to above average rainfall throughout the basin.

The average daily high flow for September 2004 was 497,000 cubic feet per second (cfs) at Marietta on September 20, 2004. Flows that are greater than 400,000 cfs constitute a scour event, which means that sediment that is currently deposited in the river is reintroduced into the water column due to the high flow and turbulence (Langland, 2000). Prior to 2004, the last scour event occurred on January 21, 1996, and had an average daily high of 556,000 cfs. One comparison worth noting is that prior to 1996, the previous scour event took place only three years earlier on April 3, 1993, with an average daily flow of 431,000 cfs. This means that there were three years for nutrients and sediment to accumulate in the streams and rivers before being scoured again in 1996. After 1996, there were eight years until the next scout event in 2004, increasing the length of time for nutrients and sediment to accumulate. The difference between these three dates can be seen in Table 36. In comparison, the TN values are significantly lower for September 2004, even though it had the second highest average daily flow. Part of this is due to the lower average monthly flow as compared to 1996 and 1993.

When looking at TP and SS, higher than expected values are found as compared to 1996. This may be due to the time difference between scour events. Had the 1993 scour event not happened, the TP and SS values for 1996 might be higher than the 2004 scour event. The differences between 2004 and 1993 also are worth noting. The scouring event prior to 1993 was in 1983, (10 years prior) creating a good comparison to 2004. Table 37 shows a more in-depth analysis of 2004 versus 1993. Since flow directly influences the levels of nutrients and SS, it is not only necessary to look at the annual flow but also to look at the mean daily high flow for the year. When comparing the annual flows from two years, as a percentage, to the percentages of nutrients and SS for those years, improvements that might have occurred can be investigated. For example, at Marietta, the 2004 annual flow and daily mean high are approximately 114.5 percent