

DISCHARGE, NUTRIENT, AND SUSPENDED-SEDIMENT TRENDS

Flow Adjusted Concentration (FAC) 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 2007. Trends were estimated based on the USGS water year, October 1 to September 30, 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. 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:

$$\text{Trend} = 100 * (\exp(\text{Slope} * (\text{end yr} - \text{begin yr})) - 1)$$

$$\text{Trend minimum} = 100 * (\exp((\text{Slope} - (1.96 * \text{sigma})) * (\text{end yr} - \text{begin yr})) - 1)$$

$$\text{Trend maximum} = 100 * (\exp((\text{Slope} + (1.96 * \text{sigma})) * (\text{end yr} - \text{begin yr})) - 1)$$

The computer application S-Plus with the USGS ESTREND library addition was used to conduct Seasonal Kendall trend analysis on

flows (Shertz and others, 1991). Trend 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 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).

Trend results for each monitoring site are presented in Tables 29 through 34. Each table lists the results for flow, the various nitrogen and phosphorus species, TOC, and SS. The level of significance was set by a 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 down for improving trends and up for degrading trends. When a time series for a particular parameter had greater than 20 percent of its observations BMDL, a trend analysis could not be completed and it was listed as BMDL.

Table 29. Trend Statistics for the Susquehanna River at Towanda, Pa., January 1989 Through December 2007

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	70.50	0.1324	-	-	-	NS
TN	600	FAC	-0.0245	<0.0001	-40.63	-37.22	-33.61	DOWN
DN	602	FAC	-0.0215	<0.0001	-37.38	-33.54	-29.45	DOWN
TON	605	FAC	-0.0311	<0.0001	-51.20	-44.62	-37.14	DOWN
DON	607	FAC	-0.0230	<0.0001	-43.30	-35.40	-26.41	DOWN
DNH ₃	608	FAC	-0.0151	0.0009	-36.76	-24.94	-10.92	BMDL
TNH ₃	610	FAC	-0.0246	<0.0001	-47.59	-37.34	-25.07	DOWN
DKN	623	FAC	-0.0220	<0.0001	-41.78	-34.16	-25.55	DOWN
TKN	625	FAC	-0.0305	<0.0001	-50.09	-43.98	-37.13	DOWN
TNOx	630	FAC	-0.0188	<0.0001	-34.57	-30.04	-25.19	DOWN
DNOx	631	FAC	-0.0187	<0.0001	-34.69	-29.90	-24.76	DOWN
TP	665	FAC	0.0005	0.9055	-12.37	0.95	16.30	NS
DP	666	FAC	-0.0016	0.6885	-16.42	-2.99	12.59	NS
DOP	671	FAC	0.1052	<0.0001	482	638	837	UP
TOC	680	FAC	-0.0030	0.0527	-10.67	-5.54	-0.11	NS
SS	80154	FAC	-0.0153	0.0117	-40.42	-25.23	-6.16	DOWN

Table 30. Trend Statistics for the Susquehanna River at Danville, Pa., January 1985 Through December 2007

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	112.92	0.0558	-	-	-	NS
TN	600	FAC	-0.0253	<0.0001	-47.30	-44.12	-40.74	DOWN
DN	602	FAC	-0.0204	<0.0001	-41.28	-37.45	-33.37	DOWN
TON	605	FAC	-0.0348	<0.0001	-60.41	-55.09	-49.04	DOWN
DON	607	FAC	-0.0285	<0.0001	-54.44	-48.08	-40.83	DOWN
DNH ₃	608	FAC	-0.0255	<0.0001	-53.55	-44.37	-33.38	BMDL
TNH ₃	610	FAC	-0.0306	<0.0001	-58.32	-50.53	-41.29	DOWN
DKN	623	FAC	-0.0269	<0.0001	-52.31	-46.14	-39.16	DOWN
TKN	625	FAC	-0.0353	<0.0001	-60.33	-55.60	-50.30	DOWN
TNOx	630	FAC	-0.0170	<0.0001	-36.50	-32.36	-27.96	DOWN
DNOx	631	FAC	-0.0171	<0.0001	-36.93	-32.52	-27.80	DOWN
TP	665	FAC	-0.0113	0.0004	-33.25	-22.89	-10.92	DOWN
DP	666	FAC	-0.0009	0.7887	-16.35	-2.05	14.69	NS
DOP	671	FAC	0.0945	<0.0001	586	779	1026	BMDL
TOC	680	FAC	-0.0091	<0.0001	-23.50	-18.88	-13.99	DOWN
SS	80154	FAC	-0.0319	<0.0001	-59.91	-51.99	-42.50	DOWN

Table 31. Trend Statistics for the West Branch Susquehanna River at Lewisburg, Pa., January 1985 Through December 2007

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	-18.73	0.6715	-	-	-	NS
TN	600	FAC	-0.0171	<0.0001	-37.21	-32.52	-27.47	DOWN
DN	602	FAC	-0.0144	<0.0001	-32.59	-28.19	-23.52	DOWN
TON	605	FAC	-0.0396	<0.0001	-66.11	-59.78	-52.26	DOWN
DON	607	FAC	-0.0335	<0.0001	-60.30	-53.72	-46.06	DOWN
DNH ₃	608	FAC	-0.0131	0.0011	-38.50	-26.01	-10.99	BMDL
TNH ₃	610	FAC	-0.0177	<0.0001	-44.67	-33.44	-19.93	DOWN
DKN	623	FAC	-0.0271	<0.0001	-54.00	-46.38	-37.50	DOWN
TKN	625	FAC	-0.0332	<0.0001	-60.20	-53.40	-45.44	DOWN
TNOx	630	FAC	-0.0059	<0.0001	-18.03	-12.69	-7.00	DOWN
DNOx	631	FAC	-0.0062	<0.0001	-18.96	-13.29	-7.22	DOWN
TP	665	FAC	-0.0129	0.0013	-37.94	-25.67	-10.99	DOWN
DP	666	FAC	-0.0237	<0.0001	-52.02	-42.02	-29.94	DOWN
DOP	671	FAC	0.0807	<0.0001	382	540	750	BMDL
TOC	680	FAC	0.0020	0.2548	-3.45	4.71	13.56	NS
SS	80154	FAC	-0.0144	0.0066	-43.45	-28.19	-8.81	DOWN

Table 32. Trend Statistics for the Juniata River at Newport, Pa., January 1989 Through December 2007

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	3.56	0.7794	-	-	-	NS
TN	600	FAC	-0.0054	<0.0001	-15.95	-11.68	-7.19	DOWN
DN	602	FAC	-0.0027	0.0123	-10.57	-6.02	-1.24	DOWN
TON	605	FAC	-0.0313	<0.0001	-58.61	-51.32	-42.74	DOWN
DON	607	FAC	-0.0234	<0.0001	-49.23	-41.62	-32.86	DOWN
DNH ₃	608	FAC	-0.0172	<0.0001	-44.03	-32.67	-19.00	BMDL
TNH ₃	610	FAC	-0.0190	<0.0001	-46.06	-35.40	-22.64	BMDL
DKN	623	FAC	-0.0243	<0.0001	-50.72	-42.82	-33.64	DOWN
TKN	625	FAC	-0.0274	<0.0001	-54.32	-46.75	-37.93	DOWN
TNOx	630	FAC	0.0014	0.2226	-2.17	3.27	9.01	NS
DNOx	631	FAC	0.0026	0.0285	0.57	6.16	12.06	UP
TP	665	FAC	-0.0184	<0.0001	-44.07	-34.51	-23.31	DOWN
DP	666	FAC	-0.0157	<0.0001	-39.94	-30.31	-19.13	DOWN
DOP	671	FAC	0.0539	<0.0001	165	245	351	UP
TOC	680	FAC	-0.0085	<0.0001	-24.51	-17.76	-10.40	DOWN
SS	80154	FAC	-0.0174	0.0011	-47.22	-32.98	-14.89	DOWN

Table 33. Trend Statistics for the Susquehanna River at Marietta, Pa., January 1987 Through December 2007

Parameter	STORET Code	Time Series/Test	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	-45.38	0.8275	-	-	-	NS
TN	600	FAC	-0.0145	<0.0001	-30.67	-26.25	-21.55	DOWN
DN	602	FAC	-0.0216	<0.0001	-40.52	-36.47	-32.14	DOWN
TON	605	FAC	-0.0313	<0.0001	-55.31	-48.18	-39.90	DOWN
DON	607	FAC	-0.0226	<0.0001	-46.58	-37.79	-27.55	DOWN
DNH ₃	608	FAC	-0.0107	0.0086	-32.53	-20.12	-5.44	BMDL
TNH ₃	610	FAC	-0.0134	0.0012	-36.51	-24.53	-10.28	DOWN
DKN	623	FAC	-0.0214	<0.0001	-44.99	-36.20	-26.01	DOWN
TKN	625	FAC	-0.0293	<0.0001	-52.62	-45.95	-38.34	DOWN
TNOx	630	FAC	-0.0054	0.0011	-16.41	-10.72	-4.64	DOWN
DNOx	631	FAC	-0.0055	0.0010	-16.93	-10.91	-4.45	DOWN
TP	665	FAC	-0.0111	0.0006	-30.85	-20.79	-9.27	DOWN
DP	666	FAC	-0.0129	0.0002	-33.96	-23.73	-11.91	DOWN
DOP	671	FAC	0.1088	<0.0001	658	882	1,173	BMDL
TOC	680	FAC	-0.0077	<0.0001	-20.35	-14.93	-9.14	DOWN
SS	80154	FAC	-0.0223	<0.0001	-48.83	-37.39	-23.40	DOWN

Table 34. Trend Statistics for the Conestoga River at Conestoga, Pa., January 1985 Through December 2007

Parameter	STORET Code	Time Series	Slope	P-Value	Slope Magnitude (%)			Trend Direction
					Minimum	Trend	Maximum	
FLOW	60	SK	2.96	0.3020	-	-	-	NS
TN	600	FAC	-0.0085	<0.0001	-21.38	-17.76	-13.97	DOWN
DN	602	FAC	0.0003	0.7947	-3.75	0.69	5.34	NS
TON	605	FAC	-0.0277	<0.0001	-53.60	-47.12	-39.73	DOWN
DON	607	FAC	0.0019	0.4987	-7.92	4.47	18.52	NS
DNH ₃	608	FAC	-0.0623	<0.0001	-79.71	-76.14	-71.93	DOWN
TNH ₃	610	FAC	-0.0666	<0.0001	-81.62	-78.39	-74.58	DOWN
DKN	623	FAC	-0.0112	<0.0001	-31.26	-22.71	-13.10	DOWN
TKN	625	FAC	-0.0343	<0.0001	-59.77	-54.57	-48.68	DOWN
TNOx	630	FAC	0.0017	0.1842	-1.93	3.99	10.26	NS
DNOx	631	FAC	0.0023	0.0812	-0.57	5.43	11.80	NS
TP	665	FAC	-0.0300	<0.0001	-55.99	-49.84	-42.84	DOWN
DP	666	FAC	-0.0252	<0.0001	-48.59	-43.99	-38.98	DOWN
DOP	671	FAC	-0.0101	0.0012	-31.07	-20.73	-8.84	DOWN
TOC	680	FAC	-0.0281	<0.0001	-51.90	-47.60	-42.92	DOWN
SS	80154	FAC	-0.0505	<0.0001	-74.56	-68.70	-61.49	DOWN