Data Assembly for Application of the CBEMP in the Lower Susquehanna River Watershed Assessment

A Report to the US Army Engineers Baltimore District

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Abstract

The US Army Corps of Engineers Baltimore District and the Maryland Department of the Environment have partnered to conduct Phase I of the Lower Susquehanna River Watershed Assessment. As part of the assessment, the Chesapeake Bay Environmental Model Package (CBEMP) will be used to assess impacts of future conditions and sediment management strategies in the Susquehanna River on the environment of Chesapeake Bay. Use of the CBEMP to fulfill goals of the Phase I Assessment requires information on the physical properties and composition of solids flowing over the Conowingo Dam, which is situated immediately upstream of the bay. The present publication reports results of a search and compilation of relevant data. The search included publications, personal communication, and inventory of data residing at US Army Engineer Research and Development Center. Data was assembled for material flowing over the dam and for characteristics of the sediment bed in Conowingo Reservoir. Information on bed sediments was compiled based on the assumption that this material would be mobilized and flow over the dam during erosion events. Multiple data sets were located and subsequently reduced to observations relevant to the study goals and useful in the CBEMP. These were observations in Conowingo Reservoir of: solids size distribution; associated carbon, nitrogen and phosphorus species and concentration; and concentration of metals which affect nutrient diagenesis in bed sediments. The report includes a listing of data bases, a data summary, and a data listing. The data compiled is sufficient for use in the CBEMP in the Phase I Assessment.

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1 Introduction

The Susquehanna River empties into the northernmost extent of Chesapeake Bay and provides more than half of the freshwater flow to the estuarine system. A series of dams and reservoirs (Figure 1) at the lower terminus of the river regulates flow and dissolved and suspended material loads into the bay. The most upstream reservoir, Lake Clarke, forms behind Safe Harbor Dam. Holtwood Dam forms Lake Aldred which sits below Lake Clarke. Conowingo Reservoir, the largest of the three, forms behind Conowingo Dam which is situated roughly six kilometers above the Chesapeake Bay head of tide.

Considerable sedimentation has occurred in the reservoirs since the dams were constructed circa 1910 – 1930. Lakes Clarke and Aldred have filled to the extent that they are in equilibrium with sediment loads coming down the river. Gravitational particle settling is balanced by erosion in these shallow systems. Although Conowingo Reservoir has lost 60% to 70% of its storage capacity (Langland and Hainly, 1997), the reservoir continues to accumulate sediment particles and associated nutrients and organic matter. Estimated time for the remaining sediment storage capacity of the reservoir to fill varies, depending on assumed loads and probability of erosion events, but estimates center around two decades remaining.

Loss of sediment storage could have environmental consequences for the Chesapeake Bay, especially the portion immediately below the dam. Sediments which pass over the dam and enter the bay, instead of settling to the reservoir bottom, may increase light attenuation, with adverse consequences for submerged aquatic vegetation. Nutrients associated with the sediments may contribute to ongoing eutrophication. Loss of storage may counter or negate load reductions planned under a recently completed Total Maximum Daily Load program (USEPA, 2010) which assumes continued deposition in Conowingo Reservoir at the current rate.

The US Army Corps of Engineers Baltimore District (USACE) and the Maryland Department of the Environment (MDE) have partnered to conduct Phase I of the Lower Susquehanna River Watershed Assessment (LSRWA). Phase I will:

- Forecast and evaluate sediment loads to the system of hydroelectric dams located on the Susquehanna River,
- Analyze hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed,

- Consider structural and non-structural strategies for sediment management, and
- Assess cumulative impacts of future conditions and sediment management strategies on Chesapeake Bay.

Critical components of the Phase I Watershed Assessment (USACE, 2011) include:

- Identification of watershed-wide sediment management strategies,
- Use of engineering models to link incoming sediment and associated nutrient projections to in-reservoir processes at the hydroelectric dams and forecast impacts to living resources in the upper Chesapeake Bay,
- Use of the Chesapeake Bay Environmental Model Package (CBEMP), a cooperative effort of the US Environmental Protection Agency Chesapeake Bay Program and the US Army Engineer Research and Development Center, to assess cumulative impacts of the various sediment management strategies to the upper Chesapeake Bay, and
- Integration of the Maryland and Pennsylvania Watershed Implementation Plans for nitrogen, phosphorus, and sediment reduction, as required to meet Chesapeake Bay TMDL’s.

Use of the CBEMP to fulfill goals of the Phase I Assessment requires information on the physical properties and composition of solids flowing over the Conowingo Dam. The present publication reports results of a search and compilation of relevant data. The search included publications, personal communication, and inventory of data residing at ERDC. Data was assembled for material flowing over the dam and for characteristics of the sediment bed in Conowingo Reservoir. Information on bed sediments was compiled based on the assumption that this material would be mobilized and flow over the dam during erosion events. Multiple data sets were located and subsequently reduced to observations relevant to the study goals and useful in the CBEMP. These were observations in Conowingo Reservoir of: solids size distribution; associated carbon, nitrogen and phosphorus species and concentration; and concentration of metals which affect nutrient diagenesis in bed sediments. The report includes a listing of data bases, a data summary, and a data listing. The data compiled is sufficient for use in the CBEMP in the Phase I Assessment.

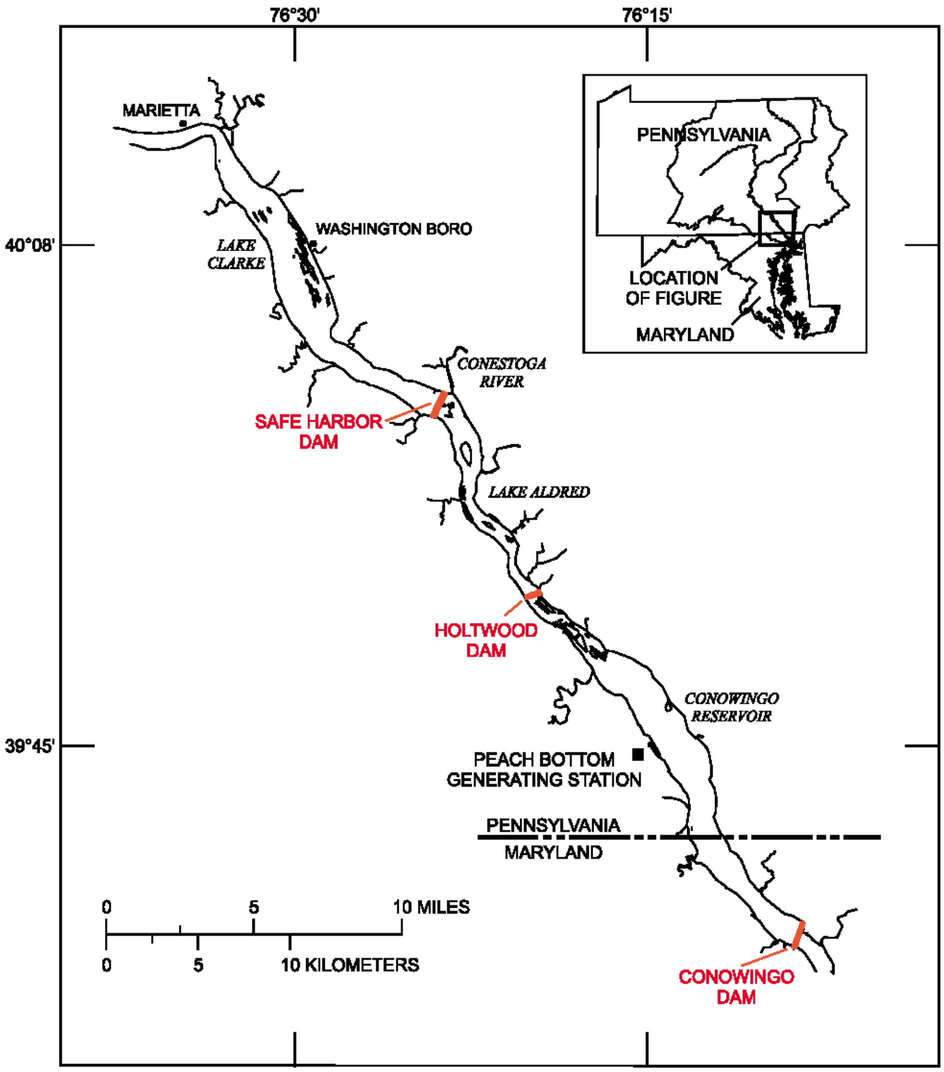

Figure 1. Lower Susquehanna River reservoir and dam system (extracted from USGS, 2003).

2 Summary of Data Sources

Table 1, below, describes the sources of data compiled for this report. A letter code in ( ) after the source citation indicates correspondence to data subsequently summarized in Table 2.

Table 1. Data Sources

Data Description	Collected	Source
Summary of 23 sediment cores from Conowingo Reservoir. Includes particle size, nitrogen (N), phosphorus (P), iron (Fe), and manganese (Mn).	Oct. 1990 - April 1991	Hainly, R., Reed, L., Flippo, H., and Barton, G. (1995). "Deposition and simulation of sediment transport in the lower Susquehanna River reservoir system," Water-Resources Investigations Report 95-4122, US Geological Survey, Denver CO. (A)
Individual observations from 22 sediment cores from Conowingo Reservoir. Analyses include size fractionation, moisture content, ammonium (NH4), nitrate (NO3), organic N, total N, total P, Fe, calcium (Ca), and Mn. This is the data base summarized by Hainly et al. (1995).	1990	Langland, Michael. (2012). Personal communication. US Geological Survey, New Cumberland PA. (B)
Summary of 29 sediment cores from Conowingo Reservoir. Includes total N, total P, and plant-available P.	Summer and fall 1996	Langland, M., and Hainly, R. (1997). "Changes in bottom-surface elevations in three reservoirs on the lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood - Implications for nutrient and sediment loads to Chesapeake Bay," Water-Resources Investigations Report 97-4138, US Geological Survey, Lemoyne PA. (C)

Individual observations from 29 sediment cores from Conowingo Reservoir. Analyses include size fractionation, moisture content, NH4, NO3, organic N, total N, inorganic P, organic P, plant-available P, total P, Fe, Ca, and Mn. This is the data base summarized by Langland and Hainly (1997).	August of 1996	Durlin, R., and Schaffstall, W. (1997). "Water Resources Data Pennsylvania Water Year 1996," Vol. 2 Susquehanna and Potomac River Basins. US Geological Survey, Lemoyne PA. (D)
Particle size distribution from 20 analyses of water flowing over Conowingo Dam. Instantaneous discharge concurrent with multiple samples exceeds the threshold for erosion in Conowingo Reservoir.	1979 - 1984	Recovered from USGS on-line data base (http://nwis.waterdata.usgs.gov/md/nwis/qwdata/?site_no=01578310&agency_cd=USGS) for USGS 01578310 SUSQUEHANNA RIVER AT CONOWINGO, MD. (E)
Analyses of particulate phosphorus (PP) and particulate inorganic phosphorus (PIP) from 52 samples of water flowing over Conowingo Dam.	2004 - 2005	Chesapeake Biological Laboratory, Solomons MD. Personal Communication. (F)
Particulate C, N, P, and TSS at Conowingo outfall. More than 100 samples, including replicates, collected at approximately monthly intervals.	2005 - 2011	Station 1.0 in the Chesapeake Bay Program Water Quality Data Base (http://www.chesapeakebay.net/data/downloads/cbp_water_quality_database_1984_present) (G)
Particle analyses at Conowingo outfall. Ten samples collected especially for this study. These include samples collected during Tropical Storm Lee. Samples were analyzed for PC, PN, PP, Fe, Mn, suspended sediment, and particle size	2010 - 2011	Jeffrey Chanat, USGS MD-DE-DC Water Science Center. Personal Communication. (H)
Analyses from 23 sediment cores from Conowingo Reservoir (21) and Susquehanna Flats (2). Analyses include bulk density, size fractions, and particulate Fe, Mn, C, N, P. The cores were analyzed at multiple depth intervals. Data selected for this study is from the top-most section, typically 25 cm deep.	2000	Edwards, R. (2006). "Comprehensive analysis of the sediments retained behind hydroelectric dams of the lower Susquehanna River," Publication 239, Susquehanna River Basin Commission, Harrisburg PA. (I)

Sequential phosphorus extractions of surficial sediments from three cores collected in Conowingo Reservoir and 1 core collected at the mouth of the Susquehanna River. Analyses indicate total phosphorus phases are 2% to 4% exchangeable phosphate, 2% to 20% calcium-bound phosphate, 30% to 60% phosphate sorbed to iron oxides, and 30% to 70% organic phosphorus.	2000	Edwards, R. (2006). "Comprehensive analysis of the sediments retained behind hydroelectric dams of the lower Susquehanna River," Publication 239, Susquehanna River Basin Commission, Harrisburg PA.(J)

3 Characteristics of Materials Flowing Over the Dam

Data from the sources listed in Chapter 2 is summarized in Table 2 below. Letters in ( ) after the citation indicate correspondence to data sources in Table 1. The original data were revised, where necessary, for consistent units. Some data sources report sediment size classes e.g. mm while others report composition e.g. clay. For conversion purposes, we assume clay represents particles less than 0.004 mm in diameter and silt represents particles greater than 0.004 mm but less than 0.063 mm. Particles greater than 0.063 mm are considered sand. This convention appears to be consistent with the scheme used by the original investigators.

Three of the four sources which report size classes for the Conowingo bed sediments indicate the majority of the bed, ≈ 75%, is silt and clay with the remainder being sand and sporadic patches of coal. The samples reported by Durlin and Schaffstall (1997) are exceptional in that they are more than half sand. The material flowing over the spillway is virtually 100% silt and clay, however, (Figure 2) even at flow rates > 11,000 $m^3 s^{-1}$, sufficient to erode the bottom (Lang, 1982; Reed and Hoffman, 1997). The data suggest a slight decline in the silt and clay fraction at the highest flows, with the remainder consisting of sand, but the trend is not statistically significant ($R^2 = 0.08$, $0.5 < p < 0.2$). Although the data are widely scattered, there is a clear and significant decline in clay fraction as flow increases ($R^2 = 0.38$, $p < 0.002$). Nevertheless, particles in the clay size class represent more than half of the solids in all but a few samples.

The concentrations of suspended solids, particulate carbon (PC), particulate nitrogen (PN), and particulate phosphorus (PP) increase, in an approximately exponential relationship, as a function of flow (Figures 3 - 6). Evidence is difficult to perceive of a change in the relationship of concentration to flow when flow exceeds the threshold for bottom erosion. Based on the composition of the bed, the PN is virtually all organic in nature. In contrast, inorganic forms can represent more than half the PP in both the bed and outflow.

Analyses of particle fraction of PC, PN, PP, as function of flow yield interesting results (Figures 7 – 9). The fractions decline, apparently exponentially, as flow increases. The PN and PP fractions asymptotically approach the composition of bed sediment (≈ 0.3% N, ≈ 1,000 ppm P). The C fraction of the particles in the outfall approaches a limit less that the composition of the bed sediments (≈ 10% C). We can't judge whether this disparity is genuine or an artifact of limited data in the bed sediments. In all cases, the asymptotic fraction is approached at flows insufficient to erode bottom sediments. We suggest the particle fractions at low flows, less than 4,000 $m^3 s^{-1}$, represent particles formed by primary production within the reservoir. At higher flows, the residence time of the reservoir is short and particle composition at the spillway represents particles entering the reservoir from upstream.

The particle fractions of Fe and Mn in the outflow show no relation to flow. Fe fraction is ≈ 5% and Mn fraction is ≈ 2,200 ppm.

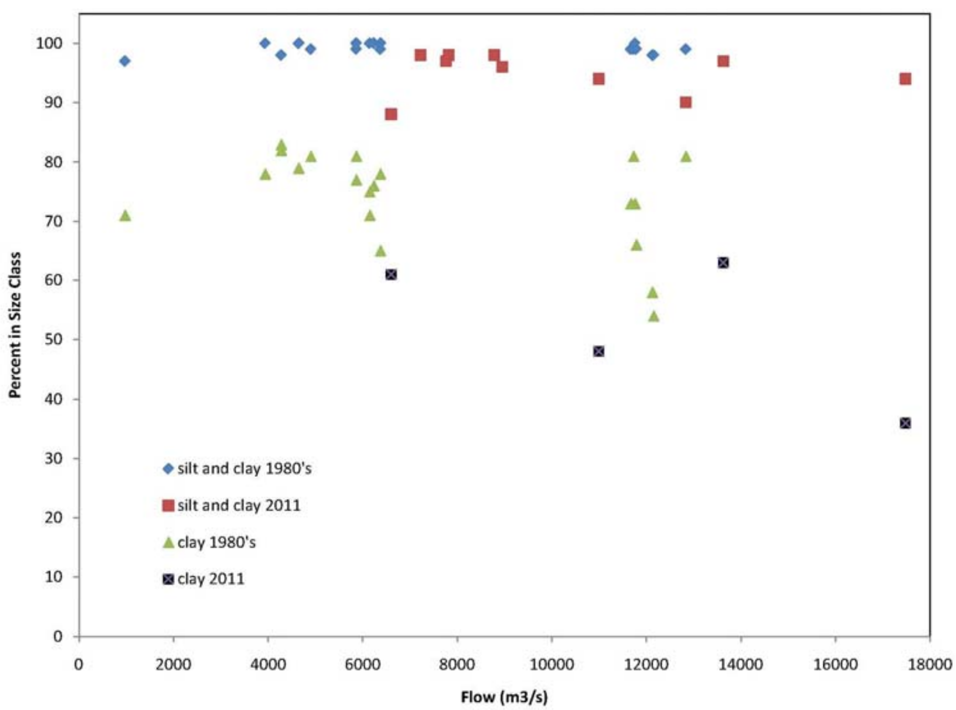

Figure 2. Fractions of clay and of clay and silt in Conowingo overflow. The data designated 1980's is from the USGS on-line data base. The data designated 2011 was collected for this study.

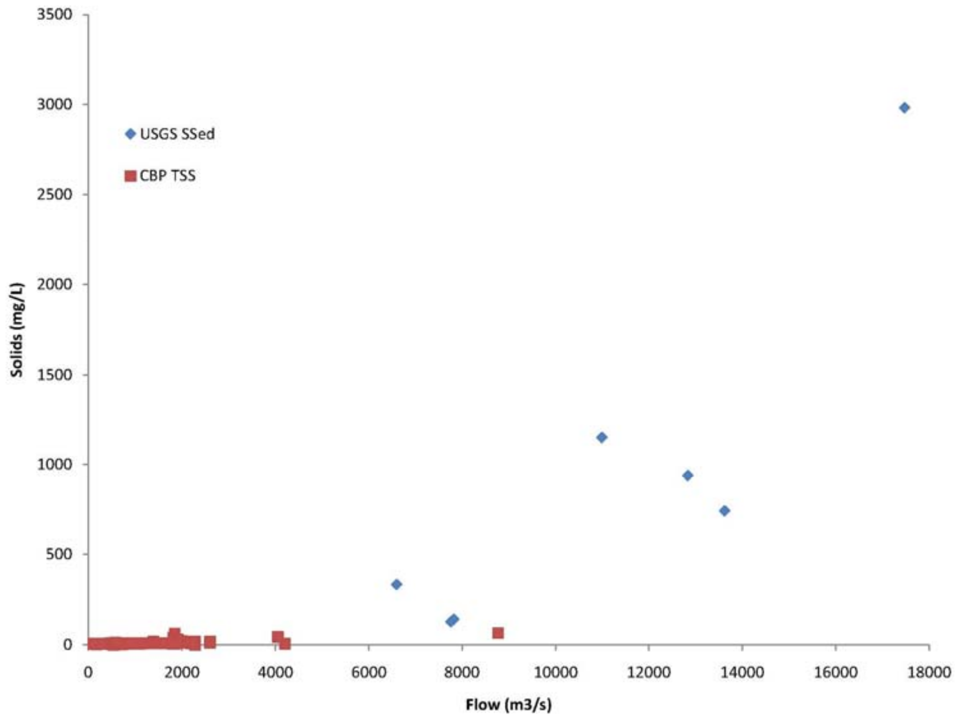

Figure 3. Suspended solids concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study and reported as suspended sediment. Data designated CBP is from the Chesapeake Bay Program data base and reported as TSS.

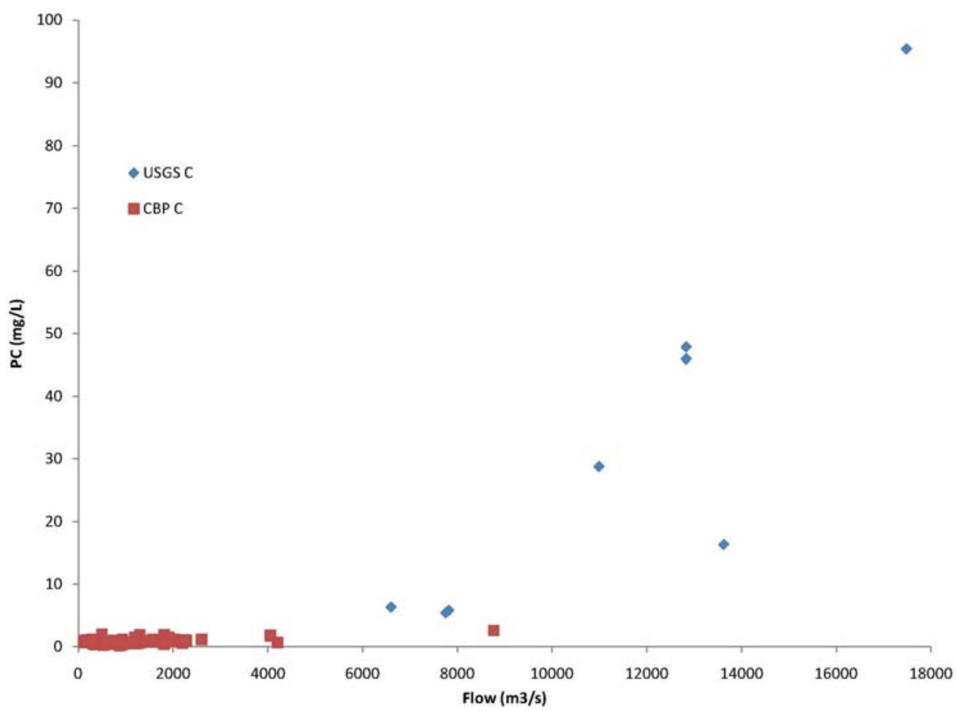

Figure 4. Particulate carbon concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

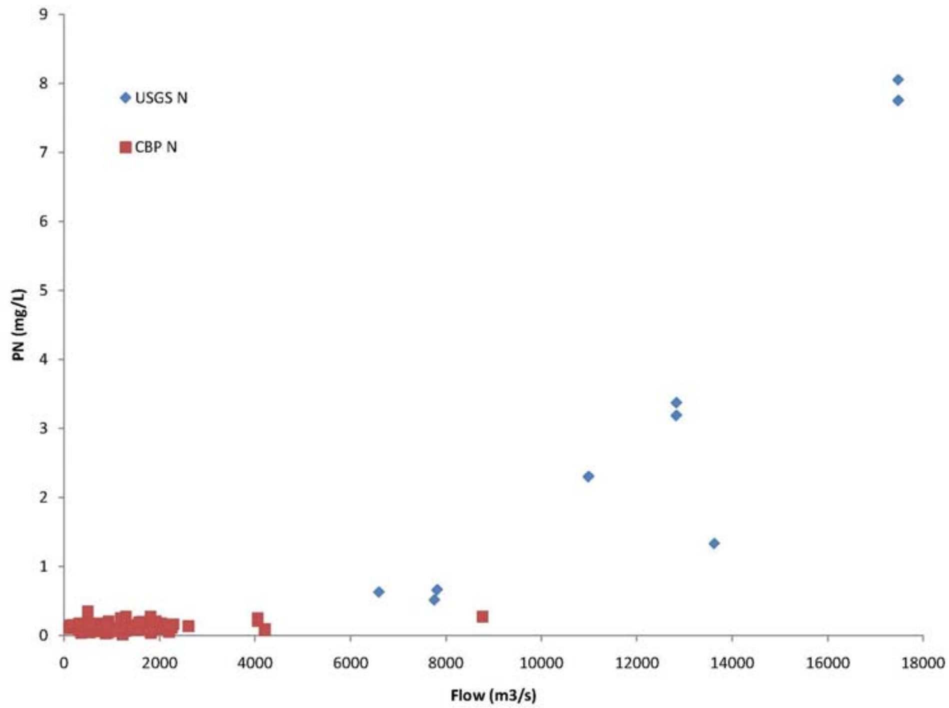

Figure 5. Particulate nitrogen concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

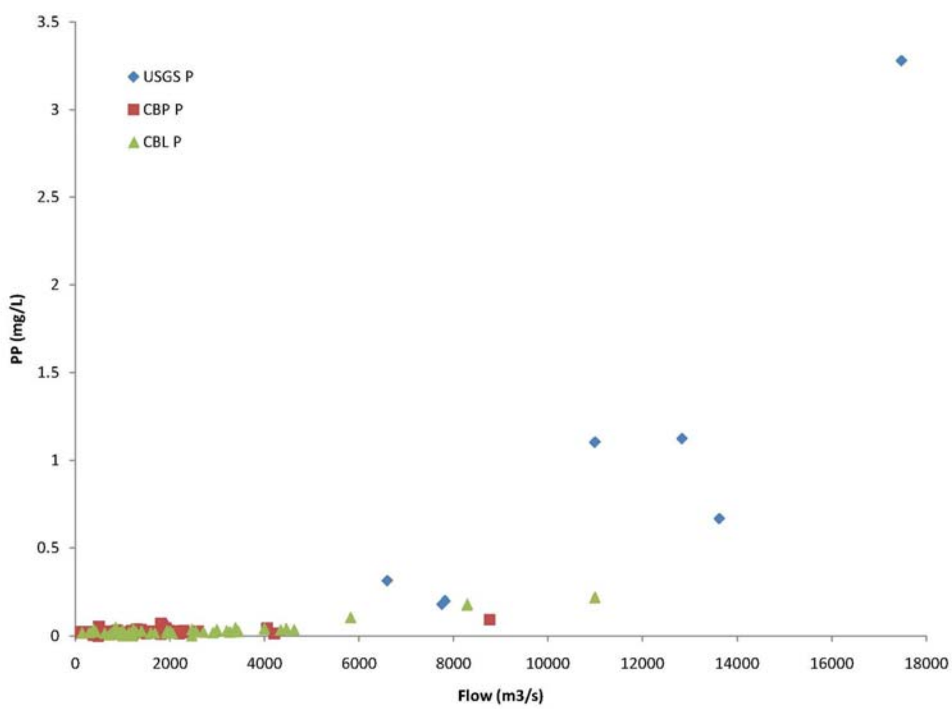

Figure 6. Particulate phosphorus concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base. Data designated CBL is from Chesapeake Biological Laboratory.

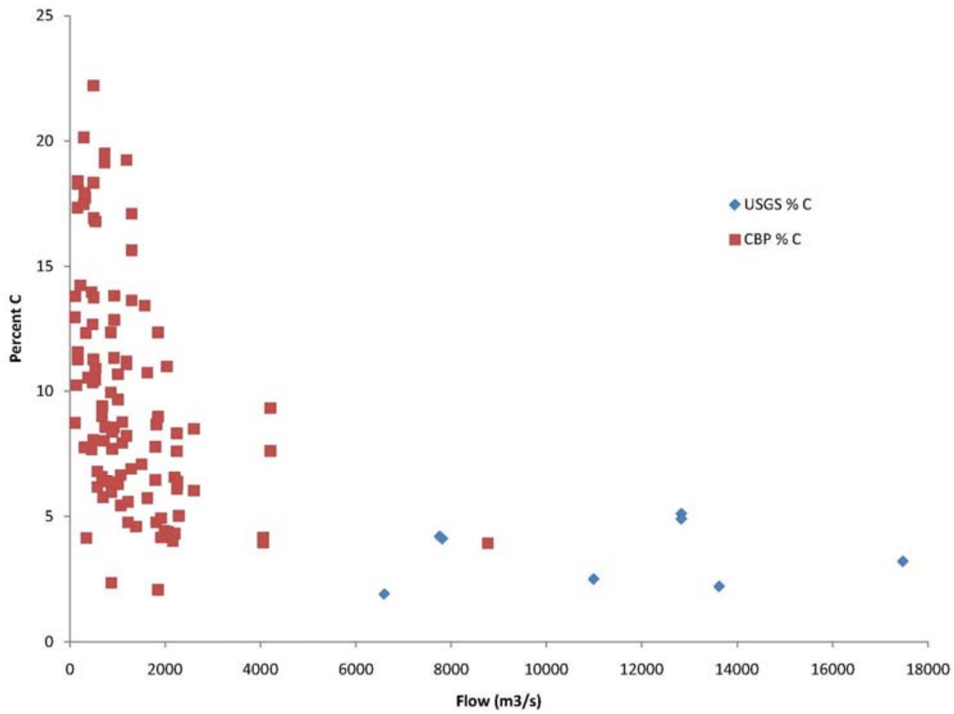

Figure 7. Carbon fraction of particles in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

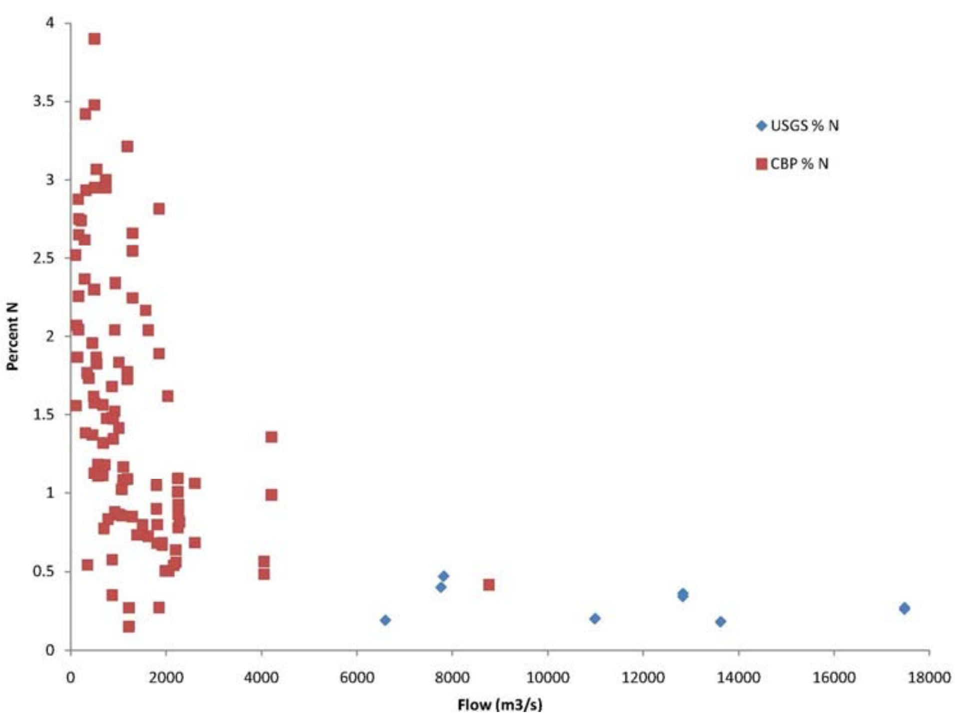

Figure 8. Nitrogen fraction of particles in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

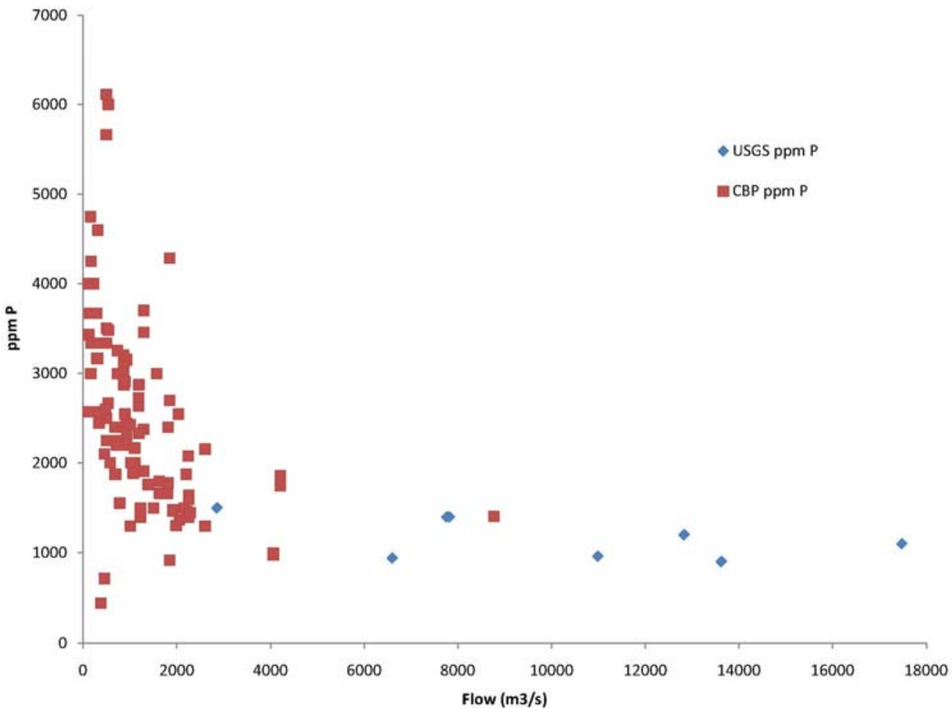

Figure 9. Phosphorus fraction of particles in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

Table 2. Summary of Data in the Bed Sediments and Dam Outflow

	Hainly et al. 1995 (A)	Langland and Hainly 1997 (C)	Publication 239 (I)	Durlin and Schaffstall 1997 (D)	USGS Fall Line Monitoring 1979 – 1984 (E)	CBP Monitoring CB1.0 (G)	USGS Fall Line Sampling 2010 – 2011 (H)	Langland Personal Comm. 2012 (B)	CBL Sample Analyses (F)
Bed Sediment % Sand	22 (1)		20.4 (avg), 70.7 (max), 0.2 (min) (3)	53.7 (4)				24.7 (4)	
Bed Sediment % Silt	46 (1)		48.2 (avg), 61 (max), 22.9 (min) (3)	35.6 (4)				45.2 (4)	
Bed Sediment % Clay	26 (1)		31.4 (avg), 50.7 (max), 5.8 (min) (3)	10.4 (4)				25.4 (4)	
Bed Sediment % Coal	6 (1)		11.7 (avg), 46 (max), 0.7 (min) (3)						
Bed Sediment NH4, mg/kg	404 (1)			122 (avg), 400 (max), 24 (min) (3)				386 (avg), 730 (max), 13 (min) (5)	
Bed Sediment NO3, mg/kg				1.0 (avg), 2.4 (max), 0.3 (min) (3)				6 (avg), 18 (max), 2 (min) (5)	
Bed Sediment Org N, mg/kg	3,020 (1)			3,672 (avg), 6,900 (max), 1,500 (min) (3)				3,109 (avg), 4,266 (max), 2,127 (min) (5)	
Bed Sediment Total N, mg/kg		3,780 (avg), 6,900 (max), 1,500 (min) (2)	3040 (avg), 4190 (max), 2080 (min) (3)	3,783 (avg), 6,900 (max), 1,500 (min) (3)				3,501 (avg), 4,303 (max), 2,218 (min) (5)	

Bed Sediment Inorganic P, mg/kg				624 (avg), 1,310 (max), 286 (min) [3]					
Bed Sediment Organic P, mg/kg				97 (avg), 272 (max), 15 (min) [3]					
Bed Sediment Total P, mg/kg	920 [1]	720 (avg), 1,390 (max), 286 (min) [2]	1,147 (avg), 1,644 (max), 571 (min) [3]	722 (avg), 1,390 (max), 286 (min) [3]				961 (avg), 1,400 (max), 370 (min) [5]	
Bed Sediment % Organic C			9.7 (avg), 23.6 (max), 4.0 (min) [3]						
Plant Available P		1.25 (avg), 3.5 (max), 0.6 (min) % of total [2]		9.1 (avg), 13.1 (max), 6.2 (min) mg/kg [3]					
Sequential P Extraction			x						
Bed Sediment Fe, mg/kg	24,400 [1]		36,000 (avg), 52,000 (max), 22,000 (min) [3]					22,727 (avg), 37,000 (max), 2,200 (min) [5]	
Bed Sediment Al, mg/kg	10,400 [1]								
Bed Sediment Mn, mg/kg	1,650 [1]							1,568 (avg), 2,400 (max), 990 (min) [5]	

Bed Sediment Ca, mg/kg								1,986 (avg), 2,600 (max), 1,500 (min) [5]	
Moisture Content, %				50 (avg), 92 (max), 32 (min) [3]				46 (avg), 65 (max), 24 (min) [5]	
Bed Sediment Size Distribution				x				x	
Fall Line Flow, m3/s							11,028 (avg), 17,479 (max), 2,861 (min) [5]		
Fall Line Solids Size Distribution					x				
Fall Line Solids % Clay					74 (avg), 83 (max), 54 (min) [5]				
Fall Line Solids % Silt and Clay					99 (avg), 100 (max), 97 (min) [5]				
Fall Line TSS, mg/L					157 (avg), 359 (max), 17 (min) [5]	11 (avg), 66 (max), 1.5 (min) [5]			
Fall Line PC, mg/L						0.880 (avg), 2.595 (max), 0.188 (min) [5]			

Fall Line PN, mg/L						0.134 (avg), 0.351 (max), 0.015 (min) (5)			
Fall Line PP, mg/L						0.023 (avg), 0.093 (max), 0.004 (min) (5)			0.036 (avg), 0.218 (max), 0.002 (min) (5)
Fall Line PIP, mg/L									0.020 (avg), 0.134 (max), 0.002 (min) (5)
P Fraction in Suspended Solids, mg/kg							1,170 (avg), 1,500 (max), 900 (min) (5)		
Fe Fraction in Suspended Solids, %							4.6 (avg), 5.4 (max), 3.6 (min) (5)		
Mn Fraction in Suspended Solids, mg/kg							2,260 (avg), 3,400 (max), 1,800 (min) (5)		
C Fraction in Suspended Solids, %							3.5 (avg), 5.1 (max), 1.9 (min) (5)		
N Fraction in Suspended Solids, mg/kg							2,967 (avg), 4,700 (max), 1,800 (min) (5)		

[1] reported mean values for Conowingo Reservoir
[2] summary values reported by authors for Conowingo Reservoir
[3] calculated from reported values for Conowingo Reservoir
[4] based on mean fractions of reported size distributions
[5] calculated from reported values

References

Lang, D. (1982). “Water quality of the three major tributaries to the Chesapeake Bay, the Susquehanna, Potomac, and James Rivers, January 1979 – April 1981,” Water-Resources Investigations Report 82-32, US Geological Survey, Towson MD.

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Reed, L., and Hoffman, S. (1997). “Sediment deposition in Lake Clarke, Lake Aldred, and Conowingo Reservoir, Pennsylvania and Maryland, 1910-93,” Water-Resources Investigations Report 96-4048, US Geological Survey.

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USEPA. (2010). “Chesapeake Bay total maximum daily load for nitrogen, phosphorus and sediment,” US Environmental Protection Agency Region 3. (http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html)

Appendix Data Listing

Individual observations from 22 sediment cores from Conowingo Reservoir.
Langland, Michael. (2012). Personal communication. US Geological Survey, New Cumberland PA.

Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Begin date	Moisture content, fraction of dry weight, percent	Ammonia, bed sediment, total, dry weight, mg/kg as nitrogen	Ammonia plus organic nitrogen, bed sediment, total, dry weight, mg/kg as nitrogen	organic N	total N	Nitrate plus nitrite, bed sediment, total, dry weight, mg/kg as nitrogen	Phosphorus, bed sediment, total, dry weight, mg/kg as phosphorus
393939	761109	12/17/1990	62	710	3900	3190	3902	2	1300
393955	761058	12/17/1990	50	380	3300	2920	3302	2	1200
394007	761124	12/6/1990	47	420	3400	2980	3402	2	1100
394010	761049	12/17/1990	61	620	3600	2980	3602	2	1300
394017	761200	12/17/1990	65	730	4000	3270	4002	2	1200
394025	761152	12/13/1990	61	600	3600	3000	3616	16	1400
394039	761150	12/13/1990	46	510	2800	2290	2802	2	1200
394104	761255	11/30/1990	54	710	3500	2790	3502	2	1300
394107	761223	12/6/1990	50	470	3000	2530	3014	14	1100
394126	761258	11/30/1990	47	590	4300	3710	4302	2	850
394148	761318	11/30/1990	48	560	3900	3340	3902	2	1100
394208	761402	11/27/1990	44	250	3500	3250	3508	8	990
394212	761335	11/27/1990	46	260	3200	2940	3218	18	930
394254	761407	11/27/1990	46	310	3600	3290	3603	3	950
394339	761407	11/27/1990	26	73	2200	2127	2218	18	370
394453	761441	11/7/1990	49	250	3400	3150	3402	2	790
394524	761545	11/20/1990	39	210	3800	3590	3802	2	730
394530	761430	11/20/1990	42	270	3700	3430	3702	2	720
394544	761523	11/7/1990	26	13	3400	3387	3405	5	520
394608	761508	11/7/1990	60	490	3200	2710	3202	2	1200
394655	761622	11/8/1990	24	40	3300	3260	3310	10	380
394704	761605	11/8/1990	25	34	4300	4266	4303	3	510

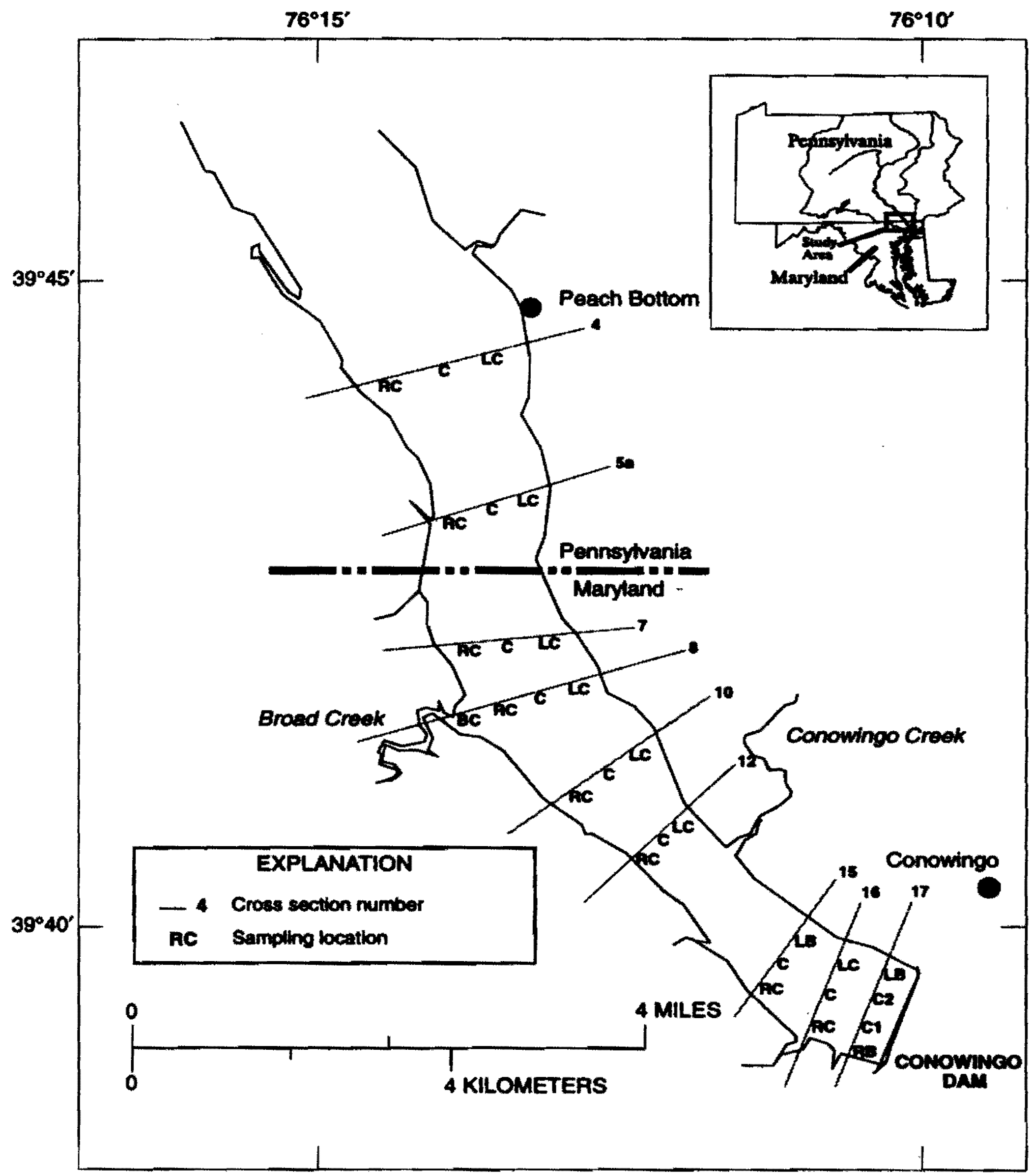
Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Begin date	Calcium, bed sediment, recoverable, dry weight, mg/kg	Manganese, bed sediment, recoverable, dry weight, mg/kg	Iron, bed sediment, total digestion, dry weight, mg/kg	Bed sediment, fall diameter (deionized water), percent < 0.004 millimeters	Bed sediment, dry sieved, sieve diameter, percent < 0.0625 millimeters
393939	761109	12/17/1990	1800	1500	19000	41	98
393955	761058	12/17/1990	2000	1500	24000	39	98
394007	761124	12/6/1990	2400	2000	24000	28	90
394010	761049	12/17/1990	1600	1400	21000	38	98
394017	761200	12/17/1990	1500	1300	16000	37	97
394025	761152	12/13/1990	1700	1700	18000	37	96
394039	761150	12/13/1990	2400	2000	9600	34	98
394104	761255	11/30/1990	1900	1700	25000	39	96
394107	761223	12/6/1990	2100	2000	21000	35	96
394126	761258	11/30/1990	2500	2100	23000	32	85
394148	761318	11/30/1990	2600	2400	24000	32	90
394208	761402	11/27/1990	2400	1900	32000	27	81
394212	761335	11/27/1990	2000	1700	2200	27	81
394254	761407	11/27/1990	2000	1600	28000	1	4
394339	761407	11/27/1990	2000	1200	33000	23	67
394453	761441	11/7/1990	1700	1400	24000	21	66
394524	761545	11/20/1990	1900	1100	34000	19	54
394530	761430	11/20/1990	2000	1300	28000	15	50
394544	761523	11/7/1990	1600	1100	27000	2	6
394608	761508	11/7/1990	1600	1200	4200	27	89
394655	761622	11/8/1990	2300	1400	37000	3	9
394704	761605	11/8/1990	1700	990	26000	2	4

Individual observations from 29 sediment cores from Conowingo Reservoir.
Durlin, R., and Schaffstall, W. (1997). "Water Resources Data Pennsylvania Water year 1996,"
Vol. 2 Susquehanna and Potomac River Basins. US Geological Survey, Lemoyne PA.
Data collected August 1996, following the flood event of January 1996.

Station	Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Moisture Content (%)	Total Nitrogen (mg N/kg)	Nitrate (mg N/kg)	NH4 (mg N/kg)	Organic Nitrogen (mg N/kg)	Total Phosphorus (mg P/kg)	Inorganic P (mg P/kg)	Organic P (mg P/kg)	Plant-Available P mg P/kg)
XC-4 RC	394436	0761355	39	3600	0.7	25	3600	401	375	26	9.9
XC-4 C	394426	0761413	34	1500	0.5	32	1500	386	369	17	8.7
XC-4 LC	394418	0761428	52	3200	0.4	180	3000	961	877	84	6.2
XC-5A RC	394330	0761341	43	2000	0.5	40	2000	572	473	99	12.4
XC-5A C	394329	0761357	47	2700	0.6	43	2700	428	323	105	10.6
XC-5A LC	394328	0761414	69	3300	0.9	130	3200	667	646	21	8.7
XC-7 RC	394240	0761335	48	3600	0.5	250	3400	866	789	77	8.7
XC-7 C	394238	0761351	39	4300	0.4	100	4200	559	502	57	8.1
XC-7 LC	394236	0761409	55	2900	0.6	190	2700	933	661	272	6.8
XC-8 RC	394219	0761321	50	4200	0.8	45	4200	496	391	105	9.9
XC-8 C	394214	0761340	44	4400	0.5	130	4300	603	588	15	12.4
XC-8 LC	394207	0761358	33	2900	0.3	70	2800	517	430	87	12.4
XC-8 Broad Ck	394158	0761416	56	3800	1	170	3600	1010	986	21	13.1
XC-10 RC	394144	0761241	35	4300	0.8	39	4300	336	239	97	11.8
XC-10 C	394136	0761258	47	5200	1.2	190	5000	617	515	102	11.2
XC-10 LC	394121	0761316	54	4600	2.4	160	4400	916	759	157	6.8
XC-12 RC	394070	0761211	63	3700	1.1	400	3300	1390	1310	77	13.1
XC-12 C	394107	0761220	32	6300	0.5	38	6300	286	202	84	6.2
XC-12 LC	394055	0761229	92	6900	1.8	24	6900	442	297	145	6.8
XC-15 RC	394001	0761134		3600	1.3	230	3400	960	884	76	7.4
XC-15 C	394010	0761125	50	4400	1.3	170	4200	782	563	219	11.2
XC-15 LC	394018	0761117	52	3700	0.9	95	3600	694	560	134	7.4

Station	Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Moisture Content (%)	Total Nitrogen (mg N/kg)	Nitrate (mg N/kg)	NH4 (mg N/kg)	Organic Nitrogen (mg N/kg)	Total Phosphorus (mg P/kg)	Inorganic P (mg P/kg)	Organic P (mg P/kg)	Plant-Available P mg P/kg)
XC-16 RC	394007	0761052	55	3000	2	120	2900	961	822	139	8.1
XC-16 C	393957	0761058	55	3900	1.3	100	3800	784	658	126	8.7
XC-16 Lt Bank	393947	0761106	49	3200	1.9	71	3100	793	683	110	6.8
XC-17 Rt Bank	394002	0761035	52	4000	1	130	3900	770	754	16	8.1
XC-17 RC	393955	0761039		3200	0.9	110	3100	832	805	27	8.1
XC-17 LC	393470	0761044	53	3700	1.2	130	3600	901	803	98	7.4
XC-17 Lt Bank	393940	0761049	57	3600	1.8	130	3500	1070	844	228	6.8

Station	Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Bed Mat Fall Diameter (% finer than 0.004 mm)	Bed Mat Sieve Dia (% finer than 0.062 mm)	Bed Mat Sieve Dia (% finer than 1.0 mm)
XC-4 C	394426	0761413	3	12	100
XC-5A C	394329	0761357	2	7	100
XC-7 C	394238	0761351	21	60	100
XC-8 C	394214	0761340	3	29	97
XC-10 C	394136	0761258	7	32	100
XC-12 C	394107	0761220	13	38	100
XC-15 C	394010	0761125	16	64	100
XC-16 C	393957	0761058	19	68	100
XC-17 RC	393955	0761039	14	70	100
XC-17 LC	393470	0761044	6	80	100



76°15′
76°10′
39°45′
39°40′
Pennsylvania
Study Area
Maryland
Peach Bottom
4
RC
C
LC
5a
Pennsylvania
Maryland
7
8
Broad Creek
BC
10
12
Conowingo Creek
Conowingo
15
16
17
LB
C2
C1
RB
CONOWINGO DAM
EXPLANATION
4 Cross section number
RC Sampling location
0
4 MILES
0
4 KILOMETERS

agency_cd - Agency Code
site_no - USGS site number
sample_dt - Date of sample
sample_tm - Time of sample
p00061 - Discharge, instantaneous, cubic feet per second
p70331 - Suspended sediment, sieve diameter, percent smaller than 0.063 millimeters
p70338 - Suspended sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters
p70339 - Suspended sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters
p70340 - Suspended sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters
p70341 - Suspended sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
p80154 - Suspended sediment concentration, milligrams per liter
#
Data for the following sites are included:
USGS 01578310 SUSQUEHANNA RIVER AT CONOWINGO, MD
#

agency_cd	site_no	sample_dt	sample_tm	p00061	p70331	p70338	p70339	p70340	p70341	p80154
5s	15s	10d	4d	12s	12s	12s	12s	12s	12s	12s
USGS	1578310	3/31/1980	10:31	151000	98	83	95	97	97	35
USGS	1578310	3/31/1980	10:30	151000	98	82	88	89	95	43
USGS	1578310	3/22/1980	10:30	173000	99	81	95	97	98	49
USGS	1578310	3/23/1980	18:30	207000	99	81	95	96	98	132
USGS	1578310	2/17/1984	11:30	453000	99	81	82	91	96	359
USGS	1578310	2/17/1984	13:10	414000	99	81	81	94	98	282
USGS	1578310	2/13/1981	15:00	164000	100	79	94	97	98	183
USGS	1578310	2/13/1981	17:00	139000	100	78	92	97	99	194
USGS	1578310	4/2/1980	11:31	225000	99	78	92	98	99	31
USGS	1578310	3/23/1980	18:31	207000	100	77	94	98	99	107
USGS	1578310	3/23/1980	14:15	220000	100	76	91	98	99	113
USGS	1578310	3/23/1980	20:30	217000	100	75	91	94	96	138
USGS	1578310	2/17/1984	13:05	415000	100	73	88	95	98	235
USGS	1578310	2/17/1984	13:11	412000	99	73	86	95	98	265
USGS	1578310	3/23/1980	14:30	217000	100	71	86	94	94	123
USGS	1578310	8/8/1979	12:00	34300	97	71	83	88	94	17
USGS	1578310	2/17/1984	13:00	416000	99	66	80	94	97	276
USGS	1578310	4/2/1980	11:30	225000	100	65	83	93	98	40
USGS	1578310	2/17/1984	12:40	428000	98	58	80	94	96	230
USGS	1578310	2/17/1984	12:30	429000	98	54	75	84	88	295

Analyses of particulate phosphorus (PP) and particulate inorganic phosphorus (PIP)
Chesapeake Biological Laboratory, Solomons MD.

Sample Date	PP (mg P/l) pcode 667		PIP (mg P/l) pcode ?	% PIP
1/3/2003	0.0234		0.0124	53.0%
1/9/2003	0.0179		0.0088	49.2%
2/4/2003	0.0071		0.0052	73.2%
2/4/2003	0.0079		0.0052	65.8%
3/5/2003	0.0222		0.0106	47.7%
4/2/2003	0.0217		0.0119	54.8%
5/7/2003	0.0024	L	0.0024	
5/7/2003	0.0230		0.0114	49.6%
6/4/2003	0.0404		0.0230	56.9%
6/4/2003	0.0419		0.0240	57.3%
6/4/2003	0.0408		0.0237	58.1%
6/4/2003	0.0416		0.0231	55.5%
6/20/2003	0.0382		0.0241	63.1%
7/1/2003	0.0024	L	0.0024	
7/1/2003	0.0283		0.0168	59.4%
8/6/2003	0.0158		0.0289	182.9%
9/4/2003	0.0283		0.0154	54.4%
9/10/2003	0.0256		0.0149	58.2%
10/14/2003	0.0198		0.0097	49.0%
11/13/2003	0.0149		0.0083	55.7%
12/17/2003	0.0356		0.0205	57.6%
1/22/2004	0.0142		0.0054	38.0%
2/10/2004	0.0489		0.0210	42.9%
3/5/2004	0.0185		0.0096	51.9%
3/15/2004	0.0150		0.0105	70.0%
4/6/2004	0.0238		0.0124	52.1%
4/6/2004	0.0281		0.0136	48.4%
4/15/2004	0.0288		0.0173	60.1%
5/5/2004	0.0024		0.0024	100.0%
5/5/2004	0.0377		0.0191	50.7%
6/16/2004	0.0349		0.0180	51.6%

Sample Date	PP (mg P/l) pcode 667	PIP (mg P/l) pcode ?	% PIP
7/6/2004	0.0192	0.0110	57.3%
8/5/2004	0.0268	0.0152	56.7%
9/13/2004	0.0464	0.0260	56.0%
9/22/2004	0.1052	0.0618	58.7%
10/13/2004	0.0219	0.0102	46.6%
11/16/2004	0.0081	0.0042	51.9%
11/29/2004	0.0261	0.0118	45.2%
12/14/2004	0.0356	0.0241	67.7%
1/10/2005	0.0415	0.0210	50.6%
1/10/2005	0.0406	0.0221	54.4%
1/27/2005	0.0154	0.0103	66.9%
2/16/2005	0.0300	0.0184	61.3%
3/7/2005	0.0095	0.0044	46.3%
3/29/2005	0.0342	0.0172	50.3%
3/31/2005	0.1800	0.1040	57.8%
3/31/2005	0.1777	0.1028	57.9%
4/4/2005	0.2175	0.1335	61.4%
4/21/2005	0.0205	0.0100	48.8%
5/12/2005	0.0155	0.0027	17.4%
6/2/2005	0.0265	0.0099	37.4%
7/20/2005	0.0373	0.0172	46.1%
8/16/2005	0.0170	0.0073	42.9%

L = "Less than"

Particulate C, N, P, and TSS at Conowingo outfall.
Station 1.0 in the Chesapeake Bay Program Water Quality Data Base

PC (mg/L)	PN (mg/L)	PP (mg/L)	TSS (mg/L)	Flow (m3/s)	CHLa (ug/L)
0.732	0.11	0.017	4	169	
0.949	0.156	0.004	9	380	7
0.966	0.145	0.024	7	121	6.73
0.688	0.087	0.02	12	1,628	0.9
0.834	0.096	0.026	19	2,057	0.9
0.525	0.051	0.015	8	2,200	1.28
0.434	0.04	0.012	5	1,815	0.75
0.47	0.066	0.012	5	682	1.5
1.209	0.178	0.028	11	2,036	10.47
1.882	0.28	0.021	11	1,296	29.9
1.205	0.137	0.026	20	2,602	4.78
1.105	0.138	0.028	13	2,602	4.19
1.285	0.168	0.057	62	1,849	
1.029	0.177	0.027	12	748	4.49
1.016	0.116	0.03	23	1,985	0.9
0.461	0.062	0.015	8	696	1.2
0.915	0.117	0.021	15	2,249	0.85
0.709	0.08	0.015	10	1,507	0.3
0.552	0.068	0.019	8	1,290	1.92
0.401	0.059	0.011	5	716	
0.966	0.154	0.037	21	1,389	3.36
0.648	0.084	0.022	15	2,206	1.5
1.075	0.204	0.018	10	1,627	23.03
0.768	0.137	0.021	10	456	3.29
1.104	0.159	0.02	6	166	2.09
0.712	0.137	0.02	5	224	5.13
0.615	0.112	0.022	6	142	2.54
0.612	0.109	0.018	7	106	3.89
0.29	0.038	0.018	7	350	3.2
0.69	0.095	0.022	11	1,016	1.79
0.318	0.044	0.011	5	926	
1.954	0.279	0.073	41	1,812	2.99
2.595	0.275	0.093	66	8,767	4.98
0.724	0.097	0.027	18	2,159	
1.208	0.195	0.027	9	1,574	14.05
0.941	0.168	0.024	9	536	5.98
1.064	0.176	0.02	6	320	6.28
1.11	0.159	0.022	9	339	5.68
0.694	0.115	0.019	4	160	4.49
0.648	0.126	0.02	5	105	5.15
0.978	0.137	0.005	7	456	3.99
0.575	0.075	0.014	9	783	3.24
0.558	0.027	0.014	10	1,223	
0.476	0.015	0.015	10	1,223	
0.322	0.045	0.009	4	497	1.39
0.451	0.063	0.01	4	497	0.85
0.526	0.07	0.013	6	1,100	2.03
0.476	0.065	0.012	6	1,100	2.03
0.899	0.189	0.027	10	1,850	17.73
0.865	0.197	0.03	7	1,850	17.94
1.231	0.195	0.03	11	1,188	11.75

1.218	0.19	0.029	11	1,188	10.68
1.5	0.247	0.038	11	1,296	12.82
1.564	0.266	0.037	10	1,296	11.96
1.106	0.187	0.018	8	933	7.48
1.157	0.211	0.021	9	933	7.26
0.77	0.137	0.022	9	924	6.41
0.828	0.149	0.023	7.3	924	6.41
0.477	0.046	0.025	8	872	9.61
0.188	0.028	0.023	8	872	9.83
0.825	0.138	0.021	6	502	7.32
1.016	0.177	0.02	6	502	5.65
0.893	0.121	0.023	14	2,255	1.34
0.942	0.139	0.024	15	2,255	1.5
0.677	0.099	0.017	7	1,008	4.7
0.641	0.11	0.0078	6	1,008	4.91
1.247	0.201	0.044	30	1,915	2.56
1.53	0.212	0.046	31	1,915	2.99
0.618	0.084	0.015	5	864	4.7
0.498	0.074	0.016	5	864	4.7
1.005	0.163	0.029	20	2,285	2.56
0.981	0.163	0.03		2,285	2.78
0.74	0.098	0.021	9	1,189	31.58
1.539	0.257	0.023	8	1,189	31.58
1.65	0.313	0.055	9	496	4.91
1.999	0.351	0.051	9	496	4.91
1.209	0.157	0.022	6	290	4.49
1.049	0.142	0.019	6	290	4.27
0.621	0.097		6	480	2.35
0.634	0.115	0.013	5	480	2.78
0.789	0.143	0.021	7	165	5.65
0.81	0.158	0.021	7	165	
0.598	0.092	0.018	9	1,070	1.71
0.49	0.077	0.017	9	1,070	1.71
0.526	0.089	0.015	8	676	3.63
0.72	0.125	0.015	8	676	3.63
0.653	0.095	0.013	7	4,206	2.85
0.609	0.079	0.014	8	4,206	2.73
0.251	0.042	0.008	2.3	538	
0.252	0.046	0.009	1.5	538	
0.78	0.12	0.012	4	732	2.42
0.766	0.118	0.013	4	732	2.35
0.989	0.131	0.027	13	2,245	7.48
1.082	0.142	0.027	13	2,245	7.9
0.623	0.084	0.014	8	1,797	3.6
0.581	0.081	0.015	9	1,797	3.47
1.871	0.254	0.044	45	4,056	1.6
1.738	0.213	0.044	44	4,056	
0.921	0.162	0.032	11	890	4.73
0.847	0.148	0.028	11	890	4.58
0.815	0.142	0.024	12	575	4.7
0.864	0.155	0.028	14	575	4.7
0.466	0.083	0.019	6	310	10.41
0.896	0.171	0.023	5	310	10.28

Particle analyses at Conowingo outfall.
Jeffrey Chanat, USGS MD-DE-DC Water Science Center.

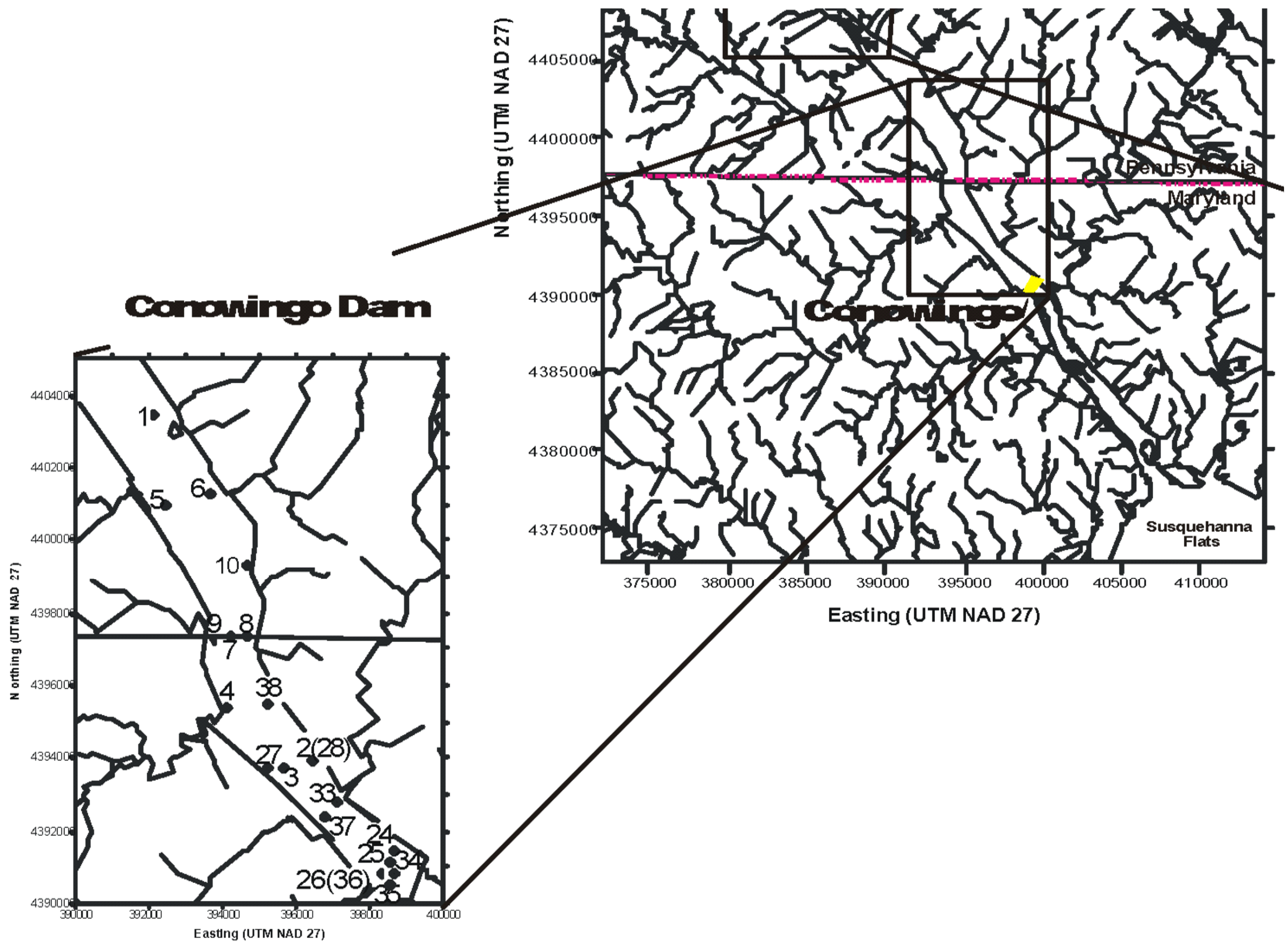
Date	Flow, m3/s	Phosphorus, ppm	Fe, %	Mn, ppm	TOC,%	TN, %	Susp. Sediment, mg/L	TOC (mg/L)	TN (mg/L)	TP (mg/L)
10/3/2010	2,861	1500	3.6	2500						
12/3/2010	7,819	1400	4.7	3000	4.1	0.47	141	5.8	0.66	0.197
3/8/2011	7,762	1400	5	3400	4.2	0.4	129	5.4	0.52	0.181
3/12/2011	12,833	1200	4.2	2100	5.1	0.36	937	47.8	3.37	1.124
3/12/2011	12,833	1200	4.4	2200	4.9	0.34	937	45.9	3.19	1.124
9/8/2011	17,479	1100	4.4	1900	3.2	0.26	2980	95.4	7.75	3.278
9/8/2011	17,479	1100	4.3	2000	3.2	0.27	2980	95.4	8.05	3.278
9/10/2011	13,626	900	5.3	1900	2.2	0.18	741	16.3	1.33	0.667
9/11/2011	10,992	960	4.9	1800	2.5	0.2	1150	28.8	2.30	1.104
9/12/2011	6,600	940	5.4	1800	1.9	0.19	332	6.3	0.63	0.312

Date	Flow, m3/s	Susp. Sediment, mg/L	Percent smaller than 0.063 mm (silt and clay)	Percent smaller than 0.004 mm (clay)
12/3/2010	7,819	141	98	
3/8/2011	7,762	129	97	
3/12/2011	12,833	937	90	
4/18/2011	7,219	206	98	
4/30/2011	8,946	184	96	
9/8/2011	17,479	2980	94	36
9/10/2011	13,626	741	97	63
9/11/2011	10,992	1150	94	48
9/12/2011	6,600	332	88	61

Analyses from 23 sediment cores from Conowingo Reservoir (21) and Susquehanna Flats (2).
Edwards, R. (2006). "Comprehensive analysis of the sediments retained behind hydroelectric dams of the lower Susquehanna River,"
Publication 239, Susquehanna River Basin Commission, Harrisburg PA.

ID	Latitude	Longitude	Intervals	%H20	Bulk Densi	%Coal	%SAND	%SILT	%CLAY	Fe (%)	Mn
1	39.78278	76.26417	10-20 in	40.75	1.6	21.74	40.84	45.23	13.93	3.3	1295.62
3	39.69333	76.21611	8-18 in	52.57	1.43	6.47	15.36	61.99	22.65	2.93	2374.78
4	39.70583	76.23611	9-19 in	38.37	1.64	10.98	52.91	37.29	9.8	3.85	2179.65
5	39.75611	76.2575	5-15 in	38.51	1.64	28.48	24.09	50.64	25.27	3.7	1123.39
6	39.76222	76.245	7-17 in	28.3	1.83	45.97	70.72	23.52	5.76	2.17	1052.46
7	39.725	76.23389	11-21 in	32.3	1.75	18.44	57.58	31.94	10.48	2.43	801.54
8	39.72472	76.22778	6-16 in	28.43	1.83	13.86	66.74	22.89	10.37	2.15	691.66
9	39.72389	76.23944	10-20 in	43.02	1.56	11.65	36.04	43.07	20.89	2.98	1659.55
10	39.74361	76.23111	3-13 in	45.48	1.53	25.36	8.93	59.35	31.72	3.91	1775.08
24	39.66917	76.18111	0-10	59.78	1.34	9.52	0.2	54.05	45.76	5.15	2328.49
25	39.66583	76.1825	23-33	52.98	1.42	5.35	5.83	60.63	33.54	3.49	2102.83
26	39.66306	76.18528	10-20 in	60.88	1.33	9.32	7.01	53.53	39.45	3.64	1800.59
27	39.68917	76.22083	7-17 in	63.43	1.3	4.82	6.21	56.11	37.68	3.53	2036.52
28	39.695	76.21083	10-20 in	60.74	1.33	1.01	0.85	61.81	37.35	3.78	2217.49
29	39.54694	76.02194	10-20 in	47.73	1.49	1.29	38.77	33.84	27.39	3.05	1117.41
30	39.54722	76.02222	10 20 in	48.65	1.48	0.46	34.38	34	31.61	2.95	973.55
33	39.68306	76.19944	10 20 in	62.91	1.31	4.24	0.36	55.05	44.59	4.14	1819.37
34	39.66611	76.17333	10-20 in	55.56	1.39	1.47	0.74	48.78	50.48	3.89	1512.63
35	39.6625	76.17444	10-20 in	68.41	1.25	2.31	0.31	49.04	50.65	4.28	3623.41
36	39.66167	76.18556	10-20 in	61.8	1.32	0.72	1.39	51.16	47.45	4.08	2304.78
37	39.67861	76.20389	10-20 in	63.61	1.3	1.84	0.36	52.99	46.65	4.1	2168.32
38	39.7075	76.22139	10-20 in	62.75	1.31	1.49	1.48	55.03	43.49	3.76	2854.29
2A	39.69556	76.2111	4-14 in	53.18	1.42	2.89	2.87	60.97	36.16	3.47	2412.41

ID	Latitude	Longitude	Intervals	P(ug/g)	%N	%C	
1	39.78278	76.26417	10-20 in	857.9	0.256	13.775	
3	39.69333	76.21611	8-18 in	1188.52	0.275	6.097	
4	39.70583	76.23611	9-19 in	1128.8	0.266	7.502	
5	39.75611	76.2575	5-15 in	696.03	0.276	17.536	
6	39.76222	76.245	7-17 in	571.43	0.224	23.634	
7	39.725	76.23389	11-21 in	701.38	0.21	14.369	
8	39.72472	76.22778	6-16 in	571.35	0.208	22.509	
9	39.72389	76.23944	10-20 in	1050.36	0.284	14.038	
10	39.74361	76.23111	3-13 in	1315.4	0.301	10.215	
24	39.66917	76.18111	0-10	1643.98	0.419	9.622	
25	39.66583	76.1825	23-33	1158.05	0.324	7.018	
26	39.66306	76.18528	10-20 in	1435.36	0.349	6.193	
27	39.68917	76.22083	7-17 in	1371.87	0.34	4.808	
28	39.695	76.21083	10-20 in	1162.49	0.326	4.815	
29	39.54694	76.02194	10-20 in	771.08	0.198	7.69	Susq Flats
30	39.54722	76.02222	10 20 in	699.98	0.188	7.364	Susq Flats
33	39.68306	76.19944	10 20 in	1466.74	0.357	4.493	
34	39.66611	76.17333	10-20 in	1131.83	0.264	4.332	
35	39.6625	76.17444	10-20 in	1714.93	0.445	4.809	
36	39.66167	76.18556	10-20 in	1402.89	0.352	4.395	
37	39.67861	76.20389	10-20 in	1401.73	0.35	4.041	
38	39.7075	76.22139	10-20 in	1375.63	0.346	4.957	
2A	39.69556	76.2111	4-14 in	1250.81	0.363	4.684	



Conowingo Dam
Conowingo
Pennsylvania
Maryland
Susquehanna Flats
Northing (UTM NAD 27)
Easting (UTM NAD 27)
4405000
4400000
4395000
4390000
4385000
4380000
4375000
375000
380000
385000
390000
395000
400000
405000
410000
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4402000
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38
27
3
2(28)
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37
24
25
34
26(36)
35