U.S. ENVIRONMENTAL PROTECTION AGENCY

SUMMARY AND CONCLUSIONS

NUTRIENT TRANSPORT AND ACCOUNTABILITY
IN THE
LOWER SUSQUEHANNA RIVER BASIN

October 1974

Technical Report 60
Annapolis Field Office
Region III
Environmental Protection Agency

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ABSTRACT

Identification of the Susquehanna River as the primary contributor of nutrients to the upper Chesapeake Bay and recognition of the need to develop a nutrient management program for their mutual protection, prompted the Annapolis Field Office, EPA, to conduct a one-year comprehensive nutrient survey in the lower Susquehanna River Basin between Northumberland, Pa. and Conowingo, Md. Three distinct hydrologic seasons were represented during the study period which provided the foundation for an in-depth evaluation of all water quality data obtained during this survey. Its principal objectives were: (1) quantitative identification of average nitrogen and phosphorus loadings and determination of seasonal variations in nutrient loadings from every major sub-basin (2) delineation of point source and non-point source nutrient contributions to establish effectiveness of controllability measures (3) seasonal mass balance of nutrient loadings in the main stem and (4) determination of the fate of nutrients in impounded areas. The report enumerates the important findings and conclusions which evolved during the intensive data analysis and interpretation and presents recommendations for future studies. Hopefully, the material presented in this report can assist in the implementation of a workable nutrient management program.

Introduction

Possibly the most serious pollution problem currently plaguing the upper Chesapeake Bay is one of progressive eutrophication stemming from the uncontrolled discharge of nitrogen and phosphorus in both the tidal and non-tidal areas of the major tributary watersheds. Consequently, during 1969 the Annapolis Field Office (AFO) embarked on a one-year monitoring study to (1) delineate significant nutrient inputs to the Chesapeake Bay, (2) quantify nutrient loadings and establish their seasonal trends, and (3) determine the relative importance of each watershed's nutrient load in affecting current biological conditions in the Bay. The obvious conclusion from this study was the primary significance of the Susquehanna River as a contributor of nitrogen and phosphorus to the Chesapeake Bay, accounting for 50, 60 and 66 percent of the total phosphorus, TKN and nitrate loadings, respectively, entering the Bay on an annual basis.

Recognizing the dramatic effect of the Susquehanna River on the water quality of the upper Chesapeake Bay and the need to develop a nutrient management program for their mutual protection, AFO initiated a comprehensive nutrient study in the lower Susquehanna Basin between Northumberland, Pa., and Conowingo, Md. The study was limited to this particular area since preliminary data analysis revealed this lower reach to be the significant nutrient contributor to the Bay. This twelve month study (June 1971 - May 1972), which

comprised weekly or bi-weekly sampling at 37 stream stations and monthly sampling of 25 major sewage treatment plant effluents, had the following principal objectives:

a) quantitative identification of average nitrogen and phosphorus loadings from every significant sub-basin in the lower Susquehanna,

b) determination of seasonal variations in nutrient loadings for individual sub-basins and their dependency on stream flow,

c) delineation of point source and non-point source nutrient contributions and determination of typical loading rates from agricultural, forested and urban areas, especially the urban Harrisburg metro area, in order to establish the potential controllability of nutrients on a seasonal basis,

d) seasonal mass balance of nutrient loadings in the Susquehanna River from the West Branch confluence to Conowingo, Md., and

e) determination of the fate of nutrients in impounded areas along the lower Susquehanna River.

This report contains an enumeration of the important findings which evolved during the course of data analysis and interpretation. In addition, the report contains the most important conclusions which can be drawn from the information presented followed by a framework of recommendations for future studies. Graphical supportive material is included in the Appendix.

It should be noted that Item 28 of the Summary and Item 23 of the Conclusion Sections of the report state the need for point source control of phosphorus to protect the upper Chesapeake Bay from excessive eutrophication. Conclusion 24 questions the effectiveness of nitrogen control at point sources in the lower Susquehanna River Basin in the absence of an accompanying reduction of the existing nitrogen load from agricultural runoff. These findings and conclusions were specifically developed in AFO Technical Report 56. Utilizing a mathematical model and the data from Technical Report 60, the combined impact of nutrient loadings from the Susquehanna River and Baltimore, Maryland on the eutrophic condition of the upper Chesapeake Bay was evaluated. Technical Report 56, "Nutrient Enrichment and Control Requirements in the Upper Chesapeake Bay, Summary and Conclusions", should be read jointly with this report.

Technical Report 56 concluded that phosphorus could be made the rate limiting nutrient in the upper Chesapeake Bay to control eutrophication or, specifically, the level of algal standing crop as measured by chlorophyll a. For Susquehanna River flows less than or equal to 30,000 cubic feet per second (cfs), a reduction of 70 percent in the existing point source phosphorus load from both the lower Susquehanna River and the Baltimore Metropolitan Area is required. At higher river flows the phosphorus reduction at point sources increases substantially. Point source control of nitrogen may not be a viable alternative to phosphorus control during any flow condition at this time without a substantial reduction in non-point sources of nitrogen.

The Commonwealth of Pennsylvania has an adopted phosphorus policy for the lower Susquehanna Basin which requires at least 80 percent removal of phosphorus from all new or modified wastewater treatment facilities. Maryland places phosphorus limitations on wastewater treatment facilities on a case by case basis in accordance with receiving water characteristics. Even with the introduction of point source phosphorus control in Maryland and Pennsylvania, the impact from expected population growth in the study area will eventually require serious consideration of non-point source control of nutrients as a supplemental measure to high degrees of phosphorus and nitrogen removal at point sources. Technological and cost considerations of phosphorus removal and the relative magnitude of non-point source nitrogen loads may make this consideration imperative. The delineation and quantification of point source and non-point source nutrient contributions for the lower Susquehanna Basin set forth in the report is substantial. It is hoped that management agencies will utilize this body of data and expand upon it where necessary to develop land-use management programs in conjunction with point source control of nutrients to allow for the accomodation of future population growth while at the same time maintaining permissable nutrient levels in the lower Susquehanna Basin and the upper Chesapeake Bay.

Summary

1) The Susquehanna River between Sunbury, Pennsylvania and Conowingo, Maryland, drains an area of approximately 9,000 square miles in south central Pennsylvania and contains a resident population (1970 census) of approximately 875,000 (25% of the Basin's total population).

2) In the lower Susquehanna River basin approximately 5%, 40%, 50% and 5% represents urban, agricultural, forested and other areas, respectively.

3) Daily flows were monitored at Conowingo Dam during the entire survey and ranged from about 4,200 cfs (Aug. 1971) to 319,000 cfs (Mar. 1972).

4) For purposes of data evaluation, the study period was separated into three distinct seasons, each characterized by a different but relatively uniform flow condition. The mean flows and mean water temperatures for each season are shown in the table below:

Period	Mean Flow (cfs x 1000's)	Mean Water Temperature °C
June - Oct., 1971	11	23.5
Nov., 1971 - Feb., 1972	37	3.6
March - May, 1972	88	12.5

5) The average seasonal concentration of nutrients measured near the mouths of the fourteen major tributaries of the lower Susquehanna River are presented as follows:

Average Nutrient Concentrations*

Susquehanna River Tributaries

(June - Oct., 1971)

Sub-Basin	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
	mg/l							
STONY CREEK	30	0.09	0.06	0.22	0.06	0.24	0.46	0.30
SHAMOKIN CREEK	123	1.10	0.10	3.34	1.86	0.31	3.65	2.17
PENNS CREEK	175	0.44	0.23	0.96	0.17	0.79	1.75	0.96
JUNIATA RIVER	1740	0.27	0.10	0.68	0.05	0.58	1.26	0.63
CONODOGUINET CR.	265	0.63	0.39	0.60	0.06	1.59	2.19	1.65
YELLOW BREECHES	210	0.18	0.13	0.37	0.13	1.32	1.69	1.45
SWATARA CREEK	560	0.51	0.43	0.55	0.10	2.10	2.65	2.20
CONEWAGO CREEK	330	0.59	0.45	0.71	0.08	1.65	2.36	1.73
CONOY CREEK	15	2.44	1.71	1.22	0.24	6.24	7.46	6.48
CODORUS CREEK	215	2.11	1.83	1.61	0.56	2.86	4.47	3.42
CHICKIES CREEK	120	0.61	0.43	0.65	0.08	5.44	6.09	5.52
CONESTOGA CREEK	400	1.47	1.10	0.93	0.17	4.60	5.53	4.77
PEQUEA CREEK	156	0.79	0.28	0.91	0.13	4.04	4.95	4.17
OCTORARO CREEK	200	0.30	0.13	0.67	0.12	2.08	2.75	2.20

*** All outliers were discriminately omitted.**

Average Nutrient Concentrations*

Susquehanna River Tributaries

(Nov., 1971 - Feb., 1972)

Sub-Basin	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
	mg/l							
STONY CREEK	80	0.06	0.03	0.20	0.06	0.14	0.34	0.20
SHAMOKIN CREEK	237	0.93	0.08	2.02	1.67	0.84	2.86	2.51
PENNS CREEK	450	0.21	0.18	0.54	0.13	1.78	2.32	1.91
JUNIATA RIVER	4975	0.16	0.12	0.37	0.08	1.00	1.37	1.08
CONODOGUINET CR.	860	0.53	0.37	0.50	0.12	3.12	3.62	3.24
YELLOW BREECHES	360	0.14	0.09	0.36	0.08	1.47	1.83	1.55
SWATARA CREEK	1570	0.55	0.48	0.79	0.31	2.41	3.20	2.72
CONEWAGO CREEK	1023	0.38	0.29	0.63	0.12	1.92	2.55	2.04
CONOY CREEK	30	2.26	1.55	2.19	1.02	7.94	10.13	8.96
CODORUS CREEK	445	1.25	1.10	1.28	0.80	3.72	5.00	4.52
CHICKIES CREEK	200	0.47	0.40	0.76	0.17	6.92	7.68	7.09
CONESTOGA CREEK	800	1.50	1.09	1.38	0.45	5.96	7.34	6.41
PEQUEA CREEK	245	0.24	0.19	0.91	0.42	5.63	6.54	6.05
OCTORARO CREEK	300	0.19	0.11	0.82	0.09	4.12	4.94	4.21

* **All outliers were discriminately omitted.**

Average Nutrient Concentrations*

Susquehanna River Tributaries

(March - May, 1972)

Sub-Basin	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
	mg/l							
STONY CREEK	109	0.04	0.03	0.26	0.06	0.13	0.39	0.19
SHAMOKIN CREEK	365	0.88	0.08	1.39	1.04	0.64	2.03	1.68
PENNS CREEK	1263	0.24	0.11	0.66	0.13	1.50	2.16	1.63
JUNIATA RIVER	10,741	0.16	0.07	0.35	0.05	0.85	1.20	0.90
CONODOGUINET CR.	1596	0.30	0.17	0.46	0.05	2.07	2.53	2.12
YELLOW BREECHES	611	0.16	0.14	0.54	0.18	1.73	2.27	1.91
SWATARA CREEK	1604	0.29	0.23	0.49	0.09	2.71	3.20	2.80
CONEWAGO CREEK	1271	0.31	0.15	0.57	0.06	1.77	2.34	1.83
CONOY CREEK	35	1.30	1.29	1.58	0.61	6.94	8.52	7.55
CODORUS CREEK	534	1.57	1.07	1.20	0.39	3.79	4.99	4.18
CHICKIES CREEK	250	0.34	0.23	0.59	0.10	7.00	7.59	7.10
CONESTOGA CREEK	1055	0.86	0.74	0.80	0.23	6.29	7.09	6.52
PEQUEA CREEK	300	0.20	0.12	0.52	0.08	5.72	6.24	5.80
OCTORARO CREEK	400	0.28	0.20	0.76	0.13	3.94	4.70	4.07

*** All outliers were discriminately omitted.**

The data shown in the preceeding tables indicate that Shamokin, Conoy, Codorus and Conestoga Creeks had the highest phosphorus concentrations during each season. During low flow periods these concentrations exceeded 1.0 mg/l. Both total and inorganic phosphorus concentrations usually decreased when stream flows increased, indicating that excessive runoff was having a diluting effect on point source discharges.

Maximum TKN concentrations (1.0 - 3.0 mg/l) were also measured in Shamokin, Conoy, Codorus and Conestoga Creeks during the low flow season and probably reflected the sizeable waste loadings received by these streams. In general, TKN behaved similar to phosphorus in that higher stream flows resulted in further dilution.

Oxidized inorganic nitrogen ($NO_2 + NO_3$) appeared to be the most prevalent nutrient monitored. Because of the importance of agricultural runoff, most streams did not experience the diluting effect observed for other forms of nutrients during high flow periods. Pequea Creek, a predominately agricultural watershed having no significant point source discharges exhibited a high $NO_2 + NO_3$ concentration but a relatively low TKN concentration for each season. Stony Creek, a predominately forested watershed, on the other hand, contained relatively low nutrient concentrations regardless of season.

Except for Shamokin Creek, a highly acidic stream where nitrification is probably inhibited, ammonia levels were quite low, especially during the warmer periods when the nitrification reaction should be most pronounced.

6) The average seasonal nutrient concentrations measured at the ten main stem Susquehanna stations are presented in the tables on the following pages.

Since the volume of flow in the Susquehanna is extremely large in comparison to the tributary flows, the river was not very responsive to a given nutrient input in terms of a concentration increase. The considerable amount of dilution present is illustrated in the comparatively low phosphorus and nitrogen concentrations shown in the following tables. Phosphorus concentrations were generally higher during the low flow periods but did not exceed 0.3 mg/l. Moreover, concentrations were consistently greater in the reach from Harrisburg to Conowingo than they were in the upper reach, probably the result of several large tributary inputs. The fairly high phosphorus concentrations observed in the vicinity of Harrisburg during the high flow period may be partially due to combined sewer overflows. It is also important to recognize the dramatic decrease in phosphorus during lower flow periods in the area of Conowingo and to a lesser extent at Safe Harbor. These impoundments appeared to represent a significant "sink" for phosphorus when detention times were long.

The maximum TKN and $NO_2 + NO_3$ concentrations (0.82 mg/l and 1.3 mg/l, respectively) were measured in the Susquehanna River between Safe Harbor and Conowingo Dams. While TKN was always greatest during low flow periods because of minimal dilution of tributary inflows, $NO_2 + NO_3$ levels were greater during the higher flow-lower temperature periods. This latter relationship reflected the effects of runoff

Average Nutrient Concentrations

Main Stem Susquehanna River

(June - Oct. 1971)

STATION	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
	mg/l							
W. BRANCH SUSQUEHANNA NORTHUMBERLAND	2760	0.12	0.05	0.38	0.08	0.39	0.77	0.47
MAIN BRANCH SUSQUEHANNA NORTHUMBERLAND	3500	0.20	0.06	0.71	0.09	0.36	1.07	0.45
SUSQUEHANNA RT. 15 SUNBURY	6200	0.21	0.06	0.64	0.17	0.38	1.02	0.55
SUSQUEHANNA RT. 22-322	7090	0.18	0.07	0.60	0.04	0.30	0.90	0.34
SUSQUEHANNA RT. 15 HARRISBURG	9095	0.25	0.18	0.57	0.08	0.41	0.98	0.49
SUSQUEHANNA RT. 83 HARRISBURG	9095	0.19	0.08	0.56	0.08	0.44	1.00	0.52
SUSQUEHANNA COLUMBIA BR.	11,300	0.29	0.07	0.72	0.07	0.42	1.14	0.49
SUSQUEHANNA SAFE HARBOR	10,800	0.25	0.07	0.80	0.33	0.54	1.34	0.87
SUSQUEHANNA HOLTWOOD	11,900	0.29	0.12	0.77	0.32	0.73	1.50	1.05
SUSQUEHANNA CONOWINGO	11,500	0.15	0.08	0.82	0.35	0.85	1.65	1.20

* **All outliers were discriminately omitted.**

Average Nutrient Concentrations

Main Stem Susquehanna River

(Nov. 1971 - Feb. 1972)

STATION	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
		mg/l						
W. BRANCH SUSQUEHANNA NORTHUMBERLAND	10,900	0.08	0.02	0.30	0.12	0.49	0.79	0.61
MAIN BRANCH SUSQUEHANNA NORTHUMBERLAND	13,400	0.19	0.06	0.54	0.27	0.88	1.42	1.15
SUSQUEHANNA RT. 15 SUNBURY	24,800	0.16	0.08	0.61	0.26	0.70	1.31	0.96
SUSQUEHANNA RT. 22-322	27,900	0.18	0.05	0.41	0.15	0.66	1.07	0.81
SUSQUEHANNA RT. 15 HARRISBURG	33,800	0.14	0.06	0.39	0.13	0.81	1.20	0.94
SUSQUEHANNA RT. 83 HARRISBURG	33,800	0.19	0.06	0.41	0.14	0.78	1.19	0.92
SUSQUEHANNA COLUMBIA BR.	38,700	0.36	0.16	0.50	0.13	0.86	1.36	0.99
SUSQUEHANNA SAFE HARBOR	37,900	0.24	0.11	0.55	0.23	1.12	1.67	1.35
SUSQUEHANNA HOLTWOOD	39,200	0.29	0.18	0.81	0.29	1.30	2.11	1.59
SUSQUEHANNA CONOWINGO	37,400	0.19	0.10	0.55	0.18	1.26	1.81	1.44

* **All outliers were discriminately omitted.**

Average Nutrient Concentrations

Main Stem Susquehanna River

(Mar. 1972 - May 1972)

STATION	MEAN FLOW (cfs)	TPO_4 as PO_4 (mg/l)	INORGANIC P as PO_4 (mg/l)	TKN as N (mg/l)	NH_3 as N (mg/l)	NO_2+NO_3 as N (mg/l)	TN (mg/l)	TIN (mg/l)
W. BRANCH SUSQUEHANNA NORTHUMBERLAND	25,400	0.08	0.04	0.23	0.07	0.44	0.67	0.51
MAIN BRANCH SUSQUEHANNA NORTHUMBERLAND	40,500	0.18	0.06	0.40	0.12	0.72	1.12	0.84
SUSQUEHANNA RT. 15 SUNBURY	65,600	0.14	0.05	0.45	0.19	0.55	1.00	0.74
SUSQUEHANNA RT. 22-322	72,500	0.16	0.05	0.39	0.10	0.57	0.96	0.67
SUSQUEHANNA RT. 15 HARRISBURG	85,000	0.20	0.09	0.38	0.08	0.70	1.08	0.78
SUSQUEHANNA RT. 83 HARRISBURG	85,000	0.22	0.10	0.48	0.14	0.69	1.17	0.83
SUSQUEHANNA COLUMBIA BR.	91,450	0.21	0.09	0.43	0.09	0.78	1.21	0.87
SUSQUEHANNA SAFE HARBOR	90,700	0.18	0.07	0.46	0.17	0.89	1.35	1.06
SUSQUEHANNA HOLTWOOD	92,200	0.19	0.09	0.42	0.11	0.91	1.33	1.02
SUSQUEHANNA CONOWINGO	88,100	0.21	0.11	0.51	0.15	0.97	1.38	1.12

*** All outliers were discriminately omitted.**

from agricultural land and reduced biological utilization rates. The Susquehanna River water appeared to be highly nitrified during high temperature periods as evidenced by the extremely low NH_3 concentrations. During low temperature periods, however, NH_3 was generally more abundant because of reduced nitrification and biological utilization rates.

7) In an attempt to establish statistically valid relationships between both nutrient concentrations and nutrient loadings versus stream flow, a series of regression analyses utilizing the appropriate sampling data were performed at each station and for each parameter. These regression analyses were made using both linear and log transforms with the latter yielding the best correlation.

A summary of the regression data for nutrient concentrations versus stream flow is presented in the following table. As can be seen, numerous regressions resulted in poor correlation based upon non-significant "t" statistics at the 5 percent level. However, several interesting conclusions can be drawn from the remaining data. In the case of total phosphorus, negative slopes ranging from about 0.2 to 0.6 were detected excepting for Pequea Creek. This would corroborate the previous discussion wherein a diluting effect was shown to occur at higher flow conditions. Moreover, these negative slopes would imply that the majority of phosphorus was contributed by wastewater discharges. Pequea Creek, on the other hand, had a large positive slope (0.97) indicating that land runoff may be the primary source of phosphorus in that watershed.

Regression Analysis Summary
Susquehanna River Tributaries*

(Concentration vs Flow)

SUB-BASIN	$T.PO_4$ Slope of Regression Equation	$T.PO_4$ T-Value	TKN Slope of Regression Equation	TKN T-Value	$NO_2 + NO_3$ Slope of Regression Equation	$NO_2 + NO_3$ T-Value
STONY CREEK	-0.30	-2.69*	0.01	0.08	-0.01	-0.11
SHAMOKIN CREEK	-0.59	-3.36*	-0.92	-9.54*	1.17	4.57*
PENNS CREEK	-0.19	-1.92	-0.07	-0.89	0.67	5.30*
JUNIATA RIVER	-0.23	-2.73*	-0.12	-1.18	0.67	3.91*
CONODOGUINET CREEK	-0.15	1.69	0.17	2.00	0.15	1.78
YELLOW BREECHES CREEK	0.14	0.79	0.67	3.22*	0.09	0.92
SWATARA CREEK	-0.21	-2.50*	0.05	0.48	0.02	0.28
CONEWAGO CREEK	-0.15	-2.11*	0.07	1.08	0.04	0.46
CONOY CREEK	0.17	-1.23	0.45	3.26*	0.03	0.17
CODORUS CREEK	-0.35	-3.64*	-0.25	-3.53*	0.14	1.92
CHICKIES CREEK	0.08	0.54	0.44	2.82*	-0.04	-0.29
CONESTOGA CREEK	-0.46	-6.28*	-0.15	-1.24	0.14	1.07
PEQUEA CREEK	0.97	3.35*	0.78	3.50*	0.42	2.96*
OCTORARO CREEK	0.18	1.23	0.42	2.42*	0.30	2.32*

* Significance at the 5 percent level

The relatively large negative slopes of the TKN regression equations indicated that Shamokin, Codorus and Conestoga Creeks all received major TKN loads from wastewater discharges. Shamokin Creek, an acid stream receiving a considerable quantity of untreated sewage, exhibited a particularly large negative slope (-0.92). At the other end of the spectrum were streams having relatively minor point source contributions, i.e. Pequea and Yellow Breeches Creeks, which showed highly positive slopes (0.78 and 0.67). The remainder of the streams appeared to be influenced by a combination of point and non-point sources insofar as TKN was concerned.

All of the sub-basin sampling stations where statistical validity was realized had a positive relationship between $NO_2 + NO_3$ and stream flow. The slopes varied from about 0.2 to over 1.0. The consistency of this relationship indicated the significant overall effect of agricultural runoff as a contributor of nitrate nitrogen especially during periods of intense runoff.

8) The main stem Susquehanna River sampling results should theoretically reflect the accumulative effect of all tributary inputs. Regression data obtained for a nutrient concentration versus stream flow relationship for the Susquehanna, which are summarized in the following table, basically substantiated this contention. In the case of phosphorus and TKN, the slope terms were very similar for every station where statistically valid data were

Regression Analysis Summary
Main Stem Susquehanna River*

(Concentration vs Flow)

SUB-BASIN	$T.PO_4$ Slope of Regression Equation	$T.PO_4$ T-Value	TKN Slope of Regression Equation	TKN T-Value	$NO_2 + NO_3$ Slope of Regression Equation	$NO_2 + NO_3$ T-Value
W. Branch Susquehanna	-0.19	-2.83*	-0.22	-2.78*	0.16	2.15*
Main Branch Susquehanna	0.01	0.16	-0.25	-4.36*	0.59	2.74*
Rt. 15 Sunbury	-0.13	-2.08*	-0.05	-0.77	0.57	4.44*
Rt. 22-322	0.00	0.03	-0.19	-2.60*	0.70	4.20*
Rt. 15 Harrisburg	0.01	0.06	-0.12	-1.45	0.90	4.74*
Rt. 83 Harrisburg	0.12	1.50	-0.06	-0.77	0.87	5.21*
Columbia	-0.20	-2.52*	-0.32	-5.02*	0.34	3.20*
Safe Harbor	-0.10	-1.75	-0.27	-3.44*	0.51	3.50*
Holtwood	-0.12	-1.37	-0.32	-3.46*	0.03	0.22
Conowingo	0.05	0.82	-0.10	-1.30	-0.01	-0.12

* Significance at the 5 percent level

realized. The range for phosphorus (-0.20 to +0.12) was somewhat lower than the values recorded for the tributary stations since the effects of land runoff, including drainage along the river itself, were more pronounced in comparison to point source discharges. A similar situation was indicated by the generally greater positive relationship between nitrate nitrogen and stream flow for the Susquehanna River. The range in slopes for TKN (-0.32 to -0.05) suggested a net diluting effect when compared to all of the tributary data presented previously. The negative relationships for phosphorus and TKN concentrations versus stream flow and the positive relationships for nitrate nitrogen versus stream flow determined for the main stem Susquehanna River were essentially in agreement with those reported for the Potomac River.*

9) Regression analyses proved much more statistically reliable when nutrient loadings and stream flow relationships were investigated. The average nutrient loadings computed for the various tributaries to the Susquehanna River from regression data are presented in the following tables for each of the three hydrologic seasons. It should be noted that average stream flows for the entire season were used, when available, rather than flows corresponding to individual sampling days.

The watersheds contributing the greatest phosphorus loads regardless of season were Conestoga and Codorus Creeks and the Juniata River. The major nitrogen contributing watersheds were Conestoga and Swatara Creeks and the Juniata River. The Juniata River was a

* Nutrients in the Upper Potomac River Basin, Jaworski, CTSL Technical Report 15, August, 1969.

significant contributor of nutrients due to its relatively large flow whereas the other streams contained considerably greater nutrient concentrations because of sizeable inputs from wastewater effluents and land runoff.

10) Average seasonal nutrient loadings computed at each of the main stem Susquehanna River stations from regression analysis and average stream flow data are shown in the following tables. A graphical mass balance analysis of these loadings will be presented and discussed in a subsequent section of this report.

Both nitrogen and phosphorus loadings throughout the lower Susquehanna River varied drastically from one season to the next because of differences in stream flow. The loadings also showed a gradual but steady increase in the downstream direction which reflected substantial inputs from several tributary watersheds. It is important to note that generally about 30-40 percent of the total phosphorus load was inorganic, regardless of spatial or temporal position. Inorganic nitrogen accounted for about 50, 65 and 80 percent of the total nitrogen load during low, mean and high flow periods, respectively. This upward shift was partly due to relatively greater increases in nitrate rather than organic nitrogen loadings from major tributary watersheds during periods of excessive runoff.

The nitrogen-phosphorus ratio (by atoms) throughout the lower Susquehanna River averaged about 34:1 during the summer season, 46:1 in the winter and 43:1 in the spring. These values are considerably greater than the elemental ratios comprising algal cellular material (15-20:1) reported in the literature.

Average Nutrient Loadings*

Susquehanna River Tributaries

(June 1971 - Oct. 1971)

SUB-BASIN	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
	lbs/day							
STONY CREEK	30	10	5	30	10	20	50	30
SHAMOKIN CREEK	123	800	50	2300	1000	300	2500	1500
PENNS CREEK	175	150	100	300	50	200	500	300
JUNIATA RIVER	1740	2000	1000	5000	500	4000	10,000	4500
CONODOGUINET CREEK	265	700	400	500	100	2100	2500	2200
YELLOW BREECHES	210	200	100	300	50	1500	2000	1600
SWATARA CREEK	560	1200	1000	1600	300	6500	8000	6800
CONEWAGO CREEK	330	700	500	1000	100	2800	3800	2800
CONOY CREEK	15	150	130	100	20	500	600	500
CODORUS CREEK	215	2000	1600	1500	600	3600	5000	4200
CHICKIES CREEK	120	300	200	300	50	3800	4100	3900
CONESTOGA CREEK	400	3000	2200	2000	300	10,000	12,000	10,000
PEQUEA CREEK	156	300	180	400	100	3800	4200	3900
OCTORARO CREEK	200	300	100	600	100	2800	3400	2900

* Due to the nature of regression analyses, TN and TIN loadings will not necessarily reflect the exact total of TKN + NO_2NO_3 and NH_3 + NO_2NO_3 loadings, respectively.

Average Nutrient Loadings*

Susquehanna Tributary Stations

(Nov. 1971 - Feb. 1972)

SUB-BASIN	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
		lbs/day						
STONY CREEK	80	20	10	80	20	60	150	100
SHAMOKIN CREEK	237	1000	50	2400	1500	700	3000	2200
PENNS CREEK	450	300	150	800	150	1000	2000	1200
JUNIATA RIVER	4975	4700	2000	12000	1500	22000	36000	24000
CONODOGUINET CREEK	860	2000	1000	2500	300	9000	11000	9000
YELLOW BREECHES	360	350	200	800	100	2800	3700	3000
SWATARA CREEK	1570	2700	2200	5000	1350	18500	24000	20000
CONEWAGO CREEK	1023	1900	1300	3800	450	9500	13000	10000
CONOY CREEK	30	300	200	250	100	1000	1200	1100
CODORUS CREEK	445	3200	2200	2800	1000	8200	11000	9000
CHICKIES CREEK	200	500	400	700	100	6200	7000	6300
CONESTOGA CREEK	800	4200	3300	3600	1000	22000	26000	23000
PEQUEA CREEK	245	700	400	1000	175	6500	7500	6700
OCTORARO CREEK	300	500	200	1100	150	4900	6000	4900

* **Due to the nature of regression analyses, TN and TIN loadings will not necessarily reflect the exact total of TKN + NO_2NO_3 and NH_3 + NO_2NO_3 loadings, respectively.**

Average Nutrient Loadings*

Susquehanna Tributary Stations

(Mar. 1972 - May 1972)

SUB-BASIN	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
		lbs/day						
STONY CREEK	109	25	15	100	25	100	200	100
SHAMOKIN CREEK	365	1200	100	2500	1700	1300	4000	3100
PENNS CREEK	1263	770	350	2200	450	6000	8000	6500
JUNIATA RIVER	10741	8500	4800	23000	3000	78000	100000	82000
CONODOGUINET CREEK	1596	3600	2000	5000	700	19000	24000	19000
YELLOW BREECHES	611	700	300	2000	300	5000	7000	5000
SWATARA CREEK	1604	2800	2200	5000	1400	19000	24000	21000
CONEWAGO CREEK	1271	2300	1500	5000	600	11000	17000	13000
CONOY CREEK	35	350	200	300	100	1200	1500	1300
CODORUS CREEK	534	3600	2500	3000	1100	10000	13000	11000
CHICKIES CREEK	250	700	450	1000	200	7500	8400	7800
CONESTOGA CREEK	1055	5000	4000	4600	1600	30000	35000	32000
PEQUEA CREEK	300	1000	500	1400	250	8300	9500	8400
OCTORARO CREEK	400	700	300	1700	200	7500	9000	7500

* Due to the nature of regression analyses, TN and TIN loadings will not necessarily reflect the exact total of TKN + NO_2NO_3 and NH_3 + NO_2NO_3 loadings, respectively.

Average Nutrient Loadings*

Main Stem Susquehanna River

(June 1971 - Oct. 1971)

STATION	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
		lbs/day						
NORTH BRANCH AT NORTHUMBERLAND	3500	3500	1000	12000	1300	6000	20000	7000
WEST BRANCH AT NORTHUMBERLAND	2760	1500	700	5000	800	5000	10000	6000
RT. 15 SUNBURY	6200	6200	2000	20000	4500	10000	34000	14000
RT. 22-322	7090	6000	2000	20000	1800	8000	28000	10000
RT. 15 HARRISBURG	9095	9700	4200	23000	3000	14000	39000	20000
RT. 83 HARRISBURG	9095	8500	3000	24000	3000	14000	39000	20000
COLUMBIA	11300	17000	4000	40000	3500	24000	65000	27000
SAFE HARBOR	10800	14000	4000	42000	15000	26000	67000	42000
HOLTWOOD	11900	16000	6000	47000	20000	48000	94000	65000
CONOWINGO	11500	9000	5000	47000	16000	49000	95000	66000

* Due to the nature of regression analyses, TN and TIN loadings will not necessarily reflect the exact total of TKN + NO_2NO_3 and NH_3 + NO_2NO_3 loadings, respectively.

Average Nutrient Loadings*

Main Stem Susquehanna River

(Nov. 1971 - Feb. 1972)

STATION	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
	lbs/day							
NORTH BRANCH AT NORTHUMBERLAND	13400	13500	4000	35000	7500	40000	80000	48000
WEST BRANCH AT NORTHUMBERLAND	10900	4600	2000	16000	4200	30000	45000	33000
RT. 15 SUNBURY	24800	20000	6500	60000	22500	70000	135000	95000
RT. 22-322	27900	26000	8000	65000	12000	80000	152000	90000
RT. 15 HARRISBURG	33800	36000	12000	74000	15000	112000	196000	130000
RT. 83 HARRISBURG	33800	37000	15000	77000	18000	113000	200000	132000
COLUMBIA	38700	45000	14000	100000	17000	146000	250000	150000
SAFE HARBOR	37900	42000	15000	105000	33000	150000	253000	200000
HOLTWOOD	39200	47000	18000	112000	48000	185000	300000	230000
CONOWINGO	37400	34000	17000	115000	39000	185000	300000	230000

* Due to the nature of regression analyses, TN and TIN loadings will not necessarily reflect the exact total of TKN + NO_2NO_3 and NH_3 + NO_2NO_3 loadings, respectively.

Average Nutrient Loadings*

Main Stem Susquehanna River

(March 1972 - May 1972)

STATION	MEAN FLOW (cfs)	TPO_4 as PO_4	INORGANIC P as PO_4	TKN as N	NH_3 as N	NO_2+NO_3 as N	TN	TIN
	----------	----------	----------	lbs/day	----------	----------	----------	----------
NORTH BRANCH AT NORTHUMBERLAND	40500	41000	13000	75000	32000	90000	255000	200000
WEST BRANCH AT NORTHUMBERLAND	25400	9000	3500	30000	11000	70000	105000	80000
RT. 15 SUNBURY	65600	48000	16000	130000	71000	280000	400000	380000
RT. 22-322	72500	70000	22000	150000	44000	350000	480000	375000
RT. 15 HARRISBURG	85000	92000	27000	160000	46000	470000	612000	450000
RT. 83 HARRISBURG	85000	100000	45000	175000	67000	475000	630000	575000
COLUMBIA	91450	97000	35000	180000	50000	485000	640000	480000
SAFE HARBOR	90700	93000	38000	185000	57000	490000	645000	565000
HOLTWOOD	92200	95000	40000	210000	38000	505000	690000	550000
CONOWINGO	88100	82000	41000	250000	76000	460000	690000	525000

* Due to the nature of regression analyses, TN and TIN loadings will not necessarily reflect the exact total of TKN + NO_2NO_3 and NH_3 + NO_2NO_3 loadings, respectively.

11) The following table shows the average daily phosphorus and nitrogen loads currently discharged by each of the major wastewater treatment facilities in the lower Susquehanna Basin. Also shown are the average per capita loadings based upon the present population served. The three areas responsible for approximately one half of the total measured phosphorus and nitrogen load from municipal point source discharges were Harrisburg, Lancaster and York.

Utilizing the average per capita loadings (0.024 lbs/day TPO_4 and 0.018 lbs/day TKN) and the entire lower basin population served by sewerage facilities (850,000), the estimated total phosphorus and nitrogen contributions from wastewater effluents were computed to be 20,400 lbs/day and 15,300 lbs/day, respectively.

12) The average daily phosphorus and nitrogen loadings discharged by the major water using industries in the lower Susquehanna River Basin are presented following the municipal wastewater table. These data were contained in the industries' NPDES permit applications and reflect the best currently available information on loading rates. While the list is probably not complete, it is believed that the industries shown in the following table constitute the bulk of the industrial nutrient contribution based upon a comprehensive compilation of industrial discharges throughout the Susquehanna Basin.

As can be seen, the total phosphorus and nitrogen loads from industrial point-source discharges were estimated to be 1,355 lbs/day and 4,800 lbs/day, respectively. Of the total nitrogen load approximately 40 percent was in the form of TKN and 80 percent was as inorganic nitrogen ($NH_3 + NO_2 + NO_3$).

Nutrient Contributions from Wastewater Effluents (Municipal)

Lower Susquehanna Basin

(June, 1971 - May, 1972)

Facility	Average Flow (MGD)	Population Served	Receiving Stream	TPO_4 lbs/day	TPO_4 lbs/cap/day	TKN lbs/day	TKN lbs/cap/day
SELINGSGROVE	1.0	7500	PENNS CREEK	200	0.03	200	0.03
SUNBURY	3.9	15300	SHAMOKIN CREEK	650	0.04	420	0.03
EAST PENNSBORO	1.4	11700	SUSQ. RIVER	450	0.04	250	0.02
MECHANICSBURG	1.2	16200	CONODOGUINET	350	0.02	120	0.01
SHIPPENSBURG	1.5	11400	CONODOGUINET	250	0.02	160	0.01
CARLISLE	3.6	20700	CONODOGUINET	950	0.05	520	0.03
LOWER ALLEN	0.6	15300	SUSQ. RIVER	140	0.01	130	0.01
HARRISBURG	17.5	156200	SUSQ. RIVER	2570	0.02	2400	0.02
NEW CUMBERLAND	0.9	9300	SUSQ. RIVER	500	0.05	325	0.03
CAMP HILL	0.8	9400	SUSQ. RIVER	230	0.02	175	0.02
MIDDLETOWN	0.6	11300	SUSQ. RIVER	200	0.02	140	0.01
LEBANON	4.7	41200	SWATARA CREEK	670	0.02	730	0.02
PALMYRA	0.5	9100	SWATARA CREEK	200	0.02	170	0.02
HERSHEY	2.0	12400	SWATARA CREEK	280	0.02	270	0.02
HANOVER	2.4	16000	CONEWAGO CREEK	530	0.03	200	0.01

Nutrient Contributions from Wastewater Effluents (Municipal)

Lower Susquehanna Basin

(June, 1971 - May, 1972)

(CONTINUED)

Facility	Average Flow (MGD)	Population Served	Receiving Stream	TPO_4 lbs/day	TPO_4 lbs/cap/day	TKN lbs/day	TKN lbs/cap/day
ELIZABETHTOWN	1.8	10700	CONOY CREEK	330	0.03	300	0.03
YORK	15.8	100500	CODORUS CREEK	2200	0.02	1800	0.02
RED LION	0.3	6700	CODORUS CREEK	150	0.02	50	0.01
PENN TOWNSHIP	1.1	7200	CODORUS CREEK	100	0.01	100	0.01
MANHEIM	0.7	7600	CHICKIES CREEK	150	0.02	100	0.01
COLUMBIA	1.0	18200	SUSQ. RIVER	280	0.02	370	0.02
LANCASTER - N	10.5	50000	CONESTOGA CREEK	1330	0.03	1200	0.02
LANCASTER - S	10.5	30000	CONESTOGA CREEK	1330	0.04	900	0.03
EPHRATA	1.0	15600	CONESTOGA CREEK	300	0.02	175	0.01
LITITZ	1.0	7800	CONESTOGA CREEK	170	0.02	120	0.02
LEMOYNE	1.0	4700	SUSQ. RIVER	200	0.04	175	0.04
TOTALS	44.7	259,000		6,540	0.024	5,290	.018

Major Industrial Point - Source Contributions
To The Lower Susquehanna River Basin

Name of Company	Location	Recovery Waters	Total Flow (MGD)	Nutrient Loadings (lbs/day)			
				T. PO_4 as PO_4	TKN as N	NH_3 as N	NO_2NO_3 as N
Bethlehem Steel Corporation	Lebanon, Pa.	Quittapahilla Creek	5.154	15	23	5	200
P. H. Glatfelter Corporation	Spring Grove, Pa.	W. Branch Codorus Creek	13.700	150	1125	625	1125
International* Paper Company	York Haven, Pa.	Susquehanna River	2.500	30	225	125	225
United Piece and Dye Corporation	York, Pa.	Susquehanna River	0.250	800	10	10	----
Hershey Foods Corporation	Hershey, Pa.	Spring Creek	24.980	340	230	120	1100
R.C.A. Corporation	Lancaster, Pa.	Conestoga Creek	2.600	20	440	65	100
TOTAL				1355	2055	950	2750

* Estimate based on historical record

13) To assist in the annual nutrient budget evaluation, it was necessary to ascertain a breakdown of land usage for the entire lower Basin. Presented in the table on the following page is a delineation of land usage for the various tributary watersheds of the Susquehanna River for the three major land use categories, namely agricultural (cropland and pasture), forested and urban.

14) In order to estimate typical nutrient yields from the two major land use areas within the Susquehanna River Basin (i.e. agricultural and forested), analyses of survey data from representative watersheds were performed. Using the Pequea Creek watershed as primarily agricultural and the Stony Creek watershed as forested, the effect of land use on both nutrient concentrations and loadings in these surface waters could be evaluated. These data were then extrapolated to develop estimates of the nitrogen and phosphorus yields (lbs/day/mi^2) for application to other agricultural and forested areas within the Susquehanna Basin.

Total phosphorus, total Kjeldahl nitrogen and nitrite-nitrate nitrogen contributions measured in these selected watersheds during each season are presented in the following tables. As can be seen, a considerable difference existed between the concentration and loading rates of all three parameters. Excepting for TKN, the agricultural runoff rates were at least an order of magnitude greater than corresponding rates for forested areas. The extremely high $NO_2 + NO_3$ concentrations (4.0 - 5.7 mg/l) characterizing the Pequea Creek watershed revealed the high mobility of the NO_3 ion, especially during periods having excessive runoff.

Delineation of Land Usage

Susquehanna River Tributaries

Watershed	Cropland		Pasture		Forest		Urban		Other	
	%	sq - mi	%	sq - mi	%	sq - mi	%	sq - mi	%	sq - mi
SHAMOKIN CREEK	15	20.5	10	13.7	60	82.2	7	9.6	8	11.0
PENNS CREEK	20	109.6	10	54.8	60	328.8	5	27.4	5	27.4
JUNIATA RIVER	23	783.4	7	238.4	62	2111.7	6	204.4	2	68.1
STONY CREEK	2	<1.0	5	1.8	90	31.5	1	<1.0	2	<1.0
CONODOGUINET CREEK	41	207.5	8	40.5	39	197.3	6	30.4	6	30.4
YELLOW BREECHES CREEK	45	99.0	8	17.6	34	74.8	6	13.2	7	15.4
SWATARA CREEK	35	201.6	8	46.1	43	247.7	7	40.3	7	40.3
CONOWAGO CREEK	51	265.2	12	62.4	28	145.6	4	20.8	5	26.0
CONOY CREEK	62	9.9	10	1.6	14	2.2	7	1.1	7	1.1
CODORUS CREEK	49	135.7	11	30.5	24	66.5	8	22.2	8	22.2
CHICKIES CREEK	62	77.5	10	12.5	14	17.5	7	8.8	7	8.8
CONESTOGA CREEK	62	295.1	10	47.6	14	66.6	7	33.3	7	33.3
PEQUEA CREEK	75	114.8	10	15.3	10	15.3	2	3.1	3	4.6
OCTORARO CREEK	58	121.8	10	21.0	22	46.2	5	10.5	5	10.5
TOTALS		2442.6		603.8		3433.9		426.1		300.1

TYPICAL AGRICULTURAL & FORESTED WATERSHEDS

JUNE - OCT. 1971

WATERSHED	D. A. mi^2	TPO_4 as PO_4			TKN as N			NO_2NO_3 as N		
		mg/l	#/D	$\#/D/mi^2$	mg/l	#/D	$\#/D/mi^2$	mg/l	#/D	$\#/D/mi^2$
PEQUEA CREEK (AGRICULTURAL)	153	0.40	300	1.96	.91	430	2.81	4.04	3800	24.84
STONY CREEK (FORESTED)	35	.09	10	.29	.22	30	.86	.24	20	.57

TYPICAL AGRICULTURAL & FORESTED WATERSHEDS

NOV. 1971 - FEB. 1972

WATERSHED	D. A. mi^2	TPO_4 as PO_4			TKN as N			NO_2NO_3 as N		
		mg/l	#/D	$\#/D/mi^2$	mg/l	#/D	$\#/D/mi^2$	mg/l	#/D	$\#/D/mi^2$
PEQUEA CREEK (AGRICULTURAL)	153	0.24	700	4.58	0.91	970	6.34	5.63	6500	42.48
STONY CREEK (FORESTED)	35	0.06	20	0.57	0.20	80	2.29	0.14	60	1.71

TYPICAL AGRICULTURAL & FORESTED WATERSHEDS

MARCH - MAY 1972

WATERSHED	D. A. mi^2	TPO_4 as PO_4			TKN as N			NO_2NO_3 as N		
		mg/l	#/D	$\#/D/mi^2$	mg/l	#/D	$\#/D/mi^2$	mg/l	#/D	$\#/D/mi^2$
PEQUEA CREEK (AGRICULTURAL)	153	0.20	1000	6.54	0.52	1400	9.15	5.72	8300	54.25
STONY CREEK (FORESTED)	35	0.04	25	0.71	0.26	100	2.86	0.13	80	2.29

15) The City of Harrisburg has been reported to have over 20 combined sewer outfalls which discharge large quantities of sanitary waste and street surface runoff directly to the Susquehanna River during periods of heavy rainfall. The effects of these discharges coupled with other urban runoff from the Harrisburg metro area were estimated from an examination of the measured nutrient loads in the Susquehanna River at both the Route 15 and the I-83 Bridge stations. As will be shown in a later section of this report (mass balance analysis), considerable increases in the total phosphorus and nitrogen loads were observed in the vicinity of Harrisburg during the high flow season. Since the Susquehanna River received no major wastewater effluents from the confluence of Conodoguinet Creek to the I-83 Bridge it was assumed that these differences in loading could be attributable to the collective effects of urban runoff (point source and non-point source).

Allowing for the possibility of nutrient re-introduction into the water column through the scouring of bottom sediment and the innundation of shoreline weeds and other sources which are apparent during the high flow periods, it appeared that approximately 6,000 lbs/day of total phosphorus and 14,000 lbs/day of total nitrogen (approximately 2/3 of which was TKN) were contributed by the entire Harrisburg urban area during the maximum flow period of March-May 1972. These figures completely overshadowed the average contributions from the area's wastewater facilities.

During the mean flow period (Nov. 1971 - Feb. 1972) respective phosphorus and nitrogen contributions from the Harrisburg metro area exclusive of wastewater effluents were estimated to be 800 lbs/day and 3,700 lbs/day (approximately 2/3 of which was TKN). During the low flow period no measurable contribution was detected.

16) In view of the fact that nutrient loads in the Susquehanna River above and below the Harrisburg area indicated an extremely large urban input, the magnitude of which may be somewhat questionable and probably not applicable to other urban areas in the Basin, the decision was made to utilize relevant literature material to provide independent estimates of typical areal nutrient loading rates exclusive of untreated sanitary sewage contributions. These estimated rates were intended to serve as a basis for developing a total urban effect on the nutrient balance in the lower Susquehanna Basin.

A summary of the relevant literature data which was used as a basis for estimating the nutrient loading rates for the urban and suburban portions of the Susquehanna River Basin are presented in the following table.

SUMMARY OF STORM WATER NUTRIENT DATA
COLLECTED FROM LITERATURE REVIEW*

LOCATION		T.PO_4	TN	INORGANIC N	ORGANIC N	NH_3	NO_3
Cincinnati, Ohio		1.08 mg/l (4.9 lbs/mi²/day)	3.1 mg/l	1.0 mg/l			
Cincinnati, Ohio (1962-63)		0.8 mg/l			1.7 mg/l	0.6 mg/l	0.45 mg/l
Susq. - City		(15.8 lbs/mi²/day)**			TKN - (28.3 lbs/mi²/day)**		(1.3 lbs/mi²/day)**
Susq. - Suburbs		(9.0 lbs/mi²/day)**			TKN - (15.4 lbs/mi²/day)**		(0.7 lbs/mi²/day)**
Washington, D.C. (1970)		1.3 mg/l (4.5 lbs/mi²/day)	2.1 mg/l (9.0 lbs/mi²/day)				
Seattle, Wash. (1959-60)		$\leq$4.2 mg/l			$\leq$9.0 mg/l		$\leq$2.8 mg/l
Durham, N.C.		(6.4 lbs/mi²/day)					
Atlanta, Ga.		0.3 - 1.6 mg/l					
Washington, D.C. TR #35	5% 50% 95%	(53 lbs/mi²/day) (10 lbs/mi²/day) (1.2 lbs/mi²/day)			TKN - (42 lbs/mi²/day) TKN - (8 lbs/mi²/day) TKN - (1.5 lbs/mi²/day)		(27.4 lbs/day/mi²) (6.45 lbs/mi²/day) (0.4 lbs/mi²/day)
Washington, D.C. Suburbs TR #35	5% 50% 95%	(10 lbs/mi²/day) (3 lbs/mi²/day) (0.3 lbs/mi²/day)			TKN - (30 lbs/mi²/day) TKN - (3.2 lbs/mi²/day) TKN - (0.6 lbs/mi²/day)		(15.6 lbs/day/mi²) (1.71 lbs/mi²/day) (0.2 lbs/mi²/day)

* SEE FOOTNOTES ON FOLLOWING PAGE

SUMMARY OF STORM WATER NUTRIENT DATA
COLLECTED FROM LITERATURE REVIEW*

(CONTINUED)

* "Urban Drainage as a Factor in Eutrophication", 1961, S.R. Weibel.

"Urban Land Runoff as a Factor in Stream Pollution", 1959-1960, 1962-1963, S. R. Weibel, R. J. Anderson, and R. L. Woodward.

"Combined Sewer Overflow Abatement Alternatives - Washington, D. C.", Roy F. Weston, Inc.

"Quality of Storm Water Drainage from Urban Land" (Selected Urban Storm Water Runoff Abstracts, July 1971 - June 1972), North Carolina and Atlanta, Georgia.

"Water Resource - Water Supply Study of the Potomac Estuary", N. A. Jaworski, L. J. Clark, K. D. Feigner, Technical Report 35, EPA, April 1971.

** Calculations based on loading rates (lb/curb mile/day) and curb mileage estimates derived from the following reports: "Water Pollution Aspects of Street Surface Contaminants", EPA Technology Series R-2-72-081, November 1972 and "Estimation of Imperviousness and Specific Curb Length for Forecasting Stormwater Quality and Quantity", Graham, Costello, Mallon, Washington Council of Governments, March 1973.

17) Based on a review of the aforementioned nutrient data summary for storm water, the decision was made to use the following loading rates applicable to city and suburban areas of the Susquehanna Basin for the high flow season. It may be noted that maximum importance was attached to the recent estimates of urban contributions such as the data presented in EPA's "Water Pollution Aspects of Street Surface Contaminants", and AFO's Technical Report No. 35.

Areal Nutrient Loads
Urban Runoff (Storm Water)
($lbs/mi^2/day$)

	$T.PO_4$	TKN	NO_3
City	20	30	15
Suburbs	10	15	10

Utilizing the above nutrient loading rates for the major cities and suburban areas of the lower Susquehanna Basin, the total non-point source urban runoff nutrient contributions to the Susquehanna River for the high flow season were determined and are contained in the table below:

Urban Runoff Contributions
Lower Susquehanna River Basin

(High Flow Season: Mar. 1972 - May 1972)

Location	Urban Land Area (mi^2)	$T.PO_4$		TKN		NO_2+NO_3	
		$lb/mi^2/day$	lb/day	$lb/mi^2/day$	lb/day	$lb/mi^2/day$	lb/day
Harrisburg	7.6	20	152	30	228	15	114
Lancaster	7.2	20	144	30	216	15	108
Lebanon	4.6	20	92	30	138	15	69
York	5.3	20	106	30	159	15	80
Urban Area exclusive of Major Cities	425.3	10	4253	15	6380	10	4253
Total Urban Area	450		4750		7120		4625

Applying the measured percentage increase in phosphorus and nitrogen urban loadings between the Rt. 15 and Rt. 83 Bridge stations during the middle and high flow periods (see statement #15), an

estimated urban runoff nutrient contribution for the middle flow period was determined.

The non-point source urban nutrient loadings (lbs/day) and average urban nutrient loading rates (lbs/mi^2/day) for the lower Susquehanna River Basin during the middle flow season are presented as follows:

Urban Runoff Contributions
Lower Susquehanna River Basin

(Middle Flow Period: November 1971 - February 1972)

Location	Urban Land Area	$T.PO_4$		TKN		$NO_2 + NO_3$	
	mi^2	lb/day/mi^2	lb/day	lb/day/mi^2	lb/day	lb/day/mi^2	lb/day
Harrisburg	7.6	2.6	20	7.8	60	3.9	30
Lancaster	7.2	2.6	19	7.8	56	3.9	28
Lebanon	4.6	2.6	12	7.8	36	3.9	18
York	5.3	2.6	14	7.8	41	3.9	21
Urban Areas exclusive of Major Cities	425.3	1.3	553	3.9	1659	2.6	1106
Total	450		608		1852		1203

It was assumed that urban runoff contributions for the low flow season were negligible and consequently were not considered in the mass balance analyses.

18) Utilizing the nutrient loading rates for urban runoff presented in statement 16 and typical population densities for large metropolitan areas in the Susquehanna Basin, i.e. Harrisburg, York and Lancaster, as well as outlying suburban areas (see table in Appendix), an attempt was made to estimate total nitrogen and phosphorus contributions assuming various percentages of sanitary sewage overflows. The graphs in the Appendix depict these contributions which should be applicable to a variety of situations where combined sewer overflows are a problem. The component representing sanitary sewage (see table below) was derived from the per capita loading rates presented in statement 11.

Areal Nutrient Loads
Sanitary Sewage

($lbs/mi^2/day$)

	$T.PO_4$	TKN	NO_3
City	225	162	0
Suburbs	75	54	0

Unfortunately, the actual quantities of untreated sanitary sewage which are bypassed during different storm intensities have not been defined for either Harrisburg, York or Lancaster. However, based upon the measured increased in nitrogen and phosphorus loadings in the Susquehanna River at Harrisburg, it would appear that a relatively large fraction of the wastewater generated in the area is transported through the combined sewer system, especially during the high flow season.

19) Applying the nutrient loading rates developed in statement #14 for agricultural and forested land to the total agricultural (3600 mi^2) and forested (4500 mi^2) areas of the lower Susquehanna River Basin, relative contributions of $T.PO_4$, TKN and $NO_2 + NO_3$ in pounds per day were determined. Inclusion of the total urban nutrient contributions as developed in statement #17 results in the following tables which show the estimated seasonal nutrient loadings in the Susquehanna River Basin for every major land-use category.

Although the total forested area exceeds the agricultural area in the Basin, the latter represented the principal land use contributor of $T.PO_4$, TKN and NO_3 (especially during the high flow season). In addition, the urban contribution of nutrients is significant during the high flow season in comparison with other land uses even though the urban area comprises only about 5% of the entire basin.

The key non-point source nutrient input to the lower Susquehanna River Basin is definitely from agricultural runoff with significant periodic augmentation by urban stormwater runoff and combined sewer overflows from the major metropolitan areas.

ESTIMATED SEASONAL NUTRIENT LOADINGS
SUSQUEHANNA RIVER BASIN
SUNBURY, PA. TO CONOWINGO, MD.

$T.PO_4$ AS PO_4

LAND USE	AREA (mi^2)	JUNE 1971 - OCT. 1971 #/D	%	NOV. 1971 - FEB. 1972 #/D	%	MAR. 1972 - MAY 1972 #/D	%
AGRICULTURAL*	3600	7050	84	16560	84	23400	75
FOREST	4500	1300	16	2560	13	3150	10
URBAN (STORM WATER)	450	--	--	600	3	4750	15
TOTAL	8550	8350	100	19720	100	31300	100

* Includes both Cropland and Pasture

ESTIMATED SEASONAL NUTRIENT LOADINGS
SUSQUEHANNA RIVER BASIN
SUNBURY, PA. TO CONOWINGO, MD.

TKN AS N

LAND USE	AREA (mi^2)	JUNE 1971 -	OCT. 1971	NOV. 1971 -	FEB. 1972	MAR. 1972 -	MAY 1972
		#/D	%	#/D	%	#/D	%
AGRICULTURAL*	3600	10120	73	22680	63	33120	62
FOREST	4500	3780	27	11250	32	13500	25
URBAN (STORM WATER)	450	- -	--	1850	5	7120	13
TOTAL	8550	13900	100	35780	100	53740	100

* Includes both Cropland and Pasture

ESTIMATED SEASONAL NUTRIENT LOADINGS
SUSQUEHANNA RIVER BASIN
SUNBURY, PA. TO CONOWINGO, MD.

NO_2NO_3 AS N

LAND USE	AREA (mi^2)	JUNE 1971 - OCT. 1971 #/D	%	NOV. 1971 - FEB. 1972 #/D	%	MAR. 1972 - MAY 1972 #/D	%
AGRICULTURAL*	3600	89420	97	153000	95	195480	93
FOREST	4500	2700	3	7650	5	9900	5
URBAN	450	--	--	1200	<1	4625	2
TOTAL	8550	92120	100	161850	100	210005	100

* Includes both Cropland and Pasture

20) The average seasonal nutrient loadings attributed to land runoff (non-point sources) and the average annual nutrient loadings attributed to municipal and industrial wastewater discharges (point sources) are summarized as follows:

NUTRIENT LOADINGS
IN THE
LOWER SUSQUEHANNA RIVER BASIN

Parameter	Point Source* Contributions (Municipal Wastewater & Industrial Discharges) lbs/day	Non-Point Source Contributions			Total (Point + Non-Point Sources)		
		June 1971 to Oct. 1971	Nov. 1971 to Feb. 1972	Mar. 1971 to May 1972	June 1971 to Oct. 1971	Nov. 1971 to Feb. 1972	Mar. 1972 to May 1972
T.PO_4 as PO_4	21,800	8,400	20,000	31,300	30,000	42,000	53,000
TKN as N	17,400	14,000	36,000	54,000	31,500	53,500	71,500
TN as N	20,100	106,000	198,000	264,000	126,000	218,000	284,000

* Average annual load applicable to each season

a) Of the total phosphorus and nitrogen loadings from the lower Susquehanna River Basin the percentages attributable to point source and non-point source discharges are as follows:

Parameter	June 1971 - Oct. 1971		Nov. 1971 - Feb. 1972		Mar. 1972 - May 1972	
	Point Source	Non-Point Source	Point Source	Non-Point Source	Point Source	Non-Point Source
$T.PO_4$ as PO_4	72	28	52	48	41	59
TKN as N	55	45	33	67	24	76
TN as N	16	84	9	91	7	93

As can be seen, non-point source contributions of $T.PO_4$ and TKN predominate when flows increase. Total nitrogen contributions from non-point sources are most significant in every season. These differences in percentage signify the increased importance of the collective load from non-point sources when runoff rates are high.

During the high flow period (March - May 1972) approximately 93 percent of the estimated 284,000 lbs/day of total nitrogen (NO_2 + NO_3 and TKN) entering the surface waters of the lower basin was from land runoff (non-point sources) with the remaining 7 percent from municipal wastewater and industrial discharges (point sources).

Of the 264,000 lbs/day of total nitrogen from land runoff, approximately 229,000 lbs/day, or 87%, was from agricultural land areas which comprise only 42% of the total drainage area in the lower basin.

b) The average annual yield, lbs/day/sq. mile, for each season based on 8,550 square miles in the lower Susquehanna River Basin (3600 mi^2 - agriculture, 4500 mi^2 - forest and 450 mi^2 - urban) is as follows:

	Average Annual Nutrient Yield *(Point + Non-Point Sources)* lbs/day/sq. mile		
Parameter	June - Oct. 1971	Nov. 1971 - Feb. 1972	Mar. 1972 - May 1972
$T.PO_4$ as PO_4	3.5	4.9	6.2
TKN as N	3.7	6.3	8.4
NO_2NO_3 as N	11.1	19.3	24.9
TN as N	14.7	25.5	33.2

Thus, the average annual yield was directly related to the runoff rates.

21) An attempt was made to mass balance the average seasonal phosphorus and nitrogen loads (TPO_4, TKN and NO_2+NO_3) in each of the tributary basins. The method employed for this analysis was to compare measured loads with expected loads in accordance with the following equation (Total Phosphorus):

$$P_t = P_w + P_a + P_f + P_u \pm P_s$$

Where:

P_t = total measured phosphorus in watershed

P_w = phosphorus in wastewater discharges

P_a = phosphorus from agricultural land

P_f = phosphorus from forested land

P_u = phosphorus from urban runoff

P_s = phosphorus lost or released in the stream channel through biological utilization, deposition, scouring, etc.

Of particular importance in this analysis is the magnitude and sign of the P_s term. The following tables, which delineate the various components of the mass balance equations, permit several conclusions to be drawn regarding P_s (or TKN_s and NO_s depending on the parameter).

The negative signs shown for most of the P_s terms, regardless of flow, indicate that phosphorus was being retained in the stream channels, bound there by sediments and/or aquatic plants. The apparent loss of nitrogen fractions which prevailed during the low flow period might be temporary, however, as indicated by the increased number of positive TKN_s and NO_s terms during flood flow

conditions when a considerable tonnage of sediment is known to be transported to the main stem of the Susquehanna River. An explanation of why nitrogen and phosphorus recoverability differ so greatly during periods of high streamflow and extensive scouring within these tributary basins may be due to the high solubility of nitrogen - especially the nitrate form.

TOTAL PHOSPHORUS MASS BALANCE

SUSQUEHANNA TRIBUTARIES

JUNE - OCT. 1971

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	SOURCES (LBS/DAY)	P_s & SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	800	650	67	24	0	741	+59	+1.8
PENNS CREEK	52	150	200	322	95	0	617	-467	-9.0
JUNIATA RIVER	102	2000	3500	2002	612	0	6114	-4114	-40.3
STONY CREEK	23	10	0	5	9	0	14	-4	-0.2
CONODOGUINET CREEK	85	700	1550	486	57	0	2093	-1393	-16.4
YELLOW BREECHES CREEK	45	200	0	229	22	0	251	-51	-1.1
SWATARA CREEK	64	1200	1150	485	72	0	1707	-507	-7.9
CONEWAGO CREEK	68	700	530	642	42	0	1214	-514	-7.6
CONOY CREEK	10	150	330	23	<1	0	353	-203	-20.3
CODORUS CREEK	36	2000	2450	326	19	0	2795	-795	-22.1
CHICKIES CREEK	20	300	150	176	5	0	331	-31	-1.6
CONESTOGA CREEK	60	3000	3100	672	19	0	3791	-791	-13.2
PEQUEA CREEK	35	300	0	255	4	0	259	+41	+1.2
OCTORARO CREEK	.18	300	0	280	13	0	293	+7	+0.4

TOTAL PHOSPHORUS MASS BALANCE

SUSQUEHANNA TRIBUTARIES

NOV. 1971 - FEB. 1972

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	P_s SOURCES (LBS/DAY)	& SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	1000	650	157	47	10	864	+136	+4.3
PENNS CREEK	52	300	200	753	187	35	1175	-875	-16.8
JUNIATA RIVER	102	4700	3500	4680	1204	265	9649	-4949	-48.5
STONY CREEK	23	20	0	11	18	1	30	-10	-0.4
CONODOGUINET CREEK	35	2000	1550	1136	112	40	2838	-838	-9.9
YELLOW BREECHES CREEK	45	350	0	534	43	20	597	-247	-5.5
SWATARA CREEK	64	2700	1150	1134	141	50	2475	+225	+3.5
CONEWAGO CREEK	68	1900	530	1500	83	25	2138	-238	-3.5
CONOY CREEK	10	300	330	53	1	1	385	-85	-8.5
CODORUS CREEK	36	3200	2450	761	38	40	3289	-89	-2.5
CHICKIES CREEK	20	500	150	412	10	10	582	-82	-4.1
CONESTOGA CREEK	60	4200	3100	1570	38	60	4768	-568	-9.5
PEQUEA CREEK	35	700	0	596	9	5	610	+90	+2.6
OCTORARO CREEK	18	500	0	654	26	15	695	-195	-10.8

TOTAL PHOSPHORUS MASS BALANCE

SUSQUEHANNA TRIBUTARIES

MAR. - MAY 1972

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	P_s SOURCES (LBS/DAY)	& SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	1200	650	224	58	100	1032	+168	+5.3
PENNS CREEK	52	770	200	1075	233	270	1778	-1008	-19.4
JUNIATA RIVER	102	8500	3500	6683	1498	2050	13731	-5231	-51.0
STONY CREEK	23	25	0	16	22	10	48	-23	-1.0
CONODOGUINET CREEK	85	3600	1550	1622	140	304	3616	-16	-0.2
YELLOW BREECHES CREEK	45	700	0	763	53	132	948	-248	-5.5
SWATARA CREEK	64	2800	1150	1620	176	403	3349	-549	-8.6
CONEWAGO CREEK	58	2300	530	2145	103	208	2986	-686	-10.1
CONOY CREEK	10	350	330	75	2	11	418	-68	-6.8
CODORUS CREEK	36	3600	2450	1087	47	275	3859	-259	-7.2
CHICKIES CREEK	20	700	150	589	12	100	851	-151	-7.6
CONESTOGA CREEK	60	5000	3100	2241	47	407	5795	-759	-13.3
PEQUEA CREEK	35	1000	0	851	11	31	893	+107	+3.1
OCTORARO CREEK	. 18	700	0	934	33	105	1072	-372	-20.7

TKN MASS BALANCE

SUSQUEHANNA TRIBUTARIES

JUNE - OCT. 1971

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	SOURCES (LBS/DAY)	P_s & SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	2200	420	96	71	0	587	+1613	+50.4
PENNS CREEK	52	300	200	462	283	0	945	-645	-12.4
JUNIATA RIVER	102	5000	1600	2872	1816	0	6288	-1288	-12.6
STONY CREEK	23	30	0	7	27	0	34	-4	-0.2
CONODOGUINET CREEK	85	500	800	697	170	0	1667	-1167	-13.7
YELLOW BREECHES CREEK	45	300	0	328	64	0	392	-92	-2.0
SWATARA CREEK	64	1600	1170	696	213	0	2079	-479	-7.5
CONEWAGO CREEK	68	1000	200	921	125	0	1246	-246	-3.6
CONOY CREEK	10	100	300	32	2	0	334	-234	-23.4
CODORUS CREEK	36	1500	3100	467	57	0	3624	-2124	-59.0
CHICKIES CREEK	20	300	100	253	15	0	368	-68	-3.4
CONESTOGA CREEK	60	2000	2835	963	57	0	3855	-1855	-30.9
PEQUEA CREEK	35	430	0	366	13	0	379	+51	+1.5
OCTORARO CREEK	18	600	0	401	40	0	441	+159	+8.8

TKN MASS BALANCE

SUSQUEHANNA TRIBUTARIES

NOV. 1971 - FEB. 1972

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	P_s SOURCES (LBS/DAY)	& SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	2200	420	217	188	40	865	+1335	+41.7
PENNS CREEK	52	800	200	1042	753	110	2105	-1305	-25.1
JUNIATA RIVER	102	12000	1600	6478	4836	800	13714	-1714	-16.8
STONY CREEK	23	80	0	16	72	5	93	-13	-0.6
CONODOGUINET CREEK	85	2500	800	1572	452	120	2944	-444	-5.2
YELLOW BREECHES CREEK	45	800	0	739	171	50	960	-160	-3.6
SWATARA CREEK	64	5000	1170	1570	567	160	3467	+1533	+24.0
CONEWAGO CREEK	68	3800	200	2077	333	80	2690	+1110	+16.3
CONOY CREEK	10	250	300	73	5	5	383	-133	-13.3
CODORUS CREEK	36	2800	3100	1054	152	100	4406	-1606	-44.5
CHICKIES CREEK	20	700	100	571	40	35	746	-46	-2.3
CONESTOGA CREEK	60	3600	2835	2173	152	150	5310	-1710	-28.5
PEQUEA CREEK	35	970	0	825	35	10	870	+100	+2.9
OCTORARO CREEK	18	1100	0	905	106	40	1051	+49	+2.7

TKN MASS BALANCE

SUSQUEHANNA TRIBUTARIES

MAR. - MAY 1972

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	SOURCES (LBS/DAY)	P_s & SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	2300	420	313	235	150	1118	+1182	+36.9
PENNS CREEK	52	2200	200	1504	940	415	3059	-859	-16.5
JUNIATA RIVER	102	23000	1600	9349	6039	3065	20053	+2947	+28.9
STONY CREEK	23	100	0	23	90	15	128	-28	-1.2
CONODOGUINET CREEK	85	5000	800	2269	564	460	4093	+907	+10.7
YELLOW BREECHES CREEK	45	2000	0	1067	214	200	1481	+519	+11.5
SWATARA CREEK	64	5000	1170	2266	708	605	4749	+251	+3.9
CONEWACO CREEK	68	5000	200	2998	416	315	3929	+1071	+15.8
CONOY CREEK	10	300	300	105	6	20	431	-131	-13.1
CODORUS CREEK	36	3000	3100	1521	190	425	5236	-2236	-62.0
CHICKIES CREEK	20	1000	100	824	50	150	1124	-124	-6.2
CONESTOGA CREEK	60	4600	2835	3136	190	600	6761	-2161	-36.0
PEQUEA CREEK	35	1400	0	1190	44	50	1284	+116	+3.3
OCTORARO CREEK	18	1700	0	1307	132	160	1600	+100	+5.6

NO_2NO_3 MASS BALANCE

SUSQUEHANNA TRIBUTARIES

JUNE - OCT. 1971

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	SOURCES (LBS/DAY)	P_s & SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	200	0	850	47	0	897	-697	-21.8
PENNS CREEK	52	200	0	4084	187	0	4270	-4070	-78.3
JUNIATA RIVER	102	4000	0	25382	1204	0	26586	-22586	-221.4
STONY CREEK	23	20	0	62	18	0	79	-59	-2.6
CONODOGUINET CREEK	85	2100	0	6160	112	0	6273	-4173	-49.1
YELLOW BREECHES CREEK	45	1500	0	2896	43	0	2939	-1439	-32.0
SWATARA CREEK	64	6500	1100	6153	141	0	7394	-894	-14.0
CONEWAGO CREEK	68	2800	0	8083	83	0	8166	-5366	-78.9
CONOY CREEK	10	500	0	286	1	0	286	+214	+21.4
CODORUS CREEK	36	3600	1150	4128	38	0	5316	-1716	-47.7
CHICKIES CREEK	20	3800	0	2236	10	0	2246	+1554	+77.7
CONESTOGA CREEK	60	10000	0	8513	38	0	8551	+1449	+24.2
PEQUEA CREEK	35	3800	0	3232	9	0	3241	+559	+16.0
OCTORARO CREEK	.18	2800	0	3547	26	0	3573	-733	-42.9

NO_2NO_3 MASS BALANCE

SUSQUEHANNA TRIBUTARIES

NOV. 1971 - FEB. 1972

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	SOURCES (LBS/DAY)	P_s & SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	700	0	1453	141	25	1619	-919	-28.7
PENNS CREEK	52	1000	0	6983	562	75	7620	-6620	-127.3
JUNIATA RIVER	102	22000	0	43406	3611	530	47547	-25547	-250.5
STONY CREEK	23	60	0	106	54	5	165	-105	-4.6
CONODOGUINET CREEK	85	9000	0	10535	337	80	10952	-1952	-22.9
YELLOW BREECHES CREEK	45	2800	0	4953	128	35	5116	-2316	-51.5
SWATARA CREEK	64	18500	1100	10522	424	105	12151	+6349	+99.0
CONEWAGO CREEK	68	9500	0	13916	249	60	14225	-4725	-69.5
CONOY CREEK	10	1000	0	489	4	5	498	+502	+50.2
CODORUS CREEK	36	8200	1150	7060	114	65	8389	-189	-5.2
CHICKIES CREEK	20	6200	0	3823	30	25	3878	+2322	+116.1
CONESTOGA CREEK	60	22000	0	14558	114	100	14772	+7228	+120.5
PEQUEA CREEK	35	6500	0	5527	26	10	5563	+937	+26.8
OCTORARO CREEK	18	4900	0	6066	79	30	6175	-1275	-70.8

NO_2NO_3 MASS BALANCE

SUSQUEHANNA TRIBUTARIES

MAR. - MAY 1972

SUB-BASIN	STREAM LENGTH (MI)	P_t MEASURED (LBS/DAY)	P_w WASTEWATER (LBS/DAY)	P_a AGRICULTURAL (LBS/DAY)	P_f FOREST (LBS/DAY)	P_u URBAN (LBS/DAY)	$P_w + P_a + P_f + P_u$ TOTAL (LBS/DAY)	P_s SOURCES (LBS/DAY)	& SINKS (LBS/DAY/MI)
SHAMOKIN CREEK	32	1600	0	1855	188	100	2143	-543	-17.0
PENNS CREEK	52	6000	0	8919	753	275	9947	-3947	-75.9
JUNIATA RIVER	102	78000	0	55433	4836	2050	62319	+15681	+153.7
STONY CREEK	23	80	0	136	72	10	218	-138	-6.0
CONODOGUINET CREEK	35	19000	0	13454	452	300	14206	+4794	+56.4
YELLOW BREECHES CREEK	45	5000	0	6326	171	150	6647	-1647	-36.6
SWATARA CREEK	64	19000	1100	13438	567	400	15505	+3495	+54.6
CONEWAGO CREEK	68	11000	0	17772	333	210	18315	-7315	-107.6
CONOY CREEK	10	1200	0	624	5	10	639	+561	+56.1
CODORUS CREEK	36	10000	1150	9016	152	250	10568	-568	-15.8
CHICKIES CREEK	20	7500	0	4883	40	100	5023	+2477	+123.9
CONESTOGA CREEK	60	30000	0	18591	152	400	19143	+10857	+180.9
PEQUEA CREEK	35	8300	0	7058	35	30	7123	+1177	+33.6
OCTORARO CREEK	18	7500	0	7747	106	100	7953	-453	-25.2

22) A seasonal mass balance analysis for the main stem Susquehanna River between Northumberland, Pa., and Conowingo Dam, Md. was performed based upon all of the regression data previously presented. The graphs in the Appendix vividly depict the relative effects of each tributary's load and the Harrisburg metro area on the phosphorus and nitrogen balances in the river. In addition, changes in mass between tributary confluences resulting from various physical, chemical and biological reactions occurring within the stream channel are illustrated. The following observations are noteworthy:

a) The impoundments along the lower Susquehanna, especially Conowingo Dam, had a profound effect on the phosphorus load in the river during the low flow periods. As can be seen, the load decreased from about 17,000 lbs/day to 9,000 lbs/day between Columbia and Conowingo. During high flow-low temperature periods this decrease diminished because of the reduced rates of biological utilization and shorter retention times in the impoundments.

b) During the high flow period a considerable increase in phosphorus (20,000 lbs/day) was detected between Penns Creek and the Juniata River. Since this area is primarily undeveloped with the total phosphorus contribution from existing land usage estimated to be less than 2,000 lbs/day, it was assumed that scouring of the bottom sediment and inundation of shoreline marsh and weeds played an important role in the phosphorus balance. The Susquehanna channel is very unique in that its width undergoes a much greater

increase than its depth when flows rise. It is also a known fact that aquatic weeds and other sources of nutrients are prevalent along the river's shore.

Allowing for contributions from land runoff, it was estimated that about 500 lbs/day/mile of total phosphorus (as PO_4) was introduced into this reach of the Susquehanna River during the maximum flow period. During the mean flow period (Nov., 1971 - Feb., 1972) this overall scouring rate was computed to be approximately 70 lbs/day/mile.

c) A comparison of wastewater effluents and other urban contributions of phosphorus in the Harrisburg metro area revealed the significance of the sewage treatment plants during low-flow periods and the over-shadowing of this load by non-point source loads during high flow periods.

d) Total nitrogen behaved much more conservatively in the Susquehanna River than phosphorus, particularly in the area of major impoundments. While the phosphorus load was reduced radically through the impoundments, nitrogen remained essentially unchanged regardless of flow.

e) The relative importance of point source and non-point source contributions of total nitrogen from the Harrisburg area for various flow conditions closely paralleled the findings presented in the above statement for phosphorus.

f) Due to excessive stratification it was not possible to adequately balance the summation of the North Branch and West

Branch nitrogen load with the measured load at Sunbury. This problem became especially acute during the high flow period when about 25,000 lbs/day of TKN could not be accounted for.

g) The effects of scouring and inundation of shoreline vegetation were not restricted to phosphorus. A review of the nitrogen data between Penns Creek and the Juniata River indicated a significant increase in load during high flow periods (60,000 lbs/day) which corresponded closely to the phosphorus profile and which could not be attributable to normal runoff from the area. Deducting the appropriate agricultural and forested runoff loads from this observed increase yielded a scouring rate of 1,200 lbs/day/mile. A rate of about 100 lbs/day/mile was computed for the mean flow condition. During low flow - high temperature periods both nitrogen and phosphorus loadings were reduced in this stream reach probably because of a physical deposition process.

h) The mass balance analysis of the nitrogen fractions (TKN and NO_3) generally corroborated the pertinent findings for total nitrogen. During the low flow period the ratio of TKN to NO_3 varied from about 2:1 in the extreme upper reach of the Susquehanna River to about 1:1 near Conowingo. This increased abundance of nitrate nitrogen may be partly due to nitrification and, more importantly, to the relatively greater nitrate loadings contributed by the various sub-basins. A similar pattern was evidenced during the mean flow condition when nitrification was minimal.

transported by the Susquehanna River, it has been estimated that only about 2 million tons actually enters the Chesapeake Bay because much sediment is trapped behind the power dams along the lower Susquehanna.

25) A summary of annual sediment yields and computed nutrient yields for a comparable time period are presented in the following table for eight stations throughout the lower Susquehanna River Basin. Except for Conestoga Creek, the data revealed a definite relationship between the tons per square mile of sediment yield and the phosphorus yield (lbs/mi^2) on an annual basis. The annual TKN yield also appeared to be strongly influenced by sediment load. The leaching and general mobility characteristics of the NO_3 ion in soil are such that a reliable correlation between sediment and NO_3 yields could not be made with existing data.

Sediment - Nutrient Yield Relationship
Susquehanna River Basin

Station	Annual Sediment Load (tons)	Sediment Yield (tons/mi^2)	Annual TPO_4 Yield (lbs/mi^2)	Annual TKN Yield (lbs/mi^2)	Annual NO_3 Yield (lbs/mi^2)
Penns Creek at Penns Creek	23,000	76	237	628	1,282
Juniata River at Newport	264,000	79	485	1,269	3,062
Susquehanna River at Harrisburg	2,600,000	110	620	1,203	2,465
Yellow Breeches Creek near Camp Hill	28,000	130	623	1,481	4,661
Swatara Creek at Harpers Tavern	73,000	220	1,328	2,265	8,580
West Conewago Creek near Manchester	110,000	220	1,051	2,056	4,962
South Branch Codorus Creek near York	26,000	350	-----	-----	-----
Conestoga Creek at Lancaster	57,000	180	2,989	2,440	14,558

26) Regression analyses performed separately with 1969 (Chesapeake Bay Nutrient Input Study, TR #47) and 1971 total nitrogen and phosphorus data at the Conowingo Dam station revealed distinct increases in loading for both parameters during the two year period. A comparison of these Susquehanna loadings is as follows:

Flow (cfs)	Total Phosphorus (lbs/day)		Total Nitrogen (lbs/day)	
	1969	1971	1969	1971
10,000	6,500	8,500	75,000	82,000
50,000	60,000	75,000	370,000	420,000
100,000	150,000	190,000	750,000	850,000

27) The data presented in the following table, which were derived from a mass balance analysis, depict the effects of different reductions at all continuous point source discharges on the river loadings at Conowingo Dam and reveal the extent of nitrogen and phosphorus controllability during different seasons and flow conditions.

MAIN STEM SUSQUEHANNA LOADINGS
ASSUMING 0, 50, 70 and 90%
PHOSPHORUS AND NITROGEN REMOVAL
UNIFORMLY AT ALL POINT SOURCES*

% STP NUTRIENT REDUCTION	JUNE - OCT. 1971				NOV. - FEB. 1972				MAR. - MAY 1972			
	$T.PO_4$	TKN	TN	TIN	$T.PO_4$	TKN	TN	TIN	$T.PO_4$	TKN	TN	TIN
0	9000	47000	95000	67000	34000	115000	300000	230000	82000	250000	690000	525000
50	6000	34000	88000	61000	28000	94000	293000	226000	77000	242000	685000	521000
70	5000	31000	86000	59000	26000	91000	291000	224000	75000	239000	682000	519000
90	3600	30000	83000	57000	24000	89000	288000	222000	73000	235000	681000	518000
AVERAGE FLOW	11,500				37,400				88,100			
Flow Duration Curve at Conowingo Dam 1928 - 1968 Historical Data	30% of Time Flow $\geq$ 11500 70% of Time Flow $\leq$ 11500				30% of Time Flow $\geq$ 37400 70% of Time Flow $\leq$ 37400				25% of Time Flow $\geq$ 88100 75% of Time Flow $\leq$ 88100			

* Exclusive of industrial inputs

&

i) As the flows increased, differences in the TKN and NO_3 loadings became less pronounced. Moreover, at times of excessive stream flow these loadings approached their maximum level much farther upstream.

23) The effects of sediments on the concentration of nutrients in surface waters as summarized by Jaworski in AFO Technical Report #15 are as follows: (1) sediments contain nutrients and act as transport mechanisms (2) due to the adsorption phenomena sediments when deposited in the stream channel also trap nutrients (3) more than 99% of the soluble nitrogen is in the form of nitrates which leach at a more rapid rate than the other forms of nitrogen, and (4) in contrast to the high mobility of nitrate nitrogen, phosphorus compounds react vigorously with soil and have a very low mobility.

24) Sediment yields calculated by USGS at over 40 sites throughout the Susquehanna Basin generally indicated that the seasonal distribution of sediment discharge is quite similar to that of water discharge. Moreover, the long-term data showed the annual sediment discharge rates to the extremely variable but strongly related to a particular year's hydrograph. On the average, the Susquehanna River transports approximately 3 million tons of sediment annually which equates to 110 tons per square mile. Extreme sediment yields vary from 20 tons per square mile in established forest land to 800 tons per square mile in denuded areas and areas disturbed by strip mining. Of the three million tons of sediment

28) In order to protect the upper Chesapeake Bay from excessive eutrophication, a combination of mathematical modeling studies and mass balance analyses have indicated that during relatively low-flow conditions ($\leq$ 30,000 cfs), 70-75 percent of the total phosphorus load from point source discharges in the lower Susquehanna Basin must be eliminated. For a river flow of 50,000 cfs, a 90 percent reduction of the point source contribution must be realized.

29) Based on the extensive body of data previously presented in this report nitrogen is largely uncontrollable in the Susquehanna Basin, especially during periods when flows and runoff rates are high. In order for the management of nitrogen to be a viable alternative during extremely low-flow periods ($\leq$ 10,000 cfs) about 90 percent of the point source loading will have to be eliminated. In view of the importance of agricultural runoff as a contributor of nitrogen, and to a lesser extent phosphorus, it is recommended that methods be devised and seriously considered to maximize control of this once regarded non-controllable source of nutrients.

Conclusions

1) The tributary streams of the lower Susquehanna River which had the highest phosphorus concentrations on both an annual and seasonal basis were:

Shamokin Creek

Conoy Creek

Codorus Creek

Conestoga Creek

2) The greatest total nitrogen concentrations both seasonally and annually, were measured in the following tributaries:

Conoy Creek

Chickies Creek

Conestoga Creek

Pequea Creek

3) Maximum nitrogen and phosphorus concentrations in the tributary streams occurred during the low flow period with the exception of oxidized inorganic nitrogen, the most abundant nutrient fraction in the study area. Higher stream flows appeared to have a "diluting" effect on the TKN and phosphorus concentrations but not on the oxidized nitrogen fraction.

4) In general, all seasonal concentrations of every nitrogen and phosphorus fraction in the Susquehanna River were dramatically higher in the reach from Harrisburg to Conowingo Dam than in the reach upstream of Harrisburg.

5) The major impoundments along the lower Susquehanna River, i.e. Conowingo and Safe Harbor, represented a significant "sink" for phosphorus, particularly during low flow periods when detention times were long.

6) Phosphorus concentrations in the Susquehanna River were not significantly influenced by variations in stream flow as were the nitrogen fractions. While TKN concentrations throughout the Susquehanna River were at a maximum during the low flow - high temperature season, NO_2+NO_3 levels increased during higher flow - lower temperature periods due to amplified effects of agricultural runoff and reduced biological activity.

7) The major phosphorus contributing streams, in terms of daily loads to the Susquehanna River, were as follows:

Conestoga Creek

Codorus Creek

Juniata River

8) Streams providing the major daily loads of nitrogen were as follows:

Conestoga Creek

Swatara Creek

Juniata River

9) Nitrogen-phosphorus ratios (by atoms) in the lower Susquehanna River varied from about 34:1 to 46:1. Approximately 30-40 percent of the total phosphorus load represented the inorganic

fraction, whereas approximately 50-80 percent of the total nitrogen load represented the inorganic fraction.

10) The total nitrogen and phosphorus contributions from municipal wastewater effluents were estimated to be about 15,000 lbs/day (5 to 25 percent of the maximum measured load in the Susquehanna River) and 20,000 lbs/day (40 to 200 percent of the maximum measured load in the river), respectively.

11) Approximately 50 percent of the total measured phosphorus and nitrogen load from municipal wastewater effluents was contributed from three areas - Harrisburg, Lancaster and York.

12) The total nitrogen and phosphorus contributions from major industrial dischargers in the lower Susquehanna River Basin were estimated to be approximately 4800 lbs/day (30% of the municipal wastewater load) and 1350 lbs/day (7% of the municipal wastewater load), respectively.

13) Runoff from agricultural land (42 percent of the study area), accounted for 75-85 percent of the non-point source phosphorus contribution, 60-70 percent of the TKN contribution, and more than 90 percent of the nitrate nitrogen contribution from all non-point sources.

14) Runoff from forested land (53 percent of the study area), accounted for 10-15 percent of the non-point source phosphorus load, 25-30 percent of the TKN load, and about 5 percent of the nitrate nitrogen load from all non-point sources.

15) During the high flow period, it has been estimated that urban storm water from a 450 square mile area accounted for about 15 percent of the non-point source phosphorus load, 13 percent of the TKN load, and a negligible percentage of the nitrate nitrogen load from all non-point sources.

16) Although the nutrient contribution from the numerous combined sewer outfalls in Harrisburg was not accurately quantified, it appeared, from a comparison of sampling data obtained above and below the majority of these sewers, that this source was quite significant, actually surpassing the measured nitrogen and phosphorus load from the Harrisburg S.T.P. during the peak flow season.

17) During the low flow season, wastewater effluents alone accounted for 16 and 72 percent of the total nitrogen and phosphorus contribution from both point and non-point sources, respectively. During the high flow condition, these percentages decreased to about 7 and 40 percent, respectively.

18) A mass balance analysis of the data collected in the tributary watersheds indicated that a significant quantity of phosphorus was retained in the stream channels through a deposition or biological utilization process during every flow season. While nitrogen showed similar loses during the low flow season, its recoverability during the higher flow periods, when scouring of the bottom sediment prevails, appeared to be greater and more widespread than phosphorus.

19) A mass balance analysis of the main stem Susquehanna River data, besides underscoring the importance of major impoundments as a sink for phosphorus, depicted a substantial introduction of both nitrogen and phosphorus into the water column during high flow periods because of scouring of the bottom sediments and innundation of shoreline vegetation. Any apparent difference in scouring characteristics of the main stem Susquehanna River and the tributary streams as related to phosphorus may be the result of higher stream velocities in the river, longer duration of high flows, sediment content and its adsorption potential, or some other complex physical behavior. During the low flow period deposition of nutrients and biological utilization by aquatic plants were significant in-stream processes implied by mass balance data.

20) The areal yields of phosphorus and TKN (lbs/mi^2) appeared to be markedly influenced by sediment yields ($tons/mi^2$) based upon average annual data collected by USGS at eight stations in the lower Susquehanna Basin. Such a relationship could not be established for NO_3.

21) A regression analysis utilizing 1969 and 1971 nutrient data collected at Conowingo Dam revealed that distinct increases in both phosphorus and nitrogen loadings for comparable stream-flows have occurred during this two year period.

22) Phosphorus is considerably more manageable than nitrogen in the lower Susquehanna River Basin during all flow conditions.

23) In order to protect the biological integrity of the upper Chesapeake Bay, a sizeable reduction (70-90 percent) in the existing

point source contribution of phosphorus must be realized.

24) The effectiveness of nitrogen control at point sources is questionable unless attention is given towards reducing the existing load from agricultural runoff.

RECOMMENDED FUTURE STUDIES

1. Select a primarily agricultural watershed to study fertilizer application practices. This study should include but not be limited to the following: determination of the present rate of application (lbs/acre) and types of fertilizer applied (quick vs. slow release); quantification of seasonal application practices (fall, summer and spring); identification of the state of the plant growth that fertilizers are applied. Study results would be compared to recommended Federal and State fertilizer application programs to determine if the existing practices of the farmers within the watershed are sound, both in terms of conservation and economics. Should it be found that excessive amounts of fertilizer are being applied, economic considerations should dictate reassessment of current practices. Subsequent to the implementation of any modified fertilization program water quality monitoring of the watershed would allow for data comparison with previous studies (Technical Report 60) to show possible nutrient reductions in the watershed.

2. Technical Report 60 concluded that the areal yields of phosphorus and TKN (lbs/mi^2) appeared to be markedly influenced by sediment yields (tons/mi^2) based upon average annual data collected by the USGS at eight stations in the lower Susquehanna Basin. Actual nutrient loadings associated with sediment yields, however, were not determined. It is recommended that a study be undertaken to

contrast a watershed farmed with a high degree of conservation measures employed versus a watershed in which conservation practices are minimal. Areal sediment yields from the two watersheds would be determined on a seasonal basis. The phosphorus content of the sediment would be determined in order to establish the relative contribution of phosphorus from the erosion of farmland under the two contrasting situations. The selection of phosphorus for this study seems appropriate because of its correlation with sediment yields (Technical Report 60) and its known adsorption to sediment particles. In addition, reduction of non-point source phosphorus input by erosion control measures in conjunction with direct point source control of phosphorus should enhance the possibilities of making phosphorus the rate limiting nutrient to control eutrophication in impoundments in the lower Susquehanna Basin and the upper Chesapeake Bay.

3. The significance of the construction industry as a non-point source of pollutants in the lower Susquehanna Basin should be examined. The scope of Technical Report 60 did not include the assessment of nutrient contributions from specific land uses. The impact of sediment loading from activities including, but not limited to, housing construction, commercial building, road construction, and water resources projects should be evaluated for the purpose of developing guidelines for erosion and sediment control for use by the various management agencies.

4. Although the nutrient contribution from the numerous combined sewer outfalls in the City of Harrisburg was not accurately quantified in Technical Report 60, the significance of the combined sewer system as a major source of nitrogen and phosphorus was established. Studies should be carried out to determine the sources of nitrogen and phosphorus in the urban runoff. The relative contribution from diffuse sources such as street debris, rainfall, snow melt, lawn fertilizer, vegetative decay, and fallout from particulate matter should be included in a study of this nature. The object of the study would be to develop guidelines for reducing the water quality impact of urban runoff.

5. Major impoundments exert considerable influence in regulating phosphorus and, to a lesser extent, nitrogen in the lower Susquehanna River. In addition, these impoundments are highly susceptable to the proliferation of aquatic plant growths because of their quiescent nature and reduced silt content. It is therefore suggested that a detailed study be undertaken in at least one of these impoundments to address the following key areas: the lateral, longitudinal and vertical distribution of nutrients on a seasonal basis; exchange rates at the mud-water interface including characterization of the bottom sediment; existing algal growth conditions and species diversity; growth potential through a series of bioassay analyses; and development of nutrient-algal relationships for inclusion in a

predictive model. The literature is abundant in material dealing with lake eutrophication and it is quite conceivable that much of it would be applicable to and assist in the design of such an impoundment study.

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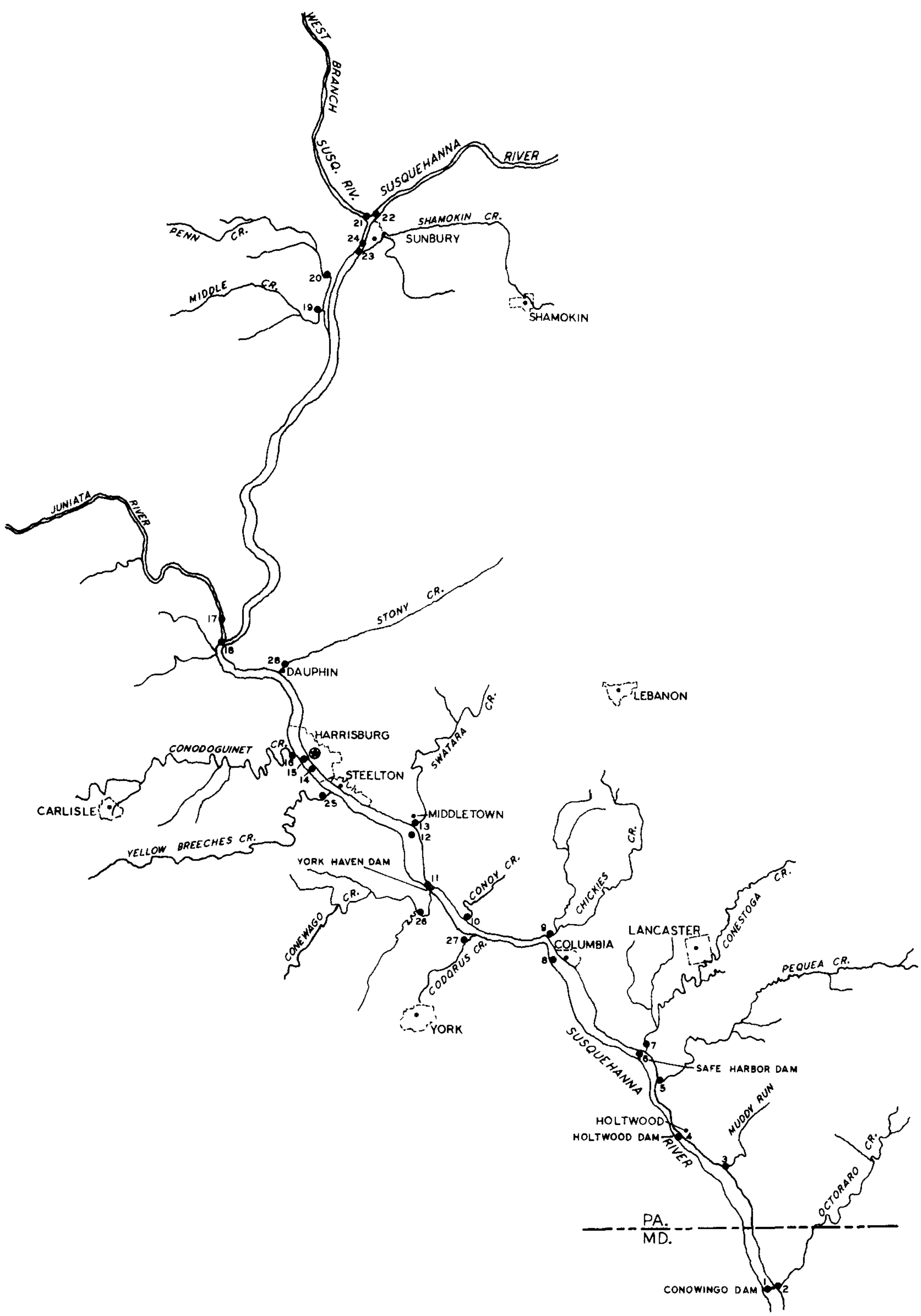
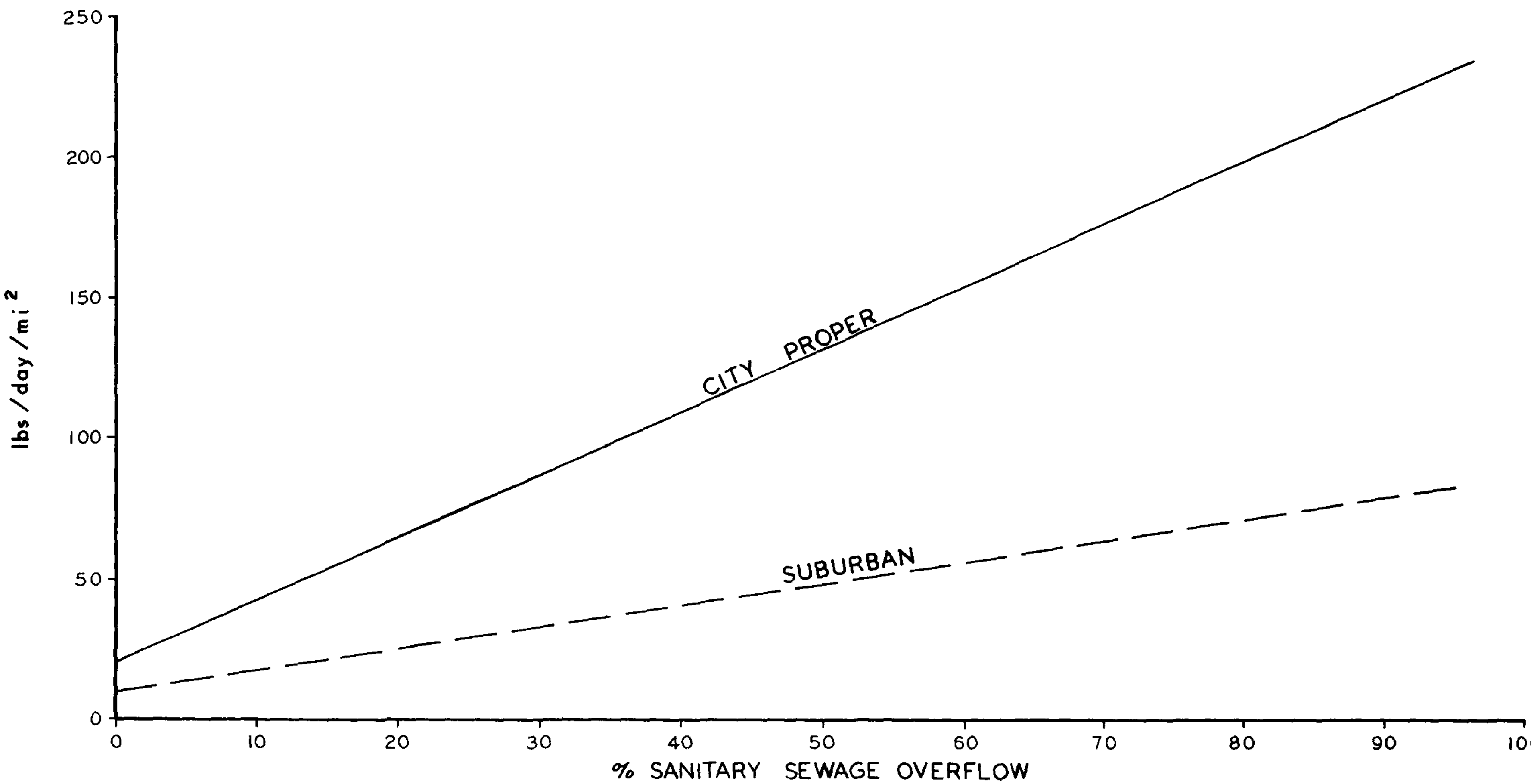
City of Sunbury
Township of East Pennsboro
Borough of Mechanicsburg
Borough of Shippensburg
Borough of Carlisle
Township of Lower Allen
Borough of New Cumberland
Borough of Camp Hill
Borough of Middletown
Borough of Palmyra
Hershey Sewage Company
Borough of Hanover
Borough of Elizabeth
Borough of Red Lion
Township of Penn
Borough of Manheim
Borough of Lemoyne
Borough of Lititz
Borough of Ephrata
Borough of Columbia
U. S. Geological Survey, Department of Interior
Philadelphia Power & Light Company
Pennsylvania Power & Light Company

APPENDIX

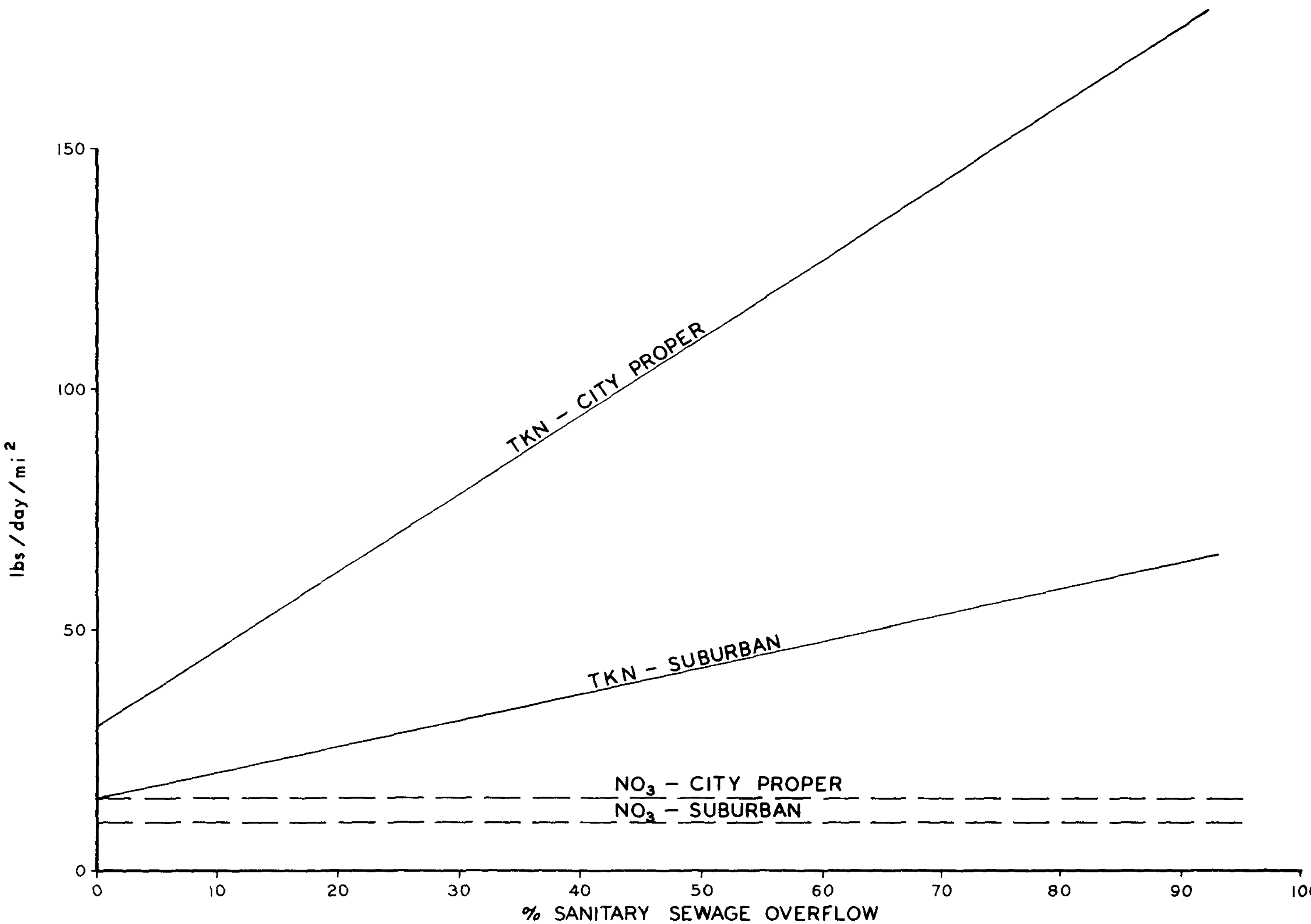
SUSQUEHANNA RIVER NUTRIENT SURVEY
SAMPLING NETWORK



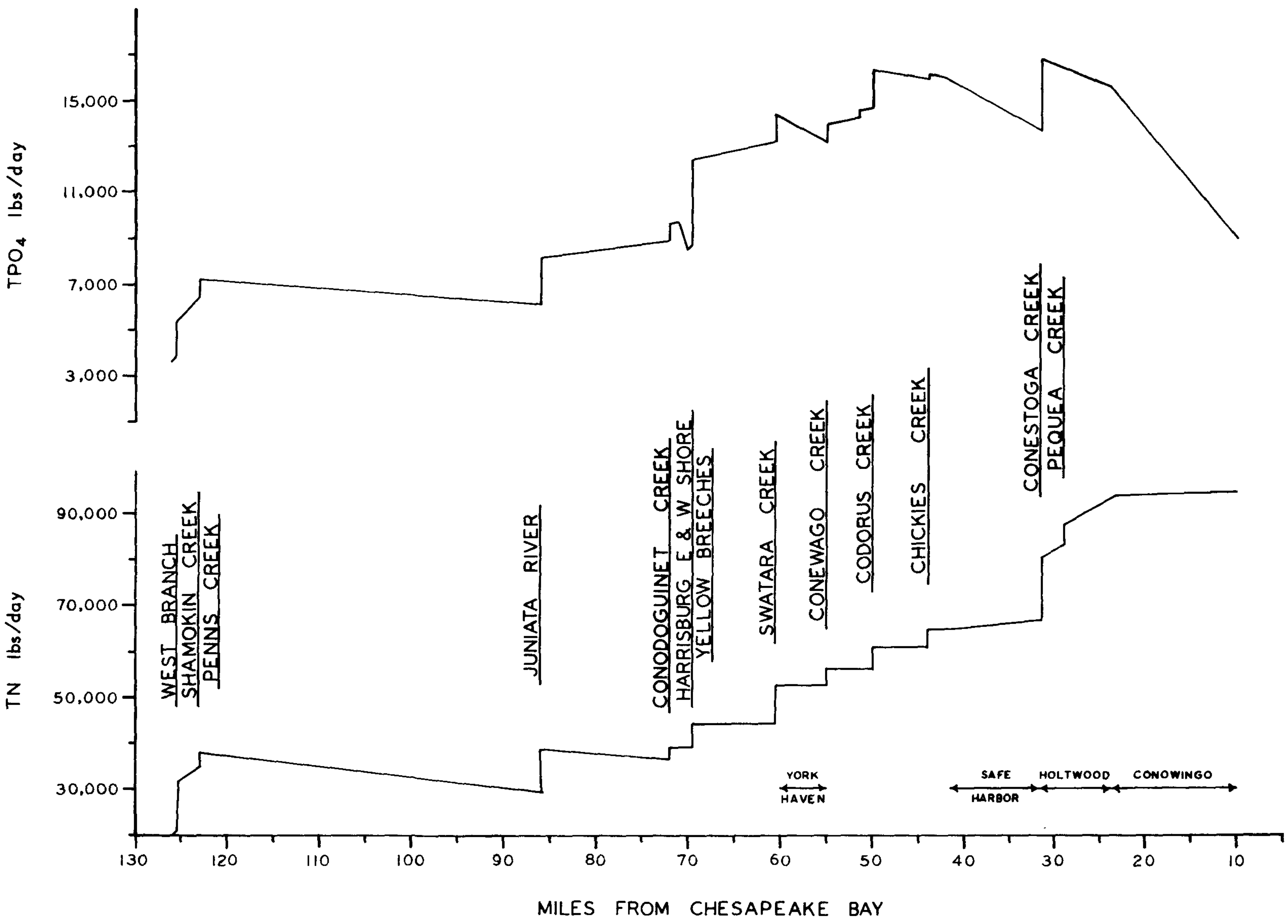
ESTIMATED PHOSPHORUS LOADINGS FROM URBAN AND SUBURBAN AREAS FOR VARIOUS PERCENTAGES OF SANITARY SEWAGE OVERFLOWS



ESTIMATED NITROGEN LOADINGS FROM URBAN AND SUBURBAN AREAS FOR VARIOUS PERCENTAGES OF SANITARY SEWAGE OVERFLOWS



NUTRIENT MASS BALANCE
SUSQUEHANNA RIVER
(JUNE - OCT, 1971)



NUTRIENT MASS BALANCE
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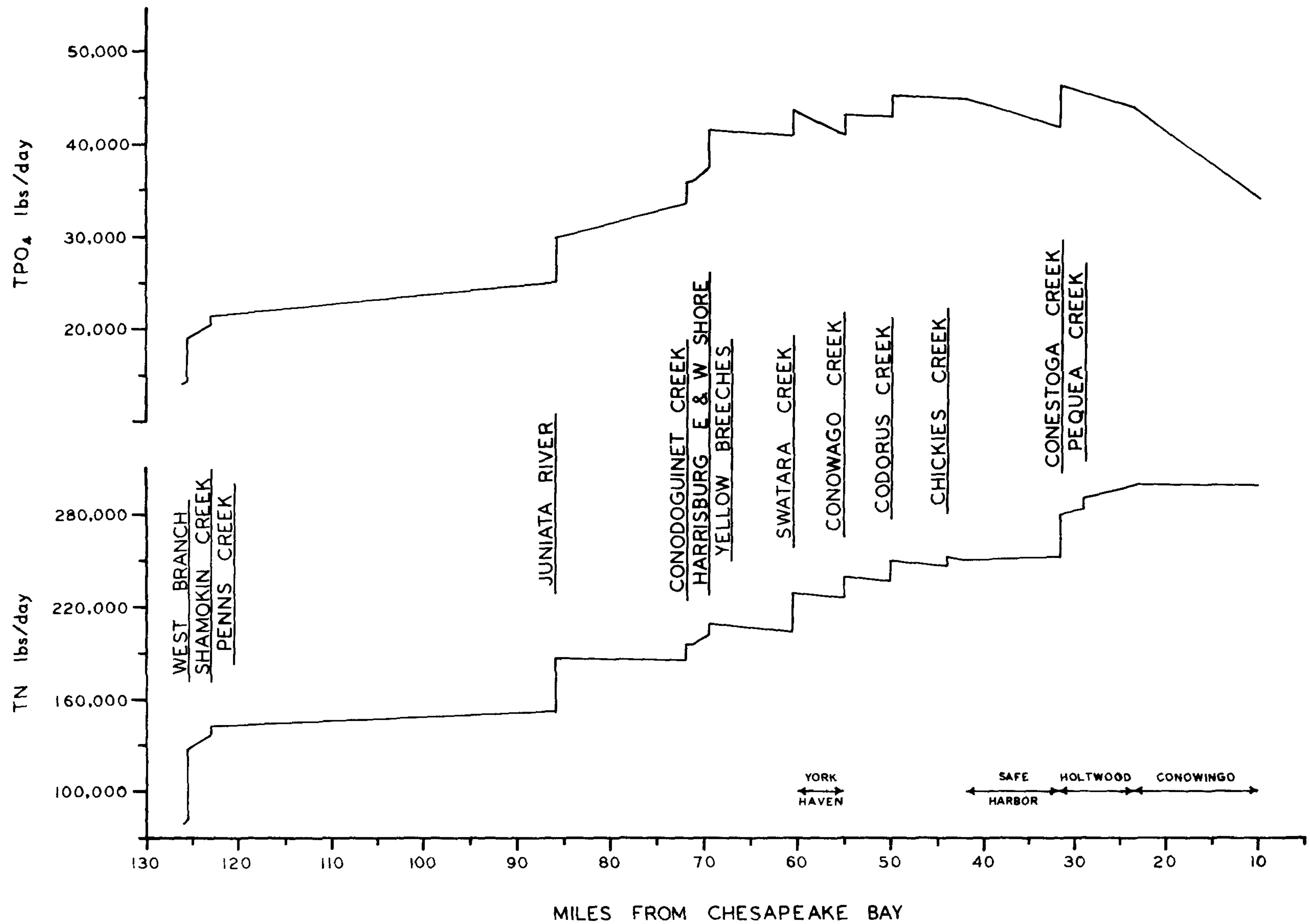
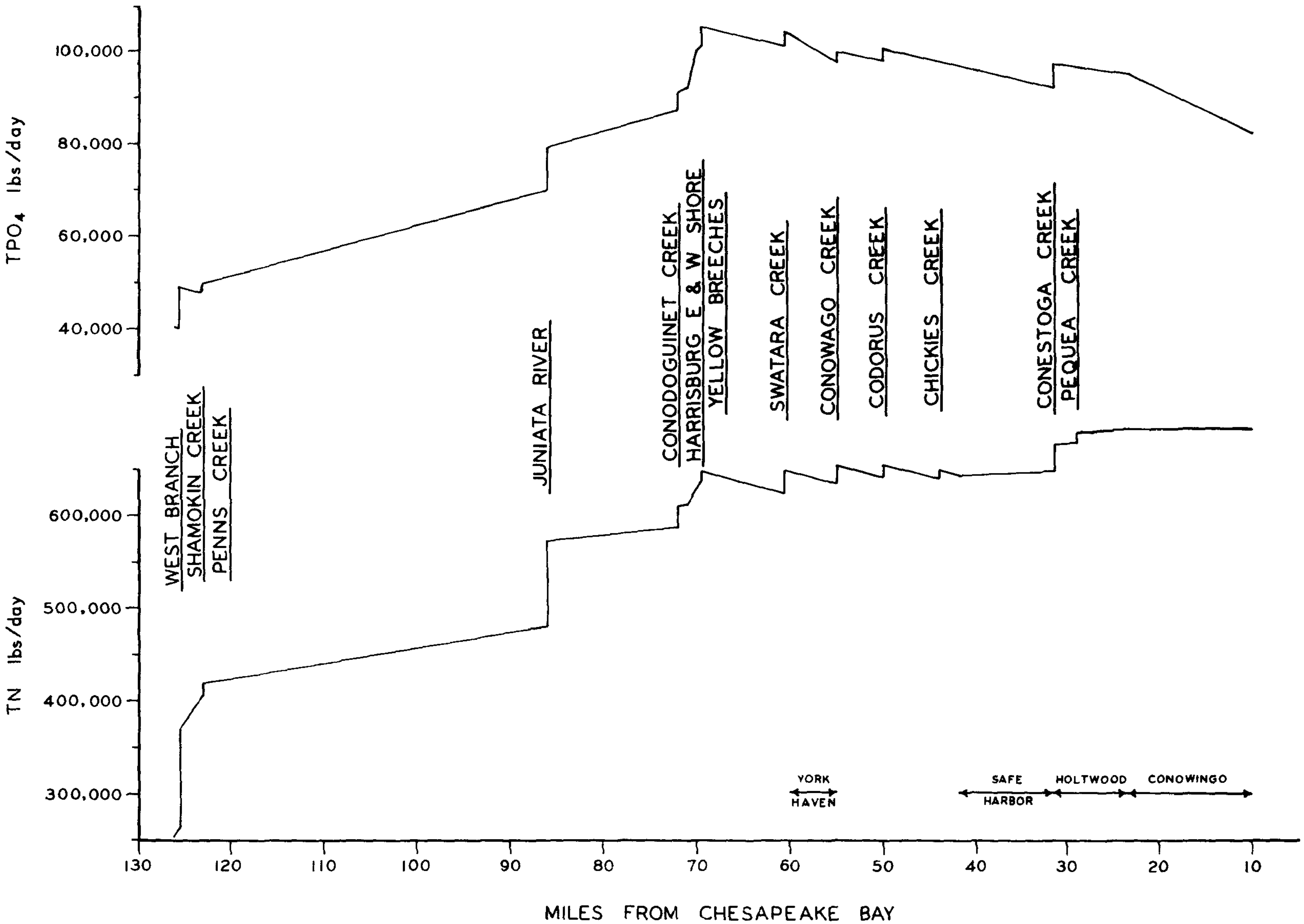
(NOV, 1971 – FEB, 1972)



NUTRIENT MASS BALANCE
SUSQUEHANNA RIVER
(MARCH - MAY, 1972)



NITROGEN MASS BALANCE
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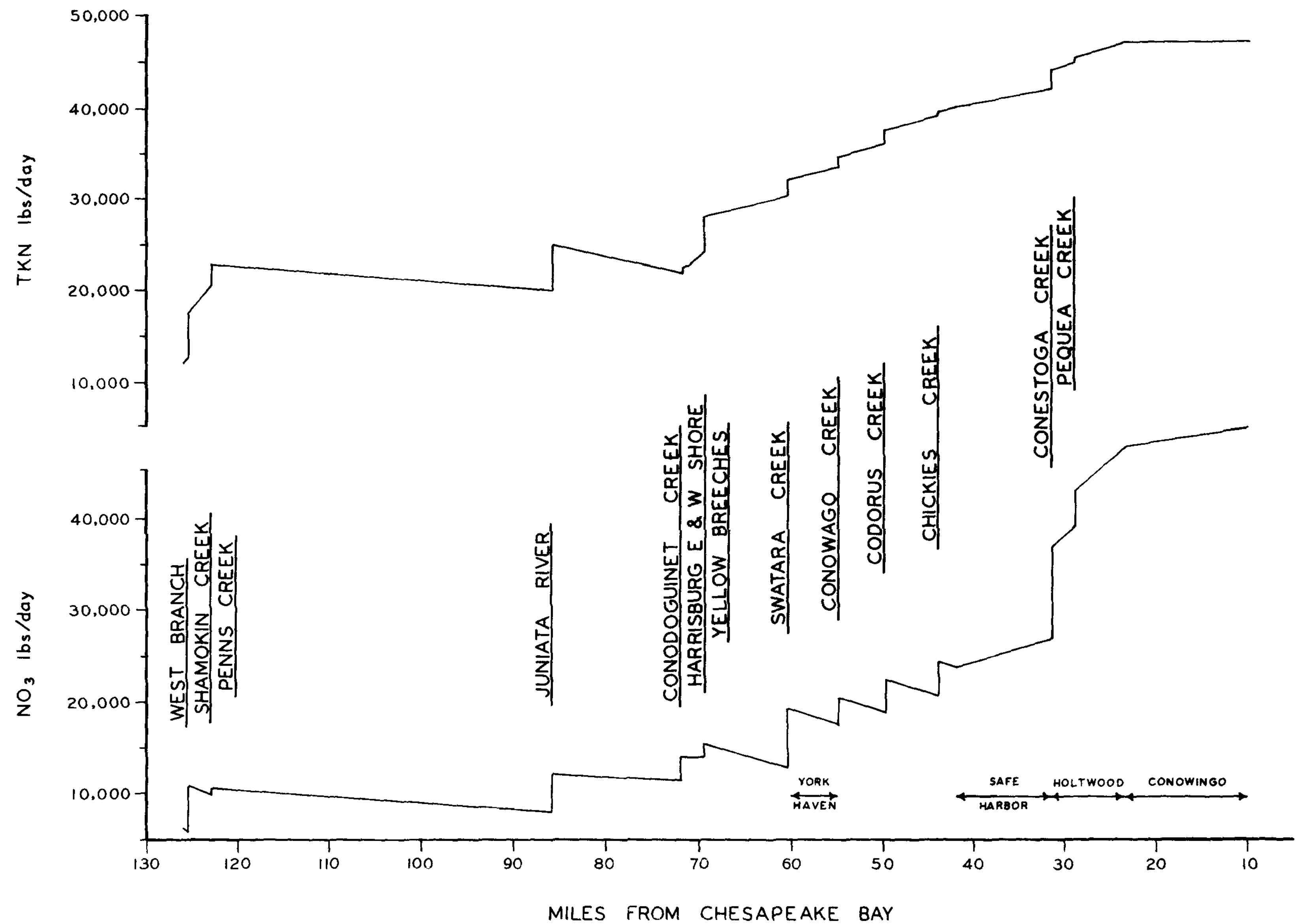

NITROGEN MASS BALANCE
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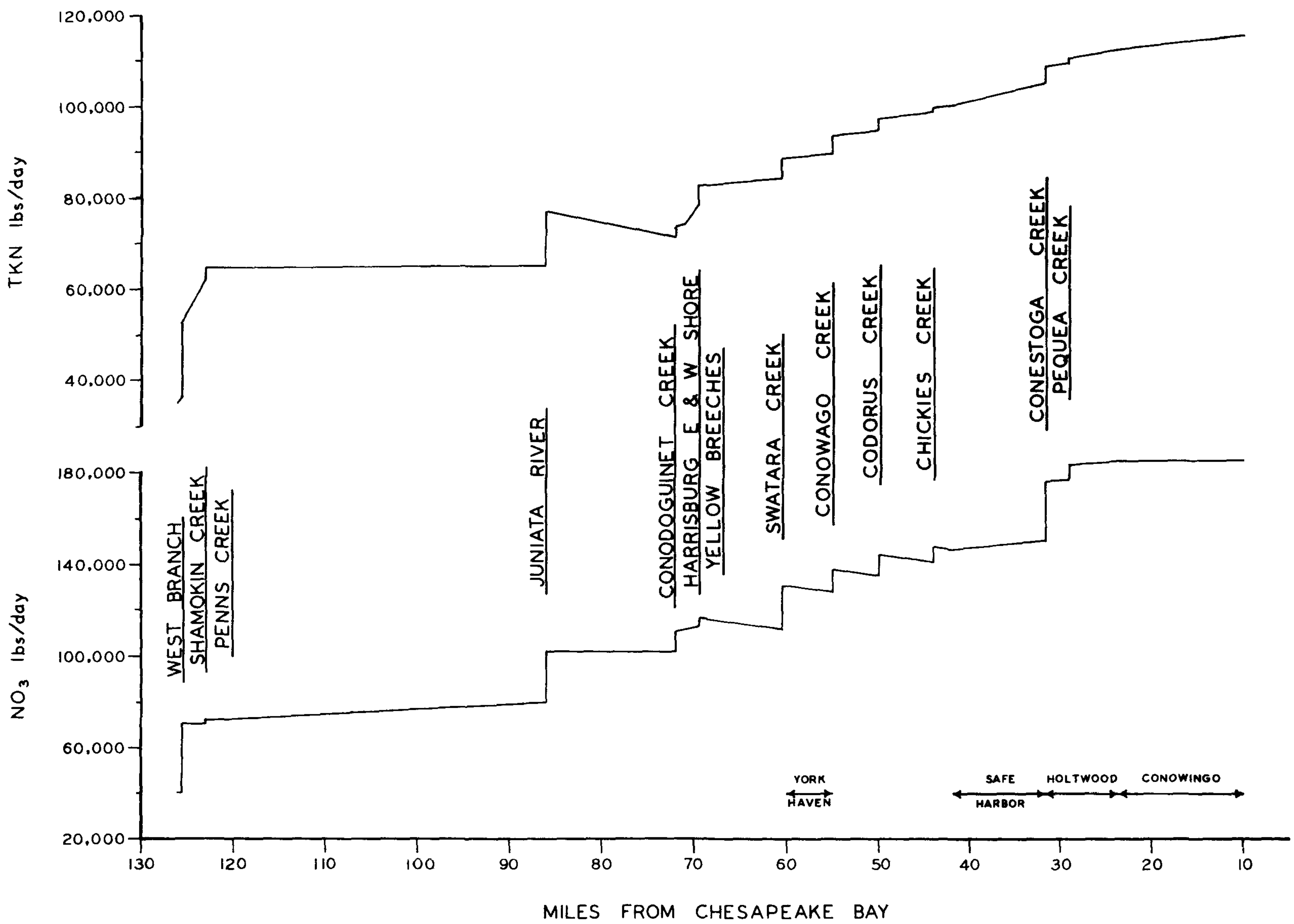
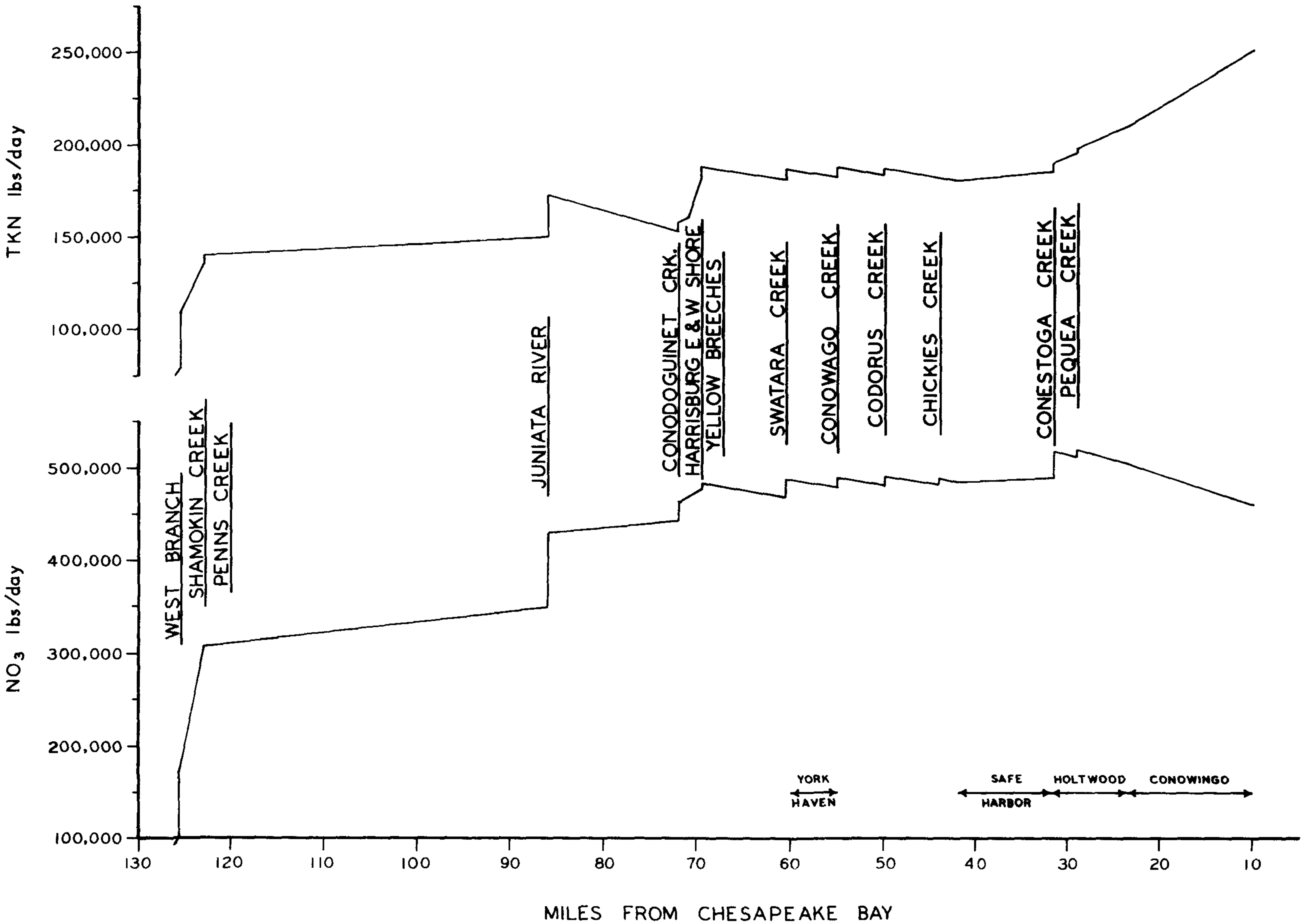
(NOV, 1971 – FEB, 1972)



NITROGEN MASS BALANCE
SUSQUEHANNA RIVER
(MARCH – MAY, 1972)



Land area figures (acres and square miles) were determined for the following sub-divisions within the lower Susquehanna River Basin:

SUB-DIVISION	AREA	LAND AREA		POPULATION	POPULATION DENSITY	
		mi^2	acres		pop/mi^2	pop/acre
Major cities of greater than 25,000 inhibitants	Harrisburg	7.6	4,864	67,880	8,931	13.45
	Lancaster	7.2	4,608	57,589	7,998	12.50
	Lebanon	4.6	2,944	28,572	6,211	9.70
	York	5.3	3,392	50,335	9,497	14.84
Major Urbanized Areas	Harrisburg	78	49,920	240,751	3,086	4.82
	Lancaster	39	24,960	117,097	3,002	4.69
	York	37	23,680	123,106	3,327	5.20
Counties	Adams	526	336,640	56,937	108	0.17
	Cumberland	555	355,200	158,177	285	0.45
	Dauphin	518	331,520	223,834	432	0.68
	Juniata	386	247,040	16,712	43	0.07
	Lancaster	946	605,440	319,693	338	0.53
	Lebanon	363	232,320	99,665	275	0.43
	Northumberland	453	289,920	99,190	219	0.34
	Perry	551	352,640	28,615	52	0.08
	Snyder	327	209,280	29,269	90	0.14
	York	909	581,760	272,603	300	0.47