U.S. ENVIRONMENTAL PROTECTION AGENCY

EPA

SUMMARY AND CONCLUSIONS

from the
forthcoming

Technical Report 56

"Nutrient Enrichment
and
Control Requirements
in the
Upper Chesapeake Bay"

MIDDLE ATLANTIC REGION-III 6th and Walnut Streets, Philadelphia, Pennsylvania 19106

EPA-903/9-73-002-a

SUMMARY AND CONCLUSIONS

from the
forthcoming

Technical Report 56

"Nutrient Enrichment
and
Control Requirements
in the
Upper Chesapeake Bay"

Annapolis Field Office
Region III
Environmental Protection Agency

EPA-903/9-73-002-a

Annapolis Field Office

Region III

Environmental Protection Agency

SUMMARY AND CONCLUSIONS

from the
forthcoming

Technical Report 56

"Nutrient Enrichment and Control Requirements
in the
Upper Chesapeake Bay"

Leo J. Clark

Daniel K. Donnelly

Orterio Villa, Jr.

August 1973

ABSTRACT

The upper portions of the Chesapeake Bay and its tidal tributaries are currently suffering from an insidious eutrophication problem as evidenced by the increased frequency and persistence of undesirable algal blooms and the dramatic changes in the Bay's natural flora which have recently been experienced. Water quality monitoring data collected between 1968 and 1971 have shown an upward trend in phosphorus levels and indicated that inorganic nitrogen may presently be the growth rate-limiting nutrient since it is almost nonexistent during peak bloom conditions. Moreover, utilizing a combination of historical field data and laboratory data to estimate biological uptake requirements led to the conclusion that phosphorus was being recycled at least twice during the algal growing season in the upper Chesapeake Bay.

In order to limit the maximum algal standing crop to 40 µg/l chlorophyll a, it was determined that total phosphorus and inorganic nitrogen concentrations should not exceed 0.12 mg/l (PO_4) and 0.8 mg/l, respectively. The achievement of these concentrations necessitates the institution of a considerable abatement program in the two areas responsible for most of the nutrient contributions to the upper Chesapeake Bay, namely the Susquehanna River Basin and the Baltimore metro area. A quasi-verified dynamic estuary water quality model was used to ascertain the maximum allowable phosphorus and nitrogen loadings from both areas to maintain the aforementioned criteria for three different Susquehanna flow conditions (10,000, 30,000 and 50,000 cfs).

For the two lower flow conditions a 70 percent reduction in the existing phosphorus load would be required from both the Susquehanna Basin and the Baltimore area. During the high flow condition a reduction of over 90 percent of the point source discharges in the Susquehanna must be realized to achieve the phosphorus criterion. Nitrogen is considerably less manageable in the Susquehanna Basin than phosphorus, especially during higher flow periods. Nitrogen control may be a feasible alternative under extremely dry weather conditions, but concentrated slugs of nitrogen associated with storm water runoff would undoubtedly contravene the criterion because of the Bay's exceptionally long flushing time.

PREFACE

This report is intended to serve as an interim document for disseminating the Annapolis Field Office's technical information on the upper Chesapeake Bay. The report presents a series of conclusions and graphically displayed supportive data relevant to the current eutrophication problem in the upper Bay. The authors hope to have a full report elaborating on these findings completed in the near future.

The Annapolis Field Office of the U. S. Environmental Protection Agency initiated a routine water quality monitoring program in the upper Chesapeake Bay during 1968 in order to evaluate the effects of a wastewater discharge from the proposed Anne Arundel County Sandy Point Sewage Treatment Plant (STP) near Annapolis, Maryland. This monitoring effort has continued to the present time and has expanded in scope to include the following objectives: investigation of recent trends resulting in the present eutrophic state of the upper Bay; delineation of major nutrient inputs to the upper Bay; mathematical model development to establish allowable loadings for these inputs under varying flow conditions so as not to exceed a given algal bloom condition; compilation of sufficient statistically valid data which would allow management decisions to be made in accordance with desired objectives. Results of AFO studies and related data collected by other interested agencies are summarized as follows:

1) The Susquehanna River is the major contributor of freshwater to the upper Chesapeake Bay and is the primary factor influencing the Bay's salinity regime and inorganic silt load. The Susquehanna exhibits a classical hydrograph of high spring flows, often exceeding 100,000 cfs, and flows of 10,000 cfs or less during the summer and fall months.
2) The net advective velocities and travel times throughout the upper Chesapeake Bay system vary directly with Susquehanna River flows. The theoretical times required

for a particle of water leaving the Susquehanna River to reach the vicinity of Annapolis, Md., a distance of approximately 32 miles, based upon a "plug flow" analysis are given below for several sustained flow conditions:

Susquehanna Flow (cfs)	Travel Times (days)
10,000	125
30,000	40
50,000	25
100,000	12

3) Sampling data collected from six transects (A through F) along the Chesapeake Bay between the entrance to Baltimore Harbor and the Severn River (see Basin Map in Appendix) indicated that nitrogen and phosphorus concentrations within each transect were relatively uniform, both laterally and vertically, and spatial differences from one transect to the next were generally small. Spatial concentration gradients between these transects were more pronounced for chlorophyll due to the effects of wind and tide action causing blooms to occur as discrete patches rather than as a uniform mixture.

4) Compositing all of the transect data collected since 1968 revealed the following:

a) Maximum concentrations of total phosphorus (as PO_4) exceeded 0.2 mg/l during the late summer and fall periods of 1969, 1970 and 1971. Minimum concentrations (0.08 - 0.12 mg/l) were consistently found during the spring. Total phosphorus concentrations in the upper Chesapeake Bay have generally shown an upward trend from 1968 to 1971.

b) Inorganic phosphorus concentrations during the period 1969 to 1971 varied from about 0.04 mg/l to 0.18 mg/l. Temporal variations in concentration paralleled those observed for total phosphorus with only slight differences in phasing noted.

c) Spatial differences in total phosphorus concentrations were not extreme in the upper Chesapeake Bay. Summer data collected from 1969, 1970 and 1971 generally showed concentrations increasing between the Sassafras River and Baltimore Harbor and remaining relatively high downstream of Baltimore Harbor.

d) Total nitrogen (TKN + NO_3) and inorganic nitrogen (NH_3 + NO_3) concentrations varied from 0.5 mg/l to 1.2 mg/l and from 0.05 mg/l to 1.0 mg/l, respectively, during the study period. Both parameters exhibited similar seasonal variations with maximum concentrations observed in the winter and spring and minimum values in the summer.

e) Of the two components comprising inorganic nitrogen, the nitrate form was predominant (0.6 mg/l vs. 0.3 mg/l ammonia nitrogen) during algal non-bloom periods while both were minimal during peak bloom periods. This, coupled with the fact that the Susquehanna River water entering the Bay is highly nitrified (refer to table on page 10), would appear to indicate that (1) the nitrification reaction ($NH_3 \rightarrow NO_3$) is comparatively insignificant in the Bay and (2) inorganic nitrogen may be the algal growth rate-limiting nutrient at the present time.

f) Organic nitrogen levels were greatest (0.4 - 0.5 mg/l) during periods of maximum algal blooms. Background amounts (0.1 - 0.2 mg/l) of refractory organic nitrogen compounds were continuously present throughout the upper Bay.

g) Neither total nor inorganic nitrogen exhibited a clearly defined upward trend between 1968 and 1971, however, adequate data were not available to establish the critical pre-bloom concentrations of these parameters during the period Dec. 1970 - April 1971.

h) Summer concentrations of inorganic nitrogen in the upper Chesapeake Bay showed a substantial decrease between the Sassafras River and Bush River. During the maximum bloom periods of 1971 a continued, but more gradual, decrease in concentrations were observed between Bush River and Annapolis whereas prior years with lower bloom intensities showed a rise in inorganic nitrogen opposite Baltimore Harbor.

i) Both maximum and average chlorophyll concentrations measured in the upper Chesapeake Bay under summer conditions have showed a significant rise between 1968 and 1971 as indicated in the following table:

Year	Max Chloro (μg/l)	Avg Chloro (μg/l)
1968	50	37
1969	50	30
1970	60	50
1971	188	100

j) During the critical bloom years of 1970 and 1971 drástic increases in chlorophyll were observed in the Bay opposite Baltimore Harbor; maximum chlorophyll levels persisted for approximately

5 miles longitudinally and then decreased sharply between the Magothy and Severn Rivers.

5) There have been subtle but important changes in the biological conditions of the upper Chesapeake Bay area which should be recognized and which may add support to several conclusions drawn strictly from chemical data.

   a) Tidal portions of upper Bay tributaries such as the Sassafras, Bohemia, Elk and Northeast Rivers have been experiencing a change in flora which is probably indicative of accelerated eutrophication. During the early 1960's sizeable blooms of water chestnut and subsequently Eurasian water milfoil were observed in these areas on several occasions. By 1968 a succession from green to blue-green algae had already occurred. Extensive blue-green algal blooms composed of _Anacystis_, _Anabaena_ and _Oscillatoria_ now inhabit many portions of the Sassafras, Elk and Northeast Rivers with increasing frequency, intensity and duration.

   b) The upper portions of the Bay proper including both mesohaline and freshwater areas have recently experienced a dramatic disappearance of the normal rooted aquatic plants. This may have serious repercussions as a prelude to further adverse biological successions. Moreover, these rooted plants have served as a nutrient "trap" especially in areas such as the Susquehanna flats. Without their biological utilization of nutrients, greater proportions of nutrients will be available to the undesirable forms of algae if inputs remain the same.

c) Ecological trends in the Bay's upper tributaries have closely paralleled those documented for the Potomac Estuary. A similar process is probably underway in the upper Chesapeake Bay itself. Visual observations of profuse algal blooms are being recorded with greater frequency and persistance and corroborate the rising trends shown by the chlorophyll data previously presented. Of major importance is the fact that the recent elevated levels of chlorophyll are in part due to increasing standing crops of undesirable blue-green forms of algae.

While chlorophyll may not be the ideal indicator for assessing the standing crop of algal communities, it is nevertheless one of the few effective tools currently available which allows us to develop rational nutrient limitations.

6) Evaluation of pertinent data collected at each station within the six transects indicated that maximum chlorophyll levels were accompanied by low concentrations of inorganic nitrogen and phosphorus. Conversely, high concentrations of these nutrients were noted when chlorophyll levels were relatively low.

7) Based upon a euphotic zone with a depth of 15 feet and a total volume of 25.5 x $10^9 ft^3$ between transects A and F, and the elemental composition analysis performed on algal cells from the Potomac Estuary, the following zonal nitrogen and phosphorus loads would theoretically be required to yield the indicated bloom concentration, as measured by chlorophyll _a_, assuming complete utilization by the cells and no re-cycling of the nutrients:

Chlorophyll (μg/l)	Inorg. Phosphorus (PO_4) (lbs)	Inorganic Nitrogen (lbs)
30	140,000	500,000
40	190,000	650,000
50	240,000	800,000
100	475,000	1,600,000

8) Historical field data collected by AFO and the Chesapeake Biological Institute (CBI) were utilized to estimate nutrient losses that may have resulted from biological uptake by the algal cells. Loading differences for inorganic nitrogen and phosphorus measured in the Chesapeake Bay zone between transects A and F during

pre-bloom and peak-bloom conditions (the difference representing nutrient uptake) are summarized in the table below:

Year	Chlorophyll (μg/l)	Inorganic Phosphorus (PO_4) (lbs)	Inorganic Nitrogen (lbs)
1965*	40	150,000	1,400,000
1968	37	**	1,400,000
1969	30	150,000	1,000,000
1970	50	250,000	1,800,000
1971	100	400,000	**

* CBI data

** Inadequate data to establish pre-bloom loading condition

9) A comparison of the data shown in the previous two tables reveals a favorable agreement between phosphorus loads required to yield a given bloom as estimated from laboratory and historical field data. In the case of nitrogen, however, loadings determined from field data were consistently double those derived from the laboratory elemental analysis data.

10) This over-utilization of nitrogen coupled with: (1) the fact that measured increases in organic nitrogen from pre-bloom to peak-bloom periods confirmed laboratory estimates of inorganic nitrogen uptake requirements to support such blooms and (2) the extremely

low phosphorus loss rates in the upper Chesapeake Bay as estimated by two independent methods reinforces the argument espoused by Dr. Donald Pritchard of the Chesapeake Bay Institute, that phosphorus was being recycled at least twice during the algal growing season.

11) A considerable quantity of nitrogen and phosphorus data has been collected from the Susquehanna River at Conowingo Dam between 1969 and 1972. Several regression analyses were performed with this data in an attempt to relate nutrient loadings with streamflow. The results of these regression analyses, all of which were statistically valid, are presented in the following table:

Susq Flow (cfs)	TPO_4	Inorg P	TN	Inorg N	NO_3
	----------	----------	lbs/day	----------	----------
10,000	7,500	3,500	80,000	58,000	40,000
50,000	50,000	30,000	400,000	300,000	250,000
100,000	120,000	75,000	800,000	600,000	530,000

12) Based on the above loadings it can be concluded that the Susquehanna water was highly nitrified and that the inorganic fractions represented an appreciable proportion of the total nitrogen and phosphorus at all flows.

13) Regression analyses performed separately with the 1969 and 1971 total nitrogen and phosphorus data revealed distinct loading increases for both parameters during the

two year period. A comparison of these Susquehanna loadings is given in the table below:

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

14) An attempt was made to compare predicted nutrient loadings for Susquehanna River inputs with those loadings actually observed in a finite volume of the Chesapeake Bay between transects A and F during the 3 year study period. This nutrient accountability analysis was based upon appropriate travel and displacement times along the upper Bay for successive parcels of Susquehanna water. The following conclusions were drawn from this analysis:

a) The average measured total phosphorus load was about 400,000 lbs whereas the average expected load from the Susquehanna was 500,000 lbs. Comparable values for inorganic phosphorus were 240,000 and 280,000 lbs respectively.

b) The average total nitrogen load measured in the Bay was 2,000,000 lbs whereas the average expected load from the Susquehanna was 4,000,000 lbs. Comparable values for inorganic nitrogen were 1,000,000 and 3,000,000 lbs respectively.

c) The expected total phosphorus loading in the Bay was a function of Susquehanna River flow and varied from about 350,000 lbs (@ 6,000 cfs) to 600,000 lbs (@ 100,000 cfs). Inorganic phosphorus behaved in a similar fashion, but varied between 150,000 and 400,000 lbs. Comparable ranges for both parameters were observed in the Bay during the study period.

d) The expected total and inorganic nitrogen loadings in the Bay (4,000,000 and 3,000,000 lbs respectively) were constant regardless of Susquehanna flow. The increased daily loadings during high flow periods were completely negated by the shorter displacement times.

e) Phosphorus appears to behave more conservatively than nitrogen on an annual basis since approximately 80-90 percent of the Susquehanna phosphorus contribution was actually measured in the Bay whereas less than 50 percent of the nitrogen load was accounted for. Phosphorus accountability exceeded 100 percent on several occasions during the low flow summer and fall periods and reached a minimum (65 percent) during high flow periods. These extremes would indicate (1) the presence of an additional phosphorus source and (2) the effects of greater silt loads and increased phosphorus adsorption and deposition rates generally accompanying high flows.

15) The following table delineates average phosphorus loadings from the Baltimore Metro Area based upon a combination of Maryland Environmental Service (MES) data*, information contained in the Federal industrial permit applications, and actual sampling data:

Source	Flow (mgd)	Total Phosphorus (lbs/day as PO_4)
Municipal	20	4,000
Industrial	750	35,000
Other	---	1,000
Totals	770	40,000

16) The following table presents a similar delineation of total and inorganic nitrogen loadings in the Baltimore Metro Area utilizing the same data sources:

*Published in report entitled "Water Quality Management Plan for Patapsco and Back River Basins"

Source	Flow (mgd)	Total Nitrogen (lbs/day)	Inorganic Nitrogen (lbs/day)
Municipal	20	5,000	3,000
Industrial	750	65,000	54,000
Other	---	5,000	3,000
Totals	770	75,000	60,000

17) Water quality data collected by MES were used to evaluate nutrient and chlorophyll distributions in the main channel of Baltimore Harbor during the summer growing season. In general, the nitrogen and phosphorus concentrations measured in the Harbor were greater than concentrations observed in adjacent reaches of the Chesapeake Bay and reflected the sizable loadings currently discharged from various municipal and industrial sources. Specifically -

a) Total phosphorus concentrations in the inner Harbor varied between 0.4 and 0.6 mg/l. The outer Harbor exhibited relatively constant although somewhat lower (0.25 - 0.35 mg/l) phosphorus levels.

b) Total nitrogen and inorganic nitrogen concentrations in the Baltimore Harbor above Sparrows Point averaged about 1.75 mg/l and 1.0 mg/l, respectively. Near the mouth of the Harbor, concentrations decreased to about 1.0 mg/l and 0.5 mg/l, respectively.

c) Maximum chlorophyll levels (70 - 100 μg/l) were measured between Sparrows Point and the Chesapeake

Bay. Chlorophyll values ranging from about 60 to 80 μg/l were measured in other portions of the Harbor.

18) Average phosphorus concentrations found across the mouth of Baltimore Harbor were consistently 0.04 mg/l higher than concentrations found in the adjacent open Bay. A similar comparison performed for inorganic nitrogen also indicated that concentrations at the mouth of Baltimore Harbor were consistently higher than comparable data from the Bay proper.

19) Considering the following - (1) that nitrogen and especially phosphorus loadings to Baltimore Harbor are quite high, actually exceeding Susquehanna loadings to the Bay during low flow periods, (2) a considerable body of data shows consistently higher levels of these nutrients in the outer Harbor than in nearby areas of the Bay, (3) the possibility of recycling of nutrients from the grossly contaminated bottom sediments in Baltimore Harbor and (4) the significant exchange characteristics between the Harbor and Bay - it appears reasonable to surmise that the Harbor adversely affects the waters of the Bay. Any nutrient management program undertaken for the protection of the upper Chesapeake Bay must include adequate control not only of discharges in the Susquehanna Basin but from the Baltimore Metro Area as well.

20) In order to limit the algal standing crop to 40 μg/l chlorophyll a, an acceptable bloom condition based upon historical observations in the Chesapeake Bay and adopted criteria for the Potomac Estuary, total inorganic phosphorus and nitrogen loadings in the euphotic zone between transects A and F should not exceed 200,000 lbs. and 1,400,000 lbs. respectively. Converting these loadings to equivalent concentrations yields the following -

Phosphorus - 0.12 mg/l as PO_4

Nitrogen - 0.8 mg/l

These limiting nutrient levels were derived from historical field data, model simulation studies and correlations with nutrient-phytoplankton relationships developed for the Potomac Estuary.

21) The EPA Dynamic Estuary Water Quality Model has been adapted to the Chesapeake Bay and its tidal tributaries upstream from Annapolis, Md. with a network comprised of 74 junctions and 88 channels. The model proved capable of simulating the hydrodynamic behavior of the upper Bay as evidenced by the accurate predictions of average tidal ranges and phasing at several USC & GS stations.

22) A review of the available field data indicated three steady state simulation periods with different

flow and algal bloom characteristics as shown below:

Period	Susq Flow (cfs)	Chlorophyll (μg/l)
May - July, 1970	23,000	50
Aug - Oct, 1970	10,000	30
April - May, 1971	50,000	20

23) Salinity data collected during two of these flow periods (10,000 and 50,000 cfs) were used to calibrate and verify the advection and dispersion components of the model. The model was then used to simulate total phosphorus and inorganic nitrogen distributions for determination of loss or uptake rates. In addition, one simulation was made during the high bloom period in an attempt to mathematically link chlorophyll with inorganic nitrogen. The results of these model studies are summarized as follows:

a) The model accurately simulated total phosphorus during the Aug - Oct (1970) and April - May (1971) periods when loss rates of 0.008 and 0.015/day, respectively, were assumed. The increased rate during the latter period probably resulted from the greater adsorption and deposition potential of the higher Susquehanna flow. Both rates were, however, much lower than expected.

b) Inorganic nitrogen was also accurately simulated on two separate occasions contingent upon the proper selection of uptake rates for first order kinetics. The rates obtained from the model (0.055 and 0.010/day) appeared to be highly dependent upon existing chlorophyll levels.

c) For the high bloom period of 1970 and using the uptake rate of 0.055/day for inorganic nitrogen, the model satisfactorily simulated the chlorophyll distribution observed in the Chesapeake Bay. Since the model assumed an immediate growth response corresponding to any loss of inorganic nitrogen, phasing differences between observed and predicted profiles did exist; however, total masses compared favorably.

24) Following calibration and limited verification, the Dynamic Estuary Model was used to perform a series of alternative runs for determining allowable total phosphorus and inorganic nitrogen loadings from the Susquehanna River and the Baltimore Metro Area to achieve the previously indicated nutrient criteria throughout the upper Chesapeake Bay. The results obtained from these model runs for three different Susquehanna flow conditions (10,000, 30,000 and 50,000 cfs) are presented in the tables following.

Allowable Loadings

Phosphorus (PO_4)

(Susq. Flow = 10,000 cfs)

Balt. Metro Area	Susq. Basin
20,000 lbs/day	3200 lbs/day (.06 mg/l)
10,000 lbs/day	7000 lbs/day (.13 mg/l)
5,000 lbs/day	(not a viable alternative)

(Susq. Flow = 30,000 cfs)

Balt. Metro Area	Susq. Basin
20,000 lbs/day	16,000 lbs/day (.10 mg/l)
10,000 lbs/day	21,500 lbs/day (.135 mg/l)
5,000 lbs/day	23,000 lbs/day (.145 mg/l)

(Susq. Flow = 50,000 cfs)

Balt. Metro Area	Susq. Basin
20,000 lbs/day	35,000 lbs/day (.13 mg/l)
10,000 lbs/day	36,000 lbs/day (.135 mg/l)
5,000 lbs/day	38,000 lbs/day (.14 mg/l)

Allowable Loadings

Nitrogen

(Susq. Flow = 10,000 cfs)

Balt. Metro Area	Susq. Basin
40,000 lbs/day	32,000 lbs/day (.60 mg/l)
30,000 lbs/day	35,000 lbs/day (.66 mg/l)
20,000 lbs/day	39,000 lbs/day (.73 mg/l)

(Susq. Flow = 30,000 cfs)

Balt. Metro Area	Susq. Basin
40,000 lbs/day	103,350 lbs/day (.65 mg/l)
30,000 lbs/day	111,300 lbs/day (.70 mg/l)
20,000 lbs/day	119,250 lbs/day (.75 mg/l)

(Susq. Flow = 50,000 cfs)

Balt. Metro Area	Susq. Basin
40,000 lbs/day	186,000 lbs/day (.69 mg/l)
30,000 lbs/day	194,000 lbs/day (.72 mg/l)
20,000 lbs/day	200,000 lbs/day (.75 mg/l)

It should be noted that the Baltimore loadings were not predicated on the protection of Baltimore Harbor waters, otherwise more stringent loadings would probably have been required.

25) In view of the uncertainty in defining the various reactions responsible for conversion of organic forms of phosphorus to inorganic forms (and vice versa); the almost immediate utilization of regenerated phosphorus by phytoplankton as hypothesized by Dr. Pritchard and somewhat substantiated by data presented in this report; and the low apparent loss rate for phosphorus, allowable phosphorus loadings from the Susquehanna Basin and the Baltimore area were developed for total and not inorganic phosphorus.

26) Inorganic nitrogen was treated as a conservative parameter in all of the model production runs. Since the criteria, hence the allowable loadings, apply primarily during pre-bloom periods this appeared to be a reasonable assumption.

27) There was insufficient field data available to calibrate or verify adequately the mathematical model for a Susquehanna River flow of 100,000 cfs and the effects of this extreme flow condition on the nutrient distribution in the upper Chesapeake Bay could not be properly evaluated.

28) Special model runs were prepared to investigate the effects of the Sandy Point STP discharge on the phosphorus concentrations in nearby areas of the Chesapeake Bay. Assuming present plant design capacity (4.2 mgd - wastewater flow; 40,000 - population served) and the realization of adequate phosphorus control in the Susquehanna Basin and the Baltimore area, the model runs demonstrated that the effects of the Sandy Point STP discharge would be minor and the phosphorus criteria in the Chesapeake Bay could still be achieved for either Susquehanna River flow. Any future expansion of this facility, however, would require a thorough investigation to determine the necessity for and extent of nutrient removal.

29) As stated previously, it is quite possible that inorganic nitrogen is presently the rate-limiting nutrient in the upper Chesapeake Bay; however, it is reasonable to expect that phosphorus can be made the rate-limiting nutrient if adequate control measures are instituted. Phosphorus is more manageable in the Susquehanna Basin than nitrogen, especially during higher flow periods. Nitrogen control may be a feasible alternative under normal dry weather conditions, but concentrated slugs of nitrogen occurring from natural runoff during short-term localized storms would probably cause the maximum allowable nitrogen concentrations previously established

to be exceeded during the long retention periods resulting from slow net seaward transport.

30) A mass balance analysis was performed on all nutrient data collected in the lower Susquehanna Basin from June 1971 to June 1972. The results obtained from this analysis were used to estimate the degree of controllability of nitrogen and phosphorus during various seasons and flow conditions. For the three Susquehanna flows investigated, the following tables depict the effects of different reductions of all point source discharges on the river loadings at Conowingo:

% Reduction	Est. Total Phosphorus Load (lbs/day)	Est. Inorganic Nitrogen Load (lbs/day)
	10,000 cfs	
0	8,300	57,000
50	5,700	53,000
70	4,600	50,000
90	3,800	47,000
	30,000 cfs	
0	27,100	187,500
50	23,000	183,500
70	21,500	182,500
90	20,000	180,000
	50,000 cfs	
0	46,000	309,000
50	41,000	305,000
70	40,000	303,000
90	38,500	301,000

31) Assuming sustained Susquehanna River flows of 10,000 and 30,000 cfs and utilizing the previous two tables, a reduction in the existing phosphorus load from both the point source discharges in the lower Susquehanna Basin and the Baltimore area of 70 percent will be required to achieve the 0.12 mg/l total phosphorus concentration limit in the Chesapeake Bay. If a sustained flow of 50,000 cfs is assumed, it is doubtful whether this criteria can be attained unless over a 90 percent reduction at each of the point source discharges in the lower Susquehanna Basin and the Baltimore area is realized. It is important to recognize that the Susquehanna River becomes increasingly significant in terms of a phosphorus management program during higher flow periods, especially for protection of the extreme upper reaches of the Bay. Unfortunately, the controllable percentage of the phosphorus load in the Susquehanna Basin decreases dramatically for such flow periods.

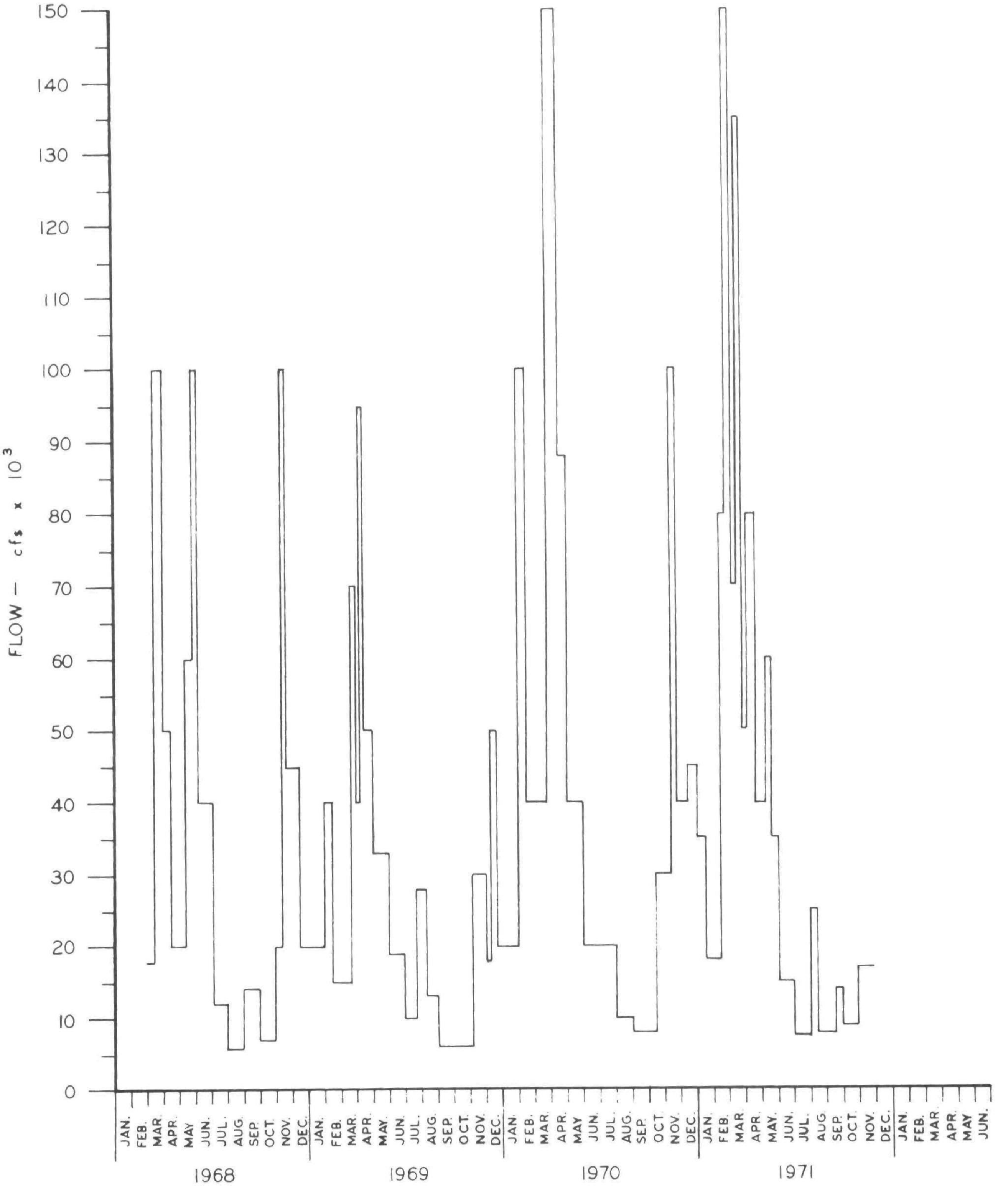
APPENDIX

UPPER CHESAPEAKE BAY

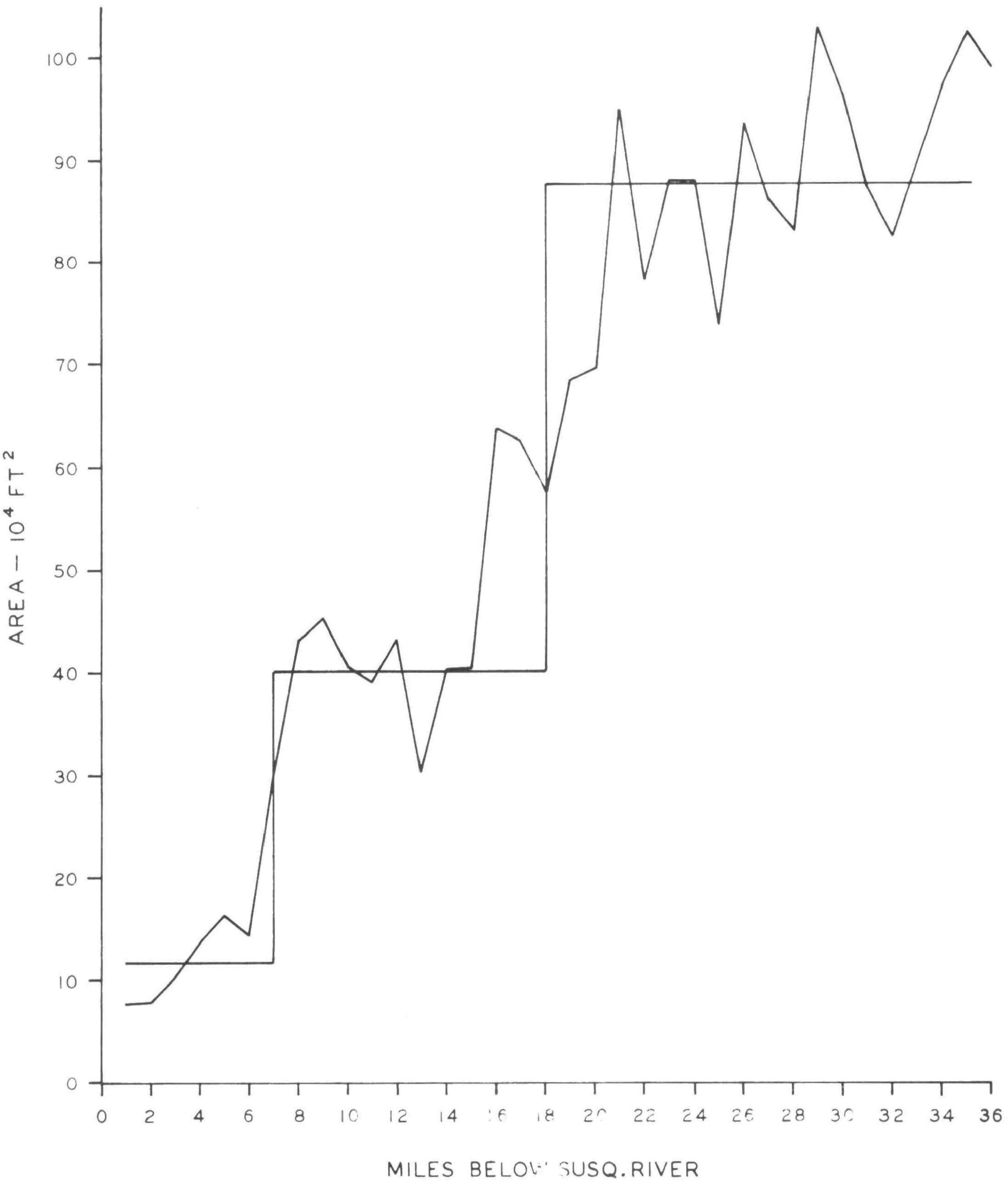
HYDROGRAPH

SUSQUEHANNA RIVER AT CONOWINGO DAM

(1968 - 1971)

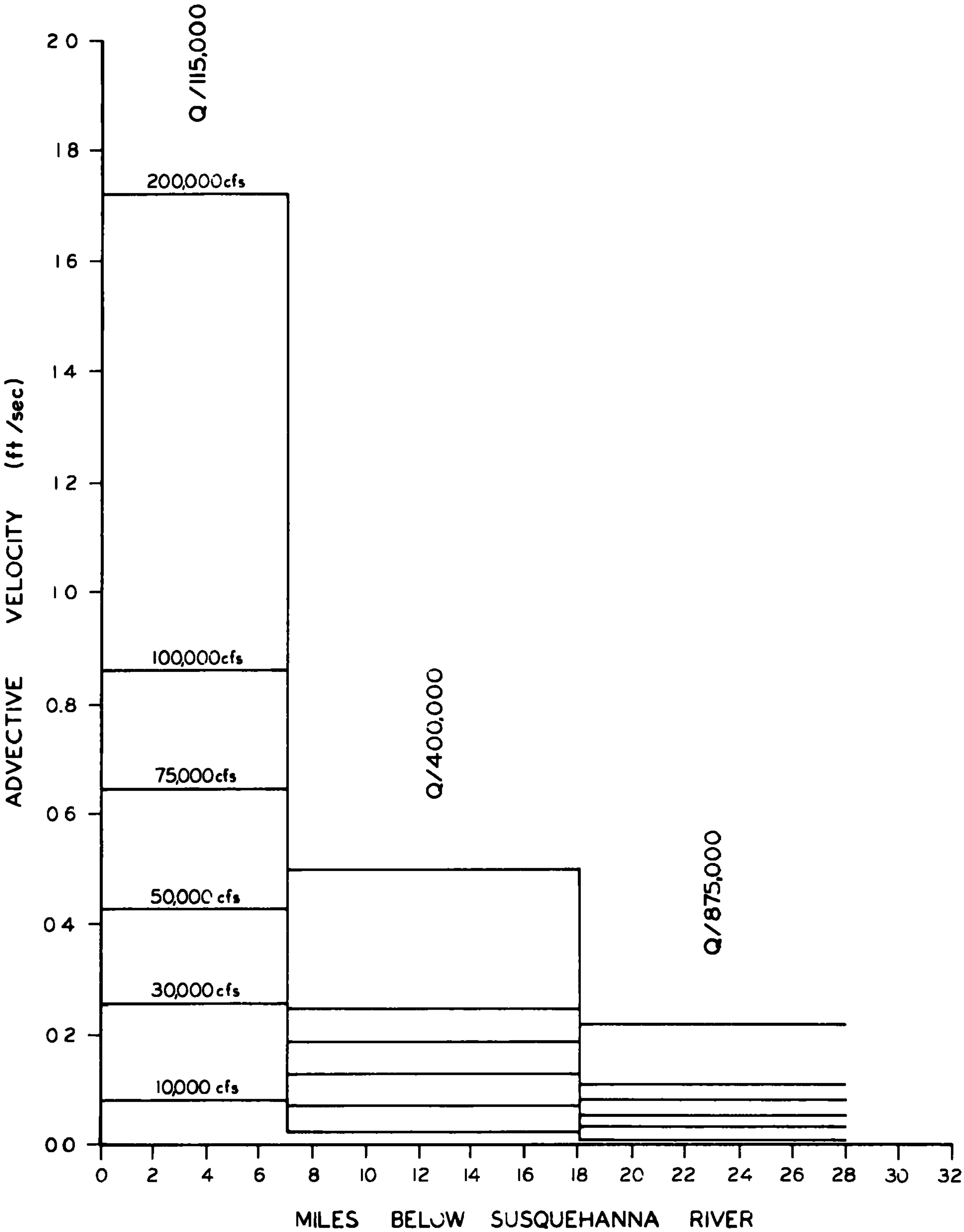


CROSS SECTIONAL AREAS
UPPER CHESAPEAKE BAY
(C B I DATA)



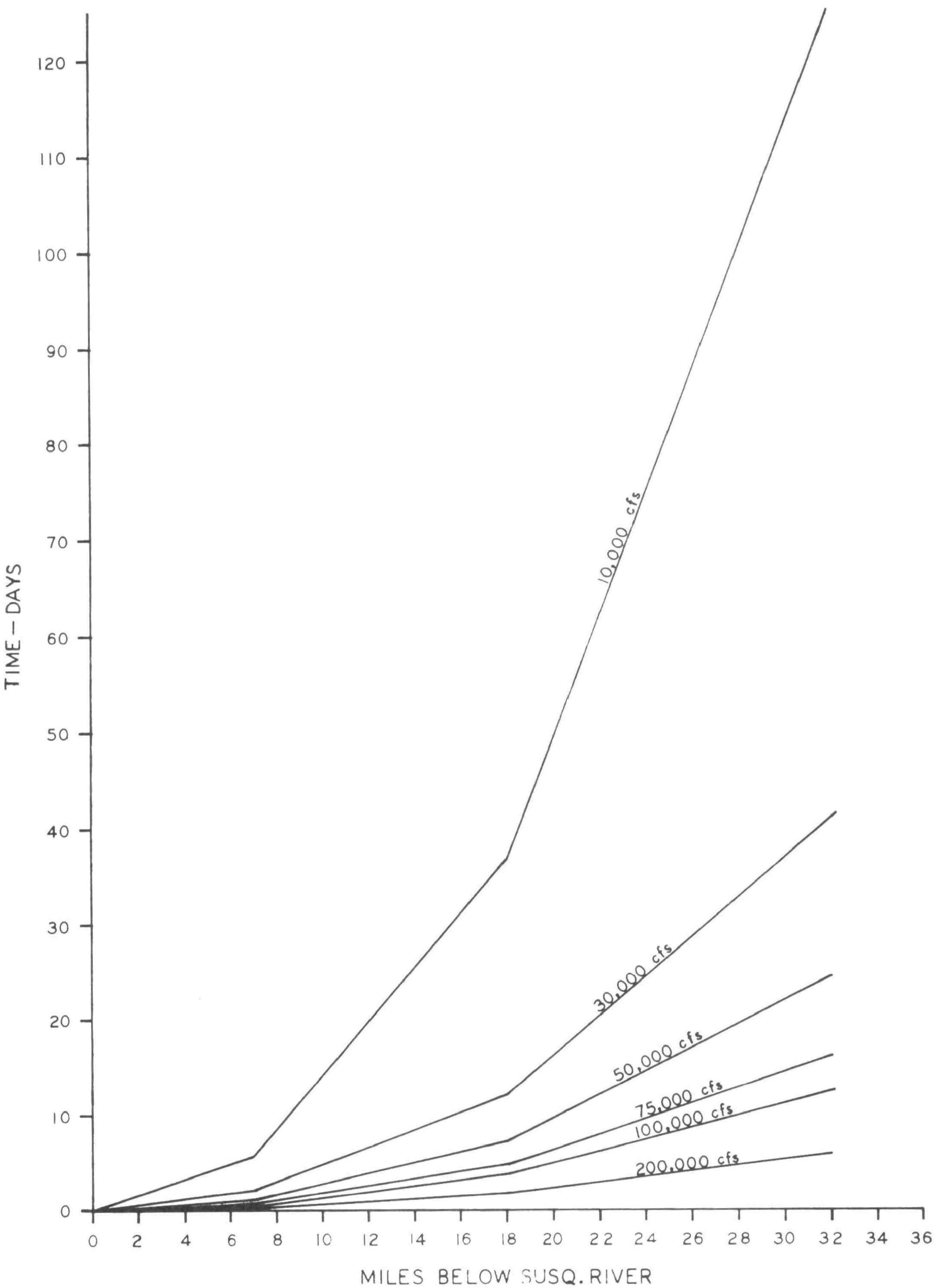
ADVECTIVE VELOCITIES vs. SUSQUEHANNA RIVER FLOW

UPPER CHESAPEAKE BAY



TRAVEL TIMES vs. SUSQUEHANNA RIVER FLOW

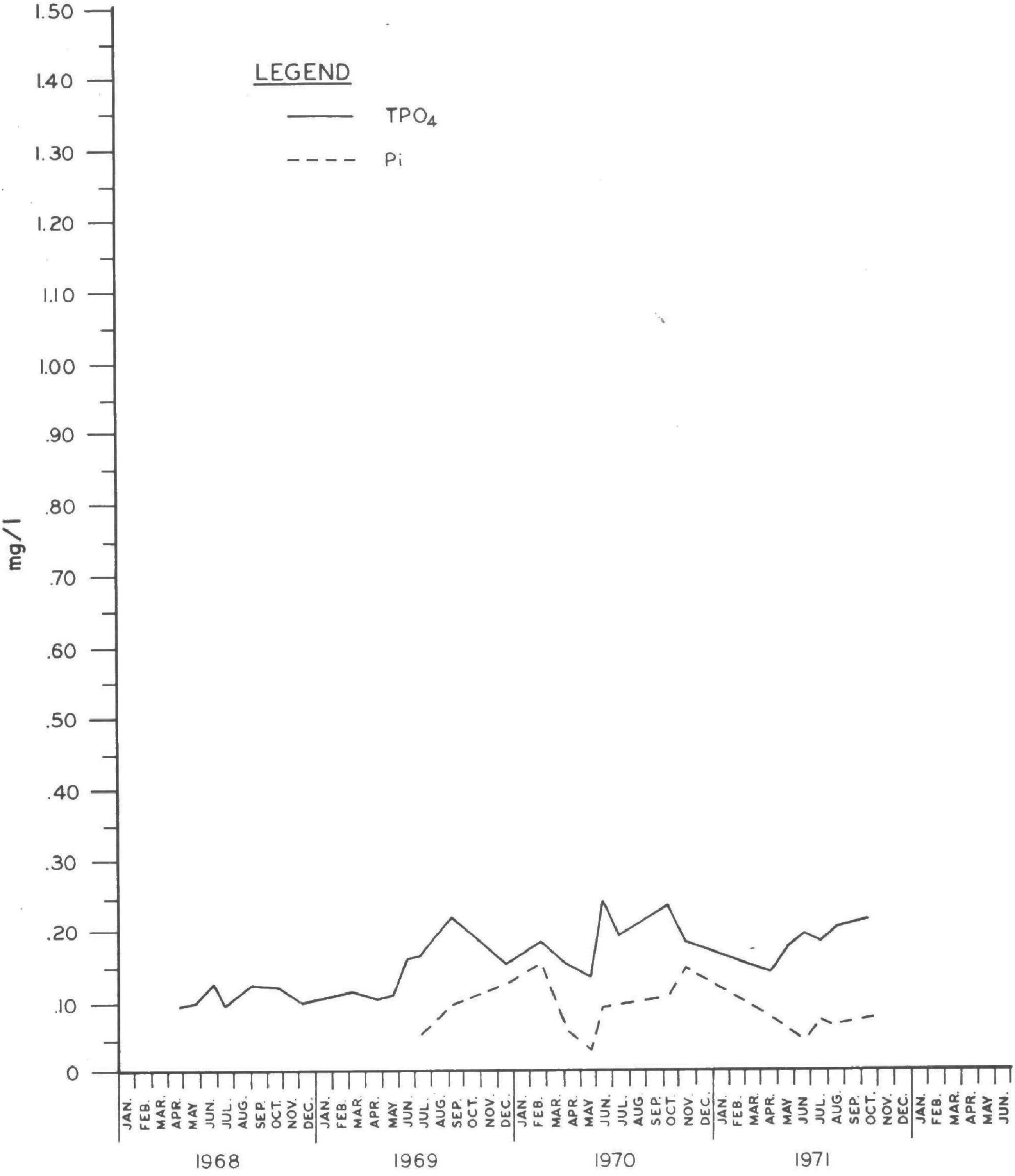
UPPER CHESAPEAKE BAY



TEMPORAL PHOSPHORUS DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT A
(AVERAGE DATA FOR TRANSECT)

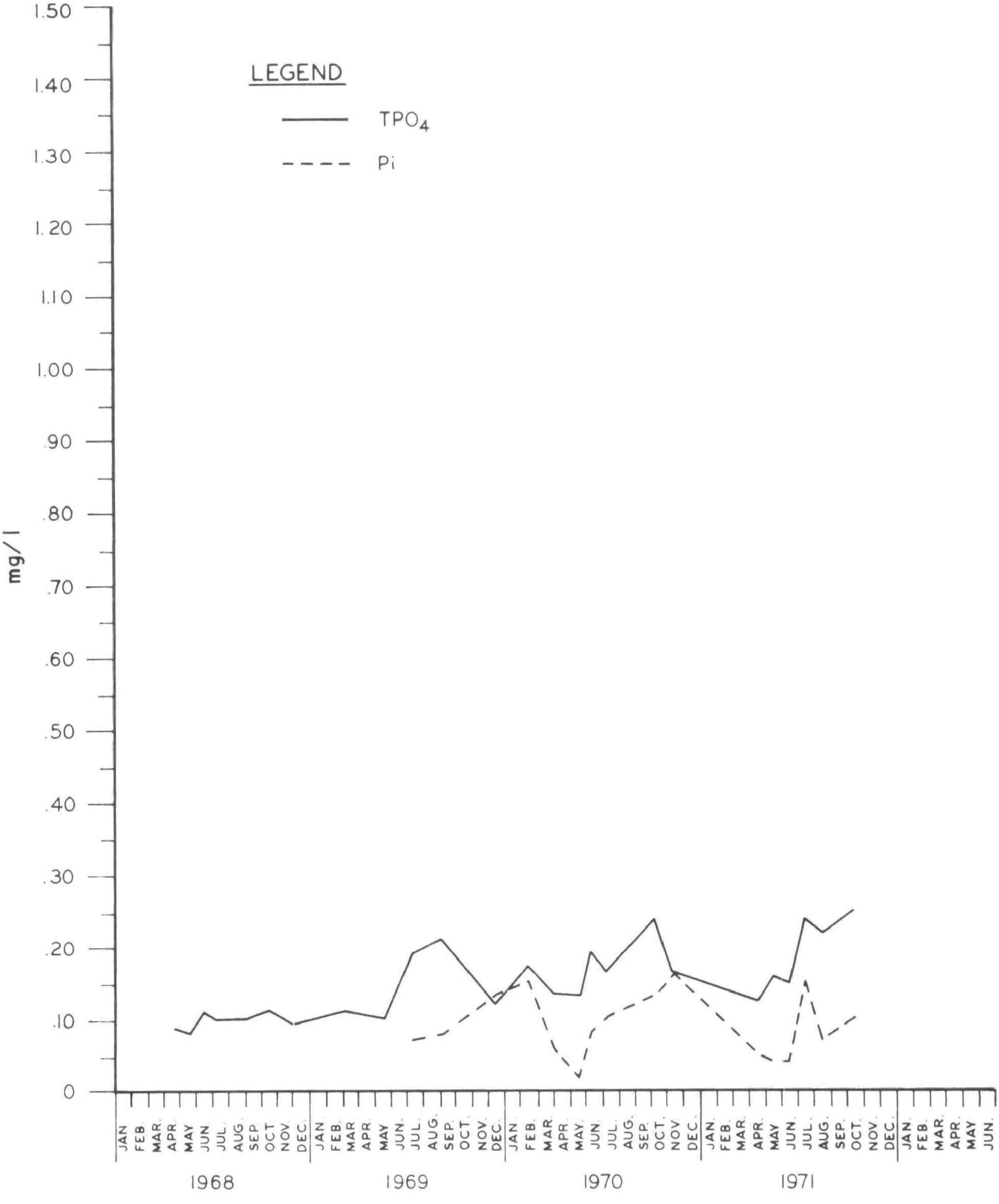


TEMPORAL PHOSPHORUS DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT B

(AVERAGE DATA FOR TRANSECT)

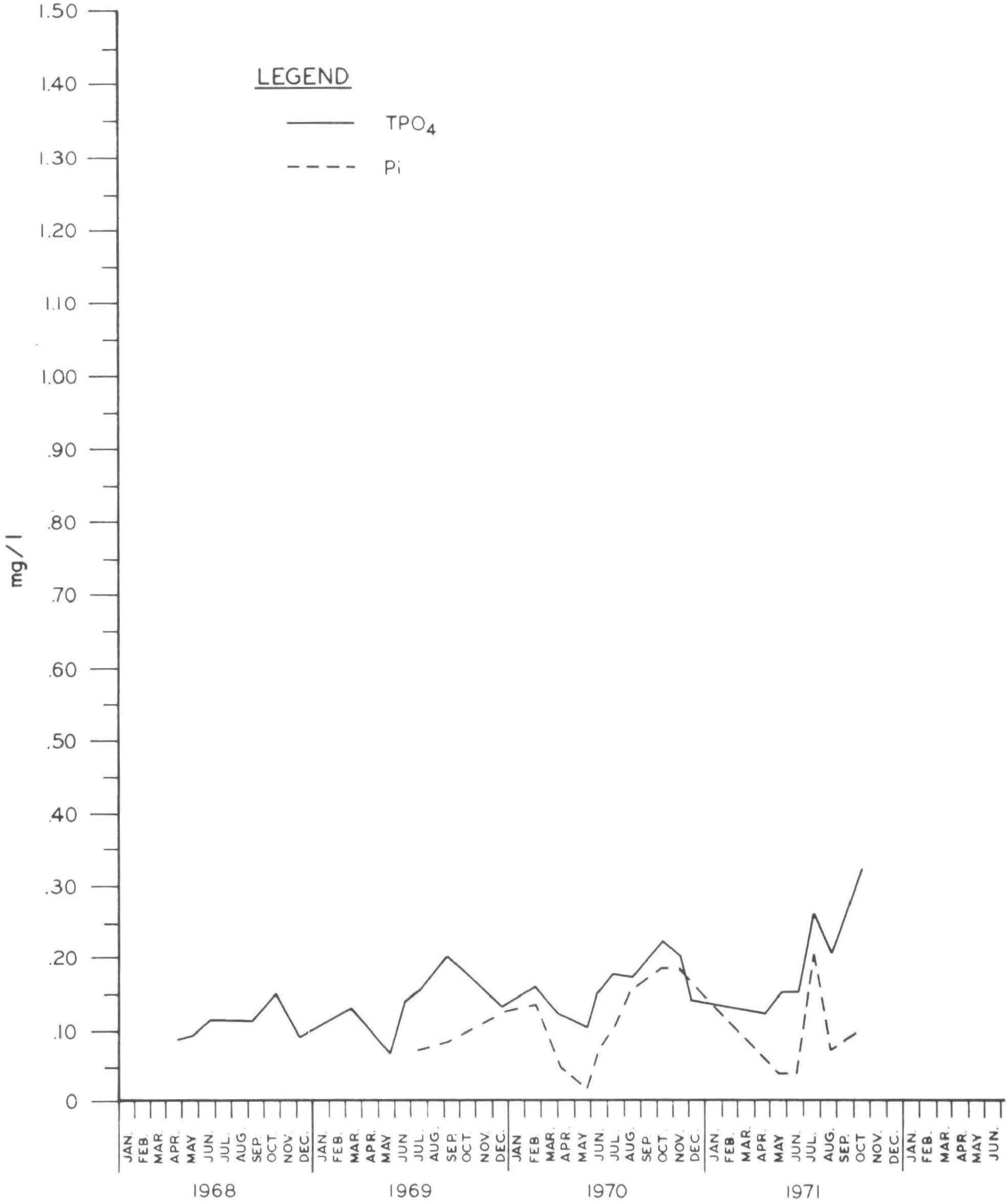


TEMPORAL PHOSPHORUS DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT C

(AVERAGE DATA FOR TRANSECT)

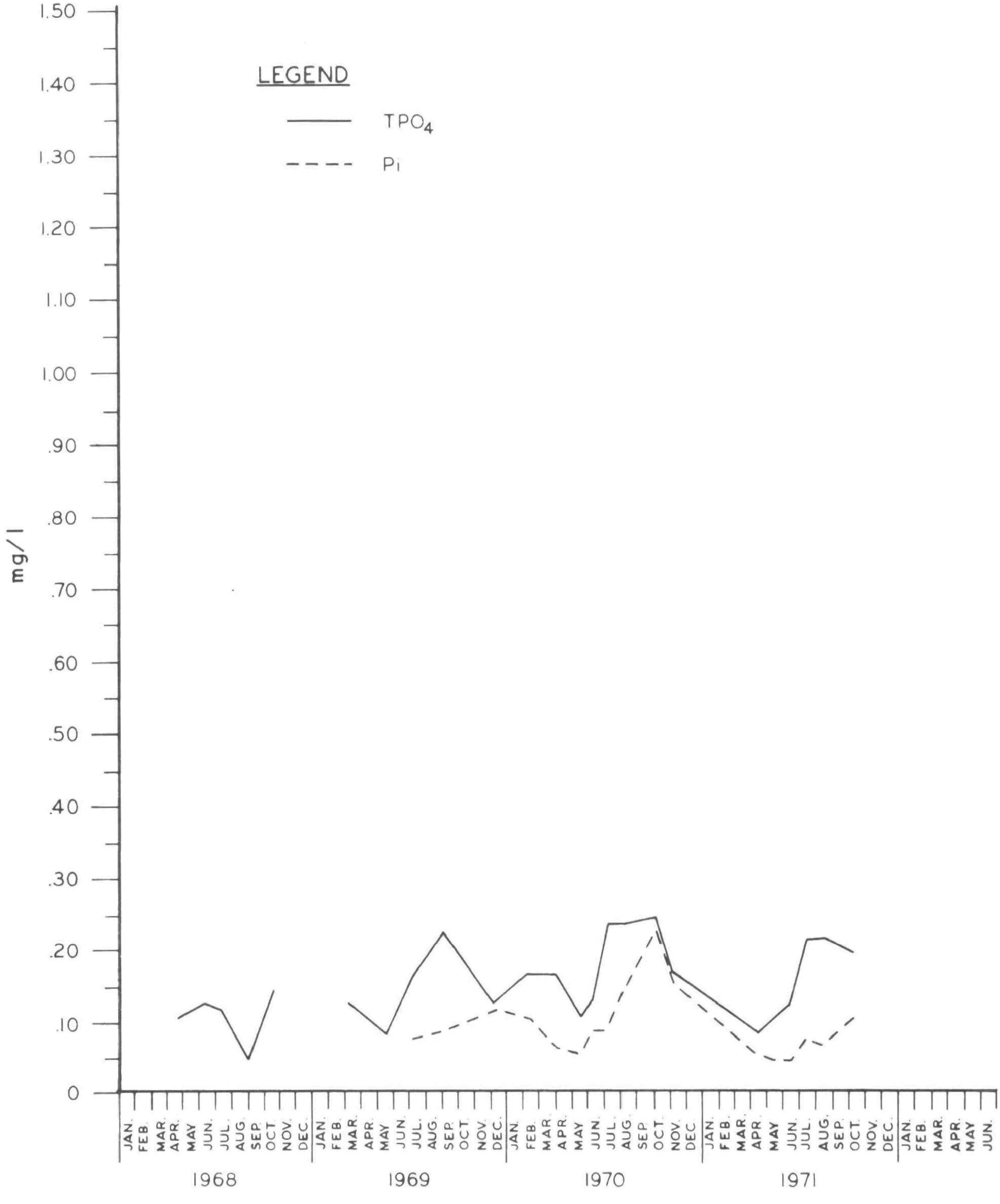


TEMPORAL PHOSPHORUS DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT D

(AVERAGE DATA FOR TRANSECT)

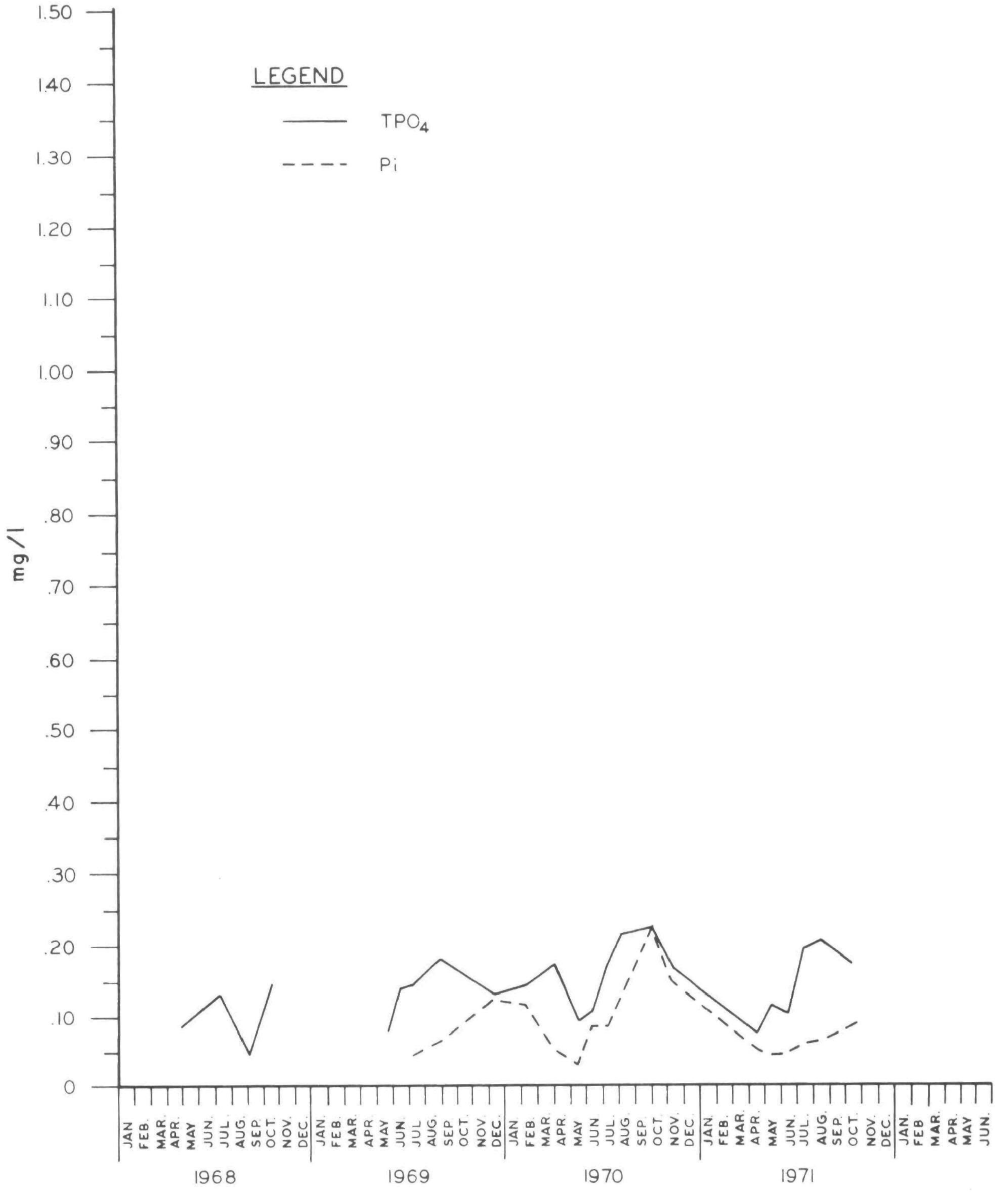


TEMPORAL PHOSPHORUS DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT E

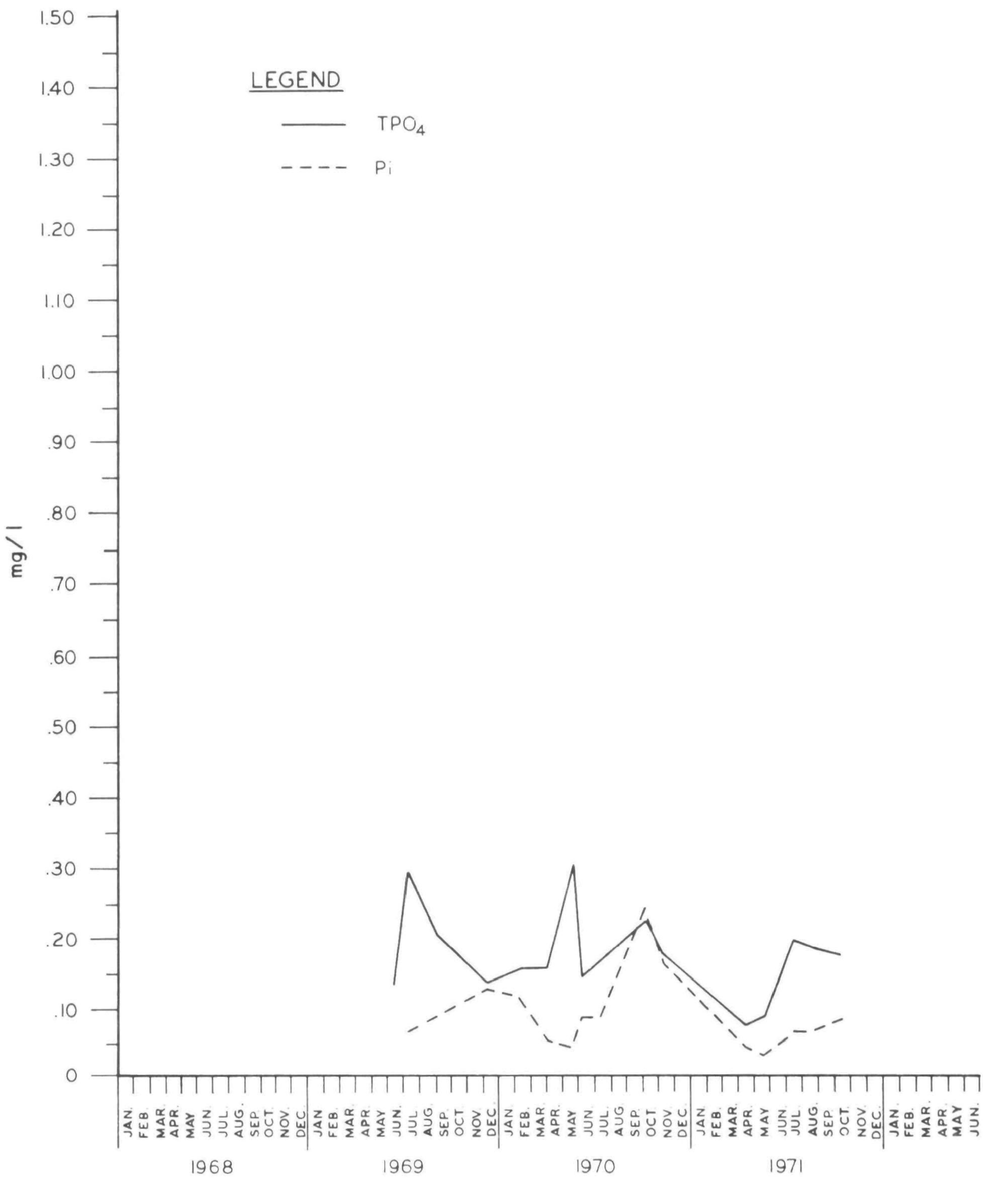
(AVERAGE DATA FOR TRANSECT)



TEMPORAL PHOSPHORUS DISTRIBUTION

UPPER CHESAPEAKE BAY

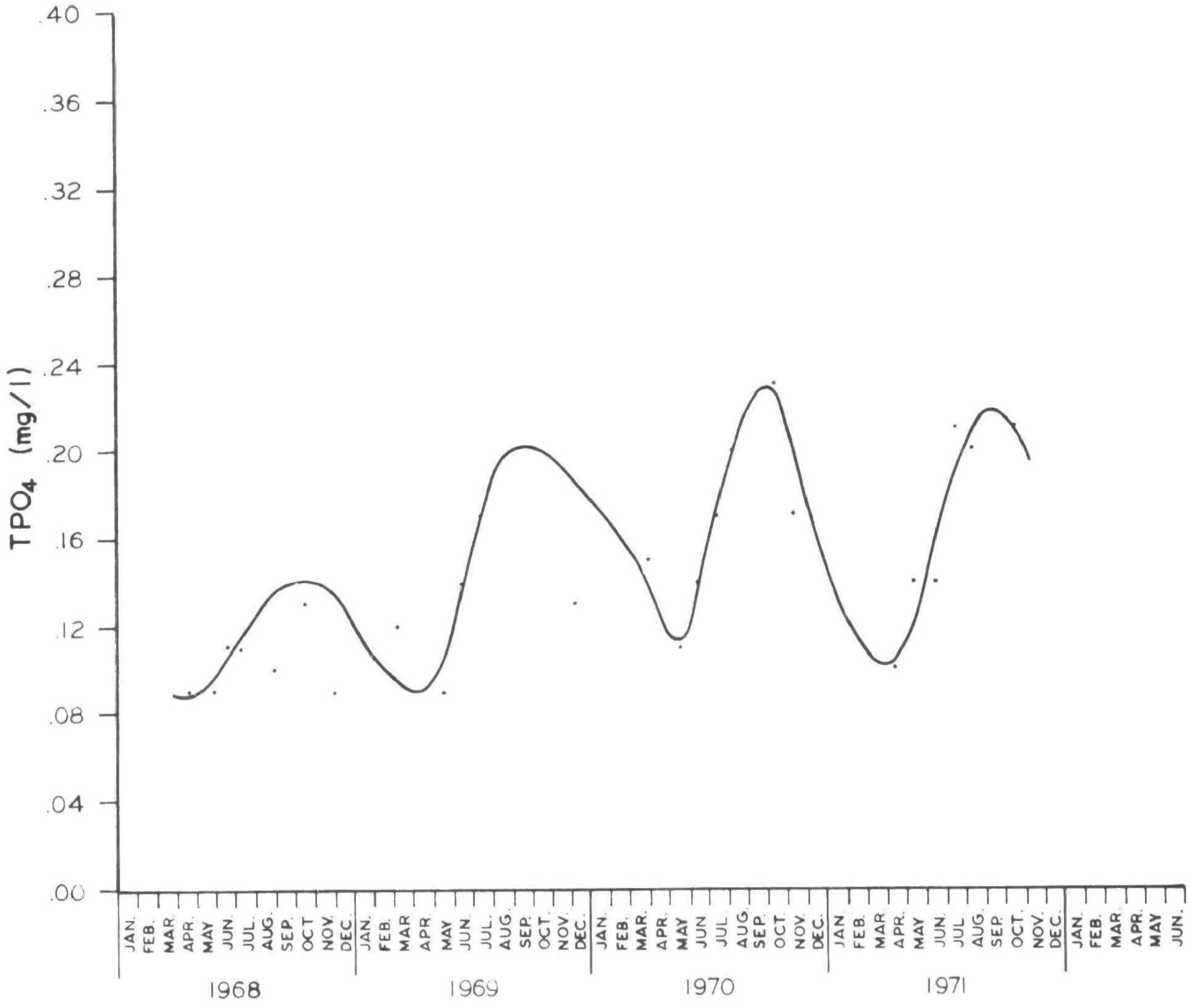
TRANSECT F
(AVERAGE DATA FOR TRANSECT)



TOTAL PHOSPHORUS CONCENTRATIONS

UPPER CHESAPEAKE BAY

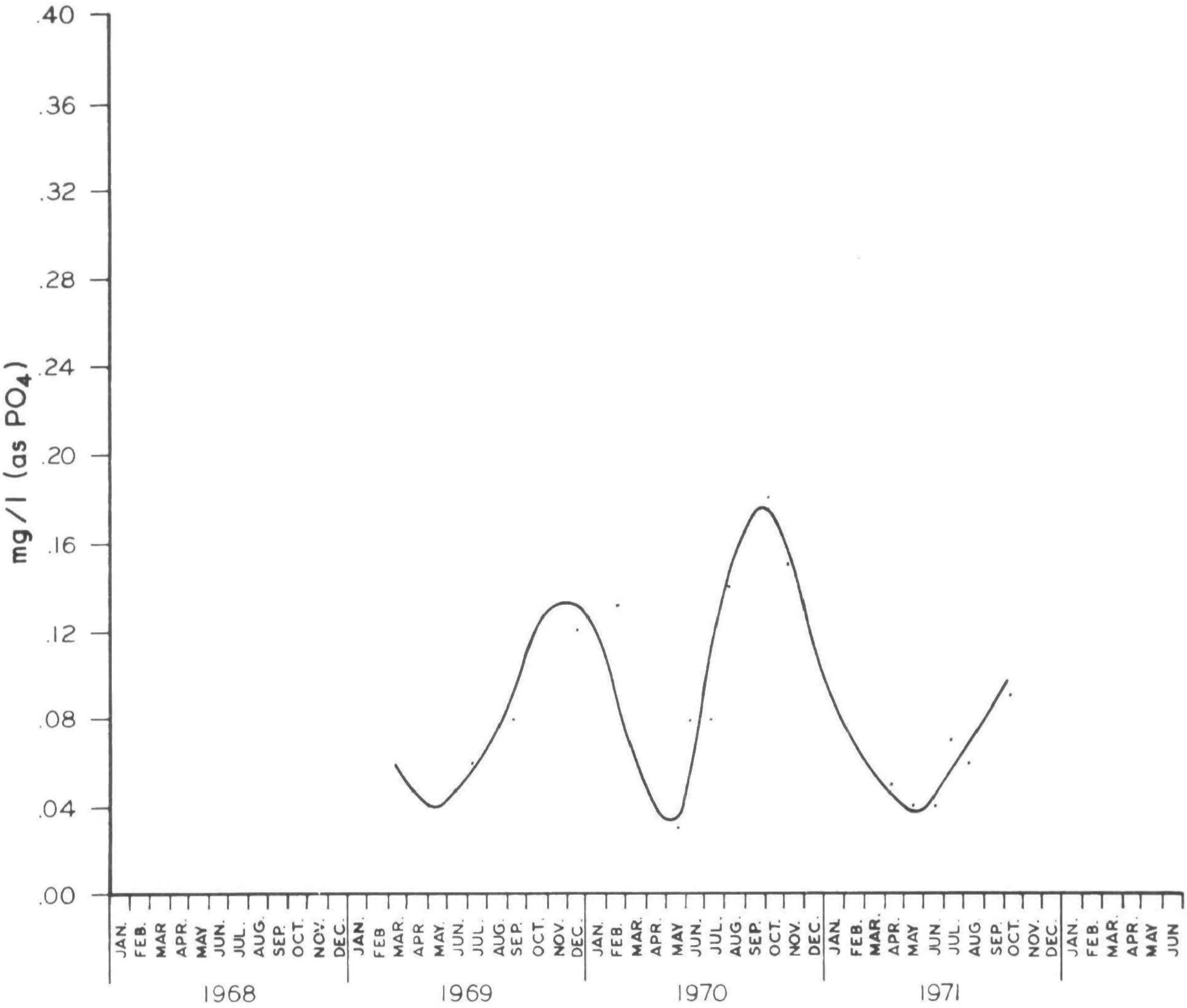
(AVERAGE DATA FOR ALL TRANSECTS)



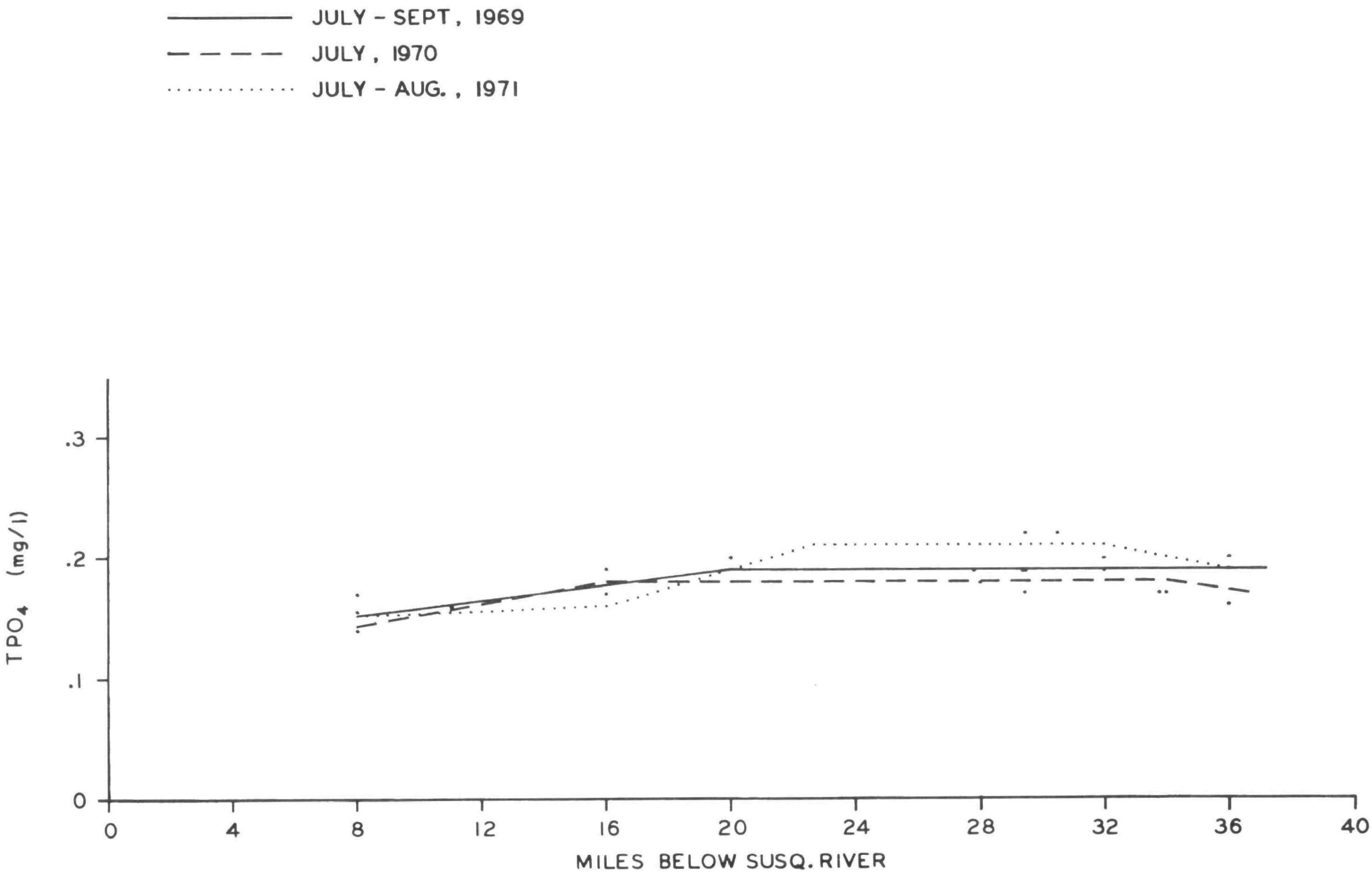
INORGANIC PHOSPHORUS CONCENTRATIONS

UPPER CHESAPEAKE BAY

(AVERAGE DATA FOR ALL TRANSECTS)



SPATIAL PHOSPHORUS DISTRIBUTIONS
UPPER CHESAPEAKE BAY

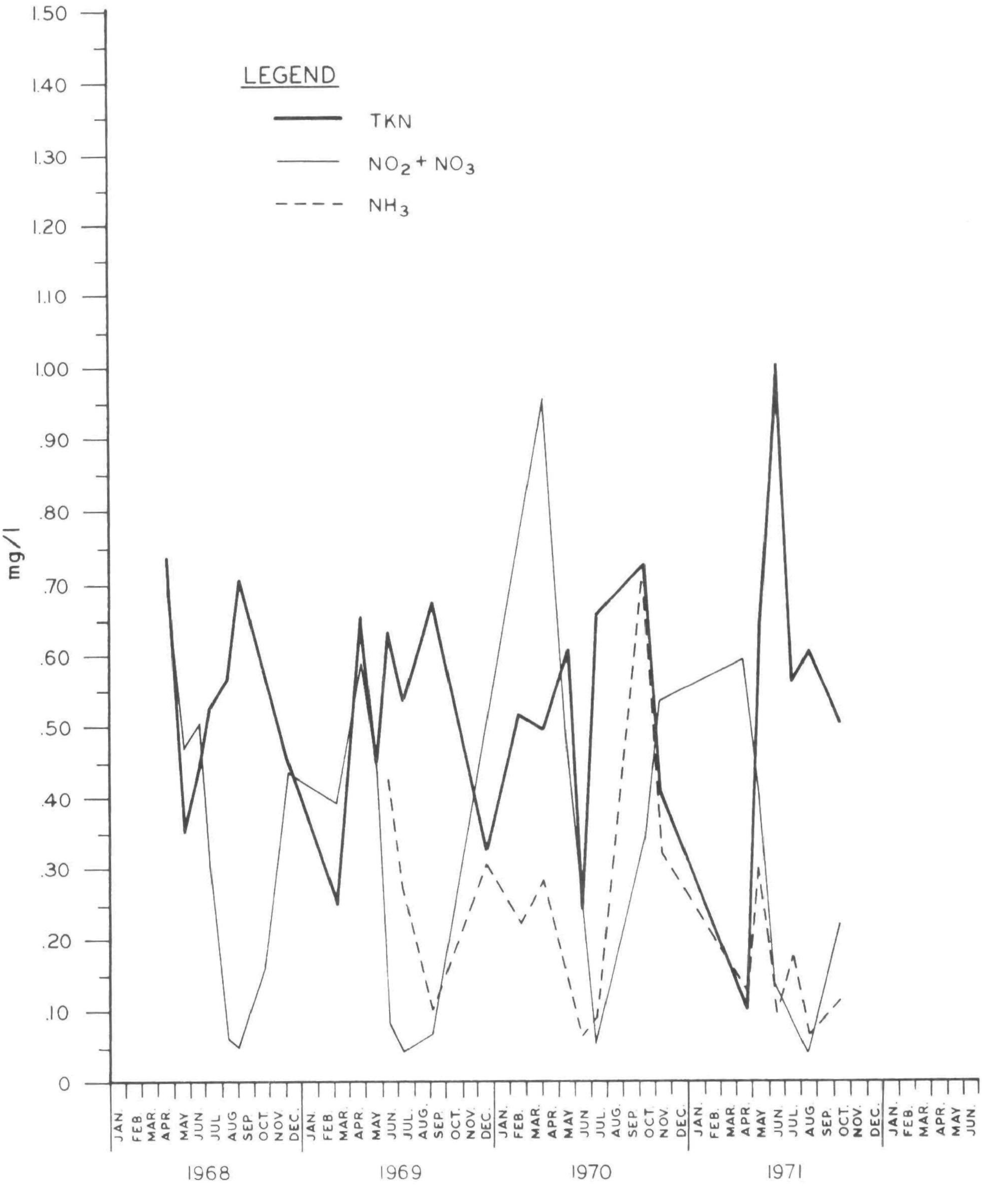


TEMPORAL NITROGEN DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT A

(AVERAGE DATA FOR TRANSECT)

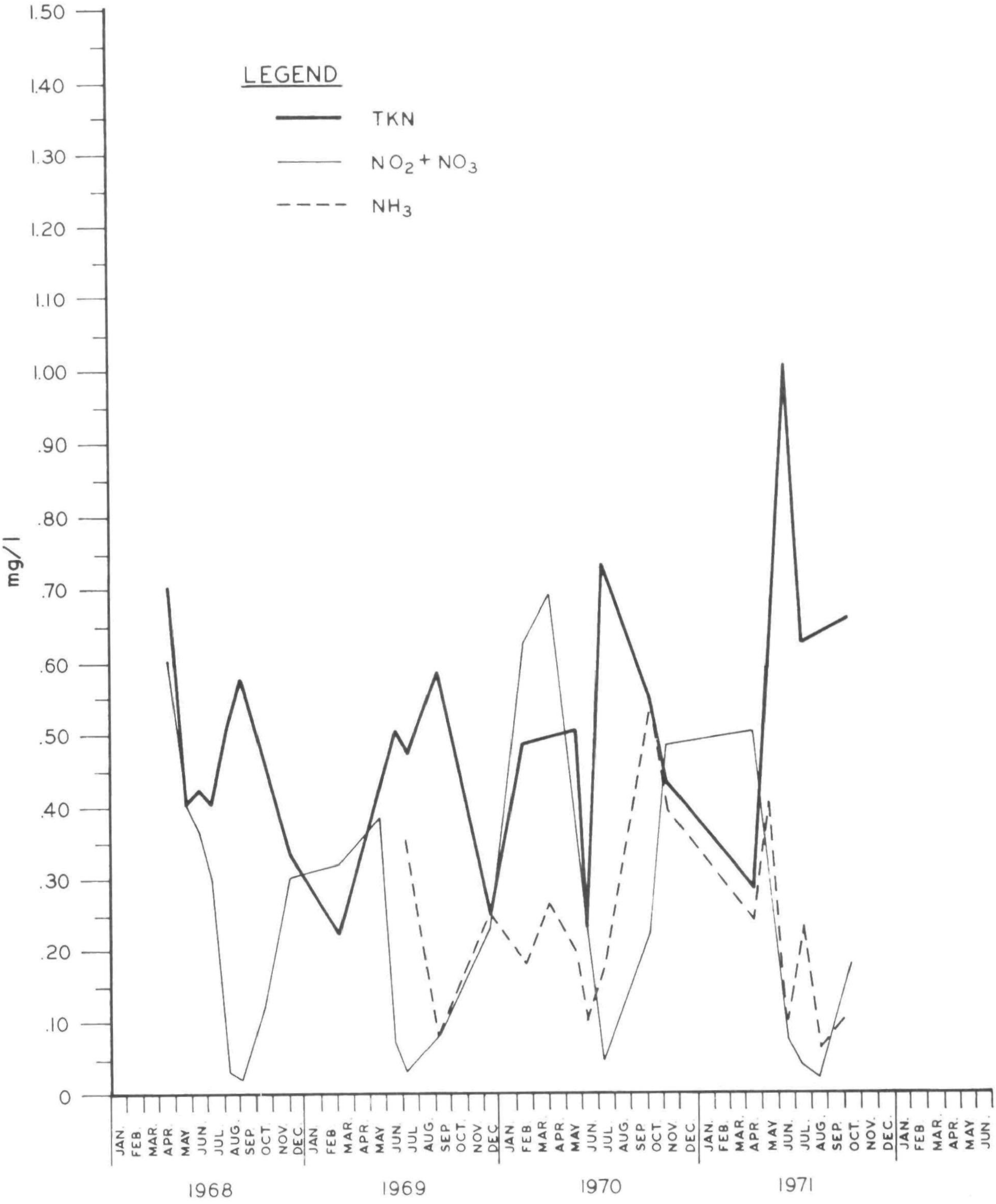


TEMPORAL NITROGEN DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT B

(AVERAGE DATA FOR TRANSECT)

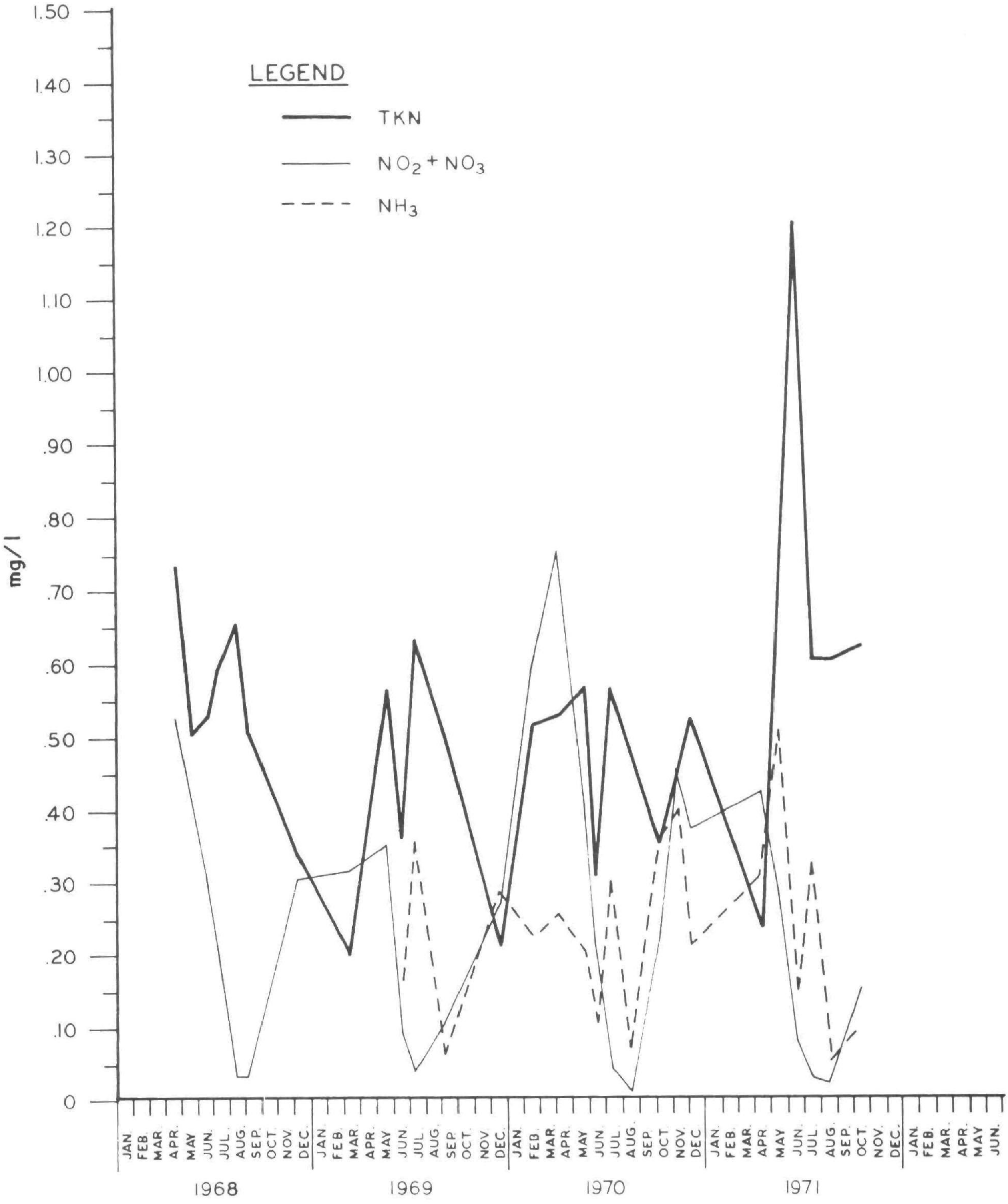


TEMPORAL NITROGEN DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT C

(AVERAGE DATA FOR TRANSECT)

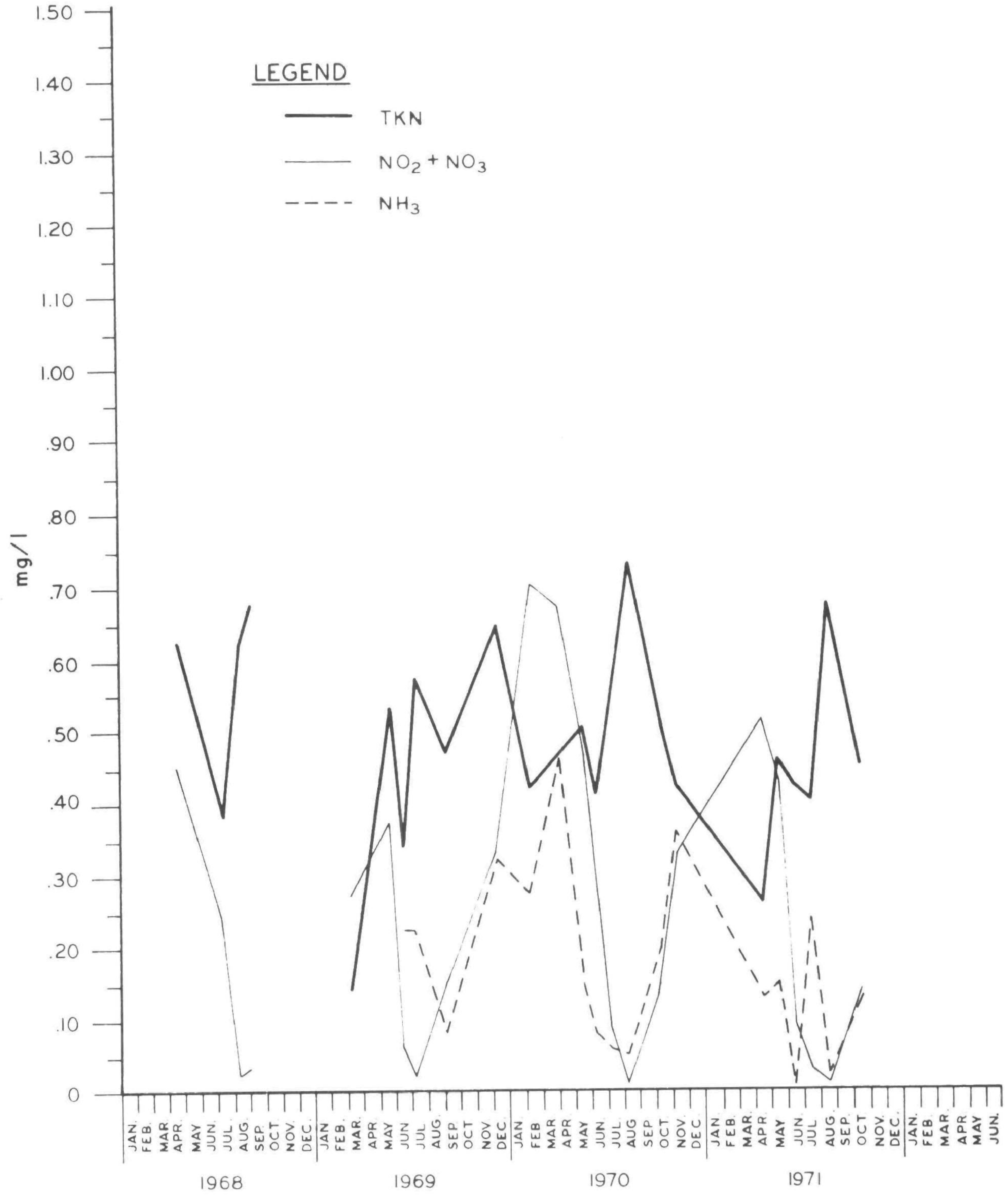


TEMPORAL NITROGEN DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT D

(AVERAGE DATA FOR TRANSECT)

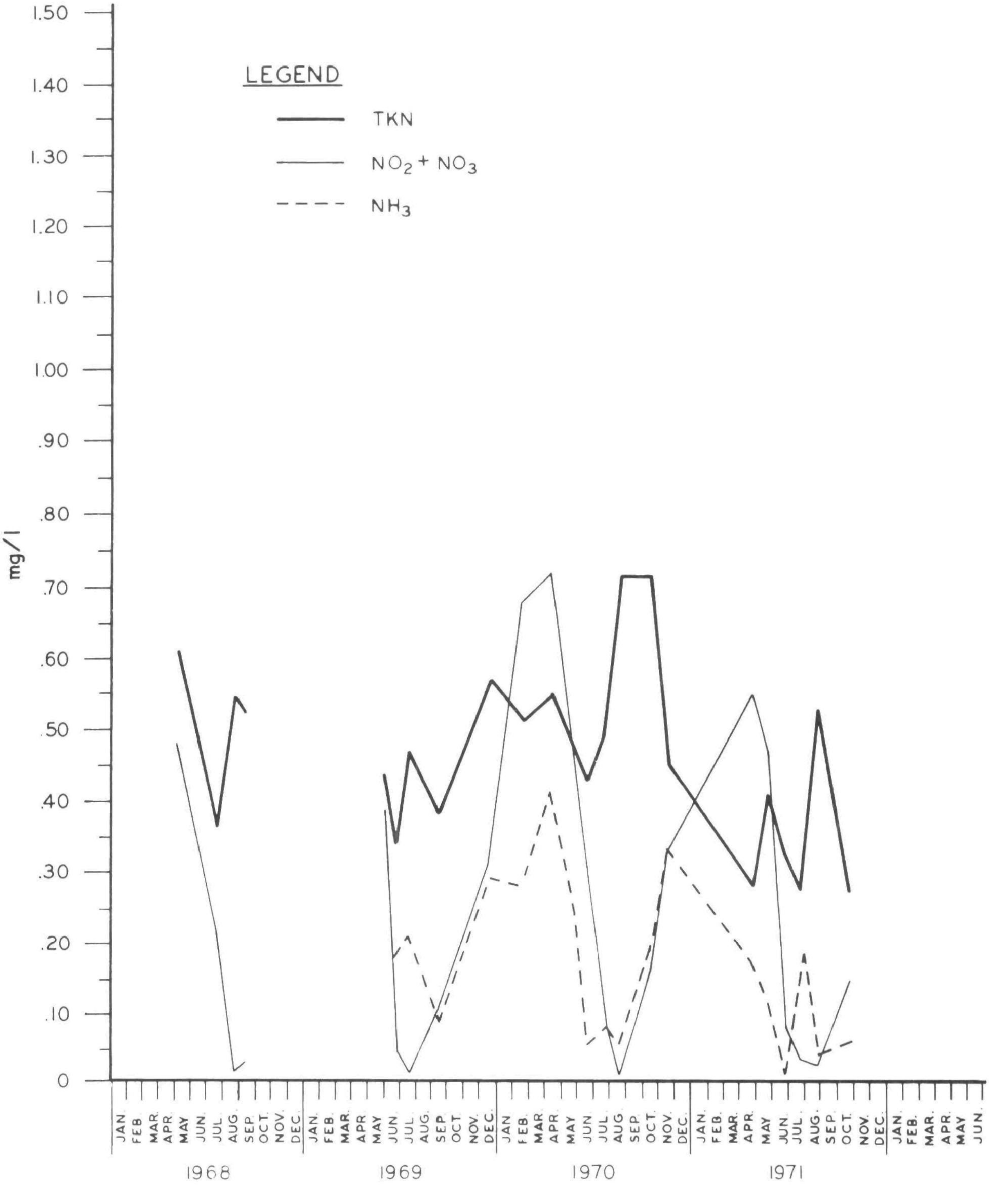


TEMPORAL NITROGEN DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT E

(AVERAGE DATA FOR TRANSECT)

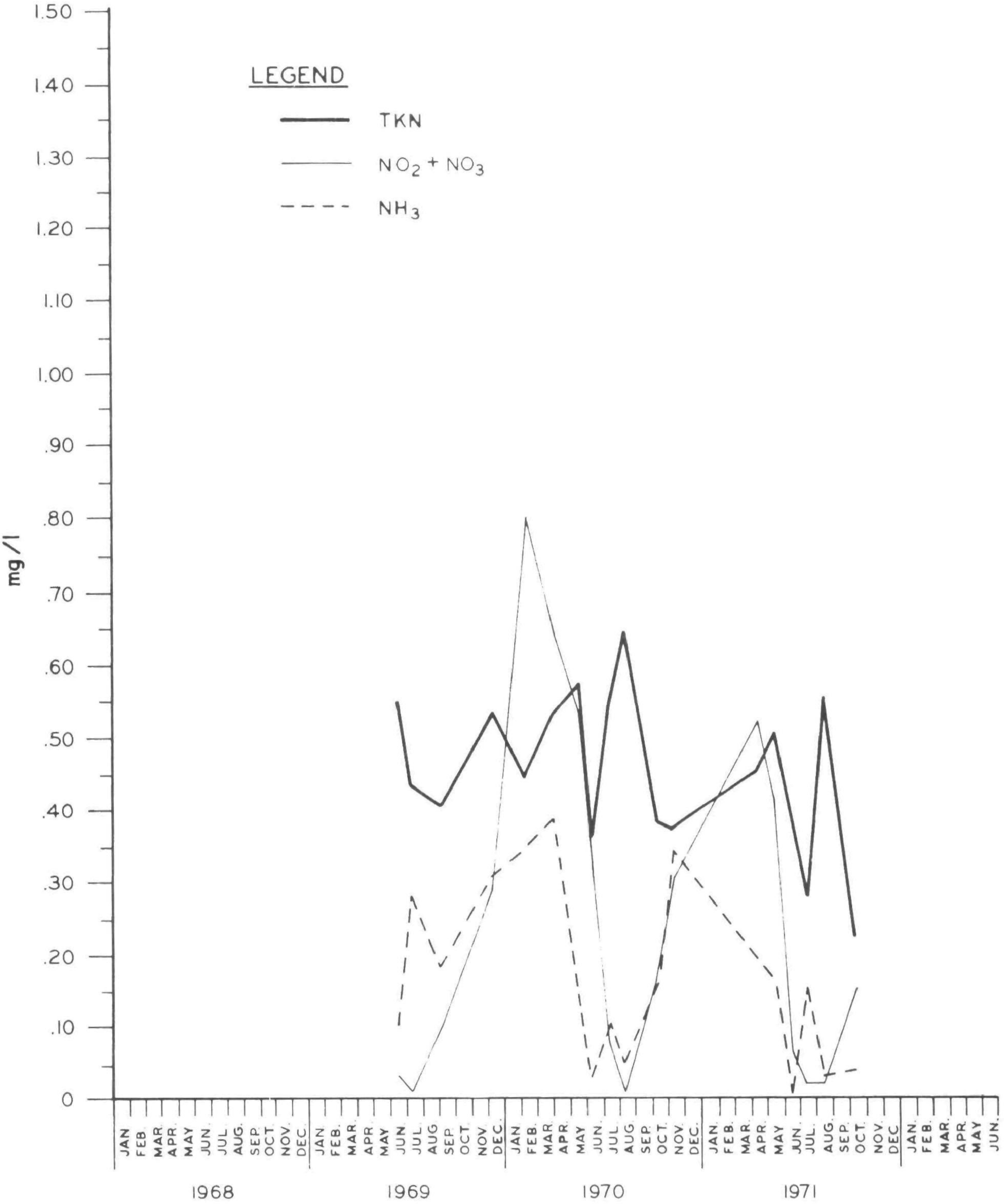


TEMPORAL NITROGEN DISTRIBUTION

UPPER CHESAPEAKE BAY

TRANSECT F

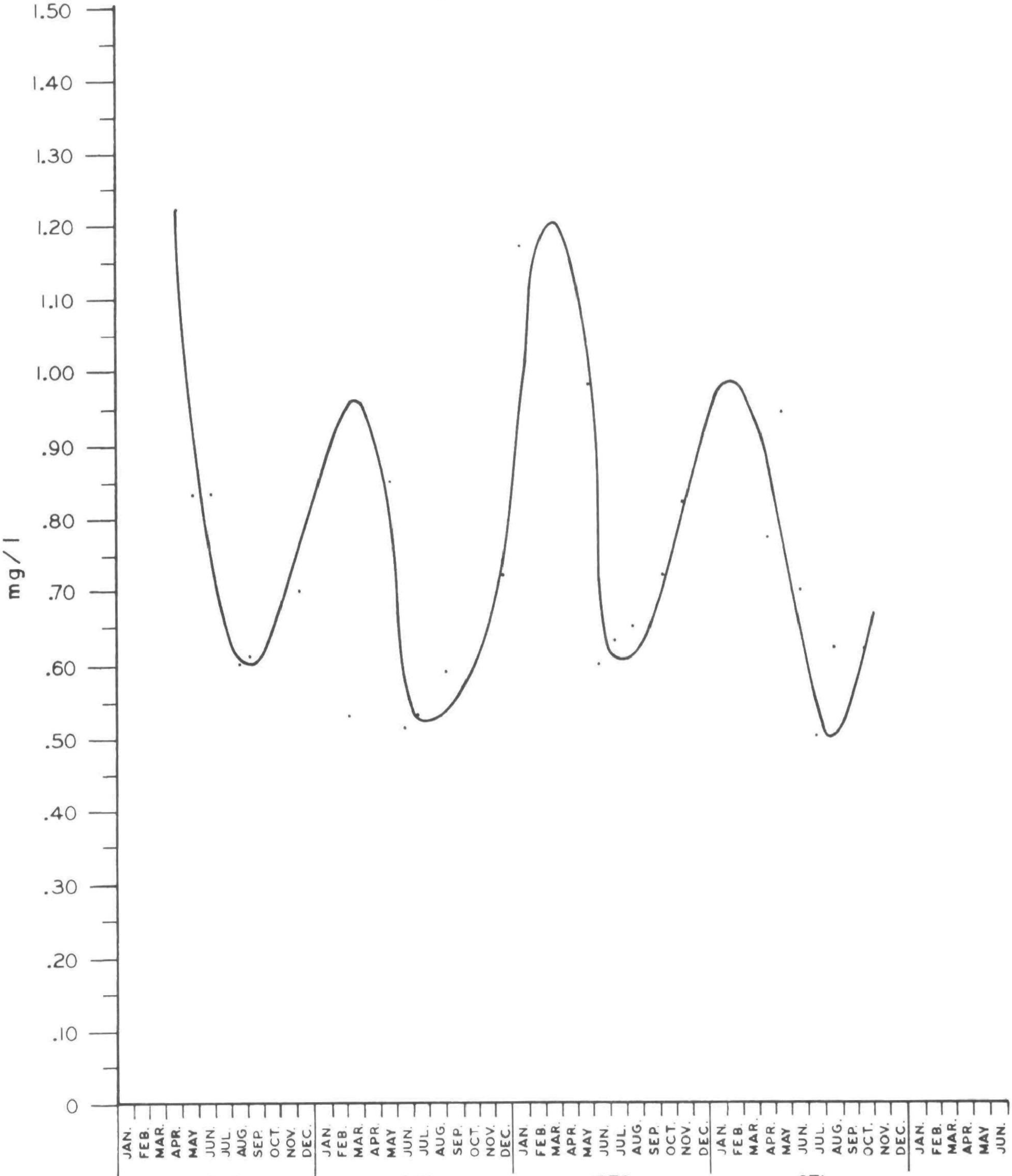
(AVERAGE DATA FOR TRANSECT)

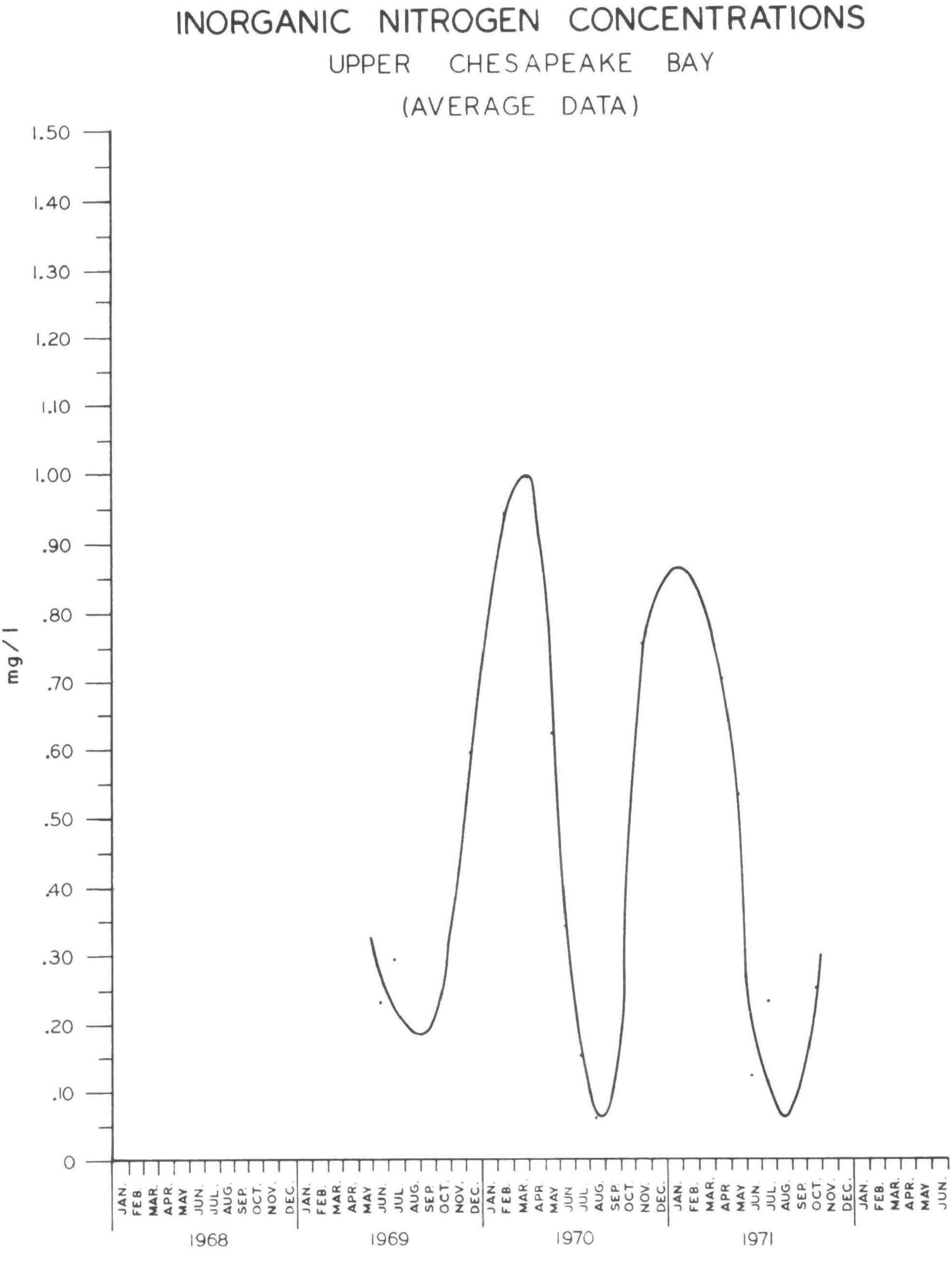


TOTAL NITROGEN CONCENTRATIONS

UPPER CHESAPEAKE BAY

(AVERAGE DATA)

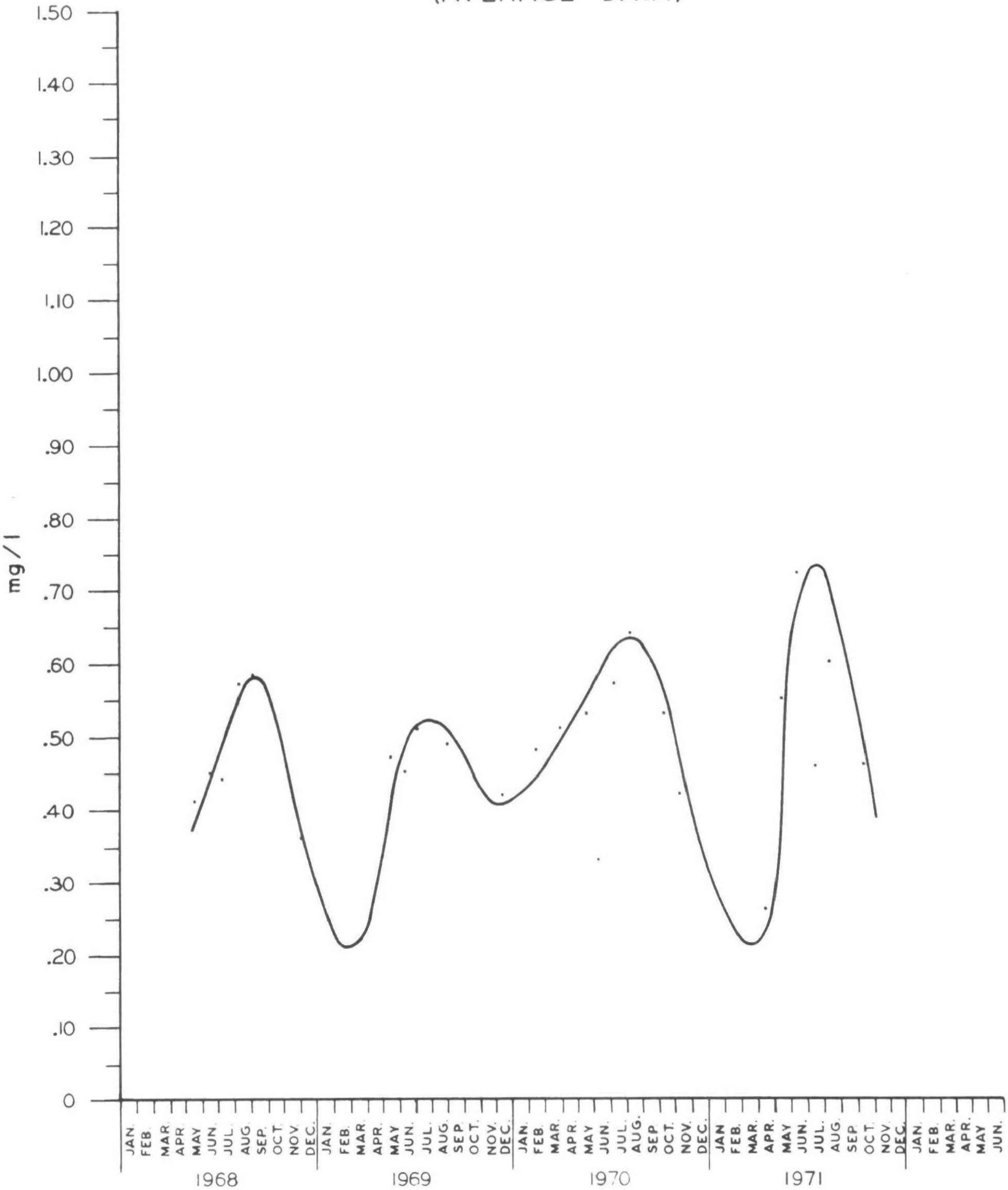



INORGANIC NITROGEN CONCENTRATIONS
UPPER CHESAPEAKE BAY
(AVERAGE DATA)
mg/l
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
1968
1969
1970
1971

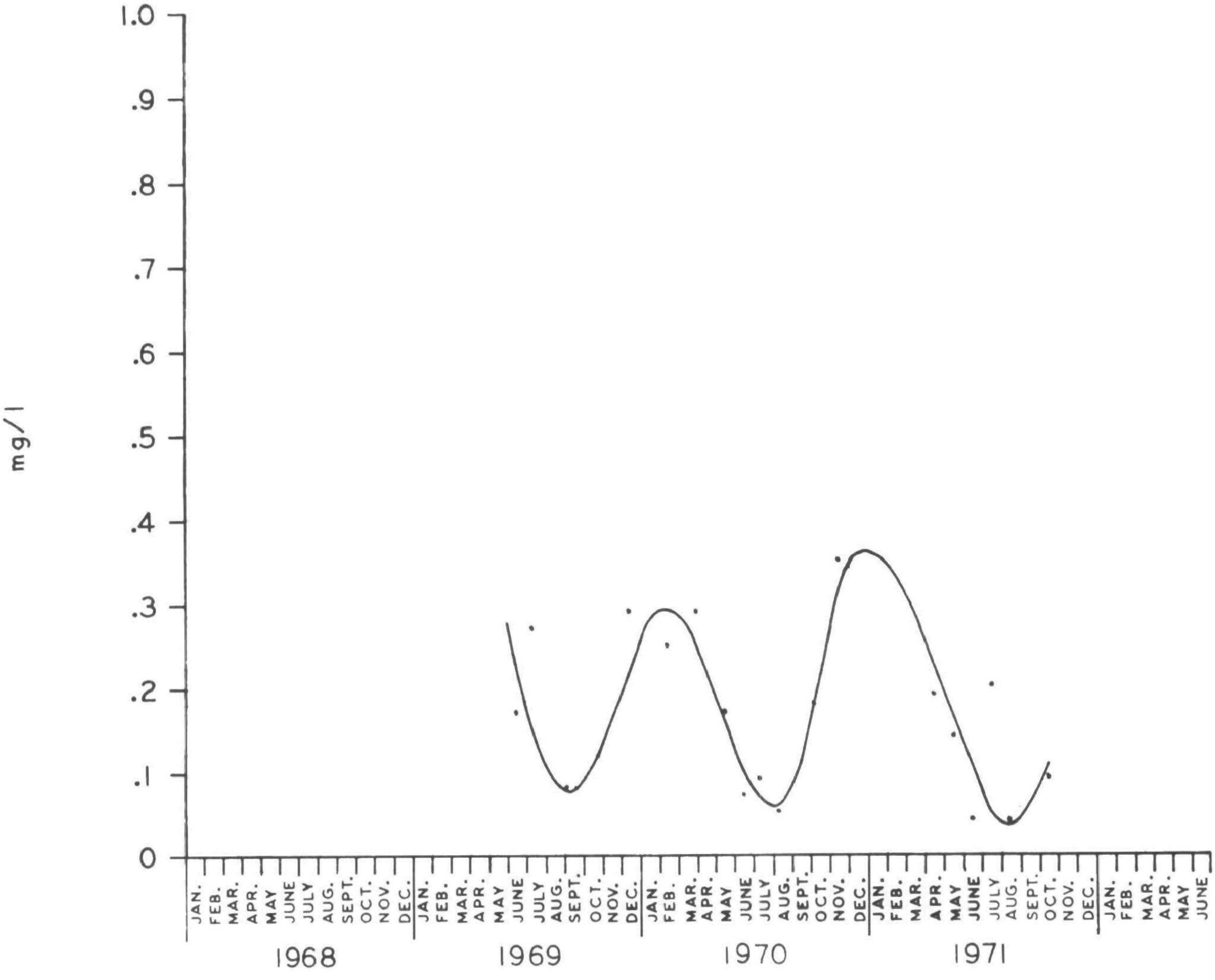
TOTAL KJELDAHL NITROGEN CONCENTRATIONS

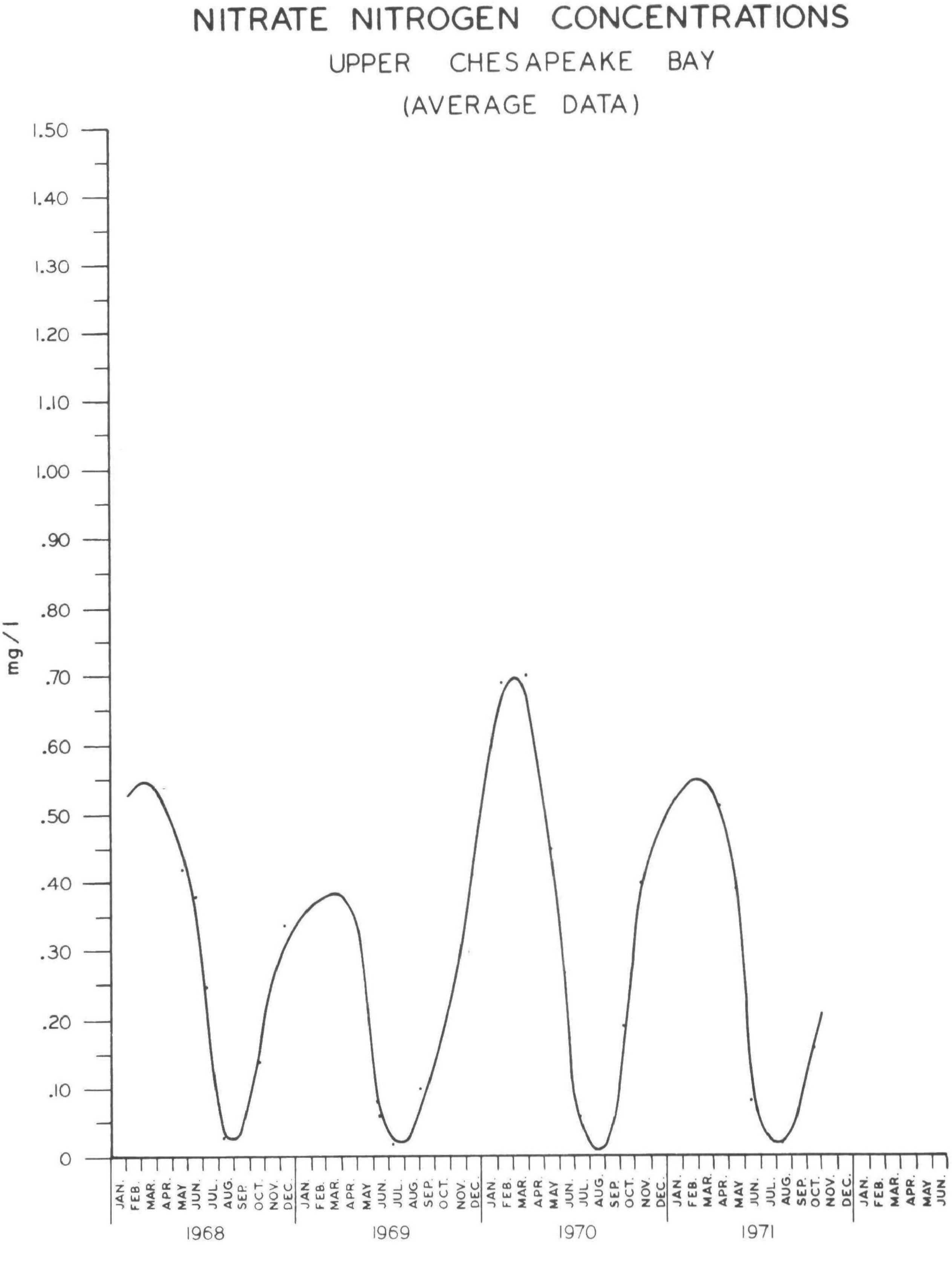
UPPER CHESAPEAKE BAY

(AVERAGE DATA)

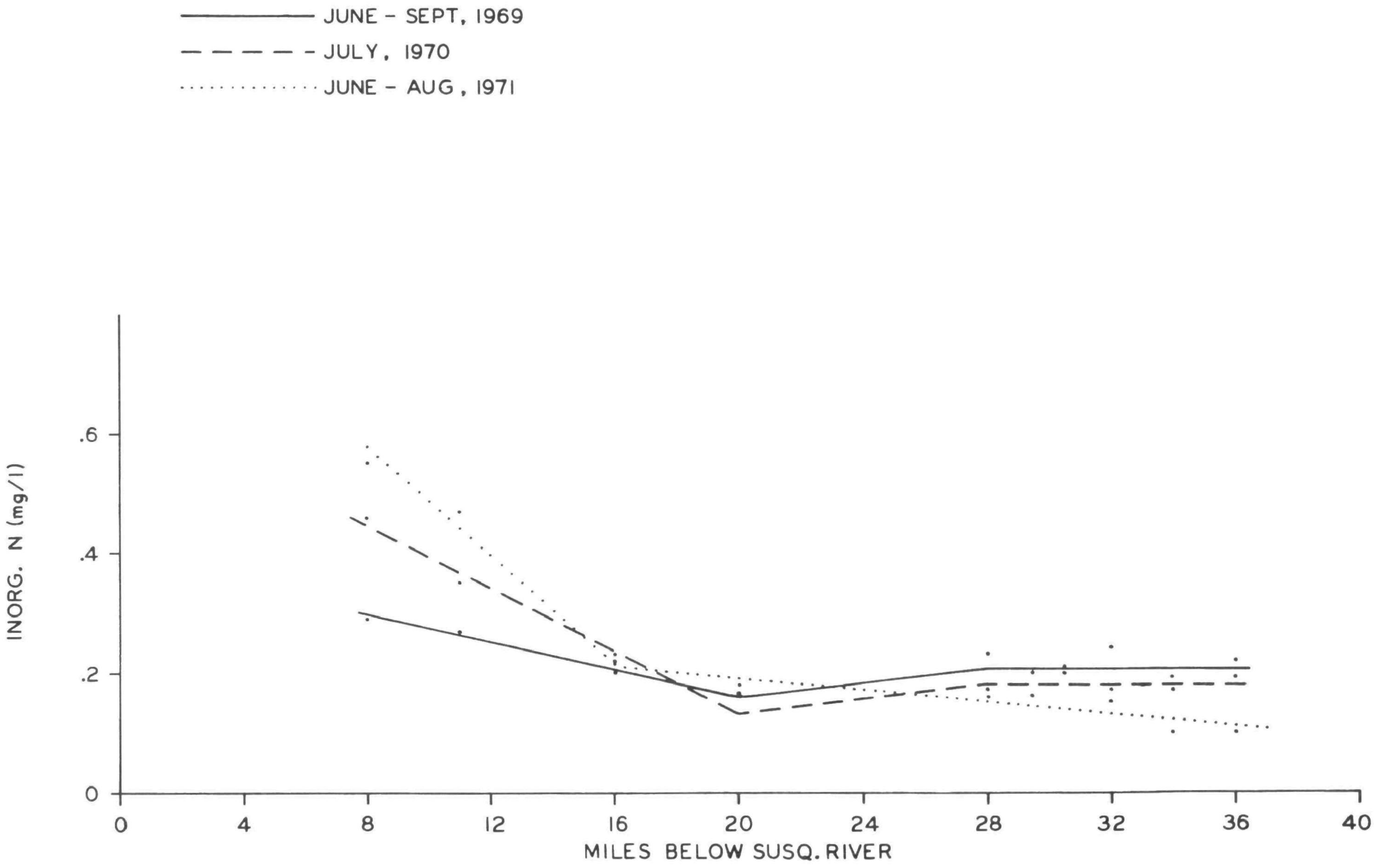


AMMONIA NITROGEN CONCENTRATIONS
UPPER CHESAPEAKE BAY
(AVERAGE DATA)

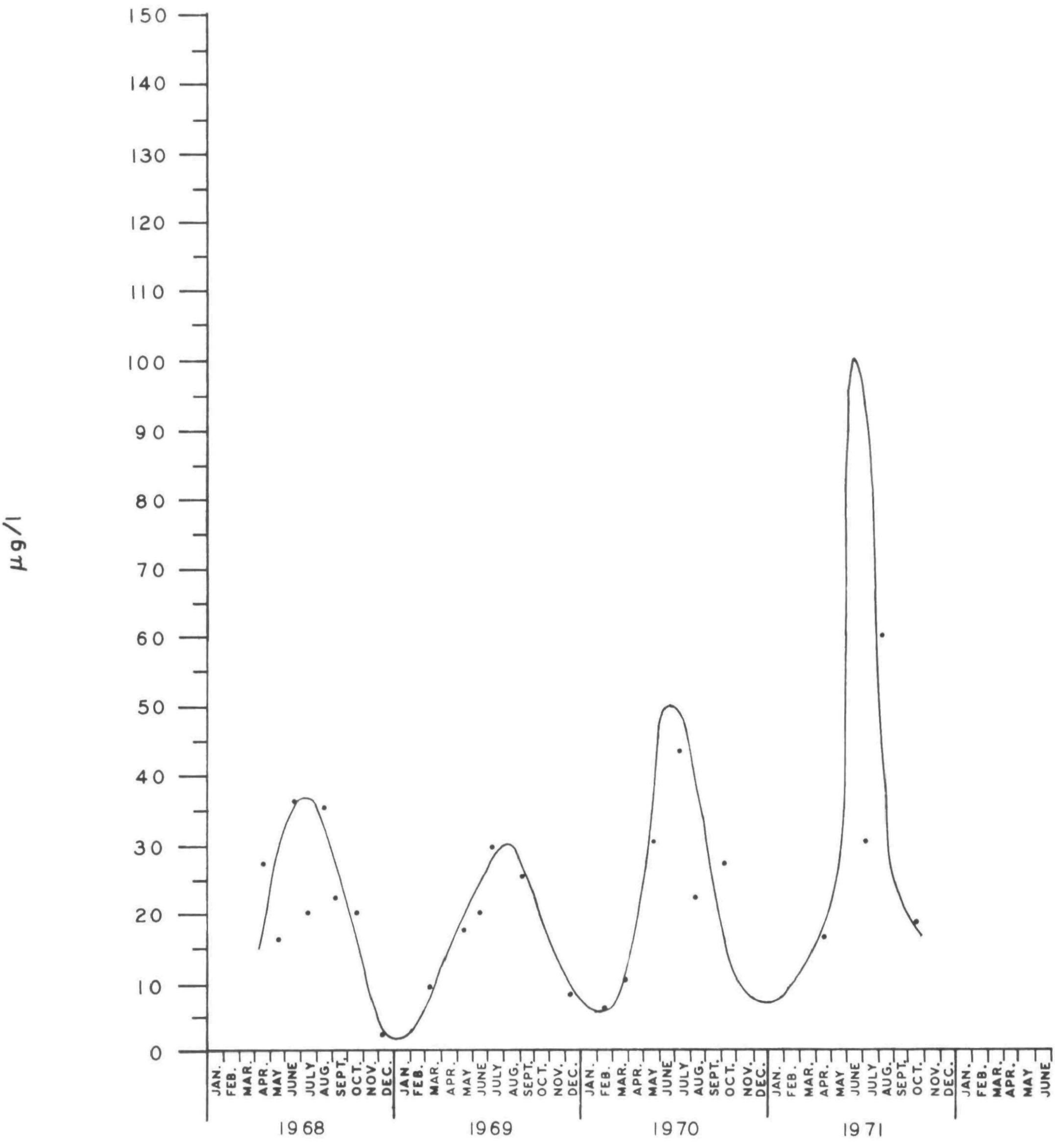


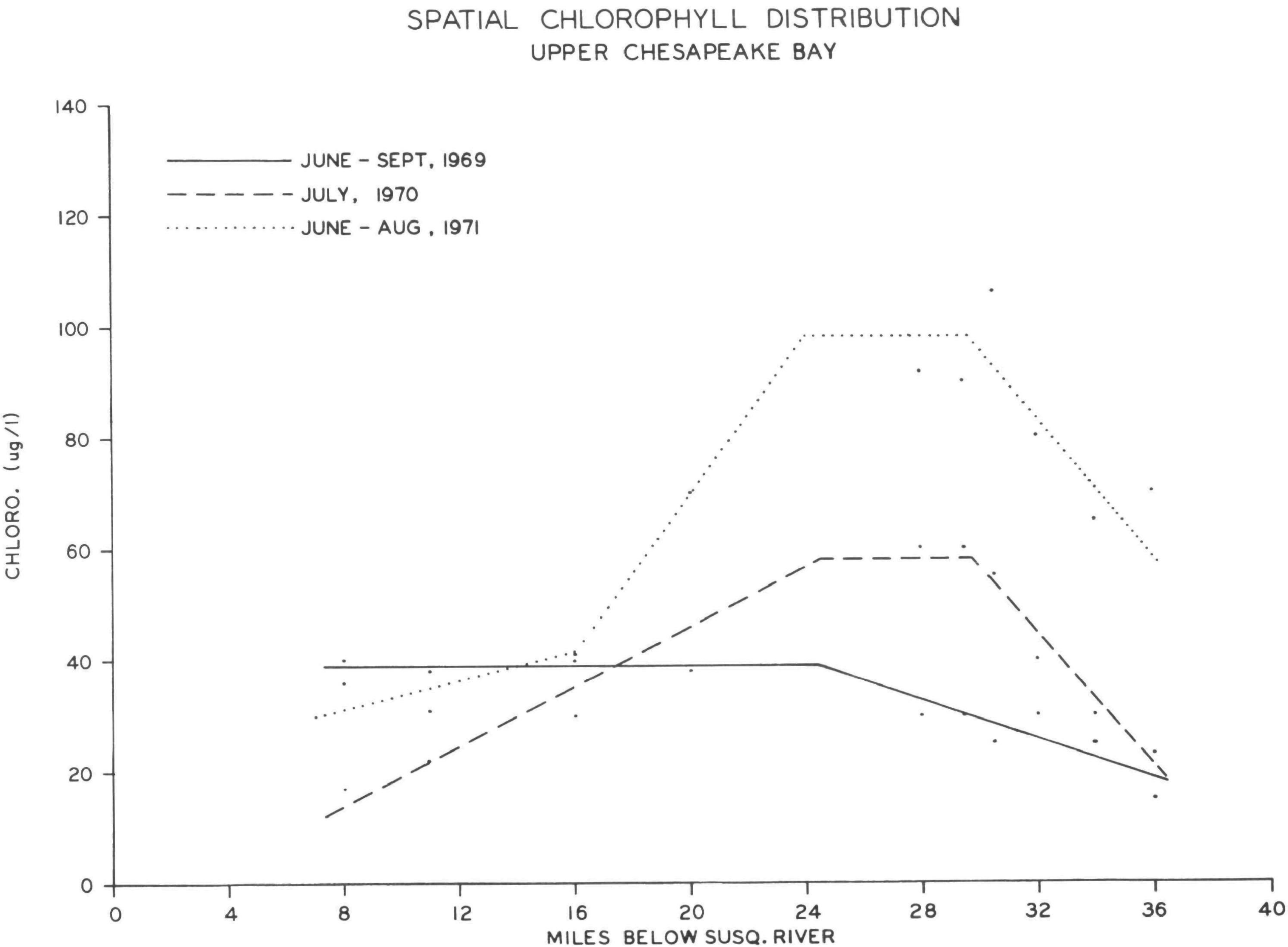

NITRATE NITROGEN CONCENTRATIONS
UPPER CHESAPEAKE BAY
(AVERAGE DATA)
mg / l
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
1968
1969
1970
1971

SPATIAL INORGANIC NITROGEN DISTRIBUTION
UPPER CHESAPEAKE BAY



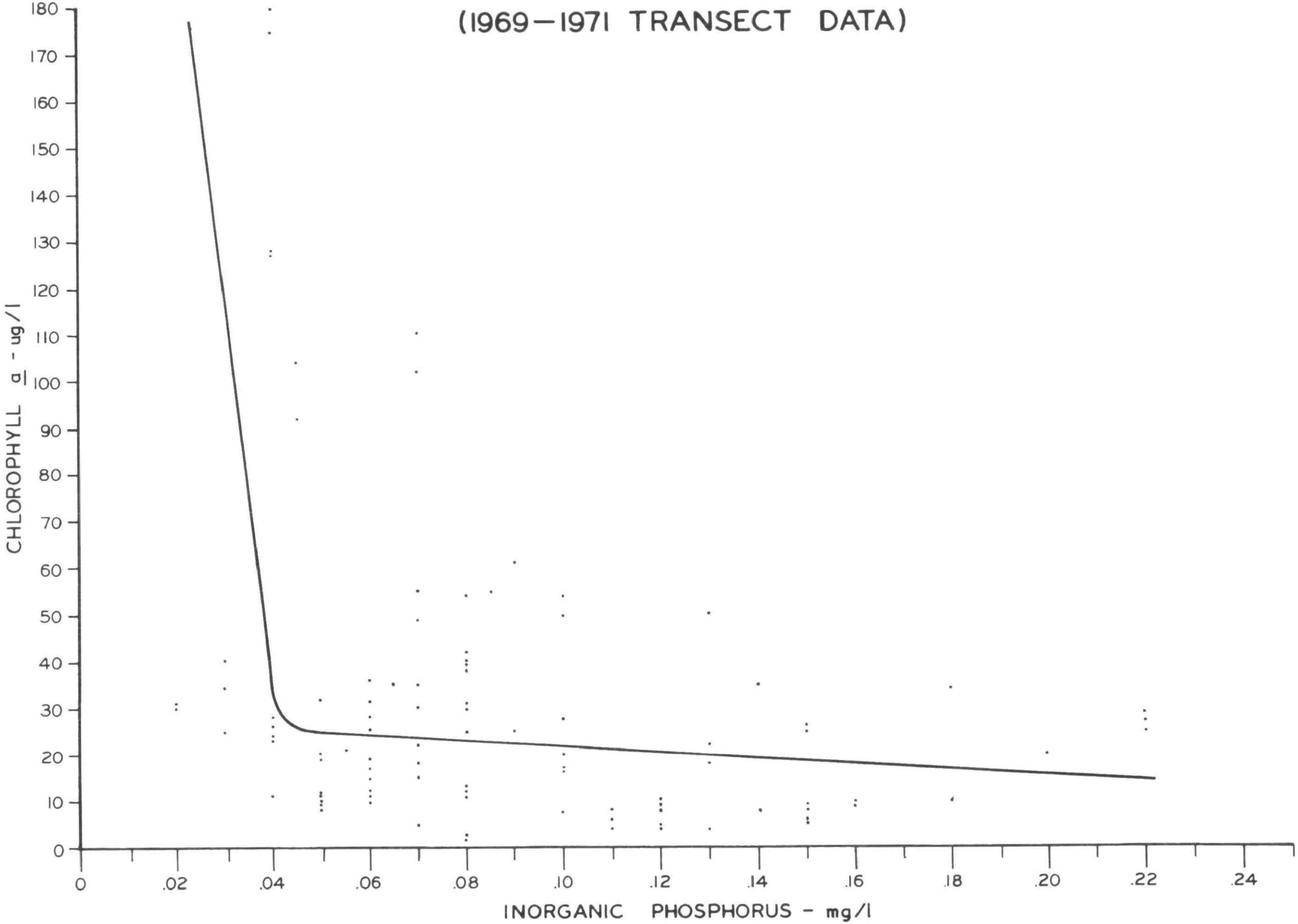
CHLOROPHYLL a CONCENTRATIONS

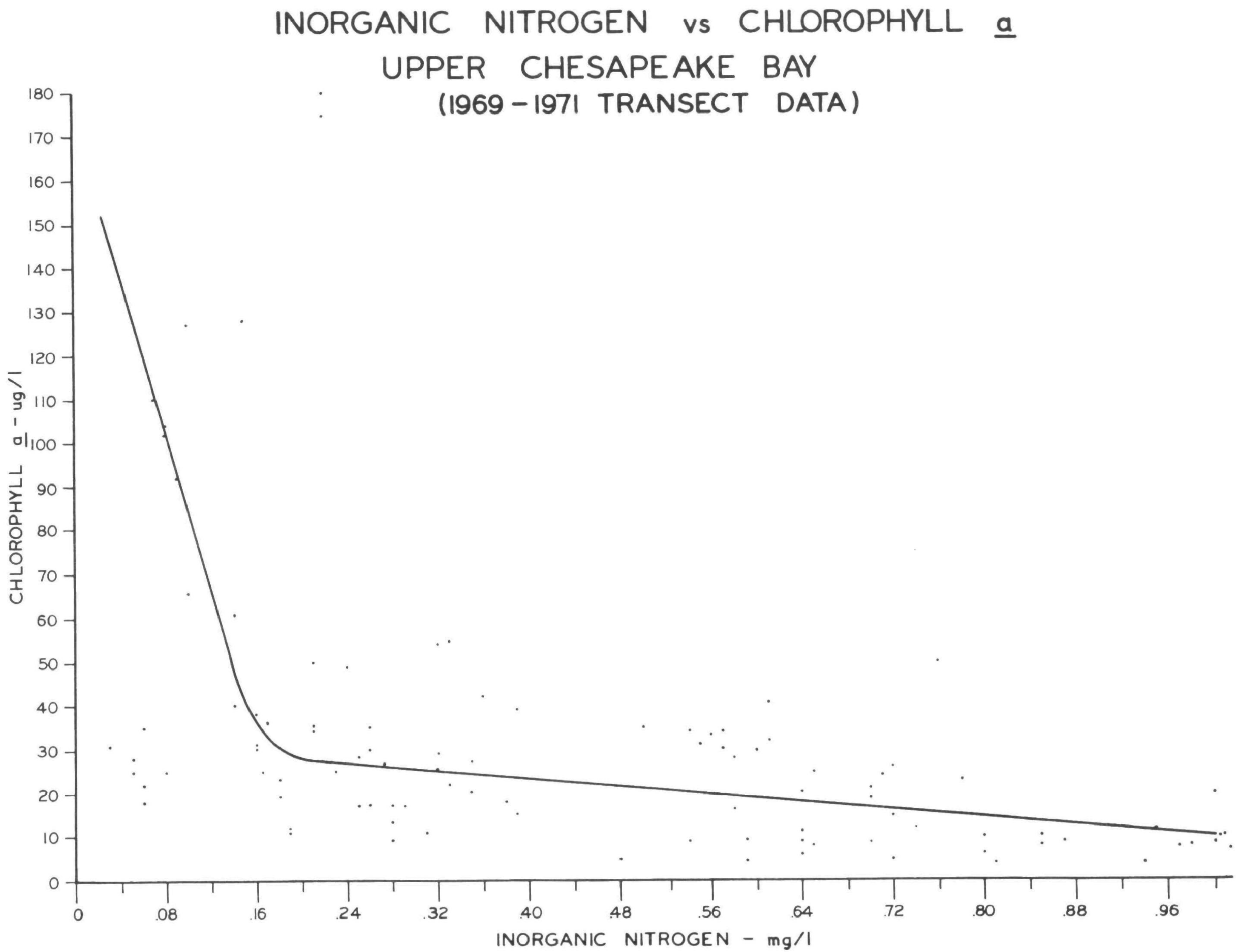




SPATIAL CHLOROPHYLL DISTRIBUTION
UPPER CHESAPEAKE BAY
JUNE - SEPT, 1969
JULY, 1970
JUNE - AUG, 1971
CHLORO. (ug/l)
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
28
32
36
40
MILES BELOW SUSQ. RIVER

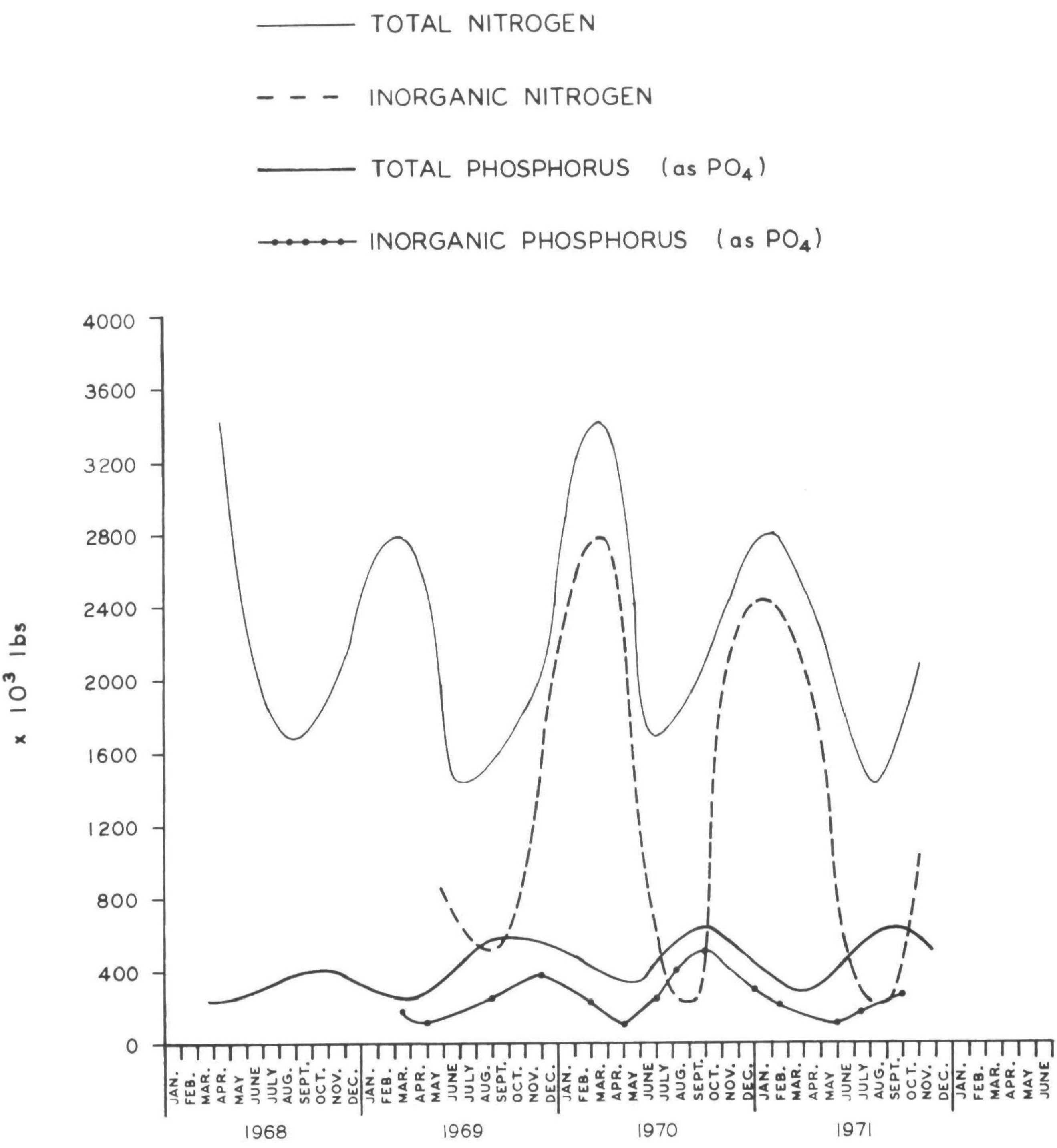
INORGANIC PHOSPHORUS vs CHLOROPHYLL a
UPPER CHESAPEAKE BAY
(1969–1971 TRANSECT DATA)

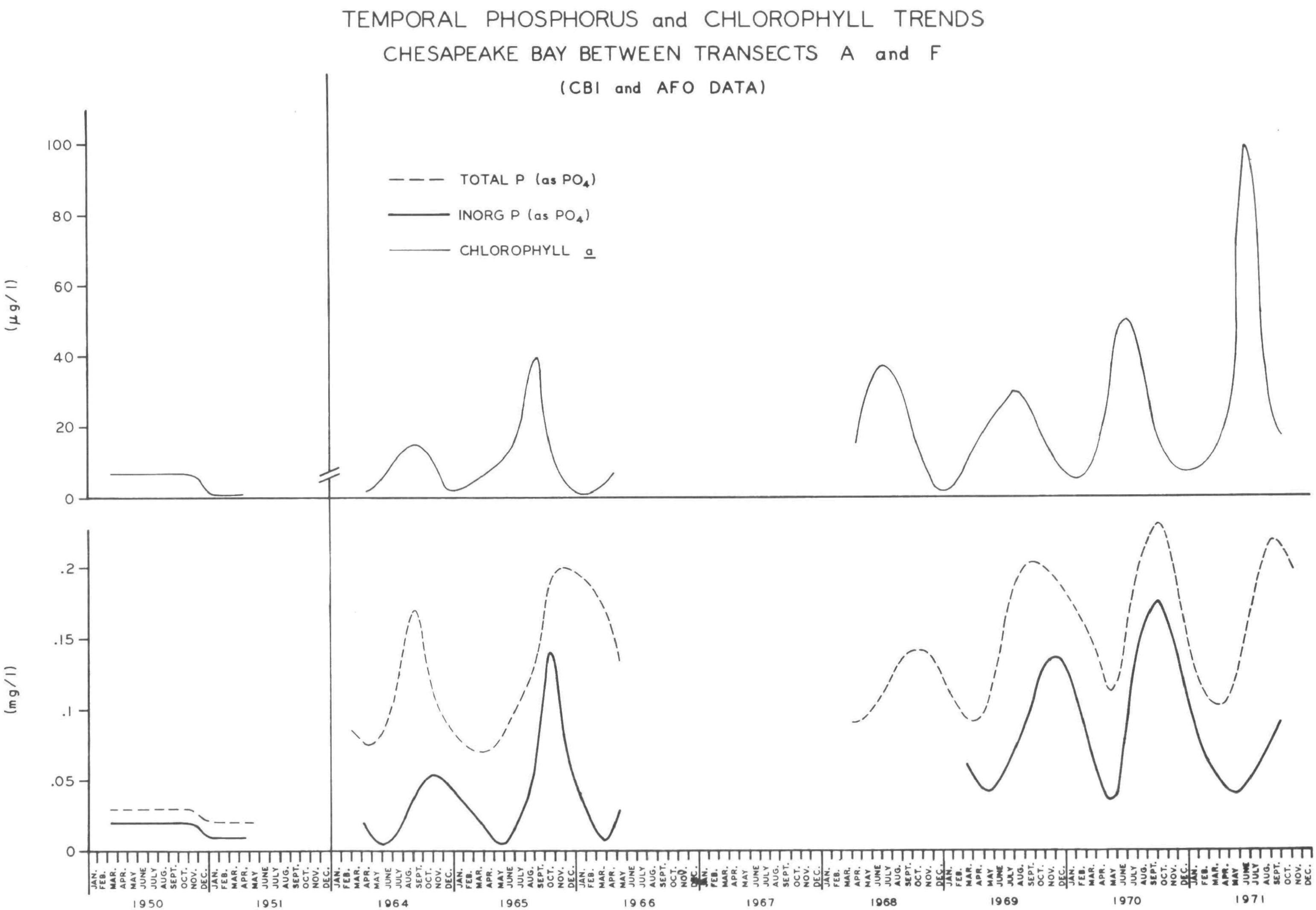




INORGANIC NITROGEN vs CHLOROPHYLL a
UPPER CHESAPEAKE BAY
(1969 - 1971 TRANSECT DATA)
CHLOROPHYLL a - ug/l
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
0
.08
.16
.24
.32
.40
.48
.56
.64
.72
.80
.88
.96
INORGANIC NITROGEN - mg/l

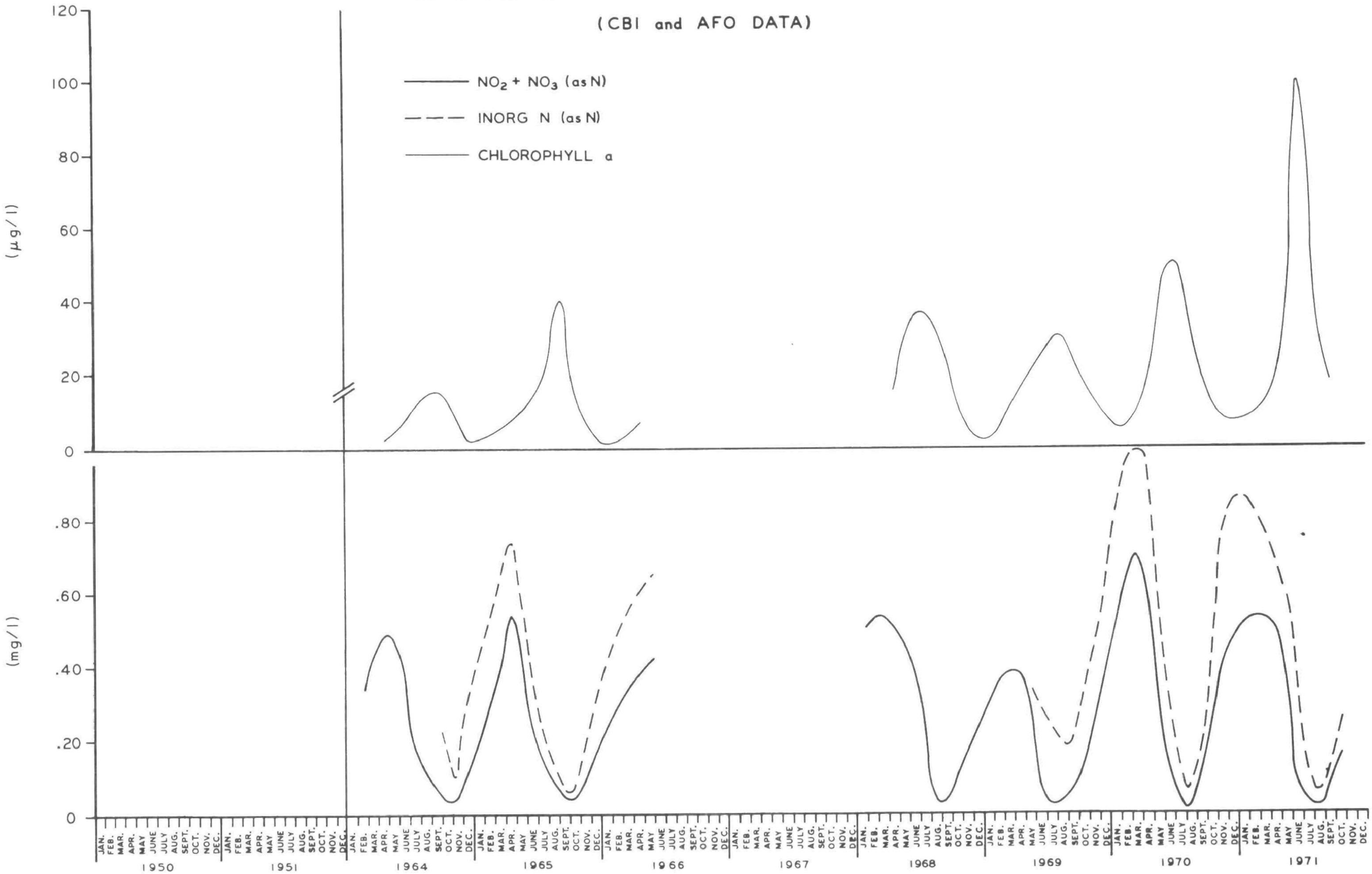
PHOSPHORUS AND NITROGEN LOADINGS
UPPER CHESAPEAKE BAY
BETWEEN TRANSECTS A & F
(volume = 45×10^{9} ft^{3})

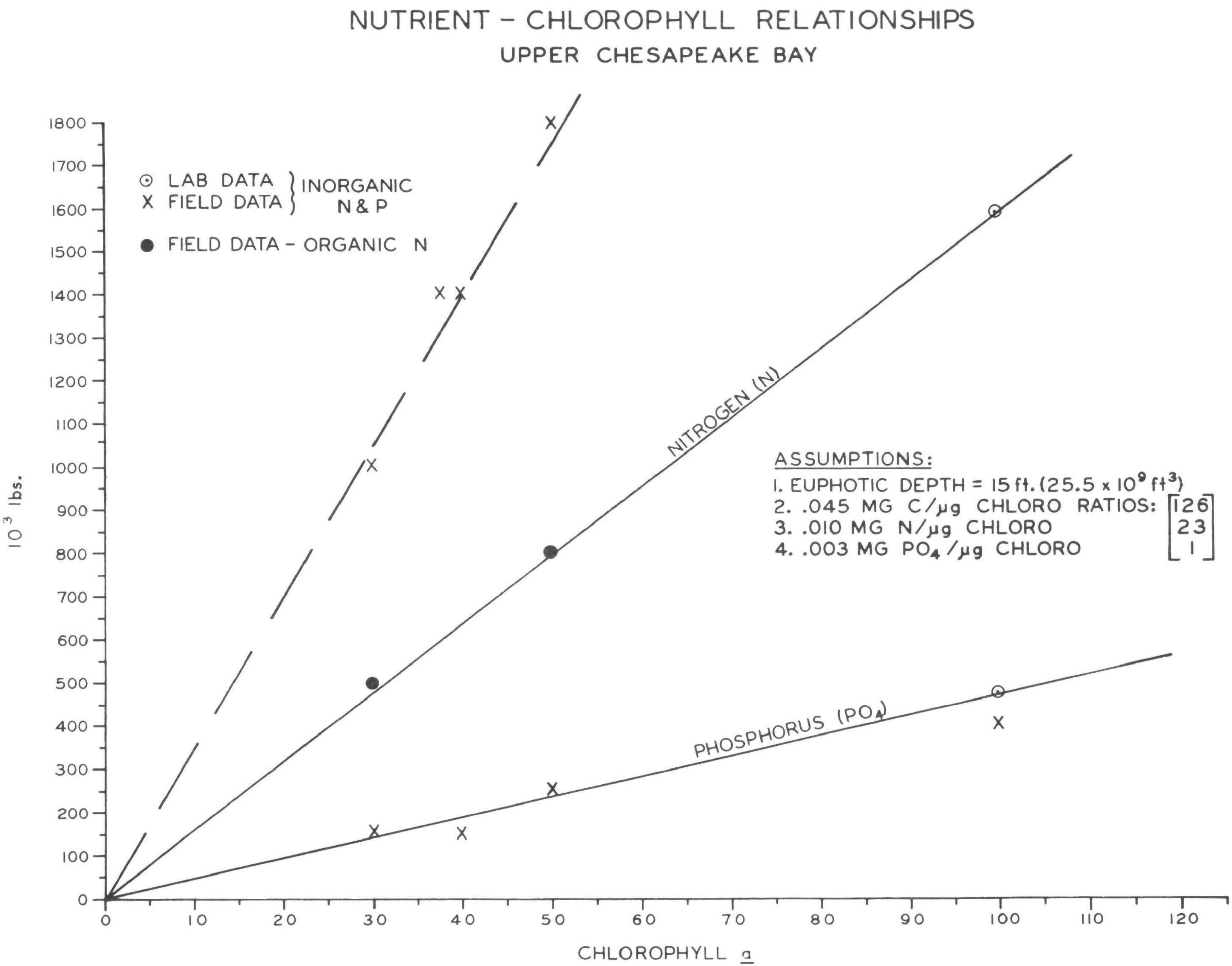




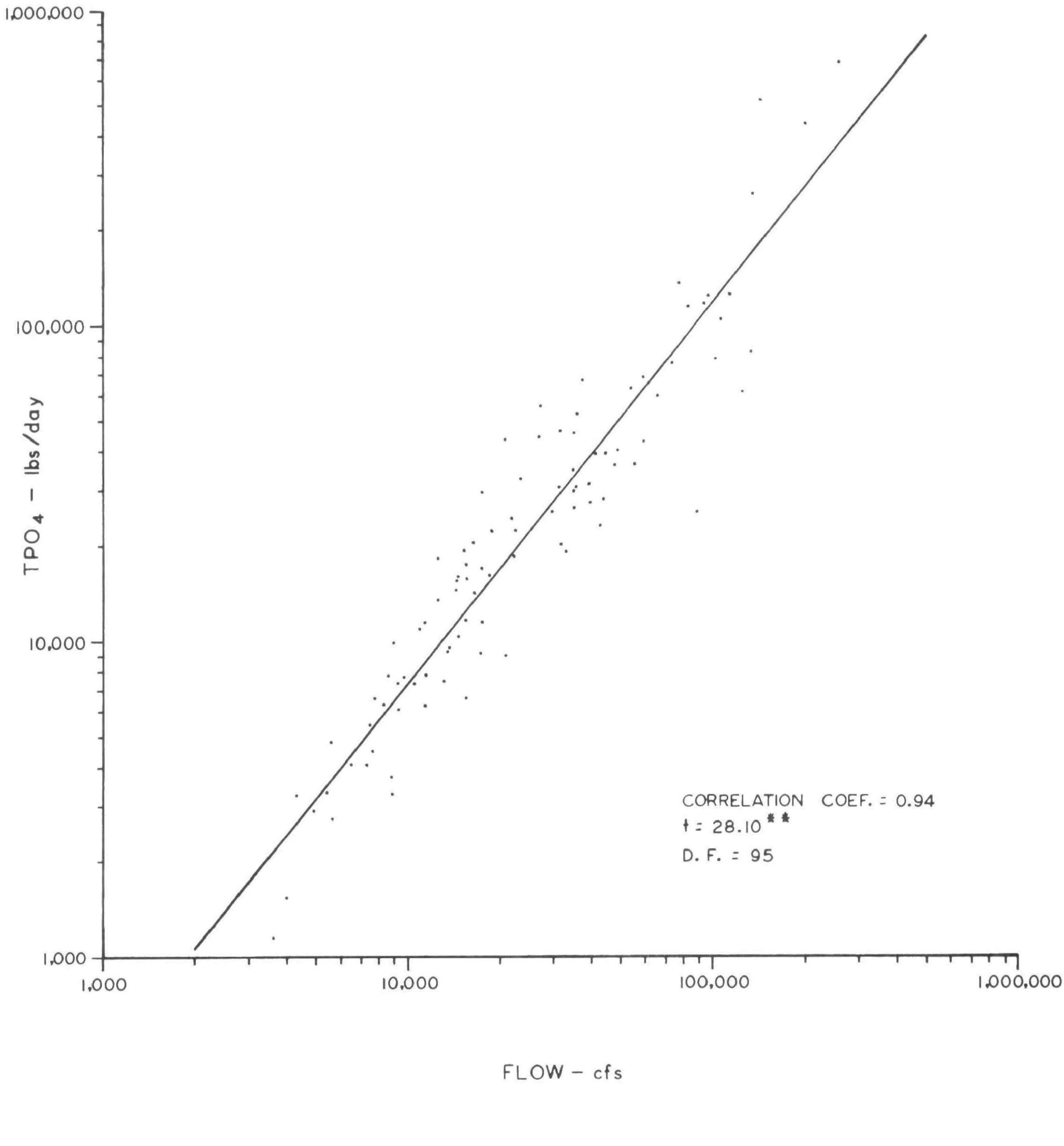
TEMPORAL PHOSPHORUS and CHLOROPHYLL TRENDS
CHESAPEAKE BAY BETWEEN TRANSECTS A and F
(CBI and AFO DATA)
TOTAL P (as PO4)
INORG P (as PO4)
CHLOROPHYLL a
(μg/l)
(mg/l)
0
20
40
60
80
100
0
.05
.1
.15
.2
1950
1951
1964
1965
1966
1967
1968
1969
1970
1971

TEMPORAL NITROGEN and CHLOROPHYLL TRENDS
CHESAPEAKE BAY BETWEEN TRANSECTS A and F
(CBI and AFO DATA)

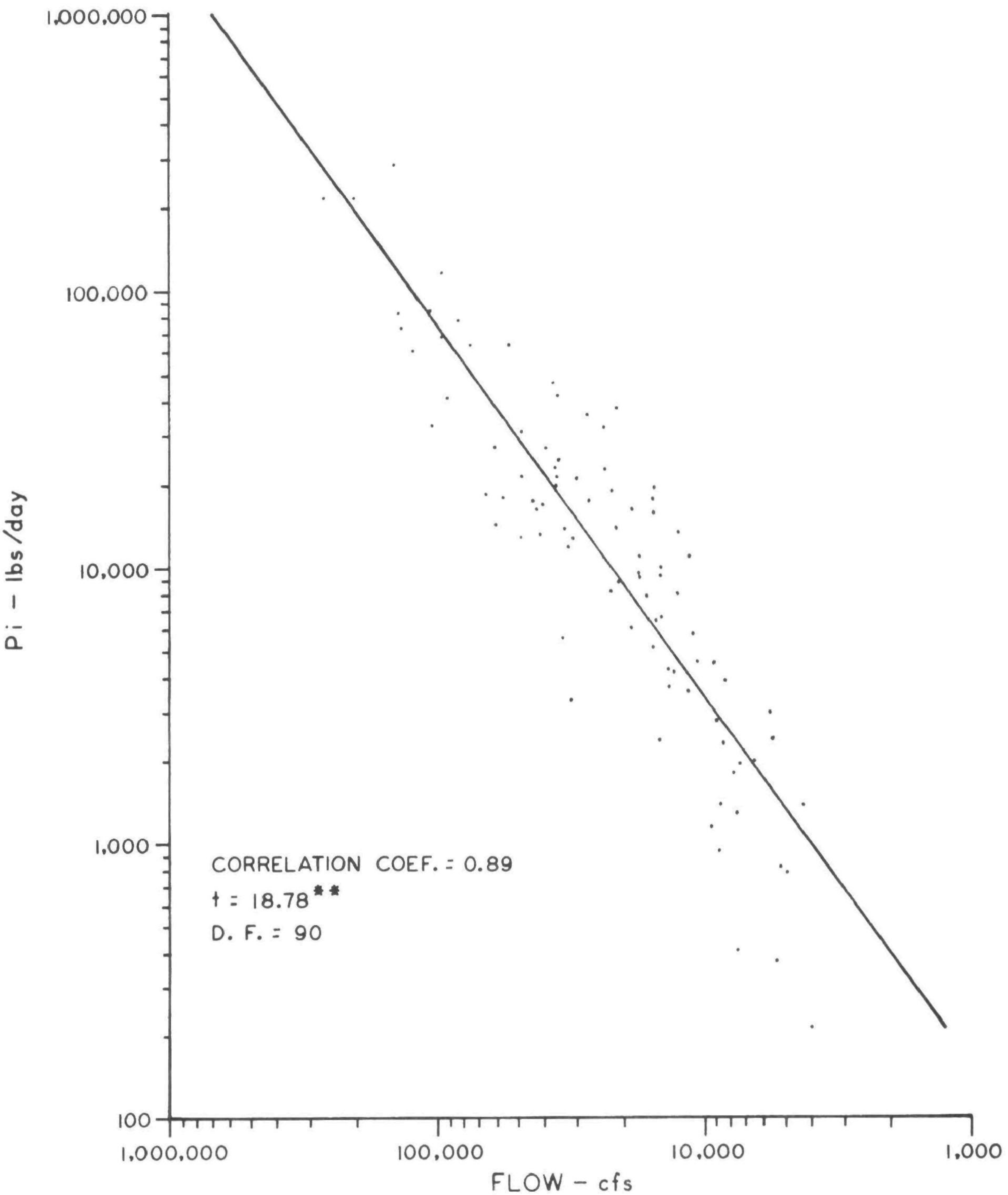



NUTRIENT - CHLOROPHYLL RELATIONSHIPS
UPPER CHESAPEAKE BAY
LAB DATA
FIELD DATA
INORGANIC N & P
FIELD DATA - ORGANIC N
NITROGEN (N)
PHOSPHORUS (PO4)
ASSUMPTIONS:
1. EUPHOTIC DEPTH = 15 ft. (25.5 x 10^9 ft^3)
2. .045 MG C/μg CHLORO RATIOS: 126
3. .010 MG N/μg CHLORO 23
4. .003 MG PO4/μg CHLORO 1
10^3 lbs.
CHLOROPHYLL a
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
10
20
30
40
50
60
70
80
90
100
110
120

REGRESSION ANALYSIS
TOTAL PHOSPHORUS LOAD vs FLOW
SUSQUEHANNA RIVER at CONOWINGO
(1969-72 DATA)



REGRESSION ANALYSIS
INORGANIC PHOSPHORUS LOAD vs FLOW
SUSQUEHANNA RIVER at CONOWINGO
(1969–72 DATA)

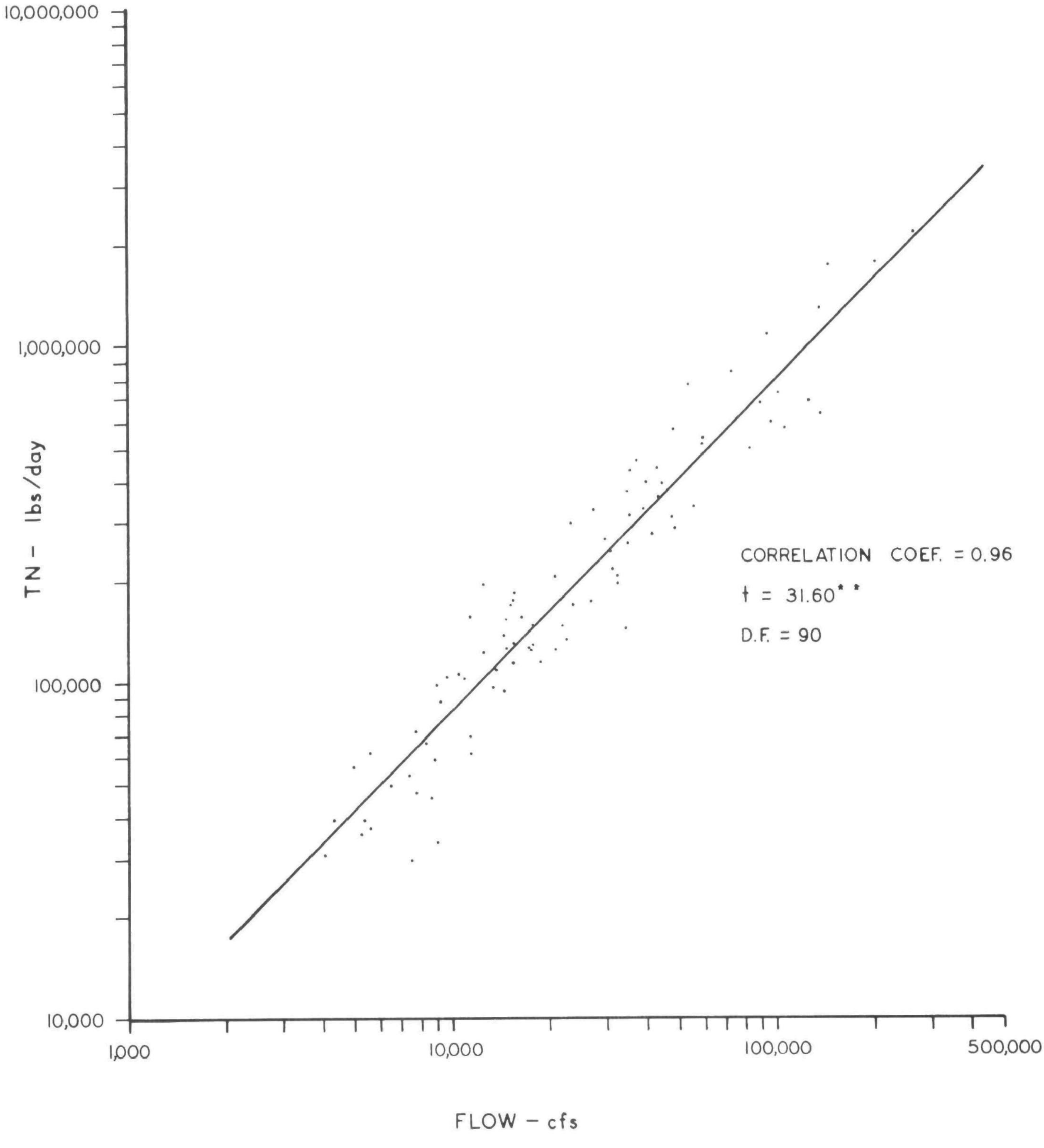


REGRESSION ANALYSIS

TOTAL NITROGEN LOAD vs FLOW

SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

(1969–1972 DATA)

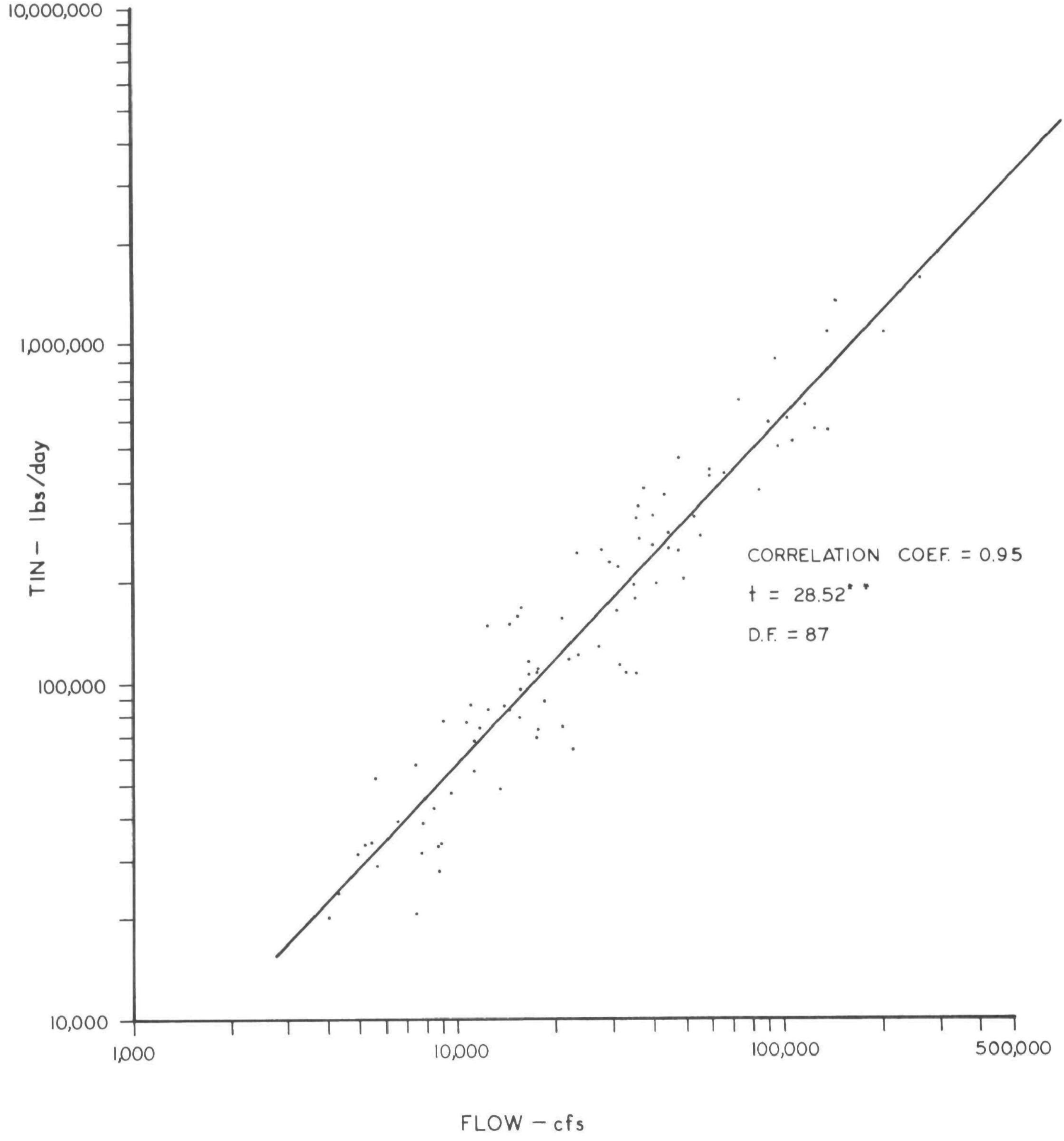


REGRESSION ANALYSIS

TOTAL INORGANIC NITROGEN LOAD vs FLOW

SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

(1969-1972 DATA)

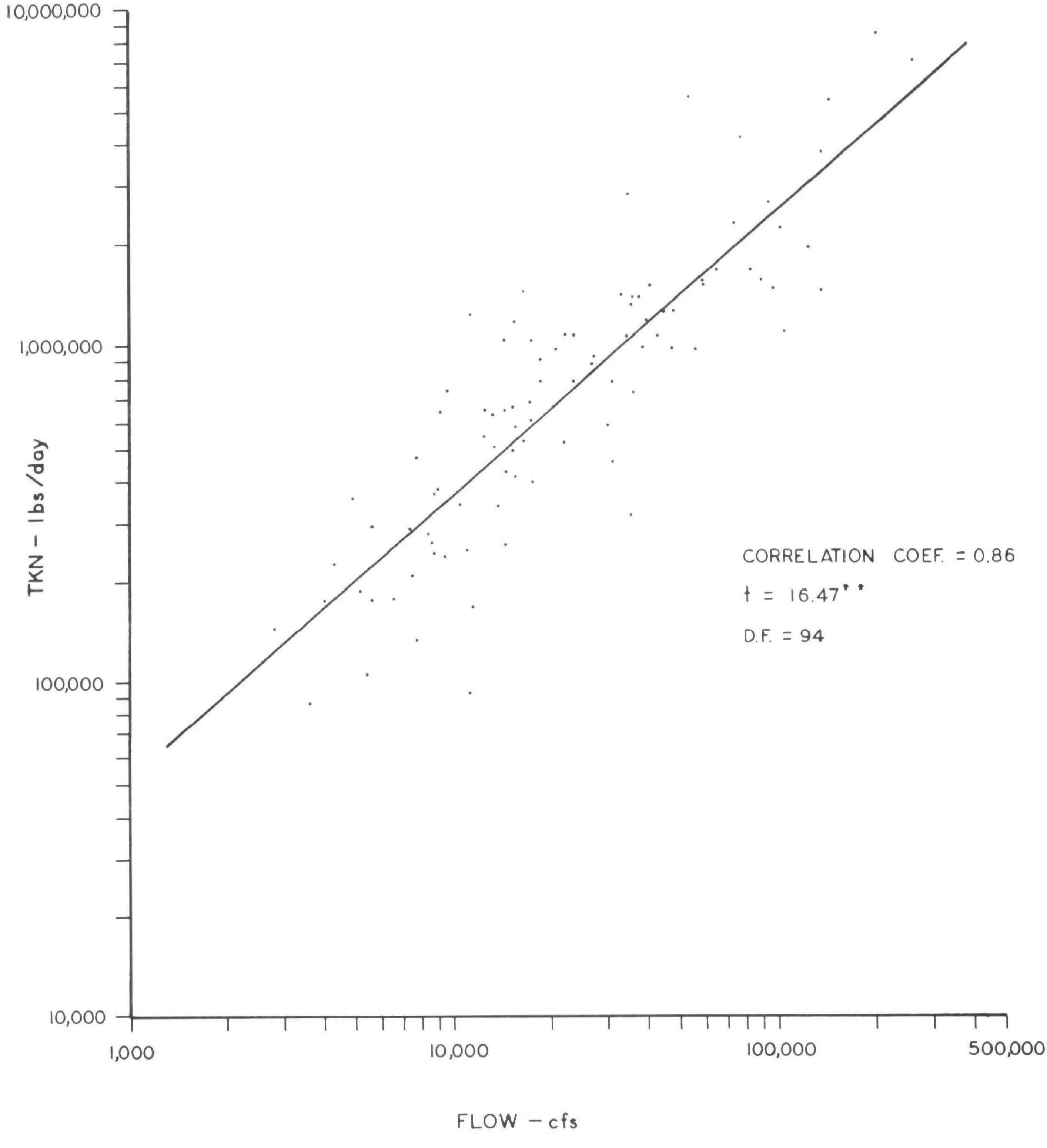


REGRESSION ANALYSIS

TOTAL KJELDAHL NITROGEN LOAD vs FLOW

SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

(1969 - 1972 DATA)

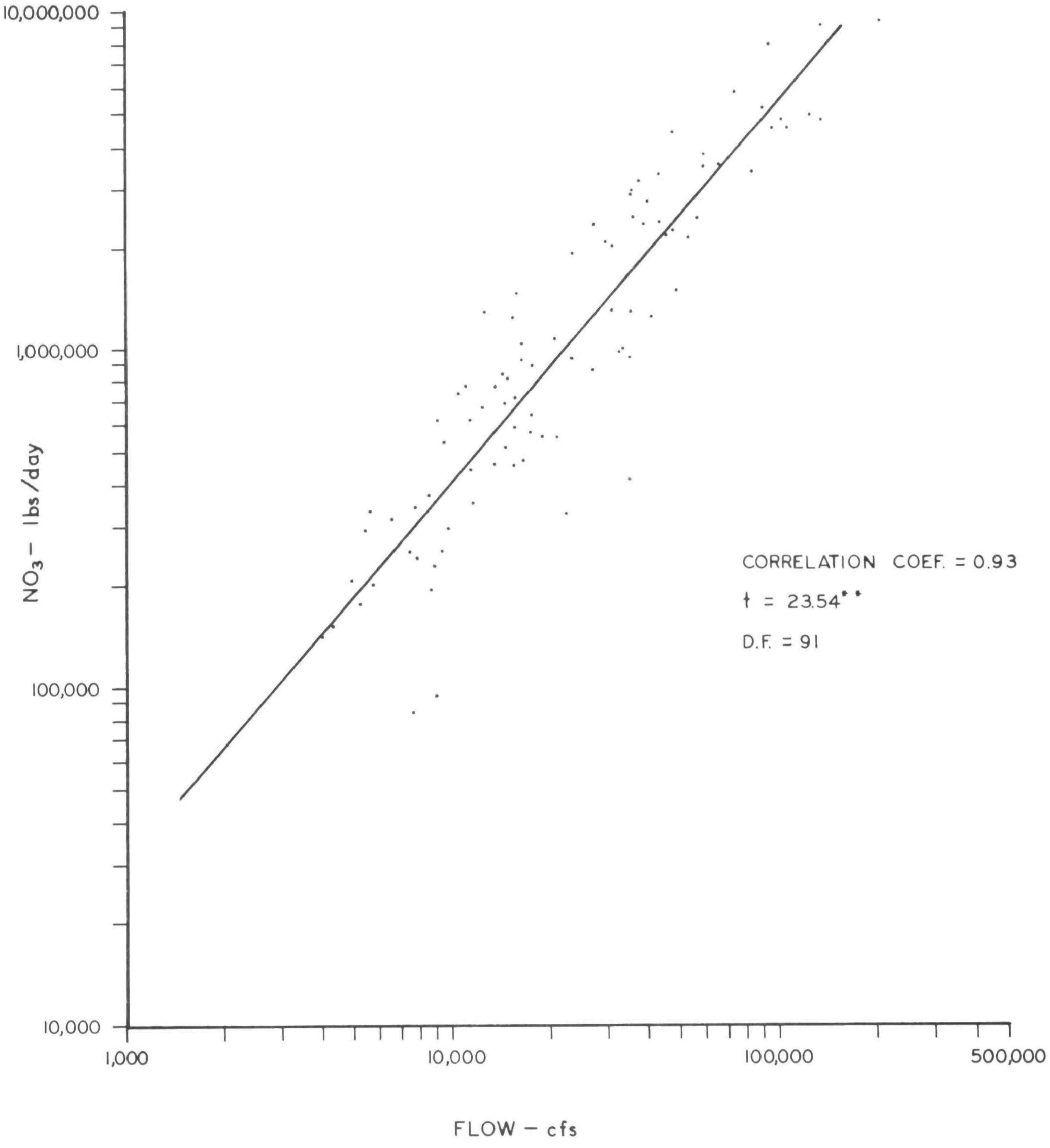


REGRESSION ANALYSIS

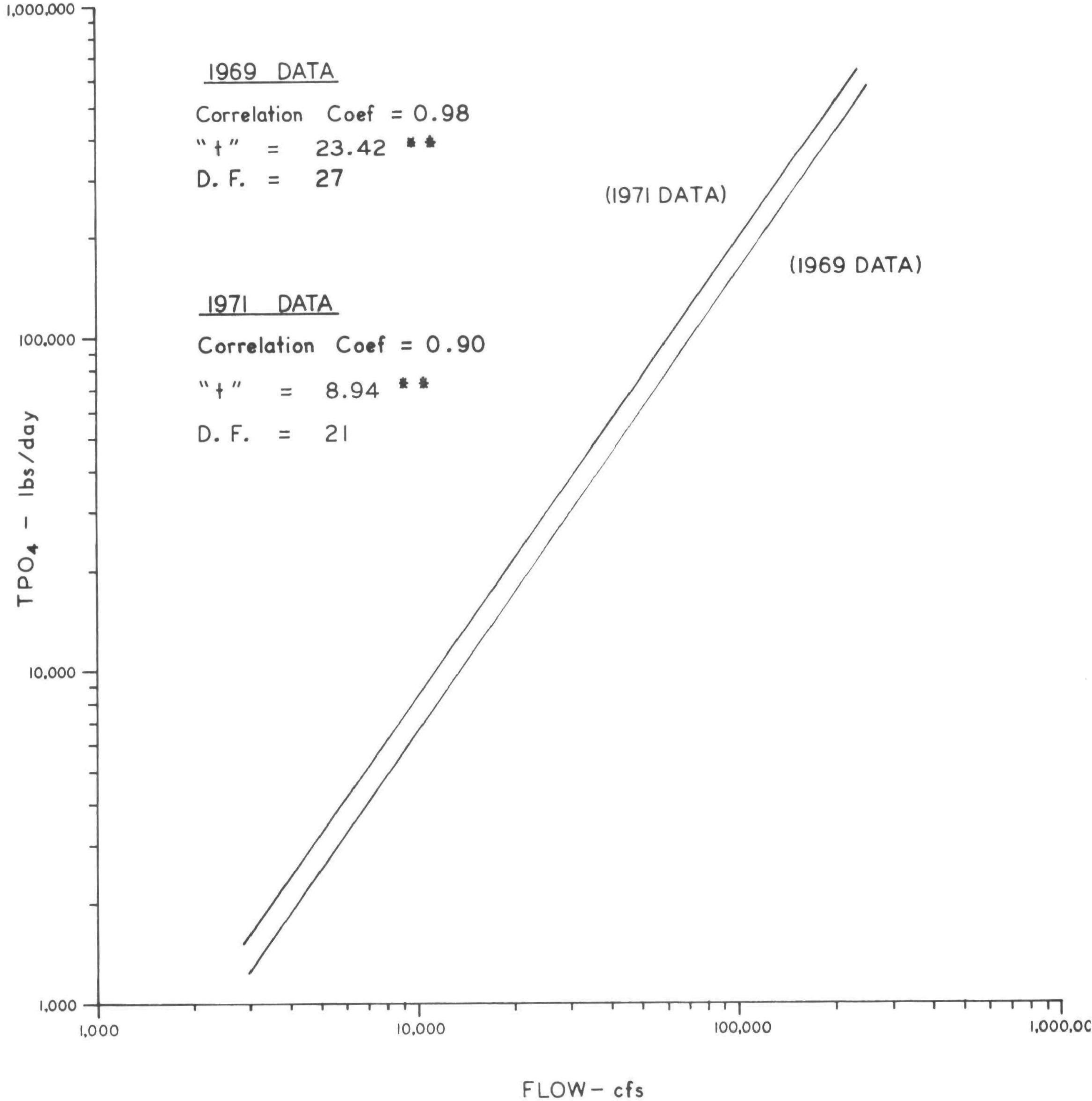
NITRATE NITROGEN LOAD vs FLOW

SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

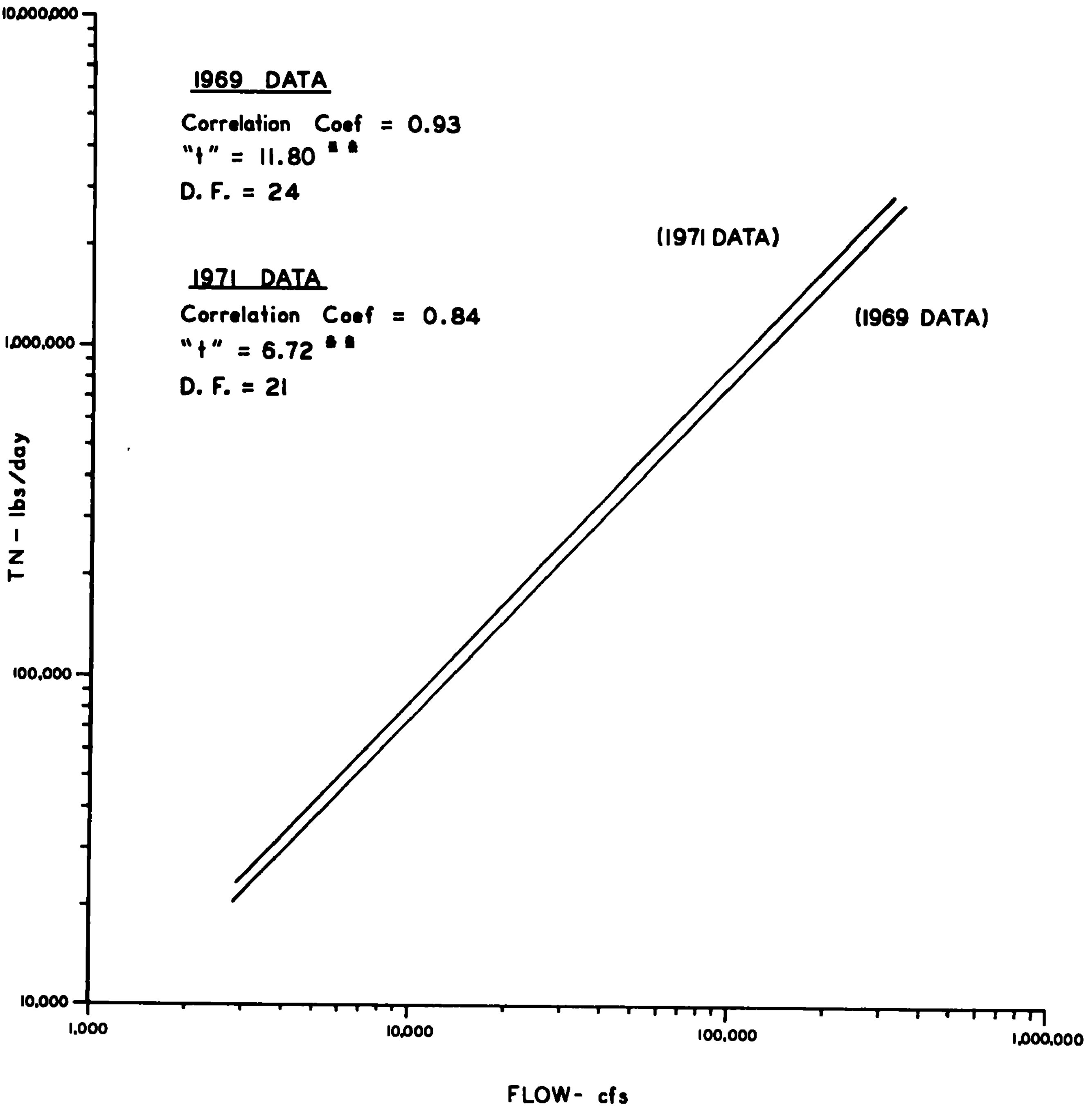
(1969–1972 DATA)

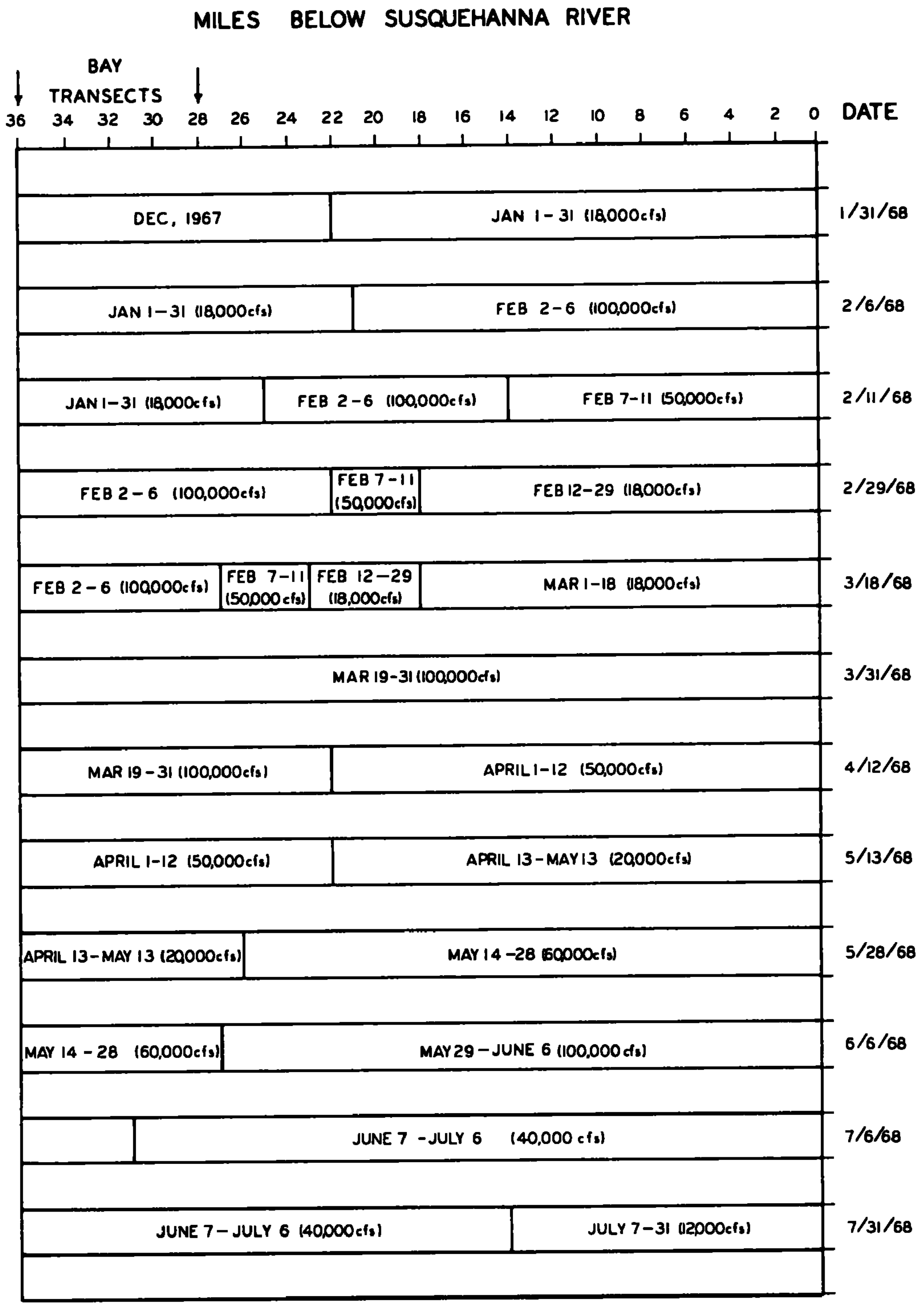


REGRESSION ANALYSIS
TOTAL PHOSPHORUS LOAD VS FLOW
SUSQUEHANNA RIVER at CONOWINGO
(1969 and 1971 DATA)

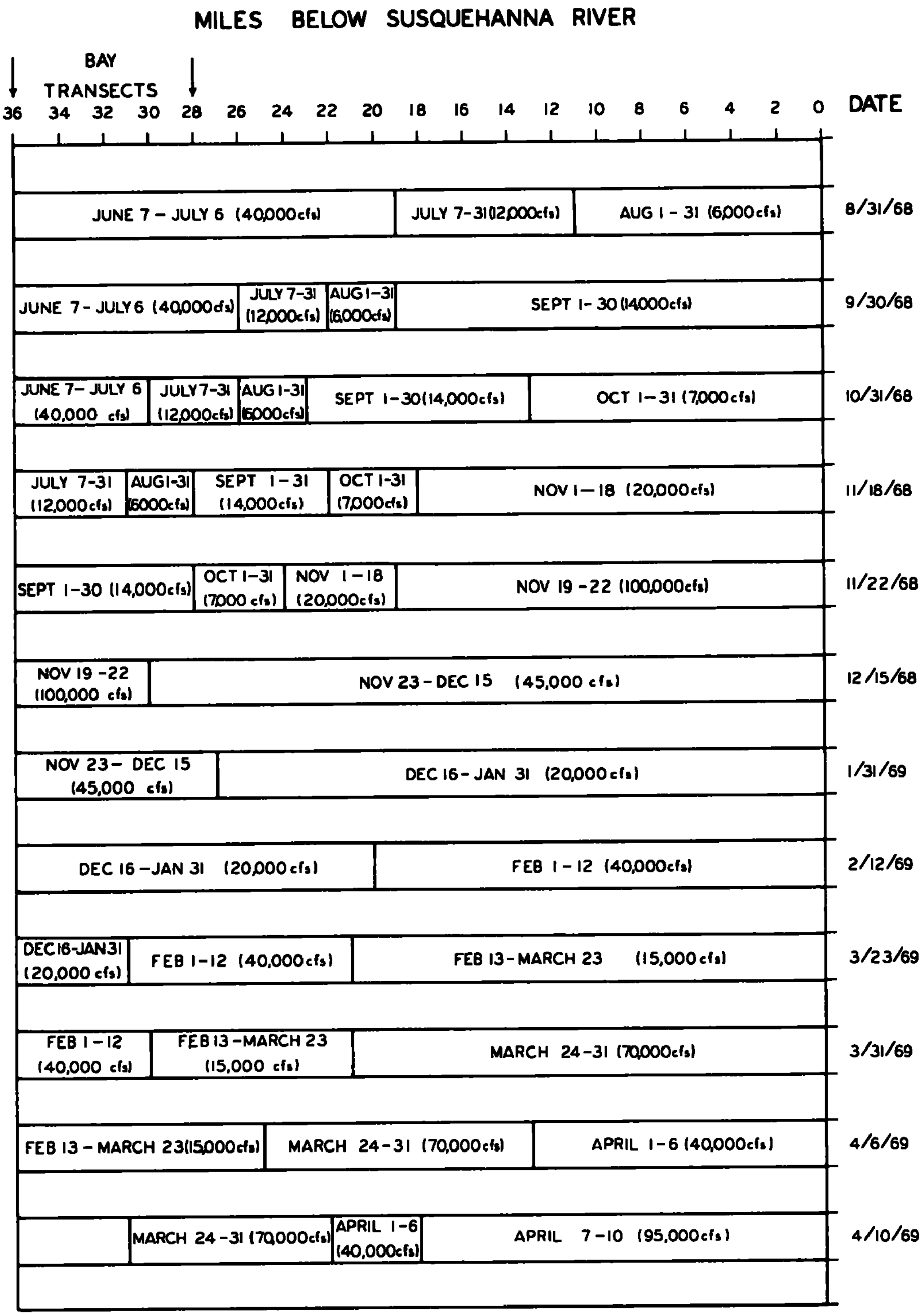


REGRESSION ANALYSIS
TOTAL NITROGEN LOAD VS FLOW
SUSQUEHANNA RIVER at CONOWINGO
(1969 and 1971 DATA)

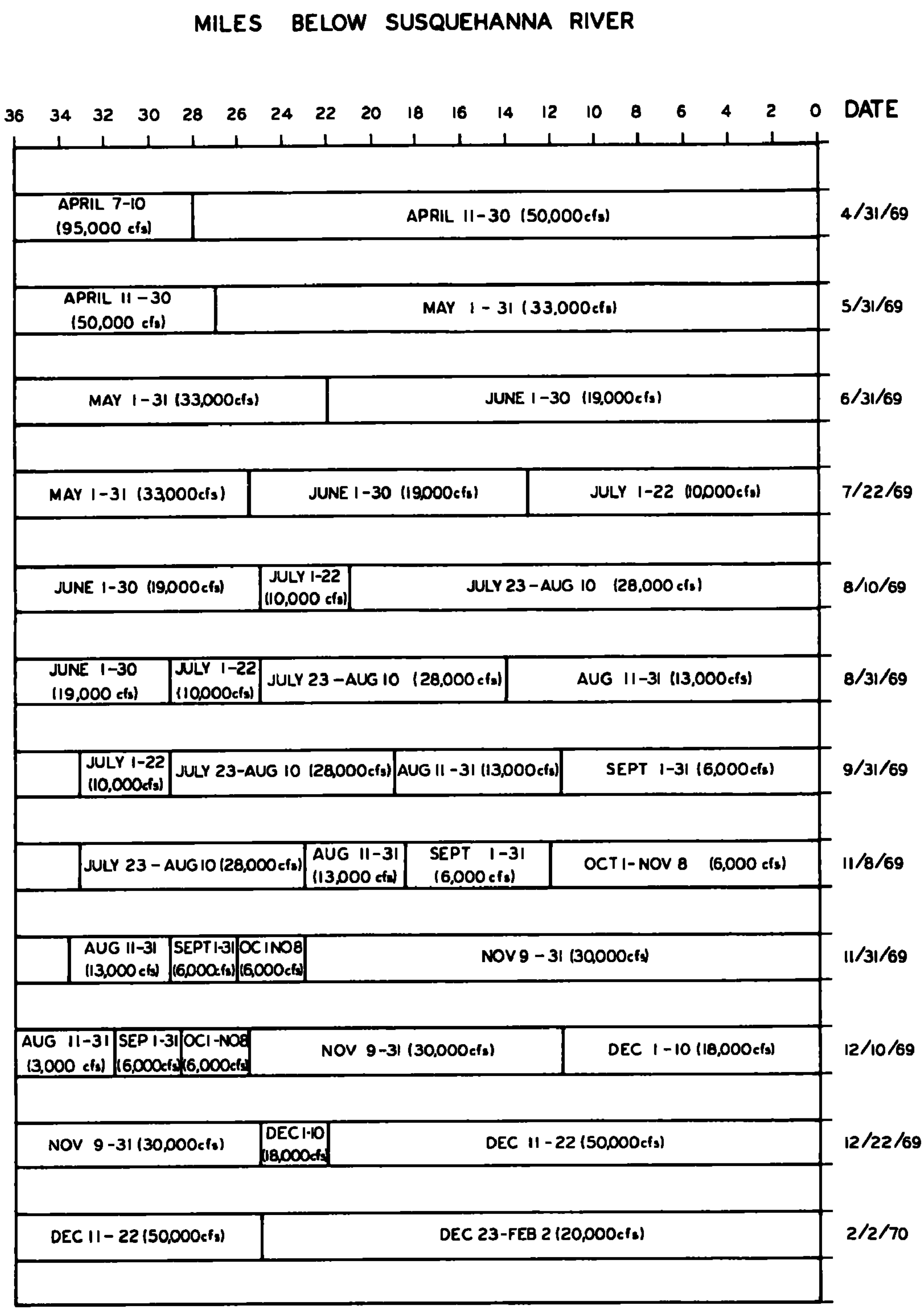




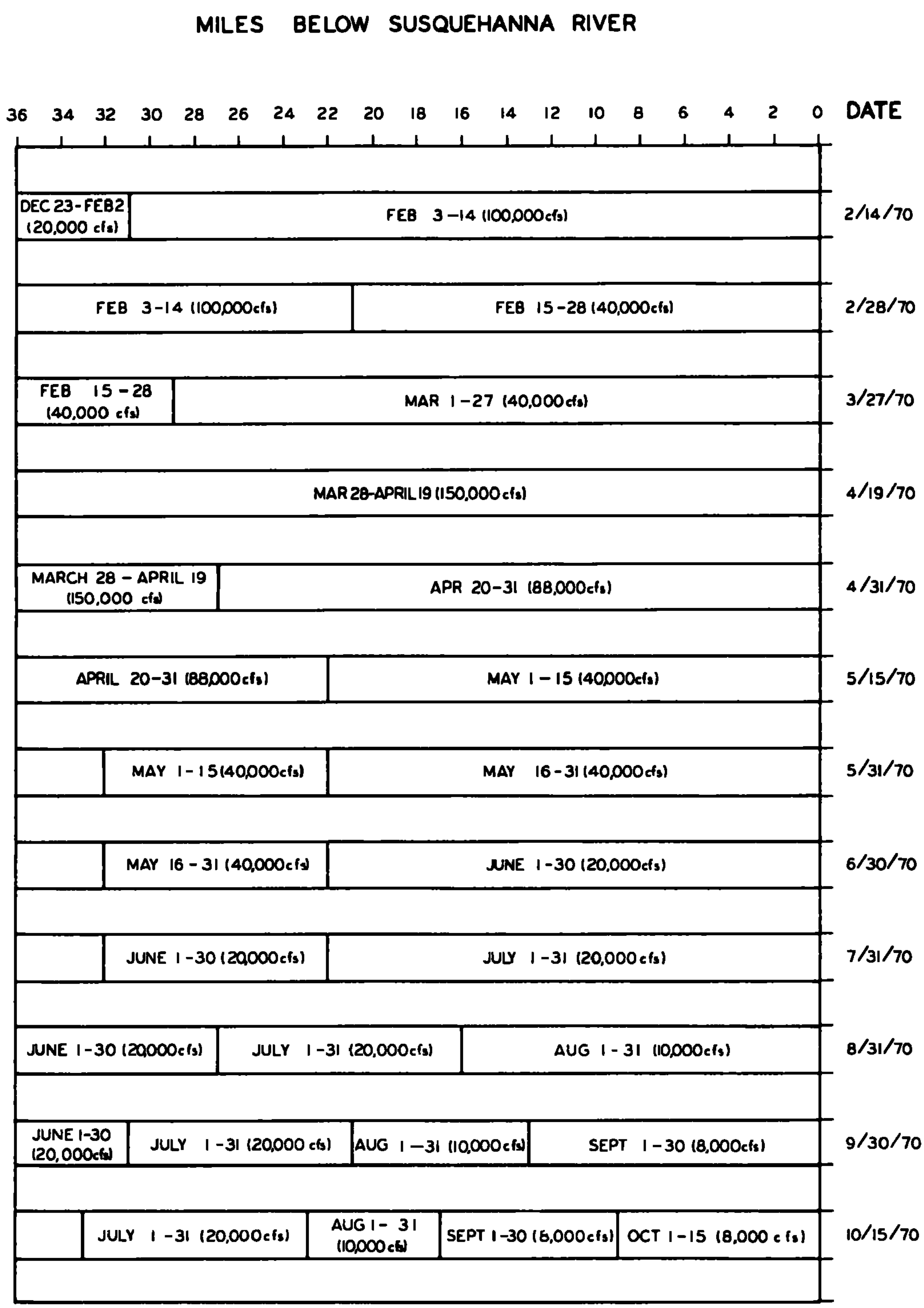
RELATIVE POSITIONS OF AVERAGE SUSQUEHANNA FLOWS
UPPER CHESAPEAKE BAY
(1968 - 1971)



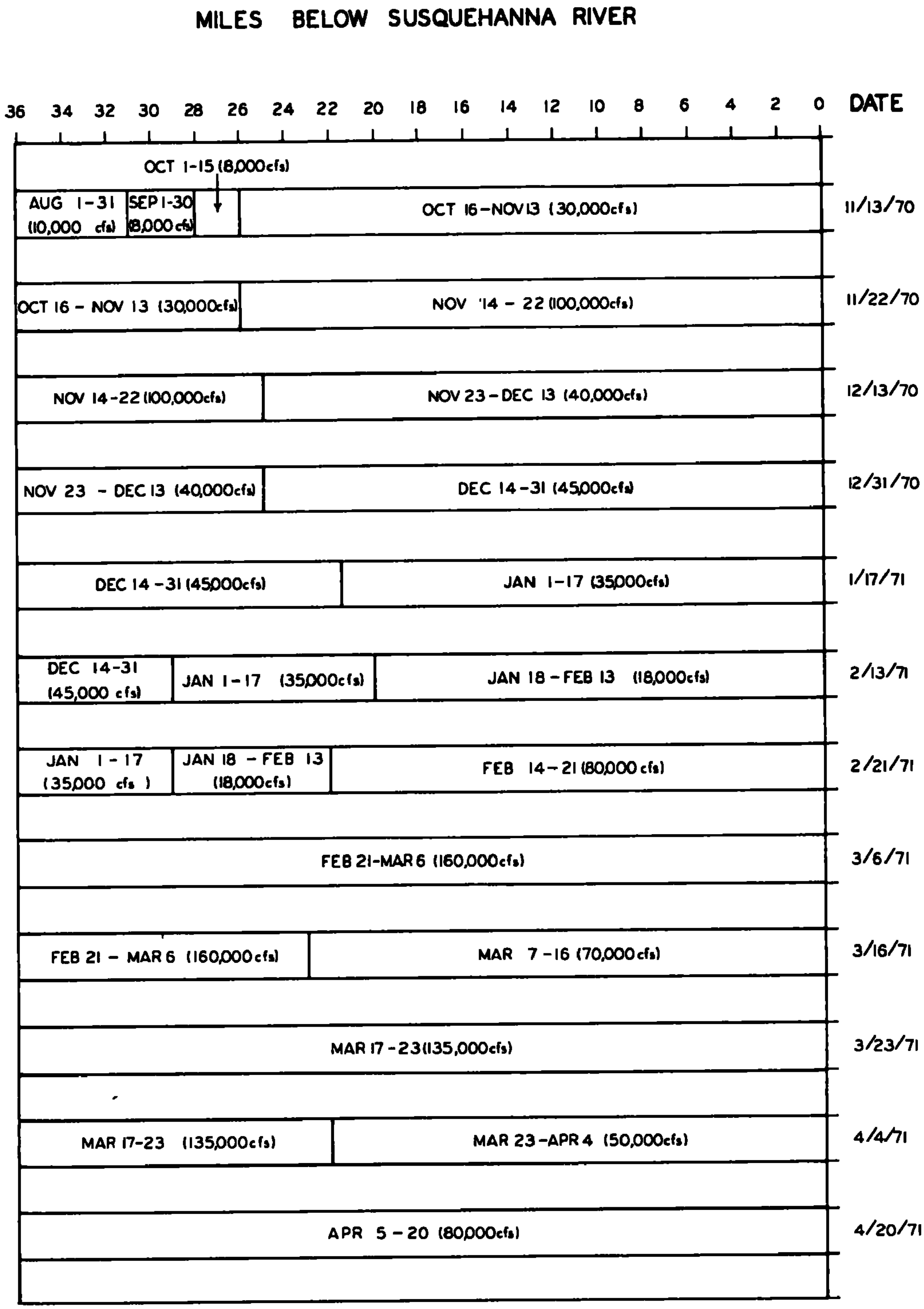
RELATIVE POSITIONS OF AVERAGE SUSQUEHANNA FLOWS
UPPER CHESAPEAKE BAY
(1968 - 1971)



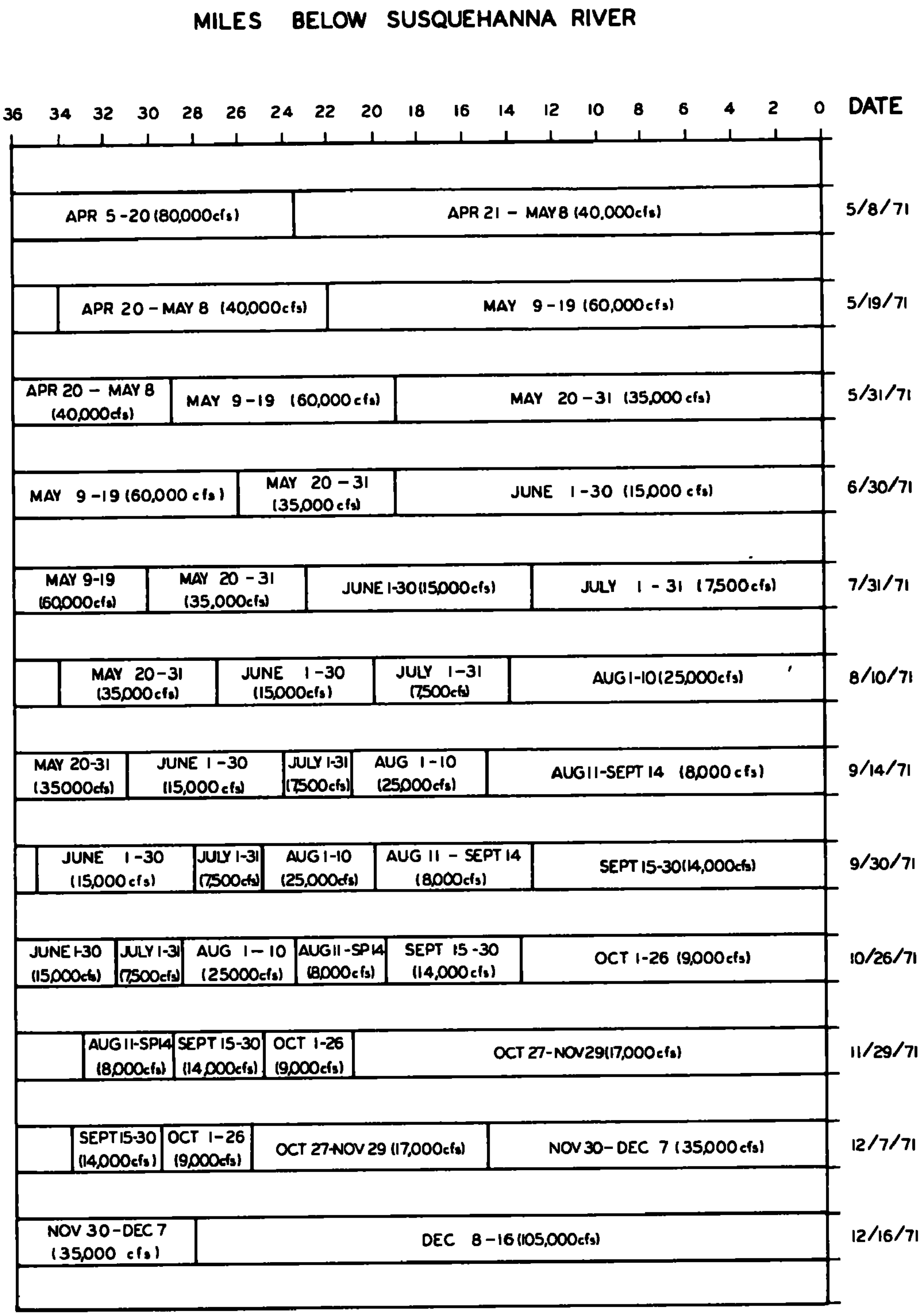
RELATIVE POSITIONS OF AVERAGE SUSQUEHANNA FLOWS
UPPER CHESAPEAKE BAY
(1968 - 1971)



RELATIVE POSITIONS OF AVERAGE SUSQUEHANNA FLOWS
UPPER CHESAPEAKE BAY
(1968-1971)



RELATIVE POSITIONS OF AVERAGE SUSQUEHANNA FLOWS
UPPER CHESAPEAKE BAY
(1968 - 1971)



RELATIVE POSITIONS OF AVERAGE SUSQUEHANNA FLOWS
UPPER CHESAPEAKE BAY
(1968 - 1971)

PHOSPHORUS RELATIONSHIPS

SUSQUEHANNA RIVER - CHESAPEAKE BAY

Date	CHESAPEAKE BAY BETWEEN TRANSECTS A & F (45×10^9 ft^3) TP (mg/l)	TP (10^3 lbs)	Pi (mg/l)	Pi (10^3 lbs)	SUSQUEHANNA RIVER AT CONOWINGO Flow at Conowingo* (cfs)	Days Required to Fill Volume (45×10^9 ft^3)	Daily TP Load at Conowingo (lbs/day)	Expected TP Load in Volume (10^3 lbs)	Daily Pi Load at Conowingo (lbs/day)	Expected Pi Load in Volume (10^3 lbs)
04/22/68	.09	252.7			100,000	5.2	117,000	608.4		
05/22/68	.09	252.7			50,000	10.4	50,000	520.0		
06/24/68	.11	308.9			100,000	5.2	117,000	608.4		
07/09/68	.11	308.9			70,000	7.6	76,000	577.6		
09/04/68	.10	280.9			40,000	13.0	39,000	507.0		
10/23/68	.13	365.0			40,000	13.0	39,000	507.0		
12/04/68	.09	252.7			20,000	26.0	17,000	442.0		
03/06/69	.12	337.0			20,000	26.0	17,000	442.0		
05/22/69	.09	252.7			50,000	10.4	50,000	520.0		
06/18/69	.14	393.1			40,000	13.0	39,000	507.0		
07/09/69	.17	477.4	.06	168.5	33,000	15.8	31,000	489.8	17,000	268.6
09/03/69	.20	561.6	.08	224.6	19,000	27.4	16,000	438.4	8,100	221.9
12/17/69	.13	365.0	.12	337.0	6,000	86.8	4,000	347.2	1,700	147.6
02/18/70	.16	449.3	.13	365.0	100,000	5.2	117,000	608.4	75,000	390.0
03/30/70	.15	421.2	.05	140.4	40,000	13.0	39,000	507.0	22,000	286.0
05/20/70	.11	308.9	.03	84.2	88,000	5.9	100,000	590.0	63,000	371.7
06/11/70	.14	393.1	.08	224.6	40,000	13.0	39,000	507.0	22,000	286.0
07/07/70	.17	477.4	.08	224.6	40,000	13.0	39,000	507.0	22,000	286.0
08/10/70	.20	561.6	.14	393.1	20,000	26.0	17,000	442.0	8,700	226.2
10/06/70	.23	645.8	.18	505.4	20,000	26.0	17,000	442.0	8,700	226.2
11/11/70	.17	477.4	.15	421.2	10,000	52.1	7,500	390.8	3,400	177.1
04/19/71	.10	280.9	.05	140.4	80,000	6.5	90,000	585.0	56,000	364.0
05/17/71	.14	393.1	.04	112.3	60,000	8.7	63,000	548.1	38,000	330.6
06/16/71	.14	393.1	.04	112.3	50,000	10.4	50,000	520.0	30,000	312.0
07/13/71	.21	589.7	.07	196.6	60,000	8.7	63,000	548.1	38,000	330.6
08/17/71	.20	561.6	.06	168.5	35,000	14.9	33,000	491.7	18,000	268.2
10/13/71	.21	589.7	.09	252.7	15,000	34.7	12,000	416.4	5,900	204.7
Approximate Averages:		400		240	45,000			500		280
Approx Av (Feb-June):		340		170	60,000			540		330
Approx Av (July-Dec):		460		290	30,000			470		240
Approximate Ranges:		250-600		100-500	6,000-100,000			350-600		150-400

*Allowing for appropriate lag time between Conowingo & Bay Transects

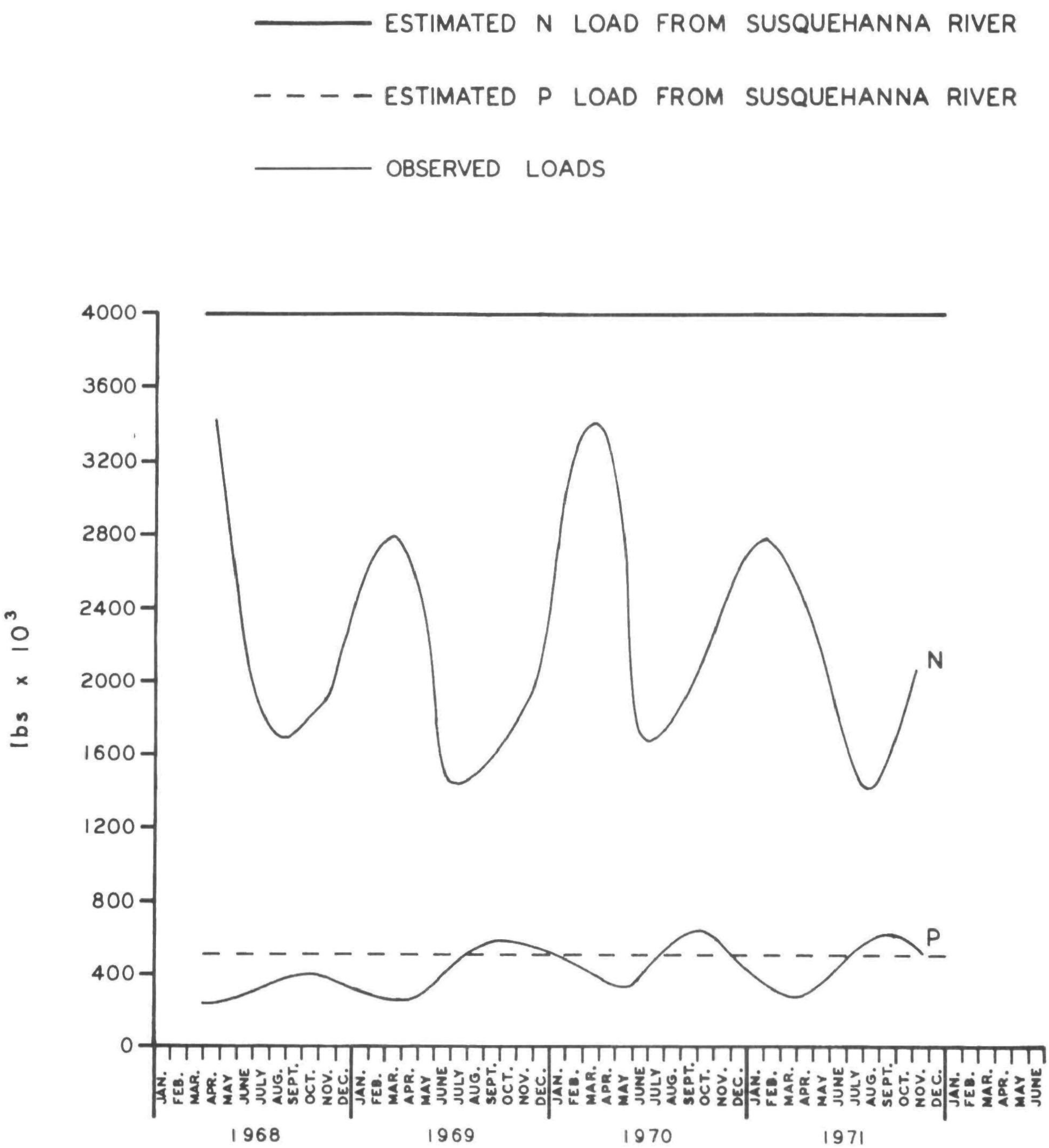
NITROGEN RELATIONSHIPS

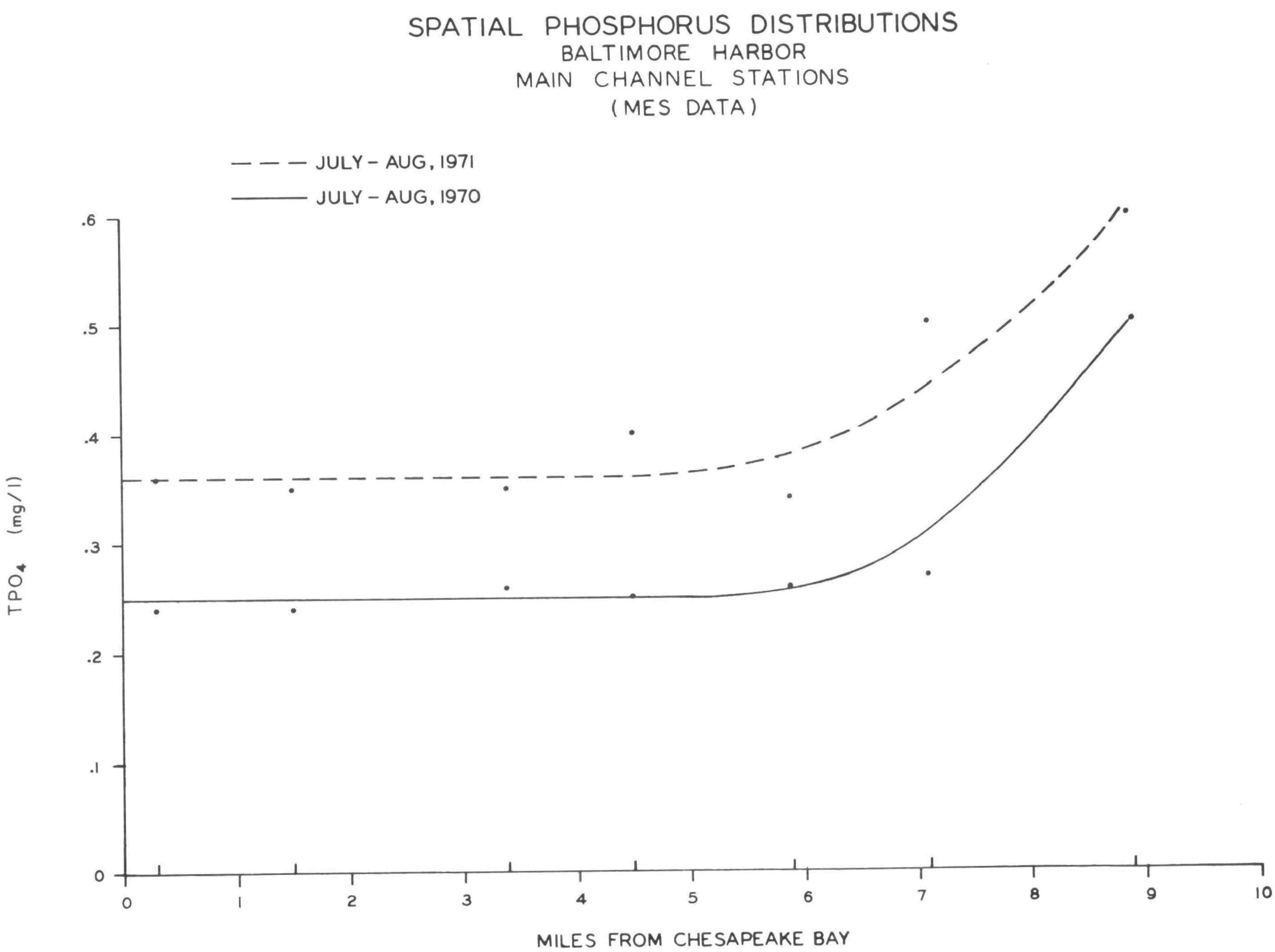
SUSQUEHANNA RIVER - CHESAPEAKE BAY

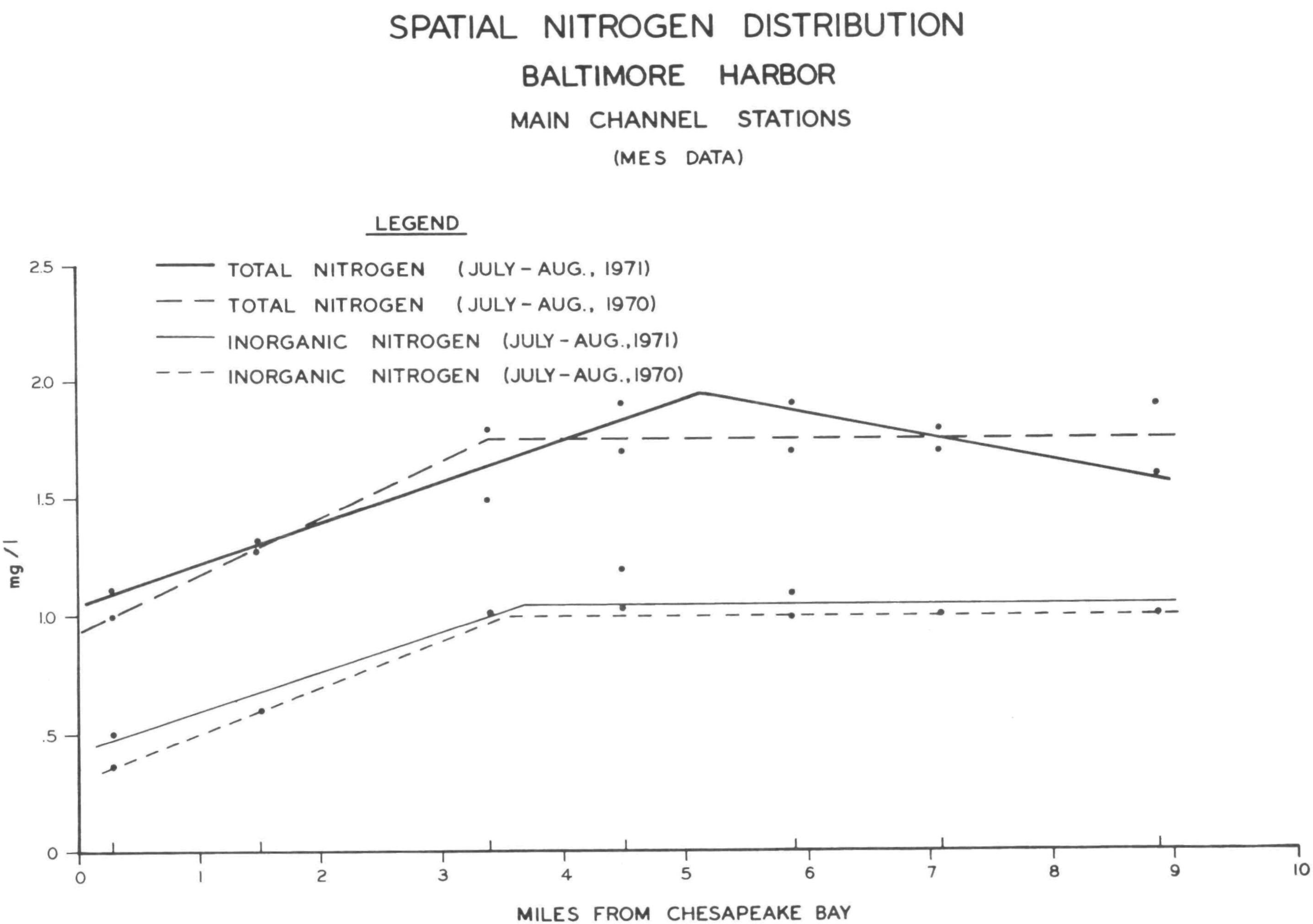
Date	CHESAPEAKE BAY BETWEEN TRANSECTS A & F (45 x 10^9 ft^3) TN (mg/l)	TN (10^3 lbs)	TIN (mg/l)	TIN (10^3 lbs)	SUSQUEHANNA RIVER AT CONOWINGO Flow at Conowingo* (cfs)	Days Required to Fill Volume (45 x 10^9 ft^3)	Daily TN Load at Conowingo (lbs/day)	Expected TN Load in Volume (10^3 lbs)	Daily TIN Load at Conowingo (lbs/day)	Expected TIN Load in Volume (10^3 lbs)
04/22/68	1.22	3,425.8			100,000	5.2	790,000	4,108.0		
05/22/68	.83	2,330.6			50,000	10.4	400,000	4,160.0		
06/24/68	.83	2,330.6			100,000	5.2	790,000	4,108.0		
07/09/68	.69	1,937.5			70,000	7.6	560,000	4,256.0		
08/12/68	.60	1,684.8			40,000	13.0	320,000	4,160.0		
09/04/68	.61	1,712.9			40,000	13.0	320,000	4,160.0		
12/04/68	.70	1,965.6			20,000	26.0	160,000	4,160.0		
03/06/69	.53	1,488.2			20,000	26.0	160,000	4,160.0		
05/22/69	.85	2,386.8			50,000	10.4	400,000	4,160.0		
06/18/69	.51	1,432.1	.23	645.8	40,000	13.0	320,000	4,160.0	235,000	3,055.0
07/09/69	.53	1,488.2	.29	814.3	33,000	15.8	265,000	4,187.0	195,000	3,081.0
09/03/69	.59	1,656.7	.18	505.4	19,000	27.4	155,000	4,247.0	110,000	3,014.0
12/17/69	.72	2,021.8	.59	1,656.7	6,000	86.8	50,000	4,340.0	34,000	2,951.0
02/18/70	1.17	3,285.4	.94	1,656.7	100,000	5.2	790,000	4,108.0	600,000	3,120.0
03/30/70	1.21	3,397.7	.99	2,780.0	40,000	13.0	320,000	4,160.0	235,000	3,055.0
05/20/70	.98	2,751.8	.62	1,741.0	88,000	5.9	690,000	4,071.0	520,000	3,068.0
06/11/70	.60	1,684.8	.34	954.7	40,000	13.0	320,000	4,160.0	235,000	3,055.0
07/07/70	.63	1,769.0	.15	421.2	40,000	13.0	320,000	4,160.0	235,000	3,055.0
08/10/70	.65	1,825.2	.06	168.5	20,000	26.0	160,000	4,160.0	116,000	3,016.0
10/06/70	.72	2,021.8	.37	1,039.0	20,000	26.0	160,000	4,160.0	116,000	3,016.0
11/11/70	.82	2,302.6	.75	2,106.0	10,000	52.1	81,000	4,220.0	57,000	2,970.0
04/19/71	.77	2,162.2	.70	1,965.6	80,000	6.5	630,000	4,095.0	480,000	3,120.0
05/17/71	.94	2,639.5	.53	1,488.2	60,000	8.7	480,000	4,176.0	360,000	3,132.0
06/16/71	.70	1,965.6	.12	337.0	50,000	10.4	400,000	4,160.0	295,000	3,068.0
07/13/71	.50	1,404.0	.23	645.8	60,000	8.7	480,000	4,176.0	360,000	3,132.0
08/17/71	.62	1,741.0	.06	168.5	35,000	14.9	280,000	4,172.0	205,000	3,054.0
10/13/71	.62	1,741.0	.25	702.0	15,000	34.7	120,000	4,164.0	87,000	3,019.0
Approximate Averages:		2,000		1,000	45,000			4,000		3,000
Approx Av (Jun-Oct):		1,700		600	40,000			4,000		3,000
Approx Av (Nov-May):		2,500		1,900	50,000			4,000		3,000
Approximate Ranges:		1,400-3,400		200-2,700	6,000-100,000			---		---

*Allowing for appropriate lag time between Conowingo & Bay Transects

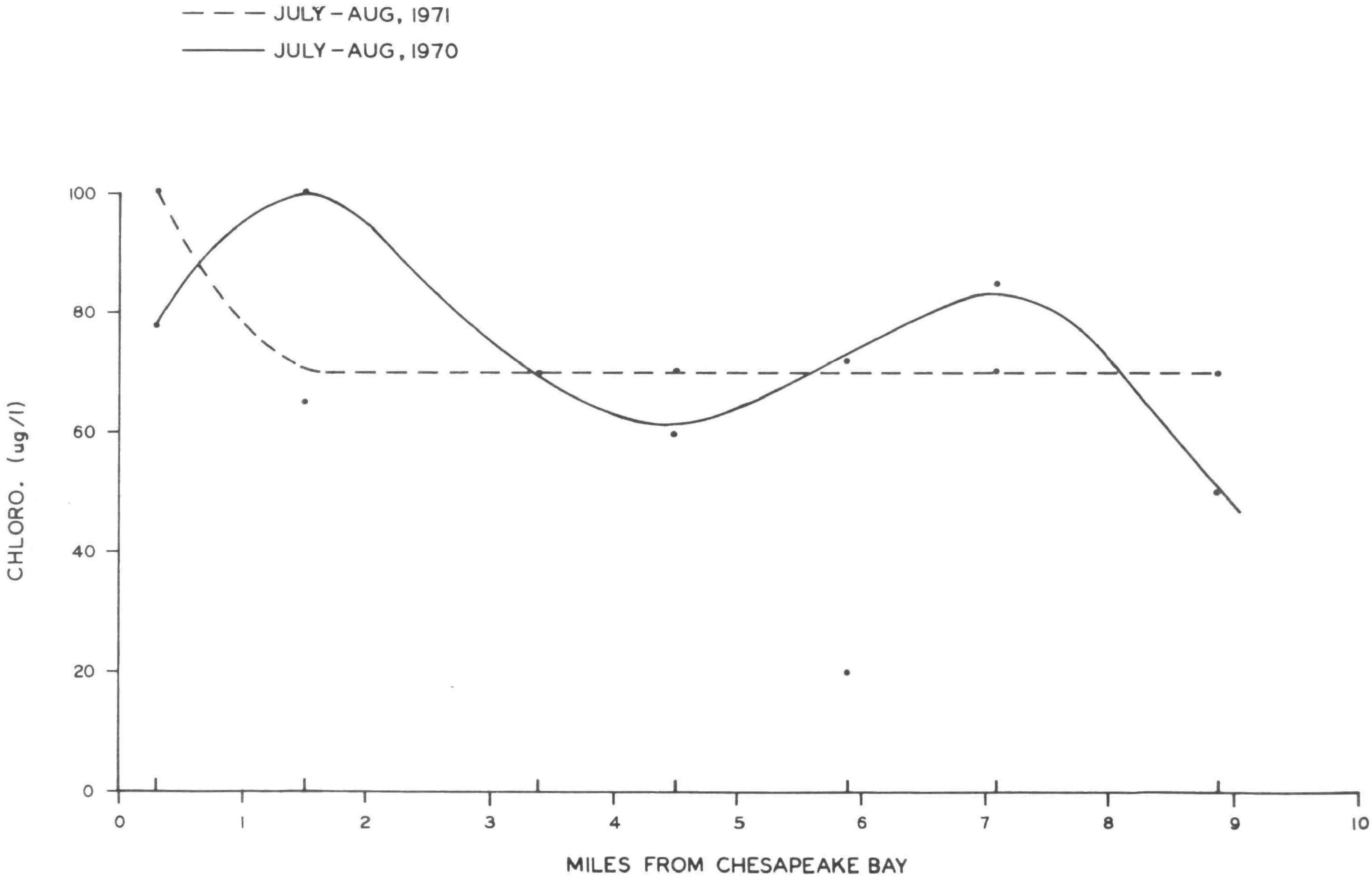
TOTAL NITROGEN & PHOSPHORUS LOADINGS
CHESAPEAKE BAY BETWEEN TRANSECTS A and F ($45 \times 10^9 ft^3$)
28 - 37 MILES BELOW SUSQUEHANNA RIVER



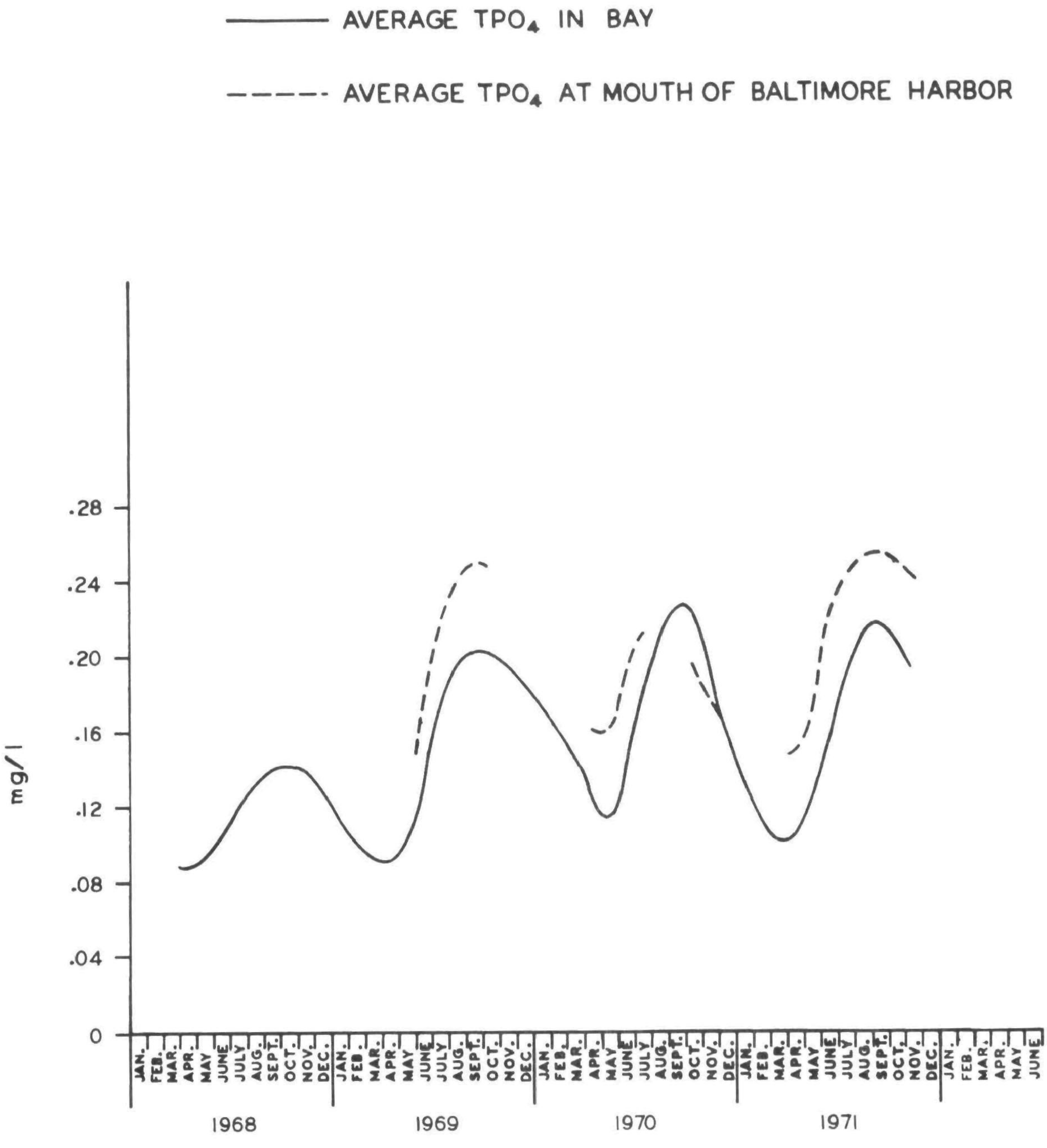

SPATIAL PHOSPHORUS DISTRIBUTIONS
BALTIMORE HARBOR
MAIN CHANNEL STATIONS
(MES DATA)
JULY - AUG, 1971
JULY - AUG, 1970
.6
.5
.4
.3
.2
.1
0
TPO_4 (mg/l)
0
1
2
3
4
5
6
7
8
9
10
MILES FROM CHESAPEAKE BAY


SPATIAL NITROGEN DISTRIBUTION
BALTIMORE HARBOR
MAIN CHANNEL STATIONS
(MES DATA)
LEGEND
TOTAL NITROGEN (JULY - AUG., 1971)
TOTAL NITROGEN (JULY - AUG., 1970)
INORGANIC NITROGEN (JULY - AUG., 1971)
INORGANIC NITROGEN (JULY - AUG., 1970)
mg / l
2.5
2.0
1.5
1.0
.5
0
0
1
2
3
4
5
6
7
8
9
10
MILES FROM CHESAPEAKE BAY

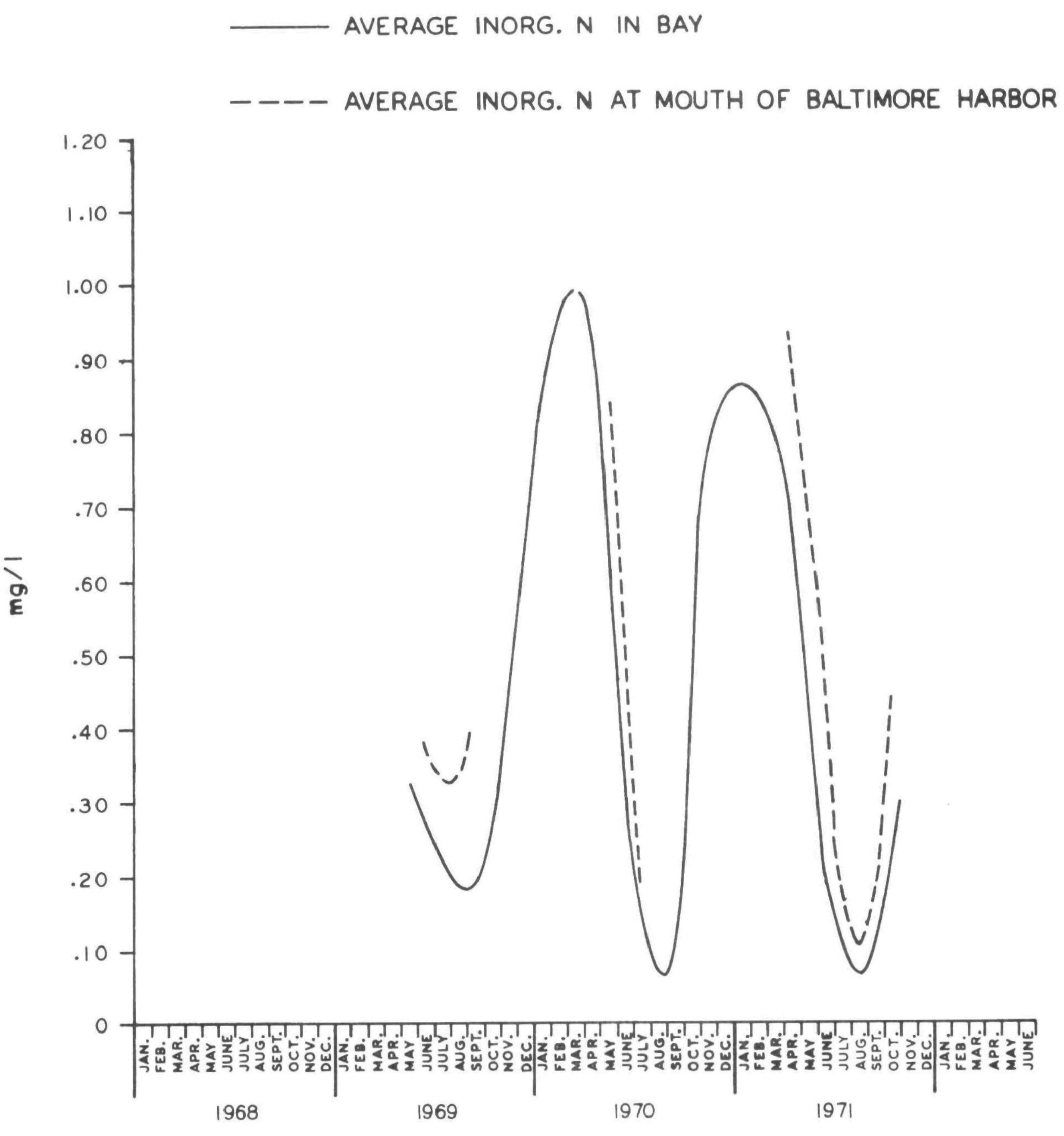
SPATIAL CHLOROPHYLL DISTRIBUTION
BALTIMORE HARBOR
MAIN CHANNEL STATIONS
(MES DATA)



COMPARISON OF TOTAL PHOSPHORUS CONCENTRATIONS IN TRANSECTS WITHIN CHESAPEAKE BAY AND TRANSECT ACROSS MOUTH OF BALTIMORE HARBOR



COMPARISON OF INORGANIC NITROGEN CONCENTRATIONS
IN
TRANSECTS WITHIN CHESAPEAKE BAY
AND
TRANSECT ACROSS MOUTH OF BALTIMORE HARBOR



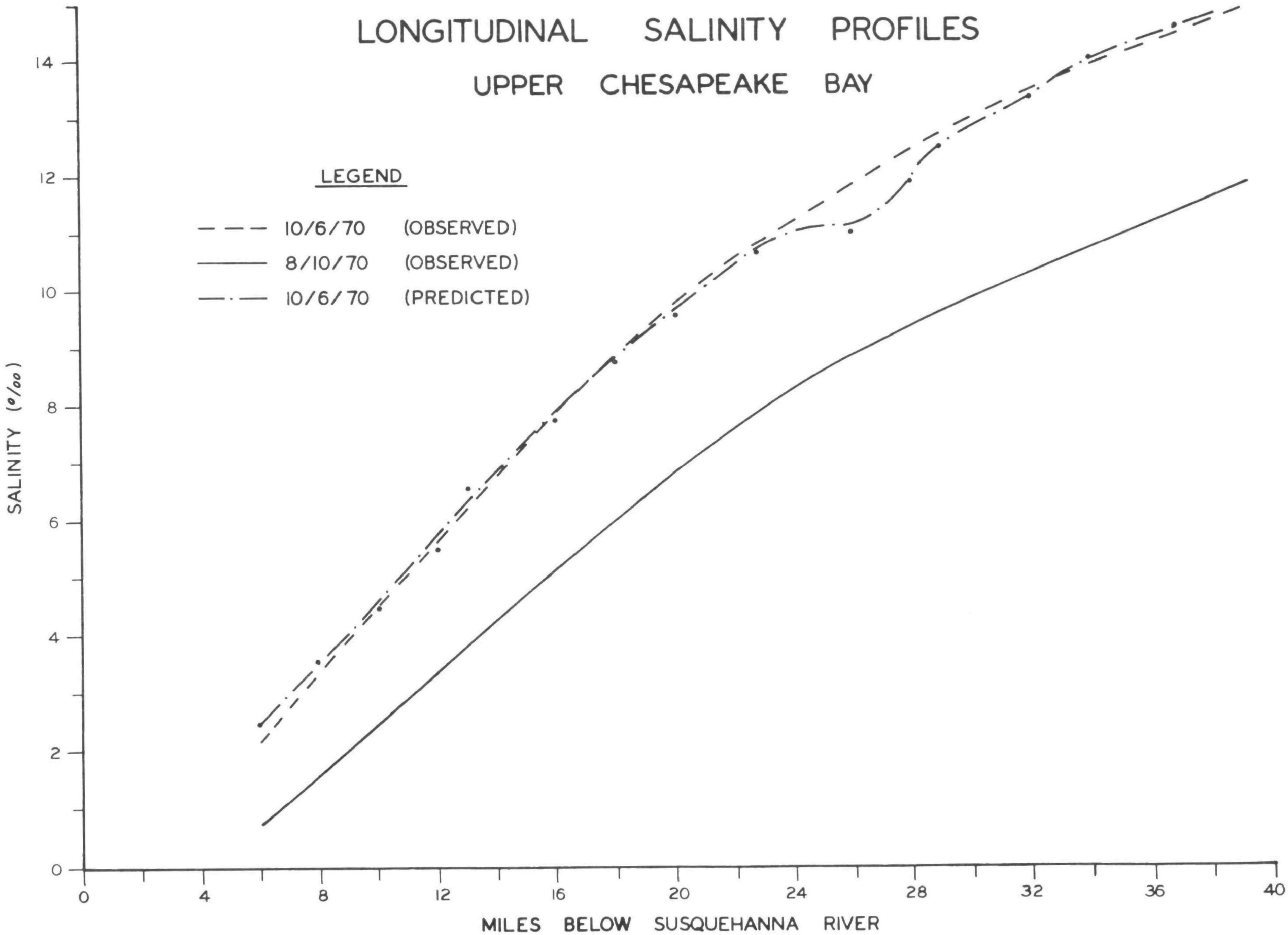
TIDAL DATA

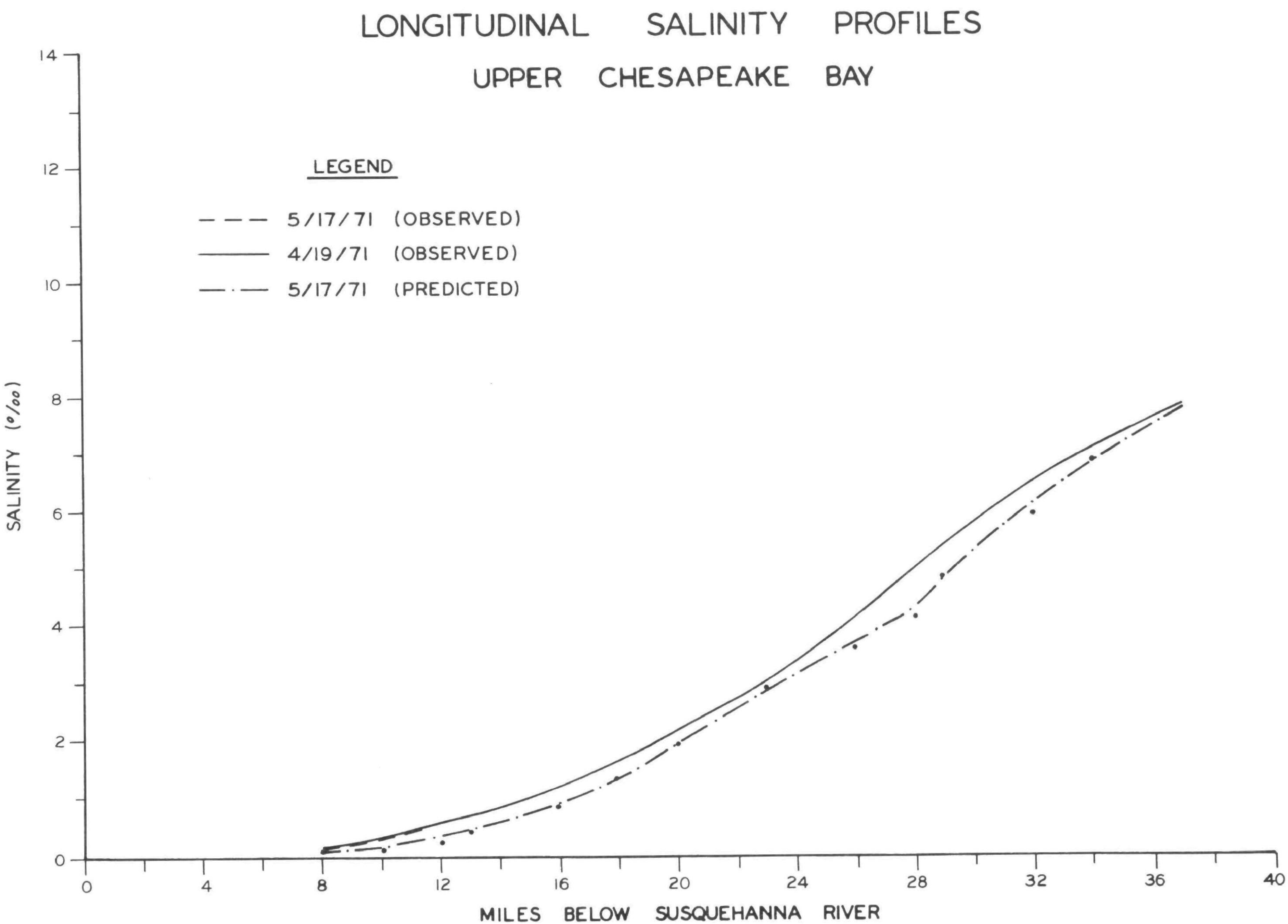
FOR

HYDRAULIC VERIFICATION

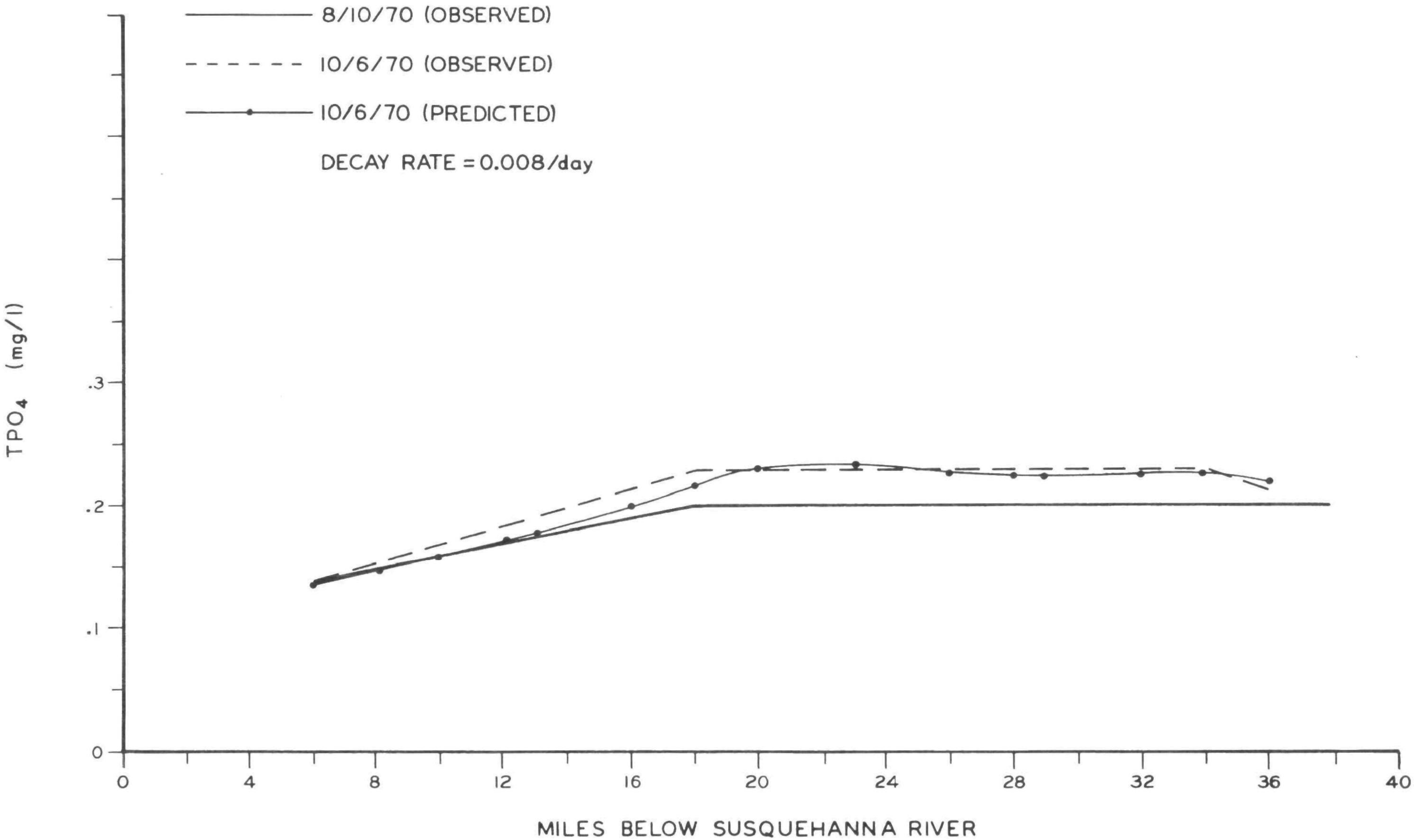
Upper Chesapeake Bay

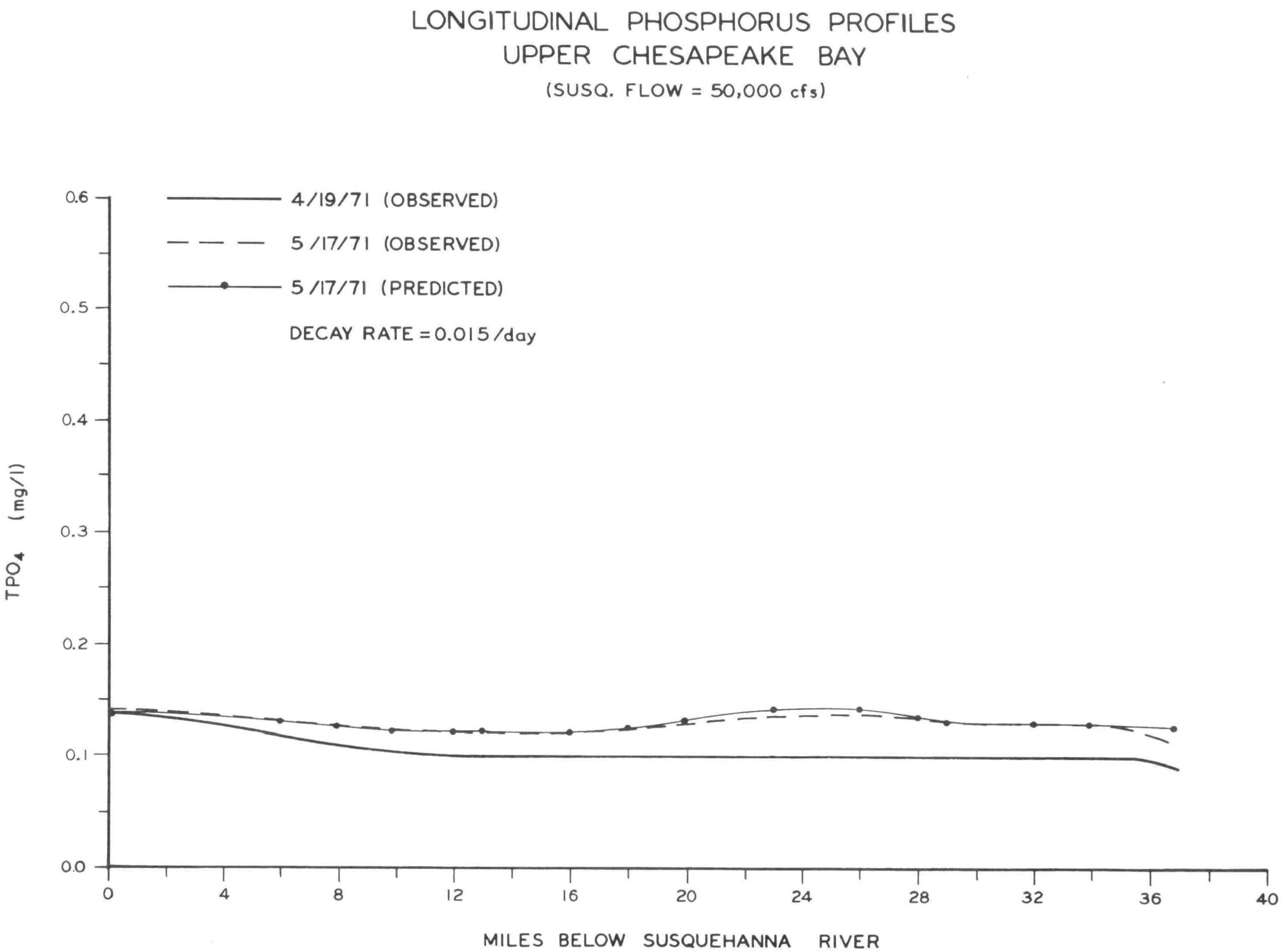
Station	Junction	Actual Range	Predicted Range	Actual Phasing (H.W.)	Actual Phasing (L.W.)	Predicted Phasing (H.W.)	Predicted Phasing (L.W.)
		-----(ft.)----		------------(minutes)-----------			
Susq. River at Havre de Grace	7	1.7	2.0	+330	+372	+354	+408
Pooles Island	34	1.2	1.3	+179	+185	+186	+192
Baltimore Fort McHenry	53	1.1	1.2	+128	+146	+126	+114
Sandy Point	70	0.8	0.9	+43	+51	+54	+42
Charleston Northeast River	10	1.9	2.1	+346	+374	+354	+396
Tolchester Beach	47	1.2	1.2	+144	+158	+168	+168
Love Point, Chester River	62	1.1	1.1	+105	+106	+114	+102
Susq. River at Port Deposit	5	2.1	2.2	+368	+434	+366	+432


LONGITUDINAL SALINITY PROFILES
UPPER CHESAPEAKE BAY
LEGEND
10/6/70 (OBSERVED)
8/10/70 (OBSERVED)
10/6/70 (PREDICTED)
SALINITY (°/oo)
MILES BELOW SUSQUEHANNA RIVER
0
2
4
6
8
10
12
14
0
4
8
12
16
20
24
28
32
36
40

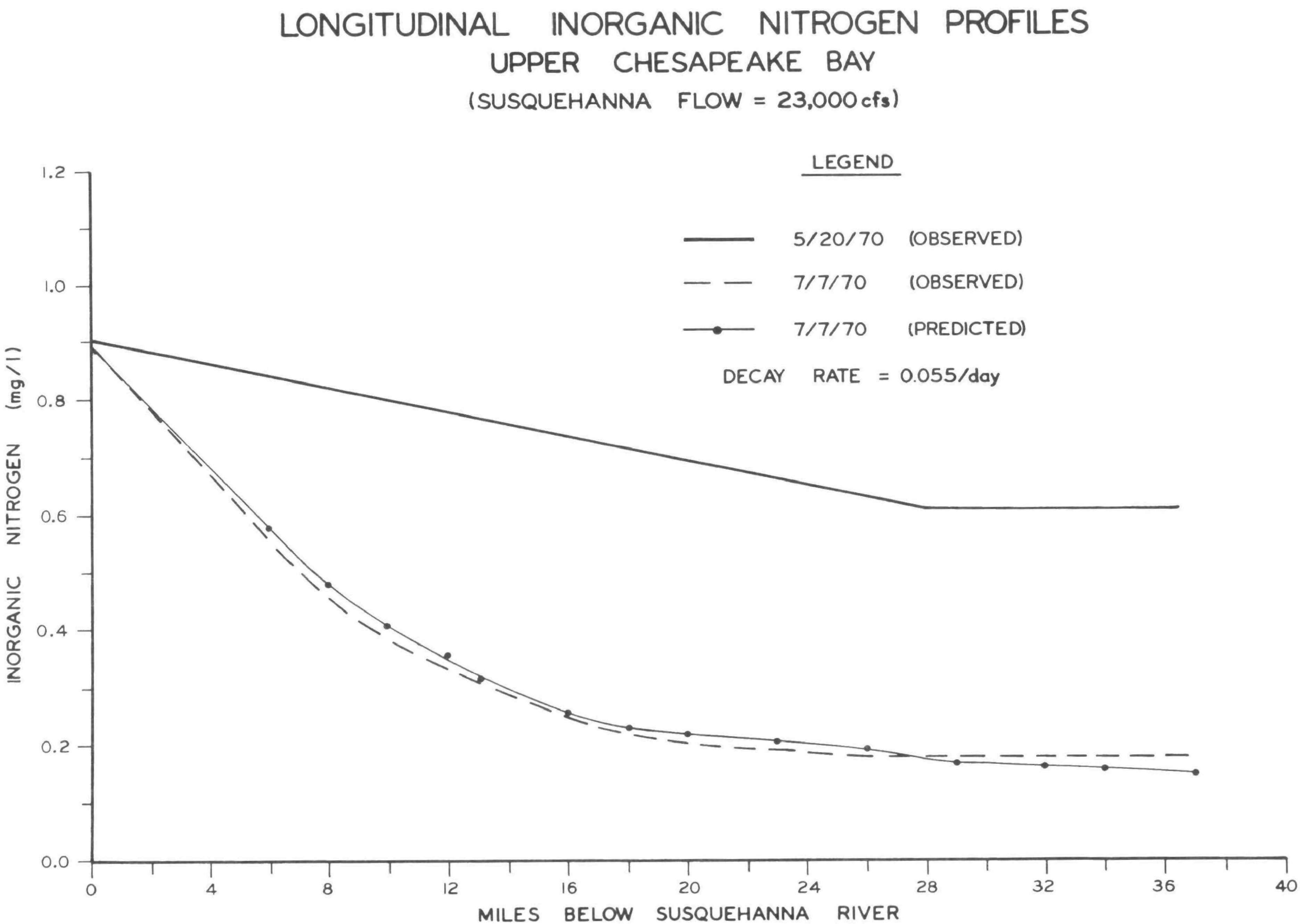

LONGITUDINAL SALINITY PROFILES
UPPER CHESAPEAKE BAY
LEGEND
5/17/71 (OBSERVED)
4/19/71 (OBSERVED)
5/17/71 (PREDICTED)
SALINITY (°/oo)
MILES BELOW SUSQUEHANNA RIVER
0
2
4
6
8
10
12
14
0
4
8
12
16
20
24
28
32
36
40

LONGITUDINAL PHOSPHORUS PROFILES
UPPER CHESAPEAKE BAY
(SUSQ. FLOW = 10,000 cfs)



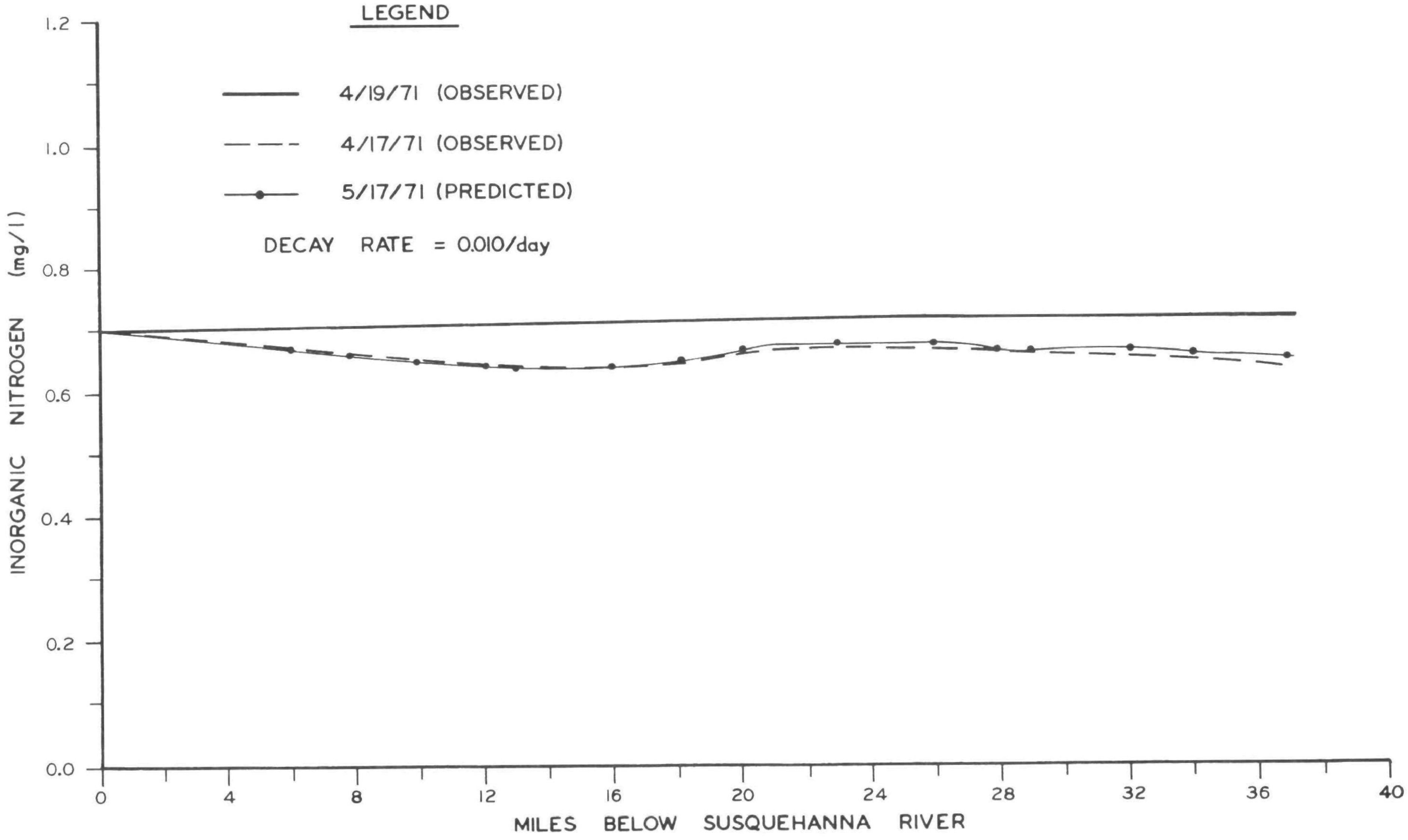


LONGITUDINAL PHOSPHORUS PROFILES
UPPER CHESAPEAKE BAY
(SUSQ. FLOW = 50,000 cfs)
4/19/71 (OBSERVED)
5/17/71 (OBSERVED)
5/17/71 (PREDICTED)
DECAY RATE = 0.015/day
TPO4 (mg/l)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
4
8
12
16
20
24
28
32
36
40
MILES BELOW SUSQUEHANNA RIVER

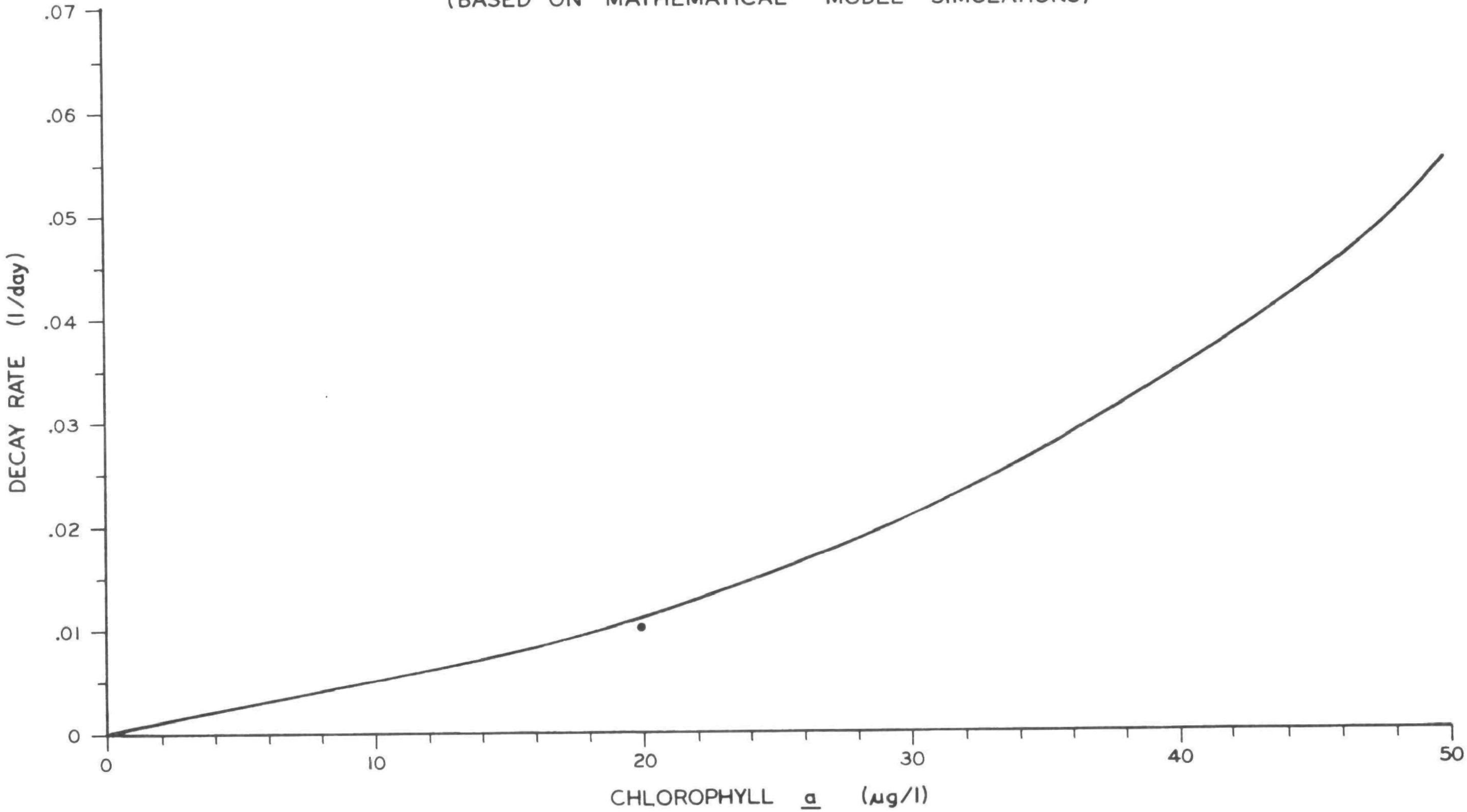


LONGITUDINAL INORGANIC NITROGEN PROFILES
UPPER CHESAPEAKE BAY
(SUSQUEHANNA FLOW = 23,000 cfs)
LEGEND
5/20/70 (OBSERVED)
7/7/70 (OBSERVED)
7/7/70 (PREDICTED)
DECAY RATE = 0.055/day
INORGANIC NITROGEN (mg/l)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
4
8
12
16
20
24
28
32
36
40
MILES BELOW SUSQUEHANNA RIVER

LONGITUDINAL INORGANIC NITROGEN PROFILES
UPPER CHESAPEAKE BAY
(SUSQUEHANNA FLOW = 50,000 cfs)



EFFECT OF CHLOROPHYLL
ON
DECAY RATE OF INORGANIC NITROGEN
UPPER CHESAPEAKE BAY
(BASED ON MATHEMATICAL MODEL SIMULATIONS)



LONGITUDINAL CHLOROPHYLL PROFILES
UPPER CHESAPEAKE BAY
(SUSQ. FLOW = 23,000 cfs)