TECHNICAL MEMORANDUM

July 1981

UPLAND DETENTION/RETENTION DEMONSTRATION PROJECT

THIRD ANNUAL REPORT TO THE

COORDINATING COUNCIL ON THE RESTORATION OF THE KISSIMMEE RIVER VALLEY AND TAYLOR CREEK/NUBBIN SLOUGH BASIN

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by

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INTERIM REPORT

Any findings, conclusions, and actual data are subject to change and/or revision.

Final publication of these data will be included in a future District Technical Publication

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ACKNOWLEDGEMENTS

The majority of funds for this study were contributed by the Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek/Nubbin Slough Basin. The author extends his gratitude to the Council staff and to the individual landowners of the various project sites who have allowed SFWMD personnel to construct facilities and maintain the ongoing monitoring program. The author wishes to thank the following SFWMD personnel, all of whom have made major contributions to the success of the monitoring and data management phases of this study: Mr. Fred Davis for his guidance and direction, Guy Germain and Elaine Rankin for their cheerful and enthusiastic efforts in carrying out the routine field work, Mary Lou Smith for her capable and thorough attention to the detail of performing laboratory analytical analyses of the water quality samples, Mr. Gary Ritter for his dual support of both the field and laboratory phases of the research effort, Mr. Art Nelson and his Data Management crew for installation and repair of water stage recorders, and Messrs. Ron Mierau, Tom MacVicar, and Andrew Fan of the Water Resources Division for their roles in providing the flow volume data necessary for doing loading calculations.

INTRODUCTION

This is the latest of an ongoing series of reports from the South Florida Water Management District (SFWMD) to the Coordinating Council for the Restoration of the Kissimmee River Valley-Taylor Creek/Nubbin Slough Basin (Council) concerning the status of the District's investigations of water quality of runoff from agricultural lands as part of the Council's Uplands Demonstration Project.

The SFWMD has been an integral participant in the project since entering into contractual agreement with the Council in the Fall of 1978. The project addresses the questions of agricultural land use practices and utilization of wetlands for enhancement of water quality as an alternative, either in whole or in part, for mitigating potential water quality degradation by contribution of runoff from said lands to the Kissimmee River and Lake Okeechobee.

The SFWMD's project responsibilities have included:

1. Achieving and maintaining hydrological integrity at each project site, and
2. Determining hydrological budgets at each project site.

These two obligations were fulfilled by the design and construction of ditches, levees, culverts and concrete flow control structures. In addition, the SFWMD was responsible for:

3. Conducting a field sampling program and performing laboratory analyses on water samples collected at the various stations on the project sites, and
4. Interpretation of hydrological and water quality data.

Previous reports to Council (SFWMD staff, 1979; Goldstein, et al., 1980; Goldstein and Ulevich, 1981) have documented the SFWMD's interest and activities. The first portion of this document will be a brief review of these activities.

The second and third portions of this document will consist of a presentation of data collected for the subject period April 1, 1979 through December 31, 1980 and its use in attempting to address the two main questions that the District set out to answer.

These are:

1. What are the effects of different agricultural land use practices in the Kissimmee River Basin on quality of runoff leaving those areas?
2. What are the impacts of detention/retention (D/R) areas on quality of water leaving agricultural areas?

The fourth section of this report contains an analysis and review of data collected from associated peripheral project studies (soil moisture and groundwater quality). The fifth and final section is a presentation of preliminary conclusions and pertinent discussion.

As of the subject date of this report, the SFWMD has attempted to meet all of its contractual obligations to the Council and has had reasonable success. The major setback in the program has been the delay between the time all physical aspects of the project were anticipated to be completed and the actual date that those aspirations became realized. For this reason, the anticipated 3-year data base at this time encompasses only 1½ years of useful data. It appears that the project will continue in some form for an additional period of time such that conclusions, presented here as preliminary, can be drawn on a more statistically sound data base.

CHAPTER I

REVIEW OF SFWMD PROJECT ACTIVITIES

INTRODUCTION

The SFWMD has contractually agreed to carry out basic hydrological engineering design studies and to perform designated construction activity at the five project study sites. Routine surface water quality and quantity monitoring are also designated as the District's responsibility. In addition, District staff attempted to monitor groundwater and soil moisture quality at each site as well as rainfall quality at three stations throughout the general project area. A brief review of the status of each of these areas of activity follows.

CONSTRUCTION

Construction activities consisted of installation or modification of existing flow controlling structures and associated dikes and levees necessary to establish hydrological integrity at each of the study sites. Control structures constructed or modified were either concrete critical depth flumes or culverts with risers and associated flashboards for water level manipulation. A large sand plug was constructed in the main channel at one of the study sites in order to force water laterally into and through adjacent marsh areas. Details of these activities are discussed in the previous SFWMD reports to Council referenced in the introduction.

HYDROLOGY

Daily flow volumes were calculated at most sampling stations following the installation of digital stage recorders. Water levels were recorded twice hourly. These data were converted to flows and summed to provide a total daily discharge. Flow data for all project study sites are available for the period of record April 1, 1980 to present. Flow data for most stations exists prior to this date and are utilized in these analyses where available. Details and theory of flume and culvert use for calculating flow are presented in Goldstein, et al.(1980).

WATER QUALITY MONITORING

The SFWMD has been contractually obligated to provide water quality monitoring on a routine and event basis. Routine surface water sampling data has been addressed in the previous reports and will be updated in this document. Event data is based on the definition of "storm event" provided to the KRVCC by letter of December 13, 1979 (Goldstein, et al., 1980). In this letter, "event" was defined in an inflow/discharge context. That is, an event would begin when water in excess of base flow began running off a watershed or flowing into a detention/retention marsh. The event was considered over when discharge directly associated with the inflow event ceased to occur. The amount of storm event data is limited due to the lack of a significant number of events occurring at the study sites over the past 1½ years.

Rainfall contributions of nitrogen (N) and phosphorus (P) have been ascertained by collecting weekly samples at the S-65D lock on the Kissimmee River, beginning in September 1979, and comparing these data with similar data from other sites (S-65B & the Okeechobee Field Station). Rainfall quantity has been measured by fourteen rainfall gauges dispersed throughout the project study area. Groundwater quality has been monitored monthly since January 1980 at sampling wells installed on each site for that purpose. Dry soil conditions were responsible for a failure to obtain soil moisture samples to make similar quality measurements.

WATER QUALITY LABORATORY

Water samples collected for the Upland Demonstration Project have been analyzed in the Okeechobee Environmental Research Center (OERC) water chemistry laboratory. The physical design of the facility, analytical techniques, and quality control procedures utilized to insure an accurate product are discussed in SFWMD staff (1979) and Goldstein, et al. (1980).

REPORTS

By contractual agreement, the SFWMD has been obligated to provide the KRVCC with two written reports each of the last two years. The result to date has been two annual progress reports and two semi-annual progress reports. These reports have addressed the status of each element of the District's project activities. Data collected through the subject date of the reports were analyzed and presented in preliminary form. Oral presentations of project status have been made periodically to the Council at regular meetings and at annual project contractor meetings. A presentation of project results is anticipated at a Council sponsored post-project symposium in Spring of 1981.

This report, written in partial fulfillment of the SFWMD's contractual obligations, is the latest written report to the Council covering the District's Upland Detention/Retention Project activities.

CHAPTER II

EFFECTS OF AGRICULTURAL PRACTICES ON WATER QUALITY

INTRODUCTION

The first section of this chapter will contain a review of the five project study site descriptions. This will be followed by a discussion of the time series water quality data that has been collected at the project study sites for the period April 1, 1979 through December 13, 1980. The third section of this chapter will describe the methodology and results of nutrient loading computations wherein hydrology data has been integrated into the data analysis procedure. The final section of this chapter will contain a discussion of the manner in which land use practices impact nutrient dynamics on the five Upland Demonstration Project sites.

SITE DESCRIPTIONS

The general locations of the five Upland Demonstration Project study sites in relation to the south Florida area and the city of Okeechobee are depicted in Figure II-1. A detailed description of each site follows:

A. ARMSTRONG SLOUGH

The Armstrong Slough site (Figure II-2) is located on Latt Maxcy Corporation property in Osceola County about six miles south of State Road 60 and east of the Kissimmee River just upstream of the S-65A control structure. Three sampling stations were established at this site where both water quality and quantity were monitored on a routine basis. One

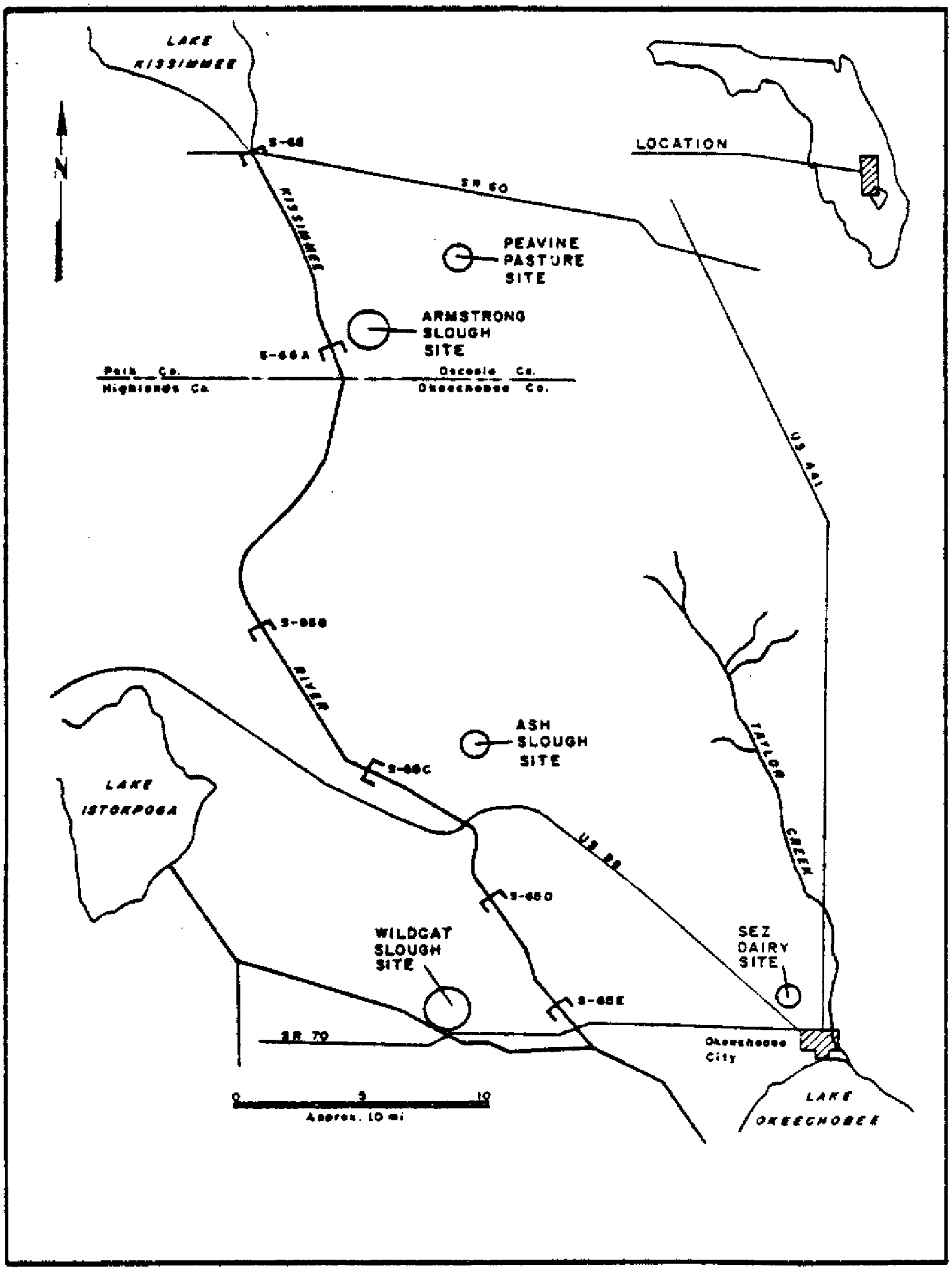


Figure II-1 STUDY SITES UPLAND DETENTION/RETENTION DEMONSTRATION PROJECT

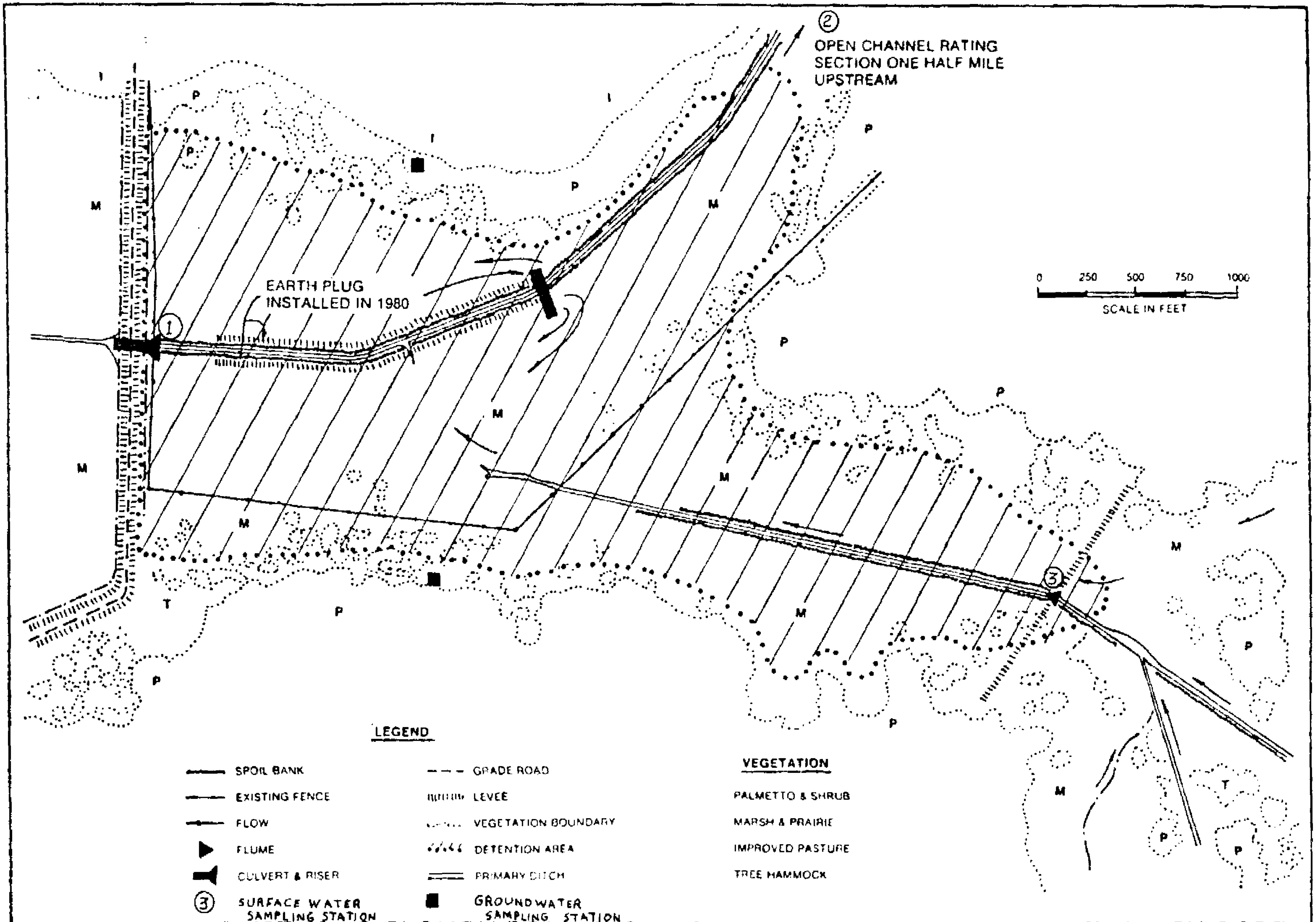


Figure II-2. ARMSTRONG SLOUGH DETENTION AREA, EL MAXIMO RANCH LATT MAXCY CORP.

sampling station was located in each of the tributary channels contributing flow into the Armstrong Slough marsh. The northernmost channel drains a watershed area of approximately 20,000 acres of mixed use agricultural land. The major land uses are light to moderate density cattle grazing and citrus groves. Citrus composes roughly 5 percent of the total watershed area. The monitoring station (Station 2) was located in a section of well defined open channel roughly one mile upstream of the site outfall culverts under the access road to the S-65A lock structure on the Kissimmee River.

The south tributary drains an area of roughly 2,000 acres of mixed pasture and native vegetation. The land is primarily used for low intensity cattle grazing. The monitoring location (Station 3) was established just upstream of the concrete flow monitoring flume which was constructed by the SFWMD to assist in making flow measurements at this location.

Prior to May of 1980, the southern tributary channel drained through an approximately 80 acre marsh before finally draining into the northern conveyance channel just upstream of the site outfall culverts. The northern channel was well defined and flow was contained within the banks at all times except during the rainfall/discharge events accompanying Hurricane David. During May 1980, SFWMD construction crews plugged the northern channel at a point about ¼ mile upstream of the outfall culverts in an attempt to create additional marsh by forcing water out of the channel and across the adjacent low lying areas. The present area of ungauged inflow to the marsh area is some 453 acres. The installation of the plug did result in creating more permanent marsh lands during normal flow conditions.

The site outfall monitoring station (Station 1) is located upstream of six 72-inch culverts under the access road to the S-65A structure. These culverts are fitted with risers and flashboards so that water levels may be manipulated on a predetermined seasonal basis or as discharge events dictate. Normal water levels in the marsh area were kept at or near 49 feet msl throughout the majority of this study.

B. ASH SLOUGH

The Ash Slough site (Figure II-3) is located in Okeechobee County about five miles north of Basinger on the J. C. Bass ranch. The site presently consists of about 240 acres of intensively ditched and improved pasture which drains into a 20 acre marsh in the headwaters of Ash Slough. Four monitoring locations were originally established at this site. The marsh receives runoff from two distinct land use units. The major portion comes from a 160 acre pasture block on the west that was extensively ditched for drainage during previous years when the land was used for vegetable growing. In recent years it has been converted to improved pasture and is used for a relatively high density cattle grazing operation (.33 cattle/acre). The sampling station is located in the sole drainage ditch that leads into the marsh, just upstream of a concrete critical depth flume installed by SFWMD personnel to enable accurate flow measurements to be made at this location.

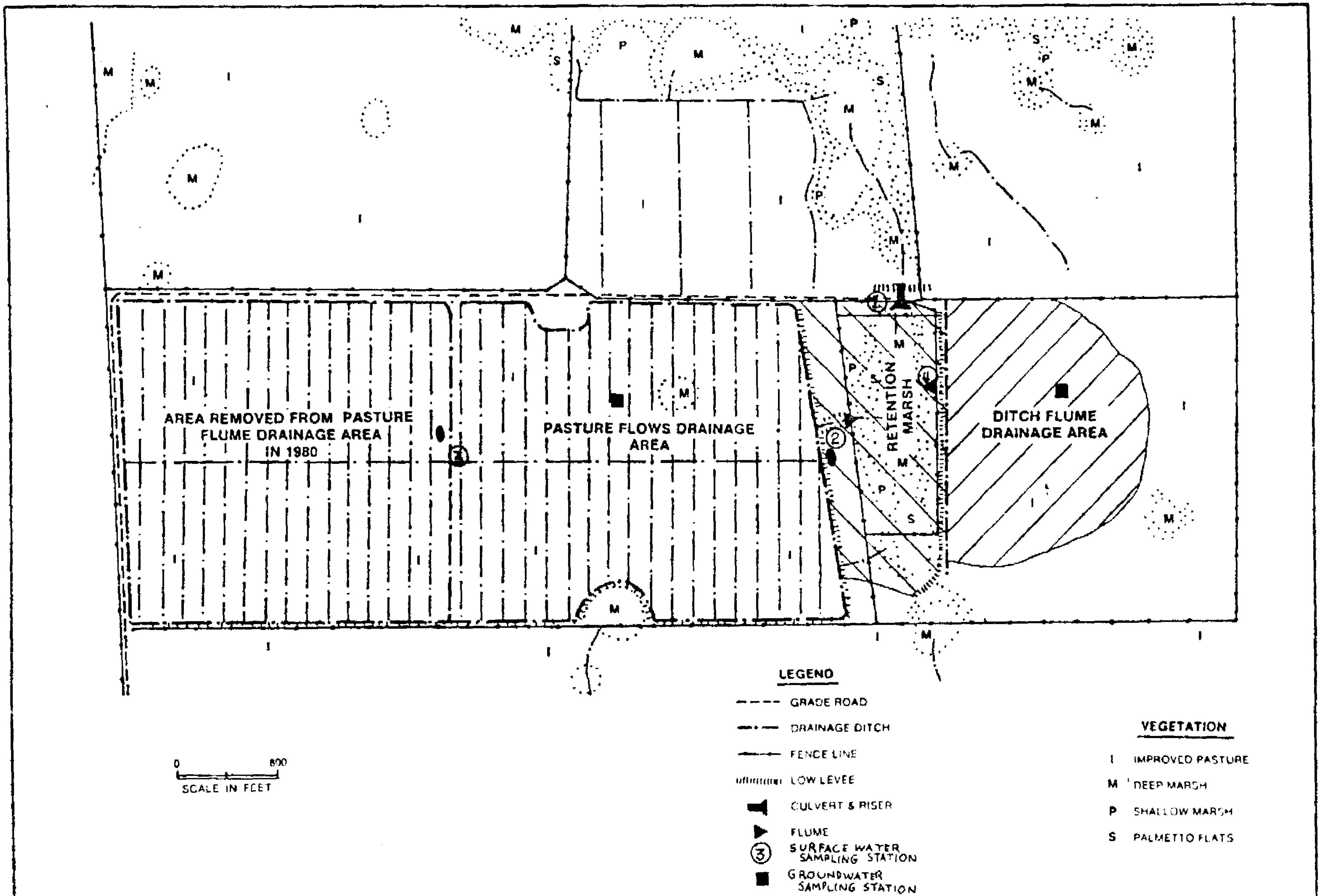


Figure II-3. ASH SLOUGH, BASS RANCH

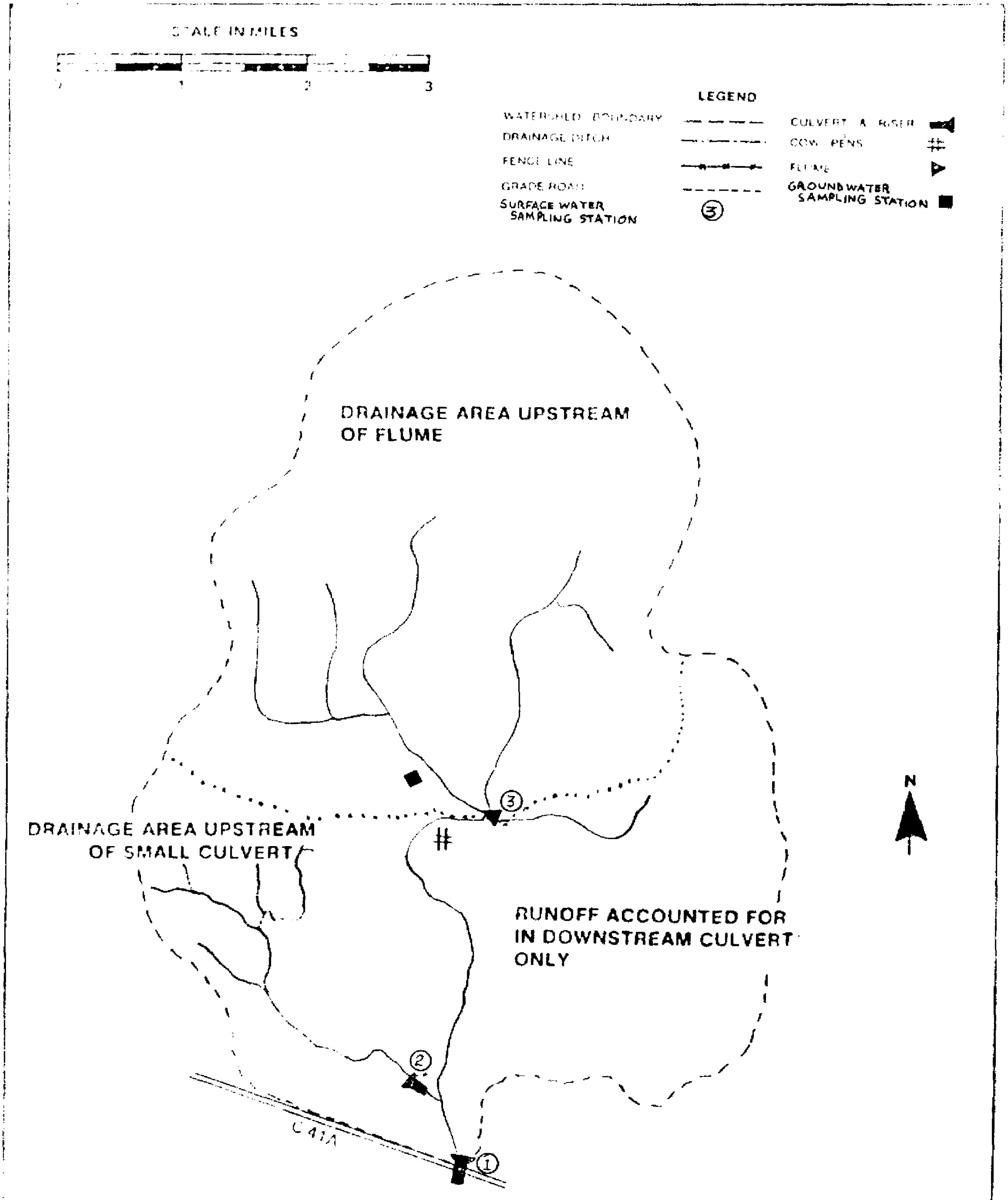
The pasture block on the east side of the marsh is unditched and is a significantly smaller watershed (26 acres). This pasture is also used for cattle grazing. A shallow interceptor ditch was dug parallel to the marsh. This ditch intercepts sheet flow runoff from the east pasture and channels it through a small critical depth flume installed to measure flow from this pasture into the marsh. This location was designated Station 4 and water quality samples are taken just upstream of the flume.

Station 3 was discontinued in February 1980 following the installation of a sand plug in the drainage ditch that allowed runoff from an additional 150 acre pasture block to flow into and through the western ditched pasture.

Station 1 was established upstream of the two 18-inch culverts through the tie-back levee installed to detain storm water runoff in the Ash Slough marsh. The culverts were fitted with risers and flashboards so that water levels in the marsh could be manipulated as the need arose. A refrigerated automatic sampling device was permanently installed in a shelter at this station.

C. WILDCAT SLOUGH

Wildcat Slough is located on Lykes Bros., Inc. ranch property in Highlands County north of Brighton at the intersection of State Road 70 and Canal C-41A (Figure II-4). Rainfall runoff from this site is conveyed through two major channels and drains into C-41A through five 72-inch culverts. The entire drainage area is about 15,680 acres. Three sampling stations



WILDCAT SLOUGH
BRIGHTON RANCH
LYKES BROS.
INC.

Figure II-4

from Mierau (1981)

were located on this site. One location was established in the main channel roughly 3 miles upstream of C-41A. This station (Station 3) drains an area of 6,400 acres of mostly native with some slightly improved rangeland. This area is used for low density (.05 cows/acre) cattle grazing. A concrete critical depth flume was installed at this location to enable collection of accurate flow measurements. Water quality samples are collected immediately upstream of this flume. A second sampling station was located in a smaller but main tributary channel that drains a 427-acre area of native rangeland and improved pasture at the western portion of the site. One 48-inch culvert with risers and flashboards was located in the channel and was used to measure flows. Water quality samples were collected immediately upstream of the culvert. Station 1 was located just upstream of the site outfall culverts at C-41A. The 5,200 acre watershed area between Site 1 and Sites 2 and 3 is predominantly unimproved pasture and supports light to moderate (.05 cows/acre) grazing pasture.

D. PEAVINE PASTURE

The Peavine Pasture site (Figure II-5) is located on Latt Maxcy Corporation property in Osceola County about two miles south of State Road 60 on the west side of Old Peavine Road. The site is approximately 600 acres of improved pasture supporting light to moderate (.20 cows/acre) grazing practices. A concrete, critical depth flume was installed at the site outfall to accurately measure runoff discharge at this location. A water quality sampling station (Station

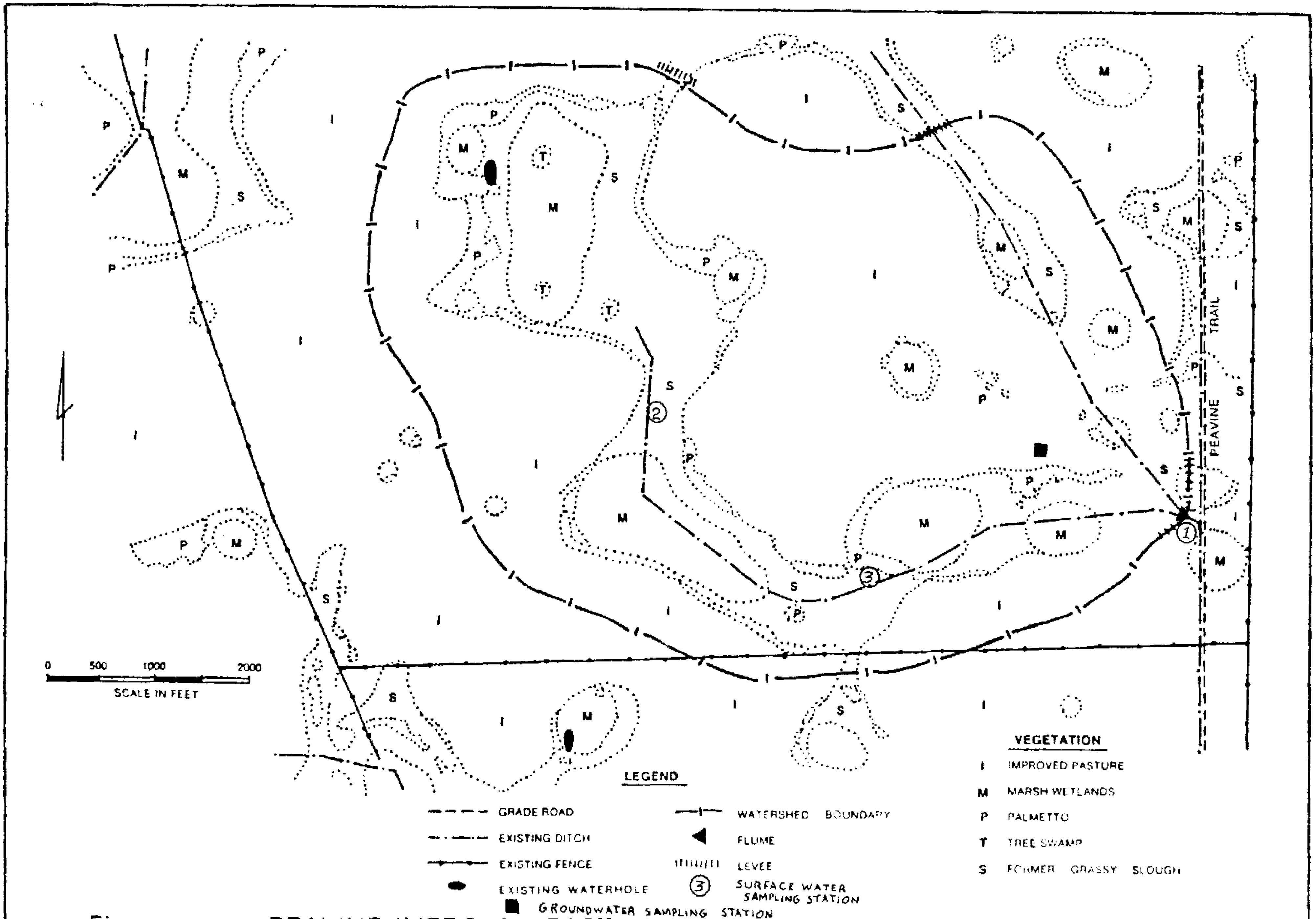


Figure II-5. PEAVINE IMPROVED PASTURE, EL MAXIMO RANCH, LATT MAXCY CORP.

1) was established immediately upstream of the flume. Two major conveyance channels converge immediately upstream of the sampling site. The northern channel is plugged at the watershed boundary. The southern channel originates on site at a location in the central portion of the watershed. Two additional water quality sampling locations were established in this channel.

E. SEZ DAIRY

The SEZ Dairy site (Figure II-6) is an 815-acre dairy located in Okeechobee County about three miles northwest of the City of Okeechobee. The western portion of the site supports a high density cattle holding and grazing dairy operation of some 500 head of milking cows plus a 200 head heifer and calfing operation. The central and eastern portions of the dairy are used for grazing and haying operations. Waste water from the milking barn complex drains into a Soil Conservation Service-designed waste stabilization lagoon system. This system consists of a 1.5 acre first stage settling lagoon and a 3.7 acre second stage holding lagoon. Conceptually, effluent from the second lagoon is released to a ditched seepage irrigation system thus putting discharged nutrients onto the land. In reality, this system suffers maintenance and management shortcomings (Goldstein and Ulevich, July 1980) such that when discharge from the lagoon system occurs, it flows directly into the perimeter ditch on the north edge of the property and is subsequently discharged directly into Wolf Creek, a

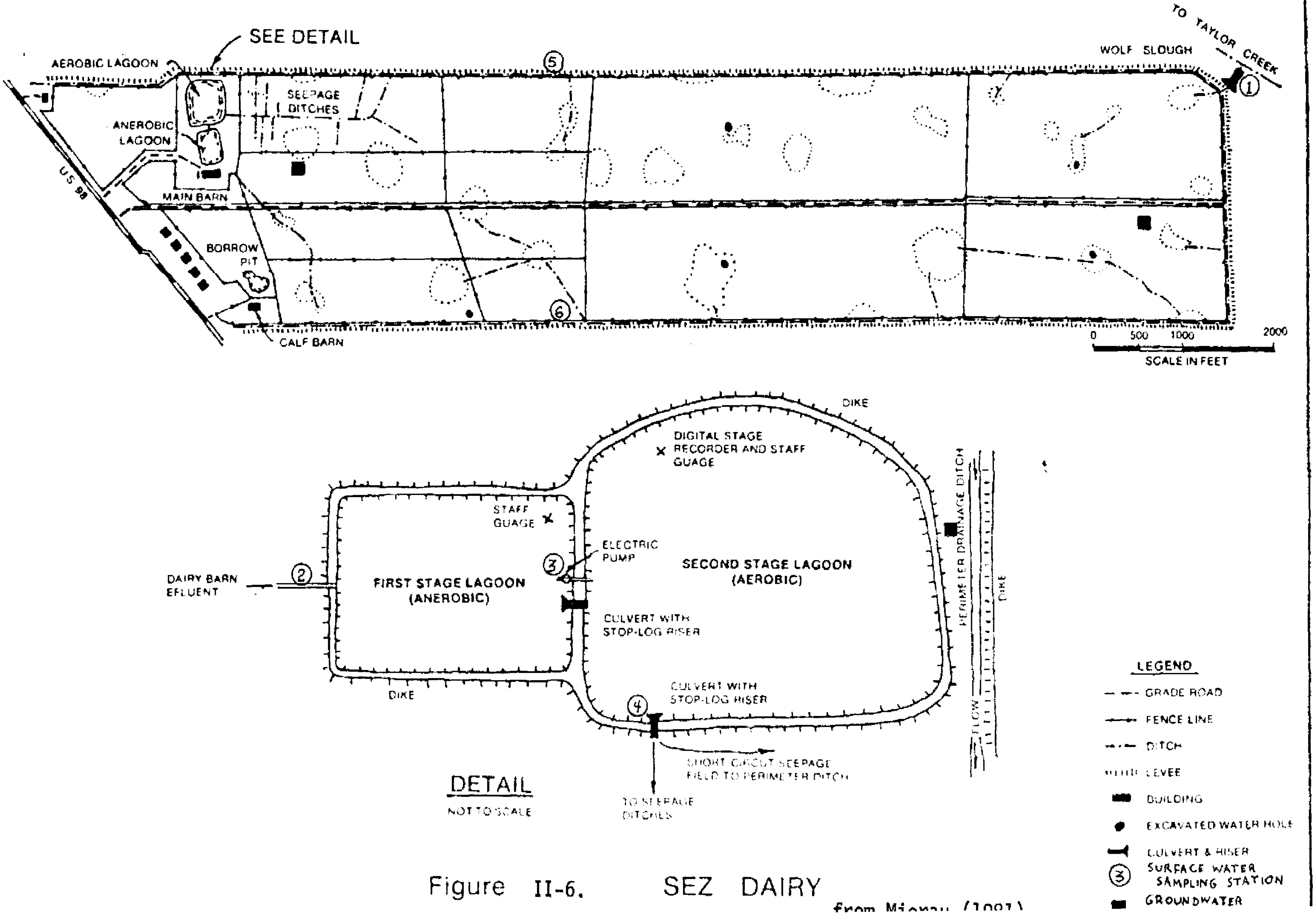


Figure II-6. SEZ DAIRY

from Mi[illegible] (19[illegible])

tributary in the Taylor Creek drainage basin.

The dairy is surrounded by a perimeter drainage ditch that discharges at only one site, the above described Wolf Creek outfall. Station 1 was located immediately upstream of the 24-inch culvert and riser system that is used for flow control at this point. Five additional water quality sampling locations were located at points throughout the dairy. Station 2 was established midway down the concrete trough that conveys barnwash to the first lagoon. Station 3 was located in the first lagoon at a point in front of the pump intake where excess water from the first lagoon is moved into the second lagoon. Station 4 is located in the second lagoon, just in front of the stage control riser and culvert at the discharge point of the second lagoon. Stations 5 and 6 were located midway down the north and south perimeter ditches, respectively. Flow volumes were monitored at the site outfall (Station 1) and at discharges from both lagoons (Stations 3 and 4).

WATER QUALITY MONITORING

Details of site preparation and methodologies of water quality sampling and laboratory analyses have been described in periodic project status reports to Council (July 1979, January 1980, and July 1980). Time series analyses of data through the report subject period were also presented in these documents. The following is a similar discussion of time series trends for the entire data set for the period of record April 1, 1979 through December 31, 1980.

ARMSTRONG SLOUGH

Previous discussions of time series data (Goldstein and Ulevich, 1980) pointed out the fact that concentrations measured at the site outfall (Station 1) reflected trends and magnitudes similar to those measured in the north tributary (Station 2) and thus, practices in that portion of the watershed would probably continue to have major impact on quality of discharge from the site. A most radical physical alteration of the site occurred during April/May of 1980 with the installation of an earthen plug in the main channel upstream of the Station 1 water quality monitoring location. The installation of this plug would be expected to directly impact water quality characteristics measured at that station. Indeed, during plug installation and replacement of the concrete flume at Station 3, turbidity levels at Stations 1 and 3 jumped noticeably. The plug installation would not be expected to have impact at the monitoring site in the south channel (Station 3) and only minimal impact, if any (due to backwater effects), at the Station 2 monitoring site in the north channel. Comparing the time series data (Figures II-7 through II-14), in most cases concentrations of water quality parameters at Station 1 seem to continue to mainly reflect trends that occur at Station 2.

Following installation of the plug, mean concentrations of all monitored chemical parameters were somewhat lower than mean concentrations of the same parameters prior to installation of the plug. That is especially noticeable for concentrations of inorganic forms of nitrogen and phosphorus which, under the low flow conditions that have prevailed following the installation of the plug, have been

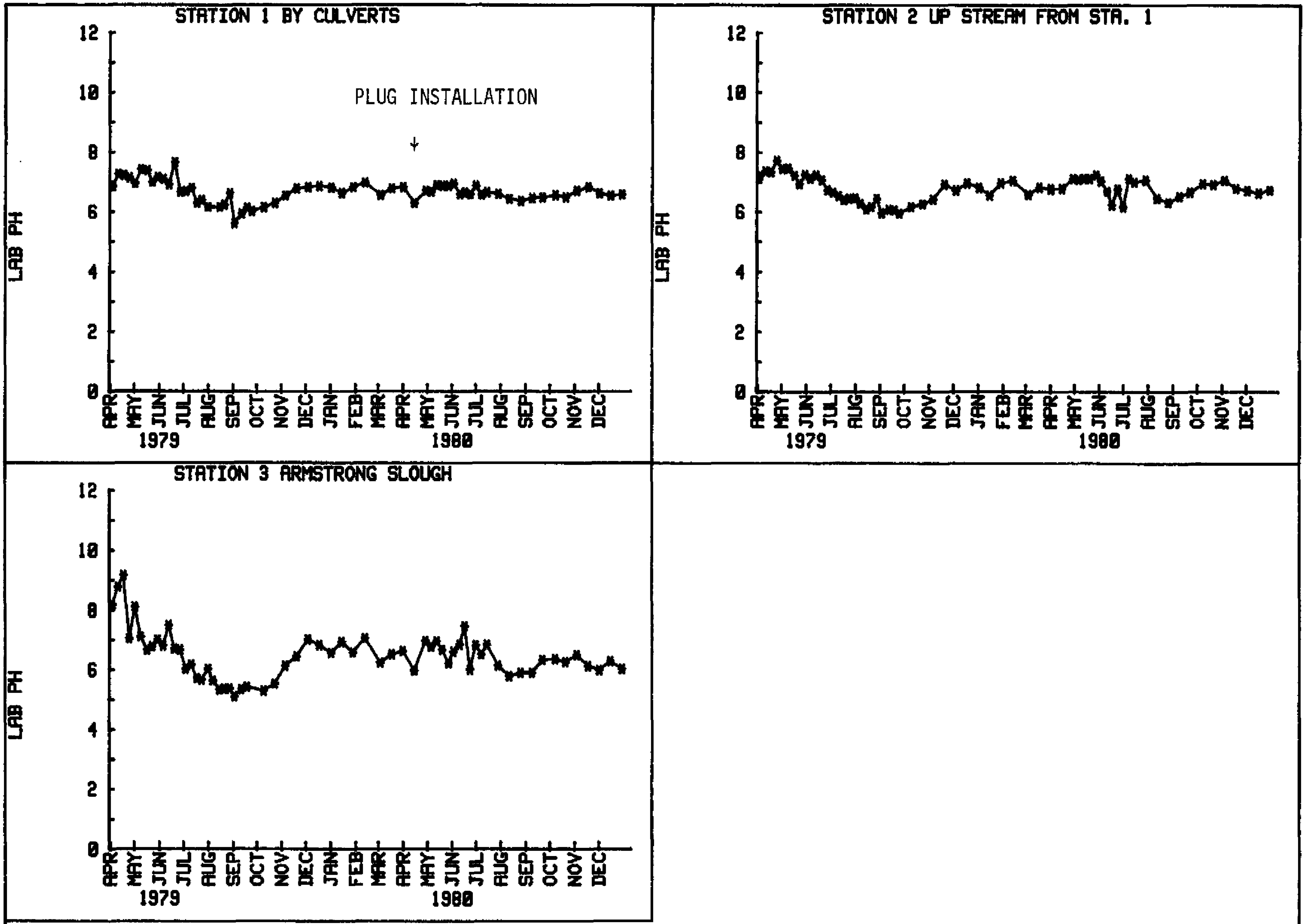


FIGURE II-7. LAB PH FOR ARMSTRONG SLOUGH

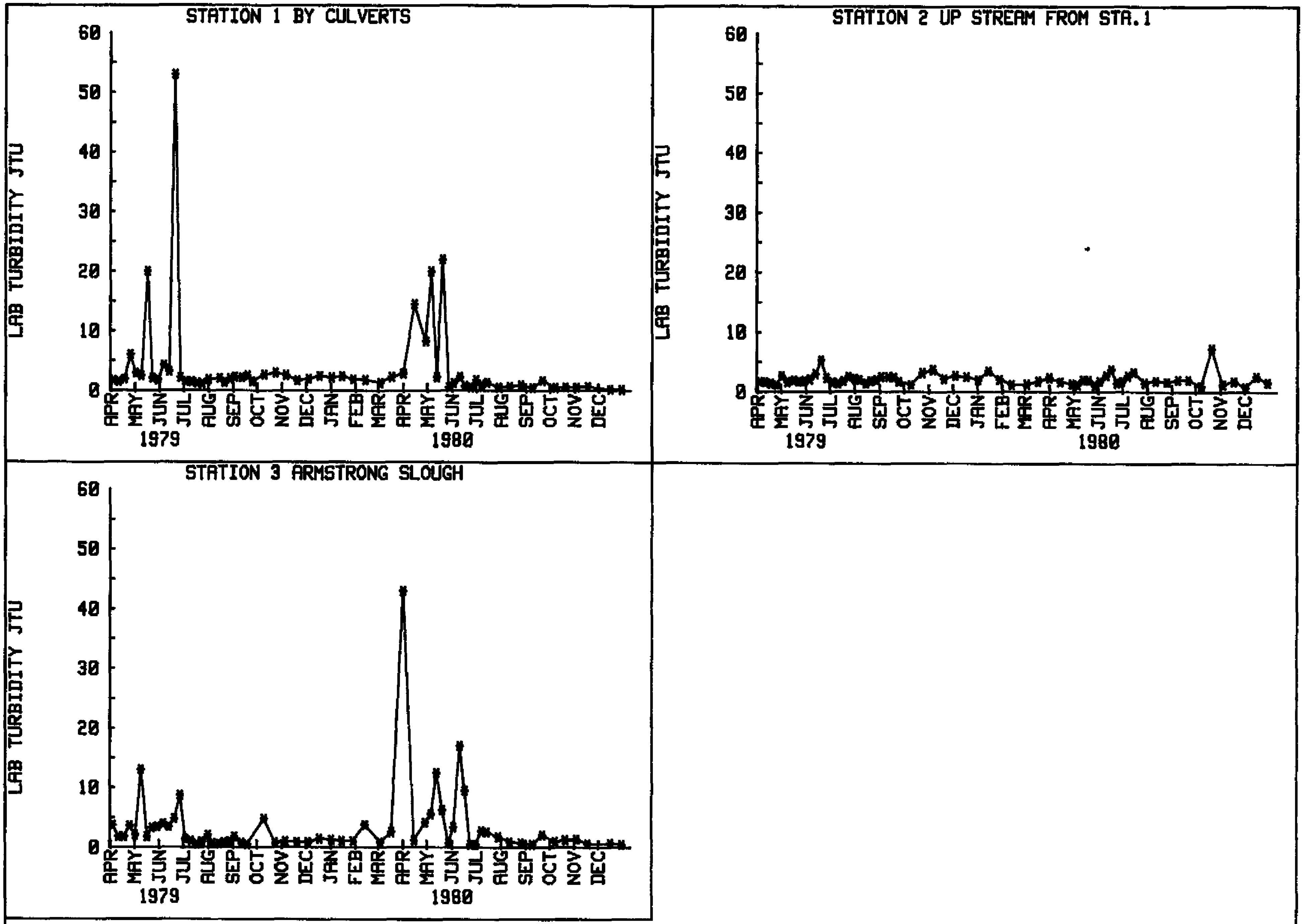


FIGURE II-8. LAB TURBIDITY FOR ARMSTRONG SLOUGH

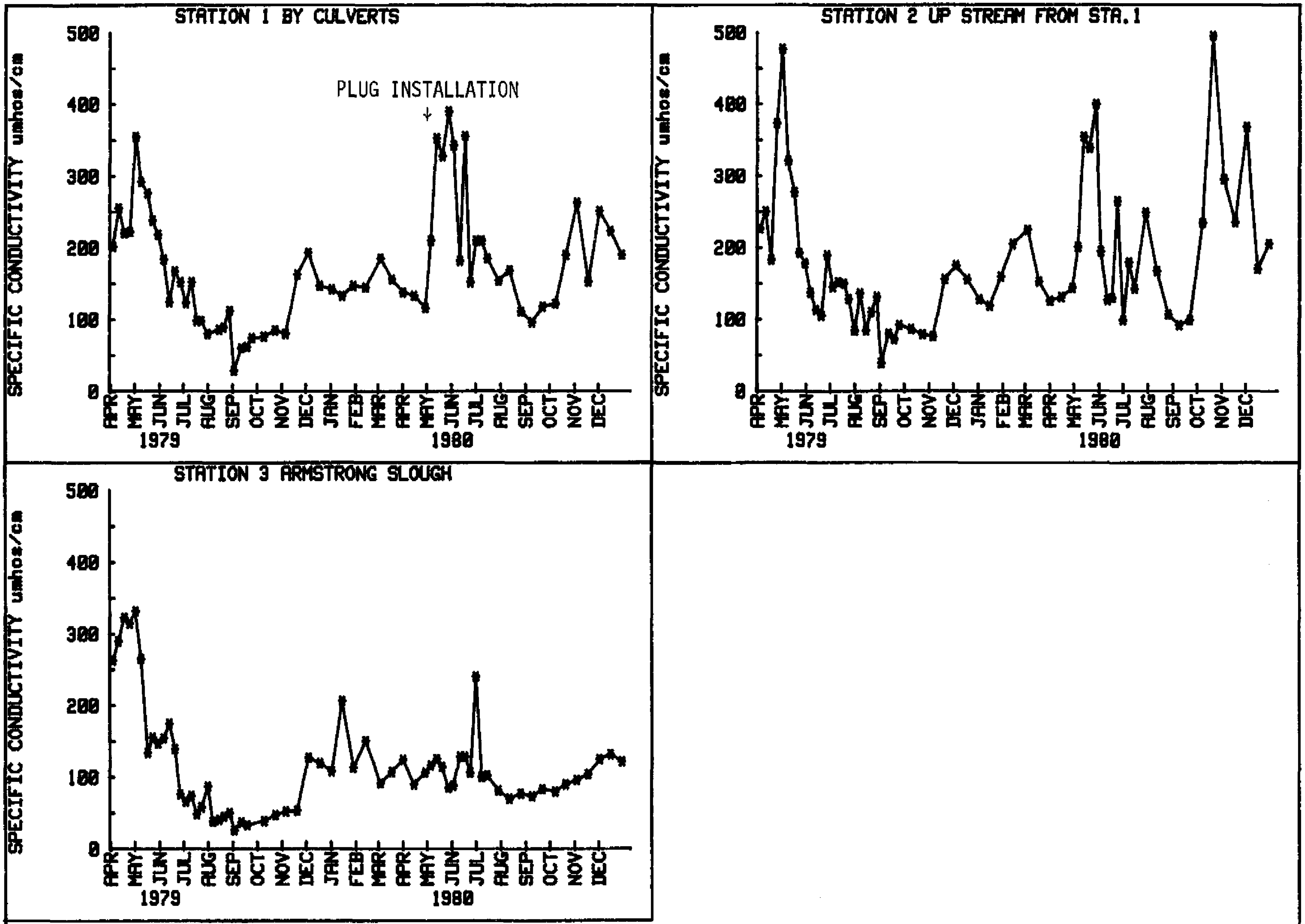


FIGURE II-9. LAB CONDUCTIVITY FOR ARMSTRONG SLOUGH

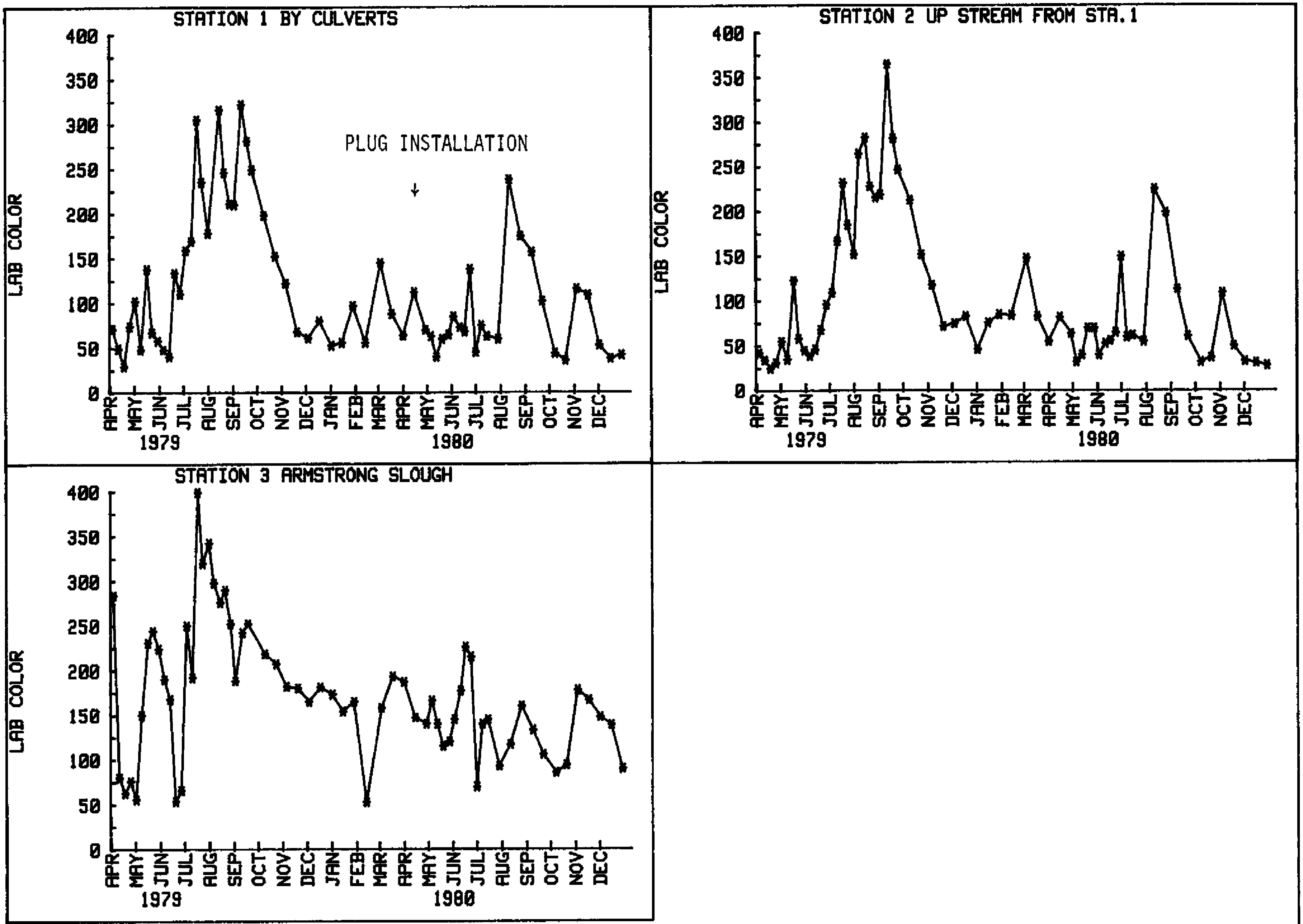


FIGURE II-10. LAB COLOR FOR ARMSTRONG SLOUGH

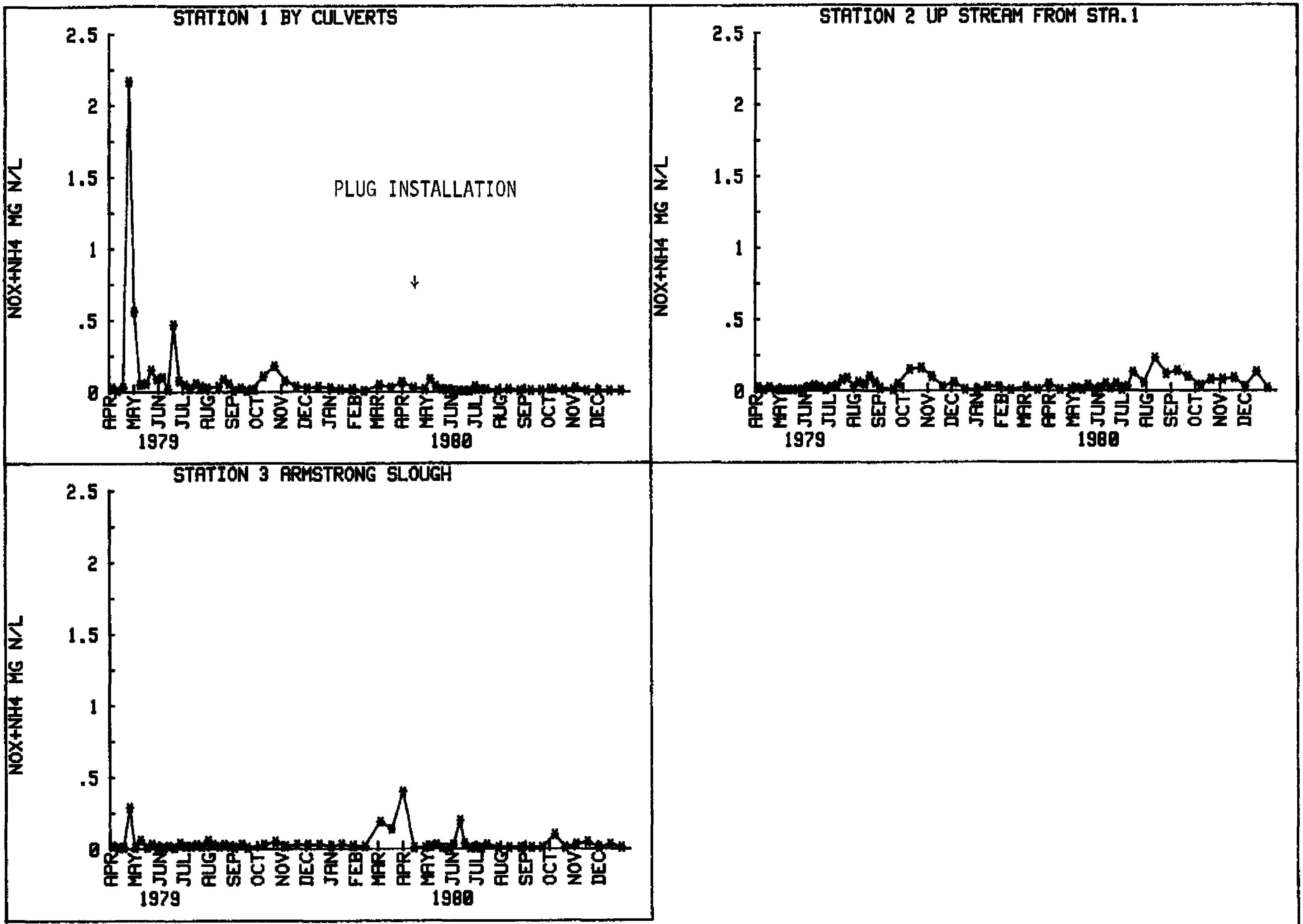


FIGURE II-11. NOX+NH4 FOR ARMSTRONG SLOUGH

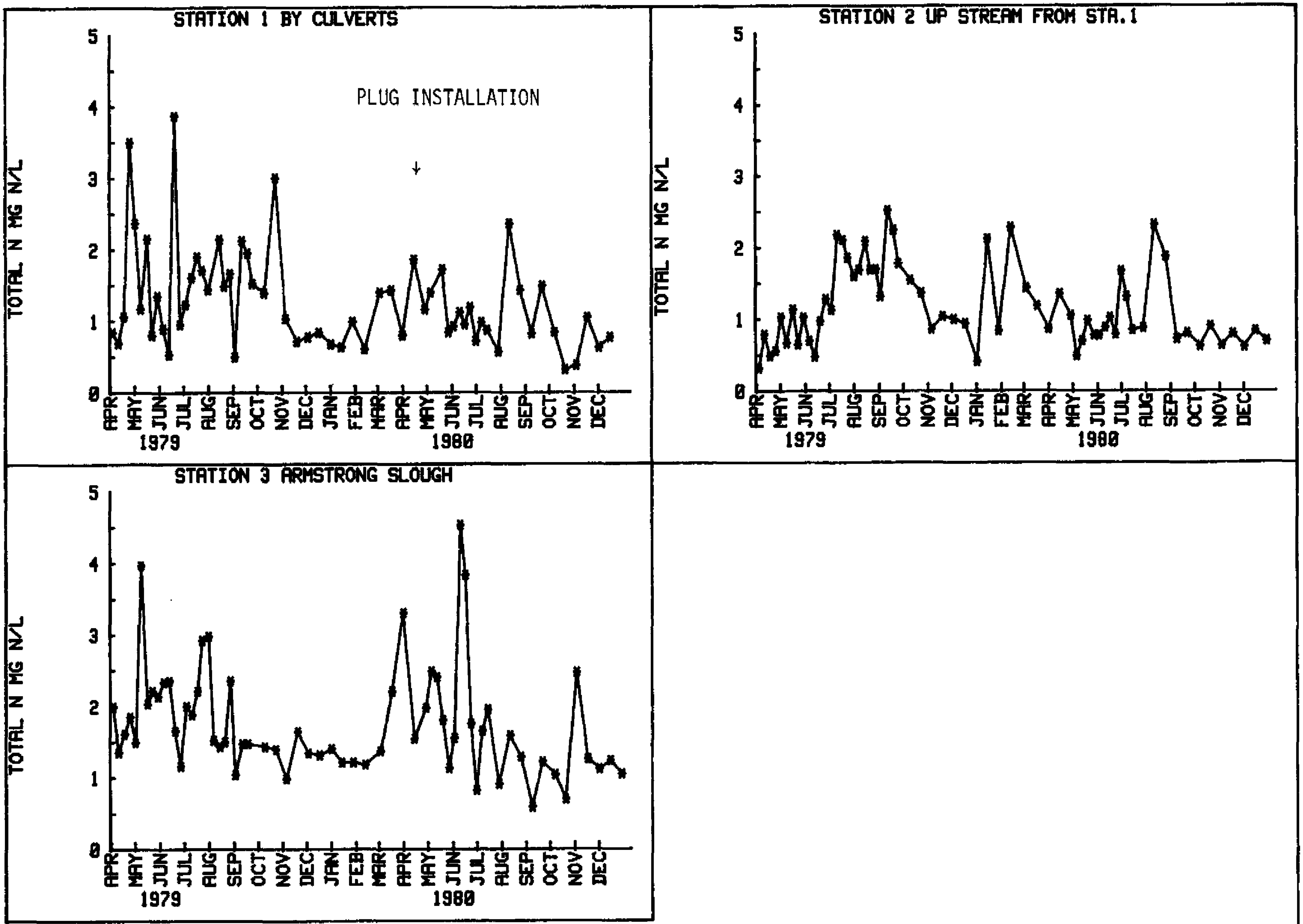


FIGURE II-12. TOTAL NITROGEN FOR ARMSTRONG SLOUGH

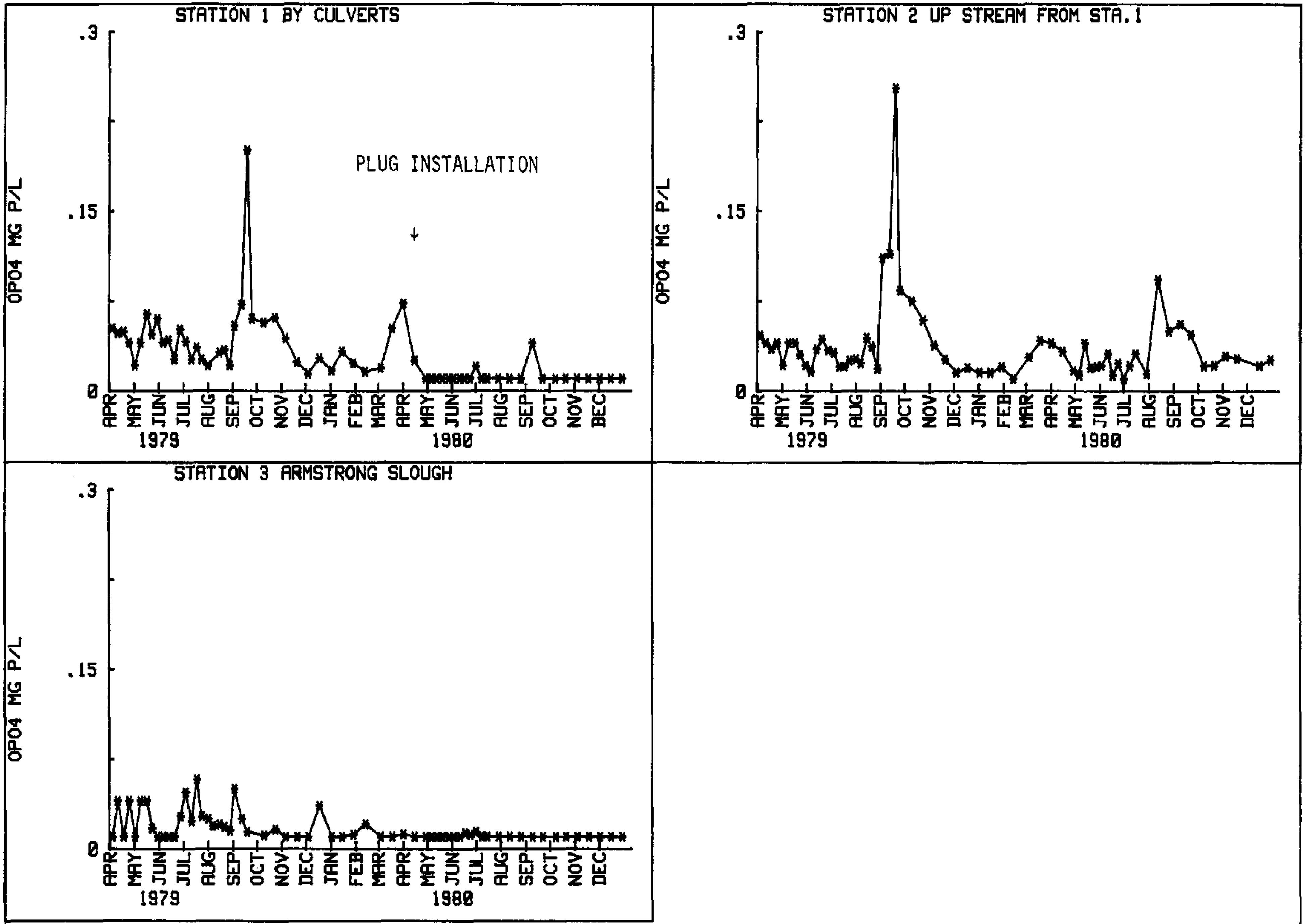
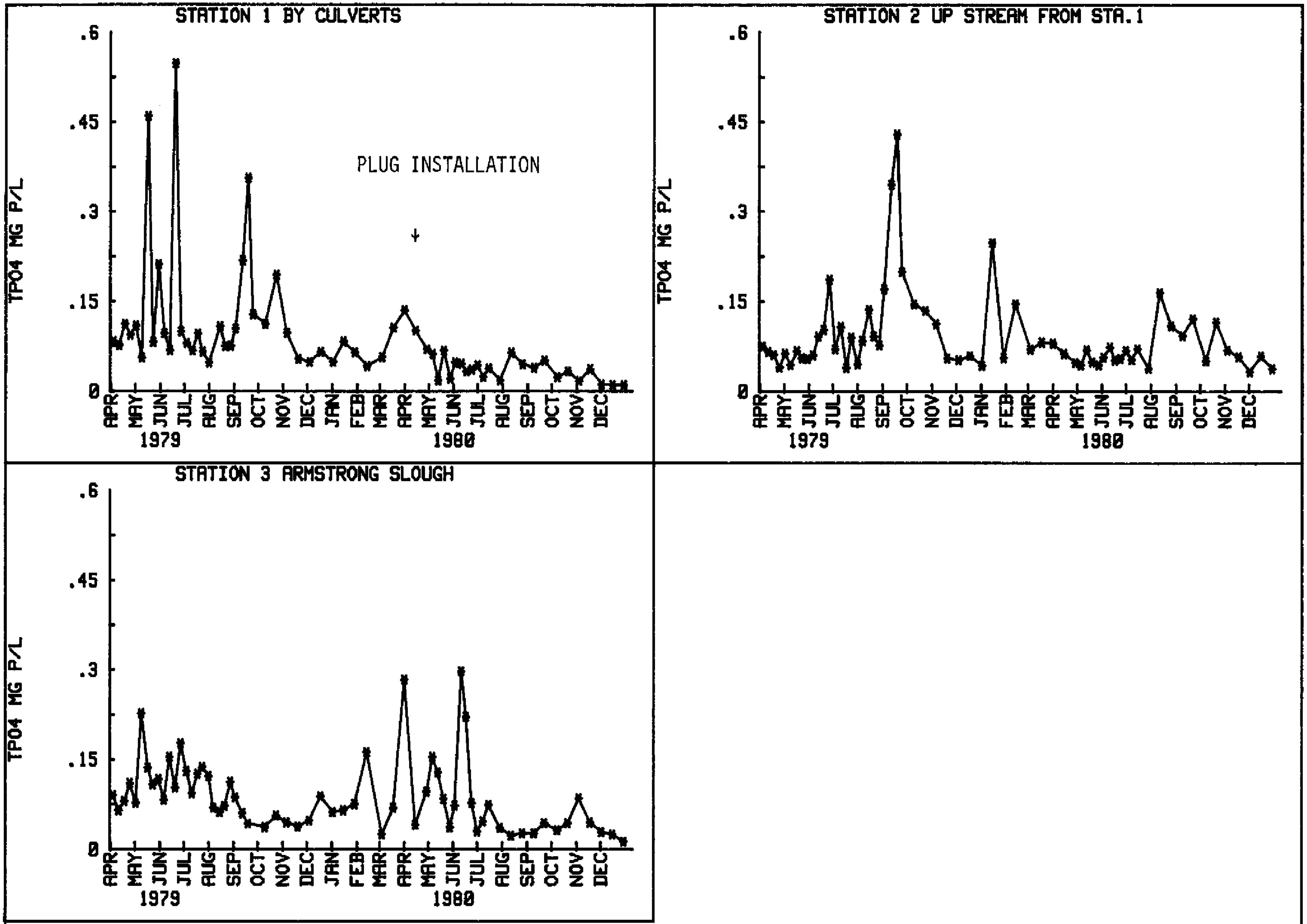


FIGURE II-13 . ORTHO PHOSPHORUS FOR ARMSTRONG SLOUGH



STATION 1 BY CULVERTS

STATION 2 UP STREAM FROM STA.1

STATION 3 ARMSTRONG SLOUGH

FIGURE II-14. TOTAL PHOSPHORUS FOR ARMSTRONG SLOUGH practically eliminated from the site discharge effluent. These data are presented in Table II-1. Following plug installation, conductivity is the only parameter that shows a mean net increase. This probably does not relate to plug installation at all, but rather to an increased use of groundwater for irrigation of citrus groves in the upper portion of the watershed during the prevailing dry conditions. All other parameters showed a mean net decrease. With the exception of pH, this net decrease was substantial, ranging from a 32.9 percent reduction for TKN to 98.3 percent reduction for NOx. Since the plug installation, inorganic forms of nitrogen and phosphorus are usually just at or below detention levels (<0.010 mg/l).

Superficially, the installation of the plug and the resulting increase in marsh area appear to have had a major impact on improving water quality leaving the site, and the percentage of decrease of each nutrient species appears to be quite impressive. In absolute terms, however, the actual reduction of mean total and inorganic nitrogen following plug installation is only 0.48 and 0.11 mg/l respectively, while the reduction of total and ortho phosphorus is 0.090 and 0.030 mg/l. In other words, influent water quality to the detention/retention marsh is not of sufficiently bad quality to adequately test the system.

Another important aspect that must be considered is the fact that these post installation data were collected during a period of abnormally low rainfall and runoff. The total rainfall measured on the site during the post-installation period was 45 cm. For this reason, contact time of water in the marsh was maximized. Normal

Table II-1

ARMSTRONG SLOUGH

Station 1

Pre and Post Channel Plug Installation Water Quality Comparison

	COND	pH	TURB	COLOR	*NOx	*NH4	*NH4+NOx	*TKN	*TOTAL N	*ORTHO P	*TOTAL P
Pre Plug April 01, 1979 - March 31, 1980											
n	37	37	37	37	37	37	37	37	37	37	37
$\overline{X}$	152.0	6.70	4.1	136.0	0.29	0.11	0.13	1.40	1.43	0.043	0.121
σ	73.0	0.46	8.8	87.2	0.58	0.31	0.36	0.76	0.80	0.031	0.111
min	29.0	5.61	1.2	29.0	0.004	0.01	0.01	0.50	0.50	0.014	0.042
max	355.0	7.66	53.0	322.0	0.341	1.83	2.17	3.74	3.87	0.201	0.548
Post Plug July 01, 1980 - Dec. 31, 1980											
n	15	15	14	15	15	15	15	14	14	15	15
$\overline{X}$	176.0	6.59	0.8	90.0	0.005	0.02	0.02	0.94	0.95	0.013	0.031
σ	51.0	0.14	0.5	60.0	0.002	0.01	0.01	0.53	0.53	0.008	0.016
min	96.0	6.37	0.2	36.0	0.004	0.01	0.01	0.32	0.32	0.010	0.010
max	263.0	6.88	1.8	238.0	0.011	0.04	0.04	2.35	2.36	0.040	0.064
% Change of Mean Following Plug Installation	+15.8	-1.6	-80.5	-33.8	-98.3	-81.8	-84.6	-32.9	-33.6	-69.8	-74.4

KEY: n=number of samples; $\overline{X}$=mean; σ=standard deviation

*All chemical parameter units are in mg/l rainfall for the same period is 122-132 cm. The ability of the system to function during periods of high flows has not yet been tested. Given less contact time with the marsh, surface treatment efficiencies may change appreciably.

Finally, the six month post-plug period of record is only half that of the pre-plug condition. Until at least a full year of data has been collected, any conclusions drawn must be considered tentative.

ASH SLOUGH

Four distinct rainfall/runoff events occurred at Ash Slough during calendar year 1980. These occurred in mid-February, early April, mid-July, and early September. During each of these periods, rainfall and subsequent runoff was sufficient to produce measurable flow into and out of the detention/retention marsh.

Comparing time series data means and graphics (Figures II-15 through II-22), mean concentrations of all quality parameters except phosphorus species are highest at the Station 1 discharge point in the marsh, followed by those at Station 2 (large flume) and finally those at Station 4 (small flume). Phosphorus species concentrations were greater at Station 2 than at the other two sampling locations. Station 3 was discontinued after February 1980 and will not be considered in this discussion. The difference in concentrations of conductivity, inorganic nitrogen, and inorganic and organic phosphorus between Stations 2 and 4 are probably reflections of the different land drainage alternatives that exist between the eastern and western sides of the marsh. Mean concentrations of inorganic nitrogen from the western block are twice those observed in inflow from the eastern side. Ortho and total phosphorus concentrations from the western block are four

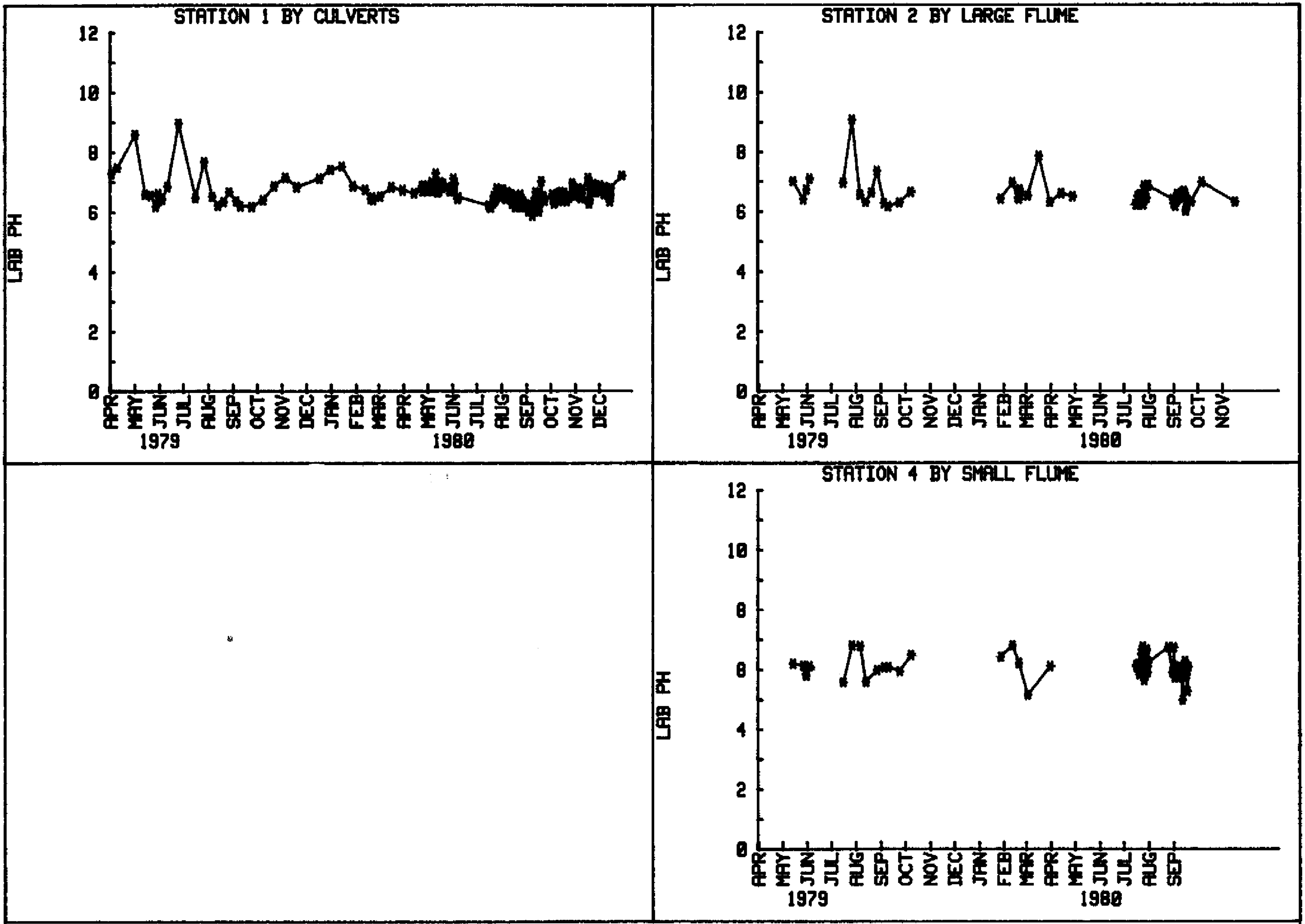


FIGURE II-15. LAB PH FOR ASH SLOUGH

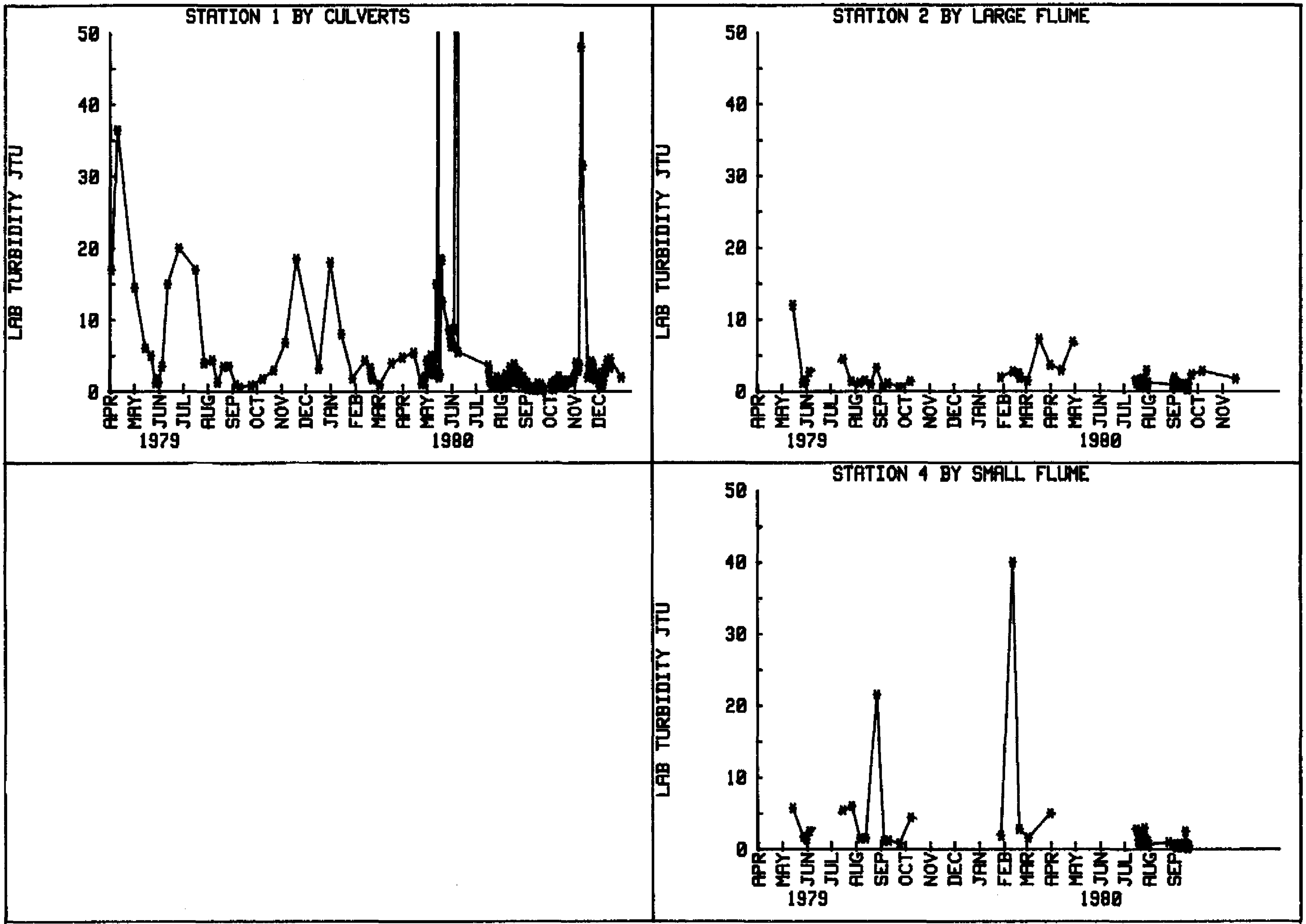


FIGURE II-16 . LAB TURBIDITY FOR ASH SLOUGH

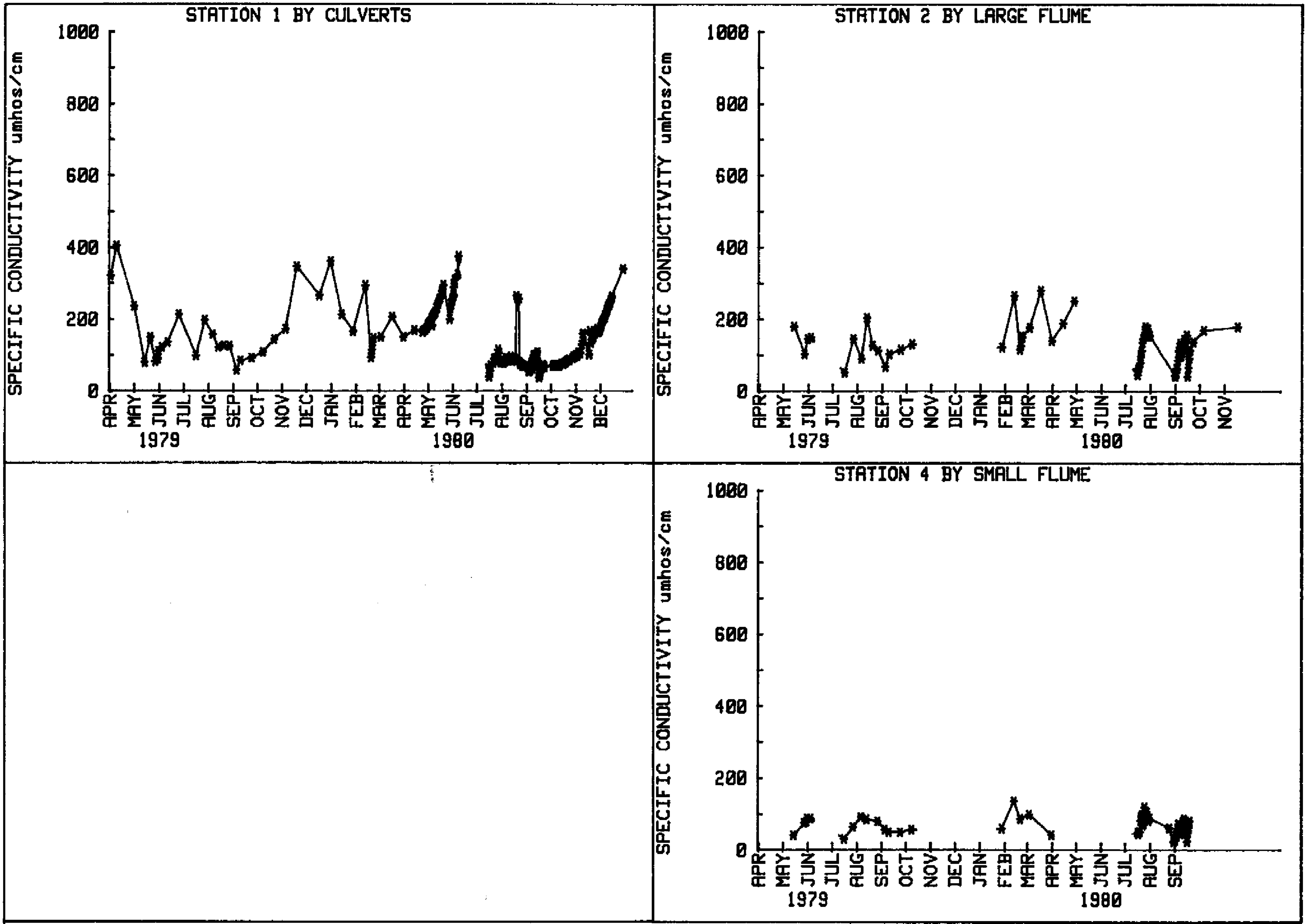


FIGURE II-17. LAB CONDUCTIVITY FOR ASH SLOUGH

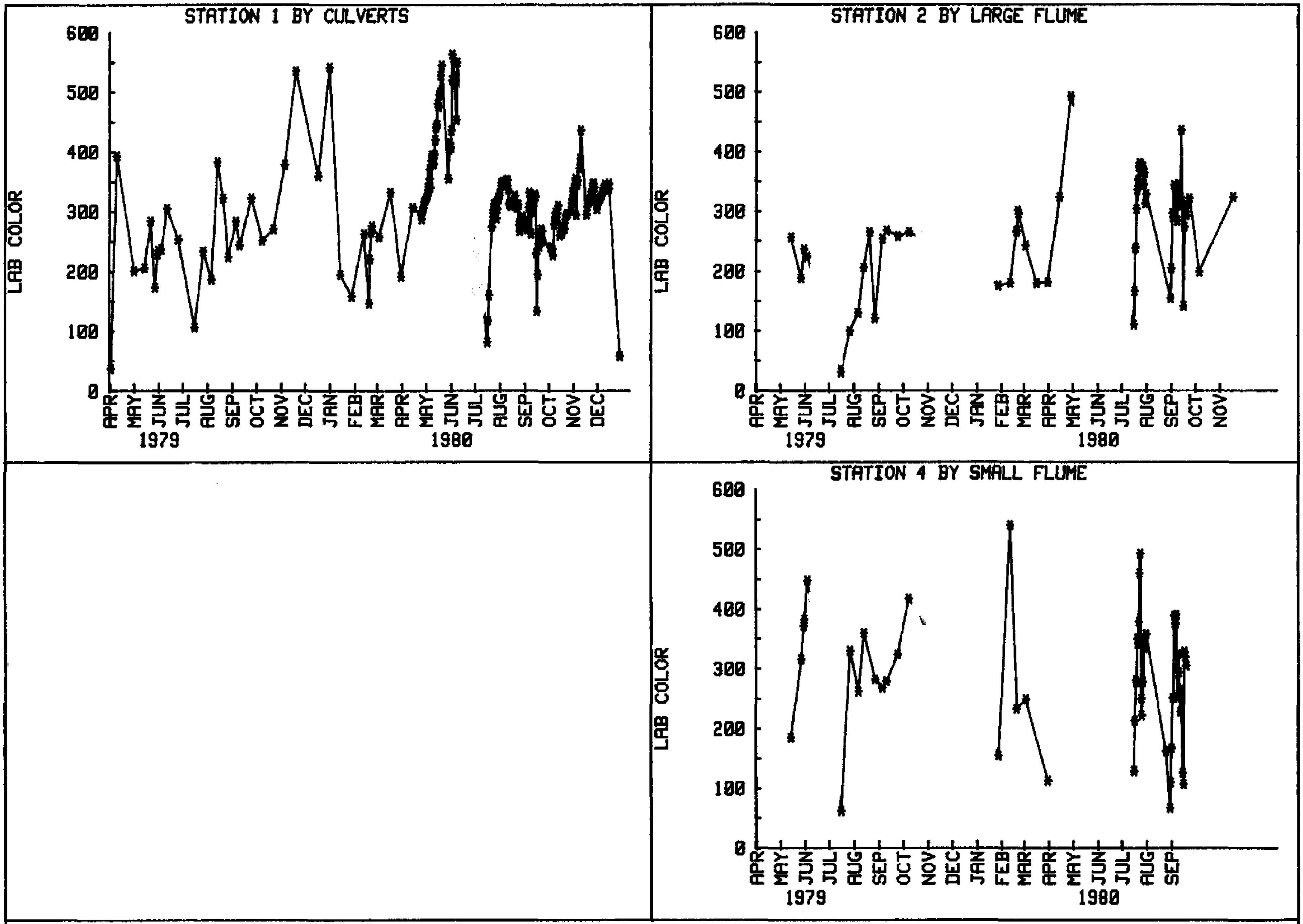
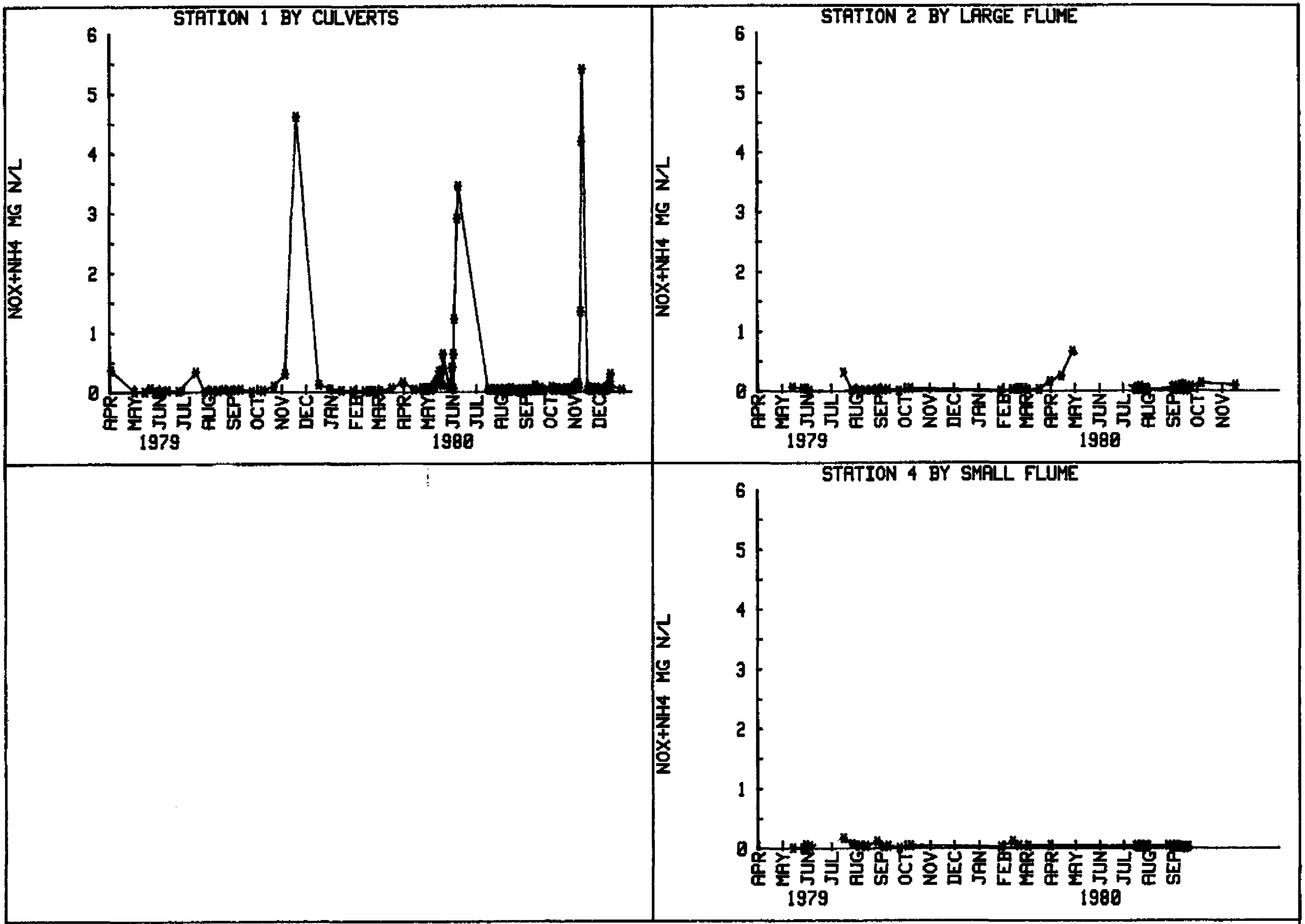


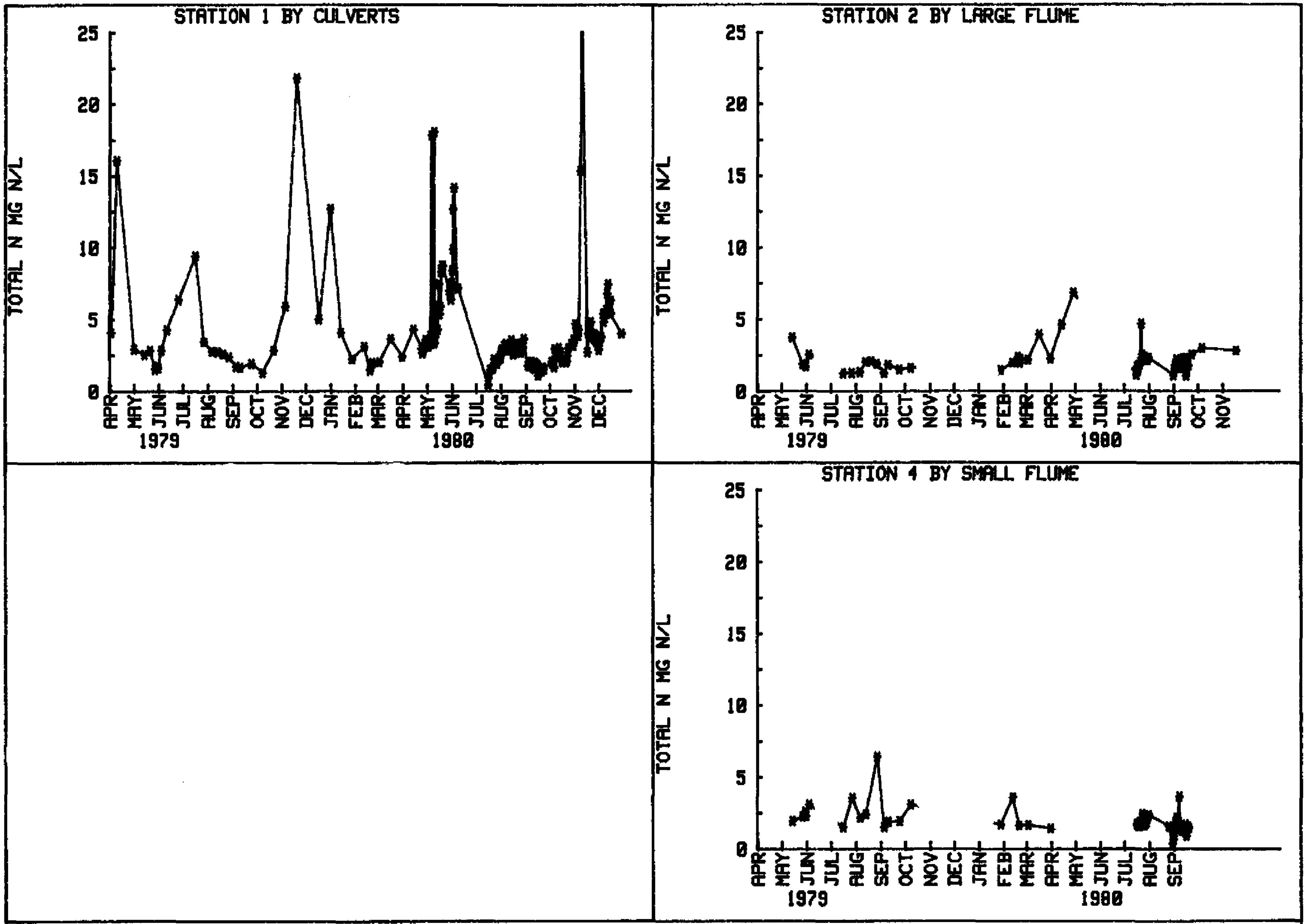
FIGURE II-18. LAB COLOR FOR ASH SLOUGH


STATION 1 BY CULVERTS

STATION 2 BY LARGE FLUME

STATION 4 BY SMALL FLUME

FIGURE II-19. NOX+NH4 FOR ASH SLOUGH


STATION 1 BY CULVERTS

STATION 2 BY LARGE FLUME

STATION 4 BY SMALL FLUME

FIGURE II-20. TOTAL NITROGEN FOR ASH SLOUGH

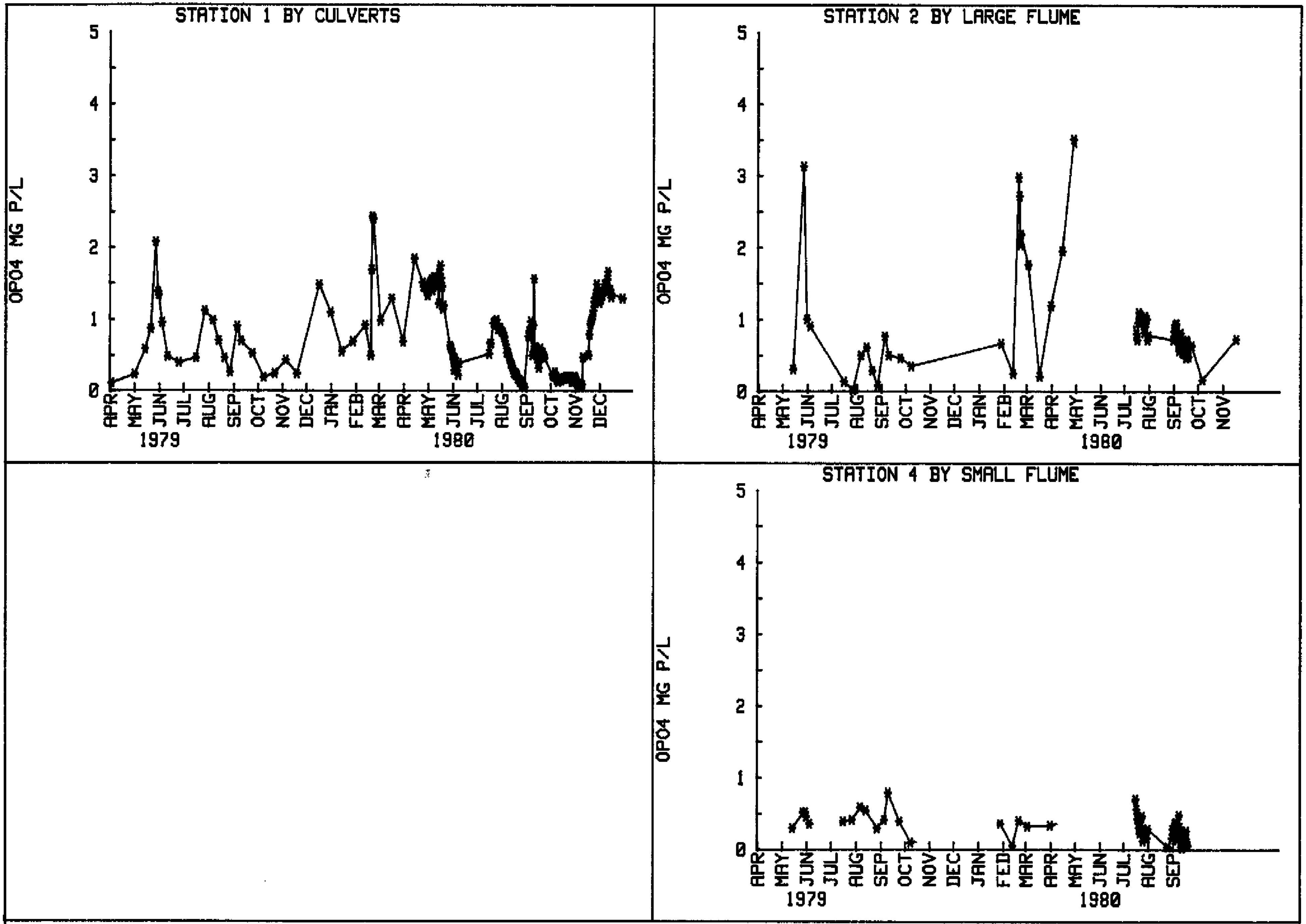


FIGURE II-21 . ORTHO PHOSPHORUS FOR ASH SLOUGH

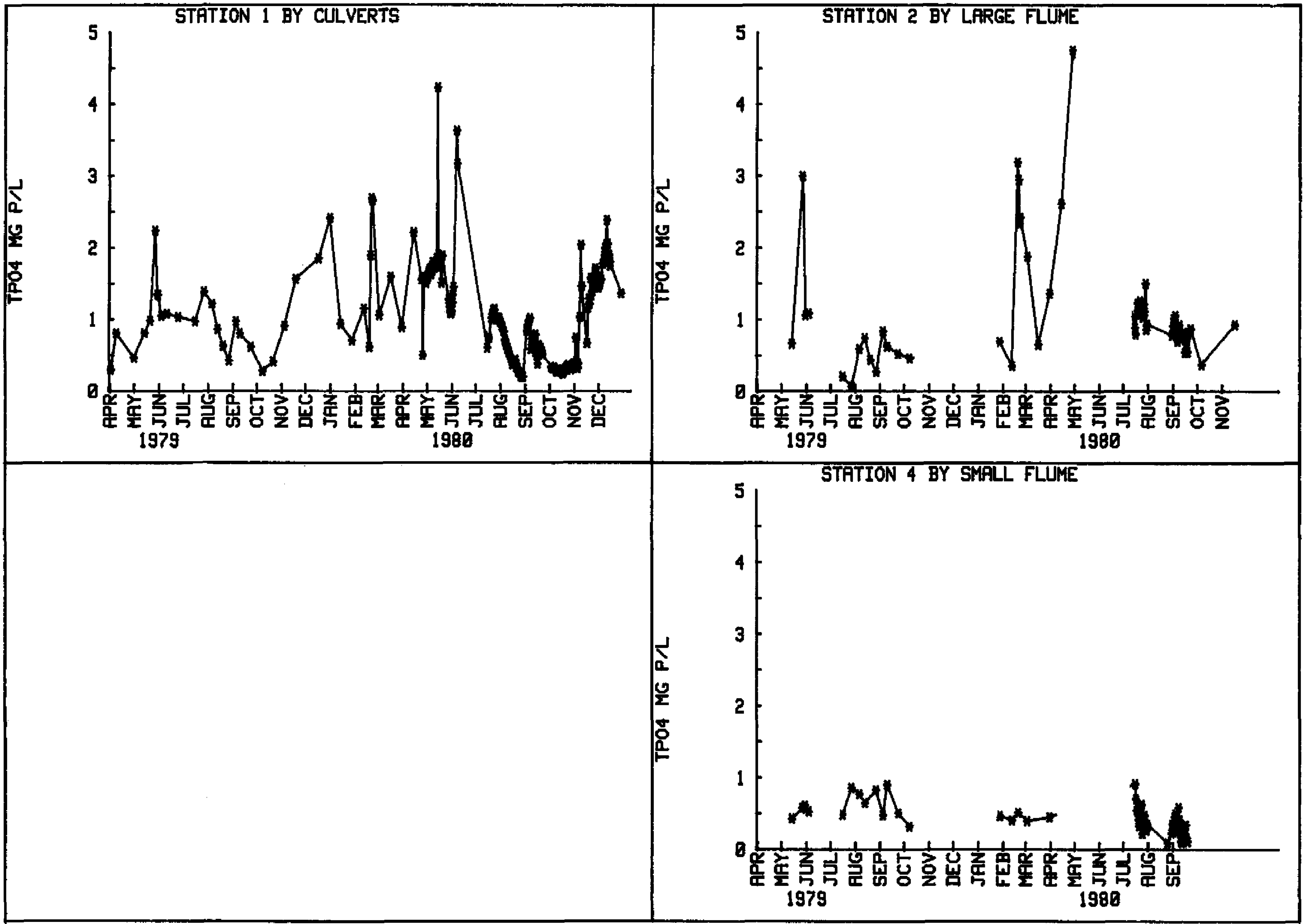


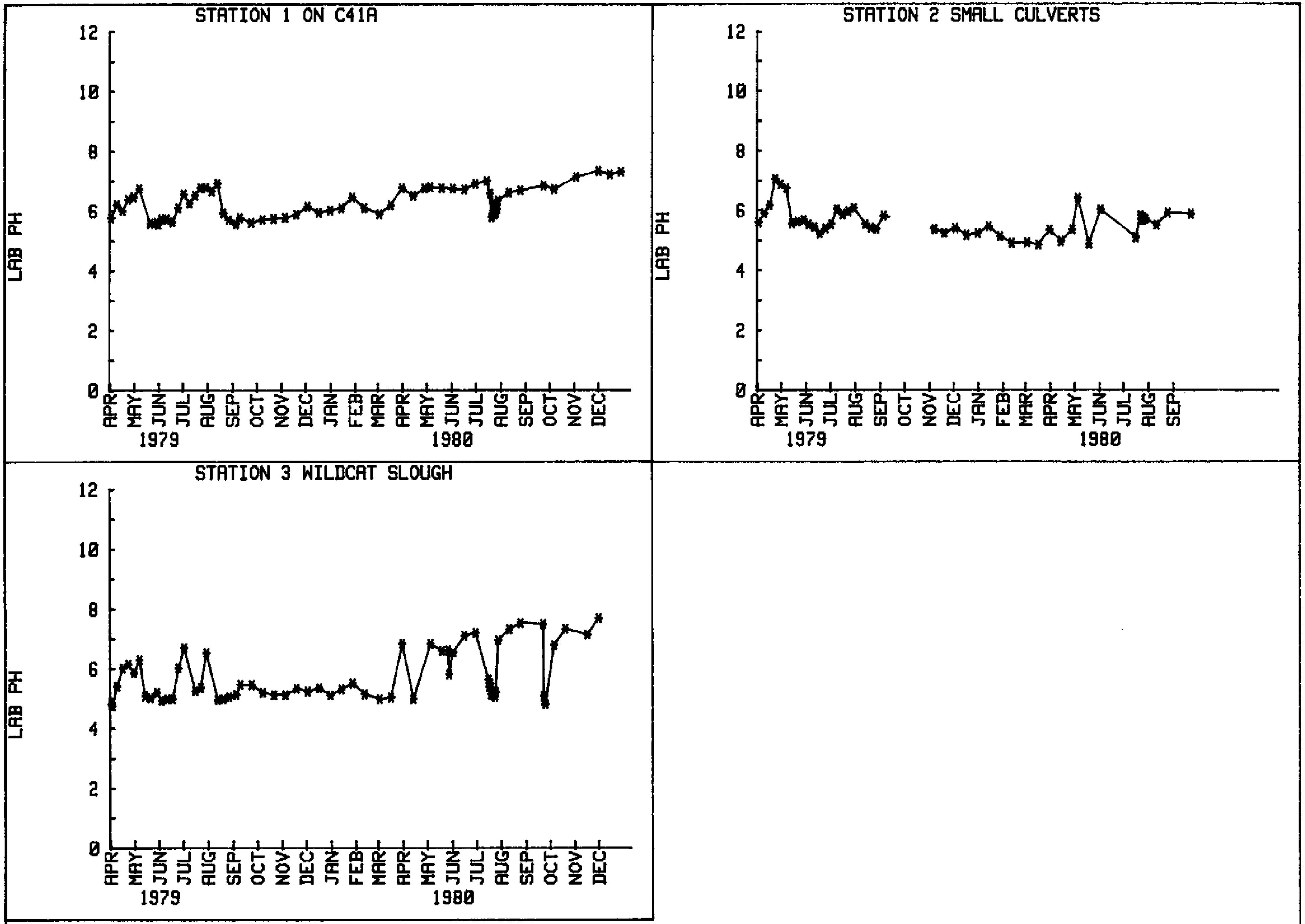
FIGURE II-22. TOTAL PHOSPHORUS FOR ASH SLOUGH and three times, respectively, of those from the eastern side.

Higher mean concentrations of all but the phosphorus species in the marsh itself probably are indicative of a concentration effect from evapotranspiration that occurs during periods of no inflow or discharge to or from the marsh. It should be noted that during each of the four observed events previously noted, concentrations measured at Station 1 decreased noticeably during the periods of inflow into the marsh.

Nitrogen continues to occur predominantly in the organic form at all three stations while phosphorus is largely inorganic. Inorganic nitrogen when,present above minimal detection limits (0.01 ppm),occurs as sharp distinct peaks which dissipate rapidly to characteristically low levels.

WILDCAT SLOUGH

Time series concentration data for water quality parameters at Wildcat Slough are presented in Figures II-23 through II-30. Concentrations of total nitrogen and total phosphorus at Station 2 (small culverts in ditch draining the western portion of the watershed) continue to behave in a manner different from those measured at Station 3 (large flume at the upper end of the main watershed). In fact, with the exception of some slight increase in total phosphorus levels at Station 3 in the last half of 1980, concentrations at both Stations 1 and 3 were rarely, if ever, much above minimum detection limits (<0.010 ppm). Concentrations at Station 2 show sharp peaks in the Spring of both 1979 and 1980. Ortho phosphorus concentrations at all three stations are at, near, or below minimum detection levels (<0.010 ppm) at all times except for a sharp Spring


STATION 1 ON C41A

STATION 2 SMALL CULVERTS

STATION 3 WILDCAT SLOUGH

FIGURE II-23. LAB PH FOR WILDCAT SLOUGH

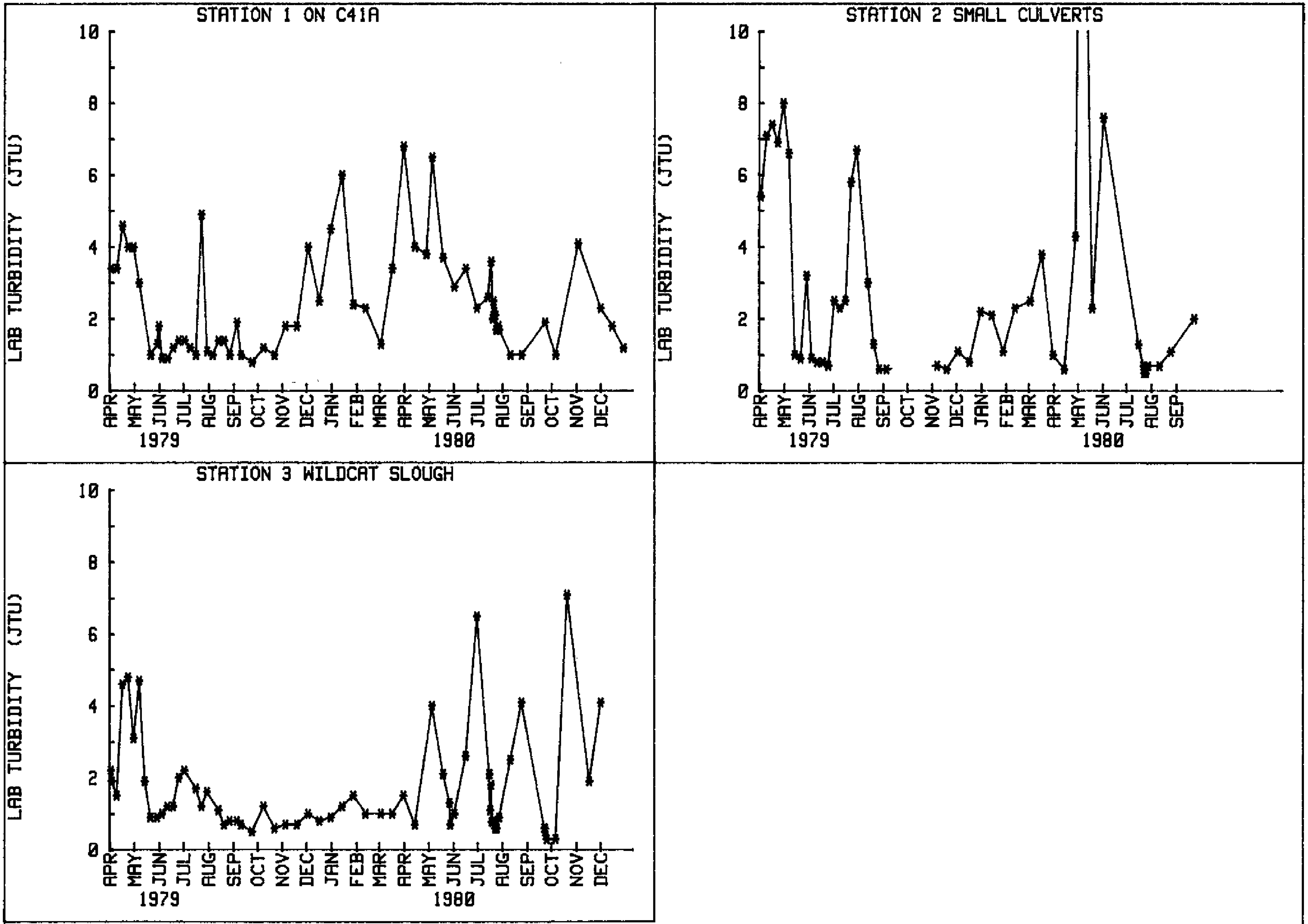


FIGURE II-24 . LAB TURBIDITY FOR WILDCAT SLOUGH

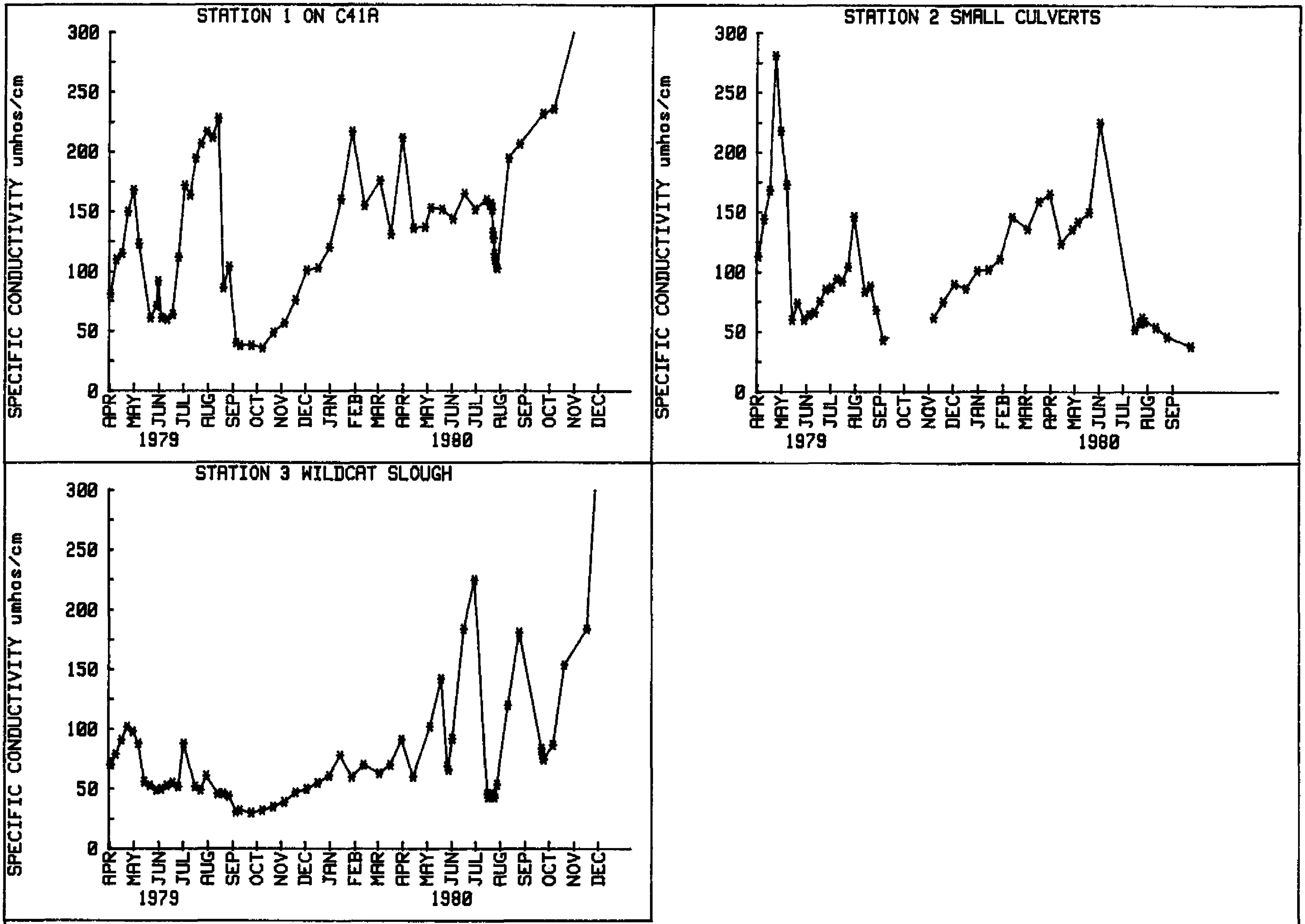
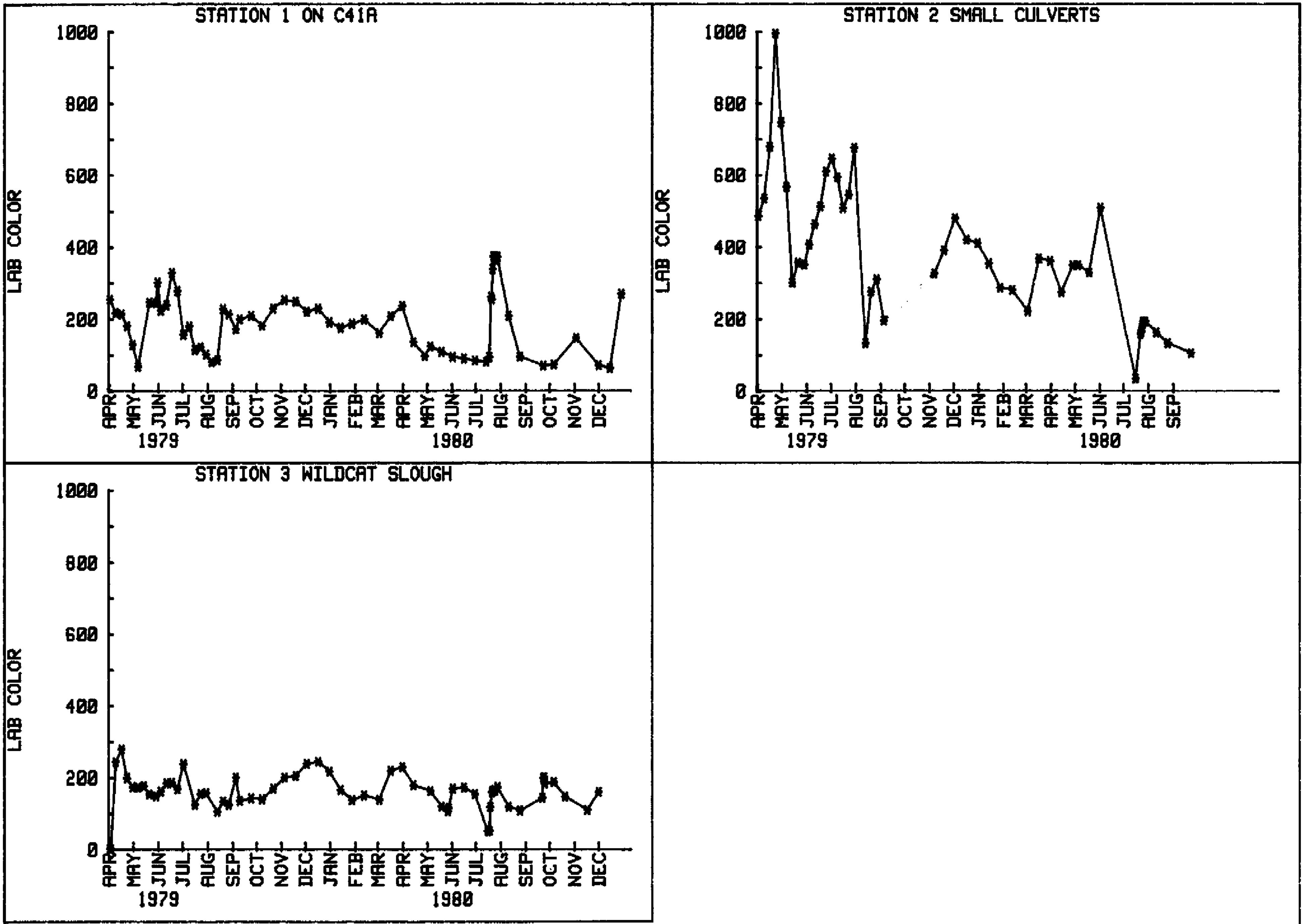


FIGURE II-25. LAB CONDUCTIVITY FOR WILDCAT SLOUGH



STATION 1 ON C41A

STATION 2 SMALL CULVERTS

STATION 3 WILDCAT SLOUGH

FIGURE II-26. LAB COLOR FOR WILDCAT SLOUGH

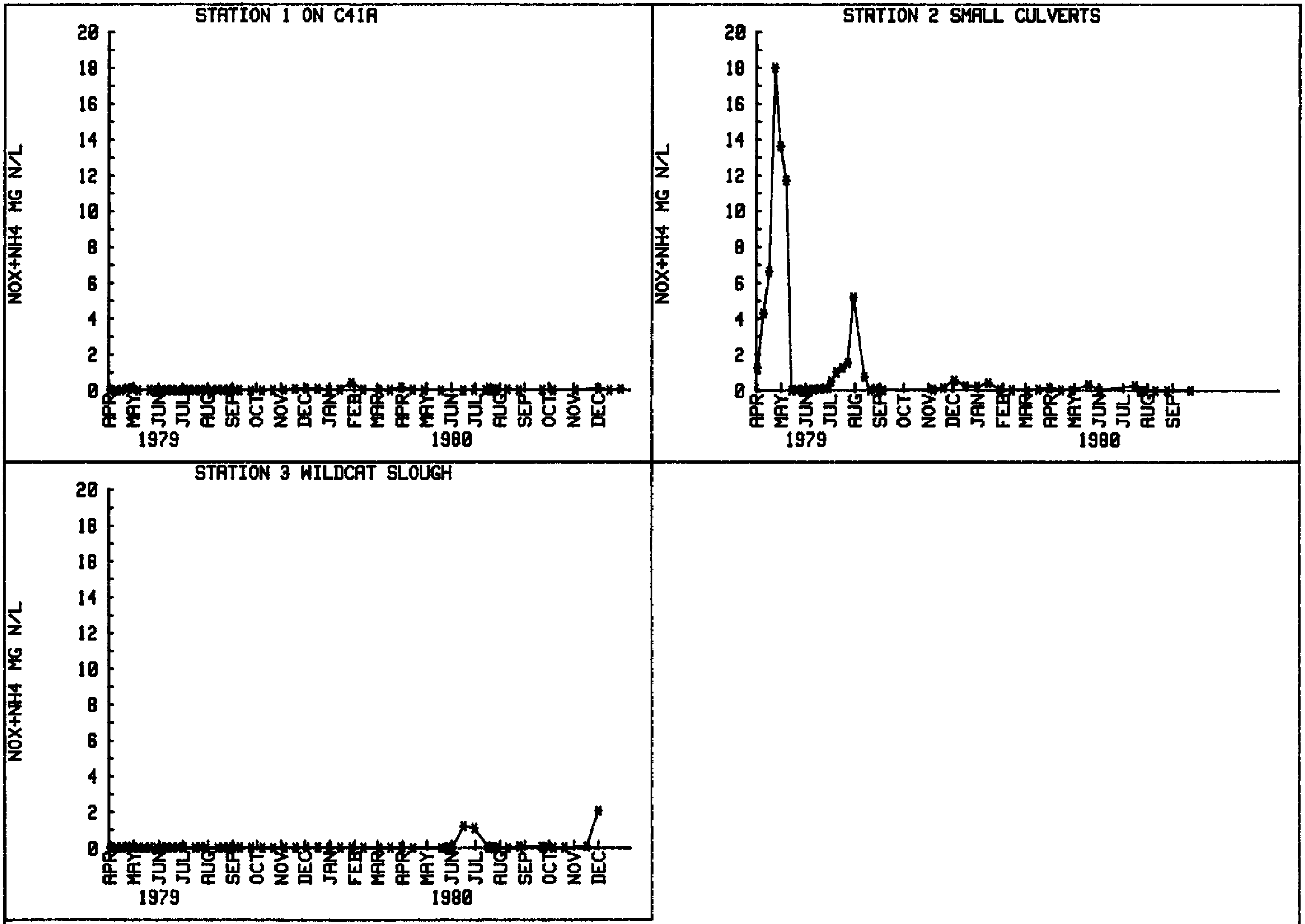


FIGURE II-27 . NOX+NH4 FOR WILDCAT SLOUGH

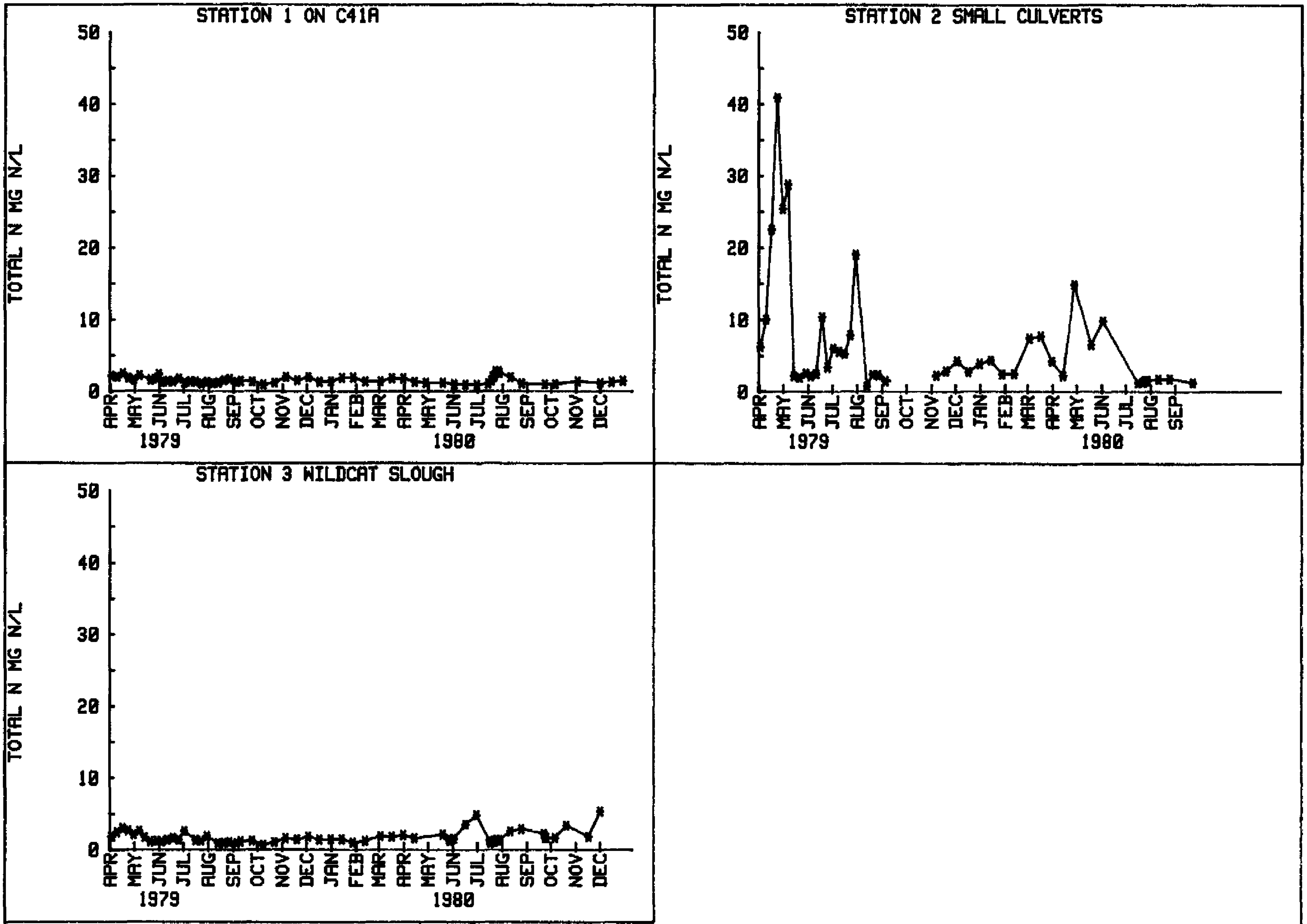


FIGURE II-28. TOTAL NITROGEN FOR WILDCAT SLOUGH

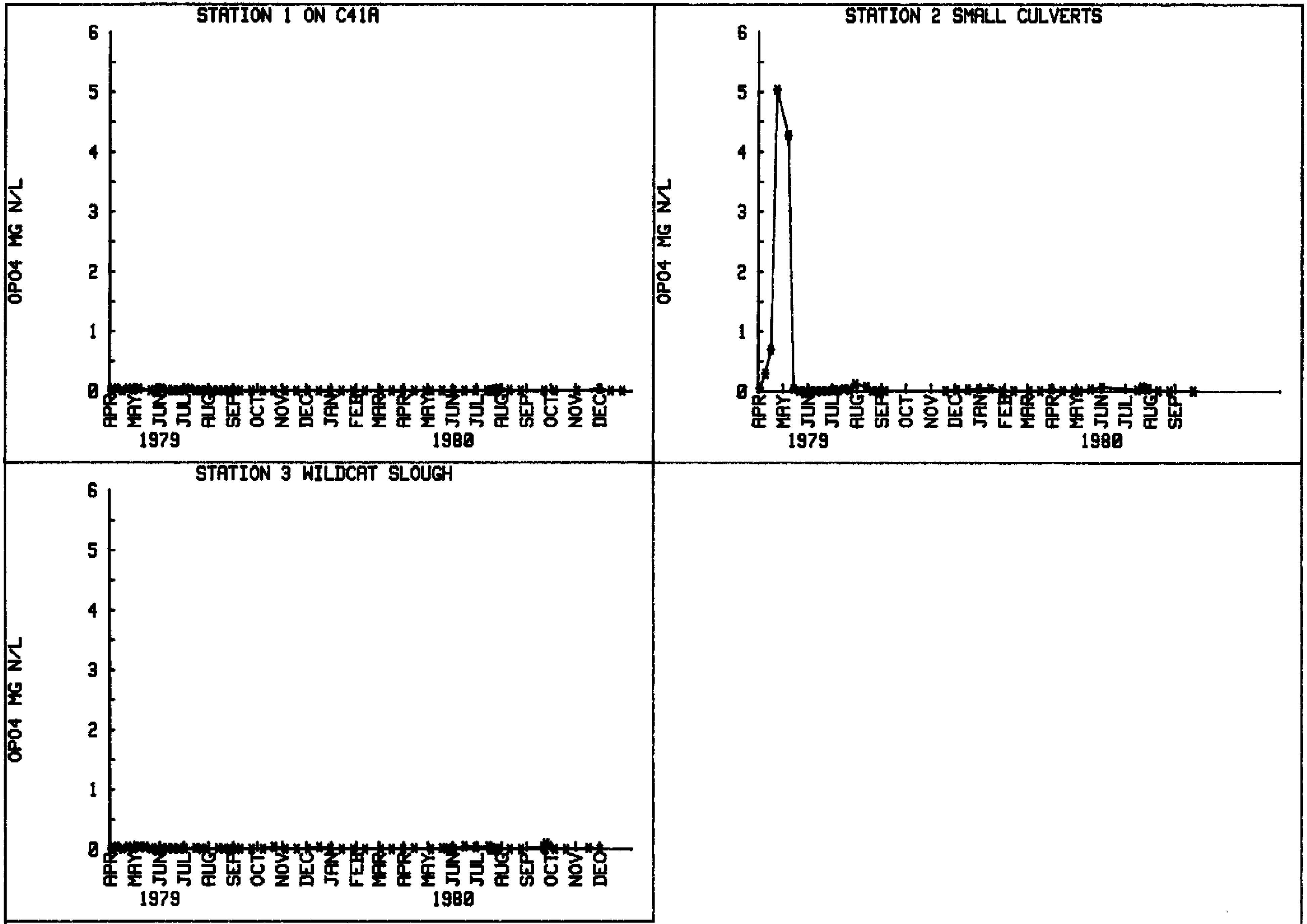


FIGURE II-29. ORTHO PHOSPHORUS FOR WILDCAT SLOUGH

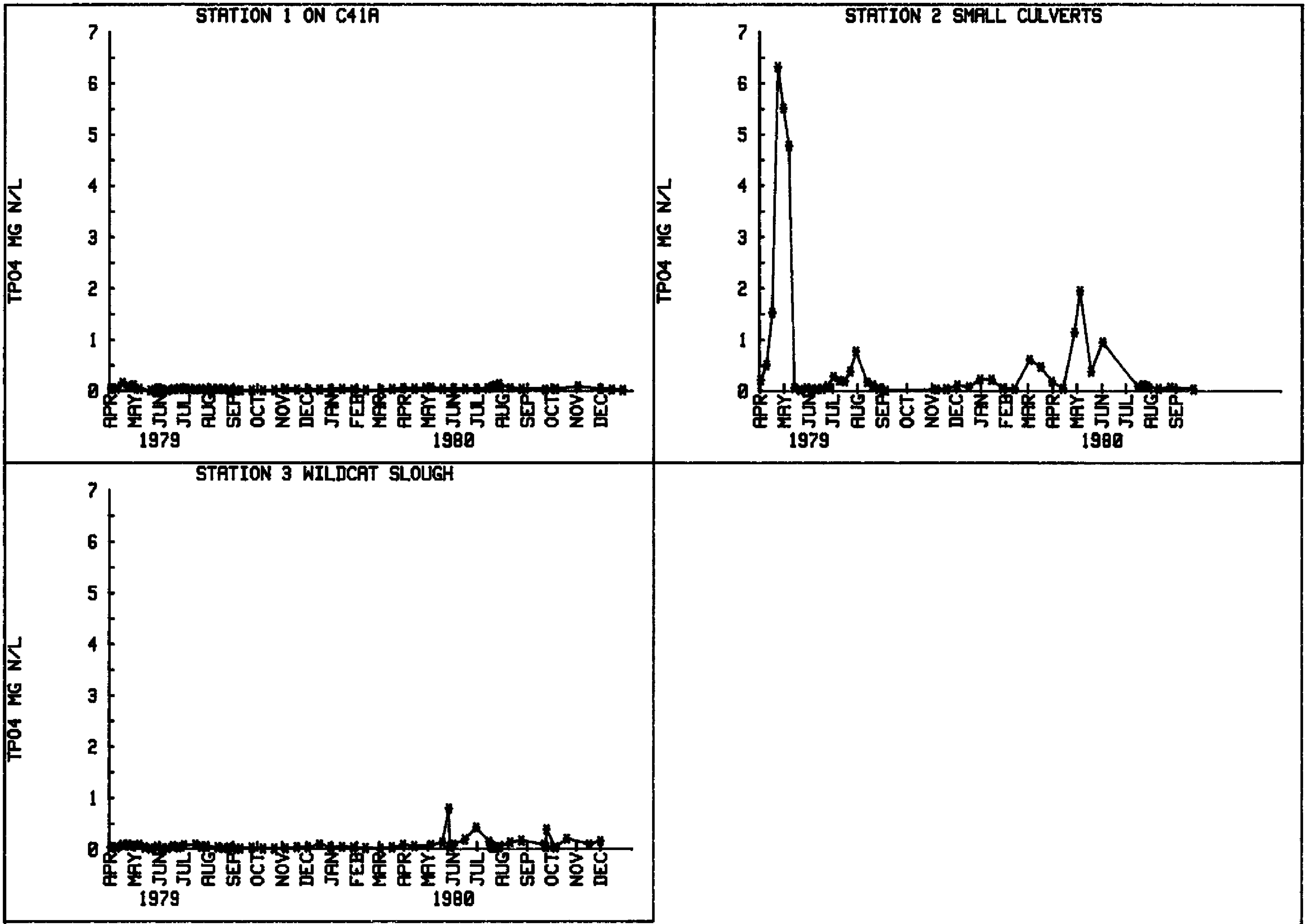


FIGURE II-30. TOTAL PHOSPHORUS FOR WILDCAT SLOUGH

1979 peak observed at Station 2. With this exception, phosphorus when present at Stations 2 and 3 is predominantly in the organic form. Phosphorus concentration levels at C-41A are always at, near, or below detection levels.

Nitrogen concentrations behave similarly to those of phosphorus. Highest total nitrogen levels were observed at Station 2. Four sharp peaks were observed, one each in Spring 1979, Summer 1979, early Spring 1980, and late Spring 1980. The Spring and Summer 1979 peaks correlate with similar sharp peaks of inorganic phosphorus during the same periods. The total nitrogen concentrations during these periods were still three to four times greater than those of inorganic nitrogen . There was no inorganic nitrogen peak in Spring 1980. As a consequence, the total nitrogen levels were of lower absolute magnitude than those that occurred in the Spring of 1979. There are higher total nitrogen concentrations accompanied by increased variability at Station 3 beginning in late April 1980. Nitrogen, when it occurs in measurable quantities, like phosphorus, appears to be predominantly in the organic form.

The obvious differences in nutrient quality characteristics between Stations 2 and 3 would seem to point to a major difference in land use practices in the contributing watersheds. Discussions with the ranch manager have shed little light on the cause of the differences in nitrogen and phosphorus concentrations at the two stations. No satisfactory explanation has yet been found for the large pulses in inorganic nitrogen and phosphorus that occurred during the Spring of 1979. In any event, concentrations of nitrogen and phosphorus species at the site outfall at C-41A remained at continually low levels.

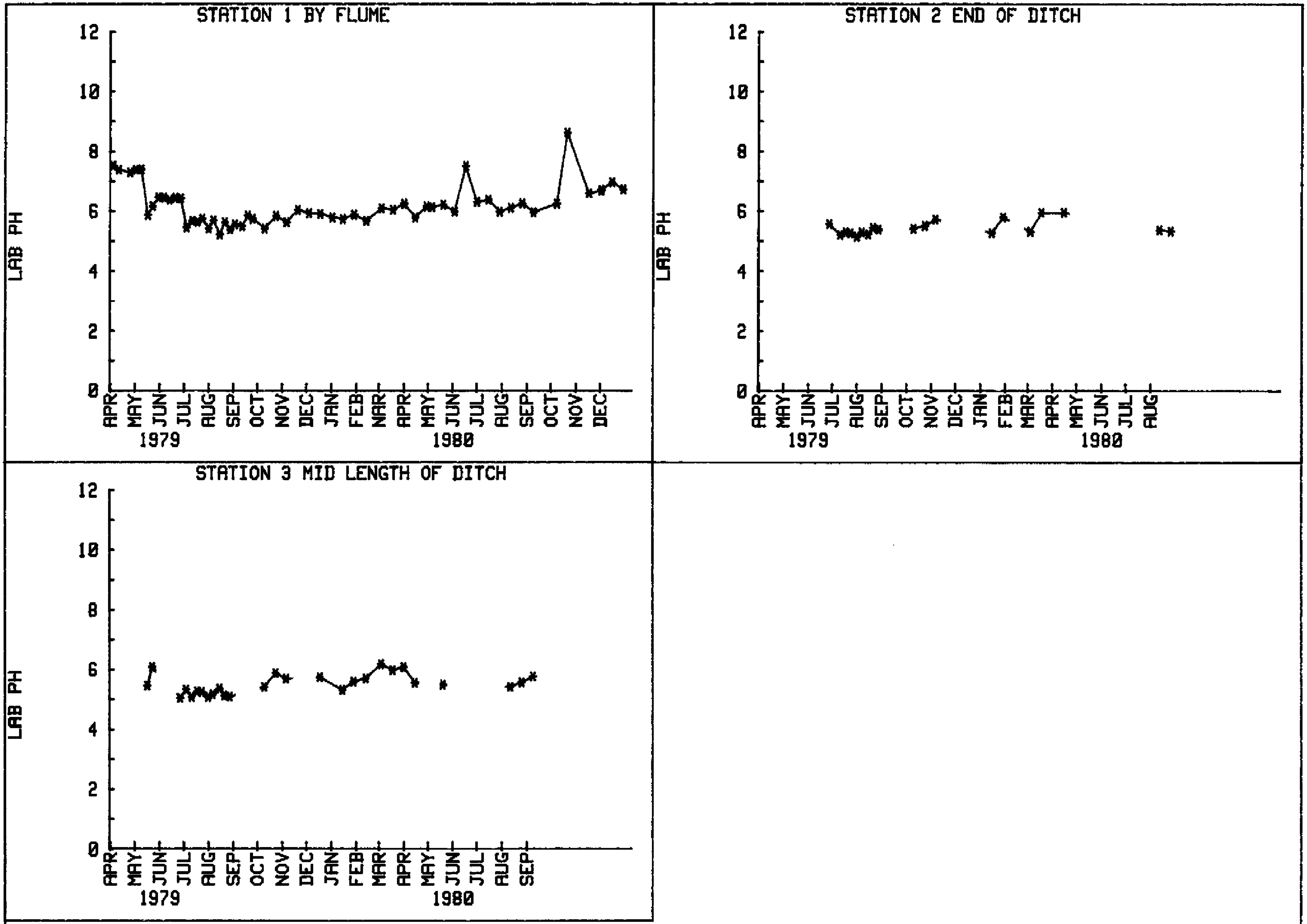
Physical parameters continued to show the most variability. Even pH, particularly at Station 3, exhibited a wider range of fluctuation than might normally be expected. The evidence suggests that higher levels here correlate with the evaporation of standing water behind the flume, though the data is too sketchy to firmly reach this conclusion.

Color levels at Station 2 continue to remain higher and more variable than those at Stations 1 and 3. This probably reflects biological activity. Maximum color levels occurred during the Spring of 1979.

Turbidity and conductivity became more erratic at Station 3 in the last half of 1980, thus following the same pattern as pH and total nitrogen. Turbidities and conductivities at Station 2 show the same distinct peaks as noted for total nitrogen. Turbidity and conductivity levels are variable at Station 1, with no definite trends being apparent. Absolute levels at all three stations are comparatively low.

PEAVINE PASTURE

The most noticeable feature of water quality time series data collected at the Peavine site is the dramatic increase of concentration of all parameters except color and pH at the site outfall (Station 1) beginning at the end of September 1980 (Figures II-31 through II-38). The magnitude of these increases above previously measured normal mean concentrations range from a four- to five-fold increase for conductivity, turbidity, and total nitrogen to an 18-fold increase in inorganic nitrogen. Total and ortho phosphorus


STATION 1 BY FLUME

STATION 2 END OF DITCH

STATION 3 MID LENGTH OF DITCH

FIGURE II-31. LAB PH FOR PEAVINE PASTURE

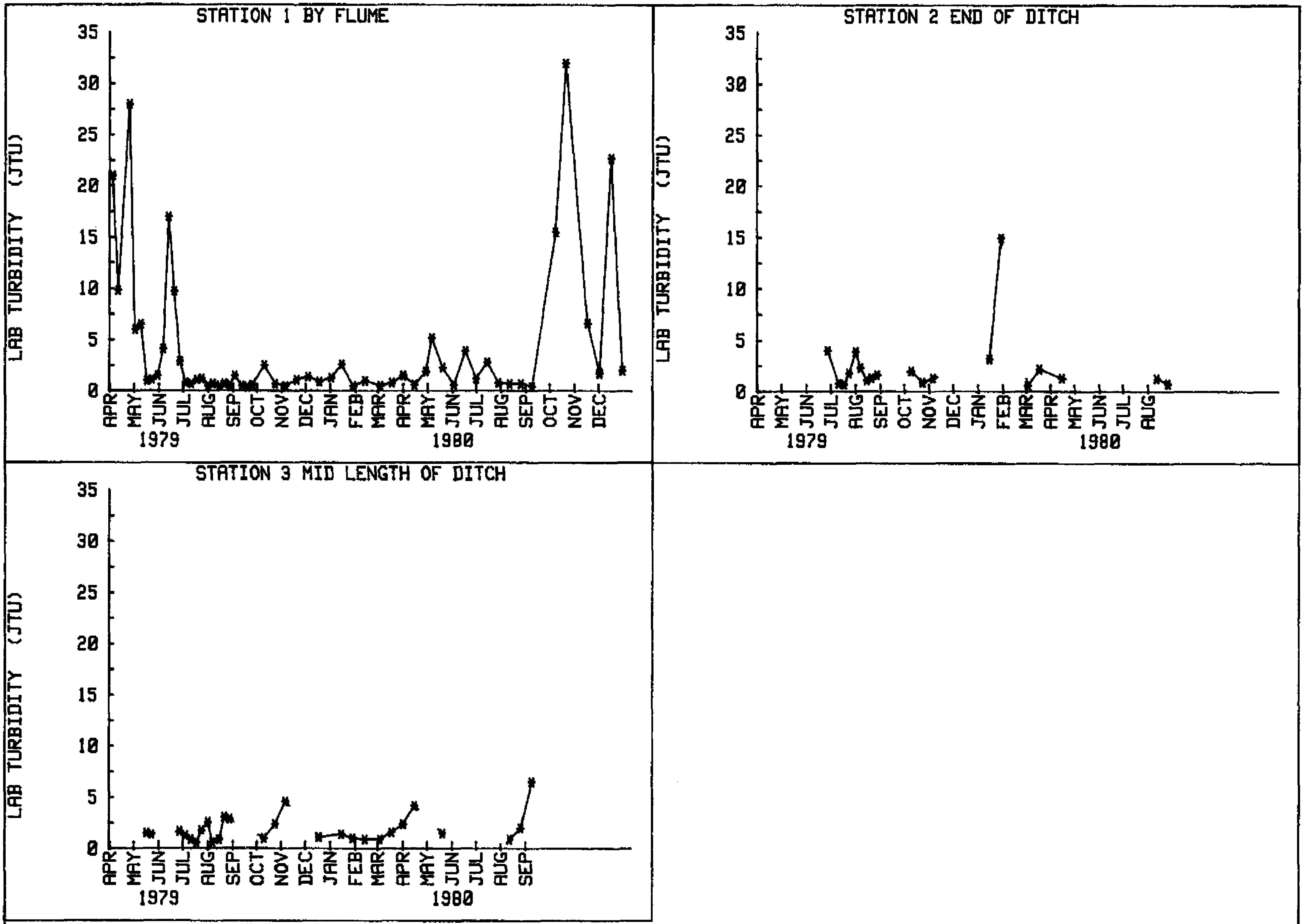


FIGURE II-32. LAB TURBIDITY FOR PEAVINE PASTURE

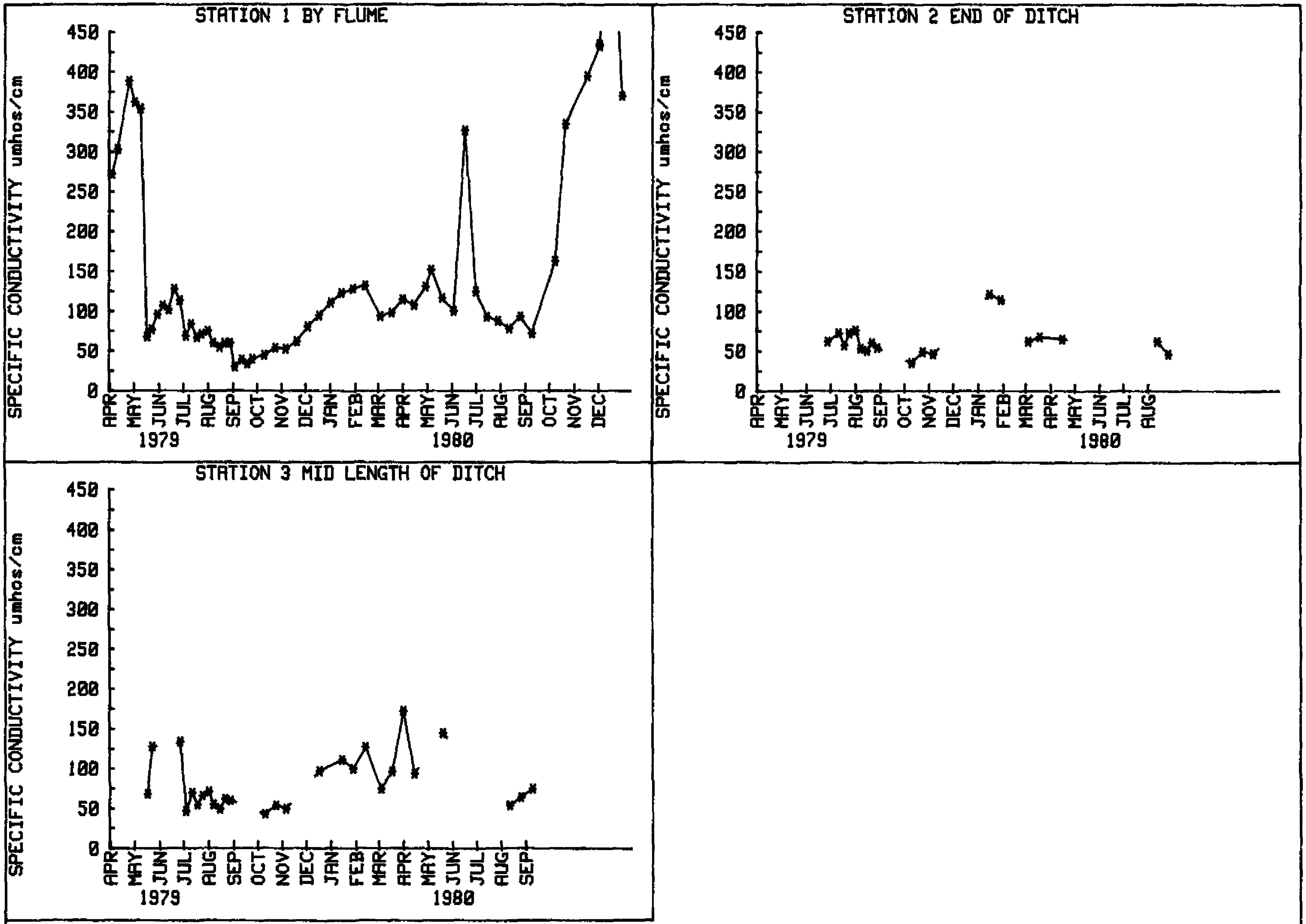


FIGURE II-33. LAB CONDUCTIVITY FOR PEAVINE PASTURE

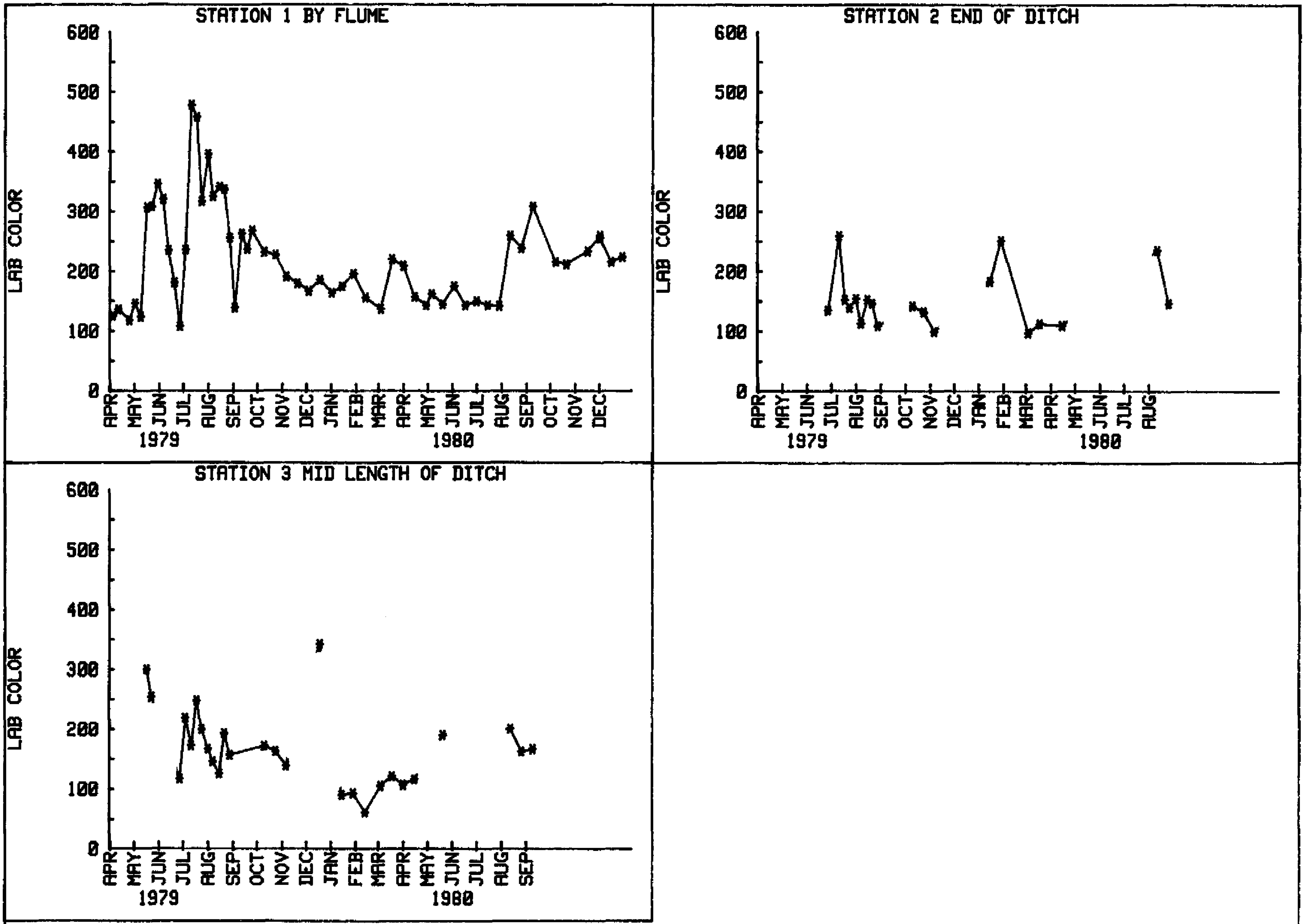


FIGURE II-34. LAB COLOR FOR PEAVINE PASTURE

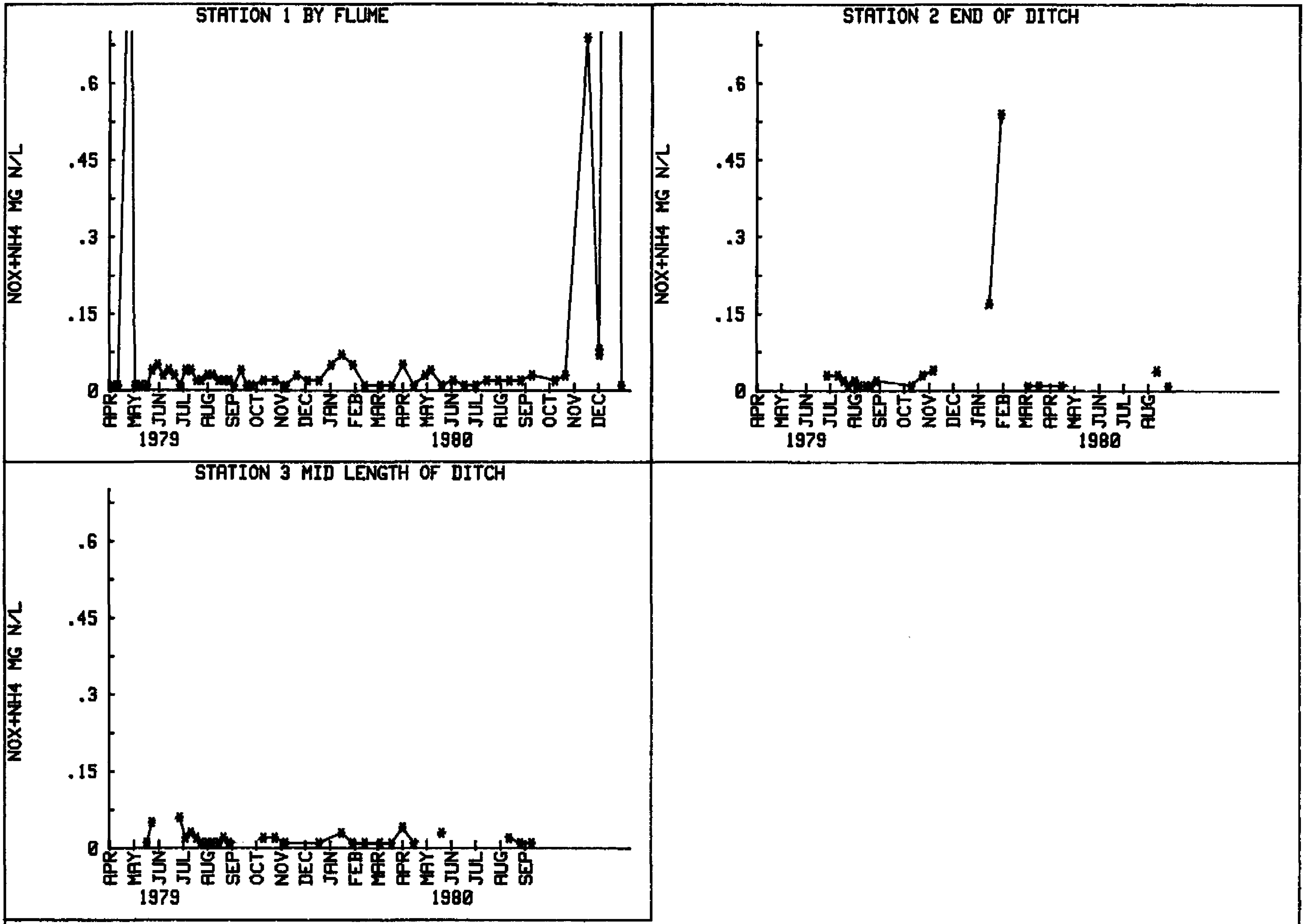
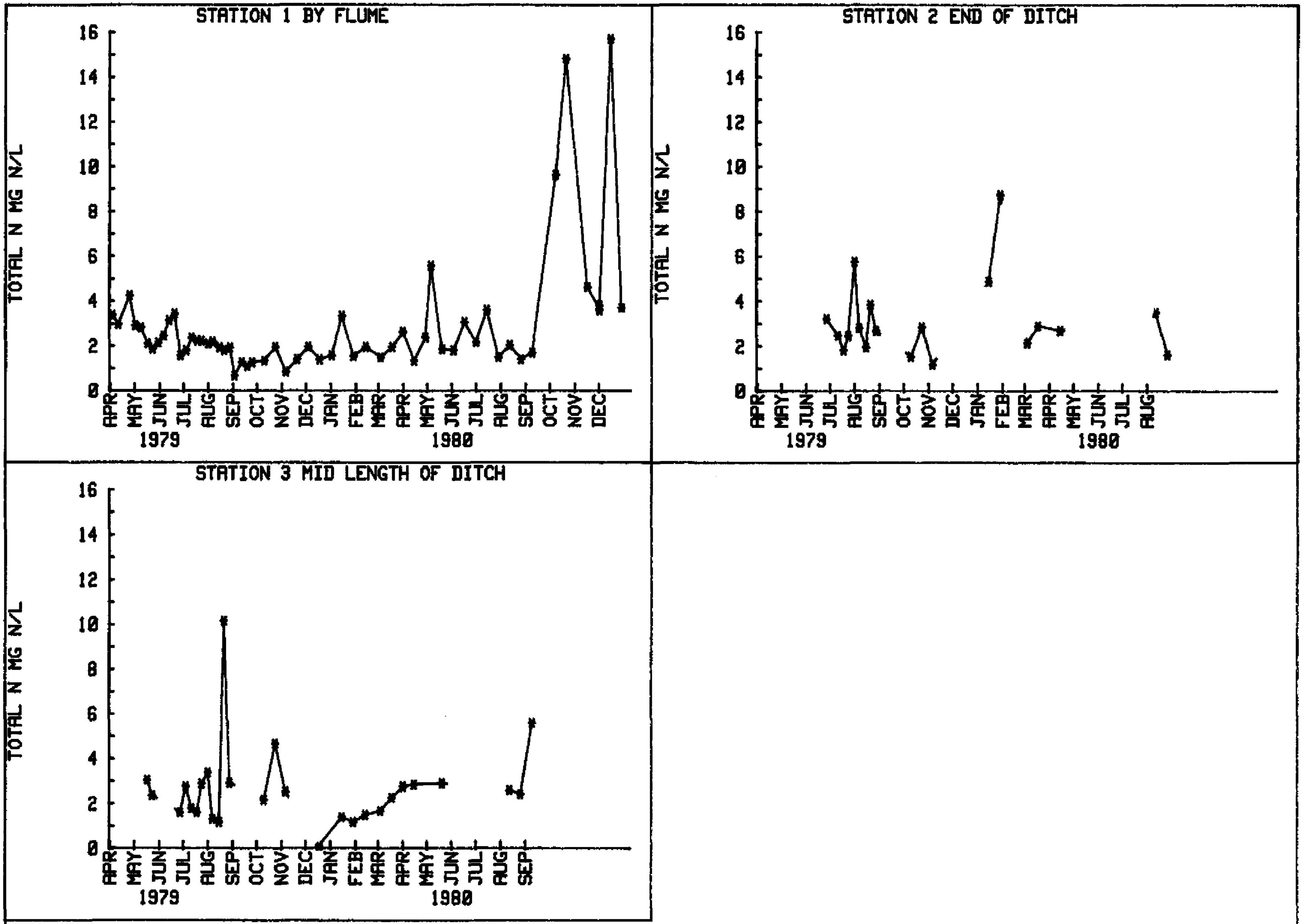


FIGURE II-35. NOX+NH4 FOR PEAVINE PASTURE



STATION 1 BY FLUME

STATION 2 END OF DITCH

STATION 3 MID LENGTH OF DITCH

FIGURE II-36. TOTAL N FOR PEAVINE PASTURE

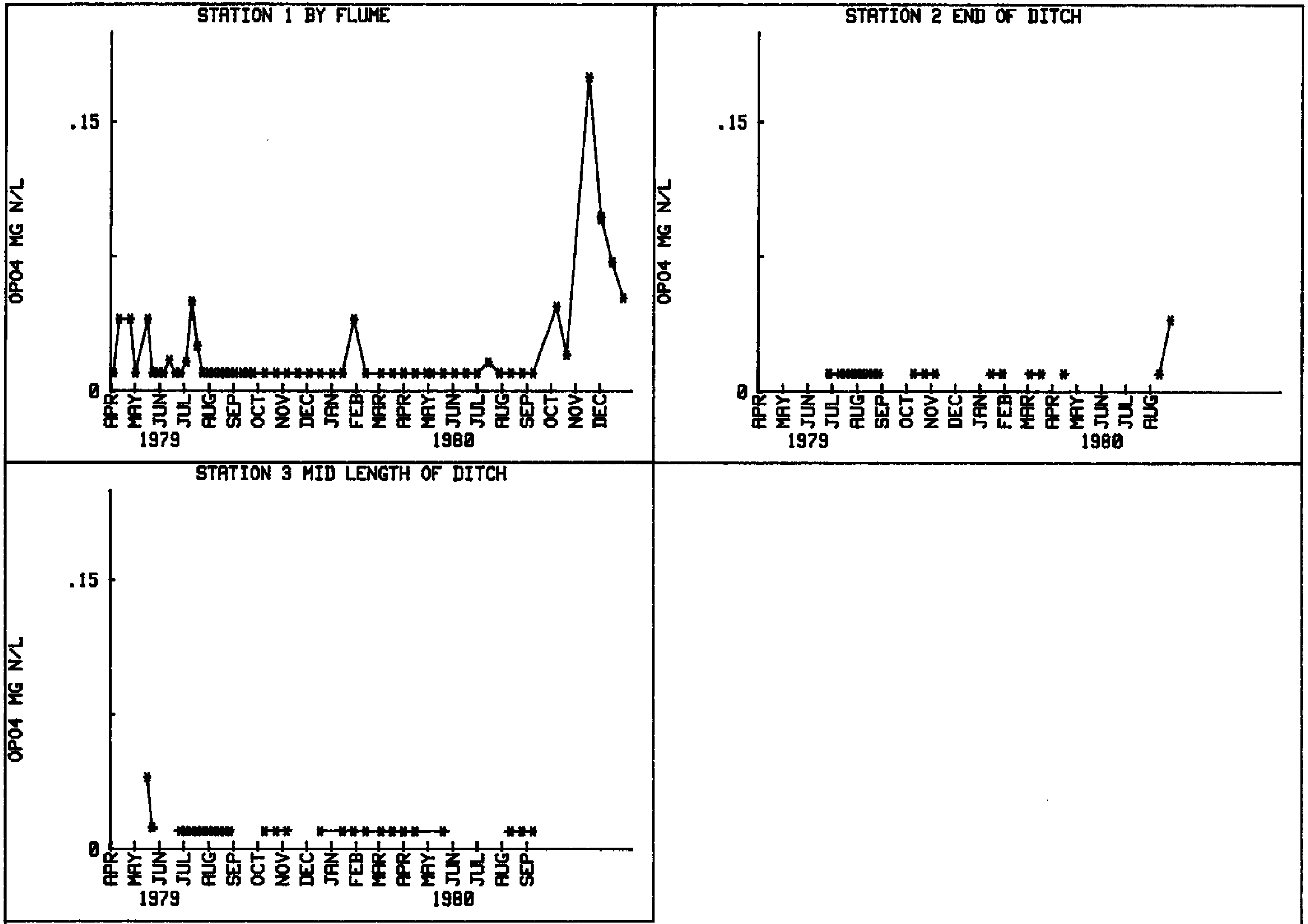
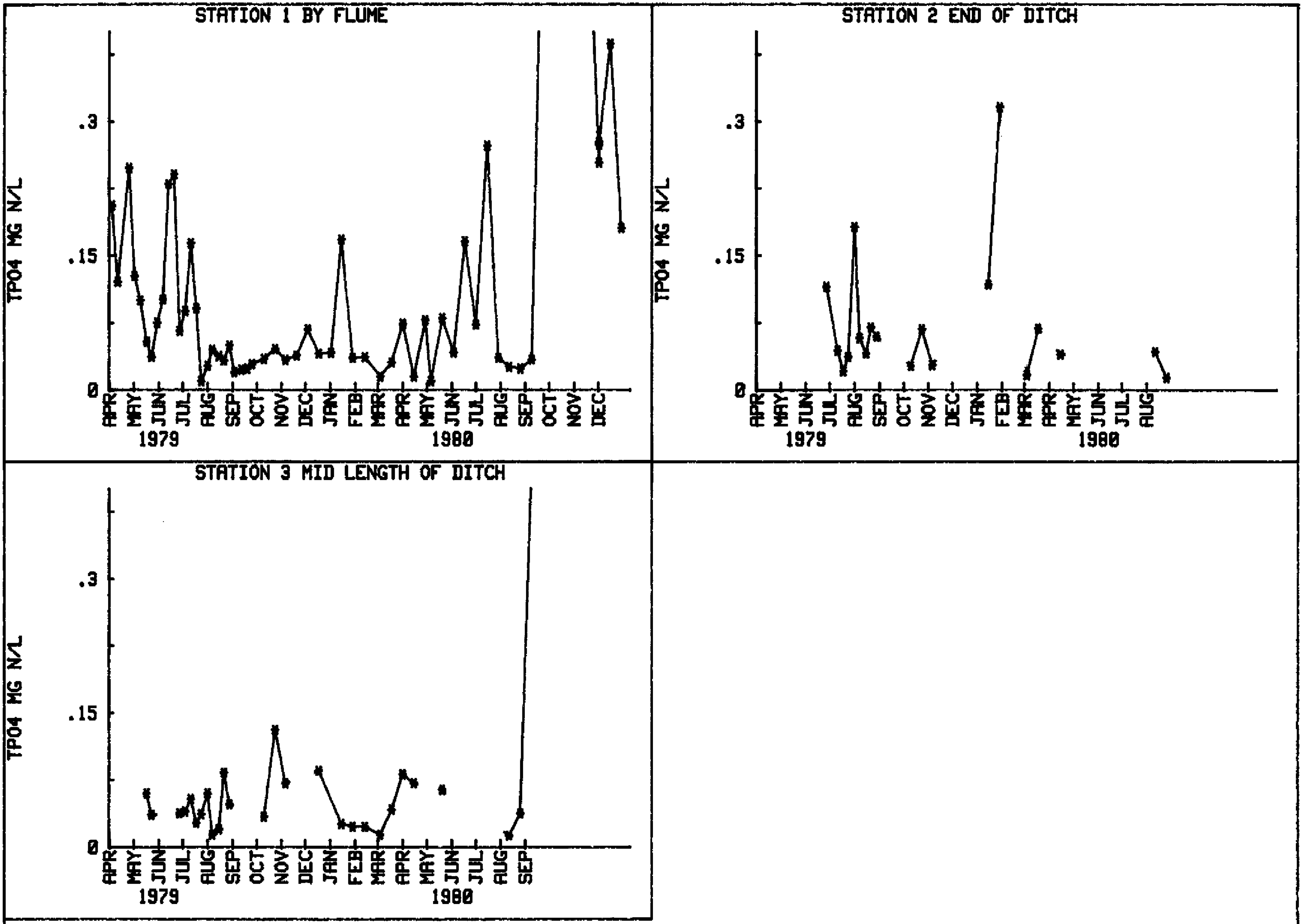


FIGURE II-37. ORTHO PHOSPHORUS FOR PEAVINE PASTURE



STATION 1 BY FLUME

STATION 2 END OF DITCH

STATION 3 MID LENGTH OF DITCH

FIGURE II-38. TOTAL PHOSPHORUS FOR PEAVINE PASTURE increases were eight- and seven-fold, respectively. The magnitude and nature of these peaks resemble similar concentration trends noted for conductivity, turbidity, and inorganic nitrogen during the April through June 1979 period. Nitrogen and phosphorus occur predominantly in the organic form. With the exception of these peaks, ortho phosphorus and inorganic nitrogen concentrations are usually at, near, or below minimum limits of detection.

In general, concentrations of all measured parameters are greater at Station 1 than those observed in the mid-pasture stations (2 and 3). Erratic tendencies in concentrations of these parameters at the mid-pasture stations can be attributed to the intermittent nature of the presence of water at these locations. Station 2 contains water for periods of short duration following sufficient antecedent rainfall. Station 3 will retain water longer but is also subject to the variables associated with dehydration and rewatering. For these reasons, no trends or distinguishing station characteristics, other than variability is the rule, can be identified.

SEZ DAIRY

With the exception of turbidity and color, physical parameters at SEZ Dairy continue to exhibit trends and levels similar to those discussed in earlier reports (Goldstein and Ulevich, 1980). The pH and specific conductivity data are shown in Figures II-39a, II-39b, II-40a, and II-40b. Turbidity levels in the barnwash seem to have become more erratic in the Fall of 1979 (Figures II-41a and II-41b). This trend continues through the Spring of 1980. This factor appears to be the cause of similar behavior of the turbidity levels in the

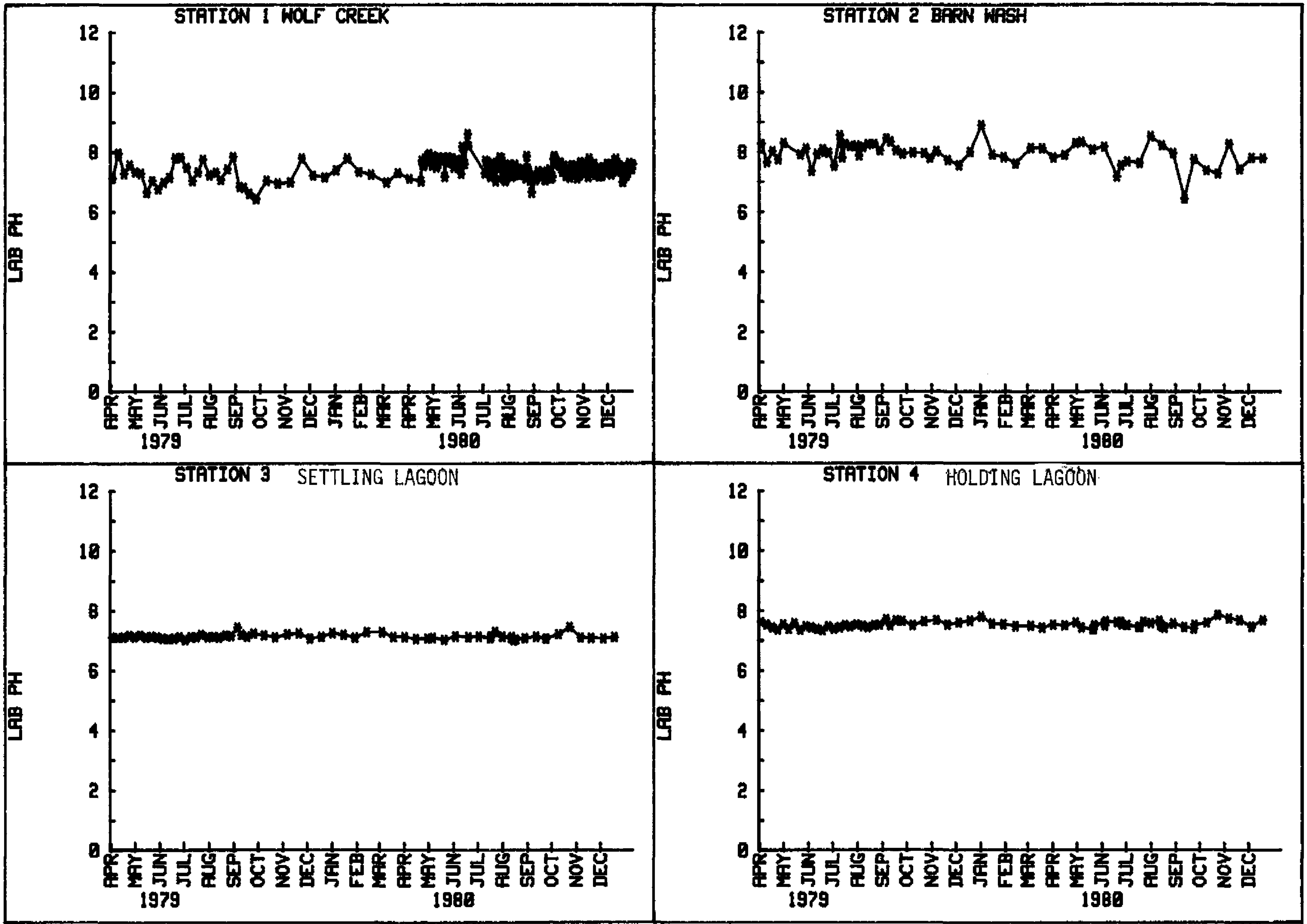
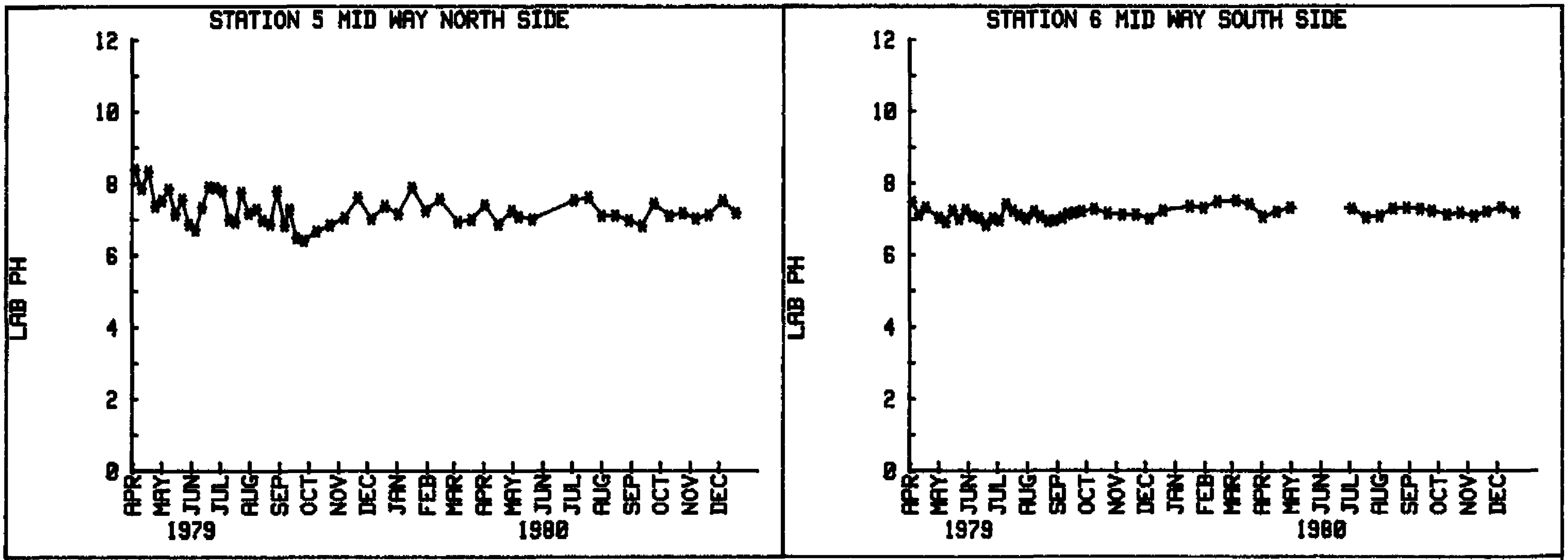


FIGURE II-39a . LAB PH FOR SEZ DAIRY



STATION 5 MID WAY NORTH SIDE

STATION 6 MID WAY SOUTH SIDE

FIGURE II-39b . LAB PH FOR SEZ DAIRY

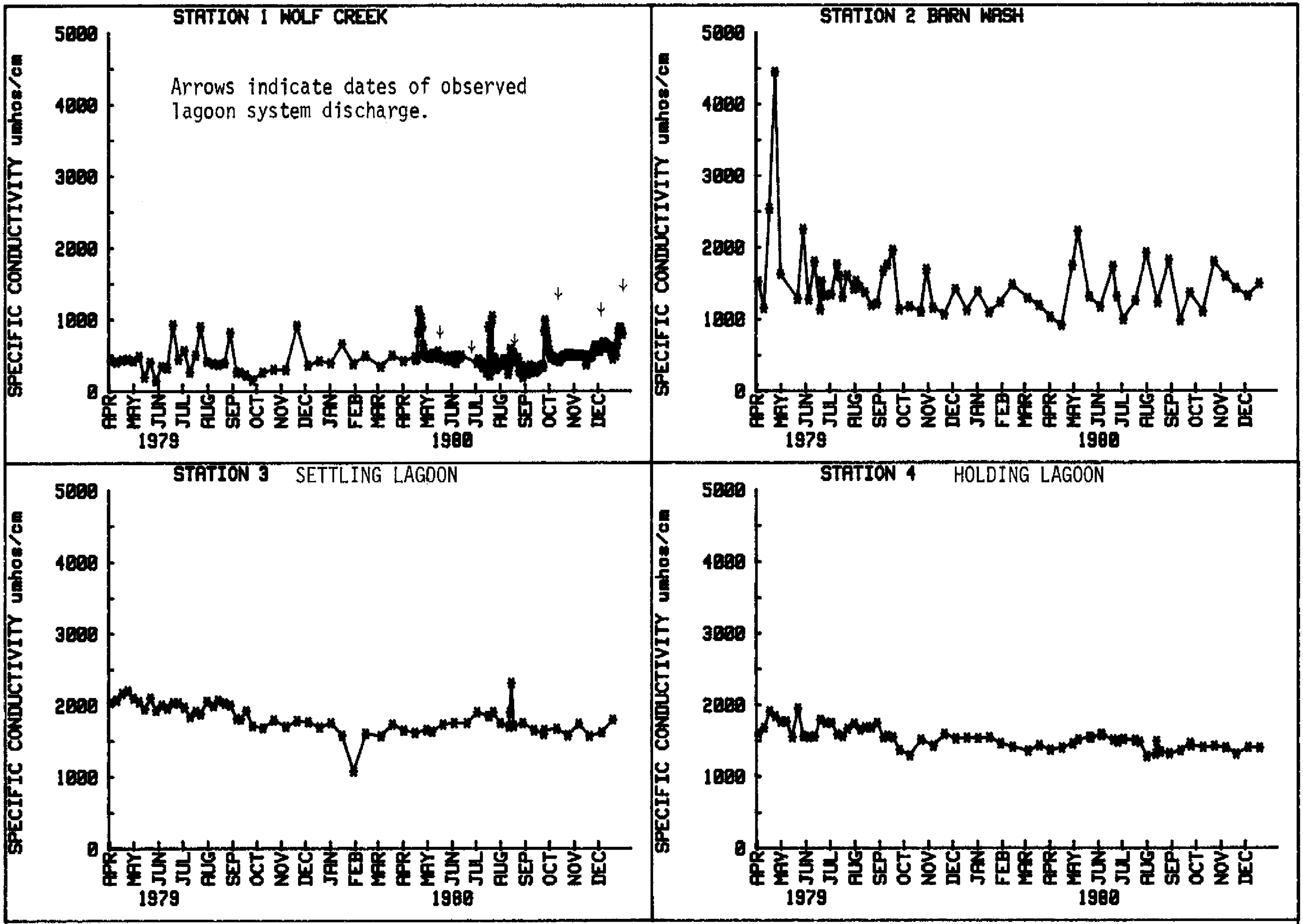


FIGURE II-40a. LAB CONDUCTIVITY FOR SEZ DAIRY

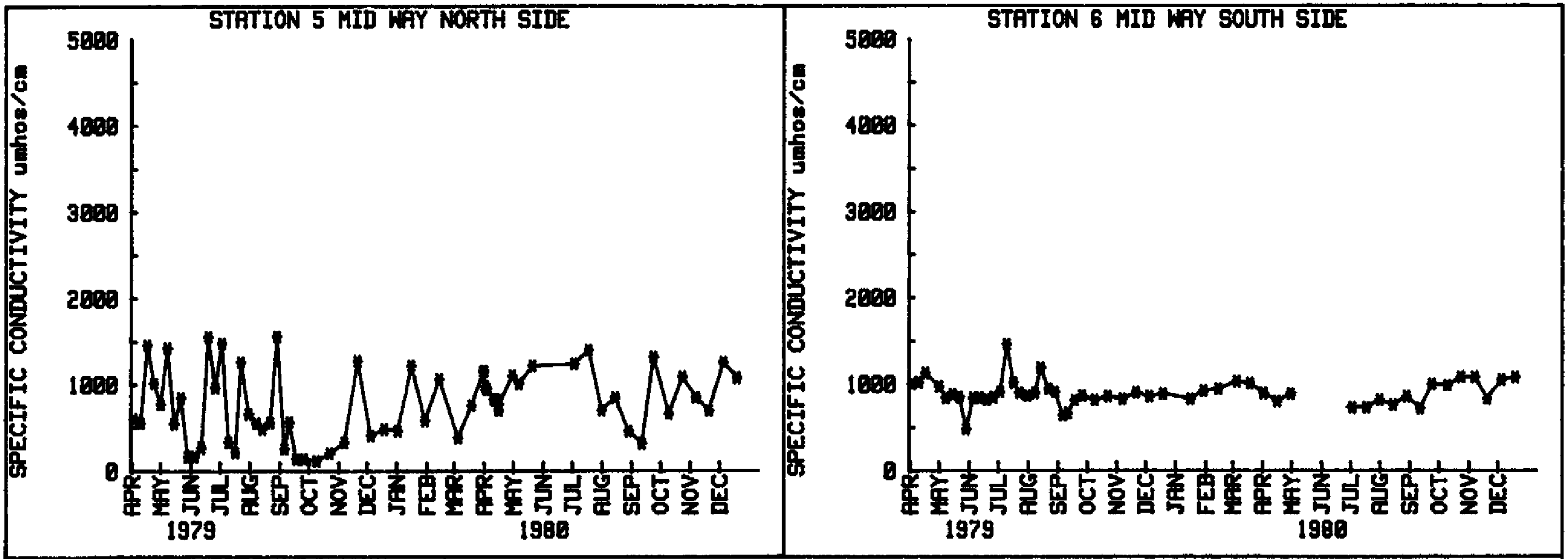


FIGURE II-40b . LAB CONDUCTIVITY FOR SEZ DAIRY

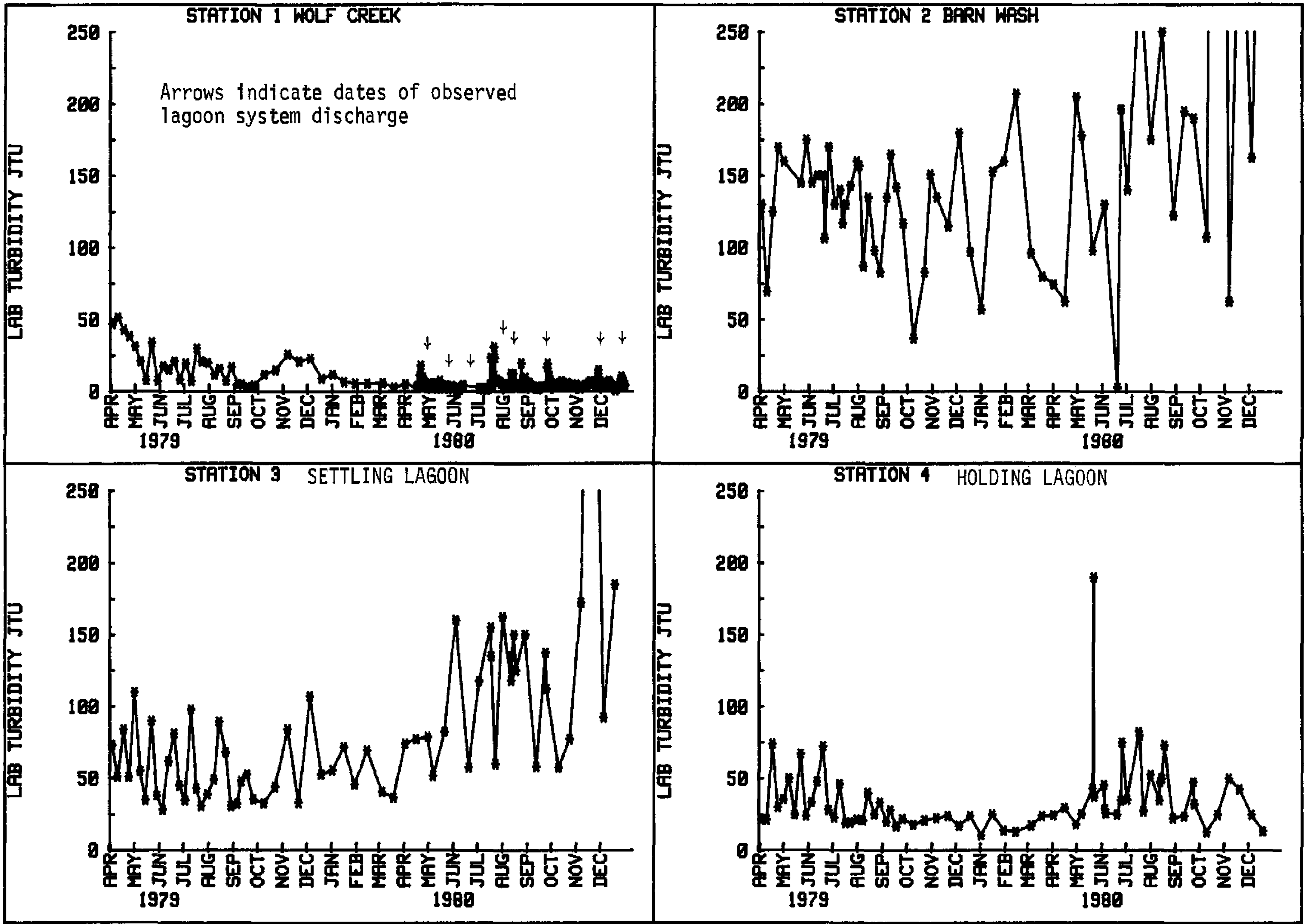


FIGURE II-41a. LAB TURBIDITY FOR SEZ DAIRY

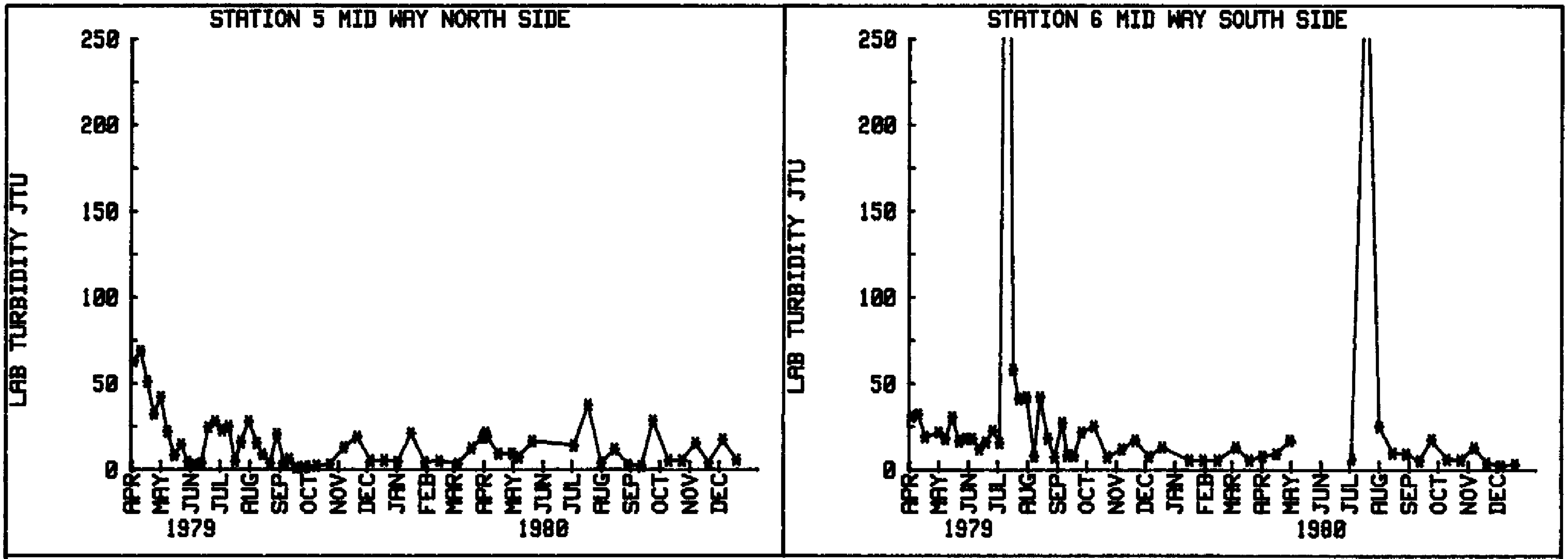


FIGURE II-41b . LAB TURBIDITY FOR SEZ DAIRY lagoon system as both the primary settling lagoon and the secondary holding lagoon show increased variability in turbidity beginning in May of 1980. Color (Figures II-42a & II-42b) may be following a seasonal trend, reaching lowest levels at all six stations during January and February.

Nitrogen and phosphorus remain at similar levels and exhibit approximately the same magnitude of variation as reported earlier (Goldstein and Ulevich, 1980). The data continues to suggest that the lagoon systems function in such a manner as to significantly reduce amounts of total nitrogen and phosphorus originally present in the barnwash. Table II-2 presents a comparison of mean concentrations of each of the water quality parameters at each stage of the treatment system beginning with the barnwash, including the two lagoons, the north perimeter ditch, and finally, the site at Wolf Creek. As this is time series data, it has not been weighted for flow versus no-flow conditions. Mean concentrations of the measured parameters in the barnwash are well within the range of those reported for the series of barnwash quality studies discussed in Goldstein and Ulevich (1980). The assumption can be made that the mean concentrations reported here would be considered indicative of long term steady-state conditions if such exist. Mean concentrations of the paramters as reported at Stations 3 and 4 (primary and secondary lagoons, respectively) undoubtedly reflect long term conditions fairly accurately as variability of the parameters measured at these stations is usually minimal.

While lower concentrations at Stations 5 and 6 seem to be the rule, regular occasional peaks in concentrations to levels

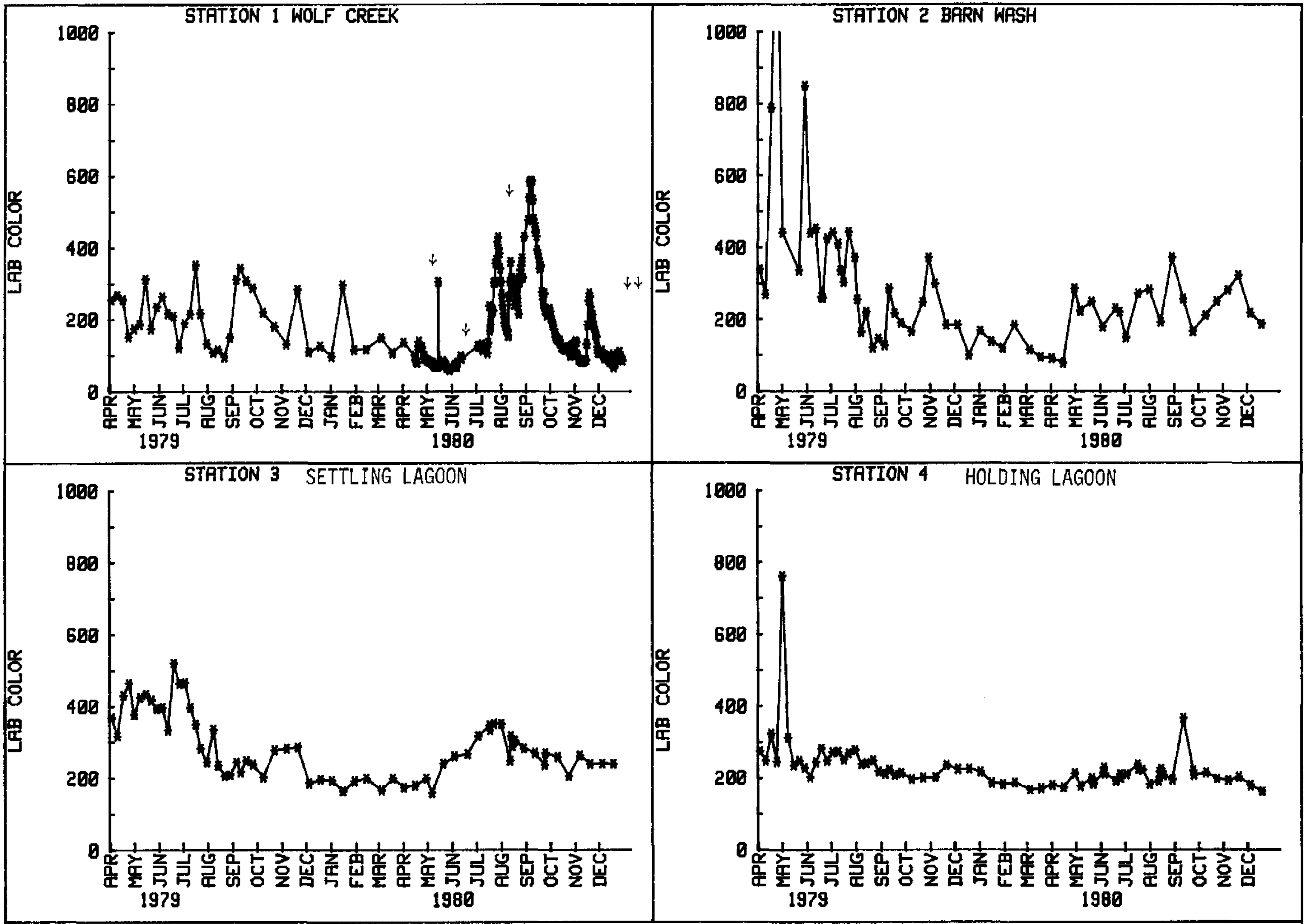


FIGURE II-42a . LAB COLOR FOR SEZ DAIRY

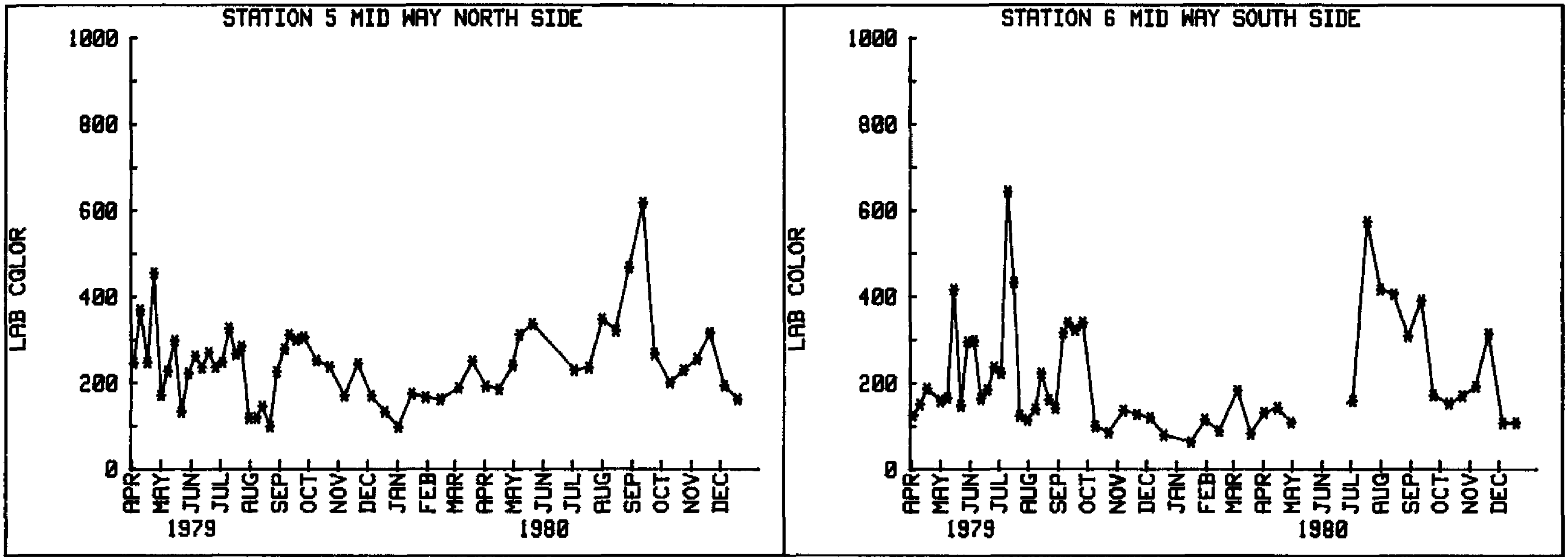


FIGURE II-42b . LAB COLOR FOR SEZ DAIRY

Table II-2 SEZ DAIRY WASTE TREATMENT SYSTEM EFFICIENCY

Data Complied for Period from 4/01/79 through 12/31/80

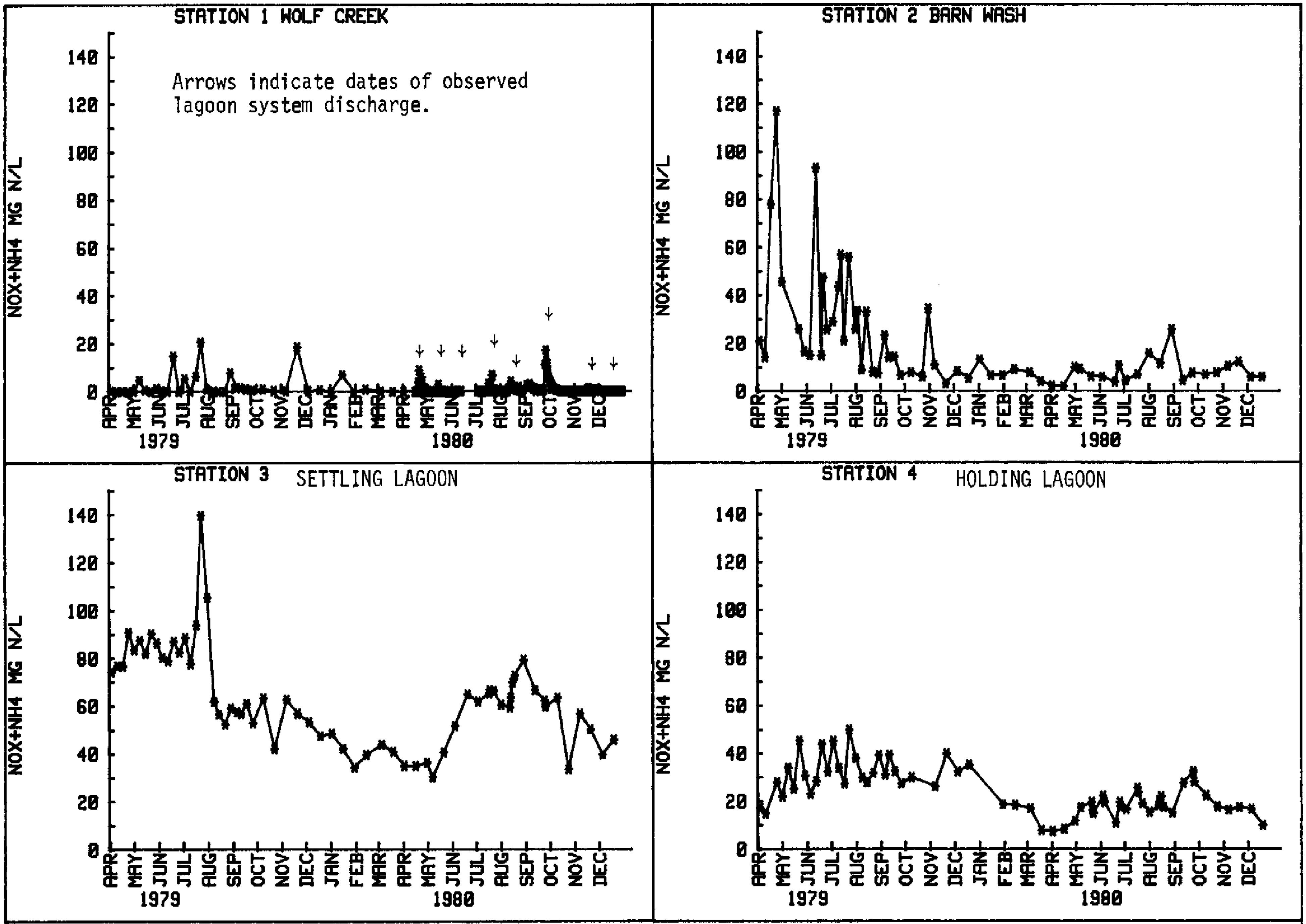
STATION	CONDUCTANCE µmhos/cm	pH	TURBIDITY	COLOR	NOx+NH4 mg/l	TOTAL N mg/l	ORTHO P mg/l	TOTAL P mg/l
2 Barnwash								
Mean	1522	7.86	153.9	300	28.61	145.26	4.604	25.934
% barnwash	100	100	100	100	100	100	100	100
% removal	---	---	---	---	---	---	---	---
3 Primary Settling Lagoon								
Mean	1824	7.13	86.3	288	63.19	103.98	3.551	23.187
% barnwash	120	91	56	96	221	71	77	89
% removal	---	9	44	4	---	29	23	11
4 Secondary Holding Lagoon								
Mean	1526	7.53	35.5	227	24.34	45.69	5.700	11.326
% barnwash	100	96	23	76	85	31	124	44
% removal	---	4	77	24	15	69	---	56
*5 Midway Perimeter Ditch								
Mean	831	7.26	16.2	249	6.01	17.32	3.962	6.897
% barnwash	55	92	11	83	21	12	86	27
% removal	45	8	89	17	79	88	14	73
*1 Wolf Creek Site Outfall								
Mean	469	7.41	6.6	210	1.25	4.46	1.293	1.880
% barnwash	31	94	4	70	4	3	28	7
% removal	69	6	96	30	96	97	72	93

*These data are gross estimates that are not corrected for flow versus no-flow conditions. In effect, these efficiencies calculated for these stations are too high. Periods of discharge from the secondary holding lagoon significantly increase concentrations of some parameters at stations 1 and 5. See text for further explanation.

more characteristically found in the secondary holding lagoon led to speculation that two separate phenomena were actually being observed at these stations. It was hypothesized that lower concentrations measured at these two stations were in fact normal "ambient" concentrations of parameters that would be present in groundwater seepage and normal rainfall runoff. These are believed to represent the water quality impacts from the pasture land use alone. The second suspicion was that high concentrations of the monitored parameters were reflections of discharge activities from the lagoon waste treatment system.

In May of 1980, an automatic sampling device was installed at the Station 1 site outfall. The device was equipped with refrigerated sample storage capacity such that samples could be taken on a regular daily basis and stored for some period without deterioration. These samples were collected and brought to the laboratory twice each week. Given this daily monitoring capability, resolution of water quality trends at this station increased to the point that regular distinct sharp peaks were observed in nitrogen, phosphorus, and turbidity levels (Figures II-40a, II-43a, II-44a, II-45a, and II-46a). In addition, the time of occurrence of these peaks could be cross-referenced with times that discharge events from the lagoon system were observed to be occurring. This correlation appears to be almost one to one.

These data confirm suspicions that mere mean concentrations of parameters measured at Stations 1 and 5 are misleading if used to determine the efficiency of the dairy waste treatment system. If one compares the peak concentrations at Station 1 with normal



Arrows indicate dates of observed lagoon system discharge.

FIGURE II-43a. NOX+NH4 FOR SEZ DAIRY

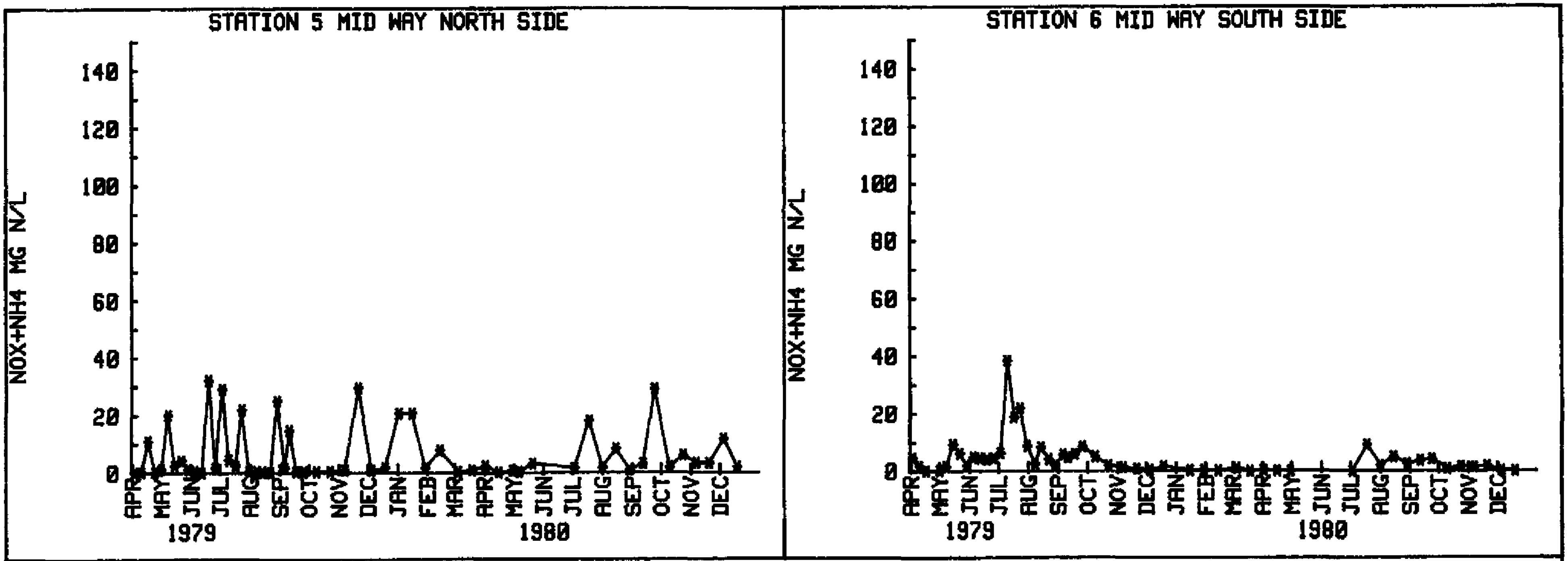


FIGURE II-43b. NOX+NH4 FOR SEZ DAIRY

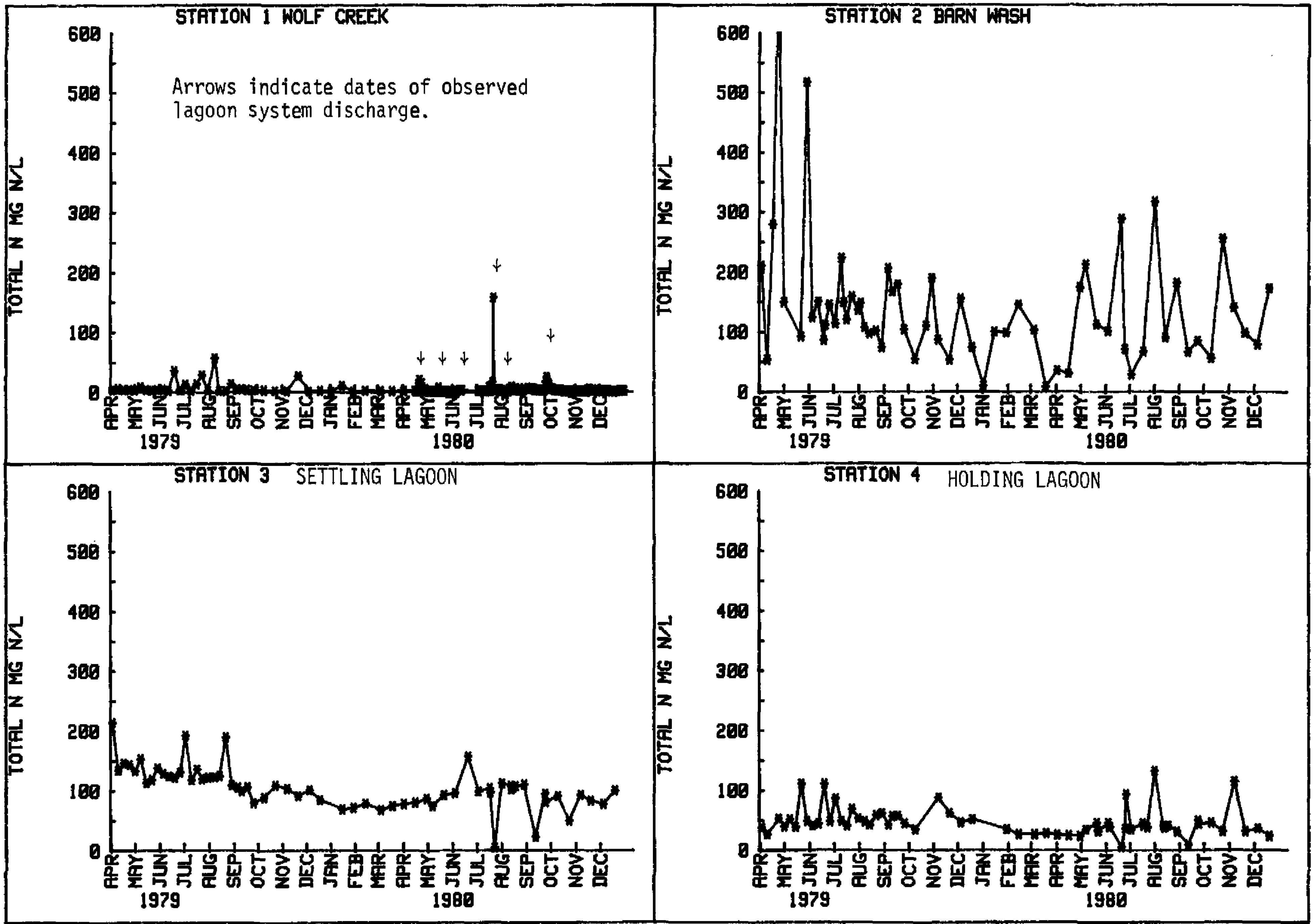
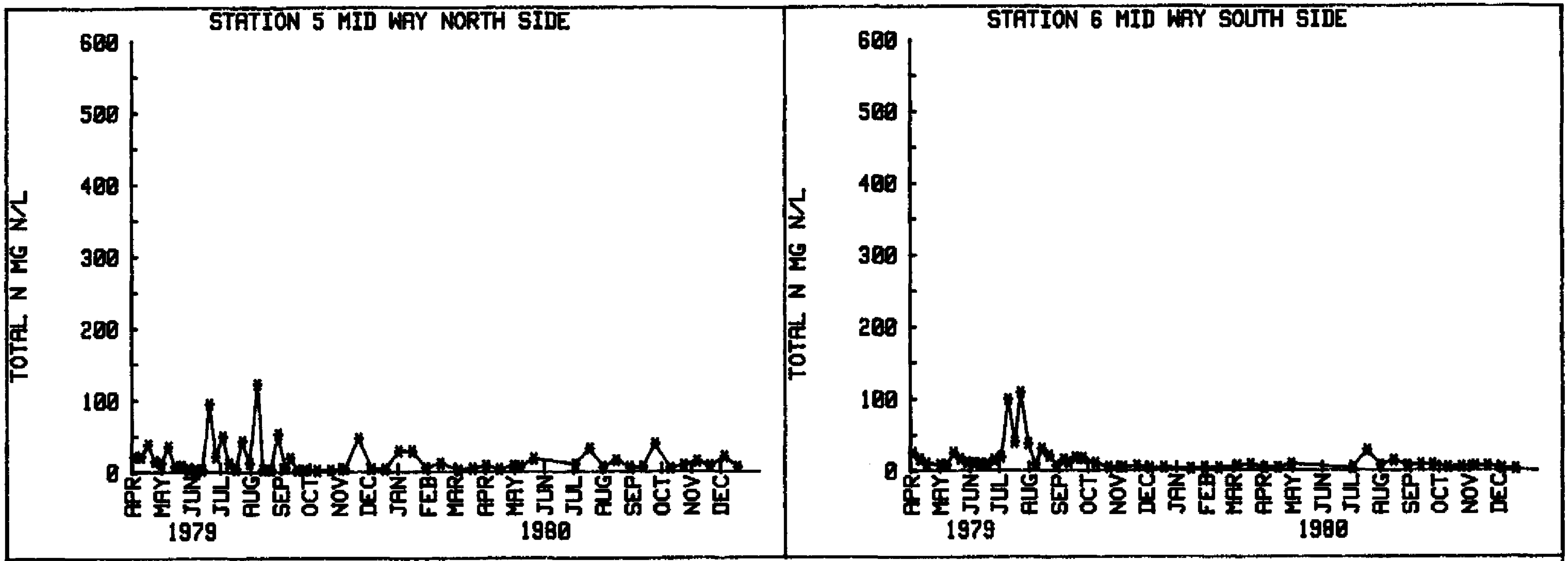
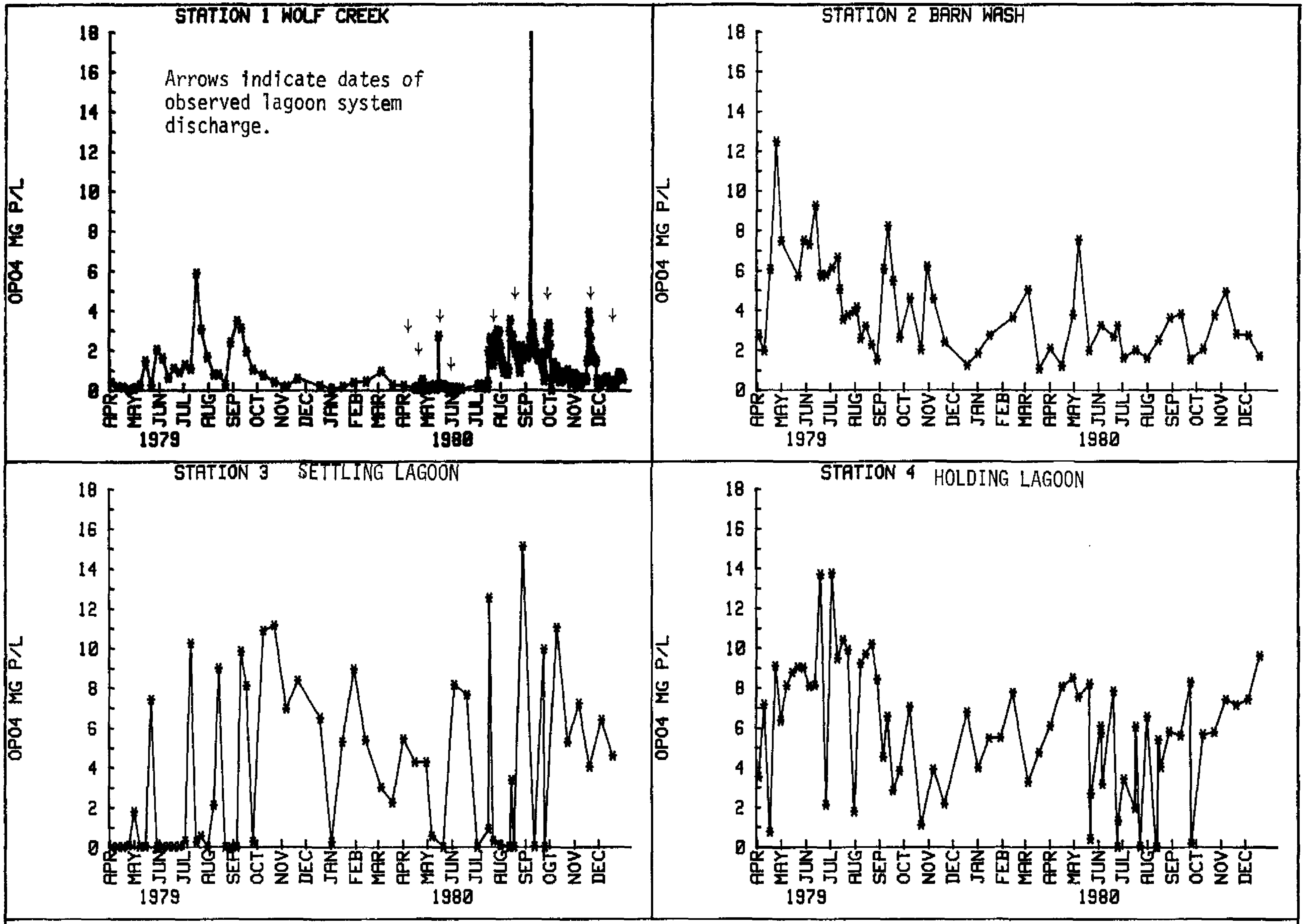


FIGURE II-44a . TOTAL NITROGEN FOR SEZ DAIRY


STATION 5 MID WAY NORTH SIDE

STATION 6 MID WAY SOUTH SIDE

FIGURE II-44b . TOTAL NITROGEN FOR SEZ DAIRY



Arrows indicate dates of observed lagoon system discharge.

FIGURE II-45a . ORTHO PHOSPHORUS FOR SEZ DAIRY

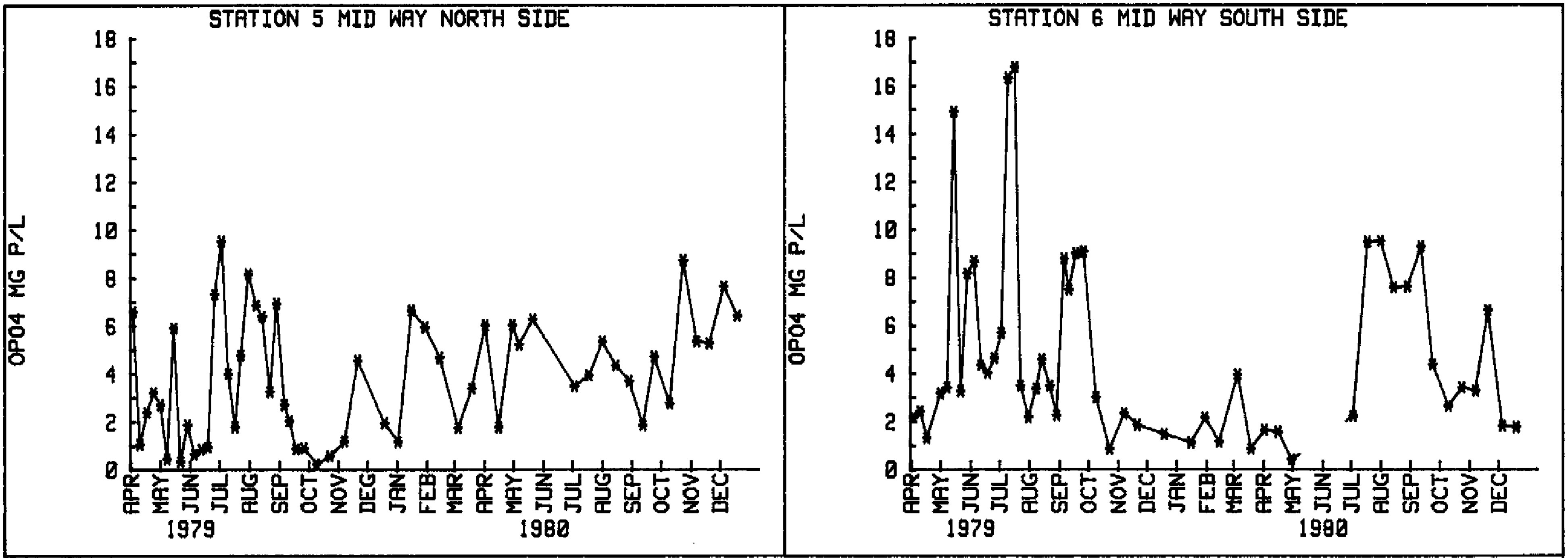
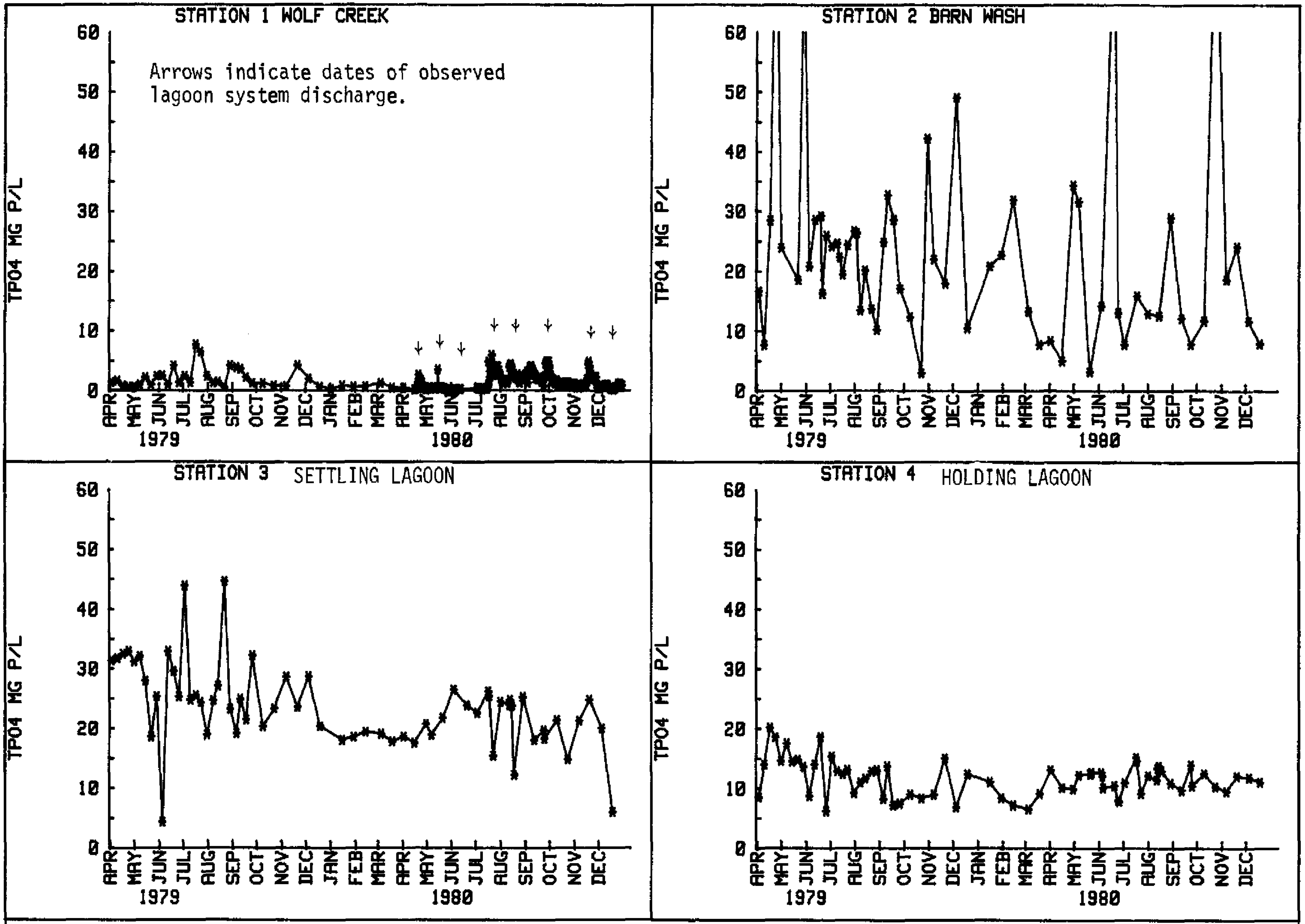


FIGURE II-45b . ORTHO PHOSPHORUS FOR SEZ DAIRY


STATION 1 WOLF CREEK

Arrows indicate dates of observed lagoon system discharge.

STATION 2 BARN WASH

STATION 3 SETTLING LAGOON

STATION 4 HOLDING LAGOON

FIGURE II-46a . TOTAL PHOSPHORUS FOR SEZ DAIRY

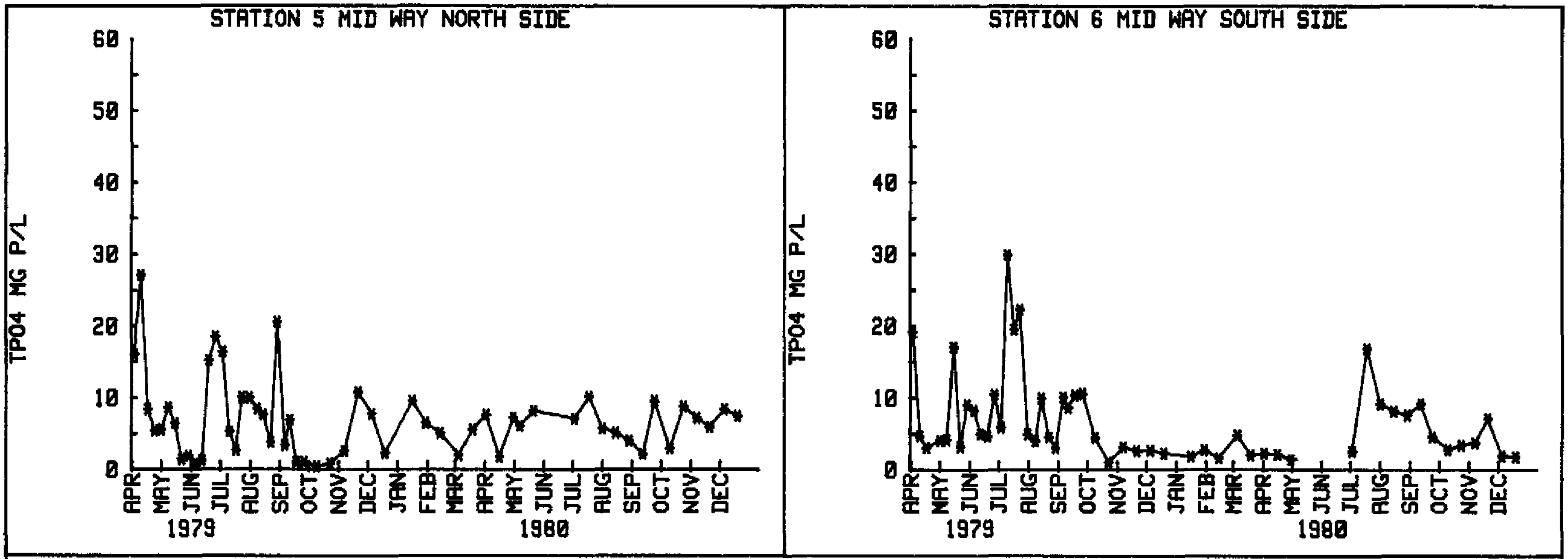


FIGURE II-46b . TOTAL PHOSPHORUS FOR SEZ DAIRY concentrations of the same parameters in discharge from the second lagoon, treatment efficiency of the system, while good, is not quite so impressive. In fact, reduction of total nitrogen and phosphorus from barnwash levels is only 56 and 69 percent, respectively. Reduction of inorganic forms is even less impressive as inorganic nitrogen is reduced only 15 percent while ortho phosphorus, if anything, is released in concentrations higher than those mean levels calculated for the barnwash.

Details of conversion of organic and inorganic forms of nitrogen and phosphorus in the lagoon and ditch system at the SEZ Dairy were discussed in Goldstein and Ulevich (1980). Additional data collected since then and presented here (Table II-3) continues to show the same types of results. The net conversion of organic nitrogen to ammonia in the anaerobic conditions that prevail in the first lagoon and its subsequent conversion back to a more predominantly organic form by the time it leaves the dairy is a characteristic feature of the system. Ortho phosphorus concentrations leaving the dairy during periods of lagoon discharge, while lower than those observed in the lagoon effluent itself, are at levels similar to those measured in the barnwash. Biogeochemical processes in the lagoon system are reducing the organic component of the phosphorus load, but as a result, the soluble reactive phosphorus load is being enhanced. When discharge from the lagoon system occurs, some reduction of the phosphorus load occurs in the perimeter ditch (probably due to adsorption and settling to the sediment, rather than direct conversion to organic forms, since the fraction of the inorganic component of the inorganic/organic phosphorus ratio continues to increase).

Table II-3

INORGANIC/ORGANIC NUTRIENT RATIOS
FOR SEZ DAIRY
SAMPLING STATIONS

Station		Nitrogen	Phosphorus
2	Barnwash	19.7	17.8
3	Primary Settling Lagoon	60.8	15.3
4	Secondary Holding Lagoon	53.3	50.3
5	North Perimeter Ditch	34.7	57.4
6	South Perimeter Ditch	29.1	71.6
1	Site Outfall at Wolf Creek	28.0	68.8

The evidence implies that dairy waste treatment lagoons may do little to alleviate the phosphorus discharge problem from the barns. Admittedly, mean total phosphorus concentrations leaving the lagoons are less than half of mean concentrations measured in the barnwash, but this loss is probably due to deposition and storage in the lagoon sediments. Anaerobic conditions that prevail there serve to convert organic to soluble forms and to set up equilibrium conditions between the ever increasing amounts of phosphorus in the sediment and the water column such that inorganic forms are kept in solution at high concentrations.

WATER QUALITY IMPACTS OF AGRICULTURAL PRACTICES

The previous discussion of time series water quality data provided some insight into concentrations of water quality parameters that are characteristic of each study site. These types of data are useful for determining if seasonal trends exist or if any type of extraordinary event either man-made or natural (e.g., plug installation or hurricane) has impact by increasing or decreasing concentrations. These types of data also provide some insight into water quality effects of various land use practices. Comparisons can be made between sites based on characteristic means, orders of magnitude, and variability, thereby providing insights into impacts of livestock stocking intensities and pasture maintenance programs.

The picture, though, cannot be complete without performing some type of analyses of the quality data in conjunction with flow weighting. That is, a determination must be made as to how volumes of water, in addition to land use practices, impact water quality. In order to accomplish this, loading calculations based on quantity and quality data are performed. As a result, concentration and volume data are transformed into a total quantity (mass). In this case, the quantities of interest are nitrogen and phosphorus species. A discussion of the loading calculation rationale and methodology follows. The remainder of the chapter will provide a flow weighted analysis of impacts of agricultural land use practices based on such loading calculations.

LOADING CALCULATION RATIONALE AND METHODOLOGY

In order to adequately determine the impacts of different types of land uses and the effectiveness of the detention/retention concept as a nonpoint source water quality treatment alternative, it is necessary to be able to calculate the quantities of each nutrient species of interest that occur over a given time interval. In order to do this, one needs to have both a measurement (or good estimate) of both the quality of water and the quantity of water that flows past a point of interest for the given time interval. An attempt has been made to collect these types of data at the relevant sampling locations on the Upland Demonstration Project sites. Water quality data has been collected routinely since early 1979. The water quantity data record is not as complete. Installation of instrumentation and flow control structures were hardly completed when rains preceding and during Hurricanes David and Frederic in Fall of 1979 caused damage to these devices that required repair or replacement (Goldstein, et al., 1979; Goldstein and Ulevich, 1980). As a result, flow volume records at some stations go back only to the Spring of 1980. For the analyses that follow, the period of record for flow measurements will vary for each station. The entire record will be used where possible (i.e., impacts of land use on watersheds); however, for analyses on effects of detention/retention areas where multiple station records are required, by necessity the period of record will coincide with the period of record of the station where the least amount of quantity data has been collected. For this reason, the records at the Armstrong and Ash Slough sites are not as complete as would be desirable. It is hoped that the ongoing nature of the project will allow us to eliminate this deficiency.

Nutrient loadings for total nitrogen, inorganic nitrogen (NOx + NH4), total phosphorus, and ortho phosphorus have been calculated at each of the pertinent surface water sampling stations in the following manner:

1. A representative nutrient species concentration for the period of interest (i.e., the interval between two routine water quality sampling dates) was calculated by computing a mean concentration using those concentrations measured on the routine sampling dates that define the interval.
2. The daily flow volumes that occurred over the same interval were summed to provide a total flow volume for the interval. Since water quality sampling occurs at or near mid-day, flow volume for that day is halved. One-half of the reported volume is assumed to occur during the interval of interest and the other half is assumed to occur during the interval immediately preceding or following the interval of interest, as the case may be.
3. The flow volume for the interval is multiplied times the mean concentration for the interval and the appropriate conversion coefficients are applied to compute a mass loading of the nutrient species of interest for the interval in kilograms.
4. The loading for the interval can be divided by the days of measured discharge at the flow control structures to determine an amount in kilograms per day of nutrient mass that passes the sampling point.

In order to determine the actual role of land use practices on a watershed, it is of essential importance to know what the role of rainfall is in contributing to nutrient loading. As rainfall is a natural process, it could be argued that nutrient loading contributed by rainfall is a normal and probably desirable process.

Mass loading of the nutrient species of interest has been calculated for the Upland Demonstration Project sites using the following methodology:

1. Rainfall quality samples were collected at three locations in the vicinity of the Upland Demonstration Project sites. These sites and the period of data collection used for this study are listed in Table II-4.
2. Samples were collected at permanent collection structures and retained in Nalgene bottles. After each significant rainfall, the sample was collected and poured into a larger Nalgene container and kept refrigerated. Rainfall samples for the week were composited in this manner. At the end of the week, the composited sample was brought to the laboratory and subsequently analyzed for nitrogen and phosphorus concentration levels.
3. The weekly quality observations for each nutrient species of interest were summed over the period of record, and mean concentrations and standard deviations were calculated.
4. A student's t-test was run as a method to compare the mean concentrations of each parameter at the three sampling locations to determine if any significant differences could be statistically detected. Computed t-scores for each pair were highly insignificant. It was thus assumed that mean concentrations of nutrient parameters in rainfall collected at each station were equally likely to occur throughout the study area.

5. Since the means for each parameter differed at the three stations, the high mean and the low mean values were chosen as representative of the maximum and minimum concentrations for each nutrient species that would be expected to characteristically occur in rainfall over the study area.
6. The maximum and minimum concentrations of each nutrient species were multiplied by the surface area of each watershed (Table II-5) in the study area and by the amount of daily rainfall measured at the study site by on-site rain gauges supplied and maintained by the U. S. Geological Survey out of Orlando, Florida. The resulting numbers were multiplied by the appropriate conversion coefficient to produce a range of kilograms of nutrient species per day loading to the watershed that could be attributed to rainfall alone.

The role of detention/retention areas as nutrient sources or sinks is determined in a similar manner. All mass loadings of the nutrient species going into the area are calculated at the inflow monitoring stations. To this is added the mass loadings contributed by rainfall over the ungauged surface area of the marsh. The total mass loads in are then compared against the total mass loads out as determined at the detention marsh outfall monitoring site. The mode of the marsh as a source or sink is determined in the same manner as described above.

This analysis is complicated somewhat by the existence of storage area in the detention/retention marsh. For example, mass loads in might exceed mass loads out for a given period when rainfall and subsequent

Table II-4 RAINFALL QUALITY SAMPLING LOCATIONS PERIOD OF RECORD

LOCATION	P. O. R.
S-65B	April 1, 1979 - February 9, 1981
S-65D	September 10, 1979 - December 31, 1980
Okeechobee Field Station	April 1, 1979 - December 31, 1980

Table II-5 CONTRIBUTING WATERSHED SURFACE AREAS FOR UPLAND DEMONSTRATION PROJECT SITES

(Acres)

ARMSTRONG SLOUGH:	
Flume	2,000
Open Channel	20,000
Marsh Area	453
Total:	22,453
ASH SLOUGH:	
Ditched Pasture	162
Unditched Pasture	26
Marsh Area	52
Total:	240
WILDCAT SLOUGH:	
Flume	6,400
Small Culverts	4,270
Upstream C-41A	5,207
Total:	15,677
PEAVINE PASTURE:	
Total:	600
SEZ Dairy:	
Wolf Creek Discharge	815
Total:	815

runoff fill the detention/retention area. This inflow from runoff will abate following the storm event. Discharge of the stored water in the marsh area, however, may continue for some longer period. For this reason, a simultaneous computation of loads in versus loads out at regular intervals may not be appropriate. This is probably the case at Ash Slough where inflows and outflows are discontinuous and occur as distinct events following periods of significant rainfall. In these instances, better results are obtained by treating the entire event from beginning of inflow to the ceasation of outflow as the interval of interest. This is a longer term approach and is applicable only in those instances where distinct events occur and can be separated. In lieu of this, long term intervals such as seasonal or annual have to be selected and resolution of the effects of individual storms is reduced.

FLOW WEIGHTED IMPACTS OF AGRICULTURAL LAND USE PRACTICES

Flow weighting provides considerable insight into the role watersheds play in contributing to or reducing the nutrient loads to receiving waters. This is especially true when one examines the sources of nutrient loads on the watershed. Sources of nutrients to the watersheds in the Upland Demonstration Project were primarily rainfall loads and supplemental fertilization by landowners. At SEZ Dairy, the waste treatment lagoon effluent was an additional source of nutrient loads at the site outfall. With the exception of the north channel at Armstrong Slough and the SEZ Dairy, all water volumes in the channels were the product of direct rainfall runoff or shallow groundwater seepage. The latter was probably a very minor contributor to the overall flow. The Armstrong Slough and SEZ Dairy watersheds, mentioned as exceptions, each received flow contributions from at least one other source. At Armstrong the source of continuous flow is probably groundwater pumped to the surface for citrus irrigation. At SEZ the additional source is groundwater utilized for dairy barn operations. This source receives treatment and is only discharged from the lagoons to impact the site outfall at irregular intervals.

In this discussion, each watershed will be addressed separately. The nitrogen and phosphorus loads in sources will be analyzed as well as the loads being discharged from the watershed at each monitoring station. Any reduction or increase in loads will be noted. A comparison of the loads contributed by each watershed will conclude this discussion.

Loading analyses were performed on each watershed for the period of record where concurrent water quality and quantity data were available. While quality data has been available at all sites since early 1979, installation of gauges, flumes, and culverts at all sites by that date was not possible. In addition, following initial installation, major repair and maintenance work was required at some of the sites. As a result, loading calculations have been made for the period of record subsequent to the completion of these major activities where a continuous record of flow volume data is available. This period varies from site to site and explains why there are more loading data associated with some sites than with others.

PEAVINE PASTURE

Data were available and loading calculations were performed for the period from July 1979 through November 1980. Rainfall over the watershed ranged from none in October 1979 to 32 cm during September 1979. The total rainfall volume peaked at 769.8 x 10^3 cubic meters during September, a good part of which was associated with Hurricane David. Discharge measurements in September are not accurate in that some flow was observed to bypass the flume and was not measured. In addition, some flow was probably contributed by adjacent watersheds as total discharge for August, September, and October 1979 exceeded total rainfall during those three months.

With the exception of the August-October 1979 period, runoff volume leaving the site at the outfall is characteristically less than 10 percent of the total rainfall volume (Tables II-6a & II-6b). During February and August 1980, runoff was roughly half the calculated rainfall volume. Discharge volumes in excess of rainfall are associated with the heavy rains that preceded and followed Hurricane David in August-October 1979. During three months no discharge occurred at the site. Rainfall during this time was completely absorbed on the watershed.

With the exception of the August-October 1979 period, percent total nitrogen reduction closely reflected the percent volume reduction of rainfall to discharge on the watershed. With the exception of October when no rainfall fell on the watershed, discharge of dissolved inorganic nitrogen and total and ortho phosphorus was well below those levels that could be attributed to rainfall alone (Figures II-47 through II-50). Indeed, with the exception of the previously discussed August through October period, discharge of these three parameters at the site outfall was practically nonexistent. The watershed was a net exporter of nutrients at no time. In fact, as much as 2.88 pounds per acre of total nitrogen and .27 pounds per acre of total phosphorus were absorbed during this study. During October 1979 when no rainfall occurred, 284.8 kg of total nitrogen and 7.5 kg of total phosphorus were exported. The discharge

Table II-6a

PEAVINE PASTURE WATERSHED

	1979					
	July	August	September	October	November	December
Total monthly rainfall on watershed (cm)	14.3	8.8	31.7	0	1.2	1.8
Total rainfall volume on watershed (m^3 x 1000)	347.9	214.7	769.8	0	29.6	44.4
Total monthly discharge volume of flume (m^3 x 1000)	47.8	267.3	1370.6	172.2	3.5	0.3
Absorption on watershed (m^3 x 1000)	300.1	-52.6	-600.8	-172.2	26.1	44.1
Percent reduction	86.2	-24.5	-78.0	0	88.2	99.3
Total Nitrogen						
Total monthly rainfall contribution (kg)	704.5	434.7	1558.8	0	60.0	90.0
Total monthly discharge from watershed (kg)	105.3	541.7	1495.5	284.8	7.8	0.6
Net uptake by watershed (kg)	599.2	-107.0	63.3	-284.8	52.2	8.4
Percent reduction	85.1	-24.6	4.1	-	87.0	93.4
Inorganic Nitrogen						
Total monthly rainfall contribution (kg)	201.8	124.5	446.4	0	17.2	25.8
Total monthly discharge from watershed (kg)	1.1	6.6	33.1	3.6	0.1	0
Net uptake by watershed (kg)	200.7	117.9	413.3	-3.6	16.1	25.8
Percent reduction	99.5	94.7	92.6	-	93.6	100.0
Total Phosphorus						
Total monthly rainfall contribution (kg)	47.5	29.3	105.1	0	4.1	6.1
Total monthly discharge from watershed (kg)	2.8	10.8	31.8	7.5	0.2	Trace
Net uptake by watershed (kg)	44.7	18.5	73.3	-7.5	3.9	6.1
Percent reduction	94.1	63.1	69.1	-	95.1	100.0
Ortho Phosphorus						
Total monthly rainfall contribution (kg)	23.0	14.2	50.9	0	2.0	2.9
Total monthly discharge from watershed (kg)	0.9	2.7	13.2	2.2	0.1	Trace
Net uptake by watershed (kg)	22.1	11.5	37.7	-2.2	1.9	2.9
Percent reduction	96.1	81.0	74.1	-	95.0	100.0

Negative values indicate export.

Table II-6b

PEAVINE

	Jan	Feb
Total monthly rainfall on watershed (cm)	2.7	2.4
Total rainfall volume on watershed (m^3 x 1000)	66.6	59.2
Total monthly discharge volume at flume (m^3 x 1000)	0.8	26.3
Absorption on watershed (m^3 x 1000)	65.8	32.9
Percent reduction	98.8	55.6
Total Nitrogen		
Total monthly rainfall contribution (kg)	134.9	119.9
Total monthly discharge from watershed (kg)	1.2	43.7
Net uptake by watershed (kg)	133.7	76.2
Percent reduction	99.1	63.6
Inorganic Nitrogen		
Total monthly rainfall contribution (kg)	38.7	34.4
Total monthly discharge from watershed (kg)	Trace	0.3
Net uptake by watershed (kg)	38.7	34.1
Percent reduction	100.0	99.1
Total Phosphorus		
Total monthly rainfall contribution (kg)	9.1	8.1
Total monthly discharge from watershed (kg)	Trace	0.7
Net uptake by watershed (kg)	9.1	7.4
Percent reduction	100.0	99.1
Ortho Phosphorus		
Total monthly rainfall contribution (kg)	4.4	4.0
Total monthly discharge from watershed (kg)	Trace	0.6
Net uptake by watershed (kg)	4.4	3.4
Percent reduction	100.0	85.0

Negative values indicate export.

PASTURE WATERSHED

1980								
March	April	May	June	July	Aug	Sept	Oct	Nov
2.1	3.7	12.2	7.3	16.2	6.1	7.6	0.9	6.4
51.8	88.8	296.1	177.6	392.3	140.0	185.0	18.5	155.4
12.1	2.2	1.3	0	1.3	82.2	2.7	0	0
39.7	86.6	294.8	177.6	391.0	57.8	182.3	18.5	155.4
76.6	97.5	99.6	100.0	99.7	41.3	98.5	100.0	100.0
104.9	329.9	599.6	359.7	794.4	283.6	374.8	37.5	314.8
23.8	4.4	1.9	0.5	10.2	128.2	7.6	0.1	0
81.1	325.5	597.7	359.2	784.2	155.4	367.2	37.4	314.8
77.3	98.7	99.7	99.9	98.7	54.8	98.0	99.7	100.0
30.1	92.3	171.8	103.1	227.5	81.2	107.3	1.1	90.2
Trace	0.1	Trace	0	0.1	1.6	0.8	0	0
30.1	92.2	171.8	103.1	227.4	79.6	106.5	1.1	90.2
100.0	99.9	100.0	100.0	100.0	98.0	99.3	100.0	100.0
7.1	12.1	40.4	24.2	53.6	19.1	25.3	2.6	21.2
0.3	0.1	0.1	0	0.3	2.0	0.1	0	0
6.8	12.0	40.3	24.2	53.3	17.1	25.2	2.6	21.2
100.0	99.9	100.0	100.0	100.0	98.2	99.3	100.0	100.0
3.5	5.9	19.6	11.8	25.9	9.3	12.2	1.2	10.3
0.1	Trace	Trace	0	0.5	0.8	0.1	0	0
3.4	5.9	19.6	11.8	25.4	8.5	12.1	1.2	10.3
97.1	100.0	100.0	100.0	98.1	91.4	99.2	100.0	100.0

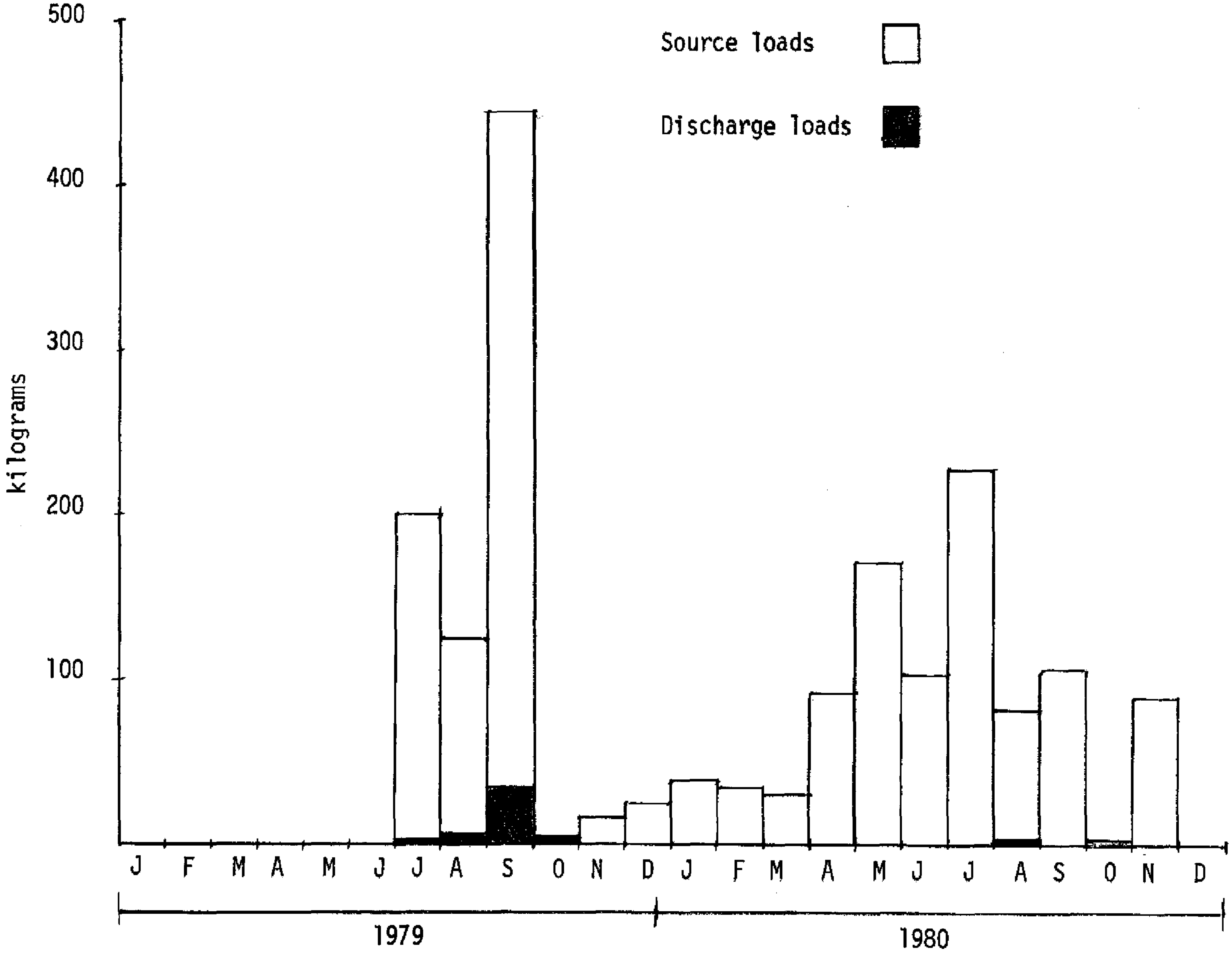
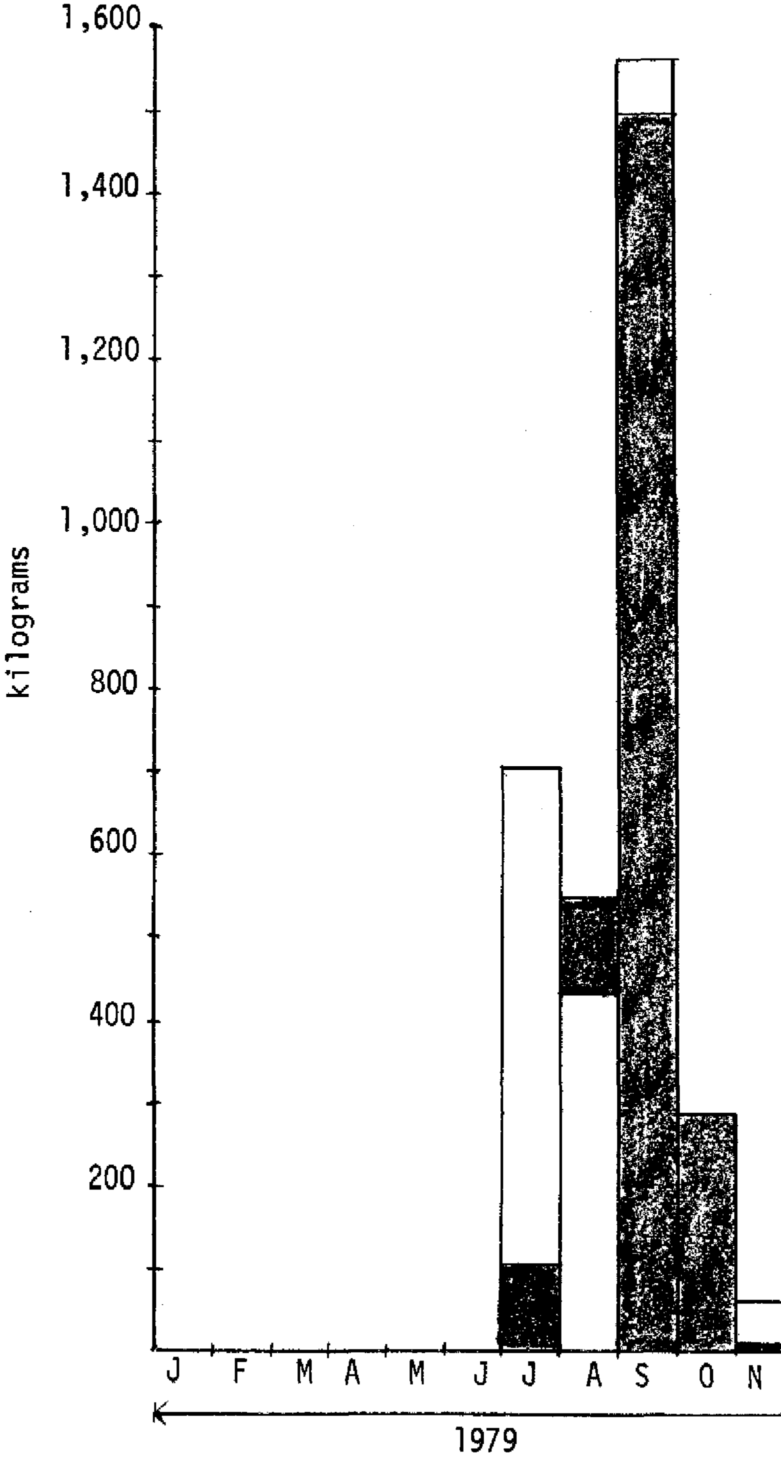


Figure II-47 MONTHLY INORGANIC NITROGEN BUDGET FOR PEAVINE WATERSHED


kilograms
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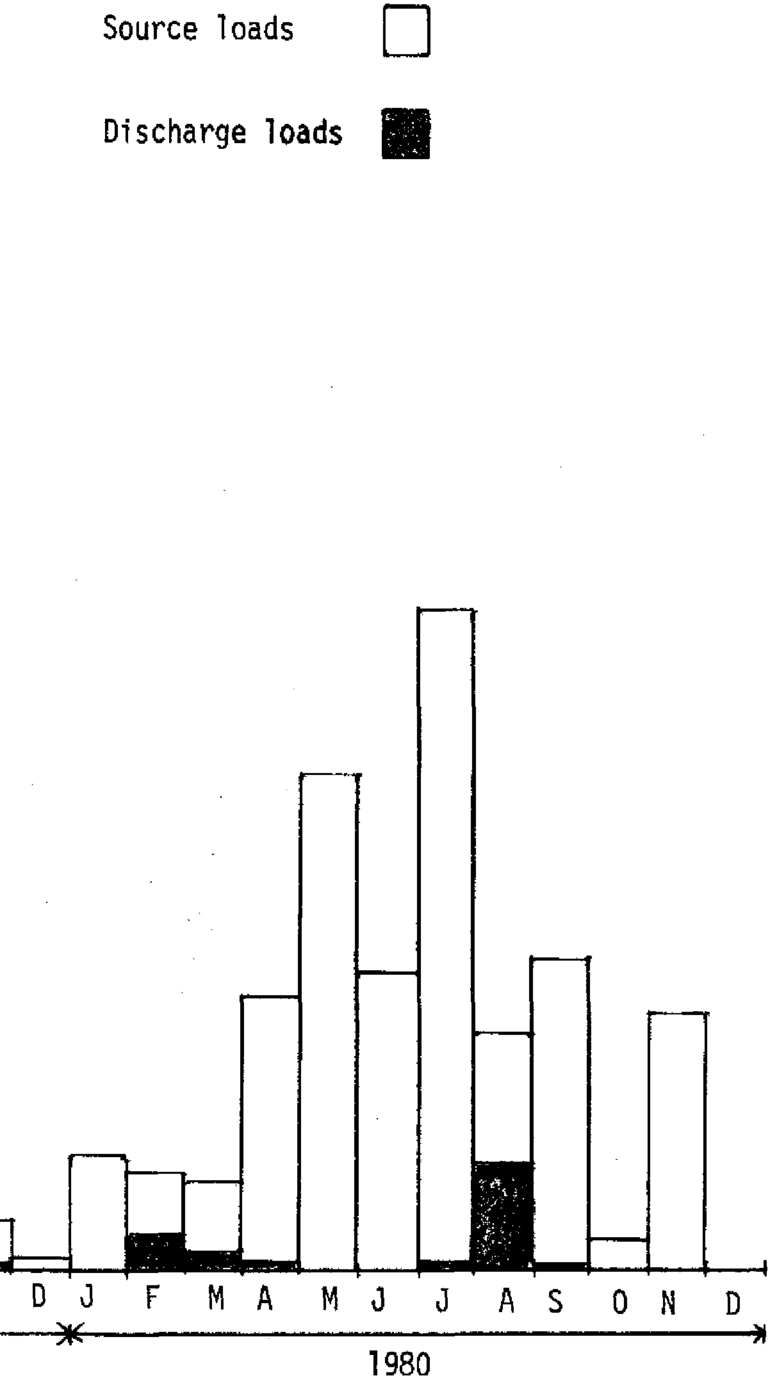
Source loads ☐
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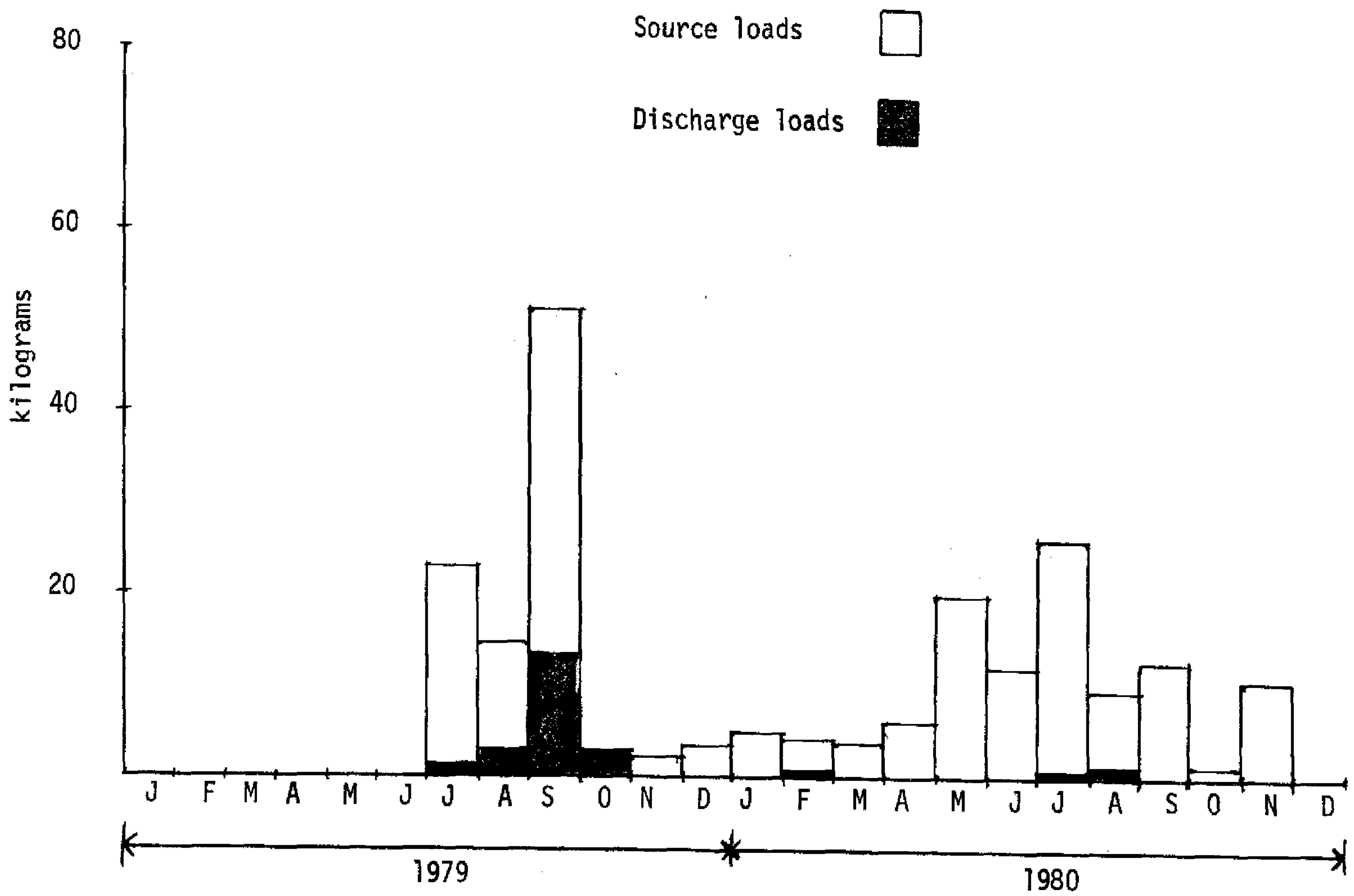

Figure II-49 MONTHLY ORTHO PHOSPHORUS BUDGET FOR PEAVINE WATERSHED

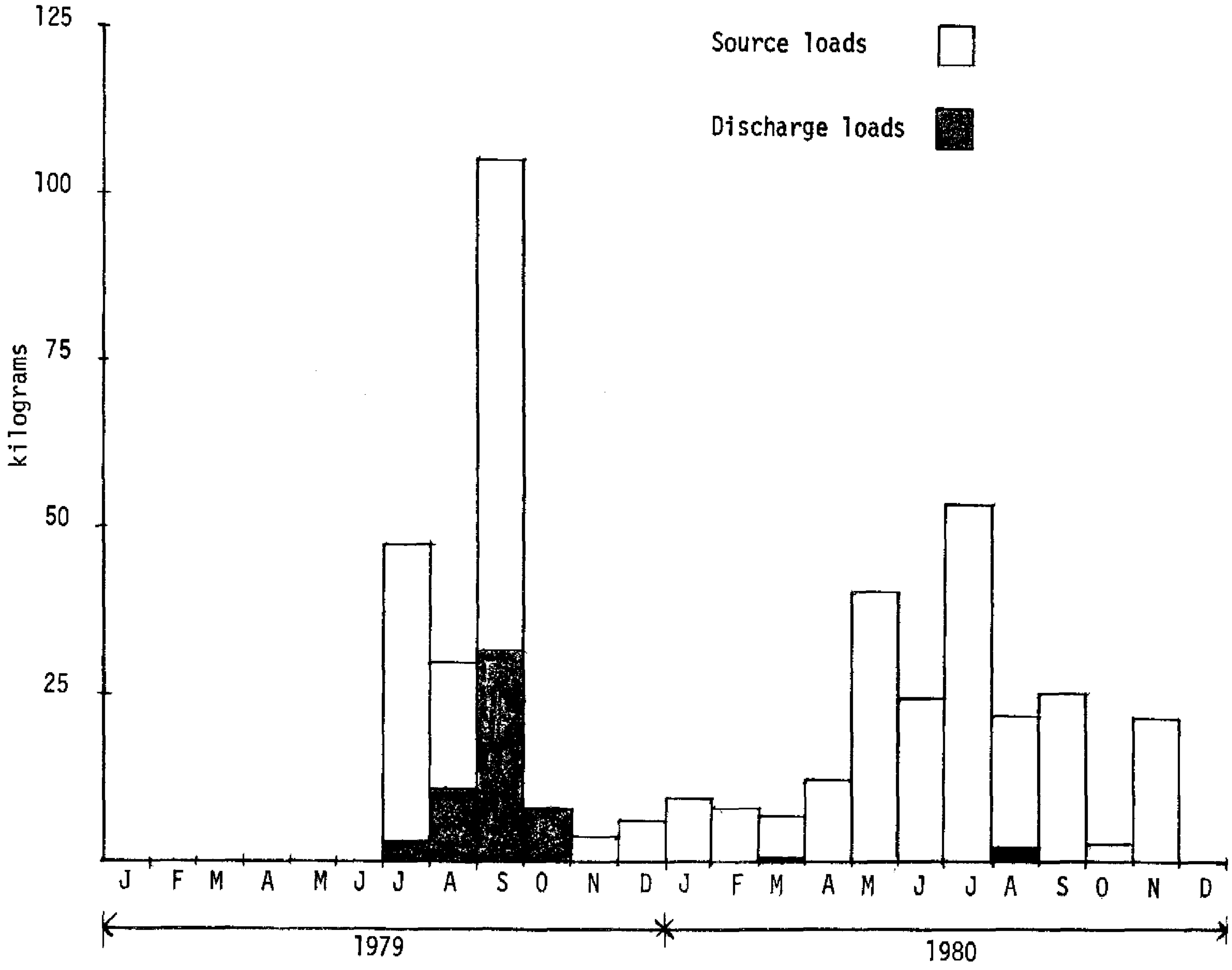

Figure II-50 MONTHLY TOTAL PHOSPHORUS BUDGET FOR PEAVINE WATERSHED at this time was from residual waters left by the heavy rains during the previous month. This being the case, the reported export merely reflects loads already dissolved in this water and not any additional export from the watershed itself.

ASH SLOUGH

Total monthly rainfall on the Ash Slough-east portion of the watershed ranged from 1,000 cubic meters to 36,900 cubic meters during and following Hurricane David (Tables II-7a & II-7b). October is the sole month where net runoff exceeds rainfall. The bulk of this appears to be water left by Hurricane David. Total rainfall volume for September and October when summed together exceeds the total discharge volume for these two months. It can be concluded that extreme rainfall events result in some detention of water on the watershed itself, as flat land and dense grass cover combine to slow the sheet flow of water across the area. With the exception of August-September 1979 and September 1980, net absorption of rainfall on the watershed was in excess of 84 percent. During eight of the 15-month period of record, little or no discharge occurred at the watershed outfall.

Some export of nitrogen appears to have occurred during September-October 1979 as total rainfall input for these months is slightly less than total discharge from the site. This export is probably in the organic particulate form as inorganic nitrogen loads were reduced 80 to 95 percent during this time. Almost all of the inorganic nitrogen in rainfall is consistently absorbed on the watershed.

Phosphorus was exported during September and October 1979.

Table II-7a

ASH SLOUGH EAST WATERSH

Total monthly rainfall on watershed (cm)
Total rainfall volume on watershed (m^3 x 1000)
Total monthly discharge volume of flume (m^3 x 1000)
Absorption on watershed (m^3 x 1000)
Percent reduction

Total Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Inorganic Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Total Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Ortho Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Negative values indicate export.

ED

1979			
September	October	November	December
35.1	1.5	1.2	5.2
36.9	1.6	1.3	5.4
29.9	7.3	0	0
7.0	-5.7	1.3	5.4
19.0	-356.3	100.0	100.0
74.7	3.3	2.6	11.1
63.7	20.2	0	0
11.0	-16.9	2.6	11.1
14.7	-512.1	100.0	100.0
21.4	1.0	0.8	3.2
1.0	0.2	0	0
20.4	0.8	0.8	3.2
95.3	80.0	100.0	100.0
5.1	0.3	0.2	0.8
15.9	3.3	0	0
-10.8	-3.0	0.2	0.8
-211.8	-100.0	100.0	100.0
2.5	0.1	0.1	0.4
11.9	2.0	0	0
-9.4	-1.9	0.1	0.4
-376.0	-1900.0	100.0	100.0

Table II-7b

ASH SLOUGH

	Jan	Feb
Total monthly rainfall on watershed (cm)	4.9	6.4
Total rainfall volume on watershed (m^3 x 1000)	5.1	6.7
Total monthly discharge volume at flume (m^3 x 1000)	.8	0
Absorption on watershed (m^3 x 1000)	4.3	6.7
Percent reduction	84.3	100.0
Total Nitrogen		
Total monthly rainfall contribution (kg)	10.4	13.7
Total monthly discharge from watershed (kg)	0.6	1.7
Net uptake by watershed (kg)	9.8	12.0
Percent reduction	94.2	87.6
Inorganic Nitrogen		
Total monthly rainfall contribution (kg)	2.7	4.0
Total monthly discharge from watershed (kg)	Trace	0.1
Net uptake by watershed (kg)	2.7	3.7
Percent reduction	100.0	97.5
Total Phosphorus		
Total monthly rainfall contribution (kg)	0.7	1.0
Total monthly discharge from watershed (kg)	0.2	0.6
Net uptake by watershed (kg)	0.5	0.4
Percent reduction	71.4	40.0
Ortho Phosphorus		
Total monthly rainfall contribution (kg)	0.4	0.5
Total monthly discharge from watershed (kg)	Trace	0.1
Net uptake by watershed (kg)	0.4	0.4
Percent reduction	100.0	80.0

Negative values indicate export.

EAST WATERSHED

1980								
March	April	May	June	July	Aug	Sept	Oct	Nov
6.7	9.4	1.8	7.6	21.6	18.9	19.5	0.9	9.4
7.1	9.9	1.9	8.0	22.8	19.9	20.5	1.0	9.9
0	1.4	0	0	1.3	1.0	11.5	0	0
7.1	8.5	1.9	8.0	21.5	18.9	9.0	1.0	9.9
85.9	100.0	100.0	100.0	94.3	95.0	43.9	100.0	100.0
14.3	20.1	3.9	16.3	46.1	40.3	41.6	1.9	20.1
0	0.8	0.8	0.8	2.3	4.7	18.4	0	0
14.3	19.3	3.1	15.5	43.8	35.6	23.2	1.9	20.1
100.0	96.0	79.5	95.1	95.0	88.3	55.8	100.0	100.0
4.1	5.8	1.1	4.7	13.2	11.5	11.9	0.1	5.8
0	Trace	Trace	Trace	Trace	Trace	0.3	0	0
4.1	5.8	1.1	4.7	13.2	11.5	11.6	0.1	5.8
100.0	100.0	100.0	100.0	100.0	100.0	97.5	100.0	100.0
1.0	1.4	0.3	1.1	3.1	2.8	2.8	0.1	1.4
0	0.3	0.3	0.3	0.6	0.4	4.2	0	0
1.0	1.1	0	0.8	2.5	2.4	-1.4	0.1	1.4
100.0	78.6	0	72.2	80.6	85.7	-50.0	100.0	100.0
0.5	0.7	0.1	0.6	1.5	1.4	1.4	0.1	0.6
0	0.3	0.3	0.3	0.5	0.3	3.1	0	0
0.5	0.4	-.2	0.3	1.0	1.1	-1.7	0.1	0.6
100.0	57.1	-200.0	50.0	66.7	78.6	-121.4	100.0	100.0

Total export of phosphorus for the two months was nearly 14 kilograms, of which approximately eleven were in the ortho form. Ortho phosphorus export appears to be correlated with months of high rainfall runoff. Ortho phosphorus is consistently the major constituent of the total phosphorus load being monitored at this location.

With the exception of the high rainfall/runoff periods previously mentioned, ortho and total phosphorus are consistently absorbed on the watershed (Figures II-51 and II-52). Total nitrogen is also almost totally absorbed except during months of extreme events. Inorganic nitrogen is absorbed almost completely by the watershed year round (Figures II-53 and II-54).

Comparison of nutrient loads in rainfall and discharge in absolute terms at Ash Slough-west (Tables II-8a and II-8b) is complicated by the reduction of effective watershed area by approximately half after January 1980. Trends in uptake or discharge of nutrients and in percentages of uptake or reduction over amounts present in rainfall alone should remain valid as the total volume of rainfall expected in runoff should be reduced by the same percentages as the total watershed area.

Discharge exceeding measured rainfall during October 1979 indicates that there was some temporary storage of heavy September rains on the watershed that continued to run off and contribute associated nutrient loads for somewhat less than a month following the rainfalls associated with Hurricane David.

With the exception of the month of April 1980, nitrogen was continually absorbed on the watershed as loads in runoff from the

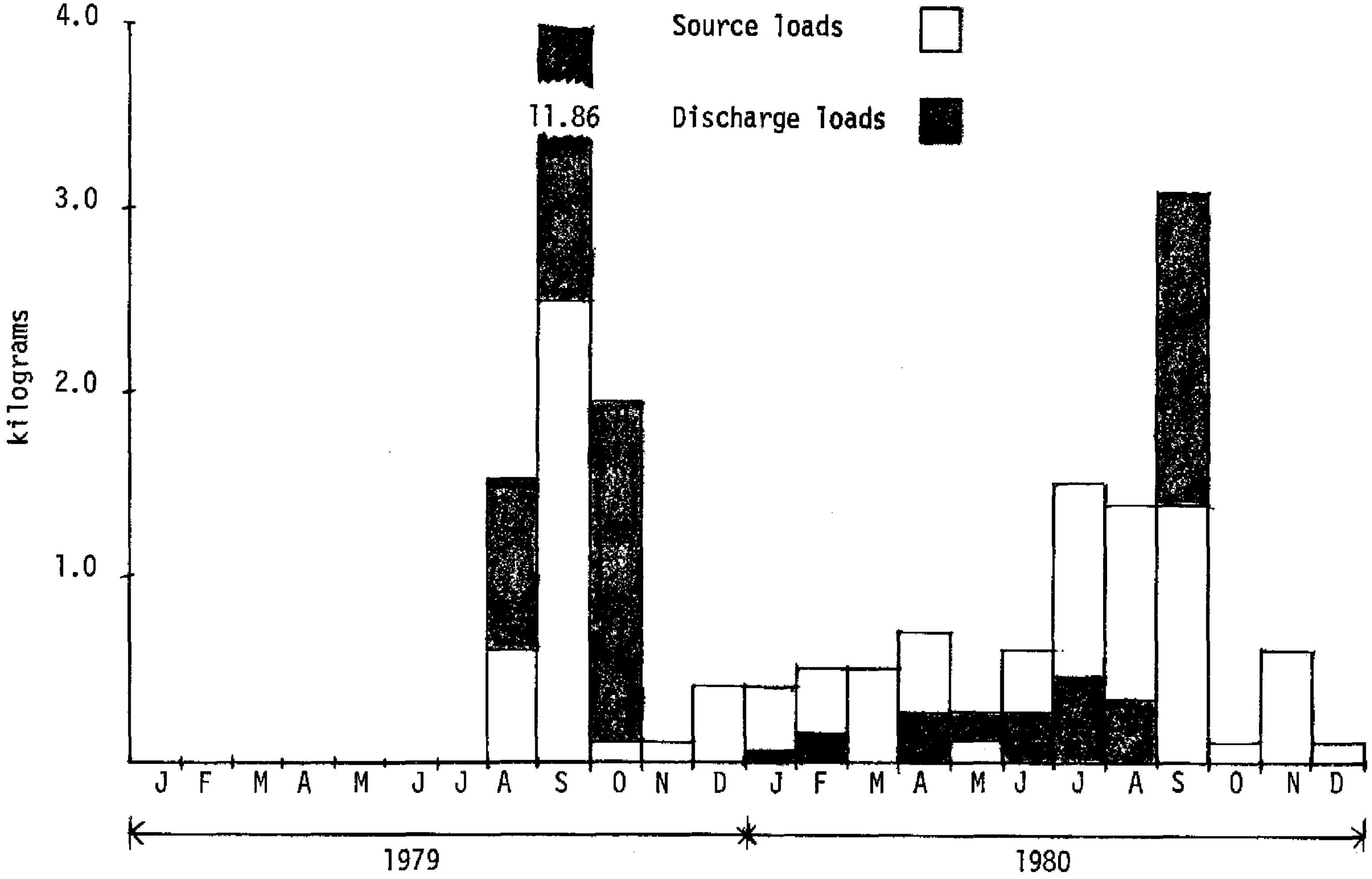

Figure II-51 MONTHLY ORTHO PHOSPHORUS BUDGET FOR ASH SLOUGH - EAST WATERSHED

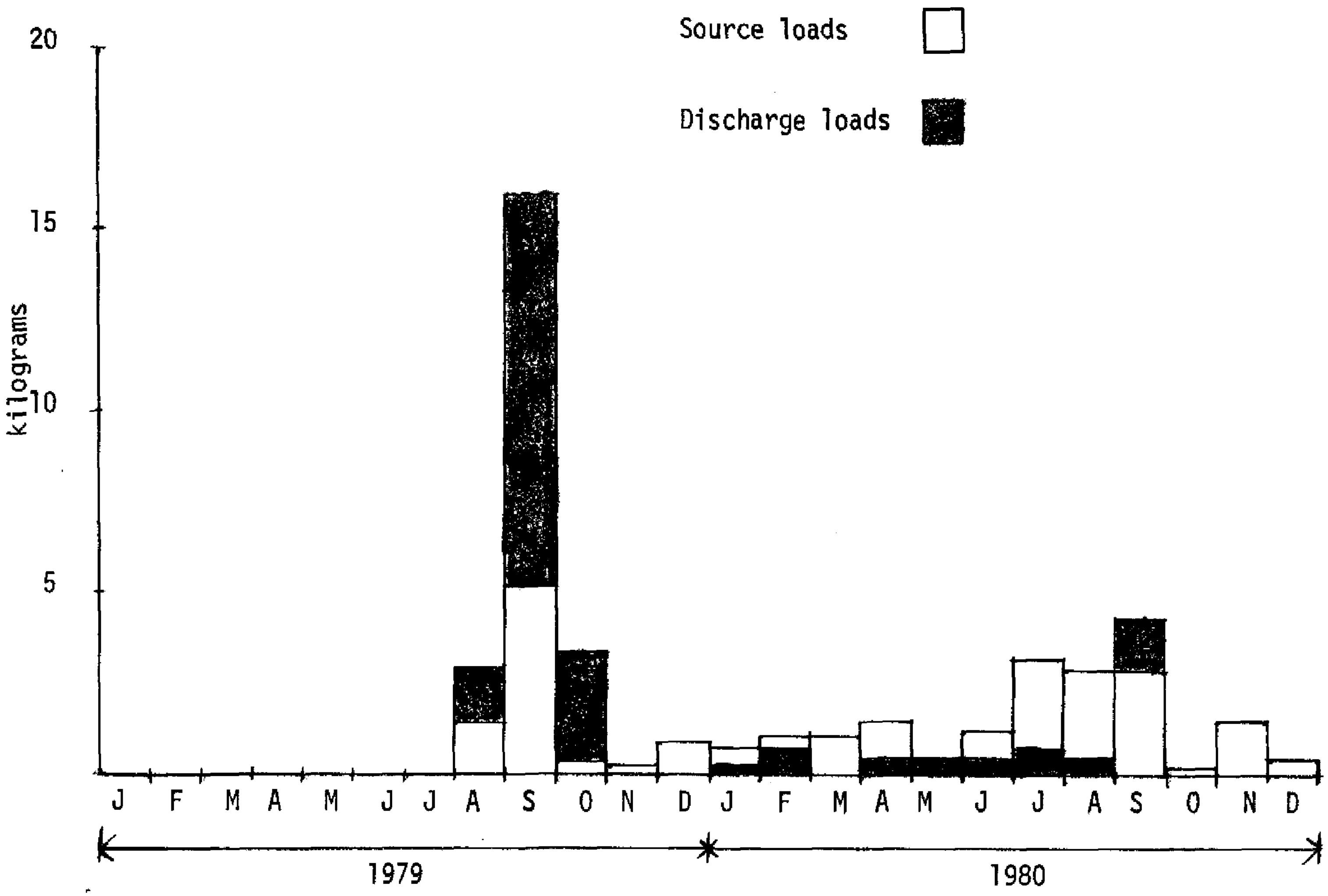

Figure II-52 MONTHLY TOTAL PHOSPHORUS BUDGET FOR ASH SLOUGH - EAST WATERSHED

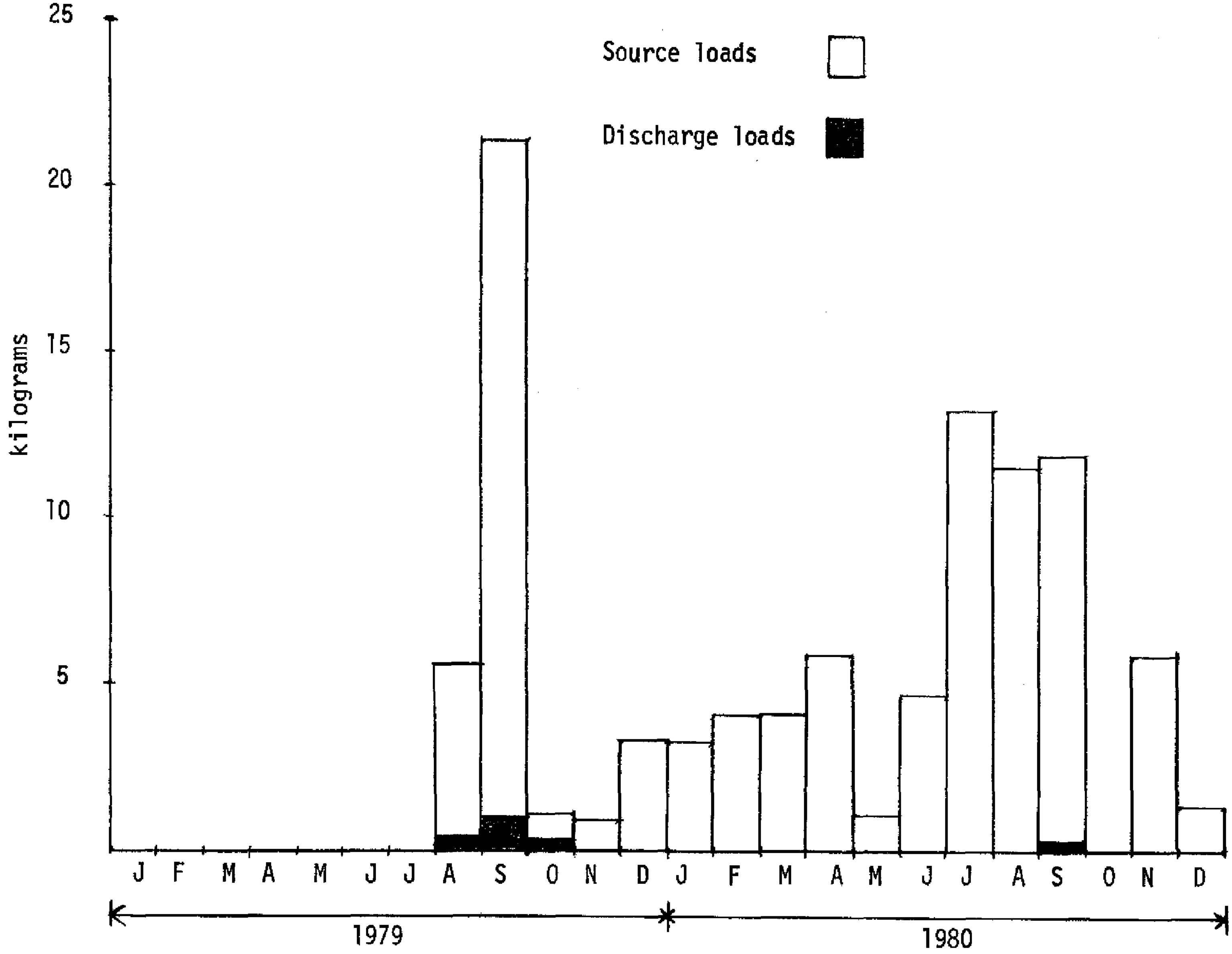

Figure II-53 MONTHLY INORGANIC NITROGEN BUDGET FOR ASH SLOUGH - EAST WATERSHED

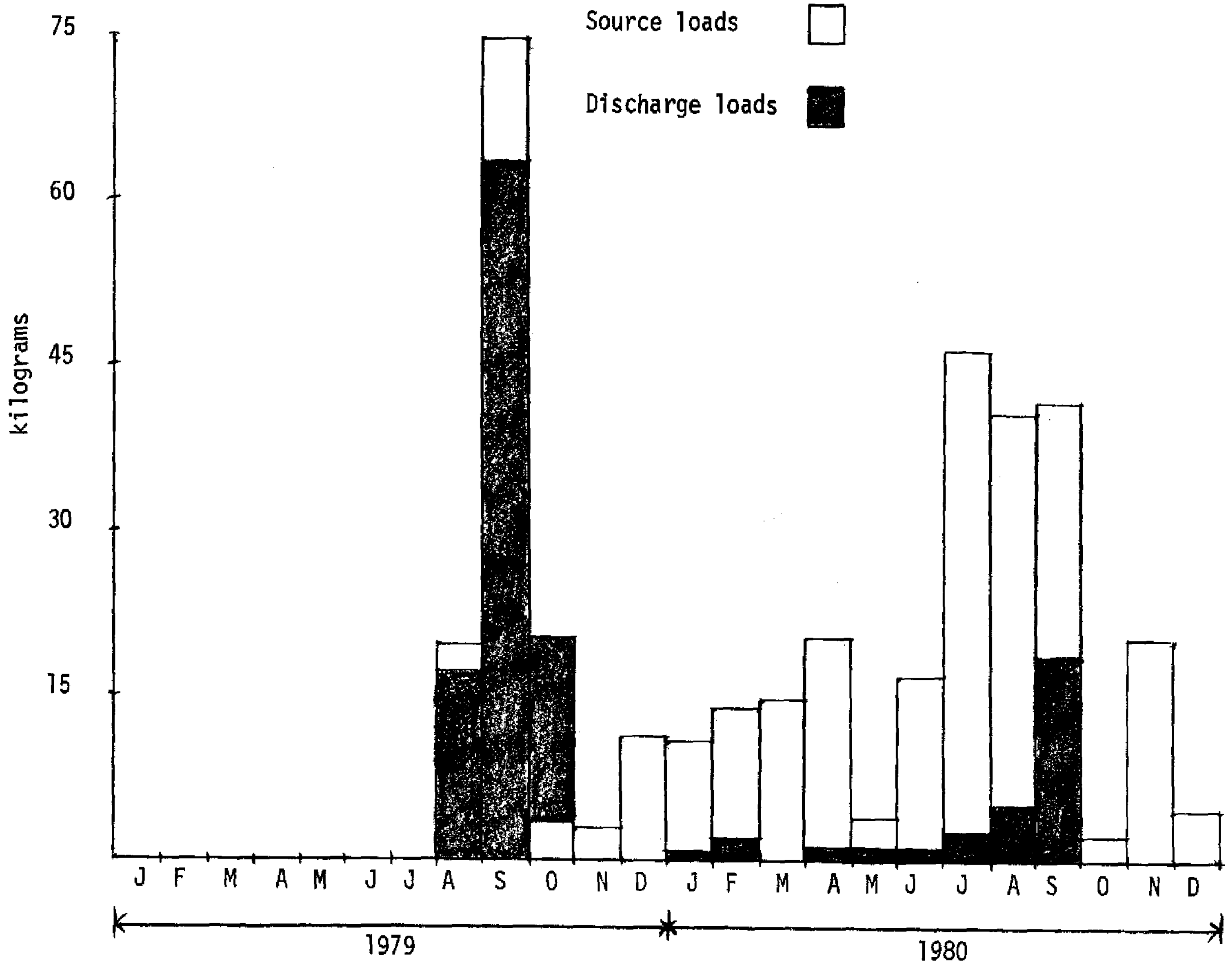

Figure II-54 MONTHLY TOTAL NITROGEN BUDGET FOR ASH SLOUGH - EAST WATERSHED

Table II-8a ASH SLOUGH WEST WATE

Total monthly rainfall on watershed (cm)
Total rainfall volume on watershed (m^3 x 1000)
Total monthly discharge volume of flume (m^3 x 1000)
Absorption on watershed (m^3 x 1000)
Percent reduction

Total Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Inorganic Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Total Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Ortho Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

* = missing data

Negative values indicate export.

SHED

1979			
September	October	November	December
35.1	1.5	1.2	5.2
44.26	19.2	15.4	65.4
>165.0	41.3	0	0
*	-22.1	15.4	65.4
*	-53.5	100.0	100.0
896.3	39.0	31.2	132.5
226.6	72.1	Trace	Trace
629.7	-33.1	31.2	132.5
70.3	-84.9	100.0	100.0
256.7	11.2	8.9	38.0
3.8	1.5	0	0
252.9	9.7	8.9	38.0
98.5	86.6	100.0	100.0
60.6	2.6	2.1	9.0
90.2	22.9	Trace	Trace
-29.6	-20.3	2.1	9.0
-48.8	-780.8	100.0	100.0
29.2	1.3	1.0	4.3
75.8	19.1	Trace	Trace
-46.6	-17.8	1.0	4.3
-159.6	-1369.2	100.0	100.0

Table II-8b ASH SLOUGH

	Jan	Feb
Total monthly rainfall on watershed (cm)	4.9	6.4
Total rainfall volume on watershed (m^3 x 1000)	61.6	80.8
Total monthly discharge volume at flume (m^3 x 1000)	0	25.5
Absorption on watershed (m^3 x 1000)	61.6	55.3
Percent reduction	100.0	68.4
Total Nitrogen		
Total monthly rainfall contribution (kg)	124.7	163.7
Total monthly discharge from watershed (kg)	Trace	41.2
Net uptake by watershed (kg)	124.7	122.5
Percent reduction	100.0	74.8
Inorganic Nitrogen		
Total monthly rainfall contribution (kg)	35.7	46.9
Total monthly discharge from watershed (kg)	0	1.1
Net uptake by watershed (kg)	35.7	45.8
Percent reduction	100.0	97.7
Total Phosphorus		
Total monthly rainfall contribution (kg)	8.4	11.1
Total monthly discharge from watershed (kg)	Trace	70.2
Net uptake by watershed (kg)	8.4	-59.1
Percent reduction	100.0	-532.4
Ortho Phosphorus		
Total monthly rainfall contribution (kg)	4.0	5.3
Total monthly discharge from watershed (kg)	Trace	62.7
Net uptake by watershed (kg)	4.0	-57.4
Percent reduction	100.0	-1083.0

* = some data missing - estimated value

Negative values indicate export.

WEST WATERSHED

1980

March	April	May	June	July	Aug	Sept	Oct	Nov
6.7	9.4	1.8	7.6	21.6	18.9	19.5	0.9	9.4
42.3	59.7	11.5	48.1	136.6	119.3	123.2	5.8	59.7
8.3	91.0	0	0	1.2*	36.3	157.0	0	0
34.0	-31.3	11.5	48.1	135.4*	83.0	-33.8	5.8	59.7
80.3	-52.4	100.0	100.0	99.1	69.6	-27.4	100.0	100.0
85.7	120.8	23.4	97.4	276.7	241.6	249.4	11.7	120.8
13.5	328.6	0	0	3.7	56.8	266.4	0	0
72.2	-207.8	23.4	97.4	273.0	184.8	-17.0	11.7	120.8
84.2	-172.0	100.0	100.0	98.7	76.5	-6.8	100.0	100.0
24.5	34.6	6.7	27.9	79.3	69.2	71.4	3.4	34.6
0.2	21.4	0	0	0.1	1.5	6.4	0	0
24.3	13.2	6.7	27.9	79.2	67.7	65.0	3.4	34.6
99.2	38.2	100.0	100.0	99.9	87.8	91.0	100.0	100.0
5.8	8.2	1.6	6.6	18.7	16.3	16.9	0.8	8.2
7.5	34.6	0	0	1.7	31.6	130.7	0	0
-1.7	-26.4	1.6	6.6	17.0	-15.3	-113.8	0.8	8.2
-29.3	-322.0	100.0	100.0	90.9	-93.9	-673.4	100.0	100.0
2.8	4.0	0.8	3.2	9.0	7.9	8.1	0.4	4.0
6.1	26.6	0	0	1.3	28.5	116.5	0	0
-3.3	-22.6	0.8	3.2	7.7	-20.6	-108.4	0.4	4.0
-117.9	-565.0	100.0	100.0	85.6	-260.8	-1338.3	100.0	100.0

watershed were 70 to 100 percent less than those expected in rainfall alone (Figures II-55 and II-56). Some net increase in total nitrogen in discharge is indicated during October 1979 and September 1980; however, these are probably just artifacts of the discharge lag following larger rainfall volumes on the watershed during the preceding months. This phenomenon does not appear to be the cause of the net export of total nitrogen during April 1980. This export is largely organic nitrogen as inorganic nitrogen loads for the same month are substantially reduced.

Inorganic nitrogen in rainfall is almost totally absorbed by the watershed. There was a net discharge of a significantly larger amount during April 1980 (over 5.5 times that discharged during the 1979 hurricane when rainfall volume on the watershed was almost four times greater). Rainfall contributions could not be blamed as the cause of this increase. No reasons for this single monthly loss of uptake capability are apparent at this time.

Phosphorus, mainly in the ortho form (Figures II-57 and II-58) is exported from the watershed in significant amounts following periods of increased rainfall. Export occurred during rains in August and September of 1979 and 1980, and during February through April 1980. Only during periods of little or no discharge did the amount in rainfall exceed that leaving the watershed.

Reduction in nitrogen load occurs either through vegetation uptake or atmospheric loss. An uptake of nitrogen and export of phosphorus would suggest that the Ash Slough-west and to some extent the Ash Slough-east watersheds are probably nitrogen limited. The source of excess phosphorus, as well as the occasional peak of excess

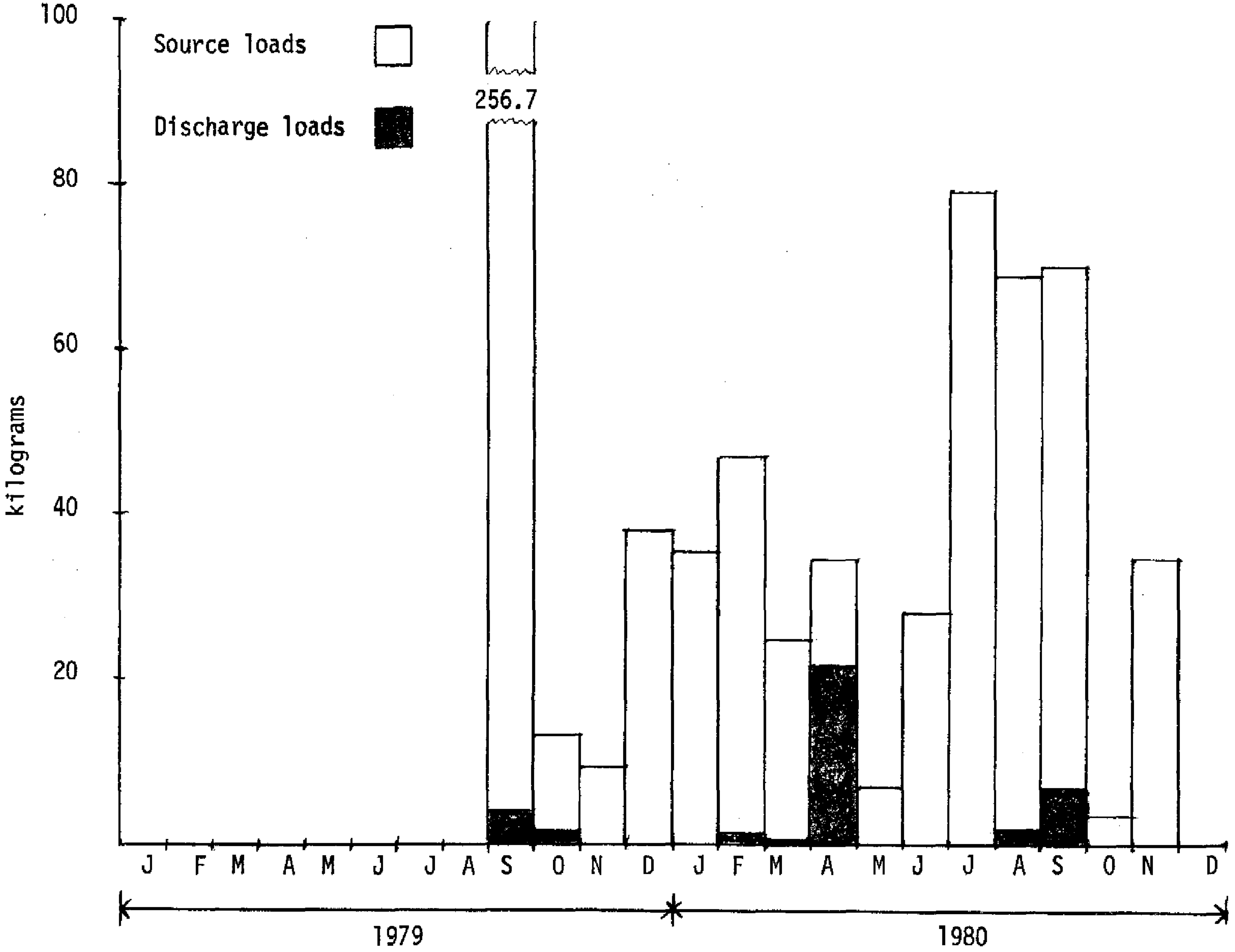

Figure II-55 MONTHLY INORGANIC NITROGEN BUDGET FOR ASH SLOUGH - WEST WATERSHED

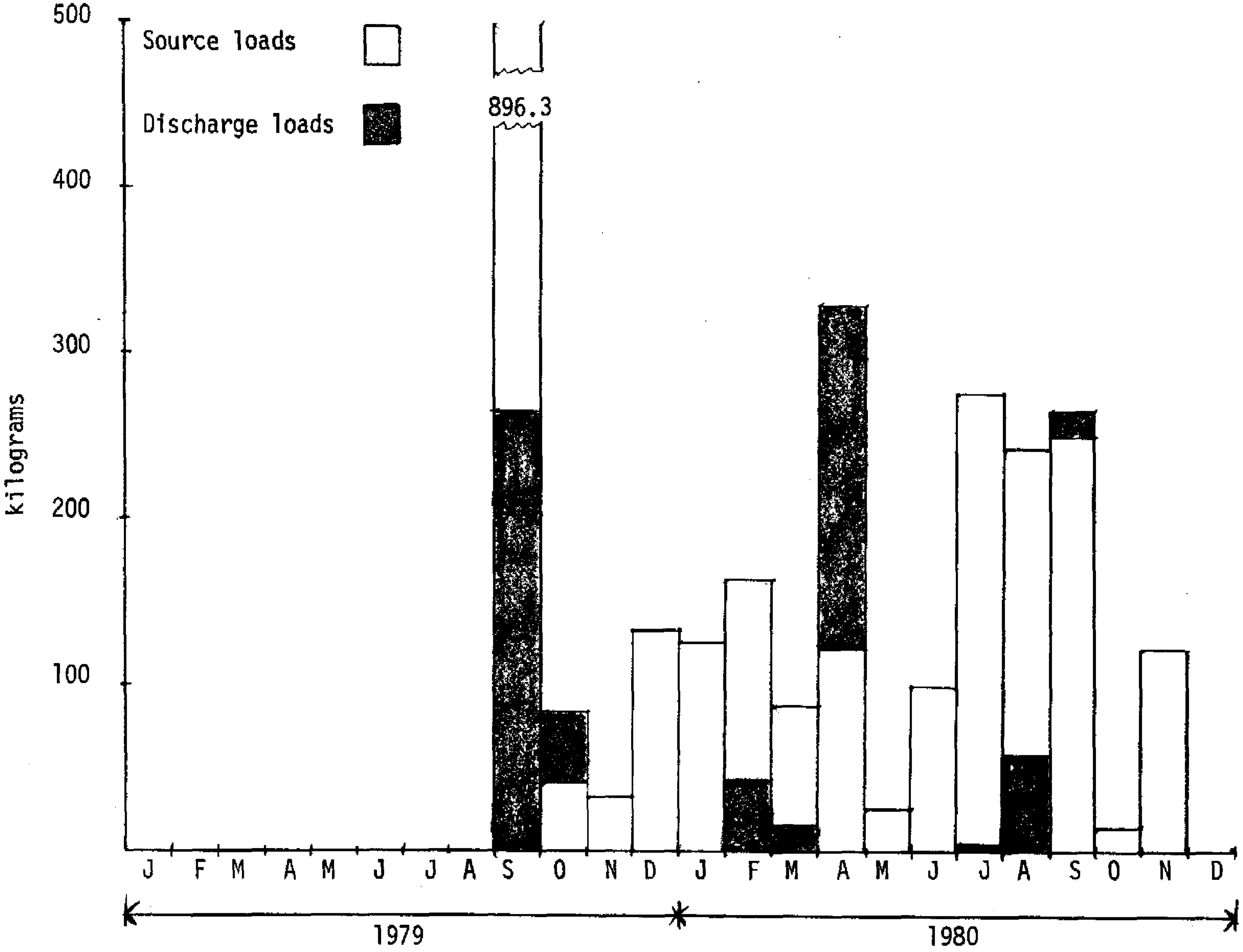

Figure II-56 MONTHLY TOTAL NITROGEN BUDGET FOR ASH SLOUGH - WEST WATERSHED

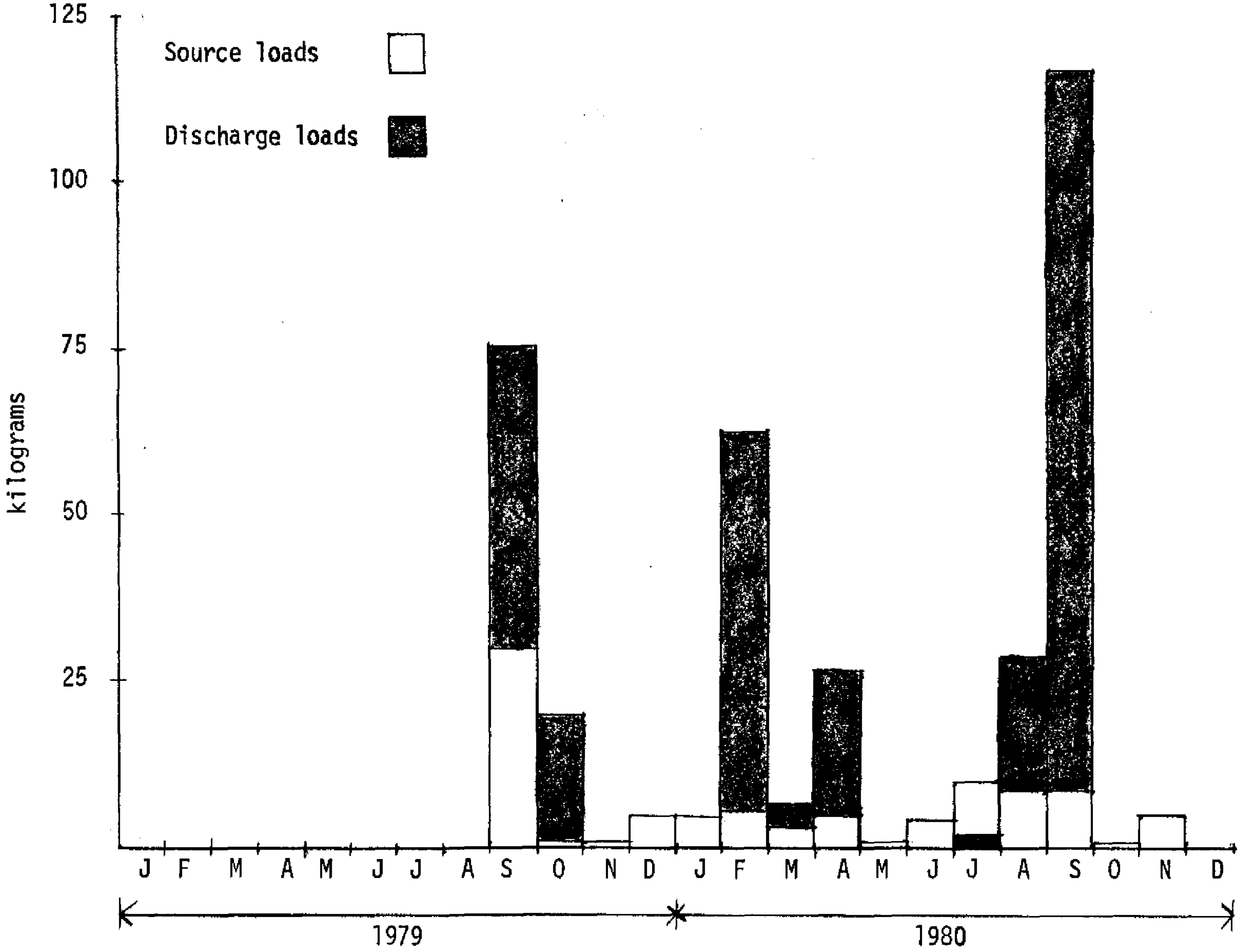

Figure II-57 MONTHLY ORTHO PHOSPHORUS BUDGET FOR ASH SLOUGH - WEST WATERSHED

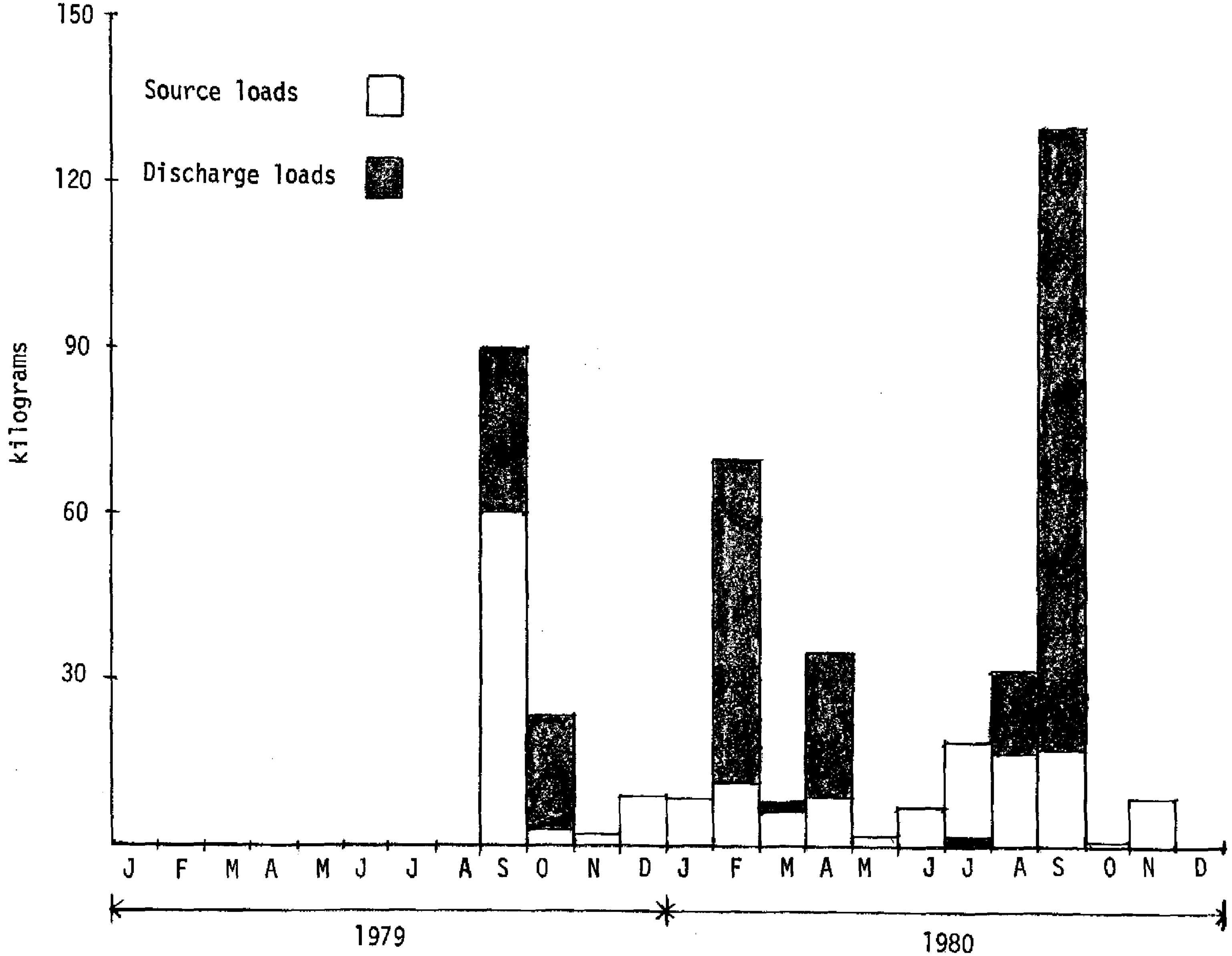

Figure II-58 MONTHLY TOTAL PHOSPHORUS BUDGET FOR ASH SLOUGH - WEST WATERSHED nitrogen, is probably fertilizer application practices conducted by the landowner.

ARMSTRONG SLOUGH

Heavy rain and subsequent runoff associated with Hurricane David increased flows at the monitoring station on the north watershed to the point that the flow monitoring stage recorder installed there was washed away. Valuable hydrological data for the post-hurricane period (September and October) was therefore not obtained. The recorder was reinstalled in October 1979, allowing a subsequent continuation of the record.

Rainfall loading and discharge load data for this watershed (Tables II-9a and II-9b) show, that under the low flow conditions which have predominated since the hurricane, that about 90 to 95 percent of the total volume of water that falls on the watershed as rain is absorbed into the ground or is lost by evapotranspiration. The data also indicates a net monthly uptake of nitrogen and phosphorus by percentage that slightly exceeds the expected uptake due to rainwater absorption or storage on the watershed. On a monthly basis, total nitrogen is consistently reduced in excess of 90 percent. Almost 100 percent of the inorganic nitrogen load is retained on the watershed (Figures II-59 and II-60). Phosphorus loads are reduced by a like amount (Figures II-61 and II-62). The watershed is an efficient and effective nutrient sink with the ability to absorb in excess of 35,400 kilograms of nitrogen and 2,400 kilograms of phosphorus during any one month.

The south watershed on the Armstrong Slough site, at

Table II-9a ARMSTRONG SLOUGH

Total monthly rainfall on watershed
Total rainfall volume on watershed (m^3 x 1000)
Total discharge volume of watershed (m^3 x 1000)
Absorption on watershed (m^3 x 1000)
Percent reduction

Total Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Inorganic Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Total Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Ortho Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

* = missing data

NORTH WATERSHED

1979				
Aug	Sept	Oct	Nov	Dec
14.0	27.7	0.3	1.8	7.0
11,349.3	22,451.9	246.7	1,480.3	5,674.6
3,138.0	*	*	168.4	131.6
8,211.3	*	*	1,311.9	5,543.0
72.4	*	*	88.6	97.7
22,982.3	45,465.0	499.6	2,997.7	11,491.2
5,658.4	*	*	179.9	110.5
17,323.9	*	*	2,817.8	11,380.7
75.4	*	*	94.0	99.0
6,582.6	13,022.1	143.1	858.6	3,291.3
215.7	*	*	18.8	6.1
6,366.9	*	*	670.6	3,285.2
96.7	*	*	78.1	99.8
1,554.9	3,075.9	33.8	117.6	777.4
305.0	*	*	15.6	5.0
1,249.9	*	*	102.0	772.4
80.4	*	*	86.7	99.4
749.1	1,481.8	16.3	56.7	374.5
103.4	*	*	6.1	4.2
645.7	*	*	50.6	370.3
86.2	*	*	89.2	98.9

Total II-9b

ARMSTRONG SLOUGH NORTH WATERSHED

	1980									
	January	February	March	April	May	June	July	August	September	October
Total monthly rainfall on watershed (cm)	4.6	7.3	4.6	5.2	10.4	11.0	21.6	10.1	2.4	0.9
Total rainfall volume on watershed (m^3 x 1000)	3700.9	5921.4	3700.9	4194.3	8388.6	8882.1	17517.4	8141.9	1973.8	740.2
Total discharge volume of watershed (m^3 x 1000)	111.6	322.6	275.3	126.8	216.7	93.3	106.6	627.6	168.8	174.5
Absorption on watershed (m^3 x 1000)	3589.3	5598.8	3425.6	4067.5	8171.9	8788.8	17410.8	7514.3	1805.0	565.7
Percent reduction	97.0	94.6	92.6	97.0	97.4	98.9	99.4	92.3	91.4	76.4
Total Nitrogen										
Total monthly rainfall contribution (kg)	7494.2	11990.8	7494.2	8493.5	16986.9	17986.2	35472.7	16487.3	3996.9	1498.8
Total monthly discharge from watershed (kg)	134.7	604.1	386.0	138.0	171.5	109.5	99.3	1136.4	155.1	139.4
Net uptake by watershed (kg)	7359.5	11386.7	7108.2	8355.5	16815.4	17876.7	35373.4	15350.9	3841.8	1359.4
Percent reduction	98.2	95.0	94.8	98.4	99.0	99.4	99.7	93.1	96.1	90.7
Inorganic Nitrogen										
Total monthly rainfall contribution (kg)	2146.5	3434.4	2146.5	2432.7	4865.4	5151.6	10160.1	4722.3	1144.8	429.3
Total monthly discharge from watershed (kg)	2.5	6.6	6.2	3.1	5.7	3.5	7.1	102.5	18.5	12.7
Net uptake by watershed (kg)	2144.0	3427.8	2140.3	2429.6	4859.7	5148.1	10153.0	4619.8	1126.3	416.6
Percent reduction	99.9	99.8	99.7	99.9	99.9	99.9	99.9	97.8	98.4	97.0
Total Phosphorus										
Total monthly rainfall contribution (kg)	507.0	811.2	507.0	574.6	1149.2	1216.8	2399.9	1115.4	270.4	101.4
Total monthly discharge from watershed (kg)	14.4	35.4	23.6	8.3	11.5	6.4	5.4	73.7	16.8	15.6
Net uptake by watershed (kg)	492.6	775.8	483.4	566.3	1137.7	1210.4	2394.5	1041.7	253.6	85.8
Percent reduction	97.2	95.6	95.3	98.6	99.0	99.5	99.8	93.4	93.8	84.6
Ortho Phosphorus										
Total monthly rainfall contribution (kg)	244.2	390.8	244.2	276.8	553.6	586.2	1156.1	573.3	130.3	48.8
Total monthly discharge from watershed (kg)	2.6	6.1	9.0	4.2	5.2	2.0	2.0	38.9	8.0	4.6
Net uptake by watershed (kg)	241.6	384.7	235.2	272.6	548.4	584.2	1154.1	498.4	122.3	44.2
Percent reduction	98.9	98.4	96.3	98.5	99.1	99.7	99.8	92.8	93.9	90.6

* = missing data

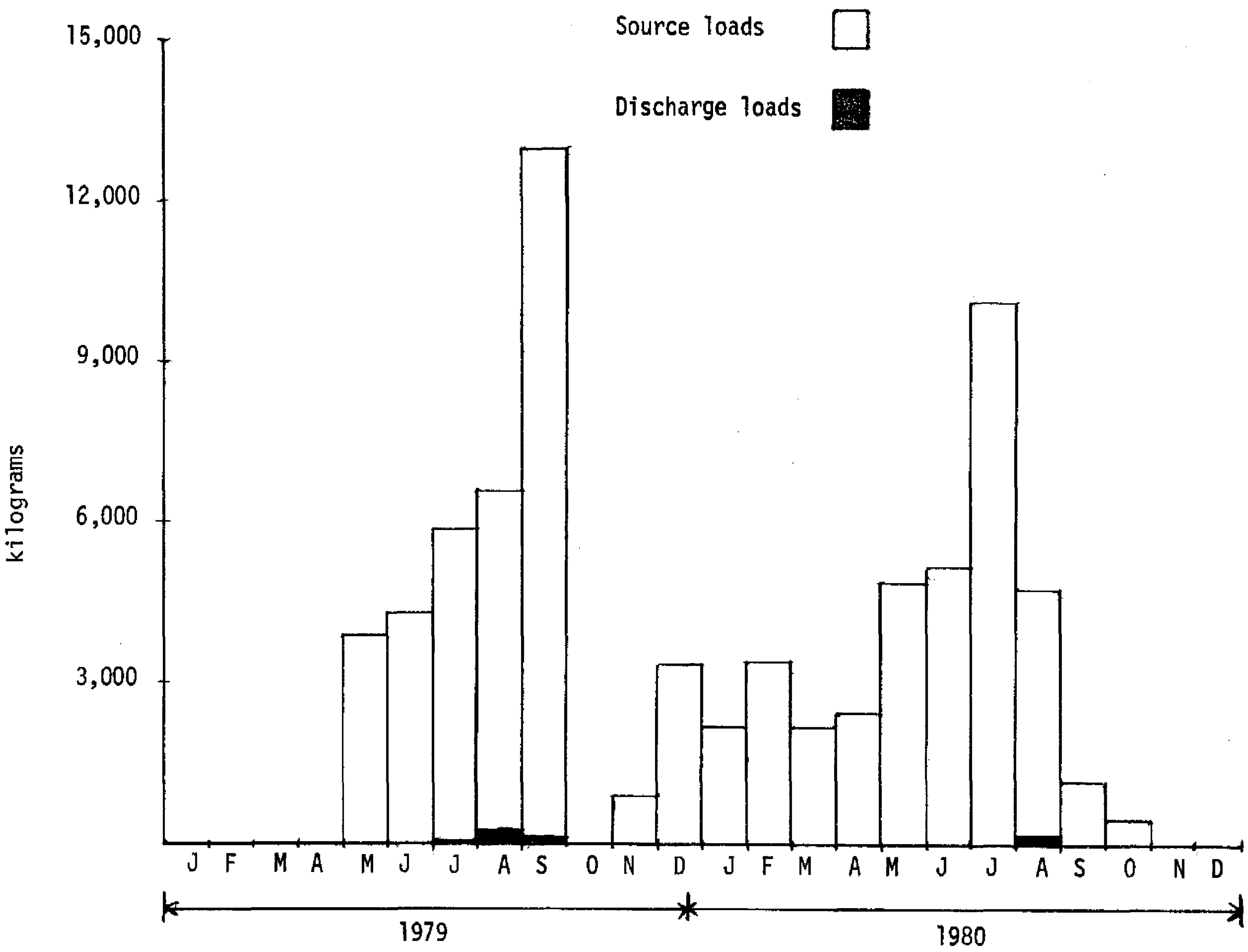

Figure II-59 MONTHLY INORGANIC NITROGEN BUDGET FOR ARMSTRONG SLOUGH - NORTH WATERSHED

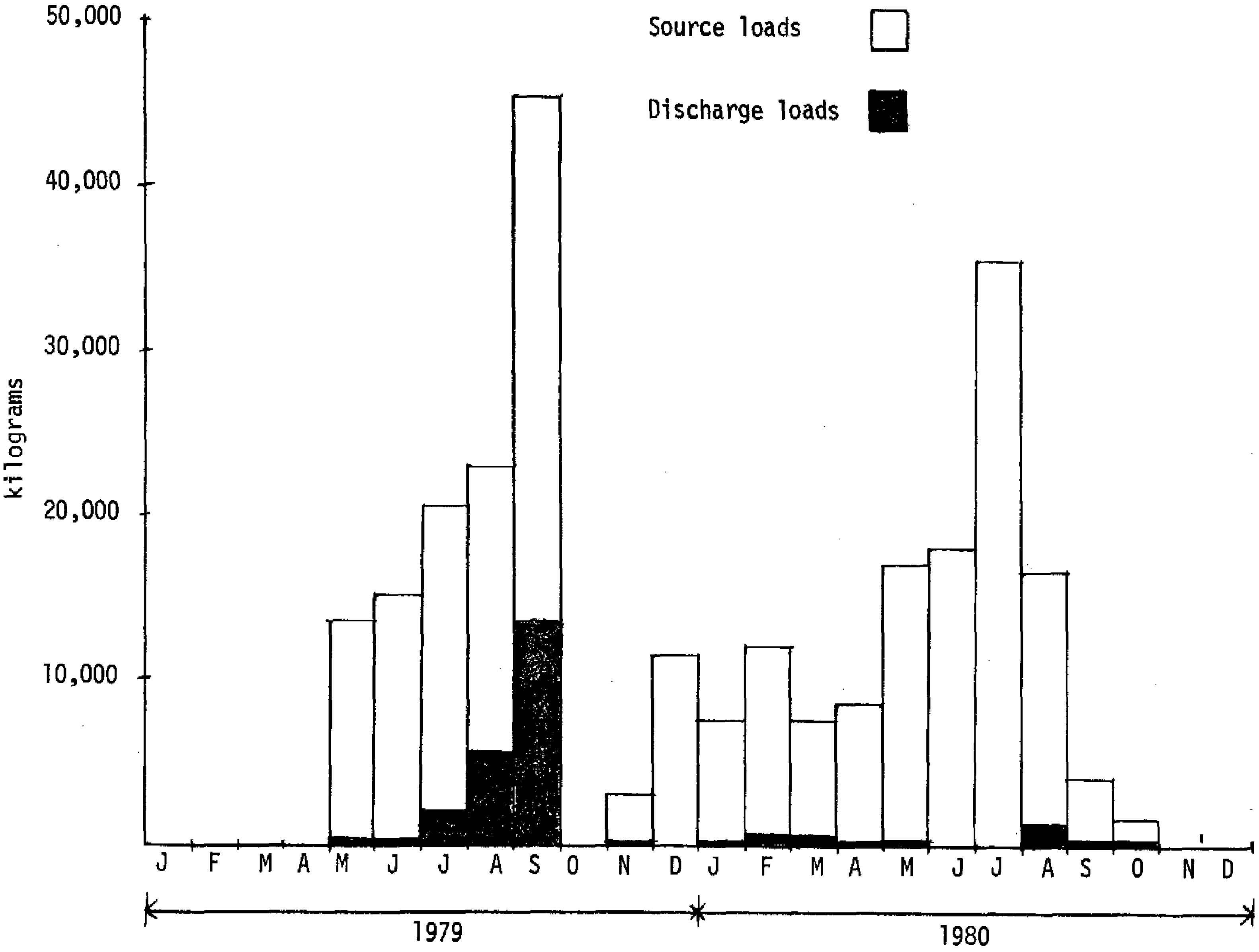

Figure II-60 MONTHLY TOTAL NITROGEN BUDGET FOR ARMSTRONG SLOUGH - NORTH WATERSHED

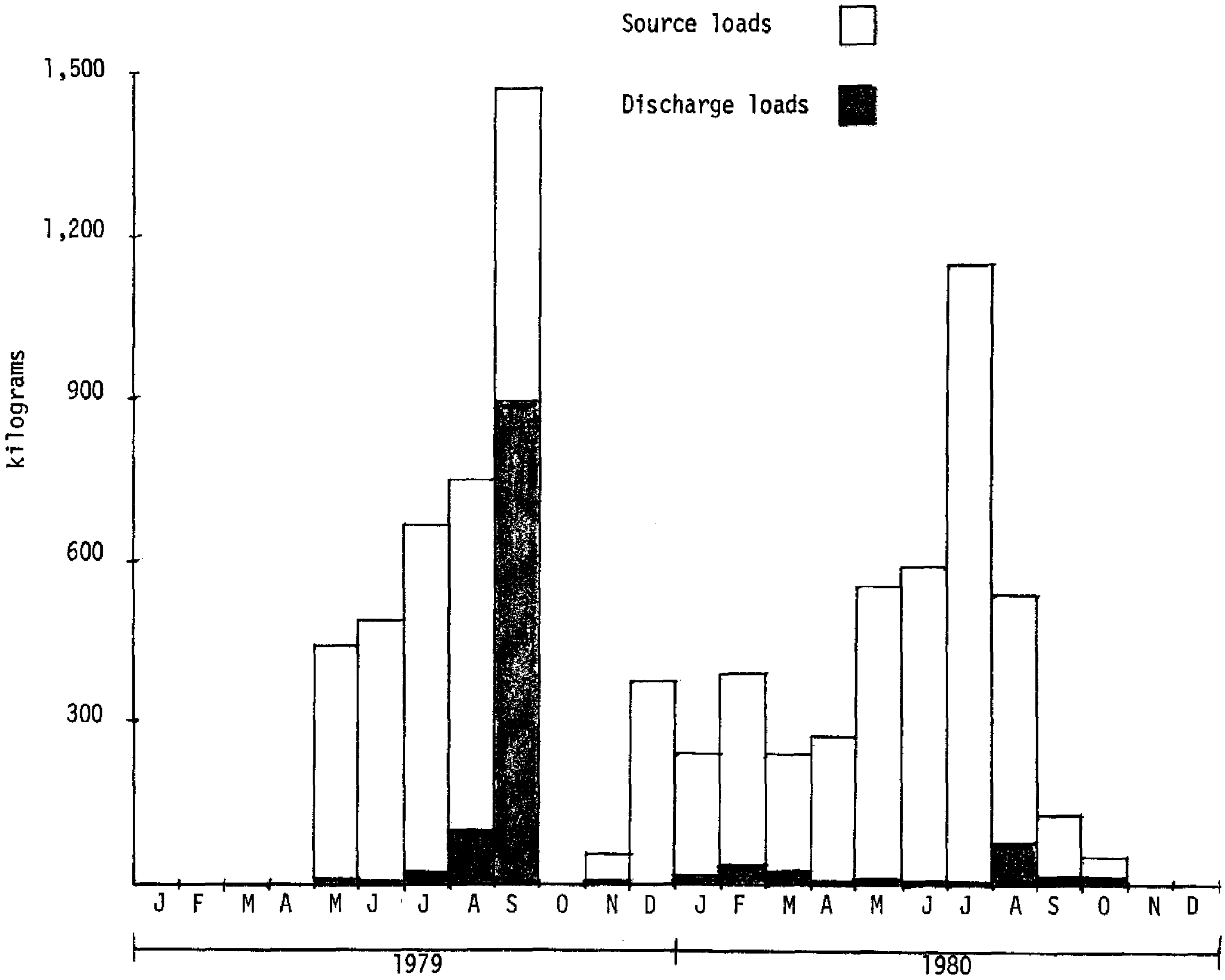

Figure II-61 MONTHLY ORTHO PHOSPHORUS BUDGET FOR ARMSTRONG SLOUGH - NORTH WATERSHED

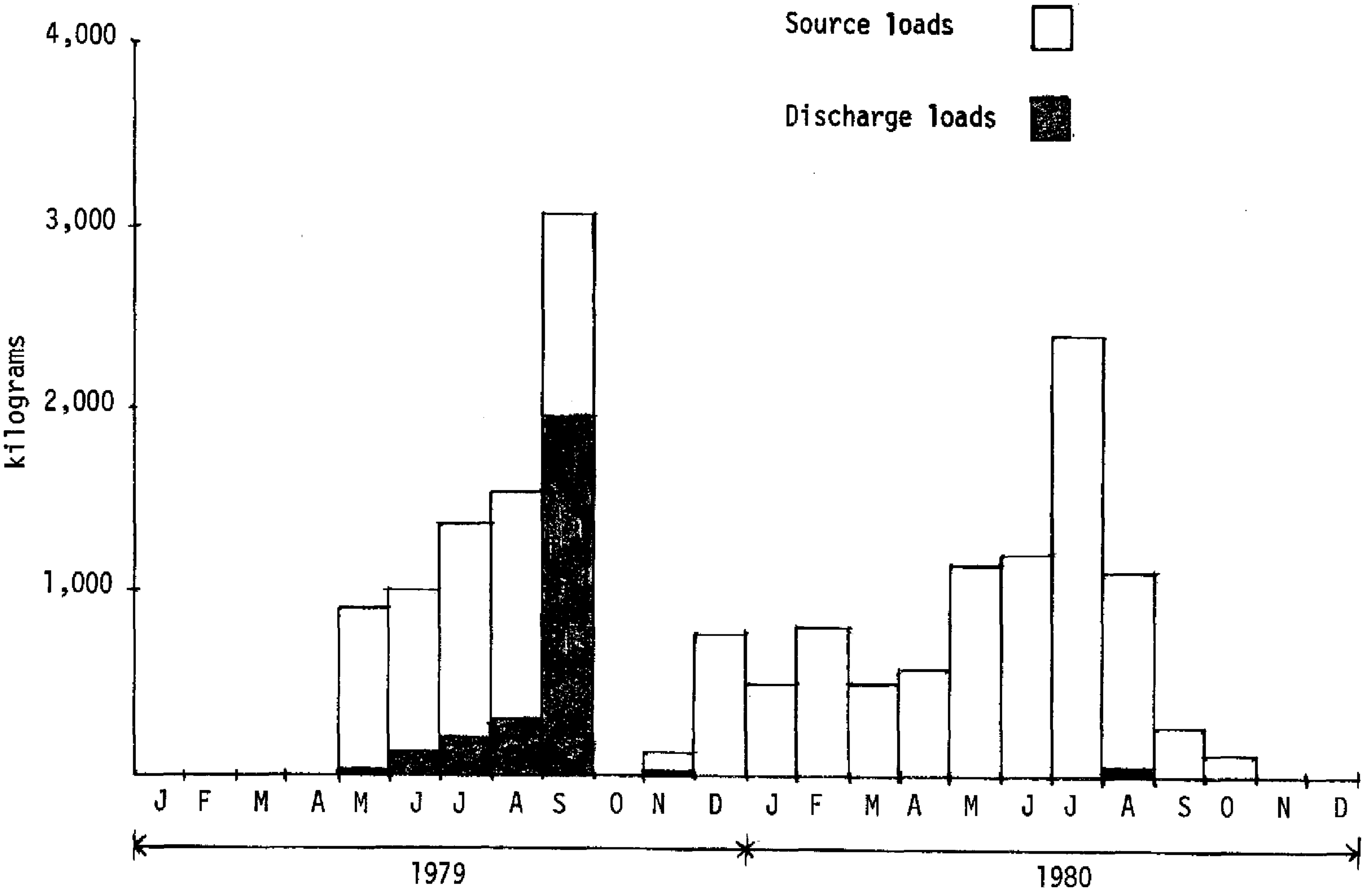

Figure II-62 MONTHLY TOTAL PHOSPHORUS BUDGET FOR ARMSTRONG SLOUGH - NORTH WATERSHED

2,000 acres, is one-tenth the size of the northern area. The land here is predominantly native rangeland. Discharge of runoff from the watershed exceeded total rainfall during two months, September and October 1980. The excess during these months was due primarily to residual runoff from heavier rains during August. The total rainfall for August, September, and October is approximately equal to total discharge from the watershed during these same three months (Table II-10).

Nitrogen and phosphorus are consistently absorbed on the watershed (Figures II-63 through II-66). Inorganic nitrogen loads are consistently reduced by 85 to 100 percent from those expected in rainfall alone. Uptake of the organic portion is consistent but not as efficient. The apparent net export noted in September 1980 is probably in effect just the load in residual runoff from heavier rains during August. The total rainfall for August, September, and October is approximately equal to total discharge from the watershed during these same three months.

The net reduction of total nitrogen for the August through October period exceeds 37 percent. Reduction of total phosphorus occurs consistently. Ortho forms are reduced in excess of 80 percent. The reduction of non-ortho phosphorus is slightly less efficient.

WILDCAT SLOUGH

The Wildcat Slough study site as previously described is composed of two distinct watersheds, each drained by a well-defined channel. The upper portion of the larger main channel drains a 6,400 acre area that is predominantly slightly improved rangeland

Table II-10

ARMSTRONG

Total monthly rainfall on watershed (cm)
Total rainfall volume on watershed (m^3 x 1000)
Total discharge volume of watershed (m^3 x 1000)
Absorption on watershed (m^3 x 1000)
Percent reduction

Total Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Inorganic Nitrogen
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Total Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Ortho Phosphorus
Total monthly rainfall contribution (kg)
Total monthly discharge from watershed (kg)
Net uptake by watershed (kg)
Percent reduction

Negative values indicate export.

SLOUGH SOUTH WATERSHED

1980

April	May	June	July	August	September	October	November
5.2	10.4	11.0	21.6	10.1	2.4	0.9	7.9
419.4	838.9	888.2	1,751.7	814.2	197.4	74.0	641.5
281.9	55.9	118.8	227.8	601.6	488.2	107.0	81.5
137.5	783.0	769.4	1,523.9	212.6	-290.8	-33.0	560.0
32.8	93.3	86.6	87.0	26.1	-147.3	-44.6	87.3
849.4	1,698.7	1,798.6	3,547.3	1,648.7	399.7	149.9	1,299.0
644.9	67.9	238.5	307.7	788.7	461.8	128.1	102.0
204.5	1,631.7	1,560.1	3,239.6	860.0	-62.1	21.8	1,197.0
24.1	96.1	86.7	91.3	52.2	-15.5	14.5	92.1
243.3	486.5	515.2	1,016.0	472.2	114.5	42.9	372.1
7.6	0.6	2.5	3.9	6.1	8.8	6.0	2.6
235.7	485.9	512.7	1,012.1	466.1	105.7	36.9	369.5
96.9	99.9	99.5	99.6	98.7	92.3	86.0	99.3
57.5	114.9	121.7	240.0	111.5	27.0	10.1	87.9
41.6	2.8	12.2	11.3	16.3	15.9	4.5	3.2
15.9	112.1	109.5	228.7	95.2	11.1	5.6	84.7
27.7	97.6	90.0	95.3	85.4	41.1	55.4	96.4
27.7	55.4	58.6	115.6	53.7	13.0	4.9	42.3
3.0	0.5	1.7	2.3	6.1	4.8	1.2	0.9
24.7	54.9	56.9	113.3	47.6	8.2	3.7	41.4
89.2	99.1	97.1	98.0	88.6	63.1	75.5	97.9

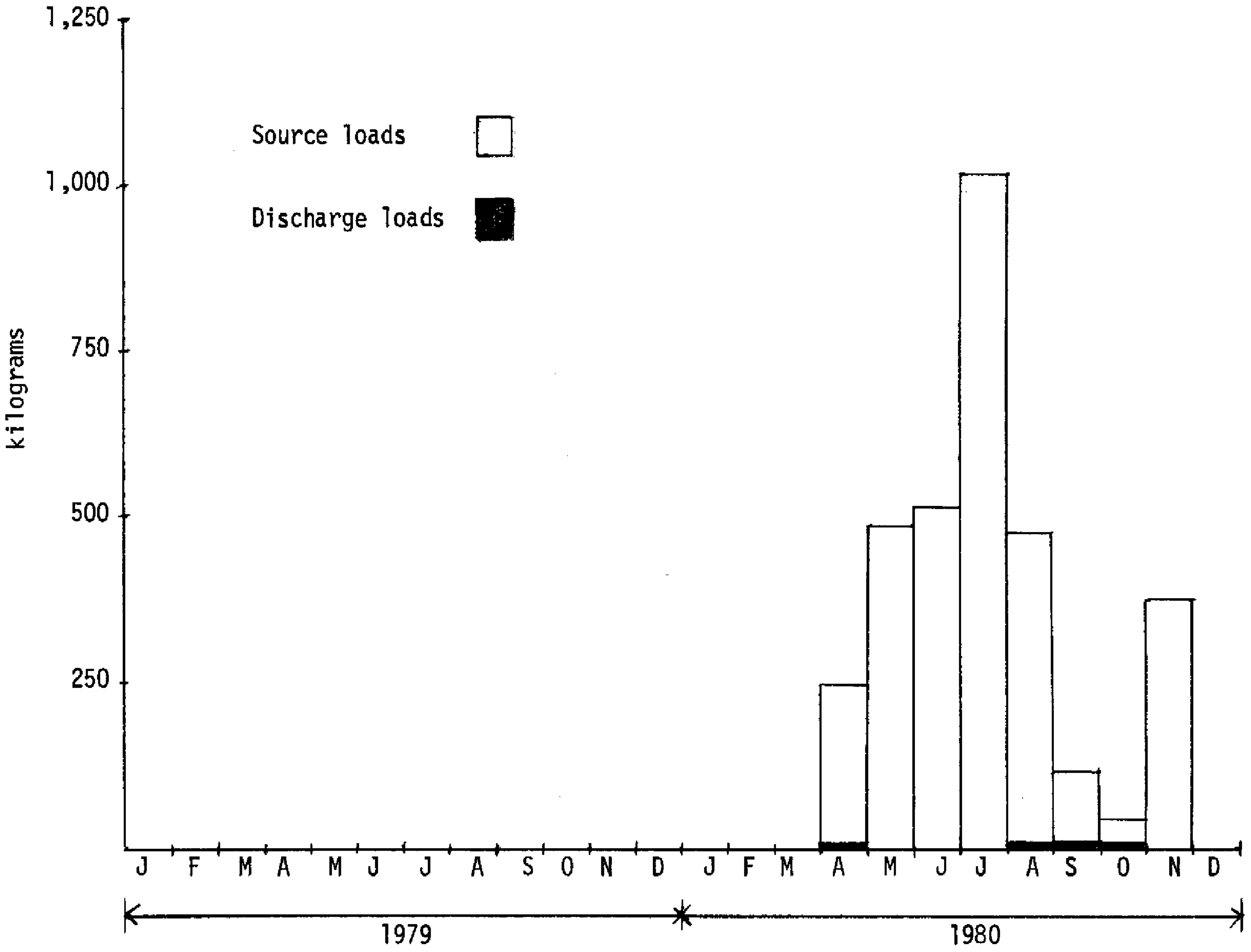

Figure II-63 MONTHLY INORGANIC NITROGEN BUDGET FOR ARMSTRONG SLOUGH - SOUTH WATERSHED

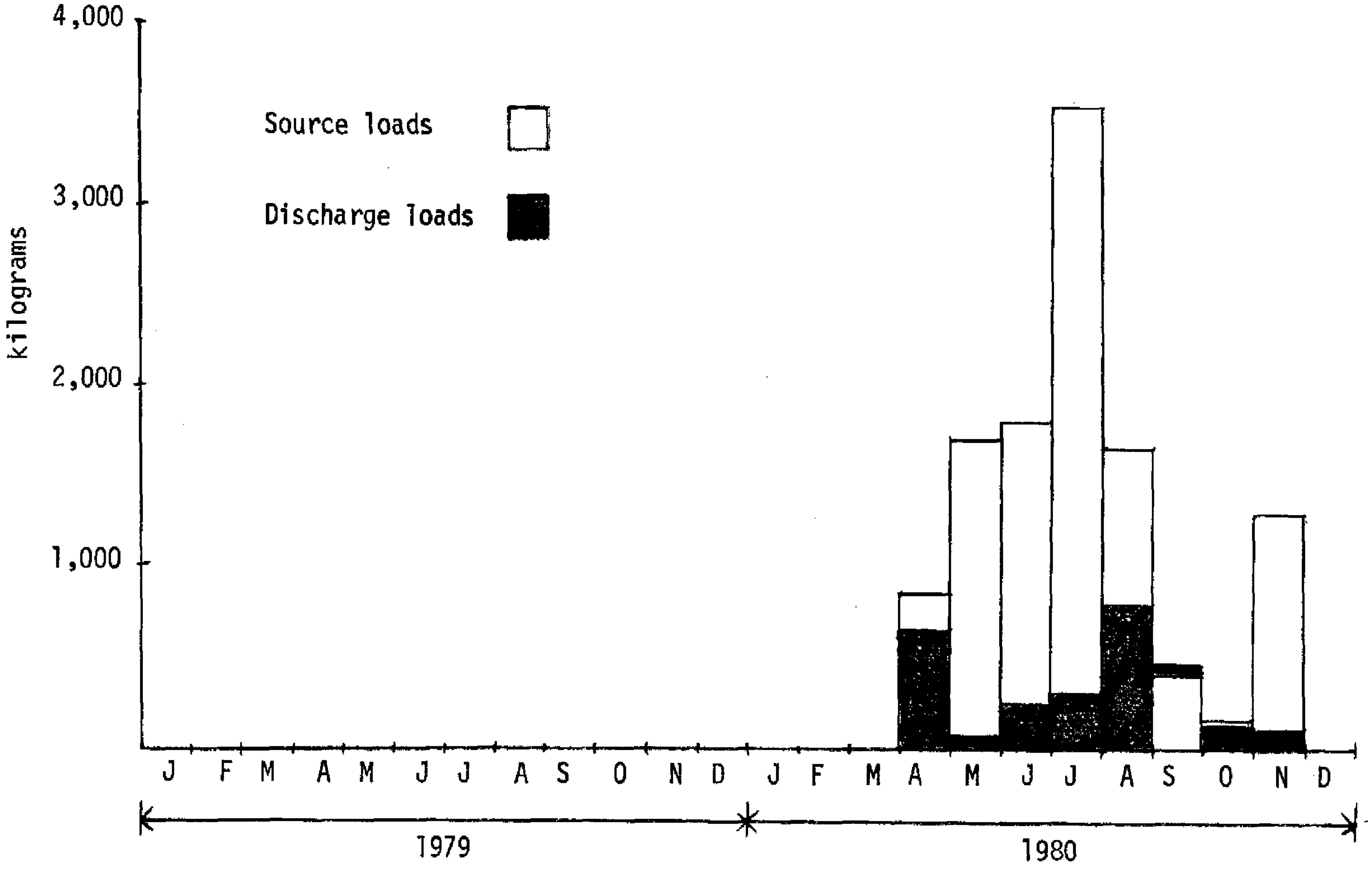

Figure II-64 MONTHLY TOTAL NITROGEN BUDGET FOR ARMSTRONG SLOUGH - SOUTH WATERSHED

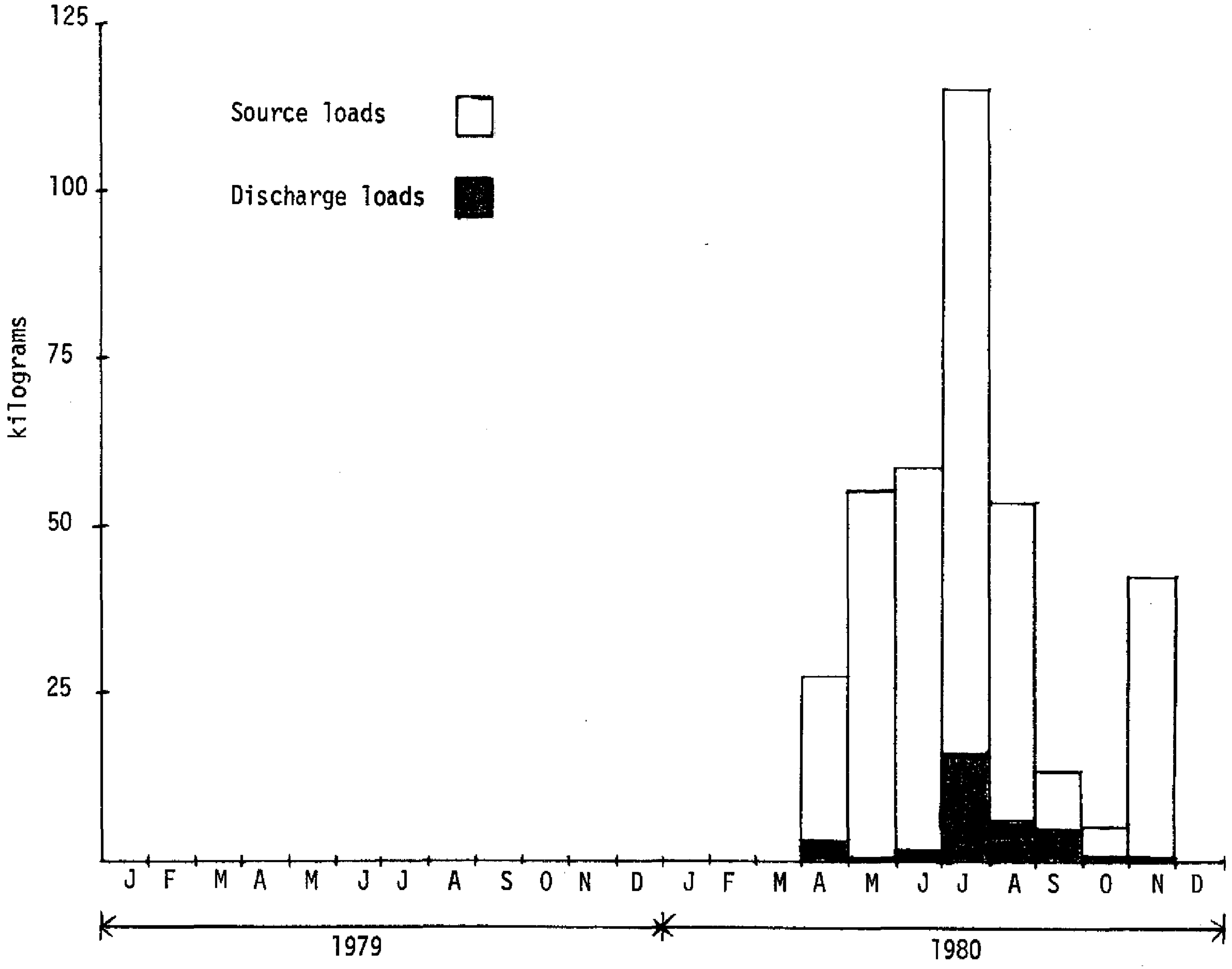

Figure II-65 MONTHLY ORTHO PHOSPHORUS BUDGET FOR ARMSTRONG SLOUGH - SOUTH WATERSHED

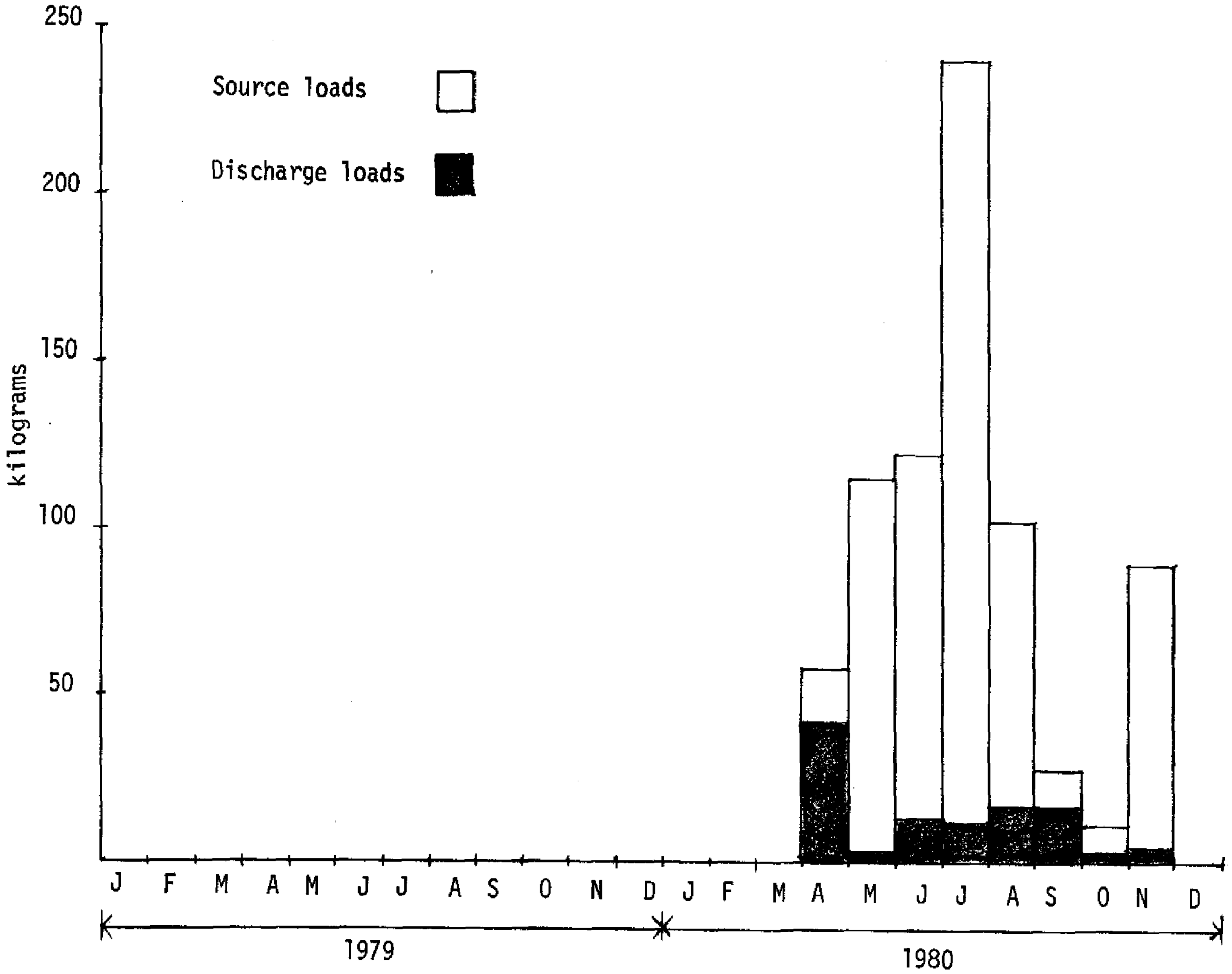

Figure II-66 MONTHLY TOTAL PHOSPHORUS BUDGET FOR ARMSTRONG SLOUGH - SOUTH WATERSHED interspersed with several small low-lying marshy areas.

With the exception of the period during and two months following Hurricane David, this watershed consistently absorbed practically all the rainfall and associated nutrients (Tables II-11a and II-11b; Figures 11-67 through II-70). Rainfall on the watershed was light and associated runoff was practically nonexistent.

Hydrology data for the western watershed draining Wildcat Slough, and for the lower portion of the main watershed, is not available at this time. Conditions over these watersheds were similar to those described above. During most of the study period, no discharge was observed to be occurring at any of the flow monitoring stations. Results of analyses, had this data been available, would undoubtedly be similar to those just described. Inaccuracies in hydrology data during the lone period of high discharge preclude drawing firm conclusions, but the data does suggest that efficiencies of nitrogen and phosphorus uptake may decrease under such conditions.

SEZ DAIRY

SEZ Dairy is representative of a typical dairy operation in Okeechobee County. The land use is characterized by high utilization areas in the vicinity of the milking barn where large numbers of cattle lounge between milking periods. The majority of the 815-acre watershed is utilized for hay production or heifer grazing areas.

Discharge at Wolf Creek is a combination of rainfall runoff, groundwater seepage into the perimeter drainage ditches, and discharge from the barnwash waste treatment lagoons. The erratic nature of the inflow sources (particularly rainfall and lagoon discharge) as well

Table II-11a

WILDCAT SLOUGH UPPER PORTION

	1979				
	Aug	Sept	Oct	Nov	Dec
Total monthly rainfall on watershed (cm)	17.1	41.8	2.1	0.6	3.0
Total rainfall volume on watershed (m^3 x 1000)	4,421.3	10,816.4	552.7	157.9	789.5
Total discharge volume of watershed (m^3 x 1000)	125.5	5,192.1†	2,001.5†	59.5	39.7
Absorption on watershed (m^3 x 1000)	4,295.8	5,624.3†	-1,448.8†	98.4	749.8
Percent reduction	97.2	52.0†	-262.1†	62.3	93.9
Total Nitrogen					
Total monthly rainfall contribution (kg)	8,953.1	21,903.2	1,119.1	319.8	1,598.8
Total monthly discharge from watershed (kg)	354.6	6,005.5†	4,998.3†	110.1	65.0
Net uptake by watershed (kg)	8,598.5	15,897.7†	-3,879.2†	209.7	1,533.8
Percent reduction	96.0	72.6†	-346.6†	65.6	95.9
Inorganic Nitrogen					
Total monthly rainfall contribution (kg)	2,564.3	6,273.5	320.5	91.6	457.9
Total monthly discharge from watershed (kg)	8.3	2.2†	0.2†	21.1	92.1
Net uptake by watershed (kg)	2,556.0	6,271.3†	320.3†	70.5	365.8
Percent reduction	99.7	100.0†	100.0†	77.0	79.9
Total Phosphorus					
Total monthly rainfall contribution (kg)	605.7	1,481.8	75.7	21.6	62.7
Total monthly discharge from watershed (kg)	8.3	108.0†	93.2†	1.9	2.7
Net uptake by watershed (kg)	597.4	1,373.8†	-17.5†	19.7	60.0
Percent reduction	98.6	92.7†	-23.1†	91.2	95.7
Ortho Phosphorus					
Total monthly rainfall contribution (kg)	291.8	713.9	36.5	10.4	30.2
Total monthly discharge from watershed (kg)	3.7	53.4†	105.4†	1.3	1.0
Net uptake by watershed (kg)	288.1	660.5†	-68.9†	9.1	29.2
Percent reduction	98.7	92.5†	-188.8†	87.5	96.7

† = these figures are estimates. Discharge exceeded that reported here as some out-of-channel flow occurred.

Negative values indicate export.

Table II-11b WILDCAT SLOU

	Jan	Feb
Total monthly rainfall on watershed (cm)	7.0	4.3
Total rainfall volume on watershed (m^3 x 1000)	1815.9	1105.3
Total discharge volume of watershed (m^3 x 1000)	53.2	130.2
Absorption on watershed (m^3 x 1000)	1762.7	975.1
Percent reduction	97.1	88.2
Total Nitrogen		
Total monthly rainfall contribution (kg)	3677.2	2238.3
Total monthly discharge from watershed (kg)	22.3	234.4
Net uptake by watershed (kg)	3654.9	2003.9
Percent reduction	99.4	89.5
Inorganic Nitrogen		
Total monthly rainfall contribution (kg)	1053.2	641.1
Total monthly discharge from watershed (kg)	0.5	3.2
Net uptake by watershed (kg)	1052.7	637.9
Percent reduction	100.0	99.5
Total Phosphorus		
Total monthly rainfall contribution (kg)	248.8	151.4
Total monthly discharge from watershed (kg)	1.3	16.0
Net uptake by watershed (kg)	247.5	135.4
Percent reduction	99.5	89.4
Ortho Phosphorus		
Total monthly rainfall contribution (kg)	119.9	72.9
Total monthly discharge from watershed (kg)	0.3	1.6
Net uptake by watershed (kg)	119.6	71.3
Percent reduction	99.7	97.8

* = missing data

GH UPPER PORTION

1980

March	April	May	June	July	Aug	Sept	Oct	Nov
4.9	5.5	8.2	7.9	15.5	7.9	5.2	1.2	8.2
1263.2	1421.1	2131.7	052.7	4026.5	2052.7	1342.2	315.8	2131.7
27.9	18.8	1.2	0	12.5	0	*	0	0
1235.3	1402.3	2130.5	2052.7	4014.0	2052.7	*	315.8	2131.7
97.8	98.7	99.9	100.0	99.7	100.0	*	100.0	100.0
2558.0	2877.8	4316.7	4156.8	153.7	4156.8	2717.9	639.5	4316.7
37.7	6.8	2.1	Trace	13.2	0	*	Trace	0
2520.3	2871.0	4314.6	4156.8	140.5	4156.8	*	639.5	4316.7
98.5	99.8	100.0	100.0	99.8	100.0	*	100.0	100.0
732.7	824.3	1236.4	1190.6	2335.4	1190.6	778.5	183.2	1236.4
0.4	0.5	Trace	0	0.6	0	*	0	0
732.3	823.8	1236.4	1190.6	2334.8	1190.6	*	183.2	1236.4
100.0	100.0	100.0	100.0	100.0	100.0	*	100.0	100.0
173.1	194.7	292.0	281.2	551.6	281.2	183.9	43.3	292.0
0.6	1.4	0.1	0	0.7	0	*	Trace	0
172.5	193.3	291.9	281.2	550.9	281.2	*	43.3	292.0
99.7	99.3	100.0	100.0	100.0	100.0	*	100.0	100.0
83.4	93.8	140.7	135.5	265.7	135.5	88.6	20.9	140.7
0.2	0.3	Trace	0	0.2	0	*	0	0
83.2	93.5	140.7	135.5	265.5	135.5	*	20.9	140.7
99.8	99.7	100.0	100.0	99.9	100.0	*	100.0	100.0

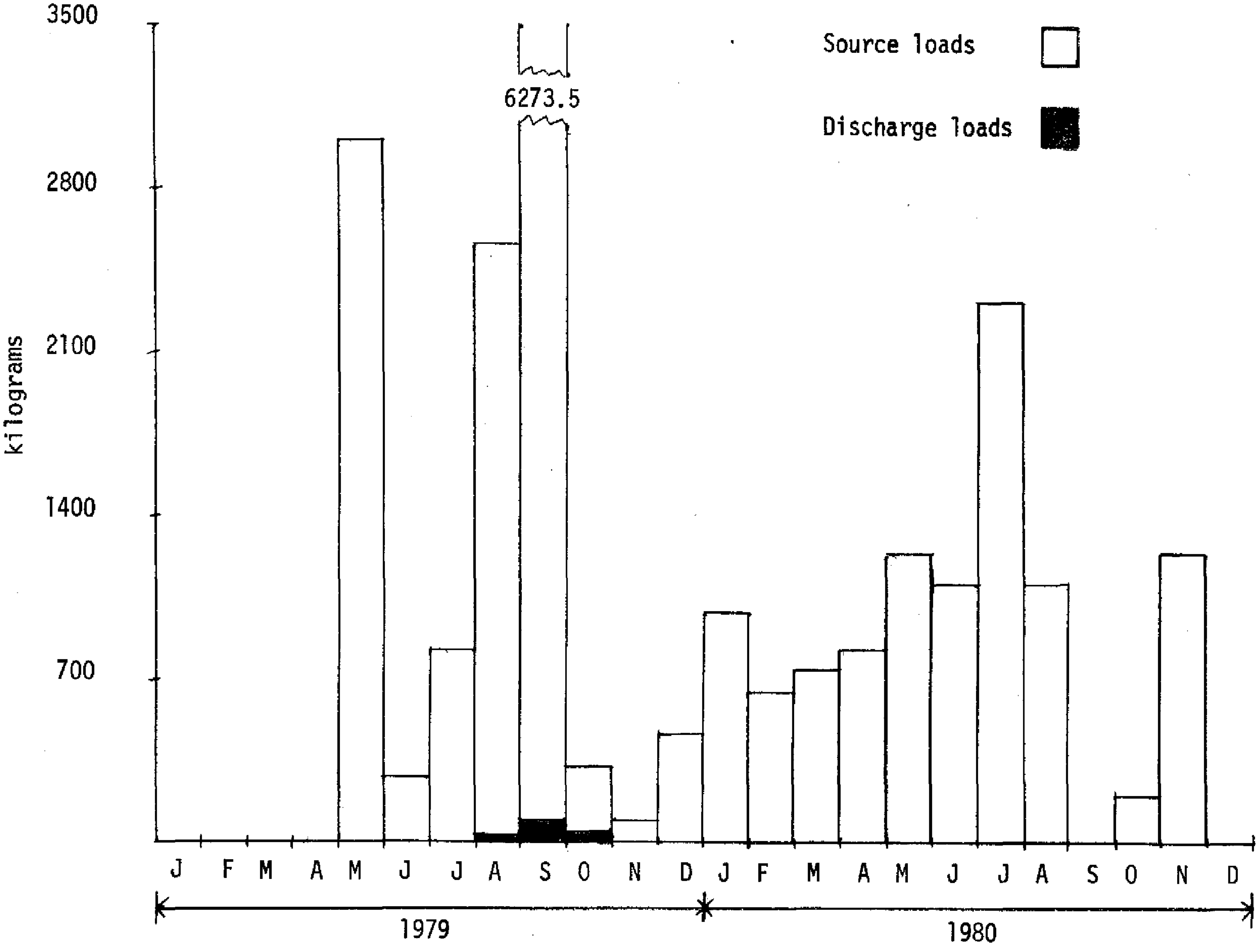

Figure II-67 MONTHLY INORGANIC NITROGEN BUDGET FOR WILDCAT SLOUGH - UPPER WATERSHED

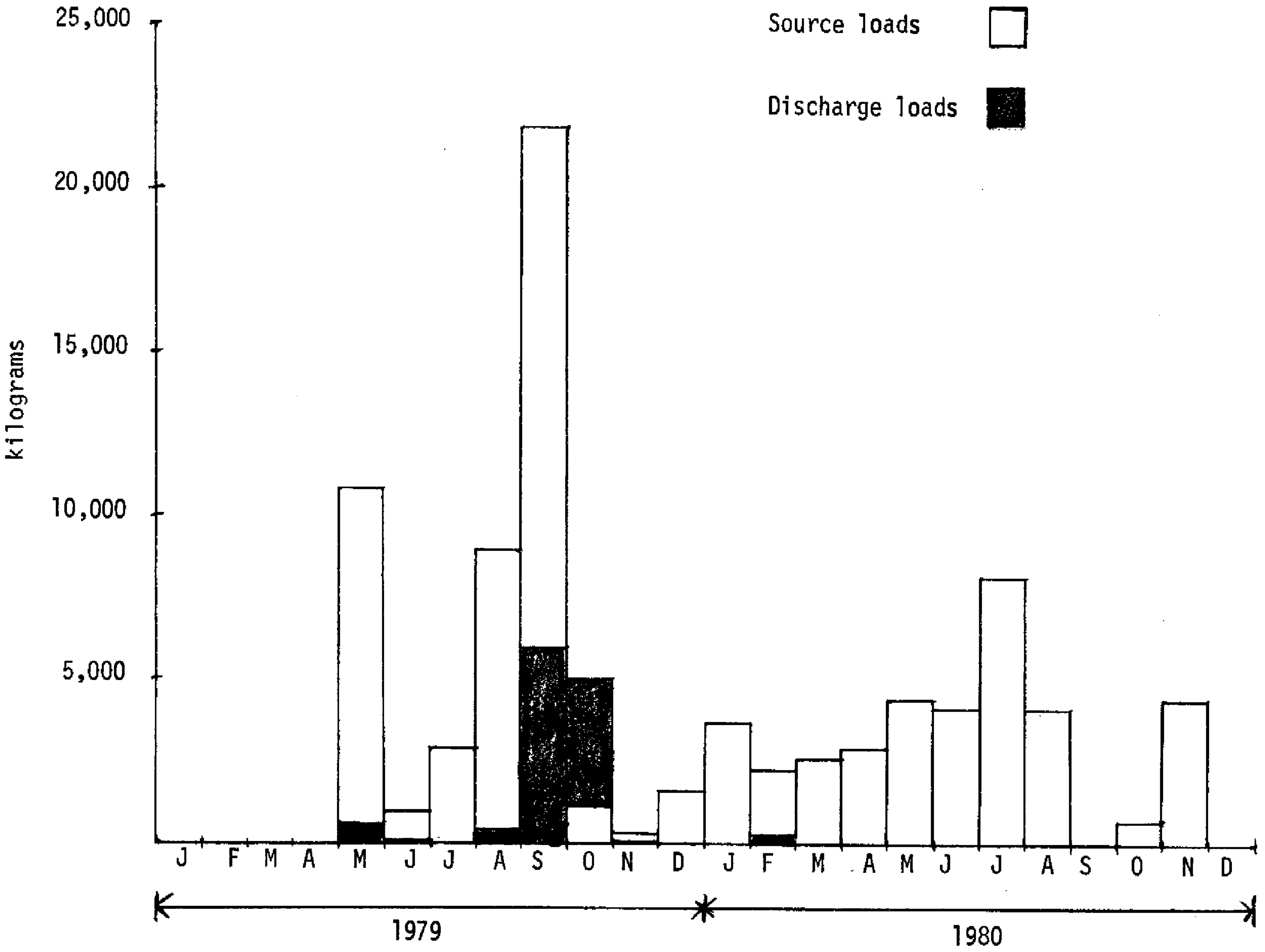

Figure II-68 MONTHLY TOTAL NITROGEN BUDGET FOR WILDCAT SLOUGH - UPPER WATERSHED

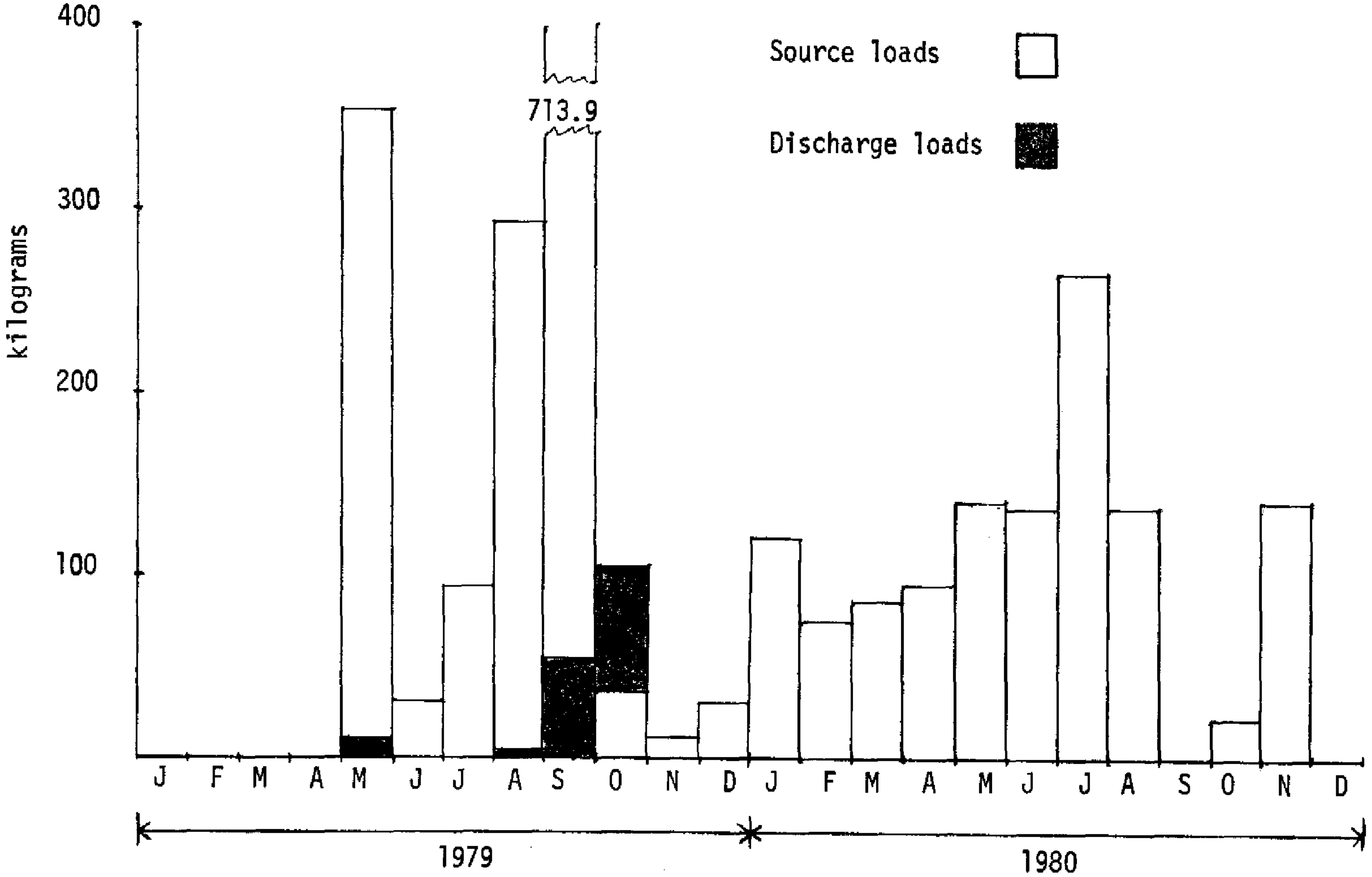

Figure II-69 MONTHLY ORTHO PHOSPHORUS BUDGET FOR WILDCAT SLOUGH - UPPER WATERSHED

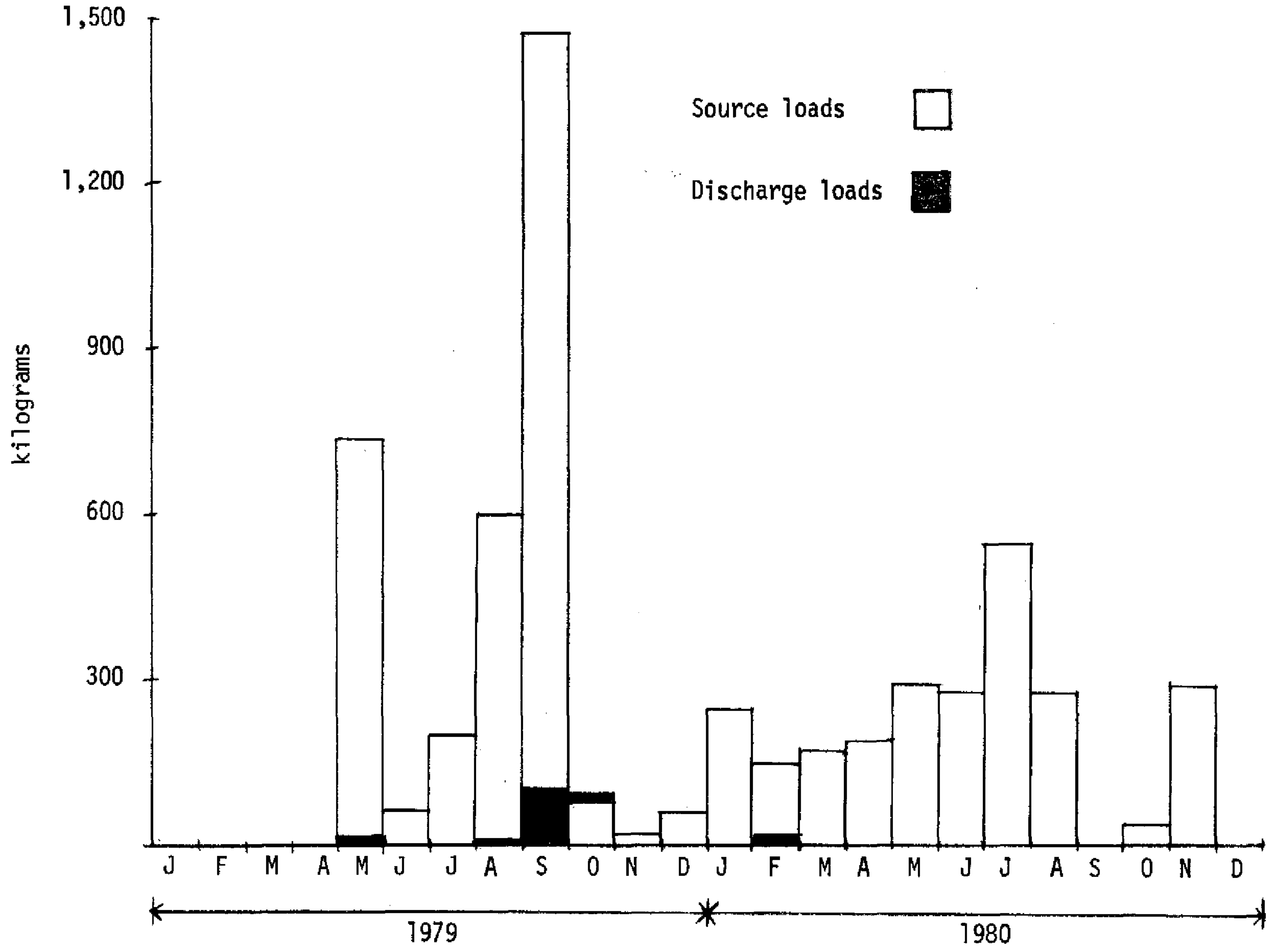

Figure II-70 MONTHLY TOTAL PHOSPHORUS BUDGET FOR WILDCAT SLOUGH - UPPER WATERSHED as the mixing that inevitably occurs, negates the possibility of determining the efficiency of each type of land use in nutrient removal. Instead, the entire dairy has to be considered as a whole singular type of land use.

A fluid and materials budget for the watershed has to take into account all the sources as well as the discharges. The sole discharge location for the dairy is at the perimeter ditch culvert at Wolf Creek. Materials and fluid sources on a monthly basis were the sum total of the rainfall on the watershed and the lagoon system discharge for each particular month. The major locations of water loss were evapotranspiration on the pasture and in the perimeter ditches. It must be emphasized that the period of record covered by these data was an abnormally dry one. No firm conclusions should be drawn on impacts of wet years on water budgets and materials reduction on this area.

Data presented in Tables II-12a and II-12b reveal that rainfall is the major contributor of water to the dairy. Discharge from the waste treatment lagoons, ranging from less than one up to seven percent of the total water input, would be relatively insignificant except for the fact that it has high concentrations of nitrogen and phosphorus and it is directed immediately into the north perimeter drainage ditch. The sole treatment that this portion of the dairy effluent receives is that which naturally occurs in the mile-long ditch between the lagoon discharge point and the site discharge point at Wolf Creek.

Nitrogen loads at Wolf Creek are consistently reduced from 56 to 97 percent of the total input with the exception of September

Table II-12a

	1979
	December
Total monthly rainfall on watershed (cm)	6.1
Total rainfall volume on watershed (m^3 x 1000)	201.1
Total monthly discharge from lagoons (m^3 x 1000)	1.1
Total volume to watershed (m^3 x 1000)	202.2
Total discharge at Wolf Creek (m^3 x 1000)	36.6
Total absorption on watershed (m^3 x 1000)	165.6
Percent reduction	81.7
Total Nitrogen	
Total monthly rainfall contribution (kg)	407.2
Total monthly lagoon contribution (kg)	52.6
Total input to watershed (kg)	459.8
Total discharge from watershed (kg)	140.9
Total reduction/export	318.9
Percent reduction/export	69.4
Inorganic Nitrogen	
Total monthly rainfall contribution (kg)	116.7
Total monthly lagoon contribution (kg)	12.7
Total input to watershed (kg)	129.4
Total discharge from watershed (kg)	57.6
Total reduction/export	71.8
Percent reduction/export	55.5

* = missing data

Negative values indicate export.

SEZ DAIRY WATERSHED

1980									
January	February	March	April	May	June	July	August	September	October
5.2	3.7	3.4	4.6	3.4	10.4	23.2	13.1	11.3	0.9
170.9	120.6	110.6	150.8	110.6	341.8	764.1	432.3	372.0	25.1
7.5	8.8	2.8	0.9	0.7	2.7	4.6	4.6	7.0	1.5
178.4	129.4	113.4	151.7	111.3	344.5	768.7	436.9	379.0	26.6
28.2	39.9	30.7	26.5	6.2	6.2	68.8	103.0	207.1	49.3
150.2	89.5	82.7	125.2	105.1	338.3	699.9	333.9	171.9	-22.7
84.2	69.2	72.9	82.5	94.4	98.2	91.0	76.4	45.4	-85.3
346.1	244.3	224.0	305.4	224.0	692.3	1547.3	875.5	753.3	50.9
*	217.8	59.5	21.3	20.9	171.9	193.3	276.1	182.2	74.0
*	462.1	283.5	326.7	244.9	864.2	1740.6	1151.6	935.5	124.9
*	99.5	67.8	117.7	11.7	21.6	338.1	506.9	1348.7	138.0
*	362.6	215.7	209.0	233.2	842.6	1402.5	644.7	-413.2	-13.1
*	78.5	76.1	64.0	95.2	97.5	80.6	56.0	-44.2	-10.5
99.2	70.0	64.2	87.5	64.2	198.3	443.2	250.8	215.8	14.6
*	136.3	40.2	12.9	9.8	46.2	101.2	78.2	196.2	32.4
*	206.3	104.4	100.4	74.0	244.5	544.4	329.0	412.0	47.0
*	22.1	5.8	35.0	0.2	0.5	54.2	125.4	489.0	29.0
*	184.2	98.6	65.4	73.8	244.0	490.2	203.6	-77.0	18.0
*	89.3	94.4	65.1	99.7	99.6	90.0	61.9	-18.7	38.3

Table II-12b

	1979
	December
Total Phosphorus	
Total monthly rainfall contribution (kg)	27.5
Total monthly lagoon contribution (kg)	3.5
Total input to watershed (kg)	31.0
Total discharge from watershed (kg)	47.3
Total reduction/export	-16.3
Percent reduction/export	-52.6
Ortho Phosphorus	
Total monthly rainfall contribution (kg)	13.3
Total monthly lagoon contribution (kg)	4.8
Total input to watershed (kg)	18.1
Total discharge from watershed (kg)	12.9
Total reduction/export	5.2
Percent reduction/export	28.7

* = missing data

Negative values indicate export.

SEZ DAIRY WATERSHED

1980									
January	February	March	April	May	June	July	August	September	October
23.4	16.5	15.1	20.6	15.1	46.7	104.3	59.0	50.8	3.4
*	55.4	33.8	14.8	7.2	18.0	59.8	55.2	77.1	17.0
*	71.9	48.9	35.4	22.3	64.7	164.1	114.2	127.8	20.4
*	33.8	24.3	17.2	2.0	2.6	220.8	268.7	634.2	60.1
*	38.1	24.6	18.2	20.3	62.1	-56.7	-154.5	-506.3	-39.7
*	53.0	50.3	51.4	91.0	96.0	-34.6	-135.3	-396.2	-194.6
11.3	8.0	7.3	8.1	7.3	22.6	50.5	28.6	24.6	1.7
*	45.9	19.3	10.2	4.6	2.6	13.8	9.2	42.0	7.7
*	53.9	26.6	18.3	11.9	25.2	64.3	37.8	66.6	9.4
*	24.7	17.0	4.4	0.9	1.3	143.1	197.5	480.0	37.1
*	29.2	9.6	13.9	11.0	23.9	-78.8	-159.7	-413.4	-27.7
*	54.2	36.1	76.0	92.4	94.8	-122.6	-422.5	-620.7	-294.7

and October when total nitrogen loads showed a total net export (Figures II-71 and II-72). These apparent exports are probably the result of rainfall runoff stored on the watershed following events in August and September. The total load to the watershed for August, September, and October exceeded the total load in the discharge by over 200 kilograms for the same three months. The lagoon waste treatment system contributes to the total nitrogen disproportionately to its total fluid contribution. The lagoon system is responsible for from 11 to 60 percent of the total nitrogen load on a monthly basis.

Inorganic nitrogen exhibited a net export only during the month of September 1980. This, too, was probably due to the temporary retention of water on the watershed such that runoff that could be attributed to the rainfall during the preceding month continued to occur.

The percent uptake of inorganic nitrogen generally exceeded that of the total nitrogen component. The net result is such that nitrogen at the Wolf Creek discharge is mainly in organic form.

Net uptake of phosphorus, when it occurs at the SEZ Dairy site, is less efficient than uptake of nitrogen. There is a net export of total phosphorus during five of the ten months period of record (Figure II-74). Discharge from the waste treatment lagoons is responsible for forty percent or more of the total load to the watershed during six of the ten months. The lagoons were responsible for less than 25 percent of the total only during December 1979.

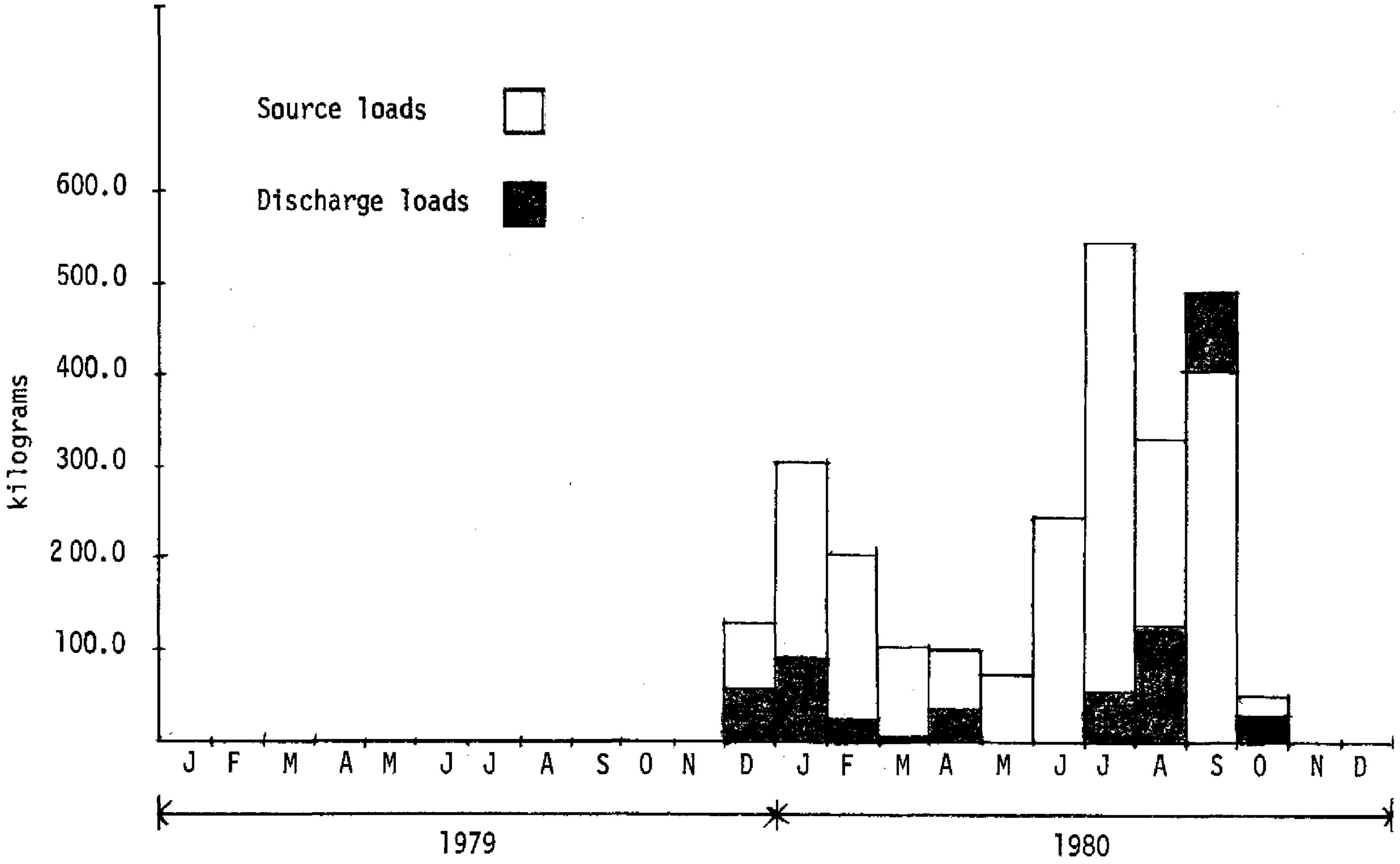

Figure II-71 MONTHLY INORGANIC NITROGEN BUDGET FOR SEZ DAIRY WATERSHED

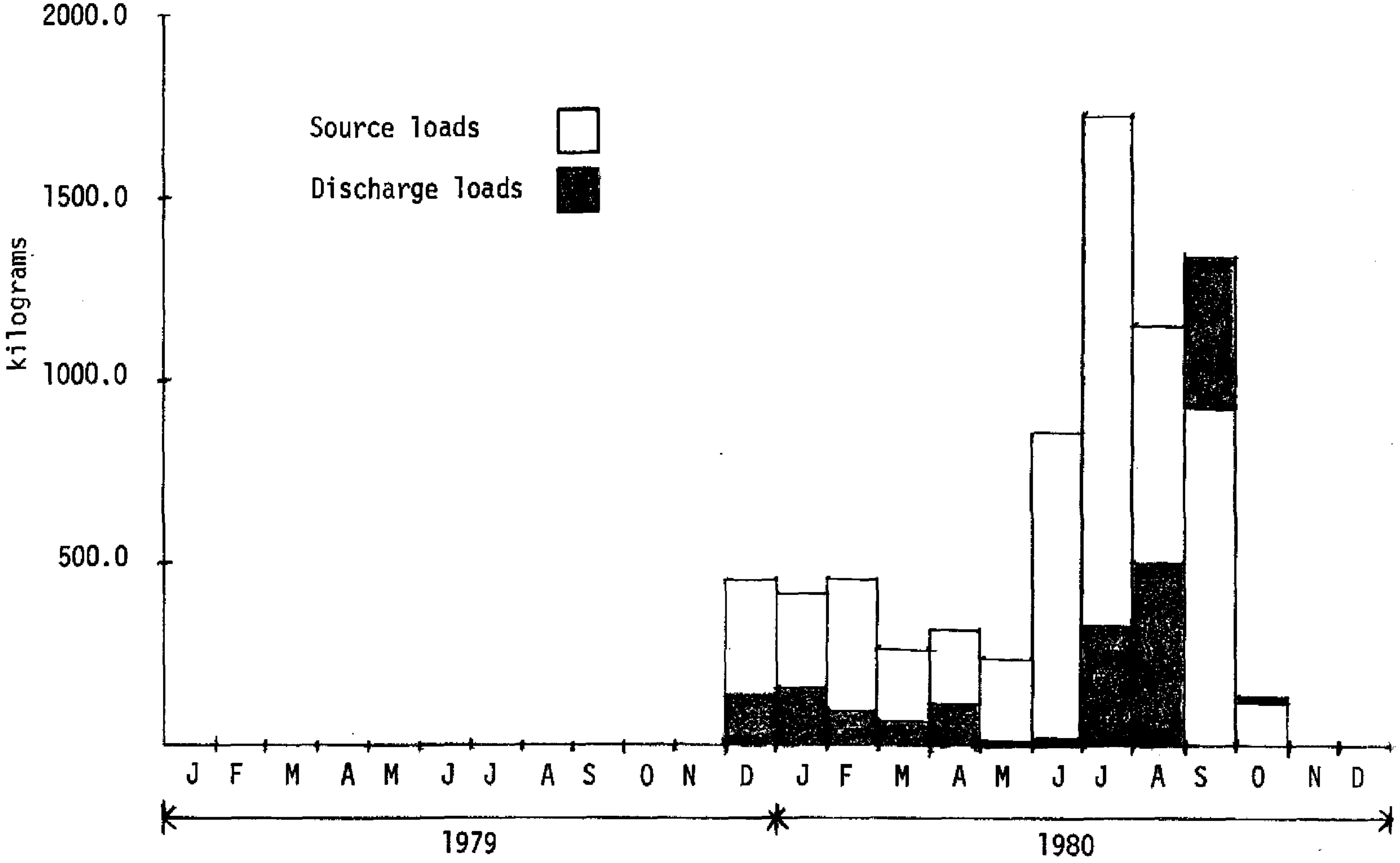

Figure II-72 MONTHLY TOTAL NITROGEN BUDGET FOR SEZ DAIRY WATERSHED

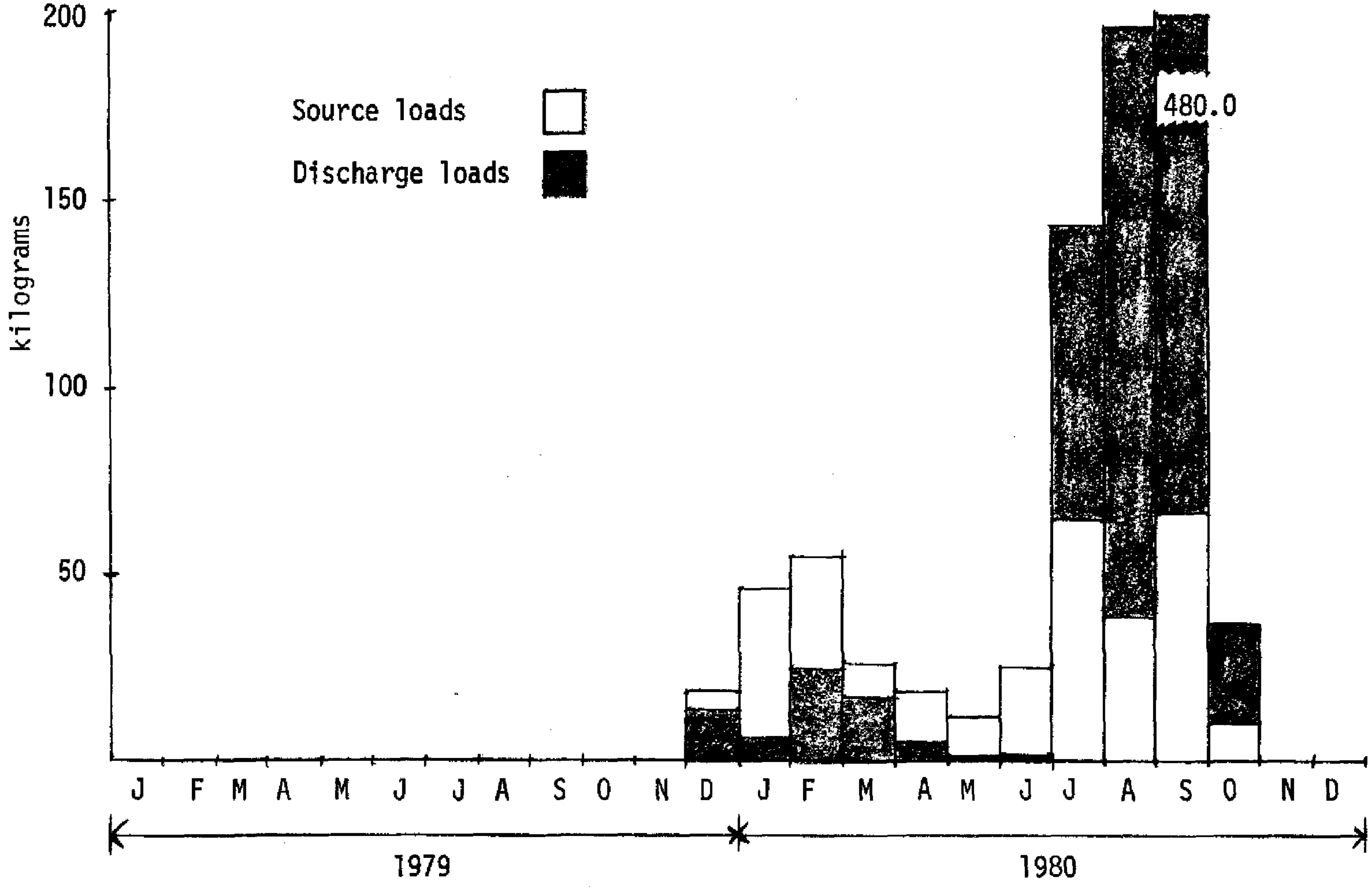

Figure II-73 MONTHLY ORTHO PHOSPHORUS BUDGET FOR SEZ DAIRY WATERSHED

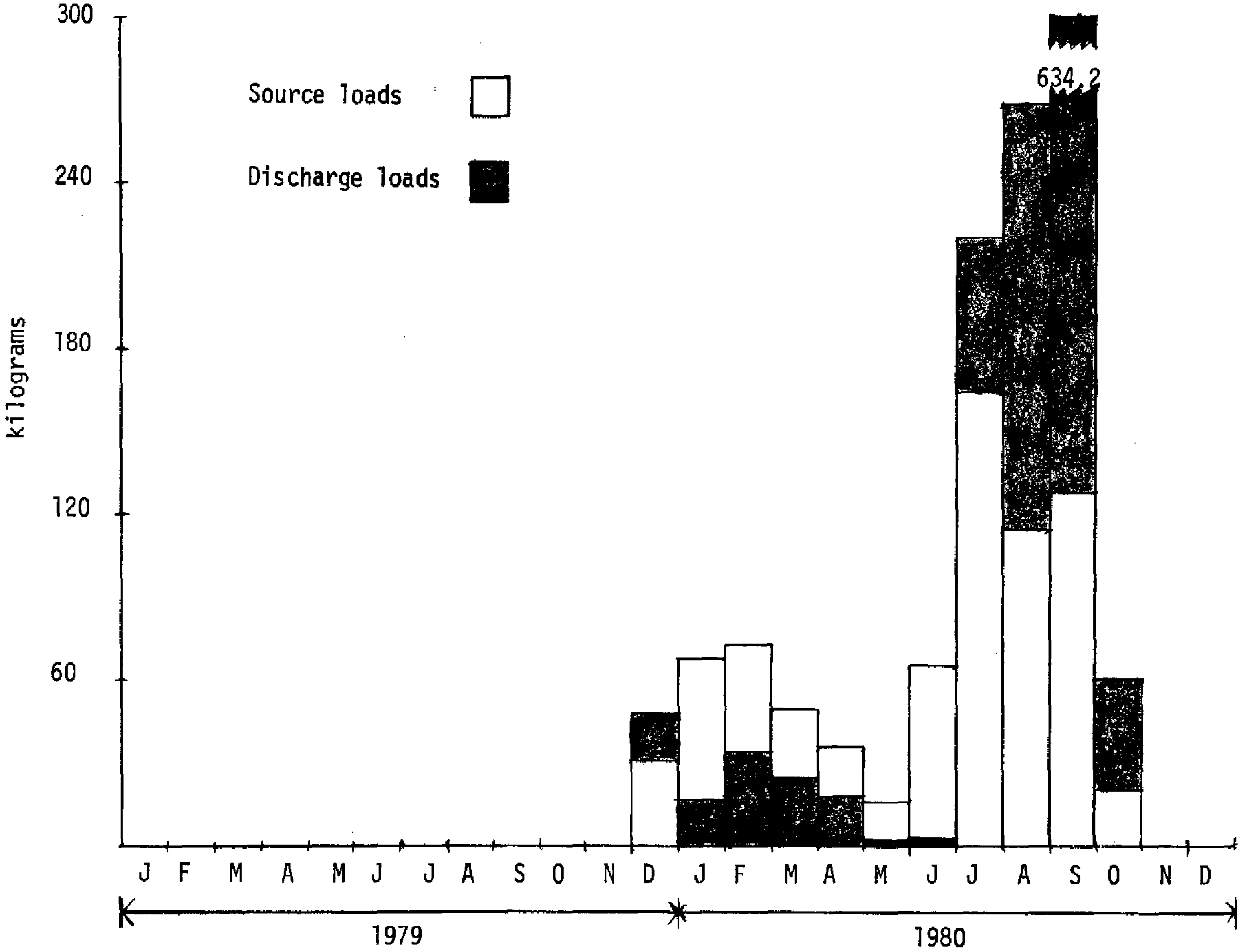

Figure II-74 MONTHLY TOTAL PHOSPHORUS BUDGET FOR SEZ DAIRY WATERSHED

INTERWATERSHED COMPARISONS

In order to evaluate the effects of land use practices as they relate to the beef and dairy cattle industry, and associated water quality of runoff from these lands, the seven watersheds comprising the Uplands Demonstration Project area have to be arranged in some order of land use intensity. This can be accomplished in terms of cattle per acre and/or pounds of fertilizer applied per acre, etc. Given these types of criteria for evaluating intensities of land uses for the project study sites, the following rankings were devised from least through most intensively used:

1. Wildcat Slough
2. Peavine Pasture
3. Armstrong Slough - South
4. Armstrong Slough - North
5. Ash Slough - East
6. Ash Slough - West
7. SEZ Dairy

The annual loadings and export rates for nitrogen and phosphorus from these watersheds are presented in Table II-13. Two watersheds stand out as contributing nitrogen and phosphorus on a per acre basis in quantities greater than any of the others. These two, SEZ Dairy and Ash Slough-west, are not surprisingly the two most intensively stocked and most efficiently drained watersheds in the Demonstration Project. Ash Slough-east is characterized by somewhat lower export rates (with the exception of nitrogen export at Armstrong Slough-north) than those calculated for the other, more

Table II-13 ANNUAL NITROGEN AND PHOSPHORUS BUDGETS FOR UPLAND DEMONSTRATION PROJECT WATERSHEDS

	Period of Record	Ash Slough East 12/01/79-11/30/80	Ash Slough West 02/01/80-11/30/80	Peavine Pasture 12/01/79-11/30/80	*Wildcat Slough 12/01/79-11/30/80	Armstrong Slough-South 04/01/80-11/30/80	Armstrong Slough-North 11/01/79-10/31/80	SEZ Dairy 12/01/79-10/31/80
TOTAL N	Total load on watershed (kg)	239.8	1391.2	3544.0	38690.3	11391.3	142390.4	6593.8
	Total load in discharge (kg)	30.1	710.2	222.2	381.5	2739.6	3364.4	2790.9
	Total load absorbed (kg)	209.7	68.1	3321.8	38308.8	8651.7	139026.0	3802.9
	Percent reduction	87.4	49.0	93.7	99.0	76.0	97.6	57.7
	Annual mean flow weighted concentration of discharge (mg/l)	1.88	2.42	1.72	<1.35	1.40	1.33	4.86
	Annual loading rate off watershed (kg/acre/yr)	1.158	5.463	0.370	0.065	2.055	0.168	4.094
INORGANIC N	Total load on watershed (kg)	68.1	398.5	1003.5	11081.8	3262.7	40783.5	2191.4
	Total load in discharge (kg)	0.4	30.7	2.9	97.3	38.1	193.3	818.8
	Total load absorbed (kg)	67.7	367.8	1000.6	10984.5	3224.6	40590.2	1372.6
	Percent reduction	99.4	92.3	99.7	99.1	98.8	99.5	62.6
	Annual mean flow weighted concentration of discharge (mg/l)	0.01	0.10	0.02	<0.34	0.02	0.08	1.43
	Annual loading rate off watershed (kg/acre/yr)	0.015	0.236	0.005	0.017	0.029	0.010	1.201
TOTAL P	Total load on watershed (kg)	16.5	94.2	228.9	2572.0	770.6	9547.9	700.7
	Total load in discharge (kg)	6.9	276.3	3.6	22.8	107.8	231.7	1311.0
	Total load absorbed (kg)	9.6	-182.1	225.3	2549.2	662.8	9316.2	-610.3
	Percent reduction	58.2	-193.3	98.4	99.1	86.0	97.6	-87.1
	Annual mean flow weighted concentration of discharge (mg/l)	0.43	0.94	0.03	<0.08	0.05	0.09	2.28
	Annual loading rate off watershed (kg/acre/yr)	0.265	2.125	0.006	0.004	0.081	0.012	1.923
ORTHO P	Total load on watershed (kg)	8.2	45.5	111.0	1239.2	371.2	4635.5	332.1
	Total load in discharge (kg)	4.9	241.7	2.1	3.6	20.5	92.9	918.9
	Total load absorbed (kg)	3.3	-196.2	108.9	1235.6	350.7	4542.6	-586.8
	Percent reduction	40.2	-431.2	98.1	99.7	94.5	98.0	-176.7
	Annual mean flow weighted concentration of discharge (mg/l)	0.31	0.82	0.02	0.01	0.01	0.04	1.60
	Annual loading rate off watershed (kg/acre/yr)	0.189	2.006	0.004	0.001	0.015	0.005	1.348

* = missing data

It appears that land use practices have a definite impact on nitrogen and phosphorus export rates from the watershed on a per unit area basis. This correlation is a direct one between increasing cattle density and nutrient export. The Ash Slough-west pasture is the most prolific exporter of both total nitrogen and all forms of phosphorus. SEZ Dairy is the leading exporter of inorganic nitrogen on a per acre basis. Wildcat Slough exports the least amount of nitrogen and phosphorus on a per acre basis. Nitrogen export rates between Wildcat Slough and Ash Slough-west differ by about two orders of magnitude. Phosphorus exports differ by as much as three orders of magnitude. Ash Slough-west and SEZ Dairy are the only sites that export either nutrient in excess of the total amounts contributed to them. This net export is limited to phosphorus, a large proportion of which is in the ortho form.

CHAPTER III

IMPACTS OF DETENTION/RETENTION SYSTEMS

INTRODUCTION

The second main purpose of this study was to determine the feasibility of using low-lying marsh areas as stormwater runoff detention/retention facilities. It has been hypothesized that detention/retention can be an efficient and cost effective means of reducing the impact of nutrient loads in stormwater runoff pulses from agricultural lands. This study was designed to test that hypothesis by creating such systems and subsequently monitoring nitrogen and phosphorus loads that were transported into and from them.

The sites chosen for this study were the natural low-lying marsh areas described at Ash Slough on the J. C. Bass ranch and the marsh area at Armstrong Slough that was created as a result of the plugging of the main drainage channel.

These marshes represent different aspects of detention/retention application both in terms of hydrological regimes and incoming nutrient loads that they were to be subjected to. Land use practices at Ash Slough as compared to Armstrong Slough resulted in higher mean concentrations of nitrogen and especially phosphorus being contributed to the dentention/retention facility (Table III-1). Hydrological characteristics are also very different. Ash Slough is a natural low area that receives and holds water during and following rainfall events. In the absence of such events of sufficient duration and intensity, water in the marsh dissipates through evapotranspiration and/or seepage until the system is left dry. Under the meteorological conditions that have prevailed during the past

Table III-1

INFLOW CONCENTRATIONS OF N AND P TO ASH AND ARMSTRONG SLOUGHS

Means & Ranges

		Ash Slough	
		West Pasture	East Pasture
Total N	mean	2.04	1.85
	range	0.21-6.94	0.28-6.82
Inorganic N	mean	0.06	0.03
	range	<0.01-0.68	<0.01-0.17
Total P	mean	1.209	0.407
	range	0.069-4.791	0.067-1.293
Ortho P	mean	1.044	0.289
	range	0.017-3.515	0.012-1.008

		Armstrong Slough	
		North Channel	South Channel
Total N	mean	1.17	1.74
	range	0.32-2.52	0.59-4.53
Inorganic N	mean	0.05	0.04
	range	<0.01-0.23	<0.01-0.40
Total P	mean	0.091	0.085
	range	0.033-0.429	0.013-0.207
Ortho P	mean	0.037	0.016
	range	<0.010-0.253	<0.010-0.058

year of this study, the marsh has remained in the dry state for extended periods.

By contrast, water is usually always present at the Armstrong Slough site. This detention/retention marsh area was created by forcing water over the banks of a continuously flowing stream. While this system, like Ash Slough, receives pulses of stormwater runoff, it is not subject to the wet/dry extremes that were observed to occur at Ash Slough.

Having these two detention/retention sites allows for comparisons to be made of the effectiveness of the concept for water quality treatment under two very different, but "typical", sets of conditions.

While not designed to specifically treat stormwater nonpoint source runoff, waste treatment lagoons designed by the U. S. Soil Conservation Service for wastewater management of effluent from dairy milking barn operations are in a sense detention/retention facilities. By defining the lagoons as such, inclusion of their effectiveness and impacts in the discussion is warranted at this time.

The following discussion will address the effectiveness of each of the detention/retention facilities for waste quality treatment studied in the Uplands Demonstration Project.

ASH SLOUGH

To assess the ability of the Ash Slough detention/retention marsh to remove nitrogen and phosphorus, a black box approach was taken. Loadings attributed to each source of inflow (all tributaries plus ungauged runoff due to rainfall) were summed to arrive at total load of each nutrient species into the marsh. Loads calculated to be leaving the site at the marsh outfall were assumed to be the total transport out of the marsh. The duration of the event at Ash Slough was defined as beginning of inflow into the marsh until cessation of outflow. All daily flows into the marsh during that period are summed to give total load in for the event. All daily flows in the discharge are summed to give total loads out for the event. Each event was considered as a separate entity and the reported gains or losses of nitrogen and phosphorus in the marsh are the net results of the entire event.

Concurrent hydrology and quality data were collected at Ash Slough during four distinct events. The first event was in progress as concurrent monitoring began. This event was the aftermath of rainfalls that preceded and occurred during Hurricane David in September 1979. In fact, over 30 days of continuous discharge from the marsh had occurred prior to commencing event-based monitoring on September 11, 1979. The remainder of this event lasted 53 days, until November 2, 1979. During this time, discharge ranged from 56 to 8,660 cubic meters per day. The total measured portion of the event was 186,600 cubic meters (151 acre ft.).

The second event occurred between February 19 through February 28, 1980. This event occurred immediately following repair of inflow measuring flumes and levee dressing earlier in the month. During this event, a total of 24,198 cubic meters (19.6 acre feet) of water was calculated to have discharged from the site. Maximum volume of water retained in the marsh during this period was calculated to be between 8,000-9,000 cubic meters. An event of this magnitude over the nine days observed time period would cause a total displacement of the maximum marsh volume at least three times over. Since the total marsh volume is usually less than the maximum for the event, the resulting residence time of water in the marsh is probably somewhat less than three days.

The third event occurred between March 31 through April 19, 1980. Computed discharge from the marsh totaled approximately 55,200 cubic meters (45 acre feet) with daily discharges ranging from 330 to 11,000 cubic meters. Maximum marsh volume during this period was about 16,000 cubic meters. While the total magnitude of this event was larger than the previous one, the extended period of time over which it occurred resulted in a potentially longer residence time for water in the marsh, roughly five and one-half days maximum.

The fourth and last event monitored during the 1980 season occurred between August 24 through September 13, 1980. This was the largest event of the 1980 season. Total volume discharged from the marsh was 119,500 cubic meters (97 acre feet). Discharge rates ranges from 291 to 19,500 cubic meters per day. Maximum marsh volume reached between 26,000 to 27,000 cubic meters. The observed event lasted 18 days. This would allow for 4.5 complete turnovers of maximum marsh volume and a residence time of four days or less.

Loadings of nitrogen and phosphorus species into and from the marsh for each event are presented in Tables III-2a and III-2b. In addition, the total reduction of load and the percentage of treatment is also calculated and listed.

From these data, it is apparent that the Ash Slough detention/

Table III-2a

1979-1980 STORM EVENTS AT ASH SLOUGH

Event # 1

Inflow: Pre 9/11/79 - 11/02/79
Outflow: Pre 9/11/79 - 11/02/79

Total Magnitude of Event 186,630 m^3 Range of Daily Discharges 56-8662 m^3

Sources of Nutrients to Marsh	Total N	NH4+NOx	Total P	Ortho P
Ditched Pasture	338.73	5.31	113.13	94.87
Unditched Pasture	58.06	0.66	14.03	10.45
Rainfall on Marsh	93.90	24.57	5.77	2.98
Total Kilograms Import	490.69	30.54	132.93	108.30
Total Kilograms Export	347.37	6.72	107.16	87.22
Difference	143.32	23.82	25.77	21.08
% Reduction	29.2	78.0	19.4	19.5

Event # 2

Inflow: 2/19/80 - 2/28/80
Outflow: 2/19/80 - 2/28/80

Total Magnitude of Event 24,300 m^3 Range of Daily Discharges 1267-5222 m^3

Sources of Nutrients to Marsh	Total N	NH4+NOx	Total P	Ortho P
Ditched Pasture	28.89	0.91	58.64	52.83
Unditched Pasture	Trace	Trace	Trace	Trace
Rainfall on Marsh	6.50	1.86	0.45	0.22
Total Kilograms Import	36.39	2.77	59.09	53.05
Total Kilograms Export	18.70	0.31	19.57	21.55
Difference	17.69	2.46	39.52	31.50
% Reduction	48.6	88.8	66.9	59.4

Table III-2b

1979-1980 STORM EVENTS AT ASH SLOUGH

Event # 3

Inflow: 3/31/80 - 4/19/80
Outflow: 4/1/80 - 4/19/80

Total Magnitude of Event 55,200 m^3 Range of Daily Discharges 300-11,000 m^3

Sources of Nutrients to Marsh	Total N	NH4+NOx	Total P	Ortho P
Ditched Pasture	315.12	20.33	26.01	20.23
Unditched Pasture	2.29	0.07	0.98	0.75
Rainfall on Marsh	39.40	11.29	2.66	1.28
Total Kilograms Import	356.81	31.69	29.65	22.26
Total Kilograms Export	176.30	5.63	81.89	67.13
Difference	180.51	26.06	-52.24	-44.87
% Reduction	50.6	82.2	export	export

Event # 4

Inflow: 8/24/80 - 9/13/80
Outflow: 8/30/80 - 9/13/80

Total Magnitude of Event 119,500 m^3 Range of Daily Discharges 300-19,500 m^3

Sources of Nutrients to Marsh	Total N	NH4+NOx	Total P	Ortho P
Ditched Pasture	198.21	5.02	106.56	96.85
Unditched Pasture	15.34	0.25	3.73	2.84
Rainfall on Marsh	129.90	34.10	8.04	3.89
Total Kilograms Import	343.45	39.37	118.33	103.58
Total Kilograms Export	340.80	5.22	109.77	93.92
Difference	2.65	34.15	8.56	9.66
% Reduction	0.8	86.7	7.2	9.3

retention marsh is fairly efficient in reducing inorganic nitrogen loads. Efficiencies of removal ranged from 78 to 88.8 percent. As might be expected, the highest efficiency occurred when incoming loads were least. Incoming loads of inorganic nitrogen for the four events ranged from 2.77 kilograms during the February 1980 event to 39.37 kilograms for the August 1980 event. No doubt the system was stressed by a far larger load prior to commencement of monitoring the after-effects of Hurricane David.

Total nitrogen loads were also consistently reduced. The percent reduction, however, was not as dramatic as that observed for the inorganic nitrogen. In fact, during the August 1980 event, the observed reduction was barely perceptible and could be attributed entirely to normal variability inherent in the sampling and analyses processes. During this event, the percent of the total load that could be attributed to organically bound nitrogen actually increased as there was a significant reduction of the inorganic fraction. Removal efficiencies of total nitrogen for the other three events ranged from 29.2 percent to 50.6 percent. The portion of the incoming nitrogen load that was inorganic ranged from 6.2 to 11.5 percent. The portion of the inorganic nitrogen load leaving the marsh ranged from 1.5 to 3.2 percent.

The Ash Slough marsh was only marginally successful in reducing phosphorus loads. Maximum reduction of total phosphorus was 67 percent during the February 1980 event. A large portion of this was probably left in solution but retained in storage in the marsh. In fact, during the subsequent event in March-April 1980, the marsh discharged twice as much total and ortho phosphorus as could be accounted for by all the inflow sources. This was the only event where actual export from the marsh occurred. Efficiency of total phosphorus reduction was 19.4 and 7.2 percent for the September 1979 and August 1980 events, respectively. There was little, if any, change in the ortho to total phosphorus ratios of either the influent or the effluent to and from the marsh during any of the four events.

ARMSTRONG SLOUGH

Loading data for the Armstrong Slough detention/retention marsh was treated using a "black box" technique similar to that employed for Ash Slough. As previously noted, hydrological regimes at the two sites are different. Unlike Ash Slough, which undergoes extremes of wet and dry conditions, the Armstrong Slough marsh remained wet continuously following the installation of the earthen plug in the main channel. Given this characteristic, and generally low rainfall amounts, it was impossible to identify any particular quantity of discharge from the marsh as having originated during any particular rainfall event. With more or less steady-state conditions being the rule, the efficiency of treatment (or lack of same) by the Armstrong Slough marsh was calculated on a continuous basis for the period from June 1, 1980 through October 31, 1980. Lack of a hydrology record after October precludes carrying the analysis out for later dates at this time.

Nutrient loads were calculated by the methodology previously described. Routine weekly or biweekly sampling dates were the nodes on which water quality calculations and loadings were based. Hydrology was supplied on a daily basis.

During the period April 1, 1980 through October 31, 1980, stages at Armstrong Slough ranged from 46.79 on May 8 to 49.50 on August 14. Low stages during the initial portion of this period were due to lowering the water level at the site to install the earthen plug in the main channel. This was accomplished in April and May. Water stages rose appreciably on May 29th and 30th following completion of the work and replacement of flashboards in the culvert risers. Subsequently, stages never dropped below 47.26. Marsh storage volume after May 30, computed from stage-storage volume relationships, ranged from roughly under two acre feet (270 m^3) to 100 acre feet (123,360 m^3).

Mean hydrological residence times were calculated on a monthly basis. The mean monthly stage was used for computation of mean marsh volume for each month, June through October (Table III-3). This figure was divided into the number of days discharge from the marsh was observed during the month to arrive at a mean residence time for water in the marsh during that month. Mean residence time of water in the marsh was least during August (4.02 days) and greatest during October when no discharge occurred.

Lack of hydrological data for the southern watershed, prior to plug installation in the main channel, precludes the possibility of doing an accurate analysis of the effectiveness of the impoundment area to remove nutrients while in its pre-plug condition. Any results would be purely conjectural. District hydrologists are currently attempting to reconstruct the record

Table III-3

MARSH VOLUME/RETENTION CHARACTERISTICS FOR ARMSTRONG SLOUGH FOLLOWING PLUGGING OF MAIN CHANNEL

	1980				
	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Average monthly volume (m^3)	86,350	92,520	111,030	86,350	46,880
Total monthly discharge (m^3)	151.360	85,515	855,525	174,745	0
Total days of discharge	15	23	31	19	0
Number of marsh volume turnovers	1.75	0.92	7.71	2.02	0
Average residence time (days)	8.6	25	4.02	9.4	---

with the data that they have available. If this proves to be feasible, a pre-plug analysis will be included in a future report.

Some export of nitrogen and phosphorus occurred during the April-May construction period. This export included both organic and inorganic species. Beginning in mid-May, however, the marsh began to consistently act as a nutrient sink for all species - either by absorption or maintaining them in temporary storage during periods of low or no discharge. Table III-4 contains a monthly summary of the nitrogen and phosphorus species loads into and out of the Armstrong Slough detention/retention marsh, the quantity retained, and the percentage of treatment attributed to the marsh. Total nitrogen loads coming into the marsh were reduced from 45 percent to effectively 100 percent when no discharge was occurring. Total phosphorus loads were simultaneously reduced from 69.6 percent during discharge to 100 percent under no discharge conditions. Inorganic nitrogen (NH4+NOx) and ortho phosphorus loads were substantially reduced. Inorganic nitrogen treatment was continually better than 94 percent and in all but one of the five cases better than 97 percent. Reduction of ortho phosphorus loads were better than 87 percent in each case.

There appears to be a tendency toward decreasing efficiency of treatment with increasing total monthly flow volumes. Least squares analyses were performed to determine the strength of this correlation for both total and inorganic nitrogen as well as total and ortho phosphorus. The correlation was very strong ($r = .94$) for both inorganic nitrogen and total phosphorus reduction. It

Table III-4 MONTHLY TREATMENT EFFICIENCY OF ARMSTRONG SLOUGH DETENTION/RETENTION MARSH FOLLOWING PLUGGING OF MAIN CHANNEL

	1980				
	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Total Nitrogen					
Sources of Inflow:					
North Channel	110.75	180.48	1055.13	155.16	156.92
South Channel	253.09	342.39	802.86	412.89	128.09
Rainfall on Marsh	409.00	526.00	679.00	229.00	24.00
Total Kilograms Import	367.93	1048.87	2536.99	797.05	309.01
Total Kilograms Export	163.24	143.98	1389.72	154.70	0
Difference	204.69	904.89	1147.27	642.35	309.01
% Reduction	55.6	86.3	45.2	80.6	100.0
Inorganic Nitrogen					
Sources of Inflow:					
North Channel	3.49	14.69	96.89	16.48	14.47
South Channel	2.51	4.16	6.30	8.25	6.04
Rainfall on Marsh	117.00	150.00	194.00	66.00	8.00
Total Kilograms Import	123.00	168.85	297.19	90.73	28.51
Total Kilograms Export	3.20	2.90	16.06	1.35	0
Difference	119.80	165.95	281.13	89.38	28.51
% Reduction	97.4	98.3	94.6	98.5	100.0
Total Phosphorus					
Sources of Inflow:					
North Channel	6.24	10.53	68.54	16.82	17.71
South Channel	12.31	12.15	15.48	15.88	4.46
Rainfall on Marsh	27.55	35.45	44.89	14.96	1.40
Total Kilograms Import	46.10	58.13	128.91	47.66	23.57
Total Kilograms Export	6.03	4.69	39.22	7.09	0
Difference	40.07	53.44	89.69	40.57	23.57
% Reduction	86.9	91.9	69.6	85.1	100.0
Ortho Phosphorus					
Sources of Inflow:					
North Channel	1.99	4.74	36.14	14.02	15.05
South Channel	1.90	2.59	5.78	4.77	1.17
Rainfall on Marsh	13.35	18.36	21.73	8.94	0.73
Total Kilograms Import	17.24	25.69	63.65	27.73	16.95
Total Kilograms Export	1.99	1.45	8.15	1.64	0
Difference	15.25	24.24	55.50	26.09	16.95
% Reduction	88.5	94.4	87.2	94.1	100.0

was moderately strong for total nitrogen (r = .79) and ortho phosphorus (r = .73). This is not too surprising as residence time in the system also tends to decrease with increasing flow through the system.

The inorganic fraction of the nitrogen load is reduced by the system. Rainfall contains the largest percentage of inorganic nitrogen (29%) followed by the north tributary (6.9%). The inorganic nitrogen in the south tributary and at the site outfall averages only 1.7 and 1.8 percent, respectively, of the total nitrogen load.

Ortho phosphorus is a significant portion of the total phosphorus load in the rainfall (monthly average = 50%) and the north channel (monthly average = 46.3 %). The ortho to total phosphorus ratio in the south channel is similar to but a little lower than that measured at the marsh outfall (24.9 and 27.9 percent, respectively). The marsh appears to be a net sink of organic and inorganic nutrients with a generally more efficient rate of uptake of soluble inorganic forms.

While this system appears to function effectively to reduce low level nutrient loads at low flow conditions, it must be pointed out again that it has not been stressed to a sufficient degree since the installation of the plug to confidently predict its ability to remove nutrient loads during storm runoff events.

SEZ DAIRY

The efficiency of the SEZ Dairy wastewater treatment lagoons to remove nutrients based on time series concentration data alone has been described earlier in this report. It was felt that refinement of this analysis would be desirable based on flow weighted rather than time series data. To accomplish this, the major difficulty that had to be overcome was the development of a methodology to measure volumes of water entering the lagoon system from the barnwash and its subsequent transfer through the lagoon system and past the point of discharge.

Developing a method to measure daily discharge from the secondary (holding) lagoon was straightforward. Water levels there are controlled by an 18-inch diameter culvert through the lagoon retaining levee with a riser and removable flashboards. As this is the only major outlet, drops in water level in the lagoon can be directly converted to discharge volume by using appropriate mathematical relationships. A Fischer & Porter digital stage recorder installed in this lagoon provided the instrumentation necessary to produce a continuous record of water levels and consequently, discharges from this lagoon.

Water volumes entering and leaving the primary (settling) lagoon were calculated based on changes in lagoon stage (read by OERC personnel daily on a staff gauge installed in the lagoon). The observed daily changes in water level were incorporated into a mathematical model developed by SFWMD engineers to convert decreasing stage levels to volume pumped to the secondary (holding) lagoon. Computations of barnwash volume were accomplished by measuring daily rises in the primary (settling) lagoon stage. This change was multiplied times the surface area of the lagoon and a correction factor was applied to compensate for daily rainfall, if any had occurred. The results are presented in Table III-5. It is believed that given relatively steady milking barn activities, barnwash volumes should remain fairly constant allowing for some normal variability based on weather conditions and other external and internal factors.

The calculated barnwash volume was grouped by month and a mean daily barnwash discharge volume was calculated for each month. These results were compared with the 100 to 150 gallons wastewater volume per cow per day rule of thumb as described in Nordstedt and Baldwin (1973). According to these criteria, a 500-cow milking operation such as SEZ Dairy should produce between 50,000 gallons (190 cubic meters) to 75,000 gallons (285 cubic meters) per day. Average daily barnwash volumes computed for each month at SEZ Dairy ranged from 46,750 gallons per day (177 cubic meters per day) in July 1980 to 72,575 gallons (275 cubic meters) per day in June 1980. Given the close agreement between the observed and predicted volumes, the mean daily volumes for each month were used to calculate the nutrient loadings from the barnwash for that month.

The major characteristic of water quality parameters of barnwash is variation. The nature and causes of this are discussed in Goldstein and Ulevich (1980). A series of mini-studies of barnwash quality revealed that in spite of extreme variation in samples taken during the day, the concentrations of any one parameter averaged over the day were remarkably similar to the data obtained

Table III-5

MONTHLY SEZ DAIRY BARNWASH VOLUME

Cubic Meters

1980	Daily Range	Daily Mean
May	161 - 411	256
June	209 - 367	275
July	25 - 292	177
August	124 - 352	246
September	142 - 348	267
October	195 - 376	262
November	36 - 555	228
December	125 - 394	242

Predicted range of barnwash volume at .38-.57 m^3/cow/day = 189-284 m^3/day (Nordstedt and Baldwin, 1973) during studies conducted on other days. With the exception of slightly lower inorganic nitrogen values, the mean concentrations of each parameter for the subject period of record April 1, 1979 through December 31, 1980, are within the ranges of the means for these parameters observed during the mini-studies. These data are presented in Table III-6.

Since the time series means of each parameter appear to represent the long term steady-state condition of barnwash quality, these values were used along with daily flow volumes for each month (Table III-5) to calculate typical expected loadings to the first lagoon that could be attributed to barnwash. These data presented as kilograms per day and total kilograms for the month are presented in Table III-7.

Mass transfer of nitrogen and phosphorus from the primary holding lagoon to the secondary settling lagoon and nutrient mass discharge from the settling lagoon were calculated using the methodology described for calculating watershed loadings. These data were grouped by month and total monthly loads and monthly percent efficiency of treatment was calculated for each stage of the lagoon system. These data are presented in Table III-8.

The most striking characteristic that these data depict is that with few exceptions, mass transfer of each nutrient on a monthly basis from the settling lagoon to the holding lagoon is significantly greater than that which can be accounted for by the loadings in the barnwash alone. The exceptions occurred only

Table III-6

SEZ DAIRY BARNWASH STUDIES

MEANS AND RANGES OF WATER QUALITY PARAMETERS

Date	n		Conductance	Color	pH	Turbidity	NOx + NH4	Total N	Ortho P	Total P
06/21/79	8	$\bar{x}$ range	1524 1130-1880	260 125-510	8.00 7.78-8.20	106.3 62-165	47.44 21.30-76.22	111.20 75.34-167.31	5.711 2.936-8.804	16.221 6.873-30.546
07/13/79	13	$\bar{x}$ range	1599 863-2910	336 64-684	7.81 7.54-8.18	117 36-155	56.90 7.60-144.69	149.58 27.06-301.89	5.059 1.343-10.050	22.292 3.593-43.521
08/03/79	22	$\bar{x}$ range	1528 1015-2400	255 102-402	7.88 7.30-8.56	157 46-650	33.47 6.03-96.47	148.12 28.83-398.87	4.145 2.053-8.861	26.363 5.887-98.674
10/30/79	24	$\bar{x}$ range	1694 231-4210	372 78-2160	7.79 7.19-8.41	151 4.8-1200	34.29 1.83-124.33	190.32 26.70-841.89	6.213 1.521-17.655	42.220 4.474-243.046
04/01/79 through 12/31/80	all	$\bar{x}$ range	1522 231-4450	300 64-2160	7.86 6.42-8.89	153.9 2.7-1200	28.61 1.83-144.69	145.26 9.01-841.89	4.604 1.077-17.655	25.984 0.733-243.046

Key: n = number of samples

$\bar{x}$ = mean of n samples

Table III-7

SEZ DAIRY NUTRIENT LOADINGS IN BARNWASH

Kilograms

	1980							
	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Total Nitrogen								
Daily	37.2	39.9	25.7	25.7	38.8	38.1	33.1	35.2
Monthly	1153.2	1197.0	796.7	1106.7	1164.0	1181.1	993.0	1091.2
NH4 + NOx								
Daily	7.3	7.9	5.1	7.0	7.6	7.5	6.5	6.9
Monthly	226.3	237.0	158.1	217.0	228.0	232.5	195.0	213.9
Total Phosphorus								
Daily	6.6	7.1	4.6	6.4	6.9	6.8	5.9	6.3
Monthly	204.6	213.0	142.6	198.4	207.0	210.8	177.0	195.3
Ortho Phosphorus								
Daily	1.2	1.3	0.8	1.1	1.2	1.2	1.0	1.1
Monthly	37.2	39.0	24.8	34.1	36.0	37.2	30.0	34.1

Table III-8

FLOW WEIGHTED SEZ LAGOON TREATMENT EFFICIENCY

kg/m^3

	1980							
	May	June	July	Aug	Sept	Oct	Nov	Dec
Total Nitrogen								
Load into Lagoon 1	.145	.145	.145	.145	.145	.145	.145	.145
Load into Lagoon 2	.081	.122	.072	.105	.114	.075	.082	.086
Percent change	-44.1	-15.9	-50.3	-27.6	-21.4	-48.3	-43.4	-40.7
Discharge from Lagoon 2	.032	.067	.042	.060	.026	.048	.052	.030
Percent change	-60.5	-45.1	-41.7	-42.9	-77.2	-36.0	.36.6	-65.1
Total % reduction from barnwash	-77.9	-53.8	-71.0	-58.6	-82.1	-66.9	-64.1	-79.3
Inorganic Nitrogen								
Load into Lagoon 1	.029	.029	.029	.029	.029	.029	.029	.029
Load into Lagoon 2	.034	.057	.065	.066	.092	.052	.050	.044
Percent change	+17.2	+96.6	+124.1	+127.6	+217.2	+79.3	+72.4	+51.4
Discharge from Lagoon 2	.015	.018	.022	.017	.028	.021	.017	.014
Percent change	-55.8	-68.4	-66.2	-74.2	-70.0	-59.6	-66.0	-68.2
Total % reduction from barnwash	-48.3	-37.9	-24.1	-41.4	-3.4	-27.6	-41.4	-51.2
Total Phosphorus								
Load into Lagoon 1	.026	.026	.026	.026	.026	.026	.026	.026
Load into Lagoon 2	.020	.024	.022	.023	.027	.019	.022	.017
Percent change	-23.1	-7.7	-15.4	-11.5	+3.8	-26.9	-15.4	-34.6
Discharge from Lagoon 2	.011	.007	.013	.012	.011	.011	.011	.011
Percent change	-45.0	-70.8	-40.9	-47.8	-59.3	-42.1	-50.0	-35.3
Total % reduction from barnwash	-57.7	-73.1	-50.0	-53.8	-57.7	-57.7	-57.7	-57.7
Ortho Phosphorus								
Load into Lagoon 1	.005	.005	.005	.005	.005	.005	.005	.005
Load into Lagoon 2	.002	.006	.002	.003	.006	.007	.006	.004
Percent change	-60.0	+20.0	-60.0	-40.0	+20.0	+40.0	+20.0	-20.0
Discharge from Lagoon 2	.007	.001	.003	.002	.006	.005	.007	.008
Percent change	+250.0	-0.8	+50.0	-33.0	0	-28.6	+16.7	+100.0
Total % reduction from barnwash	+40.0	-80.0	-40.0	-60.0	+20.0	0	+40.0	+60.0

negative percentages = reduction of load   positive percentages = increase of load during the months when comparatively lesser volumes of water were being pumped out of the lagoon.

As might be expected, time series data (Table II-2) show that mean concentrations of inorganic nitrogen in the settling lagoon are greater than those in the barnwash. Mean concentrations of the time series data for total nitrogen and total and ortho phosphorus, however, are somewhat greater for barnwash composition than those calculated in the lagoon. Quantities discharged from the first lagoon, though, often exceed those entering the lagoon via the barnwash. The results of the application of flow weighting point out the fallacies inherent in drawing conclusions based on time series quality data alone.

A net reduction of mass occurs for all monitored nitrogen and phosphorus species at the outfall from the holding lagoon. Monthly total nitrogen loads in the discharge are reduced 75 to 90 percent from their levels in the settling lagoon effluent. The inorganic portion in this load is consistently reduced on the order of 90 percent. Monthly total phosphorus loads in the discharge are reduced approximately 80 to 95 percent below those in the effluent from the settling lagoon. Ortho phosphorus reduction efficiencies are less than those noted for other nutrient species but, nonetheless, range from as low as 35 percent to as high as 86 percent on a monthly basis. In absolute terms, the total mass of nitrogen and phosphorus being discharged from the holding lagoon is, in most cases, substantially less than the mass of those nutrients entering the system in the barnwash.

The reduction in load is not due entirely to the efficiency of the holding lagoon to remove nutrients. In fact, the majority (and in some cases, all) of the apparent reduction in nutrient load can be accounted for merely by the reduction of the volume of water discharging from the holding lagoon compared with the volume of water entering it (Table III-9). Once this is accounted for, the apparent efficiency of the lagoon system to remove nutrients is significantly reduced. On a per unit volume basis of the discharge (Table III-8), the holding lagoon is consistently most efficient at reducing inorganic nitrogen loads from 55 to 75 percent on a monthly basis. It is less efficient in reducing total nitrogen and total phosphorus loads. Total nitrogen reduction efficiency was consistently between 35 and 80 percent while monthly total phosphorus reduction on a per unit volume basis ranged between 35 and 70 percent. Ortho phosphorus on a percent volume basis was exported from the lagoon in greater quantities than it was imported during four of the 8 months of the subject period. During September, monthly export of ortho phosphorus on a per unit flow basis was equal to the import into the holding lagoon. During the other three months of the subject period, ortho phosphorus loads in the lagoon were reduced from 28 to 83 percent.

Monthly total reduction of nitrogen on a percent basis from the barnwash through the lagoon system ranged from 34 to 95 percent for the inorganic form and from 54 to 82 percent for the total. Total phosphorus loads were reduced consistently from 50 to 60 percent. Ortho phosphorus loads on a per unit basis were actually greater than those in the barnwash during four of the eight months study period. Reduction of ortho phosphorus loads occurred during three months and ranged from 40 to 80 percent.

Table III-9

MONTHLY WATER MOVEMENT THROUGH SEZ LAGOON SYSTEM

	1980							
	May	June	July	Aug	Sept	Oct	Nov	Dec
Volume of barnwash	7936	8250	5487	7626	8010	8122	6840	7502
Volume pumped to holding lagoon	9832	12891	18058	20688	25585	8179	9918	20170
Percent change of volume	+23.9	+56.3	+229.1	+171.3	+219.4	+0.7	+45.0	+168.9
Volume discharged from holding lagoon	654	2666	4601	4601	7007	1542	3516	7081
Percent change of volume	-93.3	-79.3	-74.5	-77.8	-72.6	-81.1	-64.5	-64.9

Efficiency of treatment of lagoon system discharge once it reaches Wolf Creek cannot be computed on a day for day basis at this time. The mass of nutrient discharge at the site outfall results from a combination of those loads that have their origin in shallow groundwater seepage into the perimeter ditches, and surface runoff from rainfall or the surrounding pastures. The lagoon discharges, when they occur, are mixed with these other sources. The resulting discharge peaks as observed at the site outfall become less defined as they decrease in magnitude and become more diffuse.

CHAPTER IV

OTHER STUDIES

GROUNDWATER QUALITY MONITORING

Rationale and Methodology

Groundwater quality was monitored at nine stations located throughout the five project study sites. These stations were chosen with the objectives of:

1. Providing a means of comparison of groundwater quality among the study sites;
2. Determining if different land use patterns on the same site had effects on groundwater quality at different locations around the site;
3. Determining if groundwater quality at any location changes over time.

Sampling wells were drilled by personnel from the U. S. Geological Survey office in Orlando during December 1979 and January 1980. The sampling well locations and well depths are described in Table IV-1. Groundwater sampling wells are also depicted in the site description diagrams (Figures II-2 through II-6).

Wells were located in areas that were representative of the major types of land uses characteristic of the area. The homogeneity of land use practices at Wildcat Slough and Peavine Pasture necessitated the placement of only one sampling well at each site. Two wells were located at Armstrong Slough on either

Table IV-1

GROUNDWATER QUALITY SAMPLING STATIONS AND LAND USES

STATION ID	LOCATION	WELL DEPTH (meters)	LAND USE
A	SEZ Dairy, East end	2.54	Light to moderate grazing
B	SEZ Dairy, Adjacent to milking barn	2.90	Cattle staging and holding area
C	SEZ Dairy, North of lagoon system	2.36	Seepage area
D	Ash Slough, J. C. Bass Ranch	2.68	Unditched pasture, light to moderate grazing
E	Ash Slough, J. C. Bass Ranch	1.86	Ditched pasture, moderate to heavy grazing
F	Wildcat Slough, Lykes Bros., Brighton	2.43	Light grazing
G	Peavine Trail, Latt Maxcy	3.45	Light to moderate grazing
H	Armstrong Slough, Latt Maxcy, North of detention marsh	3.37	Light to moderate grazing
J	Armstrong Slough, Latt Maxcy, South of detention marsh	3.39	Palmetto stand, light grazing

side of the marsh, mainly to insure that the potential effects of impoundment and retention on water quality could be adequately monitored. Two well locations were chosen at the Ash Slough site because of the pronounced differences in pasture drainage patterns between the east and west sides of the detention/retention marsh. Runoff from the east pasture is a gentle sheet flow, while the extensive ditching on the west side channels rainfall runoff away from the land faster. Similar pronounced differences in land uses at SEZ Dairy required the drilling of three wells on that site. The land use types represented were a slightly grazed grass pasture, intensively used holding pasture adjacent to the milking barn, and the area immediately adjacent to the second waste stabilization lagoon.

Each well was cased with galvanized steel pipe. The casings were threaded at the top and were capped when not in use. In addition, a concrete collar was poured around each casing where it met the ground in order to eliminate the opportunities for surface contamination around the well casing.

Each well is sampled routinely once every four weeks. Sampling is preceded by initially pumping each well dry to purge standing water. This is accomplished by the use of a "Guzzler" hand-operated bilge pump to which is attached four meters of 1.9 cm inner diameter plastic garden hose. The hose is inserted in the well until it hits bottom. The well is then purged and the hose removed. After standing a few minutes, the well is ready to sample. The sample is collected by lowering a .5 cm inner diameter Tygon hose into the well until it touches bottom. It is then raised from one to three inches so that sediment in the bottom of the well is less apt to be taken. The Tygon hose leads through a peristaltic pump driven by a rechargeable electric drill motor.

Once the water is pumped to the surface, it is allowed to run for 30-60 seconds to clear the inside of the hose of any contaminants. The samples are then collected in two 250 ml Nalgene bottles with the hose inserted at the bottom to reduce air mixing with the sample. Each bottle is filled and allowed to overflow for 15-30 seconds. After the sample is collected, the bottles are capped and stored on ice. The Tygon sampling hose is then thoroughly rinsed inside and out with deionized water. Quality analysis on these samples is carried out at the Okeechobee laboratory.

Results

The most outstanding characteristic of the groundwater quality data is the lack of variability of the observed concentrations following an initial stabilizing period. During the stabilization period, sampling techniques and equipment were being perfected and unavoidable surface contamination introduced during installation was gradually being flushed from each well. Enough data has been collected so that the questions which the groundwater monitoring program set out to resolve can now be addressed.

Table IV-2 lists means and ranges of key chemical and physical parameters monitored during this study. The means and ranges are subsequently plotted out in Figures IV-1 through IV-3.

TABLE IV-2

GROUNDWATER QUALITY DATA SUMMARY

Means and Ranges

STUDY SITE	STATION ID		CONDUCTIVITY µmhos/cm	pH	NOX+NH4 mg/l	TOTAL N mg/l	ORTHO P mg/l	TOTAL P mg/l
SEZ Dairy	A	mean	293	6.87	0.42	4.59	0.020	0.302
		range	265-321	6.10-7.29	0.28-0.58	1.32-10.52	0.010-0.077	0.036-0.895
	B	mean	615	8.04	0.71	12.12	0.011	0.291
		range	365-790	7.48-9.34	0.01-0.90	1.33-113.46	0.010-0.016	0.018-0.433
	C	mean	1528	6.99	8.46	13.52	0.010	0.104
		range	1392-1675	6.80-7.39	0.02-11.84	8.79-18.40	0.010-0.010	0.019-0.355
Ash Slough	D	mean	189	6.05	0.24	1.58	0.010	0.123
		range	160-235	5.81-6.29	0.18-0.32	1.17-2.89	0.010-0.010	0.036-0.239
	E	mean	577	6.82	0.07	0.96	0.010	0.065
		range	518-630	6.45-6.96	0.02-0.36	0.47-2.10	0.010-0.010	0.010-0.220
Wildcat Slough	F	mean	159	6.43	0.21	1.31	0.010	0.160
		range	138-189	6.23-6.90	0.07-0.41	0.87-1.83	0.010-0.010	0.055-0.313
Peavine Pasture	G	mean	611	6.89	0.12	3.22	0.010	0.038
		range	535-740	6.64-7.10	0.09-0.18	2.88-4.00	0.010-0.010	0.022-0.078
Armstrong Slough	H	mean	118	6.13	0.07	0.76	0.036	0.166
		range	97-153	5.85-6.59	0.02-0.10	0.57-0.97	0.023-0.052	0.085-0.322
	J	mean	189	6.44	0.02	0.51	0.010	0.105
		range	160-285	6.21-6.65	0.01-0.04	0.10-1.09	0.010-0.010	0.010-0.408

Narrow ranges of conductivity and significant difference of means are outstanding characteristics of the different stations on the study sites. Various factors can cause the differences in conductivity and other water quality parameters in groundwater. Local differences in water table, soil type, and point of origin can all impact groundwater quality. For these reasons, in most cases it is difficult to assume a direct cause/effect relationship between surface land use practices and impact on groundwater quality. Results of this study, however, show two instances where land use may have significant impact. These occur at the Ash Slough and the SEZ Dairy sites. These two sites represent the areas where land use practices are most intense. Multiple sampling wells are present at these and the Armstrong Slough sites.

At Armstrong Slough where the land use practices around the wells are similar, the apparent differences in conductivity levels in the wells is relatively small. Ash Slough and SEZ Dairy, however, exhibit widely divergent conductivity levels between intrasite stations. Mean conductivity of groundwater in the ditched pasture at Ash Slough (Station E) is three times greater than that observed in groundwater in the unditched pasture (Station D) sampling location. At SEZ Dairy, mean conductivity is greatest at the station north of the holding lagoon and least at Station A in the grazing pasture farthermost from the milking barn. The high levels at Station C probably reflect seepage from the dairy waste treatment lagoons which are filled primarily with more saline groundwater pumped from deeper levels and used to clean the milking barn area.

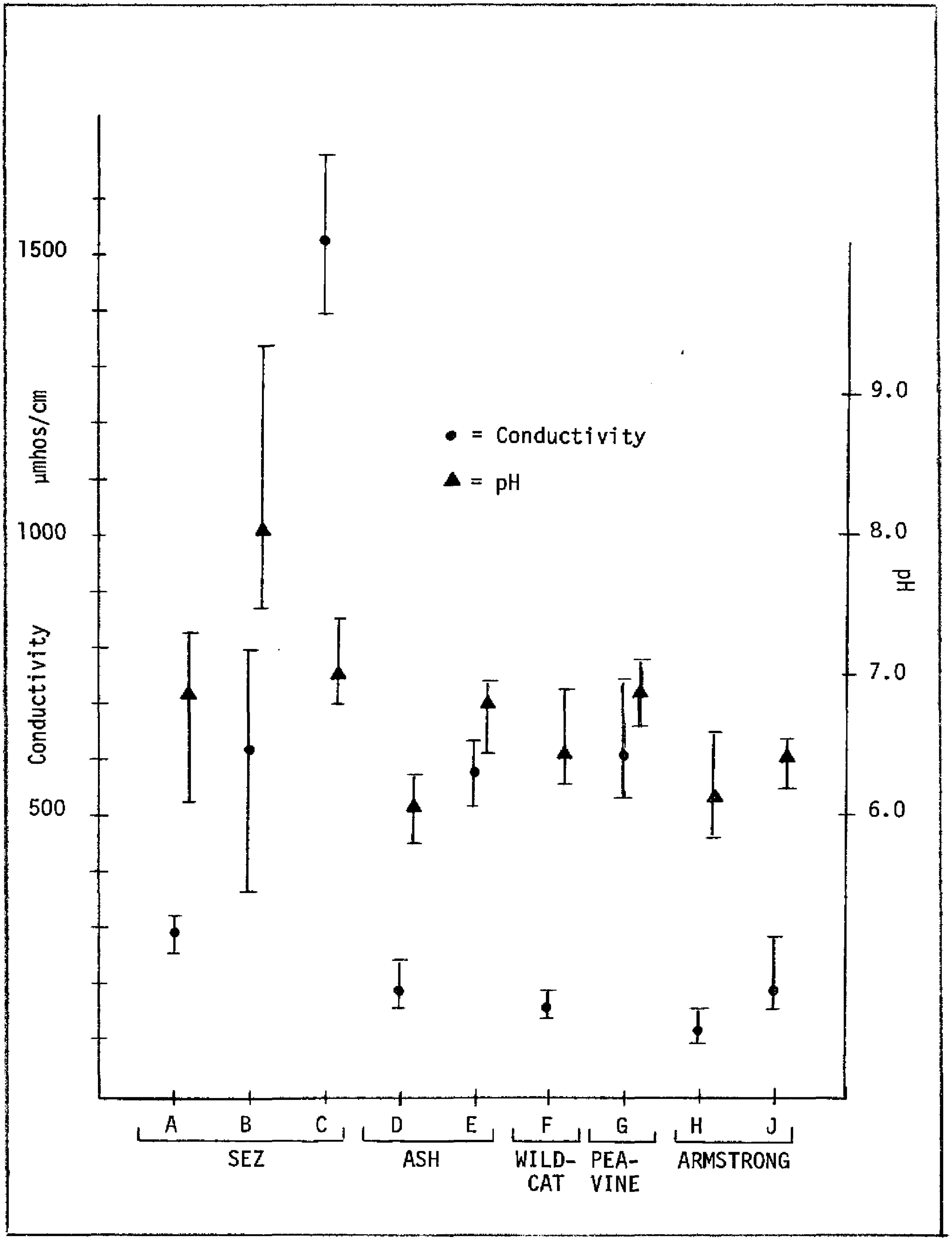

Figure IV-1. CONDUCTIVITY AND pH IN SHALLOW GROUNDWATER AT UPLAND DEMONSTRATION PROJECT SITES, 1980 - MEANS & RANGES

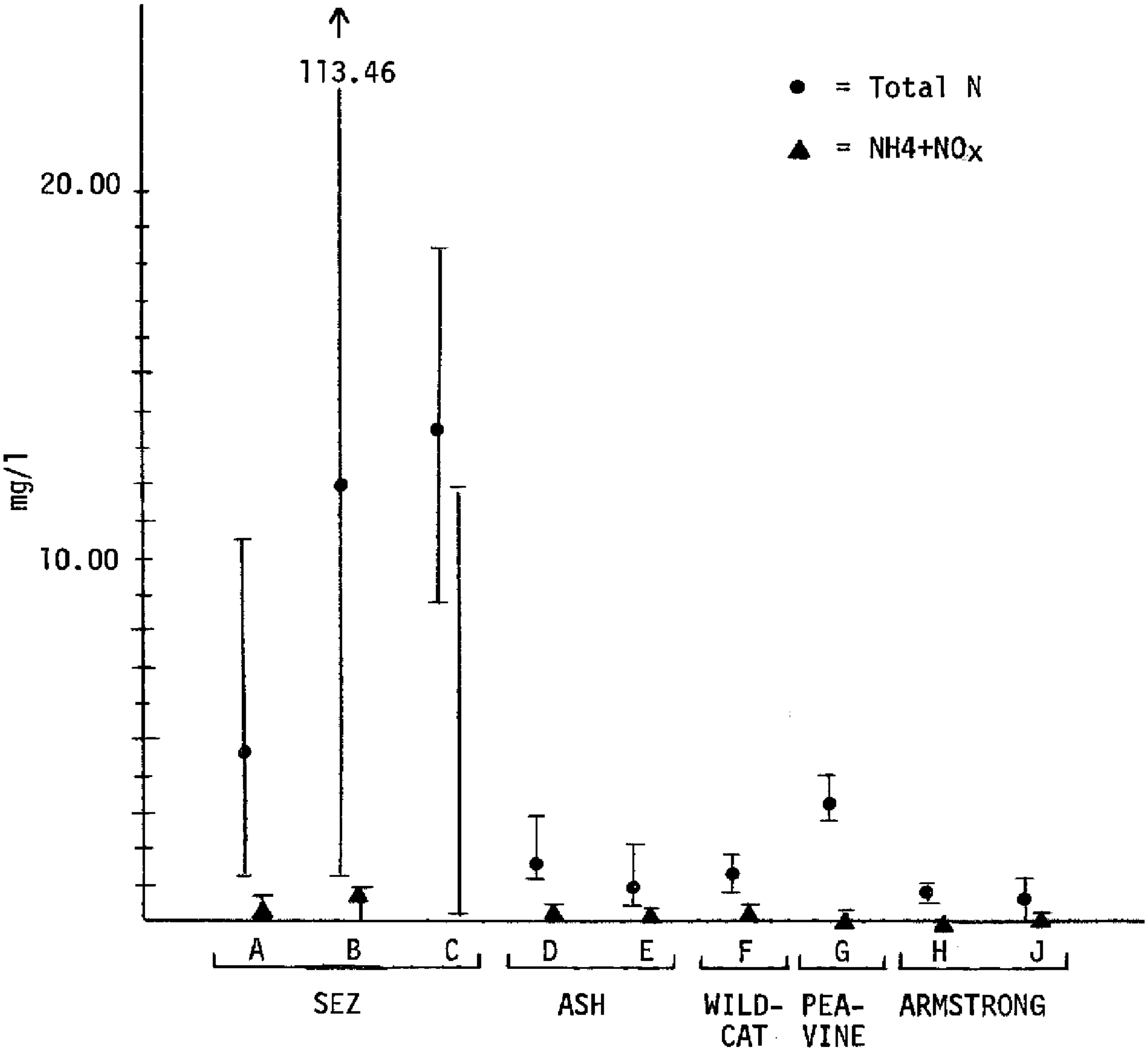

Figure IV-2. TOTAL AND INORGANIC NITROGEN CONCENTRATIONS IN SHALLOW GROUNDWATER AT UPLAND DEMONSTRATION PROJECT SITES, 1980 - MEANS & RANGES

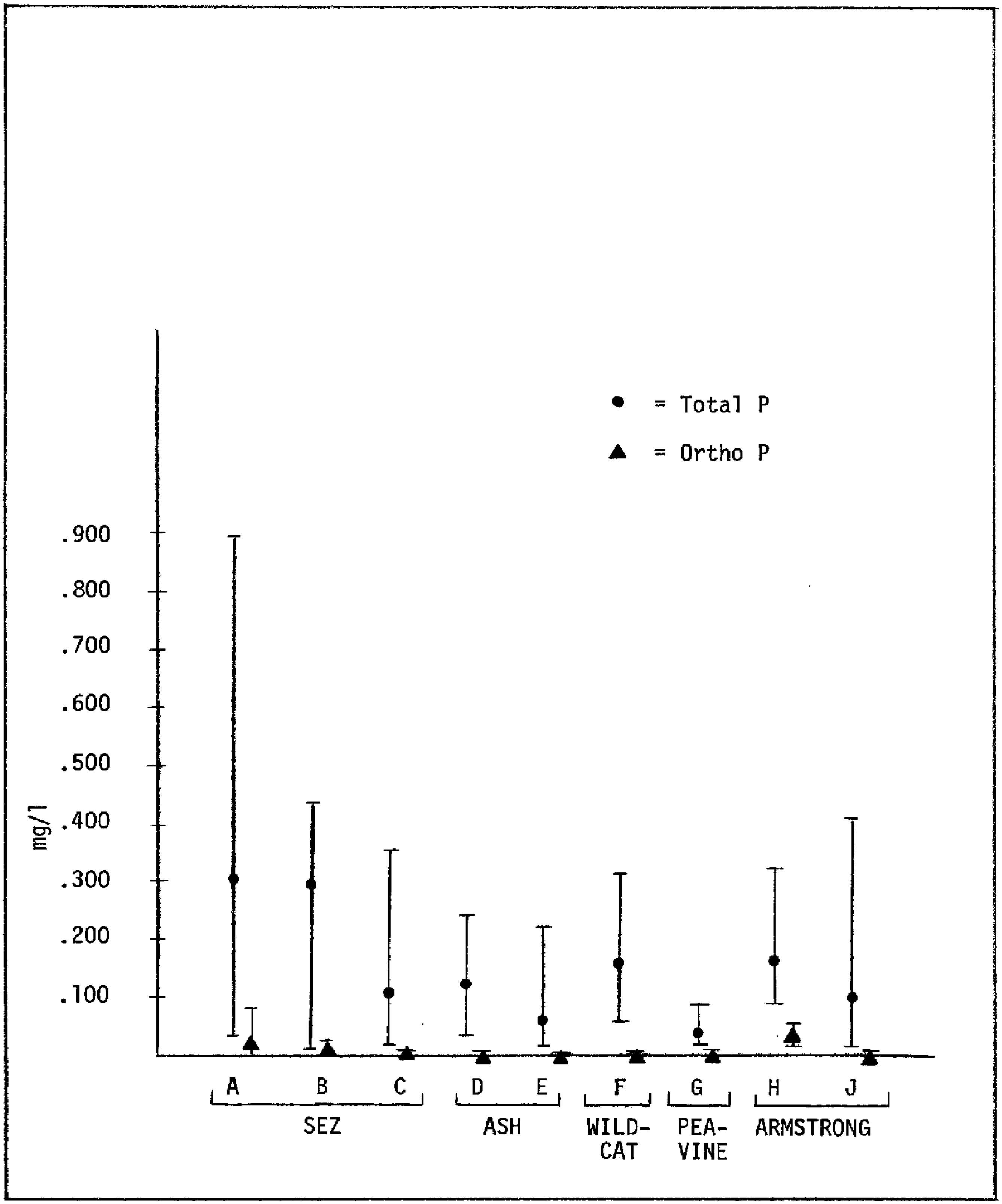

Figure IV-3. TOTAL AND ORTHO PHOSPHORUS CONCENTRATIONS IN SHALLOW GROUNDWATER AT UPLAND DEMONSTRATION PROJECT SITES, 1980 - MEANS & RANGES

Mean total nitrogen concentrations at the SEZ Dairy site are higher at all stations than those measured at any of the other sites. There is also a greater minimum/maximum range. Mean concentrations increase as one goes from grazing pasture to cattle holding area to lagoon seepage area. Inorganic N (NH4+NOx) is a relatively insignificant portion of the total N component at all nine stations with the exception of Station C north of the SEZ holding lagoon where it makes up 63 percent of the mean total and is one to two orders of magnitude greater than mean concentrations observed at the other eight stations.

Mean total P concentrations range from .038 mg/l at Peavine to .302 mg/l at Station A in the SEZ grazing pasture. Ortho P levels are generally sometimes slightly greater but usually less than detection limits.

From these data, one can conclude that in most cases groundwater quality is fairly constant. Mean concentration of parameters are usually characteristic of the individual sites. Variation is generally small, however, in those cases where land use is most intense, variation is usually greater than that observed in areas of less intense use. It is possible that some parameters of shallow groundwater are more apt to be affected by land use. Conductivity and total nitrogen appear to be examples of these. Total phosphorus appears to be affected much less, while inorganic N and ortho P appear to be affected the least, if at all.

Comparison of time series data indicates no apparent trends throughout the year. Concentration levels possibly do not change over time. This assertion remains in doubt, however, due to the limited (one year) data base and the abnormally dry conditions that have prevailed during the study. Periods of intense rainfall may have impact. The groundwater quality sampling program will continue on a routine basis for the duration of this project so that this question may be answered.

SOIL MOISTURE QUALITY MONITORING

The soil moisture quality sampling program was designed to collect a cursory amount of data on potential effects of agricultural land uses on interstitial soil moisture 12 to 18 inches below the ground surface. Three to four samples were to be collected from each of four stations, one each at four of the project sites. The sampling devices were suction lysimeters similar to those used by Montgomery, et al. (1979), for collecting interstitial soil water samples in marine seagrass flats.

The devices were inserted into the soil at 12 to 14 inch depth and surrounded by a cage of wood stakes and barbed wire to protect them from cattle. The samplers were left in place for one month following initial installation to allow stabilization of the soil and moisture around the sampler.

The initial attempt to collect soil moisture samples was late July 1980. Sampling efforts met with success at Ash Slough, Peavine Pasture, and SEZ Dairy. The soil profile at the Wildcat Slough site was too dry to achieve success in collecting a sample at that site.

The subsequent lack of adequate rainfall throughout the remainder of the year resulted in the subsurface soil dewatering to a degree that further attempts to collect soil moisture quality samples were unsuccessful at all four sites.

The lack of success of this portion of the sampling program eliminates the need for further discussion on this subject at this time.

CHAPTER V

DISCUSSION AND CONCLUSIONS

To date, the current research effort has been moderately successful in achieving the goals of answering the questions of land use and detention/retention effects on water quality as posed in the introduction. While valuable insights have been gained, the study still suffers from two major deficiencies. The first is the lack of an adequate period of record when both water quality and quantity data are available. The second deficiency, related to the first, is that the data on hand was collected during an abnormally dry year and may not reflect events during long term or more "normal" conditions. Fortunately, both deficiencies can be eliminated by continuing the current study for an additional period of time. All indications are that this will indeed be the case, as all of the principle parties involved have indicated a desire to see the study adequately achieve its objectives. Data collection is continuing uninterrupted into the 1981 calendar year. Given two more years of additional data, preliminary conclusions drawn here can be either verified or altered as the case may be.

A previous SFWMD study of nutrient flux in the Chandler Slough marsh (just downstream from the present Ash Slough study site) by Federico, et al. (1978), concluded that the marsh seemed to act as a net source of nitrogen and a net phosphorus sink. The results of the present studies of the Ash and Armstrong Slough detention/retention marshes seem to suggest that both marshes act as net annual nitrogen and phosphorus sinks. The efficiency of the Ash Slough marsh to remove phosphorus is comparatively low, though, and there are times when it is exported from the marsh in a manner that cannot be explained solely as a first flush phenomenon.

The differences in nutrient assimilative capacity of the three marshes might be explained in part by hydrological regimes and in part by land use activity in the watershed. Marsh surface area and predominant vegetative cover are also factors that probably should not be ignored. The Armstrong Slough marsh is a continually inundated system receiving at least a minimal base flow contribution from one of its tributary channels. The Ash Slough marsh is subjected to extremes of periodic inundation alternating with periods of complete emergence when no surface water remains standing on the marsh. The Chandler Slough marsh appears to be subject to a hydrologic regime somewhere between these two extremes with intermittent inflows but less frequent and shorter dry periods than at Ash Slough. Land use activities in the Ash Slough study watershed also represent an extreme in both drainage density, shown by Huber, et al. (1976), to be an important factor in quantity and quality of rainfall runoff, and by pasture maintenance activities necessary to support the cattle grazing density on the pasture that makes up the watershed.

Lack of storm events precluded the ability to confirm the existence of a "first flush" phenomenon at Armstrong Slough similar to that reported in the Chandler Slough study.

In light of current supplemental feeding practices on area dairies and the minimal needs of dairy cattle, the presence of high phosphorus levels in the waste stabilization lagoons and in runoff from the watershed is not surprising. Phosphorus has been identified as being important in the proper utilization of feed and uptake of calcium for milk production.

It is recommended that the total ration contain 0.4 percent or more of phosphorus, of which 50-65 percent appears to be absorbed during the digestive process (Harris, 1970). Supplemental feeding at SEZ Dairy is carried out in the milking barn, and phosphorus in spilled feed as well as in animal feces is flushed into the lagoon system. Nordstedt, et al. (1971), has reported the typical dairy lagoon system to be effective in reducing volatile solids and BOD given sufficient detention time in the first lagoon. They also report a decrease in phosphorus levels but note that nutrient content of the effluent from even a three-stage lagoon system is too high for direct discharge into natural waters.

Based on the data collected to date, the following conclusions can be drawn on the water quality impacts of detention/retention marshes and the agricultural land use practices in this portion of the Kissimmee River basin. It must be reiterated that these results are preliminary, being subject to the caveats set forth earlier in this discussion. Conclusions based on these results may be altered substantially as the data base is expanded and more normal hydrological conditions become established.

1. Land use intensity (as cattle grazing density) influences export rates of nutrients from respective watersheds.
2. Extensive ditching appears to decrease the nutrient assimilation capabilities of a watershed.
3. Agricultural watersheds in general absorb and store quantities of nutrients normally present in rainfall.
4. Cattle stocking densities of less than 0.25 cows per acre (1 cow/4 acres) do not appear to seriously impact water quality of runoff from the watershed.
5. Water quality impact of runoff is probably more a factor of

supplemental fertilization to maintain pasture than a direct impact of number of cattle, though the one is directly dependent on the other.

6. Runoff from dairy areas and discharge from dairy lagoons are particularly high in phosphorus. When the outfall at the dairy study site was monitored on a daily basis, distinct peaks in nitrogen and phosphorus as well as some of the physical parameters (especially conductivity) would occur coincident with observed discharge from the waste stabilization lagoon system.
7. Anaerobic conditions in the dairy waste stabilization lagoons contribute to the conversion of organic nitrogen to ammonia nitrogen, and to the suspension of ortho phosphorus in the lagoon water column.
8. The ability of the dairy lagoon system to reduce nutrient load is due primarily to the reduction of water volume of lagoon discharge from volume of discharge coming from the barn operation, not from reduction of nutrient concentrations in the water column in the lagoon.
9. The Ash Slough and Armstrong Slough detention/retention marshes appear to be annual net sinks of nitrogen and phosphorus.
10. Effluent from the Armstrong Slough marsh has consistently carried lower nitrogen and phosphorus levels than inflow into the marsh. It must be re-emphasized that influent quality is already fairly good. This fact, along with relatively long detention times, makes this result not

unexpected. The present plugged marsh system has yet to be stressed by either extreme hydrological conditions or poorer quality influent.

11. The Ash Slough marsh, while a net annual sink of nitrogen and phosphorus during this study, did periodically export significant amounts of phosphorus. This could not be correlated with either hydrologic regime or detention times. Future data may shed some light as to whether this phenomenon is seasonal or dependent on some man-induced activity in the watershed.

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