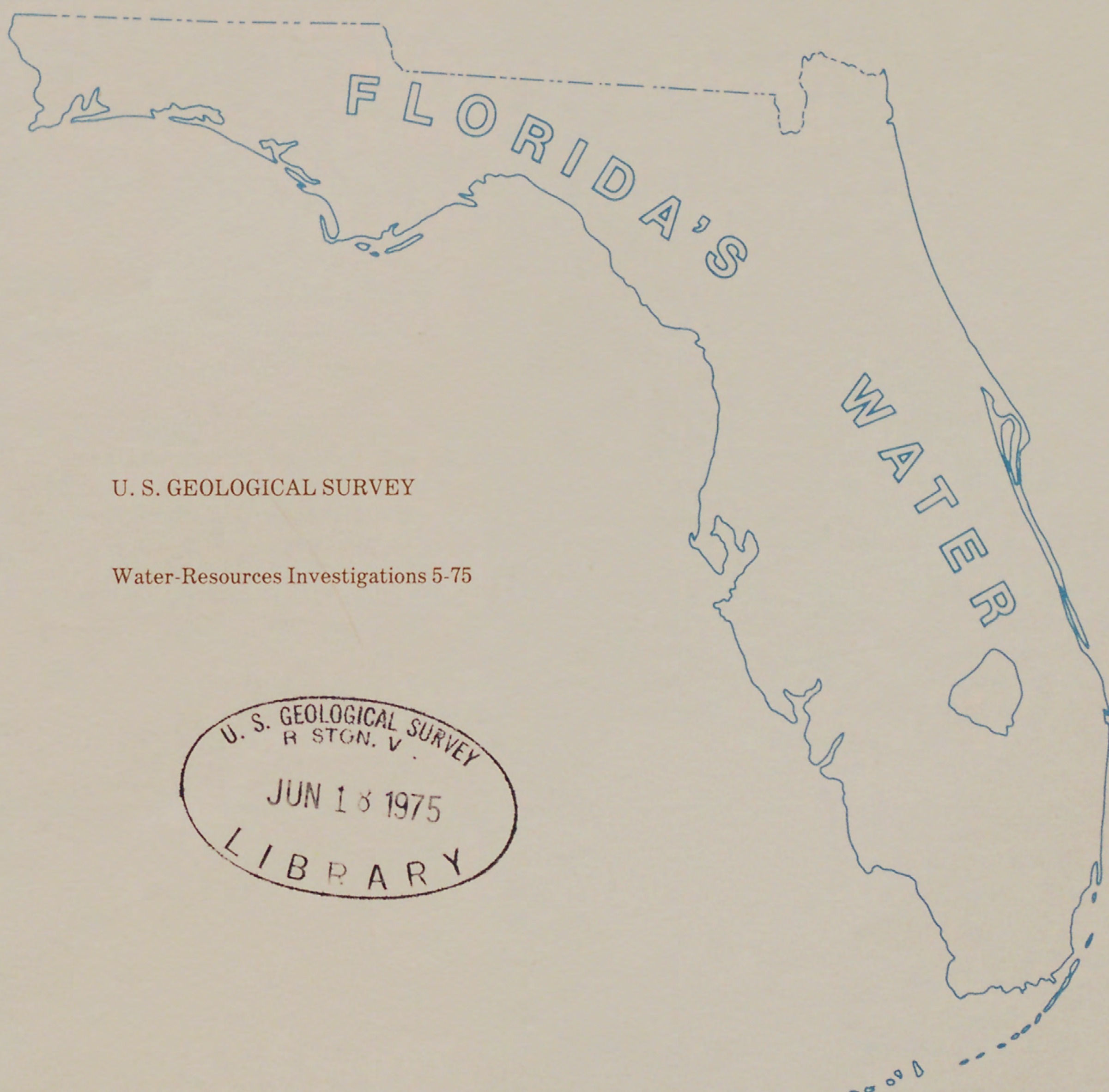
DISTRIBUTION OF NITROGEN AND PHOSPHORUS IN THE CONSERVATION AREAS IN SOUTH FLORIDA FROM JULY 1972 TO JUNE 1973



U. S. GEOLOGICAL SURVEY

Water-Resources Investigations 5-75

Prepared in cooperation with the

U. S. ARMY CORPS OF ENGINEERS

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

The following factors may be used to convert the metric units published herein to English units.

Multiply metric units	by	To obtain English units
	Length	
millimetres (mm)	0.03937	inches (in)
metres (m)	39.37	
	3.281	feet (ft)
kilometres (km)	0.6214	miles (mi)
	Area	
square kilometres (km^2)	0.3861	square miles (mi^2)
	Flow	
liters per second (l/s)	0.0353	cubic feet per second (ft^3/s)
cubic decimetres per second (dm^3/s)	0.0353	
cubic metres per second (m^3/s)	35.31	
	Mass	
tonne (t) or metric ton	1.102	ton (short)

DISTRIBUTION OF NITROGEN AND PHOSPHORUS IN THE CONSERVATION AREAS IN SOUTH FLORIDA FROM JULY 1972 TO JUNE 1973

By

Bradley G. Waller

ABSTRACT

From July 1972 to June 1973, 78 percent (5,200 metric tons or 5,700 tons) of the total nitrogen and 90 percent (207 metric tons or 228 tons) of the total phosphorus entering the conservation areas was contributed by bulk precipitation (rainfall and dry fallout). Controlled and noncontrolled surface-water discharge contributed the remainder: 22 percent (1,460 metric tons or 1,610 tons) of total nitrogen and 10 percent (22.4 metric tons or 24.7 tons) of total phosphorus. Of the water lost, 53 percent was by seepage and 47 percent by surface-water discharge, of which 11 percent flowed eastward and 89 percent southward to Everglades National Park. Most surface-water loads, 90 percent of the total nitrogen (696 metric tons or 767 tons) and 88 percent of the total phosphorus (5.2 metric tons or 5.7 tons) leaving the conservation areas entered Everglades National Park. About 5,000 metric tons (5,500 tons) of total nitrogen and nearly 220 metric tons (242 tons) of total phosphorus were apparently retained within the conservation areas. This retention constitutes 74 percent of the total nitrogen and 96 percent of the total phosphorus that entered the conservation areas from July 1972 to June 1973.

INTRODUCTION

The term "Everglades basin" as used in this report (fig. 1) extends from Lake Okeechobee in the north, southward through Everglades National Park. It is bordered on the west by the Big Cypress Swamp and on the east by agricultural lands and rapidly expanding urban areas. Within the Everglades basin are three water conservation areas utilized for water storage and recreational use. The study area (fig. 1) includes all the conservation areas except area 2B. That part of the Everglades basin between Lake Okeechobee and the conservation areas is agricultural,

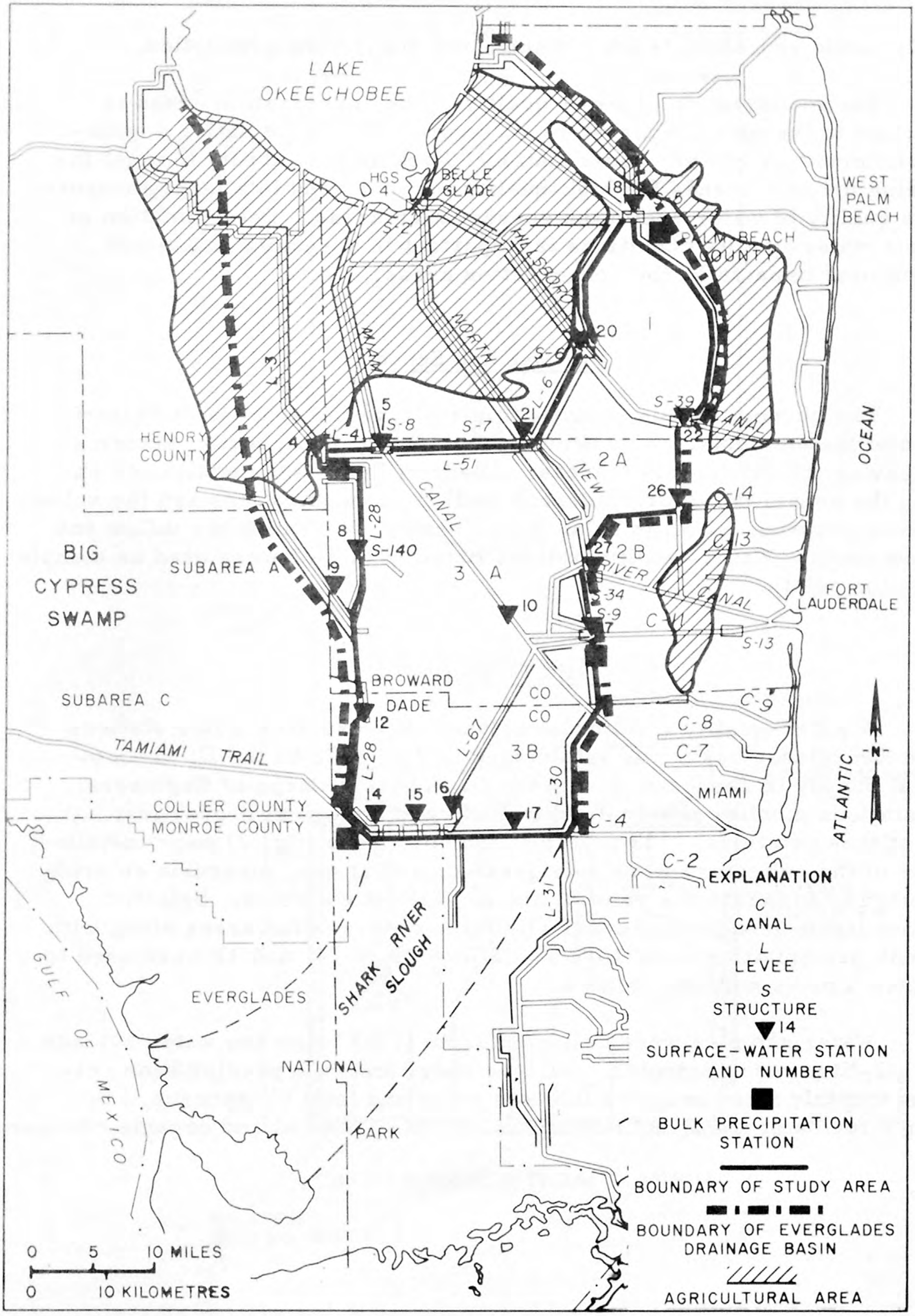

Figure 1.--Location of water-quality monitoring stations and delineation of major agricultural areas.

chiefly cattle ranching, truck farming, and sugar cane production.

The maintenance of water quality in the conservation areas is important to the marsh ecosystem. The preservation of native vegetative communities in Everglades National Park and the ability to meet increasing urban demands for high-quality water depend to a large measure on the quality of water within the conservation areas. Determination of present water-quality conditions is important in assessing urban and agricultural impacts on the conservation areas.

Purpose and Scope

The purpose of this study is to determine the sources and distribution of the nutrients, as total nitrogen and total phosphorus, entering and leaving the conservation areas. Loads of these two constituents entering the conservation areas depend on their concentrations and the volume of water involved. A mass balance was used to determine the inflow and outflow loads. Water-quality stations listed in table 1 were used as sample collection points.

Data Collection

A water-quality monitoring network of 25 surface water stations in the Everglades basin was established in July 1972 by the U. S. Geological Survey in cooperation with the U. S. Army Corps of Engineers. The stations monitor physical, chemical, and biological properties. At four of these stations, bulk precipitation collectors (fig. 2) were installed. Three of the collectors were refrigerated, and at one, mercuric chloride was used to preserve the rainfall and dry fallout collected. Selected stations (table 1) adjacent to and within the conservation areas along with the bulk precipitation collectors at stations 4, 7, 14, and 18 were used to compute a mass nutrient balance.

Water samples were collected 0.3m (1 ft) below the water surface with a 2-litre water sampler. Surface water and bulk precipitation collected monthly were analyzed for both ortho and total phosphorus, inorganic forms of nitrogen (ammonium, nitrate, nitrite) and organic nitrogen.

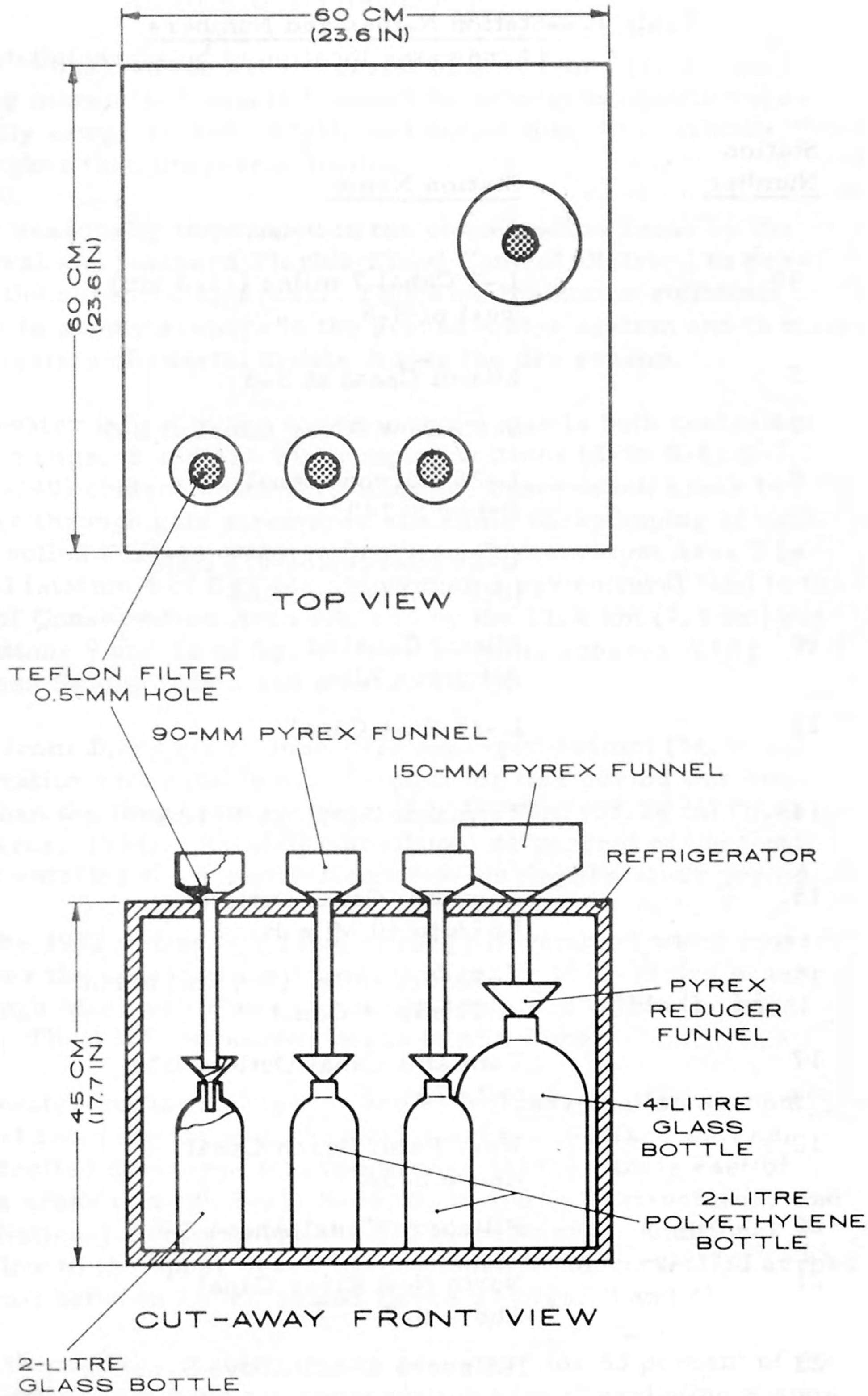

Figure 2.--Top and front views of refrigerated bulk precipitation collector.

Table 1.--Station Names and Numbers
(* indicates location of bulk precipitation station.)

Station Number	Station Name	Lat-Long or Downstream Order Number
4*	L-3 Canal 7 miles (11.3 km) west of S-8	26° 19' 45" 80° 53' 10"
5	Miami Canal at S-8	02286700
7*	South New River Canal at S-9	02285400
8	L-28 Borrow Canal Below S-140	26° 12' 40" 80° 49' 40"
9	L-28 Interceptor 0.5 mile (0.8 km) below SR84	26° 09' 45" 80° 53' 30"
10	Miami Canal at Alligator Alley	26° 08' 50" 80° 38' 10"
12	L-28 East Canal	25° 56' 00" 80° 48' 45"
14*	Tamiami Canal Ab S-12A	25° 45' 42" 80° 49' 30"
15	Tamiami Canal Outlets L67A to 40 Mile Bend	02289040
16	L67A 0.5 mile (0.8 km) north of Tamiami Canal	25° 46' 20" 80° 39' 50"
17	Tamiami Canal Outlets L30 to L67A	02289060
18 *	West Palm Beach Canal Above S-5A	02278450
20	Hillsboro Canal Above S-6	02281200
21	North New River Canal Above S-7	26° 20' 00" 80° 32' 10"
22	Hillsboro Canal Above S-10	26° 24' 00" 80° 23' 00"
26	North New River Canal Below S-34	02284700
27	Pompano Canal Below S-38	02281700

The water conservation areas consist of 3,485 km^2 (1,345 mi^2) of flat, low-lying marsh land covered chiefly by emergent aquatic vegetation, principally sawgrass and cattail, and dotted with "tree islands," areas slightly higher than the marsh land.

Water is seasonally impounded in the conservation areas by the C&SFFCD (Central and Southern Florida Flood Control District) to prevent flooding of the surrounding areas. This also maintains sufficient water in storage to supply seepage to the ground-water system and to maintain levels in a system of coastal canals during the dry season.

Surface-water inflow to the conservation areas is both controlled and noncontrolled (figs. 3 and 4). Six pumping stations (S-5, S-6, S-7, S-8, S-9, and S-140) control water flow into the conservation areas by gravity discharge through gate structures and some backpumping of canal water. Noncontrolled surface-water inflow into Conservation Area 3 is by the L-3 Canal (station 4 of fig. 1), which drains agricultural land to the north and west of Conservation Area 3A, and by the 11.4 km (7.1 mi) gap in Levee 28 (stations 9 and 12 of fig. 1), which drains subarea A (fig. 3) of the Big Cypress Swamp (Klein and others, 1970).

Rainfall from July 1972 to June 1973 averaged 886mm (34.90 in) over the conservation areas (table 2). Rainfall for this period was considerably less than the long-term average of 1,352 mm (53.24 in) (U.S. Dept. of Commerce, 1964). Rainfall contributed 41 percent of the total volume of water entering the conservation areas during the study period.

During the 1972 wet season (June through November) water moved as sheet flow over the conservation areas, and in the 1972-73 dry season (December through May) water was primarily contained within the canal system (fig. 3). The 1973 wet season began in mid-June.

Surface-water outflow, seepage, and evapotranspiration account for the water lost from the three conservation areas. Surface water is released by controlled discharge into two areas: (1) the canals east of the conservation areas through S-31, S-34, S-38 and S-39 structures, and (2) Everglades National Park through the S-12 structures. Additional surface-water flow to the upper Shark River Slough is noncontrolled across the Tamiami Trail between Levee 30 and Levee 67 (figs. 3 and 4).

Seepage through the eastern levees accounted for 53 percent of the total quantity of water lost from the conservation areas, excluding evapotranspiration. Surface-water discharge to the east accounted for 5 percent

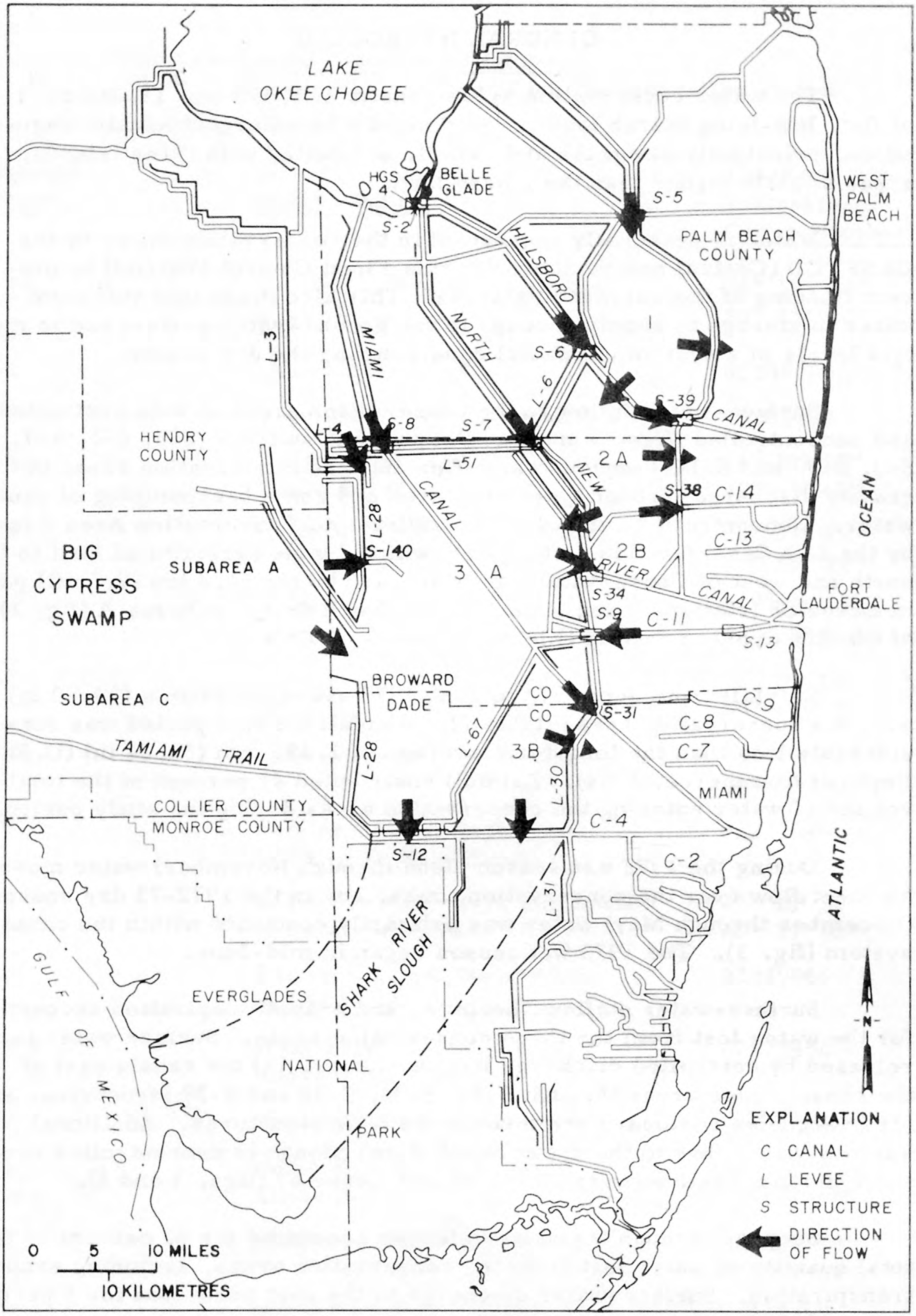

Figure 3.--Major inflow and outflow points in the conservation areas.

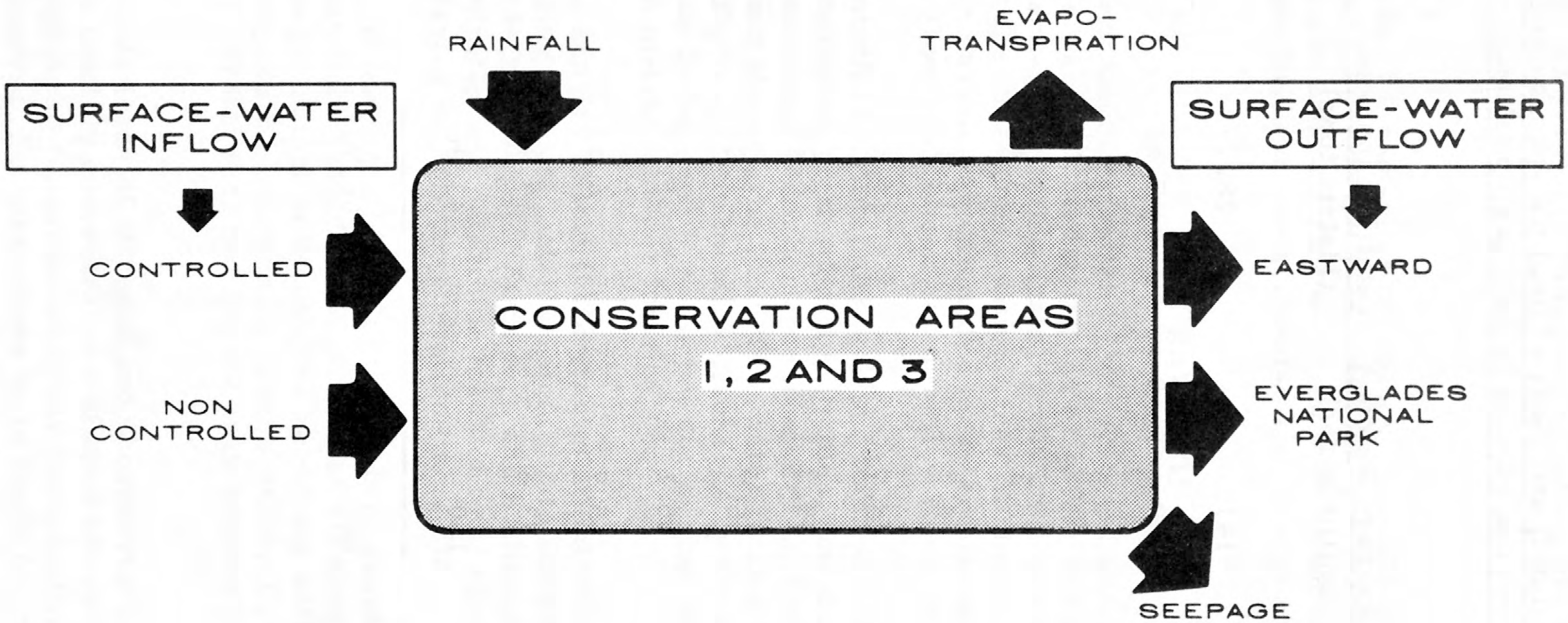

Figure 4.--Schematic model of general hydrology in the conservation areas.

Table 2. --Average rainfall and loads of total phosphorus and total nitrogen contributed by bulk precipitation.

Date	Average Rainfall (millimetres)	Total Phosphorus (Metric tons)	Total Nitrogen (Metric tons)
July, 1972	141	28.79	623.9
August	160	17.43	783.7
September	61.4	5.01	263.8
October	58.1	13.44	312.9
November	54.3	15.15	231.3
December	44.7	12.0	173.0
January 1973	35.8	8.28	138.0
February	26.7	1.27	75.5
March	55.1	35.59	354.4
April	15.7	6.42	151.6
May	73.4	19.96	937.1
June	160	43.36	1163.7
TOTAL	886	206.7	5209.5

and to the south, 42 percent. Evapotranspiration was not determined because nutrients removed from the conservation areas by gaseous diffusion are difficult to measure and important only for some nitrogen compounds.

The loads of the gaseous nitrogen compounds (ammonia and elemental nitrogen) lost were not calculated into the mass balance. They were not measured and probably were not significant when compared with the total nitrogen loads in surface-water and bulk precipitation.

MASS BALANCE

Movement and distribution of nitrogen and phosphorus in the conversation areas was evaluated using the principle of conservation of mass. All major surface-water inflow (gain) to and outflow (loss) from was determined for the three conservation areas (table 3). Precipitation (table 2) on these areas was calculated as an additional inflow (gain) and seepage (table 3) was calculated as an outflow (loss) to these areas.

Concentrations of total nitrogen and total phosphorus (tables 4 and 5) were determined from monthly samples, and discharge measurements were determined from continuous records. The monthly loads of total nitrogen and phosphorus in surface water (tables 6 and 7) were calculated by multiplying mean monthly discharge by the concentration of the two nutrients in the sample collected during that month. The loads are reported in metric tons per month.

Rainfall and dry fallout (bulk precipitation) were converted to a total volume using average monthly rainfall data for the conservation areas supplied by the Corps of Engineers and multiplied by the average nutrient concentrations to determine loads of total nitrogen and total phosphorus entering as bulk precipitation (table 2).

Seepage through the levees to the eastern coastal areas is a major component of the water budget. To determine nutrient loads leaving the system in seepage, sampling techniques requiring wells and cores of the unsaturated zone would be necessary (Jacob Rubin, U. S. Geol. Survey, oral commun., 1973). Such techniques were beyond the scope of the investigation.

To compute loads of nitrogen and phosphorus leaving in the seepage water, average monthly concentrations of total nitrogen and total phosphorus from within the conservation areas were multiplied by the seepage discharge estimates. No corrections were made for adsorption of nutrient

Table 3.--Mean monthly discharge for inflow and outflow points in the conservation areas.
(cubic metres per second)

Station	(1972) July	Aug.	Sept.	Oct.	Nov.	Dec.	(1973) Jan.	Feb.	Mar.	Apr.	May	June	Total
Inflow Points													
18	12.	7.2	2.8	1.3	3.8	1.8	3.4	2.0	1.6	0.0	1.0	13.	50
20	5.2	3.1	1.9	.37	1.1	.28	1.6	1.2	.68	.06	1.4	7.8	25
21	3.4	3.4	2.2	.45	.99	.06	1.5	.65	.20	1.7	3.6	4.7	23
5	2.8	3.4	3.7	.76	.25	.28	1.4	.82	.45	0	8.7	13.	36
7	8.7	6.7	5.3	4.8	6.4	3.1	3.4	4.3	2.1	.88	0	5.2	51
8	3.7	3.4	4.8	2.5	.23	.28	.31	.08	.06	.03	0	.54	16
4	.37	0.	.08	0	0	0	0	0	0	0	0	0	.45
9, 12	8.8	4.7	13.	3.1	3.8	1.0	1.6	.25	.08	.03	.20	.93	38
Monthly total surface inflow	45	32	34	13	17	6.8	13	9.3	5.2	2.7	15	46	239
Outflow Points													
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.56	.56	.56	1.7
26	0	0	0	0	0	0	0	0	0	2.7	1.6	1.4	5.7
27	0	0	0	0	0	0	0	0	1.1	.91	1.1	.62	3.7
22	0	0	0	.40	.45	.14	.34	.42	1.1	2.2	1.3	0	6.4
17	1.4	2.2	4.0	2.0	1.7	.76	.76	.42	.25	.06	.06	.31	14
S-12 structures 14-16	14.	7.4	20	25	24	18	13	6.2	2.5	2.0	.79	3.4	136
Monthly total surface outflow	16	9.6	24	28	26	19	14	7.0	5.0	8.4	5.4	6.3	168
Seepage Area 1 1/	5.1	5.6	6.8	6.4	6.2	6.1	6.1	6.1	5.3	4.0	2.3	4.0	64
Seepage Area 2A 1/	5.4	5.9	5.9	5.9	5.9	5.1	4.8	2.8	1.1	.56	2.8	4.0	50
Seepage Area 3B 1/	6.2	6.6	6.6	6.5	6.2	6.1	6.3	5.6	5.2	4.4	6.3	5.6	72
Monthly total Outflow seepage	17	18	19	19	18	17	17	15	12	9.0	11	14	186

1/ Seepage outflow from U. S. Corps of Engineers

Table 4.--Total nitrogen concentrations at surface inflow and outflow points in the conservation areas.
(milligrams per litre)

Station 1/	(1972) July	Aug.	Sept.	Oct.	Nov.	Dec.	(1973) Jan.	Feb.	Mar.	Apr.	May	June
Inflow Points												
18	6.3	2.9	2.7	2.0	3.1	2.6	2.3	3.9	2.4	1.6	1.6	2.0
20	4.5	4.7	3.1	2.3	2.9	2.3	2.6	3.1	4.3	1.9	1.7	4.7
21	2.7	3.1	1.9	2.5	1.9	1.9	2.3	2.4	4.6	1.6	1.6	2.6
5	2.7	2.2	3.5	2.2	2.3	1.6	3.5	1.9	2.5	2.1	1.4	1.3
7	2.0	1.7	1.7	1.8	1.6	1.4	1.7	2.0	1.6	2.0	2.4	1.4
8	2.4	1.0	2.0	1.6	1.5	1.8	1.2	2.2	1.4	1.3	1.5	1.9
4	2.0	2.3	2.5	1.6	1.2	1.0	0.9	1.4	1.1	1.2	1.1	1.3
9, 12 Avg.	1.8	1.6	2.0	1.3	0.95	0.96	1.0	1.2	1.6	1.3	1.3	1.1
Outflow Points												
10	1.8	2.0	1.8	1.2	1.4	1.9	1.6	2.2	1.6	1.4	1.5	1.5
26*	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
27*	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
22	3.6	2.0	2.4	1.9	2.4	1.5	2.1	1.6	2.4	2.0	1.6	2.1
17	2.6	1.7	1.8	1.6	1.9	1.6	2.1	1.6	1.7	1.4	1.6	1.5
14-16 Avg.	2.2	1.8	1.7	1.4	1.8	1.3	1.9	1.8	1.9	2.4	2.1	1.6

* Average value

1/ See figure 1 for location

Table 5. --Total phosphorus concentrations at surface inflow and outflow points in the conservation areas.
(milligrams per litre)

Station 1/	(1972) July	Aug.	Sept.	Oct.	Nov.	Dec.	(1973) Jan.	Feb.	Mar.	Apr.	May	June
Inflow Points												
18	0.6	0.07	0.08	0.04	0.02	0.05	0.16	0.10	0.02	0.02	0.02	0.02
20	.01	.24	.10	.01	.04	.05	.09	.06	.04	.01	.02	.01
21	T**	.12	.16	.02	.01	.07	.01	.03	.02	.02	.01	.02
5	.02	.02	.02	.02	.02	.01	.02	.03	.04	.02	.01	.01
7	T	.01	.02	.01	.00	.01	.01	.01	.01	.04	.01	.02
8	.01	.01	T	.01	.02	.01	.02	.02	.02	.02	.02	.01
4	.03	.03	.02	.02	.02	.03	.15	.20	.21	.14	.13	.07
9, 12 Avg.	T	.01	.02	.02	.02	.02	.01	.01	.01	.02	.01	.01
Outflow Points												
10	0.01	0.04	T	T	0.01	T	0.02	0.02	0.02	0.02	0.01	0.01
26	.00	.02*	0.01	0.02*	.02*	0.02*	.03	.02*	.02*	.02*	.02*	.02*
27	.02*	.02*	.02*	.02*	.02*	.02*	.02*	.02*	.02*	.02*	.02*	.02*
22	T	.02	.02	.02	.01	.02	.13	.06	.02	.01	.01	.01
17	T	.01	.01	.01	.01	.01	.01	.01	T	.02	.01	.01
14-16 Avg.	.02	.01	.02	.02	.02	.02	.01	.01	.01	.02	.01	.01

* Concentrations reported in average values for 2 years of sampling June, 1971-July 1973, except during months sampled.

** Values range between 0.001 and 0.005.

1/ See figure 1 for location.

Table 6.--Monthly nitrogen loads for inflow and outflow points in the conservation areas.
(Metric tons)

Inflow Points

Stations 1/	July 1972	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1973	Feb.	Mar.	Apr.	May	June	Surface Inflow Total
18	142.5	56.3	19.8	7.2	31.5	12.3	20.7	19.1	10.5	0	4.6	72.8	397.3
20	63.7	39.4	15.6	2.3	8.7	1.7	11.3	8.7	7.8	.3	6.7	98.5	264.7
21	25.0	28.3	10.8	3.0	5.0	.3	9.0	3.9	2.4	7.3	15.6	33.1	143.7
5	20.2	20.6	34.9	4.5	1.5	1.2	13.1	3.8	3.0	0	33.8	47.6	183.0
7	45.5	29.7	23.4	23.1	28.1	12.1	15.5	20.3	9.2	4.6	0	18.8	230.3
8	23.6	8.9	25.7	10.7	0.9	1.4	1.0	.4	.2	.1	0	2.8	75.7
4	2.0	0	.6	0	0	0	0	0	0	0	0	0	2.6
9, 12	42.1	19.9	69.7	10.7	9.7	2.7	4.4	.7	.4	.1	.7	2.7	163.8
Monthly Total Surface Inflow	364.6	203.1	200.5	61.5	85.4	31.7	75.0	56.9	33.5	12.4	61.4	276.3	1462.3

Outflow Points

Stations	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
													Surface Outflow Total
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	2.3	2.3	6.7
26	.0	.0	.0	.0	.0	.0	.0	.0	.0	12.9	7.8	7.0	27.7
27	.0	.0	.0	.0	.0	.0	.0	.0	4.0	3.2	4.1	2.3	13.6
22	.0	.0	.0	2.1	3.0	.6	1.9	1.7	7.1	11.3	5.4	0	33.1
17	9.8	9.9	19.5	8.5	8.8	3.3	4.3	1.6	1.2	.2	0	1.2	68.3
S-12 Structures, 14-16	84.4	36.3	92.3	98.3	115.6	63.2	67.6	26.2	12.9	12.2	4.4	14.2	627.6
Monthly Total Surface Outflow	94.2	46.2	111.8	108.9	127.4	67.1	73.8	29.5	25.2	41.9	24.0	27.0	777.0
													Seepage Outflow Total
Seepage from Cons. Area 1	32.9	26.3	32.3	30.6	34.5	24.8	33.4	24.6	28.4	20.0	10.6	18.4	316.8
Seepage from Cons. Area2A	34.7	27.7	28.3	28.3	32.8	20.5	26.4	11.3	6.1	2.8	13.3	18.0	350.2
Seepage from Cons. Area3B	40.2	30.7	31.7	31.2	34.3	24.8	34.6	22.2	27.6	22.0	29.6	25.9	354.8
Monthly Total Seepage Outflow	107.8	84.7	92.3	90.1	101.6	70.1	94.4	58.1	62.1	44.8	53.5	62.3	921.8

1/ See figure 1 for location

Table 7.--Monthly phosphorus loads for inflow and outflow points in the conservation areas.
(Metric tons)

	1972						1973						
	Inflow Points												
Stations[1/]	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Surface Inflow Total
18	5.02	1.93	0.17	0.09	0.24	0.10	0.53	0.34	0.37	0.00	0.06	1.78	10.63
20	1.22	0.51	.20	.01	.07	.01	.04	.67	.18	.00	.15	1.05	4.11
21	0.10	.24	.13	.02	.03	.00	.02	.19	.08	.10	.10	.90	1.91
5	.19	.25	.35	.04	.01	.01	.09	.03	.03	.03	.00	.47	1.83
7	.28	.23	.13	.52	.14	.17	.03	.10	.11	.02	.00	.08	1.81
8	.22	.14	.23	.16	.01	.01	.01	.00	.00	.0	.00	.01	0.79
4	.15	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	0.20
9, 12	.26	.18	.35	.12	.12	.03	.02	.01	.01	.00	.01	.03	1.14
Monthly Total Surface Inflow	7.44	3.48	1.61	0.96	0.62	0.33	0.74	1.34	0.78	0.12	0.79	4.21	22.42
	Outflow Points												Surface Outflow Total
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12	.07	.06	.25
27	.00	.00	.00	.00	.00	.00	.00	.00	.06	.05	.06	.03	.20
22	.00	.00	.00	.01	.01	.00	.00	.02	.07	.08	.03	.00	.22
17	.04	.05	.05	.08	.04	.02	.01	.01	.01	.00	.00	.01	.32
S-12 Structures, 14-16	.38	.16	.48	1.16	.77	.48	.81	.18	.13	.11	.04	.15	4.85
Monthly Total Surface Outflow	0.42	0.21	0.53	1.25	0.82	0.50	0.82	0.21	0.27	0.36	0.22	0.26	5.86
													Seepage Outflow Total
Seepage from Cons. Area 1	0.14	0.14	0.13	0.28	0.18	0.15	0.16	0.22	0.26	0.16	0.08	0.16	2.06
Seepage from Cons. Area2A	.14	.14	.11	.25	.18	.12	.13	.10	.05	.02	.10	.16	1.50
Seepage from Cons. Area3B	.17	.16	.12	.28	.18	.15	.17	.20	.25	.17	.22	.23	2.30
Monthly Total Seepage Outflow	0.45	0.44	0.36	0.81	0.54	0.42	0.46	0.52	0.56	0.35	0.40	0.55	5.86

1/ See figure 1 for location

species by canal sediments or levee materials; thus, a maximum possible loss was calculated.

Outflow loads (seepage and surface-water outflow) were subtracted from inflow loads (bulk precipitation and surface-water inflow) to get total retention (storage) of each constituent within the conservation areas. Net gains of total nitrogen and total phosphorus were calculated for July 1972 - June 1973 (figs. 5 and 6, table 8). Comparisons of net gains with previous periods is impossible due to lack of an integrated, periodic water-quality monitoring network in the conservation areas before July 1972.

Fires occur periodically within the conservation areas and most likely displace or remove nutrients and other constituents from the burned area. The magnitude of nutrient removal due to fires was not determined.

Nitrogen

The conservation areas gained about 5,000 metric tons (5,500 tons) of total nitrogen during the 12-month study (table 7). The average gain for each of the three wettest months, July and August 1972, and June 1973, including the near wettest month, May 1973, was 978 metric tons, in contrast to 132 metric tons for each of the remaining drier months. The greater gain during the wet months was due to greater rainfall and greater surface-water inflow to the conservation areas. The large gains incurred during May 1973 were due to high concentrations of total nitrogen in bulk precipitation.

Bulk precipitation was the single largest source of total nitrogen entering the conservation areas. It contributed about 5,200 metric tons (5,700 tons) of nitrogen (table 2), which was 78 percent of the total nitrogen that entered these areas.

The average nitrogen composition in bulk precipitation was 48 percent organic nitrogen, 29 percent ammonium, 20 percent nitrate and 3 percent nitrite. Nitrogen species at 25 surface water stations in the Everglades basin average 81 percent organic nitrogen, 9 percent ammonium, 8 percent nitrate, and 2 percent nitrite. Although the bulk precipitation collectors at three locations were refrigerated and the one at the fourth site treated with mercuric chloride, the accuracy of speciation in rainfall is doubtful due to the long collection period of 1 month.

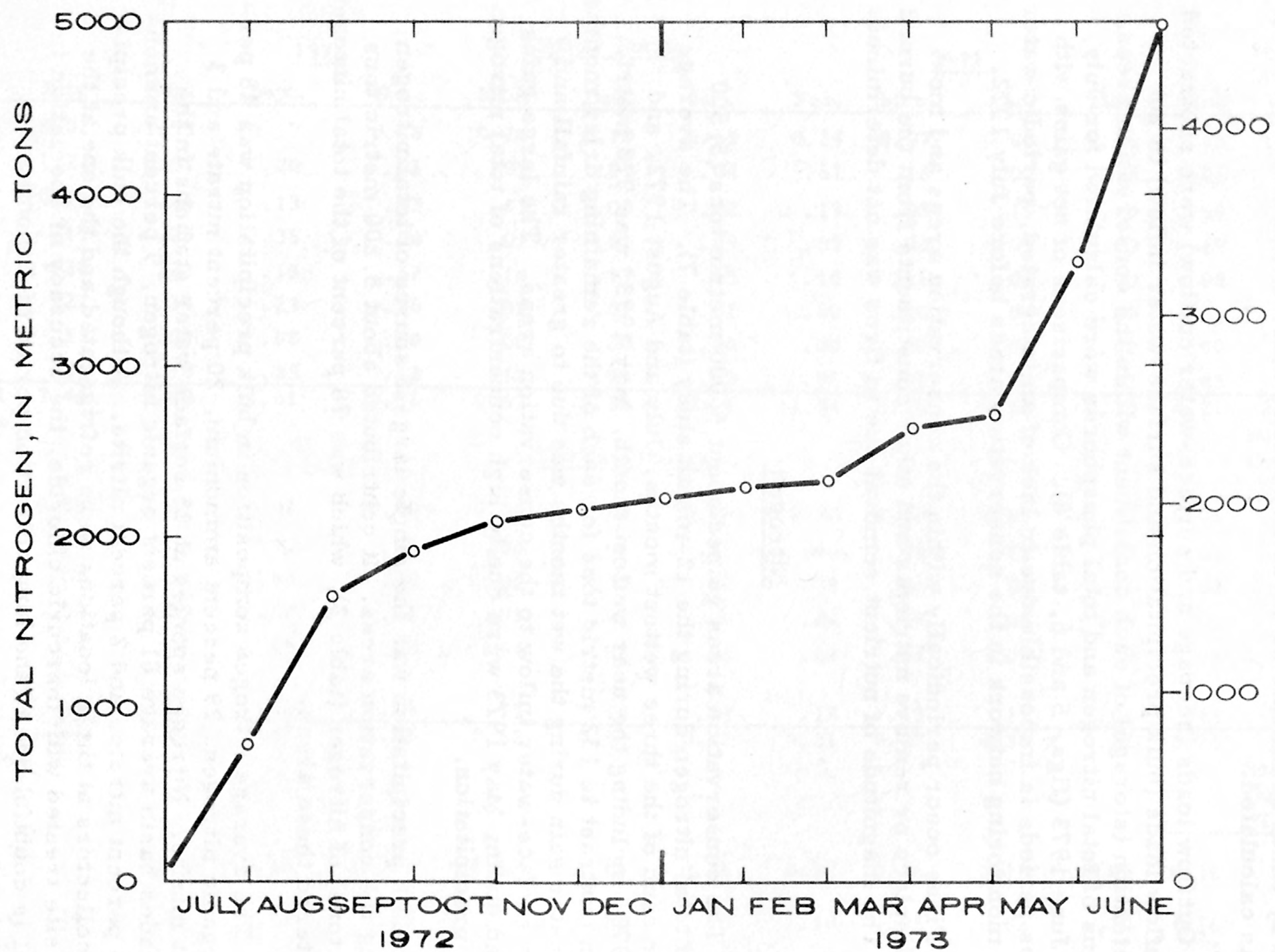

Figure 5.--Net gain of total nitrogen in the conservation areas.

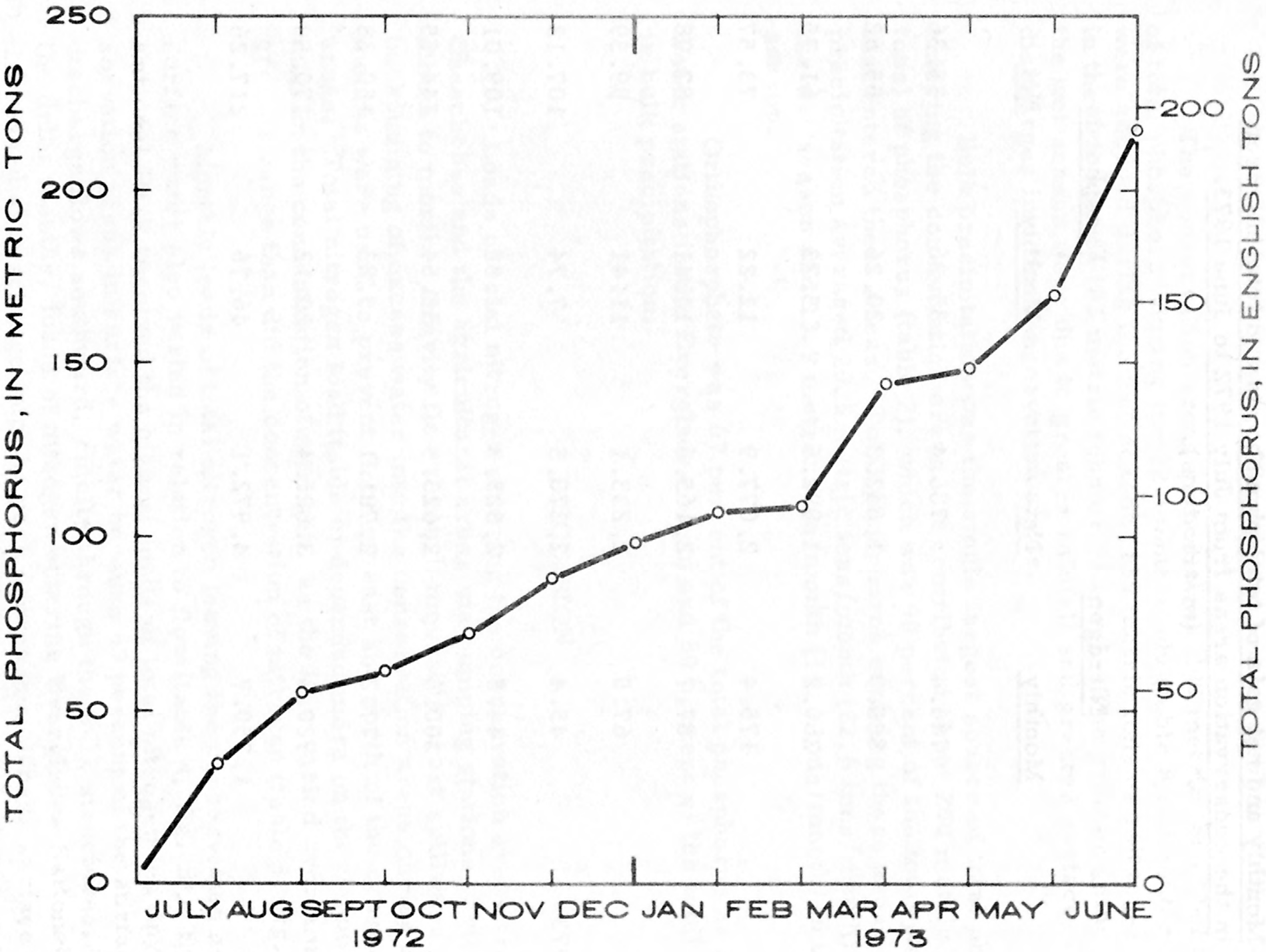

Figure 6.--Net gain of total phosphorus in the conservation areas.

Table 8. --Monthly and net gain of total phosphorus and total nitrogen in the conservation areas from July 1972 to June 1973. (metric tons)

Date	Nitrogen Monthly	Nitrogen Net	Phosphorus Monthly	Phosphorus Net
July, 1972	786.4	786.4	35.36	35.36
August	855.9	1,642.3	20.26	55.62
September	260.2	1,902.5	5.73	61.35
October	175.4	2,077.9	12.22	73.57
November	87.7	2,165.6	14.41	87.98
December	67.5	2,233.1	11.41	99.39
January 1973	45.4	2,278.5	7.74	107.13
February	44.8	2,323.3	1.88	109.01
March	300.6	2,623.9	35.54	144.55
April	77.2	2,701.1	5.83	150.38
May	920.3	3,621.4	20.12	170.50
June	1,350.7	4,972.1	46.76	217.26

Phosphorus

The conservation areas gained about 200 metric tons (242 tons) of total phosphorus during the 12-month study (table 8). Greater gains were accrued during the wet season (135 metric tons or 148 tons) than in the dry season (83 metric tons or 91 tons). The greater gains during the wet season were due to greater rainfall and greater surface-water discharges into the conservation areas.

Bulk precipitation was the single largest source of total phosphorus entering the conservation areas. It contributed about 200 metric tons (220 tons) of phosphorus (table 2), which was 90 percent of the total phosphorus that entered these areas. Total phosphorus entering these areas from bulk precipitation averaged 20.5 metric tons/month (22.6 tons/month) during the wet season and 13.9 metric tons/month (15.3 tons/month) in the dry season.

Orthophosphate was 67 percent of the total phosphorus at 25 surface water stations in the Everglades basin and 80 percent of the total phosphorus in bulk precipitation.

DISCUSSION

Loads of total nitrogen entering the conservation areas from Lake Okeechobee and the agricultural areas via pumping stations varied from month to month. Gravity flow through moveable crest spillways, and backpumping of excess water into the conservation areas during the wetter months were used to prevent flooding east and north of the conservation areas. Total nitrogen load (table 6) depended more on the volume of water than on the concentration of nitrogen, as the flow varied over a much greater range than did the concentration of nitrogen (table 4, fig. 7).

Monthly loads of total nitrogen leaving the conservation areas in surface water also varied in relation to flow (table 4, fig. 8). Everglades National Park received the highest loads of total nitrogen leaving the conservation areas in surface water because 89 percent of the surface-water discharge flows southward, chiefly through the S-12 structures. During the drier months, loads of nitrogen entering Everglades National Park decreased as discharge into the park decreased. Then, surface water discharged eastward carried much of the total nitrogen lost in surface waters (table 6).

Total phosphorus loads entering and leaving the conservation areas were also largely dependent on the volume of water being backpumped and

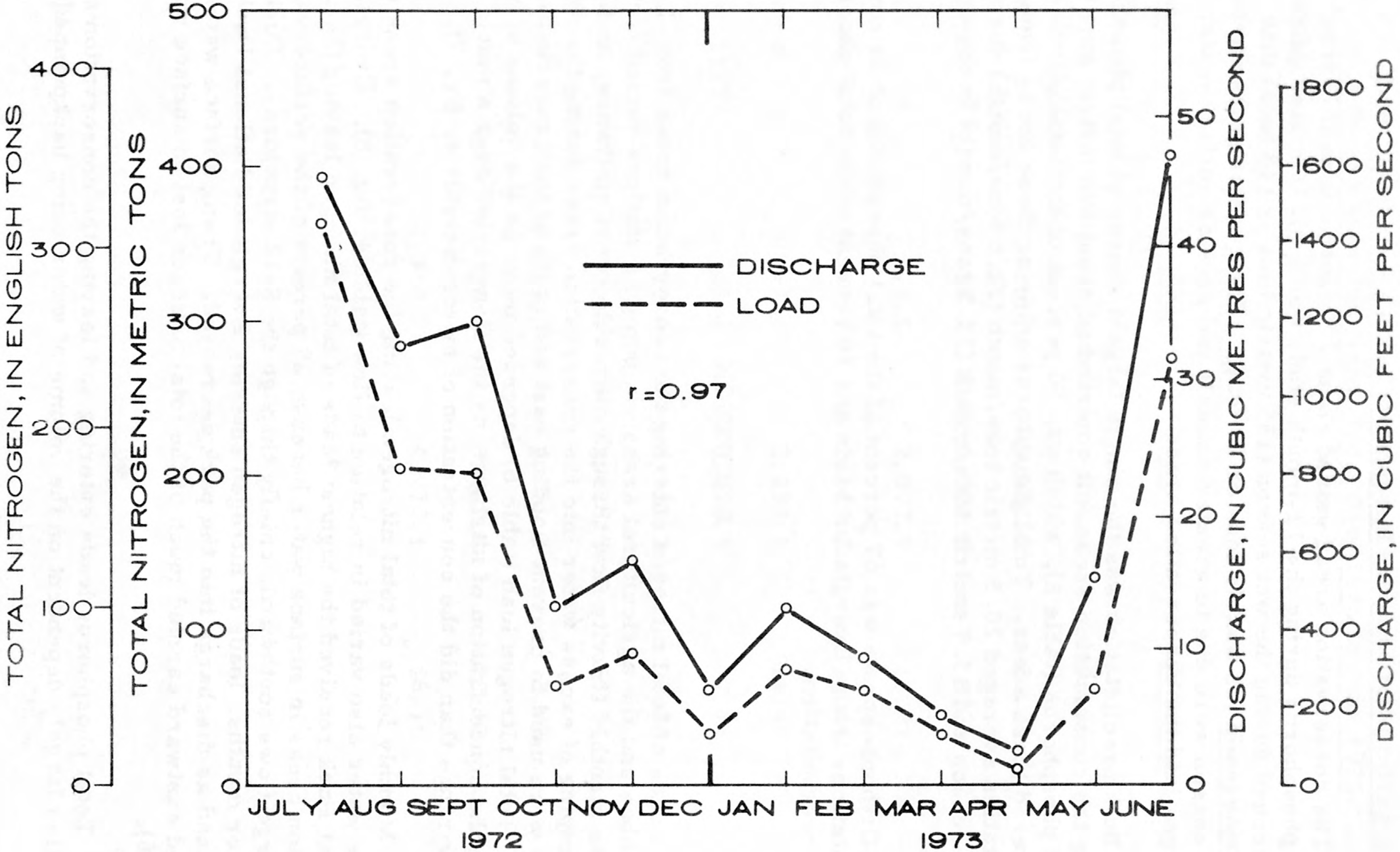

Figure 7.--Relation between monthly total nitrogen load and surface-water inflow.

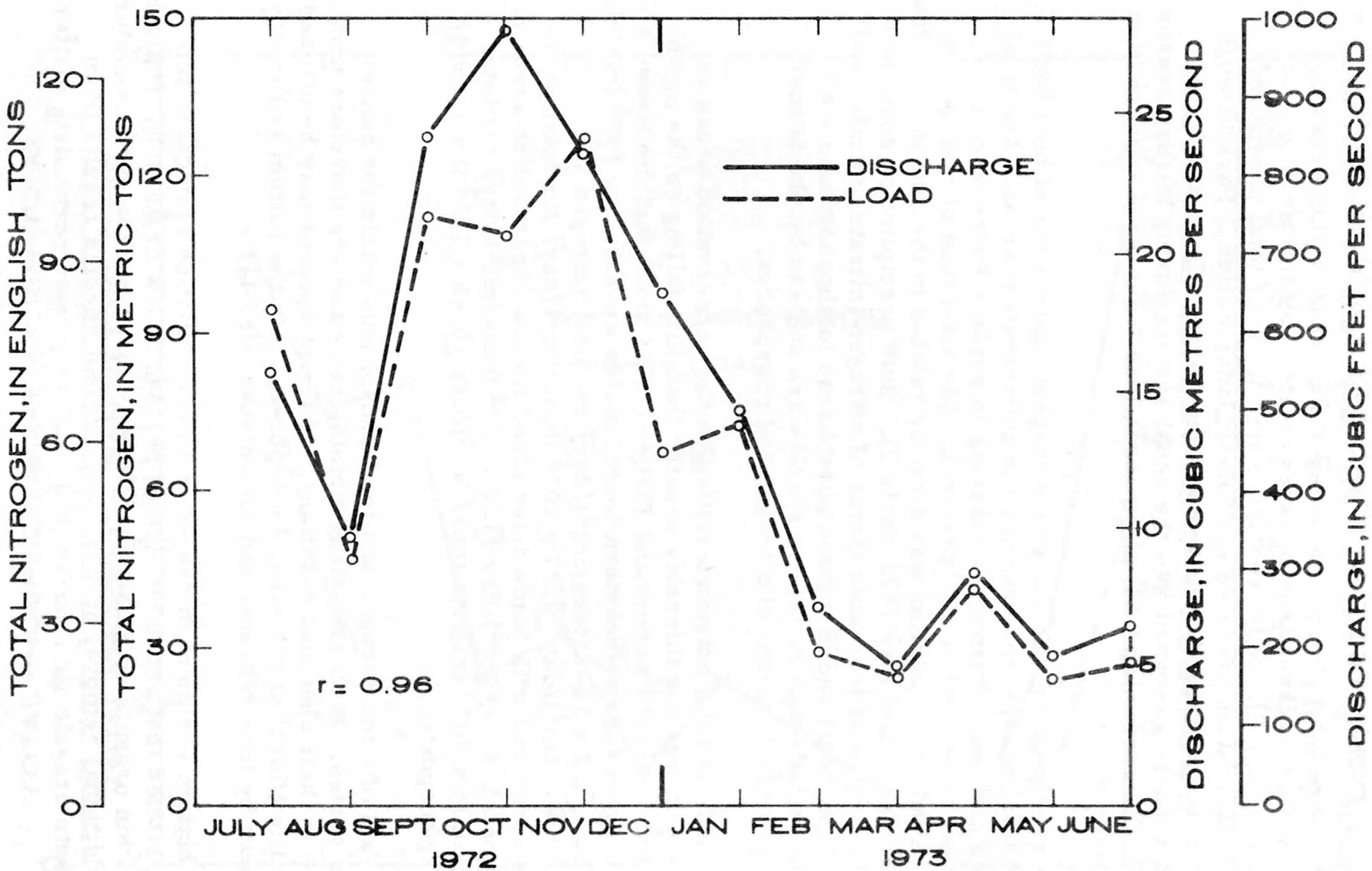

Figure 8.--Relation between monthly total nitrogen load and surface-water outflow.

discharged (table 7, figs. 9 and 10). When large volumes of water were backpumped, more total phosphorus entered the conservation areas than during months when backpumping of excess water was intermittent and of lower volume (fig. 9). Most surface-water loads of total phosphorus leaving the conservation areas entered Everglades National Park through the S-12 structures and by non-controlled flow between L-30 and L-67. Controlled discharge eastward into the canal system during the dry season accounted for the remaining total phosphorus load leaving the conservation areas in surface water.

Bulk precipitation was the single largest contributor of both total nitrogen and total phosphorus entering the conservation areas. Loads of total nitrogen and total phosphorus entering in surface water were considerably less (22 percent and 10 percent). The total load of nitrogen or phosphorus in bulk precipitation was directly related to the amount of rainfall except in March and May 1973 (table 2). Bulk precipitation contained a greater percentage of inorganic forms of nitrogen (nitrate, nitrite, and ammonia - 52 percent) and inorganic phosphorus (orthophosphate - 80 percent) than surface water. These species are utilized by plants more easily than the organic forms of nitrogen and phosphorus.

The loads of total nutrients falling on the conservation areas as bulk precipitation was considerably greater than that falling on the northwestern United States. Pearson and Fisher (1971) found that the loads of nutrients falling on the northeastern United States were 0.77×10^{-3} (metric tons/ km^2)/day [2.2×10^{-3} (tons/mi^2)/day] for total nitrogen and 0.13×10^{-3} (metric tons/ km^2)/day [0.37×10^{-3} (tons/mi^2)/day] for total phosphate. This compared with loads determined for the conservation areas of 4.1×10^{-3} (metric tons/ km^2)/day [1.2×10^{-2} (tons/mi^2)/day] for total nitrogen and 0.16×10^{-3} (metric tons/ km^2)/day [0.46×10^{-3} (tons/mi^2)/day] for total phosphate.

The fate of total nitrogen and total phosphorus within the conservation areas varies. Both are utilized biologically and are therefore non-conservative in their chemical reactions. Nutrient species may be utilized by the plant life (flora) of the area, incorporated into the bottom sediments, or broken down by invertebrates and microfauna (fig. 11).

The bottom sediment in canals is an accumulation of organic and inorganic particles that settle out during periods of low or no flow. Nutrients contained within organic sediments are largely lost from the surface-water system. Additional removal of dissolved nutrient species results from adsorption onto organic rich marsh peats and suspended particulate matter.

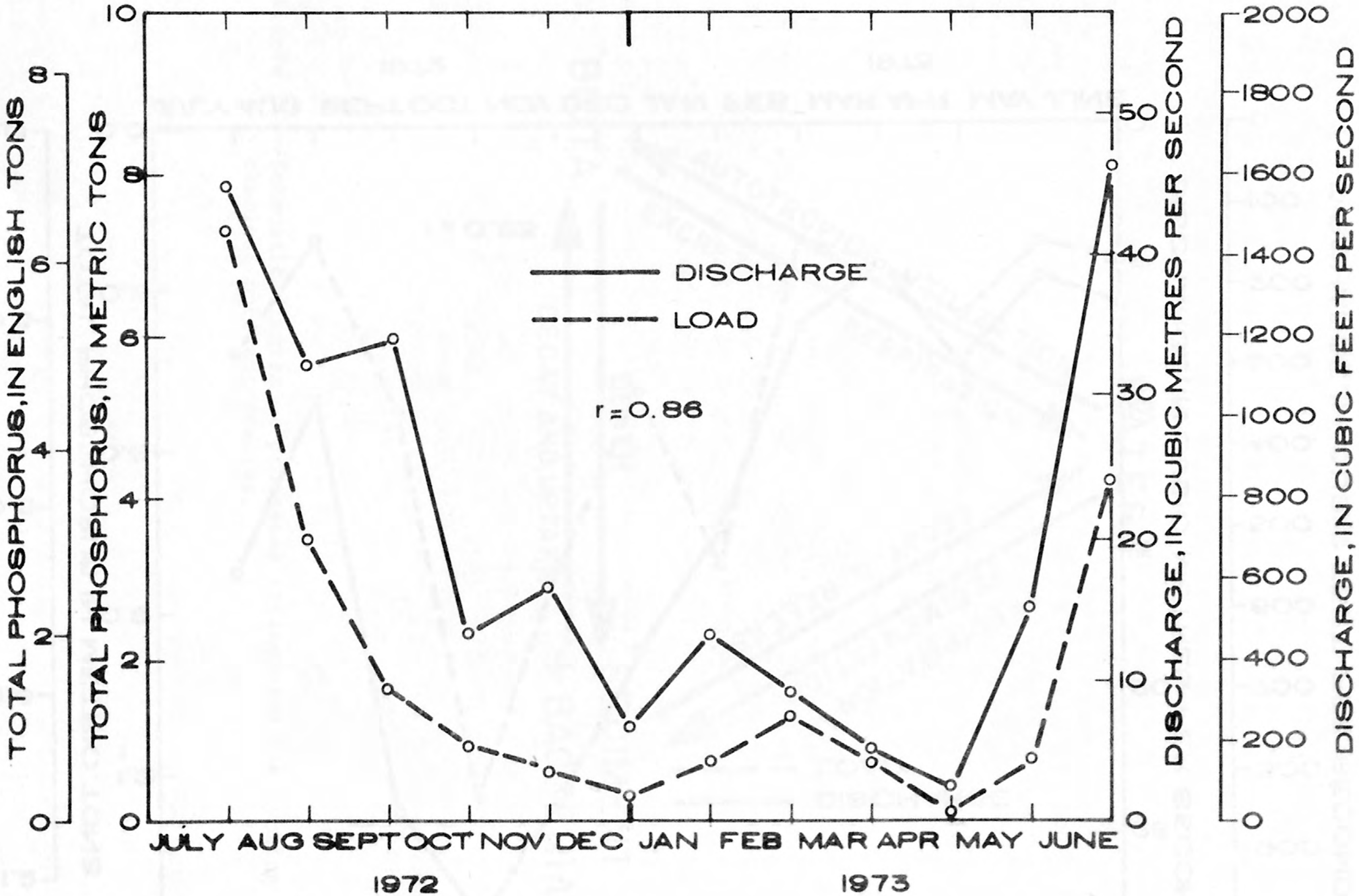

Figure 9.--Relation between monthly total phosphorus load and surface-water inflow.

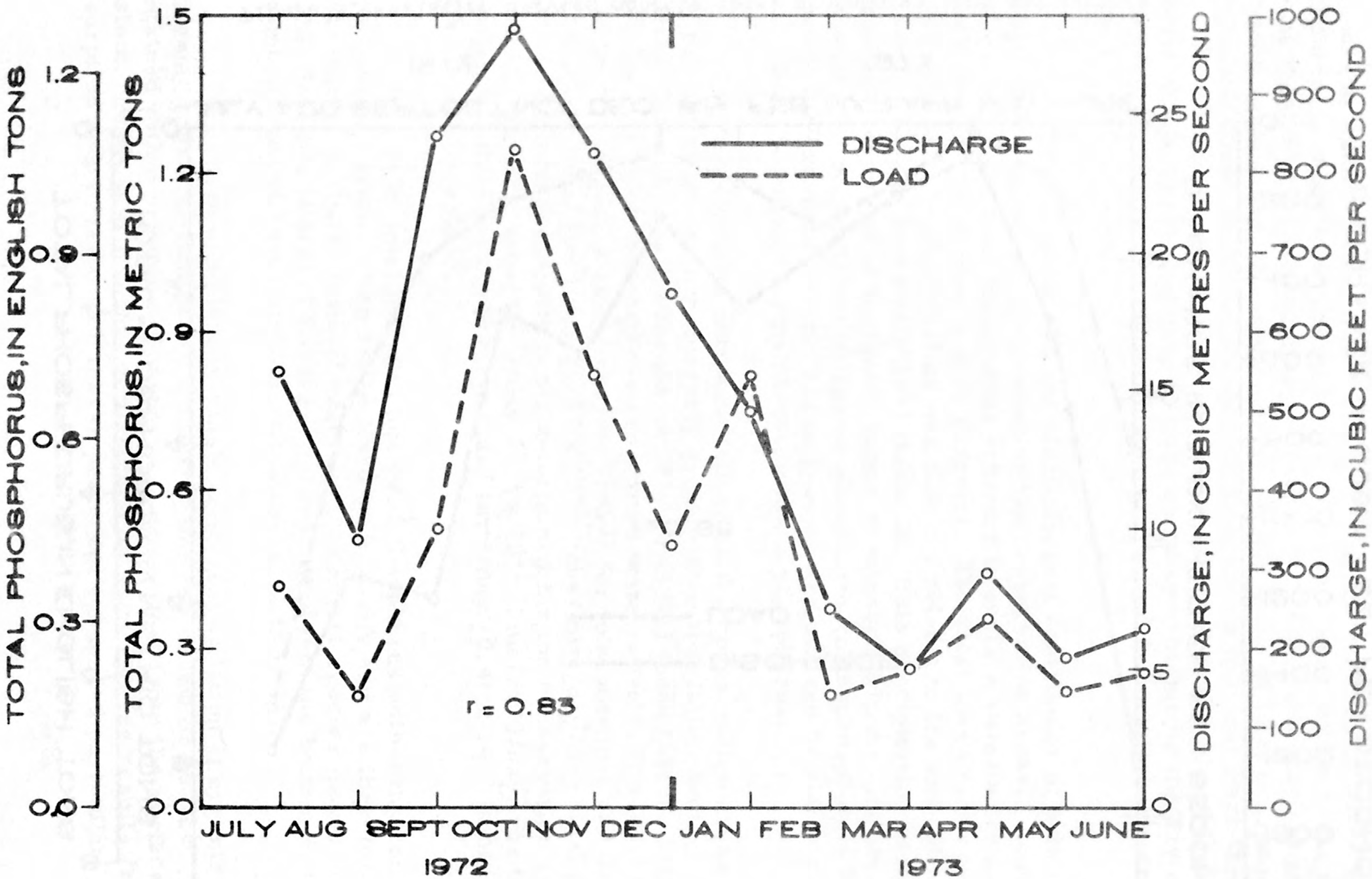

Figure 10.--Relation between monthly total phosphorus load and surface-water outflow.

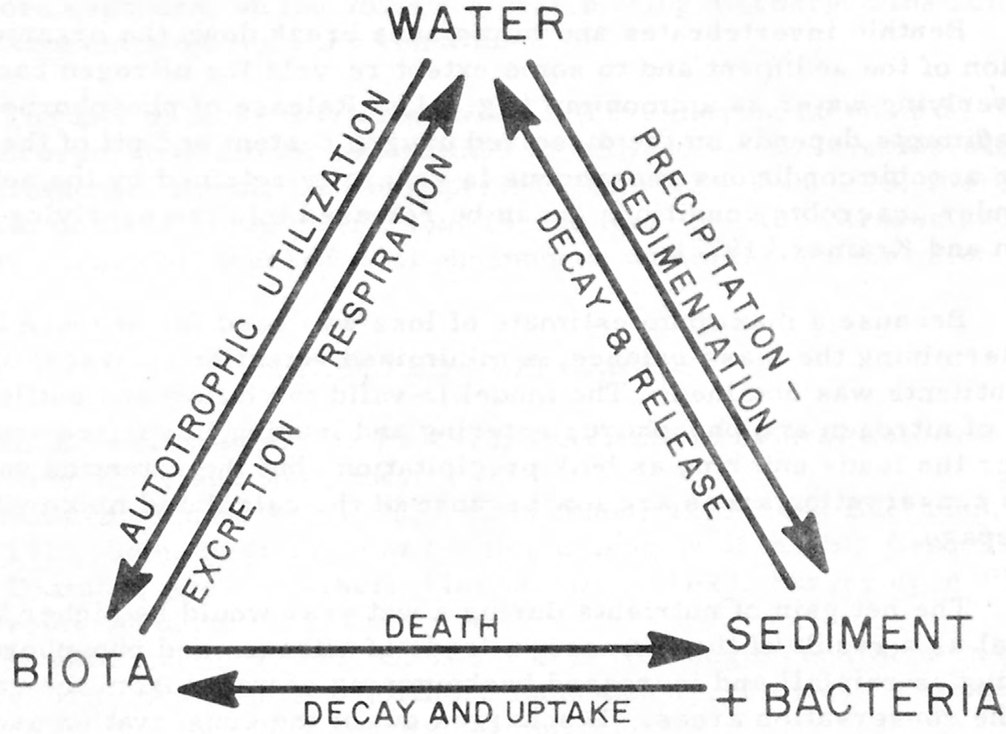

Figure 11.--Schematic diagram of processes influencing the cycling of chemical nutrient species.

The bottom sediments of canals and marsh peats constitute a "sink" in which nutrient species are lost from the overlying water and incorporated into the organic material of the sediment and peat. Nutrient species may be recycled to the overlying water column but this process is effective only during resuspension of sediments due to turbulent water flow and oxidation of peats when they are dried.

Benthic invertebrates and microfauna break down the organic fraction of the sediment and to some extent recycle the nitrogen back into the overlying water as ammonium (fig. 11). Release of phosphorus from the sediments depends on the dissolved oxygen content and pH of the water. Under aerobic conditions phosphorus is generally retained by the sediment but under anaerobic conditions it can be released into the overlying water (Allen and Kramer, 1972).

Because a maximum estimate of loss was used for seepage loads in determining the mass balance, a minimized retention (storage) of these two nutrients was obtained. The model is valid for inflow and outflow loads of nitrogen and phosphorus entering and leaving in surface water and for the loads entering as bulk precipitation, but the retention values in the conservation areas are low because of the calculated maximum loss in seepage.

The net gain of nutrients during a wet year would be higher than normal as a result of the increase in loads of nitrogen and phosphorus entering as rainfall and increased backpumping of water from the canals into the conservation areas. Discharges out of the conservation areas would also be greater than normal, but the net result would be greater retention of water and nutrients. Impoundment of water within the conservation areas increases the probability of nutrients being assimilated into the plant and animal biomass, bacterial community and bottom sediment "sink."

CONCLUSIONS

Bulk precipitation contributed 78 percent of the total nitrogen and 90 percent of the total phosphorus entering the conservation areas. Average daily loads of nutrients entering in rainfall and dry fallout were 4.1×10^{-3} (metric tons/km^2)/day [1.2×10^{-2} (tons/mi^2)/day] for total nitrogen and 0.16×10^{-3} (metric tons/km^2)/day [0.46×10^{-3} (tons/mi^2)/day] total phosphorus.

Greatest surface-water loads of nitrogen and phosphorus entered the conservation areas at the pumping stations. Greatest loads of nitrogen and phosphorus discharged out of the conservation areas entered Everglades National Park because 89 percent of the surface-water discharge flows southward.

Surface water loads of nitrogen and phosphorus varied monthly in proportion to discharge. Loads entering and leaving the conservation areas were more dependent on the volume of water being discharged than on the varying concentrations of each constituent.

The fate of these nutrients varies. They may be taken up by the flora, incorporated into the sediments, or utilized by the invertebrates and microfauna. During the study period July 1972 - June 1973, there was a net gain of about 5,000 metric tons (5,500 tons) of total nitrogen and about 220 metric tons (242 tons) of total phosphorus within the conservation areas.

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