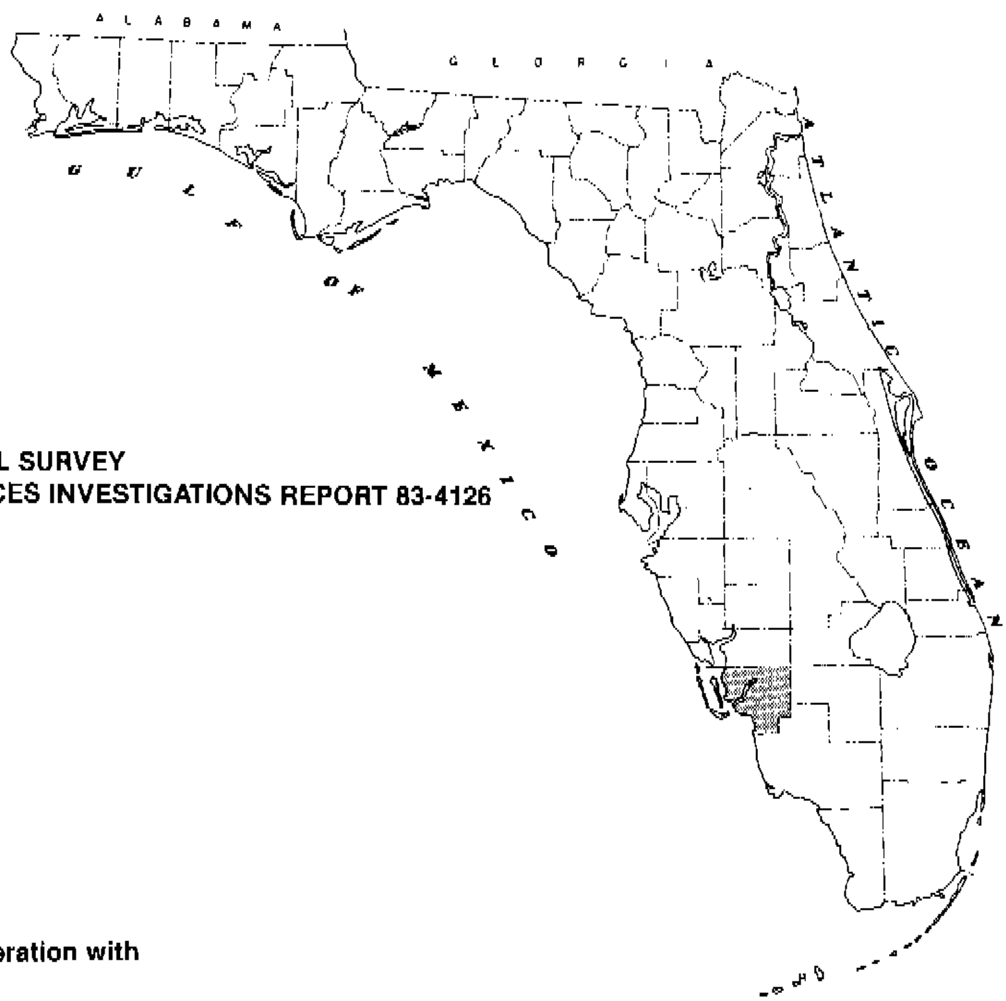
CHEMICAL AND HYDROLOGIC ASSESSMENT OF THE CALOOSAHATCHEE RIVER BASIN, LAKE OKEECHOBEE TO FRANKLIN LOCK, FLORIDA



U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 83-4126

Prepared in cooperation with

LEE COUNTY

CHEMICAL AND HYDROLOGIC ASSESSMENT OF THE CALOOSAHATCHEE RIVER BASIN, LAKE OKEECHOBEE TO FRANKLIN LOCK, FLORIDA

By Henry R. La Rose and Benjamin F. McPherson

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Tallahassee, Florida

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
inch (in)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare (ha)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton (t)	0.9072	megagram (Mg)
micromho (umho)	1.00	microsiemens (uS)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°F = 1.8°C + 32$$

CHEMICAL AND HYDROLOGIC ASSESSMENT OF THE CALOOSAHATCHEE RIVER BASIN, LAKE OKEECHOBEE TO FRANKLIN LOCK, FLORIDA

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ABSTRACT

Annual discharge (1970-79 water years) from Lake Okeechobee to the Caloosahatchee River averaged 51 percent of the total river discharge at Franklin Lock and ranged from 10 to 71 percent of total discharge. Excluding rainfall on the river surface and upstream seepage, surface and subsurface runoff from the basin accounted for the remaining total river discharge at Franklin Lock.

Concentrations of dissolved oxygen in the river (1976-79) ranged from less than 1 to 13 milligrams per liter. Concentrations fluctuated seasonally; they are lower in late summer and early autumn than during other seasons. Concentrations were lower at the headwaters site at Moore Haven than at downstream sites.

Specific conductance and ionic composition in the headwaters of the river have changed over the last 35 years. In the early 1940's, specific conductance ranged from about 200 to 500 micromho per centimeter, compared with an average of about 660 micromho per centimeter in 1975-79. Also over this span, sodium, chloride, magnesium, and sulfate increased in relative abundance compared with calcium and bicarbonate.

Nitrogen and phosphorus were in sufficient supply most of the time to support algal growth in the river. Nitrite plus nitrate nitrogen was the predominant form of inorganic nitrogen. During algal blooms, however, nitrite plus nitrate nitrogen was depleted and probably became the limiting constituents to algal growth. Average concentrations of nitrite plus nitrate were lower in most tributaries than in the river. Average concentrations of total phosphorus in many of the tributaries fell within the same range as that in the river (0.08 to 0.15 milligrams per liter), but some tributaries had lower average concentrations, and others in the eastern subbasins had higher average concentrations than the river.

Contributions of nitrite plus nitrate, orthophosphate, and total phosphorus from the basin and the river substantially exceeded the contributions from Lake Okeechobee, while contributions of ammonia nitrogen from the basin and river were quite small compared with those from the lake. Oxidation of organic material and ammonia in the river probably accounts for some of the downstream increase of nitrite plus nitrate and for the relatively small increase of ammonia nitrogen.

INTRODUCTION

The Caloosahatchee River basin in southwest Florida (fig. 1) is an important resource upon which growth and developments are imposing increasing demands. The river is used for navigation and recreation and as a source of freshwater for agricultural and municipal needs. Large quantities of water are withdrawn from the river system primarily for irrigating citrus and other crops. The river is the source of water for the Lee County water system and for the city of Fort Myers, which collectively serve an estimated population of 70,000. The river supplies about 50 percent of the municipal water for Lee County. In 1978, this amounted to 3,907 Mgal (million gallons) compared with 3,740 Mgal pumped from ground water. Use of the river as a source of water for public supply is presently under consideration by the city of La Belle in Hendry County. The river is also a source of freshwater for its estuary. As the demand for water increases, the Caloosahatchee River will become an increasingly important source of water for all types of uses.

The freshwater reach of the Caloosahatchee River extends 42 river miles from Lake Okeechobee to Franklin Lock, and drains a basin of 850 square miles of relatively flat topography (fig. 2). This drainage basin does not correspond with the U.S. Geological Survey Caloosahatchee River basin shown on the Hydrologic Unit Map prepared by the U.S. Geological Survey (1974). The basin on the Hydrologic Unit Map is 1,378 square miles and includes land that drains into both the river and its estuary, whereas the basin shown in figures 1 and 2 and referred to in this report drains only into the freshwater reach of the Caloosahatchee River. The boundaries of the basins also differ slightly in the freshwater reach because the delineation of boundaries was based on different data. The basin map in figures 1 and 2 was based on 1979 aerial photography and field surveys plus land-altitude data on 1:24,000 U.S. Geological Survey topographic maps. The topographic maps were used solely for the Hydrologic Unit Map delineation.

Historic Alterations to the River

Since the late 1800's, the Caloosahatchee River and its basin have been so altered by man that they no longer have a natural flow regime. The river is controlled by locks and dams, and the basin is a maze of canals and ditches. Parts of some tributaries have been channeled, and in some places the direction and seasonal pattern in natural runoff have been altered by interconnecting canals and pumping activities.

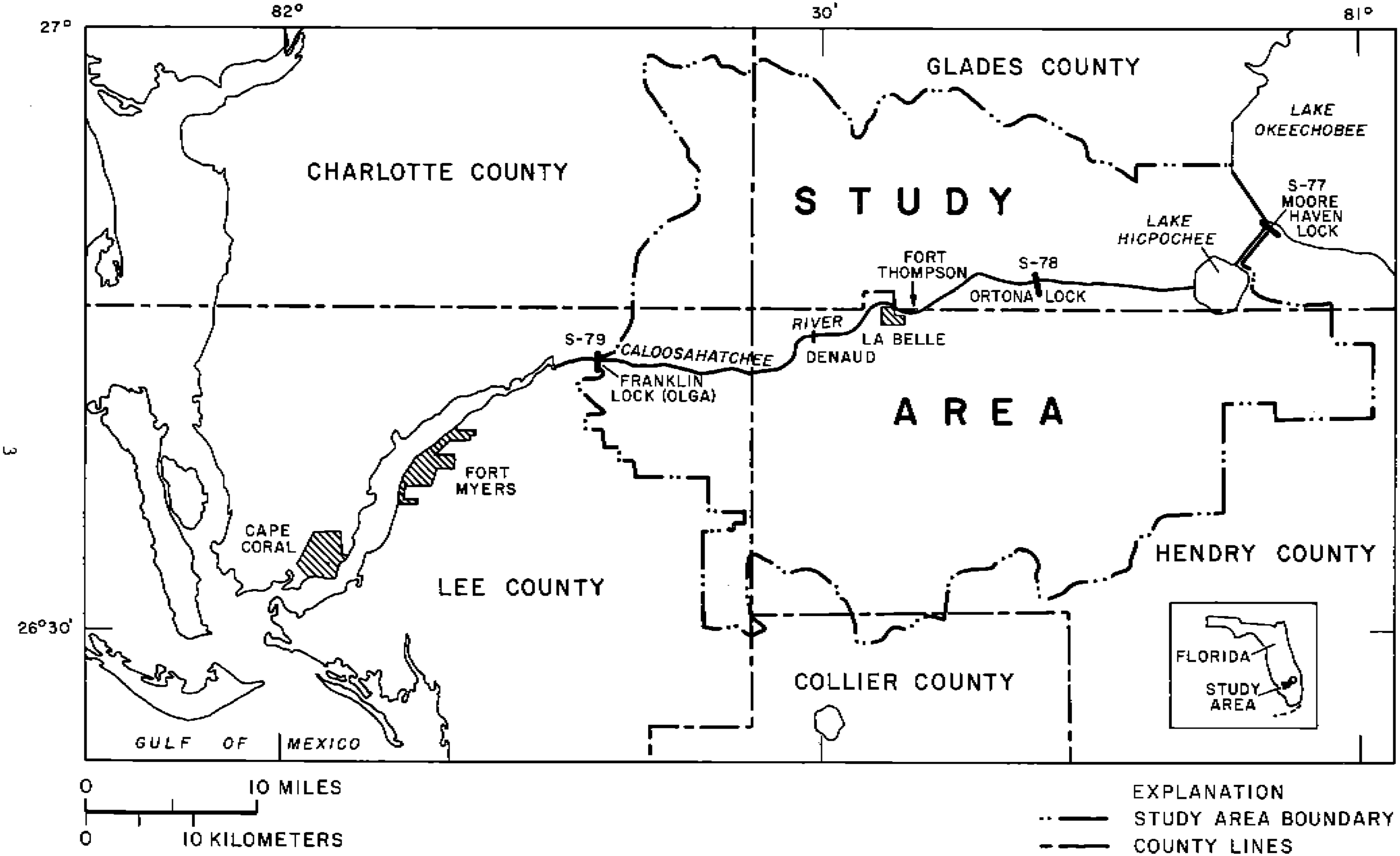


Figure 1.--Caloosahatchee River basin, study area (Lake Okeechobee to Franklin Lock) and surrounding area.

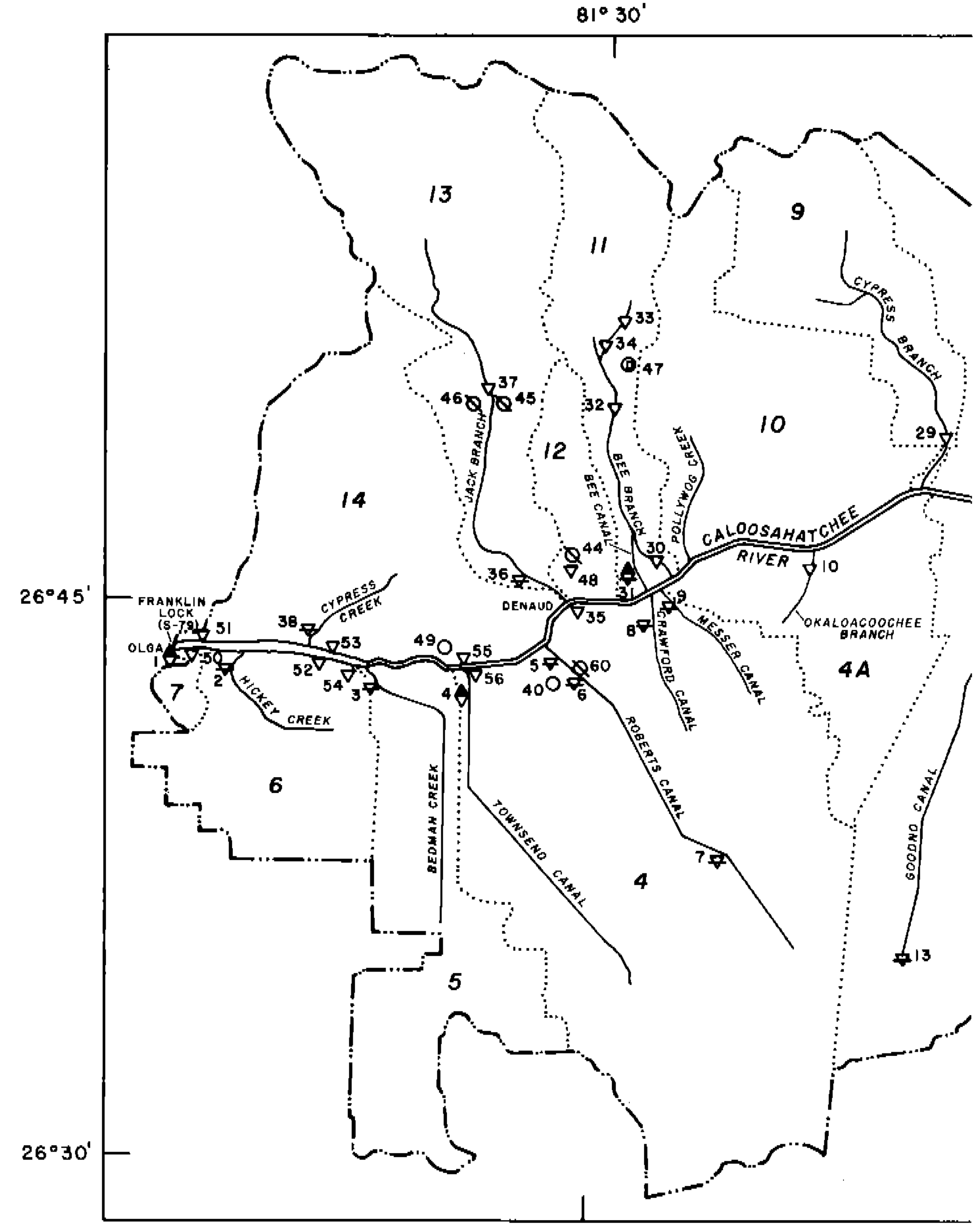
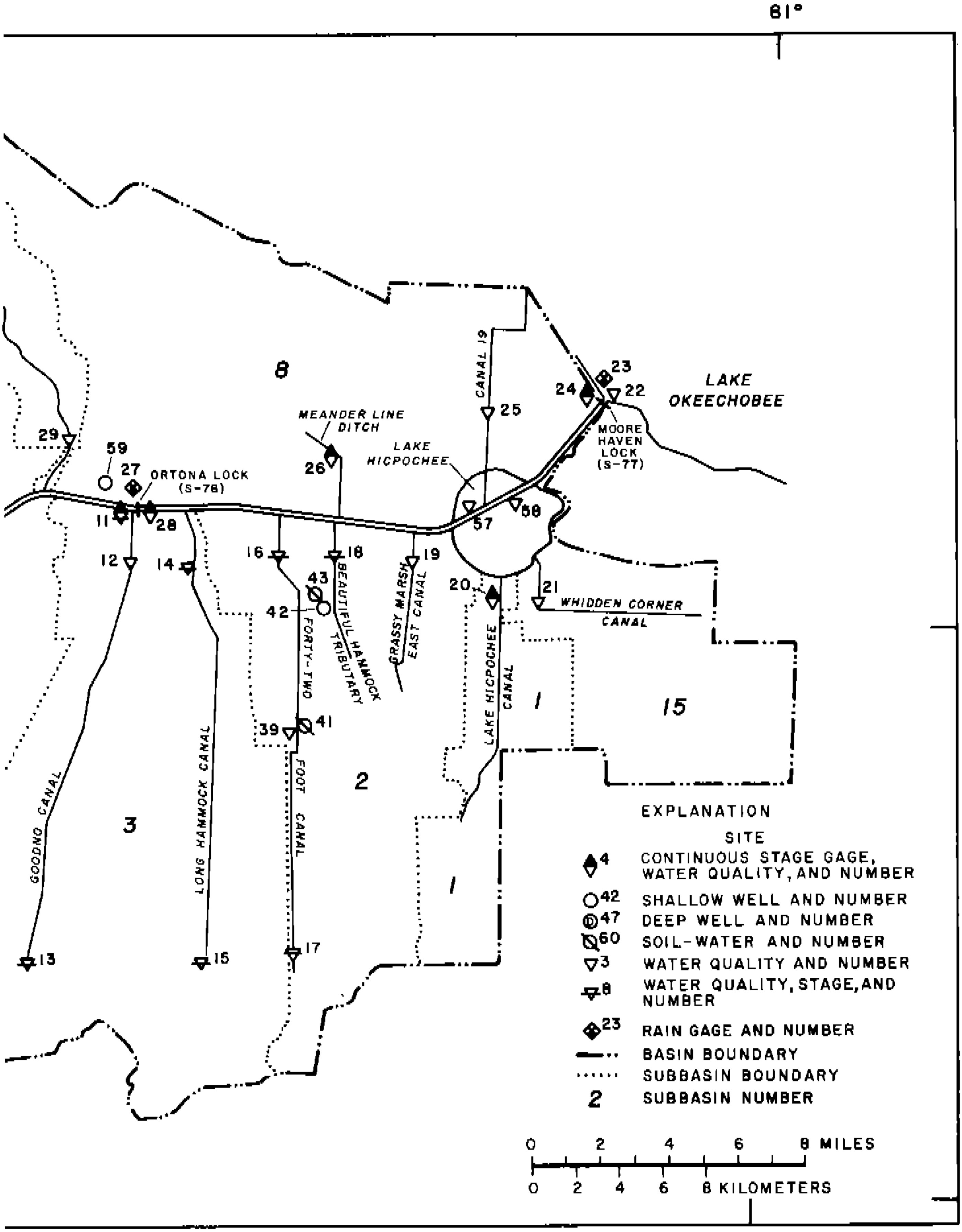


Figure 2.--Caloosahatchee River basin,



Lake Okeechobee to Franklin Lock.

The Caloosahatchee River originally flowed as a shallow, meandering stream from its headwaters in the vicinity of Lake Hicpochee to the Gulf of Mexico (Heilprin, 1887). The river was navigable by a shallow-draft schooner from the Gulf to the rapids at Fort Thompson, 1 3/4 miles east of present-day La Belle. Upstream of the rapids, small boats could ascend several miles before the channel disappeared into marshes (Heilprin, 1887). In 1881, Hamilton Disston of Philadelphia initiated a dredging project in the river that was intended to drain parts of the Everglades and lower the water level in Lake Okeechobee. The project included clearing and dredging the lower river, removing the rapids at Fort Thompson, and constructing a shallow canal from Fort Thompson to Lake Okeechobee (Will, 1964, p. 111). Heilprin traversed the newly dug canals in 1886 and reported water depths of 4 to 6 feet and currents flowing west at 2 to 3 miles an hour or more. This part of the river system is the Caloosahatchee Canal, which extends from just east of La Belle to Lake Okeechobee. In this report the term, "Caloosahatchee River," includes both the canal and the river.

The most extensive modifications to the Caloosahatchee River were made in the 1930's. The Rivers and Harbor Act of 1930 authorized the Federal Government to support drainage and navigation projects. In this year, the U.S. Army Corps of Engineers began to straighten, widen, and deepen the river. The character of the river was further altered by lock and dam structures that controlled discharge and tidal effects. The Moore Haven Lock (S-77) at Lake Okeechobee and Ortona Lock (S-78) 15 miles downstream of the lake were completed by the Corps of Engineers in 1935 (Fritz, 1963, p. 161).

In the 1960's, the Corps of Engineers carried out extensive dredging in the Caloosahatchee River and installed the largest lock and dam structure on the river, the Franklin Lock, S-79. The river from the Franklin Lock to Lake Okeechobee was deepened during the dredging to about 18 to 27 feet and widened to about 150 to 390 feet (U.S. Army Corps of Engineers, 1960).

Environmental Problems

In recent years, the environmental condition of the Caloosahatchee River has become a subject of concern to citizens and government agencies. The concern has centered on three conditions that impair or threaten to impair water quality in the freshwater reach of the river: (1) growth of algae and other aquatic plants, (2) intrusion of saline water, and (3) natural variations and the impacts of man influencing the chemical quality of the water.

Severe algal blooms occur periodically in the Caloosahatchee River and pose a particular threat because the river is used directly as a source of drinking water. Algal blooms create problems in the treatment and preparation of drinking water. Blooms are also esthetically unpleasing and can damage fish and other aquatic life by depletion of oxygen and release of toxins.

In addition to algae, water lettuce (Pistia stratiotes) and water hyacinth (Eichhornia crassipes) occasionally form dense floating mats in the river and tributaries and degrade river quality. Large masses of these floating plants reduce light penetration and can lower dissolved-oxygen concentrations in the water to near anaerobic levels. The rooted plant hydrilla (Hydrilla verticillata) grows in dense stands and can also impair quality. Unlike the floating plants, hydrilla cannot be easily flushed downstream.

Algal blooms and lush growth of other aquatic plants occur where favorable environmental conditions, including adequate nutrients, sunlight, and temperature, prevail. Of these conditions, nutrients are often singled out as being a major controlling or limiting factor. This is because growth of algae and other plants frequently increases when nutrient inputs increase. Agriculture and urban runoff and sewage effluent are common sources of nutrients to water bodies.

Salinity also degrades the quality of water. The river formerly was tidal to upstream of the city of La Belle. The dam at S-79 acts as a saltwater barrier, but the navigation lock at S-79 allows some saline water to be locked upstream into the freshwater reach. With the accompanying saltwater, seepage of shallow saline ground water and saline inflow from artesian wells also are sources of saline water to the river above S-79. Saline water is common near the bottom of the river channel for several miles upstream of S-79 (Boggess, 1972).

Another potential problem is associated with natural variations and the impacts of man that are introduced into the river and that degrade water quality. To determine if this is a serious problem, it is necessary to establish background water-quality conditions in the river and in its tributaries and other sources. To accomplish this objective, this report portrays chemical-quality characteristics in the river and river water sources, including its major tributaries and the water released from Lake Okeechobee to the river. In addition, some selected information on rainfall and ground-water sources are included in the report.

Purpose and Scope

The U.S. Geological Survey, in cooperation with Lee County, conducted an investigation of the river in 1976-79. This investigation was planned to provide a broader base of information than heretofore available on the freshwater resources of the Caloosahatchee River basin, and in particular to provide information on water-quality conditions with emphasis on nutrients and algal growth. In addition to data collected during 1976-79, some earlier data collected by the U.S. Geological Survey were included to evaluate annual variation and trends.

This report is a final product of the investigation and provides detailed and updated information on water quantity and quality in the Caloosahatchee River basin. The objectives of the report are to provide background information on water quality in the river and tributaries and to evaluate the movement of water and chemical quality of water. The report provides information on concentrations of dissolved oxygen, specific conductance, major ions, trace elements, and pesticides and characterizes seasonal changes and areal differences in nutrient concentrations. Emphasis is placed on the nutrients, nitrogen and phosphorus, because these are often implicated in algal bloom problems. Information on algal conditions in the river that was also collected as part of the U.S. Geological Survey investigation is presented in a companion report (McPherson and La Rose, 1981).

DATA COLLECTION AND METHODS

A program for the collection of data on water quality and water flow of the Caloosahatchee River and its tributaries was initiated by the U.S. Geological Survey in October 1976. The program was expanded and modified in 1977 and 1978. Generally, water level and field quality-of-water parameters including specific conductance, water temperature, and dissolved oxygen were measured monthly. Samples were collected monthly at many sites for nutrient analyses. Total organic carbon (TOC), common ions, trace elements, and pesticides were determined periodically. In the river, samples were depth-integrated except at S-79. Samples were collected just upstream of the locking structures at S-78 and S-79. At S-79, only the upper few feet were sampled routinely to avoid deeper, saline water (Boggess, 1972). At S-77, samples were collected about 1/2 mile downstream of the locking structure. In most tributaries, sampling was at the most downstream bridge.

Water-quality data were collected for rainfall plus dustfall (bulk precipitation) and for shallow ground water at a few sites. Precipitation samples were collected approximately monthly beginning in 1978 from refrigerated rain gages at S-77 and S-78. Shallow ground water was sampled intermittently from two different zones in the surficial aquifer. Some sample sites were holes dug to the water table to sample the top of the surficial aquifer at the capillary fringe (soil water samples). The remaining sites were wells drilled and cased into the surficial aquifer at various depths.

Additional data that were collected as part of other U.S. Geological Survey programs include water quality and discharge data at S-77, S-78, and S-79 as part of a long-term monitoring effort. Additional samples were collected at S-78 in 1975-76 and 1979 as part of a National Stream Quality Accounting Network (NASQAN).

Nutrient transport into and out of the river was calculated as follows: Nutrients concentrations from whole water samples were converted to nutrient loads based on daily discharge. Nutrient loads were plotted against daily discharge, and a nutrient transport rating curve developed. A flow-duration curve of water discharge was prepared for the period of consideration. Water discharges for various time intervals were taken from the flow-duration curve, and the corresponding instantaneous nutrient discharge rate was taken from the nutrient transport rating curve. Average nutrient discharge for each time interval was then computed and multiplied by the length of the time interval. These products were to give average nutrient transport in tons per day.

The data-collection sites are shown in figure 2 and listed in table 1 by site (map identification) numbers, station numbers, and brief descriptions.

HYDROLOGIC CONDITIONS IN THE BASIN

Rainfall

The amount of rainfall increases from east to west over the Caloosahatchee River basin (fig. 3). The average annual rainfall over a 20-year span (1960-79) was 48.82 inches at Moore Haven compared with 54.35 inches at Fort Myers. Average rainfall at Moore Haven ranged from 37.37 inches (1965 water year, October 1 through September 30) to 70.23 inches (1960 water year).

During the study period, 1976-79, annual rainfall in the basin was below the 20-year average in 1976 and 1977 and above the average in 1978 and 1979 (fig. 3).

The seasonal rainfall pattern at Moore Haven is shown in figure 4. Average monthly rainfall (1960-79) was less than 3 inches from November through April and more than 5 inches from May through September. In October, average rainfall was just under 4 inches. Monthly rainfall ranged from less than 1 inch to more than 18 inches (fig. 4).

Subbasins and Tributaries

The Caloosahatchee River basin is subdivided into 16 subbasins based on hydrologic and land-altitude information (La Rose and McPherson, 1980). Nine subbasins are south and seven are north of the river (fig. 2). The subbasins range in size from about 1,520 to 79,200 acres. Lake Hicpochee, which lies in the basin, occupies an additional 4,970 acres.

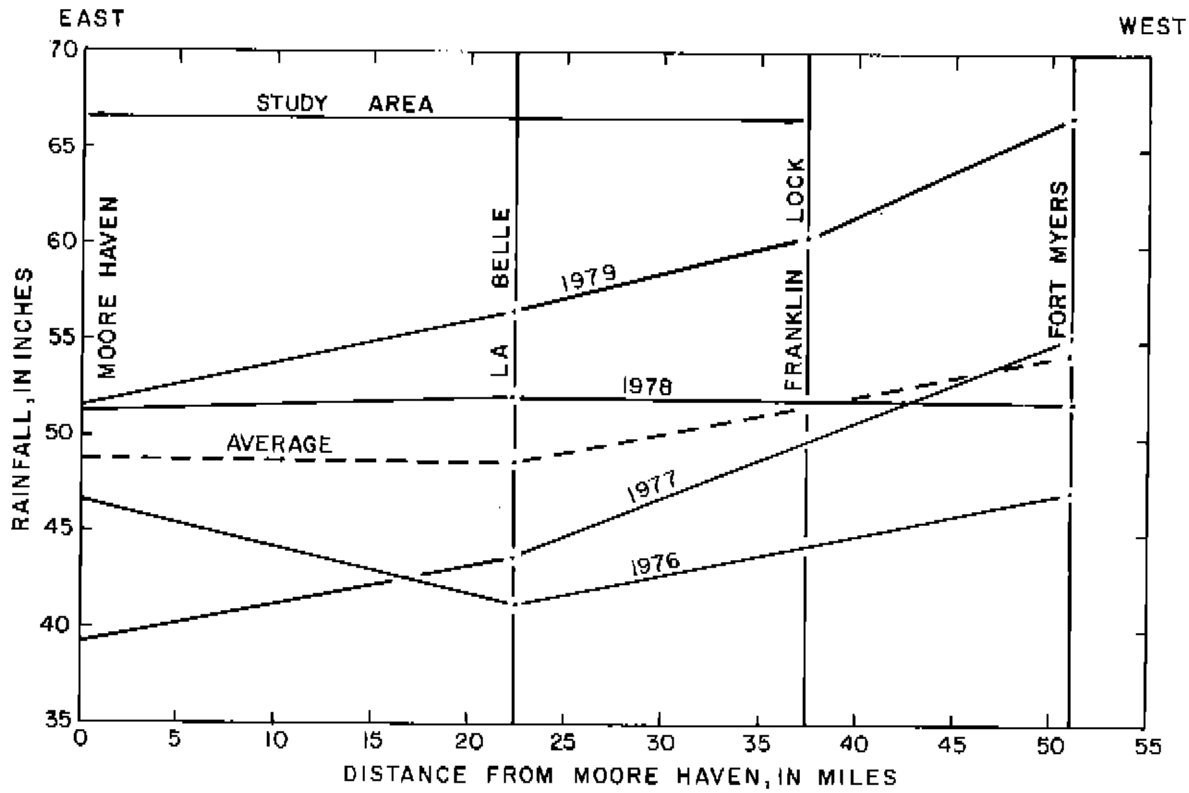


Figure 3.--Annual rainfall, 1976-79 water years, and average annual rainfall, 1960-79 water years, at Moore Haven, La Belle, and Fort Myers.

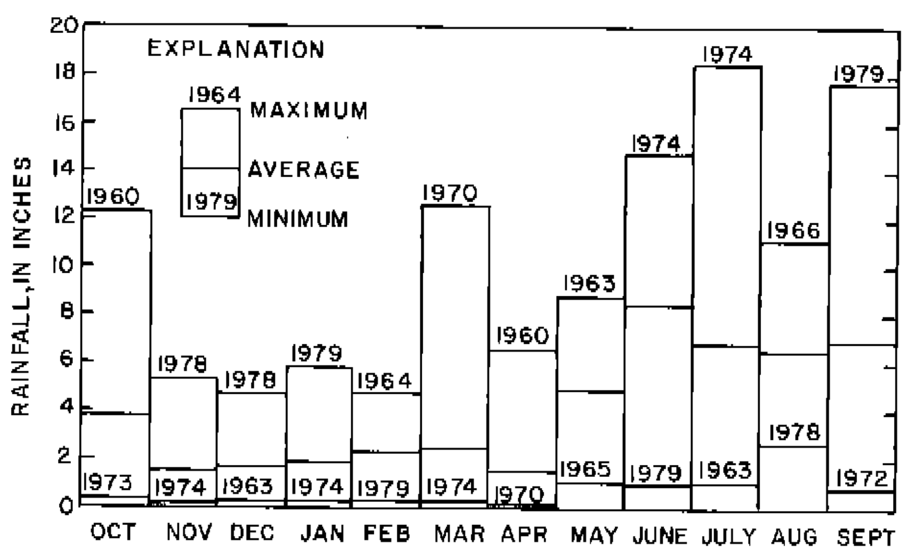


Figure 4.--Average, minimum, and maximum monthly rainfall at Moore Haven, 1960-79 water years.

Table 1.--U.S. Geological Survey sites in the Caloosahatchee River basin

Site (map I.D.) number	Station number	Description
1	02292900	Caloosahatchee River at Franklin Lock (S-79).
2	264253081402200	Hickey Creek at SR-80.
3	264230081355800	Bedman Creek at SR-80.
4	02292780	Townsend Canal at SR-80.
5	264315081310600	Banana Branch at SR-78A.
6	264346081301700	Roberts Canal at SR-80.
7	263828081261200	Roberts Canal at SR-29.
8	264417081281700	Crawford Canal at SR-80.
9	264445081274400	Messer Canal at SR-80.
10	264546081240100	Okaloacoochee Branch at SR-80.
11	264715081181700	Goodno Canal at Ortona.
12	264605081181400	Goodno Canal at SR-80.
13	263607081204700	Goodno Canal at SR-832.
14	264605081161900	Long Hammock Canal at SR-80.
15	263616081155200	Long Hammock Canal at SR-832.
16	264604081140000	Forty-Two Foot Canal at SR-80.
17	263618081133300	Forty-Two Foot Canal at SR-832.
18	264604081121300	Beautiful Hammock Tributary at SR-80.
19	264602081102000	Grassy Marsh East Canal at SR-80.
20	264508081074800	Lake Hicpochee Canal at SR-80.
21	264509081064800	Whidden Corner Canal at SR-80.
22	265029081051100	Lake Okeechobee at Rim Canal.
23	265029081051101	Rain Gage at Lake Okeechobee Rim Canal.
24	02292000	Caloosahatchee Canal at Moore Haven (S-77).
25	265000081082200	Canal 19 at SR-27.
26	264844081122200	Meander Line Ditch at SR-78.
27	264718081181504	Rain Gage at Ortona.
28	02292480	Caloosahatchee Canal at Ortona (S-78).
29	264846081201000	Cypress Branch at SR-78.
30	264529081284000	Bee Branch at SR-78.
31	264511081285700	Bee Canal at SR-78.
32	264938081292000	Bee Branch at SR-720.
33	265137081293600	Bee Branch at Silver Lake Grade.
34	265100081295500	West Bee Branch, 1.5 miles north of SR-720.
35	02292700	Caloosahatchee River at Denaud.

Table 1.--U.S. Geological Survey sites in the Caloosahatchee River basin--Continued

Site (map I.D.) number	Station number	Description
36	264510081313100	Jack Branch at Norris Road.
37	264939081330000	Jack Branch at SR-720.
38	264332081373800	Cypress Creek at SR-78.
39	264411081132900	Forty-Two Foot Canal near Ortona.
40	264235081310602	He-558; water table well at 14 feet at SR-78A.
41	264413081132701	He-906; water table in pineland near Hendry Isles Boulevard.
42	264535081130701	He-857; water table well at 17 feet at Hendry Isles Boulevard.
43	264535081130702	He-905; water table in pasture at Hendry Isles Boulevard.
44	264542081303901	He-903; water table in pineland near Denaud.
45	264938081325801	GL-311; water table in cypress stand at SR-720.
46	264939081331501	GL-312; water table in pineland at SR-720.
47	265047081290301	GL-313; deep well near Bee Branch near SR-720.
48	264539081303900	Jack Branch Tributary near Denaud.
49	264329081340402	L-2202; water table well at 17 feet at SR-78.
50	264313081405900	Caloosahatchee River at oxbow at Lee County Water Plant.
51	264319081405100	Caloosahatchee River oxbow at Lee County Water Plant.
52	264255081370900	Caloosahatchee River at first oxbow west of Alva.
53	264259081370800	Caloosahatchee River oxbow at first oxbow west of Alva.
54	02292795	Caloosahatchee River at Alva Bridge.
55	264254081332300	Caloosahatchee River at first oxbow east of Townsend Canal.
56	264246081332700	Caloosahatchee River oxbow at first oxbow east of Townsend Canal.
57	264720081085900	Caloosahatchee Canal just west of Lake Hicpochee.
58	264734081073000	Lake Hicpochee at center of lake.
59	264757081185901	GL-314; water table well at 14 feet near Ortona.
60	264327081310401	He-904; water table in pine land at SR-78A.

The subbasins south of the Caloosahatchee River have been extensively modified. Tributaries have been converted to canals in which water can flow either toward or away from the river or be diverted into other canals. For this reason, discharge from a canal may represent pumpage from the river plus natural drainage. The major southern canals that discharge into the river are Crawford Canal, Goodno Canal, Forty-Two Foot Canal, and Bedman Creek. Major southern canals that may either discharge to the river or convey water away from the river are Townsend Canal, Beautiful Hammock Tributary, Grassy Marsh East Canal, Lake Hicpochee Canal, and Whidden Corner Canal.

The subbasins north of the Caloosahatchee River are less altered than those south of the river, and tributary flow is predominantly toward the river. The major tributaries are Bee Canal, Jack Branch, and Cypress Creek, each with a mean daily discharge of about 20 ft^3/s. Canal 19 in subbasin 8 is an overflow conveyance for Lake Okeechobee, and at times of high lake levels can contribute significant discharge to the river.

Water Flow to and from the River

Water enters the Caloosahatchee River by discharge from Lake Okeechobee at Moore Haven (S-77), by runoff from basin tributaries, by direct surface and subsurface inflow, by upstream seepage and lockage from the estuary, and by direct rainfall on the river surface. Rainfall directly on the river and upstream seepage account for only a small amount of the total water budget. Rainfall on the 3.4 square miles of river surface averages about 8,730 acre-feet annually, compared with an average annual discharge of 952,870 acre-feet at S-79. Extensive tidal intrusion is blocked by the lock and dam at S-79.

Annual discharge (1970-79 water years) from Lake Okeechobee to the Caloosahatchee River averaged 51 percent of the total river discharge at S-79 (Franklin Lock) and ranged from 10 to 71 percent. Excluding rainfall on the river surface and tidal intrusion, surface and subsurface runoff from the basin account for the remaining river discharge at S-79.

During the study, 1976-79, discharge from Lake Okeechobee and from the basin was below average in 1976-78 and above average in 1979 (table 2).

Monthly discharges from the basin to the estuary at S-79, from Lake Okeechobee to the river at S-77, and from S-79 minus S-77 are given in table 3. Relatively high monthly discharges from the lake to the river occurred in August 1978 and January through March 1979. Relatively high monthly discharges from the basin to the estuary occurred in August 1978, January through March 1979, and September 1979. Annually more water was discharged from S-77 than S-79 during April.

Table 2.—Annual discharge, rainfall, and runoff for the Caloosahatchee River basin, 1970-79 water years

[Discharge shown in acre-feet]

Water year	Discharge at Moore Haven Lock (S-77)	Discharge at Franklin Lock (S-79)	Basin discharge (net difference)	Mean basin rainfall (inches)	Basin runoff (inches)
1970	1/2,690,000	1/3,767,000	1/1,077,000	65.21	1/23.76
1971	77,480	338,100	260,620	44.78	5.75
1972	98,510	2/279,500	2/180,990	47.11	2/3.99
1973	2/53,280	563,200	509,920	51.70	11.25
1974	732,800	1,611,000	878,200	53.01	19.37
1975	118,500	396,000	277,500	43.02	6.12
1976	111,700	381,600	269,900	44.98	5.95
1977	136,500	381,000	244,500	45.98	5.39
1978	243,200	682,500	439,300	51.73	9.69
1979	581,100	1,129,000	547,900	58.25	12.09
Average	484,307	952,890	468,583	50.58	10.34

1/ Maximum amounts for period shown.
2/ Minimum amounts for period shown.

Table 3.--Monthly discharge for the Caloosahatchee River at Moore Haven (S-77), Franklin Lock (S-79), and S-79 minus S-77, 1976-79 water years

[Discharge and storage shown in acre-feet]

Water year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					Monthly discharge at Moore Haven (S-77)							
1976	307	1,220	11,600	11,290	17,630	16,000	34,830	12,950	4,990	307	307	298
1977	4,190	3,320	3,240	307	926	8,220	38,080	32,950	28,000	16,660	307	298
1978	7,730	6,060	307	879	758	3,440	14,490	3,350	298	307	180,500	25,090
1979	307	1,630	543	168,300	202,300	178,100	17,320	307	7,690	1,230	3,070	298
					Monthly discharge at Franklin Lock (S-79)							
1976	57,930	3,670	1,270	3,460	26,430	14,510	11,450	21,040	37,300	42,320	100,600	61,600
1977	11,540	8,000	2,390	32,390	7,410	5,630	8,010	48,090	45,970	47,140	72,150	92,240
1978	6,430	5,340	45,940	18,940	11,350	43,980	3,660	29,850	48,590	114,000	249,800	104,600
1979	39,560	14,010	27,990	251,400	231,700	186,500	5,020	56,230	11,440	22,310	20,890	262,300
					Monthly discharge at S-79 minus S-77 1/							
1976	57,623	2,450	-10,330	-7,830	8,800	-1,490	-23,380	8,090	32,310	42,013	100,293	61,302
1977	7,350	4,680	-850	32,083	6,484	-2,590	-30,070	15,140	17,970	30,480	71,843	91,942
1978	-1,300	-720	45,633	18,061	10,592	40,540	-10,830	26,500	48,292	113,693	69,300	79,510
1979	39,253	12,380	27,447	83,100	29,400	8,400	-12,300	55,923	3,750	21,080	17,820	262,002

1/ Negative values represent more discharge at S-77 than at S-79.

The volume of the water in the river is about 30,000 acre-feet which represents a net discharge of 15,000 ft^3/s for 1 day. Under high-flow conditions, this volume of water would be discharged in less than a day (maximum discharge at S-79 was 21,400 ft^3/s, March 27, 1970), and under average conditions it would be discharged each 11 days (average discharge at S-79 for 1966-79 water years is 1,400 ft^3/s).

WATER CHEMISTRY

Dissolved Oxygen

Concentrations of dissolved oxygen and the percent saturation are shown in figures 5 and 6 for the sites on the Caloosahatchee River. Concentrations ranged from about 2 to 13 mg/L (milligrams per liter) (20 to 160 percent saturation) near the surface, and from less than 1 to 9 mg/L (10 to 90 percent saturation) near the bottom. Concentrations were 1 to 2 mg/L lower near the bottom than near the surface, but in some cases differences exceeded 6 mg/L.

Concentrations of dissolved oxygen fluctuated seasonally, being higher during winter and spring and lower in late summer and early autumn. Differences between surface and bottom waters were also more pronounced during summer and autumn, and most low concentrations were recorded during this period. Concentrations were below 4 mg/L in July, August, or September 1978 and 1979 at all the river sites. Generally, seasonal fluctuations were less and concentrations of dissolved oxygen were lower at S-77 than at the downstream sites (figs. 5 and 6).

Seasonal fluctuations in the concentration of dissolved oxygen in the river were related to a number of factors. Cool temperatures during winter and spring increase oxygen solubility in water. Warm temperatures in summer increase biological respiration and oxygen consumption. Algal populations, which increase in the river in late spring and early summer (McPherson and La Rose, 1981), become a significant source of oxygen consumption, particularly as the algal cells sink into deeper water or die. Flushing of organic material into the river with summer rains also contributes to the seasonal depletion of oxygen. Warm temperatures during summer favor vertical stratification in the water column, reducing mixing of the water. Deeper water in the river becomes isolated from its source of oxygen, and concentrations decrease.

Major Constituents and Specific Conductance

The major constituents dissolved in water are the inorganic ions. These include cations: calcium, magnesium, sodium, and potassium; and anions: bicarbonate, sulfate, chloride, and fluoride. Calcium and bicarbonate are dominant in the freshwaters of south Florida. The source of these two ions is the calcium carbonate rock and soils of the area. Sodium and chloride become dominant in brackish and marine waters.

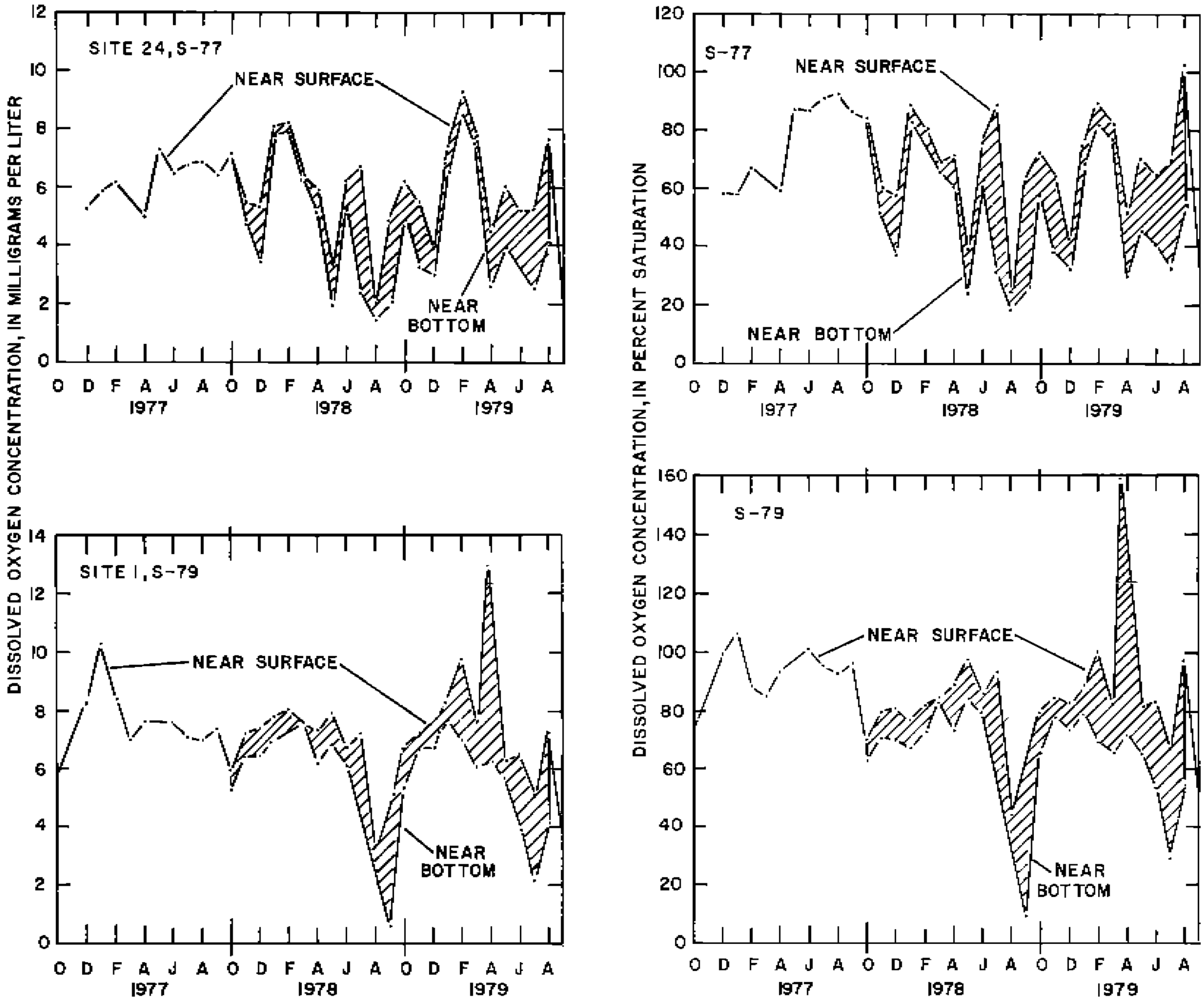


Figure 5.--Concentrations of dissolved oxygen and percent saturation in the Caloosahatchee River at S-77 and S-79, 1977-79 water years.

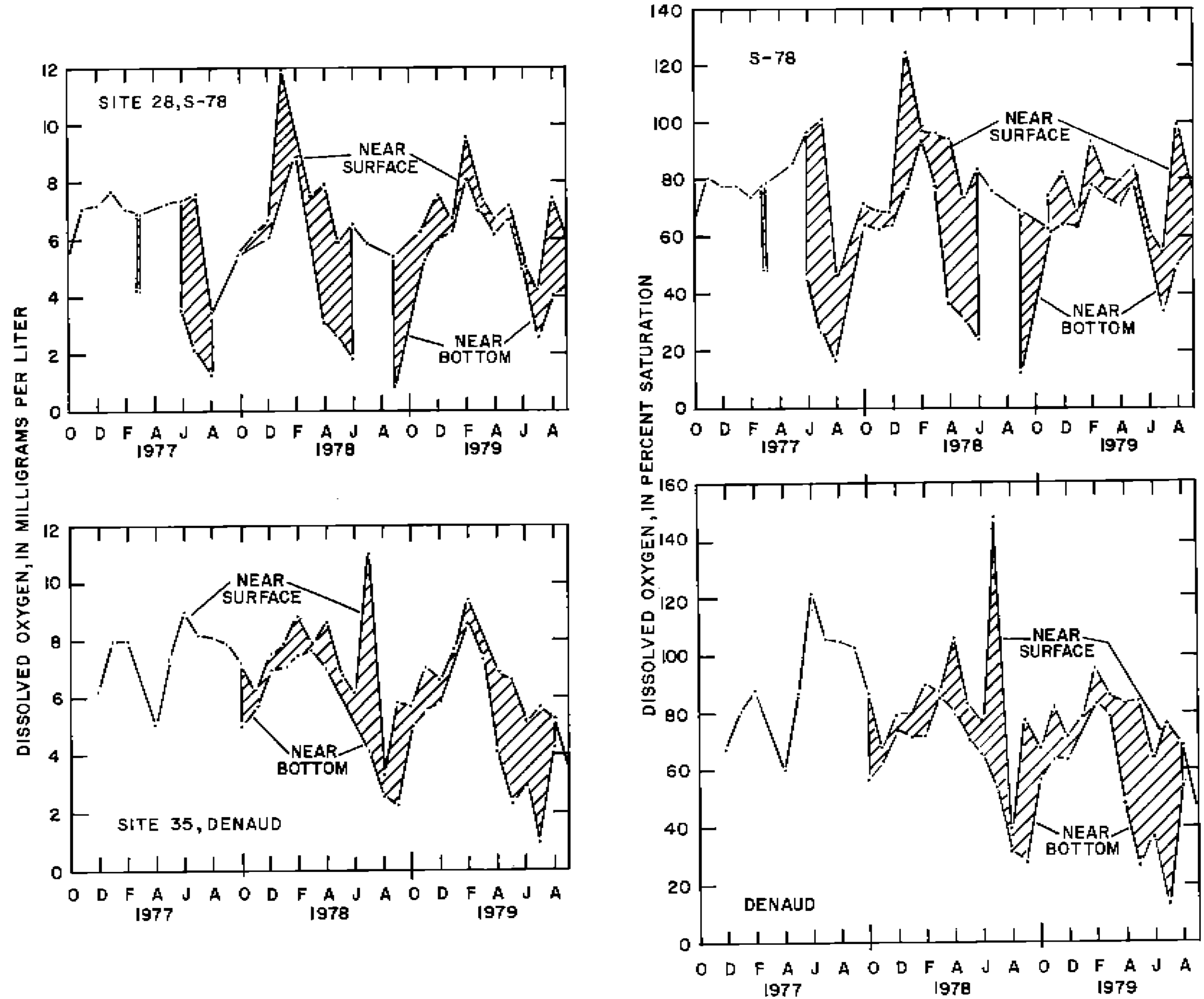


Figure 6.--Concentrations of dissolved oxygen and percent saturation in the Caloosahatchee River at Denaud and S-78, 1977-79 water years.

The concentration of ions in the Caloosahatchee River is determined by input of ions from the river's sources and by physical, chemical, and biological processes in the river. A summary of the concentrations of major ions in the river and tributaries is given in table 4. The relative composition of six major ions is portrayed with Stiff diagrams (Stiff, 1951) at selected sites (figs. 7 and 8).

The mean specific conductance, a measure of the concentration of dissolved constituents in the Caloosahatchee River is shown in table 5. On the average (1975-79), specific conductance was highest at the headwaters site at S-77, Moore Haven (660 umho [micromhos per centimeter at 25°Celsius]); and at the discharge site at S-79, Franklin Lock (704 umho near the surface, but sometimes exceeded 10,000 umho near the bottom). In the central reach of the river, specific conductance values were lower, averaging 566 and 579 umho at Ortona Lock (S-78) and Denaud, respectively.

The lower values for specific conductance in the central reach of the river were attributed to a diluting effect of the tributaries, most of which discharged water of lower specific conductance than that in the river. The increase in specific conductance downstream of S-78 and the relatively high values at S-79 indicate effects of brackish water inflow from the estuary and from groundwater sources. The lock at S-79 prevents extensive saltwater intrusion from the estuary, but some saltwater moves upstream during boat lockage (Boggess, 1972). Another source of saline water is ground water from deep artesian wells used for irrigation. Ground water may enter the river directly or indirectly in tributary inflow.

Specific conductance and ionic composition in the headwaters of the Caloosahatchee River have changed over the last 35 years. In the early 1940's, most specific conductance values at S-77 ranged from 200 to 500 umho. By the late 1970's, most values were above 500 umho. During that interval, sodium, chloride, magnesium, and sulfate increased in relative abundance compared with calcium and bicarbonate (fig. 7). These changes in the upper reach of the river are probably due to changes that have taken place in Lake Okeechobee over the years. Parker and others (1955) noted that dissolved solids in the lake in 1940-41 were about three times as great as those in its major tributaries. Joyner (1974) found that dissolved solids in the lake had increased in 1969-70 over those reported in 1940-41.

Specific conductance in the tributaries was affected by seasonal runoff, location in the basin, and saline ground water (fig. 9). Generally, specific conductance increased several hundred micromho during the dry season. Average values in tributaries were higher near the river than at sites more distant from the river (fig. 10). For example, Jack Branch at Norris Road (site 36), which is less than 1 mile from the river, had an average specific

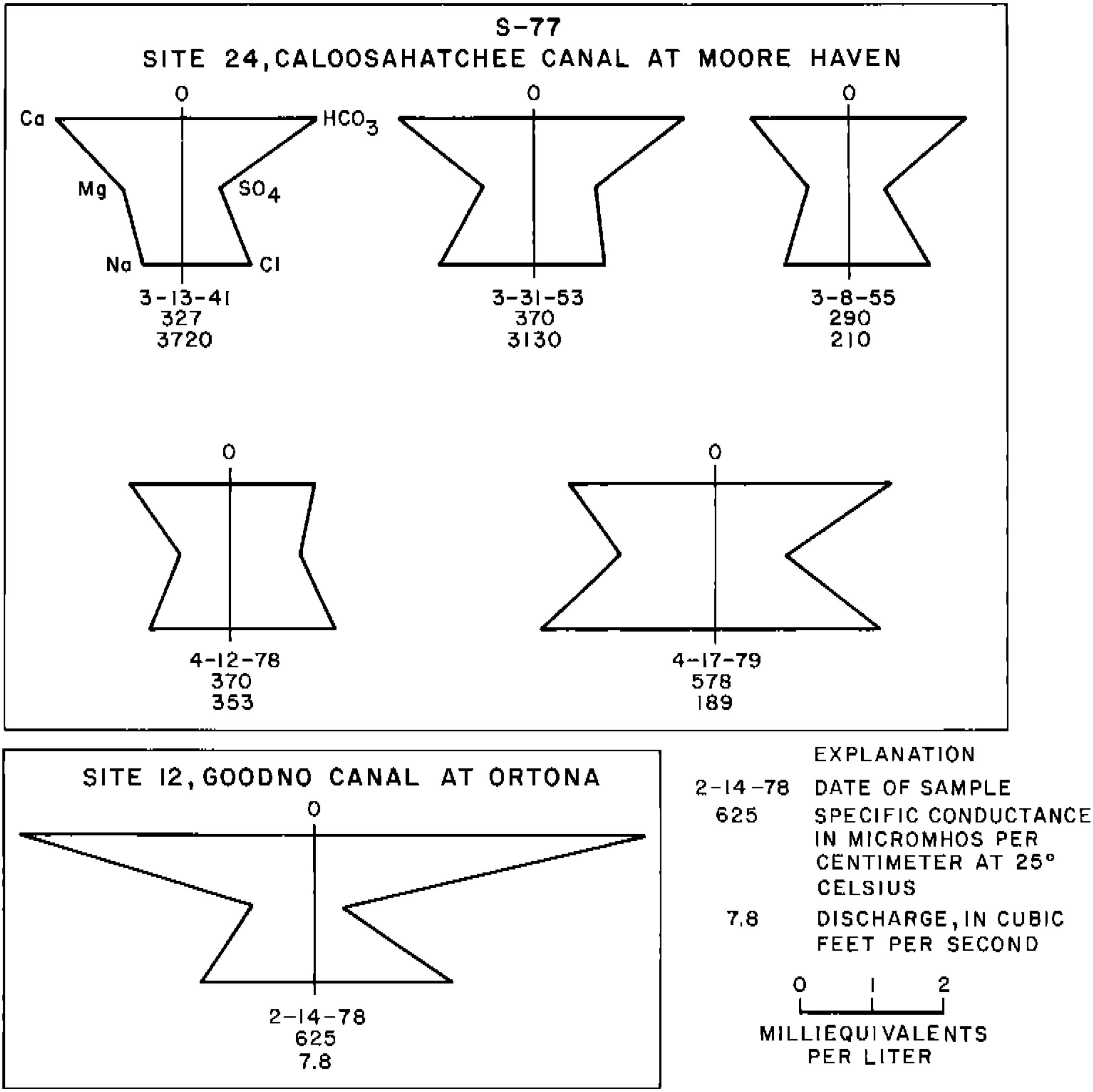


Figure 7.--Selected Stiff diagrams from the Caloosahatchee Canal at Moore Haven and from Goodno Canal at Ortona.

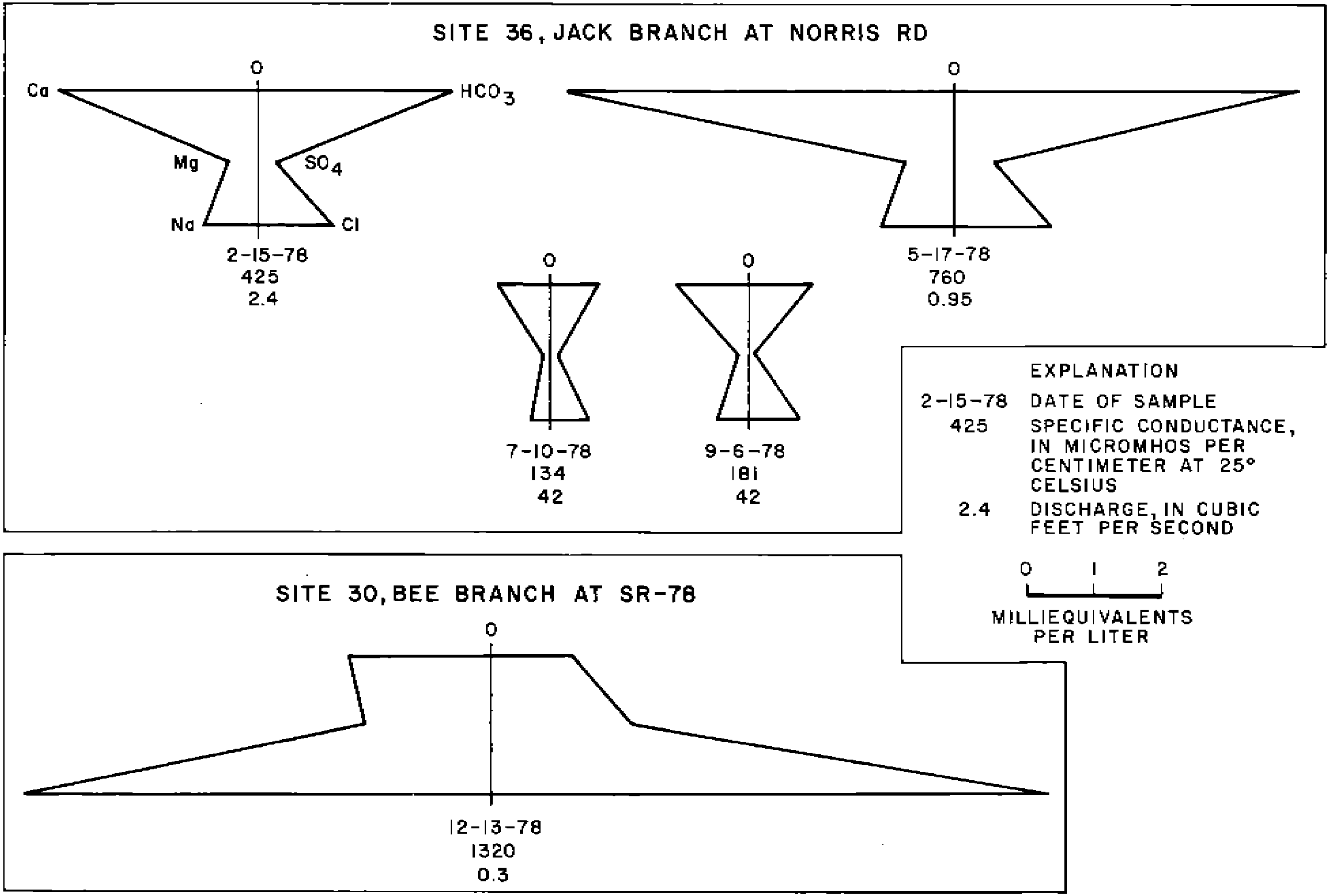


Figure 8.—Selected Stiff diagrams from Jack Branch at Norris Road and Bee Branch at State Road 78.

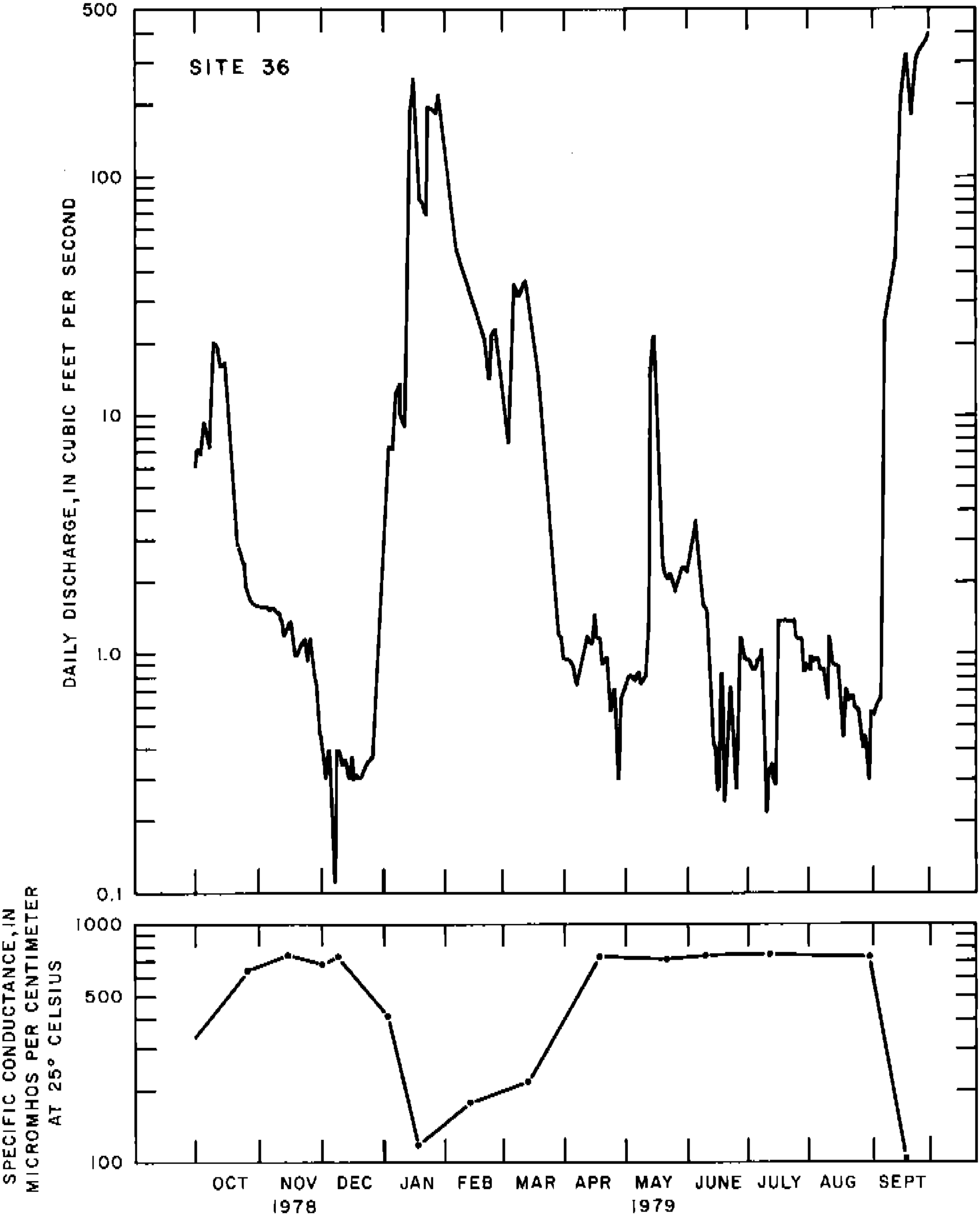


Figure 9.--Specific conductance and daily mean discharge, 1979 water year, Jack Branch at Norris Road.

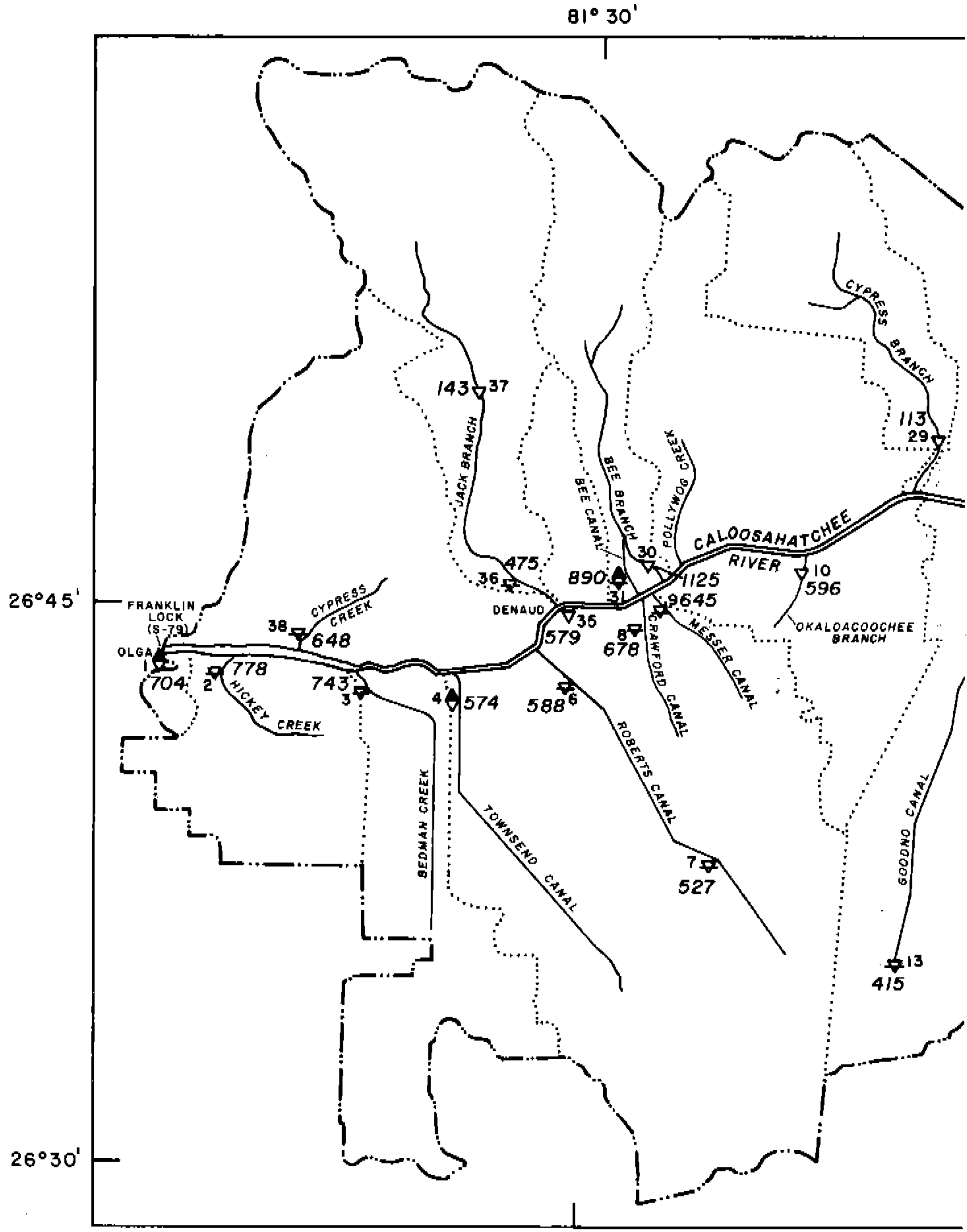
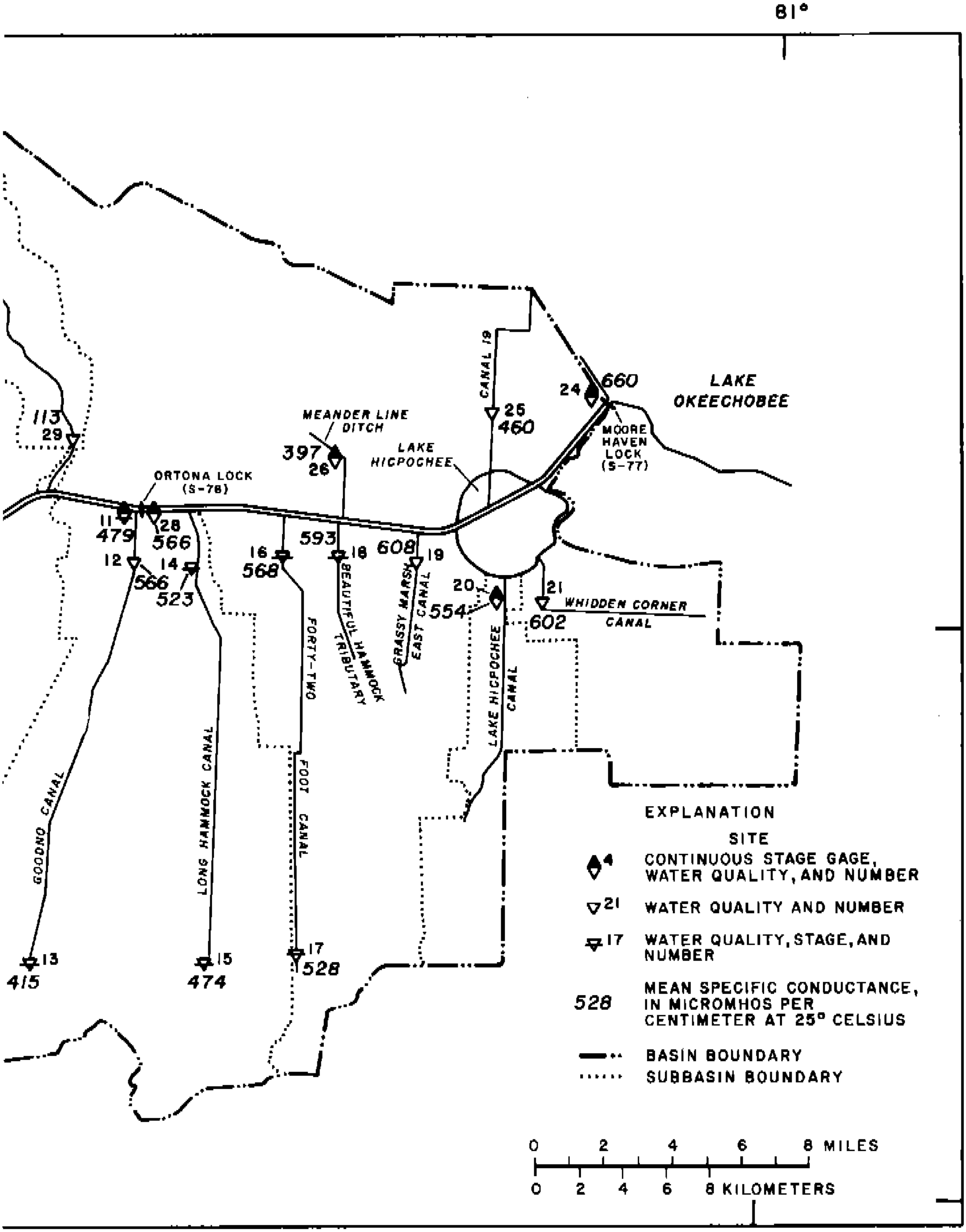


Figure 10.--Mean specific conductance at selected sites



in the Caloosahatchee River basin, 1975-79 water years.

Table 4.--Concentrations of major ions (dissolved) in the Caloosahatchee River and tributaries, 1976-79 water years

[Values shown in milligrams per liter, except for strontium which is shown in micrograms per liter]

	Number of analyses	Concentrations		
		Minimum	Maximum	Mean
Site 1, Caloosahatchee River at Franklin Lock (S-79)				
Calcium	41	40	272	72
Magnesium	41	7.9	25	14
Potassium	41	2.7	8.0	4.7
Silica	41	3.7	10	7.1
Sodium	41	4.6	140	54
Strontium	41	100	2,100	892
Chloride	43	46	270	96
Fluoride	41	.1	.6	.3
Solids residue at 180°C.	41	313	806	457
Sulfate	41	27	90	49
Bicarbonate	42	130	253	195
Site 3, Bedman Creek at State Road 80				
Calcium	4	85	110	95
Magnesium	4	8.3	14	12
Potassium	4	1.5	2.4	1.8
Silica	4	5.1	8.2	7.2
Sodium	4	21	50	35
Strontium	4	550	1,300	982
Chloride	26	40	130	70
Fluoride	4	.1	.2	.2
Solids residue at 180°C.	4	405	517	467
Sulfate	4	55	60	58
Bicarbonate	4	240	300	262
Site 4, Townsend Canal at State Road 80				
Calcium	6	47	78	63
Magnesium	6	7.0	13	11
Potassium	6	4.2	7.5	5.0
Silica	6	4.9	11	7.7
Sodium	6	24	50	36
Strontium	6	460	870	654
Chloride	28	20	100	65
Fluoride	6	.1	.4	.3
Solids residue at 180°C.	6	294	449	388
Sulfate	6	20	48	37
Bicarbonate	6	150	230	187

Table 4.--Concentrations of major ions (dissolved) in the Caloosahatchee River and tributaries, 1976-79 water years--Continued

[Values shown in milligrams per liter, except for strontium which is shown in micrograms per liter]

	Number of analyses	Concentrations Minimum	Maximum	Mean
Site 6, Roberts Canal at State Road 80				
Calcium	5	38	87	64
Magnesium	5	8.0	13	11
Potassium	5	3.4	8.0	4.5
Silica	5	3.0	11	7.8
Sodium	5	24	41	33
Strontium	5	320	740	550
Chloride	33	40	95	67
Fluoride	5	.2	.4	.2
Solids residue at 180°C.	5	267	491	387
Sulfate	5	11	72	42
Bicarbonate	5	128	220	184
Site 11, Goodno Canal at Ortona				
Calcium	3	44	81	66
Magnesium	3	4.5	10	7.5
Potassium	3	2.5	4.2	3.1
Silica	3	2.0	6.7	4.2
Sodium	3	14	35	27
Strontium	3	190	580	437
Chloride	24	15	115	49
Fluoride	3	.1	.1	.1
Solids residue at 180°C.	3	228	395	321
Sulfate	3	7.4	21	15
Bicarbonate	3	130	270	210
Site 16, Forty-Two Foot Canal at State Road 80				
Calcium	3	73	92	80
Magnesium	3	7.0	10	8.3
Potassium	3	1.8	2.7	2.4
Silica	3	1.3	8.0	4.9
Sodium	3	30	35	32
Strontium	3	380	570	453
Chloride	23	20	75	46
Fluoride	3	.1	.2	.2
Solids residue at 180°C.	3	366	426	390
Sulfate	3	18	31	23
Bicarbonate	3	230	280	250

Table 4.--Concentrations of major ions (dissolved) in the Caloosahatchee River and tributaries, 1976-79 water years--Continued

[Values shown in milligrams per liter, except for strontium which is shown in micrograms per liter]

	Number of analyses	Concentrations Minimum	Maximum	Mean
Site 19, Grassy Marsh East Canal at State Road 80				
Calcium	2	64	80	72
Magnesium	2	6.4	13	10
Potassium	2	2.4	5.9	4.2
Silica	2	4.4	8.1	6.2
Sodium	2	31	51	41
Strontium	2	400	625	512
Chloride	30	34	95	65
Fluoride	2	.4	.5	.4
Solids residue at 180°C.	2	383	429	406
Sulfate	2	16	37	26
Bicarbonate	2	200	255	228
Site 20, Lake Hicpochee Canal at State Road 80				
Calcium	4	50	68	59
Magnesium	4	4.4	7.6	6.1
Potassium	4	2.3	4.8	3.1
Silica	3	6.6	9.3	7.9
Sodium	4	17	30	24
Strontium	4	200	490	350
Chloride	29	20	115	63
Fluoride	4	.2	.4	.2
Solids residue at 180°C.	4	264	353	314
Sulfate	4	10	22	15
Bicarbonate	4	140	213	181
Site 23, Rain Gage at Lake Okeechobee Rim Canal				
Calcium	2	.6	1.0	.8
Magnesium	2	.2	.3	.2
Potassium	2	.2	1.0	.6
Silica	2	.0	.4	.2
Sodium	2	.9	1.9	1.4
Strontium	2	4	60	32
Chloride	8	.6	15	5
Fluoride	2	.0	.0	.0
Solids residue at 180°C.	2	10	12	11
Sulfate	2	.3	1.5	.9
Bicarbonate	2	4	11	7

Table 4.--Concentrations of major ions (dissolved) in the Caloosahatchee River and tributaries, 1976-79 water years--Continued

[Values shown in milligrams per liter, except for strontium which is shown in micrograms per liter]

	Number of analyses	Concentrations Minimum	Maximum	Mean
Site 24, Caloosahatchee Canal at Moore Haven (S-77)				
Calcium	15	29	100	60
Magnesium	15	9.0	27	16
Potassium	15	3.5	9.2	5.6
Silica	15	2.5	13	8.9
Sodium	15	27	76	53
Strontium	15	700	1,500	1,000
Chloride	31	50	125	88
Fluoride	15	.1	.4	.2
Solids residue at 180°C.	15	249	703	437
Sulfate	15	32	100	56
Bicarbonate	16	73	310	179
Site 26, Meander Line Ditch at State Road 78				
Calcium	4	18	67	39
Magnesium	4	2.9	9.2	5.8
Potassium	4	1.8	4.7	2.6
Silica	4	4.0	6.0	4.9
Sodium	4	11	33	21
Strontium	4	110	550	290
Chloride	26	10	80	46
Fluoride	4	.1	.1	.1
Solids residue at 180°C.	4	147	377	242
Sulfate	4	6.5	34	14
Bicarbonate	4	51	220	120
Site 27, Rain Gage at Ortona				
Calcium	5	.9	1.5	1.0
Magnesium	5	.2	.4	.2
Potassium	5	.3	1.2	.7
Silica	5	.1	.2	.1
Sodium	5	1.1	1.5	1.3
Strontium	5	8.0	50	25
Chloride	13	.4	5.0	2.2
Fluoride	5	.0	.0	.0
Solids residue at 180°C.	5	6.0	15	12
Sulfate	5	.2	1.5	.8
Bicarbonate	3	2.0	9.0	6.7

Table 4.--Concentrations of major ions (dissolved) in the Caloosahatchee River and tributaries, 1976-79 water years--Continued

[Values shown in milligrams per liter, except for strontium which is shown in micrograms per liter]

	Number of analyses	Concentrations		
		Minimum	Maximum	Mean
Site 28, Caloosahatchee Canal at Ortona (S-78)				
Calcium	51	35	84	56
Magnesium	51	6.4	21	13
Potassium	51	2.2	8.5	4.8
Silica	52	3.3	13	7.9
Sodium	51	21	69	42
Strontium	27	380	1,200	797
Chloride	60	36	120	69
Fluoride	52	.1	.9	.3
Solids residue at 180°C.	52	245	500	371
Sulfate	52	15	59	37
Bicarbonate	49	110	246	178
Site 35, Caloosahatchee River at Denaud				
Calcium	16	36	73	59
Magnesium	16	6.8	18	11
Potassium	16	2.6	5.3	4.2
Silica	16	3.5	10	7.7
Sodium	16	27	52	39
Strontium	16	450	1,100	726
Chloride	32	30	100	68
Fluoride	16	.1	.3	.2
Solids residue at 180°C.	16	247	456	376
Sulfate	16	27	63	39
Bicarbonate	18	110	274	183

Table 4.--Concentrations of major ions (dissolved) in the Caloosahatchee River and tributaries, 1976-79 water years--Continued

[Values shown in milligrams per liter, except for strontium which is shown in micrograms per liter]

	Number of analyses	Concentrations		
		Minimum	Maximum	Mean
Site 36, Jack Branch at Norris Road				
Calcium	4	17	120	55
Magnesium	4	1.8	9.2	4.6
Potassium	4	.6	2.3	1.2
Silica	4	2.7	5.5	3.7
Sodium	4	7.5	27	16
Strontium	4	70	600	262
Chloride	24	10	50	38
Fluoride	4	.09	.1	.09
Solids residue at 180°C.	4	126	437	247
Sulfate	4	4.8	29	13
Bicarbonate	4	46	360	161
Site 38, Cypress Creek at State Road 78				
Calcium	3	50	99	69
Magnesium	3	7.0	12	9.4
Potassium	3	1.1	2.1	1.6
Silica	3	4.0	5.6	4.9
Sodium	3	26	40	32
Strontium	3	480	820	680
Chloride	30	20	120	84
Fluoride	3	.1	.1	.1
Solids residue at 180°C.	3	297	474	376
Sulfate	3	9.7	20	15
Bicarbonate	3	150	290	207

Table 5.--Specific conductance in the Caloosahatchee River and selected tributaries, 1975-79 water years

[Values shown in micromhos per centimeter at 25°C]

Site number	Number of analyses	Minimum	Maximum	Mean
		River		
1 (S-79)[1/]	45	330	1,300	704
24 (S-77)	36	350	1,080	660
28 (S-78)	57	350	820	566
35 (Denaud)	36	382	760	579
		Tributaries		
2	35	480	910	778
3	26	560	940	743
6	39	350	770	588
7	24	141	760	527
8	24	590	760	678
9	24	375	780	645
10	24	390	930	596
11	27	291	685	479
13	25	130	610	415
14	24	232	805	523
15	20	124	680	474
16	25	300	710	568
17	25	96	910	528
18	24	305	835	593
19	36	365	770	608
20	25	270	880	554
21	23	440	785	602
23	9	17	105	39
25	22	235	590	460
26	24	108	695	397
27	10	13	32	18
29	23	66	400	113
30	21	104	1,550	1,125
31	19	108	2,600	890
36	26	106	775	475
37	5	82	218	143
38	35	178	980	648

1/ Values are only for surface samples.

conductance of 475 umho. Jack Branch at State Road 720 (site 37), which is several miles upstream, had an average of 143 umho. Specific conductances in Bee Canal (site 31) and Bee Branch (site 30) were higher than at any of the other tributaries as a result of an input of saline ground water used to irrigate citrus trees. During the 1975-79 water years, values in Bee Branch ranged from 104 to 1,550 umho and averaged 1,125 umho (table 5). A sample of irrigation water (site 47) collected near Bee Branch (December 13, 1978) had a specific conductance of 2,000 umho.

The ionic composition of water from the tributaries was dominated by calcium and bicarbonate, unless it was altered by saline ground water or river water. The relative amounts of calcium and bicarbonate tended to increase during the dry season with increasing ionic concentrations as shown in figure 8 for Jack Branch. Sodium, chloride, magnesium, and sulfate were relatively less abundant in the tributaries than in the river (fig. 7). Sodium and chloride, however, become dominant in water greatly affected by saline ground water as shown in figure 8 for Bee Branch.

Specific conductance of water in the surficial aquifer in the basin ranges from 137 to 3,200 umho (table 6). Sites with the higher values were probably affected by upward movement of deeper, saline artesian waters either in irrigation wells or through the rocks overlying the deeper saline aquifers.

Rainfall and dustfall were sampled for ionic composition (table 4) and for specific conductance (table 5) at S-77 and S-78 in 1978-79. Calcium, magnesium, sodium, bicarbonate, sulfate, and chloride had very low concentrations, but in proportions similar to those shown for the river at S-77 in figure 7.

Macronutrients

Nutrients are among those elements and compounds essential for life processes. Macronutrients are those required in relatively large amounts and are generally considered to be nitrogen, phosphorus, and carbon. The inorganic forms of these elements are readily available for biological uptake and can control the rate of biological productivity. The organic forms transform more slowly but are also a source for life processes.

In the Caloosahatchee River, the concentrations of inorganic nitrogen (nitrate, nitrite, ammonia) fluctuated from month to month in response to input, flushing, oxidation, and biological processes. Generally, concentrations decreased during spring and summer (fig. 11). Low values, particularly for nitrite plus nitrate (NO_2 + NO_3 as N), coincided with algal blooms (McPherson and La Rose, 1981). Concentrations of ammonia (NH_3 as N) did not show a pronounced seasonal fluctuation but generally were higher at S-77, averaging 0.14 mg/L, than at downstream sites, where concentrations averaged 0.07 to 0.09 mg/L (table 7).

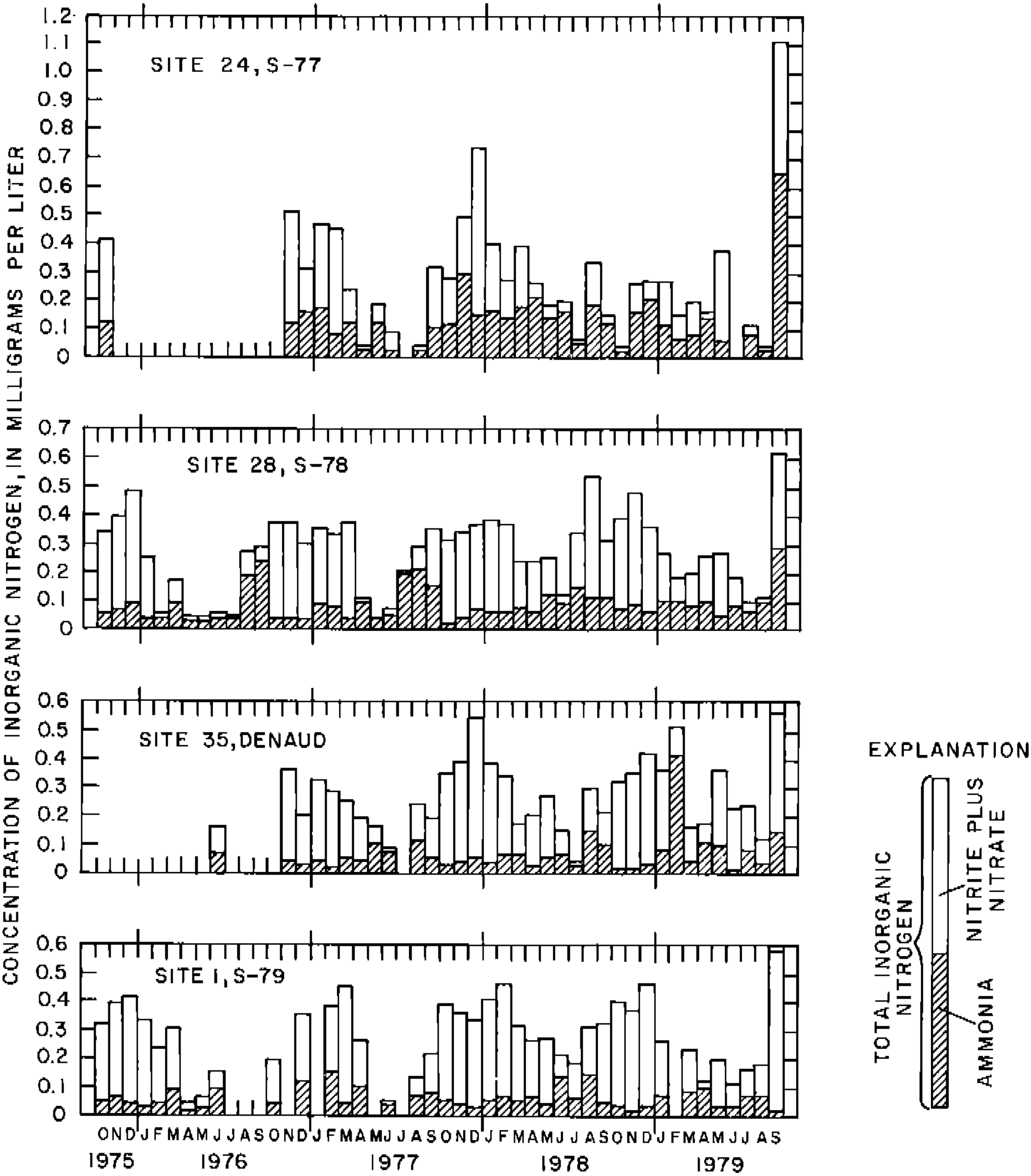


Figure 11.--Concentrations of inorganic nitrogen at four sites on the Caloosahatchee River.

Table 6.--Specific conductance of water in the surficial aquifer in the Caloosahatchee River basin, 1979

[Values shown in micromhos per centimeter at 25°C]

Site number	Date (1979)	Approximate depth, in feet, of sample below land surface	Land cover	Specific conductance
40	Jan. 3	14.0	Pine	3,200
1/41	Feb. 13	3.2	do.	395
	June 19	3.5	do.	750
42	Feb. 14	17.0	Pasture	530
	June 19	17.0	do.	480
	Sept. 17	17.0	do.	495
1/43	Feb. 13	1.9	do.	290
1/44	Jan. 3	2.1	Pine	230
	Feb. 14	1.7	do.	137
	Apr. 25	3.2	do.	258
	Sept. 17	.0	do.	260
1/45	Jan. 4	1.5	Cypress	445
	Feb. 13	.7	do.	415
	Apr. 25	2.7	do.	363
	Sept. 17	.0	do.	385
1/46	Feb. 13	1.5	Pine	1,630
49	Apr. 25	17.0	Pasture	750
	June 19	17.0	do.	780
	Sept. 17	17.0	do.	720
59	June 19	14.0	Developed	560
	Sept. 17	14.0	do.	385

1/ Samples collected at the water table.

Table 7.--Minimum, maximum, and mean for concentrations of nitrogen, phosphorus, and total organic carbon at four sites on the Caloosahatchee River, 1975-79 water years

[Values shown in milligrams per liter]

	Number of analyses	Concentrations		
		Minimum	Maximum	Mean
Site 1, Caloosahatchee River at Franklin Lock (S-79)				
Nitrite plus nitrate as N	46	0.01	0.56	0.21
Ammonia as N	46	.01	.95	.08
Organic as N	46	.10	9.0	1.33
Orthophosphate as P	46	.02	.32	.09
Total phosphorus as P	46	.04	.88	.12
Total organic carbon	37	10	43	21
Site 24, Caloosahatchee Canal at Moore Haven (S-77)				
Nitrite plus nitrate as N	35	.01	2.03	.20
Ammonia as N	35	.02	.65	.14
Organic as N	35	.13	3.80	1.54
Orthophosphate as P	35	.01	.46	.05
Total phosphorus as P	35	.02	.46	.08
Total organic carbon	22	14	50	24
Site 28, Caloosahatchee Canal at Ortona (S-78)				
Nitrite plus nitrate as N	59	.00	.43	.18
Ammonia as N	59	.02	.30	.09
Organic as N	58	.89	4.00	1.44
Orthophosphate as P	50	.02	.31	.12
Total phosphorus as P	60	.04	.56	.15
Total organic carbon	29	3.9	37	22
Site 35, Caloosahatchee River at Denaud				
Nitrite plus nitrate as N	38	.01	.49	.20
Ammonia as N	38	.02	.41	.07
Organic as N	38	.61	1.90	1.16
Orthophosphate as P	38	.02	.19	.09
Total phosphorus as P	38	.04	.23	.11
Total organic carbon	21	13	34	21

In most tributaries, concentrations of inorganic nitrogen were lower than those in the river. The predominant form of inorganic nitrogen was nitrite plus nitrate, but in a few tributaries, such as Lake Hicpochee Canal and Meander Line Ditch, ammonia was dominant (fig. 12). Average concentrations of nitrite plus nitrate were lower in all tributaries, except Messer and Crawford Canals, than in the river (fig. 13). The relatively higher average values at Messer and Crawford Canals were due to one high value each in the six or seven samples collected per canal.

Concentrations of inorganic nitrogen were higher in rainfall and dustfall samples than in surface waters. Average concentrations at the two rainfall sites, S-77 (site 23) and S-78 (site 27), were 0.45 mg/L and 0.23 mg/L for nitrite plus nitrate and 0.90 mg/L and 0.05 mg/L for ammonia, respectively.

Concentrations of phosphorus in the Caloosahatchee River are shown in figure 14 and in table 7. Orthophosphate and total phosphorus concentrations were lower at S-77 than at the downstream sites. At S-77, 61 percent of the samples had concentrations of orthophosphate less than 0.05 mg/L, and 78 percent had less than 0.1 mg/L total phosphorus. For comparison at the three other river sites, 14 percent of the samples has less than 0.05 mg/L orthophosphate (as P), and 39 percent of the samples had less than 0.1 mg/L total phosphorus. Average concentrations of total phosphorus in the river ranged from 0.08 to 0.15 mg/L (table 7).

Average concentrations of orthophosphate and total phosphorus were lower in most tributaries than concentrations in the river (fig. 15). The few tributaries that had higher average concentrations included Lake Hicpochee Canal, Meander Line Ditch, and Long Hammock Canal. Monthly concentrations in these and other selected tributaries are shown in figure 16. Highest values generally occurred in late summer or autumn. Tributaries in the northwest part of the basin, such as Jack Branch, Bee Branch, and Cypress Creek had consistently low (less than 0.1 mg/L total phosphorus) concentrations.

Concentrations of orthophosphate and total phosphorus in rainfall and dustfall samples were comparable with those in the river. Average concentrations of rainfall were 0.13 mg/L orthophosphate and 0.21 mg/L total phosphorus at S-77 (site 23), and 0.09 mg/L orthophosphate and 0.10 mg/L total phosphorus at S-78 (site 27).

Total organic carbon (TOC) is an indicator of the total amount of organic material in water. Figures 17 and 18 show the concentration of TOC at selected river and tributary sites. No seasonal pattern was evident.

Dissolved organic carbon and suspended organic carbon (DOC and SOC) were measured at several sites in the river, tributaries, and in water in the surficial aquifer (table 8). DOC accounted for virtually all the carbon in the surface water and ground water.

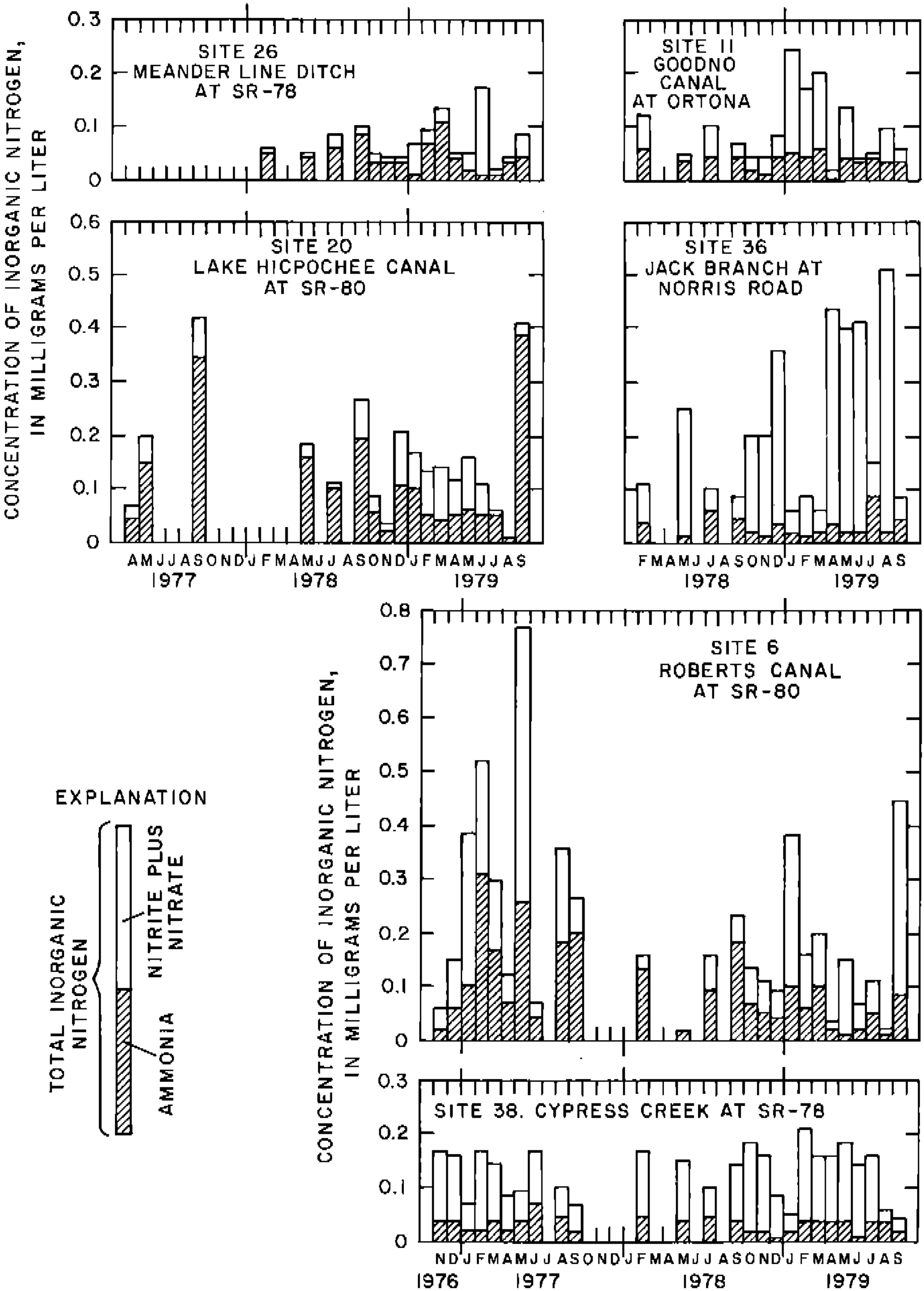


Figure 12.--Concentrations of inorganic nitrogen at selected tributary sites.

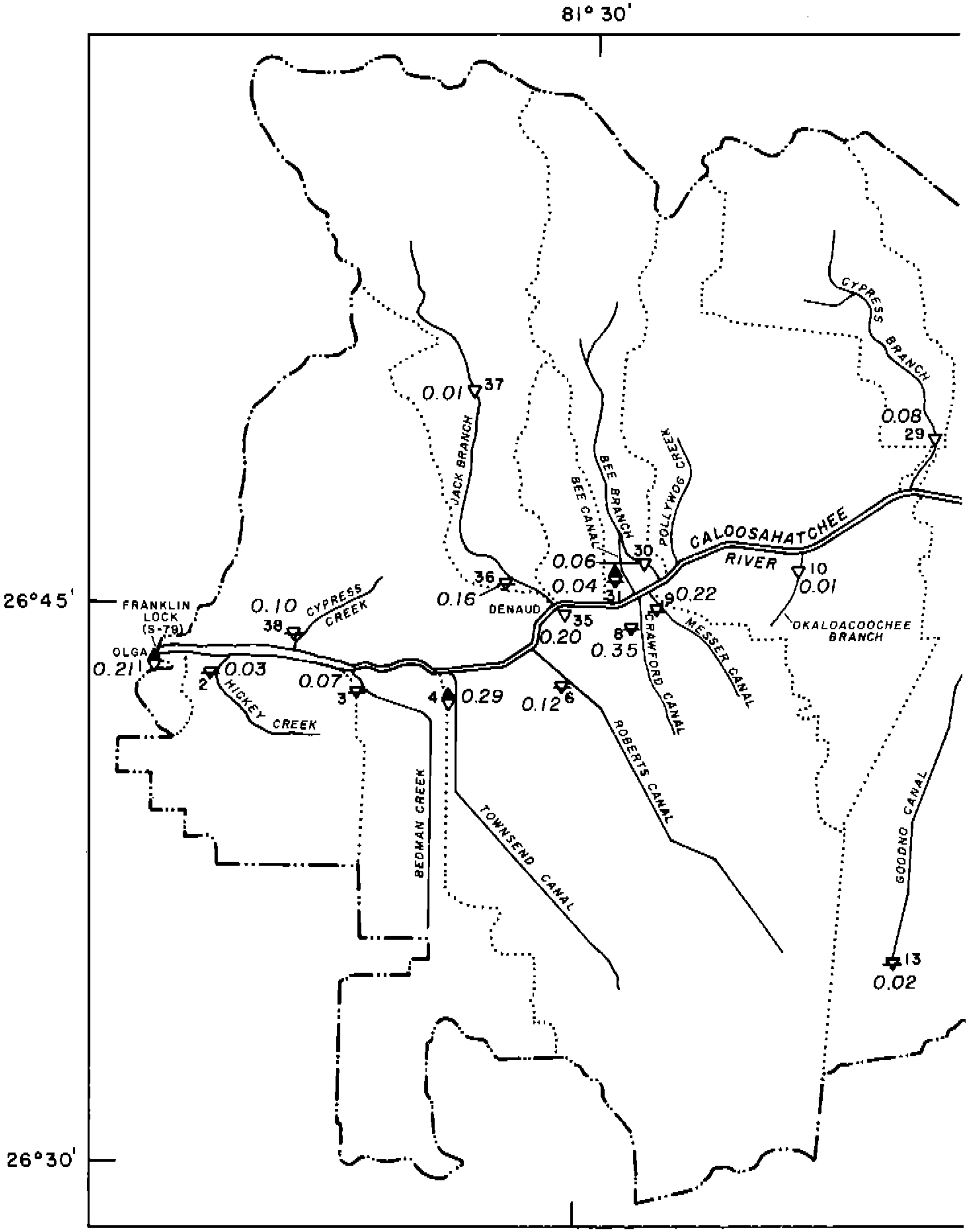
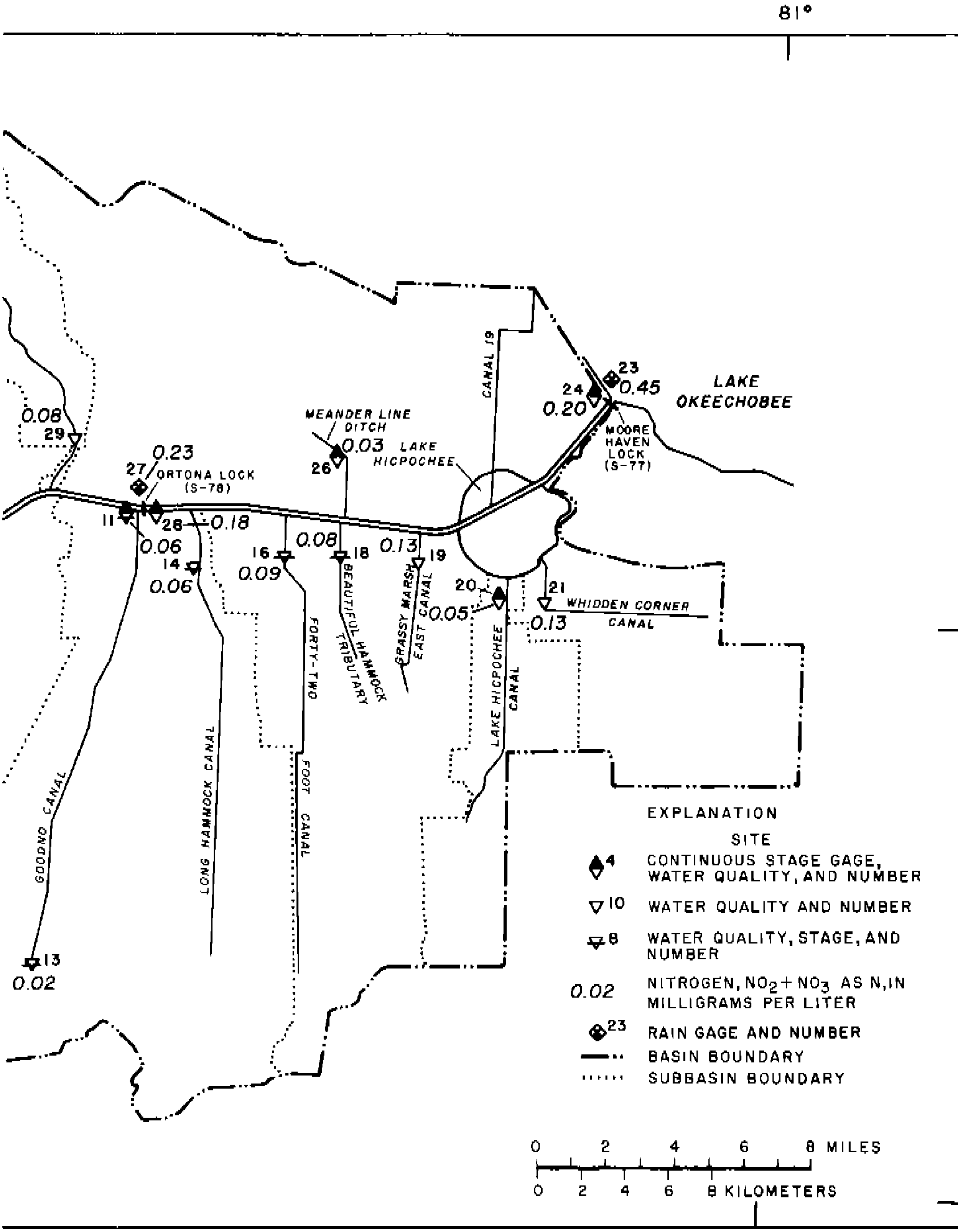


Figure 13.--Mean concentrations of total nitrite plus nitrate



(NO_2 + NO_3 as N), Caloosahatchee River and tributary sites.

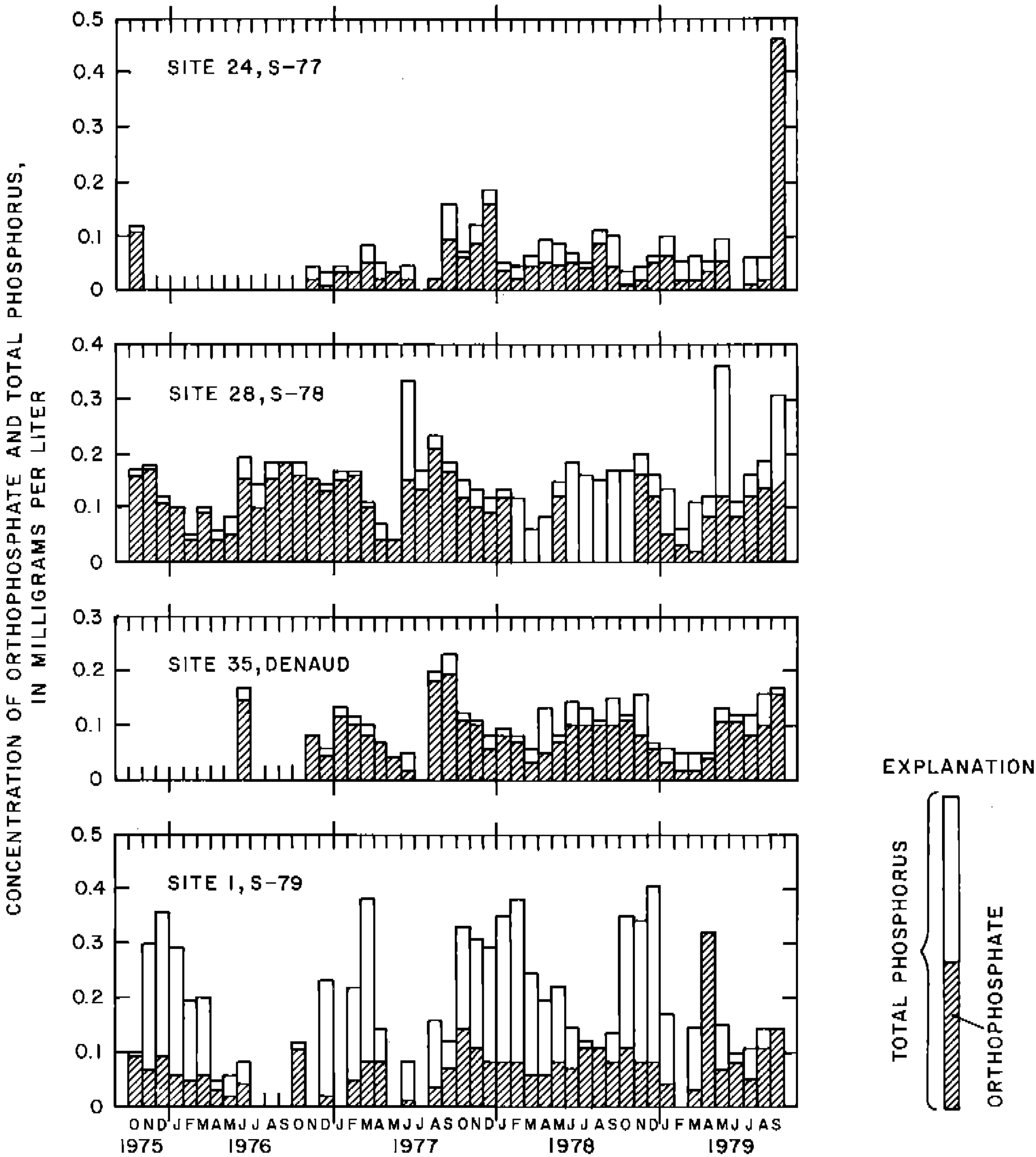


Figure 14.--Concentrations of orthophosphate and total phosphorus at four sites on the Caloosahatchee River.

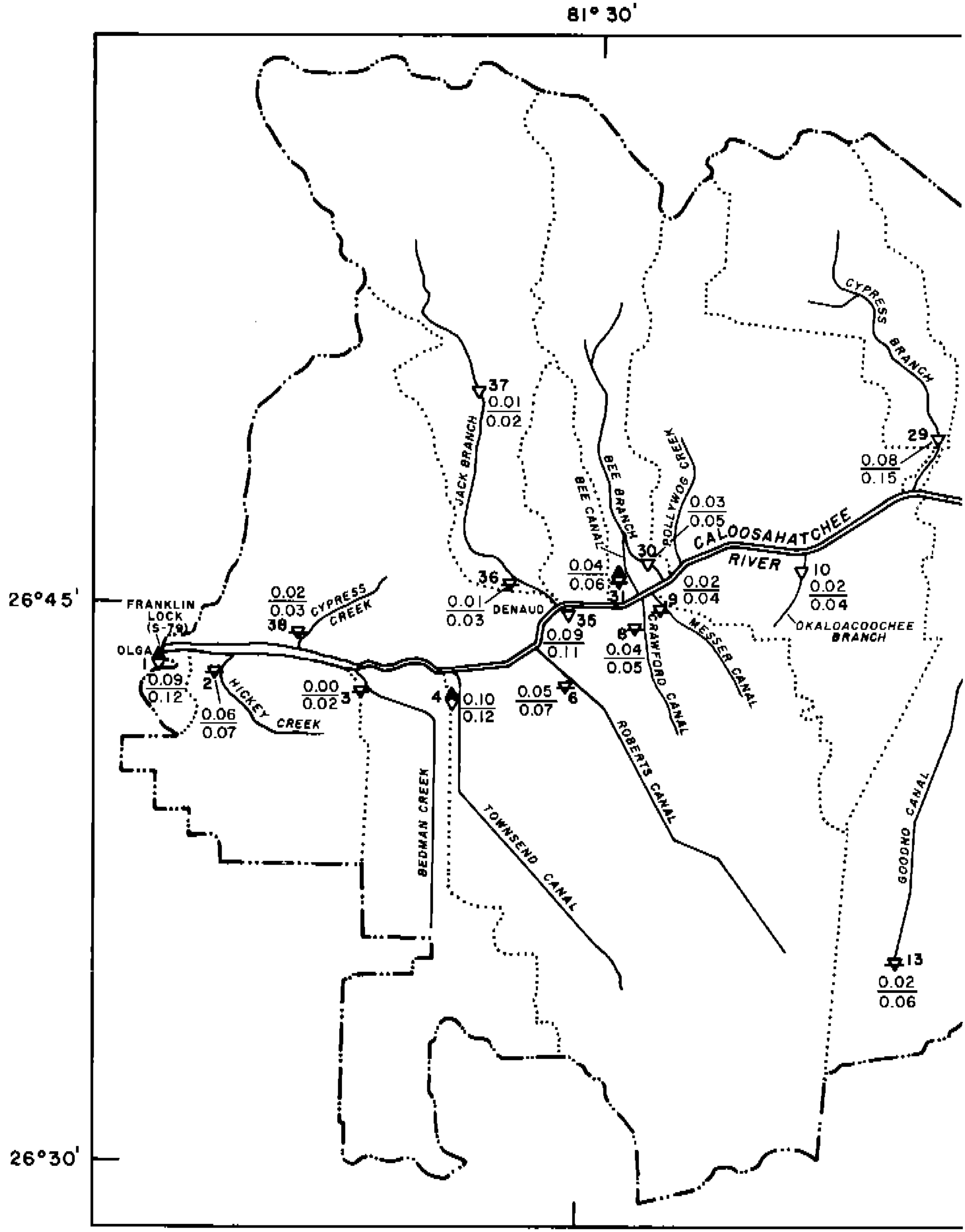
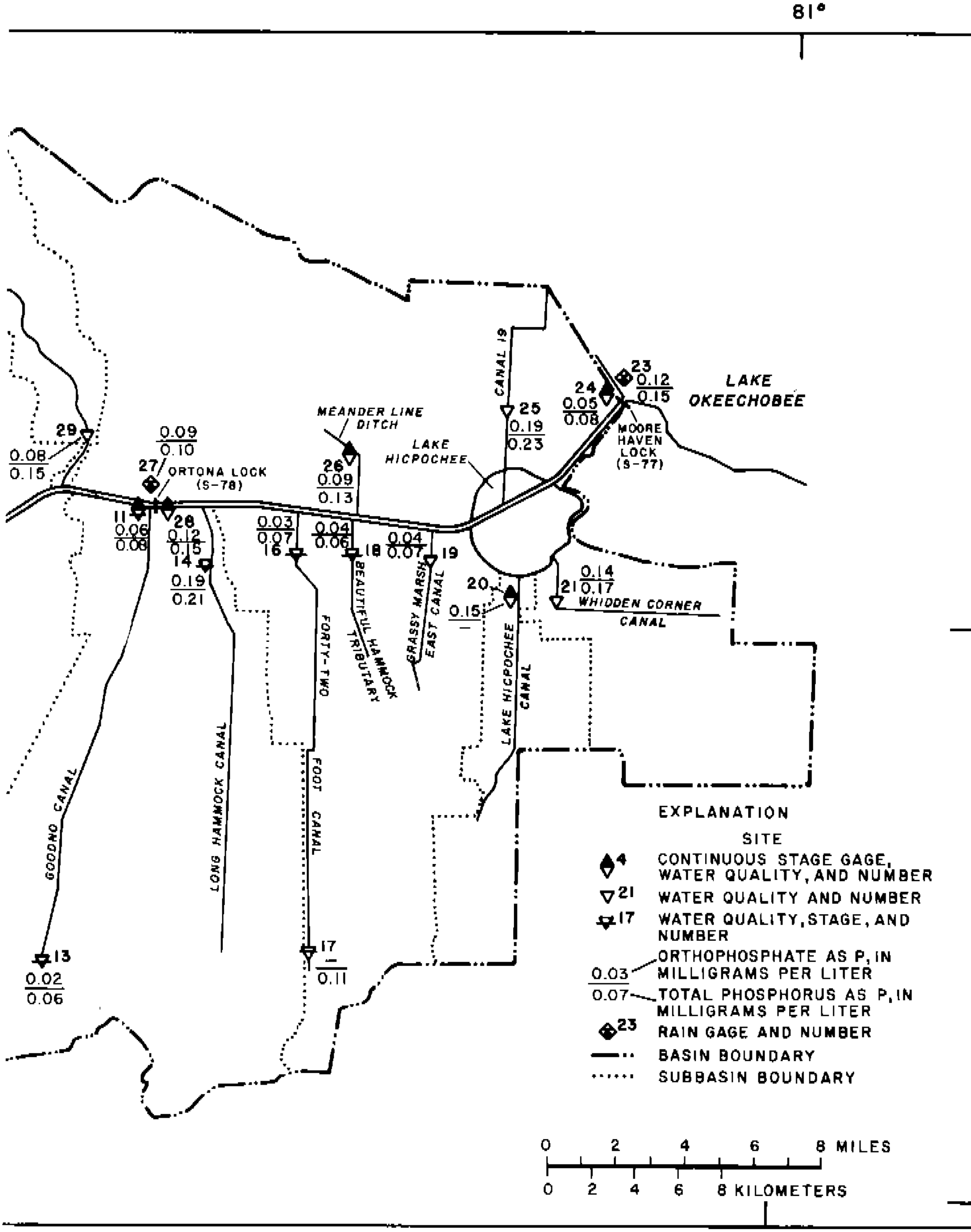


Figure 15.--Mean concentrations of orthophosphate and total



phosphorus in the Caloosahatchee River and tributary sites.

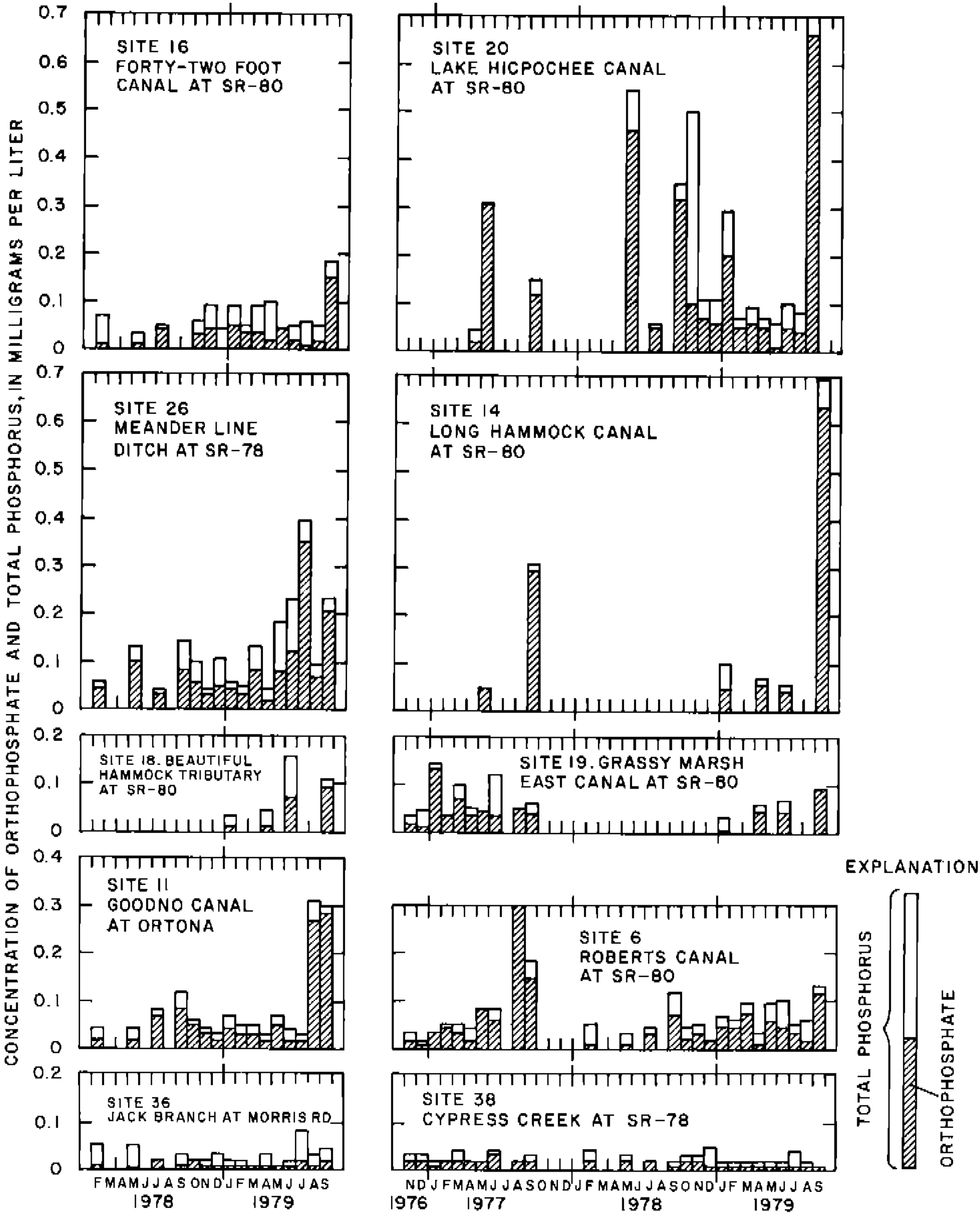


Figure 16.--Concentrations of orthophosphate and total phosphorus at selected tributary sites.

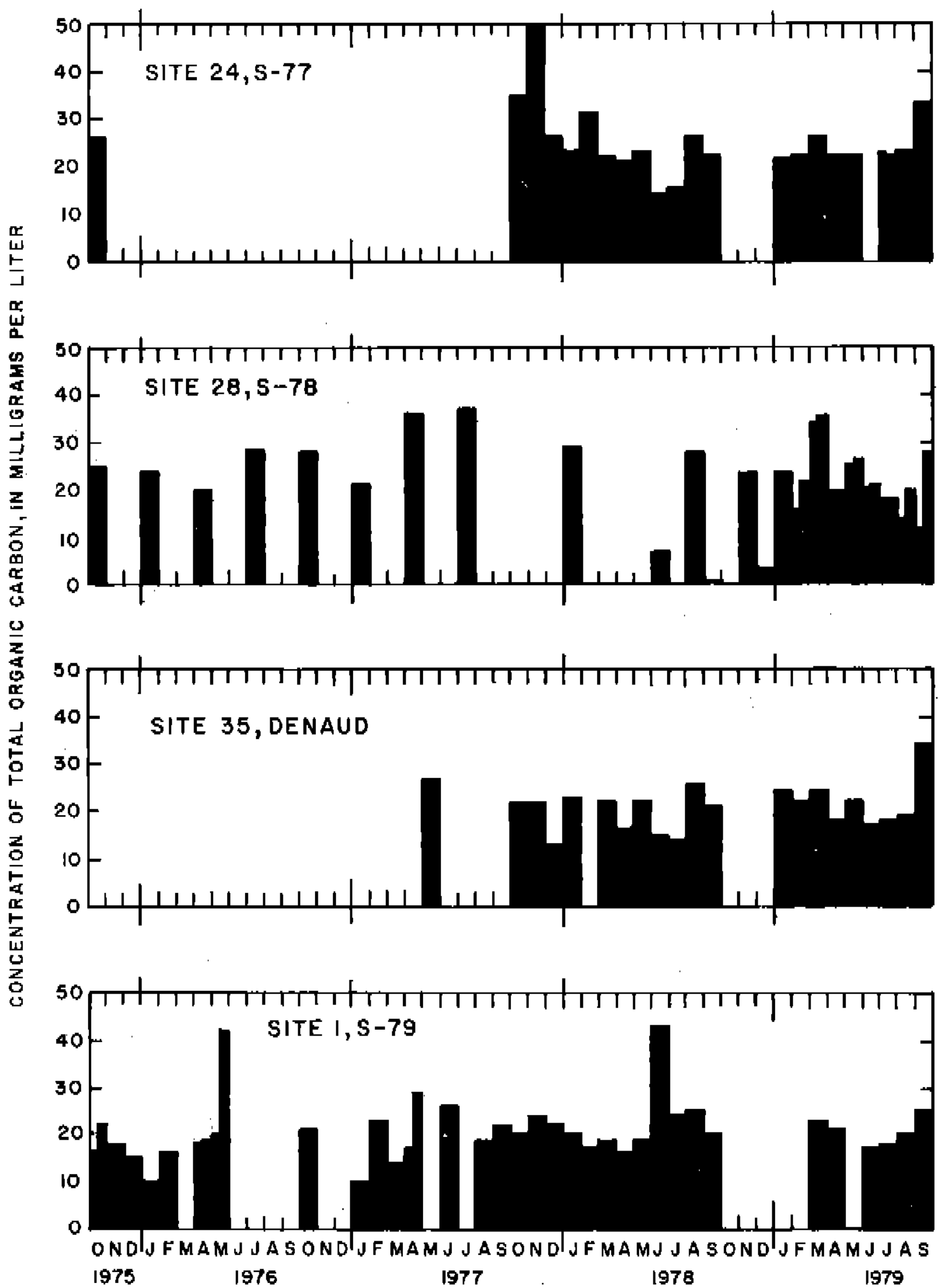


Figure 17.--Concentrations of total organic carbon at four sites on the Caloosahatchee River.

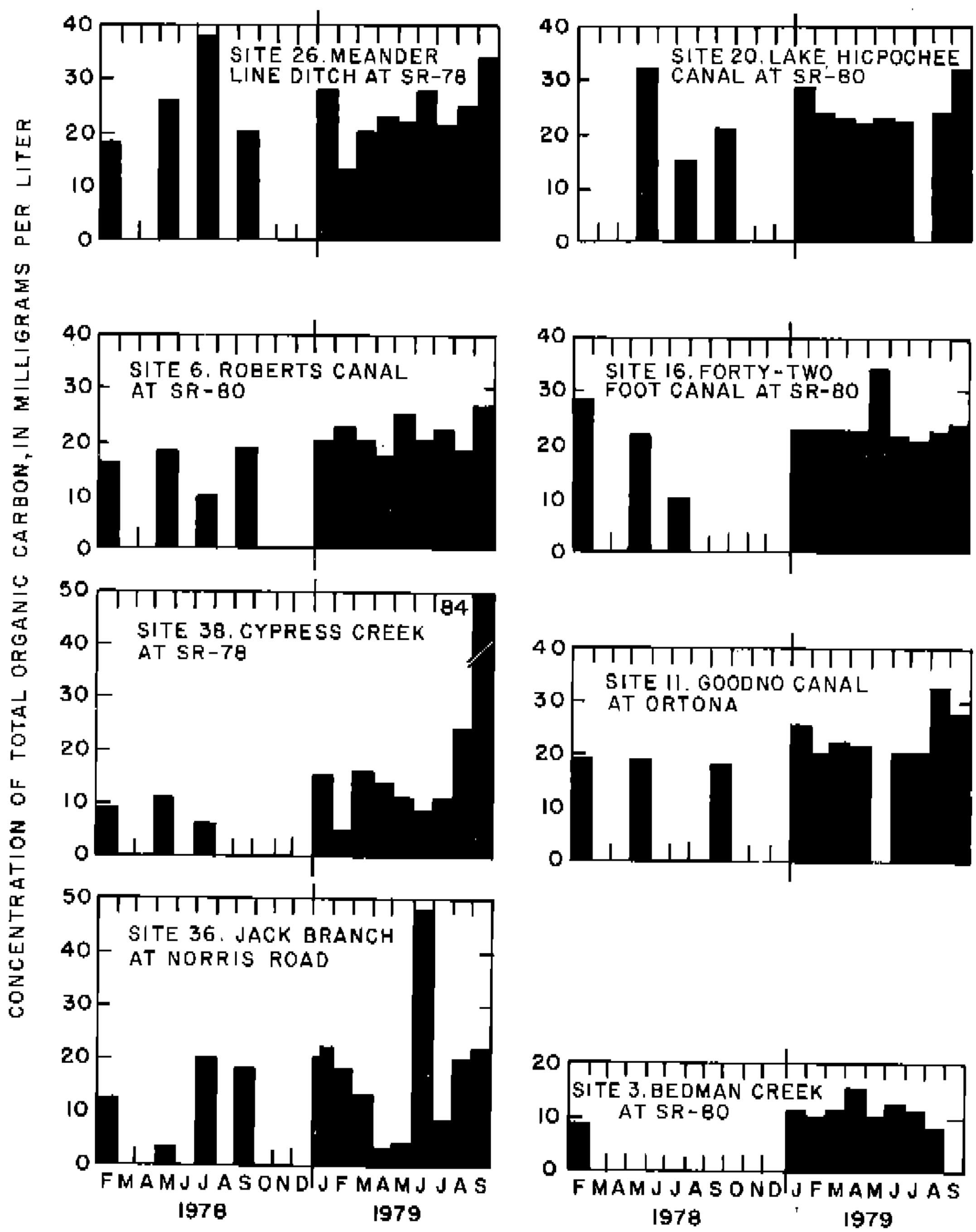


Figure 18.--Concentrations of total organic carbon at selected tributary sites.

Table 8.--Specific conductance and dissolved (DOC), suspended (SOC), and total (TOC) organic carbon in the Caloosahatchee River and tributaries and in the surficial aquifer, 1979

[Values shown in milligrams per liter, except for specific conductance which is shown in micromhos per centimeter at 25°C]

Site number	Date (1979)	Description	Specific conductance	DOC	SOC	TOC
		Caloosahatchee River and tributaries				
11	Mar. 8	Goodno Canal at Ortona	495	26	0.0	26
16	Feb. 14	Forty-Two Foot Canal at State Road 80	652	17	.2	17
37	Feb. 14	Jack Branch at State Road 720	140	14	.1	14
	Sept. 17	do.	82	--	--	--
50	Mar. 7	River at Lee County Water Plant	600	56	.0	56
51	Mar. 7	Ox bow at Lee County Water Plant	600	40	.0	40
57	Mar. 7	River just west of Lake Hicpochee	580	27	.1	27
		Water table				
41	Feb. 13	Pineland, 3.2 feet below land surface	395	28	1.5	30
43	Feb. 13	Pasture, 1.9 feet below land surface	290	48	1.5	50
44	Jan. 3	Pineland, 2.1 feet below land surface	230	62	3.7	66
	Feb. 14	Pineland, 1.7 feet below land surface	137	39	.4	39
	Sept. 17	Pineland, 0.0 feet below land surface	260	--	--	--
45	Feb. 13	Cypress stand, 0.7 feet below land surface	415	43	.4	43
	Sept. 17	Cypress stand, 0.5 feet above land surface	385	--	--	--
46	Feb. 13	Pineland, 1.5 feet below land surface	1,630	96	.6	97
		Surficial aquifer wells				
40	Jan. 3	Well depth, 14 feet below land surface	3,200	26	.1	26
42	Feb. 14	Well depth, 17 feet below land surface	530	16	.2	16
	Sept. 17	do.	495	--	--	--
49	Sept. 17	Well depth, 17 feet below land surface	720	--	--	--
59	Sept. 17	Well depth, 14 feet below land surface	510	--	--	--

Trace Elements

Trace elements are derived from rock and soil and from man's activities. Agricultural activity, for example, introduces trace elements into the atmosphere and aquatic environment through aerial and land spreading applications of fungicides and fertilizers. Common trace elements from agriculture include arsenic, copper, mercury, and zinc. Agriculture is the predominant land use in the Caloosahatchee River basin and is a likely source of trace elements in the river.

Some trace elements are essential for life; others are nonessential. Both essential and nonessential elements can be toxic, depending on concentrations and environmental conditions.

Concentrations of selected trace elements in the Caloosahatchee River and tributaries are given in tables 9-11. Concentrations were generally below levels considered toxic to aquatic life (U.S. Environmental Protection Agency, 1977a; Gough and others, 1979). With the exception of iron, concentrations did not exceed the MCL (maximum contaminant level) for drinking water established by the U.S. Environmental Protection Agency (1975a, 1975b, and 1977b). The MCL for iron is a proposed secondary drinking water regulation and is not federally enforceable. Concentrations of iron in south Florida water often exceed the U.S. Environmental Protection Agency MCL.

Concentrations of copper were slightly higher at the upstream river sites than at the downstream sites (table 9). The higher concentrations may be due to application of copper sulfate in the eastern part of the basin for control of aquatic weeds. Water lettuce is especially bothersome at S-77, where sometimes the first lockage of the day has a dense cover of this plant. At times, the river at Moore Haven has become so choked with water lettuce that boat traffic has been impossible.

Rainfall and dustfall samples, collected over a period of about 1 month at sites 23 and 27, were analyzed for selected trace elements (table 12). Concentrations of most of these elements from rainfall and dustfall samples were similar to those in the river, except for boron and manganese which were higher in the river.

Pesticides

Samples of water and bottom sediment were collected at four river sites for pesticide analyses. The insecticides: chlordane, DDT, DDD, DDE, and dieldrin; and the industrial organic compound polychlorinated biphenyls (PCB) were detected in bottom sediment (table 13).

Table 9.--Concentrations of trace elements (total) at four sites on the Caloosahatchee River, 1977-79 water years

[Concentrations shown in micrograms per liter]

	Aluminum	Arsenic	Boron	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Silicon	Zinc
Site 1, Caloosahatchee River at Franklin Lock (S-79)													
Number of samples-----	6	6	6	—	6	6	2	6	6.0	6	—	--	6
Minimum-------	40	1	30	—	0	120	0	10	.5	0	—	—	0
Maximum-------	100	5	130	--	4	370	1	20	.5	11	—	--	50
Mean----------	60	2	90	--	2	230	1	20	.5	5	—	—	20
Standard deviation---	23	1	35	—	1	113	1	5	—	4	—	--	21
Site 24, Caloosahatchee at Moore Haven (S-77)													
Number of samples-----	6	6	6	—	6	6	2	6	6	6	--	—	6
Minimum-------	10	1	80	—	1	110	1	10	.5	0	--	—	0
Maximum-------	70	4	150	—	13	350	7	30	.5	8	--	—	40
Mean----------	50	2	120	--	4	200	4	20	.5	4	--	--	20
Standard deviation---	22	1	28	—	4	89	6	8	—	3	—	--	15

Table 9.--Concentrations of trace elements (total) at four sites on the Caloosahatchee River, 1977-79 water years--Continued

[Concentrations shown in micrograms per liter]

	Aluminum	Arsenic	Boron	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Silicon	Zinc
Site 28, Caloosahatchee Canal at Ortona (S-78)													
Number of samples-----	5	17	5	12	17	17	4	17	17	6	12	6	17
Minimum-------	50	1	80	.0	0	110	0	10	.5	0	.0	.0	0
Maximum-------	140	4	200	8.0	17	750	8	30	.7	10	.0	.0	40
Mean----------	90	2	120	.9	3	330	3	20	.5	5	.0	.0	20
Standard deviation---	35	1	50	2.3	4	161	3	8	--	4	--	--	13
Site 35, Caloosahatchee River at Denaud													
Number of samples-----	6	6	6	--	6	6	3	6	6	6	--	--	6
Minimum-------	30	1	20	--	0	110	1	10	.5	1	--	--	0
Maximum-------	100	4	130	--	4	520	2	30	.5	10	--	--	50
Mean----------	60	2	90	--	2	300	2	20	.5	4	--	--	20
Standard deviation---	24	1	41	--	1	168	1	8	--	3	--	--	19
Primary[1/] regulation--	--	50	--	--	--	--	50	--	2.0	--	10	--	--
Secondary[2/] regulation--	--	--	--	--	1,000	300	--	50	--	--	--	--	5,000

1/ U.S. Environmental Protection Agency, 1975a and 1975b, National Interim Primary Drinking Water Regulations; was effective June 24, 1977.

2/ U.S. Environmental Protection Agency, 1977, Proposed Secondary Drinking Water Regulations.

Table 10.--Concentrations of trace elements (total) in tributaries of the Caloosahatchee River, 1977-79 water years

[Concentrations shown in micrograms per liter]

Site No.	Tributaries	Arsenic	Aluminum	Copper	Iron	Lead	Manganese	Mercury	Nickel	Zinc
3	Bedman Creek	2	40	2	490	3	0	0.5	0.0	10
6	Roberts Canal	3	40	3	580	0	20	.5	.0	0
11	Goodno Canal (at Ortona)	2	40	4	490	0	20	.5	.0	0
13	Goodno Canal (at SR-832)	1	40	3	650	2	10	.5	.0	0
16	Forty-Two Foot Canal	2	50	5	1,400	1	20	.5	.0	10
20	Lake Hicpochee Canal	2	60	5	990	3	80	.5	.0	20
26	Meander Line Ditch	2	110	2	1,800	1	20	.5	.0	0
31	Bee Canal	1	160	2	590	2	10	.5	.0	10
36	Jack Branch	1	110	4	430	1	10	.5	1.0	20
38	Cypress Creek	1	30	3	240	1	10	.5	.0	10
Mean		2	68	3	766	1	20	.5	.1	8

Table 11.--Concentrations of trace elements in bottom sediment at four sites on the Caloosahatchee River, 1978

[Concentrations shown in micrograms per gram]

	Site 1, at Franklin Lock (S-79)1/	Site 24, at Moore Haven (S-77)	Site 28, at Ortona (S-78)1/	Site 35, at Denaud
Arsenic	1 - 2	0	1 - 6	1
Copper	10 - 10	10	10 - 10	10
Iron	2,300 - 5,300	1,900	3,200 - 3,500	1,500
Lead	40 - 40	600	10 - 20	30
Manganese	30 - 70	60	20 - 30	30
Mercury	0 - .14	0	0 - 0	0
Zinc	20 - 30	130	10 - 100	10

1/ Two samples.

Table 12.--Concentrations of trace elements (total) in rainfall and dustfall at Lake Okeechobee and Ortona, 1979 water year

[Values shown in micrograms per liter, except for total rainfall which is shown in inches]

Period of collection	Total rainfall	Aluminum	Arsenic	Boron	Copper	Iron	Lead	Manganese	Mercury	Nickel	Zinc
				Site 23, Rain Gage at Lake Okeechobee Rim Canal							
12/12/78 to 1/16/79	5.86	30	1	0	1	80	—	0	0.5	4	10
5/21/79 to 6/13/79	1.96	50	1	--	--	60	—	10	.5	11	20
8/13/79 to 9/19/79	13.93	20	0	0	2	30	1	0	.5	0	0
				Site 27, Rain Gage at Ortona							
12/13/78 to 1/16/79	4.66	20	0	20	1	60	—	0	.5	3	30
5/21/79 to 6/12/79	2.47	20	0	7	2	100	5	0	.5	10	30
8/13/79 to 9/19/79	8.86	20	0	0	2	30	3	0	.5	0	10

Table 13.--Concentrations of pesticides in bottom sediment at four sites on the Caloosahatchee River, 1978

[Concentrations shown in micrograms per kilogram]

	Site 1, at Franklin Lock (S-79)[1]/	Site 24, at Moore Haven (S-77)[2]/	Site 28, at Ortona (S-78)[3]/	Site 35, at Denaud[4]/
Aldrin, total	0.0	0.0	0.0	0.0
Lindane, total	.0	.0	.0	.0
Chlordane	.0 - 2.0	.0	.0 - 7.0	.0
DDD, total	.7 - 8.7	1.0	.01 - 2.8	3.1
DDE, total	.0 - 20	.1	.0 - 6.4	4.6
DDT, total	.0	1.1	.0	.7
Dieldrin, total	1.1 - 7.1	.3	.0	.0
Endrin, total	.0	.0	.0	.0
Ethion, total	.0	.0	.0	.0
Toxaphene, total	.0	.0	.0	.0
Heptachlor, total	.0	.0	.0	.0
Heptachlor epoxide, total	.0	.0	.0	.0
PCB, total	180 - 540	1.0	.0 - 3.0	.0
Malathion, total	.0	.0	.0	.0
Parathion, total	.0	.0	.0	.0
Diazinon, total	.0	.0	.0	.0
Methyl parathion, total	.0	.0	.0	.0
2,4-D, total	.0	.0	.0	.0
2,4,5-T, total	.0	.0	.0	.0
Silvex, total	.0	.0	.0	.0
Trithion, total	.0	.0	.0	.0
Methyl trithion, total	.0	.0	.0	.0

1/ Three samples.
2/ One sample.
3/ Three samples.
4/ One sample.

The same suite of pesticides and related organics listed in table 13 was also analyzed in two water samples at each of the four river sites. Of these, only the herbicides, 2,4-D and silvex, were detected in the water. Concentrations of 2,4-D were 0.01 and 0.22 ug/L (micrograms per liter) (S-77), 0.08 and 0.31 ug/L (S-78), 0.04 and 0.06 ug/L (Denaud), and 0.00 and 0.01 ug/L (S-79). Silvex was detected once at Denaud (0.01 ug/L).

NUTRIENT TRANSPORT

Nutrients are transported to the Caloosahatchee River by discharge from Lake Okeechobee at S-77, by surface and subsurface runoff from the basin, by rainfall and dustfall on the river surface, and by saltwater intrusion from seepage and boat lockage at S-79. Rainfall and dustfall on the river surface and seepage from the estuary account for only a small part of the total input of nutrients because of the relatively small amount of water involved (see section on rainfall). Most of the nutrients transported to the river come from the lake and basin and include nutrients in rainfall and dustfall on these surfaces. The river discharges nutrients to the estuary at S-79.

The annual transport of nitrogen, phosphorus, and chloride into and out of the Caloosahatchee River during 1977-79 is presented in table 14. Chloride was included because it is a biologically conservative element and provides a standard by which to evaluate biological flux of nutrient values. The input loads from Lake Okeechobee and the output loads were based on monthly measurements of concentrations. Errors involved in annual loading estimates, based on a monthly chemical sampling frequency, may be as high as 13 percent (Steele, 1971).

The differences between nutrient input from Lake Okeechobee and output to the estuary (table 14) are attributed to contributions from the basin and to biological processes in the river. The differences in chloride input and output are attributed to contribution from the basin and to upstream seepage from the estuary.

Contributions of nitrite plus nitrate, orthophosphate, and total phosphorus from the basin and the river substantially exceeded the input from Lake Okeechobee, while contributions of ammonia from the basin and river were quite small compared with input from the lake. Oxidation of organic material and ammonia in the river probably accounts for some of the downstream increase of nitrite plus nitrate and for the relatively small increase of ammonia (table 14).

Table 14.--Transport of nitrogen, phosphorus, and chloride in the Caloosahatchee River annually

[Constituents shown in total tons]

Constituent and water year	Input from Lake Okeechobee at S-77	Difference (attributed to basin concentrations)	Output to estuary at S-79
Chloride			
1977	17,000	19,000	36,000
1978	27,000	37,000	64,000
1979	59,000	41,000	100,000
Nitrite plus nitrate			
1977	16	74	90
1978	32	132	164
1979	81	204	285
Ammonia			
1977	27	6	33
1978	42	21	63
1979	92	18	110
Total nitrogen			
1977	377	423	800
1978	494	986	1,480
1979	1,410	1,130	2,540
Orthophosphate			
1977	9	33	42
1978	14	61	75
1979	32	91	123
Total phosphorus			
1977	15	44	59
1978	25	80	105
1979	57	116	173

Table 15.--Basin input to the Caloosahatchee River from Jack Branch and Goodno Canal, 1979 water year

	Tons per year	Tons per acre-ft
Site 36, Jack Branch at Norris Road		
Chloride	546	0.52×10^{-1}
Nitrite plus nitrate	.85	$.81 \times 10^{-4}$
Ammonia	.60	$.56 \times 10^{-4}$
Total nitrogen	43.8	41.9×10^{-4}
Orthophosphate	.28	$.27 \times 10^{-4}$
Total phosphorus	.57	$.54 \times 10^{-4}$
Site 11, Goodno Canal at Ortona		
Chloride	1,440	1.21×10^{-1}
Nitrite plus nitrate	1.9	1.6×10^{-4}
Ammonia	1.2	1.0×10^{-4}
Total nitrogen	47.6	40.0×10^{-4}
Orthophosphate	1.9	1.0×10^{-4}
Total phosphorus	2.0	1.7×10^{-4}

A calculation of individual subbasin input was not attempted because the complex water-management systems prohibited an accurate determination of individual subbasin inflow. However, two sites--one on the north side of the river (Jack Branch) and one on the south side (Goodno Canal)--were gaged and sampled in 1979, and loads were computed for comparison of inputs. The relative input (tons per acre-feet) into the river for chloride, nitrite plus nitrate, ammonia, orthophosphate, and total phosphorus was two to more than four times larger from Goodno Canal on the south side of the river than from Jack Branch on the north side (table 15). Relative input of total nitrogen was about the same from both tributaries. The larger relative input of most nutrients from Goodno Canal is probably due to the greater agricultural development in the land drained by the canal than that drained by Jack Branch.

SUMMARY AND CONCLUSIONS

Results of this investigation are based principally upon data collected between 1976-79; however, selected historical data collected before 1976 are used to indicate long-term trends. The following are the major conclusions drawn from these results:

1. On the average, about half the water that enters the Caloosahatchee River comes from Lake Okeechobee; the other half comes from the river basin. However, this varies from year to year. Over a 10-year span (1970-79 water years), input from the lake ranged from 10 to 71 percent of the total annual input.

2. Concentrations of dissolved oxygen in the river ranged from less than 1 mg/L near the bottom to 13 mg/L near the surface. Concentrations fluctuated seasonally, being higher in winter and spring and lower in late summer and early autumn. Values were below 4 mg/L at the four river sites in late summer of 1978 and 1979. Concentrations were generally 1 to 2 mg/L lower near the river bottom than near the surface, but occasionally the difference exceeded 6 mg/L.

3. Specific conductance in the river was highest near the bottom at S-79 where it sometimes exceeded 10,000 umho/cm. This high specific conductance resulted from seepage and boat lockage of estuarine water. Average (1976-79) specific conductance from vertical river profiles was highest at S-77 (660 umho/cm) and lowest at S-78 (566 umho/cm).

4. Specific conductance increased and ionic composition changed in the headwaters of the river over the last 35 years. Sodium, chloride, magnesium, and sulfate increased in relative abundance compared with calcium and bicarbonate.

5. Specific conductance in the tributaries generally increased with nearness to the river and during the dry season. Bee Branch and Bee Canal were the most saline of the tributaries as a result of input from saline ground water from irrigation wells. Average specific conductance at Bee Branch was 1,045 umho/cm.

6. The specific conductance of shallow ground water was quite variable, ranging from 137 to 3,200 umho/cm.

7. Concentrations of nitrogen and phosphorus compounds in the river fluctuated from month to month in response to input, flushing, oxidation, and biological processes. Concentrations of nitrite plus nitrate nitrogen were virtually depleted during algal blooms. Concentrations of ammonia were higher, and orthophosphate and total phosphorus were lower, at S-77 than downstream.

8. In most tributaries, concentrations of nitrogen and phosphorus compounds were lower than those in the river. The predominant form of inorganic nitrogen in the tributaries was nitrite plus nitrate, but in a few eastern tributaries ammonia predominated. A few of these eastern tributaries also had higher average concentrations of orthophosphate and total phosphorus than in the river. The tributaries with the relatively higher concentrations of ammonia and phosphorus compounds were in subbasins with extensive agricultural development.

9. In the limited sampling for trace elements and pesticides, no serious contamination was detected.

10. Contributions of nitrite plus nitrate, orthophosphate, and total phosphorus from the basin and the river substantially exceeded input from Lake Okeechobee, while contributions of ammonia from the basin and river were quite small compared with input from the lake. Oxidation of organic material and ammonia in the river probably accounts for some of the downstream increase of nitrite plus nitrate and for the relatively small increase of ammonia.

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