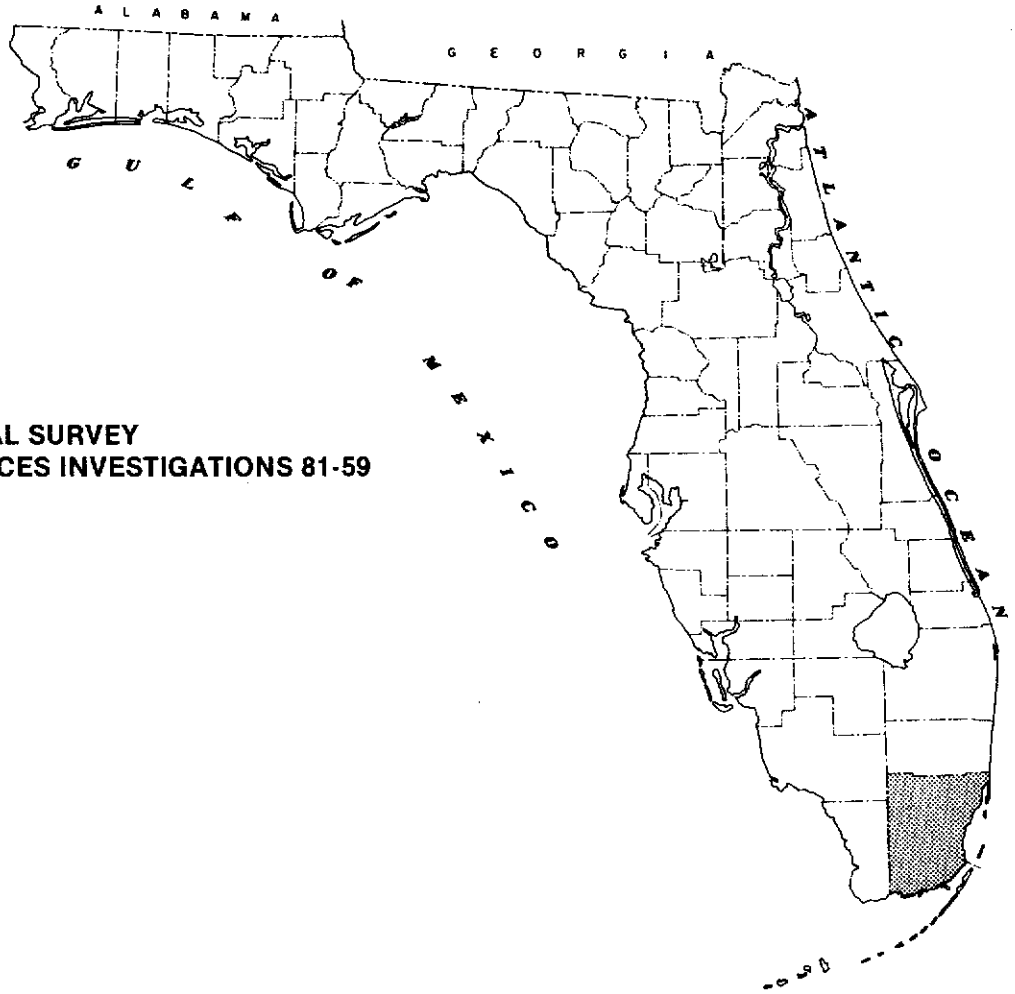
EFFECTS OF LAND USE ON SURFACE-WATER QUALITY IN THE EAST EVERGLADES, DADE COUNTY, FLORIDA



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WATER-RESOURCES INVESTIGATIONS 81-59

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Water quality was determined at five developed areas in the East Everglades, Dade County, Florida, during the 1978 wet season (June through October). Data from the developed areas were compared with data from four baseline sites in undeveloped areas to determine the effects of land use on the surface-water quality. Except for a rock-plowed tomato field (agricultural use), the developed areas have water quality similar to background sites in either the Northeast Shark River Slough or Taylor Slough.

Water quality at the rock-plowed tomato field is affected by agricultural activities and chemical application as indicated by increased concentrations of orthophosphate, organic nitrogen, organic carbon, copper, manganese, mercury, and potassium.

Chemical analyses of soil at each area indicated contamination by chlorinated-hydrocarbon insecticide residues at Coopertown and the two agricultural areas, Cracker Jack Slough and the rock-plowed tomato field. Trace element contamination occurred at both the agricultural areas (manganese) and at Coopertown (lead and zinc).

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METROPOLITAN DADE COUNTY PLANNING DEPARTMENT

Tallahassee, Florida

1982

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Factors for converting inch-pound units to International System (SI) of metric units, and abbreviations of units

Multiply	By	To obtain
	Length	
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare (ha)

EFFECTS OF LAND USE ON SURFACE-WATER QUALITY IN THE EAST EVERGLADES, DADE COUNTY, FLORIDA

By Bradley G. Waller

ABSTRACT

Water-quality characteristics were determined at five developed areas in the East Everglades, Dade County, Florida, during the 1978 wet season (June through October). These areas are designated as: Coopertown; Chekika Hammock State Park; residential area; rock-plowed tomato field; and Cracker Jack Slough agricultural area. Data from the developed areas were compared with data from four baseline sites in undeveloped areas to determine the effects of land use on the surface-water quality.

The rock-plowed tomato field was the only area where surface-water quality was affected. Water quality at this field is affected by agricultural activities and chemical applications as indicated by increased concentrations of orthophosphate, organic nitrogen, organic carbon, copper, manganese, mercury, and potassium.

The remaining four areas of land use had water-quality characteristics typical of baseline sites in nearby Northeast Shark River Slough or Taylor Slough.

Chemical analyses of soil indicated chlorinated-hydrocarbon insecticide residues at Coopertown and the two agricultural areas, Cracker Jack Slough and the rock-plowed tomato field. Trace elements in concentrations greater than base level occurred at both agricultural areas (manganese), Chekika Hammock State Park (manganese), and at Coopertown (lead and zinc).

INTRODUCTION

The East Everglades study area (fig. 1), situated between Everglades National Park and the intensively developed areas of eastern Dade County, occupies approximately 190 mi^2 of southwestern Dade County, Fla. This area is mostly undeveloped wetland bordered on the north by the Tamiami Canal, on the west and south by the Everglades National Park, and on the east by the Levee 31N and Canal 111 complex.

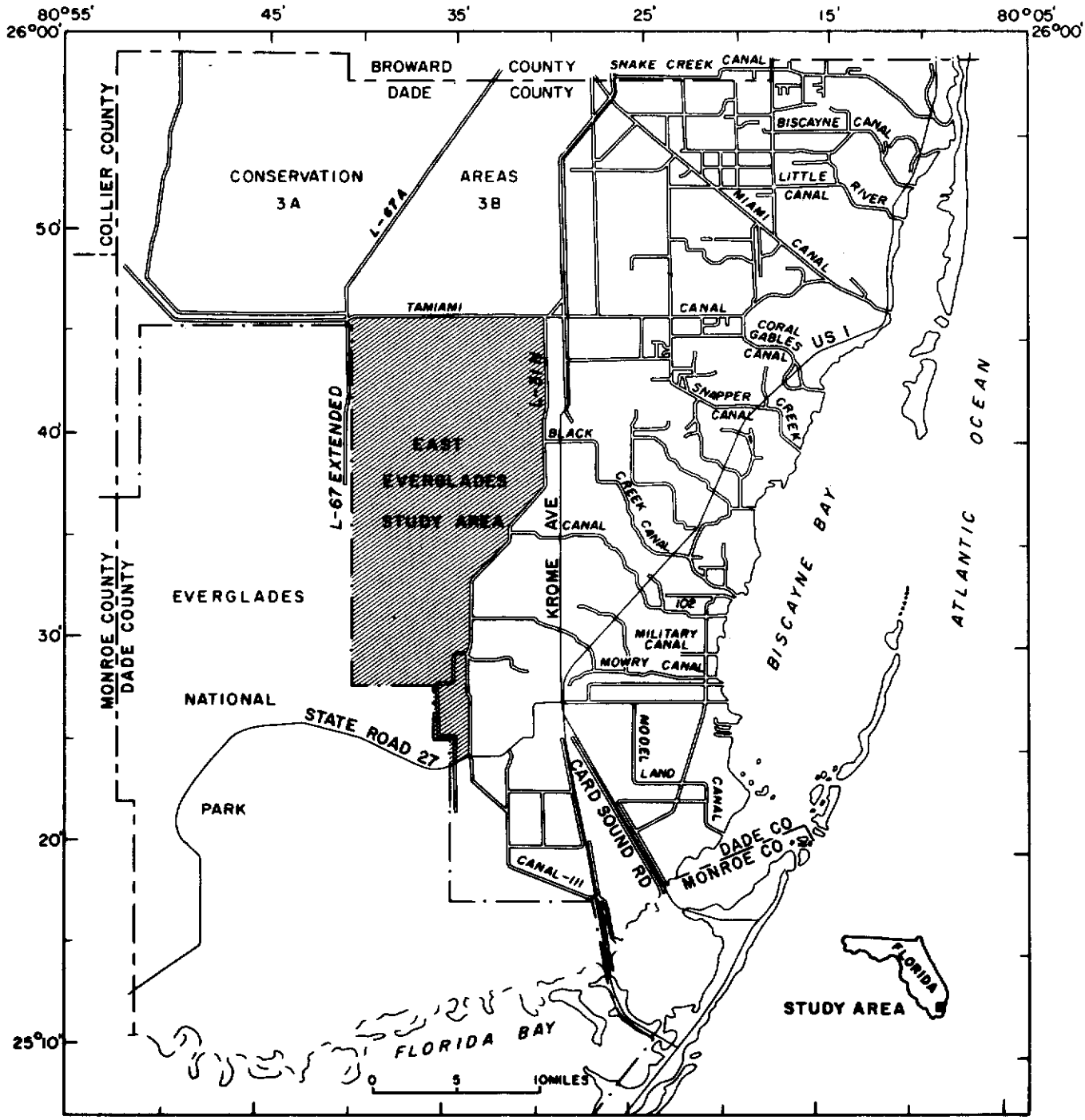

Figure 1.—Dade County showing the East Everglades study area.

As the need for more agricultural and residential land in south Dade County increased, development spread westward into the East Everglades area. The East Everglades previously was considered marginal for most development purposes because it was extensively inundated and inaccessible during times of excessive rainfall. Since 1975, development became economically more feasible due to rising land prices and an increased demand for agricultural land. Both improved and unimproved roads were constructed in the mid 1970's, and the first phases of agricultural development and increased residential use began.

Purpose and Scope

Concern by officials of both Everglades National Park and Dade County about the effects of development of land in the East Everglades for various uses created the need for additional information on the hydrology of this wetland. The hydrology of wetlands is also a major thrust of the U.S. Geological Survey. Because of this mutual interest, the U.S. Geological Survey and Dade County have cooperated in a study of one element of wetland hydrology--the effects that certain land uses have on the surface-water quality (Metropolitan Dade County Planning Department, 1978, p. 49-52).

The scope of this investigation included monthly collection of surface-water samples for chemical analysis through one wet season. The parameters analyzed and the sampling frequency are given in table 1. Samples were also collected during times of intense rainfall (event samples) that equaled or exceeded a rate of 1.0 inch per hour.

Sampling began in June 1978 and ended in October 1978. Event samples were collected in July, September, and October. Analyses for total coliform, fecal coliform, and fecal streptococci counts were made at the State of Florida Health and Rehabilitative Services laboratory in Miami. Soil samples were collected in September and analyzed for macronutrient, trace element, and chlorinated-hydrocarbon insecticide concentrations. Each soil sample consisted of a composite of five subsamples collected at different locations in the land-use area and sieved through a no. 5-mesh sieve before being processed for chemical analysis.

Acknowledgments

The author would like to thank John Cooper, Walter Kiker, and Fritz Rutzke for permitting the U.S. Geological Survey to collect soil and water samples on their properties. The author's gratitude is also extended to the Staff of Chekika Hammock State Park and Ellen Curtis of Coopertown for providing information on the

Table 1.--Parameters analyzed and sampling frequency

Parameters	Frequency
Macronutrients: organic nitrogen, ammonium nitrogen, nitrite and nitrate nitrogen, total nitrogen, orthophosphate, total phosphorus, total organic carbon (TOC), and total inorganic carbon	Monthly; June to October, 1978
Physical characteristics and field measurements: temperature, dissolved oxygen (DO), turbidity, color, pH, alkalinity, specific conductance, total residue, and suspended solids	Monthly; June to October, 1978
Bacteria: total coliform, fecal coliform, and fecal streptococci	Monthly; June to October, 1978
Event sampling[1]/ of macronutrient, total residue, trace elements (arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, potassium, and zinc), insecticides, herbicides, and polychlorinated biphenyls (PCB)	During intense rainfalls in July, September, and October, 1978

1/ Sample taken during an intense rainfall equal to or exceeding a rate of 1.0 inch per hour.

intensity of rainfall in the study area; and to Margaret L. Ronald and Vida S. Piera of the Metropolitan Dade County Department of Environmental Resources Management who provided technical assistance for this investigation. The assistance courteously provided by these people aided the author materially during the investigation.

LAND-USE AREAS SELECTED

Five developed land-use areas in the East Everglades study area were selected to determine water-quality characteristics during one wet season. These developed areas were chosen to best represent current, major uses in the East Everglades. The five areas selected were: Coopertown, Chekika Hammock State Park, residential area, rock-plowed tomato field, and Cracker Jack Slough agricultural area.

One sampling site for each land-use area was selected (fig. 2). The two principal criteria used in selecting sampling sites were: (1) the land use was typical of the East Everglades; and (2) the sampling site would be inundated during the wet season. The land-use areas and the identification numbers of the sampling sites are listed in table 2.

Four baseline sites (table 2 and fig. 2) in the East Everglades marshes were selected to provide baseline water-quality data for undeveloped areas. The baseline sites are away from any development and are considered unaffected by development. Two of these sites are in the Northeast Shark River Slough and are designated as Northeast Shark River Slough stations 1 and 2. Analyses of water samples from these are listed in tables 3 and 4. The other two baseline sites are in Taylor Slough and designated as Context Road at Bridge 27 and drainage area north of Context Road. The water-quality data for these two latter sites are listed in tables 5 and 6.

Coopertown was selected to represent a developed area in the Northeast Shark River Slough (fig. 2) and is considered typical of the developed areas along the Tamiami Trail. The developed area consists of about 3 acres on the south side of U.S. Highway 41 (Tamiami Trail) bounded on 3 sides by marsh. Occupied since 1946, it is the oldest settlement in the Northeast Shark River Slough. There are four permanent residences--a gas station, a restaurant, an airboat ride concession, and a repair shop. The sampling site is in a shallow canal and airboat trail just west of Coopertown.

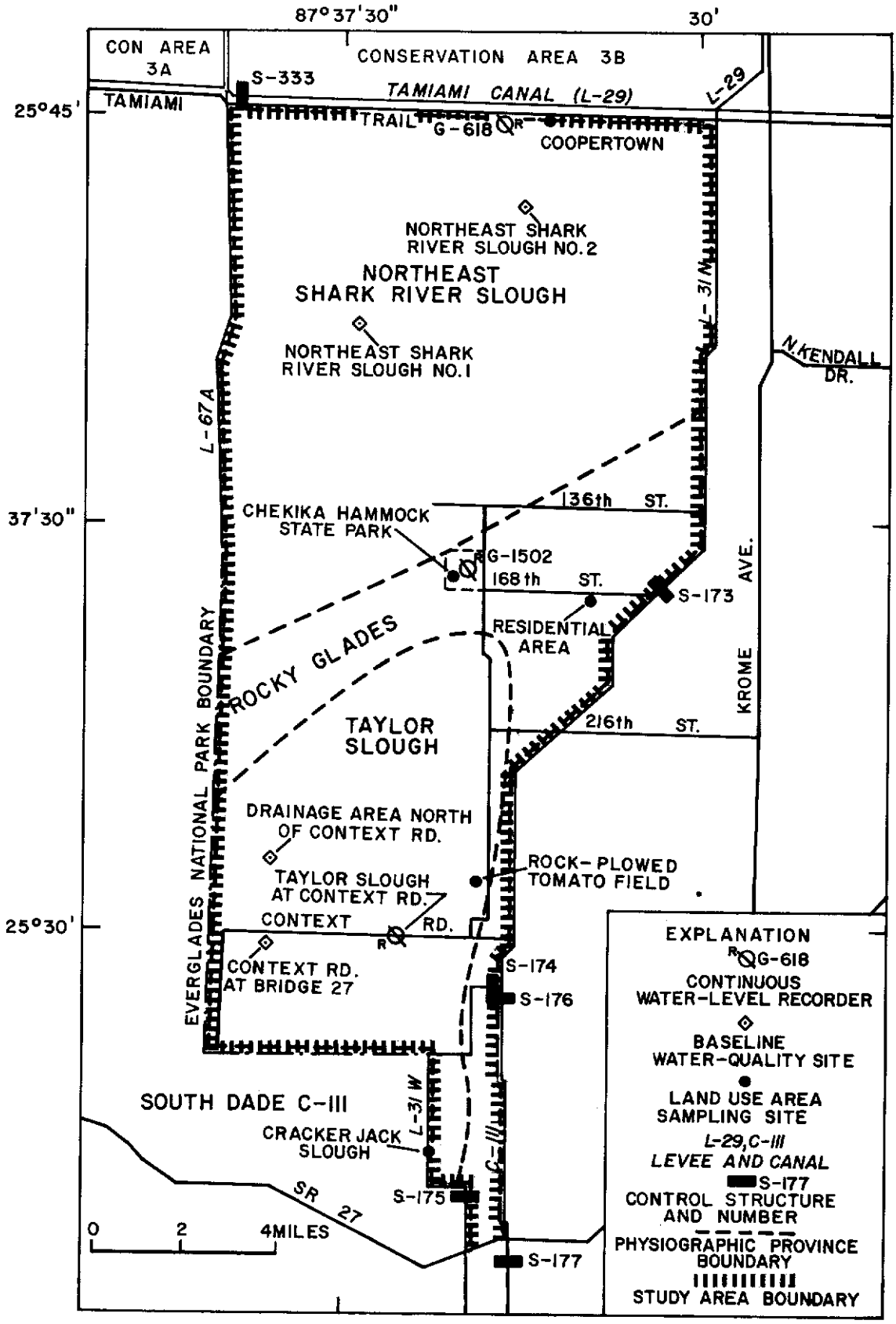

Figure 2.--Location of sampling sites in developed (land use) areas and in undeveloped (baseline) areas.

Table 2.--Designated names and identification numbers

[Locations shown in figure 2]

Land-use areas	Site identification number
Coopertown	254537080362000
Chekika Hammock State Park	253653080345300
Residential area	253630080321800
Rock-plowed tomato field	253055080335700
Cracker Jack Slough agricultural area	252523080352600
Baseline sites	
Northeast Shark River Slough Station 1	254130080380500
Northeast Shark River Slough Station 2	254315080331500
Drainage area north of Context Road, Taylor Slough	253210080402000
Context Road at Bridge 27, Taylor Slough	252953080390300

Table 3.--Physical characteristics and field measurements at Northeast Shark River Slough stations 1 and 2

Date	Time	Temperature °C	Dissolved oxygen (mg/L)	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)
				Northeast Shark River Slough station 1				
06/12/78	1000	34.0	5.1	9.0	100	-	210	465
07/12/78	1000	29.5	5.0	10.0	90	7.4	154	490
08/16/78	1030	29.5	5.1	5.0	-	7.9	136	350
09/18/78	1030	30.0	2.9	6.0	50	-	140	470
10/10/78	1045	25.0	4.1	6.0	40	-	150	-
				Northeast Shark River Slough station 2				
06/12/78	1100	33.0	11.2	4.0	80	-	-	360
07/12/78	0930	28.5	5.2	5.0	70	7.6	138	370
08/16/78	1000	29.5	6.3	2.0	-	7.9	118	300
09/18/78	1100	29.5	3.6	4.0	40	-	120	480
10/11/78	1115	25.9	7.4	2.0	40	-	130	-

Table 4.--Concentrations of macronutrients at Northeast Shark River Slough stations 1 and 2

[Chemical constituents in milligrams per liter]

Date	Time	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
		Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
Northeast Shark River Slough station 1										
06/12/78	1000	2.6	0.36	0.01	0.00	3.0	47	48	0.01	0.01
07/12/78	1000	2.0	.04	.01	.00	2.0	26	38	.00	.01
08/16/78	1030	1.9	.02	.00	.00	1.9	31	29	.00	.01
09/18/78	1030	1.9	.04	.00	.00	1.9	32	46	.00	.01
10/10/78	1045	1.5	.07	.00	.01	1.6	34	44	.00	.01
Northeast Shark River Slough station 2										
06/12/78	1100	3.1	.04	.00	.00	3.1	44	25	.00	.01
07/12/78	0930	1.8	.03	.00	.00	1.8	30	30	.00	.02
08/16/78	1000	1.5	.02	.00	.00	1.5	26	27	.00	.01
09/18/78	1100	1.6	.01	.00	.00	1.6	42	36	.00	.01
10/11/78	1115	1.6	.02	.00	.00	1.6	53	42	.00	.01

Table 5.--Physical characteristics and field measurements at Context Road at Bridge 27 and drainage area north of Context Road, Taylor Slough

Date	Time	Temperature °C	Dissolved oxygen (mg/L)	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)
				Context Road at Bridge 27				
06/14/78	1300	30.0	4.1	2.0	40	-	200	427
07/13/78	1130	28.5	4.8	3.0	40	7.2	138	300
08/17/78	1250	33.0	7.6	2.0	-	8.2	112	210
09/19/78	1220	31.0	-	1.0	20	-	-	390
10/10/78	1440	27.5	7.0	1.0	20	-	120	-
				Drainage Area North of Context Road				
06/14/78	1115	27.5	4.9	2.0	40	-	-	470
07/12/78	1030	31.0	3.9	3.0	30	7.3	138	320
08/16/78	0900	29.5	4.8	3.0	-	7.5	190	420
09/19/78	0950	-	-	1.0	20	-	-	245
10/10/78	0945	25.8	4.5	2.0	20	-	140	-

Table 6.--Concentrations of macronutrients at Context Road at Bridge 27 and drainage area north of Context Road, Taylor Slough

[Chemical constituents in milligrams per liter]

Date	Time	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
		Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
					Context Road at Bridge 27					
06/14/78	1300	0.84	0.03	0.00	0.00	0.87	22	47	0.00	0.02
07/13/78	1130	.93	.01	.00	.00	.94	6	36	.00	.01
08/17/78	1250	.64	.02	.00	.01	.67	10	22	.00	.01
09/19/78	1220	.73	.01	.00	.00	.74	27	29	.00	.01
10/10/78	1440	.63	.02	.00	.01	.66	3	42	.00	.01
					Drainage Area North of Context Road					
06/14/78	1115	1.00	.01	.00	.00	1.00	18	40	.00	.02
07/12/78	1030	.85	.01	.00	.00	.86	3	38	.00	.01
08/16/78	0900	.72	.02	.00	.00	.74	10	47	.00	.01
09/19/78	0950	.79	.01	.00	.00	.80	16	40	.00	.01
10/10/78	0945	.71	.01	.00	.00	.72	30	45	.00	.02

Chekika Hammock State Park, the largest recreational area in the East Everglades, was an obvious choice to represent a recreational land use. The State Park occupies 640 acres, chiefly low-lying marsh. Most recreational use occurs in a heavily vegetated hammock, 2 to 4 feet higher in elevation than the surrounding marsh. The hammock is used by day visitors, overnight campers, and has three permanent residences occupied by the State Park staff. The sampling site is in the marsh immediately downgradient (south) of the hammock.

The residential area selected is on the north side of Richmond Drive (S.W. 168th Street). The sampling site is in a vegetated swale. This swale receives runoff from both the pavement and the low-density (1 unit per 5 acres) residential area to the north.

The rock-plowed tomato field is a 320-acre tract of land west of Grossman Road (S.W. 232nd Avenue). This land had been rock plowed in 1976, and tomatoes were planted in the subsequent two growing seasons. Rock plowing is an agricultural practice in south Dade County that involves grinding all the surface material (limestone, marl, peat, and vegetation) to make a relatively uniform soil type that can be cultivated. The sampling site is in a depression near the center of the field.

The Cracker Jack Slough agricultural area is between Levee 31W and Canal 111. It is bounded on the north, east, and west by levees and canals and on the south by State Road 27. Prior to the construction of Levee 31W in 1968, the Taylor Slough drainage area included the northern and western sections of Cracker Jack Slough. Some of Cracker Jack Slough is low-lying and not suitable for farming due to prolonged periods of inundation, although much of that area has been ditched to provide additional drainage. The sampling site is at the intersection of one of the main drainage ditches and the L-31W Canal. A culvert under the levee with a flap gate connects the sampling site with the L-31W Canal.

GENERAL HYDROLOGY

The study area consists of three physiographic provinces, as defined by Craighead (1971), characterized by distinct topography and surface drainage. They are Northeast Shark River Slough, Rocky Glades, and Taylor Slough.

Northeast Shark River Slough (fig. 2), part of the original Everglades, is characterized by having the longest period of inundation in the East Everglades (Schneider and Waller, 1980). It is surrounded on the west, east, and north by levees and canals. Water levels and discharge are controlled for water-management purposes. Surface water generally flows in a southwesterly direction, and the soil is primarily sawgrass peat.

Rocky Glades is a poorly defined area (in terms of drainage) between the Northeast Shark River Slough and Taylor Slough. Drainage in this area is not facilitated by canals or water-management structures, and surficial flow patterns are indeterminate due to the high variability in topography. The soil is marl and peat with extensive outcrops of limestone.

Taylor Slough occupies the southern portion of the study area. There are no canals within this slough, although the L-31W Canal on the eastern edge has diverted some water to the east and south. Surface water flows in a southerly direction toward Florida Bay. The soil is primarily marl covered with a periphyton mat.

Surface water remains in the marshes of the East Everglades when the water table rises above land surface. Rainfall sometimes inundates the area when the water table is below land surface, but only for short periods. At the end of the dry season (April-May), the East Everglades is almost entirely dry except for canals and alligator holes. When the wet season begins, rainfall percolates through the surficial soil and rock to the water table, and water levels rise rapidly to the land surface. Because of the flat topography, low gradients (0.2 ft/mi), and thick vegetation in the area, surface water runs off slowly with no readily discernible velocity.

During this investigation (June through October 1978), the water level fluctuated 0.91 foot in the Northeast Shark River Slough (well G-618), 2.11 feet in the Rocky Glades (well G-1502), and 2.25 feet in the Taylor Slough (Taylor Slough at Context Road). When water levels declined in July, the water table in the rock-plowed tomato field (Taylor Slough) receded below land surface. The remaining four land-use area sampling sites were inundated the entire sampling period.

EFFECTS OF LAND USE ON WATER QUALITY

The five land-use areas selected for study during this investigation are typical of the current land use in the East Everglades study area. The hydrologic regime of the East Everglades determines the effects of land use on water quality. During the wetter months most of the area is inundated, and the effects, if any, from land use are on surface water. In the dry season when water levels decline as much as 5 feet below land surface over the area, any quality changes from a land use could affect ground water.

Many factors, both biotic and abiotic, determine the physical characteristics and concentrations of chemical constituents in water. The major factors that influence the quality of water in the five land-use areas are: (1) quality of the inflow waters; (2) volume and chemistry of rainfall; (3) chemical and physical reactions with the soils and bedrock of the East Everglades; and (4) manmade changes within and adjacent to the land-use area.

Macronutrients, Physical Parameters, and Field Measurements

Field measurements of temperature, dissolved oxygen (DO), pH, alkalinity, and specific conductance were made at the sampling sites. Samples were collected for analysis of macronutrient (carbon, nitrogen, and phosphorus) concentrations each time the sampling site was visited.

The principal sources of the macronutrient compounds in the East Everglades study area are: (1) inflow water from Conservation Areas 3A and 3B; (2) atmospheric input; (3) geochemical interactions with soils, rock, and vegetation; and (4) manmade effects, such as the addition of fertilizers and domestic sewage. Therefore, concentrations of macronutrients at the five land-use areas may reflect baseline water quality, or may reflect fertilizer application, breakdown of organic soils, death and decay of aquatic organisms, sewage, or stormwater runoff.

Macronutrient concentrations, field measurements, and physical parameters are presented by land-use areas in the following section.

Coopertown

Water quality at Coopertown (tables 7 and 8) was influenced greatly by the quality of inflow water from the Tamiami Canal. Most noticeable was the change in composition of the nitrogen species during August and September while water was being released from Conservation Area 3A into the Tamiami Canal through structure S-333. Ammonium concentrations decreased and organic nitrogen increased slightly. Ammonium concentrations greater than 0.50 milligrams per liter (mg/L) are typical of the seepage water from Conservation Area 3B that enters the Tamiami Canal from the north at this site (Waller and Earle, 1975). Ammonium concentrations are lower in the water from Conservation Area 3A. There is a large standing crop of vegetation in Conservation Area 3A which tends to decrease inorganic nitrogen concentrations (NH_4, NO_2, NO_3) but to increase organic nitrogen and organic carbon concentrations because of phytoplankton numbers and detrital material.

After August, dissolved oxygen concentration and the pH of the water decreased slightly with a corresponding increase in alkalinity (table 7). These changes with an increase in ammonium and a decrease in organic carbon suggest Conservation Area 3B as the source of inflow water. Seepage water from Conservation Area 3B is generally low in dissolved oxygen and organic carbon, and high in ammonium with a pH that remains near neutral (7.0) due to lack of a substantial plant community. The alkalinity increased because of flow through the unconsolidated material in the levee which is comprised of crushed limestone.

Table 7.--Physical characteristics and field measurements at Coopertown

Date	Time	Temperature °C	Dissolved oxygen (mg/L)	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)	Total residue at 105°C (mg/L)	Suspended solids (mg/L)
06/28/78	1410	30.5	5.0	3.0	40	7.4	203	620	377	2
07/27/78	1500	30.5	4.7	4.0	40	7.5	-	600	473	5
08/16/78	1125	29.5	3.1	3.0	60	7.5	194	540	425	5
09/21/78	1200	29.0	1.7	2.0	55	7.4	-	590	385	4
1/10/04/78	1115	28.0	1.2	3.0	40	7.1	246	600	380	5
10/19/78	1300	25.5	1.5	4.0	40	7.1	272	630	412	6

1/ Event sample.

Table 8.--Concentrations of macronutrients at Coopertown

[Chemical constituents in milligrams per liter]

Date	Time	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
		Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
06/28/78	1410	1.2	0.37	0.01	0.07	1.6	8	58	0.01	0.02
07/27/78	1500	1.0	.55	.02	.00	1.5	14	61	.01	.02
08/16/78	1125	1.4	.12	.01	.04	1.5	27	36	.00	.01
09/21/78	1200	1.4	.12	.01	.01	1.5	-	-	.00	.01
1/10/04/78	1115	1.0	.80	.00	.01	1.8	20	64	.00	.02
10/19/78	1300	0.61	1.0	.00	.00	1.6	16	61	.00	.01

1/ Event sample.

Water from the Tamiami Canal is the primary source of water at Coopertown; therefore, the quality of water in the canal is the controlling factor in determining water quality at this land-use area. There appears to be no adverse impact on water quality at Coopertown, unless it is masked by the inflow water from the Tamiami Canal. Macronutrient data from Coopertown are similar to baseline sites at Northeast Shark River Slough stations 1 and 2 (tables 3 and 4), except for ammonium concentrations which are higher at Coopertown, and average organic nitrogen and organic carbon concentrations which are higher at the baseline sites.

Chekika Hammock State Park and the Residential Area

These two land-use areas are discussed together because: (1) they are both located in the Rocky Glades; (2) both sampling sites are in vegetated swales; (3) concentrations of chemical constituents in water samples were similar; and (4) physical characteristics of the water were similar during rain events.

Water quality (tables 9-12) at these two land-use areas and at the baseline sites in Taylor Slough (tables 5 and 6) is very similar. During rain events the concentrations of both total nitrogen and organic nitrogen decreased at the recreational area due to dilution. All but one sample collected at these two areas had inorganic nutrient (NH_4, NO_2, NO_3, PO_4) concentrations in trace amounts (less than 0.10 mg/L). Also, during rain events the surface water was less mineralized due to dilution, and the color increased due to flushing of the adjacent organic soil. The effects on the quality of surface water in the East Everglades study area from these two land uses are negligible.

Rock-Plowed Tomato Field

Water samples from the rock-plowed tomato field had high concentrations of organic nitrogen, orthophosphate, and turbidity (tables 13 and 14) in comparison to baseline water quality at the two sites in Taylor Slough (tables 5 and 6). These parameters are used as indicators of agricultural chemicals and activities. Total phosphorus concentrations, for example, were up to 100 times greater during some samplings than concentrations at the baseline sites (table 6). The field was plowed in early September, and because of this agricultural preparation the concentrations of total organic nitrogen, total organic carbon, and total phosphorus species increased over previously determined concentrations. The effect of flooding a freshly plowed field generates higher concentrations of some macronutrients, but the effect is short term. Inorganic nitrogen concentrations remained less than 0.50 mg/L throughout the investigation.

Table 9.--Physical characteristics and field measurements at Chekika Hammock State Park

Date	Time	Temperature °C	Dissolved oxygen (mg/L)	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)	Total residue at 105°C (mg/L)	Suspended solids (mg/L)
06/28/78	1030	26.5	4.2	1.0	80	7.0	190	290	193	0
1/07/06/78	1900	-	-	4.0	-	7.6	138	260	175	3
07/27/78	1320	30.0	5.4	2.0	40	7.4	-	350	324	6
08/18/78	0940	29.0	4.1	2.0	40	7.5	262	450	267	7
08/22/78	1200	26.5	4.5	2.0	-	7.5	184	380	243	5
1/09/15/78	1645	-	-	6.0	70	-	-	295	217	8
09/21/78	1115	28.0	2.1	2.0	30	7.5	-	405	258	7
10/04/78	1100	28.0	.7	2.0	30	7.3	187	395	243	5
10/19/78	1120	23.0	2.9	2.0	20	7.2	233	486	312	2

1/ Event sample.

Table 10.--Physical characteristics and field measurements at the residential area

Date	Time	Temperature °C	Dissolved oxygen (mg/L)	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)	Total residue at 105°C (mg/L)	Suspended solids (mg/L)
06/28/78	1230	29.0	4.6	1.0	30	7.2	-	430	254	1
1/07/06/78	1845	-	-	2.0	-	7.6	164	360	236	0
07/27/78	1405	30.0	5.7	3.0	5	7.4	-	430	268	2
08/18/78	1015	28.5	3.6	2.0	5	7.6	262	440	247	3
08/22/78	1145	27.0	3.7	2.0	-	7.4	213	470	256	2
1/09/15/78	1630	-	-	2.0	60	-	-	265	203	5
09/21/78	1135	29.2	2.6	2.0	35	7.8	-	370	226	6
10/04/78	1115	29.0	2.0	4.0	20	7.5	203	395	214	5
10/19/78	1200	25.0	1.2	2.0	15	7.0	233	457	262	4

1/ Event sample.

Table 11.--Concentrations of macronutrients at Chekika Hammock State Park

[Chemical constituents in milligrams per liter]

Date	Time	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
		Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
06/28/78	1030	0.86	0.03	0.00	0.01	0.90	6	37	0.01	0.03
1/07/06/78	1900	.73	.02	.01	.04	.80	6	32	.01	.02
07/27/78	1320	1.1	.08	.00	.00	1.18	18	44	.01	.02
08/18/78	0940	.97	.00	.00	.00	.97	21	50	.00	.02
08/22/78	1200	.91	.03	.00	.01	.95	16	44	.00	.02
1/09/15/78	1645	.76	.02	.01	.03	.82	21	45	.01	.02
09/21/78	1115	.93	.01	.00	.00	.94	18	51	.00	.02
10/04/78	1100	.87	.01	.00	.00	.88	13	49	.00	.02
10/19/78	1120	.63	.06	.00	.00	.69	28	53	.00	.01

1/ Event sample.

Table 12.--Concentrations of macronutrients at the residential area

[Chemical constituents in milligrams per liter]

Date	Time	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
		Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
06/28/78	1230	0.63	0.01	0.00	0.00	0.64	5	50	0.00	0.01
1/07/06/78	1845	.54	.01	.00	.01	.56	4	47	.00	.01
07/27/78	1405	.59	.03	.01	.01	.64	15	51	.00	.01
08/18/78	1015	.50	.04	.00	.01	.55	18	40	.00	.01
08/22/78	1145	.41	.04	.00	.01	.46	5	56	.00	.00
1/09/15/78	1630	.54	.00	.00	.02	.56	18	42	.00	.01
09/21/78	1135	.83	.01	.00	.00	.84	-	-	.00	.01
10/04/78	1115	.72	.00	.00	.00	.72	12	54	.00	.01
10/19/78	1200	.45	.18	.00	.00	.63	4	57	.00	.01

1/ Event sample.

Table 13.--Physical characteristics and field measurements at the rock-plowed tomato field

Date	Time	Temperature °C	Dissolved oxygen (mg/L)	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)	Total residue at 105°C (mg/L)	Suspended solids (mg/L)
06/28/78	1000	25.5	4.4	5.0	70	7.0	213	410	288	10
1/07/06/78	1930	28.0	4.0	2.0	-	7.7	138	310	209	0
07/27/78	Dry	-	-	-	-	-	-	-	-	-
08/17/78	1350	32.0	2.4	2.0	60	7.7	272	540	335	7
08/22/78	1240	27.5	3.7	3.0	-	7.5	289	540	321	21
1/09/15/78	1710	-	-	50.0	160	-	-	345	312	64
09/21/78	1045	-	-	19.0	50	7.3	397	620	502	16
10/04/78	1020	28.5	2.2	7.0	40	7.4	210	475	293	16
10/19/78	Dry	-	-	-	-	-	-	-	-	-

1/ Event sample.

Table 14.--Concentrations of macronutrients at the rock-plowed tomato field

[Chemical constituents in milligrams per liter]

Date	Time	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
		Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
06/28/78	1000	3.2	0.46	0.01	0.01	3.7	28	48	1.9	1.9
1/07/06/78	1930	1.4	.05	.00	.01	1.4	17	32	1.4	1.5
07/27/78	Dry	-	-	-	-	-	-	-	-	-
08/17/78	1350	1.5	.04	.00	.00	1.5	13	69	1.1	1.1
08/22/78	1240	2.0	.14	.01	.00	2.2	20	73	.97	1.1
1/09/15/78	1710	2.7	.13	.02	.00	2.8	36	54	2.6	2.6
09/21/78	1045	2.6	.03	.01	.00	2.6	44	96	1.6	1.6
10/04/78	1020	1.7	.06	.01	.00	1.8	15	61	1.1	1.2
10/19/78	Dry	-	-	-	-	-	-	-	-	

1/ Event sample.

The rock-plowed tomato field showed a greater variation in physical characteristics (table 13) than the other four land-use areas and the Taylor Slough baseline sites except for dissolved oxygen and temperature. Throughout the sampling, color levels were higher than the two baseline sites in the Taylor Slough (table 5). After the field was prepared for planting, a corresponding change in water quality was reflected most strongly in the levels of color, turbidity, and total suspended solids. Specific conductance values were lower during rain event sampling due to dilution.

Cracker Jack Slough Agricultural Area

Macronutrient concentrations, physical characteristics, and field measurements at the Cracker Jack Slough agricultural area (tables 15 and 16) were generally lower than at the other land-use areas. Concentrations of most chemical constituents during the investigation were similar to those of the baseline water-quality sites in Taylor Slough (table 6). Total organic carbon concentrations increased slightly during the peak of the wet season (August or September). Rain events affected only the specific conductance (degree of mineralization) of the water due to dilution and did not increase any parameter concentrations to greater than baseline conditions.

Although the sampling site within Cracker Jack Slough is surrounded by extensive rock-plowed fields, the water analyses do not suggest that they are draining toward the site. The sampling site is located in a large, vegetated swale that appears to have a beneficial effect on the surface water as reflected in consistently lower concentrations of macronutrients.

Summary of Macronutrient and Field Data

Data collected from sites at developed land-use areas and at baseline sites in the East Everglades study area show that the concentrations of certain parameters change when development occurs. The physical characteristics and field measurements (table 17) indicate that all the water sampled is either neutral (pH 7.0) or slightly alkaline. The average alkalinity and inorganic carbon concentrations are higher at the land-use area sites than the baseline sites due to the exposed limerock in the areas that have been disturbed. Generally, the water in the northern part of the East Everglades study area is more mineralized and higher in color than water in the southern part, probably due to channelization of water from Conservation Areas 3A and 3B. An exception to the north to south trend of decreasing specific conductance (mineralization) and color in the surface water is the rock-plowed tomato field which is disturbed, and these parameters have higher concentrations than in water samples collected from the baseline sites.

Table 15.--Physical characteristics and field measurements at Cracker Jack Slough agricultural area

Date	Time	Temperature °C	Dissolved oxygen (mg/L)	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)	Total residue at 105°C (mg/L)	Suspended solids (mg/L)
06/28/78	0900	25.0	3.9	2.0	10	7.4	201	480	273	1
1/07/06/78	1900	26.0	5.4	1.0	-	7.6	197	410	236	0
07/27/78	1130	28.5	11.4	3.0	5	7.9	-	340	238	2
08/17/78	1010	31.0	7.4	2.0	10	8.1	121	240	172	6
08/22/78	1315	27.0	5.2	2.0	-	7.6	184	420	217	3
1/09/15/78	1740	-	-	2.0	10	-	-	325	225	5
09/21/78	1000	29.5	4.5	1.0	10	7.6	-	300	177	3
10/04/78	1000	26.5	4.0	2.0	5	7.4	190	410	219	6
10/19/78	0940	23.0	4.7	1.0	15	7.5	200	260	181	5

1/ Event sample.

Table 16.--Concentrations of macronutrients at Cracker Jack Slough agricultural area

[Chemical constituents in milligrams per liter]

Date	Time	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
		Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
06/28/78	0900	0.31	0.17	0.00	0.04	0.52	-	-	0.00	0.00
1/07/06/78	1900	.31	.12	.00	.04	.47	2	50	.00	.01
07/27/78	1130	.61	.02	.00	.00	.63	7	41	.01	.02
08/17/78	1010	.67	.00	.00	.01	.68	14	28	.00	.01
08/22/78	1315	.25	.12	.00	.03	.40	23	46	.00	.00
1/09/15/78	1740	.25	.15	.00	.03	.43	15	50	.00	.00
09/21/78	1000	.62	.02	.00	.00	.64	11	39	.00	.01
10/04/78	1000	.36	.10	.00	.02	.48	7	55	.00	.01
10/19/78	0940	.37	.04	.00	.00	.41	9	32	.00	.01

1/Event sample.

Table 17.--Average or range of physical characteristics and field measurements for all land-use areas and baseline sites

Land-use areas	Turbidity (Nephelometric turbidity units [NTU])	Color (Pt-Co units)	pH (range)	Alkalinity as $CaCO_3$ (mg/L)	Specific conductance (micromhos at 25°C)	Total residue (mg/L)	Total suspended solids (mg/L)
Coopertown	2-4	40-60	7.1-7.5	229	597	409	4.5
Chekika Hammock State Park	1-6	20-80	7.0-7.6	199	368	248	4.8
Residential area	1-4	5-60	7.0-7.8	215	402	241	3.1
Rock-plowed tomato field	2-50	40-160	7.0-7.7	253	463	323	19.1
Cracker Jack Slough agricultural area	1-3	5-15	7.4-8.1	182	354	215	3.4
Baseline sites							
Northeast Shark River Slough Stations 1 and 2	2-10	40-100	7.4-7.9	144	410	—	--
Context Road at Bridge 27 and drainage area north of Context Road, Taylor Slough	1-3	20-40	7.2-8.2	148	348	—	--

Macronutrient concentrations (table 18) in water at the rock-plowed tomato field are higher than in water from the baseline sites in Taylor Slough. Manmade effects are indicated by increased concentrations of organic nitrogen, total organic carbon, and orthophosphate. The rock-plowed tomato field is disturbed by agricultural activities, agricultural chemical applications, and dying vegetation. The macronutrient concentrations at the remaining four land-use areas are low and can be considered unaffected, being affected only by background inflow and soil type. The baseline sites in the Northeast Shark River Slough (table 18) have higher average total organic carbon concentrations than the other areas or baseline sites because of the underlying, highly organic peat soil.

Trace Elements

Trace elements were analyzed from surface-water samples collected during periods of intense rainfall at the five land-use area sites. Nearly every trace element for which analyses were made was detected (table 19) but in concentrations indicative of water-quality conditions in the Everglades marshes (Waller and Earle, 1975). The exception was higher concentrations of copper (36 ug/L [micrograms per liter]), iron (750 ug/L), manganese (680 ug/L), mercury (1.4 ug/L), and potassium (14.0 mg/L) in the rock-plowed tomato field than in the Everglades marshes (table 19). Copper, manganese, and potassium are added to agricultural fields as plant micronutrients, and mercurial compounds are used as pesticides. There is no apparent increase in trace element concentrations in the water at the other land-use areas, except for iron, 800 ug/L at Coopertown which may be a natural occurrence as iron is typically found in high concentrations (greater than 200 ug/L) in the Everglades.

Soil samples were collected in September at each land-use area and analyzed for trace elements, macronutrients, chemical oxygen demand (COD), and organic percentage (tables 20 and 21). The trace elements present in the highest concentrations were iron, lead, manganese, and zinc; other trace elements were either not detected or were present in concentrations near their detection limit. The highest iron concentrations, 2,900 ug/kg (micrograms per kilogram), was detected at Chekika Hammock State Park. Coopertown had the highest concentrations of lead (370 ug/kg) and zinc (80 ug/kg). High concentrations of manganese were detected at Chekika Hammock State Park (120 ug/kg), Cracker Jack Slough agricultural area (100 ug/kg), and the rock-plowed tomato field (89 ug/kg). The residential area had relatively low concentrations of the trace elements determined.

Table 18.--Average macronutrient concentrations for all land-use areas and baseline sites

[Chemical constituents in milligrams per liter]

Land-use areas	Nitrogen as N					Total organic carbon	Total inorganic carbon	Phosphorus as P	
	Total organic nitrogen	NH_4	NO_2	NO_3	Total nitrogen			Ortho-phosphate	Total phosphorus
Coopertown	1.10	0.49	0.010	0.020	1.58	17.0	56.0	0.003	0.015
Chekika Hammock State Park	.86	.03	.002	.010	.90	16.3	45.0	.004	.02
Residential area	.58	.04	.001	.007	.62	10.1	49.6	.000	.01
Rock-plowed tomato field	2.16	.13	.008	.003	2.09	24.7	75.6	1.52	1.57
Cracker Jack Slough agricultural area	.42	.08	.000	.020	.52	11.0	42.6	.001	.008
Baseline sites									
Northeast Shark River Slough Stations 1 and 2	2.0	.07	.002	.002	2.0	36.5	36.5	.001	.01
Context Road at Bridge 27 and drainage area north of Context Road, Taylor Slough	.78	.02	.000	.002	.80	14.5	38.6	.000	.01

Table 19.--Concentrations of trace elements in surface water collected at all land-use areas during rain events

[Chemical constituents in micrograms per liter]

Land-use areas	Date	Time	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Zinc (Zn)	Potassium (K)
Coopertown	10/04/78	1115	1	0	10	0	800	3	40	0.5	6	10	-
Chekika	07/06/78	1900	1	1	10	-	-	10	-	0.5	-	10	0.6
Hammock State Park	09/15/78	1645	1	2	10	1	200	18	0	0.7	4	10	-
Residential	07/06/78	1845	0	1	10	-	-	7	-	0.5	-	0	.4
area	09/15/78	1630	0	2	10	2	110	15	0	0.8	5	10	-
Rock-plowed	07/06/78	1930	1	2	10	-	-	9	-	0.5	-	10	14
tomato field	09/15/78	1710	1	3	10	36	750	35	680	1.4	5	30	-
Cracker Jack	07/06/78	1700	0	1	20	-	-	13	-	0.5	-	10	.5
Slough agricultural area	04/15/78	1740	0	1	10	1	220	10	0	0.5	3	10	-
Everglades[1]/			10	1	1	2	220	5	36	0.1	-	28	3.9

1/ Values are average values of 28 analyses from Waller and Earle (1975, p. 40-41) except for potassium, which is the average value of 12 analyses from Waller and Earle (1975).

Table 20.--Concentrations of trace elements in soil at all land-use areas, September 1978

[Chemical constituents in micrograms per kilogram]

Land-use areas	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Zinc (Zn)
Coopertown	0.0	10	10	10	100	370	15	0.00	10	80
Chekika Hammock State Park	.0	10	10	10	2,900	40	120	.00	10	20
Residential area	.0	10	10	10	100	20	23	.00	20	10
Rock-plowed tomato field	.0	10	10	10	0	20	89	.00	10	10
Cracker Jack Slough agricultural area	.0	10	20	20	0	20	100	.00	10	10

Table 21.--Concentrations of nitrogen, phosphorus, COD, and loss on ignition and percent organic in soil at all land-use areas, September 1978

[Chemical constituents shown in micrograms per kilogram]

Land-use areas	Kjeldahl nitrogen as N	NO_2 and NO_3 as N	Total phosphorus	COD	Loss on ignition	Percent organic
Coopertown	1,900	2.1	540	66,000	24,600	2.5
Chekika Hammock State Park	51,000	11.0	140	350,000	252,000	25.2
Residential area	22,000	3.5	280	160,000	130,000	13.0
Rock-plowed tomato field	19,000	10.0	590	110,000	73,000	7.3
Cracker Jack Slough agricultural area	13,000	43.0	1,300	93,000	63,000	6.3

Pesticides and Related Compounds

Surface-water samples for the analysis of insecticide and herbicide residues were collected during rain events at all five land-use area sites. Malathion, the only insecticide detected, was present in two water samples from the site at Chekika Hammock State Park at concentrations of 0.59 ug/L on July 6 and 0.07 ug/L on September 15. Insecticide or herbicide residues were not detected in any of the other event samples. Malathion is used commonly in south Florida to control flies and mosquitos.

Soil at each land-use area was collected in September and analyzed for chlorinated-hydrocarbon insecticides, polychlorinated biphenyls (PCB), and polychlorinated naphthalenes (PCN). The following table is a summary of the detections from the five land-use areas.

[Concentrations in micrograms per kilogram]

Land-use area	Chlordane	DDD	DDE	DDT	Dieldrin	Heptachlor epoxide	Lindane	PCB
Coopertown	57	0.0	0.0	15	1.6	0.0	1.1	53
Chekika Hammock State Park	0	.0	.0	0	.0	.0	.0	0
Residential area	3	4.2	1.6	43	.0	.0	.0	0
Rock-plowed tomato field	220	.0	2.4	0	3.5	.0	.0	0
Cracker Jack Slough agricultural area	220	19.0	80.0	100	29.0	4.4	.0	0

Additional pesticides and related compounds analyzed for but not detected were: aldrin, endosulfan, endrin, heptachlor, mirex, perthane, toxaphene, and PCN.

Chlorinated-hydrocarbon insecticides were detected in soil samples at all the land-use areas except Chekika Hammock State Park. The Cracker-Jack Slough agricultural area had the highest concentrations of chlordane, the DDT family (DDD, DDE, and DDT), dieldrin, and heptachlor epoxide. The concentrations of these chlorinated-hydrocarbon insecticides are on the same order of

magnitude as in the Everglades agricultural area south of Lake Okeechobee (Waller and Earle, 1975). The rock-plowed tomato field had high concentrations of chlordane in the soil, but the DDE and dieldrin detections are at background levels of less than 10 µg/kg. Both the residential area and Coopertown had contamination from chlordane and the DDT family. In addition, lindane and PCB were detected at Coopertown.

Indicator Bacteria

Coliform bacteria are most commonly used as indicators of domestic sewage and agricultural runoff entering a body of water. The coliform group also includes a variety of species occurring naturally in soils. Determination of fecal coliform bacteria concentrations is made to distinguish between enteric and soil coliforms. The bacteria counts indicate the relative amounts of waste matter, both naturally occurring or entering as sewage discharge, in a body of water.

Because pathogens may be associated with coliform bacteria, criteria have been established for permissible coliform levels when water is used for drinking and household uses. Total coliform counts should not exceed 20,000 cells/100 mL at any one time (National Academy of Sciences and National Academy of Engineering, 1973), and fecal coliforms should not exceed 2,000 cells/100 mL (U.S. Environmental Protection Agency, 1977).

To further distinguish between the sources of fecal coliforms, the number of fecal streptococci bacteria was determined. These bacteria are found in greater numbers within the intestines of warm-blooded animals than in human intestines. The ratios of fecal coliform to fecal streptococci bacteria (FC/FS) give an indication of the source of fecal streptococci. A ratio greater than 4.0 indicates definite contributions from human sources. A ratio less than 0.7 indicates that the coliform bacteria are derived chiefly from wildlife, livestock, or poultry wastes. Ratios ranging between 0.7 and 4.0 are not definitive because of mixed sources of fecal material.

Concentrations of total coliform, fecal coliform, and fecal streptococci bacteria were determined monthly at Coopertown, Chekika Hammock State Park, and the residential area, the three land-use areas most likely to have domestic sewage present. The concentrations at the three land-use area sites are shown in table 22. Bacterial counts at these sites exceeded one of the established criteria during one of the samplings. At Chekika Hammock State Park a total coliform count of 23,000 colonies/100 mL was determined on August 22. The FC/FS (0.15) ratio indicates the possibility that this high count is due to soil bacteria and bacteria

Table 22.--Concentrations of indicator bacteria at Coopertown, Chekika Hammock State Park, and the residential area

[Bacteria count in colonies per 100 milliliters]

Land-use areas	Date	Total coliform	Fecal coliform	Fecal strepto-cocci	Fecal coliform: fecal strepto-cocci ratio
Coopertown	06/28/78	1,900	230	126	1.82
	07/28/78	4,200	2,000	230	8.70
	08/16/78	170	24	24	1.00
	09/21/78	3,400	2	170	.01
Chekika	06/28/78	3,700	20	180	.111
Hammock	07/28/78	1,300	600	200	3.00
State	08/18/78	600	14	44	.32
Park	08/22/78	23,000	102	680	.15
Residential	06/28/78	1,100	200	200	1.0
area	07/28/78	5,400	2,400	270	8.89
	08/18/78	1,400	104	118	.88
	08/22/78	600	160	190	.84

from wildlife. The highest fecal coliform concentrations were determined at Coopertown and at the residential area on July 28. The FC/FS ratio (greater than 8) indicates the likelihood that both these high counts were due primarily from human sources. All other samples showed natural bacterial conditions at the land-use area sites.

SUMMARY

Sampling sites at five developed (land-use) areas in the East Everglades were selected to determine surface-water quality characteristics during the 1978 wet season (June through October). The five developed area sites selected were: Coopertown, Chekika Hammock State Park, residential area, rock-plowed tomato field, and Cracker Jack Slough agricultural area. Data from the developed areas were compared with data from four baseline sites in undeveloped areas to determine the effects of land use on the surface-water quality.

The water-quality data indicate that water quality in the developed areas, except the rock-plowed tomato field, does not differ greatly from water quality of either the Northeast Shark River Slough or Taylor Slough marshes (baseline sites). The water quality at Coopertown is strongly influenced by the water from the Tamiami Canal. The Chekika Hammock State Park, the residential area, and Cracker Jack Slough agricultural area sampling sites are located in either natural or manmade vegetated swales which appear to stabilize macronutrient and trace element concentrations at baseline concentrations.

Water quality at the rock-plowed tomato field is affected by agricultural activities and chemical applications. Increased concentrations of orthophosphate, organic nitrogen, turbidity, copper, manganese, and potassium are indicators of agricultural activities. The surface water within this area does not appear to affect the surrounding marsh.

During intense rainstorms, the water-quality conditions at each land-use area site changed little from previously determined conditions. The most notable change was in specific conductance values and color levels indicating dilution by rainfall and concurrent flushing of the soil. No macronutrient concentrations increased during rain events. At Chekika Hammock State Park, malathion (used for insect control) was detected in the surrounding marsh after rain events.

Chemical analyses of soil to determine insecticide residues showed that the agricultural areas and Coopertown had traces of chlorinated-hydrocarbon insecticides present. The other two land-use area sites had background concentrations (less than 10 micrograms per kilogram) of these insecticides.

High concentrations of trace elements associated with agriculture occurred in water at the rock-plowed tomato field. Trace element concentrations greater than base level occurred in soils at Chekika Hammock State Park (iron and manganese), the rock-plowed tomato field (manganese), Cracker Jack Slough agricultural area (manganese), and Coopertown (lead and zinc).

The rock-plowed tomato field was the only land-use area that had a notable effect on surface-water quality. The other four land-use area sites had little impact on the surface-water quality, although the soil in these areas contained higher concentrations of certain trace elements and insecticides.

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