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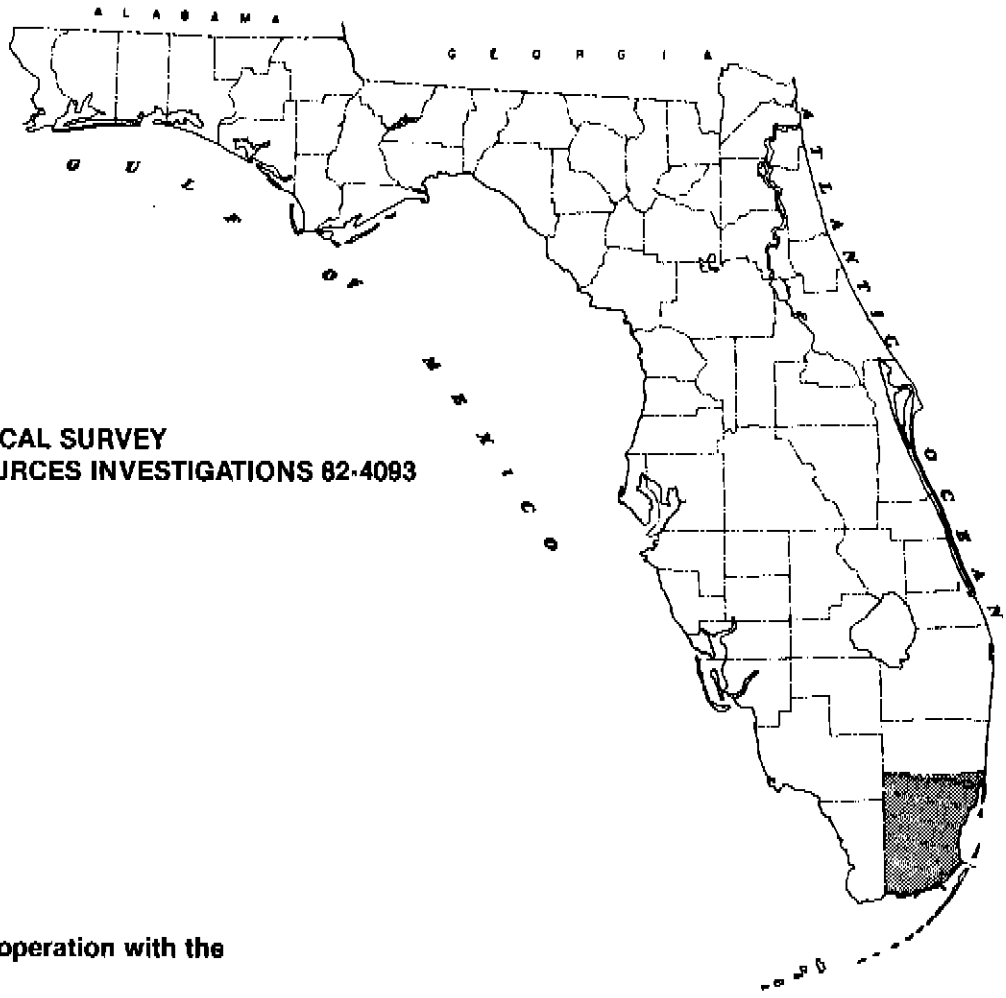
EFFECTS OF LAND USE ON GROUND-WATER QUALITY IN THE EAST EVERGLADES, DADE COUNTY, FLORIDA



U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 82-4093

Prepared in cooperation with the

METROPOLITAN DADE COUNTY PLANNING DEPARTMENT

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

By Bradley G. Waller

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Tallahassee, Florida

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

TABLES

TABLES--Continued

TABLES--Continued

TABLES--Continued

ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System of units (SI) and abbreviation 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)
	Flow	
gallon per minute (gal/min)	0.0643	liter per second (L/s)
	Temperature	
degrees Fahrenheit (°F)	0.5555 (°F-32°)	degrees Celsius (°C)
	Specific conductance	
micromho per centimeter (μmho/cm)	1.000	microsiemens (μS/cm)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

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

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ABSTRACT

Ground-water quality characteristics of the Biscayne aquifer from September 1978 through June 1979 were determined for seven land-use areas within the East Everglades in Dade County, Florida. Four agricultural areas, two low-density residential areas, and Chekika Hammock State Park were investigated. The effects of land use on the ground water were minimal in all areas; only iron, which occurs naturally in high concentrations in the Everglades, exceeded potable ground-water standards. Potassium and nitrate concentrations in certain samples increased over background concentrations in the agricultural areas. Ground water at Chekika Hammock State Park and at a citrus grove is contaminated by brackish water flowing from an artesian well.

The soil at the agricultural areas had higher concentrations of chromium, copper, and manganese than at the two residential areas or at Chekika Hammock State Park. One residential area (Coopertown) had the highest concentrations of lead and zinc and detectable polychlorinated biphenyls. Chlorinated-hydrocarbon insecticide residues in soil at three agricultural areas were higher than background concentrations.

INTRODUCTION

The East Everglades area in Dade County, Fla. (fig. 1), is 240 mi^2 of chiefly (90 percent) undeveloped wetland between the Everglades National Park on the west and the extensively developed areas of south Dade County on the east. The unconfined Biscayne aquifer underlies the entire study area and is the primary source of water for agricultural and residential use in Dade County. The East Everglades area and Water Conservation Areas 3A and 3B (fig. 1) are ground-water recharge areas for south Dade County. Because of concern about environmental and water-quality changes in the East Everglades, a moratorium was declared by Dade County officials in 1976 on further extensive agricultural or residential development until the physical, chemical, biological, and hydrological characteristics of the area could be described. In April 1978, the Metropolitan Dade County Planning Department was given the responsibility to coordinate efforts to determine how the East Everglades

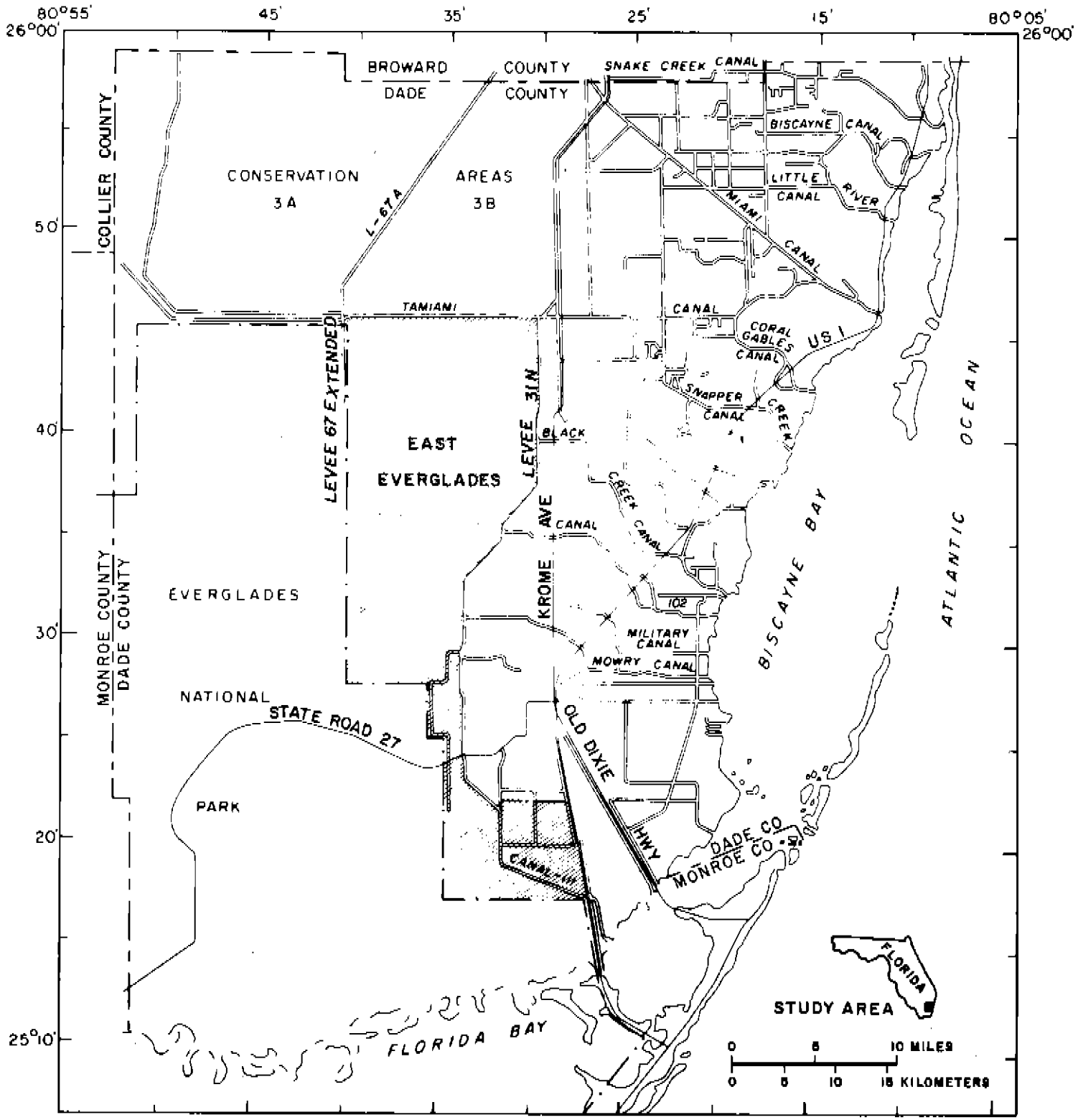

Figure 1.--East Everglades within Dade County.

ecosystem functions and to develop best management practices for the area. As part of this coordinated effort, the U.S. Geological Survey, in cooperation with the Metropolitan Dade County Planning Department, investigated the effects of certain land uses on ground-water quality. This report presents the sampling results which constitute the final output of work element IIA of the plan of study (Metropolitan Dade County Planning Department, 1978, p. 45-48).

The effects of land use on the quality of ground water in the East Everglades were evaluated by drilling and sampling 34 wells in 7 areas representing agricultural, residential, and recreational land use. These areas were selected because they are widely distributed and characteristic of land use during the time of the study (1979) in the East Everglades. Four areas are in agricultural use, the major land use in the East Everglades. The land-use areas are as follows (fig. 2):

Agricultural areas:

1. Howard Drive;
2. Citrus grove;
3. Rock-plowed tomato field;
4. Cracker Jack Slough;

Residential areas:

5. Coopertown;
6. Richmond Drive;

Recreational area:

7. Chekika Hammock State Park.

Purpose and Scope

The purpose of this investigation was to evaluate the effects of certain land uses on ground-water quality in the East Everglades. Monthly collection of ground-water samples for water-quality analysis was made at 34 wells in seven land-use areas from September 1978 through June 1979. Soil samples were collected for chemical analysis from the seven areas at the beginning of the investigation (September 1978), and from the four agricultural areas at the end of the growing season (April 1979) to determine the retention capabilities of the soil. The water-quality constituents determined in ground water and the frequency of sampling are shown in table 1.

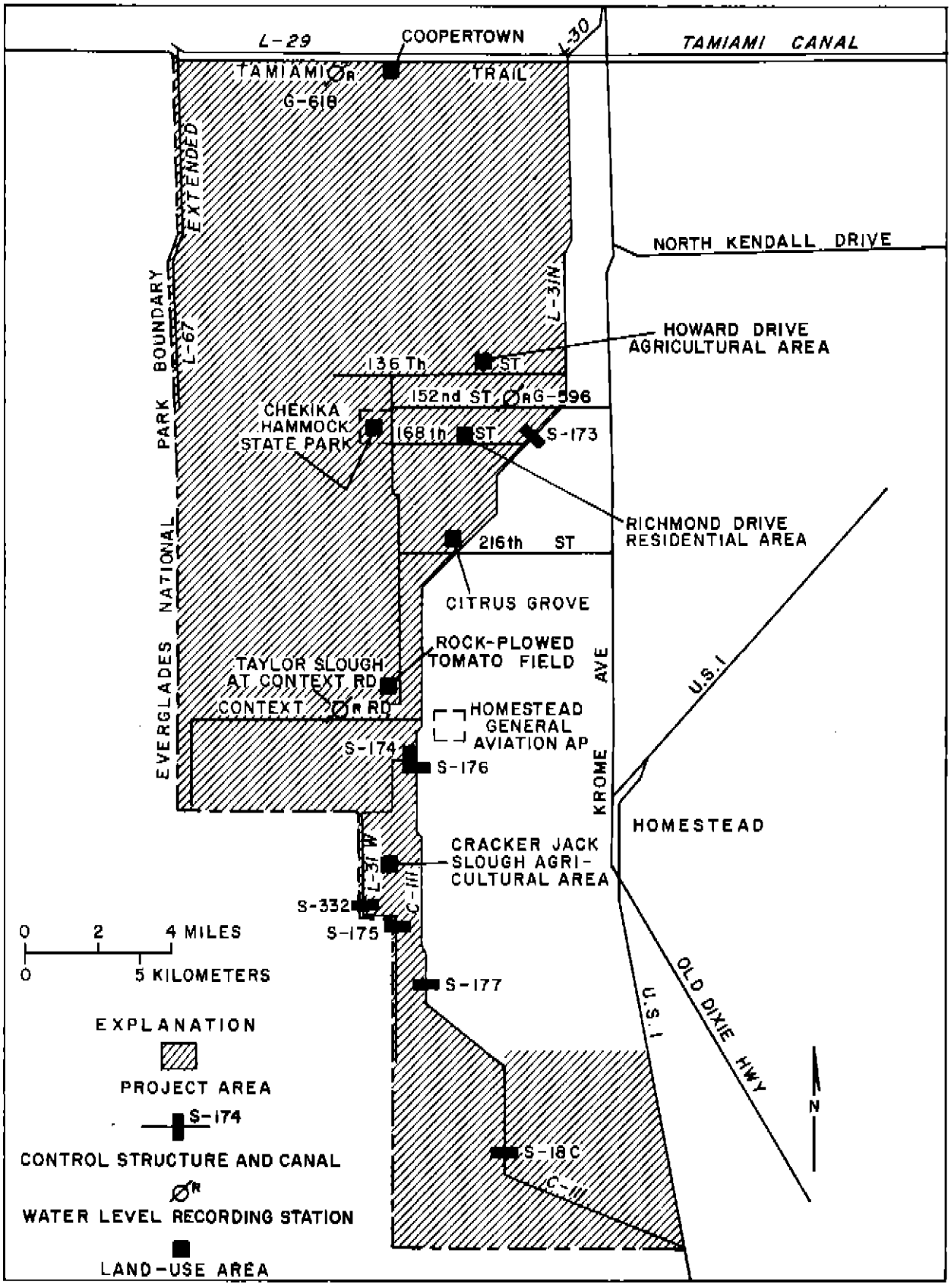

Figure 2.--Location of the seven land-use areas and water-level recorders in the East Everglades.

Table 1.--Water-quality and soil constituents determined and frequency of sampling

Constituents	Frequency
Macronutrients (organic nitrogen, ammonia, nitrite, nitrate, total nitrogen, orthophosphate, total phosphorus, and total organic carbon) and potassium.	Monthly.
Physical characteristics and field measurements (temperature, turbidity, pH, alkalinity, and specific conductance).	Monthly.
Bacteriological (total coliform, fecal coliform, and fecal streptococci).	Monthly.
Major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, bicarbonate, fluoride), hardness, color, and dissolved solids.	September and April.
Trace elements - total recoverable (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc).	November, February and May.
Insecticides, herbicides, and polychlorinated biphenyls	November.
Soil analysis (macronutrients, trace elements, chemical oxygen demand, organic content, and chlorinated hydrocarbon insecticides).	September and April.

This investigation was designed to evaluate ground-water quality during one extended growing season, September 1978 through June 1979. During September and October, before the beginning of the winter-growing season, agricultural site preparation begins. During November through April, most fields are in production, and fertilizers, pesticides, and micronutrients are applied. Irrigation is required for most crops. Most agricultural production ceases by May or June.

Acknowledgments

The author would like to thank Vida S. Piera and Margaret L. Ronald of the Metropolitan Dade County Department of Environmental Resources Management for technical assistance during this investigation. Gratitude is also extended to Walter Kiker, John Cooper, and Fritz Rudzke, Silver Palm Groves, Inc., and to the Florida Department of Natural Resources for allowing the U.S. Geological Survey to install and sample wells on their properties. Edward Koskoski of the Florida Health and Rehabilitative Service was helpful in the scheduling of bacteriological analyses.

BISCAYNE AQUIFER

The unconfined Biscayne aquifer underlies the entire study area and is the primary source of water for agricultural and residential use in Dade County. It is comprised of consolidated limestone, sandstone, sand, and shell. The general thickness of the aquifer in the East Everglades ranges from about 25 feet on the western edge (Levee 67 Extended Canal) to about 50 to 60 feet along the Levee 31 complex (fig. 3). The geologic and hydrologic characteristics of the Biscayne aquifer have been extensively described by Parker and others (1955), Schroeder and others (1958), and Klein and Hull (1978).

The East Everglades and Water Conservation Areas 3A and 3B (fig. 1) are ground-water recharge areas for the Biscayne aquifer in south Dade County. Ground-water movement is generally to the south during the dry season (November-April) and to the southeast during the wet season (May-October) (Schneider and Waller, 1980).

SAMPLING METHODS AND PROCEDURES

The seven land-use areas were selected in April and May 1978 based on the size of the particular area and the prevalence of the specific type of land use in the East Everglades. The locations of the wells at each agricultural area were based on the direction of

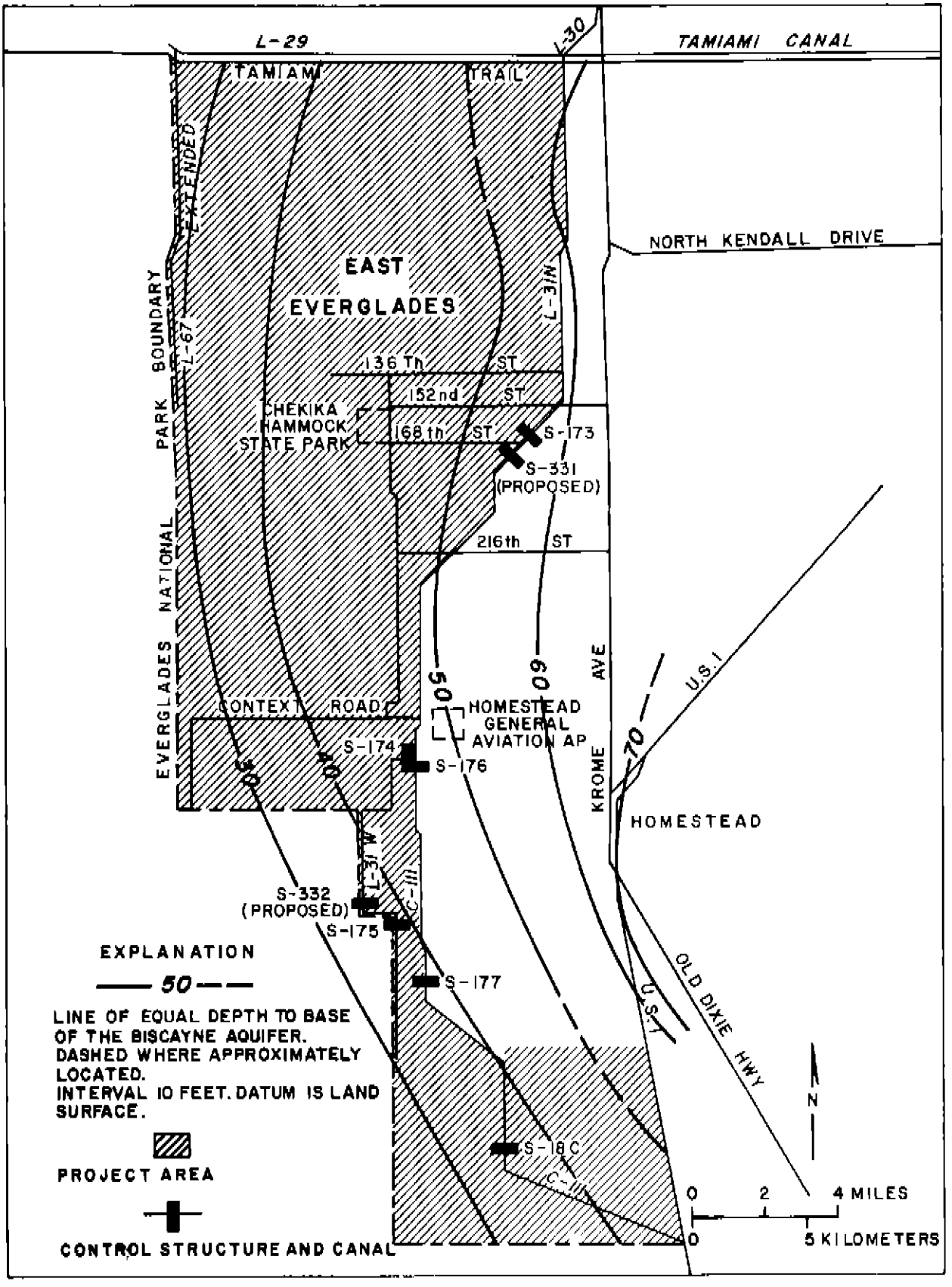

Figure 3.--Depth to the base of the Biscayne aquifer in the East Everglades.

ground-water movement. Seven wells (two upgradient, three central, and two downgradient) were located at each agricultural area. A schematic of the well locations in the agricultural areas is shown in figure 4. Two wells are near the center of each of the Coopertown and Richmond Drive residential areas and Chekika Hammock State Park; one well is 10 to 15 feet deep and one is near the base of the Biscayne aquifer (35 to 50 feet deep).

The wells were rotary drilled in July 1978. The 2-inch black iron casings were set in limestone with approximately 2 feet of open hole below the casing. All wells were finished in the Biscayne aquifer. Table 2 lists all wells by land-use area, the local well number, identification number, location (upgradient, central, downgradient), and depth.

Sampling procedures conform to the procedures used by the U.S. Geological Survey in similar investigations in south Florida (Pitt and others, 1975; Mattraw and others, 1978). Each well was pumped at about 10 gal/min until a uniform representative sample was produced based on pH, specific conductance, and temperature. A schematic of the sampling apparatus is shown in figure 5. All analyses were performed on unfiltered samples, except for major ions and dissolved solids. Soil was composited from five subsamples collected throughout the land-use area and then sieved through a No. 5-mesh sieve before chemical analysis. All chemical and physical properties of the ground water or soil (table 1) were analyzed in the field or at the U.S. Geological Survey laboratories in Ocala, Fla., and Atlanta, Ga. Analyses for total coliform, fecal coliform, and fecal streptococci concentrations were made by the Florida Health and Rehabilitative Services Laboratory in Miami.

RAINFALL AND WATER LEVELS

Rainfall data (in inches) from the Homestead Agricultural Experiment Station during the investigation were as follows:

	1978				1979					
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Rainfall	8.96	6.77	1.83	1.75	1.41	0.89	0.35	12.88	5.09	2.60
Average rainfall (35-year)	9.62	7.36	2.08	1.23	1.60	1.98	1.96	3.10	6.40	6.40
Departure from average	-0.66	-0.59	-0.25	0.52	-0.19	-1.09	-1.61	9.78	-1.31	-3.80

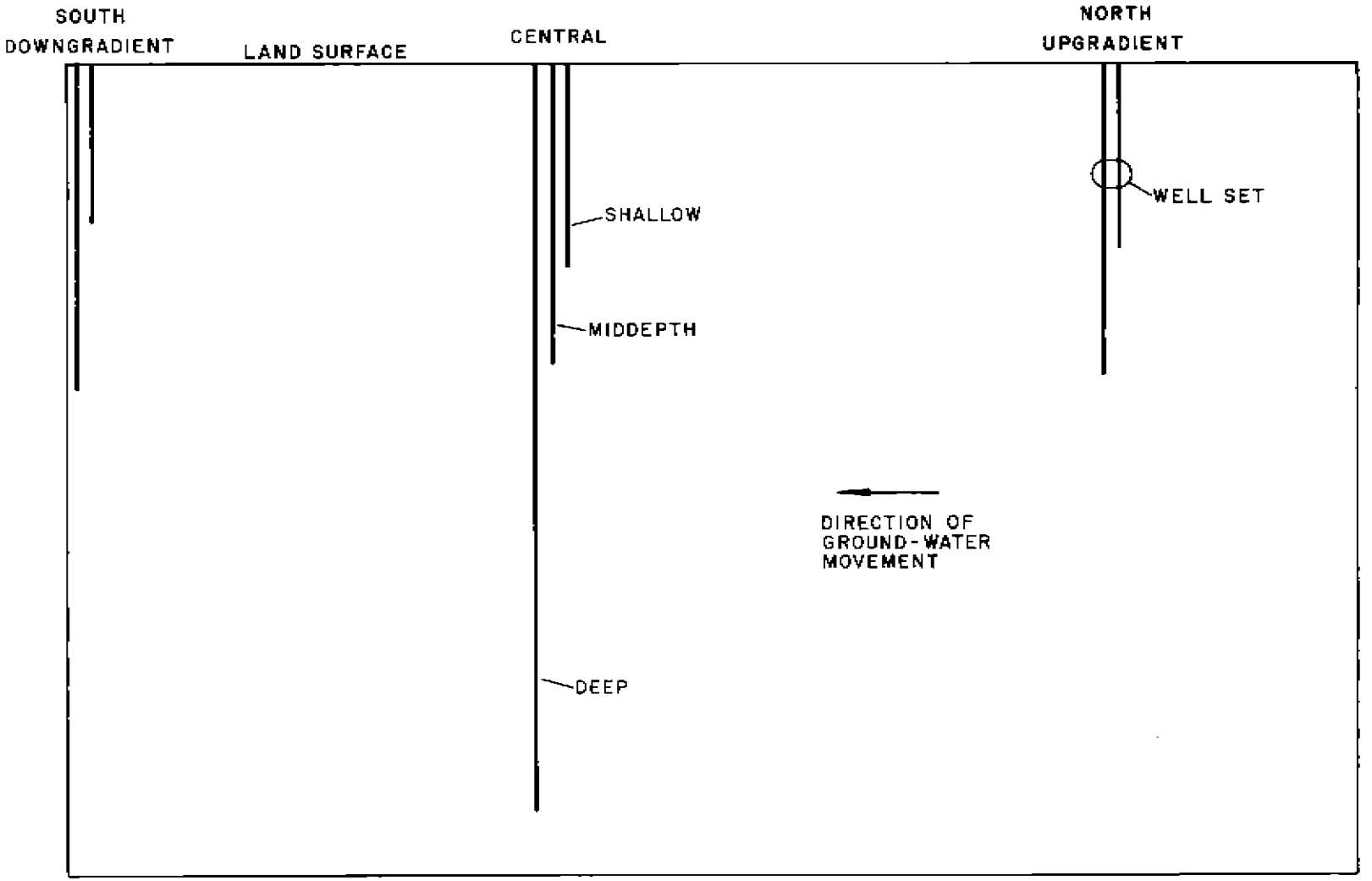

Figure 4.--Relative locations of the well sets in the agricultural land-use areas.

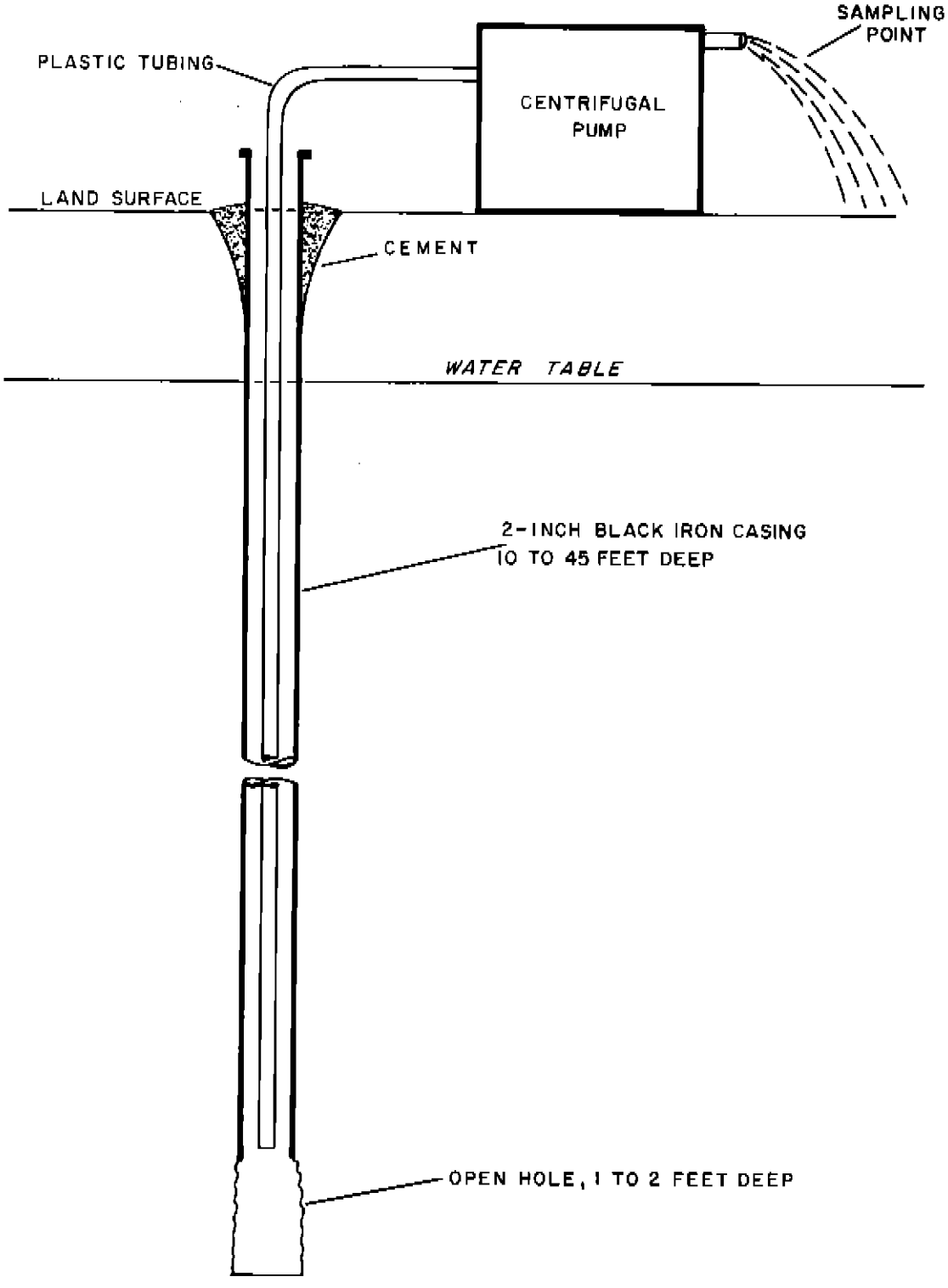

Figure 5.--Ground-water sampling apparatus.

Table 2.--Ground-water sites at seven land-use areas in the East Everglades

Well No.	Identification No.	Location	Depth (feet)
	Howard Drive agricultural area (fig. 7)		
G-3186	253907080314301	upgradient	11
G-3189	253907080314302	upgradient	20
G-3187	253842080311401	central	11
G-3190	253842080311402	central	20
G-3192	253842080311403	central	41
G-3188	253816080310701	downgradient	10
G-3191	253816080310702	downgradient	19
	Citrus grove (fig. 8)		
G-3193	253537080321801	upgradient	11
G-3196	253537080321802	upgradient	19
G-3195	253510080320701	central	12
G-3198	253510080320702	central	19
G-3199	253510080320703	central	46
G-3194	253440080314501	downgradient	11
G-3197	253440080314502	downgradient	21
	Rock-Plowed tomato field (fig. 9)		
G-3172	253112080341501	upgradient	10
G-3175	253112080341502	upgradient	16
G-3173	253045080341201	central	11
G-3176	253045080341202	central	20
G-3178	253045080341203	central	41
G-3174	253018080341201	downgradient	11
G-3177	253018080341202	downgradient	20
	Cracker Jack Slough agricultural area (fig. 10)		
G-3180	252742080344501	upgradient	21
G-3183	252742080344502	upgradient	27
G-3179	252504080340001	central	11
G-3182	252504080340002	central	21
G-3185	252504080340003	central	39
G-3181	252413080335801	downgradient	10
G-3184	252413080335802	downgradient	20
	Coopertown (fig. 12)		
G-3202	254537080362001	central	10
G-3203	254537080362002	central	34
	Richmond Drive residential area (fig. 13)		
G-3200	253630080321801	central	11
G-3201	253630080321802	central	42
	Chekika Hammock State Park (fig. 14)		
G-3204	253656080350303	central	13
G-3205	253656080350304	central	44

Water levels during the investigation declined gradually throughout the East Everglades from October 1978 to April 24, 1979 (fig. 6). Declines were as follows: 1.18 feet near Coopertown (well G-618); 3.36 feet near Richmond Drive-Howard Drive and Chekika Hammock State Park (well G-596); and 5.37 feet near the rock-plowed tomato field-Cracker Jack Slough area (Taylor Slough at Context Road) (fig. 2). On April 24-25, water levels rose abruptly in response to intense rainfall (11 inches recorded at Chekika Hammock State Park). Most agricultural areas were inundated, and agricultural activities virtually ceased for the 1979 growing season. Rainfall was less than average during May and June 1979.

GROUND-WATER QUALITY CHARACTERISTICS AT THE LAND-USE AREAS

Factors that influence the quality of ground water in the East Everglades area include: (1) quality of inflow (upgradient water quality and rainfall quality); (2) chemical characteristics of the soil; (3) composition of the Biscayne aquifer; (4) anthropogenic effects (application of agricultural chemicals, sewage effluent, and the presence of industrial compounds); and (5) dispersion, dilution, and attenuation characteristics of the aquifer. The parameters shown in table 1, sampled over the 10-month period, were selected to characterize both background water quality and to detect possible contamination. Multidepth wells were used to determine vertical change in ground-water quality.

Background Water Quality

Background wells are considered uncontaminated because they are upgradient of a land-use area. The background wells used (table 2) for the analyses in table 3 are: G-3186, G-3189, G-3172, G-3175, G-3180, and G-3183. Water from these wells shows some variation in analytical results which reflect the natural variability caused by sampling and the seasonal changes in an uncontaminated, shallow, water-table aquifer.

Water from wells G-3193 and G-3196, upgradient from the citrus grove, is not considered background because there was evidence of contamination from more highly mineralized water unrelated to land use. The water from the wells at Coopertown, Richmond Drive residential area, and Chekika Hammock State Park is near the center of the land-use areas and was, therefore, not representative of background conditions.

Background (uncontaminated) water quality in the East Everglades was established by statistical analyses of selected parameters and constituents (table 3). These statistical analyses show that:

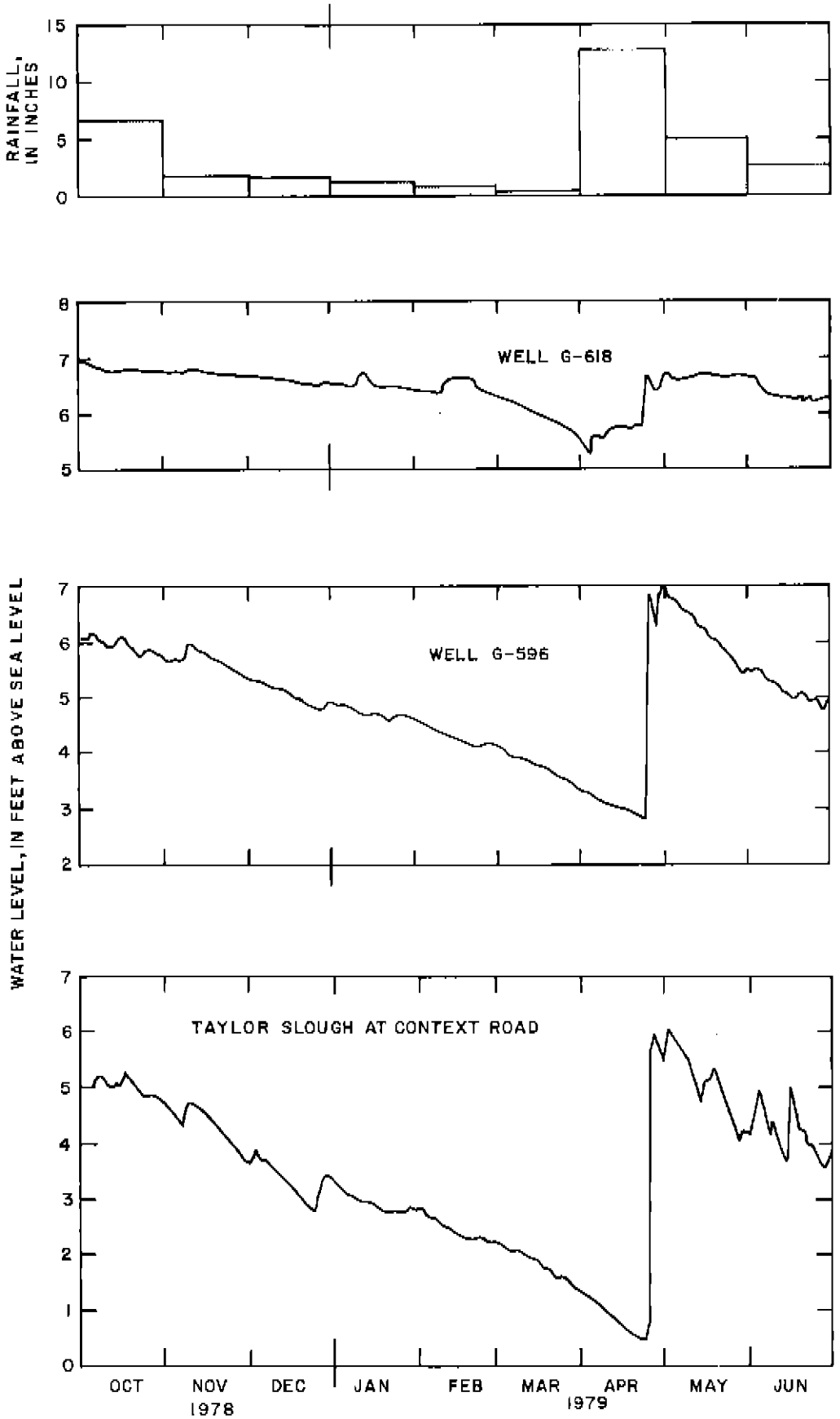

Figure 6.--Water levels at well G-618, well G-596, and Taylor Slough at Context Road, and monthly rainfall at Homestead Agricultural Experiment Station, October 1978 through June 1979.

Table 3.--Statistical summary of background water quality in the East Everglades

Characteristics	No. of samples	Average	Minimum	Maximum	Standard deviation
[Parameters and constituents in milligrams per liter]					
Temperature (°C)	51	24.4	23.0	25.5	0.6
pH	52	--	6.7	8.0	--
Color (Pt-Co units)	11	--	5	50	--
Specific conductance (umho/cm at 25°C)	46	435	385	490	28
Turbidity (NTU)	53	7	0	150	--
Carbon dioxide	50	33	3.8	83	15
Alkalinity (as $CaCO_3$)	51	221	190	361	34
Organic carbon	52	10	.0	83	11
Inorganic carbon	6	48	36	57	7.7
Total carbon	6	55	46	60	5.3
Organic nitrogen	53	.33	.06	.82	.15
Ammonia nitrogen	53	.25	.03	.44	.13
Nitrite nitrogen	53	.00	.00	.01	.00
Nitrate nitrogen	53	.01	.00	.17	.02
Total nitrogen	53	.59	.21	1.14	.24
Orthophosphate as P	53	.01	.00	.05	.01
Total phosphorus	53	.01	.00	.07	.02
Calcium	11	77	72	84	3.5
Magnesium	11	3.4	2.8	4.0	.4
Sodium	11	10	8.6	13	1.3
Potassium	48	.8	.2	9.5	1.7
Chloride	11	17	15	20	1.4
Sulfate	11	7.6	2.1	14	4.0
Fluoride	11	.1	.1	.2	.0
Silica	11	4.4	4.0	4.9	.3
Bicarbonate	51	270	230	440	42
Carbonate	15	.0	.0	.0	.0
Hardness	11	209	190	230	11
Noncarbonate hardness	11	5.8	.0	20	7.5
Dissolved solids (sum)	11	260	236	288	18
[Constituents are total recoverable and in micrograms per liter]					
Strontium	11	560	510	610	33
Arsenic[1]/	16	2	1	7	2
Cadmium	13	1	1	9	3
Chromium[1]/	16	11	10	20	3
Copper	16	.2	0	2	.6
Iron	16	920	400	1,600	430
Lead	11	2	0	10	3
Manganese[1]/	16	15	10	30	7
Nickel	16	9	2	22	7
Zinc	16	10	0	60	14
Mercury[1]/	16	.5	.5	.5	.0

1/ Values noted as less than (<) not included in calculations.

1. Temperature fluctuates in a narrow range and averages 24.4°C.

2. pH ranges from slightly acidic (6.7) to alkaline (8.0).

3. Color ranges from barely detectable, 5 Pt-Co (Platinum-Cobalt Standard) units to 50 Pt-Co units.

4. Turbidity is low, averaging 7 Nephelometric Turbidity Units, and the median value is 4.0 (NTU).

5. Average alkalinity is 221 mg/L (milligrams per liter), and the average total hardness is 209 mg/L.

Average macronutrient concentrations of water from the background wells, expressed as elemental nitrogen, phosphorus, and carbon, are as follows:

Constituents	Average (mg/L)
Organic nitrogen	0.33
Ammonia	.25
Nitrite	.00
Nitrate	.01
Total nitrogen	.59
Organic carbon	10
Orthophosphate	.01
Total phosphorus	.01

The background water is a calcium bicarbonate type, and the next most prevalent ions are sodium and chloride. Potassium has an average concentration of 0.8 mg/L. The average specific conductance is 435 μmhos/cm at 25°C, and the average dissolved-solids concentration is 260 mg/L.

Average trace-element concentrations, except for iron, were below established U.S. Environmental Protection Agency (1975, 1977) regulations and criteria in table 4. Iron concentrations are typically greater than the established criteria of 300 ug/L (micrograms per liter) in the Everglades due to natural lithologic conditions.

Land-Use Areas

Howard Drive Agricultural Area

The Howard Drive agricultural area (fig. 7) encompasses approximately 640 acres (1 mi^2) of primarily rock-plowed fields and scattered single-family dwellings. 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

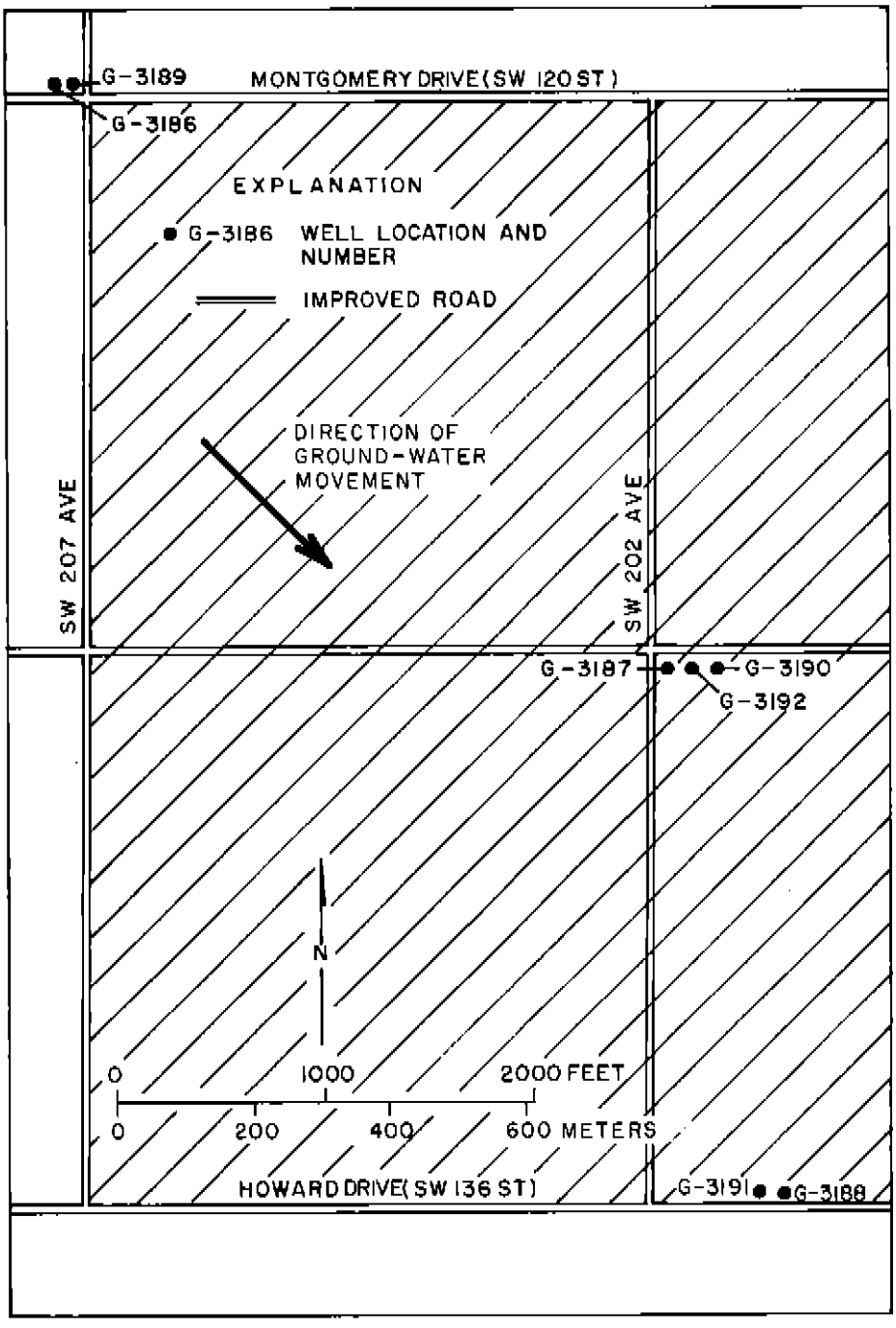

Figure 7.--Howard Drive agricultural area and well locations.

Table 4.--U.S. Environmental Protection Agency criteria and regulations for selected chemical constituents and physical characteristics in potable ground water

[Constituents in milligrams per liter, except for pH and color]

Constituents	Maximum contaminant level	Objection
Primary Drinking Water Criteria (1975)		
Arsenic	0.05	Toxic
Cadmium	.01	Toxic
Chromium	.05	Toxic
Lead	.05	Toxic
Mercury	.002	Toxic
Nitrate (as N)	10	Toxic to infants
Secondary Drinking Water Regulations (1977)		
Chloride (Cl)	250	Health (physiology) and taste
Sulfate (SO_4)	250	Health (physiology) and taste
Dissolved solids	500	Water treatment
pH	6.5-8.5	Welfare and water treatment
Color (Pt-Co units)	15	Esthetic and water treatment
Copper	1	Health and Esthetics
Iron	.3	Taste and stain
Manganese	.05	Taste and stain
Zinc	5	Health and taste

relatively uniform soil type that can be cultivated. Crops consist of tomatoes, pole beans, and tropical vegetables. Domestic animals are raised at the residences. Part of the area remained fallow during the investigation. Intensive agriculture began in November 1978 and ended in April 1979.

Physical characteristics and field measurements of the ground water are uniform throughout the area (table 5). Color is greater (20 to 60 Pt-Co units) than that established for background conditions (5 to 50 Pt-Co units) because of the proximity to the thick peat soils in the Everglades. Potassium concentrations and specific conductance are higher in the shallow and mid-depth wells at the central and downgradient wells than at the upgradient wells. The average specific conductance for all wells (484 umhos) is slightly above background (435 umhos). Average iron concentrations (1,400 ug/L) are higher than the average background concentration (920 ug/L).

Macronutrient concentrations show no trends throughout the Howard Drive agricultural area (table 6). Kjehdahl nitrogen (organic nitrogen plus ammonia nitrogen) is slightly higher at the central wells than at the upgradient or downgradient wells. The greatest organic carbon concentrations were at the downgradient shallow well G-3188.

The water is a calcium bicarbonate type (table 7). Except for iron (table 8), no trace-element concentrations exceeded U.S. Environmental Protection Agency regulations (1975) or criteria (1977).

Citrus Grove

The citrus grove occupies approximately 600 acres of relatively high land (7 to 8 feet above sea level) adjacent to Levee 31N and S.W. 216th Street (fig. 8). The grove consists of mature citrus trees on raised beds and is irrigated with overhead sprinklers or by drip irrigation. The soil is primarily marl and crushed limestone.

Ground water (table 9) in the citrus grove was more mineralized than that of background (435 µmhos) as indicated by relatively high average specific conductance (1,040 µmhos). Specific conductance decreased downgradient. Waller (1982a) describes the source and effect of this more mineralized water on the quality of the Biscayne aquifer in the East Everglades. Overall, potassium concentrations (3.0 mg/L) were higher than background (0.8 mg/L), and within the area, were highest at the shallow, central well (G-3195). Potassium concentrations tended to decrease with depth.

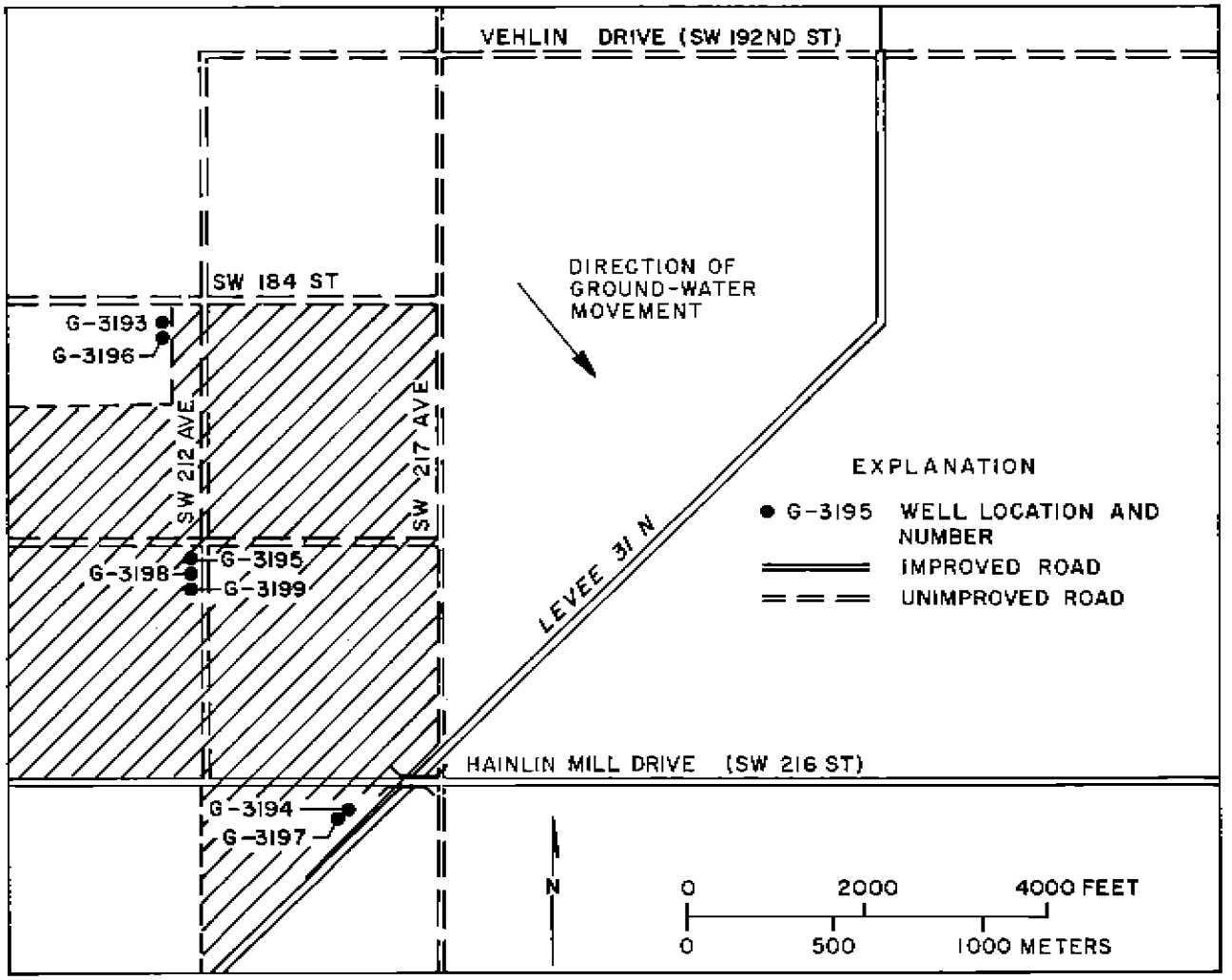

Figure 8.--Citrus grove and well locations.

Table 5.--Average or range of physical characteristics, field measurements, and potassium and iron concentrations in ground water at the Howard Drive agricultural area

Well No.	Well depth (feet)	No. of samples	Temperature (°C)	Turbidity (NTU)	Color (Pt-Co units)	pH	Alkalinity (as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Potassium (mg/L)	Iron (µg/L)
					Upgradient					
G-3186	11	10	24.4	0 - 5	40 - 40	6.9 - 7.9	234	450	0.5	1,300
G-3189	21	10	24.3	2 - 5	30 - 50	7.0 - 7.6	241	462	.2	1,400
					Central					
G-3187	11	10	24.7	3 - 6	35 - 40	6.9 - 7.3	247	498	.9	1,200
G-3190	21	10	23.7	0 - 6	20 - 60	6.9 - 7.6	250	492	.8	1,400
G-3192	43	10	23.6	3 - 8	30 - 40	6.9 - 7.5	246	490	.3	1,400
					Downgradient					
G-3188	11	10	23.7	3 - 7	20 - 50	6.6 - 8.0	249	499	1.0	1,400
G-3191	20	10	23.7	3 - 8	45 - 60	6.7 - 8.1	247	501	.7	1,400
					All wells					
G-3186 to G-3192		70	23.9	0 - 8	20 - 60	6.6 - 8.1	245	484	.6	1,400

Table 6.--Average concentrations of macronutrients in ground water at the Howard Drive agricultural area

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	No. of samples	Total organic nitrogen (as N)	Ammonium (NH_4-N)	Nitrite (NO_2-N)	Nitrate (NO_3-N)	Total nitrogen as N	Total organic carbon	Ortho-phosphate as P
				Upgradient					
G-3186	11	10	0.38	0.35	0.00	0.00	0.74	12	0.01
G-3189	21	10	.48	.37	.00	.00	.86	18	.01
				Central					
G-3187	11	10	.48	.43	.00	.00	.91	10	.01
G-3190	21	10	.50	.45	.00	.00	.95	12	.01
G-3192	43	10	.49	.46	.00	.00	.95	13	.01
				Downgradient					
G-3188	11	10	.32	.39	.00	.00	.72	28	.01
G-3191	20	10	.40	.40	.00	.00	.81	11	.01
				All wells					
G-3186 to G-3192		70	.44	.41	.00	.00	.85	15	.01

Table 7.--Concentrations of major ions, dissolved solids, and hardness in ground water at the Howard Drive agricultural area

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Strontium (Sr)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (F)	Bicarbonate (HCO_3)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness ($CaCO_3$): Calcium, magnesium	Hardness ($CaCO_3$): Noncarbonate	Silica (SiO_2)
							Upgradient									
G-3186	11	09/06/78	81	3.5	9	0.3	0.55	16	13.0	0.1	240	266	246	220	20	4.4
		04/17/79	80	3.9	10	.2	.54	17	6.8	.2	284	284	263	220	0	4.7
G-3189	21	09/06/78	84	4.0	11	.3	.58	17	10	.1	272	288	266	230	20	4.8
		04/17/79	79	4.0	11	.2	.54	17	7.4	.2	280	280	262	210	0	4.9
							Central									
G-3187	11	09/06/78	92	4.4	11	1.6	.59	21	23	.3	284	332	299	250	16	4.8
		04/18/79	84	4.2	12	.6	.58	19	17	.2	296	309	288	230	0	4.8
G-3190	21	09/06/78	90	4.5	12	.9	.64	21	25	.1	270	328	292	240	23	4.9
		04/18/79	86	4.5	14	.6	.60	19	17	.2	304	309	297	230	0	5.0
G-3192	43	09/06/78	87	4.4	12	.4	.56	21	14	.2	259	302	272	240	24	5.0
		04/18/79	85	4.3	12	.4	.58	19	16	.2	300	303	290	230	0	5.0
							Downgradient									
G-3188	11	09/06/78	96	4.0	11	1.4	.68	18	27	.1	280	325	301	260	27	4.7
		02/18/79	87	4.1	12	.9	.61	18	19	.1	300	317	294	230	0	4.6
G-3191	20	09/07/78	96	4.2	11	.8	.67	19	26	.1	270	335	296	260	36	4.8
		04/18/79	87	4.1	12	.6	.60	18	19	.2	296	299	292	230	0	4.7

Table 8.--Concentrations of trace elements in ground water at the Howard Drive agricultural area

[Concentrations in micrograms per liter]

Well No.	Well depth (feet)	Date of collection	Arsenic (As)	Cadmium (Cd)	Chromium (Cr^{+6})	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Mercury (Hg)
					Upgradient							
G-3186	11	11/28/78	1	3	10	0	1,300	30	-	10	10	<0.5
		02/20/79	1	3	10	0	1,400	30	0	10	4	< .5
		05/09/79	3	0	10	0	1,100	20	0	10	14	.5
G-3189	21	11/28/78	1	-	<10	0	1,400	20	-	10	6	< .5
		02/20/79	1	0	<10	0	1,300	20	0	0	5	< .5
		05/09/79	3	0	20	0	1,500	10	0	10	14	.5
					Central							
G-3187	11	11/13/78	1	5	10	7	1,200	20	20	30	2	< .5
		02/20/79	1	0	< 10	0	1,300	30	0	0	6	< .5
		05/09/79	1	0	20	1	1,200	< 1	1	10	18	.5
G-3190	21	11/13/78	1	6	<10	0	1,400	20	-	0	4	< .5
		02/20/79	2	0	<10	0	1,400	30	0	0	6	< .5
		05/09/79	1	0	20	1	1,400	10	2	10	15	.5
G-3192	43	11/13/78	1	-	10	1	1,400	20	-	10	6	< .5
		02/20/79	1	0	<10	2	1,700	30	0	0	4	< .5
		05/09/79	<1	0	20	0	1,200	10	0	10	16	.5
					Downgradient							
G-3188	11	11/13/78	1	8	< 10	0	1,300	10	-	30	2	< .5
		02/20/79	1	0	< 10	3	1,600	30	1	20	8	< .5
		05/09/79	<1	0	10	0	1,400	10	2	10	17	.5
G-3191	20	11/13/78	1	8	< 10	0	1,200	20	-	20	3	< .5
		02/20/79	1	0	10	0	1,200	20	1	0	7	< .5
		05/09/79	1	0	20	1	1,700	< 1	2	20	20	.5

Table 9.--Average or range of physical characteristics, field measurements, and potassium and iron concentrations in ground water at the citrus grove

Well No.	Well depth (feet)	No. of samples	Temperature (°C)	Turbidity (NTU)	Color (Pt-Co units)	pH	Alkalinity (as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Potassium (mg/L)	Iron (µg/L)
					Upgradient					
G-3193	11	10	24.2	3 - 6	10 - 25	6.9 - 8.0	227	1,130	2.8	900
G-3196	21	10	24.1	4 - 5	10 - 30	6.9 - 8.0	231	1,210	2.7	820
					Central					
G-3195	13	10	24.1	2 - 19	0 - 5	6.8 - 7.7	242	1,120	5.1	530
G-3198	20	10	24.0	4 - 8	10 - 30	6.8 - 7.7	244	1,120	3.6	790
G-3199	48	10	23.9	2 - 30	5 - 10	6.9 - 7.5	242	1,140	2.2	2,100
					Downgradient					
G-3194	10	10	24.2	1 - 15	5 - 10	6.9 - 7.9	248	769	2.4	790
G-3197	21	8	24.2	3 - 6	5 - 15	6.9 - 7.7	259	728	2.2	600
					All wells					
G-3193 to G-3199		68	24.1	1 - 30	0 - 30	6.8 - 8.0	241	1,040	3.0	950

Average macronutrient concentrations in the citrus grove are slightly higher than background conditions (table 10). The greatest nitrate and nitrite concentrations occurred in the shallow central and downgradient wells. Ammonia concentrations in the upgradient wells (0.31 and 0.38 mg/L) and total organic carbon concentrations (12 mg/L) in all the wells are higher than background levels (0.25 and 10 mg/L, respectively).

Sodium, chloride, sulfate, potassium, and magnesium concentrations (table 11) exceeded background conditions, indicating contamination from mineralized water. A more extensive discussion of this contamination is presented by Waller (1982a). Iron (table 12) was the only trace element that exceeded U.S. Environmental Protection (1977) criteria.

Rock-Plowed Tomato Field

The rock-plowed tomato field is a 320-acre tract west of S.W. 232nd Avenue between extensions of S.W. 264th Street and S.W. 280th Streets (fig. 9). The field was rock plowed in 1976, and tomatoes were planted in the two subsequent growing seasons. Planting of the 1978-79 crop began in September 1978 and was completed by the end of October. The soil is marl and crushed limestone.

The physical and chemical parameters at the rock-plowed tomato field (table 13) generally reflect background conditions (table 3). Potassium concentrations and specific conductance levels increase at both the central and downgradient wells when compared with the upgradient wells. A high turbidity level of 25 NTU at well G-3177 was caused by the open hole collapsing due to vandalism.

Macronutrient concentrations (table 14) indicated no trends and reflected background conditions. Major ion concentrations (table 15) show that the ground water is a calcium bicarbonate type. All trace-element concentrations (table 16), except for iron, are below established U.S. Environmental Protection Agency (1977) criteria (table 4).

Cracker Jack Slough Agricultural Area

The Cracker Jack Slough agricultural area is between Levee 31W and Canal 111 (fig. 10) and north of State Road 27. Field preparation for the 1978-79 growing season began in September 1978, and the fields were near full production by November 1978. The soil is a mixture of crushed limestone and marl.

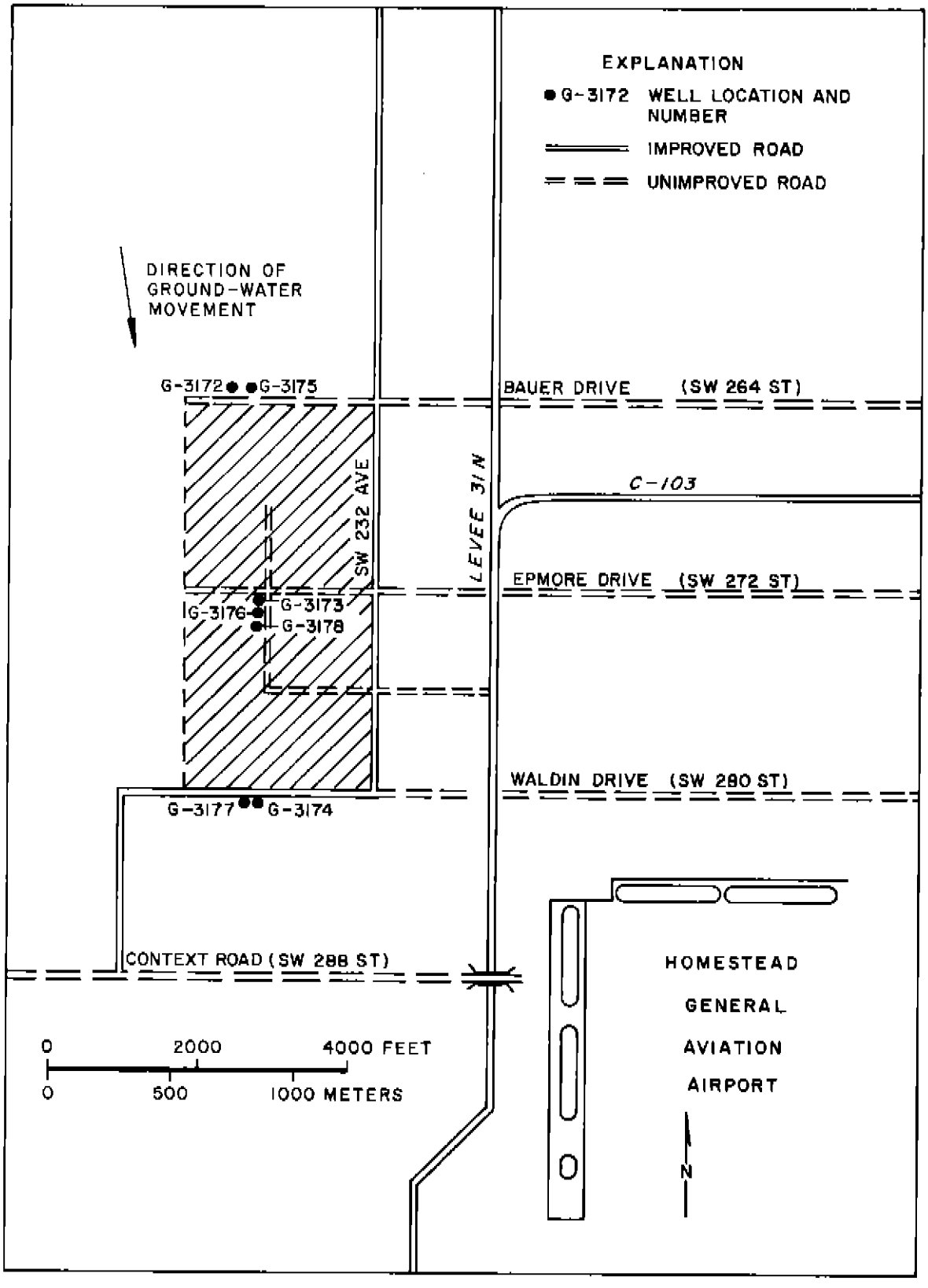

Figure 9.--Rock-plowed tomato field and well locations.

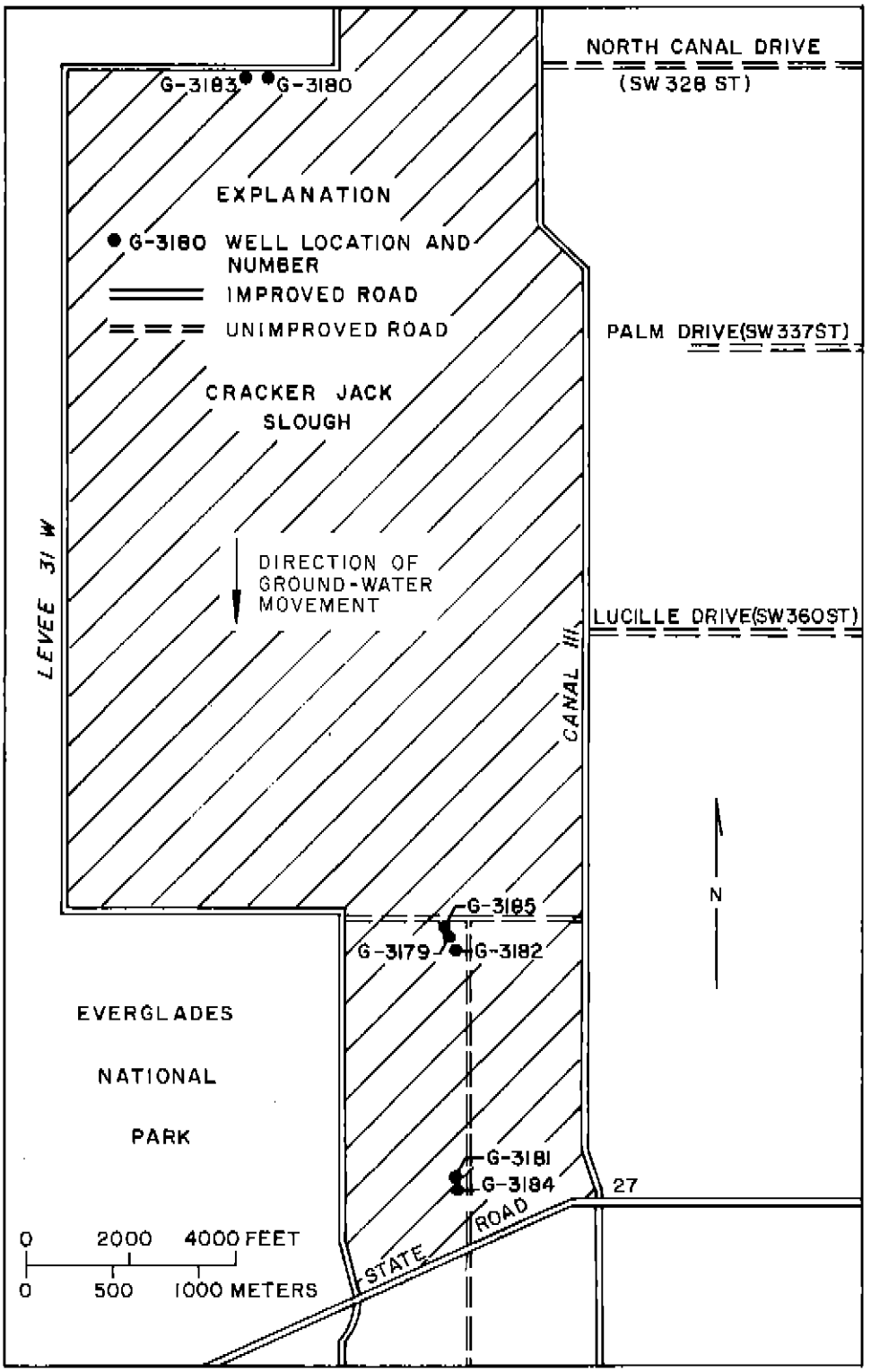

Figure 10.--Cracker Jack Slough agricultural area and well locations.

Table 10.--Average concentrations of macronutrients in ground water at the citrus grove

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	No. of samples	Total organic nitrogen (as N)	Ammonium (NH_4-N)	Nitrite (NO_2-N)	Nitrate (NO_3-N)	Total nitrogen as N	Total organic carbon	Ortho-phosphate as P
				Upgradient					
G-3193	11	10	0.63	0.38	0.00	0.01	1.0	17	0.00
G-3196	21	10	.57	.31	.00	.00	.88	18	.00
				Central					
G-3195	13	10	.62	.05	.04	.19	.90	9.9	.00
G-3198	20	10	.58	.09	.00	.00	.67	8.2	.00
G-3199	48	10	.66	.23	.00	.00	.90	9.4	.00
				Downgradient					
G-3194	10	10	.30	.08	.01	.07	.46	8.1	.02
G-3197	21	8	.37	.07	.01	.01	.46	15	.00
				All wells					
G-3193 to G-3199		68	.54	.18	.01	.04	.76	12	.00

Table 11.—Concentrations of major ions, dissolved solids, and hardness in ground water at the citrus grove

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Strontium (Sr)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (F)	Bicarbonate (HCO_3)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness ($CaCO_3$): Calcium, magnesium	Hardness ($CaCO_3$): Noncarbonate	Silica (SiO_2)
							Upgradient									
G-3193	11	09/07/78	90	8.2	120	2.6	0.64	180	82	0.1	250	625	610	260	54	3.5
		04/18/79	88	10	150	2.9	.63	220	91	.1	276	706	703	260	35	3.8
G-3196	20	09/07/78	95	9.7	140	2.3	.68	210	94	.1	250	711	679	280	73	3.7
		04/18/79	89	10	150	3.0	.63	220	91	.1	276	707	703	260	34	3.8
							Central									
G-3195	13	09/07/78	110	8.8	110	6.2	.37	180	110	.2	256	706	655	310	100	3.7
		04/18/79	95	7.8	120	3.8	.67	180	84	.1	296	653	641	270	27	3.7
G-3198	20	09/07/78	120	8.1	130	2.9	.77	190	98	.1	270	694	687	330	110	3.8
		04/18/79	96	7.8	120	3.7	.68	180	84	.1	296	651	642	270	30	3.8
G-3199	48	09/07/78	100	7.4	120	2.4	.34	190	85	.6	268	678	642	280	61	4.0
		04/18/79	95	7.1	120	2.4	.68	190	80	.1	288	650	645	270	24	4.1
							Downgradient									
G-3194	10	09/07/78	100	5.0	50	3.2	.72	80	60	.1	270	466	436	270	50	3.8
		02/18/79	89	5.0	48	2.0	.63	75	43	.1	300	429	414	240	0	3.8
G-3197	21	09/07/78	100	5.0	55	2.5	.71	82	58	.1	270	469	440	270	50	3.8
		04/18/79	91	5.1	50	1.8	.64	76	45	.1	300	434	421	250	3	3.9

Table 12.—Concentrations of trace elements in ground water at the citrus grove

[Concentrations in micrograms per liter]

Well No.	Well depth (feet)	Date of collection	Arsenic (As)	Cadmium (Cd)	Chromium (Cr^{+6})	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Mercury (Hg)
					Upgradient							
G-3193	11	11/13/78	1	4	<10	1	960	20	–	20	3	<0.5
		02/20/79	1	0	10	2	1,100	10	3	0	8	< .5
		05/09/79	2	0	30	0	630	10	0	10	20	.5
G-3196	20	11/28/78	1	–	<10	0	820	20	–	0	7	<.5
		02/20/79	1	0	<10	0	940	20	0	0	7	<.5
		05/09/79	<1	0	30	0	710	<1	2	10	22	.5
					Central							
G-3195	13	11/13/78	<1	9	10	0	350	<1	–	0	7	<.5
		02/20/79	1	0	<10	0	1,000	10	1	0	9	<.5
		05/09/79	<1	0	10	1	230	10	0	0	25	.5
G-3198	20	11/13/78	1	5	10	0	820	10	–	0	5	<.5
		02/20/79	1	0	10	0	870	10	3	10	7	<.5
		05/09/79	<1	0	20	1	690	<1	2	10	24	.5
G-3199	48	11/13/78	1	2	<10	0	1,700	20	10	20	3	<.5
		02/20/79	1	0	<10	0	2,600	20	1	0	7	<.5
		05/09/79	<1	0	20	1	2,100	10	0	10	20	.5
					Downgradient							
G-3194	10	11/13/78	<1	5	<10	0	220	10	–	0	5	<.5
		02/20/79	1	0	<10	2	2,000	10	8	0	7	<.5
		05/09/79	<1	0	10	1	150	<1	0	10	20	.5
G-3197	21	11/13/78	1	1	<10	0	520	10	11	0	4	<.5
		02/20/79	1	0	<10	0	670	20	29	20	8	<.5

Table 13.--Average or range of physical characteristics, field measurements, and potassium and iron concentrations in ground water at the rock-plowed tomato field

Well No.	Well depth (feet)	No. of samples	Temperature (°C)	Turbidity (NTU)	Color (Pt-Co units)	pH	Alkalinity (as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Potassium (mg/L)	Iron (µg/L)
					Upgradient					
G-3172	10	9	24.1	1 - 15	15 - 30	7.0 - 7.6	204	418	0.3	530
G-3175	17	9	24.4	2 - 20	10 - 20	6.7 - 7.6	207	426	.5	620
					Central					
G-3173	11	10	24.0	2 - 5	15 - 30	6.9 - 8.1	225	454	2.1	770
G-3176	21	10	24.0	2 - 6	10 - 20	6.8 - 7.7	225	453	2.0	880
G-3178	42	10	23.9	2 - 6	5 - 40	6.9 - 8.0	220	443	.8	850
					Downgradient					
G-3174	12	10	24.5	2 - 5	5 - 15	6.9 - 8.1	267	443	1.6	700
G-3177	21	10	24.2	2 - 25	5 - 20	6.8 - 8.0	223	456	1.5	930
					All wells					
G-3172 to G-3178		68	24.2	1 - 15	5 - 40	6.7 - 8.1	225	443	1.3	750

Table 14.--Average concentrations of macronutrients in ground water at the rock-plowed tomato field

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	No. of samples	Total organic nitrogen (as N)	Ammonium (NH_4-N)	Nitrite (NO_2-N)	Nitrate (NO_3-N)	Total nitrogen as N	Total organic carbon	Ortho-phosphate as P
				Upgradient					
G-3172	10	9	0.24	0.27	0.00	0.00	0.51	7.2	0.00
G-3175	17	9	.34	.28	.00	.00	.63	6.8	.00
				Central					
G-3173	11	10	.34	.29	.00	.00	.63	12	.00
G-3176	21	10	.30	.29	.00	.00	.59	9.4	.00
G-3178	42	10	.30	.33	.00	.00	.63	13	.00
				Downgradient					
G-3174	12	10	.29	.24	.00	.00	.53	9.2	.00
G-3177	21	10	.31	.25	.00	.00	.57	9.5	.00
				All wells					
G-3172 to G-3178		68	.30	.28	.00	.00	.59	9.6	.00

Table 15.--Concentrations of major ions, dissolved solids, and hardness in ground water at the rock-plowed tomato field

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Strontium (Sr)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (F)	Bicarbonate (HCO_3)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness ($CaCO_3$): Calcium, magnesium	Hardness ($CaCO_3$): Noncarbonate	Silica (SiO_2)
							Upgradient									
G-3172	10	09/07/78	77	3.1	9.2	0.3	0.56	16	4.3	0.1	230	242	228	210	17	4.1
		04/23/79	72	3.1	9.9	.3	.52	17	2.1	.1	264	242	239	190	0	4.3
G-3175	17	09/07/78	75	2.8	8.6	.3	.54	16	5.1	.1	230	236	226	200	11	4.0
		04/23/79	73	3.0	10	.3	.51	19	2.6	.1	260	251	241	200	0	4.6
							Central									
G-3173	11	09/07/78	82	3.4	9.6	2.1	.61	17	10	.1	250	273	252	220	14	4.3
		04/23/79	75	3.2	9.6	2.0	.54	16	6.1	.1	272	260	251	200	0	4.3
G-3176	21	09/07/78	82	3.4	9.8	1.7	.60	17	9.1	.1	250	266	251	220	14	4.4
		04/23/79	76	3.4	10	2.1	.56	17	7.2	.1	372	261	255	200	0	4.4
G-3178	42	09/07/78	81	3.4	9.8	.7	.59	17	5.4	.1	240	255	241	220	20	4.5
		04/23/79	75	3.4	10	1.0	.55	17	4.2	.1	264	257	246	200	0	4.5
							Downgradient									
G-3174	12	09/07/78	82	2.8	7.4	1.7	.64	12	8.9	.1	250	251	243	220	12	3.8
		02/23/79	77	3.2	9.3	1.5	.58	16	9.9	.1	272	265	256	210	0	4.1
G-3177	21	09/07/78	83	3.0	7.9	1.6	.64	13	8.1	.1	250	252	245	220	15	4.0
		04/23/79	77	3.2	9.2	1.6	.58	16	9.3	.1	272	256	255	210	0	4.1

Table 16.--Concentrations of trace elements in ground water at the rock-plowed tomato field

[Concentrations in micrograms per liter]

Well No.	Well depth (feet)	Date of collection	Arsenic (As)	Cadmium (Cd)	Chromium (Cr^{+6})	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Mercury (Hg)
					Upgradient							
G-3172	10	11/14/78	< 1	-	< 10	0	510	10	-	10	2	< 0.5
		02/20/79	1	0	10	0	680	10	3	0	6	< .5
		05/10/79	7	0	10	0	400	10	0	10	22	.5
G-3175	17	11/14/78	1	6	10	1	750	10	10	60	5	< .5
		02/20/79	1	0	< 10	0	580	10	2	0	6	< .5
		05/10/79	2	0	20	0	520	10	1	0	22	.5
					Central							
G-3173	11	11/14/78	1	0	10	0	700	10	7	0	4	< .5
		02/20/79	1	0	< 10	0	1,000	10	2	0	7	< .5
		05/10/79	1	0	10	0	600	10	2	10	19	.5
G-3176	21	11/14/78	1	1	10	0	790	< 1	6	10	2	< .5
		02/20/79	1	0	< 10	0	1,300	10	2	10	5	< .5
		05/10/79	1	0	10	1	560	20	0	0	20	.5
G-3178	42	11/14/78	1	1	10	1	670	10	7	70	5	< .5
		02/20/79	1	0	< 10	0	1,100	20	0	10	4	< .5
		05/10/79	1	0	20	0	780	20	1	10	20	.5
					Downgradient							
G-3174	12	11/14/78	1	5	< 10	0	680	< 1	42	0	4	< .5
		02/20/79	1	0	20	0	820	20	0	10	6	< .5
		05/10/79	3	0	20	0	600	10	0	0	17	.5
G-3177	21	11/14/78	1	5	10	1	790	10	40	30	3	< .5
		02/20/79	1	0	10	0	1,000	10	2	0	8	< .5
		05/10/79	2	0	20	1	1,000	10	0	10	15	.5

The physical characteristics of ground water in the Cracker Jack Slough agricultural area (table 17) generally reflect background quality (table 3). Potassium concentrations at the central and downgradient wells (4.8 to 8.6 mg/L) in the area are an order of magnitude greater than background concentrations (0.8 mg/L). Specific conductance also increased in the central and downgradient wells. Color levels are in the low range (0-35 Pt-Co units).

Macronutrient concentrations are similar to background water quality, except for downgradient, shallow well G-3181 (table 18) which has the highest average concentration of nitrite (0.6 mg/L) and nitrate (1.4 mg/L) of all the 34 wells sampled. The nitrate concentration at this well was highest in September 1978 (4.4 mg/L as N) and decreased each month during the growing season to the lowest concentration in April 1979 (fig. 11). These high nitrate and nitrite concentrations, in conjunction with relatively high average potassium concentrations (6.2 mg/L), indicate a direct effect of fertilizer application.

Major ion concentrations show that ground water in the Cracker Jack Slough agricultural area is a calcium bicarbonate type (table 19), although sulfate concentrations increased at the central and downgradient wells probably from fertilizer application. Trace-element concentrations (table 20), except for iron, are below established U.S. Environmental Protection Agency (1977) criteria (table 4).

Coopertown

Coopertown, a residential area along the Tamiami Trail (fig. 2) since 1946, is the oldest development in this part of the East Everglades. The 3-acre area has a gas station, a restaurant, and an airboat ride concession and repair shop. The two wells sampled are near the center of the development (fig. 12).

The water-quality data for Coopertown, Richmond Drive residential area, and Chekika Hammock State Park are listed in tables 21-24.

Levels of color (60-90 Pt-Co units), alkalinity (294 mg/L), and specific conductance (671 umhos) at Coopertown are greater than background levels (table 3).

Organic nitrogen (1.2 mg/L) and ammonia concentrations (1.4 mg/L) at Coopertown (table 22) are the highest sampled in the seven areas and five times higher than background concentrations (table 3). Total organic carbon concentrations (18 mg/L) also are above background conditions (10 mg/L). These increased macronutrient concentrations can be attributed to the organic Everglades peat which overlies all of the upgradient area.

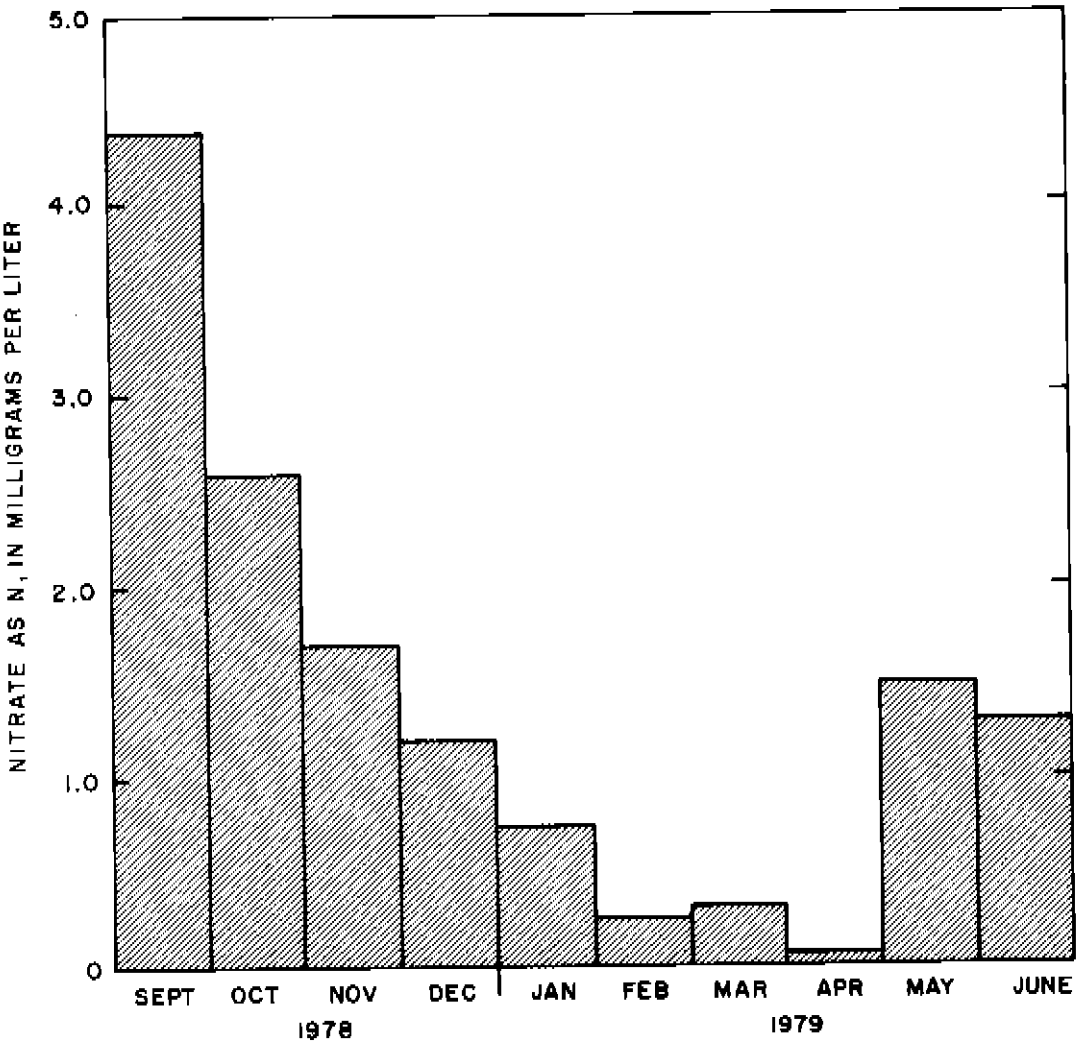

Figure 11.--Seasonal variation in the concentration of nitrate at well G-3181 (Cracker Jack Slough agricultural area), September 1978 to June 1979.

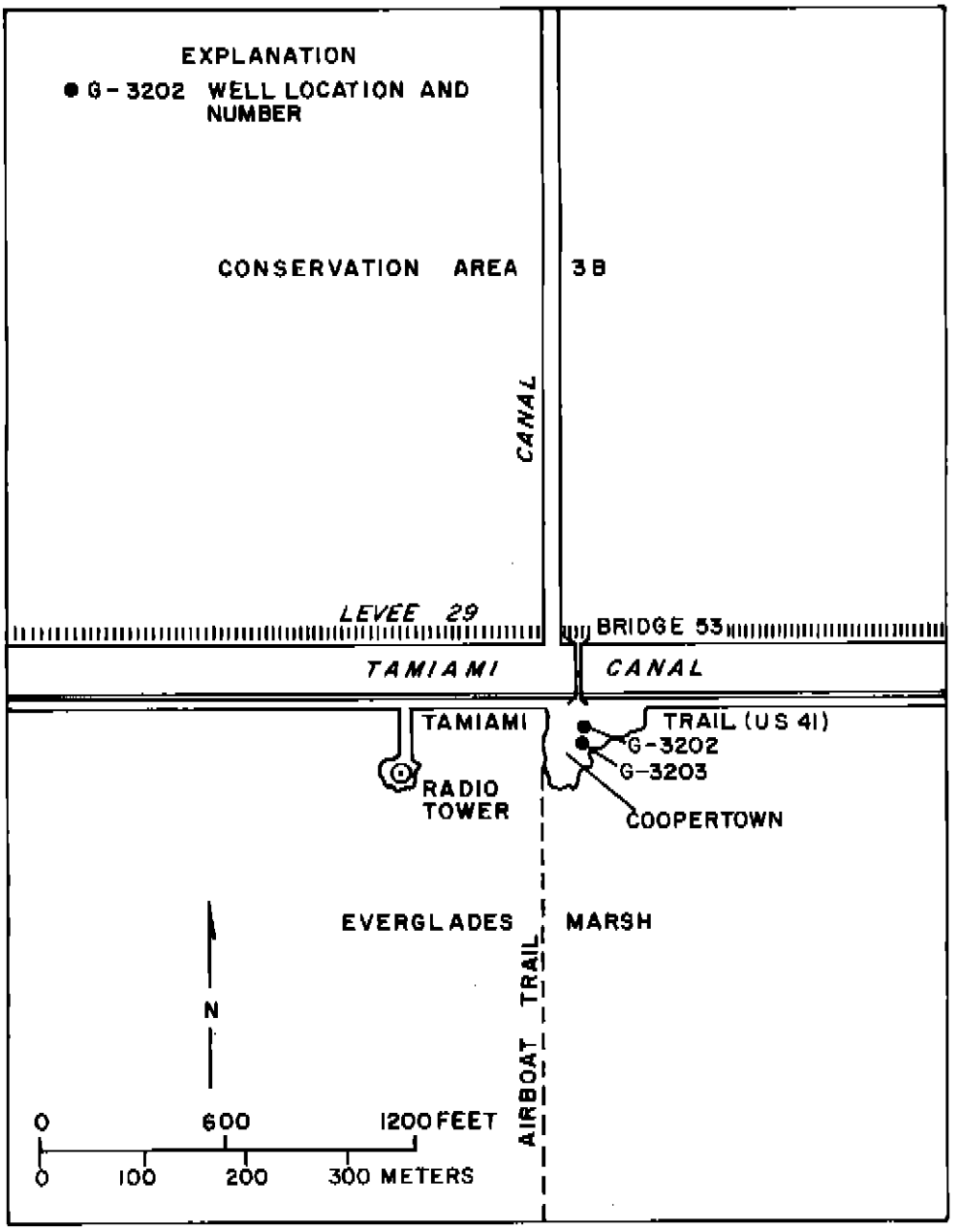

Figure 12.--Coopertown and well locations.

Table 17.--Average or range of physical characteristics, field measurements, and potassium and iron concentrations in ground water at Cracker Jack Slough agricultural area

Well No.	Well depth (feet)	No. of samples	Temperature (°C)	Turbidity (NTU)	Color (Pt-Co units)	pH	Alkalinity (as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Potassium (mg/L)	Iron (µg/L)
					Upgradient					
G-3180	21	5	25.0	2 - 3	25 - 25	7.0 - 7.9	220	414	2.2	590
G-3183	30	10	24.3	3 - 9	5 - 20	7.0 - 8.0	221	425	1.8	910
					Central					
G-3179	11	10	23.9	3 - 6	5 - 20	7.0 - 7.9	231	550	8.6	810
G-3182	21	10	23.9	4 - 10	5 - 35	7.0 - 8.0	235	552	8.1	1,000
G-3185	41	10	23.8	3 - 35	5 - 5	6.8 - 7.9	234	538	7.4	870
					Downgradient					
G-3181	10	10	25.2	1 - 13	5 - 5	7.0 - 7.7	208	519	8.4	210
G-3184	21	10	25.1	1 - 8	0 - 10	6.9 - 7.4	206	502	4.8	310
					All wells					
G-3179 to G-3185		65	24.4	1 - 35	0 - 35	6.8 - 8.0	222	505	6.2	680

Table 18.--Average concentrations of macronutrients in ground water at Cracker Jack Slough agricultural area

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	No. of samples	Total organic nitrogen (as N)	Ammonium (NH_4-N)	Nitrite (NO_2-N)	Nitrate (NO_3-N)	Total nitrogen as N	Total organic carbon	Ortho-phosphate as P
				Upgradient					
G-3180	21	5	0.24	0.06	0.00	0.00	0.30	7.6	0.01
G-3183	30	10	.24	.07	.00	.02	.34	7.9	.00
				Central					
G-3179	11	10	.37	.22	.00	.00	.59	9.7	.00
G-3182	21	10	.24	.21	.00	.00	.46	7.8	.00
G-3185	41	10	.25	.20	.00	.00	.46	15	.01
				Downgradient					
G-3181	10	10	.19	.02	.06	1.4	1.7	4.4	.00
G-3184	21	10	.24	.02	.00	.01	.28	7.8	.00
				All wells					
G-3179 to G-3185		65	.26	.12	.01	.22	.61	8.6	.00

Table 19.--Concentrations of major ions, dissolved solids, and hardness in ground water at Cracker Jack Slough agricultural area

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Strontium (Sr)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (F)	Bicarbonate (HCO_3)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness ($CaCO_3$): Calcium, magnesium	Hardness ($CaCO_3$): Noncarbonate	Silica (SiO_2)
							Upgradient									
G-3180	21	09/07/78	77	3.2	12	0.5	0.60	20	14.0	0.1	240	254	250	210	9	4.3
G-3183	30	09/06/78	78	3.1	10	.4	.61	15	7.7	.1	336	253	285	210	0	4.3
		04/23/79	76	3.2	13	.5	.60	18	11	.1	264	262	257	200	0	4.1
							Central									
G-3179	11	09/06/78	98	3.6	15	7.6	.88	26	46	.1	270	369	334	260	39	3.5
		04/23/79	93	3.8	13	8.2	.83	23	40	.1	308	342	337	250	0	3.6
G-3182	21	09/06/78	99	3.7	15	7.0	.86	27	46	.1	270	359	335	260	42	3.5
		04/23/79	93	3.8	13	8.3	.83	22	40	.1	304	335	335	250	0	3.6
G-3185	41	09/06/78	95	3.7	16	6.9	.80	28	43	.2	336	361	331	250	30	3.6
		04/23/79	90	3.6	12	7.7	.80	23	42	.1	264	335	333	240	0	3.5
							Downgradient									
G-3181	10	09/06/78	86	3.4	12	9.6	.88	24	42	.1	224	335	291	230	46	2.9
		04/23/79	82	3.6	14	7.3	.82	24	40	.1	224	306	285	220	37	3.1
G-3184	21	09/06/78	86	3.5	16	4.7	.78	28	43	.1	230	324	299	230	41	3.2
		04/23/79	80	3.5	15	5.5	.76	25	38	.1	256	301	297	220	5	3.3

Table 20.--Concentrations of trace elements in ground water at Cracker Jack Slough agricultural area

[Concentrations in micrograms per liter]

Well No.	Well depth (feet)	Date of collection	Arsenic (As)	Cadmium (Cd)	Chromium (Cr^{+6})	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Mercury (Hg)
					Upgradient							
G-3180	21	11/14/78	1	9	10	0	590	10	-	10	2	<0.5
G-3183	30	11/14/78	1	-	<10	0	700	10	-	0	3	<.5
		02/19/79	1	0	10	2	1,600	20	4	10	8	<.5
		05/10/79	<1	0	10	1	440	10	0	10	20	.5
					Central							
G-3179	11	11/14/78	1	3	10	0	680	10	-	0	5	<.5
		02/19/79	2	0	<10	0	1,000	10	1	10	6	<.5
		05/10/79	2	0	20	1	750	20	0	10	24	.5
G-3182	21	11/14/78	2	9	10	0	750	10	-	10	4	<.5
		02/19/79	1	0	<10	1	1,100	10	1	10	8	<.5
		05/10/79	2	0	50	0	1,200	20	0	10	19	.5
G-3185	41	11/14/78	1	8	10	0	720	10	41	40	2	<.5
		02/19/79	1	0	10	0	890	10	0	0	6	<.5
		05/10/79	1	0	10	1	1,000	20	0	10	25	.5
					Downgradient							
G-3181	10	11/14/78	1	8	10	3	180	10	-	30	5	<.5
		02/19/79	1	0	<10	0	280	10	0	0	7	<.5
		05/10/79	2	0	10	1	170	<1	0	0	22	.5
G-3184	21	11/14/78	1	3	<10	1	260	10	21	30	5	<.5
		02/19/79	1	0	10	0	450	20	0	0	7	<.5
		05/10/79	2	0	30	0	210	<1	0	0	40	.5

Table 21.—Average or range of physical characteristics, field measurements, and potassium and iron concentrations in ground water at Coopertown, Richmond Drive residential area, and Chekika Hammock State Park

Well No.	Well depth (feet)	No. of samples	Temperature (°C)	Turbidity (NTU)	Color (Pt-Co units)	pH	Alkalinity (as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Potassium (mg/L)	Iron (µg/L)
					Coopertown					
G-3202	10	10	24.8	2 - 25	60 - 90	6.8 - 7.5	293	674	0.8	3,000
G-3203	34	10	24.4	3 - 25	80 - 90	6.9 - 7.8	295	668	.6	3,700
Both wells		20	24.6	2 - 25	60 - 90	6.8 - 7.8	294	671	.7	3,300
					Richmond Drive residential area					
G-3200	11	10	24.7	2 - 7	20 - 20	7.0 - 8.1	246	472	.44	860
G-3201	42	10	23.7	3 - 4	20 - 50	7.0 - 8.1	248	480	.34	1,000
Both wells		20	24.2	2 - 7	20 - 50	7.0 - 8.1	247	476	.39	930
					Chekika Hammock State Park					
G-3204	12	10	24.2	3 - 23	50 - 50	7.0 - 7.6	254	734	1.0	1,600
G-3205	44	10	23.7	2 - 15	30 - 40	7.1 - 7.8	244	1,850	13	1,300
Both wells		20	24.0	2 - 23	30 - 50	7.0 - 7.8	249	1,330	6.9	1,500

Table 22.—Average concentrations of macronutrients in ground water at Coopertown, Richmond Drive residential area, and Chekika Hammock State Park

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	No. of samples	Total organic nitrogen (as N)	Ammonium (NH_4-N)	Nitrite (NO_2-N)	Nitrate (NO_3-N)	Total nitrogen as N	Total organic carbon	Ortho-phosphate as P
				Coopertown					
G-3202	10	10	1.2	1.4	0.00	0.00	2.5	18	0.02
G-3203	34	10	1.2	1.4	.00	.00	2.5	18	.02
Both wells		20	1.2	1.4	.00	.00	2.5	18	.02
				Richmond Drive residential area					
G-3200	11	10	.41	.27	.00	.01	.68	7.9	.01
G-3201	42	10	.44	.32	.00	.00	.77	18	.01
Both wells		20	.43	.30	.00	.01	.73	13	.01
				Chekika Hammock State Park					
G-3204	12	10	.62	.52	.00	.00	1.2	12	.05
G-3205	44	10	.64	.59	.00	.00	1.2	18	.02
Both wells		20	.63	.55	.00	.00	1.2	15	.03

Table 23.--Concentrations of major ions, dissolved solids, and hardness in ground water at Coopertown, Richmond Drive residential area, and Chekika Hammock State Park

[Concentrations in milligrams per liter]

Well No.	Well depth (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Strontium (Sr)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (F)	Bicarbonate (HCO_3)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness ($CaCO_3$): Calcium, magnesium	Hardness ($CaCO_3$): Noncarbonate	Silica (SiO_2)
							Coopertown									
G-3202	10	09/12/78	110	5.4	36	1.0	0.58	65	0.2	0.2	324	431	385	300	32	7.2
		04/19/79	90	6.6	50	.9	.57	81	14	.2	320	451	407	250	0	6.4
G-3203	34	09/12/78	100	6.0	31	.7	.59	55	.2	.2	353	421	374	280	0	6.4
		04/19/79	93	6.0	46	.6	.57	79	12	.2	336	450	409	260	0	6.0
							Richmond Drive residential area									
G-3200	11	09/12/78	89	3.0	9.5	.4	.65	16	8.2	.1	424	280	340	240	0	4.4
		04/19/79	80	3.6	11	.5	.56	18	9.7	.2	284	286	268	220	0	4.5
G-3201	42	09/12/78	87	3.6	11	.4	.60	18	12	.1	504	296	386	230	0	4.8
		04/19/79	79	3.7	11	.4	.54	17	10	.2	284	279	266	210	0	4.6
							Chekika Hammock State Park									
G-3204	12	09/12/78	86	3.7	42	1.6	.66	53	16	.3	304	385	359	230	0	5.1
		04/19/79	82	4.4	19	.5	.59	31	4.8	.2	306	313	398	220	0	5.3
G-3205	44	09/12/78	110	63	660	24	2.60	970	390	.6	270	2,430	2,360	540	320	10
		04/19/79	80	7.1	36	1.6	.69	54	17	.3	304	373	352	230	0	5.6

Table 24.--Concentrations of trace elements in ground water at Coopertown, Richmond Drive residential area, and Chekika Hammock State Park

[Concentrations in micrograms per liter]

Well No.	Well depth (feet)	Date of collection	Arsenic (As)	Cadmium (Cd)	Chromium (Cr^{+6})	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Mercury (Hg)
					Coopertown							
G-3202	10	09/12/78	1	13	<10	1	3,500	30	120	0	3	<0.5
		02/21/79	1	0	20	0	2,300	30	3	10	5	< .5
		05/08/79	4	0	30	1	3,100	20	2	20	16	.5
G-3203	34	09/12/78	1	6	<10	0	6,200	40	44	20	2	<.5
		02/21/79	1	0	10	0	2,200	20	0	40	4	<.5
		05/08/79	2	0	20	0	2,700	20	0	30	29	.5
					Richmond Drive residential area							
G-3200	11	11/15/78	1	-	10	0	1,100	10	-	40	2	<.5
		02/23/79	1	0	20	0	1,000	20	2	20	7	<.5
		05/08/79	3	0	20	1	480	< 1	3	30	35	.5
G-3201	42	11/15/78	1	3	10	0	1,000	10	-	0	7	<.5
		02/23/79	1	0	10	2	890	20	1	0	8	<.5
		05/08/79	3	0	30	1	1,100	< 1	1	20	17	.5
					Chekika Hammock State Park							
G-3204	12	11/15/78	1	-	10	0	1,400	20	-	0	3	<.5
		02/23/79	1	0	20	0	1,300	20	2	0	5	<.5
		05/08/79	3	0	20	1	2,200	10	1	30	20	.5
G-3205	44	11/15/78	1	-	10	0	1,600	40	-	30	4	<.5
		02/23/79	1	0	10	0	1,100	20	2	0	12	<.5
		05/08/79	3	0	20	1	1,200	10	1	0	24	.5

Ground water at Coopertown is a mixed calcium bicarbonate and sodium chloride type (table 23). This is the characteristic water type of the Levee 67A Canal which supplies recharge in this area (fig. 1) (Waller and Earle, 1975). Average iron concentrations (table 24) in ground water at Coopertown are the highest sampled in all seven areas (3,300 µg/L). A lead concentration of 120 µg/L exceeded U.S. Environmental Protection Agency (1975) criteria in one sample collected in September at the shallow well.

Richmond Drive Residential Area

Wells in the Richmond Drive residential area (fig. 13) are downgradient of scattered low density residential development near Richmond Drive. This area is on relatively high ground and is partly drained by the L-31N Canal (fig. 1). Soil is primarily marl among outcrops of limestone.

Ground-water quality at the residential area (table 21 and 22) is similar to background. The ground water is a calcium bicarbonate type (table 23). Iron (table 24) is the only trace element that exceeded U.S. Environmental Protection Agency (1977) criteria (table 4).

Chekika Hammock State Park

Chekika Hammock State Park, the largest recreational area in the East Everglades, occupies 640 acres of primarily wetland. The developed area of the park is a heavily vegetated hammock, 2 to 4 feet higher than the surrounding marsh. Most recreational use occurs in this hammock area. Within the park are campsites, day-use facilities, employee residences, a flowing artesian well (Grossman well or well S-524), and a package sewage-treatment plant. The two wells sampled are near the center of the hammock and downgradient of the sewage-treatment plant (fig. 14).

The physical characteristics of ground water at Chekika Hammock State Park reflect background conditions, except for specific conductance (table 21). The specific conductance in the shallow well (G-3204) is nearly double that of the background wells, and the deep well (G-3205) is about four times higher. This higher mineralization suggests contamination from the saline water flowing from the nearby artesian well. A more extensive discussion of the contamination caused by the Grossman well is presented by Waller (1982a). Average potassium concentrations (6.9 mg/L) exceed background conditions at this area and are also attributed to the contamination from the artesian well.

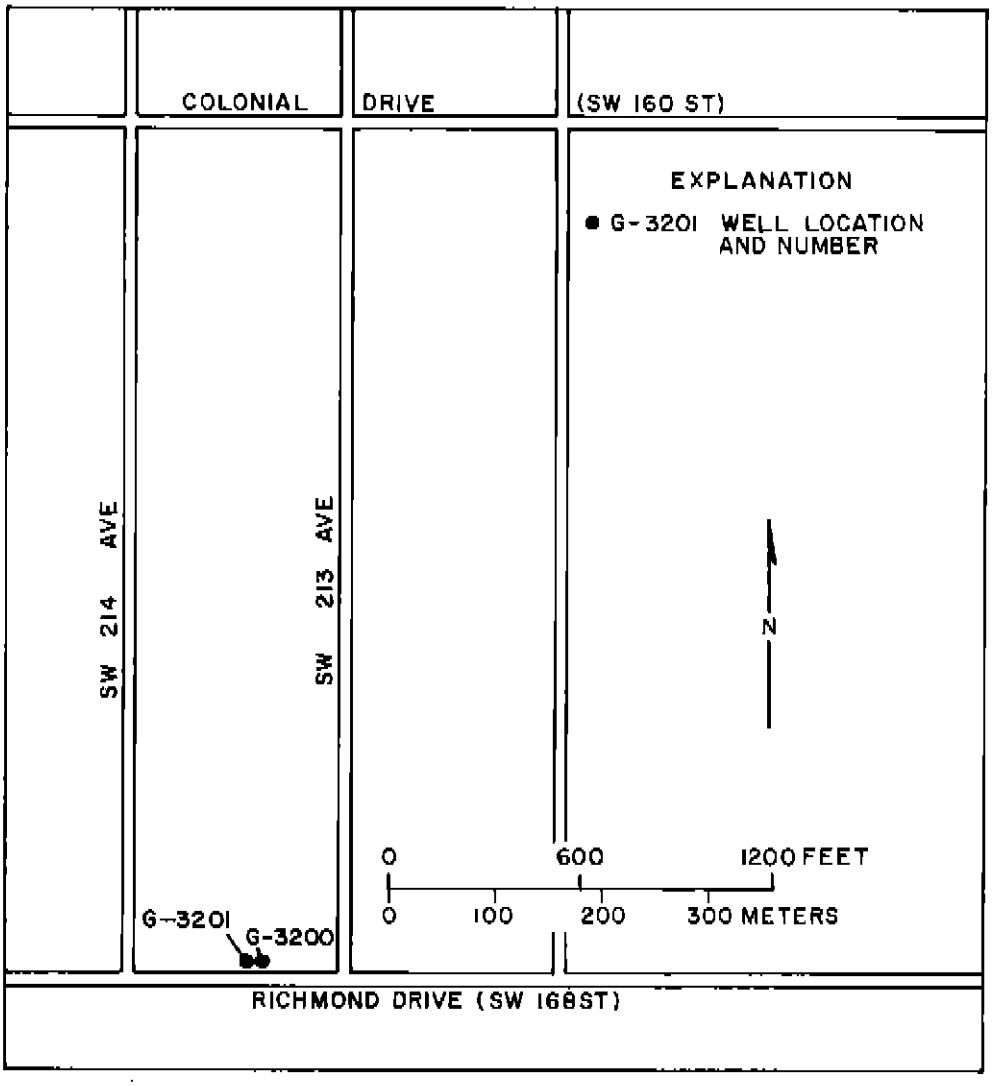

Figure 13.--Richmond Drive residential area and well locations.

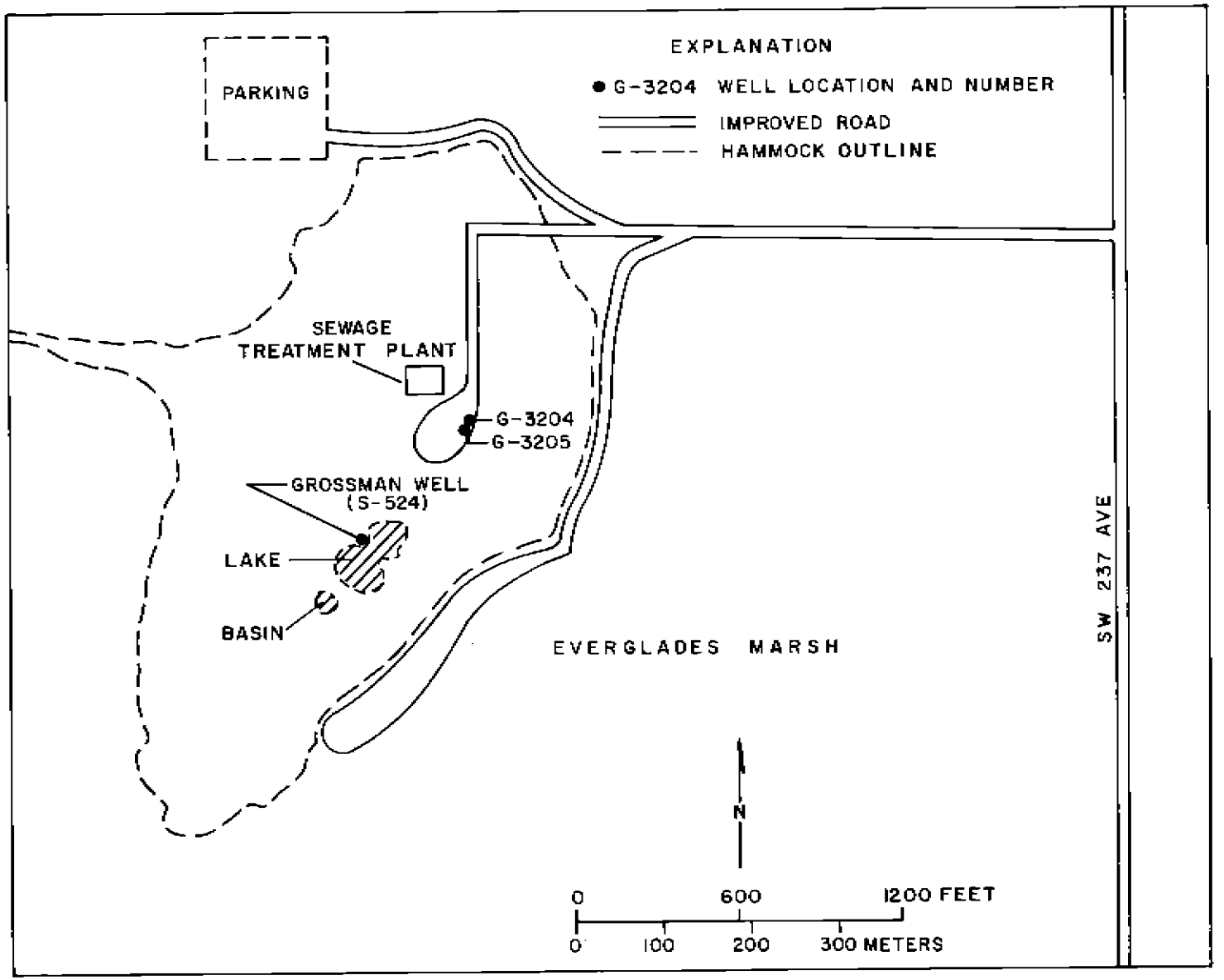

Figure 14.--Chekika Hammock State Park and well locations.

Macronutrient concentrations (table 22) generally reflect background conditions, except for higher ammonia, organic nitrogen, and total organic carbon concentrations which can be attributed to the proximity of peat in the upgradient area. The water under the peat is typically high in organic material and reduced inorganic nitrogen (ammonia).

The ground water at Chekika Hammock State Park is a mixed calcium bicarbonate, calcium sulfate, and sodium chloride type and also has higher concentrations of magnesium and potassium (table 23) than uncontaminated ground water in the East Everglades (table 3). Mineralization changes seasonally due to variations in the regional ground-water flow patterns and is most pronounced in the deep well (G-3205). When the water table is high (September, October, November, and June), the mineralization of the water from this well increases (fig. 15) because of a southeasterly, rather than a southerly, regional ground-water flow.

Summary of Physical and Chemical Parameters

A summary of physical parameters and chemical constituents at all seven land-use areas is given in tables 25 and 26. Parameters that usually exceed background (uncontaminated ground water) conditions by one standard deviation or more are as follows:

Land-use area	Parameters
Howard Drive agricultural area	Specific conductance Iron Ammonium Total nitrogen Total organic nitrogen
Citrus Grove	Specific conductance Potassium Iron Organic nitrogen Total nitrogen Nitrate
Rock-plowed tomato field	Potassium
Cracker Jack Slough agricultural area	Potassium
Coopertown	Color Alkalinity Specific conductance Iron Organic nitrogen Ammonia Total nitrogen Total organic nitrogen Orthophosphate
Richmond Drive residential area	Specific conductance Total organic nitrogen Total nitrogen
Chekika Hammock State Park	Specific conductance Potassium Iron Organic nitrogen Ammonia Total nitrogen Total organic carbon Orthophosphate

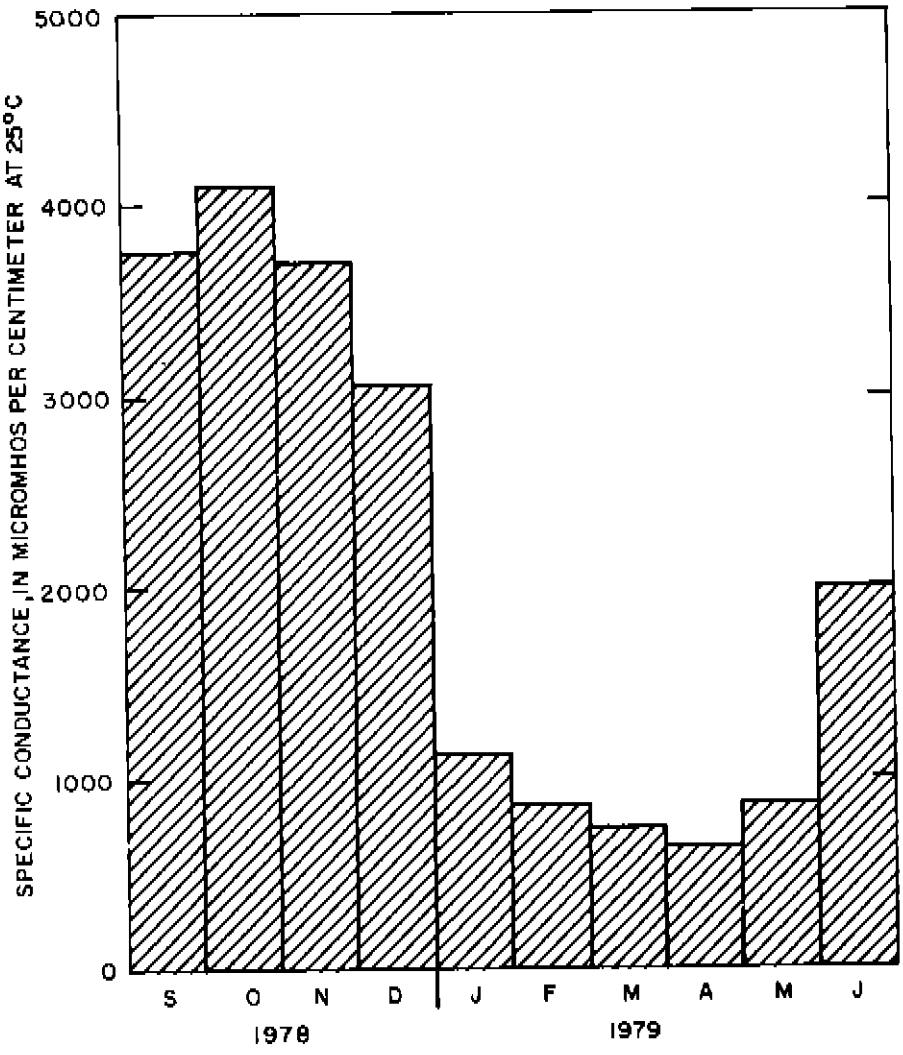

Figure 15.--Specific conductance at well G-3205 (Chekika Hammock State Park), September 1978 to June 1979.

Table 25.—Average or range of physical characteristics, field measurements, and potassium and iron concentrations in ground water at all seven land use areas

Well No.	No. of samples	Temperature (°C)	Turbidity (NTU)	Color (Pt-Co units)	pH	Alkalinity (as $CaCO_3$)	Specific conductance (µmho/cm at 25°C)	Potassium (mg/L)	Iron (µg/L)
				Howard Drive agricultural area					
G-3186-3192	70	23.9	0 - 8	20 - 60	6.6 - 8.1	245	484	0.6	1,400
				Citrus grove					
G-3189-3199	68	24.1	1 - 30	0 - 30	6.8 - 8.0	241	1,040	3.0	950
				Rock-Plowed tomato field					
G-3172-3178	68	24.2	1 - 150	5 - 40	6.7 - 8.1	225	443	1.3	750
				Cracker Jack Slough agricultural area					
G-3179-3185	65	24.4	1 - 35	0 - 35	6.8 - 8.0	222	505	6.2	680
				Coopertown					
G-3202-3203	20	24.6	2 - 25	60 - 90	6.8 - 7.8	294	671	.71	3,300
				Richmond Drive residential area					
G-3200-3201	20	24.2	2 - 7	20 - 50	7.0 - 8.1	247	476	.4	930
				Chekika Hammock State Park					
G-3204-3205	20	24.0	2 - 23	30 - 50	7.0 - 7.8	249	1,330	6.9	1,500
				Background					
Listed on page 12		24.4	0 - 150	5 - 50	6.7 - 8.0	221	435	.8	920

Table 26.--Average concentrations of macronutrients in ground water at all seven land-use areas

[Concentrations in milligrams per liter]

Well No.	No. of samples	Total organic nitrogen (as N)	Ammonium (NH_4-N)	Nitrite (NO_2-N)	Nitrate (NO_3-N)	Total nitrogen as N	Total organic carbon	Orthophosphate as P
			Howard Drive agricultural area					
G-3186-3192	70	0.44	0.41	0.00	0.00	0.85	15	0.01
			Citrus grove					
G-3193-3199	68	.54	.18	.01	.04	.76	12	.00
			Rock-Plowed tomato field					
G-3172-3178	68	.30	.28	.00	.00	.59	9.6	.00
			Cracker Jack Slough agricultural area					
G-3179-3185	65	.26	.12	.01	.22	.61	8.6	.00
			Coopertown					
G-3202-3203	20	1.2	1.4	.00	.00	2.5	18	.02
			Richmond Drive residential area					
G-3200-3201	20	.43	.30	.00	.01	.73	13	.01
			Chekika Hammock State Park					
G-3204-3205	20	.63	.55	.00	.00	1.2	15	.03
			Background					
Listed on page 12		.33	.25	.00	.01	.59	10	.01

Pesticides

In November 1978, all 34 wells were sampled and analyzed for chlorinated-hydrocarbon and phosphorthioate insecticides and the herbicides 2-4D, 2,4-5T, and silvex. No detections were noted.

Bacteriological Parameters

Indicator bacteria concentrations were determined at the three land-use areas most likely to be affected by sewage effluent--Coopertown, the Richmond Drive residential area, and Chekika Hammock State Park (tables 27-29). Coliform bacteria include a wide variety of organisms which can occur naturally in soil or which can be enteric. Fecal coliform and fecal streptococci bacteria are in the intestines of all warm-blooded animals and are used as indicators of fecal contamination. A ratio of FC/FS (fecal coliform to fecal streptococci) bacteria indicates the source of fecal contamination. A ratio of less than 0.7 indicates that the source of fecal contamination is from livestock or wildlife; a ratio greater than 4.0 indicates human sources. A total coliform count of 50 colonies per 100 milliliters is the Dade County water-quality criterion for indicator bacteria in potable ground water.

Ground water at Coopertown (table 27) had total coliform counts that ranged from 5 to 410 colonies per 100 milliliters in the shallow well (G-3202) and from 0 to 700 colonies per 100 milliliters in the deep well (G-3203).

Ground water in shallow well G-3200 at the Richmond Drive residential area (table 28) had total coliform counts ranging from less than 1 colony per 100 milliliters to a count that is given as "too numerous to count" (TNTC). Deep well G-3201 had total coliform counts ranging from less than 1 to 310 colonies per 100 milliliters.

Chekika Hammock State Park had total coliform counts (table 29) ranging from 0 to 280 colonies per 100 milliliters in shallow well G-3204, and from 0 to 230 colonies per 100 milliliters in deep well G-3205.

Analysis of the FC/FS ratio at these three areas shows that only shallow well G-3202 at Coopertown had human contamination as indicated by ratios of 41 on November 15, 1978, and 11.5 on April 19, 1978 (table 27).

Variation With Depth

Statistical analysis of the data for selected constituents of the shallow (table 30), mid-depth (table 31), and deep (table 32) wells was made to determine any change in the vertical distribution of these constituents. The following differences were observed:

Table 27.--Concentrations of indicator bacteria in ground water at Coopertown

[Concentrations in colonies per 100 milliliters]

Well No.	Date of collection	Total coliform	Fecal coliform	Fecal streptococci	FC/FS ratio
G-3202	09/12/78	42	1	20	0.05
(shallow)	10/25/78	410	1	1	1.00
	11/15/78	217	41	1	41
	12/13/78	5	1	1	1.00
	01/19/79	16	1	1	1.00
	02/23/79	6	1	1	1.00
	03/29/79	14	1	3	.33
	04/19/79	162	23	2	11.5
	05/08/79	220	1	1	1.00
	06/06/79	9	1	1	1.00
G-3203	09/12/78	46	1	1	1.00
(deep)	10/25/78	700	1	1	1.00
	11/15/78	0	0	1	--
	12/13/78	4	1	1	1.00
	01/19/79	330	21	60	.35
	02/23/79	1	1	1	1.00
	03/29/79	5	1	58	.02
	04/19/79	23	1	1	1.00
	05/08/79	38	1	1	1.00
	06/06/79	1	1	1	1.00

Table 28.--Concentrations of indicator bacteria in ground water at Richmond Drive residential area

[Concentrations in colonies per 100 milliliters]

Well No.	Date of collection	Total coliform	Fecal coliform	Fecal streptococci	FC/FS ratio
G-3200 (shallow)	09/12/78	164	18	18	1.00
	10/25/78	350	2	2	1.00
	11/15/78	12	4	1	4.00
	12/13/78	1	1	1	1.00
	01/19/79	2	0	1	--
	02/23/79	5	1	1	1.00
	03/29/79	14	1	28	.004
	04/19/79	(1)	1	1	1.00
	05/08/79	138	42	88	.48
	06/06/79	(1)	1	1	1.00
G-3201 (deep)	09/12/78	24	1	1	1.00
	10/25/78	310	1	2	.50
	11/15/78	4	0	1	--
	12/13/78	1	1	1	1.00
	01/19/79	1	0	1	--
	02/23/79	2	1	1	1.00
	03/29/79	1	1	1	1.00
	04/19/79	1	1	1	1.00
	05/08/79	118	2	2	1.00
	06/06/79	11	1	1	1.00

1/ Too numerous to count.

Table 29.--Concentrations of indicator bacteria in ground water at Chekika Hammock State Park

[Concentrations in colonies per 100 milliliters]

Well No.	Date of collection	Total coliform	Fecal coliform	Fecal streptococci	FC/FS ratio
G-3204 (shallow)	09/12/78	60	2	1	2.00
	10/25/78	280	1	1	1.00
	11/15/78	0	0	1	--
	12/13/78	1	1	1	1.00
	01/19/79	15	3	14	.21
	02/23/79	5	1	1	1.00
	03/29/79	27	2	1	2.00
	04/19/79	1	1	1	1.00
	05/08/79	71	2	4	.50
	06/06/79	1	1	1	1.00
G-3205 (deep)	09/12/78	1	1	1	1.00
	10/25/78	230	1	1	1.00
	11/15/78	0	0	1	--
	12/13/78	1	1	1	1.00
	01/19/79	1	0	1	--
	02/23/79	4	1	1	1.00
	03/29/79	7	1	7	.14
	04/19/79	8	1	1	1.00
	05/08/79	22	1	1	1.00
	06/06/79	1	1	1	1.00

Table 30.--Statistical summary of selected chemical and physical parameters in ground water from shallow wells

[Parameters in milligrams per liter, except for temperature, pH, color, specific conductance, turbidity, and iron]

Parameter	No. of samples	Average	Minimum	Maximum	Standard deviation
Temperature (°C)	140	24.3	22.5	28.5	0.9
pH	142	--	6.6	8.1	--
Color (Pt-Co units)	29	--	0	60	--
Specific conductance (µmho/cm at 25°C)	127	628	385	1,900	270
Turbidity (NTU)	144	--	0	150	--
Iron (µg/L)	43	1,000	150	3,500	730
Carbon dioxide	138	40	3.0	113	20
Alkalinity (as $CaCO_3$)	140	240	178	617	49
Organic carbon	139	12	0	82	12
Organic nitrogen	144	.45	.00	1.9	.34
Ammonia nitrogen	144	.34	.00	1.5	.33
Nitrite nitrogen	143	.01	.00	.13	.02
Nitrate nitrogen	143	.12	.00	4.4	.49
Kjeldahl nitrogen	144	.79	.04	3.1	.58
Nitrite + nitrate nitrogen	143	.13	.00	4.5	.51
Total nitrogen	144	.91	.20	4.7	.69
Orthophosphate as P	143	.01	.00	.20	.02
Potassium	130	2.6	.1	12	3.0
Bicarbonate	140	293	217	752	60

Table 31.—Statistical summary of selected chemical and physical parameters in ground water from mid-depth wells

[Parameters in milligrams per liter, except for temperature, pH, color, specific conductance, turbidity, and iron]

Parameter	No. of samples	Average	Minimum	Maximum	Standard deviation
Temperature (°C)	113	24.2	23.0	26.0	0.67
pH	116	—	6.7	8.1	—
Color (Pt-Co units)	24	—	0	60	—
Specific conductance (µmho/cm at 25°C)	106	625	391	1,290	274
Turbidity (NTU)	117	—	0	25	—
Iron (µg/L)	35	930	210	1,700	390
Carbon dioxide	114	39	3.4	93	18.5
Alkalinity (as $CaCO_3$)	116	232	125	381	36
Organic carbon	116	11	0	83	13
Organic nitrogen	117	.38	.07	1.2	.21
Ammonia nitrogen	117	.24	.00	.57	.14
Nitrite nitrogen	117	.00	.00	.04	.01
Nitrate nitrogen	117	.01	.00	.17	.02
Kjeldahl nitrogen	117	.62	.16	1.5	.29
Nitrite + nitrate nitrogen	117	.01	.00	.18	.02
Total nitrogen	117	.63	.17	1.5	.28
Orthophosphate as P	117	.00	.00	.06	.01
Potassium	106	2.4	.2	9.0	2.3
Bicarbonate	116	283	152	464	44

Table 32.--Statistical summary of selected chemical and physical parameters in ground water from deep wells

[Constituents in milligrams per liter, except for temperature, pH, color, specific conductance, turbidity, and iron]

Parameter	No. of samples	Average	Minimum	Maximum	Standard deviation
Temperature (°C)	69	23.9	23.0	25.5	0.51
pH	69	--	6.8	8.1	--
Color (Pt-Co units)	14	--	5	90	--
Specific conductance (μmho/cm at 25°C)	65	805	345	3,800	670
Turbidity (NTU)	70	--	2	35	--
Iron (μg/L)	21	1,600	670	6,200	1,210
Carbon dioxide	65	40	3.3	74	16
Alkalinity (as $CaCO_3$)	67	246	180	413	37
Organic carbon	69	15	0	90	15
Organic nitrogen	70	.56	.02	2.6	.44
Ammonia nitrogen	70	.50	.18	1.5	.38
Nitrite nitrogen	70	.00	.00	.01	.00
Nitrate nitrogen	70	.00	.00	.01	.00
Kjeldahl nitrogen	70	1.6	.24	4.0	.73
Nitrite + nitrate nitrogen	70	.00	.00	.01	.01
Total nitrogen	70	1.1	.24	4.0	.73
Orthophosphate as P	70	.01	.00	.08	.02
Potassium	63	3.5	.2	27	5.9
Bicarbonate	67	300	220	504	45

1. Temperature--A slight decrease from the shallow wells (24.3°C) to the deep wells (23.9°C).

2. Specific conductance--There appears to be more mineralized water at the base of the aquifer, but the data are influenced by the contamination from the Grossman well.

3. Iron--Concentrations are characteristically higher toward the base of the aquifer.

4. Total organic carbon and organic nitrogen--Concentrations are higher in the deep wells than in the shallow or mid-depth wells.

5. Nitrate nitrogen--Concentrations are more than 10 times higher in the shallow wells than in the mid-depth or deep wells.

6. Potassium--Concentrations appear to be fairly uniform and exceed background concentrations of all depths. Potassium concentrations are highest in the shallow wells and decrease with depth, except at Chekika Hammock State Park and at the citrus grove.

SOIL ANALYSIS

Soil samples were collected in September 1978 at all seven land-use areas, and additional samples were collected in May 1979 at the four agricultural areas after the growing season. Samples were analyzed for trace-element, insecticide-residue, and macronutrient concentrations, chemical oxygen demand, and percent organic material (tables 33-35).

Chlorinated-hydrocarbon insecticides were detected in the soil at all land-use areas, except at Chekika Hammock State Park (table 35). The Cracker Jack Slough agricultural fields had the highest concentrations of the DDT family (DDD, DDE, and DDT) and heptachlor epoxide. The concentrations were of equal order of magnitude to concentrations in the Everglades agricultural area, south of Lake Okeechobee (Waller and Earle, 1975). The rock-plowed tomato field had the highest concentration of chlordane in the soil, but the DDE and dieldrin detections were at background concentrations of less than 10 µg/kg (micrograms per kilogram). The citrus grove soil had the highest concentrations of dieldrin and relatively high concentrations of chlordane, DDE, and PCB (polychlorinated biphenyls). The Howard Drive agricultural area had one detection of dieldrin which was below background concentration. Soil in the Richmond Drive residential area and in the Coopertown residential area showed contamination from chlordane and the DDT family; in addition, lindane and PCB were detected at Coopertown.

Table 33.—Concentrations of macronutrients and chemical oxygen demand and loss on ignition (percent organic) in soil at all seven land-use areas

[Concentrations in milligrams per kilogram]

Land-use area	Date	Kjeldahl nitrogen as N	NO_2 and NO_3 as N	Total phosphorus	COD	Loss on ignition	Percent organic
Richmond Drive residential area	09/29/78	25,000	1.6	530	140,000	122,000	12.2
	05/16/79	30,000	.7	1,100	240,000	132,000	13.2
Citrus grove	09/29/78	43,000	.6	1,200	200,000	121,000	12.1
	05/16/79	29,000	2.1	760	100,000	145,000	14.5
Rock-Plowed tomato field	09/29/78	19,000	10	73,000	110,000	73,000	7.3
	05/16/79	25,000	1.0	1,600	170,000	121,000	12.1
Cracker Jack Slough agricultural area	09/29/78	19,000	10	590	110,000	73,000	7.3
	05/16/79	7,400	2.9	1,800	29,000	65,800	6.6
Coopertown	09/29/78	1,900	2.1	540	66,000	24,600	24.6
Richmond Drive residential area	09/29/78	22,000	3.5	280	160,000	130,000	13.0
Chekika Hammock State Park	09/29/78	51,000	11	140	350,000	252,000	25.2

Table 34.—Concentrations of trace elements in soil at all seven land-use areas

[Concentrations in micrograms per kilogram]

Land-use area	Date of collection	Arsenic (As)	Cadmium (Cd)	Chromium (Cr^{+6})	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Mercury (Hg)
Howard Drive agricultural area	09/29/78	0	10	10	10	0	94	20	10	20	0.00
	05/16/79	0	10	40	10	3,400	180	40	20	10	.00
Citrus grove	09/29/78	0	10	60	110	200	110	30	100	10	.00
	05/16/79	0	10	90	230	4,300	180	60	180	10	.00
Rock-Plowed tomato field	09/29/78	0	10	10	10	0	89	20	10	10	.00
	05/16/79	0	10	50	190	5,800	400	60	60	10	.00
Cracker Jack Slough agricultural area	09/29/78	0	10	20	20	0	100	20	10	10	.00
	05/16/79	0	10	30	190	1,000	310	50	70	20	.00
Coopertown	09/29/78	0	10	10	10	100	15	370	80	10	.00
Richmond Drive residential area	09/29/78	0	10	10	10	100	23	20	10	20	.00
Chekika Hammock State Park	09/29/78	0	10	10	10	2,900	120	40	20	10	.00

Table 35.—Summary of detections of chlorinated-hydrocarbon insecticide residues and related compounds in soil at all seven land-use areas

[Concentrations in micrograms per kilogram]

Land-use area	Date of collection	Aldrin	Chlordane	DDD	DDE	DDT	Dieldrin	Endrin	Heptachlor	Lindane	Toxaphene	Endosulfan	Heptachlor epoxide	Mirex	PCN	Perthane	PCB
Howard Drive agricultural area	09/29/78	0.0	0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0
Citrus grove	09/29/78	.0	68	.0	110	.0	1,600	.0	.0	.0	0	.0	.0	.0	0	.0	43
Rock-plowed tomato field	09/29/78	.0	240	.0	2.4	.0	3.5	.0	.0	.0	0	.0	.0	.0	0	.0	0
Cracker Jack Slough agricultural area	09/29/78	.0	220	19	80	100	29	.0	.0	.0	0	.0	4.4	.0	0	.0	0
Coopertown	09/29/78	.0	57	.0	.0	15	1.6	.0	.0	.0	0	.0	.0	.0	0	.0	53
Richmond Drive residential area	09/29/78	.0	40	4.2	1.6	43	.0	.0	.0	.0	0	.0	.0	.0	0	.0	0
Chekika Hammock State Park	09/29/78	.0	0	.0	.0	.0	.0	.0	.0	.0	0	.0	.0	.0	0	.0	0

Trace elements in the soil which had the highest concentrations were chromium, copper, iron, manganese, lead, and zinc; other trace elements were either not detected or were in concentrations near their detection limit. Coopertown had the highest concentration of lead (370 µg/kg). The agricultural areas generally had higher concentrations of the remaining trace elements than Richmond Drive residential area, Coopertown, or Chekika Hammock State Park. Trace elements are normally added as plant micronutrients or as a biocide. Trace-element concentrations in the soil increased from the beginning of the growing season (September) to the end (May).

Phosphorus concentrations (table 33) were higher in the agricultural areas than at the two residential areas or Chekika Hammock State Park. Phosphorus is commonly added to crops to provide an essential nutrient for growth.

The soil in the East Everglades appears to accumulate the chemicals added to increase agricultural production or eliminate pests. Increased concentrations of certain trace elements, chlorinated-hydrocarbon insecticide residues, and phosphorus were noted. The effect of the soil or bottom material in canals throughout the Everglades as a "sink" for these chemical constituents has been documented by Waller and Earle (1975), and Waller (1981 and 1982b). The soil cover accumulates these generally toxic chemical constituents before they enter the ground-water system.

SUMMARY

Ground-water quality characteristics for seven land-use areas (four agricultural, two residential, and one recreational) within the East Everglades, Dade County, from September 1978 through June 1979 are as follows:

Howard Drive agricultural area--Agriculture had little effect on ground-water quality in this land-use area. Potassium concentrations were slightly higher than background which is typical of agricultural areas. Higher color levels, specific conductance, and organic carbon and Kjeldahl nitrogen (organic nitrogen plus ammonium) concentrations are attributed to the proximity to the peat soil in the northern part of the East Everglades which is upgradient. The water is a calcium bicarbonate type. Soil contained only low concentrations of insecticide residues; also micronutrient manganese was detected at concentrations comparable to the other three agricultural land-use areas.

Citrus grove--This land use had a slight effect on the shallow ground-water quality as indicated by increased concentrations of potassium, nitrate, ammonium, and organic carbon. Specific conductance levels are higher than background and decrease downgradient. The water is a mixed calcium bicarbonate, calcium sulfate, and sodium chloride type. Soil analyses indicate contamination by dieldrin, chlordane, DDE, and PCB in addition to the trace elements--chromium, copper, manganese, and zinc.

Rock-plowed tomato field--This land use had little effect on ground-water quality at the sampling sites. Slight increases in potassium concentrations and specific conductance were noted in the shallow and mid-depth wells at the center and downgradient wells. The water is a calcium bicarbonate type. Soil contained chlordane and the trace elements--chromium, copper, manganese, and zinc.

Cracker Jack Slough agricultural area--This land use affected the quality of the shallow ground water as indicated by increased concentrations of potassium, nitrate, and sulfate at the central and downgradient wells. The downgradient, shallow well had the highest concentrations of nitrate as N (4.4 mg/L) and nitrite as N (0.13 mg/L) of any well sampled and also showed seasonal variation in these constituents. High potassium, nitrate, and sulfate concentrations indicate the effects of fertilizer application. The water is a calcium bicarbonate type. Soil analyses indicate contamination from chlordane, the DDT family, and dieldrin in addition to the trace elements--copper, manganese, and zinc.

Coopertown--This is the only residential and recreational land-use area selected which is surrounded by Everglades peat deposits. Color levels, specific conductance, and alkalinity are higher than at the other land-use areas. Organic nitrogen, ammonia, and total organic carbon were detected in higher average concentrations than at the other land-use areas. These increases are attributed to the natural water-quality characteristics of the central Everglades and are probably unrelated to land-use activities at Coopertown. The water is a mixed calcium bicarbonate and sodium chloride type. Soil contained chlordane and the DDT family and the trace elements--lead and zinc.

Richmond Drive residential area--No effects on ground-water quality were detected. Increased concentrations of Kjedahl nitrogen are attributed to proximity to organic soils. The water is a calcium bicarbonate type. Soil contained chlordane and the DDT family.

Chekika Hammock State Park--This area is affected by a flowing artesian well as indicated by the highest specific conductance levels of any of the land-use areas. The degree of mineralization changes seasonally and with depth. Kjeldahl nitrogen concentrations are slightly above background due to the proximity to Everglades peat in upgradient areas. The water changes seasonally from a mixed calcium bicarbonate, calcium sulfate, and sodium chloride type during the dry season to a calcium bicarbonate type during the wet season. This seasonal change is from a shifting of the ground-water flow patterns around the Grossman well. No insecticides or trace elements were detected in soil samples.

Iron concentrations in the East Everglades showed an areal and vertical trend. Concentrations decreased from the land-use areas in the north to land-use areas in the south. Iron concentrations generally increased with depth and was the only trace element in the ground water to exceed the U.S. Environmental Protection Agency regulations for potable water. Iron concentrations in the soil of the agricultural land-use areas increased dramatically throughout the growing season.

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