TECHNICAL MEMORANDUM

APRIL 1984

GROUNDWATER QUALITY STUDY
OF THE
WATER CONSERVATION AREAS

by

Dennis Nealon

This publication was produced at an annual cost of $101.25 or $.20 per copy to inform the public.
500 390

Groundwater Division
Resource Planning Department
South Florida Water Management District
West Palm Beach, Florida

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

The Groundwater Division of the South Florida Water Management District intended to implement a one year program entitled Groundwater Studies in the Water Conservation Areas. However, subsequent studies in the area by other agencies have made it lucrative to postpone this program. Presently, both the United States Geological Survey (USGS) and the University of South Florida (USF) are conducting research in the Water Conservation Areas (WCA). Under the direction of Dr. John Fish, the USGS is appraising the shallow aquifer of the lower east coast of Florida. The objective of the program is to establish the regional hydrogeologic framework, water quality, hydraulic properties, and water levels of the area. The USGS has completed 23 wells in the WCA, 16 of these are located in Broward County and the remainder are located in Dade County. Lithologic cuttings and water quality data have been obtained for all of the wells. A technical publication is presently in review in regard to information collected in WCA-3A. An additional report will be forthcoming on the WCA in Dade and Palm Beach Counties. A geophysical reconnaissance study of the WCA's in Broward and Dade Counties is being conducted by Dr. Mark Stewart of USF. The geophysical methods employed are electromagnetics and surface resistivity. These techniques measure the electric properties of the earth and are extremely useful in determining water qualities. Information from both agencies has been collected and will continue to be with significant findings. Due to these developments, postponement of the study by the Groundwater Division has been made in order to avoid duplication of effort. It has been anticipated that continuing this project would result in a redundancy of data since the field methods employed are the same techniques used by the USGS and USF. By delaying this project until all data has been compiled and interpreted by the agencies involved, a program can then be engineered to be consistent with their findings. Furthermore, if anomalous

conditions are discovered, the study can then be geared to resolve these conditions in detail. In this manner, both time and money can be saved as well as enhancing the incoming data to supplement the program.

Presently, the existing literature has been obtained, reviewed, and a bibliography made available. In addition, data from these sources have been compiled and represented in graphical form. Represented are water quality with depth, isochlor maps, and Stiff diagrams. The water quality illustrations indicate the heterogeneity of the aquifer as well as increased concentrations with depth.

PURPOSE

The purpose of this study was to identify areas of potable water within the Water Conservation Areas. This was to be accomplished by:

1. Drilling wells where data gaps existed.
2. Identifying the geology of the areas.
3. Analyzing the groundwater quality and monitoring the quality over time.
4. Monitoring the groundwater levels to determine the discharge and recharge in the area.

However, both the U. S. Geological Survey and the University of Florida are conducting similar studies in the Water Conservation Areas. Therefore, this program has been temporarily postponed to avoid duplication of effort with the other agencies.

Presented here is the preliminary results from the U. S. Geological Survey.

INTRODUCTION

The Water Conservation Areas occupy part of the original Everglades which are west of the Atlantic Ridge in Palm Beach, Broward, and Dade Counties. They extend just south of Lake Okeechobee and occupy the extreme northwest part of Everglades National Park. On the west they are bordered by Collier and Hendry Counties. The WCA's include 3 subdivisions: WCA-1 covers an area of 572 km^2, WCA-2 occupies 544 km^2, and WCA-3 includes 2367km^2.

The region's vegetation is a vast sawgrass marsh dotted with tree islands and interspersed with wet prairies and aquatic sloughs. Poor drainage is characteristic of the area, with an average slope of only 3cm/km between Lake Okeechobee to Florida Bay. Surface water inflow to the WCA's is both controlled and uncontrolled. Six pumping stations control water flow into the WCA's by gravity discharge, through gate structures, and by backpumping of a small portion of canal water. Most of the water within the area is derived from rainfall and partially from Lake Okeechobee. During the wetter months, water will flow either over the marshes as sheet flow or in canals, spillways, and culverts. During the drier months, water becomes ponded in the marshes and flow ceases in the canals unless it is backpumped into the WCA's (Waller, 1975).

The majority of the WCA's is underlain by the highly permeable Biscayne aquifer with the exception of its northern and western fringes. These bordering areas are comprised of a contiguous surficial aquifer of less permeability. Both aquifer systems provide the bulk of the potable water to southeast Florida. In Dade, Broward and southeast Palm Beach Counties, the Biscayne is composed of limestone, sandstone, and sand. The surficial aquifer contains a thin layer of limestone and a larger percentage of sand. Water levels in the WCA's are high, in excess of eight feet above sea level, since the region is flooded for much of the year. Therefore, the aquifer is often fully saturated and the groundwater flow follows the gradient of the land surface which is south and southeast. The high water table conditions provide a significant amount of recharge to the remaining aquifer system.

The WCA's serve five major functions: (1) provide flood protection for urban east coast areas, (2) provide municipal and agricultural water supplies, (3) maintain wellfield recharge and prevent salt water intrusion, (4) provide Everglades National Park with a guaranteed supply of water, and (5) furnish important wetland habitat for Everglades plants and habitat (Swift, 1979).

PREVIOUS INVESTIGATIONS

The groundwater resources and geology of the WCA's have not been thoroughly studied. Parker (1951 & 1955) has provided cross sections and geologic interpretation across the region. Additional information concerning the natural conditions of the Everglades is given by Schroeder (1958) and Davie (1943). Schroeder and Klein (1954) described the geology of the western edge of the Everglades. The Army Corps of Engineers (1951, 1968, & 1980) has given details on the surficial drainage system as well as the surficial geology. Leach, Klein, and Hampton (1972) have discussed the effects of water control in the region.

Several studies are concerned with the surface water quality in the WCA's. Gleason (1974) reported on the water chemistry of Water Conservation Area 2A and the adjacent canal system. The effects of the agricultural areas on water within the WCA's has been discussed by McPherson (1973) and gives particular attention to concentrations of nitrogen and phosphorus in a 1976 study. Waller (1975) also investigated the occurence of nitrogen and phosphorus in the region. Seepage through levees was estimated by Klein and Sherwood (1961).

The current investigation by USF and the USGS should provide helpful baseline data on subsurface conditions.

GEOLOGY

The Biscayne aquifer underlies most of the WCA's in southeast Florida. It is thickest in the coastal areas and wedges out in the interior. The majority of the aquifer is composed of limestone, sandstone, shell, and sand. It is primarily limestone in south and west Dade, and its sand content increases north and east. The aquifer in the WCA's is primarily composed of the Fort Thompson Formation, Caloosahatchee Marl, and a sandy limestone in the upper part of the Tamiami Formation. Underlying these units is the relatively impermeable Hawthorn Formation.

The Fort Thompson Formation forms the floor of Lake Okeechobee and the Everglades depression. It attains its maximum thickness of approximately 200 ft where it merges with the Anastasia Formation of the coastal ridge. In north Broward and southeast Palm Beach Counties, it contains more sand which makes it less permeable. To the south it is more permeable and forms the major portion of the Biscayne. Here it is white to cream limestone, calcareous sandstone, pockets of quartz, with beds of dense limestone and solution holes (Parker, 1955).

The Caloosahatchee Marl Formation underlies the Fort Thompson. It is believed to grade into the Tamiami Formation near the Atlantic Ridge. The formation is composed of sand, silt, clay, shells, and calcareous materials which are littoral deposits. The formation contains many local beds or lenses of sand and clay. Wells indicate that it thickens to the south and southeast.

The Tamiami Formation is mostly white to cream colored calcareous sandstone, sandy limestone, and beds of quartz sand. West of the WCA's, where it is exposed in Monroe and Collier Counties, it is grayish to tan and riddled with solution holes. In the Everglades and north of Fort Lauderdale, the Tamiami contains more sand and water yields are less (Parker, 1955).

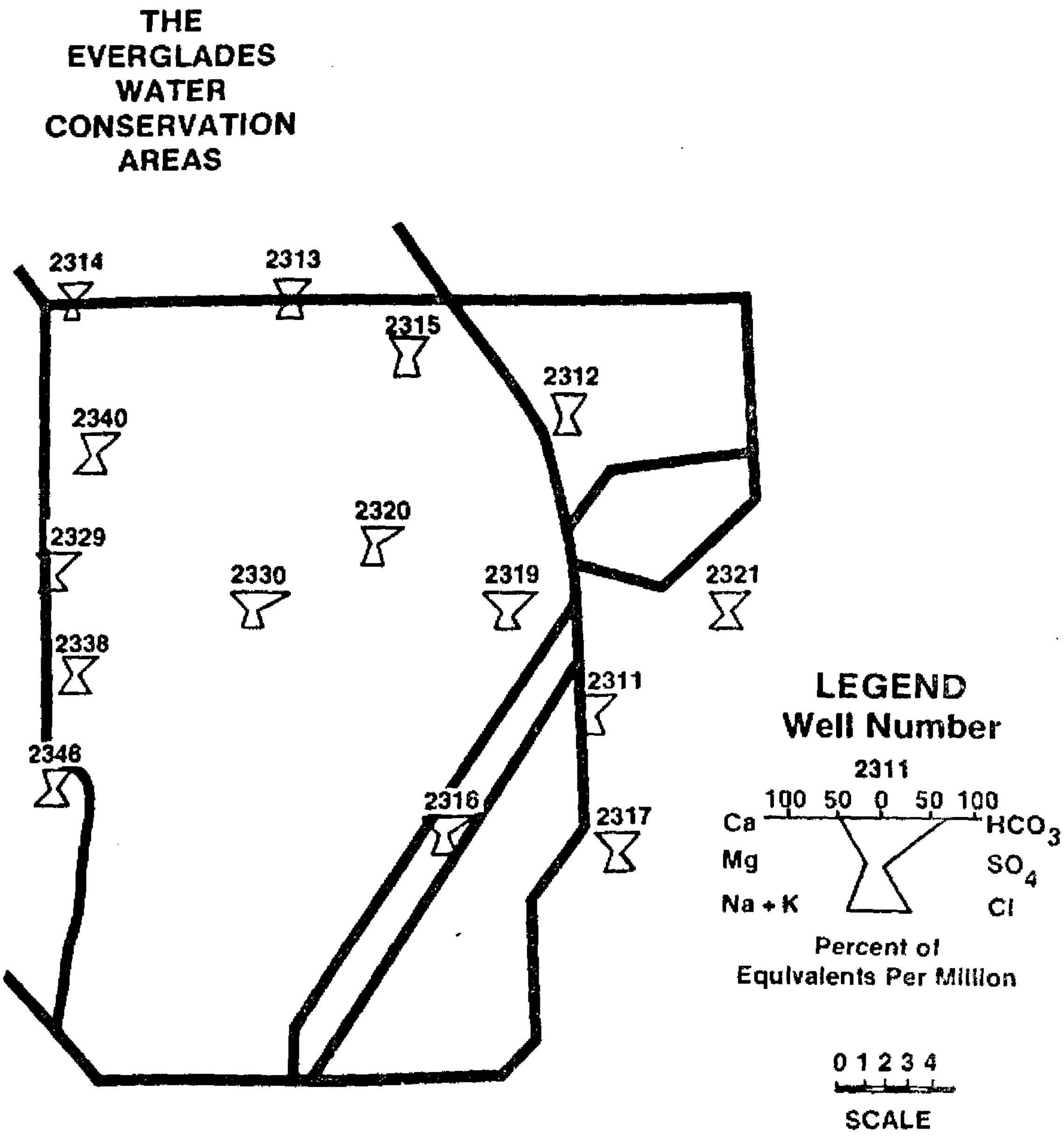
The base of the Biscayne aquifer is independent of the above formation boundaries. Klein and Causaras (1982) chose the base of the aquifer as the upper permeable bed of the Tamiami Formation. Underlying the formations which comprised the aquifer is the Hawthorn Formation. The Hawthorn contains clay, silt, and sandy marl which is relatively impermeable. This formation separates the confined artesian aquifer from the water table aquifer.

WATER QUALITY

The groundwater quality is influenced by the solution of limestone and calcareous sand. The water is classified as a calcium bicarbonate type containing significant amounts of dissolved iron. Low concentrations of potassium, sulfate and nitrogen have been found near the agricultural areas. At depth, the total dissolved solid content and chloride concentrations increase which indicate less circulation from infiltration and canal water. A major problem for municipal water suppliers is color. This is due in part to the thick organic peat soils in the WCA's.

The USGS drilled 16 wells in or adjacent to the WCA's in 1981. Water samples were taken at 10 ft intervals for both chloride concentrations and specific conductance. In addition, a full suite of water quality characteristics were obtained for each well.

To illustrate differences in water quality for individual well sites, Stiff diagrams were prepared. The illustration depicts the percentage of principal cations and anions in terms of equivalents per million. Stiff diagrams show only the percentage composition, not the total mineral content of a sample. The water samples were taken from depths of 39-109 ft., and the diagrams indicate that the water is a calcium bicarbonate type. The high bicarbonate concentration requires three materials to be present: calcium carbonate, carbonaceous material, and a base exchange material. Calcium carbonate goes into solution as calcium bicarbonate in the presence of carbon dioxide. The carbonaceous material or organic material, which is abundant in the WCA's, decomposes to produce much of the carbon dioxide in the ground. The clay minerals, which often occur near the surface, supply the base exchange material. Water samples taken at depth (particularly well 2338 which was sampled at 109 ft) shows that the calcium bicarbonate water is being replaced by a sodium chloride type. The sodium chloride water indicates the



MODIFIED STIFF DIAGRAMS
WATER QUALITY IN CONSERVATION AREAS
BROWARD COUNTY

Fig. 1

presence of connate water which is due to more impermeable beds that impede circulation.

Chloride concentrations and specific conductance were plotted at 10 ft. intervals. Chlorides are found in almost all natural waters. They may be derived from 1) natural mineral origin, 2) water that has been trapped in sediments during deposition or connate water, 3) sea water intrusion, 4) salts for agricultural purposes, 5) human and animal waste, or 6) from industrial effluent. Specific conductance is a measure of the electrical properties of water bearing formations and higher values indicate greater mineralization. An increase in chloride concentrations parallels an increase in specific conductance.

High chloride and specific conductance measurements are associated with basal sediment zones of low permeability which are mostly composed of fine silt, sand, and clay. Zones of low permeability impede circulation and thus, mineralized water is not easily flushed from the aquifer. Such zones are found intermittently throughout the aquifer - it is the basal sediments that most consistently contain highly mineralized water. Permeable beds are associated with good circulation and generally result in low chloride concentrations. Areas of high permeability are associated with solution riddled limestone and sandstone lithologies. Chloride concentrations at total depth within these wells approach values representative of the salt water interface of 1000 mg/l. However, the source of these high chlorides is a result of the low permeable zones rather than salt water intrusion. Chloride concentrations of 100 mg/l or higher, which occur in the surface water, are probably due to agricultural activities.

Isochlor maps indicate the depth to a common chloride concentration. Maps were developed for the 500, 250, and 200 mg/l isochlors. These maps do not reflect the top of the Hawthorn Formation or low permeable clays. The discrepancy between the isochlor maps, with the exception of the 200 and 250 mg/l isochlors which mimic one another and the top of the Hawthorn, represents the heterogeneity of permeability in the lithology.

Water Conservation Areas

Specific Conductance (umhos/cm) Vs Depth (ft.)

(Chloride Concentration (mg/l) Vs Depth (ft.)

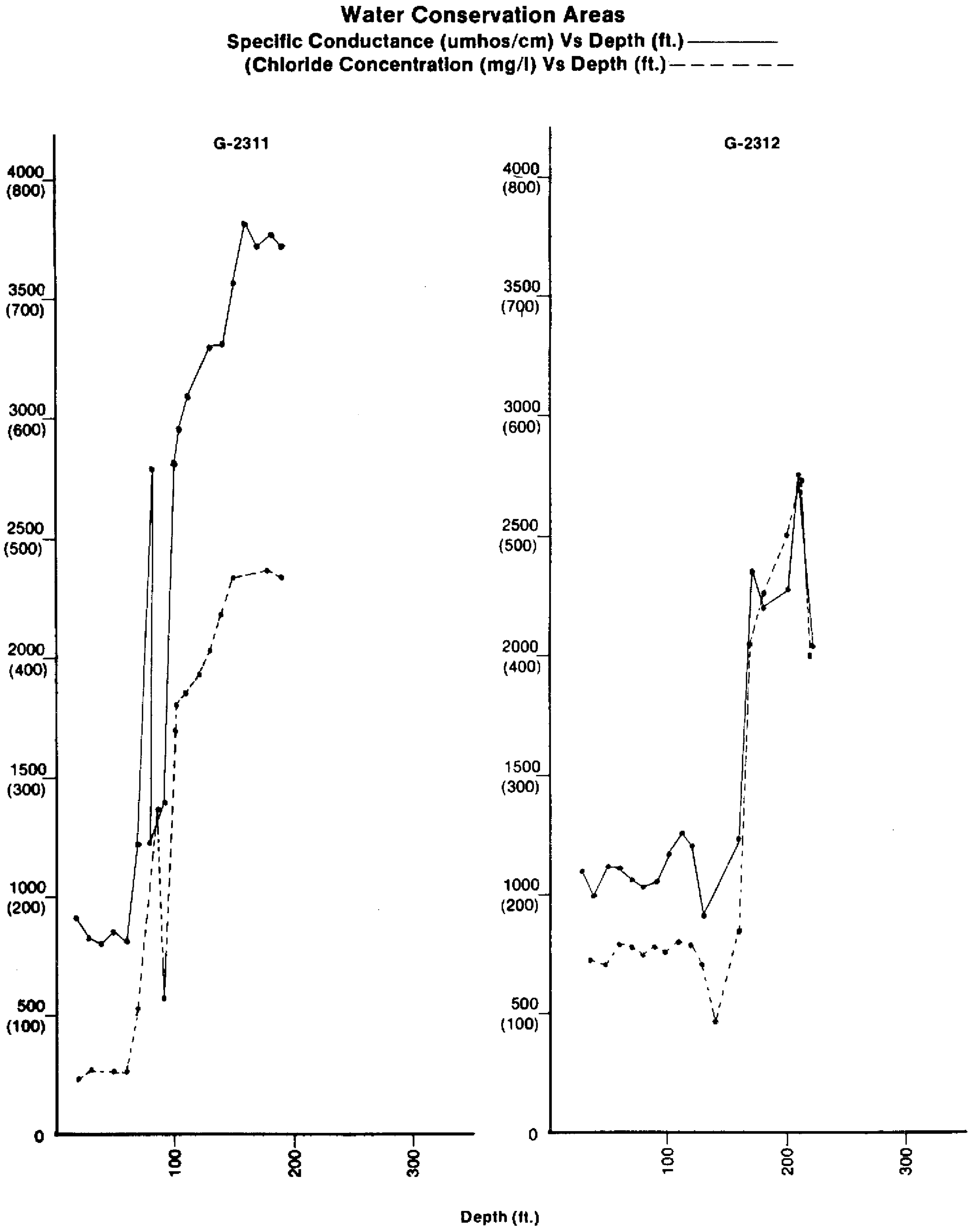


Fig. 2

Water Conservation Areas

Specific Conductance (umhos/cm) Vs Depth (ft.)————

(Chloride Concentration (mg/l) Vs Depth (ft.)– – – – – –

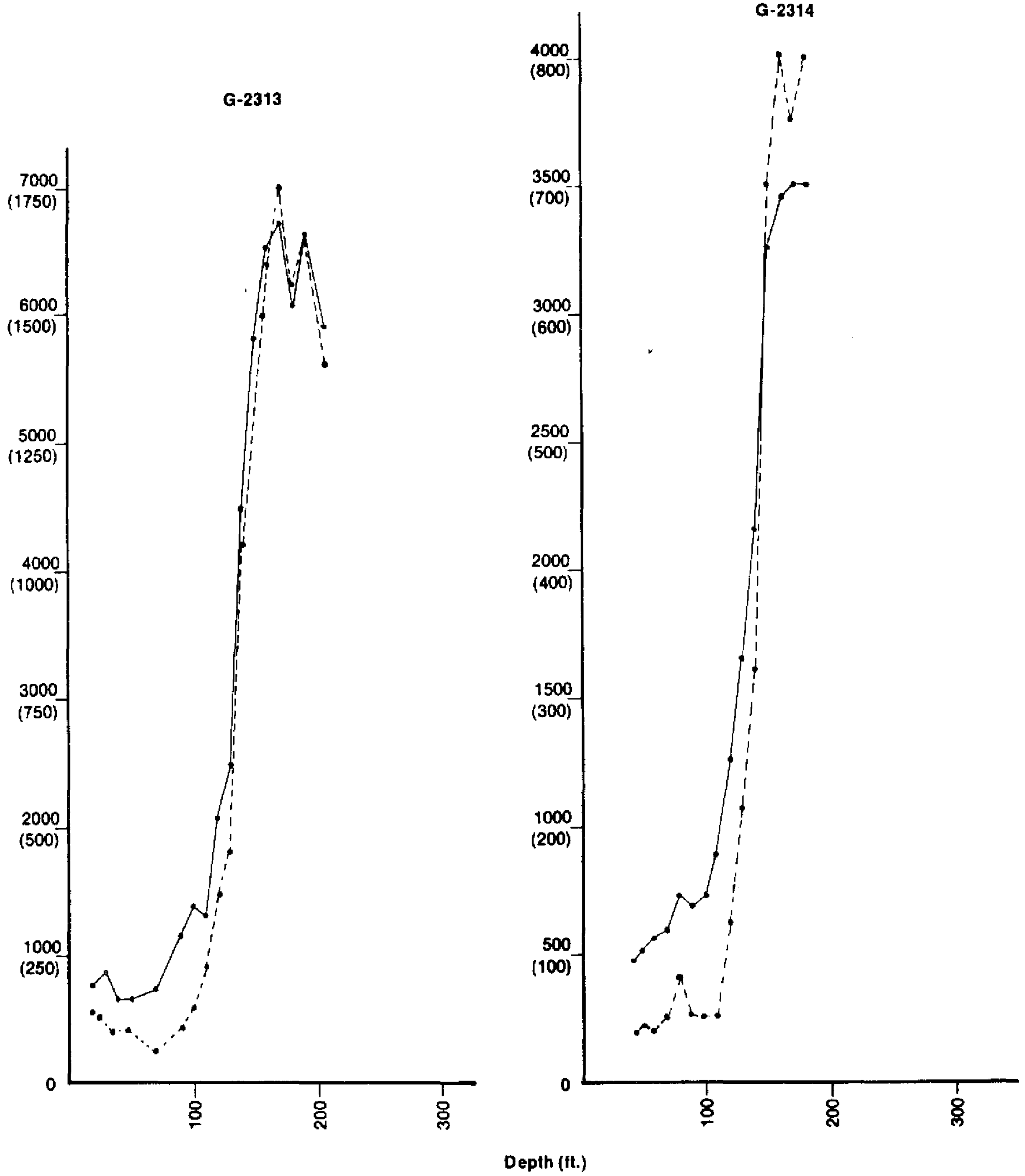


Fig. 3

Water Conservation Areas

Specific Conductance (umhos/cm) Vs Depth (ft.)——————
(Chloride Concentration (mg/l) Vs Depth (ft.)- - - - - - -

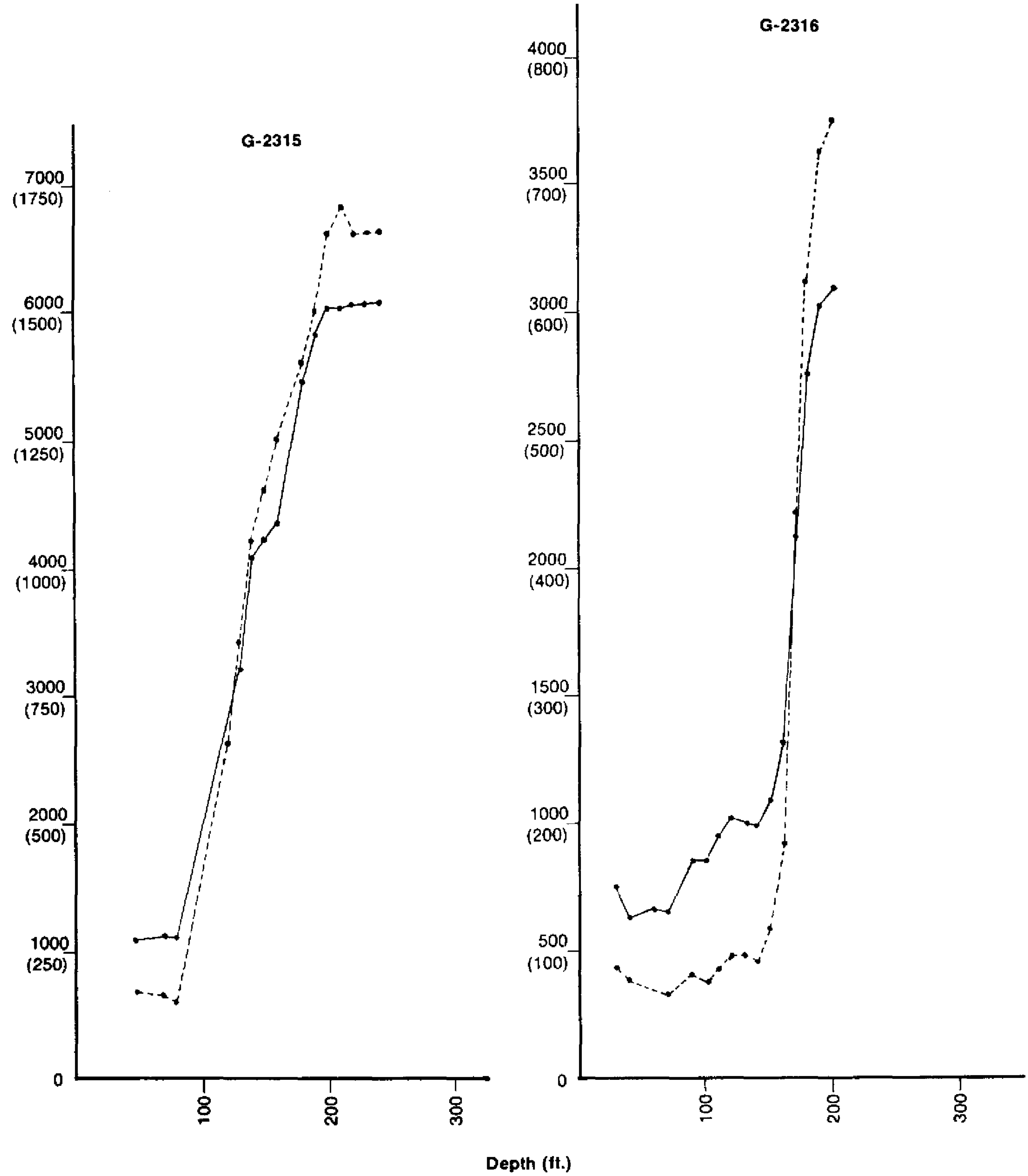


Fig. 4

Water Conservation Areas
Specific Conductance (umhos/cm) Vs Depth (ft.)——————
(Chloride Concentration (mg/l) Vs Depth (ft.)- - - - - - -

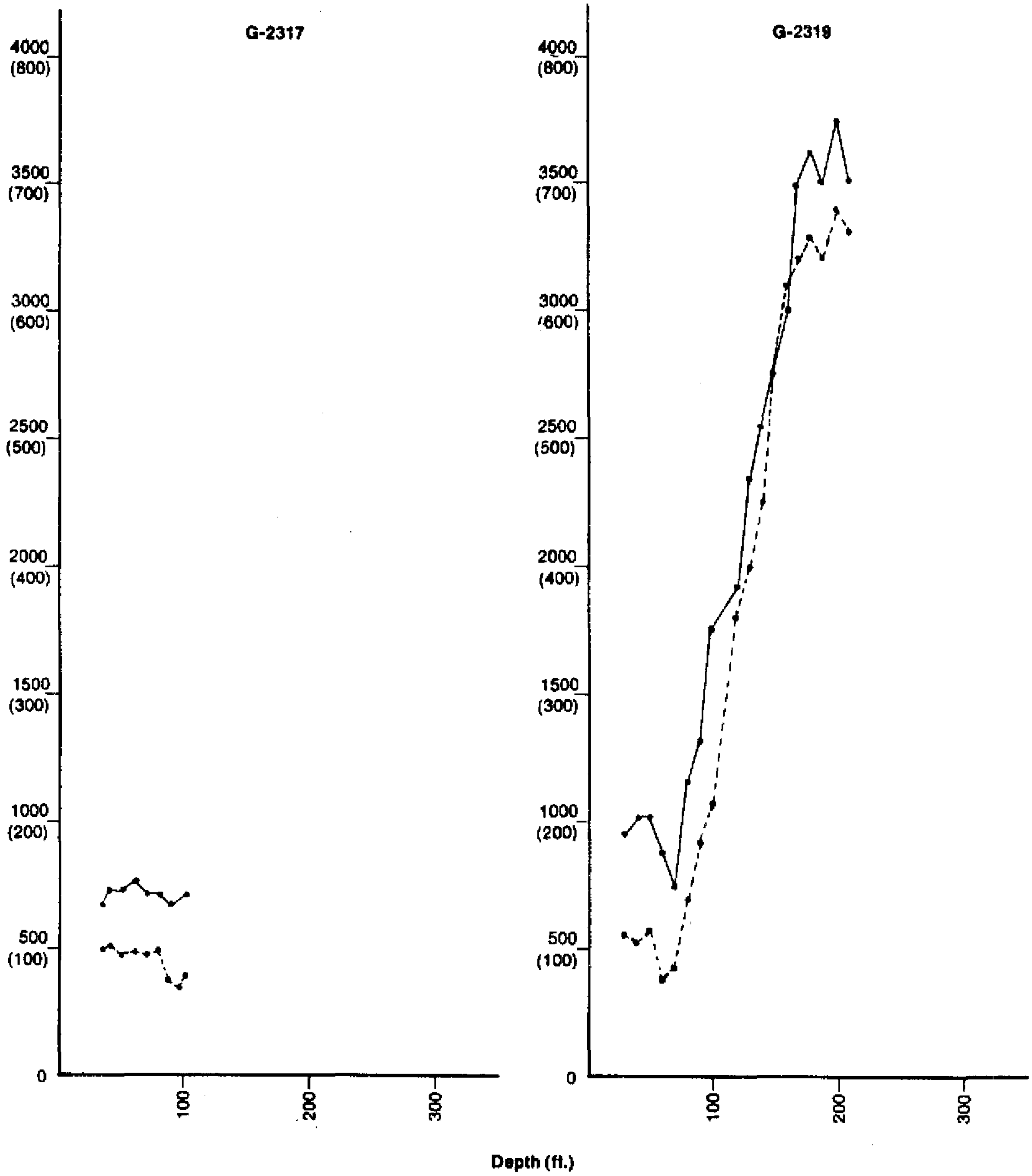


Fig. 5

Water Conservation Areas

Specific Conductance (umhos/cm) Vs Depth (ft.)———

(Chloride Concentration (mg/l) Vs Depth (ft.)— — — — —

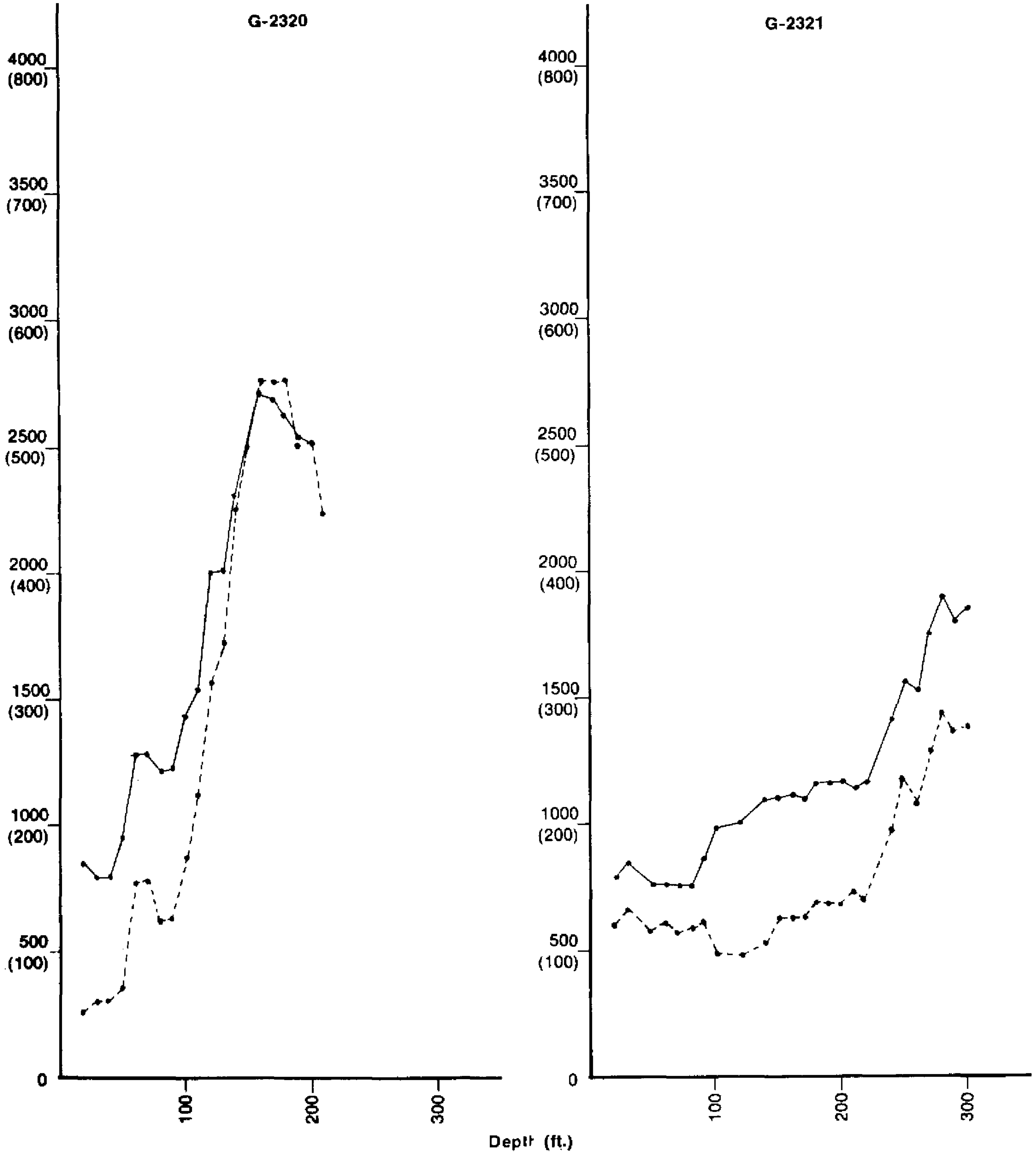


Fig. 6

Water Conservation Areas

Specific Conductance (umhos/cm) Vs Depth (ft.) ———

(Chloride Concentration (mg/l) Vs Depth (ft.) - - - - - -

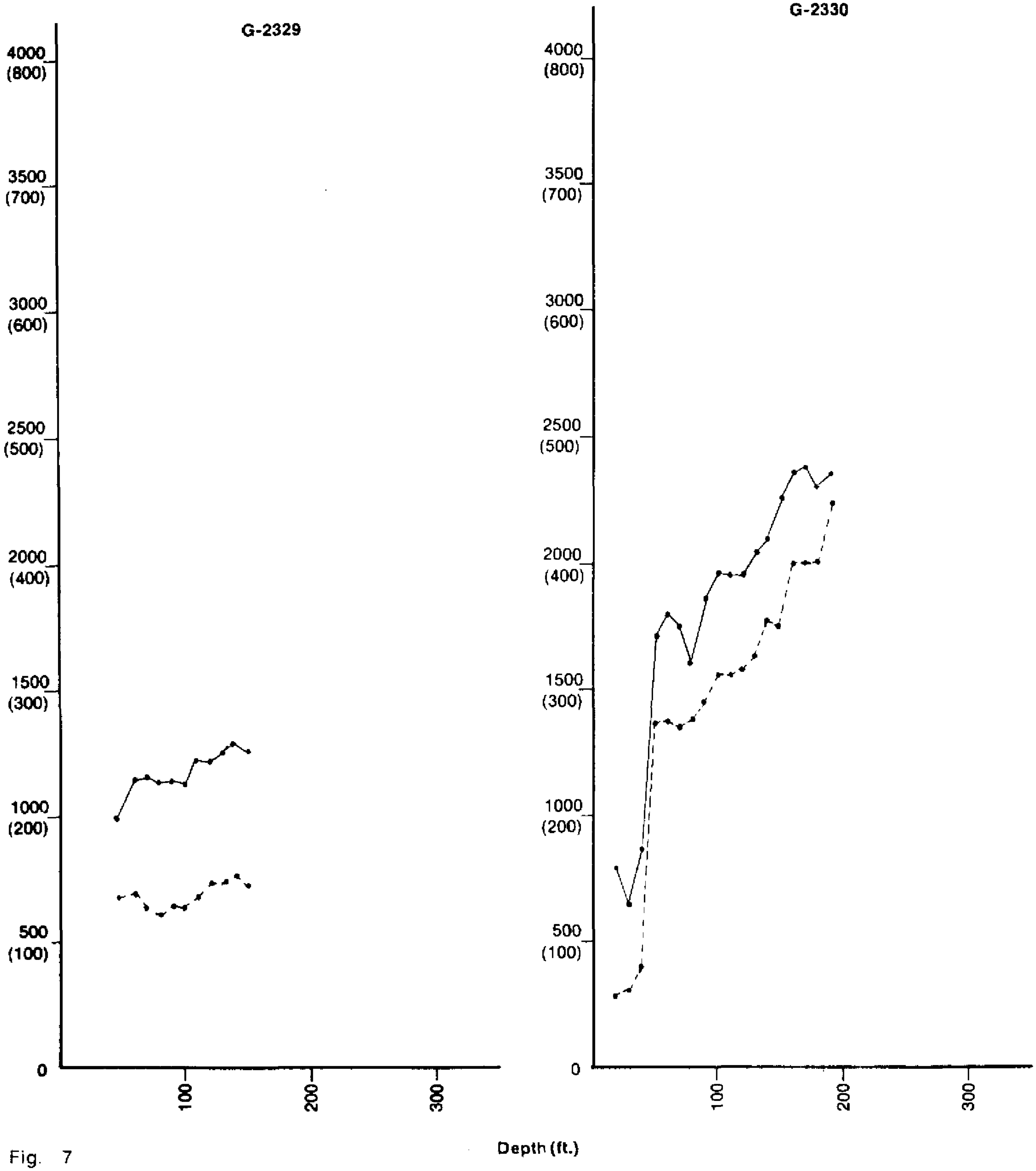


Fig. 7

Water Conservation Areas

Specific Conductance (umhos/cm) Vs Depth (ft.) ————

(Chloride Concentration (mg/l) Vs Depth (ft.) – – – – –

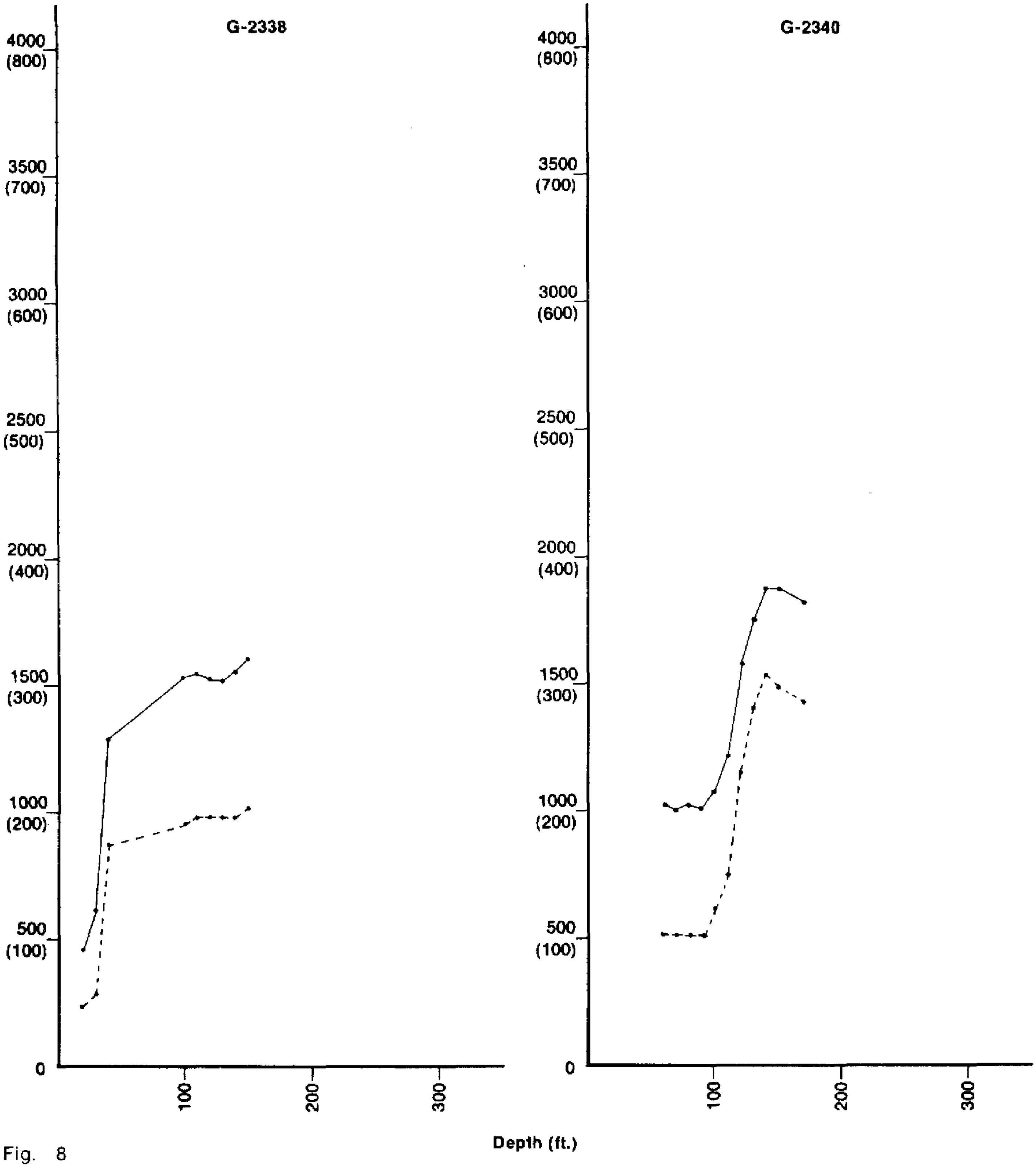


Fig. 8

Water Conservation Areas

Specific Conductance (umhos/cm) Vs Depth (ft.) ———

(Chloride Concentration (mg/l) Vs Depth (ft.) – – – – –

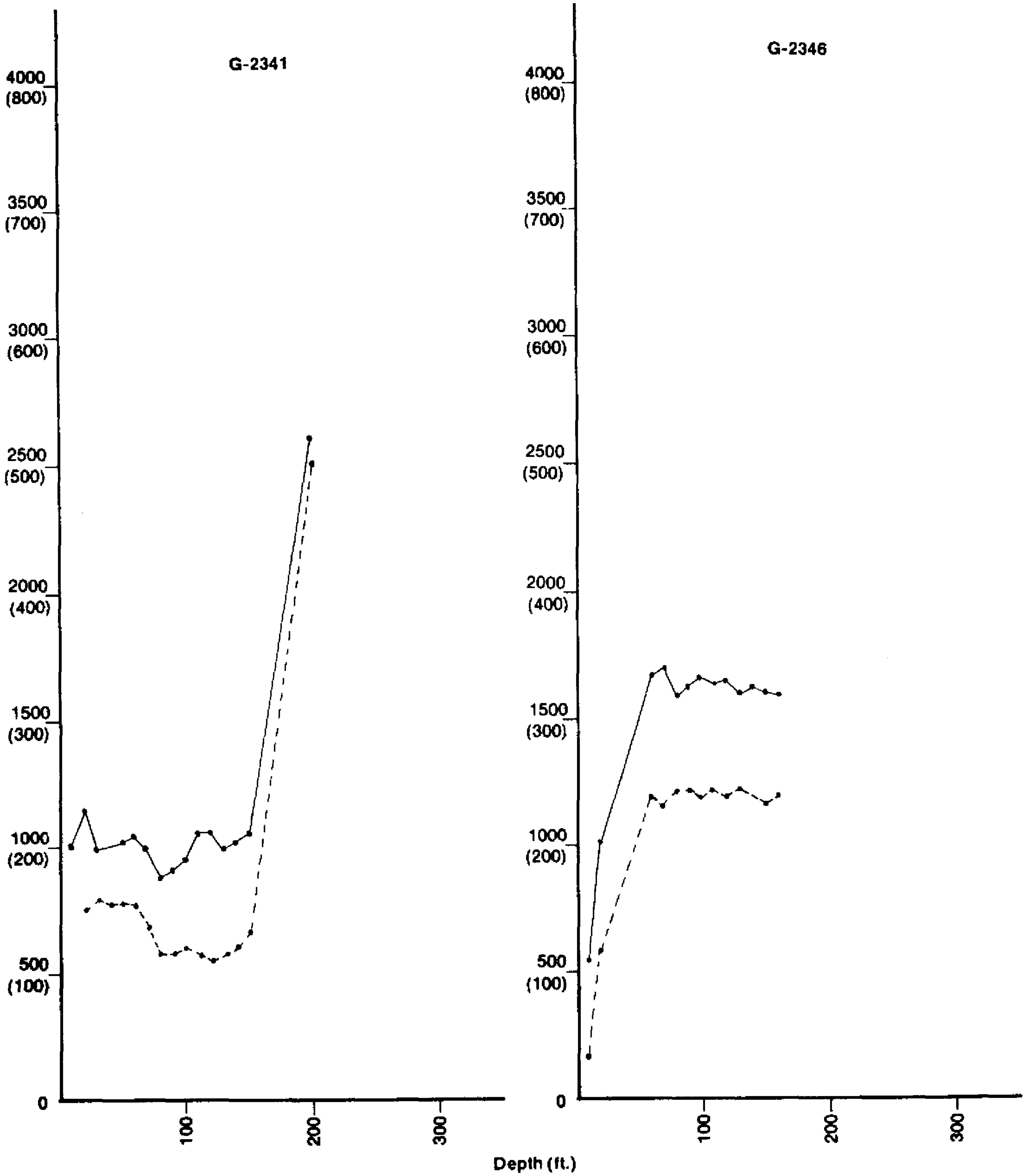
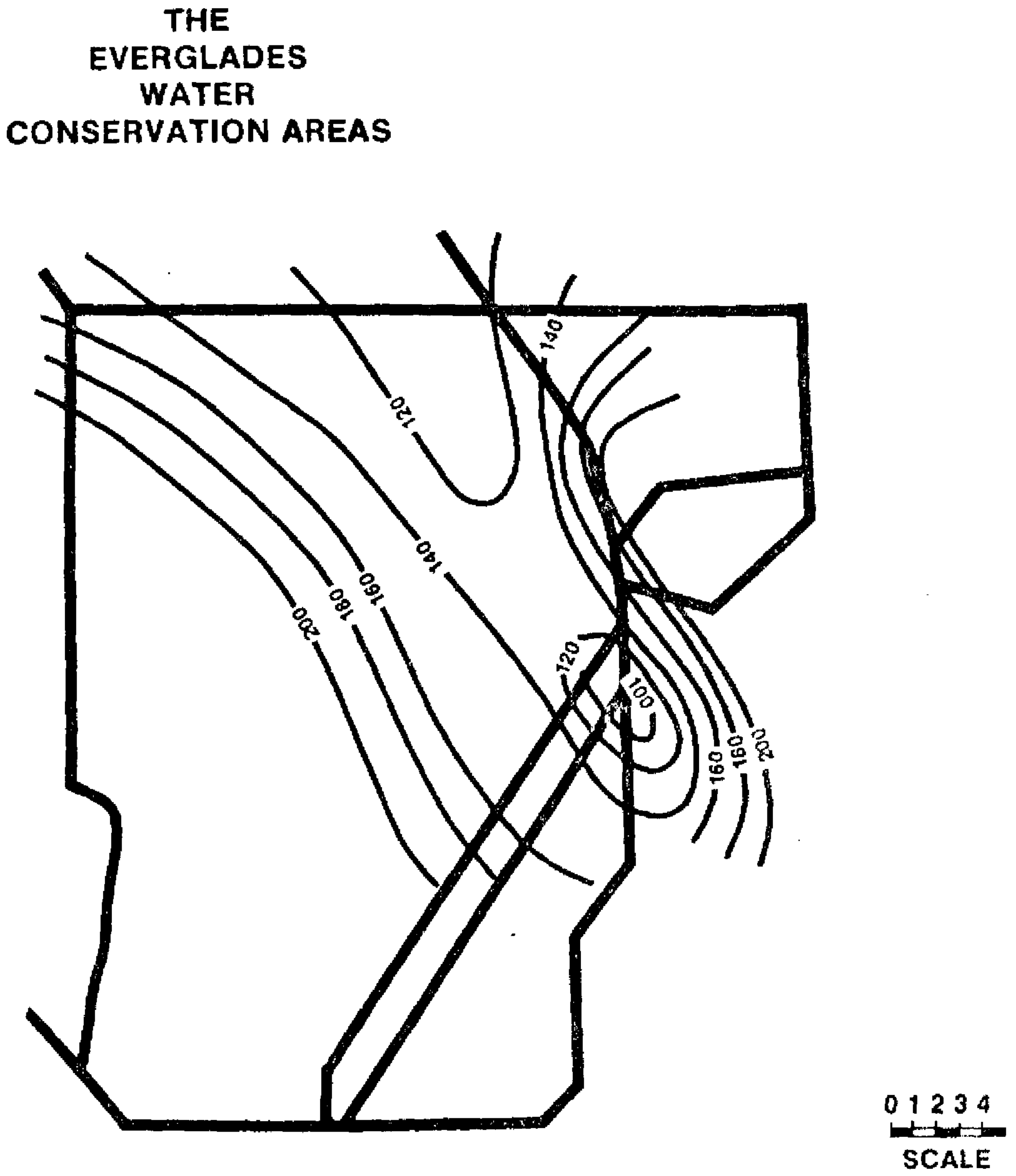


Fig. 9

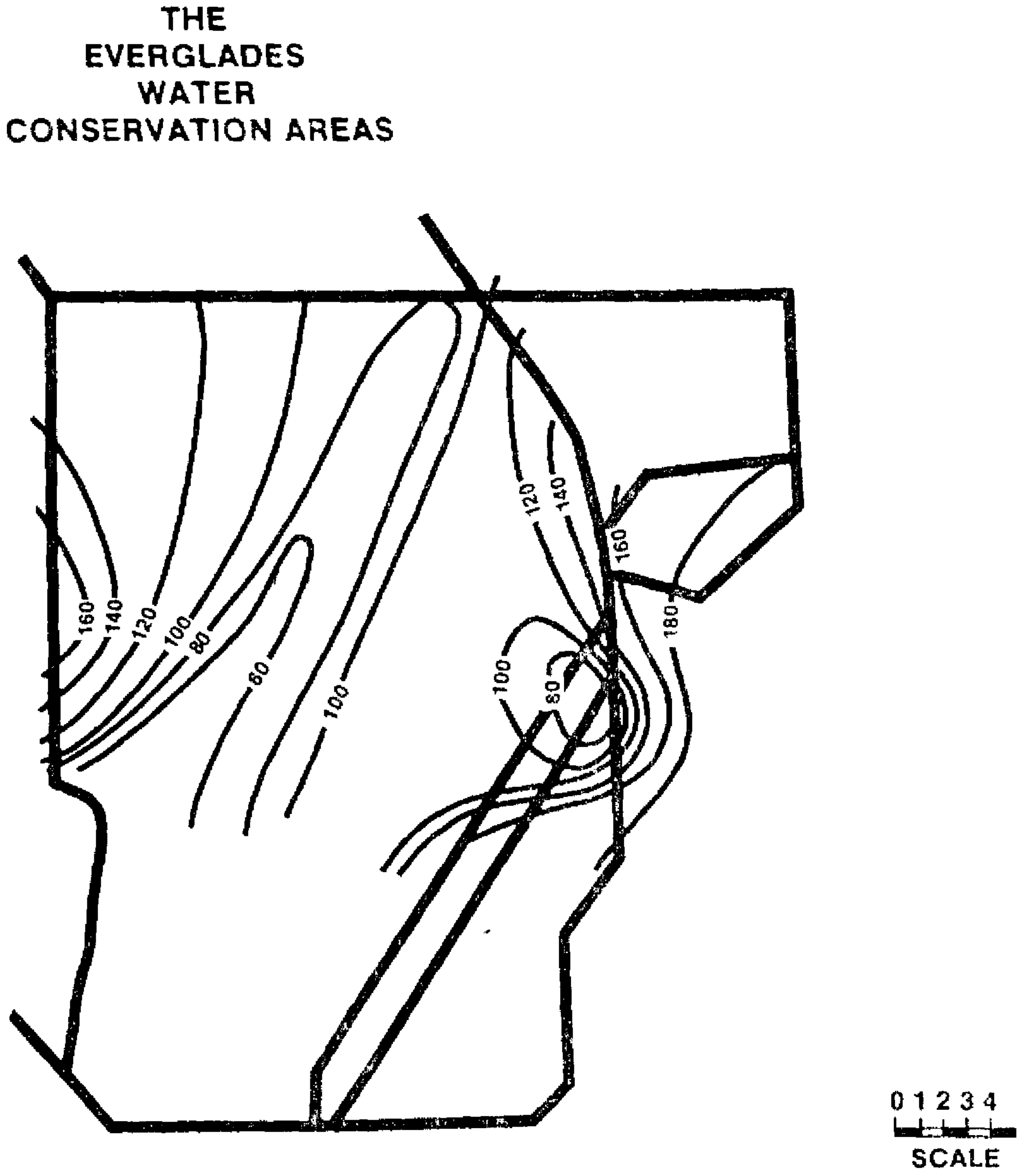


ISOCHLOR MAP AT 500 mg/L CONCENTRATION IN BROWARD COUNTY

— 20 Ft. Contour Interval
Depth Below Land Surface

(USGS Preliminary Data, 1983)

Fig. 10

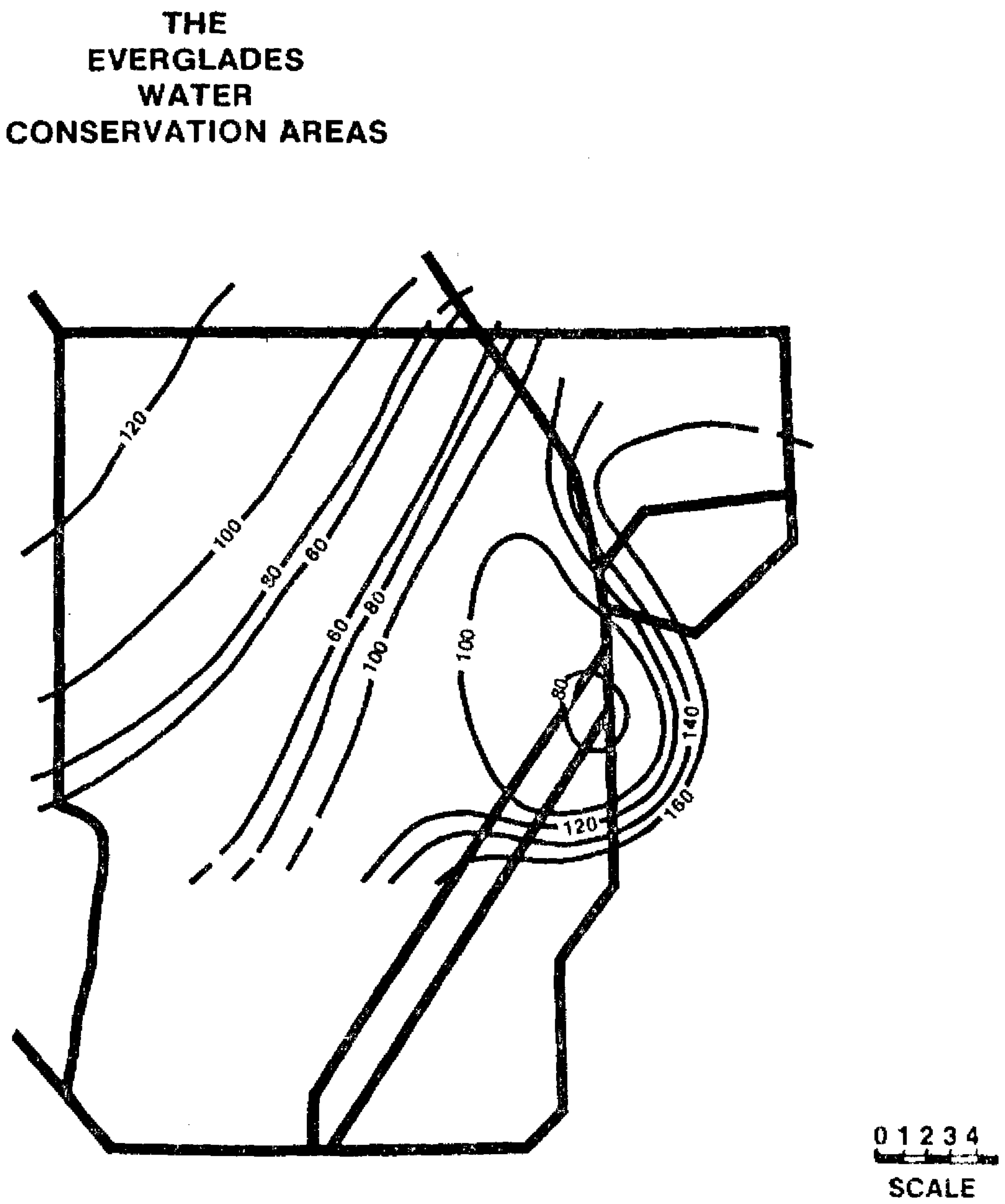


ISOCHLOR MAP AT 250 mg/L CONCENTRATION IN BROWARD COUNTY

— 20 Ft. Contour Interval
Depth Below Land Surface

(USGS Preliminary Data, 1983)

Fig. 11



ISOCHLOR MAP AT 200 mg/L CONCENTRATION IN BROWARD COUNTY

— 20 Ft. Contour Interval
Depth Below Land Surface

(USGS Preliminary Data, 1983)

Fig. 12

TABLE 1

% Meq/l

Well	Total	%Ca	%Mg	%Na+K
2311	8.60	46	17	36
2312	11.77	42	20	38
2313	8.14	59	25	16
2314	6.08	59	8	32
2315	11.38	43	22	35
2316	7.99	50	18	32
2317	7.74	54	12	34
2319	12.05	62	10	28
2320	9.83	56	23	21
2321	7.27	39	9	52
2329	11.89	37	10	53
2330	9.01	67	10	23
2338	15.31	25	11	64
2340	10.94	50	9	41
2341	10.42	43	14	43
2346	15.95	25	15	60

% Meq/l

Well	Total	%HO$_3$	%SO$_4$	%Cl
2311	8.87	67	2	31
2312	13.38	65	1	34
2313	7.99	82	0	18
2314	5.67	75	0	25
2315	12.05	57	10	33
2316	7.52	67	6	27
2317	7.76	63	0	37
2319	11.41	73	0	27
2320	11.16	85	0	15
2321	7.20	53	0	47
2329	12.44	71	1	28
2330	9.28	81	0	19
2338	15.85	59	5	36
2340	10.97	75	0	25
2341	10.59	56	3	41
2346	16.85	52	8	40

TABLE 2

Concentration in mg/l

Well	Depth Ft.	Ca	Mg	Na	K	HCO_3	SO_4	Cl
2311	49	80	18.0	70	3.4	360	7.2	100
2312	70	100	28.0	100	4.9	532	7.2	160
2313	60	96	25.0	30	1.6	400	1.2	50
2314	49	72	6.6	43	3.0	260	1.4	49
2315	49	98	30.0	90	4.4	418	60.0	140
2316	39	80	17.0	58	3.2	308	20.0	73
2317	49	84	11.0	60	1.3	300	1.0	100
2319	39	150	15.0	76	.8	506	.6	110
2320	79	110	27.0	48	1.2	580	.8	58
2321	49	56	8.0	86	2.9	232	.8	120
2329	79	88	15.0	140	7.1	540	10.0	120
2330	39	120	11.0	48	1.1	456	.3	64
2338	109	76	20.0	220	12.0	568	43.0	100
2340	69	110	12.0	100	4.5	500	.4	98
2341	59	89	18.0	100	5.8	372	13.0	150
2346	60	80	30.0	210	14.0	536	62.0	240

TABLE 3

Concentrations in meq/l with conversion

Na=.04350
K =.02557

Well	Ca .0499	Mg .08226	Na+K		HCO_3 .01639	SO_4 .02082	Cl .02821
2311	3.99	1.48	3.05	.09	5.90	.15	2.82
2312	4.99	2.30	4.35	.13	8.72	.15	4.51
2313	4.79	2.06	1.31	.04	6.56	.02	1.41
2314	3.59	.54	1.87	.08	4.26	.03	1.38
2315	4.89	2.47	3.92	.11	6.85	1.25	3.94
2316	3.99	1.40	2.52	.08	5.05	42	2.06
2317	4.19	.90	2.61	.03	4.91	.02	2.82
2319	7.49	1.23	3.31	.02	8.29	.01	3.10
2320	5.49	2.22	2.09	.03	9.50	.012	1.63
2321	2.79	.66	3.74	.07	3.80	.02	3.38
2329	4.39	1.23	6.09	.18	8.85	.21	3.38
2330	5.99	.90	2.09	.03	7.47	.01	1.80
2338	3.79	1.65	9.57	.31	9.31	.89	5.64
2340	5.49	.99	4.35	.11	8.19	.01	2.77
2341	4.44	1.48	4.35	.15	6.09	.27	4.23
2346	3.99	2.47	9.13	.36	8.78	1.29	6.77

BIBLIOGRAPHY OF WATER CONSERVATION AREAS

Corps of Engineers, 1980. Regulation Schedule Review, Water Conservation Area No. 3A: U. S. Department of the Army.

Corps of Engineers, 1968. Water Resources for Central and Southeastern Florida: U. S. Department of the Army, Main Report Serial No. 56.

Corps of Engineers, 1951. Central and Southern Florida Project, Part I Agricultural and Conservation Area, Supplement I Geology and Soils: U.S. Department of the Army Serial No. 21.

Davis, 1982. Patterns of Radiophosphorous Accumulation in the Everglades After it's Introduction into Surface Water.

Fischer, J. N., 1978. Evaluation of the High Permeability Zone of the Shallow Aquifer, Palm Beach County, Florida: Southeastern Geological Society, Publication No. 20.

Freiberger, H. J., 1973. Effects of Backpumping from the South New River Canal at Pump Station S-9 on Quality of Water in Water Conservation Area 3, Broward County, Florida: U. S. Geological Survey, Open-File Report 73026.

Galliher, C. F. and J. E. Hull, 1969. Hydrologic Conditions During 1968 in Dade County, Florida: U. S. Geological Survey, Open-File Report.

Gleason, P. J., 1974. Chemical Quality of Water in Conservation Area 2A and Associated Canals: Central and Southern Florida Flood Control District, Technical Publication No 74-1.

Grantham, R. G. and C. B. Sherwood, 1968. Chemical Quality of Water of Broward County, Florida: Florida Division of Geology, Report of Investigations No. 51.

Heaney, J. P. and W. C. Hubber, 1971. Hydrologic Reconnaissance of Conservation Areas 1, 2, and 3 of the Central and Southern Florida Project: University of Florida, Gainesville, Florida.

Hull, J. E., 1982. Hydrologic Conditions in Dade County, Florida, 1980: U. S. Geological Survey.

Hull, J. E., 1982. Hydrologic Conditions in Broward County, Florida, 1980: U. S. Geological Survey.

Hunter, M. E., 1978. What is the Caloosahatchee Marl?, Hydrology of South-Central Florida. Coastal Petroleum Company; West Palm Beach, Florida, 22nd Field Conference: Southeastern Florida Geological Society Publication No. 20.

Johnston, R. H., 1978. Planning Report for the Southeastern Regional Aquifer System Analysis: U. S. Geological Survey, OpenFile Report 78-516.

Klein, H. and C. B. Sherwood, 1961. Hydrologic Conditions in the Vicinity of Levee 30, Northern Dade County, Florida: U. S. Geological Survey, Report of Investigation No. 24, Part I.

Kohout, F. A. and J. H. Hartwell, 1967. Hydrologic Effects of Area B Flood Control Plan on Urbanization of Dade County, Florida: Florida Geological Survey Report No. 24.

Leach, S. D., et al, 1971. Hydrologic Effects of Water Control and Mangement of Southeastern Florida: Florida Department of Natural Resources, Bureau of Geology, Report of Investigation No. 60.

Leach, S. D. and C. B. Sherwood, 1963. Hydrologic Studies in the Snake Creek Canal Area, Dade County, Florida: U. S. Geological Survey, Report of Investigations No. 24, Part III.

Lutz, 1977. Water Quality and Nutrient Loadings of the Major Inflows from the Everglades Agricultural Areas to the Conservation Areas (?).

McCoy, H. J. and J. Hardee, 1970. Groundwater Resources of the Lower Hillsboro Canal Area, Southeastern Florida: Florida Department of Natural Resources, Bureau of Geology Report of Investigation No. 55.

McCoy, H. J. and C. B. Sherwood, 1969. Water in Broward County: Florida Geological Survey Map Series No. 29.

McPherson, B. F., 1973. Water Quality in the Conservation Areas of the Central and Southern Florida Flood Control District, 1970-72: U. S. Geological Survey, Open-File Report 73014.

McPherson, B. F., 1976. Nitrogen and Phosphorous Uptake in the Everglades Conservation Area, Florida, With Special Reference to the Effects of Backpumping Runoff: U. S. Geological Survey, Water Resources Investigations 5-75.

Parker, G. G., 1942. Notes on the Geology and Groundwater of the Everglades in Southern Florida: Proceedings from Florida Soil Science Society, Vol. 4.

Parker, G. G., 1955. Water Resources of Southeastern Florida: U. S. Geological Survey, Water-Supply Paper 1255.

Perkins, R. D., 1977. Depositional Framework of Pleistocene Rocks in South Florida. Part III in Quarternary Sedimentation in South Florida: The Geological Society of America Memoir 147.

Scott, W. B., 1976. Hydraulic Conductivity and Water Quality of the Shallow Aquifer, Palm Beach County, Florida: U. S. Geological Survey, Water Resources Investigations 76-119.

Sherwood, C. B., H. J. McCoy, and C. F. Galliher, 1973. Water Resources of Broward County, Florida: U. S. Geological Survey, Report of Investigations No. 65.

South Florida Water Management District, 1971. Some Aspects of the Hydrology of Conservation Area No. 3.

Waller, B. G., 1975. Distribution of Nitrogen and Phosphorous in the Conservation Areas of South Florida, July 1972 to June 1973: Geological Survey, Water Resources Investigations 76-29.

Waller, B. G. and J. E. Earle, 1975. Chemical and Biological Quality of Water in Part of the Everglades, Southeastern Florida: U. S. Geological Survey, Water Resources Investigations 56-75.