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METEOROLOGICAL AND HYDROLOGICAL ANALYSIS OF THE 1980-1982 DROUGHT

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METEOROLOGICAL AND HYDROLOGICAL ANALYSIS OF THE 1980-1982 DROUGHT

by

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Water Resources Division
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SOUTH FLORIDA WATER MANAGEMENT DISTRICT
West Palm Beach, Florida

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ACKNOWLEDGMENTS

The production of this report was made possible by the existence of a computer data base facility for daily rainfall, stage, and discharge measurements. The engineering technicians of the Water Resources Division have been responsible for maintaining and updating the data base from hundreds of gages throughout the District. Betty McVeigh handled the task of setting up and checking input data and running the Thiessen coefficient program to compute the weighted basin rainfall.

EXECUTIVE SUMMARY

The water level in Lake Okeechobee dropped consistently from 17.50 ft msl on January 1980 to a record low level of 9.75 ft msl on July 29, 1981. This rapid decline in the lake level was caused primarily by an extensive period of below normal rainfall with a coincident reduction of surface water inflow and increasing evapotranspiration (ET). In this report, the meteorological and hydrological data available from June 1, 1980 through February 28, 1982 were analyzed. Based on watershed boundaries, the entire District was divided into 14 basins. Historical drought periods were also selected for comparison. These included the periods of 1955-56, 1961-62, 1967-68, 1970-71, and 1973-74.

The rainfall analysis for each basin was based on the weighted Theissen method for all available long term rain gauges. Their deviation, and their associated frequency were analyzed for the period of June through May, June through October, and November through April for each selected drought period. As a result of these analyses, the 1980-82 drought was found to be generally more severe than the droughts of 1961-62, 1973-74, and the drought of 1970-71, for most basins, with the exception of the Lower East Coast area. The drought return intervals for the Upper Kissimmee Lakes and the Kissimmee River Basins during the drought of 1970-71 ranged from one in eight to one in 15 years, while the 1980-82 drought for the same areas was well over one in 100 years. The drought of 1980-82 in Fisheating Creek, Lake Istokpoga, and the Everglades Agricultural Areas was much more severe than the 1970-71 drought. These comparisons are presented in graphs and tables with detailed discussion in this text.

The hydrologic data analysis concentrated primarily on the major water storage areas within the District. Evapotranspiration, surface water inflow, outflow, and water deliveries were analyzed, and comparisons made with the drought periods of 1970-71 and 1973-74. The major findings of this study are briefly summarized as follows:

Approximately three million acre-feet (AF) of water was consumed during the period June 1980 through February 1982, with more than two-thirds from Lake Okeechobee. Water conservation area storage decreased by about 800,000 AF, with an estimated decline of 36,000 AF in the Upper Kissimmee Lakes.

The surface runoff contribution to Lake Okeechobee from its major tributaries was about 12.7% of normal as a result of a rainfall deficit of over 20 inches in the area from June 1981 through July 1982. The total surface water inflow to Lake Okeechobee during this period was 332,471 AF, and the total outflow (ET not included) was 1,198,050 AF, which was about 360% of the total inflow. In the water conservation areas, total inflow was about 1,070,000 AF, and the total surface water outflow amounted to 574,000 AF. Evapotranspiration and seepage in the water conservation areas accounted for 1,300,000 AF, therefore, about 800,000 AF was lost from storage.

Pan evaporation during the period from June 1980 through July 1981 was 121% of normal at Lake Alfred Experimental Station, and about 107% of normal at Belle Glade Experimental Station.

The significant reduction of inflow to Lake Okeechobee was primarily due to the deficient rainfall over the major tributaries of the lake, especially the Kissimmee River Valley. The 14 month rainfall deficit over the Upper Kissimmee Lakes was approximately 25 inches. Other deficits were 24.7 inches for the Kissimmee River Basin; 27 inches and 25 inches for the West and East Everglades Agricultural Areas, respectively, and 20.4 inches for the Fisheating Creek Basin.

An analysis of the hydrologic cycle indicates that rainfall, evaporation, infiltration, and water withdrawals are competing with each other. For example, evaporation, infiltration, and water demands increase when rainfall decreases. The analysis presented in this report will be helpful in the understanding of the forces that contributed to the severity of the 1980-1982 drought.

I. Introduction

The stage in Lake Okeechobee dropped from 17.50 ft msl in January 1980 to a record low level of 9.75 ft msl as of July 29, 1981, representing a drop of 7.75 feet in a period of 18 months. The immense amount of water lost can be visualized by comparing the volume of water in the lake per foot drop in stage. (A foot of water in the lake is equivalent to the amount of water used in the south Dade area for one year.) The 7.7 foot drop of water in the lake represents a loss of three million acre feet, or one trillion gallons of water. The cause of this rapidly declining lake level can be attributed to the lack of rainfall, the increase in water use in south Florida, and excessive evaporation.

There are five major tributary areas contributing flows to the lake. These tributaries include the following basins: Kissimmee River, Lake Istokpoga, Fisheating Creek, Everglades Agricultural Area, and Taylor Creek/Nubbin Slough. The Kissimmee River Basin receives runoff from the Upper Kissimmee Lakes system. The upper lakes system consists of canals and water control structures linking Lakes Kissimmee, Hatchineha, Cypress, Tohopekaliga, East Tohopekaliga, Hart, Mary Jane, Myrtle, Alligator, and Gentry. In addition, the Kissimmee River receives runoff directly from the valley itself south of Lake Kissimmee. The rainfall received in these major tributary areas has a great impact on the water budget of Lake Okeechobee, affectings its ability to provide water to meet demands in the Everglades Agricultural Areas, and to provide additional water for the Lower East Coast (Palm Beach, Broward, and Dade Counties), and the Everglades National Park during the peak of the dry season. Lake Okeechobee and the Lower East Coast have been stressed several times in the past, particularly during the periods of 1955-56, 1961-62, 1967-68, 1970-71, and 1973-74, (Figure 1).

In this study, meteorological and hydrological data such as rainfall, evapotranspiration (ET), surface water inflows, outflows, and water demands were investigated. The period of analysis included June 1, 1980 through February 28, 1982 representing a period of below normal rainfall. A comparison with past droughts is also presented in this report.

II. Meteorological Data Analysis

An analysis of the rainfall data, including rainfall patterns and frequencies, is discussed in this section. Comparison between the 1980-82 drought and previous droughts is also presented in this part of the report. Similar comparisons from a hydrologic point of view are illustrated in the next section.

A. Rainfall Analysis

Lake Okeechobee, the second largest fresh water lake in the United States, has a surface area of approximately 697 square miles. The amount of rainfall input to the lake has a direct effect on lake stage. The District was divided into 14 drainage basins, delineated in Figure 2.

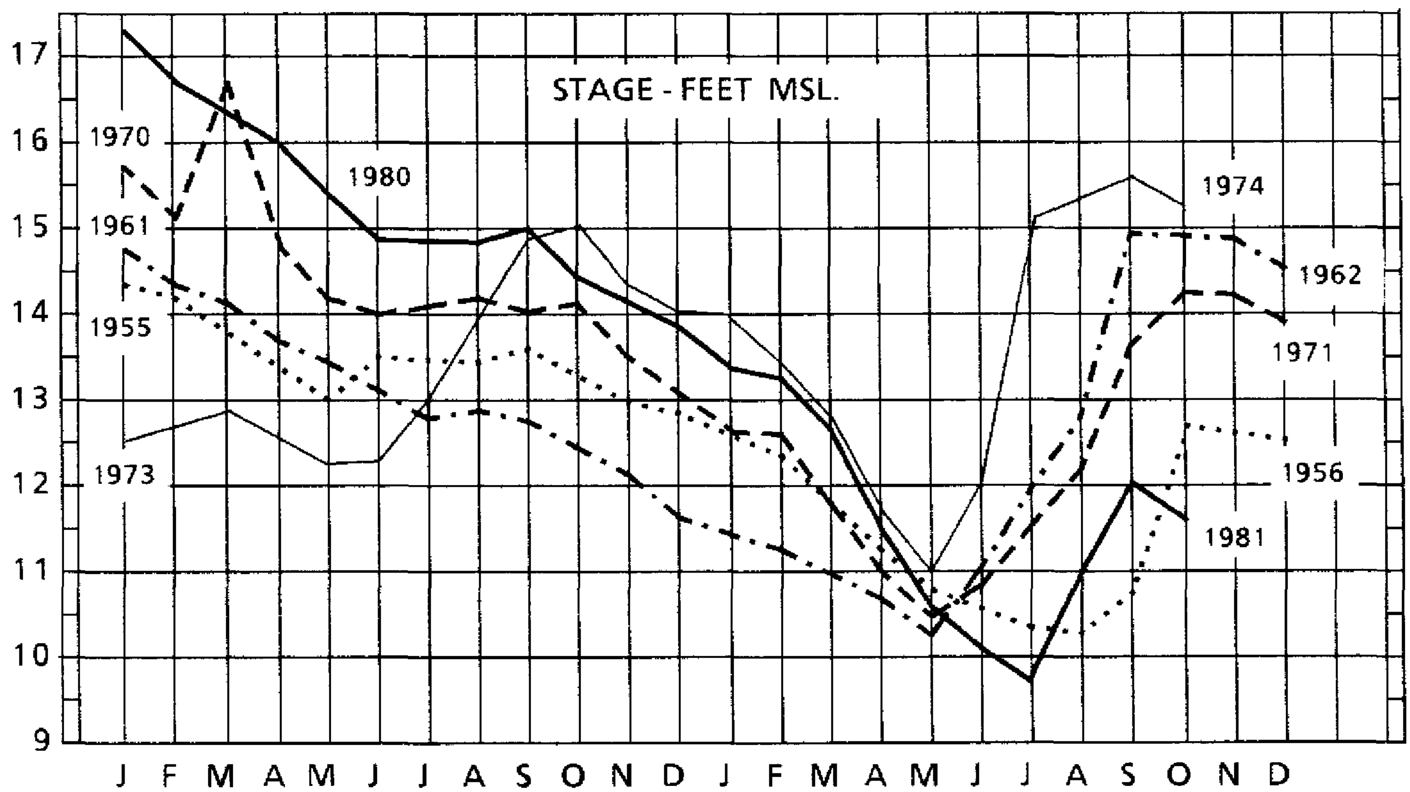

FIGURE 1. SELECTED MONTH END STAGE HYDROGRAPHS FOR LAKE OKEECHOBEE.

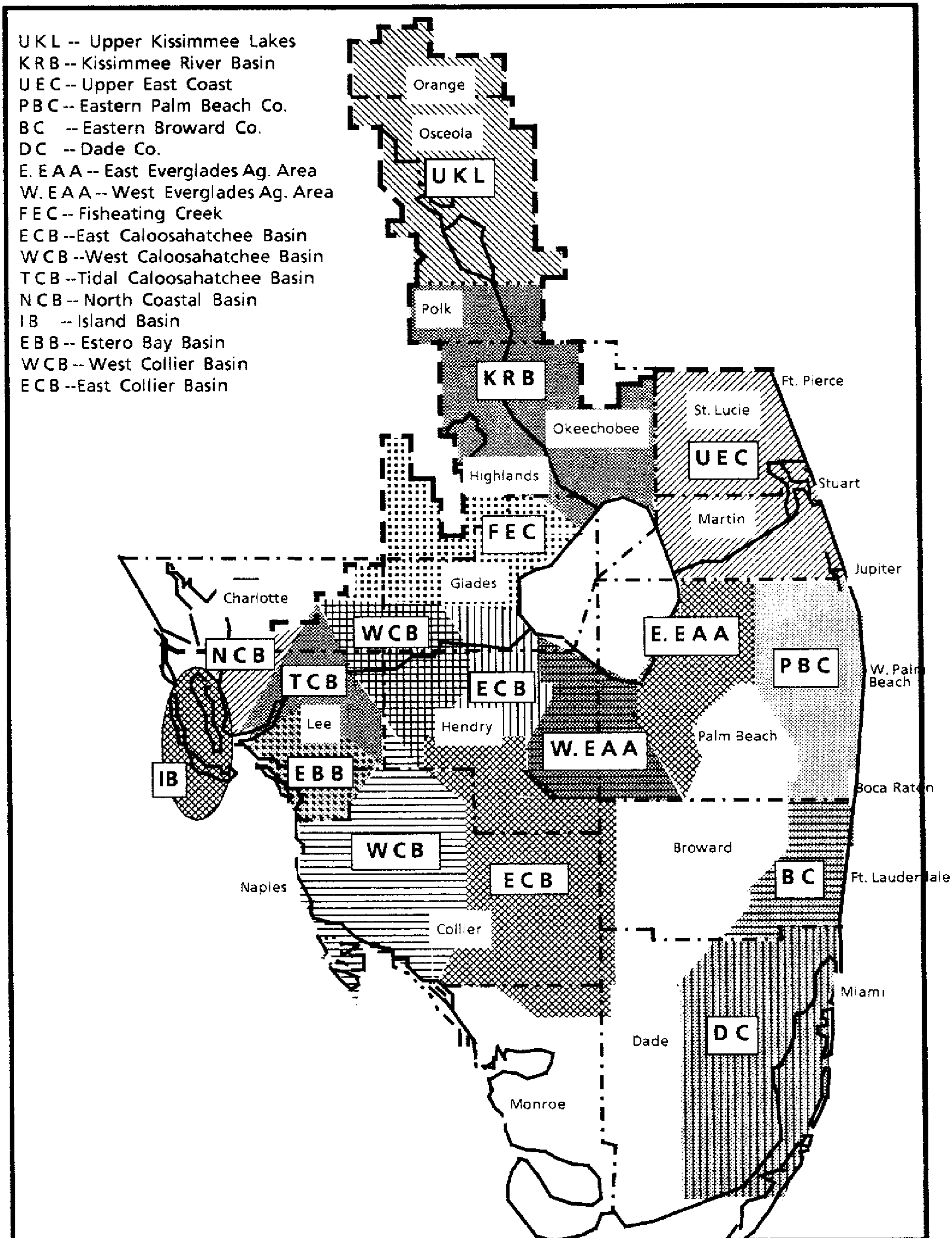

FIGURE 2. BASIN BOUNDARIES

The rainfall stations located within or around each each basin used are listed in Appendix B. The rainfall stations used in this analysis have at least 20 years of record. Monthly rainfall data from selected stations in each basin were used as input to the weighted Thiesen method to estimate the areal basin rainfall. A total of 180 stations, with approximately 40 overlapping stations, was used in this computation. Weighted rainfall data over Lake Okeechobee was available from the water budget reported by the Army Corps of Engineers. A complete tabulation of monthly averages for each basin within the District is shown in Table 1.

B. Rainfall Pattern

The National Weather Service (NWS) uses a 30-year average which is updated at 10-year intervals as the base average (normal) for each NWS rainfall station. Since this analysis deals with regional conditions, the entire period of record was used in the computation of long term average, or normal, for each rainfall station (Table 1). In order to evaluate the trend of rainfall patterns in each basin, the moving averages of 30, 20, and 10 years were computed. The results of this analysis are shown in Table 2, indicating that the occurrence of dry periods are basically the same in all District areas except the Upper East Coast and the East Collier Basin of the Lower West Coast area. Table 2 also shows that the long term weather trend was toward the dry side for most of the basins within the District. It can be speculated that the lack of "normal" hurricane activity during the last 10-20 years contributed to the rainfall deficit. Rainfall analysis over the Kissimmee River Basin indicated that the Basin had received an excess of 1.74 inches of rainfall per year from tropical depressions and hurricanes prior to 1964[1]. Since 1964 there were only two tropical storm events, and the average annual rainfall contribution from these storm events decreased to 0.54 inches per year; therefore, the lack of hurricanes and tropical storms in the last 10-20 years has had a certain relation with the decline in annual rainfall.

Figure 3 shows the 30, 20, and 10-year rainfall moving averages beginning in 1915 through 1981 for the Kissimmee River Valley Basin. The long term variation dampened out as longer periods of moving averages were used; however,

[1] N. Khanal, "Kissimmee River Basin Rainfall Analysis 4/19/81" South Florida Water Management District.

TABLE 1. AVERAGE MONTHLY RAINFALL (INCHES)

Area	Jan.	Feb.	Mar.	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
E. Palm Beach Co.	2.69	2.53	3.11	3.39	5.05	7.76	6.13	6.37	8.31	8.02	3.17	2.28	58.81
E. Broward County	2.40	2.01	2.76	3.44	5.84	7.95	6.31	6.86	8.32	8.93	3.21	2.25	60.28
Dade County	1.92	1.79	2.04	3.12	6.64	8.80	7.14	7.37	8.96	7.91	2.13	1.44	59.26
E Everglades Ag Area	1.80	1.82	2.79	2.76	5.04	8.80	7.81	7.68	8.18	4.78	1.84	1.78	55.08
W Everglades Ag Area	1.62	1.71	2.46	2.48	4.97	8.00	7.30	6.85	7.06	4.32	1.53	1.53	49.83
Upper East CoastBasin	2.33	2.31	2.76	3.02	4.39	6.44	6.16	5.54	7.65	6.70	2.55	1.91	51.76
Fisheating Creek	1.68	2.07	2.76	2.58	4.19	7.68	7.11	6.74	6.94	3.74	1.42	1.50	48.41
Upper Kissimmee Lakes	2.18	2.69	3.19	2.68	4.16	7.38	7.66	6.97	6.56	3.25	1.65	2.02	50.39
Kissimmee River	2.04	2.44	2.60	2.69	4.23	7.76	8.01	7.18	7.05	3.98	1.60	1.65	51.23
E&W Caloosahatchee Basin	1.72	2.04	2.61	2.59	4.68	8.40	7.56	7.08	7.60	3.93	1.03	1.38	50.62
East Collier Basin	1.61	1.69	2.38	2.02	5.07	9.49	8.29	7.51	8.94	4.03	1.44	1.28	53.75
West Collier Basin	1.74	1.68	2.33	1.97	4.73	9.09	8.34	7.95	9.15	3.98	1.37	1.34	53.67
Estero Basin	1.79	2.07	2.40	2.06	4.12	9.42	8.74	8.52	8.13	4.16	1.37	1.49	54.27
Tidal Caloosahatchee & North Coastal Area	1.86	2.08	2.35	2.06	3.93	8.79	8.24	8.12	8.08	3.99	1.44	1.54	52.48
District Average	1.96	2.07	2.61	2.63	4.79	8.27	7.39	7.20	7.92	5.34	1.84	1.67	53.57

the cyclical characteristics became more obvious for the 10-year moving average.

While the National Weather Service uses the 30-year average as normal, it is suggested that for many water management purposes, especially those involving long term projections, an average of the total period of record is a better measure for the normal.

In addition to annual variations, rainfall in central and southern Florida shows a seasonal pattern with dry winters and wet summers. About 70% of the annual rainfall occurs in the wet season (May through October), some basins receive over 75% of the annual rainfall during these months. The annual average rainfall ranges from 48.41 inches to 60.28 inches The overall average for the District area is 53.57 inches; the monthly average for the overall District ranges from 1.67 inches in December to 8.27 inches in June. The monthly average wet season rainfall varies within the District basins. It ranges from 3.93 inches in May in the tidal Caloosahatchee basin to 9.49 inches in June in the west Collier basin. Likewise during the dry season it ranges from 1.03 inches to 3.00 inches per month. A complete tabulation of monthly averages for each basin within the District is shown in Table 1.

C. Drought Frequency Analysis

There is an absence of a precise and universally accepted definition of drought which adds to the

TABLE 2. LONG TERM RAINFALL PATTERN

Basin and Record Period Used	Year of Moving Avg.	Highest Value	Highest Deviation Inches	Highest Period	Lowest Value	Lowest Deviation Inches	Lowest Period	Long Term Trend
Kissimmee River	30	52.53	+1.30	1919-48	48.52	-2.72	1952-81	Down
Basin (1915-1981)	20	52.64	+1.41	1918-37	46.22	-5.02	1962-81	
	10	54.50	+3.27	1951-60	44.32	-6.93	1972-81	
Upper Kissimmee	30	52.66	+2.27	1931-60	49.71	-0.42	1952-81	Inconclusive
Lakes (1915-1981)	20	53.74	+3.35	1941-60	48.24	-2.13	1962-81	
	10	54.83	+4.44	1951-60	47.65	-2.74	1972-81	
Fisheating Creek	30	50.31	+0.86	1945-74	48.15	-1.30	1952-81	Down
& Istokpoga	20	51.75	+2.37	1950-69	45.36	-4.02	1962-81	
(1932-1981)	10	55.20	+6.52	1951-60	44.45	-7.23	1972-81	
Upper East Coast	30	52.47	+1.11	1950-79	49.69	-1.67	1917-46	Up
(1914-1981)	20	53.15	+1.68	1952-71	48.93	-2.54	1916-35	
	10	54.14	+2.73	1951-60	47.00	-4.36	1916-25	
East Collier Basin	30	54.51	+1.74	1952-81	51.14	-1.63	1938-67	Up
(1927-1981)	20	57.14	+4.25	1957-76	49.13	-3.76	1937-56	
	10	59.03	+5.57	1967-76	46.49	-6.97	1942-51	
Dade County	30	60.88	+1.66	1931-60	56.91	-2.31	1952-81	Down
(1927-1981)	20	62.18	+2.81	1929-48	56.46	-2.91	1962-81	
	10	63.90	+4.50	1932-41	51.03	-8.37	1972-81	
East Everglades	30	56.79	+1.65	1931-60	53.24	-2.17	1952-81	Down
Agricultural Area	20	57.54	+2.30	1941-60	51.05	-4.19	1962-81	
(1929-1981)	10	57.45	+2.48	1951-60	48.33	-6.64	1972-81	
West Everglades	30	53.69	+1.04	1930-59	50.27	-2.38	1952-81	Down
Agricultural Area	20	54.54	+2.07	1947-66	47.14	-5.33	1962-81	
(1929-1981)	10	57.45	+5.56	1951-60	42.59	-9.30	1972-81	

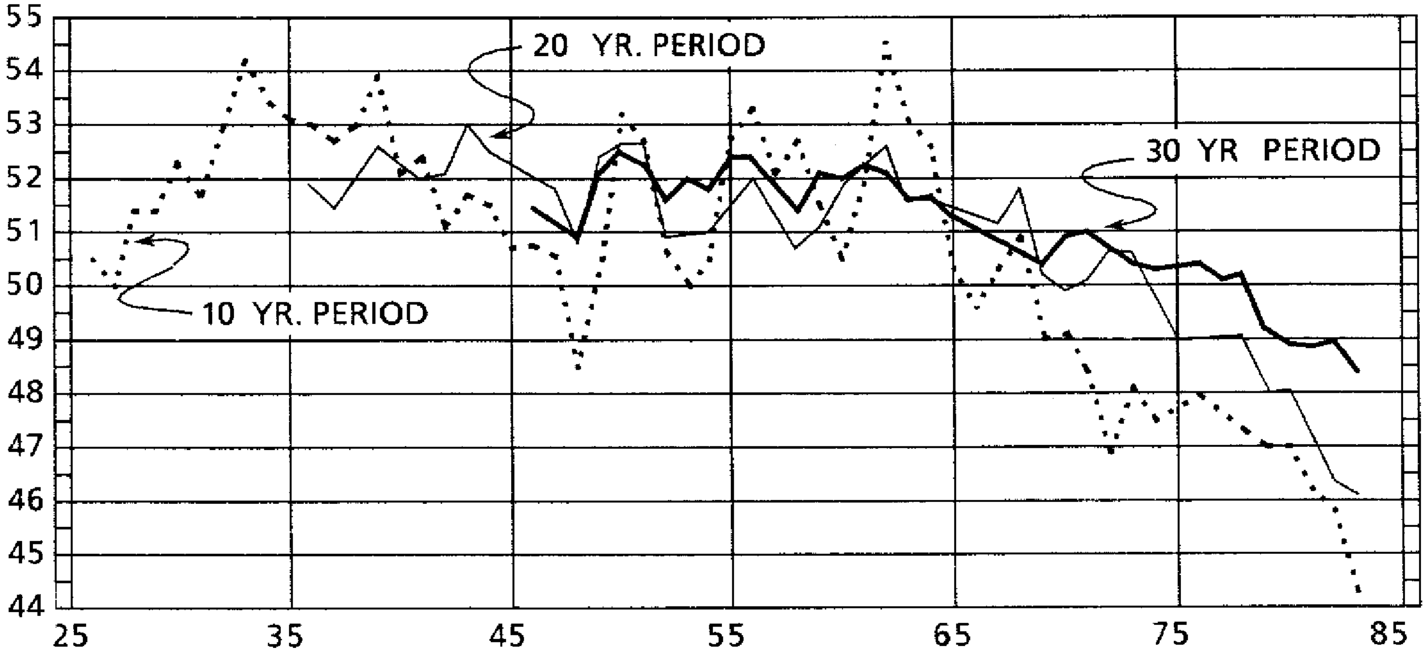

FIGURE 3. KISSIMMEE RIVER BASIN - MOVING AVERAGE RAINFALL (1915 - 1982).

confusion about whether or not a drought exists, and if it does, its severity. For the purpose of this report, drought was defined as a shortage of precipitation sufficient to adversely affect water demands. Droughts differ in three essential characteristics, intensity, duration, and spatial coverage. The statistical evaluation of the drought was performed using the log Pearson Type III distribution (Appendix A) in the smallest amount of rainfall that had occurred in a specific period or duration within a water year (November through October). A similar analysis based on rainfall deficits produced similar results.

D. Results and Discussions

Table 3 shows the monthly rainfall of each basin for the period June 1980 through February 1982. Table 5A shows the comparison of 12 months rainfall from June 1980 through May 1981 for the selected drought periods, as well as the percent of normal and associated drought frequency for the 14 basins. Table 5B shows the comparisons of the wet season rainfall (June through October) for those selected drought periods. Table 5C shows the comparisons of the dry season rainfall (November through April) for those selected drought periods; May was considered a transition month. Table 4 presents the comparisons of 21 months; i.e., June 1980 through February 1982, for those selected drought periods with indications of the percent of their normal, and amount of total deviation from normal. For purposes of comparison, a period of 21 months was chosen for the other drought periods, although the rainfall deficiency period was considerably less.

1. Drought Period: June 1980 - February 1982
   a. The total rainfall in this 21 month period over the entire District ranged from 66.3% of normal in the West Everglades Agricultural Area to 87.9% of normal in the Estero Basin, with a District average of approximately 76.1% of normal.

      The total rainfall deficit over the entire District area was 23 inches for the 21 month period. For the Everglades Agricultural Area, the Upper Kissimmee Lakes, and the East Collier Basins, the deficit was in the order of 30 inches.
   b. For the 12 month period (June 1980 - May 1981, Table 5A), the West Everglades Agricultural Area received 29 inches, which was the least among the District basins. The Upper Kissimmee Lakes and the Kissimmee River Basins received 31.4 and 32.95 inches, respect-ively and the East Collier Basin received 32.67 inches. The return intervals were well over a 1 in 100 year event, expressed in drought return frequency, The western Everglades Agricultural Area and the Upper East Coast Basins were next in severity with return intervals of over 100 and 33 years, respectively. For the coastal areas, such as the Lower East Coast and Estero Bay of the Lower West Coast, the drought return intervals ranged from 5 to 17 years.

TABLE 3. MONTHLY RAINFALL IN INCHES FOR JUNE 1980 THROUGH FEBRUARY 1982

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
East Palm Beach	5.24	8.53	5.09	6.93	3.53	3.46	1.54	0.51	3.56	1.63	0.28	5.70	4.63	5.18	14.20	7.77	2.54	3.59	1.17	1.11	3.46
East Broward	4.75	6.63	4.68	3.78	5.50	4.08	1.14	0.71	4.05	0.89	0.19	6.13	5.12	6.05	14.83	7.73	2.89	3.44	0.24	0.65	2.24
Dade County	6.62	6.76	7.29	5.59	5.54	5.15	0.94	0.61	3.93	1.32	0.07	3.62	4.84	3.35	13.48	14.91	2.70	2.52	0.43	0.57	1.84
E.Everglades Ag Area	3.91	7.73	4.50	8.06	1.76	2.49	0.80	0.57	2.10	1.83	0.19	3.86	4.07	4.83	14.84	4.94	0.39	3.86	0.18	0.75	2.19
W.Everglades Ag Area	2.97	4.66	6.44	4.03	1.44	2.05	0.81	0.45	2.35	1.31	0.11	2.38	5.58	4.20	10.34	4.07	0.49	3.59	0.06	0.44	1.77
Upper E.Coast Basin	4.02	7.90	4.68	4.66	2.21	2.79	1.43	0.59	2.23	1.01	0.40	3.25	3.56	3.70	12.65	8.05	2.37	1.41	0.58	0.89	3.46
Fisheating Creek	4.77	7.43	4.96	3.40	2.65	2.14	0.87	0.54	2.15	0.79	0.15	3.33	4.29	5.42	7.50	4.82	0.76	1.26	0.24	0.61	1.70
Upper KissimmeeLakes	4.42	5.65	4.30	2.86	0.99	4.19	0.69	0.34	3.82	1.26	0.11	2.77	4.88	4.02	8.22	4.90	1.56	1.54	2.25	1.38	1.37
Kissimmee River	4.80	6.08	5.12	3.61	1.50	3.42	1.31	0.38	3.00	1.69	0.30	1.74	5.50	4.42	7.55	5.75	1.08	1.04	0.41	1.26	2.34
E. & W. Caloos. Basin	2.20	8.25	6.88	4.69	1.37	3.29	0.69	0.71	2.21	1.54	0.26	2.65	6.78	4.85	11.82	4.47	1.02	2.26	0.34	0.70	1.91
E. Collier Basin	4.02	6.82	6.96	4.55	0.64	3.10	0.76	0.56	2.38	1.21	0.21	1.46	5.00	7.17	11.11	4.82	1.60	1.40	0.25	0.60	1.30
W. Collier Basin	3.03	7.36	12.57	8.75	0.78	3.48	0.74	0.54	1.73	1.57	0.26	1.69	8.23	9.43	10.22	3.40	0.25	1.67	0.24	0.82	1.60
Estero	2.31	8.73	11.35	7.60	2.25	3.21	0.77	0.82	1.26	1.68	0.15	5.82	10.40	6.77	15.76	4.34	0.17	0.67	0.46	0.50	2.86
Tidal & N.Coast Area	2.32	7.18	9.97	6.38	2.41	2.91	0.52	0.82	1.66	1.53	0.05	3.97	9.08	6.75	14.75	3.92	0.13	1.06	0.41	0.69	3.42
District Average	**3.96**	**7.12**	**6.77**	**5.35**	**2.33**	**3.27**	**0.93**	**0.58**	**2.60**	**1.38**	**0.20**	**3.46**	**5.85**	**5.44**	**11.95**	**5.99**	**1.28**	**2.09**	**0.51**	**0.79**	**2.25**
Lake Okeechobee	3.38	5.02	6.09	5.48	1.12	2.14	0.66	0.79	1.58	1.18	0.17	2.78	3.03	4.37	9.35	3.70	0.71	1.13	0.10	0.49	2.13

TABLE 4. RAINFALL COMPARISONS FOR SELECTED DROUGHT PERIODS

(21 Months)

	June 1955-Feb. 1957			June 1961-Feb. 1963			June 1967-Feb.1969			June 1970-Feb.1972			June 1973-Feb.1975			June 1980-Feb.1982		
	Inches	% of Norm	Deficit Inches	Inches	% of Norm	Deficit Inches	Inches	% of Norm	Deficit Inches	Inches	% of Norm	Deficit Inches	Inches	% of Norm	Deficit Inches	Inches	% of Norm	Deficit Inches
E. Palm Beach County	86.75	81.79	19.32	76.54	72.16	29.53	116.06	109.42	0	84.51	79.67	21.56	106.29	100.21	0	89.65	84.52	16.42
E. Broward County	76.80	70.77	31.72	80.40	74.09	28.12	121.49	111.95	0	72.06	66.40	36.46	90.06	82.99	18.46	85.62	78.90	22.90
Dade County	87.59	82.07	19.13	79.84	73.44	28.88	137.71	126.66	0	77.66	72.77	29.06	87.15	81.66	19.57	92.08	84.69	16.64
E. Everglades Ag Area	86.62	86.99	12.95	85.69	85.06	13.88	100.31	100.74	0	84.61	84.50	14.96	86.55	86.92	13.02	73.85	74.17	25.72
W. Everglades Ag Area	85.32	95.06	4.43	86.17	96.01	3.58	104.01	115.89	0	82.11	91.49	7.64	78.97	87.99	10.78	59.54	66.34	30.21
Upper E Coast Basin	78.69	84.30	14.66	74.67	79.99	18.68	97.22	104.15	0	94.17	100.88	0	92.69	99.29	0.66	71.84	76.96	21.51
Fisheating Creek	75.49	86.48	11.80	81.73	93.63	5.56	92.39	105.84	0	82.34	94.33	4.95	85.37	97.80	1.92	59.78	68.48	27.51
Upper Kissimmee Lakes	81.00	97.16	2.37	74.59	89.47	8.78	93.84	112.56	0	88.07	105.64	0	84.95	101.90	0	61.53	73.80	21.84
Kissimmee River	80.16	86.25	12.78	76.89	82.73	16.05	85.72	96.54	7.22	80.57	86.69	12.37	83.15	89.47	9.79	62.40	67.14	30.54
E&W Caloos. Basin	75.13	82.23	16.23	80.28	87.87	11.08	96.63	105.77	0	77.59	84.93	13.77	91.80	100.48	0	68.88	75.39	22.48
E. Collier Basin	81.80	83.44	16.23	87.80	89.56	10.23	112.20	114.45	0	89.93	91.73	8.10	111.12	113.25	0	65.92	67.72	32.11
W. Collier Basin	87.07	88.57	11.24	87.04	88.54	11.27	104.54	106.34	0	97.50	99.18	0.81	102.78	104.55	0	78.36	79.71	19.95
Estero	79.91	79.94	22.05	99.36	99.40	0.60	117.75	117.80	0	101.51	101.55	0	118.91	118.96	0	87.89	87.93	12.07
Tidal & N. Coast Area	77.77	80.49	18.85	93.24	96.50	3.38	113.41	117.38	0	85.40	88.39	11.22	102.14	105.71	0	80.13	82.93	16.49
District Average	**81.44**	**83.67**	**15.89**	**83.16**	**85.44**	**14.17**	**106.66**	**109.59**	**0**	**85.57**	**87.92**	**11.76**	**94.42**	**97.01**	**2.91**	**74.11**	**76.14**	**23.22**

TABLE 5. RAINFALL COMPARISONS FOR SELECTED DROUGHT PERIODS

	June 1955-May 1956			June 1961-May 1962			June 1967-May 1968			June 1970-May 1971			June 1973-May 1974			June 1980-May 1981		
SECTION A. 12 MONTHS	Inches	% of Normal	Freq. Years	Inches	% of Normal	Freq. Years	Inches	% of Normal	Freq. Years	Inches	% of Normal	Freq. Years	Inches	% of Normal	Freq. Years	Inches	% of Normal	freq. Years
E. Palm Beach County	40.14	68.0	18.2	35.15	60.0	83.3	57.71	98.13	2.2	30.35	63.51	40.0	60.98	103.69	1.5	46.00	78.2	7.1
E. Broward County	42.30	70.0	15.4	36.49	61.0	83.3	70.78	117.42	1.3	34.49	57.21	170.0	52.64	87.32	3.5	42.53	70.5	17.0
Dade County	50.01	84.0	5.0	34.91	59.0	90.9	73.18	123.49	1.0	35.88	60.55	67.0	51.01	86.08	4.1	47.44	80.0	6.0
E.Everglades Ag Area	45.69	83.0	6.5	38.66	70.0	35.7	50.69	92.03	3.1	38.79	70.42	35.7	43.91	79.7	9.3	37.80	68.6	50.0
W.Everglades Ag Area	46.10	93.0	3.0	35.32	71.0	20.0	57.43	115.25	1.4	34.49	69.22	18.9	38.25	76.8	10.0	29.00	57.8	125.0
Upper E Coast Basin	40.23	78.0	10.0	32.31	62.0	83.3	48.57	93.84	2.8	41.65	80.47	8.3	48.85	94.4	2.6	35.17	67.9	33.3
Fisheating Creek	39.90	82.0	5.7	33.58	69.0	28.0	46.64	96.34	2.1	34.19	70.63	25.0	41.95	86.7	3.8	33.18	68.6	28.6
Upper Kissimmee Lakes	36.93	73.0	25.0	35.15	70.0	43.0	47.30	93.87	3.1	41.15	81.66	8.3	43.48	86.3	5.4	31.40	62.2	222.0
Kissimmee River	37.77	74.0	26.3	35.23	69.0	71.4	45.95	89.69	3.4	39.40	76.91	15.4	41.44	80.9	9.1	33.95	64.3	200.0
E&W Caloos. Basin	41.47	82.0	6.3	33.44	66.0	55.5	53.83	106.34	1.6	35.75	70.62	25.0	45.43	89.7	3.3	34.74	68.7	34.0
E Collier Basin	44.25	82.0	6.5	37.33	69.0	43.5	57.73	107.40	1.7	40.43	75.22	17.5	60.19	119.9	1.2	32.67	61.0	250.0
W Collier Basin	56.72	106.0	1.6	31.21	58.0	125.0	50.20	93.53	2.7	46.66	86.94	4.2	57.25	106.7	1.6	42.50	81.1	6.3
Estero	45.54	84.0	5.0	39.91	74.0	18.2	60.49	111.45	1.3	51.04	94.05	2.5	59.43	109.5	1.4	45.95	84.6	5.0
Tidal & N. Coast Area	43.27	82.0	5.9	36.64	70.0	27.8	56.94	108.50	1.4	41.34	78.77	8.3	48.72	92.8	2.6	39.72	75.7	11.8
District Average	**43.59**	**81.0**		**35.38**	**66.0**		**55.53**	**103.70**		**39.47**	**73.68**		**49.54**	**92.5**		**37.96**	**70.9**	
SECTION B. WET SEASON ONLY																		
E. Palm Beach County	25.70	70.2	11.5	21.93	59.9	45.5	37.32	102.0	1.7	27.90	76.25	6.7	40.16	109.76	1.4	29.32	80.13	4.8
E. Broward County	28.57	74.5	6.9	23.57	61.4	35.7	44.82	116.8	1.2	27.83	72.53	8.0	35.15	91.61	1.9	25.34	66.04	16.7
Dade County	30.98	77.1	10.0	25.30	63.0	100.0	45.43	113.07	1.1	29.19	72.65	17.5	38.62	96.12	1.9	31.80	79.14	7.1
E.Everglades Ag Area	35.93	96.5	2.3	25.32	68.0	26.0	33.32	89.45	3.3	29.76	79.89	6.7	33.15	88.99	3.4	25.96	69.69	21.3
W.Everglades Ag Area	37.10	110.6	1.6	24.60	73.4	9.1	39.55	117.95	1.4	26.77	79.84	5.9	30.11	89.80	3.3	19.54	58.28	40.0
Upper E. Coast Basin	26.58	81.8	5.9	19.61	60.4	57.0	36.56	112.53	1.4	29.75	91.57	3.0	36.86	113.45	1.3	23.47	72.23	13.3
Fisheating Creek	30.38	94.3	2.4	20.75	64.4	27.8	33.09	102.73	1.7	27.53	85.47	3.7	31.82	98.88	2.0	23.21	72.06	12.5
Upper Kissimmee Lakes	24.12	75.8	12.5	21.34	67.1	55.6	34.33	107.89	1.4	26.12	82.09	6.7	30.41	95.57	2.4	18.22	57.26	455.0
Kissimmee River	26.76	78.8	8.3	21.65	63.7	77.0	32.63	96.03	2.1	27.45	80.78	6.7	30.24	88.99	3.3	21.11	62.12	100.0
E&W Caloos. Basin	33.91	98.1	2.0	20.29	58.7	62.5	37.26	107.78	1.5	28.54	82.56	3.8	35.50	102.69	1.7	23.39	67.66	18.5
E. Collier Basin	29.23	76.4	10.0	27.42	71.7	18.2	40.25	105.20	1.4	33.09	86.49	3.8	46.75	122.19	1.0	22.99	60.01	125.0
W. Collier Basin	39.78	103.3	1.8	21.26	55.2	105.0	37.91	98.44	2.1	39.91	103.64	1.8	44.92	116.65	1.2	32.49	84.37	4.5
Estero	34.23	87.8	3.3	31.52	80.9	5.7	44.81	114.99	1.3	41.21	105.75	1.6	47.60	122.16	1.2	32.24	52.73	6.3
Tidal & N Coast Area	32.77	88.0	3.6	28.47	76.5	10.0	39.89	107.17	1.5	33.01	88.69	3.3	39.50	106.13	1.5	28.16	75.93	11.1
District Average	**31.15**	**86.0**		**23.79**	**65.7**		**38.36**	**105.90**		**30.58**	**84.43**		**37.19**	**102.70**		**25.52**	**70.47**	
SECTION C. DRY SEASON ONLY																		
E. Palm Beach County	9.34	54.5	8.3	10.69	62.3	5.6	8.97	52.24	9.5	4.78	27.84	125.0	17.39	100.76	1.8	10.98	63.77	5.1
E. Broward County	9.04	56.3	7.9	9.59	59.7	6.7	10.97	68.26	4.5	3.03	18.86	360.0	13.83	86.06	2.5	11.06	68.95	4.3
Dade County	8.79	70.7	4.0	8.18	65.8	4.9	10.12	80.55	2.7	2.43	19.53	500.0	7.73	62.14	9.1	12.02	96.70	1.9
E. Everglades Ag Area	8.42	65.8	4.0	10.87	85.0	22.0	8.74	68.33	3.7	4.05	31.67	62.5	6.83	53.40	7.4	7.98	62.31	5.0
W. Everglades Ag Area	6.49	57.3	4.7	7.52	66.4	3.3	8.55	75.46	2.7	2.50	22.07	90.9	3.83	33.80	20.0	7.08	60.72	4.0
Upper E. Coast Basin	10.38	69.8	3.3	10.25	68.9	3.5	6.49	43.62	15.4	5.96	40.05	22.2	9.01	60.55	5.0	8.45	56.79	6.1
Fisheating Creek	7.78	64.8	4.9	8.21	68.4	4.2	6.81	56.70	7.4	3.23	26.89	154.0	5.59	46.54	15.4	6.64	55.29	7.7
Upper Kissimmee Lakes	8.94	62.0	5.7	9.95	69.0	4.3	7.29	50.59	10.0	10.60	73.56	3.7	8.97	62.25	5.7	10.41	69.54	4.0
Kissimmee River	7.80	60.0	6.1	9.38	72.0	3.7	6.46	49.62	11.1	7.13	54.76	8.0	11.20	86.02	2.5	10.10	77.95	3.2
E.& W.Caloos. Basin	6.18	54.4	8.0	9.52	83.7	2.6	6.67	58.66	6.3	3.61	31.75	62.5	4.28	37.64	31.3	8.70	76.61	3.0
E. Collier Basin	11.29	108.1	1.5	6.37	61.0	4.3	8.56	81.99	2.3	2.81	26.92	90.9	5.99	57.38	5.3	8.22	78.83	2.4
W. Collier Basin	9.31	89.3	1.8	6.30	60.4	4.3	7.41	71.05	2.9	4.30	41.23	15.2	5.31	50.91	7.4	8.32	88.69	1.8
Estero	6.55	58.5	5.3	7.55	67.5	3.6	7.07	63.18	4.2	6.56	58.62	5.3	6.46	57.73	5.6	7.89	70.42	3.2
Tidal & N. Coast Area	13.95	123.1	1.4	7.09	62.6	4.3	7.76	68.49	3.4	5.56	49.07	9.1	4.40	38.83	23.3	7.49	66.11	3.8
District Average		**8.88**	**69.5**		**8.68**	**67.9**		**8.00**	**62.60**		**4.75**	**37.17**		**7.91**	**61.90**		**8.96**	**70.42**

c. From June 1 through October 31, 1980 (wet season) the Upper Kissimmee Lake Basin received only 18.22 inches of rainfall, which is 57.3% of normal. The next most severe drought areas were the Kissimmee River Basin and the East Collier Basin which received nearly 60% of normal rainfall (Table 5B). The drought was in the order of 20 to 40 years return interval for the eastern basin of the Everglades Agricul-tural Area, the third most severe area.The entire District received approximately 70% of normal.

d. For the dry season (Nov. 1, 1980 through April 30, 1981), the rainfall amounts in the District basins ranged from 55.3% of normal in the Fisheating Creek Basin to 96.7% of normal in Dade County (Table 5-C). The Kissimmee Lakes and the Kissimmee River Basins received about 70% and 78% of normal, respectively, or approximately a one in four year drought.

2. <u>Drought Period: June 1970 - February 1972</u>

a. East Palm Beach, Broward, and Dade Counties, of the Lower East Coast area, experienced the greatest drought severity with rainfall deficits of 21.5, 36.5, and 29.1 inches in these 21 months. The eastern basin of the Everglades Agricultural Area, plus a portion of the Lower West Coast, were the next in drought severity with about 15 inches of rainfall deficit (Table 4). The Kissimmee River and Upper Kissimmee Lakes Basin were in the order of 86% to 106% of normal (or 12.37 inches and 0 inch rainfall deficit).

b. For the wet season, (June 1, 1970 through October 31, 1970) the rainfall average ranged from 72.7% of normal in Dade County to 106% in the Estero Basin. The Kissimmee Basins received about 81% of normal. The overall District areas received about 84% of normal (Table 5-B).

c. For the dry season, the Lower East Coast received the least amount of rainfall with a return interval of more than 100 years frequency. The entire District area received approximately 37.17% of normal, or about half of the rainfall received during the dry season of 1980-81 and 1961-62. The drought of 1970-71 was mostly limited to the Lower East Coast and a portion of the Everglades Agricultural Area, and it was primarily due to far below normal rainfall during the dry season, combined with a below normal rainfall in the preceding wet season. (Table 5-C).

3. <u>Drought Period: June 1961 - February 1963</u>

This drought period had very similar characteristics to the 1980-82 drought, but was slightly less in magnitude of rainfall deficit. The 21 months rainfall deficit was less than the 1980-82 drought in most District areas with the exception of the Lower East Coast. The rainfall amount from June 1961 through October 1961 ranged from 58% to 81% of normal. The Upper Kissimmee Lakes and the Kissimmee River Basins received about 65% of normal, which is slightly more than the 1980-82 drought for the same period. For the dry season rain-fall, the 1961-62 drought was pretty much the same as the 1980-82 drought; however, the first 12 months rainfall deficit was worse than the 1980-82 drought in several basins such as Lake Okeechobee, Dade County, and West Collier. The lake stage during this first 12 month period was lower than the first 12 months of 1980-82 (Figure 1). The recovery of the water level in Lake Okeechobee and the 21 month rainfall deficit indicated that this drought period was much shorter than the 1980-82 drought.

4. <u>Drought Periods of 1955-56, 1967-68, 1973-74, etc.</u>

The stage hydrograph shown in Figure 1 indicates that the stage in Lake Okeechobee reached a value of 10.31 ft msl during the drought period of 1955-56. This is the third lowest stage ever recorded. A comparison of rainfall deficit shown in Tables 5A and 5B indicates that this drought period was less severe than the drought periods of 1961-62, 1970-71, and 1980-82. The far below normal rainfall during the wet seasons of 1955 and 1956, and the lower stage (13.45 ft msl) at the beginning of the wet season (due to the lower regulation schedule) contributed to the lower lake stage during the 1955-56 drought period. The drought periods of 1967-68 and 1973-74 were caused by below normal rainfall during their dry seasons. The rainfall deficit, however, was much less for the 1967-68 and 1973-74 periods than for the 1961-62, 1970-71, and the 1980-82 periods.

E. <u>Summary</u>

Figures 4 through 11 are plots of accumulated rainfall from June 1980 through March

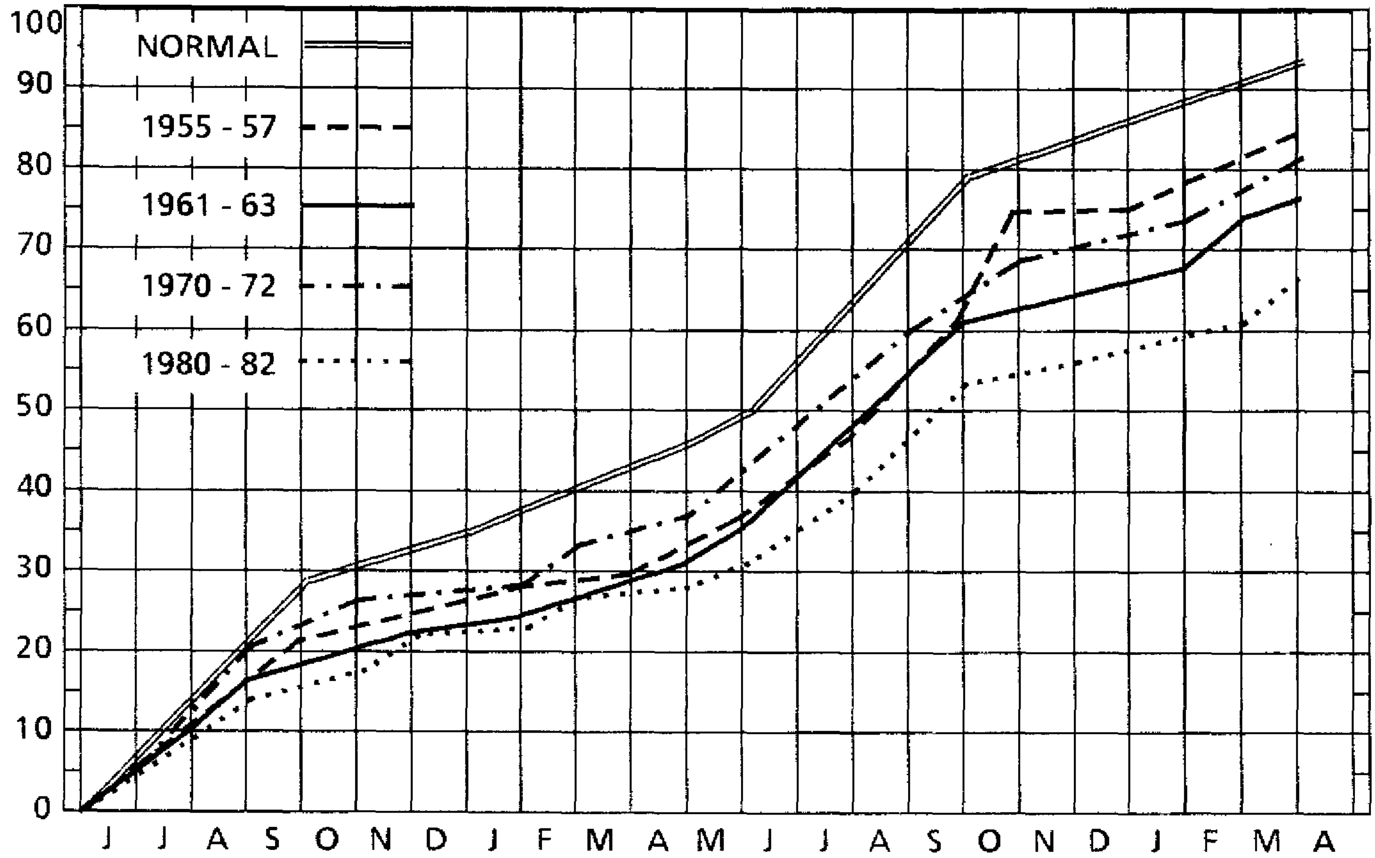

FIGURE 4. UPPER KISSIMMEE BASIN ACCUMULATED RAINFALL (inches)

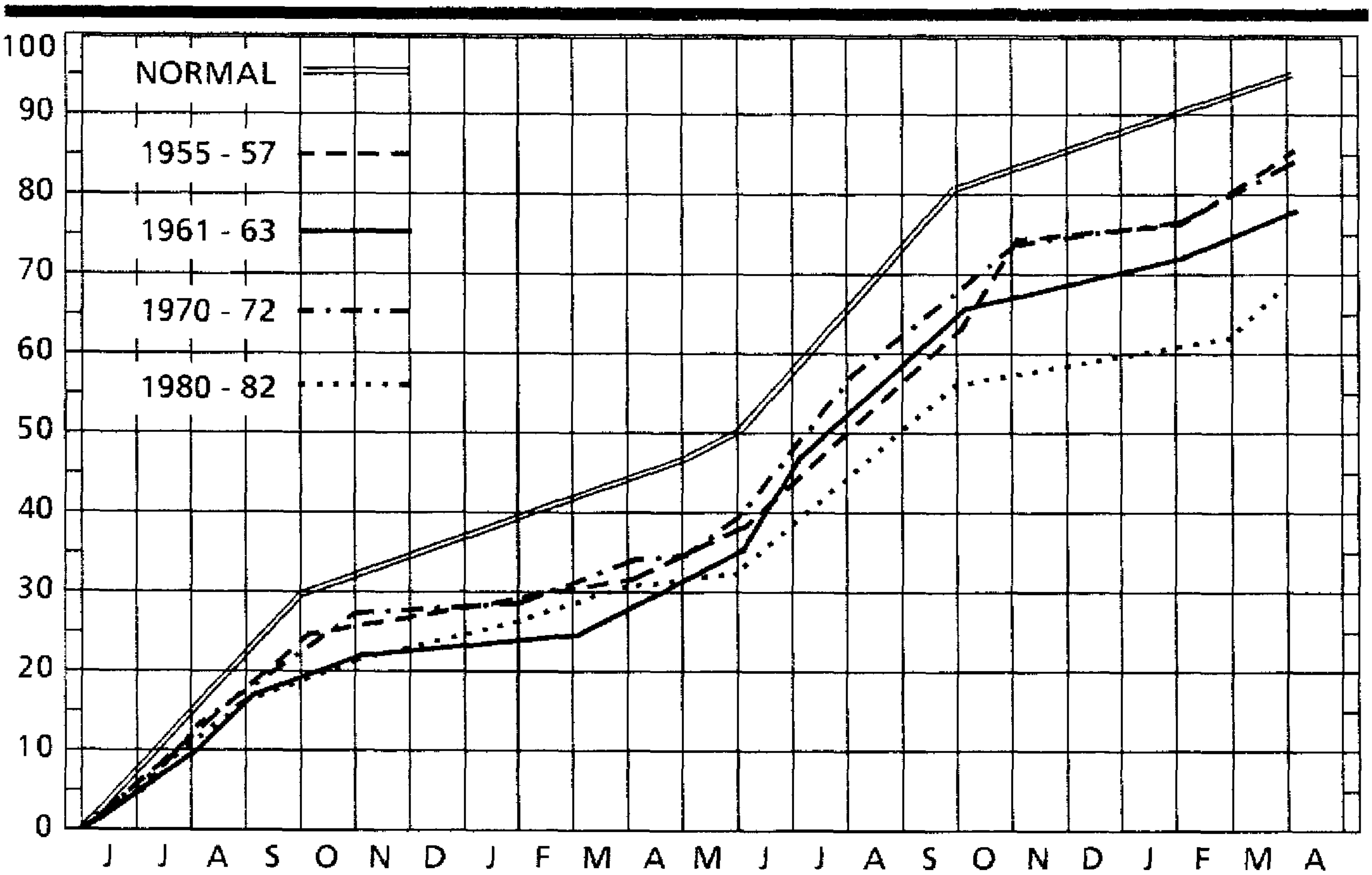

FIGURE 5. KISSIMMEE RIVER BASIN ACCUMULATED RAINFALL (inches)

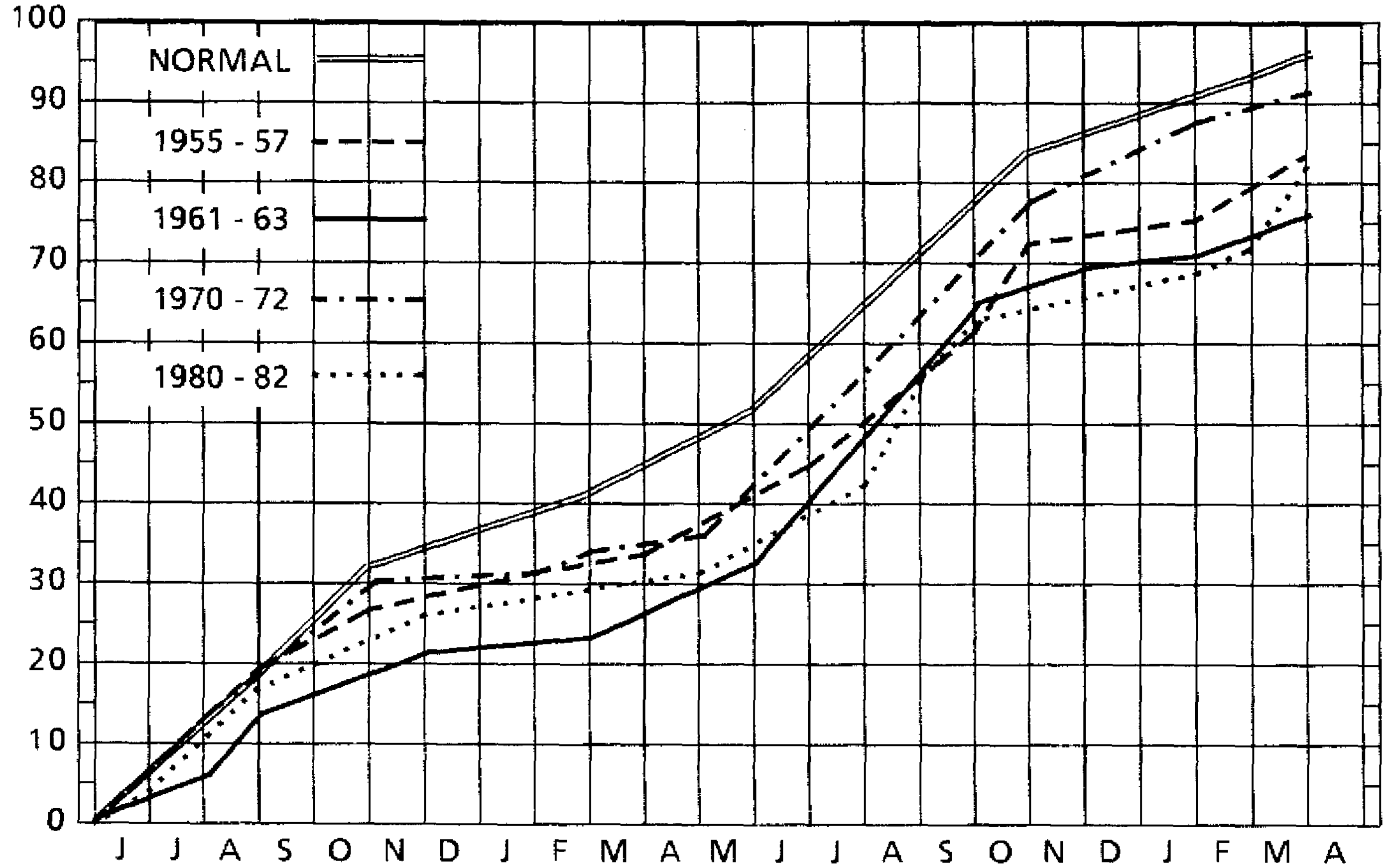

FIGURE 6. UPPER EAST COAST AREA - ACCUMULATED RAINFALL (inches)

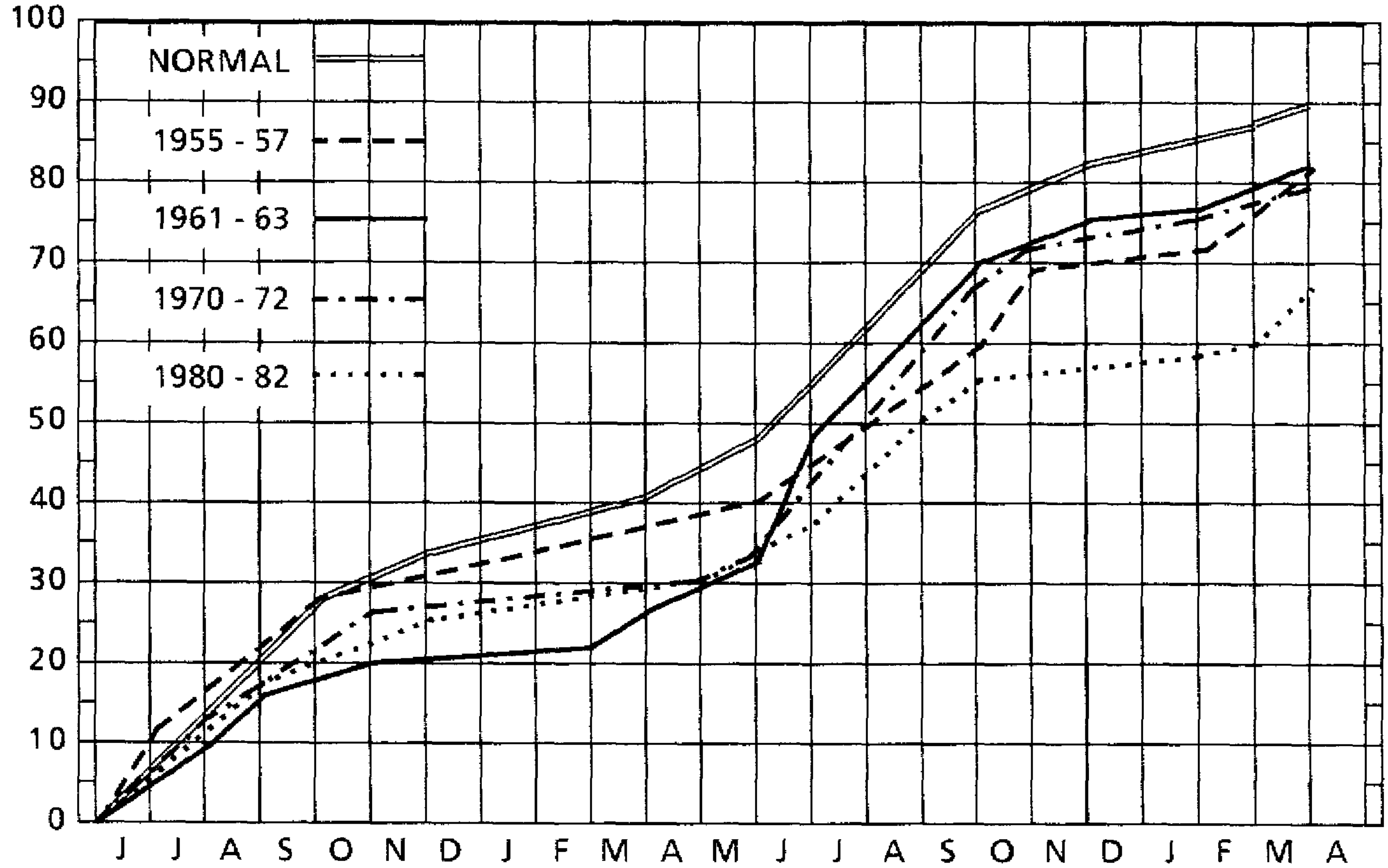

FIGURE 7. FISHEATING CREEK & C-41A BASIN ACCUMULATED RAINFALL (inches)

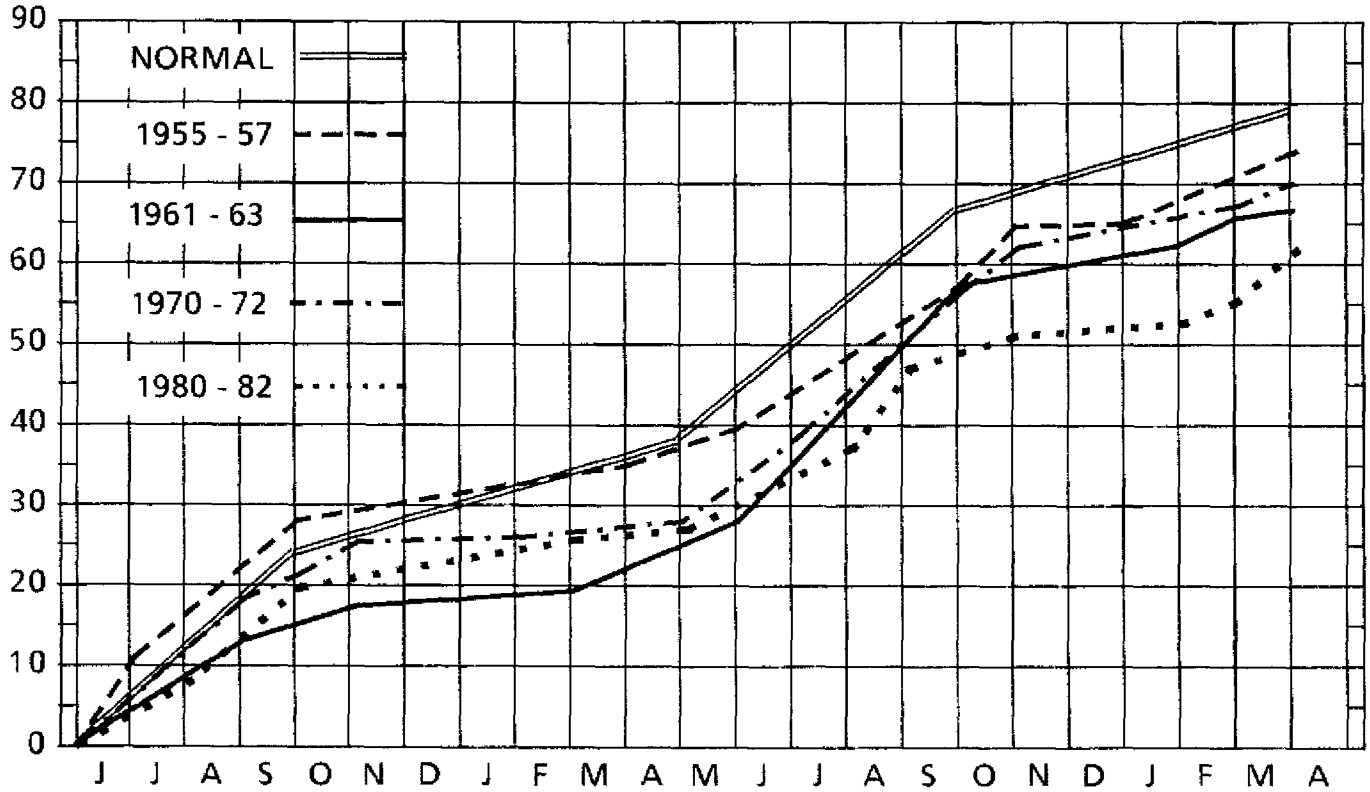

FIGURE 8. LAKE OKEECHOBEE - ACCUMULATED RAINFALL (inches)

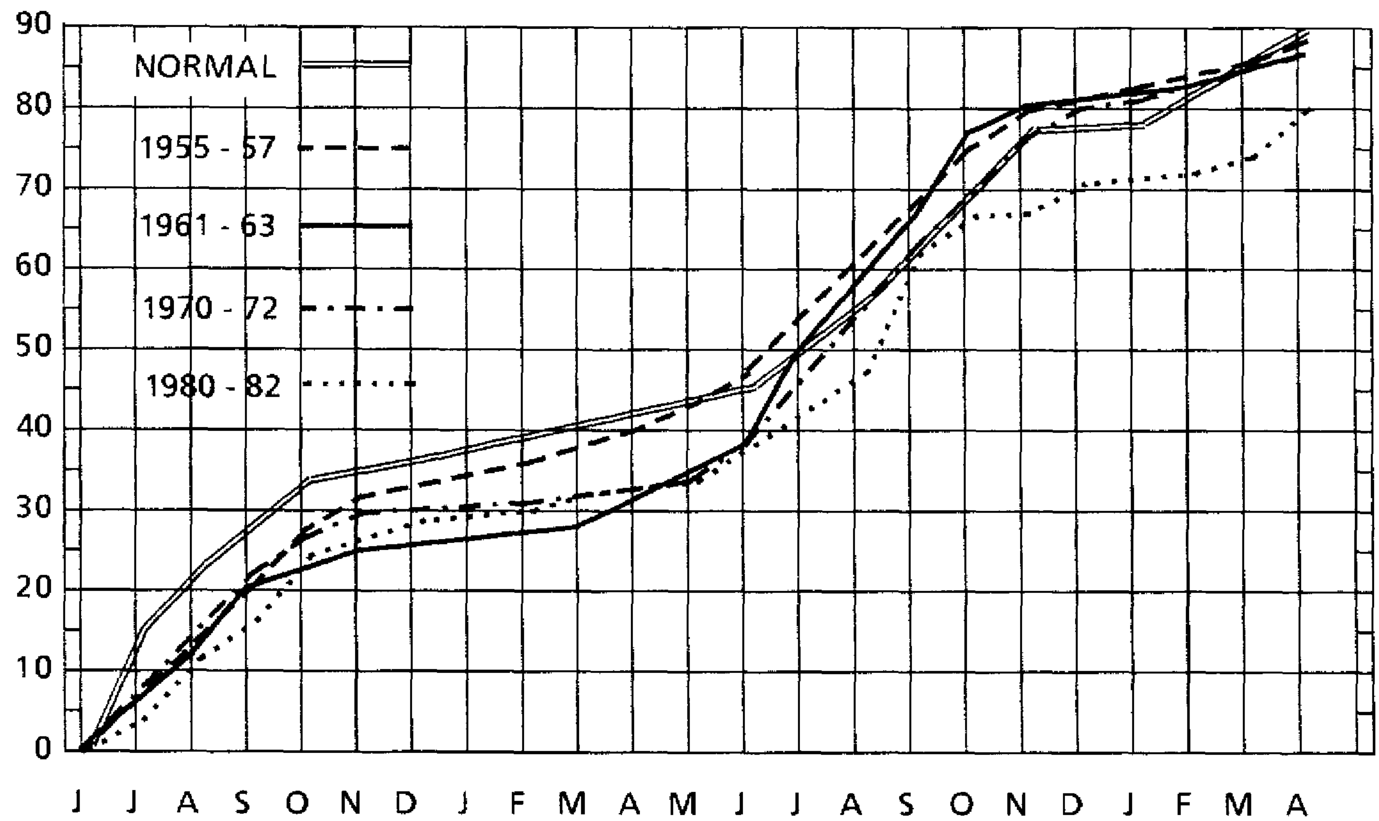

FIGURE 9. EEAA ACCUMULATED RAINFALL (inches)

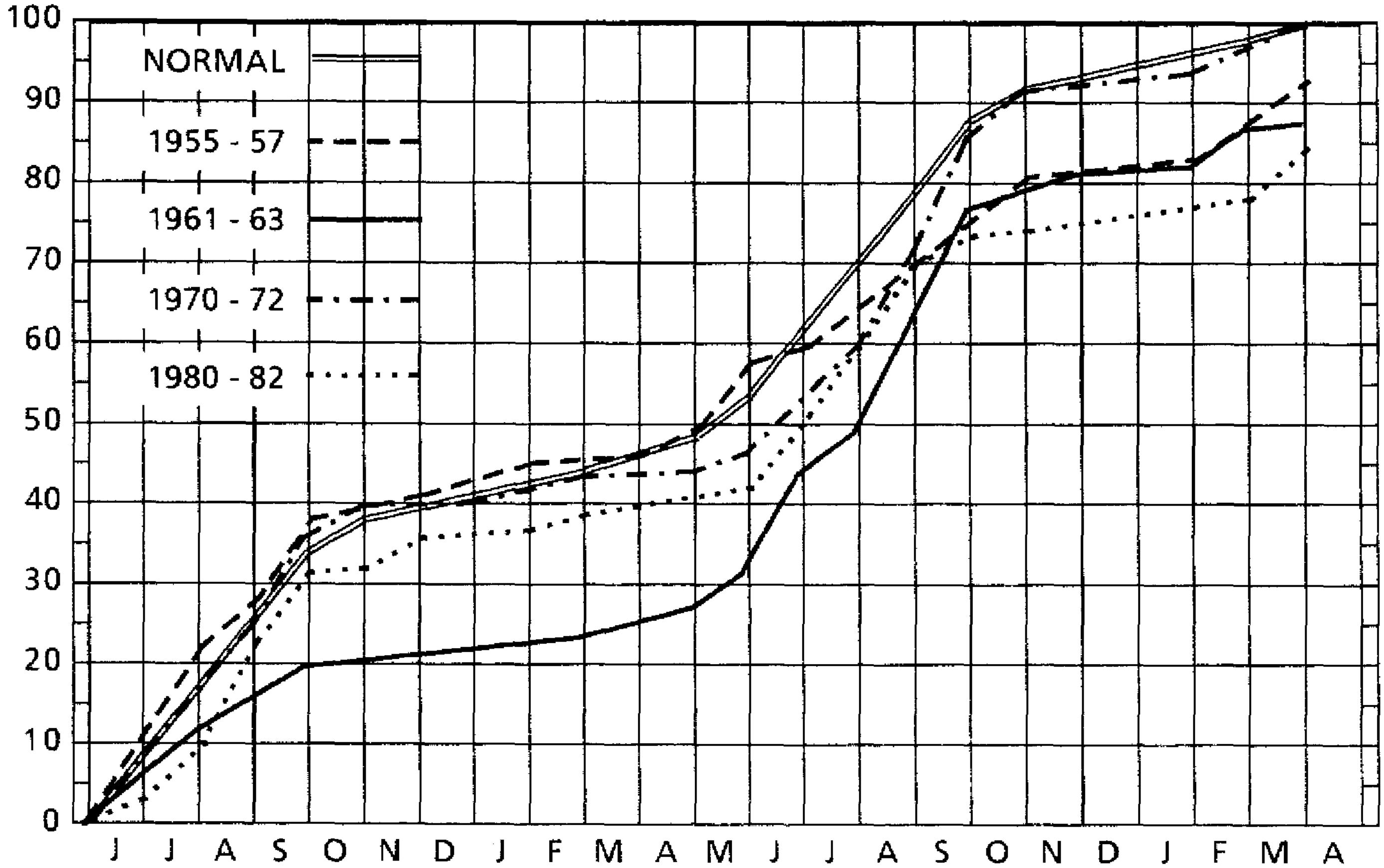

FIGURE 10. W. COLLIER BASIN ACCUMULATED RAINFALL (inches)

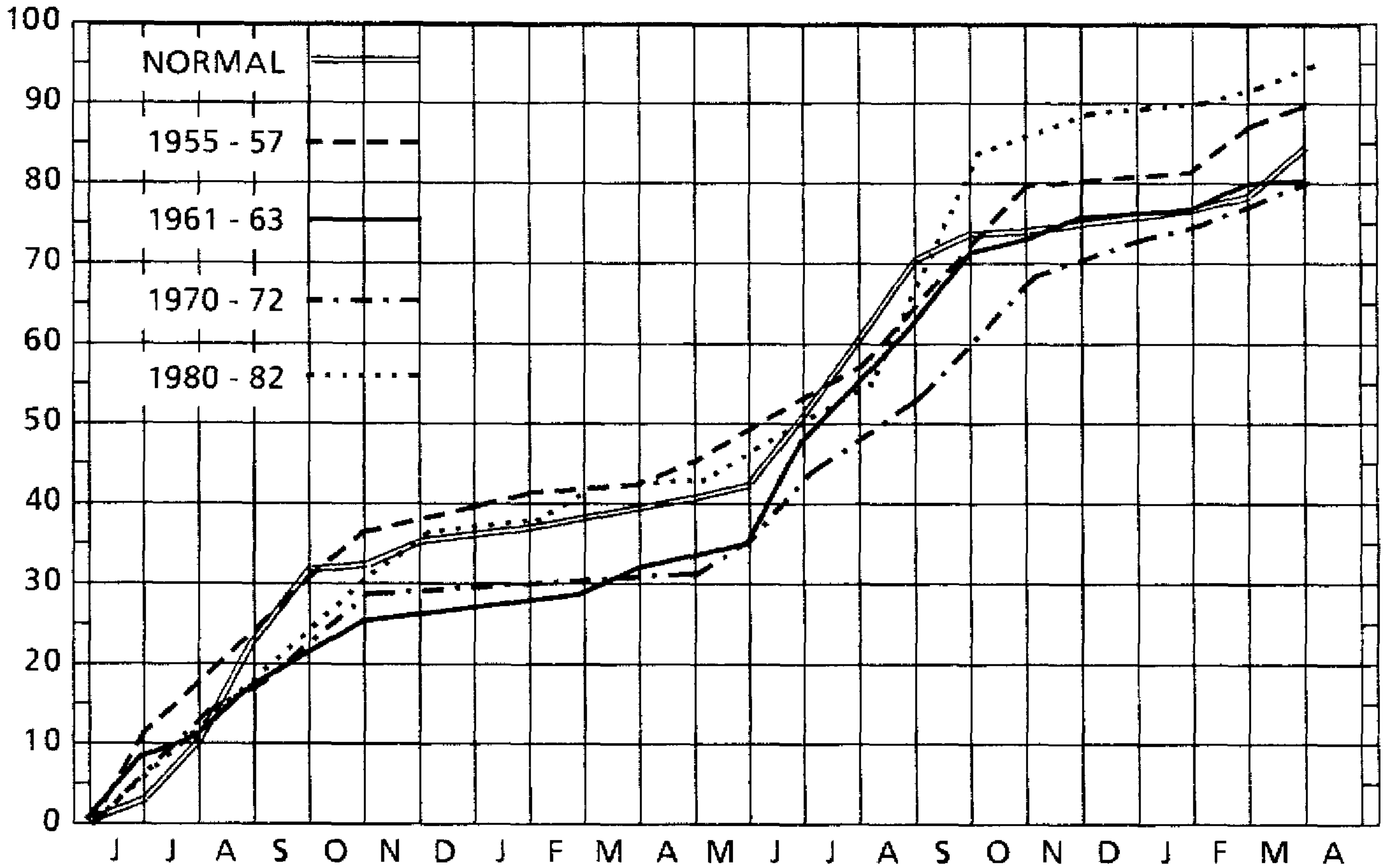

FIGURE 11. DADE COUNTY ACCUMULATED RAINFALL (inches)

1982 versus selected drought periods at various basins within the District. As a result of these comparisons, the 1980-82 drought was generally more severe in most of the basins than the droughts of 1961-62 and 1970-71, with the exception of the Lower East Coast area. The drought return intervals for the Upper Kissimmee Lakes and the Kissimmee River Basins during 1970-71 ranged from 18 to 15 years, while the 1980-82 drought for the same areas was well over one in 100 years. The 1980-82 drought for Fisheating Creek and Everglades Agricultural Areas was more severe than for the period 1970-71. As mentioned previously, the characteristics of the 1980-82 drought were quite different from the drought of 1970-71. The 1980-82 drought was triggered by a severe rainfall deficiency during the 1980 and 1981 wet seasons while the 1970-71 drought was primarily due to a lack of rainfall during the 1971 dry season compounded with a below normal rainfall in the wet seeason of 1970. The rainfall amount from June through October 1970 ranged from 73% to 105% of normal as compared to 58% to 84% of normal in 1980. For example, the rainfall amount in June through October 1980 for the Upper Kissimmee River Basin was 62% of normal. The western and eastern basins of the Everglades Agricultural Areas received 19.54 and 25.96 inches, representing a return interval of 20 to 40 years. These areas had drought severity higher than for the same period in 1970-71. The lack of normal rainfall during the wet seasons of 1980 and 1981 was the main reason why the lake stage dropped to its record low value of 9.75 ft.

III. Hydrologic Data Analysis

In this part of the report, hydrologic parameters other than rainfall were analyzed. The analysis focused on the major water storage areas within the District. The results of this in-depth hydrologic data analysis provides substantial insight into the hydrologic variables which influence the levels in the lakes and other water storage areas which provide water supplies for agricultural and urban uses. The drought period used in this hydrologic analysis was the same as the period used in the rainfall analysis, i.e. June 1, 1980 through February 28, 1982.

A. Historical Inflows to Lake Okeechobee

As discussed previously, the rainfall generated runoff in the major tributary areas of Lake Okeechobee had a significant impact on the water budget of the lake. Therefore, as a first step in performing a hydrologic analysis of the lake, all inflows to Lake Okeechobee (from its tributaries)based on historical data, were analyzed. The percentage of contribution to the lake was then computed (see Section D).

B. Analysis of Surface Water Flow and Storage

The stage readings at the beginning of each month were analyzed for each major water storage area. The stage readings for Lake Okeechobee and the Water Conservation Areas are based on either the water budget reports prepared by the Army Corps of Engineers or the U.S.G.S. published data. In a few cases, the District daily stage readings were used when the stage in the Water Conservation Areas was so low that the indicator gauges no longer adequately reflected the actual water stages of the areas. Then some adjacent canal stages were averaged to represent the water stage of the areas. The water storage was computed based on the stage-storage curves developed for these water storage areas. The storage change was computed from the difference between the stage reading at the beginning and end of each month. This storage information was then used to evaluate the relationship between rainfall deficit and the lake storage change during a selected drought period.

Table 6 summarizes the surface water runoff contribution to Lake Okeechobee during this selected drought period at each inflow point around the lake. There were several structures without flow for several months.

Table 7 summarizes the amount of water released and withdrawn from Lake Okeechobee during this period. Almost all the flow out of the lake during this period were water supply demand releases, rather than regulatory releases for flood control. Water is generally released from Lake Okeechobee to West Palm Beach, Hillsboro, North New River, and Miami Canals through the Hurricane Gate Structures (HGS) 5, 4, and 3. The water is delivered through these canals to the Water Conservation Areas and the Lower East Coast recharge areas. Most of the water is used to meet agricultural demands in the Everglades Agricultural Areas. These deliveries are frequent during drought periods. The increase of water deliveries through these structures and canals provides some indication of the water demands during a selected period; however, the water use restrictions imposed by the District during the 1980-81 drought period may not have reflected the actual crop demands.

C. Analysis of Evapotranspiration

Evapotranspiration (ET) is one of the major parameters in the hydrologic budget of the storage areas. ET, infiltration (seepage), and

TABLE 6. INFLOW TO LAKE OKEECHOBEE

FROM JUNE 1980 THROUGH FEBRUARY 1982 (AC.FT.)

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Fisheating Creek & Istokpoga Basin																					
S-84	0	353	0	120	0	0	0	0	0	0	106	0	0	0	1,202	1,805	0	0	0	0	0
S-127		1,073	1,049	889	1,688	0	450	0	0	0	0	0	0	216	0	0	0	0	0	0	0
S-72	97	1,073	424	119	0	0	0	0	0	0	0	0	0	771	1,352	829	0	0	0	0	0
S-129	974	1,224	1,567	2,698	0	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S-71	232	7,506	3,769	3,348	0	0	0	0	659	0	0	0	0	4,919	4,488	8,527	0	0	0	0	0
S-131	139	369	260	601	173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fisheating Cr.	26	1,894	3,869	10,607	2,977	744	458	194	1,144	244	4	0	0	0	305	24,482	4,381	482	77	81	105
Total	2,541	13,468	10,778	19,181	3,150	1,281	458	194	1,803	244	110	0	0	5,906	7,347	35,643	4,381	482	77	81	105
Normal	49,513	64,869	79,723	96,080	60,628	17,209	12,054	26,483	17,817	37,685	12,994	15,777	49,513	64,869	79,723	96,080	60,628	17,209	12,054	26,483	17,817
% of Normal	5.1	20.8	13.8	19.9	5.2	7.4	3.8	0.8	10.1	0.7	0.8	0.0	0.0	9.1	9.2	37.1	7.2	2.8	0.7	0.3	0.6
Kissimmee River Basins																					
S-154	0	941	396	1,281	0	92	0	0	51	0	0	0	0	0	1,640	2,210	170	0	0	0	0
S-65E	4,655	15,322	22,070	29,729	3,915	5,236	5,796	3,796	5,811	2,170	210	129	40	50	1,330	30,360	1,378	338	87	192	206
S-133	480	2,993	2,287	3,775	1,577	641	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S-191	560	5,100	800	15,450	2,270	4,120	4,560	1,614	3,140	1,000	0	387	179	1,472	45,230	51,060	2,580	1,240	930	1,060	1,550
Total	5,695	24,356	25,553	50,235	7,762	10,089	10,356	5,410	9,002	3,170	210	516	219	1,522	48,200	83,630	4,128	1,578	1,017	1,2152	1,756
Normal	73,192	129,330	158,724	170,133	121,768	40,087	25,793	76,914	83,420	99,508	65,367	63,526	73,192	129,330	158,724	170,133	121,768	40,087	25,773	76,914	83,420
% of Normal	7.8	18.8	16.1	29.5	6.4	25.17	40.2	7.0	10.8	3.2	0.3	0.8	0.3	1.2	30.4	30.9	3.4	3.9	3.9	1.6	2.4
Everglades Agricultural Areas																					
C-10A	0	0	0	1,319	0	0	0	0	0	0	0	0	800	294	11,952	35,988	5,780	0	0	0	2,020
S-4	904	2,148	2,771	3,995	0	565	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S-3 HGS-3	0	0	470	327	0	0	0	0	0	0	0	0	5,179	522	57,089	50,148	0	17,899	0	0	0
S-2 HGS-4	0	0	0	6,19	0	0	0	0	0	0	0	1,232	0	0	108,014	83,778	0	33,898	0	164	8,724
HGS-5	0	0	0	0	0	0	0	0	0	0	0	4,979	0	0	6,170	0	0	0	0	0	0
HGS-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag. Pump	3,325	9,465	7,886	22,383	0	0	0	0	0	0	0	3,194	9,584	4,153	42,807	5,750	0	0	0	0	0
Total	4,429	11,613	11,107	34,143	0	565	0	0	0	0	0	9,405	15,563	4,969	226,032	175,674	5,780	51,797	0	164	10,744
Normal	69,129	63,179	62,051	123,449	33,632	18,291	14,105	13,049	8,831	18,485	6,276	35,820	69,129	63,179	62,051	123,449	33,632	18,291	14,105	13,049	8,031
% of Normal	6.4	18.4	17.9	27.7	0.0	3.1	0.0	0.0	0.0	0.0	0.0	26.3	22.5	7.9	364.3	142.3	17.2	283.2	0.0	1.3	114.6
Upper East Coast																					
S-153	0	298	520	3,681	674	397	770	738	964	791	559	520	444	530	4,314	6,351	1,567	1,111	1,381	1,315	1,974
S-135	331	2,013	357	5,645	631	0	339	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	268	421	126	0	390	0	1,337	0	1,326	7,726	1,526	505	0	0	440	1,896
Total	331	2,311	877	9,326	1,305	665	1,530	864	964	1,181	559	1,857	444	1,856	12,040	7,877	2,072	1,111	1,381	1,755	3,870
Normal	9,048	8,705	9,290	12,230	11,051	6,529	3,149	4,358	3,249	4,395	1,070	6,618	9,048	8,705	9,290	12,230	11,051	6,529	3,149	4,358	3,249
% of Normal	3.7	26.5	9.4	76.3	11.8	10.2	48.6	19.8	29.7	26.9	52.2	28.1	4.9	21.3	129.6	64.4	18.7	17.0	43.9	40.3	119.1
Caloosahatchee River																					
	0	0	0	0	0	0	0	0	0	0	0	0	0	3,398	26,914	44,847	0	0	0	0	0

TABLE 7. OUTFLOW FROM LAKE OKEECHOBEE FROM JUNE 1980 THROUGH FEBRUARY 1982 (AC. FT.)

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Everglades Agricultural Area																					
C-10A	2,694	301	0	288	244	4,820	5,891	4,190	6,342	8,935	9,935	4,955	1,123	1,628	878	0	0	0	0	0	0
Ag. Pump	11,672	0	0	0	15,066	3,954	10,070	13,721	10,807	18,732	31,252	17,435	0	12,424	0	0	21,054	4,851	17,740	0	0
HGS-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HGS-3	37,234	17,477	2,802	0	14,651	8,462	6,151	11,381	3,076	11,923	44,702	48,762	14,620	15,007	1,814	0	5,211	4,043	9,402	7,411	1,599
HGS-4	27,790	1,920	0	0	4,323	4,715	1,544	11,773	6,484	18,948	21,668	45,865	19,058	23,543	1,145	0	8,387	3,510	16,196	6,304	2,941
HGS-5	14,302	2,470	0	35	4,490	3,157	8,881	10,297	1,462	6,132	26,513	9,213	21,650	11,394	1,809	0	6,011	3,527	12,737	6,111	5,068
Total	93,692	22,168	2,802	323	38,774	25,108	32,537	52,082	28,171	64,710	184,070	126,230	56,451	63,991	5,449	0	40,663	15,931	56,075	0	0
Normal	32,163	15,228	16,845	5,207	30,706	46,007	43,863	45,255	43,659	81,610	126,728	72,593	32,163	15,228	16,845	5,207	30,706	46,007	48,863	45,255	43,659
% of Normal	291.3	145.6	16.6	6.2	126.3	54.6	74.2	115.1	64.5	79.3	145.2	173.9	175.5	420.2	32.3	0.0	132.4	34.6	127.8	0	0
Caloosahatchee River																					
Total	63,129	2,562	1,067	298	16,096	4,764	4,655	13,373	3,906	20,301	36,996	37,137	14,279	5,141	120	0	7,295	5,088	8,642	7,666	986
Normal	40,251	40,635	69,291	9,072	33,245	25,333	18,161	37,153	38,822	53,037	68,146	32,078	40,251	40,635	69,291	9,072	33,245	25,333	18,161	37,153	38,822
% of Normal	156.8	6.3	1.5	3.3	48.4	18.8	25.6	36.0	10.1	38.3	54.3	115.8	35.5	12.7	0.2	0.0	21.9	20.1	47.6	20.6	2.5
St. Lucie Canal																					
Local	7,694	3,310	1,904	0	12,316	4,178	7,988	7,831	7,785	17,409	11,534	12,327	4,885	2,000	0	0	0	3,200	6,828	3,566	0
S-80	4,455	9,648	7,097	20,839	2,848	1,071	1,107	5,653	12,760	8,821	5,217	1,107	714	738	0	0	0	0	0	0	0
Total	12,149	12,958	9,001	20,839	15,164	5,249	9,095	13,484	20,545	26,230	16,753	13,434	5,599	2,738	0	0	0	3,200	6,828	3,566	0
Normal	24,271	47,319	57,946	11,079	25,533	23,766	2,811	14,193	16,989	29,358	33,954	7,265	24,271	47,319	57,946	11,079	25,533	23,766	2,811	14,193	16,989
%Normal	50.0	27.4	15.5	188.1	59.4	22.1	323.6	95.0	120.9	89.3	49.3	184.9	23.1	5.8	0.0	0.0	0.0	13.5	242.9	25.1	0.0

TABLE 8. EVAPORATION DATA

Period June 1980 Through February 1982 - Unit in Inches

Station	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Belle Glade	7.19	7.16	6.43	4.91	5.07	3.57	3.30	3.63	4.24	6.14	6.72	8.09	7.06	7.52	5.40	5.42	5.21	4.05	4.00	3.58	0
Lake Alfred	8.79	7.80	7.94	6.67	5.97	3.77	3.02	5.43	6.26	8.35	9.67	10.54	9.34	8.94	7.56	6.54	6.02	4.30	3.28	3.84	4.54
Lake Okeechobee	6.83	4.81	4.65	4.28	4.58	2.83	2.53	2.98	3.17	4.97	6.75	7.93	6.67	6.81	3.67	4.64	5.09	3.69	2.97	2.99	3.31
WCA-1	5.26	5.12	4.57	4.19	4.25	2.81	2.60	3.07	3.00	5.41	6.18	7.11	5.54	5.13	5.55	5.32	4.49	3.23	3.13	3.00	3.64
WCA-2A	5.26	5.12	4.57	4.19	2.81	4.25	2.60	3.07	3.00	5.41	6.18	6.61	5.54	5.13	5.55	5.32	4.49	3.23	3.13	3.00	3.64
WCA-3A	5.41	5.33	4.57	4.54	4.28	2.87	2.46	3.09	2.93	5.10	5.82	6.62	5.31	5.10	5.07	5.32	4.38	2.94	2.60	2.67	3.35

Average for Period June 1981 Through May 1982 - Unit in Inches

Station	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
Belle Glade	6.31	6.44	6.14	5.36	4.83	3.72	3.20	3.41	4.02	5.72	6.55	7.12
Lake Alfred	7.20	7.43	7.00	6.28	5.39	3.91	3.15	3.32	4.06	6.17	7.32	8.35
Lake Okeechobee	5.93	5.94	5.30	4.60	4.57	3.45	2.73	2.82	3.27	4.99	6.26	6.53
WCA-1	4.62	4.93	4.71	3.83	3.78	2.95	2.59	2.51	2.94	4.67	5.79	5.64
WCA-2A	4.62	4.93	4.60	3.61	3.78	2.95	2.59	2.51	2.94	4.67	5.79	5.41
WCA-3A	4.70	5.07	4.70	3.87	3.76	3.08	2.62	2.54	2.89	4.61	5.77	5.75

the demand withdrawals increase with coincident decreases in rainfall.

Evaporation data is a good indicator in the estimation of agricultural water demands. The pan evaporation data at Belle Glade and Lake Alfred Experimental Stations were selected as index stations, along with the evaporation data from Lake Okeechobee and the three Water Conservation Areas (Table 8). The evaporation data from Lake Okeechobee was computed by the Army Corps of Engineers based on pan evaporation data at HGS-2 and HGS-6 and then reduced by the coefficient 0.865 recommended for large water bodies like Lake Okeechobee. Evaporation data for the Water Conservation Areas was based on pan evaporation data at S-7 and the Tamiami Canal at 40-Mile Bend. The average monthly evaporation data is also shown in Table 8. The average pan evaporation at Belle Glade Experimental Station was based on the period from January 1925 through December 1981; at Lake Alfred Experimental Station, on the period May 1965-December 1981; the Water Conservation Areas, the period January 1963-December 1981. Average evaporation for Lake Okeechobee was based on the average values for the period January 1963-December 1981. These average values were considered "normal" for each area. The term "normal" was also used for flow data for these periods for base line comparison.

D. Results and Discussions

1. Historical Surface Inflow -Lake Okeechobee

The following table compares the percentage of surface inflow contributed by each of the major tributaries to the lake under historical conditions.

Tributary	% Contribution
Kissimmee River	44.84
Everglades Agricultural Area**	21.74*
Fisheating Creek & Istokpoga**	22.89
Taylor Creek/Nubbin Slough	6.82
UEC (St. Lucie Canal)	3.71

*This figure will be reduced as a result of present operational procedures in Lake Okeechobee.

**Istokpoga includes flow through S-127, S-129, S-131, S-71, S-73 and S-84.

The Kissimmee River Basins (upper and lower) contribute approximately 45% of the total inflow. Thus, the availability of rainfall, land use, and water management practices in these basins have a great impact on the lake's water budget. The Everglades Agricultural Area is one of the major users of lake water, and, at the same time, is also one of the major contributors to the lake. Since backpumping from the Everglades Agricultural Area has been suspended, over one-fifth of the water that usually flows to the lake will not be available. The diversion of agricultural runoff normally backpumped to the lake from the Everglades Agricultural Area to the Water Conservation Areas, mainly WCA-3A, has substantially reduced the amount of flow to the lake during the past few years.

2. Overall Water Storage Changes Since June 1, 1980

The overall water storage change in the Upper Kissimmee Lakes, Lake Istokpoga, Lake Okeechobee, and the three Water Conservation Areas for the period June 1, 1980 - February 28, 1982, is plotted in Figure 12. The water storage in Lake Okeechobee decreased since June 1, 1980, and the deficit increased rapidly between September 1, 1980 and July 31, 1981, with a total loss of 2,232,000 AF for the period June 1, 1980 - July 31, 1981. The storage recovered substantially during August 1981 due to Storm Dennis; however, the lake was still below the July 1980 level. Water storage inthe Water Conservation Areas increased during the wet season of 1980, began to decline after September 1, 1980, and dropped below the June 1, 1980 level by November 1, 1980, when the storage was 807,000 AF less than on June 1, 1980. The storage in the Water Conservation Areas approached regulation schedule after Storm Dennis (August 16-18, 1981). The storage change in the Upper Kissimmee Lakes and Lake Istokpoga was much less in magnitude than Lake Okeechobee and the Water Conservation Areas; about 36,000 AF less storage than the June 1980 level for the Upper Kissimmee Lakes, and a gain of 270 AF in Lake Istokpoga for the period June 1980 through July 1981.

3. Upper Kissimmee Lakes

The storage change in the Upper Kissimmee Lakes is normally due to evaporation, seepage, and regulatory releases when the lake stages exceed their regulation schedules. The gain in lake storage depends on rainfall over the basin.

Figures 13 and 14 show the readings at the beginning of each month from January 1980 through December 1982 as compared to the historical maximum, minimum, and average at Lake Tohopekaliga and Lake Kissimmee. The stage was slightly above normal during the first three months of 1980, then fell below normal until December

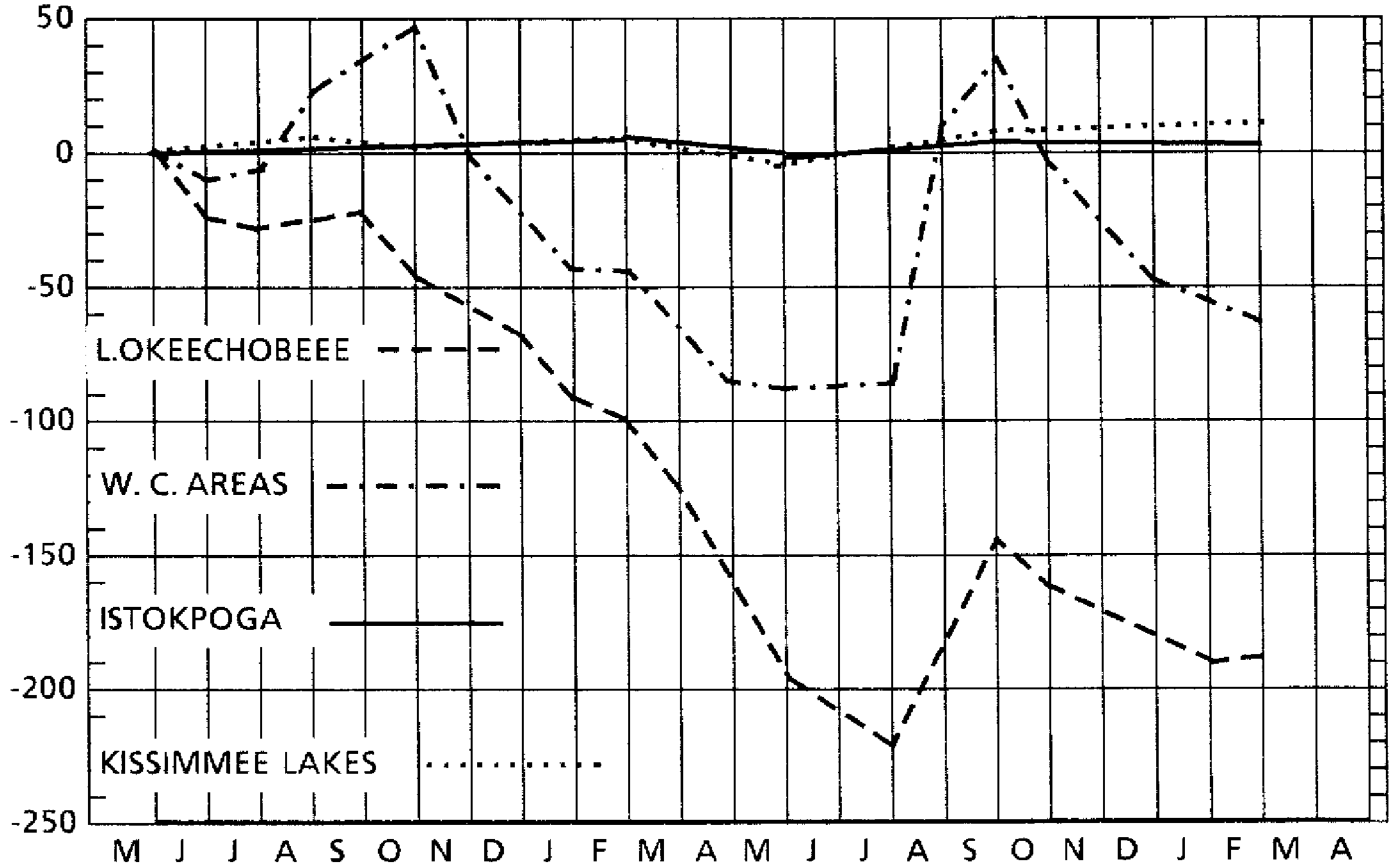

FIGURE 12. SURFACE WATER STORAGE CHANGE JUNE, 1980 TO MARCH, 1982.

1981 in Lake Tohopekaliga, and was still about two feet below normal in Lake Kissimmee.

However, during the drought period of June 1980 through December 1981 the lake stages did not drop drastically as the rain-fall deficit increased. The total water in storage by August 1981 was above the June 1980 level even though the rainfall deficit was 21.84 inches from June 1980. Figure 15 shows a plot of accumulated rainfall deficit and total lake storage change during this period. The storage decreased slightly when the rainfall deficit became greater than 14 inches; however, the storage increased even with an increase in the rainfall deficit. This implies that these lakes were receiving a certain amount of groundwater recharge, through seepage from upland basins, which was sufficient to offset the evaporation. (Refer to Table 8 for evaporation data at Lake Alfred, and Table 4 for rainfall deficit).

4. Lake Okeechobee

As previously presented, the total rainfall deficit over most of the District's area during this drought period was more than 23 inches. The Everglades Agricultural Area experienced a deficit of 25 to 30 inches; a deficit of 30.5 inches was recorded in the Kissimmee River Valley, and a deficit of 27.5 inches was observed in the Fisheating Creek and the Lake Istokpoga areas. These rainfall deficits had an unquestionable effect on the runoff contributions to Lake Okeechobee.

a. Surface Water Inflow from Fisheating Creek and Lake Istokpoga Areas

This area normally contributes about 22.9% of total inflow to Lake Okeechobee which is about 491,000 AF per year. The normal runoff contribution from these basins to Lake Okeechobee from June 1980 through February 1982 should have been 915,000 AF as compared to 107,230 AF during this drought period, or 11.7% of normal. (The analysis of monthly flows is presented in Table 6.) The percent of normal ranged from 0 to 37.1 of the monthly normal. In particular, May and June 1981 were very dry.

b. Surface Water Inflow from Everglades Agricultural Area

The total runoff contribution from June 1980 through July 1981 was only 91,794 AF as compared to 598,600 AF under normal conditions, representing only 15.3% of normal. The monthly

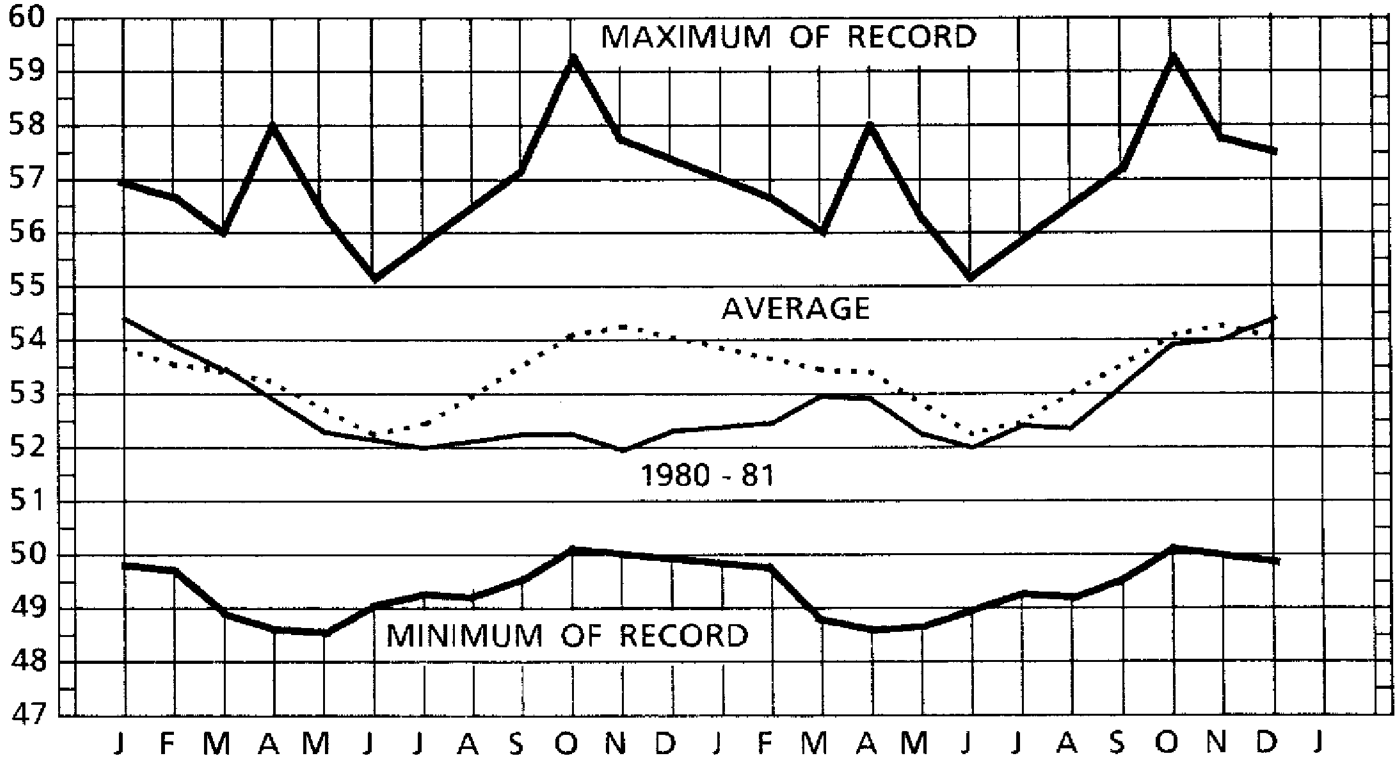

FIGURE 13. STAGE HYDROGRAPH - LAKE TOHOPEKALIGA (1980-1981)

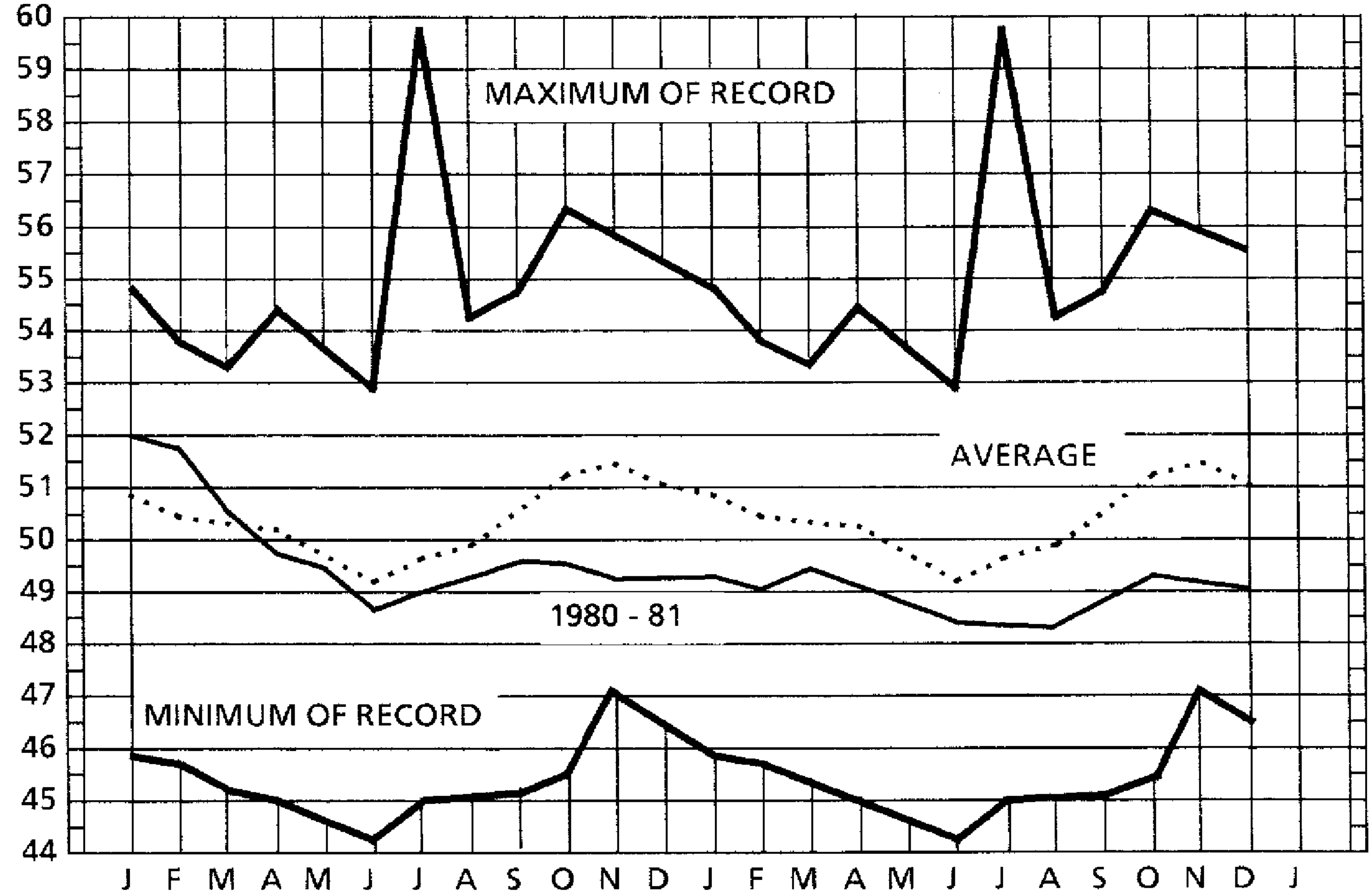

FIGURE 14. STAGE HYDROGRAPH - LAKE KISSIMMEE (1980 - 1981)

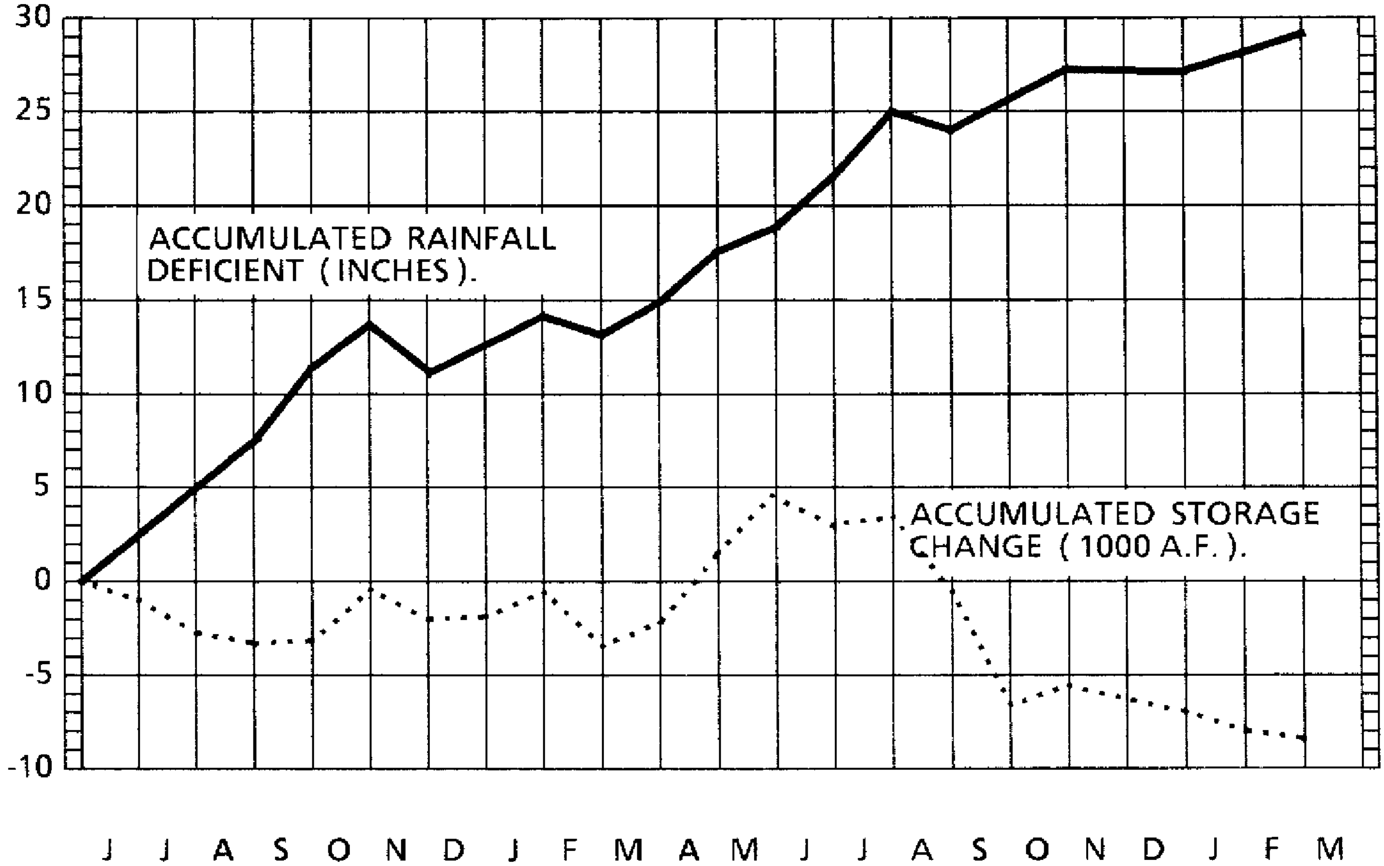

FIGURE 15. ACCUMULATED DEFICIENCIES - UPPER KISSIMMEE LAKES

comparisons with the historical normal are also shown in Table 6. The percent of the monthly normal ranged from 0 to 37.1, with several months close to zero flow during the dry season. Therefore, it is obvious that the reduction in back-pumping from the EAA to Lake Okeechobee, and the lack of rainfall, had a great deal of impact on runoff contributions to Lake Okeechobee. Due to Tropical Storm Dennis (August 16-18, 1981), runoff from the EAA was back-pumped into the lake; thus, the inflow from the EAA was substantially increased during late August and September 1981.

c. Surface Water Inflow from St. Lucie Canal Basin

The amount of inflow from this basin can be estimated from the flow through Port Mayaca lock. Since the lock was not activated until July 1978, the historical inflow to the lake from this basin was estimated by using a rainfall-runoff relationship based on the mass balance of average basin rainfall, discharges at the Port Mayaca Lock and the St. Lucie Lock, and storage change in the St. Lucie canal. The monthly inflows to Lake Okeechobee during this drought period are tabulated in Table 6.

A total of 54,200 AF was estimated through Port Mayaca lock representing 36.8% of normal.

d. Surface Water Inflow from Kissimmee River Basin

The Kissimmee River basin generally contributes about 45% of the total inflow to Lake Okeechobee. The total contribution during the period of June 1980-July 1981 (14 months) was about 154,000 AF, which is 11.8% of normal. The total contribution for the 21 month period, June 1980-February 1982, was about 295,700 AF, or 14.9% of normal. Almost the same amount of flow was contributed to the lake during the seven month period of August 1981-February 1982, than in the preceding 14 months. (See Table 6 for monthly values). The lack of runoff from the Kissimmee was one of the major factors that caused the lake stage to drop to its record low on July 29, 1981.

e. Surface Water Outflows from Lake Okeechobee

Surface water outflows from Lake Okeechobee are essentially made to meet local demands, or for regulatory releases. Table 7 illustrates the total surface water releases to the Everglades Agricultural Areas and the St. Lucie Canal and Caloosahatchee River basins as compared to the historical norm, including regulatory releases. The total releases during this 21 month period were 909,227 AF for EAA, 253,500 AF for the Caloosahatchee River, and 196,832 AF for St. Lucie Canal. Therefore, the total surface water release for this 21 month period was 1,359,559 AF as compared to the total surface water inflow of 1,094,206 AF for the same period. Evaporation is the major outflow from Lake Okeechobee.

Table 8 shows the monthly evaporation data for selected locations within the District area. As compared to the total rainfall of 55.4 inches, total evaporation lost for this 21 month period was 96.15 inches for Lake Okeechobee. This loss was 101.2% of normal. The table below summarizes the total inflow, outflow, rainfall, and evapora-tion for the period June 1980 through July 1981, and August 1981 through February 1982.

Comparison of Surface Water Inflows and Outflows in Lake Okeechobee

	June '80 July '81 (AF)	% of Normal	Aug. '81 Feb. '82	% of Normal
S.W.Inflow	332,471	12.7	761,735	58.1
Rainfall	1,405,000	68.3-	655,000	82.7
Total Inflow	1,737,471		1,416,735	
S.W.Outflow	1,198,050	78.8	161,509	26.3
Evapotrans-piration	2,771,200	102.2-	944,000	98.4
(Inches)	69.79			
Total Outflow	3,969,250		1,105,509	
(Outflow-Inflow)				
	2,231,779 Deficit		-311,226 Increase	

Total water releases from Lake Okeechobee for the period June 1980 through July 1981 were more than three times the total inflow, and the total ET losses were almost twice as much as rainfall input to the lake, and more than twice the amount of surface water outflow from the lake. Therefore, it can be concluded that far below normal rainfall and surface inflow were the primary causes of the lake stage dropping to a record low of 9.75 ft msl on July 29, 1981. The increasing rainfall and inflow during the period from August 1981 through February 1982, combined with a reduction of outflows, were the main reasons that the lake stage started to recover.

f. The Water Conservation Areas

The Water Conservation Areas receive runoff from the Everglades Agricultural Areas and a portion of the C-11 basin in Broward County; therefore, a rainfall deficit in these areas will have an impact on the amount of inflow to the WCA's.

There is a close correlation between rainfall deficit and the reduction of water storage in the Water Conservation Areas for the period June 1980 through July 1981. Due to Tropical Storm Dennis, water storage in the WCA's recovered and reached the top of regulation schedule on August 20, 1981.

The following table summarizes the total rainfall, inflows, outflows, water releases, and ET for the WCA's for the period June 1980 through July 1981 as compared to normal values.

WCA	Rainfall % Norm	Inflow % Norm	Outflow % Norm	Total Coastal Releases % Norm	ET % Norm
1	70.0	35.4	55.8	208.8	110.0
2A	67.0	35.3	73.2	80.7	110.0
3A	81.3	69.1	30.3	122.1	107.3

A drawdown in WCA-2A started November 1, 1980, causing a substantial amount of water to be released to WCA's 2B and 3A. The ET rate increased from 7% to 10% above normal. The water releases for WCA-1 were also above normal. Seepage during this period was less than normal due to lower hydraulic heads; therefore, the reduction of water storage in the WCA's was due to the lack of normal rainfall, surface water inflows, and an increase in ET in the areas. (Ref. Tables 9 , 10, and 11 f 9or quantitative comparisons.)

g. Hydrological Comparisons, of Droughts of 1970-71, 1973-74, 1980-81

Table 12 shows the comparisons of surface water inflows from tributaries to Lake Okeechobee during June through October and November through May for the droughts of 1970-71, 1973-74 and 1980-81. The surface water inflows during the 1980-81 drought were far less than during the droughts of 1970-71 and 1973-74. Inflow from the Kissim-mee River was slightly above normal during the period June 1970 through October 1970 as compared to 31% of normal for the same period in 1973, and 16% of normal for the 1980-81 drought. The surface water inflows during the dry season of 1980-81 were also far less than for other drought periods except for the St. Lucie Canal basin.

Table 13 presents the comparisons of the surface water outflows from Lake Okeechobee during the periods June-October and November-May. In general, the outflows from the lake during the 1980-81 drought were more than for the 1970-71 and 1973-74 drought periods, except for releases to the Everglades Agricultural Areas during the dry season. This was due to the water supply restrictions during the 1980-81 dry season. All these outflows were demand deliveries. The water demand increases as the rainfall decreases.

Tables 9, 10, and 11 show the comparisons of rainfall, surface water inflows, outflows and water releases in the three Water Conservation Areas for the wet (June through October) and dry (November through May) seasons.

Table 9 shows these comparisons for WCA-1. The wet season rainfall for the 1980 drought was less than other previous dry years, such as 1970, 1971, 1973, and 1974. Dry season rainfall for 1980-81 was more than for 1970-71, but less than for 1973-74. Inflows to WCA-1 during the 1980 and 1981 wet seasons were slightly more than during the 1970 wet season, but far below the 1973 inflows in the wet season. However, the inflows to WCA-1 during the dry season of 1980-81 were slightly higher than those in the 1970-71 and 1973-74 dry seasons. Outflows from WCA-1 during the wet season of 1980-81 were about the same as in 1970, 1973, and 1974, but much greater than in 1971 which was only 0.1% of normal. Outflows during the dry season of 1980-81 were slightly more than in 1970-71 and in 1973-74; however, water releases to meet local demands from WCA-1 during the 1980-81 drought were much greater than other previous droughts. Outflows from WCA-1 included the outflows through the S-10 structures and water releases through S-5A(S), S-3 at L-40 (Lake Worth Drainage District), and S-39, etc. The local dry season demand in the east Palm Beach County area from WCA-1 was 174.9% of normal as shown in the last column of Table 9.

Table 10 shows the comparisons of rainfall, inflow, outflow and water releases for WCA-2A. The wet season rainfall of the 1980-81 drought was less than other previous drought periods, in general. The dry season rainfall was slightly more than in 1970-71, but less than in 1973-74. Inflow to WCA-2A during the wet season of 1980-81 was much greater than in 1971, but less than other periods. Inflow to WCA-2A during the dry season of 1980-81 was less than other periods, which may have been due to the drawdown schedule at the time. Outflows from WCA-2A during the 1980 wet season and the 1980-81 dry season were more than in other periods, a contributing factor to the increase in outflows was the drawdown schedule in WCA-2A.

Table 11 shows the comparison of rainfall, inflow, and outflow in WCA-3A. The wet season rainfall for 1980 was 20% less than in other drought periods; however, the dry season rainfall in 1980-81 was more than in 1970-71 and in 1973-74. Surface inflows to WCA-3A were near normal for the wet seasons of 1970 and 1980, and 150% to 250% of normal for 1973 and 1974. The surface inflows to WCA-3A during the dry seasons of 1970-71, 1973-74, and 1980-81, however, were approximately 27, 47, and 50 percent of normal, respectively. Surface outflows during the wet season of 1971 were about 34% of normal as compared to 49% and 54% of normal for 1973 and 1980,

TABLE 9. COMPARISON OF RAINFALL, SURFACE WATER INFLOW AND OUTFLOW IN WCA-1

	Rainfall Inches	% of Normal	Inflow AF	% of Normal	Total Outflow AF	% of Normal	Water Releases to LEC AF	% of Normal
Period: June - October								
1970	25.44	81.5	201,850	45.0	210,362	108.6	28,732	185.4
1971	30.51	97.7	163,967	36.6	200	0.1	200	1.3
1973	34.84	111.6	296,670	66.1	158,190	81.7	760	4.9
1974	31.00	99.3	411,480	91.7	263,900	136.3	2,340	15.1
1980	22.24	71.2	216,710	48.3	188,580	97.4	61,650	397.9
1981	29.17	93.4	174,398	38.9	165,235	85.3	22,420	144.7
Period: November - May								
1970-1971	9.34	56.7	36,893	25.0	58,340	31.6	58,340	115.9
1973-1974	16.01	97.3	25,399	17.2	47,110	25.5	30,410	60.4
1980-1981	11.68	71.0	38,491	26.1	88,037	47.7	88,037	174.9

TABLE 10. COMPARISON OF RAINFALL, SURFACE WATER INFLOW AND OUTFLOW IN WCA-2A

	Rainfall Inches	% of Normal	Inflow AF	% of Normal	Total Outflow AF	% of Normal	Water Releases to L.E.C. AF	% of Normal
Period: June - October								
1970	30.78	98.3	224,450	84.7	267,037	138.6	74,710	305.1
1971	31.40	100.3	67,391	25.4	4,130	2.1	4,130	16.9
1973	29.65	94.7	254,650	96.1	116,500	59.7	4,320	17.6
1974	28.67	90.0	449,530	169.6	82,050	42.0	880	3.6
1980	22.79	72.8	192,910	72.8	280,280	143.5	28,680	117.1
1981	34.08	108.8	188,320	71.0	219,630	112.5	1,350	5.5
Period: November - May								
1970-1971	8.40	54.0	37,275	19.5	52,490	24.7	50,170	170.9
1973-1974	12.33	79.2	48,232	25.2	131,860	61.9	43,680	148.8
1980-1981	10.35	66.5	21,513	11.3	100,933	47.4	29,090	99.1

TABLE 11. COMPARISON OF RAINFALL, SURFACE WATER INFLOW AND OUTFLOW IN WCA-3A

	Rainfall Inches	% of Normal	Inflow AF	% of Normal	Outflow AF	% of Normal	Water Delivery to ENP/AF
Period: June - October							
1970	27.09	90.9	439,840	106.1	478,650	155.4	431,850
1971	28.73	96.5	381,160	92.0	106,090	34.4	104,090
1973	31.85	107.0	616,890	148.9	149,780	48.6	140,970
1974	28.54	95.8	1,058,900	255.5	324,210	105.3	324,210
1980	23.00	77.2	399,332	96.4	165,240	53.6	165,240
1981	35.92	120.6	398,493	96.2	149,840	48.6	136,450
Period: November - May							
1970-1971	7.96	54.97	91,059	26.9	152,440	19.6	132,060
1973-1974	6.62	45.72	159,236	47.0	178,290	22.9	122,190
1980-1981	12.60	87.02	169,992	49.6	172,449	22.2	130,390

TABLE 12. COMPARISON OF INFLOW TO LAKE OKEECHOBEE

	Fisheating Creek & Istokpoga Basin		Kissimmee River		Agricultural Areas		Upper East Coast	
	AF	% Normal	AF	% of Normal	AF	% of Normal	AF	% of Normal
Period: June - October								
1970	164,473	45.54	814,790	116.52	273,558	87.57	18,570	24.80
1971	355,503	90.3	371,279	56.93	607,398	189.18	43,594	58.22
1973	516,600	143.05	216,140	30.91	238,627	76.39	93,124	127.09
1974	730,339	205.4	1,507,819	231.20	385,643	120.11	96,193	128.45
1980	46,281	12.80	112,902	16.16	27,668	8.86	57,394	76.65
1981	70,996	20.0	170,380	29.27	376,955	117.41	47,343	63.23
Period: November-May								
1970-1971	4,508	3.09	240,908	53.88	26,757	22.62	1,920	4.05
1973-1974	13,777	9.46	164,150	36.71	38,914	32.90	11,244	23.72
1980-1981	2,895	1.99	38,769	8.67	11,011	9.31	17,674	37.28

TABLE 13. COMPARISON OF OUTFLOW FROM LAKE OKEECHOBEE

	Everglades Agricultural Area		Caloosahatchee		St. Lucie Canal	
	AF	% of Normal	AF	% of Normal	AF	% of Normal
Period: June - October						
1970	57,000	58.62	524,740	247.10	11,688	5.73
1971	19,757	44.65	5,299	6.19	2,872	3.37
1973	68,180	70.12	7,542	3.55	46,745	22.96
1974	29,512	66.69	66,690	77.96	27,775	32.58
1980	113,758	116.99	84,273	39.68	95,705	47.02
1981	105,327	238.02	25,837	30.20	26,218	30.75
Period: November - May						
1970-1971	561,925	129.61	98,370	34.62	35,790	16.78
1973-1974	570,066	131.49	93,100	32.76	65,056	30.51
1980-1981	357,303	82.41	117,240	41.26	108,461	50.86

respectively. The surface outflows during the dry season of 1970- 71, 1973-74, and 1980-81 were about 20% of normal. Surface outflows from WCA-3A were, generally, either releases to meet Everglades National Park demands or releases to recharge wellfields close to the Miami Canal. The system was not able to meet minimum park requirements during the wet seasons of 1971, 1973, and 1981, and the dry seasons of 1970-71, 1973-74, and 1980-81. Thiswas due to severe water shortages in the area caused by severe rainfall deficits.

IV. CONCLUSIONS

The aforementioned findings can be summarized briefly, as follows:

A. The overall water loss during the period June 1, 1980 through July 31, 1981 from the major water storage areas within the District was 3,074,730 AF. Lake Okeechobee alone lost about 2,232,000 AF, the Water Conservation Areas lost about 807,000 AF and the Upper Kissimmee Lakes lost about 36,000 AF. Lake Istokpoga gained 270 AF. The period from August 1981 through February 1982, although less than normal, was still a filling period for most of the water storage area with the exception of the Water Conservation Areas. Water storage increased substantially in the Water Conservation Areas after Tropical Storm Dennis (August 16-19, 1981). The conditions in the Lower East Coast area and the rest of the south Florida peninsula were drastically changed from drought to flooding conditions.

B. There were significant increases in evaporation in the Upper Kissimmee Basin as recorded at the Lake Alfred experimental station (approximately 121% of normal during June 1980 through July 1981). The overall evaporation for the 21 month period (June 1980 through Febru-ary 1982) was slightly above normal. The increasing rainfall deficit did not significantly decrease the storage in the Upper Kissimmee Basin lakes. This implied that the lakes were receiving a certain amount of groundwater recharge from the upland basins sufficient to compensate the increasing evaporation loss due to lack of rainfall in the basin. Lake Istokpoga had similar conditions in which the storage did not decrease further with increased rainfall deficit.

C. Total runoff contribution to Lake Okeechobee from Fisheating Creek and Lake Istokpoga during the period of June 1980-February 1982 was 11.7% of normal, and 9.8% of normal for the June 1980-July 1981 period. The rainfall deficit for the same period was 27.5 inches for the Fisheating Creek and Lake Istokpoga basins, and 25 to 30 inches for the Everglades Agricultural Area. The total runoff contribution to Lake Okeechobee during those periods from the Everglades Agricultural Area was 15.3% and 4.1% of normal, respectively. The Kissimmee River and Upper Kissimmee Lakes basins, which generally contribute approximately 45% of the total inflow to Lake Okeechobee, contributed only 14.9% of normal from June 1980 through February 1982, and was 11.8% of normal for the period June 1980 through July 1981. The total rainfall deficit was 21.8 inches for the Upper Kissimmee Lakes, and 30.5 inches for the Kissimmee River Basin. All this indicated that the far below normal rainfall in these major tributaries of Lake Okeechobee had a severe impact on the runoff contribution to the lake.

D. The overall runoff contribution to Lake Okeechobee during the June 1980-July 1981 drought period was approximately 332,500 AF, and the total outflow was approximately 1,198,000 AF (ET not included) which was 360% of the total inflow. The ET rate from the lake during this period was 69.79 inches, or 102.2% of normal, and the rainfall was 37.80% of normal; therefore, the lack of normal rainfall in the lake and its tributaries caused the lake stage to drop to a record low of 9.75 ft msl on July 29, 1981.

E. Evaporation in the Everglades Agricultural Area was about 107% of normal for the period of June 1980 through July 1981. The increasing water delivery during this period indicated an increased water demand resulting from the rainfall deficit and the increasing ET.

F. The drought for the Lower East Coast and the Water Conservation Areas ended right after the passage of Tropical Storm Dennis which caused extensive flooding in the south Dade County area. The total surface inflow to the Water Conservation Areas was about 1,070,000 AF during the drought period from June 1980 through July 1981, and the total water releases from the Water Conservation Areas to the Lower East Coast and the Everglades National Park was about 574,000 AF. Rainfall in the Water Conservation Areas was between 67% to 81% of normal, and ET ranged from 107.3% to 110% of normal. Water releases to the Lower East Coast were 208.8%, 80.7%, and 122.1% of normal for WCA-1, 2A, and 3A; therefore, the water loss in the Water Conservation Areas during this 1980-81 drought was caused by a lack of normal rainfall and an increase in ET and water supply demands.

G. The hydrological comparisons of the 1970-71, 1973-74, and 1980-81 droughts indicated that the 1980-81 drought was more severe and extensive in the District, with the exception of the Lower East Coast area.

APPENDIX A

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DROUGHT FREQUENCY

Since droughts are characterized by long duration, the analysis of meteorological drought in this study was based on the least amount of rainfall that occurred in a specific duration. These specific durations were June through October, June through May of the following year, and November through April. For a given period of available record, the lowest rainfall values for six consecutive months, within a water year, were selected for frequency analysis.

Regional rainfall was based on the major watersheds within the District. A total of 14 basins were selected. The rainfall stations located within or around each basin were used. The monthly rainfall data from these stations were checked and sorted for short term and missing records. Then the basin rainfall was computed based on the weighted Thiessen Coefficient of all available rain gauges. If there were more than one missing record, a new weighted Thiessen Coefficient was computed based on the available rain gauges. If there were only two stations available, then the basin rainfall was based on the average of these two stations. The length of record used in this analysis was approximately 50 years.

The Gumbel Extreme Theory and the Log Pearson Type III Distribution were originally chosen for the analysis of drought frequency. After several statistical tests and plots of data points (Weibull Plotting Position Formula) with values computed from the statistical distributions, it was concluded that the Gumbel Extreme Theory did not provide better results than the Log-Pearson Type III Distribution; therefore, Log-Pearson Type III Distrib-ution was considered suitable for this type of low rainfall analysis. The results of the drought frequency analysis for the 14 basins are shown in Figures A1 through A14.

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A. <u>Weibull Plotting Position Formula</u>

$$P_x(X) = \frac{M}{n+1} \times 100$$

where

$P_x(X)$ = probability of an event X equal or greater

M = largest to the smallest values

n = the number of years of record

B. <u>Log Pearson Type III Distribution</u>

1. Transform the n annual events, X_i, to their logarithmic values Y_i ; i.e. $Y_i = \log X_i$ for i = 1,2,...n
2. Compute the mean logarithm, $\overline{Y}$
3. Compute the standard deviation of the logarithms, S_y
4. Compute the coefficient of skewness, C_s, where

$$C_s = n \frac{\sum (Y - \overline{Y})^3}{(n-1)(n-2)S_y^3}$$

5. Compute $Y_t = \overline{Y} + S_y K_t$

   where K_t is the skew coefficient from Log-Pearson Type III Distribution Table obtained from C_s

6. Compute $X_t = \text{antilog } Y_t$

****

APPENDIX A FIGURES FOLLOW

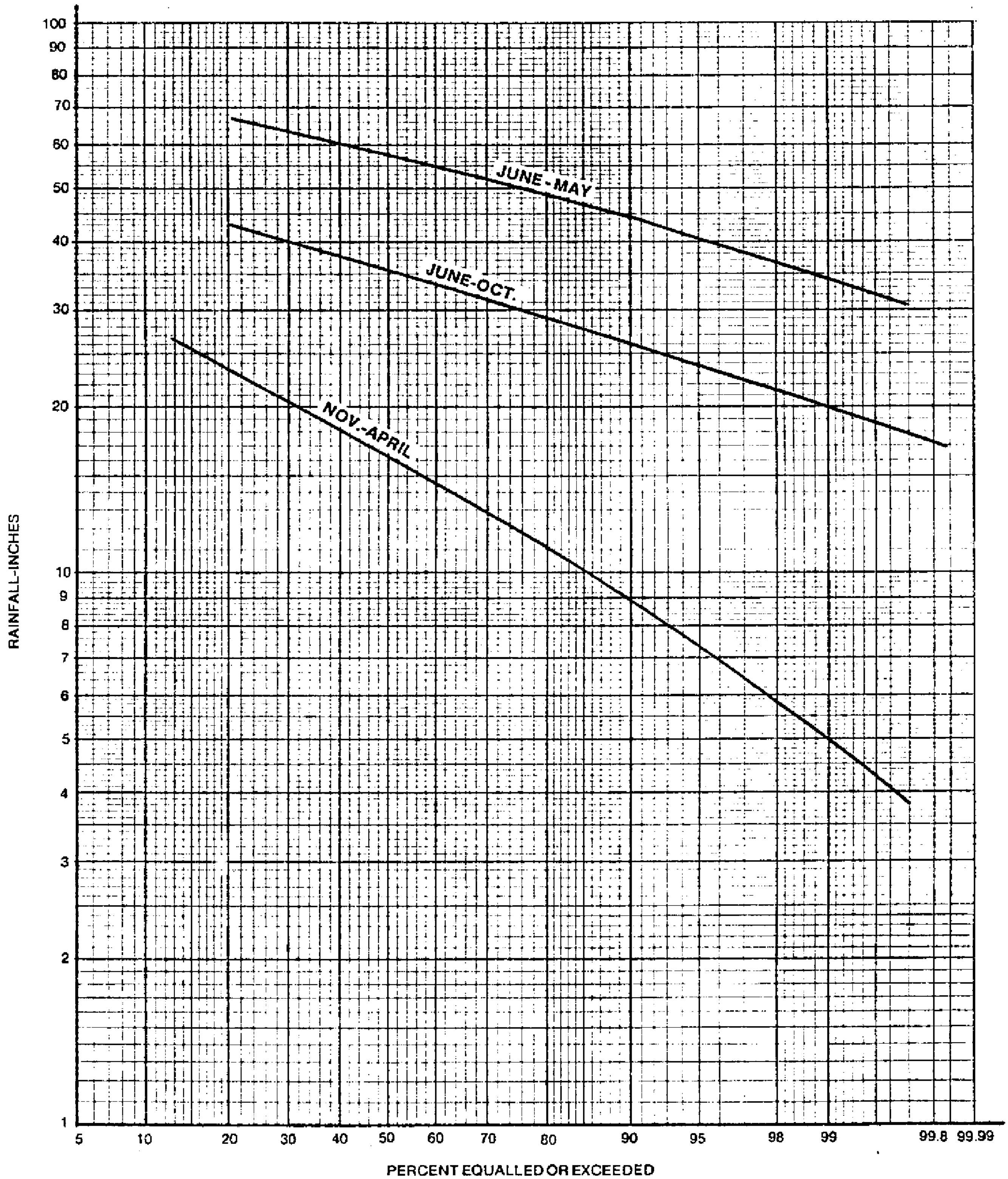

Figure A1 DROUGHT FREQUENCY CURVES FOR EASTERN PALM BEACH COUNTY

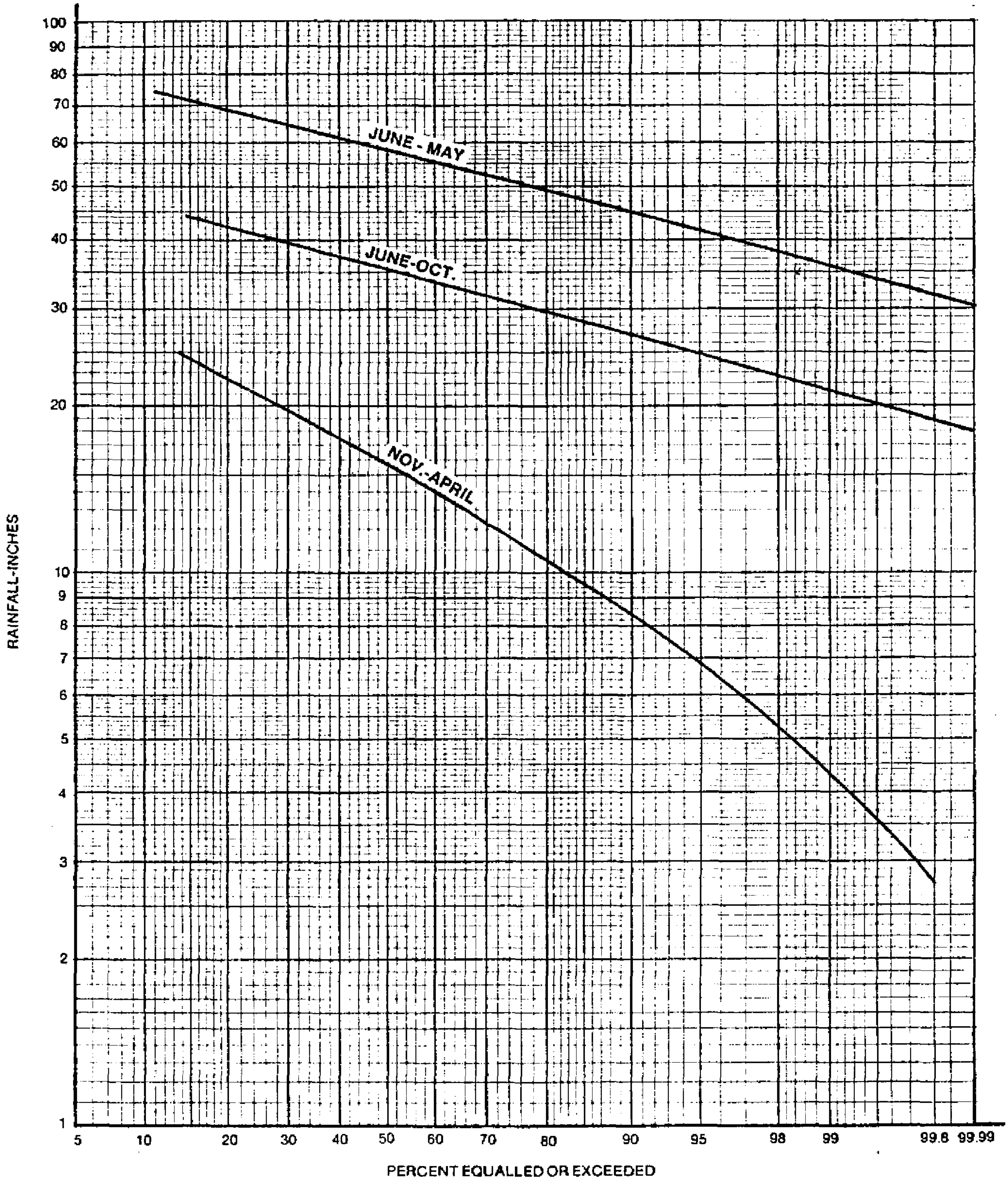

Figure A2 DROUGHT FREQUENCY CURVES FOR EASTERN BROWARD COUNTY

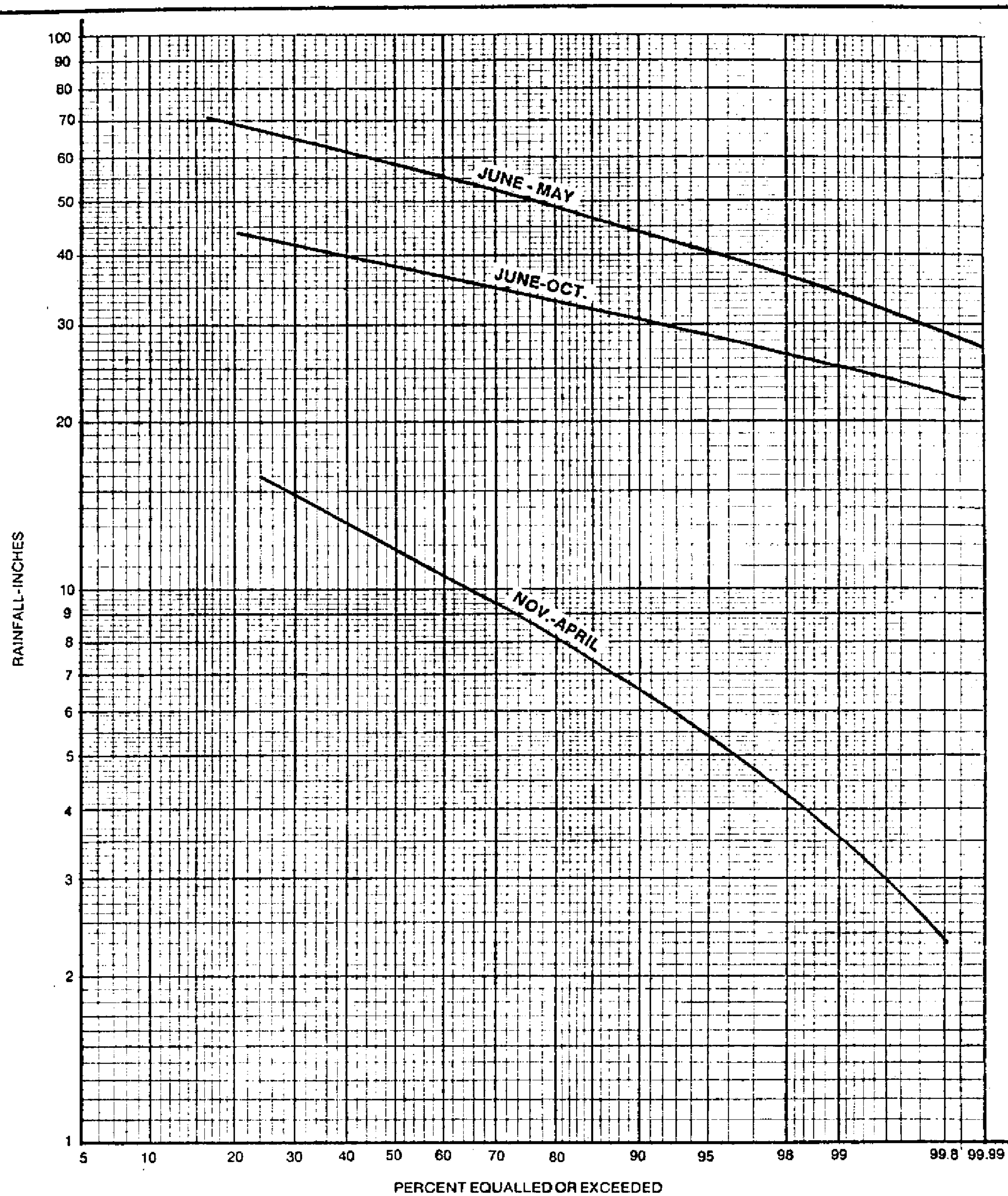

Figure A3 DROUGHT FREQUENCY CURVES FOR DADE COUNTY

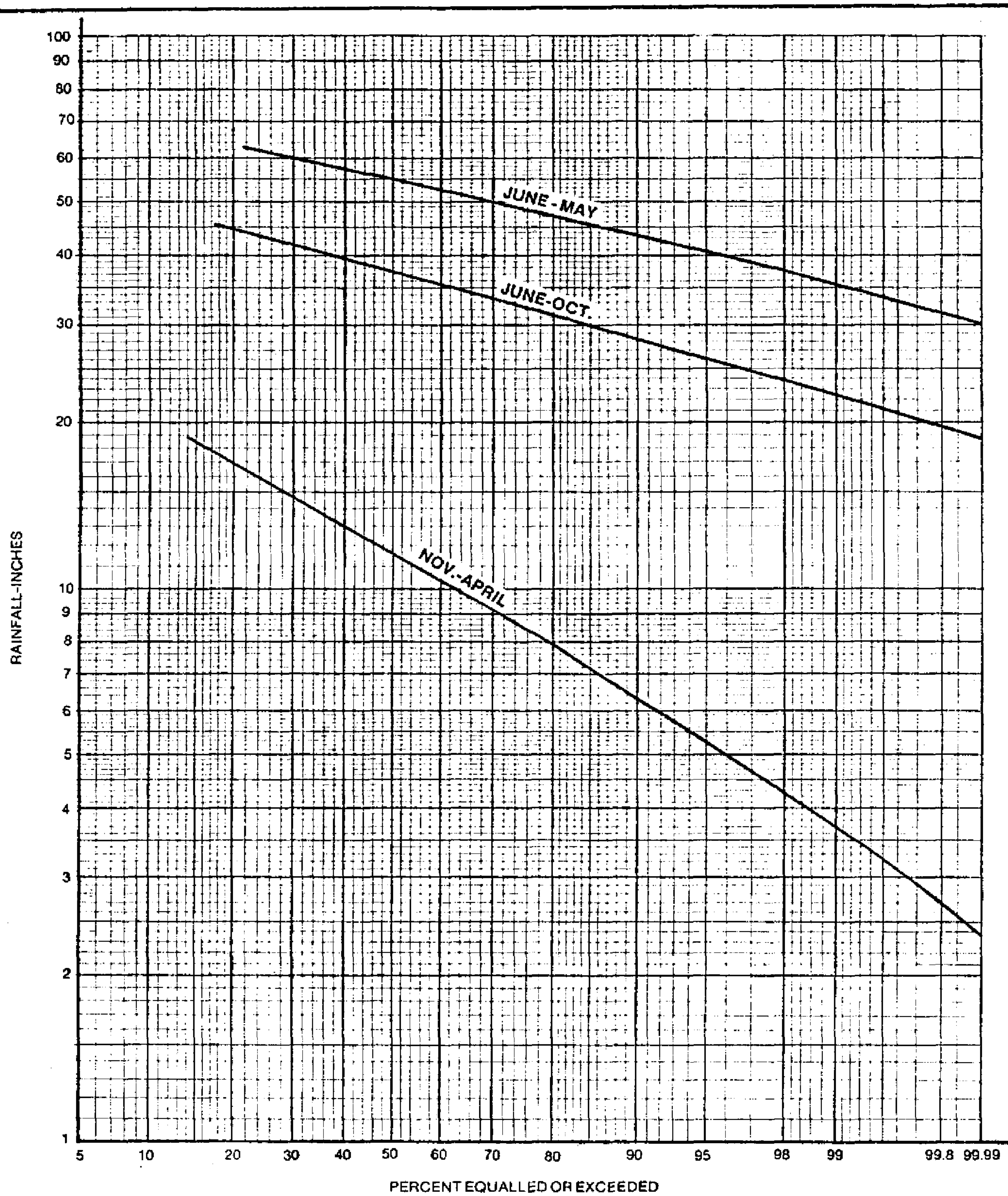

Figure A4 DROUGHT FREQUENCY CURVES FOR E. EVERGLADES AGRICULTURAL AREA

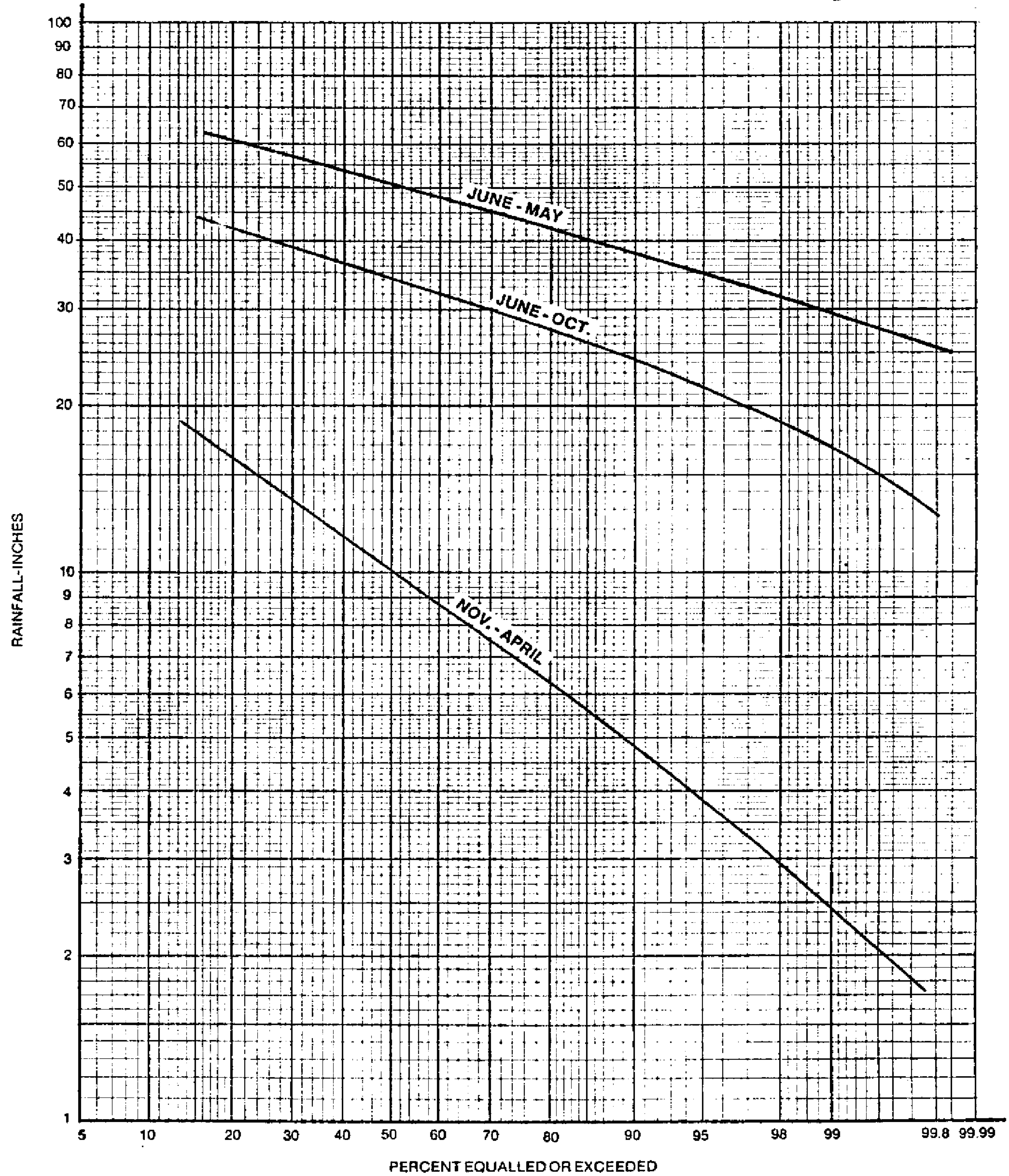

Figure A5 DROUGHT FREQUENCY CURVES FOR W. EVERGLADES AGRICULTURAL AREA

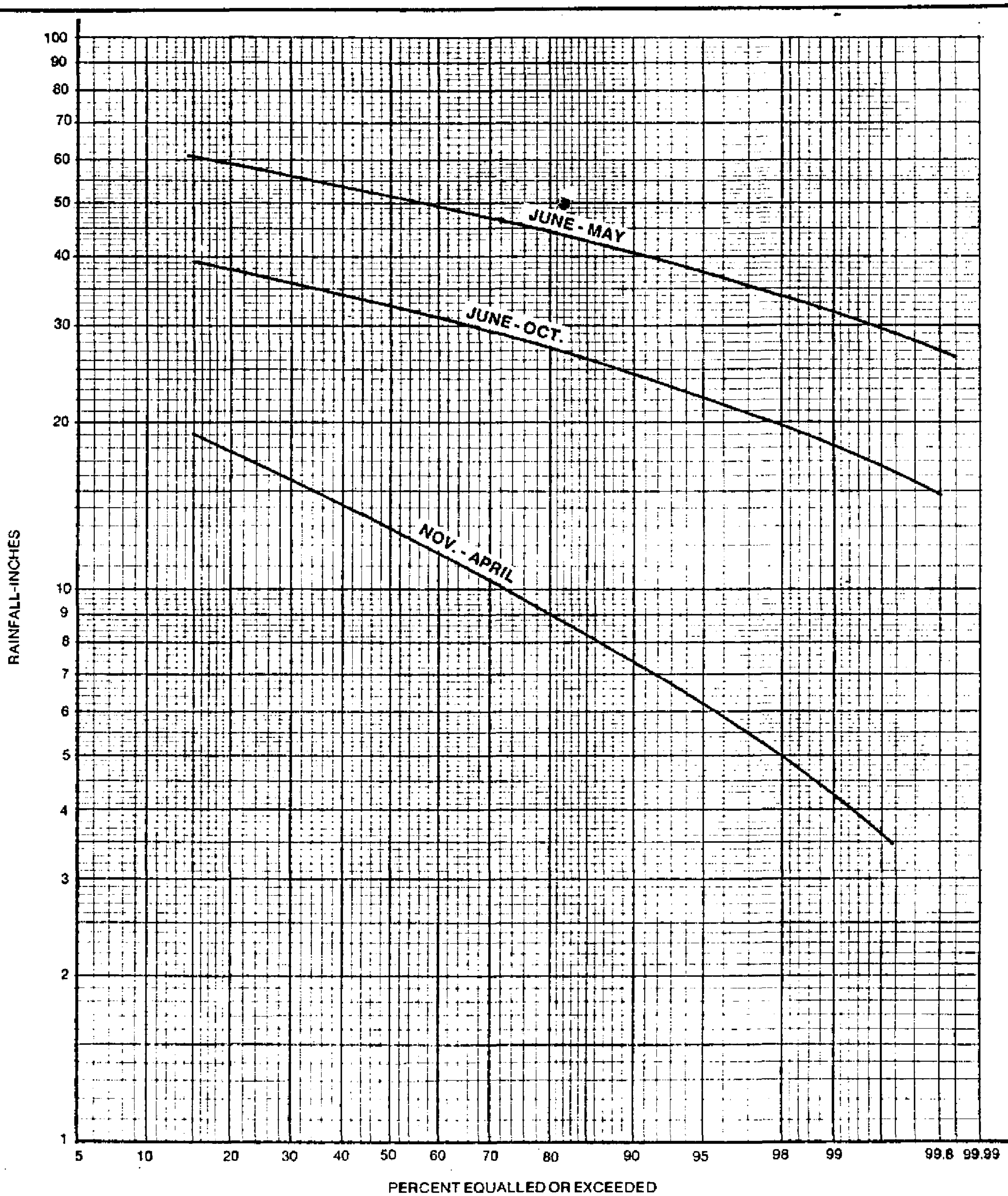

Figure A6 DROUGHT FREQUENCY CURVES FOR THE UPPER EAST COAST

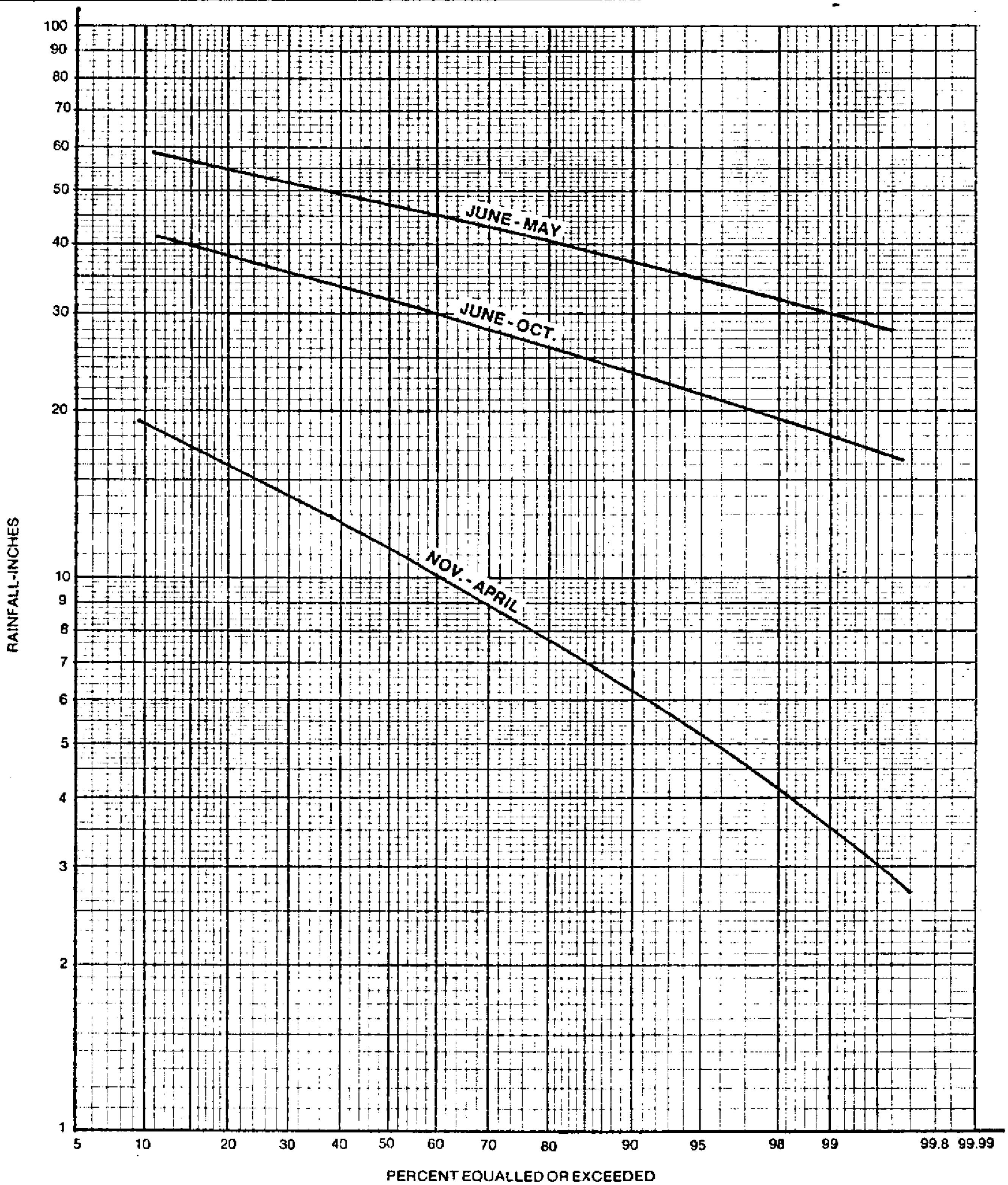

Figure A7 DROUGHT FREQUENCY CURVES FOR FISHEATING CREEK BASIN

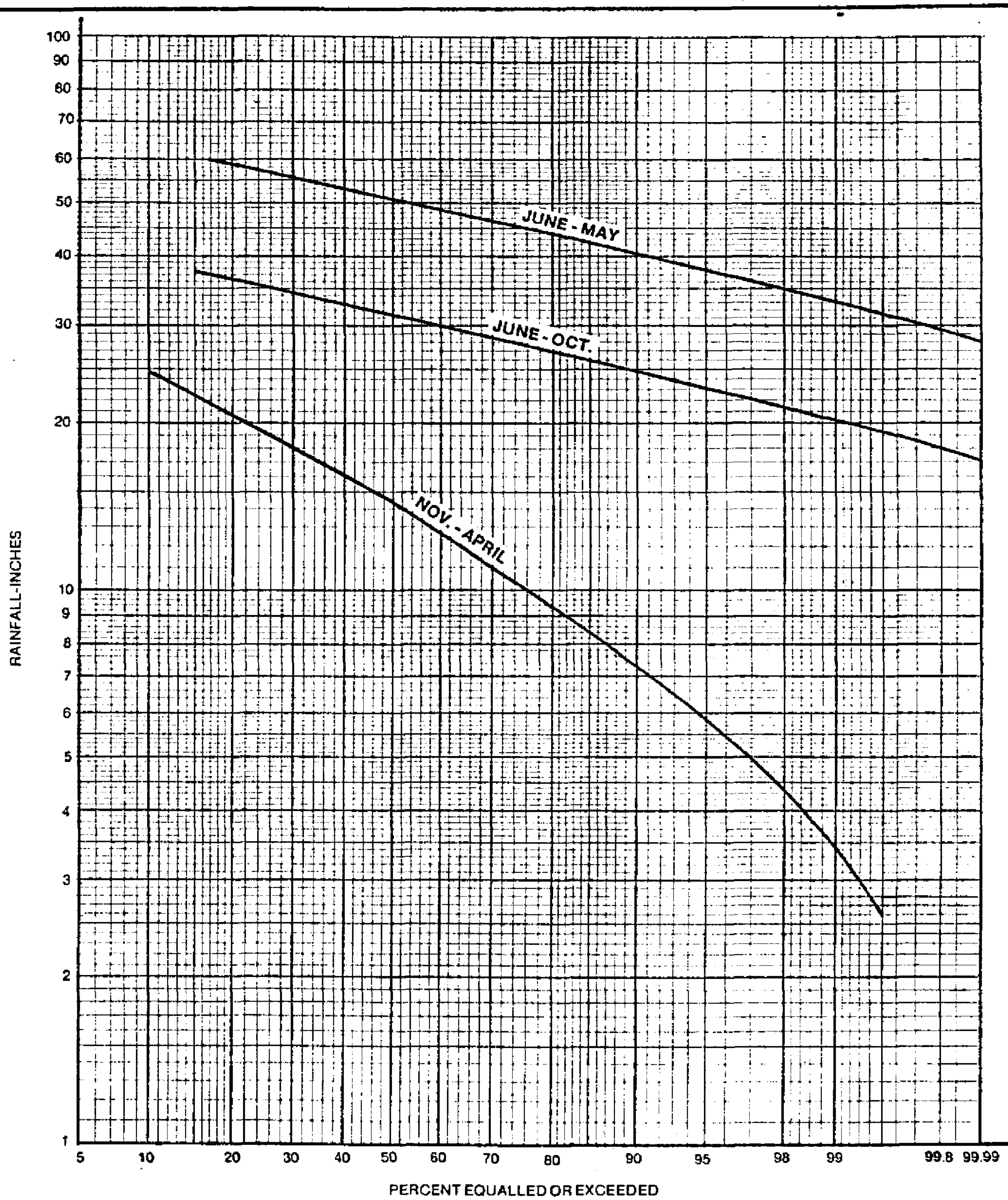

Figure A8 DROUGHT FREQUENCY CURVES FOR THE UPPER KISSIMMEE LAKES BASIN

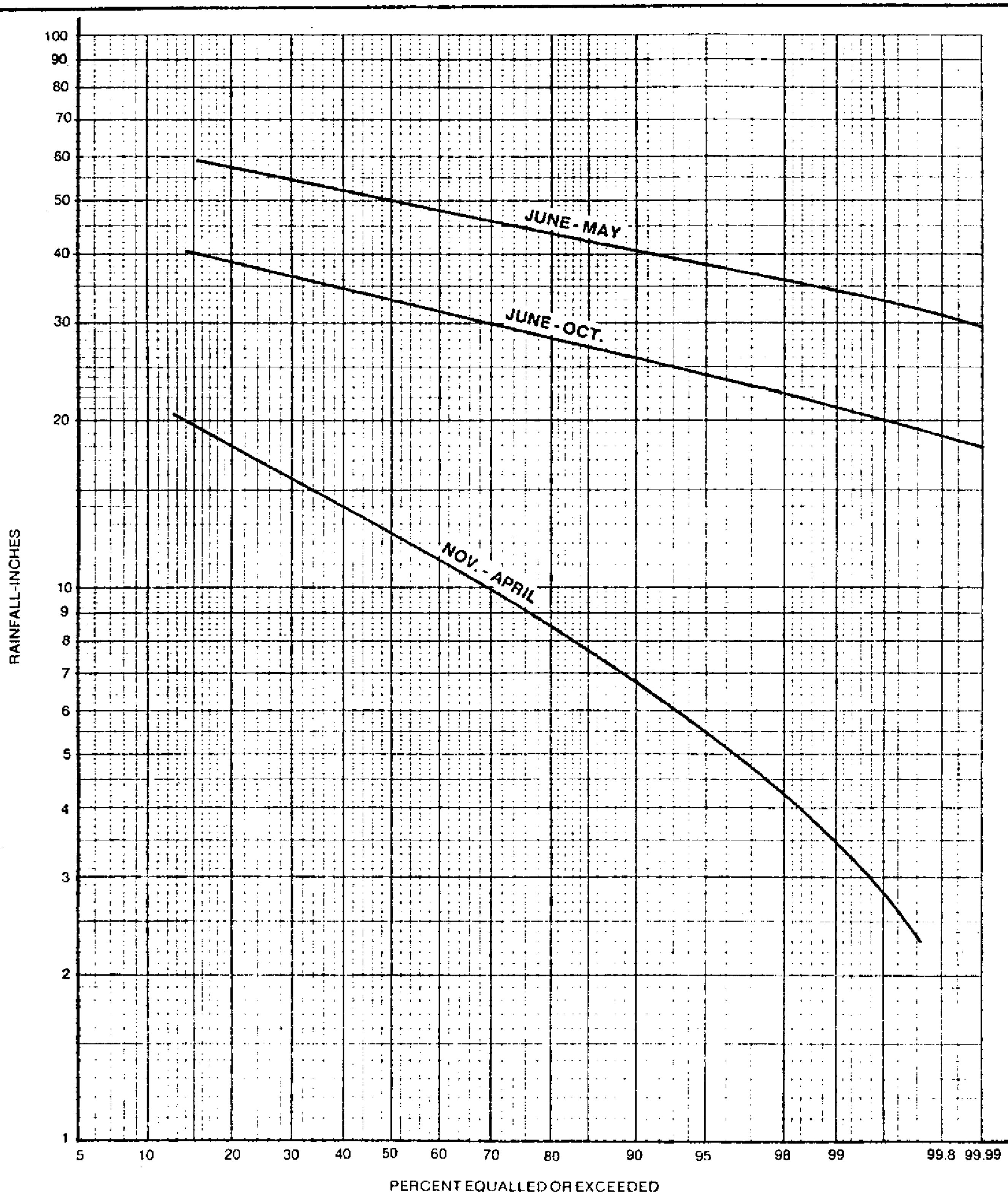

Figure A9 DROUGHT FREQUENCY CURVES FOR THE KISSIMMEE RIVER BASIN

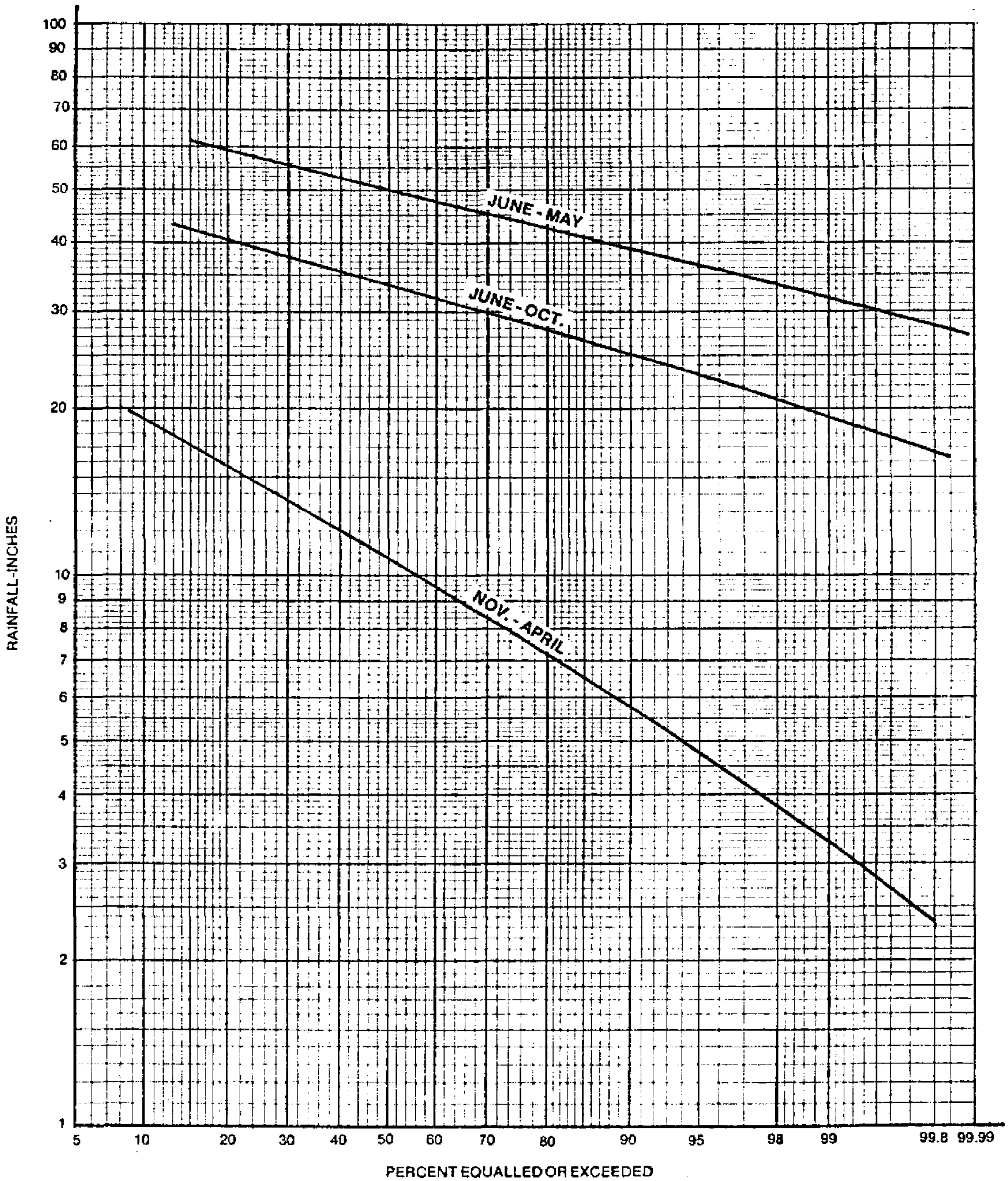

Figure A10 DROUGHT FREQUENCY CURVES FOR EAST AND WEST CALOOSAHATCHEE BASINS

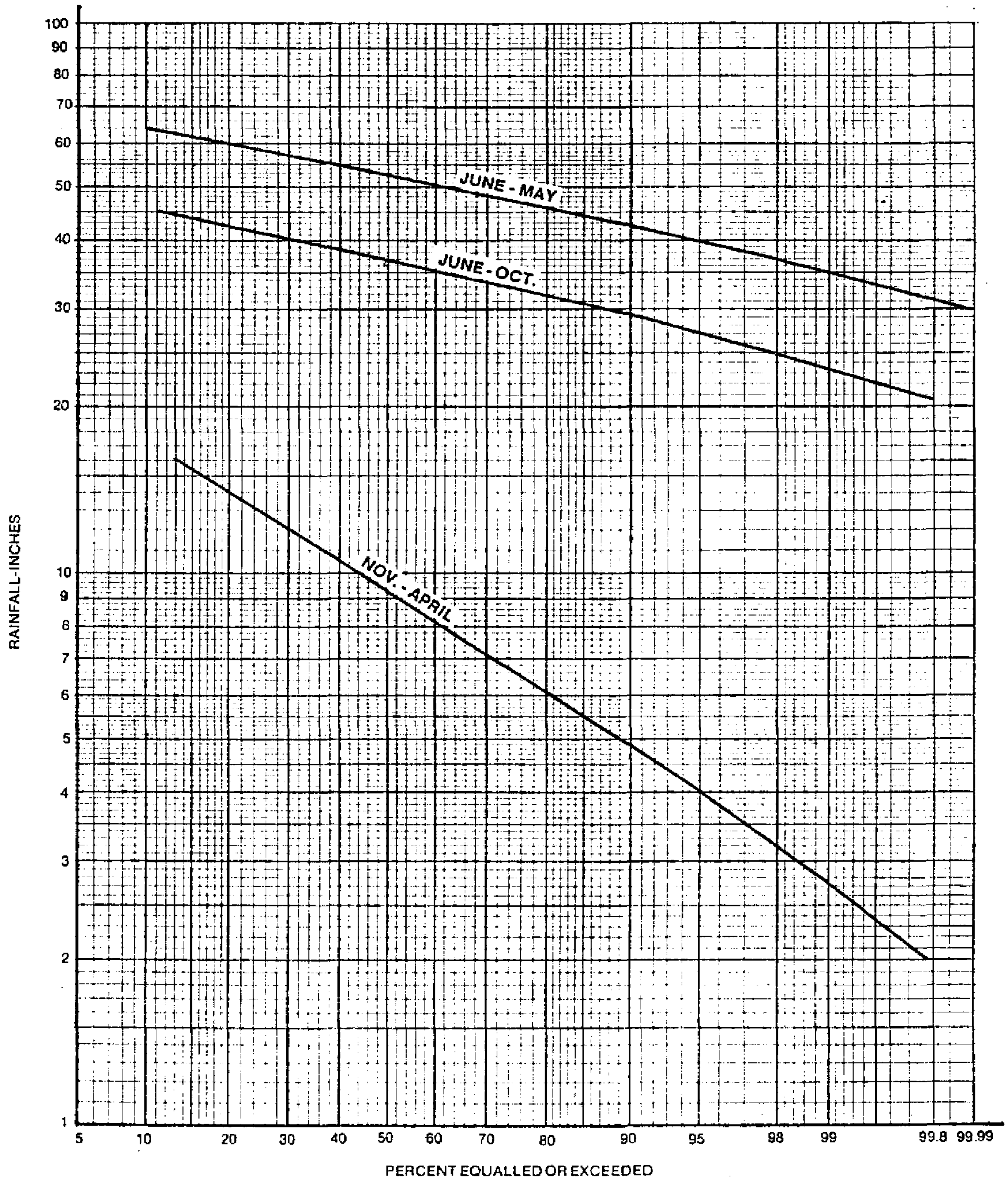

Figure A11 DROUGHT FREQUENCY CURVES FOR THE LOWER WEST COAST-EAST COLLIER BASIN

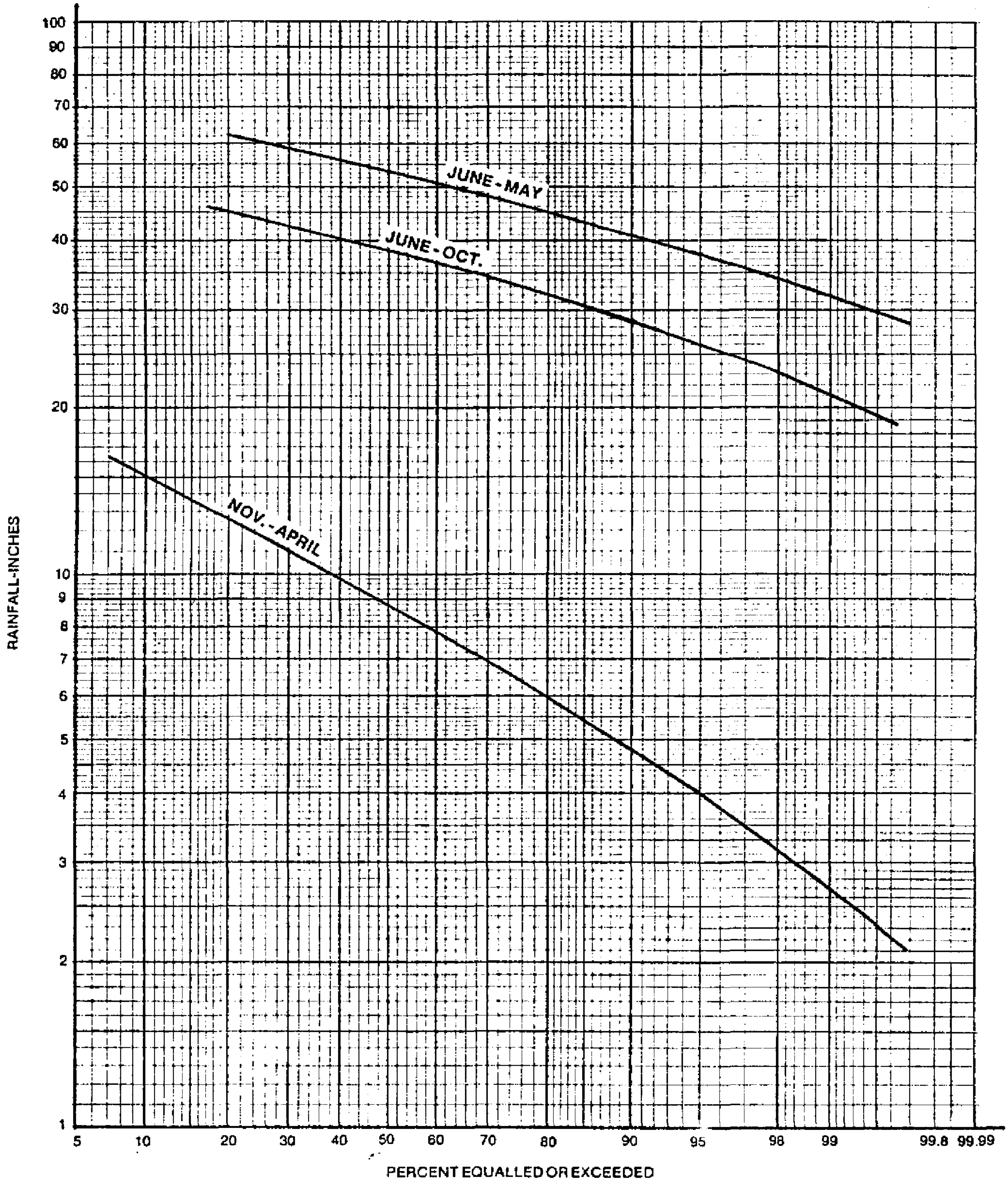

Figure A12 DROUGHT FREQUENCY CURVES FOR THE LOWER WEST COAST-WEST COLLIER BASIN

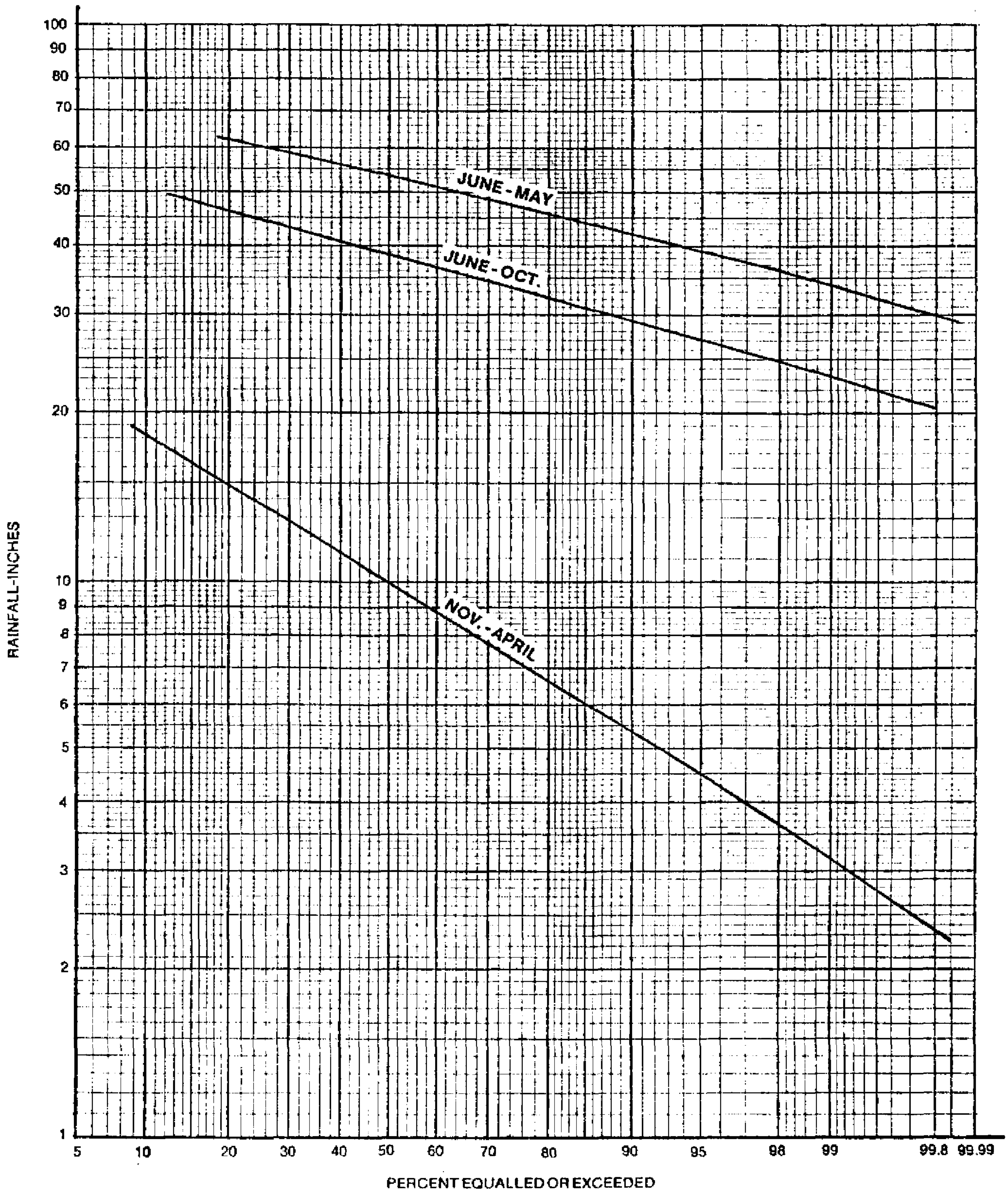

Figure A13 DROUGHT FREQUENCY CURVES FOR THE LOWER WEST COAST - ESTEREO BASIN

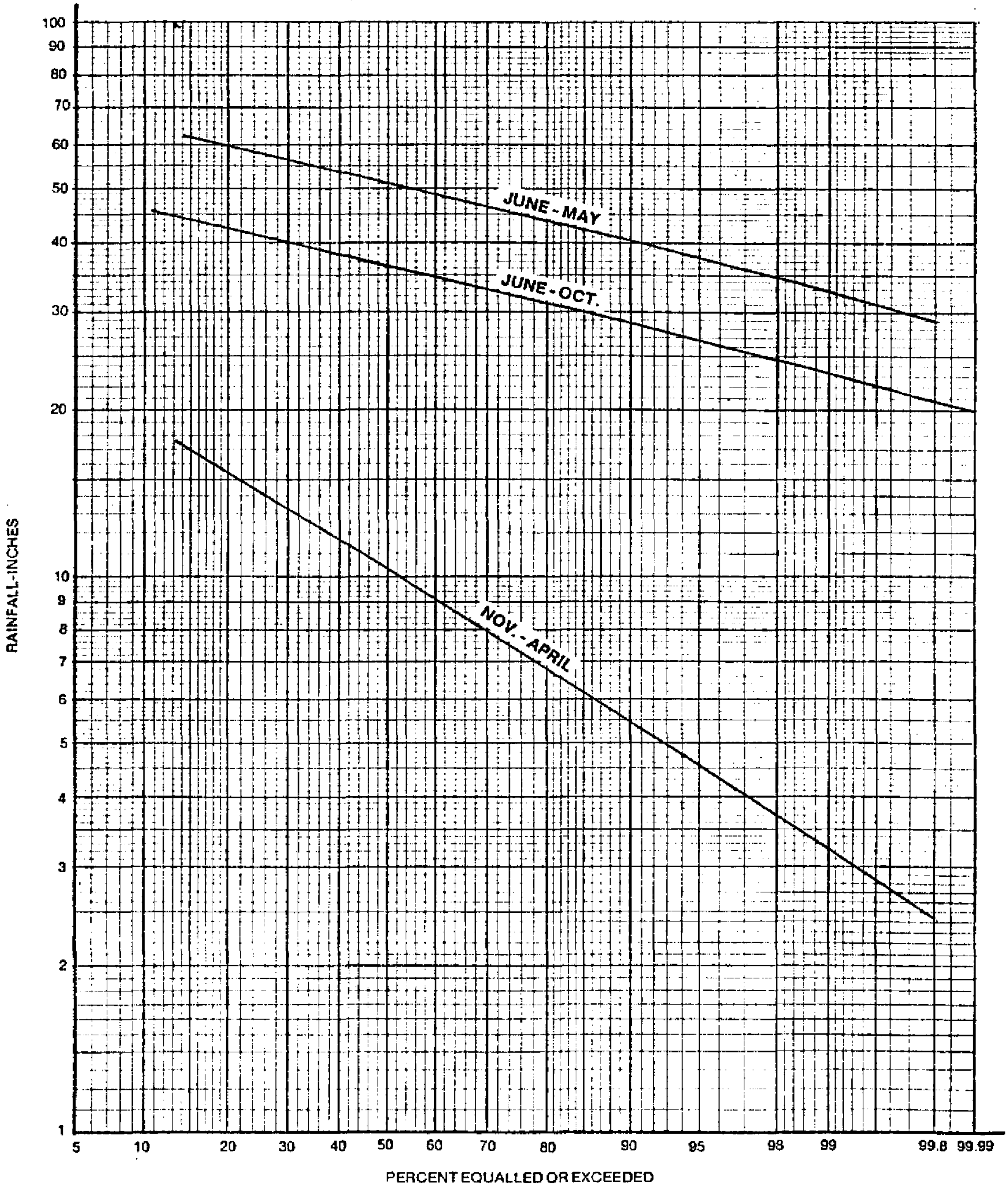

Figure A14 DROUGHT FREQUENCY CURVES FOR THE LOWER WEST COAST - TIDAL CALOOSAHATCHEE & NORTH COAST BASINS

APPENDIX B

RAINFALL STATION INFORMATION

Station	Period	Station Name	SE	TP	RG
MRF100	1963-1983	S-39	26	47	40
MRF101	1940-1983	Boca Raton at SR441	18	47	42
MRF102	1928-1983	Boca Road at Powerline	16	47	42
MRF106	1960-1983	Water Conservation Area 3-26	28	49	39
MRF107	1957-1980	Key Groves	03	50	40
MRF108	1957-1983	Dixie Water Plant	18	50	42
MRF109	1957-1983	Sewell's Lock	14	50	41
MRF115	1960-1983	S-9	27	50	39
MRF12	1962-1983	Brooks Property	01	26	30
MRF131	1931-1973	Pelican Lake 23	23	42	37
MRF138	1957-1983	Pahokee 2	27	42	38
MRF145	1971-1983	S-140	33	49	35
MRF206	1960-1983	Lehigh Acres 1	31	44	27
MRF253	1952-1982	Water Conservation Area 1-9	18	46	41
MRF254	1951-1982	Water Conservation Area 2-17	14	48	39
MRF39	1960-1983	Scotti Groves	04	36	39
MRF4003(ARST3)	1955-1976	Taylor Creek -Raulerson 3	31	35	35
MRF4005(ARST5)	1955-1976	Taylor Creek-Dixie 5	18	36	35
MRF4008(ARSI1)	1955-1973	Indian River Farms -Prange 1	06	32	39
MRF4011(CARSI4)	1951-1973	Indian River Farms -Lateral A	06	33	39
MRF4013(ARSM1)	1958-1973	Monreve Ranch-1	26	39	40
MRF4017(ARSM5)	1958-1973	Monreve Ranch-5	25	39	40
MRF46	1960-1983	Brighton	35	37	34
MRF47	1951-1982	S-193 (HGS-6)	35	37	35
MRF50	1956-1982	Indian Prairie Canal at SR 78	25	39	33
MRF5007	1972-1982	La Belle Tower	16	43	29
MRF54	1957-1983	Pratt & Whitney	24	41	40
MRF56	1951-1982	HGS-1	12	42	32
MRF57	1957-1983	Pelican Lake D.D. #2	12	42	37
MRF60	1929-1973	Benbow - U. S. Sugar	20	42	33
MRF6003(WB1641)	1900-1982	Clermont	14	23	25
MRF6005(WB7205)	1892-1982	Plant City	29	28	22
MRF6006(WB4797)	1915-1982	Lakeland WB City	36	28	23
MRF6007(WB0478	1895-1982	Bartow	08	30	25
MRF6008(WB9707)	1941-1982	Winter Haven	06	29	26
MRF6009(WB4707)	1924-1982	Lake Alfred Experiment Sta.	28	27	26
MRF6010(WB5973)	1935-1982	Mountain Lake	27	29	27
MRF6011(WB0390)	1947-1982	Babson Park	28	30	28
MRF6012(WB9401)	1933-1982	Wauchula 2N	33	33	25
MRF6013(WB0369)	1892-1982	Avon Park	22	33	28
MRF6014(WB2288)	1925-1982	DeSoto City 8SW	03	36	28
MRF6015(WB0228)	1907-1982	Arcadia	25	37	24
MRF6016(WB7395)	1914-1965	Punta Gorda	06	41	22
MRF6017(WB7397)	1965-1981	Punta Gorda 4	15	41	23
MRF6018(WB8942)	1901-1982	Titusville 2W	33	21	35
MRF6019(WB6251)	1942-1972	Nittaw 1S	26	29	33
MRF6020(WB3137)	1956-1982	Fort Drum 5NW	29	33	35
MRF6021(WB2936)	1911-1979	Fellsmere 4W	23	31	37
MRF6022(WB5612)	1937-1982	Melbourne	11	28	37
MRF6023(WB9214)	1943-1982	Vero Beach FAA Airport	34	32	39
MRF6024(WB4332)	1916-1982	Isleworth	17	23	28
MRF6025(WB3840)	1942-1979	Hart Lake	21	24	31
MRF6026(WB4620)	1893-1959	Kissimmee	22	25	29
MRF6027(WB4625)	1948-1982	Kissimmee 2	22	25	29
MRF6030(WB1869)	1955-1975	Cornwell 4NW	30	35	32
MRF6031(WB4845)	1933-1982	Lake Placid 2SW	02	37	29
MRF6032(WB3207)	1901-1982	Fort Pierce	08	35	40
MRF6033(WB6480)	1930-1974	Okeechobee 9W	24	37	33
MRF6038(WB5895)	1918-1982	Moore Haven Lock 1	12	42	32
MRF6044(WB4662)	1929-1982	La Belle	04	43	29
MRF6046(WB4866)	1943-1968	Lake Trafford	35	46	28
MRF6047(WB6078)	1942-1982	Naples	19	50	25
MRF6048(WB2850)	1924-1982	Everglades City	14	53	29
MRF6053(WB8841)	1936-1982	Tavernier	26	62	38
MRF6058(WB)1716	1923-1958	Coconut Grove 7S	24	55	40
MRF6063(WB5658)	1927-1982	Miami Beach	33	53	42
MRF6066(WB3909)	1941-1982	Hialeah	18	53	41
MRF6068(WB3171)	1953-1981	Ft. Lauderdale Experiment Sta.	22	50	41
MRF6069(WB3163)	1912-1982	Ft. Lauderdale	17	50	42
MRF6070(WB2114)	1942-1973	Dania 4 WNW	30	50	42
MRF6071(WB7254)	1941-1982	Pompano Beach	34	48	42
MRF6073(WB4198)	1890-1959	Hypoluxo	10	45	43
MRF6074(WB5182)	1941-1982	Loxahatchee	32	43	41
MRF6075(WB9625)	1939-1982	West Palm Beach Airport	31	43	43
MRF6077(WB4771)	1939-1964	Lake Hiawassee	02	23	28
MRF6080(WB1310)	1939-1967	Captiva	29	45	22
MRF6082(WB8620)	1935-1982	Stuart 1N	32	47	41
MRF6083(WB1649)	1948-1966	Clewiston	11	43	34
MRF6085(WB0887)	1943-1954	Bonita Springs 2ESE	36	47	25
MRF6093(WB3186)	1851-1982	Fort Myers	01	45	24
MRF61	1929-1973	Liberty Point	24	42	33
MRF6107(WB7760)	1949-1982	Royal Palm Ranger	14	58	37
MRF6118(WB2298)	1956-1982	Devil's Garden	34	44	32
MRF6119(WB0611)	1924-1982	Belle Glade Experiment Sta.	05	44	37
MRF6121(WB5719)	1956-1969	Miles City Tower	19	49	30
MRF6126(WB4091	1910-1982	Homestead Expereriment Sta.	35	56	38
MRF6127(WB1305)	1962-1975	Cape Sable Ranger Station	27	60	33
MRF62	1951-1982	HGS-2	11	43	34
MRF65	1929-1973	Pelican 34 - U. S. Sugar	34	42	37
MRF66	1957-1972	M & M Ranch	36	42	39
MRF67	1942-1973	Runyon - U. S. Sugar	18	43	37
MRF68	1913-1973	Ritta - U. S. Sugar	28	43	35
MRF7034(WB6485)	1937-1981	HGS-6	35	37	35
MRF7035(WB7859)	1940-1981	St. Lucie New Lock 1	13	39	40
MRF7037(WB7293)	1940-1981	Port Mayaca at St. Lucie Canal	22	40	37
MRF7039(WB1654)	1936-1981	Clewiston HGS2	11	43	34
MRF7040(WB0616)	1937-1981	Belle Glade HGS4	26	43	36
MRF7043(WB6657)	1936-1981	Ortona Lock 2	26	42	30
MRF7045(WB2923)	1941-1972	Felda	28	45	29
MRF7052(WB5035)	1941-1976	Lignumvitae Key	06	64	37
MRF7054(WB8780)	1940-1981	Tamiami Trail @ 40 mile bend	16	54	35
MRF7055(WB6318)	1940-1966	North New River Canal 1	16	45	36
MRF7057(WB5668)	1901-1981	Miami WB City	19	54	41
MRF7065(WB5663)	1939-1982	Miami WB Airport	30	53	41
MRF7067(WB6988)	1941-1981	Pennsuco 5NW	10	52	39
MRF7072(WB0845)	1948-1981	Boca Raton	19	47	43
MRF7079(WB6638)	1940-1982	Orlando WB Airport	30	22	30
MRF7088(WB8775)	1941-1966	Tamiami Canal at Dade-BrowardLevee	04	54	39
MRF7093(WB3186)	1941-1981	Fort Myers	01	45	24
MRF71	1929-1983	Miami Lock	02	43	35
MRF7126(WB4091)	1940-1981	Homestead Experimental Sta.	35	56	38
MRF72	1940-1972	South Shore	09	44	36
MRF73	1929-1983	South Bay	13	44	36
MRF76	1956-1983	S-5A	32	43	40
MRF78	1928-1983	Greenacres	23	44	42
MRF79	1957-1982	Manatee Plantation at 6 mile bend	18	44	38
MRF81	1940-1983	Lake Worth Road and E1	31	44	42
MRF84	1940-1983	Boynton Road & Military Trail	23	45	42
MRF85	1928-1983	SR-804 nr. Turnpike	20	45	42
MRF86	1957-1983	Shawano Pump 6	11	45	38
MRF87	1957-1983	Sawyer Ranch	28	45	38
MRF88	1940-1983	SR-804 & SR-7	31	45	42
MRF90	1955-1983	Lake Worth Drainage District Office	11	46	42
MRF92	1928-1983	SR-806, 7.5 mi. west of Delray	17	46	42
MRF93	1955-1982	SR-806 & SR-7	19	46	42
MRF95	1960-1982	S-6	03	46	39
MRF96	1967-1982	Big B Ranch	10	46	37
MRF98	1962-1982	S-8	06	48	36
MRF99	1973-1982	S-7	27	47	38
MRF7086(WB6323)	1942-1982	North New River Canal 2	27	47	38
MRF9008(DC001)	1960-1982	Wheeler Frye	13	54	40
MRF9018(DC018)	1953-1982	Stonebraker	17	52	42
MRF9025(DC025)	1975-1982	Kendall Lakes West	33	54	39
MRF9095(DC095)	1969-1982	Ira Ebersole	26	56	38
MRF9097(DC097)	1969-1982	Homestead Airport	05	57	38
MRF9098(DC098)	1969-1982	Tamiami Airport	16	55	39
CW001	1944-1980	West Palm Beach Water Plant	21	43	42
MRF89	1959-1982	Water Conservation Area 1-8	36	45	41

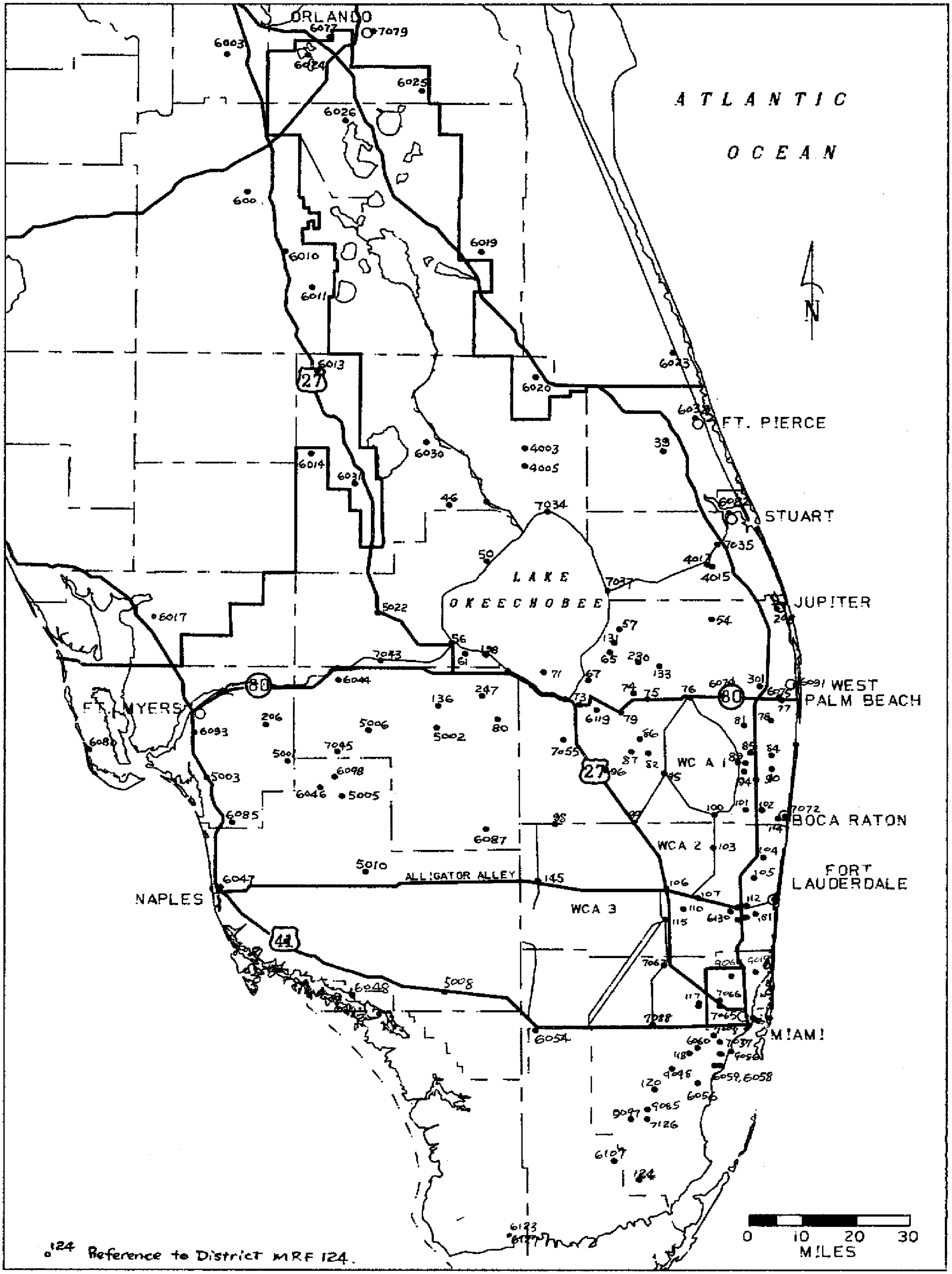

Figure B1 RAINFALL STATIONS