PRELIMINARY REPORT ON RAINSTORM OF JUNE 23-30, 1992

Department of Water Resources Evaluation
Department of Research
Operations and Maintenance Department
Regulation Department
Planning Department
Office of Government and Public Affairs

December 1992

South Florida Water Management District
West Palm Beach, Florida

DRE 315

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Data Management Division
Hydrogeology Division
Water Quality Monitoring Division
Department of Water Resources Evaluation

Everglades Research Division
Kissimmee and Okeechobee Systems Research Division
Department of Research

Operations Division
Operations and Maintenance Department

Field Engineering Division
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Upper District Planning Division
Lower District Planning Division
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EXECUTIVE SUMMARY

Average rainfall in south Florida for the month of June varies from 7.5 inches in the vicinity of Fort Pierce and Stuart to 9.5 inches in the Homestead area. However, June 1992 is recorded as one of the wettest June rainfalls for the period of record for some of the District areas such as the Lower East Coast (1940-1992), Water Conservation Area 3A (1960-1992), Lake Okeechobee (1950-1992) and Lower West Coast (1940-1992). Six different days during the month brought an average of one inch or more of rain. The Palm Beach International Airport recorded that it rained 25 days during the month.

This constant downpour of rain at the beginning of the month brought the ground water levels to ground surface elevations. Therefore, there was no ground storage left for the rainstorm of June 23-30. Rainfall, immediately after it fell on the ground, started moving as runoff. To minimize flooding of lands and environmental impacts, runoff resulting from this storm had to be either pumped or drained by gravity into Lake Okeechobee or discharged to tidal water via the Central and Southern Florida (C&SF) Project canal systems. A small volume of runoff water from the eastern portion of the Everglades Agricultural Area was backpumped to Lake Okeechobee to prevent flooding. This backpumping was performed strictly according to the Interim Action Plan (IAP) as authorized by the Florida Department of Environmental Regulation (DER). The C&SF system was operating at or near capacity from June 24 through July 28, 1992, to discharge other storm runoff to the Water Conservation Areas (WCAs).

In Lake Okeechobee, especially along the northern shore, a large fish kill was reported. This fish kill is attributed to low dissolved oxygen (less than 5 mg/l) at almost all inflow points to the Lake. Around the Lake in Okeechobee County, some areas experienced flooding. However, these same areas have experienced flooding in the past during heavy rains.

Significant amounts of nutrients were added to the WCAs as a result of the storm. Water flowing from the Lake and the Everglades Agricultural Area (EAA) to the Water Conservation Areas had high phosphorous loads, varying between 15 percent and 45 percent of total annual loads for individual stations. Nitrogen loads to the WCAs were also high, varying between 13 percent and 36 percent of the total annual load.

The South Dade area and the Lower East Coast experienced the most flooding from the storm event. Personnel from the Homestead Field Station documented numerous complaints and visited several flooded sites. No houses were reported to be flooded; however, some agricultural sites reported flooding.

The Bonita Springs area in Lee County in the Lower West Coast Planning Area also experienced significant flooding. Several houses were flooded in this area, and approximately 600 people were evacuated from their homes. Portions of Bonita Springs received the worst flooding on July 1 and July 2, several days after the severe storm. The Bonita Springs area has neither a primary nor secondary drainage system.

Large discharges to the estuaries reduced salinities and impacted estuarine fauna and flora. Freshwater discharge into the St. Lucie Estuary had a dramatic effect on the water chemistry of the system. Water discharged from the Lake, as well as local runoff discharged to the St. Lucie Estuary, lowered the salinity at the center of the North Fork from 15 parts per thousand (ppt) to freshwater within five days. Water discharged to Manatee Bay lowered the salinity levels to about 5 ppt and to about 15 ppt in Barnes Sound after structure S-197 was fully opened. Surface salinity throughout Biscayne Bay dropped 35-45 percent.

Rainfall in the Caloosahatchee basin prior to the storm resulted in a freshwater discharge to the Caloosahatchee Estuary, which receives all of its freshwater input from the Caloosahatchee River. The heavy rains associated with the storm caused conductivity to fall below 32,000 mhos/cm for almost a week. Prolonged exposure of estuarine benthic invertebrates to conductivity below 1,000 mhos/cm for a week causes mortality, as does exposure to conductivity below 32,000 mhos/cm for some species of marine benthic invertebrates.

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ACKNOWLEDGEMENTS

Several divisions and departments of the South Florida Water Management District contributed to the preparation of this report. The efforts of the Hydrologic Data Management Division staff in retrieving and processing of data were a major factor in the prompt completion of this report. Concerted efforts by the Water Quality Monitoring Division and Field Engineering Division staff members, as well as the staff members from the Fort Myers and Big Cypress Basin Offices, made timely collection and analysis of hydrologic, meterologic, water quality and flooding area data possible. Appreciation is extended to the engineering technician staff of the Kissimmee and Okeechobee Systems Division for their indispensable contribution in data processing, analysis, and graphic preparation. The United States Geological Survey (USGS), Dade County Environmental Resource Management (DERM) and the Everglades National Park (ENP) staff provided valuable information. Special thanks to Carol Goff for participation in preparation of the text.

INTRODUCTION

Floods are a common natural phenomenon in south Florida due to its topography and low land surface relief, in conjunction with occurrences of high intensity rainfall from thunderstorms, tropical depressions and hurricanes. Additionally, because of the shallow water table in the area, the rate of runoff generation in south Florida is higher than in most other areas. Therefore, the south Florida area is subject to damage from flooding.

The South Florida Water Management District has analyzed and documented reports on various storms since the early 1960s to inform the public and to provide a systematic record of rainfall events, as well as the impacts on the District's flood control system. Documentation of storm events, however, should not be considered as documentation of long-term impacts.

The objective of this report is to compile and analyze all available provisional data on hydrometeorology, water quality, and the environment, as well as descriptions of different areas that were impacted by the heavy rainfall of June 1992, and the storm of June 23-30, 1992.

METEOROLOGICAL DESCRIPTION

Meteorologically speaking, May 1992 was relatively dry. However, by the end of the month, afternoon sea breeze thunderstorms were beginning to develop. By the 3rd of June, an upper level, low pressure system covered the southeastern United States and began to drag moisture eastward from Tropical Storm Agatha off the west coast of Mexico, producing an average of 1.05 inches of rain over the South Florida Water Management District area. Above normal rains continued as a spring-like pattern set up over the District. Upper level instability, typical of spring weather, was provided by the subtropical jet stream concurrent with the summertime heat and humidity. Combined, these two factors produced above normal rain. By the 16th of the month, an upper level trough over the eastern United States brought a temporary infusion of dry air over Florida through June 21st. On the 22nd of June, a moisture plume from the northwestern Caribbean began to surge northward and interact with the subtropical jet stream, which had repositioned itself over the state. This moisture moved over the District during the night and heavy rain began to fall over parts of the District over the next eight days. During this period (June 23-30), rainfall amounts of 20.74 inches fell at Homestead Field Station, 15.25 inches at Bonita Springs and 12.28 inches at the Okeechobee Field Station. The heaviest rain fell on the night of the 25th as Tropical Depression 2 developed off the southwest coast of Florida. This depression moved northwest into Florida near Tampa where it dissipated on the 26th of June. This tropical depression produced heavy rain throughout the District. The rain continued through the 29th as moisture in the area continued to interact with the subtropical jet stream. By the 30th of the month, the subtropical ridge and the subtropical jet stream receded northward, bringing an end to heavy rains (modified from Meteorological Summary, Surface Water Conditions, June 1992, South Florida Water Management District).

RAINFALL ANALYSIS

Spatial Distribution

Prior to June 1992, on the average, below normal rainfall conditions existed in South Florida. The average rainfall for the month of May 1992 for Palm Beach, Dade and Broward counties were 1.10, 0.94 and 0.81 inches, respectively, in comparison with the monthly average of approximately 5.75 inches. Total rainfall in the Everglades Agricultural Area was 1.24 inches, in comparison with the monthly May average of 5.00 inches. The southwest coast had an average of 0.98 inch for the month of May in comparison to the long-term monthly average rainfall of 4.50 inches.

Daily rainfall values for the month of June 1992 throughout the District were compiled and stored in the District's database, DBHYDRO. Stations with complete 30-day-rainfall values were retrieved from the database for further analysis. Analysis consisted of calculating the 30-day and 8-day (June 23-30) totals, as well as selecting the 1-, 3- and 5- day maximum values. There were 152 rainfall stations with daily rainfall values in the database, of which 125 stations were used in this report. The remaining stations either had outlier rainfall values or the rainfall amount for the last day of the month was missing. Figure 1 depicts the location of the rainfall stations that were used in this report. Complete statistics of the rainfall for the 125 stations are presented in Appendix A.

Figure 2 depicts the spatial distribution of the average June rainfall values in terms of isohyetal lines (Tech. Pub 83-2, Rainfall Averages and Selected Extremes for Central and Southern Florida). As depicted in Figure 2, the average June rainfall amount varies from 7.00 inches for the Fort Pierce and Stuart area to a high of 9.5 inches in the Homestead area.

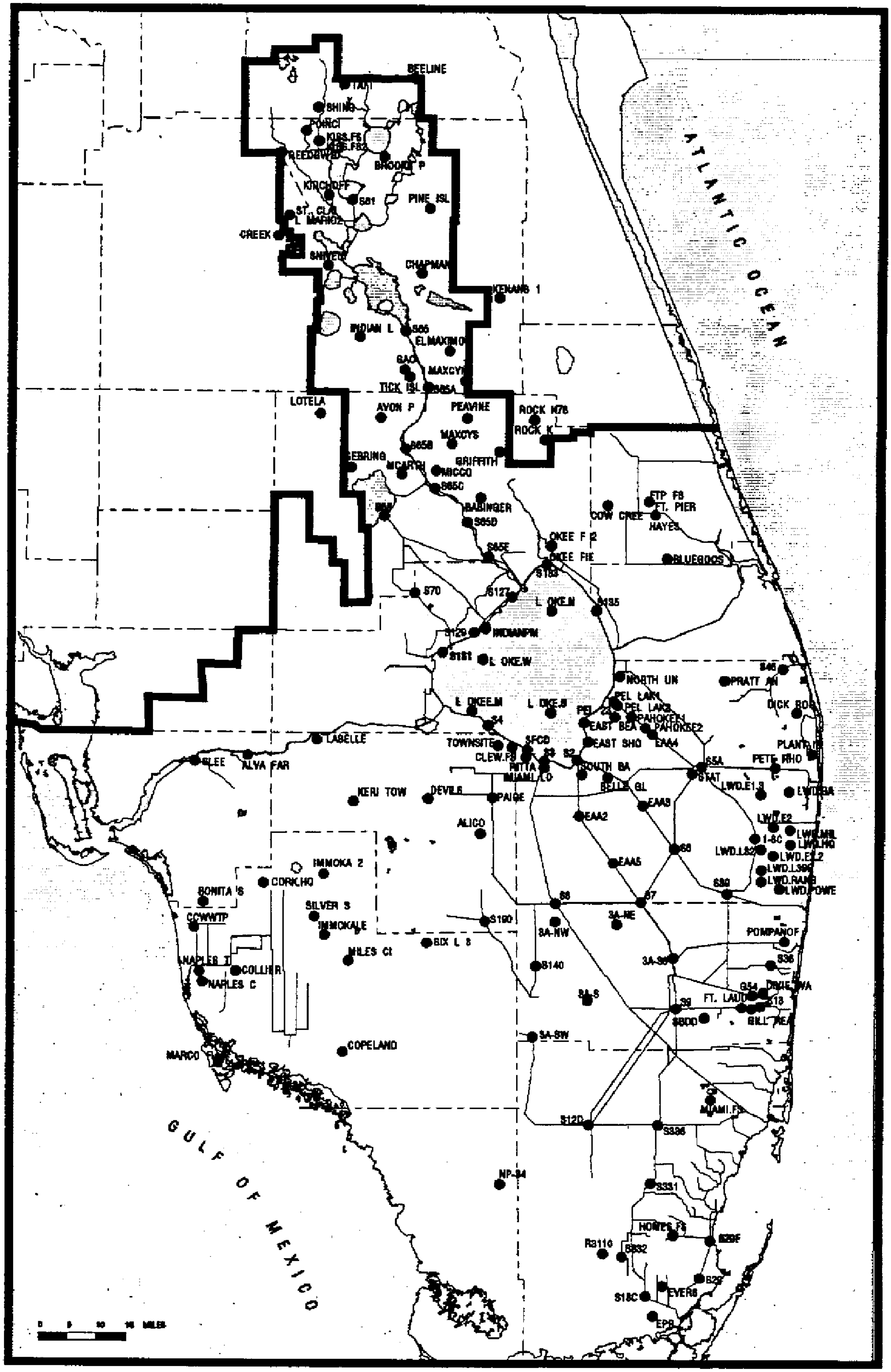


Figure 1. Rainfall Monitoring Stations in the SFWMD

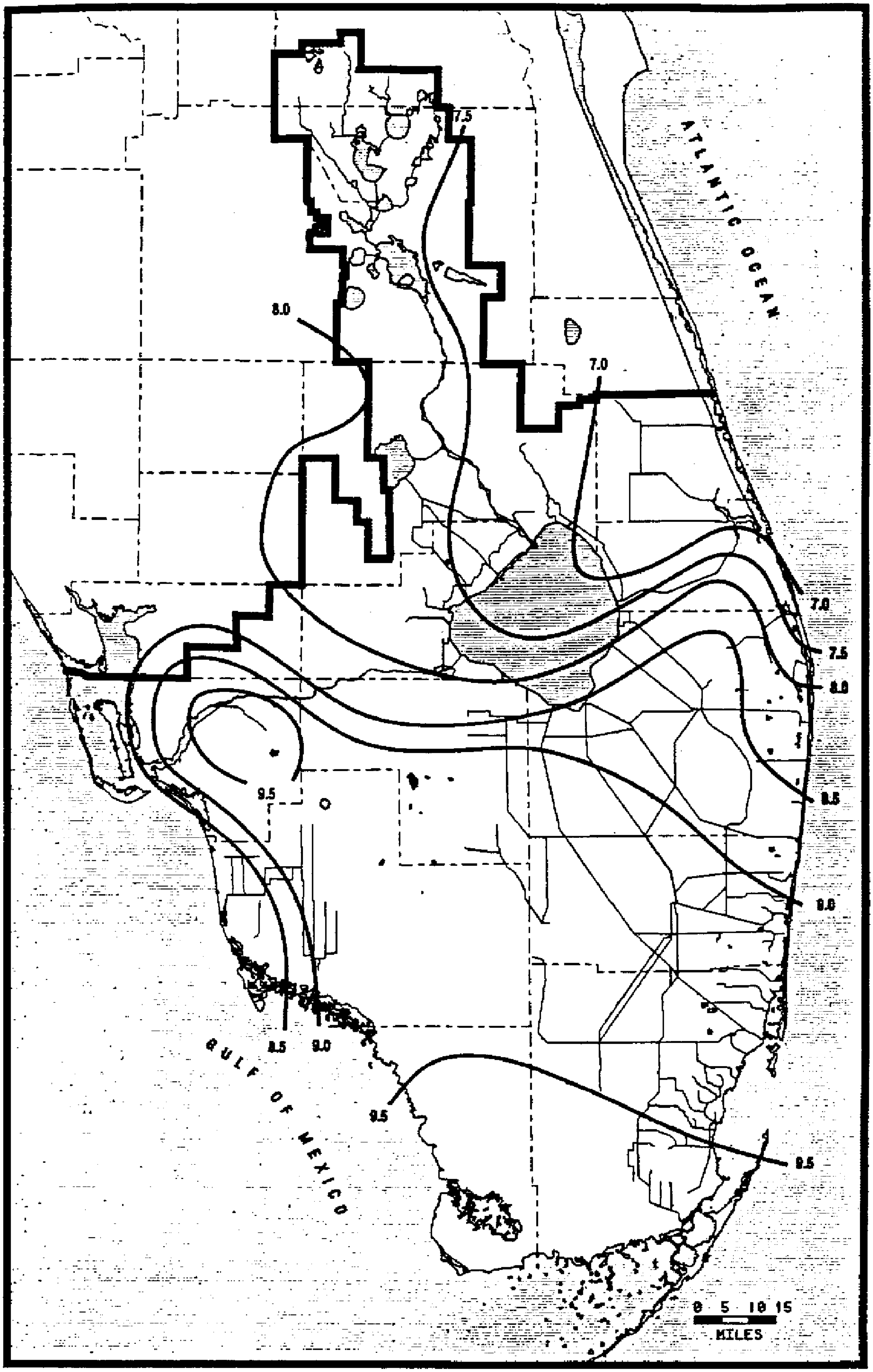


Figure 2. Monthly Average Rainfall - June (inches)

To illustrate the spatial distribution of the June 1992 rainfall within the District, isohyetal maps were plotted using the bilinear interpolation method for surface plotting. This software is available in the ARC/INFO geographic information system. Spatial distribution of the monthly total, 8-day total (June 23-30), as well as the maximum 1-, 3- and 5-day amounts, were plotted (Figures 3-7). Comparison of the June 1992 rainfall total with other years' June rainfall was made, and plotted for the Planning Areas of the District (Appendix B). These figures show that the Lower East Coast Planning Area, Water Conservation Area III-A, and Lake Okeechobee recorded the highest amount of rain for the month of June in history.

The June 1992 total rainfall for the District varied from 15 inches for the Upper East Coast Planning Area (Stuart and Fort Pierce) to more than 30 inches in the south Dade portion of the Lower East Coast Planning Area. Therefore, the June 1992 rainfall was approximately 7.5 to 20.50 inches higher than average June rainfall. Homestead Field Station recorded the highest amount of rainfall (31.21 inches) for the month in the Lower East Coast Planning Area and Bonita Springs rain gauge in the Lower West Coast Area of the District recorded 23.15 inches of total rainfall for the month.

Figure 4 illustrates the spatial distribution (isohyetal map) of the 8-day total rainfall (June 23-30, 1992). The Fort Pierce and Stuart area had a total of 8 inches of rain and the Homestead area had in excess of 20.74 inches of rain. This indicates that some areas of the District received rainfall amounts equaling or exceeding the monthly average during the last eight days of the month.

Figure 5 shows the distribution of the 5-day maximum rainfall. Homestead recorded 13.24 inches and Bonita Springs 12.72 inches. Figures 6 and 7 depict the 3-day and the 1-day distributions.

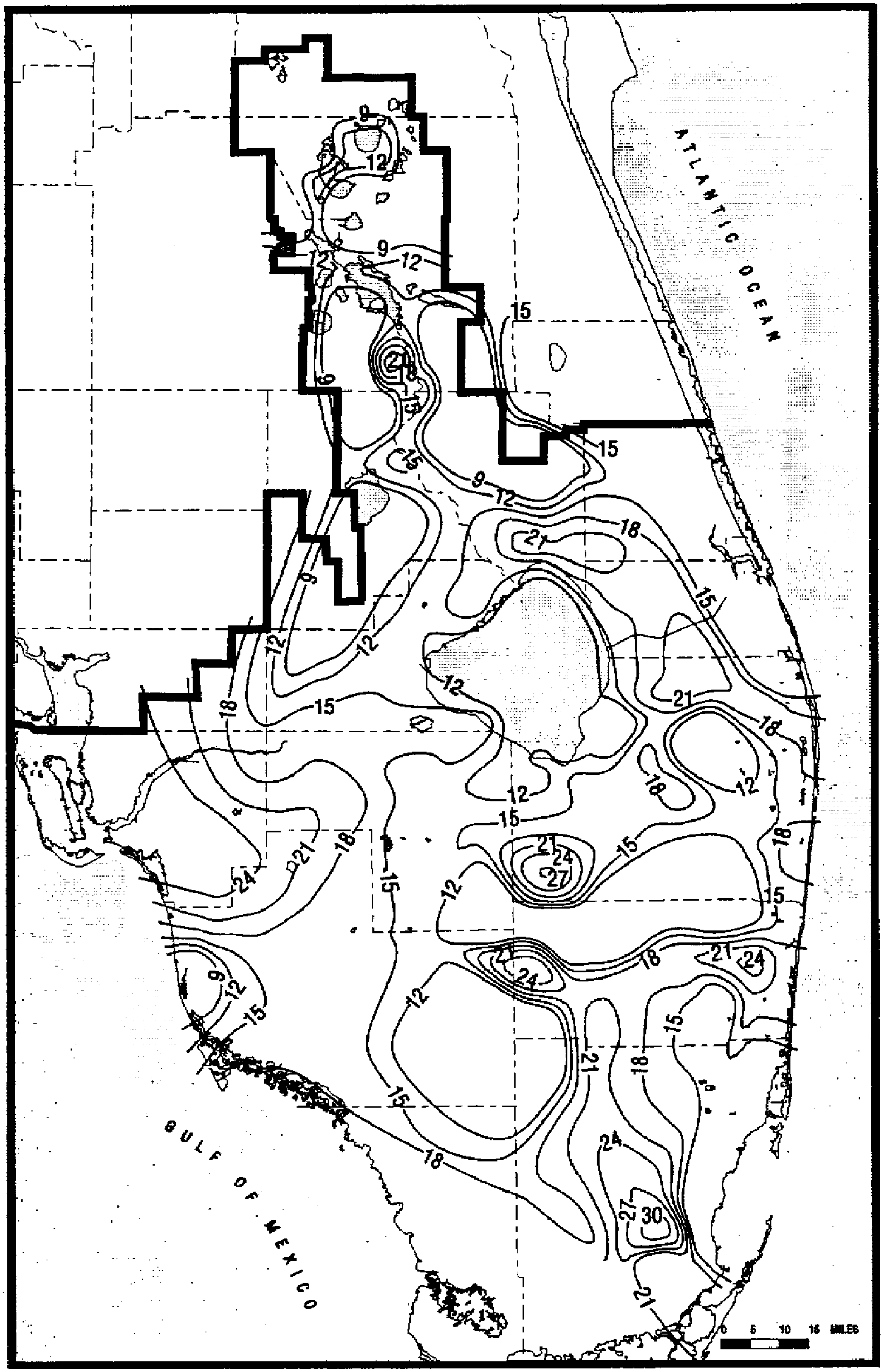


Figure 3. Monthly Rainfall Distribution, 3-Inch Contour Interval, June 1992

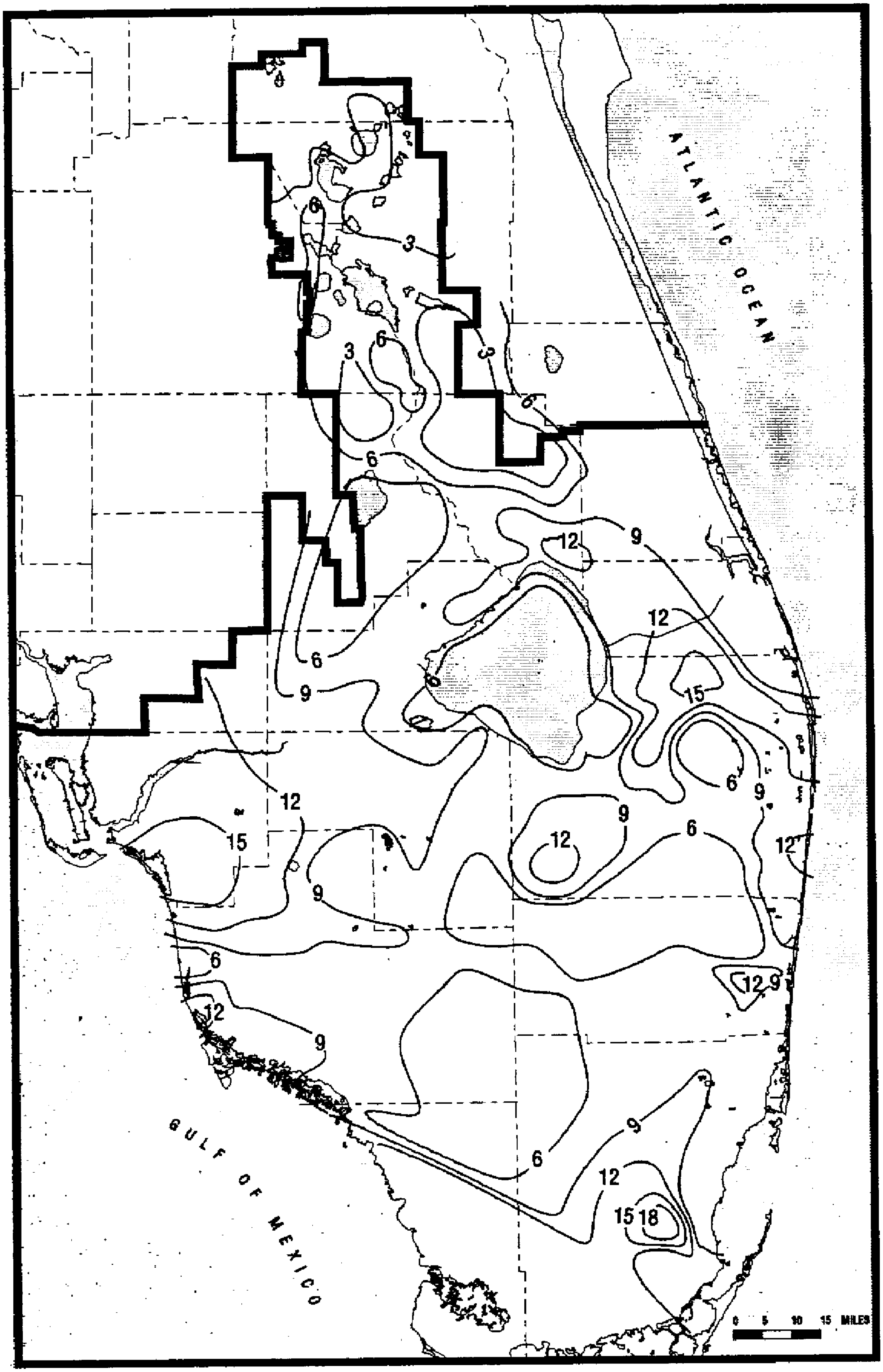


Figure 4. Eight-Day Rainfall Distribution, 3-Inch Contour Interval, June 1992

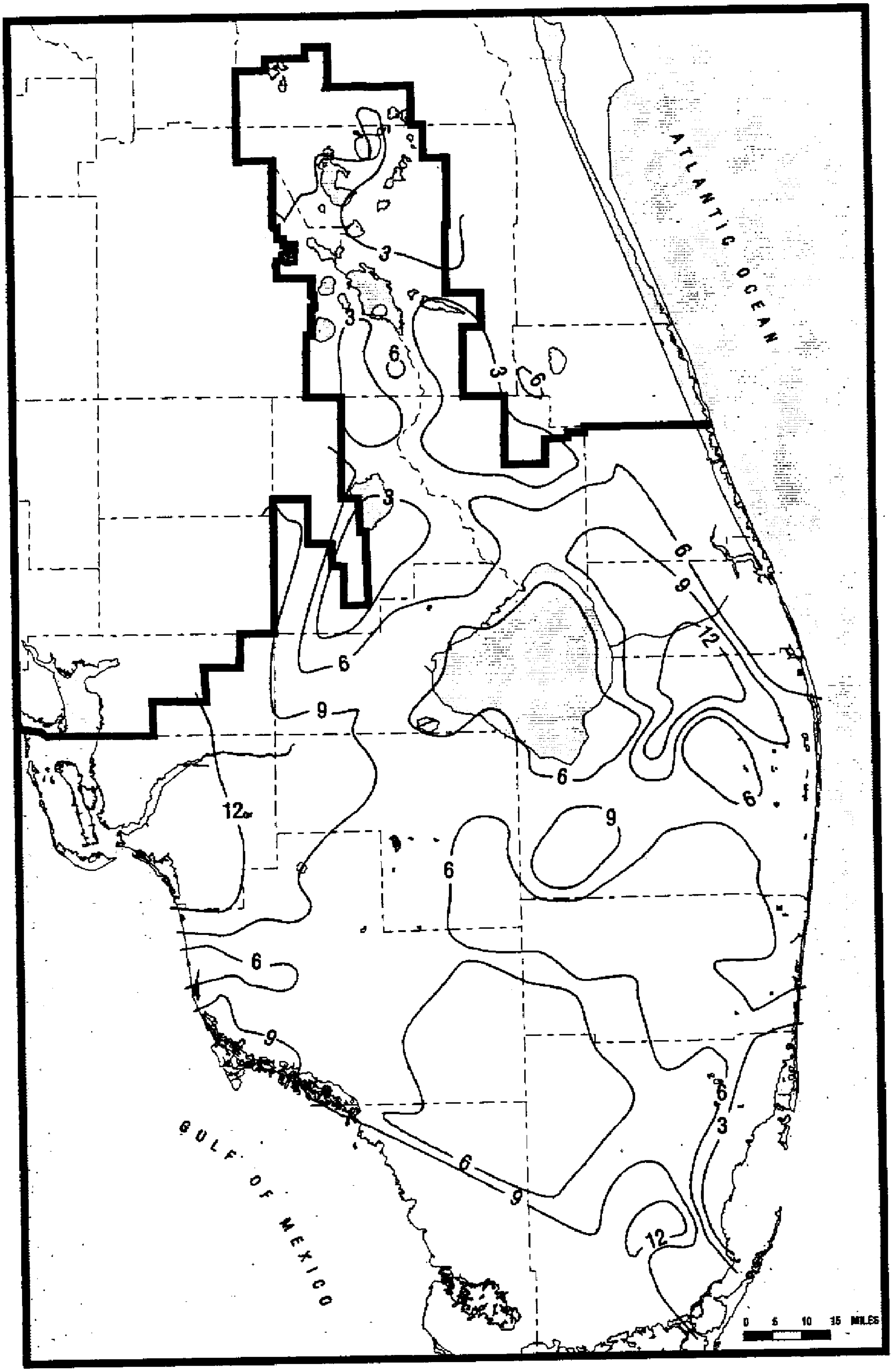


Figure 5. Five-Day Rainfall Distribution, 3-Inch Contour Interval, June 1992

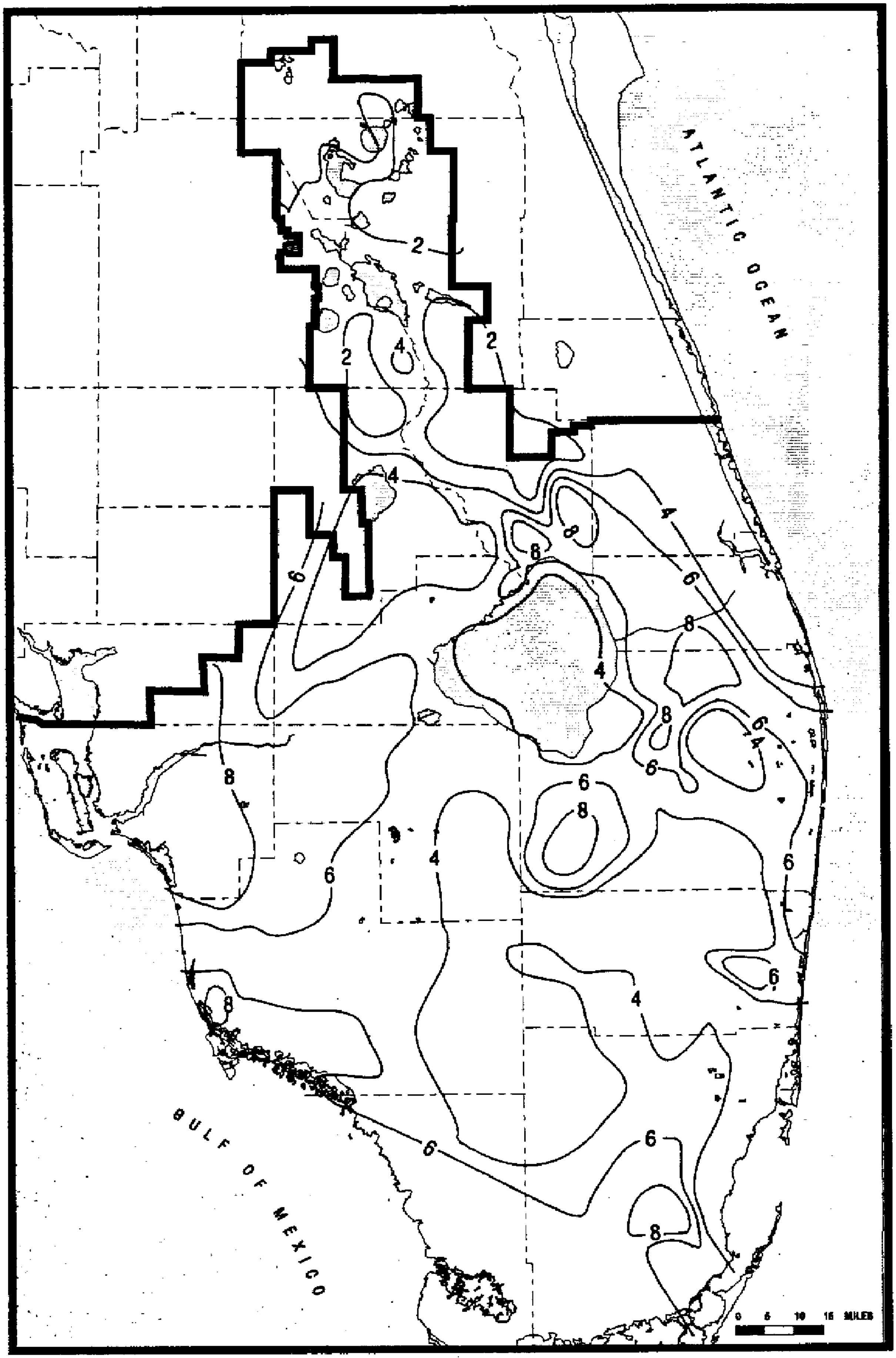


Figure 6. Three-Day Rainfall Distribution, 2-Inch Contour Interval, June 1992

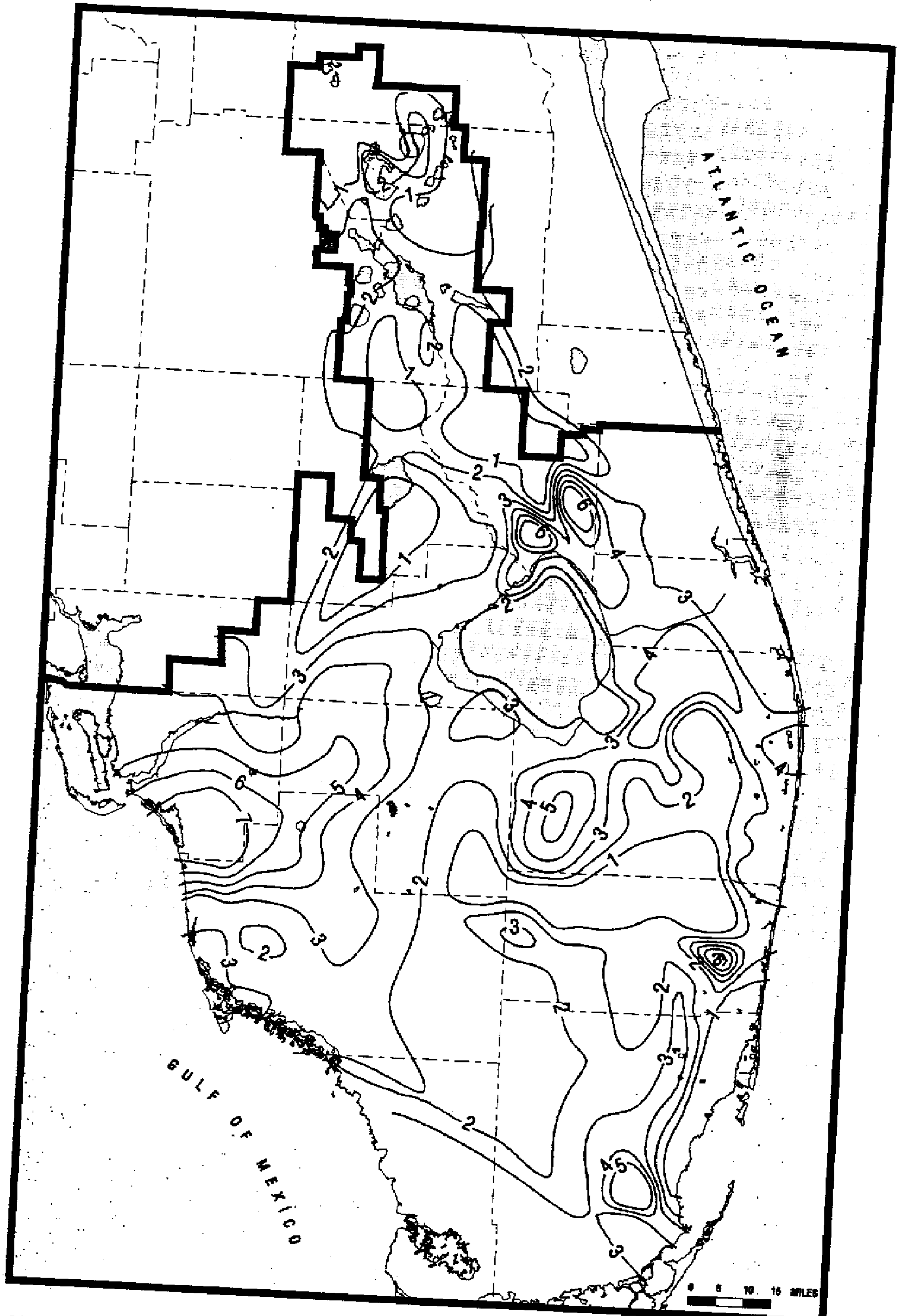


Figure 7. One-Day Rainfall Distribution, 1-Inch Contour Interval, June 1992

Frequency Estimation

Estimated rainfall amounts for various durations and frequencies are basic components for water resources analysis. Various water resources projects are designed to protect against a drought or flood of a certain duration and frequency. For example, the District pumping stations in the Everglades Agricultural Area basin, are designed to remove 3/4 inch of runoff in a day. Frequency estimation of current storm events are made and compared against the project design frequency to check operational performance.

Frequency analysis of rainfall maximums for 1-, 3- and 5-day duration has been prepared by the District (MacVicar, T., 1981, Frequency Analysis of Rainfall Maximum for Central and South Florida, Technical Publication 81-3, South Florida Water Management District). The maximum rainfall for 1-, 3- and 5-day durations for the June 1992 event can now be compared against the historic values. This will allow determination of the frequency of the June 1992 storm rainfall amount from a single station or on a basin-wide basis.

An analysis of the 1-, 3- and 5-day maximum rainfall for the June 23-30 storm for the entire District area was made. The maximum one-day rainfall of 7.85 inches was recorded at Bonita Springs in Lee County on June 29, 1992. Homestead Field Station recorded 5.55 inches of rain in one day. Comparison of the 1-day maximum rainfall at Bonita Springs with the rainfall value from the frequency map, gives a return frequency of one in 25 years. In other words, one can expect 7.85 inches of rain at Bonita Springs Station once in 25 years. Corkscrew Swamp Headquarters rainfall station, located adjacent to the Bonita Springs area, recorded a rainfall amount of 6.15 inches, which corresponds to a return period of 10 years.

The maximum 3-day rainfall amounts at the Homestead Field Station (9.76 inches), station SLEE (9.18 inches) and Bonita Springs (8.86 inches) have return periods of one in 10 years.

The maximum 5-day rainfall amount of 13.48 inches for the storm event of June 23-30, recorded at PRATT_AN rainfall station in Palm Beach County, has a return period of one in 25 years. Homestead Field Station recorded the second highest 5-day rainfall amount of 13.24 inches, which has a return period of one in 25 years. Bonita Springs rain gauge recorded 12.72 inches of rain, which also has a return period of 25 years. In the Everglades Agricultural Area, the 5-day maximum rainfall total of 12.53 inches was recorded at station EAA4. This amount has a return period of one in 50 years.

EFFECTS IN THE EVERGLADES AGRICULTURAL AREA AND LAKE OKEECHOBEE

The Everglades Agricultural Area (EAA) and the areas surrounding Lake Okeechobee (Figure 8) were affected by the June storm. The Everglades Agricultural Area is located south of Lake Okeechobee within western Palm Beach, eastern Hendry and western Martin counties. This area has over 1100 square miles of rich organic (muck) soils. This area is by far the largest single block of intensely irrigated land with extensive agricultural production within the South Florida Water Management District area.

The primary canal systems serving the EAA basin are the West Palm Beach, Hillsboro, North New River and the Miami canals, which were designed both for flood control and water supply purposes. The drainage basins for these canals and their associated pumping facilities are shown in Figure 8. The West Palm Beach Canal is served by the S-5A pumping station, which pumps directly into the Arthur Marshall Loxahatchee National Wildlife Refuge (WCA-1). The Miami Canal basin contributes storm runoff to the S-3 pumping station to the north into Lake Okeechobee and the S-8 pumping station to the south, which pumps into WCA-3A. The Hillsboro and North New River Canal basins are interconnected by the S-2 pumping station located at their northern intersection, which pumps into Lake Okeechobee. The Hillsboro basin is also served by S-6 on its southern end, which pumps runoff into WCA-1; the North New River basin is served by S-7 on its southern end, which pumps runoff into WCA-2A.

This water control system is capable of removing 0.75 inch of water from the contributing drainage area in 24 hours. This runoff removal capacity is presumed to be sufficient to keep crop damage to a minimum for storms with a return frequency up to once in six years. The duration of surface flooding for these events would be kept to less than 24 hours in these project facilities (Appendix B, Figure B-37, Line A;

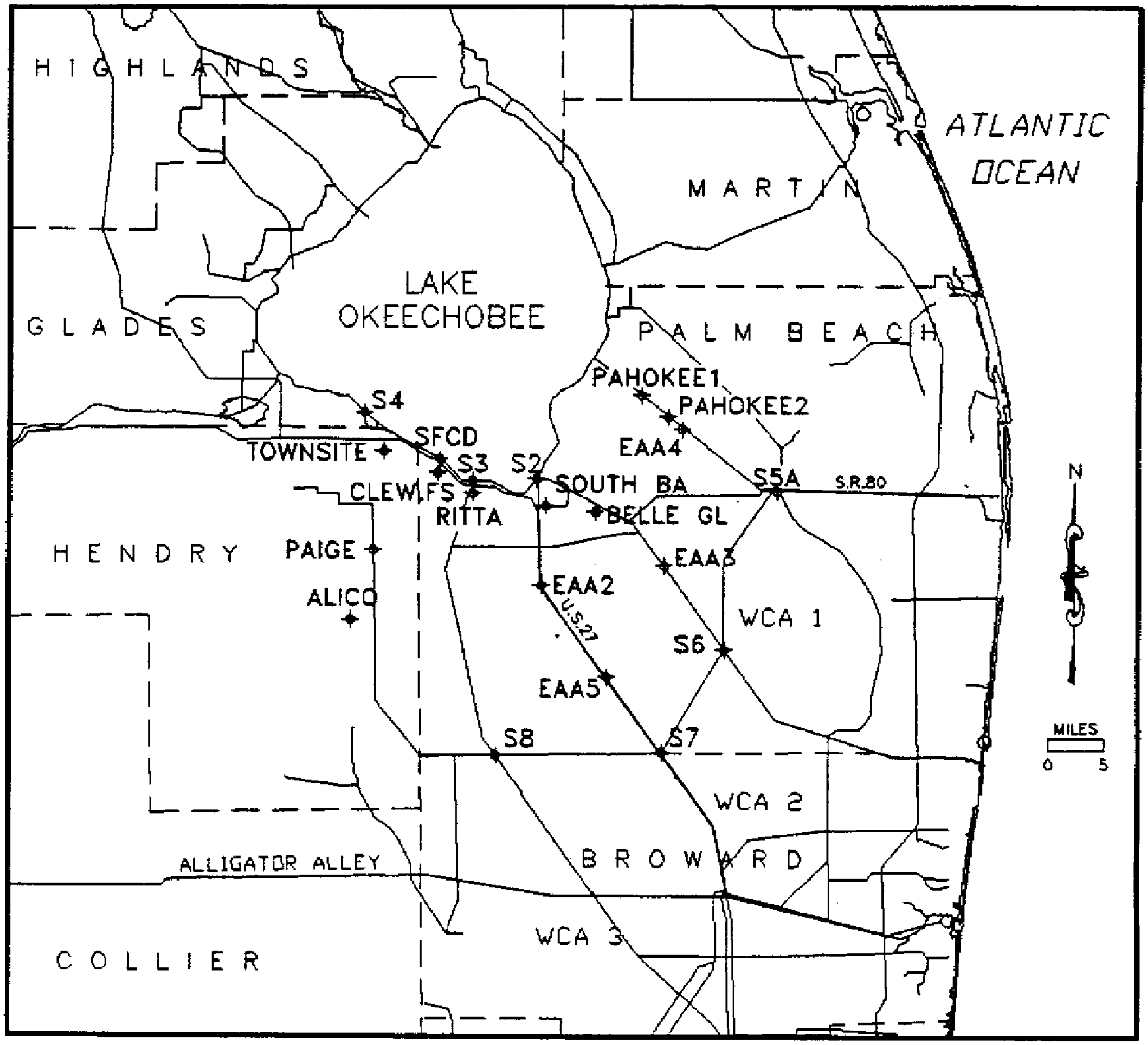


Figure 8. Lake Okeechobee and EAA with Raingauge and Water Control Structures

Partial Definite Project Report, Part 1, Central And Southern Florida Project, USACE,1951).

During the dry month of May, water releases were made to meet the crop water requirements. Therefore, prior to the storm, canal water levels were at or near optimal levels in the area. The June storm raised the canal stages to critical levels. Runoff discharge to the WCAs was not enough to prevent flooding. Therefore, a small portion of runoff water had to be backpumped to Lake Okeechobee based on the Interim Action Plan.

Rainfall Distribution

Within the EAA basin, there are several rainfall measuring stations operated by cooperators, as well as by the District. Monthly totals, as well as the maximum 1-, 3- and 5-day totals for the period June 23-30, were calculated and are presented in Table 1. It can be observed from this table that S-8 recorded the highest amount of rainfall for the month (19.72 inches). However, EAA4, which is a new station installed in the central portion of the EAA basin, recorded the highest amount for the June 23-30 period (13.48 inches).

The 1-day maximum amount was recorded at another new station, EAA2. This station recorded an amount of 5.02 inches of rain. In terms of return frequency, this max 1-day rainfall has a return period of five years.

The maximum 3-day amount was recorded at station EAA4. The total amount for the 3-day period amounted to 8.20 inches. This amount has a return period of one in 10 years.

The maximum 5-day rainfall amount in the EAA recorded at station EAA4 was 12.53 inches. This amount has a return period of 1 in 50 years.

Table 1. Rainfall Amounts (inches) for Various Durations at Stations in the Everglades Agricultural Area

Station	Monthly Total	June 23-30	Max 1-day	Max 3-day	Max 5-day
ALLICO	15.39	7.20	1.54	3.09	5.40
CLEWISTON FS	10.85	7.12	3.45	4.03	6.53
EAA2	15.32	10.26	5.02	7.93	9.34
EAA3	16.89	8.53	1.75	4.28	7.72
EAA4	17.34	13.48	4.65	8.20	12.53
EAA5	15.83	9.70	2.87	6.42	8.58
PAHOKEE1	11.71	7.31	2.62	4.14	6.20
PAHOKEE2	12.69	6.95	2.59	4.50	6.55
PAIGE	11.57	7.70	2.35	4.21	6.68
RITTA	11.61	6.91	2.57	6.22	4.58
S-2	10.56	5.02	2.42	2.91	4.53
S-3	13.94	9.06	3.82	3.33	5.01
S-4	17.16	3.82	4.82	5.43	8.28
SFCD	10.33	7.01	2.96	4.72	6.33
SOUTH BAY	15.27	5.83	2.62	3.90	4.89
TOWNSITE	13.23	8.58	3.45	4.83	7.24
S-5A	12.96	7.06	2.40	4.22	6.58
S-6	11.21	5.43	1.38	3.08	4.96
S-7	17.60	9.34	3.51	5.93	8.08
S-8	19.72	9.00	3.11	5.89	7.30
Basin Average	14.33	7.84	2.62	4.70	6.83

The central portions of the EAA basin experienced rainfall return frequencies of one in five years for a 1-day rainfall, one in 10 years for a 3-day rainfall event, and one in 50 years for a 5-day event.

Surface Water Stages in the EAA

The maximum canal stages for S-8Z and S-7Z, and the average stage for S-6Z for the month of June, 1992, are presented in Table 2. S-8Z is located at Miami Canal 15 miles below Lake Harbor, S-6Z is located at the Hillsboro Canal at 6-mile bend, and S-7Z at North New River at U.S. Sugar.

Table 2. Surface Water Stages in the EAA (feet, NGVD)

	S-8Z (max)	S-6Z (max)	S-7Z (avg)
STATION	MIAMI.15	HILL.6MI	NNRC.SFS
ALT ID	804902	803452	S7Z
DB KEY	12484	12483	5581
01-June	11.90	10.50	11.04
02-June	11.79	10.51	11.08
03-June	11.94	11.08	11.44
04-June	11.74	11.40	11.71
05-June	11.82	11.61	11.62
06-June	11.45	11.67	11.53
07-June	11.51	11.17	11.06
08-June	11.86	11.00	10.94
09-June	11.65	11.45	11.27
10-June	11.28	11.01	11.02
11-June	11.15	10.76	10.83
12-June	10.96	10.48	10.60
13-June	11.23	11.20	10.96
14-June	12.51	11.95	11.93
15-June	13.07	11.30	11.76
16-June	11.09	10.92	11.03
17-June	11.19	11.23	10.60
18-June	11.84	11.81	11.78
19-June	11.59	11.46	11.42
20-June	10.34	11.29	11.32
21-June	10.21	11.00	11.16
22-June	10.49	11.13	11.17
23-June	11.30	11.55	11.58
24-June	11.98	11.60	11.70
25-June	12.11	11.76	11.74
26-June	13.08	12.65	12.81
27-June	12.08	12.56	12.63
28-June	11.91	12.25	12.42
29-June	12.22	12.14	12.32
30-June	12.25	12.14	12.48
01-July	11.95	11.98	12.48
02 July	11.19	11.56	12.17

Table 2. Surface Water Stages in the EAA (feet, NGVD)

03-July	10.82	10.93	11.46
04-July	10.39	9.99	10.64
05-July	10.47	9.54	10.05
06-July	10.03	N/A	9.78
07-July	10.65	N/A	10.63
08-July	10.81	N/A	11.17
09-July	10.92	N/A	11.11
10-July	11.18	N/A	11.10
11-July	11.24	N/A	11.09
12-July	11.04	N/A	11.03
13-July	11.10	N/A	11.07
14-July	11.23	N/A	10.90
15-July	11.59	N/A	10.83
16-July	11.31	N/A	10.71
17-July	11.12	N/A	10.69
18-July	11.80	N/A	10.75
19-July	11.72	N/A	10.98
20-July	11.20	N/A	10.83
21-July	12.16	N/A	10.89
22-July	10.73	N/A	10.72
23-July	10.88		
24-July	11.10		
25-July	10.63		

Optimum canal stages are maintained at approximately 11.0 feet NGVD in the EAA. Canal stages were higher than the optimal stages during the entire months of June and July, 1992.

Inflows to Lake Okeechobee from EAA

During the period June 26 through July 2, a small volume of water was backpumped into the Lake through structures S-2, S-3 and S-4. This backpumping was necessary to lower water levels in the canals to prevent flooding due to rising canal stages. However, backpumping to the Lake adhered strictly to guidelines established in the Interim Action Plan (IAP) as described in the Lake Okeechobee operating permit #50-0679349 issued on September 23, 1983, from the Department of Environmental Regulation to the South Florida Water Management District (District). This discharge was in addition to the runoff water flowing to the Lake from the north. Table 3 depicts the quantity of water that was backpumped to the Lake from the June 23-30 storm event.

Table 3. Water Backpumped from the EAA to Lake Okeechobee (acre-feet)

Date	Structure S-2 Volume	Structure S-3 Volume	Structure S-4 Volume
06/26/92	2,380.00	609.00	1,380.00
06/27/92	3,642.00		1,634.00
06/28/92	3,842.00		1,759.00
06/29/92	4,150.00		1,591.00
06/30/92	4,153.00		1,638.00
07/01/92	2,737.00		912.00
07/02/92	85.00		480.00
Totals	20,989.00	609.00	9,394.00

During the first 25 days of June, the major canals in the area were maintained within their optimum ranges by discharges from the Lake and by pumping excess storm water to the Water Conservation Areas. Water was also released from Lake Okeechobee into the WCA for environmental reasons. Because of the heavy rainfall that started shortly after midnight on the 26th, water was pumped into the Water Conservation Areas. However, this was inadequate to prevent flooding and consequently, according to IAP guidelines, the District initiated backpumping to the Lake.

S-2, S-3 and S-4 pumps were operated together for one day only. Starting June 27, only S-2 and S-4 were pumping. The approximate quantity of water that was pumped to the Lake from the northern portion of the Everglades Agricultural Area was 30,992 acre-feet. A one-foot change in Lake stage approximates 450,000 acre-feet of water. Backpumping of 30,992 acre-feet of water from June 26 to July 3 corresponds to an additional 0.83 inch of water in the Lake.

Outflows from the EAA to the Water Conservation Areas

Outflows from the Everglades Agricultural Area take place through structures S-6, S-7, S-8, S-150 and S-5A. Some runoff water was diverted from Miami Canal (S-8) to the Holeyland through pump G-200A. Water from Hendry County is diverted to the EAA through culverts G-88 and G-136, and is discharged through the outlet structure S-8. Daily discharges through the above structures for the months of June and July, 1992, are presented in Table 4.

As shown in Table 4, the entire month of June was wet. Runoff water was being discharged from the basin on a regular basis during the month to maintain the canal stages at optimal levels. The storm event raised the canal stages to critical levels and more runoff had to be discharged to prevent flooding of the area.

Operation of the system during the month, and especially during the storm event, can now be checked against the design discharge from the structures.

The design discharge for S-5A pump is 4800 cfs. A peak discharge from the June 1992 storm event through this structure occurred on the 29th of June at a rate of 4274 cubic feet per second (cfs). Therefore, discharges made through this structure were within the design discharge range. A peak discharge of 2795 cfs was made on June 27 through structure S-6. The design discharge of the pumps at S-6 is 2995 cfs. A peak discharge of 2836 cfs was made on June 26 through structure S-7. The design discharge of S-7 is 2490 cfs. Discharges exceeding the design discharge were made from this structure. The design discharge was exceeded for seven days from June 26-July 2, 1992. The design discharge for structure S-8 is 4170 cfs. Daily

Table 4. Outflows from the EAA to the Water Conservation Areas (cfs)

STATION	G-200A_P	S150_C	S5A_P	S6_P	S7	S8
DB KEY	15154	4946	04964	4970	4976 +4334	06745 +06746
01-June	0	587.18	0	123.11	320.02	0
02-June	14.99	584.39	0	307.86	335.56	0
03-June	0	635.78	0	0	426.26	0
04-June	0	634.01	360.00	471.39	442.22	307.00
05-June	0	637.12	742.00	682.54	426.33	784.00
06-June	0	596.22	714.00	713.09	388.06	731.00
07-June	0	468.57	243.00	372.17	213.80	221.00
08-June	0	526.94	0	0	182.13	317.00
09-June	116.78	605.52	0	0	324.95	383.00
10-June	217.96	497.95	0	0	225.52	159.00
11-June	232.12	468.29	0	0	25.01	0
12-June	203.63	406.33	0	0	-117.79	0
13-June	208.05	544.43	0	0	73.95	23.00
14-June	141.11	688.56	0	982	384.21	596.00
15-June	136.95	176.14	841.00	2144.86	1515.11	2318.48
16-June	233.81	0	777.00	1917.37	1893.66	2234.00
17-June	211.78	0	749.00	922.43	1093.27	900.00
18-June	231.81	249.51	0	740.5	769.59	738.00
19-June	231.36	595.11	0	665.69	-0.19	633.00
20-June	230.63	603.99	0	0	-0.16	0
21-June	230.47	492.12	0	0	-0.20	0
22-June	70.02	252.22	0	0	-0.14	0
23-June	0	70.48	0	0	52.35	0
24-June	175.42	335.81	470.00	1556.43	425.11	189.00
25-June	202.95	632.52	659.00	1614.59	1989.00	724.00
26-June	202.76	228.17	3061.00	2794.28	2836.00	2663.00
27-June	231.72	-0.02	4138.00	2795.54	2748.86	3602.00
28-June	230.11	-2.53	3312.00	2789.98	2696.46	3476.00
29-June	231.35	-0.97	3566.00	2782.22	2702.64	3483.00
30-June	228.51	0	4274.00	2780.58	2725.53	3601.00
01-July	230.00		3985.00	2771.00	2668.00	3476.00
02-July	231.00		2482.00	2709.00	2629.00	2893.00
03-July	228.00		1462.52	2446.00	2478.00	2638.00
04-July	216.00		763.00	1786.00	2026.00	1776.00

Table 4. Outflows from the EAA to the Water Conservation Areas (cfs)

05-July	224.00		529.00	1178.00	1671.00	1716.00
06-July	183.00		0	558.00	1391.00	1632.00
07-July	189.00		1190.60	752.00	1674.00	1577.00
08-July	72.00		1178.00	1124.00	1711.00	2079.00
09-July	0		1081.00	905.00	1625.00	2119.00
10-July			677.00	635.00	1351.00	1986.00
11-July			781.00	638.00	1430.00	1892.00
12-July			824.00	636.00	1559.00	1831.00
13-July			817.00	669.00	1599.00	1747.00
14-July			1048.00	476.00	1507.00	1916.00
15-July			889.00	434.00	1399.00	1585.00
16-July			847.00	435.00	1301.00	1556.00
17-July			809.00	432.00	1196.00	1445.00
18-July			752.00	437.00	1156.00	1176.00
19-July			1021.00	451.00	1405.00	2021.00
20-July			1002.15	450.00	1464.00	2114.00
21-July			1182.00	450.00	1442.00	2379.00
22-July			1149.00	446.00	1159.00	2107.00
23-July			906.00	445.00	1350.00	2067.00
24-July			1090.00	503.00	1397.00	2247.00
25-July			853.00	550.00	1172.00	1845.00
26-July			846.00	512.00	1127.00	1774.00
27-July			622.00	509.00	578.00	1770.00
28-July			324.00	332.00		1083.00
29-July						0
30-July						11
31-July						20
TOTALS	4,204.29	11,514.00	53,061.00	50,837.00	65,078.00	82,261.00

discharge from this structure for the June 1992 storm event was below the design range.

The volume of water discharged from the EAA to the WCAs between June 1 and July 31 was 529,362.00 acre-feet. Backpumped runoff water to the Lake totaled 30,992.00 acre-feet. Therefore, the total volume of water removed from the EAA basin during this period was 560,354.00 acre-feet.

System Operation

The District, as local sponsor for the Central and Southern Florida Project (C&SF Project), operates the primary pumping stations according to the official Corps of Engineers (COE) manuals. The original operating level for the primary pumping stations which discharge to the WCAs was 13.0 feet (ft) mean sea level (MSL). However, the operating level of the pumping stations was later changed to 11 ft MSL because of soil subsidence. The District does not have this flexibility with the lakeshore pumps (S-2 and S-3). In 1979 the State of Florida, through the Department of Environmental Regulation, limited the use of S-2 and S-3 pumping stations to protect the health of Lake Okeechobee. The goal was to pump as little runoff as possible into the Lake, while preserving the capability of major pumps for use in an emergency. This was accomplished through a state permit to the District, the Lake Okeechobee Operating Permit, which reduced the discretionary operation and imposed an objective process for deciding whether or not to pump, based on a number of factors related to how the pumps were operated in the 1970s. The rules governing the operation of these pumps, as stated in the permit, comprise the so-called Interim Action Plan (IAP) (Tables 5a and 5b). The environmental goals of the permit have been met with over 90 percent of the EAA runoff now pumped away from the Lake. However, the point system used to control S-2 and S-3 has not been modified to reflect changing conditions in the basin. When the pumps have been operated, it is usually because the canal stage has exceeded the 13.0-foot maximum level specified in the COE manual, and the pumps must be started to comply with federal guidelines.

The COE recommended canal levels between 11.5 and 12.0 feet, but also recognized the state's legitimate concern with water quality for the Lake, and have allowed the state to balance the water quality and flood protection issues through restrictions on the use of S-2 and S-3.

Table 5a. EAA Interim Action Plan - Pumping Factors and Assigned Points

Factor	Conditions Points	Conditions Points	Conditions Points	Conditions Points
Time of week	Sat., Sun. or holiday 1	Mon.-Thurs. 2	Friday 3	---
Time of day	4 p.m. - 8 a.m. 1	Noon-4 p.m. 2	8 a.m. - noon 3	---
Average canal level	< 11' 1	11.0'-11.5' 1 11.5'-12.0' 3	12'-13' 4	> 13' 6 *always pump*
Change in canal level	Negative -1	Positive 1 -0.25 ft/hr increase	Positive 4 >0.25 ft/hr increase	-------------
Pump notification	None 0	< 100k gpm 1	> 100k gpm 4	-------------
Rain prediction	None 0	< 2" in next 6 hrs 2	> 2" in next 6 hrs 4	-------------
Rain previous 2 hrs	None 0	< 1" total 1	1"-2" total 2	> 2" total 6
Rain previous 2-48 hrs	None 0	< 4" total 1	> 4" total 3	-------------
Raining now?	No 0	Yes 1	--------------	-------------

Table 5b. Pumping Decisions

Total Points	Miami, North New River, and Hillsboro Canal Basins	West Palm Beach Canal Basin
0-11	No pumping required	No pumping required
12-20	Pump to WCA only	Pump to WCA 1
21-34	Pump to Lake Okeechobee and WCA's	Pump to WCA 1

The instantaneous stages at S-8Z and S-6Z canals rose to 13.08 and 12.65 on the 26th and 27th of June. Backpumping of the S-2, S-3 and S-4 basins was started as the stages reached critical levels.

Large discharges were also made from the EAA into the WCAs because of the rising stages. Personnel at S-5A, S-7, S-8, and S-140 were alerted to start pumping as early as possible on the morning of June 27, following heavy rains the previous night. Although water was being pumped to the WCAs at full capacity, this was not enough to prevent flooding. Therefore, in accordance with the IAP, backpumping to the Lake was started to prevent flooding of the area.

Volume Balance

The EAA area is approximately 592,960 acres. Dividing the total quantity of water that was removed from the area by the acreage (560354/592960) gives 11.34 inches of runoff from the basin. Therefore, 11.34 inches of runoff water was removed from the EAA basin for the months of June and July. Because of constant rain in the basin, daily discharges were made from the basin.

The EAA basin had an average rainfall of 14.33 inches for the month of June. The entire EAA basin is assumed to have an average uniform water table depth of 18 inches from the surface. The moisture storage capacity of the soil at field capacity in the Everglades Agricultural Area is 20 percent (Shih et al., 1983. Basinwide Water Requirements Estimation in Southern Florida. Trans. of the ASAE. Vol. 26, #3). The soil moisture-holding capacity at the assumed root zone depth, therefore, is 3.60 inches. The 11.36 inches of discharge from the basin, together with the moisture-holding capacity of 3.60 inches totaling 14.94 inches, approximately balances the average basin rainfall of 14.33 inches.

As stated earlier, 3/4 inch of runoff per day can be removed from the basin. To remove 14.33 inches of rain, it would take 19.11 days, if all project pumps were operated at full capacity. However, in practice a longer time period is necessary to remove the runoff due to channel capacity limitations and pump operating constraints.

Water Quality and Environmental Impacts

Lake Okeechobee Nutrient Loading

Water quality samples are usually collected every two to four weeks at Lake Okeechobee inflows and outflows. During and immediately following the June storm, grab samples were taken at least once from every significant inflow, usually on June 29 or July 1. At S-2, four daily grab samples were collected during the storm event. At S-191, S-154, and S-65E, auto-sampler data, as well as weekly grab sample data, were obtained. At each of these three structures, four daily composite samples were collected by auto-samplers during the storm period.

The total phosphorus and nitrogen concentrations measured from samples collected from June 23 to July 1 were multiplied by daily discharges at each structure to estimate nutrient loads. Only the auto-sampler data were used to calculate loads at S-191, S-154, and S-65E.

For the month of June, the Lake's total surface water loading of phosphorus and nitrogen was 78 and 843 tons, respectively. Of these totals, over 80 percent was contributed during the June 23-30 storm. These loads are almost twice the respective historical June averages of 42 and 471 tons.

Figures 9 and 10 show phosphorus and nitrogen inputs for each Lake inflow during the June 23-30 storm. Water inputs are also shown to allow inspection of the relative nutrient contribution per unit volume. S-71, S-2, S-191, S-4, the Industrial Canal, S-154, and Culverts 10 and 12 stand out as contributing the highest loads relative to their discharges. However, because water quality was sampled only once at most inflows, only approximate comparisons between inflows should be made. The highest phosphorus concentrations (>0.4 mg/L) were recorded at S-191, S-154, S-71, S-133, and Culvert 10. The highest nitrogen concentration levels (>5 mg/L) were at S-2, Culvert 10, Culvert 12, Culvert 12A, S-236, and the Industrial Canal.

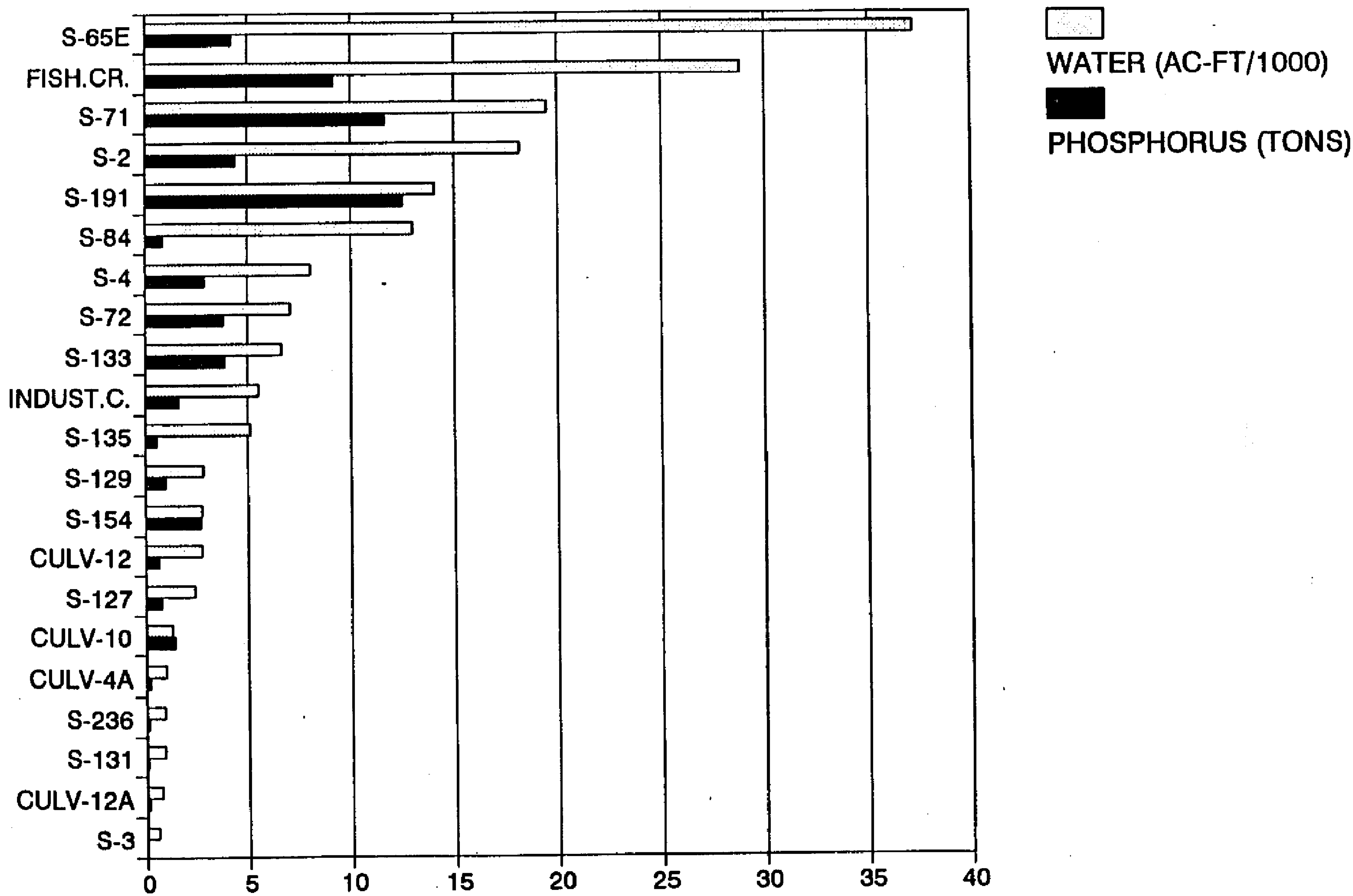


Figure 9. Phosphorus Inputs into Lake Okeechobee during June 23-30, 1992

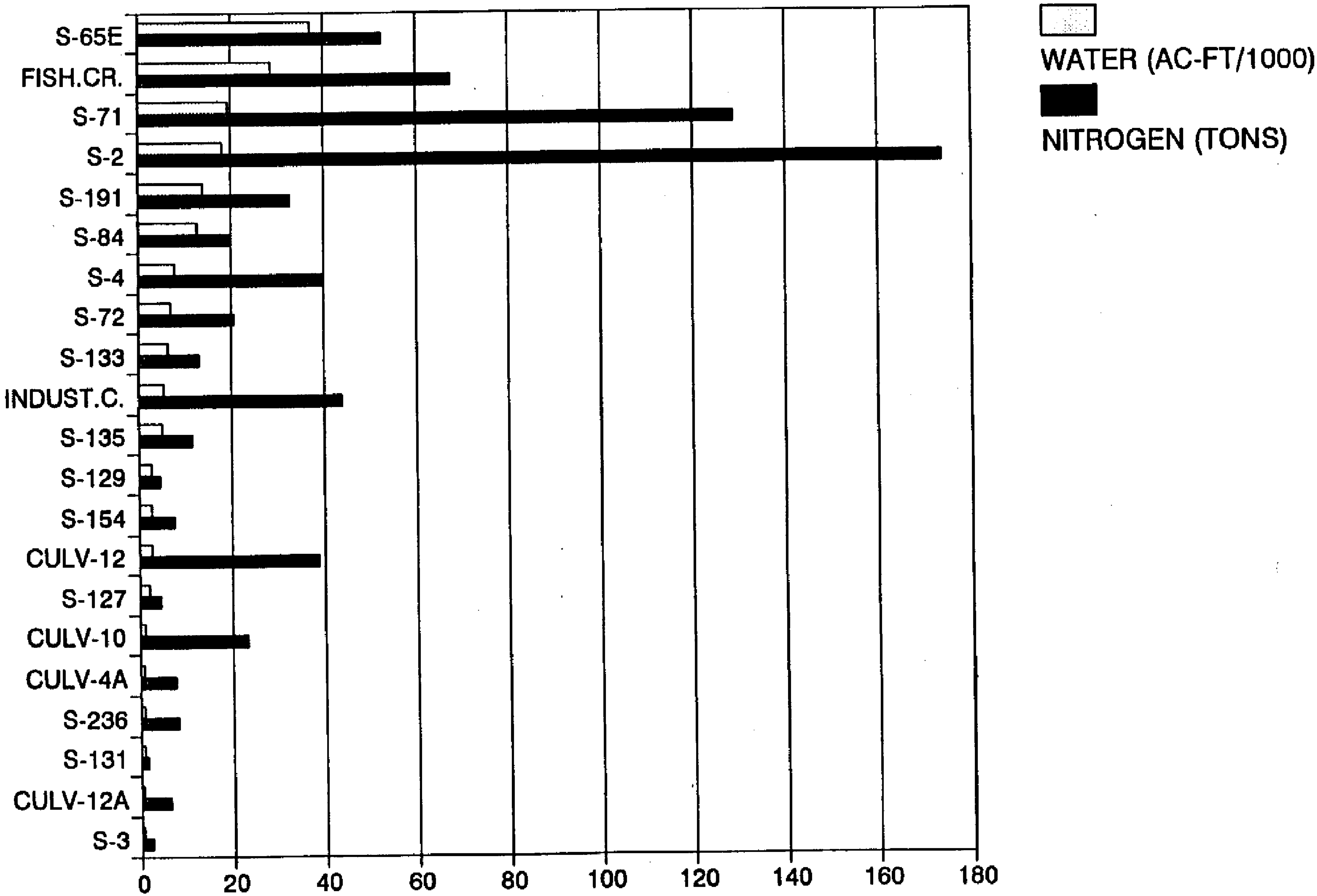


Figure 10. Nitrogen Inputs into Lake Okeechobee during June 23-30, 1992

The stormwater runoff in June and later in July caused dramatic increases in phosphorus concentrations and loads at S-191, S-154, and S-65E (Figures 11 and 12). Concentrations at S-191 and S-65E were within historical ranges for these two months, but S-154 values were much higher than normal. Auto-sampler data show that phosphorus concentrations at S-154 increased from 0.5 mg/L at the storm's start to about 1 mg/L in early July, and then peaked at over 2 mg/L. The June and July loads from these three structures totaled 75 tons, of which 44, 23, and 8 tons were contributed from S-191, S-65E, and S-154, respectively. For comparison, the average contribution (1987-91) from these structures is 217 tons per year.

Lake Okeechobee Fish Kill

During the first week of July 1992, a large fish kill was observed in Lake Okeechobee (Figure 13). Mr. Don Fox of the Florida Game and Freshwater Fish Commission (FGFWFC) estimated two million fish died during the week. Most of the dead fish were found near the Lake's northern and western shore near major tributaries and/or District control structures. The areas most affected included: Chancy Bay (S-135), Taylor Creek/Nubbin Slough (S-191), S-133, Sportsman's Village Canal, Buckhead Ridge, S-127, Indian Prairie Canal, S-129, Harney Pond Canal, and Fisheating Bay. The most commonly collected species of dead fish were: largemouth bass (*Micropterus salmoides*), bluegill sunfish (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), bullhead catfish (*Ictalurus* sp.), gar (*Lepisosteus* sp.), bowfin (*Amia calva*), mosquito fish (*Gambusia affinis*) and least killifish (*Heterandria formosa*).

More than 500,000 dead fish were reported near Buckhead Ridge. However, 82 percent were small forage fish, such as mosquito fish or least killifish, which weigh only several grams each; therefore, total biomass of dead fish in this area was small. Near Sportsman's Village, 241,000 dead fish were reported. The total biomass

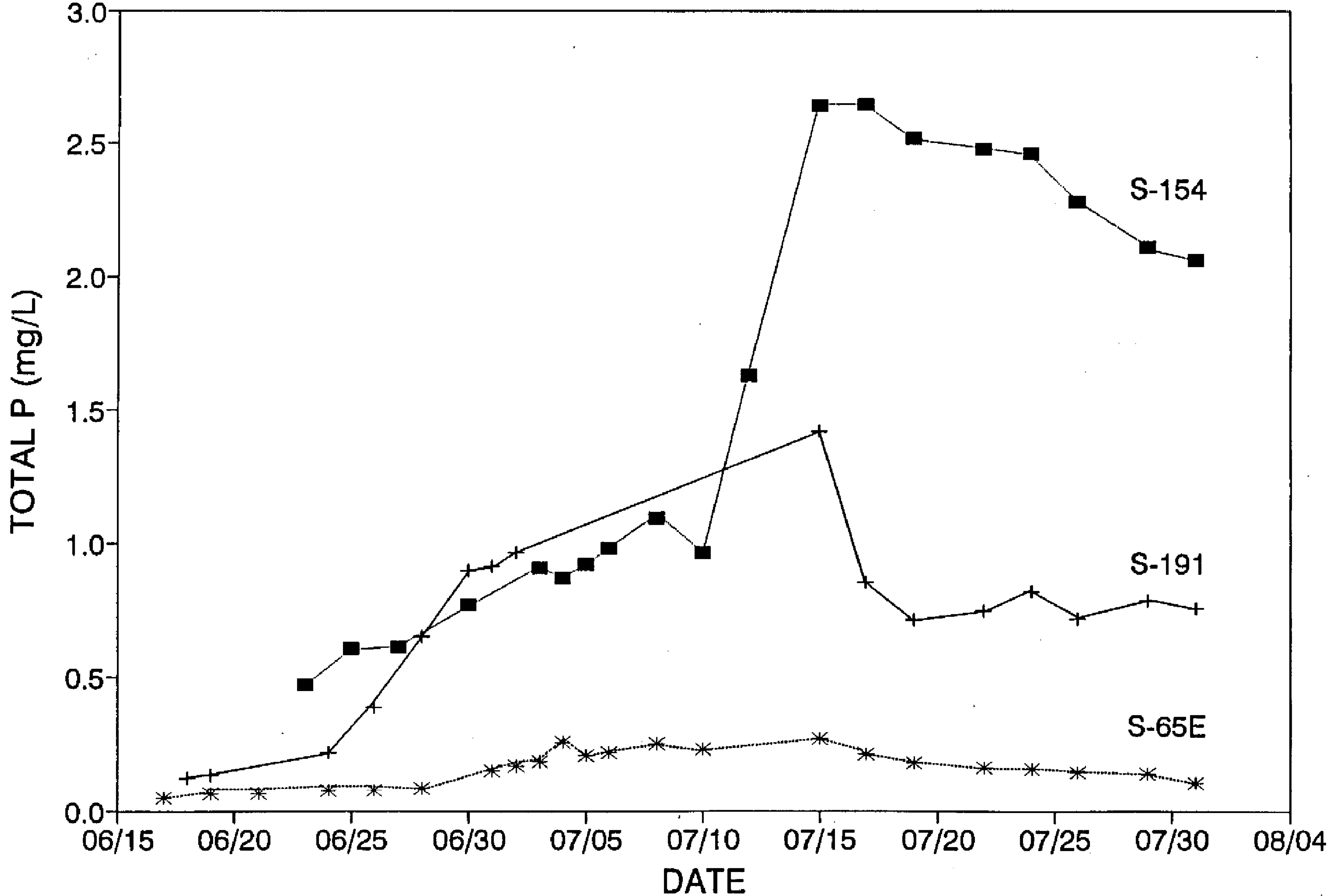


Figure 11. Phosphorus Concentrations at S-191, S-154, and S-65E

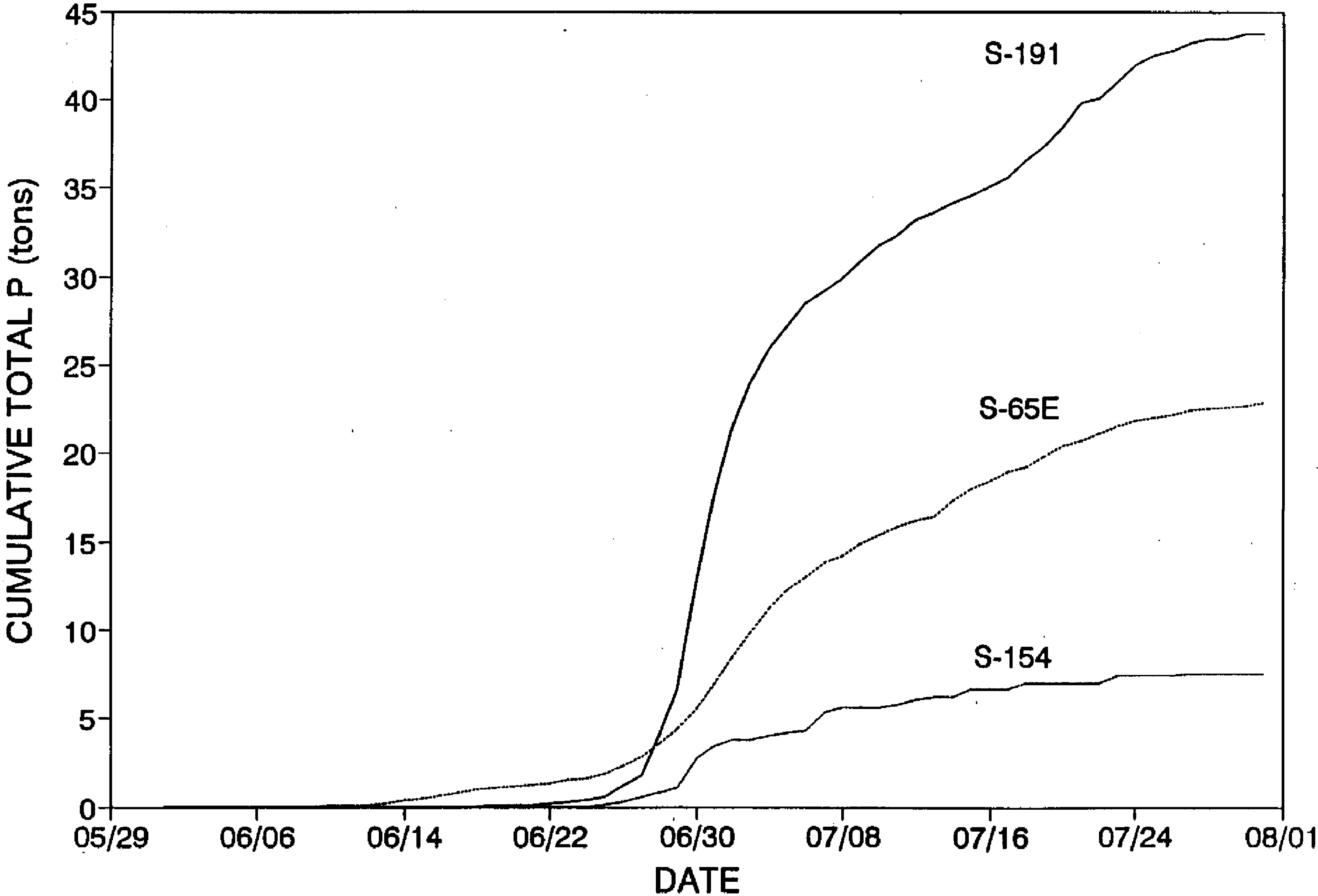


Figure 12. Phosphorus Loads from S-191, S-65E and S-154 for June-July, 1992

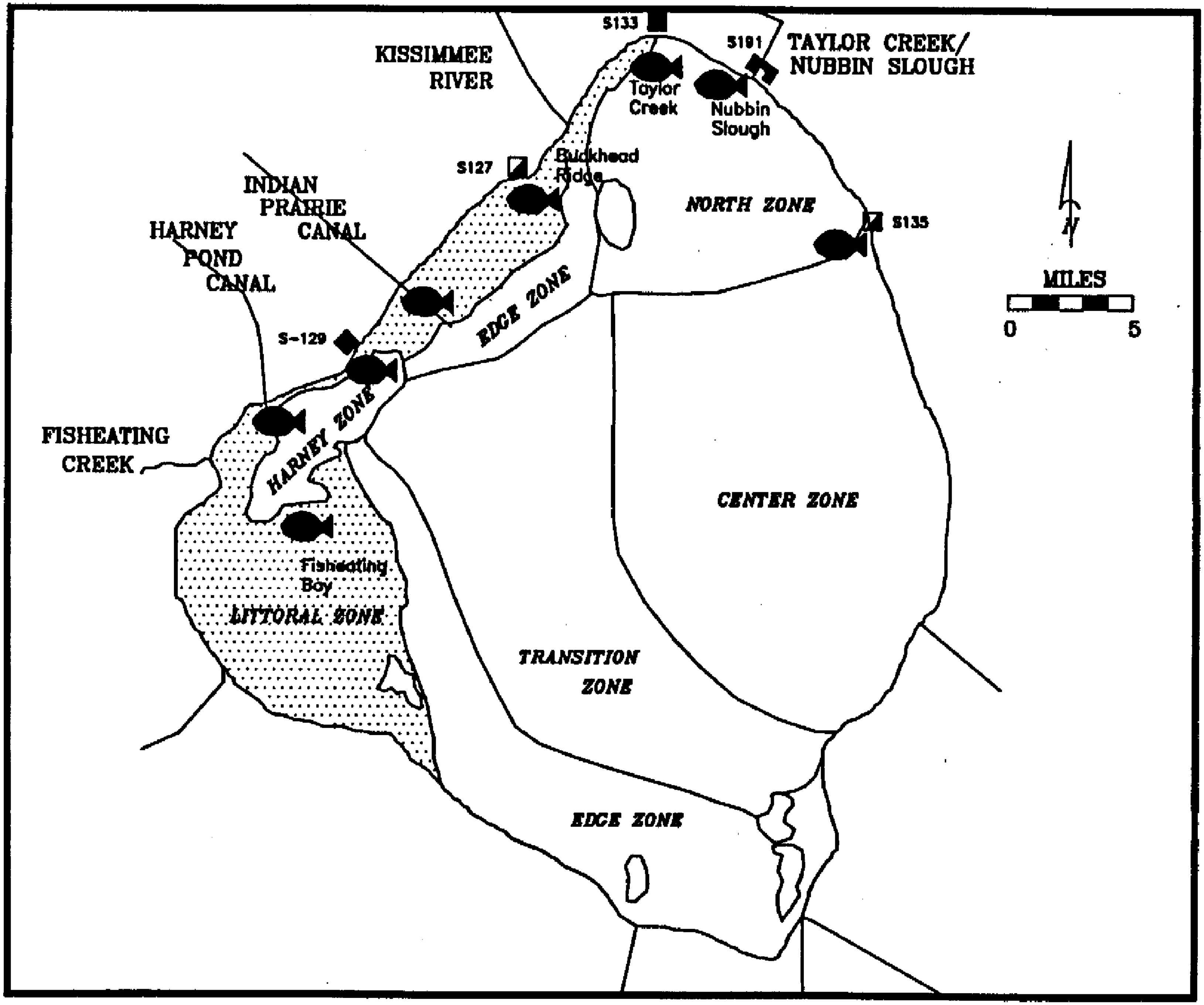


Figure 13. Reported Locations of Fish Kills, July 1-7, 1992

of dead fish was much greater there because adult sport and rough fish comprised a larger percentage of the sampled population. In Fisheating bay, dead fish were collected over an area of 25,000 acres, but density estimates were not available.

The cause of the fish kill appeared to be the extremely low dissolved oxygen (D.O.) concentrations associated with the large Lake inflows. These low D.O. levels, which lasted for more than a week in Lake Okeechobee and many of the tributary waters, suffocated the fish that were trapped near shore and in the tributary areas. SFWMD data collected during June 29-July 1 indicate that stormwater runoff caused D.O. levels to decline far below 5 mg/L at nearly all inflow points (Figure 14). During the week of July 5, the FGFWFC reported D.O. concentrations of less than 0.2 mg/l in Indian Prairie Canal, Harney Pond Canal, and near Sportsman's Village. Near Bird Island in Fisheating Bay, D.O. was measured at 0.5 mg/L. No fish kills were reported for populations farther offshore where D.O. concentrations were generally greater than 7 mg/L.

The stormwater runoff also prompted public health precautions to be taken. High fecal coliform counts were measured in the Taylor Creek watershed and a NO WATER CONTACT and NO FISH CONSUMPTION order was issued for that area.

Lake Okeechobee Algal Bloom

Following the storm event, a large algal bloom developed over parts of Lake Okeechobee during the first week of August. Although this bloom was fairly intense in some areas, surface scum was only observed for several days.

During a routine monitoring trip on August 3, an algal bloom characterized by concentrated surface scum was observed in the rim canal near Slim's Fish Camp in Belle Glade. This bloom extended northeast into Pelican Bay. Algal blooms (chlorophyll a greater than 40 mg/m^3) were also observed at five other sites in the Lake's south end and one site in the north end. Surface scum was not visible at these

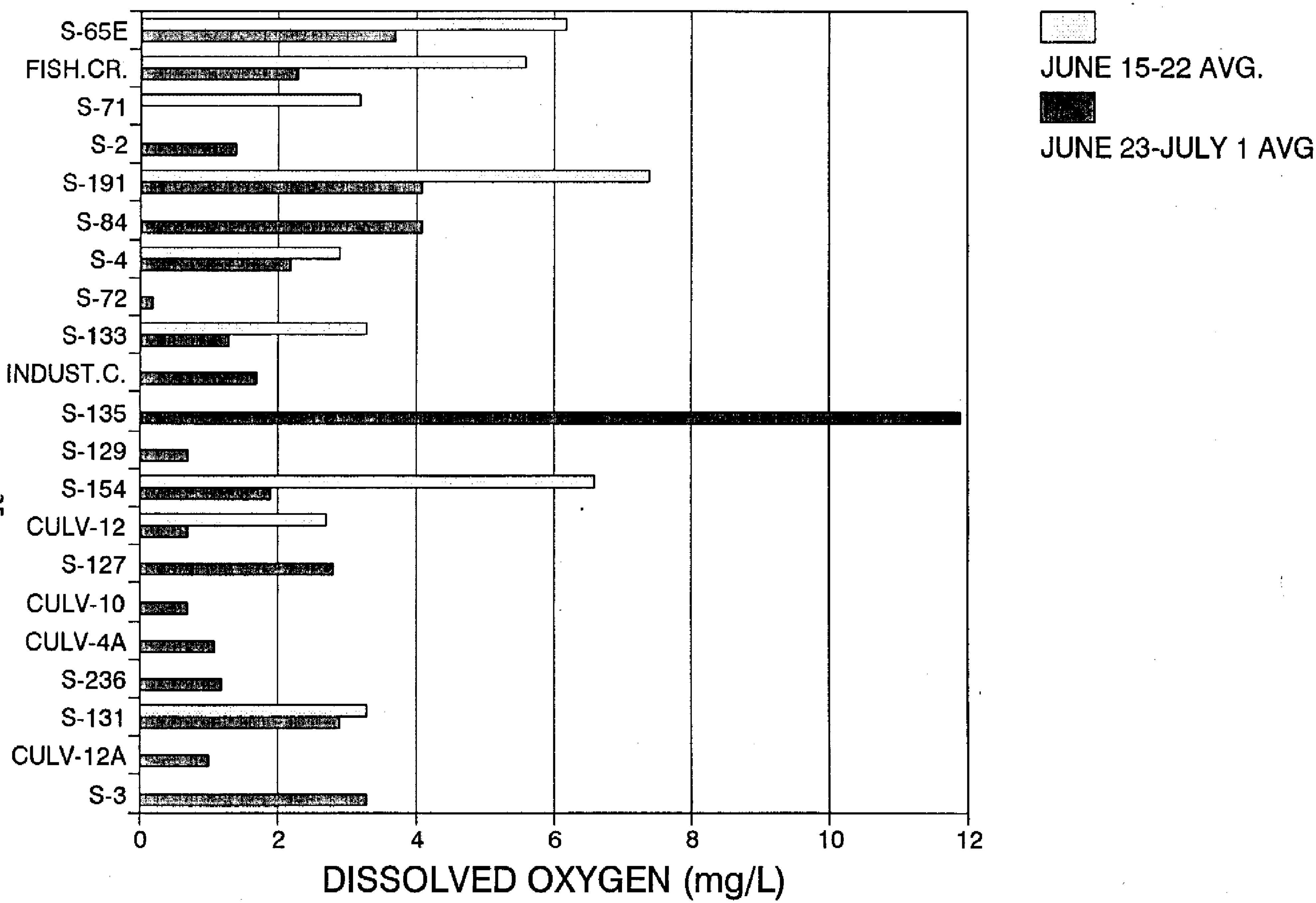


Figure 14. Stormwater Impact on Dissolved Oxygen Concentrations

sites but chlorophyll a concentrations were greater than 100 mg/m^3 at several locations. By August 5, the surface scum had dissipated, but bloom conditions were still reported in some areas of the Lake.

Effect on Dairy Best Management Practices (BMPs)

Runoff water entering the Lake came from the northern portion of the Lake where several dairy operations are located. The rainstorm experienced during the period from June 23 to June 30 was the first significant event since completion of the BMP (Best Management Practice) systems installed on the dairies north of Lake Okeechobee. Rainfall was concentrated in the southern parts of Okeechobee and Highland counties. Dairies approximately ten miles north of Okeechobee reported minor amounts of rainfall with very little effect upon their operations. Therefore, this report will concentrate upon the dairies most significantly impacted by the storm.

The BMP systems consist of a series of components for the collection, storage and land application of dairy waste and contaminated runoff. The components may be grouped as follows:

1) The High Intensity Area (HIA) is a containment/collection system designed to collect dairy cow waste and runoff from areas of high cow densities. The HIA is typically 15 to 50 acres in size for each dairy. It is designed to contain the runoff from a 25-year, 24-hour storm event.

2) The wastewater storage system is typically a 2- or 3-stage system with the first stage being an anaerobic treatment lagoon to digest the waste flushed from the milking parlor. The second and third stages are aerobic ponds sized to contain the anaerobic lagoon effluent and runoff from the HIA until it may be safely land applied. The storage pond systems typically have a surface area of 15 to 70 acres.

3) The spray fields apply the wastewater to feed crops for nutrient uptake. The spray fields are sized to balance the phosphorus loads with the anticipated crop needs. The Department of Environmental Regulation (DER) does not allow the application of wastewater until the water table is below an 18-inch depth and there is no potential for wastewater runoff. Most of the spray fields are constructed with a drainage system because the soils in the region typically have a high water table during the wet season, which prohibits the application of wastewater. The spray fields range from 60 to 240 acres in size. Drainage is accomplished with either subsurface drainage tubing or surface swales.

The storm event had the following impacts upon the BMP systems.

High Intensity Areas (HIAs). The HIAs at all dairies performed as designed. The pumping systems in the smaller HIAs were able to keep up with the rainfall to prevent excessive inundation of the ramps and loafing areas. The only surprise was at Larson Dairy, Barns 5 and 8. At these barns, the operators had to shut off the HIA pumps because the direct rainfall and runoff into the anaerobic lagoon were greater than the capacity of the outlet structure discharging into the second stage storage pond and threatened to overtop the lagoon dike. Runoff from the HIA was contained by the perimeter dike for over a week until the pumps and lagoon were able to catch up. The cow lots within the HIA were partially flooded, but significant problems were not observed.

Waste Storage Ponds. Waste storage ponds at all dairies within the storm area experienced significant increases in water levels, however, discharge at overflow structures was not observed. Fortunately, the storm event occurred early in the wet season so the storage pond levels were still quite low from the dry winter conditions. Had this storm event occurred during September or October, discharge would be anticipated from the outlet structures at a number of dairies. July was dry enough to allow wastewater irrigation to lower the storage pond levels.

Spray Fields. The spray field drainage systems performed as designed. Several dairy owners reported that the drainage systems allowed them to continue hay/forage removal operations while the rest of their farms were too wet to allow good access. Wastewater application at several sites had resumed several weeks after the storm event. At this time, observations have not been made comparing the performance of the subsurface drainage systems versus the surface swale drainage systems.

Pastures. Although the water tables were below their typical seasonal high levels, the rainfall events were intense enough to cause sheet flow at a number of sites. Pasture flooding was observed, but the duration was not great enough to cause any significant grass damage. Most pastures have recovered from the rainfall event and appear to be in typical seasonal conditions.

Water Conservation Areas Nutrient Loading

Routine water quality samples were collected at the major water control structures (S-5A, S-6, S-7, and S-8) which discharge into the Water Conservation Areas. These data were used to estimate nutrient loading to the WCAs during June 23-30.

Since auto-sampler data were not available for all sites, grab sample data were used in this analysis so valid comparisons between sites could be made. If auto-sampler data had been available, they would have been preferred for phosphorus (TP) and nitrogen (TN) loading calculations.

Large volumes of nutrient-rich water were released into the WCAs as a result of the storm. An estimated 42 tons of phosphorus and 1,405 tons of nitrogen were transported into the Water Conservation Areas via the water control structures previously mentioned (Tables 6 and 7). Loads from this eight-day period represent 19 and 18 percent of the WCAs' average annual historic phosphorus and nitrogen loads, respectively. Total phosphorus and total nitrogen loads for S-6 accounted for as much as 45 and 36 percent of the historical annual average, respectively. The historical averages listed are from the 1992 Everglades SWIM Plan. If flow proportional auto-sampler data had been included in the load calculations, loading estimates for TP would be reduced between 14 and 25 percent. Load estimates for TN would be reduced as much as 47 percent for this eight-day period (Table 8).

TABLE 6. Total Phosphorus Load (tons) to the WCAs through Structures S-5A, S-6, S-7, and S-8, June 23-30, 1992.

STATION	STORM LOAD (TP)	HISTORICAL AVG. ANNUAL TP LOAD	STORM LOAD AS A PERCENT OF ANNUAL LOAD
S-5A	13	85	15
S-6	14	31	45
S-7	8	31	26
S-8	7	74	9
TOTALS	42	221	19

TABLE 7. Total Nitrogen Load (tons) to the WCAs through Structures S-5A, S-6, S-7, and S-8, June 23-30, 1992.

STATION	STORM LOAD (TP)	HISTORICAL AVG. ANNUAL TN LOAD	STORM LOAD AS A PERCENT OF ANNUAL LOAD
S-5A	434	3366	13
S-6	430	1197	36
S-7	251	1381	18
S-8	290	1833	16
TOTALS	1405	7778	18

TABLE 8. Total Phosphorus and Total Nitrogen Loads (tons) to the WCAs using Auto-Sampler Data from S-7 and S-8, June 23-30, 1992.

STATION	STORM LOAD (TP)	STORM LOAD (TN)	STORM LOAD AS A PERCENT OF HISTORICAL (TP) AVERAGE	STORM LOAD AS A PERCENT OF HISTORICAL (TN) AVERAGE
S-7	6	139	19	10
S-8	6	125	8	7

The largest phosphorus concentrations recorded during the storm event were collected July 1st and 2nd (Table 9). If TP and TN values from these two days had been included in the load calculations, a greater percentage of the WCAs' average annual phosphorus and nitrogen loads would have been discharged into this area as a result of the storm.

TABLE 9. Measured Total Phosphorus and (Total Nitrogen) Concentration (mg/l) at Each Water Control Structure from June 23 - July 2, 1992.

DATE	S-5A	S-6	S-7	S-8
6/23/92				
6/24/92				0.105 (1.89)
6/25/92				
6/26/92	0.080			
6/27/92	0.234	0.272	0.240	0.110
6/28/92				
6/29/92	0.253 (8.59)	0.349 (9.31)	0.214 (7.17)	0.151 (7.16)
6/30/92				
7/01/92	0.301	0.392	0.338	0.206
7/02/92	0.362	0.383 (5.38)	0.304 (4.09)	0.185 (5.12)

Freshwater Discharge to St. Lucie Estuary

Discharge from the Lake, as well as the discharge of local runoff, was made through Port Mayaca to the St. Lucie Estuary during the storm. Releases from Lake Okeechobee through structure S-308 during the early part of June were made to meet water supply needs of the basin. Table 10 shows the releases that were made.

The maximum discharge of 1500 cfs was made to the St. Lucie Estuary for only the last two days of the month. This was the result of the heavy rainfall of June 26th. The design discharge of S-80 is 16,900 cfs.

Table 10. Lake Okeechobee and St. Lucie River Stages (feet) and Discharges (cfs)

Date	Port Mayaca, S-308			St. Lucie, S-80		
	Stages, up	Stages, down	Discharge	Stages, up	Stages, down	Discharge
6/01	14.33	14.25	233.00	14.20	0.45	0
6/02	14.30	14.17	172.00	14.15	0.50	0
6/03	14.19	14.17	0	14.18	0.63	0
6/04	14.33	14.26	0	14.25	0.65	0
6/05	14.35	14.33	0	14.25	0.68	0
6/06	14.29	14.29	0	14.24	0.75	0
6/07	14.31	14.30	0	14.35	1.05	0
6/08	14.29	14.26	471	14.28	1.05	0
6/09	14.35	14.33	471	14.35	1.00	0
6/10	14.44	14.41	484.00	14.38	0.85	0
6/11	14.40	14.38	392.00	14.45	0.62	0
6/12	14.39	14.40	0	14.30	0.50	0
6/13	14.33	14.32	0	14.35	0.45	0
6/14	14.38	14.41	0	14.40	0.60	0
6/15	14.42	14.44	0	14.33	0.54	0
6/16	14.43	14.52	0	14.59	0.52	0
6/17	14.51	14.51	0	14.54	0.62	0
6/18	14.49	14.48	301.00	14.42	0.65	0
6/19	14.46	14.49	0	14.45	0.75	0
6/20	14.56	14.54	0	14.50	0.95	0
6/21	14.63	14.61	0	14.60	0.80	0
6/22	14.55	14.57	0	14.56	0.60	0
6/23	14.56	14.78	0	14.56	0.62	0
6/24	14.59	14.42	0	14.37	1.00	141.00
6/25	14.55	14.41	0	14.37	0.12	115.00
6/26	15.09	14.54	0	14.50	0.75	240.00
6/27	14.73	14.69	0	14.72	0.40	788.00
6/28	15.10	14.60	0	14.48	0.40	1048.00
6/29	15.29	14.39	0	14.23	0.60	1571.00
6/30	15.55	14.84	0	14.60	1.32	1554.00

Salinity

Freshwater discharges into the St. Lucie Estuary resulting from the June storm event had a dramatic effect on the water chemistry of the system. Figure 15 reveals the rapid decline in salinity in the center of the North Fork. Basically, mean salinity at this location before the storm discharges was near 15 ppt, which was reduced to freshwater within five days. The water temperature shown in Figure 16 for the same period indicates a concurrent mixing of the water column causing a decrease in variability of temperature with depth. The variation in the concentration of dissolved oxygen also decreased over this time period (Figure 17).

Superficially, one may conclude that this change in water chemistry was a natural occurrence and, as an estuarine system, it should tolerate these changes with little long-term effect. However, these changes represented by the figures are indeed indicative of one of the major water management problems that exist in the St. Lucie Estuary.

Before major flood control works were constructed in the estuary watershed, the vast majority of runoff from the C-44 basin area was not directed to the south fork of the estuary as it is today and rapid draining of the basins for the north fork did not occur. The drainage hydrograph for the whole watershed has been compressed with abnormally high flow rates immediately following storm events. This problem is accentuated following large storm events such as the storm that occurred in late June. For example, runoff discharges as high as 2400 cfs occurred from the C-44 basin after the storm. Historically, C-44 flows to the estuary would not have occurred. Flow data for the other basins are not yet available for a more detailed study of total flow to the system; however, model runs--without C-44 runoff included--strongly indicate that historically, before flood control works were installed, the north fork seldom experienced freshwater conditions. When freshwater conditions did occur, they would not remain for an extended period.

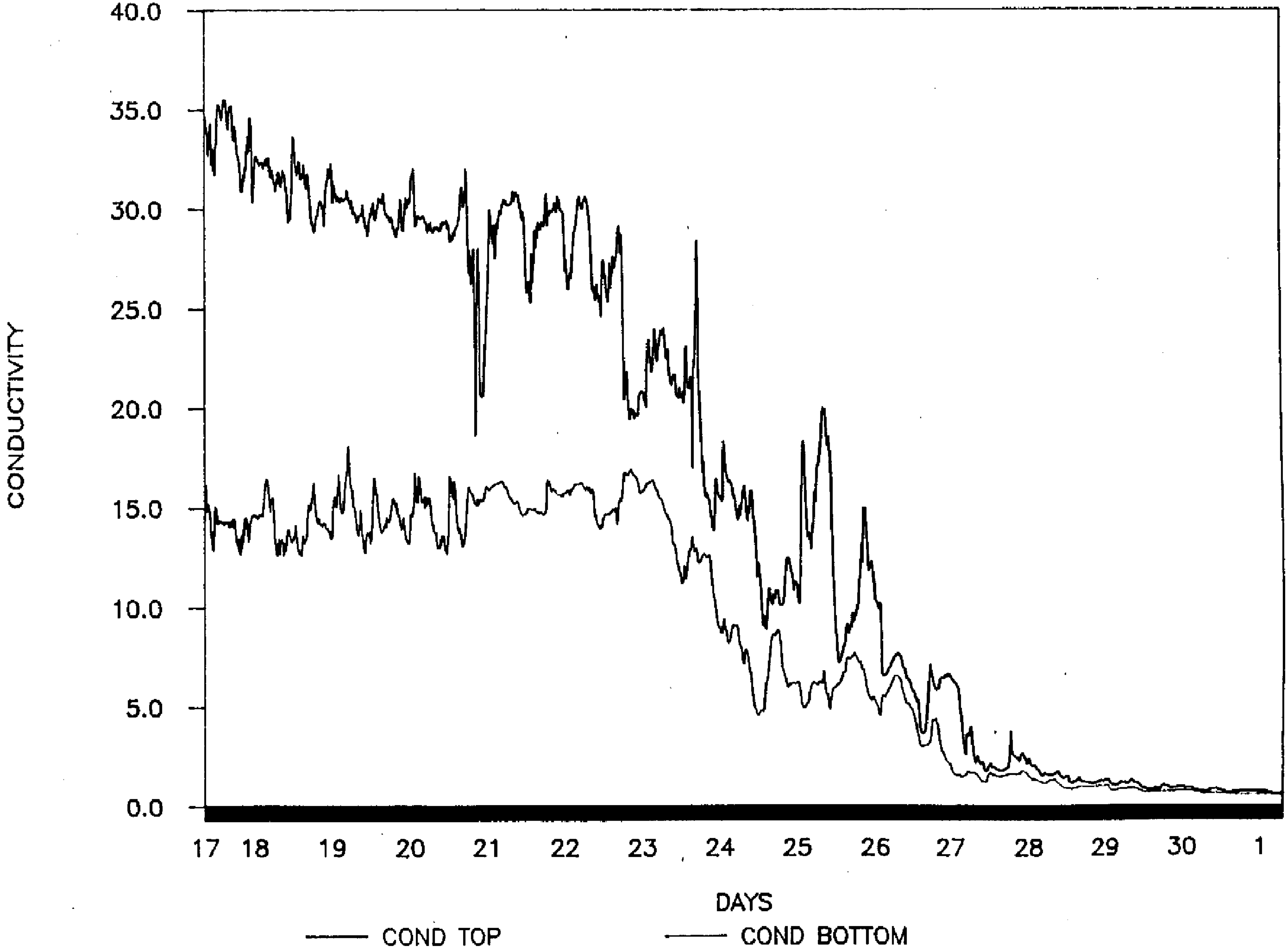


Figure 15. Conductivity (6/17-7/1), St. Lucie Estuary

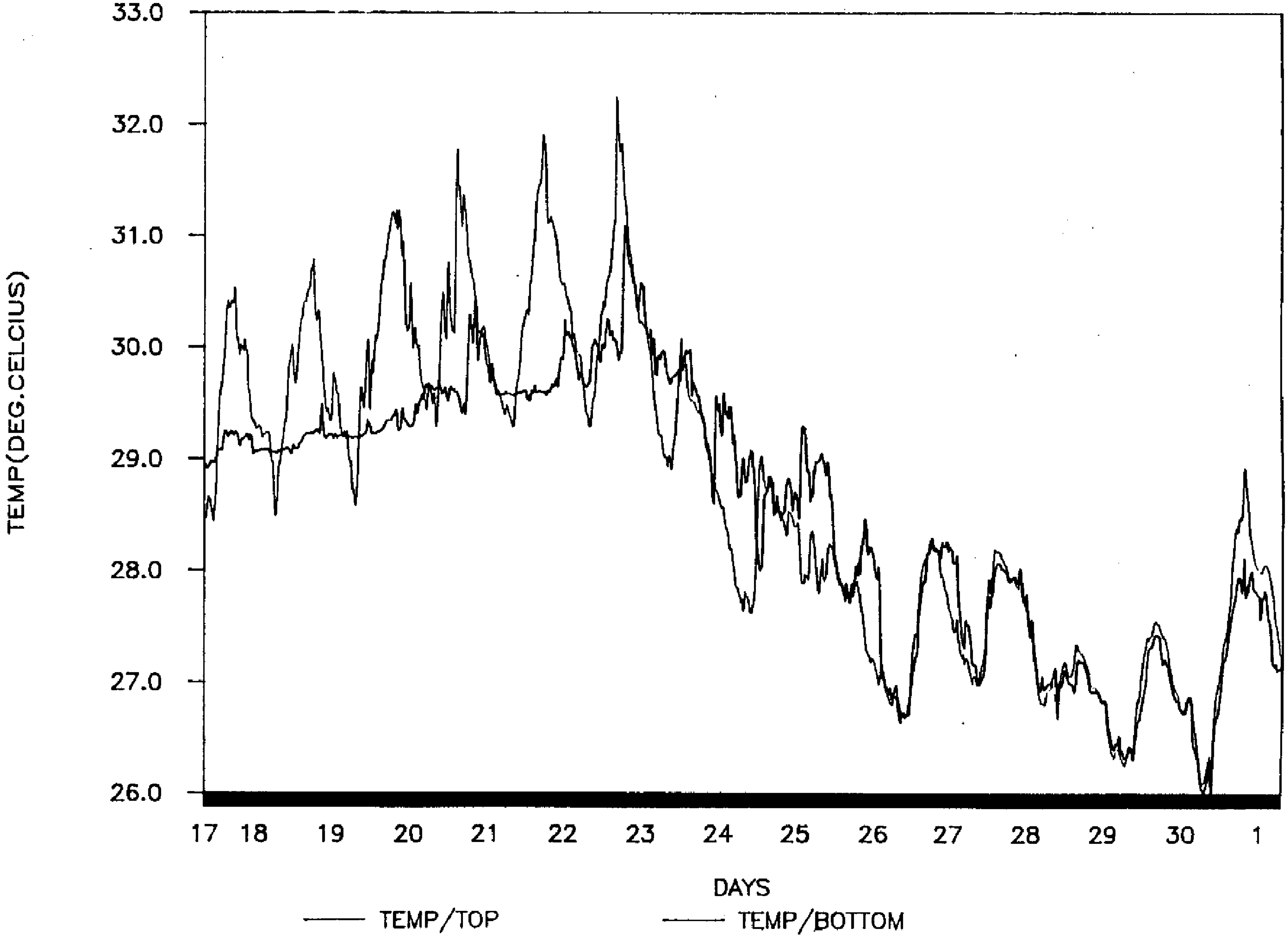


Figure 16. Temperature (6/17-7/1), St. Lucie Estuary

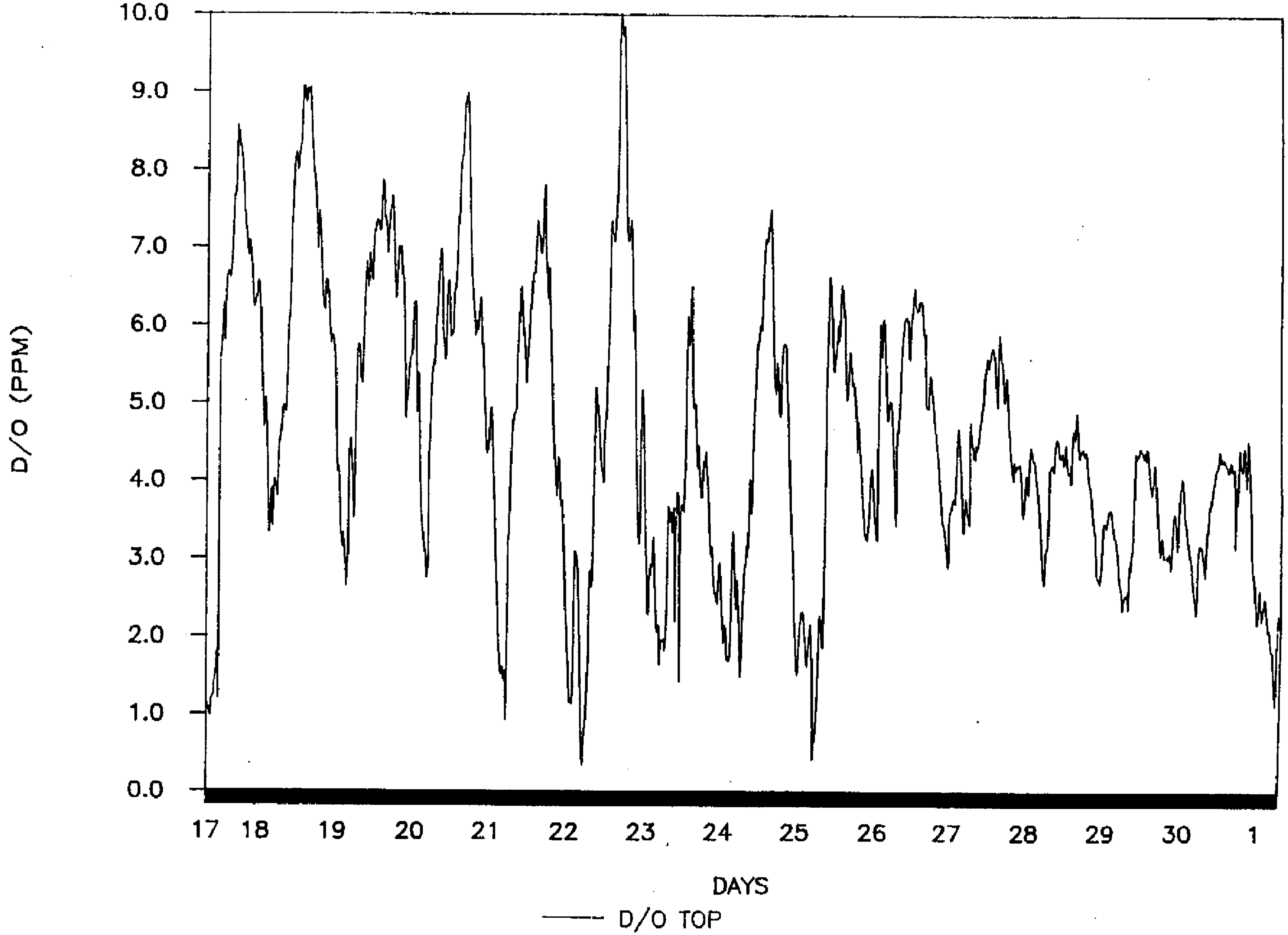


Figure 17. Dissolved Oxygen (6/17-7/1), St. Lucie Estuary

In fact, historical evidence reveals that the north and south forks supported large oyster reefs that could not tolerate freshwater conditions for extended periods.

Once freshwater conditions were established in the inner estuary, as a result of the storm under consideration, it was sustained for nearly three months due mostly to additional runoff from the C-44 basin and pulse releases from Lake Okeechobee for regulatory purposes. The already altered St. Lucie Estuary did not suffer dramatically from this individual storm event; it was just victim once again to the continuous perturbations caused by water management practices that allow extended periods of freshwater conditions in the inner estuary.

The District should continue to pursue alternative Lake Okeechobee Regulation Schedules that would allow more water to go to the south. This can only be realized if the flow capacity from the Lake to the south is increased. In addition, Indian River Lagoon SWIM efforts to make runoff discharges to the inner estuary more environmentally sensitive should continue to be supported.

Field Observations in Okeechobee County

Okeechobee Field Engineering personnel observed flooding in three areas of Okeechobee County (Figure 18). All three areas have historically experienced flooding problems during periods of heavy rain and there were no areas with severe, unusual flooding. The areas observed were:

1) The Dark Hammock Road area. The portion east of U.S. 441 experienced flooding of yards and pastures.

2) The Four Seasons Mobile Home Park. This area also experienced flooding of roads and yards. No houses were flooded.

3) Walmart Plaza # 47-00136-S. This site is a 29.4-acre commercial shopping center located on the west side of U.S. Highway 441 about 2 miles north of State Road 78.was permitted January 11, 1984, for surface water management.

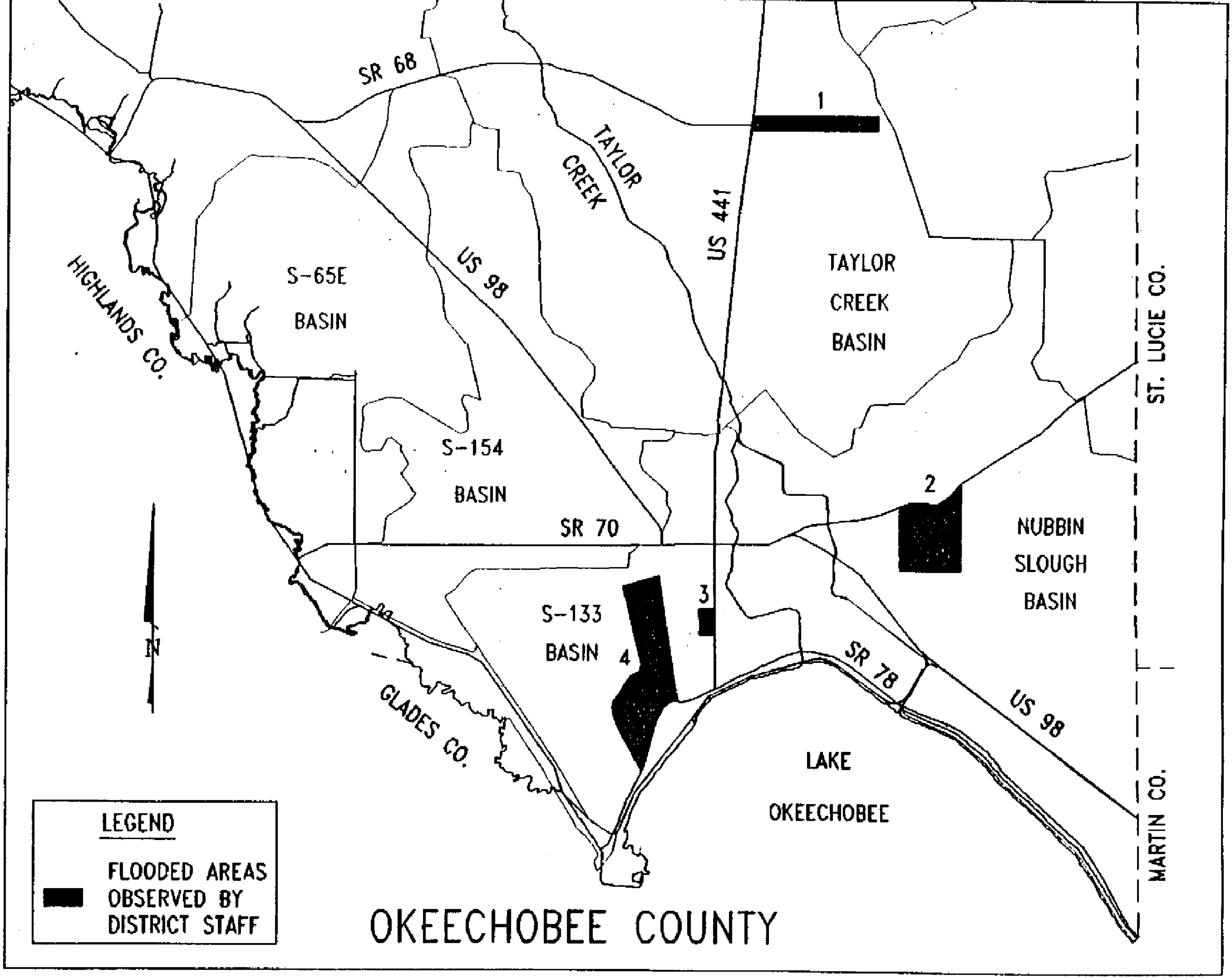


Figure 18. Flooded Area in Okeechobee County

The parking lot was permitted for a minimum elevation of 16.25' NGVD and the minimum floor was permitted at elevation 21.0' NGVD. The site was constructed at or above the minimum permitted elevations.

During the June storm, the site experienced flooding in the front parking area but no floors were flooded. This flooding was mainly due to on-site grading problems that impede the movement of storm water from the front of the site to the rear, where the detention areas are located and the outfall structure discharges to the drainage swale. This is an ongoing internal problem for the Walmart Plaza.

4) Shaded Area on Figure 18.

Outfall swales in this area do not have the necessary capacity to handle all the runoff from contributing areas after moderate to heavy rainfall events. A portion of this area northwest of the intersection of 441 and S.R. 78 was documented with standing water, and one nearby house had standing water in the yard for several days.

Comparison with the January 15-17, 1991, and March 25-27, 1970, Storm Events

Over the past 20 years, only two rainfall events have been reported in the EAA which caused significant flooding. Both of these occurred during the dry season, while the June 1992 event was a wet season storm. The most recent storm event, prior to the June 23-30, 1992, event in the Everglades Agricultural Area was a 3-day storm event on January 15-17, 1991. The average rainfall in the area was 6.6 inches. This rainfall represented the greatest 3-day dry season (November-April) rainfall in the EAA over the period of record. The rainfall was most severe in an area that is especially vulnerable to flood damage during the dry season. Backpumping to the Lake, as well as discharge to the WCAs, was necessary during this dry season storm event. The June 1992 basin average 3-day maximum rainfall is 4.70 inches, and the monthly total was 14.33 inches.

Table 11 compares the amount of water discharged in acre-feet from the EAA basin, either to the Lake or to the WCAs, during the January 1991 and the June 1992 storm events. The volume of water discharged from the EAA during the June 1992 storm event was 2.06 times that discharged for the January 1991 storm event. The higher volumes discharged during June 1992 reflect the fact that discharges were being made from the beginning of the month due to continuing rainfall in the area.

Table 11. Comparision of January 1991 Storm Event with June 1992 Storm Event

Structures	Jan. 15-17, 1991 Storm Discharges (acre-feet)	June 23-30, 1992 Storm Discharges (acre-feet)
S-2	(1/16-20) 22,950	(6/26-7/2) 20,989
S-3	(1/16-19) 4,470	(6/26) 609
S-4	0	9,394
S-5A	63,890	(6/1-7/31) 105,246
S-6	81,950	(6/1-7/28) 100,835
S-7	36,750	(6/1-7/31) 129,082
S-8	47,080	(6/1-7/31) 163,164
Totals	257,090	529,319

The 3-day January 1991 rainfall had a return period of 50 years, based on extreme value frequency analysis performed on 31 years of dry season rainfall. However, if no distinction is made of the wet and dry season storm events, then the return frequency of such an event is only one in five years. The June 1992 3-day maximum basin average rain has a return period of less than one in two years.

The EAA experienced another dry season storm on March 25-27, 1970. It was reported that during this storm event, the basin received six inches of rain during a 3-day period. However, it was reported that approximately 20,000 acres of corn and

5,000 acres of leafy vegetables, as well as pasture, were damaged. Almost 70-80 percent of the agricultural area had flooded fields during this storm. The L-8 canal reached a stage of ± 20 feet NGVD at S-76 during this storm.

EFFECTS IN SOUTHEASTERN DADE COUNTY, FLORIDA BAY AND BISCAYNE BAY

The C-111 basin in southern Dade County has an area of approximately 100 square miles (66,000 acres). During the June 1992 storm event, this area experienced flooding problems. C-111 is designed to provide flood protection from a 1-10 year storm in the basin.

There are 12 project control structures servicing the C-111 basin. They are structures S-331, S-173, S-194, S-196, S-174, S-332, S-175, S-177, S-178, S-18C and S-197. S-197 used to be an earthen plug which was recently replaced by 13 culverts with risers (Figure 19).

Rainfall Distribution

Rainfall stations in southeastern Dade County and the C-111 basin are located at S-18C, S-332, S-20, and Homestead Field Station. Table 12 depicts the rainfall values for different durations for the above stations.

Table 12. Rainfall Statistics for Stations around C-111 Basin (inches)

Stations	Monthly Total	June 23-30 Total	1-day Max.	3-day Max.	5-day Max.
S-18C	24.17	12.64	4.01	8.14	10.76
S-20	19.72	12.13	3.18	6.53	10.36
S-332	25.26	14.13	2.98	8.01	12.80
Homestead F/S	31.21	20.74	5.55	9.76	13.24
Basin Average	**25.09**	**15.16**	**3.93**	**8.11**	**11.79**
Std. Dev.	**4.10**	**3.27**	**1.01**	**1.14**	**1.25**

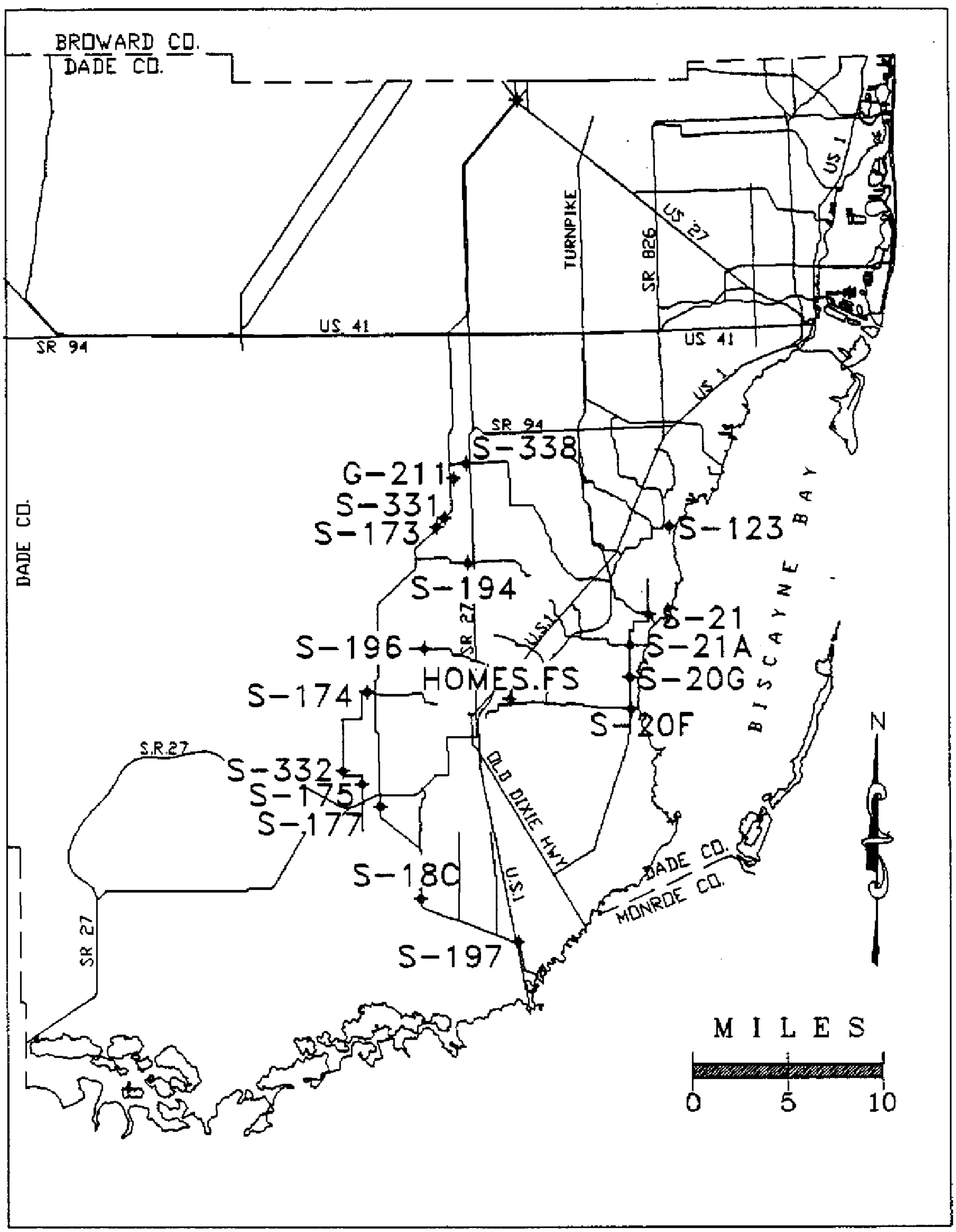


Figure 19. Control Structures around South Dade, Florida Bay and Biscayne Bay

The 1-day basin-wide rainfall for this storm event is 3.93 inches. This amount has a return period of less than two years. However, if one looks at an individual station such as the Homestead Field Station, this station recorded 5.55 inches in one day; the return period of this amount of rain is of the order of one in 3 years. Basin-wide, the 3-day maximum rainfall of 8.11 inches has a return period of one in 5 years; whereas an individual station (Homestead Field Station) recorded 9.76 inches, which has a return period of one in 10 years. The basin average 5-day max. rainfall of 11.79 inches has a return period of 1 in 10 years; whereas an individual rainfall station (Homestead Field Station) with a rainfall amount of 13.24 inches has a return period of 25 years. A design memorandum on rainfall frequency estimates for the District was developed by the Corps of Engineers as part of the Central and Southern Florida Project. The study encompassed durations from one day to one year and return periods from two to 100 years. According to this report, the basin-wide monthly total rainfall of 25.09 inches for south Dade, and especially the C-111 basin, has a return period of one in 50 years (Water Resources Division, May 1982, Report on Tropical Storm Dennis, August 16-18, 1981, South Florida Water Management District).

Therefore, it can be summarized that the area around the vicinity of the Homestead F/S experienced a 1 in 3-year return period for a 1-day storm, 1 in 10 years for a 3-day maximum storm, and 1 in 25 years for a 5-day storm. The basin average monthly total rainfall amount has a return frequency of 1 in 50 years.

Temporal distribution of rainfall for the rainfall station located at S-20 is available and is depicted in Figure 20. which shows that the maximum rainfall at this station fell during the hours between the 29th and 30th of June.

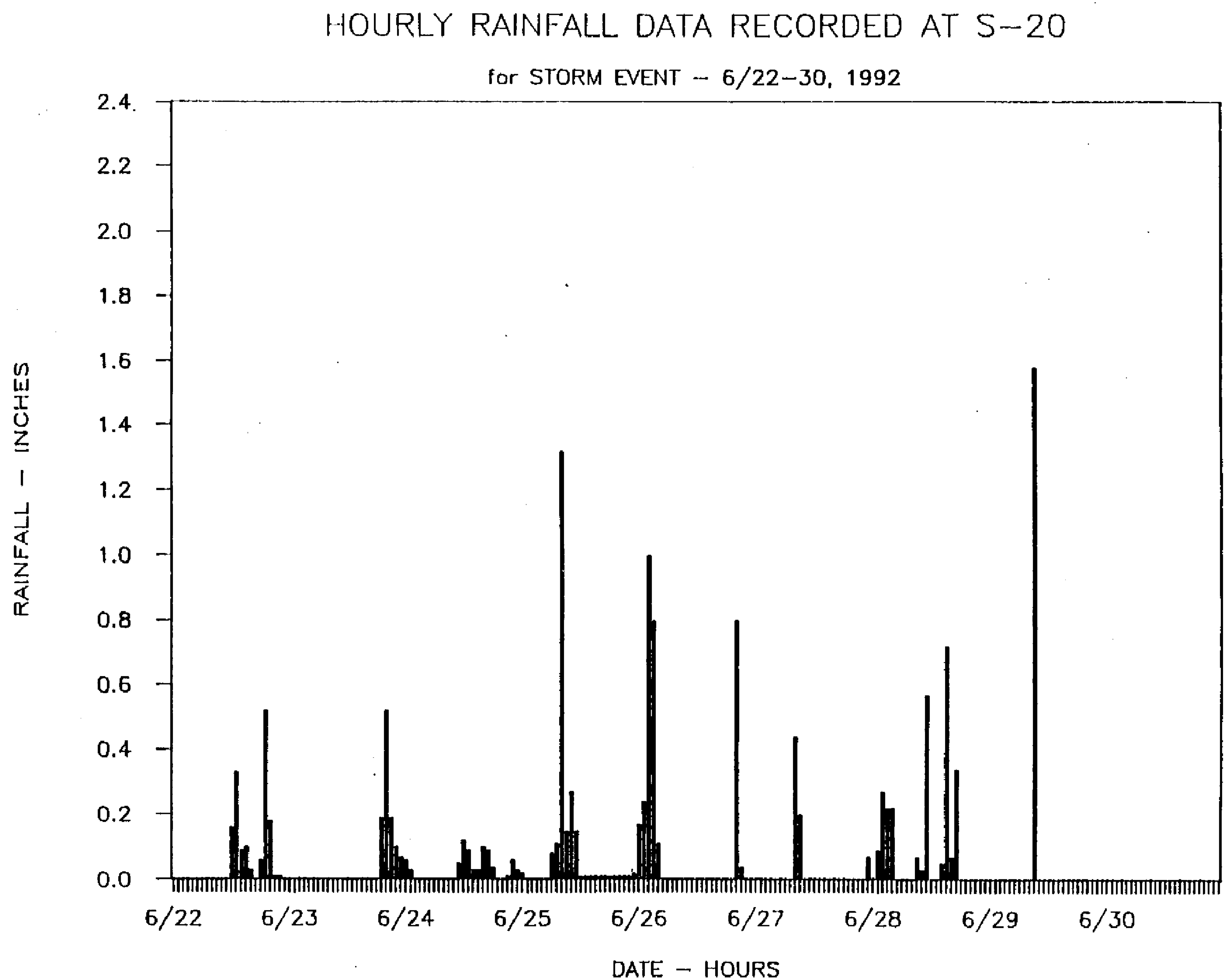


Figure 20. Temporal Distribution of Rainfall at Station S-20

Surface Water Stages

Presented in Table 13 are the June 1992 headwater (H) and tailwater (T) stages for structures around the C-111 basin area.

Table 13. Surface Water Stages around C_111 Basin (feet, NGVD)

STATION	S174_T	S177_H	S331_T	S331_H
DB KEY	12291	13154	4998	4996
01-June	2.53	1.99	2.86	3.42
02-June	2.50	1.99	2.84	3.35
03-June	2.50	1.98	2.85	3.43
04-June	2.91	2.13	3.26	4.08
05-June	3.03	2.26	3.42	4.12
06-June	3.19	2.56	3.76	4.30
07-June	3.63	3.27	4.45	4.68
08-June	3.78	3.51	4.35	4.53
09-June	3.67	3.57	4.13	4.18
10-June	3.75	3.51	4.09	4.15
11-June	3.73	3.49	4.18	4.22
12-June	3.98	3.63	4.20	4.36
13-June	4.28	3.87	4.80	4.89
14-June	4.32	4.01	5.05	4.20
15-June	4.30	4.01	4.59	4.75
16-June	4.26	3.93	4.45	4.68
17-June	4.15	3.84	4.36	4.61
18-June	4.14	3.85	4.36	4.60
19-June	4.16	3.88	4.39	4.59
20-June	4.07	3.78	4.32	4.41
21-June	4.03	3.74	4.28	4.36
22-June	4.13	3.85	4.35	4.44
23-June	4.16	3.84	4.66	4.15
24-June	4.69	3.89	5.39	4.20
25-June	5.05	4.10	5.87	5.43
26-June	5.27	4.05	5.83	6.02
27-June	5.24	3.99	5.84	6.17
28-June	5.61	4.22	6.20	6.44
29-June	5.78	4.28	6.36	6.47
30-June	5.48	3.93	6.01	6.36

The optimal normal canal stage around the Homestead area is 2.30 feet NGVD. The critical stage is 2.80 feet NGVD. It can be seen that stages were above the critical level starting June 5, 1992. According to the operational criteria established by the Corps of Engineers, the earthen plug at the lower end of the C-111 Canal near structure S-197 has to be removed whenever the headwater stage at structure S-177 reaches 4.3 feet NGVD. However, there is no earthen plug at the present time. The earthen plug was replaced with 13 culverts with risers.

Inflows to C-111 Basin

Inflows to the C-111 basin come from structures S-331 and S-173. Table 14 depicts the inflows to the C-111 basin in cfs.

Inflows coming to the basin through structures S-173 and S-332 during the entire storm period were 3977.00 and 3138.58 cfs, respectively. The total inflow to the C-111 basin is approximately 7116 cfs, or 14,112.00 acre-feet.

Table 14. Inflows to C-111 Basin (cfs)

· STATION	S-331	S-173
DB KEY	5000	6727
01-June	0	140.58
02-June	0	134.06
03-June	0	142.80
04-June	0	176.46
05-June	0	162.97
06-June	0	135.63
07-June	0	92.57
08-June	0	77.16
09-June	0	40.64
10-June	0	38.13
11-June	0	38.27
12-June	0	71.58
13-June	0	45.35
14-June	356.17	32.37
15-June	0	53.07
16-June	0	92.91
17-June	0	98.87
18-June	0	96.35
19-June	0	85.42
20-June	0	60.59
21-June	0	55.45
22-June	0	54.49
23-June	252.86	26.25
24-June	371.21	0
25-June	150.53	0
26-June	0	0
27-June	0	0
28-June	0	0
29-June	0	0
30-June	0	0
01-July		0
02-July		48.06
03-July	329.12	21.06
04-July	365.84	
05-July	345.80	

Table 14. Inflows to C-111 Basin (cfs)

STATION	S-331	S-173
06-July	300.60	
07-July	266.88	
08-July	267.08	
09-July	255.00	
10-July	220.00	
11-July	207.00	
12-July	163.15	
13-July	123.65	31.09
14-July		85.68
15-July		83.20
16-July		85.00
17-July		88.09
18-July		112.40
19-July		148.27
20-July		114.22
21-July		91.07
22-July		95.18
23-July		92.21
24-July		91.08
25-July		
26-July		
27-July		
28-July		
29-July		
30-July		
31-July		
Totals	3977.00	3138.58

Outflows from C-111 Basin

Outflows from the C-111 basin take place via structures S-175, S-332, S-18C, S-194 and S-196. During the latter part of the months of June and July, 1992, water was discharged from most of these structures. Presented in Table 15 are the discharges in cubic feet per second from these structures.

Table 15. Outflows from the C-111 Basin (cfs)

Station	S332_P	S175_C	S18C_S	S196_C	S194_C
DB KEY	6971	4644	6771	3970	3958
01-June	10.78	0	1.32	0	0
02-June	10.78	0	1.18	0	0
03-June	10.78	0	-0.81	0	0
04-June	10.78	0	3.34	0	0
05-June	10.78	0	3.72	0	0
06-June	49.43	0	4.69	30.56	40.81
07-June	48.94	0	7.61	159.06	249.55
08-June	126.50	0	8.34	109.03	155.63
09-June	130.76	0	8.13	81.02	143.46
10-June	89.21	0	8.12	75.55	136.93
11-June	149.25	0	7.49	70.74	137.46
12-June	97.86	0	138.96	42.00	136.86
13-June	151.21	0	627.82	0.40	131.63
14-June	141.62	0	690.41	-42.50	125.64
15-June	150.81	0	330.43	1.22	118.31
16-June	95.56	0	379.23	-5.37	90.94
17-June	172.27	0	400.79	-61.21	33.73
18-June	79.53	0	432.66	0.56	121.98
19-June	28.85	0	435.13	46.47	122.59
20-June	0	0	439.71	45.69	124.48
21-June	0	0	370.36	36.20	128.42
22-June	130.60	165.52	354.23	20.00	129.34
23-June	168.57	405.73	606.84	-15.78	137.95
24-June	179.66	506.14	1680.76	2.120	197.75
25-June	178.71	553.63	2110.13	52.40	158.48
26-June	152.97	570.29	2494.46	60.59	139.48
27-June	159.34	575.95	2531.97	29.91	132.34
28-June	119.11	692.90	2642.52	-2.30	120.86
29-June	172.40	683.69	2915.57	-10.77	111.32
30-June	163.36	638.46	2779.84	39.29	117.19
01-July	161.86	M	2232.50	60.41	99.24
02-July	148.73	410.38	1771.60	70.82	106.33
03-July	98.37	456.84	1258.84	64.49	104.24
04-July	71.22	455.41	963.91	55.91	100.64
05-July	0	369.02	984.60	47.34	97.04

Table 15. Outflows from the C-111 Basin (cfs)

Station	S332_P	S175_C	S18C_S	S196_C	S194_C
06-July	15.61	370.01	1069.68	34.02	96.17
07-July	96.95	360.73	1135.27	14.93	107.74
08-July	160.20	45.91	692.05	60.01	117.53
09-July	162.42	348.93	611.28	56.59	113.69
10-July	159.83	361.09	546.44	56.15	127.27
11-July	156.13	366.32	234.35	59.83	112.35
12-July	156.13	356.37	223.52	63.85	93.75
13-July	158.30	209.39	231.58	66.30	84.02
14-July	156.23	126.56	225.50	63.34	106.38
15-July	163.90	46.93	84.83	67.19	112.88
16-July	165.38	26.21	6.89	67.60	126.06
17-July	162.79	0	7.29	67.81	110.81
18-July	156.13	0	7.55	69.38	112.80
19-July	156.14		7.63	71.01	117.02
20-July	169.10		8.24	72.56	115.32
21-July	164.28		8.30	73.64	100.32
22-July	164.28		7.80	77.39	117.76
23-July	163.54			79.23	118.74
24-July	165.03			84.80	108.59
25-July	156.16			79.37	107.78
26-July	156.16			72.65	107.64
27-July	164.30			67.92	103.21
28-July	164.30			72.68	104.61
29-July				81.94	172.03
30-July				86.30	115.02
31-July				86.48	120.85
TOTALS	6,963.89	8,813.00	34,734.60	2,816.91	6,680.97

Outflow through the above structures for the June 1992 storm amounted to 119,021.00 acre-feet.

The June storm event flow exceeded the design flow, as well as the flow through Hurricane Dennis, for structures S-11, S-176, S-175 and S-18C.

Groundwater Levels

Prior to the storm, groundwater levels in the south Dade area were generally slightly less than one foot above normal. As a result of heavy rainfall, groundwater levels rose approximately four to five feet between June 21 and June 28. In most cases, groundwater levels peaked on June 28. Some wells, such as F-358, G-1251, G-3356 and G-3437, showed water levels above land surface, indicating ponding conditions near these wells. These groundwater wells are near the marsh areas. Groundwater levels in well G-3356 also exceeded maximum historical levels. Most wells showed declining groundwater levels after June 28.

Figure 21 depicts the location of the south Dade monitor wells referenced in this report. Figures 22 through 25 show daily groundwater levels for these wells from June 20 through June 30. Included on the figures are mean groundwater levels in 1991, the maximum and minimum groundwater levels for the period of record, as well as the land surface elevation.

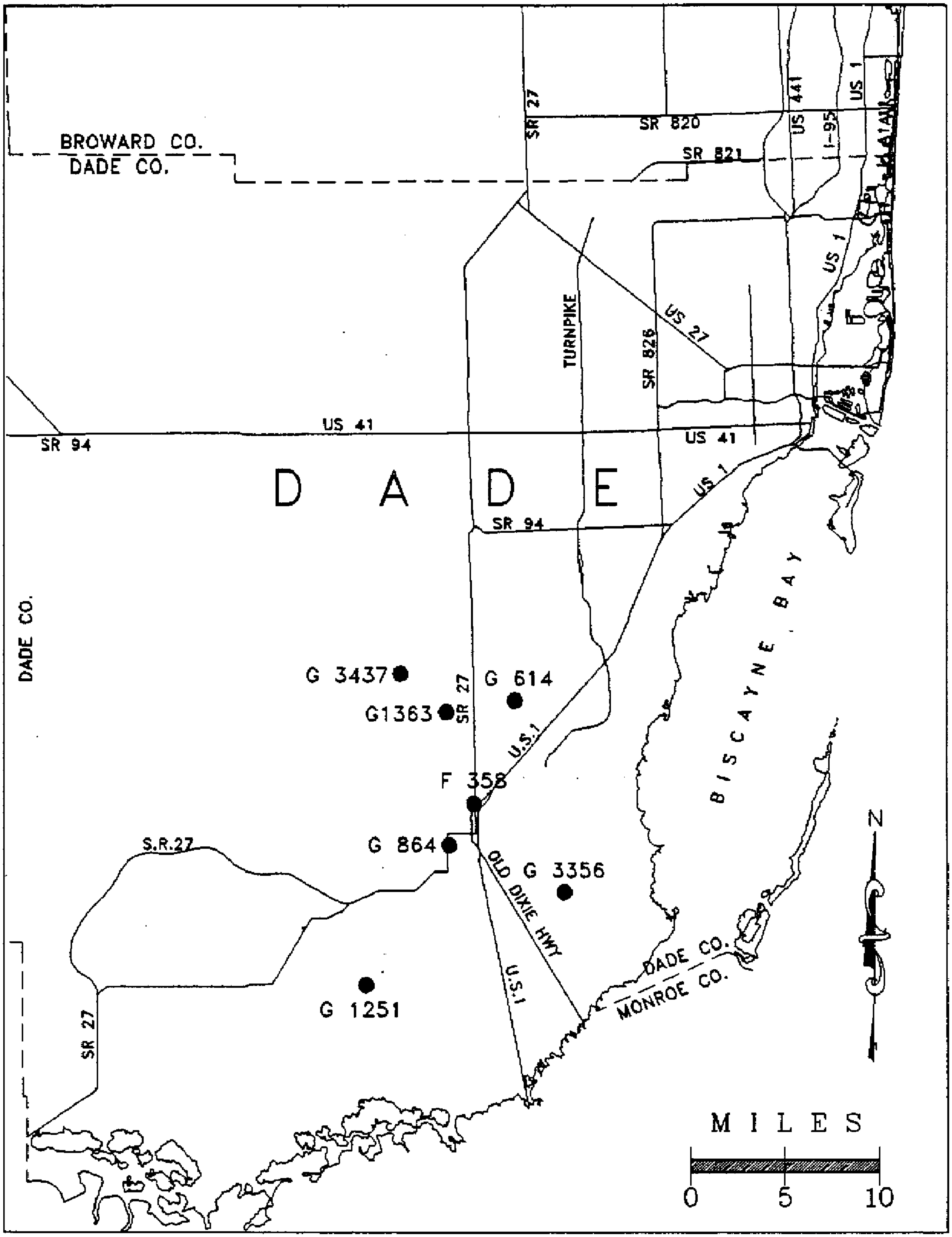
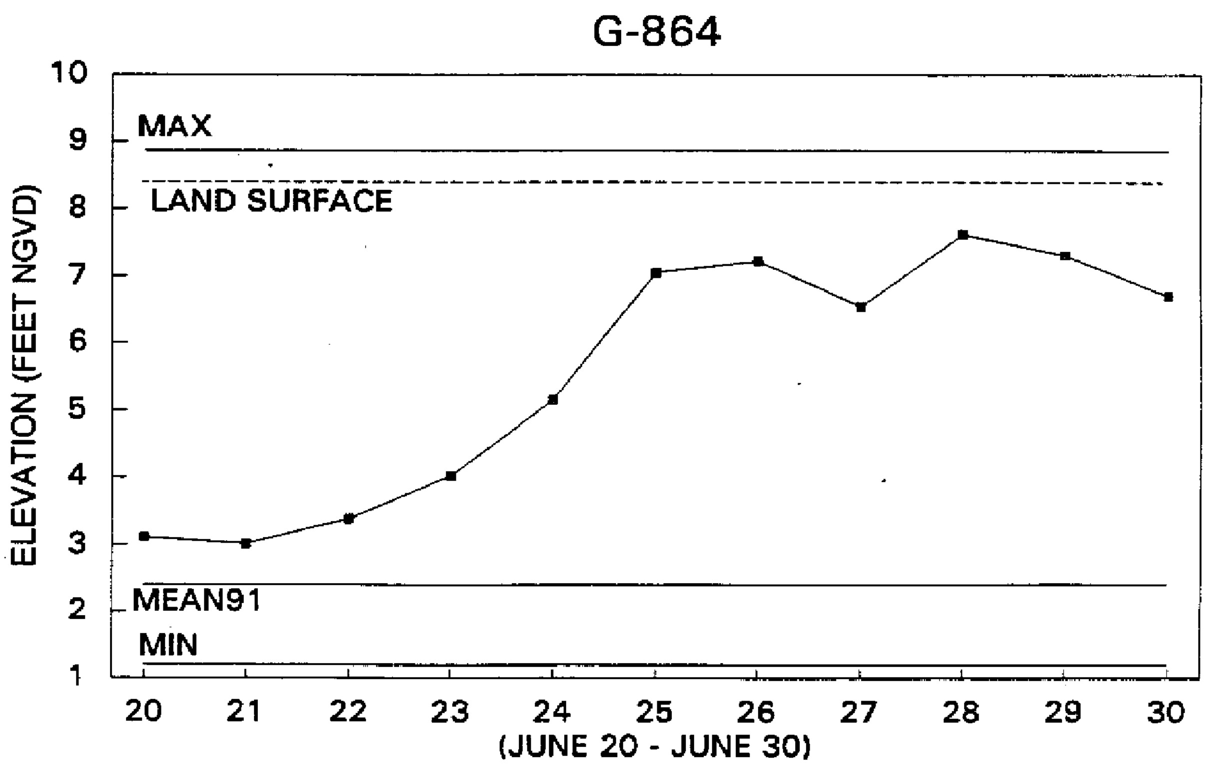
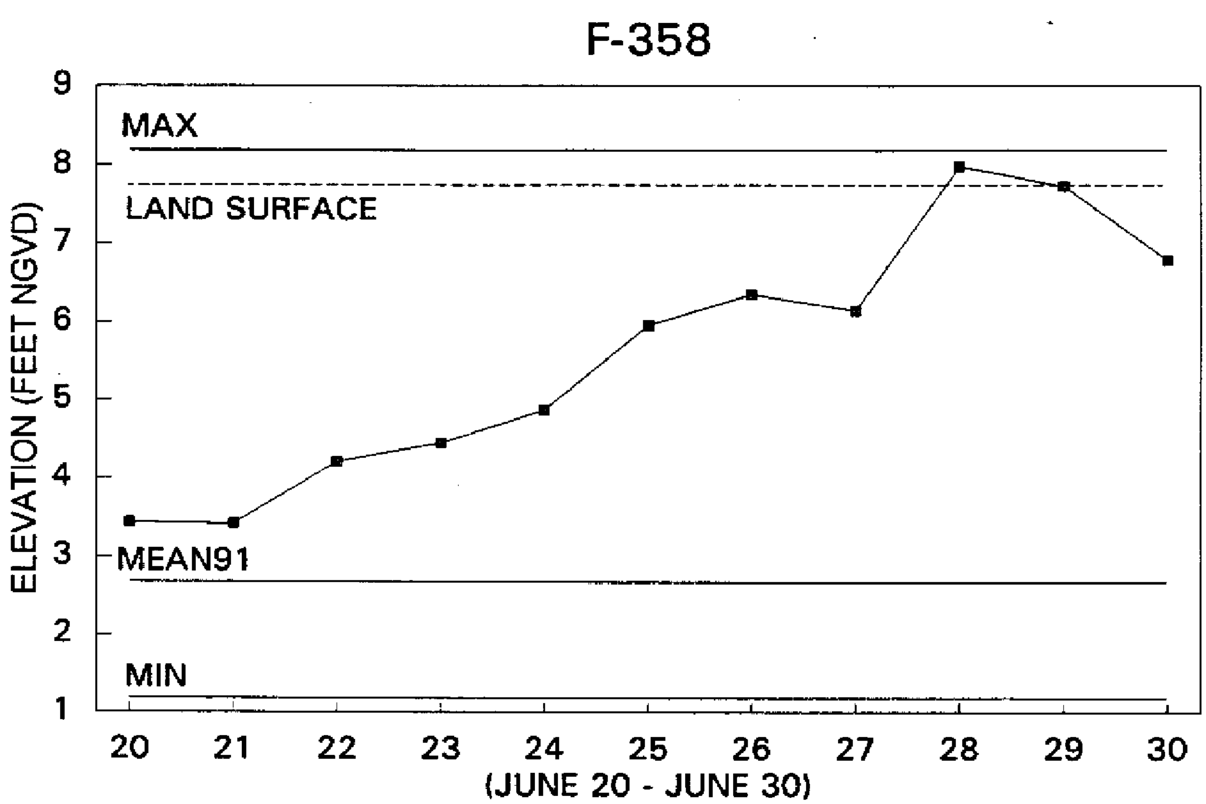


Figure 21. Groundwater Monitoring Wells in South Dade County

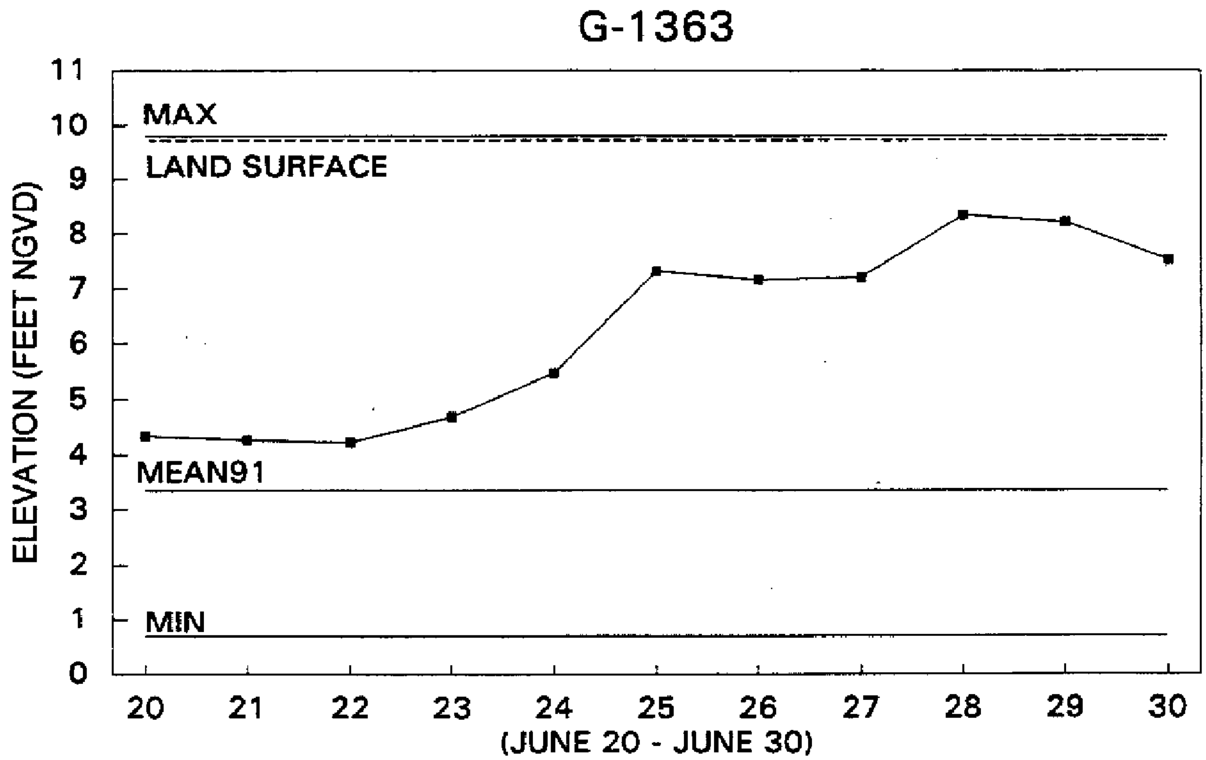


Daily Ground Water Levels near Florida City

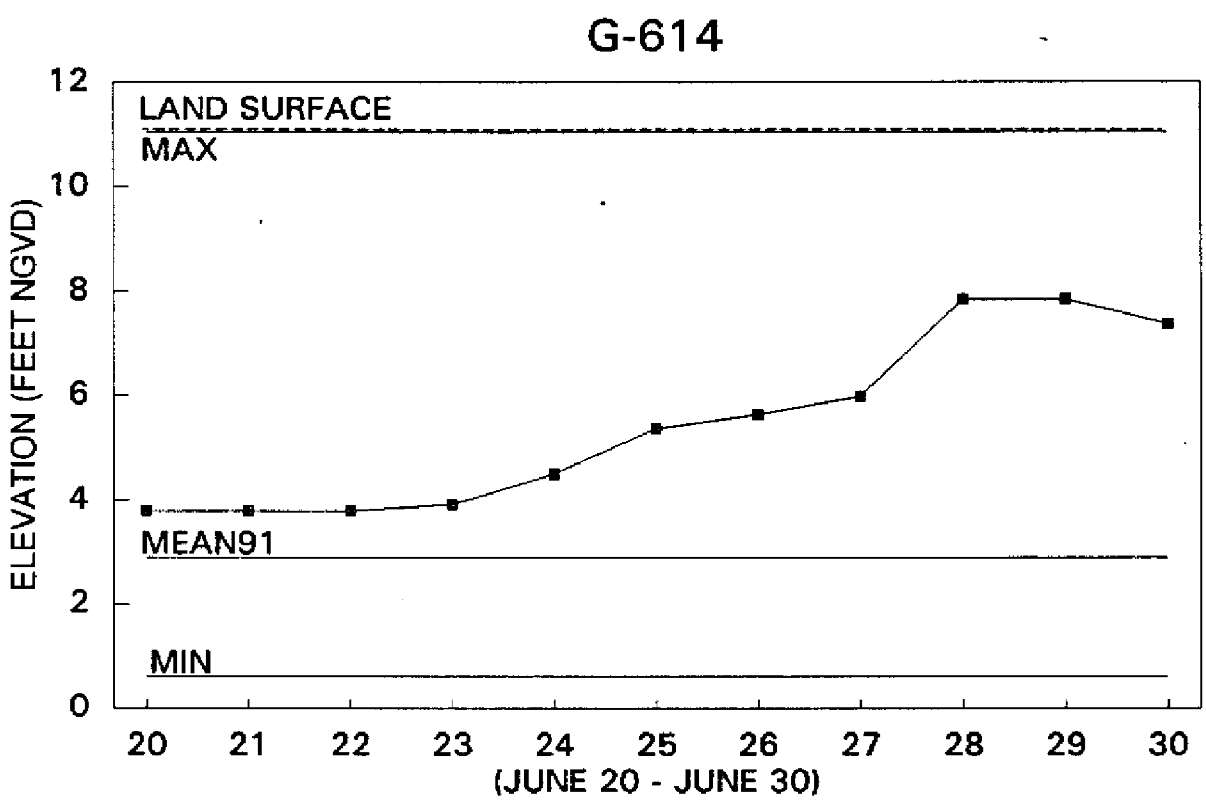


Daily Ground Water Levels at Homestead

Figure 22. Daily Groundwater Levels Near Florida City and at Homestead

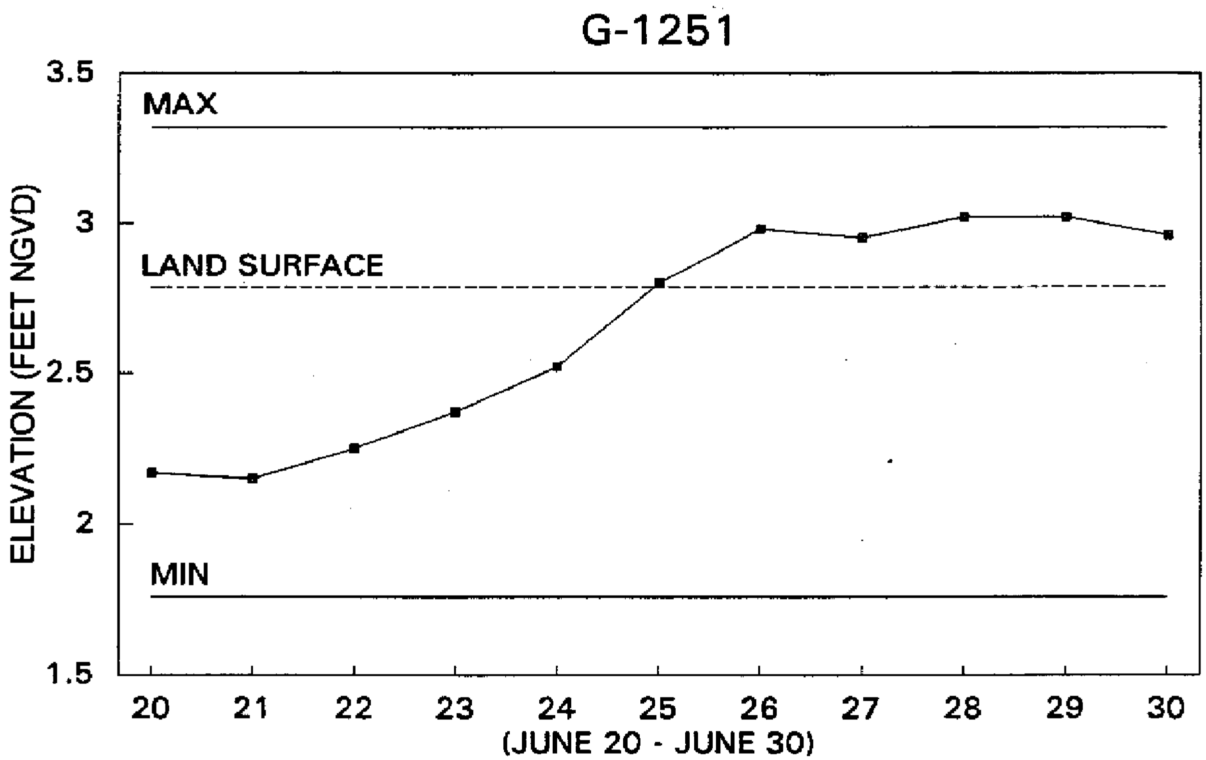


Daily Ground Water Levels 5 m NW of Homestead

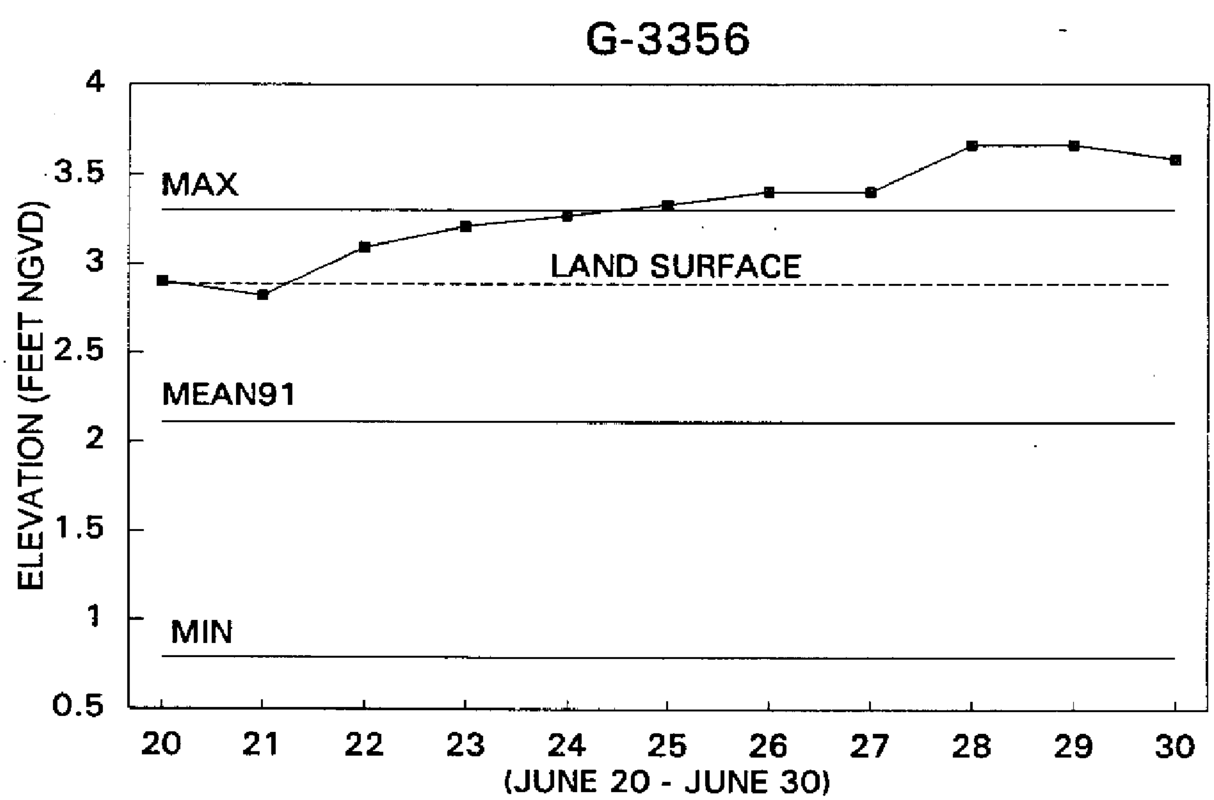


Daily Ground Water Levels at Goulds

Figure 23. Daily Groundwater Levels 5 m NW of Homestead and at Goulds



Daily Ground Water Levels 10 m SSW of Homestead



Daily Ground Water Levels 4 m SE of Florida City

Figure 24. Daily Groundwater Levels 10 m SSW of Homestead and 4 m SE of Florida City

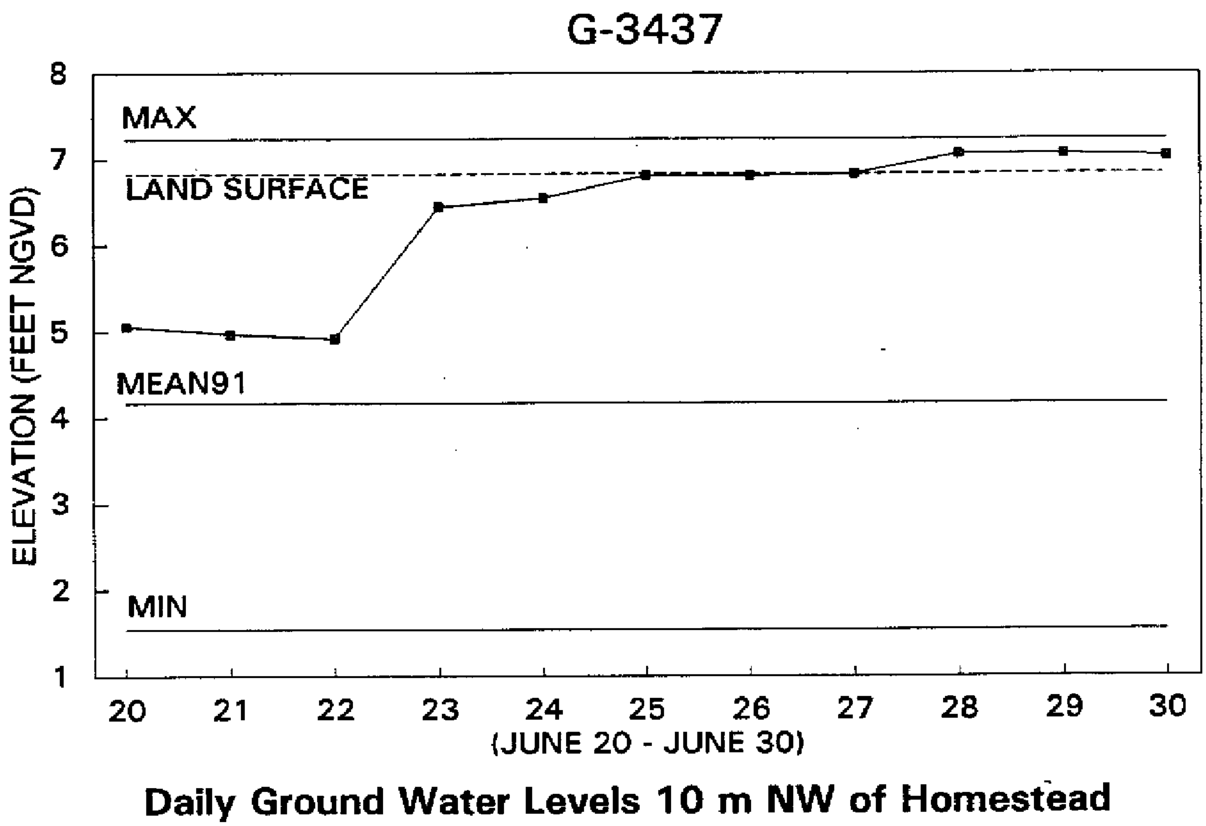


Figure 25. Daily Groundwater Levels 10 m NW of Homestead

Volume Balance

The total volume of discharge which entered the C-111 basin from inflow structures was 14,112 acre-feet. Outflow through structure S-197 was 33,910. Total outflow through all the structures was 119,021 acre-feet. The difference between the outflow and the inflow is the volume of water generated by the rainfall in the basin. Approximately 104,909 acre-feet of water was generated in the basin by rainfall alone. Dividing the volume of runoff by the basin area (66,000 acres) gives a rainfall depth of 21.64 inches. The average rainfall for the C-111 basin during the month of June was 25.09 inches. In addition to the runoff from the basin, factors such as seepage and evapotranspiration were also taking place during this period. Therefore, the runoff water generated in the basin approximates the average rainfall in the basin.

Water Quality and Environmental Impacts

Freshwater Discharge to Barnes Sound and Florida Bay

Water was discharged to Barnes Sound and the Florida Bay area through structure S-197, which consists of 13 culverts with risers. During the storm of June 1992, discharge was made through these culverts. Table 16 lists the discharges to Barnes Sound and Florida Bay in acre-feet. Approximately 33,910 acre-feet were discharged through the culvert structures during the storm event. It can also be noted that peak discharges occurred on the 29th and 30th of the month when all culverts were operational.

On June 24, three culverts out of 13 were opened. This was not enough to remove the runoff water. Therefore, on June 24, seven culverts were opened. This opening was not adequate to discharge the runoff water. Therefore, on June 28, 1992, all 13 culverts were fully open. On July 1, 1992, six out of 13 culverts were closed. By the afternoon, four more culverts were closed. By July 3, the remaining

Table 16. Discharge to Barnes Sound and the Florida Bay via Structure S-197

Date	Discharge (acre-feet)
6/24	1,085.00
6/25	2,219.00
6/26	4,005.00
6/27	4,060.00
6/28	4,647.00
6/29	5,746.00
6/30	5,432.00
7/01	3,606.00
7/02	1,561.00
7/03	1,547.00

three open culverts were closed. Total outflow from the basin during the entire storm period was 119,021 acre-feet from all other structures in the C-111 Basin.

Freshwater Discharge to Biscayne Bay

Water discharged from structures S-22, S-123, S-21, S-21A, S-20G, S-20F, and S-20, flows to Biscayne Bay. These structures discharge water from C-2, C-100, C-1, C-102, Homestead, and C-103 basins. Structure S-22 discharges water to Biscayne Bay just south of Matheson Hammock Park. Structure S-123 discharges the C-100 basin discharge to Biscayne bay east of Old Cutler Road. S-21 discharges water from the C-1 (Black Creek) basin, S-21A discharges water from C-102 basin, S-20G discharges water from the Homestead basin and S-20F, located one mile west of Biscayne Bay, discharges runoff from C-103 basin to Biscayne Bay. Discharges were made through these structures during the storm. Presented in Table 17 are the discharges made from the above structures.

Table 17. Discharge to Biscayne Bay (cfs)

Station	S22_S	S123_S	S21_S	S21A_S	S20G_S	S20F_S	S20_S
DB KEY	6778	6767	6776	6777	6775	6774	13036
01-June		0					-0.01
02-June		0					-0.01
03-June		0					0
04-June		0					0.07
05-June		0					0.14
06-June		0					0.15
07-June		0					0.17
08-June		2.58					0.19
09-June		0.24					0.20
10-June		0					0.11
11-June		0					0.10
12-June		0					0.10
13-June		0					0.10
14-June		0					0.10
15-June		0					0.10
16-June		0					0.10
17-June		0					0.09
18-June		0					0.09
19-June		0					0.01
20-June		0					0
21-June		0					0
22-June	6.76	0	493.86	420.31	323.54	1494.44	0
23-June	95.60	33.22	268.68	447.10	235.64	1018.86	105.94
24-June	541.71	385.25	685.90	838.77	370.88	1634.84	306.97
25-June	756.75	325.28	1084.57	857.92	309.45	1762.22	305.58
26-June	828.93	466.71	1179.08	1315.58	510.23	2013.53	332.38
27-June	856.53	1370.06	1188.92	1506.97	238.07	1962.41	339.54
28-June	826.54	2028.67	1276.39	1726.52	367.03	2087.70	340.16
29-June	832.98	2021.55	1278.59	1676.03	536.45	2220.68	356.72
30-June	712.96	710.80	1165.23	1367.56	445.77	1968.44	344.93
01-July	702.45	0	1105.96	896.85	194.90	1419.29	340.07
02-July	579.30	0	521.30	341.04	36.21	650.96	330.25
03-July	623.81	0	326.45	122.34	1.80	358.74	325.83
04-July	608.43	89.10	322.22	129.97	16.23	345.71	310.65
05-July	207.75	0	326.15	144.95	19.74	338.99	294.06

Table 17. Discharge to Biscayne Bay (cfs)

Station	S22_S	S123_S	S21_S	S21A_S	S20G_S	S20F_S	S20_S
06-July	8.18	0	275.13	136.84	36.22	395.07	283.52
07-July	376.31	0	255.52	113.63	18.12	358.49	306.80
08-July	401.33	0	310.37	84.42	10.41	310.91	302.21
09-July	178.52	65.01	168.45	70.35	12.82	277.33	278.46
10-July	2.62	22.31	124.70	72.75	2.00	241.46	284.36
11-July	2.76	0	9.90	74.88	12.19	270.50	263.06
12-July	3.41	0	153.90	66.12	6.70	198.92	213.01
13-July	3.21	0	118.34	132.3	33.47	280.82	217.16
14-July	3.31	0	121.81	88.18	17.58	188.09	216.41
15-July	5.56	0	96.45	62.71	14.38	194.01	209.25
16-July	2.72	0	69.64	64.24	2.410	108.64	201.05
17-July	3.50	0	70.76	53.22	5.79	113.83	192.03
18-July	3.52	0	96.09	55.32	3.92	91.86	70.85
19-July	3.53	0	8.64	51.48	5.63	84.11	0.67
20-July	3.51	0	108.16	53.51	1.86	77.27	0.57
21-July	53.06	0	119.48	50.85	7.49	66.81	0.56
22-July	103.50	1.80	105.68	58.49	12.81	146.59	0.55
23-July	2.37	4.40	80.86	24.09	3.59	138.24	0.54
24-July	2.91	0	108.37	42.78	4.01	15.06	0.42
25-July	2.10	0	8.74	27.1	4.24	63.47	0.43
26-July	2.33	0	103.49	26.8	1.75	1.64	0.42
27-July	3.22	1.18	7.10	2.97	1.74	0.89	0.37
28-July	2.53	1.09	96.94	34.29	1.88	1.86	0.33
29-July	2.64	0	81.85	4.76	1.87	72.59	
30-July	3.47		6.29	3.86	1.83	1.81	
31-July	3.49		7.69	3.16	1.85	0.87	
Totals	9,364.00	7,529.25	13,937.70	13,251.01	3,832.50	22,977.95	7,077.91
Basin Area (acres)	34,000	26,000	53,000	16,000	3,000	26,000	18,000
Runoff (inches)	6.56	6.89	6.26	19.71	30.40	21.03	9.36

Structure S-20G drains the area occupied by Homestead Air Force Base, which is approximately 3000 acres. Runoff removed from this basin was 30.40 inches. The rainfall amount measured at the Homestead F/S was 31.21 inches. Therefore, this area was under water for a few days and it took several days for the water levels to return to pre-storm conditions.

Discharges were made through these structures during Hurricane Dennis. Presented below are the design discharges for the structures, as well as the peak flow from Hurricane Dennis and the June storm.

Structure	Design Discharge, cfs	June 23-30 Storm, cfs	Dennis Peak, cfs
S-22	1915	832 (6/29/92)	2110
S-123	2300	2028 (6/28/92)	3000
S-21	2560	1278 (6/29/92)	2340
S-21A	1330	1726 (6/28/92)	2454
S-20F	2900	2220 (6/29/92)	5870
S-20G	900	536 (6/29/90)	1030
S-20	450	340 (7/01/92)	740

The peak discharge through structure S-21A was 1726 on the 29th of June. Design discharge of 1330 cfs was exceeded for four days (June 27-30) from this structure.

Salinity

Dade County Department of Environmental Resources Management (DERM) recorded salinity at about 5 parts per thousand (ppt) in Manatee Bay and about 15 ppt in Barnes Sound very shortly after the culverts at S-197 were fully opened. The salinity recorded at three permanent SWIM monitoring stations near the beginning of June were in the mid to upper 30s (Figures 26-28). One station is located at the outlet of the C-111 Canal and one each near the geographic centers of both Manatee Bay and Barnes Sound. Mixing appeared to be relatively rapid. Salinity slowly increased and at the end of July, it was in the low to mid 20s. Salinity in August remained about 50 percent below the concentration prior to the discharge event, but high enough not to produce deleterious effects to sea grasses.

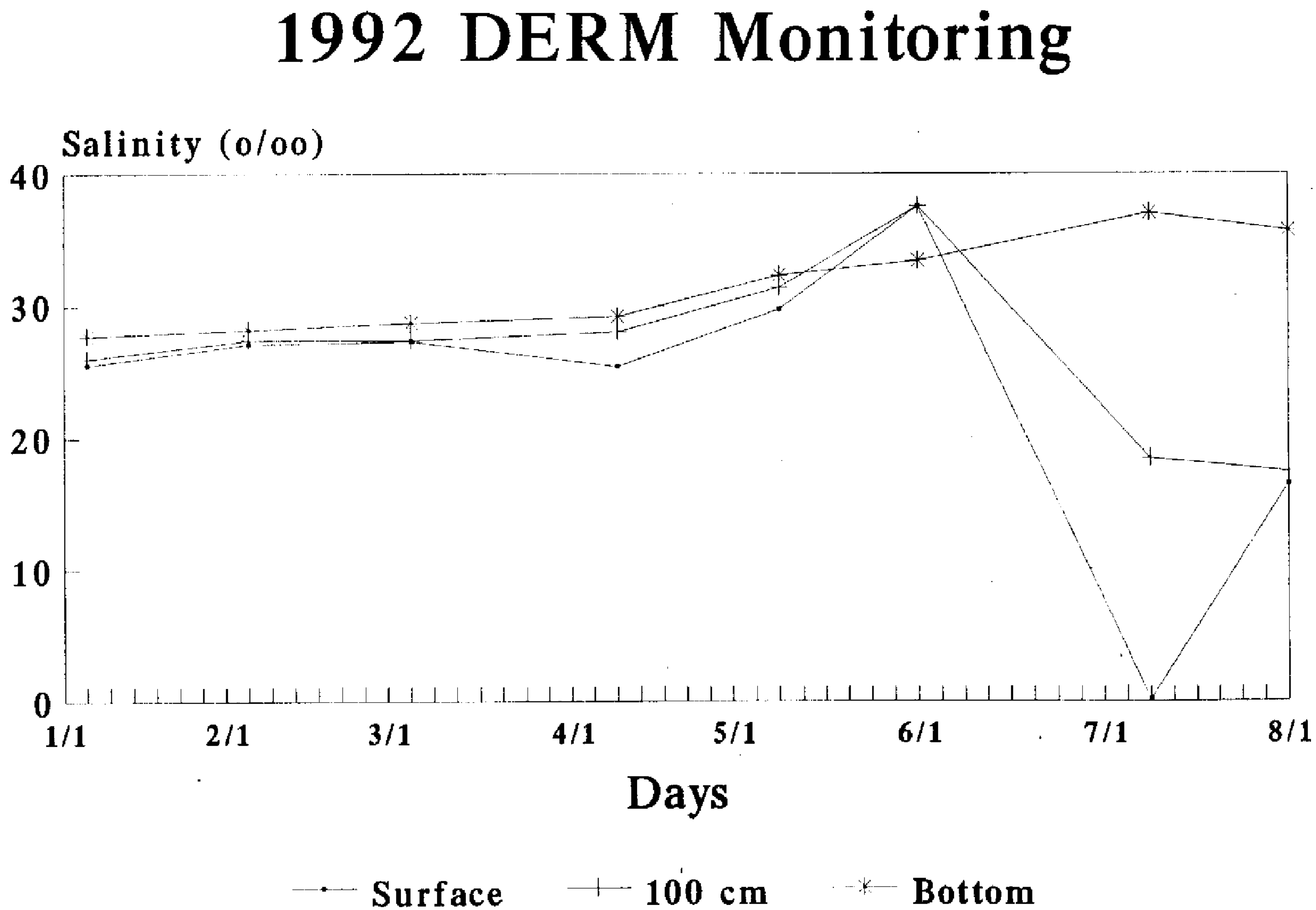


Figure 26. Salinity at C-111 Outlet

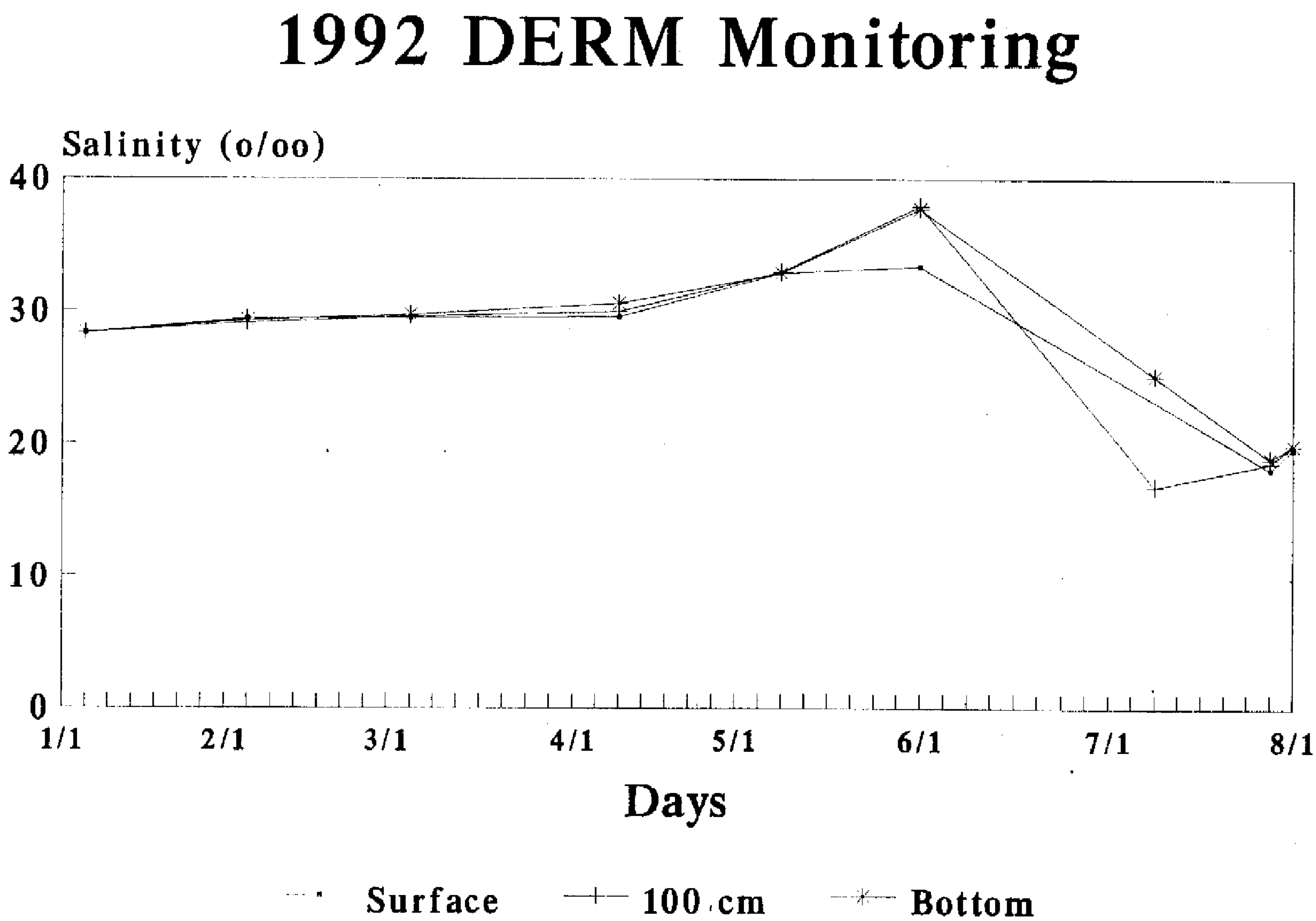


Figure 27. Salinity in Manatee Bay

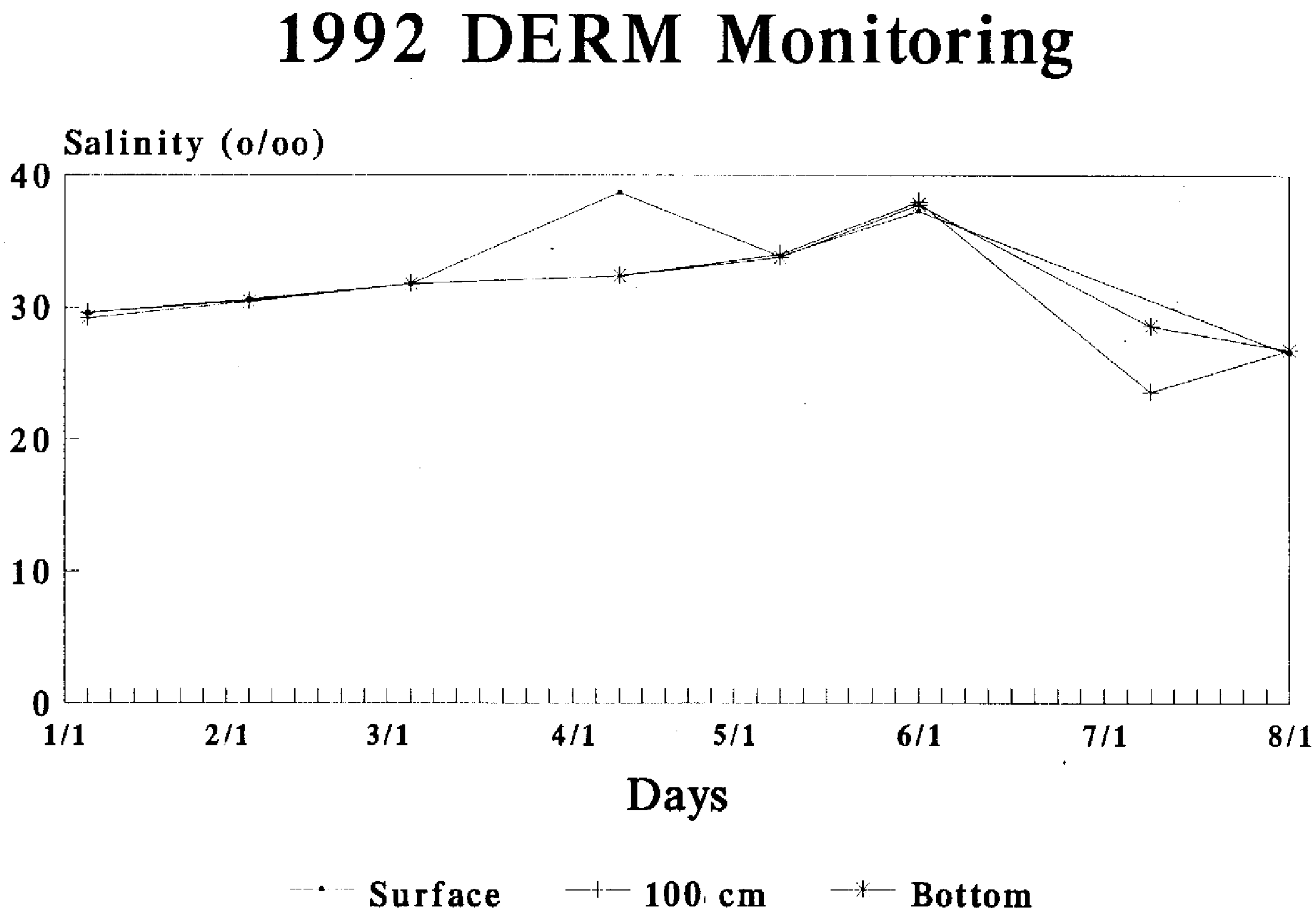


Figure 28. Salinity in Barnes Sound

West of U.S. Highway 1, freshwater flowed through the 55 gaps along the southern bank of C-111 into several small creeks and sloughs. Through these natural channels and via overland flow, freshwater entered upper Long Sound. During the second week, the freshwater had made its way downstream into Little Blackwater Sound. Through the end of July, this area remained nearly fresh.

On the east side of U.S. Highway 1, prior to the storm event, salinity levels in Manatee Bay were 29 ppt, or near the concentration of undiluted sea water (35 ppt). During the event, freshwater entered Manatee Bay via the C-111 Canal and salinity rapidly plummeted to nearly fresh throughout the Bay (Figure 29). During the second week, salinity levels in Manatee Bay increased to about 15 ppt and remained at this level.

Salinity at all but one station in Barnes Sound remained at about 20 ppt following the discharge and throughout the monitoring period. Probably because of input from the drainage area between U.S. Highway 1 and Card Sound Road, one station in upper Barnes Sound remained near 10 ppt.

Submerged Vegetation

Manatee Bay. All stands of the dominant species of submerged vegetation (*Thalassia testudinum)* remained in pre-event condition. Each blade of these sea grasses was coated by a thick deposit of microscopic algae. Bottom sediments consisted of loose decomposing material. Mats of blue-green algae occurred in confined coves. These conditions appear to have existed prior to the discharge event and may indicate a low degree of flushing action in the Bay.

One week following the event, all patches of the sea grass *Ruppia maritima* died throughout Manatee Bay. In addition, within grass beds in the immediate vicinity of the C-111 outfall, approximately one-half of the *Halodule wrightii* blades

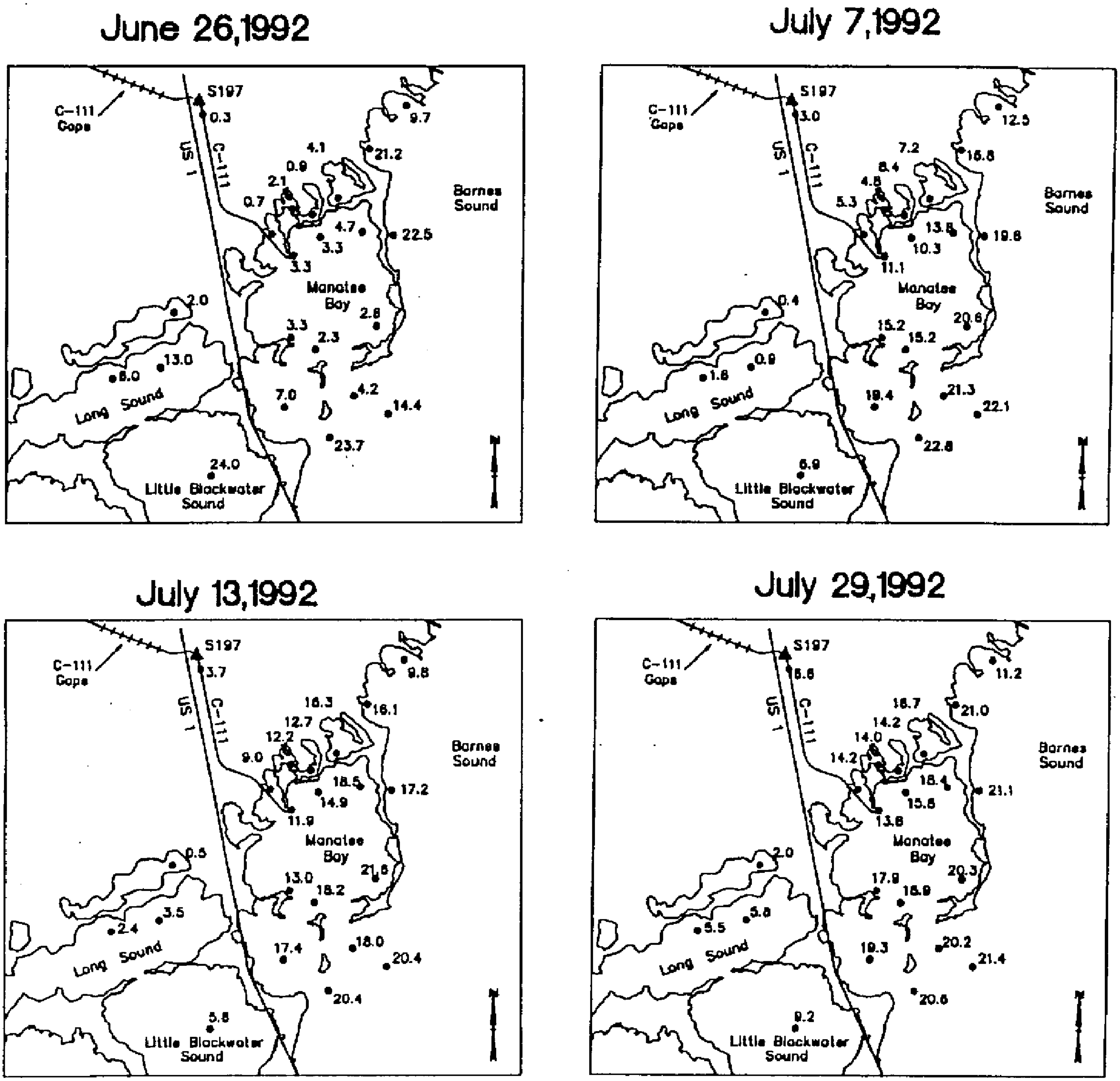


Figure 29. Manatee Bay Salinity (ppt)

lost green pigmentation and turned black. However, the remaining healthy shoots and the below-ground rhizomes persisted throughout the sampling period.

Barnes Sound. All stands of submerged vegetation appeared to be healthy in Barnes Sound throughout the monitoring period. The dominant benthic vegetation at monitoring stations located in Barnes Sound was the algae *Batophora* sp. This algae occurred in dense patches attached to the rocky bottom and loose shell fragments. Areas near the mangrove islands were dominated by lush stands of *Thalassia testudinum*. The submerged vegetation in Barnes Sound was free of the deposits of algae noted in Manatee Bay.

Long Sound/Little Blackwater Sound. At the uppermost station west of U.S. Highway 1, all patches of *Ruppia maritima* died one week following the storm event. As in Manatee Bay, although half of the *Halodule wrightii* blades turned black, the healthy shoots and rhizomes persisted throughout the sampling period. No *Thalassia testudinum* was observed before or after the storm event in this location.

All submerged vegetation (*Thalassia testudinum* and *Halodule wrightii*) at stations located in Long Sound and Little Blackwater Sound persisted throughout the sampling period.

Fauna

During all sampling trips, no fish kills were observed and many live estuarine fishes were observed in sea grass and mangrove habitats throughout the area, including gray snappers, snook, mojarras and silversides. Freshwater fishes (e.g., cichlids) moved into Manatee Bay via S-197 during the event and appeared to provide a food source for many wading birds, ospreys, dolphins and other aquatic predators gathered near the canal mouth.

Crews observed a wide variety of sponges, corals, sea anemones, and crustaceans in Barnes Sound, all in apparent good health. However, during the third week following the discharge event, a monospecific die-off of finger sponges was observed in northeastern Barnes Sound. On further investigation, many live sponges of this species were also observed nearby.

Summary

Results of the storm-event monitoring indicate distinct differences in salinity trends for the areas east and west of U.S. Highway 1. West of the highway, salinity levels dropped gradually and remained low. This was probably because of the gradual but continuous input of freshwater from the C-111 gaps and the lack of tidal influence in this area. East of the Highway, salinity levels dropped rapidly because of the sudden discharge of freshwater from the C-111 Canal. Salinities returned to mid-levels within a few days as tides induced water exchange and mixing.

Although the biotic community in Manatee Bay may not have fully returned to the conditions that existed prior to the 1988 discharge, the current event appears to have caused little additional change. Conditions in this confined area are similar to those observed in those bayous located in Florida Bay where circulation is similarly restricted. The submerged vegetation and fauna in Barnes Sound apparently recovered fully from the 1988 discharge, and appear to have been completely spared by the 1992 storm event.

Field Observations in South Dade County

Personnel from the Homestead Field Station received numerous complaints from residents in the area (Figure 30). Field Engineering personnel took videos of impacted areas that were observed from the air. The following flooded sites were documented by Homestead staff.

1) Villages of Homestead (Permit # 13-00044-S). The Villages of Homestead is a Development of Regional Impact located southeast of the City of Homestead. The

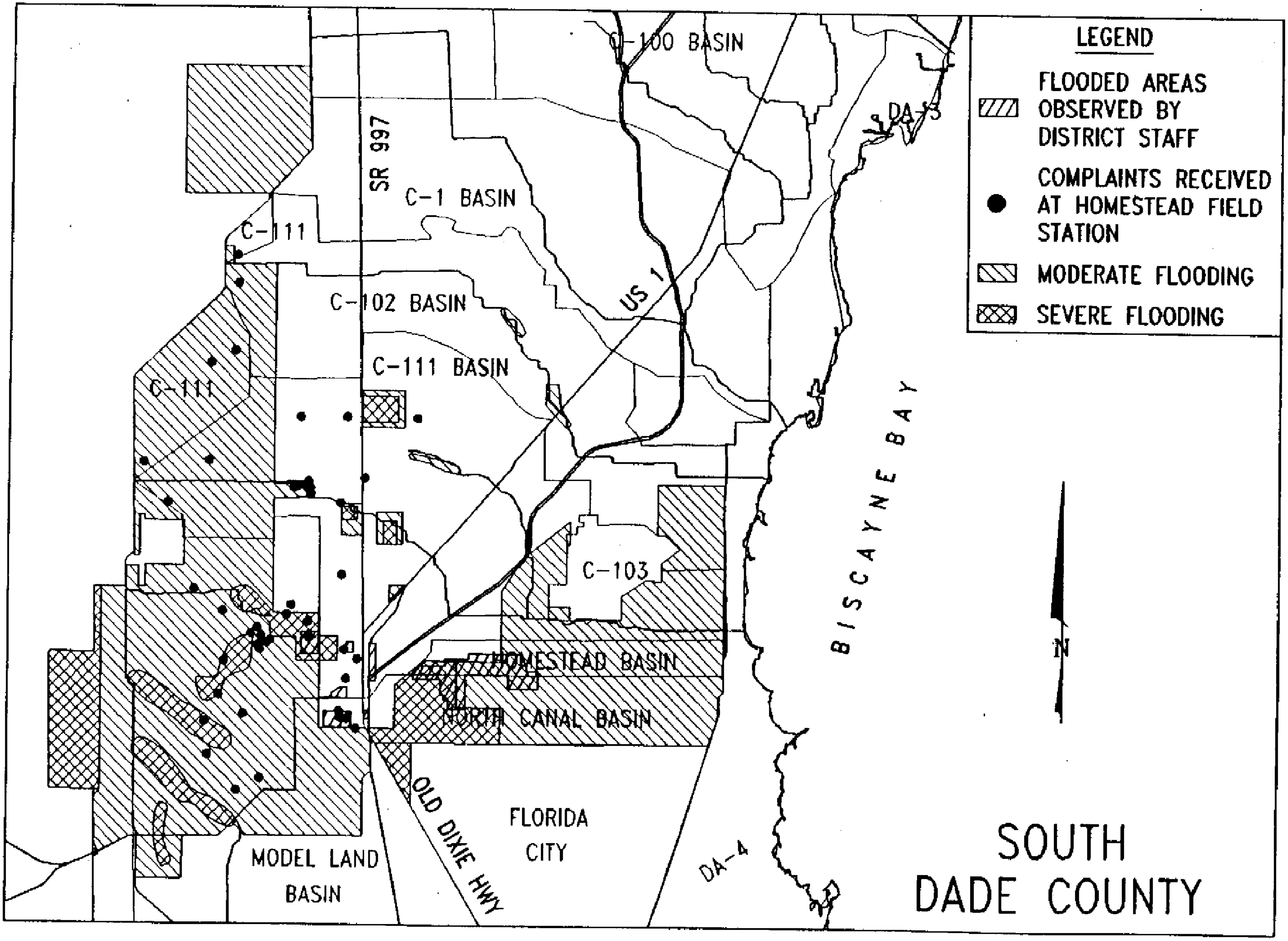


Figure 30. Flooded Area around South Dade County

site is a 3,504-acre residential community. Only portions of the site have been constructed at this time.

The original surface water management system was designed and permitted by SFWMD to retain water in on-site lakes up to the 10-year storm event. Once water reached this elevation, it was to overflow into the North Canal with eventual discharge to the L-31E Borrow Canal. On July 1, 1976, Dade County issued a mandate that prohibited positive storm water disposal systems so the site was redesigned to totally utilize drainage wells for subsurface disposal of storm runoff. The project's surface water management permit was modified November 8, 1979 to reflect this change.

The roads were designed and permitted to be protected from the 10-year storm with minimum elevations between 5.5-6.0' NGVD. Minimum floor elevations were permitted at elevation 7.5' NGVD to be protected from the 100-year, 5-day storm. In addition, all lakes in the development are to have perimeter elevations of 7.5' NGVD to prevent tidal surge from depositing and trapping salt water in the lake systems.

All roads in the project were flooded. Once the storm exceeded the design specification for the roads, the roads flooded as expected. However, no houses in the area are known to have been flooded.

2) Aquarius Mobile Home Park. All roads in this area experienced flooding.

3) Southeast Homestead - All roads in this area experienced flooding.

4) Southwest Homestead - About 75 percent of the roads in this area were flooded.

5) Southwest Florida City - Approximately 90 percent of the roads in this area were flooded. In addition, three homes had water on the floors.

6) Northwest Florida City - About half of the roads in this area had flooding.

7) Southwest Florida City - All of the roads in this area were flooded.

Some agricultural sites with surface water management permits from the District that had some flooding were:

-- 13-00112-S, Williams Potato Farm

-- 13-00118-S, Alger Farms

-- 13-00119-S, East Glades Project

Comparison of Storm Events of 1981 (Dennis), 1965 (Betsy) and 1960 (Donna) in Southeastern Dade County

The maximum 3-day rainfall recorded at the Homestead F/S during the June storm event was 9.76 inches. During Hurricane Dennis, the area of approximately 100 square miles covering Homestead and Florida City up to West Kendall reported 20 inches or more of rainfall for the period August 16-18, 1981. The most heavily concentrated rainfall associated with Hurricane Donna occurred south of Miami in the vicinity of Black Creek (C-1), where over 15 inches were recorded during the period of September 9-11, 1960.

Rainfall produced by Hurricane Betsy covered all of Dade County, ranging from 4 to 7 inches, with a maximum of 10.89 inches recorded at the rainfall station near Homestead Air Force Base for the period September 7-9, 1965.

Comparison of rainfall totals for these storm events is presented below:

STORM	DATE	RAINFALL (inches)
June 23-30, 1992	3-day Max	7.96
Dennis	16-18 Aug. 1981	20.00
Donna	9-11 Sep. 1960	15.00
Betsy	7-9 Sep. 1965	10.89

Examination of the rainfall amounts from different storm events around south Dade indicates that Dennis was the most severe storm event. The south Dade basin received 20.00 inches of rain during a 3-day period. The June 1992, 3-day maximum storm event dumped only 7.96 inches of rain during a max. 3-day period.

Therefore, without the antecedent rainfall condition, the 3-day maximum rainfall should not have any significant impact in terms of flooding in the area. However, the maximum monthly total for the June 1992 rainfall total has a return frequency exceeding one in 50 years. Therefore, the antecedent rainfall condition in the area created the flooding problem.

Comparison of Rainfall and Discharge to Barnes Sound during Other Storm Events

Water was discharged through structure S-197 during other storm events in the area. Presented below in Table 18 are the rainfall and the quantity of water discharged through the structure during storm events in the area.

Table 18. Comparison of Rainfall and Discharge from the C-111 Basin during Various Storm Events

Storm Event	Rainfall (inches)	Discharge (acre-feet)
Dennis, Aug. 1981	20.00	49,000
August 1988	8.00	40,000
Bob, July 1985	5.00	3,500
June 23-30, 1992	7.96	33,910

The earthen plug was pulled in 1981, 1982, 1985 and 1988. In 1989, the earthen plug was replaced by 13 culverts at S-197.

The above table depicts that Tropical Storm Dennis dumped 20 inches of rain in the basin during a 3-day period and approximately 49,000 acre-feet of water was discharged to Florida Bay. In comparison, the 3-day maximum rainfall from the June 1992 storm was 7.96 inches with a discharge of 33,910 acre-feet of water discharged to Florida Bay. Comparison of design discharge with Storm Dennis and June 1992 storm discharge is presented in Table 19.

Table 19. Comparision of Design -- Hurricane Dennis and the June 23-30 Discharge for C-111 Basin

Structure	Design (cfs)	Dennis (cfs)	June 23-30 (cfs)
S-177	1400	1695	(6/29) 1717
S-176	630	888	(6/30) 1023
S-174	500	550	(6/24) 457
S-175	500	534	(6/28) 692
S-332	165	ENP water supply	(6/24) 180
S-196	200 @ 1'	Under water	
S-194	190		
S-173	150		
S-178	300		
S-197	550	3430	(6/29) 2897
S-18C	2100	2170	(6/29) 2915
S-331	1160		(6/24) 371

EFFECTS IN THE LOWER WEST COAST OF FLORIDA

The Lower West Coast Basin within the South Florida Water Management District area consists of Hendry, Glades, Lee, and Collier counties, and a small portion of Charlotte County (Figure 31). The only part of the C&SF primary system serving the area is the Caloosahatchee River. However, there are secondary systems in the area which are operated and maintained by each county. The United States Geological Survey has flow measuring stations around the Lee County area. Big Cypress Basin manages surface water stages and discharges for Collier County

It was reported that the storm of June 23-30 produced heavy rainfall resulting in higher stages of water levels, thereby causing widespread flooding and beach erosion. Flooding was reported to be intense around the Bonita Springs area. Beginning June 22, 1992, the effect of a tropical depression in the Gulf of Mexico brought widespread rain in this area. No sooner had the effects of the depression dissipated than a rush of Caribbean air mass was pumping enormous moisture over the upper atmosphere of south Florida. This southwesterly moist wind flow was caused by a ridge of high pressure extending into the Atlantic Ocean and a weak front of low pressure lingering north of the state line. The combined effect of this rain-producing mechanism generated a deluge of rain on the 27th and 28th of June.

Rainfall Distribution

The rainfall stations maintained by the District in this area are Cork.Hq,CCWWTP, Slee, Collier and Alva. The Big Cypress Basin also collects rainfall data for the area included in the analysis of the June 1992 storm event. Rainfall stations and statistics for the area are presented in Table 20. The United States Geological Survey also has reported the following daily rainfall amounts (Table 21) for Lee County areas.

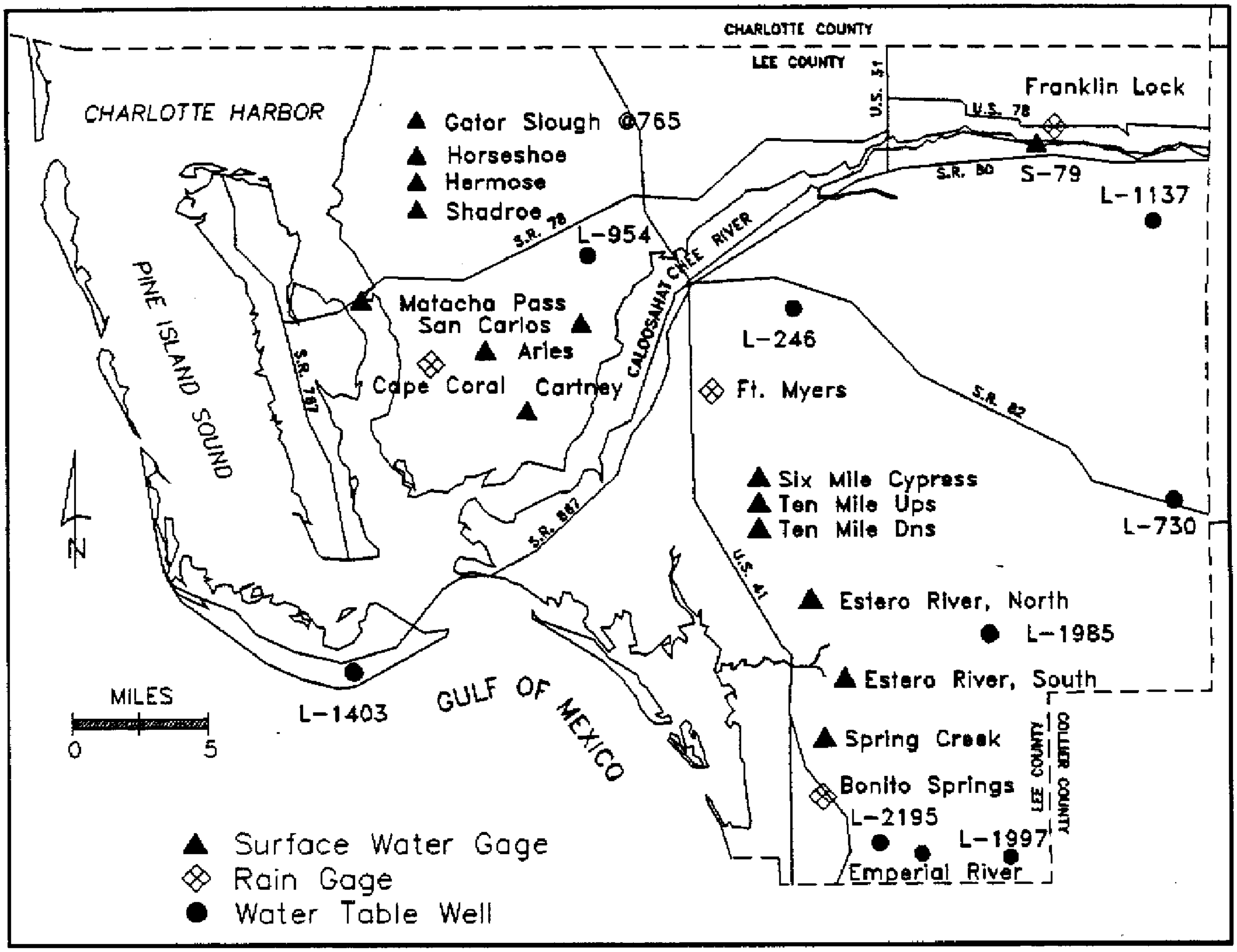


Figure 31. Lower West Coast, Florida

Table 20. Rainfall Statistics for Stations around Bonita Springs Area (inches)

Station	Monthly	23-30 June	5-Day Max.	3-Day Max.	1-Day Max.
CORK.HQ	24.53	13.83	10.50	7.65	6.16
CCWWTP	16.85	11.37	9.08	5.70	4.78
SLEE	23.62	13.62	12.68	9.18	4.50
COLLIER	12.86	8.12	5.78	4.86	2.08
BONITA SPGS.	23.15	15.24	12.72	8.86	7.85
PALM RIVER	20.15	14.65			
COLLIER/ SEMINOLE SP	20.68	18.17			
Basin Avg.	20.26	13.57			
Std. Dev.	3.86	2.92			

Table 21. Daily Rainfall for the West Coast of Florida (inches)

Date	Fort Myers	Bonita Springs	Franklin Lock	Cape Coral	Sanibel Island
6/23	0.92	0.02	0.00	0.90	4.36
6/24	1.64	2.15	0.48	1.70	1.46
6/25	1.86	1.15	1.48	1.50	2.74
6/26	2.90	2.71	2.88	4.20	0.16
6/27	0.06	0.50	1.12		0.38
6/28	4.37	0.51	1.98		1.08
6/29	0.63	7.85	2.54	4.85	0.12
6/30	0.02	0.35	0.95		0.00

An analysis of several of the recording station charts shows the varying rainfall intensities typical of southwestern Florida. Table 22 identifies the most intense portions of the overall rainfall event by various time durations. For the 1-hour, 2-

hour, 6-hour and 24-hour durations, the storm return frequencies were obtained from Rainfall Frequency Atlas for Alabama, Florida, Georgia and South Carolina for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 years, U.S. Department of Agriculture, Soil Conservation Service, Gainesville, Florida.

Table 22. Storm Frequency and Return Frequency for Bonita Springs

Raingauge Station	Storm Duration and Return Frequency			
	1-Hour	2-Hour	6-Hour	24-Hour
Bonita Springs Water Plant	2 yrs.	---	100 yrs.	25 yrs.
Corkscrew Sanctuary	---	---	---	5 yrs.

Figure 32 depicts the time distribution of rainfall at Bonita Springs. It can be observed that during the middle of June 28 and June 29, maximum rain fell at this site.

Surface Water Levels and Discharge, Lee and Collier Counties

Information on the maximum gage height, as well as the maximum discharge that took place during the storm event, is presented in Table 23 (provisional USGS data).

Table 23. Comparison of June Stage and Discharge with the Maximum of Record

Stations	Date	Gauge Height (Feet, NGVD)	Discharge (cfs)	Max. (cfs)	Record Discharge (cfs)
Imperial River	7/02/92	12.84	1020	10.21	528 (10/16/87)
Spring Creek	6/28/92	11.09	196	8.68	68 (9/2/90)
Estero River N.	6/27/92	12.81	220	13.32	264 (10/12/87)
Estero River S.	6/29/92	8.70	315	8.90	284 (10/14/87)

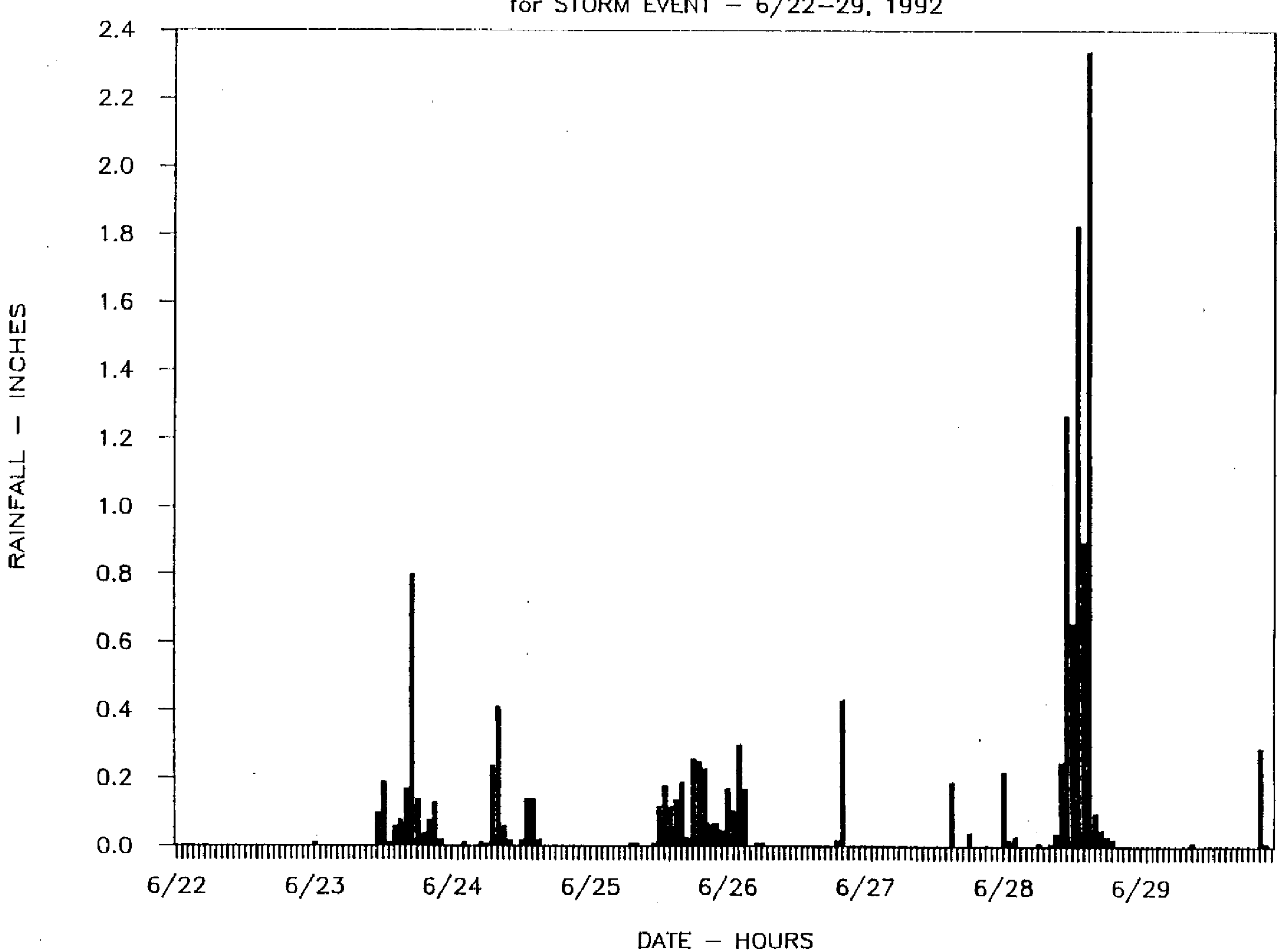


Figure 32. Hourly Rainfall Data Recorded at Bonita Springs Water Co., June 22-29, 1992

Daily discharge for the month of June for Lee County surface water streams is presented in Table 24.

It can be observed from Table 24 that the maximum discharge occurred during the period of June 23-30, 1992. However, the peak discharge of 1020.00 cfs was made on the 2nd of July.

Mean daily gauge height and discharge for both the North and South Branches of the Estero River are presented in Figures 33 and 34. Gauge height, as well as the discharge for the Imperial River near Bonita Springs, is presented in Figure 35.

For Collier County, stage hydrographs for Cocohatchee Canal at CR-951, Faka Union and Henderson Creek canals at U.S. 41, Golden Gate at Weir #55, are presented in Figures 36 through 40. It can be observed from these hydrographs that both Faka Union and Henderson canals at U.S. 41 topped their weir crest elevations. Golden Gate Canal weirs #3 and #4 also topped the weir crest elevations.

Table 24. Surface Water Discharge, Lee County (cfs)

STATION	ESTERO N	ESTERO S	GATOR S	HERMOSA	HORSE SH
DBKEY	12807	12805	6843	12789	12791
01-June	0	0.34	2.10	0.17	0
02-June	0	0.35	3.10	0.15	0
03-June	0	0.38	3.70	0.18	0
04-June	0	0.47	3.70	0.23	0.01
05-June	0	0.44	3.70	0.24	0.05
06-June	0	0.54	6.00	3.20	2.50
07-June	0	0.68	18.00	23.00	18.00
08-June	0	0.97	59.00	20.00	30.00
09-June	0	1.30	68.00	39.00	37.00
10-June	0	1.40	53.00	21.00	17.00
11-June	0	1.20	45.00	13.00	10.00
12-June	0	1.10	37.00	8.30	6.70
13-June	0	0.97	32.00	5.60	4.60

Table 24. Surface Water Discharge, Lee County (cfs)

STATION	ESTERO N	ESTERO S	GATOR S	HERMOSA	HORSE SH
14-June	0	0.66	28.00	2.50	2.80
15-June	0	0.60	25.00	3.10	2.70
16-June	0	0.77	26.00	3.60	2.20
17-June	0	1.70	24.00	14.00	7.50
18-June	0	1.10	24.00	11.00	3.90
19-June	0	0.88	25.00	8.10	2.50
20-June	0	0.74	20.00	5.10	1.00
21-June	0	0.55	20.00	1.80	0.53
22-June	0.02	0.42	19.00	1.00	0.16
23-June	0.27	0.56	15.00	1.80	0.26
24-June	0.92	4.50	50.00	29.00	26.00
25-June	8.40	11.00	276.00	108.00	136.00
26-June	7.50	78.00	739.00	666.00	438.00
27-June	99.00	61.00	545.00	105.00	180.00
28-June	149.00	157.00	629.00	569.00	380.00
29-June	113.00	315.00	740.00	255.00	330.00
30-June	66.00	298.00	519.00	89.00	148.00
June Totals	444.11	942.62	4058.30	2007.07	1787.41

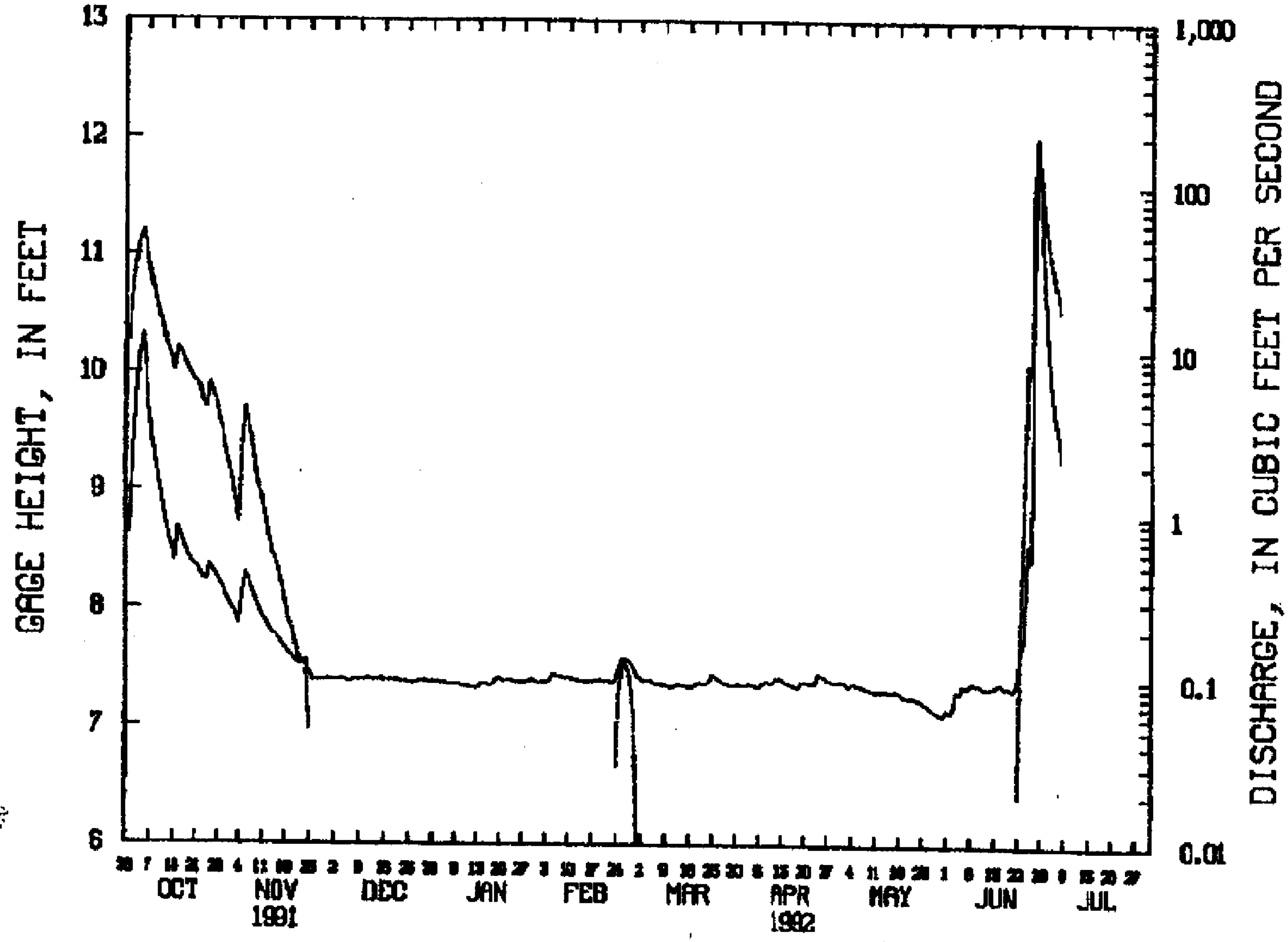
STATION	IMPERIAL	MEADE	SANCARLO	SHADROE	SPRING C
DBKEY	849	12801	12797	12793	12809
01-June	3.40	0.05	0	0	0.11
02-June	3.30	0	0	0	0.11
03-June	3.50	0.17	0	0	0.11
04-June	3.60	0.53	0	0	0.14
05-June	3.40	0.45	0	0	0.14
06-June	4.70	0.79	0	37.00	0.87
07-June	4.70	1.60	0	12.00	1.60
08-June	6.40	3.50	0	2.20	2.20
09-June	12.00	4.60	0	0.88	4.10
10-June	25.00	3.10	0	0.75	8.00
11-June	33.00	2.20	0	0.64	7.40
12-June	21.00	1.90	0	0.50	6.40
13-June	16.00	1.80	0	0.25	5.70

Table 24. Surface Water Discharge, Lee County (cfs)

STATION	ESTERO N	ESTERO S	GATOR S	HERMOSA	HORSE SH
14-June	13.00	1.70	0	0	5.30
15-June	13.00	2.10	0	0.12	5.00
16-June	11.00	3.70	1.30	0.12	4.80
17-June	9.90	6.00	4.60	2.20	5.20
18-June	8.70	4.90	4.50	0.87	5.40
19-June	6.60	5.60	4.90	0.62	5.10
20-June	4.50	5.30	3.80	0.25	4.70
21-June	4.50	4.90	3.20	0	4.10
22-June	4.20	3.60	2.70	0	3.70
23-June	6.40	3.40	5.30	0.12	4.00
24-June	26.00	8.30	24.00	9.40	23.00
25-June	73.00	21.00	58.00	78.00	36.00
26-June	177.00	47.00	96.00	198.00	77.00
27-June	303.00	33.00	41.00	26.00	81.00
28-June	523.00	68.00	128.00	164.00	113.00
29-June	829.00	75.00	107.00	95.00	155.00
30-June	967.00	45.00	41.00	39.00	125.00
01-July	1010.00				
02-July	1020.00				
03-July	990.00				
04-July	945.00				

Groundwater Levels, Lee and Collier Counties

Prior to the storm, groundwater levels in Lee and Collier counties were close to normal. As a result of the heavy rainfall, groundwater levels in the water table aquifer rose from one to four feet between June 21-30. In most cases, groundwater levels peaked on June 28. Some wells, such as L-1997 and C-496, continued to rise through June 30. Other wells showed sharp rises through June 28 and maintained those levels through June 30, while other wells showed declining groundwater levels



UNPUBLISHED DATA SUBJECT TO REVISION

Figure 33. Mean Daily Gauge Height, Mean Daily Discharge, North Branch Estero River

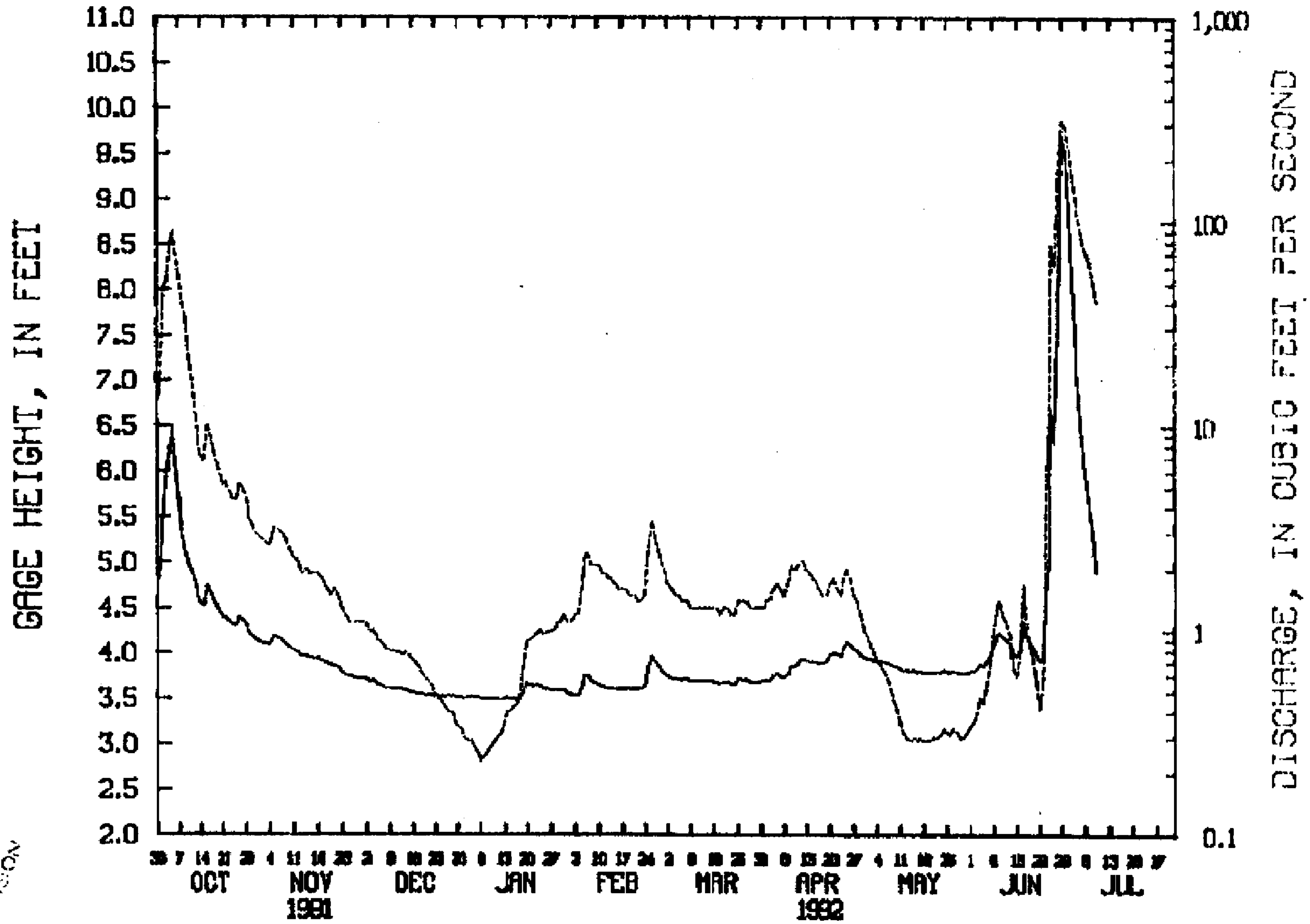


Figure 34. Mean Daily Gauge Height, Mean Daily Discharge, South Branch Estero River

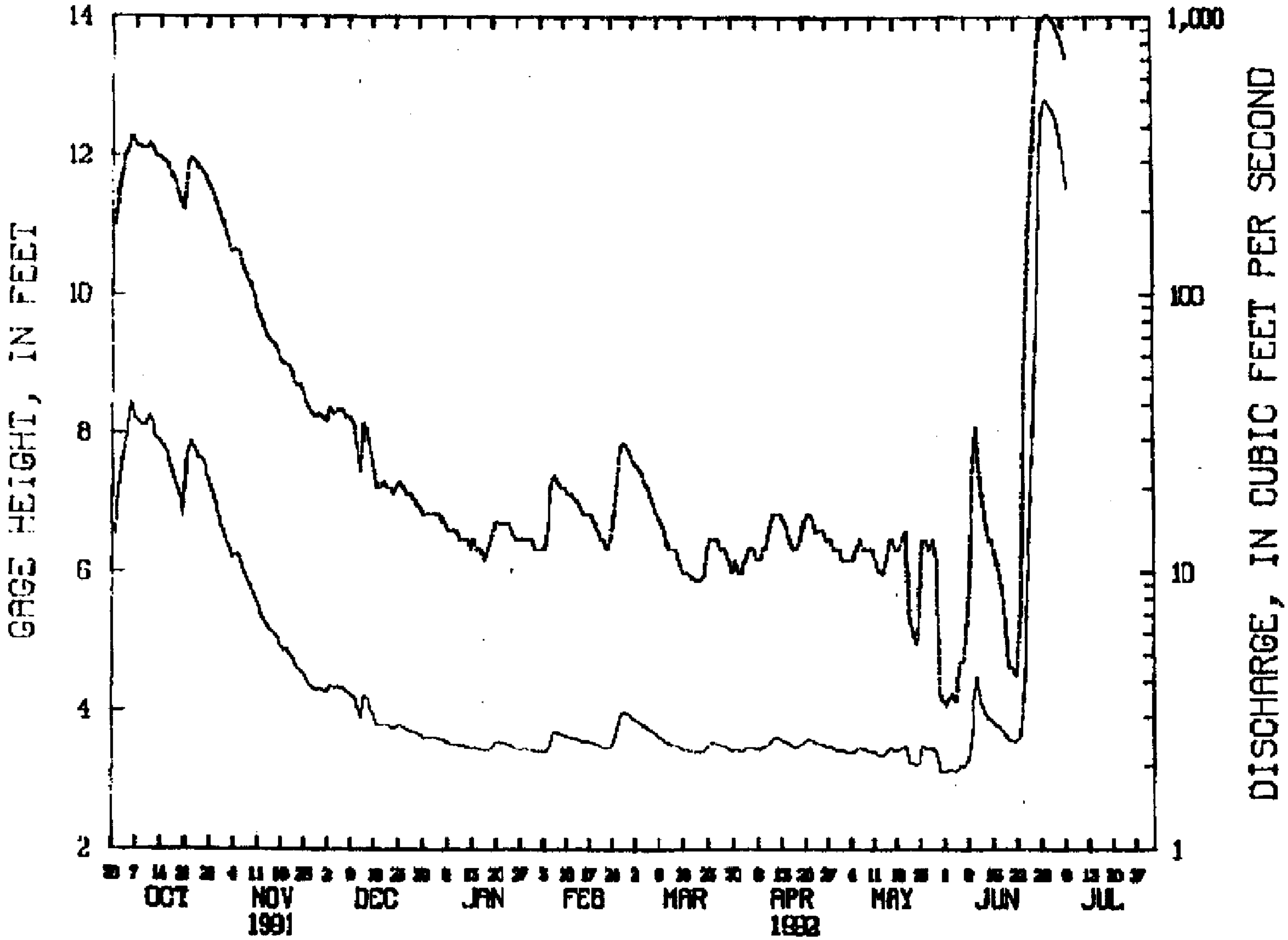


Figure 35. Mean Daily Gauge Height, Mean Daily Discharge, Imperial River

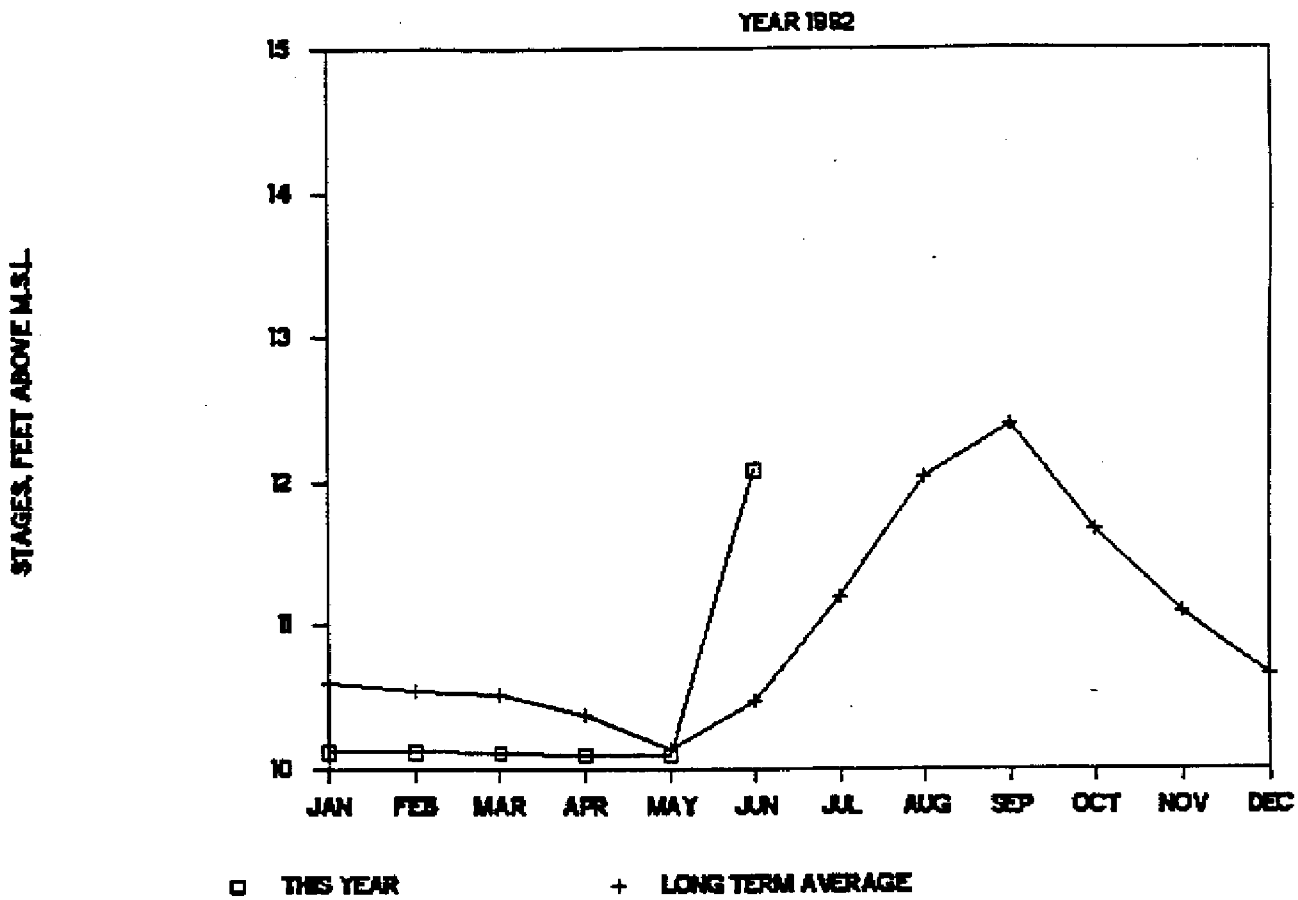
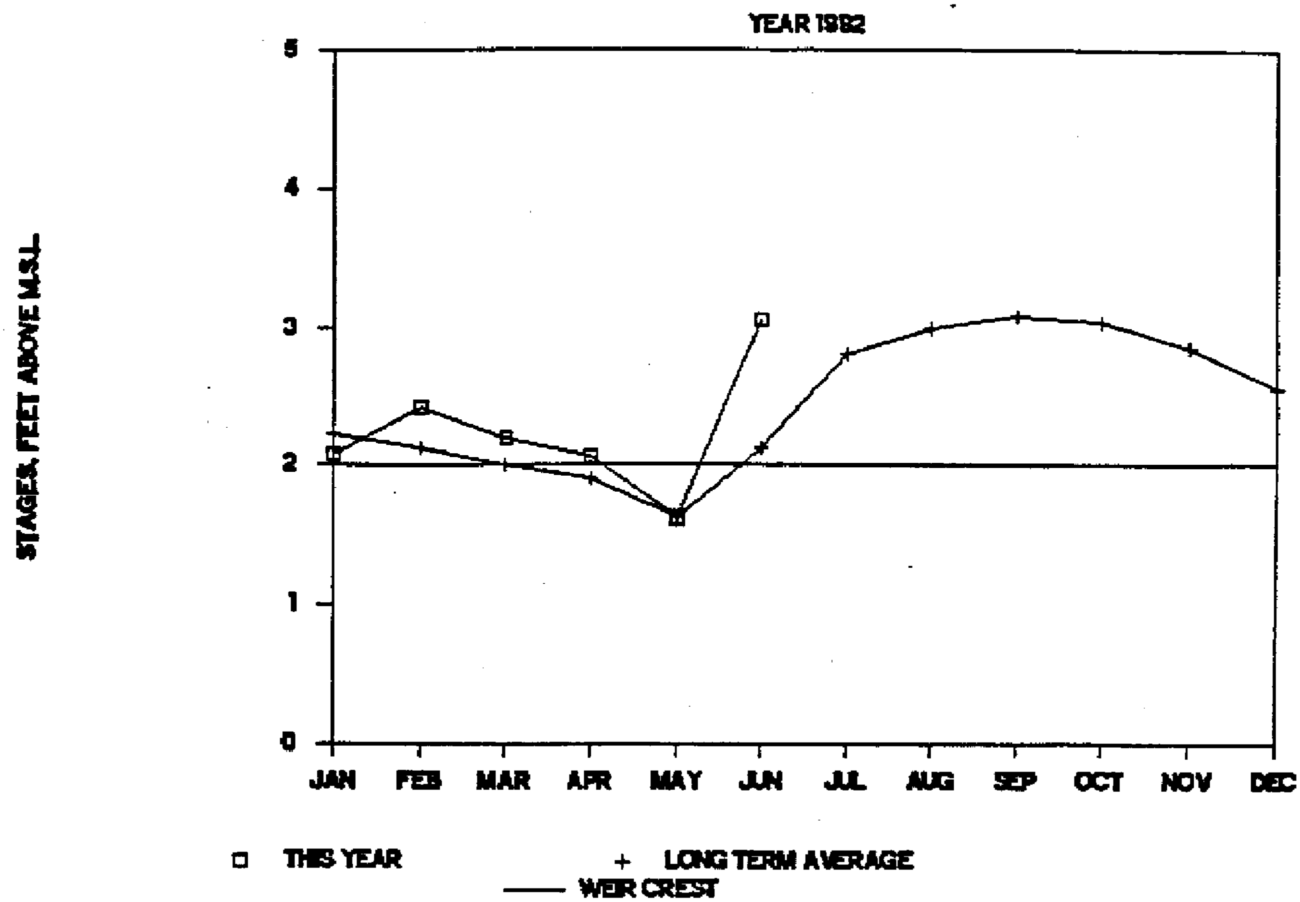


Figure 36. Cocohatchee Canal Stages at CR 951



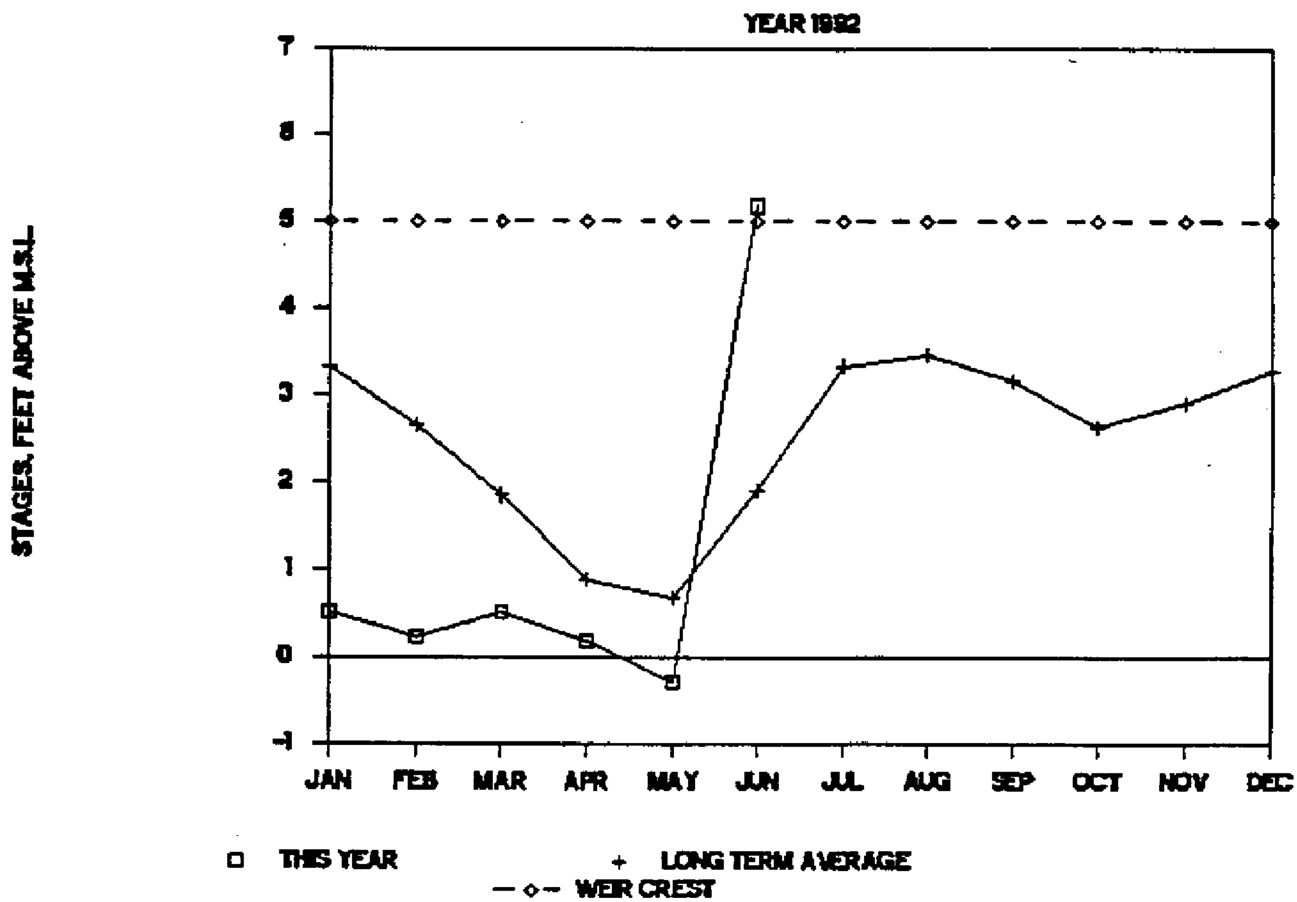
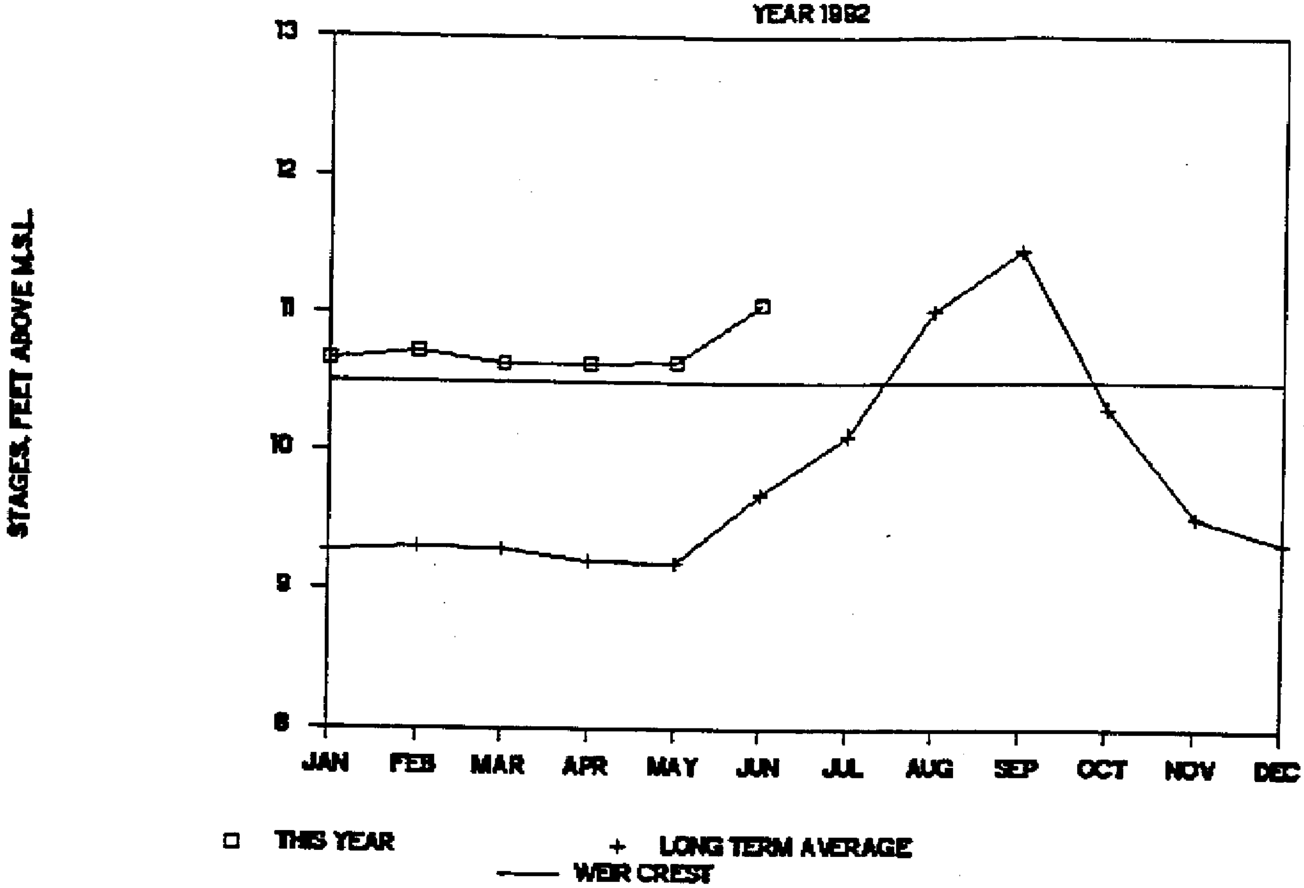


Figure 37. Faka Union Canal Stages at U.S. 41 and Henderson Creek Canal Stages at U.S. 41



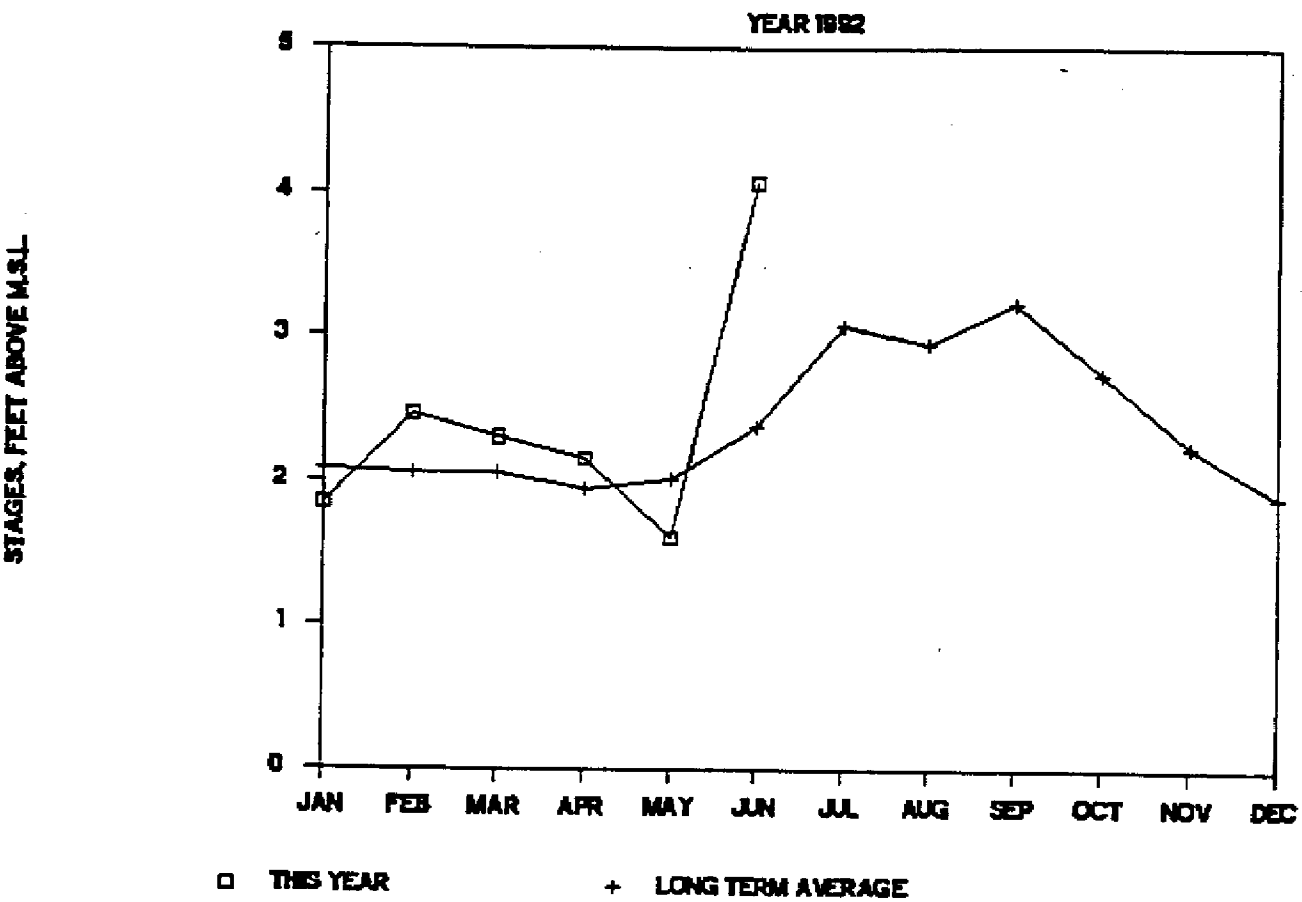
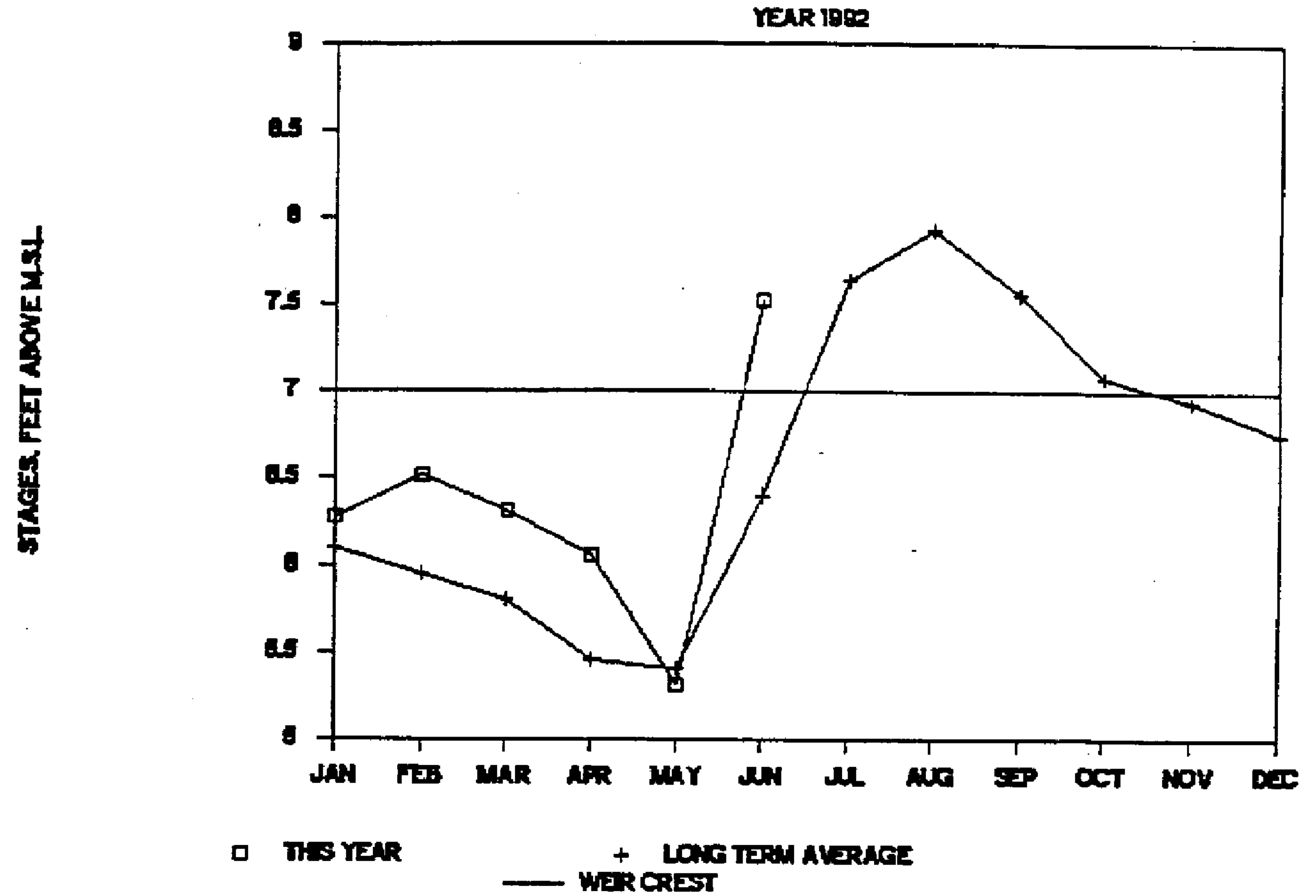


Figure 38. Golden Gate Canal Stages at Weir #5 and Cocohatchee Canal Stages at Willoughby Acres



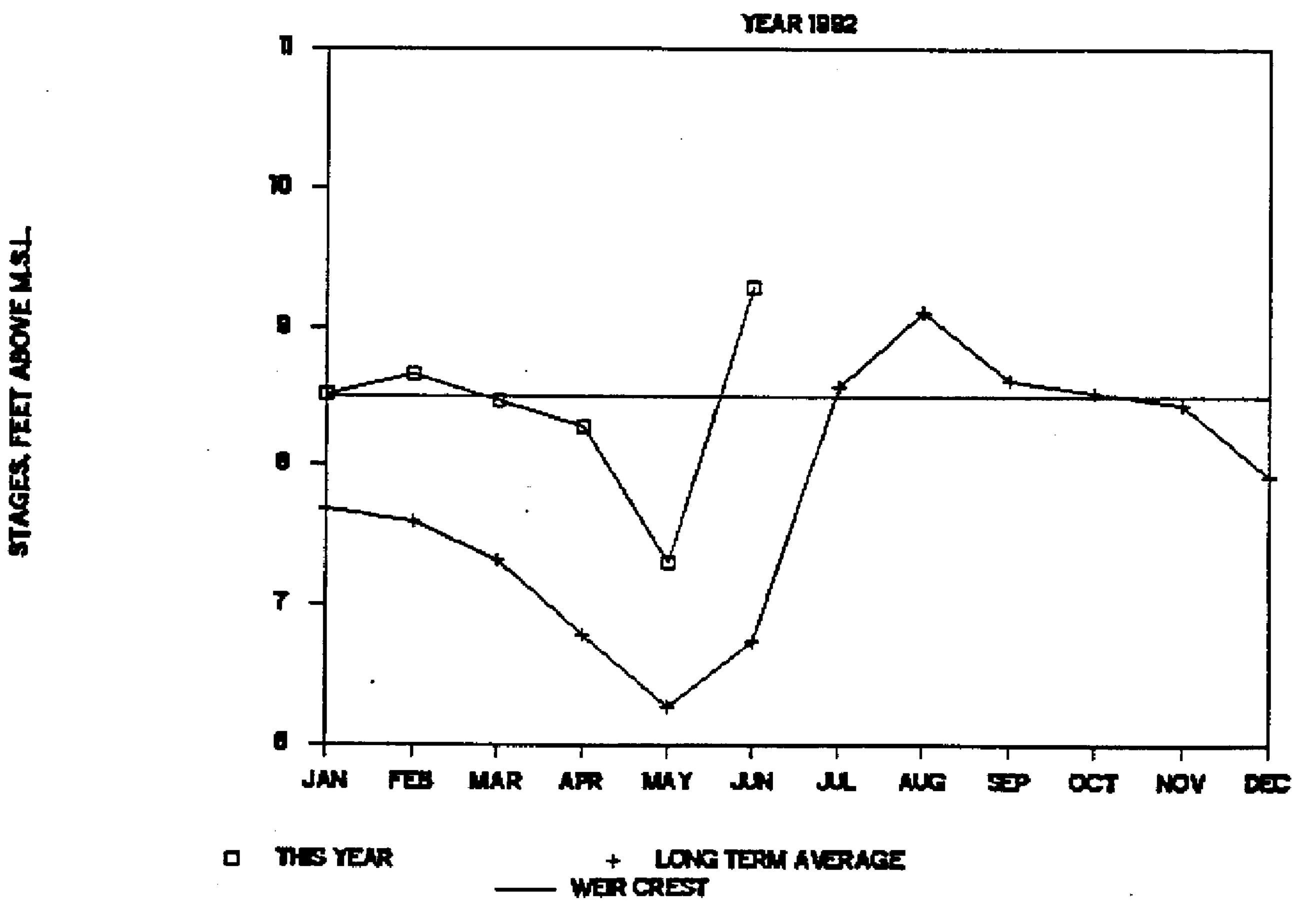
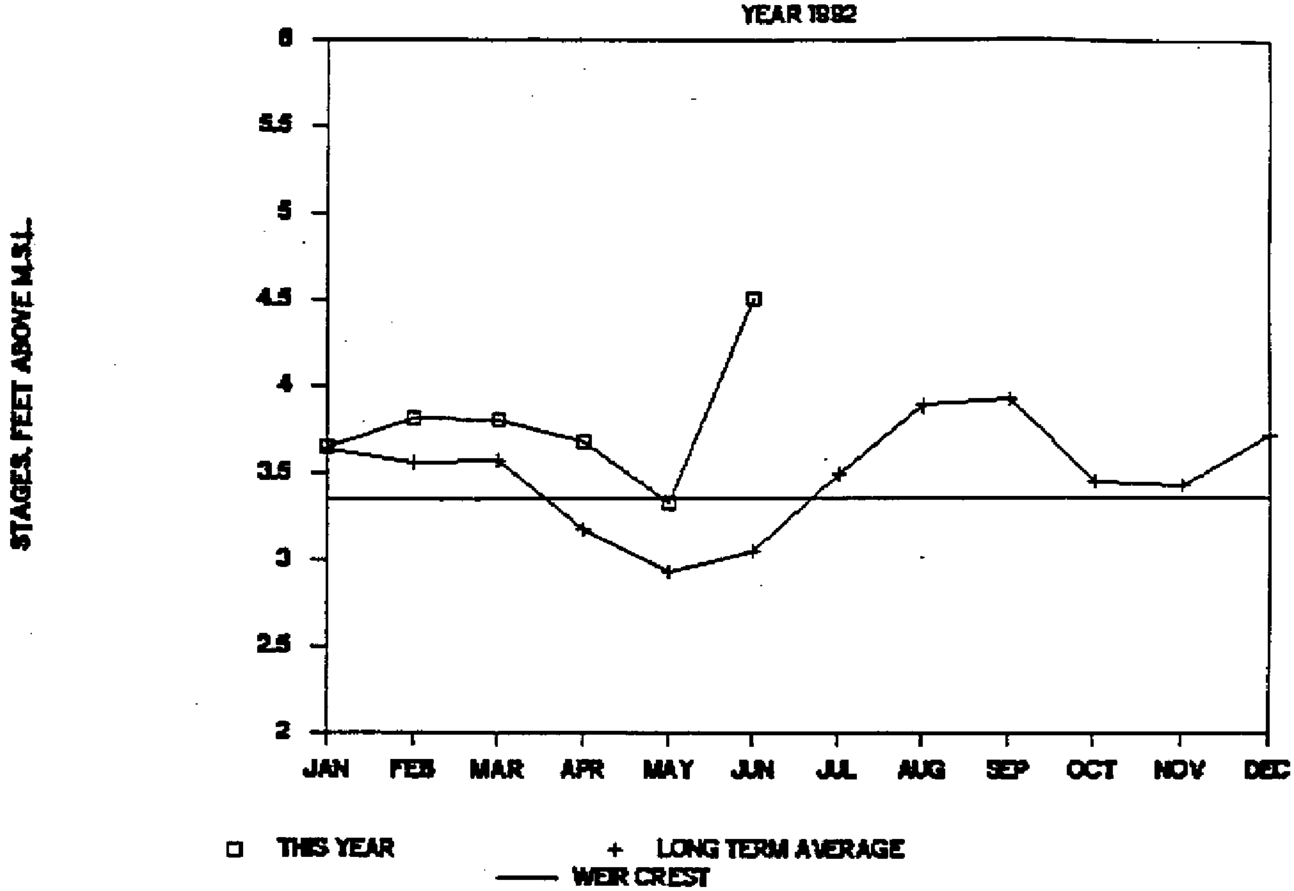


Figure 39. Golden Gate Canal Stages at Weir #3 and Golden Gate Canal Stages at Weir #4



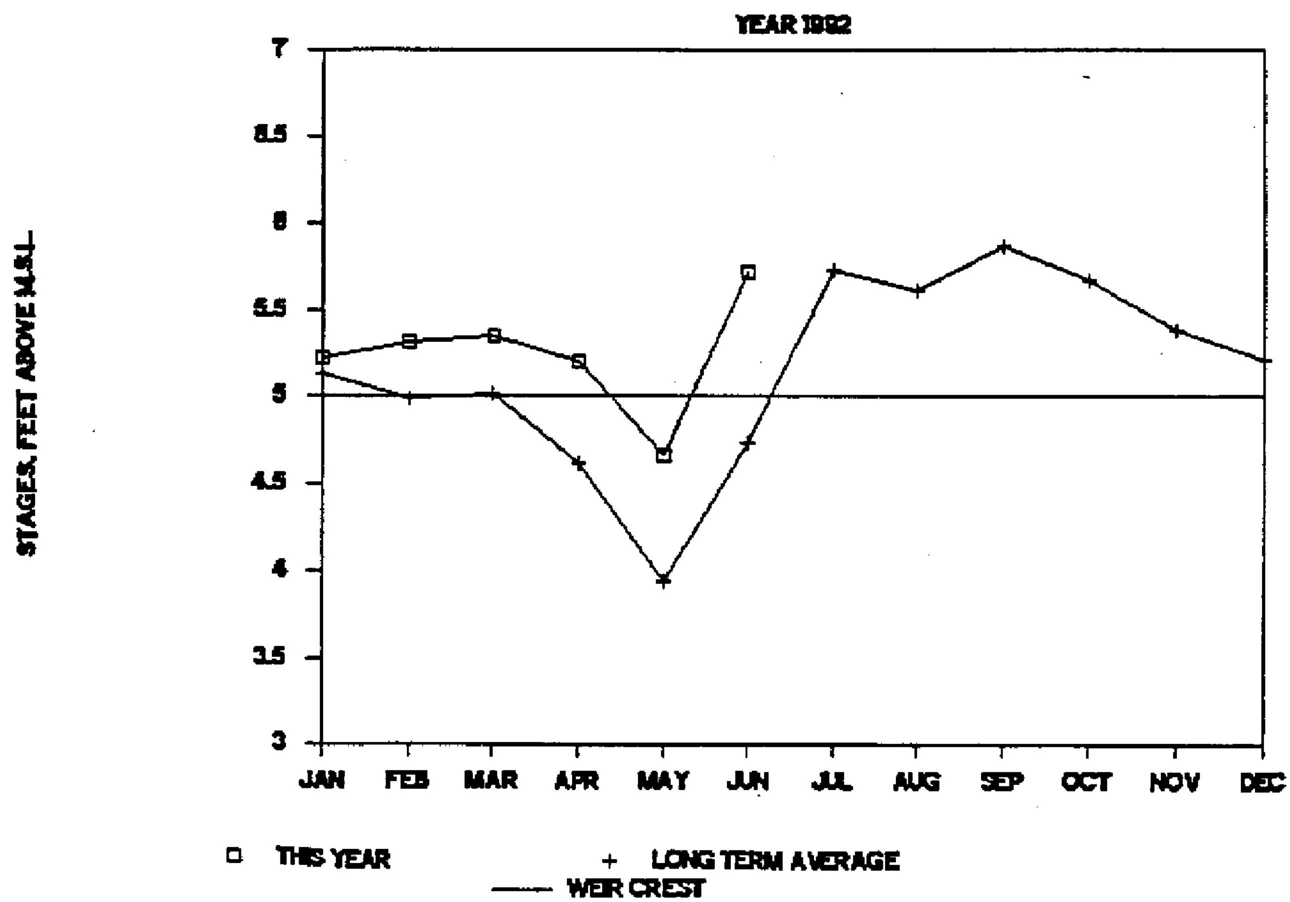


Figure 40. Golden Gate Canal Stages at Weir #1 and Golden Gate Canal Stages at Weir #2

after June 28. Water levels in wells L-1997, C-54, C-598 and C-968 temporarily rose above the land surface, indicating flooded conditions near these wells. Groundwater levels in wells C-496 and C-1071 exceeded maximum historic levels.

Figures 41 and 42 show locations of the Lee and Collier groundwater monitor wells referenced in this report. Figures 43 through 47 show daily groundwater levels for these wells from June 20 through June 30. Included on the figures are mean groundwater levels in 1991, the maximum and minimum groundwater levels for the period of record, and the land surface elevation.

Water Quality and Environmental Impacts

<u>Freshwater Discharge to Caloosahatchee Estuary</u>

Table 25 shows the stages, discharge and rain at the lake control structure, at Ortona, and at Franklin Dam downstream of the Caloosahatchee River. No discharge was made from Lake Okeechobee except for irrigation releases from June 1 to June 4 and again on June 24. However, because of local runoff flowing to the Caloosahatchee River, discharge to the estuary from S-79 was high. On the last day of the month, a maximum discharge of 11,680 cfs was made. Design discharge for S-79 is 28,900 cfs. Local runoff discharge from this structure was below the design discharge range.

Salinity/Conductivity

Five sets of continuous conductivity probes are located in Caloosahatchee Estuary (Figure 48). The probes record conductivity and store the information until it is remotely retrieved by Data Management Division staff at the West Palm Beach Field Office via cellular telephone. The data collected by these probes and each station's periodic calibration report were used to determine the impact to conductivity/salinity caused by the storm's freshwater runoff. The conductivity/

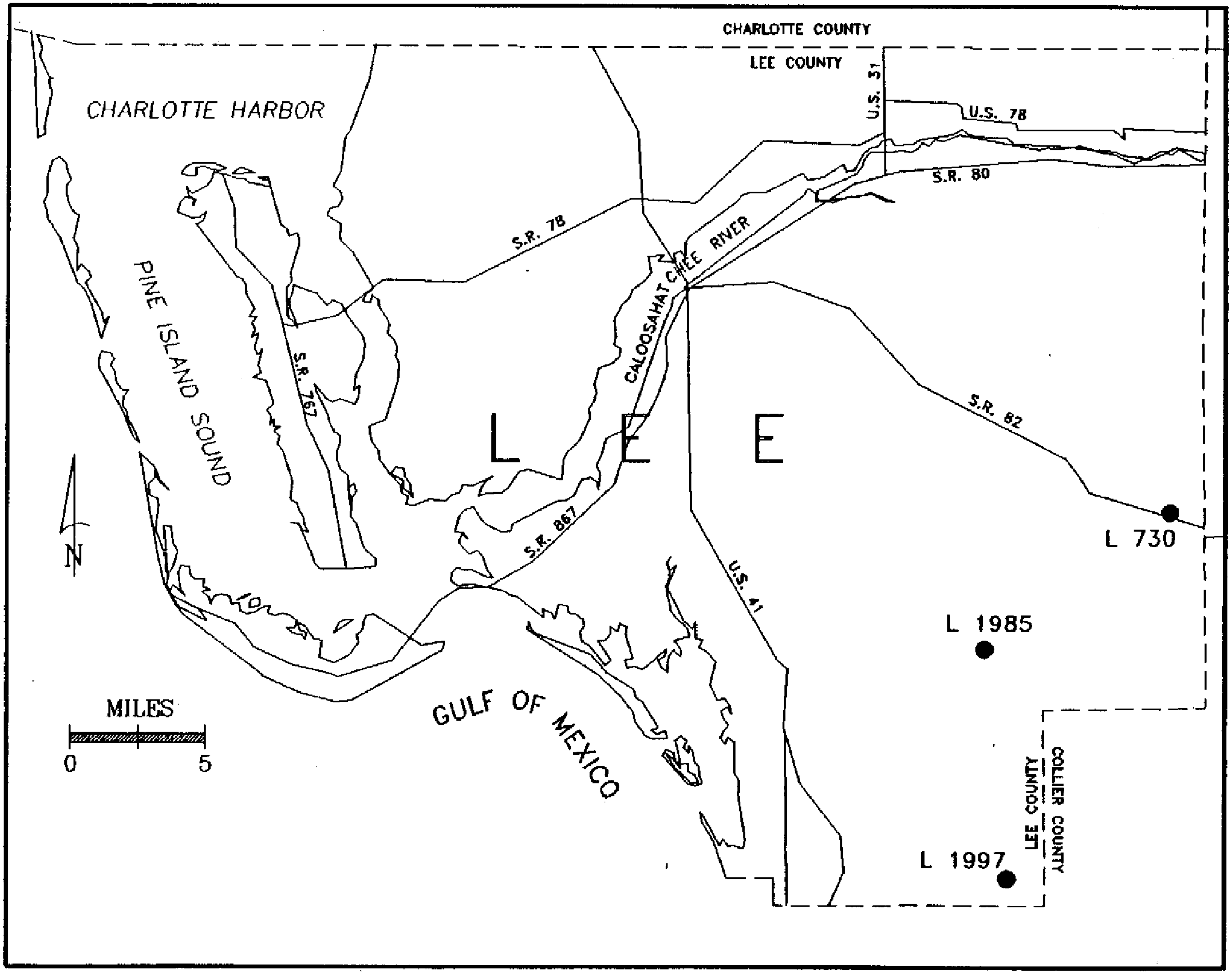


Figure 41. Groundwater Monitoring Wells in Lee County

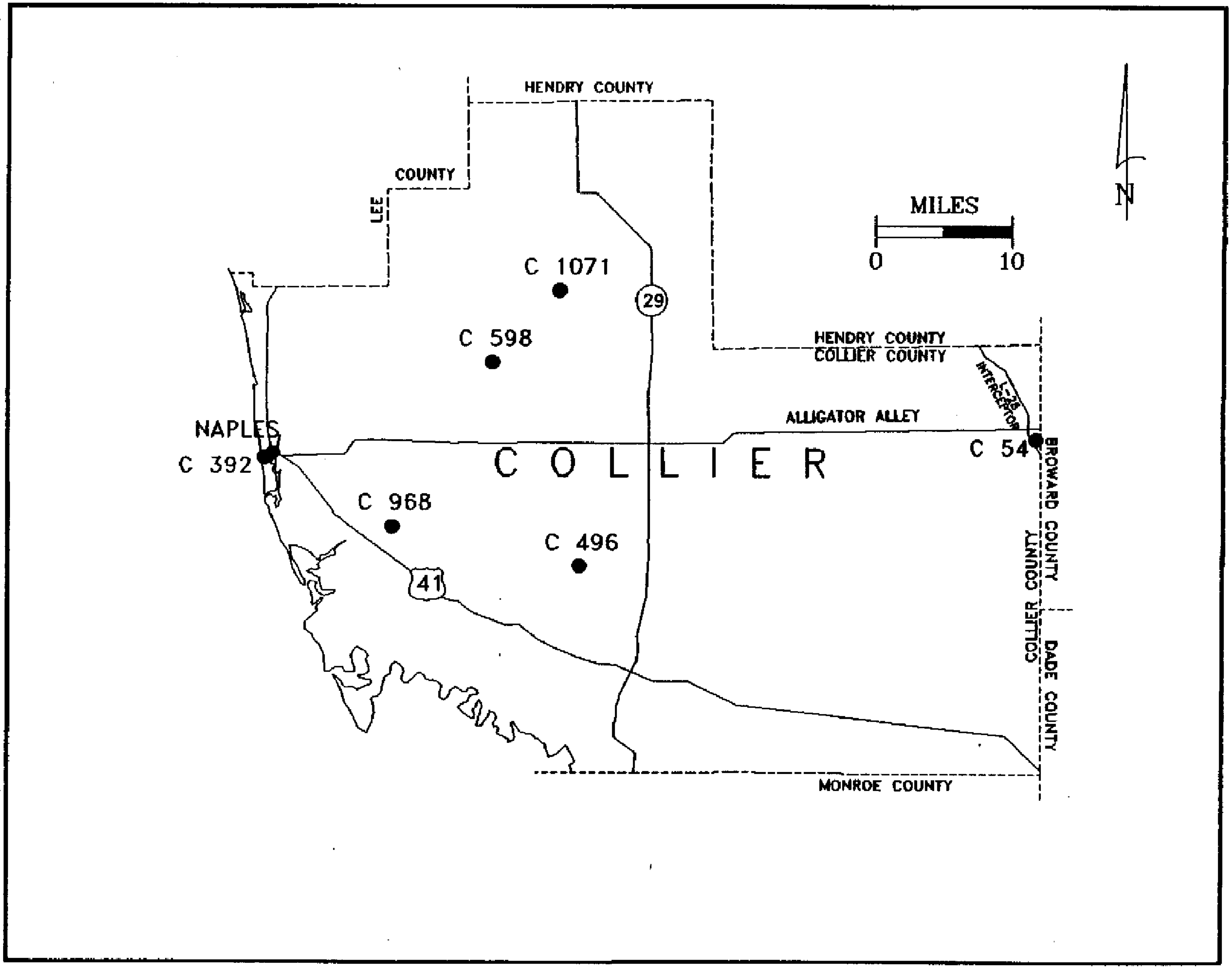


Figure 42. Groundwater Monitoring Wells in Collier County

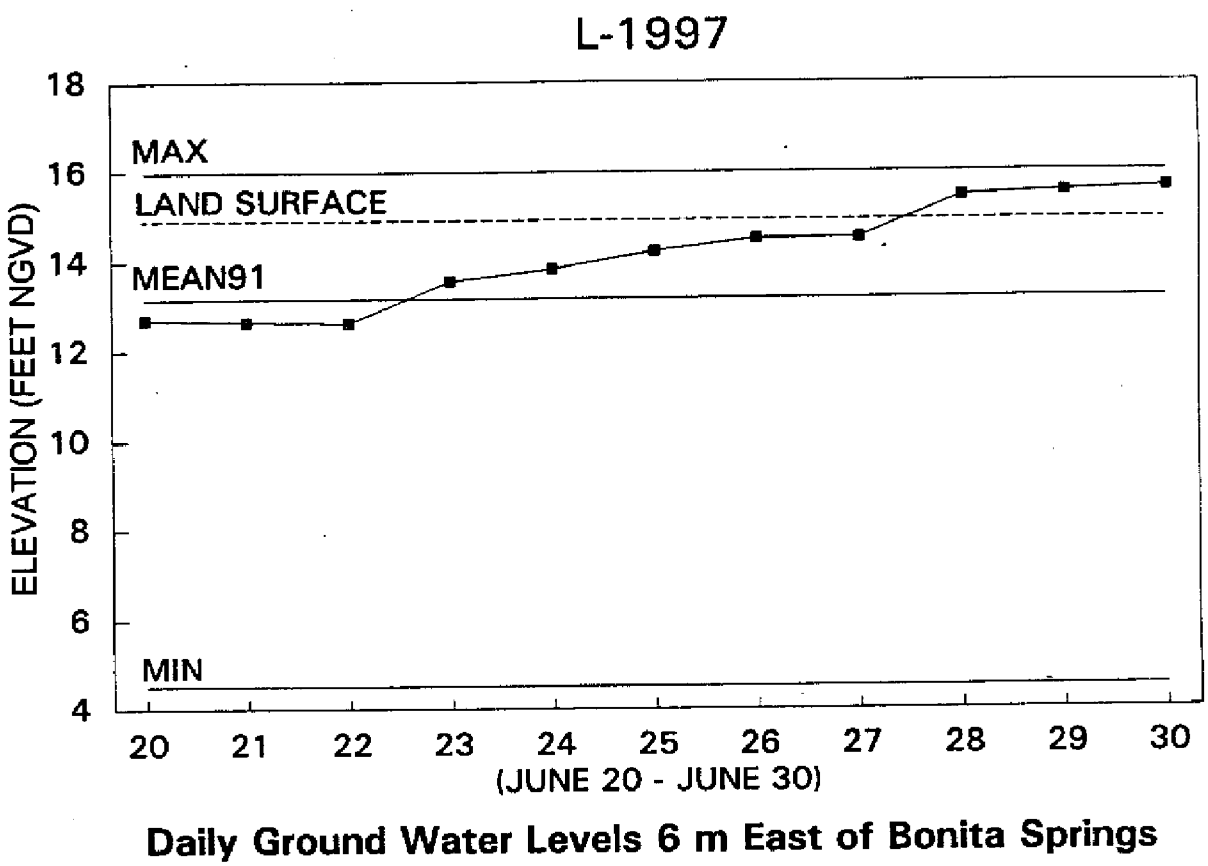
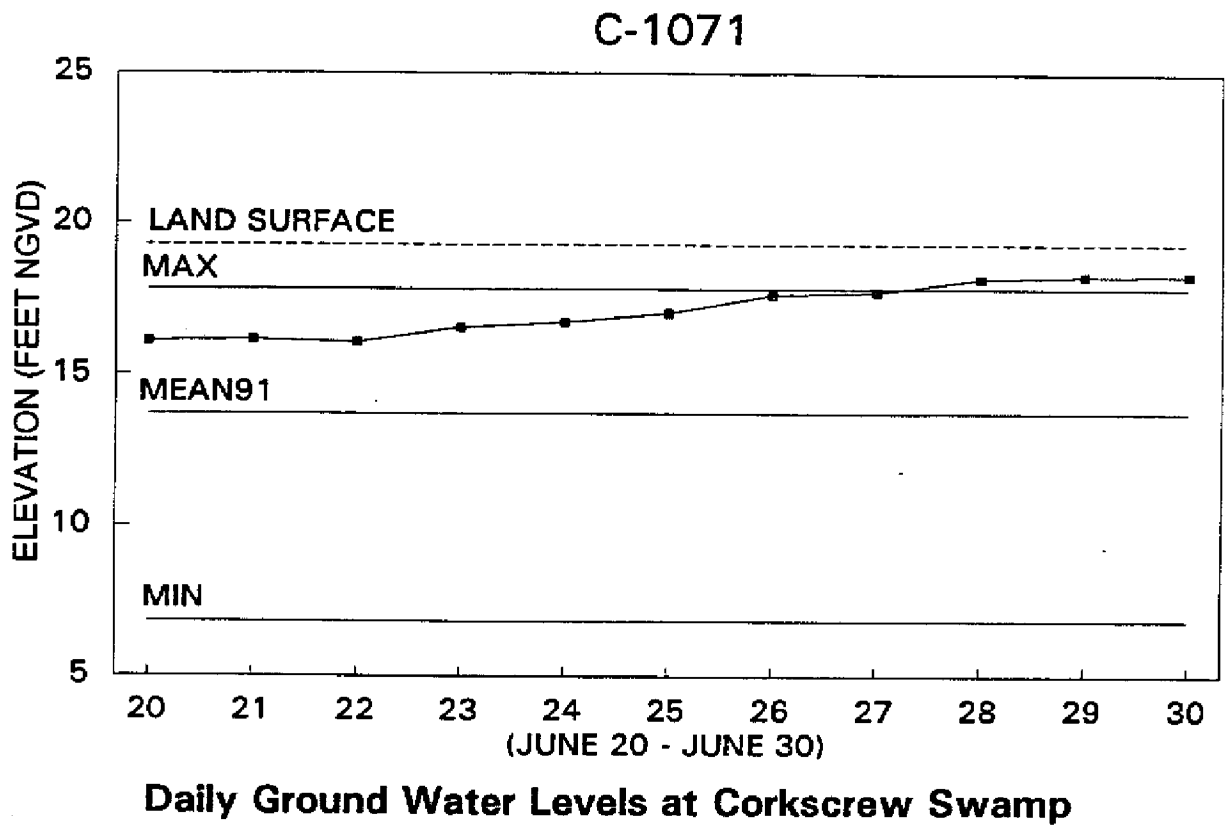


Figure 43. Daily Groundwater Levels 6 m East of Bonita Springs



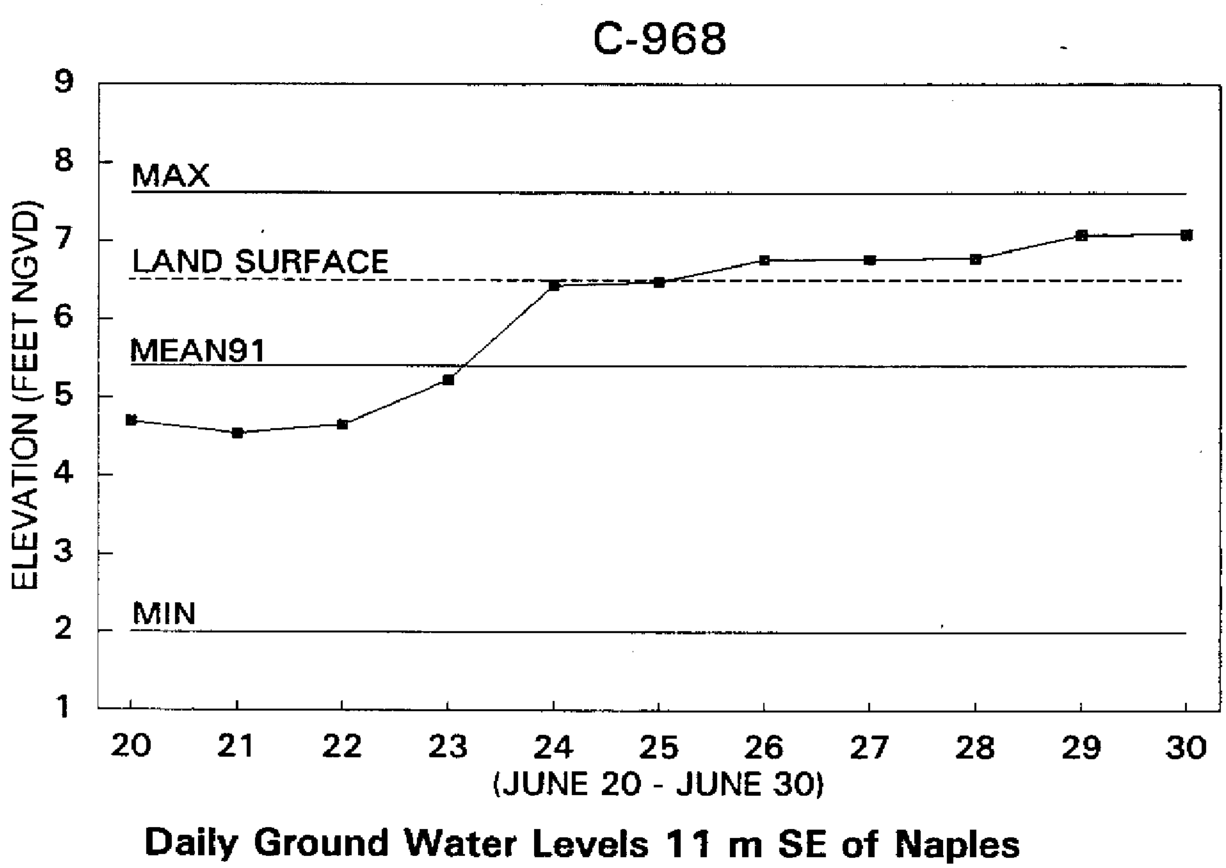
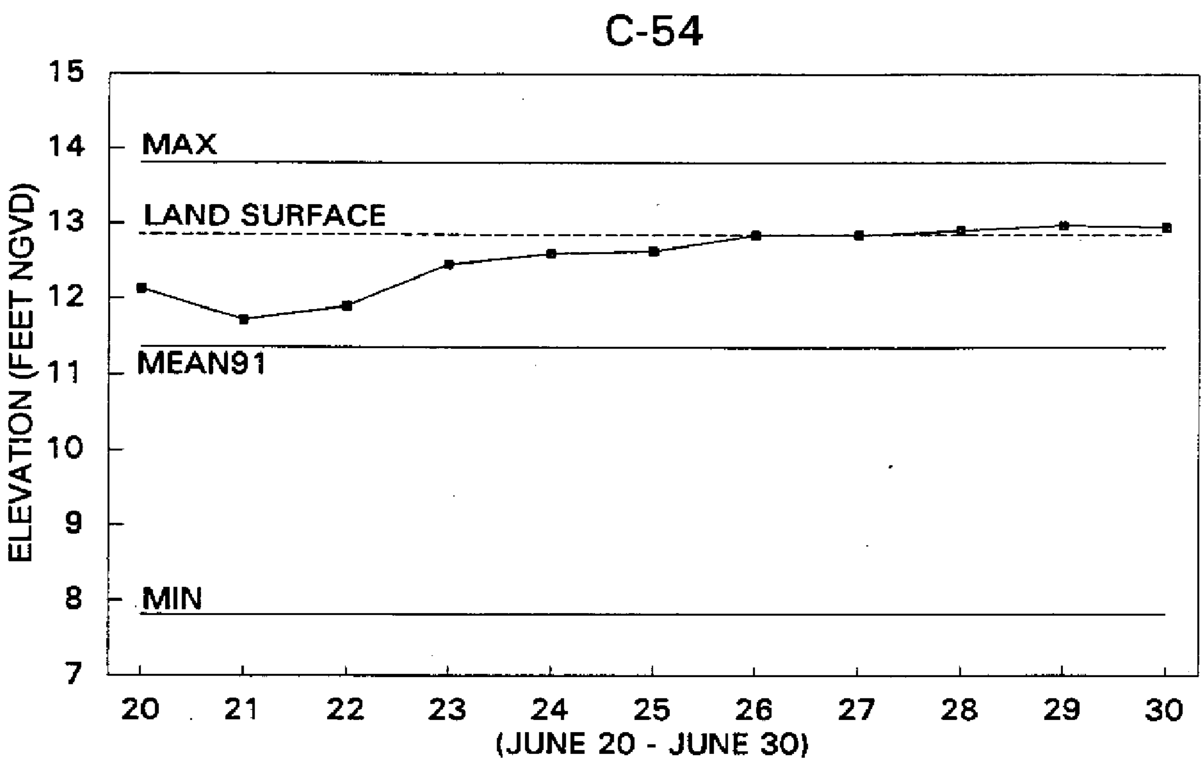
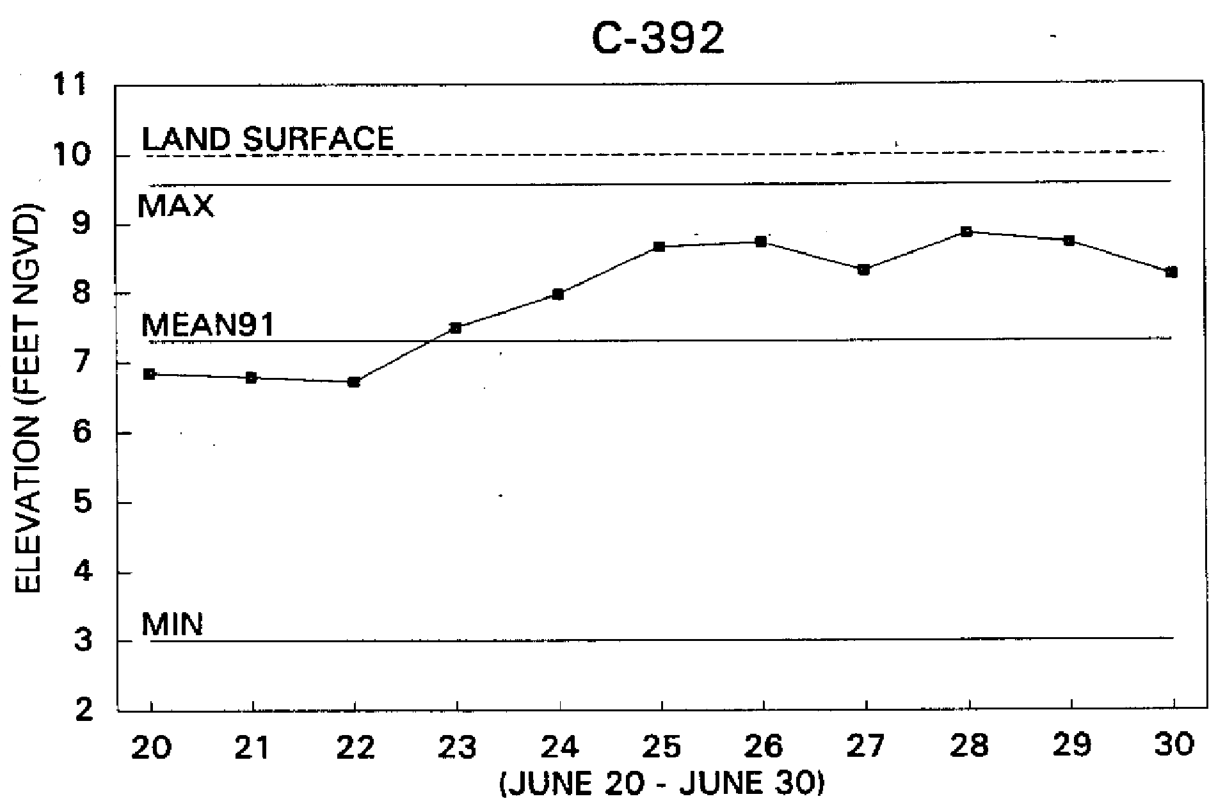


Figure 44. Daily Groundwater Levels at Corkscrew Swamp and 11 m SE of Naples

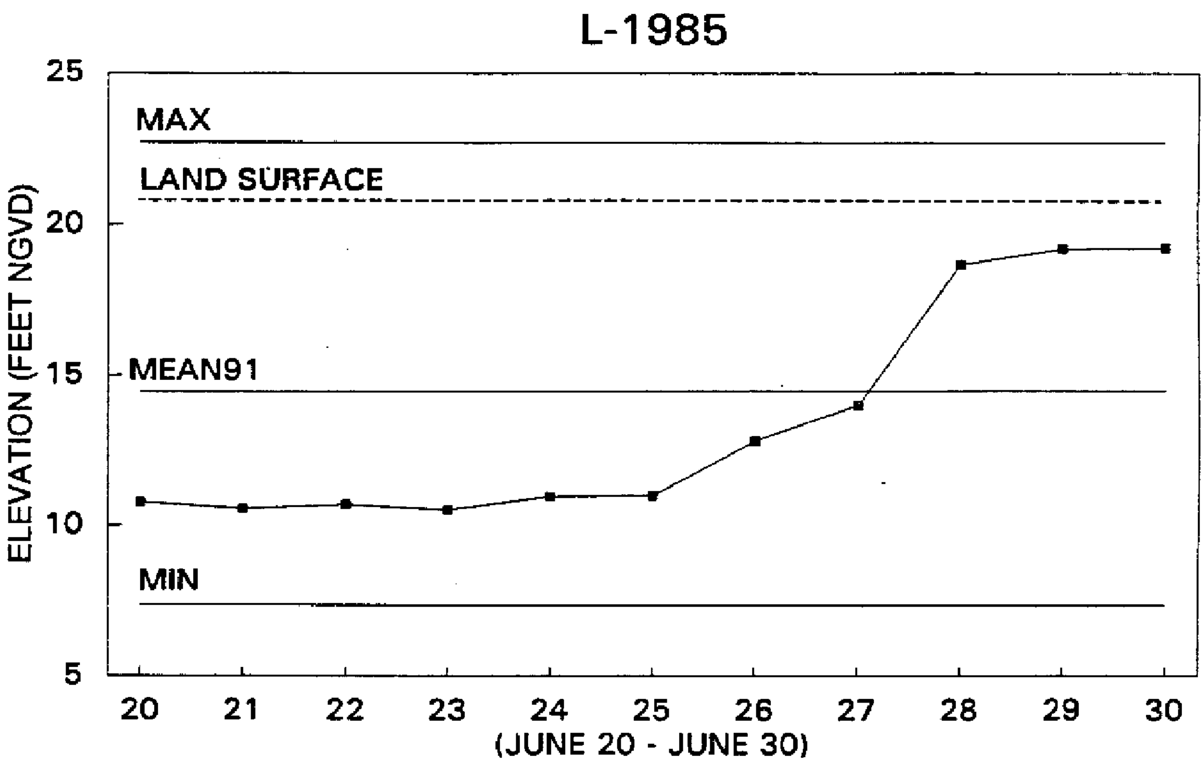


Daily Ground Water Levels at Alligator Alley

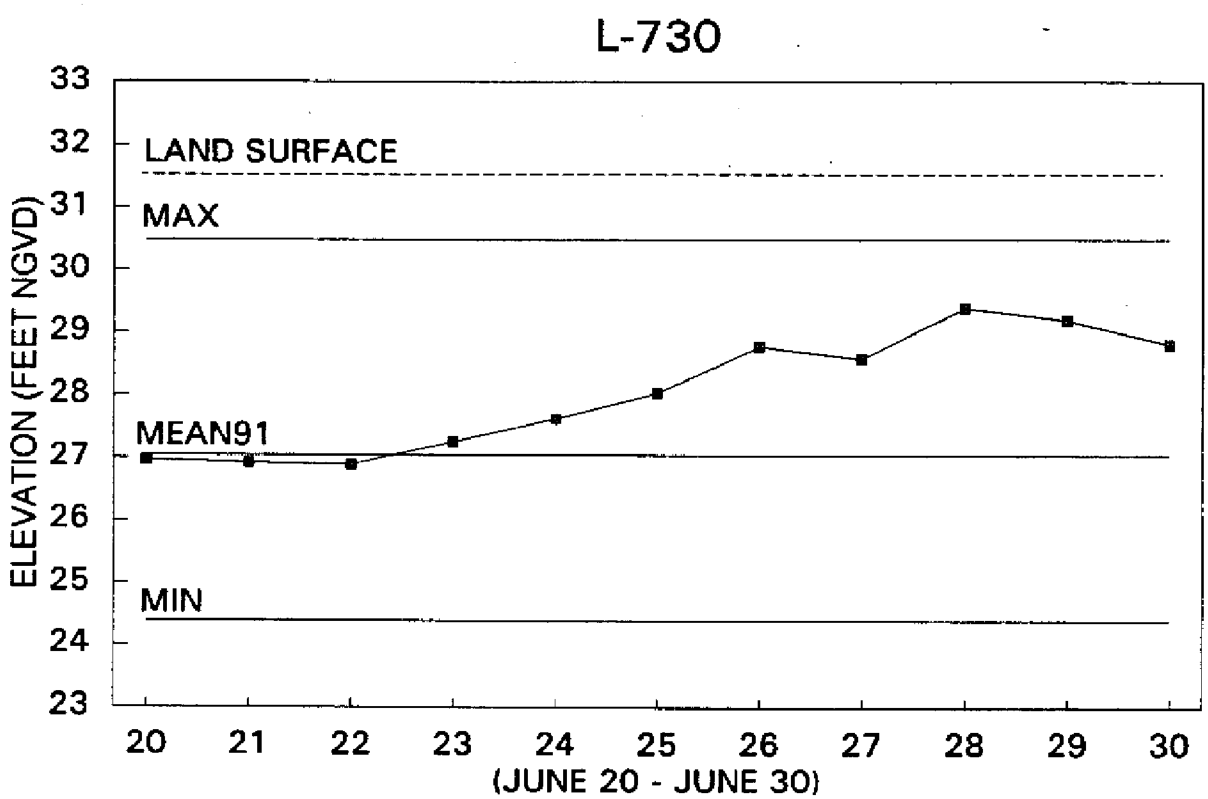


Daily Ground Water Levels at Naples

Figure 45. Daily Groundwater Levels at Alligator Alley and at Naples

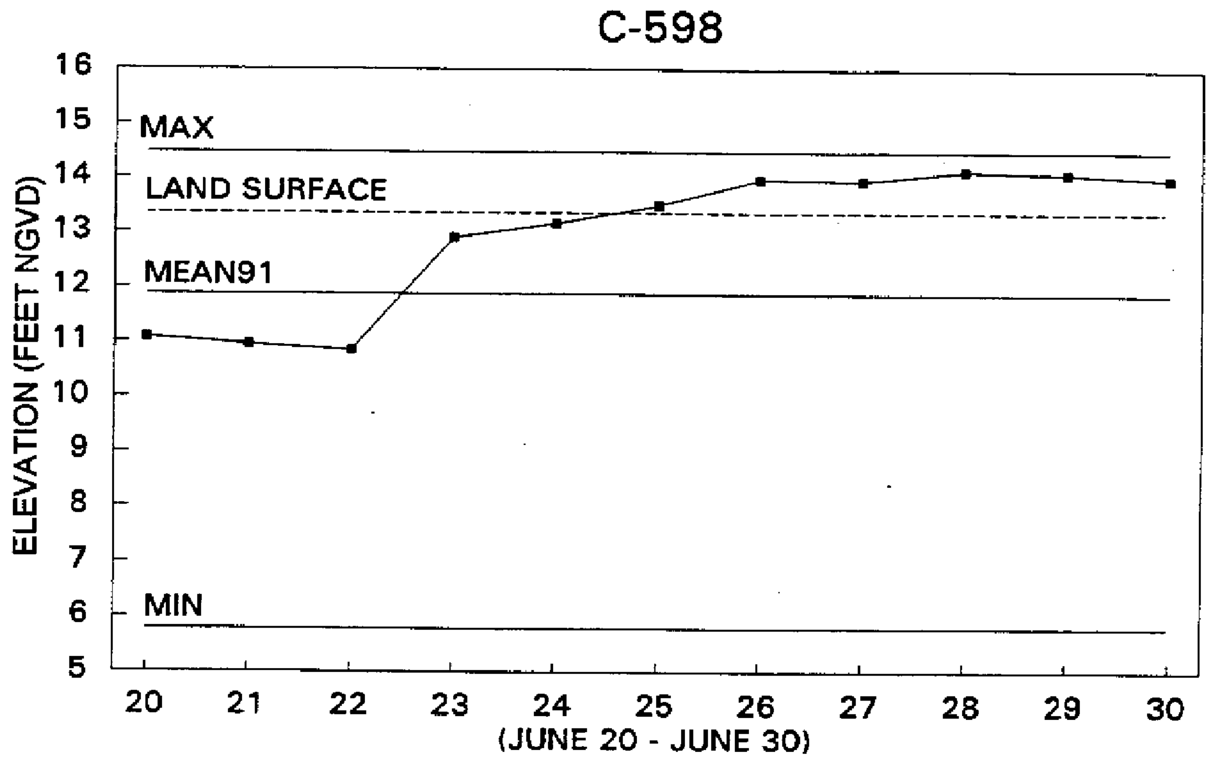


Daily Ground Water Levels at Estero

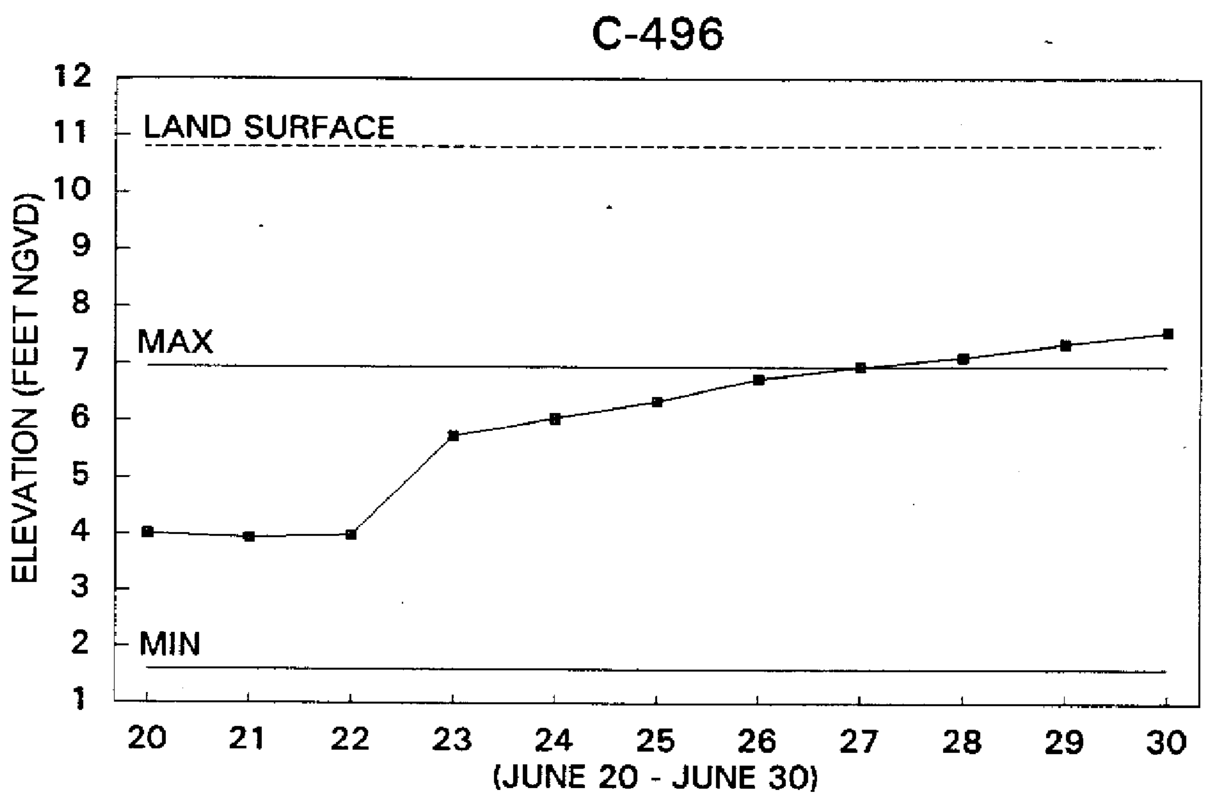


Daily Ground Water Levels at Lehigh Acres

Figure 46. Daily Groundwater Levels at Estero and at Lehigh Acres



Daily Ground Water Levels 19 m E of Naples in Big Cypress Swamp



Daily Ground Water Levels at Fakahatchee Strand

Figure 47. Daily Groundwater Levels 91 m E of Naples in Big Cypress Swamp and at Fakahatchee Strand

Table 25. Stage (feet, NGVD) and Discharge (cfs), Caloosahatchee River and Estuary

Date	S-77, Moore Haven			S-78, Ortona			S-79, Franklin		
	Stages, up	Stages, down	Discharge	Stages, up	Stages, down	Discharge	Stages, up	Stages, down	Discharge
6/01	14.26	11.06	496.00	11.04	3.14	117.00	3.27	1.25	0
6/02	14.11	10.84	378.00	10.87	2.92	0	3.10	1.15	0
6/03	14.18	11.15	511.00	11.15	3.03	50.00	3.18	1.13	0
6/04	14.16	11.13	364.00	11.15	3.23	66.00	3.41	1.30	184.00
6/05	14.15	11.38	0	11.38	2.86	400.00	3.12	1.10	1,465.00
6/06	14.18	11.08	0	11.11	3.03	632.00	3.24	1.00	1,751.00
6/07	14.03	11.05	0	11.05	2.83	633.00	3.03	2.60	1,328.00
6/08	14.25	11.20	0	11.21	3.07	900.00	3.27	0.60	1,568.00
6/09	14.29	10.98	0	11.00	3.11	583.00	3.25	0.66	1,108.00
6/10	14.28	11.17	0	11.15	3.20	250.00	3.38	0.91	555.00
6/11	14.23	10.86	0	10.37	3.10	750.00	3.26	0.96	1,544.00
6/12	14.30	11.12	0	11.10	3.18	217.00	3.37	1.30	637.00
6/13	14.25	11.53	0	11.53	3.18	432.00	3.35	1.17	1,520.00
6/14	14.28	11.44	0	11.42	3.04	1,485.00	3.18	1.40	2,873.00
6/15	14.32	11.19	0	11.18	2.82	1,677.00	2.94	1.32	3,364.00
6/16	14.54	11.59	0	11.50	3.04	1,831.00	3.12	1.26	3,465.00
6/17	14.48	11.25	0	11.21	2.85	1,859.00	2.98	1.19	4,429.00
6/18	14.51	11.20	0	11.22	3.17	1,805.00	3.32	1.00	3,635.00
6/19	14.50	10.89	0	10.95	3.00	950.00	3.18	0.60	3,653.00
6/20	14.42	11.04	0	11.05	3.22	665.00	3.50	0.80	2,026.00
6/21	14.33	11.27	0	11.28	2.65	0	2.85	0.80	1,510.00
6/22	14.32	10.94	0	10.95	3.44	283.00	3.55	0.52	852.00
6/23	14.38	10.77	0	10.76	2.90	108.00	3.10	0.90	1,310.00
6/24	14.45	10.97	95.00	10.98	3.08	0	3.26	0.97	622.00
6/25	14.52	11.14	0	11.10	2.82	316.00	2.97	1.79	1,897.00
6/26	14.73	11.83	0	11.85	3.41	1,400.00	3.35	3.13	2,891.00
6/27	14.76	11.37	0	11.18	3.41	4,033.00	3.06	1.84	8,556.00
6/28	14.98	11.76	0	11.64	4.05	4,874.00	3.23	2.20	9,714.00
6/29	15.09	11.26	0	11.11	3.79	4,664.00	2.97	2.78	10,627.00
6/30	15.34	11.30	0	11.15	3.60	5,710	2.73	2.44	11,680.00

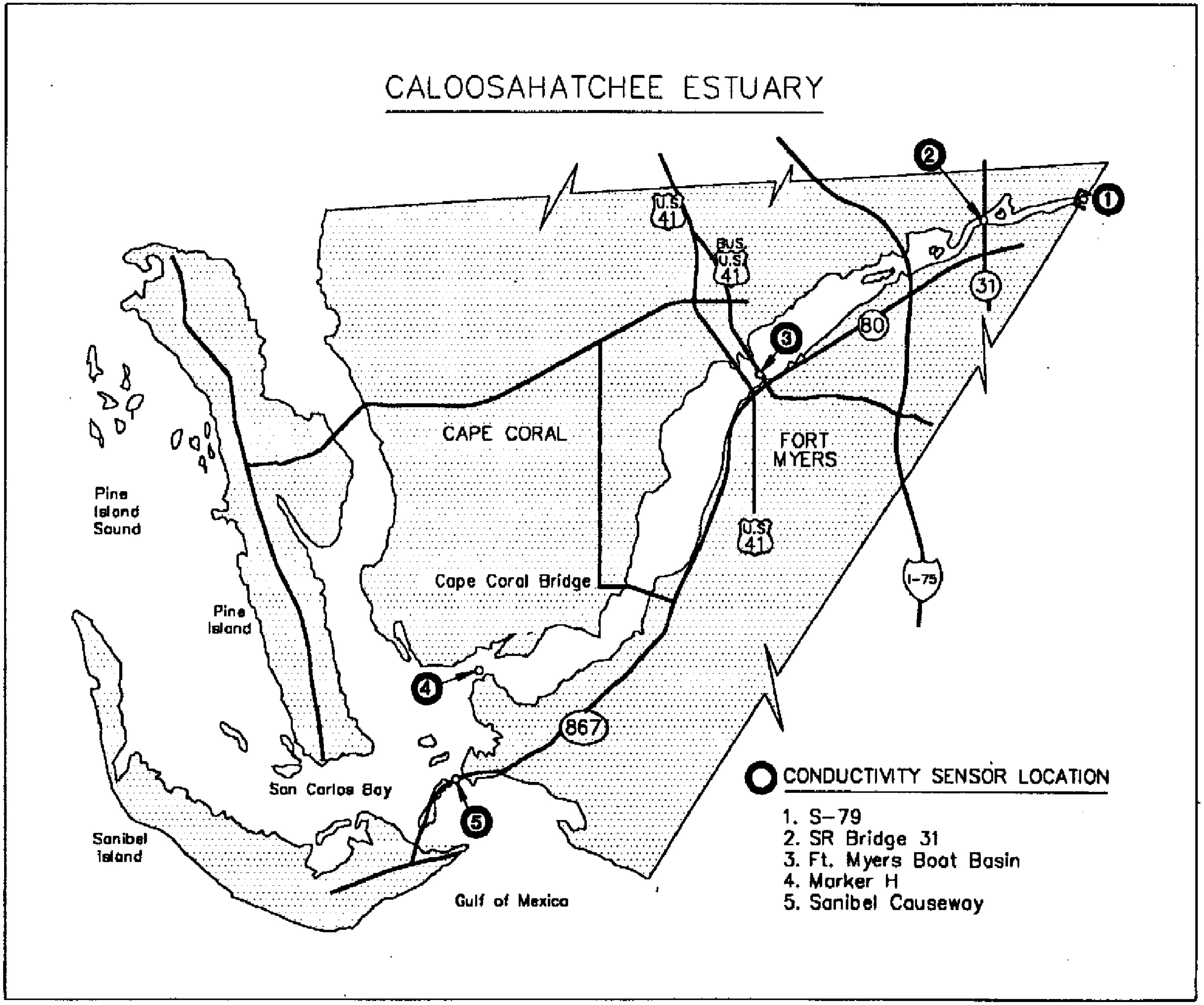


Figure 48. Conductivity Sensor Locations in the Caloosahatchee Estuary

salinity at each probe and the freshwater flow volume for May, June and July are depicted in Figures 49 and 50.

The Caloosahatchee Estuary receives almost all of its freshwater input from the Caloosahatchee River (Canal 43). Rainfall in the basin prior to the storm resulted in a freshwater discharge to the estuary through structure 79 that lowered conductivity (salinity) at the upstream stations. The heavy rains associated with the storm resulted in discharges to the estuary that peaked near 12,000 cfs. This discharge caused all the estuary upstream of the Marker H recorder to turn fresh and drove conductivity/salinity at Marker H and Sanibel Causeway to fall below 32,000 mhos/cm.

Prolonged exposure of estuarine benthic invertebrates to conductivity below 1000 mhos/cm for a week causes death, as does exposure to conductivity below 32,000 mhos/cm for some marine benthos. Sea grasses are also adversely impacted when conductivity remains below the 32,000 mhos/cm to 39,000 mhos/cm range. Freshwater conditions below 1000 mhos/cm in the estuary are common from S-79 downstream to just below the Fort Myers Boat Basin during the wet season. The benthic community that inhabits this area are tolerant of these changing conditions and were probably not seriously impacted by this storm. Marine and freshwater intolerant invertebrates begin to predominate in the lower Caloosahatchee Estuary below the Cape Coral Bridge. This lower estuarine area also supports sea grasses that become very dense in the San Carlos Bay area. Therefore, estuarine benthic invertebrates and sea grasses were probably seriously impacted downstream of the Cape Coral Bridge since freshwater conditions prevailed for more than two weeks between the Cape Coral Bridge and Marker H. Marine benthic invertebrates and sea grasses between Marker H and the Sanibel Causeway recorder were probably also adversely influenced by the freshwater discharge associated with the storm since conductivity in this area dropped below 32,000 mhos/cm for almost a week.

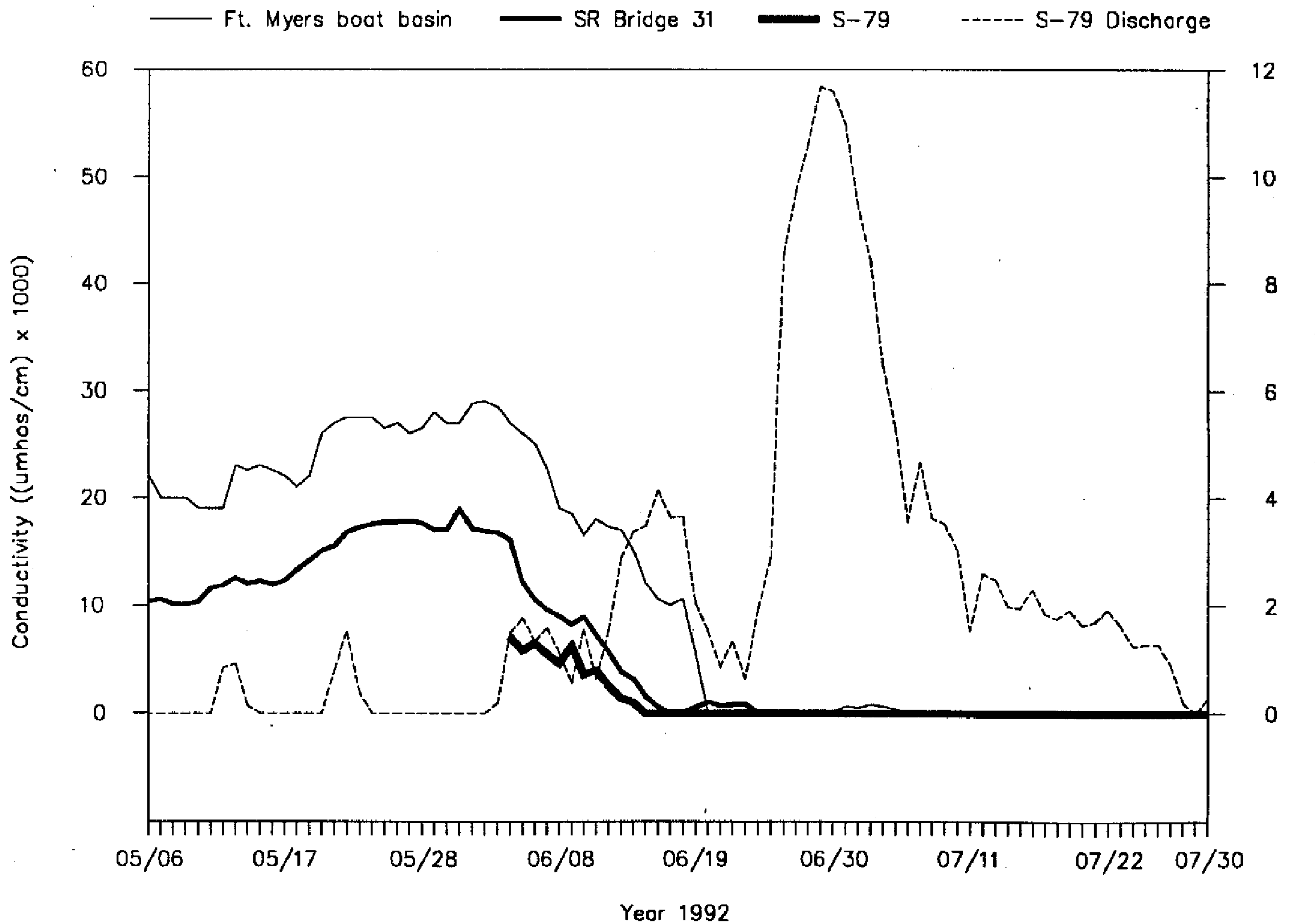


Figure 50. Conductivity at 3 Stations and Freshwater Inflow through S-79, Caloosahatchee Estuary

Field Observations, Lower West Coast

Personnel from the Field Engineering Division inspected various areas of flooding in Charlotte, Glades, Hendry, and Lee counties. Numerous inspections were performed on the ground and by helicopter from June 26 through July 6 when most of the water had receded. Descriptions of the observed flooded areas, by county, and respective comments follow (Figures 51-56).

Charlotte County

1) South of C.M. Webb. Ever Road and Cook-Brown Road were flooded, with 6 to 12 inches of water in several places. State Road 31 was flooded by sheet flow.

2) Bermed Area. Roads were flooded in residential areas.

3) Babcock #08-00004-S and Payson Groves Citrus #08-00078-S. The southern two-thirds of Babcock's property was submerged and a couple of berms around retention areas broke. Perimeter berms around farms broke, allowing water to flow through the Babcock's fields. Perimeter berms were repaired by the permittee immediately after the water receded.

4) Charlotte County Correctional Institute #08-00034-S. This site had water backing up into their surface water management system. The permitted minimum road elevation is 24.9' NGVD and the minimum floor elevation was permitted at 26.4' NGVD.

Glades and Hendry Counties

Several areas of flooding were observed in these counties. In general, large portions of Hendry County had standing water on farm fields and wooded areas, which caused farming activities to cease for several days. Several permitted orange groves had 8-12 inches of water in the groves, and several emergency overflow

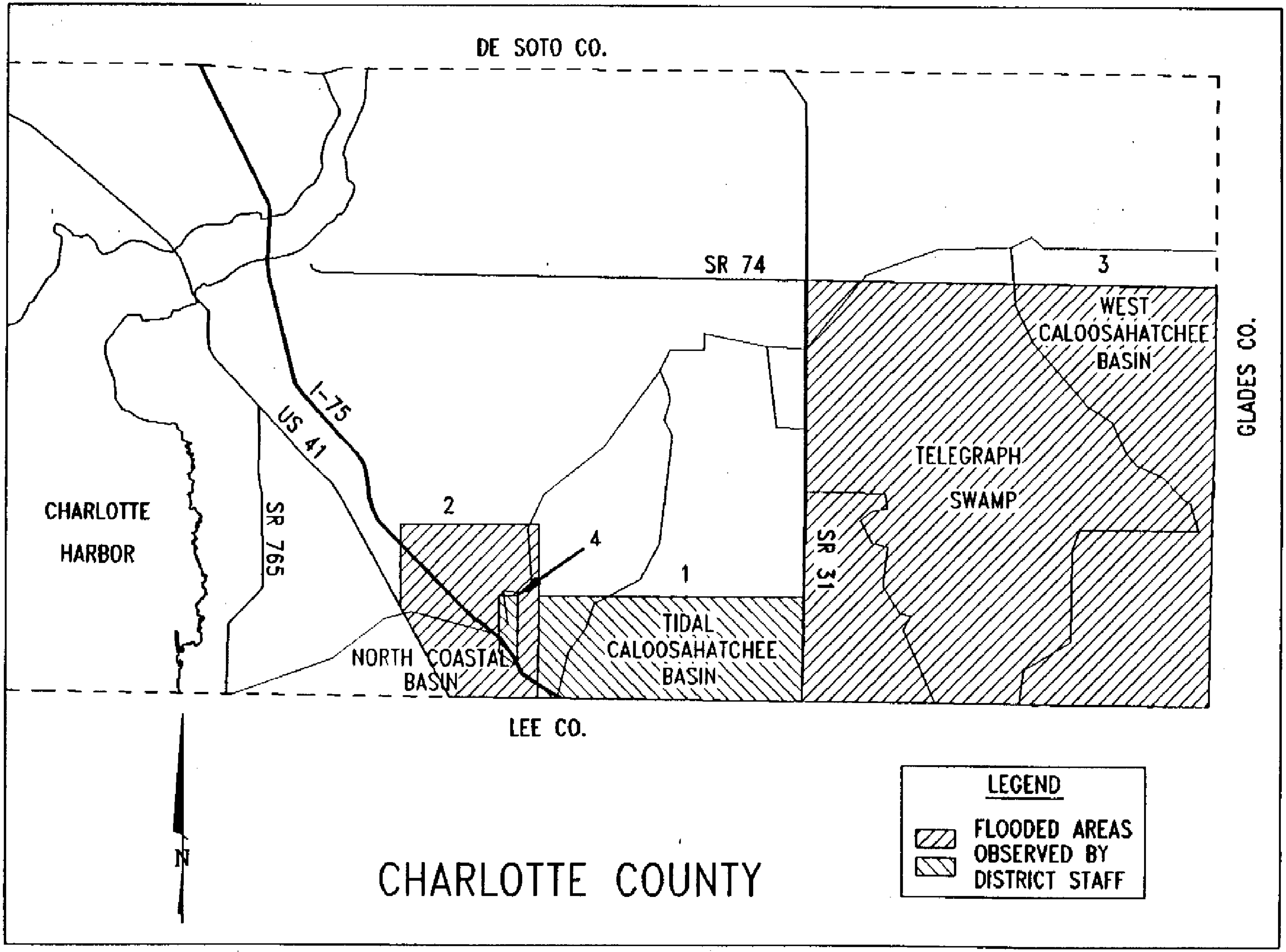


Figure 51. Flooded Areas, Charlotte County

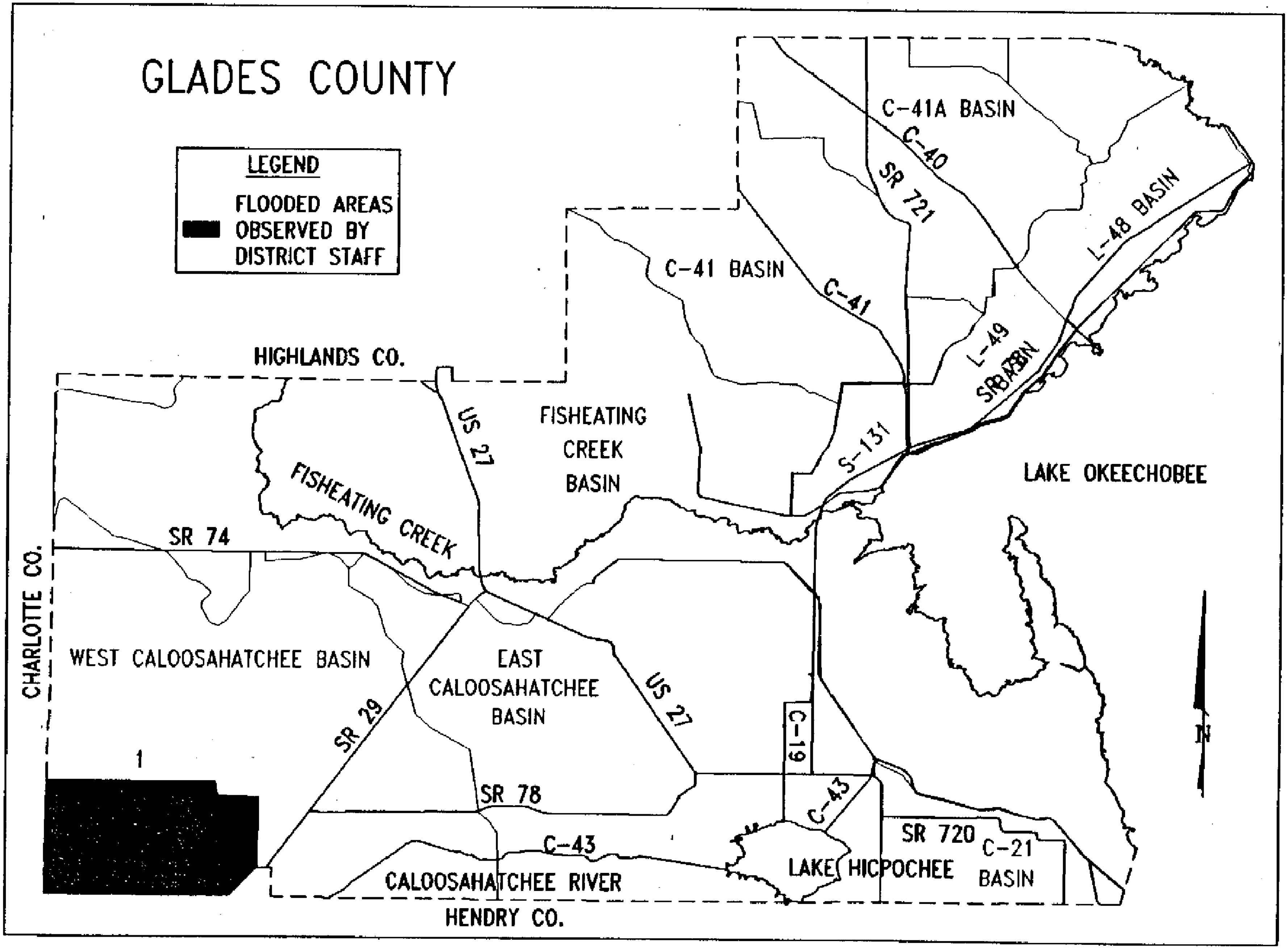


Figure 52. Flooded Areas, Glades County

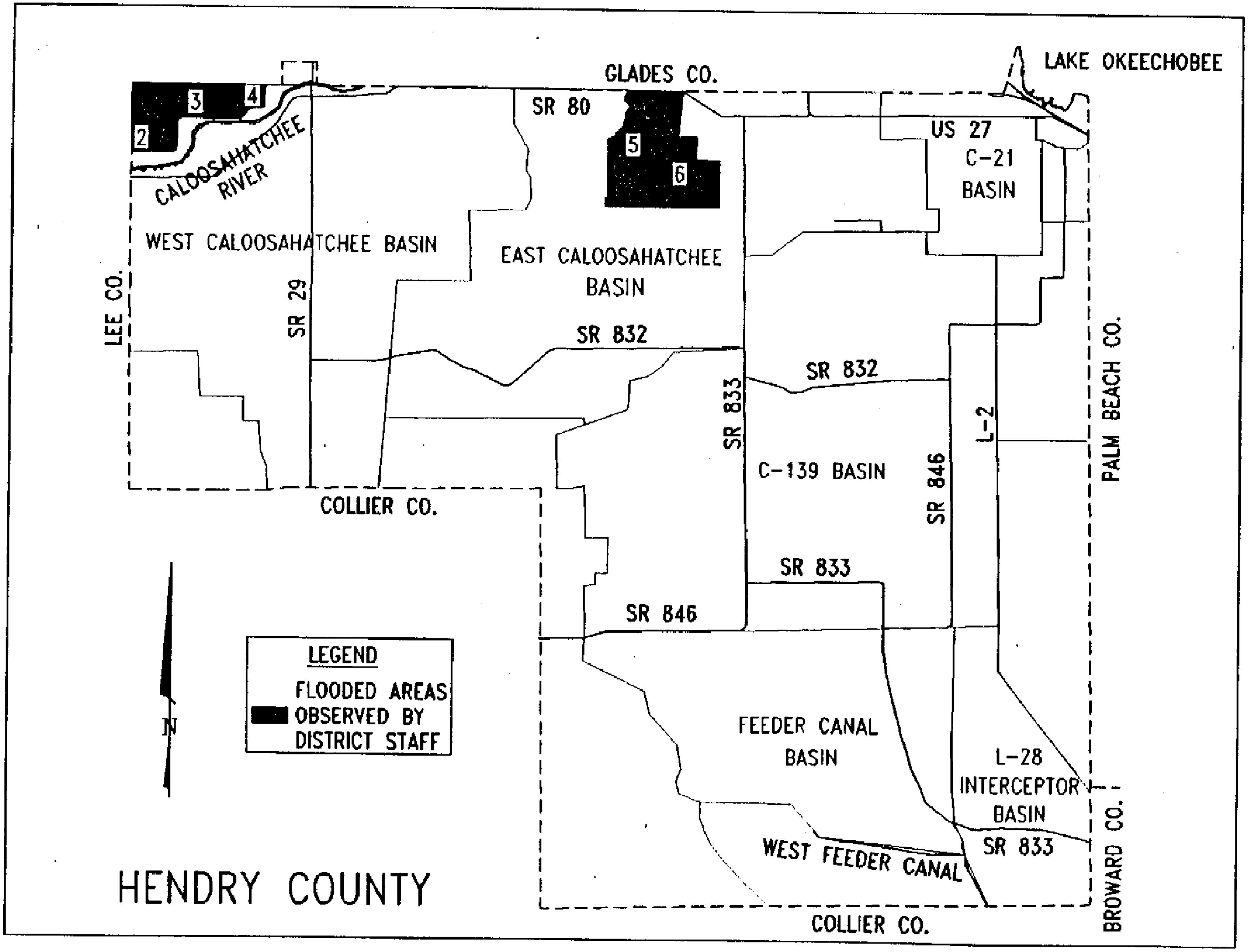


Figure 53. Flooded Areas, Hendry County

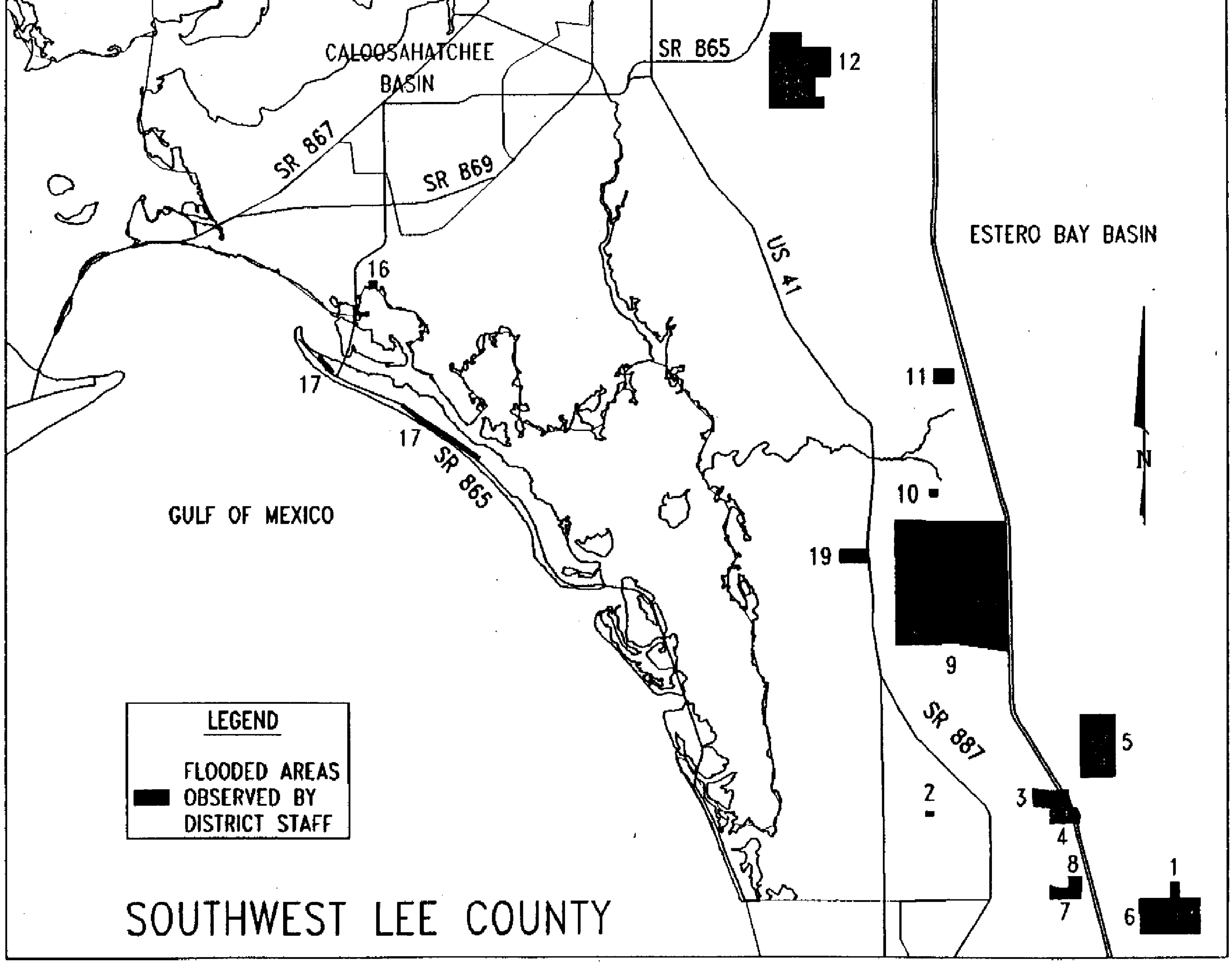


Figure 54. Flooded Areas, Southwest Lee County

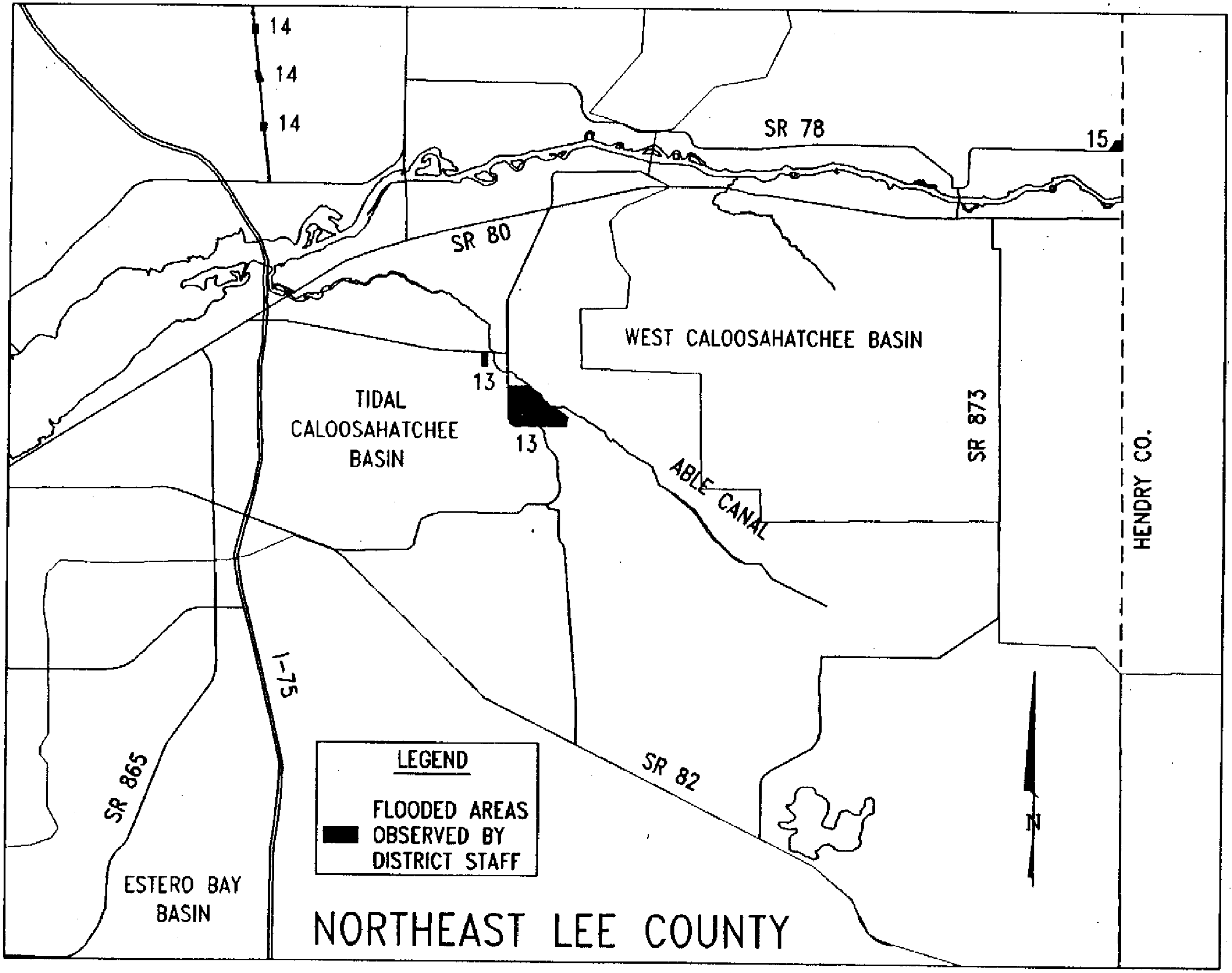


Figure 55. Flooded Areas, Northeast Lee County

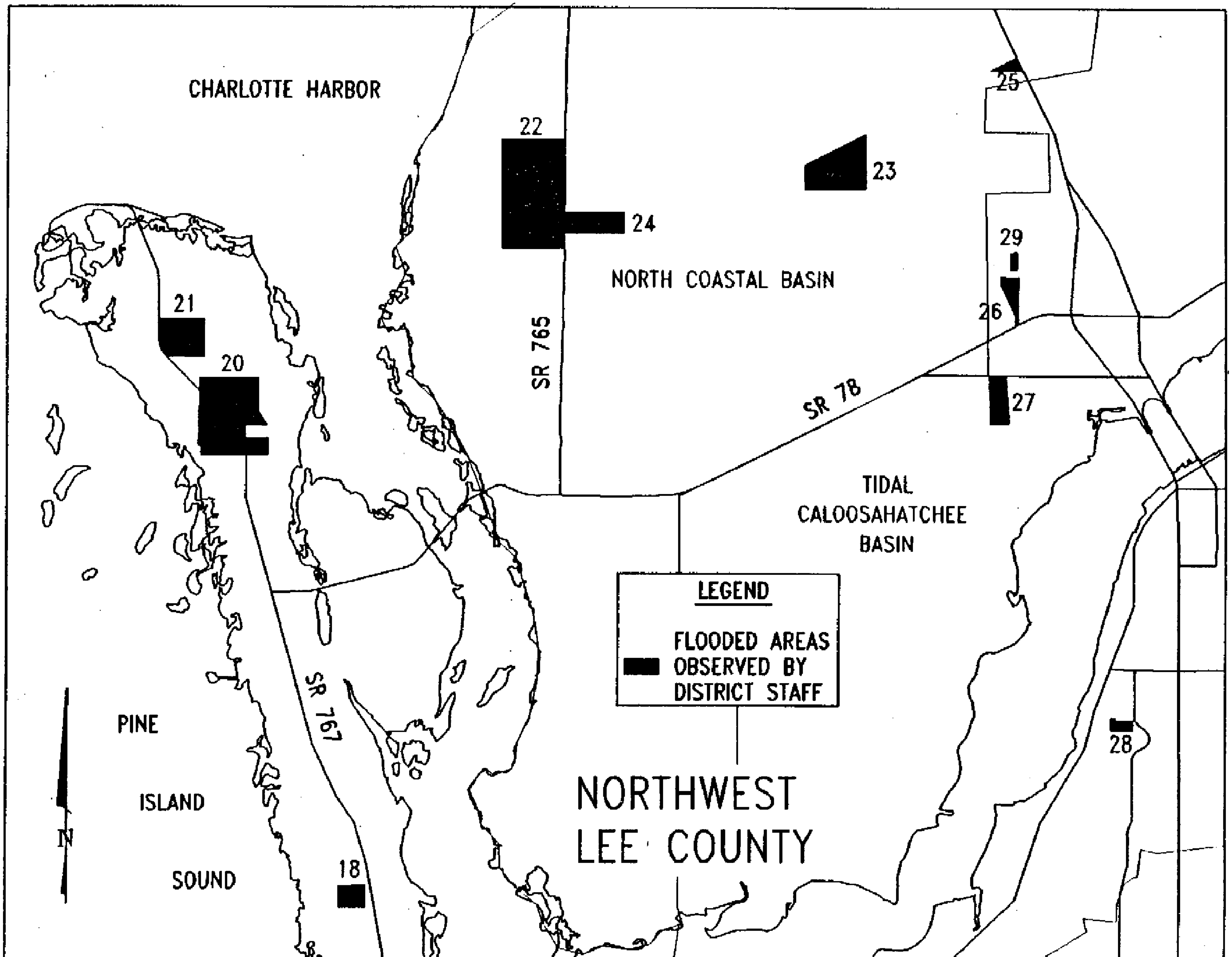


Figure 56. Flooded Areas, Northwest Lee County

structures in above-ground impoundments were seen operating. Specific areas of observed flooding were:

Glades County

1) Muse Area. A sparsely populated agricultural area. Jack's Branch and Bee Branch overflowed their banks causing flooding of fields, roads and yards.

Hendry County

2) Scott and Wendy Roads. Roads were flooded and two houses were flooded with 8-12" of water on the floors.

3) Ft. Denaud Acres. Road and yards were flooded due to Ft. Denaud Slough overflowing its banks.

4) Bee Branch Lakes. Excessive water in Bee Branch caused it to overflow its banks, causing flooding of Lake Butler Grove #26-00143-S. The permitted design storm (25-year, 3-day) elevations for each basin are 24.94', 23.37', 26.60', 23.91', and 24.73' NGVD. Also, State Road 78 was flooded with 6" of water causing one lane to be closed. Secondary roads and yards were flooded and one house was flooded with 8-10" of water on the floor.

5) Pioneer Plantation. A sparsely populated, low-lying area that historically floods. Roads were flooded with 12-18" of water.

6) Ladeca Acres. A sparsely populated, naturally low-lying area that historically floods. Roads were flooded with about 12" of water.

The following permitted orange groves were also flooded:

Ferguson Grove #22-00101-S. The permitted design storm (25-year, 3-day) elevation is 29.5' NGVD.

David Lee Grove #22-00144-S. The permitted design storm (25-year, 3-day) elevation is 31.2' NGVD.

Bob Paul Grove #26-00235-S. The permitted design storm (25-year, 3-day) elevation is 22.4' NGVD.

Hansen Grove #26-00369-S. The permitted design storm (25-year, 3-day) elevation is 18.9' NGVD.

Many other orange groves in Hendry County were also flooded.

Lee County

Imperial River Basin

The Imperial River Watershed (IRW) is located in the southern area of Lee County and is the largest watershed within Lee County, comprising approximately 86 square miles. Bonita Springs is located in this basin.

Between June 23-29, the Imperial River Basin, north of Corkscrew Road and south of Bonita Springs, received 15.24 inches of rain with 7.78 inches on June 29. The entire Imperial River Basin experienced flooding. Several permitted projects had street flooding and home flooding. About 600 residents were evacuated from their homes. Portions of Bonita Springs received the worst flooding on July 1 and 2, several days after the severest rain had ceased. This was caused by the gradual drainage of surrounding areas reaching low areas. By July 6, most of the water had receded. Areas of flooding observed by District staff are described below.

The IRW is relatively flat and discharges into Estero Bay via the Imperial River, an Outstanding Florida Waterway. The Kehl Canal, a long canal drainage system constructed in the 1960s, begins at the upper end of the natural river and extends easterly, almost to the Lee County line. This canal intercepts the sheet flow from the upper portions of the watershed and lies approximately one section north of the southern watershed boundary. The natural river is tidal for much of its length and most of its estuarine wetlands are intact. The only water control structure along this conveyance is a sheet pile weir completed in June of this year.

System Design and Flood Operations

As previously described, this watershed is large without any primary or secondary drainage system. The storm-water sheet flows to the Kehl Canal, then within this canal to the Imperial River.

There are no schedules or operations for this watershed. The banks of the Kehl are approximately 14 feet NGVD. As the sheet flow moved southwest,the flood waters reached an approximate height of 15 feet NGVD. This occurred on July 1, 1992. During this same period of time, the Imperial River was affected by a spring flood tide, which may have decreased the river's ability to discharge into Estero Bay. On July 2, 1992, the flood waters remained at 15.0 NGVD. On July 8, 1992, the flood waters had lowered to 13.7 NGVD. The flood waters peaked on or about the 4th or 5th of July.

Beginning June 30, 1992, the Lee County Emergency Operations Center (EOC) was activated and began voluntary evacuations of the area west of I-75 to Imperial Street (approximately one mile west of the Interstate), one-half mile on either side of the Imperial River. Many of these homes sustained water damage inside their homes. Sewer systems and septic tanks backed up in many areas, prompting evacuation for health reasons. The Lee County Health Department reported high quantities of fecal coliform within the flood waters surrounding these homes.

East of I-75, the flooding was worse as private roads and other improvements exacerbated the flooding. Field Engineering has documented this flooding by photography and video.

Several hundred migrant workers were evacuated from this area for a period of approximately ten days because of excessive flood waters and high quantities of fecal coliform tested in the surrounding flood waters.

On July 1, 1992, the EOC contacted the Fort Myers Area Office and requested a 24" pump to aid flood victims. Field Engineering had visited the area to investigate claims of illegal pumping of flood waters by landowners. None was observed. On July 2, 1992, the EOC contacted the District and the U.S. Army Corps of Engineers for assistance in evaluating possible solutions to relieve flooding in the Bonita Springs area. The Corps indicated they did not have the appropriate equipment to provide any relief. SFWMD Operations and Maintenance managers were dispatched from Clewiston Field Station, at Government Assistance request, for an evaluation of flood conditions. There was no physical or appropriate economical means to lower the flood waters of an 86-square-mile watershed without creating additional flooding within adjacent watersheds.

The most apparent complications that created these flood conditions include the lack of conveyance--86 square miles of watershed sheet flowing into a private man-made canal, then out a "pristine" meandering OFW river--all with little or no maintenance. Additionally, some upstream bridges east of I-75 are considered to be inadequate to convey a 25-year, 3-day storm event flow (Johnson Engineering Inc. draft report: Imperial Watershed Report). Johnson Engineering is currently working on a Surface Water Management Master Plan for the Imperial River Watershed, and has indicated the current system for existing levels of service is less than a 5-year, 1-day event.

Along with these major problems, residents of this area have installed many "odd" sized culverts without any consideration of planning and eventual outfall. Driveways crossing roadside ditches may have 36-inch culverts discharging into 24-inch culverts or they may not have any culverts at all. The main road for these residents, East Bonita Beach Road, is actually an access road for the farming community to maintain their fields.

Southwest Lee County

1) Manna Christian RV Park # 36-00781-S. Manna Christian RV Park is a mobile home park located north of East Bonita Beach Road and east of Bonita Grande Drive in Bonita Springs, Lee County. The site is a 19.5-acre residential project.

The site was originally an existing RV park converted into a residential community. Portions of roads (existing before the permit was issued) were constructed below the minimum permitted road elevation of 15.5' NGVD and were therefore prone to flooding. Newer roads are protected from the 5-year, 1-day storm. A church (existing before permit issuance) has a floor elevation below the permitted minimum required elevation of 16.3' NGVD. Newly constructed floors are to be protected from the 100-year, 3-day storm at elevation 16.3' NGVD.

The project is designed to discharge storm water into an existing ditch on the north side of Bonita Beach Road. The ditch flows west into another ditch on the east side of Bonita Grande Drive, turns north and flows into the Kehl Canal, which is an extension of the Imperial River. The site is surrounded by a berm at elevation 16.0', which is the 25-year, 3-day storm elevation.

This was the most heavily flooded area in Lee County with 24 inches of water on the roads. Two feet of water on the roads would make the water level at approximately elevation 17.5' NGVD, which is over one foot above the calculated 100-year, 3-day elevation of 16.3'. Hundreds of residents in this area had to be evacuated. The serious flooding was caused when the Imperial River overflowed its banks, flooding the entire region. There was a lag time of several days after the heaviest rainfall before the worst flooding impacted this area, when water from the upper reaches of the Imperial River Basin reached this low area. The permitted elevations do not protect this area from the flooding effects when the Imperial River is out of its banks.

Other permitted projects with only street flooding were:

2) Imperial Harbor # 36-00353-S. The permitted minimum road elevation is 9' NGVD and the minimum floor elevation was permitted at 11' NGVD.

3) Southern Pines # 36-00236-S. The permitted minimum road elevation is 12.5' NGVD and the minimum floor elevation was permitted at 14.5' NGVD.

4) Forest Mere # 36-00418-S. The permitted minimum road elevation is 14.5' NGVD and the minimum floor elevation was permitted at 16' NGVD.

5) Citrus Park # 36-00093-S. The permitted minimum road elevation is 15' NGVD and the minimum floor elevation was permitted at 15.5' NGVD.

6) Worthington Country Club # 36-01472-S. The permitted minimum road elevation is 14' NGVD and the minimum floor elevation was permitted at 15' NGVD.

7) South of Imperial River, north of Bonita Beach Road, west of I-75 to Imperial Street. Houses were flooded with 18" of water on the floors. This area experienced its worst flooding on July 1 when evacuation of residents began.

8) Imperial River Estates. Flooding of streets.

9) Sweetwater Ranch # 36-00288-S. The entire agricultural site was under water as observed from helicopter on June 29.

10) Springs Garden # 36-00908-S. This 10-acre residential site experienced road flooding. River Ranch Road was inundated with about 10" of water in the southwest corner. The permitted minimum road elevation is 15.3' NGVD and the minimum floor elevation was permitted at 16' NGVD.

11) Country Oaks # 36-00995-S. Street flooding occurred into garages in lower areas. The permitted minimum road elevation is 17.2' NGVD and the minimum floor elevation was permitted at 18.5' NGVD.

12) Eagle Ridge # 36-00318-S. Only the golf course was flooded with about 12" of water. The permitted minimum road elevations for the four basins are 17.4', 17.3', 16.7' and 16.0', and the minimum floor elevations for the four basins are permitted at 18.0' and 20.0' NGVD.

Other permitted projects in the Eagle Ridge area that experienced road flooding were:

The Woods #36-00064-S. Permitted roads at minimum elevation 13.0' and permitted floors at minimum elevation 15.0'

Briar Ridge #36-00147-S. Permitted roads at minimum elevation 15.5' and permitted floors at minimum elevation 17.0'

Black Hawk #36-00922. Permitted roads at minimum elevation 15.9' and permitted floors at minimum elevation 18.0'

16) There were two houses flooded in this area. These are older homes built lower than surrounding areas.

17) San Carlos Boulevard, Ft. Myers Beach. The road was flooded in several areas, but drained fairly quickly.

19) Fountain Lakes 36-00575-S. Two houses had water on the floors and streets were flooded for 4-6 hours. The permitted minimum road elevation is 14.0' NGVD and the minimum floor elevation was permitted at 15.5' NGVD.

Northeast Lee County

13) Orange River Basin. The Orange River was over its banks, flooding River Road and Nine Mile Run with 18" of water in some locations. Several residences also had water on the floors. Some streets had water on them several days after the rain stopped.

14) Nalle Grade Road Area. Nalle Road was under water in three locations between State Road 78 and Nalle Grade Road, and Quail Run Lane was also under water. No residences in this area had water on the floors.

15) Lee-Hendry Line at State Road 78. Between U.S. 31 and the county line, all creeks were over their banks, causing flooding in unincorporated areas north of the Caloosahatchee River. The most severe flooding was at county line ditch and at least one house had water on the floors.

Northwest Lee County

18) Palm Tree Farm. This area was completely inundated.

20) Harbor Drive. There was major road flooding. Several access roads were flooded, all downstream conveyances were over their banks, and water was within 1" of flooding one house.

21) One house was flooded, along with several yards and roads; wells and septic systems were also submerged.

22) Yucca Pen. Sheet flow caused road flooding and two houses had 4-6" of water on the floors. Wells and septic systems were submerged.

23) The Woods and Los Lomas #36-02229-S. The Woods was completely flooded; many barns and pastures were flooded, causing the evacuation of livestock from the area. Roads were submerged by sheet flow. The permitted minimum road elevation is 16.2' NGVD and the minimum floor elevation was permitted at 17' NGVD.

24) NW Cape Coral. An uninhabited area that experienced road flooding of 1-1/2'.

25) Pembroke Pines Trailer Park. Roads were flooded.

26) Corbett Road and Hancock Creek #36-00873-S. Yards, porches and pools were flooded; historical drainage was blocked by Hancock Creek development. Hancock Creek has since improved their interim water management system to allow for better drainage of Corbett Road. The permitted minimum road elevation in the lowest basin is 9.6' NGVD, and the minimum floor elevation in the lowest basin was permitted at 11.2' NGVD.

27) Willow Creek #36-00818-S. Yards and some roads were flooded. The permitted minimum road elevation is 11.5' NGVD and the minimum floor elevation was permitted at 12.4' NGVD.

28) Carillon Woods #36-00704-S. Yards were submerged. The permitted minimum road elevation is 11.45' NGVD and the minimum floor elevation was permitted at 12.3' NGVD.

29) Littleton School Area #36-02145-S. Yards and roads were flooded, and there was water in garages.

Additional flooded areas were identified by John Wilson of the Lee County Emergency Management:

-- Tropic Isles Subdivision

-- Civic Center area had road flooding

-- Old Bayshore had road flooding

-- Cape Coral had flooding of Santa Barbara and Chiquita roads

-- Roads flooded south of State Road 78

-- Six Mile Area had flooding of roads with some being inaccessible

-- San Souci Trailer Park

-- Upriver Campground had flooding from a creek that overflowed its banks

The extent of rainfall experienced in portions of Lee County far exceeded the amount the roads were designed to be protected from. Therefore, road flooding would be expected.

Comparison with Previous Storms, Lee and Glades Counties

Lee County

Toward the end of July 1991, flooding occurred in the area east of I-75. This area was impacted for a period of approximately three weeks. The impacts included septic tank flooding and local road flooding. Previous to this, the area experienced drought conditions and was not as populated. Many of the current residents have moved into the more eastern portion of the watershed during the past five years.

Glades County

Local residents do not remember conditions equal to this storm event in recent history. Other floods include one on September 20, 1962, when 7.78 inches fell within a 24 hour period; one on September 18, 1985, when 8 inches of rain fell within a 24-hour period; one on May 18, 1989, when 7.75 inches fell within a 24-hour period.

These events were all 24-hour events with some typical afternoon rain events before and after the 24-hour period. This storm differed in the amount and duration of rainfall over the 6-day period.

Several single-family homes were flooded with 12 to 18 inches of water inside the housing structure. Several of these homeowners voluntarily evacuated, however, the Emergency Operations Center was not activated and no formal evacuation was announced. Additionally, several citrus groves and vegetable farms were inundated with flood waters for several days.

PUBLIC INTERACTION

Staff from the Office of Government and Public Affairs responded to many media calls and coordinated relief efforts with local Emergency Operations Centers, county and city governments, the Governor's Office, and government agencies such as the United States Army Corps of Engineers (COE) and the Federal Emergency Management Agency (FEMA).

Many areas of the District were affected during the late June storm, but impacts varied among those areas. The Bonita Springs area in Lee County saw hundreds of local citizens evacuated because of health hazards related to flooded septic tank drainfields. Other areas were impacted because of storm runoff resulting in massive fish kills and water quality problems. Assistance provided by the Office of Government and Public Affairs includes evaluation and recommendations for temporary flood relief, interagency coordination and cooperation to minimize damage from future flood events, and issuing news releases to explain the District's operational plans with emphasis on the consequences of heavy freshwater discharges into estuarine environments.

Staff continue to handle requests from local governments to the District to provide technical and possible financial assistance for planning and implementing recommended improvements in many coastal and interior counties.

APPENDIX A

JUNE 1992 RAINFALL STATISTICS FOR STATIONS AROUND THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Station	Monthly Total	Last Week's Total	Max. Day	Max. 3 Day	Max. 5 Day
1-8_C	13.85	8.37	2.13	6.81	4.75
3A-36_R	20.04	6.35	1.32	4.70	2.90
3A-S_R	20.58	6.71	2.51	6.68	4.52
ALICO_R	15.39	7.20	1.54	5.40	3.09
ALVA FAR_R	17.17	11.89	3.15	10.29	6.54
BASSING_R	12.62	7.17	2.39	6.20	4.19
BEELINE_R	7.59	1.13	0.51	0.99	0.71
BELLE GL_R	15.24	7.41	3.25	6.68	4.98
BLUEGOOS_R	18.65	9.07	2.64	8.71	5.82
BONITA SPRINGS	23.10	15.24	7.85	12.72	8.86
BROOKS P_R	14.05	5.29	2.45	3.36	2.73
CCWWTP_R	16.85	11.37	4.78	9.08	5.70
CHAPMAN_R	13.45	4.89	1.26	3.62	2.72
CLEW.FS_R	10.85	7.12	3.45	6.53	4.03
COLLIER_R	12.86	8.12	2.08	5.78	4.86
COPELAND_R	16.36	8.65	2.80	7.90	6.40
CORK.HQ_R	23.53	13.83	6.15	10.50	7.65
COW CREE_R	15.92	8.30	2.93	7.90	5.58
CREEK_R	10.35	4.03	1.65	3.33	2.14
DEVILS_R	13.30	9.80	2.70	7.80	4.50
DICK ROG_R	17.38	11.33	2.48	7.03	5.57
DIXIE WA_R	23.22	11.74	3.80	7.83	5.05
EAA2	15.32	10.26	5.02	9.34	7.93
EAA3	16.89	8.53	1.85	7.72	4.28
EAA4	17.34	13.48	4.65	12.53	8.20
EAA5	15.83	9.70	2.87	8.58	6.42
EAST BEA_R	13.31	6.71	2.00	6.07	3.76
EAST SH_R	11.50	6.29	2.19	5.79	3.51

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JUNE 1992 RAINFALL STATISTICS FOR STATIONS AROUND THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Station	Monthly Total	Last Week's Total	Max. Day	Max. 3 Day	Max. 5 Day
EPR	24.29	12.63	4.67	10.94	7.73
FT. LAUD_R	15.28	8.82	2.15	5.57	3.42
FT. PIER_R	14.09	9.61	2.80	6.77	4.28
FTP FSA_R	14.21	6.98	2.11	6.98	4.98
G54_R	21.41	14.63	6.85	9.50	9.50
GAC_R	23.82	8.77	2.12	6.67	4.55
GILL REA_R	22.21	12.26	4.42	7.70	5.42
HAYES_R	14.35	7.36	2.88	6.68	4.16
HOMES. FR_R	31.21	20.74	7.19	13.24	9.76
IMMOKA 2_R	18.70	7.80	3.80	7.10	6.10
IMOKALE_R	15.00	9.49	3.60	6.68	5.19
INDIAN L_R	9.23	3.07	0.83	2.61	1.71
INDIANPM	12.85	7.80	1.90	6.51	4.58
KENANS 1_R	14.48	5.47	3.67	4.65	3.86
KERI TOW_R	19.20	10.60	5.00	9.20	7.10
KIRCHOFF_R	12.00	5.50	1.98	4.63	3.66
KISS.FS2_R	6.72	2.05	0.51	1.39	1.09
KISS.FS_R	9.58	2.77	1.27	2.15	1.74
L MARIO2_R	9.12	3.85	0.92	2.89	1.91
L OKEE.M_R	14.64	4.76	2.45	4.76	4.56
LABELLE_R	16.89	10.93	4.70	9.72	7.29
LOTELLA_R	14.02	6.25	1.65	5.45	4.14
LWD.E1.3_R	13.02	8.46	2.00	5.89	4.00
LWD.E2.2_R	15.02	9.97	3.00	7.26	4.90
LWD.E2_R	14.03	9.11	3.04	6.46	4.36
LWD.GA_R	16.50	11.70	3.49	7.27	5.58
LWD.HQ_R	20.40	11.41	3.27	8.16	6.40
LWD.L32_R	16.01	9.76	3.24	7.77	5.29

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JUNE 1992 RAINFALL STATISTICS FOR STATIONS AROUND THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Station	Monthly Total	Last Week's Total	Max. Day	Max. 3 Day	Max. 5 Day
LWD.L39R_R	13.47	8.11	2.39	6.11	4.28
LWD.MIL_R	16.51	9.40	2.74	6.74	5.12
LWD.POWE_R	16.50	9.72	3.37	7.30	5.58
LWD.RANG_R	12.66	9.17	3.34	7.22	4.75
MARCO FI_R	15.45	11.02	3.15	10.35	7.85
MCARTH_R	15.14	7.24	2.22	6.23	4.91
MIAMI LO_R	11.89	6.25	2.22	5.33	3.77
MIAMI.FS_R	14.27	9.31	3.29	6.69	5.19
MICCO_R	13.87	6.19	1.59	4.88	3.19
MILES CI_R	16.70	8.30	3.50	7.20	4.80
NAPLES C_R	9.18	6.77	2.64	5.77	5.21
NAPLES T_R	6.40	3.80	2.25	3.70	3.10
NORTH UN_R	14.80	9.04	3.05	8.49	5.72
OKEE F 2_R	21.08	12.38	3.49	8.70	6.50
OKEE FIE_R	21.67	11.94	5.57	8.97	8.97
PAHOKEE1_R	11.71	7.31	2.62	6.20	4.14
PAHOKEE2_R	12.69	6.95	2.59	6.55	4.50
PAIGE_R	11.57	7.70	2.35	6.68	4.21
PEL LAK1_R	12.04	7.21	2.35	6.51	4.04
PEL LAK2_R	11.75	8.10	2.80	7.65	4.36
PETE RHO_R	14.22	10.10	3.82	8.31	5.56
PLANT IN_R	18.37	12.62	4.95	8.95	6.85
POINCI_R	8.17	2.29	0.61	1.76	1.52
POMPANOF_R	15.78	10.75	2.85	8.24	6.82
PRATT AN_R	21.89	15.33	4.60	13.48	8.40
RITTA (B_R	11.61	6.91	2.57	6.22	4.58
ROCK K76_R	14.54	4.03	1.65	3.79	2.77
S127_R	13.00	9.54	4.70	8.71	6.64

APPENDIX A

JUNE 1992 RAINFALL STATISTICS FOR STATIONS AROUND THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Station	Monthly Total	Last Week's Total	Max. Day	Max. 3 Day	Max. 5 Day
S129_R	12.82	8.37	2.14	5.60	4.06
S12D_R	22.10	6.65	1.87	4.90	3.48
S131_R	10.91	7.04	2.49	6.45	4.70
S133_R	17.39	10.64	4.31	8.58	6.41
S135_R	15.62	9.88	4.08	8.05	5.23
S13_R	18.41	8.06	1.83	6.81	5.00
S140 SPW_R	26.38	8.47	3.14	6.95	4.71
S18C_R	24.17	12.64	4.01	10.76	8.14
S20_R	19.72	12.13	3.18	10.36	6.53
S2_R	10.56	5.02	2.42	4.53	2.91
S331_R	25.99	12.88	3.70	9.53	7.20
S332_R	25.26	14.13	2.98	12.80	8.01
S336_R	18.81	9.31	2.50	7.01	5.04
S36_R	24.73	6.92	2.22	6.03	4.35
S3_R	13.94	9.06	3.82	5.01	3.33
S4_R	17.16	3.82	4.82	8.28	5.43
S61_R	9.78	3.09	1.15	2.67	1.91
S65A_R	17.48	6.72	1.98	5.64	3.96
S65B_R	15.18	5.72	1.44	4.64	3.14
S65C_R	13.75	5.80	2.25	5.25	4.23
S65D_R	14.23	6.69	2.24	5.28	4.21
S65E_R	16.17	7.51	2.00	5.09	3.24
S65_R	12.87	5.02	2.11	3.85	2.98
S6_R	11.21	5.43	1.38	4.96	3.08
S70_R	12.01	6.54	1.66	5.71	3.99
S8_R	19.72	9.00	3.11	7.30	5.89
S9_R	15.77	6.35	1.32	4.77	2.97
SBDD	13.16	7.37	3.06	5.39	3.78

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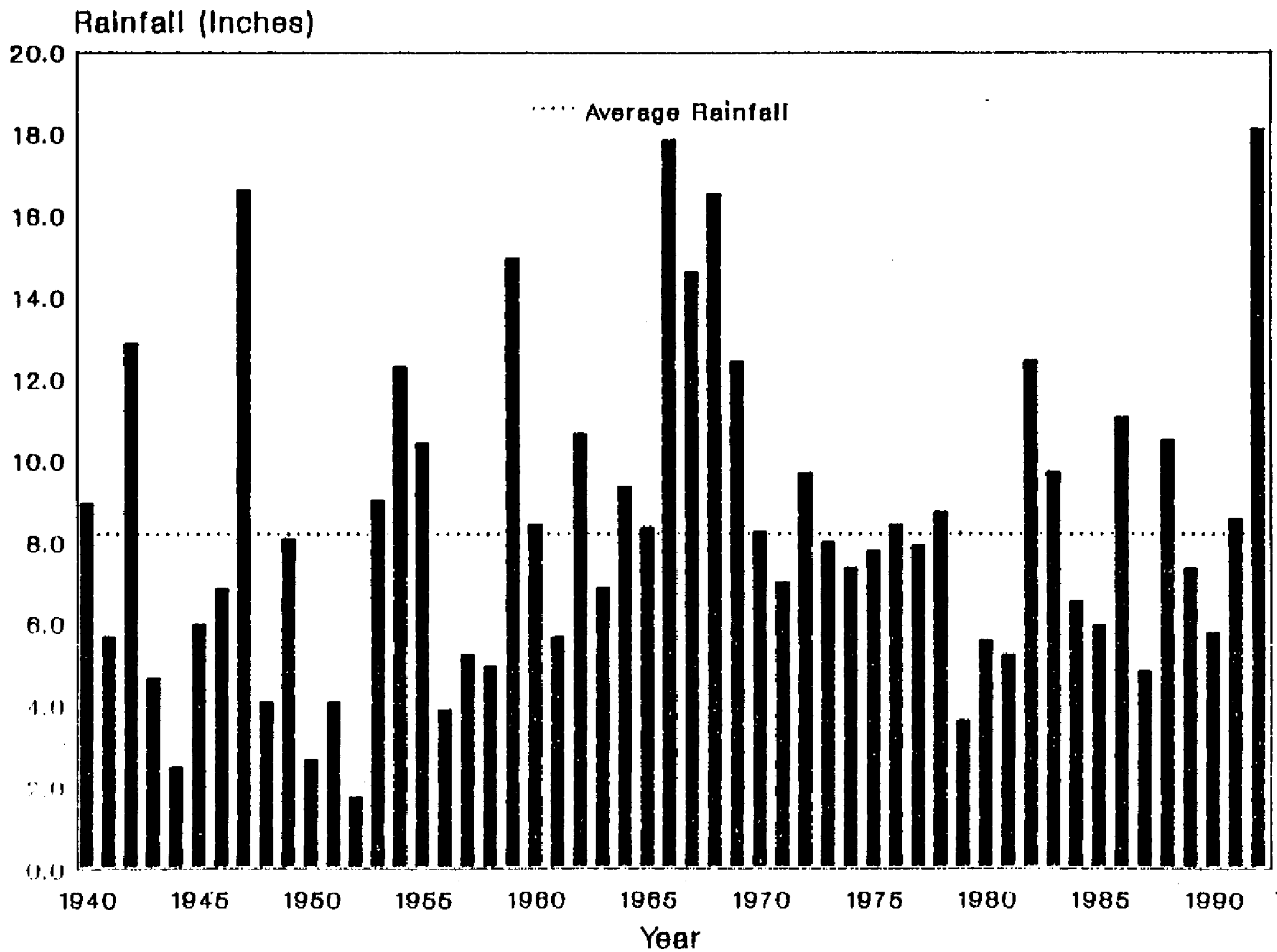
JUNE 1992 RAINFALL STATISTICS FOR STATIONS AROUND THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

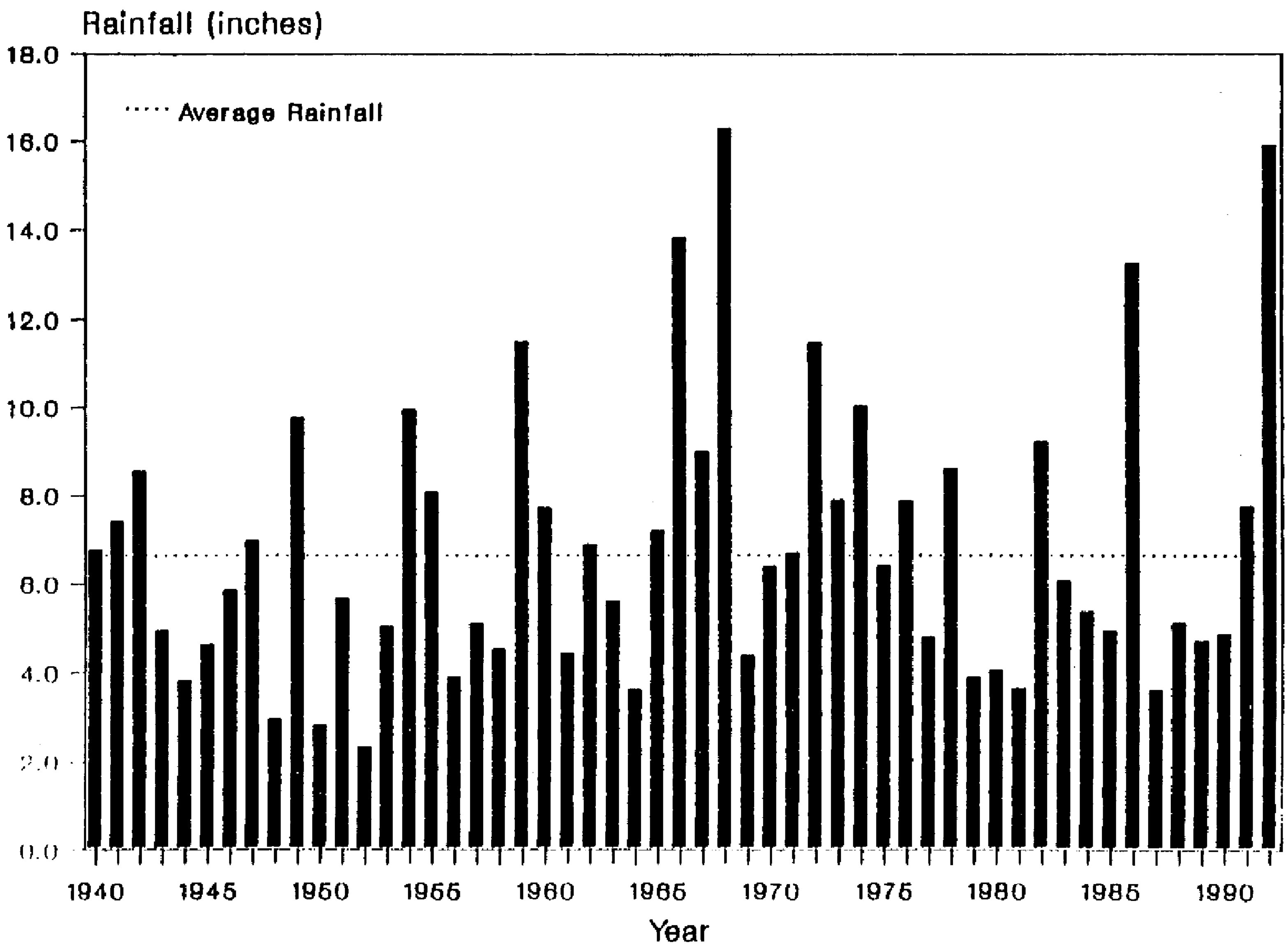
Station	Monthly Total	Last Week's Total	Max. Day	Max. 3 Day	Max. 5 Day
SEBRING_R	11.56	6.91	2.07	6.32	4.77
SFCD_R	10.33	7.01	2.96	6.33	4.72
SHING.RG	8.51	3.19	0.72	2.27	1.81
SILVER S_R	16.99	10.49	4.34	8.45	7.27
SIX L 3_R	13.74	8.42	1.99	7.35	4.51
SLEE_R	23.62	13.62	4.50	12.68	9.18
SNIVERLY_R	12.62	6.05	2.69	5.14	3.82
SOUTH BA_R	15.27	5.83	2.62	4.89	3.90
ST. CLAI_R	8.68	3.29	0.91	2.72	1.85
STAT	13.67	6.77	2.56	6.25	4.76
TAFT_R	8.12	2.11	0.69	1.86	1.49
TICK ISL_R	15.12	5.91	1.96	5.23	3.97
TOWNSITE_R	13.23	8.58	3.45	7.24	4.83

APPENDIX B

HISTORICAL JUNE RAINFALL
FOR THE PLANNING AREAS OF THE
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

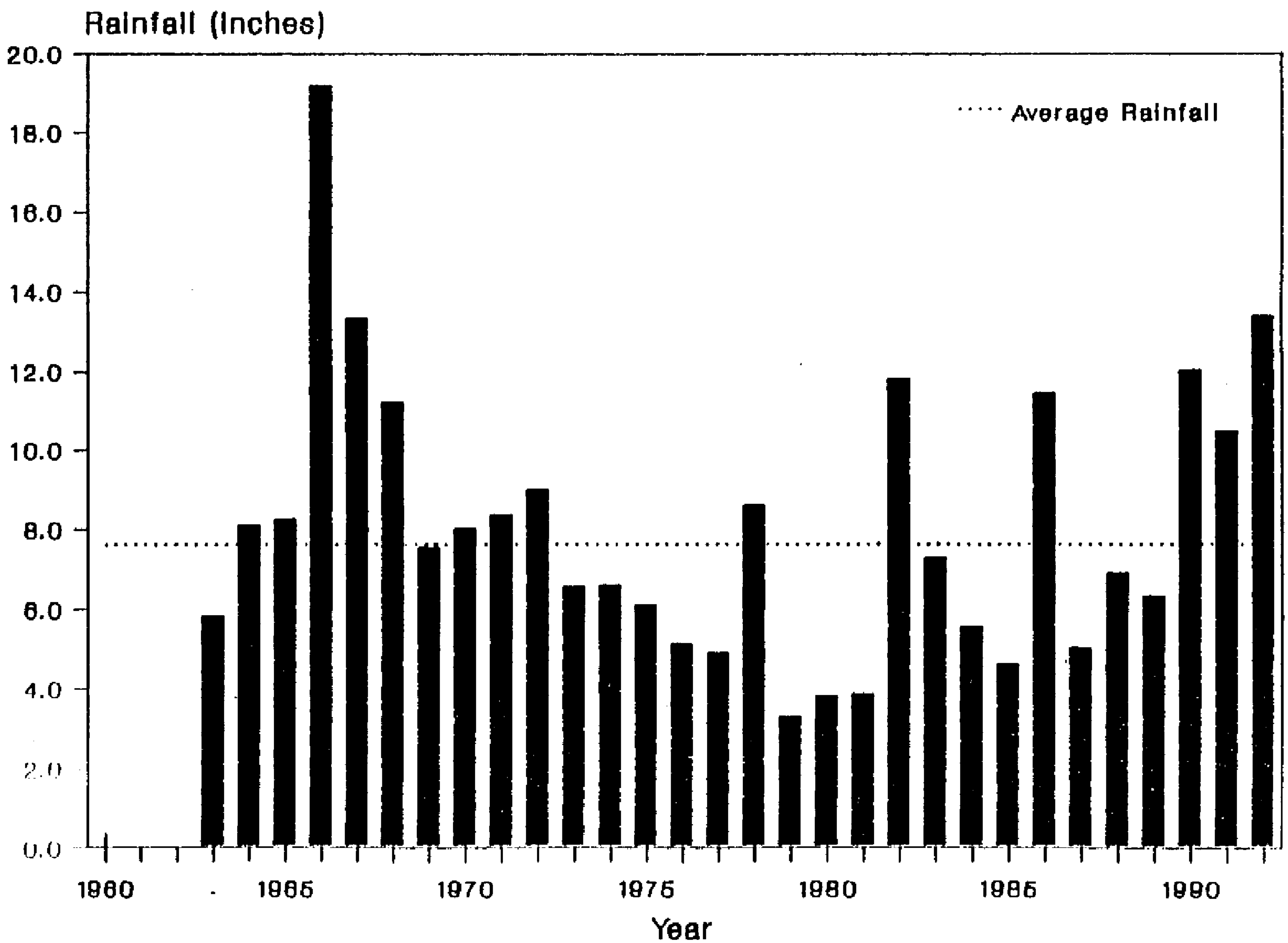


Lower East Coast Rainfall for the Month of June - Period from 1940-1992.



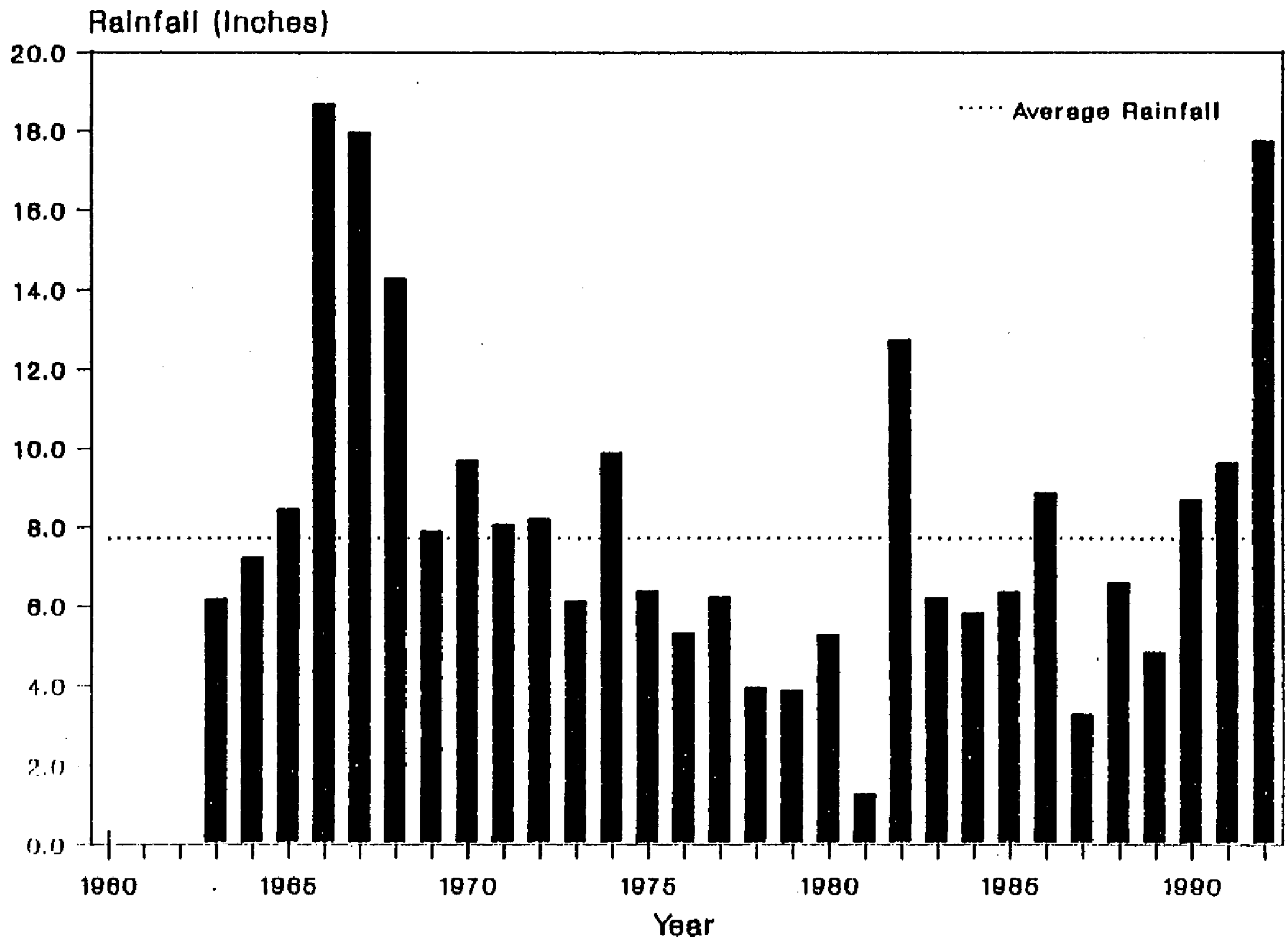
Upper East Coast Area Rainfall for the Month of June -
Period from 1940-1992.

RAIN-UEC.CHT / SMR / 6-8-92

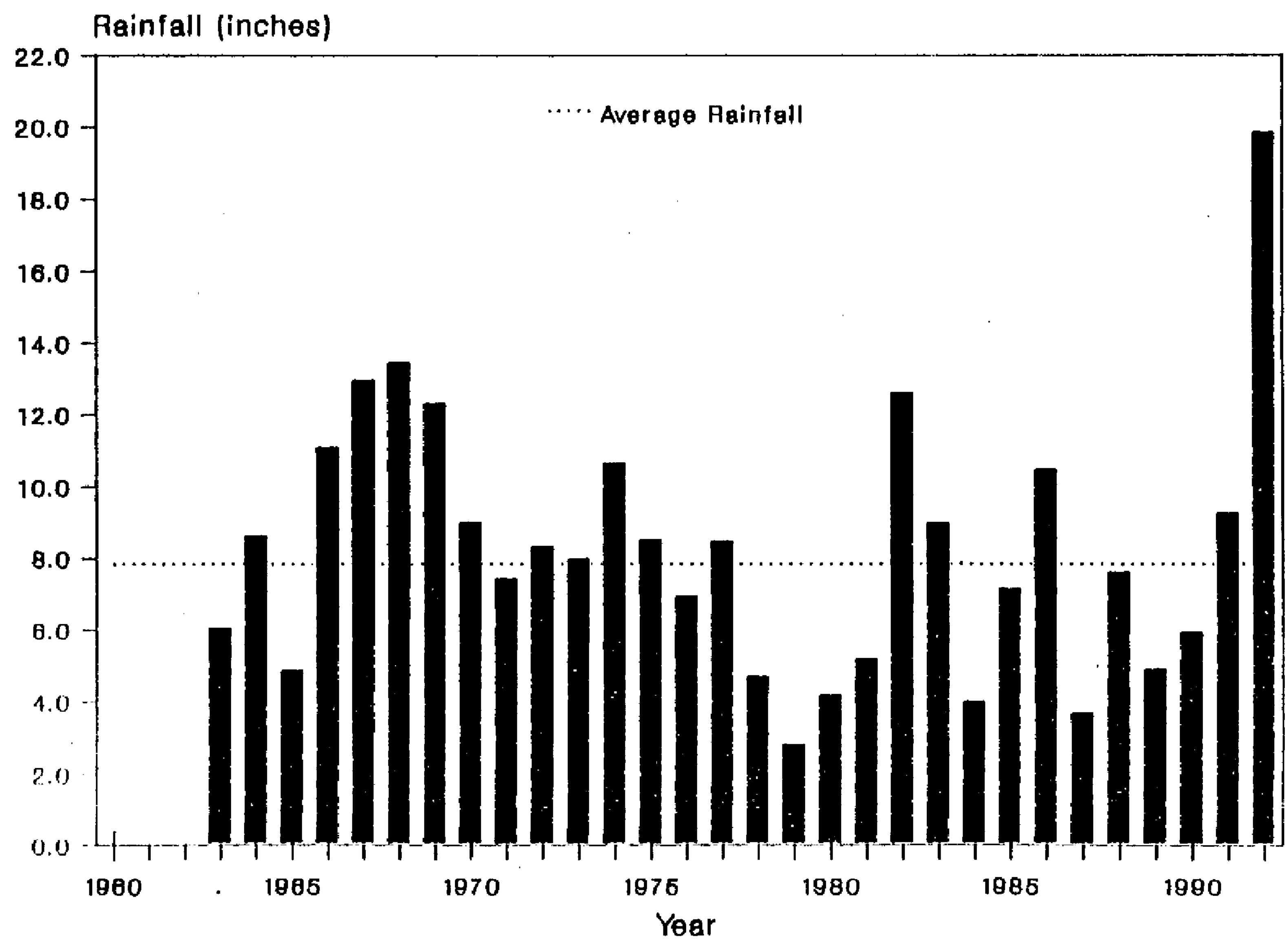


Water Conservation Area I Rainfall for the Month of June - Period from 1963-1992.

RAIN-WOI.CHT / SMR / 8-8-92

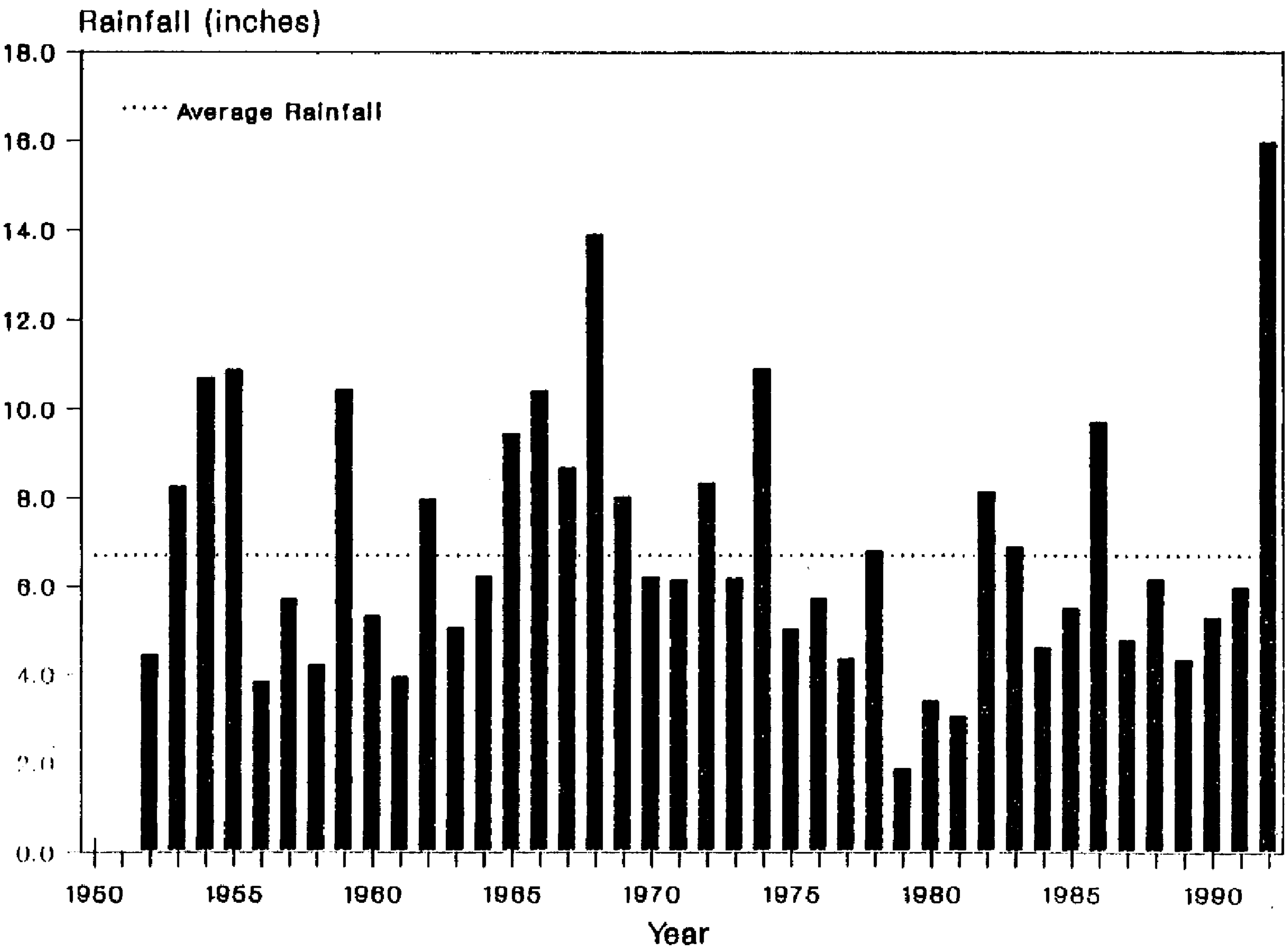


Water Conservation Area II Rainfall for the Month of June - Period from 1963-1992.

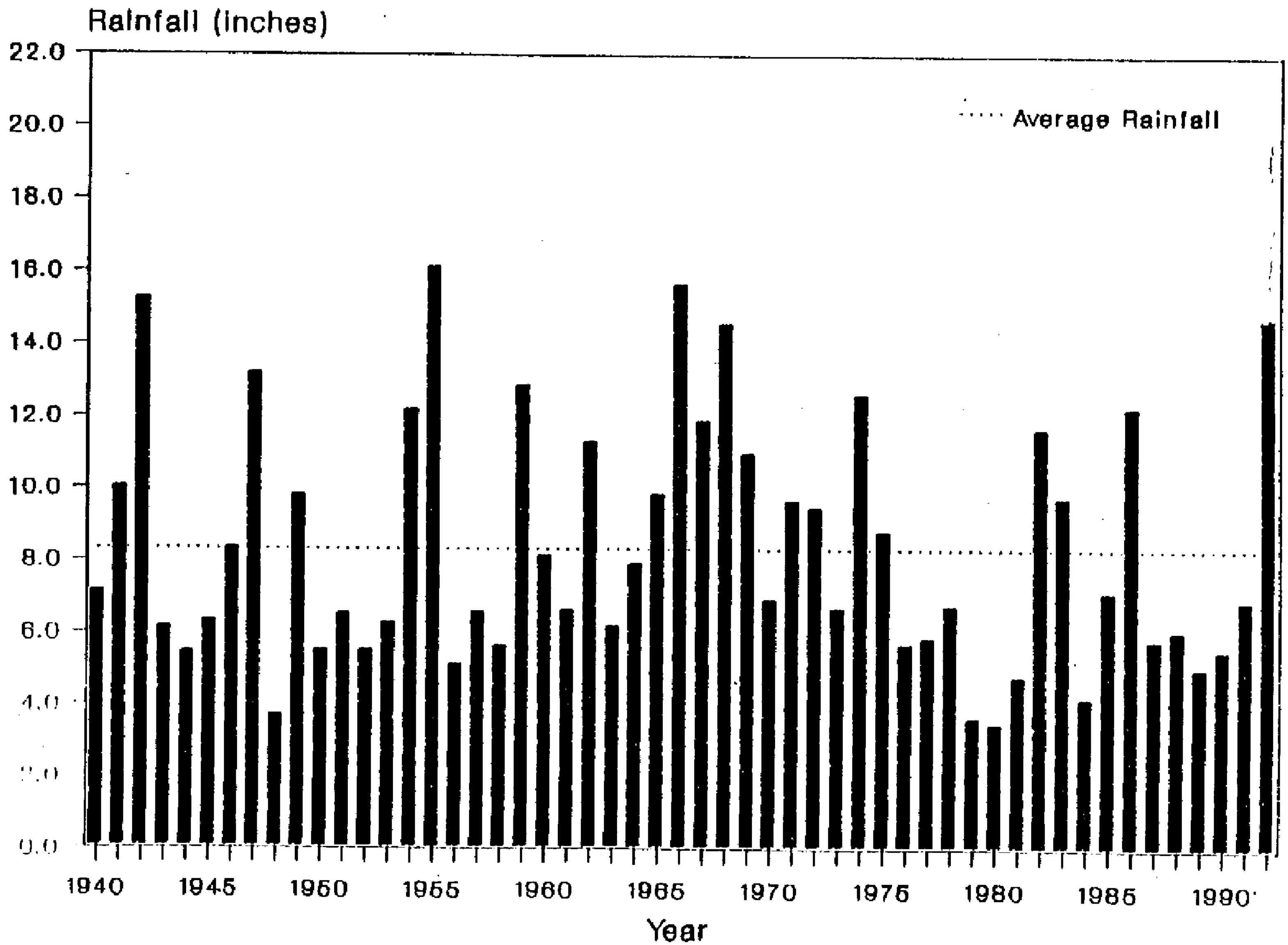


Water Conservation Area III Rainfall for the Month of June –
Period from 1963–1992.

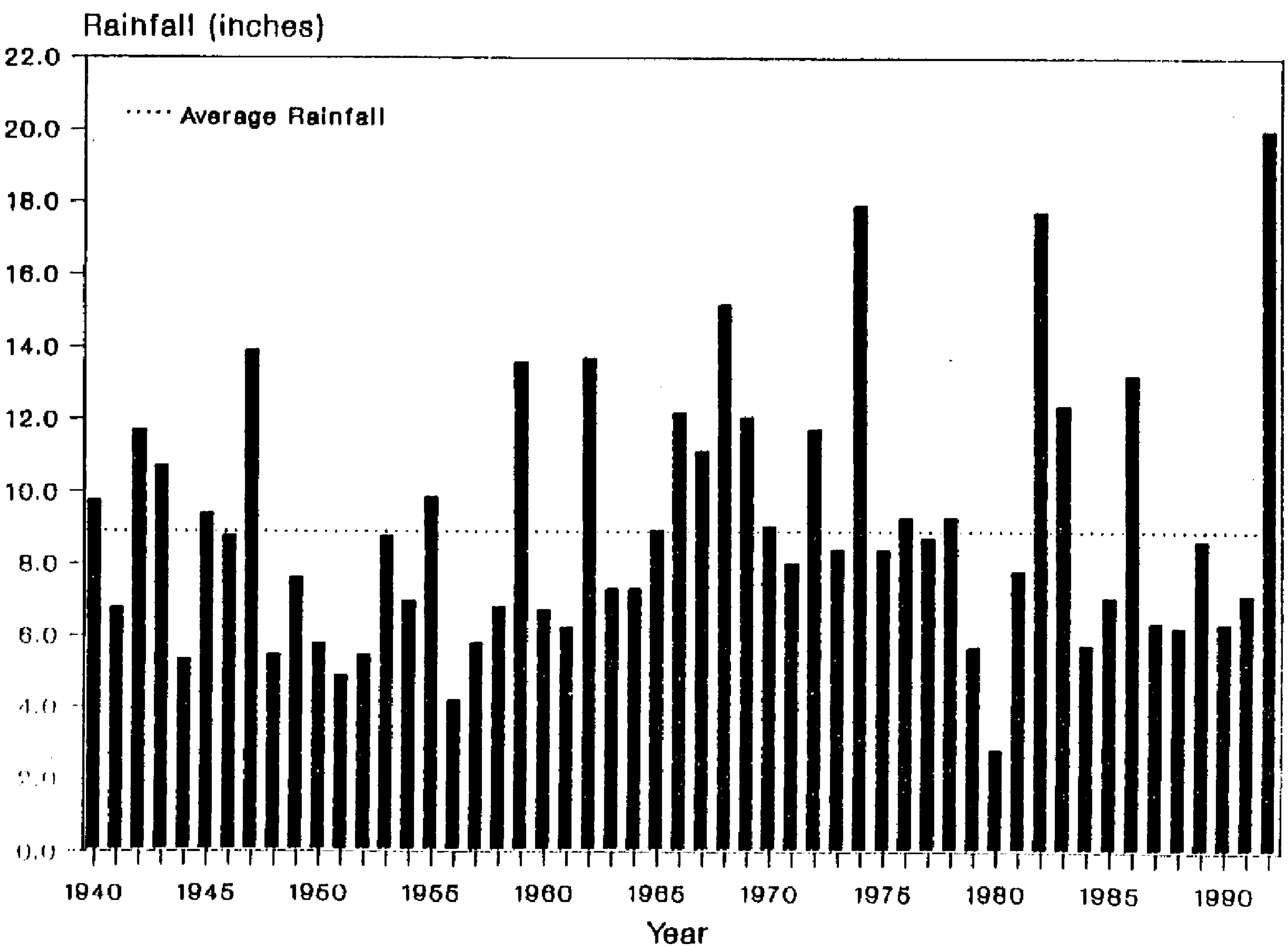
RAIN-WO3.OHT / BMR / 9-8-92



Lake Okeechobee Rainfall for the Month of June - Period from 1952-1992.

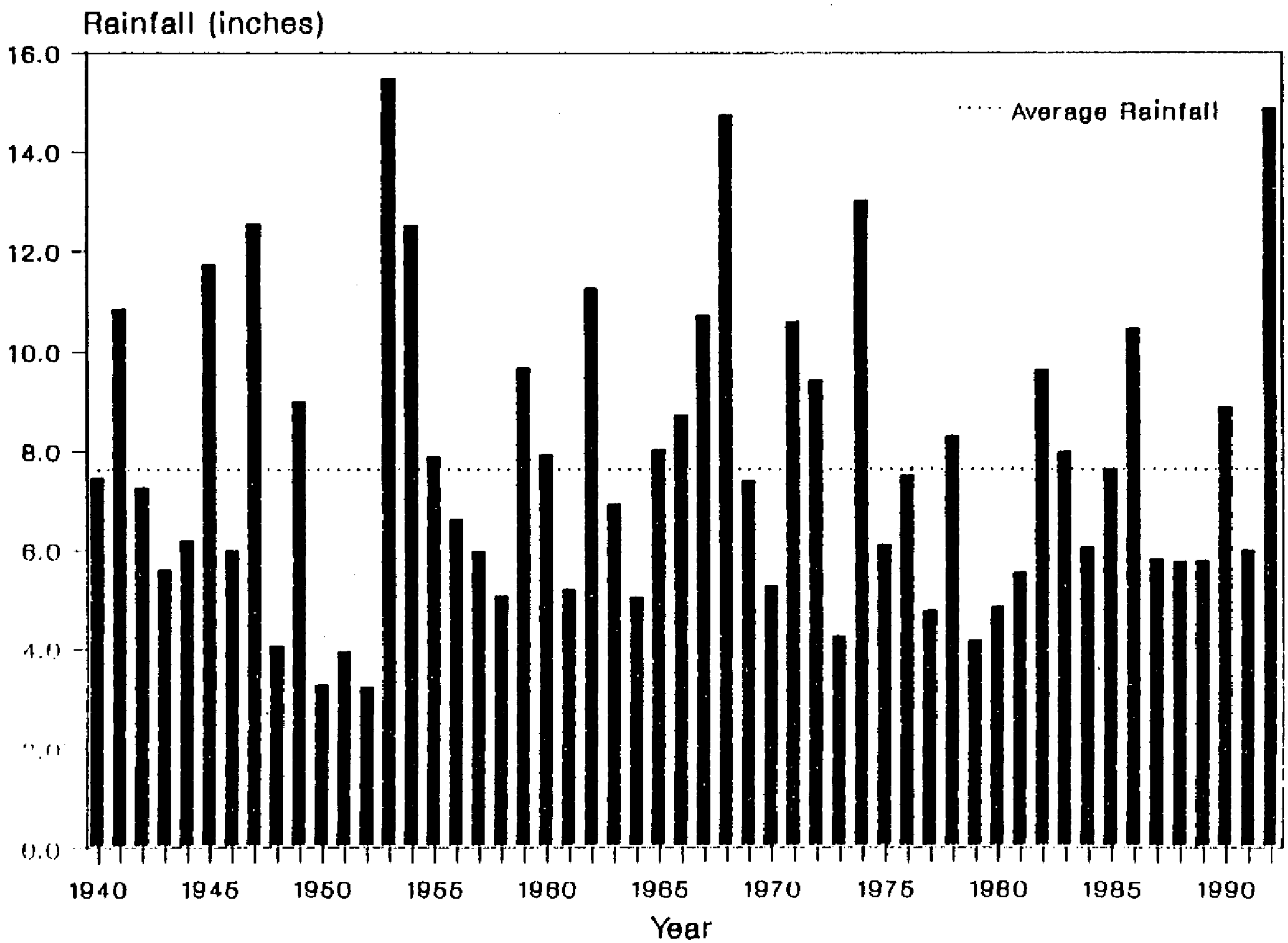


Everglades Agricultural Area Rainfall for the Month of June-
Period from 1940-1992.



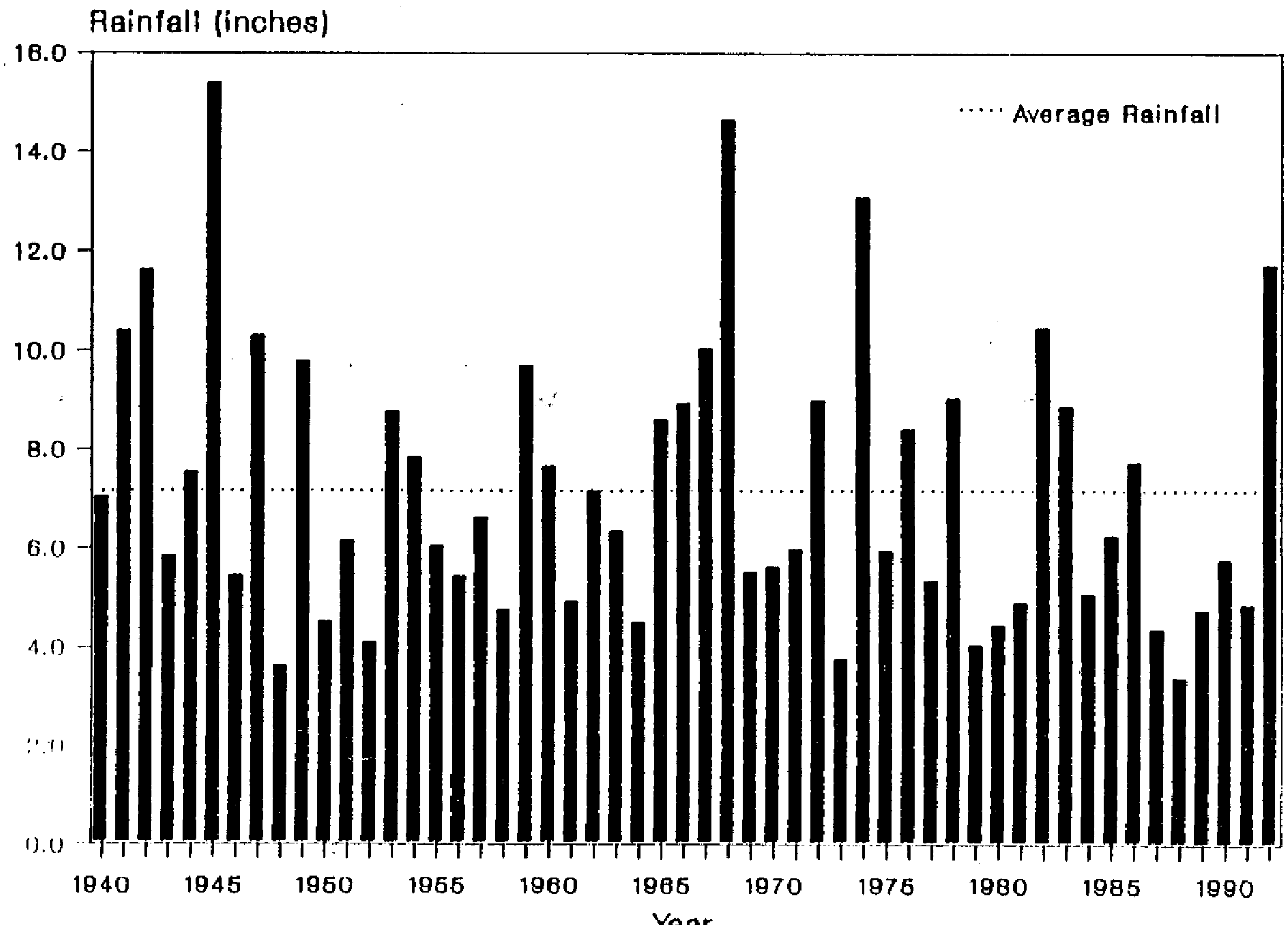
Lower West Coast Area Rainfall for the Month of June - Period from 1940-1992.

RAIN-LWC.CHT / SMR / 6-8-93



Lower Kissimmee River Area Rainfall for the Month of June -
Period from 1940-1992.

RAIN-KRB.CHT / SMR / 8-8-92



Upper Kissimmee River Basin Rainfall for the Month of June - Period from 1940-1992.

RAIN-UKR.CHT / SMR / 8-6-92