STORM EVENT OF OCTOBER 8-10, 1991

December 1991

Water Resources Engineering Division
Hydrologic Data Management Division
Department of Research and Evaluation

Operations Division
Operations and Maintenance Department

Field Engineering Division
Regulation Department

South Florida Water Management District
West Palm Beach, FL

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EXECUTIVE SUMMARY

The storm event of October 8-10, 1991 was concentrated over coastal Broward and Dade counties. Total rainfall amounts for the three-day period ranged from 0.2 inches at rain gage GW-173 in the northwest portion of Water Conservation Area 3A to almost 15 inches at Hollywood in southeast Broward County. The peak magnitude of the storm is represented by the one-day maximum rainfall of 13.47 inches at Hollywood as recorded by the National Weather Service. The estimated point precipitation frequency for the one-day rainfall depth at Hollywood is greater than 1-in-100 years.

At the time the storm occurred, strong onshore winds combined with uncommon astronomical conditions produced unusually high tides. The raised water levels, seaward of the coastal control structures, restricted drainage of stormwater in eastern Dade County. In addition, groundwater levels in Dade County were higher than normal, due to above average rainfall during the previous 30 days, and to the shutdown of the Miami Springs and Hialeah/Preston wellfields.

Flooding was widespread in Broward and Dade counties. The C-11 east basin, particularly the city of Davie, and southeast Hollywood encountered considerable street and/or house flooding. Other locations in Broward County which were inundated include Coral Springs, Sunrise, Miramar, and the Broward Resource Recovery Plant. Primary areas in Dade County which experienced street and/or house flooding are West Miami, Miami Springs, Hialeah, Miami Shores and North Miami.

The storm, although not tropical in nature, produced flooding conditions similar to what can be expected from a hurricane. The primary canal system functioned as designed. Coastal and inland structures operated effectively and there were no serious water control structure malfunctions which inhibited flood protection capabilities.

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I. METEOROLOGIC DESCRIPTION

Climatologically, October is a transitional month from the wet season to the dry season. During this period, Florida's daily cycle of afternoon thunderstorms begins to dwindle, and the region begins to come under the influence of synoptic-scale systems such as cold fronts and low pressure areas. Since residual tropical moisture is available during the early phase of the dry season, frontal systems can be expected to produce more rainfall during October than during the heart of the dry season. This rule is especially true along the Lower East Coast which normally receives about twice as much rainfall in October as the rest of the South Florida Water Management District (District).

During the period of October 8-10, 1991, a weather pattern developed over south Florida which is common for the time of year. On October 7, a cold front, which brought moderate rainfall amounts to Central and South Florida, stalled out over the southern tip of the state, and an active subtropical jet stream remained overhead. These conditions were favorable for increased rainfall activity to develop along the Dade and Broward County coastal waters. Very strong northeasterly winds began to blow showers onshore. Showers redeveloped over the warm waters of the Gulf Stream and moved inland, resulting in near continuous heavy rain over the focused area. The strong winds also acted to push already high tides up against the east coast much like a hurricane's storm surge, and inhibited water releases from control structures. This situation had been anticipated in the forecast on October 6, but by the morning of the 7th, it appeared that the winds were too northerly to produce a continuous stream of showers. Therefore, only light to moderate rainfall was forecast for the east coast overnight. By the morning of October 8, the situation was recognized as a heavy rain event and the forecast correctly called for rains to continue throughout the day. Rainfall amounts close to 14 inches fell in 24 hours in the Hollywood area, with 5-10 inch totals commonplace in Dade and Broward counties. Rainfall was the heaviest along the coast with rainfall totals diminishing inland. The winds subsided on the 9th but abundant moisture allowed a few showers to persist along the frontal boundary. These storms were slower moving due to the lighter winds; therefore, rainfall had a smaller coverage area, but remained intense with nearly 4 inches falling at Miami International Airport. Winds became northerly on October 10, with only isolated showers across the District adding a few tenths of an inch to the already high rainfall amounts.

All the weather factors were in place for more heavy rain on October 14 and 15, but extremely heavy rainfall did not occur. The same stalled frontal boundary from the previous event was over the Straits and moving north. A developing tropical cyclone near western Cuba was moving northeast, and bands of rain began to develop over the Florida Straits and through the Keys. As the tropical cyclone intensified, it was upgraded to a tropical storm (Fabian); the area of showers became more concentrated over the Bahamas on the east side of its center. Fabian passed just to the southeast of the District; heaviest rainfall stayed offshore, with significant rainfall confined to the southern Dade County area where nearly 4 inches of rain fell.

II. RAINFALL ANALYSIS

A. Spatial and Temporal Distribution of the Storm

The intense rainfall of October 8-10 was concentrated over eastern Broward and Dade counties. It began without warning, and the extent of flooding was worsened by strong easterly winds causing unusually high tides. Heavy rains for this region are not atypical during wet season periods. The average October rainfall for coastal Broward and Dade counties is 7.9 inches. This is approximately twice the depth of rainfall that the remainder of the District receives in October. Prior to the storm, the current year's rainfall for the area had been above normal (46 inches), with just over 50 inches registered in Broward County and 54 inches recorded in Dade County.

The spatial distribution of the three-day storm is shown in Figure 1. The isohyets illustrate the areal variation of the storm, and indicate that the heaviest rains occurred near the coast, between Fort Lauderdale and Miami. Recorded rainfall amounts ranged between 0.2 and 15 inches, with the highest three-day total of 14.61 inches accumulated in Hollywood. Miami International Airport received a total of 12.76 inches. Although the major portion of the storm occurred between Fort Lauderdale and Miami, significant amounts of rain fell as far south as Homestead Air Force Base, recording 8.30 inches, and to the north, where Coral Springs received 7.32 inches during the 72-hour period. Rainfall decreased towards the west where less than 16 miles from the coast 5.68 inches were registered at the South Broward Drainage District gage. The locations of the recording stations (Figure A-1) and rainfall amounts used to develop the isohyetal map are presented in Appendix A.

The magnitude of the storm may be better represented from the one-day maximum rainfall amounts. These values occurred on October 8 and are presented in Table 1, along with the location and time recorded. The maximum one-day rainfall values indicate a spatial distribution similar to the three-day rainfall distribution. Hollywood received the largest amount of rain with 13.47 inches accumulating in 24 hours. The one-day rainfall data, from the National Weather Service, was collected in 12-hour intervals. Due to a lack of hourly rainfall data in the concentrated areas of the storm, the maximum intensity of the storm was not determined.

B. Storm Frequency Estimation

The one-day rainfall of 13.47 inches recorded at the Hollywood station has a return period of greater than 100 years. Although large amounts of rain fell in other locations during a 24 hour period, most recorded point precipitation frequencies were less than or close to a 1-in-10-year event. Return periods for selected stations are presented in Table 2. The one day maximum rainfall return periods were estimated from the isohyetal maps shown in District Technical Memorandum, Frequency Analysis of One and Three-Day Rainfall Maxima for Central and Southern Florida, October 1990.

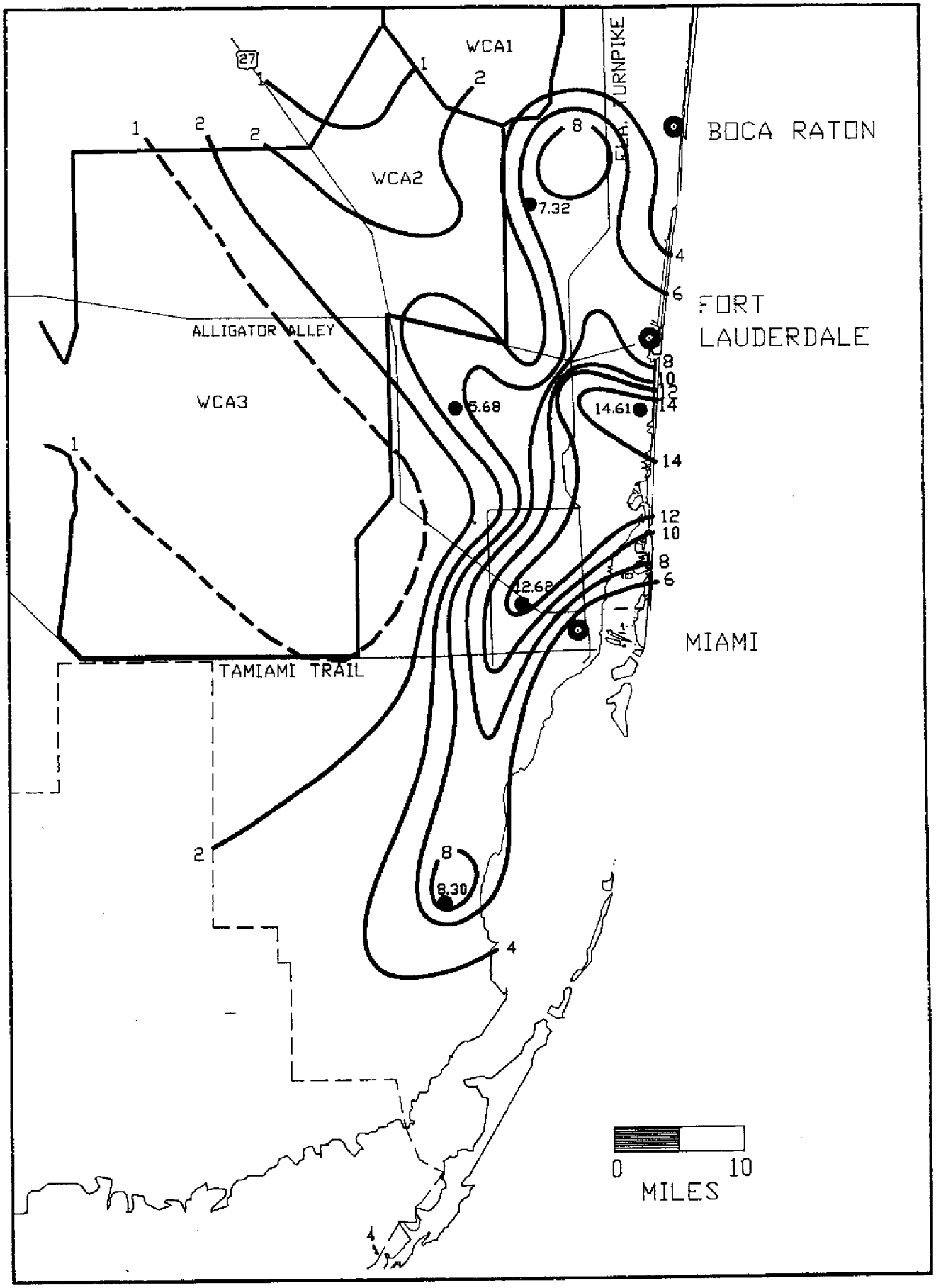

Figure 1. Isohyetal Map of the October 1991 Storm

Table 1. Maximum One-Day Rainfall

Station Name	County	Ending Hour*	Rainfall (inches)
Miami Beach	Dade	5:00 p.m.	4.13
North Dade	Dade	5:00 p.m.	4.12
Tamiami	Dade	5:00 p.m.	1.98
Miami International Airport	Dade	12:00 a.m.	8.59
Homestead Air Force Base	Dade	8:00 p.m.	7.10
Hollywood	Broward	5:00 p.m.	13.47
Fort Lauderdale	Broward	5:00 p.m.	7.09
Coral Springs	Broward	5:00 p.m.	6.65

*October 8, 1991

Return periods for three-day rainfall amounts from Gill Realty and Miami International Airport stations were determined from the exceedance probability curves shown in Figures 2 and 3. These curves assume that the historical three-day maximum data follow a Gumbel extreme value distribution. The return period is found by first locating the three-day rainfall value on the Gumbel distribution curve. The ordinate associated with this point is referred to as the probability of that three-day rainfall being equalled or exceeded in any given year at that recording station. The reciprocal of the exceedance probability is equal to the return period of the rainfall depth. The Miami International Airport and Gill Realty gages recorded three-day rainfall depths having a probability of exceedance of approximately 4 percent, or a return period of 25 years. The three-day rainfall return periods for other locations (Table 2) were estimated from the isohyetal maps shown in District Technical Memorandum, Frequency Analysis of One- and Three-Day Rainfall Maxima for Central and Southern Florida, October 1990.

Table 2. Maximum One -and Three-Day Rainfall Return Periods

Location	One-Day		Three-Day	
	Rainfall (inches)	Return Period (years)	Rainfall (inches)	Return Period (years)
Hollywood	13.47	>100	14.61	>25
Miami Int'l Airport	8.59	10	12.62	25
Homestead AF Base	7.10	10	8.30	<10
Fort Lauderdale	7.09	5	9.41	<10
Coral Springs	6.65	<5	7.32	<5
Gill Realty	6.25	<3	13.34	25

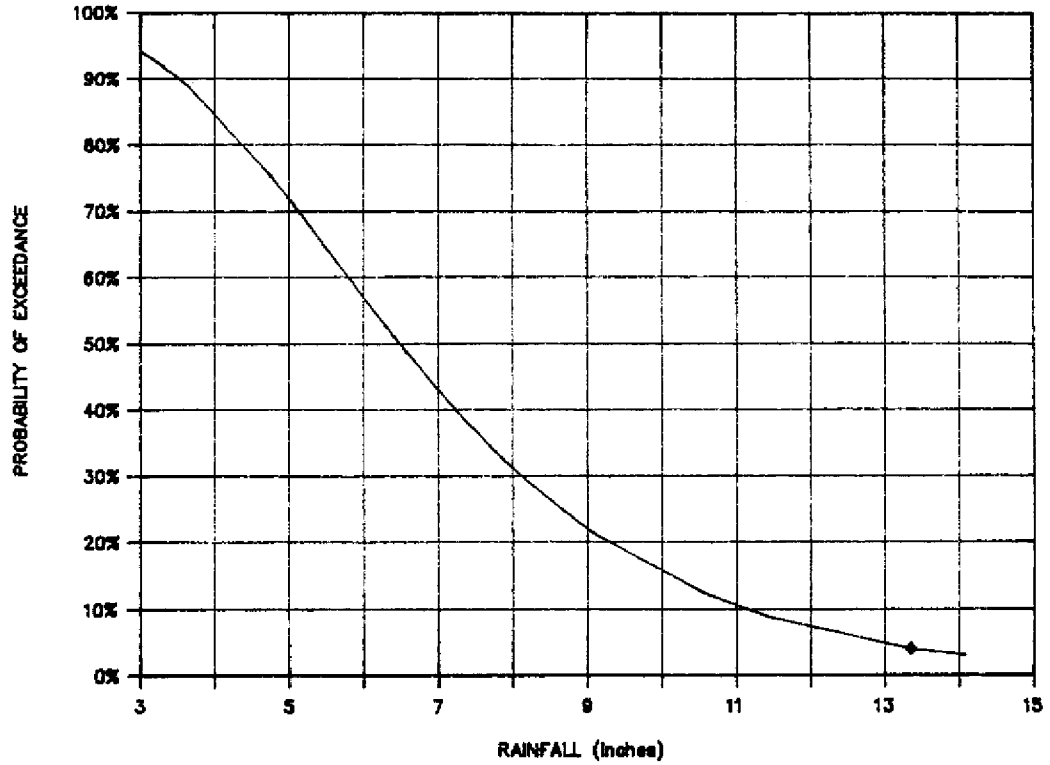

Figure 2. Three-Day Maximum Rainfall Frequency-Gill Realty Station, Broward County

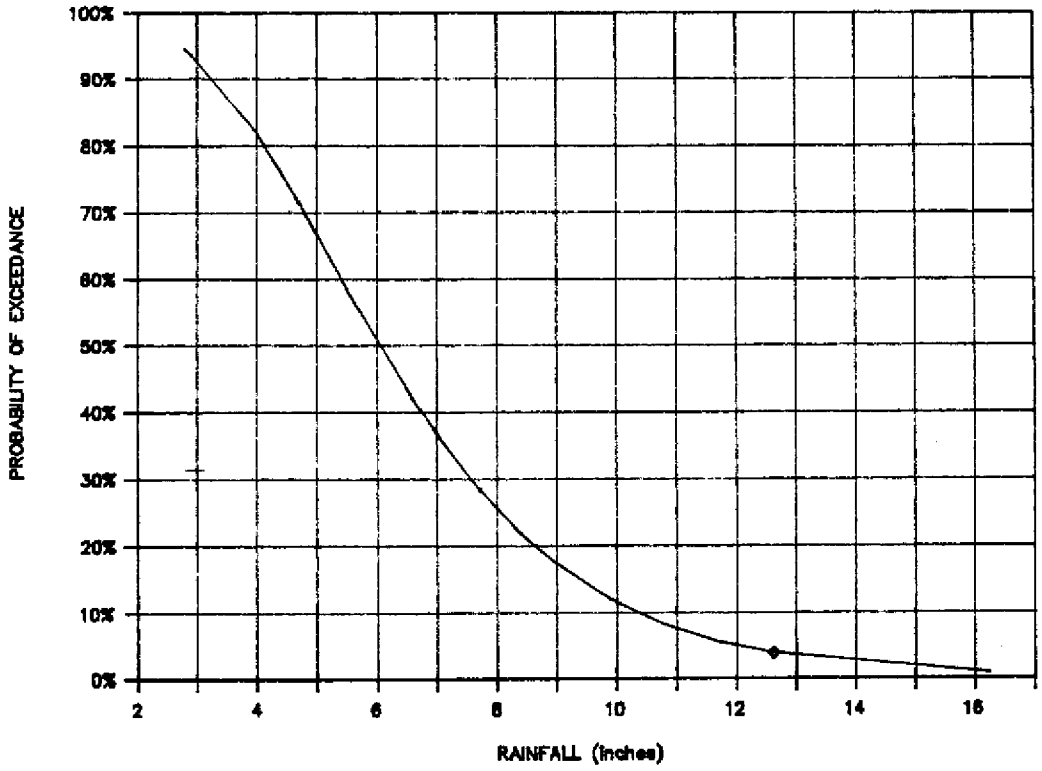

Figure 3. Three-Day Maximum Rainfall Frequency-Miami International Airport, Dade County

III. WATER LEVELS AND SYSTEM OPERATIONS

A. Water Levels

1. Groundwater Levels

Prior to the storm, water levels in wells located in Broward County were normal. Stages in these wells increased sharply between October 7 and 8. In Tamarac (G-2033) and Coral Springs (G-2031), water elevations returned to mean levels within three days after the storm. However, in southeast Broward County, the stages in wells located in Hallandale (G-1473), southeast Hollywood (F-291), and northwest Hollywood (G-1226) remained above normal for several days. G-1473 and G-1226 exceeded their prior maximums with recorded water levels of 10.95 and 9.10 feet NGVD, respectively on October 8.

In Dade County, water levels in wells were higher than normal prior to the storm event. Above normal rainfall which fell over Dade County during the previous 30 days contributed to the rise in groundwater levels. In Miami Springs (G-3, S-68) and Hialeah (G-1368A), high groundwater stages from rainfall events were also attributed to the shutdown of the Miami Springs and Hialeah/Preston wellfields. A dramatic depression of groundwater levels in this area is common due to pumping this wellfield. The District attempts to keep water levels from becoming dangerously low during the dry season by bringing in water from the Water Conservation Areas or Lake Okeechobee to recharge the aquifer system when required. Due to the rains and absence of pumping in this area, water deliveries were not made during or prior to the storm event. The lack of pumping at these wellfields (due to contamination unrelated to the storm) deprived the area of the benefit of a substantially lower water table due to drawdown effects. The groundwater level at the USGS well G-1368A in Hialeah, prior to the storm event was about +4.0 feet NGVD. Normal water elevations at this well, based on 20 years of data, is approximately -8.0 feet NGVD with an average October level of -4.0 feet NGVD. A new maximum stage was established at G-1368A and S-68 of 6.75 and 7.08 feet NGVD, respectively as a result of the October 8-10 storm. Water levels exceeded land surface elevations by 1.2 feet at G-3, 0.6 feet at S-68 in Miami Springs and 1.4 feet at G-3074 at the South Miami well.

Figure B-1 (Appendix B) shows the location of the groundwater wells referenced in this report. Stage hydrographs from October 5 through October 13 for each well are plotted in Figures B-3 through B-13. Included in these figures are the mean stage for the month of October based on data from 1974 to 1991, the maximum and minimum values for the period of record, and the land surface elevation.

2. Canal Stages

Prior to the storm, the headwater elevations at coastal structures were maintained close to their optimum level. Table 3 presents the stage prior to the storm, the peak stage, and the optimum and design stages for the headwater at critical coastal structures. Stage hydrographs (Figures B-15 through B-20) illustrate a sharp increase in water levels between October 7 and 8. Water levels remained high for three to four weeks after the storm before returning to optimum levels.

In the Hialeah area, the sanitary sewer system in the area became overloaded approximately 2 weeks prior to the storm. The overload was caused by groundwater infiltrating into the sanitary sewer mains through leaks or broken pipes in the collection system. Utility directors were forced to pump raw sewage into the surface water drainage system. The District assisted local utility directors in their efforts to bring the sewage problem under control by holding lower than normal water levels in C-6 (Miami Canal) and C-7 (Little River) by means of remote manipulation of the gate controls at S-26 and S-27 and by utilizing low tide periods to discharge larger than normal quantities of water. As a result of these operations, the headwater stages at S-26 and S-27 were close to optimum, regardless of high groundwater levels in the area.

Table 3. Water Levels October 7, 1991 and Peak Stages During the Storm as Compared to Optimum and Design Stages (feet, NGVD)

Location	Stage 10/7/91	Optimum Stage	Peak Stage	Design Stage
C-11 canal at S-13 pump	1.6	2.2	3.4	2.2-2.5
C-9 Snake Creek at S-29	2.1	2.0	3.3	3.0
C-8 Biscayne Canal at S-28	1.8	1.8	3.1	2.3
C-7 Little River at S-27	1.7	1.7	3.2	3.2
C-6 Miami Canal at S-26	2.4	2.5	3.6	4.4
C-4 Tamiami Canal at S-25B	2.6	2.5	3.7	4.4

West Miami (south of C-4), one of the impacted areas, may have been affected to some degree by hydraulic modifications made to the Tamiami Canal (C-4) in 1976. A sheet pile weir on C-4 at the Florida East Coast Railroad was removed, and a control structure (S-25B) was constructed at LeJeune Road. The modifications raised water control elevations in the portion of C-4 adjacent to West Miami. These changes were necessary to protect the water supply of the area from being contaminated by the advance of saline water into the fresh water aquifer, which serves a major portion of the water supply needs of the greater Miami area. The advance of the salt front, prior to these modifications, is documented through studies by the USGS. The changes were effective in stabilizing the advance of the salt front in protecting the water supply. The effects of the modifications on possible flooding in West Miami due to higher water control elevations were largely offset by excavation of the channel between Flagler Street and Blue Lagoon. In addition, a modern water control structure, G-93, was constructed to replace an old sheet pile weir on the Coral Gables Canal. Water levels in the West Miami area are affected by water elevations in C-4 which is controlled by S-25B, water levels in the Coral Gables Canal which is controlled by G-93, and less directly by stages in C-2 (Snapper Creek), which is controlled by S-22.

West Miami is a low-lying area which is traditionally prone to flooding problems. The District's Technical Publication 82-7, Performance of District Structures During Critical Storm Events in West Miami, and Proposed Alternatives to Reduce Flooding (September 1982), cites poor internal drainage within West Miami as the cause of frequent flooding (storms of April 23-26, 1982; Sept 3-29, 1981;

August 16-21, 1981; April 24-27, 1979; June 1-20, 1968 were documented) and presented two recommendations to help alleviate the problem: 1) improvements to the internal drainage of West Miami, and 2) replace the sheetpile weir on the Coral Gables Canal at Red Road with a modern gated structure. Some progress in improving drainage in West Miami has been made, but these have not been as extensive as required. Replacement of the sheetpile weir was accomplished by the District in 1990. While these measures were effective to a degree (less flooding with a larger rainfall total for the 1991 storm than that documented in TP 82-7), additional protection would be desirable.

The discharge hydrographs shown in Figures B-21 through B-26 reflect the operations of coastal structures. Normal flood control procedures dictate that coastal areas of Dade County receive priority drainage over the western areas. In conformance with this policy, all discharge moving eastward from the area west of Krome Avenue to C-4 or C-6, was terminated on October 8. This included diversions to the Northwest Wellfield which are normally controlled by Dade County utilities.

Tides during the storm period were unusually high. Strong onshore winds, combined with unusual astronomic conditions, raised water levels seaward of the coastal control structures to severely restrict drainage of stormwater in eastern Dade County. The chronology of events delineating the operations of the control structures is presented in the subsection "Pump and Water Control Structure Operations". The peak discharge and design discharge for selected coastal structures is presented in Table 4. The locations of canals and structures are shown in Figure B-14. Hydrographs of stage and flow at selected sites on major canals in the area affected by the storm are presented in Figures B-15 through B-26.

Table 4. Peak Discharges During Storm and Design Discharge at Tidal Structures

Location	Peak Q (cfs)	Design Q (cfs)
C-11 canal at S-13	1158	540*
C-9 Snake Creek at S-29	2039	4780
C-8 Biscayne Canal at S-28	1538	3220
C-7 Little River at S-27	1392	2800
C-6 Miami Canal at S-26	1604	3470
C-4 Tamiami Canal at S-25B	1928	2000

*pump (540 cfs), spillway (540 cfs)

B. Pump and Water Control Structure Operations

This section summarizes the sequential operations of the pump and water control structures within the region.

October 8, 1991

03:00: Heavy rains occurring in Fort Lauderdale. Heavy rain at S-13. S-33 opening in automatic mode.

04:10 Miami field station calls to check conditions - received reports of heavy rain and flooding at Arch Creek. Currently forcing discharge at S-26, S-27, S-28, S-29 to allow adequate drainage without gate oscillation which is dangerous for manatees. Still raining at Ft. Lauderdale.

04:30: Miami field station has personnel out checking for localized flooding - radar indicates rain in Miami and Ft. Lauderdale with most activity offshore.

05:00: Arch Creek structure taken off automatic operation by Miami field station personnel with gates full open because close stage is reached upstream while drainage area was still very wet.

06:30: Call for S-13 to start pumping as early as possible.

06:45: Gates at S-30 and S-32 closed. Water levels in C-6 and C-9 too high to allow drainage of western area.

07:00: S-33 gate not functioning properly. Ground crew dispatched to operate gate manually. This is successful.

07:30: Urban Flood Warning called for Miami area by National Weather Service.

07:38: Ignore incoming tide and force additional water through S-26, S-27, S-28, and S-29.

07:45: Office of Communications staff briefed on flooding in Miami area.

08:20: Current situation discussed with Lake Worth Drainage District. Due to construction which will limit discharge at several structures, they will make anticipatory discharges which will affect operation of structures S-155, S-40, and S-41.

08:30: Control of S-36 transferred to central control in order to maintain water levels below 4.0feet. One gate opened to 2.5 feet at G-93 on the Coral Gables Canal.

08:45: S-12 and S-333 adjusted to new openings mandated by "rainfall driven plan" for water deliveries to Everglades National Park. S-5A and S-6 are pumping to the EAA, S-140 is pumping to Water Conservation Area 3, and S-133 is pumping to Lake Okeechobee.

09:00: Took control of S-25B, S-25, and S-22 in addition to S-26, S-27, S-28, S-29 in Miami area to maximize flood releases. Tides are very high, but high stages upstream will limit salinity intrusion.

09:30: Homestead coastal structures S-20F, S-20G, and S-21A are set on low range to prepare for moving more water at low tide.

09:40: Lake Worth Drainage District releases start to influence water levels in E-3. S-40, S-41, and S-155 are adjusted to compensate for increases in stage in E-3 canal.

10:20: S-25 is temporarily closed to minimize flooding upstream.

11:15: S-25 is reopened. Tailwater still very high but upstream stages are rising rapidly.

11:30: Two gates are opened to 5.0 feet at G-93 on the Coral Gables Canal.

12:12: Maximum gate openings at S-22, S-25, S-25B, S-26, and S-28 consistent with tides, which remain very high.

13:00: Lake Worth Drainage District releasing to E-3 at full capacity. S-40 and S-41 are adjusted to compensate for rising stages in E-3 canal.

13:15: Gates temporarily closed at G-56 to allow divers in water to minimize fuel spill.

13:30: Raining in EAA. Night crews called in for pump stations S-9, S-13, S-5A, S-6, S-7, S-8. Pumping at S-7 and S-8 started immediately.

14:00: Okeechobee field station ensured Indian Prairie structures S-72 and S-75 are working properly.

14:16: Control of S-37B transferred to central control in order to keep balance between large flows and nonerosive velocities.

14:25: Maximize flow at S-27 and S-29

14:30: Flows at S-40 and S-41are reduced due to slow rainfall development.

15:00: Control of coastal Homestead structures S-21A, S-20F, S-20G, S-21 to manual operations in order to maximize flow.

15:36: Fort Lauderdale field station announces all night duty shift at field station, S-33, and G-56. Homestead and Miami field stations are also keeping multiple crews on duty all night.

15:40: Starting to catch up in C-14. Are now maintaining desirable stages with nonerosive velocities. Heavy discharge continues under central control.

16:40: S-333 closed in response to rising water at trigger wells.

18:15: Answerphone duty personnel briefed on current status and actions being taken.

20:00: Orders to keep maximum gate openings on all Dade County coastal structures regardless of incoming tide unless extreme increases in salinity indicate reverse flow. Water levels are very high at interior reaches.

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00:10: Dragline sent from Fort Lauderdale to S-9 to clear weed buildup.

00:30: S-123 put on low range automatic operation.

00:45: S-9 not to be shut down more than absolutely necessary until weed problem cleared. In the interim, S-9 and an extra Fort Lauderdale crew making valiant effort to manually clear weeds

06:30: More rain expected today. Moderate gate openings in Palm Beach coastal structures. Continued pumping at EAA pump stations. Moderate gate openings at Broward coastal structures, except are reduced at S-13 and S-9 where maximum pumping and combined gravity flow are continued. Dade County coastal structures continue at maximum capacity.

07:00: Reduced flow slightly at Homestead coastal structures S-21, S-20G, S-21A, S-20F to ensure nondamaging levels.

07:35: NOAA teletype stated *flooding possible today in Palm Beach County.*

08:30: Electricians on site at S-22 making adjustments to gate limit switches

09:00: Stage rising at S-33. Gate opened to 7.0 feet in order to attempt to hold stage at 4.0 feet.

09:06: S-20G temporarily closed to allow containment of oil in canal

10:00: Water levels at S-40 reaching lower limit - reduced flow to moderate level.

10:20: S-20G gate opened wide again. Oil spill contained.

10:30: Electrical/Electronic checks at S-25, S-25B. S-22 adjustment complete.

12:00: Tallahassee Emergency Management Office updated.

12:05: Stilling well at S-27 is cleared to obtain correct water level readings

12:46: Two manatees sighted upstream of S-21. Caution used when closing gates.

13:30: Limit switches at S-29 adjusted. Night crew called to pump S-5A, S-6, S-7, S-8, S-9. S-13, and S-4. Pumping at S-4 started immediately.

14:00: Fort Lauderdale crew sent to G-56. Control room radio monitored carefully in case help is needed.

14:00: S-124 opened to a 6.0 foot gate opening since some capacity now available in North New River to relieve western C-13/C14 basin.

16:20: Street flooding reported at trailer park on Canoe Lake in Martin County. Have local office investigate.

16:45: Urban Flood Advisory issued for Dade and Broward counties by National Weather Service.

18:00: Limit switches have been checked and adjusted at S-22 and S-28 to allow larger than normal gate openings. Gates opened to maximum.

18:30: Three manatees reported upstream of S-21. Use caution if necessary to close gates.

19:00: S-33 automatic gate control wants to close gate too soon. Fort Lauderdale crew dispatched to fix and/or man station if required.

21:30: Control room ordered to watch salinity readings for indication that high tides are moving water inland while gates are locked wide opened in Dade County.

22:15: S-29 salinity rising rapidly, gates closed until tide goes down. Trouble closing gates. Crew sent from Miami to fix problem.

22:35: Order to close coastal gates if tide gets too high at S-29 cancelled. Gates must be checked and cleared first - gates have not been tested at this large opening for years. Three gates at S-29 closed but fourth is stuck open.

23:25: S-4 pump station ran out of water - request leave to secure pump station. OK to stop pumping but standby to pump in case rains come.

October 10, 1991

01:30: S-29 gates fixed. Now operable through full range.

02:00: Water levels in C-13 now under control. Gate opening reduced at S-36 to maintain water levels just below 4.0 feet.

03:30: Pump station S-5A running out of water. Shut down pumps and standby.

07:25; Water levels at G-54 on North New River Canal falling rapidly. Fort Lauderdale field station crew sent to check and adjust board elevations if necessary.

09:00: Gates adjusted at Lake Kissimmee and Lake Toho for larger regulatory flow.

10:30: Stilling well at S-29 flushed to ensure good water level readings. Gates at S-28 checked.

11:00: Lake Worth Drainage District is shutting down discharge to E-3. Compensated by adjusting Palm Beach coastal structures S-155, S-40 and S-41 accordingly.

11:05: S-36 inflows to basin rising. Gate opening increased from small to moderate (through early afternoon) to compensate.

11:30: S-28 gate check in progress. Both gates cycled through full range for test.

13:30: Night crews sent to pump S-9 and S-13.

19:00: Monitor G-54, G-56, and G-57 carefully - no crew onsite but still large flow. To call Fort Lauderdale duty officer at home if serious change in water levels.

22:00: Miami field station will close at midnight - contact duty officer at home if necessary. S-153 gate will not open - sending repair crew from Okeechobee.

24:00: Orders to put one more pump on-line at G-200.

C. Field Inspection Activities

Personnel from the Field Engineering Division, along with staff from the Fort Lauderdale and Miami field stations, inspected various areas of reported flooding within Broward and Dade counties following the heavy rains of October 8, 9 and 10. Inspections were performed on October 9, 10 and 11, both on the ground and from helicopter. Flooded areas in both counties were video taped from the helicopter on October 9 and 10. Flooding was more widespread in Broward County than in Dade County, but flooding was more severe in Dade County with more homes flooded than in Broward County. A description of the inspected areas and respective comments follow.

1. Broward County (Appendix C ,figures 1, 2, and 3)

Inspections by Field Engineering and Fort Lauderdale field station staff from the helicopter and the ground documented considerable flooding in the city of Davie. Primarily, the entire C-11 east basin experienced intermittent road and floor flooding. Specific areas where staff documented flooding in the city of Davie included (numbers in brackets correspond to location on figures C-2 and/or C-3):

a. Nova High School/University: Maintenance buildings and green houses were flooded [1].

b. Emerald Isles Apartments: Parking and air conditioning units flooded to 16 inches [2].

c. Majestic Groves subdivision: Streets and yards flooded up to building foundations [3].

d. Little Ranches: Streets flooded [4].

e. Davie Road and 52nd Street: Streets and floors in lower areas flooded [5].

f. Davie Road area south of Griffin Road: Streets flooded [6].

g. Shopping Center at 441 and Griffin Road: Parking lot flooded to 20 inches [7].

h. SW 30 St/Rolling Hills Golf Course: Streets, yards and golf course flooded from 10 to 12 inches [8].

The southeast portion of the city of Hollywood also experienced considerable road and floor flooding:

i. Bamboo Lakes: Streets flooded from 6 to 20 inches (water levels reached) up to the base of trailers. Many residents were evacuated from the site [9].

j. Winn Dixie south of Miramar and east of I-95: Streets and floors flooded [10].

k. Orangebrook Golf Course: Flooded from 2 inches to 2 feet [11].

l Orangebrook Trailer Park: Streets and yards flooded from 4 to 6 inches [12].

m. Oakridge Country Club: Golf course flooded from 2 inches to 2 feet. This permitted project's drainage pumps were not operating during the storm, which resulted in the flooding [13].

n. Shopping center at Park Road and Sheridan Street: Parking lot flooded to 14 inches [14].

o. North Park Road at Johnson Sreet: Flooded from 8 to 10 inches. The centerline elevation at this intersection is 6.19 feet NGVD, making the flood stage approximately 7.0 feet NGVD [15].

p. Sunset Golf Course: Flooded from 2 inches to 2 feet [16].

q. Pembroke and Park Roads: Streets flooded to 6 inches. The centerline of this intersection is elevation 3.96 ft NGVD, making the flood stage approximately 4.5 feet NGVD [17].

There were additional isolated areas of flooding throughout Broward County which included the following locations:

r. Sunshine Acres: High water caused drainfield problems [18].

s. Sunset Strip from NW 91 Avenue to NW 96 Avenue: Street and yard flooded to 6 inches [19].

t. Pine Island Rd./Sunset Strip intersection: Flooded to 20 inches, street closed [20].

u. Godfrey Road at Wiles Road: Streets and paddocks flooded to 10 inches [21].

v. Miramar Parkway east of 441: Street closed due to flooding, depth unknown [22].

w. Broward Resource Recovery Plant: Water inside of the ash landfill breached the surrounding dike. There was no discharge of water offsite, and the breach was repaired within one day. FDER kept on top of this [23].

x. NW 39 Avenue from 4 Court to Seventh Street: Streets and yards flooded to 12 inches. Homes flooded to 4 inches [24].

Additional areas of flooding in Broward County were documented by the American Red Cross and are included in Appendix C, figures 1 and 3. Permit information and selected comments for projects which have been issued a surface Water Management Permit within inundated areas of Broward County are presented in Appendix D.

2. Dade County (Appendix C, figures 4, 5, and 6)

Affected areas of Dade County were observed by Field Engineering staff and Miami field station personnel by helicopter, and flooding was documented on video tape. Additional inspections were performed by Miami station personnel on the ground. Primary areas of documented flooding in Dade County are described below (numbers in brackets correspond to location on figures C-5 and/or C-6):

a. West Miami: Streets and homes flooded with 1 inch or more of water on floors [1].

b. Comfort Canal/Miami River: Streets flooded. Some were impassable [2].

c. Miami Springs: Severe street and house flooding [3].

d. Hialeah: Severe street and house flooding [4].

e. Miami Shores: Streets in Larchmont Gardens flooded [5].

f. North Miami: A trailer park had streets flooded and trailers in the western portion were flooded with up to 1 foot of water on the floors [6].

According to field observations, no flooding of any finished floor elevations is known to have occurred for any project in Broward and Dade counties that has been permitted and built in accordance with the District's surface water management criteria. However, inconvenience flooding of roads and parking lots did occur in certain permitted areas. This was due to the fact that roads and parking lots are designed to accommodate less severe storm events than are finished floors. In older, unpermitted areas, there was flooding of finished floor elevations.

IV. PUBLIC INTERACTION

During the storm event, Operations and Maintenance Department (OMD) staff maintained close communications with officials from Miami Springs, West Miami, and Hialeah. During a meeting requested by the Mayor of West Miami, OMD regional staff met briefly with representatives from Hialeah Gardens and Virginia Gardens. The communications consisted of continuous updates of District coastal structure operations and damage assessment. With the exception of West Miami the communications were conducted in the spirit of joint cooperation. The interaction with city officials from West Miami was addressed by the District Planning Department representative for Dade County and will not be included in this report.

District local representatives from the Planning Department, Office of Communications, and Operations and Maintenance Department maintained close communications with Dade County's Emergency Operations Center (EOC). There was continuous exchange of information relating to structure operations, flooding conditions and weather updates. Local District representatives attended an emergency meeting on October 10, the last day of the storm event, to discuss present status, and potential interaction between agencies if the wet conditions persisted. A report of the meeting was prepared and circulated by the Planning Department representative.

OMD staff from Fort Lauderdale and Miami met with representatives from the Dade County Road and Bridge Division at the Melrose Canal in Miami Springs to assess the condition of this secondary conveyance system. Dade County has maintenance responsibilities for the secondary system. County and District divers discovered obstructions to the flow along culvert locations at the Melrose Canal and the adjoining privately owned canal. District personnel from Fort Lauderdale and Miami removed the culvert obstructions in Miami Springs. Staff from Homestead and Miami alleviated flooding conditions by setting up a pump in a severely flooded section of Miami Springs and discharging to the Melrose Canal. This pump was operated for three days by District staff.

Interaction with the general public is a sensitive and difficult part of the job for District area field offices. Affected owners addressed their concerns to the District's area field offices and headquarters in West Palm Beach. The area field offices were staffed throughout the day and night to address all inquiries. The staff handling the inquiries were capable of communicating with callers and were instructed to provide the proper guidance when unable to resolve any of the inquiries.

The media generally provided an accurate account of the three-day storm event. The press kept the public informed about flooding conditions and activities of governmental and local agencies.

V. RECOMMENDATIONS

•Provide a cost-effective remote monitoring capability to reduce G-93 operational response time. This effort is currently underway.

•Continue to work with residents and local governments in Dade County to find solutions to secondary canal maintenance and conveyance capacity problems.

G-93 is a new gated spillway on the Coral Gables Canal. Prior to the construction of G-93, response time was 12-18 hours. Water levels often exceeded 4.0 feet NGVD before action could be completed. During the October storm response time was aproximately 4 hours. The rapid response kept water levels near 4.0 feet NGVD during this severe event. Although the response time to relieve flood conditions upstream of G-93 has improved significantly over preconstruction conditions, the full potential of the structure was not realized due to monitoring deficiencies. It is not possible to automate G-93 without an expensive remote override capability to protect manatees which frequently congregate at this site. The limited conveyance capability and maintenance problems associated with the Coral Gables Canal are difficult to remedy due to severe right-of-way limitations.

•Work with Dade County, DER , local residents and special interest groups for the rapid removal or repair the G-58 structure.

G-58 is an old coastal control structure on Arch Creek in North Miami. This structure is in very poor condition and should be repaired unless replacement or elimination can be justified. Flooding upstream of the structure indicates that the current capacity is inadequate.

•Improve the sanitary sewer transmission system.

Sanitary sewer discharge problems are an environmental and public safety concern. In addition, these discharges pose a threat to canal maintenance. Test results of water quality samples taken in C-6, C-7, and portions of C-4 have forced managers to reschedule weed control and diving activities in these canals.

•Decontaminate Miami Springs and Hialeah/Preston wellfields and restore moderate water supply pumping from the area.

•Continue to maintain the Melrose Canal and the FEC borrow canal.

As a result of the wellfield drawdown providing additional flood protection, routine maintenance of the secondary surface water drainage system by the Dade County Road and Bridge Division was deemphasized. The Melrose Canal, in particular, contained numerous obstructions to flow. In order to alleviate flooding in the area, the obstructions were removed by Dade County and District personnel.

•Create an interagency task force to address local drainage problems.

Address Secondary Drainage System for West Miami and C-4 control elevations.

APPENDIX A

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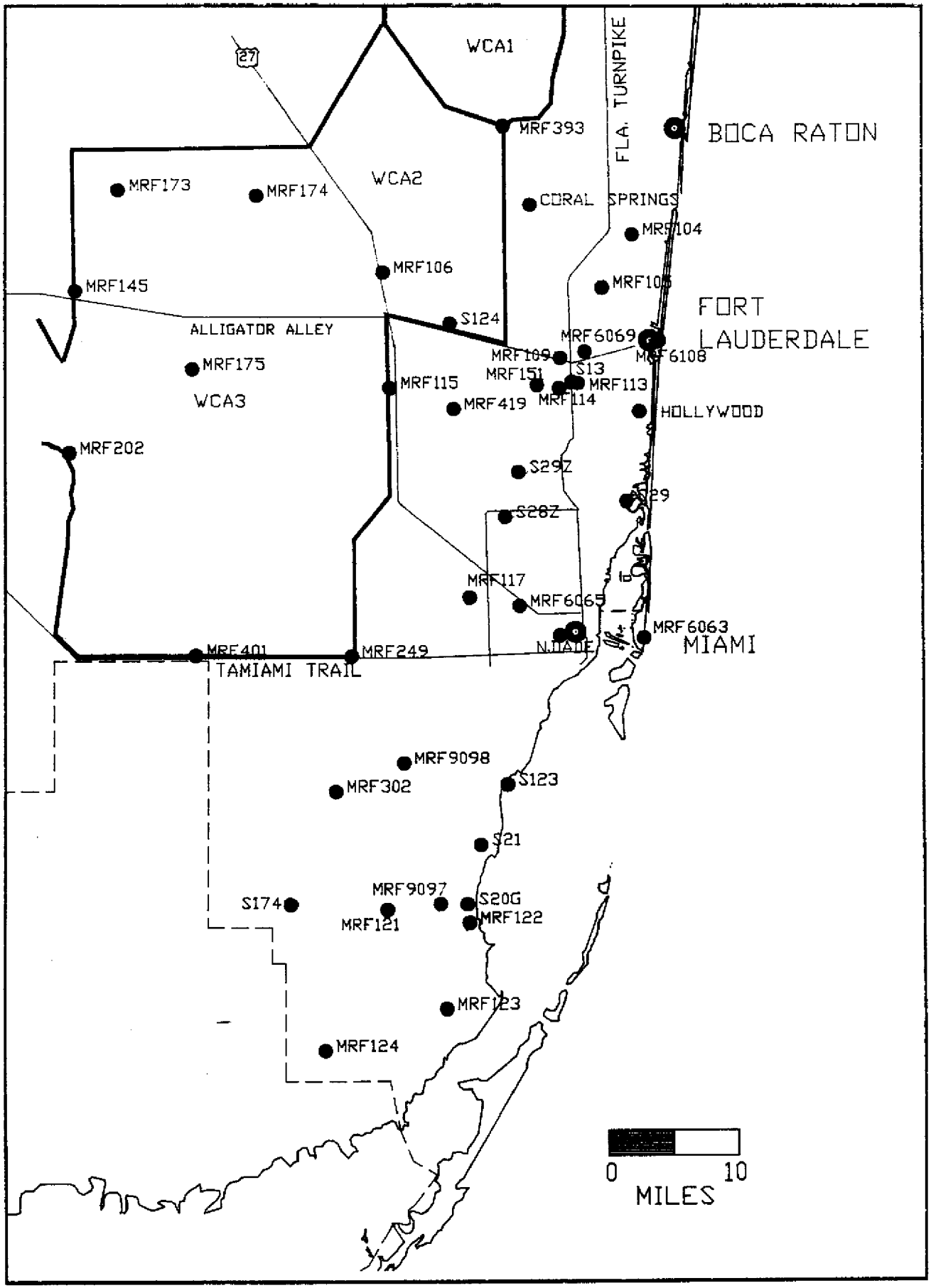

Figure A-1. Location Map for Daily Rainfall Gauges

Table A-1: Daily rainfall values at stations during the storm

MRF No.	Station Name	County	Oct. 8	Oct. 9	Oct. 10	Time	Total
104	Pompano Farmers Market	Broward	2.33	1.90	0.40	8:00 a.m.	4.63
105	S-36 SPW on C-13	Broward	5.52	1.65	0.07	9:00 a.m.	7.24
106	WCA 3-36	Broward	3.53	0.10	0.00	8:00 a.m.	3.63
109	G-54 Sewel Lakes	Broward	3.80	1.74	0.03	8:00 a.m.	5.57
113	S-13	Broward	5.30	8.19	0.15	7:00 a.m.	13.64
114	Gill Realty	Broward	6.25	6.59	0.50	9:00 a.m.	13.34
115	sS-9P NRC to CA3A	Broward	1.74	0.00	0.03	8:00 a.m.	1.77
145	S-140 SPW on L-28	Broward	0.29	0.00	0.00	8:00 a.m.	0.29
151	Ft. Lauderdale Field Station	Broward	2.18	2.10	0.12	7:00 a.m.	4.40
173	GW-173 at CA3A NW	Broward	0.13	0.10	0.00	8:00 a.m.	0.23
174	GW-174 at CA3A NE	Broward	3.65	0.00	0.00	8:00 a.m.	3.65
175	GW-175 at CA3A S	Broward	0.24	0.10	0.00	8:00 a.m.	0.34
393	S-39	Broward	0.88	1.10	1.89	8:00 a.m.	3.87
419	So. Broward Drainage Dist.	Broward	0.58	4.86	0.24	7:00 a.m.	5.68
6108	Laud Bahia Mar	Broward	2.00	3.65	0.84	8:00 a.m.	6.49
6069	Fort Lauderdale*	Broward	7.09	2.28	0.04	5:00 p.m.	9.41
	Coral Springs*	Broward	6.65	0.27	0.40	5:00 a.m.	7.32
	Hollywood*	Broward	13.47	0.79	0.35	7:00 a.m.	14.61
	S-38	Broward	0.77	2.04	0.00	7:00 a.m.	2.81
	S-124	Broward	1.51	4.20	0.00	7:00 a.m.	5.71
	S-9	Broward	0.55	2.00	0.00	7:00 a.m.	2.55
	S-29	Broward	6.79	4.21	1.82	7:00 a.m.	12.82
	S-29Z	Broward	3.62	3.09	0.73	7:00 a.m.	7.44
117	Miami Field Station	Dade	2.00	5.30	2.62	6:30 a.m.	9.92
121	Homestead Field Station	Dade	0.01	4:30	0.18	8:00 a.m.	4.49
122	S-20F SPW on C-103	Dade	0.00	6.46	0.03	7:00 a.m.	6.49
123	S-20 SPW on C-107	Dade	2.72	0.00	0.01	8.00 a.m.	2.73
124	S-18C	Dade	0.26	3.23	0.00	8:00 a.m.	3.49

*Data provided by National Weather Service

Table A-1: Daily rainfall values at stations during the storm

MRF No.	Station Name	County	Oct. 8	Oct. 9	Oct. 10	Time	Total
249	S-336 Culvert	Dade	0.81	0.03	0.14	8:00 a.m.	0.98
302	S-331P	Dade	0.36	1.50	0.38	8:00 a.m.	2.24
401	S-12D SPW L-29 at 3A	Dade	0.96	0.02	0.29	8:00 a.m.	1.27
6063	Miami Beach*	Dade	4.13	0.04	0.08	5:00 p.m.	4.25
9097	Homestead AFB*	Dade	7.10	0.70	0.50	8:00 p.m.	8.30
9098	Tamiami*	Dade	1.98	0.40	0.02	5:00 p.m.	2.40
	Miami International Airport*	Dade	8.59	4.00	0.03	12-midnight	12.62
	North Dade*	Dade	4.12	1.52	0.11	5:00 p.m.	5.75
	S-28Z	Dade	1.56	2.28	0.47	7:00 a.m.	4.31
	S-123	Dade	0.92	3.99	0.49	7:00 a.m.	5.40
	S-21	Dade	0.13	5.41	0.53	7:00 a.m.	6.07
	S-20G	Dade	0.00	6.74	0.07	7:00 a.m.	6.81
	S-174	Dade	0.01	2.41	0.57	7:00 a.m.	2.99

*Data provided by National Weather Service

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APPENDIX B

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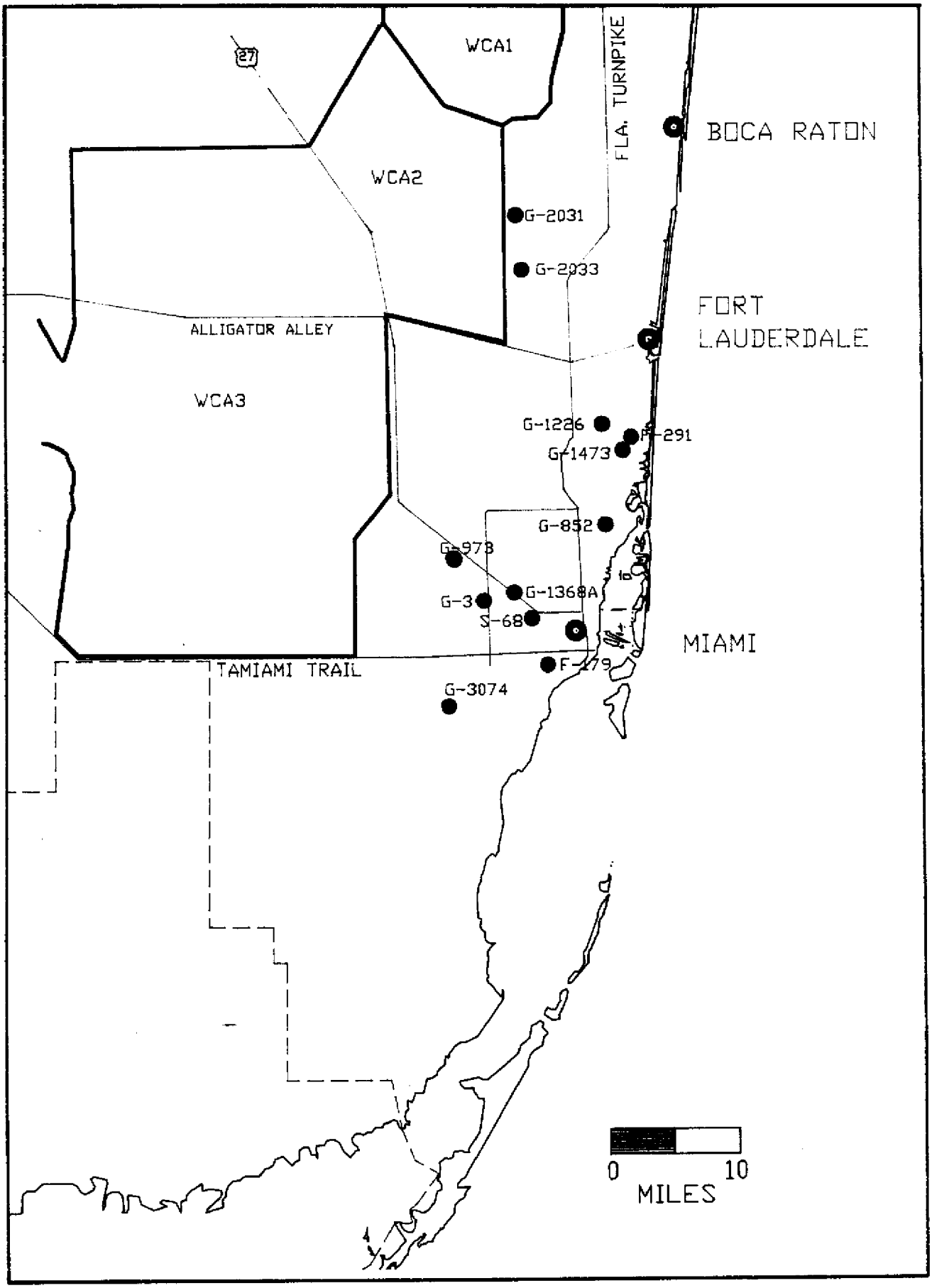


Figure B-1. Well Location Map

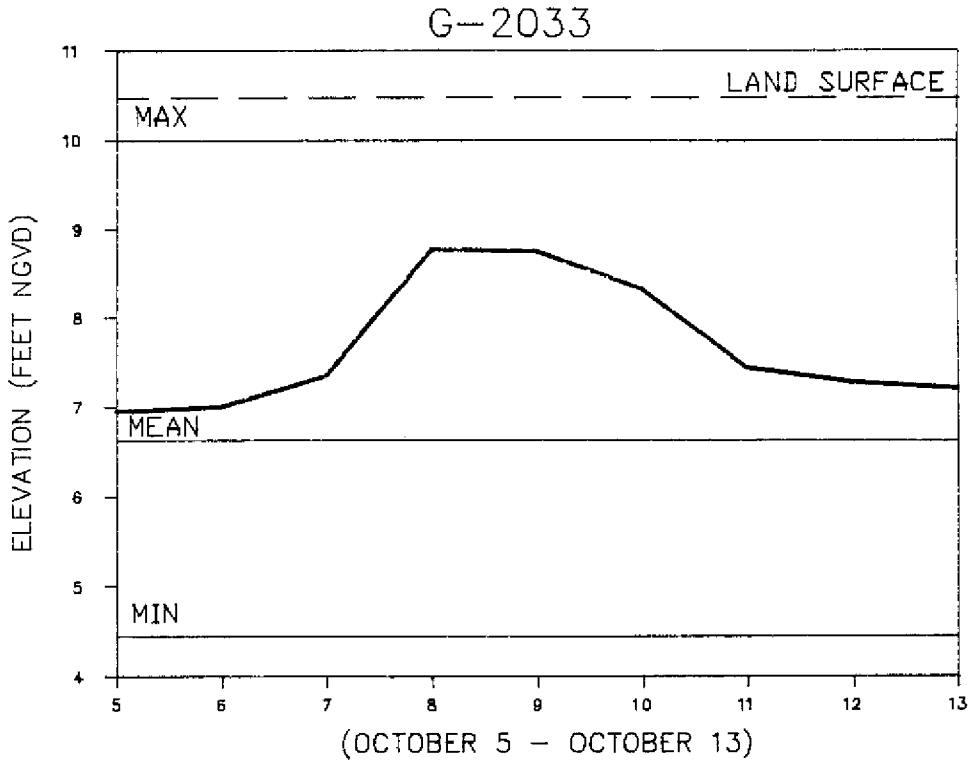


Figure B-2. Daily Groundwater Levels at Tamarac

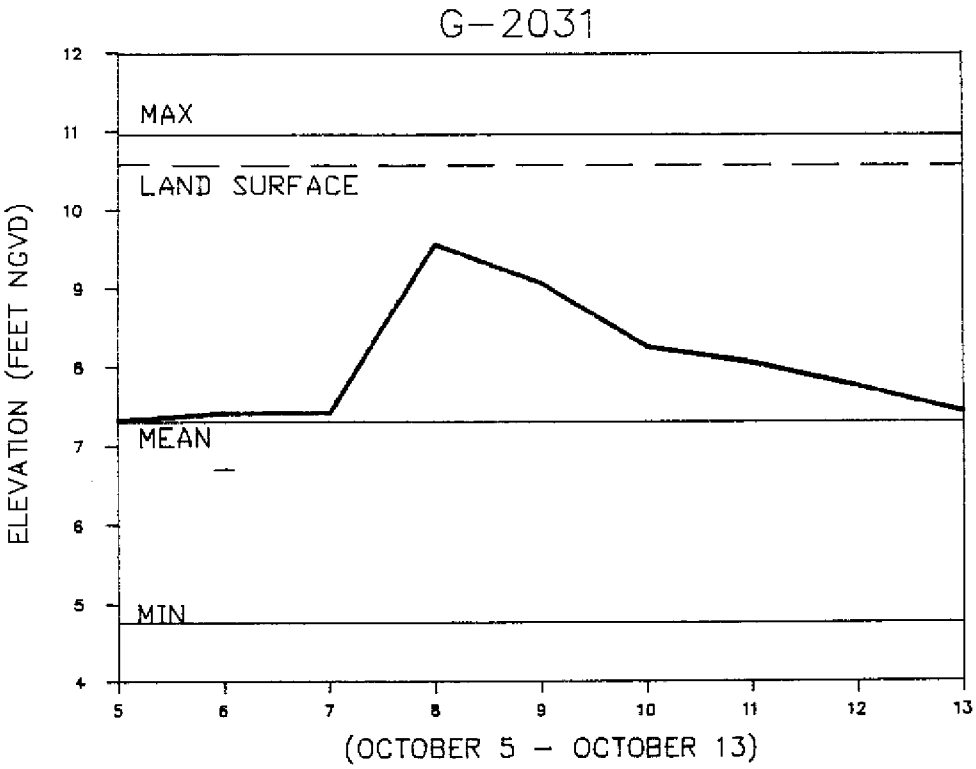


Figure B-3. Daily Groundwater Levels at Coral Springs

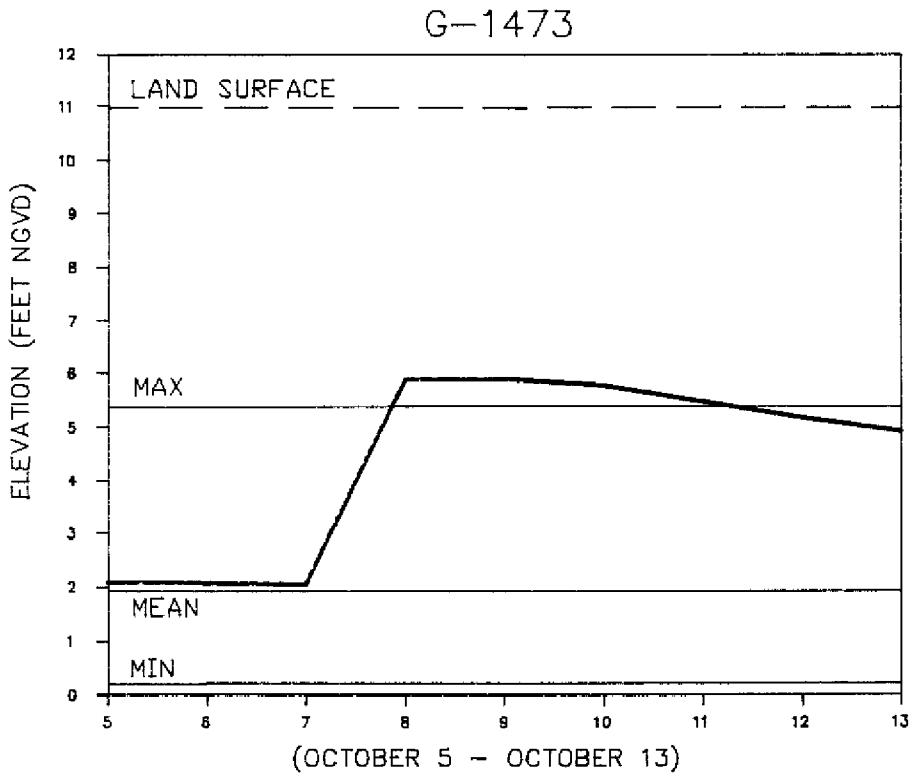


Figure B-4. Daily Groundwater Levels at Hallandale

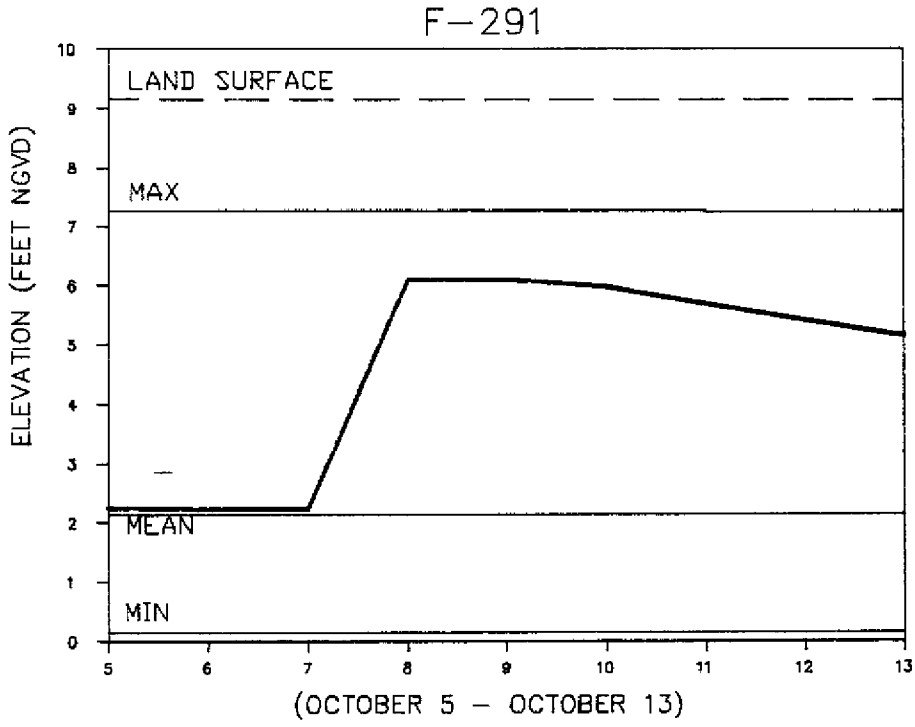


Figure B-5. Daily Groundwater Levels at South East Hollywood

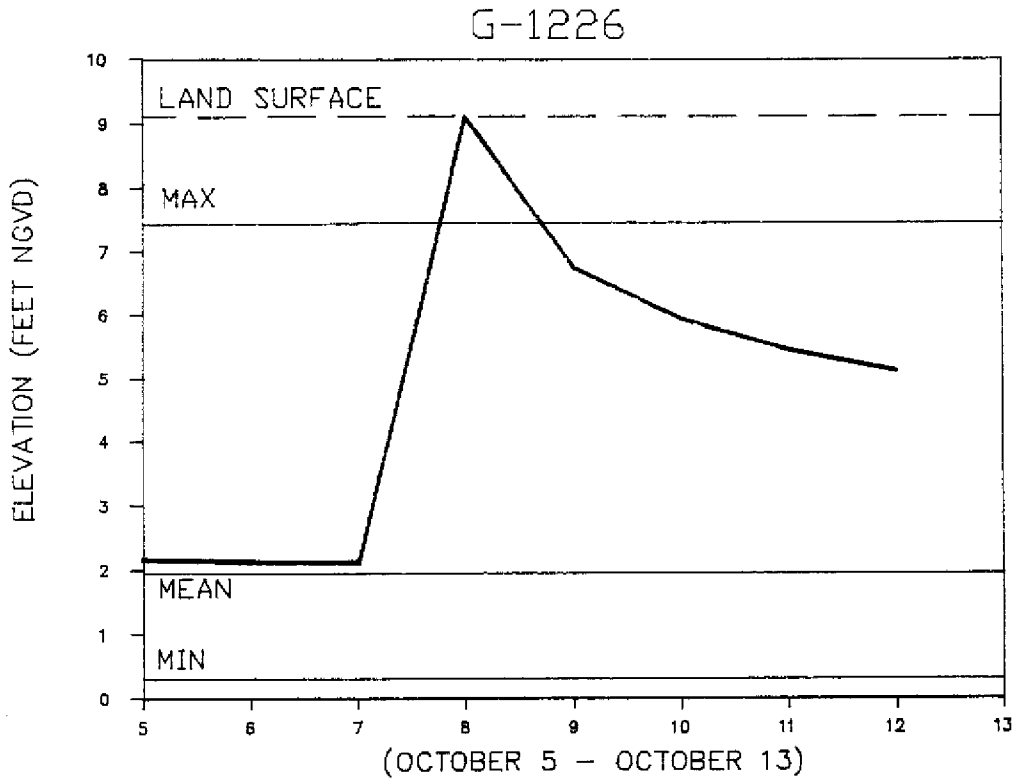


Figure B-6. Daily Groundwater Levels at North West Hollywood

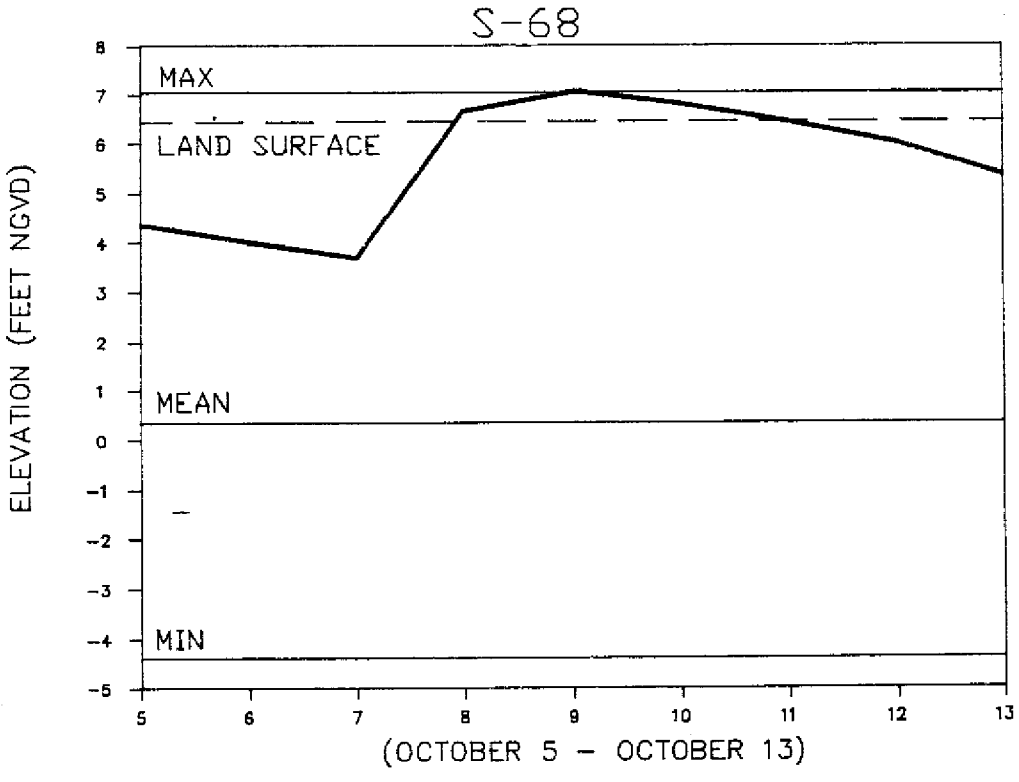


Figure B-7. Daily Groundwater Levels at Miami Springs

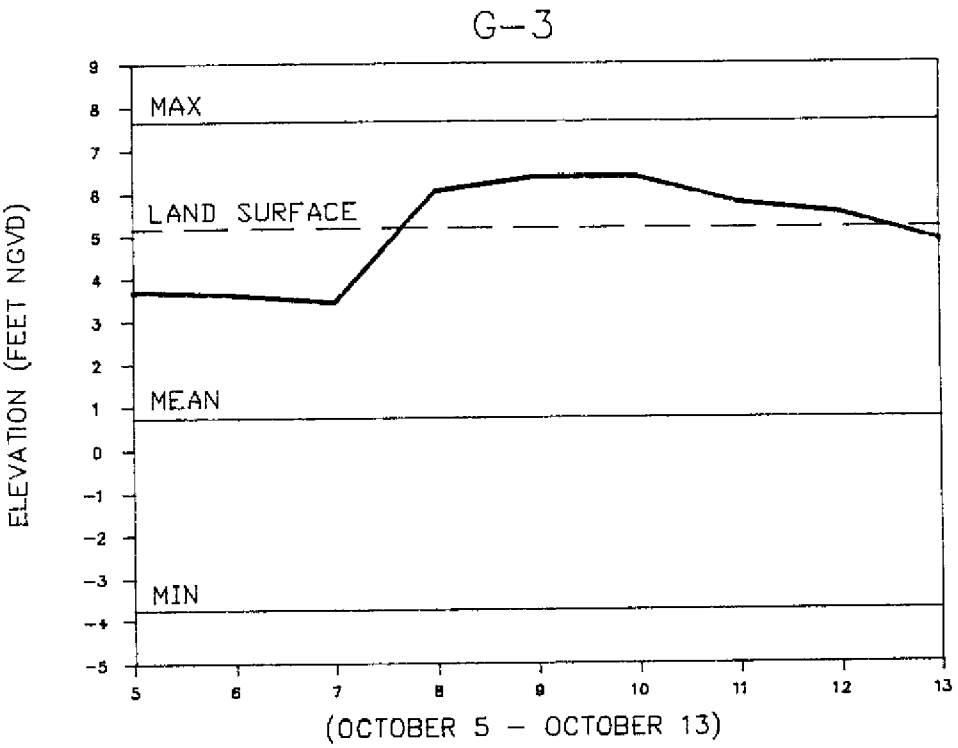


Figure B-8. Daily Groundwater Levels at Miami Springs

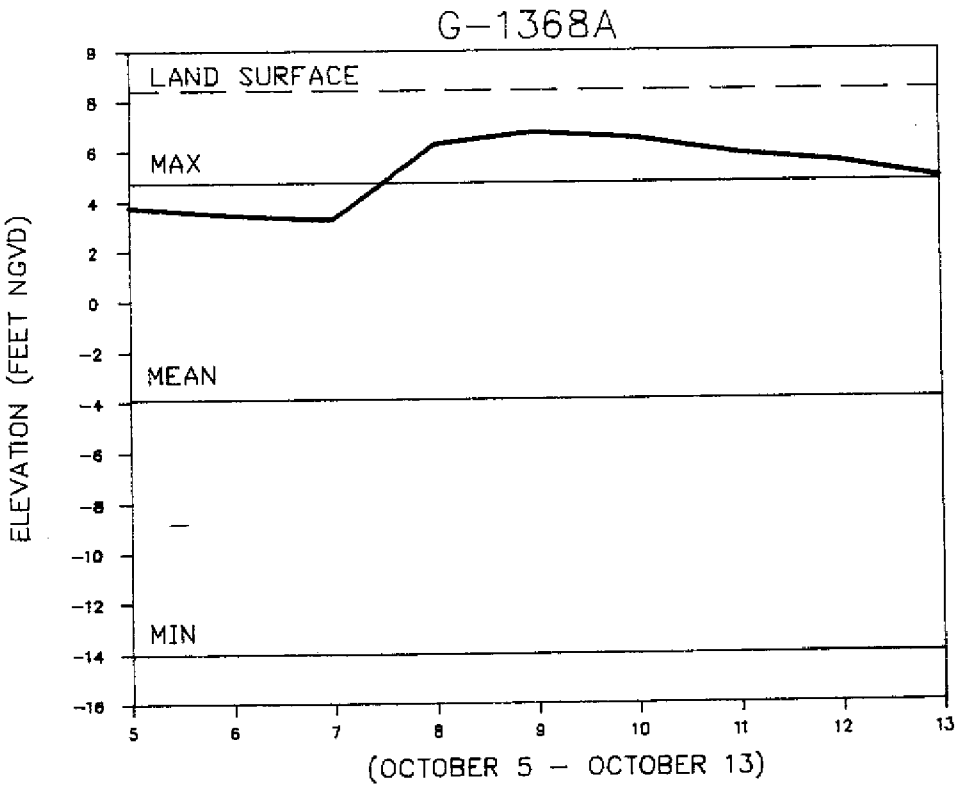


Figure B-9. Daily Groundwater Levels at Hialeah

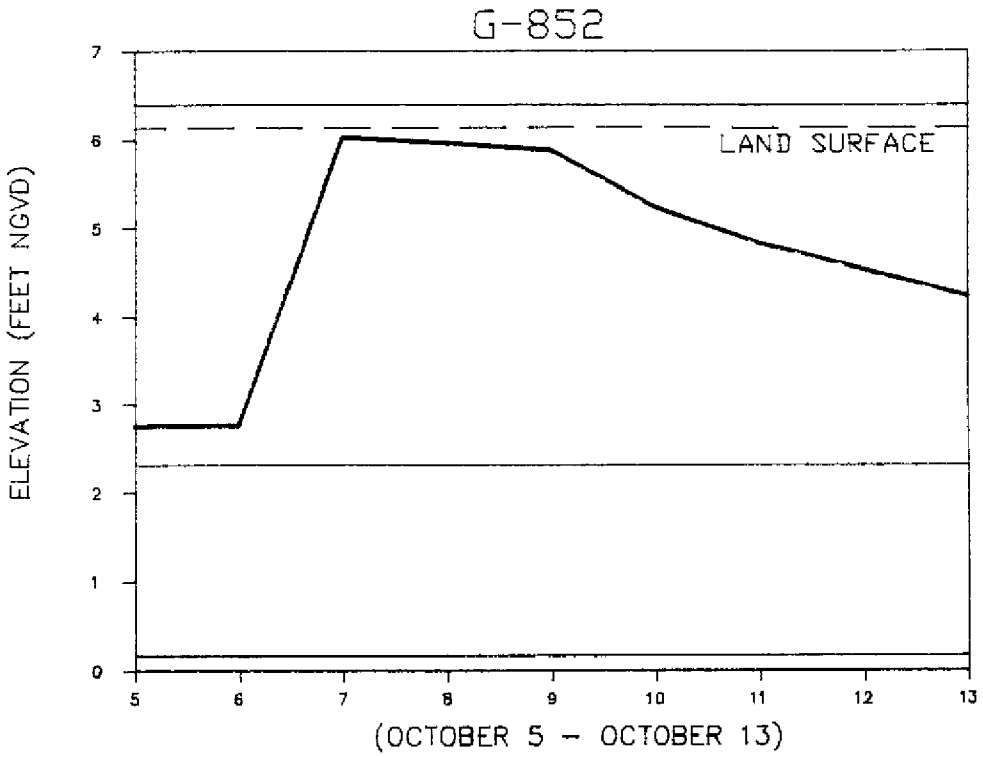


Figure B-10. Daily Groundwater Levels at North Miami Beach

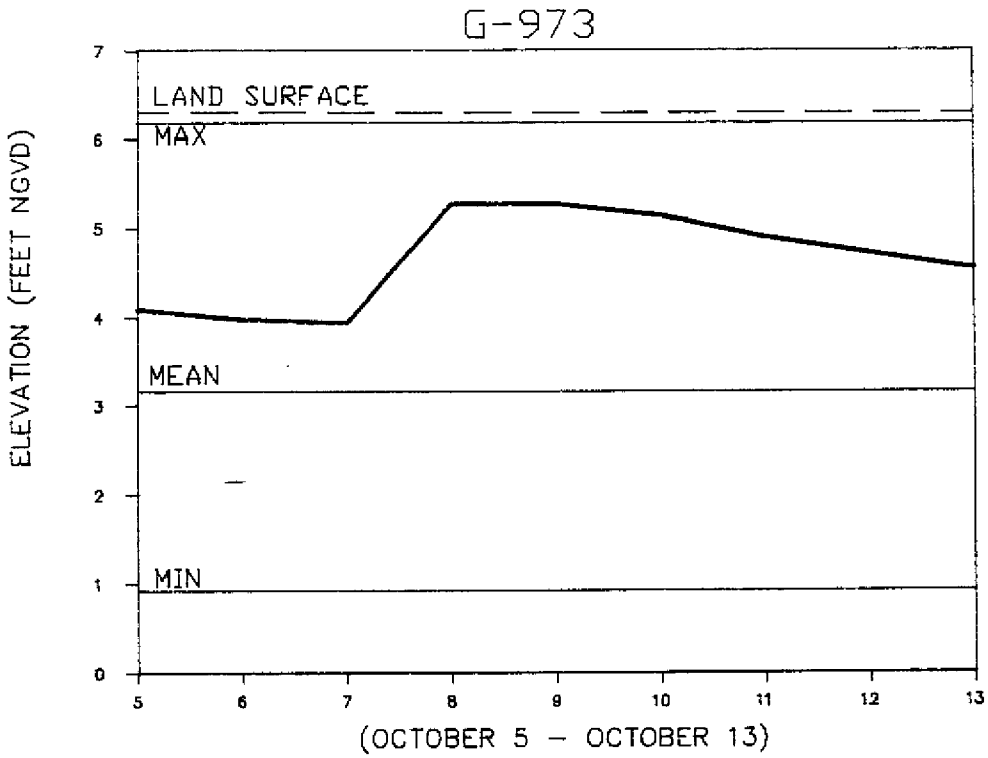


Figure B-11. Daily Groundwater Levels at Medley

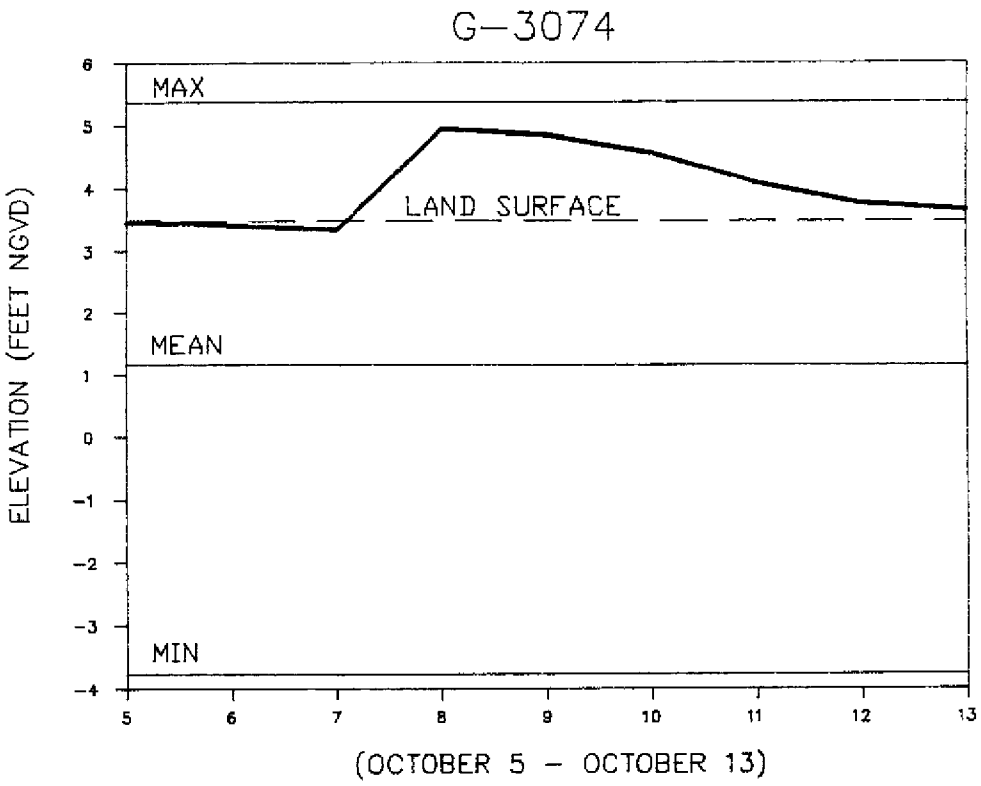


Figure B-12. Daily Groundwater Levels at South Miami

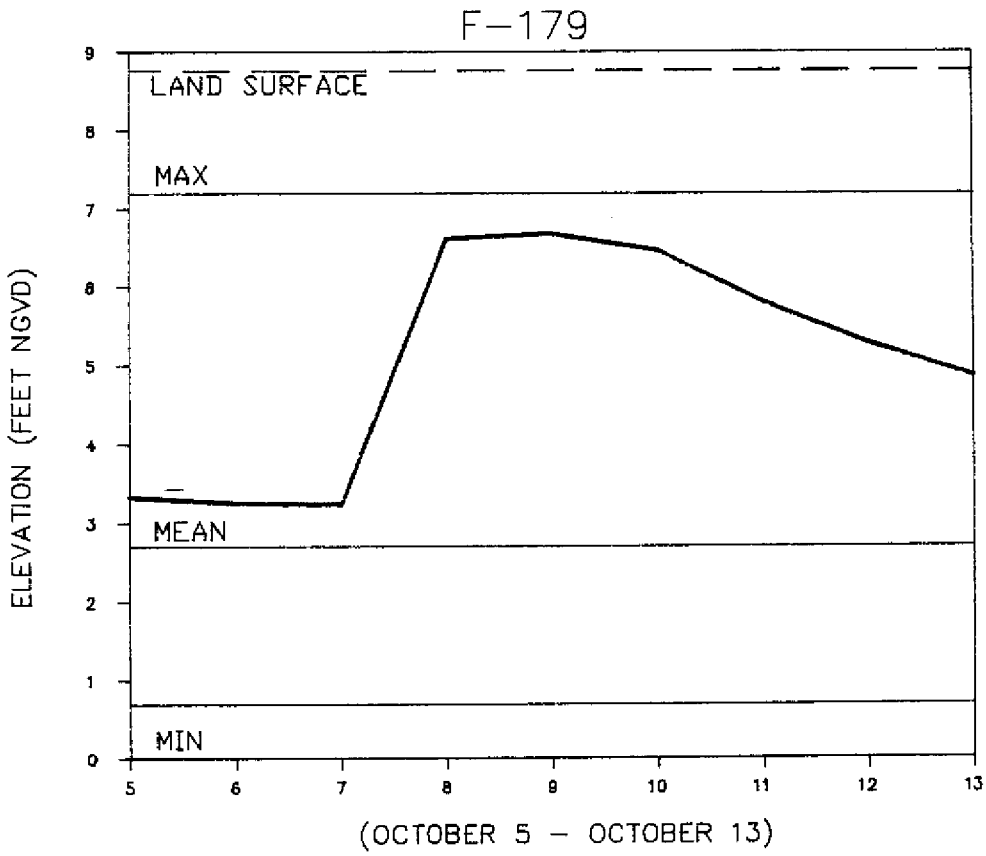


Figure B-13. Daily Groundwater Levels at Coral Gables

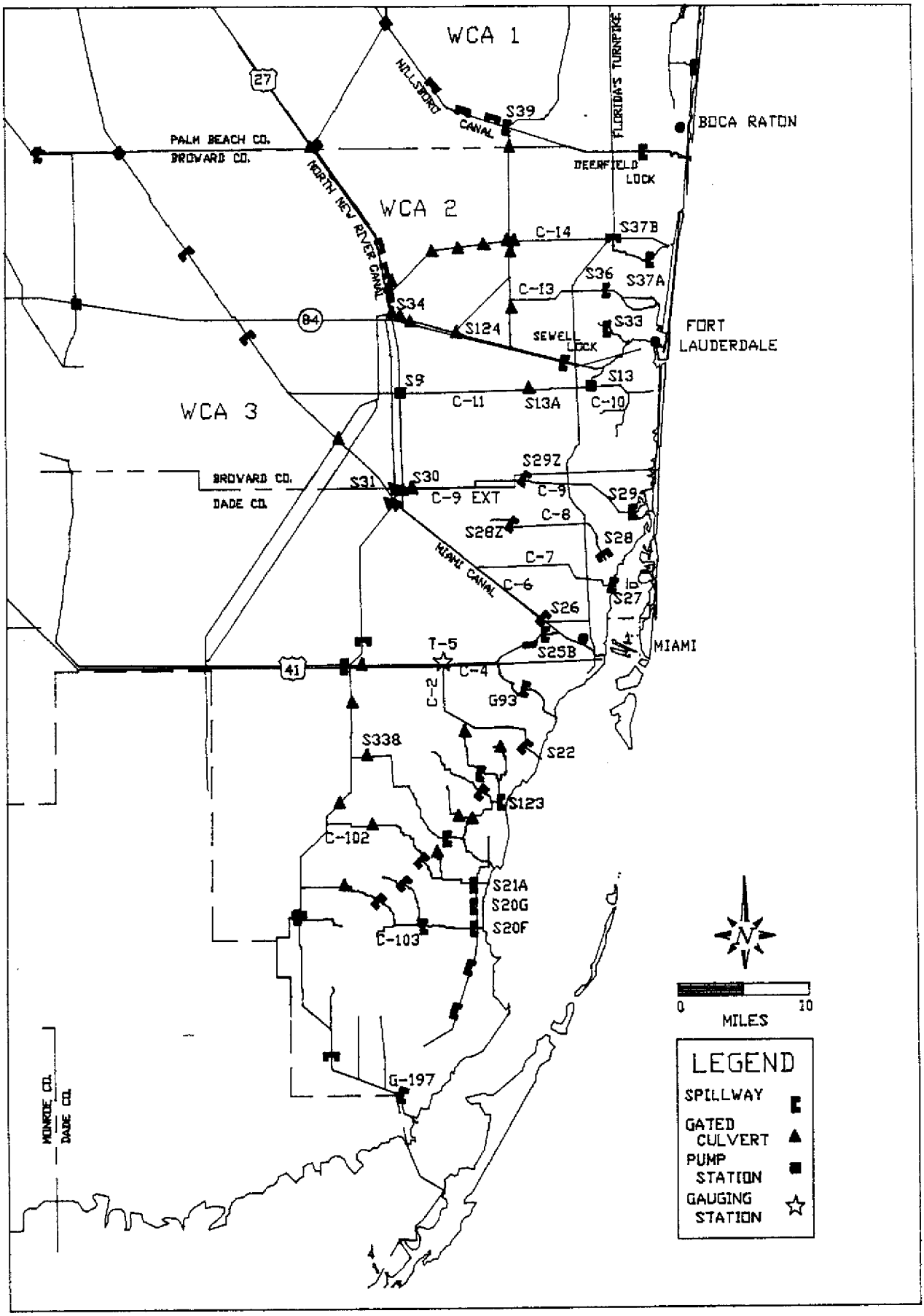
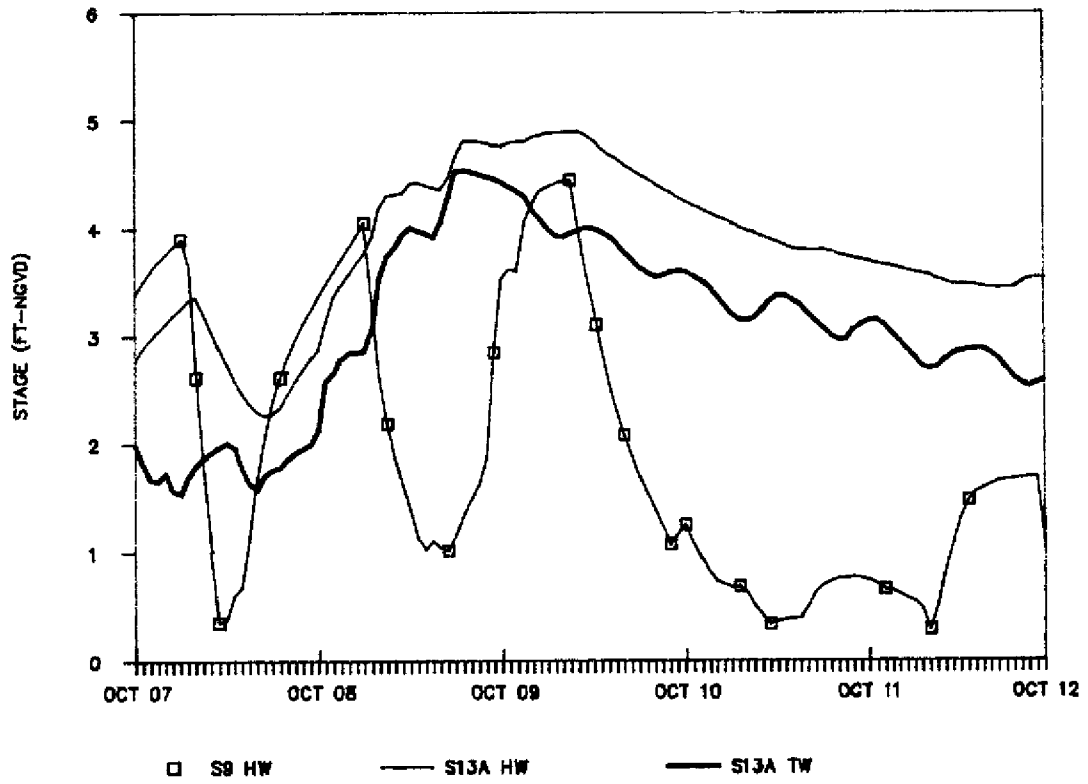


Figure B-14. Canal and Structure Location Map for the East Coast



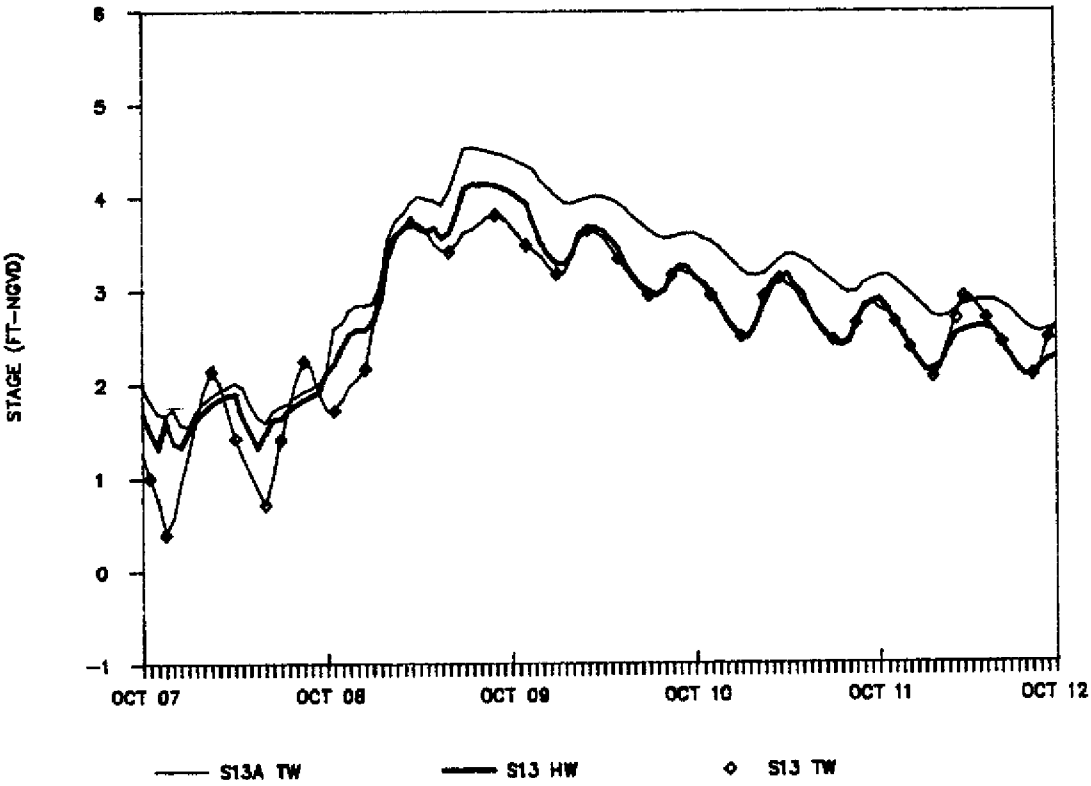


Figure B-15. Mean Hourly Stages in C-11 Canal

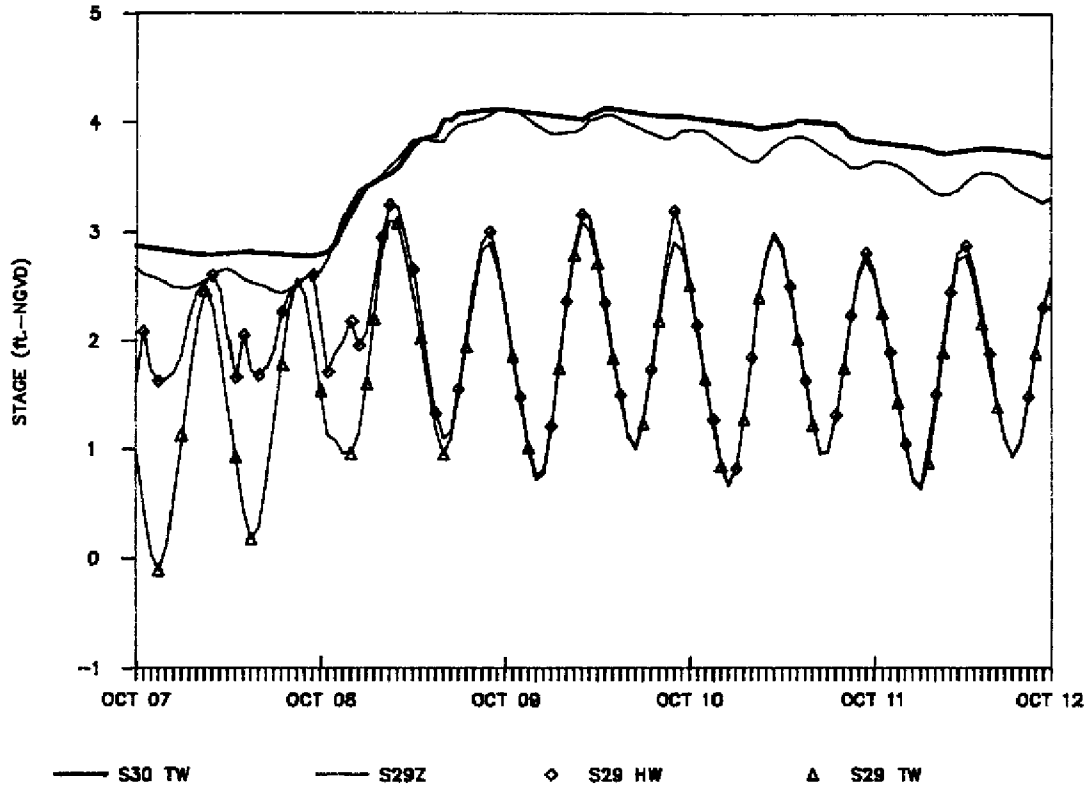


Figure B-16. Mean Hourly Stages in Snake Creek

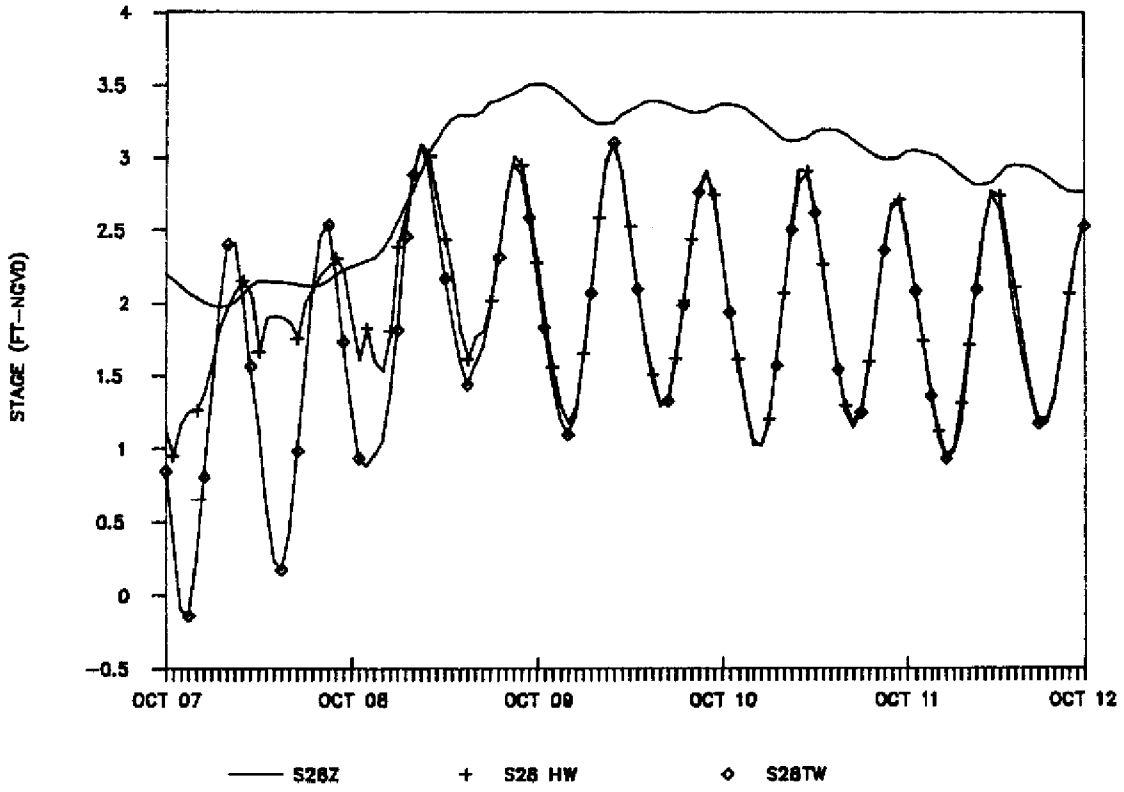


Figure B-17. Mean Hourly Stages in Biscayne Canal

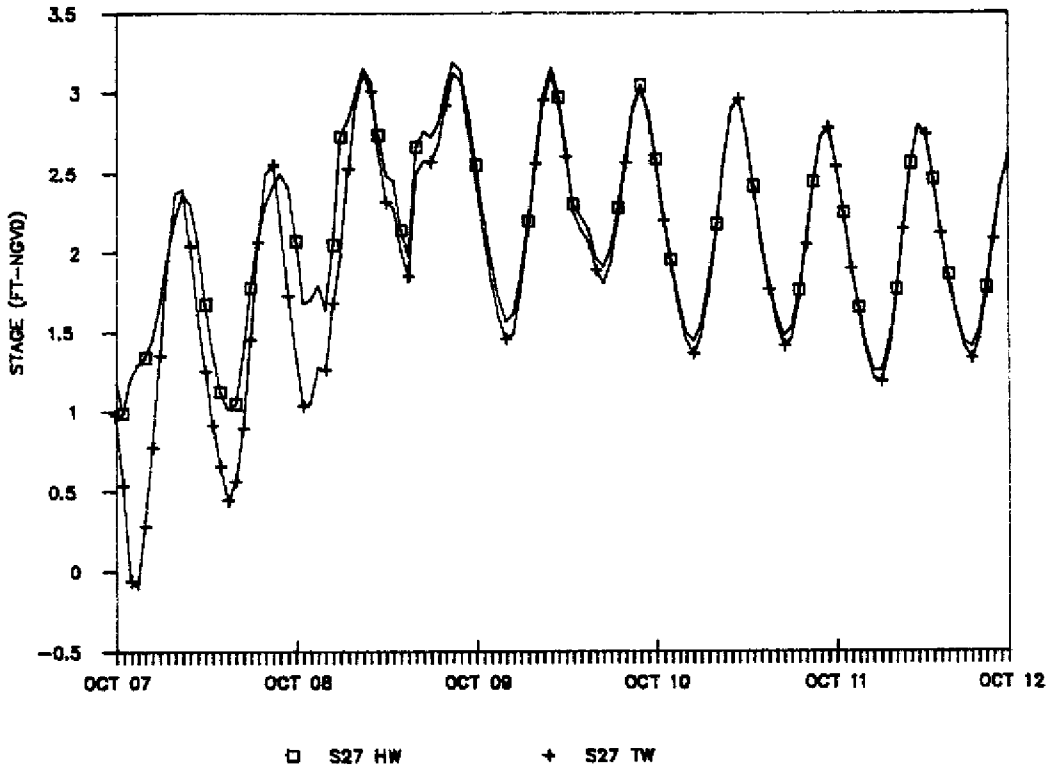


Figure B-18. Mean Hourly Stages in Little River

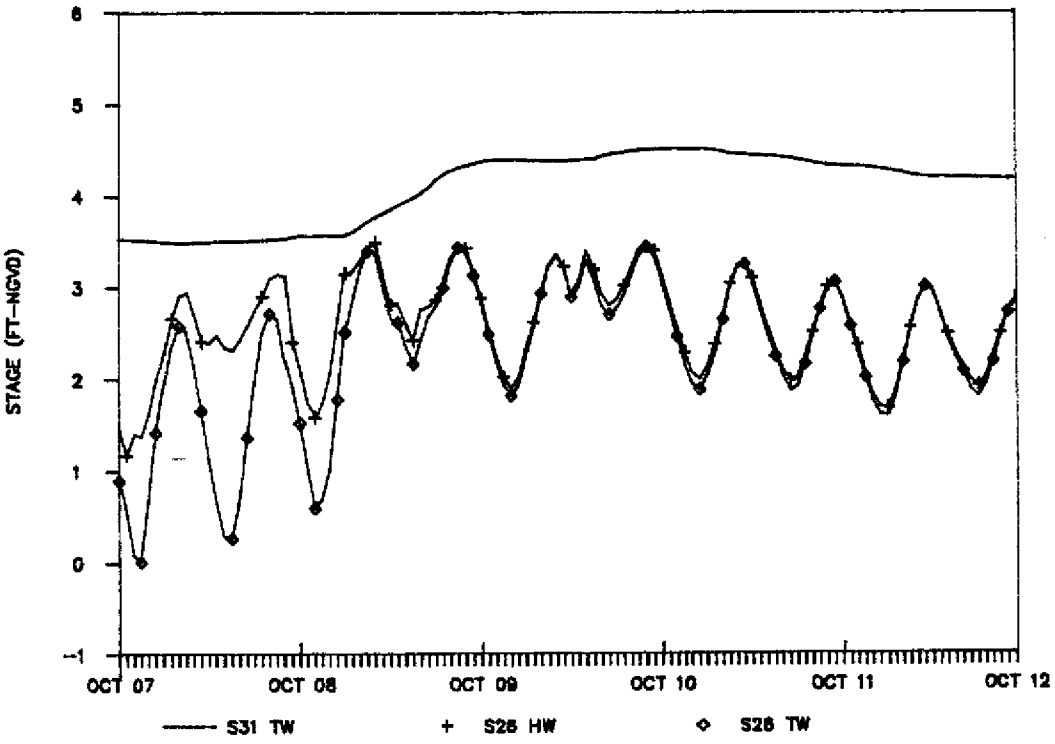


Figure B-19. Mean Hourly Stages in Miami Canal

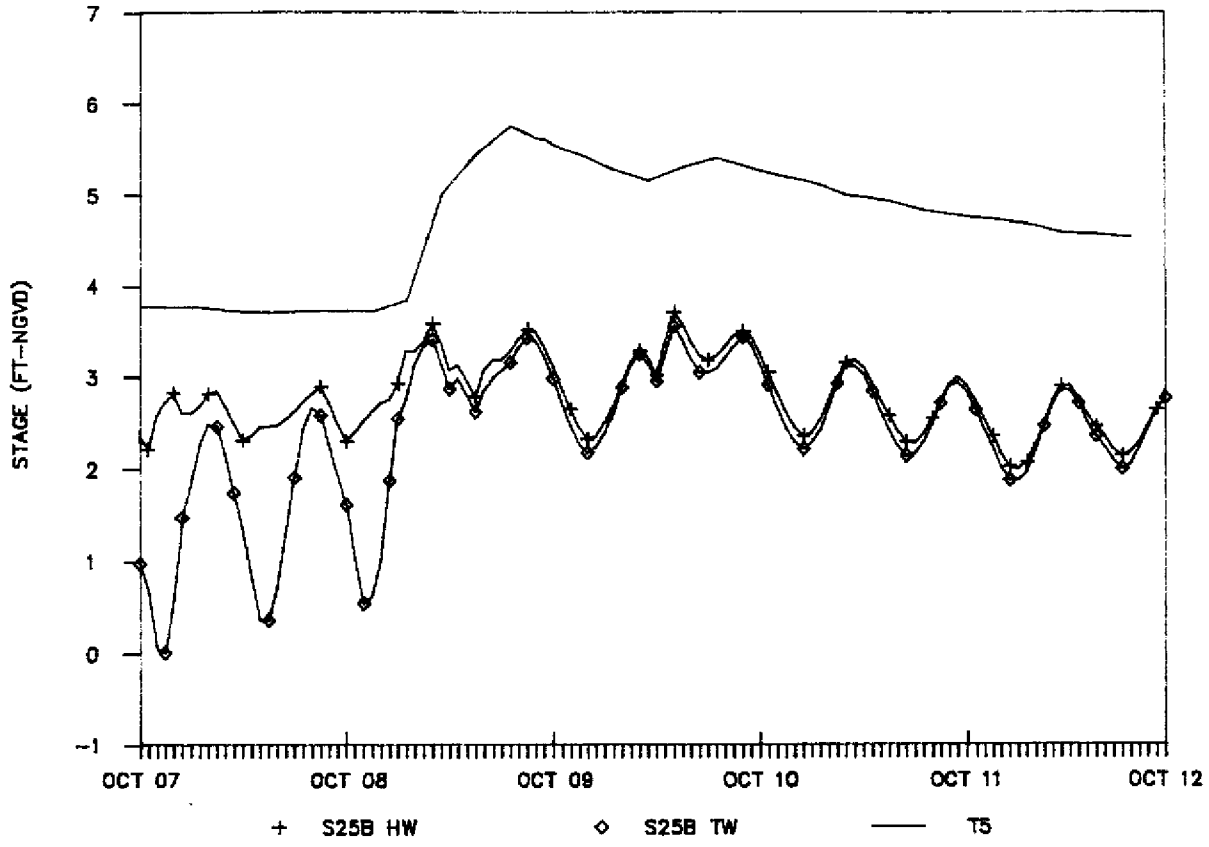


Figure B-20. Mean Hourly Stages in Tamiami Canal

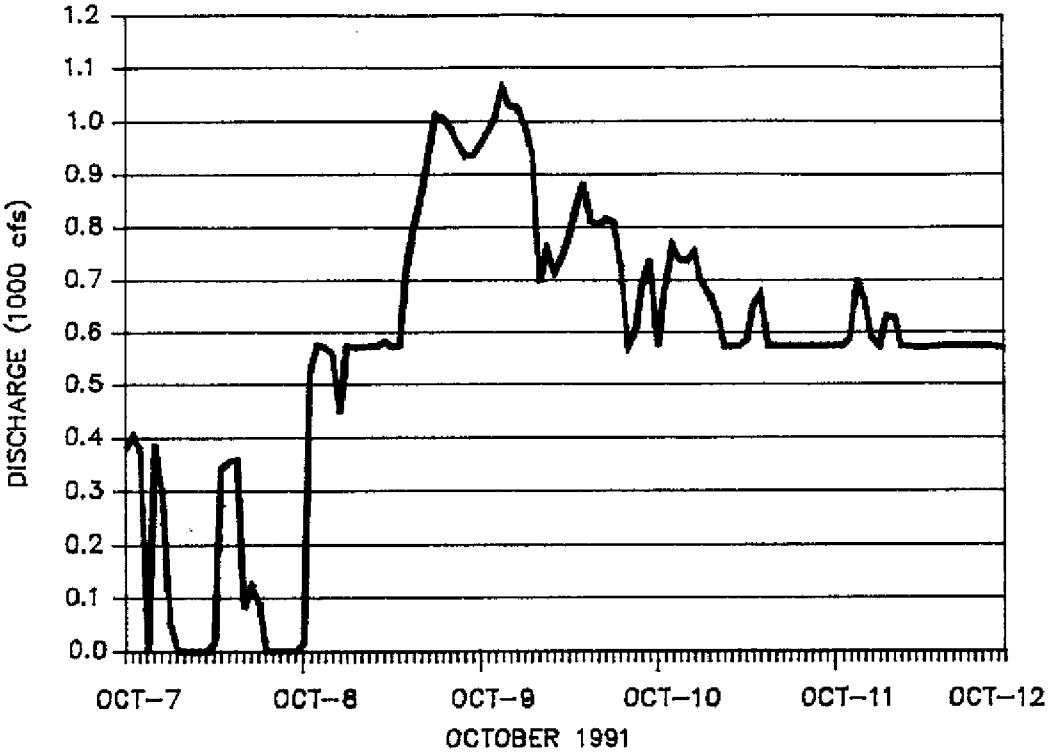


Figure B-21. Mean Hourly Discharges in C-11 Canal at S-13

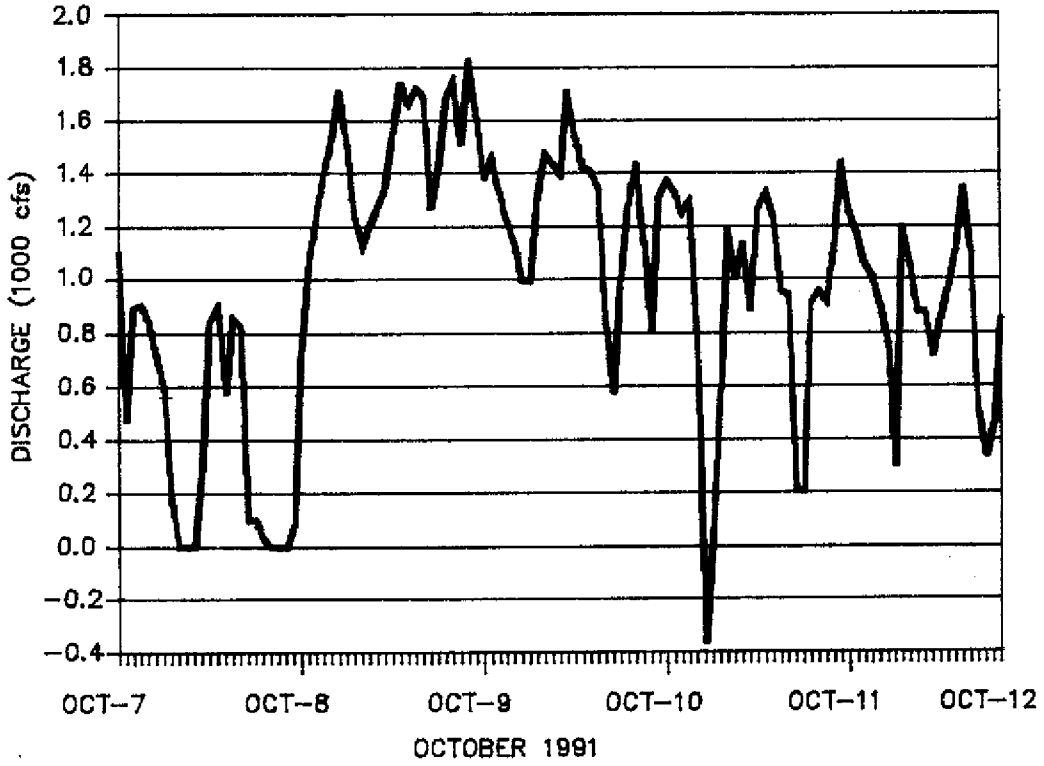


Figure B-22. Mean Hourly Discharges in Snake Creek at S-29

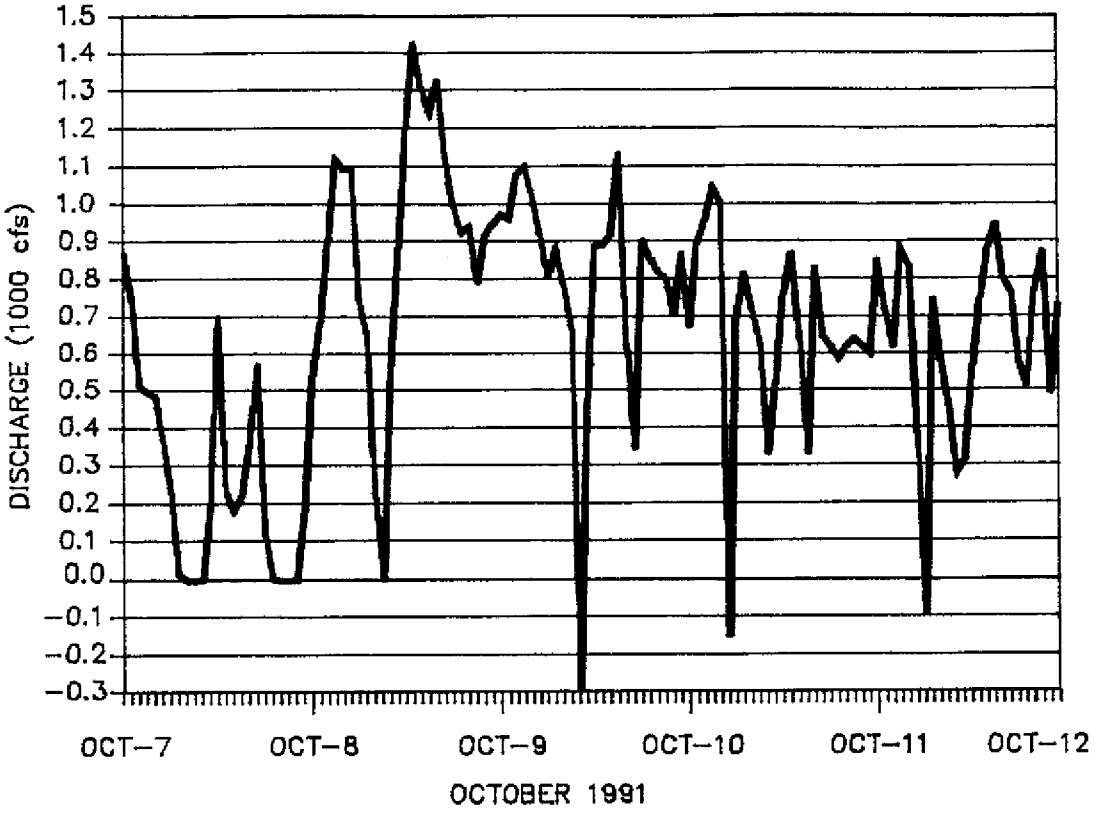


Figure B-23. Mean Hourly Discharges in Biscayne Canal at S-28

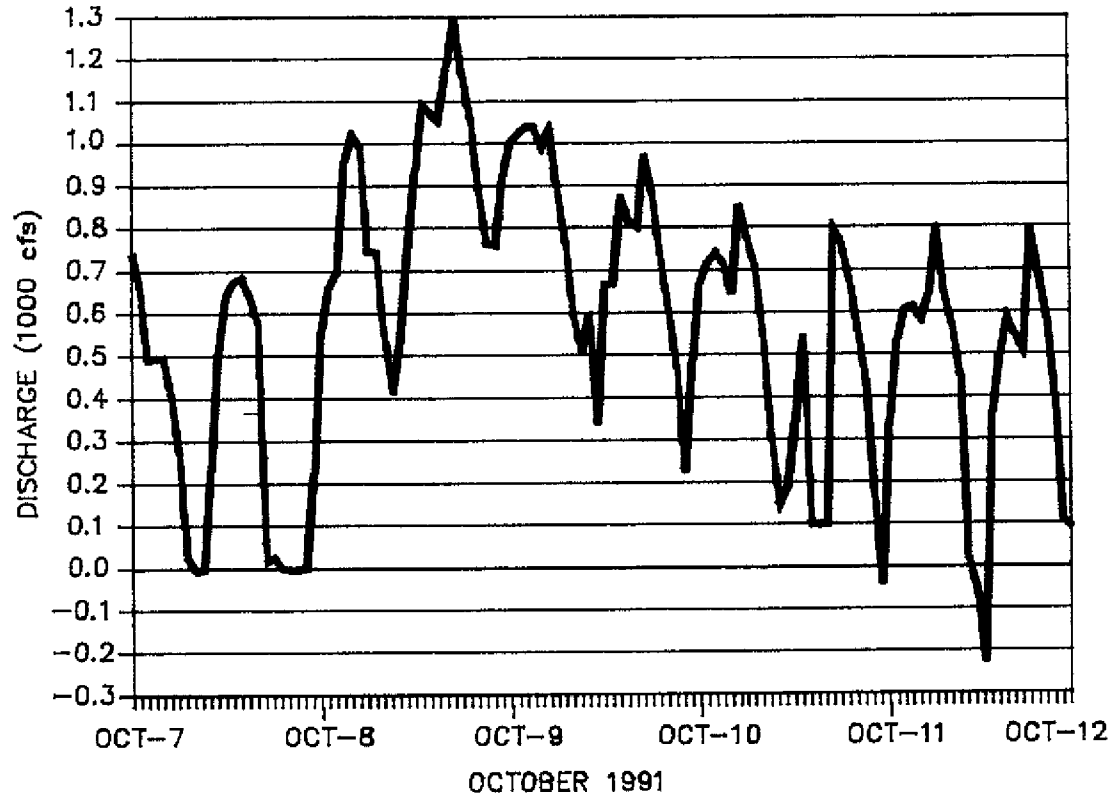


Figure B-24. Mean Hourly Discharges in Little River at S-27

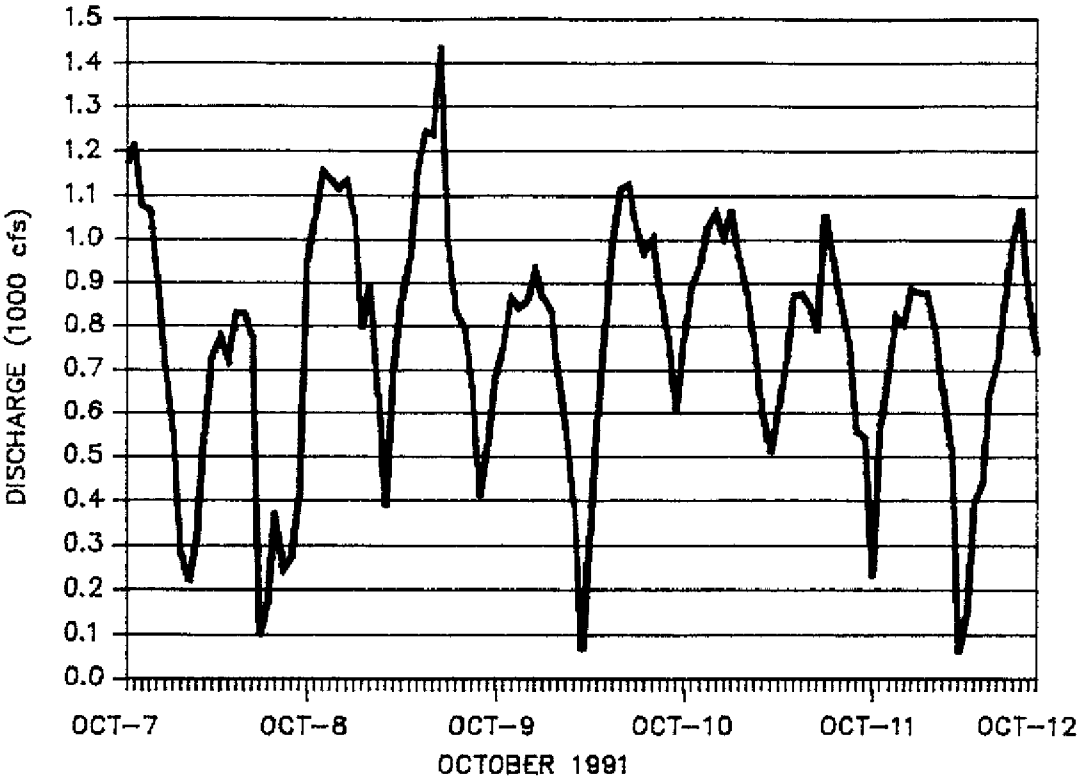


Figure B-25. Mean Hourly Discharges in Miami Canal at S-26

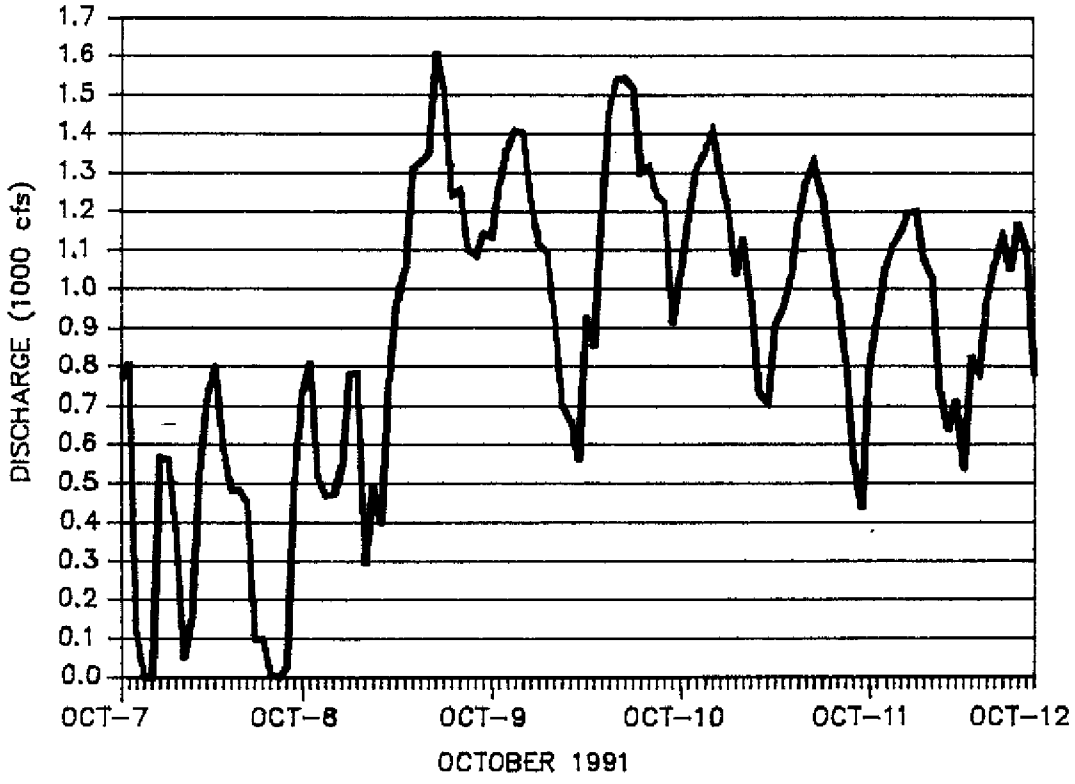


Figure B-26. Mean Hourly Discharges in Tamiami Canal at S-25B

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APPENDIX C

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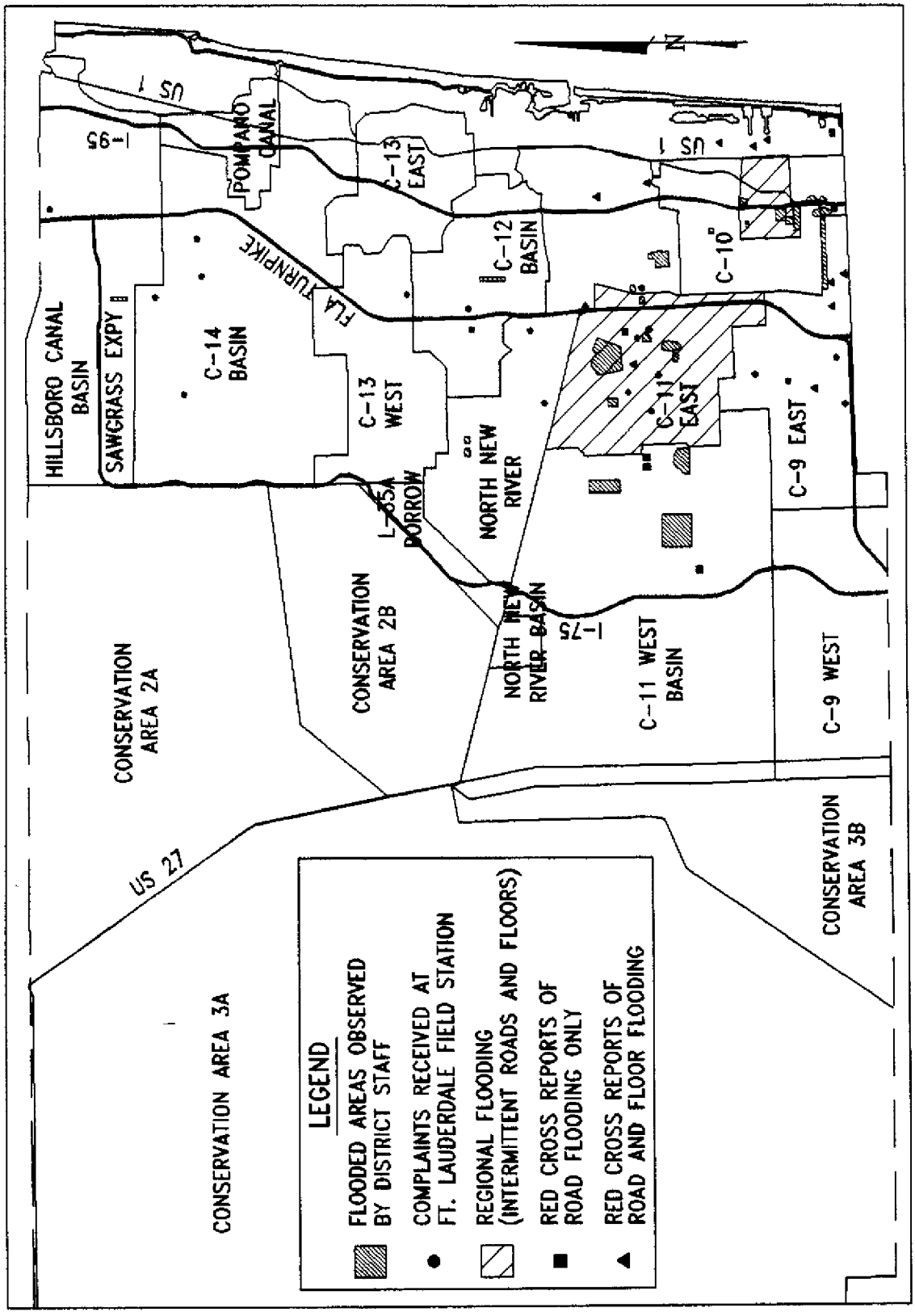

Figure C-1. Areas of Observed and Reported Flooding in Broward County

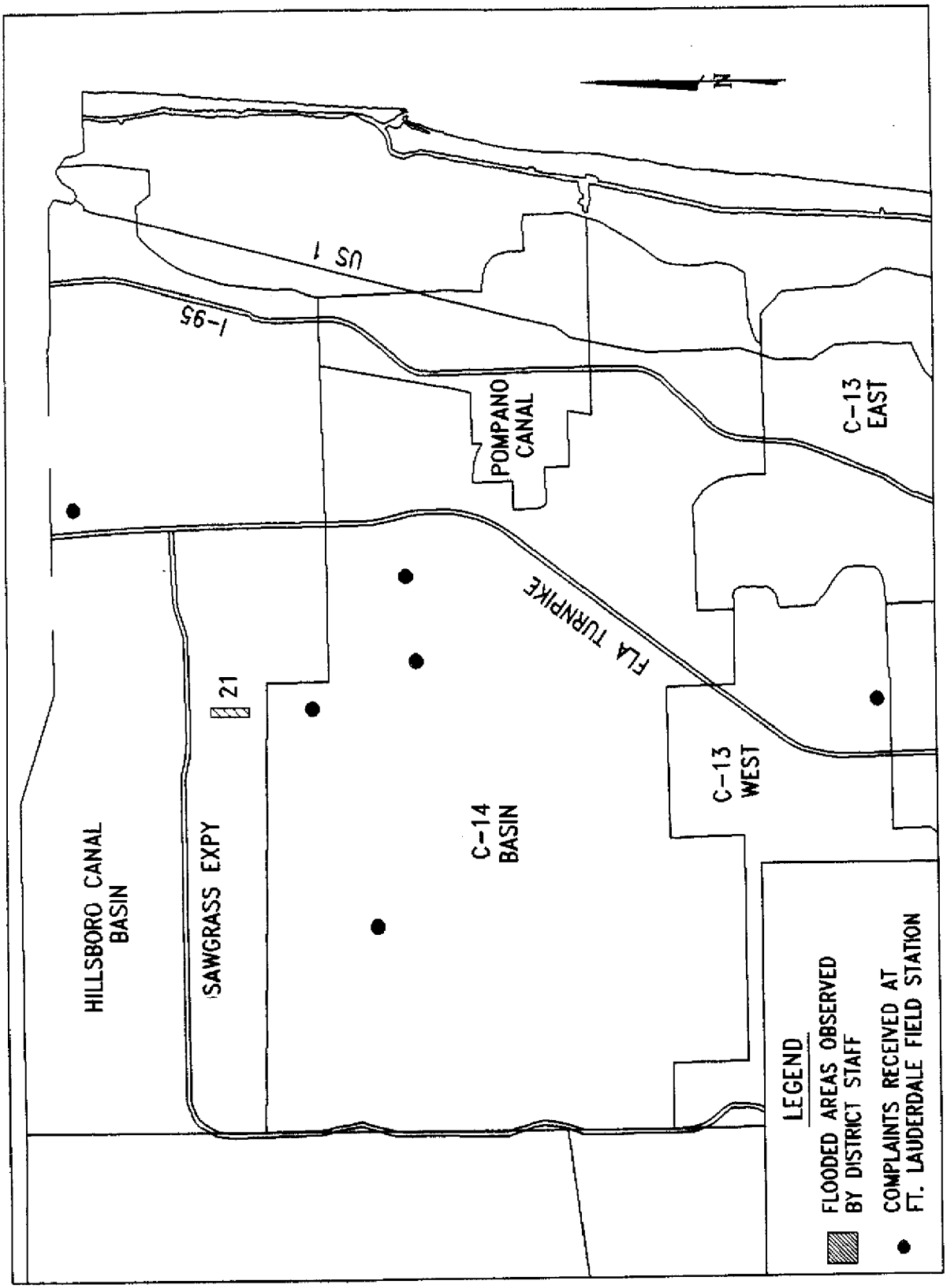

Figure C-2. Areas of Observed and Reported Flooding in North East Broward County

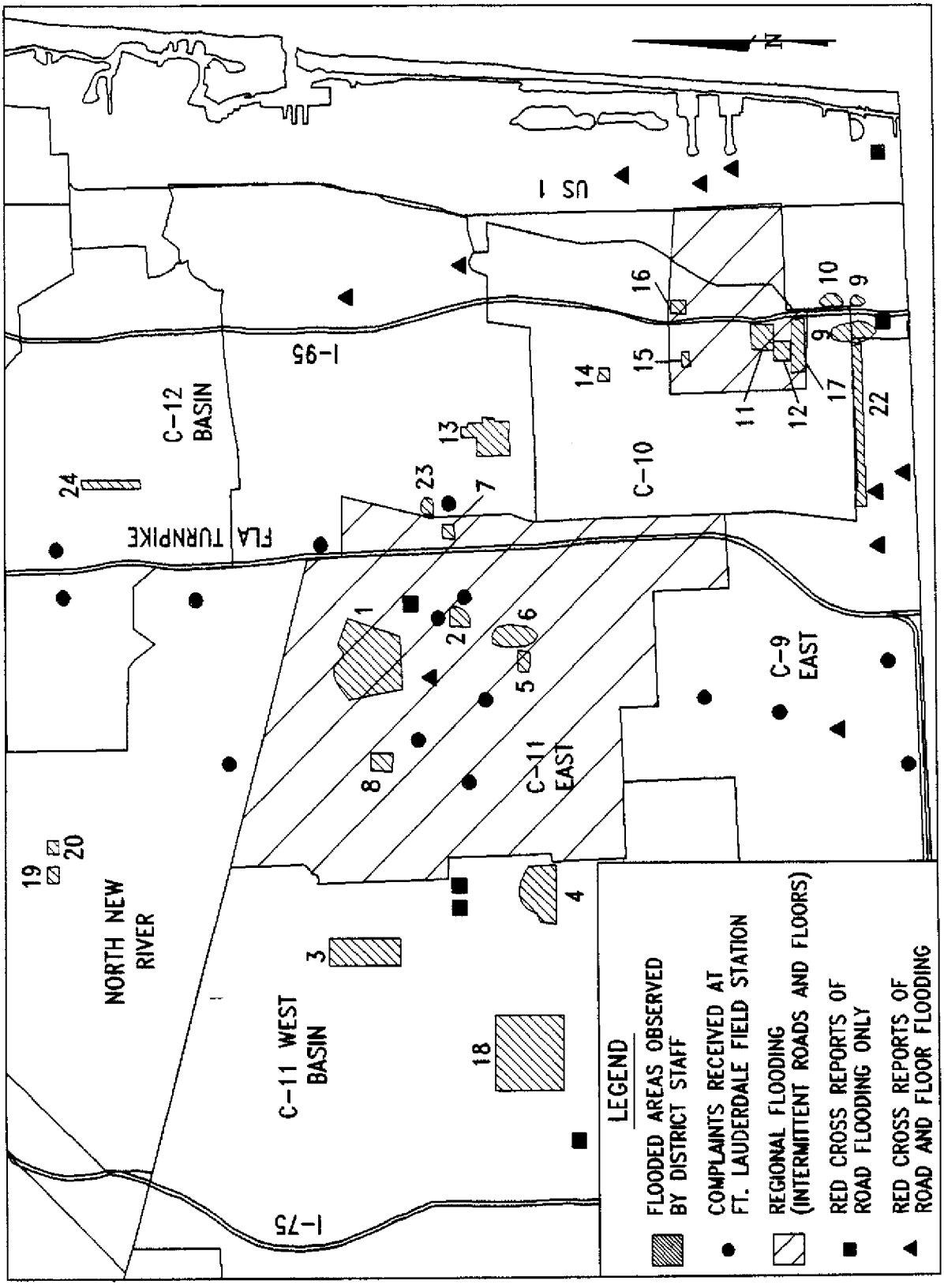

Figure C-3. Areas of Observed and Reported Flooding in South East Broward County

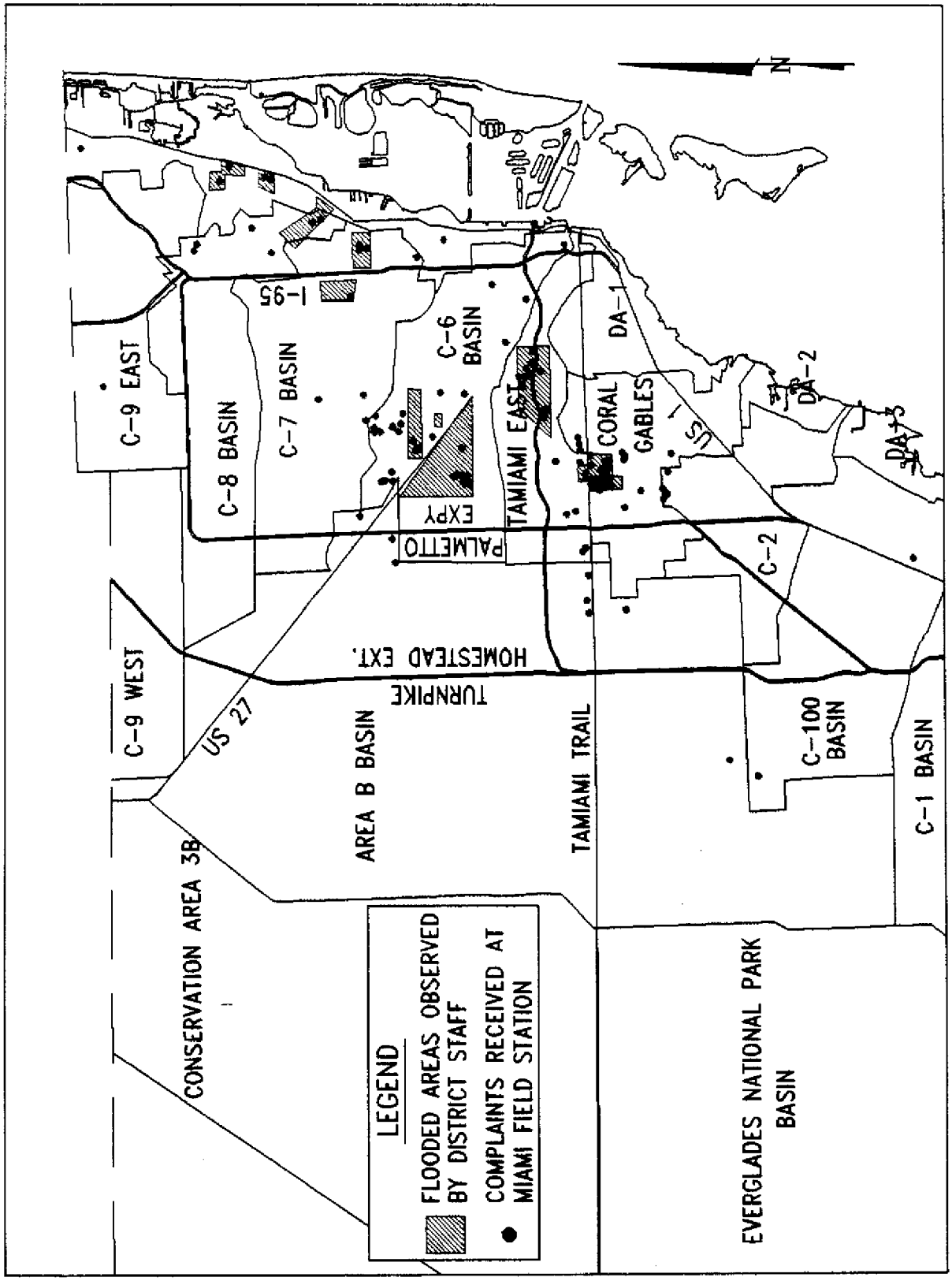

Figure C-4. Areas of Observed and Reported Flooding in Dade County

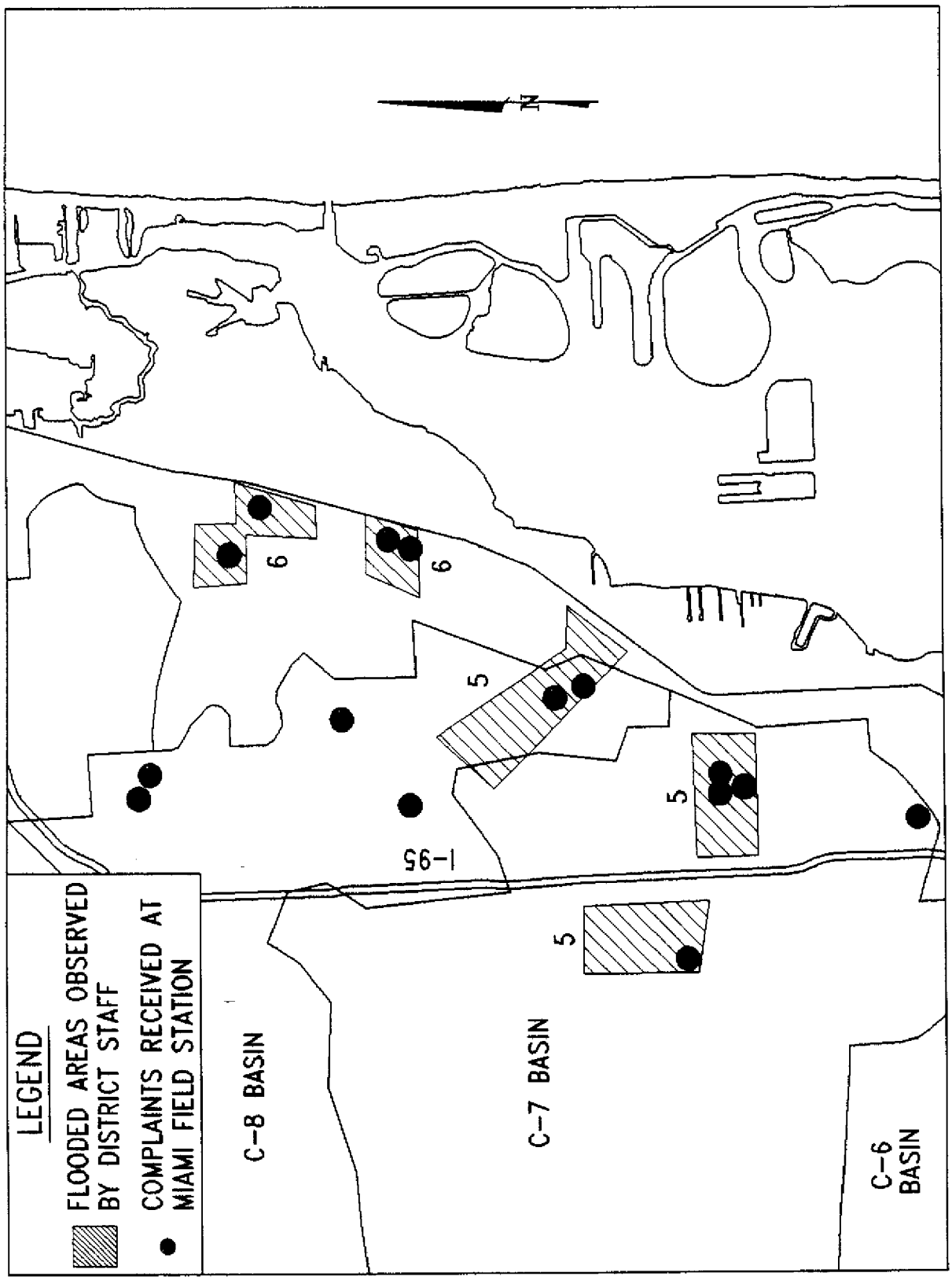

Figure C-5. Areas of Observed and Reported Flooding in North East Dade County

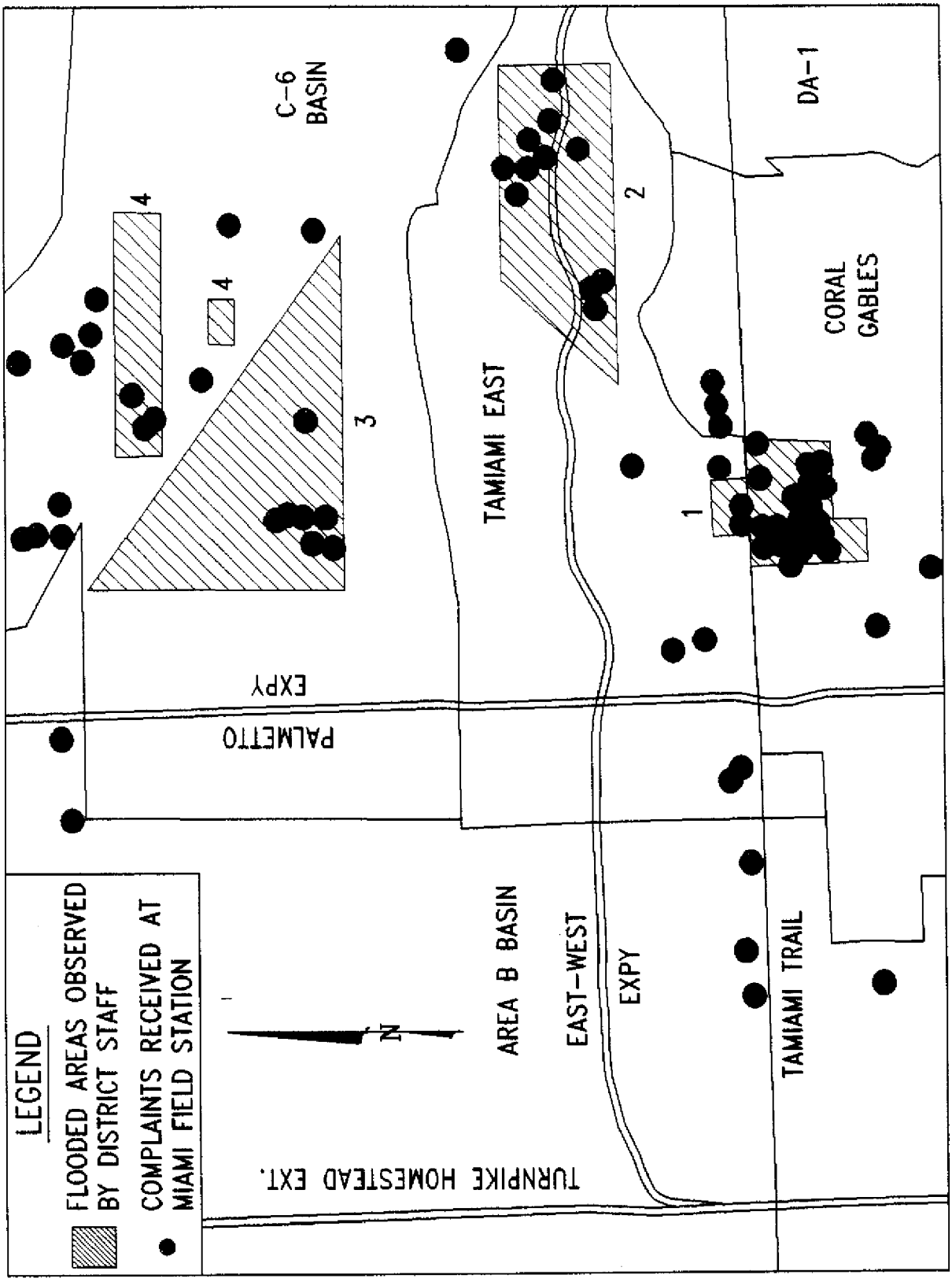

Figure C-6. Areas of Observed and Reported Flooding in Central Dade County

APPENDIX D

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PERMIT INFORMATION AND COMMENTS FOR PROJECTS WITHIN AREAS OF FLOODING IN BROWARD COUNTY
(Numbers in brackets correspond to location on figures C-2 and/or C-3)

Nova High School/University [1]

Permit 06-1472-S, Shepard Broad Law Center: The permitted minimum road elevation is 6.0 feet NGVD and the minimum floor was permitted at elevation 9.5 feet NGVD.

Permit 06-01205-S, Nova University physical plant: Permitted roads are at a minimum elevation of 6.0 feet NGVD and the minimum floor is permitted at elevation 8.0 feet NGVD.

Permit GP 83-17, cultural and living center: The minimum permitted parking lot elevation is 6.0 feet NGVD and the minimum floor elevation is 8.0 feet NGVD. The permitted control elevation for this site is only 5.4 feet NGVD, a mere 0.6 feet below the minimum parking lot elevation.

Permit 06-01640-S, Nova University, Rosenthal Student Center additions: The minimum roads were permitted at an elevation of 5.5 feet NGVD and the minimum floors at 8.39 NGVD feet.

Permit 06-00529-s, central vocational center: This area appeared to be outside of, but adjacent to, the flooded Nova High School area. Minimum permitted roads were at an elevation of 6.8 feet NGVD and floors at a minimum elevation of 9.0 feet NGVD.

Emerald Isles Apartments [2]

Permit 06-00728-S, Emerald Isles: This development had severe flooding in the parking lot and the air conditioning units were flooded. The minimum permitted parking lot elevation was 5.5 feet NGVD and the floor elevation was minimum of 7.0 feet NGVD/6.5 feet NGVD for existing buildings.

Majestic Groves [3]

Permit 06-01443-S, Crystal Grove Estates: This site appears to be adjacent to, but outside of the Majestic Groves area of flooding. The minimum permitted roads were at an elevation of 7.5 feet NGVD, and the floors were permitted at a minimum elevation of 8.5 feet NGVD.

Little Ranches [4]

Permit GP 78-22, J. R. Stone, Tract 37: Due to the age of this permit, there is no record of the minimum road or floor elevations.

Permit 06-01413, Twin Lakes: This site is located adjacent to, but outside of, the Little Ranches area of flooding. The roads were permitted at a minimum elevation of 7.0 feet NGVD and floors permitted at a minimum elevation of 8.5 feet NGVD.

52 Street, Davie [5]

Permit 06-00953-S, Exotic Acres: The roads were permitted at a minimum elevation of 6.0 feet NGVD and the floors permitted at a minimum of 7.5 feet NGVD.

Winn Dixie Supermarket [10]

Permit GP 86-115, Lakeside Shops: This project is located adjacent to, but outside of, the area of flooding. The minimum permitted parking lot elevation is 6.0 feet NGVD, the minimum road elevation is 6.9 feet NGVD, and the minimum floor elevation 8.75 feet NGVD.

Sunshine Acres [18]

Permit 06-01303-S, Heavenly Acres: Although roads and floors were not flooded, there were drainfield operation problems. Minimum roads were permitted at an elevation of 7.0 feet NGVD and floors at a minimum of 8.0 feet NGVD.

Permit 06-01115-S, St. Mark's Catholic Church: No roads were flooded with a minimum permitted elevation of 7.0 feet NGVD. No floors were flooded which were permitted at a minimum elevation of 8.0 feet NGVD.