

EFFECT OF HURRICANE BETSY
ON
PROJECT SALINITY STRUCTURES
OF THE
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT
SEPTEMBER 1965

Prepared By
Central and Southern Florida
Flood Control District

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September 1965

GENERAL RESUME OF HURRICANE BETSY

Hurricane Betsy began as a tropical disturbance in the southwestern Atlantic Ocean on August 27, 1965. It reached hurricane force northeast of Puerto Rico, traveling in a general northwesterly direction, (Plate 1). A high pressure area off the South Carolina coast caused Betsy to practically reverse its direction on September 5, turning southeastward into the Bahamas. Winds increased from 125 to 150 miles per hour as it passed slightly north of Nassau on September 7, and headed due west toward the lower end of the Florida peninsula.

As the eye approached the mainland, the wind effect on the tide increased. Gale winds extended outward 300 miles from a center about 40 miles in diameter. The eye reached the area of Key Largo at approximately 4:30a.m., September 8, with a wind velocity ranging from 100 to 140 miles per hour, and a forward speed of approximately 12 miles per hour. Its forward movement increased to 18 miles per hour as it moved westward immediately adjacent to the Florida coast, turning northwesterly on September 9, to hit the Louisiana coast at Grand Isle at approximately midnight. The maximum estimated wind in the Florida area was 160 miles per hour at the Flamingo Ranger Station on Key Largo, and the lowest barometric pressure was 28.12 inches at Tavernier.

Hurricane winds extended north along the coast to West Palm Beach, with gusts of 72 miles per hour being experienced as far north as Vero Beach. Tides varied from 3.0 feet above mean sea level at West Palm Beach, to 10.1 feet east of Homestead. Broward County tides approximated 5.7 feet above mean sea level. Above normal tides and high seas with resulting damage was extensive as far north as St. Lucie County. Summaries of the flooding and damage are given in "The Report on Flood 7-9 September 1965 in Central and Southern Florida", by the Corps of Engineers, and in a report, "Hurricane Betsy - September 8, 1965", by the Water Control Division, Dade County Public Works Department.

Data is not available on the estimated financial loss caused by wind, and by flooding. Of the estimated \$139 million damage in the State, of which \$125 million was in Dade County, by far the majority was the result of wind and wave action.

RAINFALL

Rainfall attributable to Betsy started falling in south and central Florida on September 6, and continued through September 8. Rainfall for that

area below the north shore of Lake Okeechobee, is shown on Plate 2. This isohyetal map indicates that the rainfall decreased from a maximum of 10.9 inches east of Homestead to 1.0 inches immediately north of Lake Okeechobee. A comparison of Betsy rainfall on Dade, Broward and Palm Beach Counties, and the Everglades National Park, with that of Hurricanes Donna, Cleo, and tropical storm Florence, is as follows:

Location	AVERAGE RAINFALL			
	Donna Sept. 9-10, 1960	Florence Sept. 21-25, 1960	Cleo Aug. 26-28, 1964	Betsy Sept. 6-8, 1965
Dade County	8.5	5.9	2.30	5.2
Broward County	5.0	5.1	3.32	3.0
Palm Beach County	2.9	6.2	3.37	1.5
Everglades National Park	5.9	4.6	0.43	6.4

The Betsy rainfall as predicted by the U.S. Weather Bureau, ranged from 5 to 10 inches for the Dade County area, to 4 to 5 inches for the Palm Beach area.

The Project canals of the Central and Southern Florida Flood Control District, Plate 3, vary in design capacity, depending on urban and agricultural use, from a once in 10-year runoff to approximately a once in a 150-year runoff. The Betsy rainfall in Dade County had a frequency of approximately once in four years. The low ground water table absorbed much of this rainfall, resulting in less than design runoff into Project canals.

Extensive flooding existed however in areas where secondary drainage was not sufficient to convey water to the Project canals of the District. This was particularly true in the coastal areas of Broward County.

A portion of the Project canals in Dade and Broward Counties were affected for varying distances upstream by tidal flow. The degree these stages were the result of rainfall, or of tides, cannot be determined since the volume of tidal water inflow is not available. Plates 4 and 5 indicate peak stages which occurred in specific locations in Dade and Broward Counties.

Stages in representative canals in comparison with past storm occurrences are as follows:

<u>Canal</u>	<u>Donna</u> <u>Sept. 8-11,</u> <u>1960</u>	<u>Florence</u> <u>Sept. 21-25,</u> <u>1960</u>	<u>Cleo</u> <u>Aug. 26-28,</u> <u>1964</u>	<u>Betsy</u> <u>Sept. 6-8,</u> <u>1965</u>
C-9 at N.W. 67th	3.88 (10th)	3.46 (25th)	3.40 (28th)	3.56 (9th)
C-8 at Red Road	3.62 (7th)	3.06 (24th)	2.55 (28th)	2.96 (8th)
C-7 at Palm Ave.	5.00 (10th)	3.82 (23rd)	2.81 (27th)	2.75 (8th)
Miami Canal at Broken Dam	5.00 (11th)	5.17 (24th)	4.50 (28th)	4.66 (9th)
Snapper Creek Canal at Miller Drive	6.43 (10th)	5.79 (23rd)	2.94 (27th)	4.24 (8th)
Goulds C. at Salinity Structure	-	1.94 (23rd)	2.05 (30th)	5.24 (8th)
C-13 at S-36	-	-	1.10 (28th)	4.00 (9th)
C-14 at S-37A	-	-	3.46 (28th)	3.45 (8th)
W.P.B. Canal - U.S. Hwy. 1	5.15 (10th)	8.76 (24th)	6.96 (27th)	3.20 (7th)

Predicted tide heights provided the Flood Control District by the U.S. Weather Bureau were relatively close to those actually obtained. These predictions ranged from 6 to 10 feet above normal in upper and lower Biscayne Bay, to approximately 3 feet above in the Palm Beach area, and are illustrated by Plates 4 and 5. A comparison of some representative stages in Dade County with past hurricanes is shown below.

<u>Hurricane</u>	<u>Miami Beach</u> <u>Ocean Pier</u>	<u>Miami</u>	<u>Coconut</u> <u>Grove</u>	<u>East of</u> <u>Homestead</u>	<u>Key</u> <u>Biscayne</u>
Betsy-1965	5.1	5.9	7.4	10.1	6.4
Donna-1960	3.2	4.8	5.0	7.3	-
September-1945	4.3	6.4	9.9	13.7	-
November-1935	-	6.7	8.3	8.0	5.5
September-1926	-	10.9	13+	-	8.0

Tide charts for the period September 6-11, are shown on Plate 6 for Biscayne Bay at 79th Street Causeway, Biscayne Bay at Coconut Grove, and Florida Bay at Flamingo. The approaching hurricane had little effect on the east coastal tides until the 7th when the wind began to veer from the north to the east. Peak stages were reached on the east coast at approximately 7:30a.m. when the eye was approximately 115 miles south-southeast of Miami. These peaks occurred approximately one hour prior to the high tide, and would have been even higher had the peak hurricane tide and high tide occurred concurrently.

Peak hurricane wind in Florida Bay at Flamingo occurred at approximately

2:00p.m. on the 8th, as the winds turned from the east and blew from the south, with the resultant movement of the shallow waters of the Bay against the shore. The peak stage of 7.4 feet mean sea level resulted from the hurricane and high tide occurring at approximately the same time.

PROJECT SALINITY STRUCTURE PERFORMANCE

The control structures at the lower end of the District's Project canals have two primary purposes, (1) to establish an upstream stage for maintaining a suitable ground water table by holding a head on the structure, and (2) to prevent normal tidal salinity encroachment upstream of the structure. However, these structures were not designed for high storm tides. These structures are listed in Table I, with pertinent information, including the maximum upstream stage resulting from Betsy.

The general structure operation procedure consisted of partially, or fully opening, all the structures prior to the hurricane to reduce the canal and ground water stages before the anticipated heavy rainfall. As the hurricane approached the coast the structures were set to predetermined openings the afternoon and evening of September 6th, (Plate 7). The automatic gates are designed to open or close to maintain a desirable upstream stage. They are also designed to close completely if the downstream tidal stage reaches an elevation 0.2 foot below the upstream stage. The automatic structures were all placed on manual operation since a possible power failure might occur while the gates were closed, and the possibility of extreme high tides flooding the control houses constitutes a hazardous condition for occupancy. The openings made immediately prior to the hurricane were designed to permit the anticipated rainfall to discharge through the structure without creating damaging stages before the gates could be adjusted. It was necessary, however, to hold this opening to a minimum to prevent damaging salinity encroachment from the anticipated high tides.

Winds of 40 to 50 miles per hour on the afternoon of the 6th made it mandatory that gates be set at predetermined openings prior to a possible loss of power and the occurrence of exceptionally high tides predicted by the U.S. Weather Bureau. These openings are underlined on Plate 7, and were based on, (1) the existing upstream stages when set, (2) anticipated runoff, (3) the general knowledge gained in prior hurricanes on tidal backwater through open structures. The majority of these openings varied from 2 to 3 feet.

District field personnel continued to make structure inspections and gage readings on the 7th even though whole gale winds were being felt in many locations. After a reevaluation of conditions in the late afternoon, the openings with some exceptions, were left as set the previous afternoon. The majority of the Project canals peaked the night of the 7th or on the morning of the 8th, (Table I).

Adjustment of openings, after the passing of the peak tides, were begun approximately at noon on the 8th. Portable power equipment adapted for this purpose, was used where power was off. All structures functioned

TABLE I
PROJECT
EAST COAST SALINITY STRUCTURES
WEST PALM BEACH CANAL (C-51) TO BLACK CREEK (C-1)

<u>STRUCTURE</u>	<u>CANAL</u>	<u>OPERATING EQUIPMENT</u>	<u>OPTIMUM</u>	<u>BETSY- MAXIMUM (M.S.L.)</u>	<u>REMARKS</u>
Gate & Spillway	W.P.B.C.	Manual	7.5	8.4 (8th)	U.S.Hwy. No. 1
S-41	C-16	Automatic	8.5	7.1 (7th)	60% SPF stage 8.1'
S-40	C-15	Automatic	8.5	6.7 (7th)	60% SPF stage 8.2'
Gate & Spillway	Hillsboro	Manual	7.5-8.0	5.5 (8th)	Deerfield Lock
S-37A	C-14	Automatic	3.5	5.2 (8th)	60% SPF stage 3.0'
S-36	C-13	Manual	5.5	4.8 (12th)	50% SPF stage 5.2'
S-33	C-12	Manual	3.5	4.6 (8th)	50% SPF stage 5.1'
Spillway	N.N.R.C.	Manual	3.0-4.5	3.0 (9th)	Sewell's Lock
S-13 & Spillway	C-11	Manual	2.0	2.1 (7th)	
-	C-10	-	-	-	No structure
S-29	C-9	Manual	2.5	3.9 (8th)	SPF stage 2.95'
S-28 (a)	C-8	Automatic	1.8-3.0	4.2 (8th)	SPF stage 2.20'
S-27 (a)	C-7	Automatic	1.8-3.0	4.5 (8th)	SPF stage 3.27'
Spillway 36th St.	Miami	Manual	2.7	2.5 (6th)	Oper. by Dade Co.
Spillway FEC R.R.	C-4	Manual	2.8	4.7 (8th)	Oper. by Dade Co.
S-22 (a)	C-2	Manual	1.8-3.0	6.0 (8th)	SPF stage 3.23'
S-123 (a)	C-100	Automatic	2.0-3.5	3.9 (9th)	SPF stage 3.80'
S-21 (a)	C-1	Automatic	2.0	6.1 (8th)	SPF stage 2.8'

- (1) All structures on manual during Betsy since no power available.
- (2) (a) Structure topped or bypassed.
- (3) S.P.F. - Standard Project Flood (in excess of 150 year frequency). Design does not assume tidal flooding.

properly with the following exceptions:

- S-21 on C-1 Structure topped and apparently small amount tidal bypass around south side.
- S-27 on C-7 Structure topped, and the tieback between structure and southerly bank washed out, permitting tide encroachment.
- S-22 on C-2 Structure overtopped and tidal bypass around west side.
- S-28 on C-8 Tidal bypass around structure through golf course on both sides.
- S-123 on C-100 Structure possibly topped by wave action.

Only the washout at S-27 necessitated immediate attention, the necessary fill being placed the afternoon of the 8th.

Difficulties experienced in operation immediately following the hurricane were limited to two structures, as follows:

- S-28 Flooding of access road prevented adjustment of the gate openings until 8:15p.m. of the 8th.
- S-21 A head of more than 4 feet prevented the use of portable motors to open the structure. Both gates were opened on the morning of the 9th by the use of two draglines.

Stage, discharge, gate openings and salinity data are shown for C-9 and C-2 on Plates 8 and 9 for the period September 6-11, and were selected as being generally indicative of the effect on other Project canals in Dade County, under similar conditions.

EFFECT OF OPERATION AND HURRICANE TIDE ON S-29 AT C-9

Salinity structure S-29 on C-9 (Snake Creek Canal) was neither overtopped nor bypassed. This structure was fully opened on the 6th, and left open during the hurricane because of the critical flooding in this basin at relatively low stages. Reversal of flow, as shown on the discharge graph, on Plate 8, occurred on high tide but was relatively small. This inflow reached a maximum on the 8th as the tidal stage in Biscayne Bay at North Miami (N.W.79th Street) peaked at 7.41 feet. Inflow on high tide continued through the 8th, after which tides reduced and rainfall runoff conditions resulted in continuous outflow. Tidal inflow through the 8th was 1200 acre-feet, and the total outflow was 3,600 acre-feet.

Even though the structure was open, a relatively small amount of saline encroachment occurred until the hurricane tide on the 8th. The concentration

above the structure during this period undoubtedly approached that of sea water. This concentration of chloride had reduced to 12,000 ppm on the 9th, and to 390 ppm by the 11th as the structure was partially closed. Salinity concentration of points further upstream is shown on Plate 10.

Rainfall on the 84 square mile basin of C-9 approximated 4.6 inches. The maximum discharge of 4,000 second-feet occurred for approximately one-half hour on the 9th with the structure fully open, but an abnormal high tide limited the discharge. The structure is designed for 4,790 second-feet at 2.95 feet under normal tidal conditions.

EFFECT OF OPERATION AND HURRICANE TIDE ON S-22 ON C-2

Salinity structure S-22 on C-2 (Snapper Creek Canal) was both overtopped and bypassed, with the waves lapping over the service bridge and the service road still under water on the morning of the 9th. The bypassing occurred around the west side, with a portion of the tidal inflow passing over Red Road into the adjacent low ground, and a portion into the canal above the structure.

As at S-29, it can be assumed the chloride concentration immediately above the structure on the 8th approximated that of sea water. This had reduced to 1,100 ppm by the 10th with the passage downstream of an additional 2,000 acre-feet. With the passage of an additional 5,400 acre-feet by the end of the 12th, the chlorides had reduced to 35 ppm, (Plate 10).

The structure was initially opened fully on the 6th and then closed to a 3-foot opening on each gate. A slight reversal, as indicated on the discharge graph on Plate 9, occurred on the 7th. The majority of the tidal inflow occurred with the hurricane tide on the 8th as it reached a height of 6.08 feet immediately upstream of the structure. The tidal inflow on the 7th and 8th was 660 acre-feet, and the outflow 1,660 acre-feet. The stage at Miller Drive reached 5.3 feet as a result of this tidal inflow (Plate 4).

GENERAL RESUME OF THE OPERATION AND TIDAL EFFECT ON BROWARD AND PALM BEACH COUNTY STRUCTURES

The tide height attained was not sufficient to create any overtopping or bypassing of Project salinity structures. Seaweed was found on the S-37A service bridge which is at 8.0 feet, but this is assumed to have been deposited by wave action. Table I and Plate 5.

The 5.2 foot stage in C-14 above S-37A exceeded the design stage of 2.2 feet, while the 4.8 foot stage in C-13 above S-36 exceeded the design stage by 0.1 foot. The stages on the Hillsboro Canal above the Deerfield control, C-12 above S-33, North New River Canal above Sewell's control, and C-11 above S-13, were all below the design stage.

All of these structures were open varying amounts during the actual hurricane to permit some runoff but at the same time to permit as little tidal inflow as possible, (Plate 7). The exception was S-37A which was opened

fully, since any salinities could be quickly flushed by water stored above S-37B. The only salinity data available above the salinity structures was that collected above S-37A by the City of Fort Lauderdale, which indicated a concentration of 13,900 ppm on the 7th and 140 ppm on the 14th.

S-44 on C-17, and S-46 on C-18 were opened and placed on manual operation prior to the hurricane. The weir crests were sufficiently high that no overtopping occurred. A relatively low stage of 8.4 feet was the maximum recorded above the fully opened structure on the West Palm Beach Canal above U.S. Highway No. 1. The recently completed S-40 on C-15, and S-41 on C-16, were both placed on manual operation and remained on manual during the storm to maintain stages below the optimum. (Table I) No tidal encroachment occurred in any of the Palm Beach County structures.

SUMMARY

1. Actual Betsy rainfall in Dade, Broward and Palm Beach Counties was less than that predicted by the Weather Bureau.
2. Actual Betsy tides closely approximated those predicted by the Weather Bureau.
3. Coastal structure gate openings were based upon rainfall and tide predictions, and the best estimate of runoff resulting from this rainfall.
4. Actual fresh water inflow into Project canals nowhere reached Project design values because of the comparatively light rainfall. Peak canal stages reached were the result of hurricane driven tides rather than fresh water discharges.
5. Tidal inflow into canals occurred at all locations in Dade and Broward Counties; at C-1, C-2, C-7 and C-8 tidal inflow through the partially opened gates was augmented by the bypassing or overtopping of the salinity structures by tidal waters.
6. Volume of tidal inflow was dependent on: (a) tide height and (b) volume of fresh water discharge.
7. Flushing out of salinities took place comparatively rapidly once structures could be manned and gates fully opened: exception being C-100 and C-9, both containing deep free dug areas which trapped the heavier high saline water below the design canal bottom.
8. Flood damage was largely the result of tidal flooding. Fresh water flooding occurred in some areas because of inadequacies in the secondary drainage systems.

9. Full effectiveness of the Project system was not attained at S-21 on Canal 1, due to the lack of auxiliary power for operation of gates immediately subsequent to passage of the storm.

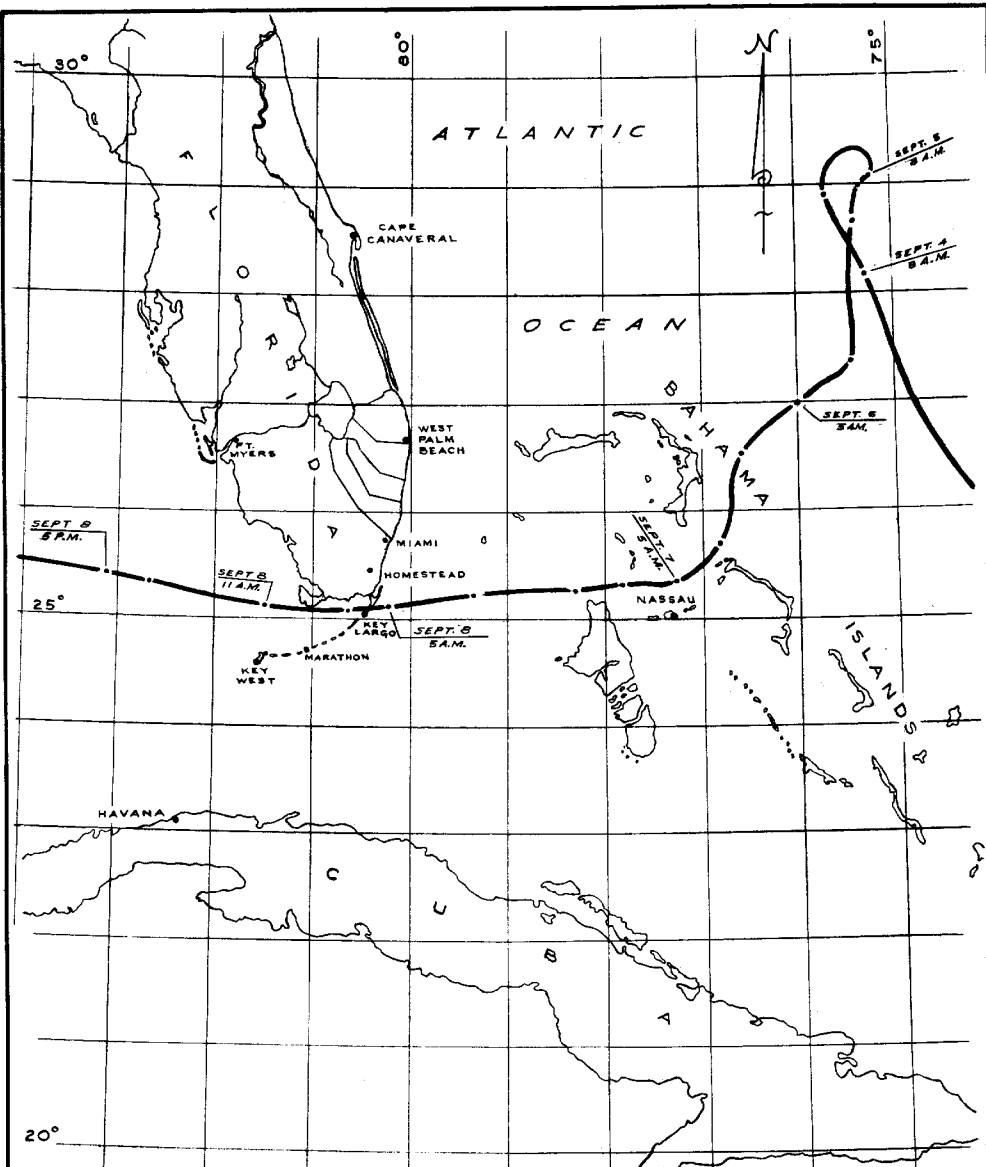
CONCLUSIONS

1. The practice of establishing gate settings at coastal structures immediately prior to the advent of a hurricane should be continued. It is evident that the risks of saline contamination, or even tidal flooding, must be balanced against the risk of fresh water flooding. The experience of Betsy indicates that the effects of a comparatively severe occurrence; that is, extremely high tides and low fresh water discharge, productive of large volumes of tidal inflow, are not long-lasting or of a permanently damaging nature. The probable risk from allowing the structures to remain open, or partially open, appears to be smaller than that which would result from keeping the gates closed during the occurrence. This is particularly true since the Project structures are not designed to withstand overtopping or bypassing under moderate to severe tide occurrences, as witness the occurrences at C-1, C-2, C-7 and C-8.
2. Risks would be further reduced if more accurate rainfall predictions were received. For example, it is quite probable that had the actual Betsy rainfalls been predicted certain of the Dade County structures would have been initially set with reduced openings, with a consequent increase in their effectiveness.
3. Auxiliary power should be provided at Project coastal structures. Difficulties in operation, in terms of manpower and time, during the period commercial power is not available would be largely eliminated.
4. At every location where feasible, construction should be undertaken to prevent the bypassing of coastal structures.
5. Undue reliance should not be placed on manning coastal structures during storm occurrences which will produce excessive tides. The experience at S-123 on Canal 100 indicates that the risk of continuing occupancy throughout the period of storm occurrence are too great in terms of the possible benefit to be derived. The logical alternative to continuous manning is (a) pre-determined gate settings, (b) provision of auxiliary power and (c) immediate visitation upon passage of the storm.

ACKNOWLEDGEMENTS

The assistance of the following agencies in supplying portions of the information and data used in preparing this report is gratefully acknowledged.

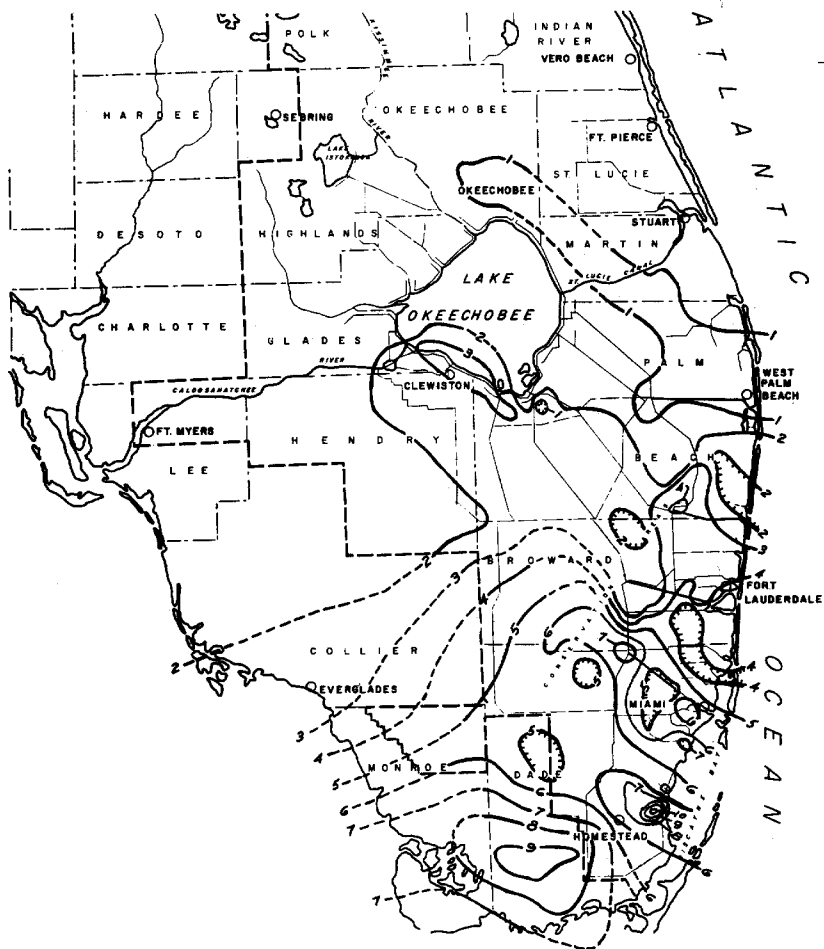
1. U.S. Weather Bureau - Miami, Florida
2. U.S. Geological Survey - Miami, Florida
3. Corps of Engineers, Department of the Army
4. Dade County Public Works Department
5. Broward County Public Works Department
6. U.S. Coast Guard



PATH OF HURRICANE BETSY
FOR PERIOD
SEPTEMBER 4-8, 1965

C. & S. F. F. C. D.

NOVEMBER 1965



ISOHYETAL MAP
 OF RAINFALL RESULTING
 FROM
 HURRICANE BETSY

C.&S.F.F.C.D.

NOVEMBER 1965

NOTE: RAINFALL FOR PERIOD
 SEPTEMBER 6-8, 1965

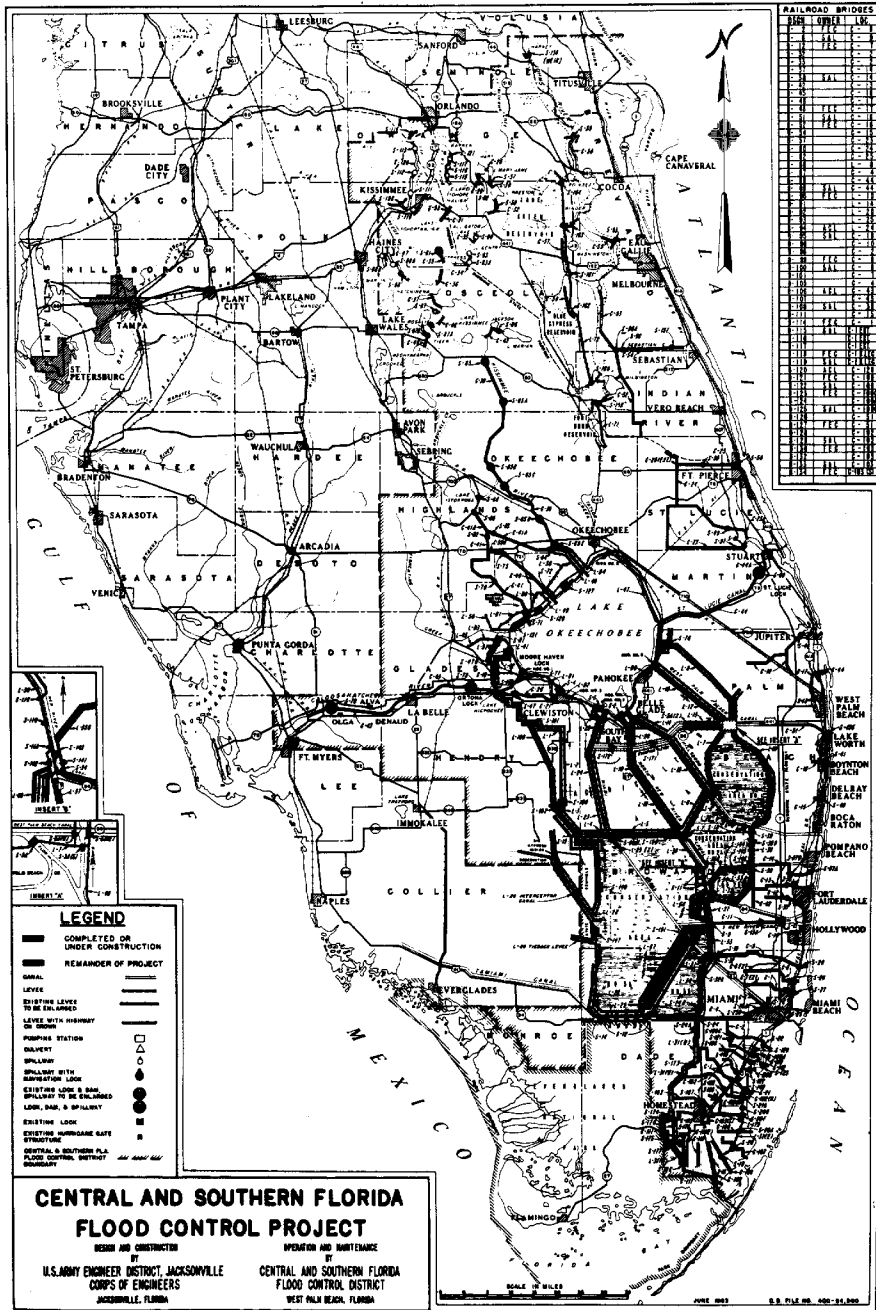
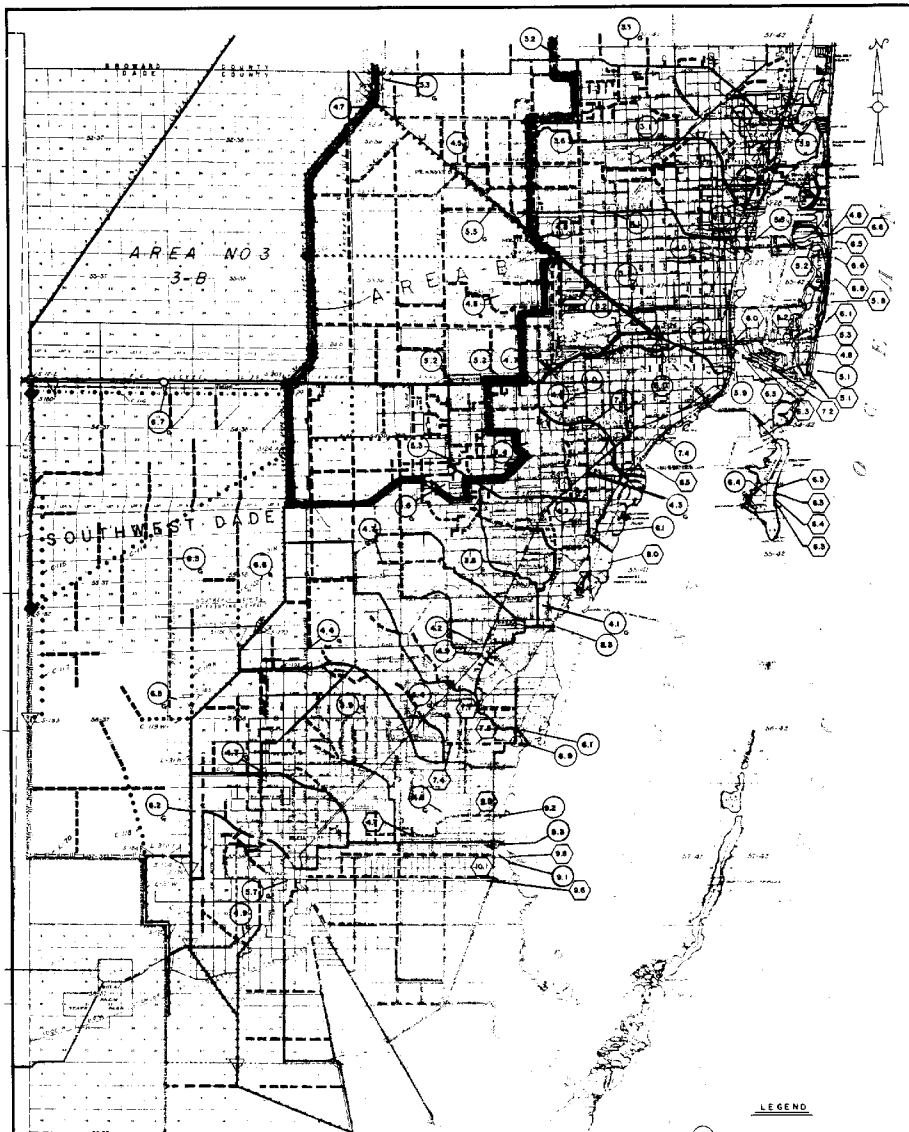


PLATE 3



DADE COUNTY
 PEAK WATER LEVELS RESULTING
 FROM HURRICANE BETSY

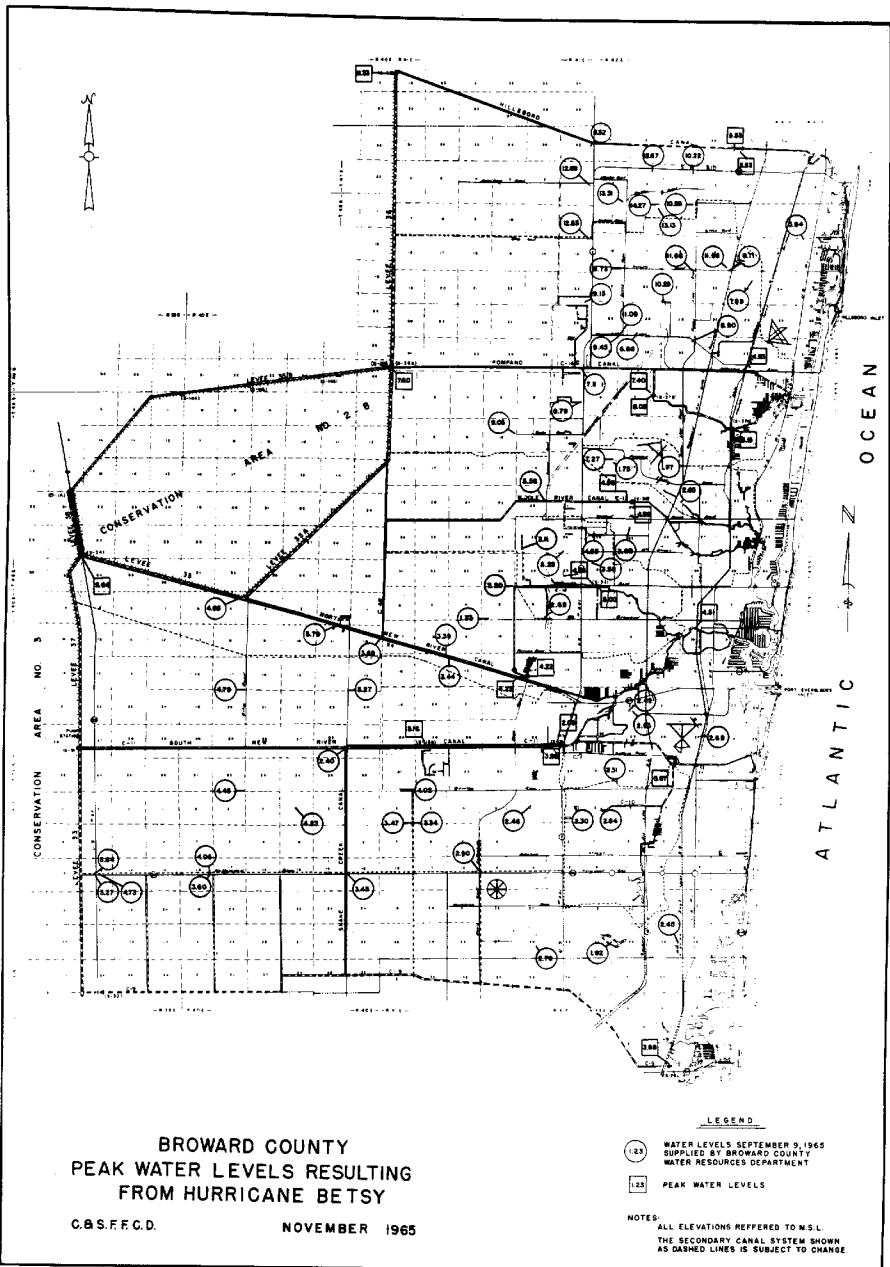
C. & S. F. F. C. D.

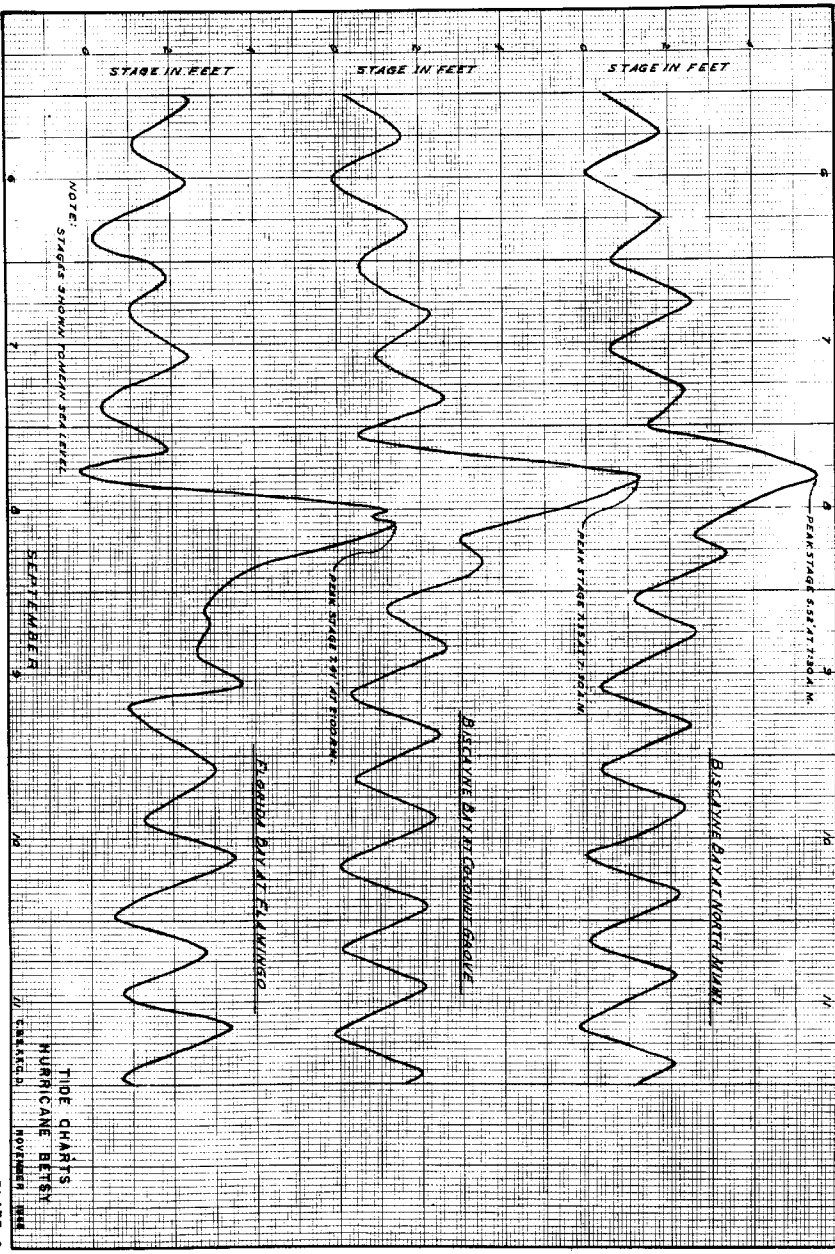
NOVEMBER 1965

- LEGEND
- 22 SURFACE WATER
 - 42 GROUND WATER RECORDERS
 - 26 HIGH WATER MARKS

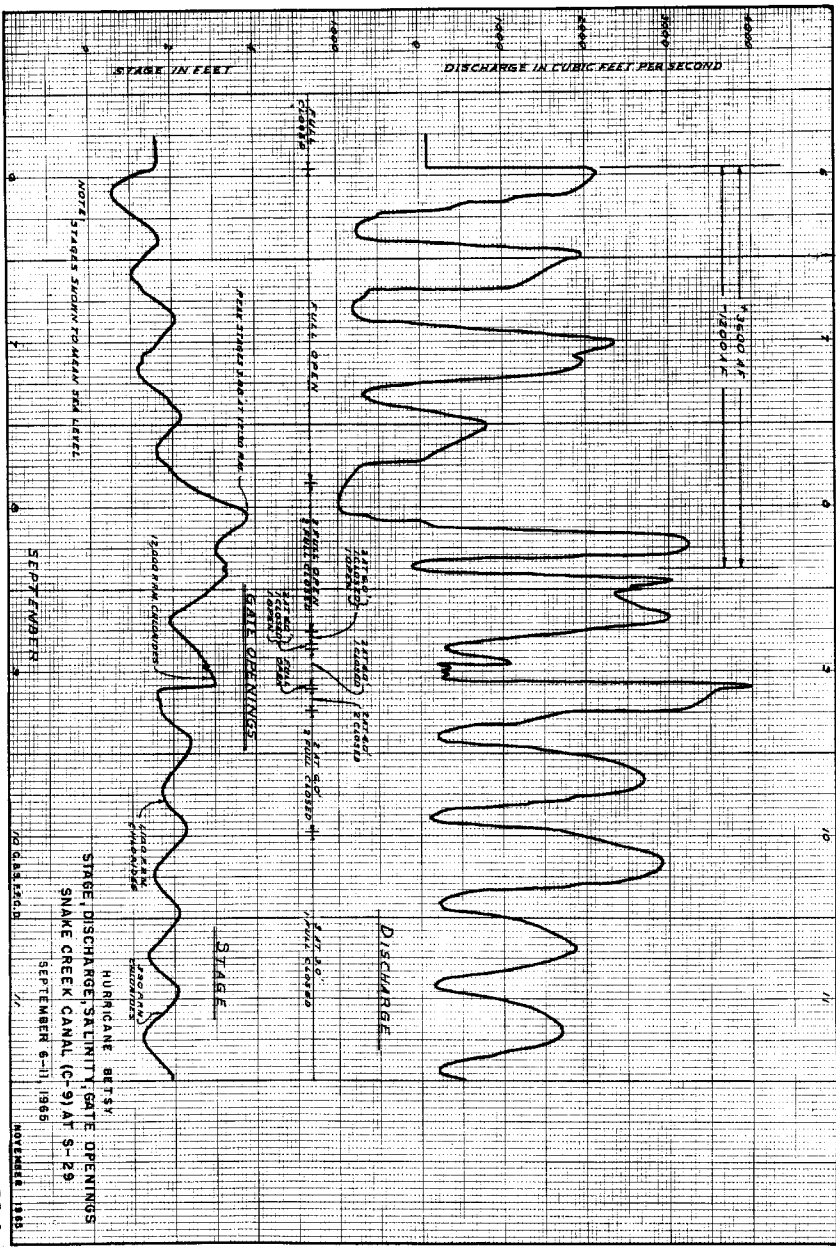
NOTE
 ALL ELEVATIONS REFERRED TO M. S. L.

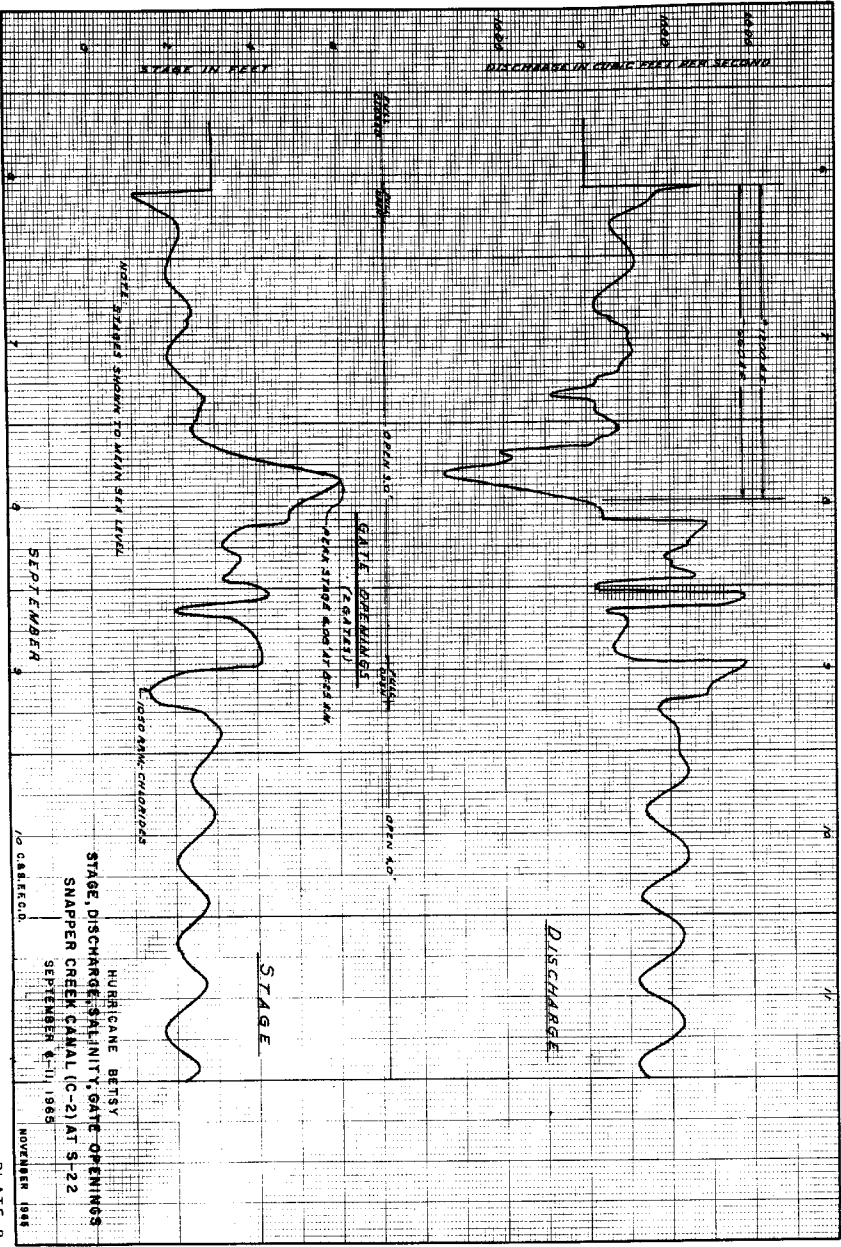
THE SECONDARY CANAL SYSTEM
 SHOWN AS DASHED LINES IS
 SUBJECT TO CHANGE





TIDE CHARTS
 HURRICANE BERT
 W. S. KERR
 NOVEMBER 1934





HURRICANE Betsy
 STAGE, DISCHARGE, SALINITY GATE OPENINGS
 SHAPPER CREEK CANAL (C-2) AT S-22
 SEPTEMBER 8-11, 1965

HURRICANE BETSY
PROJECT GATE OPERATION

West Palm Beach Canal To C-1

<u>DATE</u>	<u>OPERATION</u>	<u>REMARKS</u>
W.P.B. GATE ON WEST PALM BEACH CANAL (1 Gate)		
September 6	<u>Open 6.0 feet at 1:00pm</u>	From closed normal position
September 9	<u>Closed fully at 8:00am</u>	Return to normal operation
W.P.B. SPILLWAY ON WEST PALM BEACH CANAL (4 Bays)		
September 6	<u>All boards out of all bays at 9:00am</u>	From 3 boards in all bays
September 8	<u>4 boards in all bays at 11:00am</u>	Return to normal operation
S-41 BOYNTON CANAL (C-16) (2 Gates)		
September 6	This structure was manned during the storm and operated to maintain a headwater of 6.5 feet.	
S-40 HIDDEN VALLEY CANAL (C-15) (2 Gates)		
September 6	This structure was manned during the storm and operated to maintain a headwater of 6.5 feet.	
DEERFIELD LOCK ON HILLSBORO CANAL (1 Gate)		
September 6	<u>Open 9.00 feet at 11:00am</u>	From closed normal position
September 9	<u>Closed fully at 4:00pm</u>	Return to normal operation
DEERFIELD SPILLWAY ON HILLSBORO CANAL (5 Bays)		
September 6	<u>All boards out of all bays at 11:00am</u>	From 2 boards in all bays
September 9	<u>7 boards in all bays at 11:10am</u>	Return to normal operation
S-37B CYPRESS CREEK CANAL (C-14) (2 Gates)		
September 6	2 open 0.60 feet at 9:25pm	Fully closed and on manual control.
September 7	<u>2 open 0.40 feet at 1:00am</u>	
7	2 open 0.50 feet at 5:05am	
7	2 closed fully at 7:00am	On automatic control

<u>DATE</u>	<u>OPERATION</u>	<u>REMARKS</u>
S-37B CYPRESS CREEK CANAL (C-14)		
(Continued)		
September 7	2 open 0.70 feet at 5:00pm	On manual control
7	2 open 1.00 feet at 5:30pm	
7	<u>2 open 0.70 feet at 10:00pm</u>	
September 8	2 open 0.65 feet at 12:05am	
8	2 open 0.50 feet at 7:45pm	
September 10	2 open 0.25 feet at 8:05am	
September 11	2 closed fully at 3:25pm	Return to normal operation Placed on automatic control September 19
S-37A CYPRESS CREEK CANAL (C-14)		
(2 Gates)		
September 6	2 open 14.0 feet at 5:30pm	Top slots open and on manual control
September 7	On automatic control at 9:00am	
7	Closed fully at 2:45pm	On manual control
7	<u>2 open 14.0 feet at 4:00pm</u>	
September 8	Top slots closed at 2:45pm	On automatic control
September 11	Top slots opened at 6:30pm	Normal operation
S-36 MIDDLE RIVER CANAL (C-13)		
(1 Gate)		
September 7	<u>Open 1.0 feet at 8:30pm</u>	From 0.1 foot open
September 8	Closed fully at 9:30am	Normal operation
S-33 PLANTATION ROAD CANAL (C-12)		
(1 Gate)		
September 6	<u>Open 6.5 feet at 5:45pm</u>	Fully closed normal position
September 8	Closed fully at 2:00pm	Slots open full throughout Normal operation
S-13 SPILLWAY S. NEW RIVER CANAL (C-11)		
(1 Gate)		
September 6	Open 11.30 feet at 7:10pm	From closed normal position
September 7	Closed fully at 7:00am	
7	<u>Open 3.0 feet at 2:00pm</u>	
7	Closed fully at 3:20pm	<u>Pumping started 4:00pm</u>
September 9	Open 11.30 feet at 1:00pm	Pumping stopped at 1:00pm
SEWELL'S LOCK ON N. NEW RIVER CANAL		
(8 Bays)		
September 6	<u>All boards out of all bays at</u>	
	<u>9:30am</u>	
September 9	10 boards in all bays at 2:00pm	From normal position Normal
S-149 BLACK CREEK CANAL (C-1-N) *		
(2 Gates)		
September 6	<u>2 fully open at 6:00pm</u>	From closed position
	Remained open entire month	

<u>DATE</u>	<u>OPERATION</u>	<u>REMARKS</u>
	S-148 BLACK CREEK CANAL (C-1-W) * (2 Gates)	
September 6	<u>2 fully open at 6:00pm</u>	Fully closed position and on manual control
September 8	2 fully closed at 8:00pm	
September 9	2 fully open at 9:00am	
September 11	2 open 3.0 feet at 9:30am	
September 13	2 open 1.5 feet at 3:30pm	Normal operation, placed on automatic control Sept. 20
	S-29 ON SNAKE CREEK CANAL (C-9) (4 Gates)	
September 6	<u>4 fully open at 11:00am</u>	Fully closed normal position
September 8	2 fully closed at 8:30am	
September 9	1 fully closed, 1 fully open and 2 open 6.0 feet at 6:30am	
9	2 closed to 4.0 feet at 7:45am	
9	1 fully closed and 1 fully open	
9	2 fully closed and 2 fully open at 8:30am	
9	4 fully open at 2:00pm	
9	2 fully closed and 2 at 4.0 feet at 2:30pm	
9	2 open 6.0 feet and 2 fully closed at 5:25pm	
September 10	3 open 3.0 feet and 1 closed at 11:30am	
September 13	4 open 1.0 feet at 11:15am	For flushing
September 17	4 open 3.0 feet at 8:00am	For flushing
	S-28 ON BISCAYNE CANAL (C-8) (2 Gates)	
September 6	<u>2 fully open at 7:30am</u>	Changed from automatic to manual for hurricane
6	<u>2 open 3.5 feet at 6:00pm</u>	
September 8	1 open 7.0 feet and 1 open 12.0 feet at 4:30pm	
8	2 fully closed at 8:15pm	
September 9	1 open 8.0 feet and 1 closed at 1:00am	
9	2 open 2.0 feet at 8:30am	
9	2 open 12.0 feet at 11:15am	
9	1 open 6.0 feet and 1 open 4.0 feet at 12:00 midnight	
September 10	2 open 3.5 feet at 4:45pm	
September 12	2 changed to automatic	

<u>DATE</u>	<u>OPERATION</u>	<u>REMARKS</u>
S-27 ON LITTLE RIVER CANAL (C-7) (2 Gates)		
September 6	2 open full at 7:00am	Fully closed normal position and on manual
September 6	<u>2 open 3.0 feet at 6:00pm</u>	Power went off
September 8	2 fully closed at 8:00pm	
September 8	2 fully open at 12:00pm	
September 9	2 open 3.0 feet at 9:15am	
September 9	2 open 4.0 feet at 11:45am	
September 9	2 open 2.0 feet at 1:00pm	
September 9	1 open 1.5 feet	Return to normal operation, 1 gate and on automatic control
S-22 ON C-2 (SNAPPER CREEK) (2 Gates)		
September 6	2 fully opened at 2:00pm	From fully closed normal position
September 6	<u>2 open 3.0 feet at 6:00pm</u>	
September 9	2 fully opened at 11:00am	
September 9	2 open 4.0 feet at 4:20pm	
September 12	2 open 1.5 feet at 9:00am	Return to normal operation
S-123 ON C-100 (2 Gates)		
September 6	2 open 13.0 feet at 1:00pm	From closed normal position
September 6	2 fully closed at 8:30pm	
September 6	1 open 4.0 feet, 1 fully closed at 9:30pm	
September 6	2 fully closed at 10:30pm	
September 6	1 open 2.0 feet, 1 fully closed at 11:30pm	
September 7	<u>2 fully closed at 1:30pm</u>	
September 8	2 open 1.0 feet at 12:30pm	
September 9	1 open 12.0 feet, 1 open 10.0 feet at 8:30am	
September 9	2 open 3.0 feet at 4:00pm	
September 14	2 fully closed at 9:30am	Normal operation
S-122 ON C-100B * (2 Gates)		
September 8	2 fully open at 8:00pm	<u>Fully closed normal position</u>
September 9	2 fully closed at 10:00am	Return to normal

<u>DATE</u>	<u>OPERATION</u>	<u>REMARKS</u>
	S-21 on C-1 (BLACK CREEK) (3 Gates)	
September 6	3 fully opened at 2:00pm	Fully closed normal position and on Manual control
6	<u>2 open 2.0 feet at 6:00pm</u> <u>1 fully open</u>	
September 9	2 open 9.0 feet at 11:00am 1 fully open	
9	3 fully open at 12:00noon	
September 10	3 open 3.0 feet at 3:30pm	
September 13	3 open 0.5 feet at 3:00pm	
September 16	3 on automatic control	Return to normal operation

* First control above salinity structure.

Note: Underlined operations indicates those existing during Hurricane.

PROJECT CANAL SALINITIES
 RESULTING FROM
 HURRICANE BETSY

Location	Dist. From Lower Structure	September 1965						Remarks	
		9	10	11	12	13	14		16
C-9									
S-29	0	12:50pm 12,000	8:00am 1,100	2:00pm 390	2:00pm 525	11:15am 12,000	9:30am 130	8:00am 220	Gates closed to 1.0' opening on 13th to allow upstream stage to rise for further flushing action. Deep Section in Canal at N. Miami Avenue
Dixie Highway	1 Block			370	470	9,400	240		
N.E. 17th Ave.	1 Mile			355	275	285	255		
N. Miami Ave.	2 Miles			565	1,800		2,800		
S.R. No. 9	3 Miles			50	50	315	50		
S.R. No. 7	4 Miles					45			
		Salinity reached acceptable concentration first week in Oct.							
C-8									
S-28	0	1:20pm 5,000	8:30am 1,600	3:30pm 540	3:30pm 505	12 Noon 320	10:15am 150	8:30am 150	
Golf Course Ft. Br.	1 Block			425	375	275	195		
N.E. 6th Ave.	1 Mile			375	240	255	180		
N. Miami Avenue	2 Miles			285	25	180	135		
U.S. No. 441	3 Miles			25		180	150		
S.R. No. 9	4 Miles					25	30		
C-7									
S-27	0	1:45pm 2,800	9:00am 475	4:30pm 285	4:30pm 90	1:00pm 75	11:00am 50	9:00am 46	
FEC R.R. Bridge	1 Block			270	75	60	50		
N.E. 2nd Ave.	1 Mile			410			50		
Ft. Br. Larchment	2 Miles			700			50		
N.W. 7th Ave.	3 Miles			60	35				

PROJECT CANAL SALINITIES
 RESULTING FROM
 HURRICANE BETSY

Location	Dist. From Lower Structure	September 1965					Remarks	
		9	10	11	12	13		
C-2								
S-22	0	2:40pm 1,050			9:00am 35	4:15pm 40	2:00pm 25	2:00pm 45
Red Road	1 Block 1 Mile				35	30	25	20
C-100								
S-123	0	3:00pm 960			11:00am 3,500	2:30pm 2,455	1:45pm 4,900	
Old Cutler Road	1 Block				4,200	2,450	7,600	Salinity increased with time due to deep section in canal upstream of the structure.
Richmond Drive	2 Miles						25	
S-118	3 Miles		185		35			
			Salinity reached acceptable concentration first week in Oct.					
C-1								
S-21	0	3:30pm 7,200			12 Noon 1,100	3:00pm 240	12:45pm 285	3:00pm 100
S.W. 97th Ave.	1 Mile				370	150	110	
Old Cutler Road	2 Miles				180	120	90	
U.S. No. 1	4 Miles						65	
C-1								
S-148	0		3:25pm 820	8:30am 275	8:30am 150	3:30pm 120	12 Noon 65	46
Burr Road	1 Block						65	
Quail Roost Rd.	1 Mile			275	125	105	65	
Eureka Drive	2 Miles			205	120			
	3 Miles				100			

PROJECT CANAL SALINITIES
RESULTING FROM
HURRICANE BETSY

NOTES:

1. Salinity readings obtained by District personnel using salinity meter, "Solu Bridge", Industrial Instruments, Inc., Model No. RB3-334i, Serial No. 62753.
2. Salinity readings are in Parts Per Million of chlorides.
3. Time shown is the approximate time the reading was made at the lower structure.
4. All readings were taken just clear of bottom of canal.