South Florida Water Management Model

Documentation Report

Technical Publication 84-3

by
Thomas K. MacVicar
Thomas VanLent
Alvin Castro

"This public document was promulgated at an annual cost of $506.25, or $1.01 per copy to inform the public regarding water resource studies of the District." RP 589 5C

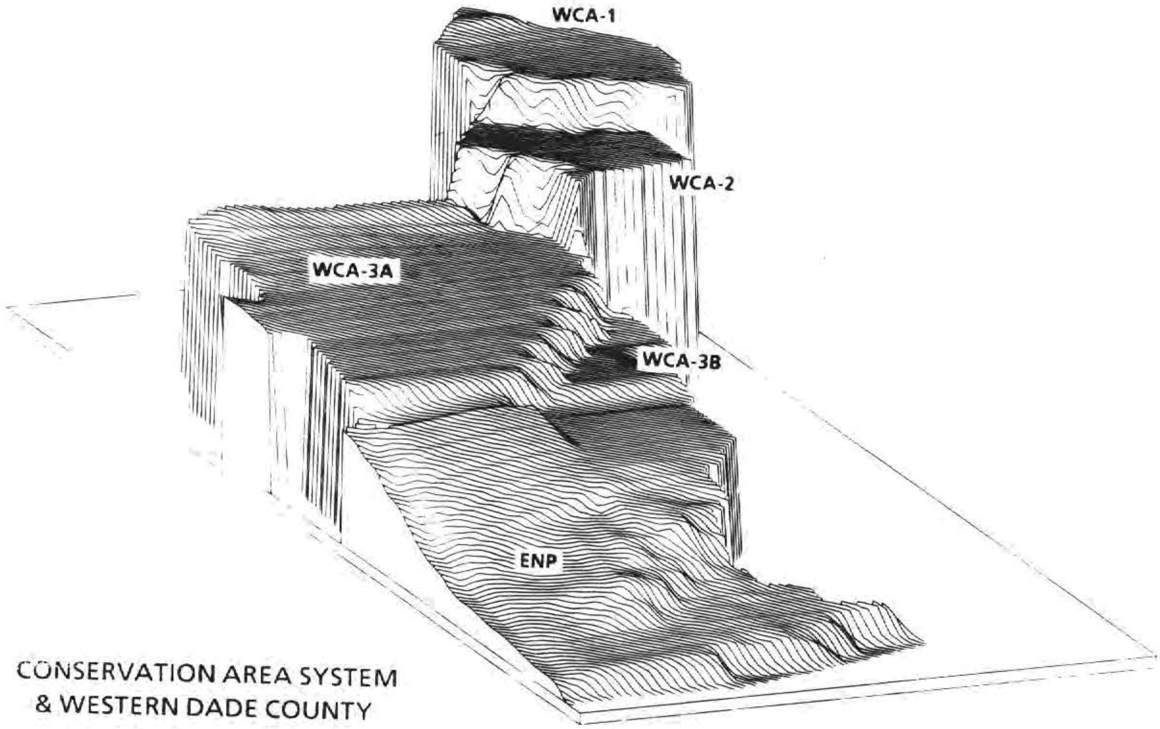
Resource Planning Department

South Florida Water Management District

Submitted Pursuant to Contract No.
DACW17-81-C-0035
December, 1983

South Florida Water Management Model

Documentation Report



Technical Publication 84-3

Acknowledgements

The South Florida Water Management Model, its data requirements, calibration and verification, and documentation were develped under contract number DACW17-81-C-0035 for the Department of the Army, Jacksonville District, Corps of Engineers. The modeling effort is a part of the Central and South Florida Water Supply Study being conducted by the Corps of Engineers.

The authors wish to thank the many individuals at the South Forida Water Management District who contributed to this project. Much credit goes to the technical staffs of the Resource Planning Department and the Technical Services Department, which provided assistance with data aquisition, computer services, and technical support.

Special recognition is due Mr. E. Ray Santee for amassing the physical data on the Big Cypress area, reorganizing the data files to accomodate the model expansion, and developing the computer logic necessary to give the model access to the reorganized data files.

Ms. Gaye Lathrop provided dedicated support in developing the many ancillary programs required to format and check the hydrologic and meteorologic data, produce organized reports on the input data and model results, and provide the computer graphics analysis of the model simulations.

Table of Contents

	Page
Acknowledgements	i
List of Tables	iv
List of Figures	v
Introduction	1
The Computer Model	3
Static Data	5
Time Series Data	6
Open Channel Flow	7
Surface Water-Canal Flow Interaction	11
Groundwater-Canal Flow Interaction	12
Canal Discharge	12
Overland Flow	14
Soil Infiltration	14
Overland Flow	15
Evapotranspiration	17
Groundwater Modeling	20
System Management Model	22
Structure Modeling	22
Lake Okeechobee	30
Everglades Agricultural Area	32
Model Operation	33
Input requirements	33
Model Definition Data	33
Canal Definition Data	41
Time Series Data	43
Static Input Data	44
Land Surface Elevations	45
Land Use Indicators	45
Canal Basin Identifiers	46
Rainfall Basin Identifier	46
Initial Groundwater Stage	46
Initial Ponded Stage	47
Aquifer Depth	47
Aquifer Permeability	47
Output Description	48
Tape 70	48
Tape 72	50
Tape 75	51

Tape 76 51
Tape 77 52
Tape 79 52
Tape 80 52
Tape 85 53
Tape 90 53
FLO2X2N 54
OUTPUT 54

Simulation of Lower East Coast **55**
Calibration and Verification of Lower East Coast 55
Presentation of Results 61

Simulation of Upper East Coast 98
Data Collection 98
Boundary Conditions 100
Modeling Approach and Assumptions 102
Model Calibration and Verification 106
Groundwater Results 108
Recommendations 110

Selected References **123**

Appendix A: Dictionary of Variables Used in the South Florida Water Mangement Model **A1**

LIST OF TABLES

Number		Page
1	Potential Evapotranspiration (In/Month) for Each Land Use Type	19
2	Structure Operations in the Management Model	27
3	Output Options	35
4	Flow Options	40
5	Output from South Florida Water Management Model	49
6	Rainfall Gages Used in the Simulation of the Lower East Coast	56
7	Canal Parameters Used in the Lower East Coast	59
8	Computed Monthly Deviation in Irrigation Demand for the EAA	61
9	Rainfall Gages Used in the Simulation of the Upper East Coast	99
10	Final Canal Parameters Used in Upper East Coast Study Calibration	105
11	Evapotranspiration Parameters Used in the LEC	110

LIST OF FIGURES

Number		Page
1	Flow Chart, South Florida Water Management Model	4
2	Block Diagram; Channel Flow Subroutine	10
3	ET Function	17
4	Stage at Gage 1-8 vs. Discharge at S-10	23
5	Stage at Gage 2-17 vs. Discharge at S-11	23
6	Stage at Gage 3-28 vs. Discharge at S-12	24
7	Stage at Gage 3B-29 vs. Base Flow at S-31	24
8	Stage at Gage 3A-4 vs. Regulatory Discharge at S-151	25
9	Stage at S-19 vs. Water Supply Release at S-151	25
10	FORTRAN Code for Typical Structure	29
11	Lake Okeechobee Operation Rule	31
12	Direction Indicator for Calculation of Levee Seepage	43
	Lower East Coast	
13	Gage Identification (Map)	62
14	Water Conservation Area 1, Gage 1-8T	69
15	Water Conservation Area 1, Gage 1-7	69
16	Water Conservation Area 2B, Gage 2-21	70
17	Water Conservation Area 2A, Gage 2-17	70
18	Water Conservation Area 3A, Gage 3-2	71
19	Water Conservation Area 3A, Gage 3-3	71
20	Water Conservation Area 3A, Gage 3-4	72
21	Water Conservation Area 3A, Gage 3-28	72
22	Collier County, L-28 Tieback	73
23	Water Conservation Area 3B, Gage 3-29	73
24	Palm Beach County, Gage PB-88	74
25	Palm Beach County, Gage PB-109	74
26	Broward County, Gage G-616	75
27	Broward County, Gage G-617	75
28	Broward County, Gage G-561	76
29	Broward County, Gage F-291	76
30	Dade County, Gage S-19	77
31	Dade County, Gage G-39	77
32	Dade County, Gage G-613	78
33	Dade County, Gage G-196A	78
34	Dade County, Gage G-618	79
35	Dade County, Gage G-596	79
36	Dade County, Gage G-1502	80
37	Everglades National Park, Gage P-207	80
38	Everglades National Park, Taylor Slough nr.Homestead	81
39	Everglades National Park, Taylor Slough nr.Royal Palm Ranger Station	81
40	Everglades National Park, Gage P-33	82
41	Everglades National Park, Gage P-36	82
42	Big Cypress Preserve, Training Airport	83
43	Big Cypress Preserve, Gage C-495	83

44 Big Cypress Preserve, Gage C-54 84
45 Big Cypress Preserve, Gage C-296 84
46 C-11 Upstream of S-13 85
47 North New River Upstream of Sewell Lock 85
48 C-111E Upstream of S-18C 86
49 C-2 Upstream of S-22 86
50 C-6 Upstream of S-26 87
51 C-9 Upstream of S-29 87
52 L-8 at West Palm Beach Canal 88
53 L-29 Borrow Canal (Tamiami Canal) 88
54 C-13 Upstream of S-36 89
55 C-14 Upstream of S-37A 89
56 Hillsboro Canal Upstream of Deerfield Lock 90
57 C-51 Upstream of S-155 90
58 Lake Okeechobee 91
59 L-67 Ext. 6 Miles South of Tamiami Canal 91

Sensitivity to Manning's 'n'

60 Water Conservation Area 1, Gage 1-7 92
61 Water Conservation Area 2A, Gage 2-17 92
62 Water Conservation Area 3A, Gage 3-2 93
63 Collier County, L-28 Tieback 93
64 Everglades National Park, P-33 94
65 Everglades National Park, Taylor Slough near Royal Palm Ranger Station 94

Sensitivity to ET

66 Water Conservation Area 1, Gage 1-7 95
67 Water Conservation Area 2A, Gage 2-17 95
68 Water Conservation Area 3A, Gage 3-2 96
69 Water Conservation Area 3A, Gage 3-28 96
70 Broward County, F-291 97
71 Everglades National Park, P-33 97

Upper East Coast

72 Upper East Coast Planning Area 101
73 C-25E, Upstream of S-99 112
74 C-25, Upstream of S-50 112
75 C-24, Upstream of S-49 113
76 C-23, Upstream of S-97 113
77 C-23E, Upstream of S-48 114
78 C-44, Upstream of S-80 114
79 Gage STL42, N. W. St. Lucie County 115
80 Gage STL125, nr. Fort Pierce 115
81 Gage STL41, S.W. St. Lucie County 116
82 Gage M147, nr. Stuart 116
83 Gage M933, nr. Palm City 117
84 Gage M928, at Indiantown 117
85 Gage M140, West of Jupiter 118
86 Calculated Groundwater Contours, October 1969 119
87 Calculated Groundwater Contours, April 1971 120
88 Calculated Groundwater Contours, October 1973 121
89 Calculated Groundwater Contours, April 1975 122

APPENDIX A

DICTIONARY OF VARIABLES USED IN THE SOUTH FLORIDA WATER MANAGEMENT MODEL

DICTIONARY OF VARIABLES USED IN THE SOUTH FLORIDA WATER MANAGEMENT MODEL

VARAIABLE	LOCATION	DESCRIPTION
A,B,C,D,E	GWF	INTERMEDIATE TERMS OF THE BOUSINESQ EQUATION DESCRIBING GROUNDWATER FLOW
ADEP	CHNLF	ADJUSTMENT TO CANAL STAGE AT BEGINNING OF TIME STEP DUE TO UPSTREAM INFLOWS (FT)
AGP	/AGDATA/	CONTAINS THE DIFFERENCE BETWEEN DELIVERIES AND CONSUMPTION IN THE EVERGLADES AGRICULTURAL AREA. A POSITIVE SIGN INDICATES A DEFICIENCY.
AQDEP(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, CONTAINS THE AQUIFER DEPTH (FT BELOW GROUND SURFACE)
ARF(NZONE)	/STAT/	ARRAY INDEXED BY -RAINFALL ZONE- , CONTAINS THE MONTHLY RAINFALL SUM
CA1	INDATA	INITIAL STAGES IN WCA1 (FT MSL)
CA2A	INDATA	INITIAL STAGES IN WCA2A (FT MSL)
CA2B	INDATA	INITIAL STAGES IN WCA2B (FT MSL)
CA3A	INDATA	INITIAL STAGES IN WCA3A (FT MSL)
CA3B	INDATA	INITIAL STAGES IN WCA3B (FT MSL)
CAP	CHNLF	CAPACITY AVAILABLE IN CANAL (FT^3)
CAREA	CHNLF	CANAL SURFACE AREA (FT^2)
CDP(NCH,12)	//	ARRAY INDEXED BY -CANAL NUMBER,MONTH-, CONTAINS THE MONTH END CANAL STAGE (FT MSL)
CFDP	KNFLOWS	CONVERSION FACTOR FROM CFS*DAYS TO DEPTH OVER ONE NODE
CFSOTH	SFWMM	DAILY INFLOW TO LAKE OKEECHOBEE NOT SPECIFIED AS A KNOWN FLOW POINT (CFS)
CGINFM(NCH)	//	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE MONTHLY SUMMATION OF THE GROUNDWATER COMPONENT OF INFLOW TO THE CANAL (ACRE-FT)
CGINFT	CHNLF	DAILY GROUNDWATER CONTRIBUTION (FT^3)
CHDEP(NCH)	//	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE DAILY STAGES FOR EACH CANAL (FT MSL)
CHHC(NCH)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE CANAL-AQUIFER INTERACTION COEFFICIENT FOR EACH CANAL (FT/DAY PER FT OF HEAD)
CL(NCH)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE LENGTH OF EACH CANAL (FT)
CMN	CHNLF	ARRAY INDEXED BY -CANAL NUMBER-, STORES THE MINIMUM MONTHLY STAGE (FT MSL)
CMX	CHNLF	ARRAY INDEXED BY -CANAL NUMBER-, STORES THE MAXIMUM MONTHLY STAGE
CNM(NCH)	/C/	CHARACTER ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE 5 CHARACTER NAME OF EACH CANAL
COUT	CHNLF	VOLUME OF OUTFLOW CALCULATED FROM HYPOTHETICAL WEIR FORMULA (FT^3)
COUTD	CHNLF	DAILY SUMMATION OF COUT (FT^3)
COUTM(NCH)	//	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE MONTHLY SUMMATION OF WEIR FLOW OUT OF EACH CANAL. (ACRE-FT)

CREG	/STAT/	ARRAY INDEXED INCREMENTALLY, CONTAINS THE REGULATION STAGES FOR CANALS SPECIFIED AS HAVING REGULATION SCHEDULES. THE ARRAY IS BUILT BY STACKING THE FOLLOWING DATA FOR EACH CANAL : -NUMBER OF CANAL- X 100 + NUMBER OF POINTS READ IN (12 OR 2) FOR THE CANAL, FOLLOWED BY THE REGULATION STAGE DEFINITION POINTS THEMSELVES. THIS INFORMATION IS THEN STACKED DOWNWARD FOR EACH SUCCESSIVE CANAL WITH A REGULATION SCHEDULE
CREL(NCH)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE CREST ELEVATION OF THE HYPOTHETICAL WEIR (FT MSL).
DAY1	/STAT/	LOGICAL VARIABLE SET TO TRUE ON THE FIRST DAY
DETEN(NZONE)	/STAT/	ARRAY INDEXED BY -ZONE-, CONTAINS THE DEPTH OF SURFACE STORAGE. (FT)
DISTNC(3)	/STAT/	ARRAY INDEXED BY -DIRECTION-, CONTAINS DISTANCE IN THE THREE PRINCIPLE DIRECTIONS: VERTICAL, HORIZONTAL AND DIAGONAL.
DLHMX	CHNLF	MAXIMUM CHANGE IN GROUNDWATER STAGE ALLOWABLE DUE TO CANAL-AQUIFER INTERACTION (FT)
DPLAST	CHNLF	CHANNEL DEPTH FROM PREVIOUS ITERATION (FT MSL)
DRZ(NLU)	/STAT/	ARRAY INDEXED BY -LAND USE TYPE-, CONTAINS THE DEEP ROOT ZONE FOR EACH LAND USE TYPE.
DSUM	CHNLF	CUMULATIVE DISTANCE OF CHANNEL LENGTH, SUMMED IN THE NODAL LOOP
DSWLM(NCH)	//	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE MONTHLY SUMMATION OF THE CANAL STORAGE TERM (ACRE-FT)
DT	/STAT/	TIME INCREMENT (DAYS)
DX	/STAT/	NODE INCREMENT IN X DIRECTION (FT)
DY	/STAT/	NODE INCREMENT IN Y DIRECTION (FT)
ELLS(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, CONTAINS THE LAND SURFACE ELEVATIONS (FT MSL)
ET	OVLNF	DAILY ET VALUE RETURNED BY SUBROUTINE ETCOMP (FT)
ETD	OVLNF	DAILY ET DEFICIT, TO BE TAKEN FROM GROUNDWATER (FT)
ETM	//	ARRAY INDEXED BY -NODE-, CONTAINS THE MONTHLY ET SUMMATION (IN)
FACTOR	ETCOMP	MONTHLY FACTOR FOR EVERY MONTH IN SIMULATION TO CONVERT PET TO ET FOR THE MONTH
FILIM	OVLNF	MAXIMUM DAILY SOIL INFILTRATION (FT)
FIMAX	OVLNF	MAXIMUM AVAILABLE SOIL STORAGE FOR INFILTRATION (FT)
FLNM(NFLPTS)	/C/	ARRAY INDEXED BY -FLOW NUMBER-, CONTAINS THE 6 CHARACTER NAME FOR THE FLOW POINT
FNM	CNLDATA	CHARACTER VARIABLE CONTAINING NAME OF KNOWN FLOW POINT JUST READ IN
GDAR	/STAT/	SURFACE AREA OF ONE NODE (FT^2)
GWD	ETCOMP	DIFFERENCE BETWEEN STAGE AND LAND SURFACE (FT)
GWDTH(NCH)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE LENGTH OF CREST FOR HYPOTHETICAL WEIR OUTFLOW STRUCTURE (FT)
GWGRAD	CHNLF	HEAD DIFFERENCE BETWEEN CANAL AND AQUIFER STAGE (FT)
GWSMX	CHNLF	MAXIMUM ALLOWABLE CANAL-AQUIFER HEAD DIFFERENTIAL BASED UPON CANAL CAPACITY (FT)
H(NODE)	//	ARRAY INDEXED BY -NODE-, CONTAINS THE GROUNDWATER STAGES IN THE NODE (FT MSL)
HD	OVLNF	HEAD AT DOWNSTREAM NODE (FT)

HDC(NCH)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE TOTAL CHANGE IN ELEVATION BETWEEN THE UPSTREAM AND DOWNSTREAM ENDS OF A CANAL. (FT)
HDIFF	CHNLF	INCREMENTAL STAGE DIFFERENCE BETWEEN CURRENT NODE AND DOWNSTREAM END (FT)
HM	OVLNF	AVERAGE HEAD THROUGH ADJACENT NODES (FT)
HU	OVLNF	HEAD AT UPSTREAM NODE (FT)
I		COUNTER OR SCRATCH VARIABLE
IAGFLOW	/AGDATA/	ARRAY INDEXED BY -AG POINT NUMBER,I-, WHERE I=1 CONTAINS THE DISCHARGE(CFS) AND I=2 IS THE DRAINAGE BASIN INDICATOR
IBSN(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, CONTAINS THE CANAL BASIN INDICATOR FOR EACH NODE
IC	CNLDATA	ORIENTATION OF CANAL THROUGH NODE
ICALCPT(NCALCPT)	/ROUTC/	ARRAY INDEXED BY -1...NCALCPT-, CONTAINS THE FLOW NUMBERS OF STRUCTURES TO BE MANAGED.
IDAY	//	INDEX IN DAILY LOOP, CONTAINS THE CURRENT DAY OF THE MONTH
IDFL(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, COUNTS THE NUMBER OF DAYS THE NODE IS PONDED IN ONE YEAR
IDV	KNFLOWS	NUMBER OF DESTINATIONS FOR KNOWN FLOW, STORED IN KFL ARRAY
IFLO37A	/ROUTC/	FLOW NUMBER OF S-37A
IFLOS10	/ROUTC/	FLOW NUMBER OF S-10
IFLOS11	/ROUTC/	FLOW NUMBER OF S-11
IFLOS12	/ROUTC/	FLOW NUMBER OF S-12
IFLOS13	/ROUTC/	FLOW NUMBER OF S-13
IFLOS26	/ROUTC/	FLOW NUMBER OF S-26
IFLOS32	/ROUTC/	FLOW NUMBER OF S-31
IFLOS34	/ROUTC/	FLOW NUMBER OF S-34
IFLOS38	/ROUTC/	FLOW NUMBER OF S-38
IFLS151	/ROUTC/	FLOW NUMBER OF S-151
IFLS333	/ROUTC/	FLOW NUMBER OF S-333
IFLS339	/ROUTC/	FLOW NUMBER OF S-339
IFLS340	/ROUTC/	FLOW NUMBER OF S-340
IFLS344	/ROUTC/	FLOW NUMBER OF THE PADRICK PASS CULVERTS, S-344
IFYR	/STAT/	FIRST YEAR OF SIMULATION
IG18	/ROUTC/	NODE NUMBER OF GAGE 1-8
IG217	/ROUTC/	NODE NUMBER OF GAGE 2-17
IG3A2	/ROUTC/	NODE NUMBER OF GAGE 3A-2
IG3A28	/ROUTC/	NODE NUMBER OF GAGE 3A-28
IG3A3	/ROUTC/	NODE NUMBER OF GAGE 3A-3
IG3A4	/ROUTC/	NODE NUMBER OF GAGE 3A-4
IG3B29	/ROUTC/	NODE NUMBER OF GAGE 3B-29
IG616	/ROUTC/	NODE NUMBER OF GAGE G-616
IG617	/ROUTC/	NODE NUMBER OF GAGE G-617

II		COUNTER
ILGTH	CHNLF	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE CANAL ORIENTATION INDICATOR
INDEX		COUNTER
INTO(NCH,NOUT)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER, 1...NUMBER OF OUTFLOWS-, CONTAINS THE CANAL NUMBERS OF THE OUTFLOW POINTS RECIEVING WATER FROM THE HYPOTHETICAL WEIR
IOPT	KNFLOWS	OPTION TO INDICATE ORIGIN AND DESTINATION OF KNOWN FLOW POINT
IP	INDATA	SCRATCH ARRAY USED TO SET PRINT OPTIONS
ISUM(MAXY)	/STAT/	ARRAY INDEXED BY -ROW-, CONTAINS THE SUMMATION OF THE NUMBER OF NODES IN ALL THE LOWER ROWS
ISYR	INDATA	STARTING YEAR OF KNOWN FLOW DATA
IT	OVLNF	INDEX USED TO DETERMINE DIRECTION OF OVERLAND FLOW CALCULATION
ITER	CHNLF	COUNTER TO INCREMENT NUMBER OF TIME STEPS PER DAY FOR THE CHANNEL FLOW CALCULATIONS
IX	INDATA	SCRATCH ARRAY FOR X COORDINATES
IXM1	GWF	NODE POINTER FOR LOCATION ONE NODE WEST
IXP	SFWMM	SCRATCH VARIABLE CONTAINING THE X COORDINATE OF WELLFIELD LOCATION
IXP1	GWF	NODE POINTER FOR LOCATION ONE NODE EAST
IY	INDATA	SCRATCH ARRAY FOR Y COORDINATES
IYEAR	/STAT/	INDEX FOR YEARLY LOOP, REFERENCED AS YEARS FROM BEGINNING OF SIMULATION - 1
IYM1	GWF	NODE POINTER FOR LOCATION ONE NODE SOUTH
IYP	SFWMM	SCRATCH VARIABLE CONTAINING THE Y COORDINATE FOR WELLFIELD LOCATION
IYP1	GWF	NODE POINTER FOR LOCATION ONE NODE NORTH
IZ		COUNTER
IZONE(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, CONTAINS THE ZONE NUMBER USED TO FIND THE RAINFALL, AQUIFER STORAGE COEFFICIENT, SURFACE DETENTION DEPTH, AND SOIL INFILTRATION RATE
J		COUNTER
JI		COUNTER
JJ		COUNTER
JJYY		COUNTER
K		COUNTER
K2,K2K3,K3,K3K4	KNFLOWS	VARIABLES USED TO ROUTE FLOWS BASED UPON IOPT. CORRESPOND TO KFL ARRAY
KCN		COUNTER
KFL	/STAT	ARRAY INDEXED BY -SUM OF IDV'S OF PREVIOUS KNOWN FLOW POINTS-, CONTAINS THE DESCRIPTION OF THE FLOW POINT IN THIS ORDER: IOPT,IDV,K1...K4
KFLO(NFLPTS)	/ROUTC/	ARRAY INDEXED BY -FLOW NUMBER-, CONTAINS THE DAILY FLOW RATE FOR EACH KNOWN FLOW (CFS)
KI		COUNTER
KK		COUNTER
L		COUNTER

LBOT	PRINTLP	BOTTOM ROW OF DATA TO BE SENT TO LINE PRINTER
LCALCPT	CNLDATA	LOGICAL SET TRUE IF KNOWN FLOW IS TO BE MANAGED
LCNB(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, CONTAINS THE CANAL BASIN INDICATOR FOR EACH NODE
LNODES(NLEV)	/STAT/	ARRAY INDEXED BY -LEVEE NUMBER-, CONTAINS THE NUMBER OF NODAL POINTS IN THE LEVEE
LOCW(NWELL)	/STAT/	ARRAY INDEXED BY -WELL NUMBER-, CONTAINS THE NODAL NUMBER OF THE WELLFIELD LOCATION
LP(15)	/STAT/	LOGICAL ARRAY CONTAINING THE PRINT OPTIONS
LS11ON	/ROUTC/	LOGICAL VARIABLE INDICATING WHETHER S11 CAN BE OPERATED
LS13ON	/ROUTC/	LOGICAL VARIABLE INDICATING WHETHER S13 CAN BE OPERATED
LS151FL	/ROUTC/	LOGICAL VARIABLE INDICATING S-151 IS RELEASING REGULATORY DISCHARGES
LS151WS	/ROUTC/	LOGICAL VARIABLE INDICATING S-151 IS OPERATING IN A WATER SUPPLY MODE
LS9ON	/ROUTC/	LOGICAL VARIABLE INDICATING S9 IS OPERATIONAL
LSF	/STAT/	ARRAY INDEXED BY -1...TOTAL NUMBER OF POINTS ON SURFACE FLOW LINES,1...2-. LOCATION LSF(I,1) CONTAINS THE NODAL LOCATION AND LSF(I,2) CONTAINS THE SURFACE FLOW NUMBER ASSOCIATIED WITH THE POINT.
LUTYP(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, CONTAINS THE LAND USE TYPE FOR EACH NODE
LVNAME(NLEV)	/C/	ARRAY INDEXED BY -LEVEE NUMBER-, CONTAINS THE 5 CHARACTER REPRESENTATION OF LEVEE NAME
LVP	/STAT/	ARRAY INDEXED BY -LEVEE POINT NUMBER, 1...3-, LVP(I,1) CONTAINS THE X COORDINATE, LVP(I,2) CONTAINS THE Y COORDINATE AND LVP (I,3) CONTAINS THE DIRECTION IN WHICH TO FIND THE GRADIENT
MAXX(MAXY)	/STAT/	ARRAY INDEXED BY -ROW-, CONTAINS THE X COORDINATE OF THE EASTERN-MOST NODE OF THE ROW
MAXXT	/STAT/	MAXIMUM NUMBER OF NODES IN THE EAST-WEST DIRECTION
MAXY	/STAT/	MAXIMUM NUMBER OF NODES IN THE NORTH-SOUTH DIRECTION
MINX(MAXY)	/STAT/	ARRAY INDEXED BY -ROW-, CONTAINS THE X COORDINATE OF THE WESTERN-MOST NODE IN THE ROW
MONTH	//	INDEX FOR THE MONTHLY LOOP, CONTAINS THE CURRENT MONTH
MSG		CHARACTER VARIABLE USED TO STORE DIAGNOSTIC MESSAGES
MTRP(NMTR)	/STAT/	ARRAY INDEXED BY -1...NUMBER OF MONITOR LOCATIONS -, CONTAINS NODAL LOCATIONS OF GROUNDWATER STAGES TO BE WRITTEN TO PLOT FILE
MXOV(MAXY)	/ STAT/	ARRAY INDEXED BY -ROW-, CONTAINS THE EASTERN-MOST NODE FOR THAT ROW IN WHICH OVERLAND FLOW IS PERMITTED
N		POINTER REFERRING TO CANAL NUMBER (1...NCH)
NAGPTS	/AGDATA/	NUMBER OF FLOW POINTS BORDER THE EAA
NAGNODE(4)	/AGDATA/	ARRAY INDEXED BY - CANAL BASIN-6 -, CONTAINS THE NUMBER OF NODES IN THE EAA BASIN REFERRED TO WITH THE INDEX
NCA	//	VALUE FROM 1 TO 4 INDICATING THE DIRECTION OF ITERATION FOR GROUNDWATER FLOW
NCALCPT	/ROUTDUM/	THE TOTAL NUMBER OF POINTS TO BE MANAGED BY MANAGEMENT MODULE
NCH	/STAT/	NUMBER OF CHANNELS IN MODEL
NDATA	INDATA	NUMBER OF DATA VALUES EXPECTED ON A LINE OF INPUT

NDSF	CNLDATA	NUMBER OF NODES IN SURFACE FLOW LINE
NFLO(NFPLTS,3)	/STAT/	ARRAY INDEXED BY -FLOW NUMBER,1...3-. NFLO(I,1) CONTAINS THE MINIMUM MONTHLY FLOW,
NFLO(I,2)		IS THE MAXIMUM MONTHLY FLOW, AND NFLO(I,3) IS THE MONTHLY SUM
NFLPTS	/STAT/	NUMBER OF KNOWN FLOW POINTS
NLEV	/STAT/	NUMBER OF LEVEES THROUGH WHICH SEEPAGE IS TO BE CALCULATED
NMC	/STAT/	NUMBER OF CANALS TO BE MONITORED AND WRITTEN TO SPECIAL PLOT FILE
NMTR	/STAT/	NUMBER OF NODES TO BE MONITORED AND WRITTEN TO SPECIAL PLOT FILE
NODCR(NCH)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE NUMBER OF NODES THROUGH WHICH THE CANAL PASSES
NODE		POINTER USED TO DETERMINE A GRID CELL'S LOCATION IN THE STORAGE ARRAYS
NODE2	OVLNF	NODAL LOCATION OF ADJACENT NODE
NODE37A	/ROUTC/	NODAL LOCATION FOR S-37A
NODEC	CHNLF	NODAL VALUES FOR CANAL LOCATION, INDEXED BY -1...NUMBER OF NODES ON CANAL-.
NODECN	/STAT/	NODAL LOCATIONS OF ALL THE POINTS CONTAINING CANALS. STORED BY STACKING THE POINTS FOR THE ITH CANAL ABOVE THE POINTS DEFINING THE (I + 1)TH CANAL
NODES13	/ROUTC/	NODAL LOCATION OF S-13
NODES19	/ROUTC/	NODAL LOCATION OF GAGE S-19
NODES26	/ROUTC/	NODAL LOCATION FOR S-26
NODES9	/ROUTC/	NODAL LOCATION FOR S-9
NODESWL	/ROUTC/	NODAL LOCATION OF SEWELL LOCK
NODS151	/ROUTC/	NODAL LOCATION FOR S-151
NOUT(NOUT)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE NUMBER OF CANALS TO WHICH THE HYPOTHETICAL WEIR OVERFALL WILL BE SENT
NREG	/STAT/	NUMBER OF CANALS FOR WHICH REGULATION STAGES ARE SPECIFIED
NS333CK	/ROUTC/	NODAL LOCATION OF S-333 TAILWATER CONSTRAINT
NSF	/STAT/	NUMBER OF POINTS THROUGH WHICH A SURFACE FLOW LINE PASSES
NSTEP	/STAT/	NUMBER OF ITERATIONS PER DAY TO BE MADE IN THE CHANNEL FLOW SUBROUTINE
NUMD(12)		ARRAY INDEXED BY -MONTH-, CONTAINS THE NUMBER OF DAYS IN THE MONTH
NW	SFWMM	COUNTER FOR NUMBER OF WELLS
NWELL	/STAT/	TOTAL NUMBER OF WELLFIELDS IN MODEL
NYEAR		NUMBER OF YEARS IN SIMULATION
NZONE	/STAT/	NUMBER OF ZONES, USED FOR RAINFALL, AQUIFER STORAGE COEFFICIENTS, AND SURFACE DETENTION
OFM	OVLNF	INTERMIEDIATE TERM IN MANNING'S EQUATION, CONTAINS MANNING'S 'N' AND TIME
OFML(NLU,2)	/STAT/	ARRAY INDEXED BY -LAND USE TYPE,1..2-. OFML CONTAINS THE NESSARY COEFFICIENTS TO CALCULATE MANNINGS 'N' AS A FUNCTION OF DEPTH.
OLDH	/STAT/	SPARE STORAGE ARRAY
OLDP	/STAT/	SPARE STORAGE ARRAY
OUTMX	CHNLF	MAXIMUM VOLUME AVAILABLE FOR WEIR OVERFALL (FT^3)

OVLFLO(NODE,2)	//	ARRAY INDEXED BY -NODE,1...2-. OVLFLO(I,1) CONTAINS THE OVERLAND FLOW VOLUME IN EAST-WEST DIRECTION, AND OVLFLO(I,2) CONTAINS THE OVERLAND FLOW VOLUME IN THE NORTH-SOUTH DIRECTION (FT^3)
PDVOL	CHNLF	VOLUME OF WATER IN PONDING AVAILABLE FOR SEEPAGE INTO CANAL (FT^3)
PET(NLU,12)	/STAT/	ARRAY INDEXED BY -LANE USE TYPE, MONTH-. CONTAINS MONTHLY PET VALUES FOR EACH LAND USE TYPE (IN/DAY)
PEVP	ETCOMP	MONTHLY PET VALUE (IN/DAY)
PLTNM(MNTR)	/C./	CONTAINS THE 5 CHARACTER NAMES OF NODES TO BE SENT TO PLOT FILE
POND(NODE)	//	ARRAY INDEXED BY -NODE-, CONTAINS THE PONDING DEPTH REFERENCED TO GROUND SURFACE FOR EACH NODE (FT)
PUMP(NWELL,12)	/STAT	ARRAY INDEXED BY -WELL NUMBER, MONTH-. CONTAINS THE MONTHLY PUMPAGES FOR EACH WELLFIELD (MGD)
Q	KNFLOWS	DISCHARGE TO BE ROUTED BASED UPON IOPT
Q	ROUTE	CALCULATED DISCHARGE
QU(NCH)	//	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE INFLOW TERM FOR EACH CANAL (FT^3)
QUM(NCH)	//	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE MONTHLY SUMMATION OF INFLOW (ACRE-FT)
RAIN(NZONE)	SFWMM	ARRAY INDEXED BY -ZONE-, CONTAINS THE RAINFALL FOR EACH ZONE (IN)
RCAR	CHNLF	SUMMATION OF CANAL SURFACE AREA IN NODAL LOOP
RCHG(NODE)	//	ARRAY INDEXED BY -NODE-, CONTAINS THE RECHARGE TERM FOR EACH NODE (FT)
REG	CNLDATA	STORAGE FOR REGULATION STAGES READ IN
RF	CHNLF	RAINFALL OCCURING IN BASIN AVAILABLE TO FALL DIRECTLY ON CANAL
RFIN	CHNLF	ARRAY INDEXED BY -CANAL NUMBER-, STORES VOLUME ADDED TO CANAL BY RAINFALL
RNPLSET	/LAKE/	INCREMENTAL DAILY STAGE ADDED TO LAKE OKEECHOBEE TO ACCOUNT FOR RAINFALL AND ET (IN)
S(NZONE)	/STAT/	ARRAY INDEXED BY -ZONE-, CONTAINS THE AQUIFER STORAGE COEFFICIENT
S1...S9	INDATA	SUMMATION OF PET FOR EACH LAND USE TYPE
SEEPLMO	CHNLF	VOLUME OF GROUNDWATER SEEPAGE THAT WOULD RESULT IN EQUILIBRIUM BETWEEN CANAL AND AQUIFER (FT^3)
SEEP(NLEV)	/STAT/	ARRAY INDEXED BY -LEVEE NUMBER-, CONTAINS THE MONTHLY SUM OF SEEPAGE UNDER LEVEE (FT^3)
SFNAME	/C/	CHARACTER ARRAY CONTAINING THE NAME OF THE SURFACE FLOW LINE
SFQ	/STAT/	ARRAY INDEXED BY -SURFACE FLOW NUMBER-, CONTAINS THE MONTHLY SUM OF THE OVERLAND FLOW IN THE SPECIFIED DIRECTION
SGR	/STAT/	ARRAY CONTAINS THE SUMMATION OF THE SEEPAGE GRADIENTS, USED IN CALCULATING LEVEE SEEPAGE
SINF(NZONE)	/STAT/	ARRAY INDEXED BY -ZONE-, CONTAINS THE MAXIMUM SOIL INFILTRATION RATE (IN/DAY)
SRZ(NLU)	/STAT/	ARRAY INDEXED BY -LAND USE TYPE-, CONTAINS THE SHALLOW ROOT ZONES FOR EACH LAND USE TYPE. THE SIGN CONVENTION IS SPECIFIED SUCH THAT NEGATIVE IS BELOW GROUND. (FT)
STAGE	CHNLF	STAGE OF SURFACE WATER IN NODE THROUGH WHICH CANAL PASSES (FT MSL)
STAGELO	/LAKE/	DAILY STAGE IN LAKE OKEECHOBEE
STAR	CNLDATA	CHARACTER VARIABLE CONTAINING '*'
STEP	CHNLF	REAL VALUE OF ITER
SUM	CHNLF	ERROR TERM IN CANAL SUMMARY (FT^3)
SWLAST	CHNLF	INITIAL CANAL STAGE BEFORE DAILY ITERATIONS
TH	GWF	TRANSMISSIVITY AT NODE
TKX(NODE)	/STAT/	ARRAY INDEXED BY -NODE-, CONTAINS THE AQUIFER TRANSMISSIVITY (FT^2/DAY)
TX(2)	GWF	HARMONIC MEANS OF TRANSIMISSIVITIES IN X DIRECTION
TY(2)	GWF	HARMONIC MEANS OF TRANSMISSIVITIES IN Y DIRECTION

VIN	CHNLF	DAILY TOTAL OF OVERLAND INFLOW (FT^3)
VINM(NCH)	//	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE MONTHLY SUM OF THE OVERLAND FLOW INFLOW TO EACH CANAL (ACRE-FT)
VOF	OVLNF	VELOCITY OF OVERLAND FLOW VOLUME IN DIRECTION OF ITERATION (FT^3)
VOLTOLO	/LAKE/	VOLUME INTO LAKE OKEECHOBEE FROM ALL KNOWN FLOW POINTS IN MODEL (FT^3)
WDTHOV	OVLNF	WIDTH OF GRID BOUNDARY ACROSS WHICH FLOW MAY OCCUR (FT)
WFLD		CHARACTER VARIABLE USED TO STORE DIAGNOSTIC MESSAGES
WIDTH(NCH)	/STAT/	ARRAY INDEXED BY -CANAL NUMBER-, CONTAINS THE CHANNEL WIDTHS FOR EACH CANAL (FT)
XLGTH	OVLNF	LENGTH OF GRID BOUNDARY ACROSS WHICH FLOW MAY OCCUR (FT)
XM,YM,XP,YP	GWF	INTERMEDIATE VALUES USED TO CALCULATE HARMONIC MEANS
XSPC	INDATA	GRID SPACING IN X DIRECTION (MILES)
YSPC	INDATA	GRID SPACING IN Y DIRECTION (MILES)
ZN	OVLNF	MANNINGS 'N'

I. INTRODUCTION

To assist in the evaluation of water management options, the South Florida Water Management District has developed a large scale hydrologic model capable of simulating the integrated system of surface and groundwater resources present in south Florida. The model is an analytical tool for addressing regional water management issues related to changes in the design or operation of the works of the Central and Southern Florida Flood Control Project.

The hydrologic simulation model was initially developed specifically for the heavily managed flood control and water supply systems of Dade, Broward, and Palm Beach Counties. The dominant hydrologic characteristics dictated the physical processes that had to be modeled while the large area and long periods to be analyzed limited the complexity of the computer algorithms that could be used.

In the eastern portion of the area, the highly permeable surface aquifer and the interaction between the canal system and the aquifer were the primary considerations. To the west, the Water Conservation Areas and the Everglades dominate. Here the important processes are overland flow and groundwater movement to the east. Evapotranspiration is important in all areas. To realistically model these phenomena and to be able to delineate the areal extent and duration of flooding, as well as pinpoint excessive drawdown at municipal wellfields, a numerical model based on a distributed nodal network is required.

The scope of the modeling effort favored the selection of simplified mathematical formulations that were computationally efficient and whose data requirements could be satisfied without the need for additional field work. Many of the physical variables (aquifer permeability, Manning's overland flow coefficient, etc.) that control hydrologic activity can only be estimated within a fairly large range. Incorporating more sophisticated mathematical techniques will improve results only when the physical parameters can be more precisely defined. A concerted effort has been made to obtain the best physical data available. Variables that were known to be poorly defined were calibrated by comparing the model's results with historical hydrological measurements.

This report details the results of applying the model to two planning areas, the Lower East Coast (LEC) and the Upper East Coast (UEC). The LEC model covers Dade, Broward, Palm Beach, and parts of Monroe and Collier Counties. The area includes all the Water Conservation Areas, the Everglades Agricultural Area, most of Big Cypress National Preserve and Everglades National Park, and the urban areas of the Lower East Coast.

The computer model is large and very complex, with enormous data requirements. Reliable use of the model requires a thorough knowledge of the physical system as well as a clear understanding of the assumptions and limitations of the modeling techniques. Although it is not easy to use, the LEC model is capable of providing accurate answers to regional water management questions for which there is no acceptable alternative means of analysis.

The Upper East Coast model is more limited in scope. Although the model employs the same basic methodology, the area is much smaller and its hydrologic features are not as complex. The modeling was done with the same grid size as the LEC simulations and produced adequate predictions of the hydrologic response. The data set available for calibration was very limited and the large grid size hampered the simulation of local conditions in the developing eastern portion of the area. Considering the relatively small size of the area, it is both feasible and desirable to reduce the grid size to promote a more reliable representation of the hydrology near the urban areas and the major canals.

II. THE COMPUTER MODEL

Figure 1 shows the major hydrologic processes and the order in which they are computed by the model. A rectangular or square node network is used to describe the area being modeled. The regional nature of the application requires relatively large grid blocks. The Lower East Coast planning area model encompasses 6,880 square miles. A two by two mile node spacing is used, resulting in a node size of four square miles. The model uses a time step of one day. This is the minimum time increment for which hydrologic data such as rainfall, evaporation, and structure discharge is generally available. Since most simulations cover a period of years, a time step of less than one day is impractical. With these limitations, the model cannot be expected to provide detailed flood routing results for short duration storms or to precisely define the cone of depression around municipal wellfields. However, it does simulate regional flooding in undeveloped areas and also indicates excessive groundwater drawdowns when they occur.

To simplify programming and to cut down on computer time requirements, there is no iteration between surface and groundwater routines within one time step. An explicit technique is used for the numerical solution of the groundwater stage distribution for the same reasons.

Since all hydrologic processes are modeled independently within one time step, the order of calculation was chosen to handle the most transient phenomenon first.

Conceptually, the LEC model can be separated into two major components, the physical or hydrologic model, and the system management model. The hydrologic segment assimilates all the descriptive data concerning the physical system and the time series hydrologic data that drives it. Using a series of

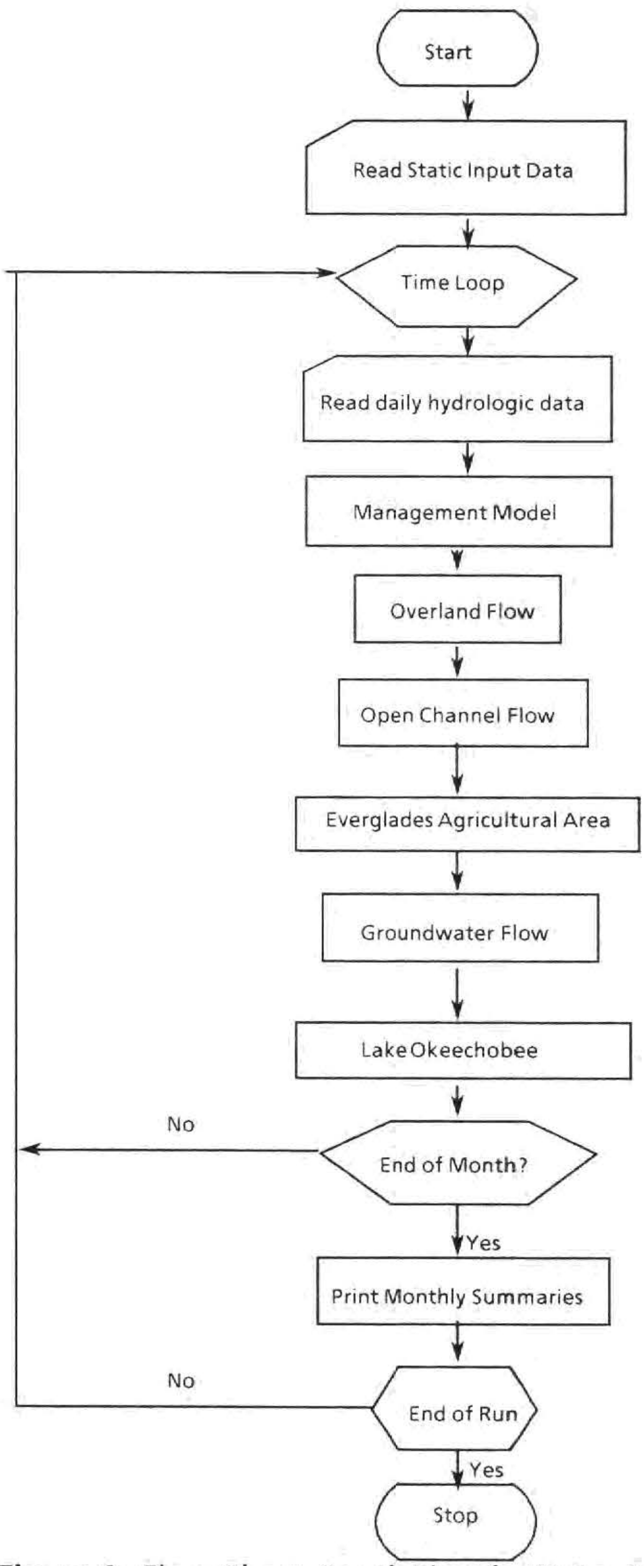


Figure 1. Flow Chart, South Florida Water Management Model

mathematical approximations for the processes involved, the water table position at every node in the system is computed. Evapotranspiration at each node and discharge through structures are also estimated by the hydrologic model. This segment is the heart of the model and it is this portion that is tested, adjusted, and verified during the calibration and verification simulations. It is capable of running alone provided the daily discharge rates at the major structures are supplied as input data to the model. For calibration and verification purposes, specifying the daily flow rates is not a problem since historical discharges must be used and these are available for all the major structures in the system. Providing daily flow values becomes a problem when analyzing modifications to the system or changes in the historical operating rules.

The system management routines were devised to allow the model to compute daily discharge at major structures when conditions make the historical flow data invalid. The management model scans the hydrologic conditions throughout the system at the end of each day of simulation. It then computes the next day's flow rate for the structures being managed based on the stage discharge relationship and the specific operational policy for each structure. The model is not capable of performing the detailed hydraulic analysis necessary to calculate an accurate value of discharge that will occur on a specific day. It is capable of choosing a realistic rate within the limits of the stage discharge function supplied by the user.

A. Static Data

The physical system to be modeled is defined by setting the appropriate value for all relevant variables at each node. A series of variables also must be defined for each canal in the model area. Initializing these variables is the first task of the computer program. The following variables are defined at each node point; land surface elevation (ft msl), initial stage (ft msl), aquifer thickness (ft), aquifer permeability (ft/day), land use type, surface water flow basin identifier, and rainfall basin identifier. Each canal requires the following variables: width (ft), regulation stage (ft) (can be fixed or vary seasonally or monthly), hydraulic connectivity coefficient (ft/day/ft of head difference between the canal and aquifer), gate width of outflow structure, canal number receiving outflow, overland flow basin identifier, and the location of each node over which the canal passes.

Other run definition data include the starting year and the number of years for the simulation; maximum number of rows and columns of nodes and the node spacing in miles; number and nodal location of all wellfields; number of specified structure flow points (the model will not calculate flow through these structures, but will obtain daily discharge values from a time series data file); number of land use types; aquifer storage coefficients and soil infiltration rates for each rainfall basin; total number of canals; surface water detention depth; Manning's coefficients, and evapotranspiration parameters.

These parameters will be discussed in greater detail in the description of the portion of the model where they are used. There is also a series of print and plot options which are set initially to determine which monthly and daily summaries are written by the program, and which data points are stored in a special file for later plotting.

B. Time Series Data

The hydrologic simulation model is essentially a system response predictor in which the system consists of the Biscayne aquifer, the major canal network, the Water Conservation Areas, etc. Response is measured in terms of groundwater and surface water stage throughout the area. The model is driven by typical hydrologic activity such as rainfall, evapotranspiration, open channel flow through major structures, and groundwater withdrawals at wellfields. The most obvious hydrologic input is rainfall. The first thing done by the program each model day is to add the day's rainfall to the POND variable at every node. The POND variable stores the surface water depth at each node for use in the channel flow, overland flow, or groundwater flow subroutines. During calibration, historical rainfall must be used. For the Lower East Coast, the area was divided into 15 rainfall basins. Up to ten rain gages were used to compute the daily rainfall values for each basin. All nodes in the model are assigned a basin identifier to indicate which rainfall amount is used at the node.

The model has the capability of estimating structure discharge in canals, or daily discharges can be specified and used as a known input to the model. For calibration, as much daily flow data as was available was read into the model. These flows were either added to or subtracted from the appropriate canal volume at the beginning of each time step.

Pumpage amounts at major wellfields must be supplied. A recharge variable is defined for each node. Wellfield withdrawals are subtracted from recharge at the node where the wellfield is located. Actual pumpage figures were used whenever possible. These are only available as monthly totals; therefore, a daily average pumpage rate is used for each month at each well.

C. <u>Open Channel Flow</u>

The goal of producing a regional model that simulates long periods of time is not compatible with the data requirements and mathematical techniques necessary to accurately model open channel flow. Most canal models use a small time step (one hour or less) and very accurate canal and watershed specification data.

With over 70 canals encompassing more than 1,200 miles, it is not possible to incorporate a sophisticated flood routing procedure in this model. However, the canals in South Florida have certain characteristics which permit major simplifications to be made in the computation of canal stages. Nearly all canals in the LEC have nearly flat canal surface profiles and there is extensive interaction between the canals and the surface aquifer. Therefore, simplifications of the channel flow process can be made while still maintaining the critical functions of drainage during times of excess rainfall, and interbasin transfer and aquifer recharge during dry periods.

The canal routine developed for this model is a mass balance procedure that sums all the inflows and outflows of a canal to determine the water surface position at the end of each time step. The canals are defined as continuous channel reaches with flow control structures at the upstream and downstream end, and nowhere in between. The location of the canals is defined by specifying the model node points over which the canal passes, beginning at the upstream end and proceeding in order to the downstream end.

The channel flow subroutine, which is used once each day, performs all the computations for every canal in the model. The routine has three major iteration loops. The outside loop is controlled by the total number of canals in the model (NCH) and insures that all canals will be analyzed in the order in which they are initially read in by the model. NSTEP is one of the run definition variables read in at the beginning of a model run. The middle loop executes NSTEP times, which is the number of channel flow time steps per day.

Increasing NSTEP increases the stability of canal stage estimations by reducing the magnitude of the stage change due to large daily flows through the structures at either end of the canal. Since this routine is a water balance procedure and the hydrologic inputs are on a daily basis, the benefits of increasing NSTEP are limited. NSTEP values greater than four do not affect the results sufficiently to warrant the increased computer time. The inner loop steps through each canal node point to calculate the overland flow and groundwater seepage interactions with the canal. Figure 2 shows the flow chart for the canal flow subroutine.

The upstream inflow, QU, is added to the canal volume in the time step loop before canal node calculations are begun. QU can be a known historical flow or a calculated outflow from another canal. QU is converted from a volume to a change in depth over the entire length of the canal. The canal node loop is then iterated for each canal and the seepage and overland inflow terms are summed for each node to determine their effect on the average canal stage. Only the average stage for an entire canal is retained in memory by the program. This stage is referenced to mean sea level and represents the stage at the downstream end of the canal. The canal parameter HDIFF is used to estimate the actual canal stage at nodes other than the downstream end. HDIFF is the average surface water change in elevation from the upstream end to the downstream end. The stage at each node is found using

$$SWL = SWLD + (HDIFF(N) \times (CL(N) - DSUM)/CL(N)) \quad (1)$$

where

HDIFF(N) imposed head drop from upstream to downstream end of the n^{th} canal,

SWL is the stage at an interior node (used in the seepage and overland inflow calculations),

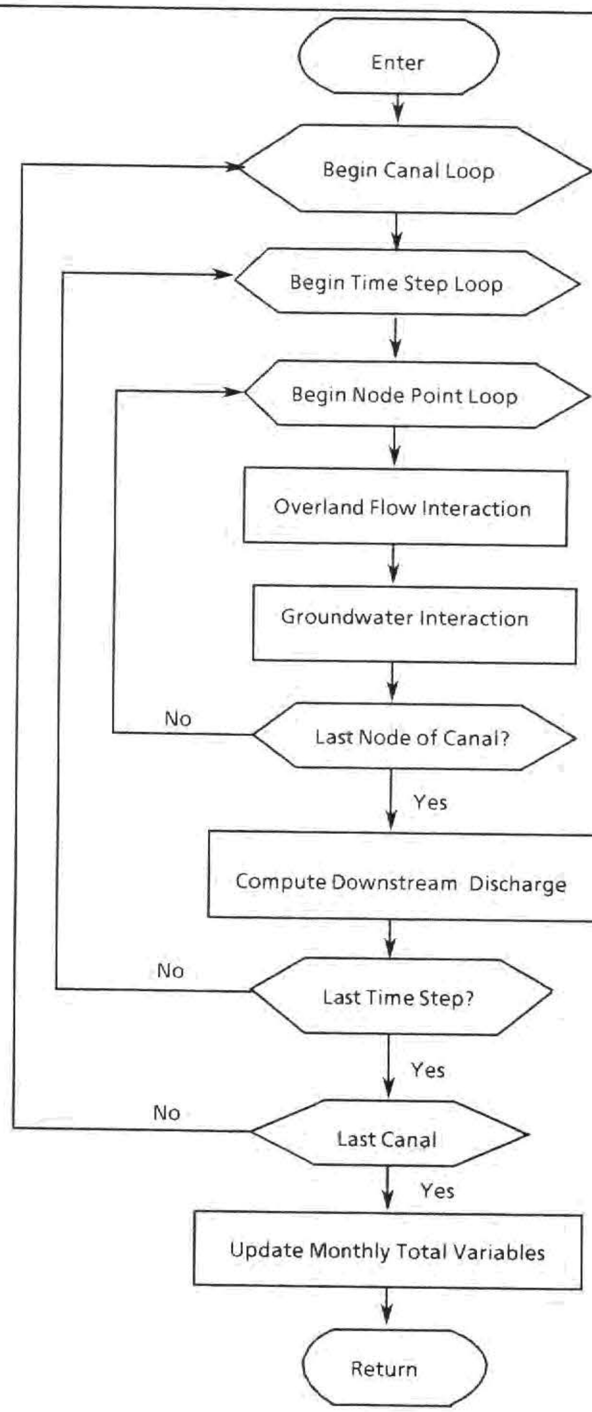


Figure 2. Block Diagram; Channel Flow Subroutine

SWLD	is the stage at the downstream end,
CL(N)	is the total length of the canal,
DSUM	is the length of the canal from the upstream end to the current node.

1. **Surface Water - Canal Flow Interaction**

The overland flow volume into or out of a canal at a node point is calculated using a simple volume distribution technique based on the difference between the canal stage and the surface water stage at the node. Each canal has an overland flow indicator that determines whether or not surface flow is allowed into or out of a canal. Canals with levees on both sides are not allowed to interact with surface water in the model.

When surface flow to or from a canal is indicated, the volume of interaction at the node is calculated to put the canal and surface water stages in temporary equilibrium at that point. When the canal stage is higher, water flows out until the two stages are equal. When the surface stage is greater, the receiving capacity of the canal is calculated (the stage difference times the surface area of the canal at that node). If there is sufficient surface volume to supply that amount, the two stages will reach equilibrium. If there is insufficient surface water available, the surface stage is reduced to its minimum value and the volume removed is added to the canal.

A surface detention depth is defined for each zone in the model. No overland flow occurs at water depths below this level.

2. Groundwater - Canal Flow Interaction

The groundwater seepage term at each canal node is determined with the following equation:

$$CGINF(node) = (SWL - H(node)) \times CHHC(N) \times DIST \times WIDTH(N) \times STEP \quad (2)$$

where

H(node)	is the groundwater head at the canal node. If the soil is saturated, the ponding depth at the node is added to H,
CHHC(node)	is a coefficient related to the channel-aquifer hydraulic connectivity. There is very little field work to use as a guide for the selection of this term; consequently it is used as a calibration variable for this model. (ft/day per foot of head),
DIST	is the length of the canal sub-reach at the node,
WIDTH(N)	is the length of the nth canal,
STEP	is the number of channel time steps per day.

Volume checks must be made to insure that the seepage calculated in equation (2) does not cause the head difference to change sign in one day. The volume that would cause the canal stage to reach equilibrium with the groundwater is calculated and compared with CGINF from equation (2). The lower of the two values is used as the actual canal seepage at that node.

3. Canal Discharge

Outflow through the downstream structure of a canal can be specified through the time series input file or estimated by the model. If calculated by the model, two procedures are available. A simple weir flow approximation can be used based on the computed canal stage and the regulation stage specified for the canal. If the computed stage is less than the regulation stage, the outflow is set to zero. When the stage is above regulation, the following weir equation is used to estimate discharge in cubic feet.

$$COUT = C \times DTS \times GWDTH \times (SWLD - CREL) \times (64.34 \times (SWLD - CREL))^{1/2} \quad (3)$$

where

COUT	is t the volume of water passing over the weir in one day (ft^3),
DTS	is the time step in seconds (86400/step),
GWDTH	is the weir crest length,
CREL	is the regulation stage (used as the weir crest elevation),
SWLD	is the canal stage at the downstream node.

The weir equation is used only for convenience. Most of the control structures in south Florida are gated spillways or culverts with risers. To use the appropriate rating curves to compute flow for each structure is a very involved process requiring accurate knowledge of the upstream and downstream stages. These stages cannot be reliably estimated with this model, so a simple technique that reflects the general management policy was chosen. It has proven to be acceptable for canals whose major function is flood control.

Canal deliveries for water supply or regulatory discharges from the Water Conservation Areas cannot be estimated with a weir formula. If these flows are not specified as input data, they must be computed by the program. The management model treats each structure (or group of structures) separately. The individual operating rules are checked against the hydrologic conditions at the specified locations. If the situation, such as a Water Conservation Area above regulation, calls for a structure to be opened, then a stage-discharge formula is applied to the conditions existing in the model to calculate the discharge. For existing stuctures, these formulas have been derived from historical data. Structures that have been operated on a consistent, well defined stage criterion can be modeled very accurately based on the historical stage discharge relationship. Other structures such as S-39, that have been operated in a less consistent manner not readily tied to a stage data location, are much harder to simulate. For these structures, and proposed new structures that are being modeled, an assumed discharge relationship must be used. This will provide realistic flow values based on the operational goals for the structure and the most appropriate stage monitoring locations in the model. A more detailed discussion of the management model, along with some examples of individual routines, is presented later in this report.

D. Overland Flow

The three processes modeled in this section of the program and the order in which they are computed are soil infiltration, overland flow, and evapotranspiration.

1. Soil Infiltration

At the beginning of each time step, the rainfall depth for that day is added to the surface ponding variable, POND, at each node point. A simplified approach to soil infiltration based on a constant infiltration rate, defined for each basin, is then used to determine how much of the surface water could possibly infiltrate. This potential infiltration is calculated using the following equation:

$$POTINF = SINF\,(node) \times DT \qquad (4)$$

where

POTINF	is the potential infiltration volume expressed in terms of depth (ft) over a grid cell,
SINF	is the constant infiltration rate (ft/day),
DT	is the time step in days.

Next the soil storage volume, MAXINF, is determined using

$$MAXINF = S \times (ELLS\,(node) - H\,(node)) \qquad (5)$$

where

S	is the soil storage coefficient,
ELLS	is the land elevation at the node (ft.msl),
H	is the water table position at the node (ft.msl).

The actual infiltration is the lowest of the three variables POND, PONTINF and MAXINF. There is no provision in the model for unsaturated soil storage. The soil column is conceptualized as being totally saturated below the water table and completely dry above. This is not an obvious simplification, but since both the infiltration and evapotranspiration routines ignore the unsaturated zone, the net effect of this assumption on the water table estimation is within the accuracy limits of regional modeling.

2. Overland Flow

Overland flow is an important phenomenon in the Water Conservation Areas and in the large undeveloped areas away from the coast. Manning's equation is used for surface flow calculations. A roughness coefficient is defined for each land use (or vegetation) type. For urban and agricultural areas a fixed value is used, (.007 and .05 respectively). At open land nodes Manning's "n" is estimated by an equation of the form $n = AxH^b$. A and b can be estimated initially based on field studies and adjusted in a calibration process using the model. Typical values for A and B are 0.5 and -.77 respectively. H is the average water depth of the two nodes for which the flow is being calculated.

The equation to compute the volume of overland flow between nodes is

$$VOF = \frac{1.49W}{nL^{\frac{1}{2}}} H^{5/3} (HU - HD)^{\frac{1}{2}} \frac{DT}{2} \quad (6)$$

where

VOF	is the volume of overland flow (ft),
W	is the width of the flow channel (DX or DY) (ft),
n	is Manning's roughness coefficient,
L	is the distance between nodes (DX or DY) (ft),
H	is the depth of flow. An average of the surface water depth at the two adjacent nodes is used (ft),
HU & HD	are the upstream and downstream stages at the adjacent nodes (ft),
HD	POND (node 2) + ELLS (node 2),
DT	is the time step (seconds).

The equation is solved once in the east-west direction, and once in the north-south direction. Therefore DT is divided by 2.

The overland flow volume is converted to depth in feet over a grid cell and added to ponding at the appropriate node. A check is made to insure that the surface water gradient does not change sign in one time step. If the volume calculated in Manning's equation would reverse the gradient, VOF is reduced to the amount that would allow the stage to reach equilibrium between the two nodes.

A basin indicator value is assigned to every node in the model. The major surface water areas have unique indicators to associate node points within a particular basin. The overland flow computations are carried out only between nodes whose basin indicator values are equal. Unique basin numbers are assigned to all the major water impoundment areas and to the portion of Dade County west of the L-31 levee. In the Everglades Agricultural Area, basins are defined to represent the drainage basin from a given structure. A special basin number is available for nodes that represent levees that are not part of the Water Conservation Area system. The nodes along the L-67EXT levee are given this specification.

3. Evapotranspiration

The ET rate is related to the amount of soil moisture available at a specific time and place in the simulation. The method chosen was the concept of potential ET, PET, along with a linear reduction equation to calculate actual ET based on the depth to the water table. The conceptual model is shown in Figure 3. PET is the maximum ET that would occur when there are no hydrological or meteorological factors to limit plant growth. PET varies with land use, cover type, and time of year. The model currently uses a set of 12 monthly PET values for each land use category. Each land use also has a shallow root zone (SRZ) and deep root zone (DRZ) term associated with it that are used to determine the actual amount of ET that will be used. The calibration of the ET and root zone parameters, along with a sensitivity analysis of ET and Manning's 'n' is presented in Part V.

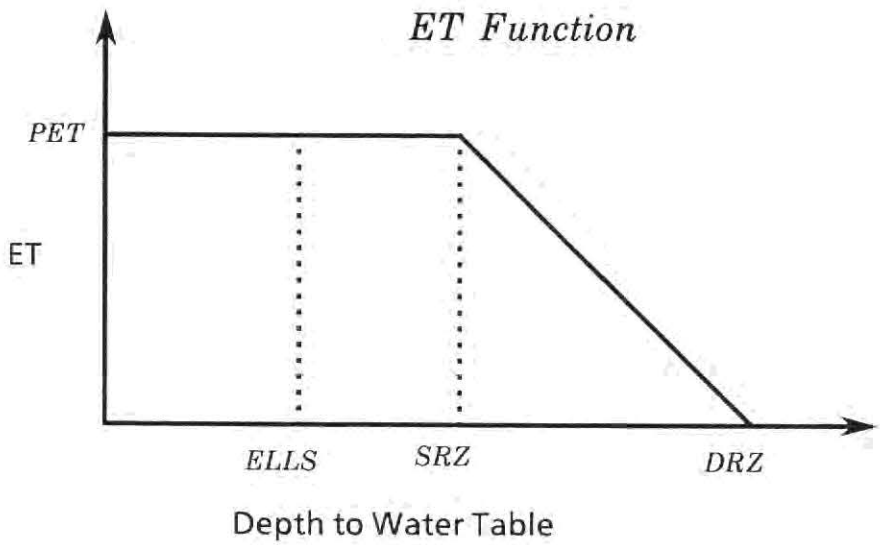


Figure 3. ET Function

ET = PET when the water table is at or above the shallow root zone

ET = 0 when the water table is below the deep root zone.

When the water table is between the shallow and the deep root zone,

$$ET = PET^{*} (DRZ - DWT)/(DRZ - SRZ) \quad (7)$$

Where DWT is the distance from the land surface to the water table,

$$DWT = (ELLS(x,y) - H(x,y)) \quad (8)$$

For agricultural land use, however, it was assumed that the ET was a constant multiplied by the PET. This constant was calibrated from historical data.

TABLE 1. Potential Evapotranspiration (In/Month) for Each Land Use Type

	Land Use (See Legend below)								
Month	1	2	3	4	5	6	7	8	9
1	1.56	2.72	2.79	2.05	2.50	2.85	2.22	2.40	1.98
2	1.79	2.69	3.35	2.39	3.00	3.42	2.62	2.82	2.34
3	2.50	3.39	4.63	3.35	4.14	4.14	4.73	3.72	3.32
4	2.82	3.71	5.47	3.89	4.90	5.59	4.26	4.59	3.80
5	3.18	4.80	5.94	4.24	5.31	6.06	4.62	4.97	4.12
6	2.87	4.79	5.20	3.71	4.65	5.31	4.10	4.41	3.65
7	2.92	5.21	5.44	3.98	4.87	5.56	4.18	4.50	3.73
8	2.92	5.10	5.41	3.94	4.84	5.52	3.99	4.30	3.56
9	2.47	4.50	4.58	3.35	4.10	4.68	3.49	3.75	3.11
10	2.34	3.50	4.38	3.09	3.92	4.47	3.17	3.41	2.83
11	1.76	2.92	3.32	2.38	2.97	3.39	2.43	2.62	2.17
12	1.56	2.60	2.79	2.05	2.50	2.85	2.08	2.24	1.86
Annual Total (Inches)	28.69	45.90	53.30	38.40	47.69	54.43	40.88	44.03	36.48

Land Use:

1. Urban
2. Agricultural
3. Marsh I
4. Vacant Land
5. Big Cypress
6. Marsh II
7. Agricultural--Truck Crops
8. Agricultural--Sugar Cane
9. Agricultural--Irrigated Pasture

E. Groundwater Modeling

The groundwater portion of the model is based on the finite difference approximation of the linearized, two-dimensional, transient, subsurface flow equation for unconfined aquifiers.

$$T_x \frac{\partial^2 h}{\partial x^2} + T_y \frac{\partial^2 h}{\partial y^2} = S \frac{\partial h}{\partial t} + RCHG \tag{9}$$

T_x and T_y are the transmissivity values in the x and y directions, respectively. S is the aquifer storage coefficient and RCHG is the recharge term, which includes wellfield pumpage, groundwater seepage to or from canals and surface ponding, and ET.

When discretized for finite difference solution, this becomes

$$T_{x1} \frac{(h_{i-1,j} - h_{i,j})}{\Delta x} + T_{x2} \frac{(h_{i+1,j} - h_{i,j})}{\Delta x} + T_{y1} \frac{(h_{i,j+1} - h_{i,j})}{\Delta y} + T_{y2} \frac{(h_{i,j-1} - h_{i,j})}{\Delta y} =$$

$$S_{i,j} \frac{(h^t_{i,j} - h^{t-1}_{i,j})}{\Delta t} + RCHG_{i,j} \tag{10}$$

where i and j are the x, y coordinate identifiers; Δx and Δy are the grid block sizes, and Δt is the time step. The T_{x1}, T_{x2}, T_{y1}, T_{y2} are arithmetic means of the transmissivity for the adjacent grid points.

There are several means of solving the discretized groundwater equation. To minimize computer time and provide stability during computations, the Saul'yev method of solution was chosen (B. Carnahan, Applied Numerical Methods, P.451). This technique has the advantage of being an unconditionally stable, explicit procedure that eliminates the need for iteration within a single time step.

The finite difference groundwater equation is solved from four different directions in four succeeding time steps. The boundary conditions must be specified, then the solution algorithm proceeds in a straightforward manner. For example, assume the solution at time t is proceeding in the positive y direction along rows $j = 1$ to $j = y$ max at column $x = i$. The only unknowns in the equation are $h_{i,j}$, $h_{i+1,j}$, $h_{i,j+1}$. By substituting the values from the previous time step for $h_{i+1,j}$ and $h_{i,j+1}$, the only unknown remaining is $h_{i,j}$ and the equation can be solved explicitly for this term.

Other than the specified boundary conditions, the recharge term RCHG includes the major stimuli that could result in groundwater fluctuations. These include ET, groundwater seepage, either through surface ponding or canal-aquifer interaction, and wellfield pumpage. Wellfield pumping is treated as a negative recharge since water is being removed from the system. The volume removed by pumping is converted to an equivalent depth of groundwater and is subtracted uniformly over the entire grid cell. The model does not compute drawdown at the well site.

III. SYSTEM MANAGEMENT MODEL

A system management model is incorporated into the South Florida Water Management Model (SFWMM) to allow the computation of discharges at any flow point, except boundary inflows. The system management model is conceptually split into three categories: the Everglades Agricultural Area, Lake Okeechobee, and the remainder of the modeling area. Each of these areas apply different procedures in determining the structure discharges.

A. Structure Modeling

For each structure, FORTRAN code is explicitly written to estimate discharges based upon desired operational criteria. In general, operational criteria specify the conditions under which the structure will be operated. These operating rules have as their basis groundwater-surface water stages. Once the determination has been made that the structure is to be opened, a stage vs. discharge relationship is consulted to determine the discharge at the flowpoint.

The system management model has as its basic assumption that groundwater-surface water stages are indicative of the overall hydrologic conditions and, therefore, can be used to manage the outflows. Historical stages and discharges are used to develop stage vs. discharge correlations. The stage-discharge relationships are not based upon equations of flow through culverts or gated weirs. They are correlations based upon historical stages and discharges. Modified culvert and gated weir relationships have been applied with some success using the upstream and downstream groundwater-surface water stages, however. . Figures 4 through 9 present the historical basis on which the stage vs. discharge curves were derived for certain

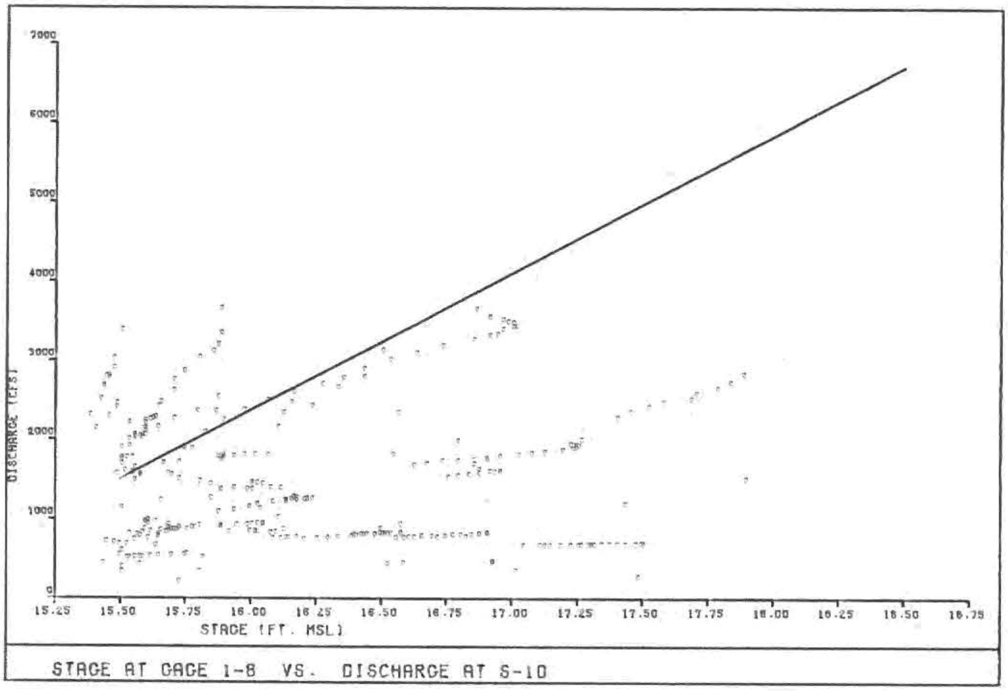


FIGURE 4.

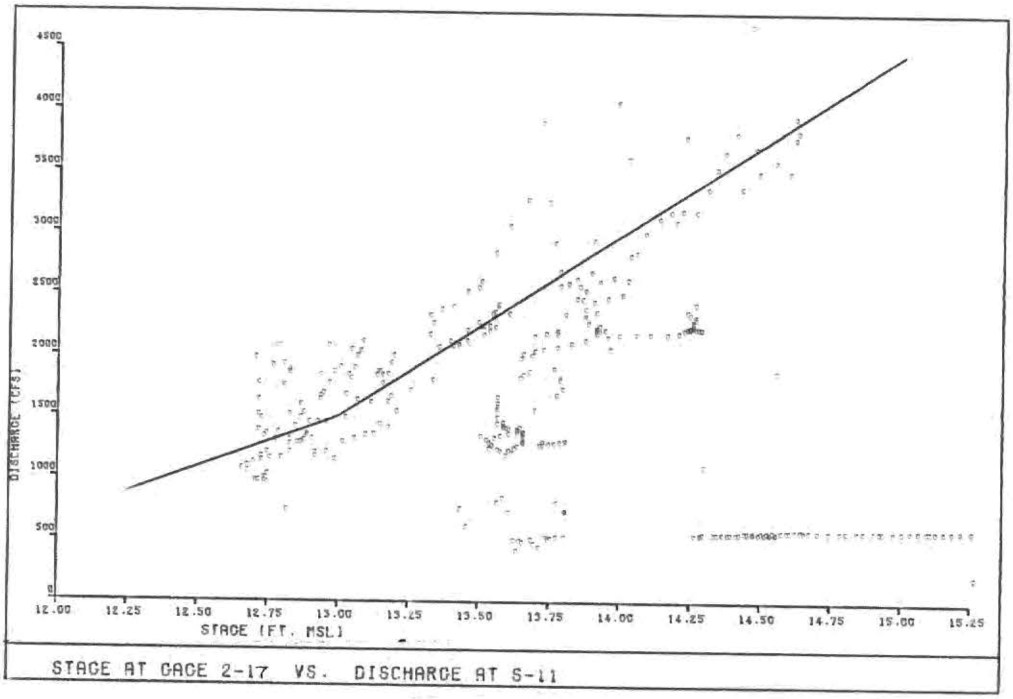
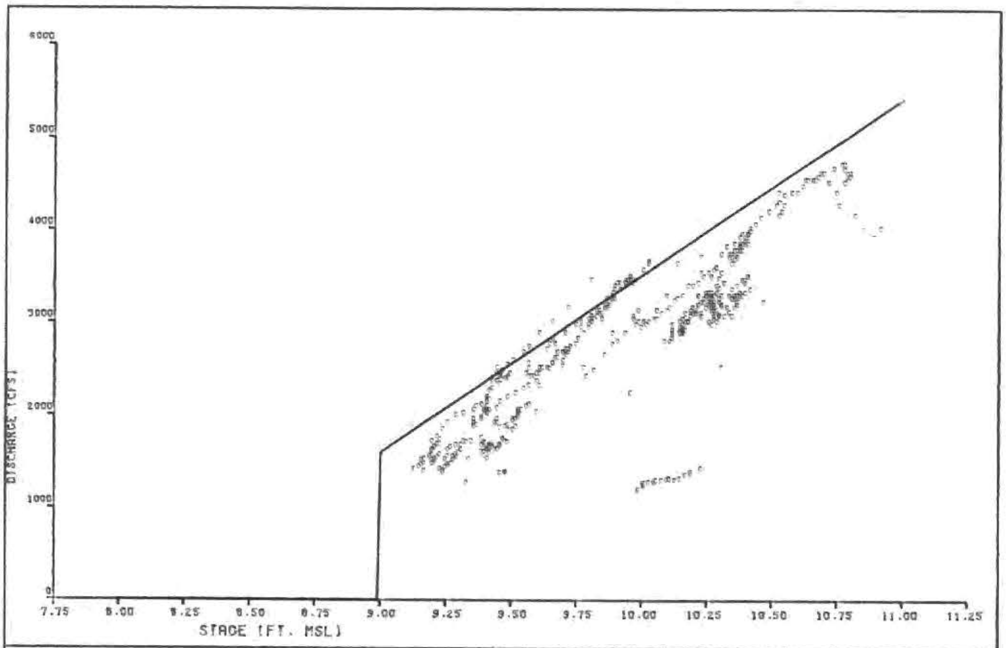
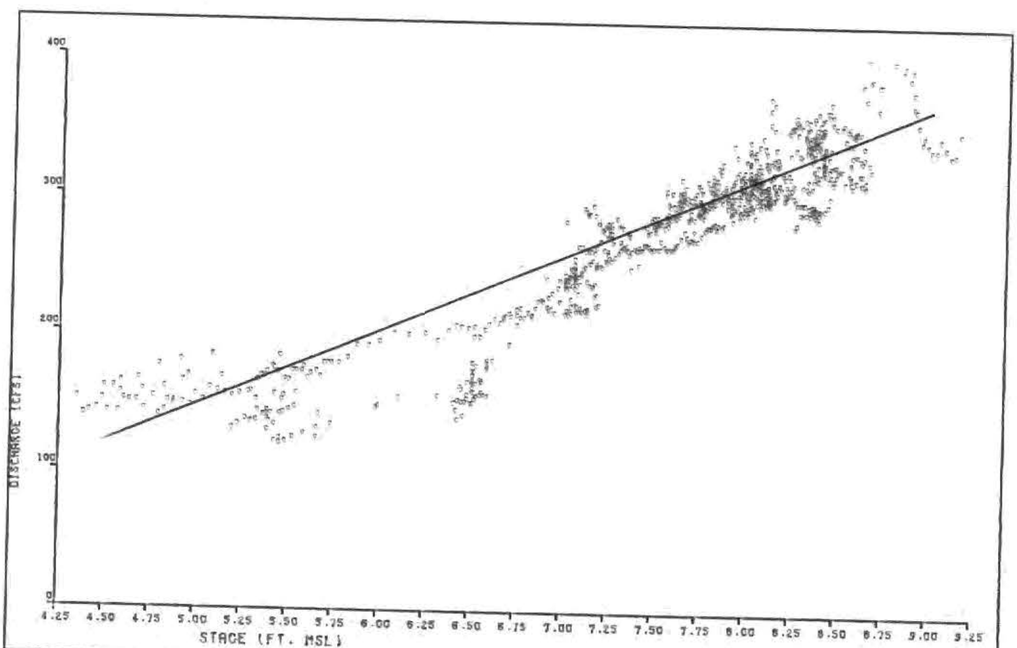


FIGURE 5.



STAGE AT GAGE 3-28 VS. DISCHARGE AT S-12

FIGURE 6.



STAGE AT GAGE 3B-29 VS BASE FLOW AT S-31

FIGURE 7.

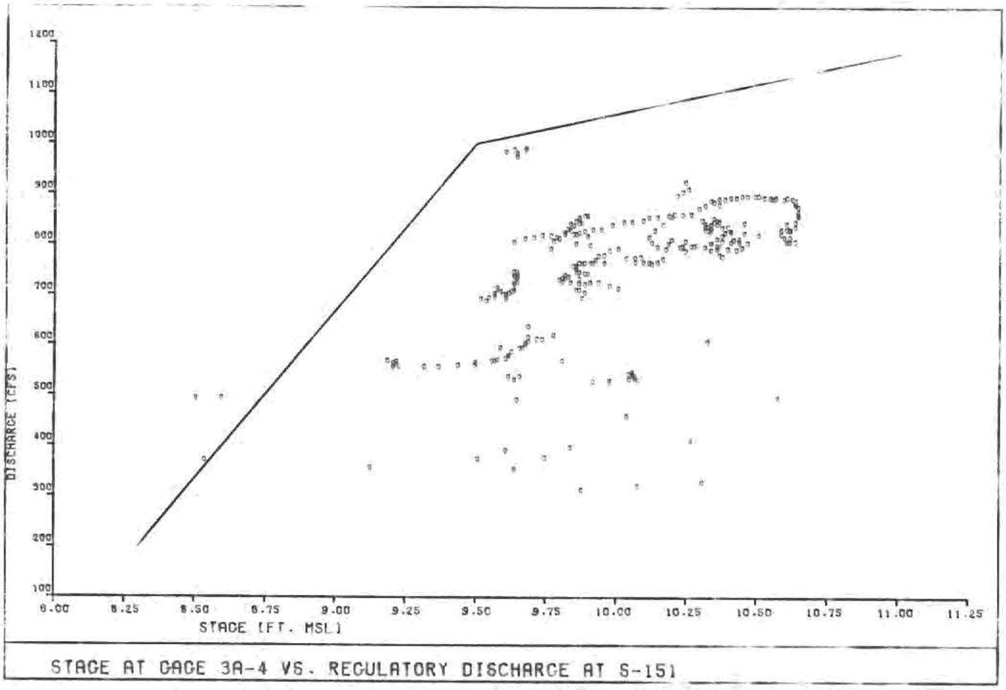


FIGURE 8.

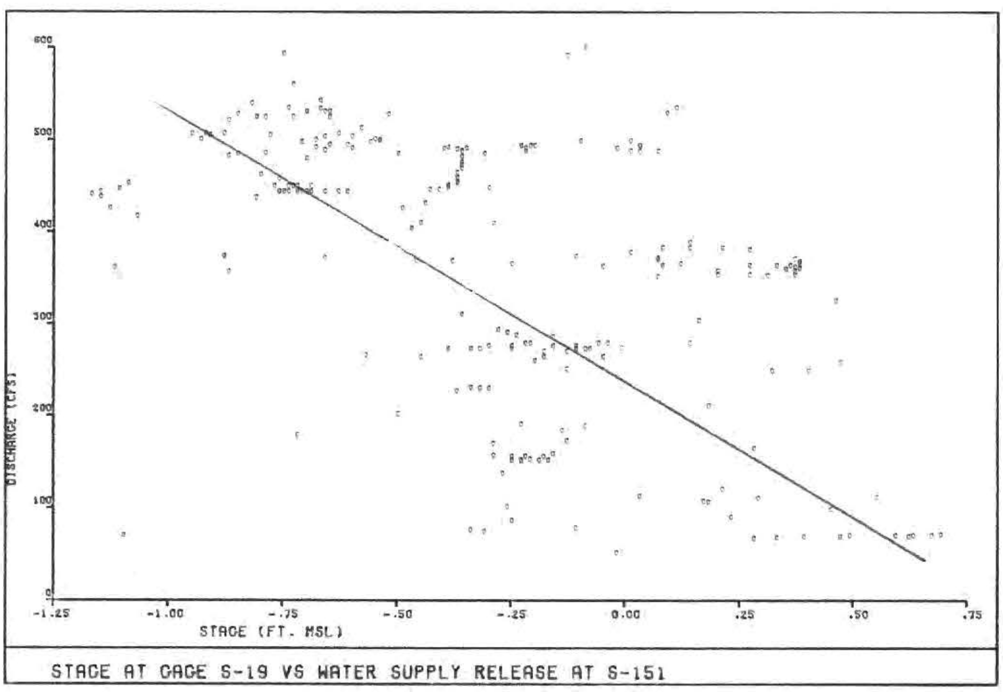


FIGURE 9.

key structures. The historical data is represented by points, while the solid line is the equation chosen to describe the points. This solid line is the stage vs. discharge correlation used to calculate discharge once it has been determined that the structure is to be operated.

Figure 7 shows the historical stage vs. discharge data for S-12 while Figure 4 shows the same relationship for S-10. Both sets of structures were supposedly operated in response to regulation schedules; however, S-12 has good correlation, while S-10 exhibits a great degree of scatter. Although the matter can be explained by gate operation, regional water conditions, extraordinary events, etc., it does highlight some of the difficulties which may be encountered in precisely determining the stage vs. discharge correlation for any given structure.

The criteria under which a structure is opened are usually fairly well defined, such as a regulation schedule for the Water Conservation Areas, or water conditions at key locations. These criteria can sometimes be inferred from the historical stage vs. discharge relations. For other structures, such as S-39, the historical combination of irrigation demand, water supply, and regulatory releases make the operation rule so pragmatic that calibration becomes difficult. In such cases, it is usually desirable to describe theoretical and/or design operation, and not calibrate the discharge to historical flows. It is also possible that construction has altered a structure so as to make the historical stage vs. flow relationship inaccurate, such as S-151. The historical curve must then be modified to reflect this change when modeling the present project. Table 2 shows the operation rules used to define the operation of the structures in the LEC.

TABLE 2 Structure Operations in the Management Model

Structure/s	Operation
S-10	Regulatory release when WCA-1 is above regulation. Historical discharge is correlated to gage 1-8C.
S-11	Regulatory release when WCA-2A is more above its regulation stage than WCA-3A is above its regulation stage. Keyed to gage 2-17.
S-12	Regulatory release when WCA-3A is above regulation. Minimum ENP delivered all other times. Keyed to gage 3-28.
S-151	Dry season regulatory releases passed to WCA-3B if stage there is less than 9.0'. If WCA-3B is above 9.0' during dry season regulatory releases, then pass the release through S-31. If wet season regulatory release, send to WCA-3B only if stage is less than 9.0'. Key to gage 3-4. If S-19 indicates water supply releases are necessay, then pass flows through S-31.
S-31	Pass base flow keyed to gage 3-29. Pass dry season S-151 regulatory release if WCA-3B is above 9.0'.
S-26	Operate based upon stages in drainage basin, represented by gage S-19.
S-34	Regulatory releases when downstream basin allows. (Checks gages G-617). Water supply deliveries based upon gage G-617.
S-9	Operate when stage near pump exceeds 4.0'.
S-13	Operate based upon stage near pump.
S-38	Regulatory releases based upon WCA-2A stage and stage at downstream node. Water supply based upon G-616.
S-37A	Operate based upon nearby stage.
S-39	Regulatory releases from WCA-1 when downstream node permits.

Table 2 - continued

Name	Operation
S2(HGS-4), S3(HGS-3), HGS5, S5A, S6,S7, S8	Operate based upon Interim Action Plan and Ever-glades Agricultural Area water demands.
S-77,S-308	Regulatory releases from Lake Okeechobee.
S-333	Pass regulatory releases from WCA-3A when possible. Keyed to gage 3-28.
S-339, S-340	Closed except to pass water supply releases through S-151.
S-344, S-343	Regulatory releases from WCA-3A.
All others	Weir flow

In determining the location of the monitoring points to be used as the basis for a structure's operation rule, the modeler may choose any point where a good correlation is expected, or where enough historical data exists to derive a historical correlation. It is recommended that canal stages not be used in any management routines. When canal stages are used in lieu of groundwater stages in the present management scheme, the result is an instability in the flow calculations. This is because the canal stages could change drastically if large volumes were removed or added.

As an example of a typical managed structure, S-12 is examined. Figure 10 shows the FORTRAN source code in the system management model used to calculate discharges at the S-12 structures.The first IF statment is true only when S-12 has been specified for discharge calculation. If not specified to be

```
IF (INFLO .EQ. IFLOS12) THEN
     RMIN3A    = 7.0
     STG3A4    = H(IG3A4) + POND(IG3A4)
     STG3A3    = H(IG3A3) + POND(IG3A3)
     STG3A28   = H(IG3A28) + POND(IG3A28)
     STGCA3A   = (STG3A4 + STG3A3 + STG3A28)/3
     DELTA     = STGCA3A - RMAXCA3(MONTH,IDAY)
     IF (DELTA .GT. O.) THEN
          Q = 1912.*(STG3A28-9.)+1250.
          IF(Q.LT.VOLENP(MONTH)/86400.) Q =
          VOLENP(MONTH)/86400.
          KFLO(IFLOS12) = IFIX(Q)
     ELSEIF (STGCA3A .GT. RMIN3A) THEN
          VOL = VOLENP(MONTH)
          KFLO(IFLOS12) = IFIX(VOL/86400.)
     ELSE
          KFLO(IFLOS12) = 0
     ENDIF
ENDIF
```

FIGURE 10. FORTRAN Code for Typical Structure (S-12)

calculated, the model will use historical data. The code first checks the stage at WCA 3 gages used to determine the three gage average (STG3A3, STG3A4, STG3A28), then computes the three gage average (STGCA3A). The function RMAXCA3 returns the value of the regulation schedule on any given day and the three gage average is checked to determine if WCA-3A is above regulation. If the area is above regulation, then a regulatory discharge is calculated and returned to the main model via the KFLO(NFLPTS) array. If the

WCA-3A stage is below regulation (DELTA .LT.0), then a determination as to the minimum ENP delivery is made (VOLENP(month)). This method and its variations are used to control most structures. When FORTRAN code is not explicitly defined in the management model, the assumption of weir flow is made. When weir flow is assumed, all calculated outflows will appear in the COUT term listed in the monthly canal summaries. If there exist values for this flow point in the known flow file, the discharge contained in this file will be ignored.

B. Lake Okeechobee

The system management model has special provisions to manage Lake Okeechobee. Fidelity in modeling the present project was given priority over calibration to historical stages and discharges when designing the management model. With completion of the Port Mayaca Lock, the operation rules regarding the lake have been significantly altered. These new operational criteria are what the system management model presently uses to manage lake Okeechobee.

Figure 11 shows the criteria by which the decision to release water from Lake Okeechobee was made. The stage vs. discharge relations were based upon the design criteria instead of historical data. Since, historically, the Lake stage rarely exceeded 15 ft msl due to a regulation schedule lower than the present one, the historical stage vs. discharge correlations would have little validity under present operating conditions. Stages in Lake Okeechobee are computed using a water budget method. Each day, all inflows from areas not in the modeled area are read and added to the water budget. Also, a daily incremental stage, incorporating historical ET and rainfall over the lake, is read in and input to the water budget equation. Then, the managed outflows are

Zone	Agricultural Canals	Caloosahatchee River	St. Lucie canal
A	Pump maximum practicable to conservation areas for regulaton after removal of local runoff	Up to maximum capacity (9,3000 c.f.s. at S-77) without local flooding	Up to maximum discharge at S-308C
B	Same as above	Up to 4500 c.f.s. at S-77	Up to 2,500 c.f.s. at S-80, except when exceeded by local inflow
C	No regulatory discharge	No regulatory discharge	No regulatory discharge
	First Piority	Second priorty	Third Priority

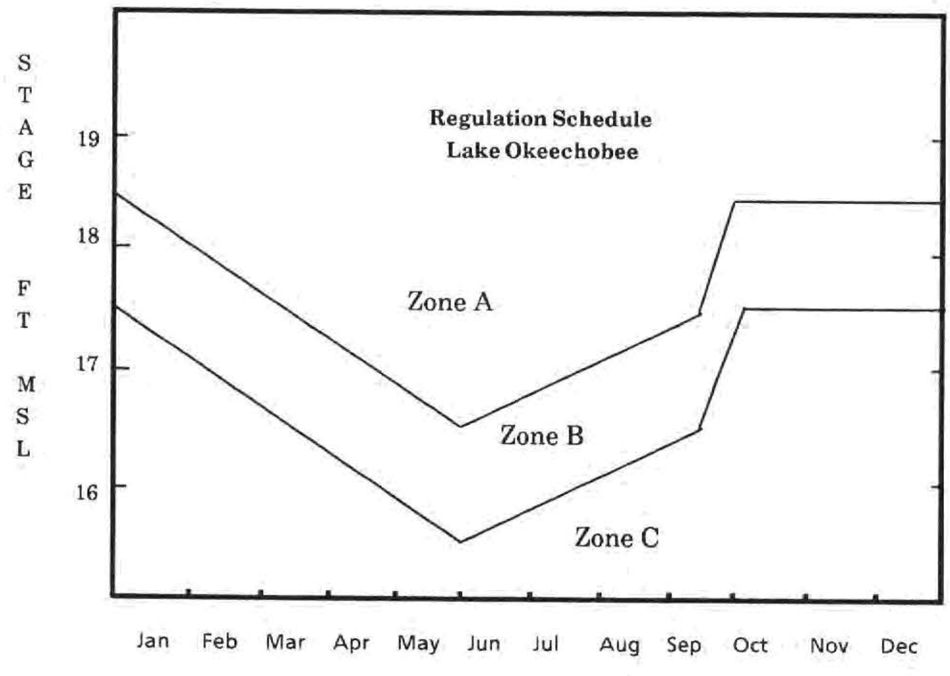


Figure 11. Lake Okeechobee Operation Rules

summed and added in the water budget. The new stage is then computed, to be used as the basis for the calculation of the next day's outflow.

C. Everglades Agricultural Area

The modeling of the Everglades Agricultural Area (EAA) has as its premise that groundwater stages are forced to reside between narrow limits. Any excess will be removed and any deficiency will be added such that the water table will always stay within those limits. Another unique feature of the EAA is that when water is either added or removed from the area, it is added or removed directly to/from the groundwater. Each structure has a defined drainage basin and water is added or subtracted uniformly from each node in the basin.

The Interim Action Plan of backpumping to Lake Okeechobee is assumed to be in effect. This plan is modeled by assuming that when the southern pump stations (S-8, S-7, S-6, S-5A) have reached capacity, the pump stations on the lake will become operative. When all outlets for a given drainage basin are at capacity, the groundwater stage is then forced to rise in that basin, exceeding the upper limit. Each successive day will attempt to restore the groundwater level to the accepted range.

IV. MODEL OPERATION

The South Florida Water Management Model has a voluminous data requirement and is capable of producing large amounts of information. This section defines those data requirements and the input formats, and describes the various outputs which the model can generate.

A. Input Requirements

The input requirements fall into four general categories: model definition data, canal definition data, static input data, and time series data. The model definition data includes those parameters that define the areal extent, simulation length, monitor location, output options, PET values, structures to be managed, etc. The canal definition defines the locations of each canal and its characteristics, levees under which seepage is to be calculated, and defines surface flow lines. The static input data consist of that data defined for each nodal point, such as initial conditions, aquifer characteristics, and land use type. The time series data include rainfall, flows, wellfield pumpage, and other inputs required on a daily basis.

1. Model Definition Data

A file must exist in the job environment named "LECDEF". This file will be opened and the necessary information extracted. This file is built according to the specfications which follow.

The first line of this file contains:

IFYR -	the first year of the simulation,
NYEAR -	the number of years in the simulation,
DT -	the incremental time step (days),
MAXY	maximum number of nodes in the y (north-south) direction,

NFLPTS the number of known flow points in the model. (Must include those points to be managed.)

NWELL number of wellfields in model,

NZONE - number of zones grid is broken into. Used for rainfall, surface detention, soil infiltration, and aquifer storage coefficients,

XSPC,

YSPC - grid spacing in X and Y directions, respectively (miles),

NLU - number of land use types,

NMTR - number of ground water monitoring points to be written in plot file,

NLEVS - number of levees across which seepage will be calculated (not used).

The format for this line is (I5, I3, F3.0, 4I3, 2F3.0, 3I3).

The next line of input allows the user to monitor canal stages in the system and save the stages to a special plot file. The line is input with a free format and is structured as:

MNC - number of canals to be monitored,

MTRC - array containing the channel number of canals to be monitored (23 max).

The third line of the file contains the output options. These options are shown in Table 3. The line is input with a free format, with a '0' signifying rejection or '1' signifying acceptance, in the location corresponding to the option. The default value is rejection. With these output options, the user is able to request various types of information, or various trace levels. Furthermore, many debug traces are imbedded in the source code, but are inactive. To obtain very detailed traces, the user is directed to examine the specific subroutine in which a trace is desired and to activate the necessary code, usually by removing the comment indicator, or an absolute GO TO statement.

TABLE 3 Output Options

OPTION	EFFECT	LOCATION
1	Print static input data	TAPE75
2	Print canal, levee, surface flowline specifications	TAPE79
3	Print summary of known flows	TAPE72
4	Print wellfield pumpages	TAPE75
5	Print monthly canal summaries	TAPE72
6	Print end month stage, ponding, maximum monthly stages	TAPE90
7	Print inundation frequencies	TAPE90
8	Print end month stages	TAPE70
9	Print end month ponding	TAPE70
10	Print monthly ET totals	TAPE70
11	Prints daily information instead of end-month information when used with options 6,7,8,9,10 ------**caution**------ This option generates large amounts of data and should be applied with care	TAPE70
12	Daily canal stages	TAPE85
13-15	Not used	

The next section of "LECDEF" is used to define the areal extent of the model. The modeling boundaries are defined by specifying the maximum and minimum horizontal coordinates for each vertical step or row. The actual number of lines depends upon the number of nodes to be modeled. The first array to be read in is the MAXX array, which defines the eastern extent of the modeling area. The eastern boundary can be described by the set of coordinates

$$(MAXX(i),i), i = 1,2, ...,MAXY \tag{11}$$

The format used to input these variables is (14I3).

The second array, MINX, is used to describe the western boundary. This array contains the minimum X coordinate for each value of Y, using the Cartesian grid. Therefore, the western boundary is described by the set of points

$$(MINX(i),i), i = 1,2, ..., MAXY. \tag{12}$$

The input format is (14I3).

A third array is used to describe the eastern-most extent of overland flow. By specifying the extent of overland flow, great savings in execution time can be realized by not having to calculate overland flow in areas where such flow is prevented by the existence of drainage work, e.g., the urbanized coastal areas. The western extent of overland flow is assumed to be the western model boundary; the eastern boundary can be described by the set of coordinates

$$(MXOV(i),i), i = 1,2, ..., MAXY. \tag{13}$$

The format is (14I3).

The next line contains the initial stages in the Water Conservation Areas and Lake Okeechobee. They are input in this order: CA3A, CA3B, CA2A, CA2B, CA1, Lake Okeechobee. The format used is (6F5.2). The initial Water Conservation Area stages are used to set the initial ponding depth for those areas, while the Lake Okeechobee stage is used as the initial value for the water budget calculations.

The next 12 lines are used to describe the potential evapotranspiration for each land use type in the model. A two-dimensional array, PET(12,NLU) where NLU is the number of land uses, is used to store the PET values. PET is input as the average maximum ET daily rate (ft/day) for each month, using a (9F7.0) format for each of the 12 lines.

Following PET, the remaining parameters of the ET model, the root zones, are defined for each land use type. For both the deep root zone and the shallow root zone, the sign convention is taken such that below ground is the positive direction. The array SRZ(NLU) stores the shallow root zones for each land use read in using a (10F6.0) format. Next, the array DRZ(NLU), containing the deep root zones, is input with a (10F6.0) format.

Following the ET model input, the Manning's 'n' coefficients are specified for each land use type. The Manning's 'n' is a function of depth and previously defined as

$$n = AxH^{b} \tag{14}$$

where

n is Manning's 'n',
H is the ponded depth,
A, b are coefficients.

The first line following the deep root zone is the 'A' coefficients, with the succeeding line being the 'b' coefficients. Both lines use a (10F16.0) format.

The next three inputs have to do with seepage and ponding. The maximum soil infiltration rate, stored in SINF(NZONE), must be given for each zone. The rate (ft/day) is input with a (15F4.2) format. Next, the aquifer storage coefficient, S(NZONE), is input using a (15F4.2) format. The aquifer storage coefficient is dimensionless. Following the storage coefficient, the surface detention depth is specified. The surface detention depth (ft) is used to define the surface storage, or the threshold depth at which overland flow occurs. The detention depth is stored in the DETEN(NZONE) array, and is needed for each zone; the input format is (15F4.2).

The next lines are the names and locations of monitoring points. The number of lines is NMTR. The format for these variables is (A5,2I3), where the name, PLTNM(NMTR), is five characters long followed by the X and Y coordinates, respectively, of the monitored location.

The final line in "LECDEF" is used to control the management model. The flow number of the structure to be managed (1 through NFLPTS) is specified. The following is input with a free format:

NCALCPT - number of points to be managed,
ICALCPT - flow numbers of points to be managed.

The next model definition file is the flow point file, locally named "KFLPTS2", which outlines the disposition of the known flows to be used in the model. The file contains the following variables for every known flow destination and origin point:

FNM	6 character name for the flow point,
IOPT	Flow numbers of points to be managed (See Table 4)
IDV	number of destination points for flow,
K1,K2,K3,K4	
	canal numbers of (X,Y) coordinates of the flow destination points. These values will be coordinates or canal indicators based upon the value of IOPT. Table 4 gives a detailed explanation.

The above variables are read in with a (A5,6I4) format. The last four integers have different meanings, depending on which option has been selected (IOPT). Table 4 describes each flow option and what the interpretation of the K1...K4 variables would be under each possible value of IOPT.

The IDV variable gives the number of distribution points for the flow. For example, S-150 flow is sent to two different nodes so IDV is set to 2. Both outflow points must have consecutive entries in the "KFLPTS2" file.

The user is also able to define variable regulation schedules for any canal in the model area. These are the last lines for file "KFLPTS2". There is a line for each canal regulation stage to be controlled seasonally. There are two ways of specifying seasonal regulation stages: 1) by entering the beginning month stage for each calendar month, or 2) by entering two numbers corresponding to the wet and dry season stage, respectively. The data entry for either case is:

NC -	canal number which uses this regulation schedule,
N -	number of points (N = 12 for monthly regulation or N = 2 for seasonal),
REG -	array containing regulation stage values.

TABLE 4

Flow Options

OPTION (IOPT)	RESULT
0	Special option to handle the complicated situation near S-31. The option forces the execution of code specially designed for S-31 and nearby structures.
1	Flow from outside the model to ponding at node (K1,K2). An example of this option would be half of the L-3 flows into the northwest corner of WCA-3A.
2	Flow from outside of model to canal K1. Examples of this are flows from Lake Okeechobee into the nearby canals.
3	Flow from pond (K1,K2) to pond (K3,K4). This option is not used in the LEC model.
4	Flow from pond (K1,K2) to canal K3. This option is not used in the LEC model.
5	Flow from canal K1 to pond (K2,K3). Examples of this option are S144, S145, S146 between CA-2A and CA-2B.
6	Flow from canal K1 to canal K2. Examples of this type would be S151, S12, etc.
7	Special option for structures bordering the EAA. The flow is from basin K1, from canal K2. The sign of K2 is significant. A positive indicates from canal K2 to the EAA, while a negative indicates from the EAA to canal K2. An example would be S7 from the EAA to borrow canal L-38.

If N = 12, the daily regulation stage is found by linear interpolation between the month end dates. When N = 2, the dry season value is the first specified by REG value, and the wet season is the second. Linear interpolation is used to define the regulation stages for the transition months, May and October.

2. Canal Definition Data

Two separate files are used to store all the data needed to describe each canal in the model. The first file must be named locally "CNDTA22"; it contains the physical parameters necessary for each canal. The first record (format (2I5)) contains:

NCH - number of canals in the model,

NSTEP - the number of increments the daily time step is divided into when making channel flow calculations.

The rest of the file contains one line for each canal with the

following canal variables:

CNM - five character name of canal,

HDC - total change in elevation between canal water surface at the upstream and dowstream nodes (ft),

WIDTH - width of canal; must be constant for entire length (ft),

CREL - crest elevation of hypothetical weir (ft msl); can be varied by use of seasonal regulation stages,

GWDTH - length of crest of hypothetical weir (ft),

CHHC - canal-aquifer connectivity coefficient,

LCNB - basin indicator in which canal is located. This variable is used to check whether overland flow from the node is allowed into the canal,

NOUT - number of outflow points for the weir overfall,

INTO - array containing identifiers of receiving points. This is usually the canal number of the canal(s) downstream of the control structure. Other possible values are -1 for no outflow calculation or 0 for ocean outfall. INTO defines only the destination of the flow calculated by the hypothetical weir approach. Flow points with known flows or flows calculated by the management model should not be included.

The format for these records is (A5, F4.1, 4F8.0, 1X, I5, I6, 4I5).

The remaining canal data file, locally called "CANAL22" gives the geographic location of each canal by specifying the model node points through which the canal passes. There is one entry in the file for each canal. The order of canals in "CANAL22" must exactly correspond with the order specified in the previous canal definition file "CNDTA22". The format is (A5, I3, 2X, 6(I3), 10 (/10X, 7(3I3)), and the elements of each entry are:

- CNM - 5 character canal name,
- NODCR - number of node points through which canal passes,
- IXC, IYC - (X,Y) coordinates, respectively, of canal node point,
- ICL - indicator specifying the orientation of the canal through this node point. Number 1 indicates vertical, 2 indicates horizontal, and 3 indicates diagonal. This is used in computation of channel length.

The model is also capable of estimating seepage under levees and summing surface flow across arbitrary boundaries. The locations of these levees and surface flow lines are added to "CANAL22" after the canals have been defined. The format is as for the canal definition and the variables input are:

- LVNAME- 5 character alpha-numeric description of levee,
- LNODES- number of nodes through which levee passes,
- XCN, YCN- (X,Y) coordinates, respectively, of the levee node point,
- ICL - indicator of direction in which seepage will be calculated. The directions and corresponding indicators are shown in Figure 12.

The surface flow lines definitions follow immediately after the levee definitions, separated by an 'XXXX'. The format is also (A5, I3, 2X, 6(I3), 10(/10X, 7(3I3)), and the variables input are:

- SFNAME - 5 character description of surface flow line,
- NDSF - number of nodes through which the surface flow line passes,
- XCN, YCN- (X,Y) coordinates, respectively, of surface flow point,

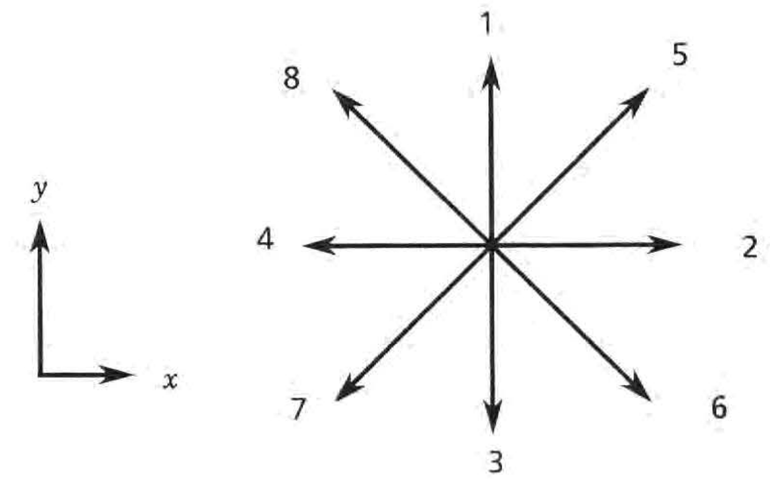


Figure 12. Direction indicator for calculation of levee seepage

ICL - Sign of this indicator is used to detect the desired direction of flow and sum the over land flow in that direction. A positive sign will sum the north-south flows, while a negative sign sums the east-west flows. The absolute value of this indicator is a sort key unique to each surface flow line. The user assigns these values in a south to north manner.

3. Time Series Data

The known flow data, stored in a file locally called "LECFLO", is read in on a daily basis. Discharge (cfs) is given for every known flow point, even if the flow is to be calculated by the management model. The first line of this file contains the beginning year of the flow data. The second line gives a five character name corresponding to each known flow point. The remaining records (one for each day of the simulation) contain the flow for every known flow point in the model in a (43I5) format.

The rainfall data is contained in a file named "BRF6975". The file is organized in such a way that every day rainfall (inches) is read in for each basin. Also, on the same line as the rainfall, a daily incremental stage (inches) and daily Lake Okeechobee inflow (cfs) are read in. The inflow discharge is a lumped discharge representing all the flows not modeled and the incremental stage accounts for daily ET, rainfall, seepage, and error terms. The input format is (16F6.0).

Wellfield pumpages are stored in a file locally named "WELLDAT". Each line contains the following data:

WLFD -	6 character indentifer of wellfield,
IXP, IYP-	(X,Y) coordinates, respectively, of wellfield,
PUMP -	the average daily withdrawal rate (MGD per month) for each of the 12 months.

The array PUMP (NWELL, 12) contains the pumpages for all wellfields for one year. The file "WELLDAT" is organized in such a way that all wellfields are grouped by year. In this way, one year of pumpages may be input by reading NWELL lines. Therefore, the total number of lines in "WELLDAT" is the number of wellfields times the number of years in simulation. The format used to input the above variables is (A6, 2(3X,I4), 12F5.0).

4. Static Input Data

The static data are defined at each node and would include aquifer characteristics, initial conditions, land surface elevations, land use indicators, rainfall and canal basin indicators. These data are contained in a file locally named "STATDTA" with the order in the sequence outlined below.

a. <u>Land Surface Elevations</u>

The land surface elevation in ft msl must be specified for each node. The input variables are:

JY - Y-coordinate (row) of data on this card image,

IX1, IX2 - beginning X coordinate and ending X coordinate (column) of the data on this card image, respectively,

ELLS - land surface elevations (ft msl).

The format to read land surface elevations is (3X, 3I3, 11F6.2). Therefore, IX1 and IX2 can, at most, differ by 10. The number of lines needed depends upon the number of nodes modeled.

b. <u>Land Use Indicators</u>

Each node must have the land use specified for it. The land use indicator is specified by the number of the land use type, defined in the run definition file. The input variables are:

JY - Y-coordinate (row) of the data on this card image,

IX1, IX2 - beginning X coordinate and ending X coordinate (column) of the data on this card image, respectively,

LUTYP - land use type indicator for each node.

The format to read land use indicators is (3X, 3I3, 27I2). Therefore, IX1 and IX2 can at most differ by 26. The number of lines needed depends upon the number of nodes modeled.

c. **Canal Basin Identifiers**

The canal basin indicators are used in the Everglades Agricultural Area to control the water table, and in other areas to limit overland flow. Overland flow will not occur between nodes unless these basin identifiers are equivalent. The input variables are:

JY - Y coordinate (row) of data on this card image,

IX1, IX2 - beginning and ending X coordinates (columns), respectively, of data on this card image,

IBSN - canal basin indicator array.

Input format is (3X, 3I3, 27I2). The number of lines depends upon the number of nodes modeled.

d. **Rainfall Basin Identifier**

The rainfall basin indicator specifies the rainfall zone to which each node belongs. The number of zones is defined on the first line of the run definition file. The input variables are:

JY - Y coordinate (row) of data on this card image,

IX1, IX2- beginning and ending X coordinates (columns), respectively, of data on this card image,

IZONE - rainfall basin indicator.

The input format is (3X, 3I3, 27I2). The number of lines depends upon the nodes modeled.

e. **Initial Groundwater Stage**

The initial groundwater stage in ft msl must be specified for each node. The value cannot exceed the land surface elevation of the node. Input variables are:

JY - Y coordinate (row) of data on this card image,

IX1, IX2- beginning and ending X coordinates (columns), respectively, of data on this card image,

H - groundwater stage (ft msl).

The format used is (3X, 3I3, 11F6.2).

f. **Initial Ponded Stage**

The initial ponding depth, in units of feet above ground surface, must be specified for each node. Input variables on each line are:

JY - Y coordinate (row) of data on this card image,

IX1, IX2 - beginning and ending X coordinates (columns), respectively, of data on this card image,

POND - ponding (ft).

The format is (3X, 3I3, 11F6.2).

g. **Aquifer Depth**

The thickness of the surficial aquifer, in feet, is also specified for every node. Variables on each line are:

JY - Y coordinate (row) of data on this card image,

IX1, IX2 - beginning and ending X coordinates (columns) of data on the card image,

AQDEP - aquifer depths (ft).

The format is (3X, 3I3, 11F6.2).

h. **Aquifer Permeability**

The permeability of the surface aquifer is given to the model at every node in units of feet per day $*10^{-4}$. The variables on each line are:

JY - Y coordinate (row) of data on this card image, IX1, IX2 - beginning and ending X coordinates (columns) respectively, of data on this card image,

AQPERM - aquifer permeabilities. (ft/day * 10^{-4}).

B. Output Description

Most output for the SFWMM is written to unnamed FORTRAN tapes. The quantity and levels of output are selected in the run definition file (LECDEF), explained in the input requirements section. This section describes the information contained in the files generated by the model.

Table 5 shows a summary of the model outputs and their FORTRAN tape numbers. The rest of this section details the contents of those tapes.

1. Tape 70: The file could contain the month end stage and ponding information, as well as monthly ET for the period of simulation. The user may generate all this information by accepting LP(8), LP(9), LP(10), (see Table 3). This file is designed to give results that can be sent to the line printer, and is formated to give a two-dimensional line printer graphics output. The first line contains a table of contents for the file. Every remaining line is written with a key in the first column.

   Both the table of contents and the key column use the following information:

Key	Information Contained on Line
1	Stage for Lower East Coast (LEC)
2	Ponding for LEC
3	ET for lower LEC
4	Stage for Big Cypress Basin
5	Ponding for Big Cypress Basin
6	ET for Big Cypress Basin

TABLE 5 **Output from South Florida Water Management Model**

Information	LP	File	Comments
End of month stages, line printer ready	8	TAPE70	Stages are grouped by basin, (Lower East Coast or Big Cypress Basin)
End of month stages	6	TAPE90	No basin grouping, not acceptable for printing
End of month ponding, line printer ready	9	TAPE70	Ponding is grouped by basin (LEC or Big Cypress)
End of month ponding	6	TAPE90	No basin grouping, not acceptable for printing
Monthly ET Totals	10	TAPE70	Values grouped by basin (LEC or Big Cypress) - line printer ready
Inundation frequency	7	TAPE90	No basin grouping, not acceptable for printing
Daily values	11	-	Prints all the above information on a daily basis
Maximum monthly stages and day of occurrence	6	TAPE90	No basin grouping, not acceptable for printing
Canal summaries	5	TAPE72	Suitable for printing
Known flow summaries	3	TAPE72	Suitable for printing
Wellfield pumpage summary	4	TAPE75	Suitable for printing
Echo of canal specifications	2	TAPE79	Suitable for printing
Echo of levee specifications	2	TAPE79	Suitable for printing
Echo of surface flow specifications	2	TAPE79	Suitable for printing
Echo of static data	1	TAPE75	Suitable for printing
Stage plot file	---	TAPE76	Automatic, used as input for graphics generation
Canal plot file	---	TAPE77	Automatic, used as input for graphics generation
Yearly canal summary	---	TAPE79	Automatic, suitable for printing

Table 5. continued

Information	LP	File	Comments
Daily canal stages	12	TAPE85	Suitable for printing
Water Conservation Area water budgets	---	TAPE80	Automatic, not suitable for direct printing. To be used with a report generator
Levee seepage and surface flow line volumes	---	TAPE80	Automatic, not suitable for printing. Data will not exist unless levees or surface flow lines are specified
Daily known flows	---	FLO2X2N	Contains flows calculated and/or used by model. It is a look-a-like to "FLO2X2"

The table of contents contains a '1' or a '0' in the location corresponding to each of the six keys. A '1' indicates that the file contains the data corresponding to the key, and a '0' indicates that the data is not on the file. Every subsequent line contains an integer (1 through 6) in column 1 which indicates the type of information contained on the line. A small program can then be written to sort the information and the user can extract the desired results.

2. Tape 72: This file could contain end-of-month flow and canal summaries. The file may be sent directly to the line printer following its generation. The flow summaries may be requested by signaling LP(3), and the canal summaries are generated by LP(5). (See Table 3.) The flow summary reports the minimum and maximum discharges (cfs) which occurred during the month, and the volume (acre-ft) of water through each structure during the

month. This value is the flow used by the model, either known or managed. The canal summaries contain the following information:

- CNL - canal name preceded by the canal number,
- CRE - crest elevation (ft msl) at which weir overfall occurs,
- CSMAX - maximum monthly canal stage (ft msl),
- CSMIN - minimum monthly canal stage (ft msl),
- COUT - volume sent over the weir to the downstream canal(s) (acre-ft),
- SEEPAGE- groundwater contribution to canal. Negative indicates groundwater recharge (acre-ft),
- INFLO - contribution from upstream weirs and known flow points (acre-ft),
- OVLF - contribution from surface water inflow. Negative indicates flow out of the canal to ponding. (acre-ft),
- DSWLM - change in canal storage (acre-ft).

3. Tape 75: This tape could contain the static data echo and the wellfield pumpage summary. The static data echo is produced by LP(1) and the wellfield pumpage summary is a result of LP(4) being accepted. This file is designed to be sent directly to the line printer. The LEC and Big Cypress areas are split so as to allow the same format used when printing end-month stage, ponding, and monthly ET. The wellfield summary contains the monthly pumpages in MGD for all of the modeled wellfields.

4. Tape 76: This tape contains the stage summary file for those monitoring points requested in the run definition file. The date and end-month stage are printed out for the period of simulation. This file is used to generate a "plot file" that can be used to graphically represent stages. The format used is (2I3, I5, 23F6.2). The first line of the file contains the names of the node points as

defined in the run definition file, in a (I3, 10X, 23A6) format. This file is automatically generated.

5. Tape 77: In the run definition file, the user may request canal stages to be stored in a "plot file". Tape77 is the "plot file" for the canal stages. The first line of the file contains the canal names in a (I3,10X, 23A6) format, while the remaining lines contain the date and stages in a (2I3, I5, 23F6.2) format. This file is automatically generated.

6. Tape 79: This file could contain a canal data echo, levee data echo, surface flow lines data echo, and the month-end canal stages in a yearly summary. The data echos are all given with LP(2) set while the canal stage summary is automatically produced. This file is designed so that no modification is required before it is sent to the printer.

7. Tape 80: This tape stores the levee seepage estimates, the surface flow line volumes, and the water budget output. All the information is generated automatically. The file is not meant to be sent directly to the line printer and contains various tags and keys useful in sorting and editing. All data having to do with levee seepage volumes have the alphanumeric tag 'LV' imbeded in the line. Therefore, to extract levee seepage volumes, the user must search for all lines containing the 'LV' tag. Similarly, to get information of seepage gradients across those levees, the tag 'SG' is imbeded in the line. To extract information on surface flow lines, an 'SF' tag must be sifted from the file. The water budget information contains a 'BG' tag to differentiate it from the levee

seepage and surface flow information. Furthermore, the water budget data contains a key to sort out in which water budget the line belongs. This key is saved in column 4 on the header and in column 3 on every line thereafter (immediately following the 'BG' tag). The code for the keys is:

Key	Code
1	Water budget for WCA-1
2	Water budget for WCA-2A
3	Water budget for WCA-3A
4	Water budget for WCA-2B
5	Water budget for WCA-3B

8. Tape 85: The model is capable of generating canal stages on a daily basis when LP(12) is activated. These daily stages are stored in Tape 85. Caution should be used in requesting output on a daily basis since the enormous quantities of output produced could quickly swamp the mass storage devices.

9. Tape 90: When LP(6) is activated, the model will generate a special file on which end-month stage, ponding, and maximum monthly stage data are stored. Inundation frequency is also stored in this file when LP(7) is accepted. This file is not meant to be routed to the printing device, but to serve as raw data for various report generation programs. The data is stored in a format such that the Big Cypress and LEC basins are not split and every node is output. Keys are placed in column 1 to aid in sorting the data; they have the following code:

Key	Code
1	End of month stage
2	End month ponding
3	Inundation frequency
4	Maximum monthly stage and day of occurrence

It should be noted that no dates are imbedded in the file and the results of the first day are also dumped into this file. Inundation frequency is given in months/year. The format used for the stage, ponding, and inundation frequency is (A,47F6.2). The maximum monthly stage and day of occurrence is stored in a coded format. The result is dumped in an (A47I7), in which the first three digits of the I7 format represent the day of occurrence and the next four digits are the maximum stages multiplied by 100.

10. FLO2X2N: This file is the only named file produced by the model. It contains the discharges (cfs) that were either used or computed by the model. The file is formated exactly as the "FLO2X2" file, which contains the daily known flow inputs. Therefore, this file can be used as input to other runs or report generators in exactly the same manner as "FLO2X2".

11. OUTPUT: The information written to output is basically an echo of that found in the definition files. Some run time results are sent to the output file: the stage monitoring locations requested in the run definition files. In production runs at the SFWMD, job control language is used to edit the FORTRAN tapes containing the generated results and then the desired results are sent to this file.

V. SIMULATION OF THE LOWER EAST COAST

This chapter is devoted to a presentation of the calibration and verification results for the Lower East Coast. A brief explanation of the calibration procedure is put forth, and a sensitivity analysis of the major calibrated parameters is also presented.

A. Calibration and Verification of the Lower East Coast

The calibration procedure for the Lower East Coast was essentially the same as for a pilot study. As much data as possible was collected to be used as input or calibration bench marks. The period 1969-1971 was chosen as the calibration period because it contained the extremes of severe drought and heavy rainfall within the three-year span. The period of 1973-1975 was then chosen as a verification period. This time span contains two "average years" and one dry year.

Since the calibration is sensitive to rainfall, structure discharge, and wellfield withdrawals, considerable effort was made to define those inputs as accurately as possible. Most raingages in or near the area were used in an attempt to make the rainfall simulation as realistic as possible. Table 6 provides a list of the raingages used in the simulation. Discharges of major structures were obtained from USGS reports. These reports are published each year under the title Water Resources Data for Florida, Volume 2: South Florida. When not found there, the information was requested from the Data Management Division of the SFWMD. Withdrawals from major wellfields were supplied directly by the utilities. Minor wellfield pumpages were estimated based upon their permit applications filed with the Water Use Division of the SFWMD.

Table 6. Rainfall Gages Used in the Simulation of the Lower East Coast

Station	County	Description	SE	TN	RG
MRF6054	Dade	Tamiami Canal @ 40 Mile Bend	16	54	35
MRF6107	Dade	Royal Palm Ranger	14	58	37
MRF124	Dade	S-18C	33	58	38
MRF9097	Dade	Homestead Airport	5	57	38
MRF6120	Dade	Homestead Exp. Station	35	56	38
MRF6060	Dade	South Miami 5W	32	54	40
MRF12	Dade	Homestead Field Station	8	57	39
MRF120	Dade	S-194	1	56	38
MRF118	Dade	Railing Property	6	55	40
MRF9008	Dade	Wheeler Property	13	54	40
MRF122	Dade	S-20F	17	57	40
MRF124	Dade	S-18C	33	58	38
MRF7120	Dade	Trail Glades Range	4	54	39
MRF291	Dade	WCA-3 S-12D	24	54	36
MRF6066	Dade	Hialeah	18	53	41
MRF6068	Broward	Lauderdale Exp. Station	22	50	41
MRF117	Dade	Miami Field Station	16	53	40
MRF110	Broward	Carrol Ranch	16	50	40
MRF115	Broward	S-9	27	50	39
MRF151	Broward	Ft. Lauderdale Field Station	33	50	41
MRF7076	Dade	Pennsuco 5NW	10	52	39
MRF6069	Broward	Fort Lauderdale	17	50	42
MRF105	Broward	S-36	20	49	42
MRF113	Broward	S-13	25	50	41
MRF109	Broward	Sewell's Lock	14	50	41
MRF108	Broward	Dixie Water Plant	18	50	42
MRF9018	Dade	Stonebreaker	17	52	42
MRF173	Broward	WCA-3A - Northwest	30	40	36
MRF174	Broward	WCA-3A - Northeast	11	48	37
MRF98	Broward	S-8	6	48	36
MRF288	Broward	WCA 3 - 3	10	49	38
MRF106	Broward	WCA 3 - 26	28	49	39
MRF95	Broward	Key Groves	3	50	40
MRF103	Broward	WCA 2-19	24	48	40
MRF100	Palm Beach	S-39	26	47	40
MRF6071	Broward	Pompano Beach	34	48	42
MRF101	Palm Beach	Boca Raton@SR441-LWDD	18	47	42
MRF104	Broward	Pompano Farmer's Market	34	48	42
MRF172	PalmBeach	Vaugh Recorder	27	44	35
MRF128	Palm Beach	Wetherald - US Sugar	29	44	36
MRF73	Palm Beach	South Bay	13	44	36
MRF57	Palm Beach	Pelican Lake Drainage Dist #1	12	42	37
MRF135	Palm Beach	Pelican Lake Drainage Dist #2	2	42	37
MRF58	Palm Beach	Osceola Farms	17	42	38
MRF6119	Palm Beach	Belle Glade Experiment Sta	5	44	37
MRF96	Palm Beach	Big B Ranch	10	46	37
MRF99	Broward	S-7	27	47	38

Table 6. continued

Station	County	Description	SE	TN	RG
MRF135	Palm Beach	Pahokee	18	42	38
MRF82	Palm Beach	Shawano Pump 5	25	42	38
MRF252	Palm Beach	WCA 1-7	34	45	38
MRF253	Palm Beach	WCA 1-9	18	46	41
MRF95	Palm Beach	S-6	3	46	39
MRF89	Palm Beach	WCA 1-8	36	45	41
MRF102	Palm Beach	Boca Rd @Powerline	16	47	42
MRF612	Monroe	Flamingo	9	61	34
MRF277	Palm Beach	Dick Rogers' Property	1	42	42
MRF76	Palm Beach	S-5A recorder	32	43	40
MRF220	Palm Beach	S-5A standard can	32	43	40
MRF54	Palm Beach	Pratt and Whitney	24	41	40
MRF66	Palm Beach	M&M Ranch	36	42	39
MRF6074	Palm Beach	Loxahatchee	32	43	41
MRF5008	Collier	Monroe Tower	14	53	32
MRF6048	Collier	Everglades	14	53	29
MRF78	Palm Beach	Greenacres	23	44	42
MRF81	Palm Beach	LakeWorth Rd @E1	31	44	42
MRF6075	Palm Beach	WPB Airport	31	43	43
MRF77	Palm Beach	WPB Field Station	6	44	43
MRF301	Palm Beach	Plant Intake-City of WPB	21	43	42

Close attention was paid to the accumulation of static data, which includes land surface elevations, aquifer characteristics, land use types, and drainage basins. Land surface elevations were obtained from contour maps when the grid was superimposed. The maps were on file in the Map Room of the SFWMD and were generated from Corps of Engineers and SFWMD surveys. Aquifer characteristics were obtained from various USGS sources. For Palm Beach County, the information was obtained from the USGS publication, "Hydraulic Conductivity and Water Quality of the Shallow Aquifer, Palm Beach County, Florida," (USGS Water Resources Investigation 76-119). Aquifer depth in Palm Beach County was based upon the USGS report, "Geologic Data from Test Drilling in Palm Beach County, Florida" (Open file report 76-713). For Dade and Broward Counties, "Biscayne Aquifer, Southest Florida" (USGS

Water Resource Investigation 78-107) was the primary source. In addition, Appel (1973) provides much data on the aquifers along the coasts of Dade and Broward Counties. Aquifer parameters were calibrated only when data was sparse or to provide smooth transition between aquifers. The 1973 land use was provided by the Land Resources Division of the SFWMD.

The two major hydrologic unknowns to be calibrated were evapotranspiration rates and friction losses during overland flow. To a much lesser extent, the canal-aquifer connectivity coefficient (CHHC) and the gate width (GWDTH) for the hypothetical weir were also calibrated. Table 7 shows the final canal parameters As a starting point for agricultural ET, the values from Mierau (1974) were used. All ET rates were essentially calibrated, as were root zones. Manning's 'n' coefficients used in the computation of overland flow were taken from a Corps of Engineers' report "Everglades Gaging Program Progress Report for Period Ending December 31, 1956" (Report No. 6, dated July 1957). A sensitivity analysis to ET rates and Manning's 'n' is presented in the next section.

The Everglades Agricultural Area of western Palm Beach County was calibrated on the assumption that water levels are maintained within a narrow range. When water was removed or added to this area, it was assumed to be in response to maintaining groundwater stages within that range. Table 8 shows the calibration error for the Everglades Agricultural Area. The values shown are an indication of how well historical discharges matched the assumption of holding the groundwater stage within the narrow range.

More importance was placed upon the model being able to accurately predict groundwater-surface water stages than canal stages. This is because it is assumed that groundwater stages are more indicative of regional water

Table 7. Canal Parameters Used in the Lower East Coast

	CNL	HDROP	WIDTH	CREL	GWIDTH	CHHC	LCNB	NOUT	IOUT		
1	L-8	0.0	75.0	11.0	50.0	5.00	0	1	3		
2	C-18	2.5	30.0	11.0	30.0	10.00	0	1	0		
3	MCNL	2.0	50.0	12.0	15.0	10.00	1	1	4		
4	C-17	0.0	75.0	6.0	50.0	5.00	0	1	0		
5	L-10	0.0	100.0	12.0	80.0	5.00	9	1	8		
6	C-51	4.8	160.0	8.0	40.0	2.00	0	1	0		
7	AGR4	0.0	100.0	12.0	80.0	.01	10	1	5		
8	AGR3	0.0	100.0	12.0	80.0	.01	9	1	5		
9	AGR2	0.0	100.0	12.0	80.0	.01	8	1	11		
10	AGR1	0.0	100.0	12.0	80.0	.01	7	1	18		
11	L-20	0.0	120.0	11.0	120.0	5.00	8	2	18	9	
12	WPCB	0.0	100.0	12.5	80.0	.10	88	1	-1		
13	LWD1	0.0	80.0	13.5	80.0	2.00	0	3	6	28	14
14	LWD2	0.0	60.0	13.5	60.0	2.00	0	3	74	28	15
15	LWD3	0.0	60.0	13.5	60.0	2.00	0	3	74	28	21
16	CGBLS	0.0	100.0	2.0	50.0	2.00	0	1	0		
17	C-16	0.0	75.0	6.5	40.0	5.00	0	1	0		
18	L-25	0.0	110.0	11.0	100.0	2.00	0	2	10	9	
19	L-5	0.0	100.0	12.0	60.0	2.00	0	1	9		
20	CA-1	0.0	50.0	16.0	10.0	2.00	1	1	-1		
21	C-15	0.0	75.0	6.5	50.0	3.00	0	2	0	74	
22	L -4	0.0	50.0	11.0	45.0	5.00	12	1	23		
23	C-60	.5	50.0	10.0	45.0	5.00	3	1	-1		
24	MIAMI	2.0	100.0	10.0	60.0	1.00	3	1	25		
25	CA-3	2.0	150.0	7.6	50.0	1.00	3	1	-1		
26	L-38	1.0	75.0	12.0	30.0	2.00	2	1	-1		
27	CA-2A	1.0	60.0	12.0	10.0	1.00	2	1	-1		
28	HLSB	2.0	80.0	6.7	15.0	2.00	88	1	0		
29	C-14	1.0	100.0	6.0	55.0	4.00	0	1	30		
30	C-14E	0.0	150.0	4.0	55.0	.50	0	1	0		
31	C-13	.5	80.0	4.2	35.0	.50	0	2	35	0	
32	C-13E	0.0	60.0	.5	45.0	2.00	88	1	0		
33	C-12	0.0	60.0	3.0	45.0	5.00	0	1	-1		
34	C-7	0.0	100.0	2.0	30.0	5.00	0	1	0		
35	NNRC	0.0	80.0	4.0	60.0	1.00	0	1	39		
36	L-37	0.0	75.0	6.0	45.0	10.00	24	1	37		
37	C-11W	0.0	160.0	4.0	25.0	4.00	0	1	38		
38	C-11	0.0	100.0	1.5	45.0	4.50	0	1	37		
39	C-57	0.0	450.0	1.0	100.0	4.00	0	1	41		
40	L-33	0.0	100.0	5.5	20.0	10.00	24	2	43	37	
41	C-10	0.0	420.0	1.0	110.0	8.00	0	1	0		
42	C304	0.0	50.0	8.0	45.0	7.00	5	1	-1		
43	C -9	.3	150.0	2.0	25.0	4.00	0	1	0		
44	L28A	.5	50.0	7.2	10.0	1.00	6	1	-1		
45	L-30	0.0	110.0	5.0	65.0	10.00	0	2	55	53	
46	C-DRN	6.0	50.0	4.0	15.0	1.50	0	2	17	6	
47	C -8	0.0	50.0	1.8	45.0	5.00	0	1	-1		
48	DBLEV	0.0	75.0	4.5	45.0	10.00	0	1	53		
49	C -6	.5	80.0	2.0	50.0	2.00	0	1	34		

Table 7 continued

50	C-SPC	0.0	100.0	4.8	40.0	5.00	0	1	53		
51	L-67E	0.0	50.0	5.0	45.0	5.00	44	1	-1		
52	L-29	0.0	80.0	7.0	45.0	7.00	6	1	-1		
53	C- 2	0.0	150.0	3.0	200.0	1.50	0	2	54	0	
54	C-6E	0.0	100.0	.4	95.0	10.00	0	1	0		
55	L31N	0.0	50.0	5.0	62.0	10.00	0	2	57	61	
56	C100C	0.0	45.0	4.0	40.0	2.00	0	1	59		
57	C-1W	0.0	60.0	5.0	60.0	10.00	0	1	63		
58	C100	0.0	45.0	4.0	40.0	2.00	0	1	59		
59	C100A	0.0	45.0	4.0	40.0	2.00	0	1	0		
60	C-1N	0.0	45.0	5.0	25.0	2.00	0	1	63		
61	L-31	0.0	60.0	5.5	55.0	15.00	0	3	65	62	69
62	C102	0.0	50.0	4.0	20.0	10.00	0	1	64		
63	S-21	.3	45.0	1.5	40.0	10.00	0	1	0		
64	C102N	0.0	25.0	2.0	20.0	6.00	0	1	0		
65	C103S	0.0	50.0	3.0	12.0	10.00	0	1	67		
66	C103N	0.0	50.0	4.0	15.0	10.00	0	1	67		
67	S-179	0.0	55.0	2.0	45.0	10.00	0	1	0		
68	L31W	0.0	60.0	3.0	45.0	5.00	3	1	-1		
69	C111	0.0	80.0	3.0	30.0	5.00	0	1	72		
70	C-NO	0.0	50.0	.5	45.0	10.00	0	1	0		
71	FLCY	0.0	50.0	.5	45.0	10.00	0	1	0		
72	C111E	0.0	60.0	2.0	22.0	10.00	0	1	73		
73	S-18C	0.0	80.0	2.0	20.0	5.00	0	1	0		
74	LWD4	0.0	60.0	12.0	60.0	2.00	0	2	6	46	
75	HLBSO	0.0	50.0	9.8	30.0	2.00	0	1	29		
76	L28W	1.0	40.0	11.0	20.0	2.00	88	1	99		
77	HW29	13.0	40.0	.2	75.0	1.00	6	1	0		
78	CA-2B	0.0	40.0	8.8	10.0	2.00	4	1	-1		

conditions, and are far less susceptible to transient, operations-induced phenomena. Therefore, when assessing calibration performance, close attention was paid to groundwater-surface water stages.

TABLE 8. Computed Monthly Deviation Averages (10^3 AC-FT) in Irrigation Demands for the EAA

Month	Truck Crops	Sugar Cane	Irrigated Pasture
1	5	4	1
2	4	6	1
3	5	7	1
4	5	8	1
5	0*	1	-1
6	0*	-7	-9
7	0*	0	-1
8	0*	6	0
9	0*	3	0
10	-13	5	1
11	4	3	0
12	4	3	0

*Truck crops are not grown during the summer months in the Everglades Agricultural Area.

Note: A negative sign indicates withdrawal of excess water from the EAA to meet water table requirements. A positive sign indicates the addition of water to the EAA to meet irrigation demands.

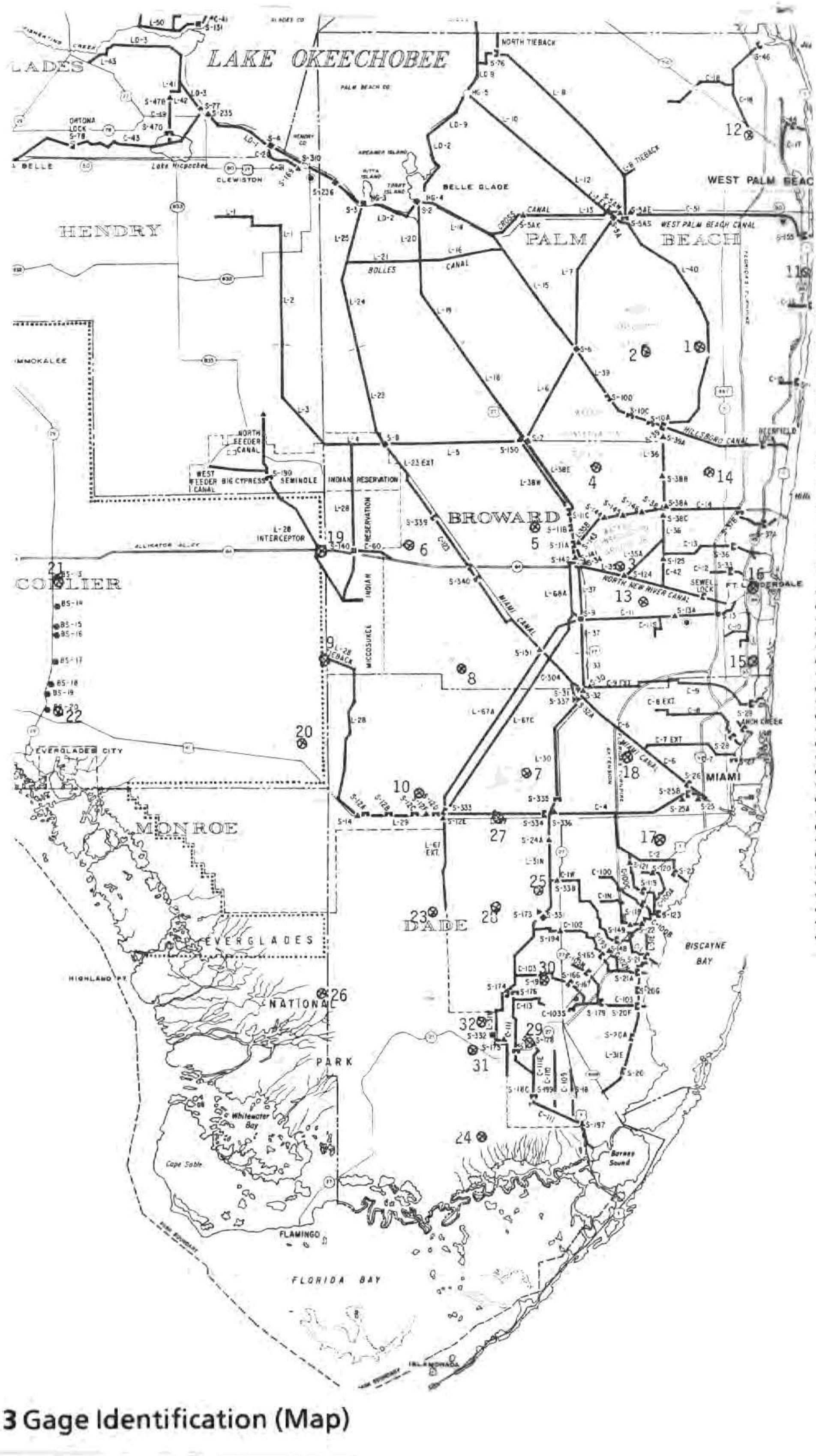
B. Presentation of Results

This section presents a brief discussion of the calibration and verification results for the LEC. A vicinity map showing the location of the gages is shown in Figure 13.

Everglades Agricultural Area

1. Table 8

This table gives the volumetric error associated with the calibration of the Everglades Agricultural Area. The volumes shown are the monthly differences between the theoretical crop requirements and the historical



Monitoring Points
1.) 1-8T
2.) 1-7
3.) 2B-21
4.) 2A-17
5.) 3A-3
6.) 3A-2
7.) 3B-29
8.) 3A-4
9.) L-28TB
10.) 3A-28
11.) PB-88
12.) PB-108
13.) G-617
14.) G-616
15.) F-291
16.) G-561
17.) G-39
18.) S-19
19.) C-54
20.) TRNP
21.) C-296
22.) C-495
23.) P-33
24.) P-207
25.) G-596
26.) P-36
27.) G-618
28.) G-1502
29.) G-613
30.) G-196A
31.) TSRP
32.) TSHO

Figure 13 Gage Identification (Map)

deliveries, assuming that the water table was maintained between very narrow limits. The next error is 47,000 acre-feet per year, which represents approximately 9% of the total annual demand, or about .1' per year error in the computed Lake Okeechobee stage.

Water Conservation Area 1

2. Figures 14-15

These hydrographs indicate that the model will predict true WCA 1 stages with a high degree of confidence. The verification period indicates that the model accurately predicts the "average year" response of the marsh.

Water Conservation Areas 2A and 2B

3. Figures 16-17

Water Conservation Areas 2A and 2B response is depicted in these hydrographs. For the 1969-1971 calibration period WCA 2A responds well, as does WCA 2B; however, during the verification period, the stages predicted do not match historical. This is the single case where the model failed to verify. In order to ascertain whether this represents a failure of the model or inaccurate input data, these gages will be scrutinized by using a different verification period (1976-1982) when data is available.

Northern Water Conservation Area 3A

4. Figures 18-19

The gages are representative of Water Conservation Area 3A north of Alligator Alley. Gage 3-2 (the "deer gage"), shows excellent response to all water conditions. The 3-3 gage, while not always predicting low stages, shows that the model correctly responds to S-11 discharges.

Southern Water Conservation Area 3A

5. Figures 20-21

These hydrographs show how the southern portion of WCA-3A performs. Gage 3-4 shows remarkably good correlation, primarily due to its isolated location. Gage 3A-28 shows the model correctly predicts system response to S-12 discharges, and the timing and depth of drydowns in the southern pool of WCA-3A.

L-28 Tieback

6. Figure 22

The model results compare favorably with historical stages near the L-28 tieback levee during the limited available record. This suggests good response in the Big Cypress/WCA-3A connection.

Water Conservation Area 3B

7. Figure 23

Water Conservation Area 3B response is illustrated in this hydrograph. The correlation is very good for the entire period.

Eastern Palm Beach County

8. Figure 24

This monitoring well is located near the coast in Palm Beach County. The calibration here is fairly good considering the well is located in an urban basin and thereby subject to canal- induced transient effects.

9. Figure 25

This gage is located on the edge of the West Palm Beach water catchment area. It indicates that model response in the sloughs and marshes of north central Palm Beach County (the Corbett area, the water catchment area, Loxahatchee Slough, etc.) should be acceptable.

Broward County

10. Figure 26

This gage is located in northern Broward County, and during the period of calibration, was primarily an agricultural basin. This is also suggested by the rapid fluctuations in historical stage. The model cannot incorporate the many small canals which regulate the phreatic surface. It does, however, present a fairly good indication of stage in the area.

11. Figures 27-29

These three gages are located in urban basins in Broward County. The model is unable to track the rapid fluctuations occurring after each storm and the quick stage reductions. This is primarily due to its inability to incorporate secondary and tertiary canal systems, which contribute greatly to drainage in the area, and to the model's relatively coarse grid resolution. While the model is unable to accurately predict stages at any instant, it does give a fairly good indication of overall water conditions.

Dade County

12. Figures 30-31

These gages are of special importance due to their proximity to large MDSWA wellfields. The response is quite good considering the proximity to major canals and the urban locations. The only apparent difficulty was the model's inability to reflect stage increases at S-19 caused by water supply deliveries via the Miami Canal. This is under investigation and will be examined with other data sets.

13. Figures 32-33

These two gages are representative of model response in southeastern Dade County. Both gages show excellent correlation. It would seem that the model is consistently unable to predict peak stages in the area. This is due to a model assumption. The model assumes that all rainfall seeps directly into the aquifer and shows up as an increase in the stage of the phreatic surface. In actuality, however, subsurface run-off, in the form of partially saturated flow, contributes a large portion of the storm runoff. This partially saturated flow does not show up in historical groundwater stages, but will be considered groundwater flow by the model. Considering this, the model results are extremely good in south Dade.

14. Figures 34-36

These gages are all located in the East Everglades. All three show good response in comparison to historical data. G-1502 consistently fails to reach drawdowns of 7 ft below ground surface. However, G-1502 is located on a rock outcrop and these drawdowns may indicate the surrounding area is responsible for the water withdrawal.

Everglades National Park

15. Figures 37-39

All three of these gages are in Taylor Slough. The calibration and verification results closely matched historical response.

16. Figures 40-41

P-33 and P-36 are located in Shark Slough, in Everglades National Park. Both gages showed very good correlation with historical. This is of special interest since it suggests the model correctly responds to S-12 discharges through Shark Slough.

Big Cypress Preserve

17. Figures 42-45

These four monitoring wells are representative of the Big Cypress Preserve. All four gages are near the boundary or along major canals, and show good response. It can be inferred that the interior of the Big Cypress Preserve will respond at least as well.

Canal Stages

18. Figures 46-59

Almost as a rule, the model was able to accurately predict stages in channels not managed for urban or agricultural drainage (e.g., C-111, L-29), but could not give accurate stages in canals subject to heavy, transient, storm water inflows (e.g., NNRC, C-14). This was considered acceptable as long as the average canal stage was accurate enough to provide reasonably good boundary conditions in the calculation of groundwater stages.

Sensitivity Analysis

19. Figures 60-71

The major calibration parameters for the model were evapotranspiration and friction losses during overland flow. The sensitivity analysis shows that, for the Water Conservation Areas, stages are extremely sensitive to the ET rate while they are relatively insensitive to changes in Manning's 'n'. This is primarily due to the fact the water is impounded throughout most of the conservation areas and overland flow velocities are extremely small. However, south of the Tamiami Canal, the regime changes from being impounded to a flow dominated system. Gages in Shark Slough especially show sensitivity to Manning's 'n' (Figure 64).

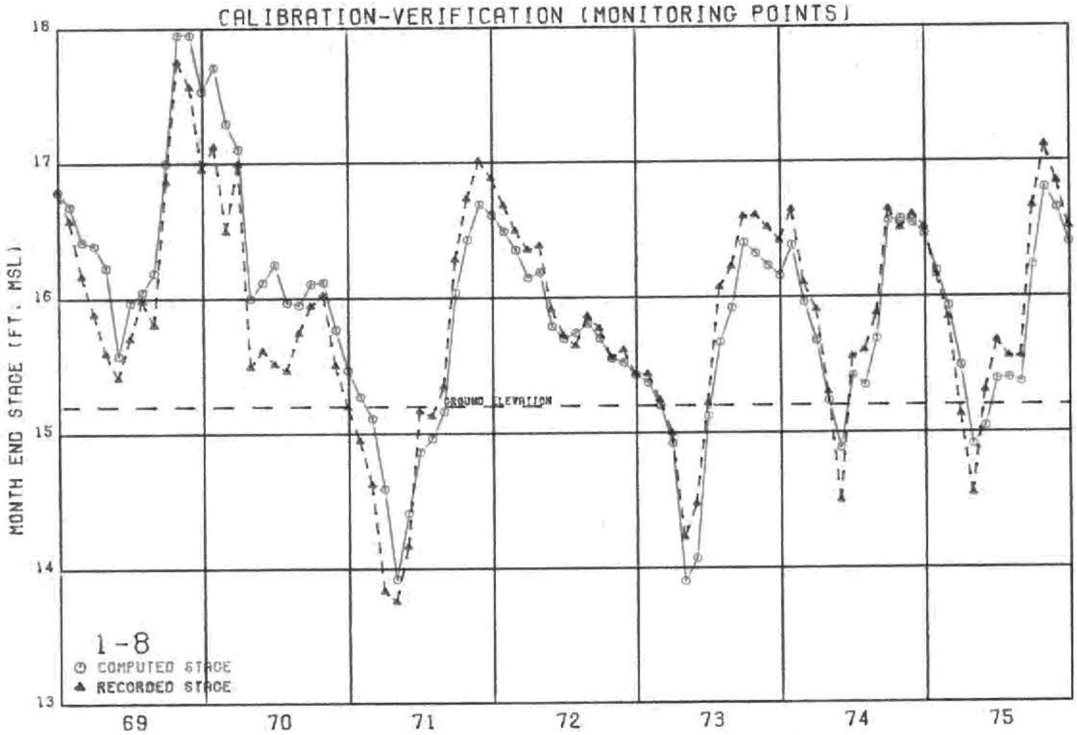


Figure 14 Water Conservation Area 1, Gage 1-8T

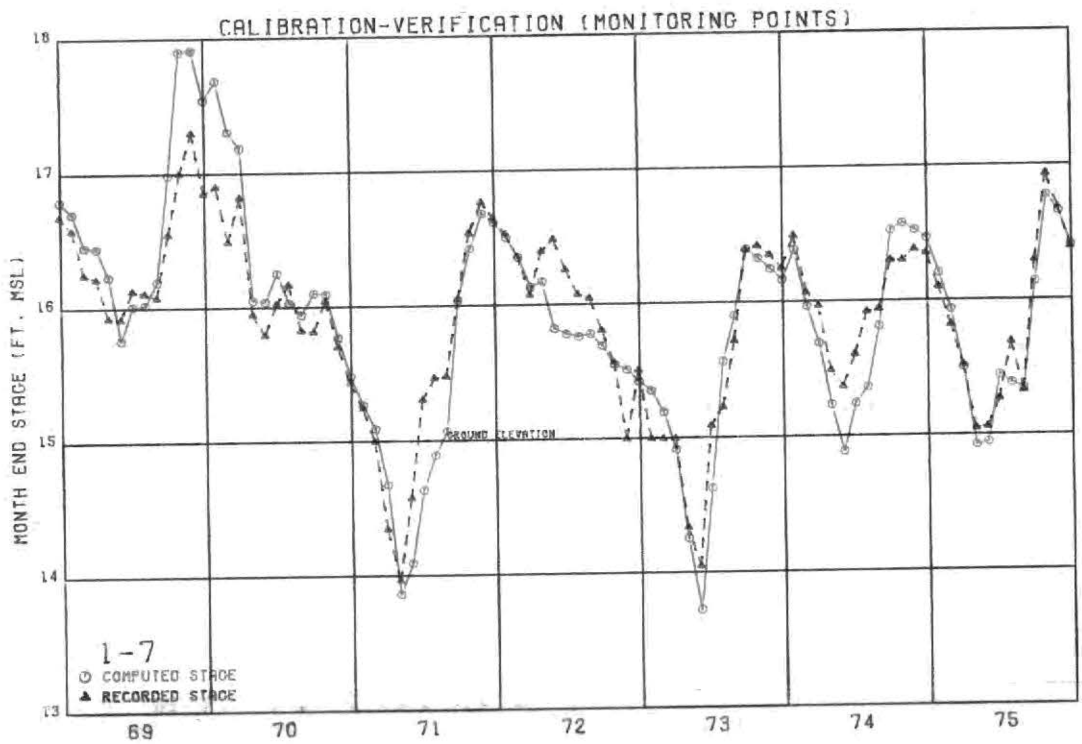


Figure 15 Water Conservation Area 1, Gage 1-7

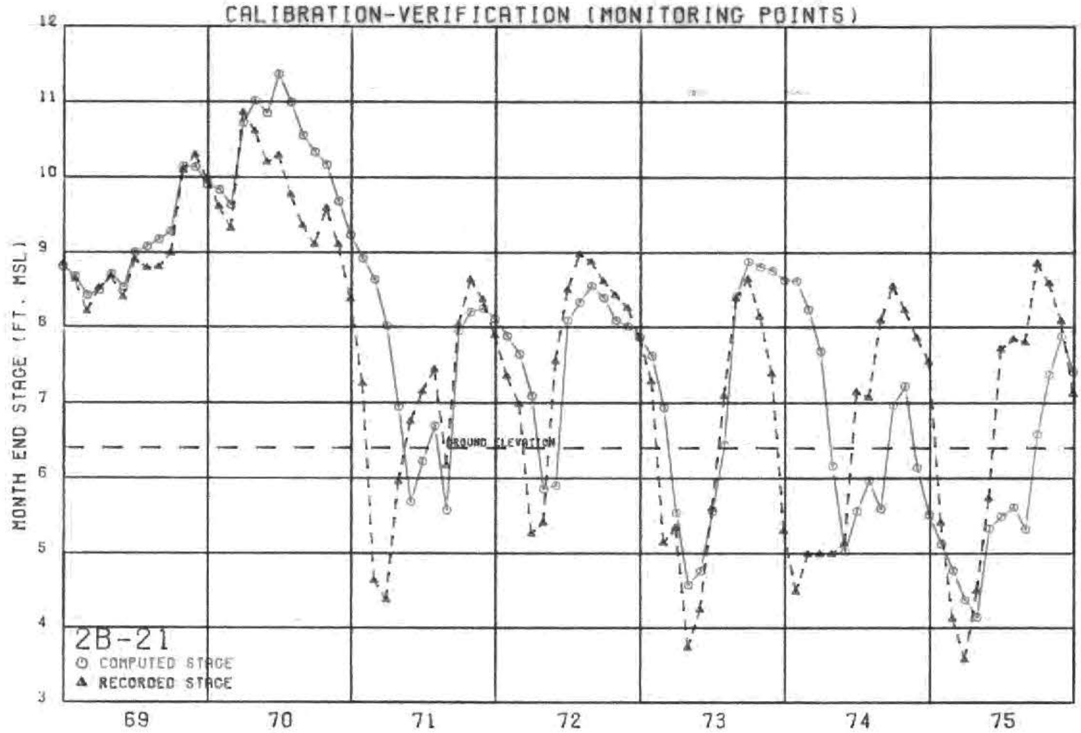


Figure 16 Water Conservation Area 2B, Gage 2-21

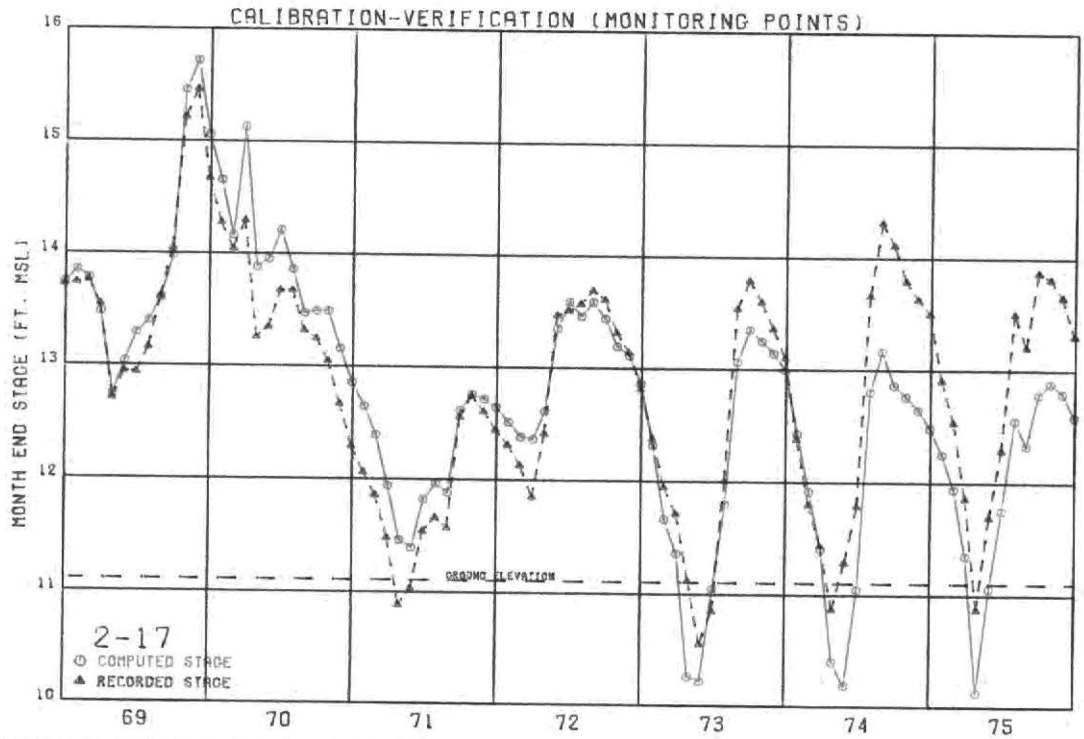


Figure 17 Water Conservation Area 2A, Gage 2-17

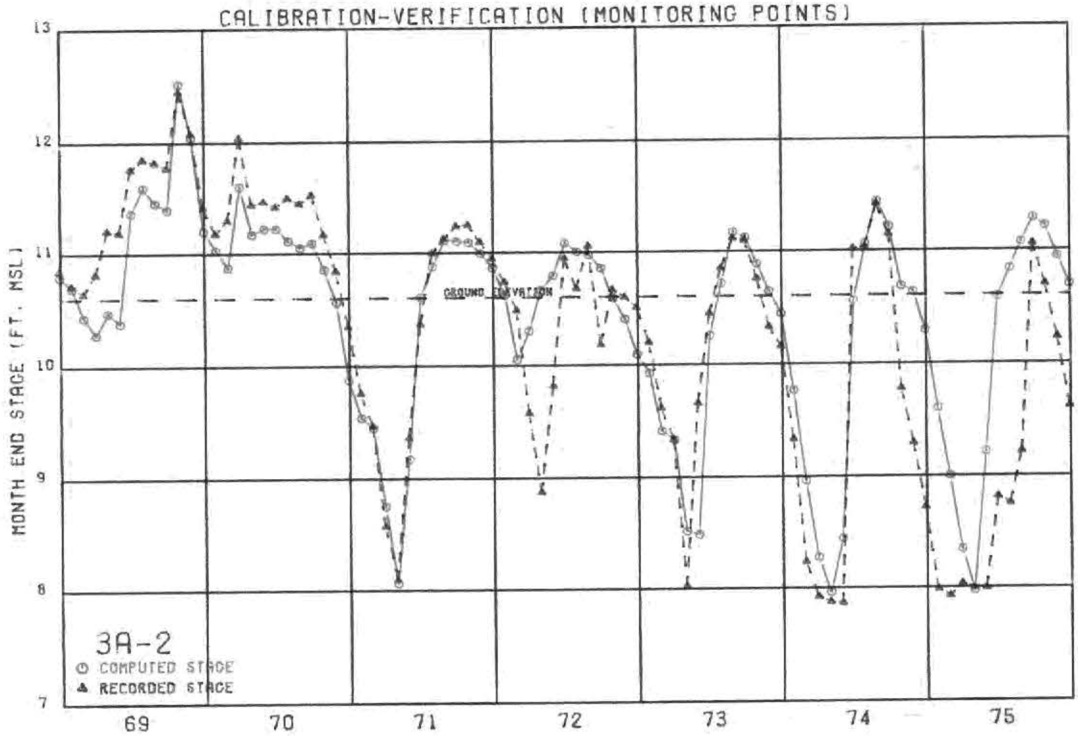


Figure 18 Water Conservation Area 3A, Gage3-2

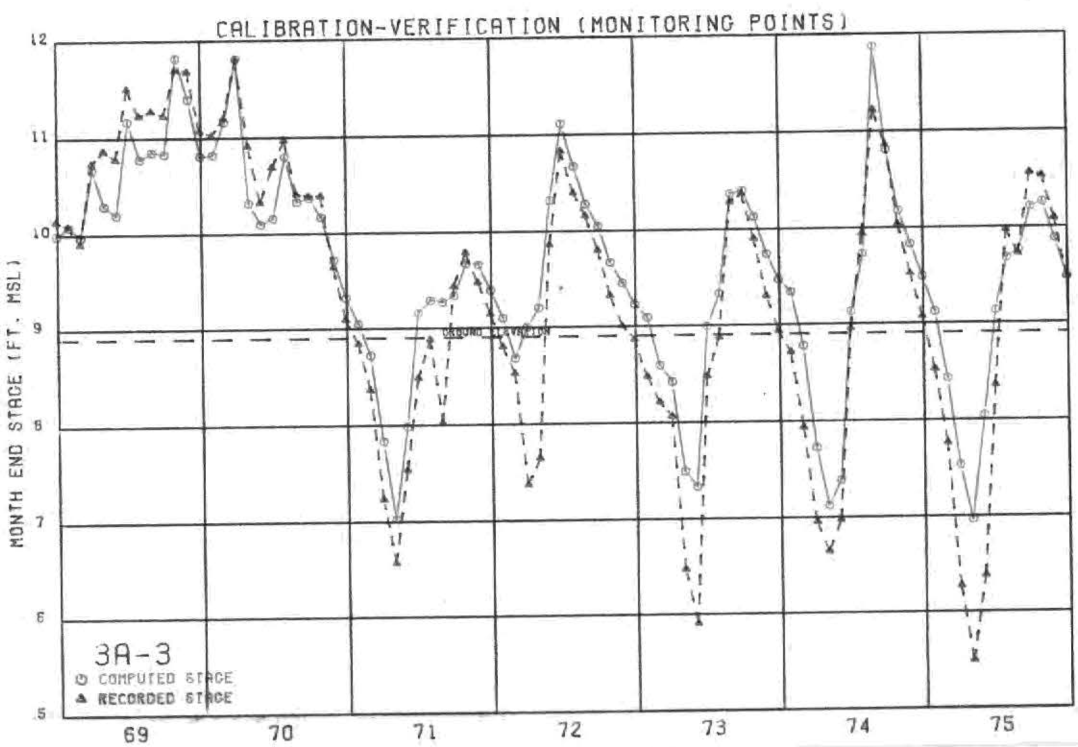


Figure 19 Water Conservation Area 3A, Gage 3-3

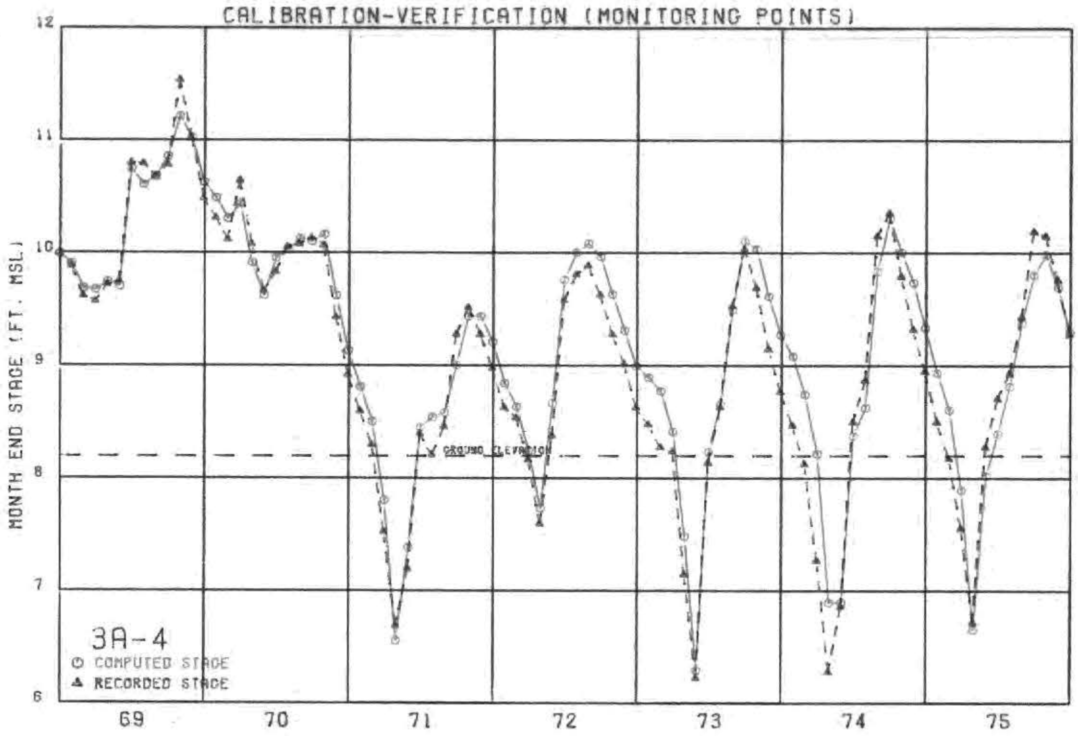


Figure 20 Water Conservation Area 3A, Gage 3-4

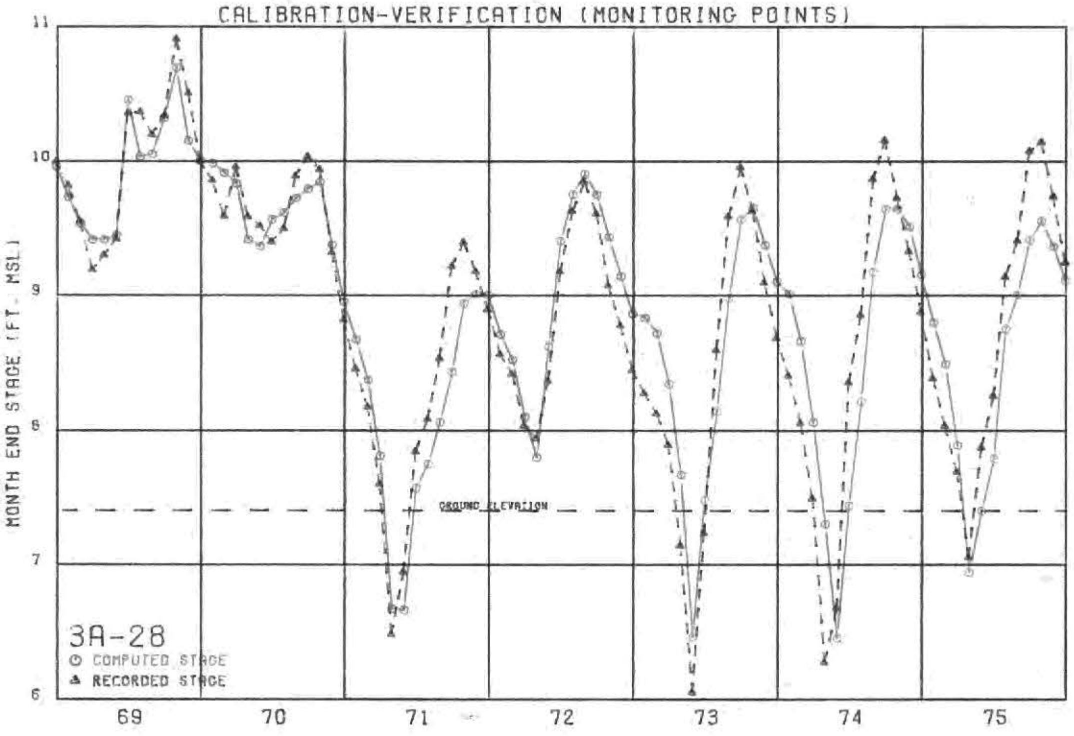


Figure 21 Water Conservation Area 3A, Gage 3-28

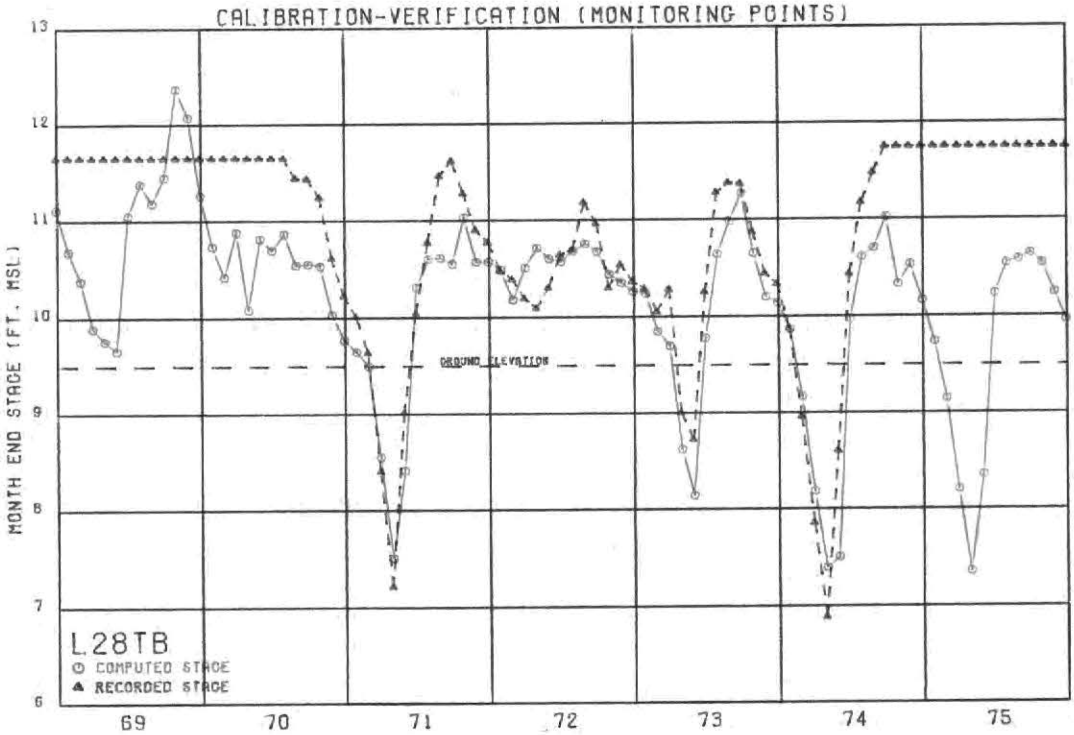


Figure 22 Collier County, L-28 Tieback

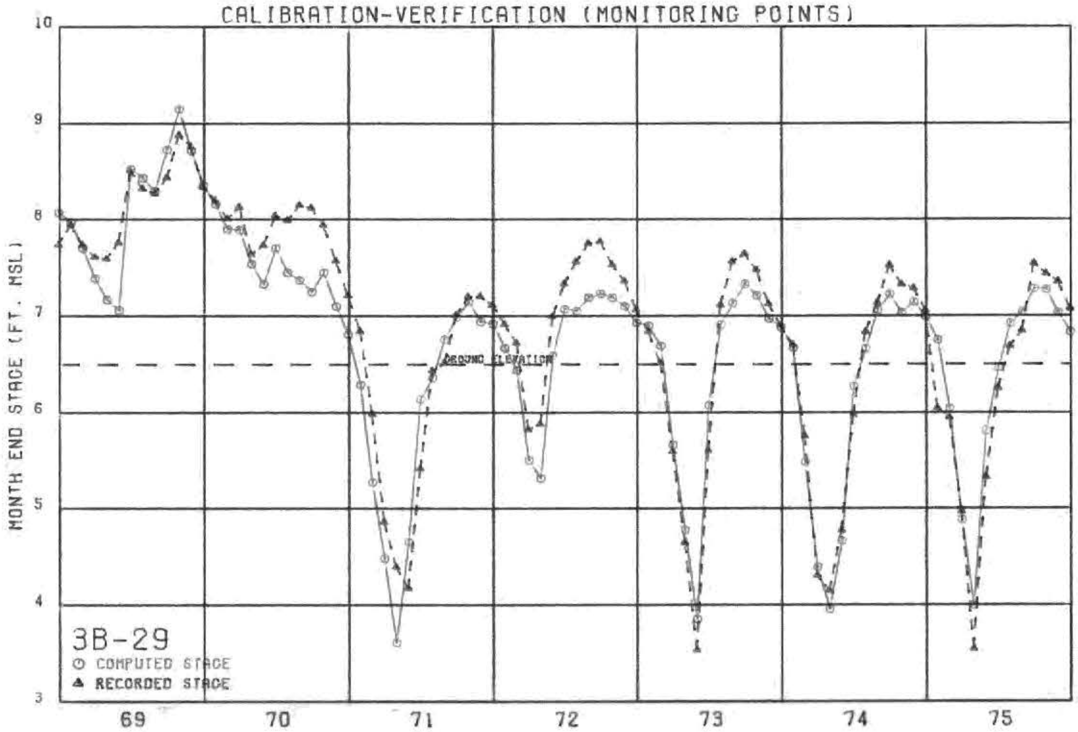


Figure 23 Water Conservation Area 3B, Gage 3-29

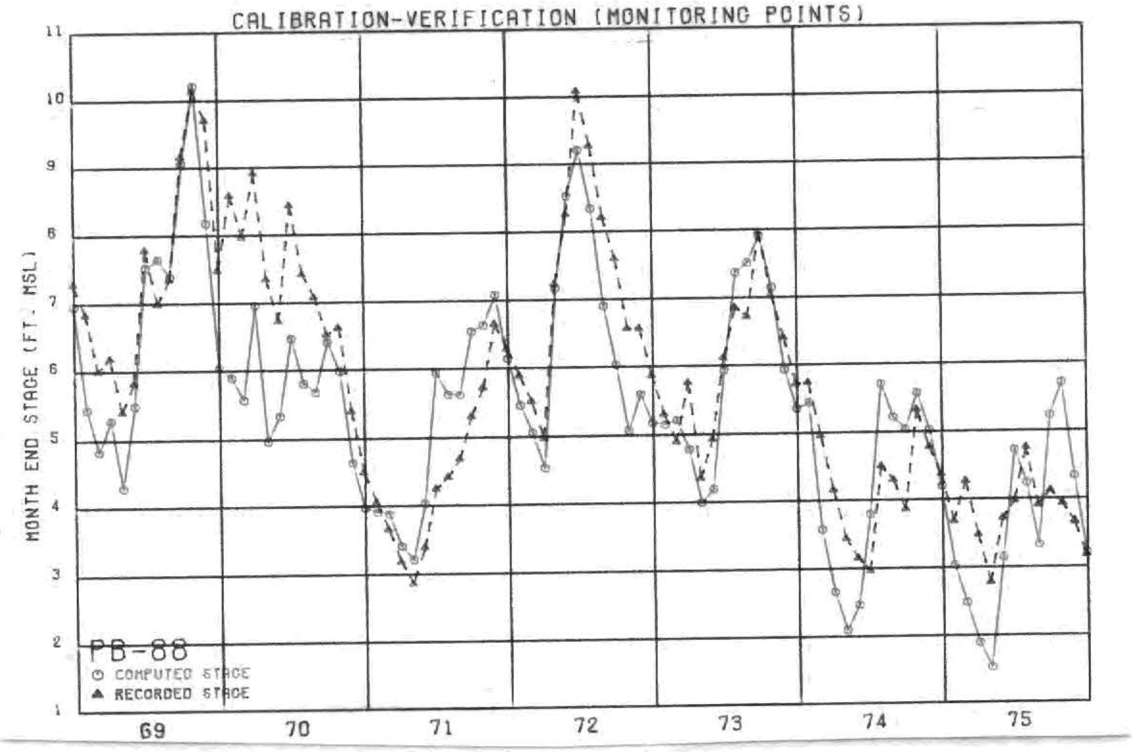


Figure 24. Palm Beach County, Gage PB-88

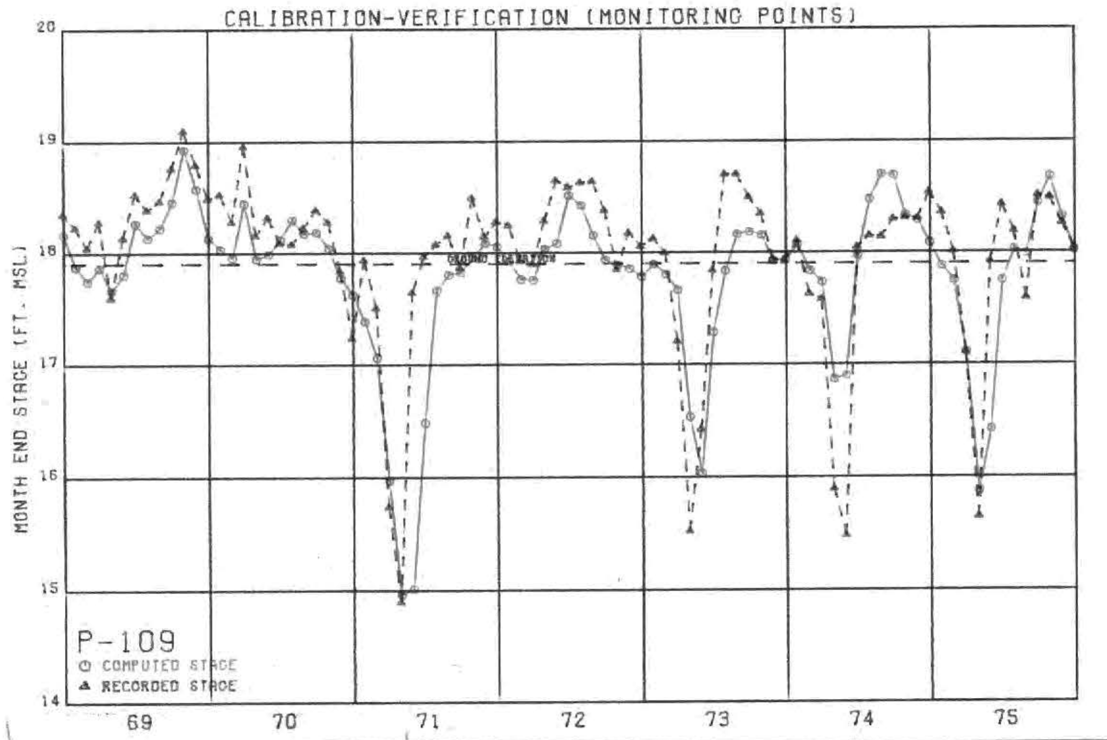


Figure 25 Palm Beach County, Gage PB-109

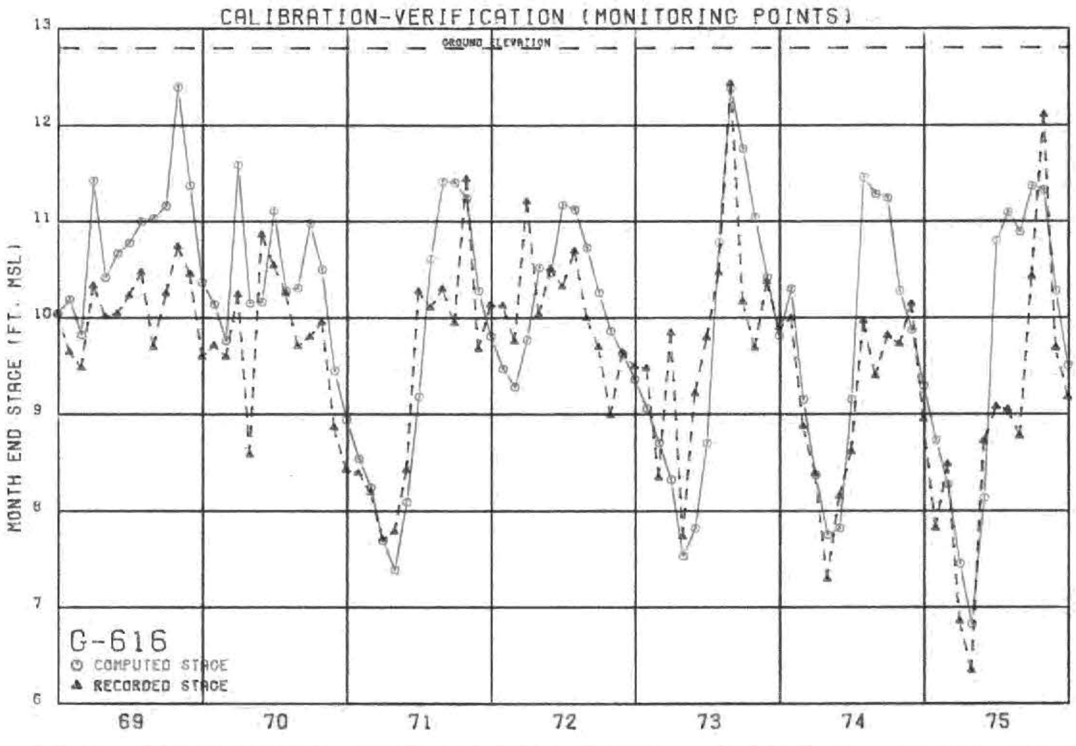


Figure 26 Broward County, Gage G-616

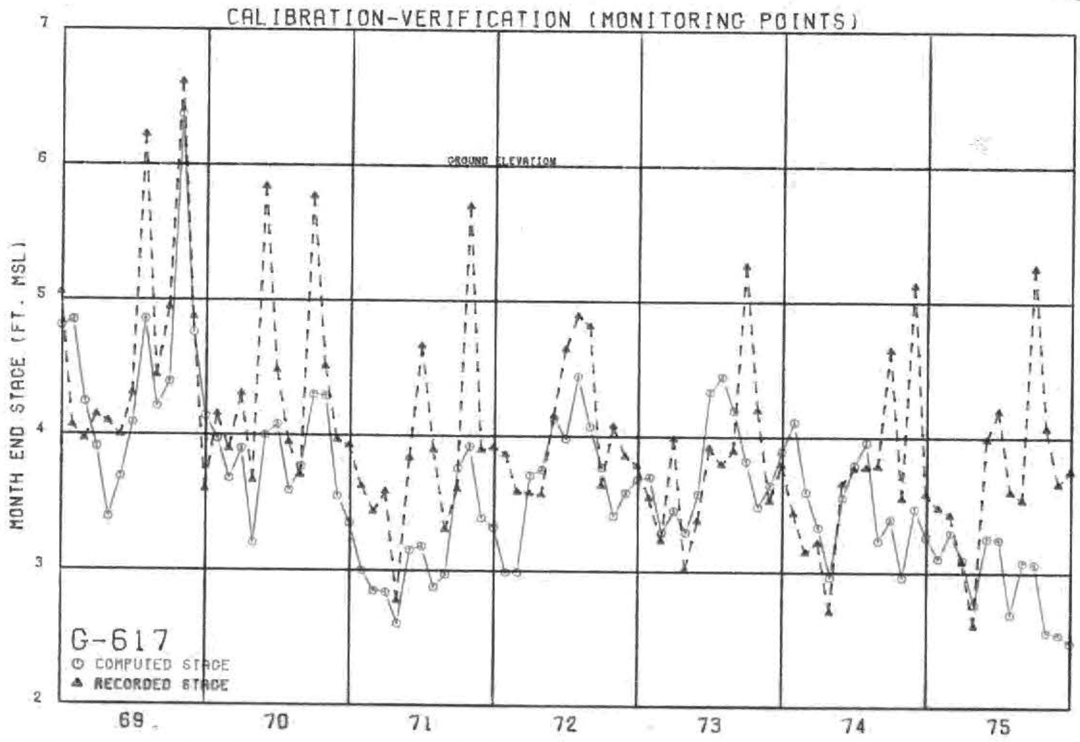


Figure 27 Broward County, Gage G-617

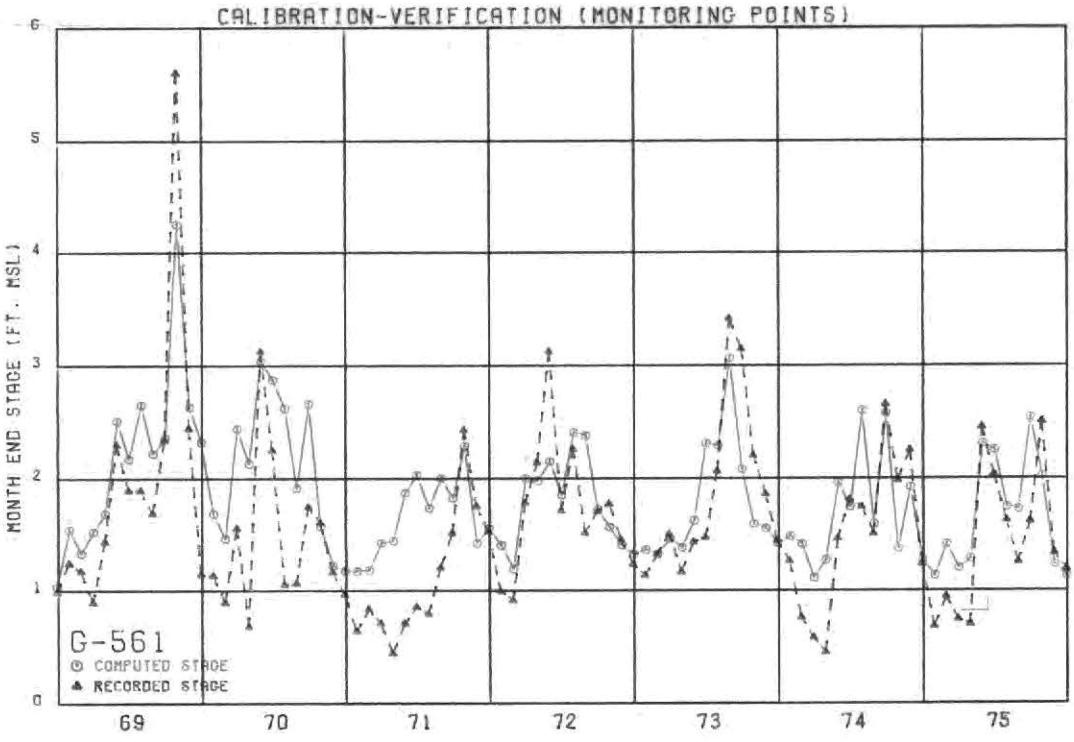


Figure 28 Broward County, Gage G-561

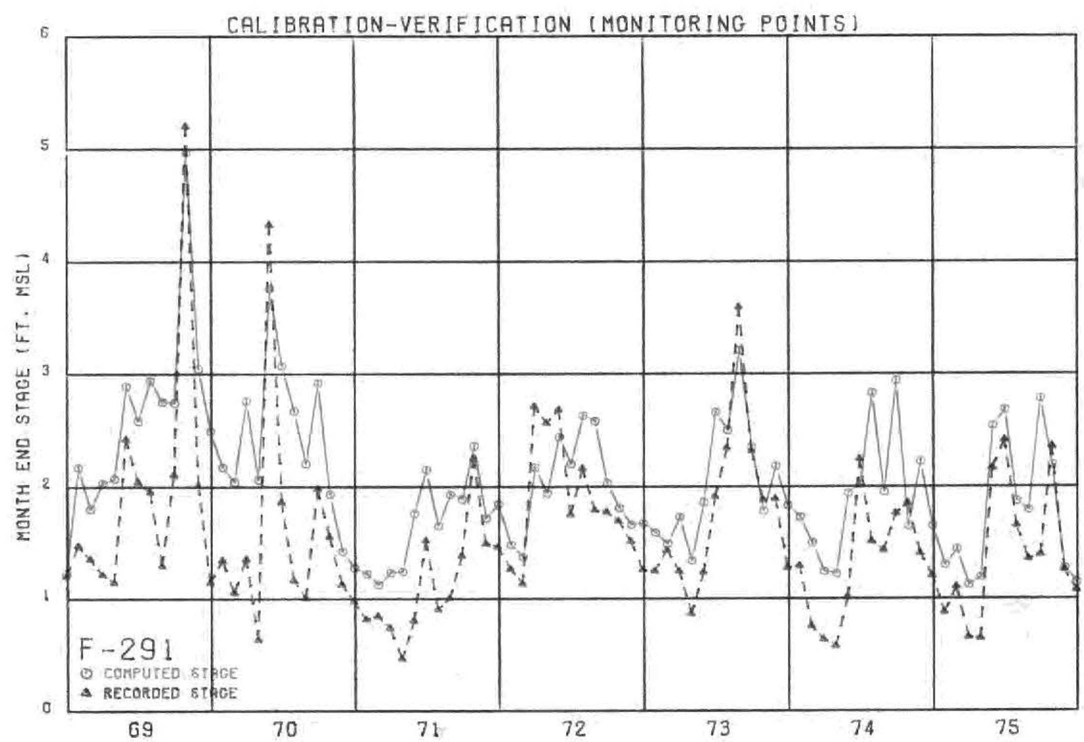


Figure 29 Broward County, Gage F-291

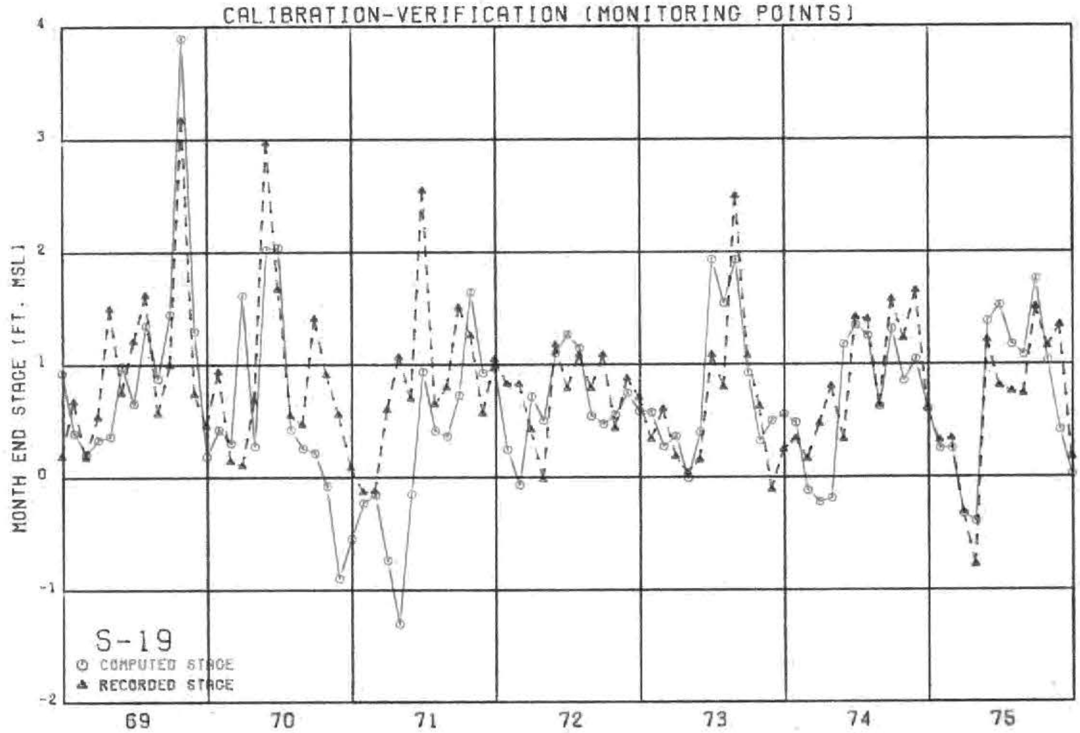


Figure 30 Dade County, Gage S-19

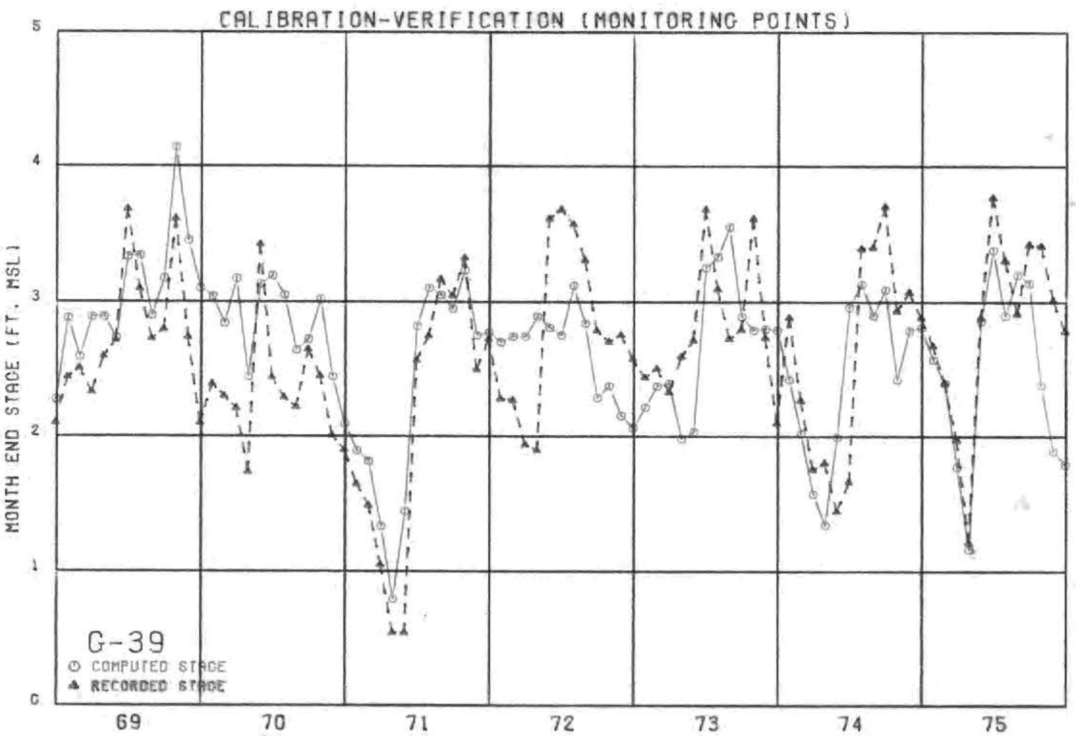


Figure 31 Dade County, Gage G-39

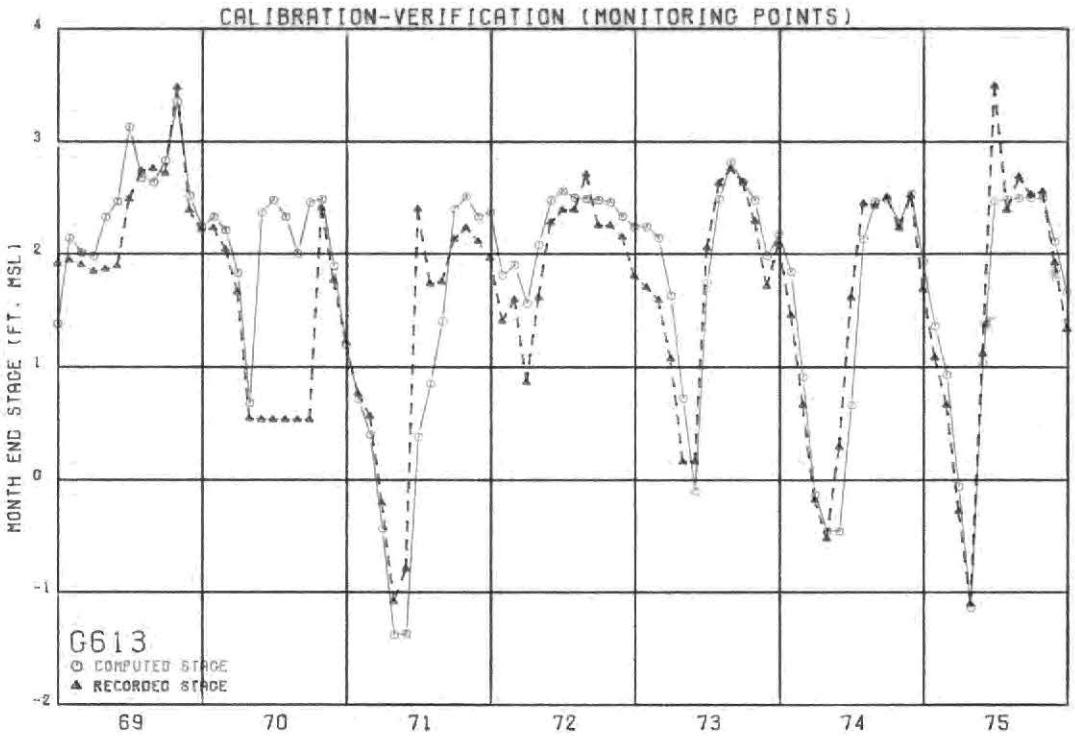


Figure 32 Dade County, Gage G-613

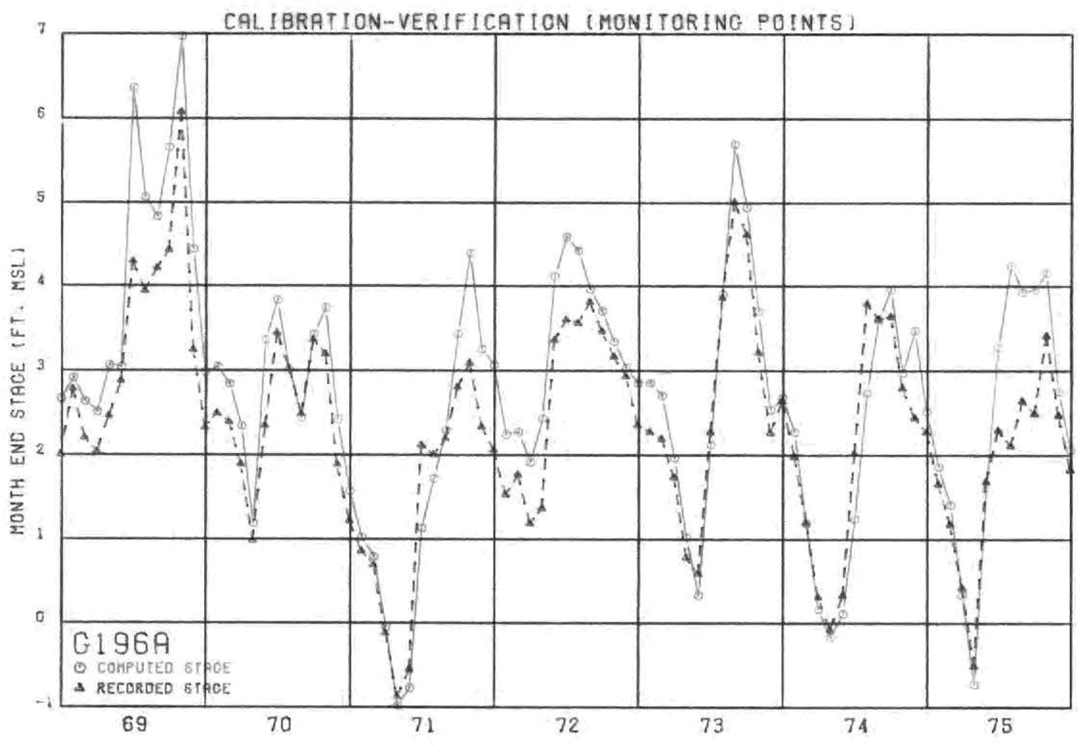


Figure 33 Dade County, Gage G-196A

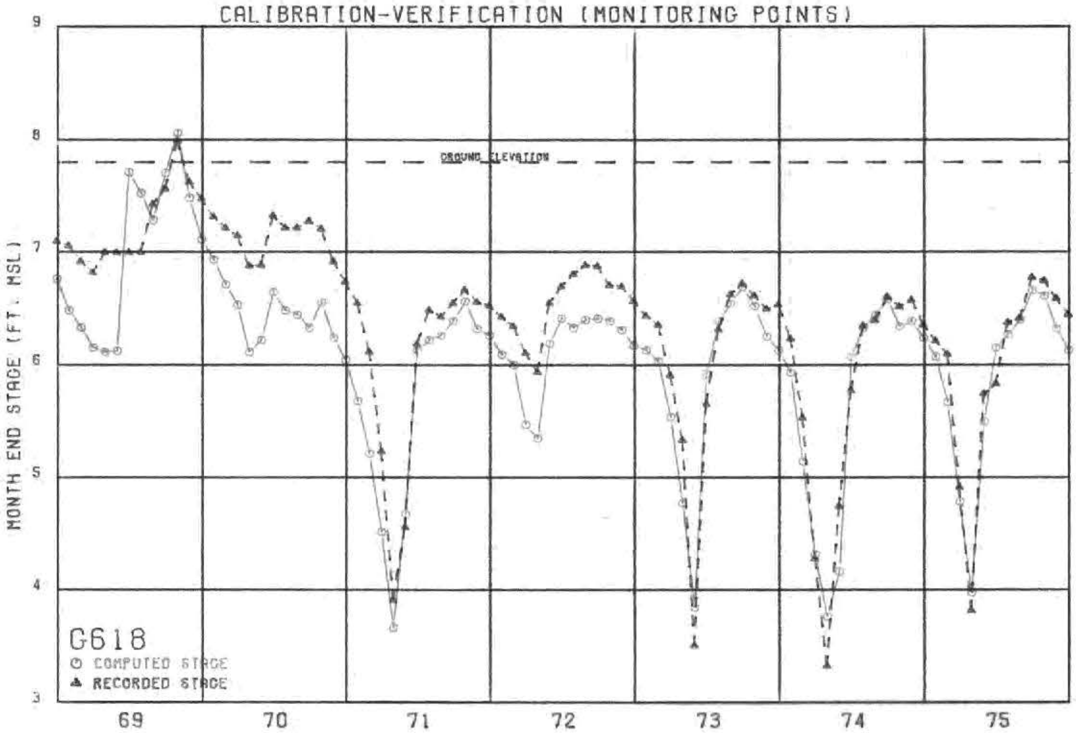


Figure 34 Dade County, Gage G-618

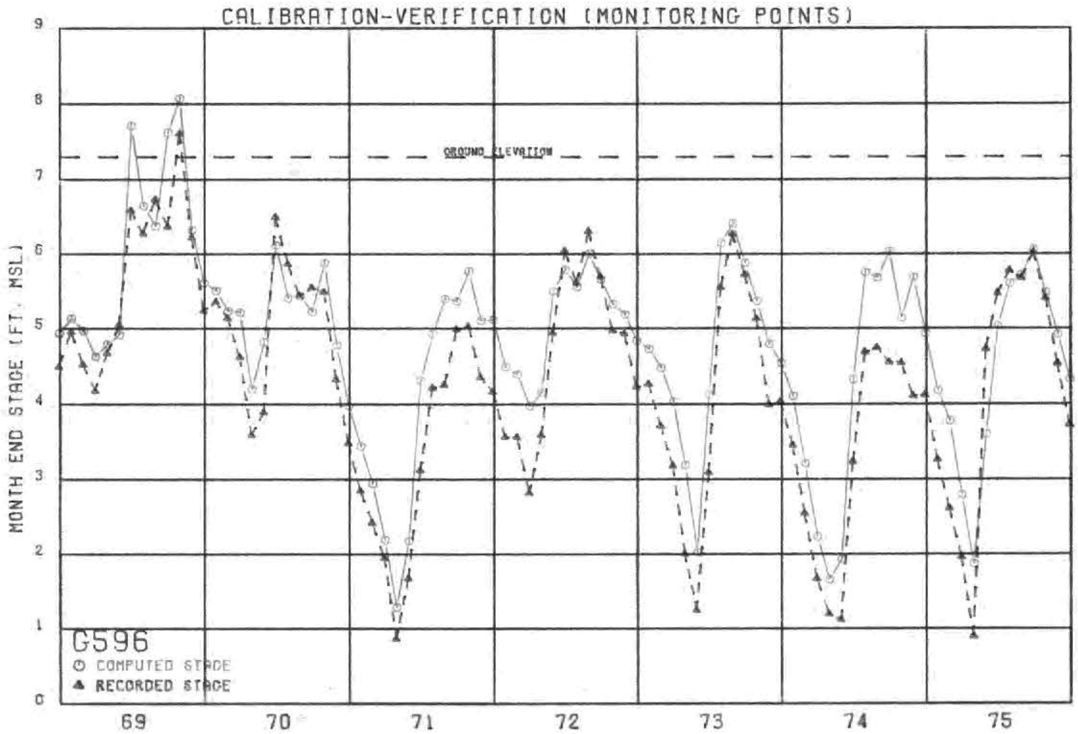


Figure 35 Dade County, Gage G-596

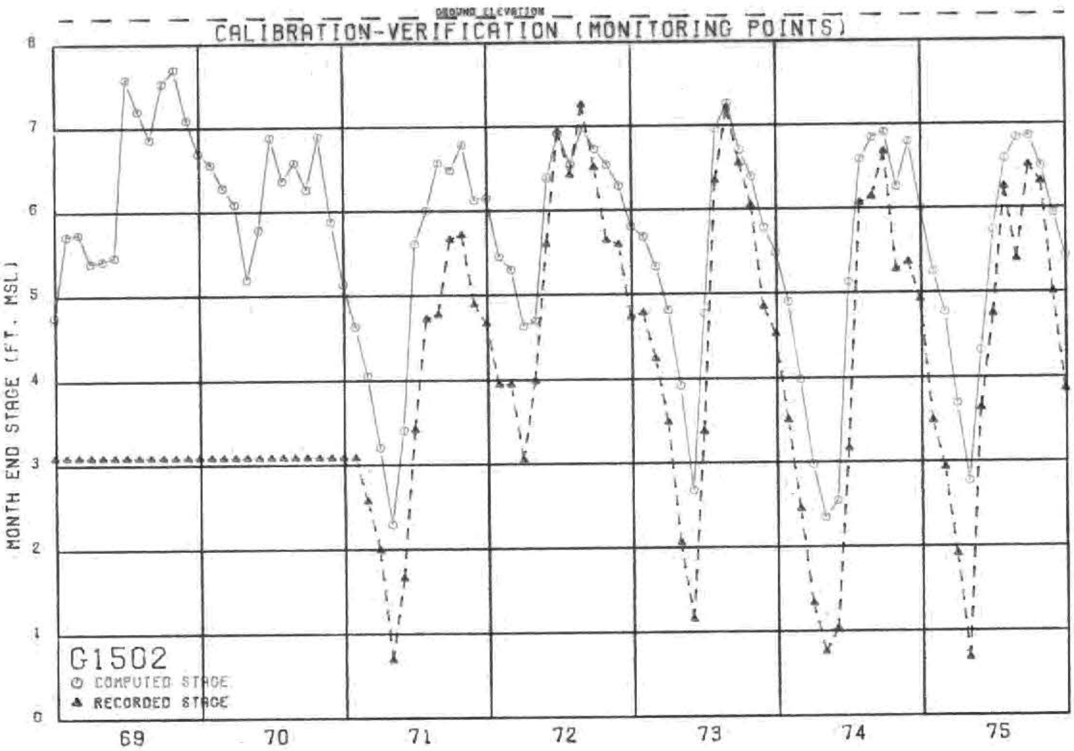


Figure 36 Dade County, Gage G-1502

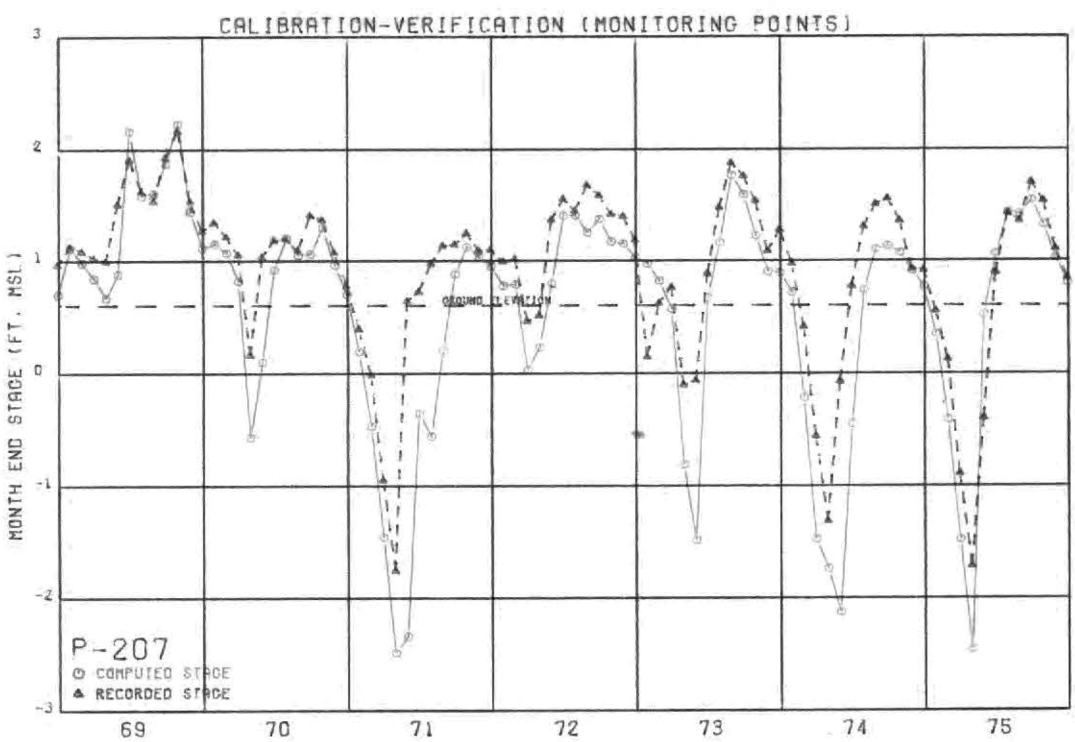


Figure 37 Everglades National Park, Gage P-207

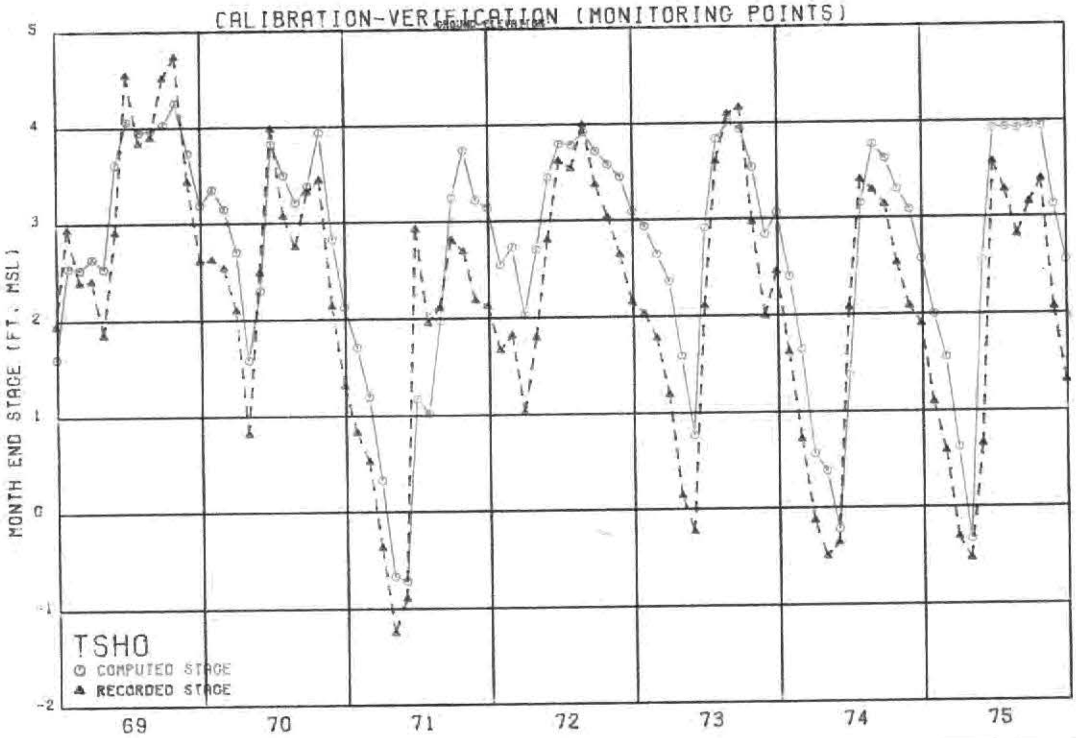


Figure 38 Everglades National Park, Taylor Slough near Homestead

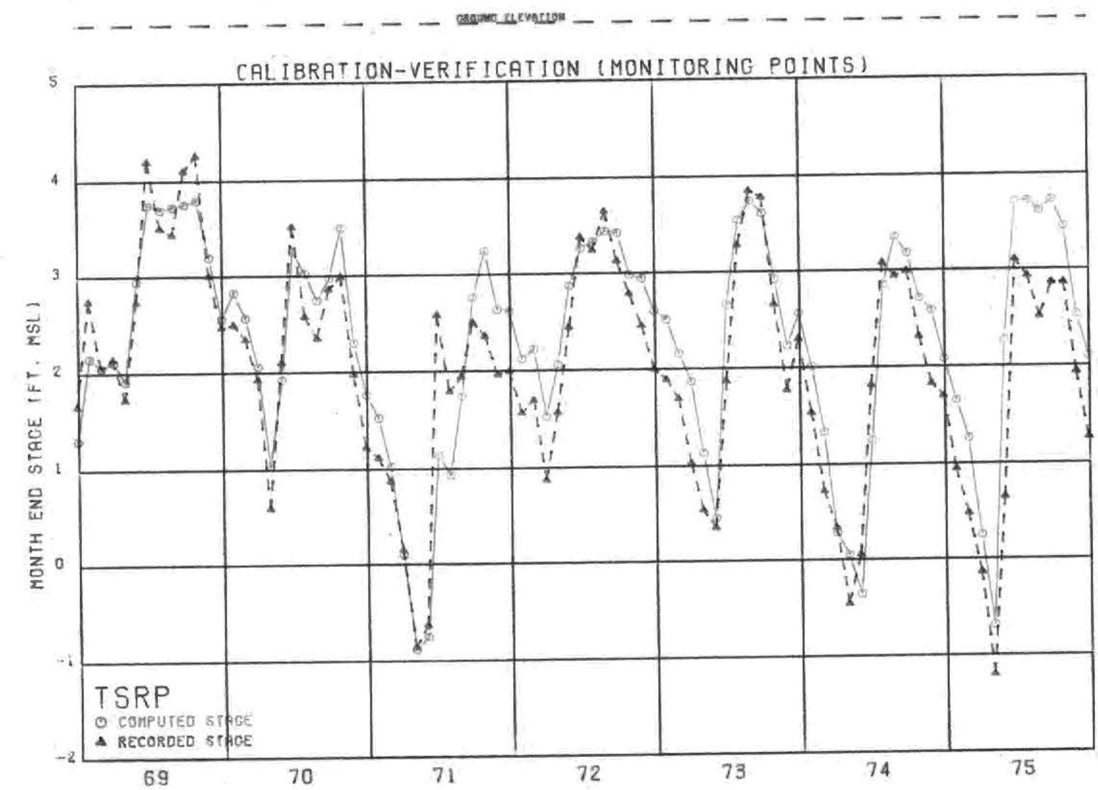


Figure 39 Everglades National Park, Taylor Slough near Royal Palm Ranger Station

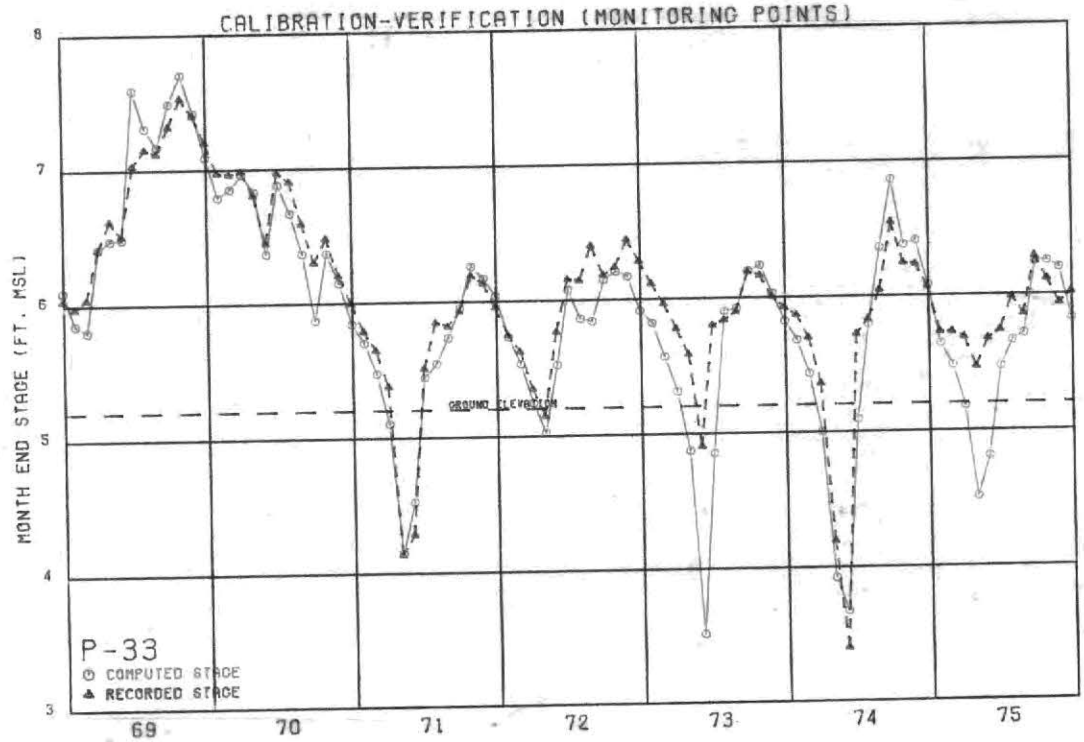


Figure 40 Everglades National Park, Gage P-33

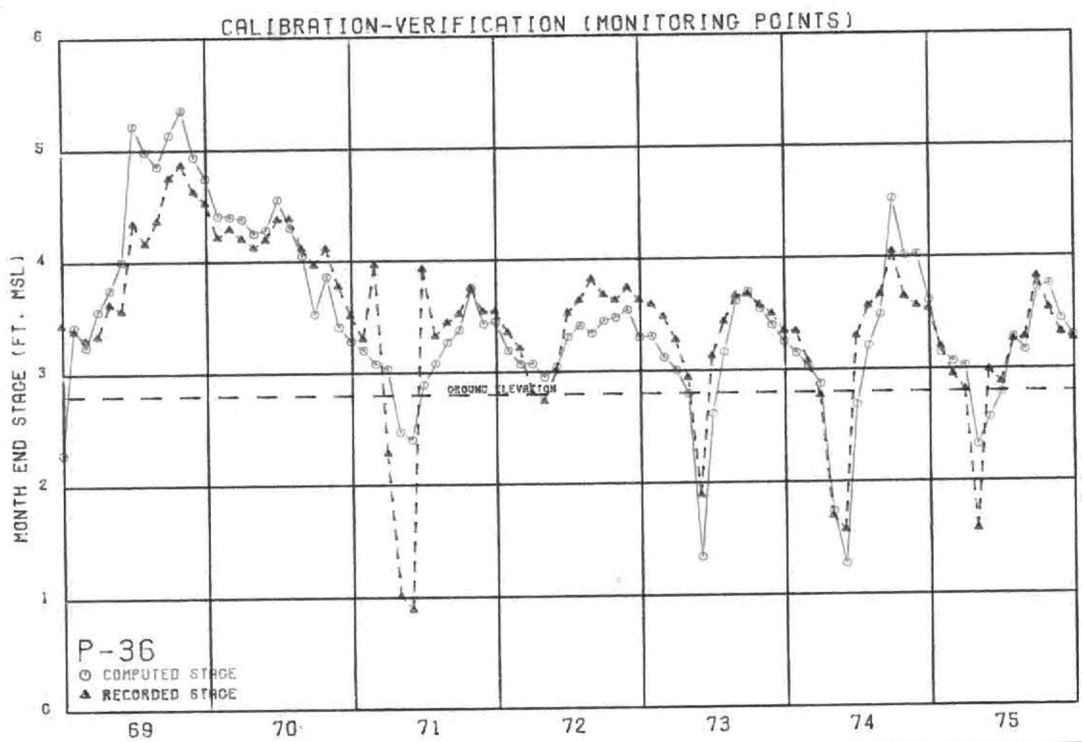


Figure 41 Everglades National Park, Gage P-36

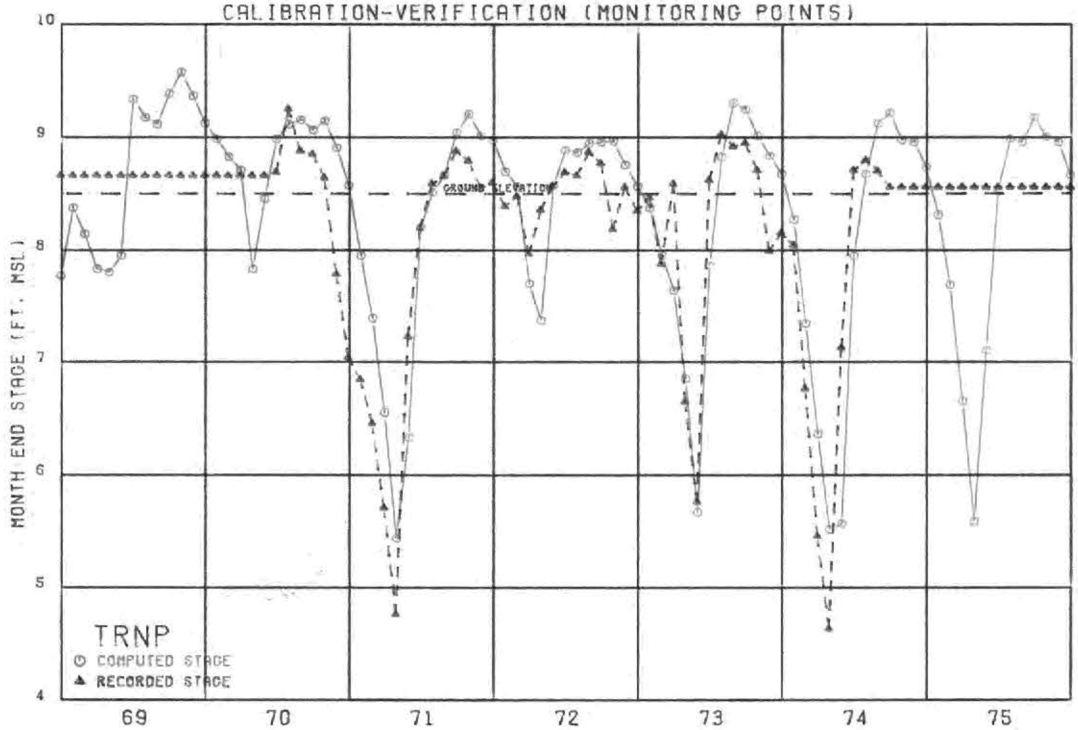


Figure 42 Big Cypress Preserve, Training Airport

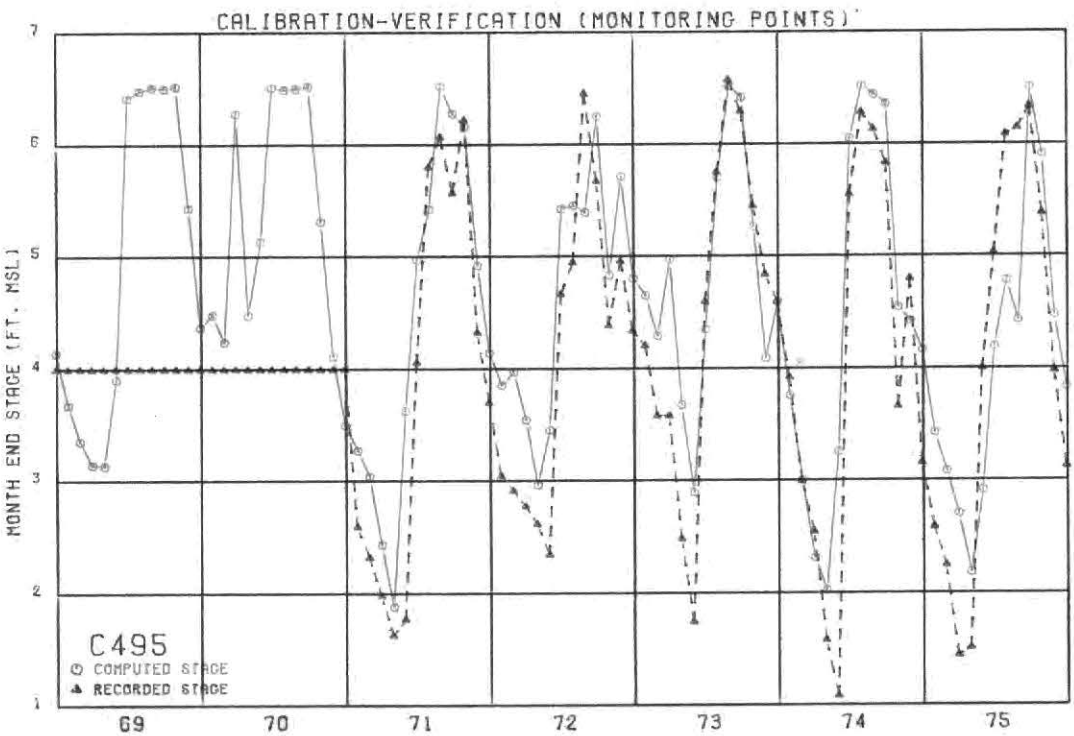


Figure 43 Big Cypress Preserve, Gage C-495

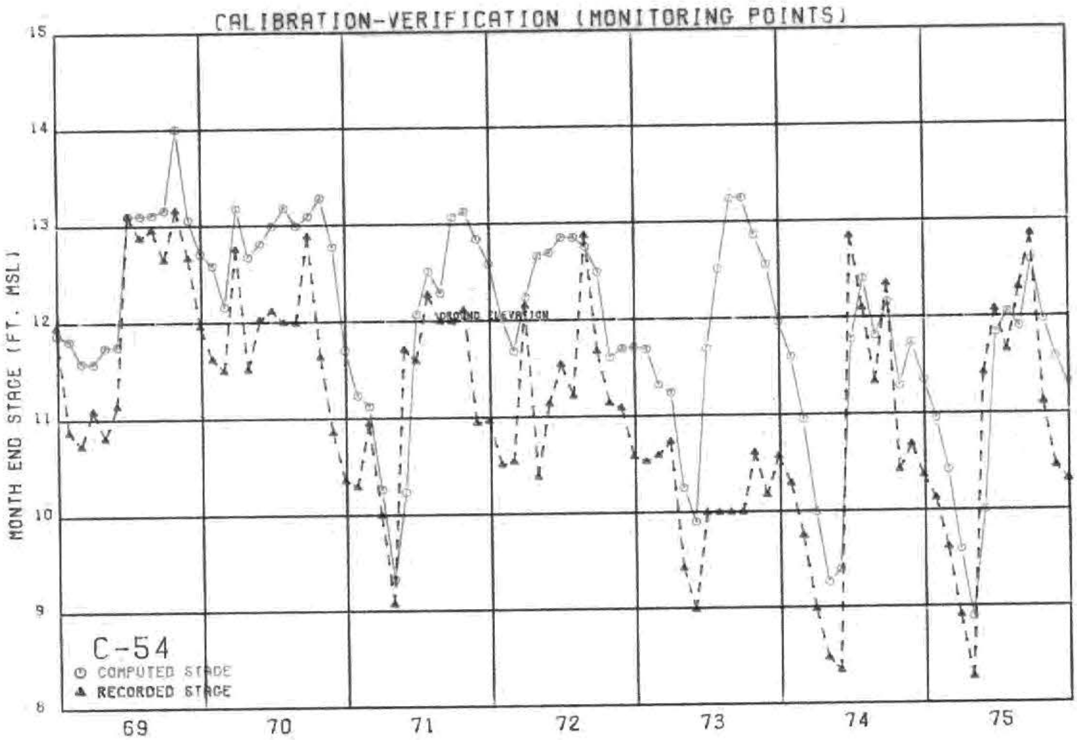


Figure 44 Big Cypress Preserve, Gage C-54

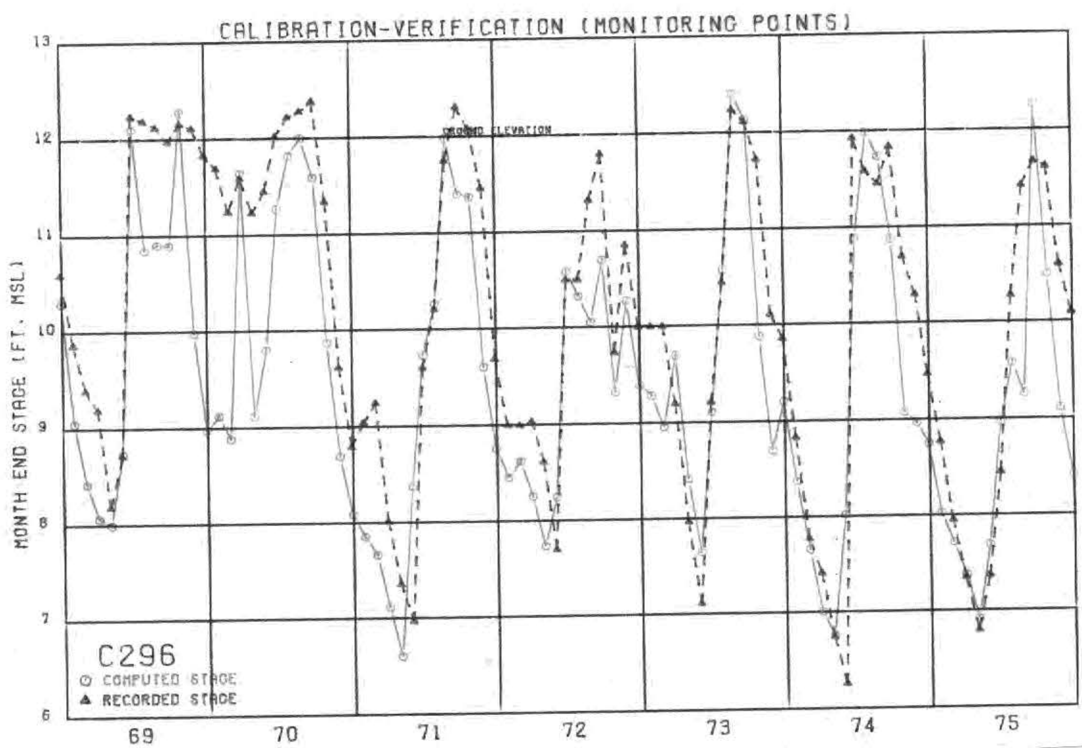


Figure 45 Big Cypress Preserve, Gage C-296

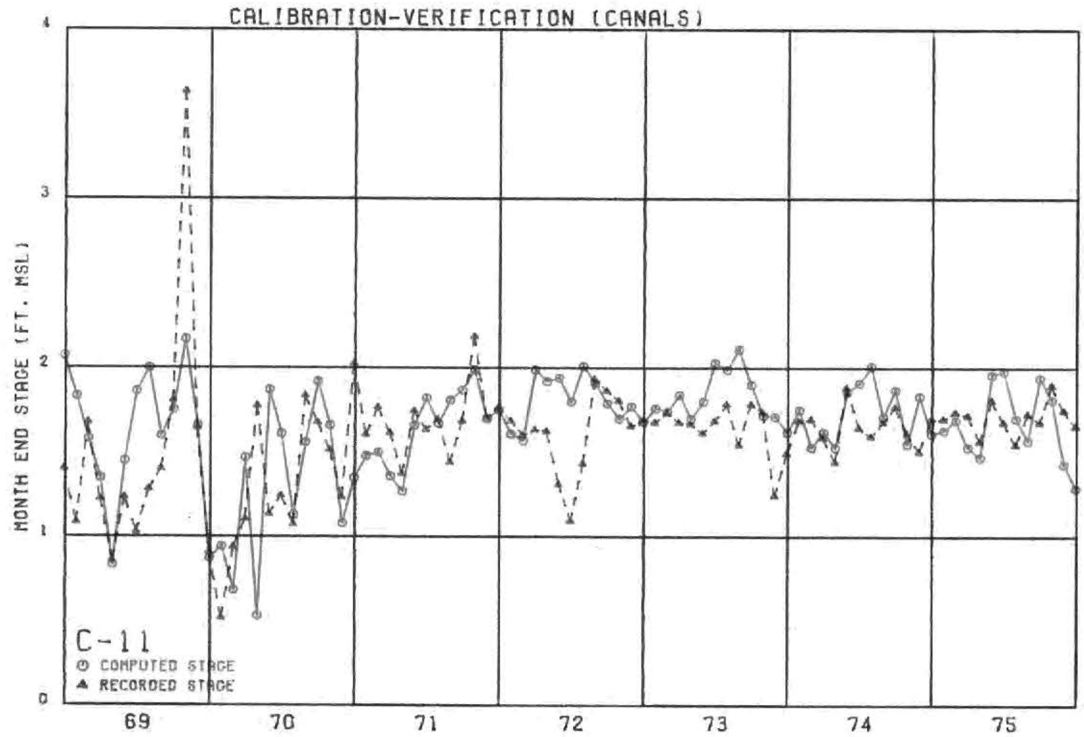


Figure 46 C-11 Upstream of S-13

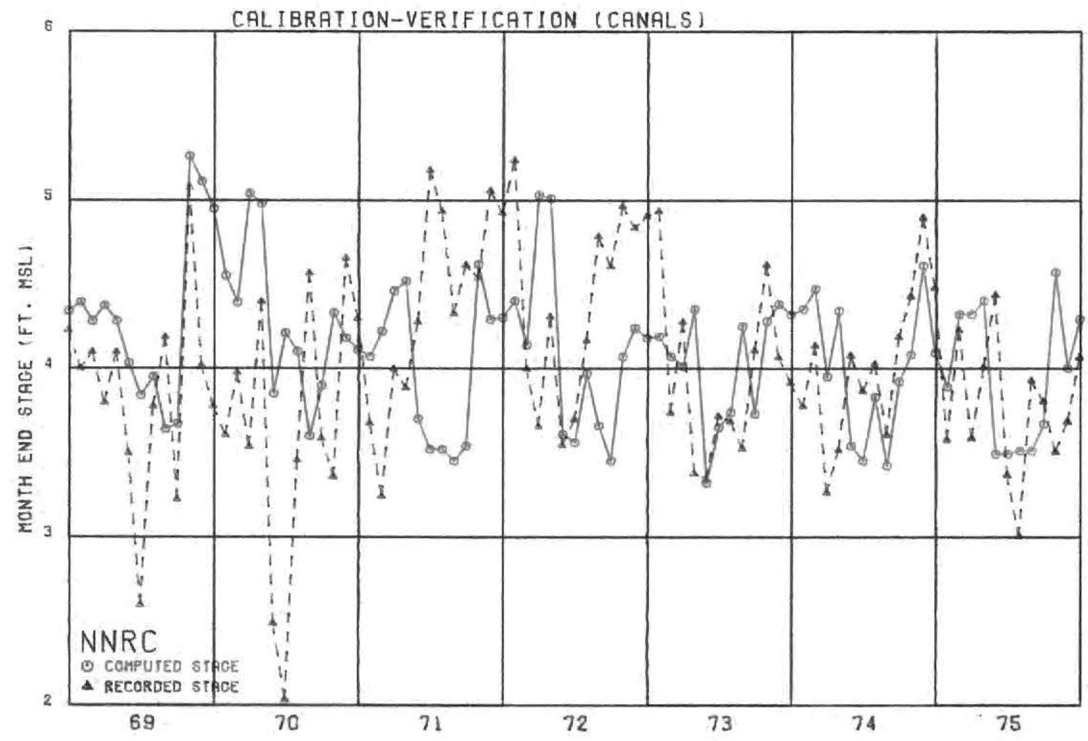


Figure 47 North New River Upstream of Sewell Lock

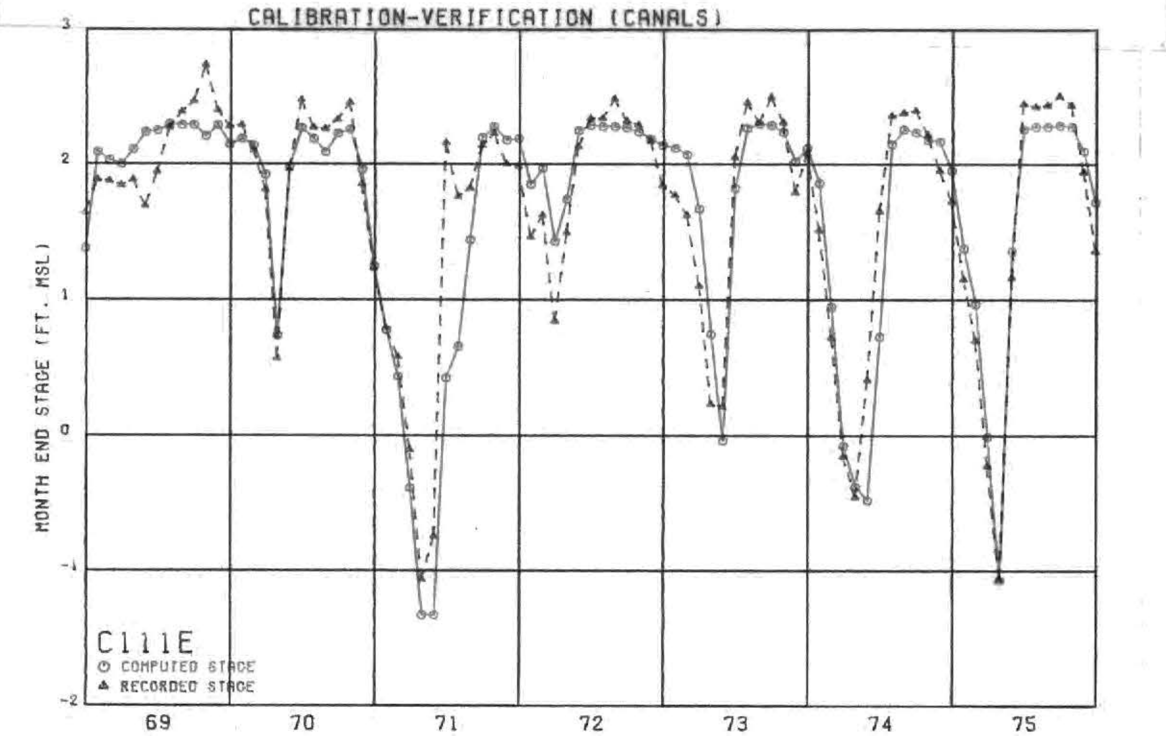


Figure 48 C-111E Upstream of S-18C

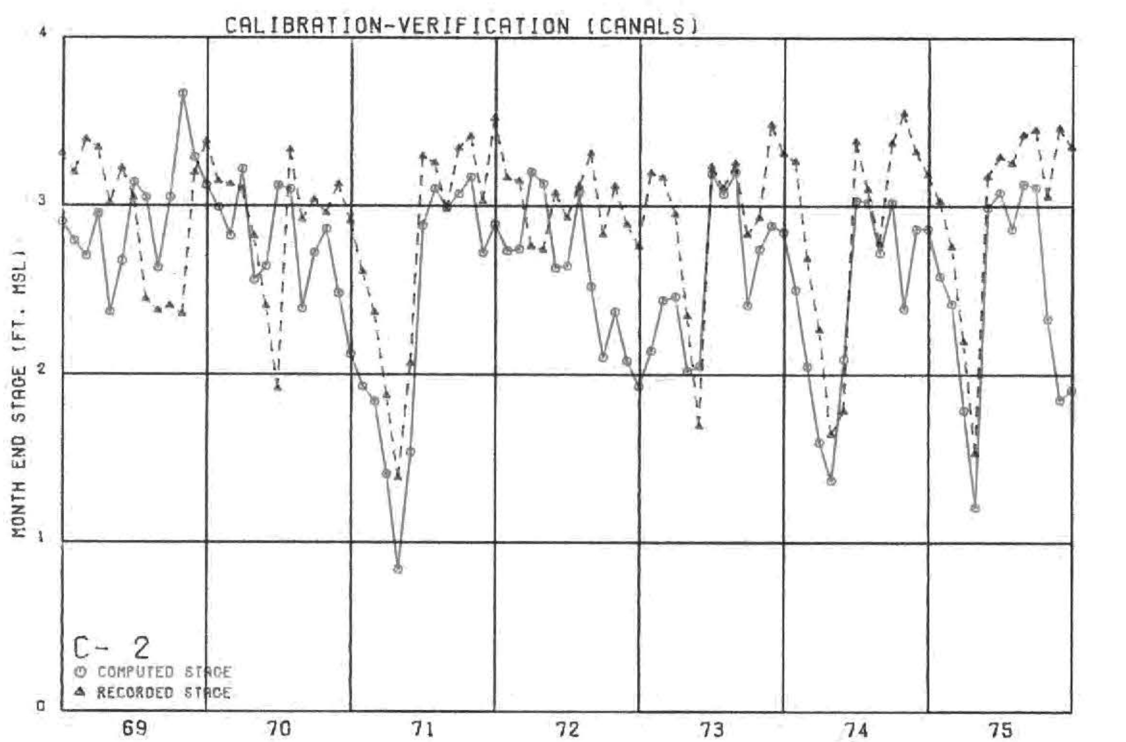


Figure 49 C-2 Upstream of S-22

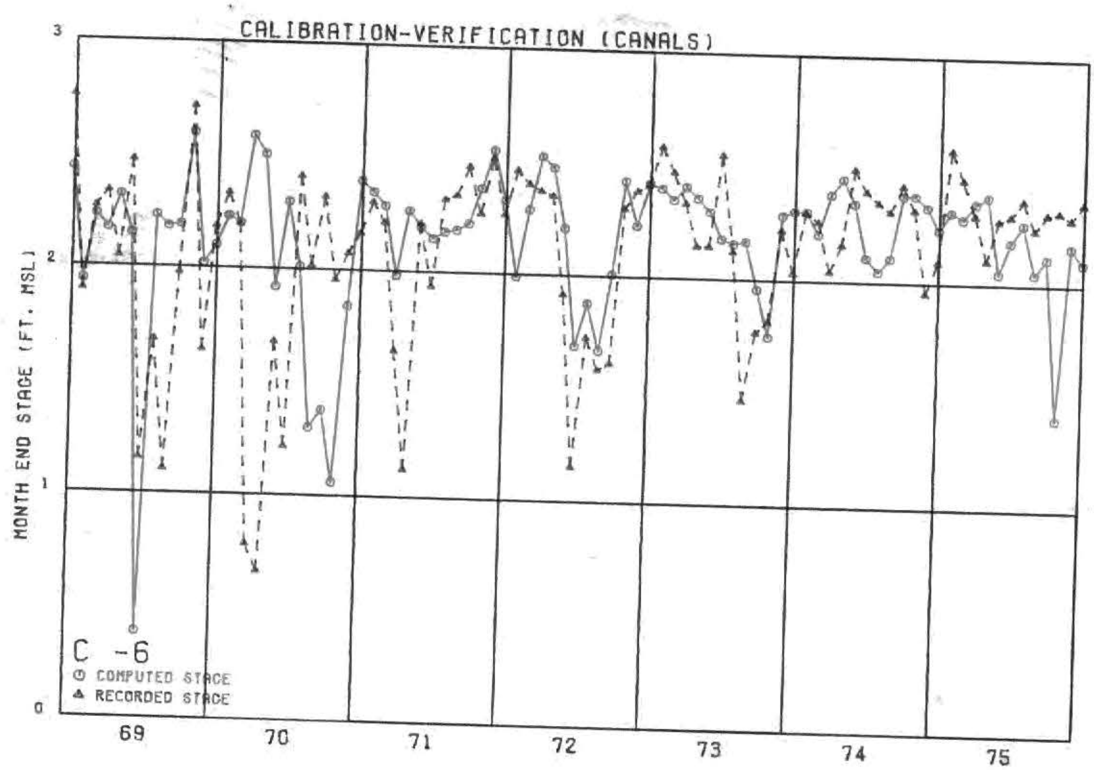


Figure 50 C-6 Upstream of S-26

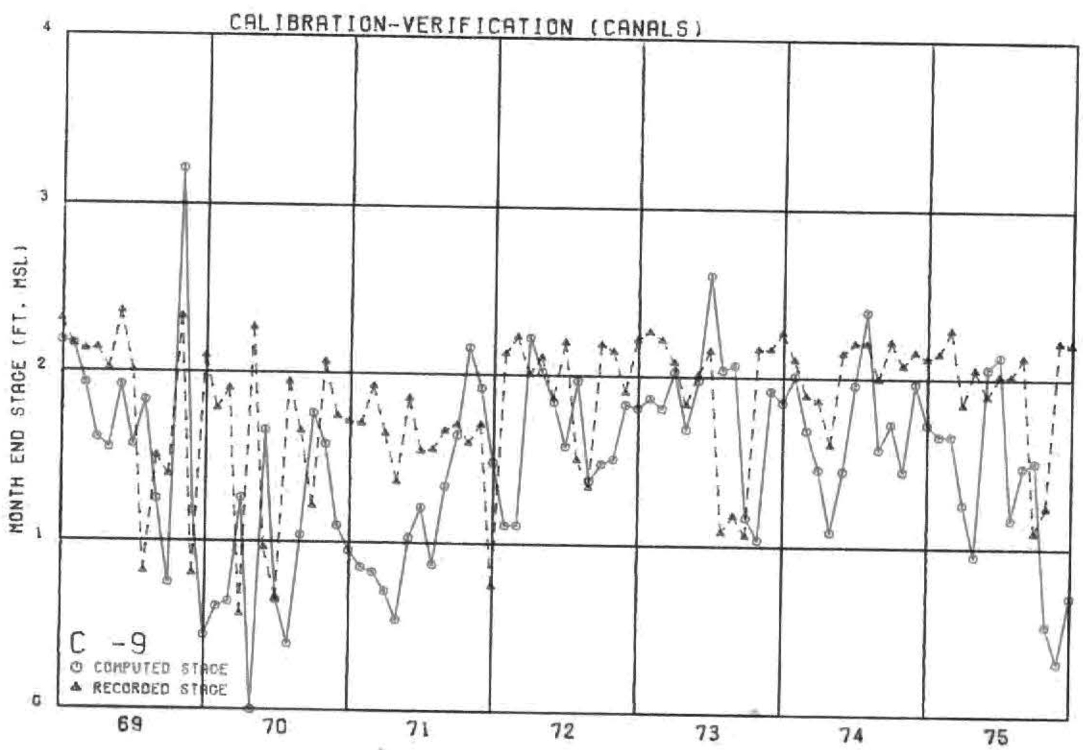


Figure 51 C-9 Upstream of S-29

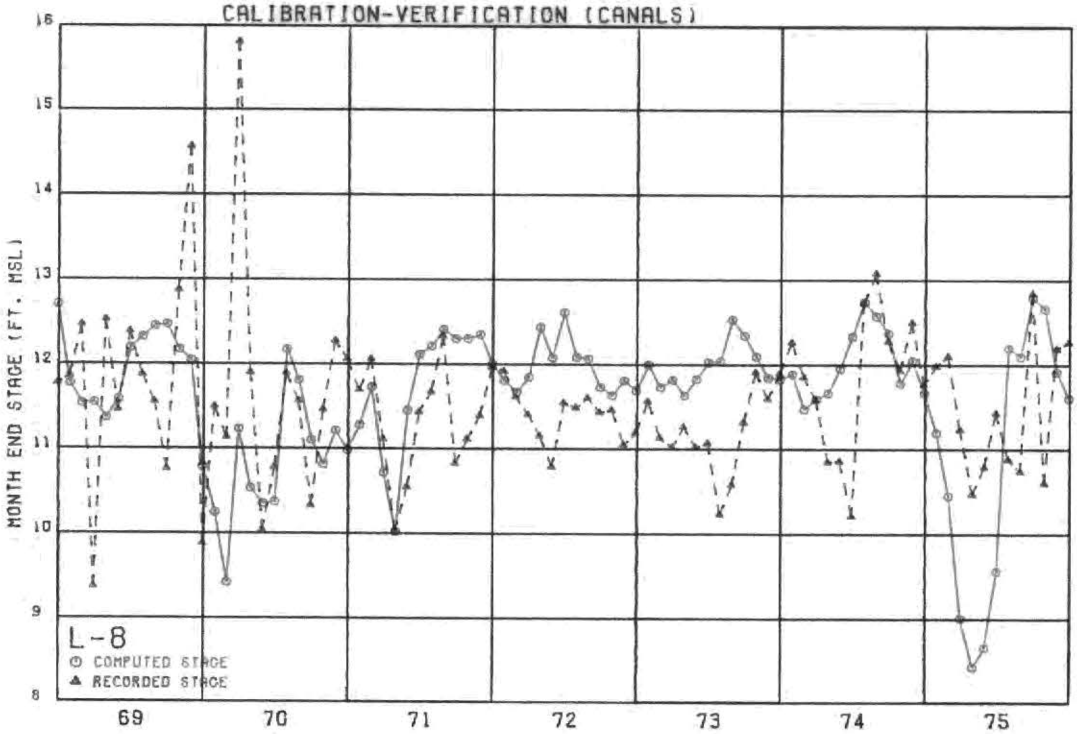


Figure 52 L-8 at West Palm Beach Canal

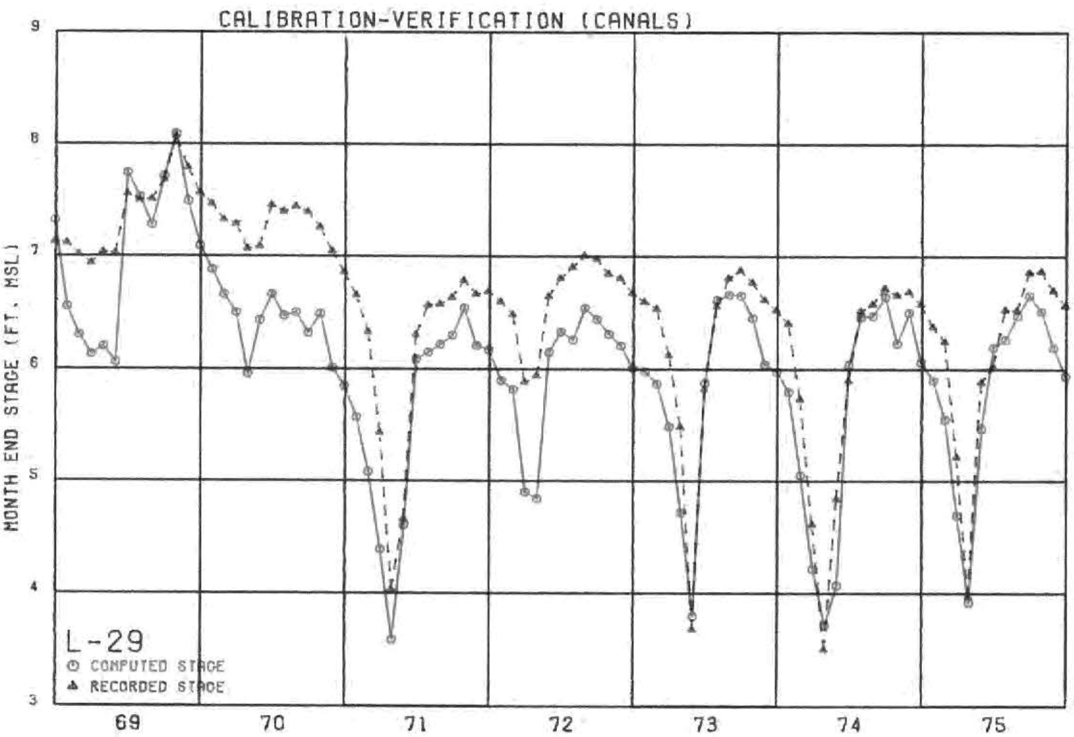


Figure 53 L-29 Borrow Canal (Tamiami Canal)

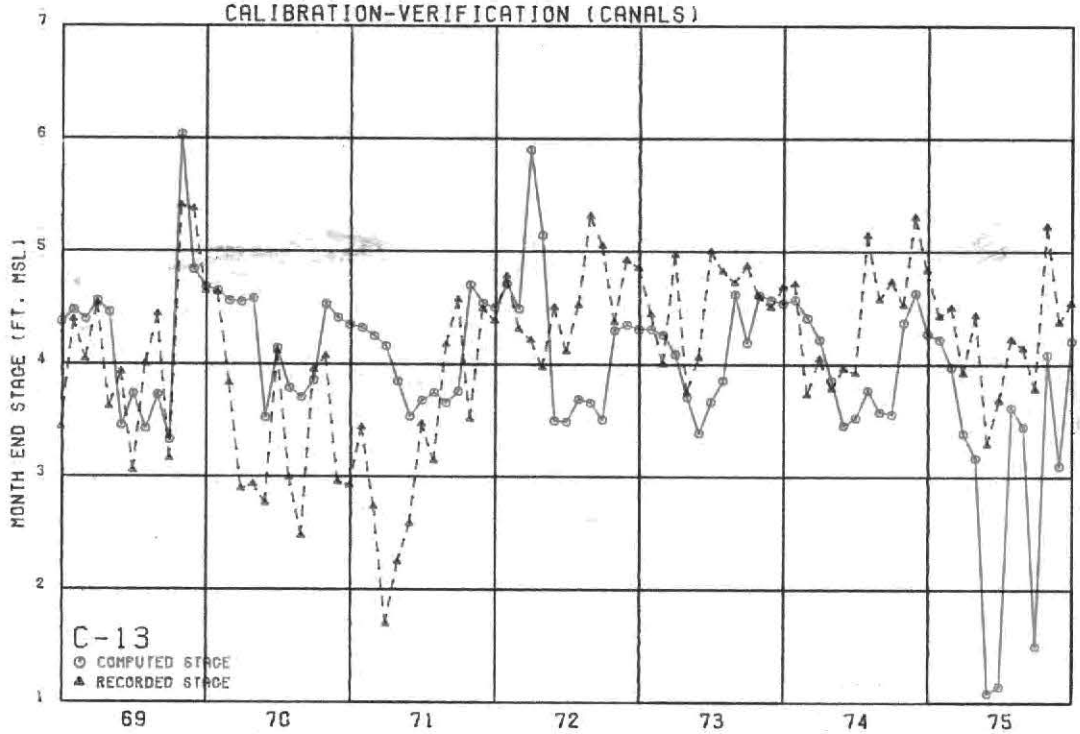


Figure 54 C-13 Upstream of S-36

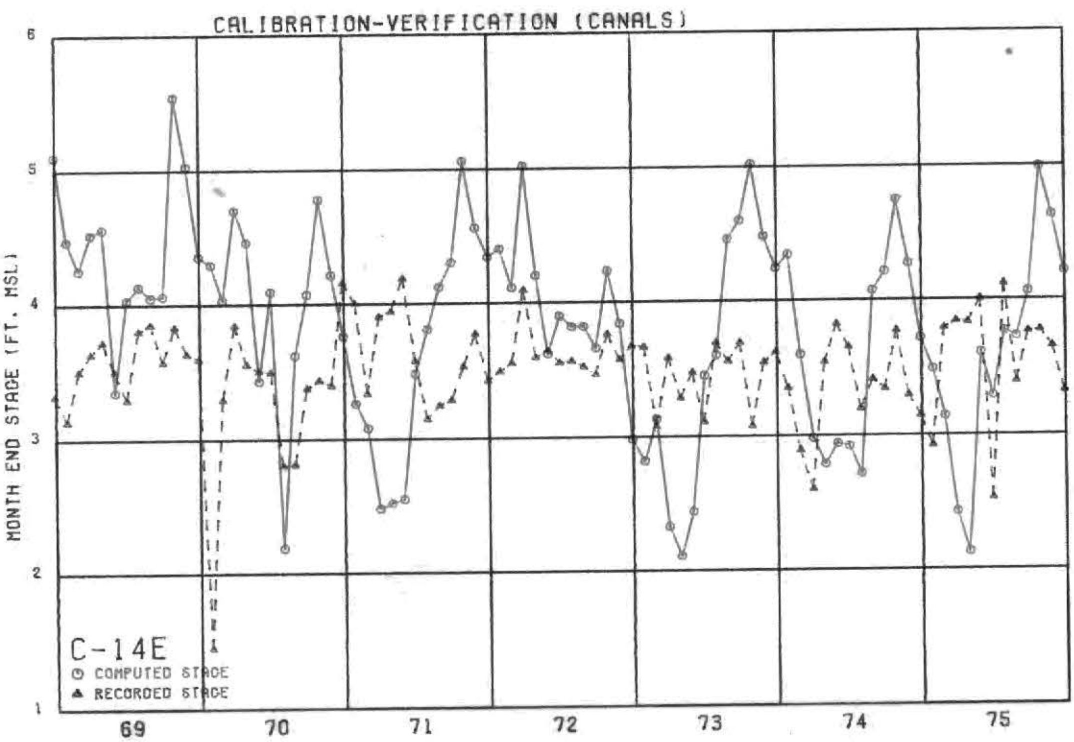


Figure 55 C-14 Upstream of S-37A

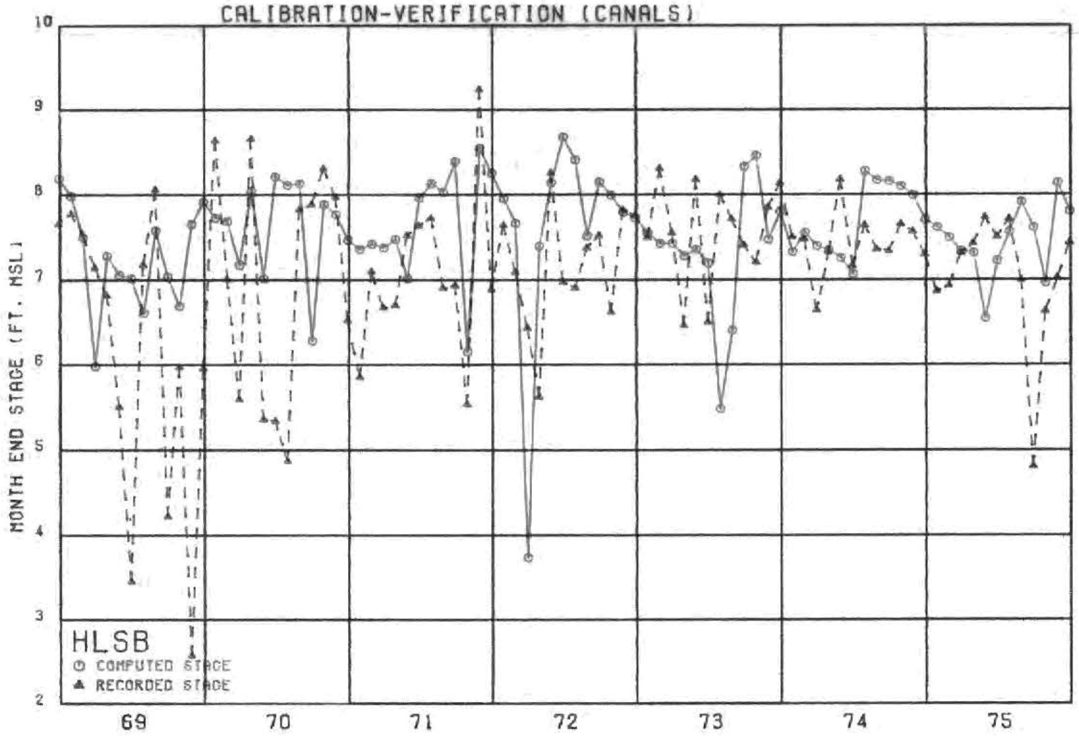


Figure 56 Hillsboro Canal Upstream of Deerfield Lock

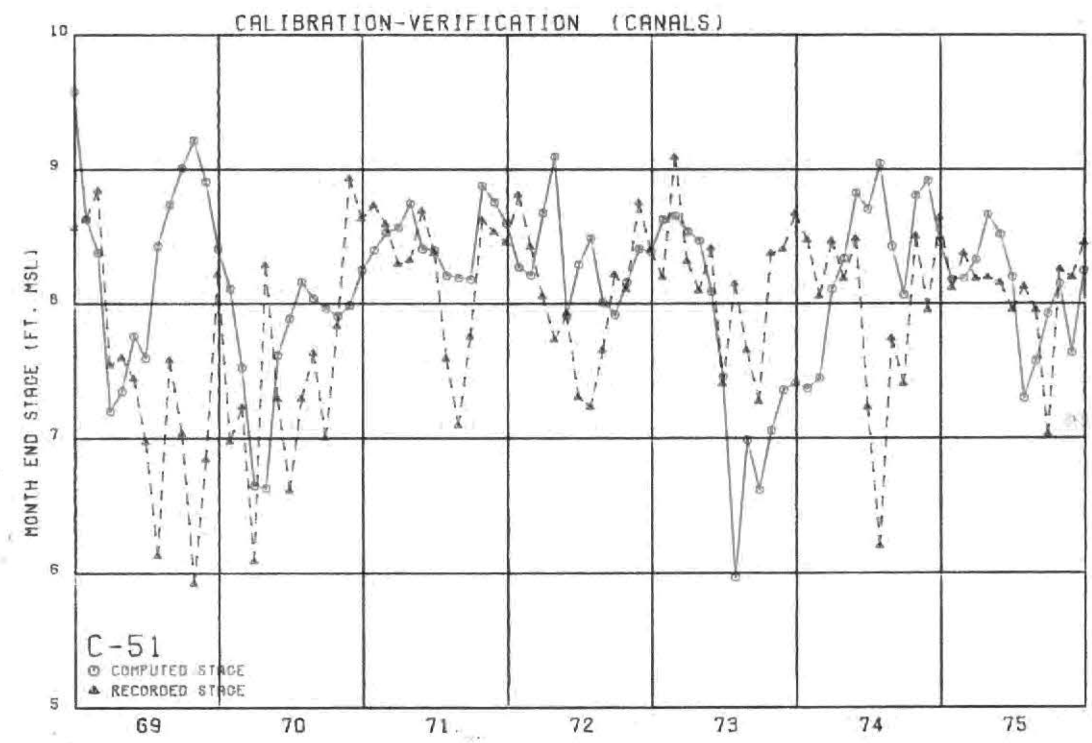


Figure 57 C-51 Upstream of S-155

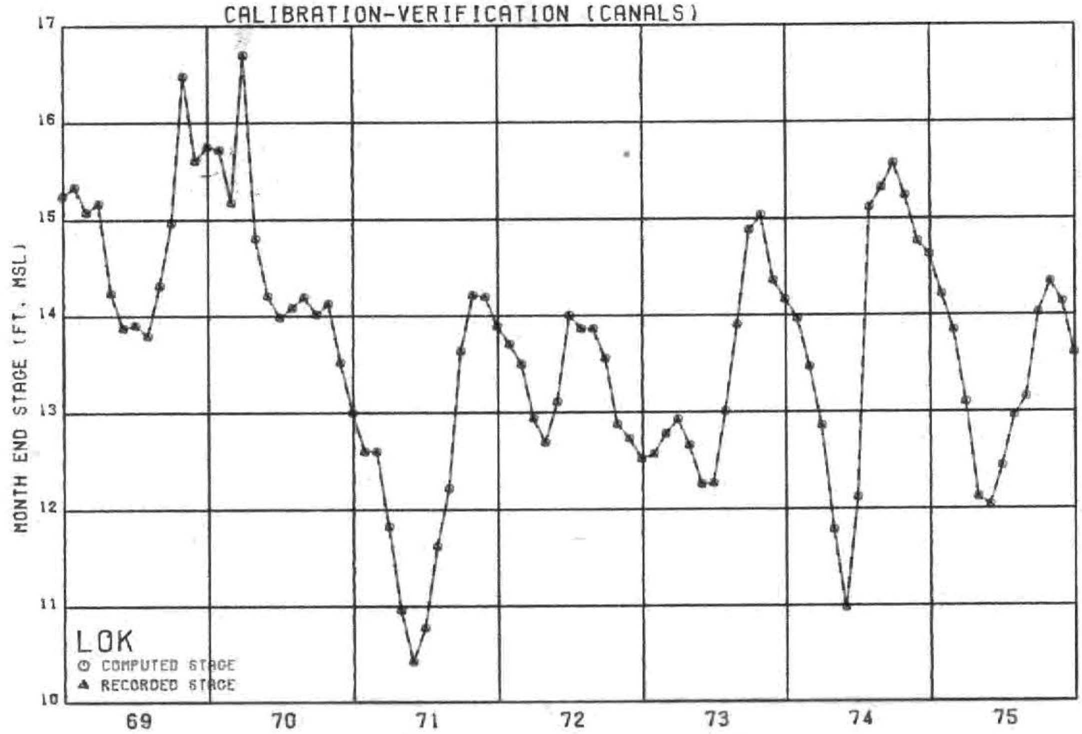


Figure 58 Lake Okeechobee

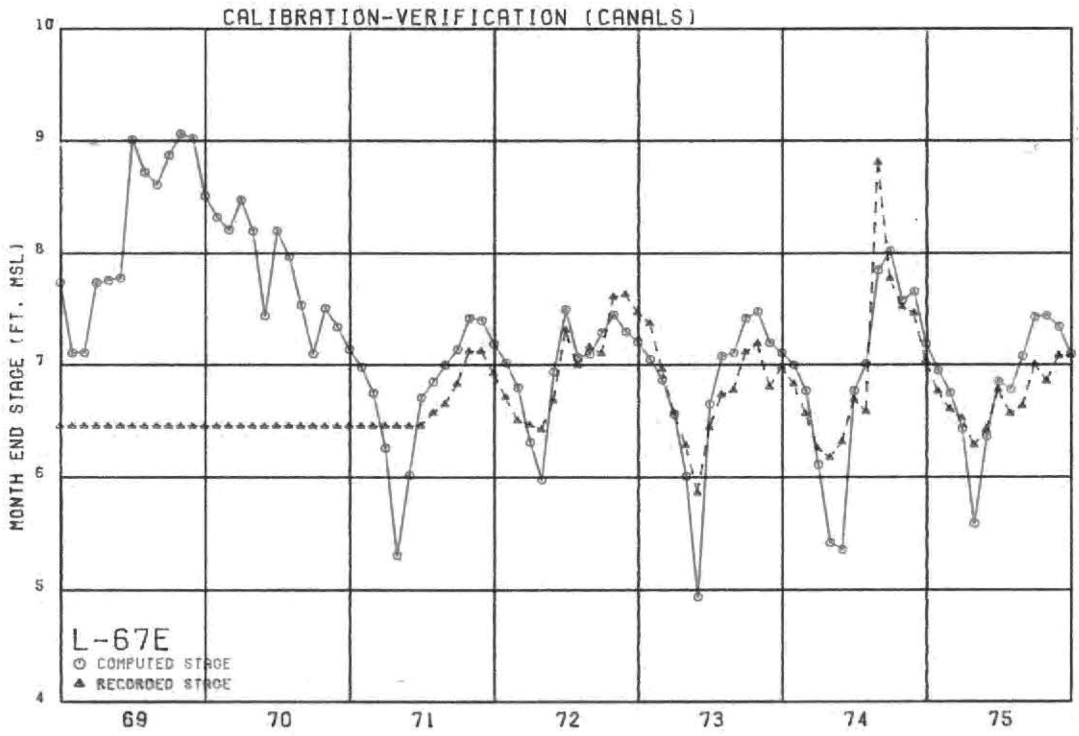


Figure 59 L-67 Ext.6 Miles South of Tamiami Canal

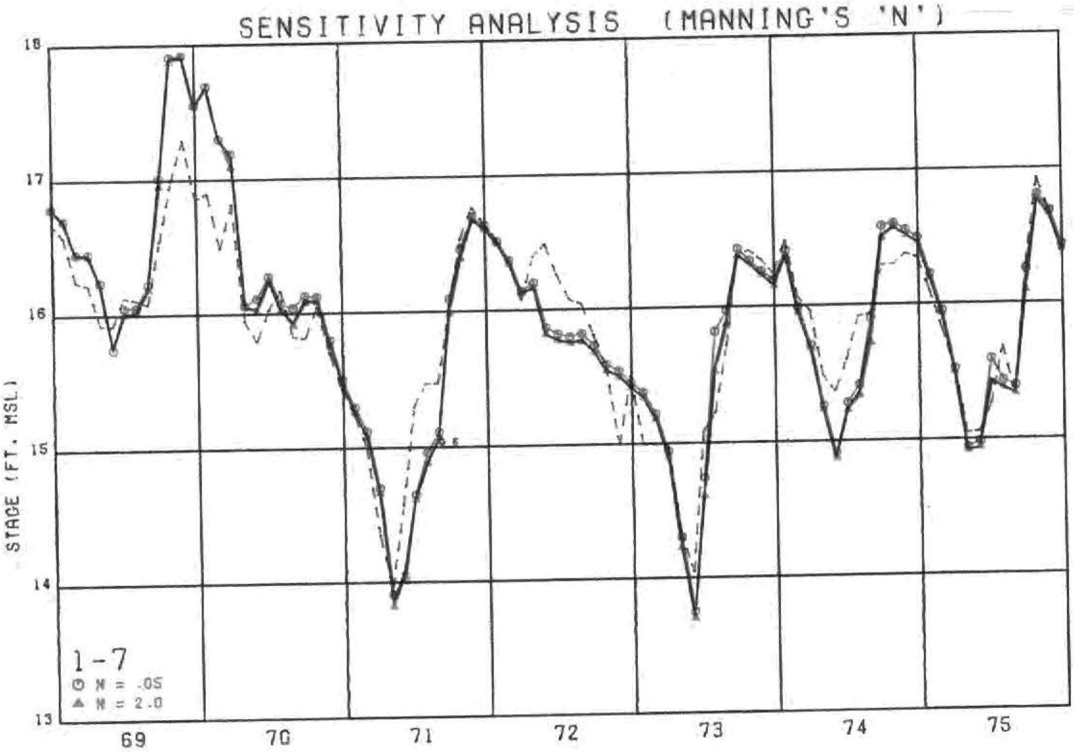


Figure 60 Water Conservation Area 1, Gage 1-7

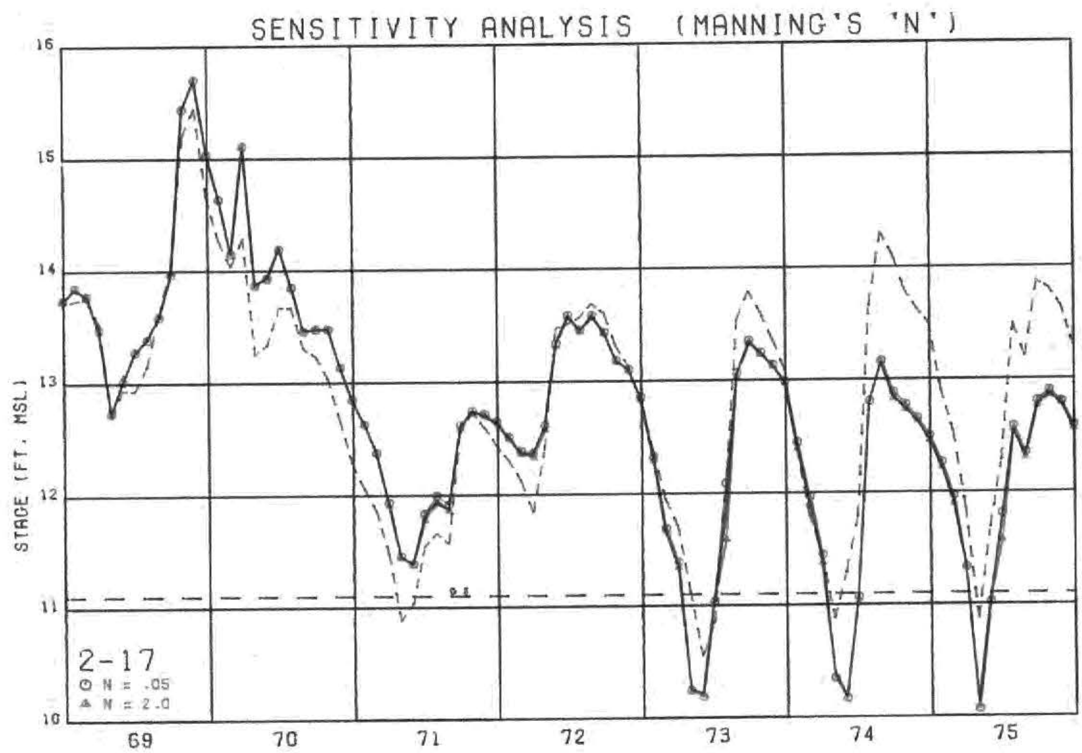


Figure 61 Water Conservation Area 2A, Gage 2-17

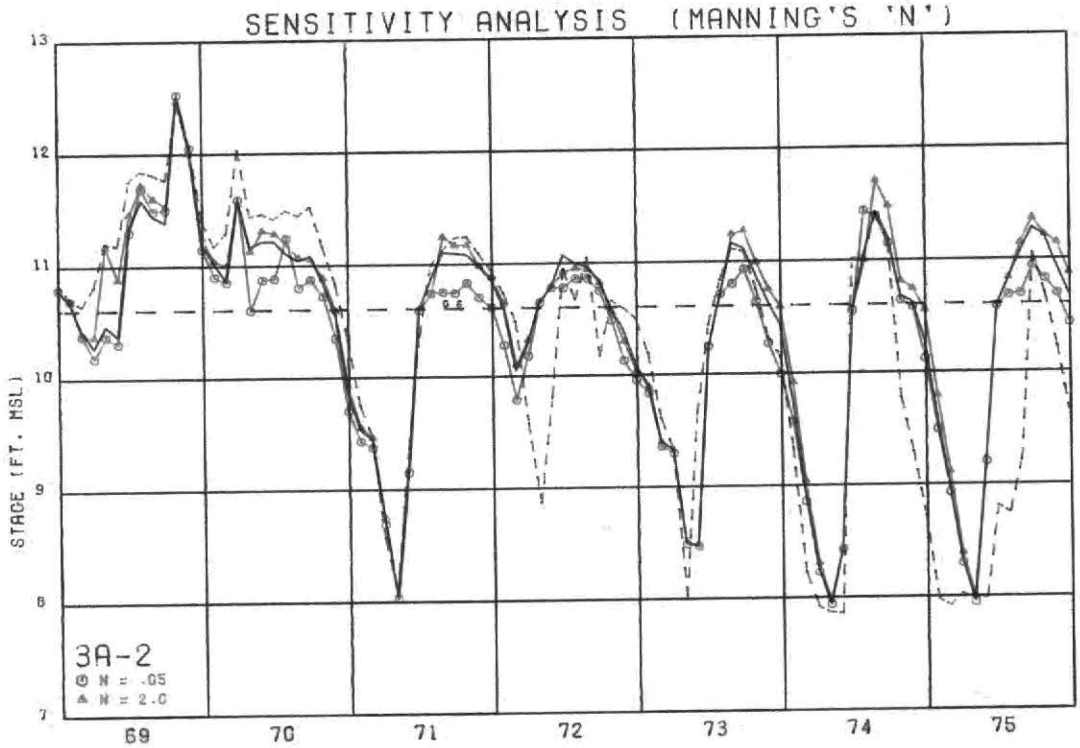


Figure 62 Water Conservation Area3A, Gage3-2

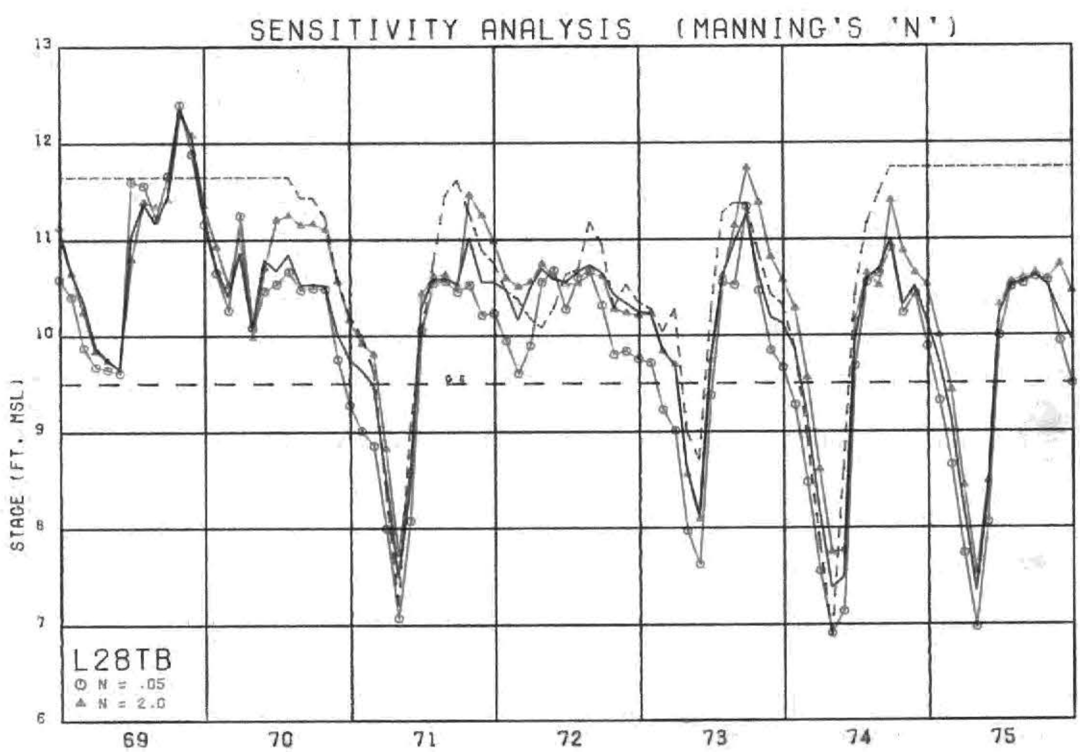


Figure 63 Collier County, L-28 Tieback

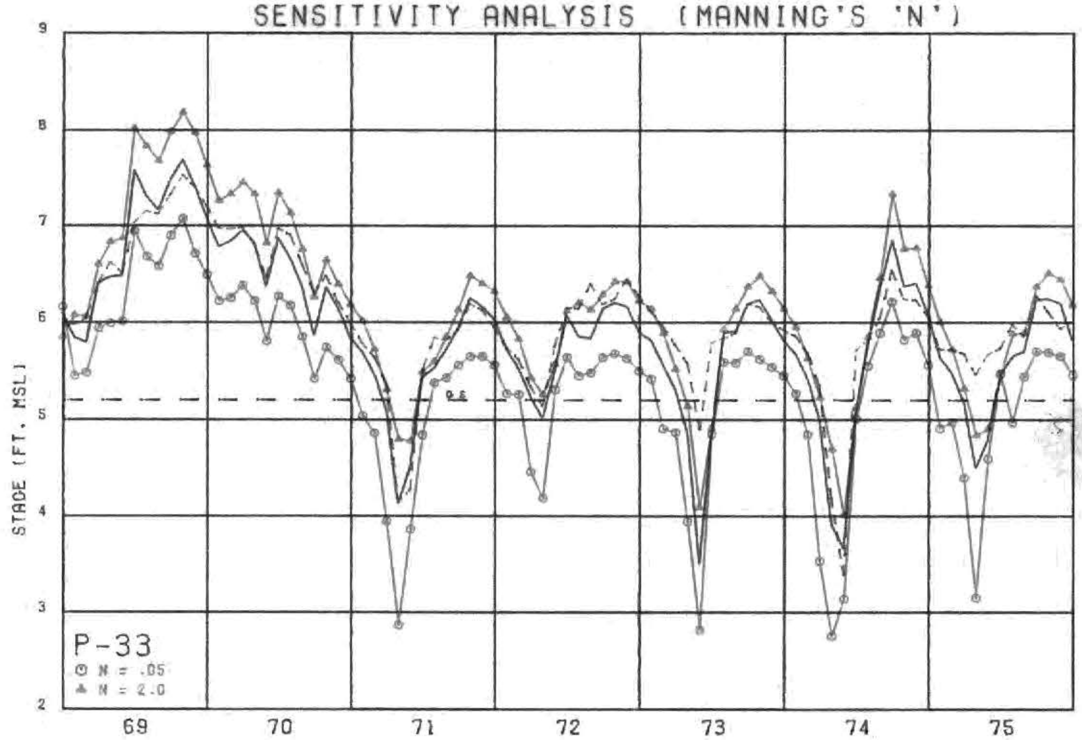


Figure 64 Everglades National Park, P-33

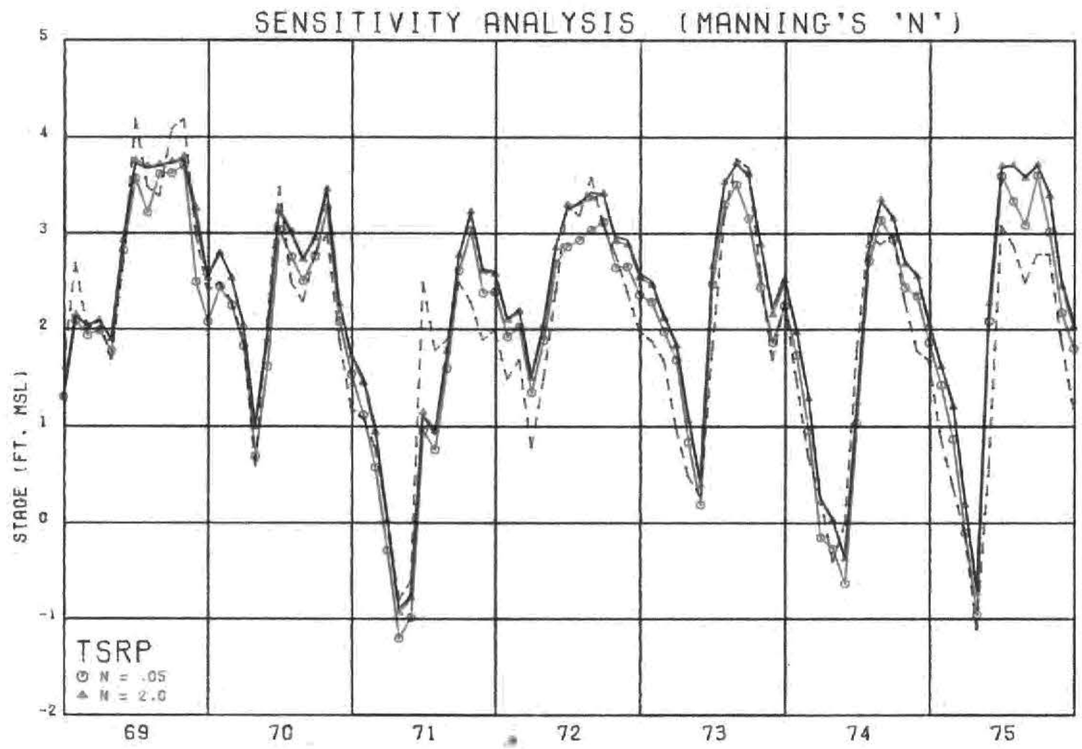


Figure 65 Everglades National Park, Taylor Slough near. Royal Palm Ranger

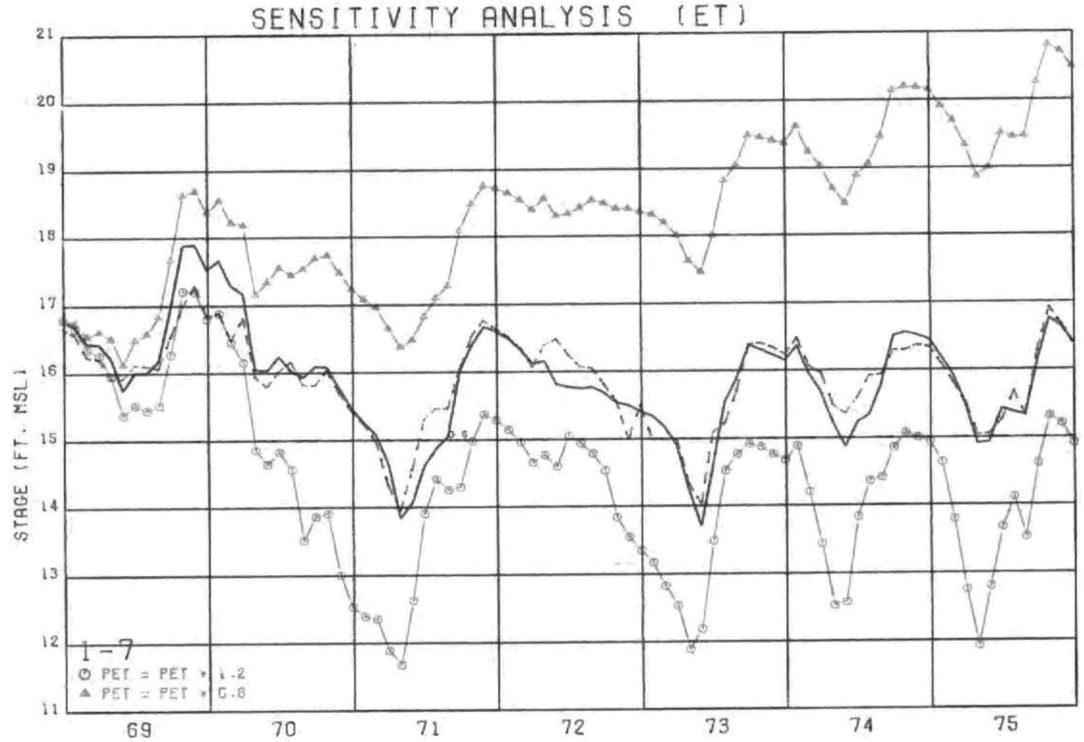


Figure 66 Water Conservation Area 1, Gage 1-7

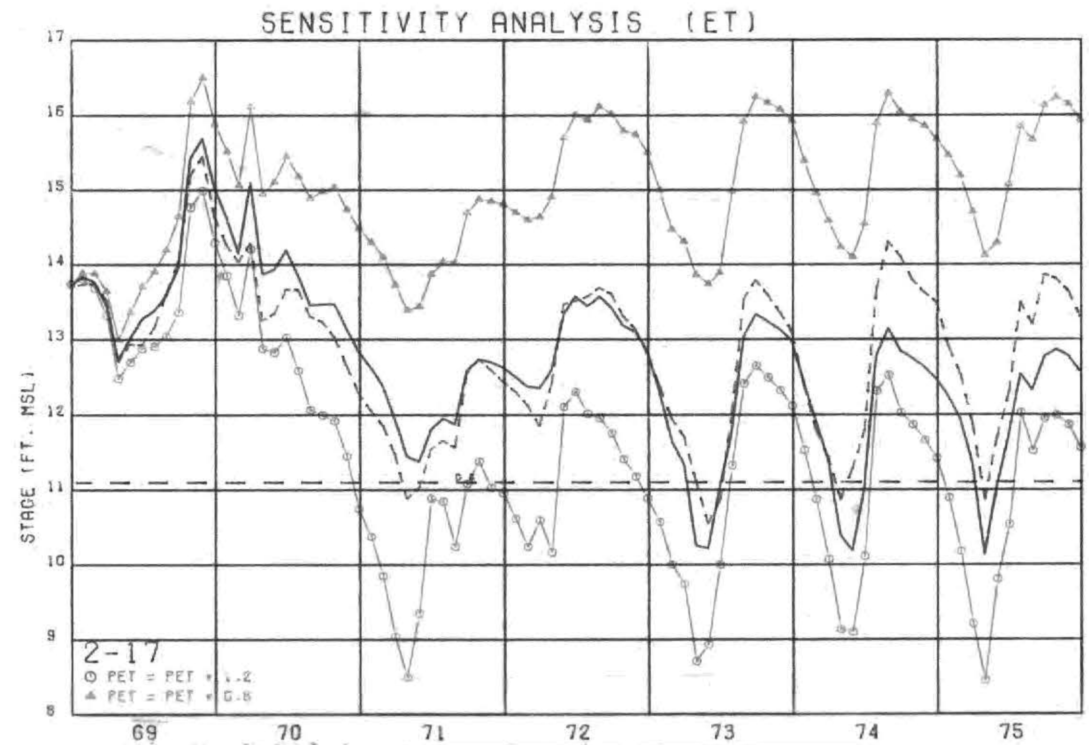


Figure 67 Water Conservation Area 2A, Gage 2-17

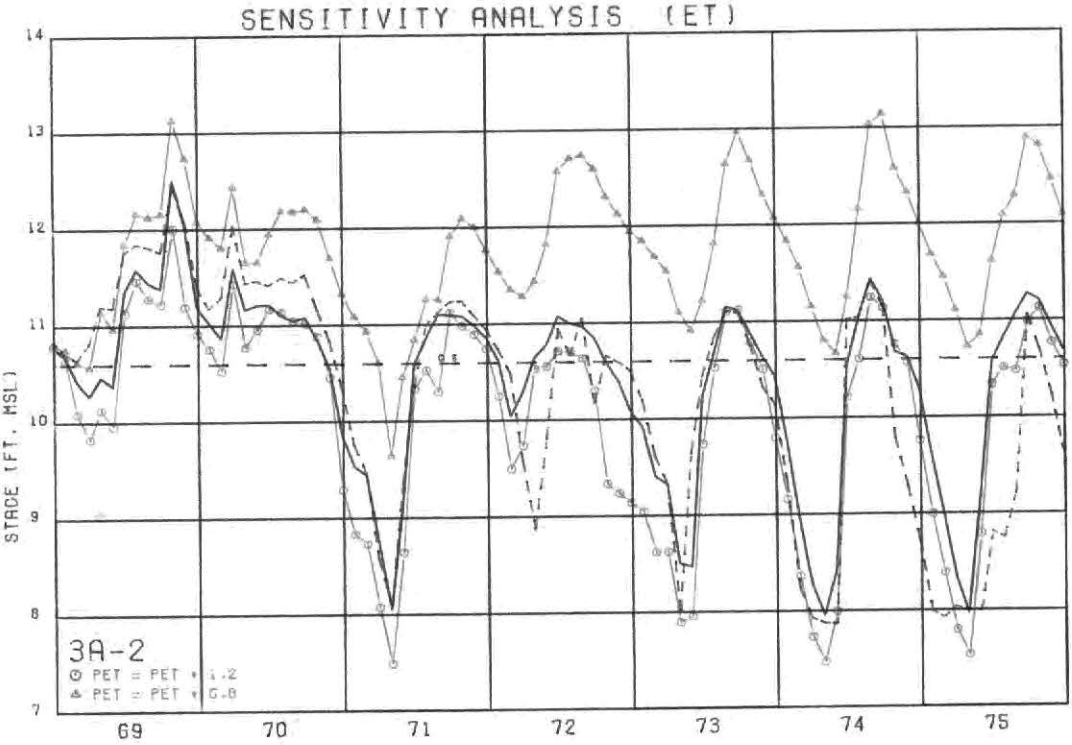


Figure 68 Water Conservation Area 3A, Gage 3-2

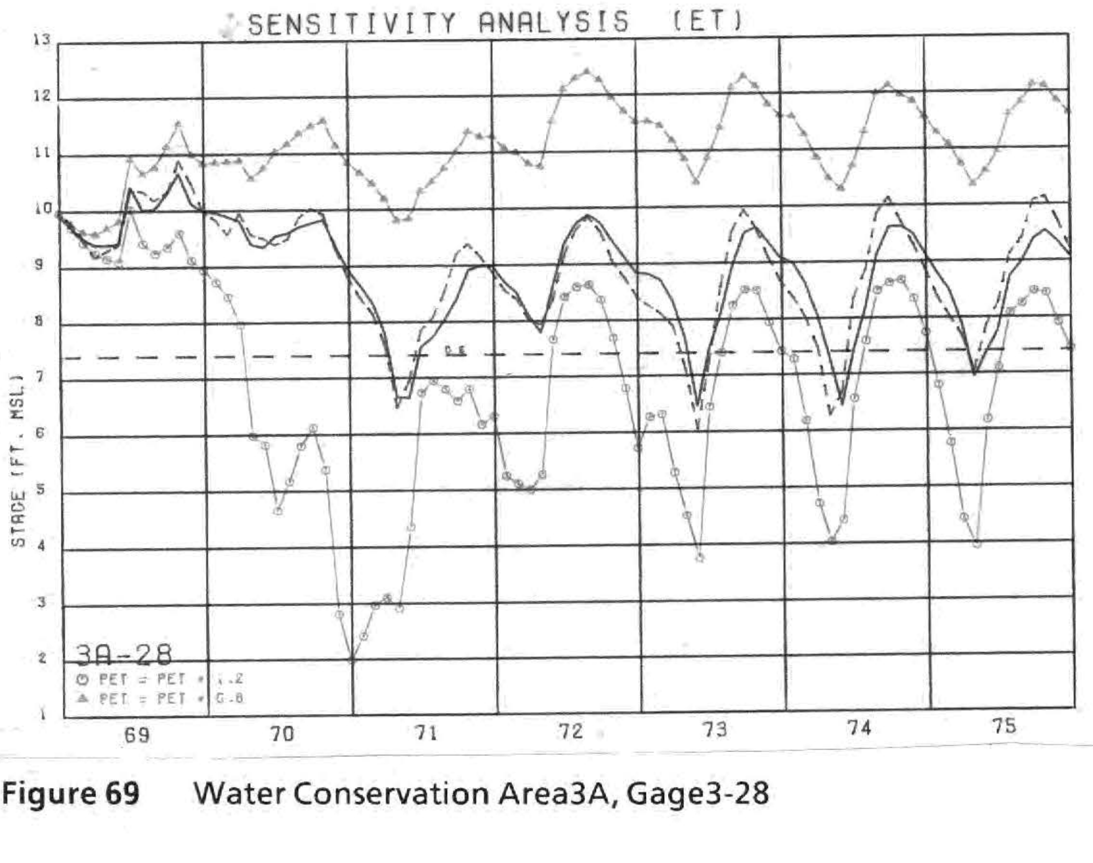


Figure 69 Water Conservation Area3A, Gage3-28

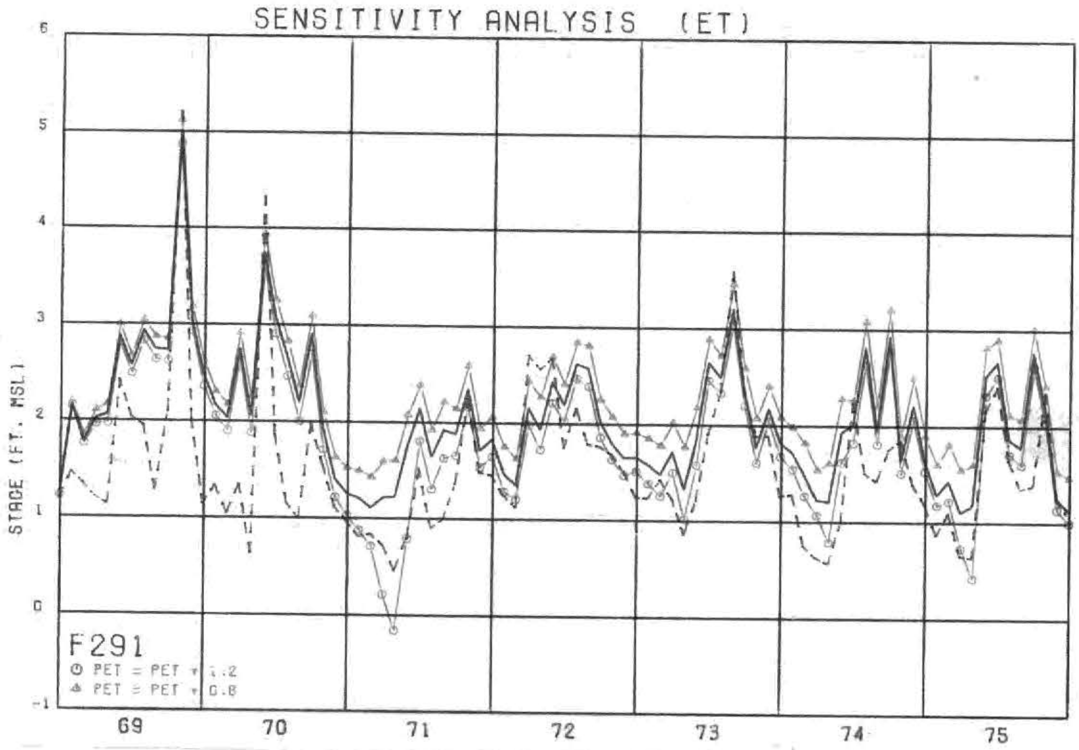


Figure 70 Broward County, F-291

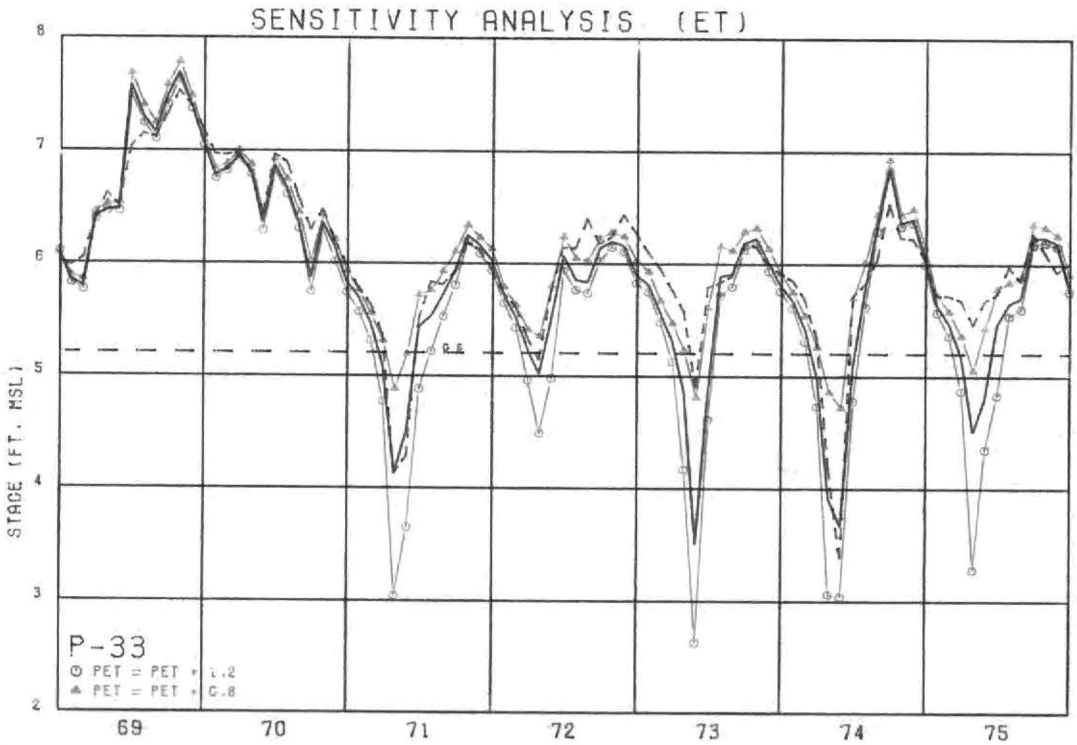


Figure 71 Everglades National Park, P-33

VI. SIMULATION OF THE UPPER EAST COAST

The Upper East Coast Planning Area consists of Martin, St. Lucie and eastern Okeechobee Counties. The major drainage canals servicing the study area are C-25 (Belcher Canal), C-24 (Diversion Canal), C-23 (County Line Canal), and C-44 (St. Lucie Canal). Each of these canals is regulated through the use of discharge control structures. In addition, numerous secondary drainage canals, serving local agricultural interests, are regulated by several local drainage control districts. These secondary canals tie into the major project canals, or natural streams, to receive or discharge water as the need arises.

Before man-made channels diverted the process, natural surface flows in the UEC flowed south-southwest to Lake Okeechobee and to the Everglades through the Allapattah Marsh, and north through the St. Johns River Marsh. Natural drainage to the ocean occurred via Five Mile and Ten Mile Creeks through the north fork of the St. Lucie River, in addition to the south fork of the St. Lucie River. The Loxahatchee Marsh, in the southeastern region of the study area, drains into the Loxahatchee River to the ocean.

Most of the southward and northward drainage has been permanently diverted eastward by man-made practices. Several excellent publications describing the hydrological, geophysical, topographical, and other general characteristics pertinent to the study area are listed at the end of this report.

A. Data Collection

The periods selected for calibration and verification were the years 1969-1971 and 1973-1975, respectively. The periods offered an opportunity to examine model response to extreme wet and dry conditions. The calibration and verification periods are the same as those chosen in the pilot and LEC study area. Since the Army Corps of Engineers wanted the capability to simultaneously run the SFWMM for the UEC and the LEC planning areas, a 2 x 2 mile grid network was selected to model the UEC.

To make the rainfall data as realistic as possible, the UEC study area was divided into six sub-basins. Each available rainfall station was weighted with respect to location in each sub-basin. The estimated daily rainfall values were then uniformally distributed to the respective sub-basins. All rainfall data were obtained from SFWMD data files and the stations are listed in Table 9.

Table 9. Rainfall Gages Used in the Simulation of the Upper East Coast

Station	County	Description	SE	TN	RG
MRF5052	St. Lucie	Adam's Tower	6	36	38
MRF148	St. Lucie	Cow Creek Ranch	9	36	37
MRF39	St. Lucie	Scotti Groves	4	36	39
MRF6020	Okeechobee	Fort Drum 5NW	29	33	35
MRF143	Okeechobee	Rocking K Ranch	38	33	35
MRF197	St. Lucie	Strazzula Groves	38	34	38
MRF6032	St. Lucie	Fort Pierce	8	35	40
MRF37	St. Lucie	Fort Pierce standard can	24	35	39
MRF5053	St. Lucie	Fort Pierce Tower	33	35	39
MRF7092	Indian River	Vero Beach 4NW	6	33	39
MRF40	St. Lucie	Hayes Recorder	19	36	39
MRF147	St. Lucie	Peacock Ranch	16	37	39
MRF44	Okeechobee	Okeechobee Field Station	13	37	35
MRF150	Martin	S-135	8	39	37
MRF5034	Okeechobee	Okeechobee FS Hdqts	34	36	35
MRF6082	Martin	Stuart IN	32	37	41
MRF7037	Martin	Port Mayaca -St. Lucie Canal	22	40	37
MRF51	Martin	Port Mayaca Lock	22	40	37
MRF144	Okeechobee	S-133	4	38	35
MRF54	Palm Beach	Pratt and Whitney	24	41	40
MRF4015	Martin	Monreve Ranch #3	27	39	40
MRF49	Martin	St. Lucie Lock (COE)	13	39	40
MRF7035	Martin	St. Lucie New Lock	13	39	40
MRF4013	Martin	Monreve Ranch #1	26	39	40
MRF4015	Martin	Monreve Ranch #2	27	39	40
MRF53	Palm Beach	Jupiter near S-46	2	41	42

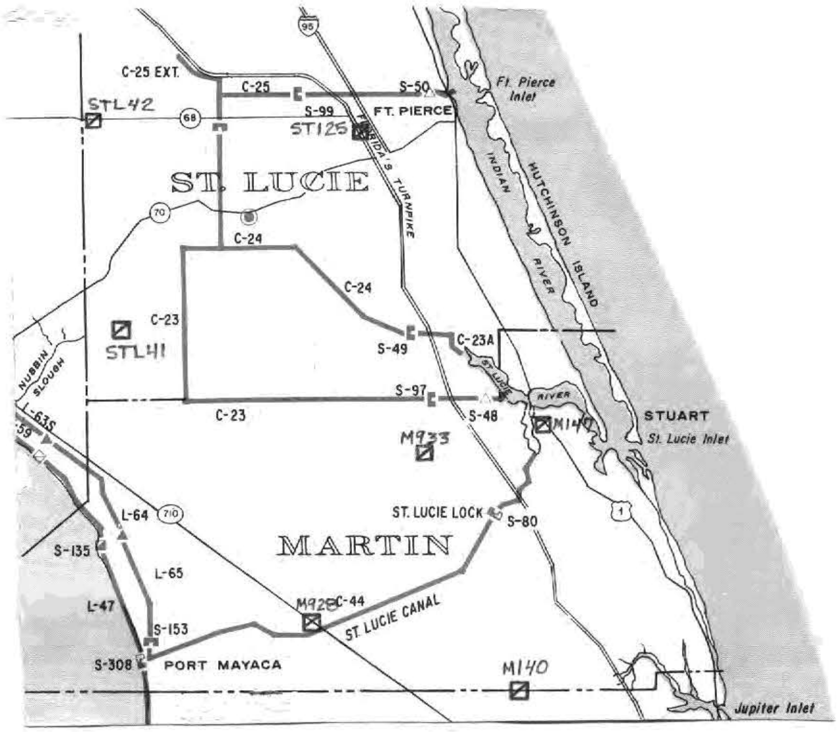
Available discharge and stage data at the major structures were obtained from SFWMD files. Groundwater stage data for monitored wells were obtained from published U.S.G.S. reports and unpublished hydrographs supplied by the U.S.G.S. Data on topographical soil and surficial aquifer characteristics were obtained from survey maps available at the SFWMD. Initial groundwater condition estimates for dry conditions were obtained from private publications available at the SFWMD reference center. These estimates are realistic approximations based on observed groundwater levels for several years. Available data on surficial aquifer transmissivities were sketchy, at best, requiring interpolation and extrapolation based on observable ranges.

Wellfield withdrawals for major wellfields were obtained from monthly pumpage reports supplied by the utilities. Linear regression analysis, based on seasonal fluctuations, was required to estimate withdrawals when not available. Land use information for the study area was obtained from maps available at the SFWMD.

B. Boundary Conditions

Figure 72 represents the UEC study area simulated by the SFWMM using a 2 x 2 mile x-y grid network. The entire area was modeled using 347 nodes, representing 1,388 square miles.

The northern (Row 22) and southern (Row 1) boundaries were chosen to penetrate approximately two miles into Indian River and Palm Beach Counties, respectively. The western boundary (Column 1) extends four miles into Okeechobee County and includes the northeastern shoreline of Lake Okeechobee. The extra boundary nodes were added to reduce the effect of boundary assumptions on nodes in the study area.



☒ Monitoring points for calibration of groundwater calculations.

Figure 72 Upper East Coast Planning Area

Several simplified boundary conditions were incorporated in the SFWMM. The groundwater boundary conditions consist of a constant head of 0.0 (ft msl) at the coastal boundary, while the northern, southern, and western boundaries are modeled as no flow boundaries. Since these nodes lie outside the simulated study area, the impact of the assumptions on calculated stages for interior nodes adjacent to the boundaries is not significant. For surface water, ponding is set to zero at the southern and coastal boundaries to promote overland flow out of the study area.

C. Modeling Approach and Assumptions

Since the SFWMM is primarily a hydrologic model, and canals serve as boundaries for groundwater-surface water flows and for water conveyance, the importance of adequately simulating groundwater stages was given precedence over the simulation of canal stages.

There was little reliable stage and discharge data for many of the major structures during the desired calibration and verification periods. Data on S-153, S-308, S-48, and the Orange Avenue control structure on C-25 was either unknown or so fragmented as to prove inadequate for calibration purposes. In addition, available data on the Radebaugh control culverts and the C-23 control culverts were not available.

As a partially offsetting approach, outflows were calculated from these structures based on available data on regulation stages and structural dimensions. These outflows were diverted to the proper canals according to actual practices. Since S-308 did not come on-line until 1977, it was not included in the calibration and verification analysis.

Before S-308 existed, C-44 was a hydraulic extension of Lake Okeechobee. Inflow and outflow relationships between C-44 and Lake Okeechobee were dependent on the head difference between Lake Okeechobee and C-44 stages.

Since, during the period used for calibration (1969-1971) and verification (1973-1975) S-308 was not in existence, it was necessary to model C-44 as a free flow system. An analysis of historical data showed that during dry periods, S-80 releases were very low, normally less that 500 cfs. Likewise, during wet periods, releases were mostly higher than 500 cfs. In order to estimate releases from Lake Okeechobee prior to the construction of S-308, it was assumed that if the historical releases were less than 500 cfs, there was no inflow from Lake Okeechobee and only releases from local secondary canals were simulated. Historical releases at S-80 were then assumed to be those associated with lockage and leakage losses. If the historical S-80 discharges were above 500 cfs, the Lake Okeechobee inflow was assumed to be a percentage of the historical S-80 discharge. This percentage was used as a calibration parameter and it was estimated to be 88% during heavy releases.

St. Lucie canal outflow to Lake Okeechobee occurred when heavy, localized drainage inflows and overland flow, coupled with light releases from S-80, resulted in stages in the St. Lucie canal higher than those in the lake. This condition was prevalent during wet seasons from mid 1970 through 1975, when average yearly hydrologic conditions were near or drier than normal.

In simulating this free flow process, the head difference between C-44 and Lake Okeechobee was assumed to occur between the downstream end of S-308 (Port Mayaca) and the lake. This also assumes that the stage in C-44 is constant throughout the reach. The physical model then compares the calculated average daily stage for C-44 with the historic daily Lake Okeechobee stages. Whenever the average stage for C-44 is greater than the recorded stage of Lake Okeechobee, the physical model calculates the volume of outflow that would correspond to the head difference between the canal and the lake, using a modified weir equation.

An attempt to simulate drainage practices on a local scale was conducted. Through the use of several reports on the local drainage districts and the U.S.G.S. quadrangle maps, the major agricultural and grazing drainage canals and laterals were hydraulically simulated by the basic physical model. Close attention was directed to location, outflow destination, and regulation stages, if known, for each of these secondary canals. Canal stages were regulated to conform with historically observed groundwater levels, when possible. For instance, the Main No. 1 and Header canals located at Fort Pierce Farms and North St. Lucie River Drainage Districts, respectively, were simulated in the analysis. These canals were numbered from 1 to 31 in a general north to south direction (Table 10).

Two modeling assumptions were required when simulating hydrological processes for pastureland. The first assumption entailed modeling all grazing (improved and unimproved) areas as vacant lands. This was required to prevent excessive water table drawdowns by evapotranspiration (ET) consumption during the drier periods, as occurred when pasturelands were modeled as agricultural areas.

The second assumption required that all improved pastureland nodes were drained, but not irrigated in the calibration runs. This served to prevent excessive drawdowns in the water table, and to promote maximum drainage to the project canals. This approach further offsets the lack of known flow

TABLE 10. FINAL CANAL PARAMETERS USED IN UEC STUDY CALIBRATION

CNM	HDROP	WIDTH	CREL	GWDTH	CHHC	WCNL	NOUT	INTO	
TRPKC	0.0	65.0	22.0	25.0	0.1	0	1	8	
CANLA	1.0	50.0	24.0	40.0	0.1	0	1	1	
CANLB	0.0	50.0	22.0	40.0	0.1	0	1	1	
CNL-1	0.0	35.0	20.0	20.0	0.1	0	1	8	
CNL-2	0.0	40.0	20.0	15.0	6.0	0	1	8	
CNL-3	0.0	45.0	17.5	30.0	6.0	0	1	35	
MCNL	0.0	65.0	17.5	50.0	7.0	0	1	0	
C-25E	0.0	70.0	20.0	45.0	5.0	0	2	9	18
C-25	0.0	90.0	12.3	22.0	5.5	0	1	0	
CNL-5	0.0	60.0	20.5	40.0	0.1	0	1	18	
NHDCL	0.0	65.0	20.0	20.0	7.5	0	1	35	
CNL-6	0.0	60.0	21.0	50.0	0.1	0	1	18	
CNL-7	0.0	60.0	22.0	50.0	0.1	0	1	18	
SHDCL	0.0	60.0	21.0	30.0	0.1	0	1	35	
CNL-8	1.0	60.0	21.0	40.0	0.1	0	1	18	
CNL-9	0.0	40.0	19.0	25.0	5.0	0	1	35	
CL-10	1.0	45.0	21.0	25.0	5.0	0	1	35	
C-24	0.0	120.0	19.0	50.0	4.5	0	1	19	
C23A	0.0	500.0	1.6	500.0	5.0	0	1	36	
CL-11	0.0	60.0	28.5	10.0	0.1	0	1	27	
CL-12	0.0	60.0	20.0	30.0	0.80	0	1	27	
CL-13	3.0	60.0	20.0	45.0	2.5	0	2	27	34
CL-14	0.0	50.0	22.0	10.0	7.5	0	2	27	18
CL-15	0.0	40.0	23.0	10.0	0.1	0	1	27	
CL-16	0.0	40.0	24.0	10.0	5.0	0	1	27	
CL-17	0.0	45.0	22.0	10.0	0.1	0	1	27	
C-23	0.0	130.0	20.0	10.0	4.0	0	1	28	
C-23E	0.0	140.0	7.0	11.0	1.5	0	1	32	
L-64	0.0	45.0	17.5	30.0	6.0	0	2	0	30
L-65	0.0	60.0	19.0	45.0	5.0	0	1	0	
SFSTL	0.0	375.0	.05	375.0	0.13	0	1	32	
STLR	0.0	2500.0	0.05	2500.0	0.05	0	1	0	
ENBSL	5.0	100.0	22.0	100.0	5.0	0	2	27	34
WNBSL	3.0	100.0	24.0	100.0	5.0	0	1	0	
TNMCR	0.0	150.0	10.0	75.0	5.0	0	1	36	
NFSTL	0.0	550.0	1.0	550.0	7.5	0	1	32	
C-44	0.0	275.0	14.0	175.0	3.0	0	1	-1	
CL-18	0.0	45.0	23.0	30.0	8.0	0	1	37	
CL-19	0.0	50.0	23.5	25.0	0.1	0	1	37	
CL-20	0.0	60.0	27.0	50.0	0.1	0	1	37	
CL-22	0.0	80.0	20.5	60.0	6.5	0	1	37	
CL-23	0.0	45.0	25.0	20.0	5.0	0	1	37	
CL-24	0.0	45.0	18.0	35.0	7.5	0	1	31	
CL-25	0.0	100.0	12.0	100.0	8.0	0	1	0	
CL-26	5.0	75.0	36.0	40.0	0.1	0	1	34	
CL-27	2.0	50.0	26.0	30.0	0.1	0	1	33	
CL-28	2.0	50.0	25.0	30.0	0.1	0	1	0	
CL-29	0.0	50.0	28.5	10.0	0.1	0	1	27	
CL-30	0.0	40.0	22.0	35.0	0.1	0	1	18	
CL-31	0.0	75.0	23.0	40.0	0.1	0	1	37	
C-23N	0.0	40.0	19.0	10.0	7.5	0	1	18	

data for these canals. The hydraulic connectivity coefficient for agricultural drainage canals was varied to coincide with assumed irrigation practices.

The majority of the monitored wells were located at, or adjacent to, grazing areas, and the calibration and verification results for these wells were generally good .

D. Model Calibration and Verification

The results of the calibration and verification efforts are graphically illustrated following Part F. Table 10 summarizes the final canal parameters obtained from the calibration effort.

The availability and accuracy of historical data for canal inflows and accounting for localized drainage practices made calibration of the physical model difficult for the desired period. Available discharge records on structures S-99, S-50, and S-48 are suspect. Flow data from these structures have not been calculated accurately during the desired period of study.

As a result of the lack of reliable data, an attempt was made to calibrate the physical response of C-25E, C-25, and C-24 by calculating outflows during the calibration period, rather than incorporating the suspect structural discharge data (see Figures 73-75). Calculated inflows from the Radebaugh and C-23 culverts, in addition to the Orange Avenue control structure and secondary canals were estimated, although they could not be quantitatively calibrated due to a lack of data. Canal C-25E, as simulated by the physical model, includes that portion of C-25 upstream of control structure S-99, in addition to the extension parallel to the Florida Turnpike.

Referring to Table 10, the major canal calibration parameters were the hydraulic connectivity coefficient (CHHC) and the hypothetical weir length

(GWIDTH). The regulation stage (CREL) chosen was very important since calculated average daily canal stages exceeding it will result in outflow calculations by the physical model. A representative weir coefficient of 0.75 was used with the equation for every canal.

Simulating historical seasonal fluctuations in canal stages by calculating outflows, instead of using accurate historical releases, presents an inherent difficulty. Since the physical model calculates outflows assuming a constant weir length and regulation stage for a particular canal, it cannot accurately simulate management responses to heavy storm events. This limitation is most obvious when attempting to calibrate canals with gated downstream structures such as C-25E, C-24 and C-23.

The calibration and verification results for C-25 (upstream of S-50) and C-23E (upstream of S-48) are shown in Figures 74 and 77, respectively. These results are superior to those encountered for the three previous canals. Since these canals have fixed crest or uncontrolled spillways downstream, the results are not as heavily dependent on localized management practices as they are on natural hydrological fluctuations. Therefore, historical stage fluctuations are better simulated by the physical model. The hypothetical weir lengths on these two canals were kept small, when compared to their widths, to produce the desired variability in the calculated results. This was necessary since the calculated outflows from C-25E (S-99) and C-23 (S-97) are usually underestimated during heavy structural operations.

The verification results for all canals essentially produced the same problems encountered during calibration. Those canals calibrated adequately produced acceptable results during verification. Continued calibration, with the present flow data limitations and physical representation of the UEC, will not improve canal results enough to justify further effort for the calibration and verification periods. To improve the results using this model will require recalibration using a finer node network to more accurately describe local conditions.

E. Groundwater Results

Problems encountered with the groundwater calibrations were again due to localized drainage practices; however, once secondary canals were simulated, these problems were minimized in most areas. To further improve groundwater calibration on a local and regional basis, the surface water detention depths were adjusted according to sub-basin locations. This greatly improved groundwater model response to heavy rainfall events, and, therefore, improved simulation of historical hydrological trends.

Calibration results for observation well M147 (Figure 82), were the poorest of all the wells investigated. Located near the south fork of the St. Lucie River and the municipal wellfields of the City of Stuart, well M147 is highly sensitive to fluctuations in the water table arising from these two influences. Groundwater stages at M147 have been observed to fall below mean sea level during 1972, 1974, and 1975 , primarily due to the influence of the adjacent wellfields. The difficulty in calibrating well M147 resulted from the large grid size (4 sq. miles) used during simulation. This forced the observation well and Stuart wellfields to lie on the same node . The sensitivity of the well to either the wellfield withdrawals or S-80 releases was, therefore, very difficult to isolate and calibrate. Referring to Figure 82, the large peaks experienced in November 1969 and March 1970 were a result of an increase in the water table due to heavy releases from S-80 into the south fork of the St. Lucie, and the wet conditions prevalent. As a result, the two calibration parameters that most heavily influenced the simulation of M147 were determined to be the sub-basin's water detention depth (SWDD) and the south fork of the St. Lucie hydraulic connectivity coefficient (CHHC) estimations. Both SWDD and CHHC were forced to remain within .10 -.15 and .05 - .15, respectively. The final calibration values chosen for these two parameters in the simulation of M147 were 0.13 ft and 0.13 ft/day per ft, respectively. Decreasing the grid size would make a better calibration at this well possible.

The calibration and verification results for the rest of the observation wells active during the desired periods were adequate. Seasonal fluctuations were simulated effectively for practically all years investigated. Variations from observed stages are due largely to uncertainties in localized drainage and the limitations of modeling with a large grid size of 4 sq. miles.

The simulated groundwater stages, for wet (October) and dry (April) conditions for the entire study area area shown in Figures 86-89. The months chosen represent the wettest and driest conditions which prevailed during the calibration and verification periods. The results follow historical seasonable fluctuations reasonably well. Table 11 lists the final ET parameters used by the physical model in simulating the UEC. Adjustments to the effective root lengths, in vacant and swamp areas, improved calibration of groundwater stages during drier periods.

F. <u>Recommendations</u>

Although the calibration and verification efforts for the major canals in the UEC were hampered by the lack of data, the groundwater model was successfully calibrated and verified with one exception (well M147). Since the

Table 11. Evapotranspiration Parameters Used in the UEC
(SRZ = shallow root zone, DRZ = deep root zone)

Land Use	SRZ	DRZ	Pet (Annual)
1. Urban	3.0	12.0	20.5"
2. Agricultural	3.0	5.0	44.6"
3. Swamp	1.0	4.0	53.2"
4. Vacant Land	1.5	7.0	38.4"

PET (Avg. In/Day) for Each Land Use

Month	1	2	3	4
January	.036	.067	.091	.066
February	.046	.092	.118	.085
March	.058	.116	.150	.108
April	.067	.150	.180	.130
May	.073	.170	.191	.137
June	.068	.146	.172	.124
July	.067	.158	.176	.128
August	.067	.155	.174	.127
September	.059	.133	.154	.112
October	.054	.116	.142	.100
November	.042	.090	.109	.079
December	.036	.067	.091	.066

SFWMM is primarily designed to simulate and project hydrological phenomena, the current study indicates that the physical model can be adequately applied to the UEC.

The poor quality of available historical discharge records resulted in inadequate simulations of canal stages for the desired periods. A further attempt to calibrate canal stages with calculated outflows, though generally more successful, failed to simulate stage fluctuations adequately in the heavily managed canals (C-25E, C-24, and C-23). The large grid size resulted in oversimplification of hydrological and topographical data estimations required as input to the physical model. Therefore, model simulation of natural hydrological processes and localized drainage influences was adversely affected.

To improve the calibration and verification of the physical model of the UEC area, a period after the construction of the Port Mayaca structure should be used. Discharge data for S-99, S-97, S-49 and S-48 is under revision by the Data Management Division of the SFWMD and is expected to be corrected and verified by June of 1984. Once this data is available, a recalibration (using a recent period) will be performed and considerable improvement, particularily in the C-23, C-24, and C-25 canals, is expected. A finer grid system could improve results if the UEC model is to be run independant of the LEC version.

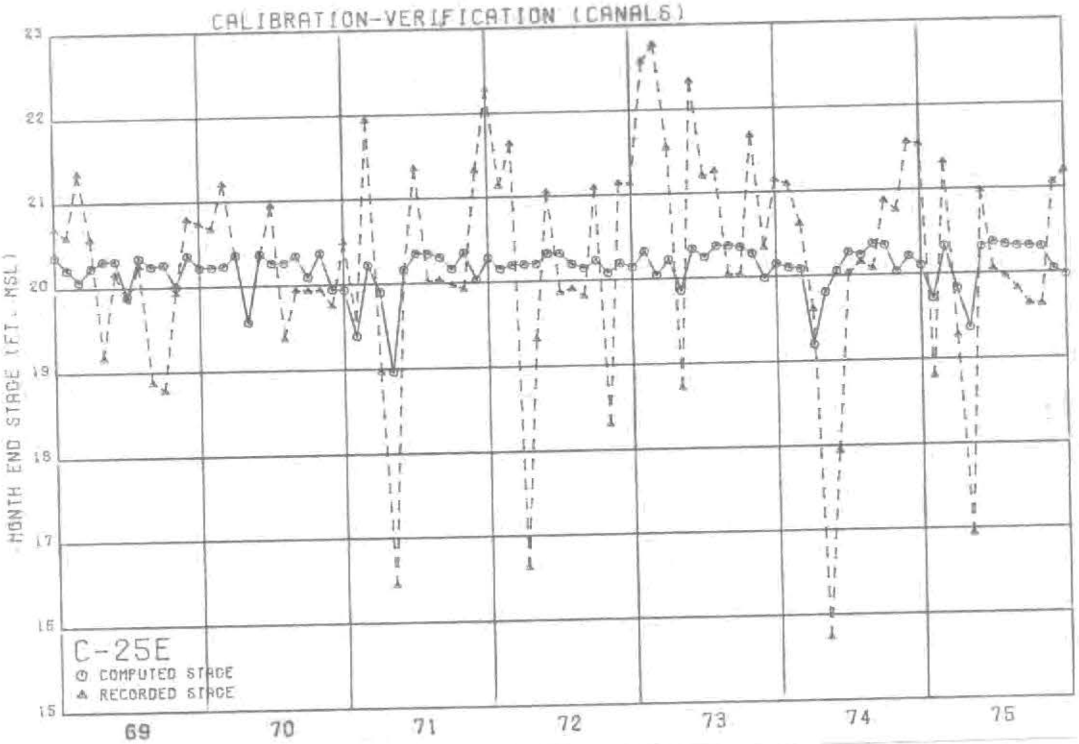


Figure 73 C-25E, Upstream of S-99

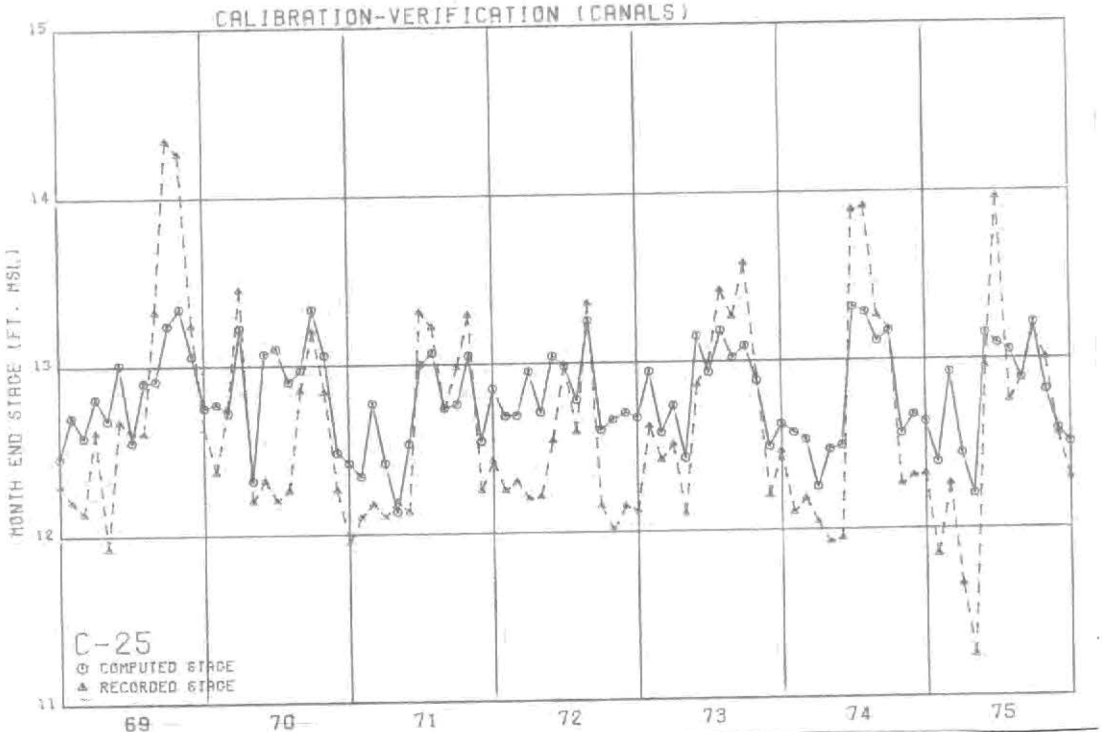


Figure 74 C-25, Upstream of S-50

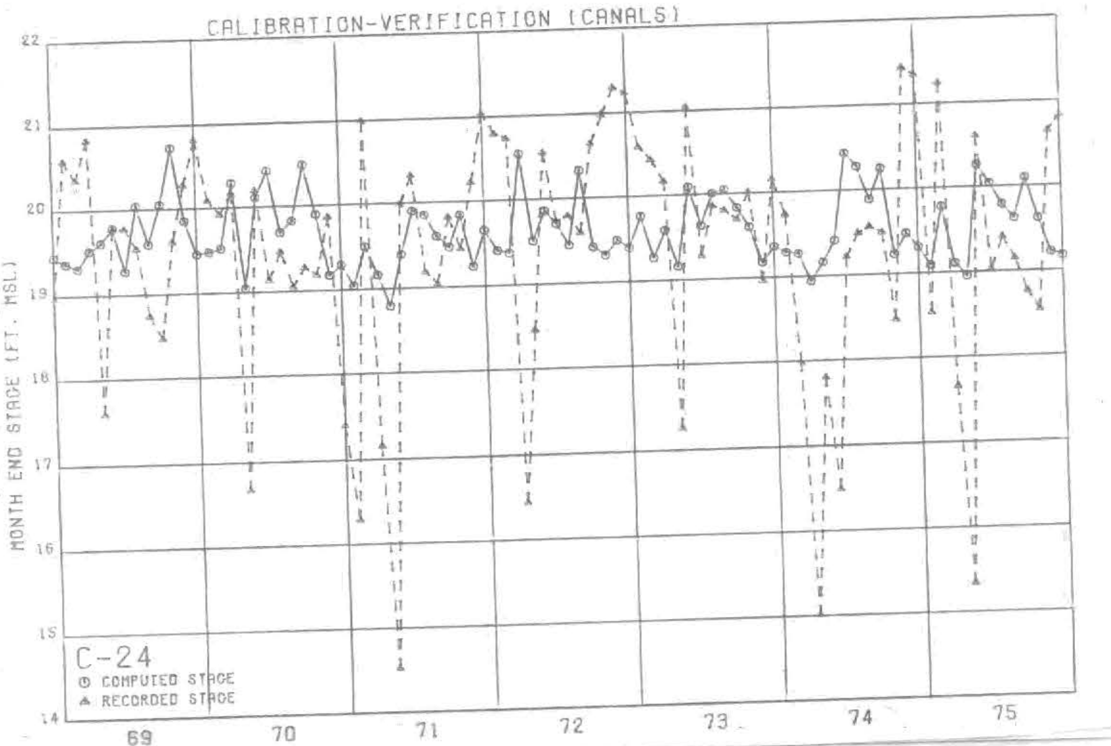


Figure 75 C-24, Upstream of S-49

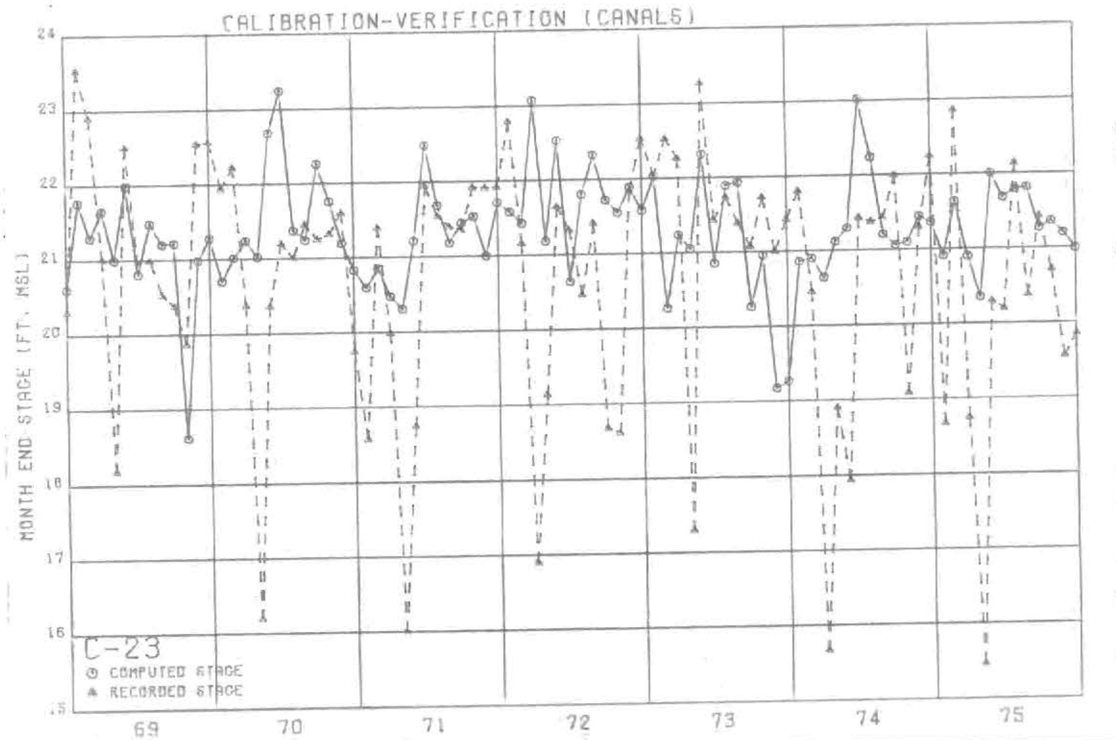


Figure 76 C-23, Upstream of S-97

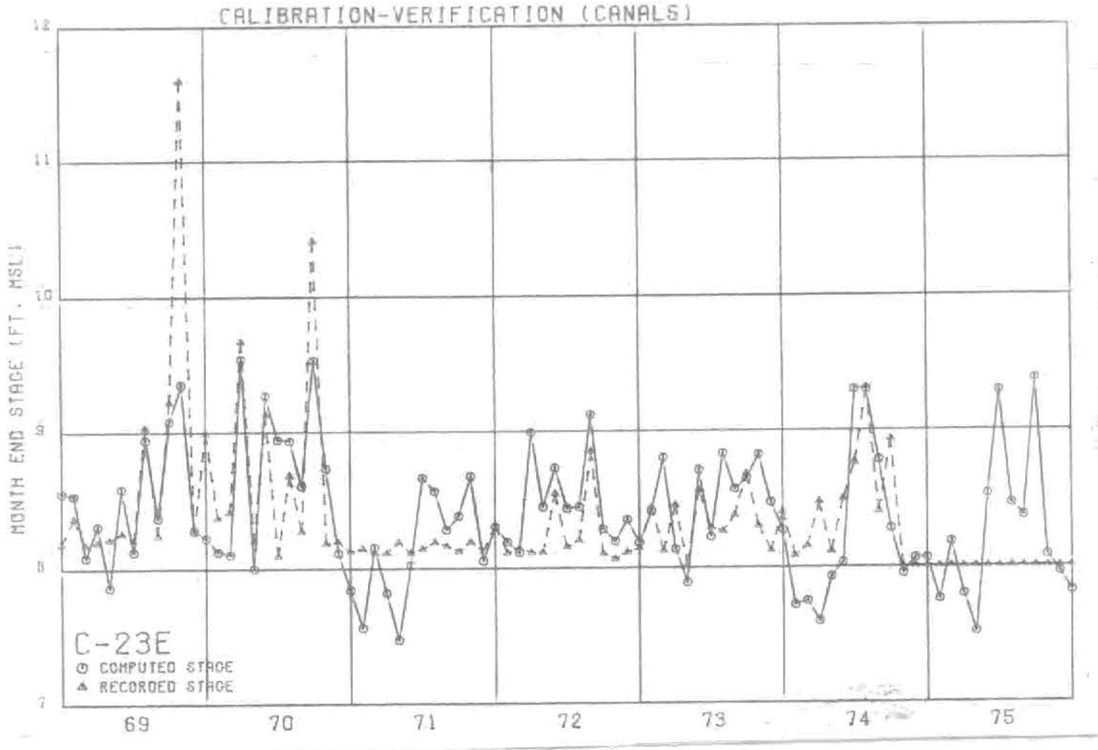


Figure 77 C-23E, Upstream of S-48

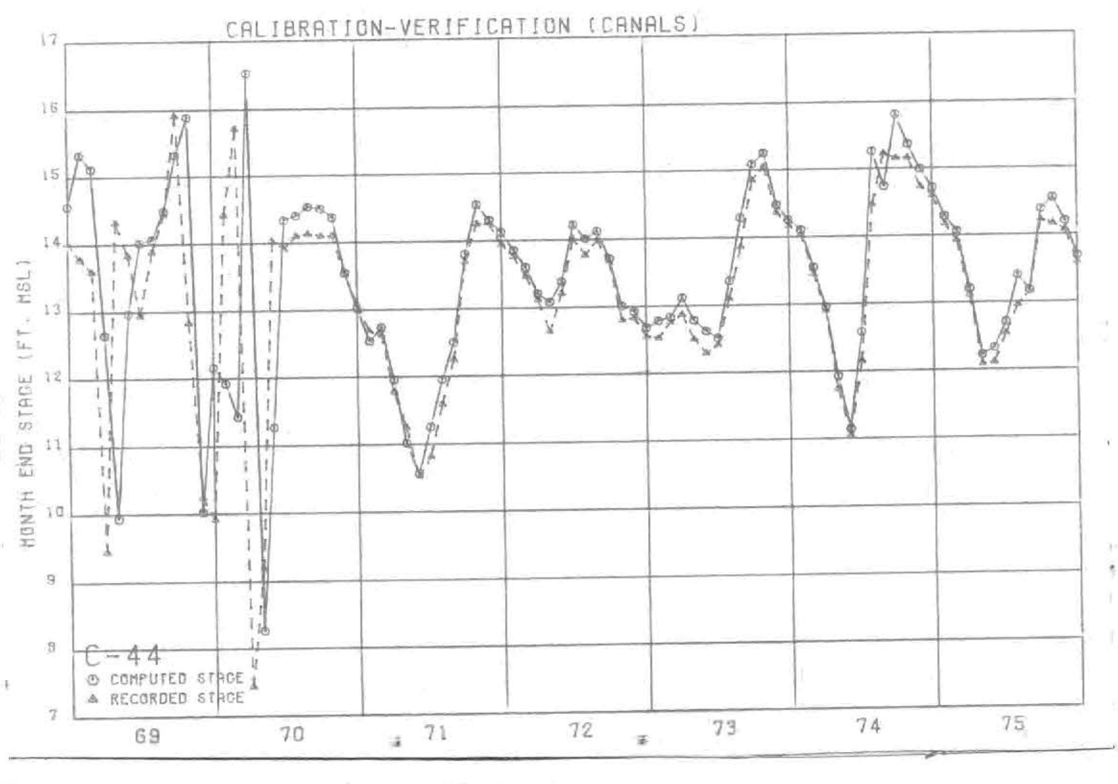


Figure 78 C-44, Upstream of S-80

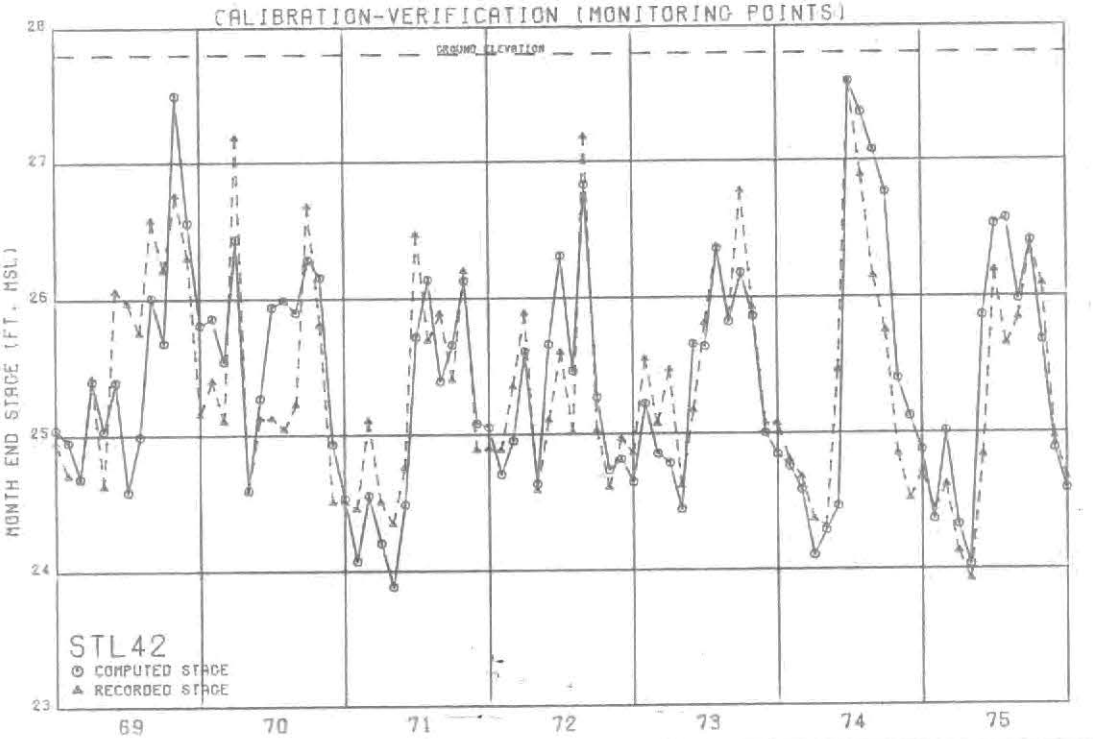


Figure 79 Gage STL42, N. W. St. Lucie County

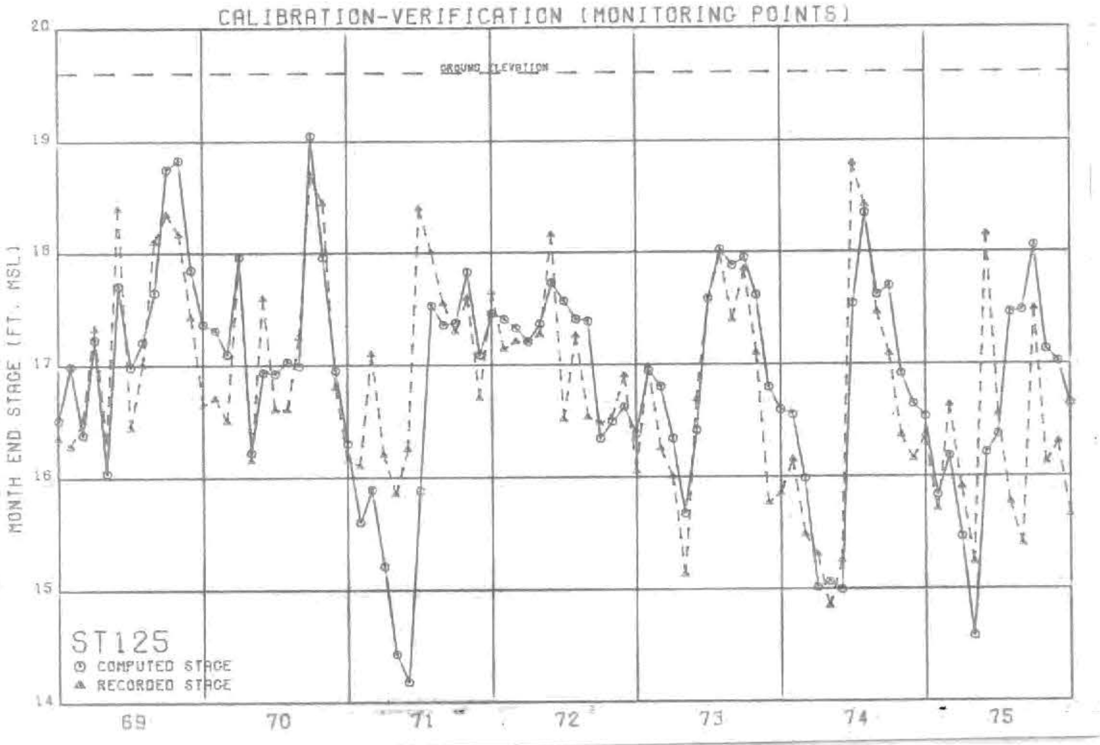


Figure 80 Gage STL125, nr. Fort Pierce

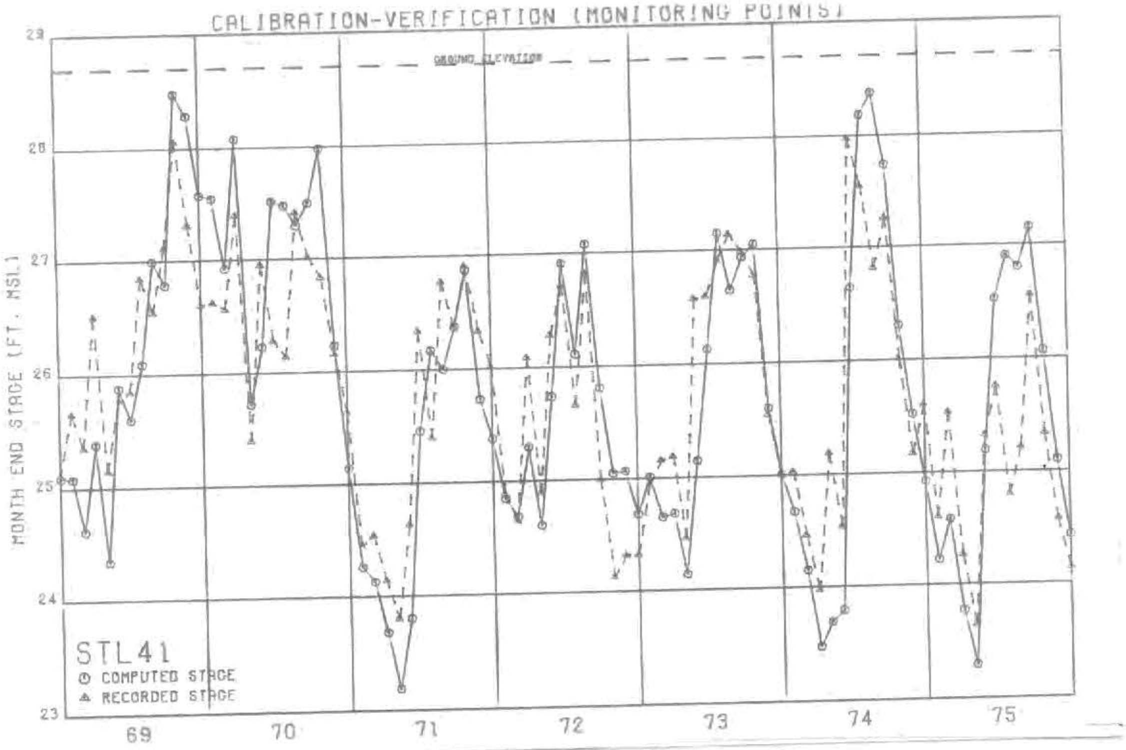


Figure 81 Gage STL41, S.W. St. Lucie County

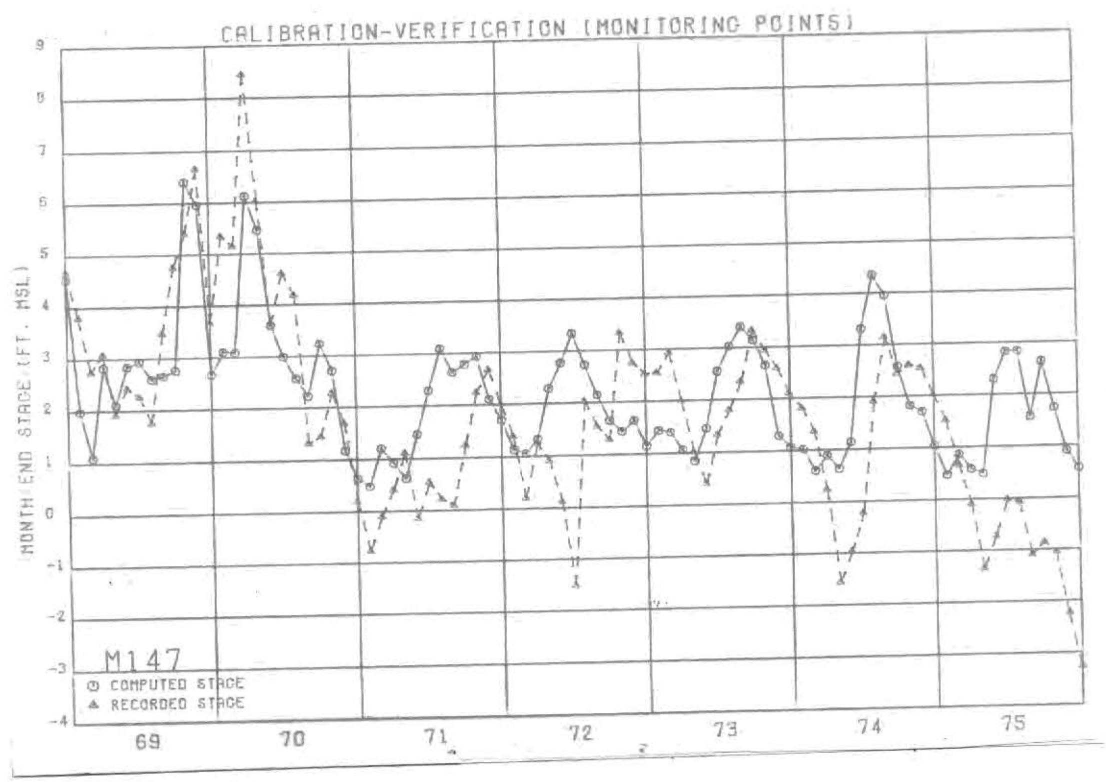


Figure 82 Gage M147, nr. Stuart

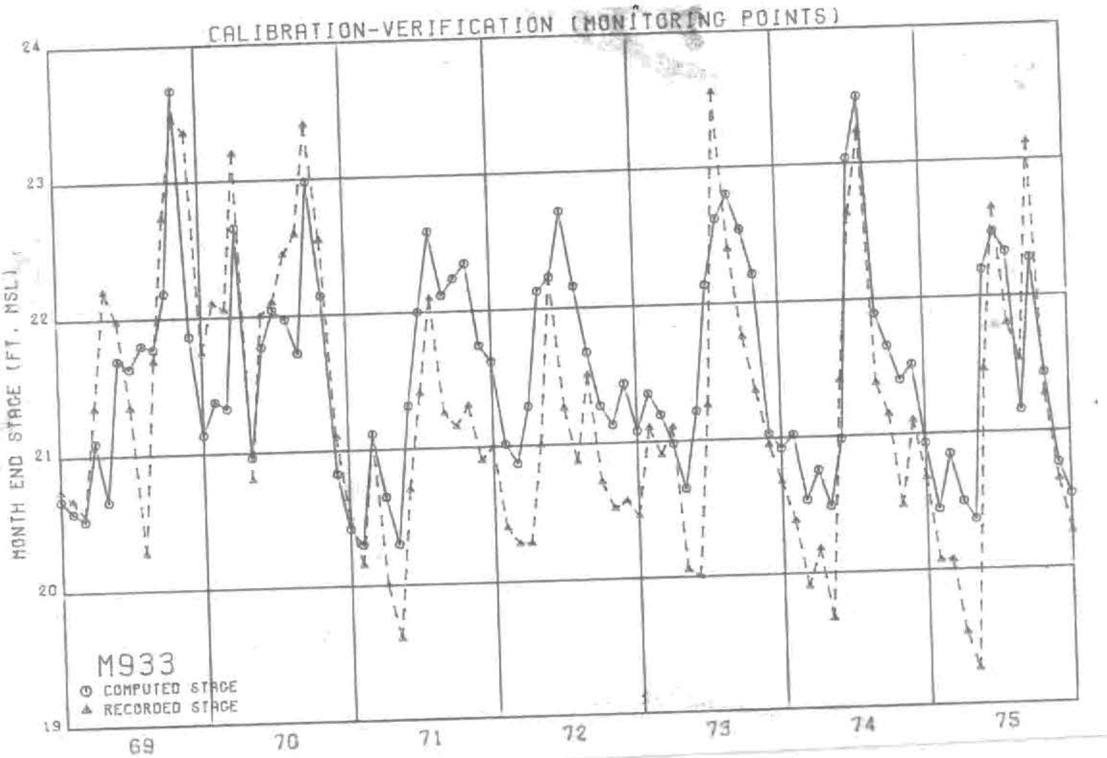


Figure 83 Gage M933, nr. Palm City

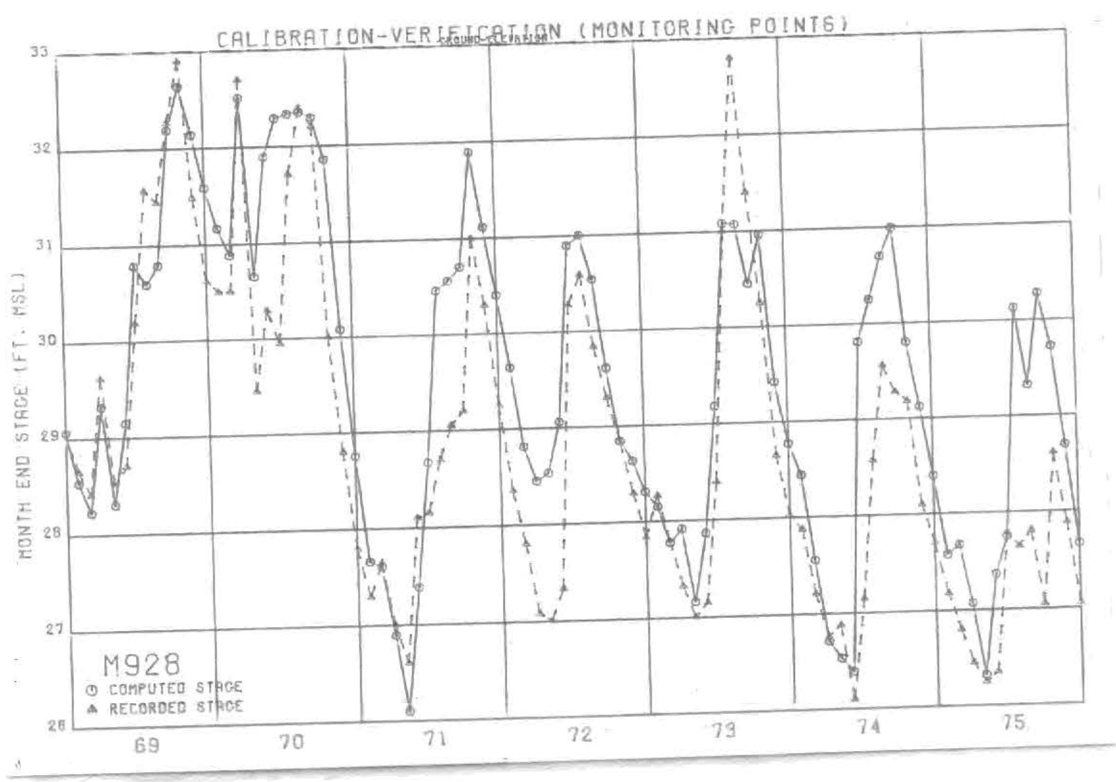


Figure 84 Gage M928, at Indiantown

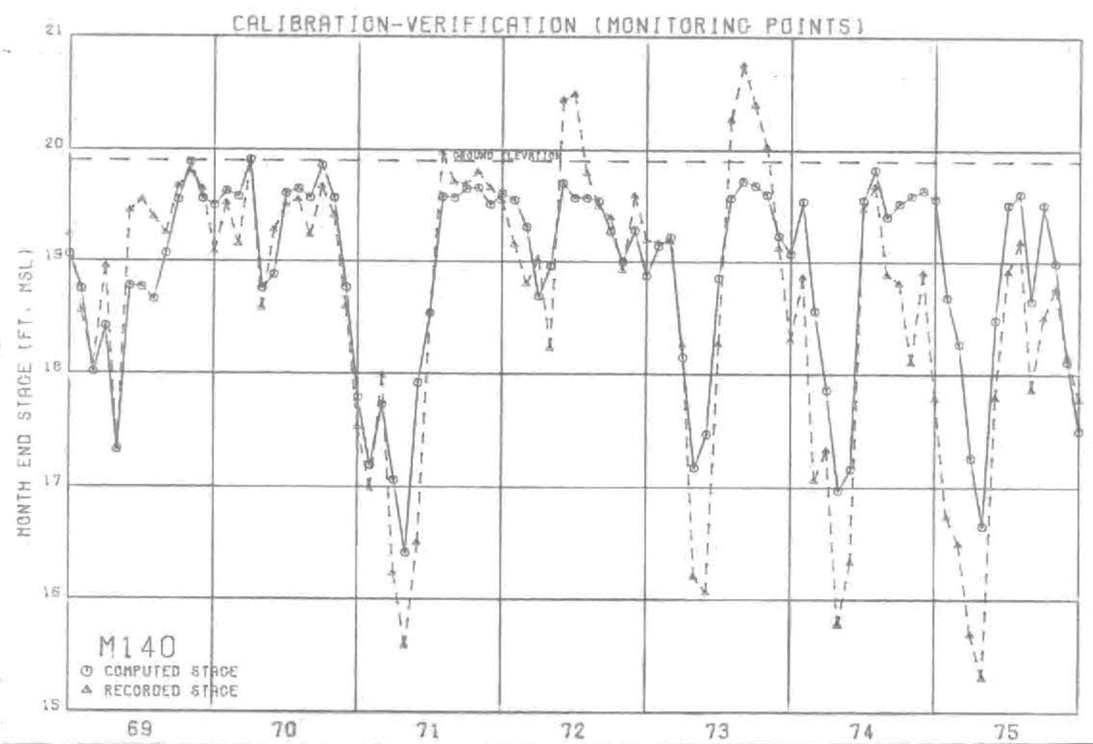


Figure 85 Gage M140, West of Jupiter

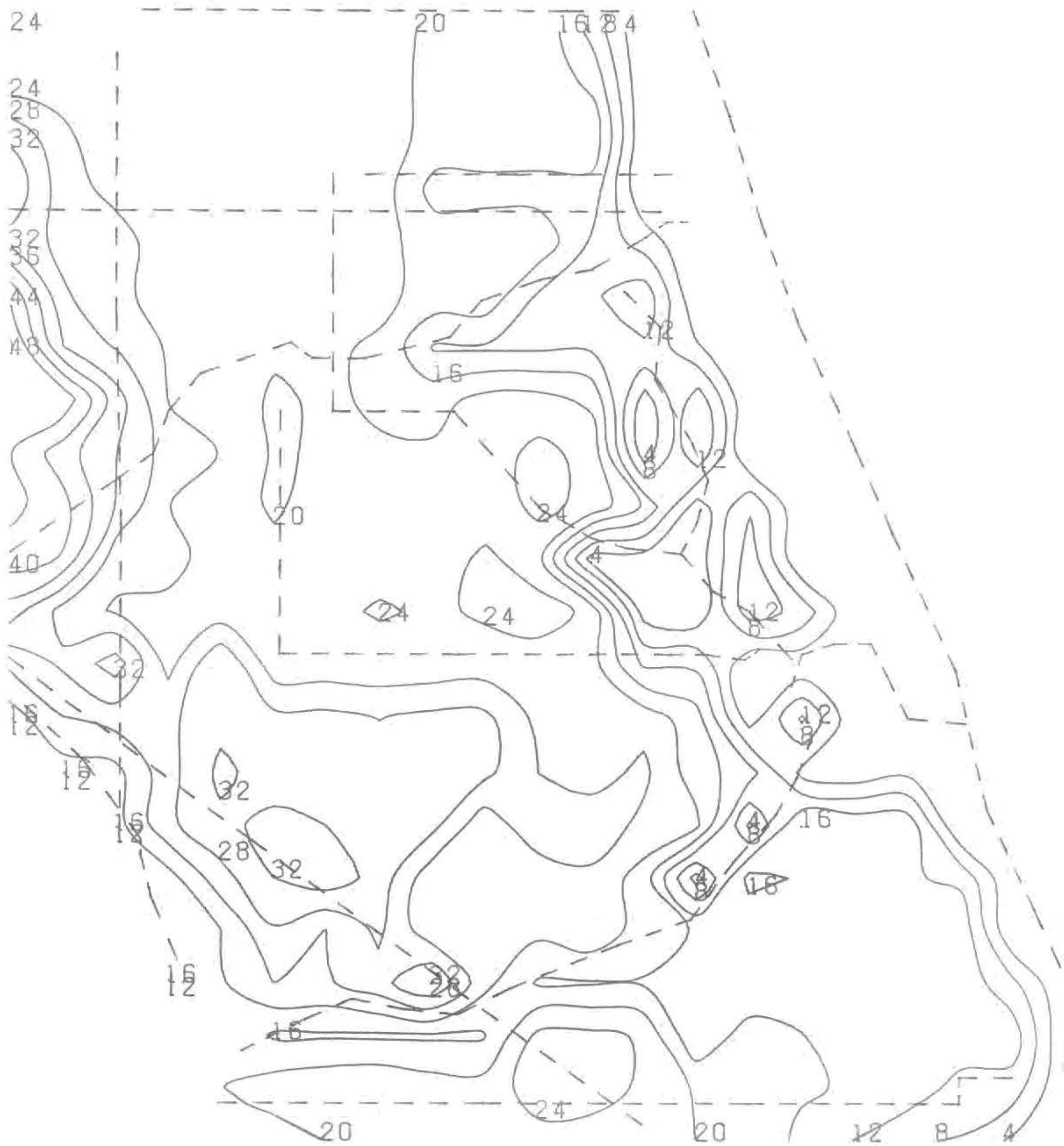


Figure 86 Calculated Groundwater Contours, October 1969

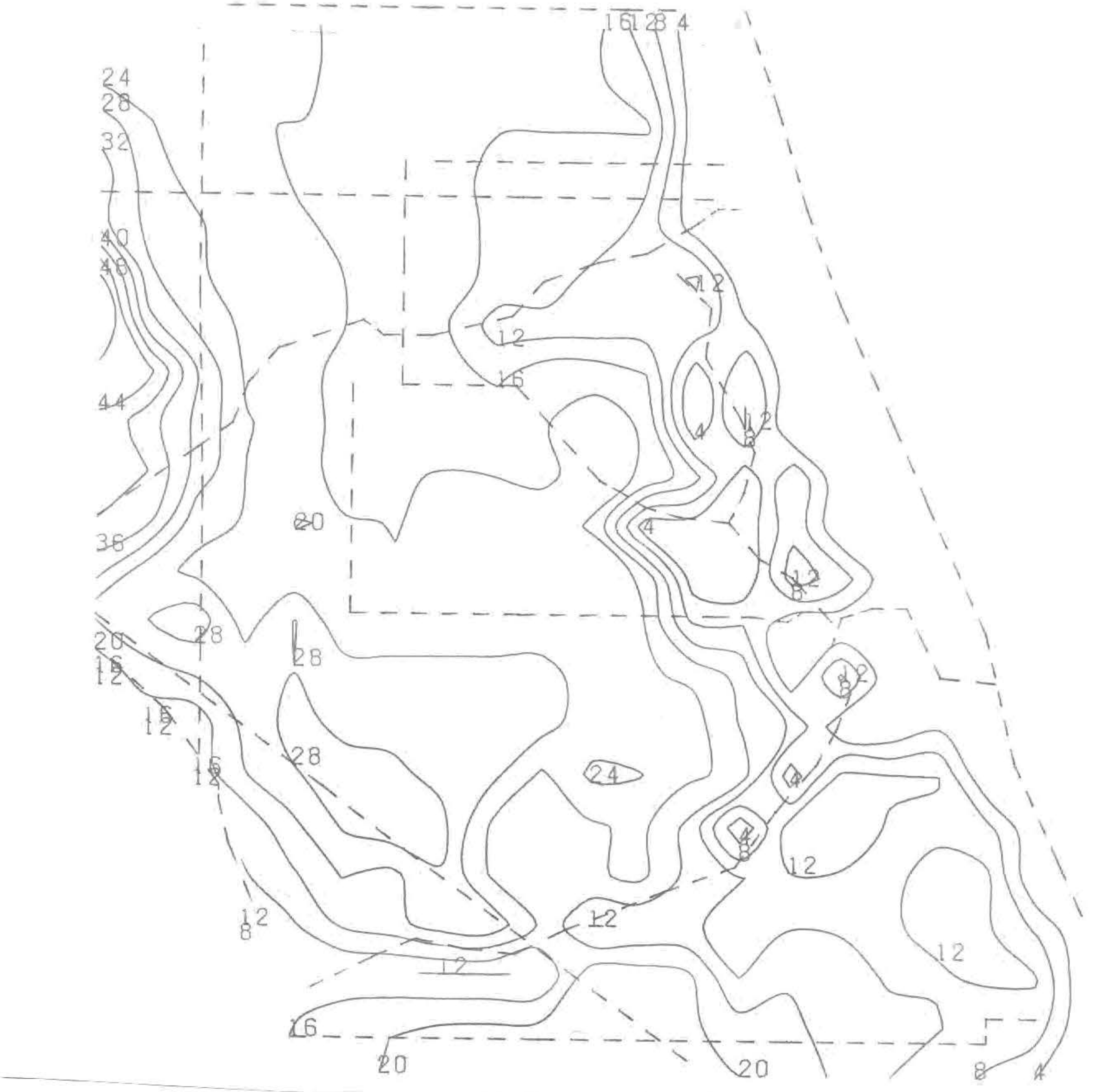


Figure 87 Calculated Groundwater Contours, April 1971

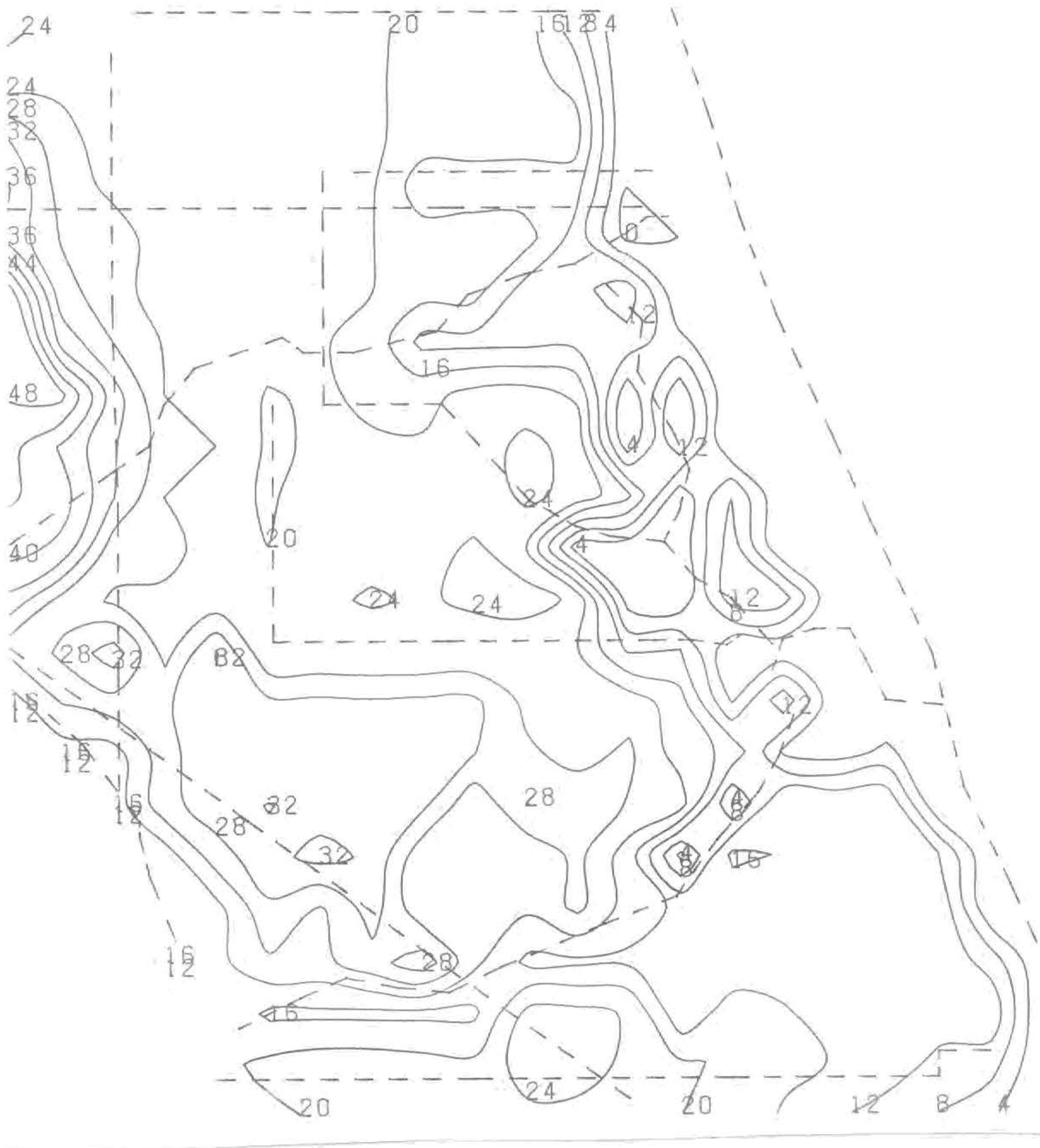


Figure 88 Calculated Groundwater Contours, October 1973

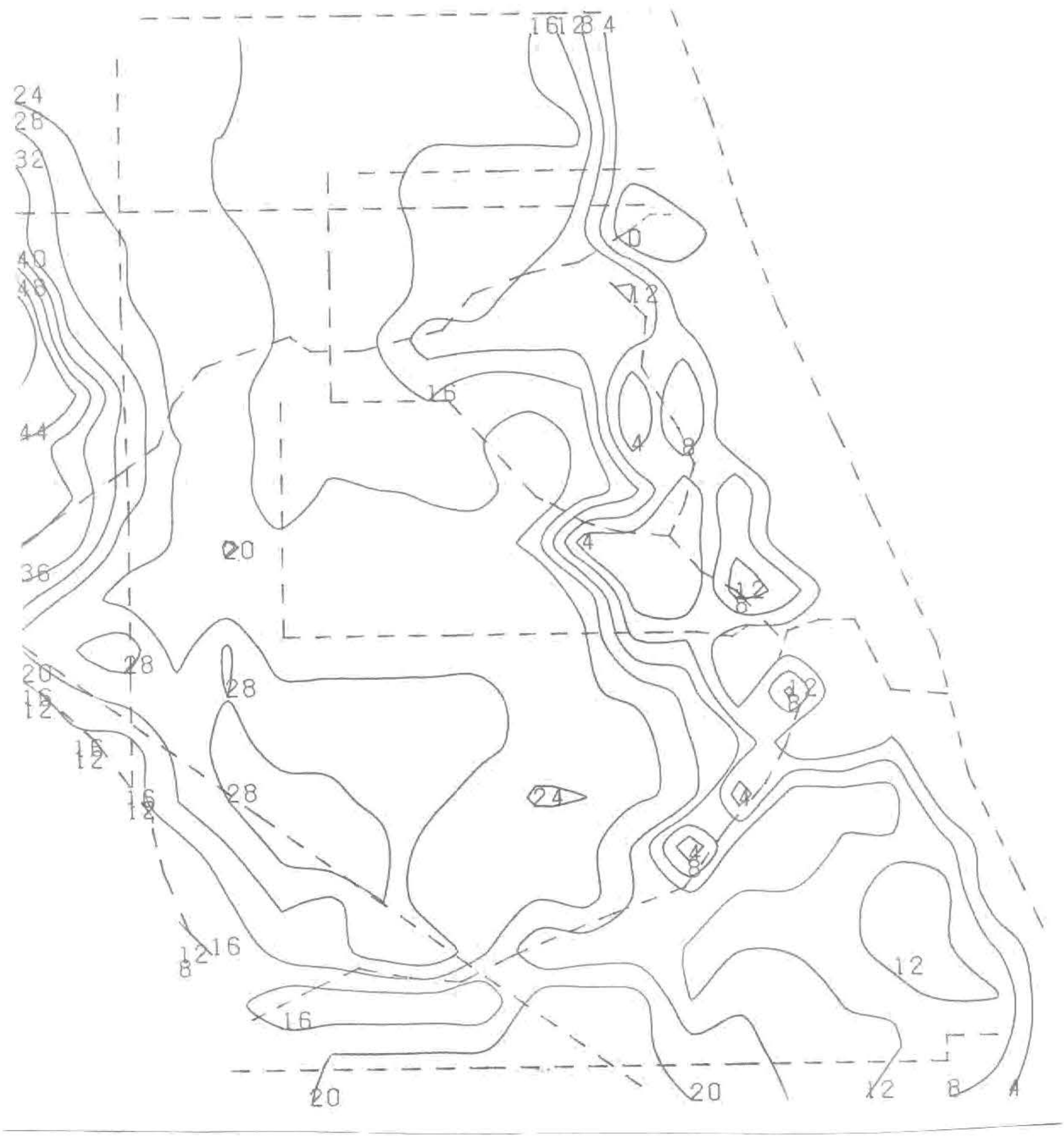


Figure 89 Calculated Groundwater Contours, April 1975

SELECTED REFERENCES

Appel, Charles A. Electrical Analog Study of a Hydrologic System in Southeast Florida, U.S.G.S. Open File Report 73004, 1973.

Martin County Water Conservation Committee. Comprehensive Plan for Water Control for Martin County. A Report on Martin County's Water Control Problems as Related to Central and Southern Florida Flood Control District. September 1960.

Mierau, Ronald. Supplemental Water Use in the Everglades Agricultural Area. Central and Southern Florida Flood Control District Technical Publication #74-4, June, 1974.

St. Lucie Soil Conservation District, et al. Watershed Work Plan, North St. Lucie River Drainage District Watershed, St. Lucie County, Florida. April 1958.

St. Lucie Soil Conservation District, et. al. Work Plan for Ft. Pierce Farms Drainage District Watershed, St. Lucie County, Florida. May 1965.

United States Geological Survey. Water Available in Canals and Shallow Sediments in St. Lucie County, Florida, by H. W. Bearden. 1972.

United States Geological Survey. Water Resources Setting, MartinCounty, Florida, by R. Adam Miller. February 1978.