DRAFT

Proposed Minimum Water Level Criteria for Lake Okeechobee, the Everglades, and the Biscayne Aquifer within the South Florida Water Management District

Appendices

Appendix A -- Supplemental Information for the Biscayne Aquifer including Well Monitoring Data
Appendix B -- Stage Duration Curves
Appendix C -- Head Water Curves
Appendix D -- Summary of Minimum Flows and Levels Issues, Final Report of the Scientific Peer Review Panel
Appendix E -- Literature Review
Appendix F -- Supplemental Environmental Resource Information

Prepared by Staff of:

Water Supply Department

South Florida Water Management District
West Palm Beach, Florida

January 2000

***

DRAFT

Proposed Minimum Water Level Criteria
for Lake Okeechobee, the Everglades,
and the Biscayne Aquifer within
the South Florida Water Management District

Appendix A

Supplemental Information for the
Biscayne Aquifer
including Well Monitoring Data

Prepared by Staff of:

Planning Department

South Florida Water Management District

West Palm Beach, Florida

January, 2000

APPENDIX A - SUPPLEMENTAL INFORMATION FOR THE BISCAYNE AQUIFER

AQUIFER WATER LEVEL/WATER QUALITY MONITORING RESULTS.

The District's primary focus in developing a minimum level for the Biscayne aquifer involved the review and analysis of water level and water quality data from more than 500 wells located along the lower east coast. Water level and water quality data collected from these wells were analyzed to determine if a relationship exists between water levels, duration of low water level events and subsequent movement of the salt water interface in response to these low water events. Water level data from each well was evaluated to determine average dry season and wet season water levels as well as long term trends. Chloride concentrations were also examined to determine whether or not the salt water front (a) had reached a particular well, (b) appeared to be stable, and/or (c) appeared to be either moving inland or retreating seaward. Stage duration curves were developed for each coastal water control structure to determine mean (50th percentile) and standard deviation (i.e., the 84th percentile) water levels at each salinity control structure. These data are discussed below.

In addition to the above effort, detailed statistical analyses were preformed on 49 monitoring wells in Broward County to investigate the correlation between the observed chloride concentration and water table elevation. Each monitor well was classified based upon its distance to the coast and its geographical location. Water levels were converted to equivalent fresh water heads to account for the denser salt water contained in some wells. These data are presented in **Table A-1**.

Although no significant correlation was noted between equivalent freshwater heads and chloride concentration, statistical analyses showed a relationship between the duration of low water periods and seasonal versus permanent movement of the salt water interface. For example, monitoring well G-1179 showed that in 1985 average annual water levels were depressed for a period of four months resulting in a noticeable movement of the saline interface. The salt water front retreated back to its former position after water levels had recovered during the following year. However, in 1989/90, when average annual water levels were depressed for an extended period of time, the salt water front moved inland and did not return to it's previous position. These observations support the numerical simulations conducted by Merritt (1996) which show that short term water level fluctuations do not result in long term movement of the salt water interface. However, permanent movement of the interface appears to occur when water levels are depressed for more than six months, thus affecting the average annual water level at that location.

Review of historical water level and water quality data from over 500 wells located along Florida's lower east coast (Table A-2) showed that the relationship between chloride concentration and water levels were not as strongly correlated as might have been expected. In general, the higher the water level, the less likely saltwater was present in the well. However, even under conditions where freshwater levels were in excess of five feet NGVD, six percent of the observations showed chloride concentrations in excess of 1,000 ppm. In addition, when water

Table 1. Summary of selected monitoring wells in Broward County.

No.	Station	Depth (ft)	Zone	Dist	No. of Obs	Chloride Concentration		
						Mean (ppm)	S.D. (ppm)	Corr. Coeff
1	G-2074	168	D	2	59	9973	2082	-0.115
2	G-1433	142	D	2	2	925	247	1.000
3	G-1435	196	D	3	1	32	0	0.000
4	G-1432	109	D	2	1	11000	0	0.000
5	G-1473	126	D	2	81	42	13	-0.210
6	G-2409	83	D	3	75	20	5	-0.142
7	G-2410	205	D	3	79	46	6	-0.079
8	G-1597	155	D	3	33	366-	43	-0.060
9	G-2073	157	D	4	25	49	15	-0.477
10	G-2073	157	D	4	30	125	26	-0.328
11	G-2425	203	D	3	34	80	12	-0.236
12	G-2426	91	D	3	27	33	5	-0.035
13	G-1240	197	D	4	41	127	85	-0.275
14	G-1237	190	C	4	5	1244	296	0.740
15	G-2260	23	C	6	2	28	3	-1.000
16	G-2489	3	C	6	2	2300	283	1.000
17	G-2125	57	C	7	55	41	7	-0.475
18	G-2121	180	C	7	4	330	85	0.753
19	G-1344	177	C	7	49	85	75	-0.118
20	G-2123	181	C	7	2	58	3	1.000
21	G-2124	110	C	7	4	23	12	0.044
22	G-2128	60	C	6	49	22	13	-0.200
23	G-2127	189	C	6	58	18	4	-0.069
24	G-2130	59	C	6	57	33	8	-0.137
25	G-2126	168	C	6	1	16	0	0.000
26	G-2122	134	C	7	57	32	8	-0.178
27	G- 854	195	C	5	57	1886	256	0.665
28	G- 515	184	C	7	20	855	71	-0.218
29	G-1343	199	C	6	61	75	17	-0.358
30	G-2091	124	B	5	36	43	8	-0.179
31	G-1211	174	B	4	3	14	4	-0.997
32	G- 820	215	B	5	11	18	6	-0.169
33	G-2054	140	A	2	5	9480	559	0.070
34	G-2062	138	A	2	37	8378	2354	0.161
35	G-2055	180	A	2	33	2391	1205	0.124
36	G-2149	107	A	2	28	137	57	-0.036
37	G-2344	96	A	2	26	34	4	0.046
38	G-2067	44	A	1	1	12	0	0.000
39	G-2063	77	A	1	6	15833	2401	-0.270
40	G-2147	16	A	1	2	34	8	-1.000
41	G-2064	200	A	1	8	6339	6598	0.914
42	G-2277	112	A	2	28	27	6	-0.510
43	G-2254	186	A	2	10	19	8	-0.568
44	G-2060	204	A	2	13	23	19	-0.242
45	G-1272	195	A	2	2	15	10	-1.000
46	G-2257	94	A	2	8	25	5	-0.447
47	G-1228	194	A	2	2	1225	389	1.000
48	G-2256	106	A	2	11	19	10	-0.521
49	G-2259	26	A	2	3	15	4	-0.979

levels were below sea level (i.e. less than 0 feet NGVD), only 41 percent of the readings had chloride concentrations in excess of 1,000 ppm. As shown in Table A-2, the number of wells with high chloride readings decreased with increasing water levels.

Table 2. Lower East Coast Monitoring Well Observations.

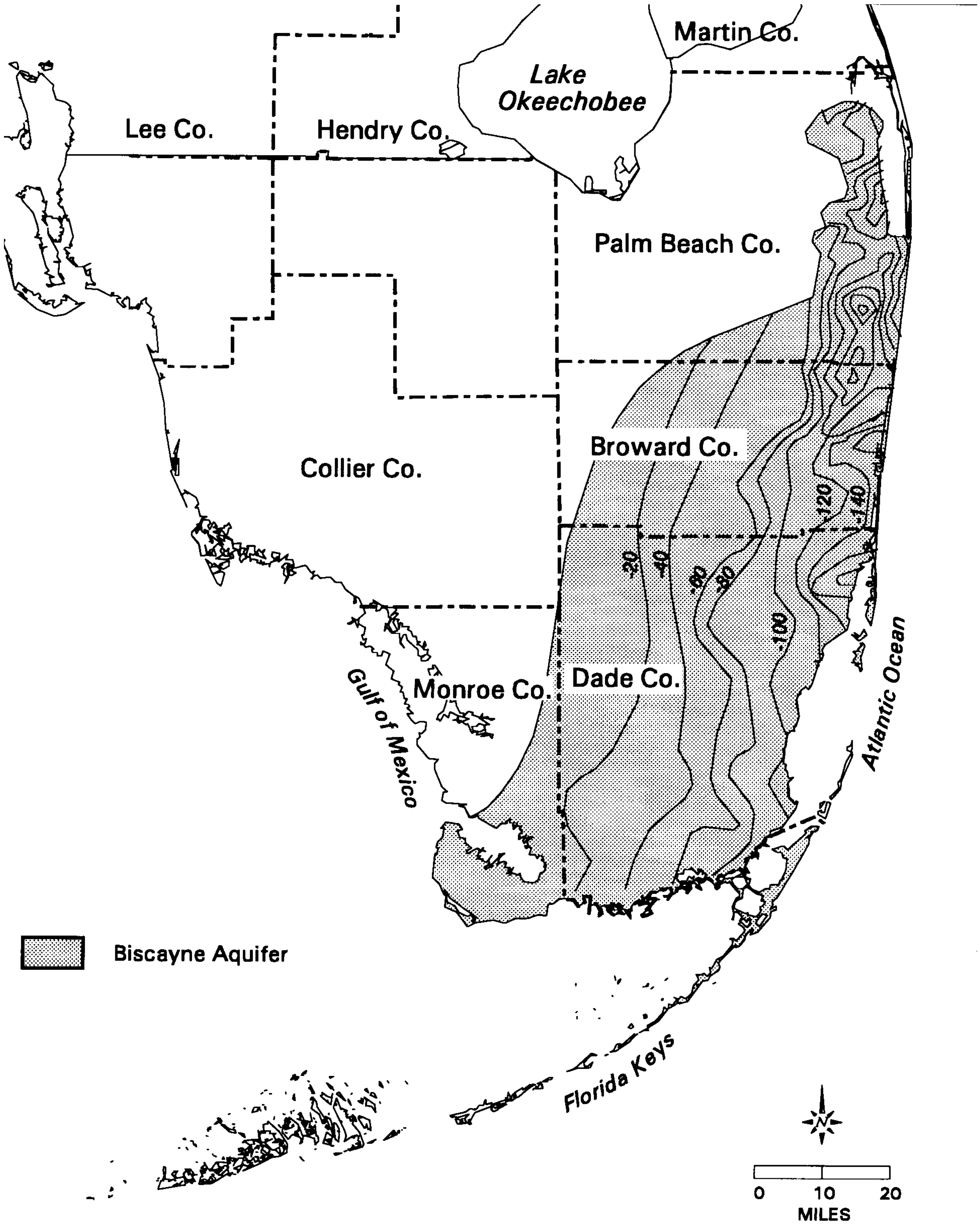
Water level (feet NGVD)	Freshwater Observations	Saltwater Observations	Percent Saline
Less than 0	256	182	41%
Between 0 and 1	994	490	33%
Between 1 and 2	1996	578	22%
Between 2 and 3	1713	455	20%
Between 3 and 4	759	170	18%
Between 4 and 5	410	63	13%
Greater than 5	515	34	6%

It should be noted that some of the monitoring well data may have been influenced by localized pumping or adjacent surface water management systems. These sources may artificially raise or lower the water table compared to non-stressed conditions. However, the results indicate that the strict use of water levels as a criterion for prevention of saltwater intrusion, without considering other factors, could potentially result in inaccurate conclusions.

THEORETICAL VERSUS ACTUAL POSITION OF THE SALTWATER INTERFACE.

For comparison purposes, the theoretical Ghyben-Herzberg (GHR) relationship was analyzed to determine its ability to stabilize the saltwater interface. The GHR takes into account water levels, density differences of saltwater and freshwater and thickness of the aquifer to determine the distance to the saltwater interface. The depth to the base of the Biscayne aquifer in Miami Dade, Broward and Palm Beach Counties was determined from existing hydrogeologic work conducted by Fish (1988), Fish and Stewart (1991), and Shine *et al*. (1989). The depth to the base of the Biscayne aquifer is presented in **Figure A-1.** As shown, the base of the Biscayne aquifer is generally deeper to the north and is thicker along the coast.

Figure 1. Contours at 20-foot Intervals showing the depth to the base of the Biscayne aquifer in Dade, Broward and Palm Beach counties.



An average water level potentiometric map was also generated based on available water level data developed from monitoring wells, canal stages (due to their direct connection between the aquifer) and historical information (based on references cited elsewhere in this section). Results are shown in **Figure A-2** and illustrate the impact that various withdrawals and surface water management systems have within the LEC planning area, including general lowering of the water levels along the coast.

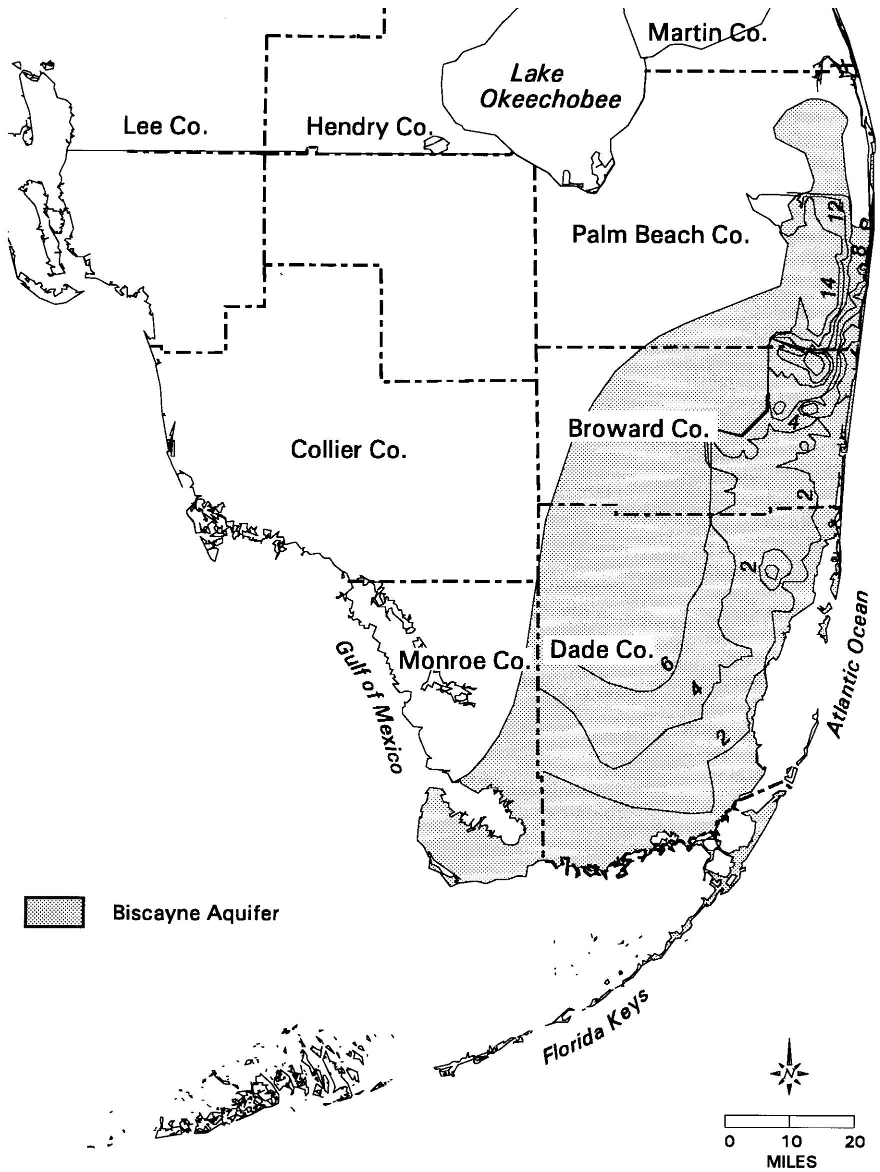


Figure 2. Contours at 2 Foot intervals Showing average water level potentiometric surfaces derived from monitoring well data, canal stages and historical data for the Biscayne Aquifer in Dade, Broward and Palm Beach Counties.

By using the thickness shown on the Biscayne aquifer map (**Figure A-1**) and data from the average water level map (**Figure A-2**), the theoretical position of the saline interface based on the GHR, was calculated as presented in **Figure A-3.** Also superimposed on **Figure A-3**, is the actual position of the saline interface. Results of these analyses indicate that the actual position of the saline interface is seaward of the theoretically calculated GHR location. These data suggest that the GHR provides a relatively conservative estimate of the required freshwater head necessary to stabilize the salt water interface and support Kohout's (1960) work, which reported that up to 20 percent of the saline water that intrudes the Biscayne aquifer is returned to sea along the seepage face.

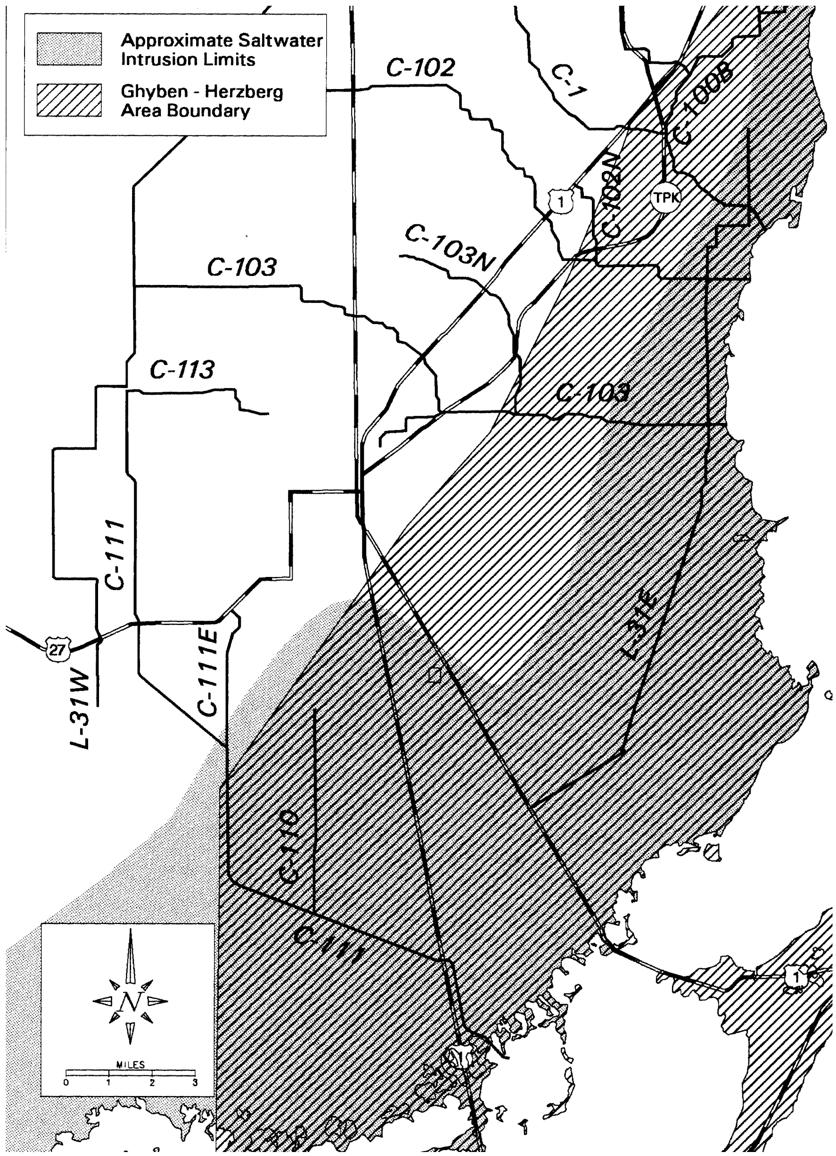


Figure 3. Theoretical position of the saline interface based on the Ghyben-Herzberg relationship in the Biscayne aquifer in Dade, Broward and Palm Beach counties.

Another method used to establish the freshwater/saltwater interface was the review and analysis of chloride and water level data from approximately 200 long-term monitoring wells located within the Lower East Coast planning area. Average dry and wet season water levels and average chloride concentrations were calculated for each well over time and well depths were recorded. Individual data from each monitor well are provided in the following tables of this Appendix. Analyses of these data indicated that when water levels were maintained at, or above the level calculated by the GHR, approximately 95% of those wells showed no significant indication of saltwater intrusion. However, for wells that had water levels below those specified by the GHR, more than 40% experienced some form of salt water intrusion.

These results indicate that the GHR provides estimates of water levels to prevent salt water intrusion that may be too conservative (i.e., more water than necessary may be set aside to protect the aquifer against saltwater intrusion than is absolutely necessary). Therefore, District staff relied upon the statistical evaluation and review of historical water level and water quality data acquired from Lower East Coast monitoring wells and canals as the primary method for establishing minimum water level criteria for the Biscayne aquifer.

MAINTENANCE OF COASTAL CANAL STAGES TO CONTROL SALTWATER INTRUSION.

South Florida Water Management Model

The SFWMD maintains the coastal canal network to provide drainage for agricultural and urbanized areas during rainfall events and recharge local ground water resources during periods of drought. In setting a minimum water level to prevent saltwater intrusion of the Biscayne aquifer, it was necessary to evaluate the effect of the primary canal network on water levels within the Biscayne aquifer. To increase our understanding of this relationship, two separate model simulations were run using the South Florida Water Management Model (SFWMM):

1. In the first simulation, the system was operated under present conditions. Coastal canals <u>were maintained</u> by the regional system during drought periods, and continued to receive water from the WCA system and Lake Okeechobee during low rainfall years.
2. In the second simulation, coastal canals <u>were not maintained</u> for water supply purposes during drought years. District operations incorporated into the model run did not attempt to maintain dry season water levels in the coastal canals.

Results of simulations 1 and 2 above were compared at 20 key monitoring locations. **Table A-3** below provides a summary of these results, including key monitoring locations where groundwater levels were predicted to fall below 1 ft NGVD along the coast..

Table 3: Number of months water levels indicated potential threat of saltwater intrusion along the lower east coast of Florida.

Well Location	Maintained Canal Scenario*	Non-Maintained Canal Scenario*
Florida City	0	44
Taylor Slough	2	9
Homestead	6	13
Cutler Ridge	0	3
Miami	0	2
North Miami	0	2
North Miami Beach	0	1
Hollywood	39	36
Fort Lauderdale	13	30
Ft. Lauderdale Airport	11	13
North Lauderdale	10	23
Pompano Beach	12	13
Deerfield Beach	16	11
Highland Beach	1	171
Boca Raton	38	58
Palm Beach Gardens	165	165
Lake Worth	48	31
Jupiter	31	31

* =Results from South Florida Water Management Model,

Results of these two simulations were compared at 20 key monitoring locations. **Table A-3** provides a summary of these results. When the coastal canals were not maintained during dry periods, there was an increase in the number of days that coastal groundwater levels fell below 1 foot NGVD and the threat of saltwater intrusion significantly increased. When coastal water levels were below 1 ft NGVD for longer periods of time, a reverse gradient developed as coastal aquifer water levels fell near or below sea level. Denser saltwater from the ocean could then move inland into the freshwater portions of the aquifer.

A review of **Table A-3** indicates that water levels did not decrease for all areas along the Lower East Coast as a result of not maintaining the coastal canal structures. In northern Palm Beach County, monitoring wells within the cities of Jupiter and Palm Beach Gardens did not record any change in water levels. This is because the canal network in northern Palm Beach County is not directly connected to the regional system and receives little water from outside sources other than rainfall. In addition, northern Palm Beach County is outside of the northern extent of the Biscayne aquifer.

In central and southern Palm Beach County, there was a significant increase in the number of times canal water levels fell below 1 ft NGVD in the Boca Raton and Highland Beach areas. This was primarily a result of not maintaining the Lake Worth Drainage District canal network. In contrast, canal water levels appeared to improve in the vicinity of Lake Worth and Deerfield Beach immediately adjacent to the primary tidal discharge structures under the non-maintained canal scenario. This may be a result of increased water levels in the interior storage basins resulting in higher discharges to tide during rainfall events resulting in higher water levels immediately around these discharge structures. However, it appears that all coastal areas of central and southern Palm Beach County are directly influenced by maintained canal levels (**Table A-3**).

In central and northern Broward County, coastal water levels also declined under the non-maintained canal level scenario, indicating that the entire area is influenced by the regional canal network. However, coastal southern Broward County does not appear to be affected by regionally maintained canal levels (**Table A-3**). For example, the Hollywood monitoring area actually showed a slight increase in water levels as a result of not maintaining the canal network. Such increases along the coast of southeastern Broward County may be due to increased seepage flows eastward from Water Conservation Area 3B.

All of Miami Dade County appears to be influenced by the levels maintained in the regional canal network (**Table A-3**). Depressed water levels were noted for coastal areas of Miami Dade County from North Miami Beach southward to Taylor Slough. The largest increase in depressed heads occurred in southern Dade County (as shown in **Table A-3** for Florida City, Taylor Slough and Homestead): where the total number of months that water levels fell below 1 ft NGVD increased from 8 months under the maintained canal scenario to 66 months under the non-maintained canal scenario.

Results of the SFWMM simulations indicate, that for most areas, coastal water levels appear to be highly influenced by water levels in the regional canal network. Water levels in the coastal canals largely govern the expected inland extent of the saline interface. Managing coastal canals at appropriate water levels during drought periods appears to be a viable option for stabilizing the saltwater interface and preventing further inland migration of the saltwater front.

EVALUATION OF COASTAL CANAL STAGES.

Since it appears that the coastal canals help maintain water levels along the lower east coast of Florida, an evaluation of canal stage levels was necessary. Upstream canal water levels from eleven (11) primary canals were obtained from historical records. Daily stages, where available, were obtained from each structure for the period of 1980 to the present. Structures in south Miami Dade County were not included in the evaluation due to the uncertainty associated with developing minimum flows and levels for Biscayne Bay and Florida Bay. Hydrographs and stage duration plots for each structure were developed for the same time frame and are provided in **Appendix B**.

The mean stage (50th percentile) and the 84th percentile stage for each structure are presented in **Table A-4**. The 84th percentile was selected because statistically it represents one standard deviation from the mean. Also included in **Table A-4** is the canal maintenance level utilized by the SFWMM. The levels used in the SFWMM represent the average water level at each structure, during times when water supply deliveries were made, as determined from an evaluation of historical canal stages. When simulated canal stages fall below this level, the SFWMM simulates the importation of water into the canal from the Everglades system or Lake Okeechobee.

Table 4. Stages at Key Water Management Structures Along Florida's Lower East Coast (stages are in feet NGVD).

Canal/Water Management Structure	Mean or 50th percentile Stage (ft NGVD)	84th Percentile[1] (ft NGVD)	Canal Stages Maintained by SFWMD[2] (ft NGVD)
C-51/S-155	8.12	7.74	7.80
C-16/S-41	8.23	7.72	7.80
C-15/S-40	8.39	7.59	7.80
Hillsboro Canal/G-56	7.43	6.75	7.00
C-14/S-37B	6.82	6.60	6.50
C-13/S-36	4.43	4.15	3.80
North New River/G-54	3.68	3.28	3.50
C-9/S-29	2.16	1.90	1.80
C-6/S-26	2.55	2.07	2.00
C-4/S-25B	2.55	1.95	2.20
C-4/S-22	2.86	2.04	2.20

1 = 84th percentile represents one standrad deviation from the mean.

2 = Canal stages maintained by the District at specific canals as simulated by the South Florida Water Management Model.

The model simulation results show a general decline in coastal canal levels maintained by the District from north to south. This is due primarily to the difference in the topography of these two areas. With the exception of the Coastal Ridge, ground level elevations decrease from 15 - 20 ft. NGVD in Palm Beach County, to less than 5 ft. NGVD in parts of southwestern Broward and Miami Dade County. Local canal levels must be maintained below the local ground elevation to prevent urban and agricultural flooding.

Localized Salt Water Intrusion Modeling

The final approach used in this study of saltwater intrusion along the Lower East Coast was the application of an existing saltwater intrusion model to study the position of the saline interface under various simulated conditions. The model code utilized for this approach is the SWICHA model developed by Andersen *et al.* (1986). The SWICHA model is a finite element solute transport/flow model capable of simulating saltwater intrusion in the south Florida area (Andersen *et al*. 1986). The two-dimensional cross sectional model was slightly modified to allow various simulations at idealized transects along the southeast coast of Florida.

Five separate transects along the southeast coast of Florida were simulated. These transects (or slices) through the aquifer, are located in north-central Miami Dade, south Broward, central Broward, northern Broward and south-central Palm Beach counties. Each transect was generally orientated in an east-west direction, with the eastern boundary of the model situated along the coast. Saltwater intrusion modeling was not conducted in south Miami Dade County. Such modeling will need to be done when minimum flows and levels are determined for Biscayne Bay and Florida Bay. Modifications were needed to account for variations in aquifer thickness and transmissivities consistent with the existing two-dimensional cross sectional model at each site (Fish and Stewart 1991; Fish 1988; and Shine *et al.* 1989). The thickness of the model cross-section is equal to the depth to the base of the Biscayne aquifer. Three scenarios were run at steady-state conditions and assumed a constant, effective aquifer recharge rate of six inches per year, to simulate drought conditions (Andersen *et al*. 1986).

Three scenarios were run at each transect to simulate various canal maintenance operations as follows:

1. Setting the minimum canal stage, based on the mean stage or 50th percentile as derived from stage duration curves developed for each canal from the historical data base.
2. Setting the minimum canal stage, based on the 84th percentile derived from stage duration curves developed from the historical data base.
3. For comparison purposes, setting the minimum canal stage, based on the theoretical Ghyben-Herzberg relationship (GHR).

SWICHA Modeling Results

South-Central Palm Beach County Transect:

The first transect is located in south-central Palm Beach County. This idealized cross section assumes a maximum depth of the Biscayne aquifer of 160 ft with a maximum composite transmissivity of 170,000 ft^2/day (Shine *et al.* 1989). The western edge of the model is assumed to be maintained at an elevation similar to the Lake Worth Drainage District (LWDD) E-4 canal. The LWDD E-4 canal is directly connected to the SFWMD C-51 canal and, for this simulation, is assumed to be maintained at an elevation similar to structure S-155 illustrated in **Table A-4**. Thus the three scenarios simulated canal stages at 8.12 ft NGVD, 7.74 ft NGVD, and 5.00 ft NGVD.

The results of the SWICHA model simulations are presented in **Figure A-4**. Results suggest that controlling C-51 at 8.12 ft NGVD or 7.74 ft NGVD shows little difference in the position of the saline interface. This may be due to the fact that water is flowing toward the Lake Worth Lagoon at a rate that is sufficient to minimize movement of the saline interface. However, when the levels in C- 51 are lowered to 5.00 ft NGVD, inland migration of the saline interface was observed. The front appears to have moved an additional 800-1000 ft inland compared to the other two scenarios. Movement of this degree could potentially affect existing coastal wellfields. Both the 8.12 ft and 7.74 ft NGVD canal stages appear to maintain the position of the saline interface. The 5.0 ft level, which was based on the GHR, appears to be unsatisfactory, due to the potential movement of the saline interface and impact on wellfields located near the coast.

Northeastern Broward County Transect:

The second transect is located in northeastern Broward County. This idealized cross section assumes the maximum depth of the Biscayne aquifer to be 200 ft with a composite transmissivity of 120,000 ft^2/day (Fish, 1988). The western edge of the model is assumed to be maintained at an elevation similar to the Hillsboro Canal. The salinity control structure on the Hillsboro Canal is G-56 and the western boundaries are maintained at the elevations specified in Table A-4. Therefore, canal stages that were simulated for each of the three scenarios were 7.43, 6.75, and 5.00 ft NGVD. Model results showed little difference between the position of the saline interface, whether the inland stage was maintained at either the mean, or 84 percentile level (Figure A-4). However, the saltwater front in this instance appears to move inland an additional 600 feet when the GHR level is used as the minimum. Similar to southeastern Palm Beach County, a number of major wellfields are located along the coast in northeastern Broward County that could be jeopardized by additional movement of the saline interface. Therefore, the 5.00 ft NGVD level appears unsatisfactory due to potential movement of the saline interface and possible impacts on existing coastal wellfields.

Central Broward County Transect:

The third transect is located in northeastern Broward County. This idealized cross section is based on the assumption that the Biscayne aquifer has a maximum depth of 160 ft and a composite transmissivity of 170,000 ft/day (Fish, 1988). The western edge of the model is assumed to be maintained at an elevation similar to the North New River Canal. The salinity control structure on the Hillsboro Canal is G-54 and the western boundaries are maintained at the elevations specified in **Table A-4**. Therefore, the three scenarios simulated the canal stages at 3.68, 3.28 ft, and 4.0 ft NGVD.

Figure A-4 also shows results of these three simulations. There is minimal difference between the position of the saline interface when either the mean stage or the GHR stage is used, even though these two stages differed by 0.32 ft. However, when canal levels are simulated at a maintained stage of 3.28 ft, the saline interface moves several hundred feet inland in contrast to the other two scenarios. These results suggest that little benefit can be anticipated by increasing the canal stage from 3.68 ft to 4.00 ft. However, lowering the canal stage from 3.68 to 3.28 ft may cause significant movement of the saline interface.

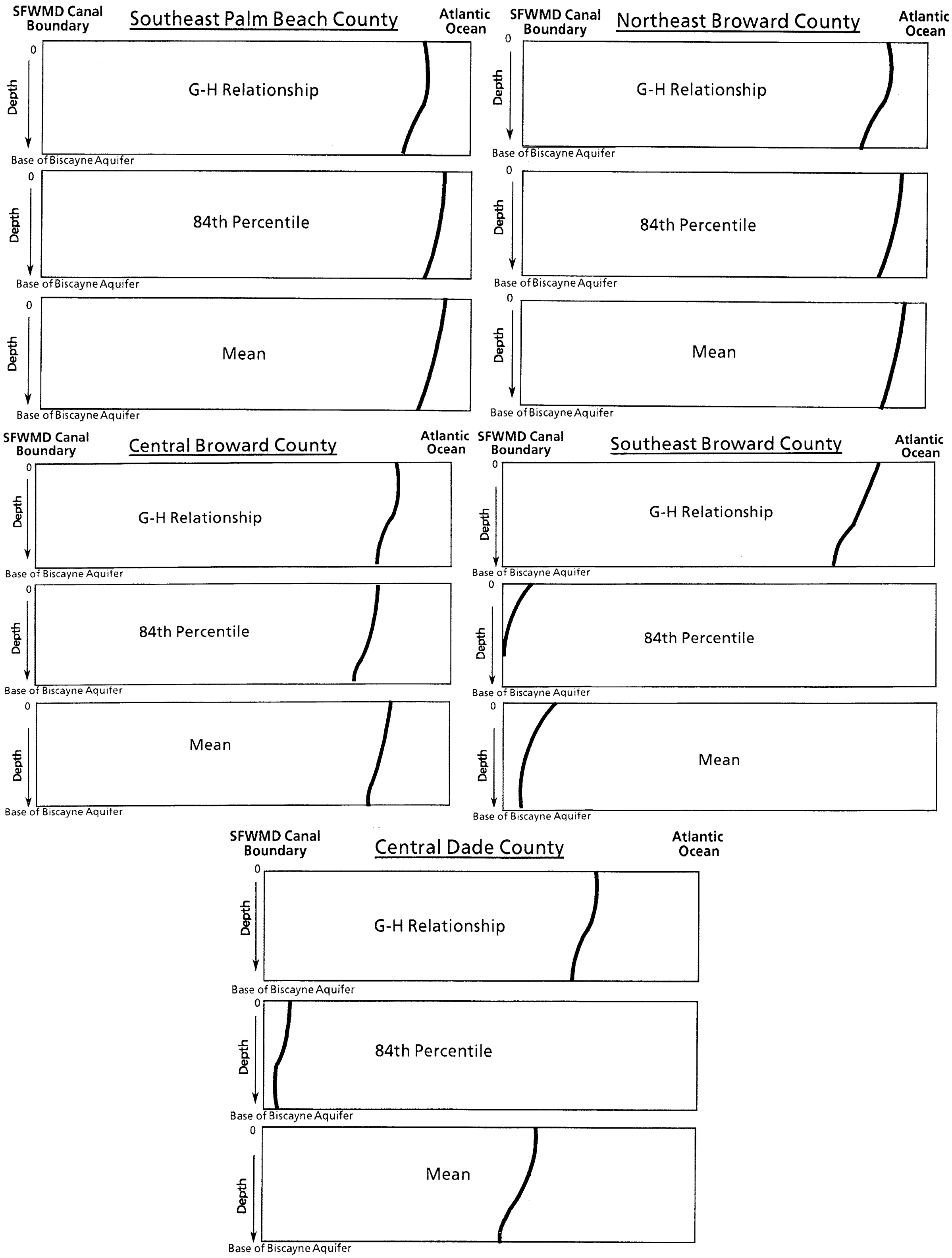


Figure 4. Simulated position of the saline interface when stages in the coastal canals are maintained the mean, 84th percentile and calculated Ghyben-Herzber relationship water levels.

Southeastern Broward County Transect:

The fourth transect is located in southeastern Broward County. This idealized cross section assumes an aquifer thickness of 200 ft with a composite transmissivity of 170,000 ft^2/day (Andersen *et al.* 1986). The western edge of the model is assumed to be maintained at an elevation similar to the C-9 Canal. The salinity control structure on the C-9 Canal is S-29 and the western boundaries are maintained at elevations shown in **Table A-4**. Therefore, the three scenarios simulated maintenance of canal stages at 2.16, 1.90, and 4.00 ft NGVD. These results are presented in **Figure A-4**. The model failed to properly converge when the western boundary was maintained at 2.16 ft and 1.90 ft NGVD. This indicates that the salt water front may not be stable under existing conditions. The results of an unstable interface are supported by the monitoring data in the area which shows continued inland migration of the saline interface. The results suggest that the saltwater front could be stabilized if a mound of freshwater, approximately 4.00 ft deep, could be created along the coast. However, it may not be feasible to use the C-9 canal to maintain such a level due to the potential for flooding in southern Broward and Northern Dade County.

North-Central Dade County Transect:

The final transect is located in north-central Dade County. This idealized cross section assumes a Biscayne aquifer thickness of 140 ft with a composite transmissivity of 1,000,000 ft^2/day (Fish and Stewart, 1991). The western edge of the model is assumed to be maintained at an elevation similar to the Miami Canal. The salinity control structure on the Tamiami Canal is S-25B and the western boundaries are maintained at the elevations specified in **Table A-4**. Therefore, the three scenarios simulated maintenance of minimum canal stages of 2.55 ft, 1.95 ft, and 3.20 ft NGVD at S-25.

The three SWICHA model simulations for Dade County presented in **Figure A-4**, once again indicate that model predictions fail to properly converge when stages are maintained at 1.95 ft NGVD along the western boundary resulting in an unstable saltwater front. However, the front appears to be stabilized in approximately the same position when the western boundary is maintained at either 2.55 ft or 3.25 ft. Results of this simulation confirm Andersen's (1986) observation that changes in head of even a few tenths of a foot may have widespread implications on the position of the saline interface within the Biscayne aquifer.

Results of these three model simulations showed historical canal water levels to range between the mean (50th percentile) and one standard deviation from the mean (84th percentile) for each of the five transects modeled. These results show that maintenance of canal levels within these ranges are the most appropriate for preventing further movement of the saline interface without adversely affecting flood control. These data represent the closest fit for establishing minimum flows and levels for each of the five transects modeled. Based on a review of these modeling results, proposed minimum levels for each of the District’s eleven primary water management structures are presented in **Table 8** in the main body of this report**.**

SURFACE AND GROUNDWATER FLOWS IN SOUTH DADE COUNTY, FLORIDA.

The situation in South Miami Dade County is highly complex. Historically, ground water flowed eastward and discharged into Biscayne Bay, while surface waters generally flowed southward towards the eastern Everglades, eventually reaching Florida Bay, Barnes Sound and Card Sound. With subsequent draining of South Miami Dade County, both surface and ground water flows to Biscayne Bay were significantly altered (Buchanan and Klein. 1976). Ground water and surface water flows toward northeastern Florida Bay also appear to have been altered, although additional work is needed to determine the extent. In addition to drainage, salinity regimes and circulation patterns in Florida Bay and Barnes Sound appear to have been modified by the construction of Flagler's Florida Keys Railroad (McIvor, *et al*., 1994).

A secondary problem in southern Miami Dade County is the relatively thin soil. Due to these shallow soils, canals are cut into the oolitic and bryozoan facies of the Miami Limestone and have penetrated into the Fort Thompson Formation in some areas. As a result, these canals are directly connected to some of the most permeable sections of the Biscayne aquifer. It is therefore difficult to maintain canal stages for extended periods of time without using a significant volume of water from regional storage.

For the reasons discussed above, this report will not establish minimum flows and levels for Florida Bay, Biscayne Bay, Card Sound, and Barnes Sound, located in southern Miami Dade County. Results of this study and others show that a strong relationship exists between the position of the saltwater interface and the volume of ground water that flows into these important estuaries. However, District staff is concerned that setting a minimum level for the Biscayne aquifer in South Miami Dade County, based solely on maintaining the existing position of the saline interface has the potential to restrict critical ground water and surface flows that move east towards Biscayne Bay and south towards Florida Bay. Setting a MFL for southern Miami Dade County based solely on this information could result in unsatisfactory ground water and surface water flows to these estuaries. Therefore, it is recommended that the MFL for the Biscayne aquifer in southern Miami Dade County be developed concurrently with the development of MFLs for Biscayne Bay, Florida Bay, Card Sound and Barnes Sound.

Table 5. Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
G 515	0.93	1.38	770.00	920.00	843.85	211	-4.35	-3.89
G 820	1.31	2.99	18.00	5.00	11.34	224	-4.29	-2.61
G 820A	3.67	5.23	4.40	5.00	4.70	102	1.12	2.68
G 854	2.66	3.11	1600.00	2100.00	1939.66	206	-2.49	-2.04
G1211	0.00	0.00	18.00	18.00	18.75	1	0.00	0.00
G1212	2.46	3.64	82.00	34.00	40.29	1	2.44	3.61
G1212A	2.19	2.82	28.00	21.00	33.05	83	0.11	0.75
G1228	2.02	2.82	2100.00	1400.00	1360.00	194	-2.83	-2.03
G1232	2.56	3.59	16.00	28.00	21.42	205	-2.57	-1.54
G1237	0.80	1.92	1000.00	1200.00	1212.00	200	-4.20	-3.08
G1240	1.28	1.65	240.00	200.00	124.85	197	-3.64	-3.27
G1241	2.27	2.99	58.00	3100.00	913.25	215	-3.11	-2.38
G1272	1.16	3.00	13.00	34.00	20.24	198	-3.79	-1.95
G1272A	0.00	0.00	25.00	27.00	25.67	59	0.00	0.00
G1340	2.17	3.08	50.00	34.00	39.80	217	-3.25	-2.34
G1343	1.89	2.73	64.00	88.00	76.45	210	-3.36	-2.52
G1344	1.32	1.70	250.00	80.00	88.68	182	-3.23	-2.85
G1347	0.34	1.21	40.00	34.00	38.52	200	-4.66	-3.79
G1432	0.00	0.00	11000.00	11000.00	11167.61	1	0.00	0.00
G1433	-0.03	-0.04	1200.00	12000.00	8709.30	150	-3.78	-3.79
G1434	-0.13	0.03	7100.00	10000.00	8691.67	192	-4.93	-4.77
G1435	0.59	1.40	42.00	7400.00	3526.10	204	-4.51	-3.70
G1446	0.00	0.00	2200.00	8600.00	7875.00	1	0.00	0.00
G1472	0.00	1.51	42.00	42.00	42.00	18	0.00	0.00
G1473	1.21	1.72	36.00	46.00	41.26	132	-2.09	-1.58
G1548	1.66	2.30	650.00	580.00	618.98	187	-3.01	-2.38
G1549	0.00	0.00	28.00	68.00	50.76	184	0.00	0.00
G1597	1.22	1.72	410.00	260.00	355.04	163	-2.85	-2.35
G2000	1.66	2.34	800.00	620.00	722.04	192	-3.14	-2.46
G2001	2.24	3.80	320.00	410.00	360.26	54	0.89	2.45
G2038	1.27	2.16	34.00	37.00	35.50	143	-2.30	-1.42
G2039	1.24	1.76	32.00	51.00	37.25	1	1.22	1.74
G2040	1.18	2.19	120.00	92.00	64.07	177	-3.24	-2.23
G2053	0.00	0.00	4800.00	3700.00	4500.00	1	0.00	0.00
G2054	2.79	2.94	9700.00	11000.00	9708.82	142	-0.76	-0.61
G2055	2.53	3.47	40.00	4300.00	2520.61	180	-1.97	-1.03
G2055A	0.00	0.00	9700.00	4500.00	8954.32	1	0.00	0.00
G2060	-1.97	0.22	14.00	5.00	30.07	211	-7.24	-5.05
G2062	0.66	1.09	9700.00	4900.00	8224.10	139	-2.81	-2.38
G2063	0.10	0.49	15000.00	16000.00	16633.80	82	-1.95	-1.56
G2064	0.75	1.70	1700.00	12000.00	11461.32	201	-4.27	-3.32
G2067	1.41	3.13	12.00	12.00	12.00	45	0.29	2.01
G2073	1.35	1.77	110.00	140.00	121.95	190	-3.40	-2.98
G2073A	1.43	1.95	68.00	48.00	42.55	157	-2.49	-1.98
G2074	0.22	1.32	6600.00	11000.00	9473.59	168	-3.98	-2.88
G2090	2.87	3.86	22.00	32.00	39.98	101	0.34	1.34
G2091	1.81	2.35	44.00	54.00	43.11	124	-1.29	-0.75
G2121	0.00	0.00	330.00	300.00	292.07	185	0.00	0.00
G2122	1.35	2.01	38.00	34.00	31.81	135	-2.03	-1.36
G2123	0.00	3.90	58.00	36.00	51.64	182	0.00	0.00
G2124	0.00	0.00	40.00	36.00	24.22	1	0.00	0.00
G2125	1.73	2.28	42.00	32.00	38.70	58	0.28	0.83
G2126	0.00	0.00	18.00	28.00	20.91	169	0.00	0.00
G2127	1.12	1.52	24.00	18.00	21.53	190	-3.63	-3.23
G2128	1.12	1.47	70.00	8.00	35.53	61	-0.41	-0.06
G2129	1.38	1.99	18.00	12.00	13.92	180	-3.12	-2.51
G2130	1.19	1.79	34.00	26.00	31.84	60	-0.31	0.29
G2147	1.39	0.00	40.00	28.00	34.00	16	0.99	-0.40
G2149	1.99	2.82	18.00	310.00	145.23	137	-1.43	-0.60
G2156	11.97	13.00	21.00	19.00	17.00	100	9.47	10.50
G2160	0.00	0.00	17.00	25.00	23.80	145	0.00	0.00
G2160A	0.00	0.00	5.70	15.00	8.80	53	0.00	0.00
G2161	0.00	0.00	83.00	80.00	81.33	200	0.00	0.00
G2161A	0.00	0.00	3.00	8.00	4.50	55	0.00	0.00
G2176	1.58	2.23	190.00	470.00	186.37	171	-2.70	-2.04

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion
† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued) Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
G2176A	1.57	2.22	36.00	32.00	32.30	63	-0.01	0.64
G2180	1.52	2.30	180.00	170.00	177.14	106	-1.13	-0.35
G2199	0.00	0.00	89.00	89.00	89.00	42	0.00	0.00
G2201	0.00	0.00	69.00	69.00	69.00	41	0.00	0.00
G2254	2.38	4.99	18.00	20.00	18.45	1	2.35	4.97
G2255	0.00	2.65	7100.00	17000.00	14118.18	203	0.00	0.00
G2256	2.17	3.32	14.00	48.00	27.62	110	-0.58	0.57
G2257	1.65	3.34	18.00	52.00	28.38	94	-0.70	0.99
G2259	2.38	3.26	10.00	16.00	13.20	26	1.73	2.61
G2260	0.00	0.00	28.00	13.00	22.20	1	0.00	0.00
G2261	0.00	0.00	140.00	110.00	146.67	1	0.00	0.00
G2262	0.00	0.00	1300.00	1400.00	1320.00	1	0.00	0.00
G2263	0.00	0.00	21.00	960.00	262.75	1	0.00	0.00
G2264	0.00	0.00	40.00	39.00	39.18	1	0.00	0.00
G2265	0.00	0.00	240.00	38.00	232.00	1	0.00	0.00
G2266	0.00	0.00	46.00	8.00	36.50	1	0.00	0.00
G2267	0.00	0.00	42.00	54.00	48.00	1	0.00	0.00
G2268	0.00	0.00	42.00	48.00	35.62	168	0.00	0.00
G2269	0.00	0.00	38.00	38.00	41.11	50	0.00	0.00
G2270	0.00	0.00	70.00	64.00	73.12	184	0.00	0.00
G2274	3.65	5.74	19.00	21.00	20.00	130	0.40	2.49
G2274A	4.55	6.57	19.00	19.00	19.00	57	3.13	5.15
G2275	3.63	5.30	12.00	10.00	12.00	157	-0.29	1.37
G2276	0.00	0.00	18.00	40.00	119.63	200	0.00	0.00
G2277	2.44	3.91	24.00	30.00	29.67	131	-0.84	0.64
G2278	3.00	4.29	24.00	28.00	20.50	203	-2.07	-0.78
G2281	0.00	0.00	79.00	79.00	79.00	40	0.00	0.00
G2283	0.00	0.00	69.00	69.00	69.00	40	0.00	0.00
G2285	0.00	0.00	66.00	66.00	66.00	40	0.00	0.00
G2294	1.08	1.83	56.00	98.00	103.83	135	-2.29	-1.54
G2295	0.00	0.00	10.00	64.00	27.34	1	0.00	0.00
G2296	0.00	0.00	23000.00	19000.00	21000.00	1	0.00	0.00
G2311	0.00	0.00	95.00	910.00	555.68	1	0.00	0.00
G2312	0.00	0.00	150.00	320.00	174.24	1	0.00	0.00
G2313	0.00	0.00	130.00	1700.00	719.64	1	0.00	0.00
G2314	0.00	0.00	38.00	800.00	267.30	1	0.00	0.00
G2315	0.00	0.00	140.00	1700.00	845.00	1	0.00	0.00
G2316	0.00	0.00	73.00	680.00	209.11	1	0.00	0.00
G2317	0.00	0.00	100.00	74.00	88.44	1	0.00	0.00
G2318	0.00	0.00	64.00	100.00	77.15	1	0.00	0.00
G2319	0.00	0.00	110.00	720.00	410.10	1	0.00	0.00
G2320	0.00	0.00	58.00	550.00	271.00	1	0.00	0.00
G2321	0.00	0.00	130.00	260.00	142.00	1	0.00	0.00
G2322	0.00	0.00	130.00	350.00	141.50	1	0.00	0.00
G2323	0.00	0.00	140.00	320.00	147.87	1	0.00	0.00
G2325	0.00	0.00	90.00	120.00	26.62	1	0.00	0.00
G2327	0.00	0.00	18.00	900.00	330.17	1	0.00	0.00
G2328	0.00	0.00	39.00	220.00	89.21	1	0.00	0.00
G2329	0.00	0.00	130.00	140.00	133.33	1	0.00	0.00
G2330	0.00	0.00	62.00	450.00	294.80	1	0.00	0.00
G2338	0.00	0.00	58.00	200.00	183.45	1	0.00	0.00
G2340	0.00	0.00	100.00	300.00	195.20	1	0.00	0.00
G2341	0.00	0.00	150.00	500.00	151.67	1	0.00	0.00
G2342	0.00	0.00	35.00	140.00	79.18	1	0.00	0.00
G2344	0.00	0.00	26.00	70.00	26.38	1	0.00	0.00
G2344A	0.83	1.96	26.00	28.00	30.78	93	-1.49	-0.36
G2344B	-0.02	2.75	8.00	8.00	8.00	52	-1.32	1.45
G2345	0.00	0.00	35.00	530.00	88.38	103	0.00	0.00
G2345X	0.00	0.00	27.00	32.00	28.17	103	0.00	0.00
G2346	0.00	0.00	120.00	240.00	234.29	1	0.00	0.00
G2347	0.00	0.00	40.00	8300.00	5425.05	1	0.00	0.00
G2348	0.00	0.00	44.00	1500.00	390.80	122	0.00	0.00
G2349	0.00	0.00	76.00	10000.00	2796.57	136	0.00	0.00
G2350	0.00	0.00	44.00	1400.00	254.17	171	0.00	0.00
G2351A	-0.44	-0.43	46.00	9300.00	6712.86	1	-0.46	-0.45
G2352	0.00	1.87	32.00	310.00	273.56	1	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion
† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
G2353	0.00	0.00	28.00	1500.00	489.00	237	0.00	0.00
G2354	0.00	0.00	41.00	550.00	148.10	231	0.00	0.00
G2355	0.00	0.00	73.00	73.00	73.00	96	0.00	0.00
G2355A	0.00	0.00	140.00	140.00	140.00	53	0.00	0.00
G2356	0.00	0.00	55.00	59.00	57.67	96	0.00	0.00
G2356A	0.00	0.00	49.00	60.00	54.00	56	0.00	0.00
G2357	0.00	0.00	77.00	76.00	76.67	83	0.00	0.00
G2357A	0.00	0.00	75.00	73.00	75.67	56	0.00	0.00
G2358	0.00	0.00	80.00	78.00	78.33	100	0.00	0.00
G2358A	0.00	0.00	100.00	110.00	110.00	49	0.00	0.00
G2359	5.74	5.97	28.00	29.00	28.67	101	3.22	3.44
G2359A	5.77	5.95	28.00	27.00	26.67	59	4.29	4.47
G2360	0.00	0.00	18.00	18.00	17.67	100	0.00	0.00
G2360A	0.00	0.00	4.00	4.00	4.00	51	0.00	0.00
G2361	4.97	5.01	39.00	42.00	41.33	82	2.92	2.96
G2361A	5.04	5.05	24.00	27.00	26.00	45	3.92	3.92
G2362	0.00	0.00	110.00	110.00	106.67	61	0.00	0.00
G2362A	0.00	0.00	110.00	110.00	106.67	24	0.00	0.00
G2363	0.00	0.00	25.00	21.00	23.00	80	0.00	0.00
G2363A	0.00	0.00	28.00	40.00	34.33	20	0.00	0.00
G2364	0.00	0.00	37.00	39.00	35.33	80	0.00	0.00
G2364A	0.00	0.00	9.00	9.00	9.00	19	0.00	0.00
G2365	0.00	0.00	24.00	57.00	46.67	74	0.00	0.00
G2365A	0.00	0.00	28.00	23.00	26.25	35	0.00	0.00
G2365B	0.00	0.00	16.00	19.00	16.33	1	0.00	0.00
G2366	0.00	0.00	47.00	54.00	52.00	57	0.00	0.00
G2366A	0.00	0.00	57.00	49.00	53.00	28	0.00	0.00
G2367	0.00	0.00	100.00	100.00	99.67	65	0.00	0.00
G2367A	0.00	0.00	98.00	92.00	95.00	25	0.00	0.00
G2368A	0.00	0.00	5.00	7.40	6.20	11	0.00	0.00
G2369	0.00	0.00	21.00	20.00	20.33	75	0.00	0.00
G2369A	0.00	0.00	17.00	23.00	20.00	22	0.00	0.00
G2370	-1.24	0.57	38.00	37.00	38.00	101	-3.77	-1.96
G2370A	-0.86	0.85	11.00	10.00	12.67	51	-2.13	-0.42
G2371	0.00	0.00	50.00	50.00	50.00	80	0.00	0.00
G2371A	0.00	0.00	43.00	43.00	43.00	14	0.00	0.00
G2372	0.00	0.00	58.00	58.00	58.00	105	0.00	0.00
G2372A	0.00	0.00	14.00	14.00	14.00	32	0.00	0.00
G2373	0.00	0.00	120.00	120.00	120.00	60	0.00	0.00
G2373A	0.00	0.00	120.00	120.00	120.00	21	0.00	0.00
G2374	0.00	0.00	31.00	31.00	31.00	93	0.00	0.00
G2374A	0.00	0.00	10.00	10.00	10.00	34	0.00	0.00
G2385	0.00	0.00	41.00	43.00	43.00	1	0.00	0.00
G2385A	0.00	0.00	43.00	41.00	42.00	1	0.00	0.00
G2386A	0.00	0.00	15.00	130.00	104.75	1	0.00	0.00
G2386B	0.00	0.00	93.00	140.00	110.88	1	0.00	0.00
G2386C	0.00	0.00	110.00	140.00	112.12	1	0.00	0.00
G2386D	0.00	0.00	7.80	7.00	11.98	1	0.00	0.00
G2386E	0.00	0.00	40.00	17.00	30.44	1	0.00	0.00
G2386F	0.00	0.00	95.00	22.00	42.25	1	0.00	0.00
G2386G	0.00	0.00	6.00	9.00	11.30	1	0.00	0.00
G2386H	0.00	0.00	33.00	7.00	15.64	1	0.00	0.00
G2386I	0.00	0.00	35.00	9.00	21.50	1	0.00	0.00
G2386J	0.00	0.00	68.00	73.00	69.67	1	0.00	0.00
G2386K	0.00	0.00	98.00	91.00	95.67	1	0.00	0.00
G2386L	0.00	0.00	7.60	6.20	5.80	1	0.00	0.00
G2386M	0.00	0.00	3.20	2.00	2.53	1	0.00	0.00
G2386N	0.00	0.00	64.00	68.00	65.33	1	0.00	0.00
G2386O	0.00	0.00	68.00	62.00	62.00	1	0.00	0.00
G2386P	0.00	0.00	23.00	11.00	19.00	1	0.00	0.00
G2387A	0.00	0.00	93.00	95.00	84.67	1	0.00	0.00
G2387B	0.00	0.00	84.00	94.00	83.33	1	0.00	0.00
G2387C	0.00	0.00	97.00	100.00	101.75	1	0.00	0.00
G2387D	0.00	0.00	87.00	83.00	83.33	1	0.00	0.00
G2387E	0.00	0.00	77.00	90.00	78.25	1	0.00	0.00
G2387F	0.00	0.00	220.00	140.00	190.00	1	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion

† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
G2408	1.30	1.83	56.00	56.00	56.00	1	1.27	1.80
G2409	1.19	1.78	48.00	34.00	20.50	83	-0.89	-0.30
G2410	1.27	1.88	46.00	350.00	68.74	205	-3.86	-3.25
G2419	0.00	0.00	110.00	140.00	123.33	1	0.00	0.00
G2420	0.00	0.00	130.00	130.00	126.67	1	0.00	0.00
G2421	0.00	0.00	140.00	120.00	130.00	1	0.00	0.00
G2422	0.00	0.00	110.00	140.00	86.20	1	0.00	0.00
G2423	0.00	0.00	140.00	120.00	130.00	1	0.00	0.00
G2424	0.00	0.00	120.00	120.00	116.67	1	0.00	0.00
G2425	1.46	1.98	24.00	26.00	70.78	203	-3.61	-3.09
G2426	1.53	2.01	30.00	74.00	35.56	91	-0.74	-0.26
G2441	0.00	2.21	34.00	210.00	267.41	181	0.00	0.00
G2445	0.00	0.00	64.00	320.00	216.74	132	0.00	0.00
G2447	0.00	0.00	26.00	58.00	52.51	135	0.00	0.00
G2477	1.77	2.38	34.00	36.00	37.92	75	-0.11	0.51
G2478	1.69	2.33	40.00	68.00	54.30	195	-3.19	-2.54
G2480	2.45	3.79	46.00	60.00	67.86	102	-0.10	1.24
G2487	0.00	0.00	4400.00	6500.00	3827.50	3	0.00	0.00
G2488	0.00	0.00	7500.00	6300.00	4348.00	1	0.00	0.00
G2489	1.25	0.00	2500.00	4100.00	2900.00	1	1.23	-0.03
G2490	0.00	0.00	1400.00	1500.00	1625.00	4	0.00	0.00
G2491	0.00	0.00	2000.00	4600.00	2522.00	3	0.00	0.00
G2492	0.00	0.00	37.00	32.00	30.00	8	0.00	0.00
G2493	0.00	0.00	62.00	60.00	62.50	11	0.00	0.00
G2494	0.00	0.00	940.00	80.00	663.33	15	0.00	0.00
G2509	2.12	2.45	47.00	68.00	81.00	1	2.10	2.43
G2516	0.00	0.00	42.00	42.00	42.00	1	0.00	0.00
G2523	0.00	0.00	52.00	48.00	43.00	1	0.00	0.00
G2612	0.00	0.57	28.00	120.00	169.69	273	0.00	0.00
G2614	0.00	0.00	360.00	64.00	231.00	50	0.00	0.00
G2615	0.00	0.00	44.00	660.00	665.92	175	0.00	0.00
G2616	0.00	0.00	40.00	300.00	100.24	1	0.00	0.00
G2617	59.19	58.91	1100.00	1100.00	1120.00	1	59.16	58.89
G2618	58.83	59.61	600.00	630.00	622.86	1	58.81	59.58
G2619	59.63	59.52	1100.00	1100.00	1122.22	1	59.60	59.50
G2620	58.04	58.01	1400.00	1500.00	1533.33	1	58.02	57.99
G2621	0.00	0.00	330.00	4200.00	2977.69	300	0.00	0.00
G2704	3.78	-1.53	40.00	40.00	40.00	1	3.75	-1.55
G2708	8.46	8.78	14.00	14.00	14.00	1	8.44	8.76
G2711	3.76	4.40	52.00	52.00	52.00	10	3.51	4.15
G2712	4.28	4.72	18.00	18.00	18.00	10	4.03	4.47
G2713	6.83	6.99	16.00	16.00	16.00	1	6.80	6.97
G2716	2.50	3.28	16.00	16.00	16.00	10	2.25	3.03
G2718	3.36	3.66	32.00	32.00	32.00	150	-0.39	-0.09
G2719	4.44	5.14	34.00	34.00	34.00	55	3.07	3.77
G2721	8.32	8.30	22.00	22.00	22.00	1	8.29	8.27
G2722	9.49	9.63	40.00	40.00	40.00	1	9.47	9.61
G2723	2.96	2.04	12.00	12.00	12.00	1	2.93	2.02
G2724	3.71	4.04	18.00	18.00	18.00	174	-0.64	-0.31
G2725	2.71	2.90	260.00	160.00	178.00	170	-1.54	-1.35
G2726	8.64	8.83	18.00	18.00	18.00	1	8.61	8.81
G2728	2.90	3.21	54.00	54.00	54.00	20	2.40	2.71
G2729	2.60	2.94	34.00	34.00	34.00	156	-1.30	-0.96
G2730	2.13	2.67	8600.00	7100.00	7850.00	162	-1.92	-1.38
G2731	2.64	2.87	10.00	10.00	10.00	170	-1.61	-1.38
G2732	3.40	2.73	16.00	34.00	28.80	1	3.38	2.71
G2733	3.10	3.37	16.00	34.00	28.80	100	0.60	0.87
G2735	3.63	3.85	24.00	24.00	24.00	150	-0.12	0.10
G2737	2.50	2.93	190.00	270.00	272.50	150	-1.25	-0.82
G2738	4.23	4.82	30.00	30.00	30.00	1	4.20	4.80
G2807	0.00	2.01	38.00	34.00	39.00	1	0.00	0.00
G2852	9.01	9.18	35.00	40.00	41.50	130	5.76	5.93
G1352	-0.01	2.70	210.00	210.00	210.00	160	-4.01	-1.30
S 830	0.00	0.00	3800.00	2400.00	2781.25	1	0.00	0.00
S1414	0.00	0.00	80.00	52.00	72.67	1	0.00	0.00
S1488	0.00	0.00	44.00	38.00	42.00	1	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion

† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
S1489	0.00	0.00	36.00	36.00	35.00	1	0.00	0.00
S2003	0.00	0.00	71.00	71.00	71.00	1	0.00	0.00
S1533M	0.00	0.00	7100.00	7100.00	7100.00	1	0.00	0.00
F 2A	1.92	3.18	350.00	92.00	208.20	1	1.90	3.16
F 5	0.46	1.53	150.00	170.00	142.00	1	0.44	1.50
F 45	2.09	2.62	140.00	170.00	135.81	85	-0.04	0.49
F 214	2.12	2.73	94.00	24.00	73.44	1	2.09	2.71
F 237A	0.00	0.00	400.00	160.00	294.55	1	0.00	0.00
F 279	1.69	1.83	1400.00	2800.00	1900.00	117	-1.24	-1.10
F 297	0.00	0.00	1700.00	1700.00	1700.00	1	0.00	0.00
F 298	0.00	0.00	1300.00	1400.00	1350.00	1	0.00	0.00
F 390	0.00	0.00	280.00	200.00	234.44	1	0.00	0.00
F 414	0.13	1.36	32.00	28.00	35.62	65	-1.50	-0.26
F 441	0.65	1.64	50.00	28.00	47.13	57	-0.77	0.21
F 481	1.26	1.59	360.00	260.00	310.00	1	1.24	1.57
F 483	1.70	2.01	120.00	66.00	91.12	1	1.67	1.99
G 354	3.89	4.62	640.00	90.00	131.86	90	1.64	2.37
G 355	1.74	2.03	310.00	100.00	202.00	83	-0.34	-0.04
G 430	0.00	3.73	44.00	32.00	34.86	98	0.00	0.00
G 432	1.18	1.75	32.00	2000.00	1145.42	100	-1.32	-0.75
G 548	1.47	1.87	490.00	100.00	210.72	97	-0.96	-0.56
G 570	1.04	1.85	850.00	64.00	234.77	87	-1.14	-0.32
G 571	0.67	1.11	630.00	62.00	117.01	95	-1.71	-1.27
G 576	2.64	3.22	220.00	16.00	121.15	97	0.21	0.80
G 577	-0.53	0.41	320.00	1.30	98.53	99	-3.01	-2.06
G 581A	2.28	2.80	24.00	16.00	16.08	1	2.25	2.78
G 788	0.00	0.00	42.00	44.00	42.67	1	0.00	0.00
G 894	1.72	2.23	1400.00	34.00	177.30	76	-0.18	0.33
G 896	2.29	2.63	330.00	500.00	557.35	74	0.44	0.78
G 901	2.61	3.07	28.00	2200.00	674.98	96	0.21	0.67
G 939	1.62	1.93	2000.00	1500.00	2475.19	60	0.12	0.43
G1009B	2.80	2.88	18.00	22.00	34.27	100	0.30	0.38
G1035A	0.00	0.00	1000.00	1600.00	1254.38	1	0.00	0.00
G1179	1.87	2.25	4600.00	4300.00	4297.21	51	0.60	0.97
G1180	0.83	1.33	22.00	14.00	27.47	67	-0.84	-0.34
G1183	1.92	2.43	20.00	16.00	48.27	47	0.74	1.25
G1251	1.50	2.21	22.00	36.00	36.95	59	0.02	0.74
G1256	0.00	0.00	6900.00	6700.00	6359.67	1	0.00	0.00
G1264	1.70	2.18	76.00	94.00	77.36	7	1.53	2.01
G1265A	0.00	0.00	6600.00	5300.00	5048.24	1	0.00	0.00
G1268	2.23	2.13	250.00	220.00	427.69	1	2.20	2.11
G1270	1.94	2.38	26.00	20.00	21.79	27	1.27	1.70
G1350	1.50	2.12	100.00	24.00	52.61	1	1.48	2.10
G1351	1.66	1.94	2000.00	120.00	768.31	1	1.63	1.91
G1352	2.14	2.25	180.00	90.00	114.30	160	-1.86	-1.75
G1354	1.49	2.43	500.00	16.00	151.42	103	-1.09	-0.15
G1355	0.00	0.00	2800.00	2400.00	3162.50	154	0.00	0.00
G1356	0.00	0.00	1500.00	950.00	990.00	1	0.00	0.00
G1357	0.00	0.00	1300.00	22.00	661.00	203	0.00	0.00
G1603	2.00	2.47	4900.00	700.00	1751.14	1	1.98	2.45
G1604	1.93	2.89	28.00	62.00	53.99	62	0.38	1.34
G1604A	2.42	3.08	20.00	22.00	22.88	92	0.12	0.78
G3061	43.49	0.00	1200.00	1200.00	1200.00	1	43.46	-0.03
G3062	0.00	0.00	1200.00	1200.00	1200.00	1	0.00	0.00
G3124	0.00	0.00	72.00	72.00	72.00	12	0.00	0.00
G3157	0.00	3.58	22.00	94.00	26.55	110	0.00	0.00
G3158	0.00	0.00	24.00	10.00	18.60	1	0.00	0.00
G3159	0.00	0.00	190.00	56.00	188.93	1	0.00	0.00
G3160	0.00	0.00	20.00	72.00	44.00	1	0.00	0.00
G3161	0.00	0.00	380.00	400.00	404.29	1	0.00	0.00
G3162	1.80	2.09	310.00	1100.00	574.23	92	-0.50	-0.21
G3163	0.00	0.00	32.00	32.00	29.33	1	0.00	0.00
G3164	0.00	0.00	78.00	100.00	92.46	1	0.00	0.00
G3165	0.00	0.00	80.00	18.00	23.93	1	0.00	0.00
G3166	0.00	0.00	180.00	38.00	171.04	1	0.00	0.00
G3167	0.00	0.00	230.00	78.00	153.51	1	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion

† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
G3205	0.00	0.00	62.00	62.00	62.00	1	0.00	0.00
G3224	0.00	0.00	32.00	13.00	33.96	1	0.00	0.00
G3226	8.66	0.00	690.00	440.00	481.43	1	8.64	-0.03
G3229	0.00	0.00	850.00	290.00	359.52	85	0.00	0.00
G3235	0.00	0.00	44.00	48.00	46.08	1	0.00	0.00
G3235A	1.70	2.09	46.00	50.00	38.73	1	1.68	2.06
G3250	-3.32	-0.57	90.00	200.00	244.71	116	-6.22	-3.47
G3253A	-1.93	1.82	53.00	53.00	53.00	1	-1.95	1.79
G3260A	1.53	3.04	45.00	45.00	45.00	1	1.51	3.01
G3261A	1.87	3.01	50.00	50.00	50.00	1	1.84	2.99
G3262A	1.95	3.05	61.00	61.00	61.00	1	1.92	3.03
G3263A	1.94	3.12	45.00	45.00	45.00	1	1.92	3.09
G3264A	2.16	2.83	37.00	37.00	37.00	50	0.91	1.58
G3276	-0.42	1.70	51.00	51.00	51.00	1	-0.45	1.68
G3281	-1.67	0.72	45.00	45.00	45.00	1	-1.69	0.69
G3284	-1.05	0.50	41.00	41.00	41.00	1	-1.07	0.48
G3284A	0.74	2.06	45.00	45.00	45.00	1	0.72	2.03
G3284B	1.08	2.26	45.00	45.00	45.00	1	1.05	2.24
G3285	-2.83	0.00	37.00	37.00	37.00	1	-2.86	-0.03
G3285A	-0.84	0.00	43.00	43.00	43.00	1	-0.86	-0.03
G3286	0.60	1.44	39.00	39.00	39.00	1	0.57	1.42
G3286A	-4.20	-5.83	33.00	33.00	33.00	1	-4.22	-5.86
G3287	0.60	1.25	34.00	34.00	34.00	1	0.57	1.22
G3287A	-0.24	0.63	32.00	32.00	32.00	1	-0.26	0.61
G3288	2.30	3.27	43.00	43.00	43.00	1	2.27	3.25
G3288A	1.78	2.46	41.00	41.00	41.00	1	1.76	2.43
G3289	-0.12	0.85	45.00	45.00	45.00	1	-0.14	0.83
G3290	1.13	2.31	45.00	45.00	45.00	1	1.10	2.28
G3291	0.67	1.70	45.00	45.00	45.00	1	0.64	1.67
G3293	-0.98	3.38	23.00	23.00	23.00	1	-1.00	3.36
G3294	0.00	0.00	85.00	76.00	135.65	1	0.00	0.00
G3294B	0.00	0.00	96.00	96.00	96.00	78	0.00	0.00
G3295	0.00	0.00	16.00	97.00	40.95	1	0.00	0.00
G3295B	0.00	0.00	37.00	37.00	37.00	70	0.00	0.00
G3296	0.00	0.00	48.00	420.00	133.47	191	0.00	0.00
G3296B	0.00	0.00	33.00	33.00	33.00	56	0.00	0.00
G3297	0.00	0.00	64.00	190.00	134.62	1	0.00	0.00
G3297B	0.00	0.00	98.00	98.00	98.00	67	0.00	0.00
G3298	1.83	2.87	50.00	43.00	47.55	166	-2.32	-1.28
G3299	0.00	0.00	34.00	740.00	283.46	1	0.00	0.00
G3299B	0.00	0.00	42.00	42.00	42.00	90	0.00	0.00
G3299D	0.00	0.00	380.00	380.00	380.00	1	0.00	0.00
G3300	0.00	0.00	58.00	87.00	8675.23	1	0.00	0.00
G3300B	0.00	0.00	860.00	860.00	860.00	36	0.00	0.00
G3300D	0.00	0.00	100.00	100.00	100.00	1	0.00	0.00
G3301	0.00	0.00	38.00	39.00	36.27	173	0.00	0.00
G3301B	0.00	0.00	34.00	34.00	34.00	70	0.00	0.00
G3302	0.00	0.00	95.00	56.00	72.07	1	0.00	0.00
G3302B	0.00	0.00	53.00	53.00	53.00	84	0.00	0.00
G3303	0.00	0.00	62.00	290.00	127.70	182	0.00	0.00
G3303B	0.00	0.00	77.00	77.00	77.00	70	0.00	0.00
G3304	0.00	0.00	56.00	85.00	52.90	186	0.00	0.00
G3304B	0.00	0.00	46.00	46.00	46.00	73	0.00	0.00
G3305	0.00	0.00	46.00	50.00	43.50	177	0.00	0.00
G3305B	0.00	0.00	38.00	38.00	38.00	60	0.00	0.00
G3306	0.00	0.00	8.00	8.00	8.00	215	0.00	0.00
G3306B	0.00	0.00	37.00	37.00	37.00	97	0.00	0.00
G3306D	0.00	0.00	59.00	59.00	59.00	130	0.00	0.00
G3307	0.00	0.00	42.00	6600.00	6205.38	1	0.00	0.00
G3307B	0.00	0.00	39.00	39.00	39.00	60	0.00	0.00
G3308	0.00	0.00	44.00	39.00	42.64	170	0.00	0.00
G3308B	0.00	0.00	600.00	600.00	600.00	50	0.00	0.00
G3309	0.00	0.00	58.00	79.00	83.81	175	0.00	0.00
G3309B	0.00	0.00	99.00	99.00	99.00	64	0.00	0.00
G3310	0.00	0.00	36.00	10.00	21.95	1	0.00	0.00
G3310B	0.00	0.00	31.00	31.00	31.00	59	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion

† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
G3310C	0.00	0.00	10.00	10.00	10.00	133	0.00	0.00
G3311	0.00	0.00	26.00	15.00	21.00	217	0.00	0.00
G3311B	0.00	0.00	18.00	18.00	18.00	53	0.00	0.00
G3311D	0.00	0.00	13.00	13.00	13.00	160	0.00	0.00
G3312	0.00	0.00	18.00	15.00	16.89	1	0.00	0.00
G3312A	0.00	0.00	15.00	15.00	15.00	28	0.00	0.00
G3313	0.00	0.00	52.00	24.00	36.55	213	0.00	0.00
G3313B	0.00	0.00	45.00	45.00	45.00	53	0.00	0.00
G3314A	0.00	0.00	42.00	40.00	26.00	1	0.00	0.00
G3314C	0.00	0.00	13.00	13.00	13.00	1	0.00	0.00
G3315A	0.00	0.00	19.00	19.00	19.00	30	0.00	0.00
G3315C	0.00	0.00	16.00	19.00	17.50	117	0.00	0.00
G3316	0.00	0.00	62.00	8100.00	4545.41	1	0.00	0.00
G3316A	0.00	0.00	41.00	41.00	41.00	30	0.00	0.00
G3316C	0.00	0.00	8200.00	8200.00	8200.00	1	0.00	0.00
G3317	0.00	0.00	20.00	1600.00	1365.12	1	0.00	0.00
G3317B	0.00	0.00	16.00	16.00	16.00	1	0.00	0.00
G3318	0.00	0.00	18.00	750.00	583.76	1	0.00	0.00
G3318A	0.00	0.00	17.00	17.00	17.00	23	0.00	0.00
G3318B	0.00	0.00	610.00	610.00	610.00	1	0.00	0.00
G3318C	0.00	0.00	790.00	790.00	790.00	1	0.00	0.00
G3319	0.00	0.00	30.00	13.00	19.27	240	0.00	0.00
G3319B	0.00	0.00	11.00	11.00	11.00	81	0.00	0.00
G3320	0.00	0.00	29.00	29.00	29.00	86	0.00	0.00
G3320B	0.00	0.00	29.00	29.00	29.00	50	0.00	0.00
G3322	0.00	0.00	1200.00	12000.00	10372.73	1	0.00	0.00
G3323	0.00	0.00	2900.00	2900.00	2900.00	1	0.00	0.00
G3323B	0.00	0.00	1200.00	1200.00	1200.00	1	0.00	0.00
G3324	0.00	0.00	24.00	570.00	2046.96	1	0.00	0.00
G3324B	0.00	0.00	31.00	31.00	31.00	30	0.00	0.00
G3324C	0.00	0.00	13000.00	13000.00	13000.00	1	0.00	0.00
G3326	-1.92	1.55	53.00	53.00	53.00	1	-1.94	1.53
G3332	1.55	4.31	54.00	54.00	54.00	1	1.53	4.28
G3334	0.00	0.00	44.00	36.00	36.80	1	0.00	0.00
G3334A	0.00	0.00	30.00	29.00	29.67	1	0.00	0.00
G3334B	0.00	0.00	32.00	29.00	31.83	1	0.00	0.00
G3335	0.00	0.00	30.00	27.00	29.00	1	0.00	0.00
G3335A	0.00	0.00	27.00	27.00	28.00	1	0.00	0.00
G3336	1.88	2.54	34.00	42.00	40.21	38	0.93	1.59
G3337	1.76	2.32	84.00	86.00	92.51	100	-0.74	-0.18
G3338	2.02	2.48	48.00	70.00	61.43	58	0.57	1.03
G3339	1.86	2.32	60.00	94.00	79.52	58	0.41	0.87
G3340	1.60	2.06	4300.00	2600.00	3385.71	48	0.40	0.86
G3341	1.74	2.23	16.00	20.00	18.41	1	1.71	2.20
G3342	1.69	2.14	2400.00	2400.00	2562.96	79	-0.29	0.17
G3343	1.24	1.74	22.00	27.00	25.82	1	1.21	1.71
G3344	2.17	2.68	230.00	84.00	107.83	59	0.70	1.20
G3345	1.63	1.88	1700.00	2500.00	2117.14	79	-0.35	-0.10
G3346	1.52	2.05	8300.00	7500.00	7831.82	1	1.50	2.02
G3347	1.49	2.15	3900.00	200.00	3700.00	1	1.47	2.12
G3348	1.74	2.13	78.00	19.00	178.19	62	0.19	0.58
G3349	1.48	1.88	3800.00	5600.00	5077.42	66	-0.17	0.23
G3350	1.90	2.24	20.00	45.00	21.50	83	-0.17	0.16
G3351	1.72	2.20	2100.00	2400.00	2121.43	1	1.69	2.17
G3358	0.00	0.00	18.00	18.00	18.00	1	0.00	0.00
G3359	0.00	0.00	20.00	20.00	20.00	1	0.00	0.00
G3360	0.00	0.00	33.00	33.00	33.00	1	0.00	0.00
G3361	0.00	0.00	39.00	39.00	39.00	1	0.00	0.00
G3362	0.00	0.00	58.00	58.00	58.00	1	0.00	0.00
G3363	0.00	0.00	67.00	67.00	67.00	1	0.00	0.00
G3364	0.00	0.00	20.00	20.00	20.00	1	0.00	0.00
G3365	0.00	0.00	11.00	11.00	11.00	1	0.00	0.00
G3366	0.00	0.00	32.00	32.00	32.00	1	0.00	0.00
G3367	0.00	0.00	360.00	450.00	582.50	1	0.00	0.00
G3368	0.00	0.00	34.00	34.00	34.00	1	0.00	0.00
G3369	0.00	0.00	620.00	620.00	620.00	1	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion
† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
G3370	0.00	0.00	15.00	9.40	12.20	1	0.00	0.00
G3371	0.00	0.00	17.00	17.00	17.00	1	0.00	0.00
G3372	0.00	0.00	47.00	47.00	47.00	1	0.00	0.00
G3373	0.00	0.00	45.00	45.00	45.00	9	0.00	0.00
G3374	0.00	0.00	200.00	200.00	200.00	1	0.00	0.00
G3375	0.00	0.00	14.00	14.00	14.00	1	0.00	0.00
G3376C	0.00	0.00	8.80	8.80	8.80	1	0.00	0.00
G3377B	0.00	0.00	11.00	11.00	11.00	1	0.00	0.00
G3377C	0.00	0.00	11.00	11.00	11.00	1	0.00	0.00
G3378A	0.00	0.00	27.00	19.00	22.00	1	0.00	0.00
G3378B	0.00	0.00	21.00	18.00	20.50	1	0.00	0.00
G3378C	0.00	0.00	50.00	20.00	29.43	1	0.00	0.00
G3379A	0.00	0.00	22.00	22.00	22.00	1	0.00	0.00
G3379B	0.00	0.00	26.00	23.00	22.29	1	0.00	0.00
G3379C	0.00	0.00	15.00	21.00	18.88	1	0.00	0.00
G3380A	0.00	0.00	21.00	22.00	21.50	1	0.00	0.00
G3380B	0.00	0.00	21.00	22.00	22.50	1	0.00	0.00
G3380C	0.00	0.00	15.00	22.00	18.71	1	0.00	0.00
G3381A	0.00	0.00	36.00	51.00	44.00	1	0.00	0.00
G3381C	0.00	0.00	37.00	51.00	42.33	1	0.00	0.00
G3382A	0.00	0.00	37.00	49.00	41.71	1	0.00	0.00
G3382B	0.00	0.00	35.00	49.00	41.00	1	0.00	0.00
G3382C	0.00	0.00	34.00	50.00	40.88	1	0.00	0.00
G3383A	0.00	0.00	38.00	50.00	43.17	1	0.00	0.00
G3383B	0.00	0.00	38.00	49.00	42.17	1	0.00	0.00
G3383C	0.00	0.00	37.00	48.00	39.67	1	0.00	0.00
G3384A	0.00	0.00	2500.00	2600.00	2240.00	1	0.00	0.00
G3384B	0.00	0.00	960.00	1100.00	1032.00	1	0.00	0.00
G3384C	0.00	0.00	790.00	1300.00	845.71	1	0.00	0.00
G3385A	0.00	0.00	9800.00	10000.00	9900.00	1	0.00	0.00
G3385B	0.00	0.00	1200.00	1200.00	1242.86	1	0.00	0.00
G3385C	0.00	0.00	520.00	630.00	488.75	1	0.00	0.00
G3386A	0.00	0.00	1500.00	1400.00	1360.00	1	0.00	0.00
G3386B	0.00	0.00	1200.00	1200.00	1200.00	1	0.00	0.00
G3386C	0.00	0.00	160.00	330.00	204.29	1	0.00	0.00
G3387A	0.00	0.00	29.00	35.00	31.75	1	0.00	0.00
G3387B	0.00	0.00	30.00	32.00	30.00	1	0.00	0.00
G3387C	0.00	0.00	27.00	29.00	28.80	1	0.00	0.00
G3388A	0.00	0.00	32.00	32.00	30.75	1	0.00	0.00
G3388B	0.00	0.00	29.00	33.00	30.17	1	0.00	0.00
G3388C	0.00	0.00	36.00	48.00	38.57	1	0.00	0.00
G3396A	0.00	0.00	64.00	63.00	64.00	1	0.00	0.00
G3396B	0.00	0.00	65.00	63.00	64.00	1	0.00	0.00
G3398A	2.50	2.88	23.00	24.00	23.33	1	2.48	2.86
G3398B	0.00	0.00	25.00	27.00	26.00	1	0.00	0.00
G3399B	0.00	0.00	24.00	23.00	23.50	1	0.00	0.00
G3399C	0.00	0.00	27.00	24.00	25.50	1	0.00	0.00
G3400A	0.00	0.00	38.00	38.00	38.00	1	0.00	0.00
G3400B	0.00	0.00	40.00	42.00	41.00	1	0.00	0.00
G3401A	0.00	0.00	37.00	42.00	39.50	1	0.00	0.00
G3401B	0.00	0.00	38.00	42.00	40.00	1	0.00	0.00
G3403A	0.00	0.00	34.00	36.00	35.00	1	0.00	0.00
G3403B	0.00	0.00	7.10	30.00	18.55	1	0.00	0.00
G3405C	0.00	0.00	19000.00	19000.00	19000.00	1	0.00	0.00
G3406B	0.00	0.00	20000.00	20000.00	20000.00	1	0.00	0.00
G3407A	0.00	0.00	20000.00	20000.00	20000.00	1	0.00	0.00
S 68A	0.00	0.00	420.00	250.00	269.64	1	0.00	0.00
S 531	0.00	0.00	26.00	42.00	33.59	1	0.00	0.00
PB 445	17.18	17.52	48.00	48.00	48.00	11	16.90	17.24
PB 467	0.00	0.00	55.00	38.00	48.82	98	0.00	0.00
PB 490	1.51	2.00	1600.00	390.00	572.10	127	-1.66	-1.17
PB 491	2.90	3.25	6200.00	14000.00	10384.76	207	-2.27	-1.93
PB 492	2.28	3.12	25.00	20.00	23.87	163	-1.80	-0.95
PB 555	3.61	4.31	36.00	26.00	26.33	200	-1.39	-0.69
PB 565	3.58	3.35	10.00	52.00	31.00	22	3.03	2.80
PB 567	2.60	3.03	30.00	34.00	30.36	93	0.28	0.70

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion

† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
PB 568A	0.00	0.00	92.00	90.00	91.67	41	0.00	0.00
PB 568B	0.00	0.00	79.00	67.00	73.00	52	0.00	0.00
PB 568C	0.00	0.00	63.00	60.00	63.00	77	0.00	0.00
PB 569B	0.00	0.00	50.00	50.00	50.00	43	0.00	0.00
PB 569C	0.00	0.00	39.00	39.00	39.00	73	0.00	0.00
PB 595	1.22	1.61	12000.00	11000.00	9961.60	114	-1.63	-1.24
PB 596	1.84	2.18	55.00	40.00	77.54	62	0.29	0.63
PB 605	0.00	0.00	60.00	60.00	60.00	49	0.00	0.00
PB 606	0.00	0.00	53.00	53.00	53.00	48	0.00	0.00
PB 610B	0.00	0.00	71.00	66.00	69.25	73	0.00	0.00
PB 620	7.55	8.10	18.00	14.00	22.10	32	6.75	7.30
PB 632	3.43	4.06	2500.00	7200.00	5291.85	272	-3.37	-2.74
PB 634	0.00	0.00	12000.00	18000.00	15086.96	1	0.00	0.00
PB 689	24.30	24.69	22.00	22.00	22.00	17	23.87	24.27
PB 690	1.54	1.19	5500.00	6600.00	8483.72	1	1.51	1.17
PB 692	0.86	1.41	10000.00	13000.00	68748.94	1	0.83	1.38
PB 693	3.46	4.30	29.00	990.00	325.25	275	-3.42	-2.58
PB 694	3.57	4.11	130.00	2200.00	1039.75	249	-2.66	-2.12
PB 710	3.19	3.60	64.00	44.00	63.14	18	2.74	3.15
PB 711	8.69	9.64	23.00	35.00	20.00	23	8.11	9.06
PB 717	21.22	21.86	24.00	21.00	22.50	1	21.19	21.84
PB 718	0.00	0.00	32.00	32.00	32.00	1	0.00	0.00
PB 732	5.66	6.57	48.00	48.00	48.00	100	3.16	4.07
PB 738	0.00	0.00	79.00	57.00	68.00	1	0.00	0.00
PB 746	2.43	2.90	98.00	68.00	99.29	82	0.38	0.85
PB 752	3.76	4.89	15.00	18.00	16.50	23	3.18	4.31
PB 789	4.33	4.79	30.00	12.00	39.00	20	3.83	4.29
PB 808	0.00	0.00	49.00	57.00	53.33	150	0.00	0.00
PB 809	10.07	10.85	28.00	28.00	26.40	145	6.45	7.22
PB 832	1.00	1.40	51.00	74.00	70.49	141	-2.52	-2.13
PB 833	0.00	0.00	54.00	12.00	44.47	1	0.00	0.00
PB 834B	2.34	3.35	2400.00	3500.00	5187.36	201	-2.68	-1.68
PB 835B	2.30	3.25	100.00	78.00	76.53	120	-0.70	0.25
PB 843	0.00	0.00	580.00	580.00	580.00	1	0.00	0.00
PB 849	2.29	0.00	620.00	2500.00	1317.14	1	2.26	-0.03
PB 875	13.40	14.04	53.00	33.00	42.00	24	12.80	13.44
PB 880	13.36	13.88	49.00	120.00	69.26	118	10.41	10.93
PB 889	3.38	3.87	1800.00	2400.00	2149.30	200	-1.62	-1.13
PB 895	2.87	3.37	36.00	30.00	44.25	19	2.40	2.90
PB 896	2.89	3.45	35.00	32.00	35.92	85	0.77	1.33
PB 897	2.22	2.62	51.00	93.00	55.70	23	1.65	2.05
PB 898	0.00	0.00	210.00	210.00	210.00	95	0.00	0.00
PB 900	14.46	14.73	40.00	40.00	40.00	63	12.89	13.16
PB 917	1.73	0.00	7200.00	6500.00	6850.00	85	-0.39	-2.12
PB 921	0.96	1.49	8900.00	11000.00	9695.00	150	-2.79	-2.26
PB 922	0.66	0.03	15.00	40.00	43.00	140	-2.84	-3.47
PB 928	8.52	9.09	33.00	33.00	31.88	115	5.65	6.21
PB 929	0.00	0.00	24.00	24.00	24.33	65	0.00	0.00
PB 931	0.00	0.00	25.00	27.00	24.20	90	0.00	0.00
PB 934	0.00	0.00	73.00	87.00	69.50	15	0.00	0.00
PB 935	15.51	15.83	38.00	38.00	38.00	48	14.31	14.63
PB 936	0.00	0.00	58.00	53.00	55.50	15	0.00	0.00
PB 940	0.00	0.00	100.00	100.00	100.00	65	0.00	0.00
PB 941	0.00	0.00	71.00	71.00	71.00	85	0.00	0.00
PB 942	0.00	0.00	72.00	68.00	67.00	65	0.00	0.00
PB 943	0.00	0.00	120.00	120.00	120.00	70	0.00	0.00
PB 944	0.00	0.00	27.00	27.00	27.00	75	0.00	0.00
PB 947	2.86	3.38	30.00	24.00	32.49	87	0.69	1.20
PB 948	1.66	2.12	1300.00	10000.00	6863.95	175	-2.72	-2.26
PB 949	3.57	4.28	220.00	1700.00	635.37	196	-1.33	-0.62
PB1006	2.19	2.63	72.00	60.00	54.62	17	1.77	2.20
PB1008	0.00	0.00	62.00	62.00	62.00	19	0.00	0.00
PB1009	0.00	0.00	30.00	30.00	30.00	16	0.00	0.00
PB1010	0.00	0.00	14.00	14.00	14.00	18	0.00	0.00
PB1011	0.00	0.00	37.00	37.00	37.00	26	0.00	0.00
PB1013	0.00	0.00	25.00	28.00	26.50	15	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion
† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
PB1014	0.00	0.00	26.00	26.00	26.00	15	0.00	0.00
PB1015	0.00	0.00	17.00	20.00	18.33	16	0.00	0.00
PB1016	0.00	0.00	21.00	21.00	21.00	22	0.00	0.00
PB1020	0.00	0.00	25.00	24.00	24.50	116	0.00	0.00
PB1022	1.50	0.00	1900.00	1900.00	1900.00	1	1.48	-0.03
PB1026	0.00	0.00	27.00	27.00	27.00	84	0.00	0.00
PB1033	0.00	0.00	110.00	110.00	110.00	115	0.00	0.00
PB1035	0.00	0.00	100.00	89.00	94.50	86	0.00	0.00
PB1037	0.00	0.00	11.00	10.00	10.50	24	0.00	0.00
PB1060	0.00	0.00	38.00	38.00	38.00	68	0.00	0.00
PB1061	0.00	0.00	23.00	23.00	23.00	42	0.00	0.00
PB1063	7.27	7.90	52.00	60.00	58.98	134	3.92	4.55
PB1085	0.00	0.00	67.00	69.00	68.00	87	0.00	0.00
PB1088	0.00	0.00	140.00	140.00	140.00	1	0.00	0.00
PB1089	10.34	11.26	93.00	35.00	71.00	135	6.96	7.88
PB1091	0.00	0.00	42.00	42.00	42.00	100	0.00	0.00
PB1094	0.00	0.00	210.00	200.00	205.00	100	0.00	0.00
PB1097	15.50	16.15	53.00	65.00	59.00	90	13.25	13.90
PB1098	0.00	0.00	82.00	82.00	82.00	80	0.00	0.00
PB1099	0.00	0.00	1100.00	1100.00	1100.00	90	0.00	0.00
PB1100	0.00	0.00	77.00	71.00	74.00	1	0.00	0.00
PB1101	0.00	0.00	33.00	32.00	32.50	95	0.00	0.00
PB1103	0.00	0.00	37.00	37.00	37.00	120	0.00	0.00
PB1104	0.00	0.00	37.00	38.00	37.50	105	0.00	0.00
PB1107	14.05	14.37	170.00	170.00	170.00	105	11.42	11.75
PB1108	13.80	14.41	130.00	130.00	130.00	90	11.55	12.16
PB1109	0.00	0.00	860.00	840.00	850.00	1	0.00	0.00
PB1110	0.00	0.00	20.00	20.00	20.00	55	0.00	0.00
PB1111	14.57	0.00	10.00	50.00	30.00	1	14.55	-0.03
PB1122	0.00	0.00	19.00	19.00	19.00	55	0.00	0.00
PB1123	0.00	0.00	14.00	14.00	14.00	25	0.00	0.00
PB1124	0.00	0.00	140.00	140.00	140.00	1	0.00	0.00
PB1126	0.00	0.00	120.00	120.00	120.00	1	0.00	0.00
PB1127	0.00	0.00	11.00	11.00	11.00	25	0.00	0.00
PB1128	0.00	0.00	290.00	290.00	290.00	1	0.00	0.00
PB1129	0.00	0.00	60.00	60.00	60.00	30	0.00	0.00
PB1131	0.00	0.00	88.00	88.00	88.00	30	0.00	0.00
PB1134	0.00	0.00	140.00	140.00	140.00	1	0.00	0.00
PB1135	0.00	0.00	56.00	56.00	56.00	1	0.00	0.00
PB1151	3.26	3.89	39.00	330.00	36.03	138	-0.19	0.44
PB1152	12.43	13.22	110.00	28.00	69.00	1	12.40	13.20
PB1153	12.43	13.02	28.00	28.00	28.00	1	12.41	12.99
PB1155	13.45	14.10	39.00	20.00	29.80	75	11.57	12.23
PB1156	14.45	14.58	37.00	37.00	37.00	1	14.43	14.55
PB1157	13.69	14.00	46.00	22.00	38.67	1	13.67	13.98
PB1160	5.33	6.04	10.00	10.00	10.00	20	4.83	5.54
PB1236	0.00	0.00	44.00	44.00	44.00	1	0.00	0.00
PB1428	0.00	0.00	220.00	1700.00	1073.00	127	0.00	0.00
PB1455	3.73	4.27	30.00	26.00	26.12	157	-0.20	0.35
PB1456	4.82	5.41	22.00	22.00	20.77	193	0.00	0.59
PB1457	4.48	5.14	21.00	24.00	26.43	203	-0.60	0.06
PB1460	0.00	0.00	21.00	39.00	30.00	30	0.00	0.00
PB1461	0.00	0.00	170.00	170.00	170.00	1	0.00	0.00
PB1462	0.00	0.00	200.00	200.00	200.00	1	0.00	0.00
PB1463	0.00	0.00	250.00	1200.00	523.33	1	0.00	0.00
PB1464	0.00	0.00	440.00	440.00	440.00	1	0.00	0.00
PB1465	0.00	0.00	1800.00	1700.00	1750.00	1	0.00	0.00
PB1466	0.00	0.00	220.00	220.00	220.00	1	0.00	0.00
PB1467	0.00	0.00	3200.00	3200.00	3200.00	1	0.00	0.00
PB1468	0.00	0.00	600.00	600.00	600.00	1	0.00	0.00
PB1469	0.00	0.00	180.00	180.00	180.00	1	0.00	0.00
PB1471	0.00	0.00	880.00	460.00	670.00	1	0.00	0.00
PB1472	0.00	0.00	140.00	140.00	140.00	1	0.00	0.00
PB1473	0.00	0.00	350.00	320.00	335.00	1	0.00	0.00
PB1475	0.00	0.00	120.00	120.00	120.00	1	0.00	0.00
PB1476	0.00	0.00	110.00	110.00	110.00	1	0.00	0.00

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion

† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

Table 5 (Continued). Data from Individual Biscayne Aquifer Monitoring Wells

Well ID	Dry season avg.water level (ft)	Wet season avg.water level (ft)	Initial Chloride (ppm)	Latest Chloride (ppm)	Avg. Chloride (ppm)	Well Depth (ft)	Dry Season Protection Criterion	Wet Season Protection Criterion
PB1477	0.00	0.00	540.00	530.00	535.00	1	0.00	0.00
PB1478	0.00	0.00	130.00	130.00	130.00	1	0.00	0.00
PB1480	0.00	0.00	100.00	160.00	130.00	1	0.00	0.00
PB1481	0.00	0.00	9400.00	9400.00	9400.00	1	0.00	0.00
PB1482	0.00	0.00	9400.00	9400.00	9400.00	1	0.00	0.00
PB1483	0.00	0.00	9600.00	9600.00	9600.00	1	0.00	0.00
PB1484	0.00	0.00	5300.00	5400.00	5350.00	1	0.00	0.00
PB1485	0.00	0.00	4200.00	4200.00	4200.00	1	0.00	0.00
PB1486	0.00	0.00	4200.00	4200.00	4200.00	32	0.00	0.00
PB1496	2.92	3.54	34.00	310.00	84.36	200	-2.08	-1.46
PB1510	14.30	0.00	250.00	250.00	250.00	1	14.28	-0.03
PB1512	14.39	0.00	190.00	190.00	190.00	1	14.37	-0.03
PB1514	14.70	0.00	24.00	24.00	24.00	1	14.68	-0.03
PB1517	14.59	0.00	6.40	6.40	6.40	1	14.57	-0.03
PB1519	14.89	0.00	14.00	14.00	14.00	1	14.87	-0.03
PB1520	11.59	14.48	17.00	20.00	30.68	22	11.04	13.93
PB1522	0.00	0.00	34.00	29.00	30.71	22	0.00	0.00
PB1524	16.86	18.05	520.00	550.00	441.19	1	16.84	18.02
PB1547	16.41	17.19	6.00	10.00	8.00	115	13.53	14.32
PB1548	16.26	16.89	60.00	50.00	54.00	60	14.76	15.39
PB1552	16.92	17.78	560.00	580.00	577.50	1	16.89	17.75
PB1553	16.78	18.33	640.00	490.00	566.67	1	16.76	18.31
PB1560	17.72	19.24	1200.00	1100.00	1125.00	1	17.69	19.21
PB1561	17.78	20.33	2300.00	2200.00	2250.00	1	17.76	20.31
PB1583	17.44	17.00	190.00	140.00	134.00	1	17.42	16.98
PB1584	0.00	0.00	22.00	21.00	22.33	1	0.00	0.00
PB1585	0.00	0.00	27.00	24.00	25.50	1	0.00	0.00
PB1589A	0.00	0.00	65.00	26.00	110.33	1	0.00	0.00
PB1589B	0.00	0.00	67.00	70.00	73.00	1	0.00	0.00
PB1589C	0.00	0.00	58.00	58.00	58.00	1	0.00	0.00
PB1589D	0.00	0.00	50.00	65.00	64.33	1	0.00	0.00
PB1589E	0.00	0.00	27.00	24.00	29.00	1	0.00	0.00
PB1589F	0.00	0.00	26.00	99.00	45.00	1	0.00	0.00
PB1590A	17.61	18.60	32.00	16.00	22.67	1	17.59	18.57
PB1590B	0.00	0.00	120.00	220.00	200.00	1	0.00	0.00
PB1590C	0.00	0.00	280.00	210.00	220.00	1	0.00	0.00
PB1590D	0.00	0.00	280.00	140.00	213.33	1	0.00	0.00
PB1590E	0.00	0.00	280.00	240.00	256.67	1	0.00	0.00
PB1590F	0.00	0.00	96.00	96.00	100.67	1	0.00	0.00
PB1590G	0.00	0.00	13.00	15.00	14.67	1	0.00	0.00
PB1609A	0.00	0.00	10.00	11.00	12.67	1	0.00	0.00
PB1609B	0.00	0.00	11.00	15.00	15.33	1	0.00	0.00
PB1609C	0.00	0.00	33.00	110.00	53.67	1	0.00	0.00
PB1609D	0.00	0.00	150.00	160.00	153.33	1	0.00	0.00
PB1609E	0.00	0.00	51.00	65.00	63.67	1	0.00	0.00
PB1609F	0.00	0.00	94.00	140.00	111.33	1	0.00	0.00
PB1609G	0.00	0.00	20.00	47.00	28.67	1	0.00	0.00
PB1609H	0.00	0.00	20.00	9.00	12.80	1	0.00	0.00
PB1643	5.69	6.35	26.00	32.00	28.00	87	3.52	4.17
PB1647	4.07	5.22	30.00	24.00	24.67	1	4.05	5.20
PB1651	0.00	0.00	36.00	39.00	41.63	1	0.00	0.00
PB1652	0.00	0.00	39.00	37.00	41.68	1	0.00	0.00
PB1653	0.00	0.00	140.00	120.00	119.43	1	0.00	0.00
PB1669	4.76	6.10	38.00	34.00	36.56	131	1.48	2.82
PB1686	4.10	5.31	34.00	40.00	38.00	126	0.95	2.16

*Average Dry season water level minus theoretical head necessary to prevent saltwater intrusion

† Average Wet season water level minus theoretical head necessary to prevent saltwater intrusion

*

DRAFT

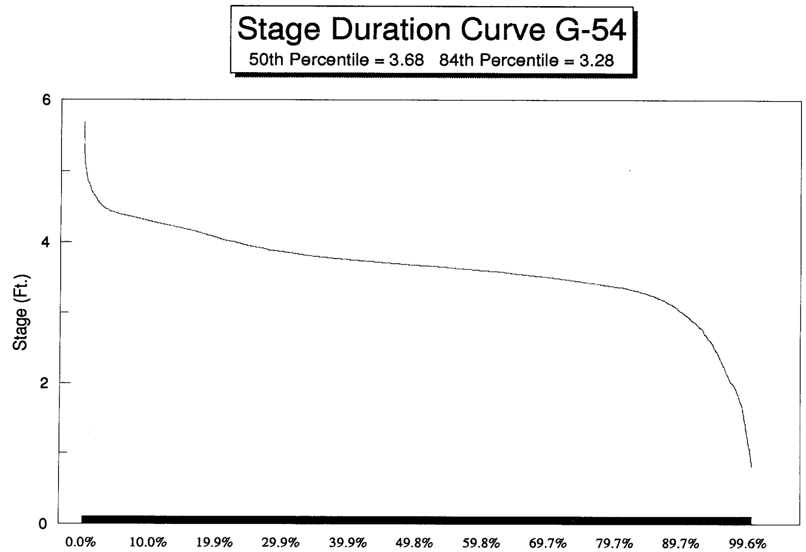
Proposed Minimum Water Level Criteria
for Lake Okeechobee, the Everglades,
and the Biscayne Aquifer
within the
South Florida Water Management District

Appendix B -

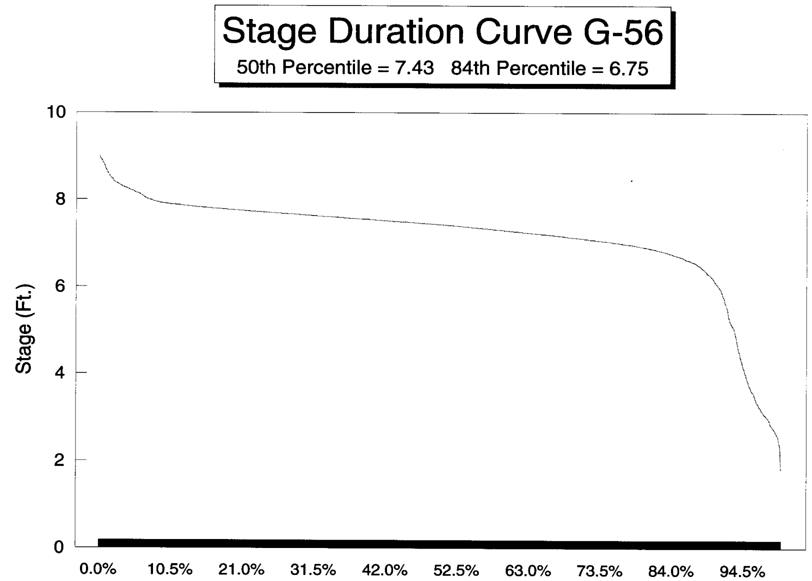
Stage Duration Curves for Key Coastal Water Control Structures in Dade, Broward and Palm Beach Counties

Prepared by Staff of:

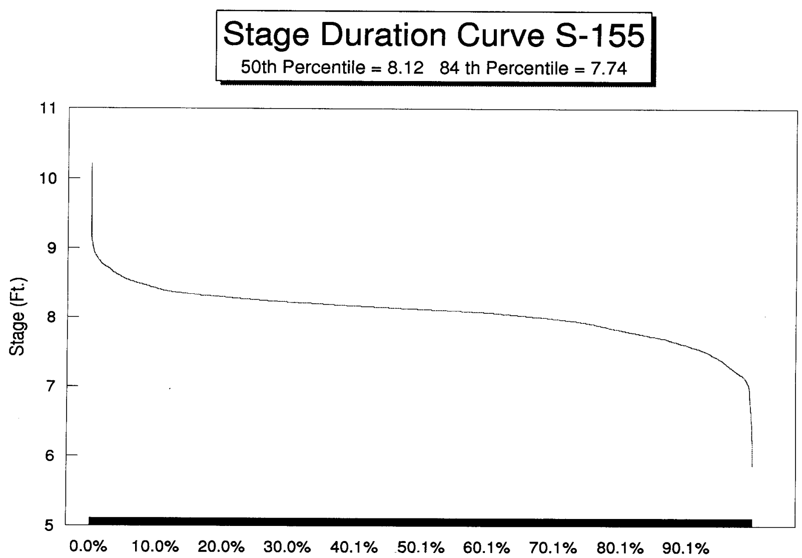
Planning Department
South Florida Water Management District
West Palm Beach, Florida
May 11, 1998



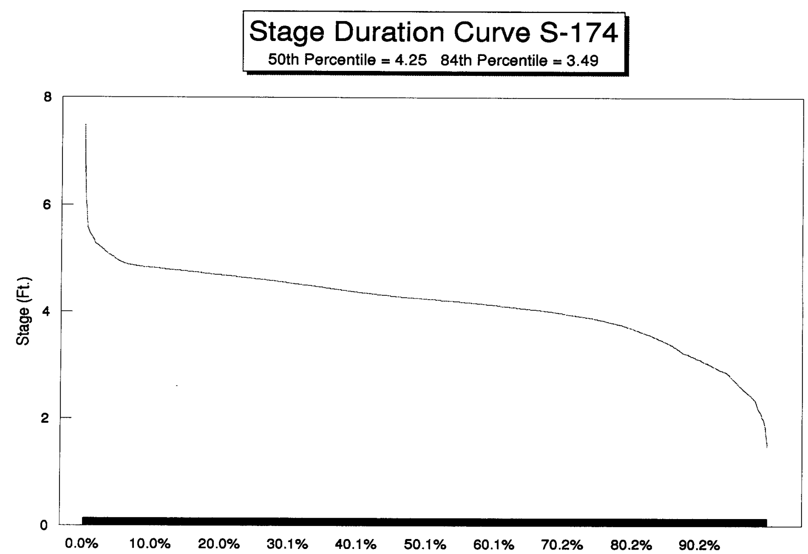
Stage Duration Curve G-54
50th Percentile = 3.68   84th Percentile = 3.28
Stage (Ft.)
6
4
2
0
0.0%
10.0%
19.9%
29.9%
39.9%
49.8%
59.8%
69.7%
79.7%
89.7%
99.6%



Stage Duration Curve G-56
50th Percentile = 7.43   84th Percentile = 6.75
Stage (Ft.)
10
8
6
4
2
0
0.0%
10.5%
21.0%
31.5%
42.0%
52.5%
63.0%
73.5%
84.0%
94.5%



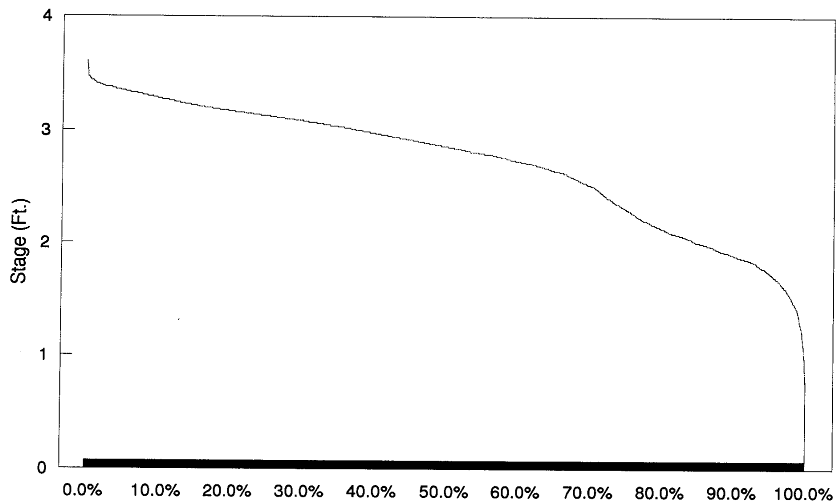
Stage Duration Curve S-155
50th Percentile = 8.12   84 th Percentile = 7.74
Stage (Ft.)
11
10
9
8
7
6
5
0.0%
10.0%
20.0%
30.0%
40.1%
50.1%
60.1%
70.1%
80.1%
90.1%



Stage Duration Curve S-174
50th Percentile = 4.25   84th Percentile = 3.49
Stage (Ft.)
8
6
4
2
0
0.0%
10.0%
20.0%
30.1%
40.1%
50.1%
60.1%
70.2%
80.2%
90.2%

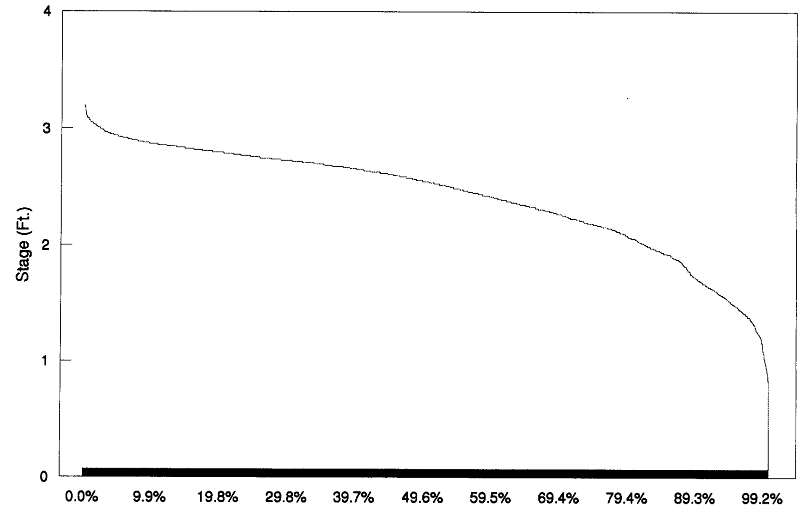
Stage Duration Curve S-22

50th Percentile = 2.86   84th Percentile = 2.04



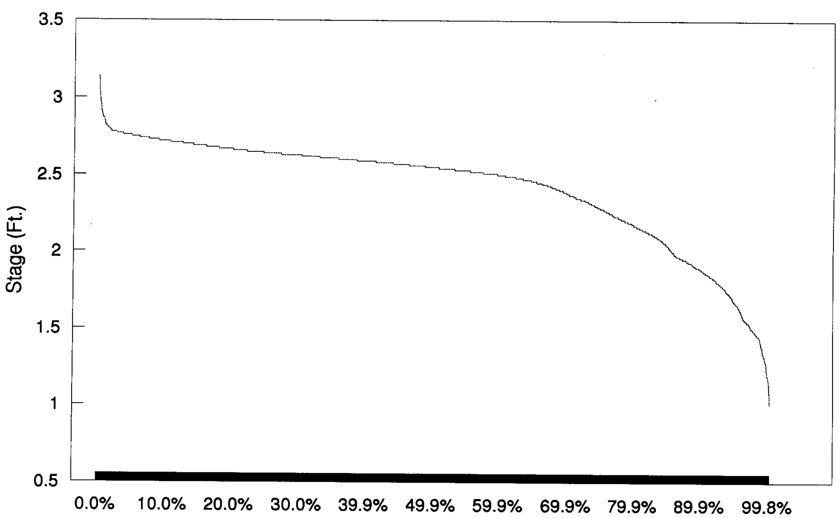
Stage Duration Curve S-25B

50th Percentile = 2.55   84th Percentile = 1.95



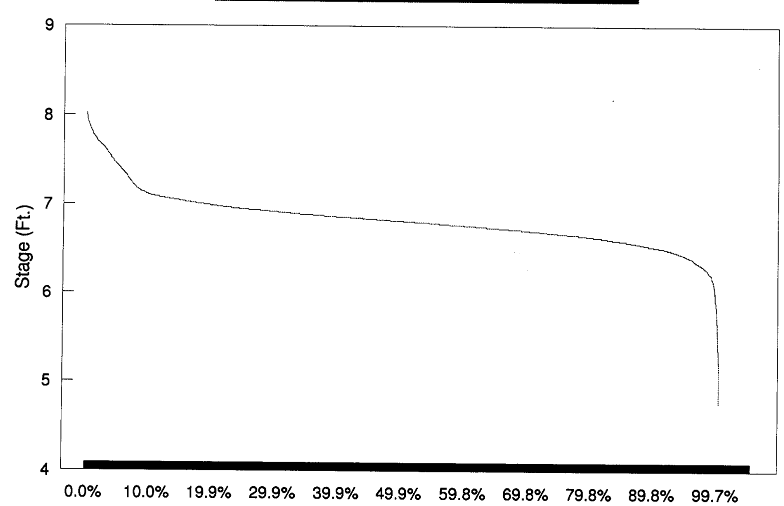
Stage Duration Curve S-26

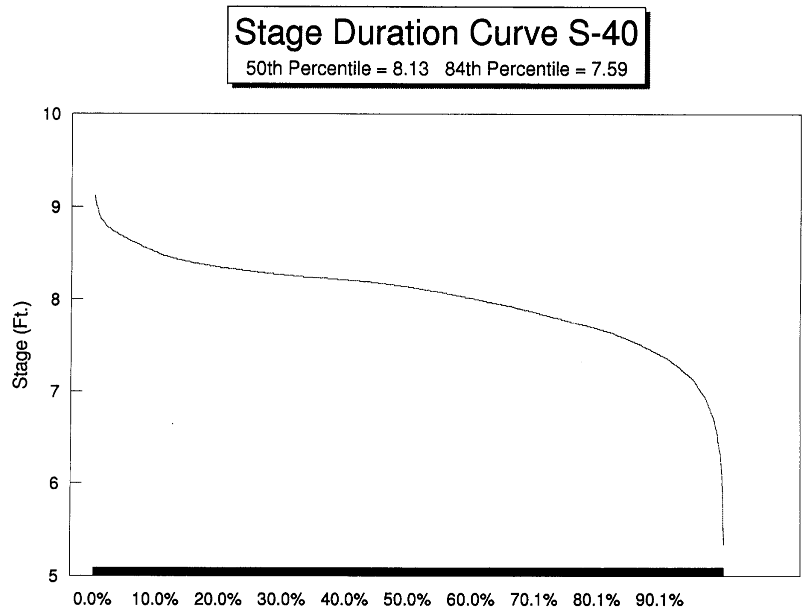
50th Percentile = 2.55   84th Percentile = 2.07

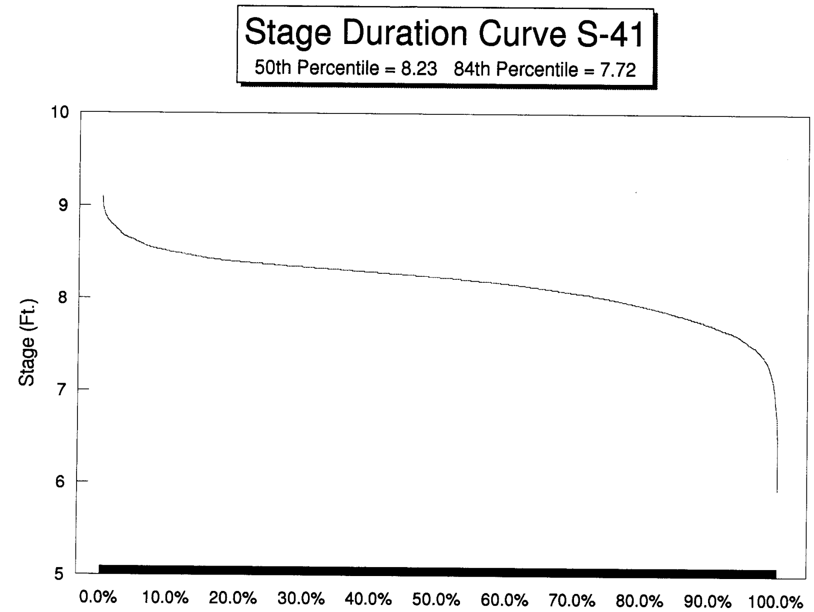


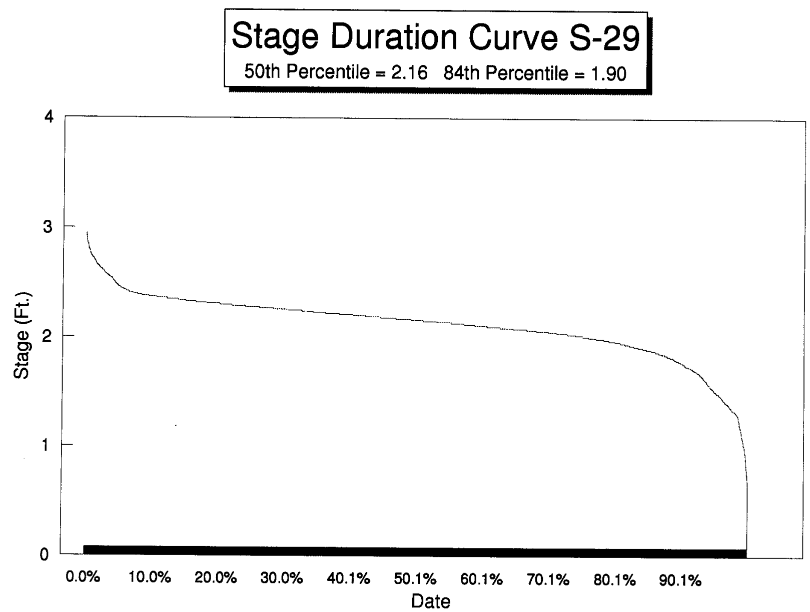
Stage Duration Curve S-37B

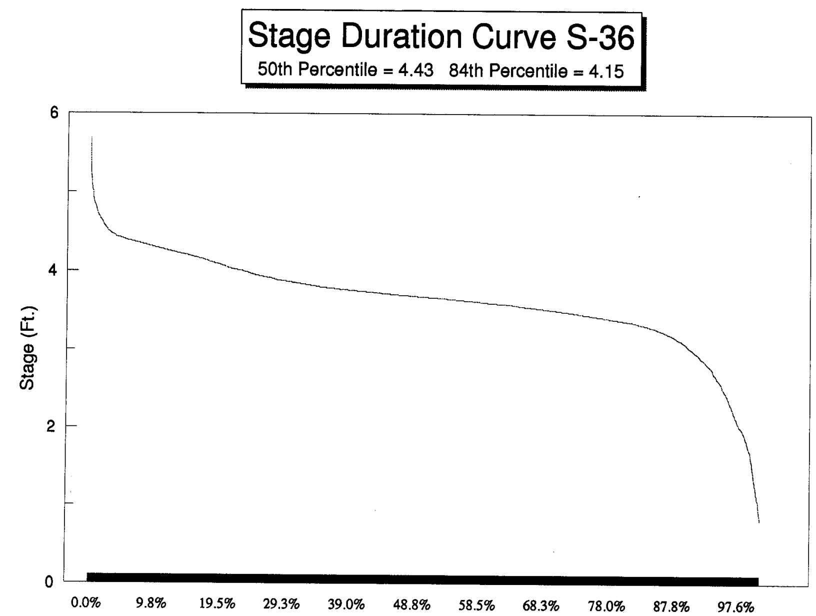
50th Percentile = 6.82   84th Percentile = 6.60




Stage Duration Curve S-40
50th Percentile = 8.13 84th Percentile = 7.59
Stage (Ft.)
10
9
8
7
6
5
0.0% 10.0% 20.0% 30.0% 40.0% 50.0% 60.0% 70.1% 80.1% 90.1%


Stage Duration Curve S-41
50th Percentile = 8.23 84th Percentile = 7.72
Stage (Ft.)
10
9
8
7
6
5
0.0% 10.0% 20.0% 30.0% 40.0% 50.0% 60.0% 70.0% 80.0% 90.0% 100.0%


Stage Duration Curve S-29
50th Percentile = 2.16 84th Percentile = 1.90
Stage (Ft.)
4
3
2
1
0
0.0% 10.0% 20.0% 30.0% 40.1% 50.1% 60.1% 70.1% 80.1% 90.1%
Date


Stage Duration Curve S-36
50th Percentile = 4.43 84th Percentile = 4.15
Stage (Ft.)
6
4
2
0
0.0% 9.8% 19.5% 29.3% 39.0% 48.8% 58.5% 68.3% 78.0% 87.8% 97.6%

*

DRAFT

Proposed Minimum Water Level Criteria

for Lake Okeechobee, the Everglades,

and the Biscayne Aquifer

within the

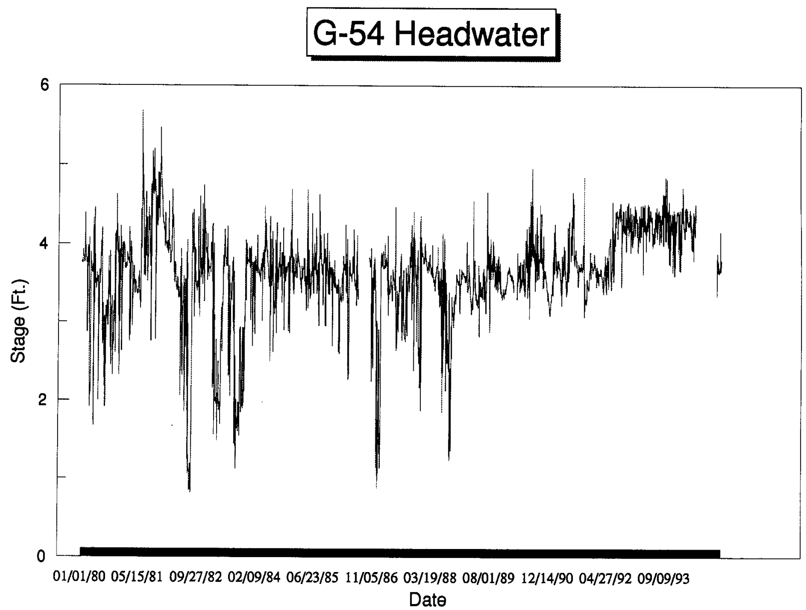
South Florida Water Management District

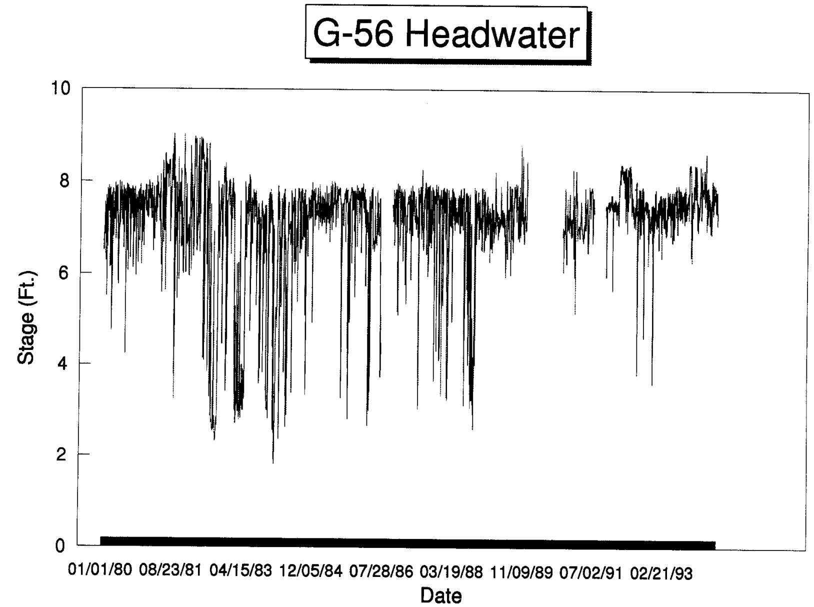
Appendix C -

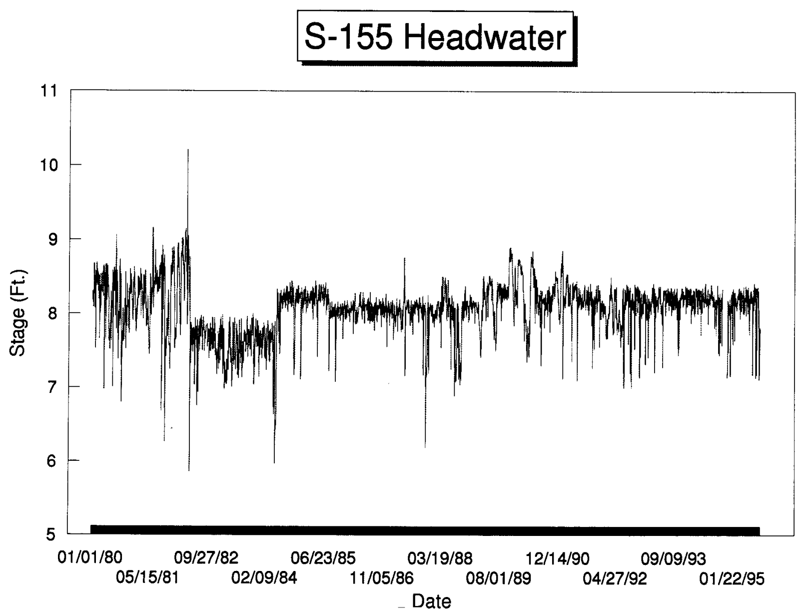
Head Water Stages for Key Coastal Water Control Structures in Dade, Broward and Palm Beach Counties

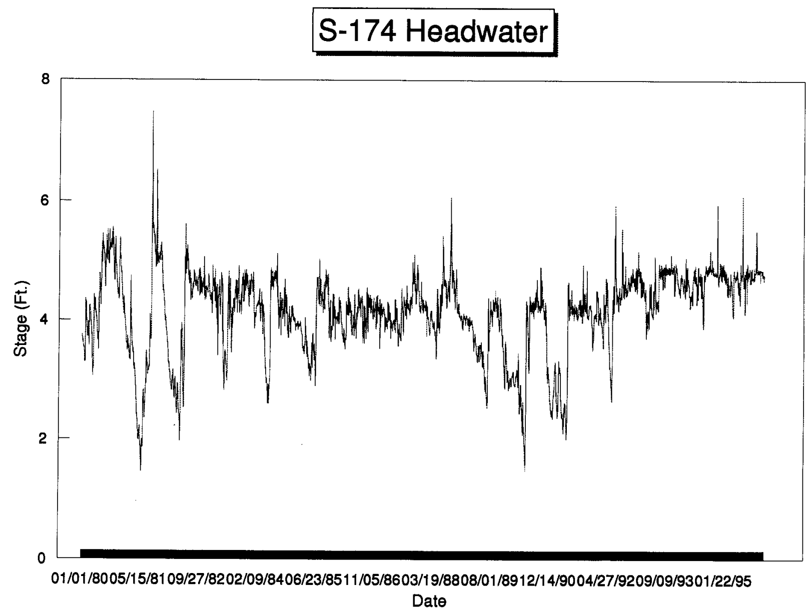
Prepared by Staff of:

Planning Department
South Florida Water Management District
West Palm Beach, Florida
May 11, 1998

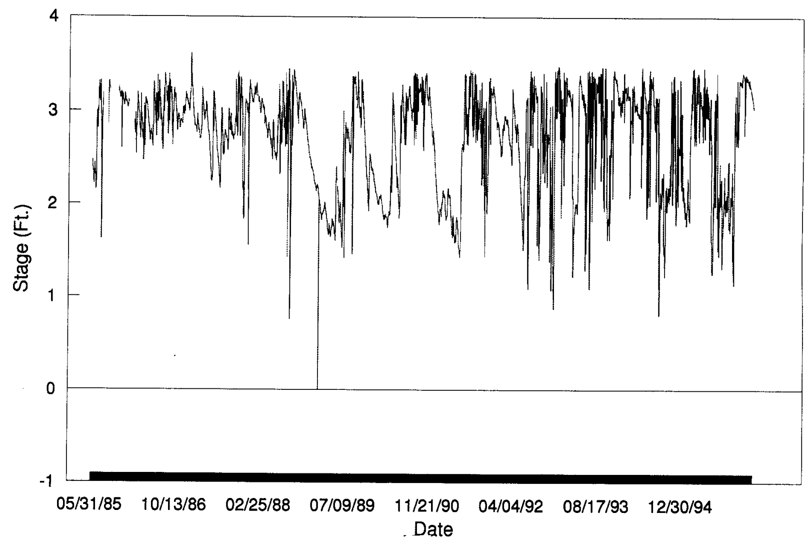

G-54 Headwater
Stage (Ft.)
0
2
4
6
01/01/80 05/15/81 09/27/82 02/09/84 06/23/85 11/05/86 03/19/88 08/01/89 12/14/90 04/27/92 09/09/93
Date


G-56 Headwater
Stage (Ft.)
0
2
4
6
8
10
01/01/80 08/23/81 04/15/83 12/05/84 07/28/86 03/19/88 11/09/89 07/02/91 02/21/93
Date

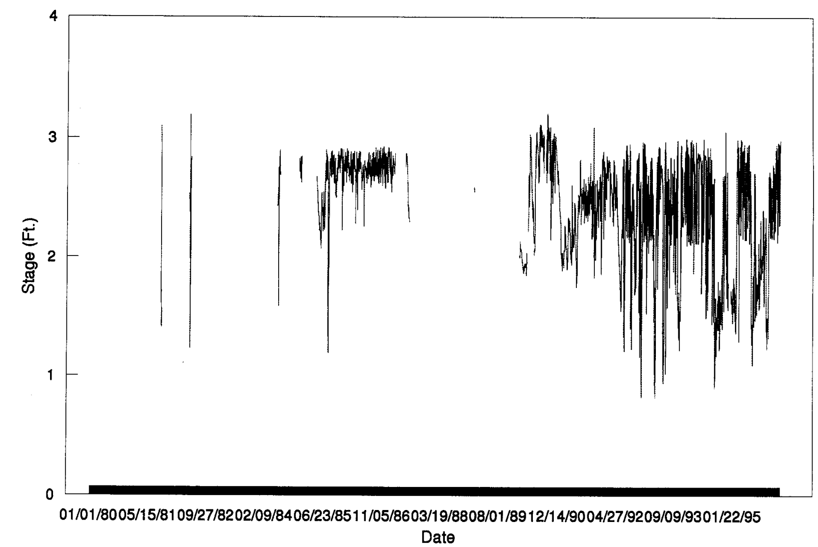

S-155 Headwater
Stage (Ft.)
5
6
7
8
9
10
11
01/01/80 09/27/82 06/23/85 03/19/88 12/14/90 09/09/93
05/15/81 02/09/84 11/05/86 08/01/89 04/27/92 01/22/95
Date


S-174 Headwater
Stage (Ft.)
0
2
4
6
8
01/01/8005/15/8109/27/8202/09/8406/23/8511/05/8603/19/8808/01/8912/14/9004/27/9209/09/9301/22/95
Date

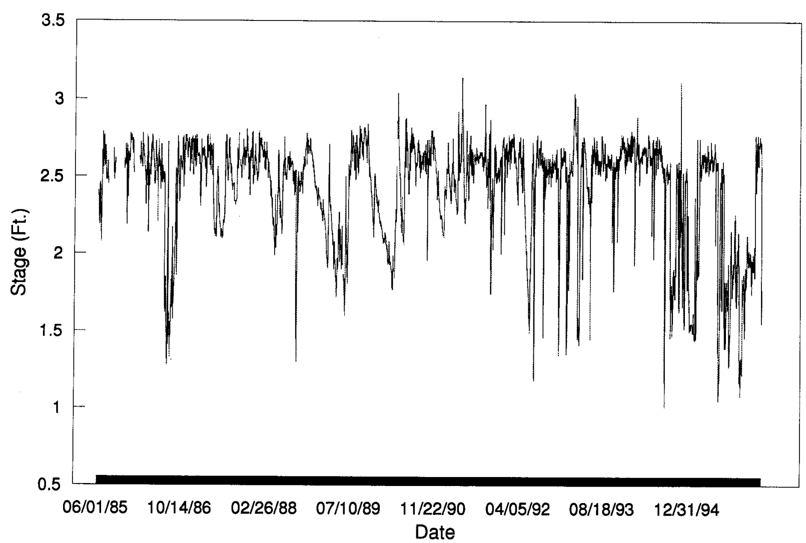
S-22 Headwater



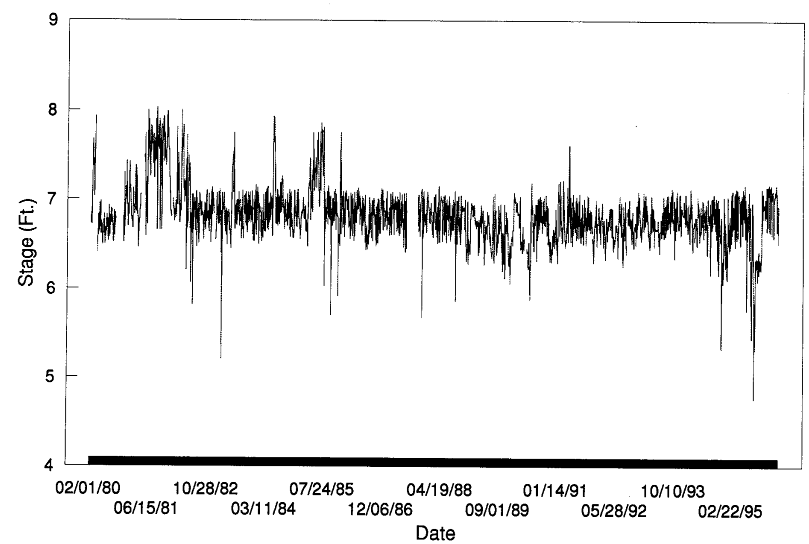
S-25B Headwater

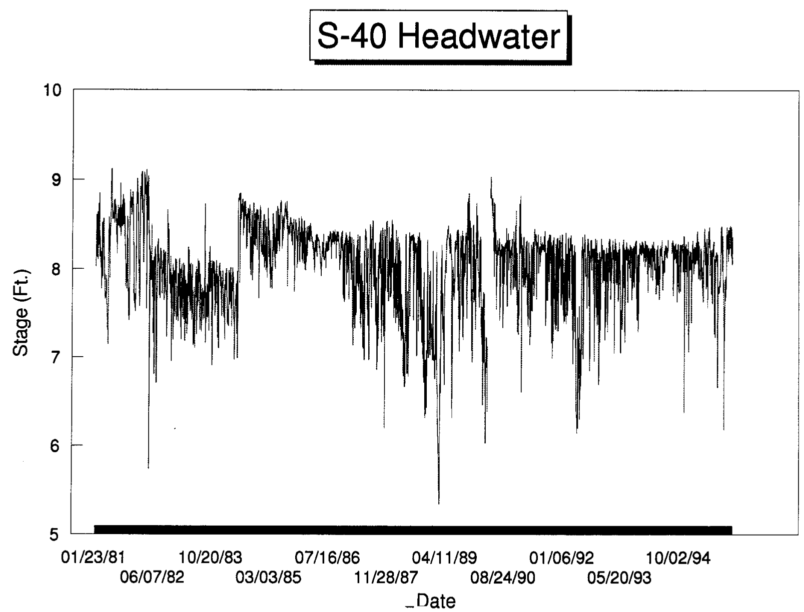


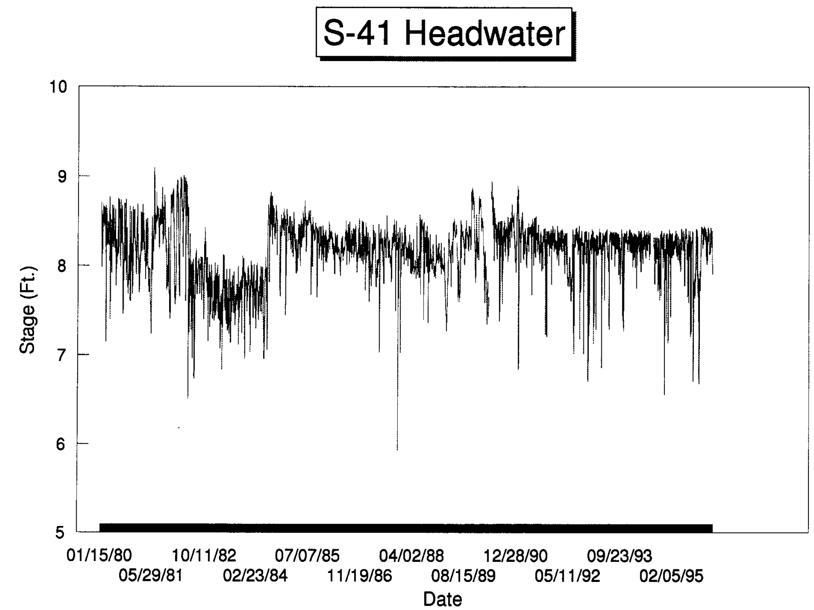
S-26 Headwater

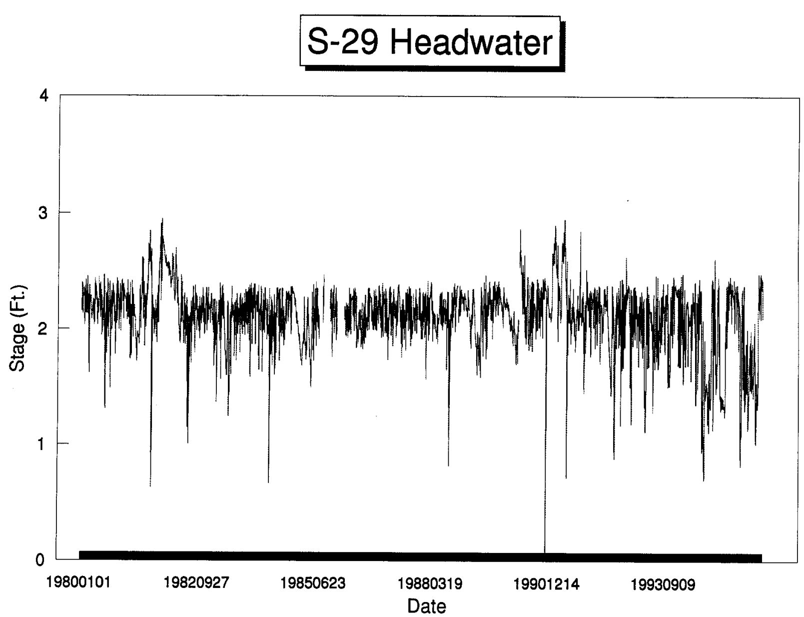


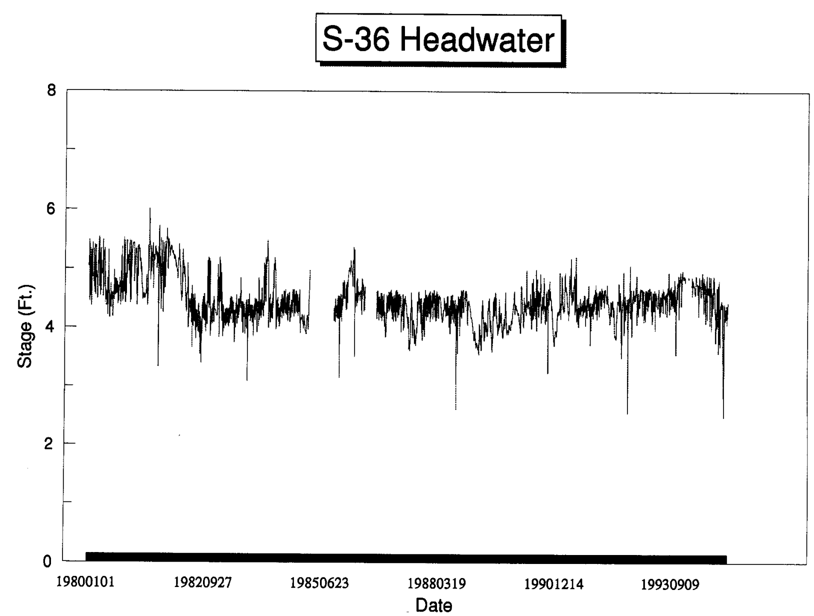
S-37B Headwater




S-40 Headwater
Stage (Ft.)
10
9
8
7
6
5
01/23/81
06/07/82
10/20/83
03/03/85
07/16/86
11/28/87
04/11/89
08/24/90
01/06/92
05/20/93
10/02/94
_Date


S-41 Headwater
Stage (Ft.)
10
9
8
7
6
5
01/15/80
05/29/81
10/11/82
02/23/84
07/07/85
11/19/86
04/02/88
08/15/89
12/28/90
05/11/92
09/23/93
02/05/95
Date


S-29 Headwater
Stage (Ft.)
4
3
2
1
0
19800101
19820927
19850623
19880319
19901214
19930909
Date


S-36 Headwater
Stage (Ft.)
8
6
4
2
0
19800101
19820927
19850623
19880319
19901214
19930909
Date

APPENDIX D -- COMMENTS AND RESPONSES

Table of Contents

APPENDIX D - COMMENTS AND RESPONSES

I. Comments and Responses to Frequently Asked Questions

GENERAL COMMENTS

1. Consider the Entire Ecosystem.

Minimum Flows and Levels should be discussed in the context of the entire system, since decisions made in one area may impact management options in adjacent and downstream areas.

In developing Minimum Flows and Levels, the entire Everglades needs to be considered as a functioning unit, beginning with the needs of Florida Bay and the Biscayne Aquifer (at the lowest points in the system) and proceeding north to the Kissimmee headwaters. Fully addressing this issue is considered to be a major component of system restoration. Restoration of flow is a critical component of the overall Everglades system restudy efforts, since options will be examined that include removal of structures or features that impede flow, and filling-in or otherwise modifying channels that presently expedite flow to the wrong places.

2. Flows vs. Water Levels.

This report emphasizes development of minimum water levels, whereas the legislation refers to minimum flows as well as minimum levels.

Providing adequate flow of water through the system is a complex issue that is not easy to address with the tools available. The rate at which water moves through the Everglades (especially the marshes) is too slow to measure by any conventional monitoring technique, hence flow rates are unknown in most of the system. Flow is inferred from water depths and gradients across large areas. Therefore, it is assumed that maintaining adequate water *levels* in Everglades National Park, for example, will ensure that *flow* occurs into Florida Bay. Restoration of flow is a critical component of the overall Everglades system restudy efforts, since options will be examined that include removal of structures or features that impede flow.

3. Interconnections Between Areas.

The fact that the various managed areas are interconnected, means that criteria for one area cannot be set independently of the other areas. Although each of the managed areas has different requirements, operation and needs of the system in its entirety must be considered to adequately protect the resource.

The proposed criteria were designed (in part) to be applicable throughout the system, and to avoid the temptation (as much as possible) to develop different criteria for separate areas. The importance of interconnections is best shown in Florida Bay. There is no way to deal directly with the freshwater flow requirements for Florida Bay, since most fresh water moves into the bay through groundwater seepage and ungaged overland flow through Everglades National Park. The intent of the District (with concurrence from Everglades National Park staff) is to establish appropriate water level conditions in the Park. It is assumed that if these levels are achieved, sufficient water will flow by gravity and seepage to Florida Bay.

4. Minimum vs. Maximum Levels.

The discussion of significant harm cannot be addressed without also considering maximum flows and levels.

District staff concur that establishing ***minimum*** levels alone may not be sufficient to protect the resource from harm due to floods or extended periods of high water conditions. Setting minimum levels is viewed as a starting point from which to define the necessary hydrologic regime for the entire Kissimmee - Lake Okeechobee - Everglades Ecosystem. Achieving the required water levels throughout this system is an overall, long-term restoration goal. ***Maximum*** levels for Lake Okeechobee and the water Conservation areas are presently controlled by the regulation schedules for these areas, but the overall ability of these criteria to protect the resource is uncertain. As a result, new or revised maximum water level criteria are being considered in the Lower East Coast Regional Water Supply Planning process for certain areas, such as WCA-3A, 3B and 2A, to protect existing tree islands. Use of the Natural Systems Model to determine hydrologic management criteria for the Everglades also provides a means to identify maximum water level criteria. The model simulates water conditions throughout the system that can be used to determine maximum water levels and the appropriate statistical frequency for occurrence of such levels.

5. Limited Monitoring Data.

A major limitation for developing this plan is the lack of extensive, accurate or complete historical water level or ecological data and observations throughout most of South Florida.

Limited data are available for some parts of the system during the past 20 years and limited data at certain locations extend back to the turn of the century. Almost no information is available that describe conditions that existed before drainage canals were constructed.

Even today we have relatively crude and widely spaced monitoring capabilities in the Everglades (a few gages spread across millions of acres). With such tools, there is a great risk that by the time these gages indicate a problem, it may be very extensive. We also run the risk that very large problems may occur in the system that cannot be detected with existing methods. For these reasons, we consider the proposed criteria to be very conservative, in the sense that if we detect a problem at all, it is could potentially be a very big problem.

6. Using Models to Assess Ecosystemwide Impacts.

The plan is based largely on the use of mathematical simulation models rather than on direct data and observations.

The use of mathematical models is an approximate technique, but most scientists agree that it provides the best known means to attempt to reconstruct historical conditions and to expand the limited number of observational data available to cover a larger geographical area. This approach was endorsed by technical experts at the meeting of the Lower East Coast Water Supply Scientific Advisory Group that was held in August, 1994. Models also, to a certain extent, provide a means to assess needs of, and impacts on, the entire ecosystem rather than focusing on specific management areas.

Results of the model runs are analyzed to determine changes in water levels throughout the system. *Triggers* (water level conditions that result in the release of more water into or through the system) are used to modify or direct performance of the model. *Performance measures* (water levels that indicate the relative status or condition of particular areas) are used to determine impacts. The use of models allows District staff and other reviewers to compare responses that occur within different areas and systemwide. The Natural Systems Model indicates how the system may have performed historically (prior to construction of water control facilities and provides some indication of how it perhaps should be modified to perform in the future (restoration targets). The South Florida Water Management Model and historical data indicate how the existing system operates. The use of these two models together makes it possible to identify conditions or circumstances when it may be appropriate to move water from one part of the system to another to achieve a balancing of benefits and impacts.

Using the Natural Systems and South Florida Water Management models alone as the basis to develop criteria has some well-recognized limitations and may not give appropriate results for some areas within the system. For that reason the District decided not to solely rely on model results but rather to modify the results with actual data from field research, where such data were available. The choice of soil characteristics and water depths represents such a resource-based approach. Data from the Natural Systems Model were only used to establish criteria for parameters or areas where adequate data could not be obtained by other means (e.g. to establish proposed return frequencies).

7. How Minimum Flows and Levels Criteria Will Be Used.

It is not clear during the implementation to what extent these criteria will be used primarily to guide operational decisions or as regulatory triggers.

Effects of current supply side management practices and various options will be analyzed as part of the modeling of the Minimum Flows and Levels technical criteria. Phased implementation will be considered if modeling or other studies indicate that implementing the proposed Minimum Flows and Levels and associated regulatory actions will have significant impacts. Phasing and adaptive management are also part of the long-term efforts associated with the Lower East Coast Regional Water Supply Plan and the Restudy.

The saltwater intrusion criteria proposed in this document are intended primarily protect water resources (water quality) to maximize reasonable beneficial uses of water, not to protect any particular permitted user or class of users. Modeling results will indicate how these proposed criteria impact the frequency and severity of declared water shortages.

8. Significant Harm.

The term, significant harm, needs to be clearly defined and consistently applied. The choice of saltwater intrusion (salinity) as a measure of harm for the Biscayne Aquifer does not adequately consider other sources of harm (e.g. pollutants) or biological impacts on estuarine resources.

Permanent or long term (decades) loss of habitat or water resource component is considered to constitute a "significant" impact on the resource. By this standard, the existing water management system and practices have already done significant harm to the system. Minimum flows and levels are designed primarily to keep conditions from getting worse. Impacts to existing and future agricultural and municipal users, identified in terms of water shortage frequency, severity and duration, and the threat of saltwater intrusion, will be documented in the Lower East Coast Regional Water Supply Plan.

The proposed soil criteria attempt to address the issue of harm to the resource by identifying conditions that are likely to result in oxidation or burning of soils and/or damage to their overlying ecosystems that will require decades or longer to recover from or restore. Such damages are considered to be significant in the sense that allowing such conditions to persist does not constitute sustainable management of water resources.

The Lower East Coast Regional Water Supply Plan and the United States Army Corps of Engineers and other agencies, through the Restudy process, will incorporate and further define the concepts of significant harm and sustainability of water resources. The proposed Minimum Flows and Level criteria represent the lower level of the restoration process and provide a performance measure to determine how well the system is being managed as we make changes and move forward. Minimum Flows and Levels also provide a starting point for determining water supply delivery and allocation capabilities for regulation, permitting and future planning. Preliminary modeling results indicate that these proposed criteria are not dramatically different from current management practices.

9. Establishment of Significant Harm - Process.

The process for establishing and implementing Minimum Flows and Levels and determining significant harm is not clearly evident from this report. How does this process differ from the Lower East Coast Regional Water Supply Planning process?

The process for development of Minimum Flows and Levels will run parallel to that for Lower East Coast water supply planning. This revised, ***"Proposed Minimum Water Flows and Levels Criteria for the Lower East Coast Planning Area"*** document is being developed simultaneously with the plan. The modeling studies that are being done top analyze plan alternatives and options also include the proposed Minimum Flows and Levels criteria. The document describing the proposed Minimum Flows and Levels criteria and the Lower East Coast plan will both be completed before Minimum Flows and Levels rule making begins.

The use of interim or phase-in steps to achieve Minimum Flows and Levels is part of the District's overall adaptive management strategy. We will identify those areas or aspects where these levels are not achieved, estimate the effects of short term and long term actions that should be initiated to eventually achieve Minimum Flows and Levels, and describe how the Minimum Flows and Levels relate to overall, long-term restoration goals. In addition, we must recognize that our initial proposed management goals may not be perfect. We will therefore have to monitor how the system performs over time with these criteria in place and modify the criteria, if necessary, to improve results.

10. Significant Harm Definitions for Different Resources.

Section 373.042 requires minimum levels to be set at a point identifying significant harm to water resources. The statute also requires that minimum flows be set at a point identifying significant harm to both water resources and ecology of an area.

For the purposes of this report, the primary water resource components that are being considered in the Lower East Coast Planning Area are: ecological functions of wetland systems in the Everglades and Lake Okeechobee, the ability of the Biscayne Aquifer to maintain local water tables and provide potable water, and the ability of Everglades muck and marl soils to support viable natural plant and animal communities.

This document describes what is known of the cause and effect relationships between water levels and flows and associated impacts to water resources and the related natural environment. This includes determination of how water levels or redistribution affect flows and levels and the degree of impact that can be associated with varying flows and levels. The point at which such impacts becomes "significant," in terms of aerial extent and degree, is a policy issue that needs to be resolved.

Ecology.

One aspect of the definition of harm for water resources is based on impairment of ecological function of aquatic systems. This applies to wetlands, lakes and rivers. These systems must maintain their ability to sustain viable plant and animal communities, in conjunction with their other water resource functions.

Aquifers.

Aquifers have a different set of issues, since withdrawals from particular aquifers may or may not be tied to ecological function of surface water resources. In the case of the Biscayne Aquifer, where the linkage is clear, withdrawals are constrained through the permit process, by the impacts on nearby wetland systems, but also by the potential to degrade water quality in the aquifer due to saltwater intrusion. Minimum Flows and Level definition of harm is based on similar criteria

Wetlands.

For this initial pass at developing Minimum Flows and Levels criteria for wetlands, harm is defined to occur when the duration and/or frequency of water level reductions is thought create a substantial risk that long-term damage could occur to soils and the vegetation and other related values such as fish, wildlife etc. that depend on them. In the long term, management that promotes such damage is not considered to be sustainable. In no case are we contending that the damage is "permanent" or "irreversible" or that muck soils lost in this manner could not be replaced, although full recovery may occur on a "geological" time scale.

Muck Soils.

In the case of muck soils, we are proposing that harm occurs when the muck becomes dry and burns. Since muck is deposited at a rate of about 1/2 to 1 inch of muck per hundred years or so, loss of an inch of muck may represent 100 to 200 years of deposition. Loss of a foot of muck may thus represent 1200 to 2400 years of deposition. Such damage occurs (and has historically occurred) sporadically in the natural system on an occasional and largely localized basis. Widespread damage of this sort could not have occurred very often or the Everglades would not contain the massive muck deposits that exist in some areas today.

Marl Soils.

In the case of marl soils, the situation is more complex, because we are not contending that reduction in water levels results in loss of soils. Extended dehydration can result in compaction of marl soils, which means that when the area is reflooded to the same level, the water depth may be different and the vegetation communities may change. Also dehydration below certain levels results in almost complete loss of soil moisture at the surface, resulting in the probable death of components of the overlying plant and animal communities. We are proposing that these conditions constitute more than the normal amount of expected harm to the system. How much of this "more than normal" harm has to occur before the effect on the resource becomes "significant, " is a policy issue that remains to be resolved. We have proposed Minimum Flows and Levels criteria based on certain assumptions concerning these policy factors, as specified in the report.

Lake Okeechobee.

Although the relative tradeoffs in managing Lake Okeechobee need to be considered during subsequent policy and rule making discussions, has regionally-important natural resource values. Some provision needs to be made to protect these resources for a variety of reasons, such as its economic value to sports and recreation, and the habitat and food source it provides for threatened and endangered species.

The scientific basis for developing minimum water levels for the Lake is based on analysis of historical data (much like the Natural Systems Model approach that was used in the Everglades) and on information from the literature that documents the effects of low water conditions on ecosystem components and species of particular concern. In this case, emphasis was not placed primarily on soils, but rather on protecting the lake's littoral zone from adverse changes to the size, distribution, and species composition of native vegetation communities.

11. Integration with Supply Side Management.

How will these proposed Minimum Flows and Levels criteria be integrated with the District's drought management procedures?

The District's Supply Side Management policies for allocation and distribution of water during severe drought events have been integrated with these Minimum Flows and Levels criteria and analyzed as part of the modeling component of the Lower East Coast Regional Water Supply Plan.

12. Seasonal Differences in Minimum Flows and Levels.

These proposed Minimum Flows and Levels criteria do not appear to consider or account for natural seasonal patterns of water level fluctuation.

For this initial proposal, seasonal minimum levels were not defined for two primary reasons:

- We have not found a clearly defined scientific basis in the literature for establishing such levels, and;
- The concept of minimum flows is initially intended to address sustained low water conditions, whenever they may occur, because these are considered to be periods when the system is subject to one form of harm that may affect the system for a long period of time. The proposed criteria are intended to indicate when the ecosystem is especially vulnerable to severe fire conditions that could result in large scale destruction of peat soils. Such concerns are generally not an issue during the wet season

Seasonality issues are incorporated in existing regulation schedules and in operational criteria for coastal basins. Seasonal changes are also an implicit feature of the District's day to day management practices, which focus on water supply in dry periods and flood control in the wet season. Hydrologic and operational features and requirements for Lake Okeechobee and the Water Conservation Areas drive water levels, independent of our ability to control levels through Minimum Flows and Levels. Better definition of seasonal water requirements for these systems will be a component of overall system a restoration using the Natural Systems Model and the Central and Southern Florida Flood Control Project restudy.

In estuaries, rainfall and local runoff generally keep salinities moderate to low throughout the wet season, and it is mostly during the dry season that hypersalinity becomes a problem.

13. Setting Minimum Flows and Levels is Not a Restoration Tool.

Minimum Flows and Levels are not a means to achieve restoration, they are simply a means to protect existing conditions.

The concept has been proposed that Minimum Flows and Levels really constitute a means of achieving "maximum impacts short of significant harm" in terms of resource protection. Another similar concept was stated by the LEC committee, i.e. the "significant harm threshold point," that represents the water levels at which harm first becomes apparent. Both of these are considered to be useful constructs in terms of understanding the thought processes behind minimum flows and levels and their implications. It is clear from these definitions that Minimum Flows and Levels are not viewed as a means of achieving restoration but rather to assure that the current condition of the resources is not further degraded during extreme events. Different management criteria will be needed to ensure that the resource improves over time, toward some eventual goal of "restoration." These restoration criteria are being defined in the Lower East Coast Regional Water Supply Plan process and the Central and Southern Florida Flood Control Project Restudy.

14. Identify Criteria that Constitute Significant Harm to Existing Legal Users.

This document fails to identify and consider criteria that would constitute "significant harm" to existing legal users.

The concept of significant harm is discussed to some extent in the text. For the purpose of this analysis, harm to a natural system has been defined as permanent or long term (decades) loss of habitat, community, species, or a water resource component. Past and current development and management practices have already harmed the system. In a similar manner, harm to agricultural and municipal users can be identified in terms of water shortage frequency, severity and duration, and threat of saltwater intrusion. The proposed Minimum Flows and Levels criteria were designed to protect the resource by documenting cause and effect relationships between water levels and flows and associated impacts to water and related natural environment resources and establishing a level of impact that is considered to be harmful to long term sustainability. Restoration is designed to eliminate or reduce harm that has occurred in the past. Subsequent impact analysis and rule making will more accurately establish the amount of harm that is occurring to both natural systems and human uses by documenting effects on resources, water shortages and saltwater intrusion.

15. Impacts on Existing Users.

The same types of criteria that were developed and used to define harm to the environment need to be developed and applied to existing legal users.

Although the criteria proposed in this report were initially established primarily on the basis of protecting natural systems, the criteria will be used as input to the South Florida Water Management Model. The effects of implementing these criteria on existing and future water demands will be analyzed. Adjustments can be made to investigate various possible options for applying these criteria, with the objective to both protect the resource and provide comparable (recent historical) levels of water delivery to coastal basins. Further studies of this nature will be conducted, in conjunction with the various water supply options that are analyzed in the Lower East Coast Regional Water Supply Plan.

The purpose of this document and proposed criteria is not to establish flow and level restrictions for particular canals, structures or basins. This report does not contain any recommended operational changes. The purpose is to build a common understanding of the underlying concepts and terminology. The revised criteria will be incorporated, and used to evaluate options presented, in the Lower East Coast Regional Water Supply Plan. Actual operational, regulatory and management criteria will established later, as part of the rule making and implementation process. Impacts of the proposed criteria on existing legal users, in conjunction with the various water supply options, will be assessed during all of these activities.

16. Separation of Scientific From Policy Issues.

In the Lake Okeechobee,/Everglades/Biscayne Aquifer system, it is impossible to separate the "science" of significant harm from the "policies" that formed the basis for constriction of the Central and Southern Florida Flood Control Project.

This document has attempted to place primary emphasis on scientific and resource-based issues, but obviously these cannot be considered in a total vacuum. The Everglades is presently a highly altered and highly managed system that has been "optimized" to meet multiple objectives. It is clear that the management objectives of the Central and Southern Florida Flood Control Project facilities have changed during recent history, and will continue to change over time. The exact magnitude and nature of these changes are not clear because they are constantly evolving in response to public attitudes and resulting policy decisions.

17. Physical Limitations to the Existing Water Management System.

These criteria may be difficult to implement because of local topographic features, operational or structural constraints

We recognize that the existing water management and delivery systems create special problems. Efforts to further characterize and correct these problems will be identified in the LEC plan and subsequent long-term restoration efforts. Minimum Flows and Levels cannot now be achieved effectively in certain parts of the Everglades because of physical limitations in the system. Operational and policy actions can only accomplish a certain amount. Limited flexibility of existing water management facilities will also hamper efforts to achieve long-term restoration goals. Facilities may have to be built, removed or modified to solve localized problems in some areas as part of the United States Army Corps of Engineers Restudy process.

BISCAYNE AQUIFER:

18. Harm due to Salinity vs. Harm due to Other Pollutants.

The choice of salinity as the sole indicator for the Biscayne Aquifer does not adequately address water quality, filtration and absorption of nutrients and pollutants, transfer of detrital material or sediment loads, or biological impacts on estuarine resources.

Salinity was chosen as a criterion because the District is primarily responsible for protecting the resource from salt water intrusion and water flows and levels have a direct impact on this parameter. Other agencies such as United States Environmental Protection Agency, Dade County Department of Environmental Resource Management, Florida Department of Health and Rehabilitative Services and Florida Department of Environmental Protection have primary responsibility to deal with other sources of aquifer contamination and environmental impact. Most aquifer contaminants tend to occur as isolated plumes originating from a definite source. Regional criteria have not been established for such occurrences and they are better handled and resolved through individual permit criteria and a case-by-case analysis. In developing initial Minimum Flows and Levels criteria for the Biscayne Aquifer, emphasis was placed on factors that could readily be controlled and monitored by and at the existing regional water management facilities -- canals, structures and monitoring network.

19. Maintenance Levels for Canals in South Dade.

District data show that the proposed minimum levels will not be maintained consistently in some south Dade County Canals, especially east of L-31 and South of Snapper Creek

Maintenance of water levels in the south Dade canals is a complex issue that has not been fully analyzed or resolved. A number of factors have to be considered before Minimum Flows and Levels criteria can be developed for this area, including the following:

1. The District cannot or does not maintain water levels in some South Dade canal systems, because the porous surficial aquifer acts like a sieve. If we attempted to maintain constant groundwater levels in these areas, we may sacrifice operational flexibility.
2. If the District decides to maintain some Minimum Flows and Levels at certain structures in South Dade canals, it is not clear which structures should be selected. It is clear from the data that any levels that can be maintained at structures along the coast will be inadequate because the front is already located miles inland from these structures. Therefore, the alternatives are to either a) retreat to the inland structures or b) attempt to maintain a sufficiently high water level along the coast to flush out the existing saltwater wedge, which would require tremendous amounts of water. Discharge of water for this purpose would have to be analyzed to determine the degree to which it constituted a reasonable-beneficial use.
3. To further compound these issues, if we abandon the coastal structures, the groundwater flow component into Biscayne Bay may be greatly reduced. At this point, groundwater minimum flow criteria for Biscayne Bay have not been established and we do not anticipate being able to set such criteria until some of the

ongoing research and modeling efforts have been completed. Without some estimate of required groundwater flow to the bay, it is impossible to set an exact water level along the coast.

4. Levels proposed for L-31 may be increased to protect ENP as well as to stabilize the saltwater interface.

These are just some of the problems that need to dealt with before we can adequately answer your comments concerning south Dade. The water levels proposed in this report are suggested as interim criteria to measure system performance until better data and more operational flexibility can be developed. Minimum Flows and Levels for these areas will be addressed again during the process of defining criteria for Biscayne Bay.

20. MFL Criteria Differ from Regulatory Criteria.

The proposed criteria for the Biscayne Aquifer appear to differ from existing regulatory criteria. How will water shortage rules and regulatory program be imposed on top of the proposed Minimum Flows and Levels?

The proposed minimum flows and levels definition differs from existing regulatory criteria because the Minimum Flows and Levels definition is applied throughout the entire interconnected regional system. Existing regulatory criteria are applied to site specific conditions, based on actual land elevation and water table conditions, adjacent wetlands, including isolated systems, and are established relative to existing water level conditions. The District will determine exactly how these proposed Minimum Flows and Levels will affect the regulatory process and the phased management of water shortages during the rule making process.

21. Saltwater Intrusion is Not a Problem in Some Areas.

There are some locations in South Florida where variation and movement of the saltwater interface can occur without substantial harm.

Staff concurs that further migration of the salt front may not be a problem in some areas of the Biscayne Aquifer. Based on these considerations, Minimum Flows and Levels criteria are not recommended for certain canals and basins where such conditions are believed to exist.

22. The Biscayne Aquifer is Currently Experiencing Harm.

Saltwater intrusion into the Biscayne Aquifer already threatens existing wellfields during drought periods.

The goal is to prevent further migration of the saltwater interface rather than to attempt to reverse harm that may already have occurred. The ability to move the front to a new location further seaward is primarily limited by the high transmissivity of the aquifer and the need to provide adequate flood protection to coastal basins.

23. Impacts of MFLs on Future Water Use.

How do these proposed criteria consider the future water needs for public water supply and agricultural water use?

The impacts of these minimum levels on existing and future users (2010 demands) of the water resource will be determined through modeling studies and the Lower East Coast Regional Water Supply Plan (LEC Plan) before rules are implemented. The proposed criteria are essentially the same as current practices and are not expected to have substantial impacts on existing users. Effects on future users will be assessed during development of the LEC Plan. The Minimum Flows and Levels criteria will provide an additional form of protection for the Biscayne Aquifer by imposing minimum levels for canals. Options to help meet needs of future users while not exceeding these proposed Minimum Flows and Levels criteria will be examined in the Lower East Coast Regional Water Supply Plan. Additional options will be examined during the United States Army Corps of Engineers Restudy process as part of achieving overall Everglades system restoration.

24. Protection of Other Aquifer Resource Functions.

All of the functions provided by the Biscayne Aquifer that depend on water levels, including flows in canals and rivers, support for plants and wildlife, littoral zones, lake levels, wetlands, soils, etc. should be considered when establishing Minimum Flows and Levels.

Protection of the wide range of functions provided by the Biscayne Aquifer that are related to water levels, including canal and river flows, lake levels and littoral zones, mitigation and protection of wetlands, prevention of subsidence, etc. will be addressed in the Lower East Coast Regional Water Supply Plan, during the Minimum Flows and Levels rule making process, and the United States Army Corps of Engineers Restudy of the Central and Southern Florida Flood Control Project.

25. Some Canals are Not Addressed by MFL Criteria.

Minimum Flows and Levels criteria only address certain canals and may have very localized influence over regional groundwater levels.

Present canal operation and maintenance levels were considered during development of these criteria. Other factors also influence canal levels, such as drainage, flood control and water supply requirements. These other needs will generally require that the stages in the canals be maintained higher than the proposed Minimum Flows and Levels criteria. Criteria were only established for canals that are part of the interconnected regional system, i. e., that can deliver water from Lake Okeechobee or the Water Conservation Areas to the coast. Canals that only provide local drainage capacity were not included in this initial analysis. Water levels in areas that are not influenced directly by the canals will be managed on the same basis as they are today. Canal levels and flows will also be addressed in the Lower East Coast Regional Water Supply Plan and during development of Minimum Flows and Level criteria for Biscayne Bay. Additional modeling is also underway to identify the area of influence for each canal. The proposed minimum levels for the canals may be modified, if such changes can be shown to offer greater protection

A minimum water level was not established for C-13 and S-34 because this canal has no direct connection to Lake Okeechobee (see above).

26. Analysis of Aquifer Data.

The report does not indicate exactly which historical or theoretical aquifer and canal data were used in the analysis.

More detailed information, including additional analysis of historical canal water level data and salt content of particular wells will be provided in the next draft.

27. Effects of Consumptive Use and Surface Water Management Permits.

The stated definition of Minimum Flows and Levels does not consider other impacts on groundwater levels that may be occurring, such as the effects of consumptive use withdrawals and surface water management systems,

Other impacts on groundwater levels that may be occurring will be addressed in greater detail in the revised document and in the LEC Plan. The regulatory discussion will be expanded to clarify the comparison and distinction between saltwater intrusion caused by drainage and well withdrawals. Canal water levels and permitted wellfield withdrawals were considered during development of Minimum Flows and Levels criteria and subsequent modeling to determine effects of these criteria. Other needs that control canal levels , such as drainage, flood control and self-supplied water requirements, and effects of remedial options, will be considered as part of the Lower East Coast Regional Water Supply Plan process. Canal levels and flows and water levels in the Biscayne Aquifer will also be addressed in development of Minimum Flows and Levels for Biscayne Bay.

28. Effects on Canal and Structure Operations

How will the proposed criteria affect canal and structure operations?

The extent to which the proposed criteria will change, alter or impact specific water management practices for the various canals and structures has yet to be determined. No actual changes to current operational, regulatory or management practices have been proposed at this time, but some changes may be recommended in the Lower East Coast Regional Water Supply Plan. Subsequent rule making will need to address water shortage emergency provisions to allow flexibility to deliver water to surficial aquifers when needed to prevent long term damage such as saltwater intrusion.

Preliminary modeling results indicate that the proposed criteria apparently have very little effect relative to current management practices. The criteria will increase protection of the Biscayne Aquifer by imposing minimum levels for canals. Additional modeling is underway to identify the area of influence for each canal. Minimum levels in some canals may be modified to offer greater protection. This section of the report will be rewritten to more clearly state the issues and concerns related to Minimum Flows and Levels, identify proposed interim criteria and layout strategy to develop more detailed Minimum Flows and Levels according to the schedule presented in the District Water Management Plan (April 1995).

29. The Proposed Minimum Levels May be Too Low.

The proposed minimum water levels at key structures appear to be much too low to prevent saltwater intrusion.

The criteria proposed in the Minimum Flows and Levels report are being applied as a means to evaluate how well the system is performing. No actual changes to current operational practices are proposed at this time. The water levels proposed for canals such as S-25B, S-26, S-22, C-51 and Hillsboro may be to low to adequately protect the wellfields that are located further seaward, between the canal and the saline interface. The proposed water levels were primarily intended to protect resources near the canals.

Additional modeling work is presently underway to look at increasing levels in C-51 and the Hillsboro canals above the levels specified in the report to see if these changes can provide increased protection for users located east of the structures.

LAKE OKEECHOBEE

30. Long Term Effects of Maintaining MFLs.

Long term maintenance of the minimum water levels proposed in this plan could result in damage to the system.

This issue is addressed, to some extent, through the return frequency component of the criteria, which indicates that these the criteria should not be exceeded more often than they were historically. In addition, our present operational capabilities do not give us sufficient control to be able to "maintain" these levels on a continuing basis, nor is there any biologically-driven need or desire to do so. This means that if future weather patterns are similar to historical patterns, during wet periods the system will be wet throughout, and there is little that could be done to "maintain" the minimum water levels.

31. Exposure of the Lake Bottom.

Most prior studies of Lake Okeechobee have emphasized the adverse effects that high water levels on the Lake. The basis for choosing a minimum level and duration for Lake Okeechobee is not clear, since low lake stages may arguably provide some important benefits.

Exposure of the bottom in itself is not an adverse impact, since existing marsh vegetation would not lose contact with the water table or capillary water. This conclusion holds true as long as one does not consider that fish spawning, larval fish development, and foraging depend on some minimal level of standing water above the sediment surface.

Frequent or prolonged loss of this standing water in critical habitat areas could have major impacts on lake fisheries.

32. Creating New Marsh.

Because of the gentle slope of the lake, it would appear that additional new marsh would be created at lower water levels.

This generally is not true for Lake Okeechobee. At the south end of the lake, there is potential for marsh expansion towards the mid-lake region, but along the edge of the large western marsh region, there is a relatively sharp drop off in depth. Furthermore, the high concentrations of suspended sediments in the lake water greatly limit light penetration into the water column, and restrict plant expansion lakeward. For these reasons, lower lake levels are not expected to cause widespread expansion of marsh.

33. Use of Drawdowns to Improve Lake Ecosystems.

Wouldn't the occurrence of Lower levels on a periodic basis have the effect of "drawdowns" practiced in other lakes, such as Lake Apopka, to control the spread of exotic macrophytes, including Hydrilla?

Given the scientific evidence that drawdowns would harm native vegetation communities in the lake's marsh zone, including Eleocharis and bulrush, we do not feel that such a management strategy could be justified on the basis of possible Hydrilla control. On the other hand, it is a valid point to say that periodic low water levels may benefit the wading bird communities "by concentrating prey resources." This issue is described in the document, and it was one of the conclusions of the Lake Okeechobee Ecosystem Study. The key point here is frequency and duration -- if the drawdowns occur too often or for too long, they will be harmful to the biota. The proposed return frequency for 11 ft events agrees well with conclusions from the Lake Okeechobee Ecosystem Study, and also reflects the natural return frequency for drought events during the last 40 years.

34. Torpedograss.

[2] It appears that the proposed minimum levels are based on minimizing the potential spread of torpedograss. If this is the management objective, other means for weed control should be considered and evaluated.

The proposed minimum water level criteria for Lake Okeechobee are designed to prevent substantial harm to the water resources, including biological communities, with a major focus on fish and birds. Plant community structure is the major determinant of habitat value for these animals (as documented in District and Florida Game and Fresh Water Fish Commission scientific research), and vegetation community structure is a function of hydroperiod (as documented in the results of the Lake Okeechobee Ecosystem Study). Scientific evidence indicates that if water levels fall below the 11 ft NGVD criterion for long periods of time, or if these events occur with a high frequency, critical animal habitat will be lost.

As an example, it has been documented that largemouth bass spawn and forage in bulrush communities, which occur between the 11 and 12 ft NGVD contour in the lake. Prolonged low water levels are expected to have harmful effects on this habitat and its estimated $175 million fishery (FGFWFC estimate, 1996). One of the changes expected to occur at low water levels is a replacement of *Eleocharis* by torpedo grass, primarily in the Moonshine Bay region of the lake. However, this is just one expected impact -- not the major driving force for the criteria selection. These points will be clarified in a revised version of the lake criteria.

THE EVERGLADES

35. Rocky Glades Criteria.

Water levels in these areas should be managed not only to protect soils and vegetation, but to ensure survival of invertebrates and small fishes that live in the flooded system and survive dry conditions in the bottom of pinnacle rock solution features. Perhaps more conservative conditions in terms of water level drawdowns and return frequencies should be considered. Exact relationships need to be defined by field investigations.

We do not disagree that more conservative criteria may be appropriate to protect aquatic resources of the Rocky Glades, but we were limited in our analysis by a lack of scientific data. If you can provide us with additional information to develop these criteria, we will be happy to consider them and revise or criteria if appropriate. The District may also consider supporting research and monitoring efforts in the Rocky glades during the next several years as a means to develop better information.

36. Marl Forming Wetlands.

The criterion for protection marl soils is not clearly stated. Is it based on protection of soils themselves or the other biota that live in and on these soils?

Marl soils tend to provide more capillary action to move water toward the surface than is provided by muck soils. Marl can therefore remain moist when water levels drop further below ground (24 to 30 inches for marl as opposed to 12 inches for muck). However, once the capillary effect is broken, marl soils dry very rapidly and to a very low soil moisture level. It is the judgment of our scientists, and supported by evidence from the scientific literature, that such extreme dry conditions result in death of the overlying shallow-rooted and surficial vegetation communities (such as periphyton) and any eggs or larvae of animals that could otherwise be sustained in moist soils. Such damage, although not irreversible, constitutes a major, "more than normal," setback to Everglades plant and animal communities when it occurs more frequently or for longer periods of time than such events occurred historically. The acceptable duration of water levels below ground was more difficult to establish for marl wetlands, because there was no definitive scientific evidence or opinion to provide a basis for determination. Results of model simulations indicated a range from 49 to 105 days, with an average of 75 days, for marl soils flanking Shark River slough. Since there was no other basis to choose a different number, 75 days was selected as the criterion.

As indicated in the report, the District will continue to work with staff of ENP to refine the depth and duration of minimum levels for both peat and marl soils in the Park.

37. Harm to Muck Soils.

The definition of harm for Everglades peat soils needs to be explained further.

Please see the discussion of muck soils (Topic No. 9) above. The proposed definition of significant harm for muck soils is based on the occurrence of dry conditions that may result in loss of muck due to burning. Loss of muck is considered to be significant harm because muck is an integral part of the historical northern Everglades Ecosystem that takes a long time to replace. Thus the harm caused a severe burn may last for many years or even centuries and is therefore considered as significant. The issues of aerial extent, frequency, depth of muck destruction, and time needed to replace the resource, are critical components of the definition of "significant" that must be resolved through technical and policy discussions.

Minimum Water Depth.

The one foot value for muck soils was chosen, based on information from the literature, as a representative depth of water below the surface that would sustain sufficient moisture at the surface through capillary action, to protect the soils from a moderate fire.

Effects of Fires.

Under extreme conditions in localized areas, a severely hot fire could possibly force water out of the soil first and then cause it to burn, even if the water is less than a foot below ground. Thus it is possible that "significant" damage could occur within the system with the proposed criteria in place. However. it is felt that the chances of such occurrences are very small and that the damage would tend be localized.

Muck depths in the Everglades are highly variable due to many factors besides fire frequency and water depth. These factors include depth to bedrock, land surface elevation, proximity to canals, and the presence of favorable water quality conditions (low pH and low dissolved solids) for muck deposition. Generally, muck soils are more than a foot deep throughout the Water Conservation Areas.

Duration.

The 30 day period of time that water is below ground was derived primarily from data in the literature, based on actual field studies of muck wetlands. A similar analysis of data from the Natural Systems Model indicated a range in duration of water levels below ground from 25 to 81 days with an average of 57 days. The 30-day criterion was chosen in favor of the 57-day criterion because a) there were was actual information from the literature to support this value, and b) it represents a somewhat more conservative and "safer" approach. It is proposed that exceeding this criterion on a frequent and sustained basis, greatly increases the likelihood that significant harm can occur to the system. The details of how the District will incorporate this criterion into regulatory and operational actions will be further analyzed during preparation of the Lower East Coast Regional Water Supply Plan.

Frequency.

The scientific literature and historical data indicate that peat burning was a natural occurrence in the Everglades. However, these studies also indicate that such burning occurred infrequently and was limited in spatial extent. Because of the great variability in elevations and depths of muck soils in the Everglades, the relatively sparse distribution of monitoring locations, and the fact that the minimum levels will not be "maintained" but only used as indicators or triggers, indicates that some areas of the Everglades will continue to experience peat fires. The intent is not to eliminate such fires, but rather to attempt to modify their frequency and extent to more closely mimic historical conditions.

FUNDING SOURCES

38. Funding Sources.

More considerations should be given to the use of user's fees as a source of funding.

While user fees have precise definitions, we are looking more closely at them in response to the committee's questions. User fees can be charged to current users for something discrete like raw water; it is more difficult to charge a user fee for a public good, such as flood protection. We see no apparent barriers to prevent this approach. Again, the revenues gained may not be sufficient to offset the cost of implementing and collecting these fees.

II. COMMENTS RECEIVED FROM THE SCIENTIFIC PEER REVEW PANEL 9/22/98

Final Report of the Peer Review Panel Concerning Proposed Minimum Water Level Criteria for Lake Okeechobee, the Everglades, and the Biscayne aquifer within the South Florida Water Management District (September 22, 1998).

PEER REVIEW PANEL:

1. Jeffrey L. Jordan, Ph.D., Chair, Professor Agricultural & Applied Economics, University of Georgia
2. John M. Shafer, Ph.D., Director & Professor, Earth Sciences & Resource Institute, 3. University of South Carolina
3. Donald M. Kent, Ph.D. Partner, Wetland Design Group, Ipswich, Massachusetts
4. Ellen van Donk, Ph.D. Head, Dept. of Food Chain Studies, NIOO-Centre for Limnology, The Netherlands

5. Charles L. Coultas, Ph.D. Retired Professor, Soil Science & Horticulture, Florida A&M University

INTRODUCTION

The responsibility of this panel was to review the technical data, methodologies, and conclusions made in the development of the minimum flows and levels (MFL) criteria for three hydrologic systems in South Florida: Lake Okeechobee, the Biscayne Aquifer, and the Everglades. In addition, the panel's responsibilities included the consideration and inclusion of input from the public workshop conducted on August 31 and September 1, 1998, where relevant. This report summarizes the panels finding regarding the key facts as found in the literature and information presented during the workshop and conclusions and recommendations on the subjects raised by both the South Florida Water Management District (SFWMD) staff and public participants.

In reviewing the draft MFL criteria (prepared by the SFWMD staff and dated July 8, 1998), the general questions that the panel addressed included:

1. Did the draft document present a defensible scientific basis for setting ***initial*** (emphasis added) minimum flows and levels (MFL) within each of the three hydrologic systems? Were the approaches or concepts described in the document scientifically sound and based on the best available information?
2. Were the proposed criteria logically supported by "best available information" presented in the main body of the document? What additions, deletions or changes would enhance the validity of the document?
3. Are there other approaches to setting the criteria that should be considered? Is there available information that has not been considered by the SFWMD staff?

In essence, the panel's task was to determine if the appropriate scientific models and applications were employed, if all relevant data were used, and if the MFL criteria were a logical consequence of the science and the data. In fulfilling this task, it was necessary for the panel to understand the policy and legal issues as set by the Governing Board of the SFWMD. This was particularly important in the case of the definition of significant harm as outlined in the draft report. The panel found the report to be clear and understandable in establishing these concepts.

GENERAL PANEL RESPONSE TO THE DRAFT REPORT

As a general response to the above three questions, the panel recognizes that South Florida water resources comprise an integrated, dynamic water resource system. As such, behavior of each component, beginning with Lake Okeechobee, influences, and often controls, the behavior of other components. This circumstance is clearly acknowledged in the draft document. Additionally, the panel recognizes the numerous and sometimes contradictory functions of the three hydrologic water systems. As is the case in most places in the U.S., there are many legitimate and statutory demands on the three hydrologic systems. From drinking water to agriculture, to the health of the ecosystems involved, the panel recognizes that the SFWMD must balance, and determine how the hydrologic systems can best serve, the various demands. The panel has found that the draft document presents a logical, well-supported case for the proposed MFL criteria. In general, the recommendations are backed by reference to appropriate scientific findings in published literature and SFWMD experience and research. The SFWMD, however, should identify federal, state, and local regulations that may constrain or otherwise affect the establishment of minimum flows and levels. In some instances, described below, there is concern regarding the physical feasibility of achieving the recommended minimum flows and levels. This suggests the need for thorough monitoring of the MFLs that are implemented.

Whether directly or by implication, the SFWMD has appeared to rank the importance of the water resource functions that are to be reestablished, preserved, or enhanced. From our reading, the draft document implies that intervention and abatement of salt water intrusion in the Biscayne Aquifer is the highest concern regarding integrated management of the water resources under control of the SFWMD. Establishment of minimum levels in Lake Okeechobee is, in part, designed for "protecting the Biscayne Aquifer against salt water intrusion." Similarly, the minimum recommended water levels for the Everglades are designed to "provide ground water recharge and prevent salt water intrusion of the Biscayne Aquifer." If in fact the issue of salt water intrusion is the primary concern of the SFWMD, the draft document should state that clearly and early. The report could state that the focus or primary interest in establishing minimum levels is to control salt water intrusion and that an integrated approach to controlling the levels in Lake Okeechobee, the Everglades, and the Biscayne Aquifer is necessary to accomplish this objective. If other water resource functions are equally important this should also be noted early in the document. Whatever the perceived emphasis of the report, the panel recognizes that the SFWMD must consider and balance all of the competing water resource functions of the three hydrologic systems. Water demands of the environment, water supply, prevention of salt water intrusion, as well as navigation and recreation areas, must all be considered in developing the MFLs.

Regarding data issues, the draft document presents the SFWMD *interpretations* of much of the "best available information" without presenting the raw data. While much of these data are in the Appendix document, more could be included in the main document. There are basic pieces of data that could be included in the draft document that would help the reader evaluate the inferences made by the SFWMD. For example, there is ample discussion regarding the role of rainfall in driving the systems and the effects of seasonal variation in rainfall. There is, however, no chart of long term average monthly precipitation, for any recording station, presented in the draft document. The same holds true for ground water issues.

Overall, the panel found the draft report to be well written, scientifically sound, and adequately referenced. The report made a clear connection between policy foundations and the reviewable technical issues. Particularly, the report made clear the issues of significant harm and the point at which such harm occurs. The report also made clear those indicators of significant harm for each of the three hydrologic systems. The report should, however, make clear that MFLs are set to prevent the occurrence of significant harm.

The structure and layout of the report was clear. The panel was impressed by the amount, and integration, of information used in developing the MFL criteria. The panel was also impressed with the willingness of the SFWMD staff to accept and encourage any input that would improve the MFL criteria setting process. The bulk of this report will examine the MFL proposals for each of the three hydrologic systems.

REVIEW OF INDIVIDUAL HYDROLOGIC SYSTEMS

Lake Okeechobee

Before construction of the Herbert Hoover Dike, Lake Okeechobee had a larger pelagic and littoral zone contiguous with the Florida Everglades. Output from the SFWMD "Natural System Model," as well as historical data noted in the report, indicates that the lake levels fluctuated between 17 and 23 feet NGVD. Following the construction of the dike, the lake has experienced numerous occasions when lake levels have been below 11 feet NGVD for prolonged periods of time. When the water level is below 11 feet NGVD, nearly the entire littoral zone is dry and not available as a habitat for fish and other aquatic life. This also includes critical habitats such as Moonshine Bay and the peripheral bulrush communities. Further, a short hydroperiod may play a role in determining rates of expansion of exotic plants and the ability to eradicate them. The invasion of exotic species seems to be promoted by water levels lower than 11 feet NGVD. The influence of hydroperiods on invasion of exotic plants is based only on observational data. Experimental ecological research is needed to obtain a more complete understanding of the response of native and exotic vegetation to water levels of 11 feet NGVD and lower. Particularly, the effects of hydroperiod on torpedo grass are not clear. The subsequent secondary impacts on fish and wildlife are even more complex, and require a sophisticated research approach.

Thus, the panel concludes that based on the draft document, and information presented at the public workshop, the MFL criteria of 11 feet NGVD is appropriate given current information. However, the long-term effects and cumulative impacts of low lake levels (less than 11 feet NGVD) are uncertain. The draft report notes that a science-based criterion for return frequency will likely remain elusive, given the long-term (decades) nature of data that would be required to support that attribute.

The panel is concerned about the minimum of 10 feet NGVD allowed in the draft for the period of April 15 to July 15. It is clear from Figure 12 (page 52) that it is not anticipated that the 10 feet minimum would occur for the entire period. Rather, a 10 feet minimum level is anticipated to occur for only a short period around the first of June. The panel does recognize that this minimum level for April 15 to July 15 follows Zone C which moves the district into Phase 3 water restrictions. The panel also understands that this minimum period is in response to the competing demands for water beyond the littoral zone of the lake.

Given the potential for significant harm (or at least the uncertainty regarding the potential for significant harm), best available information suggests that *initial* minimum water levels to prevent potential significant harm to littoral zone fish and wildlife habitat should be not less than 11 feet. At best, the draft report should acknowledge the lack of information to support littoral zone, fishery, and wildlife functions at levels below 11 feet. An alternative criteria may be minimum water levels of not less than 12 feet every three years and not less than 11 feet every seven years.

The panel recognizes that other water resource functions of the lake are competitive with the water demands of the environment (i.e., littoral zone). For example, water supply development, prevention of saltwater intrusion, and maintenance of navigation and recreation access, are other water resource functions that must be considered by the District's Governing Board. Maximization of all these functions during a rainfall deficient period will be difficult. Therefore, the SFWMD should describe what tradeoffs and risks among these competing water resource functions were considered by the District in development of the minimum level criteria.

Biscayne Aquifer

In reviewing the MFLs for the Biscayne Aquifer it became clear to the panel that no actual direct minimum water levels for the Biscayne Aquifer were recommended. A surrogate criterion (i.e., a minimum canal stage) is used to achieve minimum water levels in the Biscayne Aquifer. While this approach has merit and is easily implemented, it does not directly address the minimum water levels in the aquifer.

The report should clearly explain the difference in recommending minimum water table elevations (i.e., minimum levels in the Biscayne Aquifer) versus minimum canal levels. The report should also discuss the spatial extent of ground water influence via the Lower East Coast (LEC) canal system and locations where the canals may not directly control water table elevations.

Some water resource functions are competitive. For example, two of the water resource functions identified for the Biscayne Aquifer are water supply development and prevention of salt water intrusion. Presumably, maximizing both functions will be difficult. As in the case of Lake Okeechobee, the SFWMD should describe what tradeoffs among competing water resource functions were considered in developing the minimum levels for the Biscayne Aquifer.

The effect of maintaining minimum water levels in the Everglades, in terms of raising ground water levels in the Biscayne Aquifer along the LEC, should be addressed in the final document. There is interaction between the water levels in the Everglades, canals, and the Biscayne Aquifer, and ground water flow to the coast. The final report should describe to what extent water levels in the Everglades are hydraulically disconnected from Biscayne Aquifer levels along the LEC via the intervening canal system.

Historic Biscayne Aquifer inter-annual water table fluctuations need to be more clearly referenced and noted in the text. For areas of the Biscayne Aquifer not under the direct influence of canal stage, an analysis of historic water level fluctuations may be an alternative method of establishing minimum water level criteria.

Sonenshein (1997) Figure 1 shows that, at least in Dade County, the landward extent of the salt water interface in the Biscayne Aquifer as estimated in 1995 is not, except for a few locations, significantly different from the estimated position of the interface in 1984. Within the inherent uncertainty in the data, there may or may not be a difference between the location of the salt water interface in 1984 and 1995. An alternative approach to establishing minimum flows for mitigation or abatement of salt water intrusion is to address each individual problem location (e.g., well field), on a case by case basis. The panel recognizes the SFWMD does address these issues as part of their permitting process. However, this can be aided by three-dimensional density dependent ground water flow and solute transport modeling.

The panel also identified a number of technical issues regarding MFLs for the Biscayne Aquifer:

1. Literature coverage and interpretations.

There is a wealth of literature concerning the hydrology/hydrogeology of Southeast Florida, the Biscayne Aquifer, and salt water intrusion. Although an exhaustive literature search was undertaken by the SFWMD, it does not appear that an equally exhaustive review of the identified literature was completed. Interpretations seem consistent with the published findings. There is, however, repeated reference to the lack of correlation between fresh water heads and chloride concentrations. Yet, these same data are used to "verify" the validity of using the Ghyben-Herzberg relationship as criteria for setting minimum levels for the Biscayne Aquifer.

Parker, et al., (1955) is extensively cited throughout the draft document. While it may be the major early work describing the water resources of southeastern Florida, several more recent publications may incorporate more recent data and interpretations.

2. Evaluation of water level and water quality data from wells and canals.

The only ground water level map presented in the draft document is in the appendix (Figure A.2) which shows the average potentiometric surface. Knowledge of the historic inter-annual Biscayne Aquifer water table fluctuation would be useful, especially due to the assertion regarding short term versus longer term water level fluctuations and their relationship to the movement of the salt water interface. Appendix table A.5 in the draft document contains data for intra-annual water table fluctuations. However, these data are not contoured, nor is it clear how these data were used in the development of the minimum water level criteria for the Biscayne Aquifer other than to attempt to validate the Ghyben-Herzberg relationship.

Ground water quality data (i.e., chloride data) were analyzed extensively. The conclusion drawn indicates there is no significant correlation between water level data and chloride concentrations. However, it is ultimately the fresh water head and water extraction that controls salt water intrusion. More consideration could be given to the historic variability in ground water levels and how the modern system may be artificially manipulated in light of pre- development ground water behavior. Rather than an arbitrary minimum level for the Biscayne Aquifer along the LEC, the report could consider how the ground water levels fluctuated prior to development and control. This information may shed light on natural intra-annual variability and offer an alternative to the static levels recommended based on canal levels necessary to hold the salt water wedge at its present location. In essence, more flexibility in minimum levels, especially away from the influence of well fields, may allow a better optimization of the other components of the system.

There is considerable discussion in the draft document regarding the importance of rainfall as the system "forcing" mechanism. No hydrograph is presented for the period of record for any recording station in the area. The draft report should also mention what influence, if any, tidal fluctuations have on the dynamics of the hydraulic behavior of the Biscayne Aquifer.

3. Ghyben-Herzberg relationship.

Many of the public comments regarding the Biscayne Aquifer centered on the Ghyben-Herzberg relationship and its appropriate use in this case. In theory, the Ghyben-Herzberg relationship is a reasonable approach for establishing minimum levels for the Biscayne Aquifer to prevent salt water intrusion. However, several factors reduce the appropriateness of the Ghyben-Herzberg relationship for such purposes. The Ghyben-Herzberg relationship assumes static equilibrium and a hydrostatic pressure distribution in the fresh water region with stationary seawater. These theoretical conditions result in a sharp interface between salt water and fresh water. In actuality, static equilibrium does not exist and there are significant vertical ground water flow components associated with well field pumping and Biscayne Aquifer discharge to the sea. Consequently, the sharp interface becomes a dynamic transition zone where salinity concentrations vary spatially and temporally. The coefficient of 40 for the Ghyben-Herzberg relationship ($Z_s = 40 Z_f$), where Z_s is the depth below sea level to the salt water interface, and Z_f is the height of the water table above sea level, is based on the density of open ocean water of approximately 1.025 gm/cm^3. If the density of coastal sea water is slightly less than 1.025 gm/cm^3 then the depth to the salt water interface estimated by the Ghyben-Herzberg relationship is proportionately greater. For example, if the density of the seawater is 1.020 gm/cm^3 then the depth to the salt water interface is 50 times the height of the freshwater table above sea level.

The SFWMD should clearly explain how the Ghyben-Herzberg relationship did, or did not, influence the recommended minimum levels in the LEC canals and hence the

Biscayne Aquifer. The draft document (Appendix A, pg. A-1) states that "Additional water level/water quality information was examined to verify the validity of using the Ghyben-Herzberg relationship as criteria for setting minimum levels for the Biscayne Aquifer." This statement suggests that the Ghyben-Herzberg relationship was used to set the Biscayne Aquifer minimum levels. If this is not the case, as indicated in the public meeting, then the report should more clearly describe how the minimum levels were determined.

4. Movement and duration of chloride and salinity gradients.

The movement and duration of chloride and salinity gradients appear to be well documented in the literature (*Sonenshein*, 1995; *Kohout*, 1960; etc.). However, from Sonenshein's (1997) analysis, a conclusion can be drawn that, although there has been an increase in developed lands and associated demands for potable water, the ground water system has greater capacity for development without widespread salt water intrusion than may be recognized. The panel is aware that there exists uncertainty regarding this conclusion. For example, Fish (1988; pages 1-2) noted, concerning Broward County, that large scale pumping from municipal well fields will generally lower the water table and induce salt water intrusion. The draft document also cites similar conclusions from Parker, et al (1955).

Figure 17 (pg. 71) in the draft document needs to be more carefully explained. The basis (i.e., data source) for the figure is uncertain. The text discussing Figure 17 states that "When groundwater (sic) levels are depressed for periods in excess of six months duration, permanent movement of the saline interface may result... " However, the schematic diagram Figure 17 does not seem to support this conclusion. The "below minimum level for 180 days" line does return to the 1 ppt chloride line while the "below minimum level for 365 days" line does not return to 1 ppt chloride. However, there is no indication as to when (i.e., between 180 days and 365 days) the system fails to recover. The report only indicates that chloride concentrations do not recover in 365 days.

5. SFWMD Modeling Efforts.

No information is provided in the draft document concerning how the South Florida Water Management Model addresses the hydraulic connection and communication between canals and the ground water system. This is a crucial issue because the minimum water level criterion recommended for the Biscayne Aquifer is partially supported by the results of the model simulations. The discussion in Appendix A, (Section III) needs to remind the reader that the "results" presented are from simulations, not observations.

Assuming that there is effective communication between the canals and the Biscayne Aquifer water table, maintaining a stage in the canals greater than the regional water table elevation creates many spatially distributed line sources. The report should indicate, in general, the lateral extent of the influence of the canals on the water table.

Everglades

The panel agrees that the choice of hydric soils as MFL indicators in the Everglades is appropriate because the peat and marl soils are the primary substrates that support the Everglades. These soils support all major plant associations and animal communities that characterize the Everglades.

The MFL criteria are generally supported by the best available information. However, Stephens' (1974) conclusion that peat soil loss (or subsidence) occurs at a ground water level maintained at -1 feet warrants investigation to understand the potential consequences of the proposed MFL. Also, and more significantly, the proposed MFL may allow significant harm in areas with peat soil shallower than 1 foot, and marl soils with depths shallower than 1.5 feet. The MFL process should identify these areas, determine the extent and significance of these areas, and consider modification of the proposed MFL or generation of new MFL for these areas. The Florida Game and Fresh Water Fish Commission and Everglades National Park have offered to assist in identifying shallow soil areas.

Additionally, depending on topographic variations, a minimum water level of 1.0 foot below land surface for peat soils may be hydraulically incompatible with a drawdown of 1.5 feet in marl soils in some locations where the marl soils are in close proximity to the peat soils. This concern may be particularly valid for an east to west transect from Rocky Glades (marl) to Shark River Slough (peat). It may not be possible to hold water levels at 1.0 foot below land surface in peat soils when water levels drop to 1.5 feet below land surface in adjacent marl soils.

Furthermore, because the water level in the Everglades is a surface expression of the water table or actually the water table (depending on whether water levels are above or below ground surface), the minimum levels proposed for the Everglades are minimum levels for the Biscayne Aquifer where it underlies the Everglades.

The MFL process would likely benefit from comparison to actual water levels, vegetation, and fauna. Soil loss and burn issues as related to water level would benefit from bench-scale or field plot experiments. Also fieldwork and/or laboratory experiments are necessary to analyze the impact of return frequencies of short hydroperiods on the oxidation of peat. Additionally, more knowledge of peat accretion and marl deposition, (the most basic functions of a sustainable Everglades), should be generated in relation to different hydroperiods.

In conclusion, the panel strongly agrees that the use of hydric soils as a indicator of MFLs for the Everglades is appropriate. However, because the soils are diverse, the MFLs will need to be adapted to fit this diversity. Where the organic soils are thick (i.e. over three feet), the one foot depth for 30 days duration or less (1.5 feet depth for 90 days duration with marl) may be appropriate. Because the thinner soils are probably in a higher position in the landscape, a higher ground water level than proposed in this report may need to be maintained. For these reasons, the panel is concerned that the one foot MFL for

30 days for the organic soils and 1.5 feet MFL for 90 days within marl soils may produce significant harm in some areas.

Biscayne and Florida bays

It is clear that MFLs for the Biscayne and Florida bays are beyond the scope of work of this panel and the initial efforts to propose MFLs for the three hydrologic systems. However, it is the view of this panel, given the considerable public comment on this issue, that we must address this issue at least in the context of recommendations to the governing board of the SFWMD.

In dealing with this issue, the panel considered whether MFLs for the Everglades could be set without including the Florida and Biscayne bays. While recognizing that Florida Bay is part of the Everglades, the panel is not convinced that setting *initial* MFLs is impossible without MFLs for the Florida and Biscayne bays. The panel recognizes the systems are integrated and believes MFLs for the Florida and Biscayne bays should be moved up in the process to as soon as possible.

While the panel believes the current effort can continue, the influence, or impact, of the proposed minimum flows and levels recommended for Lake Okeechobee, the Everglades, and the Biscayne Aquifer on Florida Bay should be estimated. The South Florida Water Management Model and associated performance measures can be used to provide this qualitative insight.

Furthermore, a sufficiency review should be conducted to examine completed surface and ground water data, especially data that illustrates the relationship between upstream water levels and flows on bay and estuary water and salinity levels. Based upon this review, the SFWMD, in conjunction with other stakeholders, should determine the appropriate time and mechanism for proposal of MFLs for these areas. Also, the sufficiency review may provide a qualitative estimate of the potential effects of proposed MFLs for Lake Okeechobee, Everglades, and Biscayne Aquifer.

The final report should address the level of risk of significant harm to the Florida and Biscayne bays if significant harm standards are exceeded in the three hydrologic systems under review. This concern could be addressed using simulations performed by the South Florida Water Management Model. Finally, some public workshop participants noted that new literature on Florida and Biscayne bays has been generated since the current MFL process began. The panel encourages the SFWMD to consider any new data available. However, the panel strongly believes that the term "best available information" means data and reports must be peer reviewed and published to be considered adequate.

MISCELLANEOUS COMMENTS ON THE DRAFT REPORT

Page 12, middle paragraph, second sentence - "The WCAs, located south of Lake Okeechobee and *east* of the heavily urbanized..." The WCAs are *west* of the urbanized LEC.

Page 16, Figure 3 and the accompanying discussion is not clear. A better map should be found.

Page 30, The report should make clear that MFLs are set to prevent the occurrence of significant harm. The sentence in the first paragraph should read, "at the point before which significant harm would occur".

Page 34 (first full paragraph) While it is large, table F-1 is not only significant, but informative as a summary of the issues. Could that table be edited and included in the body of the report?

Page 35, second paragraph - reference to Figure F-1 in Appendix F as a bathymetry map of Lake Okeechobee is incorrect. Figure F-1 is the location of indicator regions.

Page 42 - Reference to table 1 needs page.

Page 44 (bottom) - Could use brief table showing what phases 1 to 4 entail.

Page 51, third paragraph - text incorrectly refers to Figure 8. It is Figure 9 that contains the Supply-Side Management Zones referred to in the text.

Page 63, Table 3b - "Minimum Depth (feet)..." should be specified as below ground surface.

Page 63, Table 3b (note 1) - there is no Figure F-2 in Appendix F as indicated in the note. The figure referred to is Figure F-1.

SUMMARY OF MAJOR CONCLUSIONS AND RECOMMENDATIONS

Conclusion 1: Long-term and cumulative effects of levels below 11 feet NGVD on the littoral zone of Lake Okeechobee are too uncertain to set MFL.

Regarding Lake Okeechobee, the panel concludes that the long-term effects and cumulative impacts on the littoral zone of lake levels below 11 feet NGVD are too uncertain to set MFL below 11 feet even for brief periods. The panel believes that current "best available information" suggests that the MFL criteria of 11 feet NGVD is appropriate for protection of the littoral zone of Lake Okeechobee. However, the panel recognizes that other water resource functions are competitive with the littoral zone demands on Lake Okeechobee. For example, water supply development and prevention of saltwater intrusion are other functions to be considered, although to maximize all three functions will be difficult.

Recommendation 1:

The report should acknowledge the inadequacy of the information to support littoral zone, fishery, and wildlife functions at levels below 11 feet. Alternatively, the report must present more compelling information regarding whether or not significant harm will occur below 11 feet. The report should also state more clearly why the periods below 11 feet are necessary. Issues of salt water intrusion and other water needs met by the lake need to be clarified.

Recommendation 2:

The SFWMD should describe what tradeoffs and risks among competing water resource functions were considered in developing the MFL for Lake Okeechobee.

Recommendation 3:

The long-term effects of a MFL of 10 feet are not immediately evident, and would benefit from a more complete understanding of the response of native and exotic vegetation to this water level. Understanding the relationship between the duration of minimum water levels and potential impacts is especially critical.

Recommendation 4:

The final report should include a graphic showing the average annual water budget for Lake Okeechobee. The budget should include the major components of inflow, storage in the lake, and outflow/loss (i.e., evaporation, transpiration, controlled releases, and ground water interaction directly associated with the lake).

Recommendation 5:

The report should make clear near the beginning that the focus or primary interest in establishing minimum levels is to control salt water intrusion and that an integrated approach to controlling the levels in Lake Okeechobee, the Everglades, and the Biscayne Aquifer is necessary to accomplish this objective.

Recommendation 6:

A chart should be included of long-term average monthly precipitation for any recording station.

Conclusion 2: The approach used to establish minimum water levels in the Biscayne Aquifer has merit but does not directly address the issue.

It appears that no actual direct minimum water levels for the Biscayne Aquifer were recommended. A surrogate criterion (i.e., a minimum canal stage) is used to achieve minimum water levels in the Biscayne Aquifer. While this approach has merit and is easily implemented, it does not directly address the direct issue of minimum water levels in the aquifer.

Recommendation 7:

The report should clearly explain the difference in recommending minimum water table elevations (i.e., minimum levels in the Biscayne Aquifer) versus minimum canal levels. The report should also discuss the spatial extent of ground water influence via the LEC canal system and locations where the canals may not directly control water table elevations.

Recommendation 8:

As with Lake Okeechobee, the report should describe what tradeoffs among competing water resource functions were considered in developing the minimum levels for the Biscayne Aquifer.

Recommendation 9:

The effect of maintaining minimum water levels in the Everglades, in terms of raising ground water levels in the Biscayne Aquifer along the LEC should be addressed in the final document. There is interaction between the water levels in the Everglades, canals, and the Biscayne Aquifer and ground water flow to the coast. The final report should describe to what extent water levels in the Everglades are hydraulically disconnected from Biscayne Aquifer levels along the LEC via the intervening canal system.

Recommendation 10:

For areas of the Biscayne Aquifer not under the direct influence of canal stage, an analysis of historic water level fluctuations may be an alternative method of establishing minimum water level criteria.

Recommendation 11:

An alternative approach to establishing minimum flows for mitigation or abatement of salt water intrusion is to address each individual problem location (e.g., well field), on a case by case basis. This can be accomplished by three-dimensional density dependent ground water flow and solute transport modeling.

Recommendation 12:

More consideration could be given to the historic variability in ground water levels and how the modern system may be artificially manipulated in light of pre-development ground water behavior. More flexibility in minimum levels, especially away from the influence of well fields, may allow a better optimization of the other components of the system.

Recommendation 13:

The report should present a hydrograph for the period of record for any recording stations in the area to help explain the importance of rainfall as the system "forcing" mechanism.

Recommendation 14:

The report should mention what influence, if any, tidal fluctuations have on the dynamics of the hydraulic behavior of the Biscayne Aquifer.

Recommendation 15:

The SFWMD should clearly explain in the draft document the use of the Ghyben-Herzberg relationship and how it did, or did not, influence the recommended minimum levels in the LEC canals and hence the Biscayne Aquifer.

Recommendation 16:

The final report should provide more information on how the South Florida Water Management Model addresses the hydraulic connection and communication between canals and the ground water system.

Recommendation 17:

The final report should indicate, in general, the lateral extent of the influence of the canals on the water table.

Conclusion 3: use of hydric soils as an indicator of MFLs is appropriate, but the MFLs will need to be adapted to fit the diversity of soils present in the region.

The panel strongly agrees that the use of hydric soils as an indicator of MFLs is appropriate. However, because the soils are diverse, the MFLs will need to be adapted to fit this diversity. Where the organic soils are thick (i.e., over three feet), the one foot depth for 30 days duration (1.5 feet depth for 90 days with marl) may be appropriate. Because the thinner soils are probably in a higher position in the landscape, a higher ground water level than proposed in this report may need to be maintained.

Conclusion 4: Special consideration should be given to areas with less than one foot of peat soil, and less than 1.5 feet of marl soils.

The proposed MFLs may allow significant harm in areas with peat soil more shallow than one foot, and marl soils with depths more shallow than 1.5 feet. The MFL process should identify these areas, determine the extent and significance of these areas, and consider modification of the proposed MFLs or generation of new MFLs for these areas. The panel further concludes that the minimum levels may not be hydraulically feasible where marl soils exist near peat soils.

Recommendation 18:

Because the water level in the Everglades is a surface expression of the water table or actually the water table (depending on whether water levels are above or below ground surface), the minimum levels proposed for the Everglades are minimum levels for the

Biscayne Aquifer where it underlies the Everglades. The draft document should acknowledge this fact.

Recommendation 19:

The MFL process would likely benefit from comparison to actual water levels, vegetation, and fauna. Soil loss and burn issues as related to water level would benefit from bench-scale or field plot experiments. Also fieldwork and/or laboratory experiments are necessary to analyze the impact of return frequencies of short hydroperiods on the oxidation of peat and more knowledge of peat accretion and marl deposition needs to be generated in relation to different hydroperiods.

Recommendation 20:

The panel recommends that more food web studies in the Everglades be conducted. It appears there is insufficient knowledge available regarding the effects of different hydroperiods on the functioning of higher trophic levels in the Everglades ecosystem.

Conclusion 5: It is possible to set *initial* MFLs for the three hydrologic systems under consideration prior to setting MFLs for the other systems.

While recognizing the integrated nature of the three hydrologic systems and the Florida and Biscayne bays, the panel concludes that it is possible to set *initial* MFLs for the three hydrologic systems under consideration prior to setting MFLs for the other systems.

Recommendation 21:

The panel recommends that MFLs for the Florida and Biscayne bays be moved up in the District's priority water body list.

Recommendation 22:

The South Florida Water Management Model and associated performance measures should be used to help estimate the impact of the proposed MFLs on the Florida and Biscayne bays.

Recommendation 23:

A sufficiency review should be conducted to determine if any new data or information has surfaced that illustrates the relationships between ecosystem water levels, flows, and bay and estuary water and salinity levels.

III. STAFF RESPONSE TO PEER REVIEW PANEL CONCLUSIONS AND RECOMMENDATIONS

4. Panel Recommendation: *The report should acknowledge the inadequacy of the information to support littoral zone, fishery, and wildlife functions at levels below 11 feet…the report must present more compelling information regarding whether significant harm will not occur below 11 feet.*

Response: Staff added text explaining the inadequacy of current information and discussed research efforts to acquire needed information (see new section: Proposed MFL Research and Monitoring). Staff also added the concept of dual MFL criteria (Operational MFL & Water Supply Planning MFL) which addresses the concern about the frequency that water levels are allowed to fall below 11 ft. without causing significant harm.

1. Panel Recommendation: *The SFWMD should describe what tradeoffs and risks among competing water resource functions were considered in developing the MFL for Lake Okeechobee.*

Response: Staff did not address directly address this issue in this document, however it will be addressed as part of the MFL Recovery Plan evaluation based on model simulation results.

2. Panel Recommendation: *The final report should include a graphic showing the average annual water budget for Lake Okeechobee.*

Response: This was not included. Staff is working on adding a brief summary of the lake budget based on the SFWMM 1995 base case.

3. Panel Recommendation: *The report should make clear near the beginning whether the focus or primary interest in establishing minimum levels is to control salt water intrusion and that an integrated approach to controlling the levels in Lake Okeechobee, the Everglades, and the Biscayne Aquifer is necessary to accomplish this objective*.

Response: This was not the primary intent or interest of the report. Staff revised the conclusion section to correct this misconception.

4. Panel Recommendation: *A chart should be included to show long-term average monthly precipitation for any recording station.*

Response: Completed. See Chapter 1, pages 7-8.

5. Panel Recommendations: *a) No actual direct minimum water levels for the Biscayne Aquifer were recommended. A surrogate criterion (i.e., a minimum canal stage) is used to achieve minimum water levels…While this approach has merit and is easily implemented, it does not directly address the direct issue of minimum water levels in the aquifer.*

b).The report should clearly explain the difference in recommending minimum levels in the Biscayne Aquifer versus minimum canal levels.

Response: a) and b). The Biscayne aquifer criteria were revised by staff to better explain these differences. See pages 97-98 which explains the relationship between setting minimum levels in canals, monitoring water levels and saltwater intrusion in groundwater wells and implementing water shortage restrictions based on ambient water levels and chloride concentrations in the aquifer.

6. Panel Recommendation: *The report should also discuss the spatial extent of ground water influence via the LEC canal system and locations where the canals may not directly control water table elevations.*

Response: We do not have sufficient monitoring data to determine where the lateral influence of one canal leaves off and the influence of the next adjacent canal begins. Canal water levels appear to have overlapping influence in the 11 basins included in the table. In other basins, especially southern Miami-Dade County, the relationship between canal levels and water table elevations is less clear (see also answer to No. 16).

7. Panel Recommendation: *An alternative approach to establishing minimum flows for mitigation or abatement of salt-water intrusion is to address each individual problem location (e.g., well field), on a case by case basis. This can be accomplished by three-dimensional density dependent ground water flow and solute transport modeling.*

Response: Staff does not agree with the panel's recommendation. To address each individual problem area on a case-by case basis is beyond the scope of this regional analysis. This scale of analysis is being conducted as part of the WPA study and the LECRWSP effort. Site specific analyses of individual wellfields are conducted in conjunction with the issuance of Consumptive Use Permits. Results of local modeling efforts will be considered in the development of the MFL Recovery Plan.

8. Panel Recommendation: *For areas of the Biscayne Aquifer not under the direct influence of canal stage, an analysis of historic water level fluctuations may be an alternative method of establishing minimum water level criteria.*

Response: Historic data that has been collected since construction of the C&SF Project was used by the District to develop its present operational criteria. The current operational water levels are the proposed minimum water level criteria for these basins. These operational criteria will continue to be used, to maintain existing levels of protection.

9. Panel Recommendation: *More consideration could be given to the historic variability in ground water levels and how the modern system may be artificially manipulated in light of pre-development ground water behavior.*

Response: This type of analysis was not performed for the MFL study, but has been addressed in the Restudy. When Restudy options are fully implemented, as a component of the MFL Recovery Plan, it is anticipated that critical features of pre-development ground water behavior will also be restored.

10. Panel Recommendation: *The effect of maintaining minimum water levels in the Everglades, in terms of raising ground water levels in the Biscayne Aquifer along the LEC should be addressed in the final document.*

Response: This issue is not directly addressed in the MFL report. However, modeling studies conducted for the Restudy indicate that as water levels in the Everglades are increased to meet restoration goals, additional ground water seeps eastward into coastal areas of the Biscayne Aquifer. This additional groundwater flow is more than sufficient to meet LEC water supply needs during most years. During extreme drought conditions, additional water will also need to be provided to the LEC from surface water storage facilities, groundwater (ASR) storage and from reuse and other sources. The amount and sources of the additional water needed during these extreme events will be addressed in the LECRWSP and MFL Recovery Plan

11. Panel Recommendation: *There is interaction between the water levels in the Everglades, canals, and the Biscayne Aquifer and ground water flow to the coast. The final report should describe to what extent water levels in the Everglades are hydraulically disconnected from Biscayne Aquifer levels along the LEC via the intervening canal system.*

Response: This issue is addressed in greater detail in the Restudy and in the WPA analysis. Due to the high transmissivity of the Biscayne Aquifer, there is still a direct hydraulic connection between Everglades water levels and levels in the coastal areas of the Biscayne Aquifer. Some proposals that are part of the Restudy and WPA may reduce or eliminate that connection through backpumping of water from coastal basins (further reducing groundwater levels in eastern basins) construction of seepage barriers (that block groundwater flow) or construction of intervening lakes (which may lower adjacent groundwater levels and lose water from the aquifer due to evaporation). Effects of such proposals will be further considered in the LECRWSP and the MFL Recovery Plan.

12. Panel Recommendation: *The report should mention what influence, if any, tidal fluctuations have on the dynamics of the hydraulic behavior of the Biscayne Aquifer.*

Response: Tidal fluctuation effects were not addressed. There is mention that "…as salt water moves inland, a significant portion of the diluted sea water is circulated back toward the sea along the zone of diffusion. It is estimated that up to 20 percent of the salt water that intrudes the aquifer is returned to seawater, with the remaining 80 percent being retained in the aquifer (Kohout, 1960)…."

13. Panel Recommendation: *The SFWMD should clearly explain in the draft document the use of the Ghyben-Herzberg relationship and how it did, or did not, influence the recommended minimum levels in the LEC canals and hence the Biscayne Aqu*ifer.

Response: Pages 51-52 and 86-87 of the Final document have been revised omitting inappropriate references to the GHR as method for determining the MFL for the Biscayne aquifer.

14. Panel Recommendation: *The final report should provide more information on how the SFWMM addresses the hydraulic connection and communication between canals and the ground water system.*

Response: This was not done in the revised document. For more information the reader is referred to SFWMM documentation "A primer to the South Florida Water Management Model (version 3.5)", April 1999 (SFWMD, 1999).

15. Panel Recommendation: *The final report should indicate, in general, the lateral extent of the influence of the canals on the water table.*

Response: See new language and Figure on pages 85-86 that show the historical influence of canals and saltwater intrusion in the greater Miami area from 1904-1995. In general, review of historical data indicates that early canal construction activities acted as sources of saltwater intrusion. Prior to construction of water control structures, saltwater intrusion occurred first along the coastal canals and followed the course of these canals inland. Once structures were in place, this intrusion was halted and to some extent reversed. Monitoring of the saltwater intrusion line indicates that the locations of structures along the canals themselves still appear to represent points of maximum intrusion and that the influence of holding higher levels in these canals extends for several miles to either side. In the 11 basins identified in this report, the influence of one canal appears to overlap with the influence of the next canal to form a more or less continuous line of protection in northern Dade, Broward and southern Palm Beach Counties.

16. Panel Recommendation: *Where the organic soils are thick (i.e., over three feet), the one foot depth for 30 days duration (1.5 feet depth for 90 days with marl) may be appropriate. Because the thinner soils are probably in a higher position in the landscape, a higher ground water level than proposed in this report may need to be maintained.*

Response: We have looked at this issue and we could find not simple way to establish a MFL for these thinner soils at this point in time. Evaluation of NSM data under low rainfall conditions actually showed that water levels typically receded below our proposed criteria for some of the thinner marl soils located east and west of SRS. Thus, the current criteria may actually be conservative with respect to protecting these areas.

17. Panel Recommendation: *Water level in the Everglades is a surface expression of the water table -- the minimum levels proposed for the Everglades are minimum levels for the Biscayne Aquifer where it underlies the Everglades. The draft document should acknowledge this fact.*

Response: This language was added to the report. See page 80.

18. Panel Recommendation: *The MFL process would likely benefit from comparison to actual water levels, vegetation, and fauna. Soil loss and burn issues as related to water levels would benefit from bench-scale or field plot experiments. Also fieldwork and/or laboratory experiments are necessary to analyze the impact of return frequencies of shortened hydroperiod on the oxidation of peat and more knowledge of peat accretion and marl deposition, needs to be generated in relation to different hydroperiods*.

Response: This is partially addressed in the new section entitled "Proposed MFL Research and Monitoring." As part of the MFL Recovery Plan there should be a section which discusses the link between establishment of the interim MFL and proposed research and monitoring efforts underway to validate and/or refine the proposed MFL. Current research and monitoring efforts presented herein do not specifically explain how these data will be analyzed and evaluated to quantitatively validate or refine the MFL criteria proposed in this report.

19. Panel Recommendation: *The panel recommends that more food web studies be conducted in the Everglades. It appears there is insufficient knowledge available regarding the effects of different hydroperiods on the functioning of higher trophic levels in Everglades ecosystems.*

Response: See new section entitled "Proposed MFL Research and Monitoring.

20. Panel Recommendation: *The panel recommends that MFLs for Florida Bay and Biscayne Bay be moved up in the District's MFL priority water body list.*

Response: Florida Bay was recently moved up on the District's MFL priority list.

21. Panel Recommendation: *The SFWMM and associated performance measures should be used to help estimate the impact of the proposed MFLs on Florida Bay and Biscayne Bay.*

Response: Will be done as part of MFL Recovery Plan model simulations.

22. Panel Recommendation: *A MFL sufficiency review should be conducted for Florida and Biscayne Bays*

Response: Complete for Biscayne Bay, draft report has been developed for Florida Bay and is under revision.

**

DRAFT

PROPOSED MINIMUM WATER LEVEL CRITERIA FOR LAKE OKEECHOBEE, THE EVERGLADES, AND THE BISCAYNE AQUIFER WITHIN THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Appendix E -

Minimum Flows and Levels
Literature Review

Prepared by Staff of:

Planning Department

South Florida Water Management District

West Palm Beach, Florida

January 19, 1998

Appendix E - Minimum Flows and Levels Literature Review

The following sections describe the guidelines and methods that were used to conduct the literature search and review reports that were received.

INTRODUCTION

Information was needed that describes the range of water levels that occur during drought conditions within **hydric soils (organic peat and marl**) within the Everglades and similar peat or marl based wetland systems. This search was limited primarily to include studies that were conducted within south Florida, and to document water depths that occur naturally during drought conditions within the following 5 soil types:

Loxahatchee peat

Everglades peat

Perrine marl

Ochopee marl

Rockland marl

INFORMATION NEEDED

The specific information that we sought for each of the above five soils types included the following:

1. What are the optimum conditions for the formation of each soil type?

2.What is the minimum water depth, duration and frequency of occurrence that water levels fall below ground level during a drought for each soil type?. In other words, on average, how low do water levels drop below ground during low water years? How long do these events last? and what is their return frequency (1 in 3 year event, 1 in 10 year event, etc.)?

Results of the literature search identified those technical publications or reports that discussed these specific hydric soil types and the hydrological conditions associated with each soil type during drought periods.

The District was also interested in reviewing publications that:

1. documented the nature and extent of impacts that occurred within the Everglades (or any other south Florida wetland system) due to altered hydroperiods, reduced water levels, or overdrainage.

2. identified the effects of fire within the Everglades system.

SEARCH CRITERIA

The following topics and key words were used as a basis for a search using the Dialog® literature review service through the SFWMD library:

Florida hydric soils

Optimum conditions for the formation of:

Loxahatchee peat

Everglades peat

Perrine marl

Ochopee marl

Rockland marl

S. Florida organic peat soils

S. Florida marl soils

Soil subsidence (in the Everglades),

Everglades water levels,

Role of fire, effects of fire in the Everglades, fire return frequency

Effects of drought in the Everglades

Effects of drought on Everglades plant communities

Effects of altered hydroperiods in the Everglades

Drainage, overdrainage, and reduced water level impacts in the Everglades

OTHER SOURCES

In addition, an examination was made of the District library and of prior technical publications and reports. Professional staff were also surveyed to determine if they knew of, or had copies of, relevant literature. Four recent water level/ hydroperiod studies conducted for and by the District were reviewed, in conjunction with a review of bibliographies from the articles and reports obtained.

REVIEW OF REPORTS

Once the search was completed, District staff reviewed this list of references and obtained copies of those articles and reports that appeared to include water level or hydroperiod data for natural systems within the Everglades for detailed examination. A group comprised of wetland biologists, agricultural engineers and a soils scientist was assigned to read the selected documents, summarize directly pertinent information and indicate the degree to which the document was useful for the purposes of the investigation. All documents that were received by August 30, 1996 were examined by District staff to ascertain their relevance to this study.

The final product of this work was a bibliography of wetland literature related to naturally occurring ranges of hydroperiods and water levels for different plant communities. Each relevant article was summarized, using a standard format that included the following information:

(1) reference citation;

(2) study location;

(3) study purpose;

(4) study period;

(5) vegetation communities;

(6) water levels;

(7) hydroperiod (days per year that water was above land surface); and

(8) other.

The focus of the review was to document natural water level and hydroperiod information for Everglades soil types; however, the "other" category was included in case the reviewer encountered additional information which could potentially be useful during subsequent wetland impact evaluations.

RESULTS

Results of the consultant reports and prior studies by District staff were examined first. A report by Environmental Sciences and Engineering (1991) provided information on natural water levels and hydroperiods throughout the South Florida Water Management District and included water level and hydroperiod information specific to the Lower West Coast Planning Area (LWCPA) in Glades, Hendry, Lee and Collier counties. The Gee and Jenson (1993) report focused on the Corkscrew Regional Ecosystem Watershed area and included summaries of additional hydroperiod and water level studies within the LWCPA. The Final Report of an expert panel, which was convened by the District in 1994 to examine water level effects on wetlands in the LWCPA. Finally, a literature review was conducted by the SFWMD (1995) to document hydrologic impacts on wetlands in the LWCPA.

The articles and reports that were identified in the literature search are listed in the bibliography that follows. The presence of and asterisk (*) in front of the citation indicates that a copy of the article was obtained for review. Those articles or reports that included natural water level and hydroperiod information that were particularly relevant to our work in the Everglades are listed in the literature cited section of the main report.

Ref. No.	Reference
1	Alexander, T.R. and A.G. Crook. 1973. Recent and Long Term Vegetation Changes and Patterns in South Florida, Part I, Preliminary Report, South Florida Ecological Study, Appendix G, University of Miami, Coral Gables, Florida
2	Alexander, T.R. and A.G. Crook 1984. Recent vegetational changes in South Florida. In: Environments of South Florida: Present and Past II, 2nd Edition, Memoir II, Miami Geol. Soc., Coral Gables, Fla. pp. 199-210.
3	Anderson, P.F. 1986. Numerical modeling of groundwater flow and saltwater transport in the vicinity of Hallandale, Florida. Geotrans, Herdon, Va, 176 p
4	Anderson, D.L.and R.B Beverly. 1985. The effects of drying upon extractable phosphorus, potassium and bulk density of organic and mineral soils of the Everglades. Madison, Wis.: The Society.Journal - Soil Science Society of America. v. 49 (2) p. 362-366.
5	Andersen, P.F., White, H.O., Mercer, J.W., and Huyakorn, P.S., 1986. Numerical modeling of groundwater flow and saltwater transport in the vicinity of Hallandale, Florida. Geotrans, Herdon, Va, 176 p.
6	Andreis, H.J. 1976. A water table study on an Everglades peat soil:effects of sugarcane and on soil subsidence. The Sugar Journal, Nov. 1976. pp. 8-12.
7	Aumen, N.G. 1995. History of human-related impacts to Lake Okeechobee, Florida(U.S.A.), related research, and lake management issues. Archiv fur Hydrobiologie, Advances in Limnology, 45, 1-30.
8	Aumen, N.G. and S. Gray. 1995. Research synthesis and management recommendations from a five-year, ecosystem-level study of Lake Okeechobee, Florida (USA). Archiv fur Hydrobiologie, Advances in Limnology, 45, 343-356.
9	Aumen, N.G. and R.G. Wetzel. 1995. Ecological Studies on the Littoral and Pelagic Systems of Lake Okeechobee, Florida (USA). Archiv fur Hydrobiologie, Advances in Limnology, Volume 45.
10	Bachoon, D. and R.D. Jones. 1992. Potential rates of methanogenesis in sawgrass marshes with peat and marl soils in the Everglades. Florida International University, Miami, FL. Exeter: Pergamon Press, Soil biology and biochemistry, v. 24 (1) p. 21-27.
11	Bancroft, G.T. 1993. Florida Bay-An endangered North American jewel. The Florida Naturalist, Spring 1993.
12	Bancroft, G.T., A.M. Strong, R.J. Sawicki, W. Hoffman, S.D. Jewell 1994. Relationships among wading bird foraging patterns, colony locations, and hydrology in the Everglades. In: Davis, S.M. and J.C. Ogden (Eds) 1994. Everglades: The Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL.
13	Bayley, S. and H T. Odum. 1976. Simulation of interrelations of the Everglades' marsh, peat, fire, water and phosphorus. Ecol Model 2 (3): 169-188.
14	Bear, J., 1972. Dynamics of fluids in porous media. American Elsevier, New York, NY, 764 p.
15	Beardsley, D W, T W. Casselman, and B. G. Volk. 1972. Organic soil subsidence in the upper Everglades. Sunshine State Agr Res Rep, 17 (2): 8-10. map.
16	Bell, F.W. 1987. The Economic Impact and Valuation of the Recreational and Commercial Fishing Industries of Lake Okeechobee, Florida. Technical Report, Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
17	Bennetts, R.E., M.W. Collopy and S.R. Beissinger. 1988. Nesting ecology of snail kites in Water Conservation Area 3A. Tech. Report Number 31. Florida Cooperative Fish and Wildlife Research Unit, Department of Wildlife and Range Science, University of Florida, Gainesville, FL, 174 pp.

18	Benson, M.A. and R.A. Gardner. 1974. The 1971 drought in South Florida and its effects on the hydrologic system. U.S. Geol. Surv., Water Resources Investigations, 12-774, 46 pp.
19	Bodle, M. J., A.P. Ferriter and D.D. Thayer, 1994. The biology, distribution and ecological consequences of Melaleuca quinquenervia in the Everglades. In: Davis, S.M. and J.C. Ogden (Eds). Everglades: The Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL.
20	Boesch, D.F., N.E. Armstrong, C.F. D'Elia, N.G. Maynard, H.W. Paerl, and S.L. Williams. 1993. Deterioration of the Florida Bay ecosystem: an evaluation of the scientific evidence. Report to the Interagency Working Group on Florida Bay, Nat. Fish and Wildlife Foundation, Nat. Park Service, So. Fla. Water Management District, Sept. 15, 1993. 27 pp.
21	Brooks, H.D. 1974. Lake Okeechobee. In: Gleason, P.J. (ed.) Environments of South Florida: Past and Present, Memoir 2, Miami Geological Society, Miami FL. pp. 256-286.
22	Browder, J.A. 1974. Regional control of ecosystem areas by varying water levels. Pages 655-656 *in* H.T. Odum, K.C. Ewel, J.W. Ordway, M.K. Johnston, and W.J. Mitsch, editors. Cypress wetlands for water management, recycling, and conservation. University of Florida, Center for Wetlands, Gainesville, Florida. 1st Annual Report to National Science Foundation and Rockefeller Foundation.
23	Browder, J. A. 1985. Relationship between pink shrimp production on the Tortugas grounds and water flow patterns in the Florida Everglades. Bull. Mar. Sci. 37(3):839-856.
24	Browder, J.A. 1981. Perspective on the ecological causes and effects of the variable algal component of southern Everglades periphyton. South Florida Research Center Report T-643, National Park Service, Everglades National Park, Homestead, FL.
25	Browder, J.A. 1982. Biomass and primary production of microphytes and macrophytes in periphyton habitats of the southern Everglades. South Florida Research Center Report T-662, National Park Service, Everglades National Park, Homestead, FL.
26	Bryan, K. 1928. Change in plant associations by change in ground water level. Ecology **9**:474-478.
27	Browder, J. A., C. Littlejohn and D. Young. 1976. The South Florida study. Center for Wetlands, Uni. of Florida, Gainesville, Fl.
28	Buchanan, T.J. and J.H. Hartwell . 1972. Analysis of water level data for Everglades National Park, Florida. U.S. Geo. Sur. Open-file Rep. FL-720004, 30 pp.
29	Burdine, H.W. and J.R. Crockett. 1978. Water table management for organic soil conservation and crop production in the Florida Everglades. Gainesville, Fla. The Station Bulletin Florida. Agricultural Experiment Station. (801). 22 p. ill., maps.
30	Carlisle V.W. and F.C. Watts. 1995. Factors of soil formation and Florida soils in Hydric Soils of Florida Handbook, Second Edition, V.W. Carlisle, (Ed.) Florida Association of Environmental Soil Scientists, Gainesville, FL.
31	Carter, M.R., L.A. Burns, T.R. Cavinder, K.R. Dugger, P.L. Fore, D.B. Hicks, H.F. Revels and T.M. Schmidt. 1973. Ecosystems analysis of the Big Cypress Swamp and estuaries. Ecological Report Number DI-SFEP-74-51, U.S. Environmental Protection Agency, Athens, GA, 375 pp.
32	Chinn Fatt, J. and J.D. Wang. 1987. Canal discharge impacts on Biscayne Bay salinities. Research/Resources Management Report SER-89, United States Department of the Interior, National Park Service, Southeast region, Atlanta, GA, 229 pp.
33	Clayton,B.L., J.R. Neller and R.V. Allison 1942. Water control in the peat and muck soils of the Florida Everglades. Bull. 378, Uni. of Fla. Agr. Exp. St., Gainesville, Fla. 74 pp.
34	Cohen, A. D. 1984. Evidence of fires in the ancient Everglades and coastal swamps of southern Florida. In: Gleason (ed.) Environments of South Florida: Past and Present. Miami Geological Society, Miami FL. pp. 459-464.
35	Cohen, A.D. and T.D. Davies. 1989 (abstract). Petrographic/botanical composition and significance of the peat deposits of Florida Bay. Bull. Mar. Sci., 44(1). Presented at Symposium on Florida Bay, a Subtropical Lagoon. U.S. National Park Service/Everglades National Park and University of Miami/ Rosenstiel School of Marine and Atmospheric Science. 1-5 June 1987.

36	Cohen, A.D. and W. Spackman, Jr. 1984. The petrology of peats from the Everglades and coastal swamps of southern Florida. In: Gleason, P. J. (ed.), Environments of South Florida: Present and Past II, 2nd Edition, Memoir II, Miami Geol. Soc., Coral Gables, Fla. pp. 352-374.
37	Costanza, 1975. The spatial distribution of land use systems, incoming energy and energy use in South Florida from 1900 to 1973. Masters Research Project, Department of Architecture, University of Florida, Gainesville, FL 254 pp.
38	Cox, S.C., D. Lewis, S. McCollum, M. Bledsoe and R. Marrotte. 1988. Subsidence study of the Everglades Agricultural Area for the South Florida Water Management District. U.S. Department of Agriculture, Soil Conservation Service, Palm Beach Soil and Water Conservation District, Green Acres, FL, 25 pp.
39	Craft C. B. ,S. Bartow and C. J. Richardson. 1994. Reconstructing historical changes in Everglades hydrologic regimes associated with anthropogenic hydroperiod alterations. Duke Univ., Durham, NC, Bulletin of the Ecological Society of America 75 (2 PART 2). 79th Annual Meeting of the Ecological Society of America, Knoxville, Tennessee, USA, August 7-11, 1994.
40	Craft, C.B. Richardson, C.J. Peat accretion and N, P, and organic C accumulation in nutrient-enriched and unenriched everglades peatlands. Tempe, Ariz. : Ecological Society of America.Ecological applications. Aug 1993. v. 3 (3) p. 446-458.
41	Craighead, F. C., Sr. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Fla. Naturalist, 41: 69-74.
42	Craighead, F.C. Sr. 1969. Vegetation and recent sedimentation in Everglades National Park., Fla. Nat. 42:157-166
43	Craighead, Frank C., Sr. 1966. The effects of natural forces on the development and maintenance of the Everglades, Florida.Everglades Natl. Park, Homestead, FL, Research Report - National Geographic Society no. 1966 p. 49-66
44	Dachnowski-Stokes, A.P. 1930. Peat profiles in the Everglades in Florida: the stratigraphic features of the "upper" Everglades and correlation with environmental changes. Jour. Wash. Acad. Sci., 20:89-107.
45	Dachnowski-Stokes, A.P. and R.V. Allison 1928. A preliminary on blue-green algae marl in southern Florida in relation to the problem of coastal subsidence. Jour. Wash. Acad. Sci., 16:476-480.
46	Davies, T.D. 1980. Peat Formation in Florida Bay and Its Significance in Interpreting the Recent Vegetational and Geological History of the Bay Area, Ph.D. dissertation, The Pennsylvania State University, University Park.
47	Davis, J. H., 1943. The natural features of Southern Florida, especially the vegetation, and the Everglades. St. of Fla. , Dept. of Conserv., Geol. Survey, Geol. Bull. No. 225, 311 pp.
48	Davis, J. H. 1946. The peat deposits of Florida. Fla. Geool. Surv., Bull. 30: 1-247.
49	Davis, S.M., L.H. Gunderson, W.A. Park, J.F. Richardson, and J.E. Mattson, 1994. Landscape dimension, composition, and function in a changing Everglades ecosystem. In: Davis, S.M. and J.C. Ogden (eds) 1994. *Everglades: The Ecosystem and Its Restoration*. St. Lucie Press, Delray Beach, FL.
50	Davis, S.M. and J.C. Ogden (Eds) 1994. Everglades: The Ecosystem and Its Restoration. St. Lucie press, Delray Beach, FL. 826 pp.
51	DeAngelis, D. L. 1994. Synthesis: Spatial and temporal characteristics of the environment. In: Davis, S.M. and J.C. Ogden (Eds) 1994. *Everglades: The Ecosystem and Its Restoration*. St. Lucie press, Delray Beach, FL. pp. 307-322
52	Dineen, J.W. 1972. Life in the tenacious Everglades. *In Depth Report* 1(5):1-10. Central and Southern Flood Control District, West Palm Beach, FL.
53	Doren, R.F. and R. M. Rochefort. 1984. Summary of Fires in Everglades National Park and BIg Cypress National Preserve, 1981. U.S. Dept. of Interior, Nat. park Serv., So. Fla. Res. Center, Rep. SFRC-84/01.

54	Duever, M.J. 1982. Tropical peatland hydrology. Presentation at Tropical Peatlands Workshop on June 1-2, 1982, Indianapolis. Ecosystem Research Unit, Naples, Florida.
55	Duever, M. J. 1986. The Big Cypress National Preserve (second edition) O. Res. Rept. No. 8, Nat. Audbon Soc., New York, N.Y. , 444 pp.
56	Duke Wetland Center. 1990. Phase One: A Preliminary Assessment of Nitrogen and Phosphorus Accumulation and Surface Water Quality in Water Conservation Areas 2A and 3A of South Florida. Publication 90-01. School of Forestry and Environmental Studies, Duke University, Durham, NC.
57	Environmental Science and Engineering, Inc. 1991. Hydroperiods and water level depths of freshwater wetlands in South Florida: A review of the scientific literature. Prepared for the South Florida Water Management District, West Palm Beach, Florida.
58	Fenemma, R.A., C.J. Neidrauer, R.A. Johnson, T.K. MacVicar, and W.A. Perkins, 1994. A computer model to simulate natural Everglades hydrology. In: Davis, S.M. and J.C. Ogden (Eds) 1994. *Everglades: The Ecosystem and Its Restoration*. St. Lucie press, Delray Beach, FL. pgs. 249-290.
59	Fish, J.E., 1988. Hydrogeology, aquifer characteristics, and ground- water flow of the Surficial Aquifer System, Broward County, Florida. U.S. Geological Survey Water-Resources Investigations Report 87-4034, Tallahassee, FL, 92 p.
60	Fish, J.E., and Stewart, M., 1991. Hydrogeology of the Surficial Aquifer System, Dade County, Florida. U.S. Geological Survey Water-Resources Investigations Report 90-4108, Tallahassee, FL, 50 p
61	Florida Bay Initiative. 1994. Adaptive Management Plan. Ft. Lauderdale, FL.
62	Fogarty, M. J. 1984. The ecology of the Everglades alligator. In: Gleason, P. J. (ed.), 1984. Environments of South Florida: Present and Past II, 2nd Edition, Memoir II, Miami Geol. Soc., Coral Gables, Fla. pp. 211-218.
63	Fox ,D.D., S. Gornak, T.D. McCall, D.W. Brown and C.J. Morris. 1995. Lake Okeechobee fisheries investigations. State of Florida, Florida Game and Freshwater Fish Commission, Lake Okeechobee-Kisssimmee River Project. Completion Report (Fiscal years 1992-1993 and 1994-1195). Fla. Game and Fresh water Fish Comm., Tallahassee, Fl., 177 pgs.
64	Furse, J.B. and D.D. Fox 1994. Economic fishery valuation of five vegetation communities in Lake Okeechobee, Florida. Proceeedings of Annual Conference Southeast Association of Fish and Wildlife Agencies, 48, ppp. 575-591.
65	Freeze, R.A. and Cherry, J.A., 1979. Groundwater. Prentice Hall, Inc., Englewood Cliffs, NJ, 604 p.
66	GCSSF. 1995. Initial Report. Report to Governor Lawton Chiles. October 1, 1995. Governor's Commission for a Sustainable South Florida. Coral Gables, FL.
67	Gilbert, K.M., J.D. Tobe, R.W. Cantrell, M.E. Sweeley, and J. R. Cooper. 1995. The Florida Wetlands Delineation Manual. Fla Dept. of Environmental Protection and the five Water Management Districts.
68	Givens, L. S. 1956. Water level management- its effect on the ecology, wildlife, and fisheries resources of Loxahatcheee Refuge. Letter concerining Conservation Areas 1 and 2. U.S. Dept. of Interioir, Fish and Wildlife Service, Atlanta, Ga. Sept. 1956.
69	Gleason, P. J. 1972. The origin, sedimentation, and stratigraphy of a calcite mud located in the southern freshwater Everglades. Ph.D. Thesis, College of Earth and Mineral Science, Pennsylvania State University, Penn. 355 pgs.
70	Gleason, P. J. and W. Spackman, Jr. 1974. Calcareous periphyton and water chemistry in the Everglades. In: Gleason, P. J. (ed.) 1974. Environments of South Florida: Present and Past II, Memoir II, Miami Geol. Soc., Coral Gables, Fla. pp. 146-181.
71	Gleason, P. J., A.D. Cohen, W.G. Smith, H.K. Brooks, P.A. Stone, R.L. Goodrick, and W. Spackman, Jr. 1974. The environmental significance of Holocene sediments from the Everglades and saline tidal plain. In: Gleason, P. J. (ed.) Environments of South Florida: Present and Past II, Memoir II, Miami Geol. Soc., Coral Gables, Fla.

72	Gleason, P.J. and P.A. Stone. 1994. Age, origin, and landscape evolution of the Everglades peatland. In: *Everglades: The Ecosystem and Its Restoration*. S.M. Davis and J.C. Ogden (Eds.), St. Lucie Press, Delray Beach, FL., chap. 7.
73	Gleason, P.J. and P.A. Stone. 1974. Special Report on the Effects of Recent Burning of Conservation Area 3 North of Alligator Alley. South Florida Water Management District Report.
75	Gordon, A.S., W.J. Cooper, and D.J. Scheidt. 1986. Denitrification in marl and peat sediments in the Florida Everglades. Washington, D.C.: American Society for Microbiology. Applied and environmental microbiology. v. 52 (5) p. 987-991. maps.
76	Gunderson, L. H., 1987. Historical hydropatterns in vegetation communitie of Everglades National Park. In: Freshwater Wetlands and Wildlife, Ninth Annual Symposium, Savannah River Ecology Laboratory, Savannah, Ga.
77	Gunderson, L.H. and W. F. Loftus. 1993. Competing land uses imperil the biotic communities of a vast wetland. South Florida Research Center, Everglades National Park, Homestead, FL.
78	Gunderson, L.H. and J.R Snyder. 1994. Fire patterns in the southern Everglades In: *Everglades: The Ecosystem and Its Restoration*. S.M. Davis and J.C. Ogden (Eds.), St. Lucie Press, Delray Beach, FL., pgs 291-306.
79	Harrington, R.W., Jr. 1973. Effects of fire in the ecosystem. Part I, Appendix K. In: So. Fla. Envir. Proj., Univ. of Miami, Coral Gables, FL, 156 pp.
80	Haunert, D.E. 1988. Sedimentation characteristics and toxic substances in the St. Lucie Estuary, Florida. Technical Publication 88-10. South Florida Water Management District, West Palm Beach, FL. 40 pp.
81	Hofstetter, R.H. and Parsons, F. 1975. Effects of fire in the ecosystem. Part II. Appendix K In: South Florida Environmental Project, Uni. of Miami, Coral Gables, Fla. 64 pp.
82	Havens, K.E., L.A. Bull, G.A. Warren, T.L. Crisman, E.J. Phlips and J.P. Smith. 1996. Food web structure in a subtropical lake ecosystem. *Oikos*, in press.
83	Hoffman, W., G.T. Bancroft, R.J. Sawicki. 1994. Foraging habits of wading birds in the Water Conservation Areas of the Everglades. In: Davis, S.M. and J.C. Ogden (eds) 1994. *Everglades: The Ecosystem and Its Restoration*. St. Lucie Press, Delray Beach, FL
84	Hoffmeister, J.E., 1974. Land from the Sea, Miami, FL, 143 p.
85	Hofstetter, R.H. and Parsons, F. 1975. Effects of fire in the ecosystem. Part II. Appendix K In: South Florida Environmental Project, Uni. of Miami, Coral Gables, Fla. 64 pp.
86	Hofstetter, R.H. and R.S. Sonenshein. 1980. Vegetative changes in a wetland in the vicinity of a well field, Dade County, FL. USGS Water Resources Investigations Report 89-4155, Tallahassee, FL.
87	Hofstetter, R. H. and F. Parsons. 1975. Effects of Fire in the Ecosystem: An Ecological Study of the Effects of Fire on the Wet Prairie, Sawgrass Glades, and Pineland Communities of South Florida. Part II (Final rept. May 73-Jun 75) Miami Univ., Coral Gables, Fla. Dept. of Biology.Sponsor: Department of the Interior, Atlanta, Ga., South Florida Environmental Project.Report No.: EVER-N-48; DI-SFEP-74-09, 78p.
88	Hutchinson, G.E. 1957. A Treatise on Limnology, Volume.1 Geography, physics, and chemistry, John Wiley and Sons, New York, N.Y.1015 pp.
89	Huyakorn, P.S., Mercer, J.W., and Andersen, P.F., 1986. SWICHA: A Three-Dimensional Finite Element Code for Analyzing Seawater Intrusion in Coastal Aquifers. Geotrans, Herndon, VA, 167 p.
90	Isdale, P. 1984. Flourescent bands in massive corals record centuries of coastal rainfall. Nature Vol. 310:578-579.
91	Jones, L.A. 1948. Soils, geology and water control in the Everglades region. Bull. Vol. 442, University of Florida Agricultural Experiment Station. Prepared in cooperation with the USDA Soil Conservation Service. Gainesville, FL, 168 pp.

92	Johnson, R. A., J. I. Wagner, D. J. Grigsby, V. A. Stern . 1988. Hydrologic effects of the 1984 through 1986 L-31 canal drawdowns on the northern Taylor slough basin of Everglades National Park.Res. Cent., ENP, Homestead, FL, United States, 45 p.
93	Klein, H. and B. G. Waller. 1985. Synopsis of saltwater intrusion in Dade County, Florida, through 1984. Dept. of the Interior, U.S. Geol. Surv., Water Resources Invest., Report 85-4101.
94	Klein, H., J.T. Armbruster, B.F. McPherson and H.J. Freiberger. 1975. Water and the south Florida environment. Water Resources Investigation 24-75. U.S. Geological Survey, Tallahassee, FL, 165 pp.
95	Knipling, E.B., V.N. Schroeder and W.G. Duncan. 1971. CO_2 evolution from Florida organic soils. Soil and Crop Science Soc. of Florida Proce., Vol. 30, pp 320--326.
96	Kohout, F.A. 1960. Cyclic flow of salt water in the Biscayne aquifer of southeastern Florida. Journal of Geophysical Research, V 65 (7), p 2133-2141.
97	Kohout, F. A. 1964. Flow of fresh water and salt water of the Biscayne Aquifer of the Miami area, Florida. U.G. Geol. Surv. Water-Supply Paper 1613-C.
98	Kohout, F.A. and S.D. Leach. 1964. Salt-water movement caused by control- dam operation in the Snake Creek Canal, Miami, Florida. Fla. Geol. Surv., Report of Invest. 24, Part IV, 49 pp.
99	Koszalka, E.J. 1995. Delineation of saltwater intrusion in the Biscayne aquifer, eastern Broward County, Florida, 1990. U.S. Geological Survey Water-Resources Investigations Report 93-4164.
100	Kushlan, J.A. 1980. Population fluctuations of Everglades fishes. Copeia 1980 (4): 870-874.
101	Kushlan, J.A. 1972. An ecological study of an alligator pond in the Big Cypress Swamp of Southern Florida. University of Miami, Coral Gables, FL. MS Thesis.
102	Kushlan, J.A. 1986. The Everglades: Management of cumulative ecosystem degradation. In: Proceedings of the Conference: Managing Cumulative Effects in Florida Wetlands, Held Oct. 17-19, Sarasota, Fla., New College Envir. Stud. Prog. Publ. No. 37, Omni Press, Madison, WI, pp. 61-82.
103	Kushlan, J.A. and B.P. Hunt. 1979. Limnology of an alligator pond in South Florida. Fla. Sci. 42(2): 65-84.
104	Kushlan, J.A. and M.S. Kushlan. 1980. Water levels and alligator nesting in the Everglades. Second Conference on Scientific Research in National Parks, San Francisco.
105	Kushlan, J.A., J.C. Ogden and A.L. Higer. 1975. Relation of water level and fish availability to wood stork reproduction in the southern Everglades, Florida. U.S. Geol. Surv. Rep. 75-434, Tallahassee, FL.
106	Leach, S.D., H. Klein and E.R. Hampton. 1972. Hydrologic effects of water control and management of southeastern Florida. U.S. Geol. Surv. Rep. of Invest. No. 60, 115 pp.
107	Lietz, C.,T. Richards , and R. Krulikas. 1995. Water resources data, Florida, 1994, Volume 2B, South Florida Ground Water. U.S. Geological Survey Water-Data Report FL-94-2B. Miami, FL, 780 p.
108	Lockhart, C.S. 1995. The effect of water level variation on the growth of Melaleuca seedlings from the Lake Okeechobee littoral zone. MS Thesis, Department of Biological Sciences, Florida Atlantic University, Boca Raton, FL.
109	Lodge, T.E. 1994. The Everglades Handbook:Understanding the Ecosystem St. Lucie Press, Delray Beach, Fl.
110	LOLZTG. 1988. Assessment of Emergency Conditions in Lake Okeechobee littoral Zone: Recommendations for Interim Management. Preliminary report by the Lake Okeechobee Littoral Zone Technical Group (LOLZTG) to John R. Wodraska, Executive Director, South Florida Water Management District, West Palm Beach, FL.
111	Loftus, W.F., R.A. Johnson, and G. Anderson. 1992. Ecological impacts of the reduction of groundwater levels in the rocklands In: Proc.. 1st Int. Conf. of Ground water Ecology, J.A. Stafford and J.J. Simon (Eds.) American Water Resources Association, Bethesda Md. pp.198-208.

112	Loftus, W.F. and Anne-Marie Ekland. 1994. Long-term dynamics of an Everglades small-fish assemblage. In: Everglades: The Ecosystem and Its Restoration. S.M. Davis and J.C. Ogden (Eds.), St. Lucie Press, Delray Beach, FL., pp. 461-484.
113	Loveless, C.M.1959. A study of the vegetation of the Florida Everglades. Ecology, 40(1):1-9.
114	Maltby, E. and P.J. Dugan. 1994. Wetland ecosystem protection, management, and restoration. *In*: Davis, S.M. and J.C. Ogden (eds) 1994. Everglades: The Ecosystem and Its Restoration. St. Lucie press, Delray Beach, FL.
115	McDowell, L.L., J.C. Stephens, and E.H. Stewart. 1969. Radiocarbon chronology of the Florida Everglades peat. Soil Sci. Soc. Am. Proc. 33:743-745.
116	McCollum, S. H., V. W. Carlisle, B.G. Volk. 1976. Historical and current classification of organic soils in the Florida Everglades. Proc. Soil Crop Sci. Soc. Fla. 35: 173-177. Map. Ref.
117	McIvor, C.C., J.A. Ley and R.D. Bjork. 1994. Changes in Freshwater Inflow from the verglades to Florida Bay Including effects on Biota and Biotic Processes: A Review. In: Davis, S.M. and J.C. Ogden (Eds) 1994. Everglades: The Ecosystem and Its Restoration. St. Lucie press, Delray Beach, FL.
118	McPherson, B. F. 1971 . Hydrobiological characteristics of Shark River estuary, Everglades National Park, Florida Open-File Report, 113 p.
119	McPherson, B. F. 1973 Vegetation in relation to water depth in Conservation Area 3, Florida. Open File Report #73025, U.S. Geol. Surv., Tallahassee, Florida.
120	McPherson, B.F., G.Y. Hendrix, H. Klein and H.M. Tysus. 1976. The environment of south Florida: a summary report. U.S. Geological Survey Professional Paper 1011, 81 pp.
121	Ogden, J.C. W. F. Loftus and W. B. Robertson, Jr. 1987. Woodstorks, wading birds and freshwater fishes. Statement Paper. U.S. Army Corps of Engineers, General design memorandum on modified deliveries to Everglades National Park, South Florida Research Center, Homestead, FL.
122	Park, W.A. and C. McVoy (in prep.) Evaluation of the Natural Systems Model description of pre-drainage hydrology in the Everglades, FL., Draft Statement of Work, in preparation.
123	Parker, G.G. 1945. Saltwater encroachment in southern Florida. American Water Works Association Journal 37 (6): 526-542.
124	Parker, G.G. 1948. Geology and groundwater of the Everglades Region. University of Florida Agriculture Exp. Sta., Bull. 442.
125	Parker, G.G. 1984. Hydrology of the pre-drainage system of the Everglades in southern Florida. In: Gleason, P.J. (Ed.). *Environments of South Florida: Present and Past II*. Miami Geological Society, Coral Gables, FL, pp 28-37.
126	Parker, G.G., G.E. Ferguson and S.K. Love. 1955. Water resources of southeastern Florida with special reference to the geology and groundwater of the Miami area. Water Supply Paper 1255, U.S. Geological. Survey, U.S. Government Printing Office, Washington, D.C., 965 pp
127	Perkins, W.A. and T.K. MacVicar. 1991. A computer model to simulate natural south Florida hydrology, Draft report, South Florida Water Management District, West Palm Beach, FL.
128	Pesnell, G.L. and R.T. Brown, III. 1973. The vegetation of the Lake Okeechobee, Florida (map). Central and Southern Florida Flood Control District. West Palm Beach, FL.
129	Pesnell, G.L., and R.T. Brown, III. 1977. The major plant communities of Lake Okeechobee, **Florida and their associated inundation characteristics as determined by a gradient analysis. South Florida Water Management District, West Palm Beach, Florida. Technical Publication 77-1**, 68 pp. + map.
130	Platt, N.G. and V.P. Wright 1992 Palustrine carbonates and the Florida Everglades; towards an exposure index for the fresh-water environment? Journal of Sedimentary Petrology vol. 62 no. 6 p.1058-1071
131	Puri, H.S. and R.O. Vernon. 1964. Summary of the geology of Florida and guidebook to the classic exposures. Fla. Geol. Surv. Spec. Publ., No. 5, 312 pp.

132	Restrepo, J., C. Bevier, and D. Butler. 1992. A three dimensional finite difference ground water flow model of the Surficial Aquifer System, Broward County, Florida. Tech. Pub. 92-05, South Florida Water Management District, West Palm Beach, FL.
133	Richardson, C.J. and C.B. Craft. 1990. Phase one: a preliminary assessment of nitrogen and phosphorus accumulation and surface water quality in Water Conservation Areas 2A and 3A of South Florida. Duke Wetland center, Duke University, Durham, N.C.
134	Richardson C J; Craft C B; Qualls. 1990. Peat accretion and phosphorus storage in the Everglades Florida, 75TH Annual meeting of the EcologicaL Society of America on perspectives in ecology: past, present, and future, snowbird,UTAH, USA, July 29-August 2, 1990. Bull Ecol Soc Am 71 (2Suppl.). 1990. 302.
135	Richardson, J.R., T.T. Harris, and K.A. Williges 1995. Vegetation correlations with in various environmental parameters in the Lake Okeechobee littoral marsh ecosystem. Archiv. fur Hydrobiologie, Advances in Limnology, vol. 45, pp.41-61.
136	Robertson, W.B. Jr. 1953. A survey of the effects of fire in Everglades National Park. Everglades National Park, National Park Service, United States Department of the Interior, Homestead, FL.
137	Robertson, W. B. and J.A. Kushlan. 1984. The southeastern Florida avifauna. In:Gleason (ed.) *Environments of South Florida: Past and Present*. Miami Geological Society, Miami FL.
138	Rose, P.W., M.D. Flora and P.C. Rosendahl. 1981. Hydrologic impacts of L-31 (W) on Taylor Slough, Everglades National Park. South Florida Research Center Report T-612. South Florida Research Center, Everglades National Park, Homestead, FL.
139	Schmitz, D.C. and T.C. Brown. 1994. An assessment of invasive non- indigenous species in Florida's Public Lands. Technical Report, Florida Department of Environmental Protection, Tallahassee, FL.
140	Schomer, N.S. and R.D. Drew. 1982. An ecological characterization of the lowerEverglades, Florida Bay, and the Florida Keys. FWS/OBS-82/58.1. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C., 246 pp.
141	Schortemeyer, J. L. 1980. An evaluation of water management practices for optimum wildlife benefits in Conservation Area 3A. Florida Game and Freshwater Fish Commission, Ft. Lauderdale, FL.
`142	Scientific Working Group. 1995. Record of the proceedings of the Scientific Working Group meetings of August 29-31, 1994 conducted at the Palm Beach Hilton Hotel, West Palm Beach, Florida in support of the Lower East Coast Regional Water Supply Plan, South Florida Water Management District, West Palm Beach, FL.
143	Schroeder, M.C., H. Klein and N.D. Hoy. 1958. Biscayne aquifer of Dade and Broward counties, Florida. Florida Geological Survey Report of Investigations, Number 17, 56 pp.
144	Sheng, Y.P. and H.K. Lee. 1991. Computation of phosphorus flux between the vegetation area and the open water in Lake Okeechobee. Final Report, Contract Investigation. Prepared for South Florida Water Management District, West Palm Beach FL.
145	SFWMD. 1989. Interim Surface Water Improvement and Management (SWIM) Plan for Lake Okeechobee. South Florida Water Management District. West Palm Beach, FL.
146	SFWMD. 1992. Draft Surface Water Improvement and Management Plan for the Everglades. Planning Department, South Florida Water Management District. WPB, FL.
147	SFWMD 1993a. Surface Water Improvement and Management (SWIM) Plan. Update for Lake Okeechobee, Volume 1 Planning Document. South Florida Water Management District, West Palm Beach FL. January, 1993
148	SFWMD. 1993b. Public Water Supply Permit Renew, City of Hallandale. South Florida Water Management District. WPB, FL.
149	SFWMD, 1994. Lower West Coast Water Supply Plan. Planning Department, South Florida Water Management District. West Palm Beach, FL. February, 1994

150	SFWMD. 1995. An update of the Surface Water Improvement and Management Plan for Biscayne Bay. Planning Dept. South Florida Water Management District. WPB, FL.
151	SFWMD, in prep. Water Supply Plan for the Lower East Coast Planning Area of South Florida. Planning Department, South Florida Water Management District. West Palm Beach, FL.
152	Shih, S.F. and J.A. Doolittle. 1984. Using radar to investigate organic soil thickness in the Florida Everglades.Madison, Wis. : The Society.Soil Science Society of America journal. May/June 1984. v.48 (3) p. 651-656. ill.
153	Shih, S.F., E.H. Stewart, L.H. Allen, Jr., and J.W Hilliard. 1979. An investigation of subsidence lines in 1978. University of Florida Belle Glade, Fla. : The Center.Belle Glade AREC research report EV - Florida UniversityAgricultural Research and Education Center. Feb 1979. (1979-1) 28 p.
154	Shih, S.F. J.W. Mishoe, J.W. Jones and D.L. Myhre. 1978. Modeling the subsidence of Everglades organic soil. transactions of the ASE, Vol. 21, pp.1151-1156.
155	Shine, M., D. Padgett, and W.M. Barfknect. 1989. Ground water resource assessment of eastern Palm Beach County, Florida. Technical Publication #89-4, South Florida Water Management District, West Palm Beach, FL.
156	Smith, J.P., J.R. Richardson and M.W. Callopy. 1995. Foraging habitat selection among wading birds (Ciconiiformes) at Lake Okeechobee, Florida, in relation to hydrology and vegetative cover. *Archiv fur Hydrobiologie*, Advances in Limnology, 45, 247-285.
157	Smith, W. G. 1968. Sedimentary environments and Environmental Change in the Peat Forming Area of South Florida, Ph.D. dissertation, The Pennsylvania State University, University Park.
158	Smith, J.P., J.R. Richardson and M.W. Callopy. 1995. Foraging habitat selection among wading birds (Ciconiiformes) at Lake Okeechobee, Florida, in relation to hydrology and vegetative cover. *Archiv fur Hydrobiologie*, Advances in Limnology, 45, 247-285.
159	Sodek, F. III. and V.W. Carlisle. 1995. Soil profile and horizon designations in Hydric Soils of Florida Handbook, Second Edition, V.W. Carlisle, (ED.) Florida Association of Environmental Soil Scientists, Gainesville, FL.
160	Sonenshein, R.S.,E.J. and Koszalka. 1995. Water-table trends and saltwater intrusion in the Biscayne aquifer, Dade County, Florida, through 1993. U.S. Geological Survey (in press).
161	Spackman, W., C.P. Dolson, and W. Riegel. 1966. Phytogenic organic sediments and sedimentary environments in the Everglades-Mangrove complex Part 1. Evidence of a transgression sea and its effects on environments of the Shark River area of southwestern Florida. *Palaeontographica*. 117(8):135-152.
162	Stephens, J.C. and L. Johnson. 1951. Subsidence of organic soils in the upper Everglades region of Florida. Soil Science Society of Florida proceedings, Vol. XI, pp. 191-237.
163	Stephens, J.C. and W.H. Speir. 1969. Subsidence of organic soils in the U.S.A. Int. Assoc. of Scientific Hydrology. Pub. No. 89, pp. 523-534.
164	Stephens, J.C. 1984. Subsidence of Organic soils in the Florida Everglades - a review and update. In: Gleason (ed.) *Environments of South Florida: Past and Present.* Miami Geological Society, Miami FL.
165	Stephens, J. C. The relationship of sub-surface hydrology to water control and land use in the Everglades, Pt. II of Further studies of geological relationships affecting soil and water conservation and use in the Everglades.Soil Sci. Soc. Fla. Proc. v. V-A, p. 56-76, app. p.77-94, illus. incl. index map.
166	Stewart, E.H. and W.C. Mills. 1967. Effect of depth to water table and plant density on evapotranspiration rate in southern Florida. American Society of Agriculture and Engineering, Transactions 10 (2): 746-747.
167	Stone, P.A. 1978. Floating Islands--Biogeomorphic Features of Hillsboro Marsh, Northeastern Everglades, Florida, M.A. thesis, Florida Atlantic University, Boca Raton, FL.

168	Stone, P.A. and P.J. Gleason. 1983. Environmental and paleoenvironmental significance of organic sediments (peats) in southeastern United States. In: *Variation in Sea Level on the South Carolina Coastal Plain*, D.J. Colquhoun (Ed.) Department of Geology, University of South Carolina, Columbia, pp. 121-141.
169	Swift, D. R., C. Anclade, and I.H. Kantrowitz. 1987. Algal blooms in Lake Okeechobee, Florida and management strategies to mitigate eutrophication. *National Water Summary 1987- Hydrological Events and Water Supply and Use.* U.S. Geological Survey Water Supply Paper 2350.
170	Swift, D.R. and R.B. Nicholas. 1987. Periphyton and water quality relationships in the Everglades Water Conservation Areas. Technical Publication 87-2. South Florida Water Management District, West Palm Beach, FL.
171	Tabb, D.C. and E.S. Iversen. 1971. A survey of the literature relating to the South Florida ecosystem. University of Miami, Rosenstiel School of Marine and Atmospheric Sciences, ML #71098. Oct., 1971, 205 pp.
172	Tabb, D.C., T.R. Alexander, T.M. Thomas and N. Maynard. 1967. The physical,biological and geological character of the area south of C-111 canal in extreme southeastern Everglades National Park. Report to the U.S. National Park Service, Institute of Marine Sciences, University of Miami, Miami, FL. ML #67103, 55 pp.
173	Takekawa, J. E. and S. R Beissinger. 1989. Cyclic drought dispersal and the conservation of the snail kite in Florida USA Lessons in critical habitat. Sch. Forestry and Environmental Studies, Yale Univ., New Haven,Conn. 06511, USA.Conserv Biol 3 (3). 1989. 302-311.
174	Tanner, G.W., J.M. Wood and R. Hassoun. 1987. Comparative graminoid community composition and structure within the northern portion of Everglades National Park, Northeast Shark River Slough, Water Conservation Area 3A, and Water Conservation Area 3B. Draft final report to U.S. Army Corps of Engineers, University of Florida, Gainesville.
175	Tarver, D.P., J.A. Rodgers, M.J. Mahler and R.L. Lazor. 1986. Aquatic and Wetland Plants of Florida. Bureau of Aquatic Plant Research and Control, Florida Department of Natural Resources, Tallahassee, FL.
176	Taylor, D.L. 1981. Fire history and fire records for Everglades National Park 1948-1979. U.S. Department of Interior, National Park Service, South Florida Research Center Report T-619 (April), 121 pp. + 2 maps (mimeo).
177	Taylor, D.L. and R.F. Doren 1982. A summary of fires in Everglades National Park and Big Cypress National Preserve, 1980. U.S. Department of Interior, Naitonal Park Service, South Florida Resource Center, Report T-663.
178	Todd, D.K. 1980. Groundwater Hydrology. John Wiley & Sons, NY, 535 p.
179	Tropical BioIndustries, Inc. 1990. Hydroperiod conditions of key environmental indicators of Everglades National Park and adjacent East Everglades area as guide to the selection of an optimum water plan for Everglades National Park. Tropical BioIndustries, Inc., Miami, FL.
180	USACE. 1990. General Design Memorandum: Modified Water Deliveries to Everglades National Park. Parts I and II. United States Army Corps of Engineers Jacksonville, FL. July, 1990.
181	USACE. 1992. Water control plan for Water Conservation Areas- Everglades National Park, and ENP-South Dade Conveyance System, Central and Southern Florida Project for Flood Control and other Purposes, Jacksonville District,, Jacksonville, FL., October 1992.
182	USACE. 1994. Central and Southern Florida Project. Final Integrated General Reevaluation Report and Environmental Impact Statement. Canal 111 (C-111), South Dade County, Florida., Jacksonville District,, Jacksonville, FL., May 1994.
183	USDA 1974. Soil Survey of Palm Beach County Area, Florida. Palm Beach Soil and Water Conservation District, Lake Worth, Florida.
184	Vogl, R.J. 1973. Effects of fire on the plants and animals of a Florida wetland. American Midland National 89: 334-347.

185	Volk, B.G. 1973.Everglades histosol subsidence: CO_2 evolution as affected by soils type, temperature and moisture. Soil and Crop Science Soc. of Florida Proc. Vol. 32. pp. 132-135.
186	Volk, B.G., S.D. Schemnitz, J.F. Gamble and J.B. Sartain. 1975. Baseline data on Everglades soil-plant systems: elemental composition, biomass and soil depth. In: Howell, F.G., Gentry, J.B. and Smith, M.H. (eds.), Mineral cycling in southeastern ecosystems. Available as CONF-740513, NTIS, U.S. Department of Commerce, Springfield, VA.
187	Wade, D.D., J.J. Ewel, and R. Hofstetter. 1980. Fire in south Florida ecosystems. General tech. Report SE-17. U.S. Dept. of Agriculture Forest service Asheville, N.C.
188	Wallace, H.E., W.H. Herke, N.F. Schlaack, Jr., F.J. Ligas and C.M. Loveless. 1960. Recommended program (of wildlife management) for Conservation Area 3. Florida Game and Fresh Water Fish Commission, Vero Beach, Florida, pp. ii-iii, 1-17, plus Appendices A through E on Fisheries, Waterfowl, Frogs, Deer, Vegetation, respectively.
189	Waller, B.G. 1985. Drought of 1980-82 in southeast Florida with comparison to the droughts of 1961-62 and 1970-71. U.S. Geol. Surv. Water-Resources Invest. Rep. 85-4152, 29 pp.
190	Watson, I. and J.W. Herr. 1985. Hydrogeology of the Biscayne Aquifer. Florida Science 48(3): 154-161.
191	White, W.A. 1970. The geomorphology of the Florida peninsula. *Florida Bureau of Geology* Bulletin Number 51.
192	Wu, Yegang, F. Sklar, K. Gopu, K. Rutchey 1996. Fire simulations in the Everglades landscape using parallel programing. In: Ecological Modeling (in press).
193	Worth, D. F. 1988. Environmental responses of Water Conservation Area 2A to reduction in regulation schedule and marsh drawdown. Technical Publication 88-2. South Florida Water Management District, West Palm Beach, FL.
194	Zaffke, M. 1983. Plant communities of Water Conservation Area 3A: Baseline documentation prior to the operation of S-339 and S-340. Tech. Memo. South Florida Water Management District, West Palm Beach, FL.

References Obtained from Minimum Flows and Levels Literature Review 8/96

**

DRAFT

Proposed Minimum Water Level Criteria

for Lake Okeechobee, the Everglades,

and the Biscayne Aquifer within
the South Florida Water Management District

Appendix F

Supplemental Environmental Information

Prepared by Staff of:

Water Supply Department

South Florida Water Management District

West Palm Beach, Florida

January 26, 2000

APPENDIX F - MFLS SUPPLEMENTAL ENVIRONMENTAL INFORMATION

Lake Okeechobee

EFFECTS OF HIGH/LOW LAKE STAGES.

Table F-1 provides a detailed matrix of the effects of high and low water levels on the Lake Okeechobee ecosystem. This information is broken down into a series of high and low water level categories, bracketing what is considered the optimal range (12 to 15 ft NGVD) of seasonal water level fluctuations for the lake. **Table F-1** provides documented evidence regarding the effects of a particular water level range and its impact (both positive and negative) on the ecology of Lake Okeechobee. **Figure F-1** is a bathymetric map that can be used to determine which areas of the lake are exposed at various water levels.

These data do not however, explicitly address the issue of return frequency or duration of flooding or drying. For the effects listed, it is assumed that the magnitude of the impact will increase with increased duration or return frequency of events. It is important to recognize the effects listed here are "direct" effects of high or low lake levels. Under conditions when lake levels are high, it is also likely that nutrient inputs from the watershed will also be elevated. This change in nutrient status could also impact ecosystem attributes. These additional effects are not considered here, but are described in the document entitled "Lake Okeechobee Conceptual Model and Hydrologic Performance Measures" (Havens and Rosen 1997).

Everglades

"INDICATOR REGIONS"

Figure F-2 provides a graphic of the location of specific "Indicator Regions" within the Everglades system as used in the Natural Systems Model (NSM) and the South Florida Water Management Model (SFWMM). Indicator regions are defined as groupings of model grid cells within the NSM and SFWMM identified by similar vegetation coverage and soil type. These smaller subareas were developed to average model output over a larger, multiple groupings of similar cells, rather than looking at a single (2 X 2 mile) cell represented by a single water management gage.

Table F-1. Matrix of Effects of High and Low Water levels on the Lake Okeechobee Ecosystem.

<table>
<tr><th>Water Level or Range</th><th>Ecological Effects</th><th>Information Base
(numbers in parentheses refer to a reference list attached to this table)</th></tr>
<tr><td>>17 ft
(at this lake level, entire littoral zone is flooded with water depths ranging from 2-5 ft. deep depending on location)</td><td>Negative Effects:
1 damage to bulrush and critical fish habitat at lake shore and littoral fringe due to wave erosion
2 loss of submerged aquatic vegetation due to insufficient light penetration
3 Loss of spikerush communities, expansion of cattail, increase in torpedo grass at higher elevations of the marsh
4 increased circulation of nutrient & sediment-rich water from mid-lake to near-littoral zone
5 increase in lake-wide total phosphorus concentrations, possibly due to greater net internal loading
6 higher phosphorus concentrations in water discharged to downstream ecosystems
7 transport of nutrients into pristine areas within the littoral zone, with nutrient-induced shifts in periphyton and plant community structure
8 extensive loss of nesting and foraging habitat for wading birds
9 reduced reproductive success for alligator populations
10 loss of willow habitat (preferred wading bird and snail kite nesting areas) with prolonged flooding
11 loss of habitat for certain mammals (e.g., bobcats)
12 reduced germination of native plant species in areas that are inundated for long periods of time
13 loss of habitat for Okeechobee gourd, a federally-endangered plant
Positive Effects:
14 reduced germination of melaleuca and torpedo grass</td><td>1 observations of wave impacts and comprehensive fisheries surveys by FGFWFC (1)
2 plant survey data from high water period and lab experiments (2)
3 vegetation studies documented by Milleson (8)
4 statistical analysis of water quality data and hydrodynamic model output (3,4)
5 statistical analysis of w. quality data (3)
6 statistical analysis of water quality data (3)
7 hydrodynamic model output and results of nutrient-addition mesocosm experiments (4,5,6)
8 results from Lake Okeechobee Ecosystem Study (LOES) (7)
9 information provided by FGFWFC staff from yearly alligator nesting surveys
10 results from LOES (7)
11 preliminary results from District / USACE) study of animal use of littoral zone
12 documented by Milleson (8)
13 observations by District and USFWS staff
14 exp. research on melaleuca germination and growth (9) and influence of water depths on torpedo grass growth and biomass (10)</td></tr>
<tr><td>>16 ft
(at this lake level, entire littoral zone is flooded with water depths ranging from 1-4 ft. deep depending on location)</td><td>Negative Effects:
1 Similar impacts as listed for > 17 ft. NGVD, except that the loss of bulrush community due to wave action (item 1) is not as great a concern at this water level
Positive Effects
2 same effects as listed for >17 ft. level</td><td>see corresponding items above, under > 17 ft Category</td></tr>
<tr><td>>15 ft
(entire littoral zone is flooded with water depths ranging from a few inches to 2-3 ft. deep depending on location)</td><td>Negative Effects:
1 Similar impacts as listed for > 17 ft. NGVD, except that the loss of bulrush due to wave action (item 1) is not as great a concern at this water level, and nutrient transport into the interior marsh (item 6) is less likely at this lake stage.
Positive Effects:
2 same effects as listed for >17 ft. level</td><td>see corresponding items above, under > 17 ft Category</td></tr>
</table>

Table F-1 (Con't). Matrix of effects of high and low water levels on the Lake Okeechobee ecosystem.

Water Level or Range	Ecological Effects	Information Base (numbers in parentheses refer to a reference list attached to this table)
15 ft to 12 ft Range (approx. 50% of the time lake stages fluctuate between these two levels) At 12 ft. NGVD approx. 73% of the marsh is exposed as dry land	**Positive Effects:** Natural water level fluctuations in response to seasonal rainfall within this range are considered to ecologically benefit the littoral zone as well as other lake societal values (fishing, ecotourism, recreation, navigation). 1 optimization of prey resources for water birds 2 enhanced germination of native plants 3 reinvigoration of willow stands 4 facilitation of beneficial fires that can burn away cattail and torpedo grass 5 provide hydroperiods and water depths that will support spike rush (Eleocharis) communities in Moonshine Bay, a critical habitat currently threatened by torpedo grass expansion during dry periods. 6 peripheral bulrush habitat still has standing water and can be used as nesting and foraging habitat by largemouth bass and other recreationally important fish species. 7 increased light penetration results in the regrowth of beneficial submerged aquatic vegetation such as pond weed or eel grass when lake levels fall within the 12 –13 ft. range. 8 absence of many harmful effects associated with higher or lower lake levels **Negative Effects:** 9 when lake levels fall to 12 ft for extended periods, upper elevations of the littoral zone dry out and allow for the expansion of melaleuca, torpedo grass and other terrestrial species. Recent success in the melaleuca eradication program to date may, in part, be a result of lake levels not falling to these levels for the past several years.	1-4 Results from LOES (7) 5 GIS maps of littoral zone flooding, GIS vegetation maps, experimental studies at UF regarding torpedo grass growth under standing water (10) 6 see items 1 and 7 above, under the > 17 ft category 7 see item 2 above, under the > 17 ft category 9 observations of rapid melaleuca expansion following the 1989 drought, and results of experimental research at FAU (9) and UF (10)
<12 ft When Lake levels fall < 12 NGVD more than 73% of the marsh is exposed as dry land	**Negative Effects:** 1 Large regions of the marsh dry out and become available for invasion by Melaleuca, torpedo grass and terrestrial weeds 2 large areas of the marsh are no longer available as nesting or foraging habitat for fish, wading birds and other aquatic dependent wildlife. 3 Stabilized water levels within this range allow cattails to expand and out-compete bulrush and other native species within the littoral zone. 4 Increased predation of wading bird nests **Positive Effects:** 5 enhanced germination of native plants 6 reinvigoration of willow stands 7 increased frequency of beneficial fires that can burn away cattail and torpedo grass thatch 8 most of Moonshine Bay is still inundated, and the peripheral bulrush community is usable as a fishery habitat 9 improved water quality nearshore with increased light penetration resulting in the regrowth of beneficial submerged aquatic vegetation (especially in southern region of the lake) 10 migratory waterfowl (diving ducks) utilization of open water areas of the lake generally increases. 11 consolidation/oxidation of organic sediments which improve water quality.	1 see item 9 under the 12-15 ft category 2 results from LOES (7) 3-6 results from LOES (7) 7 see item 2 above, under the > 17 ft category 8-9results from LOES (7) 10FGFWFC waterfowl surveys of the lake 11FGFWFC studies of other Florida lake drawdowns

Table F-1 (Con't). Matrix of effects of high and low water levels on the Lake Okeechobee ecosystem

Water Level or Range	Ecological Effects	Information Base (numbers in parentheses refer to a reference list attached to this table)
<11 ft When Lake levels fall < 12 NGVD more than 94% of the marsh is exposed as dry land	**Negative Effects:** 1 nearly the entire marsh is available for invasion by melaleuca, torpedo grass, Brazilian pepper, and other exotic plants whose germination or growth is inhibited by standing water 2 most of the marsh can no longer function as a spawning habitat for fish, aquatic invertebrates, or other wetland biota 3 at this lake level, the Moonshine Bay region becomes dry, and can no longer function as a valuable fishery habitat, or as a habitat for the federally-endangered snail kite 4 at this level, the peripheral bulrush community is exposed, and can no longer function as an important habitat for bass and other economically-important fish. In addition, extreme low lake stages allow cattails to replace bulrush at the outer fringes of the marsh. 5 at low lake stages snail kite nesting and foraging success on the lake are significantly reduced. 6 significant increase in the frequency of severe fires which consume wetland vegetation, soils and wildlife habitat **Positive Effects** 7 same as above for the < 12 ft. category	1 see item 9 under the 12-15 ft category 2 observations of animal use of different regions of the marsh 3 GIS maps of littoral flooding and exposure; observations animal use of different regions of the marsh; information provided by USFWS regarding snail kite ecology 4 GIS maps of littoral flooding and exposure; information provided by FGFWFC regarding fish use of native plant communities (1) 5 Bennetts *et al.*1994 6 D. Fox, FGFWFC, personal communication | 7 7 see corresponding information above, under the <12 ft. category
<10 ft When Lake levels fall < 12 NGVD more than 99% of the marsh is exposed as dry land	**Negative Effects:** 1 Generally the same effects as at <11 ft, since critical regions of the marsh have already dried out at higher elevations of the marsh. Overall ecological effects are more severe per unit of time at this level, but scientific information in support of this view is lacking. 2 At low lake stages snail kite nesting and foraging success are significantly reduced. Historically (1981) many snail kites abandoned the lake and disperse to other areas when lake levels approach 10.0 ft or less. **Positive Effects:** 3 same as above, under the < 12 ft category 4 during extreme droughts shallow open water areas of the lake become critical foraging habitat for South Florida wading bird populations	1 see corresponding information above, under the <12 ft. category 2 Bennetts *et al.* 1994 4 David, (11); Zaffke (13)

References

3. Furse, J.B. and D.D. Fox. 1994. Economic valuation of five vegetation communities in Lake Okeechobee, Florida. Proceedings of the Annual Southeast Association of Fish and Wildlife Agencies 48: 575-591.
4. Steinman, A.D., R.H. Meeker, A.J. Rodusky, W.P. Davis, and S.J. Hwang. 1997. Ecological properties of charophytes in a large subtropical lake. Journal of the North American Benthological Society 16: 781-793.
5. Havens, K.E. 1997. Water levels and total phosphorus in Lake Okeechobee. Lake and Reservoir Management 13: 16-25.
6. Sheng, Y.P. 1993. Lake Okeechobee phosphorus dynamics study: hydrodynamics and sediment dynamics – a field and modeling study. South Florida Water Management District, West Palm Beach, FL.
7. Havens, K.E., T.L. East, S.J. Hwang, A.J. Rodusky, B. Sharfstein, and A.D. Steinman. Algal responses to nutrient additions in a littoral mesocosm experiment: biomass, productivity, and nutrient uptake rates. Oikos, in revision.
8. Havens, K.E., T.L. East, A.J. Rodusky, and B. Sharfstein. Littoral community responses to nitrogen and phosphorus: an experimental study of a subtropical lake. Aquatic Botany, in review.
9. Aumen, N.G. and R.G. Wetzel. 1995. Ecological studies of the littoral and pelagic systems of Lake Okeechobee, Florida (USA). Archiv fur Hydrobiologie, Volume 45.
10. Milleson, J.F. 1987. Vegetation changes in the Lake Okeechobee littoral zone 1972-1982. Technical Publication 87-3, South Florida Water Management District, West Palm Beach, FL.
11. Lockhart, C.S. 1995. The effect of water level variation on the growth of melaleuca seedlings from the Lake Okeechobee littoral zone. MS Thesis, Florida Atlantic University, Boca Raton, FL.
12. Thayer, P.L. and W.T. Haller. 1990. Fungal pathogens, *Phoma* and *Fusarium*, associated with declining populations of torpedo grass growing under high water stress. Proceedings of the European Weed Research Society, 8th Symposium on Aquatic Weeds.
13. Davis, Peter 1993. Wading Bird use of Lake Okeechobee relative to water conditions. Wilson Bulletin
14. Bennetts, R.E., M.W. Collopy, and J. A. Rodgers Jr. 1994. The snail kite in the Florida Everglades: a food specialist in a changing environment In.: Davis, S.D and J. Ogden (eds) *Everglades: The ecosystem and Its Restoration*. St. Lucie Press, Delray Beach, Fl.
15. Zaffke, M. 1983. Wading bird utilization of Lake Okeechobee marshes 1977-1981. Tech. Pub. 84-9, South Florida Water Management District, West Palm Beach, Fl.
16. Havens, K. and B. Rosen 1997. Lake Okeechobee Conceptual Model and Hydrologic Performance Measures, Internal Technical Document. Planning Department, South Florida Water Management District, West Palm Beach, Fl.

Figure F-1. Lake Okeechobee Bathymmetry

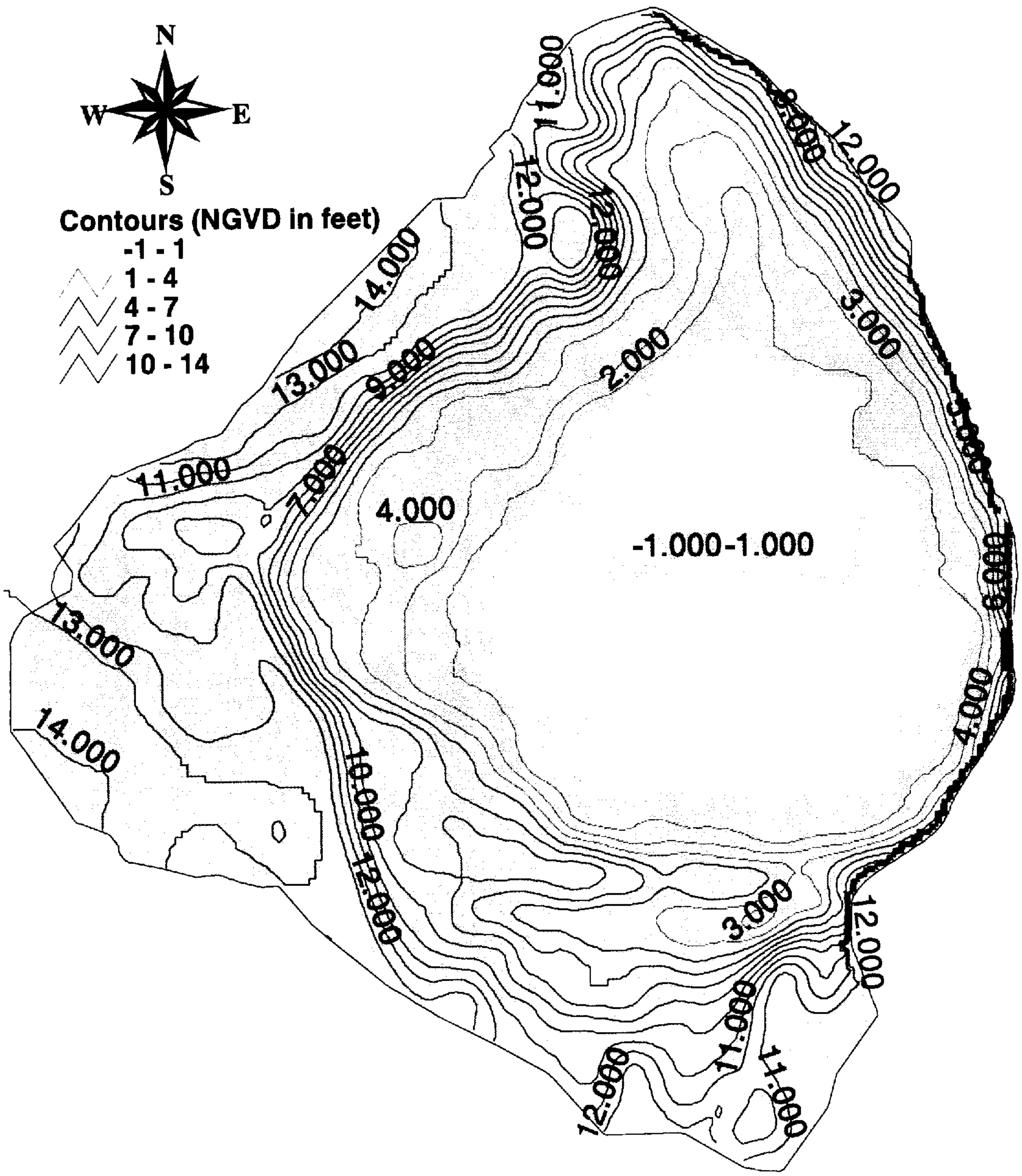


Figure F-2. Everglades Indicator Regions.