APPENDIX D

Environmental Hydrologic Analysis of Alternatives

Appendix D.
Environmental Hydrologic Analysis of the Alternatives

The environmental goal of the USJRBP is to restore and preserve the ecological integrity of this unique wetland\riverine ecosystem. Primary environmental objectives are to restore or preserve the natural attributes of species diversity and abundance, community diversity, and productivity of economically important species. To achieve these objectives our efforts focus on restoring the natural hydrologic regime. By re-creating a hydrologic regime that mimics natural conditions, optimum soil and vegetation characteristics will be maintained. This, in turn, will help provide other environmental benefits such as enhanced fish and wildlife habitat and improved water quality.

To guide restoration efforts in the USJRBP, we have developed environmental hydrologic criteria for each of the project areas. The environmental hydrologic criteria are a series of hydrologic statistics that form the boundaries of a natural hydrologic regime. To meet environmental goals, these boundaries should not be exceeded. In this sense, the hydrologic criteria are best viewed as constraints.

To better define what constitutes the natural hydrologic regime, studies were conducted within the Blue Cypress Marsh Conservation Area (BCMCA) to determine the relationship between hydrologic conditions and spatial vegetation patterns. These studies were conducted in the BCMCA because aerial photographs indicate vegetation communities have changed little in this area in the past 40 years, and because daily water elevations were available back to the year 1956. Results revealed that distributions of plant communities in the BCMCA reflected a gradient in long-term hydrologic conditions caused by topographic relief.

Initially, five hydrologic characteristics were identified as ecologically significant. These were: mean depth, inundation frequency, maximum depths, magnitude of water-level fluctuation, and timing of water level fluctuation. Using historical water level data, each of these hydrologic conditions were numerically described. Numerical values were further refined into the initial set of hydrologic criteria (or constraints), proposed to govern water regulation when levels were below established flood control schedules (Table D-1). Two additional conditions, water level recession rates, and minimum water levels for lakes, were later recognized as being important and were added to the list. The hydrologic criteria were reviewed and refined through frequent discussions between District staff and representatives of the Florida Fish and Wildlife Conservation Commission, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers.

The range of elevations and marsh types in the upper St. Johns River basin make the development of a single set of numerical operational criteria for the entire project area unrealistic. Therefore, criteria were developed relative to a set of critical elevations (minimum, maximum and central) determined specifically for each project area (Figure D-1). Minimum and maximum critical elevations are defined as those elevations

that delimit the majority of wetland acreage and are derived from inflection points on the stage-area curves (Figure D-1). The central critical elevation corresponds to the arithmetic mean of these two values.
Table D-1. Environmental hydrologic criteria established to guide hydrologic restoration of wetlands in the USJRBP. Determination of critical elevations is illustrated in Figure D-1.

1. **MEAN STAGE – The long term (30 yr.) average water depth should be no less than the mean critical marsh elevation.** (This corresponds to the mean ground elevation of each transect).

2. **INUNDATION FREQUENCY - The inundation frequency of the mean critical marsh elevation should be at least 60%.** (This will prevent soil subsidence and ensure that the mean water level is not attained from a strongly skewed inundation frequency curve.)

3. **MAXIMUM 14, 30 AND 60 DAY WATER ELEVATIONS - The water elevation should not exceed 4 ft, 3.5 ft, or 2.5 ft above the minimum critical elevation for more than 14, 30 or 60 continuous days respectively, more frequently than once every 10 years.** (These criteria will prevent flooding from damaging established marsh plant communities).

3. **MINIMUM RANGE OF YEARLY FLUCTUATION - The maximum critical elevation should be flooded for at least 30 continuous days in at least 25% of the years and the minimum critical elevation should be exposed for at least 30 continuous days in 20-30% of the years.** (This re-establishes natural water level fluctuation patterns).

4. **TIMING OF FLUCTUATION - Timing of fluctuation should be such that minimum water levels occur between April 1 and June 30 in more than 50% of the years and maximum water levels occur between September 1 and November 31 in more than 50% of the years.** (This restores the natural seasonality of water level fluctuations.)

5. **STAGE RECESSION RATES – Stage recession rates should not exceed 1.2 ft during any 30 day period or exceed 0.5 ft during any 7 day period when stages are less than or equal to one ft above the maximum critical marsh elevation.** (Restores natural rates of water level recession.)

2. ENVIRONMENTAL HYDROLOGIC CRITERIA FOR SJMCA

In areas of the USJRB where there is relatively little topographic relief over a broad expanse of marsh, we use a single stage-area curve for setting critical elevations. However, in the SJMCA, where elevation gradients are more extreme and the floodplain is highly constricted, this approach was discovered to be inappropriate. We modified our approach to accommodate the special morphometric characteristics of the SJMCA by using weighted perimeter instead of stage-area curves to determine critical elevations (Table D-2). Using this approach, critical elevations were established along three east-west cross-sections that passed near the Sixmile, Mulberry Mound, and Big Bend water level gauging stations (Figure D-2). Due to the proximity to water level recorders, we will be able to model how well hydrologic criteria are met after project completion. The weighted perimeter curves used to establish critical marsh elevations in the SJMCA are illustrated in Figure D-3, D-4, and D-5.

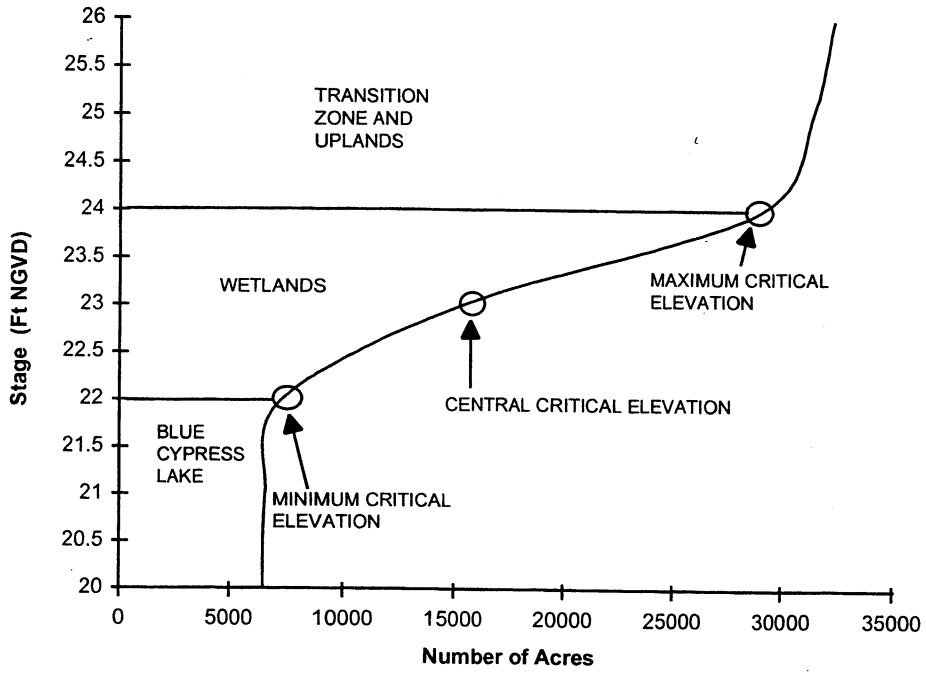

Figure D-1. Stage-area curve for the BCMCA showing critical marsh elevations and their relationship to wetland acreage.

Table D-2. Critical marsh elevations along the Sixmile, Mulberry Mound and Big Bend transects in the SJMCA determined from weighted perimeter curves.

Project Area	*Critical Elevations (ft NGVD)*		
	Central	*Maximum*	*Minimum*
Sixmile	21.0	21.5	20.5
Mulberry Mound	18.1	18.6	17.5
Big Bend	17.0	17.8	16.2

3. ENVIRONMENTAL HYDROLOGIC CRITERIA FOR TFMCA

Ground elevations in the TFMCA vary between 13.0 and 20.0 ft NGVD (Figure D-6). Because of this gradient, the entire TFMCA cannot be restored to marsh if it is operated as a single hydrologic management unit. Instead, under any of the alternatives considered, deeper ponded habitat will be created in the northern half of TFMCA and marsh habitat will be created toward the southern end. The original GDM recognized that ponding in the northern half of the TFMCA would be unavoidable because of soil subsidence. Therefore, creation of dead storage was necessary to produce desirable hydrologic regimes on other portions of the TFMCA marsh (Brooks and Lowe 1984). Ecological benefits to having a broad connection between deep and shallow water habitats were recognized. During the dry season the ponded area will provide deep-water refugia for aquatic organisms that occur in the marsh. As water levels rise during the wet season, these organisms will rapidly recolonize reflooded habitats. As dry season water levels recede these organisms, many which serve as prey, would be concentrated along the receding water line and in

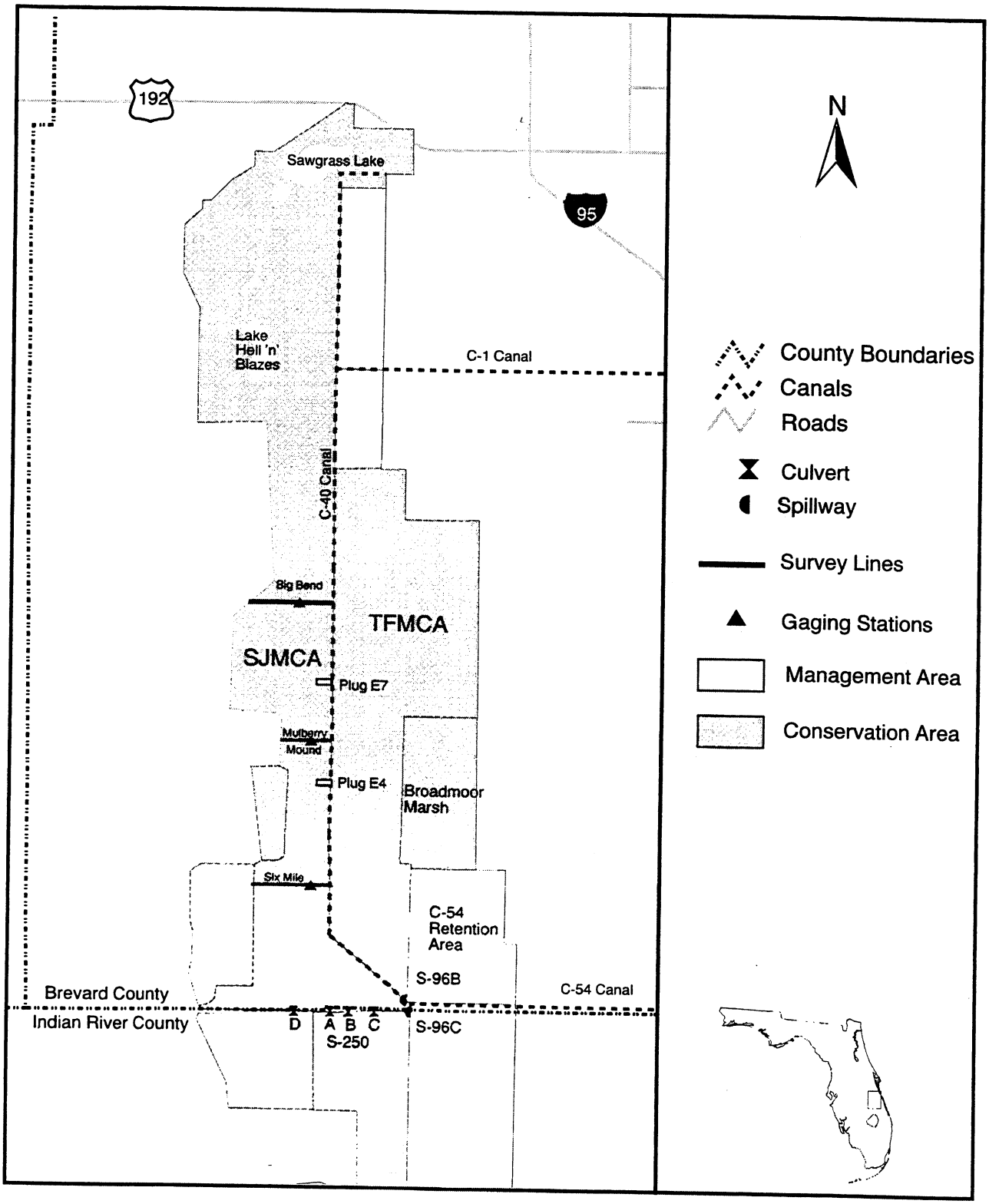

Figure D-2. Project location and plan view.

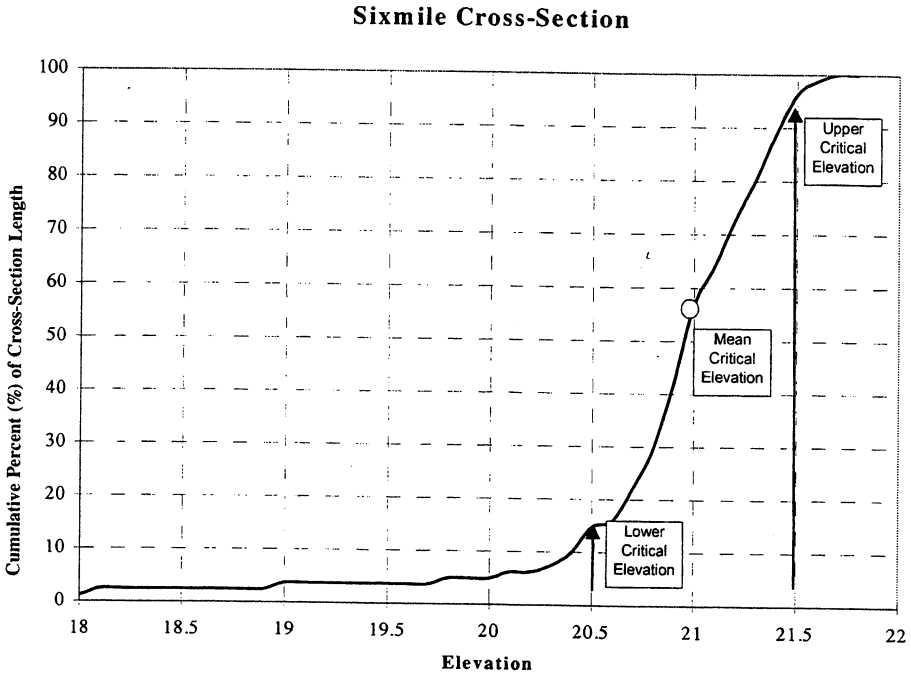

Figure D-3. Central, maximum (upper) and minimum (lower) critical elevations along the Sixmile Marsh transect.

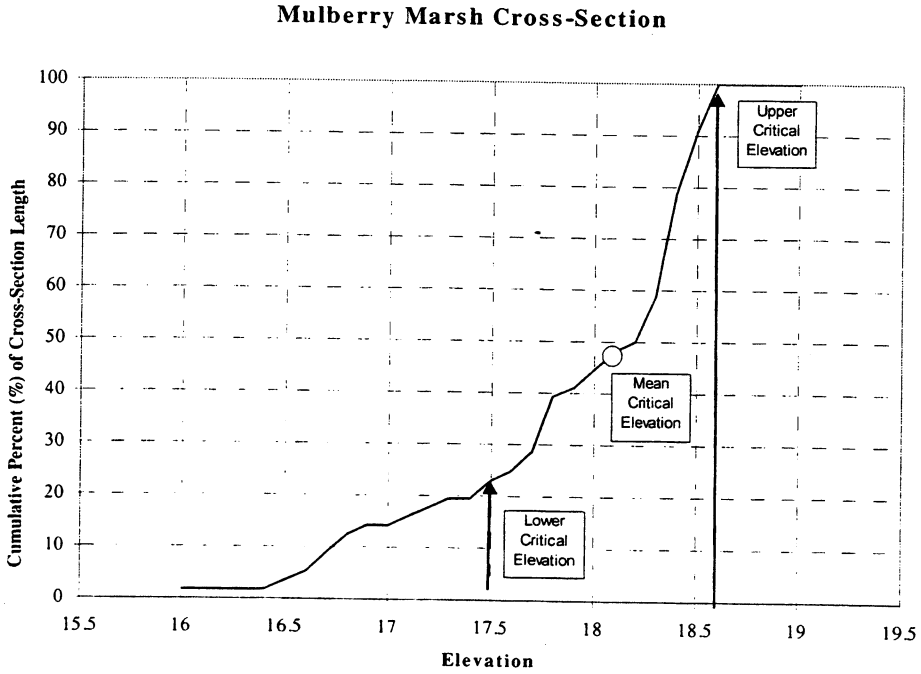

Figure D-4. Central, maximum (upper) and minimum (lower) critical elevations along the Mulberry Mound transect.

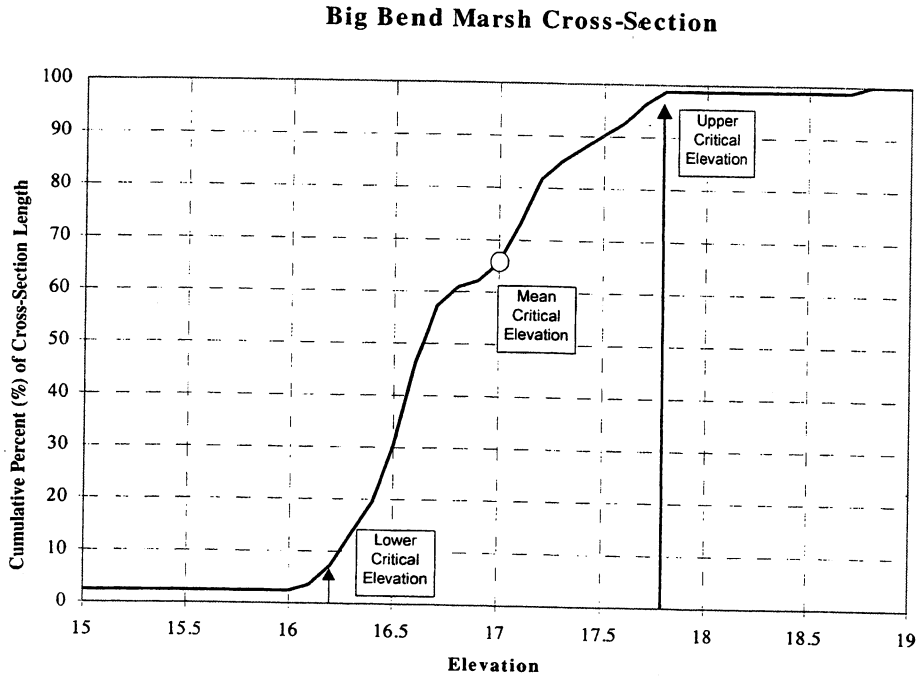

Figure D-5. Central, maximum (upper) and minimum (lower) critical elevations along the Big Bend Marsh Transect.

shallow water habitats where optimum feeding conditions would be provided for wading birds, larger sportfish, and other wildlife.

Early in the process of developing a final design for TFMCA it was also recognized that there was a potential for a sport-fishery to develop in the permanently ponded area of the TFMCA that could have a high recreational value (D. Cox FFWC, Pers. comm.). FFWCC fisheries biologists expressed concerns, however, that potential anoxia occurring in conjunction with extreme low water events could cause extensive fish kills. Although fish kills are not uncommon and occur naturally, if they occur too frequently they would seriously compromise the recreational value of the area. To address these concerns, we developed environmental hydrologic criteria for the TFMCA that attempt to maximize wetlands restored while minimizing the intensity and duration of extreme low water events. The intent of the criteria was to reach a balance that provides for minimizing short-term fluctuations in the deep open-water habitat, while still allowing drydowns of the remaining marsh to occur at the appropriate durations and frequencies needed to maintain emergent marsh vegetation (Table D-3; Figure D-6).

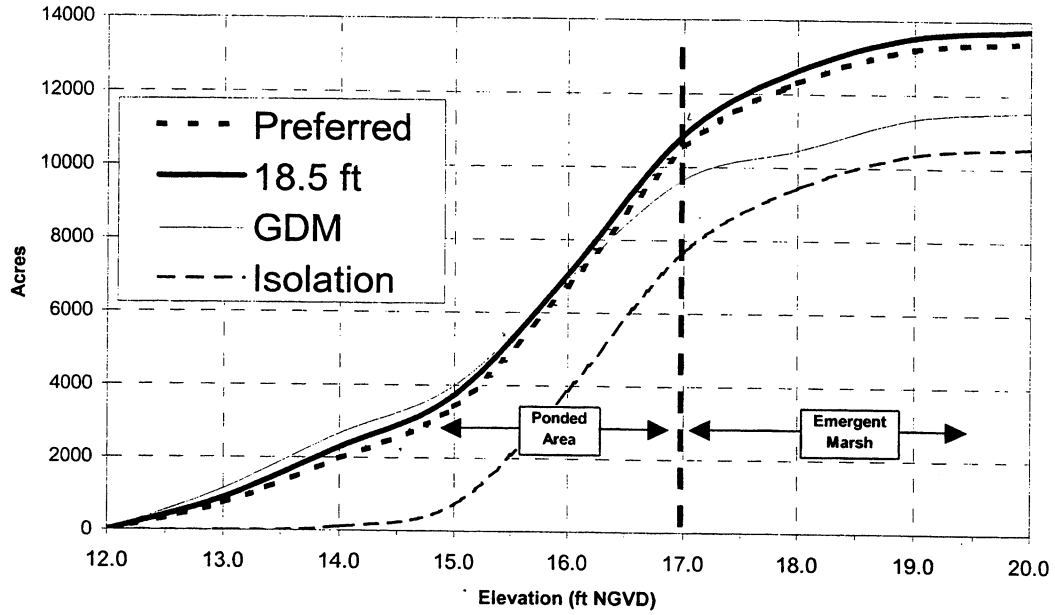

Figure D-6. TFMCA stage-area curves for the No Action or GDM, the 18.5, the Isolation, and the Preferred Alternatives.

Table D-3. Environmental hydrologic criteria for TFMCA if the area is managed as a single interconnected unit (No Action and Preferred Alternatives).

1. **MEAN STAGE - The long-term (30 yr.) average water elevation should be no less than 18.0 ft NGVD.** (This corresponds to the mean ground elevation of those areas of the TFMCA to be restored to wetlands.)

2. **INUNDATION FREQUENCY – The inundation frequency of the 18.0 ft elevation should be at least 60%.** (This will prevent soil subsidence in wetland areas and ensure that the mean water level of 18.0 ft NGVD is not attained from a strongly skewed inundation frequency curve.)

3. **MINIMUM DRYING LEVEL – The 17.0 ft NGVD elevation should be exposed for at least 60 continuous days every 5 to 10 years. The 17.5 ft elevation should be exposed for at least 30 continuous days every 2 to 5 years.** (This allows for wetland plant community establishment and for the other ecological benefits of marsh drydown.)

4. **TIMING OF FLUCTUATION – Timing of fluctuation should be such that minimum water levels occur between April 1 and June 30 in more than 50% of the years and maximum water levels occur between September 1 and November 31 in more than 50% of the years.** (This restores the natural seasonal variability of water level fluctuations.)

5. **STAGE RECESSION RATES – Stage recession rates should not exceed 1.2 ft during any 30 day period or exceed 0.5 ft during any 7 day period when stages are less than 19.0 ft.** (Establishes natural rates of water level recession. The 19.5 ft elevation corresponds to the level at which the entire TFMCA is flooded.)

6. **MINIMUM WATER LEVELS –The 16.5 ft NGVD elevation should be inundated at least 95% of the time. Water levels should not fall below 16.0 ft more frequently than once every 4.0 years.** (This criterion is needed to protect the integrity of the sport fishery in the TFMCA. Florida Game and Fresh Water Fish Commission biologists have recommended that minimum average water depth not fall below 3.0 ft. At an elevation of 16.5 ft approximately 1,650 acres will have depths exceeding 3.0 ft.)

3. HYDROLOGIC MODELING

Hydrologic evaluation of each of the alternatives considered was conducted using simulated water level data generated by the Upper St Johns River Basin Hydrologic Model (Suphunvorranop and Tai 1982). Simulated water levels were derived from historic rainfall records and calculated runoff. Hydrologic statistics, such as 30-year mean depth, were compared to environmental criteria. If criteria for TFMCA were not met, discharge schedules through S-257 were altered and simulations performed again. For SJMCA, hydrologic simulations were performed to attempt to meet environmental hydrologic criteria along all cross–sections simultaneously.

Water management plans presented in this plan are based upon simulated hydrologic data derived from 57 years (1942 - 1998) of historic rainfall data. Because these data may not reflect future rainfall conditions and because of the degree of uncertainty inherent in this type of modeling effort, hydrologic model simulations may not accurately represent actual post-project hydrologic conditions. Therefore, discharge schedules may have to be modified if post-project monitoring indicates the environmental hydrologic criteria are not being met.

. HYDROLOGIC EVALUATION OF THE ALTERNATIVES

3.1. SJMCA

We did not attempt to quantify the extent of overdrainage that would occur in the SJMCA if there were complete hydrologic reconnection with TFMCA, but accepted the original GDM assumption that during low flow conditions water would drain from SJMCA to the lower elevations of TFMCA. Instead, we focused hydrologic modeling efforts on determining the percent of the total discharge downstream of S-96B and S-96C and the canal plug configuration that would be needed to assure appropriate hydrologic conditions were maintained in SJMCA. Early modeling efforts indicated that an approximate 50/50 split of the total discharge, during periods of both high and low flow, was needed to, at least, tentatively meet this goal. In addition, hydrologic modeling indicated that environmental hydrologic criteria established for SJMCA could only be met by installing and operating gated control structures in the C-40 canal plugs. Without canal plugs the marsh would continue to be overdrained by the canal during low flow periods. Without operable culverts in the plugs, however; the marsh upstream of the plugs would be constantly inundated.

We then used two-dimensional modeling to determine optimal plug location and dimensions. This modeling effort indicated that optimum plug placement would be at the current location of Canal Plug E-7 and just downstream of Canal Plug E-4 (Figure D-2). Culverts were designed to pass a maximum of 100 cfs downstream with optimum headwater and tailwater conditions. Hydrologic criteria were best met opening the culverts fully during the dry season months of April, May, and June and closing the culverts from July through March.

A summary analysis of how well the environmental hydrologic criteria for SJMCA at the Sixmile, Mulberry Mound and Big Bend gauging stations are met is presented in Tables D-4, D-5, and D-6. Detailed model results are presented in table format in Appendix E. These analyses represent hydrologic conditions in SJMCA that would be created in the SJMCA under 18.5 ft, Isolated Wetlands, or the Preferred Alternative.

For practical purposes we could also assume that these results are comparable to results that would also be obtained for the No Action Alternative if we had flexibility to configure the system to ensure a complete 50/50 split of all discharges downstream of S-96B and S-96C.

Hydrologic criteria for SJMCA were mostly met. At the Sixmile, Mulberry Mound and Big Bend transects the inundation frequencies of the central critical elevations ranged from 72% to 85%. (Tables D-4, D-5, D-6). Recession rate were somewhat rapid at the Six Mile site and the area dried more frequently than in the desired 20% to 30% of the years. The same was true for the Big Bend site; however; the Mulberry Mound site did not dry frequently enough. Our analyses suggest any alternative will meet the environmental hydrologic criteria for SJMCA. However, modifications to the operation schedules of the culvert structures will likely still be needed to "fine tune" our management strategies to meet all criteria. Given the constraints of the model, further hydrologic modeling to fine tune a discharge schedule at this point is unwarranted. We recommend operating the plugs under the schedule proposed in this plan after they have been constructed, and then adjusting the operation schedules in the future if criteria are not met.

Table D-4. Environmental hydrologic criteria-related performance summary for SJMCA, Sixmile transect. Hydrologic data were simulated for the period 1942 - 1998.

Criteria	Criteria	Simulated Data	Criteria Met?
Mean Water Level	≥ 21.0 ft.	21.19 ft.	Yes
Freq. Of Inundation	21.0 ft. ≥ 60%	72%	Yes
Maximum Water Elevation **14 Day** **30 Day** **60 Day**	More than 1/10 Years Not To Exceed: 24.5 ft. 24.0 ft. 23.5 ft.	Never Occurred	Yes
Minimum Range of Yearly Fluctuation **High** **Low**	Continuous 30 Day Levels High= 21.5 Low=20.5 High in ≥25% of years Low in 20–30% of years	Occurred In: 71% of Years 63% of Years	 Yes **No**
Timing of Fluctuation **Minimum Levels** **Maximum Levels**	During > 50% of Years Occurs Between Apr. 1 - June 30 Sept. 1 - Nov. 31	Occurred In: 100% of Years 50% of Years	 Yes Yes
Recession Rates **7 Day** **30 Day**	> Than 95% of Time < 0.5 ft. <1.2 ft.	Met: 92% of time 94% of time	 **No** **No**

3.2 TFMCA

Simulated stage duration curves for all the Alternatives are presented in Figure D-7. Predicted water levels were highest under the Preferred Alternative and lowest under the Isolated Wetlands Alternative. For the most part, the GDM, the 18.5 ft, and the Preferred Alternatives met all the

Table D-5. Environmental hydrologic criteria-related performance summary for SJMCA, Mulberry Mound transect. Hydrologic data were simulated for the period 1942 - 1998.

Criteria	Criteria	Simulated Data	Criteria Met?
Mean Water Level	≥18.1 ft.	19.07 ft.	Yes
Freq. Of Inundation	18.1 ft. ≥ 60%	85%	Yes
Maximum Water Elevation	More than 1/10 Years Not To Exceed:	Occurred:	
14 Day	21.5 ft.	Once Every 28 Years	Yes
30 Day	21.0 ft.	Once Every 56 Years	Yes
60 Day	20.5 ft.	Never Occurred	Yes
Minimum Range of Yearly Fluctuation	Continuous 30 Day Levels		
High	High= 18.6 Low=17.5	Occurred In:	
Low	High in ≥25% of years	100% of Years	Yes
	Low in 20–30% of years	11% of Years	**No**
Timing of Fluctuation	During > 50% of Years Occurs Between	Occurred In:	
Minimum Levels	Apr. 1 - June 30	91% of Years	Yes
Maximum Levels	Sept. 1 - Nov. 31	53% of Years	Yes
Recession Rates	> Than 95% of Time	Met:	
7 Day	< 0.5 ft.	97% of time	Yes
30 Day	<1.2 ft.	98% of time	Yes

Table D-6. Environmental hydrologic criteria-related performance summary for SJMCA, Big Bend transect. Hydrologic data were simulated for the period 1942 - 1998.

Criteria	Criteria	Simulated Data	Criteria Met?
Mean Water Level	≥17.0 ft.	17.5 ft.	Yes
Freq. Of Inundation	17.0 ft. ≥ 60%	76%	Yes
Maximum Water Elevation	More than 1/10 Years Not To Exceed:	Occurred:	
14 Day	20.2 ft.	Once Every 5.6 Years	**No**
30 Day	19.7 ft.	Once Every 8.0 Years	**No**
60 Day	19.2 ft.	Once Every 8.0 Years	**No**
Minimum Range of Yearly Fluctuation	Continuous 30 Day Levels		
High	High= 17.8 Low=16.2	Occurred In:	
Low	High in ≥25% of years	77% of Years	Yes
	Low in 20–30% of years	48% of Years	**No**
Timing of Fluctuation	During > 50% of Years Occurs Between	Occurred In:	
Minimum Levels	Apr. 1 - June 30	39% of Years	**No**
Maximum Levels	Sept. 1 - Nov. 31	58% of Years	Yes
Recession Rates	> Than 95% of Time	Met:	
7 Day	< 0.5 ft.	96% of time	Yes
30 Day	<1.2 ft.	96% of time	Yes

environmental hydrologic criteria. Under the Isolated Wetlands Alternative, water levels fell below 16.0 ft NGVD too frequently. A summary analysis of how well the environmental hydrologic criteria established for

TFMCA are met under each alternative are presented in Tables D-7, D-8, D-9, and D-10. Detailed model results are presented in table format in Appendix E.

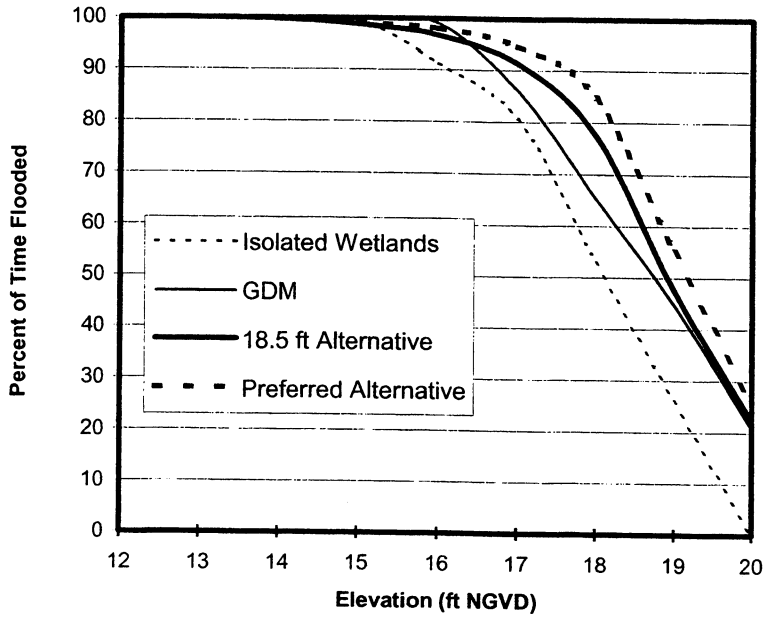

Figure D-7. Simulated stage duration curves in TFMCA for the four alternatives considered.

Table D-7. Environmental hydrologic criteria-related performance summary in the TFMCA for the GDM Alternative. Hydrologic data were simulated for the period 1942 - 1998.

Criteria	Criteria	Simulated Data	Criteria Met?
Mean Water Level	≥18.0 ft.	18.62 ft	Yes
Freq. Of Inundation	18.0 ft. ≥ 60%	65%	Yes
Minimum Water Elevation	16.5 ft. ≥ 95%	95.4%	Yes
One Day Minimum	< 16.0 ft. should not occur in more than 1/4 years	1 in 11.2 Years	Yes
Minimum Drying Level	Continuous 30 Day Levels	Occurred In:	
Low	Low=17.5 ft. every 2 to 5 Years	Every 1.8 Years	Yes
	Continuous 60 Day Levels		
High	High= 17.0 ft. every 5 to 10 Years	Every 3.5 Years	Yes
Timing of Fluctuation	During > 50% of Years		
	Occurs Between	Occurred In:	
Minimum Levels	Apr. 1 - June 30	51% of Years	Yes
Maximum Levels	Sept. 1 - Nov. 31	61% of Years	Yes
Recession Rates	> Than 95% of Time	Met:	
7 Day	< 0.5 ft.	>99% of time	Yes
30 Day	<1.2 ft.	>99% of time	Yes

Table D-8. Environmental hydrologic criteria-related performance summary for the Isolated Wetlands Alternative. Hydrologic data were simulated for the period 1942 - 1998.

Criteria	Criteria	Simulated Data	Criteria Met?
Mean Water Level	≥18.0 ft.	18.00 ft	Yes
Freq. Of Inundation	18.0 ft. ≥ 60%	53%	No
Minimum Water Elevation	16.5 ft. ≥ 95%	86.2%	**No**
One Day Minimum	< 16.0 ft. should not occur in more than 1/4 years	1 in 2.7 Years	**No**
Minimum Drying Level	Continuous 30 Day Levels	Occurred In:	
Low	Low=17.5 ft. every 2 to 5 Years	Every 1.4 Years	**No**
High	Continuous 60 Day Levels High= 17.0 ft. every 5 to 10 Years	Every 2.4 Years	**No**
Timing of Fluctuation	During > 50% of Years Occurs Between	Occurred In:	
Minimum Levels	Apr. 1 - June 30	51% of Years	Yes
Maximum Levels	Sept. 1 - Nov. 31	61% of Years	Yes
Recession Rates	> Than 95% of Time	Met:	
7 Day	< 0.5 ft.	>99% o/f time	Yes
30 Day	<1.2 ft.	>99% of time	Yes

Table D-9. Environmental hydrologic criteria-related performance summary for the 18.5 ft Alternative. Hydrologic data were simulated for the period 1942 - 1998.

Criteria	Criteria	Simulated Data	Criteria Met?
Mean Water Level	≥18.0 ft.	18.80 ft.	Yes
Freq. Of Inundation	18.0 ft. ≥ 60%	77.5%	Yes
Minimum Water Elevation	16.5 ft. ≥ 95%	94.8%	Yes
One Day Minimum	< 16.0 ft. should not occur in more than 1/4 years	1 in 9.3 Years	Yes
Minimum Drying Level	Continuous 30 Day Levels	Occurred In:	
Low	Low=17.5 ft. every 2 to 5 Years	Every 2.7 Years	Yes
High	Continuous 60 Day Levels High= 17.0 ft. every 5 to 10 Years	Every 5.6 Years	Yes
Timing of Fluctuation	During > 50% of Years Occurs Between	Occurred In:	
Minimum Levels	Apr. 1 - June 30	47% of Years	**No**
Maximum Levels	Sept. 1 - Nov. 31	56% of Years	Yes
Recession Rates	> Than 95% of Time	Met:	
7 Day	< 0.5 ft.	>99% of time	Yes
30 Day	<1.2 ft.	>99% of time	Yes

Table D-10 Environmental hydrologic criteria-related performance summary for the Preferred Alternative. Hydrologic data were simulated for the period 1942 - 1998.

Criteria	Criteria	Simulated Data	Criteria Met?
Mean Water Level	≥18.0 ft.	19.1 ft.	Yes
Freq. Of Inundation	18.0 ft. ≥ 60%	84.9	Yes
Minimum Water Elevation	16.5 ft. ≥ 95%	96.5	Yes
One Day Minimum	< 16.0 ft. should not occur in more than 1/4 years	1 in 9.3 Years	Yes
Minimum Drying Level	Continuous 30 Day Levels	Occurred In:	
Low	Low=17.5 ft. every 2 to 5 Years	Every 3.5 Years	Yes
	Continuous 60 Day Levels		
High	High= 17.0 ft. every 5 to 10 Years	Every 5.6 Years	Yes
Timing of Fluctuation	During > 50% of Years		
	Occurs Between	Occurred In:	
Minimum Levels	Apr. 1 - June 30	47% of Years	**No**
Maximum Levels	Sept. 1 - Nov. 31	56% of Years	Yes
Recession Rates	> Than 95% of Time	Met:	
7 Day	< 0.5 ft.	>99% of time	Yes
30 Day	<1.2 ft.	>99% of time	Yes

5. LITERATURE CITED

Suphunvorranop, T., and C. T. Tai. 1982. *Upper St. Johns Hydrologic Model Users Manual.* St. Johns River Water Management District Technical Publication 82-4. Palatka Fla.