112th Congress, 2d Session – – – – – – – – – – – – House Document 112–132

CENTRAL AND SOUTHERN FLORIDA PROJECT: COMPREHENSIVE EVERGLADES RESTORATION PLAN C–111 SPREADER CANAL WESTERN PROJECT

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, THE DEPARTMENT OF DEFENSE

TRANSMITTING

A REPORT ON THE AUTHORIZATION OF THE C–111 SPREADER CANAL WESTERN PROJECT

VOLUME 5 OF 5

AUGUST 7, 2012.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

U.S. GOVERNMENT PRINTING OFFICE

77–056 WASHINGTON : 2012

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

CENTRAL AND SOUTHERN FLORIDA PROJECT
COMPREHENSIVE EVERGLADES RESTORATION PLAN
C-111 SPREADER CANAL WESTERN PROJECT

FINAL INTEGRATED PROJECT IMPLEMENTATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT

Volume 5 – Appendices B-H

January 2011

US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

This Report Contains [5] Volumes
You Are Here

Volume 1 – Main Report

- Executive Summary
- Section 1 – Introduction
- Section 2 – Existing Conditions/Affected Environment
- Section 3 – Future "Without Project" Condition
- Section 4 – Identification of Problems and Opportunities
- Section 5 – Formulation and Evaluation of Alternatives
- Section 6 – The Recommended Plan
- Section 7 – Environmental Effects
- Section 8 – Plan Implementation
- Section 9 – Coordination, Public Views, and Comments
- Section 10 – Recommendations
- Section 11 – List of Preparers
- Section 12 – Index
- Section 13 – Glossary of Terms
- Section 14 – Acronym List
- Section 15 – References

Volume 2 – Annex A-B

- Annex A – FWCA and Endangered Species Act Compliance
- Annex B – NEPA Information

Volume 3 – Annex C-F

- Annex C – Analyses Required by WRDA 2000 and State Law
- Annex D – Draft Project Operating Manual
- Annex E – Project Monitoring Plan
- Annex F – Reports Provided by RECOVER to Support the PIR

Volume 4 – Appendix A

- Appendix A – Engineering Part I
- Appendix A – Engineering Part II, HTRW Reports

Volume 5 – Appendix B-H

- Appendix B – Cost Estimates
- Appendix C – Environmental Information
- Appendix D – Real Estate
- Appendix E – Agency / Public Coordination
- Appendix F – Plan Formulation and Evaluation
- Appendix G – Economic and Social Considerations
- Appendix H – Recreation Plan

CENTRAL AND SOUTHERN FLORIDA PROJECT
C-111 SPREADER CANAL WESTERN PROJECT

FINAL PROJECT IMPLEMENTATION REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

US Army Corps
of Engineers®

U.S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT

SOUTH FLORIDA WATER
MANAGEMENT DISTRICT

January 2011

APPENDIX B
COST ESTIMATES

TABLE OF CONTENTS

B.0 COST ESTIMATES B-1
B.1 GENERAL INFORMATION B-1
B.1.1 Selected Plan B-2
B.1.2 Plan Formulation Cost Estimates B-3
B.1.3 Project Schedule B-6
B.1.4 Risk Analysis B-6
B.1.5 Total Project Cost Summary B-6
B.2 PLAN FORMULATION COST ESTIMATES B-7
B.3 MCACES/MII COST ESTIMATE B-13
B.3.1 Quantity Takeoff Sheet and Calculation Estimate B-26
B.4 SCHEDULE B-63
B.5 RISK AND UNCERTAINTY ANALYSIS B-69
B.6 TOTAL PROJECT COST SUMMARY B-103

LIST OF FIGURES

Figure B-1 Total cfs vs. Cost per cfs Based on Historic Pricing B-5
Figure B-2 Real Estate Cost B-26

LIST OF TABLES

Table B-1 Pump Station Historic Pricing B-5
Table B-2 Pump Station Costs by cfs Based on Chart B-6
Table B-3 Cost Summary B-7
Table B-4 Alternative 1D B-9
Table B-5 Alternative 2D Short B-9
Table B-6 Alternative 2D Long B-10
Table B-7 Alternative 3D B-10
Table B-8 Alternative 6D B-11
Table B-9 Summary–Rounded FY09 ..... B-11
Table B-10 Total Project Cost Summary B-104

B.0 COST ESTIMATES

B.1 GENERAL INFORMATION

United States Army Corps of Engineers cost estimates for planning purposes are prepared in accordance with the following guidance:

- Engineering Technical Letter (ETL) 1110-2573, Construction Cost Estimating Guide for Civil Works, dated 30 September 2008
- Engineer Regulation (ER) 1110-1-1300, Cost Engineering Policy and General Requirements, 26 March 1993
- ER 1110-2-1302, Civil Works Cost Engineering, 15 September 2008
- ER 1110-2-1150, Engineering and Design For Civil Works Projects, 31 August 1999
- ER 1105-2-100, Planning Guidance Notebook, 22 April 2000, as amended
- Engineer Manual (EM) 1110-2-1304 (Tables revised 30 March 2007), Civil Works Construction Cost Index System, 31 March 2000
- CECW-CP Memorandum For Distribution, Subject: Initiatives To Improve The Accuracy Of Total Project Costs In Civil Works Feasibility Studies Requiring Congressional Authorization, 19 Sep 2007
- CECW-CE Memorandum For Distribution, Subject: Application of Cost Risk Analysis Methods To Develop Contingencies For Civil Works Total Project Costs, 3 Jul 2007
- Cost and Schedule Risk Analysis Process, March 2008

The goals of the cost estimating for the C-111 Spreader Canal (C-111 SC) study are to present a Total Project Cost (construction and non-construction costs) for the recommended plan at the current price level to be used for project justification/authorization and to project costs forward in time for budgeting purposes. In addition, the costing efforts are intended to produce a final product (cost estimate) that is reliable and accurate and that supports the definition of the Government's and the non-Federal sponsor's obligations. The cost estimating effort for the C-111 SC study also yielded a series of alternative plan formulation cost estimates for decision making. The final set of plan formulation cost estimates used for plan selection rely on construction feature unit pricing and are prepared in Civil Works Breakdown Structure (CWBS) format to the sub-feature level. The cost estimate supporting the National Ecosystem Restoration plan (Selected Plan) is prepared in MCACES/MII format to the CWBS subfeature level. This estimate is base on the 60% North Component and 30% South Component drawings dated September 15, 2009. The 2008 MII Costbook, 2007 MII Region 3 equipment rate and current local wage rates were used to develop this estimate. A fully funded (escalated for inflation through project completion) cost estimate, the Baseline Cost Estimate or Total Project Cost Summary, will also be developed. A risk analysis that addresses uncertainties

in and sets contingencies for Selected Plan cost items has been prepared. A discussion of the risk analysis is included at the end of this appendix.

B.1.1 Selected Plan

The Recommended Plan was chosen by the Project Delivery Team according to Cost Effectiveness/Incremental Cost Analysis procedures and resulted directly from the plan formulation described above. The Economics Appendix fully describes the plan selection. The scope of work for the Selected Plan is found in the draft Appendix A, Engineering. The MCACES/MII cost estimate for the Selected Plan (***SECTION B.3***, below) is based on that scope and is formatted in the CWBS. The notes provided in the body of the estimate detail the estimate parameters and assumptions. These include pricing at the June 29, 2009 price level. The estimate includes both construction and non-construction costs. The construction costs fall under the following feature codes:

- 08 Roads, Railroads & Bridges
- 09 Channels and Canals
- 11 Levees and Floodwalls
- 13 Pumping Plant
- 15 Floodway Control-Diversion Structures

The non-construction costs fall under the following feature codes:

- 01 Lands and Damages
- 30 Planning, Engineering and Design
- 31 Construction Management

Construction Costs. The features of the Selected Plan for this project were designed by South Florida Water Management District, the project's non-Federal sponsor) under its A8 program. The costing of these features by Jacksonville District estimating contractors is to comply with Corps guidance. These costs are for project authorization and budgeting only and may bear no significance to crediting. Office of Management and Budget Circular A-87 establishes principles and standards for determining costs for Federal awards carried out through agreements with State and local governments and federally-recognized Indian tribal governments (governmental units). Engineer Circular (EC) 1165-2-208 provides guidance on in-kind contributions. These and other applicable publications and processes will form the basis for determining crediting as well as all applicable terms under any Project Partnership Agreement that may be executed for the implementation of this project.

The following markups were applied to the direct costs:

- Job Office Overhead (North 10.89% and South 11.26%)
- Home Office Overhead (3%)
- Profit (8%)
- Bonds and Insurance (1.5%)

An owner cost, contingency developed from the risk analysis, was added to the contractor costs. Additional information follows on the risk analysis. Major risk factors are shown in the sensitivity analyses.

Non-construction Costs. Non-construction costs include Real Estate, Planning, Engineering and Design (PED), and Construction Management (Supervision and Administration, S&A). Real Estate costs were provided by Real Estate Division. These costs are best described in the Real Estate Appendix, Appendix D. Contingencies for the Real Estate costs were provided. The Real Estate risk analysis is further described below.

Planning, Engineering and Design costs are broken down into Preconstruction, Engineering and Design (PED), and the Project Implementation Report (PIR). PED costs were solicited from Engineering Division via the Project Manager, as suggested by the guidance. Twelve percent of the total construction cost is used as the total rate for engineering costs through construction, as is customary in Jacksonville District's Cost Branch. The cost for the PIR was provided to Cost Branch via the Project Manager and represents funds spent to date plus funds expected to be spent through report completion.

Construction Management costs were solicited from Construction-Operations Division via the Project Manager, again as suggested by the guidance. Eight percent is used as the rate for Construction Management costs for the cost estimate for the Tentatively Selected Plan. This percentage is based on actual funds spent for construction management on past contracts. When this percentage is calculated by Construction-Operations Division for planning projects it is itemized to show amounts allocated for each task anticipated to occur during construction. Only the gross percentage is shown herein.

The main report details both cost allocation and cost apportionment for the Federal government and the non-Federal sponsor. Also included in the main report are the non-Federal sponsor's obligations (items of local cooperation).

B.1.2 Plan Formulation Cost Estimates

For the plan formulation cost estimates, unit prices for each major or variable construction element were developed in MCACES/MII. These unit prices were entered into spreadsheets that differentiated each plan by the quantities

required to construct the plans. The spreadsheets are included in this appendix (***SECTION B.2***). The spreadsheets are formatted according to the CWBS and include construction and the non-construction costs PED and S&A. The project features were developed by the broad PDT (including the non-Federal sponsor, other stakeholders and the Corps in-house PDT) and refined by the PDT as necessary. Designs and quantities for the construction elements were provided to Cost Branch by the Engineering Technical Lead (see the Engineering Appendix for construction methods, design assumptions and design data). Preconstruction, Engineering and Design costs and Construction Management costs were calculated using percentages; at this level of estimating they are assumed to be ten percent and eight percent, respectively.

The plan formulation process for this study involved many iterations. Since the costs for the plans were calculated via spreadsheet software it was fairly simple to adjust them as time went by (for example, as unit prices increased due to changes in price level), as plan components changed and as plans were added or removed from consideration. Only the final plan formulation tables are provided herein.

The final plan formulation costs are provided in ***TABLE B-3*** through ***TABLE B-9***. ***TABLE B-3*** shows the summary of all six plans considered during final formulation (in Fiscal Year 2009 dollars), including construction cost, PED cost at 10% of construction costs, S&A cost at 8% of construction costs and total cost. This table does not include real estate costs, relocation cost or any other costs associated with the project such as monitoring costs or operations and maintenance costs.

Historic pricing was applied in the final plan formulation for the pumping plant. The tables and chart below summarize the historic pricing and show how it was extended to provide costs for this study. ***TABLE B-1*** is a compilation of award prices for pump stations designed/contracted by Jacksonville District since 2000. ***FIGURE B-1*** plots these prices and a curve is constructed between them, resulting in a regression equation. ***TABLE B-2*** uses this regression equation to calculate prices for pump stations at varying capacities, measured in cubic feet per second (cfs.) These are the prices used in the cost estimate.

TABLE B-1: PUMP STATION HISTORIC PRICING

Pump Station	Date Awarded	Total Cost	Cost FY 09$	Pump Size	Total cfs	Cost/cfs FY 09$
361	4/19/2001	$2,170,000	$3,300,268	3e/25 cfs	75	$44,004
9A	9/19/2000	$5,915,495	$9,076,029	2d/175 cfs, 2e/75 cfs	500	$18,152
357	9/20/2005	$10,388,921	$12,321,819	4d/125 cfs,1e/75 cfs	575	$21,429
362	9/30/2000	$29,109,915	$44,662,775	3d/960 cfs, 2d/550 cfs, 2e/110 cfs	4200	$10,634
319	3/30/2000	$27,283,338	$41,860,295	3d/960 cfs, 2d/550 cfs	3980	$10,518
385	5/17/2004	$3,988,583	$5,080,495	4e/40 cfs	160	$31,753
382	9/26/2003	$9,617,529	$13,885,283	3d/160 cfs, 160 cfs, 60 cfs	380	$36,540
383	9/26/2003	$1,012,371	$1,461,609	2e/15 cfs, 25 cfs	40	$36,540

Notes: FY stands for Fiscal Year. 'Cubic feet per second' is abbreviated 'cfs'. Electric is abbreviated 'e'. 'Diesel' is abbreviated 'd'.

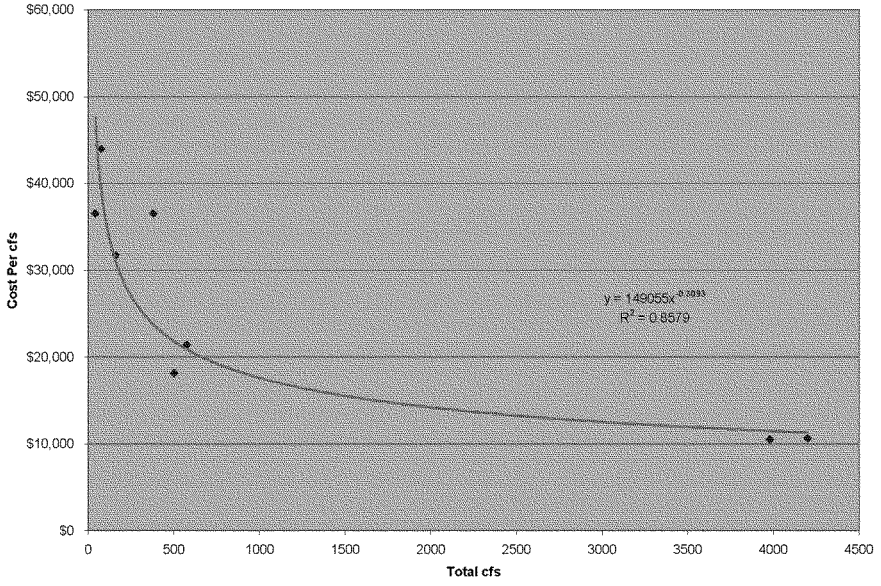


FIGURE B-1: TOTAL CFS VS. COST PER CFS BASED ON HISTORIC PRICING

TABLE B-2: PUMP STATION COSTS BY CFS BASED ON CHART

CFS	$/CFS	Station cost	Rounded
5	$90,606	$453,028	$500,000
10	$73,122	$731,217	$800,000
15	$64,503	$967,549	$1,000,000
20	$59,012	$1,180,234	$1,200,000
25	$55,076	$1,376,904	$1,400,000
30	$52,056	$1,561,688	$1,600,000
40	$47,624	$1,904,975	$2,000,000
50	$44,448	$2,222,415	$2,300,000
75	$39,209	$2,940,704	$3,000,000
100	$35,871	$3,587,125	$3,600,000
125	$33,479	$4,184,873	$4,200,000
150	$31,643	$4,746,492	$4,800,000
200	$28,949	$5,789,859	$5,800,000
250	$27,019	$6,754,663	$6,800,000
300	$25,537	$7,661,154	$7,700,000
375	$23,834	$8,937,786	$9,000,000
400	$23,363	$9,345,217	$9,400,000
420	$23,013	$9,665,511	$9,700,000
500	$21,805	$10,902,476	$11,000,000
600	$20,609	$12,365,612	$12,400,000
660	$20,011	$13,207,042	$13,300,000
Notes: The formula used is y=145103x-0.3093 and is taken from the chart above. 'CFS' stands for cubic feet per second.			

B.1.3 Project Schedule

The current project schedule is included herein.

B.1.4 Risk Analysis

The current Risk Analysis is included herein.

B.1.5 Total Project Cost Summary

The Total Project Cost Summary includes escalation through project completion. The cost estimate for the Selected Alternative Plan is prepared with an identified price level date. Inflation factors are used to adjust the pricing to the project schedule according to the CWBS. This estimate is known as the Fully Funded Cost Estimate or Total Project Cost Summary. It includes all Federal and non-Federal costs: Lands, Easements, Rights of Way and Relocations;

construction features; Preconstruction Engineering and Design; Construction Management; Contingency; and Inflation.

B.2 PLAN FORMULATION COST ESTIMATES

TABLE B-3: COST SUMMARY

Alternative	Cost	Construction Duration (Months)
1C	$36,000,000	16
1D	$39,000,000	16
2D Short	$52,000,000	22
2D Long	$53,000,000	22
3D	$60,000,000	24
6D	$210,000,000	36

TABLE B-4: ALTERNATIVE 1D

Location	Component	Clearing and Grubbing (ac)			Channels and Canals									Levees and Floodwalls						Pump Plant						Flexible Gates and Sluice Structures							Notes
		Quantity (ac)	Unit Cost ($)	Cost ($)	Construct Backfill	Bottom Width (ft)	Extent Width (ft)	Liner Depth (ft)	Length (ft)	Volume (cy)	Liner Area (sf)	Unit Cost ($/sf)	Cost ($)	Construct Excavate	Height (ft)	Length (ft)	Volume (cy)	Unit Cost ($/cy)	Cost ($)	Number of Structures	Number of Bays per Structure	Pump Hp per Bay	Unit Cost ($)	Cost ($)	Construct Remove	Type	Number of Structures	Gate Diameter (ft)	Gate Length (ft)	Unit Cost ($/sf)	Per Ea	Cost ($)	
Bray Pond Area	Bray Pond Detention Basin (PPDB)	530	3,000	1,653,300																													
	Pump for PPDB (electric)																			1	3	550	13,000,000	16,000,000									
	Weir for PPDB													Construct	3	22,000	74,100	$9.00	$ 667,200														
	Canal from Pump to PPDB				Construct	15	30		9,500	157,000		54.00	8,478,000																				
	8' Thick Canal Liner from Pump to PPDB							33	9,500		300,400	8.00	2,400,200																				
S-111C	Pump for C-111				Backfill	10	110		1,500	66,700		8.00	533,300																				Note: preliminary design, volumes to be refined for all new
Levee C-111 (E Levee)	Water Control Structure (formerly S-197)																								Construct	Structure	Bridge	10	7	56	225.00	2,520,000	Contractor is to remove/use a structure similar to S-197, located just south of the levee at the east of Levee C-111.
	Pump for L-31E at S-356				Backfill	10	10		100	700		8.00	5,600																				Estimate based on L-31E borrow canal dimensions.
	TOTALS	530		1,653,300	Construct					157,000			10,591,700	Construct			74,100		5,112,500					16,000,000							2,520,000	
					Backfill					67,400			526,900																				
												Total:	11,120,600																				
	TOTAL COST FOR CONSTRUCTION	30,834,300																															
	INCLUDING PED, CM	46,577,600																															

TABLE B-5: ALTERNATIVE 2D SHORT

Location	Component	Clearing and Grubbing (ac)			Channels and Canals									Levees and Floodwalls						Pump Plant						Flexible Gates and Sluice Structures							Notes
		Quantity (ac)	Unit Cost ($)	Cost ($)	Construct Backfill	Bottom Width (ft)	Extent Width (ft)	Liner Depth (ft)	Length (ft)	Volume (cy)	Liner Area (sf)	Unit Cost ($/sf)	Cost ($)	Construct Excavate	Height (ft)	Length (ft)	Volume (cy)	Unit Cost ($/cy)	Cost ($)	Number of Structures	Number of Bays per Structure	Pump Hp per Bay	Unit Cost ($)	Cost ($)	Construct Remove	Type	Number of Structures	Gate Diameter (ft)	Gate Length (ft)	Unit Cost ($/sf)	Per Ea	Cost ($)	
Bray Pond Area	Bray Pond Detention Basin (PPDB)	530	3,000	1,653,300																													
	Pump for PPDB (electric)																			1	3	75	11,700,000	14,700,000									
	Weir for PPDB													Construct	3	29,000	74,100	$9.00	$ 667,900														
	Canal from Pump to PPDB				Construct	15	33		9,500	157,000		10.00	4,540,000																				Also graded for 225 cfs
	8' Thick Canal Liner from Pump to PPDB							33	9,500		300,400	8.00	2,400,200																				
Feature Area	Pump for Alcove B Control (C-111 - interim)																			1	3	75	11,700,000	15,700,000									
	Canal from Pump for Alcove B Canal				Construct	15	33		9,000	72,000		10.00	4,662,000																				Also graded for 225 cfs
	8' Thick Canal Liner							33	2,400		79,200	8.00	1,344,854																				
	Berm for Alcove B Canal (West side only)													Construct	3	16,000	35,600	$9.00	$ 1,708,800														To be no higher than the only difference between short and long versions. They have the same pump size and same deliver canal
	Plug for Alcove B Canal				Backfill	14	33		900	24,900		8.00	200,400																				Uses proposed plugs, volumes used for all three
S-111B	Plug for S-111B				Backfill	18	110		1,600	65,700		8.00	525,600																				Note: preliminary design, volumes to be refined for all new
Levee L-31N	Water Control Structure (formerly S-197)																								Construct	Structure	Bridge	10	7	56	225.00	2,520,000	Construct in the centerline a structure identical to S-197, located just south of the levee at the east of Levee C-111.
	Plug for L-31E at S-356A				Backfill	18	33		800	700		8.00	5,600																				Estimate based on L-31E borrow canal dimensions.
	TOTALS	530		1,653,300	Construct					548,000			11,340,000	Construct			85,100		6,870,100					29,400,000							2,520,000	
					Backfill					107,200			857,600																				
												Total:	12,405,600																				
	TOTAL COST FOR CONSTRUCTION	31,000,700																															
	INCLUDING PED, CM	43,394,700																															

Page 1

Page 1

TABLE B-6: ALTERNATIVE 2D LONG

Location	Component	Clearing and Grubbing (ac)			Channels and Canals									Levees and Floodwalls					Pump Plant					Roadway, Culvert and Bridge Structures							Notes
		Quantity (ac)	Unit Cost ($)	Cost ($)	Construct Type	Bottom Width (ft)	Bottom Width (ft)	Water Depth (ft)	Length (ft)	Volume (cy)	Liner Area (sf)	Liner Unit Cost ($)	Cost ($)	Construct Degree	Height (ft)	Length (ft)	Volume (cy)	Unit Cost ($)	Cost ($)	Number of Structures	Number of Bays per Structure	Pump (cfs) per Bay	Unit Cost ($)	Cost ($)	Construct Remove	Type	Number of Structures	Culvert Diameter (ft)	Culvert Length (ft)	Culvert Type	Unit Cost ($) Per Ea	Cost ($)	
Frog Point Area	Frog Point Detention Basin (FP03)	532	3,000	1,843,000																											
	Pump for FP06 (electric)																			1	3	75	11,100,000	11,100,000								
	Berm for FP06													Construct	3	23,000	74,000	65.00	5,112,000													
	Canal from Pump to FP06				Construct	6	30		5,500	76,000		64.00	4,864,000																			
	6" Thick Canal Liner from Pump to FP06							6.0	5,500		627,400	6.00	4,800,200																			
Aerojet Area	Pump for Aerojet Canal or C-111 (electric)																				3	75	11,100,000	11,100,000								
	Canal from Spillway to Aerojet Canal				Construct	6	30		8,000	72,000		64.00	3,850,000																			
	6" Thick Canal Liner							6.0	4,640		259,840	6.00	2,048,824																			
	Berm for Aerojet Canal (beginning w/ pump)													Construct	3	21,000	69,600	65.00	4,802,400													
	Pipes for Aerojet Canal				Backfill	14	19		600	34,000		6.00	276,400																			
S-11 D	Pipes for C-111				Backfill	10	180		1,500	66,700		6.00	433,600																			
Levee L-111	Water Control Structure (work S-197)																								Construct	Weirs	10	7	90	250,000	2,500,000	
	Pipes L-31E at S-25A				Backfill	10	10		100	700		6.00	6,600																			
	TOTALS	538		1,843,000	Construct					181,000			15,840,864	Construct			163,700		9,915,369					27,200,000							2,500,000	
					Backfill					102,500			107,500																			
												Total	15,947,364																			
	TOTAL COST FOR CONSTRUCTION	52,553,364																														
	INCLUDING PED, CM	53,604,757																														

TABLE B-7: ALTERNATIVE 3D

Location	Component	Clearing and Grubbing (ac)			Channels and Canals									Levees and Floodwalls					Pump Plant					Roadway, Culvert and Bridge Structures							Notes
		Quantity (ac)	Unit Cost ($)	Cost ($)	Construct Type	Bottom Width (ft)	Bottom Width (ft)	Water Depth (ft)	Length (ft)	Volume (cy)	Liner Area (sf)	Liner Unit Cost ($)	Cost ($)	Construct Degree	Height (ft)	Length (ft)	Volume (cy)	Unit Cost ($)	Cost ($)	Number of Structures	Number of Bays per Structure	Pump (cfs) per Bay	Unit Cost ($)	Cost ($)	Construct Remove	Type	Number of Structures	Culvert Diameter (ft)	Culvert Length (ft)	Culvert Type	Unit Cost ($) Per Ea	Cost ($)	
Frog Point Area	Frog Point Detention Basin (FP03)	538	3,000	1,843,000																											
	Pump for FP06 (electric)																			1	3	75	11,100,000	11,100,000								
	Berm for FP06													Construct	3	23,000	74,000	65.00	5,112,000													
	Canal from Pump to FP06				Construct	6	30		5,500	76,000		64.00	4,864,000																			
	6" Thick Canal Liner from Pump to FP06							6.0	5,500		682,400	6.00	4,800,200																			
Aerojet Area	Pump to Aerojet Reservoir or C-111 (electric)																				3	75	11,100,000	11,100,000								
	Canal from Spillway to Aerojet Reservoir				Construct	6	30		8,000	72,000		64.00	3,850,000																			
	6" Thick Canal Liner							6.0	4,640		282,200	6.00	2,048,864																			
	Aerojet Reservoir	538	3,000	1,843,000																											
	Berm for Aerojet Reservoir													Construct	3	23,000	74,000	65.00	5,112,000													
	Seepage Pump for Aerojet Reservoir																															
	Pipes for Aerojet Canal				Backfill	14	20		800	34,000		6.00	276,400																			
C-111D	Pipes for C-111D				Backfill	10	180		1,500	66,700		6.00	532,600																			
Levee L-111	Water Control Structure (work S-197)																								Construct	Weirs	10	7	90	250,000	2,500,000	
	Pipes to L-31E at S-25A				Backfill	10	10		100	700		6.00	6,600																			
	TOTALS	1,068		3,686,000	Construct					114,000			15,864,864	Construct			148,200		10,225,800					27,000,000							2,500,000	
					Backfill					102,200			107,600																			
												Total	15,972,264																			
	TOTAL COST FOR CONSTRUCTION	53,607,464																														
	INCLUDING PED, CM	71,000,357																														

Page 1

TABLE B-8: ALTERNATIVE 6D

		Clearing and Grubbing (ac)			Channels and Canals							Levees and Floodwalls						Pump Plant					Floodway Control and Direct Structures								
Location	Component	Quantity (ac)	Unit Cost ($)	Cost ($)	Construct/ Backfill	Depth (ft)	Bottom Width (ft)	Length (ft)	Volume (cy)	Unit Cost ($)	Cost ($)	Construct/ Degrade	Height (ft)	Length (ft)	Volume (cy)	Unit Cost ($)	Cost ($)	Number of Structures	Number of Bays per Structure	Pump cfs per Bay	Unit Cost ($)	Cost ($)	Construct/ Remove	Type	Number of Structures	Culvert Diameter (ft)	Culvert Length (ft)	Weir (cfs)	Unit Cost ($)	Cost ($)	Notes
Frog Pond Area	Seepage Barrier																						Construct	Seepage Barrier	1		55,000		3,750	206,250,000	Construction methods were based on initial recommendations for the Slurry Trench Method as considered for EAA.
Area at Area	None																														Cost per foot is based on RCM cost for L-31N (L-33) Seepage Management Pilot Project (SMPP).
C-110	Plugs for C-110				Backfill	10	110	1,500	66,700	5.00	333,000																				Nine unpaved plugs, volumes listed are for all nine.
Lower C-111	Water Control Structure (mmc S-197)																						Construct	Shoaling Riser RCP	13	7	66		228,000	2,938,000	Concept is to construct a structure identical to S-197, located just south of the tion to the east on lower C-111.
	Plug in L-31E at S-25A				Backfill	10	10	100	700	8.00	5,600																				Estimate based on L-31E sponsor canal dimensions.
	TOTALS	0		0	Construct							Construct			0		0					0								209,188,000	
					Backfill						539,200																				
										Total	539,200																				
	TOTAL COST FOR CONSTRUCTION	209,727,200																													
	INCLUDING PED, CM	251,672,640																													

Page 1

TABLE B-9: SUMMARY–ROUNDED FY09

Alternative	Cost in FY 09 $ Total	Cost in FY 09 $ Construction Only	Construction Duration (Month)
1C	$44,000,000	$36,000,000	16
1D	$47,000,000	$39,000,000	16
2D Short	$62,000,000	$52,000,000	22
2D Long	$64,000,000	$53,000,000	22
3D	$72,000,000	$60,000,000	24
6D	$252,000,000	$210,000,000	36

Notes:
1 - This duration is base on eight crews, each working 40 hours per week. (1000 SF/Day/Crew/Shift)

15

B.3 MCACES/MII COST ESTIMATE

Print Date Fri 19 November 2010 | U.S. Army Corps of Engineers | Time 15:11:09
Eff. Date 11/19/2010 | Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_zqs_w_cont_w esc.
Jacksonville District Report Selections | Title Page

WESTERN C-111 SPREADER CANAL PROJECT IMPLEMENTATION REPORT AND ENVIRONMENTAL ASSESSMENT

Project Location--The C-111 Spreader Canal project area is approximately 40 - 45 miles Southwest from downtown Miami, Miami-Dade County, Florida. The Frog Pond detention area is proposed to be situated in Township 57 South, Range 38 East in Section 30 and 31 and in Township 58 South, Range 38 East in Section 6. The pump stations are proposed to be located in Township 57 South, Range 38 East in Section 31, Township 58 South, Range 38 East in section 6, 7, and 8, The proposed plugs are situated in Township 59 South, Range 38 East in Section 10 and 11; Township 58 South, Range 40 East in Section 19, and in Township 57 South, Range 40 East in section 32. The proposed culverts are anticipated to be constructed within areas above described Sections, Townships and Ranges.

Project Description--The TSP Alternative 2D-Short with no Spreader Canal contains approximately 530 acres within the Frog Pond Area for the proposed Frog Pond Detention Area. Additionally, approximately 24 acres in the Frog Pond will be required for pumps, berms and a canal. The lands in the Frog Pond area were approved for acquisition under the C-111 South Dade Project in the 1994 General Design Memorandum and will be provided as an item of local cooperation under that project.

Estimated by U.S.COST, Inc.
Designed by WRScompass
Prepared by Milton Switanek
Preparation Date 11/19/2010
Effective Date of Pricing 11/19/2010
Estimated Construction Time 613 Days
This report is not copyrighted, but the information contained herein is For Official Use Only.

Labor ID: LFL3009 EQ ID: EP07R03 | Currency in US dollars | TRACES MII Version 3.01

17

Print Date Fri 19 November 2010 | U.S. Army Corps of Engineers | Time 15:11:09
Eff. Date 11/19/2010 | Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mps_w_cont_w esc. | Table of Contents
Jacksonville District Report Selections

Project Notes v

Project Cost Summary Report 1

60 C-111 Spreader Canal, Phase 1 North Components 1

08 Roads, Railroads, and Bridges 1

09 Channels and Canals 1

13 Pumping Plant 1

30 Planning, Engineering and Design 1

31 Construction Management 1

60 C-111 Spreader Canal, Phase 1 South Components 1

09 Channels and Canals 1

13 Pumping Plant 1

15 Floodway Control-Diversion Struc 1

30 Planning, Engineering and Design 1

31 Construction Management 1

Lands and Damages For Both North & South Components 1

01 Lands and Damages 1

Recreation Costs 1

14 Total Recreation Investment 1

Contract Cost Summary Report 2

60 C-111 Spreader Canal, Phase 1 North Components 2

Labor ID: LFL3009 EQ ID: EP07R03 | Currency in US dollars | TRACES MII Version 3.01

Print Date Fri 19 November 2010
Eff. Date 11/19/2010

U.S. Army Corps of Engineers
Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mps_w_cost_w esc
Jacksonville District Report Selections

Time 15:11:09

Table of Contents

08 Roads, Railroads, and Bridges 2
09 Channels and Canals 2
13 Pumping Plant 2
30 Planning, Engineering and Design 2
31 Construction Management 2
60 C-111 Spreader Canal, Phase 1 South Components 2
09 Channels and Canals 2
13 Pumping Plant 2
15 Floodway Control-Diversion Struc 2
30 Planning, Engineering and Design 2
31 Construction Management 2
Lands and Damages For Both North & South Components 2
01 Lands and Damages 2
Recreation Costs 2
14 Total Recreation Investment 2
Project Direct Costs Report 3
60 C-111 Spreader Canal, Phase 1 North Components 3
08 Roads, Railroads, and Bridges 3
09 Channels and Canals 3
13 Pumping Plant 3

Labor ID: LFL2009 EQ ID: EP07R03

Currency in US dollars

TRACES MII Version 3.01

19

Print Date Fri 19 November 2010 | U.S. Army Corps of Engineers | Time 15:11:09
Eff. Date 11/19/2010 | Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mps_w_cont_w esc
Jacksonville District Report Selections | Table of Contents

30 Planning, Engineering and Design 3
31 Construction Management 3
60 C-111 Spreader Canal, Phase 1 South Components 3
09 Channels and Canals 3
13 Pumping Plant 3
15 Floodway Control-Diversion Struc 3
30 Planning, Engineering and Design 3
31 Construction Management 3
Lands and Damages For Both North & South Components 3
01 Lands and Damages 3
Recreation Costs 3
14 Total Recreation Investment 3

Labor ID: LFL2009 EQ ID: EP07R03 | Currency in US dollars | TRACES MII Version 3.01

Print Date Fri 19 November 2010 | U.S. Army Corps of Engineers | Time 15:11:09
Eff. Date 11/19/2010 | Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mps_w_cont_w esc
Jacksonville District Report Selections | Project Notes Page v

Date	Author	Note
6/22/2009	H. Campbell	The U.S. Army Corps of Engineers (USACE), Jacksonville District in cooperation with its co-sponsor, the South Florida Water Management District (SFWMD), is completing a Draft Project Implementation Report (PIR) and Environmental Assessment (EA) for the Western C-111 Spreader Canal Project in Miami-Dade County. This draft report describes the purpose and need, location, recommended plan and other alternatives considered. It also includes the data that was collected and generated, analyses, and evaluations made with regards to the alternatives that were formulated leading to the selection of a recommended plan for implementation. This draft report will be circulated for comment in accordance with National Environmental Policy Act (NEPA) review processes. The Chief's report will be prepared based on the Final Project Implementation Report. Features of the Selected Alternative Plan for this project were designed and by SFWMD under its A8 program. The costing of these features have been estimated utilizing the 2008 MCACES/MII database. Inclusion of these costs is for project authorization and budgeting only and may bear no significance to crediting. OMB Circular A-87 establishes principles and standards for determining costs for Federal awards carried out through agreements with State and local governments and federally-recognized Indian tribal governments (governmental units). EC 1165-2-208 provides guidance on in-kind contributions. These and other applicable publications and processes will form the basis for determining crediting as well as all applicable terms under any project partnership agreement that may be executed for the implementation of this project. The Accelar8 project for the C-111 Basin is currently at the 30 percent design level, with a preliminary design for the Frog Pond Detention Area being completed for review. The current configuration of the Detention Area is for a three-cell detention area at a size of 700 acres. Surface flows would be diverted from the C-111 and a groundwater mound would be built west of the C-111 and south of the detention area. The mound would serve to reduce an eastward migration of flow away from Taylor Slough. During the dry season, the detention area could serve as a water storage facility during large storm events, with a storage capacity of over 1000-acre feet.
6/22/2009	H. Campbell	Scope of Work: Documents Used as the Basis for this Estimate: 1)30% South Components drawings and 60% North Components drawings, dated September 15, 2008. Major Project Features: The C-111 Spreader project is located in southern Miami-Dade County in an area bounded by Everglades National Park, the Florida City-Homestead area, and Manatee Bay. This project covers three geographic areas, 1)Frog Pond Detention Area, 2)Aerojet Canal and 3) Intermediate Water Control Features. The Frog Pond Detention Area includes the project features a)Pump station (S-200) with a 225 CFS capacity, b)A concrete-lined, above ground, conveyance channel, c)An above ground cascading header channel, d)A three cell above ground detention area of approximately 462 acre. The Aerojet Canal area includes the project features a)Pump station (S-199) with a 225 CFS capacity, b)A concrete-lined, above ground, conveyance channel, c)An above ground cascading header channel, d)The unlined northern extension of the Aerojet Canal. The Intermediate Water Control Features area includes the project features a) A operable structure (S-198) in the lower C-111 Canal south (downstream) of the existing S-18C structure, b) A plug in the L-31E Canal near S-20A, c)Ten plugs in the C-110 Canal, d)Operational changes at S 20. Federal and non-Federal Cost Sharing Requirements: As provided to CESAJ-EN-C from CESAJ-PD via e-mail dated 6/23/08, "Under the Comprehensive Everglades Restoration Program (CERP) Design Agreement, the planning and design phases of all CERP projects are cost shared 50:50 between the Corps and SFWMD. The total of real estate and construction, and OMRRR are also 50:50. This would be recommended in the Preliminary Implementation Report (PIR) and included in the PPA (formerly Project Cooperation Agreement). HTRW remediation is an exception. It would be 100% non-federal." Volatile Cost Items: Two categories of volatile cost items are fuel (gasoline, on-road diesel and off-road diesel) and materials (e.g., fabrication materials for the pumping equipment, steel, concrete). Risk Analysis: A risk analysis has been prepared for this estimate. Construction is scheduled to begin in September 1, 2009 and end April, 2011, lasting 30 months. Mid-point of construction would be at 10 months, or July 2010. Construction Windows: There are no known environmental windows at this time. Escalation: This estimate is priced in FY 2009 dollars and escalation to FY 2010 using the EM 1110-2-1304 CWBS indexes dated 30 Sept 2008. The construction costs were escalated by feature code, while the PED and S&A were escalated using the composite indexes as indicated below: 08 Roads, Railroads & Bridges - 742.05/761.45 = 2.61% 09 Channels & Canals - 709.74/728.20 = 2.61% 11 Levees & Floodwalls - 754.16/773.88 = 2.61% 13 Pumping Plant - 748.86/768.44 = 2.61% 15 Floodway Control Structure - 736.10/755.34 = 2.61%

Labor ID: LRL2009 EQ ID: EP07F03 | Currency in US dollars | TRACES MII Version 3.01

Print Date Fri 19 November 2010 | U.S. Army Corps of Engineers | Time 15:11:09
Eff. Date 11/19/2010 | Project C111SP0101: C-111 Spreader Canal Final Estimate 16Nov10_mps_w_cont_w esc
Jacksonville District Report Selections | Project Notes Page vi

Date	Author	Note

30 PED & 31 S&A - 740.7/760.04 = 2.61%

1. Taxes: Sales tax is applied at 7.0%.
2. FOOH: See detailed estimate
3. HOOH: Applied at 3% of running costs for prime contractor.
4. Profit: Applied at 8% of running costs for the prime contractor.
5. Bond: Applied at 1.5% of running costs.
6. Price Level: The documents prepared by the SFWMD, which were used as the basis of this estimate were prepared in September 2008 and reflects FY 2008 pricing, these cost values are escalated from FY 2008 dollars to FY 2009 dollars in this MII estimate.
7. Productivity: N/A
8. Overtime Usage: None.
9. Contingency: The percentages listed below have been applied in this estimate.

01 Lands & Damages - 34%
08 Roads, Railroads & Bridges - 15%
09 Channels & Canals - 27%
13 Pumping Plant - 21%
15 Floodway Control Structure - 24%
30 PED - 7%
31 S&A - 12%

10. PED costs: The CORPS's PED are calculated at 12% of cost to prime for construction features, the SFWMD's PED and the Project Implementation Report costs were provided.
11. S&A costs: The CORPS's PED are calculated at 8% of cost to prime for construction features and the SFWMD's S&A cost previously provided have been proprated for the for both components.

Site Access: The project location is south of Miami, Florida, near Florida City. Specific project feature construction sites are accessible via major highway/local roads/improved roadways.

Fill Material: Borrow material for the Spreader canal/Aerojet Canal Extension associated with C-111, will be imported from off-site.

Unusual Conditions (Soil, Water, and Weather): Florida has two weather seasons, the rainy season from June 1 to October 31 and the dry season from November 1 to May 31. Ground waters vary from 4" to 4'-4" below ground surface. Hard porous limestone bedrock is at a depth of about 7 inches to 15 inches.

Unique Construction Techniques: It is anticipated that a prudent, well-equipped contractor can perform the construction.

Equipment and Labor Availability and Distance Traveled: This estimate assumes equipment and labor availability of a prudent and well-equipped contractor, as indicated in Engineer Instructions 01D010, 1 Sep 1997 (Unified Facilities Criteria 3-700-02A, 01 March 2005). Due to the project's location in Homestead, FL, and proximity to Miami, FL, it is assumed that the distance traveled is within a day's commute.

Environmental Concerns During Construction: See note above on Environmental Windows.

Acquisition Plan: The All features are to be constructed by SFWMD, according to their policy and regulations.

Sub-contracting Plan: The prime contractor will be a heavy civil contractor and do the clearing & grubbing, embankment placement, excavation and installion of the aggregate and weir surfacing. The drilling & blasting, structural concrete, mechanical, electrical, controls, and general construction work will be subcontracted.

Labor ID: LFL3009 EQ ID: EP07B03 | Currency in US dollars | TRACES MII Version 3.01

Print Date Fri 19 November 2010 U.S. Army Corps of Engineers Time 15:11:09
Eff. Date 11/19/2010 Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mps_w_cont_w esc
Jacksonville District Report Selections Project Notes Page xii

Date	Author	Note
		Effective Dates for Labor, Equipment and Material Pricing: June 2009
10/13/2010	Switanek: reprice	PIR dated Sept 2010 had 2010 Cost Estimate. It was requested by the PM to ensure the PIR reflects 2011 Cost Estimate dollars for Head Quarters review. No change occured with the SOW to reflect changes to the Cost Estimate otherthan reprice to 2011 dollars. Reprice for the following items: Original Estimate was: 5.25% Reprice Estimate is : 3.125% Offroad Diesel was: $2.242/gal Offroad Diesel reprice is: $2.50/gal Original Escalation was: 0.0% Reprice Escalation is: 1.10% Total Cost for Year 2010 Estimate was: $158,777,272 Total Cost for Year 2011 Estimate is : $162,074,000
11/1/2010	Switanek:monitoring	Added as of 1 Nov 10: 1. 3-year monitoring of ecological and hydraulic monitoring during the construction phase of contract. The CERP Master Agreement requires operational testing and monitoring. The first three years are a requirement of the Master Agreement. We have a policy letter to capture these cost. The remaining years after the three will be O&M and will be conducted through the OMRR&R Cost. Operations Division should include in their out year budget. 2. Policy Letter: WESTERN C-111 SPREADER CANAL PROJECT IMPLEMENTATION REPORT AND DRAFT ENVIRONMENTAL ASSESMENT USACE - JACKSONVILLE DISTRICT COST ENGINEERING DX TPCS REVISED CERTIFICATION As of16 January, 2010 the Walla Walla District, Cost Engineering Directory of Expertise (Dx) for Civil Works, re-certifies the Western C-111 Spreader Canal Project Implementation Report and Draft Environmental Assessment. Re-certification is a result of added funding to support project monitoring. The revised values are: 2011 Fully Funded Amount: $173,398,000 The Walla Walla Cost Dx representatives have provided an adequate Agency Technical Review (ATR) of the 2010 Budget and Total Project Cost, studying the project scope, report, cost estimates, schedules, escalation, and contingencies in accordance with ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering. Dane Skarbek Chief, Cost Engineering Walla Walla District
11/19/2010	Switanek: cert. cost	Cost was certified on 16 Nov 10 for the 2011 reprice. Certified by John P. Skarbek

Labor ID: LPL2009 EQ ID: EP07R03 Currency in US dollars TRACES MII Version 3.01

Print Date Fri 19 November 2010 U.S. Army Corps of Engineers Time 15:11:09
Eff. Date 11/19/2010 Project C111SP0102: C-111 Spreader Canal Final Estimate 18Nov10_mpx_w_cont_w esc
Jacksonville District Report Selections Project Notes Page viii

Date Author	Note
	CH. Cost engineering Branch Walla Walla District
	Note: The TPCS uses rounded values in order to populate the WBS feature cost and the project totals $162,125,000; fully funded the TPCS equates to about $173,676,000 where as the mii estimate reflects a total price of $162,015,670.

Labor ID: LPL3009 EQ ID: EP07R03 Currency in US dollars TRACES MII Version 3.01

24

Print Date Fri 19 November 2010
Eff. Date 11/19/2010

U.S. Army Corps of Engineers
Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mgs_w_cost_w esc
Jacksonville District Report Selections

Time 15:11:09

Project Cost Summary Report Page 1

Description	Quantity	UOM	ContractCost	Escalation	Contingency	SIOH	ProjectCost
Project Cost Summary Report			129,122,038	862,248	32,031,384	0	162,015,670
60 C-111 Spreader Canal, Phase 1 North Components	1.00	EA	52,990,299	582,893	10,701,844	0	64,275,036
08 Roads, Railroads, and Bridges	1.00	EA	210,107	2,311	31,863	0	244,281
09 Channels and Canals	1.00	EA	30,401,153	334,413	7,991,247	0	38,726,813
13 Pumping Plant	1.00	EA	6,262,174	68,884	1,329,522	0	7,660,581
30 Planning, Engineering and Design	1.00	EA	11,989,827	131,888	848,520	0	12,970,235
31 Construction Management	1.00	EA	4,127,037	45,397	500,692	0	4,673,127
60 C-111 Spreader Canal, Phase 1 South Components	1.00	EA	25,192,908	277,122	4,535,407	0	30,005,436
09 Channels and Canals	1.00	EA	5,833,744	64,171	1,533,458	0	7,431,374
13 Pumping Plant	1.00	EA	5,521,118	60,732	1,172,189	0	6,754,039
15 Floodway Control-Diversion Struc	1.00	EA	4,221,233	46,434	1,024,240	0	5,291,907
30 Planning, Engineering and Design	1.00	EA	7,145,230	78,598	505,668	0	7,729,495
31 Construction Management	1.00	EA	2,471,582	27,187	299,852	0	2,798,622
Lands and Damages For Both North & South Components	1.00	EA	50,735,832	0	16,742,825	0	67,478,657
01 Lands and Damages	1.00	EA	50,735,832	0	16,742,825	0	67,478,657
Recreation Costs	1.00	LS	203,900	2,233	51,308	0	256,541
14 Total Recreation Investment	1.00	EA	203,900	2,233	51,308	0	256,541

Labor ID: LFL2009 EQ ID: EP07R03

Currency in US dollars

TRACES MII Version 3.01

Print Date:Fri 19 November 2010 U.S. Army Corps of Engineers Time 15:11:09
Eff. Date 11/19/2010 Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mpo_w_cost_w esc
Jacksonville District Report Selections Contract Cost Summary Report Page 2

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost
Contract Cost Summary Report				118,038,098	1,618,868	119,453,966	9,465,072	129,122,038
60 C-111 Spreader Canal, Phase 1 North Components	1.00	EA	Prime Contractor - North	45,857,707	659,712	46,517,419	6,472,880	52,990,299
08 Roads, Railroads, and Bridges	1.00	EA	Prime Contractor - North	172,800	0	172,800	37,307	210,107
09 Channels and Canals	1.00	EA	Prime Contractor - North	25,003,033	0	25,003,033	5,398,120	30,401,153
13 Pumping Plant	1.00	EA	Prime Contractor - North	4,565,010	659,712	5,224,721	1,037,453	6,262,174
30 Planning, Engineering and Design	1.00	EA	30 E&D Prime	11,989,827	0	11,989,827	0	11,989,827
31 Construction Management	1.00	EA	31 S&A Prime	4,127,037	0	4,127,037	0	4,127,037
60 C-111 Spreader Canal, Phase 1 South Components	1.00	EA	Prime Contractor - South	21,241,558	959,157	22,200,715	2,992,192	25,192,908
09 Channels and Canals	1.00	EA	Prime Contractor - South	4,624,387	0	4,624,387	1,209,357	5,833,744
13 Pumping Plant	1.00	EA	Prime Contractor - South	3,871,656	654,934	4,526,591	994,527	5,521,118
15 Floodway Control-Diversion Struc	1.00	EA	Prime Contractor - South	3,128,703	304,223	3,432,926	788,307	4,221,233
30 Planning, Engineering and Design	1.00	EA	30 E&D Prime	7,145,230	0	7,145,230	0	7,145,230
31 Construction Management	1.00	EA	31 S&A Prime	2,471,582	0	2,471,582	0	2,471,582
Lands and Damages For Both North & South Components	1.00	EA	01 Lands and Damages Prime	50,735,832	0	50,735,832	0	50,735,832
01 Lands and Damages	1.00	EA	01 Lands and Damages Prime	50,735,832	0	50,735,832	0	50,735,832
Recreation Costs	1.00	LS		203,000	0	0	0	203,000
14 Total Recreation Investment	1.00	EA		203,000	0	0	0	203,000

Labor ID: LFL2009 EQ ID: EP07R03 Currency in US dollars TRACES MII Version 3.01

Print Date Fri 19 November 2010
Eff. Date 11/19/2010

U.S. Army Corps of Engineers
Project C111SP0102: C-111 Spreader Canal Final Estimate 16Nov10_mps_w_cont_w esc
Jacksonville District Report Selections

Time 15:11:09
Project Direct Costs Report Page 3

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost
Project Direct Costs Report				7,585,641	7,651,155	18,159,500	7,969,293	76,672,508	118,038,098
60 C-111 Spreader Canal, Phase 1 North Components	1.00	EA	Prime Contractor - North	5,864,236	6,121,328	10,015,885	7,739,393	16,116,864	45,857,707
08 Roads, Railroads, and Bridges	1.00	EA	Prime Contractor - North	0	0	0	172,800	0	172,800
09 Channels and Canals	1.00	EA	Prime Contractor - North	5,444,541	5,938,110	6,771,670	6,848,713	0	25,003,033
13 Pumping Plant	1.00	EA	Prime Contractor - North	419,696	183,219	3,244,216	717,880	0	4,565,010
30 Planning, Engineering and Design	1.00	EA	30 E&D Prime	0	0	0	0	11,989,827	11,989,827
31 Construction Management	1.00	EA	31 S&A Prime	0	0	0	0	4,127,037	4,127,037
60 C-111 Spreader Canal, Phase 1 South Components	1.00	EA	Prime Contractor - South	1,721,405	1,529,827	8,143,615	229,900	9,616,812	21,241,558
09 Channels and Canals	1.00	EA	Prime Contractor - South	651,806	864,996	2,905,585	172,700	0	4,624,387
13 Pumping Plant	1.00	EA	Prime Contractor - South	421,356	183,656	3,265,765	880	0	3,871,656
15 Floodway Control-Diversion Struc	1.00	EA	Prime Contractor - South	619,043	481,176	1,972,164	56,320	0	3,128,703
30 Planning, Engineering and Design	1.00	EA	30 E&D Prime	0	0	0	0	7,145,230	7,145,230
31 Construction Management	1.00	EA	31 S&A Prime	0	0	0	0	2,471,582	2,471,582
Lands and Damages For Both North & South Components	1.00	EA	01 Lands and Damages Prime	0	0	0	0	50,735,832	50,735,832
01 Lands and Damages	1.00	EA	01 Lands and Damages Prime	0	0	0	0	50,735,832	50,735,832
Recreation Costs	1.00	LS		0	0	0	0	203,000	203,000
14 Total Recreation Investment	1.00	EA		0	0	0	0	203,000	203,000

Labor ID: LPL2009 EQ ID: EP07R03

Currency in US dollars

TRACES MII Version 3.01

27

B.3.1 QUANTITY TAKEOFF SHEET AND CALCULATION ESTIMATE

REAL ESTATE COST - ALTERNATIVE 2D SHORT									
OWNER	**Acres**	**Est Value**	**# Parcels**	**# Imp**	**Imp $**	**SFWMD Actual Acquisition $**	**Non FED Admin $***	**Fed Admin***	**Total**
Private	776.06	$28,719,588	128	0	$0		$1,723,175	$287,196	$30,729,959
Miami-Dade	9.98	$498,902	2	0	$0		$29,934	$4,989	$533,825
Miami-Dade DERM-EEL	121.08	$680,580	25	0	$0		$40,835	$6,806	$728,220
FPL	955.00	$1,432,500	7	0	$0		$85,950	$14,325	$1,532,775
STATE	15.00	$900,000	6	0	$0		$54,000	$9,000	$963,000
SFWMD	9,687.53	$0	34	0	$0	$4,083,729	$412,972	$40,837	$4,537,539
TOTAL	**11,564.65**	**$32,231,569**	**202**	**0**	**$0**	**$4,083,729**	**$2,346,867**	**$363,153**	**$39,025,318**
						25% Contingency on $34,528,617			$8,632,154
							TOTAL		**$47,657,472**

FIGURE B-2: REAL ESTATE COST

Sheet1

CIVIL QUANTITY TAKEOFF

C-111 Spreader Canal
Miami-Dade County, FL

North Berms

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009	
					System :North Components Channels				Phase : All Task	
					_	_	_		Est. : Campbell	
						Metric	No			
					Discription				Total	U/M
Page 16					Profile - F - PL -	Inlet Channel Leeve				
								SF/ SQ IN		
				A	Measured Area	16.7395	SQ IN	1000	16739.5	SF
				B	Stn 12+00 to 38+00 =				2600.0	LF
				C	Height above Ex. Grade = (A / B)				6.44	LF
				D	Designed Top Of Berm Elev				9.00	FT
				E	Avg Exist Grade Elev	2.56	FT (Calculated)		3.00	FT (Used)
				F	Top Of Rock Elevation				2.50	FT
				G	Surficial material Thickness				0.50	FT
				H	Top Of Berm Length PL2: 125+40 to PL:11+00 + PL:11+00 to 38+00				2889.00	LF
				I	Constructed Top Of Berm Elev				9.30	FT
				J	Berm Height				6.80	LF
				K	Top Of Berm Width				14.00	LF
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF
				M	Base Of Berm Area				197607.6	SF
				N	Berm Sloped Length One Side Only				27.27	LF
					Clear & Grub at Inlet Channel Leeve - M / 43560					4.54 ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					3659 BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)/27					29977 CCY
					Grade Berm Slope - H x N x 2 / 9					17506 SY
Page 16					Adjustment at PL2:125+40 to PL:11+00	Inlet Channel Leeve				
				a	Top Of Berm Area	Measured			7554.81	SF
				b	Berm Height				6.80	LF
				c	Slope Adjustment				-81.10	LF
				d	Base Of Berm Area				5348.89	SF
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.12 ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					99 BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - (((((b*4)/2)*b)*c)+(a*b))					1625 CCY
					Grade Berm Slope - c x N / 9					-246 SY
Page 16					Adjustment at PL2:125+40 to PL:11+00	Inlet Channel Leeve				
				a	Top Of Berm Area	Measured			1000.00	SF
				b	Berm Height				6.80	LF
				c	Slope Adjustment				3.49	LF
				d	Base Of Berm Area				1094.928	SF
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.03 ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					20 BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - (((((b*4)/2)*b)*c)+(a*b))					264 CCY
					Grade Berm Slope - c x N / 9					11 SY
Page					DDT for 6" Conc Liner @ Conc Liner - PL: 12+37 to PL:38+00				Inlet Channel Leeve	
				g	Liner Length				2563.00	LF
				h	Liner Height				4.50	LF
				i	Sloped Width				18.00	LF
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27					-854 CCY

North Berms

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					Profile - G - PL -	Inlet Channel Leeve					
								SF/ SQ IN			
				A	Measured Area	12.2670	SQ IN	1000	12267.0	SF	
				B	Stn 38+00 to 56+37 =				1837.0	LF	
				C	Height above Ex. Grade = (A / B)				6.68	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.32	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL:38+00 to 54+87				5449.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				372711.6	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					8.56	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					6902	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					56540	CCY
					Grade Berm Slope - H x N x 2 / 9					33019	SY
Page			DDT for 6" Conc Liner @ Conc Liner - PL: PL:38+00 to 54+87						Inlet Channel Leeve		
				g	Liner Length				1687.00	LF	
				h	Liner Height				4.50	LF	
				i	Sloped Width				18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27					-562	CCY
Page 16					Profile - G - PL -	Inlet Channel Leeve 50' Transition					
				C	Height above Ex. Grade = (A / B)				#DIV/0!	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	#DIV/0!	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL:54+87 to 55+37				50.00	LF	
				I	Avg Constructed TOB Elev	9.3' & 10.3'			9.80	FT	
				J	Berm Height				7.30	LF	
				K	Avg Top Of Berm Width	14' & 40'			27.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				85.40	LF	
				M	Base Of Berm Area				4270	SF	
				N	Berm Sloped Length One Side Only				29.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.10	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					79	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					760	CCY
					Grade Berm Slope - H x N x 2 / 9					325	SY
Page			DDT for 6" Conc Liner @ Conc Liner - PL: PL:354+87 to 55+37						0		
				g	Liner Length				50.00	LF	
				h	Liner Height				4.50	LF	
				i	Sloped Width				18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27					-17	CCY

3of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Profile - G - PL - Inlet Channel Leeve @ 100' Maint Berm						
				C	Height above Ex. Grade = (A / B)				#DIV/0!	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	#DIV/0!	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL:55+37 to 56+37				100.00	LF	
				I	Constructed TOB Elev				10.30	FT	
				J	Berm Height				7.80	LF	
				K	Top Of Berm Width				40.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				102.40	LF	
				M	Base Of Berm Area				10240	SF	
				N	Berm Sloped Length One Side Only				31.28	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.24	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					190	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					2057	CCY
					Grade Berm Slope - H x N x 2 / 9					695	SY
Page					DDT for 6" Conc Liner @ Conc Liner - PL: PL:55+37 to 56+37				0		
				g	Liner Length				100.00	LF	
				h	Liner Height				4.50	LF	
				i	Sloped Width				18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27					-33	CCY
Page 16					Profile - M - PL4 - Inlet Channel Leeve						
								SF/ SQ IN			
				A	Measured Area	17.5956	SQ IN	1000	17595.6	SF	
				B	Stn 12+00 to 38+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.77	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.23	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL4: 11+40 to 38+00				2660.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				181944	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					4.18	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					3369	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					27601	CCY
					Grade Berm Slope - H x N x 2 / 9					16118	SY

4of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal					Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL					Date : 06/11/2009		
					System :North Components Channels					Phase : All Task		
										Est. : Campbell		
						Metric	No					
					Discription						Total	U/M
Page 16					Adjustment at BL:123+89 to PL4:11+40	Inlet Channel Leeve						
				a	Top Of Berm Area	Measured				3955.0	SF	
				b	Berm Height					6.80	LF	
				c	Slope Adjustment					0.00	LF	
				d	Base Of Berm Area					18811	SF	
				e	Avg Berm Height					4.8	LF	
				f	Sloped Berm Area - d-a					14856	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560						0.43	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27						348	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - (((f*e)+(a*b))/27						3637	CCY
					Grade Berm Slope - f / 9						1651	SY
Page 16					Adjustment at BL:123+89 to PL4:11+40	Inlet Channel Leeve						
				a	Top Of Berm Area	Measured				0.00	SF	
				b	Avg Berm Height					4.80	LF	
				c	Slope Adjustment					186.00	LF	
				d	Base Of Berm Area					3571.2	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560						0.08	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27						66	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - (((((b*4)/2)*b)*c)+(a*b))						317	CCY
					Grade Berm Slope - (c x (b x 4)) / 9						397	SY
Page 16					**Adjustment at PL4:25+13 to 27+54 & PL3: 123+00**					**Inlet Channel Leeve**		
				a	Top Of Berm Area	Measured				21241.30	SF	
				b	Berm Height					6.80	LF	
				c	Slope Adjustment					108.76	LF	
				d	Base Of Berm Area					24199.572	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560						0.56	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27						448	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - (((((b*4)/2)*b)*c)+(a*b))						5722	CCY
					Grade Berm Slope - c x N / 9						330	SY
Page 16					**DDT for 6" Conc Liner @ Conc Liner - PL4: 10+00 to PL4:38+00**					**Inlet Channel Leeve**		
				g	Liner Length					2808.70	LF	
				h	Liner Height					4.50	LF	
				i	Sloped Width					18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x i x 0.5') /27						-936	CCY
Page ??					**Profile - N - PL4 -**	**Inlet Channel Leeve**						
								SF/ SQ IN				
				A	Measured Area	8.8095	SQ IN	1000		8809.5	SF	
				B	Stn 38+00 to 54+00 =					1600.0	LF	
				C	Height above Ex. Grade = (A / B)					5.51	LF	
				D	Designed Top Of Berm Elev					9.00	FT	
				E	Avg Exist Grade Elev	3.49	FT (Calculated)			3.49	FT (Used)	
				F	Top Of Rock Elevation					2.50	FT	
				G	Surficial material Thickness					0.99	FT	
				H	Top Of Berm Length PL4: 38+00 to 52+50					1450.00	LF	
				I	Constructed Top Of Berm Elev					9.30	FT	
				J	Berm Height					6.80	LF	
				K	Top Of Berm Width					14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope					68.40	LF	
				M	Base Of Berm Area					99180	SF	
				N	Berm Sloped Length One Side Only					27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560						2.28	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27						3652	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)						15046	CCY
					Grade Berm Slope - H x N x 2 / 9						8786	SY

5of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Subsystem	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009	
					System :North Components Channels				Phase : All Task	
									Est. : Campbell	
					Discription	Metric	No		Total	U/M
Page 16				DDT for 6" Conc Liner @ Conc Liner - PL4: 38+00 to 52+50				Inlet Channel Leeve		
				g	Liner Length			1450.00	LF	
				h	Liner Height			4.50	LF	
				i	Sloped Width			18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27				-483	CCY
Page 16					Profile - N - PL4 -	Inlet Channel Leeve 50' Transition				
				C	Height above Ex. Grade = (A / B)			0.00	LF	
				D	Designed Top Of Berm Elev			9.00	FT	
				E	Avg Exist Grade Elev	9.00	FT (Calculated)	3.00	FT (Used)	
				F	Top Of Rock Elevation			2.50	FT	
				G	Surficial material Thickness			0.50	FT	
				H	Top Of Berm Length PL:52+50 to 53+00			50.00	LF	
				I	Avg Constructed TOB Elev	9.3' & 10.3'		9.80	FT	
				J	Berm Height			7.30	LF	
				K	Avg Top Of Berm Width	14' & 40'		27.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope			85.40	LF	
				M	Base Of Berm Area			4270	SF	
				N	Berm Sloped Length One Side Only			29.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560				0.10	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27				79	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)				760	CCY
					Grade Berm Slope - H x N x 2 / 9				325	SY
Page				DDT for 6" Conc Liner @ Conc Liner - PL4:52+50 to 53+00				0		
				g	Liner Length			50.00	LF	
				h	Liner Height			4.50	LF	
				i	Sloped Width			18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27				-17	CCY
Page 16					Profile - N - PL4 -	Inlet Channel Leeve @ 100' Maint Berm				
				C	Height above Ex. Grade = (A / B)			0.00	LF	
				D	Designed Top Of Berm Elev			9.00	FT	
				E	Avg Exist Grade Elev	9.00	FT (Calculated)	3.00	FT (Used)	
				F	Top Of Rock Elevation			2.50	FT	
				G	Surficial material Thickness			0.50	FT	
				H	Top Of Berm Length PL4:53+00 to 54+00			100.00	LF	
				I	Constructed TOB Elev			10.30	FT	
				J	Berm Height			7.80	LF	
				K	Top Of Berm Width			40.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope			102.40	LF	
				M	Base Of Berm Area			10240	SF	
				N	Berm Sloped Length One Side Only			31.28	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560				0.24	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27				190	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)				2057	CCY
					Grade Berm Slope - H x N x 2 / 9				695	SY
Page				DDT for 6" Conc Liner @ Conc Liner - PL4: 53+00 to 54+00				0		
				g	Liner Length			100.00	LF	
				h	Liner Height			4.50	LF	
				i	Sloped Width			18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27				-33	CCY

North Berms

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
	Summary For Inlet Channel Leeve										
		Clear & Grub								21.43	ACR
		Remove surficial material to Top Of Rock, Includes topsoil.							19102	BCY	
		Strip & Stockpile Topsoil for reuse				558850	SF			10349	BCY
		Excavate, load and haul balance of surficial soil, 10 mile haul								8753	BCY
		Purchase/Place/Compact Embankment Total								143427	CCY
				Embankment Volume - Top 12"				8101	CCY	9559	LCY
				Embankment Volume - Below Top 12"				131404	CCY	155057	LCY
						Crushed Rock		3921	CCY		
								143427	CCY		
		Grade Berm Slope								79612	SY
		Top of Berm Area								24303	SY
	Spread topsoil & Seed @ Slopes NIC Lined area					558850	SF	12418.89	LCY	62094	SY
	Summary For Inlet Channel Base & Liner										
		Clear & Grub						88287	SF	2.03	ACR
		Excavate, load and haul surficial soil, 10 mile haul								8540	BCY
		Rip, Excavate, Haul Rock for Liner Granular Base - 12"						105877	SF	3921	BCY
		6" Th. Conc Liner - Flat				4398	Long				
		12" Th Granular Base at Liner						105877	SF	11764	SY
		6" Concrete Slab						88287	SF	1635	CY
				Finish & Cure Conc Liner				9809.7	SY	88287	SF
				WWF Reinf						92701	SF
				6" Edge Form						13193	LF
				Exp Joint & Sealer						4358	LF
		6" Th. Conc Liner - Sloped				8809	Length		18	Width	
		12" Th Granular Base at Liner						0	SF	0	SY
		6" Concrete Slab						158556.6	SF	2936	CY
				Finish & Cure Conc Liner						158557	SF
				WWF Reinf						166484	SF
				6" Edge Form						16809	LF
				Exp Joint & Sealer						7928	LF
		6" Th Aggregate Surfacing						218723.1	SF	24303	SY

North Berms

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Profile - T - IL3 - Detention Cell S Leeve						
								SF/ SQ IN			
				A	Measured Area	10.5751	SQ IN	1000	10575.1	SF	
				B	Stn 10+00 to 26+00 =				1600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.61	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.39	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length Stn 12+30 to PL3: 11+38				1485.86	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				101632.82	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					2.33	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					1882	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)/27					15418	CCY
					Grade Berm Slope - H x N x 2 / 9					9004	SY
Page 16					Adjustment at IL4: 25+44 to PL3 11+38 Detention Cell S Leeve						
				a	Top Of Berm Area	Measured			9022.79	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				-128.20	LF	
				d	Base Of Berm Area				5535.75	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.13	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					103	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((((b*4)/2)*b)*c)+(a*b))/					1833	CCY
					Grade Berm Slope - c x N / 9					-388	SY
Page 16					Profile - O - PL3 - Detention Cell S Leeve						
								SF/ SQ IN			
				A	Measured Area	16.8106	SQ IN	1000	16810.6	SF	
				B	Stn 12+00 to 38+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.47	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.53	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length 11+38 to 38+00				2662.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				182080.8	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					4.18	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					3372	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					27622	CCY
					Grade Berm Slope - H x N x 2 / 9					16131	SY

8of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Adjustment at PL?:0+0 to PL:0+00	Detention Cell S Leeve					
				a	Top Of Berm Area	Measured			1000.00	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				-3.49	LF	
				d	Base Of Berm Area				905.072	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.02	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					17	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - {(((((b*4)/2)*b)*c)+(a*b)}					240	CCY
					Grade Berm Slope - c x N / 9					-11	SY
Page 16					Profile - P - PL3 -	Detention Cell S Leeve					
								SF/ SQ IN			
				A	Measured Area	16.7460	SQ IN	1000	16746.0	SF	
				B	Stn 38+00 to 64+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.44	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.56	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length 38+00 to 46+72				872.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				59644.8	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					1.37	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					1105	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x {(I+L)/2) x J}					9048	CCY
					Grade Berm Slope - H x N x 2 / 9					5284	SY
	Summary For Detention Cell S Leeve										
					Clear & Grub					8.03	ACR
					Remove surficial material to Top Of Rock				6478	BCY	
					Strip & Stockpile Topsoil for reuse	268372	SF			4970	BCY
					Excavate, load and haul balance of surficial soil, 10 mile haul					1508	BCY
					Purchase/Place/Compact Embankment Total				54127	CCY	
					Embankment Volume - Top 12"			2974	CCY	3509	LCY
					Embankment Volume - Below Top 12"			51153	CCY	60361	LCY
								54127	CCY		
					Grade Berm Slope					30019	SY
					Top of Berm Area					8922	SY
	Topsoil & Seeding @ Slopes NIC Lined area					268372	SF	6460.811	LCY	29819	SY
					6" Th Aggregate Surfacing			80301	SF	8922	SY
	Summary For Detention Cell S										
					Clear & Grub			4934703	SF	113.29	ACR
					Remove surficial material to Top Of Rock					365534	BCY

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Profile - P - PL3 -	Detention Cell C Leeve					
								SF/ SQ IN			
				A	Measured Area	16.7460	SQ IN	1000	16746.0	SF	
				B	Stn 38+00 to 64+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.44	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.56	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL3: 46+72 to 64+00				1728.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				118195.2	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					2.71	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					2189	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)/27					17930	CCY
					Grade Berm Slope - H x N x 2 / 9					10471	SY
Page 16					Profile - Q - PL3 -	Detention Cell C Leeve					
								SF/ SQ IN			
				A	Measured Area	16.9032	SQ IN	1000	16903.2	SF	
				B	Stn 64+00 to 90+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.50	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.50	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length 64+00 to 84+66				2066.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				141314.4	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					3.24	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					2617	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					21437	CCY
					Grade Berm Slope - H x N x 2 / 9					12519	SY
Page 16					Adjustment at PL3" 68+00	Detention Cell C Leeve					
				a	Top Of Berm Area	Measured			1000.00	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				3.49	LF	
				d	Base Of Berm Area				1094.928	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.03	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					20	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - {((((b*4)/2)*b)*c)+(a*b)}					264	CCY
					Grade Berm Slope - c x N / 9					11	SY

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Profile - U - IL2 -	Detention Cell C Leeve					
								SF/ SQ IN			
				A	Measured Area	13.3883	SQ IN	1000	13388.3	SF	
				B	Stn 10+00 to 30+00 =				2000.0	LF	
				C	Height above Ex. Grade = (A / B)				6.69	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.31	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length IL2: 13+00 to 28+04				1504.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				102873.6	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					2.36	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					1905	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					15606	CCY
					Grade Berm Slope - H x N x 2 / 9					9114	SY
Page 16					Profile - U - IL2 -	Detention Cell C Leeve					
								SF/ SQ IN			
				A	Measured Area	13.3883	SQ IN	1000	13388.3	SF	
				B	Stn 10+00 to 30+00 =				2000.0	LF	
				C	Height above Ex. Grade = (A / B)				6.69	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.31	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length				0.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				0	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.00	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					0	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					0	CCY
					Grade Berm Slope - H x N x 2 / 9					0	SY
Page 16					Adjustment at IL2: 11+87 to 13+08	Detention Cell C Leeve					
				a	Top Of Berm Area	Measured			3492.9	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				8951.9	SF	
				e	Avg Berm Height				4.8	LF	
				f	Sloped Berm Area - d-a				5459	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.21	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					166	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((f*e)+(a*b))/27					1850	CCY
					Grade Berm Slope - f / 9					607	SY

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					Adjustment at R_2: 28+04 Detention Cell C Leeve						
				a	Top Of Berm Area	Measured			19231.52	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				108.20	LF	
				d	Base Of Berm Area				22174.56	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.51	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					411	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((b*4)/2)*b)*c)+(a*b))					5214	CCY
					Grade Berm Slope - (c x (b x 4)) / 9					327	SY
	Summary For Detention Cell C Leeve										
					Clear & Grub					9.06	ACR
					Remove surficial material to Top Of Rock				7307	BCY	
					Strip & Stockpile Topsoil for reuse	297429	SF			5508	BCY
					Excavate, load and haul balance of surficial soil, 10 mile haul					1800	BCY
					Purchase/Place/Compact Embankment Total					62302	CCY
					Embankment Volume - Top 12"			3626	CCY	4278	LCY
					Embankment Volume - Below Top 12"			58676	CCY	69238	LCY
								62302	CCY		
					Grade Berm Slope					33048	SY
					Top of Berm Area					10877	SY
	Topsoil & Seeding @ Slopes NIC Lined area					297429	SF	7160.326	LCY	33048	SY
					6" Th Aggregate Surfacing			97896	SF	10877	SY
	Summary For Detention Cell C										
					Clear & Grub			5579482	SF	128.09	ACR
					Remove surficial material to Top Of Rock					413295	BCY

North Berms

System	Subsystem	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Profile - Q - PL3 - Detention Cell N Leeve						
								SF/ SQ IN			
				A	Measured Area	16.9032	SQ IN	1000	16903.2	SF	
				B	Stn 64+00 to 90+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.50	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.50	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL3: 84+66 to 90+00				534.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				36525.6	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.84	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					676	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)/27					5541	CCY
					Grade Berm Slope - H x N x 2 / 9					3236	SY
Page 16					Profile - R - PL3 - Detention Cell N Leeve						
								SF/ SQ IN			
				A	Measured Area	16.7547	SQ IN	1000	16754.7	SF	
				B	Stn 90+00 to 116+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				6.44	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.56	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length 64+00 to 84+66				2600.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				177840	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					4.08	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					3293	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					26978	CCY
					Grade Berm Slope - H x N x 2 / 9					15755	SY
Page 16					Adjustment at PL3" 110+00 Detention Cell N Leeve						
				a	Top Of Berm Area	Measured			1000.00	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				3.49	LF	
				d	Base Of Berm Area				1094.928	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.03	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					20	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((b*4)/2)*b)*c)+(a*b))					264	CCY
					Grade Berm Slope - c x N / 9					11	SY

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Profile - V - IL -	Detention Cell N Leeve					
								SF/ SQ IN			
				A	Measured Area	13.5958	SQ IN	1000	13595.8	SF	
				B	Stn 9+00 to 30+00 =				2100.0	LF	
				C	Height above Ex. Grade = (A / B)				6.47	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.53	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length IL2: 13+00 to 28+37				1537.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				105130.8	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					2.41	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					1947	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x {(I+L)/2) x J}					15948	CCY
					Grade Berm Slope - H x N x 2 / 9					9314	SY
Page 16					Profile - V - IL2 -	Detention Cell N Leeve					
								SF/ SQ IN			
				A	Measured Area	13.5958	SQ IN	1000	13595.8	SF	
				B	Stn 9+00 to 30+00 =				2100.0	LF	
				C	Height above Ex. Grade = (A / B)				6.47	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	2.53	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length				0.00	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				0	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.00	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					0	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x {(I+L)/2) x J}					0	CCY
					Grade Berm Slope - H x N x 2 / 9					0	SY
Page 16					Adjustment at IL2: 11+87 to 13+00	Detention Cell N Leeve					
				a	Top Of Berm Area	Measured			3492.9	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				3951.9	SF	
				e	Avg Berm Height				4.8	LF	
				f	Sloped Berm Area - d-a				5459	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.21	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					166	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - {(f*e)+(a*b)}/27					1850	CCY
					Grade Berm Slope - f / 9					607	SY

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					Adjustment at IL2: 28+37 Detention Cell N Leeve						
				a	Top Of Berm Area	Measured			19231.52	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				108.20	LF	
				d	Base Of Berm Area				22174.56	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.51	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					411	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((b*4)/2)*b)*c)+(a*b))					5214	CCY
					Grade Berm Slope - (c x (b x 4)) / 9					327	SY
Page ??					Profile - S - IL3 - Detention Cell N Leeve						
								SF/ SQ IN			
				A	Measured Area	4.3209	SQ IN	1000	4320.9	SF	
				B	Stn 116+00 to 123+00 =				700.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				9.00	FT	
				E	Avg Exist Grade Elev	9.00	FT (Calculated)		9.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				6.50	FT	
				H	Top Of Berm Length Stn 116+00 to 123+00				700.0	LF	
				I	Constructed Top Of Berm Elev				9.30	FT	
				J	Berm Height				6.80	LF	
				K	Top Of Berm Width				14.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40	LF	
				M	Base Of Berm Area				47880	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					1.10	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					11527	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					7263	CCY
					Grade Berm Slope - H x N x 2 / 9					4242	SY
	Summary For Detention Cell N Leeve										
		Clear & Grub								9.17	ACR
		Remove surficial material to Top Of Rock							18040	BCY	
		Strip & Stockpile Topsoil for reuse				301410	SF			5582	BCY
		Excavate, load and haul balance of surficial soil, 10 mile haul								12458	BCY
		Purchase/Place/Compact Embankment Total								63059	CCY
					Embankment Volume - Top 12"			3664	CCY	4323	LCY
					Embankment Volume - Below Top 12"			59396	CCY	70087	LCY
								63059	CCY		
		Grade Berm Slope								33490	SY
		Top of Berm Area								10991	SY
	Topsoil & Seeding @ Slopes NIC Lined area					301410	SF	7256.168	LCY	33490	SY
		6" Th Aggregate Surfacing						98918	SF	10991	SY
	Backfill existing canal 20' wide x 10' deep					2353.0	LF			17430	ECY
					Dewatering w/ 4" pump @ 570 GPM	13944	CY	3.43	Pump Day	2816628	Gal
	Summary For Detention Cell N										
		Clear & Grub						5894363	SF	135.32	ACR
		Remove surficial material to Top Of Rock								436619	BCY

15of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Sub-system	Assem. Cat	Assembly		Description	Metric	No		Total	U/M
					Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009	
					System :North Components Channels				Phase : All Task	
									Est. : Campbell	
								SF/ SQ IN		
Page 16					Profile - T - IL3 - Header Channel Eastern Berm & Wiers					
				A	Measured Area	10.5751	SQ IN	1000	10575.1 SF	
				B	Stn 10+00 to 26+00 =				1600.0 LF	
				C	Height above Ex. Grade = (A / B)				6.61 LF	
				D	Designed Top Of Berm Elev				9.00 FT	
				E	Avg Exist Grade Elev	2.39	FT (Calculated)		3.00 FT (Used)	
				F	Top Of Rock Elevation				2.50 FT	
				G	Surficial material Thickness				0.50 FT	
				H	Top Of Berm Length Stn 11+61 to 12+30				69.00 LF	
				I	Constructed Top Of Berm Elev				9.30 FT	
				J	Berm Height				6.80 LF	
				K	Top Of Berm Width				14.00 LF	
				L	Base Of Berm Width w/ 1V:4H Slope				68.40 LF	
				M	Base Of Berm Area				4719.6 SF	
				N	Berm Sloped Length One Side Only				27.27 LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.11 ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					87 BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)/27					716 CCY
					Grade Berm Slope - H x N x 2 / 9					418 SY
Page 16					Adjustment at IL3: 10+00 to 11+60 Header Channel Eastern Berm & Wiers					
				a	Top Of Berm Area	Measured			13002.8 SF	
				b	Berm Height				6.80 LF	
				c	Slope Adjustment				250.00 LF	
				d	Base Of Berm Area				17230 SF	
				e	Avg Berm Height				6.8 LF	
				f	Average Berm Area - (a + d)/2				15116 SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.40 ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					319 BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((f*e)/27					3807 CCY
					Grade Berm Slope					756 SY
Page 16					Profile - H - BL - Header Channel Eastern Berm & Wiers					
								SF/ SQ IN		
	******			A	Measured Area	7.9247	SQ IN	1000	7924.7 SF	
				B	Stn 12+00 to 24+00 =				1200.0 LF	
				C	Height above Ex. Grade = (A / B)				0.00 LF	
				D	Designed Top Of Berm Elev				5.00 FT	
				E	Avg Exist Grade Elev	5.00	FT (Calculated)		3.00 FT (Used)	
				F	Top Of Rock Elevation				2.50 FT	
				G	Surficial material Thickness				0.50 FT	
				H	Top Of Berm Length 10+32 to 24+00				1368.00 LF	
				I	Constructed Top Of Berm Elev				5.30 FT	
				J	Berm Height				2.80 LF	
				K	Top Of Berm Width				5.00 LF	
				L	Base Of Berm Width w/ 1V:4H Slope				27.40 LF	
				M	Base Of Berm Area				37483.2 SF	
				N	Berm Sloped Length One Side Only				11.23 LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.86 ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					694 BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					2298 CCY
					Grade Berm Slope - H x N x 2 / 9					3413 SY

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
Page 16					Profile - I - BL -	Header Channel Eastern Berm & Wiers					
								SF/ SQ IN			
				A	Measured Area	16.9666	SQ IN	1000	16966.6	SF	
				B	Stn 24+00 to 50+00+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				5.00	FT	
				E	Avg Exist Grade Elev	5.00	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length 24+00 to 50+00+00 less 700' Wier & 96' @ 49+				1804.00	LF	
				I	Constructed Top Of Berm Elev				5.30	FT	
				J	Berm Height				2.80	LF	
				K	Top Of Berm Width				5.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				27.40	LF	
				M	Base Of Berm Area				49429.6	SF	
				N	Berm Sloped Length One Side Only				11.23	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					1.13	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					915	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					3031	CCY
					Grade Berm Slope - H x N x 2 / 9					4501	SY
Page 16					Profile - J - BL -	Header Channel Eastern Berm & Wiers					
								SF/ SQ IN			
				A	Measured Area	16.7551	SQ IN	1000	16755.10	SF	
				B	Stn 50+00 to 76+00 =				2600.00	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				5.00	FT	
				E	Avg Exist Grade Elev	5.00	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length 50+00 to 76+00+00 less 700' Wier				1900.00	LF	
				I	Constructed TOB Elev				5.30	FT	
				J	Berm Height				2.80	LF	
				K	Top Of Berm Width				5.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				27.40	LF	
				M	Base Of Berm Area				52060	SF	
				N	Berm Sloped Length One Side Only				11.23	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					1.20	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					964	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					3192	CCY
					Grade Berm Slope - H x N x 2 / 9					4741	SY
Page 16					Profile - K - BL -	Header Channel Eastern Berm & Wiers					
								SF/ SQ IN			
				A	Measured Area	17.6132	SQ IN	1000	17613.2	SF	
				B	Stn 76+00 to 102+00 =				2600.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				5.00	FT	
				E	Avg Exist Grade Elev	5.00	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length 76+00 to 102+00+00 less 96' @ 87+00				2504.00	LF	
				I	Constructed Top Of Berm Elev				5.30	FT	
				J	Berm Height				2.80	LF	
				K	Top Of Berm Width				5.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				27.40	LF	
				M	Base Of Berm Area				68609.6	SF	

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
						Metric	No				
					Discription					Total	U/M
				N	Berm Sloped Length One Side Only				11.23	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					1.58	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					1271	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					4207	CCY
					Grade Berm Slope - H x N x 2 / 9					6248	SY
Page ??					Profile - L - BL -	Header Channel Eastern Berm & Wiers					
								SF/ SQ IN			
				A	Measured Area	15.3321	SQ IN	1000	15332.1	SF	
				B	Stn 102+00 to 126+00 =				2400.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				5.00	FT	
				E	Avg Exist Grade Elev	5.00	FT (Calculated)		5.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				2.50	FT	
				H	Top Of Berm Length 102+00 to 123+89 less 700' Wier				1489.00	LF	
				I	Constructed Top Of Berm Elev				5.30	FT	
				J	Berm Height				2.80	LF	
				K	Top Of Berm Width				5.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				27.40	LF	
				M	Base Of Berm Area				40798.6	SF	
				N	Berm Sloped Length One Side Only				11.23	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.94	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					3778	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					2502	CCY
					Grade Berm Slope - H x N x 2 / 9					3715	SY
Page 16					Adjustment at PL?:0+0 to PL:0+00	Header Channel Eastern Berm & Wiers					
				a	Top Of Berm Area	Measured			0.00	SF	
				b	Berm Height				2.80	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				0	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.00	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					0	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((b*4)/2)*b)*c)+(a*b))					0	CCY
					Grade Berm Slope - c x N / 9					0	SY
Page 16					Adjustment for	Header Channel Intermediate Wiers					
				a	Top Of Berm Area	Measured			0.00	SF	
				b	Berm Height				2.80	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				0	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.00	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					0	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((b*4)/2)*b)*c)+(a*b))					0	CCY
					Grade Berm Slope - c x N / 9					0	SY
Page 16					Adjustment at PL?:0+0 to PL:0+00	Header Channel Eastern Berm & Wiers					
				a	Top Of Berm Area	Measured			0.00	SF	
				b	Berm Height				2.80	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				0	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.00	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					0	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((b*4)/2)*b)*c)+(a*b))					0	CCY
					Grade Berm Slope - c x N / 9					0	SY

18of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
					_	_	_		Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					Adjustment at PL?:0+0 to PL:0+00	Header Channel Eastern Berm & Wiers					
				a	Top Of Berm Area	Measured			0.00	SF	
				b	Berm Height				2.80	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				0	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.00	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					0	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - {{{{(b*4)/2}*b)*c)+(a*b)}					0	CCY
					Grade Berm Slope - c x N / 9					0	SY
Page 16					DDT for 6" Conc Liner @ Conc Liner - PL4: 38+00 to 52+50				Header Channel Eastern Berm		
				g	Liner Length				0.00	LF	
				h	Liner Height				4.50	LF	
				i	Sloped Width				18.00	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27					0	CCY
Page 16					Wiers - Section D	Header Channel Eastern Wiers - 3 EA x 700'					
								SF/ SQ IN			
				A	Measured Area	0.0000	SQ IN	1000	0.0	SF	
				B	???				0.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				4.22	FT	
				E	Avg Exist Grade Elev	4.22	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Wier Length = 3 x 700'				2100.00	LF	
				I	Constructed Top Of Berm Elev				4.52	FT	
				J	Berm Height				2.02	LF	
				K	Top Of Berm Width				5.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				21.16	LF	
				M	Base Of Berm Area				44436	SF	
				N	Berm Sloped Length One Side Only				8.10	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					1.02	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					823	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					2055	CCY
					Grade Berm Slope - H x N x 2 / 9					3780	SY
Page					DDT for 6"Armor Flex Liner				0		
				g	Liner Length				2100.00	LF	
				h	Liner Height				2.02	LF	
				I	Liner Flat & Sloped Width				21.16	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27					-823	CCY
Page 16					Wiers - Section E	Header Channel Intermediate Wiers - 2 EA x 83'					
								SF/ SQ IN			
				A	Measured Area	0.0000	SQ IN	1000	0.0	SF	
				B	???				0.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				3.50	FT	
				E	Avg Exist Grade Elev	3.50	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Wier Length = 3 x 700'				166.00	LF	

19of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Sub-system	Assem. Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
				I	Constructed Top Of Berm Elev				3.80	FT	
				J	Berm Height				1.30	LF	
				K	Top Of Berm Width				5.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				15.40	LF	
				M	Base Of Berm Area				2556.4	SF	
				N	Berm Sloped Length One Side Only				5.21	LF	
					Clear & Grub at Inlet Channel Leeve - M / 43560					0.06	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - B x K / 27					47	BCY
					Purchase, Place & Compact Embankment at Inlet Channel Leeve - B x ((I+L)/2) x J)					82	CCY
					Grade Berm Slope - H x N x 2 / 9					192	SY
Page			DDT for 6"Armor Flex Liner						0		
				g	Liner Length				166.00	LF	
				h	Liner Height				1.30	LF	
				i	Liner Flat & Sloped Width				15.40	LF	
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((h x I x 0.5') /27					-47	CCY
Page 16					Additional Berm Header Channel Intermediate Wiers						
				a	Top Of Berm Area	Measured			833.0	SF	
				b	Berm Height				1.30	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				6983.14	SF	
				e	Avg Berm Height				1.3	LF	
				f	Average Berm Area - (a + d)/2				3908	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.16	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					129	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((f*e)/27					188	CCY
					Grade Berm Slope					683	SY
	Summary For Header Channel Eastern Berm & Wiers							11400			
		Clear & Grub								7.45	ACR
		Remove surficial material to Top Of Rock							9028	BCY	
		Strip & Stockpile Topsoil for reuse				209036	SF			3871	BCY
		Excavate, load and haul balance of surficial soil, 10 mile haul								5157	BCY
		Purchase/Place/Compact Embankment Total								21207	CCY
			Embankment Volume - Top 12"					2647	CCY	3123	LCY
			Embankment Volume - Below Top 12"					18560	CCY	21901	LCY
								21207	CCY		
		Grade Berm Slope								28448	SY
		Top of Berm Area								7940	SY
	Topsoil & Seeding @ Slopes NIC Lined area					209036	SF	5032.346	LCY	23226	SY
			ArmorFlex Articulated Conc Block Liner							46992	SF
	Summary For Header Channel Base										
		Clear & Grub						2070326	SF	47.53	ACR
		Remove surficial material to Top Of Rock								153357	BCY

North Berms

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
					System :North Components Channels				Phase : All Task		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					Measured From Plan	Western Header Channel Leeve					
Page 16					Add at PL2:11+50 to 44+50	Western Header Channel Leeve					
				a	Top Of Berm Area	Measured			48200.0	SF	
				b	Berm Height				6.80	LF	
				c	Slope Adjustment				0.00	LF	
				d	Base Of Berm Area				165000	SF	
				e	Avg Berm Height				4.8	LF	
				f	Sloped Berm Area - d-a				116800	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					3.79	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					3056	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((f*e)+(a*b))/27					32904	CCY
					Grade Berm Slope - f / 9					12978	SY
Page 16					Adjustment at PL4:60+00 & 211+00				Inlet Channel Leeve		
				a	Top Of Berm Area	Measured			2000.00	SF	
				b	Berm Height				7.00	LF	
				c	Slope Adjustment				6.80	LF	
				d	Base Of Berm Area				2190.4	SF	
					Clear & Grub at Inlet Channel Leeve - d / 43560					0.05	ACR
					Remove surficial material to Top Of Rock at Inlet Channel Leeve - G x d / 27					41	BCY
					Purch/Place/Compact Embankment at Inlet Channel Leeve - ((((b*4)/2)*b)*c)+(a*b))					543	CCY
					Grade Berm Slope - c x N / 9					21	SY
					Inlet Canal						
	Summary For Western Header Channel Leeve										
				Clear & Grub						3.84	ACR
				Remove surficial material to Top Of Rock					3096	BCY	
				Strip & Stockpile Topsoil for reuse		116985	SF			2166	BCY
				Excavate, load and haul balance of surficial soil, 10 mile haul						930	BCY
				Purchase/Place/Compact Embankment Total						33447	CCY
					Embankment Volume - Top 12"			1859	CCY	2194	LCY
					Embankment Volume - Below Top 12"			31588	CCY	37273	LCY
								33447	CCY		
				Grade Berm Slope						12998	SY
				Top of Berm Area						5578	SY
	Topsoil & Seeding @ Slopes NIC Lined area					116985	SF	2816.316	LCY	12998	SY
					Inlet Canal						
				Clear & Grub				19061	SF	0.44	ACR
				Remove surficial material to Top Of Rock					706	BCY	
				Strip & Stockpile Topsoil for reuse		4568	SF			85	BCY
				Excavate, load and haul balance of surficial soil, 10 mile haul						621	BCY
				Drill, Blast and Excavate Canal						728	BCY
				Purchase/Place/Compact Embankment Total						2648	CCY
					Embankment Volume - Top 12"			289	CCY	341	LCY
					Embankment Volume - Below Top 12"			2359	CCY	2784	LCY
								2648	CCY		
				Grade Berm Slope				4568	SF	508	SY
				Top of Berm Area				7795	SF	866	SY
	Topsoil & Seeding @ Slopes NIC Lined area					4568	SF	109.9704	LCY	508	SY

21of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

North Berms

System	Sub-system	Assem. Cat.	Assembly	Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
				Proj. Location :Miami-Dade County, FL				Date : 06/11/2009		
				System :North Components Channels				Phase : All Task		
								Est. : Campbell		
				Discription	Metric	No			Total	U/M
				Pump Station No. 1						
			Clear & Grub				32300	SF	0.74	ACR
			Remove surficial material to Top Of Rock					1196	BCY	
			Strip & Stockpile Topsoil for reuse		17447	SF			323	BCY
			Excavate, load and haul balance of surficial soil, 10 mile haul						873	BCY
			Drill, Blast and Excavate Intale & Discharge Pools						814	BCY
			Purchase/Place/Compact Embankment Total						4287	CCY
				Embankment Volume - Top 12"			534	CCY	630	LCY
				Embankment Volume - Below Top 12"			3753	CCY	4429	LCY
							4287	CCY		
			Grade Berm Slope				4568	SF	508	SY
			Top of Berm Area				14406	SF	1601	SY
		Topsoil & Seeding @ Slopes NIC Lined area			17447	SF	420.0204	LCY	1939	SY
				24" Rip-Rap, 12" Stone Bedding w/ GeoTex & Filter Fabric					1014	SF
				12" Concrete Apron	117	SY			1050	SF
				1/1.5/8 Asphalt Pavement	601	SY			5407	SF
				6" Conc Liner					2808	SF
				Weed/Safety Floating Barrier w/ 2 ea Anchor Post					70	LF
				In-Bank Stilling Well w/ 58 LF of in-take Pipe					2	EA
				Timber Pile w/ Staff Gauge					2	EA
				6' Security Fence	540.00	LF			476	LF
				6' x 16' Dbl Gate					4	EA

22of22 C-111SC Civil_QTO 061609hc.xls 6/24/2009

Sheet1

CIVIL QUANTITY TAKEOFF

C-111 Spreader Canal
TEST 2

South Aerojet Berms & Channels

System	Sub-system	Assem Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
					Proj. Location : TEST 2				Date : 06/11/2009	
					System :North Components Channels				Phase : South	
					_	_	_		Est. : Campbell	
					Discription	Metric	No		Total	U/M
Page 16					**Proposed Berm Elev. 3.5 - Around Exist. AeroJet Canal**					
								SF/ SQ IN		
				A	Measured Area	0.0000	SQ IN	1000	0.0	SF
				B	Stn 12+00 to 31+73 & 12+00 to 52+00=				0.0	LF
				C	Height above Ex. Grade = (A / B)				0.00	LF
				D	Designed Top Of Berm Elev				3.50	FT
				E	Avg Exist Grade Elev	0.00	FT (Calculated)		0.00	FT (Used)
				F	Top Of Rock Elevation				-0.50	FT
				G	Surficial material Thickness				0.50	FT
					Top Of Berm Length Stn 12+00 to 31+73 & 12+00					
	Stn 12+00 to 31+73 & 12+00 tp 52+00 Plus Turn Berm (01+65)						=	6138	LF	
								6138	LF	
				H	Top Of Berm Length Stn 250+00 to 235+83				6138.00	LF
				I	Constructed Top Of Berm Elev				3.80	FT
				J	Berm Height				4.30	LF
				K	Top Of Berm Width				2.00	LF
				L	Base Of Berm Width w/ 1V:3H Slope				27.80	LF
				M	Base Of Berm Area				170636.4	SF
				N	Average Sloped Berm Length				17.24	LF
					Clear & Grub at Elev. 3.5 - Around Exist. AeroJet Canal - M / 43560				3.92	ACR
					Remove surficial material to Top Of Rock at Elev. 3.5 - Around Exist. AeroJet C				3160	BCY
					Purch/Place/Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - B x ((H+L)/2) x J/				14565	CCY
					Grade Berm Slope - H x N x 2 / 9				23519	SY
					Summary For Proposed Berm Elev. 3.5 - Around Exist. AeroJet Canal					
					Clear & Grub				3.92	ACR
					Remove surficial material to Top Of Rock			3159.93	BCY	
					Strip & Stockpile Topsoil for reuse	170636	SF		3160	BCY
					Excavate, load and haul balance of surficial soil, 10 mile haul				0	BCY
					Purchase ?? /Place/Compact Embankment Total				14565.25	CCY
					Embankment Volume - Top 12"			455	CCY	537 LCY
					Embankment Volume - Below Top 12"			14111	CCY	16650 LCY
								14565	CCY	
					Grade Berm Slope				18960	SY
					Top of Berm Area				1364	SY
					Topsoil & Seeding @ Slopes NIC Lined area	170636	SF	4107.913	LCY	18960 SY

South Aerojet Berms & Channels

System	Sub-system	Assem Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location : TEST 2				Date : 06/11/2009		
					System :North Components Channels				Phase : South		
					_	_	_		Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					Proposed Berm Elev. 4.5 - Around Exist. AeroJet Canal						
								SF/ SQ IN			
				D	Designed Top Of Berm Elev				4.50	FT	
				E	Avg Exist Grade Elev	0.00	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
					Top Of Berm Length Stn 128+33 to 163+71 & Stn 163+71 to 227+68						
							=	9935	LF		
								9935	LF		
				H	Top Of Berm Length Stn 250+00 to 235+83				9935.00	LF	
				I	Constructed Top Of Berm Elev				4.80	FT	
				J	Berm Height				2.30	LF	
				K	Top Of Berm Width				2.00	LF	
				L	Base Of Berm Width w/ 1V:3H Slope				15.80	LF	
				M	Base Of Berm Area				156973	SF	
				N	Average Sloped Berm Length				9.22	LF	
					Clear & Grub at Elev. 3.5 - Around Exist. AeroJet Canal - M / 43560					3.60	ACR
					Remove surficial material to Top Of Rock at Elev. 3.5 - Around Exist. AeroJet C					2907	BCY
					Purch/Place/Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - B x ((I+L)/2) x J/					7532	CCY
					Grade Berm Slope - H x N x 2 / 9					20362	SY
	Summary For Proposed Berm Elev. 4.5 - Around Exist. AeroJet Canal										
			Clear & Grub							3.60	ACR
			Remove surficial material to Top Of Rock					2907	BCY		
			Strip & Stockpile Topsoil for reuse			156973	SF			2907	BCY
			Excavate, load and haul balance of surficial soil, 10 mile haul							0	BCY
			Purchase ?? /Place/Compact Embankment Total							7532	CCY
				Embankment Volume - Top 12"				736	CCY	868	LCY
				Embankment Volume - Below Top 12"				6796	CCY	8020	LCY
								7532	CCY		
			Grade Berm Slope							20362	SY
			Top of Berm Area							2208	SY
	Topsoil & Seeding @ Slopes NIC Lined area					156973	SF	3778.98	LCY	17441	SY

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
					Proj. Location : TEST 2				Date : 06/11/2009	
					System :North Components Channels				Phase : South	
					_	_	__		Est. : Campbell	
					Discription	Metric	No		Total	U/M
Page 16					**Lined Channel**	**Leeve**				
								SF/ SQ IN		
				A	Measured Area	0.0000	SQ IN	1000	0.0	SF
				B	Stn 250+00 to 235+83 =				0.0	LF
				C	Height above Ex. Grade = (A / B)				0.00	LF
				D	Designed Top Of Berm Elev				8.00	FT
				E	Avg Exist Grade Elev	8.00	FT (Calculated)		3.00	FT (Used)
				F	Top Of Rock Elevation				2.50	FT
				G	Surficial material Thickness				0.50	FT
					Top Of Berm Length Stn 250+00 to 235+83					
					Stn 250+00 to 235+84 West Berm		=	5330	LF	
					Stn 251+00 to 232+00 West Berm Deduct @ Headwall		=	-64	LF	
					Stn 250+00 to 235+84 East Berm		=	5330	LF	
					Stn 250+00 ADD for Curved End Berm		=	88	LF	
					Less East & West Transition Berm		=	-100.00	LF	
					Less East & West Maint. Berm		=	-200.00	LF	
								10384	LF	
				H	Top Of Berm Length Stn 250+00 to 235+83				10384.00	LF
				I	Constructed Top Of Berm Elev				8.30	FT
				J	Berm Height				5.80	LF
				K	Top Of Berm Width				14.00	LF
				L	Base Of Berm Width w/ 1V:4H Slope				43.00	LF
				M	Base Of Berm Area				446512	SF
				N	Average Sloped Berm Length				15.59	LF
					Clear & Grub at Elev. 3.5 - Around Exist. AeroJet Canal - M / 43560					10.25 ACR
					Remove surficial material to Top Of Rock at Elev. 3.5 - Around Exist. AeroJet C					8269 BCY
					Purch/Place/Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - B x ((I+L)/2) x J)					63573 CCY
					Grade Berm Slope - H x N x 2 / 9					35969 SY
Page				DDT for 6" Conc Liner @ Conc Liner - PL: 12+37 to PL:38+00					Leeve	
				g	Liner Length				10384.00	LF
				h	Liner Height				4.50	LF
				i	Sloped Width				10.01	LF
					Purch/Place/Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - ((h x I x 0.5) /27					-1925 CCY

4of15 C-111SC Civil_QTO South 061809WL-hc.xls 6/24/2009

South Aerojet Berms & Channels

System	Sub-system	Assem Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location : TEST 2				Date : 06/11/2009		
					System :North Components Channels				Phase : South		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					East & West Lined Channel Leeve 50' Transition						
								SF/ SQ IN			
				A	Measured Area	0.0000	SQ IN	1000	0.0	SF	
				B	Stn 38+00 to 56+37 =				0.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				8.00	FT	
				E	Avg Exist Grade Elev	8.00	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL:54+87 to 55+37				100.00	LF	
				I	Avg Constructed TOB Elev	8.3' & 10.3'			9.30	FT	
				J	Berm Height				6.80	LF	
				K	Avg Top Of Berm Width	14' & 40'			27.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				81.40	LF	
				M	Base Of Berm Area				8140	SF	
				N	Berm Sloped Length One Side Only				27.27	LF	
					Clear & Grub at Elev. 3.5 - Around Exist. AeroJet Canal - M / 43560					0.19	ACR
					Remove surficial material to Top Of Rock at Elev. 3.5 - Around Exist. AeroJet C					151	BCY
					Purchase, Place & Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - B x ((I+L)/2					1365	CCY
					Grade Berm Slope - H x N x 2 / 9					606	SY
Page					DDT for 6" Conc Liner @ Conc Liner - PL: PL:354+87 to 55+37				0		
				g	Liner Length				100.00	LF	
				h	Liner Height				4.50	LF	
				i	Sloped Width				10.01	LF	
					Purch/Place/Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - ((h x I x 0.5') /27					-19	CCY

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location : TEST 2				Date : 06/11/2009		
					System :North Components Channels				Phase : South		
					_	_	__		Est. : Campbell		
					Discription	Metric	No			Total	U/M
Page 16					**East & West Lined Channel**				**@ 100' Maint Berm**		
								SF/ SQ IN			
				A	Measured Area	0.0000	SQ IN	1000	0.0	SF	
				B	Stn 38+00 to 56+37 =				0.0	LF	
				C	Height above Ex. Grade = (A / B)				0.00	LF	
				D	Designed Top Of Berm Elev				10.00	FT	
				E	Avg Exist Grade Elev	10.00	FT (Calculated)		3.00	FT (Used)	
				F	Top Of Rock Elevation				2.50	FT	
				G	Surficial material Thickness				0.50	FT	
				H	Top Of Berm Length PL:55+37 to 56+37				200.00	LF	
				I	Constructed TOB Elev				10.30	FT	
				J	Berm Height				7.80	LF	
				K	Top Of Berm Width				40.00	LF	
				L	Base Of Berm Width w/ 1V:4H Slope				102.40	LF	
				M	Base Of Berm Area				20480	SF	
				N	Berm Sloped Length One Side Only				31.28	LF	
					Clear & Grub at Elev. 3.5 - Around Exist. AeroJet Canal - M / 43560					0.47	ACR
					Remove surficial material to Top Of Rock at Elev. 3.5 - Around Exist. AeroJet C					379	BCY
					Purchase, Place & Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - B x ((I+L)/2					4114	CCY
					Grade Berm Slope - H x N x 2 / 9					1390	SY
Page					DDT for 6" Conc Liner @ Conc Liner - PL: PL:55+37 to 56+37				0		
				g	Liner Length				200.00	LF	
				h	Liner Height				4.50	LF	
				i	Sloped Width				10.01	LF	
					Purch/Place/Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - ((h x I x 0.5') /27					-37	CCY

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly	Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
				Proj. Location : TEST 2				Date : 06/11/2009		
				System :North Components Channels				Phase : South		
				_	_	__		Est. : Campbell		
				Discription	Metric	No			Total	U/M
				Summary For Lined Channel Leeve						
				Clear & Grub					10.91	ACR
				Remove surficial material to Top Of Rock			8798.74	BCY		
				Strip & Stockpile Topsoil for reuse	234712	SF			4347	BCY
				Excavate, load and haul balance of surficial soil, 10 mile haul					4452	BCY
				Purchase ?? /Place/Compact Embankment Total					67071	CCY
				Embankment Volume - Top 12"			5781	CCY	6621	LCY
				Embankment Volume - Below Top 12"			61290	CCY	72323	LCY
							67071	CCY		
				Grade Berm Slope					37965	SY
				Top of Berm Area					17342	SY
				Topsoil & Seeding @ Slopes NIC Lined area	234712	SF	5650.485	LCY	26079	SY
				Summary For Inlet Channel Base & Liner						
				Clear & Grub			108451	SF	2.49	ACR
				Remove surficial material to Top Of Rock					8033	BCY
				Rip, Excavate, Haul Rock for Liner Granular Base - 12"			119111	SF	4412	CCY
				6" Th. Conc Liner - Flat	5330	Long				
				12" Th Granular Base at Liner			119111	SF	13235	SY
				6" Concrete Slab			108451	SF	2008	CY
				Finish & Cure Conc Liner					108451	SF
				WWF Reinf					113874	SF
				6" Edge Form					15990	LF
				Exp Joint & Sealer					5290	LF
				6" Th. Conc Liner - Sloped	10684	Length			10 Width	
				12" Th Granular Base at Liner			0	SF	0	SY
				6" Concrete Slab			106973.6	SF	1981	CY
				Finish & Cure Conc Liner					106974	SF
				WWF Reinf					112322	SF
				6" Edge Form					20340	LF
				Exp Joint & Sealer					9616	LF

7of15 C-111SC Civil_QTO South 061809WL-hc.xls 6/24/2009

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
					Proj. Location : TEST 2				Date : 06/11/2009	
					System :North Components Channels				Phase : South	
					_	_	__		Est. : Campbell	
					Discription	Metric	No		Total	U/M
Page 16					**Unlined Intake Canal East & West Leeve**					
								SF/ SQ IN		
				A	Measured Area	0.0000	SQ IN	1000	0.0	SF
				B	Stn 12+00 to 38+00 =				0.0	LF
				C	Height above Ex. Grade = (A / B)				0.00	LF
				D	Designed Top Of Berm Elev				7.00	FT
				E	Avg Exist Grade Elev	7.00	FT (Calculated)		3.00	FT (Used)
				F	Top Of Rock Elevation				2.50	FT
				G	Surficial material Thickness				0.50	FT
					Top Of Berm Length Stn 237+30 to 244+00 and Stn 51+00 to 76+00					
		Stn 237+30 to 244+00 & 51+00 to 76+00 Berm - North of PS 2					=	3170	LF	
					Less East & West Transition Berm		=	0.00	LF	
					Less East & West Maint. Berm		=	0.00	LF	
								3170	LF	
				H	Top Of Berm Length - East & West				6340	LF
				I	Constructed Top Of Berm Elev				7.30	FT
				J	Berm Height				4.80	LF
				K	Top Of Berm Width				40.00	LF
				L	Base Of Berm Width w/ 1V:3H &1V:2H Slope				64.00	LF
				M	Base Of Berm Area				405760	SF
				N	Average Sloped Berm Length				12.90	LF
					Clear & Grub at Elev. 3.5 - Around Exist. AeroJet Canal - M / 43560				9.31	ACR
					Remove surficial material to Top Of Rock at Elev. 3.5 - Around Exist. AeroJet C				7514	BCY
					Purch/Place/Compact Embankment at Elev. 3.5 - Around Exist. AeroJet Canal - B x ((I+L)/2) x J)/				58610	CCY
					Grade Berm Slope - H x N x 2 / 9				18175	SY

8of15 C-111SC Civil_QTO South 061809WL-hc.xls 6/24/2009

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location : TEST 2				Date : 06/11/2009		
					System :North Components Channels				Phase : South		
					_	_	__		Est. : Campbell		
					Discription	Metric	No			Total	U/M
					Summary For Unlined Intake Canal East & West Leeve						
					Clear & Grub					9.31	ACR
					Remove surficial material to Top Of Rock			7514	BCY		
					Strip & Stockpile Topsoil for reuse	163572	SF			3029	BCY
					Excavate, load and haul balance of surficial soil, 10 mile haul					4485	BCY
					Purchase ?? /Place/Compact Embankment Total					58610	CCY
					Embankment Volume - Top 12"			9393	CCY	11083	LCY
					Embankment Volume - Below Top 12"			49217	CCY	58076	LCY
								58610	CCY		
					Grade Berm Slope					18175	SY
					Top of Berm Area					28178	SY
					Topsoil & Seeding @ Slopes NIC Lined area	163572	SF	3937.844	LCY	18175	SY

South Aerojet Berms & Channels

System	Sub-system	Assem Cat	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
					Proj. Location : TEST 2				Date : 06/11/2009	
					System :North Components Channels				Phase : South	
					_	_	_		Est. : Campbell	
					Discription	Metric	No		Total	U/M
Page 16					Unlined Intake Canal Excavation					
								SF/ SQ IN		
				A	Measured Area	25.7200	SQ IN	1000	25720.0	SF
				B	Stn 237+30 to 244+00 & 51+00 to 76+00 =				3170.0	LF
				C	AVG Depth of Channel Invert Below Ex. Grade = (A / B)				-8.11	LF
				D	Designed Bottom Of Channel Elev				0.00	FT
				E	Avg Exist Grade Elev	8.11	FT (Calculated)		3.50	FT (Used)
				F	Top Of Rock Elevation				2.50	FT
				G	Surficial material Thickness				1.00	FT
				H	Bottom Of Channel Length Stn 237+30 to 244+00 & 51+00 to 73+0				3170.00	LF
				I	Constructed Bottom Of Channel Elev				5.50	FT
				J	AVG Rock Depth of Channel Excavation				7.11	LF
				K	Bottom of Channel Width				10.00	LF
				L	Top of Channel Width AT Top of Rock w/ 1V:2H Slope				38.45	LF
					Top of Channel Width AT Existing Grade				42.45	LF
				M	Top Of Channel Area AT Grade				134580	SF
					Top Of Channel Area AT Top of Rock				121900	SF
				N	Channel Sloped Length One Side Only				0.00	LF
					Clear & Grub at Unlined Intake Canal - M / 43560				3.09	ACR
					Remove surficial material to Top Of Rock at Unlined Intake Canal - B x G x L / 2				4984	BCY
					ROCK EXCAVATION				20234	CCY
					Grade Channel Slope - (H x (K + (N x 2)) / 9				0	SY
	Summary For Unlined Intake Canal Excavation									
			Clear & Grub						3.09	ACR
			Remove surficial material to Top Of Rock						4,984	BCY
			Rock Excavation Total						20,234	CCY

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location : TEST 2				Date : 06/11/2009		
					System :North Components Channels				Phase : South		
									Est. : Campbell		
					Discription	Metric	No			Total	U/M
					Pump Station No. 2						
			Clear & Grub					34366	SF	0.79	ACR
			Remove surficial material to Top Of Rock						1273	BCY	
			Strip & Stockpile Topsoil for reuse			19513	SF			361	BCY
			Excavate, load and haul balance of surficial soil, 10 mile haul							911	BCY
			Drill, Blast and Excavate Intale & Discharge Pools							632	BCY
			Purchase/Place/Compact Embankment Total							5152	CCY
				Embankment Volume - Top 12"				698	CCY	824	LCY
				Embankment Volume - Below Top 12"				4454	CCY	5256	LCY
								5152	CCY		
			Grade Berm Slope					1561	SF	173	SY
			Top of Berm Area					18850	SF	2094	SY
	Topsoil & Seeding @ Slopes NIC Lined area					19513	SF	469.7574	LCY	2168	SY
					24" Rip-Rap, 12" Stone Bedding w/ GeoTex & Filter Fabric					1014	SF
					12" Concrete Apron	114	SY			1024	SF
					1/1.5/8 Asphalt Pavement	803	SY	854	SY	7230	SF
					6" Conc Liner					2617	SF
					Weed/Safety Floating Barrier w/ 2 ea Anchor Post					90	LF
					In-Bank Stilling Well w/ 58 LF of in-take Pipe					2	EA
					Timber Pile w/ Staff Gauge					2	EA
					6' Security Fence	593.00	LF			513	LF
					6' x 16' Dbl Gate					5	EA

11of15 C-111SC Civil_QTO South 061809WL-hc.xls 6/24/2009

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly	Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002	
				Proj. Location : TEST 2				Date : 06/11/2009	
				System :North Components Channels				Phase : South	
				_	_	__		Est. : Campbell	
				Discription	Metric	No		Total	U/M
				C-110 Canal Plug					
				Plug 1					
							SF/ SQ IN		
				Measured Plug Area	2.75	SQ.IN	1000	2750.0	SF
				Width A				11.45	LF
				Width B				79.27	LF
				AVG. Width				45.36	LF
				Fill Plug Volume				4620.00	CY
				Plug 2					
							SF/ SQ IN		
				Measured Plug Area	2.61	SQ.IN	1000	2610.0	SF
				Width A				12.33	LF
				Width B				81.04	LF
				AVG. Width				46.69	LF
				Fill Plug Volume				4512.88	CY
				Plug 3					
							SF/ SQ IN		
				Measured Plug Area	2.74	SQ.IN	1000	2740.0	SF
				Width A				12.31	LF
				Width B				81.16	LF
				AVG. Width				46.74	LF
				Fill Plug Volume				4742.74	CY
				Plug 4					
							SF/ SQ IN		
				Measured Plug Area	1.34	SQ.IN	1000	1340.0	SF
				Width A				11.90	LF
				Width B				79.23	LF
				AVG. Width				45.57	LF
				Fill Plug Volume				2261.37	CY
				Plug 5					
							SF/ SQ IN		
				Measured Plug Area	1.41	SQ.IN	1000	1410.0	SF
				Width A				11.60	LF
				Width B				75.48	LF
				AVG. Width				43.54	LF
				Fill Plug Volume				2273.76	CY
				Plug 6					
							SF/ SQ IN		
				Measured Plug Area	1.68	SQ.IN	1000	1680.0	SF
				Width A				10.58	LF
				Width B				63.94	LF
				AVG. Width				37.26	LF
				Fill Plug Volume				2318.40	CY

13of15 C-111SC Civil_QTO South 061809WL-hc.xls 6/24/2009

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly							
				Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
				Proj. Location : TEST 2				Date : 06/11/2009		
				System :North Components Channels				Phase : South		
				_	-	_		Est. : Campbell		
				Discription	Metric	No			Total	U/M
				Plug 7						
							SF/ SQ IN			
				Measured Plug Area	2.06	SQ.IN	1000	2060.0	SF	
				Width A				11.42	LF	
				Width B				73.61	LF	
				AVG. Width				42.52	LF	
				Fill Plug Volume				3243.74	CY	
				Plug 8						
							SF/ SQ IN			
				Measured Plug Area	2.74	SQ.IN	1000	2740.0	SF	
				Width A				11.68	LF	
				Width B				63.18	LF	
				AVG. Width				37.43	LF	
				Fill Plug Volume				3798.45	CY	
				Plug 9						
							SF/ SQ IN			
				Measured Plug Area	3.20	SQ.IN	1000	3200.0	SF	
				Width A				10.75	LF	
				Width B				52.95	LF	
				AVG. Width				31.85	LF	
				Fill Plug Volume				3774.81	CY	
				Plug 10						
							SF/ SQ IN			
				Measured Plug Area	2.92	SQ.IN	1000	2920.0	SF	
				Width A				10.75	LF	
				Width B				49.62	LF	
				AVG. Width				30.19	LF	
				Fill Plug Volume				3264.45	CY	
				Summary for C-110 Canal Plug				**34,811**	**CY**	

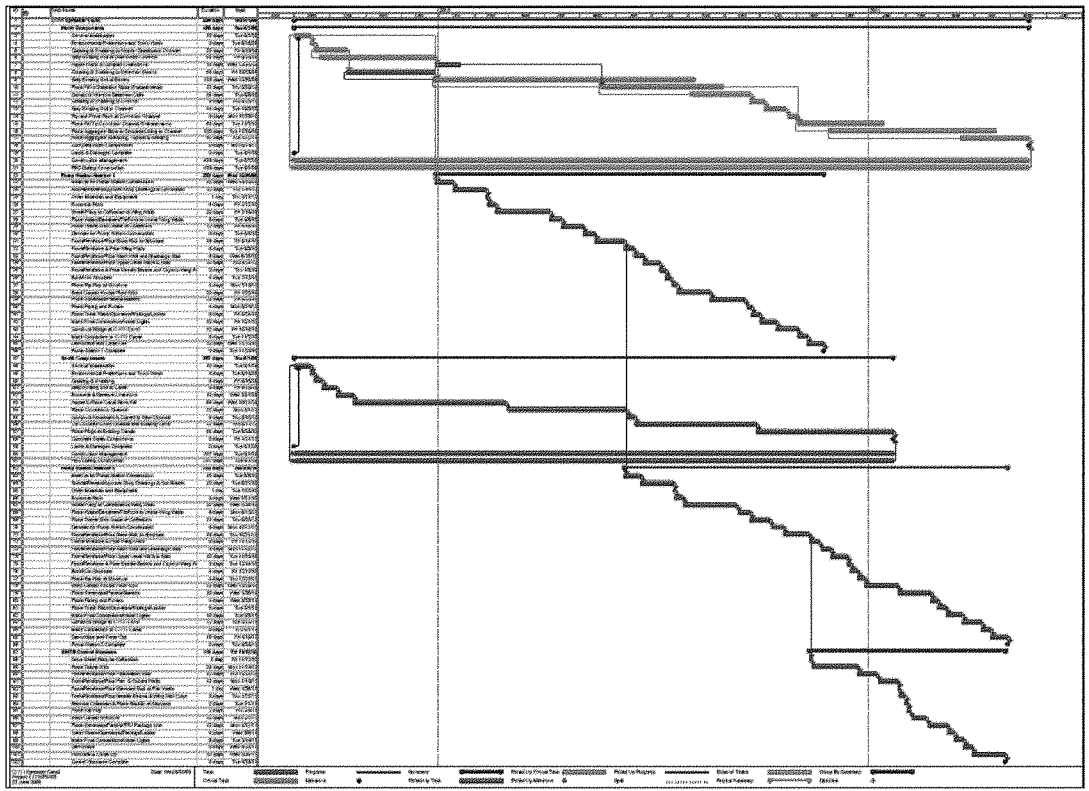
14of15 C-111SC Civil_QTO South 061809WL-hc.xls 6/24/2009

South Aerojet Berms & Channels

System	Sub-system	Assem. Cat.	Assembly		Proj. Name :C-111 Spreader Canal				Proj.# : 4090.002		
					Proj. Location : TEST 2				Date : 06/11/2009		
					System :North Components Channels				Phase : South		
					_	_	__		Est. : Campbell		
					Discription	Metric	No			Total	U/M
					L-31 E Canal Plug						
					L-31 E Plug						
								SF/ SQ IN			
					Measured Plug Area	1.61	SQ.IN	1000	1610.0	SF	
					Width A				11.11	LF	
					Width B				53.56	LF	
					AVG. Width				32.34	LF	
					Fill Plug Volume				1928.12	CY	
					Summary for L-31 E Canal Plug				1,928	CY	
					S197-B Water Control Structure						
				Clear & Grub				34366	SF	0.79	ACR
				Remove surficial material to Top Of Rock					1273	BCY	
				Strip & Stockpile Topsoil for reuse		19513	SF			361	BCY
				Excavate, load and haul balance of surficial soil, 10 mile haul						911	BCY
				Drill, Blast and Excavate intale & Discharge Pools						632	BCY
				Purchase/Place/Compact Embankment Total						5152	CCY
					Embankment Volume - Top 12"			698	CCY	824	LCY
					Embankment Volume - Below Top 12"			4454	CCY	5256	LCY
								5152	CCY		
				Grade Berm Slope				1561	SF	173	SY
				Top of Berm Area				18850	SF	2094	SY
			Topsoil & Seeding @ Slopes NIC Lined area			19513	SF	469.7574	LCY	2168	SY
					24" Rip-Rap, 12" Stone Bedding w/ GeoTex & Filter Fabric					1014	SF
					12" Concrete Apron	114	SY			1024	SF
					1/1.5/8 Asphalt Pavement	803	SY	854	SY	7230	SF
					6" Conc Liner					2617	SF
					Weed/Safety Floating Barrier w/ 2 ea Anchor Post					90	LF
					In-Bank Stilling Well w/ 58 LF of in-take Pipe					2	EA
					Timber Pile w/ Staff Gauge					2	EA
					6' Security Fence	593.00	LF			513	LF
					6' x 16' Dbl Gate					5	EA

15of15 C-111SC Civil_QTO South 061809WL-hc.xls 6/24/2009

B.4 SCHEDULE



Schedule Productivity Assumptions:

C-111 Spreader Canal

- Clear & Grub Light Brush & Trees: 3 Acres/Day/Crew
- Stockpile Fill: Haul to within 200'; 1,512 CY/Day
- Excavate & Haul Fill: Strip & Pile: 2,625 CY/Day; 10 Mile Travel Distance
- Excavate and Haul Rock: 840 CY/Day
- Crush, Haul & Place Rock: 650 CY/Day (Limited by Crush & Haul)
- Embankments: Haul from 10 Miles (20 Mile Cycle); 12 CY Trucks; 12 Trucks in Rotation; 60 CY/Day/Truck (720 CY/Day (12 Trucks))
- Placement/Compaction Rate: Greater than delivery rate (1,540 CY/Day)
- Form/Pour Concrete Slab: 3,425 SF/Day/Crew
- 3 CY Front End Loader Topsoil Spreading: 1,575 CY/Day;
- Seed & Fertilize: 9,000 SY/Day/Crew
- Geotextile Placement: 2400 SY/Day/Crew
- Remove/Place Rip-Rap: 62 CY/Day (5 Person Crew + Crane + Trucks) 4 Crews
- Armorflex Concrete Block to Wiers: 1470 SF/Day
- Rock Fill: 800 Tons/Day (50 lb Average); 62 CY/Day Equivalent
- Aggregate Base: 835 SY/Day;
- Sheet Pile Removal: 200 VLF/Day (1 Crews: 4 Laborers, Foreman and Crane each Crew)
- Sheet Pile Placement: 22 Lbs/SF; Average 43 Foot Depth; say 650 VLF (800 SF)/Day/Crew; 1 Crews
- 8" CMU: 415 SF/Day
- Base Slab Reinforce/Pour: 60 CY/Day
- Elevated Slab Form/Reinforce/Pour: 15 CY/Day
- Wall Foundation Excavation: 36 CY/Day/Crew; 3 Crews (108 CY/Day)
- Wall Foundation Reinforce/Pour: 45 CY/Day/Crew; 1 Crew
- Treme Slab Pour: 115 CY/Day
- Wall/Sluice Gate Wall Form/Reinforce/Pour: 4 0 CY/Day/Crew; 1 Crew
- 8" Stone Base: 200 CY/Day/Crew

B.5 RISK AND UNCERTAINTY ANALYSIS

US Army Corps
of Engineers®

COST AND SCHEDULE RISK ANALYSIS
C-111 SPREADER CANAL PROJECT
JACKSONVILLE DISTRICT

U.S. Cost Contract No. W912EP-08-D-0007
Task Order No. 001

Prepared for:

U.S. COST INCORPORATED
Atlanta, Georgia

Prepared by:

Risk Strategics
The Risk & Decision Analysis Company

RISK STRATEGICS, LLC
Bellingham, Washington

October 27, 2009

TABLE OF CONTENTS

EXECUTIVE SUMMARY ES-1

MAIN REPORT 1

1.0 PURPOSE 1

2.0 BACKGROUND 1

3.0 REPORT SCOPE 1

3.1 Project Scope 2

3.2 USACE Risk Analysis Process 2

4.0 METHODOLOGY / PROCESS 3

4.1 Identify and Assess Risk Factors 4

4.2 Quantify Risk Factor Impacts 4

4.3 Analyze Cost Estimate and Schedule Contingency 5

5.0 KEY ASSUMPTIONS AND LIMITATIONS 6

6.0 RESULTS 7

6.1 Risk Register 7

6.2 Cost Risk Analysis - Cost Contingency Results 9

6.3 Schedule Risk Analysis – Schedule Contingency Results 11

6.4 Combined Cost and Schedule Contingency Results 13

7.0 MAJOR FINDINGS/OBSERVATIONS 15

8.0 RECOMMENDATIONS 16

LIST OF TABLES

Table ES-1. Recommended Plan Contingency Summary ES-2

Table ES-2. Feature Level Contingency at P80 ..... ES-3

Table 1. Cost Contingency Summary 9

Table 2. Schedule Contingency Summary 11

Table 3. Recommended Plan Contingency Summary 13

Table 4. Feature Level Contingency at P80 15

LIST OF FIGURES

Figure 1. Sensitivity Analysis – Cost Contingency 10

Figure 2. Sensitivity Analysis – Schedule Contingency 12

Figure 3. Remaining Cost Risk Analysis 14

LIST OF APPENDICES

Risk Register ..... APPENDIX A

EXECUTIVE SUMMARY

The purpose of this report is to document the results of the Cost and Schedule Risk Analysis (CSRA) performed for the C-111 Spreader Canal project located in south Miami-Dade County, Florida. The CSRA results reflect both cost and schedule risks and are intended to define contingency for the remaining base cost estimate on the Recommended Plan for the project.

The CSRA was prepared in accordance with US Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for both cost and schedule risks for all project features. The resulting study provides a Recommended Plan cost estimate summary indicating the estimated remaining base costs, contingencies, and escalation for a fully funded project.

The C-111 Spreader Canal project technical scope, cost estimates, and schedules were developed by the USACE Jacksonville District and serve as the basis for the risk analysis. In general terms, the project scope consists of the following features:

- Roads, Railroads, and Bridges (North)
- Channels and Canals (North)
- Pumping Plant (North)
- Planning, Engineering and Design (North)
- Construction Management (North)
- Channels and Canals (South)
- Pumping Plant (South)
- Floodway Control - Diversion Structure (South)
- Planning, Engineering and Design (South)
- Construction Management (South)
- Lands and Damages (North and South)

Summary of Findings

Table ES-1 was developed as part of the CSRA and provides total Recommended Plan cost contingencies for the C-111 Spreader Canal project calculated at various confidence level intervals and rounded to the nearest thousand dollars. Contingency values are rounded to the nearest one-tenth of one percent. The total Recommended Plan cost contingency was quantified as approximately $31.7 million at the eighty-percent confidence level (P80) or about 23.4% of the remaining base cost estimate of approximately $135,652,000.

ES-1

To combine cost and schedule contingency results into the total cost contingency presented in Table ES-1, schedule contingency was used to calculate the additional hotel costs and escalation risk impact of project delays. These calculated costs were then added to the cost contingency amount to reflect the USACE standard for presenting the estimated cost for the fully funded project amount.

The P80 level is the contingency value most commonly reported for programming and management purposes within USACE. These results reflect contingencies based on both the cost and schedule risk analyses. It should be noted that use of P80 as a decision criteria is a risk adverse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level.

Table ES-1. Recommended Plan Contingency Summary

Confidence Level	Remaining Base Cost + Contingency	Contingency ($)	Contingency (%)
P0	$129,964,000	($5,688,000)	-4.2%
P10	$143,398,000	$7,746,000	5.7%
P20	$146,542,000	$10,890,000	8.0%
P30	$149,270,000	$13,618,000	10.0%
P40	$151,915,000	$16,263,000	12.0%
P50	$154,656,000	$19,004,000	14.0%
P60	$157,847,000	$22,195,000	16.4%
P70	$161,835,000	$26,183,000	19.3%
P80	**$167,338,000**	**$31,686,000**	**23.4%**
P90	$175,314,000	$39,662,000	29.2%
P100	$214,853,000	$79,201,000	58.4%

The key cost risk driver identified through sensitivity analysis is *Real Estate Acquisition Cost Uncertainty* which contributes about 45.0 percent of statistical cost variance during *Monte Carlo* simulation. *Volatile Fuel Prices*, *Volatile Steel and Concrete Prices*, *Volatile Craft Labor Prices*, and *Contract Acquisition Strategy* are also important cost risk drivers which together contribute about 48.7 percent of statistical cost variance.

The key schedule risk drivers identified through sensitivity analysis are *Earthwork Quantity Uncertainty* and *Construction Sequencing*, which respectively contribute about 39.4 percent and 21.5 percent of statistical schedule duration variance during *Monte Carlo* simulation. *Contract Acquisition Strategy*; *Pump Station Test, Commission and Startup*; *Agency Coordination*; and *Project Cooperation Agreement are* also important

schedule risk drivers which together contribute about 24.2 percent of statistical schedule variance.

Table ES-2 provides a breakdown of C-111 Spreader Canal project Recommended Plan contingency by WBS feature at P80. Values in Table ES-2 are rounded to the nearest dollar or nearest one-tenth of one percent.

Table ES-2. Feature Level Contingency at P80

Feature	Remaining Base Cost	Contingency ($)	Contingency (%)	Remaining Base Cost + Contingency
Roads, Railroads, and Bridges (North)	$211,574	$31,887	15.1%	$243,461
Channels and Canals (North)	$24,358,108	$6,284,077	25.8%	$30,642,185
Pumping Plant (North)	$8,744,997	$1,825,646	20.9%	$10,570,643
Planning, Engineering and Design (North)	$17,967,342	$1,208,258	6.7%	$19,175,600
Construction Management (North)	$4,127,037	$507,704	12.3%	$4,634,741
Channels and Canals (South)	$6,013,907	$1,517,126	25.2%	$7,531,033
Pumping Plant (South)	$5,713,465	$1,251,808	21.9%	$6,965,273
Floodway Control - Diversion Structure (South)	$4,416,504	$1,070,904	24.2%	$5,487,408
Planning, Engineering and Design (South)	$10,688,630	$718,783	6.7%	$11,407,413
Construction Management (South)	$2,471,582	$304,052	12.3%	$2,775,634
Lands and Damages (North and South)	$50,735,832	$16,965,755	33.4%	$67,701,587

Summary of Recommendations

Several recommendations are provided in the CSRA, as follows:

1. Periodically update the CSRA and employ a PDT Brainstorming Session to further identify and assess project risks. Risk events are dynamic and should be evaluated regularly through all phases of design, construction and O&M. To fully recognize its benefits, CSRA should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

ES-3

2. Consider the entire risk analysis curve for budgeting and scheduling purposes. The amount of contingency included in project control plans usually depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans.

3. Develop a standalone Risk Management Plan or substantially incorporate the key elements of risk management into the Project Management Plan. The key elements of project risk management include risk management planning, risk identification, risk analysis, risk responses, and risk monitoring/control. The CSRA focuses on risk identification and risk analysis but is not intended to address the other key elements of risk management.

4. Use the risk register routinely as a tool for tracking the status of risks. Updating the risk register as risks are realized or eliminated during project execution may simplify periodic CSRA updates and maintain PDT focus on key risk drivers.

ES-4

MAIN REPORT

1.0 PURPOSE

The purpose of this report is to document the results of the Cost and Schedule Risk Analysis (CSRA) performed for the C-111 Spreader Canal project located in south Miami-Dade County, Florida. The CSRA results reflect both cost and schedule risks and are intended to define contingency for the remaining base cost estimate on the Recommended Plan for the project.

2.0 BACKGROUND

The C-111 Canal is the southernmost canal of the Central and South Florida Flood Control Project and is located in south Miami-Dade County. The canal serves a basin of approximately 100-square-miles and functions primarily to provide flood protection and drainage for the agricultural areas to the west and south of Homestead, Florida. Southwest of Homestead and Florida City and just south of the agriculturally developed area, C-111 is joined by C-111E and courses south to southeast through extensive marl wetland prairie and coastal mangrove marsh before it ends in Manatee Bay.

The C-111 Canal and S-18C (located just south of the confluence of C-111E and C-111) were completed in 1966 and the S-197 structure was completed in 1970. S-197 provides a gravity outlet for storm water runoff during flood conditions and acts as a barrier to prevent saltwater intrusion into the freshwater wetlands of the Southern Glades Wildlife and Environmental Area located to the north of the Everglades National Park's (ENP) eastern panhandle. The C-111 Canal is also the final segment of the South Dade Conveyance System for maintaining water supply and flood protection. The C-111 Canal also provides a means to deliver water to ENP's Taylor Slough and the eastern panhandle area to meet the minimum water delivery schedule, under Federal Statute (P.L. 91-282).

3.0 REPORT SCOPE

The scope of the risk analysis report is to calculate the Recommended Plan cost estimate contingencies for various confidence levels using the risk analysis processes as mandated by US Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for both cost and schedule risks for all project features. The resulting study provides a Recommended Plan cost risk analysis summary indicating the estimated remaining base costs, contingencies, and escalation for a fully funded project.

3.1 Project Scope

The C-111 Spreader Canal project technical scope, cost estimates, and schedules were developed by the USACE Jacksonville District and serve as the basis for the risk analysis. In general terms, the project scope consists of the following features:

- Roads, Railroads, and Bridges (North)
- Channels and Canals (North)
- Pumping Plant (North)
- Planning, Engineering and Design (North)
- Construction Management (North)
- Channels and Canals (South)
- Pumping Plant (South)
- Floodway Control - Diversion Structure (South)
- Planning, Engineering and Design (South)
- Construction Management (South)
- Lands and Damages (North and South)

3.2 USACE Risk Analysis Process

The risk analysis process for this study generally follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering Directory of Expertise for Civil Works (Cost Engineering DX). The risk analysis process reflected within this report uses probabilistic cost and schedule risk analysis methods within the framework of the Oracle Crystal Ball software application. The risk analysis results are intended to serve several functions, one being the establishment of reasonable contingencies reflective of various levels of confidence to successfully accomplish the project work within that established contingency amount. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analysis should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, this risk analysis was performed to substantially meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering DX.
- Memorandum from Major General Don T. Riley (US Army Director of Civil Works), dated July 3, 2007.
- Engineering and Construction Bulletin issued by James C. Dalton, P.E. (Chief, Engineering and Construction, Directorate of Civil Works), dated September 10, 2007.
- Engineering Regulation ER 1110-2-1150 dated August 31, 1999.
- Engineering Regulation ER 1110-2-1302 dated September 15, 2008.
- Engineering Technical Letter ETL 1110-2-573 dated September 30, 2008.

4.0 METHODOLOGY / PROCESS

The risk analysis process used for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the Recommended Plan cost estimate to achieve any desired level of cost confidence. A parallel process was also used to determined the probability of various project schedule duration outcomes and quantify the required schedule contingency (float) needed in the schedule to achieve any desired level of schedule confidence.

In simple terms, contingency is an amount added to an estimate (cost or schedule) to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost Engineering DX guidance for cost and schedule risk analysis generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk adverse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. Consistent with Cost Engineering DX guidance, the *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software application (Oracle Crystal Ball) that is an add-in to Microsoft Excel.

3

The C-111 Spreader Canal project Recommended Plan cost estimate was prepared by Jacksonville District in MII, the second generation of the Micro-Computer Aided Cost Estimating System (MCACES). The Recommended Plan schedule was prepared by Jacksonville District using the Microsoft Project scheduling software application. Because Crystal Ball is an Excel add-in, the cost estimate and schedule were recreated in Excel format from their native MII and Microsoft Project formats, respectively. The level of detail recreated in the Excel-format cost estimate and schedule is sufficient for risk analysis purposes, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in Section 6.

4.1 Identify and Assess Risk Factors

Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from various members of the project delivery team (PDT) was obtained by Jacksonville District by circulating a preliminary risk register to key PDT members for review and comment. A subsequent PDT meeting was also held.

4.2 Quantify Risk Factor Impacts

The quantitative impacts of risk factors on project plans were analyzed using a combination of professional judgment, empirical data and analytical techniques. Risk factor impacts were represented by probabilistic distribution functions (density functions) for inputs into the Crystal Ball software application. The probabilistic distribution functions are used to describe the characteristic population (tendencies) of the risk factor inputs. The following elements of each risk factor were addressed in the risk factor quantification process:

- Maximum possible value for the risk factor.
- Minimum possible value for the risk factor.
- Most likely value (the statistical mode), if applicable.
- Nature of the probability density function used to approximate risk factor uncertainty.
- Mathematical correlations between risk factors.
- Affected cost estimate and schedule elements.

4

Risk factor quantification focused on the various project features as presented in the Recommended Plan cost estimate and listed in Section 3.1 (Project Scope). This was done because it was recognized that the various features carry differing degrees of risk as related to cost, schedule, design complexity and design progress.

The resulting product from risk factor identification, assessment and quantification was captured within a risk register for both cost and schedule risk concerns. The risk register is presented in Appendix A.

4.3 Analyze Cost Estimate and Schedule Contingency

Contingency was analyzed using the Crystal Ball software application. *Monte Carlo* analysis was performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified in the risk register. Contingencies were calculated by applying only the moderate and high level risks identified for each option (*i.e.*, low-level risks were not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies).

For the cost estimate, contingency was calculated as the difference between the cost forecast at various confidence level intervals and the remaining base cost estimate. The remaining base cost estimate is the most likely cost estimate less any assumed contingency.

For the schedule, contingency was calculated as the difference between the duration forecast at various confidence level intervals and the base schedule duration. The duration contingency was then used to estimate *hotel* costs (see next paragraph) and calculate the additional time value of money impact of project delays that are included in the presentation of total cost contingency in Section 6. The resulting time value of money, or added escalation risk, and hotel costs are added into the cost contingency amount to reflect the USACE standard for presenting the estimated cost for the fully funded project amount.

Hotel costs are fixed costs that are inherently incurred as a result of schedule delays. These fixed costs may include general site conditions, rents, project management, supervision and administration, and elements of home office or field office overhead. In practice, sufficiently detailed cost estimates and resource-loaded schedules are often not available to support detailed *hotel* cost estimates for risk analysis and only rough order of magnitude estimates can be developed.

Total contingency (reflecting cost and schedule impacts) was allocated on a WBS feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation was used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of total project contingency being allocated to features with relatively higher estimated cost uncertainty.

5

5.0 KEY ASSUMPTIONS AND LIMITATIONS

Key assumptions and limitations are those that are most likely to significantly affect the determinations of contingency presented in the CSRA. The key assumptions and limitations are important to help ensure that project leadership and other decision makers understand the steps, logic, and decisions made in the risk analysis, as well as any resultant implications on the use of outcomes and results.

The following list identifies the key risk analysis assumptions and limitations within the context of the C-111 Spreader Canal project CSRA. For each item, the context is first provided and then followed by the key assumption or limitation.

1. Risk Identification and Assessment Process: Brainstorming is an information gathering technique frequently used for identifying and assessing risks. The goal of brainstorming is to obtain a comprehensive list of project risks. The PDT usually performs brainstorming, often in a facilitated setting with a multidisciplinary set of experts. Cost Engineering DX guidance identifies the use of a PDT Brainstorming Session for risk identification and assessment; however, the technique was not used for the C-111 Spreader Canal project CSRA. Risks were identified and assessed based on PDT input obtained by Jacksonville District by circulating a preliminary risk register to key PDT members for review and comment. A subsequent PDT meeting was also held. The utility of CSRA results may be reduced as a result of the risk identification and assessment process used.

2. Unknown Decisions or Decision Makers: The CSRA was prepared using a framework to generate contingency information that is appropriate for use by USACE decision makers for scheduling, budgeting, and project control purposes. The framework may generate results that are appropriate for use by a wide variety of decision makers or stakeholders; however, the assumed use of CSRA results is limited to scheduling, budgeting, and project control. Other uses by unknown decision makers may not be appropriate.

3. Dynamic Risks: Risk events are dynamic, not static, and should be evaluated regularly through all phases of design, construction and O&M (if required). The CSRA is based on the identification and assessment of risks as of the date of this document. Reduced utility of current CSRA results should be assumed if the likelihood and impact of risks change over time.

4. Causal Relationships: With the exception of risk events identified as correlated in the risk register, it is assumed that the impacts of risks are independent and that the realization of one risk does not cause the realization of another. Significant variance of the risk model results from actual project costs and schedules may be experienced if significant causal relationships exist between risks assumed to be independent.

6

5. Conservation of Market Pricing Risk: The CSRA assumes that market pricing risks are not created or destroyed but can only be transferred or shared *at a price* as a result of various contract acquisition strategies. As an example, it is assumed that a contractor will add a level of contingency to a fixed price bid, relative to a cost reimbursable bid, that is reflective of the risk transferred contractually from the Government to the contractor. Other aspects of contract acquisition strategies not related to market pricing, such as the management cost of modifications or claims, are not included in this assumption. Any contract acquisition strategy that actually transfers market pricing risk to a contractor *at no cost* to the Government is not reflected in the CSRA.

6. *Unknown Unknown* and *Unknowable Risks*: The Cynefin Framework describes decision-making contexts, in part, by characteristic types of uncertainty. Simple, complicated, complex and chaotic contexts within the framework are respectively associated with *known known*, *known unknown*, *unknown unknown* and *unknowable* uncertainties. The CSRA process focuses on *known known* and *known unknown* risks and is not intended to quantify the impacts of *unknown unknown* or *unknowable* risks. Significant variance of the risk model results from actual project costs and schedules may be experienced if *unknown unknown* or *unknowable* risks, as defined in the Cynefin Framework, are realized.

6.0 RESULTS

The results of the C-111 Spreader Canal project CSRA are provided in the following sections. In addition to contingency calculation results, sensitivity analyses are presented to provide decision makers with an understanding of variability and the key contributors to the cause of this variability.

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The risk register for the C-111 Spreader Canal project is presented as Appendix A. The risk register reflects the results of risk factor identification and assessment, risk factor quantification, and contingency analysis.

The C-111 Spreader Canal project risk register identifies 35 risks that are organized into the following categories:

- Project Management and Organizational Risks
- Real Estate, Utilities and Relocations Risks
- Design Risks
- Construction Risks
- External Risks

In regard to project cost, 23 risks are rated as either moderate level or high level based on the risk level matrix identified in Cost Engineering DX guidance. Twenty-two risks are identified as either moderate level or high level in regard to project schedule. Contingencies were calculated by applying only the moderate and high level risks identified for each option (*i.e.*, low-level risks were not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies).

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project lifecycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting risk analysis feedback and project control input.
- Identifying risk transfer, elimination or mitigation actions required for implementation of risk management plans.

8

6.1 Cost Risk Analysis - Cost Contingency Results

Table 1 provides the cost contingencies for the C-111 Spreader Canal project calculated at various confidence level intervals and rounded to the nearest thousand dollars. Contingency values are rounded to the nearest one-tenth of one percent. Cost contingency was quantified as approximately $29.0 million at P80 (about 21.3% of the remaining base cost estimate of approximately $135,652,000).

Table 1. Cost Contingency Summary

Confidence Level	Remaining Base Cost + Contingency	Contingency ($)	Contingency (%)
P0	$129,964,000	($5,688,000)	-4.2%
P10	$142,743,000	$7,091,000	5.2%
P20	$145,578,000	$9,926,000	7.3%
P30	$148,039,000	$12,387,000	9.1%
P40	$150,442,000	$14,790,000	10.9%
P50	$152,928,000	$17,276,000	12.7%
P60	$155,850,000	$20,198,000	14.9%
P70	$159,542,000	$23,890,000	17.6%
P80	**$164,613,000**	**$28,961,000**	**21.3%**
P90	$171,711,000	$36,059,000	26.6%
P100	$203,852,000	$68,200,000	50.3%

Sensitivity analysis generally ranks the relative importance of each risk. The Crystal Ball software uses a statistical measure (contribution to variance) that approximates the importance of each risk contributing to variability of cost outcomes during *Monte Carlo* simulation. In variance-based sensitivity analysis, expectation values have to be evaluated to generate a global sensitivity measure. Because expectation values are means (probability-weighted averages), using the importance measures to calculate the contingency associated with a risk at any given confidence level would generally not be meaningful. Furthermore, variance-based sensitivity analysis may provide misleading results for correlated risks.

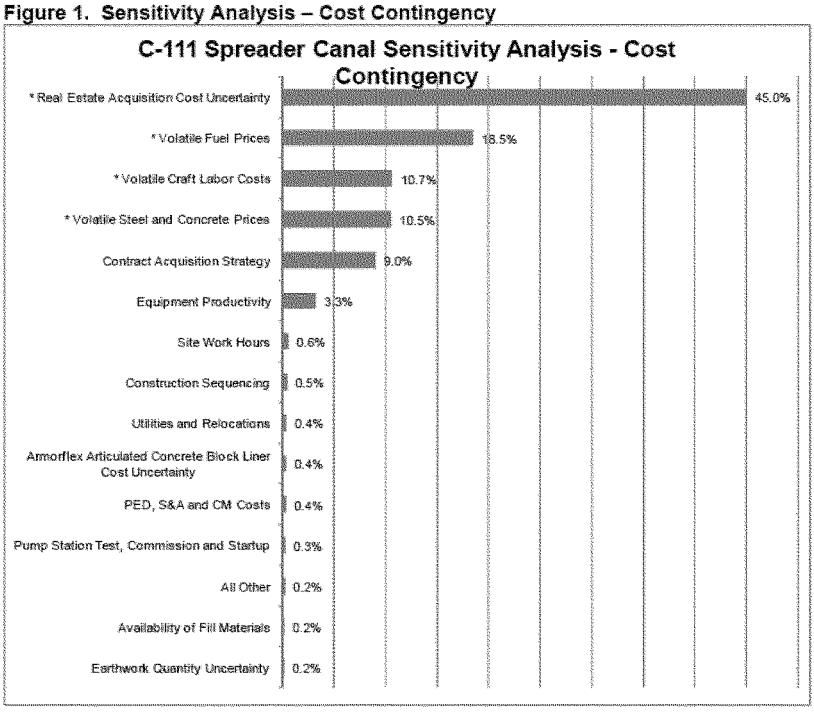
Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register, sensitivity analysis results can also be used to support development of strategies to eliminate, mitigate, accept or transfer key risks.

The risks considered as key or primary cost drivers are ranked in order of importance in contribution to variance bar charts. Opportunities that have a potential to reduce project cost and are shown with a negative sign; risks are shown with a positive sign to reflect

the potential to increase project cost. A longer bar in the sensitivity analysis chart represents a greater potential impact to total project cost.

Figure 1 presents a sensitivity analysis that includes the moderate and high level cost risks identified in the risk register for the C-111 Spreader Canal project. Risks that contribute less than 0.1% of statistical cost variance during *Monte Carlo* simulation are omitted from the figure.

Figure 1. Sensitivity Analysis – Cost Contingency



Note: Variance-based sensitivity analysis provides quantitative information about the importance of the risks; however, extrapolations or ancillary uses of the information are not recommended. Rather than evaluation of contingency, the primary intended use of sensitivity analysis is evaluation of the risk model. Risks preceded by an asterisk are correlated with one or more other risks as indicated in the risk register. Variance-based sensitivity analysis may provide misleading results for correlated risks.

The key cost risk driver identified through sensitivity analysis is *Real Estate Acquisition Cost Uncertainty* which contributes about 45.0 percent of statistical cost variance during *Monte Carlo* simulation. *Volatile Fuel Prices*, *Volatile Steel and Concrete Prices*, *Volatile Craft Labor Prices*, and *Contract Acquisition Strategy* are also important cost risk drivers which together contribute about 48.7 percent of statistical cost variance.

6.3 Schedule Risk Analysis – Schedule Contingency Results

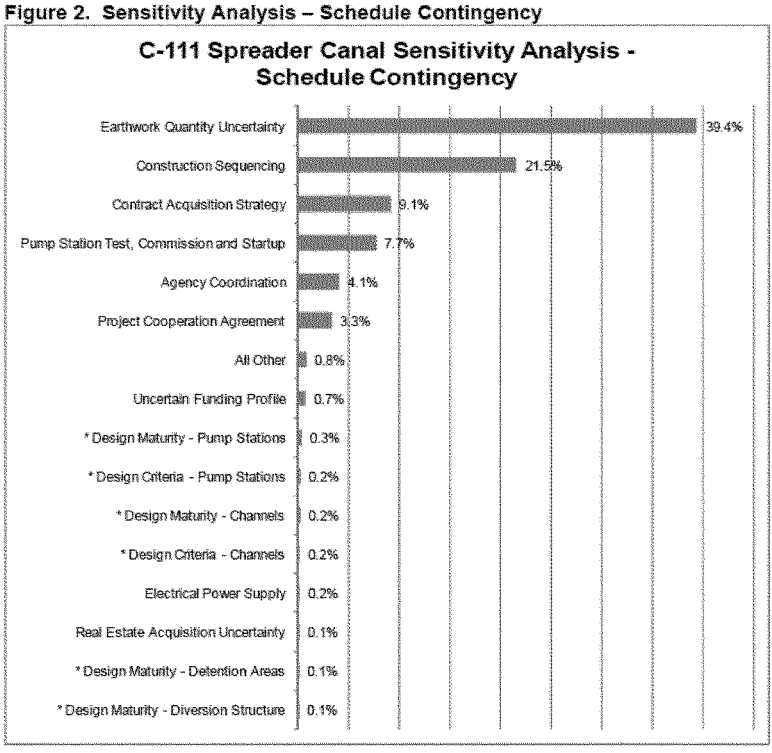
Table 2 provides the schedule duration contingencies for the C-111 Spreader Canal project calculated at various confidence level intervals and rounded to the nearest day. Contingency values are rounded to the nearest one-tenth of one percent. Schedule duration contingency was quantified as 203 days at P80 (about 32.6% of the base construction schedule duration of approximately 623 days). It is important to note that these results reflect only those contingencies established from the schedule risk analysis and do not reflect the influences of schedule float.

Table 2. Schedule Contingency Summary

Confidence Level	Base Duration + Contingency (calendar days)	Contingency (calendar days)	Contingency (%)
P0	623	-	0.0%
P10	672	49	7.9%
P20	695	72	11.6%
P30	715	92	14.8%
P40	733	110	17.7%
P50	752	129	20.7%
P60	772	149	23.9%
P70	794	171	27.4%
P80	**826**	**203**	32.6%
P90	891	268	43.0%
P100	1,431	808	129.7%

Figure 2 presents a sensitivity analysis that includes the moderate and high level schedule duration risks identified in the risk register for the C-111 Spreader Canal project. Risks that contribute less than 0.1% of statistical schedule variance during *Monte Carlo* simulation are omitted from the figure.

Figure 2. Sensitivity Analysis – Schedule Contingency



Note: Variance-based sensitivity analysis provides quantitative information about the importance of the risks; however, extrapolations or ancillary uses of the information are not recommended. Rather than evaluation of contingency, the primary intended use of sensitivity analysis is evaluation of the risk model. Risks preceded by an asterisk are correlated with one or more other risks as indicated in the risk register. Variance-based sensitivity analysis may provide misleading results for correlated risks.

12

As shown in Figure 2, the key schedule risk drivers identified through sensitivity analysis are *Earthwork Quantity Uncertainty* and *Construction Sequencing*, which respectively contribute about 39.4 percent and 21.5 percent of statistical schedule duration variance during *Monte Carlo* simulation. *Contract Acquisition Strategy*; *Pump Station Test, Commission and Startup*; *Agency Coordination*; and *Project Cooperation Agreement are* also important schedule risk drivers which together contribute about 24.2 percent of statistical schedule variance.

6.4 Combined Cost and Schedule Contingency Results

Table 3 provides total Recommended Plan cost contingencies for the C-111 Spreader Canal project calculated at various confidence level intervals and rounded to the nearest thousand dollars. Contingency values are rounded to the nearest one-tenth of one percent. To combine cost and schedule contingency results into a total cost contingency, schedule contingency was used to calculate the additional hotel costs and escalation risk impact of project delays. These calculated costs were then added to the cost contingency amount to reflect the USACE standard for presenting the estimated cost for the fully funded project amount.

The total Recommended Plan cost contingency was quantified as approximately $31.7 million at P80, or about 23.4% of the remaining base cost estimate of approximately $135,652,000. About 9.0 percent of the total cost contingency is associated with schedule risk (*i.e.*, about 2.1 out of the 23.4 total percentage points). It is important to note that these results reflect contingencies based on both the cost and schedule risk analyses.

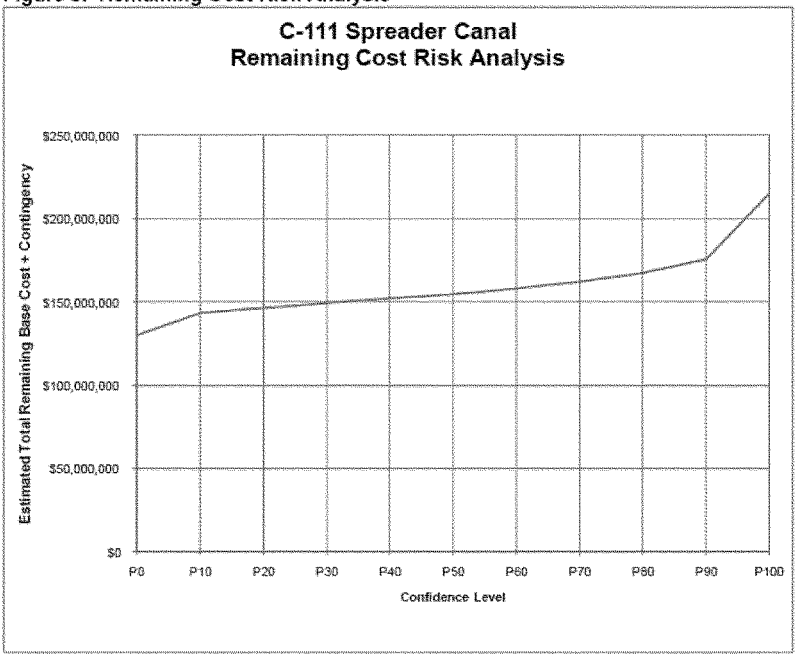
Table 3. Recommended Plan Contingency Summary

Confidence Level	Remaining Base Cost + Contingency	Contingency ($)	Contingency (%)
P0	$129,964,000	($5,688,000)	-4.2%
P10	$143,398,000	$7,746,000	5.7%
P20	$146,542,000	$10,890,000	8.0%
P30	$149,270,000	$13,618,000	10.0%
P40	$151,915,000	$16,263,000	12.0%
P50	$154,656,000	$19,004,000	14.0%
P60	$157,847,000	$22,195,000	16.4%
P70	$161,835,000	$26,183,000	19.3%
P80	**$167,338,000**	**$31,686,000**	**23.4%**
P90	$175,314,000	$39,662,000	29.2%
P100	$214,853,000	$79,201,000	58.4%

13

Figure 3 provides a summary graph of the C-111 Spreader Canal project Recommended Plan risk analysis.

Figure 3. Remaining Cost Risk Analysis



14

Table 4 provides a breakdown of Recommended Plan contingency by WBS feature at P80.

Table 4. Feature Level Contingency at P80

Feature	Remaining Base Cost	Contingency ($)	Contingency (%)	Remaining Base Cost + Contingency
Roads, Railroads, and Bridges (North)	$211,574	$31,887	15.1%	$243,461
Channels and Canals (North)	$24,358,108	$6,284,077	25.8%	$30,642,185
Pumping Plant (North)	$8,744,997	$1,825,646	20.9%	$10,570,643
Planning, Engineering and Design (North)	$17,967,342	$1,208,258	6.7%	$19,175,600
Construction Management (North)	$4,127,037	$507,704	12.3%	$4,634,741
Channels and Canals (South)	$6,013,907	$1,517,126	25.2%	$7,531,033
Pumping Plant (South)	$5,713,465	$1,251,808	21.9%	$6,965,273
Floodway Control - Diversion Structure (South)	$4,416,504	$1,070,904	24.2%	$5,487,408
Planning, Engineering and Design (South)	$10,688,630	$718,783	6.7%	$11,407,413
Construction Management (South)	$2,471,582	$304,052	12.3%	$2,775,634
Lands and Damages (North and South)	$50,735,832	$16,965,755	33.4%	$67,701,587

7.0 MAJOR FINDINGS/OBSERVATIONS

This section provides a summary of significant risk analysis results that are identified in the preceding sections of the report. Risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes. Results also provide tools to support decision making and risk management as projects progress through planning and implementation.

Major findings and observations of the risk analysis are listed below.

1. The total Recommended Plan cost contingency was quantified as approximately $31.7 million at P80, or about 23.4% of the remaining base cost estimate of approximately $135,652,000. About 9.0 percent of the total cost contingency is associated with schedule risk (*i.e.*, about 2.1 out of the 23.4 total percentage points). It is important to note that these results reflect contingencies based on both the cost and schedule risk analyses.

2. The key cost risk driver identified through sensitivity analysis is *Real Estate Acquisition Cost Uncertainty* which contributes about 45.0 percent of statistical cost variance during *Monte Carlo* simulation. *Volatile Fuel Prices, Volatile Steel and Concrete Prices, Volatile Craft Labor Prices,* and *Contract Acquisition Strategy* are also important cost risk drivers which together contribute about 48.7 percent of statistical cost variance.

3. The key schedule risk drivers identified through sensitivity analysis are *Earthwork Quantity Uncertainty* and *Construction Sequencing*, which respectively contribute about 39.4 percent and 21.5 percent of statistical schedule duration variance during *Monte Carlo* simulation. *Contract Acquisition Strategy*; *Pump Station Test*, *Commission and Startup*; *Agency Coordination*; and *Project Cooperation Agreement are* also important schedule risk drivers which together contribute about 24.2 percent of statistical schedule variance.

8.0 RECOMMENDATIONS

This section provides several general recommendations based on the major CSRA findings and observations. CSRA does not address all key elements of project risk management and, accordingly, the list of recommendations should not be considered comprehensive. The recommendations are as follows:

1. Periodically update the CSRA and employ a PDT Brainstorming Session to further identify and assess project risks. Risk events are dynamic and should be evaluated regularly through all phases of design, construction and O&M. To fully recognize its benefits, CSRA should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

16

2. Consider the entire remaining cost risk analysis curve (Figure 3) for budgeting and scheduling purposes. The amount of contingency included in project control plans usually depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans.

3. Develop a standalone Risk Management Plan or substantially incorporate the key elements of risk management into the Project Management Plan. The key elements of project risk management include risk management planning, risk identification, risk analysis, risk responses, and risk monitoring/control. The CSRA focuses on risk identification and risk analysis but is not intended to address the other key elements of risk management.

4. Use the risk register routinely as a tool for tracking the status of risks. Updating the risk register as risks are realized or eliminated during project execution may simplify periodic CSRA updates and maintain PDT focus on key risk drivers.

17

APPENDIX A

RISK REGISTER

Risk No.	Risk or Opportunity Event	Concerns	Project Cost				Project Schedule								
			Likelihood	Impact	Risk Level	Rough Order Impact ($)	Likelihood	Impact	Risk Level	Rough Order Impact (mo)	Variance Distribution	Correlation to Other(s)	Risk Owner	Affected Project Component	Project Implications
PROJECT MANAGEMENT AND ORGANIZATIONAL RISKS															
PM-1A	South Component Earthen Plug Quantity Uncertainty	South component earthen plug quantity may be low. Designer previous estimate had below the current quantity measured from the drawing. This risk affects the expected accuracy of the cost estimate.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	PM	Earthen Plugs	Cost and Schedule
PM-1B	Earthwork Quantity Uncertainty	Final earthwork quantity might vary depending upon actual rock depth. Earthwork quantity is measured based on the design elevation profile average of 3' for existing grade, and 2.5' for existing rock. Variance in actual existing grade and rock depth will affect the actual berm earthwork quantity. This risk affects the expected accuracy of the cost estimate.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	SIGNIFICANT	HIGH	1.5 mo - 6 mo	Uniform	N/A	PM	Earthwork	Cost and Schedule
PM-1C	Armorflex Articulated Concrete Block Liner Cost Uncertainty	Cost for Armorflex Articulated Concrete Block Liner at weirs in Distribution Channel may vary. Material quote has been requested, but has not received any quote yet. This risk affects the expected accuracy of the cost estimate.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Uniform	N/A	PM	Armorflex Articulated Concrete Block Liner	Cost
PM-2	Construction Sequencing	The Northern and Southern parts of the project may be built simultaneously or in sequence. The selected approach impacts the timing of engineering and procurement, as well as related escalation assumptions.	LIKELY	MARGINAL	MODERATE	$50K - $250K	UNLIKELY	CRITICAL	MODERATE	6 mo - 18 mo	Triangle	N/A	PM	All Construction	Cost and Schedule
PM-3	Contract Acquisition Strategy	The recommended plan is being advertised, awarded, and constructed under the non-Federal Sponsor's State Expedited Program prior to any Federal appropriation. Currently, no Federal contracting action is scheduled. Any State contracting issues would not affect the project schedule and be worked out prior to any congressional appropriation. However, any State contracting issues could cause project cost impacts. Additionally, delays in completing pre-construction PED could result in delaying procurement and the construction start date.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	SIGNIFICANT	HIGH	1.5 mo - 6 mo	Triangle	N/A	PM	Total Project	Cost and Schedule
PM-4	PED, S&A and CM Costs	Costs estimates based on historical data and/or percentages of construction costs may not reflect future contractor bidding strategies.	UNLIKELY	SIGNIFICANT	MODERATE	$250K - $1.25M	UNLIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Triangle	N/A	PM	PED S&A CM	Cost
PM-5	Competition for Key USACE Staff	Reduced availability of key in-house staff could impact the project manager's ability to execute the project. However, the project is a District priority with a dedicated team and high management visibility.	VERY UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	VERY UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk

A-1

Risk No.	Risk or Opportunity Event	Concerns	Project Cost				Project Schedule								
			Likelihood	Impact	Risk Level	Rough Order Impact ($)	Likelihood	Impact	Risk Level	Rough Order Impact (mo)	Variance Distribution	Correlation to Other(s)	Risk Owner	Affected Project Component	Project Implications
PM-6	Uncertain Funding Profile	A delay in project authorization could affect the project schedule, but because the recommended plan is being constructed prior to authorization the project costs would likely not be affected.	VERY UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	UNLIKELY	CRITICAL	MODERATE	6 mo - 18 mo	Triangle	N/A	PM	Total Project	Schedule
REAL ESTATE, UTILITIES & RELOCATIONS RISKS															
REL-1	Real Estate Acquisition Cost Uncertainty	For the lands in Private Ownership (776 acres) there could be an increase in the cost; however, a detailed revaluation was recently performed using three independent appraisers that have all agreed on the land values used in the cost estimate. The PDT feels that the new valuation using multiple appraisers reduces the likelihood of the risk occurring. For the remaining lands, the amount of acres could vary since the lands determined for the project are based on modeling.	UNLIKELY	CRITICAL	MODERATE	$1.25M - $10M	UNLIKELY	SIGNIFICANT	MODERATE	1.5 mo - 6 mo	Uniform	REL-7 REL-8 REL-9	Real Estate	Lands and Damages	Cost and Schedule
REL-2	Real Estate Plan Uncertainty	Costs and schedules may be impact if the Real Estate Plan is not adequately developed at this time.	VERY UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	VERY UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
REL-3	Electrical Power Supply	Power supply routing and cost responsibility for pump stations is undetermined.	VERY LIKELY	MARGINAL	MODERATE	$50K - $250K	VERY LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	Real Estate	Pumping Plant/Utilities/Electrical	Cost and Schedule
DESIGN RISKS															
DES-1	Design Criteria - Pump Stations	Standards or guidance for design may be revised at any time. Pump station design may be impacted by changes in other design elements.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	DES-2 DES-4	Engineering	Pumping Plants	Schedule
DES-2	Design Criteria - Channels	Standards or guidance for design may be revised at any time. Channel design may be impacted by changes in other design elements.	UNLIKELY	SIGNIFICANT	MODERATE	$250K - $1.25M	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	DES-4	Engineering	Channels	Cost and Schedule
DES-3	Design Criteria - Detention Areas	Standards or guidance for design may be revised at any time. Detention area design may be impacted by changes in other design elements.	UNLIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
DES-4	Design Criteria - Diversion Structure	Standards or guidance for design may be revised at any time. Diversion structure design may be impacted by changes in other design elements.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	DES-2	Engineering	Diversion Structure	Schedule
DES-5	Design Maturity - Pump Stations	Hydrology and hydraulics, geotechnical, and structural design are currently not well defined. Pump station design may be impacted by changes in other design elements.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	DES-6 DES-7 DES-8	Engineering	Pumping Plants	Cost and Schedule
DES-6	Design Maturity - Channels	Hydrology and hydraulics, geotechnical, and structural design are currently not well defined. Channel design may be impacted by changes in other design elements.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	DES-6 DES-7 DES-8	Engineering	Channels	Cost and Schedule

A-2

95

Risk No.	Risk or Opportunity Event	Concerns	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Risk Owner	Affected Project Component	Project Implications
			Likelihood	Impact	Risk Level	Rough Order Impact ($)	Likelihood	Impact	Risk Level	Rough Order Impact (mo)					
DES-7	Design Maturity - Detention Areas	Hydrology and hydraulics, geotechnical, and structural design are currently not well defined. Detention area design may be impacted by changes in other design elements.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	DES-5 DES-6 DES-8	Engineering	Detention Areas	Cost and Schedule
DES-8	Design Maturity - Diversion Structure	The structure appears to have an uncertainty associated with it regarding height and full functional objective. Hydrology and hydraulics, geotechnical, and structural design are currently not well defined. Diversion structure design may be impacted by changes in other design elements.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	SIGNIFICANT	HIGH	1.5 mo - 6 mo	Triangle	DES-5 DES-6 DES-7	Engineering	Diversion Structure	Cost and Schedule
CONSTRUCTION RISKS															
CON-1	Site Work Hours	On-site activities or adjacent land uses/owners may cause unanticipated work restrictions. Additionally, contractor bids may vary from cost estimate and schedule assumptions regarding overtime.	UNLIKELY	SIGNIFICANT	MODERATE	$250K - $1.25M	UNLIKELY	SIGNIFICANT	MODERATE	1.5 mo - 6 mo	Triangle	N/A	SFWMD	All Construction	Cost and Schedule
CON-2	Site Access Restrictions	Unanticipated site access, lay down and work staging area restrictions may impact productivity and construction management.	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
CON-3	Availability of Fill Materials	Fill, riprap, stone base and bedding availability assumptions may not be valid, resulting in additional costs or delays. On-site and off-site borrow areas are not yet identified. Often material expected onsite varies from is assumed.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	Material Costs - All Fill	Cost and Schedule
CON-4	Disposal of Excavated Materials	Unanticipated haul and disposal costs may result if on-site stockpiling assumptions are not valid.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	All Excavation	Cost and Schedule
CON-5	Equipment Productivity	The estimated productivity of equipment and equipment operators is based on historical data and may not be reflective of conditions actually experienced.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	All Construction	Cost and Schedule
CON-6	HTRW	Presence of a degree of HTRW always poses additional risks to a project. Cost estimate assumptions regarding sharing of HTRW remediation costs (100% non-Federal) may not be valid.	UNLIKELY	SIGNIFICANT	MODERATE	$250K - $1.25M	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	Triangle	N/A	SFWMD	All Excavation	Cost
CON-7	Volatile Fuel Prices	Future prices for gasoline, on-road and off-road diesel are uncertain and have a high historic volatility. Project requires significant use of heavy equipment and hauling/transportation.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Triangle	CON-8 CON-9 REL-1	SFWMD	All Construction	Cost
CON-8	Volatile Steel and Concrete Prices	Future prices for steel and concrete are uncertain and have a high historic volatility. Project requires significant use of concrete and steel.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Triangle	CON-7 CON-9 REL-1	SFWMD	Materials - Steel and Concrete	Cost

A-3

96

Risk No.	Risk or Opportunity Event	Concerns	Project Cost				Project Schedule								
			Likelihood	Impact	Risk Level	Rough Order Impact ($)	Likelihood	Impact	Risk Level	Rough Order Impact (mo)	Variance Distribution	Correlation to Other(s)	Risk Owner	Affected Project Component	Project Implications
CON-9	Volatile Craft Labor Costs	Craft labor costs could be subject to unanticipated, large contemporaneous local projects. Assumptions regarding local labor availability may not be valid, resulting in added costs (e.g., per diem costs).	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Triangle	CON-7 CON-8 REL-1	SFWMD	All Craft Labor	Cost
CON-10	Equipment Availability	Project requires significant use of heavy equipment. Pump station components may have long lead times for acquisition.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
CON-11	Unanticipated Adverse Weather	Wet weather conditions that differ significantly from assumptions may impacts costs and schedules.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
CON-12	Utilities and Relocations	Unanticipated existing utilities may be impacted by the project.	VERY LIKELY	MARGINAL	MODERATE	$50K - $250K	VERY LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	All Construction	Cost and Schedule
CON-13	Pump Station Test, Commission and Startup	Pump stations have a relatively high level of technical complexity and will require testing during startup and commissioning to ensure performance. Quality issues not identified early may delay project startup.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	SIGNIFICANT	HIGH	1.5 mo - 6 mo	Uniform	N/A	SFWMD	All Construction	Cost and Schedule
EXTERNAL RISKS															
EXT-1	Political Uncertainty	Political opposition to the project may emerge at local, state or Federal levels. However, the non-Federal Sponsor initiated a very elaborate public involvement process to ensure widespread public support for the recommended plan. No negative public comments have been received to date.	VERY UNLIKELY	SIGNIFICANT	LOW	N/A Low Level Risk	VERY UNLIKELY	SIGNIFICANT	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
EXT-2	Project Cooperation Agreement	Unanticipated PCA issues may arise, resulting in project delays or changes to cost sharing assumptions.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	UNLIKELY	CRITICAL	MODERATE	6 mo - 18 mo	Triangle	N/A	PM	Total Project	Schedule
EXT-3	Agency Coordination	The project requires significant coordination with agency personnel related to NEPA issues. NEPA and other regulatory concerns should be addressed proactively to minimize schedule delays in regulatory decisions, permitting and real estate acquisition.	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	LIKELY	SIGNIFICANT	HIGH	1.5 mo - 6 mo	Triangle	N/A	PM	Total Project	Schedule

A-4

97

Risk No.	Risk/Opportunity Event	Concerns	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/ POC	Affected Project Component	Project Implications
			Likelihood	Impact	Risk Level	Rough Order Impact	Likelihood	Impact	Risk Level	Rough Order Impact					
CON-3	Availability of Fill Materials	Fill, riprap, stone base and bedding availability assumptions may not be valid, resulting in additional costs or delays. Onsite and off-site borrow areas are not yet identified. Often material expected onsite varies from is assumed.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	Material Costs - All Fill	Cost and Schedule
CON-4	Disposal of Excavated Materials	Unanticipated haul and disposal costs may result if on-site stockpiling assumptions are not valid.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	All Excavation	Cost and Schedule
CON-5	Equipment Productivity	The estimated productivity of equipment and equipment operators is based on historical data and may not be reflective of conditions actually experienced.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	All Construction	Cost and Schedule
CON-6	HTRW	Presence of a degree of HTRW always poses additional risks to a project. Cost estimate assumptions regarding sharing of HTRW remediation costs (100% non-Federal) may not be valid.	UNLIKELY	SIGNIFICANT	MODERATE	$250K - $1.25M	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	Triangle	N/A	SFWMD	All Excavation	Cost
CON-7	Volatile Fuel Prices	Future prices for gasoline, on-road and off-road diesel are uncertain and have a high historic volatility. Project requires significant use of heavy equipment and hauling/transportation.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Triangle	CON-8 CON-9 REL-1	SFWMD	All Construction	Cost
CON-8	Volatile Steel and Concrete Prices	Future prices for steel and concrete are uncertain and have a high historic volatility. Project requires significant use of concrete and steel.	LIKELY	SIGNIFICANT	HIGH	$250K - $1.25M	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Triangle	CON-7 CON-9 REL-1	SFWMD	Materials - Steel and Concrete	Cost

A-5

Risk No.	Risk/Opportunity Event	Concerns	Project Cost				Project Schedule								
			Likelihood	Impact	Risk Level	Rough Order Impact	Likelihood	Impact	Risk Level	Rough Order Impact	Variance Distribution	Correlation to Other(s)	Responsibility/ POC	Affected Project Component	Project Implications
CON-9	Volatile Craft Labor Costs	Craft labor costs could be subject to unanticipated, large contemporaneous local projects. Assumptions regarding local labor availability may not be valid, resulting in added costs (e.g., per diem costs).	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	Triangle	CON-7 CON-8 REL-1	SFWMD	All Craft Labor	Cost
CON-10	Equipment Availability	Project requires significant use of heavy equipment. Pump station components may have long lead times for acquisition.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
CON-11	Unanticipated Adverse Weather	Wet weather conditions that differ significantly from assumptions may impacts costs and schedules.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
CON-12	Utilities and Relocations	Unanticipated existing utilities may be impacted by the project.	VERY LIKELY	MARGINAL	MODERATE	$50K - $250K	VERY LIKELY	MARGINAL	MODERATE	2 wks - 1.5 mo	Triangle	N/A	SFWMD	All Construction	Cost and Schedule
CON-13	Pump Station Test, Commission and Startup	Pump stations have a relatively high level of technical complexity and will require testing during startup and commissioning to ensure performance. Quality issues not identified early may delay project startup.	LIKELY	MARGINAL	MODERATE	$50K - $250K	LIKELY	SIGNIFICANT	MODERATE	1.5 mo - 6 mo	Uniform	N/A	SFWMD	All Construction	Cost and Schedule
EXTERNAL RISKS															
EXT-1	Political Uncertainty	Political opposition to the project may emerge at local, state or Federal levels. However, the non-Federal Sponsor initiated a very elaborate public involvement process to ensure widespread public support for the recommended plan. No negative public comments have been received to date.	VERY UNLIKELY	SIGNIFICANT	LOW	N/A Low Level Risk	VERY UNLIKELY	SIGNIFICANT	LOW	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk	N/A Low Level Risk
EXT-2	Project Cooperation Agreement	Unanticipated PCA issues may arise, resulting in project delays or changes to cost sharing assumptions.	UNLIKELY	MARGINAL	LOW	N/A Low Level Risk	UNLIKELY	CRITICAL	HIGH	6 mo - 18 mo	Triangle	N/A	PM	Total Project	Schedule

A-6

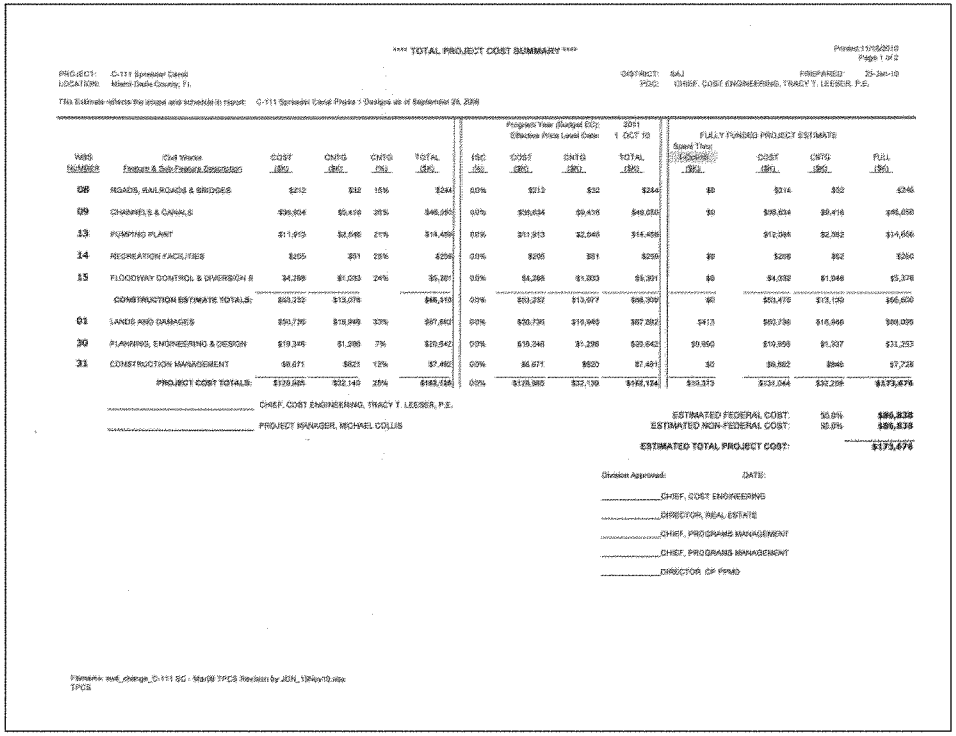
Risk No.	Risk/Opportunity Event	Concerns	Project Cost				Project Schedule								
			Likelihood	Impact	Risk Level	Rough Order Impact	Likelihood	Impact	Risk Level	Rough Order Impact	Variance Distribution	Correlation to Other(s)	Responsibility/ POC	Affected Project Component	Project Implications
EXT-3	Agency Coordination	The project requires significant coordination with agency personnel related to NEPA issues. NEPA and other regulatory concerns should be addressed proactively to minimize schedule delays in regulatory decisions, permitting and real estate acquisition.	LIKELY	NEGLIGIBLE	LOW	N/A Low Level Risk	LIKELY	SIGNIFICANT	HIGH	1.5 mo - 6 mo	Triangle	N/A	PM	Total Project	Schedule

A-7

B.6 TOTAL PROJECT COST SUMMARY

Due to policy change a final adjustment was made to the MCACES cost estimate; therefore it should be noted that the value of the estimate and TPCS are inconsistent with the value shown in the Risk Report. The changes made to the cost estimate were minor and did not have a significant impact to individual components or the project's overall risk.

TABLE B-10: TOTAL PROJECT COST SUMMARY



**** TOTAL PROJECT COST SUMMARY ****

Printed:11/12/2010
Page 1 of 2

PROJECT: C-111 Spreader Canal
LOCATION: Miami-Dade County, FL

DISTRICT: SAJ
PREPARED: 25-Jan-10
PDC: CHIEF, COST ENGINEERING, TRACY T. LEESER, P.E.

This Estimate reflects the scope and schedule in report: C-111 Spreader Canal Phase 1 Designs as of September 28, 2009

Program Year (Budget EC): 2011
Effective Price Level Date: 1 OCT 10

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	FSC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FULLY FUNDED PROJECT ESTIMATE Spent Thru 1-Oct-10 ($K)	COST ($K)	CNTG ($K)	FULL ($K)
08	ROADS, RAILROADS & BRIDGES	$212	$32	15%	$244	0.0%	$212	$32	$244	$0	$214	$32	$246
09	CHANNELS & CANALS	$36,934	$9,416	26%	$46,050	0.0%	$36,934	$9,416	$46,050	$0	$36,934	$9,416	$46,050
13	PUMPING PLANT	$11,913	$2,546	21%	$14,459	0.0%	$11,913	$2,546	$14,459		$12,046	$2,562	$14,656
14	RECREATION FACILITIES	$205	$51	25%	$256	0.0%	$205	$51	$256	$0	$208	$52	$260
15	FLOODWAY CONTROL & DIVERSION S	$4,268	$1,033	24%	$5,301	0.0%	$4,268	$1,033	$5,301	$0	$4,032	$1,046	$5,378
	CONSTRUCTION ESTIMATE TOTALS:	$53,232	$13,078		$66,310	0.0%	$53,232	$13,077	$66,309	$0	$53,476	$13,139	$66,609
01	LANDS AND DAMAGES	$50,736	$16,946	33%	$67,682	0.0%	$50,736	$16,946	$67,682	$413	$50,736	$16,946	$68,095
30	PLANNING, ENGINEERING & DESIGN	$19,346	$1,286	7%	$20,642	0.0%	$19,346	$1,286	$20,642	$0,950	$19,956	$1,337	$21,253
31	CONSTRUCTION MANAGEMENT	$6,671	$821	12%	$7,492	0.0%	$6,671	$820	$7,491	$0	$6,882	$846	$7,728
	PROJECT COST TOTALS:	$129,985	$32,140	25%	$162,124	0.0%	$129,985	$32,139	$162,124	$39,373	$131,044	$32,268	$173,676

_____ CHIEF, COST ENGINEERING, TRACY T. LEESER, P.E.

_____ PROJECT MANAGER, MICHAEL COLLIS

ESTIMATED FEDERAL COST:	50.0%	$86,838
ESTIMATED NON-FEDERAL COST:	50.0%	$86,838
ESTIMATED TOTAL PROJECT COST:		$173,676

Division Approved: DATE:

_____ CHIEF, COST ENGINEERING

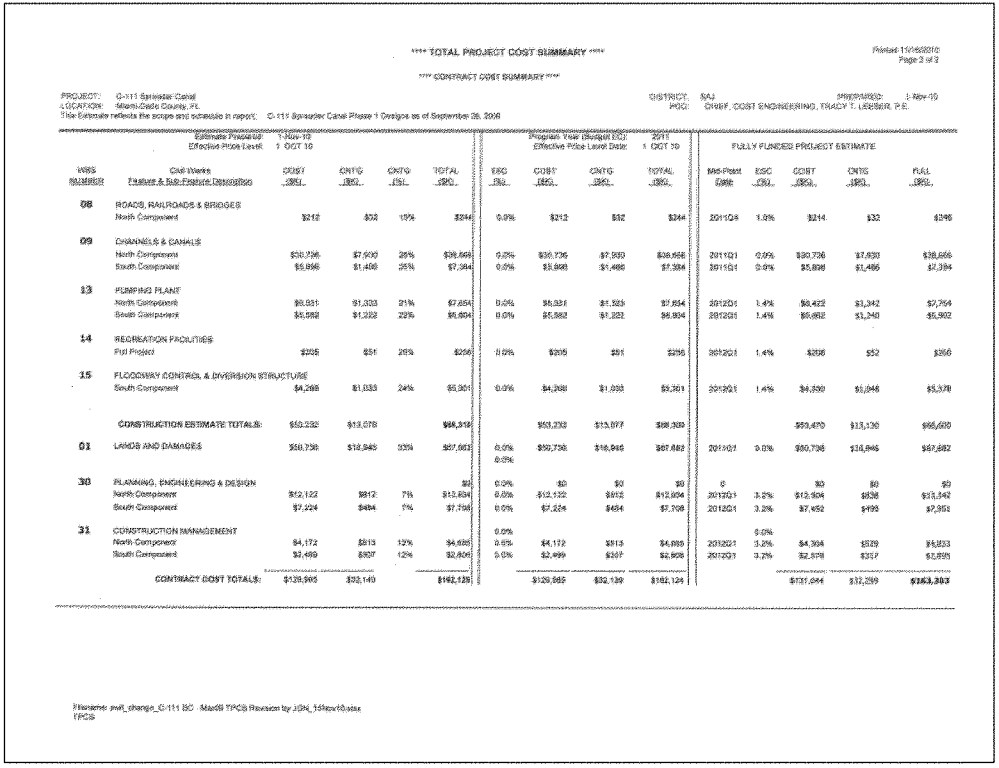
_____ DIRECTOR, REAL ESTATE

_____ CHIEF, PROGRAMS MANAGEMENT

_____ CHIEF, PROGRAMS MANAGEMENT

_____ DIRECTOR, CP PMD

Filename: evil_change_C-111 SC - Mar09 TPCS Revision by JDN_19Nov10.xlsx
TPCS



**** TOTAL PROJECT COST SUMMARY ****

Printed 11/15/2010
Page 2 of 2

**** CONTRACT COST SUMMARY ****

PROJECT: C-111 Spreader Canal
LOCATION: Miami-Dade County, FL
This Estimate reflects the scope and schedule in report: C-111 Spreader Canal Phase 1 Design as of September 28, 2008

DISTRICT: SAJ
PREPARED: 1-Nov-10
POC: CHIEF, COST ENGINEERING, TRACY T. LEESER, P.E.

Estimate Prepared: 1-Nov-10
Effective Price Level: 1 OCT 10

Program Year (Budget EC): 2011
Effective Price Level Date: 1 OCT 10

WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FULLY FUNDED PROJECT ESTIMATE Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
08	ROADS, RAILROADS & BRIDGES													
	North Component	$212	$32	15%	$244	0.0%	$212	$32	$244	2011Q4	1.0%	$214	$32	$246
09	CHANNELS & CANALS													
	North Component	$30,736	$7,930	26%	$38,666	0.0%	$30,736	$7,930	$38,666	2011Q1	0.0%	$30,736	$7,930	$38,666
	South Component	$5,898	$1,486	25%	$7,384	0.0%	$5,898	$1,486	$7,384	2011Q1	0.0%	$5,898	$1,486	$7,384
13	PUMPING PLANT													
	North Component	$6,031	$1,333	21%	$7,854	0.0%	$6,031	$1,333	$7,854	2012Q1	1.4%	$6,422	$1,342	$7,764
	South Component	$5,682	$1,222	22%	$6,904	0.0%	$5,682	$1,222	$6,904	2012Q1	1.4%	$5,682	$1,240	$6,902
14	RECREATION FACILITIES													
	Full Project	$205	$51	25%	$256	0.0%	$205	$51	$256	2012Q1	1.4%	$208	$52	$260
15	FLOODWAY CONTROL & DIVERSION STRUCTURE													
	South Component	$4,268	$1,033	24%	$5,301	0.0%	$4,268	$1,033	$5,301	2012Q1	1.4%	$4,330	$1,048	$5,378
	CONSTRUCTION ESTIMATE TOTALS:	$53,232	$13,078		$66,310		$53,232	$13,077	$66,309			$53,470	$13,130	$66,600
01	LANDS AND DAMAGES	$50,738	$16,945	33%	$67,683	0.0%	$50,738	$16,945	$67,682	2011Q1	0.0%	$50,738	$16,945	$67,682
						0.0%								
30	PLANNING, ENGINEERING & DESIGN				$0	0.0%	$0	$0	$0	0		$0	$0	$0
	North Component	$12,122	$812	7%	$12,934	0.0%	$12,122	$812	$12,934	2012Q1	3.2%	$12,904	$838	$13,342
	South Component	$7,224	$484	7%	$7,708	0.0%	$7,224	$484	$7,708	2012Q1	3.2%	$7,452	$499	$7,951
31	CONSTRUCTION MANAGEMENT					0.0%					0.0%			
	North Component	$4,172	$913	12%	$4,685	0.0%	$4,172	$913	$4,685	2012Q1	3.2%	$4,304	$929	$4,833
	South Component	$2,499	$307	12%	$2,806	0.0%	$2,499	$307	$2,806	2012Q1	3.2%	$2,578	$317	$2,895
	CONTRACT COST TOTALS:	$129,985	$32,140		$162,125		$129,985	$32,139	$162,124			$131,044	$32,259	$163,303

Filename: swit_change_C-111 SC - Mar09 TPCS Revision by JGN_15Nov10.xlsx
TPCS

C-111 Spreader Canal Western Project Final PIR and EIS January 2011
B-105

APPENDIX C
ENVIRONMENTAL INFORMATION

TABLE OF CONTENTS

C.0 ENVIRONMENTAL INFORMATION C-1
C.1 AFFECTED ENVIRONMENT C-1
C.1.1 Vegetative Communities C-1
C.1.2 Fish and Wildlife Resources C-2
C.1.3 Exotic Species C-3
C.1.4 Threatened and Endangered Species C-3
C.1.4.1 American Crocodile C-3
C.1.4.2 American Alligator C-4
C.1.4.3 Eastern Indigo Snake C-5
C.1.4.4 Florida Panther C-5
C.1.4.5 West Indian Manatee C-6
C.1.4.6 Wood Stork C-6
C.1.4.7 Cape Sable Seaside Sparrow C-7
C.1.4.8 Everglades Snail Kite C-7
C.1.4.9 Bald Eagle C-8
C.1.4.10 Wading Birds C-8
C.2 ESSENTIAL FISH HABITAT C-9
C.3 CLIMATE (SEA LEVEL RISE) C-9
C.3.1 Sea Level Rise C-10
C.3.2 Evaluation of the Effect of Sea Level Rise on the C-111 Spreader Canal Western Project C-11
C.4 LANDSCAPE: GEOLOGY AND SOILS C-29
C.5 WATER MANAGEMENT (OPERATIONS) C-29
C.5.1 Flood Control C-29
C.5.2 Forecasted Hydrologic Conditions C-30
C.5.3 Water Supply Demands C-30
C.6 WATER QUALITY C-35
C.6.1 Nutrients C-35
C.6.2 Phosphorus C-35
C.6.3 Total Suspended Solids C-37
C.6.4 Pesticides C-39
C.6.4.1 Pesticides in Surface Water and Sediment C-39
C.6.4.2 The Trend of Pesticides in Surface Water and Sediment C-42
C.6.4.3 Pesticide in Groundwater C-42
C.6.5 Mercury C-42
C.6.5.1 Mercury Trend Analysis C-43
C.6.6 Salinity C-45
C.6.6.1 Salinity Trend Analysis C-46
C.6.7 Other Toxicants/Pathogens C-48
C.7 AIR QUALITY C-48
C.8 CULTURAL RESOURCES C-48
C.8.1 Cultural Resources Correspondence C-49
C.9 SOCIOECONOMICS C-57
C.9.1 Population C-57
C.9.2 Economy C-57

C.9.3 Agriculture C-57
C.9.3.1 Future Agricultural Use C-58
C.9.4 Study Area Land Use C-58
C.9.4.1 Public Land Management C-59
C.9.4.2 Roads and Other Barriers to Sheetflow C-59
C.9.4.3 Mitigation Projects C-59
C.9.5 Recreation C-63
C.9.5.1 Recreation Demand C-65
C.9.5.2 State Recreation Trends C-65
C.10 NOISE C-66
C.11 AESTHETICS C-66
C.12 REFERENCE LIST C-67
C.13 BENEFIT EVALUATION METHODOLOGY C-69
C.13.1 Description of Performance Metric Calculations C-76
C.13.1.1 Simulation Model Setup C-83
C.13.1.2 PM 1.5 Flow Timing, Distribution and Volume C-87
C.13.1.3 PM 2.4 Coastal Zone Salinities C-93
C.13.1.4 PM 2.1 Vegetation Hydroperiods C-109
C.13.2 Aggregate Benefit Calculations C-114
C.13.3 Benefit Assessment Risk and Uncertainty Analysis C-116
C.13.3.1 Modbranch Model Uncertainty C-116
C.13.3.2 Uncertainty in Habitat Response to Hydrologic Change C-117
C.13.3.3 Performance Metric Uncertainty C-119
C.13.3.4 Conclusions C-125
C.14 CONCEPTUAL ECOLOGICAL MODELS C-127
C.14.1 Florida Bay C-127
C.14.2 Mangrove Estuaries C-141
C.14.3 Southern Marl Prairies C-152
C.14.4 Ridge and Slough C-164
C.15 BENEFITS ASSESSMENT MODEL DOCUMENTATION C-175

LIST OF TABLES

Table C-1 LEC Service Area 3 ..... C-32
Table C-2 LEC Service Area 3 ..... C-34
Table C-3 SFWMD Total Endosulfan Concentrations from The C-111E Canal at S-178 ..... C-40
Table C-4 SFWMD Total Endosulfan Concentrations from The C-111 Canal at S-177 ..... C-41
Table C-5 Miami-Dade County Population Estimates 2000-2050 (1,000) C-57
Table C-6 Counties within Scorp Planning Regions Potentially Affected by Alternative Restoration Plans C-63
Table C-7 Regional Outdoor Recreation Facilties Region 11 (1998) C-64
Table C-8 Demand and Facility Needs (1997 and 2110) Selected Recreation Activities Treasure Coast (Scorp Region 11) C-66
Table C-9 Hydroperiod Target for Vegetation within Ecological Zones C-70
Table C-10 Project Alternatives and Model Runs Used in Final Benefits Analysis C-77
Table C-11 Final Array of Alternatives C-78
Table C-12 Annual Rainfall Analysis for District 5 and District 6 ..... C-86
Table C-13 Results for Performance Metric 1.5 Flow Timing, Distribution and Volume C-93
Table C-14 Stage Versus Salinity Regression Results C-97
Table C-15 Results for Performance Metric 2.4 Coastal Salinities C-107
Table C-16 Results for Performance Metric 2.1 Vegetation Hydroperiod for All Indicator Zones C-114
Table C-17 Results for PM2.1 Vegetation Hydroperiod for Taylor Slough Indicator Zone. C-114
Table C-18 Overall Benefit Assessment Results (Normalized to Account for Affected Area) C-115
Table C-19 Ranking Analysis of Project Benefits by Performance Metric C-121
Table C-20 Average Annual Structure Flows As Predicted by Existing Conditions and Future Conditions Modbranch Model Runs (Average of 1978, 1989, and 1995) C-122

LIST OF FIGURES

Figure C-1 The Trend of Flow Weighted Total Phosphorus Concentration at S-178 ..... C-36
Figure C-2 The Trend of Flow Weighted Total Phosphorus Concentration at S-177 ..... C-37
Figure C-3 The Trend of Flow Weighted Total Suspended Solids Concentration at S-178 ..... C-38
Figure C-4 The Trend of Flow Weighted Total Suspended Solid Concentration at S-177 ..... C-39
Figure C-5 The Trend of Methyl Mercury at S-18C C-44
Figure C-6 The Trend of Total Mercury At S-18C C-44
Figure C-7 The Trend of Salinity at Top Layer of West Highway Creek C-46
Figure C-8 The Trend of Salinity at Bottom Layer of West Highway Creek C-47
Figure C-9 Modbranch Model Domain C-74
Figure C-10 Modbranch Simulation Grid C-75

Figure C-11 Indicator Regions Used in Performance Metrics 1.5, 2.4, and 2.1 ..... C-76
Figure C-12 Alternatives 1C and 1D C-79
Figure C-13 Alternatives 2C and 2D C-80
Figure C-14 Alternatives 3C and 3D C-81
Figure C-15 Alternatives 6C and 6D C-82
Figure C-16 Location of Flow Transects Used in PM 1.5 ..... C-89
Figure C-17Transect TA-1 Flow Hydrograph from 1995 Simulation Results C-91
Figure C-18 Indicator Regions Used With Performance Measure 1.5 Flow, Timing and Distribution C-92
Figure C-19 Salinity Monitoring Stations and Upstream Groundwater Stage Stations Used in PM 2.4 ..... C-96
Figure C-20 Taylor River Predicted Salinities C-101
Figure C-21 Long Sound Predicted Salinities C-102
Figure C-22 Little Madeira Bay Predicted Salinities C-103
Figure C-23 Joe Bay Predicted Salinities C-104
Figure C-24 Manatee Bay Predicted Salinities C-105
Figure C-25 Barnes Sound Predicted Salinities C-106
Figure C-26 Example of Salinity Index Calculations C-107
Figure C-27 Indicator Regions Used With Performance Metric 2.4 Coastal Zone Salinities C-108
Figure C-28 Indicator Regions Used With PM 2.1 Vegetation Hydroperiod C-111
Figure C-29 Vegetation Hydroperiod Distribution for Taylor Slough Indicator Region . C-112
Figure C-30 Net Project Benefits Versus Hydrologic Conditions C-118
Figure C-31 Comparison of Exceedance Frequency of S-197 Flows for 1978 Year Model Run for Future Conditions C-124
Figure C-32 Comparison of Exceedance Frequency of S-197 Flows for 1995 Year Model Run for Existing Conditions C-125

C.0 ENVIRONMENTAL INFORMATION

C.1 AFFECTED ENVIRONMENT

This section defines the present status of various environmental parameters within and adjacent to the project area and identifies trends and assumptions of those elements under a future without project scenario in a detailed narrative.

See ***TABLE 3-3*** in ***SECTION 3*** for a summary of the differences between the existing conditions and the future without project conditions on project lands for environmental conditions.

C.1.1 Vegetative Communities

The spatial extent of the natural areas within the project study area has the potential to change considerably through the year 2050. Natural areas that are not already in public ownership or identified for public acquisition are likely to be developed. Lands identified for acquisition under non-CERP public land acquisition plans that are proximal to developed areas are also likely to be developed because of rapidly rising land costs and limitations on public funding for land acquisition. The section of Ecological Zone 2 (shrub-dominated freshwater marsh) east of Card Sound Road would not exist as a natural area. Future development would also have numerous secondary effects. The wetlands in the northern part of Ecological Zone 3 (sawgrass with tree islands) could transition from a sawgrass-dominated marsh to cattail-saltbush-dominated wetlands due to poor water quality from residential runoff and decline of available freshwater. Changes in availability and distribution of freshwater and further disruption of natural sheet flow from discontinuities in hydrology due to levees, roads, and canals will further exacerbate the changes occurring in the natural sawgrass, marl prairie, tree island, and mangrove ecotones. Sea level rise will create the potential for further expansion of salt tolerant plant species into the freshwater marsh areas. Disruption of natural fire cycles and extent can have several effects that will increase in the future without project scenario. Control of fire intensity and extent due to potential for impacts on human infrastructure can encourage establishment of woody plant species that would normally be eliminated as well as selection against more fire tolerant species such as sawgrass and muhly grass. Reduction of water availability can cause fires to burn more intensely than natural, killing plant species that would normally survive a more natural "cool burning" fire as well as permitting organic soils to burn. Concurrently, unnatural flooding can inhibit fires and beneficial vegetation changes. All of these processes will be exacerbated due to increased urbanization in the future. Due to land disturbance and projected lower water levels, invasive plant species such as melaleuca (*Melaleuca quinquenervia*), Australian pine (*Casuarina spp.*), and Brazilian pepper (*Schinus terebinthifolius*) will become more widespread. With the lack of project

monitoring and maintenance, there would be an increase in other exotic plants including *Lygodium spp.* and shoebutton Ardisia (*Ardisia elliptica*).

Tree islands, an important component of the everglades habitat for a variety of native plant species not adapted to growing directly in flooded marshes, are being variously impacted by changes in water management and invasion of exotic plant species. The future without project appears to offer little benefit to offset these ongoing detrimental effects.

Observations from field visits and examination of aerials over the past four years indicate that the existing wetlands are experiencing an increasing level of all terrain vehicles" (ATV) usage. This trend is likely to continue in any areas where ownership patterns make access control difficult or impossible. The impacts resulting from unauthorized ATV usage in the natural areas include loss of vegetation, altered microtopography, and channelized surface water flow in vehicle ruts instead of overland sheet flow. This has implications for both hydrology and vegetation, since preferential pathways for overland flow can result in changed local hydrology, which in turn can affect vegetation patterns.

C.1.2 Fish and Wildlife Resources

The region supports a variety of wetland dependent wildlife, including several state- and federally-listed endangered and threatened wildlife species. A reduction of the wetland function and value of coastal and inland habitats within and adjacent to the C-111 Spreader Canal (C-111 SC) project study area associated with the spread of development and land conversion, is likely to result in an overall loss of fish and wildlife resources within the project area in the future. Disruption of the natural hydrology has resulted in aquatic vegetation community changes and a resultant disruption of aquatic productivity and function that has had repercussions throughout the food chain including wading birds, raptors, larger predatory fishes, reptiles (crocodiles and alligators), and mammals. These effects would likely continue given demands associated with environmental changes for the next 40 years.

Productivity of native fish species, many are important as prey species for wading birds, has been and will continue to be depressed due to water management practices and other factors previously discussed. Introduction and spread of a wide range of exotic fish species has increasingly been problematic in the project study area. The causative factors for this exotic fish problem include illegal introductions, unnatural habitat due to construction of canals and impoundments, and the establishment of vectors for travel and refugia (linear canals and deeper water) unlike the natural Everglades environment. Evaluation of the effects on occurrence and productivity of native fish species is controversial at best, but some studies report that the effect is negative and will be exacerbated in the next 40 years. Maintenance of the popular sport fishery

for non-native species such as the butterfly peacock (*Cichla ocellaris*) and native largemouth bass (*Micropterus salmoides*) should remain largely unaffected in the future without the C-111 SC project.

C.1.3 Exotic Species

The spread of invasive exotic plant species such as Brazilian pepper, Australian pine, Lygodium and shoebutton Ardisia has resulted in the conversion of large acreages with a variety of native vegetative species to less diverse and in some cases mono-specific vegetative cover with reduced value as wildlife cover. An increased coverage of exotic vegetation associated with continued land disturbance is anticipated in a 40 year future-without project scenario. Likewise, marsh areas subjected to higher levels of phosphorus are prone to support the invasion and spread of cattail which further reduces habitat quality and marsh and aquatic wildlife species diversity. Urbanization and associated habitat changes and anthropogenic effects (i.e., pets, exotic species releases, wildlife mortality) will further negatively affect vegetative and wildlife native species number and occurrence. These effects are expected to worsen over the next 50 years.

C.1.4 Threatened and Endangered Species

Urbanization, water demands, direct loss of habitat, and other demands for land, as well as degradation of existing habitat function, will likely result in a continued decline in populations of threatened, endangered, and state listed species during the next 50 years. A discussion of species of particular concern follows.

C.1.4.1 American Crocodile

Habitat loss due to development required to support a rapidly growing human population along coastal areas has been and continues to be the primary factor endangering the American crocodile (*Crocodylus acutus*) in Florida. Field and laboratory data suggest that low nest success combined with high hatchling mortality were the primary factors affecting survival. Florida and Biscayne bays are undergoing a number of changes affecting the present and future health of these ecosystems. Crocodile survival is linked to regional hydrological conditions, particularly rainfall, water levels, and salinity. Alternatives for improving water delivery into south Florida estuaries may change salinities, water levels, and availability of nesting habitat in the receiving bodies of water. The rate of mortality of hatchling crocodiles is correlated with the distance that hatchlings have to disperse to find nursery habitat. Nursery habitat is characterized by areas that are protected from wind and wave action, have a salinity range from 0 to 20 parts per thousand (ppt), abundant food, and shelter from predators. Crocodile growth rates are associated with the timing and

intensity of salinity levels. American crocodiles thrive in healthy estuarine environments, and are particularly dependent on natural freshwater deliveries. Crocodiles would benefit from restoration of freshwater flow into their estuarine habitat, and harmed by diversion or restriction of flow. Quantity, timing, and distribution of flow are important. Freshwater flows would continue to be diverted to the ocean through canals which would not be beneficial to crocodiles.

Collisions with automobiles continue to be the major documented cause of mortality of crocodiles in Florida with most of these have occurring on US Highway 1 or Card Sound Road. Management of large crocodiles needs to focus on expanding protected habitat and reducing road mortality of large individuals. Combined, many of the natural and anthropogenic factors described above have resulted in adverse effects to the American crocodile. Compared to historical estimates of 1,000 to 2,000 animals populations had declined to a low that apparently occurred sometime during the 1960s or 70s estimated to be between 100 and 400 non-hatchlings (Ogden, 1978). The American crocodile population in south Florida has increased substantially over the last 25 years and is estimated at around 500 to 1,000 individuals including hatchlings. Habitat protection has accounted for much of this increase but would be unlikely to produce a much greater population increase given potential future human encroachment, development, and land use changes.

C.1.4.2 American Alligator

The American alligator (*Alligator mississippiensis*) is a keystone species of the south Florida ecosystem. The American alligator's role as a top predator and its effect on the structuring of plant communities and associated aquatic animals (Mazzotti and Brandt, 1994) make it an ideal indicator of ecosystem health. Population growth and survival depends directly on the hydrologic functioning of south Florida watersheds. Each of these watersheds has experienced, and continues to experience, substantial degradation. Current water management practices have and will continue to result in a high and unpredictable rate of nest flooding. Historically, maximum summer water levels were positively correlated with water levels during alligator nest construction. This natural predictability has been lost. Historically, alligators were abundant in prairie habitats of the eastern floodplain, and along the edge habitats of deeper sloughs. Pre-drainage occupancy of the deep water, central sloughs was relatively low. Given the shortened hydroperiod and lowered water tables in the Everglades caused by drainage (Fennema et al., 1994; Van Lent et al., 1993; VanZee, 1999), the alligator has mostly abandoned the southern marl prairies, and today and for the foreseeable future without project scenario, the distribution of the alligator in the southern Everglades is shifted to sloughs, canals, and some deeper areas (Craighead, 1968; Mazzotti and Brandt, 1994).

C.1.4.3 Eastern Indigo Snake

In south Florida, the eastern indigo snake (*Drymarchon corais couperi*) is widely distributed but is not commonly found in great numbers in the wetland complexes of the Everglades. They can however be found in pine rocklands, tropical hardwood hammocks, tree islands, coastal prairies, mangroves, freshwater marshes, abandoned agricultural land and human altered habitat such as levee banks. Because of its relatively large home range, the eastern indigo snake is especially vulnerable to habitat loss, degradation, and fragmentation caused by residential and commercial construction and agriculture, and (Lawler, 1977; Moler, 1985). Habitat destruction and alteration for the present and foreseeable future will be most substantial along the coasts, in the Florida Keys, and along the high ridges of south-central Florida, where human population growth will continue to accelerate. Agricultural interests continue to destroy large expanses of suitable habitat throughout the project area. Even with continued habitat destruction and alterations, this species will probably persist in most areas if large, unfragmented pieces of suitable habitat persist. However, continued habitat fragmentation will result in isolated small groups of eastern indigo snakes that cannot ensure the continuation of viable populations.

C.1.4.4 Florida Panther

Florida panther (*Puma concolor coryi*) habitat in the C-111 SC project study area includes habitat designated as primary/dispersal zone in the Landscape Conservation Strategy for the Florida Panther in South Florida. This habitat (primary/dispersal zone) is considered to be the most important area needed to support a self-sustaining panther population. Population viability analysis projections indicate that under existing demographic and genetic conditions the panther could be extinct in 24 to 63 years (Seal et al., 1992). Environmental factors affecting the panther include: habitat loss and fragmentation, contaminants, prey availability, human-related disturbance and mortality, disease, and genetic erosion (Dunbar, 1993). Present and probable future population growth and agricultural expansion in south Florida are compromising the ability of natural habitats to support a self-sustaining panther population. The C-111 SC project study area has not been documented in recent years to be heavily used by Florida panthers compared to the current core panther population in Everglades National Park (ENP) and big Cypress National Preserve. A future without project scenario for the Florida panther for the next 50 years however would not contribute to Florida panther recovery and the Landscape Conservation Strategy for the Florida panther in South Florida.

C.1.4.5 West Indian Manatee

The major threats faced by the West Indian manatee (*Trichechus manatus*) today and continuing into the future are many fold. Collisions with watercraft in recent years account for an average of 25 percent of known manatee deaths in Florida annually. Deaths attributed to water control structures and navigational locks represent four percent of known manatee deaths. The future of the current system of warm-water refuges for manatees is uncertain as deregulation of the power industry in Florida occurs, and if minimum flows and levels are not established and maintained for the natural springs. There are also threats to habitats caused by coastal development throughout much of the West Indian manatee's Florida range. Florida's human population is growing significantly in conjunction with intensive coastal development with the greater part occurring in the 35 coastal counties. Natural wintering sites in south Florida have been and continue to be altered by activities such as rip-rapping and bulk-heading shorelines, diverting or capping sources of warmer water, and elimination of foraging and resting areas. Demands for water for residential, industrial, and agricultural purposes from the aquifer have and will continue to diminish spring flows as will paving and water diversion projects in spring recharge areas. Nutrient loading from residential and agricultural sources is promoting the growth of algae and clouded water columns, reducing available forage in seagrass beds and refuges. There are threats from natural events such as red tide and cold events. Survival of the West Indian manatees will depend ultimately on maintaining the integrity of ecosystems and habitat sufficient to support a viable manatee population. The majority of West Indian manatee observations in the C-111 SC project study area have been in the C-111 Canal below S-197, the Card Sound Road borrow canal south of the L-31E confluence, the Turkey Point Power Plant outfall canals south of the cooling pond, and along various keys in Florida Bay and the sounds. A future without project scenario for this project will do little to change the accelerating threats faced by the West Indian manatee.

C.1.4.6 Wood Stork

The prognosis of the United States (U.S.) wood stork (*Mycteria americana*) population over the next 50 years is partially dependent on the success of the overall Comprehensive Everglades Restoration Plan (CERP). It is believed that by restoring the quantity, quality, timing, and distribution of flows in the remaining Everglades wetlands that the prey base so critical to wood storks during the breeding season would be recovered in both the estuarine and freshwater systems. No critical habitat or documented nesting colonies exists in the C-111 SC project study area. The C-111 SC project area is suitable foraging habitat for wood storks and within the maximum 18.6-mile core foraging area of documented nesting colonies outside the project area. Almost all of the freshwater marsh and estuarine areas in the project study area can be

considered suitable wood stork foraging habitat. Although approximately 35 percent of the original foraging grounds were lost, the quality of much of the remaining wetlands has become and will continue to be degraded as foraging habitats, if efforts to restore the south Florida ecosystem are successful, a system with heterogeneity and inherent variability would be recreated, which should provide the prey base necessary to restore the wood stork in south Florida.

C.1.4.7 Cape Sable Seaside Sparrow

The Cape Sable seaside sparrow (CSSS) (*Amodramus maritimus mirabilis*) occupies short-hydroperiod mixed-marl prairies characterized by muhlenbergia grass with relatively short hydroperiods. The CSSS avoids sawgrass dominated areas with longer hydroperiods as these areas do not usually allow a suitable dry period for nesting. Conversely, the CSSS avoids areas where woody vegetation has encroached due to overdrainage. In the Taylor Slough area increased water levels due to pumping have precipitated vegetation community dominance shifts to the detriment of CSSS breeding habitat. CSSS have a high level of site fidelity, meaning that they will occupy former optimal habitat areas long after conditions become unacceptable for reproduction. If current water management that results in higher unnatural water levels continues, the CSSS faces an unnaturally high risk of extinction. The role that fire plays in CSSS ecology is not well understood. While fire is a natural part of the everglades ecology, and can serve to reduce the density of sawgrass and woody vegetation, it can prevent vegetation from becoming too thick to allow CSSS nesting and preclude the sparrows from effectively foraging for food, as well as provide adequate cover from predators. The CSSS populations in the western portion of the C-111 SC project study area (specifically subpopulations C and D) have already declined to near record lows and will continue to decline unless the hydrologic regimes are changed to reduce the frequency of fire in subpopulation C and reduce the frequency of flooding in subpopulation D.

C.1.4.8 Everglades Snail Kite

No designated critical habitat for the Everglades snail kite (*Rostrhamus sociabilis plumbeus*) is found within the C-111 SC project study area. Wetlands in the Everglades region supporting the Everglades snail kite include Taylor Slough and the C-111 Basin west of US Highway 1. The project is expected in general depending on the alternative selected and final water management regime, to have an overall benefit to Everglades snail kites by providing improved seasonal foraging habitat and recovery of native marsh vegetation and prey species. Recent population data collected appears to indicate that the Everglades snail kite population in Florida is declining. The reasons for the decline are unclear but anthropogenic activities; hydrologic management, aquatic weed control, natural climatic fluctuations, and possibly West Nile virus

all could conceivably have had an effect. The principal threat to the Everglades snail kite in south Florida is the loss or degradation of wetlands for agricultural and urban development. Degradation of water quality, particularly runoff of phosphorus from agricultural and urban sources is another threat to the Everglades snail kite. The Everglades was historically an oligotrophic system, but major portions have become eutrophic. Nutrient enrichment leads to growth of dense stands of herbaceous emergent vegetation, floating vegetation (primarily water hyacinth and water lettuce) and woody vegetation, which inhibits the ability of Everglades snail kites to find food. Urbanization, water demands, direct loss of habitat, and other demands for land, as well as degradation of existing habitat function will likely result in a continued decline of the Everglades snail kites during the next 40 years.

C.1.4.9 Bald Eagle

No recent bald eagle (*Haliaeetus leucocephalus*) nesting activity has been recorded in the C-111 SC project study area. Suitable foraging habitat for bald eagles does exist throughout the project area. Preferred habitat for bald eagles consists of large, open-water bodies for foraging and suitable perch and nesting sites nearby. Creation of storage reservoirs, storm water treatment areas (STAs), and large canals could provide this open water habitat. New electrical lines associated with urbanization and any pumps installed with water control structures could present an electrocution hazard for bald eagles. In Florida overall, bald eagle nesting has increased substantially since the early 1970s; however, in the ENP, nesting has remained relatively constant during the same period. A future without project scenario in the C-111 SC project study area would offer no habitat enhancements to expand bald eagle populations in the project area and could increase electrical line hazard due to increased urbanization and associated infrastructure.

C.1.4.10 Wading Birds

Although there are fluctuations in nesting success for wading birds that are driven by climatic as well as water control related issues, in general, nest numbers and success of wading birds have decreased dramatically across south Florida over the past 100 years. These results are especially evident in data collected for wood storks and white ibis (*Eudocimus albus*). Although data is less complete and suggests regional and short-time period increases for species such as the great egret (*Casmerodius albus*), great blue heron (*Ardea herodias*), cattle egret (*Bubulcus ibis*) and little blue heron (*Egretta caerulea*). Evidence suggests that the degree to which these species populations have increased system-wide and over the longer periods of time is less convincing. A long-term scenario that does not include habitat restoration components of CERP currently being evaluated would undoubtedly result in a continued overall decline in

wading bird species due to continued encroachment into habitat and anthropogenic influences on water supply.

Historically the area northeast of Florida Bay in the southwest portion of the C-111 SC project area was the most productive sub-region of the bay for roseate spoonbill (*Ajaja ajaja*) (Lorenz et al., 2002). This area has more recently been heavily impacted by water control structures and management measures that supply water to these foraging grounds (Lorenz, 2000). Nesting effort success in other active sub-regions compared to the northeastern sub-region gives increased credibility to the conclusion that the observed decline is anthropogenic in nature. Other sub-regions in roseate spoonbill nesting habitat are buffered by distance from water management practices. Unless major changes are implemented to water management practices that affect roseate spoonbill habitat and Florida Bay in general, these areas will continue to decline in ecologic health with resultant further detrimental effects on roseate spoonbill.

The extent of wetlands needs to be maximized by restoring degraded marshes in the project study area wherever possible. The natural connectivity in the system should be increased by reducing compartmentalization and the critical features of natural hydrology should be replicated. Hydroperiod restoration in presently over-drained marl wetland areas will increase the frequency of years when prolonged wet season and natural drying patterns produce and concentrate fishes to attract larger seasonal aggregations of foraging birds. The interspersion of slough and wet prairie habitats into areas of dense grass, development of tree islands, and protection of areas that are currently most productive needs to be accomplished in the future. Where possible, water management needs to be conducted to lengthen hydroperiods without greatly deepening water levels. Few of these project related environmental benefits will be realized in a future without project scenario over the next 50 years.

C.2 ESSENTIAL FISH HABITAT

A lack of freshwater sheet flows into the coastal areas of Barnes Sound and Florida Bay will continue to increase salinity levels in the nearshore and estuarine biological communities, thus reducing the functional value and spatial extent of those systems. A future without project is likely to result in an overall decrease in the diversity of species within those habitats.

C.3 CLIMATE (SEA LEVEL RISE)

The potential problem for the C-111 SC project concerning future climatic forecasts is sea level rise. Sea level rise of approximately 14 centimeters (5.5 inches) is forecasted for 2050 resulting in many affects to the overall system. Some examples of future impacts would be continual creeping of saltwater inland, water supply, and flood protection, by raising the groundwater system.

C.3.1 Sea Level Rise

The Environmental Protection Agency (EPA) published historic rates of sea level rise at various locations in the United States. The historic rate of sea level rise at Miami Beach is 2.39 millimeters/year with a standard error of 0.22.

Under the current trend at Miami Beach sea level will rise 14 centimeters between 1990 and 2050. Adding 14 centimeters to the normalized values, the median estimate for 2050 sea level rise is 24 centimeters and the one percent chance of sea level rise would be 49 centimeters. Alternately, there is a 50-percent chance that sea level will rise at least 24 centimeters or 0.8 feet, which reflects an expected future sea level trend of 0.013 feet/year during the 1990 to 2050 period.

C.3.2 Evaluation of the Effect of Sea Level Rise on the C-111 Spreader Canal Western Project

Evaluation of the Effect of Sea Level Rise
on the C-111 Spreader Canal Western Project
November 10, 2009

1.0 INTRODUCTION

The C-111 Spreader Canal Western project's purpose is "to improve deliveries and enhance the connectivity and sheetflow in the Model Lands and Southern Glades areas, reduce wet season flows in the C-111 Canal, and decrease potential flood risk in the lower south Miami-Dade County areas," as described in the Comprehensive Everglades Restoration Plan (CERP) (WRDA, 2000). Water that currently flows through the C-111 Canal will be routed south to the coast through Taylor Slough. General elevations in the project area range from approximately +6.0 – 0.0 feet National Geodetic Vertical Datum (NGVD29). Elevations across the site generally decrease in a southwest to southerly direction. ***Figure 1*** is a map of the project area with the project features (Frog Pond Detention Area, Aero-Jet Canal Feature).

U.S. Army Corps of Engineers (USACE) planning guidance (Engineering Circular [EC] 1165-2-211) calls for evaluating the effects of sea level rise (SLR) under multiple scenarios. The multiple scenarios recommended include analysis of SLR at low, intermediate and high levels at 20, 50, and 100 years following the completion of project construction. The historic SLR as measured at the National Oceanic and Atmospheric Administration (NOAA) Key West tide station is 2.24 millimeters per year (mm/yr).

This paper provides a discussion of the effects of SLR on the project area as well as on the restoration benefits anticipated to result from project implementation. The restoration benefits projected for this project are associated with the rehydration of freshwater wetlands and reduced salinity conditions in nearshore areas downstream of Taylor Slough. SLR has been calculated by the USACE Jacksonville District for the low, intermediate and high scenarios at five-year intervals per EC 1165-2-211 guidance. The results of this analysis are presented in ***Table 1*** and ***Figure 2***.

1

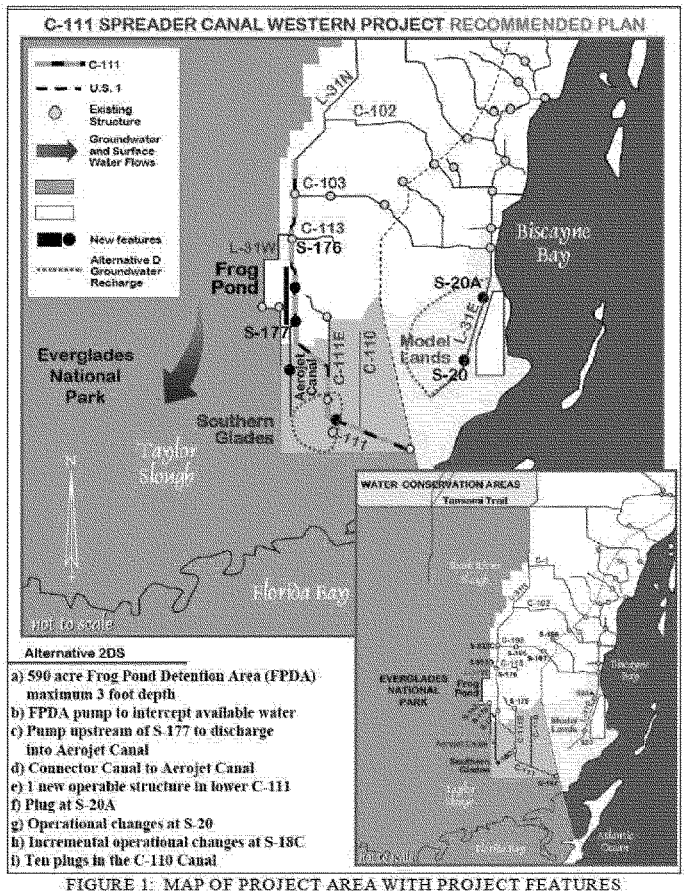


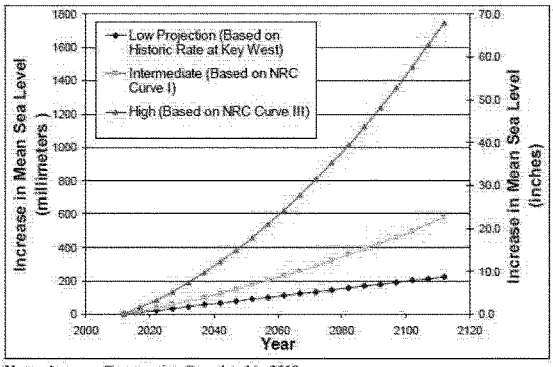
FIGURE 1: MAP OF PROJECT AREA WITH PROJECT FEATURES

2

TABLE 1: SEA LEVEL RISE AT 5-YEAR INTERVALS FOR LOW, INTERMEDIATE, AND HIGH PROJECTIONS

Year of Analysis	t_2 (years)	Low Projection (Based on Historic Rate at Key West) (mm)	Intermediate (Based on NRC Curve I) (mm)	High (Based on NRC Curve III) (mm)	Low Projection (Based on Historic Rate) (inches)	Intermediate (Based on NRC Curve I) (inches)	High (Based on NRC Curve III) (inches)
2012	26	0	0	0	0.0	0.0	0.0
2017	31	11	18	40	0.4	0.7	1.6
2022	36	22	37	84	0.9	1.4	3.3
2027	41	34	57	134	1.3	2.2	5.3
2032	46	45	78	189	1.8	3.1	7.4
2037	51	56	100	248	2.2	4.0	9.8
2042	56	67	124	313	2.6	4.9	12.3
2047	61	78	149	383	3.1	5.9	15.1
2052	66	90	175	458	3.5	6.9	18.0
2057	71	101	202	538	4.0	8.0	21.2
2062	76	112	230	623	4.4	9.1	24.5
2067	81	123	260	712	4.9	10.2	28.0
2072	86	134	291	807	5.3	11.4	31.8
2077	91	146	322	907	5.7	12.7	35.7
2082	96	157	356	1012	6.2	14.0	39.9
2087	101	168	390	1122	6.6	15.3	44.2
2092	106	179	425	1237	7.1	16.7	48.7
2097	111	190	462	1357	7.5	18.2	53.4
2102	116	202	500	1482	7.9	19.7	58.4
2107	121	213	539	1612	8.4	21.2	63.5
2112	126	224	579	1748	8.8	22.8	68.8

3



Note: Assumes Construction Completed in 2012

FIGURE 2: PROJECTED SEA LEVEL RISE AT C-111 SPREADER CANAL

2.0 GENERAL EFFECTS OF SEA LEVEL RISE

Historic sheetflow conditions prior to drainage created pooling of freshwater upstream from mangrove estuaries and prolonged freshwater flows into the estuaries. The canal network has resulted in the reduction of freshwater volume and duration which has shortened the hydroperiod, reduced freshwater pooling along the sawgrass/mangrove ecotone, and disrupted sheetflow. Florida Bay became more saline due to the loss of freshwater inputs from Taylor Slough as water management features (drainage canals) were constructed in Southern Miami-Dade County. Restoring pre-drainage volume, distribution, and duration will prolong the pooling of freshwater and increase volume and duration of freshwater to the estuaries (Davis et al., 2005). Additional freshwater through Taylor Slough will decrease salinity, leading to the increase of growth and survival of estuarine species. One expectation of the restoration in this area is that changing the patterns of freshwater flows going into Florida Bay will drive the seagrass community and trophic web toward the pre-drainage condition (Rudnick et al., 2005).

The effect of SLR on C-111 basin habitat will vary depending upon the location and elevation of the affected lands. The habitat coverage for the project area is shown and described in ***Figure 3*** and ***Table 2***, respectively. The project map and elevation profile of Taylor Slough relative to the existing mean sea level (MSL) are shown in ***Figure 4*** and ***Figure 5***. The ecological zone map indicates that the much of the southern glades is sawgrass wetland. The transition zone

between the freshwater habitat is located south of the sawgrass wetlands and this area is dominated by mangrove forest and white zone habitat. Based on the topography and habitat coverage, it appears that SLR will impact the southern portion of Taylor Slough and the southern glades in general. As sea level rises, the white zone habitat and mangrove forest will move north into the sawgrass habitat areas. Nearshore shallow estuarine habitat that is targeted for salinity improvement by this project will slowly move north as MSL rises. Peat soils in the southern portion of Taylor Slough may decompose and disappear as saltwater intrudes into the former freshwater grammanoid marsh areas.

Many tidal creeks have already disappeared in coastal wetland as a result of sedimentation and with vegetation surrounding the landscape. Restoring freshwater flows through the estuary will help maintain open watercourses; however, SLR is expected to modify the patterns of connectivity through coastal wetlands and create increased sediment loads (Davis et al., 2005). In addition to SLR, climate change may result in more extreme weather events. If SLR is accompanied by an increase in tropical storm intensity and frequency, the rate of soil accumulation may increase and partially offset higher MSL conditions. (Hurricane Wilma resulted in approximately five centimeters accumulation of sediment deposits in the mangrove zones in 2005 (Whelan, 2009).)

Under higher rates of SLR, the increase in groundwater stages and in surface water depths will result in a loss of flood protection for the area. Changes to the open/close operating criteria at canal structures may be instituted as water managers attempt to counteract the effects of SLR on flood protection and salinity control. The SLR related increase of groundwater stage in the northern part of the project area could provide increased hydration to the area to the extent that the water management practices are not significantly modified in an effort to continue to provide flood protection to lands east of the L-31N and C-111 Canal alignments. With no change to water management operations, lands to the east of the C-111 Canal that are still farmland will likely be abandoned and revert to freshwater wetland habitat since farming is likely to be uneconomical in the face of increased flooding. (This is an observed phenomena in the nearby Model Lands where acreage previously farmed in the 1940s to 1960s has reverted to wetlands due to SLR related increased flooding among other factors.)

The ecological benefits associated with this project are related to the enhancement of freshwater wetland hydroperiod in and around Taylor Slough and the improvement (reduction) in salinity conditions in the nearshore areas downstream of Taylor Slough. To assist in the evaluation of the likely effects of SLR on project benefits, the areas where the freshwater rehydration benefits are expected to occur were projected onto flood prediction maps generated under different MSL conditions. The mapping of the likely freshwater wetland benefits

5

was created using difference mapping techniques that were generated using the groundwater stage output from the future without project scenario and the selected plan (Alternative 2DShort) scenario. For freshwater wetland related project benefits, the degree to which the flooded area covers the benefitted zone under the "wet" condition simulation scenario was used as an indication of how these benefits are likely to be impacted by SLR. (The average and dry condition simulation results shown in ***Figure 6*** and ***Figure 7*** were not used in this analysis since the wet condition benefited area extends furthest to the south.)

The estimation of the effect of SLR on the salinity benefits resulting from this project is less quantitative than that done for the freshwater wetland benefits. Given the gentle slope of Taylor Slough and other areas of the southern glades, SLR is expected to result in the translocation of estuarine nursery habitat northward as MSL increases. In Taylor Slough, man-made boundaries such as a levee or canal that would limit the northward march of the estuarine environment are presently many miles from the existing shoreline. Under the lower to moderate SLR projections, it is possible that SLR will actually provide a greater area of estuarine habitat than that presently. There is some uncertainty in the prediction of viable estuarine habitat since it depends upon local scale topography and future changes to the landscape resulting from peat soil decomposition and storm event related sediment deposition.

As with the predictions of future rates of SLR, there is uncertainty in the estimation of effects to project related ecosystem benefits due to the accuracy and reliability of the datasets used in this analysis. The MSL flood prediction maps are based upon topographic data that is known to be accurate to within plus or minus 0.5 feet. The land elevation is assumed to be static over the 20, 50, and 100 year periods; however, topographic change is likely to occur as a result of SLR and other natural processes. In addition to these sources of topographic uncertainty, the benefitted area mapping is based upon ModBranch model output that has a groundwater stage prediction accuracy estimated at 0.5 feet. Despite these limitations and inherent uncertainties, the analysis is presented as it is the most reliable information available at this time.

Using the methodology described above, qualitative assessments of the SLR impact to project benefits are discussed for three SLR projections at three different points in time.

2.1 PROJECTED EFFECT OF SEA LEVEL RISE AT 20 YEARS POST CONSTRUCTION

The low projection for SLR at 20 years is 1.8 inches, the intermediate projection is 3.1 inches, and the high projection is 7.4 inches. The location of the benefited areas relative to the flood lines for MSL and MSL+1 foot conditions are shown in ***Figure 5*** and ***Figure 6***. After 20 years, the low and moderate projections of

SLR should not have an adverse effect on the benefits predicted for freshwater wetland rehydration. This conclusion is based on visually interpolating from ***Figure 5*** and ***Figure 6*** the probable flood line given two to three inches of SLR. The quantity of water available for diversion by the project features should not change significantly under the low and moderate SLR projections at 20 years so related benefits should be achievable. Based on the topography shown for Taylor Slough, the high projection of sea level rise after 20 years (7.4 inches) will result in a minor MSL encroachment of the freshwater wetland benefit area (***Figure 6***). A comparison of location of the flood lines in ***Figure 5*** and ***Figure 6*** provide a rough estimate of the area of sawgrass wetlands that will convert to mangrove, white zone, and shallow estuarine habitat. Relative to the future without condition, the project will likely result in a reduction of the conversion of sawgrass habitat to transitional and saltwater habitat due to the additional freshwater diverted into Taylor Slough.

The impact on SLR on salinity benefits in the nearshore zone over the next 20 years is expected to be minimal under all three projections since the zone of optimal salinity conditions will move upland (northward) over time. Under the low SLR projection, it is likely that deposition in the nearshore, mudbank, and mangrove areas will match SLR so that there is minimal change in average embayment depth. Under the moderate to high SLR projections, there may be some change in the total area where salinity conditions are optimal for some mesohaline and oligohaline species. However, given the gentle slope of the topography of Taylor Slough and the lack of man-made barriers such as levees or canals, it is unlikely that mesohaline and oligohaline areas will be completely eliminated by SLR under any scenario in 20 years. At the higher SLR estimate, some reduction in the severity and duration of hypersaline conditions in Barnes Sound, Manatee Bay, and Florida Bay proper is likely since the rate of exchange of bay water with ocean water will increase.

TABLE 2: EFFECTS ON RESTORATION BENEFITS AFTER 20 YEARS OF SEA LEVEL RISE

20 years of SLR	Freshwater Wetland Rehydration	Nearshore Salinity Conditions
Low (1.8 inches)	No effect	No effect
Intermediate (3.1 inches)	No effect	Minimal Location Shift
High (7.4 inches)	Minor (<10%)	Location Shift

7

2.2 PROJECTED EFFECT OF SEA LEVEL RISE FOR LOW, INTERMEDIATE, AND HIGH AT 50 YEARS POST CONSTRUCTION

The low projection for SLR at 50 years is 4.4 inches, the intermediate projection is 9.1 inches, and the high projection is 24.5 inches (***Table 3***). The project related freshwater wetland benefits are not expected to be affected by SLR at the low rate projection in 50 years. Based on ***Figure 9***, at the intermediate SLR prediction for 50 years of nine inches, approximately ten percent of the freshwater wetlands identified as benefiting from the project will be impacted by SLR. Based on ***Figure 10***, approximately 33 percent of the freshwater wetlands identified as benefiting from the project will be impacted by SLR under the high projection estimate of 24 inches in 50 years.

Under the low projection at 50 years, the MSL flood line is not directly adjacent to an existing man-made canal or levee and there is no natural topography that limits the areal expanse of shallow estuarine habitat areas. Since there is minimal change to the size of the estuarine habitat zone, no significant reduction in project related salinity benefits are anticipated for the 50 year low SLR projection. The estimated MSL+SLR flood lines for the intermediate and high SLR projection as interpreted from ***Figure 9*** and ***Figure 10*** show that lands directly adjacent to the C-111 Canal will be flooded. This would indicate that SLR under the 50 year intermediate and high scenarios could be constrained by the area available for estuarine habitat. However, since the C-111 Canal is generally perpendicular to the shoreline and flooding occurs on both sides of the canal, the actual constraint on estuarine habitat area is limited. With no effective constraint on the translocation of estuarine habitat under one to two feet of SLR (equal to intermediate and high estimates at 50 years) there is no expected reduction of saltwater related benefits. The moderate to high estimates of SLR at 50 years is likely to result in a reduction of hypersaline conditions in Florida Bay as exchange with ocean water will increase over present volumes. The related reduction of hypersaline conditions in Barnes Sound and Manatee Bay should enhance nearshore habitat in those areas.

TABLE 3: EFFECTS ON RESTORATION BENEFITS AFTER 50 YEARS OF SEA LEVEL RISE

50 years of SLR	Freshwater Wetland Coverage in Taylor Slough	Nearshore Salinity Conditions
Low (4.4 inches)	Not Significant	Not Significant
Intermediate (9.1 in)	Minor (10% reduction)	Location shift
High (24.5 inches)	Significant (33% reduction)	Location shift

8

2.3 PROJECTED EFFECT OF SEA LEVEL RISE FOR LOW, INTERMEDIATE, AND HIGH AT 100 YEARS POST CONSTRUCTION

Analyzing the effect of SLR at 100 years is a requirement of EC 1165-2-211; however, it is important to recognize that the CERP and all its anticipated benefits were based on a fifty (50) year planning horizon. Any benefits lost to SLR after 50 years would have accrued in the absence of SLR after the anticipated life of the project and are not used to justify the project in the cost effectiveness/incremental cost analysis (CE/ICA). With that said, the low projection for SLR at 100 years is 8.8 inches, the intermediate projection is 22.8 inches, and the high projection is 68.8 inches (***Table 4***). Based on ***Figure 9***, at the low SLR prediction for 100 years of 8.8 inches, approximately ten percent of the freshwater wetlands identified as benefiting from the project will be impacted by SLR. Based on ***Figure 10***, approximately 33 percent of the freshwater wetlands identified as benefiting from the project will be impacted by SLR under the moderate projection estimate of 22.8 inches in 100 years. Under the high SLR scenario for 100 years, all of the freshwater benefits resulting from the project would be lost; however, as mentioned earlier, the 100 year timeframe is beyond the 50 year planned lifespan of the project.

Under the low projection at 100 years, the MSL flood line is not directly adjacent to an existing man-made canal or levee and there is no natural topography that limits the areal expanse of shallow estuarine habitat areas (see ***Figure 9***). The estimated MSL+SLR flood lines for the intermediate SLR projection at 100 years as interpreted from ***Figure 10*** show that lands directly adjacent to the C-111 Canal will be flooded. This would indicate that SLR under the 100 year intermediate scenario could be constrained by the area available for estuarine habitat. However, since the C-111 Canal is generally perpendicular to the shoreline and flooding occurs on both sides of the canal, the actual constraint on estuarine habitat area is limited. With no effective constraint on the translocation of estuarine habitat under one to two feet of SLR (equal to low and intermediate SLR estimates at 100 years) there is not expected reduction of saltwater related benefits. The high estimate of SLR at 100 years may reduce the area available for estuarine habitat (see ***Figure 11***); however, this will depend upon whether man-made flood protection barriers are constructed in locations that limit the extent of nearshore shallow areas suitable for estuarine habitat. Under the high SLR estimate at 100 years salinity conditions within Florida Bay would become much more marine like since not only would the average depth of the bay more than double from 1.0+ meters to 3 meters, the eastern Florida Key islands that serve as a barrier to ocean exchange will nearly disappear under MSL.

TABLE 4: EFFECTS ON RESTORATION BENEFITS AFTER 100 YEARS OF SEA LEVEL RISE

100 years of SLR	Freshwater Wetland Rehydration	Nearshore Salinity Conditions
Low (8.8 inches)	Minor (10% reduction)	Location shift
Intermediate (22.8 inches)	Significant (33% reduction)	Location Shift
High (68.8 inches)	All lost	Location Shift and losses

3.0 DESIGN CONSIDERATIONS AND SSEA LEVEL RISE

There is a good deal of uncertainty surrounding the magnitude of SLR over the next 50 to 100 years. To reduce the risk associated with implementing the project, flexibility in the design and operation features can be incorporated into the project during the planning phases. Also features planned and operated for one purpose can be repurposed as SLR begins to affect water management needs in the future. For instance, the planned S-198 structure that is located half way between S-18C and S-197 is designed to primarily assist in rehydrating adjacent wetlands by holding the groundwater stage slightly higher than otherwise. As SLR begins to impact MSL, the ability of the S-197 structure to provide salinity control benefits will diminish. The S-198 structure will then begin to provide the salinity control benefits by limiting northward migration of the saltwater front within the C-111 Canal. Similarly as SLR contributes to marginal decreases in the C-111 Canal systems ability to provide flood protection due to increased tail water conditions at S-197 and S-18C as well as increased average groundwater stages, the project's S-200 and S-199 pump stations could be used to assist in removing the marginal increase in flood flows from the C-111 Canal. Increases in groundwater stage due to SLR can also be mitigated to some extent by using the two project pump stations to send more freshwater through Taylor Slough than would be available in the absence of SLR.

4.0 CONCLUSION

The effects of SLR have been analyzed per EC 1165-2-211. This analysis looked at the effect of SLR on the benefits predicted for the selected alternative (2DShort). The results indicate that within the 50-year planning horizon, the freshwater wetland rehydration benefits attributed to the selected plan will be diminished as much as 33 percent as determined by comparing the flood prediction maps for 2 feet of SLR (high projection for 50 years) with the benefited area projection. Benefit impact would be somewhat higher if the mean higher high water elevation controls habitat shift rather than the MSL line.

10

Nearshore salinity benefits are not expected to be significantly impacted by the 50 year high SLR projection estimate. Limited impacts to project benefits were seen at the low and moderate SLR projections at 50-years. Though a similar analysis was not carried out for the remaining with-project alternatives; the results would be similar since all of the alternatives also focus on features located at the Frog Pond and Aerojet Canal as does the selected plan.

Under the high SLR scenario at 100 years, the project benefits will not occur. As mentioned above, the project is justified based on a 50-year project lifespan. The effects of SLR on project benefits that occur after the 50-year project lifespan should be treated the same as benefits that occur after the project lifespan. In other words, effects that occur after the 50 year project lifespan should not be considered for plan selection or determination of project viability.

There is no doubt that SLR over the last 100 years has impacted Taylor Slough, the southern glades, and the downstream nearshore estuarine habitat. This is evident by the landward migration of the white zone habitat and the abandonment of farming activities in the extreme southern glades. Water management alterations such as the C-111 and L-32N canals have likely exacerbated the impact of past SLR by significantly reducing surface and groundwater deliveries to Taylor Slough and the southern glades. Relevant ecological literature as well as best professional judgment supports the conclusion that augmenting flows to Taylor Slough is critical to preserving the sawgrass habitat and nearshore estuarine salinity conditions downstream. Given the possibility of peat decomposition caused by landward migration of the salt habitat front, it is critical to the Taylor Slough ecosystem that additional freshwater flows are diverted into this basin. Without augmenting Taylor Slough flows, it is apparent that the future without project scenario will result in accelerated loss of the functional sawgrass habitat under intermediate and high SLR projections as compared to the selected project scenario.

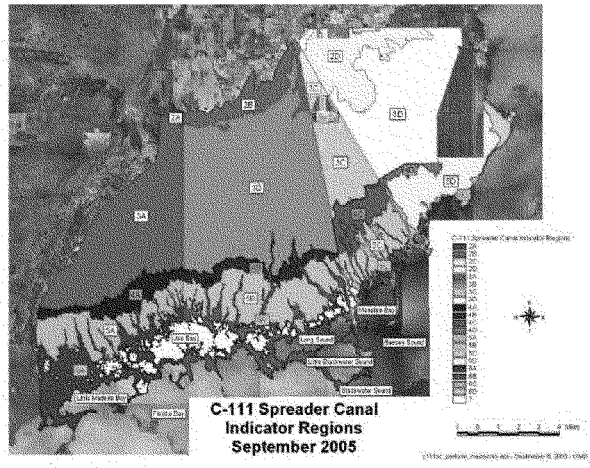


FIGURE 3: HABITAT MAP OF C-111 SPREADER CANAL PROJECT AREA

TABLE 5: VEGETATION AND HYDROPERIOD FOR HABITAT ZONES

Zone	Hydroperiod	Existing Landscape	Existing Vegetation and Hydroperiod Response
2	130-180 days – hydroperiod range for the dry phase that should support muhly-mixed graminoids	Shrub dominated forested wetland	Freshwater wetland habitat. Brazilian pepper (*Schinus terebinthifolius*), Australian pine (*Casuarina* spp.), dahoon holly (*Ilex cassine*), swamp bay (*Persea palustris*), sweet bay (*Magnolia virginiana*), willow (*Salix caroliniana*), and sawgrass (*Cladium jamaicense*). Discontinuous hydroperiod controls overall plant distribution.
3	150-330 days - hydroperiod range.	Sawgrass	Freshwater wetland habitat. Sawgrass, muhly grass (*Muhlenbergia capillaris*), swamp bay, dahoon holly, wax myrtle (*Myrica cerifera*), willow, and cocoplum (*Chrysobalanus icaco*), sweet bay, myrsine (*Rapanea guianensis*), bald cypress (*Taxodium distichum*), and pond apple (*Annona glabra*). Continuous hydroperiod is more relevant to aquatic fauna productivity.
4	240-330 days - hydroperiod range.	Mixed graminoid with mangroves	Sawgrass, swamp bay, dahoon holly, wax myrtle, cocoplum, myrsine, poisonwood (*Metopium toxiferum*), buttonwood (*Conocarpus erectus*), red mangrove (*Rhizophora mangle*), stoppers (*Eugenia* spp.), spicewood (*Calyptranthes pallens*), and cocoplum
5	240-330 days - hydroperiod range.	White zone ecotone	Salt tolerant Dwarf red mangroves, sparse graminoids. Discontinuous hydroperiod controls plant distribution.
6	240-330 days - hydroperiod range.	Coastal forest	Red mangrove, white mangrove (*Laguncularia racemosa*), Brazilian pepper , Australian pine, wax myrtle,, poisonwood,, buttonwood, spicewood, myrsine, stoppers, white indigo berry (*Randia aculeata*). Desired salinities are 5-15 ppt necessary to sustain oligohaline and mesohaline conditions.

13

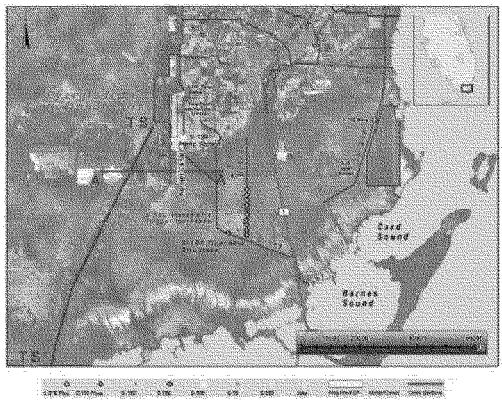


FIGURE 4: C-111 SPREADER CANAL WESTERN FEATURES MAP WITH TAYLOR SLOUGH TRANSECT TS – TS'

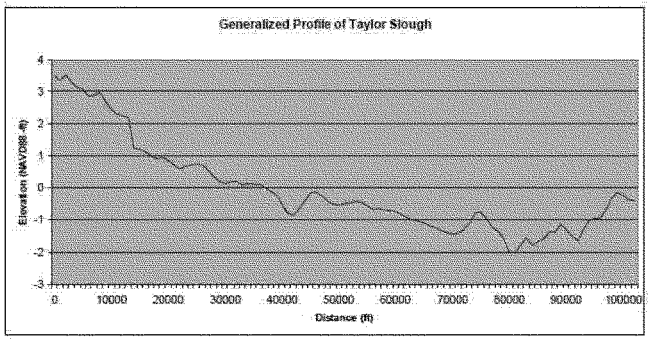


FIGURE 5: GENERALIZED TOPOGRAPHIC PROFILE OF TAYLOR SLOUGH

14

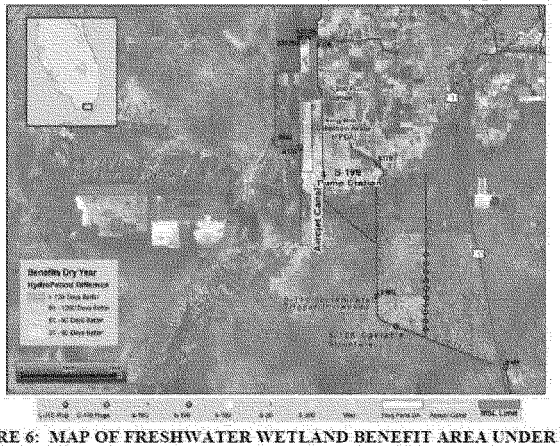


FIGURE 6: MAP OF FRESHWATER WETLAND BENEFIT AREA UNDER DRY YEAR CONDITIONS AND EXISTING MEAN SEA LEVEL CONDITIONS

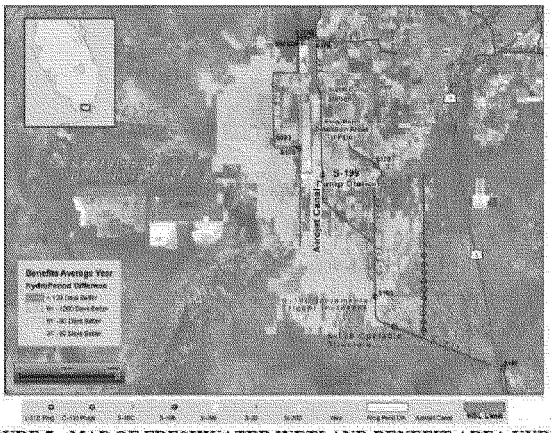


FIGURE 7: MAP OF FRESHWATER WETLAND BENEFIT AREA UNDER AVERAGE YEAR CONDITIONS AND EXISTING MEAN SEA LEVEL

15

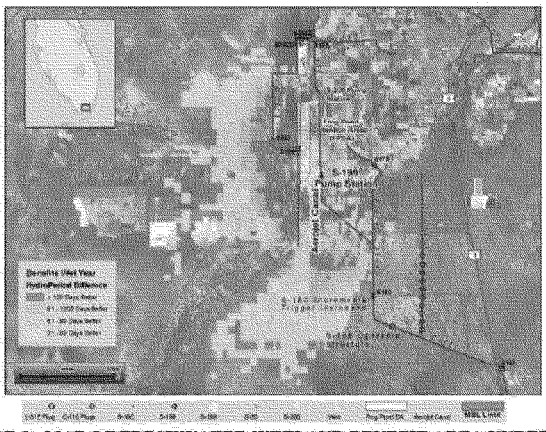


FIGURE 8: MAP OF FRESHWATER WETLAND BENEFIT AREA UNDER WET YEAR CONDITIONS AND EXISTING MEAN SEA LEVEL

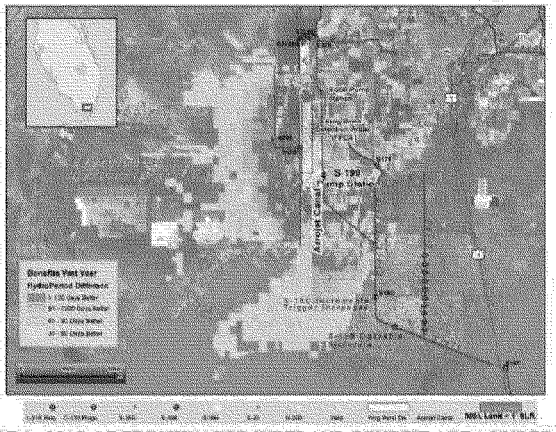


FIGURE 9: MAP OF FRESHWATER WETLAND BENEFIT AREA UNDER WET YEAR CONDITIONS AND EXISTING MEAN SEA LEVEL + 1 FOOT SEA LEVEL RISE

16

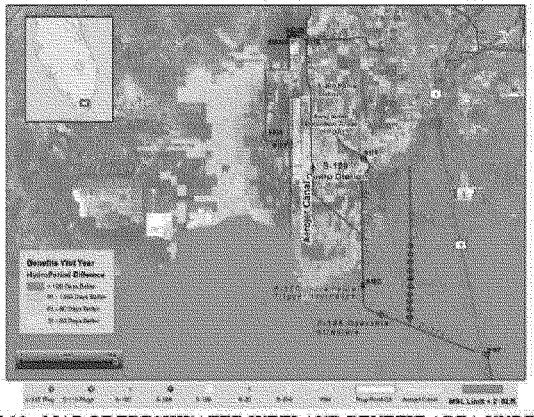


FIGURE 10: MAP OF FRESHWATER WETLAND BENEFIT AREA UNDER WET YEAR CONDITIONS AND EXISTING MEAN SEA LEVEL + 2 FOOT SEA LEVEL RISE

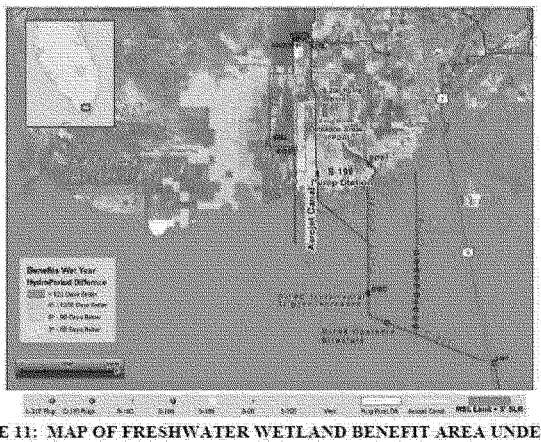


FIGURE 11: MAP OF FRESHWATER WETLAND BENEFIT AREA UNDER WET YEAR CONDITIONS AND EXISTING MSL + 3 FOOT SLR.

17

REFERENCES

Davis, S.M., D.L. Childers, J.J. Lorenz, H.R. Wanless, and T.E. Hopkins. 2005. A conceptual model of ecological interactions in the mangrove estuaries of the Florida Everglades. *Wetlands*, Vol. 25, No. 4, pp. 832-842.

Rudnik, D.T., P.B. Ortner, J.A. Browder, and S.M. Davis. 2005. A conceptual ecological model of Florida Bay. *Wetlands*, Vol. 25, No. 4, pp. 870-883.

Kevin R. T. Whelan, Thomas J. Smith III, Gordon H. Anderson, and Michelle L. Ouellette, Hurricane Wilma's Impact on Overall Soil Elevation and Zones Within The Soil Profile in a Mangrove Forest. South WETLANDS, Vol. 29, No. 1, March 2009, pp. 16–23

18

C.4 LANDSCAPE: GEOLOGY AND SOILS

Based on current land use indicators, the landscape of the project area would be developed consistent with the surrounding land use patterns. As a result of development, the existing wetland soils located in the area would be altered. Wetland soils would be drained and/or displaced with fill materials to support the urban development.

C.5 WATER MANAGEMENT (OPERATIONS)

Combined Structural and Operational Plan (CSOP) is a water control plan that will define how the South Dade Conveyance System (SDCS) as well as the Water Conservation Areas (WCA) 3A and 3B will be operated based on the structural features in the authorized 1994 C-111 General Reevaluation Report (GRR) and the 1992 Modified Water Deliveries (MWD) General Design Memorandum (GDM). The operational recommended plan with all structural features authorized in the 1994 C-111 GRR and MWD with the current operations of Interim Operating Plan (IOP) will be considered as the defining future without for this project area. This plan is defined in the CSOP plan as the "No-Action" plan and is considered as one of the base planning conditions modeled with Mod-Branch as well as the Regional (2x2) model. However, it is unclear what the ultimate operational plan will be for future without. Currently, two model runs have been completed by the CSOP team referred to as the "East" and "West" bookends. The purpose of these runs were to originally define what is considered as the minimum and maximum bracketed operational plans for this project taking into consideration full restoration to the ENP (West) and flood control, water supply, and saltwater intrusion (East).

The Combined Operational Changes (COP) plan is undetermined at this time; since COP will potentially be working under different plan formulation constraints than the predecessor CSOP project (i.e. 8.5 constraint at Tamiami Trail instead of no constraint, with the associated need for controllable MWD conveyance features), the end result will be different than the CSOP TSP plan from January 2005.

C.5.1 Flood Control

Flooding has been a concern for all residents of Miami-Dade County. In the future, flooding would still be a concern in spite of millions of dollars in capital improvement projects from local, state and federal governments, many areas could still suffer repeated flood damages, due to large storms, above the water management system capacity.

As agricultural land use changes to urban, and wetland encroachment continues, the number and extension of flooded areas may increase. The actual level of

service may be reduced, particularly the low-lying areas, developed prior to the implementation of the current flood criteria standards and agricultural land encroached by urban development.

C.5.2 Forecasted Hydrologic Conditions

The hydrology of the C-111 SC future without project condition includes structural and operational modifications to the water management system as detailed in the 1993 GDM for the MWD to ENP and the 1994 GRR for the C-111, plus 2001 C-111 GRR Supplement. These projects will be installed upstream in the system to divert flows from L-31N and C-111 to the Northeast Shark River Slough and Taylor Slough portions of ENP.

Coastal salinity control structures will continue to operate in the future without project condition in accordance with the design operating criteria. However, a continued sea level rise may make it necessary to operate the canals at higher levels to avoid saltwater intrusion. Also, point sources of freshwater discharge will continue through the C-111 Canal to the estuarine systems of Manatee Bay and Barnes Sound. The natural areas present in the Southern Glades and the Model Lands area of South Miami-Dade County will remain hydrologically disconnected in the future without project condition, separated by US Highway 1 and Card Sound Road.

Hydrology in the future without condition will also be affected by land use changes. Current CERP land use projections for the project area indicate that urban development will remain spatially constrained, and agricultural lands will increase only slightly. However, recent trends show that urban development, specifically residential land use, may increase significantly, and that agricultural land use will decrease. The hydrologic affects of land use changes in the future without project condition will be captured by the project modeling. The most recent 2050 land use projections will be provided by Miami-Dade County for the C-111 SC future without project condition.

C.5.3 Water Supply Demands

An understanding of the *future without project* water supply demands is essential to understanding the amount of water available for the ecosystem restoration associated with the proposed C-111 SC project. In an effort to estimate existing water use, and in order to predict the overall demands on the water supply in the year 2050, the U.S. Army Corps of Engineers (USACE) commissioned a report entitled Municipal and Industrial (M&I) Water Use Forecasts, Initial Comprehensive Everglades Restoration Plan (CERP) Update (2003). It is the contents of this report which provides the basis for the majority of the text which follows.

Within the aforementioned report, water use forecasts were developed for various sectors including public and self-supply domestic (residential), commercial, industrial, government, and unaccounted-for water loss. The M&I water use forecasts were developed using the IWR-MAIN Water Demand Management Suite, a computerized water resource planning tool that allows the development of water use forecasts and the evaluation of water conservation reports. Although IWR-MAIN runs and report are limited to M&I uses, water use in agriculture, mining, and power generation are addressed later within this text.

Within the report, M&I forecasts were provided for all or part of nine individual counties. In order to accurately project their needs, the counties were divided into a series of service areas. The proposed project area is wholly contained within the service area described as Lower East Coast Service Area 3 (LECSA 3). Based on the foregoing, discussions regarding project relevant M&I water use forecasts will be limited to users within LECSA 3.

LECSA 3 consists of almost all of the developed areas along the Atlantic Coast within Miami-Dade County and the Florida Keys portion of Monroe County. The Miami-Dade Water and Sewer Authority and the Florida Keys Aqueduct Authority, which serve most of the public supplied population in Miami-Dade and Monroe counties, were contacted to obtain water use data. The Miami-Dade Water and Sewer Authority sells water wholesale to communities within the county and retail to residential and commercial customers throughout the county. U.S. Geological Survey (USGS) water use estimates and monthly water use data for the retail customers of the Miami-Dade Water and Sewer Authority and the Florida Keys Aqueduct Authority were used to calibrate the IWR-MAIN models to the water use patterns of LECSA 3.

M&I water use for the LECSA in 2000 was estimated at 373.2 million gallons per day (mgd) (which included 21.5 mgd for Monroe County). Under the "most-likely" scenario, by 2050, water use is projected to increase to 502.3 mgd (which includes 23.2 mgd for Monroe County). The most likely scenario includes the average University of Florida Bureau of Economic & Business Research (BEBR) population projections, coupled with average rainfall, and an assumption of compliance with currently enacted conservation measures. ***TABLE C-1*** provides a breakdown of M&I baseline and conservation adjusted water use projections, in five year increments, by sector. As shown in the table, for medium BEBR populations, the 2050 M&I water use projections range from a projected high of 622.8 mgd to a possible low of 404.1 mgd.

TABLE C-1: LEC SERVICE AREA 3

M&I BASELINE AND CONSERVATION ADJUSTED WATER USE,
MOST-LIKELY POPULATION SCENARIO, 2000-2050

		Baseline Water Use (MGD)			Conservation-Adjusted Water Use (MGD)		
Year	Sector	Dry	Wet	Annual	Dry	Wet	Annual
2000	Residential	236.0	233.0	234.8	236.0	233.0	234.8
	Commercial	72.9	71.3	72.2	72.9	71.3	72.2
	Industrial	7.1	7.1	7.1	7.1	7.1	7.1
	Government	6.9	6.9	6.9	6.9	6.9	6.9
	Unaccounted	52.6	51.8	52.2	52.6	51.8	52.2
	Total Municipal	**375.5**	**370.1**	**373.2**	**375.5**	**370.1**	**373.2**
2005	Residential	250.4	247.2	249.1	239.8	236.7	238.5
	Commercial	78.2	76.4	77.4	77.1	75.3	76.3
	Industrial	6.8	6.8	6.8	6.8	6.8	6.8
	Government	7.3	7.3	7.3	7.2	7.2	7.2
	Unaccounted	55.8	55.0	55.4	53.8	53.0	53.5
	Total Municipal	**398.5**	**392.7**	**396.1**	**384.7**	**379.0**	**382.3**
2010	Residential	266.6	263.2	265.2	246.0	242.7	244.6
	Commercial	83.4	81.6	82.6	81.2	79.4	80.5
	Industrial	6.5	6.5	6.5	6.4	6.4	6.4
	Government	7.8	7.8	7.8	7.5	7.5	7.5
	Unaccounted	59.3	58.4	58.9	55.5	54.7	55.2
	Total Municipal	**423.5**	**417.5**	**421.0**	**396.6**	**390.6**	**394.1**
2015	Residential	283.0	279.5	281.6	252.8	249.3	251.3
	Commercial	88.7	86.7	87.9	85.5	83.6	84.7
	Industrial	6.2	6.2	6.2	6.1	6.1	6.1
	Government	8.2	8.2	8.2	7.8	7.8	7.8
	Unaccounted	62.8	61.9	62.5	57.3	56.4	56.9
	Total Municipal	**449.0**	**442.6**	**446.3**	**409.4**	**403.2**	**406.8**
2020	Residential	297.3	293.6	295.8	258.5	254.9	257.0
	Commercial	94.1	92.0	93.2	89.9	87.9	89.1
	Industrial	5.9	5.9	5.9	5.7	5.7	5.7
	Government	8.7	8.7	8.7	8.1	8.1	8.1
	Unaccounted	66.1	65.1	65.7	59.0	58.0	58.6
	Total Municipal	**472.0**	**465.3**	**469.2**	**421.2**	**414.7**	**418.5**
2025	Residential	311.2	307.4	309.6	264.5	260.7	262.9
	Commercial	99.2	97.1	98.4	94.2	92.1	93.3
	Industrial	5.6	5.6	5.6	5.4	5.4	5.4
	Government	9.1	9.1	9.1	8.4	8.4	8.4
	Unaccounted	69.2	68.2	68.8	60.6	59.7	60.2
	Total Municipal	**494.3**	**487.4**	**491.5**	**433.0**	**426.3**	**430.2**
2030	Residential	324.1	320.2	322.5	270.1	266.2	268.5
	Commercial	104.0	101.7	103.0	98.0	95.9	97.1
	Industrial	5.3	5.3	5.3	5.1	5.1	5.1
	Government	9.5	9.5	9.5	8.7	8.7	8.7
	Unaccounted	72.1	71.1	71.7	62.1	61.2	61.7
	Total Municipal	**515.0**	**507.8**	**512.0**	**444.0**	**437.1**	**441.1**
2035	Residential	340.4	336.3	338.7	278.4	274.4	276.8
	Commercial	110.0	107.7	109.0	103.1	100.9	102.2
	Industrial	5.0	5.0	5.0	4.7	4.7	4.7
	Government	10.0	10.0	10.0	9.1	9.1	9.1
	Unaccounted	75.7	74.7	75.3	64.3	63.3	63.9
	Total Municipal	**541.2**	**533.7**	**538.1**	**459.7**	**452.5**	**456.7**
2040	Residential	356.9	352.6	355.1	287.2	283.1	285.5
	Commercial	116.1	113.6	115.1	108.3	105.9	107.3
	Industrial	4.6	4.6	4.6	4.4	4.4	4.4
	Government	10.5	10.5	10.5	9.5	9.5	9.5
	Unaccounted	79.4	78.3	79.0	66.6	65.6	66.2
	Total Municipal	**567.5**	**559.7**	**564.3**	**475.9**	**468.4**	**472.8**
2045	Residential	371.8	367.3	369.9	295.2	291.0	293.4
	Commercial	119.8	117.4	118.8	111.2	108.9	110.2
	Industrial	4.3	4.3	4.3	4.0	4.0	4.0
	Government	11.0	11.0	11.0	9.8	9.8	9.8
	Unaccounted	82.5	81.4	82.0	68.4	67.3	67.9
	Total Municipal	**589.4**	**581.4**	**586.1**	**488.6**	**481.0**	**485.4**
2050	Residential	386.9	382.3	384.9	303.6	299.2	301.8
	Commercial	126.9	124.2	125.8	117.4	114.8	116.3
	Industrial	4.0	4.0	4.0	3.7	3.7	3.7
	Government	11.5	11.5	11.5	10.1	10.1	10.1
	Unaccounted	86.1	84.9	85.6	70.8	69.6	70.3
	Total Municipal	**615.3**	**606.8**	**611.8**	**505.6**	**497.6**	**502.3**

Under the BEBR high population scenario, LECSA 3's annual average baseline M&I water use is projected to increase to 769.9 mgd (including 32.9 mgd for Monroe County) by 2050, while the high population annual average conservation-adjusted M&I water use is projected to increase to 622.8 mgd (of which Monroe County is projected to account for 30.2 mgd).

Under the BEBR low population scenario, LECSA 3's annual average baseline M&I water use is projected to increase to 483.3 mgd by 2050 (including 17.7 mgd in Monroe County), while the low population conservation-adjusted M&I water use is projected to increase to 404.1 mgd (of which Monroe County is projected to account for 16.4 mgd).

In addition to the scenarios described above, the IWR-MAIN model was used to project M&I water use during a 1-in-10 Year Drought Condition. As shown in ***TABLE C-2***, under the 1-in-10 year drought scenario, the annual average M&I baseline water use is projected to increase from 373.2 mgd (in 2000) to 618 mgd by 2050 (including 25.4 mgd in Monroe County). M&I water use projections assuming compliance with water conservation measures are projected at 508.5 mgd by 2050, of which 23.5 mgd is projected for use in Monroe County. Conservation-adjusted water use projections are also presented within the table.

It is important to note that the M&I water use projections presented excluded self supplied (i.e. non municipal supplied) irrigation for agriculture, golf course, and landscaping, deep well withdrawals from the brackish Floridan aquifer, and other non-consumptive uses. An example of the latter being water "used" in rock mining operations, which is generally returned immediately after use. In the case of Floridan aquifer withdrawals, because they represent a withdrawal of the water far removed from the Everglades system, they are beyond the domain of the employed models, and will not be considered within this text.

Self-supplied landscape irrigation demand estimates for the entire LECSA are based on future land use maps developed for local government comprehensive plans, and are anticipated to increase by 48 percent to an average annual demand of 499,000 acre-feet. Similarly, self-supplied golf course irrigation within the LECSA is estimated to increase by 31 percent with average annual demand of 71,800 acre-feet.

Agricultural irrigation within the LECSA includes irrigation for row crops, citrus, tropical fruits and nurseries. Overall, most agricultural irrigation is expected to decline in the future with the exception of nursery irrigation, which is expected to increase. Total agricultural irrigation demands for the entire LECSA are estimated to decline by 28 percent to a total annual average demand of 136,600 acre-feet. Nursery irrigation within the LECSA is estimated to increase by 164 percent to a total annual average demand of 52,900 acre-feet.

TABLE C-2: LEC SERVICE AREA 3

M&I BASELINE AND CONSERVATION ADJUSTED WATER USE,
1-10 YEAR DROUGHT W/ MOST-LIKELY POPULATION SCENARIO, 2000-2050

		Baseline Water Use (MGD)			Conservation-Adjusted Water Use (MGD)		
Year	Sector	Dry	Wet	Annual	Dry	Wet	Annual
2000	Residential	236.0	233.0	234.8	236.0	233.0	234.8
	Commercial	72.9	71.3	72.2	72.9	71.3	72.2
	Industrial	7.1	7.1	7.1	7.1	7.1	7.1
	Government	6.9	6.9	6.9	6.9	6.9	6.9
	Unaccounted	52.6	51.8	52.2	52.6	51.8	52.2
	Total Municipal	**375.5**	**370.1**	**373.2**	**375.5**	**370.1**	**373.2**
2005	Residential	254.2	251.0	252.9	243.7	240.5	242.3
	Commercial	78.0	76.3	77.3	76.9	75.2	76.2
	Industrial	6.8	6.8	6.8	6.8	6.8	6.8
	Government	7.3	7.3	7.3	7.2	7.2	7.2
	Unaccounted	56.4	55.6	56.0	54.4	53.6	54.1
	Total Municipal	**402.7**	**397.0**	**400.3**	**388.9**	**383.2**	**386.6**
2010	Residential	270.6	267.3	269.2	250.0	246.7	248.7
	Commercial	83.2	81.4	82.5	81.1	79.3	80.3
	Industrial	6.5	6.5	6.5	6.4	6.4	6.4
	Government	7.8	7.8	7.8	7.5	7.5	7.5
	Unaccounted	59.9	59.1	59.6	56.1	55.3	55.8
	Total Municipal	**428.1**	**422.0**	**425.5**	**401.1**	**395.2**	**398.6**
2015	Residential	287.3	283.8	285.9	257.1	253.6	255.7
	Commercial	88.5	86.5	87.7	85.3	83.4	84.5
	Industrial	6.2	6.2	6.2	6.1	6.1	6.1
	Government	8.2	8.2	8.2	7.8	7.8	7.8
	Unaccounted	63.5	62.6	63.1	58.0	57.1	57.6
	Total Municipal	**453.8**	**447.4**	**451.1**	**414.2**	**408.0**	**411.6**
2020	Residential	301.8	298.1	300.2	263.0	259.4	261.5
	Commercial	93.9	91.8	93.0	89.7	87.7	88.9
	Industrial	5.9	5.9	5.9	5.7	5.7	5.7
	Government	8.2	8.2	8.2	7.8	7.8	7.8
	Unaccounted	66.7	65.8	66.3	59.6	58.7	59.2
	Total Municipal	**476.4**	**469.8**	**473.7**	**425.8**	**419.3**	**423.1**
2025	Residential	315.9	312.0	314.3	269.1	265.4	267.6
	Commercial	99.0	96.9	98.1	93.9	91.9	93.1
	Industrial	5.6	5.6	5.6	5.4	5.4	5.4
	Government	9.1	9.1	9.1	8.4	8.4	8.4
	Unaccounted	69.9	68.9	69.5	61.3	60.4	60.9
	Total Municipal	**499.5**	**492.6**	**496.6**	**438.2**	**431.5**	**435.4**
2030	Residential	329.0	325.0	327.3	274.9	271.1	273.3
	Commercial	103.7	101.5	102.8	97.8	95.7	96.9
	Industrial	5.3	5.3	5.3	5.1	5.1	5.1
	Government	9.1	9.1	9.1	8.4	8.4	8.4
	Unaccounted	72.8	71.8	72.3	62.9	61.9	62.5
	Total Municipal	**519.9**	**512.7**	**516.9**	**449.1**	**442.1**	**446.2**
2035	Residential	345.5	341.3	343.7	283.5	279.5	281.8
	Commercial	109.8	107.5	108.8	102.9	100.7	102.0
	Industrial	5.0	5.0	5.0	4.7	4.7	4.7
	Government	10.0	10.0	10.0	9.1	9.1	9.1
	Unaccounted	76.5	75.5	76.1	65.1	64.1	64.7
	Total Municipal	**546.8**	**539.3**	**543.6**	**465.3**	**458.1**	**462.3**
2040	Residential	362.1	357.8	360.3	292.4	288.3	290.7
	Commercial	115.8	113.4	114.8	108.0	105.7	107.1
	Industrial	4.6	4.6	4.6	4.4	4.4	4.4
	Government	10.5	10.5	10.5	9.5	9.5	9.5
	Unaccounted	80.3	79.2	79.8	67.4	66.4	67.0
	Total Municipal	**573.4**	**565.5**	**570.1**	**481.7**	**474.2**	**478.6**
2045	Residential	377.2	372.8	375.4	300.7	296.4	298.9
	Commercial	121.2	118.8	120.2	112.5	110.2	111.5
	Industrial	4.3	4.3	4.3	4.0	4.0	4.0
	Government	11.0	11.0	11.0	9.8	9.8	9.8
	Unaccounted	83.6	82.5	83.1	69.5	68.4	69.0
	Total Municipal	**597.3**	**589.3**	**594.0**	**496.5**	**488.9**	**493.3**
2050	Residential	392.5	387.9	390.6	309.3	304.9	307.4
	Commercial	126.6	124.0	125.5	117.1	114.6	116.0
	Industrial	4.0	4.0	4.0	3.7	3.7	3.7
	Government	11.5	11.5	11.5	10.1	10.1	10.1
	Unaccounted	87.0	85.8	86.5	71.6	70.5	71.2
	Total Municipal	**621.5**	**613.1**	**618.0**	**511.9**	**503.8**	**508.5**

C.6 WATER QUALITY

Water quality of the lower C-111 Basin has been affected by upstream pollution loadings and changes in water delivery system changes. The May 1994 GRR mentioned mercury and nutrients as the greatest threats to water quality in the region. Currently, elevated mercury levels are still a concern. Ongoing studies increasingly identify global atmospheric loading as the likely source of regional mercury contamination, redistribution of that mercury into areas could have a significant effect. Nutrients, total suspended solids, pesticides and to some extent, salinity have become the primary focus of water quality protection efforts in the southern Everglades region.

C.6.1 Nutrients

The Everglades is a naturally low-nutrient system--the background concentration of total phosphorus (TP) within pristine areas of ENP is thought to be in the range of 6 to 10 parts per billion (ppb). Many agree that the minimum TP concentration that causes an imbalance in natural vegetation patterns and periphyton algal communities could be as low as 10 ppb. The 10 ppb TP criterion has been incorporated in the 2003 Everglades statute passed by the State of Florida legislature and the phosphorus rule adopted by the State of Florida ERC (Everglade Forever Act, 2003). Anthropogenic sources of TP to the lower C-111 Basin resulted in changes in vegetation patterns and periphyton communities. Following extensive Federal litigation and mediation (U.S. vs. SFWMD, et al., 11 July 1991), a settlement agreement was adopted that set short-term and long-term phosphorus limits in discharges to the Everglades including Taylor Slough and the Coastal Basins in the C-111 Canal Watershed. Nutrient loads delivered to ENP through the lower C-111 Basin will vary depending upon the source of the water and the location where water is delivered.

C.6.2 Phosphorus

Times series analyses of the water quality data show that total phosphorus (TP) concentrations within the C-111 Basin (both in the agricultural areas and in the ENP) occasionally exceed the 11 ppb inflow limit for Taylor Slough and the Coastal Basins. This limit will become effective December 30, 2006. The basin receives water from S-178 on the C-111E Canal that showed the highest TP concentrations (24 ppb) of any structure in the C-111 Basin (Pfeuffer, 1998). An increase in groundwater flow is proposed from ENP into Taylor Slough through S-332D, potentially reducing water availability to the lower C-111 Basin, which would reduce the dilution rate of TP in the lower basin. Water discharged from C-111 Basin canals to the Taylor Slough and Panhandle areas of ENP are originated from water from local runoff and seepage from the South Dade Agricultural Area adjacent to the C-111 canals. TP loads and concentrations at

the S-18C structures are influenced by the relative magnitude of contributions from these water sources.

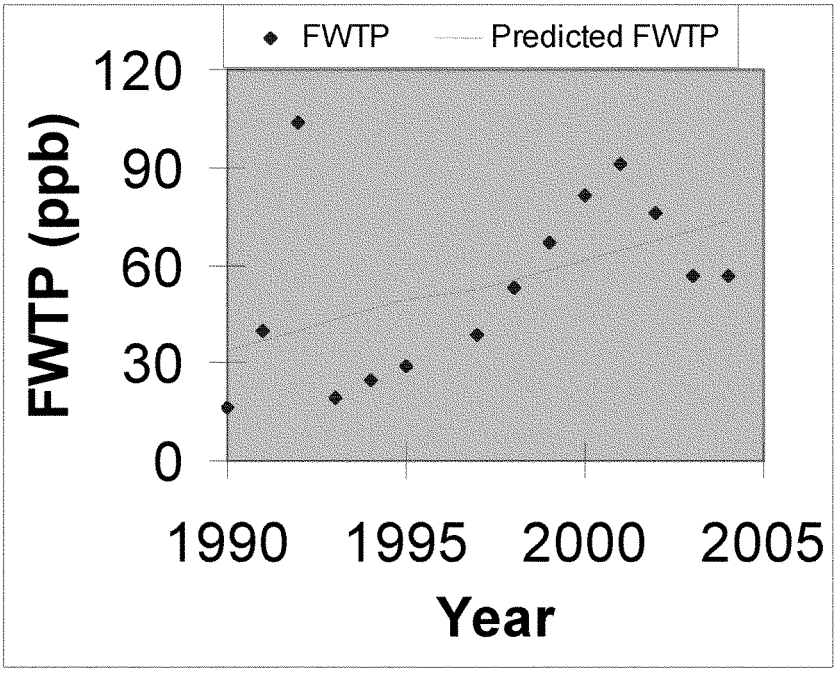


FIGURE C-1: THE TREND OF FLOW WEIGHTED TOTAL PHOSPHORUS CONCENTRATION AT S-178

The trend analysis at S178 indicates that the flow weighted TP concentration (FWTP) fluctuated during the past 15 years. There was an insignificant increase for FWTP concentration (P=0.0975) with an annual 3 ppb increase rate. The flow weighted TP concentration is stabilized at about 60 ppb in the most recent years. If the trend portrayed in ***FIGURE C-1*** continues, the FWTP will be at 60 ppb in the future without project condition.

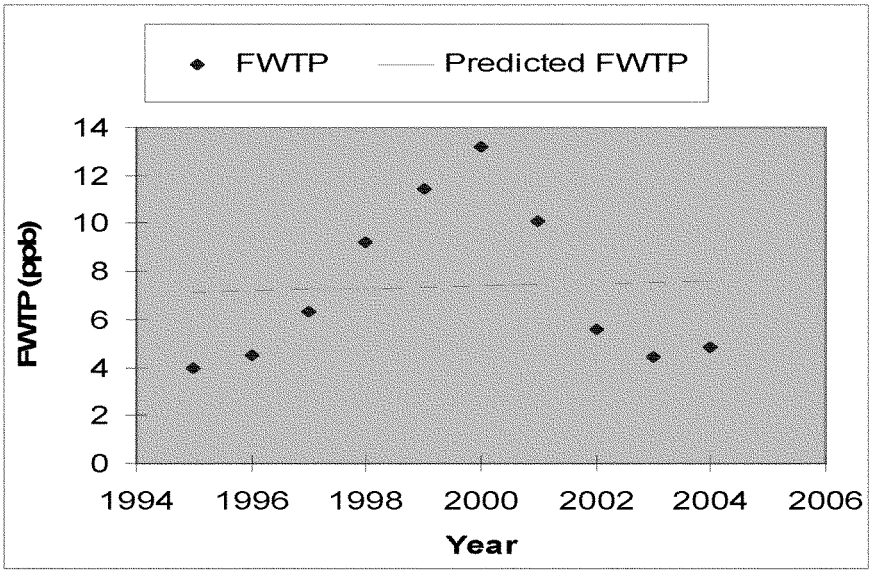


FIGURE C-2: THE TREND OF FLOW WEIGHTED TOTAL PHOSPHORUS CONCENTRATION AT S-177

The TP trend analysis at S-177 indicates that the FWTP increased from 1995 to 2000 and decreased from 2000 to 2003, and it has been stabilized at about 5 ppb after 2002. The increase was insignificant (P=0.90) for FWTP from 1995 to 2004. If the trend portrayed in ***FIGURE C-2*** continues, the FWTP will be less than 6 ppb in the future without project condition.

Since completion of the May 1994 GRR, efforts have been made to minimize the opening of S-197 and to increase sheet flow through the Panhandle of ENP to Florida Bay by removing the spoil mounds along the south bank of a 5-mile reach of lower C-111. This not only reduced impacts to Manatee Bay and Barnes Sound but also the over-drainage of adjacent marshes associated with large S-197 discharges. The SFWMD is currently conducting studies to determine the nutrient concentrations in water flowing from the lower C-111 spoil mound removal area to adjacent marshes, the Panhandle of ENP and Florida Bay.

C.6.3 Total Suspended Solids

Total suspended solids (TSS) have been used as performance measure for this project.

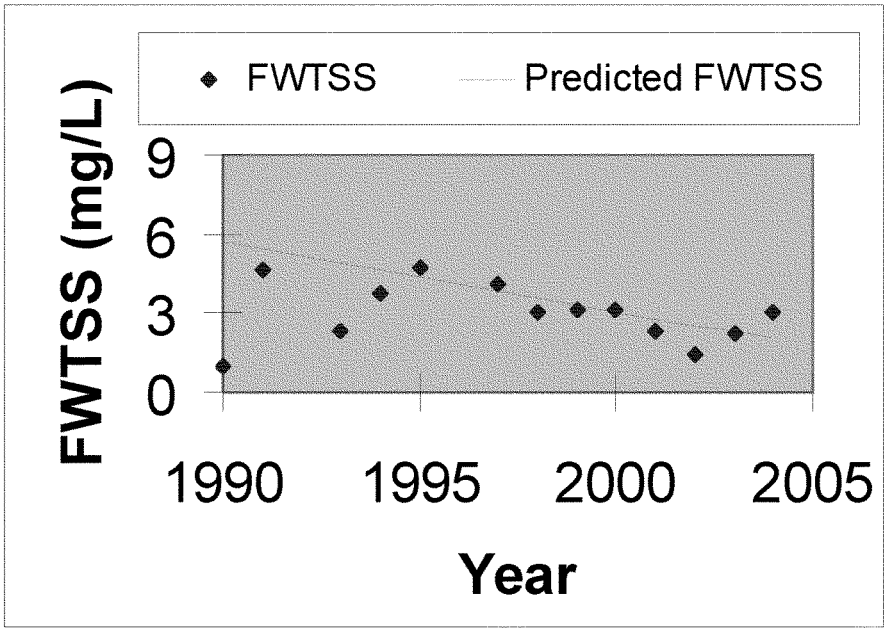


FIGURE C-3: THE TREND OF FLOW WEIGHTED TOTAL SUSPENDED SOLIDS CONCENTRATION AT S-178

The TSS trend analysis at S-178 indicates that the flow weighted total suspended solids (FWTSS) fluctuated during the past 15 years. The FWTSS shows an insignificant decrease (P=0.20) with time at the annual rate of 0.26 mg/L. The FWTSS is about 3 mg/L in recent years. If the trend portrayed in ***FIGURE C-3*** continues, the FWTSS will be under 3 mg/L in the future without project condition.

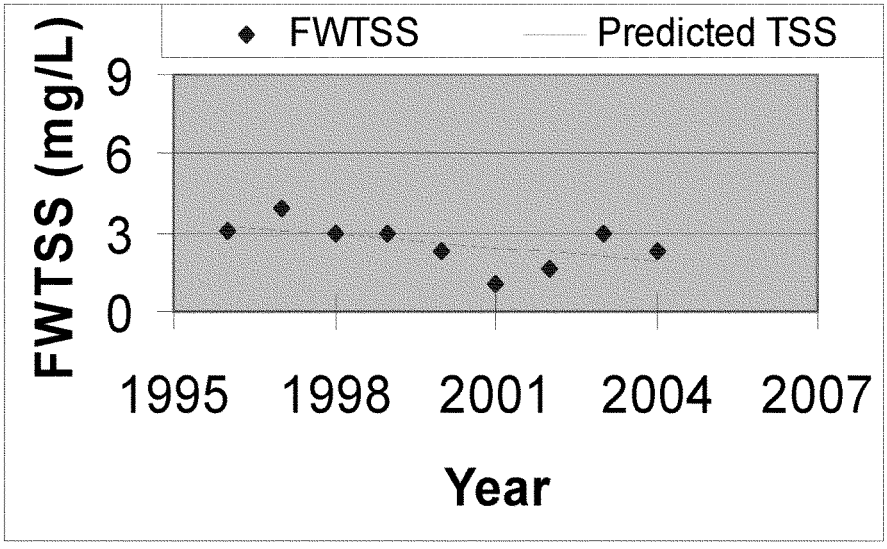


FIGURE C-4: THE TREND OF FLOW WEIGHTED TOTAL SUSPENDED SOLID CONCENTRATION AT S-177

The TSS trend analysis at S-177 indicates that the FWTSS fluctuated. The annual decrease rate of 0.17 mg/L was insignificant (P=0.13). The FWTSS was under 3 mg/L in recent years. If the trend portrayed in ***FIGURE C-4*** continues, the FWTSS will be under 3 mg/L in the future without project condition.

C.6.4 Pesticides

The Homestead agricultural area, which generally lies northeast of the proposed project features sustains a productive agricultural industry, whose success depends, in part, on the use of agro-chemicals including pesticides. Pesticide concentrations found in surface water and sediment appear to be generally decreasing over time as a result of conversion of private lands to conservation, implementation of better management techniques, and a move away from using older pesticide formulations

C.6.4.1 Pesticides in Surface Water

Between 1993 and 1997, the National Oceanic and Atmospheric Administration (NOAA) conducted a contaminant study (Scott et al., 2002), and determined that endosulfan, atrazine, chlorpyrifos, and chlorothalonil were present in the canal adjacent to agricultural areas within the C-111 Basin. At Structure S-178,

approximately ten percent of the samples obtained from the canal sites were determined to have exceeded the freshwater criterion for total endosulfan.

Data collected by the Non-Federal Sponsor (NFS) confirms that elevated levels of endosulfan (see ***TABLE C-3***) historically existed within the C-111-E canal near structure S-178. Specifically, the NFS's data indicates that, water drawn from the canal near S-178 exceeded the freshwater criterion for total endosulfan during 7 (of 34) sampling events between 1993 and 2000. It is important to note that during that period, the worst case concentration (in 1994) was more than 5 times the freshwater standard.

In contrast to the earlier (NFS collected) S-178 data, similar data collected between 2001 and 2009 (from within the C-111-E canal near structure S-178), indicated only a single minor exceedance (.001 microgram per liter) of the 0.056 µg/L standard, which is well within the uncertainties of the laboratory method

TABLE C-3: SFWMD TOTAL ENDOSULFAN CONCENTRATIONS FROM THE C-111E CANAL AT S-178

Station	Year	*Range of detected values (µg/L)	# sampling events	# of detections	# events exceeding 0.056 µg/L F.A.C. 62-302 Class III Freshwater Standard
S-178	1993	BDL - 0.064	5	3	2
	1994	BDL - 0.298	6	3	3
	1995	BDL - 0.038	4	1	0
	1996	BDL - 0.08	4	3	1
	1997	BDL - 0.0168	4	1	0
	1998	BDL - 0.0128	4	1	0
	1999	BDL - 0.037	4	1	0
	2000	BDL - 0.058	3	2	1
	2001	BDL - 0.014	4	2	0
	2002	BDL - 0.0297	4	1	0
	2003	BDL - 0.028	4	1	0
	2004	BDL - 0.044	4	3	0
	2005	BDL - 0.034	4	2	0
	2006	BDL - 0.0043	4	1	0
	2007	BDL - 0.057	4	2	1
	2008	BDL - 0.0064	4	1	0
	2009	BDL - 0.022	4	1	0
*BDL - Indicates Concentration is Below Detection Limits					

More importantly from the project perspective, total endosulfan data collected between 1993 and 2009 (see ***TABLE C-4*** below) from the C-111 Canal near structure S-177, which is representative of the project's source water, indicated no exceedances of the freshwater criterion for total endosulfan between 1993 and 2009. Based on this, and other data, all water diverted by the project will meet current State of Florida numerical water quality standards for pesticides.

TABLE C-4: SFWMD TOTAL ENDOSULFAN CONCENTRATIONS FROM THE C-111 CANAL AT S-177

Station	Year	*Range of detected values (µg/L)	# sampling events	# of detections	# events exceeding 0.056 µg/L F.A.C. 62-302 Class III Freshwater Standard
S-177	1993	BDL - 0.035	5	3	0
	1994	BDL - 0.034	6	2	0
	1995	BDL - 0.041	4	1	0
	1996	BDL - 0.013	4	1	0
	1997	BDL - 0.02	4	2	0
	1998	BDL	4	0	0
	1999	BDL	4	0	0
	2000	BDL - 0.039	3	2	0
	2001	BDL	4	0	0
	2002	BDL - 0.036	4	1	0
	2003	BDL - 0.0080	4	1	0
	2004	BDL - 0.0170	4	3	0
	2005	BDL - 0.018	4	1	0
	2006	BDL - 0.028	4	1	0
	2007	BDL - 0.0085	4	2	0
	2008	BDL - 0.0081	4	1	0
	2009	BDL - 0.015	4	1	0
*BDL - Indicates Concentration is Below Detection Limits					

It is believed that endosulfan, and other pesticide, concentrations will continue to decrease over time as a result of conversion of private lands to conservation, implementation of better management techniques, and a move away from using older pesticide formulations.

C.6.4.2 Pesticides in Sediments

The Non-Federal Sponsor (NFS) has chartered Phase I and Phase II studies on properties either owned, or to be acquired for project use. The results of these studies were used to determine if the land under consideration is suitably clean for the intended use, or if some form of change is necessary prior to plan implementation.

During the course of these studies, the NFS determined that detectable levels of Total Chlordane, 4,4-DDT, 4,4-DDD, and 4,4-DDE were present in the soils within the project footprint. However, as described in ***Annex B.2.2.3***, none of these residual pesticides were found at concentrations violating Federal or State standards for agricultural (commercial & industrial) land use.

C.6.4.3 Pesticide in Groundwater

Pesticides have been sampled for, but not detected in the groundwater below the lands considered for this project. However, uncapped water-wells used as a water supply source for mobile irrigation equipment are suspected as likely avenues of pesticides contamination of groundwater in non-project land areas where farming continues to be practiced. To address this potential groundwater contamination source, implementation of an agricultural BMP program that includes well capping is under way within the basin.

C.6.5 Mercury

Mercury is a persistent, bioaccumulative toxicant and, as such, can build up in the food chain to levels that are harmful to both human and ecosystem health. Since 1989, Florida has been known to have a mercury problem in both freshwater and coastal systems. In Florida Bay, consumption advisories have been issued for select fish species (e.g., Snook, Red drum, Great Barracuda, Spotted Sea Trout, Crevalle Jack, Gray Snapper, and Tripletail) due to tissue mercury levels (Florida Department of Health, 2004). Recent surveys continue to find fish from eastern Florida Bay, near mainland inflows, to have mercury levels elevated relative to other parts of the bay (Evans et. al., 2003; Evans and Crumley, in review), relative to other estuaries in south Florida (Adams and McMichael, 2003) and, relative to other estuaries along the Gulf of Mexico (Ache et al., 2000).

Generally, the ultimate source of total mercury (THg) to most water bodies is atmospheric loading. A recent study of Florida Bay's mercury problem found direct atmospheric deposition to be the dominant source of THg inputs to the system, at least for the larger basins (Rumbold et al. 2004). Indirect atmospheric deposition and surface water runoff was of greater importance in THg loading to smaller basins that had substantial surface water inflows.

However, the concern is not as much about the absolute quantity of THg, but how much of it is in the more toxic and bioaccumulative form – methylmercury (MeHg). Mercury is methylated primarily by sulfate-reducing bacteria in aquatic sediments. Generally, only a very small percentage of the THg in atmospheric deposition is in the methyl form. Not surprisingly, atmospheric loading was found to be less important than surface water loading as the source of MeHg to Florida Bay (Rumbold et al., 2004). Interestingly, MeHg export from Taylor Slough, via Taylor River, exceeded inputs to the basin from S332D, suggesting elevated MeHg production within the downstream marsh, particularly within the mangrove transition zone (Rumbold et al., 2004). Equally interesting in this context, MeHg export from Taylor Slough (i.e., to Little Maderia Bay) appeared to be equal or exceed total inputs from the C111 Basin (i.e., to Joe Bay via a number of small creeks). The factor or factors responsible for the difference in MeHg export between the two basins are as yet unknown but may include watershed size (i.e., spatial extent of marsh where methylation occurs) or net rates of mercury methylation, which is a function of hydrology, water quality and biogeochemistry.

The May 1994 GRR noted mercury as one of the greatest threats to water quality in the region. Currently, elevated mercury levels are still a concern. Ongoing studies increasingly identify global atmospheric loading as the likely source of regional mercury contamination. Schmidt and Evans (personal communication) reported that all of the fish have mercury in them. The average mercury concentration tends to be higher for most, but not all, species in the Taylor River/Little Madeira Bay area than in the C-111/Joe Bay area. Mercury and methylmercury in water and sediments seems to a bit higher there too. In the current data set, 42 percent of gray snapper exceeded the 0.5 ppm Hg level in the TR/LMB area but only 14 percent in the C-111/JB area. For crevalle jacks the proportions exceeding 1.5 ppm Hg were 32 percent and 17 percent, respectively.

C.6.5.1 Mercury Trend Analysis

The trend analysis was conducted at S-18C. The trend analysis indicates that the levels of Methyl Mercury fluctuated. The annual increase of 0.0028 ng/L was statistically insignificant (P= 0.61707). If the trend portrayed in ***FIGURE C-5*** continues, the methyl mercury concentration will continue to fluctuate with time in the future without project condition.

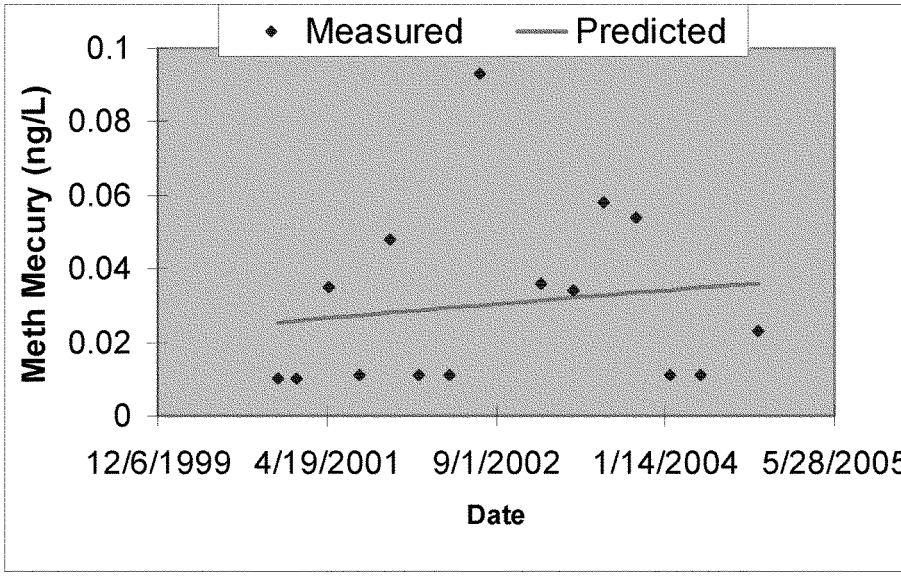


FIGURE C-5: THE TREND OF METHYL MERCURY AT S-18C

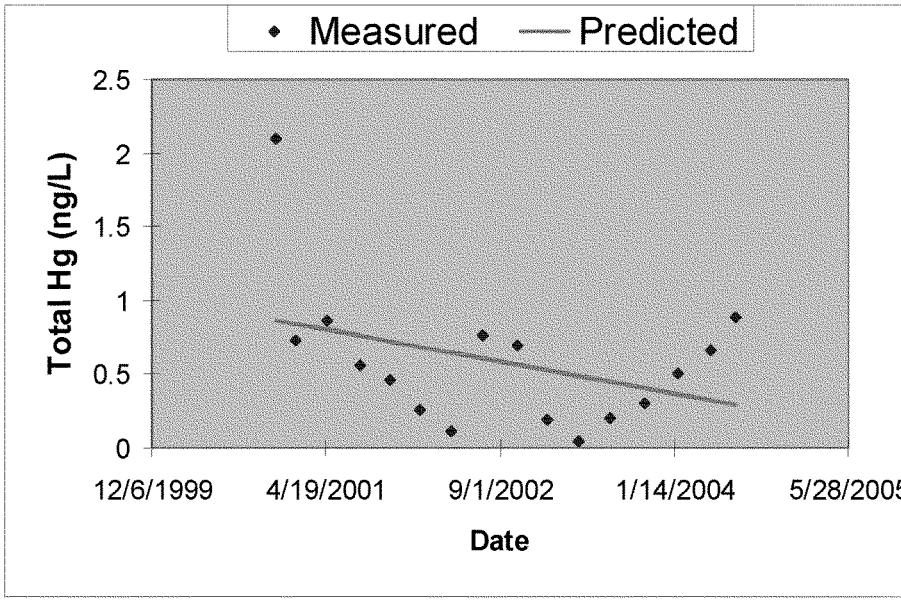


FIGURE C-6: THE TREND OF TOTAL MERCURY AT S-18C

The trend analysis indicates that levels of Total Mercury fluctuated. The analysis shows an annual decrease of 0.16 ng/L, which was statistically insignificant (P= 0.1409). If the trend portrayed in ***FIGURE C-6*** continues, the total mercury concentration will continue to fluctuate with time in the future without the project condition.

Because the mercury cycle is complex with many non-linear processes, it is difficult to account for current trends, let alone forecast future mercury trajectories without project conditions. Recent downward trends in mercury bioaccumulation in fish, alligators and wading birds at several locations in south Florida, particularly WCA 3A, have been ascribed to decreases in mercury emissions and deposition (for review, see Axelrad et al., 2005). However, more recent data may suggest localized decreases in water-column sulfate concentrations and, as result, reductions in methylation rates, played a role in these declines (D. Krabbenhoft and W. Orem, USGS, pers. communication; though the reason for the decreased sulfate remain unclear). The latter hypothesis is strengthened by observations that mercury bioaccumulation has not declined uniformly across the system as one might expect if it were due to reductions in atmospheric deposition. For example, mercury levels have either not declined or have rebounded at several locations within ENP, including Florida Bay (Strom and Graves, 2001; Evans et al., 2003; Axelrad et al., 2005; Rumbold, 2005). The hypothesis that localized reductions in sulfate led to declines in mercury bioaccumulation in WCA-3A is further supported by recently observed increases in mercury deposition at the three Mercury Deposition Network sites in south Florida, including the Baird Research Center site in ENP (Rumbold, 2005). Given this, if without project the spatial extent of the marsh within the C-111 Basin remains unchanged and methylation rates are not altered in the marsh (by changes in water quality, hydrology, etc.), one might expect mercury levels in the marsh and downstream estuary to fluctuate and possibly increase with time.

C.6.6 Salinity

To provide flood protection during large storm events, drainage water has been discharged from the lower C-111 Canal through S-197 into the Manatee Bay/Barnes Sound area of Southern Biscayne Bay. The magnitude of the impacts on Manatee Bay and Barnes Sound caused by the resulting rapid changes in salinity depends on the duration and total volume of these discharges. During these storm events, impacts of the drainage also occur in the marshes adjacent to the C-111 Canal. In addition, freshwater sheetflow is diverted from Northeast Florida Bay and discharged as a point source into Manatee Bay/Barnes Sound. The C-111 Basin drains into eastern Florida Bay through Taylor Slough and overland flows from the lower C-111. Florida Bay currently experiences salinity imbalances that are believed to be caused, in part, by changes in the historic timing and quantity of freshwater delivered from the

C-111 Basin. SFWMD, in conjunction with FIU, is currently performing monitoring of salinity levels in Florida Bay.

C.6.6.1 Salinity Trend Analysis

The trend analysis was conducted at West Highway Creek. The trend analysis indicated that the salinity fluctuated. The trend of annual increases at the rate of 0.41 ppt was statistically significant (P= 0.0002). The mean salinity was 11.9 ppt for the top layer. If the trend portrayed in ***FIGURE C-7*** continues, the salinity will be increase with time in the future without project condition.

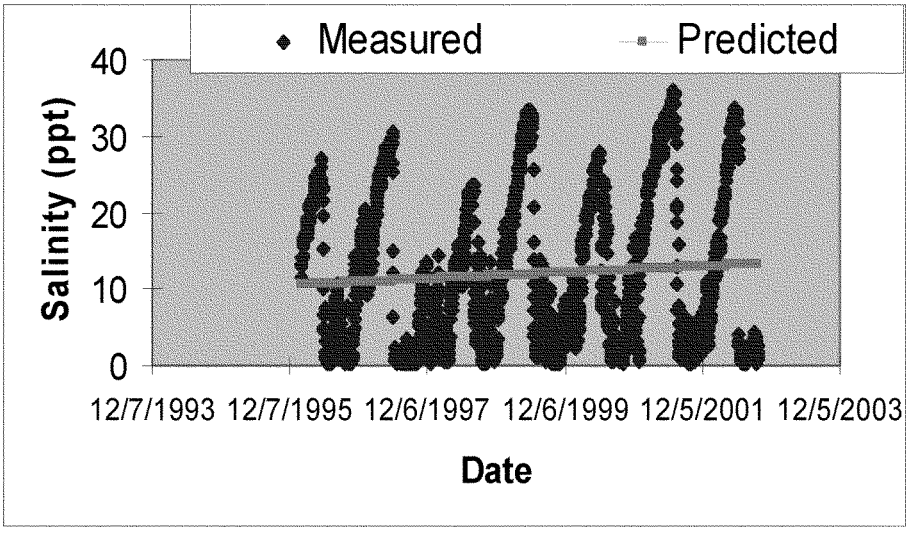


FIGURE C-7: THE TREND OF SALINITY AT TOP LAYER OF WEST HIGHWAY CREEK

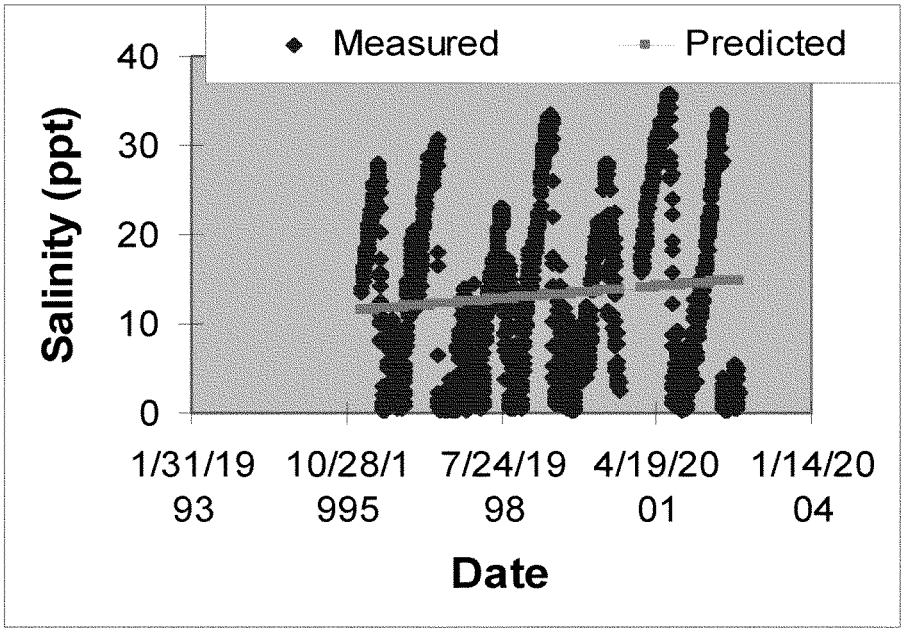


FIGURE C-8: THE TREND OF SALINITY AT BOTTOM LAYER OF WEST HIGHWAY CREEK

The trend analysis indicates that the salinity fluctuated at the bottom layer of West Highway Creek. The trend of annual increase rate at 0.51 ppt was statistically significant (P = 0.000006). The mean salinity was 13.1 ppt for the bottom layer. If the trend portrayed in ***FIGURE C-8*** continues, the salinity will increase with time in the future without project condition.

The unnatural variations in salinity that northeastern Florida Bay, Manatee Bay, and Barnes Sound have experienced due to the construction and operation of the C-111 Canal system would continue to exasperate into the future. Only a reintroduction of sheetflow will help reestablish freshwater marshes, particularly those east of US Highway 1, that have become saline due to rerouting discharges through the C-111 system. Until native habitat is reestablished and salinity fluctuations reduced, adverse impacts to fish and wildlife resources, including listed species, are expected to increase in a future without project scenario.

C.6.7 Other Toxicants/Pathogens

Sediment quality and toxicant/pathogen input is a stressor of the Biscayne Bay conceptual model. It is linked to dissolved and suspended solids inputs and sediment contamination. These stressors are particularly significant in urban estuaries, where contaminants such as pathogens, heavy metals and synthetic organic chemicals may enter the system through stormwater runoff, sewage or industrial discharges, and agricultural practices. Because of low solubility in water and dilution, many of these contaminants may be difficult to detect in water, but they tend to associate with sediments and may accumulate to levels known to cause biological effects. Current conditions show that toxicants such as heavy metals, PCBs, pesticides and PAHs have accumulated in urban area sediments of Biscayne Bay and its tributaries to levels known to cause toxicity and other biological effects (McDonald, 1994). Water column toxicants and pathogens such as ammonia and sewage-related pathogens are also present. Changes in water management practices may affect conveyance of contaminated sediments or change exposure pathways.

C.7 AIR QUALITY

The direct air emissions impact of no action would eliminate approximately 16 tons per year of nitrogen oxides (500 cfs, ~ 1000 BHP diesel driver). However, it is anticipated that significant number of smaller emission sources would be created over the next several decades as the land is developed. It is difficult to predict future air emissions generated within the current C-111 spreader footprint, because great development and pro-business pressures may force this land to be used to meet the ever-increasing expansion needs of Miami.

C.8 CULTURAL RESOURCES

A review of the Florida Master Site Files indicated several known archaeological sites within the C-111 Spreader Canal project area, which includes the site of Flagler Railroad. However, after a site visit to the project area, and due the remote location of the C-111 Spreader Canal project, it is unlikely that a future without conditions with have an impact on any historical properties. Consultation with the Florida State Historical Preservation Officer is ongoing and construction will not commence until the Section 106 process is complete. This determination has been made in compliance with Section 106 of the National Historic Preservation Act of 1966 (PL89-665), as amended in 2000; its' implementing regulations (36 CFR Part 800) and the Archaeological and Historic Preservation Act of 1974 (PL93-291), as amended.

C.8.1 Cultural Resources Correspondence

FLORIDA DEPARTMENT OF STATE
Kurt S. Browning
Secretary of State
DIVISION OF HISTORICAL RESOURCES

Ms. Natalie Garrett
U.S. Army Corps of Engineers
701 San Marco Blvd.
Jacksonville, Florida 32207

October 16, 2008

Re: DHR Project File No.: 2008-05829 / Received by DHR: September 5, 2008
DRAFT: Phase I Archaeological Survey of the C-111 Spreader Canal, Miami-Dade County, Florida

Dear Ms. Garrett:

Our office received and reviewed the above referenced draft survey report in accordance with Section 106 of the *National Historic Preservation Act of 1966* (Public Law 89-665), as amended in 1992, and *36 C.F.R., Part 800: Protection of Historic Properties*, and Chapter 267, *Florida Statutes*, for assessment of possible adverse impact to cultural resources (any prehistoric or historic district, site, building, structure, or object) listed, or eligible for listing, in the National Register of Historic Places (NRHP).

In June 2008, New South Associates, Inc. (NSA) conducted an archaeological and historical Phase I survey of the C-111 Spreader Canal project area on behalf of the U.S. Army Corps of Engineers. NSA identified one previously unrecorded historic resource group within the project area during the investigation.

NSA determined that the historic road and canal system (8DA11433) does not appear to be eligible for listing on the NRHP based on its lack of significant historical associations or distinctive design.

NSA determined that the proposed project will have no effect on the railroad or other cultural resources listed, or eligible for listing, on the NRHP. NSA recommends no further investigation of the project area.

Based on the information provided, our office concurs with the determinations of the U.S. Army Corps of Engineers.

However, in order to be complete and sufficient in accordance with Chapter 1A-46, *Florida Administrative Code*, the final report must contain the following revisions:

- **Shovel Test Maps:** The text indicates that no subsurface testing was conducted at Area G, but there is a map plotting shovel tests in the report. The report is also missing shovel test maps for Areas H and I.
- **Photograph or Digital Image:** A black and white archival quality photograph or digital image conforming to Florida Master Site File standards must be included with the resource group form for 8DA11433.

500 S. Bronough Street • Tallahassee, FL 32399-0250 • http://www.flheritage.com

☐ Director's Office (850) 245-6300 • FAX: 245-6436
☐ Archaeological Research (850) 245-6444 • FAX: 245-6452
☑ Historic Preservation (850) 245-6333 • FAX: 245-6437

Ms. Garrett
October 16, 2008
Page 2

- **Unexpected Discoveries:** The report must contain recommendations in the event that unexpected archaeological discoveries are encountered during project activities.

- **Curation:** The report must indicate where project records will be curated.

For any questions concerning our comments, please contact April Westerman, Historic Preservationist, by electronic mail at amwesterman@dos.state.fl.us, or by phone at (850) 245-6333. We appreciate your continued interest in protecting Florida's historic properties.

Sincerely,

Frederick P. Gaske, Director, and
State Historic Preservation Officer

Xc: Greg Smith, New South Associates
804-C Anastasia Boulevard
St. Augustine, Florida 32080

Planning Division
Environmental Branch

JAN 12 2009

Mr. Frederick P. Gaske
State Historic Preservation Officer
Division of Historical Resources
500 South Bronough Street
Tallahassee, Florida 32399-0250

Re: DHR Project File No.: 2008-05829

Dear Mr. Gaske:

Enclosed is a single bound copy and CD of the final report, *Phase I Cultural Resources Survey, C-111 Spreader Canal, Miami-Dade County, Florida* by New South Associates. This report is provided in accordance with the procedures contained in 36 CFR, Part 800 ("Protection of Historic Properties"). This report contains the revisions requested by your office in the letter dated October 16, 2008.

One site 8DA11433 was recorded but is recommended not eligible for the National Register of Historic Places and no further preservation of it is recommended. The planned undertaking will have no effect on any significant historical resources and no further archeological evaluations are recommended for this project. We seek your concurrence with this finding.

If you have any questions regarding this report, please contact Ms. Natalie S. Garrett at 904-232-1250 or natalie.s.garrett@usace.army.mil. A response within 30 days after receipt of this letter would be appreciated.

Sincerely,

Eric P. Summa
Chief, Environmental Branch

Enclosures

Garrett/CESAJ-PD-ES/1250/NS 6 Jan 2009
Cintron/CESAJ-PD-ES Jan 12
Summa/CESAJ-PD-E

L:\group\PDES\Garrett\C-111SC\C-111SCshpoSem.doc

Planning Division
Environmental Branch

JAN 14 2009

Mr. Willard S. Steele
Tribal Historic Preservation Officer
Seminole Tribe of Florida
HC-61, Box 21-A
Clewiston, Florida 33440

Dear Mr. Steele:

We have enclosed a single bound copy of the final report, *Phase I Cultural Resources Survey, C-111 Spreader Canal, Miami-Dade County, Florida* by New South Associates. This report is provided in accordance with the procedures contained in 36 CFR, Part 800 ("Protection of Historic Properties").

If you have any questions regarding this report, please contact Ms. Natalie S. Garrett at 904-232-1250 or natalie.s.garrett@.usace.army.mil. A response within 30 days after receipt of this letter would be appreciated.

Sincerely,

Eric P. Summa
Chief, Environmental Branch

Enclosures

Garrett/CESAJ-PD-ES/1250/ 6 Jan 2009
RC Cintron/CESAJ-PD-ES 12 Jan
Summa/CESAJ-PD-E

L:\group\PDES\Garrett\C-111SC\C-111SCshpoSem.doc

Planning Division
Environmental Branch

Mr. Steve Terry
NAGPRA & Section 106 Representative
Miccosukee Tribe
Post Office Box 440021
Miami, Florida 33144-0021

Dear Mr. Terry:

We have enclosed a brief summary of the final report, *Phase I Cultural Resources Survey, C-111 Spreader Canal, Miami-Dade County, Florida* by New South Associates. This summary is provided as you requested and in accordance with the procedures contained in 36 CFR, Part 800 ("Protection of Historic Properties").

If you have any questions regarding this report or if you would like a complete bound copy of the final report, please contact Ms. Natalie S. Garrett at 904-232-1250 or natalie.s.garrett@.usace.army.mil. A response within 30 days after receipt of this letter would be appreciated.

Sincerely,

Eric P. Summa
Chief, Environmental Branch

Enclosures

Garrett/CESAJ-PD-ES/1250/ 14 Jan 09
Cintron/CESAJ-PD-ES 14 Jan 09
Summa/CESAJ-PD-E

L:\group\PDES\Garrett\C-111SC\C-111SC-Miccosukee.doc

TRIBAL HISTORIC
PRESERVATION OFFICE
SEMINOLE TRIBE OF FLORIDA
AH-TAH-THI-KI MUSEUM
HC-61, BOX 21A
CLEWISTON, FL 33440
(863) 983-6549

TRIBAL OFFICERS:
MITCHELL CYPRESS
CHAIRMAN
MOSES OSCEOLA
VICE CHAIRMAN
PRISCILLA D. SAYEN
SECRETARY
MICHAEL D. TIGER
TREASURER

SEMINOLE TRIBE OF FLORIDA
TRIBAL HISTORIC PRESERVATION OFFICE

Department of the Army
Jacksonville District Corps of Engineers
Planning Division Environmental Branch
P.O. Box 4970
Jacksonville, Florida 32232-0019

Friday, January 16, 2009

Subject: C-111 Spreader Canal

Dear Natalie S. Garrett,

The Tribal Historic Preservation Office of the Seminole Tribe of Florida (STOF-THPO) has received your correspondence concerning the aforementioned project. The STOF-THPO concurs with the findings of "no effect" for the APE of this project. However, the STOF-THPO would like to be informed should any archaeological and/or historic resources be discovered inadvertently during the construction process. We thank you for the opportunity to review the information that has been sent to date regarding this project.

For any additional correspondence regarding this project, please reference **THPO-002972.** We look forward to working with you in the future.

Sincerely,

FOR

Willard Steele,
Tribal Historic Preservation Officer

Direct routine inquiries to:

Dawn Hutchins,
Compliance Review Supervisor

Ah- Tah- Thi- Ki Museum, HC-61, Box 21-A, Clewiston, Florida 33440
Phone (863) 902-1113 ♦ Fax (863) 902-1117

FLORIDA DEPARTMENT OF STATE
Kurt S. Browning
Secretary of State
DIVISION OF HISTORICAL RESOURCES

February 13, 2009

Ms. Natalie Garrett
U.S. Army Corps of Engineers
Planning Division – Environmental Branch
Post Office Box 4970
Jacksonville, Florida 32232-0019

Re: SHPO/DHR Project File No.: 2009-165 / Received: January 15, 2009
Final: Ph*ase I Archaeological Survey, C-111 Spreader Canal, Miami-Dade County, Florida*
New South Associates, St. Augustine, Florida; November 3, 2008
Contract No. : W912EP-04-D-0030

Dear Ms. Garrett:

This office received and reviewed the final revised survey report in accordance with Section 106 of the National Historic Preservation Act of 1966 (Public Law 89-665) as amended in 1992; as well as Chapter 1A-46, *Florida Administrative*. We concur that the planned undertaking will have no effect on historic properties and no further identification or evaluation is required unless the project perimeters change.

If you have any questions concerning our comments, please contact Laura Kammerer, Deputy State Historic Preservation Officer for Review and Compliance, at 850-245-6333 or lkammerer@dos.state.fl.us.

Sincerely,

Frederick P. Gaske, Director, and
State Historic Preservation Officer

500 S. Bronough Street • Tallahassee, FL 32399-0250 • http://www.flheritage.com

☐ Director's Office (850) 245-6300 • FAX: 245-6436
☐ Archaeological Research (850) 245-6444 • FAX: 245-6452
☑ Historic Preservation (850) 245-6333 • FAX: 245-6437

From: Steve Terry
To: Garrett, Natalie S SAJ;
Subject: C-111 Spreader Canal
Date: Tuesday, March 10, 2009 9:41:31 AM

THe Miccosukee Tribe received the summary of the Phase I Cultural Resources Survey, C-111 Spreader Canal, Miami-Dade County, Florida. After consultation with Mr. Fred Dayhoff, the Tribe has determined that there are no impacts to Tribal historic, traditional, or sacred sites. However, due to the fact that an archaeological site was found. we request that an archaeologist be present during any ground disturbing activity.

Thank you for consulting with the Miccosukee Tribe. Please contact me if you have any questions.

Steve Terry
NAGPRA & Section 106 Coordinator for
Fred Dayhoff
NAGPRA & Section 106 Representative
Miccosukee Tribe
P.O. Box 440021
Miami, FL 33144-0021
(305) 223-8380, Ext. 2243
Stevet@miccosukeetribe.com

C.9 SOCIOECONOMICS

C.9.1 Population

The aggregated population of the relevant census tracts in the study area had a 2000 census population of *114,042 (The affected census tracts are: 103, 104, 105, 107.03, 107.04, 108, 109, 110.01, 110.03, 110.04, 111, 112, 113, 114, 115 block 1 and 115 block 2). A corresponding figure from the 1990 census is unattainable because, due to population growth, the previous census tracts were subdivided to create the current tracts. In Miami-Dade County the population increased 16.3 percent during the 1990 to 2000 period. The population of Florida and the United States increased 23.5 percent and 13.1 percent respectively over the same period.

Population in Miami Dade County is expected to increase over 69 percent from 2000 to 2050. Florida, as a whole is projected to grow over 80 percent by 2050. The projected growth of the South Florida Nine-County area is anticipated to be 78 percent over the same 50-year period. An accurate estimate of future population in the affected census tracts is unattainable.

**TABLE C-5* was computed through delineation of the study area, to the "block group" level of 2000 Census tracts.

TABLE C-5: MIAMI-DADE COUNTY POPULATION ESTIMATES 2000-2050 (1,000)

Area	2000	2010	2020	2030	2040	2050
Florida	15,982.4	18,866.7	21,792.6	24,528.6	27,118.7	29,714.5
Miami-Dade County	2,253.4	2,554.3	2,862.0	3,148.1	3,499.2	3,810.6

Source: BEBR Projections, US Census (2000)

C.9.2 Economy

Future economic growth within the study area is expected to remain consistent with the population growth of the area, while maintaining a mix of service, retail, and administrative jobs.

C.9.3 Agriculture

Agriculture is a significant irrigated land user of the Lower East Coast region; however, the Lower East Coast is anticipated to have large increases in urban

land uses between 2000 and 2050. Agricultural land use represents less than one-quarter of the land use in the service area, and in many areas will be virtually non-existent in the future.

As urban landscape and M&I water demands increase, shortages will become more prevalent leading to greater restrictions and restrictions.

C.9.3.1 Future Agricultural Use

Agriculture within the study is expected to remain a strong economic force in the study are, while conceding little to no ground to urban development.

Using the South Florida Water Management Model (2x2), it is determined that by 2050 agriculture will utilize 13,440 acres. Of this agricultural acreage, over 8,300 will be utilized for row crop production and over 5,100 will be utilized for citrus production.

Additionally, ornamental tree nursery/farming will play a role as demand for these goods becomes more prevalent.

C.9.4 Study Area Land Use

Two future land use projections were used to address the issue of build-out in the C-111 Spreader Canal study area. The first land use projection was the Comprehensive Development Master Plan, as issued by Miami-Dade County Department of Planning and Zoning, which is effective from the years of 2005 through 2015. The second land use projection was the 2050 Basic Land Use, as used by the South Florida Water Management Model (v5.4, 2050B2), a model that represents delineated land in a two mile by two mile grid.

The Miami-Dade Comprehensive Plan (future conditions mapped from 2005 through 2015) depicts Homestead and Florida City as remaining a mix of low and medium-high density residential, business and office areas, and some industrial areas. The west and southwest of the 2 main residential areas will remain agricultural areas, containing row and tree crops, as well as ornamental nurseries and various agricultural concerns (these agricultural areas will extend until the park boundaries are reached). To the east, bordering Homestead Air Force Base, will remain a mix of agriculture, industrial (extractive) and business. South of Florida City, with the exception of mining operations directly south of the urban areas will remain environmentally protected areas (marl prairie). To the north and northwest will remain agricultural, while northeast (towards Miami, along the South Dixie Highway and Florida Turnpike) is projected to maintain growth as a mix of residential, business and institutional.

The South Florida Water Management Model BLU (conditions through 2050), shows maintenance of the Comprehensive Plan land usage through 2050, with a higher population density in Florida City and Homestead. Additionally, environmental impacts as a result of CERP implementation have been updated.

It should be noted that, although the comprehensive plans issued by each county are used to forecast future land use, these assumptions are subject to change. Additional build out for urban sprawl and changes in county planning policy usually require changes and modification in the long range planning forecast.

C.9.4.1 Public Land Management

It is expected that in the Future Without Project scenario, land management within ENP, SGWEA, Southern Glades Addition, and Model Lands would continue in a similar way as the present time. Given the likelihood of further residential development, fire suppression, and degradation of water quality and quantity in the area, management practices might become increasingly concentrated on eradicating exotic plants, such as Brazilian pepper, shoebutton ardesia, and old world climbing fern. Land management practices in the SGWEA, Southern Glades Addition, and Model Lands may also deal with restoration and law enforcement activities associated with further development to the north, including increased wetland disturbance due to illegal off road vehicle use, illegal solid waste dumping, and poaching.

C.9.4.2 Roads and Other Barriers to Sheetflow

In the Future Without Project scenario, the current roads and barriers would still exist, and the wetland habitat would be significantly more degraded than in the existing conditions. U.S. Highway 1 will be a four-lane highway, but will have nine box culverts and two wildlife crossings to partially alleviate the impacts caused by widening this barrier.

C.9.4.3 Mitigation Projects

There are several major existing mitigation projects within the C-111 SC project area, all of which will continue to exist in the Future Without Project scenario. Some of the mitigation projects are complete and some are still in the process of being completed. They were permitted by a combination of Miami-Dade County (MD) DERM, SFWMD, FDEP, and/or the USACE. See below for a description of those mitigation projects.

There are also a few very small tracts of lands that were required to set aside certain designated lands for preservation, totaling no more than 10 acres, as a condition of Miami-Dade County DERM permits. Due to their size, scattered

locations, and lack of other mitigation activities, they are not included in the descriptions below.

1. **FDOT Mitigation Plan for US 1 Improvements**: This Mitigation Plan was permitted in the early 1990's by the USACE, SFWMD, FDEP, and Miami-Dade County DERM separate from, and several years prior to the construction permits for the US 1 improvements between Florida City and Key Largo. Construction was completed in the mid 1990's and the mitigation is considered to be successfully completed. This mitigation package included 4 components: (a) Backfilling of C-109; (b) Removal of the Spoil Mound on the west side of US 1 between Florida City and the Game & Fish Access Road; (c) Removal of the C-111 Spoil Mound on the east side of C-111 between US 1 and Barnes Sound; and (d) Improvements at the Crocodile Lakes National Wildlife Refuge (CLNWR) on Key Largo. The SFWMD owns the lands on which the first 3 components were constructed and the federal government owns the CLNWR lands.

   Other components of the Mitigation Plan were approved as part of the construction permits, including a series of culverts and animal crossings under US 1 between Florida City and C-111 and C-111 and the Miami-Dade – Monroe county line. These are being constructed as part of the current US 1 construction activities and will be subject to future monitoring and maintenance per the permit conditions. FDOT also recently modified its permits to fill an eastern borrow ditch on FDOT owned ROW along US 1 between Florida City and C-111. This mitigation area will be subject to the standard maintenance and monitoring permit requirements for demonstrating success.

   All of the FDOT mitigation projects will be maintained in perpetuity.

2. **FPL Everglades Mitigation Bank (EMB):** A Conceptual Permit for the entire EMB and a construction permit for Phase 1 of the EMB were permitted by the USACE, FDEP, and Miami-Dade County DERM in October 1996. Phase 2 of the EMB was permitted by the same agencies in October 2003. Phase 1 includes 4,223 acres and Phase 2 includes 9,026 acres, for a total of 13,249 acres. Conservation easements for all the FPL EMB lands (Phases 1 and 2) were conveyed to the SFWMD and FDEP and recorded on November 6, 1996. FPL is responsible for the continued long term management of the EMB lands in order to maintain the approved mitigation credits.

   Phase 1 components included: (a) removal of exotics and nuisance vegetation; (b) removal of the C-108 Canal and an east-west canal and associated dike by re-grading and using the excess fill to backfill the canal; and (c) replanting

the disturbed areas. All construction activities have been completed, determined to be successful, and final mitigation credits were released by the permitting agencies in 2008. Most of the mitigation credits for Phase 1 have been sold.

Phase 2 components include: (a) installation of 40 control structures in the southern portion of the L-31E Canal; (b) installation of 6 culverts in Tallahassee Road; (c) construction of a weir in the Card Sound Road Canal; (d) removal of existing roads, berms, and dikes and other improvements to restore flows in the EMB; (e) installation of a plug in the Sea Dade Canal; (f) installation of a connection between the Sea Dade Canal and the S-20 Outfall Canal; (g) creation of a crocodile nesting area in the crocodile sanctuary; (h) creation of essential fish habitat in the vicinity of the old discharge canal; (i) creation of a small berm just west of the L-31 E canal to create temporary feeding areas for birds; (j) on-going exotic control activities.

Components a, b, and g are complete. The remaining components are scheduled for completion this year or are in the design phase and scheduled for completion the following year.

The permitted EMB credits were determined based on Existing Without Project conditions and do not consider the benefits to the EMB that could occur as a result of the C-111 Spreader Canal Project.

3. **CEMEX (formerly known as Florida Rock & Sand and RMC Singletary):** The Mitigation Plan for this project was designed to meet the combined mitigation requirements of the USACE, FDEP, and Miami-Dade County DERM for the Lake D Mining Project and currently encompasses approximately 1727 acres.

   Permits were issued in the mid 1990's and mitigation activities have been on-going since then, including the following components: (a) exotic removal and control activities on the 1147 acre mitigation parcel on the west side of US 1 and on the remaining lands owned by CEMEX in the triangular area north of Lakes A, B, C, and D; (b) creation of a monitoring network and collection of hydrologic data; (c) topographic survey of the proposed mitigation lands in the triangular area; (d) development and implementation of a limited hydrologic study of the Card Sound Road Canal and the east-west ditches in the triangular area; (f) restoration activities, including scrape down of the areas between and the creation of littoral zones around Lakes A, B, C, and D; and (g) donation of the mitigation lands to the SFWMD or an alternate entity.

CEMEX and Miami-Dade County DERM are currently negotiating the transfer of the mitigation lands to the Miami-Dade County EEL program which is expected to occur sometime this year. In addition to the 1147 acres west of US 1, CEMEX will transfer the 580 acres it currently owns in the triangular area north of Lakes A, B, C, and D. (Note: Of the remaining lands in the northern triangular area, the SFWMD owns 104.10 acres, Miami-Dade County owns 161.17 acres, and private entities own 219.03 acres. Public acquisition, primarily by Miami-Dade County, of some of the smaller tracts of privately owned lands is continuing to occur.)

As part of the transfer discussions, Miami-Dade County DERM has proposed that CEMEX fill in the Card Sound Road Canal from its southern property boundary to the northern extent of the canal near the junction of US 1 and Card Sound Road in order to improve the hydrology of the mitigation lands in the northern triangular area. In conjunction with this, MD DERM plans to ask FDEP to return to CEMEX the $20,000 being held in escrow for the installation of a control structure in Card Sound Road. (Note: The proposed structure in the Card Sound Road Canal is now being constructed by FPL as part of the EMB Phase 2 permitted activities.)

Per the FDEP permit conditions for Lake D, once the mining activities and required restoration activities in Lakes A, B, C, and D are completed, all of the remaining CEMEX lands (including the mined water bodies and adjacent lands) will be transferred to the State of Florida (or another acceptable public entity). This is not expected to occur before ~2020 based on the permitted mining schedule for Lake D and the approved restoration plan for all four lakes.

4. **Atlantic Civil, Inc. (ACI):** The approved Mitigation, Monitoring and Maintenance Plan for the original mining operation permitted in 2000 was designed to meet the combined mitigation requirements of the USACE, SFWMD, and Miami-Dade County (MD) DERM and encompasses a total of 1858 acres. These permits have since expired and permit modifications, including a revised mining operation and additional mitigation, are currently under review by the original permitting agencies and FDEP. A portion of the lands covered by the original permits has been sold and new acres are being included in the permit modifications.

   In the meantime, the originally authorized mitigation activities are continuing, as documented in the quarterly reports submitted by ACI to the permitting agencies.

   The permit conditions in the original permits required compliance with the success criteria spelled out in the approved Mitigation Plan and designated

ACI as the responsible entity for long term maintenance of the mitigation lands. The primary component of the mitigation plan was the removal of exotic and nuisance vegetation on the mitigation lands. SFWMD and DERM permit conditions also required a recorded conservation easement. These easements were recorded in 2000 and encompass all of the mitigation lands. The conservation easement specifically prohibits the types of land use and activities (i.e., buildings, roads, other structures, excavation, fill) associated with residential or commercial development.

Although the USACE permit did not require a recorded conservation easement, the USACE permit did require preservation of the same number and location of mitigation acres as the MD DERM Permit. In addition, the recorded conservation easement for MD Dade County also grants a perpetual right to the COE "to enter the property to ensure that restoration conditions are maintained."

The extent to which adjacent (non-mitigation) lands may be developed in the future is unknown as this time, but such development will be subject to the existing Miami-Dade County and Florida City Comprehensive Plan designations for these lands and Land Development and Permitting regulations in effect at the time, as well as any applicable SFWMD, FDEP and USACE permitting requirements. (Note: Subsequent to the issuance of the construction permits to Atlantic Civil, Inc., a portion of the lands owned by Atlantic Civil, Inc., including some of the mitigation lands, were annexed into the City of Florida City.)

C.9.5 Recreation

The SCORP is the best source of information on recreation demand and supply at the state and regional scales. It divides the state into 11 planning regions, each with clusters of counties. As indicated in ***TABLE C-6,*** Region 11 is the planning region that encompasses the study area.

TABLE C-6: COUNTIES WITHIN SCORP PLANNING REGIONS POTENTIALLY AFFECTED BY ALTERNATIVE RESTORATION PLANS

Region	Counties
Region 11	Broward
	Miami Dade
	Monroe

Source: Florida Department of Environmental Protection, 2000.

The SCORP organizes outdoor recreation in Florida into 47 categories that encompass a variety of recreation activities including team sports (e.g., basketball and baseball), individual sports (e.g., golf and tennis), hunting, fishing, swimming, and boating. ***TABLE C-7*** presents descriptive information on the recreation facilities in SCORP Regions 11 for study area specific recreation categories. These resource-based categories were selected as those that could potentially be affected by the hydrologic changes or ecological changes associated with the alternative restoration plans. This table also includes percentages of the statewide totals for the recreation categories.

TABLE C-7: REGIONAL OUTDOOR RECREATION FACILTIES REGION 11 (1998)

Resource / Facility	Region 11	% of State Total	State Total
Outdoor Recreation Areas	2,080	10%	13,097
Outdoor Recreation Acres	3,038,475	5%	10,850,904
Land Acres	1,831,363	6%	9,077,004
Water Acres	1,207,112	4%	1,773,900
Total Hunting Acres	871,151	5%	6,168,716
Hunting Land Acres	869,573	5%	6,046,955
Hunting Water Acres	1,578	24%	121,761
Camping			
Cabins	388	9%	4,460
RV / Trailer Camp Sites	10,603	8%	138,576
Tent Camp Sites	1,081	11%	10,214
Trails			
Hiking Trails (miles)	277	7%	3,904
Horseback Riding Trails (miles)	921	64%	1,443
Nature Trails (miles)	107	10%	1,043
Freshwater Catwalks	40	5%	803
Boating			
Canoe Trails (miles)	296	11%	2,587
Freshwater Boat Ramp Lanes	235	12%	1,973
Freshwater Marinas	6	1%	511
Freshwater Slips / Moorings	303	3%	11,758
Saltwater Marinas	366	33%	1,123
Saltwater Marina Slips	14,470	32%	45,839

Source: Florida Department of Environmental Protection. 2000

C.9.5.1 Recreation Demand

Profiles of existing and future recreation demand in the study area can be developed by drawing on a variety of information at the national, state, regional, and local levels.

In general, the variety of recreational interests in the U.S. appears to be increasing along with recreational participation rates. As future recreation needs and interests develop, it is important to recognize that participation in specific types of recreational activities is often linked to demographic factors such as age and income. For example, participation in activities requiring vigorous exercise is considerably higher for young people than for senior citizens. However, the elderly population has increasing recreation participation because of the growing awareness of the importance of physical fitness. Participation in most activities is low for those with family incomes below $25,000 per year. Interestingly, participation is also low for those with family incomes greater than $100,000 per year. Most outdoor recreational activities appear to be enjoyed largely by the middle class, those with family incomes between $25,000 and $75,000 per year.

C.9.5.2 State Recreation Trends

Recreation demands were developed for the SCORP through surveys of residents and tourists. The Division of Recreation and Parks conducts periodic surveys of resident and tourist participation in recreation activities to estimate outdoor recreation in Florida. The recreation participation information was derived from the 2000 surveys conducted by the University of Florida, Department of Recreation, Parks, and Tourism. Participation in outdoor recreation activities is expressed in terms of user-occasions, which occur each time an individual participates in a single outdoor recreation activity. The number of user-occasions was calculated for each planning region as well as the entire state by type of activity. Demand was estimated for 1997, 2000, 2005 and 2010 by applying the per capita participation rates to population projections.

TABLE C-8 presents 1997 and projected 2010 demands for the selected recreation activities in SCORP Planning Region 11. This table includes user-occasions as well as facility/resource needs. As part of the without-project conditions, all of the regions are expected to have significant increases in demands for the selected recreation activities with a commensurate need to increase development of the regions' recreation resources and facilities.

TABLE C-8: DEMAND AND FACILITY NEEDS (1997 AND 2110) SELECTED RECREATION ACTIVITIES TREASURE COAST (SCORP REGION 11)

Activity	Units	Resources / Facility Needs		Demand (user-occasions)	
		1997	2010	1997	2010
Hunting	Acres	79,349	235,428	663,841	772,849
RV / Trailer Camping	Camp Sites	0	0	2,203,445	2,779,565
Tent Camping	Camp Sites	10	317	888,761	1,136,981
Hiking	Miles	252	413	1,282,041	1,672,767
Saltwater Beach Activities	Miles	8	36	32,119,905	44,168,645
Freshwater Fishing	Feet	8,356	12,051	774,929	924,095
Nature Study	Miles	0	0	1,456,739	1,988,143
Bicycle Riding	Miles	1,241	1,608	19,654,556	24,089,784

Source: Florida Department of Environmental Protection, 2000.

In sum, the Region 11 ecosystems support a significant amount of outdoor recreation in the Lower East Coast of Florida. A significant portion of the expenditures comes from tourists. As can be seen from ***TABLE C-8*** above, the activities that have a lack of supply for recreation purposes are hiking, freshwater fishing and bicycle riding. These are all resources that could potentially be increased through the C-111 Spreader Canal project.

C.10 NOISE

Noise impacts associated with implementation of any of the proposed project alternatives is not likely to increase over what is presently associated with the C-111 Spreader Canal Project area.

C.11 AESTHETICS

The C-111 Spreader Canal Study Area has a diverse mix of urban, agricultural and wildlife conservation land uses. With an anticipated increase in urbanization, changes in the project area are expected to reflect population growth. Aesthetically, there will be more build-out with less open and agricultural lands in the future without scenario.

C.12 REFERENCE LIST

Craighead, F.C. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Florida Naturalist 41:2-7, 69-74, 94.

Dunbar, M.R. 1993. Florida panther biomedical investigation. Annual performance report, July1, 1992 to June 30, 1993. Study no. 7506, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Fennema, R.J., 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). Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, Florida, pp. 249-289.

Lawler, H.E. 1977. The status of Drymarchon corais couperi (Holbrook), the eastern indigo snake, in the southeastern U.S.A. Herpetological Review 8(3):76-79.

Lorenz, J.J. 2000. Impacts of water management on roseate spoonbills and their piscine prey in the coastal wetlands of Florida Bay. Ph.D. Dissertation, University of Miami, Coral Gables, FL.

Lorenz, J.J., J.C. Ogden, R.D. Bjork, and G.V.N. Powell. 2002. Nesting pattern of roseate spoonbills in Florida Bay 1935-1999; implications of landscape scale anthropogenic impacts. In: Porter, J.W. and K.G. Porter (eds). The Everglades, Florida Bay and coral reefs of the Florida Keys, an ecosystem sourcebook. CRC Press, Boca Raton, FL. pp. 555-598.

Mazzotti, F.J., and L.A. Brandt. 1994. Ecology of the American alligator in a seasonally fluctuating environment. In: Davis, S.M., and J.C. Ogden (eds). Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, Florida, pp. 485-505.

Moler, P.E. 1985. Home range and seasonal activity of the eastern indigo snake Drymarchon corais couperi, in northern Florida. Final performance report, Study E-1-06, III-A-5. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Ogden, J.C. 1978. Status and nesting biology of the American crocodile, Crocodylus acutus (Reptilia, Crocodylidae) in Florida. Journal of herpetology 12(2);183-196.

Seal, U.S., R.C. Lacey, and workshop participants. 1992. Genetic management strategies and population viability of the Florida panther. Report to the U.S. Fish and Wildlife Service, by the Conservation Breeding Specialist Group, Species Survival Commission, IUCN; Apple Valley, Minnesota.

Van Lent, T.A., R.A. Johnson, and R.J. Fennema. 1993. Water management in Taylor Slough and effects on Florida Bay. Technical Report 93-3, South Florida Natural Resources Center, Everglades National Park, Homestead, Florida.

VanZee, R. 1999. Natural System Model Version 4.5 Documentation Report. Draft report, South Florida Water Management District, West Palm Beach, Florida.

C.13 BENEFIT EVALUATION METHODOLOGY

The benefit evaluation methodology relies upon conceptual ecological models developed for the Greater Everglades ecosystem as a framework around which the Project Delivery Team [PDT] evaluates the ecological consequences of various project alternatives. Specifically, the subset of Greater Everglades ecosystem conceptual ecological models identified as being relevant to the study area by the Project Delivery Team are as follows: 1) Everglades Ridge and Slough Conceptual Ecological Model (Ogden, 2005); 2) Southern Marl Prairies Conceptual Ecological Model (Davis et al, 2005); 3) Conceptual Model of Ecological Interactions in the Mangrove Estuaries (Davis et al., 2005); and 4) Conceptual Ecological Model of Florida Bay (Rudnick et al., 2005).

The overarching objective of the C-111 SC Western project is to alter the existing timing, distribution, and flow of water in Taylor Slough such that the hydrology better matches the historic condition. The specific project objectives for the C-111 SC Western project are listed as follows:

0. Restore the quantity, timing, and distribution of water delivered to Florida Bay via Taylor Slough to levels nearest as possible to the estimated pre-drainage conditions;
1. Improve hydroperiods and hydropatterns in the Southern Glades and Model Lands. The hydroperiods will be improved to optimal levels to support historical vegetation patterns nearest as possible to the estimated pre-drainage conditions.
2. Return coastal zone salinities in western Florida Bay to levels as close as possible to estimated pre-drainage conditions by restoring upstream water levels in eastern Everglades National Park.

The historic hydrology of the southern glades provided sheet flow that resulted in long-duration pooling of freshwater upstream of estuaries. The C-111 / L-31 canal system has reduced the duration and volume of freshwater flows delivered to the southern glades, and reduced the duration of freshwater pooling along the sawgrass/mangrove ecotone.

The expectation is that providing a more natural pattern of freshwater flow within Taylor Slough will result in improved freshwater wetland habitat as well as improved salinity in downstream portions of near shore Florida Bay. A more natural hydrologic pattern will decrease the frequency and duration of hypersaline events which will increase the growth and survival of estuarine species within the affected nearshore estuarine areas downstream of Taylor Slough. Extending the hydroperiod of freshwater wetlands within Taylor Slough will result in greater coverage of long-hydroperiod periphyton assemblages as opposed to short-hydroperiod periphyton. Short-hydroperiod periphyton is not preferred since it is less diverse than long-hydroperiod periphyton and it also is

composed of more filamentous cyanopacteria that provides less food value to native species.

Alterations of freshwater flow patterns and volumes have reduced the occurrence of mesohaline, oligohaline, and freshwater marshes and sloughs, and allowed the landward expansion of saltwater and mangrove wetlands, including low-productivity, sparsely vegetated dwarf mangrove communities typical of the hypersaline or white zone. The desired hydroperiods necessary to restore the marl prairie vegetation mosaic vary somewhat for each ecological zone. The range of desired hydroperiods for the various vegetative types in each ecological zone is displayed below in ***TABLE C-9***.

TABLE C-9: HYDROPERIOD TARGET FOR VEGETATION WITHIN ECOLOGICAL ZONES

Zone	Hydroperiod Target	Existing Landscape	Existing Vegetation and Hydroperiod Response
2	130-180 days – hydroperiod range for the dry phase that should support muhly-mixed graminoids	Shrub dominated forested wetland	Brazilian pepper (*Schinus terebinthifolius*), Australian pine (*Casuarina* spp.), dahoon holly (*Ilex cassine*), swamp bay (*Persea palustris*), sweet bay (*Magnolia virginiana*), willow (*Salix caroliniana*), and sawgrass (*Cladium jamaicense*). Discontinuous hydroperiod controls overall plant distribution. Water levels in May and June are important in determining germination success of invasive exotic seedlings.
3	150-330 days - hydroperiod range that should support sawgrass-dominated wetlands	Sawgrass	Sawgrass, muhly grass (*Muhlenbergia capillaris*), swamp bay, dahoon holly, wax myrtle (*Myrica cerifera*), willow, and cocoplum (*Chrysobalanus icaco*), sweet bay, myrsine (*Rapanea guianensis*), bald cypress (*Taxodium distichum*), and pond apple (*Annona glabra*). Continuous hydroperiod is more relevant to aquatic fauna productivity. Looking for longer continuous hydroperiod to improve food base. Also looking for longer hydroperiod (discontinuous) to indicate freshwater influence may extend coastward.
4	240-330 days - hydroperiod range that should support mixed graminoid with mangroves	Mixed graminoid with mangroves	Sawgrass, swamp bay, dahoon holly, wax myrtle, cocoplum, myrsine, poisonwood (*Metopium toxiferum*), buttonwood (*Conocarpus erectus*), red mangrove (*Rhizophora mangle*), stoppers (*Eugenia* spp.), spicewood (*Calyptranthes pallens*), and cocoplum
5	240-330 days - hydroperiod range necessary to restore this freshwater wetland ecotone	White zone ecotone	Dwarf red mangroves, sparse graminoids. Discontinuous hydroperiod controls plant distribution, and may indicate whether salinity improvements are likely over existing conditions. Regression line slope will support discussions on whether available water will positively affect wading bird feeding in coastal areas.
6	240-330 days - hydroperiod range necessary to establish estuarine conditions	Coastal forest	Red mangrove, white mangrove (*Laguncularia racemosa*), Brazilian pepper , Australian pine, wax myrtle,, poisonwood,, buttonwood, spicewood, myrsine, stoppers, white indigo berry (*Randia aculeata*). Desired salinities are 5-15 ppt necessary to sustain oligohaline and mesohaline conditions.

Hydroperiod targets for wetland restoration range from a minimum of 130 days for shrub dominated forested wetlands and sawgrass habitat to 240 days for graminoid, and coastal forest habitat. Salinity targets in the near shore zone are 5 to 20 psu (practical salinity units) for crocodiles, 10 to 25 psu for juvenile seatrout, 10 to 20 psu for juvenile silver perch and eastern oysters, and 5 to 15 psu for widgeon grass. Restoration benefits are typically measured by determining project related increases in the fraction of the landscape that meets critical habitat quality thresholds (hydroperiod, salinity). When evaluating the significance of project induced hydrologic changes it is important to understand the breakpoints where a change is large enough to result in improved habitat conditions.

The ecological evaluations of project alternatives require a general understanding of conditions reasonably anticipated to exist in the absence of project-related activities (i.e., the future without-project condition), and those that might be expected with each of the project alternatives (i.e., with-project conditions). Performance measures associated with the above-referenced conceptual ecological models, developed by CERP's Restoration Coordination and Verification [RECOVER] Evaluation Team [ET] for application with the South Florida Water Management Model [SFWMM] were reviewed for potential applicability to this project's study area and modeling strategy. Specifically, those performance measures included the following:

- Greater Everglades 1, 2, and 3
- Southern Estuaries 1, 3, and 5

Due to differences in hydrologic model codes (SFWMM versus Modbranch), scale (regional versus local), temporal and spatial resolution (coarse versus fine), and simulated period of record (36-year continuous versus three individual average, wet, and dry-year simulations), it was recognized that performance measures conceptualized for application with the SFWMM could not be used directly with the developed Modbranch model. As such, the PDT developed performance metrics capable of measuring the ecologically-significant hydrologic stressors of the RECOVER performance measures, but at a scale and in a manner that is more appropriate for the finer-resolution, basin-specific Modbranch model application.

The primary objective of features included in the PIR is to improve the timing and distribution of freshwater discharges to Florida Bay via improved retention of water lost as seepage from Taylor Slough to the C-111 Canal. As a result, performance measures designed to detect intended and unintended impacts within the study area associated with greater retention of water in eastern Everglades National Park were applied during alternative evaluations. The applied performance metrics identified and measured changes in timing of

overland flow distributed to Taylor Slough, and hydroperiods and water depths/stages within the study area. The performance metrics applied during evaluation of management measures discussed in this PIR include the following:

- Sheetflow timing, distribution, and volume (PM 1.5)
- Stage-inferred coastal zone salinities (PM 2.4)
- Hydroperiod-inferred vegetation communities (PM 2.1)

As presented by the aforementioned conceptual ecological models, empirical relationships between hydrologic conditions, nutrient availability, vegetation communities, and habitat utilization by fish and wildlife exist to varying degrees. The PDT understood and recognized the significance of ranges, time series, and thresholds on analyses performed during evaluation of alternative plans and their likelihood of achieving restoration goals. The large study area, its low topographic relief, its sensitivities to hydrologic stresses (magnitude, return frequency, and seasonality of inundation events), and its sensitivities to preceding conditions/trends (among other stressors) complicated the team's efforts to develop prescriptive targets and to develop response functions as one might interpret results. For instance, a priori selection of target vegetation community "end states" and idealized geographic distributions of "optimal" hydrologic conditions for each can yield targets that are not fully compatible (or physically achievable) in the same landscape and treat ecotonal conditions as less than desirable. Likewise, model abstractions employed during development of the hydrologic model domain and inaccuracies in predicted stages and resultant water depths complicate such evaluation efforts. It was found that vegetation community hydrologic tolerances, thresholds, and time series requirements relied on prediction of water depths to a level of precision and accuracy that was difficult to obtain and/or demonstrate.

Given these and other constraints, the PDT elected to develop a pre-drainage hydrologic computer model of the study area as the target (for remnant natural areas) and measure success as the degree to which various measures differed from the target condition. The concept of using pre-drainage hydrology is based on the reasonable premise that restoring the pre-drainage hydrology would lead to restoration of the natural habitats, biota, and species. Many of the Restudy ecological targets developed for the CERP were derived from the Natural Systems Model version of South Florida Water Management District Model (SFWMD 2x2). The pre-drainage model used in this project is a derivative of the NSM2x2 model used in the CERP. The model used here is also referred to as the NSM; however, it is based on the MODBRANCH model rather than the SFWMD2x2. The boundary conditions for the NSM version of the South Dade MODBRANCH model were taken from the NSMv4.6 2x2 model. The advantage of using a pre-drainage hydrologic simulation is that it establishes target conditions that are subjected to the same general abstractions used in the

synthesis of the alternative simulations. This minimizes the introduction of error/uncertainty that might result from response functions and yields physically continuous hydrologic conditions across the landscape. Landscape-scale and ecotonal hydrologic targets that may or may not drift in the landscape from one water year to the next can then be reliably considered.

As discussed in the engineering appendix of this report, the Modbranch model was configured for three individual one-year simulations (i.e., an average year, a dry year, and a wet year). A copy of the calibration report for this model as well as a discussion of the selection of the hydrologically representative periods are included in the PIR. Following the methodology employed to establish targets in the Restudy Report, the PDT determined that the hydrologic conditions resulting from the Modbranch simulation of a passive, pre-drainage landscape's response to precipitation would serve as an appropriate target condition for the C-111 SC project. The MOBRANCH model domain is shown in ***FIGURE C-9*** and the MODBRANCH model simulation grid is shown in ***FIGURE C-10***. The indicator regions for the entire study area are shown below in ***FIGURE C-11***. Taylor Slough, shown in black in this figure, runs from the L-31W Levee south to Florida Bay. The map shows the extent of the area in which hydrologic conditions may be altered as part of this project. The landwater portion of this area is approximately 155,098 acres. The nearshore and Florida Bay portion of the study area is 97,302 acres.

To identify the potentially affected area of the project, the team first considered limiting the indicator regions to only those areas which would experience a significant and measurable change in hydroperiod or salinity. These areas are generally located directly downstream or adjacent to project features for the considered alternatives. This method of sizing the indicator regions was abandoned in favor of a more expansive area of potential impact since large indicator regions would show both areas of hydrologic benefit and areas where water deliveries are reduced. Since the C-111 Spreader project diverts water rather than augments water deliveries, the project delivery team felt that having large indicator regions is essential to capturing both positive and negative effects of the project.

Though the project benefits are estimated by multiplying the area of the indicator regions by a projected change in the habitat index, this methodology is not intended to drive the real estate requirements for the project. For instance, the entire area of the indicator regions does not have to be acquired in order to assure that project benefits are protected. The reasons for this are: 1) Most of the wetland rehydration benefits will occur in those land identified in a real estate analysis as being significantly hydrologically modified. Much of this land is already within the boundary of Everglades National Park. 2) Areas outside of the "significantly hydrologically modified" lands are generally areas where some

decrease in hydroperiod conditions are expected and thus not contributing benefits and should not be part of the lands acquired to protect project benefits. 3) Salinity benefits that accrue from the project occur in navigable waters and thus these submerged lands generally are not acquired.

Irrespective of the differences between the real estate lands analysis and the benefits methodology for this project, the vast majority of the 155,000 acres of fresh and saltwater wetland identified in the indicator regions is already protected via ownership by the Local, State, or Federal agencies.

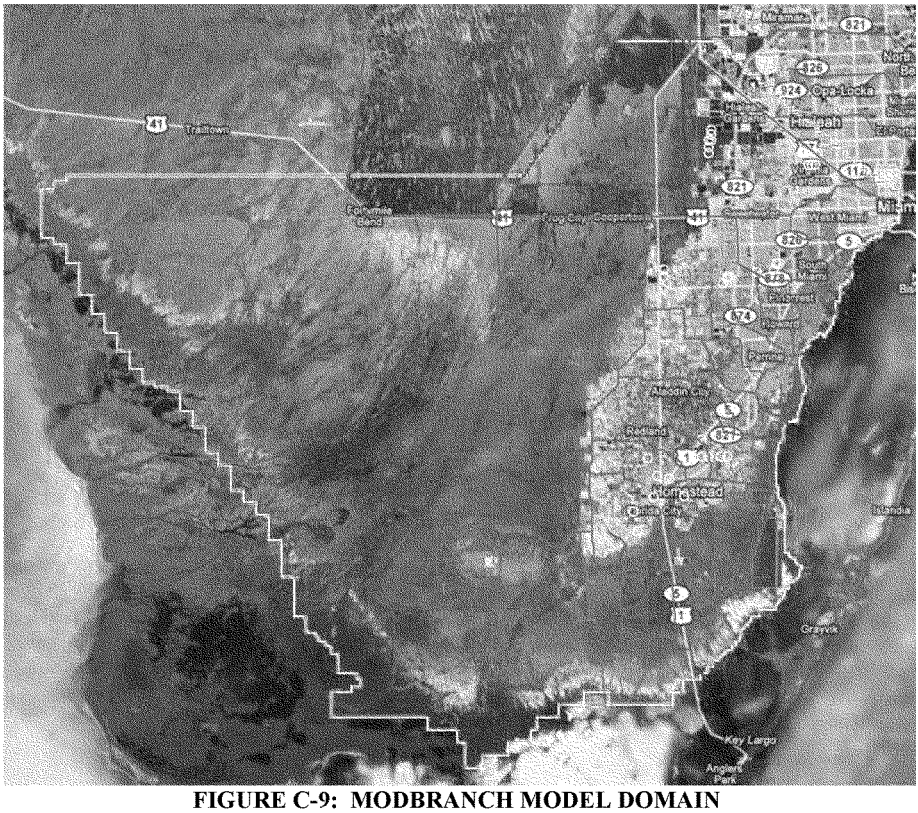


FIGURE C-9: MODBRANCH MODEL DOMAIN

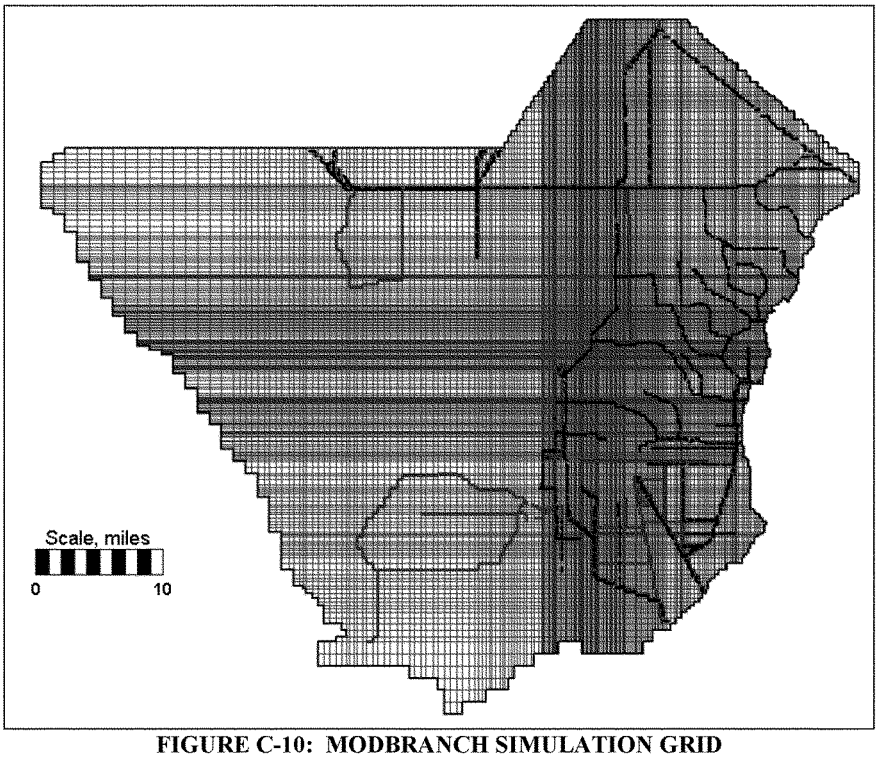


FIGURE C-10: MODBRANCH SIMULATION GRID

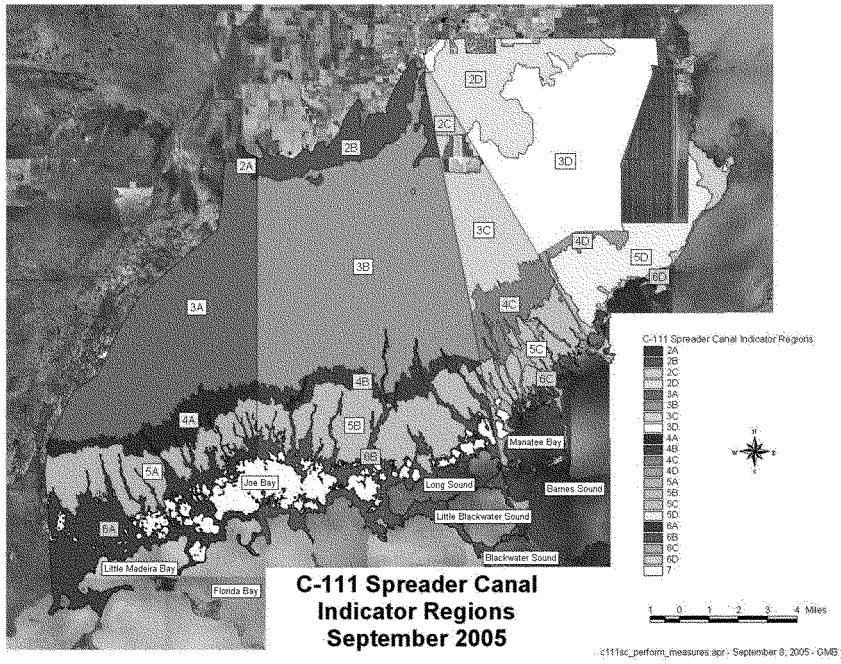


FIGURE C-11: INDICATOR REGIONS USED IN PERFORMANCE METRICS 1.5, 2.4, AND 2.1

C.13.1 Description of Performance Metric Calculations

TABLE C-10 includes the name and model run identifier for each of the alternatives. ***FIGURE C-6*** includes short descriptions of each of the final alternatives. ***FIGURE C-12*** through ***FIGURE C-15*** show the major features of each of the final alternatives. Note that the difference between Alternative 2DShort and 2DLong is the length of the Aerojet Canal feature. A description of each alternative is found in the formulation section of this report. Details regarding the hydrologic simulation efforts are found in the Engineering Appendices. Background information for each of the three performance metrics as well as the results of their application to the alternatives is provided below.

TABLE C-10: PROJECT ALTERNATIVES AND MODEL RUNS USED IN FINAL BENEFITS ANALYSIS

Alternative Name	Model Run
No Action Alternative	FWO (Future Without Conditions)
Existing Conditions	ECB (Existing Conditions Baseline)
Alternative 1C	Alt1C
Alternative 1D	Alt1D
Alternative 2D Short	Alt2DS
Alternative 2D Long	Alt2DL
Alternative 3D	Alt3D
Alternative 6D	Alt6D

TABLE C-11: FINAL ARRAY OF ALTERNATIVES

No-Action	Future Without Project Condition
Alternative 1C	Includes FPDA approximately 530 acres with maximum depth of 3 feet, pump for FPDA intercepts available water.
Alternative 1D	Includes FPDA approximately 530 acres with maximum depth of 3 feet, pump for FPDA intercepts available water, plus: one new operable structure in the lower C-111, incremental operational changes at S-18C, one plug at S-20A, operational changes at S-20, and 10 plugs located in the C-110 Canal.
Alternative 2DS	Includes FPDA approximately 530 acres with maximum depth of 3 feet, pump for FPDA intercepts available water, gravity structure upstream of S-177 to discharge into approximately half of the Aerojet Canal, plus: one new operable structure in the lower C-111, incremental operational changes at S-18C, one plug at S-20A, operational changes at S-20, and 10 plugs located in the C-110 Canal
Alternative 2DL	Includes FPDA approximately 530 acres with maximum depth of 3 feet, pump for FPDA intercepts available water, gravity structure upstream of S-177 to discharge into the entire length of the Aerojet Canal, plus: one new operable structure in the lower C-111, incremental operational changes at S-18C, one plug at S-20A, operational changes at S-20, and 10 plugs located in the C-110 Canal
Alternative 3D	Includes FPDA approximately 530 acres with maximum depth of 3 feet, pump for FPDA intercepts available water, pump upstream of S-177 to discharge into Aerojet Reservoir, plus: one new operable structure in the lower C-111, incremental operational changes at S-18C, one plug at S-20A, operational changes at S-20, and 10 plugs located in the C-110 Canal.
Alternative 6D	Construct seepage barrier from northern portion of L-31W (just west of S-332D) south along FPDA to the southern end of Aerojet Canal, plus: one new operable structure in the lower C-111, incremental operational changes at S-18C, one plug at S-20A, operational changes at S-20, and 10 plugs located in the C-110 Canal.

Note: A complete description and map of each alternative can be found in ***APPENDIX F***.

The benefits calculations were done using Excel spreadsheets developed specifically for this project. The documentation of the four primary spreadsheets as well as a description of how to use them is appended to the end of the benefits methodology section of this appendix.

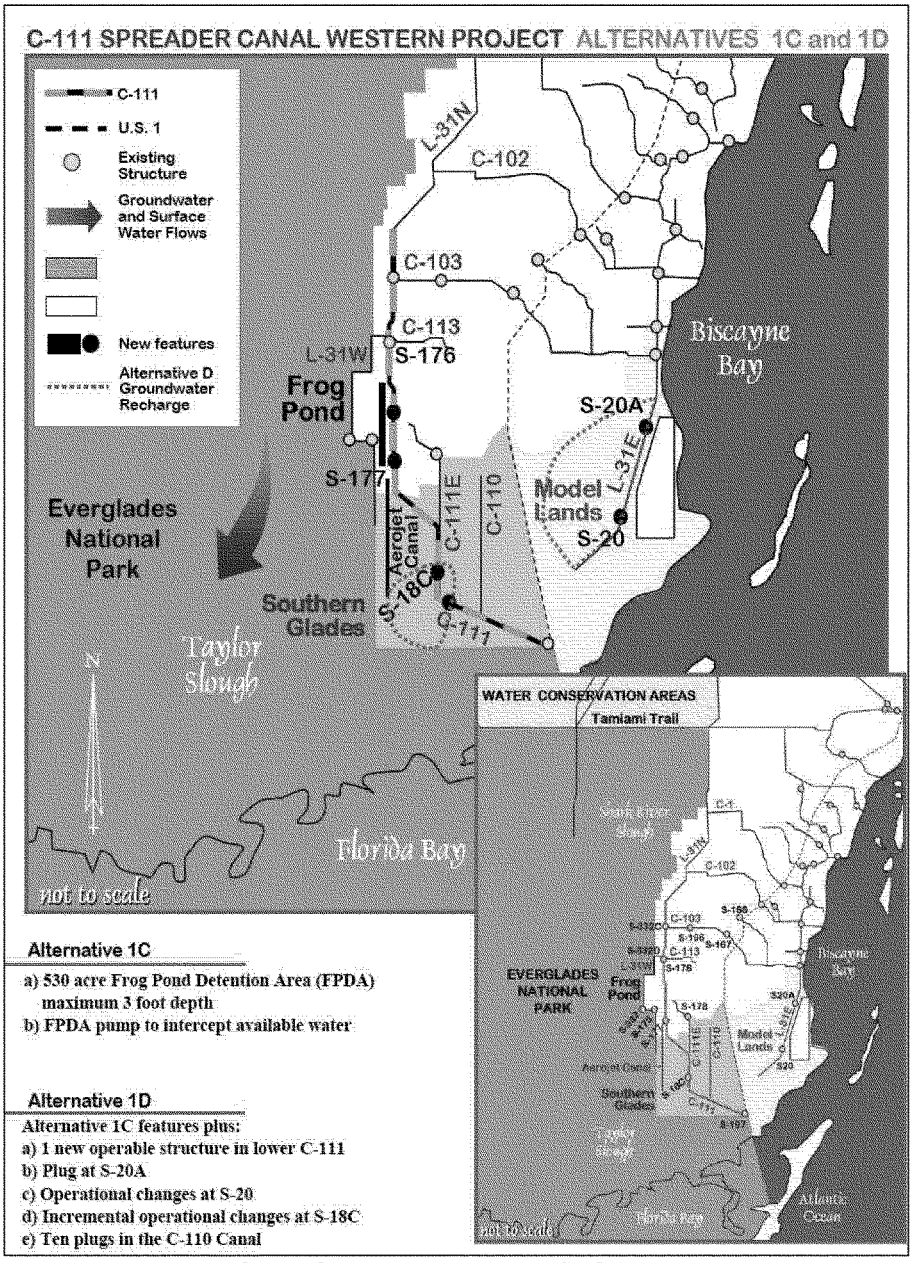


FIGURE C-12: ALTERNATIVES 1C AND 1D

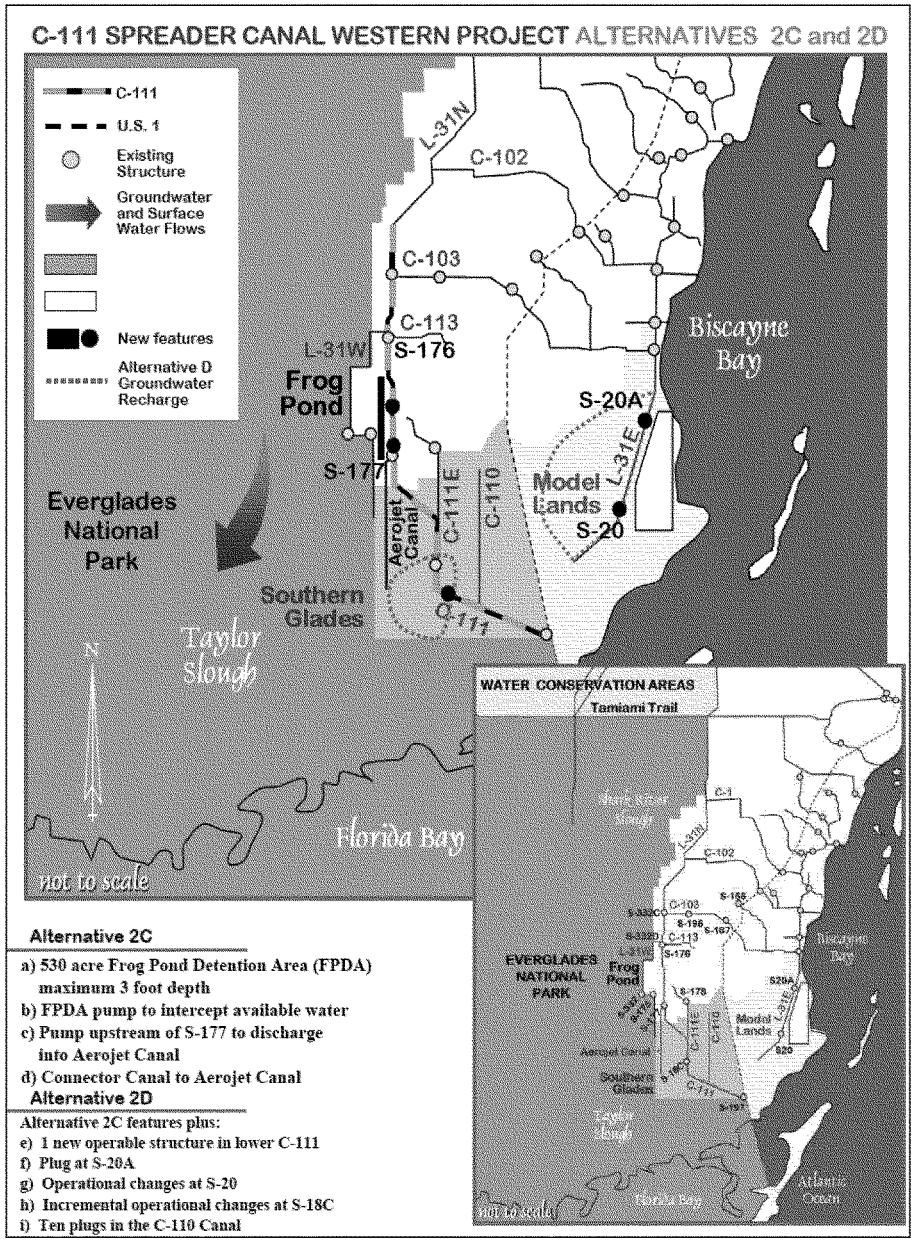


FIGURE C-13: ALTERNATIVES 2C AND 2D

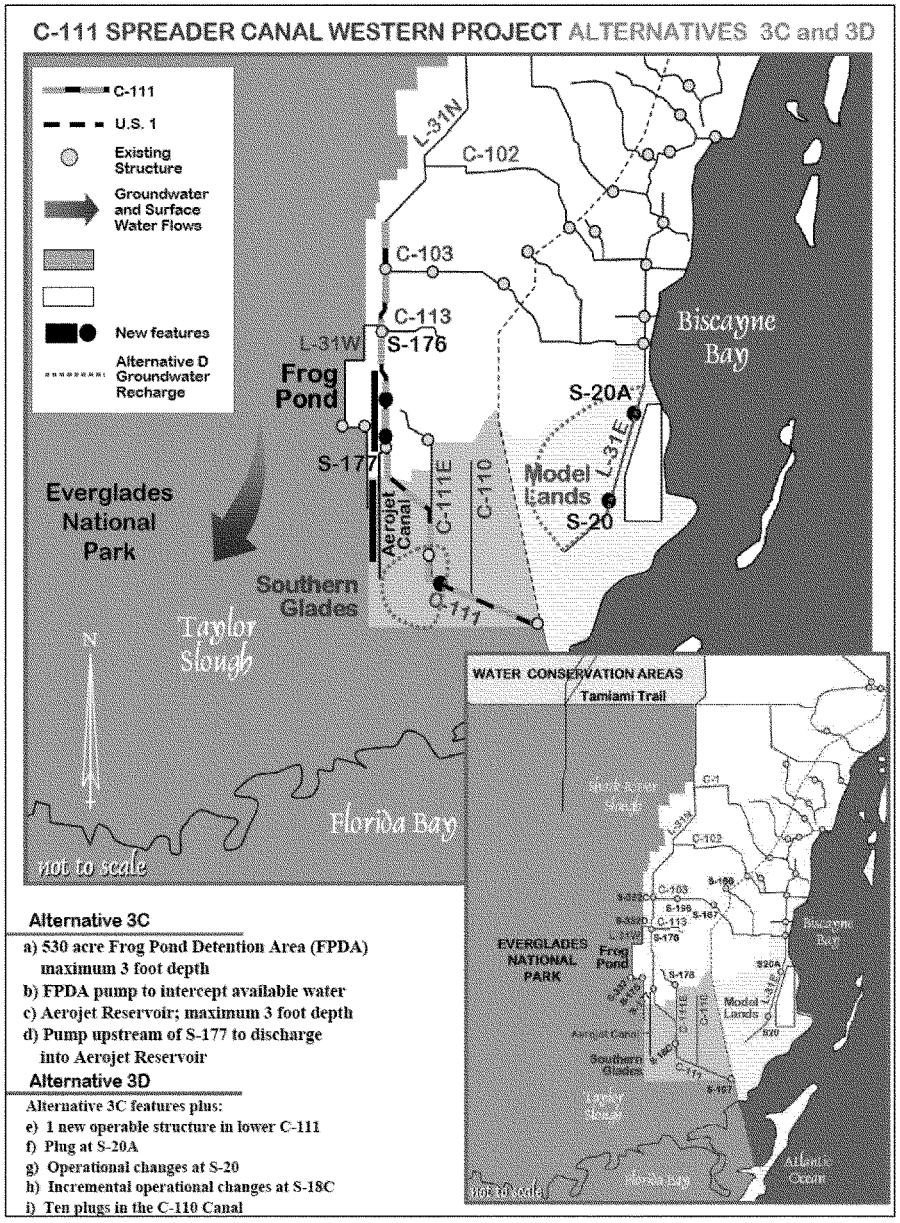


FIGURE C-14: ALTERNATIVES 3C AND 3D

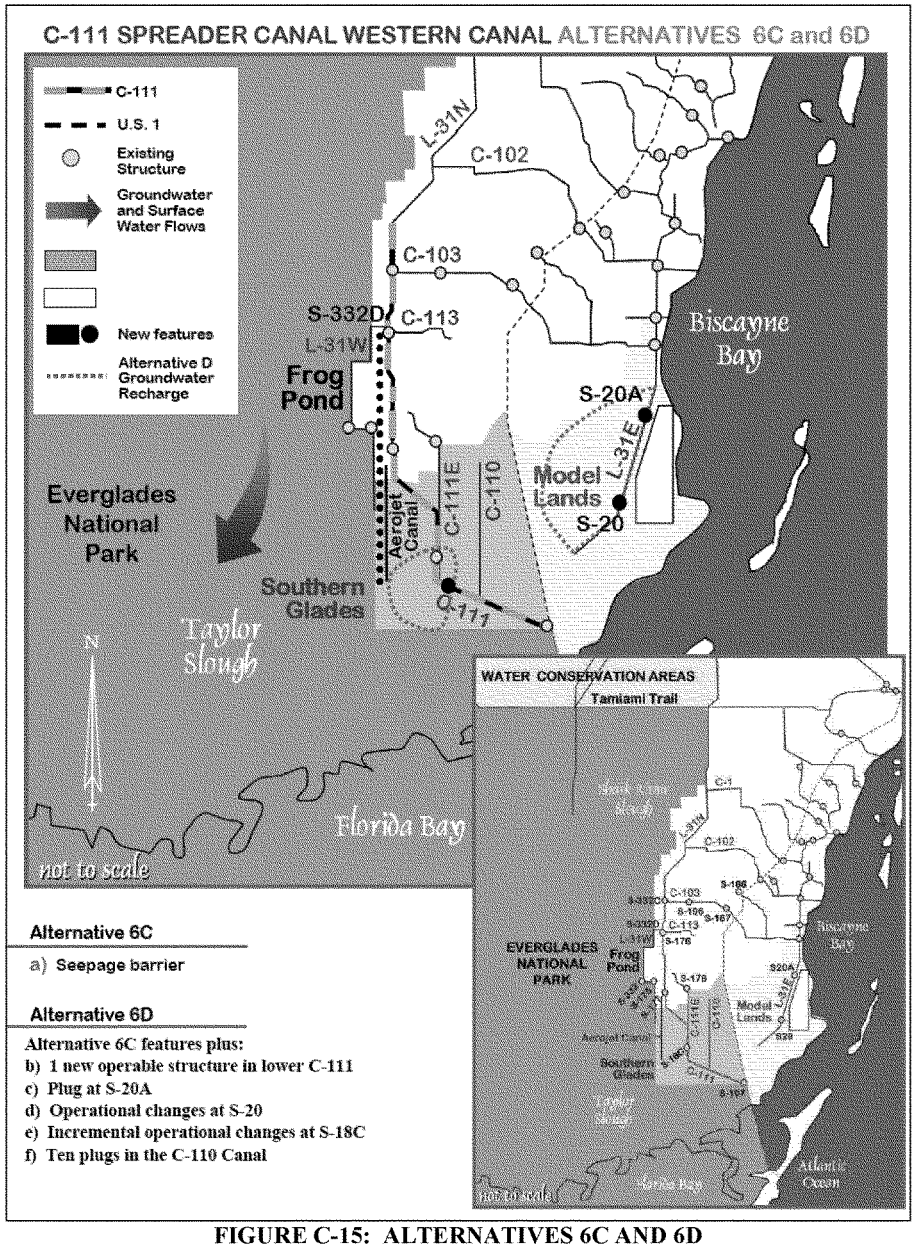


FIGURE C-15: ALTERNATIVES 6C AND 6D

C.13.1.1 Simulation Model Setup

The boundary conditions used in the Modbranch modeling vary by alternative. The FWO uses boundary conditions and structure operations that reflect no implementation of CERP features but the implementation of the Modified Water Deliveries project which is intended to provide additional flow to Northeast Shark River and Taylor Sloughs. The with-project alternatives (1C, 1D, 3D, 2DS, 2DL, and 6D) use boundary conditions and structure operations similar to the FWO alternative. The ECB (Existing Conditions Baseline) alternative uses boundary conditions as they were during the base year (2000). The ECB alternative does not incorporate Modified Water Deliveries so the flows down L-31W and C-111 tend to be less than that provided in the FWO condition. The NSM (natural system model) hydrologic condition uses boundary conditions that were generated using a regional model that does not include the South Florida canal network. Additional detail regarding the boundary condition assumptions used in each model run are provided in the engineering appendices.

Benefits were estimated for each alternative using three hydrologic conditions (wet, dry, average) as simulated using the MODBRANCH model. The method used to determine representative years for wet, dry, and average conditions was based upon monthly rainfall data. The National Climatic Data Center has a complete 108-year record of monthly rainfall the two regions that fall within the MODBRANCH model domain. The majority of the MODBRANCH model domain is found in Florida District 5; however, Florida District 6 comprises eastern portion of the model where most of the project features are located. The method is based, not on total annual rainfall, but on the basis of how many months each year were relatively wet, dry, or average. The reasoning is that an average year should be mostly average months, a wet year should be mostly wet months and a dry year should be mostly dry months. ***TABLE C-12*** shows the two Districts with each year sorted according to the number of months that fall into one of five categories. The categories are real dry, dry, average, wet, and real wet. These terms are defined as shown below.

Conditions	**Definition (R_{ave} = average monthly rainfall and σ the monthly standard deviation for the 108 year period)**
Real Dry	Monthly rainfall $< R_{ave} - \sigma$
Dry	$R_{ave} - \sigma <$ Monthly rainfall $< R_{ave} - \sigma/2$
Average	$R_{ave} - \sigma/2 <$ Monthly rainfall $< R_{ave} + \sigma/2$
Wet	$R_{ave} - \sigma <$ Monthly rainfall $< R_{ave} + \sigma$
Real Wet	$R_{ave} + \sigma <$ Monthly rainfall

The data are examined and for each year the number of months that fall into each of the categories is counted. A score is assigned to each year; each real dry month is 2 points, each dry month is 1 point, each wet month is –1 point and each real wet month is –2 points (no points given for an average month). Using this method, an average year would have a score of approximately 0 with dry years having a high score and wet years having a low score.

Dry Year
Among the top three driest years in both districts, the only year common to both districts is 1975. The total rainfall for this year is about 46.4 inches in both districts. However, this value puts it in the wetter end of the driest third of the years in District 5 (there are 10 other years that are drier based on total rainfall). The traditional dry year is 1989. In District 6, this was ranked as the driest years using this rainfall scoring method. However, in District 5, it is closer to the average years. This is due to the fact that 8 out of 12 months were classified as average months in District 5.

Wet Year
The period from 1994 to1995 is in the wet end of the tables, with both being in the top three wet years for District 5 and in the top six for District 6. The year 1995 presents not only high rainfall total but also indicates a wet antecedent condition (1994).

Average Year
Previous modeling efforts have designated 1986 as the "average" year. However, this is a misleading year because the first five months of 1986 were wetter than the first five months of 1995 (a wet year). By sorting by the number of average months, then the number of wet months, and finally by the number of dry months, it appears that 1978 is the best representative of an "average" year. In District 5, 1978 has 9 average months, 2 nearly average months (slightly dry or wet), and only 1 anomalous month (real wet). The anomalous month is December, which is only about 1 inch higher than normal. In District 6, it has 8 average and 4 nearly average months. This makes it a slightly better candidate for the average year than 1986.

The wet, dry, and average hydrologic conditions are intended to represent average and extreme conditions under which the proposed features would have to perform. Hydrology in the C-111 Basin is significantly affected by structure operation as well as rainfall patterns. How the results from the three simulated years should be combined to arrive at an estimate of the long-term average beneficial lift is largely based on best professional judgment. It is likely that the flood control/ water supply system tends to dampen the impact and occurrence of extreme hydrologic conditions. Ideally, the results would be combined using return frequency to set the individual weighting of each year's results. However, determining the return frequency of a particular hydrologic condition based on

rainfall alone will not completely address the weighting question since predictions of habitat improvement also require knowledge of antecedent habitat as well as antecedent hydrologic conditions. The PDT performed a sensitivity analysis to see if reasonable weighting of the years affected the selection of the preferred alternative. A discussion of this sensitivity analysis is found in the uncertainty discussion.

TABLE C-12: ANNUAL RAINFALL ANALYSIS FOR DISTRICT 5 AND DISTRICT 6

Sorted from Driest to Wettest

	District 5 1965-2001			Number of Months in Each Category							District 6 1965 - 2001			Number of Months in Each Category					
	Average Yearly Rainfall = 51.9", Standard Deviation = 7.0"										Average Yearly Rainfall = 59.3", Standard Deviation = 9.4"								
Rank by total Rainfall (1=least)	108 year Rank	Year	Rain (blue ~ average, red~dry, green~wet)	RealDry	Dry	Average	Wet	Real Wet	Score	Rank by total Rainfall (1=least)	108 year Rank	Year	Rain (blue ~ average, red~dry, green~wet)	RealDry	Dry	Average	Wet	Real Wet	Score
3	10	1981	42.8	4	2	5	0	1	8	**1**	**2**	**1989**	39.1	**4**	**5**	**3**	**0**	**0**	13
2	9	2000	42.7	2	5	4	0	1	7	3	10	1975	46.5	4	2	5	1	0	9
11	27	1975	46.3	3	4	3	1	1	7	2	8	1971	45.8	3	5	2	2	0	9
1	8	1988	42.7	3	3	4	1	1	6	5	19	1970	50.9	4	2	3	2	1	6
4	11	1990	43.3	1	5	5	0	1	5	11	32	1981	54.3	5	2	2	0	3	6
5	13	1976	44.0	1	5	5	0	1	5	4	12	1974	48.1	2	4	4	1	1	5
15	40	1974	**48.9**	3	3	4	0	2	5	9	30	1985	53.8	2	4	4	1	1	5
7	17	1971	44.7	2	2	7	1	0	5	20	62	1979	**60.3**	2	4	4	0	2	4
10	22	1967	45.7	2	3	5	2	0	5	15	46	1965	**57.8**	3	3	3	1	2	4
12	31	1996	47.2	2	4	3	2	1	4	6	21	1988	51.9	2	3	5	0	2	3
25	69	1970	**54.2**	3	3	3	1	2	4	23	72	1992	**62.6**	3	2	4	1	2	3
6	14	1985	44.3	1	4	5	1	1	3	8	29	1987	53.8	3	0	7	0	2	2
8	**19**	**1989**	45.4	**2**	**1**	**8**	**0**	**1**	3	7	27	1990	53.6	1	4	3	4	0	2
20	59	1987	**52.8**	3	2	4	1	2	3	17	53	1996	**58.9**	2	2	4	4	0	2
13	34	1973	47.7	2	2	5	3	0	3	12	39	1973	**56.1**	0	3	8	0	1	1
19	**53**	**1986**	**51.7**	**4**	**0**	**4**	**2**	**2**	**2**	18	58	1967	**59.5**	2	1	7	0	2	1
18	44	1965	**50.1**	1	3	6	0	2	1	13	41	1976	**56.3**	3	1	5	0	3	1
33	94	1968	60.4	2	3	3	2	2	1	**10**	**31**	**1978**	54.2	**0**	**2**	**8**	**2**	**0**	**0**
17	42	1972	**49.7**	2	2	4	3	1	1	21	65	1977	**60.8**	2	0	7	2	1	0
14	38	1984	**48.4**	3	2	2	3	2	1	19	59	1984	**59.9**	3	1	4	1	3	0
22	66	1992	**53.9**	3	2	2	3	2	1	**22**	**66**	**1986**	**60.8**	**3**	**1**	**4**	**1**	**3**	**0**
21	65	1993	**53.5**	0	3	7	1	1	0	36	104	1968	78.7	2	3	2	3	2	0
26	78	1966	**55.2**	1	2	7	0	2	0	27	88	2001	68.5	2	2	4	1	3	-1
16	41	1977	**49.4**	2	3	3	1	3	0	30	95	1999	70.6	2	3	3	0	4	-1
28	87	2001	57.5	2	2	4	2	2	0	14	45	2000	**56.9**	0	5	2	4	1	-1
9	20	1980	45.6	2	1	6	0	3	-1	16	48	1980	**58.0**	0	3	6	1	2	-2
27	79	1998	**55.3**	2	2	4	1	3	-1	25	78	1998	64.6	3	1	3	1	4	-2
24	68	1979	**54.0**	2	3	2	1	4	-2	29	90	1982	69.0	1	4	2	2	3	-2
23	**67**	**1978**	**53.9**	**0**	**1**	**9**	**1**	**1**	**-2**	26	79	1993	65.9	0	3	6	0	3	-3
30	91	1999	58.3	0	3	5	1	3	-4	24	74	1972	**63.2**	2	2	2	3	3	-3
29	89	1997	57.6	1	1	6	1	3	-4	28	89	1991	68.6	0	2	6	1	3	-5
32	93	1982	60.2	0	2	6	2	2	-4	**35**	**103**	**1995**	74.3	**0**	**3**	**4**	**2**	**3**	**-5**
36	104	1983	63.4	2	2	2	2	4	-4	32	100	1983	72.4	1	0	6	2	3	-6
31	92	1991	58.6	0	2	6	0	4	-6	33	101	1966	73.0	0	2	5	2	3	-6
34	97	1994	61.0	0	1	4	5	2	-8	34	102	1969	73.1	0	1	6	2	3	-7
37	**106**	**1995**	70.4	**0**	**2**	**4**	**1**	**5**	**-9**	31	98	1997	71.7	1	0	4	5	2	-7
35	103	1969	63.4	0	0	6	3	3	-9	37	105	1994	78.0	0	3	2	0	7	-11

C.13.1.2 PM 1.5 Flow Timing, Distribution and Volume

The Flow Timing, Distribution and Volume performance metric is designed to characterize how much of the freshwater discharge flowing to tide from the Everglades is concentrated at Taylor Slough (i.e., moving toward central Florida Bay) and when, during the year, the discharges are occurring. The surface and groundwater flows predicted by the Modbranch model are used by this performance metric. ***FIGURE C-16*** shows the location of flow transects that were calculated by post-processing the surface and groundwater flow fields from the Modbranch model runs. This performance metric utilizes two sub-indices. The Timing sub-index utilizes the inland Taylor Slough flow transect (TA-1). The Distribution sub-index utilizes all of the inland flow transects (TA-1, TA-2, TA-3, TA-4, and TA-5) to estimate the proportion of total flow directed to TA-1 (Taylor Slough). Volume sub-index directly compares the total annual volume through transect TA-1 from the target condition (NSM) to the TA-1 volume for each of the alternatives. ***FIGURE C-17*** shows the transect TA-1 1995 simulation year hydrographs for all of the with-project alternatives.

To calculate the three sub-indices, time series of fresh water discharges (surface and groundwater) from the study area to tide, and across the inland transects were synthesized from the Target (NSM), Baseline (FWO), and Project Alternative (1C, 1D, 2DS, 2DL, 3D, and 6D) simulations using scripts/programs prepared by the Modbranch modeler(s). As with the Greater Everglades Ridge / Slough PM developed by RECOVER, flow transects are established both in areas targeted for restoration as well as those areas that might not do as well because of a restoration project. Most of the features are located in the vicinity of transect T-A1. The timing and volume sub-indices uses this transect exclusively since the project focus is on rehydrating Taylor Slough. Data from the other four "A-Series" transects (T-A2, TA-3, TA-4 and TA-5) are used in the distribution sub-indices to measure the percentage of flow sent to TA-1 relative to all transect A flows. (Note that TA-5 is not shown in ***FIGURE C-16*** but it goes from the east end of TA-4 and stair steps to the FPL cooling ponds.)

The transect time series were further processed in an Microsoft Excel workbook using cell-based formulae to determine the Baseline and Project Alternative conditions' deviation from the Target condition. The objective of the timing and distribution sub-indices is to minimize each alternative's deviation from the target condition (in terms of discharge timing, and fraction of total discharge to tide made across the Taylor Slough transect). For these two sub-indices, the resulting measure of agreement with the Target condition was expressed as an index of 0.0 to 1.0 (with 1.0 representing an ideal match to the target, 0.0 representing little/no resemblance to the target condition) for the Baseline condition and each Project Alternative condition. The volume sub-indices is simply a normalized comparison of the target (NSM) total annual flow in transect TA-1 to the total annual flow in TA-1 for each alternative. The overall

performance metric is computed by taking the average of the three sub-indices to compute the average sheetflow functionality for Taylor Slough. To arrive at a measure-specific computation of habitat units, the resulting measure of sheetflow functionality was multiplied by the potentially affected area of 98,472 acres located in Little Madeira Bay (2,361 acres), Northeast Florida Bay (70,000 acres), and Taylor Slough (26,111 acres) since these are the areas likely affected by increased flows to Taylor Slough. ***FIGURE C-18*** shows the indicator regions for this performance metric. The raw model output, the spreadsheets, the processed model output, and associated indices and habitat unit computations were presented to and reviewed by the PDT during its assessment of project alternatives.

The equation for the computation of the timing sub-index is:

- Timing Sub-index $T = (\sum^{1}_{365} TT_{TA\text{-}1} - \sum^{1}_{365} DFTT_{TA\text{-}1}) / \sum^{1}_{365} TT_{TA\text{-}1}$
- Where:
- $\sum^{1}_{365} TT_{TA\text{-}1}$ = Target Timing: This is computed as sum of daily cumulative flow fractions over 365 day simulation period for transect TA-1.
- $\sum^{1}_{365} DFTT_{TA\text{-}1}$ = Difference from Target Timing: This is the daily deviation from target cumulative flow. It is computed by calculating the $TT_{TA\text{-}1}$ for the alternative and the target, subtracting the daily difference, then summing the absolute daily differences.

The equation for the computation of the distribution sub-indices is:

- Distribution Sub-index $D = (\sum^{1}_{365} TD_{TA\text{-}1} - \sum^{1}_{365} DFTD_{TA\text{-}1}) / \sum^{1}_{365} TD_{TA\text{-}1}$
- Where:
- $\sum^{1}_{365} TD_{TA\text{-}1}$ = Target Distribution for Transect TA-1: This is the daily fraction of total target transect flow. This is computed by first calculating the fraction of daily total transect flow (sum flows, TA-1, TA-2, TA-3, TA-4, TA-5) that is sent to TA-1, then summing the daily TA-1 flow fractions over the simulation period (365 days).
- $\sum^{1}_{365} DFTD_{TA\text{-}1}$ = Daily Difference from Target Distribution for transect TA-1: This is the sum of the daily deviations in Flow Fraction for TA-1 in the alternative relative to the target. This is computed by computing $TD_{TA\text{-}1}$ for the target and for the alternative, calculating the daily difference, then summing the absolute daily differences over the simulation period (365 days).

The equation for the computation of the volume sub-indices is:

- Volume Sub-index V = $\sum^{1}_{365} Q_{TA\text{-}1\ (Alternative)} / \sum^{1}_{365} Q_{TA\text{-}1\ (Target)}$
- Where:
- $\sum^{1}_{365} Q_{TA\text{-}1\ (Alternative)}$ = Daily flow to transect TA-1 for Alternative as measured in acre-feet. This is computed by summing the total flow in transect TA-1 over the simulation period (365 days).
- $\sum^{1}_{365} Q_{TA\text{-}1\ (Target)}$ = Daily flow to transect TA-1 for Alternative as measured in acre-feet. This is computed by summing the total flow in transect TA-1 over the simulation period (365 days).

Note that it is possible for this sub-indices to exceed 1.00 when the flow in transect TA-1 for a given alternative exceeds the target flow for transect TA-1. In this case, the volume sub-index is set to 1.00 so that restoration potential does not exceed the maximum.

The overall PM 1.5 indices result, reported at hydrologic restoration units (HRU) is computed by averaging the three sub-indices and multiplying this by the area of effect. The equation for this is:

PM1.5 = (T+D+V)/3 * A.
Where:
T = Timing Sub-index
D = Distribution Sub-index
V = Volume Sub-index
A = Area of impact (98,472 acres)

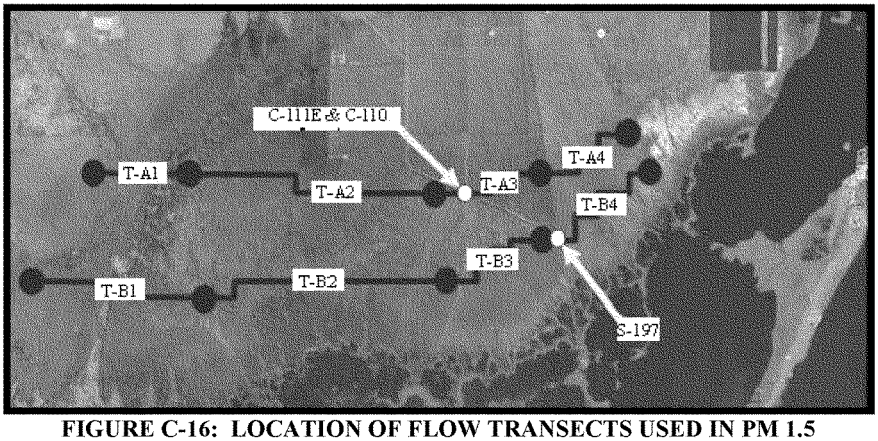


FIGURE C-16: LOCATION OF FLOW TRANSECTS USED IN PM 1.5

TABLE C-13 shows results for PM1.5 when the three model run (1978, 1989, and 1995) results are equally weighted. The results for each of the three sub-indices (Timing, Distribution, and Volume are shown along with the net hydrologic restoration units calculated for the with project alternatives. The overall Scenario HRU score for this performance metric is computed by taking the average of the three indices and multiplying this by the pre-drainage target acreage (98,472). With equal weighting of the three sub-indices, alternatives 2DShort, 2DLong, and 3D score the highest for PM1.5.

A review of the sub-indices shows the relative contribution of each sub-index to the overall lift score. For future alternative conditions, the timing index varies from 88 to 93 percent agreement with the target flow timing conditions. This limited change in the hydrologic timing sub-index is a reflection of the lack of water storage features in any of the considered alternatives. Those alternatives with the greatest potential to retain or detain water score the highest in terms of achieving the timing target for Taylor Slough. For 6D, the cutoff wall likely prevents undesirable seepage losses from Taylor Slough drainage to the C-111 Canal perhaps in effect providing more in-ground storage of water than the other alternatives.

The future project condition results for the Taylor Slough Distribution sub-index shows a range from 85 to 88 percent agreement with the target flow distribution conditions. This sub-index shows little difference between the alternatives. The future with project condition results for the Taylor Slough Volume sub-index shows a range from 79% to 108% percent of NSM flows. Alternatives 2DShort, 2DLong, and 3D score the highest on the volume index as they appear to divert more water into the Taylor Slough transect (TA-1) than even the target (NSM) condition. Though alternative 6D scores relatively good in the timing and distribution sub-indices, it has a relatively low score for the volume sub-index. One conclusion that might be drawn from this is that features that passively retard flow (via a cutoff wall) must be augmented with dynamic pumping features in order to maximize habitat restoration. It appears that of the three PM1.5 sub-indices, the volume sub-index provides the greatest contribution of hydrologic lift as measured by the difference from the FWO condition. The PDT considered using a non-equal weighing scheme to sum up the contribution from the three sub-indices; however, the team felt that an equal weighting scheme was optimal since it equally favors three of the four CERP restoration goals (Quantity, Quality, Timing, and Distribution).

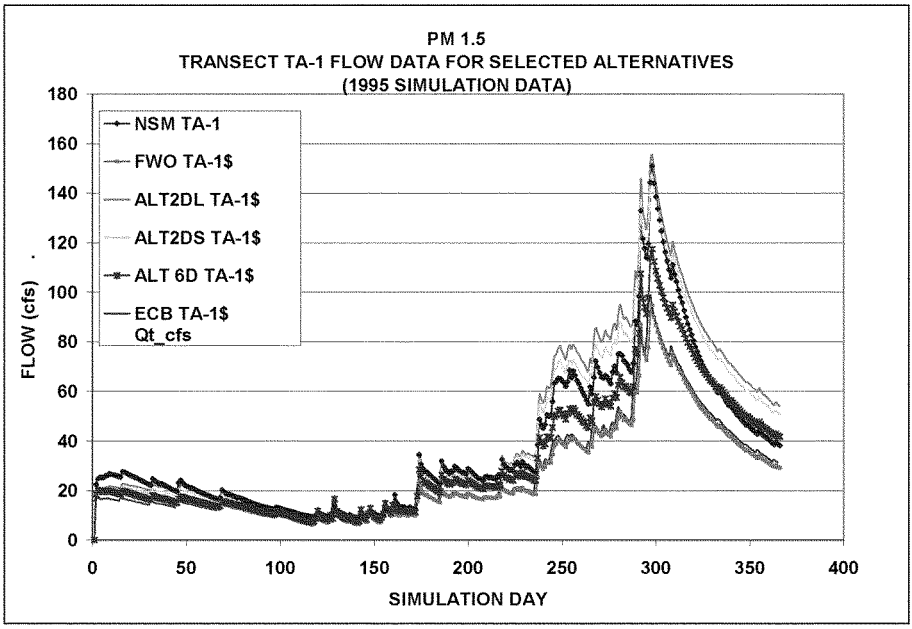


FIGURE C-17: TRANSECT TA-1 FLOW HYDROGRAPH FROM 1995 SIMULATION RESULTS

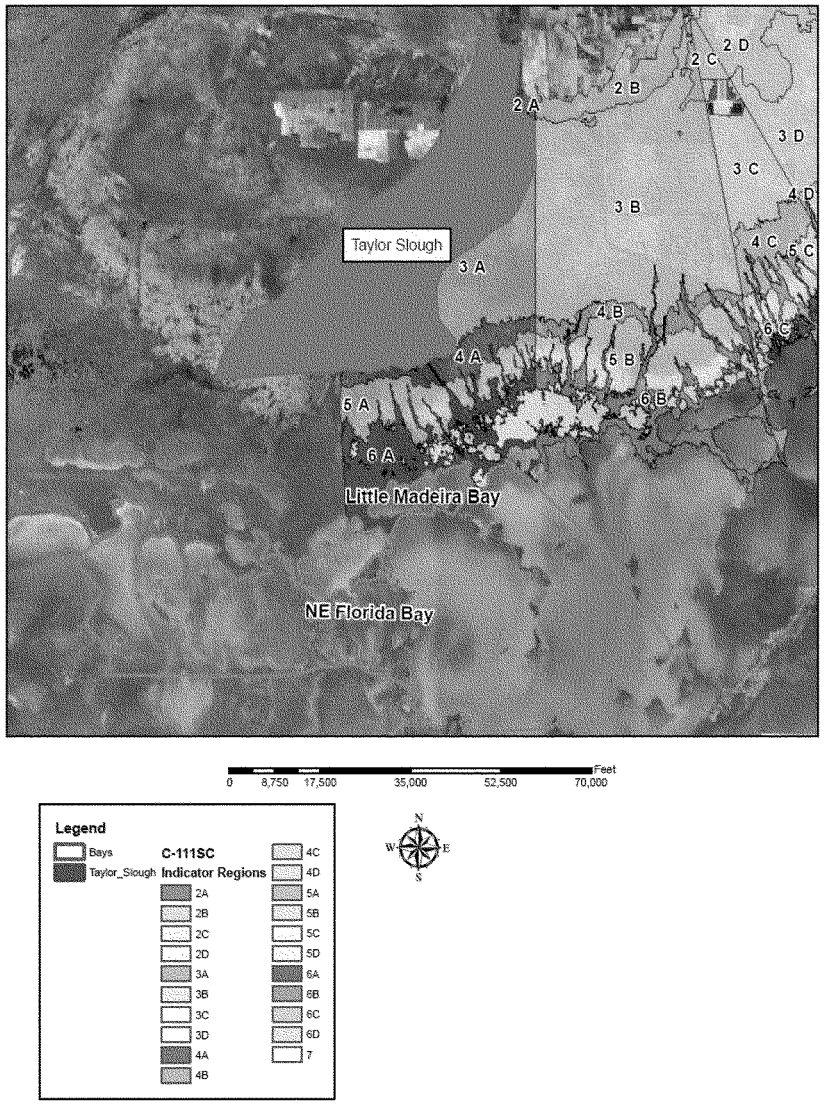


FIGURE C-18: INDICATOR REGIONS USED WITH PERFORMANCE MEASURE 1.5 FLOW, TIMING AND DISTRIBUTION

TABLE C-13: RESULTS FOR PERFORMANCE METRIC 1.5 FLOW TIMING, DISTRIBUTION AND VOLUME

Simulation Year Weighting			PM 1.5 Area of Effect		98472	acres		
1978	33%							
1985	33%							
1995	33%							
ALTERNATIVE	Timing		Volume		Distribution		Total	Net from FWO
Sub-Indices Weight	0.33		0.33		0.33		1.00	
	% NSM	HRU	% NSM	HRU	% NSM	HRU	HRU	HRU
Pre-Drainage/Target	100%	32,824	100%	32,824	100%	32,824	98,472	
FWO	93%	30,581	88%	28,861	71%	23,372	82,814	-
Alt_1C	92%	30,278	85%	27,865	79%	25,924	84,068	1,254
Alt_1D	93%	30,403	87%	28,496	80%	26,174	85,073	2,259
Alt_2DS	89%	29,307	87%	28,601	102%	32,824	90,733	7,919
Alt_2DL	88%	29,037	87%	28,626	108%	32,824	90,487	7,673
Alt_3D	90%	29,418	87%	28,577	105%	32,824	90,818	8,004
Alt_6D	93%	30,641	88%	28,918	84%	27,683	87,243	4,429
ECB	95%	31,152	91%	29,899	73%	23,968	85,019	2,205

C.13.1.3 PM 2.4 Coastal Zone Salinities

The present hydrologic management scheme in the C-111 Basin results in elevated salinity conditions in the near shore portion of Florida Bay that is directly downstream of Taylor Slough while also contributing to rapid and extreme salinity swings in Barnes Sound and Manatee Bay when the S-197 structure is opened. The major goals of the C-111SC Western Project are to reduce hyper-salinity conditions downstream of Taylor Slough and decrease the frequency and magnitude of discharges through the S-197 structure.

The physiography of the mangrove transition zone along the NE shore of Florida Bay is unique. Freshwater flows south from Taylor Slough and the C-111 Basin towards the Bay largely as sheet flow; but within this estuarine transition zone,

this flow is focused into a few distinct tidal creeks that ultimately empty into the Bay itself. These creeks are the few breaks in the Buttonwood Ridge, which runs along this shoreline and prevents overland flow in either direction except during extreme events (e.g. hurricane storm surges). Thus, freshwater inflows to NE Florida Bay from the study area are via point sources (either these tidal creeks or the C-111 Canal just below the S-197). Given these site conditions, predicting the impact on salinity that will result from diverting water from the C-111 Canal into the headwaters of Taylor Slough is not trivial. One typical approach would be to create an uplands hydrology model that predicts surface and groundwater flow at the boundary between the upland project area and the estuarine project area. A hydrodynamic salinity mixing model is then used to predict the resulting changes to nearshore salinity conditions for each project alternative. These complex modeling systems present their own set of difficulties related to calibration and verification. The funding and time to conduct such an effort has not been available for the C-111 SC Western Project. The project team used an alternative and admittedly cruder method of predicting changes to near shore salinity that is based on observed relationships between groundwater stage and salinity.

The result is a stage-inferred coastal zone salinities measure that characterizes how coastal embayment salinities vary during the year as estimated using stage-salinity relationships described by existing stage-based salinity regression equations provided by Everglades National Park (2009, Everglades National Park). Like the other two performance measure, PM2.4 is a "distance from target" performance measure that compares salinity duration curves computed based on simulated groundwater stages. Given that the project redistributes the available water rather than distributes "new" water, this performance measure evaluates changes both directly downstream of Taylor Slough and downstream of the S-197 structure as a means of measuring the net effect to nearshore salinity conditions within the probable area of impact.

C.13.1.3.1.1 Stage-Salinity Equations

Staff at the South Florida Natural Resource Center which is part of Everglades National Park provided the regression equations that link groundwater stage in the Southern Everglades to near shore salinity conditions in Florida Bay and Barnes Sound/Manatee Bay. ***FIGURE C-19*** shows the locations of the salinity stations and the groundwater stage stations used in this analysis. Stage and salinity datasets for the period between 1996 and 2008 were used in the regression. No filtering of the datasets was done to remove salinity records for periods when flow at S-197 was known to occur. The results of the regression equations are shown below in ***TABLE C-14***. Two groundwater stage records were used to develop these relationships. The P-37 station which is located in Western Taylor slough was regressed against the Taylor River salinity station. The predicted Taylor River salinity was then used to develop regression

relationships for Long Sound, Little Madeira Bay, and Taylor Creek/Joe Bay. The EVER1 groundwater stage monitoring site is regressed against salinity stations in Manatee Bay, Middle Key, and Barnes Sound. The correlation coefficients for these regression equations range from 0.16 to 0.60. The Barnes Sound and Manatee Bay stations have the lowest correlation coefficients. This is likely due to the influence of S-197 discharges on the relationship between salinity at these stations and stage in the nearby southern glades.

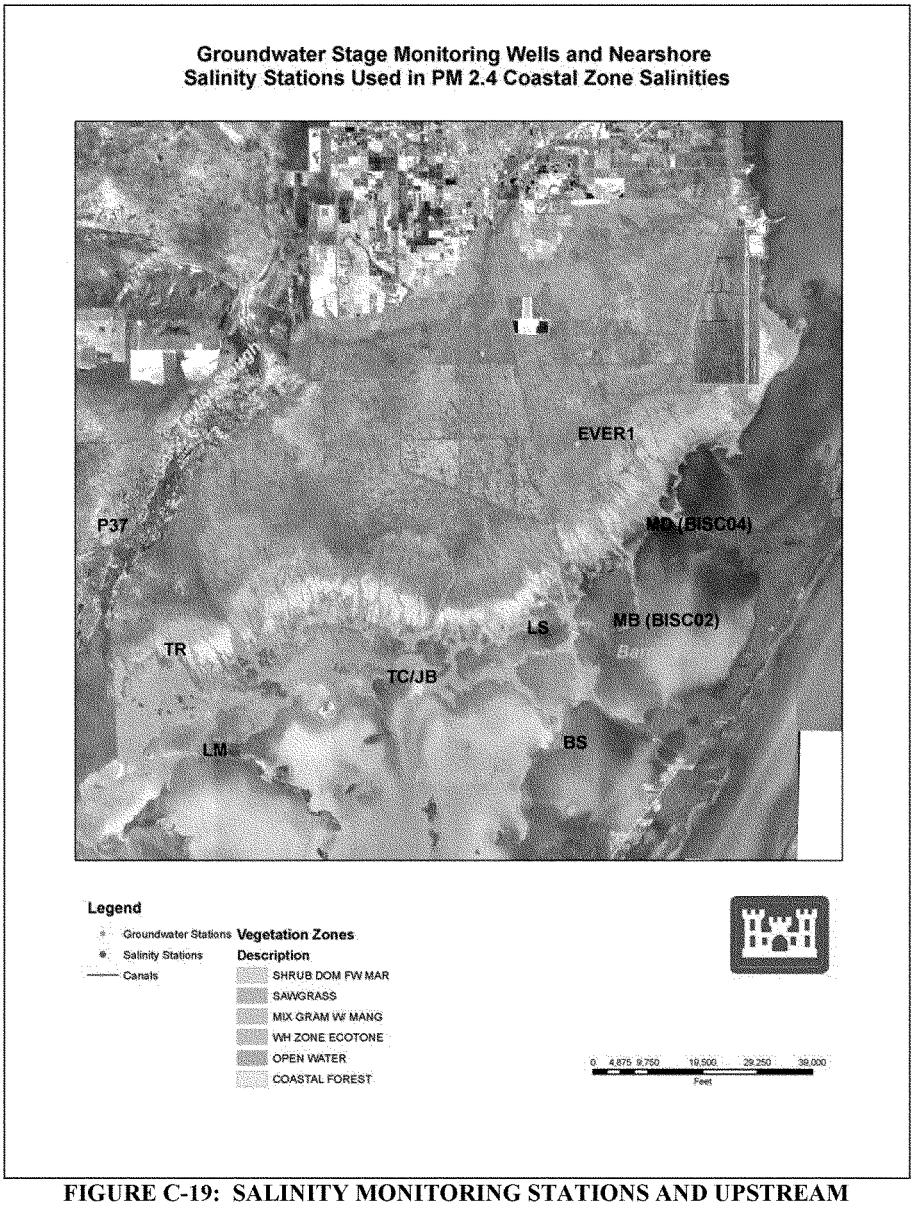


FIGURE C-19: SALINITY MONITORING STATIONS AND UPSTREAM GROUNDWATER STAGE STATIONS USED IN PM 2.4

TABLE C-14: STAGE VERSUS SALINITY REGRESSION RESULTS

Equation	Location	**R^2**
(TR_salinity) = -14.152(P37_stage) + 28.926	Taylor River	0.4628
(LS_salinity) = 0.6021(TR_salinity) + 14.981	Long Sound	0.5875
(LM_salinity) = 0.5102(TR_salinity) + 18.886	Little Madeira Bay	0.6037
(TC_salinity) = 0.6681(TR_salinity) + 13.826	Taylor Creek/Joe Bay	0.5435
(BISC02_salinity) = -1.4775(EVER1_stage) + 40.554	Manatee Bay	0.1624
(BISC06_salinity) = -10.28(EVER1_stage) + 47.274	Middle Key	0.4775
(BS_salinity) = -6.3939(EVER1_stage) + 39.713	Barnes Sound	0.1723
Note: MD salinity from station BISC06, MB salinity from station BISC02		

Stage time series were synthesized from the Target, Baseline, and Project Alternative simulations using scripts/programs prepared by the Modbranch modeler(s). Daily salinity estimates for five near shore areas (Long Sound, Little Madeira Bay, Joe Bay, Manatee Bay, and Barnes Sound) were then predicted using the stage-salinity relationships in ***TABLE C-14***. The salinity predictions for Taylor River and each of the estuarine areas are shown in ***FIGURE C-20*** through ***FIGURE C-25***. These graphs show that for average and dry hydrologic conditions, there is little difference between any of with and without project alternatives. However under the dry and average hydrologic conditions, the target (NSM) provides generally lower salinity for areas west of the C-111 Canal outlet. For Barnes Sound and Manatee Bay, the salinity predicted for the target condition (NSM) under dry and average conditions is approximately 1 psu higher than it is for with- and without project conditions. Under wet hydrologic conditions (1995), differences between the various with-project alternatives are evident. At Taylor River, the existing condition (ECB) and alternative 1C have markedly higher salinities than either the target condition or the other with-project alternatives for the first 130 days of the simulated year. For much of the remaining portion of the year, the ECB and alternative 1C have lower salinities than the target or other alternatives. This same general pattern is observed for estuarine areas downstream of Taylor River (Long Sound, Little Madeira Bay, and Joe Bay) and to a lesser degree in Barnes Sound and Manatee Bay.

There is no evidence in these results that indicate an increase in salinity conditions that is due to increased evapotranspiration within the freshwater wetlands targeted for rehydration. This may be because, any increased evapotranspiration in wetland areas targeted for rehydration is be balanced by a decrease in evapotranspiration in other non-targeted wetland areas.

The salinity predictions presented in ***FIGURE C-20*** to ***FIGURE C-25*** were used to estimate salinity improvement benefits resulting from with and without project alternatives. Salinity benefits were estimated by creating an index to measure the degree to which target salinity conditions were achieved by each of the alternatives. The salinity indices for each of the five salinity stations are computed for each alternative by first calculating the number of days the salinity is within a particular range over the course of the simulated year. The number of days in each salinity range is then converted into a percent of time by dividing by the duration of the simulation period (365 days). Ten salinity distribution bins are set up in increments of 5 ppt (0 to 5 ppt, 5-10 ppt, and so on up to 45 ppt. The difference between NSM and alternative salinity duration distributions are calculated by subtracting the NSM result from the alternative result for each salinity bin. The overall index is calculated by taking the sum of absolute salinity bin differences and subtracting this from one. ***FIGURE C-26*** shows a graphical representation of this process. The column in this figure that is labeled "NSM" contains the duration distribution by salinity range for the target (NSM) condition. The column labeled "2DLONG" contains the duration distribution by salinity range for this alternative. The column labeled "2DLONG – NSM" contains the result of subtracting the NSM salinity bin durations from the 2DLONG salinity bin durations. The result is computed by subtracting the sum of absolute results in the "2DLONG – NSM" column from one. This calculation method has two notable characteristics. The first is that all of the salinity bins are weighted equally regardless of ecological significance. The second is that absolute deviation from the target condition is scored and not direction of deviation. In other words, both higher and lower salinity conditions than the target result in a lower index score.

The resulting measure of agreement with the Target condition is expressed as an index of 0.0 to 1.0 (with 1.0 representing an ideal match to the target, 0.0 representing little/no resemblance to the target condition) for each coastal embayment for the Baseline condition and each Project Alternative condition. To arrive at a measure-specific computation of habitat units, the resulting measure of salinity-related habitat function is multiplied by the acreage of the affected embayments. This performance metric is applied to an area of 14,626 acres located in Long Sound (2,153 acres), Joe Bay (3,389 acres), Little Madeira Bay (2,361 acres), Manatee Bay (2,497 acres), and Barnes Sound (4,226 acres) as shown in ***FIGURE C-27***. Only 25% of the total area of Barnes Sound (16,902 acres) is used here since much of Barnes Sound is not directly adjacent to the mangrove fringe shoreline as it is for the other four embayments. The raw model output, the spreadsheets, the processed model output, and associated indices and habitat unit computations were presented to and reviewed by the PDT during its assessment of project alternatives.

TABLE C-15 shows results for PM 2.4 when the three model run (1978, 1989, and 1995) results are equally weighted. Results are provided for Barnes Sound, Manatee Bay, Joe Bay, Little Madeira Bay, and Long Sound nearshore areas. The overall Scenario HRU score is computed by multiplying the acreage of each nearshore area by the corresponding salinity index.

The results for Barnes Sound (BS) show that alternative 2DS performs somewhat better than the other future condition scenarios. The Manatee Bay (MB) shows no difference between the future alternative conditions. This is a result of all predicted salinities ranging from 35 to 40 psu regardless of hydrologic conditions or alternative scenario. The results for Joe Bay indicate that alternative 2DShort provides the greatest lift to this area. The lift for 2DShort in Joe Bay is equivalent to about 10% of the FWO scenario HRU result. In Long Sound and Little Madeira Bay, the 2DLong, 2DShort, and 3D alternatives do marginally better than the other future scenarios. The resulting improved salinity conditions net HRUs for the with-project alternatives ranges from 287 for alternative 1D to 520 for alternative 2DShort.

The overall result for this performance metric shows that alternative 2DShort scores the highest in terms of meeting the desired salinity target derived from the natural systems hydrology. This alternative provides an increase of 4% over the future without condition and a 7% increase over the existing condition scenario. A review of ***FIGURE C-25*** shows that the target scenario (NSM) actually provides higher, thus more undesirable, salinities in Barnes Sound and Manatee Bay than that provided by the with-project alternatives. (The NSM condition provides higher salinities because the C-111 canal is not in place facilitate rehydration of the ENP panhandle and model lands).

It is apparent from the graphs showing the predicted salinities and from the overall salinity benefit results that the method used to estimate future salinity conditions and translate this into an estimate of habitat restoration is not particularly sensitive to the hydrologic modifications planned for the various project alternatives. There are several potential reasons for this. One reason is that the regression equations that link salinity to stage are not particularly robust. This is not unexpected since complex hydrodynamic modeling is usually performed to obtain reliable estimates of salinity changes that result from upstream hydrologic modifications.

Another cause of limited salinity sensitivity is the use of the Modbranch model as the source of groundwater stage prediction. The physiography of the mangrove transition zone along the NE shore of Florida Bay is unique. Freshwater flows south from Taylor Slough and the C-111 Basin towards the Bay largely as sheet flow; but within this estuarine transition zone, this flow is focused into a few distinct tidal creeks that ultimately empty into the Bay itself.

These creeks are the few breaks in the Buttonwood Ridge, which runs along this shoreline and prevents overland flow in either direction except during extreme events (e.g. hurricane storm surges). Thus, freshwater inflows to NE Florida Bay from the study area are via point sources (either these tidal creeks or the C-111 Canal just below the S-197). The MODBRANCH model does not explicitly simulate tidal creeks because there is little to no information to calibrate or verify flows in these creeks. Preferential overland flow paths occur within the model based upon the topography data used to define the average grid cell elevation. The smallest grid cell size is approximately 200 ft on side so the bottom elevation of a 1 to 4 meter wide tidal creek would not likely be the defining elevation of a given grid cell since grid cell elevations are based on the average elevation within the cell. Given the lack of tidal creek representation in the Modbranch model, it is very probable that PM 2.4 underestimates improvements in salinity downstream of Taylor Slough. Despite these problems, the project delivery team felt that it was important to address project affects on nearshore salinity and in the absence of a better salinity metric, PM 2.4 would be used for this purpose. Fortunately, PM 1.5 which measures the quantity, timing, and distribution of flow to Taylor Slough is an effective surrogate measure of the potential to improve salinity downstream of Taylor Slough.

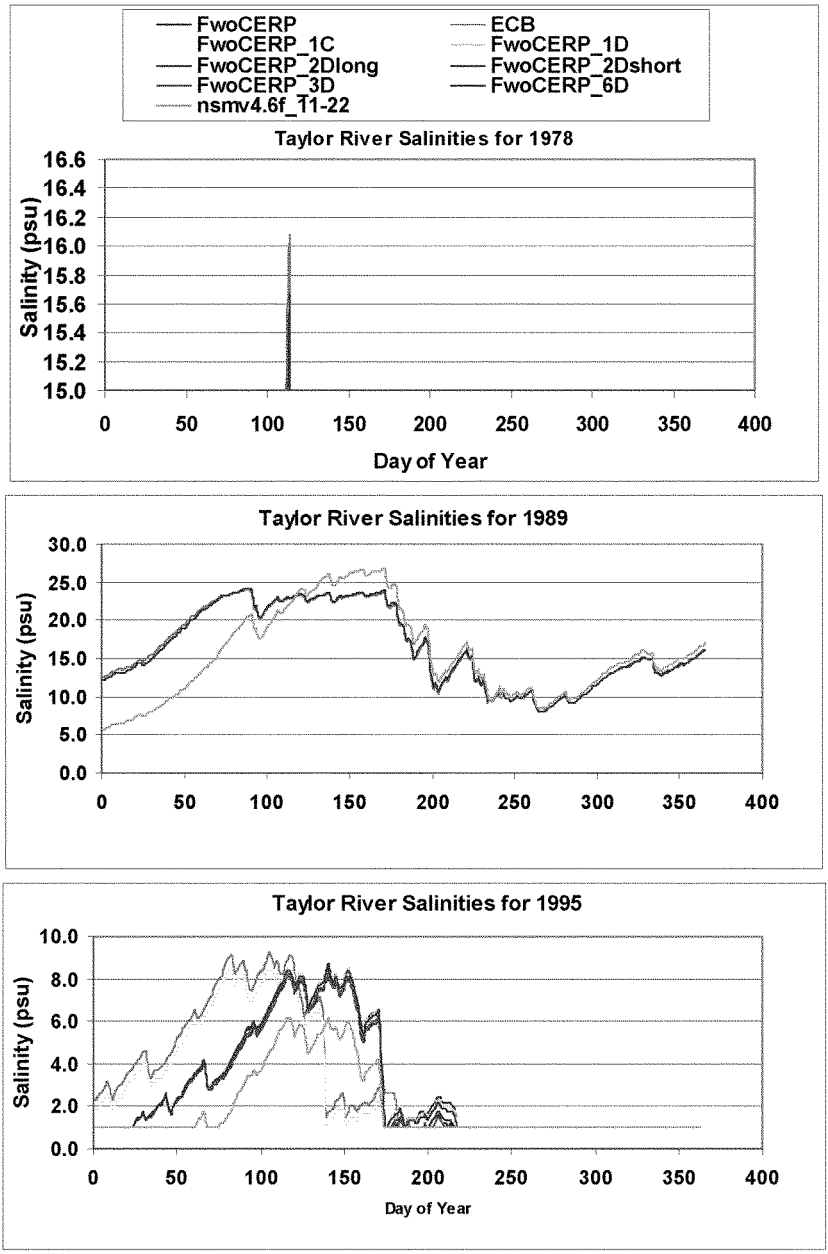


FIGURE C-20: TAYLOR RIVER PREDICTED SALINITIES

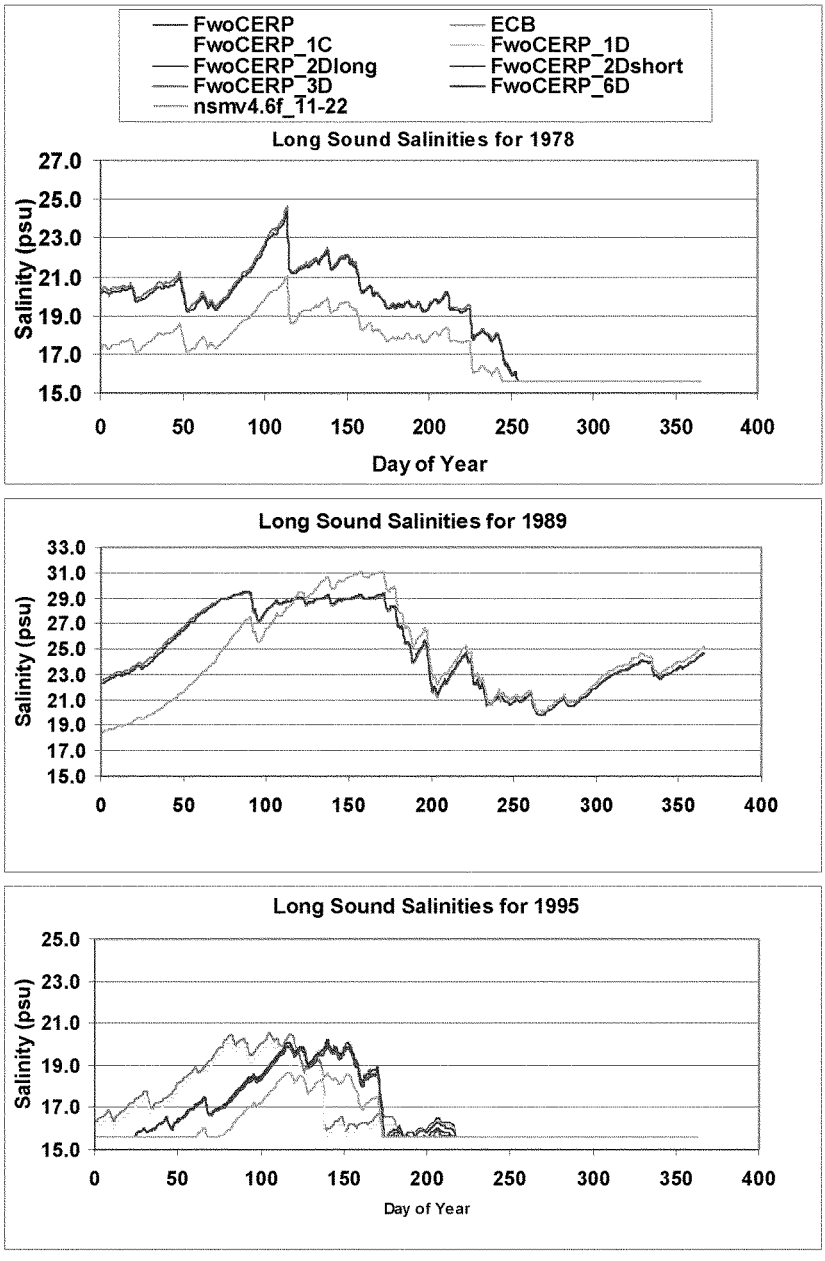


FIGURE C-21: LONG SOUND PREDICTED SALINITIES

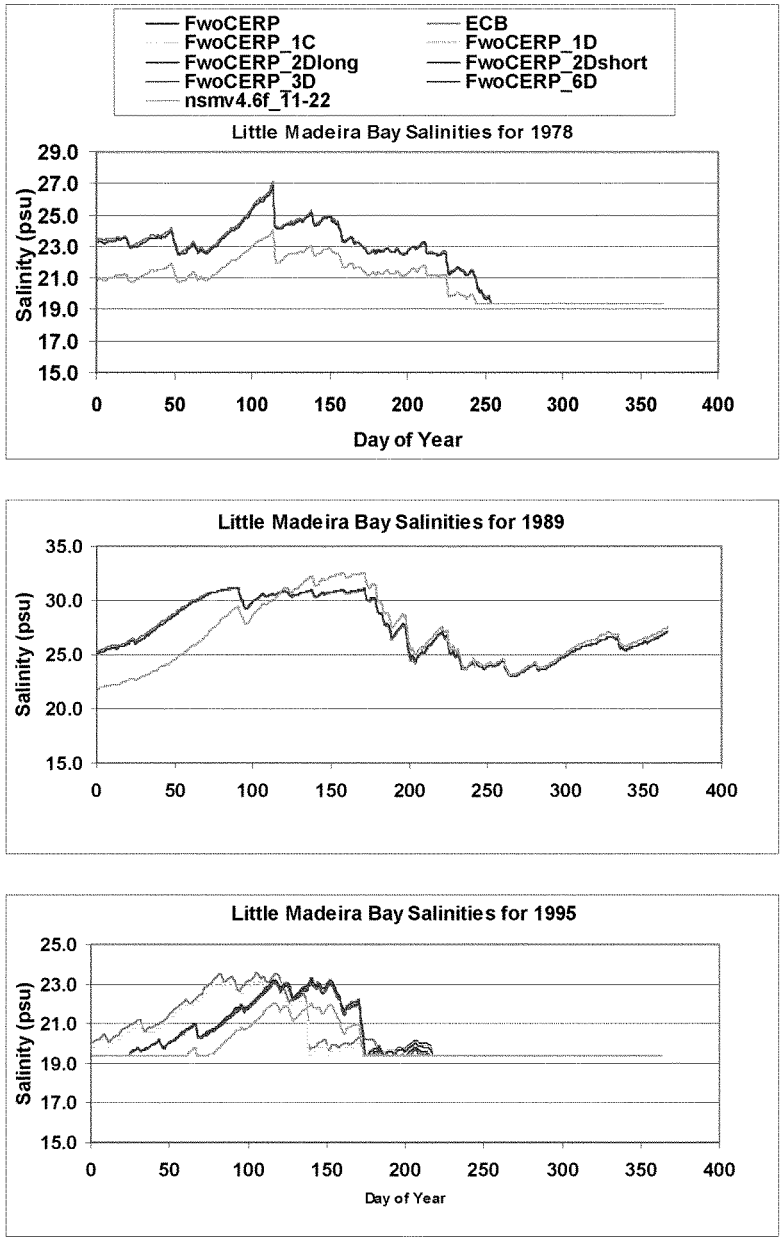


FIGURE C-22: LITTLE MADEIRA BAY PREDICTED SALINITIES

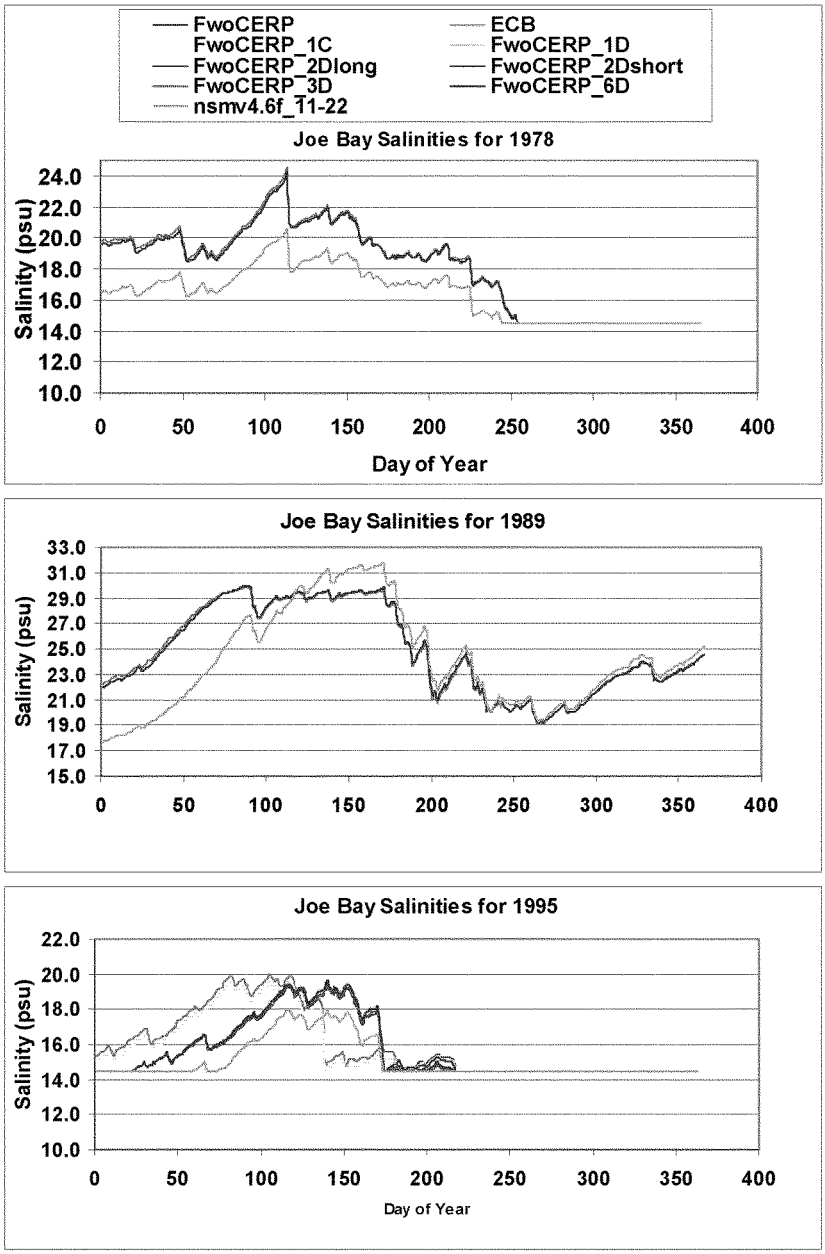


FIGURE C-23: JOE BAY PREDICTED SALINITIES

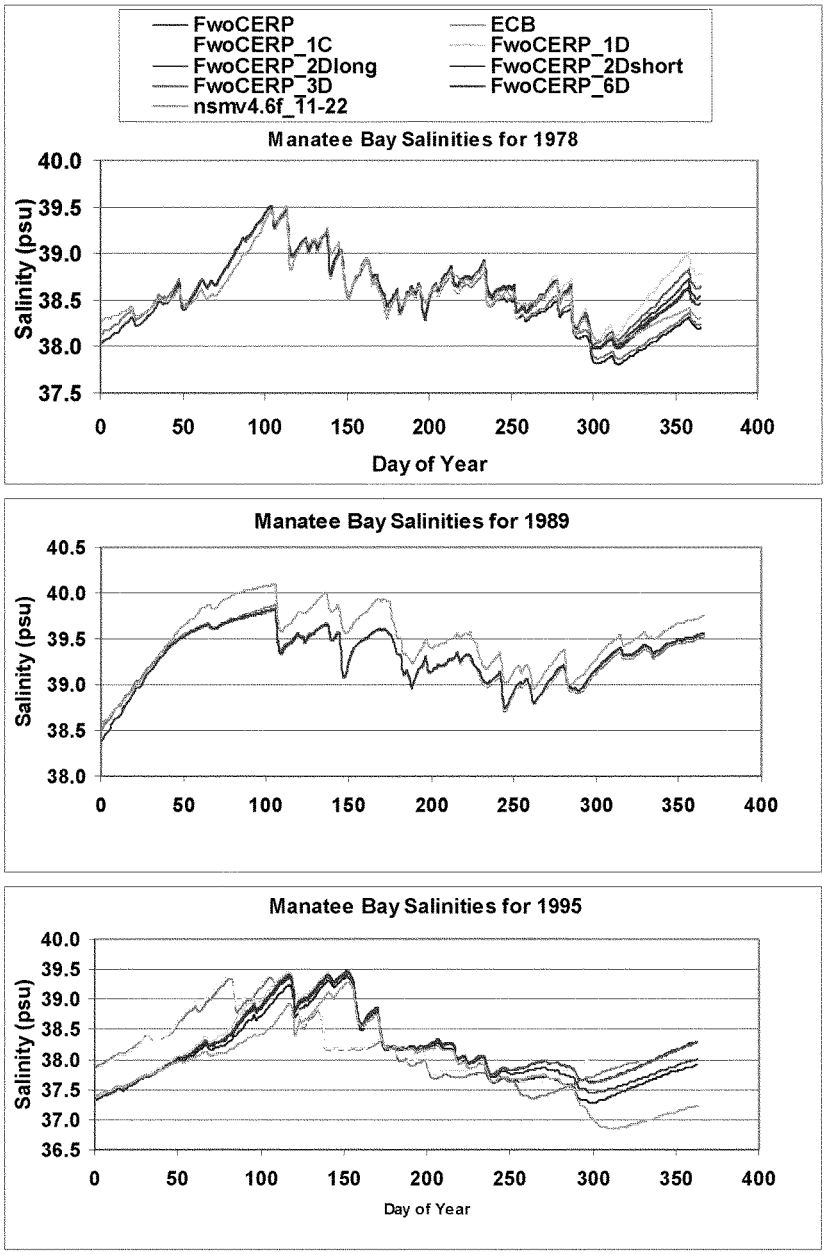


FIGURE C-24: MANATEE BAY PREDICTED SALINITIES

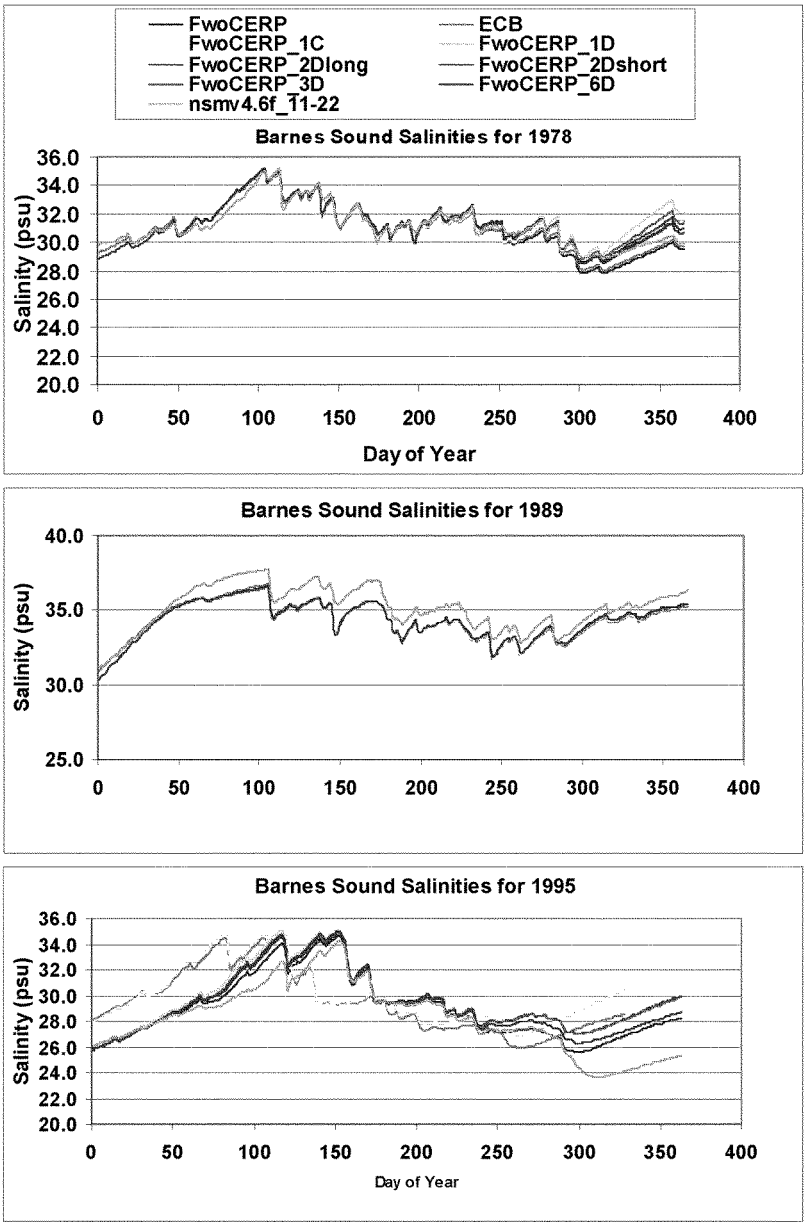


FIGURE C-25: BARNES SOUND PREDICTED SALINITIES

Salinity Bins	NSM		2DLONG		2DLONG - NSM		Result
O to 5.00	0%		0%		0%		
5.01 to 10.00	0%		0%		0%		
10.01 to 15.00	0%		0%		0%		
15.01 to 20.00	9%		1%		-7%		
20.01 to 25.00	56%	-	56%	=	0%	==>	64%
25.01 to 30.00	24%		42%		18%		
30.01 to 35.00	11%		0%		-11%		
35.01 to 40.00	0%		0%		0%		
40.01 to 45.00	0%		0%		0%		
above 45.01	0%		0%		0%		

FIGURE C-26: EXAMPLE OF SALINITY INDEX CALCULATIONS

TABLE C-15: RESULTS FOR PERFORMANCE METRIC 2.4 COASTAL SALINITIES

Simulation Year Weighting		PM 2.4 Area of Effect	14,626	acres	
1978	33%				
1985	33%				
1995	33%				

Scenario	Individual Sub-Measure HRU Scores (Computed)					Sub-Measure Composite HRU Score	Net from FWO
	BS	MB	JB	LM	LS	Total	HRU
Pre-Drainage/Target	4,226	2,497	3,389	2,361	2,153	14,626	
FWO	2,813	2,392	1,990	1,900	1,370	10,465	-
Alt_1C	3,106	2,392	2,002	1,904	1,370	10,775	310
Alt_1D	3,083	2,392	2,002	1,904	1,370	10,752	287
Alt_2DS	3,160	2,392	2,101	1,930	1,402	10,986	520
Alt_2DL	3,130	2,392	2,108	1,930	1,402	10,961	496
Alt_3D	3,137	2,392	2,095	1,925	1,402	10,952	487
Alt_6D	3,137	2,392	2,046	1,921	1,374	10,871	405
ECB	2,960	2,392	1,718	1,805	1,241	10,115	(350)

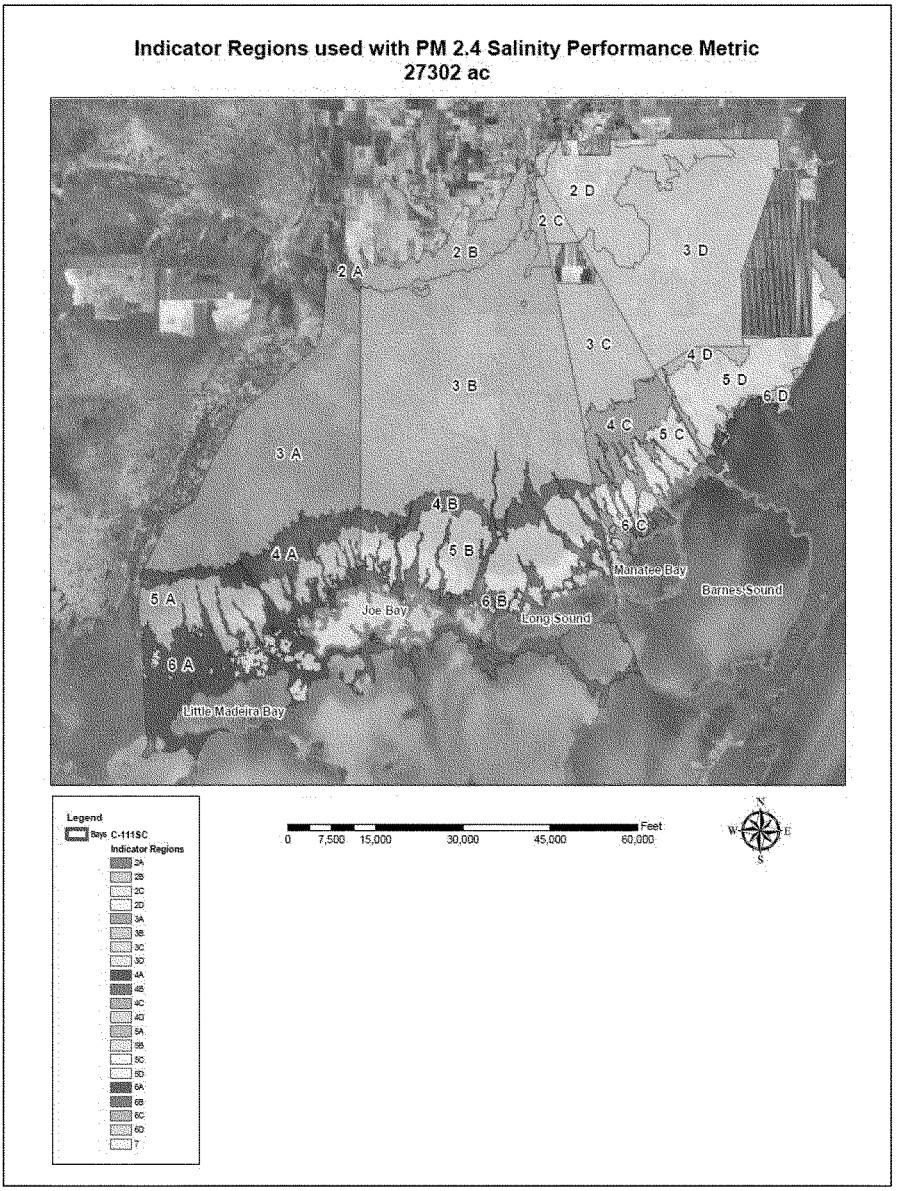


FIGURE C-27: INDICATOR REGIONS USED WITH PERFORMANCE METRIC 2.4 COASTAL ZONE SALINITIES

C.13.1.4 PM 2.1 Vegetation Hydroperiods

The hydroperiod-inferred vegetation communities' measure characterizes annual hydroperiods within defined indicator regions across the entire study area by describing how much of each indicator region (i.e., percent area) experiences a given hydroperiod (i.e., of 0 to 365 days; divided generally into 30-day hydroperiod classes/groupings).

The linkage between hydroperiod and habitat type for each wetland type is described in ***TABLE C-9***. One objective of the project is to restore and promote long hydroperiod wetlands in Taylor Slough. A map of the indicator regions used in this performance measure is shown in ***FIGURE C-28***.

The vegetation hydroperiod metric is a measure of the degree to which a given alternative matches the target hydroperiod distribution for all of the indicator regions. This metric is intended to be an indicator of (or surrogate for) vegetation community type. The following steps are used to calculate this metric:

1. Compute % area subject to different hydroperiods (expressed in terms of 30 day brackets: 0-30, 31-60, 61-90, etc.) This preprocessing was done by the MODBRANCH modeler using the model grid hydrology results (daily stage relative to land elevation for each grid.).
2. For each indicator zone subtract the NSM % area for all of the hydroperiods brackets.
3. Sum the absolute difference in hydroperiod percentages.
4. Subtract the sum of absolute differences from 1 to compute the index of hydroperiod correlation with the target condition.
5. If the sum of absolute differences is greater than 1, then the index of hydroperiod correlation is set to zero for that indicator zone.
6. Multiply the hydroperiod correlation index for that indicator zone by the acreage of the indicator zone to compute the HRUs for that indicator zone.
7. Sum up all of the indicator zone HRUs to get the overall HRUs for that alternative under the given hydrologic conditions (wet, dry, average).

FIGURE C-29 shows the hydroperiod distribution for Taylor Slough (indicator region TS). Similar hydroperiod distributions were computed for all alternatives and indicator regions. Those outputs were summarized for each indicator region as "percent of the total area" experiencing a hydroperiod within a certain hydroperiod range (e.g., 10% experienced a hydroperiod of 1-30 days; 5% experienced a hydroperiod of 31-60 days, etc.). Rather than use two or three hydroperiods that are critical to a particular type of landscape vegetation, the project team elected to divide the year into twelve hydroperiod ranges and compute the fraction of land within an indicator region meeting each hydroperiod range. This methodology was selected because it sets a hydroperiod target for the full range of vegetation rather than just specific landscape

vegetations such as grammanoid, hardwood, or estuarine wetlands. The advantage of this approach is that it is more appropriate for a large scale project located in a topographically flat region where small changes in elevation (<0.5 ft) can result in significant differences in hydroperiod and thus wetland type.

The objective of this metric is to minimize each alternative's deviation from the target. The deviation from the target was estimated by computing the sum of the absolute difference between the target areal hydroperiod distribution and the alternative areal hydroperiod distribution. The resulting measure of agreement with the Target condition was expressed as an index of 0.0 to 1.0 (with 1.0 representing an ideal match to the target, 0.0 representing little/no resemblance to the target condition) for each indicator region for the Baseline condition and each Project Alternative condition. To arrive at a measure-specific computation of habitat units, the resulting average measure of hydroperiod-related (i.e., vegetation community relative abundance within the indicator region) habitat function was multiplied by the acreage of the affected area. This performance metric was applied to an area of 155,098 acres which represents the entire area of wetland landscape identified in ***FIGURE C-28*** (Indicator regions 1A-D, 2A-D, 3A-D, 4A-D, 5A-D, and 6A-d) as well as Taylor Slough. The raw model output, the spreadsheets, the processed model output, and associated indices and habitat unit computations were presented to and reviewed by the PDT during its assessment of project alternatives.

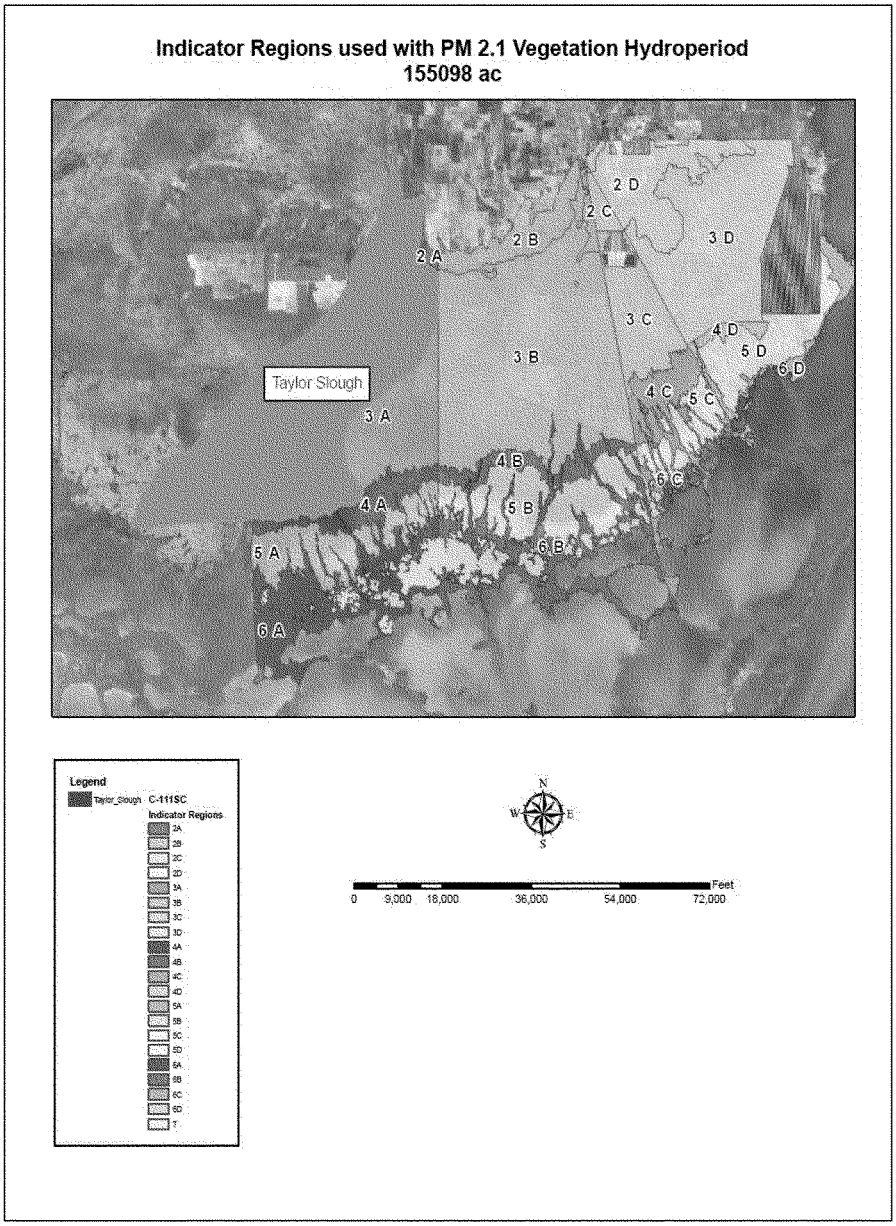


FIGURE C-28: INDICATOR REGIONS USED WITH PM 2.1 VEGETATION HYDROPERIOD

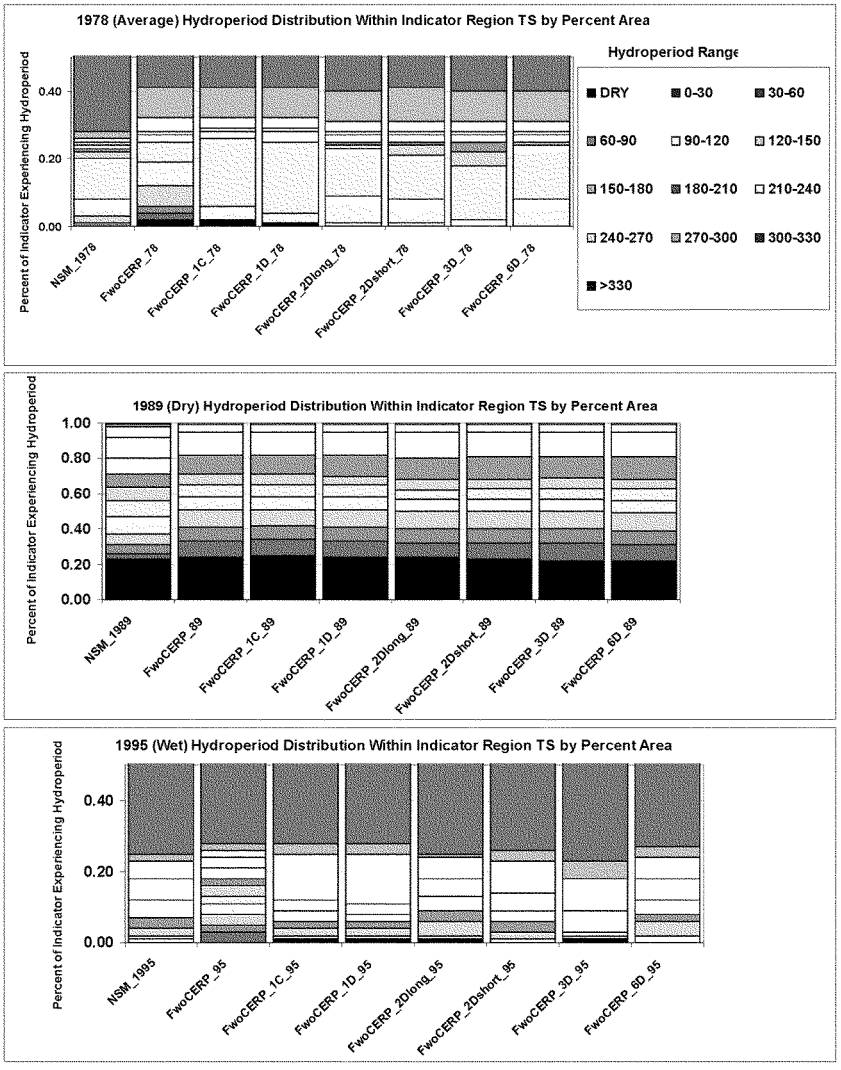


FIGURE C-29: VEGETATION HYDROPERIOD DISTRIBUTION FOR TAYLOR SLOUGH INDICATOR REGION

TABLE C-16 shows results for PM 2.4 when the three model run (1978, 1989, and 1995) results are equally weighted.

The Scenario HRU Score for each alternative is computed by taking the average of the three hydroperiod indices and multiplying this by the pre-drainage target acreage. As measured using this metric, under average hydrologic conditions, all of the with-project alternatives except alternatives 1C and 1D provide improved vegetation hydroperiod conditions relative to the No Action Alternative. Under average year conditions, only alternative 6D provides better hydroperiod conditions than the No Action Alternative. Under dry year conditions, most of the with-project alternatives perform only slightly better than the No Action Alternative. Alternative 6D is slightly worse than the FWO scenario under dry conditions. This is not a surprising result for any of the with project alternatives since during dry years there is very little water to be diverted or detained by project features. Under wet year hydrologic conditions, alternatives 1C and 1D provide significantly less favorable hydroperiod results than the FWO scenario. Alternative 6D provides the most favorable hydroperiod results under wet hydrologic conditions. A review of the PM2.1 calculations shows that alternatives 1C and 1D do somewhat worse for Taylor Slough but significantly under perform in indicator region 3B under average and wet hydrologic conditions. Overall, alternative 6D provides the greatest HRU lift when PM2.1 is applied to all of the indicator zones.

TABLE C-17 shows the net hydroperiod associated lift when PM 2.1 is applied only to Taylor Slough which is the primary restoration target of this project. In this table, it appears that alternative 2DShort and the ECB (existing condition baseline) fair the best in comparison to the FWO scenario. Alternative 6D scores somewhat less than alternative 2DShort when only Taylor Slough is evaluated as opposed to scoring significantly better than 2dShort when all of the indicator zones are evaluated. Alternatives 1C and 1D have positive scores if only Taylor Slough is considered as opposed to markedly negative HRU scores if all of the zones are evaluated.

The final benefits assessment results use PM 2.1 as applied to all of the indicator zones so that net regional hydroperiod benefits are measured. The analysis of PM1.5 hydroperiod benefits in Taylor Slough, though not used in the final benefits calculations, demonstrates that alternative 2DShort is the optimal with-project future condition for hydroperiod enhancement if the project focus is Taylor Slough.

TABLE C-16: RESULTS FOR PERFORMANCE METRIC 2.1 VEGETATION HYDROPERIOD FOR ALL INDICATOR ZONES

Simulation Year Weighting		PM 2.4 Area of Effect	155,098	acres
1978	33%			
1985	33%			
1995	33%			

Scenario	Individual Sub-Measure HU Scores (Computed)			Sub-Measure Composite HU Score	Net from FWO
	Avg	Dry	Wet		HRU
Pre-Drainage/Target	51,699	51,699	51,699	155,098	
FWO	23,133	33,695	23,527	80,356	-
Alt_1C	19,172	33,788	20,767	73,727	(6,629)
Alt_1D	20,109	34,033	20,564	74,706	(5,650)
Alt_2DS	22,869	34,435	25,300	82,604	2,248
Alt_2DL	22,781	33,506	24,525	80,812	456
Alt_3D	21,561	34,301	24,457	80,319	(37)
Alt_6D	25,260	33,518	27,346	86,124	5,768
ECB	24,370	33,232	25,246	82,848	2,492

TABLE C-17: RESULTS FOR PM2.1 VEGETATION HYDROPERIOD FOR TAYLOR SLOUGH INDICATOR ZONE.

Scenario	1978	1989	1995	Average HRUs	Net FWO (HRUs)
Pre-drainage/ Target				26,111	
FwoCERP	14,361	14,622	19,844	16,276	-
FwoCERP_1C	15,405	14,622	20,889	16,972	696
FwoCERP_1D	14,883	14,100	20,367	16,450	174
FwoCERP_2Ds	18,017	13,578	23,761	18,452	2,176
FwoCERP_2Dl	18,017	13,578	24,022	18,539	2,263
FwoCERP_3D	16,450	13,578	20,889	16,972	696
FwoCERP_6D	16,972	13,578	23,761	18,104	1,828
ECB	13,839	13,056	21,933	16,276	-

C.13.2 Aggregate Benefit Calculations

For each of the performance metrics, an overall result was computed by taking a simple average of the wet, average, and dry years. The team considered using a weighting system to combine the results from the three hydrologic conditions; however, since there are multiple ways in which these conditions could be defined (based on annual rainfall, based on seasonal rainfall, based on stage, based on structure flows based on habitat response to hydrologic conditions), the team determined that there was considerable uncertainty in assigning a return frequency (weighting) to each of the hydrologic conditions. To address the

significance of weighting, a sensitivity analysis has been done to evaluate benefit estimates under different hydrologic condition weighting schemes. Aggregation of individual performance metrics for the Target, the Baseline, and each Project Alternative condition, was done by adding the measure-specific habitat unit results for the three individual performance measures. Since two of the performance measures cover the same area (PM 1.5 and 2.1 both cover Taylor Slough), the results for individual performance measures are adjusted to remove double counting of project benefits so that the total acreage of benefited acreage computed by adding the three performance metric application acreages does not exceed the study area acreage (239,724 acres).

TABLE C-18 shows the aggregated results for all performance measures when the three model run (1978, 1989, and 1995) results are equally weighted. (The results in ***TABLE C-18*** do not match the results for PM1.5, PM2.4, and PM2.1 shown in ***TABLE C-13***, ***TABLE C-15*** and ***TABLE C-17*** because when multiple PMs are used, the total net benefit is normalized to account for double counting of affected area that occurs when two or more PMs cover the same land area.)

TABLE C-18: OVERALL BENEFIT ASSESSMENT RESULTS (NORMALIZED TO ACCOUNT FOR AFFECTED AREA)

Simulation Year Weighting			Total Area of Effect (no double counting)			
1978	33%			239,724	acres	
1985	33%					
1995	33%					
Scenario	PM1.5 FlowTDV	PM2.4 Salinity	PM2.1 VegHydro	Total HRU	Adjusted HRU	Net FWO
Pre-Drainage/Target	98,472	14,626	155,098	268,196	239,724	
FWO	82,814	10,465	80,356	173,635	155,202	-
Alt_1C	84,068	10,775	73,727	168,570	150,674	(4,528)
Alt_1D	85,073	10,752	74,706	170,531	152,427	(2,775)
Alt_2DS	90,733	10,986	82,604	184,322	164,755	9,553
Alt_2DL	90,487	10,961	80,812	182,260	162,911	7,709
Alt_3D	90,818	10,952	80,319	182,089	162,758	7,556
Alt_6D	87,243	10,871	86,124	184,237	164,678	9,476
ECB	85,019	10,115	82,848	177,982	159,087	3,885

The results in ***TABLE C-18*** indicate that 2DShort provides the greatest lift while 1C provides the least lift relative to the No Action Alternative. Alternative 6D provides the second best lift while 2DLong provides the third best lift.

C.13.3 Benefit Assessment Risk and Uncertainty Analysis

There is no standardized methodology for predicting ecosystem benefits that result from habitat restoration projects. For the Corps planning process, the most apparent adverse risks of employing a given benefit estimation methodology are: 1) the most effective project alternative is not selected for implementation, 2) the selected project provides significantly fewer benefits than estimated, or 3) the selected project significantly harms the resource. An uncertainty analysis is typically used to reduce the likelihood of the three adverse outcomes listed above. For the C-111 Spreader Canal project, the two most apparent sources of uncertainty in the estimated project benefits arise from the use of the Modbranch model for the prediction of changes to hydrology and the use of the three performance metrics to represent the ecological significance of the predicted change in hydrologic conditions.

C.13.3.1 Modbranch Model Uncertainty

To address model accuracy and precision, the Modbranch model was calibrated and verified prior to its application to the C-111 Spreader Canal project. Hydrologic models such as Modbranch can be used in a stochastic or deterministic manner. Stochastic use of the model might require running hundreds or even thousands of iterations each one with a unique set of plausible boundary condition and parameter estimates. The output from the hundreds of model runs would then be post-processed to provide the average response along with an estimate of variance or standard deviation. In the case of the C-111 Spreader project, the team determined that because of the simulation time (40 hours per 1-year run), the resources to perform such a stochastic analysis were not available. (Of course, parameterizing a regional implementation of the Modbranch model would require stochastic information for hydrogeologic parameters that is simply not available). Alternatively, the team determined model output uncertainty could be minimized by simulating the alternatives under two boundary conditions (existing and future) and three hydrologic conditions (wet year, dry year, and average year). This approach reduces uncertainty by providing information for a limited stochastic assessment of the impact of the various alternatives on hydrology. The use of different output datasets from the Modbranch model presents one source of uncertainty since the various types of model output have differing levels of accuracy and precision. The model generates surface and groundwater flow as well as canal flow. The model is calibrated for groundwater stage but not for surface and groundwater flow. Performance metrics that rely upon groundwater stage output utilize more reliable information than metrics that rely upon flow outputs.

Another Modbranch related source of uncertainty is specific to the salinity performance measure PM 2.4. This PM likely underestimates changes to near shore salinity in response to increased groundwater stage as predicted by

Modbranch. This is not entirely unexpected given how the Modbranch model represents the mangrove transition zone that connects the southern glades to Florida Bay. The physiography of the mangrove transition zone along the NE shore of Florida Bay is unique. Freshwater flows south from Taylor Slough and the C-111 Basin towards the Bay largely as sheet flow; but within this estuarine transition zone, this flow is focused into a few distinct tidal creeks that ultimately empty into the Bay itself. The MODBRANCH model does not explicitly simulate tidal creeks because there is little to no information to calibrate or verify flows in these creeks. Preferential overland flow paths occur within the model based upon the topographic data used to define the average grid cell elevation. The smallest grid cell size is approximately 200 ft on side so the bottom elevation of a 1 to 4 meter wide tidal creek would not likely be the defining elevation of a given grid cell since grid cell elevations are based on the average elevation within the cell. Given the lack of tidal creek representation in the Modbranch model, it is very probable that PM 2.4 underestimates improvements in salinity downstream of Taylor Slough since the model configuration would tend to disperse the diverted flow over a wider area rather than keep it in defined creeks with higher stages that would be translated into greater salinity improvement as measured by PM 2.4.

C.13.3.2 Uncertainty in Habitat Response to Hydrologic Change

Another source of uncertainty in project benefits results from the lag between habitat response and hydrologic change. Ecological patterns and processes in Everglades wetlands respond to inter-annual variability in rainfall (amount & timing) and canal flows and inputs (which are management driven and do not always parallel rainfall patterns) in many ways. Ecological processes often respond to environmental drivers with time lags of longer than months (e.g. years) and changes in ecological patterns nearly always lag environmental changes by several years. The performance measures average a time series of results across three year types (wet, dry, and average) and across seasons to create one habitat unit score. However, each year type and season may not be an equally important predictor of ecological benefits. For example, extreme salinity during dry years may be ecologically limiting and, thus, perhaps weigh more heavily in the scoring. Multi-year lags in ecological and/or hydrologic responses were not critical to interpretation of the MODBRANCH model output in the context of the three PMs since these lags are likely on the order of 5 to 10 years while the project planning timeframe is 50-years.

A sensitivity analysis was done to determine the impact of different hydrologic / habitat response weighting schemes. The wet, dry, and average hydrologic conditions are intended to represent average and extreme conditions under which the proposed features would have to perform. Ideally, the results would be combined using return frequency to set the individual weighting of each year's results. However, determining the return frequency of a particular

hydrologic condition based on rainfall, canal flow, and/or groundwater stage, will not completely address the weighting question since predictions of habitat improvement also require knowledge of antecedent habitat as well as antecedent hydrologic conditions. ***FIGURE C-30*** shows the effect on benefits of various hydrologic return period weighting schemes. When the wet, dry, and average results are equally weighted, alternatives 2DShort and 6D provide roughly the same HRU results. If average hydrologic conditions drive habitat response, alternative 6D provides significantly greater HRU benefits than alternatives 2DShort and 2DLong. If dry hydrologic conditions drive habitat response, alternatives 2DShort and 3D do the best and alternative 6D provides little benefit. If wet hydrologic conditions drive habitat response, then alternative 6D and 2DShort do the best and alternatives 2DLong and 3D provide a good response. If either dry, average, or wet hydrologic conditions are responsible for 50% of the habitat response, which are all plausible realities, then alternatives 2DShort and 6D appear to provide the greatest lift. Under the plausible habitat response hypotheses, alternative 2DShort appears to be most robust of the future with project scenarios. Alternative 6D does better than 2DShort under several hypotheses; however, if dry hydrologic conditions are controlling, alternative 2DShort is preferred. This analysis also shows that extreme values for one year type do not overwhelm the scores for alternatives 2DShort, 2DLong and 3D. This lessens the possibility that important results for other year types that may be more representative of longer term trends of interest are obscured by using the average of the three year types.

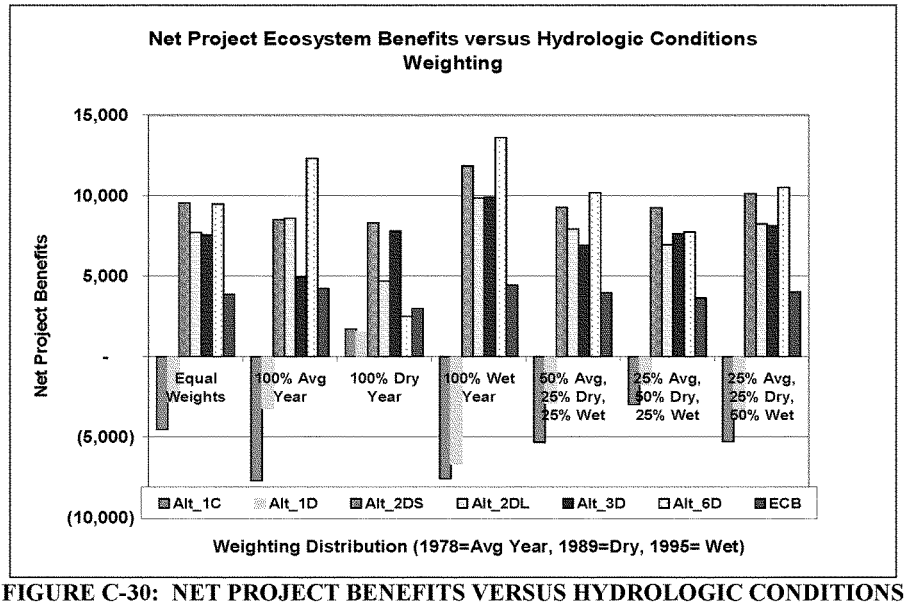


FIGURE C-30: NET PROJECT BENEFITS VERSUS HYDROLOGIC CONDITIONS

This sensitivity analysis shows that in the context of the three PMs evaluated here, potential multi-year lags in ecological and/or hydrologic responses appear not to be a critical consideration for the selection of alternative 2DShort since this alternative is the most robust of alternatives in producing benefits under different hydrologic conditions.

C.13.3.3 Performance Metric Uncertainty

The C-111 Spreader Canal project is a water resource based ecosystem restoration effort targeting freshwater wetlands and near shore estuarine zones. As such, the primary means of altering habitat functionality is through the diversion or addition of surface water flows. The premise of the benefits assessment methodology is that changes to habitat functionality can be quantified by comparing differences between hydrologic outputs resulting from alternative implementation. There are several sources of uncertainty in the application of the performance metrics. One source of uncertainty is the use of target habitat conditions derived from a "natural systems" version of the Modbranch model in which man-made drainage features (canals, culverts, gates, etc.) were not present. The use of the natural system condition as a target appears to be ideal since it represents full restoration; however, in practice it presents an unachievable goal since most of the man-made drainage features will not be removed as part of this or any other conceivable restoration project in the area. The PDT understands that use of the unachievable NSM as a target inadvertently results in clustering of benefit scores, even when there are significant differences between alternatives. Nonetheless, the use of the natural system hydrology as the target condition is necessary since no other target hydrologic condition is readily available or would be acceptable to the all agency representatives on the project delivery team.

A second source of uncertainty is the degree to which the post-processing methods used to convert Modbranch model output into performance metric signals accurately reflects the direction and magnitude of changes to habitat functionality. Unfortunately, this source of uncertainty cannot be addressed directly given the theoretical nature of the alternative analysis and the lack of comparable data from existing restoration efforts. To minimize the risk and uncertainty of selecting a less than optimal alternative using this set of benefit predictions, the results are supplemented by other Modbranch simulation output as well as additional analysis of the performance measure outputs. This is used here as a second line of evidence to justify the selection of the optimal project plan.

The range of benefit estimates provided in ***TABLE C-19*** was created by applying one or more of the PMs under the assumption that some combination of PMs provides a reliable estimate of the achievable ecological benefits. Given that each PM is applied to a different area of affect and each PM may provide a more

or less reliable signal, it is logical to consider the use of one or more of the PM results when attempting to quantify the range of benefits. The rankings of project alternatives in ***TABLE C-19*** shows that Alternative 2DShort is the best and Alternative 6D is second best regardless of which PM or combination of PMs are used. No combination of the three performance measures could be used to justify the selection of alternatives 1C or 1D. Alternative 6D provides the most lift if only the vegetation hydroperiod (PM2.1) measure is used to evaluate project benefits. Alternative 3D provides slightly higher lift than 2DShort if only the timing, distribution and volume (PM1.5) measure is used to evaluate project benefits.

Though the uncertainty surrounding the three PMs is not easily quantifiable some qualitative information is available. For instance, PM2.1 is largely based upon groundwater stage differences. The source of these predicted stages is the Modbranch model. This model has been calibrated and verified for stage and is regarded as accurate within plus or minus 0.6 ft. Performance Measure 1.5 relies upon groundwater and surface water flow through transects as calculated by the Modbranch model. Though this Modbranch model is calibrated for stage which has a direct influence on groundwater flux, the groundwater flux itself is not directly calibrated or verified. The equations used to translate stage to salinity for PM2.4 are applied to the target natural system condition though the regression equations used to predict the salinities were not developed using data measured during natural system hydrologic conditions.

TABLE C-19: RANKING ANALYSIS OF PROJECT BENEFITS BY PERFORMANCE METRIC

	All PMs	PM 1.5	PM 2.4	PM 2.1	PM 1.5/2.4	PM 1.5/2.1	PM 2.4/2.1	
FWO								
Alt_1C	(4,528)	1,254	310	(6,629)	1,531	(4,822)	(6,320)	
Alt_1D	(2,775)	2,259	287	(5,650)	2,493	(3,042)	(5,363)	
Alt_2DS	9,553	7,919	520	2,248	8,263	9,120	2,769	
Alt_2DL	7,709	7,673	496	456	7,998	7,291	952	
Alt_3D	7,556	8,004	487	(37)	8,314	7,147	450	
Alt_6D	9,476	4,429	405	5,768	4,733	9,147	6,173	
Ranking Analysis								
	All PMs	PM 1.5	PM 2.4	PM 2.1	PM 1.5/2.4	PM 1.5/2.1	PM 2.4/2.1	Overall Rank
FWO								
Alt_1C	6	6	5	6	6	6	6	5
Alt_1D	5	5	6	5	5	5	5	4
Alt_2DS	1	2	1	2	2	2	2	1
Alt_2DL	3	3	2	3	3	3	3	3
Alt_3D	4	1	3	4	1	4	4	3
Alt_6D	2	4	4	1	4	1	1	2

None of the three performance metrics directly takes into account canal and structure flows predicted by the Modbranch model. Since two of the primary goals of the C-111 Spreader project are to reduce S-197 flows and to increase Taylor Slough deliveries, an investigation of projected canal flows can be used to indicate probable impacts to affected habitat. ***TABLE C-20*** shows the average annual structural flows predicted for each alternative under the existing and future hydrologic conditions as averaged from the three simulated years. The project objective for Taylor Slough is to send more water from the C-111 Canal into the slough. Under the existing and future hydrologic conditions, Alternatives 2DLong and 2DShort provide the greatest diversion of water into Taylor Slough as measured by the reduction in flow through S-18C. Alternative 6D is not as effective in diverting water into Taylor Slough as reflected in the results for PM 1.5 which is focused on measuring the timing, distribution, and volume of flow sent to Taylor Slough.

TABLE C-20: AVERAGE ANNUAL STRUCTURE FLOWS AS PREDICTED BY EXISTING CONDITIONS AND FUTURE CONDITIONS MODBRANCH MODEL RUNS (AVERAGE OF 1978, 1989, AND 1995)

Existing Conditions Model Runs Annual Average Flow (ac-ft/yr)							
	ECB	ECB_1C	ECB_1D	ECB_2DS	ECB_2DL	ECB_3D	ECB_6D
S332d	54800	56051	56791	45433	40748	44770	57579
S-174	13945	14476	15384	12882	17620	14596	6226
S-176	6897	10587	10917	5554	6534	7834	7289
S-177	68353	68156	63258	26534	32101	46302	131485
S-18C	106103	45011	43828	37749	36874	64825	44932
S-197	95521	103154	77240	38186	49181	76368	206976
S-FBDA	0	86687	90601	42101	36806	42930	0
S-AJET	0	0	0	37974	35017	31863	0
Relative Impact to Taylor Slough (best to worst)							
	Based on ranking S-18C Flows from low to high						
		2DL>2DS>1D>6D>1C>3D>ECB					
Future Conditions Model Runs Average Annual Flow (ac-ft/yr)							
	FWO	FWO_1C	FWO_1D	FWO_2DS	FWO_2DL	FWO_3D	FWO_6D
S332d	127717	125344	125586	122663	124390	123073	135612
S-174	0	0	0	0	0	0	0
S-176	20741	25767	25643	15367	15095	24394	22295
S-177	148373	140824	93406	51251	53023	47648	285504
S-18C	140997	75478	85962	58117	54691	96916	107148
S-197	237798	197186	123581	72073	58715	92302	468129
S-FBDA	0	133044	133556	60374	60039	63692	0
S-AJET	0	0	0	53957	50159	52663	0
Relative Impact to Taylor Slough (best to worst)							
	Based on ranking S-18C Flows from low to high						
		2DL>2DS>1C>1D>3D>6D>FWO					

The project objective for eastern Florida Bay (Barnes Sound) is to reduce the frequency and magnitude of discharges through the S-197 structure because these discharges result in rapid salinity swings that are deadly to estuarine biota in Barnes Sound. While additional flow through the S-197 structure is not necessarily bad, alternatives that reduce the incidence of peak flow events through this structure necessarily will improve the estuarine habitat in eastern Florida Bay. Historically, the S-197 structure was only opened in emergency conditions. Because of this, the minimum flow rate that result in excessively low salinity in Manatee Bay and Barnes Sound is not known with certainty; however, there is evidence that S-197 flows in excess of 1500 cfs cause ecological harm to these estuary water bodies (personal communication with Eric Stabenau, Phd, ENP, October 2009). In ***TABLE C-20***, it is evident that

Alternative 6D results in a significant increase in the total flow through the S-197 structure.

FIGURE C-31 and ***FIGURE C-32*** show that relative to Alternative 2D Short and 2D Long, Alternative 6D provides a significant increase in the exceedance frequency of high flow events through the S-197 structure as indicated by the analysis of the 1995 flow data. The increase in the frequency of high flow events (Flow > 1500 cfs) indicates that Alternative 6D will likely harm Barnes Sound. This may be an indication that PM2.4 does not reliably measure impacts associated with high flows and greatly reduced salinity conditions as might occur if Alternative 6D were to be implemented. In ***TABLE C-20***, alternative 2DShort appears to provide significantly more flow through S-197 than alternative 2DLong indicating a potential for more harm to Barnes Sound. However, the true difference between these two alternatives is better illustrated in ***FIGURE C-17*** and ***FIGURE C-18*** which show that Alternative 2DShort provides no increase relative to 2DLong in the frequency of flows greater than 1,500 cfs. It is the higher flow volumes that result in undesirable salinity conditions in Barnes Sound and not the total annual average flow.

The comparison of S-197 flow exceedance curves provides additional evidence that alternative 2DShort is preferable to 6D. It also shows that relative to the future and existing condition hydrology scenarios, most of the with-project alternatives will reduce the frequency of harmful high volume releases through the S-197 structure. This should provide some nearshore salinity benefits. The reduction in high flow events through the S-197 structure is not directly measured by the three primary performance measures used to justify this project. While including the S-197 high flow analysis to the list of performance measures was considered by the PDT, the team ultimately decided to use it as a secondary performance measure due to the inability to simulate more than the three years of S-197 flows. The team felt that a longer term simulation effort would be required to analyze the significance of reducing relatively rare high flow events at S-197.

Sea level rise (SLR) presents an unavoidable source of uncertainty in project benefits. The effect of SLR on project benefits was analyzed per EC 1165-2-211. At 20 years after project construction, at the high rate projection for SLR, approximately 10% reduction in freshwater wetland benefits and no apparent impact to salinity benefits would be expected. At 50 years after project construction, at the high rate projection for SLR, approximately 33% reduction in freshwater wetland benefits and no apparent impact to salinity benefits would be expected. The SLR discussion is presented in Section 7 of the report.

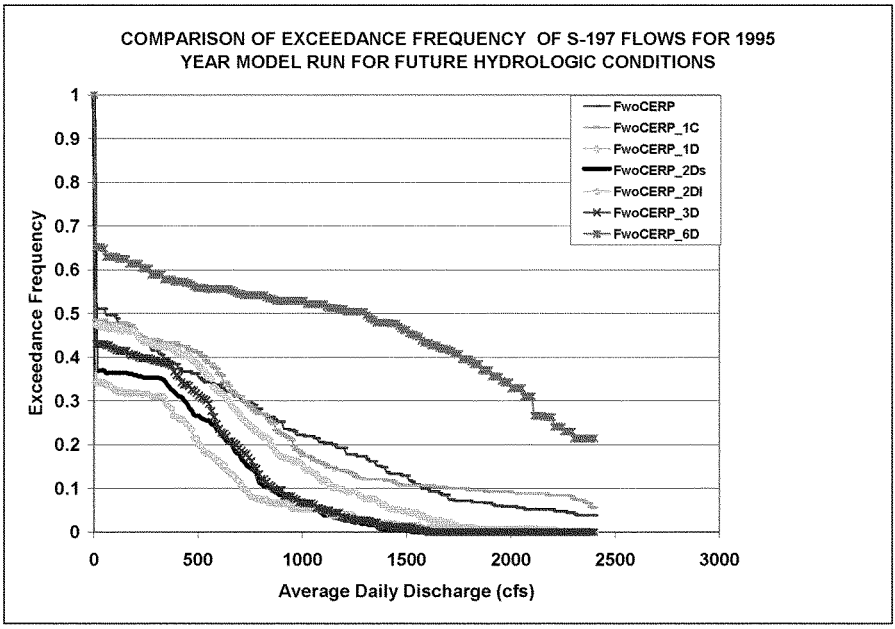


FIGURE C-31: COMPARISON OF EXCEEDANCE FREQUENCY OF S-197 FLOWS FOR 1978 YEAR MODEL RUN FOR FUTURE CONDITIONS

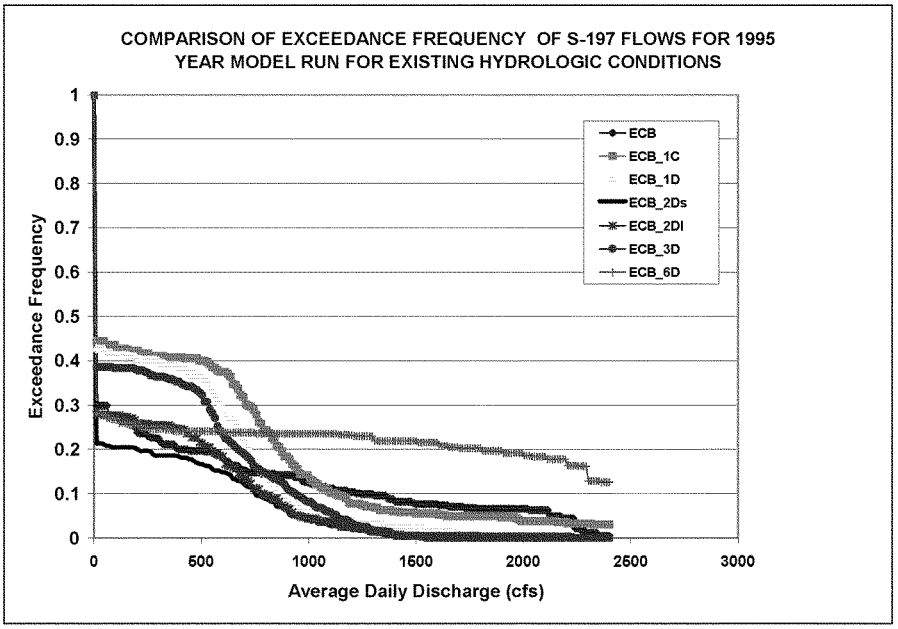


FIGURE C-32: COMPARISON OF EXCEEDANCE FREQUENCY OF S-197 FLOWS FOR 1995 YEAR MODEL RUN FOR EXISTING CONDITIONS

C.13.3.4 Conclusions

In general, the estimation of habitat restoration benefits is less a science than an art. In addition to a lack of universal measurements of "habitat condition", there is little agreement within the scientific community regarding what constitutes scientifically defensible metrics and evaluation procedures. For each project, the study team is responsible for conceiving and implementing benefit assessment methods that likely are unique since study areas as well as hydrologic modeling tools are project specific. As with any ecosystem benefits estimation methodology, there are unlimited ways in which modeling results can be mathematically manipulated to arrive at a single number that represent the net project benefits. One methodology is not necessarily more correct than the next; however, it is important that logical methods are used and can be adequately defended. For the C-111 Spreader Canal project, the project delivery team created performance metrics with the goal of quantifying the expected change to habitat functionality that will result from project implementation. The team limited the assessment to three performance metrics that were design to address the critical aspects of project hydrology: timing and distribution of flows, wetland hydroperiods, and salinity conditions in the nearshore. One significant

complexity with developing a benefit estimation system (in this case Modbranch modeling followed by performance metric post-processing) is that the outcome and utility of the system is difficult to predict before applying it to the project planning efforts. In this case, the benefits estimation system was successfully applied to the evaluation of the project alternatives.

The risk and uncertainty analysis of the benefits assessment results was done in a qualitative manner since the benefit stream was not characterized stochastically. In the absence of stochastic information on benefits, other data was extracted from the Modbranch model to support the results of the benefit assessment. An analysis of this data generally supports the results of the benefit assessment methodology in that Alternatives 2DShort and 2DLong are likely to provide more enhancement of habitat in Taylor Slough and Barnes Sound than would result from Alternatives 1C, 1D, or 3D.

Ultimately the goal of the project planners is to select the most effective project alternative using methods that minimize the potential of implementing a project that results in little or negative habitat enhancement. As part of the uncertainty analysis of the benefits assessment, secondary lines of evidence (Taylor Slough and S-197 flow analyses) were evaluated to ensure that the considered alternatives would provide benefits and would not cause negative impacts to habitat. This additional information supports the benefit analysis results for Alternative 2DShort and 2DLong but provides evidence that the results for 6D did not capture apparent potential impacts associated with this alternative. Therefore, these benefit assessment results should be further scrutinized if Alternative 6D rises to the top of the CE/ICA.

The C-111 Spreader Canal team believes that the methodology for habitat benefits used here employs available models, local knowledge, and scientific rigor to the extent practicable. While there is no single "right answer" to the estimation of habitat restoration benefits, independent review of the metrics and methodologies used here was conducted under the guidance of the Corps Center for Planning Excellence in September of 2009. Many of the reviewers suggestions were incorporated into the benefits assessment tools and the revised product has improved in terms of its scientific credence and overall quality.

C.14 CONCEPTUAL ECOLOGICAL MODELS

C.14.1 Florida Bay

WETLANDS, Vol. 25, No. 4, December 2005, pp. 870–883
© 2005, The Society of Wetland Scientists

A CONCEPTUAL ECOLOGICAL MODEL OF FLORIDA BAY

David T. Rudnick[1], Peter B. Ortner[2], Joan A. Browder[3], and Steven M. Davis[4]

[1] *Coastal Ecosystems Division*
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida, USA 33406
E-mail: drudnic@sfwmd.gov

[2] *Atlantic Oceanographic and Meteorological Laboratory*
National Oceanic and Atmospheric Administration
4301 Rickenbacker Causeway
Miami, Florida, USA 33149

[3] *Southeast Fisheries Science Center*
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
75 Virginia Beach Drive
Miami, Florida, USA 33149

[4] *RECOVER Section*
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida, USA 33406

Abstract: Florida Bay is a large and shallow estuary that is linked to the Everglades watershed and is a target of the Greater Everglades ecosystem restoration effort. The conceptual ecological model presented here is a qualitative and minimal depiction of those ecosystem components and linkages that are considered essential for understanding historic changes in the bay ecosystem, the role of human activities as drivers of these changes, and how restoration efforts are likely to affect the ecosystem in the future. The conceptual model serves as a guide for monitoring and research within an adaptive management framework. Historic changes in Florida Bay that are of primary concern are the occurrence of seagrass mass mortality and subsequent phytoplankton blooms in the 1980s and 1990s. These changes are hypothesized to have been caused by long-term changes in the salinity regime of the bay that were driven by water management. However, historic ecological changes also may have been influenced by other human activities, including occlusion of passes between the Florida Keys and increased nutrient loading. The key to Florida Bay restoration is hypothesized to be seagrass community restoration. This community is the central ecosystem element, providing habitat for upper trophic level species and strongly influencing productivity patterns, sediment resuspension, light penetration, nutrient availability, and phytoplankton dynamics. An expectation of Everglades restoration is that changing patterns of freshwater flow toward more natural patterns will drive Florida Bay's structure and function toward its pre-drainage condition. However, considerable uncertainty exists regarding the indirect effects of changing freshwater flow, particularly with regard to the potential for changing the export of dissolved organic matter from the Everglades and the fate and effects of this nutrient source. Adaptive management of Florida Bay, as an integral part of Everglades restoration, requires an integrated program of monitoring, research to decrease uncertainties, and development of quantitative models (especially hydrodynamic and water quality) to synthesize data, develop and test hypotheses, and improve predictive capabilities. Understanding and quantitatively predicting changes in the nature of watershed-estuarine linkages is the highest priority scientific need for Florida Bay restoration.

Key Words: ecosystem restoration, estuaries, Florida Bay, Everglades, adaptive management, seagrass, freshwater flow, salinity effects

BACKGROUND

Florida Bay is a triangularly shaped estuary, with an area of about 2200 km² that lies between the southern tip of the Florida mainland and the Florida Keys (Figure 1). About 80% of this estuary is within the boundaries of Everglades National Park and much of the remainder is within the Florida Keys National Marine Sanctuary. A defining feature of the bay is its shallow depth, which averages about 1 m (Schomer and Drew 1982). Light sufficient to support photosynthesis can reach the sediment surface in almost all areas of the bay, resulting in dominance of seagrass beds as both a habitat and a source of primary production. The shallowness of Florida Bay also affects its circulation and salinity regime. Except for basins near the northern coast (near freshwater sources), the bay's water column is vertically well-mixed and usually isohaline. In contrast, its complex network of shallow mud banks restricts horizontal water exchange among the bay's basins and between these basins and the Gulf of Mexico (Smith 1994, Wang et al. 1994). In areas with long residence times, the salinity of Florida Bay water can rise rapidly during drought periods due to excess of evaporation over precipitation and freshwater inflow (Nuttle et al. 2000). Salinity levels as high as twice that of seawater have been measured (McIvor et al. 1994). Another defining feature of the bay is that its sediments are primarily composed of carbonate mud, which can scavenge inorganic phosphorus from bay waters (DeKanel and Morse 1978).

Until the 1980s, Florida Bay was perceived by the public and environmental managers as being a healthy and stable system, with clear water, lush seagrass beds, and highly productive fish and shrimp populations. In the mid-1980s, however, catches of pink shrimp decreased dramatically (Browder et al. 1999), and in 1987, a mass mortality of turtle grass (*Thalassia testudinum* Banks & Soland ex. Koenig) beds began (Robblee et al. 1991). By 1992, the ecosystem appeared to change from a clear water system, dominated by benthic primary production, to a turbid water system, with algae blooms and resuspended sediments in the water column. The conceptual ecological model presented here focuses on these changes in seagrass communities and water quality as central issues to be considered by environmental managers.

The Florida Bay Conceptual Ecological Model is one of eleven regional models that are being used as tools for synthesis, planning, assessment, and communication within the adaptive management framework of the Everglades Restoration Plan. This framework and a summary of all of the conceptual ecological models are described in Ogden et al. (2005). Overviews of the history and challenges of Everglades restoration are presented in Ogden et al. (2005) and Sklar et al. (2005). The format and symbols of the Florida Bay model follows that of Ogden et al. (2005) and the other conceptual models published in this issue of *Wetlands*. Furthermore, the organization of this paper follows the conceptual model diagram, with major sections on drivers and stressors, and ecological attributes (generally structural components of the ecosystem) and their links to stressors. A final section considers expectations and uncertainties regarding future responses to restoration efforts.

This simple model does not address spatial complexity in Florida Bay. Florida Bay is, indeed, not so much a singular estuary, but a complex array of more than forty basins, with distinct characteristics, that are partitioned by a network of mud banks and islands (Schomer and Drew 1982, Fourqurean and Robblee 1999). The structure of vegetative habitats, as well as water quality and ecosystem processes, vary distinctly with this spatial variation. Nevertheless, only a single, generic model is described and intended to summarize the main characteristics and trends of the bay. While the structure of this model is appropriate for most areas of the bay, the relative importance of model components differ considerably among subregions. Any application of this model (e.g., recommendations for a specific set of monitoring parameters and guidelines) must accommodate the degree of spatial variability of the bay.

EXTERNAL DRIVERS AND ECOLOGICAL STRESSORS

Following observations of Florida Bay's dramatic ecological changes in the 1980s, it was commonly assumed that a direct cause of these changes was a long-term increase in salinity, which in turn was caused by the diversion of freshwater away from Florida Bay via South Florida Water Management District canals. However, subsequent research has indicated that these ecological changes may not be attributable to a single cause. While decreased freshwater inflow and resultant increased salinity have been part of the problem, it appears that other human activities, as well as natural forces, may have also played a role (Boesch et al. 1993, Armentano et al. 1997, Fourqurean and Robblee 1999). The conceptual ecological model presented here includes both natural and anthropogenic sources of stress (Figure 2). The discussion of external drivers and ecological stressors below is organized by stressor (ovals in Figure 2), with consideration of the main drivers (rectangles in Figure 2) that influence each stressor.

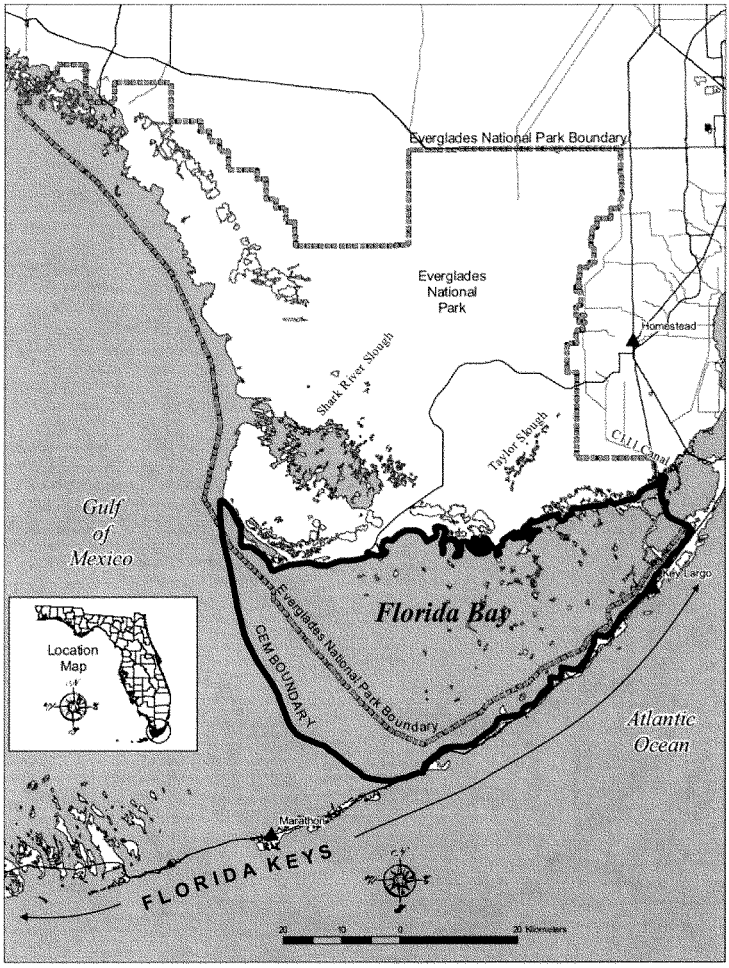


Figure 1. Geographic setting and boundary of the Florida Bay Conceptual Ecological Model (CEM).

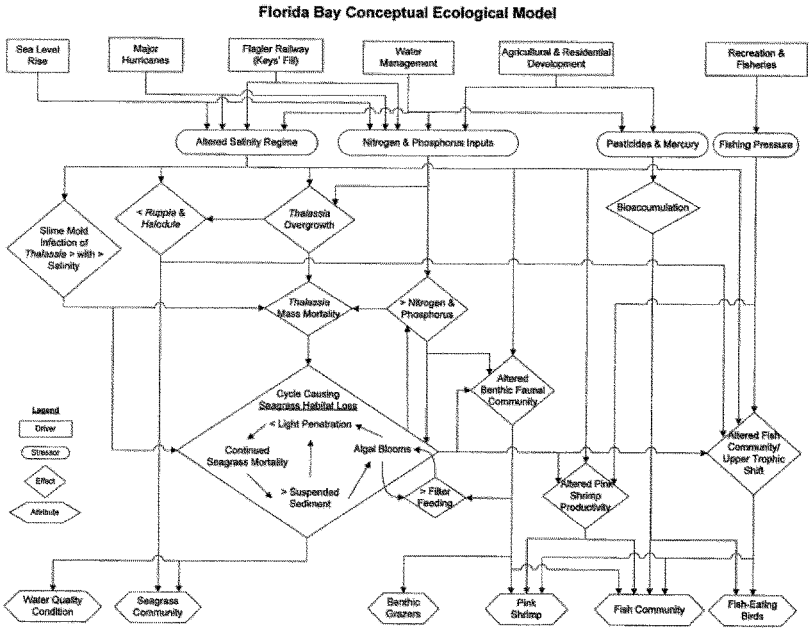


Figure 2. Florida Bay Conceptual Ecological Model Diagram. The format of this figure follows Ogden et al. (2005). Rectangles represent major external drivers of ecological change, ovals represent ecological stressors, diamonds represent ecological linkages and functions that mediate the effect of stressors on atributes, and hexagons represent ecosystem attributes to be monitored as part of the adaptive assessment process. Increases or decreases noted in diamonds with "< *Ruppia* and *Halodule*" and "> Nitrogen and Phosphorus" refer to pre-restoration changes.

Altered Salinity Regime

Florida Bay's salinity regime varies greatly over time and space. This variation ranges from coastal areas that can be nearly fresh during the wet season, to large areas of the central bay that can have salinity levels near 70 psu during prolonged droughts, to nearly stable marine conditions (about 35 psu) on the western boundary of the bay or near Florida Keys' passes. The main factors that determine the salinity regime in the bay are the inflow of freshwater from the Everglades, the difference between rainfall and evaporation over the bay, and exchange with marine waters of the Gulf of Mexico and Atlantic Ocean. Both freshwater inflow and exchange with the Atlantic have changed drastically in the past hundred years, resulting in an alteration of the bay's salinity regime (Swart et al. 1999, Brewster-Wingard et al. 2001, Dwyer and Cronin 2001).

Freshwater inflow to Florida Bay decreased in volume and changed in timing and distribution during the twentieth century because of water management. Hydrologic alteration began in the late 1800s but accelerated with construction of drainage canals by 1920, the Tamiami Trail by 1930, and the Central and South Florida (C&SF) Project and the South Dade Conveyance System from the early 1950s through 1980 (Light and Dineen 1994). With diversion of freshwater to the Atlantic and Gulf of Mexico coasts to the north, the bay's mean salinity inevitably increased. Isotopic studies of carbonate preserved in coral skeletons and bur-

ied ostracod shells confirmed this trend (Swart et al. 1999, Dwyer and Cronin 2001). Paleoecological studies also indicated that salinity variability within the bay also changed during the twentieth century, with an increase in variability in the northeastern bay, where freshwater inflows are channelized (Brewster-Wingard et al. 2001), and a decrease in variability in the southern bay (Swart et al. 1999).

Paleoecological studies indicated that a cause of salinity changes in the southern bay was construction of the Flagler Railway across the Florida Keys from 1905 to 1912 (Swart et al. 1996, 1999). In the nineteenth century, prior to railway construction and water management, southern Florida Bay had a lower mean salinity and more frequent periods of low (10 psu–20 psu) salinity than during the twentieth century. The extent and frequency of high salinity events in the southern bay does not appear to have changed between centuries. The bay's salinity regime changed abruptly around 1910 because passes between the Keys were filled to support the railway. Thus, water exchange between Florida Bay and the Atlantic Ocean was decreased, and this probably caused an increase in water residence time and a change in water circulation patterns within the bay.

Two important natural controls of salinity, sea-level rise and the frequency of major hurricanes, must also be considered. Florida Bay is a very young estuary, the product of sea level rising over the shallow slope of the Everglades during the past 4,000 years (Wanless et al. 1994). With rising sea level, the bay not only became larger but also became deeper. With greater depth, exchange of water between the ocean and the bay increased. All else being equal, this would result in a more stable salinity regime with salinity levels increasingly similar to the ocean. However, a factor that has counteracted rising sea level is accumulation of sediment, which makes the bay shallower. Most sediment that accumulates in Florida Bay is carbonate precipitated from water by organisms living in the bay (Bosence 1989). The extent to which these sediments accumulate is a function of the biology of these organisms (including skeletal carbonate production), chemical dynamics in the water column and sediments, and the physical energy available to transport some of these sediments from the bay. Major hurricanes are thought to be important high-energy events that can flush the bay of accumulated sediments. However, since 1965, no major hurricane has directly affected Florida Bay. Resultant sediment accumulation, with associated alteration of depth, circulation patterns, residence time, salinity, and nutrient storage may have influenced ecological changes in recent decades.

Nitrogen and Phosphorus Inputs

Productivity and food-web structure in all ecosystems are strongly influenced by internal nutrient cycling and import and export of these nutrients. Throughout the world, estuarine ecosystems have undergone dramatic ecological changes because they have been markedly enriched by nutrients derived from human activity (National Research Council 2000). These changes have often been catastrophic, with loss of seagrasses, increased algal blooms, and increased incidence of hypoxic and anoxic events. Augmentation of nitrogen and phosphorus inputs to an estuary is a potentially important stressor.

The degree to which nitrogen and phosphorus inputs have stressed Florida Bay is unclear. In general, the bay is relatively rich in nitrogen and poor in phosphorus, especially towards the eastern region of the bay (Boyer et al. 1997). This spatial pattern is at least partly a function of natural biogeochemical processes (e.g., P retention by the bay's carbonate sediments and relatively low N in adjacent marine waters) and thus may have existed prior to recent human influences. Little direct evidence confirms that nutrient inputs to the bay or concentrations within the bay have increased during the past century, but with expanding agricultural and residential development in South Florida, and particularly development of the Florida Keys, some nutrient enrichment almost certainly has occurred (Lapointe and Clark 1992, Orem et al. 1999). Anthropogenic nutrients that enter Florida Bay are derived not only from local sources (fertilizers and other wastes from agricultural and residential areas), but also from remote sources. Contributions of nutrients from atmospheric deposition and from the Gulf of Mexico, which may include nutrients from the phosphate fertilizer industry of the Tampa-Port Charlotte area and residential development from Tampa to Naples, are significant external nutrient sources (Rudnick et al. 1999).

Different sub-regions of the bay are differentially influenced by these local or remote sources, depending on the magnitude of inputs, relative abundance of different nutrients, internal cycling pathways and rates, and water residence time (Boyer et al. 1997, Rudnick et al. 1999, Childers et al. 2005). Algal bloom occurrence in the central and western bay is influenced by a combination of these factors (Tomas et al. 1999, Brand 2002). Despite the lack of definitive data, it is, nevertheless, a reasonable hypothesis that a chronic increase in nutrient inputs occurred in Florida Bay in the twentieth century and that this increase contributed to the bay's recent ecological changes. Development of a water quality model driven by appropriately scaled hydrodynamic and hydrologic models is essential to understand and evaluate quantitatively the po-

tential effects of past nutrient inputs and predict the effects of future management scenarios.

Water management is a driver of nutrient stress in that the canal system can transport materials through wetlands toward the bay, decreasing nutrient retention by wetlands and thereby increasing inputs to the bay. Altered nutrient transport via canals may also alter the chemical composition of nutrients entering the bay. These inputs from the Everglades and the Gulf of Mexico are affected not only by changes of freshwater flowing from Taylor Slough and Shark River Slough, but also by changes in the bay's circulation. Nutrient cycling and retention within the bay are sensitive in particular to changes in residence time (a function of circulation) that were caused by Flagler Railway construction, as well as the balance of sea-level rise and sedimentation or sediment removal by major hurricanes. Hurricanes may be particularly important, as nutrients (organic and inorganic) can accumulate in sediments, and the absence of major hurricanes during the past few decades may have resulted in an accumulation of nutrients.

Pesticides and Mercury

With the widespread agricultural and residential development of South Florida, application and release of pesticides and other toxic materials has increased. Deposition of mercury from local and global sources has also increased in the past century and is of particular concern because of high concentrations of methylmercury in upper trophic level species (Cleckner et al. 1998). Altered biogeochemistry resulting from changes in water quality (e.g., sulfate availability), which in turn affects methylation rates, has also played a role in increased mercury bioaccumulation (Cleckner et al. 1999). Pesticides and mercury are of concern because they can affect human health through consumption of fish or other biota with high concentrations of these toxins and because other species also may be adversely affected by these compounds. To date, no evidence links observed ecological changes in Florida Bay to inputs of toxic compounds. Nevertheless, endocrine-disrupting endosulfans, with concentrations that could have biological effects, have been found in upstream canals and the biota of associated lakes (Scott et al. 2002, G. Graves, personal communication). Additionally, mercury levels remain elevated in fish in eastern Florida Bay despite decreases observed elsewhere (Strom and Graves 2001, Evans et al. 2003). Water management affects the distribution of these toxic materials and potentially their transport to Florida Bay (Scott et al. 2002, Rumbold et al. 2003). Controlling water levels in wetlands may also influence the decomposition of pesticides and mercury methylation rates because these processes are sensitive to the presence of oxygen and sulfate in soils, which are affected by water levels.

Fishing Pressure

For any species that is the target of recreational or commercial fishing, fishing pressure directly affects population dynamics and community structure. Commercial fishing has been prohibited within Everglades National Park since 1985, but populations that live outside of the Park boundaries for at least part of their life cycle, including most of Florida Bay's sportfish species, are affected by fisheries (Tilmant 1989). Recreational fishing pressure within the Park also affects these populations (e.g., the size structure of the gray snapper assemblages [Faunce et al. 2002]).

ECOLOGICAL ATTRIBUTES

The set of Florida Bay's attributes presented here (hexagons in Figure 2) includes both indicators of ecosystem condition and attributes deemed to be intrinsically important to society. Attributes, in most cases, are biological components of the ecosystem, including seagrass, mollusks, shrimp, fish, and birds, but also an aggregated attribute (water-quality condition) that includes phytoplankton blooms, turbidity, and nutrient concentrations. While the list of biological components is broad, it is clear from their links to stressors (see diamonds and associated arrows, linking to stressors in ovals, in Figure 2) that these attributes are not equally weighted; the most significant and causally interconnected attribute of this conceptual ecological model is the seagrass community. Details of each attribute and its linkages to the conceptual model's set of stressors are given below.

Seagrass Community

The structural and functional foundation of the Florida Bay ecosystem is its seagrass community (Zieman et al. 1989, Fourqurean and Robblee 1999). These plants are not only a highly productive base of the food web, but are also a principal habitat for higher trophic levels and strongly influence the physical and chemical nature of the bay. Understanding how seagrasses affect water quality is essential to understanding the bay's current status and predicting its response to restoration and other human activities.

Seagrasses affect water quality by three mechanisms: nutrient uptake and storage, binding of sediments by their roots, and trapping of particles within their leaf canopy. With growth of dense seagrass beds, these mechanisms drive the bay towards a condition

of clear water, with low nutrient availability for algae growth within the water column and low concentrations of suspended sediment in the water. Paleoecological studies and historic observations suggest that *T. testudinum* in Florida Bay proliferated and increased in density during the mid-twentieth century (Brewster-Wingard and Ishman 1999, Zieman et al. 1999, Cronin et al. 2001), while other common species (*Halodule wrightii* Aschers and *Ruppia maritima* Linnaeus) likely decreased in distribution and density. From the 1960s through the mid-1980s, dense *T. testudinum* beds expanded throughout central and western Florida Bay, and the water column was reported to be crystal clear (Zieman et al. 1999). Largely following the conceptual model of Zieman et al. (1999), we hypothesize that with the onset of a *T. testudinum* mass-mortality event in 1987 (Robblee et al. 1991), the three mechanisms given above reversed, initiating a cycle (large diamond in Figure 2) that contributed to additional seagrass habitat loss (or at least inhibited recolonization) and favored the persistence of more turbid water with episodic algal blooms (Stumpf et al. 1999).

Causes of the 1987 mass-mortality event can be considered at two time scales—a multi-decadal period that poised *T. testudinum* beds for collapse and a short-term period (of days–months) in 1987 when proximate factors triggered mortality (Zieman et al. 1999). We hypothesize that changes in two stressors, salinity and a chronic and low-level increase in nutrient availability, occurred over several decades and caused *T. testudinum* beds to grow to an unsustainable density (designated "overgrowth" in Figure 2) by the mid-1980s. It is also likely that a decrease in shoal grass (*Halodule wrightii*) and widgeon grass (*Ruppia maritima*) occurred with the *T. testudinum* increase. *Thalassia testudinum* overgrowth may have occurred because the species had a competitive advantage over other seagrass species when the bay's salinity regime was stabilized, with few periods of low salinity (Zieman et al. 1999). Nutrient enrichment also may have played a role, with a chronic accumulation of nutrients caused by increased inputs over decades or decreased outputs because of the absence of major hurricanes or closure of Florida Keys' passes. Once *T. testudinum* beds were poised for collapse, multiple factors that acted over a short time scale are hypothesized to have been a proximate cause of mortality in 1987. These factors are thought to be related to high respiratory demands of dense grass beds and accumulated organic matter. During the summer of 1987, with high temperatures and hypersaline water, respiratory demand may have exceeded photosynthetic production of dissolved oxygen, causing sulfide concentrations to increase to lethal concentrations (diagram from Durako et al. in McIvor et al. 1994, Carlson et al. 1994). This hypothesis regarding the proximate cause of seagrass mass mortality is supported by a recent *in situ* study in Florida Bay (Borum et al. 2005) that showed the importance of anoxia and sulfide in surficial sediments as a potential cause of *T. testudinum* mortality.

Regardless of the cause of the mass-mortality event, once this event was initiated, the ecology of Florida Bay changed. A cycle resulting in continuing seagrass habitat loss is depicted in the conceptual ecological model. Continued seagrass mortality results in increased sediment resuspension (Prager and Halley 1999, Stumpf et al. 1999) and increased nutrient (nitrogen and phosphorus) release from sediments, stimulating phytoplankton growth in the water column. The presence of both phytoplankton and suspended sediment result in decreased light penetration to seagrass beds. This decreased light can limit seagrass growth and sustain the feedback loop.

Dynamics of this feedback loop are probably not independent of the salinity regime. Seagrass wasting disease, caused by a slime mold (*Labyrinthula* sp.) infection, is more common at salinities near or greater than seawater (≥ 35 psu) than at low (15 to 20 psu) salinities (Blakesley et al. 2003). High salinity may have played a role in the initial seagrass mass mortality event but more likely has served to promote seagrass re-infection since that event. Incidence of this disease may therefore be directly affected by water management actions.

If the state of the seagrass community is to be used as a criterion to decide success of environmental restoration efforts, scientists and managers must specify the desirability of alternative states. Based on studies of historic changes of seagrass communities in Florida Bay and anecdotal information (Brewster-Wingard and Ishman 1999, Zieman et al. 1999, Cronin et al. 2001), it is likely that the Florida Bay of the 1970s and early 1980s, with lush *T. testudinum* and clear water, was probably a temporary and atypical condition. From an ecological perspective, restoration should generally strive for a more diverse seagrass community with lower *T. testudinum* density and biomass than during that anomalous period. A diversity of seagrass habitat is expected to be beneficial to many upper trophic level species (Thayer et al. 1999).

Water Quality Condition

Water quality condition reflects the light field, nutrient availability in the ecosystem, and algal blooms in the water column. All of these characteristics are closely related to the condition of seagrasses and food web structure and dynamics of the bay. While these characteristics have been monitored and researched since the early 1990s, earlier information is scarce for

salinity and almost non-existent for the above water quality characteristics. Thus, at the present time, we do not know whether nutrient inputs to the bay have actually increased in recent decades or whether periods with sustained algal blooms and high turbidity occurred in the past.

Studies of nutrient export from southern Everglades canals and creeks flowing into Florida Bay have provided insights regarding the relationship between patterns of freshwater discharge, nutrient dynamics, and output to Florida Bay (Rudnick et al. 1999, Davis et al. 2003, Sutula et al. 2003). Results show that phosphorus loads to the bay do not greatly increase with increased freshwater inputs to the bay, but given the phosphorus limitation of the eastern bay, any increase in phosphorus availability is likely to affect productivity patterns. Unlike phosphorus, total nitrogen loads probably do increase with more freshwater flow (Rudnick et al. 1999), and algal growth in western and sometimes central Florida Bay can be nitrogen limited (Tomas et al. 1999). The potential thus exists for hydrologic restoration to increase nitrogen loading and stimulate phytoplankton blooms (Brand 2002). Because most of the nitrogen that is exported from the Everglades to the bay is in the form of organic compounds (Rudnick et al. 1999), the fate of these compounds within the bay is a critical unknown; if these compounds are easily decomposed and their nitrogen becomes available to algae, then increased freshwater flow could stimulate algal growth. In addition to organic nitrogen decomposition rates, other critical unknowns regarding the availability of nitrogen for algal productivity include rates of nitrogen fixation and denitrification within the bay and the residence time of water in bay's sub-basins.

Finally, as emphasized earlier, light penetration through Florida Bay waters is a key to the health of seagrasses. Light penetration is largely a function of turbidity from algae and suspended sediment. Although light levels were potentially limiting to seagrass growth during the early and mid-1990s, in more recent years, only the northwest corner of the bay is potentially light-limiting (Kelble et al. 2005). For successful restoration of Florida Bay, light penetration must be sufficient to ensure viable seagrass habitat. Such a light-penetration criterion has been used in other estuaries (Dennison et al. 1993) and is an important success criterion for Florida Bay.

Benthic Grazers

Consumption of phytoplankton by bivalves and other benthic filter feeders and suspension feeders (especially sponges and tunicates) may have significant impacts on the distribution, magnitude, and duration of algal blooms. Increases or decreases in algal blooms may be related to significant increases or decreases in grazer abundance and biomass. Decreased grazing may have occurred in the 1990s because of seagrass habitat loss, which could have decreased grazer abundance. Additionally, grazers may have been negatively affected by cyanobacterial blooms (*Synechococcus* sp., the dominant phytoplankter in central Florida Bay's blooms [Phlips and Badylak 1996]). These blooms may have played a role in the large-scale mortality of sponges in southern Florida Bay in the early 1990s (Butler et al. 1995). Such a loss of grazers would have enabled larger blooms to occur, decreasing light penetration, and thereby reinforcing the feedback loop of seagrass mortality and algal blooms.

Benthic grazers abundance, biomass, species composition, and distribution are valuable in a monitoring program not only because of their functional link with phytoplankton blooms, but also because these grazers are ecological indicators. Paleoecological and recent studies of the bay have inferred that long-term changes in molluscan species composition are largely a function of salinity and seagrass habitat availability (Brewster-Wingard and Ishman 1999).

Pink Shrimp

Pink shrimp (*Farfantepenaeus duorarum* Burkenroad) are economically important to society as a highly valued fishery species and are also ecologically important as a major dietary component of game fish and wading birds. Furthermore, pink shrimp are an indicator of Florida Bay's productivity because the bay and nearby coastal areas are primary shrimp nursery grounds. This nursery supports the shrimp fishery of the Tortugas grounds (Ehrhardt and Legault 1999). Hydrologic and ecological changes in the Everglades and Florida Bay may have impacted this fishery, which experienced a decrease in annual harvest from about 4.5 million kg per year in the 1960s and 1970s to only about 0.9 million kg per year in the late 1980s (Ehrhardt and Legault 1999). This decrease may have been associated with seagrass habitat loss or high salinity (50 to 70 psu) during the 1989–1990 drought; experiments have shown that pink shrimp mortality rates increase with salinities above about 35 psu, and growth rates are optimal at 30 psu (Browder et al. 2002). Shrimp harvest statistics indicate that shrimp productivity increases with increasing freshwater flow from the Everglades (Browder 1985). This may be because greater freshwater inflows reduce the frequency, duration, and spatial coverage of hypersaline events in Florida Bay (Browder et al. 1999, 2002). The statistical relationship between indices of freshwater flow and shrimp productivity is sufficiently robust to be

used by the National Marine Fisheries Service in management of the offshore fishery (Sheridan 1996).

Fish Community

The health of Florida Bay's fish populations is of great importance to the public; sport fishing is a major economic contributor to the region (Tilmant 1989). Recruitment, growth, and survivorship of these fish populations are affected by many factors, including salinity, habitat quality and availability, food-web dynamics, and fishing pressure. Changes in mangrove and seagrass habitats are likely to influence the structure and function of the fish community. However, seagrass mass mortality appears to have had a greater influence on fish community structure than on the absolute abundance of fish; no dramatic bay-wide decreases in fish abundance were observed along with seagrass mass mortality (Thayer et al. 1999). Rather, a shift in fish species composition occurred as a result of seagrass habitat loss and sustained algal blooms. When demersal fish markedly declined, pelagic fish such as the bay anchovy, which feed on phytoplankton, increased (Thayer et al. 1999). More recently, changes in the opposite direction have been observed (Powell et al. 2001). While causes of these changes are not well-established, there is no question that stressors, such as altered salinity regimes, not only affect upper trophic level populations directly but also affect them indirectly through habitat and food-web changes.

Another important stressor that needs to be considered with regard to fish populations is the impact of pesticides and mercury. As concentrations of mercury and some pesticides greatly increase in upper trophic level species, such as sport fish (via the process of bioaccumulation) that people eat, a human health issue potentially exists. Pesticides and mercury can also have ecological impacts by physiologically stressing organisms (particularly reproductive functions). While toxic contaminant inputs to Florida Bay do not appear to be associated with recent large-scale changes in the bay ecosystem, biotic exposure to toxicants could change in association with restoration-related changes in upstream water management.

Among the many fish species that could be used as indicators of the health of the ecosystem's upper trophic level, the spotted sea trout (*Cynoscion nebulosus* Cuvier in Cuvier and Valenciennes) is unique because it is the only major sport fish species that spends its entire life in the bay (Rutherford et al. 1989). Changes in the bay's sea trout population and toxic residues in this species thus reflect changes in the bay itself, as well as upstream restoration actions that affect the quantity and quality of water entering the bay. Sea trout are a particularly good restoration indicator for central Florida Bay, where they are commonly found and where prolonged periods of hypersalinity are common. This species is known to be sensitive to hypersalinity; density of post-larvae has been found to be greatest at an intermediate salinity range of 20–40 psu (Alsuth and Gilmore 1994). For northeastern Florida Bay, the abundance of common snook (*Centropomus undecimalis* Bloch), red drum (*Sciaenops ocellatus* Linnaeus, 1766), crevalle jack (*Caranx hippos* Linnaeus), and mullet are also being considered as potential restoration indicators.

Fish-Eating Birds

Florida Bay and its mangrove coastline are important feeding and breeding grounds for waterfowl and wading birds. Conceptual ecological models for other regions of the Everglades, particularly the Everglades Mangrove Estuaries Conceptual Ecological Model (Davis et al. 2005), present more detailed descriptions of the use of bird populations as ecological indicators and consider a wide variety of birds. For the Florida Bay Conceptual Ecological Model, we consider only fish-eating birds that are characteristic of the marine environment, such as great white herons, reddish egrets, osprey, brown pelicans, and cormorants. These birds are important predators within the bay and are potentially impacted by any stressors that affect their prey base, including salinity changes, nutrient inputs, toxic compounds, and fishing pressure. As with other top predators, these bird species may also be especially vulnerable to toxic contaminants.

RESTORATION RESPONSES: EXPECTATIONS AND UNCERTAINTIES

In this section, we present a prospective view of Everglades restoration. The Conceptual Ecological Model, while largely based on past ecological dynamics, still serves as a guide. The foremost purpose of this section is to identify those components and linkages (with associated ecological processes) that are most sensitive to changing watershed management, have a strong effect on the entire estuarine ecosystem, and yet are poorly understood relative to the information needs of the adaptive management process. This includes consideration of salinity and hydrodynamics, nutrient inputs and phytoplankton blooms, and benthic habitat and higher trophic level responses to restoration. Working hypotheses regarding each of these high priority aspects of the Florida Bay conceptual model are also presented here. We use the term "working hypothesis" in the sense that the described predictions and relationships, while generally not test-

able with strict experimental control, can be assessed as part of a long-term adaptive management program.

Salinity Responses

The conceptual model explicitly illustrates the central importance of water management on the Florida Bay ecosystem, largely mediated through changing salinity. An expectation of the Everglades restoration plan is that salinity in the bay will decrease, expanding the spatial extent and duration of oligohaline to polyhaline conditions, while decreasing the extent and duration of hypersaline conditions. However, a quantitative understanding of the relationship between wetland hydrologic conditions, freshwater flow, and resultant salinity throughout the bay is still lacking. An important step toward gaining this understanding and a predictive capability for environmental management is the synthesis of a broad array of available hydrologic, hydrodynamic, and salinity information within a hydrodynamic model. Development of such a model is challenging, given the shallow and complex morphology of Florida Bay. To date, restoration planning has only used simple statistical estimates of salinity, largely as a function of wetland water stages, and these estimates have been limited to near-shore embayments. Predicting salinity change within the entire bay requires understanding of changing water inputs, exchanges, and circulation. The effects of restoration efforts thus will be strongly influenced not only by changing freshwater flow, but also by sea-level rise and changing bay morphology.

Working Hypotheses: Relationships of Mud Bank Dynamics, Sea-Level Rise, and Circulation. Circulation and salinity patterns, and thus ecological patterns, are strongly influenced by Florida Bay's mud banks, which are dynamic features. The response of these banks to sea-level rise and the changing frequency and intensity of tropical storms cannot confidently be predicted. Based on the persistence of mud-bank spatial distributions over centuries and past patterns of accretion (Wanless and Tagett 1989), we hypothesize that sediments will accrete on banks at rates comparable to rates of sea-level rise and that the spatial pattern of banks and basins will remain largely unchanged in future decades, despite the likelihood that tropical storm activity will increase during the coming decade (Goldenberg et al. 2001). If these hypotheses are true, then water circulation within the bay will continue to be restricted by mud banks, even with sea-level rise, and exchange of bay water with seawater of the Atlantic Ocean and Gulf of Mexico will not markedly increase. However, as the depth of basins increases (historic sediment accretion of banks has greatly exceeded sediment accretion in basins; Wanless and Tagett (1989)), the residence time of water in basins and the potential for stratification and oxygen stress would also increase. Moreover, with increased depth, light penetration to seagrass communities would decrease. Alternatively, if mud bank accretion does not keep up with sea-level rise, the exchange and circulation of Gulf of Mexico and Atlantic water in Florida Bay will increase, shifting the bay from an estuarine to a more marine system and minimizing the influence of any watershed restoration actions. Such increased circulation could also ameliorate the historic effect of the Flagler Railway and Keys Highway, which decreased water exchange between the bay and Atlantic, increased water residence time in the bay, and probably changed circulation and salinity patterns. Finally, with rising sea level, the mangrove shoreline along the northern bay will likely move inland.

Water Quality Responses

Restoration of the Everglades will have effects on the watershed's estuaries beyond changing freshwater input and salinity. Restoration will also affect material (particularly dissolved nutrient) inputs as stormwater treatment areas decrease nutrient inputs to the Everglades (Chimney and Goforth 2001) and changing hydrologic conditions modify biogeochemical cycles and transport within the wetlands. Changing flow and salinity will affect biogeochemical cycling within the estuaries via direct effects of salinity on abiotic processes (e.g., phosphorus sorption-desorption) and indirect effects of changing community structure and associated physical and biogeochemical characteristics (e.g., sediment stabilization and resuspension with changing seagrass cover). The ecological consequences of these changes are uncertain, but one concern is that phytoplankton blooms could be stimulated by Everglades restoration because of potential increases in nitrogen inputs (Brand 2002). Nevertheless, an expectation of Everglades restoration is that such a change in Florida Bay water quality will not occur. Development of a coupled hydrodynamic-water quality model of the bay, combined with monitoring and research of biogeochemical processes will improve understanding and adaptive management responses to this and other aspects of the restoration.

Working Hypotheses: Relationships of Water Quality and External Nutrient Sources. Changing the flow of water through the Everglades and resultant changes in the structure and function of these wetlands will alter the delivery of materials to downstream coastal ecosystems, including Florida Bay. Quantitative predictions of these changes are not possible at this time, but

it is reasonable to expect that phosphorus outputs from the Everglades, which are very low, will not change, and nitrogen outputs from the Everglades, which are much greater (Rudnick et al. 1999), could change. Given that most nitrogen output is in the form of dissolved organic matter (DOM), a major uncertainty is the extent to which this DOM can be decomposed by heterotrophic bacteria and phytoplankton and provide nutrients (particularly nitrogen) for phytoplankton. Depending upon the proportion of this bioavailable DOM and the relationship of DOM quality and quantity to freshwater flow, restoration of natural water inflows from the Everglades could affect the composition, magnitude, duration, and distribution of phytoplankton blooms.

Hydrologic restoration of the Everglades could also affect Florida Bay water quality by changing water circulation and water residence time in the bay. Increased freshwater inputs from the Everglades, with lower phosphorus concentrations than in Gulf of Mexico waters, could decrease phosphorus inputs from the Gulf (moving the zone of influence of P-limiting Everglades water westward in the bay) and thus decrease the density and prevalence of *Synechococcus* blooms in central Florida Bay (Boyer and Jones 1999). Furthermore, the magnitude of phytoplankton blooms varies as a function of the residence time of waters within the bay's basins and exchange of these waters with adjacent marine waters. Increased freshwater flow, along with the potential restoration of passes through the Florida Keys, could decrease bay water residence time and phytoplankton blooms.

Working Hypotheses: Relationships of Water Quality and Changing Internal Bay Structure and Function. Everglades restoration will affect Florida Bay water quality via changes in the bay's internal biogeochemical cycles. These internal changes will likely be mediated through changing seagrass community structure and function. An expectation of the restoration is that changing salinity will increase seagrass species diversity and spatial heterogeneity such that large scale *T. testudinum* die-off events will be prevented. In turn, water-quality degradation associated with such events will be prevented. Die-off events can increase phytoplankton growth because of increased sedimentary nutrient mobilization, decreased benthic uptake of nutrients and resultant reduction in competition for water-column nutrients, and decreased grazing pressure from benthic filter feeders (due to loss of their habitat). Sediment resuspension due to seagrass die-off can supply additional water-column nutrients via both porewater advection and desorption of surface-bound nutrients from resuspended particles. The latter process is salinity dependent and will be affected by hydrologic restoration, which may thus influence phosphorus availability for phytoplankton (with lower phosphorus availability as a function of lower salinity).

Nitrogen cycling and availability within the bay are likely to change with restoration, and these internal changes are likely to have greater effects on phytoplankton production than those derived from changing nitrogen inputs from the Everglades. Recent studies found that rapid and variable rates of nitrogen fixation and denitrification occur within bay sediments (particularly benthic microbial mats) and seagrass beds (Nagel 2004, Evans 2005). There is high uncertainty regarding the magnitude of large-scale (space and time), integrated rates of nitrogen cycling, and changes that may occur with restoration.

Seagrass Community and Trophic Web Response

An expectation of Everglades restoration is that changing patterns of freshwater flow toward more natural patterns will drive Florida Bay's seagrass community and trophic web toward its pre-drainage condition.

Working Hypotheses: Multiple Factors Affect the Florida Bay Seagrass Community. Spatial coverage, biomass, production, and taxonomic composition of seagrass beds in Florida Bay are controlled by the combined and inter-related effects of light penetration, epiphyte biomass, nutrient availability, sediment depth, salinity, temperature, sulfide toxicity, and disease. Decreased salinity caused by increasing freshwater flow will have a direct effect on seagrass communities through physiological mechanisms, resulting in greater spatial heterogeneity of seagrass beds, a decrease in the dominance of *T. testudinum*, and an increase in coverage by other seagrass species (*H. wrightii* through much of the bay and *R. maritima* near the northern coast of the bay). Decreased salinity will also decrease the infection of *T. testudinum* by the slime mold, *Labyrinthula*. Light availability will depend upon phytoplankton growth and sediment resuspension, which depend both on nutrient availability, grazing, and stabilization of sediments by seagrass beds.

Working Hypotheses: Changing Salinity and Seagrass Habitat Will Alter Fish Community Structure. Fish and invertebrate species in Florida Bay are expected to be affected by Everglades restoration efforts via responses to changing salinity and habitat. Decreasing salinity, and especially reducing the frequency and duration of hypersaline events, will increase the growth and survival of estuarine species (especially juvenile pink shrimp and juvenile spotted seatrout) and enhance

the use of Florida Bay as a nursery. Increased seagrass habitat diversity and heterogeneity (with less area covered by high density *T. testudinum*) and minimizing large-scale *T. testudinum* die-off events will increase the survivorship and population size of these and other higher trophic level species. Both recreational and commercial fisheries are thus expected to benefit from Everglades restoration.

ACKNOWLEDGMENTS

We thank the many scientists and managers who have worked together to develop and explore the concepts that are presented here. This work reflects the collective effort of participants in several workshops and conferences, leading toward a consensus of inference and professional judgment that we present in this paper. In particular, we thank Tom Armentano, Joe Boyer, Larry Brand, Paul Carlson, Mike Durako, Jim Fourqurean, Bob Halley, Gary Hitchock, John Hunt, Bill Kruczynski, Jerry Lorenz, Chris Madden, Doug Morrison, Bill Nuttle, Ed Phlips, Mike Robblee, Darren Rumbold, Tom Schmidt, Steve Traxler, Hal Wanless, and (last, but far from least) Jay Zieman. We also thank Deborah Drum, Shawn Sculley, and anonymous reviewers for review comments, Douglas Wilcox for review and editorial comments, and special thanks to Kim Jacobs for assistance in preparing and initial editing of this paper.

LITERATURE CITED

Alsuth, S. and R. G. Gilmore. 1994. Salinity and temperature tolerance limits for larval spotted seatrout, *Cynoscion nebulosus* C. (Pisces: Sciaenidae). International Journal for the Exploration of the Sea. Council Meeting Papers, ICES-CM-1994/L:17.

Armentano, T., R. Brock, J. Hunt, W. Kruzynski, D. Rudnick, S. Traxler, N. Thompson, P. Ortner, K. Cairnes, M. Robblee, and R. Halley. 1997. Strategic Plan for the Interagency Florida Bay Science Program. Everglades National Park, Florida Bay Program Management Committee [www.aoml.noaa.gov/flbay], Homestead, FL, USA.

Blakesley, B. A., D. M. Berns, and M. O. Hall. 2003. Infection, infestation, and disease: differential impacts of *Labyrinthula* sp. on the seagrass *Thalassia testudinum* (Banks ex König) in Florida Bay, USA. p. 135–137. *In* Florida Bay Program & Abstracts, Joint Conference on the Science and Restoration of the Greater Everglades and Florida Bay Ecosystem (http://conference.ifas.ufl.edu/jc/FB.pdf). University of Florida, Gainesville, FL, USA.

Boesch, D., N. Armstrong, C. D'Elia, N. Maynard, H. Paerl, and S. Williams. 1993. Deterioration of the Florida Bay Ecosystem: an evaluation of the scientific evidence. Report to the Interagency Working Group on Florida Bay [www.aoml.noaa.gov/flbay]. Everglades National Park, Homestead, FL, USA.

Borum, J., O. Pedersen, T. M. Greve, T. A. Frankovich, J. C. Zieman, J. W. Fourqurean, and C. J. Madden. 2005. Oxygen and sulfide dynamics in the tropical seagrass, *Thalassia testudinum*, Florida Bay (USA). Journal of Ecology 93:148–158.

Bosence, D. W. J. 1989. Biogenic carbonate production in Florida Bay. Bulletin of Marine Science 44:49–433.

Boyer, J. N., J. W. Fourqurean, and R. D. Jones. 1997. Spatial characterization of water quality in Florida Bay and Whitewater Bay by multivariate analysis: zones of similar influence (ZSI). Estuaries 20:743–758.

Boyer, J. N. and R. D. Jones. 1999. Effects of freshwater inputs and loading of phosphorus and nitrogen on the water quality of Eastern Florida Bay. p. 321–329. *In* K. R. Reddy, G. A. O'Connor, and C. L. Shelske (eds.) Phosphorus Biogeochemistry in Sub-Tropical Ecostysems: Florida as a Case Example. CRC/Lewis Publishers, Boca Raton, FL, USA.

Brand, L. E. 2002. The transport of terrestrial nutrients to South Florida coastal waters. p. 353–406. *In* J. W. Porter and K. G. Porter (eds.) The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. CRC Press, Boca Raton, FL, USA.

Brewster-Wingard, G. L. and S. E. Ishman. 1999. Historical trends in salinity and substrate in central and northern Florida Bay: a paleoecological reconstruction using modern analogue data: Estuaries 22:369–383.

Brewster-Wingard, G. L., J. R. Stone, and C. W. Holmes. 2001. Molluscan faunal distribution in Florida Bay, past and present: an integration of down-core and modern data. Bulletins of American Paleontology 361:199–231.

Browder, J. A. 1985. Relationship between pink shrimp production on the Tortugas grounds and water flow patterns in the Florida Everglades. Bulletin of Marine Science 37:839–856.

Browder, J. A., V. R. Restrepo, J. K. Rice, M. B. Robblee, and Z. Zein-Eldin. 1999. Environmental influences on potential recruitment of pink shrimp (*penaeus duorarum*) from Florida Bay nursery grounds. Estuaries 22:484–499.

Browder, J. A., Z. Zein-Eldin, M. D. Criales, M. B. Robblee, and T. L. Jackson. 2002. Dynamics of pink shrimp recruitment in relation to Florida Bay salinity and temperature. Estuaries 25:1335–1371.

Butler, M. J. IV, J. H. Hunt, W. F. Herrnkind, M. J. Childress, R. Bertelsen, W. Sharp, T. Matthews, J. M. Field, and H. G. Marshall. 1995. Cascading disturbances in Florida Bay, USA: cyanobacterial bloom, sponge mortality, and implications for juvenile spiny lobsters *Panulirus argus*. Marine Ecology Progress Series 129:119–125.

Carlson, P. R, L. A. Yarbro, and T. R. Barber. 1994. Relationship of sediment sulfide to morality of *Thalassia testudinum* in Florida Bay. Bulletin of Marine Science 54:733–74.

Childers, D. L., J. N. Boyer, S. E. Davis, C. Madden, D. Rudnick, and F. Sklar. 2005. Nutrient concentration patterns in the oligotrophic "upside-down" estuaries of the Florida Everglades. Limnology and Oceanography (in press).

Chinnney, M. J. and G. Goforth. 2001. Environmental impacts to the Everglades ecosystem: a historical perspective and restoration strategies. Water Science and Technology 44:93–100.

Cleckner, L. B., P. G. Garrison, J. P. Hurley, M. L. Olson, and D. P. Krabbenhoft. 1998. Trophic transfer of methyl mercury in the northern Florida Everglades. Biogeochemistry 40:347–361.

Cleckner, L. B., C. C. Gilmour, J. P. Hurley, and D. P. Krabbenhoft. 1999. Mercury methylation in periphyton of the Florida Everglades. Limnology and Oceanography 44:1815–1825.

Cronin, T. M., C. W. Holmes, G. L. Brewster-Wingard, S. E. Ishman, H. Dowsett, D. Keyser, and N. Walbel. 2001. Historical trends in epiphytal ostracodes from Florida Bay: implications for seagrass and macro-benthic algal variability. Bulletins of American Palaeontology 361:159–197.

Davis, S. E. III, D. L. Childers, J. W. Day, D. T. Rudnick, and F. H. Sklar. 2003. Factors affecting the concentration and flux of materials in two southern Everglades mangrove wetlands. Marine Ecology Progress Series 253:85–96.

Davis, S. M., D. L. Childers, J. J. Lorenz, H. R. Wanless, and T. E. Hopkins. 2005. A conceptual model of ecological interactions in the mangrove estuaries of the Florida Everglades. Wetlands 25: (In Press).

DeKanel, J. and J. W. Morse. 1978. The chemistry of orthophosphate uptake from seawater on to calcite and aragonite. Geochemica Cosmochemica Acta 42:1335–1340.

Dennison, W. C., R. J. Orth, K. A. Moore, J. C. Stevenson, V. Carter, S. Kollar, P. Bergstrom, and R. A. Batiuk. 1993. Assessing water quality with submersed aquatic vegetation. Bioscience 43: 86–94.

Dwyer, G. S. and T. M. Cronin. 2001. Ostracode shell chemistry as a paleosalinity proxy in Florida Bay. Bulletins of American Paleontology 361:249–276.

Ehrhardt, N. M. and C. M. Legault. 1999. Pink shrimp (*Farfantepenaeus duorarum*) recruitment variability as an indicator of Florida Bay dynamics. Estuaries 22:471–83.

Evans, D. W., P. H. Crumley, D. G., Rumbold, and S. Niemczyk. 2003. Mercury in Fish from Eastern Florida Bay. p. 199–201. *In* Florida Bay Program & Abstracts, Joint Conference on the Science and Restoration of the Greater Everglades and Florida Bay Ecosystem [Available at http://conference.ifas.ufl.edu/jc/FB.pdf]. University of Florida, Gainesville, FL, USA.

Evans, J. L. B. 2005. The effect of benthic microalgal photosynthetic oxygen production on nitrogen fluxes across the sediment-water interface in a shallow, sub-tropical estuary. M.S. Thesis. University of Maryland, College Park, MD, USA.

Faunce, C. H., J. J. Lorenz, J. E. Ley, and J. E. Serafy. 2002. Size structure of gray snapper (*Lutjanus griseus*) within a mangrove "no-take" sanctuary. Bulletin of Marine Science 70:211–216.

Fourqurean, J. W. and M. B. Robblee. 1999. Florida Bay: a history of recent ecological changes. Estuaries 99:345–357.

Goldenberg, S. B., C. W. Landsea, A. M. Mestas-Nuñez, and W. M. Gray. 2001. The recent increase in Atlantic hurricane activity: causes and implications. Science 293:474–479.

Kelble, C. R., P. B. Ortner, G. L. Mitcheock, and J. N. Boyer. 2005. Attenuation of photosynthetically available radiation (PAR) in Florida Bay: potential for light limitation of primary producers. Estuaries 28:560–571.

Lapointe, B. E. and M. W. Clark. 1992. Nutrient inputs from the watershed and coastal eutrophication in the Florida Keys. Estuaries 15:465–476.

Light, S. S., and J. W. Dineen. 1994. Water control in the Everglades: a historical perspective. p. 47–84. *In* S. M. Davis and J. C. Ogden (eds.) Everglades: the Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL, USA.

McIvor, C. C., J. A. Ley, and R. D. Bjork. 1994. Changes in freshwater inflow from the Everglades to Florida Bay including effects on biota and biotic processes: a review. p. 117–146. *In* S. M. Davis and J. C. Ogden (eds.) Everglades: the Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Nagel, E. D. 2004. Nitrogen fixation in benthic microalgal mats: an important internal source of "new" nitrogen to benthic communities in Florida Bay. M.S. Thesis. University of Maryland, College Park, MD, USA.

National Research Council. 2000. Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution. National Academy Press, Washington, DC, USA.

Nuttle, W. K., J. W. Fourqurean, B. J. Cosby, J. C. Zieman, and M. B. Robblee. 2000. Influence of net freshwater supply on salinity in Florida Bay. Water Resources Research 36:1805–1822.

Ogden, J. C., S. M. Davis, K. J. Jacobs, T. Barnes, and H. E. Fling. 2005. The use of conceptual ecological models to guide ecosystem restoration in south Florida. Wetlands 25:(in press).

Orem, W. H, C. W. Holmes, C. Kendall, H. E. Lerch, A. L. Bates, S. R. Silva, A. Boylan, M. Corum, M. Marot, and C. Hedgman. 1999. Geochemistry of Florida Bay sediments: nutrient history at five sites in eastern and central Florida Bay. Journal of Coastal Research 15:1055–1071.

Phlips, E. J. and S. Badylak. 1996. Spatial variability in phytoplankton standing crop and composition in a shallow inner-shelf lagoon, Florida Bay, FL, USA. Bulletin of Marine Science 58:203–216.

Powell, A. B., G. W. Thayer, M. Lacroix, and R. Cheshire. 2001. Interannual changes in juvenile and small resident fish assemblages, and seagrass densities in Florida Bay. p. 199–200. *In* 2001 Florida Bay Science Conference Abstracts, [http://conference.ifas.ufl.edu/FloridaBay/abstract.pdf]. University of Florida, Gainesville, FL, USA.

Prager, E. J. and R. B. Halley. 1999. The influence of seagrass on shell layers and Florida Bay mudbanks. Journal of Coastal Research 15:1151–1162.

Robblee, M. B., T. R. Barber, P. R. Carlson, Jr., M. J. Durako, J. W. Fourqurean, L. K. Muehlstein, D. Porter, L. A. Yarbro, R. T. Zieman, and J. C. Zieman. 1991. Mass mortality of the tropical seagrass *Thalassia testudinum* in Florida Bay (USA). Marine Ecology Progress Series 71:297–299.

Rudnick, D. T., Z. Chen, D. Childers, J. Boyer, and T. Fontaine. 1999. Phosphorus and nitrogen inputs to Florida Bay: the importance of the Everglades watershed. Estuaries 22:398–416.

Rumbold, D. G., L. Fink, D. Evans, D. Krabbenhoft, and M. Olson. 2003. Source identification of Florida Bay's methylmercury problem: mainland runoff versus atmospheric deposition and in situ production. p. 233–235. *In* Florida Bay Program & Abstracts, Joint Conference on the Science and Restoration of the Greater Everglades and Florida Bay Ecosystem [http://conference.ifas.ufl.edu/jc/FB.pdf]. University of Florida, Gainesville, FL, USA.

Rutherford, E. S., T. W. Schmidt, and J. T. Tilmant. 1989. Early life history of spotted seatrout (*Cynoscion nebulosus*) and gray snapper (*Lutjanus griseus*) in Florida Bay, Everglades National Park, Florida. Bulletin of Marine Science 44:49–64.

Schomer, N. S. and R. D. Drew. 1982. An ecological characterization of the lower Everglades, Florida Bay, and the Florida Keys. United States Fish and Wildlife Service, Office of Biological Services, Washington, DC, USA.WS/OBS-82/58. 1.

Scott, G. I., M. H. Fulton, E. F. Wirth, G. T. Chandler, P. B. Key, J. W. Daugomah, D. Bearden, K. W. Chung, E. D. Strozier, S. Silvertsen, A. Dias, M. Sanders, J. M. Macauley, L. R. Goodman, M. W. LaCroix, G. W. Thayer, and J. R. Kucklick. 2002. Toxicological studies in tropical ecosystems: an ecotoxicological risk assessment of pesticide runoff in south Florida estuarine ecosystems. Journal of Agricultural and Food Chemistry 50:4400–4408.

Sheridan, P. 1996. Forecasting the fishery for pink shrimp, *Penaeus duorarum*, on the Tortugas grounds, Florida. Fishery Bulletin 94: 743–755.

Sklar, F. H., M. J. Chimney, S. Newman, P. McCormick, D. Gawlik, S. Miao, C. McVoy, W. Said, J. Newman, C. Coronado, G. Crozier, M. Korvela, and K. Rutchey. 2005. The ecological-societal underpinnings of Everglades restoration. Frontiers in Ecology and the Environment 3:161–169.

Smith, N. P. 1994. Long-term gulf-to-Atlantic transport through tidal channels in the Florida Keys. Bulletin of Marine Science 54:602–609.

Strom, D. G. and G. A. Graves. 2001. A comparison of mercury in estuarine fish between Florida Bay and Indian River Lagoon, Florida, U.S.A. Estuaries 24:597–609.

Stumpf, R. P., M. L. Frayer, M. J. Durako, and J. C. Brock. 1999. Variations in water clarity and bottom albedo in Florida Bay from 1985 to 1997. Estuaries 22:431–444.

Sutula, M., B. Perez, E. Reyes, J. W. Day Jr., and D. Childers. 2003. Spatio-temporal variability in material exchange between the southeastern Everglades wetlands and Florida Bay. Estuarine, Coastal, and Shelf Science 57:757–781.

Swart, P. K., G. F. Healy, R. E. Dodge, P. Kramer, J. H. Hudson, R. B. Halley, and M. B. Robblee. 1996. The stable oxygen and carbon isotopic record from a coral growing in Florida Bay: a 160 year record of climatic and anthropogenic influence. Paleogeography, Paleoclimatology, Paleoecology 123:219–237.

Swart, P. K., G. F. Healy, L. Greer, M. Lutz, A. Saied, D. Anderegg, R. E. Dodge, and D. Rudnick. 1999. The use of proxy chemical records in coral skeletons to ascertain past environmental conditions in Florida Bay. Estuaries 22:384–397.

Thayer, G. W., A. B. Powell, and D. E. Hoss. 1999. Composition of larval, juvenile, and small adult fishes relative to changes in environmental conditions in Florida Bay. Estuaries 22:518–533.

Tilmant, J. T. 1989. A history and an overview of recent trends in the fisheries of Florida Bay. Bulletin of Marine Science 44:3–33.

Tomas, C. R., B. Bendis, and K. Johns. 1999. Role of nutrients in regulating plankton blooms in Florida Bay. p. 323–337. *In* H. Kumpf, K. Steidinger, and K. Sherman (eds.) The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management. Blackwell Science. Malden, MA, USA.

Wang, J. D., J. van de Kreeke, N. Krishnan, and D. Smith. 1994. Wind and tide response in Florida Bay. Bulletin of Marine Science 54:579–601.

Wanless, H. R., R. W. Parkinson, and L. P. Tedesco. 1994. Sea level control on stability of Everglades wetlands. p. 199–223. *In* S. M.

Davis and J.C. Ogden (eds.) Everglades: the Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Wanless, H. R. and M. G. Tagett. 1989. Origin, growth and evolution of carbonate mudbanks in Florida Bay. Bulletin of Marine Science 44:454–489.

Zieman, J. C., J. W. Fourqurean, and T. A. Frankovich. 1999. Seagrass die-off in Florida Bay (USA): long-term trends in abundance and growth of of *Thalassia testudinum* and the role of hypersalinity and temperature. Estuaries 22:460–470.

Zieman, J. C., J. W. Fourqurean, and R. L. Iverson. 1989. Distribution, abundance and productivity of seagrasses and macroalgae in Florida Bay. Bulletin of Marine Science 44:292–311.

Manuscript received 28 February 2005; revisions received 14 September 2005; accepted 4 October 2005.

C.14.2 Mangrove Estuaries

WETLANDS, Vol. 25, No. 4, December 2005, pp. 832–842
© 2005, The Society of Wetland Scientists

A CONCEPTUAL MODEL OF ECOLOGICAL INTERACTIONS IN THE MANGROVE ESTUARIES OF THE FLORIDA EVERGLADES

Steven M. Davis[1], Daniel L. Childers[2], Jerome J. Lorenz[3], Harold R. Wanless[4], and Todd E. Hopkins[5]

[1] *South Florida Water Management District*
3301 Gun Club Road
West Palm Beach, Florida, USA 33406

[2] *Florida International University*
University Park
Miami, Florida, USA 33199

[3] *National Audubon Society*
115 Indian Mound Trail
Tavernier, Florida, USA 33070

[4] *Department of Geological Sciences*
University of Miami
Coral Gables, Florida, USA 33124

[5] *United States Fish and Wildlife Service*
1339 20th Street
Vero Beach Florida, USA 32960

Abstract: A brackish water ecotone of coastal bays and lakes, mangrove forests, salt marshes, tidal creeks, and upland hammocks separates Florida Bay, Biscayne Bay, and the Gulf of Mexico from the freshwater Everglades. The Everglades mangrove estuaries are characterized by salinity gradients that vary spatially with topography and vary seasonally and inter-annually with rainfall, tide, and freshwater flow from the Everglades. Because of their location at the lower end of the Everglades drainage basin, Everglades mangrove estuaries have been affected by upstream water management practices that have altered the freshwater heads and flows and that affect salinity gradients. Additionally, interannual variation in precipitation patterns, particularly those caused to El Niño events, control freshwater inputs and salinity dynamics in these estuaries. Two major external drivers on this system are water management activities and global climate change. These drivers lead to two major ecosystem stressors: reduced freshwater flow volume and duration, and sea-level rise. Major ecological attributes include mangrove forest production, soil accretion, and resilience; coastal lake submerged aquatic vegetation; resident mangrove fish populations; wood stork (*Mycteria americana*) and roseate spoonbill (*Platelea ajaja*) nesting colonies; and estuarine crocodilian populations. Causal linkages between stressors and attributes include coastal transgression, hydroperiods, salinity gradients, and the "white zone" freshwater/estuarine interface. The functional estuary and its ecological attributes, as influenced by sea level and freshwater flow, must be viewed as spatially dynamic, with a possible near-term balancing of transgression but ultimately a long-term continuation of inland movement. Regardless of the spatio-temporal timing of this transgression, a salinity gradient supportive of ecologically functional Everglades mangrove estuaries will be required to maintain the integrity of the South Florida ecosystem.

Key Words: Everglades, South Florida, ecosystem restoration, conceptual ecological model, mangrove forest, tidal creeks, estuaries, salinity gradients, water management, sea-level rise, estuarine geomorphology, fish communities, wood stork, roseate spoonbill, American crocodile

BACKGROUND

A brackish water ecotone of coastal bays and lakes, mangrove and buttonwood forests, salt marshes, tidal creeks, and upland hammocks separates Florida Bay, southern Biscayne Bay, and the Gulf of Mexico from the freshwater Everglades. The model boundary from Turkey Point west to Lostman's River delineates the interface of Biscayne and Florida Bays and the Gulf of Mexico that is affected by freshwater flows from

the Everglades (Figure 1). The Everglades mangrove estuaries are characterized by salinity gradients that vary spatially with topography and seasonally and inter-annually with rainfall, tide, and freshwater flow from the Everglades. Because of their location at the lower end of the Everglades drainage basin, Everglades mangrove estuaries are particularly vulnerable to changes in sea level and freshwater flow.

Everglades mangrove estuaries and their ecological attributes, as influenced by sea-level rise and increased freshwater flow (in both volume and duration), must be viewed as spatially dynamic, with a possible near-term balancing of transgression but ultimately a long-term continuation of inland movement. Regardless of the spatio-temporal timing of this transgression, a salinity gradient supportive of ecologically functional Everglades mangrove estuaries will be required to maintain the integrity of the South Florida ecosystem.

EXTERNAL DRIVERS AND ECOLOGICAL STRESSORS

All ecological processes and attributes in the mangrove coastline of the southern Everglades are hydrologically controlled by sheet flow from the freshwater wetlands to the north interacting with sea level in the Gulf of Mexico and Florida Bay (Figure 2). Responses to changes in freshwater flow from the implementation of CERP are relatively short term in comparison to the longer-term, progressively increasing changes resulting from relative sea-level rise.

Freshwater Flow

Construction and operation of South Florida's water management system during the Twentieth Century has depleted freshwater flow to the Everglades mangrove estuaries and has altered its timing and distribution (McIvor et al. 1994, VanZee 1999). There are numerous examples of how ecological patterns and processes in the mangrove estuaries are closely linked to patterns of hydrology, salinity, and supply of marine-derived phosphorus, all of which have been altered by reduced freshwater flow (Chen and Twilley 1999, Ross et al. 2000). Because the upstream freshwater Everglades system is so oligotrophic and phosphorus-limited (Noe et al. 2001), the ocean is the source of the limiting nutrient to these estuaries. This "upside-down" characteristic of Everglades estuaries is a defining feature and plays a strong role in the interaction of geomorphology and productivity (Childers et al. 2005).

Additionally, Childers et al. (2005) suggested that water residence time, particularly during the dry months, plays a key role in phosphorus cycling in Everglades mangrove estuaries. Along west coast systems, such as Shark River, low freshwater inflows at this time allow salinity incursions up-estuary, extending the influence of the marine phosphorus source to the oligohaline ecotone. In the Florida Bay mangrove zone, though, the loss of freshwater inflow effectively eliminates flushing, and water residence times are long. During this time, Childers et al. (2005) hypothesized that internal recycling of phosphorus (primarily via subtidal and open water processes) and nitrogen (primarily mediated by the mangrove wetlands) dominate dry season dynamics.

Sea-Level Rise

The rate of relative sea-level rise for South Florida increased above recent decadal rates beginning about 1930. Since that time, South Florida has had a relative sea-level rise of about 23 cm (Wanless et al. 1994). This is a rate of 30 cm per century. Anticipated response to global warming is projected to result in a global increase in sea level of about 60 cm in the coming century. Sea-level rise may massively reconfigure geomorphology, circulation patterns, salinity patterns, and ecological processes during the Twenty-First Century (Wanless et al. 1994).

Non-Native Plants and Fishes

The introduction and spread of non-native plants and fishes are additional drivers and stressors on the Everglades mangrove estuaries, although they are not included in this model because of the overwhelming influences of sea level and hydrology. The Mayan cichlid presently dominates the fish community in mangrove wetlands east of Taylor Slough (Trexler et al. 2001), and the non-native plants Brazilian pepper (*Schinus terebinthifolius* Raddi) and common colubrine (*Colubrina asiatica* (L.) Brongn) have invaded mangrove forests. Although less pervasive than sea level and freshwater flow, potential impacts from the spread of non-native plants and fishes merit a better understanding of their ecological roles and potentials for control.

ECOLOGICAL ATTRIBUTES

Mangrove Forest Production, Soil Accretion, and Resilience

Mangrove forests (red mangroves [*Rhizophora mangle* Linnaeus], black mangroves [*Avicennia germinans* (L.) Linnaeus], white mangroves [*Laguncularia racemosa* (L.) Gaertn.f.)], and buttonwood [*Conocarpus erectus*]) dominate primary productivity and soil accretion within the Everglades mangrove estuaries

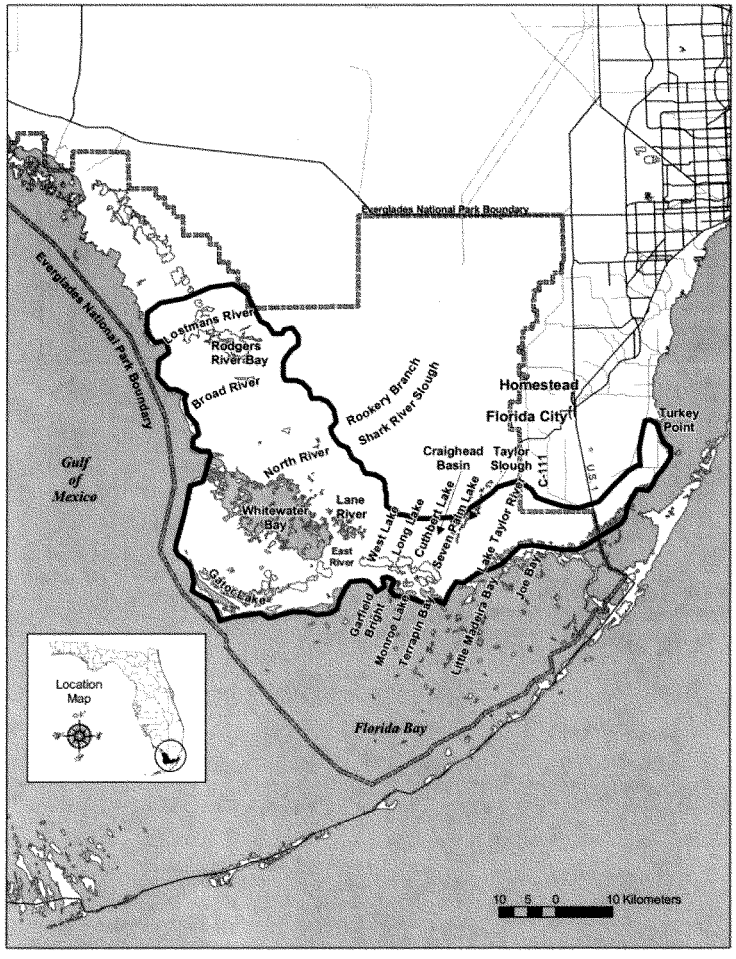


Figure 1. Boundary of the Everglades Mangrove Estuaries Conceptual Ecological Model.

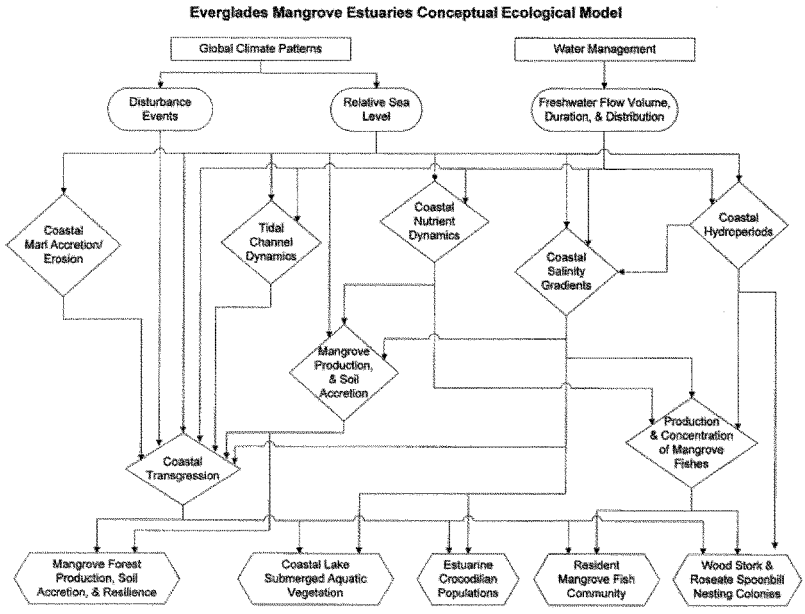


Figure 2. Everglades Mangrove Estuaries Conceptual Ecological Model diagram.

(Twilley 1998, Chen and Twilley 1999, Childers et al. 1999, Davis et al. 2004). That productivity appears to reflect the nutrient status of the estuarine interface, which is related to mixing of phosphorus-poor water from the freshwater Everglades with relatively phosphorus-rich water from the Gulf of Mexico (Davis et al. 2001 a, b, Davis et al. 2003, Childers et al. 2005).

Aboveground biomass and production in the mangrove forests of Shark River Slough and other Gulf estuaries increase from the ecotone toward the Gulf of Mexico, reflecting the direct connection of these systems to the marine phosphorus source (Chen and Twilley 1999, Rudnick et al. 1999, Childers et al. 2005). Trees in the forests near the Gulf are able to allocate more biomass to aboveground growth. The dwarf mangrove forests along the northern margin of Florida Bay reflect suppressed levels of aboveground productivity and seedling development, as influenced by minimal P supply from either the oligotrophic marshes of the southern Everglades or Florida Bay (Koch 1997, Koch and Snedaker 1997, Satula et al. 2003, Childers et al 2005). High belowground production rates in the dwarf mangrove forests appear to be a biomass allocation phenomenon in which mangroves in the oligotrophic southern Everglades are foraging for nutrients (Krauss et al. 2003). The counter-intuitive expectation is that maintenance of oligotrophic conditions in the southern Everglades [by increased freshwater inflows] may promote peat accretion in these mangroves.

Red mangrove forests in South Florida can potentially accrete organic peat substrate at 2–6 mm/year. Disturbances (major hurricanes, fire, freeze, and changing flushing) disrupt that rate and commonly result in phases of substrate subsidence from decay (Smith et al. 1994, Cahoon and Lynch 1997). Nutrient limitation and salinity stress also reduce that rate.

An important feature for maintenance of an existing wetland environment, its recovery following disturbance events such as hurricanes, freezes, fires, or salinity changes, or the successful shift from one wetland type to another is maintenance of good flushing by either fresh or saline waters (Wanless et al. 1995).

Where flow and flushing diminish, wetland communities collapse (Wanless and Vlaswinkel 2005). This is true for long-term maintenance of mangrove communities and for mangrove communities invading former sawgrass wetlands.

Terrestrial communities embedded in the mangrove forests include tropical forest communities and halophytic prairies. Midden forests, thatch palm (*Thrinax* spp.) hammocks, mixed coastal hammocks, and buttonwood hammocks contribute to local and landscape species diversity within the mangrove zone (including providing substrate for epiphytes) and are able to persist because of the presence of elevated substrates like storm berms and human-originated deposits (Craighead and Gilbert 1962, Craighead 1971). Halophytic prairies dominated by *Batis maritima* Linnaeus, *Salicornia* spp., and *Blutaparon vermiculare* (L.) Mears) appear to represent a long-term landscape element that becomes established where tropical storms alter coastal soils in such a way that mangrove and buttonwood forests are killed (Craighead and Gilbert 1962, Craighead 1971, Armentano et al. 1995).

Coastal Lake Submerged Aquatic Vegetation Communities

Coastal lakes such as Seven Palm Lake, Cuthbert Lake, Long Lake, West Lake, Lake Monroe, and the Taylor River ponds support seasonal beds of SAV under oligohaline to mesohaline conditions. Species richness and total and species-specific percent cover of SAV found in the lakes, ponds, and bays that make up this aquatic network vary both seasonally and interannually in patterns that are related to salinity (Morrison and Bean 1997). Salinity ranges for the suite of 10–12 species, including bladderwort (*Utricularia* spp.) and naiads (*Najas* spp.) are well-documented, with an upper limit of approximately 5–8 ppt, muskgrass (*Chara* spp.) under mesohaline salinities of approximately 15–20 ppt, and widgeon grass (*Ruppia maritima* Linnaeus) under mesohaline salinities of 10–25 ppt.

Waterfowl species that once occurred in large numbers in coastal lakes and basins of the mangrove zone (Kushlan et al. 1982) are dependent on SAV as their primary food resource. The local declines of American coot (*Fulica americana* J.F. Gmelin), lesser scaup (*Aythya affinis* Eyton, 1838), American widgeon (*Anas americana* J.F. Gmelin), and white-cheeked pintail (*Anas bahamensis* Linnaeus) correspond to decline in that food resource, despite overall resurgence of populations in other parts of North America. Recent high-rainfall years have witnessed an increase in coot numbers on West Lake to approximately 2,000 during winter 1996–1997 (O.L. Bass, Jr., Everglades National Park, pers. comm.) but not to the population size of approximately 50,000 that over-wintered there until the 1960s (Kushlan et al. 1982).

Resident Mangrove Fish Populations

Oligohaline wetlands of the mangrove estuary support a resident community of small fishes that is functionally important as an intermediate trophic level supporting wading birds and other higher consumers (Lorenz 2000). Density and seasonal concentration of small marsh fishes in the mangrove zone like sheepshead minnows (*Cyprinodon variegatus* Lacepede), sailfin mollies (*Poecilia latipinna* Lesueur), topminnows (*Fundulus chrysotus* Guenther), rainwater killifish (*Lucania parva* Baird and Girard), and sunfish (*Lepomis marginatus* Holbrook) reflect estuarine salinity, nutrient status, hydroperiod, and drying patterns (Lorenz 2000, Trexler and Loftus 2000), all of which are controlled by freshwater flow and sea level.

The resident fish assemblage decreases in density and size distribution when salinity exceeds 5–8 ppt (Lorenz 1997, 1999, 2000). This relationship has been demonstrated for Florida Bay mangrove wetlands, but not for Gulf of Mexico estuaries. Furthermore, salinity is inversely auto-correlated with hydroperiod in Florida Bay mangrove wetlands, and the relative contribution of each of these variables is not known.

Densities of small fishes in Shark River Slough are approximately 50 percent greater at Rookery Branch, near the interface with the Gulf of Mexico, in comparison to more upstream sites (Trexler and Loftus 2000). Greater fish densities at Rookery Branch hypothetically correspond to enhanced nutrient status and productivity in that area (Childers et al. 1999). In contrast, lower fish densities at the estuarine interface of Taylor Slough relative to sites upstream (Lorenz 1999, 2000, Trexler and Loftus 2000) correspond to low nutrient status and productivity there. Receding water levels following an extended annual hydroperiod can concentrate small fishes in Craighead Basin, at the estuarine interface of Taylor Slough, to densities comparable to the estuarine interface of Shark River Slough (Lorenz 2000).

Relationships of fish populations to hydrology in gulf estuaries are unknown. Populations of small marsh fishes in gulf estuaries may respond to hydroperiod and water recession patterns very differently than Everglades marsh fish communities because of more complex topography created by a dendritic pattern of tidal creeks. Tidal creeks may further influence the resident mangrove fish community as corridors for immigration of juveniles of more marine species.

Wood Stork and Roseate Spoonbill Nesting Colonies

Large nesting colonies of wood storks (*Mycteria americana*, Linnaeus) and great egrets (*Ardea alba*, Linnaeus) in the Everglades during the early 1900s were concentrated in Everglades mangrove estuaries (Ogden 1994). East River, Lane River, Rookery Branch, Broad River, and Rodgers River Bay colonies, in the headwaters of the tidal rivers entering the Gulf of Mexico, supported approximately 90 percent of the total nesting population of these and other wading bird species in the Everglades during the period 1931–1946. Additional colonies along the southern mainland of Florida Bay included Gator Lake, Mud Lake, Mud Hole (located east of Gator Lake), Cuthbert Lake, and Madeira Rookery. All of these coastal nesting colonies collapsed during the second half of the Twentieth Century (Ogden 1994). Larger fishes, such as sunfish and topminnows that grow to 10 cm in length, are considered to be particularly important in the diets of wood storks due to their higher vulnerability to capture (Ogden et al. 1978).

A decrease in roseate spoonbill (*Platelea ajaja*, Linnaeus) nesting in northeast Florida Bay and a shift of nesting distribution from eastern to western Florida Bay accompanied the collapse of the wood stork nesting colonies (Powell et al. 1989, Bjork and Powell 1994, Lorenz et al. 2002). Small fishes have been reported to be the primary diet of roseate spoonbills in Florida Bay (Allen 1942, Powell and Bjork 1990, Dumas 2000). Relatively sparse populations of marsh fishes along the estuarine interface of northeast Florida Bay today require very specific wetland drying patterns to concentrate them and make them available in densities adequate to support spoonbill nesting. Lorenz (2000) reported a water-depth threshold of 12 cm, averaged over the 21-day post-hatching period of roseate spoonbills, that is necessary to concentrate the fish prey base in Taylor Slough coastal sites. Water-level recession to 12-cm depth during that period can concentrate normally low fish density in that region to 85 fish per square meter in remaining pockets of water. The 12-cm depth threshold fits well with success or failure of spoonbill nesting in northeast Florida Bay colonies.

Collapse of coastal wood stork and great egret colonies, and of northeast Florida Bay roseate spoonbill colonies, corresponded to construction of the Central and South Florida (C&SF) Project and the resulting reduction of freshwater flow to the estuarine interface compared to Natural Systems Model (NSM) simulations (VanZee 1999).

Estuarine Crocodilian Populations

The American alligator (*Alligator mississippiensis* Daudin) was historically abundant and nested in freshwater mangrove areas of the Everglades (Craighead 1968). Today, nesting is limited, and few juveniles are observed. Salinity is a major factor limiting distribution and abundance of alligators in estuarine habitats (Dunson and Mazzotti 1989, Mazzotti and Dunson 1989). Alligators lose the capacity to we estuarine habitats for feeding, growth, and reproduction when salinity exceeds oligohaline levels (Joanen 1969). When alligators occur in salt water, it is usually to feed, and there is always a freshwater refugium in close proximity (Jacobsen 1983, Tamarack 1988). In a natural experiment in North Carolina, alligators that were exposed to diversion of freshwater flows due to construction of a power plant relocated to the diversion canal to maintain access to fresh water.

Small alligators are especially vulnerable to exposure to salt water. In laboratory experiments, small alligators ceased feeding and should signs of stress when exposed to salinities greater than 10 ppt (Lauren 1985). Alligators do feed and gain mass at 4 ppt (Mazzotti and Dunson 1984). For these reasons, alligators are good indicators of restoring freshwater flows to estuarine systems and the subsequent reestablishment of an extensive freshwater/brackish water zone.

The American crocodile (*Crocodylus acutus* Cuvier) dwells in ponds and creeks of the mangrove estuaries of Florida Bay (Ogden 1976, Mazzotti 1983). American crocodiles are tolerant of a wide salinity range as adults because of their ability to osmoregulate (Mazzotti 1989). Juvenile crocodiles lack this ability (Mazzotti 1989), however, and their growth and survival decrease at salinities exceeding 20 ppt (Mazzotti and Dunson 1984, Mazzotti et al. 1988, Moler 1991). Juvenile crocodiles tend to seek freshwater pockets, such as black mangrove stands, when those choices are available.

ECOLOGICAL EFFECTS: LINKAGES BETWEEN STRESSORS AND ATTRIBUTES

Coastal Transgression

The stability/instability of the shoreline and coastal wetlands in the southern Everglades is manifest through the dynamic interaction of freshwater outflows, sea-level rise, and saline water inflow, the rate of import/export of sediment, and the capability of the sedimentary environment or bio-sedimentary substrate level to respond to changes in water level. In this time of rapidly rising sea level (Wanless et al. 1997), most mangrove communities are presently losing area of coverage (Wanless et al. 2000). In the coming century, the coastal mangrove community can be expected to become increasingly dissected. Sustained rates of accretion of coastal marl shorelines of Florida Bay prob-

ably are also incapable of keeping up with predicted rates of sea-level rise, and over-topping and breaching of embankments during storm events are likely under future scenarios of rising sea level.

Where rates of peat or marl elevation buildup do not keep up with rates of sea-level rise, shoreline transgression and landward salinity intrusion will lead to mangrove erosion along shorelines and mangrove movement into interior landscapes. Saline intrusion into freshwater wetlands underlain by peat substrate may lead to wetland collapse and transformation to open, saline ponds and estuaries (Wanless and Vlaswinkel 2005). Saline intrusion into marl substrate wetlands results in an advancing zone of diminished productivity (white zone) (Ross et al. 2002). Restoration of freshwater flow volume, timing, and distribution may slow the inland movement but will not change the rate of erosion along the shoreline.

The coastal Everglades have also been re-configured during the past century by filling in of tidal creeks. Siltation and mangrove encroachment of tidal creeks (Craighead 1971, Meeder et al. 1996) has progressed to the extent that open water courses that were described earlier this century are no longer recognizable (G. Simmons, gladesman, pers. comm.). Reduced freshwater flow volume and rising sea level are probable contributing factors.

Coastal Hydroperiods and Salinity Gradients

Pre-drainage hydrologic conditions in the southern Everglades produced prolonged pooling of freshwater just upstream from the mangrove estuaries and prolonged durations of freshwater flow into the estuaries (VanZee 1999). The freshwater pooling and inflow supported wide salinity gradients, including a broad oligohaline zone, in the mangrove estuaries.

A combination of reduced freshwater flow and increased relative sea-level rise has resulted in higher salinities in the formerly oligohaline mangrove zone and significant saline intrusion into former freshwater marshes of the lower Everglades (Ross et al. 2000, Ross et al. 2002). Although surface-water salinities fluctuate laterally through wet and dry seasons, saline ground-water intrusion has moved and remains far inland of the position prior to drainage.

White Zone

At the landward interface of the mangrove estuaries with marl wetlands, a "white zone" band of sparse, mixed mangrove and graminoid vegetation that appears white on color infrared or black-and-white aerial photos. As with any upper bound on an oligohaline ectone, this zone integrates the balance between freshwater flow and sea-level rise (Ross et al. 2002). Egler (1952) described the white zone as a band of low, open vegetation separating mangrove swamps adjacent to the southeast saline Everglades coast (Taylor Slough to Turkey Point) from sawgrass marshes of the interior. Its composition included a mixture of sawgrass (*Cladium jamaicense* Crantz), spikerush (*Eleocharis* spp.), and red mangrove. He considered the inner edge to mark the farthest extent of storm tides. Ross et al. (2000) documented changes in extent and plant species composition of the white zone since Eglers work. They found movement toward the interior of less than 1 km up to about 4 km throughout the region over about 50 years. Movement was maximal in areas where virtually all freshwater has been blocked by canals and management (wetlands east of US 1), and minimal in wetlands where water flow was less impacted by canals, levees, and management (wetlands west of US 1 and directly south of the C-111 Canal). These patterns suggest that freshwater inflows [at least] partially counteract transgression driven by sea-level rise. Working along a hydrologically isolated coastal transect south of Turkey Point, Meeder et al. (1996) documented an inland movement of the interior boundary of the white zone of 1.9 km during 1940–1994. This distance equated to a vertical shift of 13 cm during a period in which sea level rose by only 11 cm.

WORKING HYPOTHESES FOR RESTORATION

Coastal Transgression

Sustained buildup of substrate by physical and biological processes in many coastal marl and mangrove environments of South Florida will not be capable of keeping up with rates of sea-level rise during the twenty-first century. Where rates of peat or marl elevation do not keep up with rates of sea-level rise, shoreline transgression and landward salinity intrusion into mangrove and freshwater wetlands will occur.

White Zone

If sea level continues to rise at its current rate or faster, the leading edge of the white zone will continue to move toward the interior, except along tidal creeks or major drainages. These changes will be least evident in areas in which freshwater input is augmented and greatest in areas cut off from freshwater flow.

Coastal Tidal Channel Characteristics

The dendritic pattern, channel width and depth, flow volume, and material transport of tidal watercourses through the coastal mangrove estuaries are controlled

by sea level interacting with the volume, timing, and distribution of sheet flow and channel flow from the southern Everglades. Many tidal creeks through coastal wetlands of the Everglades have disappeared entirely during the past century because they have been filled in with sediments and with the vegetation of surrounding landscapes. Reduced freshwater flow volume and rising sea level are probable contributing factors. Restored freshwater inflow from the Everglades is expected to help sustain open watercourses through the estuary that will more closely resemble historic patterns, yet sea-level rise is expected to modify the patterns of connectivity through the coastal wetlands and create increased sediment loads.

Coastal Hydroperiod and Depth Patterns

Sheet flow in the southern Everglades prior to drainage produced persistent pooling of fresh water upstream from the mangrove estuaries and prolonged freshwater flow into the mangrove estuaries. Reduced volume and duration of freshwater flow have shortened hydroperiods in the southern Everglades, disrupted in sheet flow, and reduced duration of pooling along the sawgrass/mangrove ecotone. Restoration of pre-drainage volume, distribution, and duration of sheet flow in the southern Everglades will prolong pooling of fresh water along the sawgrass/mangrove interface and increase volumes and durations of freshwater flow to the estuaries.

Coastal Salinity Gradients

Prolonged pooling of fresh water upstream of the mangrove estuaries and prolonged patterns of freshwater flow supported a wide salinity gradient, including a broad oligohaline zone, in the mangrove estuary. A combination of historical reduced freshwater flow and increased relative sea-level rise have resulted in higher salinities in the formally estuarine mangrove zone and significant saline intrusion into former freshwater marshes of the lower Everglades. Increasing seasonal freshwater sheet flow to the lower Everglades is expected to provide a broader zone of salinity gradients in the lower Everglades and coastal wetlands and should, in the short term, re-establish an oligohaline zone in the coastal wetlands. Over a long-term period, rising sea level is expected to result in high tides overtopping coastal marl ridges and saline waters penetrating more deeply through tidal channels and mangrove forests, shifting the areas of fresh and lower salinity waters inland.

Production and Organic Soil Accretion of Coastal Mangrove Forests

Production and organic soil accretion in the mangrove forests of the coastal Everglades are controlled by phosphorus availability, with relatively large inputs from marine sources and small inputs from freshwater sources. Increased freshwater sheet flow caused by implementation of CERP projects is expected to maintain low nutrient conditions in the southern Everglades mangrove estuaries and in the oligohaline ecotone forests of the western mangrove estuaries. Low nutrient conditions are expected to enhance belowground productivity by mangroves, which will maintain peat production and soil elevation increases—ultimately enhancing the ability of these low salinity forests to maintain themselves against sea-level rise.

Resilience of Coastal Mangrove Forests

Resilience of the mangrove forests of the coastal Everglades after disturbance is dependent on hydrologic flushing by either fresh or saline water, which is driven by sea level and sheet flow from the Everglades. Resilience also varies with soil fertility. Improved freshwater flow and flushing through the lower Everglades and coastal wetlands (through both channel and sheet flow) are expected to aid in recovery of wetlands from catastrophic setbacks (from hurricanes, fire, freeze, and salinity changes).

Coastal Lake Submerged Aquatic Vegetation and Waterfowl

Prolonged periods of elevated salinity in coastal lakes and basins, resulting from diminished freshwater flow volume and duration, have reduced seasonal duration and cover of communities of SAV along shorelines and in tributaries. SAV communities will persist in larger beds, longer into the dry season, and lower in the estuarine system when oligohaline to mesohaline conditions are restored upon resumption of natural freshwater flow volume and duration.

Resident Mangrove Fish Populations

The wet-season density, size structure, and relative abundance of resident mangrove fish populations are directly related to the time since the last dry-down, the length of time the marsh was dry, and salinity in coastal ecotones. Responses of fishes are non-linear and species-specific. The concentration of resident mangrove fishes into high-density patches where wading birds can feed effectively is controlled by the rate of dry-season water-level recession and local topography/

habitat heterogeneity. Restoration of persistent pools of fresh-to-oligohaline water along the interface where mangrove forests meet the Everglades will support increased densities, size distributions, and seasonal concentrations of resident mangrove fishes due to combined effects of prolonged hydroperiod, enhanced drying patterns, and extended periods of freshwater to oligohaline salinity.

Wood Stork and Roseate Spoonbill Nesting Colonies

The collapse of coastal wood stork and great egret nesting colonies in the tributary headwaters and southern mainland of the Everglades mangrove estuary, and the abandonment of roseate spoonbill nesting colonies in islands of northeast Florida Bay, are attributed to declines in population densities and seasonal concentrations of marsh fishes and other wading bird prey in the southern Everglades. Restoration of densities and seasonal concentrations of resident mangrove fishes in persistent pools of fresh-to-oligohaline water immediately upstream from the mangrove forests will provide the necessary prey base in juxtaposition to nesting habitats to re-establish coastal nesting colonies of wood stork and great egret and northeast Florida Bay nesting colonies of roseate spoonbill.

American Alligator

American alligator distribution, abundance, reproduction, and body condition in the Everglades mangrove estuaries are controlled by salinity. Reduced freshwater flow into the mangrove estuaries of the southern Everglades has resulted in succession of former freshwater mangrove areas to saltwater systems, reducing American alligator populations in tidal rivers and tributaries. With the resumption of natural patterns of volume, timing, and distribution of flow to the Everglades, the American alligator is expected to repopulate and resume nesting in the freshwater reaches of tidal rivers in the mangrove estuaries.

American Crocodile

American crocodile relative density and juvenile growth, survival, and condition increase when salinity fluctuates below 20 ppt in shoreline, pond, and creek habitats in Everglades mangrove estuaries. Alteration of location and quantity of freshwater flow to the mangrove estuaries has lowered the relative density of crocodiles in areas where freshwater has been diverted and decreased growth and survival of juvenile crocodiles throughout the estuary in areas of higher salinities. Restoration of Volume, timing, and distribution of freshwater flow will result in an increase in relative density of crocodiles in areas of restored flow, such as Taylor Slough/Taylor River drainage. Reestablishing the salinity gradient in the estuary will increase growth and survival of juvenile crocodiles throughout the estuary.

ACKNOWLEDGMENTS

We gratefully acknowledge the following individuals who participated in workshops leading to the development of the Everglades Mangrove Estuaries Conceptual Model: Tom Armentano, Tom Bancroft, Tomma Barnes, Sonny Bass, Laura Brandt, Joan Browder, Gwen Burzycki, Evan Chipouras, Craig Faunce, Peter Frederick, Dale Gawlik, Lee Hefty, Lorraine Heisler, Marguerite Koch, Bill Loftus, Frank Mazzotti, Linda McCarthy, Heather McSherry, Doug Morrison, Jon Moulding, Bill Nuttle, John Ogden, Robert Pace, Sue Perry, Mary Ann Poole, Mike Robblee, Bill Robertson, Mike Ross, David Rudnick, Tom Schmidt, Fred Sklar, Tom Smith, Sam Snedaker, Skip Snow, Tim Towles, Steve Traxler, Joel Trexler, Dewey Worth, and Elizabeth Zenker. Partial support was provided to Dan Childers for conceptual model development and for preparation of this manuscript by the National Science Foundation through the Florida Coastal Everglades LTER Program (DEB-9910514). We particularly thank Dr. Jack Gentile for facilitating the initiation of conceptual models for South Florida ecosystem restoration and for informing the conceptual model teams of the process for conceptual model development.

LITERATURE CITED

Allen, R. P. 1942. The Roseate Spoonbill. Dover Publications, New York, NY, USA.

Armentano, T. V., R. F. Doren, W. J. Platt, and T. Mullins. 1995. Effects of Hurricane Andrew on coastal and interior forests of southern Florida: overview and synthesis. Journal of Coastal Research Special Issue 2:111–114.

Bjork, R. D. and G. V. N. Powell. 1994. Relations between hydrologic conditions and quality and quantity of foraging habitat for roseate spoonbills and other wading bird in the C-111 basin. National Audubon Society final report to South Florida Research Center, Everglades National Park, Homestead, FL, USA.

Cahoon, D. R. and J. C. Lynch. 1997. Vertical accretion and shallow subsidence in a mangrove forest of southwestern Florida, USA. Mangroves and Salt Marshes 1:173–186.

Carter, R. W. G. 1988. Coastal Environments. Academic, London, UK.

Chen, R. and R. R. Twilley. 1999. Patterns of mangrove forest structure and soil nutrient dynamics along the Shark River Estuary, Florida. Estuaries 22:955–970.

Childers, D. L, J. N. Boyer, J. W. Fourqurean, R. Jaffe, R. D. Jones, and J. Trexler. 1999. Coastal oligotrophic ecosystems research—the coastal Everglades. Regional controls of population and ecosystem dynamics in an oligotrophic wetland-dominated coastal landscape. A research proposal to the Long-Term Ecological Research (LTER) in Land/Ocean Margin Ecosystems, National Science Foundation, Washington, DC, USA.

Childers, D. L., J. N. Boyer, S. E. III. Davis, C. J. Madden, D. T. Rudnick, and F. H. Sklar. 2005. Nutrient concentration patterns in the oligotrophic "upside-down" estuaries of the Florida Everglades. Limnology & Oceanography (in press).

Craighead, F. C. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Florida Naturalist 41:2–7, 69–74, 94.

Craighead, F. C. 1971. The Trees of South Florida. University of Miami Press, Miami, FL, USA.

Craighead, F. C., Sr. and V. C. Gilbert. 1962. The effects of Hurricane Donna on the vegetation of southern Florida. The Quarterly Journal of the Florida Academy of Sciences 25:1–28.

Davis, S. B., J. E. Cable, D. L. Childers, C. Coronado-Molina, J. W. Day, C. D. Hittle, C. J. Madden, D. T. Rudnick, E. Reyes, and F. H. Sklar. 2004. Importance of episodic storm events in controlling ecosystem structure and function in a Gulf Coast estuary. Journal of Coastal Restoration 20:1198–1208.

Davis, S. E. III, D. L. Childers, J. W. Day, Jr., D. T. Rudnick, and F. H. Sklar. 2001a. Wetland-water column exchanges of carbon, nitrogen, and phosphorus in a Southern Everglades dwarf mangrove. Estuaries 24:610–622.

Davis, S. E. III, D. L. Childers, J. W. Day, Jr., D. T. Rudnick, and F. H. Sklar. 2001b. Nutrient dynamics in vegetated and unvegetated areas of a southern Everglades mangrove creek. Estuarine Coastal Shelf Science 52:753–768.

Davis, S. E. III, D. L. Childers, J. W. Day, Jr., D. T. Rudnick, and F. H. Sklar. 2003. Factors affecting the concentration and flux of materials in two southern Everglades mangrove wetlands. Marine Ecology Progress Series 253:85–96.

Dumus, J. 2000. Roseate Spoonbill (Ajaia ajaia). *In* A. Poole and F. Gill (eds.) The Birds of North America. The Academy of Natural Science, Philidelphia, PA, USA.

Dunson, W. A. and F. J. Mazzotti. 1989. Salinity as a limiting factor in the distribution of reptiles in Florida Bay: a theory for the estuarine origin of marine snakes and turtles. Bulletin of Marine Sciences 44:229–244.

Egler, F. E. 1952. Southeast saline Everglades vegetation, Florida, and its management. Vegetation 3:213–265.

Jacobsen, T. 1983. Crocodilians and islands: status of the American alligator and the American crocodile in the lower Florida Keys. Florida Field Naturalist 11:1–24.

Joanen, T. 1969. Nesting ecology of the alligators in Louisiana. Proceedings of the Annual Conference Southeast Association of Game Fish Commission 23:141–151.

Koch, M. S. 1997. Rhizophora mangle (red mangrove) seedling development into the sapling stage across resource and stress gradients in subtropical Florida. Biotropica 29:427–439.

Koch, M. S. and S. C. Snedaker. 1997. Factore influencing *Rhizophora mangle* L. seedling development in Everglades carbonate soils. Aquatic Botany 59:87–98.

Krauss, K. W., J. A. Allen, and D. R. Cahoon. 2003. Differential vertical accretion and elevation change among aerial root type mangrove forests. Estuarine and Coastal Shelf Science 56:251–259.

Kushlan, J. D., O. L. Bass Jr., and L. C. McEwan. 1982. Wintering waterfowl in Everglades National Park. Everglades National Park, South Florida Research Center, Homestead, FL, USA. Report T-670.

Lauren, D. J. 1985. The effect of chronic saline exposure on the electrolyte balance, nitrogen metabolism, and corticosterone titer in the American alligator, *Alligator mississippiensis*. Comprehensive Biochemical Physiology 81A:217–223.

Lorenz, J. J. 1997. The effects of hydrology on resident fishes of the Everglades mangrove zone. National Audubon Society Final Report to South Florida Research Center, Everglades National Park, Homestead, FL, USA.

Lorenz, J. J. 1999. The response of fishes to physical-chemical changes in the mangroves of northeast Florida Bay. Estuaries 22: 500–517.

Lorenz, J. J. 2000. The impact of water management on roseate spoonbills and their piscine prey in the coastal wetlands of Florida Bay. Ph.D. Dissertation, University of Miami, Coral Gables, FL, USA.

Lorenz, J. J., J. C. Ogden, R. D. Bjork, and G. V. N. Powell. 2002. Nesting patterns of Roseate Spoonbills in Florida Bay 1935–1999: implications of landscape scale anthropogenic impacts. p. 555–598. *In* J. W. Porter and K. G. Porter (eds.) The Everglades, Florida Bay and Coral Reefs of the Florida Keys, an Ecosystem Sourcebook. CRC Press, Boca Raton, FL:555–598.

Mazzotti, F. J. 1983. The ecology of *Crocodylus acutus* in Florida. Ph.D. Dissertation. Pennsylvania State University. University Park, PA, USA.

Mazzotti, F. J. 1989. Factors affecting nesting success of the American crocodile, *Crocodylus acutus*, in Florida Bay. Bulletin of Marine Sciences 44:220–228.

Mazzotti, F. J., A. Dunbar-Cooper, and J. A. Kushlan. 1988. Desiccation and cryptic nest flooding as probable causes of embryonic mortality in the American crocodile, *Crocodylus acutus*, in Everglades National Park, Florida. Florida Scientist 52:65–72.

Mazzotti, F. J. and W. A. Dunson. 1984. Adaptations of *Crocodylus acutus* and alligator for life in saline water. Comprehensive Biochemical Physiology 79A:641–646.

Mazzotti, F. J. and W. A. Dunson. 1989. Osmoregulation in crocodilians. American Zoology 29:903–920.

McIvor, C. C., J. A. Ley, and R. D. Bjork. 1994. Changes in freshwater inflow from the Everglades to Florida Bay including effects on biota and biotic processes. p. 117–146. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Meeder, J. F., M. S. Ross, G. Telesnicki, P. L. Ruiz, and J. P. Sah. 1996. Vegetation analysis in the C-111/Taylor Slough basin. Document 1: The southeast saline Everglades revisited: a half-century of coastal vegetation change. Document 2: Marine transgression in the southeast saline Everglades, Florida: rates, causes and plant sediment responses. Southeast Environmental Research Program, Florida International University, Miami, FL, USA. Final report for Contract C-4244.

Moler, P. E. 1991. American crocodile population dynamics. Florida Game and Freshwater Fish Commission, Tallahassee, FL, USA.

Montague, C. L. and R. G. Wiegert. 1990. Salt marshes. *In* R. L. Myers and J. J. Ewel (eds.) Ecosystems of Florida. University of Central Florida Press, Orlando, FL, USA.

Morrison, D. and D. L. Bean. 1997. Benthic macrophyte and invertebrate distribution and seasonality in the Everglades-Florida Bay ecotone. National Audubon Society Final Report to South Florida Research Center, Everglades National Park, Homestead, FL, USA.

Noe, G., D. L. Childers, and R. D. Jones. 2001. Phosphorus biogeochemistry and the impacts of phosphorus enrichment: why are the Everglades so unique? Ecosystems 4:603–624.

Ogden, J. C. 1976. Crocodilian ecology in southern Florida. *In* National Park Service. Research in the Parks: Transactions of the National Park Centennial Symposium, 1971. United States Department of the Interior, National Park Service, Washington, DC, USA. Symposium Series No. 1.

Ogden, J. C. 1994. A comparison of wading bird nesting colony dynamics (1931–1946 and 1974–1989) as an indication of ecosystem conditions in the southern Everglades. p. 533–570. *In* S. M. Davis and J. C. Ogden (eds.) Everglades: the Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Ogden, J. C., J. A. Kushlan, and J. A. Tilmont. 1978. The food habits and nesting success of wood storks in the Everglades National Park in 1974. United States National Park Service, Washington, DC, USA. Natural Resources Report 16.

Powell, G. V. N. and R. D. Bjork. 1990. Relationships between hydrologic conditions and quality and quantity of foraging habitat for roseate spoonbills and other wading birds in the C-111 basin. National Audubon Society second annual report to South Florida Research Center, Everglades National Park, Homestead, FL, USA.

Powell, G. V. N., R. D. Bjork, J. C. Ogden, R. T. Paul, A. H. Powell, and W. B. Robertson, Jr. 1989. Population trends of some South Florida wading birds. Wilson Bulletin 101:436–457.

Ross, M. S., E. E. Gaiser, J. F. Meeder, and M. T. Lewin. 2002. Multi-taxon analysis of the "white zone": A common ecotonal feature of the South Florida coastal wetlands. p. 205–238. *In* J. W. Porter and K. G. Porter (eds.) The Everglades, Florida Bay,

and Coral Reefs of the Florida Keys: an Ecosystem Sourcebook. CRC Press, Boca Raton, FL, USA.

Ross, M. S., E. H. Gaiser, J. F. Meeder, and M. T. Lewin. 2002. Multi-taxon analysis of the "White Zone," a common ecotonal feature of South Florida coastal wetlands. p. 205–238. *In* J.W. Porter and K.G. Porter (eds.) Everglades, Florida Bay, and Coral Reefs of the Florida Keys. CRC Press, Delray Beach, FL, USA.

Ross, M. S., J. F. Meeder, J. P. Sah, P. L. Ruiz, and G. J. Telesnicki. 2000. The southeast saline Everglades revisited: 50 years of coastal vegetation change. Journal of Vegetation Science 11:101–112.

Rudnick, D. T., Z. Chen, D. L. Childers, J. N. Boyer, and T. D. Fontaine. 1999. Phosphorus and nitrogen inputs in Florida Bay: the importance of the Everglades watershed. Estuaries 22:398–416.

Smith, T. J. III, M. B. Robblee, R. Wanless, and T. W. Doyle. 1994. Mangroves, hurricanes, and lightning strikes. Bioscience 44:256–262.

Sutula, M., B. Perez, E. Reyes, D. Childers, S. Davis, J. Day, D. Rudnick, and F. Sklar. 2003. Factors affecting spatial and temporal variability in material exchange between the Southeastern Everglades wetlands and Florida Bay (USA). Estuarine Coastal and Shelf Science 56:1–25.

Tamarack, J. L. 1988. Georgia's coastal island alligators, variations and habitat and prey availability. p. 105–118. *In* Proceedings of the Eighth Working Meeting of the Crocodile Specialist Group, IUCN—Gland, Switzerland.

Trexler, J. C. and W. F. Loftus. 2000. Analysis of relationships of Everglades fish with hydrology using long-term data bases from the Everglades National Park. Report to Everglades National Park, Homestead, FL, USA.

Trexler, J. C., W. F. Loftus, F. Jordan, J. Lorenz, J. Chick, and R. M. Kobza. 2001. Empirical assessment of fish introductions in a subtropical wetland: an evaluation of contrasting views. Biological Invasions 2:265–277.

Twilley, R. R. 1998. Mangrove wetlands. p. 445–473. *In* M. G. Messina and W. H. Conner (eds.) Southern Forested Wetlands Ecology and Management. CRC Press, Delray Beach, FL, USA.

VanZee, R. 1999. Natural System Model version 4.5 documentation report. South Florida Water Management District, West Palm Beach, FL, USA.

Wanless, H. R., P. Oleck, L. P. Tedesco, and B. E. Hall. 2000. Next 100 years of evolution of the Greater Everglades ecosystem in response to anticipated sea level rise: nature, extent and causes. Greater Everglades Ecosystem Restoration Science Conference 2000:174–176.

Wanless, H. R., R. W. Parkinson, and L. P. Tedesco. 1994. Sea level control on stability of Everglades wetlands. p. 199–223. *In* S. M. Davis and J. C. Ogden (eds.) Everglades: the Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Wanless, H. R., L. P. Tedesco, J. A. Risi, B. G. Bischof, and S. Gelsanliter. 1995. The Role of Storm Processes on the Growth and Evolution of Coastal and Shallow Marine Sedimentary Environments in South Florida. Field Trip Guide, The 1st SEPM Congress on Sedimentary Geology, St. Petersburg, FL, USA.

Wanless, H. R. and B. Vlaswinkel. 2005. Coastal landscape and channel evolution affecting critical habitats at Cape Sable, Everglades National Park, Florida. Final Report to Everglades National Park, United States Department of the Interior, Homestead, FL, USA.

Manuscript received 28 February 2005; revisions received 13 September 2005; accepted 3 October 2005.

C.14.3 Southern Marl Prairies

WETLANDS, Vol. 25, No. 4, December 2005, pp. 821–831
© 2005, The Society of Wetland Scientists

SOUTHERN MARL PRAIRIES CONCEPTUAL ECOLOGICAL MODEL

Steven M. Davis[1], Evelyn E. Gaiser[2], William F. Loftus[3], and April E. Huffman[1]
[1] *South Florida Water Management District*
West Palm Beach, Florida, USA 33406

[2]*Florida International University*
Miami, Florida, USA 33199

[3] *United States Geological Survey*
Homestead, Florida, USA 33034

Abstract: About 190,000 ha of higher-elevation marl prairies flank either side of Shark River Slough in the southern Everglades. Water levels typically drop below the ground surface each year in this landscape. Consequently, peat soil accretion is inhibited, and substrates consist either of calcitic marl produced by algal periphyton mats or exposed limestone bedrock. The southern marl prairies support complex mosaics of wet prairie, sawgrass sawgrass (*Cladium jamaicense*), tree islands, and tropical hammock communities and a high diversity of plant species. However, relatively short hydroperiods and annual dry downs provide stressful conditions for aquatic fauna, affecting survival in the dry season when surface water is absent. Here, we present a conceptual ecological model developed for this landscape through scientific concensus, use of empirical data, and modeling. The two major societal drivers affecting the southern marl prairies are water management practices and agricultural and urban development. These drivers lead to five groups of ecosystem stressors: loss of spatial extent and connectivity, shortened hydroperiod and increased drought severity, extended hydroperiod and drying pattern reversals, introduction and spread of non-native trees, and introduction and spread of non-native fishes. Major ecological attributes include periphyton mats, plant species diversity and community mosaic, Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), marsh fishes and associated aquatic fauna prey base, American alligator (*Alligator mississippiensis*), and wading bird early dry season foraging. Water management and development are hypothesized to have a negative effect on the ecological attributes of the southern marl prairies in the following ways. Periphyton mats have decreased in cover in areas where hydroperiod has been significantly reduced and changed in community composition due to inverse responses to increased nutrient availability. Plant species diversity and community mosaics have changed due to shifting gradients to more terrestrial or more aquatic communities, displacement of native communities by non-natives, expansion of woody plants, high-intensity dry season fires, tree-island burnout, and reduced microtopography resulting from alligator population decline. Cape Sable seaside sparrow populations are threatened by nest destruction resulting from extended hydroperiods, drying pattern reversals, and high intensity dry season fires, as well as by the expansion of woody plants into graminoid wetland habitats. Populations of marsh fishes and associated aquatic fauna that constitute the aquatic prey base for higher vertebrates have decreased in density and changed in species composition and size structure due to loss of wetland spatial extent, shortened hydroperiod, increased drought severity, loss of aquatic drought refugia in solution holes and alligator holes, and spread of exotic fishes. American alligator populations have declined in the Rocky Glades, and alligator holes have filled with sediment, as a result of shortened hydroperiod and increased drought severity. Habitat options for wading birds to forage during the early dry season and during unusually wet years have been reduced due to loss of spatial extent and shortened hydroperiod.

Key Words: Everglades, marl prairie, conceptual ecological model, ecosystem restoration, periphyton, Cape Sable seaside sparrow, wetland plant communities, American alligator, marsh fish populations

BACKGROUND

About 190,000 ha of higher-elevation, freshwater marshes flank either side of Shark River Slough (Figure 1). In these systems, water levels typically drop below the ground surface each year (Davis et al. 1994). Consequently, peat accretion is inhibited, and substrates consist either of marl produced by periphyton mats or exposed limestone bedrock (Gleason 1972).

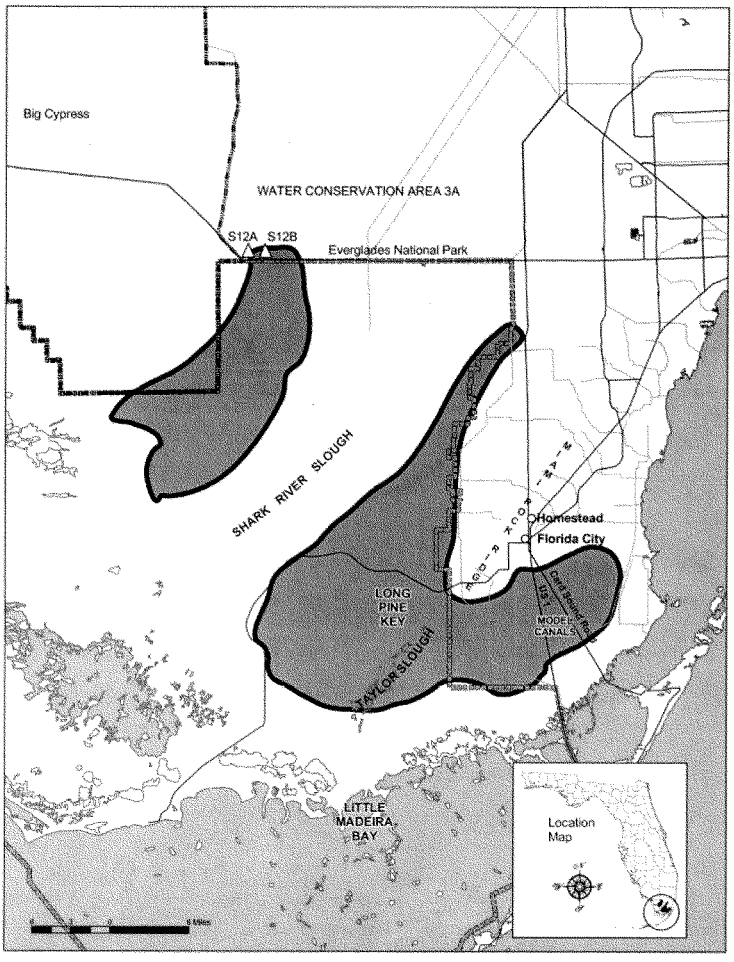


Figure 1. Boundary of the Southern Marl Prairies Conceptual Ecological Model.

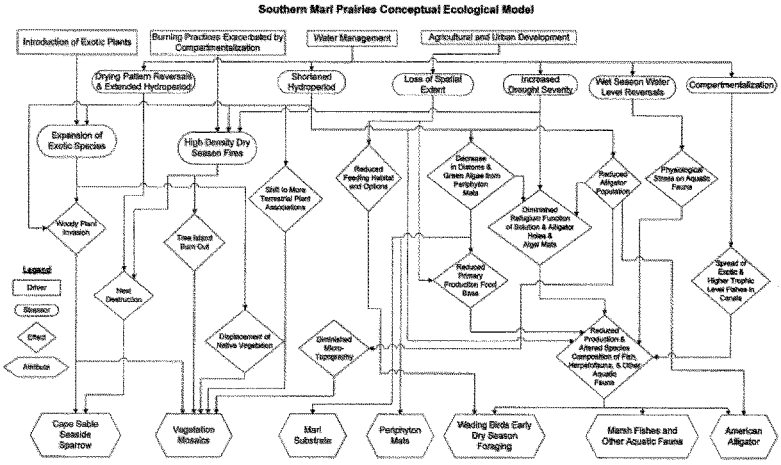


Figure 2. Diagram of the Southern Marl Prairies Conceptual Ecological Model.

The southern marl prairies are mosaics of wet prairie, sawgrass, tree islands, and tropical hammock communities that support a high diversity of plant species (Olmstead and Loope 1984). Included in this landscape are the Rocky Glades, which are north of Long Pine Key, have the shortest hydroperiod wetlands in the system, and contain exposed karst formations of limestone pinnacles and solution holes. Deposits of marl and organic sediments are limited to solution holes in the Rocky Glades. The southern marl prairies east of Shark River Slough comprise the watershed for Taylor Slough, a wetland channel that meanders through higher-elevation prairies south of Long Pine Key, emptying into Taylor River and Little Madeira Bay. Organic deposits and slough plant communities in Taylor Slough demonstrate prolonged periods of inundation compared to its surrounding marl prairie-Rocky Glades watershed. Ephemeral hydrologic characteristics of the southern marl prairies pose stresses to wetland animal communities, affecting survival through the dry season when standing water disappears (Loftus et al. 1990, Loftus and Eklund 1994). Alligator holes, solution holes, and neighboring sloughs provide important refugia for aquatic fauna during dry periods (Craighead 1968, Loftus et al. 2001).

In this paper, we present a conceptual ecological model for the southern marl prairies. This model is the result of workshops that brought together scientific experts on this landscape, their empirical data, and models for the landscape. Scientists identified external drivers, stressors, ecological attributes, and critical linkages between the attributes and the stressors. This conceptual model is being used to plan and evaluate the progress of Everglades restoration actions in an adaptive management framework. The ecological attributes are being monitored across the landscape and, in concert with success criteria defined for each, will be used to assess the degree of restoration success. As restoration proceeds, monitoring data will inform scientists and managers whether the direction of recovery is proceeding as expected.

EXTERNAL DRIVERS AND ECOLOGICAL STRESSORS

Major societal drivers affecting the southern marl prairies are water management practices and agricultural and urban development (Figure 2). These drivers lead to five groups of ecosystem stressors: (1) loss of spatial extent and connectivity, (2) shortened hydroperiod and increased drought severity, (3) extended hydroperiod and drying pattern reversals, (4) introduction and spread of non-native trees, and (5) introduction and spread of non-native fishes.

Agricultural and Urban Development

Development represents a direct loss of spatial extent of southern marl prairie wetlands through conversion of marshes to farmland and housing (Davis et al. 1994). Development of eastern portions of the prairies has reduced spatial extent of these landscapes and has isolated portions of the Taylor Slough watershed. Connectivity to upland habitats has been disrupted by development of eastern portions of these wetlands and of most of the Miami Rock Ridge. Lost spatial extent and connectivity to uplands on the eastern side of the southern marl prairies cannot be restored on a large scale and must influence expectations for ecosystem restoration. Developed areas of South Florida have also been the source of non-native species that have invaded the southern marl prairies to the east of Shark River Slough.

Water Management Practices

The construction and operation of the Central and Southern Florida Project (Light and Dineen 1994) has directly influenced the southern marl prairies since the 1960s through the construction of the L-29 levee and canal and the four S-12 discharge gates along the northern border of Everglades National Park, the L-31 levees and canals along the eastern border, and the C-111 levees and canals dissecting the southeastern panhandle of the park. Major effects on the southern marl prairies were six-fold. 1) To the east of Shark River Slough, natural patterns of water flow from the north were cut off, shortening hydroperiods and increasing severity of droughts. 2) To the west of Shark River Slough, regulatory discharges from Water Conservation Area 3A through the S-12A and S-12B outflow gates released unseasonable pulses of water, extending hydroperiods and reversing natural drying patterns during the dry season. 3) In the Taylor Slough basin and panhandle of Everglades National Park, operation of the L-31 and C-111 canal systems resulted in unseasonable flows and hydroperiods to provide flood protection to agricultural lands to the east. 4) Corridors of warm and deep-water habitat created by canal excavation allowed expansion of native predatory fishes and non-native fishes into wetlands where they might not persist naturally (Howard et al. 1995). 5) Flood protection provided by the L-31 and C-111 canals promoted further agricultural and urban development of the marl prairies and adjacent uplands to the east of L-31, resulting in loss of spatial extent and connectivity to upland habitats. 6) Connectivity within the marl prairies has been further interrupted by the C-111 system and by US Highway 1 and Card Sound Road, which connect the mainland to the Florida Keys.

Shortened Hydroperiod and Increased Drought Severity

Prior to drainage, the southern marl prairies to the east of Shark River Slough were flooded two to nine months annually depending on the elevation and year, as indicated by the Natural System Model (NSM) (Van Lent et al. 1993, Fennema et al. 1994, VanZee 1999). Under present conditions, most of the southern marl prairies east of Shark River Slough remain dry for an average of nine months each year (Van Lent et al. 1993, Fennema et al. 1994, VanZee 1999). Shortened hydroperiods are exacerbated by wet season water-level reversals. Field observations indicate that when water depth drops to less than 5 cm during a period of flooding, aquatic fauna population densities decrease, survivors retreat to refugia in solution holes or alligator holes, and population recovery is slowed (Loftus and Eklund 1994, Trexler et al. 2003).

Extended Hydroperiod and Drying Pattern Reversals

The southern marl prairies west of Shark River Slough are geographically isolated from human population centers on Florida's lower east coast. Consequently, these wetlands have escaped the compartmentalization, development, and lowered water-table stressors of their eastern counterparts. To the contrary, the western marl prairies are negatively impacted by extended flooding because water that once flowed eastward into northeastern Shark River Slough is presently diverted west through the S12A and S12B discharge gates of Water Conservation Area 3A. Those deliveries are compounded by drying pattern reversals caused by regulatory water releases through the S12A and S12B structures.

Loss of Spatial Extent and Connectivity

Physical alterations to the southern marl prairies include development and compartmentalization. Conversion of eastern portions of the southern marl prairies to agriculture and residential development has reduced the spatial extent of aquatic habitat and production, essentially removing these areas from the Everglades ecosystem. Levees that bound and dissect the southern marl prairies on the east side of the Everglades, including the L-31 levee, C-111 system, US Highway 1, and Card Sound Road, geographically alter hydrologic patterns and break connectivity of wetlands to adjacent uplands.

Introduction and Spread of Exotic Trees

Construction of the canal and levee system has resulted in adverse effects on the marl prairies and

Rocky Glades through the introduction and spread of non-native species. Melaleuca (*Melaleuca quinquenervia* (Cav.) Blake), Brazilian pepper (*Schinus terebinthifolius* Raddi), and Australian pine (*Casuarina equisetifolia* Linnaeus) are the most widespread invasive trees that have spread into native plant communities of the southern marl prairies. Reductions in hydroperiod have fostered their rapid expansion (Olmstead and Loope 1984, Armentano et al. 1995, Jones and Doren 1997).

Introduction and Spread of Exotic Fishes

The release and establishment of breeding populations of tropical aquarium fishes has occurred in canals that border and dissect the southern marl wetlands. Presently, ten species have been recorded as established in the southern Everglades, with additional species in the canal system (Loftus 2000, Loftus et al. 2003). The L-29, C-111, and L-31 canal systems, in particular, have provided corridors for these fishes to enter the wetlands (Howard et al. 1995).

ECOLOGICAL ATTRIBUTES

Periphyton Mat

Extensive benthic mats of calcitic algae, and the marl soils that they form (Gleason 1972), distinguish the southern marl prairies from other physiographic regions of the Everglades. The benthic mats overlay limestone bedrock in transitional wetlands where hydroperiods of ~2–9 months are too short for accretion of peat soils. Rates of marl accretion are directly related to spatial extent and production of the mats (Gleason 1972). Most of the plant communities described by Olmstead and Loope (1984) and Gunderson (1994) for this region are supported by marl soils.

Periphyton production in marl prairies is highly seasonal and driven by water delivery and availability of nutrients. In the dry season, the surface of periphyton mats can dessicate while underlying material remains moist (Thomas et al. 2002). This moisture, largely retained by copious polysaccharides produced in the wet season by coccoid cyanobacteria (Donar et al. 2004), provides a refuge for other algae, sustaining them through the dry season. Upon rewetting in the wet season (through direct rainfall or managed water delivery), phosphorus is rapidly desorbed from the periphyton mat into the water column (Gottlieb et al. 2005). Algal and bacterial production is then stimulated by wetting and increased availability of dissolved phosphorus in the water column. The recovering periphyton sequesters all desorbed phosphorus within 5–7 days of reflooding and thereafter regulates water-column concentrations to ambient marsh levels of 5–10 ug L^{-1} indicative of oligotrophy (Thomas et al. 2006) in a manner similar to that shown for periphyton from longer hydroperiod sloughs (Gaiser et al. 2004a). Biomass production in submersed periphyton mats then continues to exceed decomposition for approximately 3–4 months after rewetting, when accumulated biomass is sloughed from the bedrock surface and carried downstream (Thomas et al. 2002). Periphyton biomass estimates during the peak of the wet season range from 2,000 to 4,000 g m^{-2} in the wet prairie, in most cases exceeding plant biomass and being an order of magnitude greater than comparable long-hydroperiod mats (Gottlieb et al. 2005).

The regular cycle of drying and rewetting experienced by short-hydroperiod periphyton mats encourages a different assemblage of species compared to long-hydroperiod counterparts. Short-hydroperiod periphyton communities are less diverse than long-hydroperiod mats and are dominated volumetrically by sheathed, filamentous cyanobacteria, including *Schizothrix calcicola* and *Scytonema hofmanni* (Agardh Ex Born. and Flah.; Gleason and Spackman 1974). These taxa are common in many shallow, limestone-based systems including marine stromatolites (Gottlieb et al. 2005) and also dominate the short-hydroperiod periphyton mats in the estuarine mangrove ecotone in the Everglades (Gaiser et al. 2004b). These and related cyanobacterial filaments are primarily responsible for marl formation, which results when their production exceeds respiration, increasing the pH and causing calcium carbonate precipitation in the microenvironment around their sheath (Gleason 1972). They grow either on the limerock substrate or attached to other plants, often including *Utricularia subulata* L. and *Chara* spp., which increases the biotic precipitation of calcite (Gleason 1972). This algal flora changes to a non-calcareous flora dominated by green algae in areas that are poorly buffered (i.e., the interior of Water Conservation Area 1; Gleason and Spackman 1974). In calcareous mats, filamentous plants create a matrix that supports the growth of numerically-dominant coccoid cyanobacteria. Common representatives in marl prairie periphyton are *Chroococcus* spp., *Chroococcidiopsis* spp., and *Aphanothece* spp., which are encased in a thick polysaccharide sheath that further serves to bind the periphyton mat together (Gottlieb et al. 2005) and resist drying (Thomas et al. 2002). The polysaccharide can comprise up to 90% of benthic periphyton mats (Donar et al. 2004) and serves as a substrate for colonization by other algae and bacteria. Compared to long-hydroperiod marshes, diversity of diatoms and green algae is low in short-hydroperiod wetlands, presumably due to their compromised ability to withstand frequent drying (Gottlieb et al. 2005). It is possible

that biomass of benthic, sediment-associated periphyton has increased in marl prairie habitat adjacent to canals and perhaps in more widespread areas elsewhere in the Everglades that have received increased loads of calcium and bicarbonate released from disturbed limestone.

One consequence of increased dominance of cyanobacteria over diatoms and green algae in short-hydroperiod mats may be increased resilience to grazing. The calcite-rich cyanobacterial matrix has been implicated as key to explaining the apparent inability of grazers to suppress periphyton growth (Geddes and Trexler 2003) and, consequently, the depauperate assemblage of primary consumers found in the Everglades (Turner et al. 1999). This reduced edibility of periphyton was probably always a factor in the historical marl prairie where calcite crystals and filamentous algae dominate periphyton biomass (Gleason and Spackman 1974). The dominant consumers of short-hydroperiod periphyton appear to be gastropods (Browder et al. 1994) but few studies have assessed the assimilation efficiency of snails that consume periphyton or the importance of snail production to upper levels of the food web.

Plant Species Diversity and Community Mosaic

A unique feature of the southern marl prairies is the high species richness of flora. Within the mosaic of low-stature graminoid communities, sawgrass and muhly grass (*Muhlenbergia filipes* M. A. Curtis) dominate, although more than 100 species of mostly herbaceous plants have been reported (Olmstead and Loope 1984). Natural hydrologic patterns in marl wetlands support gradients of vegetation subtypes that are aligned sequentially along hydrologic gradients ranging from 1–2 month hydroperiods (dominated by *Schizachyrium rhizomatum* (Swallen) Gould) to 3–5 month hydroperiods (dominated by muhly grass) to 6–8 month hydroperiods (dominated by sawgrass). Hydrologic patterns that maintain these community gradients also support higher-elevation tropical hammocks that occur as islands within marl prairies. These forests support flora of West Indian origin unique to South Florida and the Florida Keys and contain large numbers of rare and threatened plant species in South Florida (Gunderson 1994, Meeder et al. 1996, Armentano et al. 2002, T. G. Troxler Gann, Florida International University, pers. comm.).

Cape Sable Seaside Sparrow

The Cape Sable seaside sparrow is an endangered species endemic to marl prairies of the southern Everglades. Three major breeding colonies include the western sub-population in marl prairies west of Shark River Slough, the eastern sub-population east of mid-Shark River Slough, and the central sub-population to the east of southwestern Shark River Slough (Pimm 1995). The sparrow depends on predictably dry conditions during its spring nesting period, which corresponds to the late dry season (Pimm 1995), usually April–June in sites free of standing shrubs or trees. Construction of nests approximately 10 cm above ground at the bases of tussocks of muhly grass and other marsh graminoids makes the sparrow vulnerable both to spring wildfires and unseasonable water-depth increases (dry season water level reversals). Successful nesting requires approximately 45–60 days of nearly dry conditions without fire. The sparrows usually raise one or two broods per season, although they may raise a third brood if weather conditions allow (K. Palmer, United States Fish and Wildlife Service, pers. comm.).

Marsh Fishes and Associated Aquatic Fauna Prey Base

Population density, size structure, and relative abundance of fishes in marl prairies are limited by annual duration of uninterrupted flooding (Trexler et al. 2003). The annual drying pattern typical of marl prairies limits small fish density to less than 10 fish/m^2, compared to 60 fish/m^2 in areas of Shark River Slough with multi-year hydroperiods. This difference occurs because fish density is directly related to the period of population recovery between marsh drydowns (Loftus and Ekland 1994, Trexler et al. 2003). Relative abundance of fish species also responds to hydroperiod. Blue-fin killifish (*Lucania goodie* Jordan), golden topminnow (*Fundulus chrysotus* Guenther), lake chubsucker (*Erimyzon sucetta* Lacepede), and spotted sunfish (*Lepomis punctatus* Valenciennes in Cuvier and Valenciennes, 1831) are uncommon in shorter-hydroperiod wetlands (Trexler et al. 2003), compared with eastern mosquitofish (*Gambusia holbrooki* Girard, 1859), flagfish (*Jordanella floridae* Goode and Bean in Goode, 1879), and marsh killifish (*Fundulus confluentus* Goode and Bean in Goode, 1879). Relative abundance affects size structure, in that the lake chubsucker and spotted sunfish represent larger species in the native fish assemblage of marl prairies.

In a system where water levels typically fall below ground surface each year, remnant pools of standing water in solution holes and alligator holes during the dry season enable the survival of aquatic and amphibious fauna such as fish, crayfish (*Procambarus alleni* Faxon, 1884), and herpetofauna, including alligators (Dalrymple 1987, Loftus et al. 1992, Mazzotti and Brandt 1994, Dalrymple pers. comm.).

Small marsh fishes and associated aquatic fauna are

the major prey for wading birds that forage and nest in the Everglades (Bjork and Powell 1994, Ogden 1994). The constraint that annual drying patterns place on fish populations suggests that macroinvertebrates and herpetofauna may increase in importance as intermediate trophic levels and prey bases for higher consumers in marl systems (Fleming pers. comm. in Ogden 1994). Crayfish constitute an important prey item for many vertebrates that have decreased in abundance with drainage of the Everglades, including pig frogs (*Rana grylio* Stejneger), otters (*Lontra Canadensis* Schreber, 1777), American alligators, white ibis (*Eudocimus albus* Linnaeus), and glossy ibis (*Plegadis falcinellus* Linnaeus) (Momot et al. 1978, Kushlan and Kushlan 1979, Hogger 1988, Hobbs et al. 1989). Herpetofauna of short-hydroperiod wetlands reach greater abundance in habitats with longer hydroperiods and higher water tables (Dalrymple 1987, Dalrymple pers. comm.).

American Alligator

The American alligator was historically abundant and nested in the Rocky Glades north of Long Pine Key (Craighead 1968, Mazzotti and Brandt 1994), where it excavated sediments from large solution holes in limestone bedrock to form alligator holes. Alligator population distribution and abundance vary geographically in the southern marl prairies in that nesting is limited to areas where irregularities in the bedrock surface allow for excavation of alligator holes. Hence, high densities of alligator populations and holes in the southern marl prairies were concentrated in the Rocky Glades prior to drainage.

Alligator holes provided aquatic habitats in which alligators, and many other groups of aquatic fauna, survived the few months of dry conditions that occurred most years in the Rocky Glades (Craighead 1968). By the excavation of holes and nest mounds, the alligator also created micro-topographic gradients that supported aquatic as well as terrestrial plants and animals and provided nest sites for other species of marsh reptiles in the Rocky Glades (Craighead 1971, Kushlan 1974, Deitz and Jackson 1979, Kushlan and Kushlan 1980).

Wading Bird Early Dry Season Foraging

Southern marl prairies provided foraging opportunities for wading birds during unusually wet years and early in the dry season when water is too deep to allow successful foraging elsewhere in the southern Everglades (Fleming pers. comm. in Ogden 1994). Drying edges extended along elevation gradients from upland pine flatwoods and moved across marl prairies to the lower-elevation ridge and slough and coastal landscapes as dry seasons progressed under pre-drainage conditions in the southern Everglades. The drying edges concentrated aquatic prey organisms and made them available to wading birds. Early dry season foraging opportunities possibly contributed to early formation of nesting colonies and consequent nesting success.

ECOLOGICAL EFFECTS: WORKING HYPOTHESES ABOUT CRITICAL LINKAGES BETWEEN STRESSORS AND ATTRIBUTES

Working hypotheses were developed about critical linkages between stressors and attributes for the southern marl prairies. These hypotheses determine content and organization of this conceptual ecological model. Hypotheses are organized by attribute.

Periphyton Mat

Periphyton Mat in Relation to Shortened Hydroperiod and Increased Drought Severity. The shortening of hydroperiods in the southern marl prairies due to drainage activities can influence periphyton structure and composition. Severely reduced hydroperiods can result in further reduction in diatom and green algal species in the periphyton mat, leaving the mat to be comprised of mostly mat-forming filamentous cyanobacteria and associated calcitic matrix (Gottlieb et al. 2005). This shift may further reduce the edibility of the periphyton mat, as the filamentous algae are coated with calcium carbonate crystals that impede digestion by most grazers (Browder et al., 1994). Further, the matrix of cyanobacterial filaments creates pocketed refuges for more edible algae, making them inaccessible to consumers (Geddes and Trexler 2003). The effect of decreased hydroperiod on net annual production of periphyton mats has not been elucidated, but because periphyton production is limited to periods during which the mats are flooded, a severely reduced wet season should substantially decrease annual production. Reduced periphyton production would decrease marl soil accretion rates in areas with hydroperiods reduced below 1–2 months per year.

While no study has yet examined the sequence of changes in periphyton mat characteristics along the full gradient of hydroperiod represented in the Everglades, Gottlieb et al. (2005) provided the first detailed comparison of short- and long-hydroperiod periphyton communities. Their study verified contrasts in community structure. (1) Short-hydroperiod periphyton mats are bottom-dwelling (sediment or plant-stem associated) as opposed to long-hydroperiod mats, which are predominantly found attached to floating macrophytes such as *Utricularia purpurea* (Walt.). (2) Short

hydroperiod mats have a lower species diversity than long-hydroperiod mats. (3) Short-hydroperiod mats have an order of magnitude higher aerial dry weight and ash-free dry weight (organic) biomass than long-hydroperiod mats. (4) The inorganic (primarly calcitic) portion of the biomass is much larger in short- than long-hydroperiod periphyton mats (70–90% vs. 30–70%, respectively). Although the ranges of hydroperiod represented by Gottlieb et al. (2005) exceed those present in the historical and modern marl prairie, this study showed that long- and short-hydroperiod periphyton mats converge structurally and compositionally when exposed for long duration to the alternate hydroperiod regime. This indicates that shifts in periphyton composition due to changes in water delivery to the Everglades should be readily visible, making periphyton a useful early indicator of impending change at the ecosystem level.

In addition to hydrologic impacts of water management on periphyton biomass and composition, impacts due to water quality alterations are also expected. Swift (1984) showed that periphyton growth rates in the marl were significantly influenced by site differences in water quality (i.e., major ion content, Ph, and phosphorus composition) independent of hydrologic factors. Increased water delivery may increase supply of calcium and bicarbonate, further encouraging development of benthic periphyton dominated by calcite-precipitating blue-green algae. In fact, shifts from high-diversity green algae, diatom, and blue-greeen assemblages to mats dominated by filamentous cyanobacteria have been noted in paleoecological studies of areas adjacent to canals, where water management alterations increased pH and ion concentrations in downstream marshes (Slate and Stevenson 2000). Increased phosphorus availability in this naturally oligotrophic environment could also substantially alter species composition and production. Gaiser et al. (2004, 2005) experimentally showed that increased phosphorus supply above background levels of 5–10 $\mu g\ L^{-1}$ causes a reduction in periphyton biomass and an altered competitive environment favoring green algae and diatoms over blue-green algae. These results were found to be applicable to periphyton across a full range of hydroperiod settings in a subsequent study that related biomass and composition to P gradients across the Everglades landscape (Gaiser et al. 2005). Significant negative relationships between P availability and periphyton biomass were evident even within the Taylor Slough marl prairie where P gradients are relatively shallow (Gaiser et al. 2005). This research and that of Thomas et al. (2002) showed that increased P delivery, particularly in areas peripheral to canals, can override effects of increased pH and calcium availability and result in a reduction in periphyton biomass in recipient marl prairie marsh.

Plant Species Diversity and Community Mosaic

Plant Species Diversity and Community Mosaic in Relation to Shortened Hydroperiod, Increased Drought Severity, and Introduction and Spread of Non-Native Trees. Shortened hydroperiod and lowered water table in overdrained marl prairies east of Shark River Slough alter plant species composition of macrophyte vegetation toward more terrestrial plant species (Hilsenbeck et al. 1979, Hofstetter and Hilsenbeck 1980). Vegetation sub-types that grow at the upper end of the hydrologic gradient expand, while the distribution of vegetation sub-types that grow at the lower end of the hydrologic gradient contracts. Other direct effects of shortened hydroperiod and lowered water table on marl prairie vegetation include 1) invasion of woody shrubs and trees such as willow (*Salix caroliniana* Michx) into graminoid wetlands (Armentano et al. 1995), 2) displacement of native plant communities by exotic trees including Brazilian pepper and melaleuca (Olmstead and Loope 1984, Armentano et al. 1995, Jones and Doren 1997), and 3) loss of vegetation heterogeneity associated with the micro-topography of alligator holes (Craighead 1968).

Shortened hydroperiod and lowered water table in overdrained marl prairies also result in more intense wildfires exacerbated by prolonged dry seasons (Gunderson and Snyder 1994), which alter herbaceous plant species composition and contribute to burn-out of islands of tropical hammocks and pine forests (Loope and Urban 1980). Wildfire intensity and tree-island damage are augmented by a shift in fire seasonality from naturally-occurring, lightning-ignited fires during the early wet season to burning practices by humans during the protracted dry season (Gunderson and Snyder 1994). Roads on levees contribute to human caused fires by allowing arsonists access to marshes and by creating a source of ignition from vehicle sparks (G. Burzycki, Dade County Department of Environmental Resource Management, pers. comm.).

Cape Sable Seaside Sparrow

Cape Sable Seaside Sparrow in Relation to Extended Hydroperiod and Drying Pattern Reversals, and to Shortened Hydroperiod and Increased Drought Severity. Shortened hydroperiod, in combination with increased drought severity, limits reproductive success and survival in the eastern subpopulation of the Cape Sable Seaside Sparrow by increasing frequency and severity of nest-destroying fires, and by enabling invasion of woody plants in the absence of fire (Pimm

1995). Dry season water-level reversals reduce nesting success of the western sub-population, where regulatory water releases through the S12A and S12B outflow gates of Water Conservation Area 3A contribute to reversals and subsequent nest drowning (Pimm 1995). The central subpopulation is the most stable because of its remote location, although it is vulnerable to naturally-occurring dry season fires.

Sustainability of the Cape Sable seaside sparrow in the southern marl prairies requires maintenance of three stable sub-populations and breeding colonies in areas where they presently occur (Pimm 1995). Maintenance of each sub-population requires successful nesting at least seven out of ten years. Sustainability also requires a total population size, based on a five-year running average, ranging from a minimum of 2,000–3,000 birds to as many as 6,600 birds during particularly good years, with trends in increasing population shared among the three sub-populations (USFWS 2000).

Marsh Fishes and Associated Aquatic Fauna Prey Base

Marsh Fishes and Associated Aquatic Fauna Prey Base in Relation to Loss of Spatial Extent and Connectivity, Shortened Hydroperiod, and Lowered Water Table, and Introduction and Spread of Non-Native Fishes. Loss of spatial extent of southern marl prairies east of Shark River Slough through conversion of areas east of L-31 to agricultural and urban land use represents a proportional loss of populations of fish and other aquatic fauna that once inhabited that region (Davis et al. 1994). That loss is considered to be irreversible, short of reflooding developed areas and reconnecting them to the remaining natural system.

Shortened hydroperiod in the remaining southern marl prairies east of Shark River Slough limits fish density, size structure, and representation of long-hydroperiod species to levels below those expected under natural hydrologic conditions (Loftus et al. 1990, Loftus and Eklund 1994, Turner et al. 1999, Trexler et al. 2003). Reductions in hydroperiod also reduce population density and alter species composition of small herpetofauna, based on abundance in short-hydroperiod habitats in relation to rainfall and water levels on Long Pine Key (Dalrymple 1987, G. Dalrymple pers. comm., Everglades Research Group, Inc.).

Lowered water table in combination with shortened hydroperiod in overdrained marl prairies has reduced dry season minimum water levels and increased the frequency and duration of the drying of solution holes and alligator holes (Dalrymple 1987, Loftus et al. 1992, Dalrymple pers. comm.). The function of dry-season refugia is diminished or eliminated under prolonged dry conditions when minimum water levels fall below the bottom of solution holes and alligator holes.

The spread of non-native fishes into the southern marl prairies east of Shark River Slough seems to be affecting survival of native fish populations due to occupancy of solution holes. The black acara cichlid (*Cichlasoma bimaculatum* Linnaeus) is particularly common in holes during the dry season, where it probably preys on native species. By the end of the dry season, black acaras are often the sole species remaining in many solution holes (Kobza et al. 2004). The combination of prolonged confinement in the holes, and the presence of several species of non-native fishes, may have turned the holes into sinks for native fishes.

American Alligator

American Alligator in Relation to Shortened Hydroperiod and Lowered Water Table. Decline in alligator abundance and reproduction in the Rocky Glades, where it was once abundant, is attributed to shortened hydroperiods, lowered water tables, and resulting loss of aquatic habitat required for survival (Craighead 1968, Mazzotti and Brandt 1994). Cumulative effects leading to a reduced aquatic prey base probably also contributed to the demise of the alligator in marl prairies. The reduced alligator population allowed depressions that were previously alligator holes to fill in, reducing the dry season refugia and micro-topographic gradients that the holes formerly provided (Craighead 1971, Kushlan 1974, Deitz and Jackson 1979, Kushlan and Kushlan 1980). A positive feedback loop appears to exist from beneficial hydroperiods and water tables to alligator populations, to alligator holes, to aquatic fauna density and distribution, and back to alligator populations. That feedback loop is assumed to have been functional under pre-drainage conditions in the Rocky Glades, where alligators were formerly abundant, although it is clearly not functional in the drained marshes today.

Wading Bird Early Dry Season Foraging

Wading Bird Early Dry Season Foraging in Relation to Loss of Spatial Extent and Marsh Aquatic Fauna Prey Base. Prior to drainage, southern marl prairies provided shallow-water foraging opportunities for wading birds early in the dry season, at a time when water was too deep to allow successful foraging in Shark River Slough (Fleming pers. comm. in Ogden 1994). Early dry season foraging opportunities likely contributed to early formation of nesting colonies and consequent nesting success. Today, much of the area

has dried by the time migratory wading birds arrive in the system in autumn (Loftus et al. 1992).

Loss of spatial extent reduces the range of habitat options that are available at any given time for faunal populations (DeAngelis and White 1994). In the case of the southern marl prairies, agricultural and urban development of higher elevation wetlands east of Levee L-31 have directly reduced shallow-water foraging habitat options for wading birds during unusually wet years and early in the dry season, when water is too deep to allow successful foraging elsewhere in the southern Everglades (Fleming pers. comm. in Ogden 1994). Urban and agricultural development of the higher elevation eastern fringes of the southern Everglades, in combination with drying of marl prairies earlier in the dry season, have truncated in time and space the drying marsh edge and the concentration of aquatic prey organisms. During very wet years, the edge no longer occurs or occurs only briefly at the end of the dry season. In years with more typical rainfall, the edge may occur throughout the dry season, but it passes through the marl prairies very early and is well into the center of Shark Slough by the time it is needed to fuel wading bird nesting (Ogden 1994, Fleming pers. comm. in Ogden 1994).

ACKNOWLEDGMENTS

We gratefully acknowledge the following individuals who participated in workshops leading to the development of the Southern Marl Prairies Conceptual Ecological Model: Tom Armentano, Tomma Barnes, Sonny Bass, Laura Brandt, Joan Browder, Cheryl Buckingham, Gwen Burzycki, John Chick, Dan Childers, Peter Frederick, Dale Gawlik, Lorraine Heisler, David Jones, Frank Mazzotti, Paul McCormick, Heather McSharry, Sue Newman, Bill Nuttle, John Ogden, Sue Perry, Mary Ann Poole, Ken Rice, Mike Ross, Winnie Park Said, Fred Sklar, Skip Snow, Joel Trexler, Joseph Walsh, and Dewey Worth. We particularly thank Dr. Jack Gentile for facilitating the initiation of conceptual models for South Florida ecosystem restoration and for informing the conceptual model teams of the process for conceptual model development.

LITERATURE CITED

Armentano, T. V., R. F. Doren, W. J. Platt, and T. Mullins. 1995. Effects of Hurricane Andrew on coastal and interior forests of southern Florida: overview and synthesis. Journal of Coastal Research Special Issue 2:111–114.

Armentano, T. V., D. T. Jones, M. Ross, and B. W. Gamble. 2002. Vegetation pattern and process in tree islands of the southern Everglades and adjacent areas. p. 225–282. *In* F. H. Sklar and A. van der Valk (eds.) Tree Islands of the Everglades. Kluwer Academic Publishers, Boston, MA, USA.

Bjork, R. D. and G. V. N. Powell. 1994. Relations between Hydrologic Conditions and Quality and Quantity of Foraging Habitat for Roseate Spoonbills and Other Wading Birds in the C-111 Basin. National Audubon Society Final Report to South Florida Research Center, Everglades National Park, Homestead, FL, USA.

Browder, J. A., P. J. Gleason, and D. R. Swift. 1994. Periphyton in the Everglades: spatial variation, environmental correlates, and ecological implications. p. 379–418. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Craighead, F. C. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Florida Naturalist 41:2–7, 69–74, 94.

Craighead, F. C. 1971. The Trees of South Florida, Volume 1. University of Miami Press, Coral Gables, FL, USA.

Dalrymple, G. H. 1987. The herpetofauna of Long Pine Key in relation to vegetation and hydrology. p. 72–86. *In* R. C. Szaro (ed.) Management of Amphibians, Reptiles, and Small Mammals in North America: Proceedings of the Symposium: July 19–21, 1988, Flagstaff, AZ, USA. Rocky Mountain Forest and Range Experiment Station, United States Department of Agriculture Forest Service, Fort Collins, CO, USA. General Technical Report RM-166.

Davis, S. M., L. H. Gunderson, W. A. Park, J. R. Richardson, and J. E. Mattson. 1994. Landscape dimension, composition, and function in a changing Everglades ecosystem. p. 419–444. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

DeAngelis, D. L. and P. S. White. 1994. Ecosystems as products of spatially and temporally varying driving forces, ecological processes, and landscapes: a theoretical perspective. p. 9–27. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Deitz, D. C. and D. R. Jackson. 1979. Use of alligator nests by nesting turtles. Journal of Herpetology 13:510–512.

Donar, C. M., K. W. Condon, M. Gantar, and E. E. Gaiser. 2004. A new technique for examining the physical structure of Everglades floating periphyton mat. Nova Hedwigia 78:107–119.

Fennema, R. J., C. J. Neidrauer, R. A. Johnson, T. K. MacVicar, and W. A. Perkins. 1994. A computer model to simulate natural Everglades hydrology. p. 249–289. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Gaiser, E. E., J. H. Richards, J. C. Trexler, R. D. Jones, and D. L. Childers. 2005. Periphyton responses to eutrophication in the Florida Everglades: Cross-system patterns of structural and compositional change. Limnology and Oceanography 50:342–355.

Gaiser, E. E., L. J. Scinto, J. H. Richards, K. Jayachandran, D. L. Childers, J. D. Trexler, and R. D. Jones. 2004a. Phosphorus in periphyton mats provides best metric for detecting low-level P enrichment in an oligotrophic wetland. Water Research 38:507–516.

Gaiser, E. E., J. C. Trexler, J. H. Richards, D. L. Childers, D. Lee, A. L. Edwards, L. J. Scinto, K. Jayachandran, G. B. Noe, and R. D. Jones. 2005. Cascading ecological effects of low-level phosphorus enrichment in the Florida Everglades. Journal of Environmental Quality 34:717–723.

Gaiser, E. E., A. Wachnicka, P. Ruiz, F. Tobias, and M. S. Ross. 2004b. Diatom indicators of ecosystem change in coastal wetlands. p. 127–144. *In* S. Bortone (ed.) Estuarine Indicators. CRC Press, St. Lucie, FL, USA.

Gleason, P. 1972. The origin, sedimentation, and stratigraphy of a calcitic mud located in the southern fresh-water Everglades. Ph.D. Dissertation. Pennsylvania State University, University Park, PA, USA.

Gleason, P. J. and W. Spackman, Jr. 1974. Calcareous periphyton and water chemistry in the Everglades. Environments of South Florida Present and Past, Miami Geological Society Memoir 2, Miami, FL, USA.

Geddes, P. and J. C. Trexler. 2003. Uncoupling of omnivore-mediated positive and negative effects on periphyton mats. Oecologia 136:585–595.

Gottlieb, A., J. H. Richards, and E. E. Gaiser. 2005. The effects of

desiccation resistance and rewetting on the community structure of Everglades periphyton. Aquatic Botany 82:99–112.

Gunderson, L. H. 1994. Vegetation of the Everglades: determinants of community composition. p. 323–340. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Gunderson, L. H. and J. R. Snyder. 1994. Fire patterns in the southern Everglades. p. 291–305. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Hilsenbeck, C. E., R. H. Hofstetter, and T. R. Alexander. 1979. Preliminary Synopsis of Major Plant Communities in the East Everglades Area, Vegetational Maps Supplement. University of Miami, University of Miami Report, Coral Gables, FL, USA.

Hobbs, H. H., III, J. P. Jass, and J. V. Huner. 1989. A review of global crayfish introductions with particular emphasis on two North American species (Decapoda, Cambaridae). Crustaceana 56:299–316.

Hofstetter, R. H. and C. E. Hilsenbeck. 1980. Vegetational studies of the east Everglades. Final Report to Dade County Planning Department for East Everglades Resources Planning Project, Miami, FL, USA.

Hogger, J. B. 1988. Ecology, population biology and behaviour. p. 114–144. *In* D. M. Holdich and R. S. Lowery (eds.) Freshwater Crayfish: Biology, Management and Exploitation. Timber Press, Portland, OR, USA.

Howard, K. S., W. F. Loftus, and J. C. Trexler. 1995. Seasonal Dynamics of Fishes in Artificial Culvert Pools in the C-111 Basin, Dade County, Florida. Everglades National Park, Homestead, FL, USA.

Jones, D. B. and R. F. Doren. 1997. Distribution, biology and control of *Schinus terebinthifolius* in southern Florida with special reference to Everglades National Park. p. 81–93. *In* J. H. Brock, M. Wade, P. Tysek, and D. Green (eds.) Plant Invasions: Studies From North America and Europe, Backhuys Publishers, Lyden, The Netherlands.

Kobza, R. M., J. C. Trexler, W. F. Loftus, and S. A. Perry. 2004. Community structure of fishes inhabiting hydrological refuges in a threatened Karst wetland and its implications for ecosystem management. Biological Conservation 116:153–165.

Kushlan, J. A. 1974. Observations on the role of the American alligator (*Alligator mississippiensis*) in the southern Florida wetlands. Copeia 1974:993–996.

Kushlan, J. A. and M. S. Kushlan. 1979. Observations on the crayfish in the Everglades, Florida, USA. Crustaceana, Supplement 5: 115–120.

Kushlan, J. A. and M. S. Kushlan. 1980. Everglades alligator nests: nesting sites for marsh reptiles. Copeia 1980:930–932.

Light, S. S. and J. W. Dineen. 1994. Water control in the Everglades: A historical perspective. p. 47–84. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Loftus, W. F. 2000. Inventory of the fishes of Everglades National Park. Florida Scientist 63:27–47.

Loftus, W. F., M. C. Bruno, K. J. Cunningham, S. A. Perry, and J. C. Trexler. 2001. The ecological role of the karst wetlands of southern Florida in relation to system restoration. p. 8–15. *In* E. L. Kuniansky (ed.) U. S. Geological Survey, Karst Interest Group Proceedings, St. Petersburg, FL, USA. USGS Water Resources Investigations Report 01-4011, Athens, GA.

Loftus, W. F., J. D. Chapman, and R. Conrow. 1990. Hydrological effects on Everglades marsh food webs, with relation to marsh restoration efforts. p. 1–22. *In* G. Larson and M. Soukup (eds.) 1986 Conference on Science in the National Parks Proceedings, Volume 6: Fisheries and Coastal Wetlands Research. George Wright Society, Hancock, MI, USA.

Loftus, W. F. and A. M. Eklund. 1994. Long-term dynamics of an Everglades fish community. p. 461–483. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Loftus, W. F., R. A. Johnson, and G. H. Anderson. 1992. Ecological impacts of the reduction of ground water levels in short-hydroperiod marshes of the Everglades. p. 199–207. *In* J. A. Stanford and J. J. Simons (eds.) Proceedings of the First International Conference on Ground Water Ecology. American Water Resources Association, Middleburg, VA, USA.

Loftus, W. F., L. G. Nico, J. Kline, S. A. Perry, and J. C. Trexler. 2003. Recent fish introductions into southern Florida freshwaters, with implications for the greater Everglades region. Published abstract, Second Greater Everglades Ecosystem Restoration Conference, April 2003, Palm Harbor, FL, USA.

Loope, L. L. and N. H. Urban. 1980. A survey of fire history and impact in tropical hardwood hammocks in the east Everglades and adjacent portions of Everglades National Park. South Florida Research Center, Everglades National Park, Homestead, FL, USA. Report T-592.

Mazzotti, F. J. and L. A. Brandt. 1994. Ecology of the American alligator in a seasonally fluctuating environment. p. 485–505. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Meeder, J., M. Ross, G. Telesnicki, and P. Ruiz. 1996. Vegetation analysis in the C-111/Taylor River Slough basin. Final report to the South Florida Water Management District, West Palm Beach, FL, USA. Contract C-4244.

Momot, W., H. Gowing, and P. Jones. 1978. The dynamics of crayfish and their role in the ecosystem. American Midland Naturalist 99:10–35.

Ogden, J. C. 1994. A comparison of wading bird nesting colony dynamics (1931–1946 and 1974–1989) as an indication of ecosystem conditions in the southern Everglades. p. 533–570. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Olmstead, I. C. and L. L. Loope. 1984. Plant communities of Everglades National Park. p. 167–184 *In* P. J. Gleason (ed.) Environments of South Florida: Past and Present II, Miami Geological Society, Coral Gables, FL, USA.

Pimm, S. L. 1995. Population Ecology of the Cape Sable Seaside Sparrow (*Ammodramus maritima mirabilis*). Annual Report 1995. Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN, USA.

Slate, J. E. and R. J. Stevenson. 2000. Recent and abrupt environmental change in the Florida Everglades indicated from siliceous microfossils. Wetlands 20:346–356.

Swift, D. R. 1984. Periphyton and water quality relationships in the Everglades Water Conservation Areas, Environments of South Florida Present and Past, Miami Geological Society Memoir 2, Miami, FL, USA.

Thomas, S., E. Gaiser, M. Gantar, A. Pinowska, L. Scinto, and R. Jones. 2002. Growth of calcareous epilithic mats in the margin of natural and polluted hydrosystems: phosphorus removal implications in the C-111 basin, Florida Everglades, USA. Lake and Reservoir Management 18:323–329.

Thomas, S. E., E. E. Gaiser, M. Gantar, L. J. Scinto, and R. D. Jones. 2006. Quantifying the response of dry, calcareous periphyton mats to wetting in a short-hydroperiod, oligotrophic subtropical wetland. Aquatic Botany 84:(in press).

Trexler, J. C., W. F. Loftus, and J. H. Chick. 2003. Setting and Monitoring Restoration Goals in the Absence of Historical Data: Monitoring Fishes in the Florida Everglades. p. 351–376. *In* D. E. Busch and J. C. Trexler (eds.) Monitoring Ecoregional Initiatives: Interdisciplinary Approaches for Determining Status and Trends of Ecosystems, Island Press, Washington, DC, USA.

Turner, A. M., J. C. Trexler, C. F. Jordan, S. J. Slack, P. Geddes, J. Chick, and W. F. Loftus. 1999. Targeting ecological features for conservation: standing crops in the Florida Everglades. Conservation Biology 13–4:898–911.

USFWS. 2000. Milti-species Recovery Plan. United States Fish and Wildlife Service, Washington, DC, USA.

Van Lent, T. A., R. A. Johnson, and R. J. Fennema. 1993. Water management in Taylor Slough and effects on Florida Bay. South Florida Natural Resources Center, Everglades National Park, Homestead, FL, USA. Technical Report 93-3.

VanZee, R. 1999. Natural System Model Version 4.5 Documentation Report. Draft report, South Florida Water Management District, West Palm Beach, FL, USA.

Manuscript received 7 March 2005; revisions received 13 September 2005; accepted 4 October 2005.

C.14.4 Ridge and Slough

WETLANDS, Vol. 25, No. 4, December 2005, pp. 810–820
© 2005, The Society of Wetland Scientists

EVERGLADES RIDGE AND SLOUGH CONCEPTUAL ECOLOGICAL MODEL

John C. Ogden
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida, USA 33406
E-mail: jogden@sfwmd.gov

Abstract: A conceptual ecological model of the effects of the major anthropogenic stressors on the Everglades ridge and slough system was developed as a planning tool for designing and assessing the Everglades restoration program. The pre-drainage Everglades ridge and slough system was an expansive, hydrologically integrated, long-hydroperiod, low-nutrient freshwater marsh, characterized by low-velocity sheet-flow, long-term water storage capacity, moderate-to-deep organic soils, and alternating sawgrass ridges and more open-water slough communities. Depth, distribution, and duration of surface flooding in this environment largely determined vegetation patterns, as well as distribution, abundance, seasonal movements, and reproductive dynamics of all aquatic and many terrestrial animals. Drivers on the system are urban and agricultural expansion, industrial and agricultural practices, water management practices, and human influences on species composition. These drivers lead to five major ecosystem stressors: reduced spatial extent, degraded water quality, reduced water storage capacity, compartmentalization, and exotic species. Attributes that are affected by these stressors and can be used as indicators of restoration success include periphyton, marsh plant communities, tree islands, alligators, wading birds, and marsh fishes, invertebrates, and herpetofauna.

Key Words: conceptual ecological model, Everglades, freshwater wetland, restoration planning

BACKGROUND

In its pre-drainage condition, the ridge and slough portion of the Everglades was an expansive, long-hydroperiod, freshwater marsh, characterized by low-velocity sheet-flow, moderate-to-deep organic soils, and alternating sawgrass ridges and more open-water slough communities (Tropical BioIndustries Inc. 1990, Gunderson and Loftus 1993, Davis et al. 1994, Gunderson 1994, Olmsted and Armentano 1997, Browder and Ogden 1999). The pre-drainage ridge and slough systems were dominated by sawgrass (*Cladium jamaicense* Crantz), water lily (*Nymphaea* sp.), and wet prairie (*Eleocharis* sp. and *Rhynchospora* sp.) communities. A spatially variable mosaic of discreet hardwood hammock, bay head, and willow tree islands occurred throughout, ranging from widely spaced in the central Everglades to more densely distributed in Shark River Slough. The ridge and slough system modeled here (Figure 1) is that portion of the Everglades basin where Loxahatchee or Everglades peat soils occur (the combined "wet prairie/slough, tree island, sawgrass mosaic" and "sawgrass dominated mosaic" in Davis et al. 1994). The ridge and slough system makes up the deeper central portion of the Everglades basin. On a much smaller scale, ridge and slough systems occur on both eastern and western flanks of Shark Slough in the southern Everglades (e.g., Middle and Lostman's Sloughs). These flanking sloughs are imbedded within the boundaries of the region described by the Southern Marl Prairies Conceptual Ecological Model. The ridge and slough Everglades was a principal center for primary and secondary production and interannual survival of aquatic organisms in pre-drainage, freshwater wetlands of southern Florida.

The Everglades ridge and slough conceptual model was developed as a means of evaluating, synthesizing, and organizing existing understandings of key ecological linkages in the ridge and slough system. The purpose of this and other conceptual models developed for the greater Everglades basin has been to build scientific consensus regarding the source of major anthropogenic stressors on the ridge and slough system, ecological effects of these stressors, and the best set of living indicators (attributes) that can serve as measures of the responses of the system to the recently initiated Comprehensive Everglades Restoration Plan (USACE and SFWMD 1999). Stressors, attributes, and assumptions in the conceptual model have been used to guide the design of restoration plans and as a basis for creating performance measures for assessing how well the plans perform. The ridge and slough conceptual model was developed by a multi-disciplinary team of Everglades researchers and resource specialists during a series of workshops. More details on develop-

Ogden, EVERGLADES RIDGE AND SLOUGH CEM 811

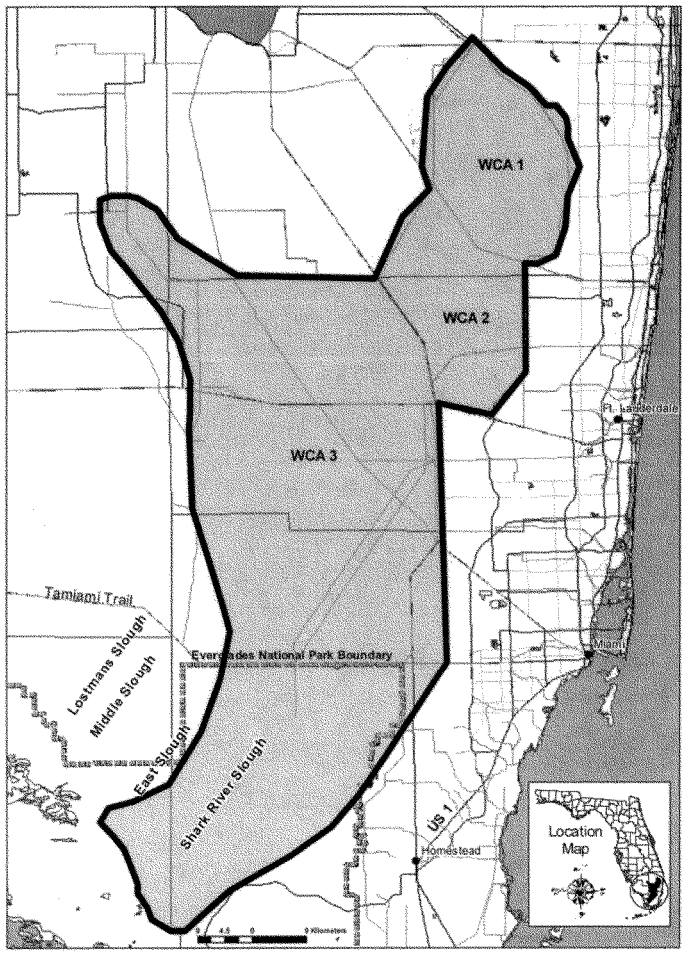


Figure 1. Boundary of the remaining Everglades ridge and slough system, as described in the Ridge and Slough Conceptual Ecological Model. The ridge and slough system includes Water Conservation Areas (WCAs) 1–3 and central portions of Everglades National Park.

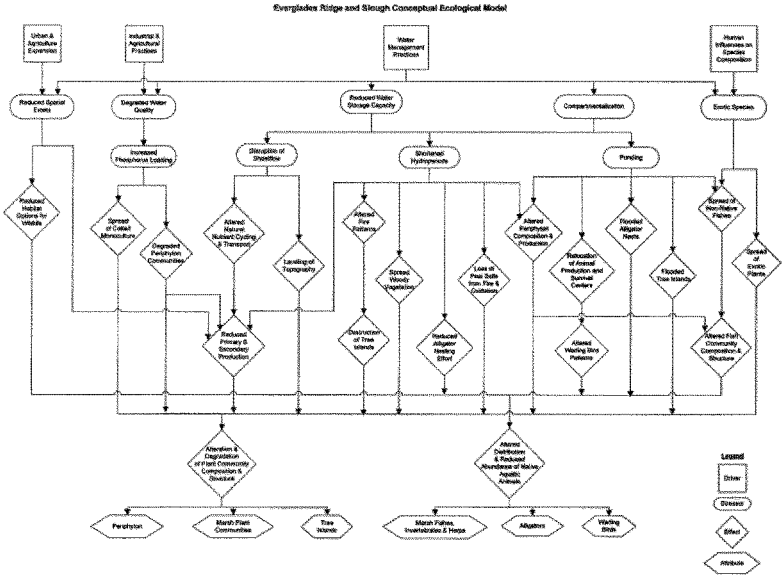


Figure 2. Everglades Ridge and Slough Conceptual Ecological Model Diagram. External drivers are shown as squares or rectangles, internal stressors as ovals, the ecological effects as diamonds, and the key attributes as hexagons (see Ogden et al. 2005).

ment and use of conceptual models in the Everglades restoration process, including development of performance measures for assessing ecosystem responses in the context of the objectives of the Comprehensive Everglades Restoration Plan, are presented in Ogden et al. (2003) and Ogden et al. (2005).

EXTERNAL DRIVERS AND ECOLOGICAL STRESSORS

During workshops to develop the Everglades Ridge and Slough Conceptual Ecological Model, four major sources of societal influences (drivers) on Everglades ridge and slough systems were identified: urban and agricultural expansion, industrial and agricultural practices, water management practices, and human influences on species composition. These drivers lead to five major ecosystem stressors: reduced spatial extent, degraded water quality, reduced water storage capacity, compartmentalization, and exotic species. Combined effects from these stressors explain much of the ecological changes that have occurred in the ridge and slough system (Figure 2). The four societal drivers, their respective stressors, and the ecological significance of the pre-stressed condition in the natural system are briefly discussed below.

Urban and Agricultural Expansion

Drainage of wetlands and subsequent conversion of ridge and slough habitat into agricultural and urban uses have reduced total spatial extent of the ridge and slough system in the main Everglades from 490,000 ha in the pre-drainage system to 365,000 ha in the current system (Davis et al. 1994). Space was the one physical characteristic of South Florida wetlands that was necessary for all other physical and ecological components of these systems to be in place. Broad

spatial extent of the pre-drainage ridge and slough system was essential for collecting and storing the amount of regional rainfall that was required to maintain ecological vigor of these systems (Davis and Ogden 1994, Ogden et al. 1999). Large spatial extent provided the foundation for processes that created and maintained a mosaic of habitats in a low profile terrain (Craighead 1971, DeAngelis and White 1994). Disturbances, such as fire, freezes, tropical storms, and animal-related impacts (e.g., an abundance of alligator [*Alligator mississippiensis* Daudin] created ponds and trails), served to increase the complexity of habitats, as well as the range of habitat choices for species of wildlife with either small or large home ranges (Craighead 1968, Davis and Ogden 1994, DeAngelis 1994, Duever et al. 1994, Gunderson and Snyder 1994). Extensive space was necessary for supporting robust numbers of animals requiring extensive feeding and hunting ranges during different seasons and a range of hydrologic conditions. For example, location of feeding and nesting sites for white ibis (*Eudocimus albus* Linnaeus) and other wading birds, snail kites (*Rostrhamus sociabilis* Vieillot), and other common aquatic birds shifted across large spatial scales, across seasons and years, in response to variability in hydrologic patterns (Kushlan 1979, Bennetts et al. 1994, Hoffman et al. 1994, Ogden 1994). The large number of ponds and depressions occurring over an extensive region allowed for comparatively sedentary species such as the alligator to maintain very large regional numbers (Craighead 1968). The large spatial extent enabled the system-wide aquatic production in this nutrient-poor ecosystem that was necessary to support large numbers of wading birds and alligators (Browder 1976, Mazzotti and Brandt 1994).

Industrial and Agricultural Practices

Another stressor on the Everglades ridge and slough system is degraded water quality. Increased phosphorus loads, originating as by-products from an array of agricultural and urban industrial practices, have been hypothesized to have had greatest ecological significance in alterations in water and soil quality in the ridge and slough systems (Spalding and Forrester 1991, Browder et al. 1994, Davis 1994).

The pre-drainage ridge and slough Everglades was a shallow, clear-water, low-nutrient system (Davis et al. 1987, SFWMD 1992). Aside from fire and infrequent frosts, the unique vegetation of the Everglades evolved in response to both low-nutrient water quality conditions and seasonal fluctuations of water levels. Gleason and Spackman (1974) described a periphyton community in the northeastern Everglades that may be a remnant of a more widespread community prior to the impacts of elevated phosphorus levels. This is a non-calcareous periphyton (less than 10% calcium carbonate) community that is rich in desmids, a type of green algae found most abundantly in low-mineral, oligotrophic waters.

Water Management Practices

All five major ecological stressors acting on ridge and slough systems, reduced spatial extent, introduction and spread of degraded water, reduced water storage capacity, compartmentalization, and introduction and spread of exotic species, have had part or all of their origins in water management practices. Major objectives of water management have included water supply and flood protection, which have been achieved by means of a complex system of structural and operational modifications to the natural system. These modifications have 1) contributed to substantial reduction in spatial extent, 2) provided a network of canals and levees that have accelerated spread of degraded water and exotic species, 3) greatly reduced water-storage capacity within the remaining natural system, 4) compartmentalized the system into an unnatural mosaic of ponded and overdrained marshes in the Water Conservation Areas, 5) substantially disrupted natural patterns of sheet-flow direction, location, and volume, and 6) shortened hydroperiods, resulting in extensive desiccation of soils (SFWMD 1992, Science Subgroup 1993, Davis and Ogden 1994, Fennema et al. 1994, Light and Dineen 1994).

Pre-drainage ridge and slough Everglades was a single, hydrologically integrated system, with water depth and distribution (temporally and spatially) largely determined by seasonal and annual rainfall, evaporation, transpiration, natural topography, outflow through natural streams into the ocean, and the system's capacity for surface- and ground-water storage of water (SFWMD 1992, Fennema et al. 1994). A key feature of the pre-drainage system was its large water storage capacity for extended periods of time, resulting in a system that was much wetter (but not necessarily deeper) than the current system. Water storage was facilitated by natural damming effects of the east coast ridge and downstream coastal embankments, large spatial extent of the system, sponge-like properties of peat soils, and slow flow rates through extensive marshes. As a result, pre-drainage Everglades sloughs maintained multi-year surface-water hydroperiods throughout deeper, central marshes and along the downstream, marsh-mangrove ecotone and extensive, shallow water "edges" that varied both spatially and temporally among seasons and years. Depth, distribution, and duration of surface flooding in this environment largely determined the vegetation patterns, as well as the dis-

tribution, abundance, and seasonal movements and reproductive dynamics of all of aquatic and many terrestrial animals in the Everglades (Kushlan 1989, Davis and Ogden 1994, Holling et al. 1994, Walters and Gunderson 1994).

Human Influences on Species Composition

During the recent period of rapid human settlement and development of South Florida, especially post-World War II, hundreds of non-indigenous species of plants and animals have been brought into the region. Through human actions, both intended and unintended, many of these species have successfully established what appears to be sustainable and expanding invasive populations, within native communities and habitats (Science Subgroup 1994, Doren 2000, Goodyear 2000). These introductions are altering landscape patterns, food webs, and biodiversity. The exotic species issues of primary concern in the ridge and slough Everglades include 1) invasions by melaleuca (*Melaleuca quinquenervia* (Cav.) Blake), Brazilian pepper (*Schinus terebinthifolius* Raddi), and old world climbing fern (*Lygodium microphyllum* (Cav.) R. Br) and 2) the distribution and abundance of non-native fishes (Loftus and Kuslan 1987, Loftus et al. 1990, Goodyear 2000, Thayer et al. 2000).

ECOLOGICAL ATTRIBUTES

Periphyton

Species composition of algal mats in the ridge and slough Everglades is broadly controlled by water depth, duration of surface flooding, and water chemistry (Browder et al. 1994). These algal mats are important as a food web base and for oxygenating the water column. Communities of green algae and diatoms may be especially important to periphyton grazers.

Water management practices and changes in water chemistry, including increased levels of total phosphorus, have changed spatial distribution and species composition of periphyton mats (Browder et al. 1994, Davis 1994). Shortened hydroperiods cause a reduction in the proportion of diatoms and green algae and an increase in calcareous blue-green algae, thus reducing food value of periphyton and affecting overall productivity of the Everglades. In nutrient-enriched areas, species characteristic of low-nutrient waters are replaced by filamentous species.

Marsh Plant Communities

The pre-drainage Everglades ridge and slough system was a network of discreet sawgrass strands (ridges) and more open water sloughs dominated by water lilies, spikerush (*Eleocharis* sp.), and beakrush (*Rhynchospora* sp.) (Gunderson and Loftus 1993, Gunderson 1994). It has been hypothesized that flow volumes in the pre-drainage ridge and slough system were largely responsible for maintaining sharply discreet community and elevation differences between ridges and sloughs (Sklar et al. 2000). Sloughs, deeper than ridges, were the primary refugia for aquatic animals during dry periods and were the most important wading bird foraging habitats in freshwater areas of the Everglades.

Reduced water storage capacity of the managed Everglades and compartmentalization of the northern and central ridge and slough system have disrupted sheetflow patterns, have created areas that are either overdrained or are more deeply flooded than was the case in the pre-drainage system, have substantially altered affects of fire on marsh communities, and have altered rates and magnitude of flooding and drying events. As a result, sawgrass has invaded sloughs and wet prairies, beak rush communities have been lost, woody plants have invaded marsh communities, and extent and species composition of marsh communities have become extensively altered (Kolopinski and Higer 1969, Davis et al. 1994, Sklar et al 2000). Substantial increases in levels of total phosphorus in water and soil have converted both ridge and slough communities into extensive beds of cattails (*Typha* sp.).

Tree Islands

Discreet hardwood tree and shrub islands are a conspicuous feature of the Everglades ridge and slough system. Depending on elevation, these islands are dominated by swamp hardwoods (e.g., red maple [*Acer rubrum* Linnaeus], willow [*Salix caroliniana* Michx.], redbay [*Persea borbonia* (Linnaeus) Spreng.], and pond apple [*Annona glabra* Linnaeus]) or upland temperate and tropical species (e.g., strangler fig [*Ficus aurea* Nutt.], hackberry [*Celtis laevigata* Willd.], stoppers [*Eugenia* spp.], and mastic [*Mastichodendron foetidissimum* (Jacq) H.J. Lam]). Gawlik and Rocque (1998) found that the terrestrial habitats provided by tree islands support more species of resident and migratory birds than any other habitat in the central Everglades. Because the maximum elevations of the highest tree islands are only slightly above mean annual maximum water levels, tree islands with their less-flood-tolerant vegetation are among the most sensitive components of the Everglades ridge and slough systems to changes in hydrology (van der Valk et al. 1998).

Water management practices have substantially impacted Everglades' tree islands (van der Valk et al.

1998, Sklar et al. 2000). An increase in the frequency and duration of unnatural high water events during wet seasons and an increase in the frequency and intensity of fire during dry seasons has damaged or destroyed many tree islands. The number of tree islands in Water Conservation Area 3 decreased from 1,041 to 577 between 1940 and 1995 (Patterson and Finck 1999, Sklar et al. 2000). For this same period, the total spatial extent of tree islands in Water Conservation Area 3 decreased by 5,478 hectares (61.5%).

Marsh Fishes, Invertebrates, Reptiles, and Amphibians

Everglades ridge and slough systems were the most important centers of secondary production in freshwater marshes of South Florida. In addition, deeper, open sloughs were the principal refugia for fishes and aquatic invertebrates during low water periods and were the places in the Greater Everglades where great numbers of wading birds concentrated to forage during dry seasons (Kushlan 1986, Hoffman et al. 1989, Loftus and Eklund 1994).

Total abundance (numbers and biomass) and availability as prey of fishes, crayfish (*Procambarus* spp.), grass shrimp (*Palaemonetes paludosus* Gibbes), frogs, and turtles in the ridge and slough system has been greatly altered due to combined affects of reduced spatial extent of total wetlands, increased frequencies and durations of dryouts in remaining wetlands, altered water recession rates, and possible reductions in secondary production associated with shifts in periphyton composition (Browder et al. 1994, Loftus and Eklund 1994, Trexler and Jordan 1999).

Alligators

Alligators were abundant throughout the pre-drainage Everglades. Largest numbers and densities in the pre-drainage system apparently were in broad marl prairies that flanked the southern ridge and slough Everglades and in the inner, freshwater mangrove forest zone downstream from the southern Everglades (Craighead 1968). In the modern Everglades, alligators are most numerous in remaining ridge and slough systems (Craighead 1968, Mazzotti and Brandt 1994).

Alligator numbers have been greatly reduced in the marl prairies because of over drainage and substantially lowered ground-water levels (especially during dry seasons). Numbers have been reduced in lakes and streams of the mainland mangrove forest because of reduced freshwater flow from the Everglades and resulting higher salinities in these waters. Conversely, alligators may have increased in some portions of ridge and slough systems (particularly Shark River Slough) where management practices have lowered wet season depths, thereby increasing extent of suitable, shallowly flooded nesting and foraging habitat. Improved conditions for nesting have not occurred in all portions of remaining ridge and slough systems, particularly in Water Conservation Areas 2 and 3 where compartmentalization has caused unnaturally deep water in southern conservation areas and overdrained conditions in northern areas. Alligators have also suffered in managed system because of increased frequencies of nest flooding caused by impoundments and regulatory flows, reduced survival of juveniles in canals during low water periods, and poor rates of growth and development due to reduced prey populations in overdrained marshes (Jacobsen and Kushlan 1984, Kushlan and Jacobsen 1990).

Wading Birds

The largest and most persistent wading bird nesting colonies in the pre-drainage Everglades were located at the southern edge of the ridge and slough system along the marsh/mangrove ecotone at the lower end of Shark River Slough and in the downstream mangrove region (Ogden 1994). The unusually large "super colonies" (nesting numbers greater than one standard deviation in excess of long-term annual mean) that periodically formed in the historical Everglades were believed to have been a response by wading birds to extreme peaks in prey abundance created in the system by effects of multi-year wet and dry cycles (Frederick and Ogden 2001).

Wading birds in the current managed system have shown a 75 to 90% reduction in number of nesting birds compared to 1930s numbers (primarily by snowy egrets (*Egretta thula* Molina), tricolored herons (*Egretta tricolor* Muller, 1776), white ibis, and wood storks [*Mycteria americana* Linnaeus]), have relocated colonies away from estuaries and into the impounded central and northern Everglades, and for white ibis and wood storks, have altered the timing of nesting compared to historical patterns (Ogden 1994). Percentage of wading birds nesting in and adjacent to the southern ridge and slough system in southern Everglades National Park has decreased from greater than 90% during the 1930s to less than 5% for 1996–1999 (Gawlik 1999). The vast majority of wading birds now nest in the Water Conservation Areas.

Number of nesting birds has been reduced largely because of a substantial decrease in abundance and availability of aquatic prey base caused by water management practices that have overdrained large portions of remaining sloughs and have altered location, seasonal timing, and magnitude of high water and low water events relative to traditional colony locations.

These hydrologic changes have served to alter location and timing of centers of prey concentrations in the system. For animals such as wading birds, which operate over large spatial scales, compartmentalization and peripheral drainage have combined to convert a single, expansive wetland system into several, much smaller and hydrologically independent systems. Levees and canals have replaced shallowly flooded marsh edges with more deeply flooded marsh along levee slopes.

KEY HYPOTHESES FOR ECOLOGICAL EFFECTS

Primary ecological effects of the five stressors in the Everglades Ridge and Slough Conceptual Ecological Model are described by key hypotheses developed during conceptual ecological model workshops. These hypotheses build on earlier Everglades hypotheses presented in Davis and Ogden (1994) and Ogden et al. (1999). These hypothetical statements determine the content and organization of the Everglades Ridge and Slough Conceptual Ecological Model and are presented here, organized by stressor. Additional supporting information on the broad causal relationships in the greater Everglades basin is presented in Ogden et al. (2005).

Reduced Spatial Extent

Spatial extent of the ridge and slough Everglades has been reduced from an estimated 490,000 ha in the pre-drainage system to 365,000 ha in the current system (a loss of 25%). The large extent and comparatively longer hydroperiods that characterized the original ridge and slough system made it the major center for total secondary production in the freshwater Everglades and the most important refugia for survival of aquatic animals during dry seasons and years.

Degraded Water

The pre-drainage ridge and slough system was characterized by clear, clean water; low levels of nutrients; and a periphyton community dominated by species of green algae and diatoms. Slower flow rates, unnatural patterns of ponding and over drainage, and addition of excess nutrients have greatly altered water and soil chemistry of Everglades sloughs. Soil oxidation has resulted in increases in surface concentrations of phosphorus. Excess nutrients have contributed to conversion of extensive strands and patches of sawgrass into dense cattail "plains," resulting in loss of plant diversity and a reduction in extent of useable wildlife habitat (e.g., for foraging wading birds). The increased nutrient loadings also have shifted dominance of periphyton communities to species of blue-greens, resulting in considerable disruption in aquatic food chains.

Reduced Water Storage Capacity

The ridge and slough Everglades has lost much of its original capacity to store natural volumes of water due to reduction in spatial extent of marshes. Two hypothetical statements have been developed for this effect.

Wet Season. Greater than historical (pre-drainage) water depths occur in the ridge and slough system when spatial extent of natural wetlands (and of man-made water storage areas) is insufficient to hold and distribute wet season and/or wet year volumes of water that enter the system either as rain or surface flow. As a result of this reduction in region-wide storage capacity, water becomes "stacked" to unnatural depths in marshes during wet seasons and wet years. Increased wet season/wet year depths lead to flooding of tree islands, loss of shallow feeding habitat for wading birds, altered and stressed periphyton communities (reduced light penetration), flooding of alligator nests and reduced quality of alligator feeding conditions, and altered species composition and size classes of fishes.

Dry Season. Greater than historical (pre-drainage) frequencies and durations of marsh dryouts occur in the ridge and slough system when spatial extent of natural wetlands (and of man-made water storage areas) is insufficient to hold wet season and wet year accumulations of water into the following dry season and dry years, respectively. As a result, water is not available to maintain marsh and ground-water levels during dry periods. Increased frequencies and durations of dry out lead to increased rates of loss of organic soils due to increased fire and oxidation, which affects microtopography and structure and distribution of plant communities; spread of woody vegetation into marshes; reduced survival of fishes, small reptiles, amphibians, and aquatic invertebrates; altered periphyton communities (diatoms/greens to blue-greens); reduced alligator nesting effort (dry marshes during courtship period); and expansion of sawgrass into slough communities (i.e., a degradation of the discreet ridge/slough mosaics).

Compartmentalization

The ridge and slough Everglades have been converted from a single, hydrologically integrated ecosystem to a collection of hydrologically independent systems (Science Coordination Team 2003). This change

was brought about by the current network of internal levees and canals, and water management operational criteria that were established for each discreet compartment. Internal canals and levees have disrupted directions, timing and rates of sheet-flow and have created deep water corridors and mosaics of shallowly and deeply flooded marshes that are unnatural in location, juxtaposition, and duration and depth of flooding. Reduced rates of sheet-flow have contributed to leveling of pre-drainage ridge and slough topography, the loss of large amounts of open slough habitats, and disrupted dynamics of cycling and transport of natural nutrients. Ponding, in place of strong seasonal and multi-year differences in flow rates and volumes that once characterized the interior Everglades, has also contributed to disruption of dynamics of cycling and transport of nutrients and has substantially reduced levels of primary and secondary production in the system. The patchwork of overdrained and overflooded marshes has changed locations and times when and where aquatic animals operate in the Everglades. Wading bird nesting colonies have moved away from traditional estuarine locations and have relocated around less productive pools that have been created in each impoundment. Deep-water corridors and habitats have altered dynamics and sizes of alligators and fishes and have opened up much of the Everglades to invasions by exotic fishes. Canal flows have degraded water quality by introducing toxins and additional nutrients into interior marshes.

Exotic Species

Exotic plants have invaded marsh and tree island communities in the ridge and slough Everglades, resulting in substantial shifts in species composition and community structure, and where exotic plants have formed dense "stands," have reduced habitat diversity (e.g., where Brazilian pepper, *Melaleuca*, and old world climbing fern have invaded tree islands). The introduction and spread of non-native fishes into localized habitats of the Everglades marshes may alter the dynamics of marsh fish communities, foraging behavior of wading birds, or genetic biodiversity.

CRITICAL ECOLOGICAL PATHWAYS

The key hypotheses described above are converted into critical ecological pathways in the Ridge and Slough Conceptual Ecological Model. These pathways show that the principal, broad-scale ecological responses from the combined affects of the five major ecosystem stressors acting on the ridge and slough systems have been 1) a substantial alteration and degradation in natural patterns of plant community composition and structure and 2) substantial changes in distribution, and reductions in abundance among many of the native animals that are dependant on aquatic habitats and food webs. Relative contribution made by each stressor along different pathways to these two primary ecological effects is not well known. For example, presence of physical and biological thresholds, some of which may have been crossed as a result of effects of stressors, have yet to be demonstrated for most functions and relationships in the sloughs (an exception might be the 10 parts per billion value for phosphorus). Nevertheless, current understandings of ridge and slough systems, as expressed by participants at conceptual ecological model workshops, suggest that the following ecological pathways have been most important for explaining how these two broad-scale, ecological responses have been linked to stressors:

- Pathway that links reduced spatial extent with reduced habitat options for wildlife and reduced, regional primary, and secondary production.
- Pathway that links degraded water quality with increased phosphorus loading, resulting in spread of cattail monocultures, degraded periphyton communities, and reduced marsh production.
- Pathway that links reduction in water storage capacity (shortened hydroperiods) and compartmentalization with an array of ecological effects characteristic of overdrained marshes, including a spread in woody vegetation, altered periphyton communities, loss of peat soils, altered fire patterns, reduced numbers of nesting alligators, and reduced marsh production.
- Pathway that links compartmentalization (including disrupted sheet-flow) and reduced water storage capacity with a loss in the ridge and slough microtopography, altered nutrient cycling and transport, and reduced primary and secondary production.
- Pathway that links reduction in water storage capacity and compartmentalization (including ponding) with flooded tree islands and alligator nests, altered nutrient cycling and transport, altered periphyton communities, altered fish communities, and altered wading bird foraging and nesting patterns.
- Pathway that links exotic species with spread of non-native fishes, altered fish communities, and spread of exotic plants.

RESEARCH QUESTIONS

Key uncertainties regarding causal relationships in the Everglades Ridge and Slough Conceptual Ecological Model need to be researched. Recommended research to support this conceptual ecological model identified during the ridge and slough workshops is discussed in this section.

Causal Factors Determining Spatial Coverage, Directionality, and Persistence of Sawgrass Ridges, Sloughs, and Tree Islands in the Landscape. How do hydrologic patterns (depth and flow) and fire interact to sustain spatial coverage, directionality, and coexistence of sawgrass ridges, open-water sloughs, and tree islands that characterized pre-drainage landscapes? What are the respective roles of sheet-flow and fire as causal factors that sustain discreet, directional slough systems and prevent encroachment by sawgrass? What are the respective roles of hydrologic variables and fire as causal factors that sustain viable tree islands and prevent drowning under high-water conditions and burn-out under low-water conditions?

Prevention and Reversal of Cattail Spread under Conditions of Elevated Soil Phosphorus in Nutrient-Enriched and Non-Enriched Areas in the Landscape. In nutrient-enriched areas of the ridge and slough landscape, how can current trends of cattail expansion be reversed once phosphorus inputs are reduced? In overdrained, non-enriched areas of the ridge and slough landscape, how can elevated phosphorus concentrations in subsided peat be sequestered in forms that are unavailable for cattail growth upon recovery of more natural hydropatterns?

Functional Role of Periphyton Mats in Driving Food Webs. How are populations of marsh fishes and other aquatic fauna related to spatial cover, primary productivity, and taxonomic composition of periphyton mats?

Functional Importance of Crayfish in Everglades Food Webs. What is the functional importance of crayfish as an intermediate trophic level and prey base supporting higher consumers, in that the former abundance of white ibis and otter (*Lutra Canadensis* Schreber) suggests that the Everglades was dominated by a crayfish-based food web? How are crayfish population density and taxonomic composition related to annual and interannual patterns in hydroperiod and depth, including droughts?

Causal Factors Related to Formation of Wading Bird Super Colonies. What triggers formation of super colonies of white ibis and other wading birds following the infrequent, multi-year droughts that characterized the historical system? What are functional contributions and interrelationships of pulsed nutrient releases, reduction in numbers of predatory fishes, and spikes in abundance of small aquatic prey (particularly crayfish) in supporting super colony formation?

SUMMARY

The Everglades Ridge and Slough Conceptual Ecological Model provides us with a framework for planning, evaluation, and assessment of Everglades restoration. Monitoring the key attributes described in the model and addressing the uncertainties expressed in the Research Questions section will strengthen our ability to assess ecosystem responses in the context of the objectives of the Comprehensive Everglades Restoration Plan (see Odgen et al. 2003 and Ogden et al. 2005 for more details).

ACKNOWLEDGMENTS

The Everglades Ridge and Slough Conceptual Ecological Model is the cumulative result of contributions from many scientists and resource specialists in South Florida, who participated in one or more workshops over a period of several years beginning in January 1997. I thank these people: Tom Armentano, Oran Bass, Sarah Bellmund, Chris Madden, Doug Morrison, Sue Perry, and Skip Snow with the National Park Service; Joan Browder with the National Marine Fisheries Service; David Busch with the U.S. Forest Service; Lorraine Heisler, Robert Pace and Mary Ann Poole with the U.S. Fish and Wildlife Service; Bill Loftus and Mike Robblee with the U.S. Geological Survey; Jon Moulding with the U.S. Army Corps of Engineers; Steve Davis, Dale Gawlik, and Fred Sklar with the South Florida Water Management District; Linda McCarthy with the Florida Department of Agriculture and Consumer Services; Peter Frederick and Frank Mazzotti with the University of Florida; Tim Towles with the Florida Fish and Wildlife Conservation Commission; Herb Zebuth with the Florida Department of Environmental Protection; Gynn Burzycki with Miami-Dade County; Tom Bancroft formerly of the National Audubon Society; and Melanie Steinkamp formerly of the U.S. Fish and Wildlife Service.

I want to recognize three people for their special contributions to the development and refinement of this model. Steve Davis has supported the conceptual model process from its inception in the Everglades restoration program and has chaired numbers of the conceptual model workshops. Kim Jacobs at the South Florida Water Management District has contributed superior science editing skills to the preparation of this manuscript. Finally, the late Bill Robertson, National Park Service, was leader to us all as we struggled to understand an ecosystem that was substantially altered long before our time.

LITERATURE CITED

Bennetts, R. E., M. C. Collopy, and J. A. Rodgers, Jr. 1994. The snail kite in the Florida Everglades: a food specialist. p. 507–532. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Browder, J. A. 1976. Water, wetlands, and wood storks in southwest

Florida. Ph.D. Dissertation. University of Florida, Gainesville, FL, USA.

Browder, J. A., P. J. Gleason, and D. R. Swift. 1994. Periphyton in the Everglades: spatial variation, environmental correlates, and ecological implications. p. 379–416. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Browder, J. and J. C. Ogden. 1999. The natural South Florida system II: pre-drainage ecology. Urban Ecosystems 3:125–158.

Craighead, F. C., Sr. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Florida Naturalist 41:2–7, 69–74, 94.

Craighead, F. C., Sr. 1971. The Trees of South Florida. Volume 1: The Natural Environments and Their Succession. University of Miami Press, Coral Gables, FL, USA.

Davis, S. M. 1994. Phosphorus inputs and vegetation sensitivity in the Everglades. p. 357–378. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Davis, S., L. Gunderson, R. Hofstetter, D. Swift, and B. Walter. 1987. An assessment of the potential benefits to the vegetation and water resources of Everglades National Park and the southern Everglades ecosystem associated with the General Design Memorandum to Improve Water Deliveries to Everglades National Park. South Florida Research Center, Everglades National Park, Homestead, FL, USA. Statement paper.

Davis, S. M., L. H. Gunderson, W. A. Park, J. Richardson, and J. Mattson. 1994. Landscape dimension, composition, and function in a changing Everglades ecosystem. p. 419–444. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Davis, S. M. and J. C. Ogden. 1994. Towards ecosystem restoration. p. 769–796. *In* Davis, S.M. and J.C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

DeAngelis, D. L. 1994. Synthesis: spatial and temporal characteristics of the environment. p. 307–320. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

DeAngelis, D. L. and P. S. White. 1994. Ecosystems as products of spatially and temporally varying driving forces, ecological processes, and landscapes. p. 9–27. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Doren, R. F. 2000. Weeds won't wait. An assessment of invasive plants in Florida. South Florida Ecosystem Restoration Task Force and Working Group, Miami, FL, USA.

Duever, M. J., J. F. Meeder, L. C. Meeder, and J. M. McCollom. 1994. The climate of South Florida and its role in shaping the Everglades ecosystem. p. 225–248. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Fennema, R. J., C. J. Neidrauer, R. A. Johnson, W. A. Perkins, and T. K. MacVicar. 1994. A computer model to simulate natural South Florida hydrology. p. 249–289. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Frederick, P. C. and J. C. Ogden. 2001. Pulsed breeding of long-legged wading birds and the importance of infrequent severe drought conditions in the Florida Everglades. Wetlands 21:4.

Gawlik, D. E. (ed.). 1999. South Florida wading bird report, volume 5. South Florida Water Management District, West Palm Beach, FL, USA.

Gawlik, D. E. and D. A. Rocque. 1998. Avian communities in bayheads, willowheads, and sawgrass marshes of the central Everglades. Wilson Bulletin 110:45–55.

Gleason, P. J. and W. Spackman, Jr. 1974. Calcareous periphyton and water chemistry in the Everglades. p. 146–181 *In* P. J.Gleason (ed.) Environments of South Florida: Present and Past. Miami Geological Society, Miami, FL, USA. Memoir 2.

Goodyear, C. 2000. Initial status survey of nonindigenous animals in South Florida. South Florida Ecosystem Restoration Working Group, Miami, FL, USA. May 2000 draft.

Gunderson, L. H. 1994. Vegetation of the Everglades: determinants of community composition. p. 323–340. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Gunderson, L. H. and W. F. Loftus. 1993. The Everglades. p. 199–255. *In* W. H. Martin, S. G. Boyce, and A. C. Echternacht (eds.) Biotic Communities of the Southern United States. John Wiley and Sons, New York, NY, USA.

Gunderson, L. H. and J. R. Snyder. 1994. Fire patterns in the southern Everglades. p. 291–305. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Hoffman, W., G. T. Bancroft, and R. J. Sawicki. 1989. Wading Bird populations and distributions in the Water Conservation Areas of the Everglades, 1985–1988. South Florida Water Management District, West Palm Beach, FL, USA.

Hoffman, W., G. T. Bancroft, and R. J. Sawicki. 1994. Foraging habitat of wading birds in the water conservation areas of the Everglades. p. 585–614. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Holling, C. S., L. H. Gunderson, and C. J. Walters. 1994. The structure and dynamics of the Everglades system: guidelines for ecosystem restoration. p. 741–756. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Jacobsen, T. and J. A. Kushlan. 1984. Population status of the American alligator (*Alligator mississippiensis*) in Everglades National Park. South Florida Research Center, Everglades National Park, Homestead, FL, USA.

Kolipinski, M. C. and A. L. Higer. 1969. Some aspects of the effects of the quantity and quality of water on biological communities in the Everglades National Park. United States Geological Survey, Washington, DC, USA. Open File Report 69007.

Kushlan, J. A. 1979. Feeding ecology and prey selection in the white ibis. Condor 81:376–389.

Kushlan, J. A. 1986. Responses of wading birds to seasonally fluctuating water levels: strategies and their limits. Colonial Waterbirds 9:155–162.

Kushlan, J. A. 1989. Wetlands and wildlife, the Everglades perspective. p. 773–790. *In* R. R. Sharitz and J. W. Gibbons (eds.) Freshwater Wetlands and Wildlife, United States Department of Energy, Oak Ridge, TN, USA. Symposium Series No. 61.

Kushlan, J. A. and T. Jacobsen. 1990. Environmental variability and the reproductive success of Everglades alligators. Journal of Herpetolology 24:176–184.

Light, S. S. and J. W. Dineen. 1994. Water control in the Everglades: a historical perspective. p. 47–84. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Loftus, W. F., J. D. Chapman, and R. Conrow. 1990. Hydrological effects on Everglades marsh food webs, with relation to marsh restoration efforts. p. 1–22. *In* G. Larson and M. Soukup (eds.) 1986 Conference on Science in the National Parks Proceedings, Volume 6: Fisheries and Coastal Wetlands Research. George Wright Society, Hancock, MI, USA.

Loftus, W. F. and A. Eklund. 1994. Long-term dynamics of an Everglades small-fish assemblage. p. 461–483. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Loftus, W. F. and J. A. Kushlan. 1987. Freshwater fishes of southern Florida. Bulletin Florida State Museum 31:147–344.

Mazzotti, F. J. and L. A. Brandt. 1994. Ecology of the American alligator in a seasonally fluctuating environment. p. 485–505. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Ogden, J. C. 1994. A comparison of wading bird nesting colony dynamics (1931–1946 and 1974–1989) as an indication of ecosystem conditions in the southern Everglades. p. 533–570. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Ogden, J. C., S. M. Davis, and L. A. Brandt. 2003. Science for a regional ecosystem monitoring and assessment program: the Flor-

ida Everglades example. p. 135–160. *In* D. E. Busch and J. C. Trexler (eds.) Monitoring Systems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, DC, USA.

Ogden, J. C., J. Browder, J. H. Gentile, L. H. Gunderson, R. Fennema, and J. Wang. 1999. Environmental management scenarios: ecological implications. Urban Ecosystems 3:159–184.

Ogden, J. C., S. M. Davis, K. J. Jacobs, T. Barnes, and H. E. Fling. 2005. The use of conceptual ecological models to guide ecosystem restoration in south Florida. Wetlands 25: (in press).

Olmsted, I. and T. V. Armentano. 1997. Vegetation of Shark Slough, Everglades National Park. South Florida Natural Resources Center, Everglades National Park. Homestead, FL, USA. Report 97-001.

Patterson, K. and R. Finck. 1999. Tree islands of WCA3. Aerial photointerpretation and trend analysis project summary report. South Florida Water Management District, West Palm Beach, FL, USA.

Science Coordination Team. 2003. The role of flow in the Everglades ridge and slough landscape. Science Coordination Team, South Florida Ecosystem Restoration Task Force, Miami, FL, USA.

Science Subgroup. 1993. Federal objectives for the South Florida restoration. South Florida Management and Coordination Working Group, South Florida Ecosystem Restoration Task Force, Miami, FL, USA.

Science Subgroup. 1994. South Florida ecosystem restoration: scientific information needs. Management and Coordination Working Group, Interagency Task Force on the South Florida Ecosystem, Miami, FL, USA.

SFWMD. 1992. Surface water improvement and management plan for the Everglades: supporting information needs document. South Florida Water Management District, West Palm Beach, FL, USA.

Sklar, F., L. Brandt, D. DeAngelis, C. Fitz, D. Gawlik, S. Krupa, C. Madden, F. Mazzotti, C. McVoy, S. Miao, D. Rudnick, K. Rutchney, K. Tarboton, L. Vilchek, and Y. Wu. 2000. Hydrological needs—effects of hydrology on the Everglades. p. 2–1 to 2–62. *In* Everglades Consolidated Report. South Florida Water Management District, West Palm Beach, FL, USA.

Spalding, M. G. and D. J. Forrester. 1993. Effects of parasitism and disease on the nesting success of colonial wading birds (ciconiiformes) in southern Florida. Nongame Wildlife Program Report NG88-008, Florida Game and Fresh Water Fish Commission, Tallahassee, FL, USA.

Thayer, D., A. Ferriter, M. Bodie, K. Langeland, K. Serbesoff, D. Jones, and B. Doren. 2000. Exotic plants in the Everglades. p. 14–1 to 14–48. *In* Everglades Consolidated Report. South Florida Water Management District, West Palm Beach, FL, USA.

Trexler, J. and F. Jordan. 1999. Fish and aquatic macroinvertebrate population studies in the Water Conservation Areas. Final report for South Florida Water Management District contract no. C-E6636, West Palm Beach, FL, USA.

Tropical BioIndustries, Inc. 1990. Hydroperiod conditions of key environmental indicators of Everglades National Park and adjacent east Everglades area as guide to selection of an optimum water plan for Everglades National Park, Florida. Final report for contract with United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL, USA.

USACE and SFWMD. 1999. Central and Southern Florida Project comprehensive review study final integrated feasibility report and programmatic environmental impact statement. U.S. Army Corps of Engineers, Jacksonville district, Jacksonville, FL, USA and South Florida Water Management District, West Palm Beach, FL, USA.

van der Valk, A., F. Sklar, D. Mason, D. Gawlik, P. Wetzel, S. Newman, C. McVoy, Y. Wu, S. Miao, S. Krupa, and M. Korvela. 1998. Proposed plan of work for tree island research. Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, FL, USA.

Walters, C. J. and L. H. Gunderson. 1994. A screening of water policy alternatives for ecological restoration in the Everglades. p. 757–767. *In* S. M. Davis and J. C. Ogden (eds.) Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL, USA.

Manuscript received 18 October 2004; revisions received 29 August 2005; accepted 28 September 2005.

C.15 BENEFITS ASSESSMENT MODEL DOCUMENTATION

README FILE
C-111 SPREADER CANAL, BENEFITS ASSESSMENT MODEL
October 27, 2009

NOTES:

The C-111SC project benefits assessment model, revised in October 2009, includes the following spreadsheets.

Matrix_Summary....xls: This spreadsheet is used to compute the final benefit estimates for the project. It references several other spreadsheets so the user must be aware of, and properly adjust, spreadsheet 'LINKS'.

PM2.1_Veg_Hydro_oct09.xls: This spreadsheet contains the data and calculations for PM2.1. The results that are referenced in the Matrix spreadsheet are located at the bottom of the INDEX_SUMMARY TAB. The data in this spreadsheet was copied manually into the correct locations. There is not import procedure.

PM2.4_Salinity_Calcs_Oct09.xls: This spreadsheet contains the data and calculations for the PM2.4. This spreadsheet imports data from CSV datafiles contained in the PM2.4 directory. The user should be familiar with macros that access these files. The macro that does the importing is invoked using the button at the top right of the FILESETUP TAB. Note that there are 27 CSV data files in the PM2.4 data sub-directory. Note that to operate the import macro properly, one must open one of these files so that the EXCEL referenced directory is set internally (seems like a bug in VBA.)

PM1.5 FILES: These files (listed below) are used to calculate PM1.5 index results for each alternative. The final results for each alternative are contained in the OUTPUT_SUMMARY TAB of each file. The data in these files is copied manually. There is no import procedure. (Note: There is a copy/sort macro for preparing exceedance frequency curves of distribution data. This macro is not used in the calculations. As a result of some editing, the macro does not work properly in any of the spreadsheets except for FWO. It will either be fixed in the other sheets, or deleted.)

FWO_Pm1.5_Oct09.xls
Alt1D_Pm1.5_Oct09.xls
Alt1C_Pm1.5_Oct09.xls
Alt2Ds_Pm1.5_Oct09.xls
Alt2DL_Pm1.5_Oct09.xls

Alt3D_Pm1.5_Oct09.xls
Alt6D_Pm1.5_Oct09.xls
ECB_Pm1.5_Oct09.xls

Please Call Mark Shafer, US Army Corps, Jacksonville, (904) 232-3594 if you have any questions.

DOCUMENTATION OF MATRIX_Summary_C111sc_oct09v2.xls

STUDY AREA

This sheet contains the acreages for each of the sub areas. The impacted zones for each of the PMs is determined by acreages assigned to the various indicator regions in this sheet.

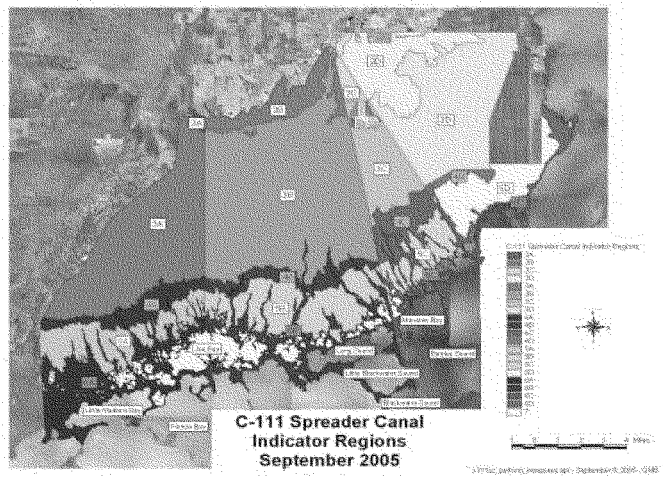
For the Salinity PM2.4, the acreages assigned are from the nearshore estuarine zones. These embayments are: Barnes Sound, Long Sound, Little Madiera Bay, Joe Bay, and Manatee Bay.

For the Flow Timing, Distribution, and Volume PM1.5, the acreages assigned are the Florida Bay areas directly downstream of Taylor Slough. They are: Little Madiera Bay, Taylor Slough, and Northeast Florida Bay.

For the Vegetation Hydroperiod PM2.1, the acreages assigned are the freshwater wetland areas most likely to experience altered hydroperiods. These sub-indicator areas are:

Landscape Type 2: Scrub dominated forest wetlands
Landscape Type 3: Sawgrass
Landscape Type 4: Mixed Grammanoid with mangroves
Landscape Type 5: White zone ecotone
Landscape Type 6: Coastal forest
Taylor Slough

The map below shows the areal coverage of each sub-indicator region.



PM1.5 FlowTDV

This tab contains the index calculations for the Flow Timing, Distribution and Volume PM.

Cell B1: Name of PM
Cell B2: Acreage affected by PM (references STUDY_AREA TAB)
Range C14..H14: Contains the weighting assigned to each sub-measure. Range must add to 1.
Cell B14: Checks sum of C14..H14 to ensure it equals 1. If = 1, then reports "Ready" if not then reports, "Weight not equal to 1". Errors propagate an results are not available.
Range B19..B29: Overall hydrologic restoration units calculated for this PM. Equations check for error in weighting and other inputs.
Range C19.. H29: Index values from PM calculation spreadsheets. The cells reference tables located at bottom of this tab.
Range C35..H43: Calculation of hydrologic restoration units for each sub-measure. These equartions check to see if a result is needed, the selects the minimum of the calculated result or the maximum weighted area (this prevents more than 100% restoration credit.
Range B50..F59: The table located in this range is where the index values for the timing and distribution sub-PMs data is imported to this spreadsheet. The cells reference values in other spreadsheets so the user must use caution to ensure that the latest results are referenced. IF THE USER IS UNSURE, IT IS BEST TO OPEN THE REFERENCED SPREADSHEETS, AND USE THE "LINK" MENU ITEM TO CHANGE THE REFERENCE SOURCE.
Range B50..F59: The table located in this range is where the flow totals for taylor slough and all the transect flows are imported to this spreadsheet. The values are used in range C19..H29 as input to the hydrologic restoration unit calculations. The user must use caution since these cells reference other spreadsheets.

The final settings for the weighting are 0.33 assigned to Taylor Slough Timing, 0.33 assigned to Taylor slough distribution, and 0.33 assigned to Taylor Slough Flow Volume. The overall Transect-A flow, Timing, and distribution are not used since the project is focused on Taylor Slough.

Also, flow in C-111x is not used in the calculation of the distribution sub-indices. See the individual PM1.5 spreadsheets to confirm this. Inclusion of C-111x flows distorts comparisons with NSM since it has no canal.

THE OVERALL RESULTS FROM THIS TAB ARE REFERENCED IN THE OUTPUT_SUMMARY TAB.

PM2.4 SALINITY TAB

The overall hydrologic restoration units are computed in this tab using the index results computed using the PM2.4 calculation spreadsheet.

The PM2.4 calculation spreadsheet was revised to include refined regression equation results.

This TAB is set up in the same manner as the PM1.5 TAB. The index data is imported into the worksheet by equations located in range B48...G60. These cell equations reference an different spreadsheet so caution must be used to ensure the proper data is being applied.

The weighting of the five estuarine areas is set to: 0.05 for Barnes Sound, 0.20 for Middle Key, 0.25 for Long Sound, 0.25 for Joe Bay, and 0.25 for Little Madiera Bay. This distribution was chosen for two reasons.

1) The focus of the project is on Taylor Slough and downstream estuarine zones. So 75% of weight is assigned to nearshore areas downstream of Taylor Slough.
2) Barnes Sound is given 0.05 weight because its total area of 16,000 acres includes areas that are not directly affected by overland flows. The weighting of 0.05 is 25% of the weight assigned to areas with acreage of 2,500 to 3,000 acres, therefore, after weighting, Barnes Sound equivalent acreage is similar to that assinged for the other nearshore areas (see row 36 for weighted acreages for comparison).

THE OVERALL RESULTS FROM THIS TAB ARE REFERENCED IN THE OUTPUT_SUMMARY TAB.

PM2.1 VEGH TAB

This tab is where the index values calculated in the PM2.1 spreadsheet are imported and the associated hydrologic restoration units are calculated.

The TAB is set up in a manner similar to the other two PM TABS. The data is imported using equations that reference the PM 2.1 calculation spreadsheet in range B48..F57. Again caution should be used to ensure that the proper data is obtained from the referenced spreadsheet.

This PM does not have sub-indices or different weights applied to some of the indicator regions. The weighting for each of the three year simulation results can be adjusted here (unlike the other 2 PMs). Presently, each of the three years is accorded the same weight. This is done because the PDT could not justify weighting the year simulation results unequally. A sensitivity analysis of the weighting applied to the three simulation conditions will be done for all three PMs as part of the final report for the project (November 2009).

THE OVERALL RESULTS FROM THIS TAB ARE REFERENCED IN THE OUTPUT_SUMMARY TAB.

OUTPUT_SUMMARY TAB

This tab is where the overall hydrologic restoration unit results are calculated and presented. This tab includes a toggle/scroll button that allows the user to review the results for individual PMs and all combinations of the PMs. Since two of the PMs have overlapping areas of impact, the equations used to calculate the overall result include the math to adjust for double counting of benefits by more than one PM.

Prior to using this page, the user should open and review all input spreadsheets to ensure that the correct data is available. The user should check the "LINKS" button in the edit menu to ensure that referenced spreadsheets are the correct. The best method for doing this is to open each of the primary spreadsheets, edit the LINKS in this spreadsheet, then go through each PM spreadsheet.

PM 1.5 VEGETATION HYDROPERIOD SPREADSHEET

SPREADSHEET OVERVIEW

The Comprehensive Everglades Restoration Effort seeks to address imbalances in the Quantity, Quality, Timing and Distribution (QQTD). This performance measure looks at Timing and Distribution of flows specifically directed at Taylor Slough. The performance measure normalizes daily flow volumes into percent of annual cummulative flow, and percent of daily flow directed at Taylor slough relative to surface/subsurface flows passing north to south in the area of interest.

This spreadsheet is used to post-process groundwater transect data from the MODBRANCH simulation output. The data in the spreadsheets is manually transferred from the modeling output files and placed in the appropriate TABS for each simulated year. Each alternative has its own spreadsheet so the final calculated index value from each of these spreadsheets is manually transferred to the Matrix Summary Spreadsheet.

The spreadsheet calculates overland flow and near-surface groundwater flow (MODBRANCH model layers 1, 2, and 3) that passes through 5 transects out through the MODBRANCH model domain. For Transect TA-3, which crosses the C-111 canal, the canal flow is added to the summed overland flow (the flow record from the corresponding reach in MODBRANCH provides the estimate of canal flow at the transect - canal intersection.

The single key stroke macro that exists in this spreadsheet is used to sort flow distribution output for use in exceedance frequency graphing. This macro is not integral to the vegetation hydroperiod index calculations.

The spreadsheet is used by simply placing the datasets for each simulation in the appropriate TAB (and spreadsheet). The OFFSET EQUATION PARAMETER settings should be properly adjusted if the MODBRANCH output file format is changed. (The OFFSET equation is used in this case to allow easy fixes of the calculations in the case where the MODBRANCH output dataset formatting is changed. Output format changes did happen over the course of the modeling efforts.)

NOTE: Use of the PM1.5 Spreadsheets requires that the user understand the input data format and can make the necessary adjustments to the OFFSET EQUATION settings on the UserPage.

1978T_FLOW TAB

This tab contains the input dataset for the 1978 simulated results for a given alternative. This data is manually copied into the spreadsheet. The format of the dataset is as follows:

Row Descriptions

- Rows 1-3: Simulate Meta-data that identifies model run and file structure location.
- Rows 6-8: Transect data information, Name of simulation, transect name, transect length (not used)
  - Note that these are repeated at the head of each transect dataset.
- Rows 11-378: Daily data for each of the 10 columns.
- Rows 379-398: Summary data for each layer of the model for the preceeding transect.
- Row 399: Next transect data follows. Data from each of the transects requires approximately 390 rows.
  - The data file contains data for all "A" and "B" transects though only transect A is used.

Column Descriptions

- Column A: Day of Simulation (1 through 365)
- Column B: Layer 1 flow in cfs (average cfs over day). This is overland flow in MODRANCH model.
- Column C: Layer 2 flow in cfs. This is first GW layer in MODBRANCH model. It is used in calcs.
- Column D: Layer 3 flow in cfs. This is second GW layer in MODBRANCH model. It is used in calcs.
- Column E: Layer 4 flow in cfs. This is third GW layer in MODBRANCH model. It is not used in calcs.
- Column F: Layer 5 flow in cfs. This is fourth GW layer in MODBRANCH model. It is not used in calcs.
- Column F: Layer 5 flow in cfs. This is fourth GW layer in MODBRANCH model. It is not used in calcs.

Column G: Average depth of overland flow. This is not used in PM 1.5 calculations.
Column H: Fraction wet. This is not used in PM 1.5 calculations.
Column I: Average slope of GW flow. dH/dx. This is not used in PM 1.5 calculations.
Column J: Maximum slope of GW flow dH/dx in transect. This is not used in PM 1.5 calculations.
Column K: C-111x flow (cfs). This is the flow in the C-111 canal at the intersection with the Transect 3-A. This is only applicable to this transect.

DATA_SETUP TAB

The data setup tab is used to set the row and columns offsets used to locate the transect data in the transect data tabs (1978T_Flow, 1989T_Flow, 1995T_Flow). The OFFSET EQUATION SETTINGS box (range A4..G11) is where the offset values for row and column are placed. The offset values are critical to the calculations since the equations in the ALT_CALCS TAB use this information to properly reference input data. Below is a description of the offset data information.

Range C5..G5: This contains the row number for each transect that contain the first reference of the transect name. For instance, row 7 contains the first identifier of transect TA-1. The first identifier is in cell B7 of the input data tabs. The C5..G5 range is referred to as the "Transect Range Starting Row".

Range C6..G6: The cells in this range use the OFFSET function to identify the name of the transect. If the name of the transect is not shown in these cells, then the row number(s) identified in row 5 are incorrect. (This is a manual check of offset data.)

Range C7..G11: These cells are used to identify the Column offsets. Row 7 contains the column offset values for the layer 1 data from the MODBRANCH model (column b in data TABS.). Row 8 contains the column offset values for layer 2 data from the MODBRANCH model (column c in transect flow data TABS). Row 9 contains column offset values for layer 3 of the MODBRANCH model. Row 10 contains the column offset value for the C-111x flows that are only applicable to Transect TA-3. Row 11 is available but unused. Note that this range is conditionally formatted to provide a green background when the values entered in the cells are not equal to 100. When set to 100, the cells are formatted to provide a light blue background. Setting the cells equal to 100 is equivalent to referencing data from the 100th column to the right in the transect flow data tabs. OFFSET equations in the ALT_CALCS TAB will calculate a value of zero as a result of setting the column offset to 100. This particular setup provided flexibility to the benefits assessment team as they developed the performance metric.

Range E16..E18: Rows 17, 18, and 19 of this range are used to check the source file names of the data. If the three names do no agree in terms of the alternative, or if there is duplication of simulated year, the data in the transect flow tabs should be checked. Row 16 is computed using the name of the first datafile. The calculated value in row 16 is used in the graphs in the OUTPUT_SUMMARY TAB.

The tab includes some simple suggestions to ensure that the user is accessing the correct data.

The macro button located on the bottom right of the tab is used to copy and sort flow distribution data from the alternative and the target conditions. This macro is not used to import data nor is the product of its actions used in the calculation of benefits. It is only kept to facilitate additional data analysis outside of the benefits assessment.

ALT_CALCS TAB

This tab is where the actual calculation of the overall vegetation hydroperiod indices is done. An explanation of the calculations within each group of columns is provided below.

Daily CFS. Columns C..H:
Uses OFFSET equation to sum up layer flow for each of 5 transects. The total daily flow is calculated in column H. OFFSET equations reference cells in Range A8..G15 to determine relative location of each datapoint.

Accumulated AF. Columns I..N:
Sums of the cummulative flow over the 365 day simulation period of each year for each transect. Converts cfs results in C..H to acre-feet. Uses IF statement to check to see if first day of year to prevent adding one years results to the next year.

Difference in 7-DayAve Q: Columns O...T:
These columns are not used in the PM calculations but were used in the past for exceedance graphing. Starting on the 8th-day of the year, it computes prior 7-day average flow for current day and subtracts prior days average 7-day flow. This is done for both the alternative condition and the target condition in the TARGET_CALCS TAB.

% of Total Transect Flow by Day. Columns U...Z:
These columns are used in the Distribution PM.
Computes fraction of transect flow that passes through each transect as compared to total transect flow on a daily basis. This is used in the distribution performance measure for comparison of target distribution patterns.

Daily % of Annual Total transect flow. Columns AA..AF:
These columns are used in the Timing PM.
Computes fraction of cummulative flow that has occurred relative to total annual flow for each transect and in column AF the same calculation for all transect flow. This is used in timing performance measure. The IF statement is used to ensure proper calculation in case where there is no daily flow (protects against division by zero errors.)

Difference in Daily CFS. Columns AH..AM:
These columns are NOT used in the PM Calculations but are used in the Graphs.
Calculates difference in daily flow (cfs) between target and alternative flow records located in columns C..H in the ALT_CALCS and TARGET_CALCS TABS.

Difference in Accumulated AF. Columns AN..AS
These Columns are not used in the PM Calculations but are used in Graphs.
Calculates difference in daily flow (a-f) between target and alternative flow records located in columns I...N in the ALT_CALCS and TARGET_CALCS TABS.

Difference in Daily % of Total Transect Flow. Columns AT...AY
These columns are used in the Distribution PM calculations.
The absolute sum of differences between target and alternative percent of total water distributed to an individual transect (in this case transect TA-1) is used here as the measure of agreement between the alternative and the target flow distribution patterns.
On daily basis, difference in percent of total transect flow accorded each transect is computed by subtracting target % of total transect flow (Column U..Z in Target_Calcs) from alternative % of total transect flow (Columns U..Z in Alt_Calcs).
Rows 22 through 24 are where sums of absolute difference from target condition are calculated.

Difference in % of Annual Total. Columns AZ..BE:
These columns are used in the Timing PM calculations.
On daily basis, difference in percent of a single transects accumulated flow is computed by subtracting target % of transect flow (Columns AA..AF in Transect_Calcs) from alternative

% of transect flow (Columns AA:AF in Alt_Calcs).
Rows 22 through 24 are where sums of absolute difference from target condition are calculated.
The absolute sum of differences between target and alternative percent of timing of flows for a given transect (in this case transect TA-1) is used here as the measure of agreement in flow timing between the alternative and the target condition.

Alternative, Sorted Difference in 7-day/Avg Q. Columns BF..BK:
These columns are not used in the PM Calculations but in preparing exceedance graphs.
Data in these columns are copied from columns O..T and sorted from low to high. The copy / paste /sort actions are accomplished using a keystroke macro activated in the DATA_SETUP TAB.

Target, Sorted Difference in 7-day/Avg Q. Columns BL..BQ:
These columns are not used in the PM Calculations but in preparing exceedance graphs.
Data in these columns are copied from columns O..T and sorted from low to high. The copy / paste /sort actions are accomplished using a keystroke macro activated in the DATA_SETUP TAB.

Overall Calculations

Timing Index: Range AA19..AF21:
These cells contain the final results for the timing measure for each transect, each year, and for all transects.
The overall result:

Timing Index = (TSDF- DDF) / TSDF
where:
TSDF = Target Sum of Daily Flow Fraction
TSDF = Σ (Target Daily Fraction of Annual Flow) (computed in Columns AA..AF in Target_Calcs)
The results of this function range from 1 (all flow on last day of year) to 365, all flow on first day of year.

DDF = Differences in Daily Flow Fraction (Alternative - Target)
DDF = Σ(Absolute Daily Difference between Target and Alternative Fraction of Annual Flow) (computed in columns AZ...BE)
The results of this function range from 0 (complete match with Target condition) to up to 365 (no match at all with Target condition).

Distribution Index: Range U19..Z21:
These cells contain the final results for the timing measure for each transect, each year, and for all transects.
The overall result:

Distribution Index = (DFTF- DDFF) / DFTF
where:
DFTF = Daily Fraction of Target Total Transect Flow
DFTF = Σ (Target Daily Fraction of transect Flow) (computed in Columns U..Z in Target_Calcs)
The results of this function range from 0 (No flow to this transect) to 365, all flow occurs in this transect.

DDFF = Daily Difference in Flow Fraction by Transect
DDFF = -Σ(Absolute Daily Difference between Target and Alternative Fraction of Total Transect Flow) (computed in columns AT...AY)
The results of this function range from 0 (complete match with Target condition) to up to 365 (no match at all with Target condition).

TARGET_CALCS

The data and calculations in this TAB are for the TARGET condition (NSM). The calculations are identical to many of those performed in the ALT_CALCS TAB.

Calculation Ranges

Daily CFS: Columns C..H:
Accumulated AF: Columns I..N:
Difference in 7-DayAve Q: Columns O...T:
% of Total Transect Flow by Day: Columns U...Z:
Daily % of Annual Total transect flow: Columns AA..AF:

The calculated data in these ranges are compared to the equivalent results for Alternative datasets.

OUTPUT_SUMMARY TAB

This page contains graphics showing flow hydrographs, flow timing, and distribution.

Top Left Graph: Volume Hydrograph: This graph uses flow data in Columns I..N of the Alt_Calcs tab.
Top Middle Graph: Timing: Percent of Annual Discharge. Uses data in columns AA..AF.
Top Right Graph: Distribution: Percent of total transect flow per day. Used data in columns U..Z of Alt_Calcs.
Bottom Left Graph: Volume: Deviation from target. Graph shows difference between Alt and Target Flows. Uses data in columns AN..AS.
Bottom Middle Graph: Timing: Difference in % of annual total flow. Uses data in columns AZ..BE of Alt_Calcs.
Bottom Right Graph: Distribution: Difference in % of total transect discharge. Uses columns AT..AX.

Output Summary: Range AE19..AH21. Contains the timing and distribution index results for TS (Taylor Slough) and all transects. Only columns AE and AF for Taylor Slough are used in final Matrix Summary report.
The output summary index values are used in the Matrix Summary spreadsheet to compute final hydrologic benefit numbers.

Flow Summary: Range A21..I24. This contains the total annual flow for Transect TA-1, and the sum of all transects for each simulated year. The purpose is to show the difference in total flows between the alternative and the target conditions.

PM 2.4 SALINITY SPREADSHEET DOCUMENTATION

MODEL DOCUMENTATION

VBA MACROS

There are five Visual Basic for Applications (VBA) macros in this spreadsheet. Annotation in the macros themselves provide the documentation. The module number and name is provided below:

Module 1: Salinity Calc Subroutine (calculates salinities based on input data and equations.)
Module 2: ChartToDocument Subroutine (copies graphs to document. Not used.)
Module 3: AutoCalcOff Subroutine (turns of auto recalculation to speed macro.)
Module 4: ImportData Subroutine. Connected to button on FILESETUP TAB. It imports data into spreadsheet.
Module 5: Blank. No VBA code
Module 6: Q subroutine. (turns on auto recalculation).
Module 7: Summary_Calcs subroutine. This is connected to a button on the OUTPUT_SUMMARY TAB. This subroutine steps through the embayments and copies data for input to the Matrix spdsht.

INPUT FILE FORMAT

This spreadsheet is intended to be used with MODBRANCH output that has been specifically formatted for importing into the worksheet pages. The input files must be CSV files with six columns of data. The first row of data is the header line. The field names are: Time, P37, CP, EPGW, R127, and EVER1. Rows 2 through 366 contain the stage results for the simulation year for each GW monitoring station. Note that the provided MODBRANCH GW stage output files might need to be reformated to place the GW station data in the correct field. Also, check to see if the simulation duration is 365 days or 395 days. If its 395 days, then the first 30 days of spin-up period results have to be deleted.

The input files should be placed in a folder that can be properly referenced on the FileSetup tab.

OPERATING SPREADSHEET

The spreadsheet includes an automated keystroke macro that is invoked by clicking on the button located on the FILESETUP TAB. This macro imports pre-processed MODBRANCH data, places it in the appropriate tab, then calculates salinities based upon pre-programmed regression equations. The spreadsheet includes a macro button to tab through the salinity results for each of the nearshore embayments. The overall results are found on the scoring page. The final results from this PM are manually transferred to the Matrix summary spreadsheet.

NOTE: BEFORE OPERATING THE SPREADSHEET, BE SURE TO MAKE THE ACTIVE FILE DIRECTORY THE SAME AS THE LOCATION WHERE THE INPUT FILES ARE. DO THIS BY OPENING AN INPUT DATAFILE THEN CLOSING IT. (IF THIS IS NOT DONE, MACRO CANNOT FIND THE INPUT FILES).

A description of each TAB follows.

FILESETUP TAB

This tab contains calculation settings and file directory information necessary to input stage data and compute salinities using regression equations that relate stage to salinity. Documentation of the input cell locations and operating instructions are provided within the tab itself.

NSM TAB

This tab contains the stage and computed salinities for the target condition. These data are used as the basis of comparison. The data is imported by the INPORTDATA macro which also invokes the SALINITYCALCS macro to compute salinities. The regression equations used in the SalinityCalcs macro were developed by Eric Stabenau of

the Everglades National Park research staff.

Revised Regression Equations provided by Eric Stabenau, Phd (ENP)
in October 2009 by Mark Shafer
Period of Record 1996-2008. GW Stations: P37, EVER1. Stations Chosen because they are not directly adjacent to canals.

TAYLOR RIVER SALINITY
(TR_salinity) = -14.152(P37_stage) + 28.928 R-squared = 0.4828
LONG SOUND SALINITY
(LS_salinity) = 0.6021(TR_salinity) + 14.961 R-squared = 0.5875
LITTLE MADIERA BAY SALINITY
(LM_salinity) = 0.5102(TR_salinity) + 18.886 R-squared = 0.6037
JOE BAY SALINITY BASED ON TAYLOR CREEK SALINITY STATION
(TC_salinity) = 0.6681(TR_salinity) + 13.826 R-squared = 0.5435
MANATEE BAY SALINITY BASED ON BISC02 STATION
(BISC02_salinity) = -1.4775(EVER1_stage) + 40.554 R-squared = 0.1624
MIDDLE KEY SALINITY BASED ON BISC06 STATION
(BISC06_salinity) = -10.28(EVER1_stage) + 47.274 R-squared = 0.4775
BARNES SOUND SALINITY
(BS_salinity) = -6.3930(EVER1_stage) + 39.713 R-squared = 0.1723

WO
FutureWQ
Alt1
Alt2
Alt3
Alt4
Alt5
Alt6

These tabs contain the imported stage data and computed salinities for the with/without project alternatives. These datasets are compared against the NSM (target) dataset in the SALINITIES TAB.

Range: A1..F1096: This contains the imported stage data for the three years of simulation for the given alternative. The name of the alternative is copied from the datafile into cell G1.

Range: K1...Q1096: This contains the computed salinity data generated by the data import/salinityCalc macro that is invoked by hitting the button in the FILESETUP TAB. Column K, which is unlabeled contains the computed Taylor River salinity. Under high stage conditions where computed salinity is less than 1 ppt, the SalinityCalc macro sets Taylor River to 1.001.

Range: G2..G4: This contains the file name extracted from the input datafiles as well as the file name referenced in the FILESETUP TAB. This should be used as a manual check to see if the data files are copied from the proper MODBRANCH output files.

SALINITIES TAB

This TAB is where the daily difference between NSM (target) salinities and the alternative salinities are computed. To save computation space, differences for each embayment are calculated on at a time. The OFFSET function is used in conjunction with a macro slider bar that steps through each of the seven embayments to reference the correct column within each of the data/salinity tabs.

Range: A4..A1096: Columns containing Year and day of year. Not used in Calcs but in Graphs
Cell: C1. Location of offset value used in OFFSET Functions.
Range: C4..K1096: Salinities for each alternative. These are extracted from the data/salinity tabs using the offset function. The OFFSET Function for each equation in this cell references the J column of the data/salinity tabs. The offset value which is controlled by the slider button in the OUTPUT_SUMMARY TAB. The offset value is located in the SALINITIES TAB in cell C1.

The spreadsheet uses the OFFSET function to grab these salinity values as a method of minimizing calculations.

SCORING TAB

This tab is where the salinity results are parsed into salinity bins by duration of occurrence. The data for these calculations are referenced from the SALINITIES TAB which is controlled by the slider button in the OUTPUT Summary TAB. There are 10 salinity ranges used (0 to 5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, 25 to 30, 30 to 35, 35 to 40, 40 to 45, and 45 to infinity.) The salinity bin calculations for 1978 are located in rows 2 through 12. For 1988 they are in rows 15 through 25. For 1996 they are in rows 28 through 38.

Columns A...B. These columns define the salinity range evaluate in each row.

Columns C...K: These columns count the number of days in which the salinity is within the given range. These cells use the COUNTIF Function to count the number of occurances where salinity is less than the maximim range referenced for that salinity bin and then subtracts the total count of occurances for salinity in lower range bins.

Columns L..T: These columns contain the difference in salinity bin occurrences as measured agains NSM (target) salinity duration distributions. The equations are set to take a given alternatives salinity bin result and subtract the equivalent NSM salinity bin result (located in Column C).

Columns V..D: These columns contain the percent of time that salinity is within a given range. The percent of time is calculated as the number of days salinity is within a given range (columns C..K) divided by 365 (duration of year).

Columns AE...AM: These columns contain the percent of time that a with project alternative differs from the NSM (target) in terms of number of days that salinity is within a particular range (salinity bin). The percentage of time is calculated as number of days different from NSM (calculated in columns C..K) divided by the total number of days in a year (365). The ability to adjust values by weighting the differences by salinity bin is included by incorporation of a "Penalty Multiplier" factor for each salinity Bin. The PDT determined that equal weights was preferable so each multiplier is set to 1 as a default.

Range A41..C53: Penalty Multiplier factors. These allow the user to apply different weights to deviations in critical salinity bin ranges. The PDT played with these factors but determined that it was not useful so set each multiplier to 1.

Columns AN..AV: These columns contain the summary calculations for each simulation year. The overall degree of salinity match between the NSM (target) condition and the project alternatives is calculated by subtracting the absolute sum of differences in salinity bin distribution (columns AE..AM) from 1. (The equation is a bit more complicated than this since it sums up the salinity bin fractions for NSM (in column V) and subtracts the absolute sum from this and then divides by the sum of salinity bin fractions for NSM. This was done to ensure that simulation periods other than 365 days would not result in calculation error.

The numbers located in RANGES AN3..AV3, AN16..AV16, and AN29..AV29 are reported in rows 6, 7, and 8 of the OUTPUT_SUMMARY TAB for each of the embayments as the scroll-tab button is moved from one end to the other.

Note a copy of the scroll-tab button is located in this TAB. It is linked to all other scroll-tabs in the spreadsheet.

OUTPUT_SUMMARY TAB

This tab contains the final output results in terms of relative (from 0 to 1) match of a given alternative to the NSM (target) condition. Output for each of the embayments (Barnes Sound to Taylor Slough) is calculated automatically and temporarily stored in rows 5, 6, 7, and 8 of this TAB as the scroll tool is used.

The "Compute Summary Output" is connected to an automated keystrock macro that steps through the calculations for each embayment that is used in the Matrix Summary Spreadsheet. This data is normally copied manually between the two spreadsheets.

SALINITY_GRAPHS TAB

This tab contains graphics of the salinity records for each of the embayments. The graphs are controlled using a copy of the scroll-tab button.

PM2.1 VEGETATION HYDROPERIOD SPREADSHEET DOCUMENTATION

DOCUMENTATION: THIS PROVIDES SOME INFORMATION ON THE SPREADSHEET LAYOUT AND USE.

General Information. Data is input into this spreadsheet manually from post-processed MODBRANCH files. The final result is found in the INDEX_SUMMARY TAB. The final result is copy and pasted to the Matrix Summary spreadsheet and combined with the results from the other two PMs.
TAB descriptions are color coded.
OPERATING INSTRUCTIONS: This spreadsheet is intended for use by C-111SC project team members.
The user should consult with the spreadsheet developers for help to ensure that the spreadsheets are properly operated. Generally, the user should copy/paste new MODBRANCH output into the appropriate cell ranges. Calculations are automated with no need to invoke a macro or other static program.

Contact
Contact: Mark Shafer (904) 232-3594 mark.d.shafer@usace.army.mil

OVERALL EXPLANATION OF CALCUATIONS:
The critical assumption for this PM is that target condition hydroperiods are preferred and that the degree of matching with the target condition is an appropriate measure of the desireability of the alternative that provides that result.

The spreadsheet calculates the degree to which simulated hydroperiod patterns match the target condition as defined by Natural System Model Hydrology (MODBRANCH version calculated using SFWMD2x2 NSM v4.2 boundary conditions.). The degree of hydroperiod match is calculated by comparing the percent of total area inundated for 12 different hydroperiod durations for a given alternative to the NSM hydroperiod duration coverage pattern (for each indicator region). The absolute sum of differences is computed across the hydroperiod bins and reported degree of hydroperiod pattern match for each indicator region is computed as 1 minus the absolute sum of differences. Where the absolute sum of differences exceeds 1, the degree of match is set to zero (this provides logical bounds for degree of hydroperiod match.)

The overall result for a given alternative is computed by taking the average of all of the indicator regions for a given simulation year and alternative. The result is area weighted.

DATA TAB
This tab contains the output dataset for vegetation hydroperiod from MOBRANCH for every model run.
DATA IN THIS TAB IS MANUALLY COPIED INTO THE SPREADSHEET. (Originally, a macro was used but this is no longer the case.)

Column A: Contains names of the sub-region for each row of data. See map of sub-regions.

Column B: Contains acreage of each of the sub-reaches for each row of data.

Column C through Q: Each column contains fraction of area experiencing a given hydroperiod duration. The hydroperiod duration is in top row of each output dataset (rows 3, 20, 57 etc.)

Rows 3 through 78: Contains the NSM output for the three simulated years.
1978 output: Rows 3 through 24
1989 output: Rows 3 through 51
1995 output: Rows 57 through 78.

Rows 82 through 786

Contains vegetation hydroperiod output from the With / Without project alternatives

Table D-1. Starting Row of Each Output Dataset by Simulation Year

Alternative	Starting Row		
	1978	1986	1995
FWO	85	112	139
1C	166	193	220
1D	247	274	301
2DL	328	355	382
2DS	409	436	463
3D	490	517	544
6D	571	598	625
ECB	652	679	706

COMPUTATIONS TAB

Column A: Dry Acreage as fraction of area of a given indicator sub-region.
Computation of fraction of acreage in each indicator sub-region that is never wet (zero hydroperiod). This is computed by summing the total fraction of acreage in columns F through Q in the DATA TAB. These columns correspond to all 12 separable hydroperiod duration bins (0-30, 30-60, 60-90, 90-120, 12-150, 150-180, 180-210, 210-240, 240-270, 270-300, 300-330, 330-360). Columns C, D, E of DATA TAB are not used in this computation. The equations in Column A are set up using IF statements to ensure that a negative result is not calculated.

Column B: Blank.

Column C: Name of the indicator sub-region. Computed using direct reference to cells in DATA TAB.

Column D: Acreage of the total area in each indicator sub-region. Computed using direct reference to cells in DATA TAB.

Column E: Difference between fraction acreage with zero hydroperiod under alternative condition and equivalent NSM condition. Note that in this case, "DRY" acreage fraction is computed in Column A.

Column F-Q: Difference between NSM and equivalent alternative in fraction of acreage for each of the 12 hydroperiod duration bins.
Calculated by subtracting NSM result from equivalent alternative for each indicator sub-region and each hydroperiod duration bins.

Column S: Sum of absolute differences between NSM and equivalent alterntive for each indicator sub-region.

Column T: Degree of agreement between NSM and equivalent alternative for each indicator sub-region.
Calculated as 1 minus sum of absolute differences (Column S). Equation ensures no negative results by setting the result to zero when the Column T exceeds 1. This means that degree of agreement with NSM is bounded between zero (indicating no agreement) and 1 (indicating complete agreement).

HYDROPERIOD_SUMMARY TAB

This tab contains graphical representations of the vegetation hydroperiod data. One graph for each of the three simulated years is provided. The arrow buttons (located at cells A39, A44, are used to tab through each of the indicator sub-regions. These arrow buttons are linked to arrow buttons in the INDEX_SUMMARY and GRAPHICS tabs.

Interpretation of the graphs: The length of each individual color corresponds to the fraction of acreage meeting a particular hydroperiod duration. The hydroperiod duration results are ordered from the shorted hydroperiod (dry) to the wettest (330-360 days). For instance, for indicator sub-region 6C, the 1989 results show that for NSM the fraction of acreage that is never wet is approximately 65%. The fraction of acreage for this indicator region with hydroperiod 330-360 days is 12 % for NSM for 1989.

INDEX, SUMMARY

Range: A1..K11 - Summary Results by Indicator Region. Graph shows results by sub-indicator region for each alternative by simulated year, as well as an average of the three years (weighted if desired).

Range D8..K10. Indicator region results for each alternative and year. Calculated using OFFSET function, with row offset equal to button counter (Cell B8) and reference cell equal to the row/column of indicator 2A results for each of the model year result datasets. The weighting factors (B4, B5, B6) allow user to apply unequal weights to the three simulated years. (They are set to 1 as default.)

Range D11-K11: Average results for a given indicator region. Weighting is normalized using cell B7 which is computed as sum of individual weights in B4, B5, and B6.

Range: A13..L35. Results from Average year (1978) simulations for each alternative for each indicator region.
A40..L62. Results from Dry year (1989)
A67..L84. Results from Wet year (1995)
These three ranges are formatted such that results in column A through K are shown in green if the they are greater than or equal to the value in column L (maximum of all future conditions (excludes ECB since it is an existing condition.). If the result in each cell is less than the maximum it is shown in black. The purpose of this formatting convention is allow the user to determine if there is any one alternative that stands out from the pack.

Column A: Indicator region name (hard coded)
Column B: total acreage by indicator region (hard coded)
Column C: Percent Match with NSM (compared to NSM). This is a check of the equations. 100% indicates that the equations are comparing the correct NSM indicator region against itself. Since the underlying equations in the COMPUTATIONS tab have fixed and relative cell references, when they are copied, they reference the correct cells. If this column does not indicate 100% then the equations are not correct. (This is a quality control feature.)
Column D: Results from column T in COMPUTATIONS TAB are referenced here for the three simulated years for the 6D alternative.
Column E: FWO results from column T in COMPUTATIONS TAB.
Column F: 1C results from column T in COMPUTATIONS TAB.
Column G: 1D results from column T in COMPUTATIONS TAB.
Column H: 2DL results from column T in COMPUTATIONS TAB.
Column I: 2DS results from column T in COMPUTATIONS TAB.
Column J: 3D results from column T in COMPUTATIONS TAB.
Column K: ECB results from column T in COMPUTATIONS TAB.
Column L: Computation of maximum result by indicator region for future project conditions (excludes ECB).

Range: A13..K35 Overall Result Calculation for each Alternative for the average year 1978.
Calculated as the average of all of the indicator regions. This is not weighted by area.
Similar calculations are found in A40..k40 for 1989 year and in A67 for 1995 year.

Range: D92..K94 OVERALL REPORTED RESULTS FOR THIS PM.
Results are simply referenced from lines 13, 40, and 67.

Range: D101...H110 THIS TABLE CONTAINS THE FINAL RESULTS THAT ARE REFERENCED IN THE MATRIX SPREADSHEET.

GRAPHICS TAB

This tab contains the same graphs as included in HYDROPERIOD_SUMMARY and INDEX_SUMMARY TABS. The purpose of this tab is to facilitate easy printing of graphics in one figure. This tab is not used in the benefits calculations.

APPENDIX D
REAL ESTATE

TABLE OF CONTENTS

D.0 REAL ESTATE D-1
D.1 SCOPE OF THIS REPORT D-1
D.2 STATEMENT OF PURPOSE OF THE REAL ESTATE PLAN D-1
D.3 DESCRIPTION OF PRIOR REP PREPARED FOR THE PROJECT D-1
D.4 PROJECT AUTHORIZATION D-1
D.5 PROJECT LOCATION AND DESCRIPTION OF THE RECOMMENDED PLAN ELEMENTS D-2
D.6 DESCRIPTION OF REAL ESTATE REQUIRED FOR PROJECT LERRD D-7
D.7 EXISTING FEDERAL PROJECTS D-11
D.8 FEDERALLY OWNED LANDS D-11
D.9 NON-FEDERAL SPONSOR OWNED LANDS AND CREDITING D-11
D.9.1 Frog Pond D-11
D.9.2 Southern Glades D-11
D.10 CREDITING CONSIDERATIONS: D-12
D.11 UNIFORM RELOCATION ASSISTANCE ACT, PUBLIC LAW 91-646 ..... D-13
D.12 NAVIGATIONAL SERVITUDE AND OTHER LANDS D-13
D.13 INDUCED FLOODING D-13
D.14 MINERAL AND TIMBER ACTIVITIES D-18
D.15 NON-FEDERAL AUTHORITY TO PARTICIPATE IN THE PROJECT D-18
D.16 ESTATE ANALYSIS D-20
D.16.1 Estates Required for Comprehensive Everglades Restoration Plan Projects D-20
D.17 PROPOSED ESTATES D-23
D.18 ZONING ORDINANCES D-24
D.19 ACQUISITION SCHEDULES D-24
D.20 HAZARDOUS, TOXIC OR RADIOLOGICAL WASTE (HTRW) D-25
D.21 CULTURAL RESOURCES D-25
D.22 RECREATIONAL USE OF PROJECT FEATURES D-26
D.23 PROJECT SUPPORT D-26
D.24 BASELINE COST ESTIMATE D-26
D.25 REAL ESTATE MAPS D-29
D.26 EXHIBITS D-30
D.26.1 Exhibit "A" D-30
D.26.2 Exhibit "B" D-54

LIST OF TABLES

Table D-1 Main Project Features D-10
Table D-2 Baseline Cost Estimate D-28
Table D-3 Mcases Cost Estimate D-29

LIST OF FIGURES

Figure D-1 Project Area D-6
Figure D-2 Recreation Features D-8
Figure D-3 Project Map and Impacted Lands D-17
Figure D-4 Project Map D-30

D.0 REAL ESTATE

D.1 SCOPE OF THIS REPORT

The scope of this real estate plan for the Project Implementation Report (PIR) identifies the land, easements, rights of way, relocations, borrow and disposal (LERRD) issues and status of real estate activities for the Recommended Plan. The information presented in this appendix is based on available information provided by the Project Delivery Team (PDT) members. It presents an estimate of the project LERRD requirements and a description of the nature and scope of the non-Federal sponsor's responsibility and estimate of the LERRD. The information presented in this report is tentative in nature and will be addressed more fully upon receipt of the final engineering design drawings, and other relevant information required for determining the full scope of the real estate requirements and needs for the project.

D.2 STATEMENT OF PURPOSE OF THE REAL ESTATE PLAN

The Real Estate Plan (REP) completed for the PIR is to estimate the overall real estate requirements, costs, acquisition schedules, and other real estate requirements necessary for the Central and Southern Florida (C&SF), Comprehensive Everglades Restoration Plan (CERP), C-111 Spreader Canal (C-111 SC) project, as required by ER 405-1-12, Chapter 12.

D.3 DESCRIPTION OF PRIOR REP PREPARED FOR THE PROJECT

The C-111 SC project was discussed in the C&SF project, Comprehensive Review Study (Yellow Book/Restudy), Appendix "F," Real Estate Plan; dated April 1999, as Component WW5. In addition, other areas of discussion are in Sections 9.1.8.26, C-111N Spreader Canal (WW5) and Section 10.6.2.7, C-111N Spreader Canal of Volume 1 of the "Yellow Book/Restudy." The letter "N" has been dropped from further use. The Yellow Book/Restudy comprises ten volumes and is the document that was the basis for the authorized CERP.

D.4 PROJECT AUTHORIZATION

The authority for this project is contained within the Water Resources Development Act (WRDA) 2000. (Copy provided as Exhibit A). The "Design Agreement between the Department of the Army and the South Florida Water Management District (SFWMD) for the Design of Elements of the Comprehensive Plan for the Everglades and South Florida Ecosystem Restoration Project" contains additional guidance.

The WRDA of 2000 provides guidance and authority for implementing the CERP. Section 601, of the Act states:

(b) CERP -

(1) APPROVAL

(A) IN GENERAL.—Except as modified by this section, the Plan is approved as a framework for modifications and operational changes to the C&SF Project that are needed to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection. The Plan shall be implemented to ensure the protection of water quality in, the reduction of the loss of fresh water from, and the improvement of the environment of the South Florida ecosystem and to achieve and maintain the benefits to the natural system and human environment described in the Plan, and required pursuant to this section, for as long as the project is authorized.

(c) ADDITIONAL PROGRAM AUTHORITY -

(1) IN GENERAL - *To expedite implementation of the Plan, the Secretary may implement modifications to the Central and Southern Florida Project that--*

(A) *are described in the Plan; and*

(B) *will produce a substantial benefit to the restoration, preservation and protection of the South Florida ecosystem.*

(2) PROJECT IMPLEMENTATION REPORTS - *Before implementation of any project feature authorized under this subsection, the Secretary shall review and approve for the project feature a project implementation report prepared in accordance with subsections (f) and (h).*

(d) AUTHORIZATION OF FUTURE PROJECTS -

(1) IN GENERAL- *Except for a project authorized by subsection (b) or (c), any project included in the Plan shall require a specific authorization by Congress.*

(2) SUBMISSION OF REPORT - *Before seeking congressional authorization for a project under paragraph (1), the Secretary shall submit to Congress--*

(A) *a description of the project; and*

(B) *a project implementation report for the project prepared in accordance with subsections (f) and (h).*

D.5 PROJECT LOCATION AND DESCRIPTION OF THE RECOMMENDED PLAN ELEMENTS

Project Location–The C-111 SC project area (See ***FIGURE D-1***) is approximately 40 - 45 miles southwest from downtown Miami, Miami-Dade County, Florida. It is the southernmost canal of the C&SF Flood Control Project and serves a basin of approximately 100 square miles primarily to provide flood protection and drainage for the agricultural areas to the west and south of the city of Homestead, Florida. Part of the C-111 SC project area falls within South Dade Wetlands, which includes the Model Lands and the Southern Glades lands. The western portion of the Model Lands is made up of the wetlands in the north

C-111 Basin, located adjacent to the C-111 Canal, east of Everglades National Park (ENP), west of U.S. Highway 1, north of Southwest 424th Street and south of State Road (SR) 9336, with the exception of active agricultural land. The eastern portion of the Model Lands includes the wetlands south of Southwest 344th Street (Palm Drive), east of U.S. Highway 1, and south to Biscayne Bay, Card Sound and Barnes Sound.

The Southern Glades region is bounded by ENP to the south and west, U.S. Highway 1 to the east, and the Model Lands to the north except for the far western edge, west of C-111E, that extends further north to the boundary of the Frog Pond.

RECOMMENDED PLAN ELEMENTS

The C-111 SC Western Project Recommended Plan is Alternative 2D Short (2DS) and includes the following features:

- Frog Pond Detention Area
- Aerojet Road Canal
- One New Operable Structure in the Lower C-111 Canal
- Incremental Operational Changes at S-18C
- One Plug at S-20A
- Operational Change at Existing Structure S-20A
- Ten Plugs in the C-110 Canal Plugs

The Frog Pond Detention Area and Aerojet Road Canal feature are intended to work in unison to create an approximately nine-mile hydraulic ridge. The ridge will serve to block groundwater flows from moving into the C-111 Canal, therefore retaining water in Taylor Slough and improving the quantity, timing, and duration of flows into Florida Bay. The remaining features of the Recommended Plan will serve to provide a jumpstart to environmental restoration in the Southern Glades and Model Lands.

FROG POND DETENTION AREA

As currently envisioned, water that otherwise would be discharged via S-177 is routed to the proposed above ground, 590 acre Frog Pond Detention Area (FPDA) via a proposed S-200 pump station (225 cfs) to be constructed downstream of S-176. The FPDA is designed to meet the requirements of a Low Hazard Potential Facility. The perimeter containment levee has an elevation of +9.0 feet NAVD88. The average height above existing ground elevation is about 5.5 feet. The S-200 pump station, which will trigger at stages slightly lower than S-177's current open criteria [Interim Operational Plan (IOP)] will discharge to a concrete-lined, aboveground, conveyance channel, that discharges

to an aboveground, cascading header channel located along the western side of the proposed aboveground FPDA.

The cascading header channel will assist in prevention of seepage losses from Taylor Slough and will ensure that available water is staged higher prior to discharge into one of three individual cells within FPDA. Cascading water levels will be maintained by constructing two 80-foot long east-west weirs at 1/3 points along the length of the header canal. The weir crest elevations are set to be 0.5 ft above existing ground elevation.

Just upstream of the two header weirs and just upstream of the southern levee of the southern detention area cell, 80-foot long north-south weirs will be constructed between the header canal and FPDA cells. The weirs crest elevations are set to be 1.2 ft above existing ground elevation.

Note: Planning level design of the FPDA was established at 530 acres for alternative comparison purposes. The size of the FPDA has increased to 590 acres after preliminary detailed modeling and design.

AEROJET CANAL

Similar to the FPDA, water that otherwise would be discharged via S-177 is routed to the Aerojet Road Canal that is proposed to be extended several thousand feet to the north. The northern limit of the existing Aerojet Canal presently lies approximately one mile south of Ingraham Highway. Although plugged at various locations, its overall length currently extends a distance of approximately 4.6 miles. It is proposed to effectively extend the northern limit of the canal to a point approximately 2,300 feet south of State Road (SR) 9336 as an unlined above ground open channel, to construct a concrete-lined above ground channel between the northern canal extension and S-199, construct perimeter grading around all unlined portions of the canal north of the east-west borrow canal, construct a new earthen weir with crest elevation 1.0 foot below adjacent natural ground, and convert all existing plugs over that same length to similar weirs. A second, S-199 pump station (225 cfs), will have the same triggers as S-200 and will be constructed immediately upstream of S-177 (downstream of State Road 9336). S-199 will discharge into a concrete-lined, aboveground channel which will be constructed parallel to (south of) SR 9336. The conveyance channel will, in turn, discharge to an above ground, unlined, northern extension of the Aerojet Canal.

The intent of the Aerojet Road Canal features is to extend the hydraulic ridge created by the FPDA south of SR 9336, thus reducing Taylor Slough seepage from what is reportedly the leakiest section of the C-111 Canal system. The reduction of seepage losses keeps water within the natural system, increasing

project benefits. Similar to the FPDA header canal, cascading water levels will be maintained within the Aerojet Road Canal by converting 3 existing earthen plugs to broad crested weirs and construction of a new broad crested weir. The crest elevations will be 1 foot below adjacent existing grades, and the canal will include sufficient freeboard to prevent levee bank from being overtopped.

SECONDARY WATER CONTROL FEATURES:

ONE OPERABLE STRUCTURE IN THE LOWER C-111 CANAL

The plan also includes the construction of an operable structure within the lower C-111 Canal. The proposed structure is intended to create groundwater mounding, thereby reducing current levels of seepage from the lower C-111 Canal while preserving existing levels of flood damage reduction.

INCREMENTAL OPERATIONAL CHANGES AT S-18C

In order to maximize restoration opportunities, the plan includes incremental operational changes in the current "open and close" triggers at existing structure S-18C. The "open and close" triggers will be increased in increments of no more than 0.1-feet per year and the total change in either trigger shall not exceed 0.4-feet. Stage override triggers will be established immediately downstream of S-177 and/or in the adjacent agricultural lands to establish a "backstop" at which S-18C triggers will return to their existing levels. The incremental operational changes at S-18C will serve to supplement groundwater mounding in the lower C-111 area.

PLUG AT S-20A AND OPERATIONAL CHANGES AT S-20

The plan includes the construction of a permanent plug at existing structure S-20A in the L-31E Canal, and operational changes at existing structure S-20. The proposed plug near S-20A and proposed operational changes at S-20, specifically raising the "open and close" triggers to 0.5-feet, are intended to restore hydroperiods within the Model Land.

C-110 CANAL PLUGS

Finally, the plan includes construction of earthen plugs at key locations within the C-110 Canal in order to promote sheet flow within the Southern Glades. As currently envisioned, ten plugs will be constructed at semi-regular intervals by returning the existing spoil material from the canal banks to the canal. Any remaining spoil not utilized in construction of the plugs will be placed into the canal to further promote sheetflow and to lessen the effects of the of any remaining canal segments.

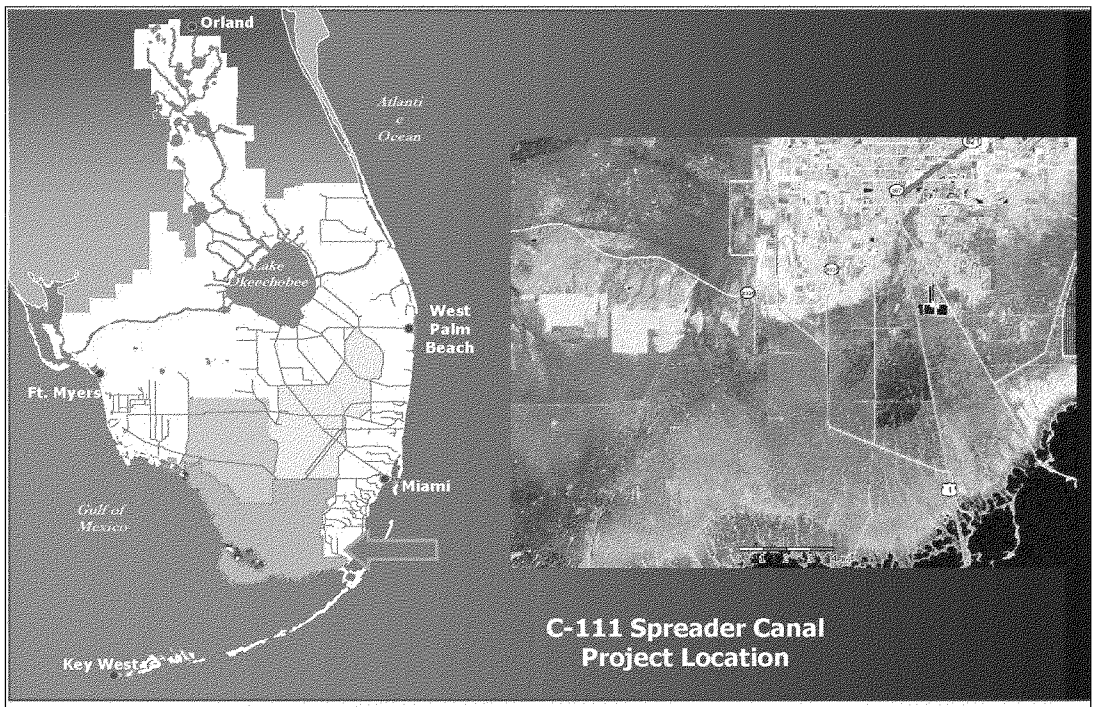


FIGURE D-1: PROJECT AREA

D.6 DESCRIPTION OF REAL ESTATE REQUIRED FOR PROJECT LERRD

Temporary Work Areas: All required temporary staging and stockpile areas would occur within the lands to be acquired or required for project purposes. Therefore, no additional lands are anticipated to be required for temporary purposes outside the footprint of the project lands.

Borrow and Disposal Sites: No off-site borrow or disposal sites will be required. It is anticipated that embankment construction materials will be generated from on-site excavations within the interior portion of the proposed footprint. It is also anticipated that excavated material from the construction project will be utilized for borrow material; therefore, no additional disposal material or borrow site is anticipated; however, if it is determined that the quantities of available fill material will not be sufficient, additional fill material may be obtained using offsite commercial sites. This additional material would be treated as a construction cost.

Access to the Project Area: No additional lands will be required for access, ingress and egress purposes. Ingress and egress would be via federal, state, municipal, county roads, and roads and SFWMD canal rights-of-way owned to the non-federal sponsor for project purposes.

Recreation Features: Proposed recreation facilities and activities would be ancillary to the proposed C-111 SC Western project and work harmoniously with project purposes. The proposed recreation components include: 1) a trailhead and parking, and 2) an impoundment cell multi-use trail. The levees will serve as raised trails. The proposed recreation would be developed within these components and their structures to provide restoration compatible recreation facilities and activities. The proposed project recreation facilities would help to fill four Statewide Comprehensive Outdoor Recreation Plan (SCORP) regional deficits and link with other regional recreation facilities. An example of this concept would be to link the proposed project component recreation sites via greenway or blueway to connect and extend points of destination with federal, state, county and private facilities. An international pool of visitors may be expected at the proposed project recreation facilities once developed.

No additional real estate would be required for the proposed recreation features since all proposed features would be located on project fee title lands. Credit for the lands where recreational features are located will be applied to the structural components of the project. ***FIGURE D-2*** shows the location of the of the recreation features.

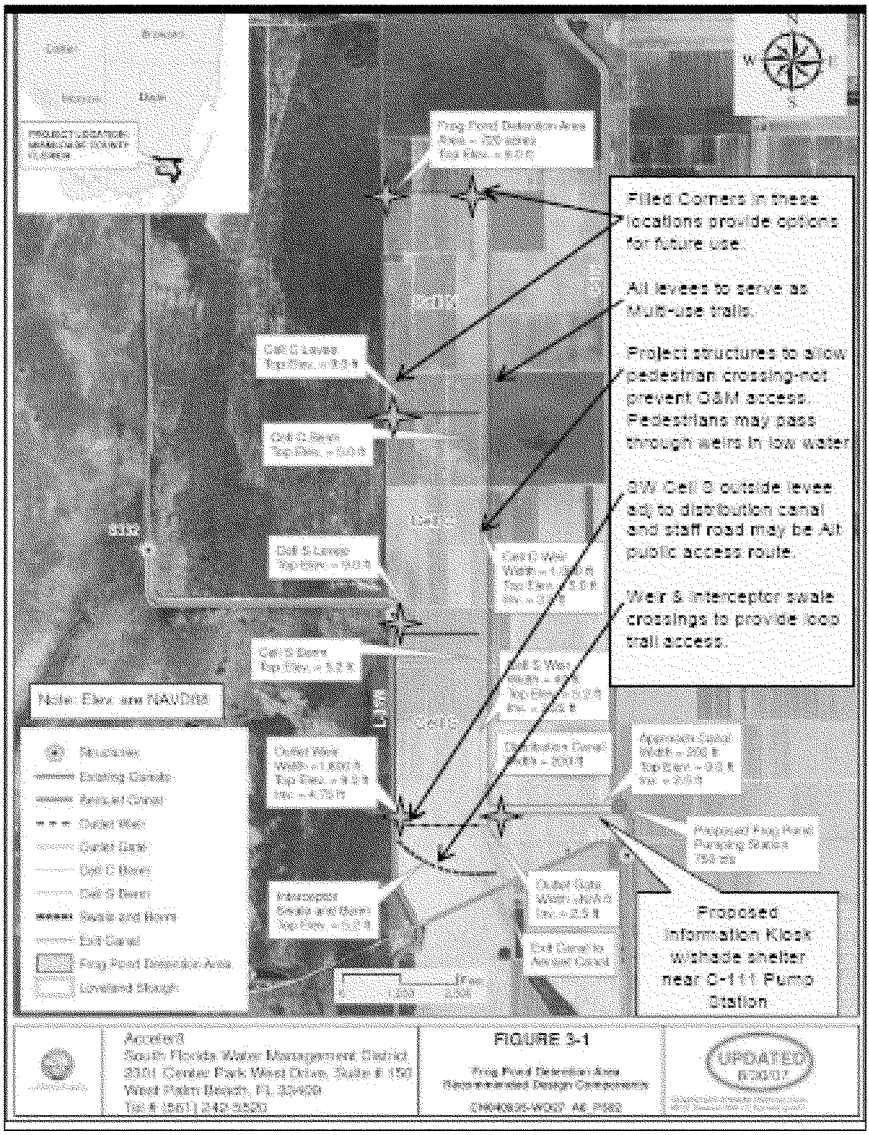


FIGURE D-2: RECREATION FEATURES

Facility, Utility Relocations:
There are electrical utilities that will require relocation along the west perimeter levee that will be constructed. These electrical lines are permitted to Florida Power and Light by the SFWMD and will be relocated at the expense of FP&L. The SFWMD permit requires the permittee FP&L to relocate the lines if the lands are required for a SFWMD or Corps Project. The Florida Power and Light (FP&L) Mitigation Bank and RMC Mitigation Area are both located within the proposed project area of the C-111 SC Western project area. Any possible hydrological effects that would occur within these lands as a result of the proposed project would be beneficial. Any increase hydroperiods in these lands would only serve to increase intended ecological functions. As such, no compensatory mitigation is proposed to offset any effects on the two mitigation areas as a result of the proposed project.

"ANY CONCLUSION OR CATEGORIZATION CONTAINED IN THIS REPORT THAT AN ITEM IS A UTILITY OR FACILITY RELOCATION TO BE PERFORMED BY THE NON-FEDERAL SPONSOR AS PART OF ITS LERRD RESPONSIBILITIES IS PRELIMINARY ONLY. THE GOVERNMENT WILL MAKE A FINAL DETERMIANATION OF THE RELOCATIONS NECESSARY FOR THE CONSTRUCTION, OPERATION, OR MAINTENANCE OF THE PROJECT AFTER FURTHER ANALYSIS AND COMPLETION AND APPROVAL OF THE FINAL ATTORNEY'S OPINIONS OF COMPENSABILITY FOR EACH OF THE IMPACTED UTILITIES AND FACILITIES."

TABLE D-1 shows the current acreage calculated as required for the Recommended Plan:

TABLE D-1: MAIN PROJECT FEATURES

Location	Component	ACRES	Real Estate Interest
Frog Pond Area - SFWMD owned	Frog Pond Detention Area (FPDA)	560	FEE
See Note 1 Below	Pump for FPDA (diesel)	0.5	FEE
	Pump for FPDA (electric)	0.5	FEE
	Berm for FPDA	22.84	FEE
	Canal from Pump to FPDA	6.54	FEE
Aerojet Area - SFWMD owned	Pump for Aerojet Canal on C-111 (diesel)	0.5	FEE
See Note 2 below	Pump for Aerojet Canal on C-111 (electric)	0.5	FEE
	Canal from Spillway to Aerojet Canal	6.2	FEE
	Berm for Aerojet Canal	11.16	FEE
Lower C-111- SFWMD owned	Water Control Structure (mimic S-197)	1	FEE
See Note 3 below	Second Water Control Structure (mimic S-197)	1	FEE
	Plug in L-31E at S-25A	0.5	FEE
Sub-Total		**611**	
OTHER:	**Impacted Lands**		
SFWMD Owned		9,688	FEE
Miami-Dade County		131	FEE - Supplemental Agreement
State of Florida		15	FEE - Supplemental Agreement
Florida Power & Light		955	Easement
Private Owners*		776	FEE
Sub-Total		**11,565**	
Total Project Footprint Proposed (ROUNDED UP)		**12,176**	

Note 1 Lands in the Frog Pond area are within the C-111 South Dade project
Note 2 Lands in the Aerojet Area required for these structures are within the Impacted Lands
Note 3 Lands in the Lower C-111 are within the right of way of the C&SF project

(*)The planning level modeling predicted approximately 776 remaining acres which are owned by private parties could be impacted by the operation of the project. SFWMD has agreed to acquire in fee privately owned lands which are jointly determined to be, or to have been, impacted by operation of the project.

For purposes of this report, only the impacted lands identified above at 11,564.65 acres are valued, since the lands within the Frog Pond will be

provided for the C-111 South Dade Project and other lands were provide for the Central and Southern Florida Project.

D.7 EXISTING FEDERAL PROJECTS

Currently the recommended plan contains approximately 590 acres within the Frog Pond area which were approved for acquisition under the C-111 South Dade project in the 1994 General Design Memorandum and will be provided as an item of local cooperation under that project. Additional lands required along the Lower C-111 Canal and the L31East Canal for water control structures and plugs are located within the current canal rights of way which were provided as an item of local cooperation for the C&SF project. These lands estimated at approximately 21 acres will also be made available for this project at no cost.

The proposed C-111 SC project is situated at the "end" of the Everglades, where the wetland system ceases overland flow and empties into Florida Bay and its associated estuarine environments. The C-111 SC project would only receive water from other CERP projects. The proposed project would not send water to any other systems nor would any other projects rely on it for operations.

D.8 FEDERALLY OWNED LANDS

There are no Federally owned lands within the Project footprint.

D.9 NON-FEDERAL SPONSOR OWNED LANDS AND CREDITING

The information below is assumed to be applicable to this project; however, upon further determination of Sponsor's land for the recommended plan, such information may be revised or deleted from the REP, as follows:

D.9.1 FROG POND

The Frog Pond acreage consisting of 5,215 acres, which was acquired by the SFWMD in April 1996. As these lands are part of the C-111 South Dade project, the 590 acres required for this project will be credited under the C-111 South Dade project.

D.9.2 SOUTHERN GLADES

SFWMD owns approximately 9,688 acres south of the Frog Pond area in the Southern Glades area which are within the lands impacted by the Project. Under current guidance set forth in paragraph D.11 below, SFWMD will receive credit for the fair market value at time of certification.

D.10 CREDITING CONSIDERATIONS:

This report takes into consideration for crediting purposes the Congressional Authority, the Programmatic Regulations, the draft Six Program-Wide Guidance Memoranda, dated July 2007.

The CERP Congressional Authority which reads, in part, that the non-federal sponsor will be responsible for all land, easements, rights-of-way, and relocations necessary to implement the Plan; and the Sponsor will be *afforded credit toward the non-Federal share of the cost of carrying out the project.* It also states that credit *"...will be afforded to the non-Federal Sponsor, regardless of the date of acquisition, the value of lands or interests in land acquired by non-Federal interests."*

In accordance with CECW-SAD memorandum dated July 30, 2009 signed by the Director of Civil Works, U.S. Army Corps of Engineers the current guidance for the CERP, Land Valuation and Crediting is as follows:

a. Consistent with long-standing USACE practice, and as supported by the unique land credit provision for CERP contained in Section 601 (e)(5)(A) of WRDA 2000, tracts acquired by the SFWMD that are acquired and provided in furtherance of a CERP project should be valued and credited as individual tracts regardless of whether the acquisition was prior to or after execution of the PPA for that project. This general principle would not apply where the SFWMD acquired contiguous tracts that are required for a CERP project but it acquired such tracts prior to the PPA for a reason and use other than for implementation of the CERP project. A determination that a tract was acquired "in furtherance of a CERP project" should be supported by documentation existing at the time of acquisition.

b. The unique statutory land credit provision for CERP projects is clear that the non-Federal sponsor will be afforded credit for the value of lands, or interests in lands, that it provides in accordance with a PIR "regardless of the date of acquisition." *See* Section 601 (e)(5)(A) of WRDA 2000. To effectuate the clear intent of Congress reflected in this credit provision, land use restrictions imposed in furtherance of a CERP project after acquisition of a tract by the SFWMD should not be considered in valuing that tract for crediting purposes.

c. For the same reasons as expressed in subparagraph b. above, demolition of improvements after a tract was acquired in furtherance of a CERP project should not change the approach to value from that applicable at the time of acquisition. Accordingly, the tract should be valued for crediting purposes as it was improved when acquired by the SFWMD. To accomplish this result, the contributory value of the improvements, as of the date of the SFWMD's acquisition, should be added to the market value of the land on the date it is provided for the project as appraised in accordance with its highest and best use on the date of acquisition.

3. Incidental Costs. The SFWMD has requested that it be afforded credit for the costs incurred by other non-Federal governmental entities incidental to acquisition of project lands by such entities. The wording of Section 601 (e)(5)(A) is clear that credit may be afforded only for "incidental costs for land acquired by a non-Federal sponsor." Credit may be afforded for traditional incidental acquisition costs that are incurred by SFWMD (such as appraisal costs, mapping costs, or relocation assistance benefits) as well as costs actually incurred by SFWMD in obtaining the required real property rights from other non-Federal governmental entities. However, to be eligible for credit to be afforded to the SFWMD for incidental acquisition costs, SFWMD must have, in fact, incurred those costs.

For the "determination that a tract was acquired "in furtherance of a CERP project" should be supported by documentation existing at the time of acquisition." Set forth in paragraph a. above, the Jacksonville District and SFWMD agreed that lands acquired after April 30, 1999, the date of publication of the Comprehensive Everglades Restoration Plan, is the date when lands were acquired for a CERP Project.

D.11 UNIFORM RELOCATION ASSISTANCE ACT, PUBLIC LAW 91-646

Based on current analysis there is one residential property that will be impacted by the project to the extent that relocation will be required. Under Public Law (PL) 91-646, the landowner may be entitled to certain relocation benefits, which may be in the form of replacement housing payments or rental assistance payment and a payment for moving of household goods and personal property. For planning purpose relocation payments are estimated to be $100,000. Upon certification of the LERRD, SFWMD will be required to demonstrate compliance with the requirements of PL 91-646 including that landowners have been properly advised of their rights under the program and that which evidence appropriate benefit determinations. To include:

- Number of persons, farms, and businesses displaced.
- Estimate of all PL 91-646, Title II costs and contingencies.
- Discuss/describe availability of replacement housing and any need for last resort housing benefits.

D.12 NAVIGATIONAL SERVITUDE AND OTHER LANDS

The navigation servitude is not applicable to this project.

D.13 INDUCED FLOODING

Section 601(h)(5) of WRDA 2000 contains a Savings Clause that provides protection for existing legal sources of water that will be eliminated or

transferred due to project implementation and for no significant and adverse reduction in the level of service for flood protection that was in existence on the date of enactment and in accordance with applicable law. Section 601(h)(5) provides:

> *(5) SAVINGS CLAUSE.--*
> *(B) MAINTENANCE OF FLOOD PROTECTION.--Implementation of the Plan shall not reduce levels of service for flood protection that are--*
> *(i) in existence on the date of enactment of this Act; and*
> *(ii) in accordance with applicable law.*

As a result of the above section, a Takings Analysis compares the condition existing in December 2000 to the conditions after construction and implementation of the Recommended Plan.

The MODBRANCH model was used as part of the C-111 Spreader Canal (to estimate the flooding impacts of alternative 2D Short. Alternative 2D Short was modeled and compared to the Existing Condition Base. The MODBRANCH model is described in more detail in ***APPENDIX A, ENGINEERING, SECTION A.10***. MODBRANCH is a hybrid code that couples MODFLOW, a three-dimensional groundwater flow model with Branch, a one-dimensional canal routing model. ***FIGURE A-20***, in ***APPENDIX A*** shows the model domain (blue line) superimposed on an aerial photograph of the area. Major canals are shown in red. This figure illustrates the complexity of the area. Land elevations vary from the high Atlantic Ridge to the low Everglades. Land use varies from urban to suburban to agricultural to wilderness. Both, ground water and overland flow are simulated by the MODFLOW part of MODBRANCH. MODFLOW is a pseudo-three-dimensional, finite difference, ground water model (McDonald and Harbaugh, 1988). This model requires defining a model "grid" of specified numbers of rows, columns, and layers. The width of each row or column is determined by required resolution in specific areas. The model grid is shown in ***FIGURE A-21***, in ***APPENDIX A*** with major canals superimposed. The model is bounded by the Biscayne Bay to the east; Florida Bay to the south; and, the Gulf of Mexico to the west. The northern boundary is roughly 2 miles north and parallel to the following canals: C-6, L-30, L-67C and L-29. The model grid is made up of 239 rows, 259 columns, and 5 layers. The grid resolution varies horizontally from a minimum of 207 feet to a maximum of 5000 feet. Levees are defined by using the horizontal flow barrier package of MODFLOW. The U.S. Army Corps of Engineers, Jacksonville District, made additional model refinements and extended the model domain which was used in previous studies. Various Performance Measures were developed for the flood impacts. For flood impact analysis, hydroperiods are computed as the number of days within a specified season that the water depth exceeds a specified value. The data are divided into two seasons (wet and dry) and eleven depth values are used (+/-2.0,

+/-1.5, +/-1.0, +/-0.5, +/-0.25, 0.0 ft). A second flood impact Performance Measure is the longest single duration water is above a stage that is specified between 0 and 24" below the ground, in increments of 2". This Performance Measure is useful in determination of impacts on various crops. Both types of data were provided for each cell to allow further post-processing using GIS packages.

After modeling was completed, an analysis was completed to determine the impacted lands for the recommended plan. The analysis compared the Existing Condition Dec 2000 to alternative 2DS – wet year, dry year, average year. The team worked with the geographic information system specialists to produce a formula to be applied to alternative 2DS which would provide an initial determination of the impacted lands. After the modeling data for alternative 2DS along with the modeling data for Existing Condition Base (ECB) was provided to GIS, they used the data to create extensive spreadsheets, maps and data information for review by the team to determine what lands were impacted. The comparison had to account for changes in hydrology that would be significant enough that land acquisition would be required. The formula ultimately used compared the recommended plan to the Existing Base Condition. The comparison accounted for both groundwater and surface water impacts to different land classes.

The impacted lands for alternative 2DS were initially analyzed and computed based on the compilation of the following three criteria:

Criteria 1: Non-Agricultural Lands (40days+30 percent)

Alternative Annual Hydroperiod (at surface) is greater than 40 days longer than Existing Condition Base (ECB) run and this value is greater than 30 percent longer than ECB for any of the three years (Average year, Dry year, Wet year)

Criteria 2: Agricultural Lands for Dry Season (Any increase of Hydroperiod at-.5ft)

Alternative Dry Season Hydroperiod (at -.5ft) is greater than 5 days longer than ECB Dry Season Hydroperiod (at -.5ft) for any of the three years (Average year, Dry year, Wet year)

Criteria 3: Agricultural Lands for Wet Season (30days+20 percent)

Alternative Wet Season Hydroperiod (at -.5ft) is greater than 30 days longer than ECB wet season Hydroperiod (at -.5ft) AND this value is greater than 20 percent longer than ECB for any of the three years (Average year, Dry year, Wet year)

Extensive Spreadsheet Data was then provided by GIS that showed the hydrologic changes for each of the "impacted grid cells", including impacts in each year; impacts in the wet seasons of each year; impacts in the dry season of

each year; and the percentage of each individual parcel impacted. For the non-agricultural lands, a more detailed analysis was conducted to determine if the impacts were significant. For instance, if the Existing Condition had no shown hydroperiod but for the alternative there was a 40 day increase in hydroperiod across the entire year which would be a 30 percent increase, the lands impacted by this increase were screened out. This was applied to each alternative. Non-agricultural land impacts had to be significant to remain "impacted".

There was also a separate data spreadsheet developed for the agricultural lands for each alternative, which showed the hydroperiod differences in the Dry Season and Wet Season between each alternative and the Existing Condition Base for each of the years analyzed (Dry Year 1989, Average Year 1978 and Wet Year 1995). An analysis was then conducted for the agricultural lands to determine what were significant and adverse conditions warranting acquisition of a real estate interest. Any increase in any Dry Season (November through April) of over 5 days was considered as requiring acquisition of a real estate interest (Criteria 2 above). For the Wet Seasons, the increase had to meet not only Criteria 3 above, but it had to increase the entire hydro-period to greater than 80 days.

Once all this data was analyzed each parcel or percentage of the parcel was reviewed to determine if only a portion (and what portion) or all of the parcel would have to be acquired. Once the analysis was complete, the information was provided to Real Estate Division to provide a cost estimate.

The lands belonging to the Everglades National Park were not valued. The lands in the Frog Pond area were approved for acquisition under the C-111 South Dade project in the 1994 General Design Memorandum and will be provided as an item of local cooperation under that project. Therefore the real estate cost for lands required for each Alternative within the Frog Pond were not included under the C-111 Spreader Canal project real estate costs.

Total impacted lands were determined to be approximately 11,564.65 acres for Alternative 2D Short. SFWMD owns approximately 9,687.53 acres within the impacted lands in Alternative 2D Short. The SFWMD owned lands were valued in fee using estimated market value and actual SFWMD administrative costs. Miami-Dade County owns approximately 131.06 acres within the impacted lands and were valued in fee using estimated market value, but will be provided by Supplemental Agreement. The State of Florida owns approximately 15 acres and were valued in fee using estimated market value, but will be provided by Supplemental Agreement. Florida Power & Light owns approximately 955 acres, which are encumbered by a Conservation Easement conveyed to SFWMD and the State for a Mitigation Bank, a flowage easement will be acquired over these lands. The remaining 776.06 acres of land are all privately owned and were valued in fee using estimated market value.

Alternative 2D Short contains approximately 590 acres of lands within the Frog Pond Area. The lands in the Frog Pond area were approved for acquisition under the C-111 South Dade project in the 1994 General Design Memorandum and will be provided as an item of local cooperation under that project. Therefore the real estate cost for lands required for Alternative 2D Short within the Frog Pond were not included under the C-111 Spreader Canal project.

Model Uncertainty-All numerical model studies have limitations. Many of these are related to the specific computer code chosen for a particular study. Other limitations are related to the field data that is available or lack thereof. Lastly, model studies are also limited by the schedule dictated by project requirements. All of these limitations impart various sources of error or limit the evaluation to an appropriate level of detail. This model study does have limitations and should be used with caution. A discussion of the limitations of this model study is included in ***APPENDIX A, ENGINEERING, SECTION A.10.2.1.2.***

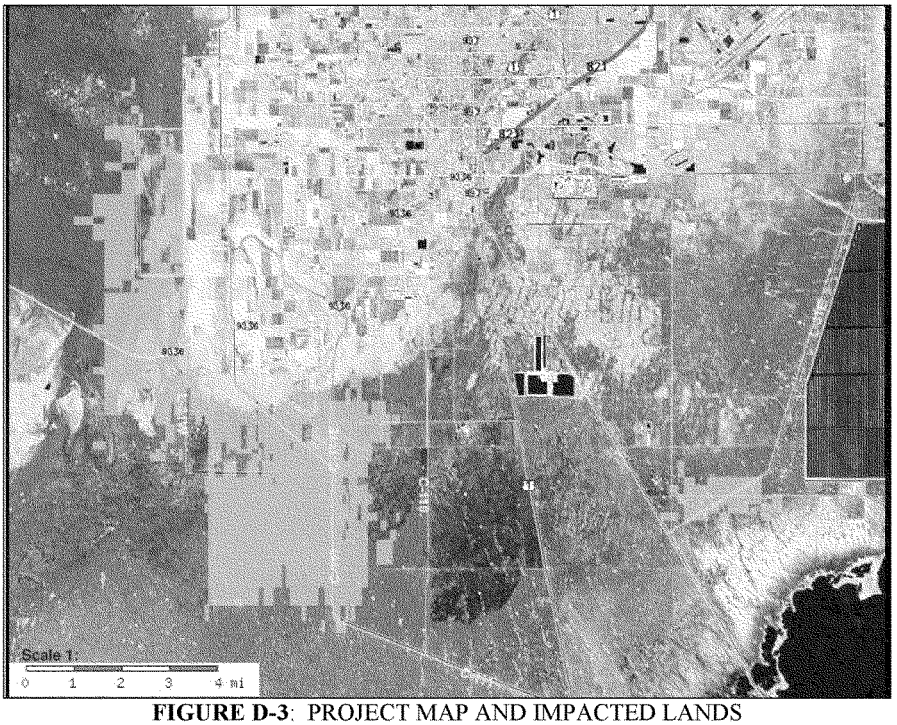


FIGURE D-3: PROJECT MAP AND IMPACTED LANDS

As discussed in Appendix C, the benefit evaluation methodology identifies approximately 155,000 acres of fresh and saltwater wetlands and 98,000 acres of nearshore and bay area as within the area of potential impact of this project. To identify the potentially affected area of the project, the benefits assessment team first considered limiting the indicator regions to only those areas which would experience a significant and measurable increase in hydroperiod. These areas are generally located directly downstream or adjacent to project features and for the considered alternatives this area is no larger than 20,000 acres in size. This method of sizing the indicator regions was abandoned in favor of a more expansive area of potential impact since large indicator regions would measure both areas of hydrologic benefit and areas where water deliveries are reduced. Since the C-111 Spreader project diverts water rather than augments water deliveries, the project delivery team felt that having large indicator regions was essential to capturing both positive and negative effects of the project.

Though the project benefits are estimated by multiplying the area of the indicator regions by a projected change in the habitat index this methodology is not intended to drive the real estate requirements for the project. For instance, the entire area of the indicator regions does not have to be acquired in order to assure that project benefits are protected. The reasons for this are: 1) Most of the wetland rehydration benefits will occur in those land identified in the real estate analysis as being significantly hydrologically modified. 2) Areas outside of the "significantly hydrologically modified" lands are generally areas where some decrease in hydroperiod conditions are expected and thus not contributing benefits and should not be part of the lands acquired to protect project benefits. 3) Salinity benefits that accrue from the project occur in navigable waters and thus are not included in the lands to be acquired.

Irrespective of the differences between the real estate lands analysis and the benefits methodology for this project, the vast majority of the 155,000 acres of fresh and saltwater wetland identified in the indicator regions is already protected via ownership by the Local, State, or Federal agencies.

D.14 MINERAL AND TIMBER ACTIVITIES

Preliminary investigations indicate that there are no known present or anticipated mineral or timber activities in the vicinity of the proposed project that may affect construction, operation, or maintenance of the project.

D.15 NON-FEDERAL AUTHORITY TO PARTICIPATE IN THE PROJECT

The SFWMD was created by virtue of Florida Statutes, Chapter 373, Section .069 which reads as below and as stated in Exhibit "B" of this report, as follows:

The SFWMD was created by virtue of Florida Statutes, Chapter 373, Section .069 to further the State policy of flood damage prevention, preserve natural resources of the State including fish and wildlife and to assist in maintaining the navigability of rivers and harbors. (There are other enumerated purposes but they are not directly applicable to this Project.)

The SFWMD is empowered to

> *Cooperate with the United States in the manner provided by Congress for flood control, reclamation, conservation, and allied purposes in protecting the inhabitants, the land, and other property within the district from the effects of a surplus or a deficiency of water when the same may be beneficial to the public health, welfare, safety, and utility. (Section 373.103)*

SFWMD has authority to act as the local sponsor for the CERP project pursuant to Florida Statutes Section 373.1501, the text of which is set forth on Exhibit "B" of this Appendix.

To carry out the above purposes, the SFWMD is empowered to

> *...hold, control, and acquire by donation, lease, or purchase, or to condemn any land, public or private, needed for rights-of-way or other purposes, and may remove any building or other obstruction necessary for the construction, maintenance, and operation of the works; and to hold and have full control over the works and rights-of-way of the district.(Section 373.086)*

The term *works of the district* is defined by Section 373.019 to be

> *...those projects and works, including, but not limited to, structures, impoundments, wells, and other water courses, together with the appurtenant facilities and accompanying lands, which have been officially adopted by the governing board of the district as works of the district.*

Section 373.139 specifically empowers the SFWMD

> *...to acquire fee title to real property and easements therein by purchase, gift, devise, lease, eminent domain, or otherwise for flood control, water storage, water management, and preservation of wetlands, streams and lakes, except that eminent domain powers which may be used only for acquiring real property for flood control and water storage.*

The SFWMD does have specific authority to condemn lands within the C-111 SC project area under the general condemnation authority of Ch. 373.

D.16 ESTATE ANALYSIS

For the basis of this report, land for all features and components have been valued in fee title, except for the Florida Power & Light lands which will be provided via a flowage easement and were not valued. If additional data is developed and provided, or as more definite plans and specifications are developed, lesser estates, in accordance with Chapter 12, ER 405-1-12 and the Programmatic Regulations, the draft Six Program-Wide Guidance Memoranda dated July 2007, may be determined to be appropriate. Based on the following analysis it was determined that fee will be required to construct and perform Operation, Maintenance, Repair, Rehabilitation, and Replacement (OMRR&R) for the project. The July 2007 draft of the Six Program-Wide Guidance Memoranda in Section 1.10.3 provides that an analysis to determine the estates required for implementation of a project should be determined using the following guidelines.

D.16.1 Estates Required for Comprehensive Everglades Restoration Plan Projects

For all lands determined to be required for Comprehensive Everglades Restoration Plan projects, the interests required for implementation generally will be fee simple, based on assumptions that all or a significant portion of the rights in the land will be required for project purposes. Although fee acquisition should be the standard estate for Comprehensive Everglades Restoration Plan projects, lesser estates such as flowage or conservation easements should be considered, as appropriate, if the benefits of the project can still be achieved with the lesser estate. The project implementation report should provide the rationale for such lesser estates.

To verify the appropriateness of fee simple acquisition or less than fee acquisition, the project implementation report must include the following analysis and the conclusions must be reflected in the appropriate report sections. The level of detail required for the analysis will vary depending on the project feature involved.

Determine the rights that are required to construct and perform operation, maintenance, repair, rehabilitation, and replacement for the C-111 SC Western project:

- Identify the affirmative rights on the land that are required to implement the project.
- In addition to affirmative rights that may be required, identify restrictions on use (restrictive covenants) by the fee owner that are required so as not to interfere with project purposes and outputs.
- Identify the length of time that the affirmative rights or restrictive covenants are needed for the project.

- Determine whether constructed project features may need to be modified over time due to uncertainties in science, formulation, or design (adaptive management).
- Determine whether project land, or portions thereof, will be open for public use (either active or passive uses).

Other Factors to be Considered:

- Compare the cost/value of specific types of easements to fee value.
- Assess potential for severance damages from fee acquisition.
- Determine whether public owners have legal capability to convey fee.
- Assess stewardship / operation, maintenance, repair, rehabilitation, and replacement considerations regarding the risk and consequences of encroachment on project land by adjacent owners; the risk and consequences of violation of easement terms by fee owners; and monitoring and enforcement capabilities of sponsor.
- Assess negative perception by public of private benefits or gain due to landowner reservations where easements are selected.
- Assess whether State Marketable Title Act requires re-recording of easement instruments.

Total impacted lands were determined to be approximately 11,564.65 acres for Alternative 2D Short

SFWMD owns approximately 9,687.53 acres within the impacted lands in Alternative 2D Short. The SFWMD owned lands were valued in fee using estimated market value and actual SFWMD administrative costs.

Miami-Dade County owns approximately 131.06 acres within the impacted lands, which will be provided by supplemental agreement as set forth below and were valued in fee using estimated market value. The State of Florida owns approximately 15 acres, which will be provided by supplemental agreement as set forth below and were valued in fee using estimated market value. Florida Power & Light owns approximately 955 acres which are encumbered by a Conservation Easement conveyed to SFWMD and the State for a Mitigation Bank, a flowage easement will be acquired over these lands and were not valued. The remaining approximately 776.06 acres of land are all privately owned and were valued in fee using estimated market value.

In accordance with the terms of ARTICLE III - LANDS, EASEMENTS, RIGHTS-OF-WAY, RELOCATIONS AND COMPLIANCE WITH PUBLIC LAW 91-646, AS AMENDED of the MASTER AGREEMENT BETWEEN THE DEPARTMENT OF THE ARMY AND SOUTH FLORIDA WATER MANAGEMENT DISTRICT FOR COOPERATION IN CONSTRUCTING AND OPERATING, MAINTAINING, REPAIRING, REPLACING AND REHABILITATING AUTHORIZED

PROJECTS UNDER THE COMPREHENSIVE EVERGLADES RESTORATION PLAN, entered into on August 13, 2009, subparagraph E. provides: The Government recognizes that the Non-Federal Sponsor in limited circumstances will be entering into supplemental agreements with the State of Florida or another Florida governmental entity whereby (1) the State of Florida or another Florida governmental entity, rather than the Non-Federal Sponsor, has acquired or will acquire required lands, easements, and rights-of-way, and (2) the State of Florida or another Florida governmental entity will dedicate the land interests it owns to the *authorized CERP Project* and ensure that such lands, easements, and rights-of-way are retained in public ownership for uses compatible with the purposes of the *authorized CERP Project* and shall not be conveyed, transferred, altered, or otherwise encumbered without the advance written consent of the Non-Federal Sponsor and the Government these supplemental agreements shall be limited in effect to the signatory parties and shall not reduce or alter in any way the requirements of this Master Agreement and any *PPA* that makes the Non-Federal Sponsor solely responsible for providing lands, easements, and rights-of-way that are required for the construction, operation, maintenance, repair, replacement, and rehabilitation of the *authorized CERP Project.*

For the lands owned in fee by Florida Power and Light, SFWMD was conveyed a Conservation Easement for a mitigation bank. In order to have the ability to flow water over these lands for project purposes, a perpetual flowage easement will be required.

For the remainder of the impacted lands (those owned by SFWMD approximately 9,687.53 acres or in private ownership approximately 776.06 acres) fee title will be required. SFWMD owns approximately 9,687.53 acres in a block ownership that is currently zoned as a protected area. They have acquired these lands over the past 15+ years and as a result of their acquisition, the lands remain largely in an undisturbed state. A review of the hydrologic impacts to these lands was undertaken as part of the takings analysis performed by the Jacksonville District Office of Counsel. It is the intent of the project to increase water levels on these lands to enhance environmental benefits. The takings analysis concluded the hydrologic impacts required at a minimum a flowage easement be acquired.

The District found no specific market data to adequately compare the cost/value of a flowage easement to fee value as prescribed above. These invaluable wetlands are situate adjacent to the Everglades National Park and are critical to the increased flowage of water into the Park. While the 9,687.53 acres constitute approximately 84% of the lands required for the project, they represent only 33% of the estimated land costs ($16.4 million out of some $49 million). Even if it is assumed that a cost/value analysis might indicate a flowage easement as the appropriate estate, a fee estate is considered prudent given the relatively low

cost and critical location of these lands. Additionally, fee will readily allow for future operational changes without necessitating any additional interests in land. While the District was unable to specifically address the cost difference between fee and easement the District concluded that the Fee estate would be appropriate for the SFWMD property.

D.17 PROPOSED ESTATES

Based on the analysis set forth above, the following estates will be required:

Standard Estates

Standard Estate Fee

The fee simple title to the land described in Schedule A, subject, however to existing easements for public roads and highways, public utilities, railroads and pipelines.

Standard Perpetual Flowage Easement

The perpetual right, power, privilege and easement permanently to overflow, flood and submerge (the land described in Schedule A) (and to maintain mosquito control) in connection with the operation maintenance of the project as authorized by the Act of Congress approved _____, and the continuing right to clear and remove and brush, debris and natural obstructions which, in the opinion of the representative of the United States in charge of the project, may be detrimental to the project, together with all right, title and interest in and to the timber, structures and improvements situate on the land; provided that no structures for human habitation shall be constructed or maintained on the land, that no other structures shall be constructed or maintained on the land except as may be approved in writing by the representative of the United States in charge of the project, and that no excavation shall be conducted and no landfill placed on the land without such approval as to the location and method of excavation and/or placement of landfill; the above estate is taken subject to existing easements for public roads and highways, public utilities, railroads and pipelines; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used and enjoyed without interfering with the use of the project for the purposes authorized by Congress or abridging the rights and easement hereby acquired; provided further that any use of the land shall be subject to Federal and State laws with respect to pollution.

Non Standard Estates

In conjunction with this report, Jacksonville District Real Estate Division is hereby requesting approval to use the following non-standard estates for this project.

Miami-Dade County and Miami-Dade County DERM and State of Florida

In accordance with the terms of ARTICLE III - LANDS, EASEMENTS, RIGHTS-OF-WAY, RELOCATIONS AND COMPLIANCE WITH PUBLIC LAW 91-646, AS AMENDED of the MASTER AGREEMENT BETWEEN THE DEPARTMENT OF THE ARMY AND SOUTH FLORIDA WATER MANAGEMENT DISTRICT FOR COOPERATION IN CONSTRUCTING AND OPERATING, MAINTAINING, REPAIRING, REPLACING AND REHABILITATING AUTHORIZED PROJECTS UNDER THE COMPREHENSIVE EVERGLADES RESTORATION PLAN, entered into on August 13, 2009, subparagraph E. provides: The Government recognizes that the Non-Federal Sponsor in limited circumstances will be entering into supplemental agreements with the State of Florida or another Florida governmental entity whereby (1) the State of Florida or another Florida governmental entity, rather than the Non-Federal Sponsor, has acquired or will acquire required lands, easements, and rights-of-way, and (2) the State of Florida or another Florida governmental entity will dedicate the land interests it owns to the *authorized CERP Project* and ensure that such lands, easements, and rights-of-way are retained in public ownership for uses compatible with the purposes of the *authorized CERP Project* and shall not be conveyed, transferred, altered, or otherwise encumbered without the advance written consent of the Non-Federal Sponsor and the Government these supplemental agreements shall be limited in effect to the signatory parties and shall not reduce or alter in any way the requirements of this Master Agreement and any *PPA* that makes the Non-Federal Sponsor solely responsible for providing lands, easements, and rights-of-way that are required for the construction, operation, maintenance, repair, replacement, and rehabilitation of the *authorized CERP Project.*

D.18 ZONING ORDINANCES

Preliminary investigation indicates that no enactments of zoning ordinances are proposed in lieu of, or to facilitate, acquisition in connection with the project.

D.19 ACQUISITION SCHEDULES

SFWMD currently owns or controls all but the approximately 776 acres of private owned land and the lands owned by FPL required for project purposes. The real estate acquisition schedule will be coordinated with the PDT. The real

estate required for each construction contract must be acquired and certified by the Chief, Real Estate Division prior to the advertisement for construction. The project schedule will be updated to allow sufficient time for acquisition and certification of real estate prior to advertisement for construction. An acquisition schedule will be developed jointly with the Project Manager, SFWMD and SAJ Real Estate.

D.20 HAZARDOUS, TOXIC OR RADIOLOGICAL WASTE **(HTRW)**

The Non-Federal Sponsor (NFS) has chartered Phase I and Phase II studies on properties either owned, or to be acquired for project use. The results of these studies were used to determine if the land under consideration is suitably clean for the intended use, or if some form of change is necessary prior to plan implementation. Although none of these residual pesticides were found at concentrations violating Federal or State standards for the existing or proposed land uses, the USFWS concluded that hydration of the soils within some former agricultural lands represented a potential risk to two USFWS Trust Species, the Snail Kite and Osprey.

The removal of existing surficial soils is integral to the design of the project as a cost-effective measure to permanently reduce or eliminate exotic and nuisance vegetation and as a means to provide a stable subgrade for support of the proposed levees and structures. Therefore Soil Management Plans (Appendix C) were developed in order to reconcile the project's inherent soil excavation plans, which are integral to the design, with HTRW concerns. The Soil Management Plans were developed in consultation with and reviewed by the USFWS and the Florida Department of Environmental Protection (FDEP) who concur that the plan provides sufficient protection to the trust species. As such, there are no HTRW issues regarding Real Estate for the proposed project.

D.21 CULTURAL RESOURCES

The USACE is reviewing information regarding historical properties that might be affected by the C-111 SC Western project, in compliance with Section 106 of the National Historic Preservation Act of 1966 (PL 89-665), as amended in 2006; its implementing regulations (36 CFR Part 800) and the Archaeological and Historic Preservation Act of 1974 (PL 93-291), as amended.

A review of the Florida Master Site Files indicated several known archaeological sites and the probability of unrecorded sites within the C-111 SC Western project area. A Phase I cultural resources survey was conducted in the Area of Potential Effects. The survey identified a single historic resource (8DA11433), a limestone road likely constructed in the 1930s. It is not considered eligible for the National Register of Historic Places. With the concurrence of the State Historic Preservation Officer, the Corps has determined that the planned

undertaking will have no effect on any significant cultural resources. This determination has been made in compliance with Section 106 of the National Historic Preservation Act of 1966 (PL 89-665), as amended; it's implementing regulations (36 CFR Part 800) and the Archaeological and Historic Preservation Act of 1974 (PL93-291), as amended.

If during project development, unanticipated discoveries are made, construction will stop and the Corps' archeologist, State Historic Preservation Officer, and consulting Tribes will be notified. If these unanticipated discoveries include human remains, this would also require notification of the state archeologist in compliance with Chapter 872.05, Florida Statutes, or the county medical examiner if the remains are less than 75 years old.

D.22 RECREATIONAL USE OF PROJECT FEATURES

The C-111 SC Western Storage Reservoir proposed recreation was discussed with study team members. It consists of a trailhead with parking, traffic controls, a shade shelter with interpretive board, approximately 6.8 miles of multi-use levee trails atop the impoundment cell levees and levees adjacent to the Aerojet Canal. Restoration compatible recreation use would include: hiking, biking, bank fishing, nature study, bird watching, FWC managed hunts and equestrian use. The proposed recreation would help to fill existing and projected SCORP 2000 recreation deficits for Region 11 and public needs recorded during the CERP Master Recreation Plan Outreach in 2006 and 2008. Recreation total investment costs are estimated to be $203,000.

D.23 PROJECT SUPPORT

There is no known or anticipated opposition to the project by landowners in the project area, or any known or anticipated ownership concerns that could impact the project. SFWMD already owns most of the lands that are required for project purposes. If the sponsor is unable to negotiate the purchase of lands from willing sellers, it is anticipated that they will be granted authority to acquire by condemnation if necessary.

D.24 BASELINE COST ESTIMATE AND MCACES COST ESTIMATE

The real estate cost estimates for Alternative 2D Short only includes the cost for the approximately 11,564.65 acres of land that are identified as impacted lands and as shown in the Baseline Cost Estimate (***TABLE D-2***) and MCACES Cost Estimate (***TABLE D-3***). Lands within the Frog Pond and the Lower C-111 are not included in the project cost estimate as SFWMD will provide these lands under the C-111 South Dade project or the C&SF project.

Engineering Regulation 1110-2-1302, paragraph. 20.a states that: "cost risk analysis is the process of identifying and measuring the cost impact of project uncertainties of the estimated Total Project Cost (TPC). It shall be accomplished as a joint analysis between the cost engineer and the designers or appropriate PDT members that have specific knowledge and expertise on all possible project risks." The Engineering Regulation defines TPC as "all Federal and authorized non-Federal costs represented by the Civil Works Work Breakdown Structure features and respective estimates and schedules, including the lands and damages, relocations, project construction costs..."

The Jacksonville District solicited the services of Risk Strategics, LLC in coordination with the Cost Engineering Directory of Expertise at the Walla Walla District (NWW) to assist in the completion of the Cost and Schedule Risk Analysis (CSRA) using the Crystal Ball software. Pursuant to ER 1110-2-1302 paragraph 20.a(1): "HQUSACE mandates the use of the nationally recognized software Crystal Ball, an Excel-based Monte-Carlo risk simulation software, to conduct cost risk analysis."

As mandated in the 19 September 2007 memorandum, Subject: Initiatives to Improve Accuracy of Total Project Costs in Civil Works Feasibility Studies Requiring Congressional Authorization, NWW will direct the Agency Technical Review (ATR) "of cost estimates, construction schedules, and contingencies included in all decision documents requiring Congressional authorization." The Jacksonville District vetted the CSRA through the ATR process and NWW approved the contingencies based on the report prepared on 17 September 2009. The report, located in Appendix C of the PIR, describes the methodology, process, key assumptions, and limitations of the risk analysis. It also explains the results, major findings, observations, and recommendations of the risk analysis.

Based on the CSRA a contingency of 33 percent or $16,742,825 was applied to the Real Estate cost estimates on the Selected Plan based on the contingency recommended in the report prepared on 27 October 2009 by Risk Strategics, LLC. This contingency was not applied to the SFWMD administrative costs already expended in the amount of $412,972.

TABLE D-2: BASELINE COST ESTIMATE

SUMMARY OF BASELINE COST ESTIMATE				
PROJECT: C-111 SPREADER CANAL WESTERN				
DATE: October 2009				
LANDS AND DAMAGES:				
ESTATE	ACRES	NON-FEDERAL COST	FEDERAL COST	TOTAL
FEE-Private	776.06	$29,202,354	$0	
FEE-Miami -Dade to be provided by Supplemental Agreement	131.06	$1,455,491	$0	
FEE-State of Florida to be provided by Supplemental Agreement	15.00	$900,000	$0	
FEE-SFWMD	9687.53	$16,254,394	$0	
FEE-FROG POND SFWMD provided under C-111 South Dade Project	590.00	$0	$0	
EASEMENT			$0	
FP&L	955.00	$0	$0	
SUBTOTAL		$47,812,239	$0	
CONTINGENCY 33% on $47,812,239 non-fed funds		$15,778,039		
SUBTOTAL	12,154.65	$63,590,278	$0	$63,590,278
IMPROVEMENTS	1	$445,000	$0	
SEVERANCE:	0	$0	$0	
MINERALS		$0	$0	
SUBTOTAL	0	$445,000	$0	
CONTINGENCY 33% on $445,000 non-fed funds		$146,850	$0	
SUBTOTAL		$591,850	$0	$591,850
TOTAL LANDS AND DAMAGES				**$64,182,128**
ACQ/ADMIN				
FED			$479,122	
NON-FED EXPENDED		$412,972	$0	
NON-FED FUTURE		$1,999,471	0	
SUBTOTAL		$2,412,443	$479,122	
FED CONTINGENCY 33% ON $479,122			$158,110	
NON-FED CONTINGENCY 33% ON $1,999,471		$659,825		
	SUBTOTAL	**$3,072,268**	**$637,232**	**$3,709,501**
TOTAL PROJECT COSTS		**$67,254,396**	**$637,232**	
TOTAL ESTIMATED RE COSTS (RD DOWN)				**$67,890,000**

TABLE D-3: MCASES COST ESTIMATE

MCASES PROJECT REAL ESTATE COSTS				
PROJECT: C-111 SC Western				
DATE: October 2009				
01A	PROJECT PLANNING	FEDERAL	NON-FEDERAL	TOTALS
	Other	130,000	0	130,000
	Project Cooperation Agreement	15,000	0	15,000
01AX	Contingencies (33%)	47,850	0	47,850
	Subtotal	192,850	0	**192,850**
01B	LANDS AND DAMAGES/PERMITS			
01B40	Acquisition/Review of PS	314,122		314,122
01B20	Acquisition by PS		1,899,471	1,899,471
01B20	Prior Acquisition by PS		412,972	412,972
01BX	Contingency (33%) on Fed and (33%) on $1,899,471 non-Fed	103,660	626,825	730,486
	Subtotal	417,782	2,939,268	**3,357,051**
01F	PL 91-646 ASSISTANCE			
01F20	By PS	0	10,000	10,000
01FX	Contingencies (33%)	0	3,300	3,300
	Subtotal	0	13,300	**13,300**
01R	REAL ESTATE LAND PAYMENTS			
01R1B	Land Payments by PS		48,257,239	48,257,239
01R2B	PL91-646 Relocation Payment by PS			0
01R2D	Review of PS	20,000	90,000	110,000
01RX	Contingencies (33%)	6,600	15,954,589	15,961,189
	Subtotal	26,600	64,301,828	**64,328,428**
	TOTALS	**637,232**	**67,254,396**	
	ROUNDED DOWN TO			**67,890,000**

Administrative costs were estimated as follows: 1% of the total land costs were estimated for Federal Administrative costs and non-Federal Administrative costs were estimated using 6% on all other land costs except for the lands already acquired by the sponsor. For those lands owned by SFWMD, actual administrative costs were used in accordance with CERP guidance.

D.25 REAL ESTATE MAPS

Project Maps: Real Estate Planning Map C-111 SC Western project is a conceptual map which shows the project features and ownerships and color coded in the legend (***FIGURE D-4***).

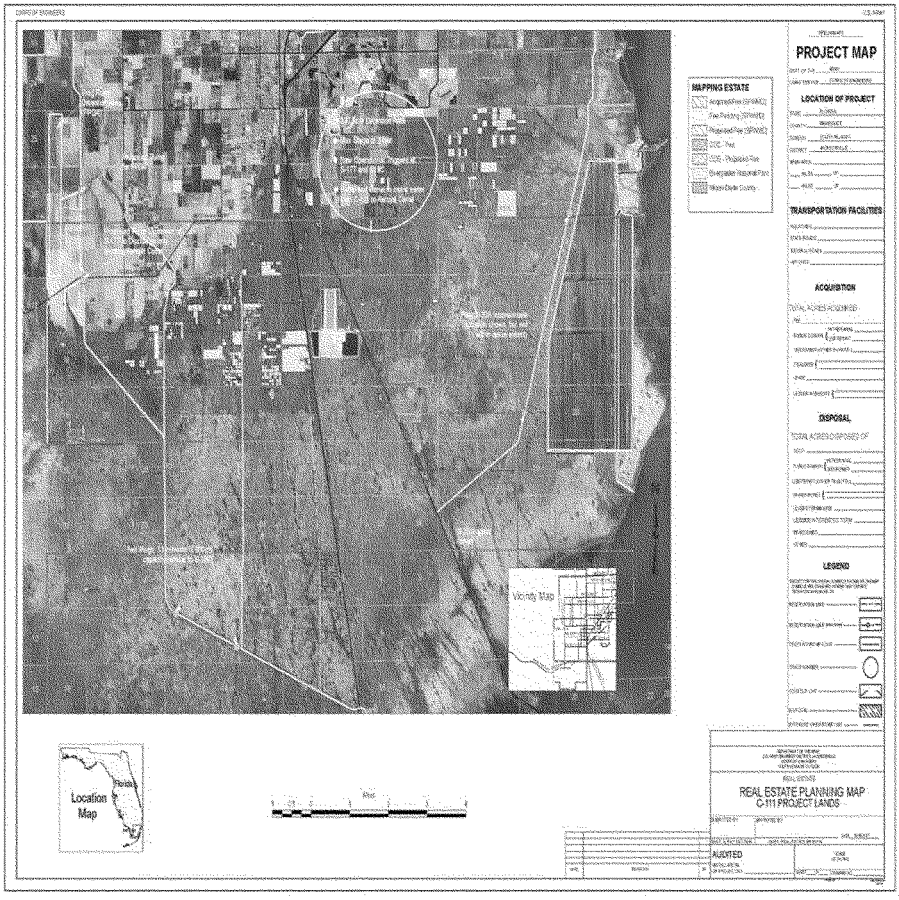


FIGURE D-4: PROJECT MAP

D.26 EXHIBITS

D.26.1 EXHIBIT "A"

Project Authorization

Study Authority

The Central and Southern Florida Project Comprehensive Review Study included the Water Preserve Areas Feasibility Study. The Restudy was

authorized by Section 309(l) of the Water Resources Development Act of 1992 (Public Law 102-580) which states:

"(1) CENTRAL AND SOUTHERN FLORIDA. -- The Chief of Engineers shall review the report of the Chief of Engineers on central and southern Florida, published as House Document 643; 80th Congress, 2nd Session, and other pertinent reports, with a view to determining whether modifications to the existing project are advisable at the present time due to significantly changed physical, biological, demographic, or economic conditions, with particular reference to modifying the project or its operation for improving the quality of the environment, improving protection of the aquifer, and improving the integrity, capability, and conservation of urban water supplies affected by the project or its operation."

This study is also authorized by two resolutions of the Committee on Transportation and Infrastructure, United States House of Representatives, dated September 24, 1992. The first resolution states:

> *"Resolved by the Committee on Public Works and Transportation of the United States House of Representatives, That the Board of Engineers for Rivers and Harbors, is requested to review the report of the Chief of Engineers on Central and Southern Florida, published as House Document 643, Eightieth Congress, Second Session, and other pertinent reports, to determine whether modifications of the recommendations contained therein are advisable at the present time, in the interest of environmental quality, water supply and other purposes."*

The second resolution states:

"Resolved by the Committee on Public Works and Transportation of the United States House of Representatives, That the Board of Engineers for Rivers and Harbors, is requested to review the report of the Chief of Engineers on Central and Southern Florida, published as House Document 643, Eightieth Congress, Second Session, and other pertinent reports, to determine whether modifications of the recommendations contained therein are advisable at the present time, in the interest of environmental quality, water supply and other purposes for Florida Bay, including a comprehensive, coordinated ecosystem study with hydrodynamic modeling of Florida Bay and its connections to the Everglades, the Gulf of Mexico, and the Florida Keys Coral Reef ecosystem."

The Water Resources Development Act of 1996 was enacted on October 12, 1996. Section 528 of this Act (Public Law 104-303) entitled "Everglades and South Florida Ecosystem Restoration" authorized a number of ecosystem

restoration activities and also provided specific direction and guidance for the Restudy. The provisions of Section 528 concerning the Restudy are:

"(b) RESTORATION ACTIVITIES -

(1) COMPREHENSIVE PLAN -

(A) DEVELOPMENT -

(i) PURPOSE - The Secretary shall develop, as expeditiously as practicable, a proposed Comprehensive Plan for the purpose of restoring, preserving, and protecting the South Florida ecosystem. The Comprehensive Plan shall provide for the protection of water quality in, and the reduction of the loss of fresh water from, the Everglades. The Comprehensive Plan shall include such features as are necessary to provide for the water-related needs of the region, including flood control, the enhancement of water supplies, and other objectives served by the Central and Southern Florida Project.

(ii) CONSIDERATIONS - The Comprehensive Plan shall--

(I) be developed by the Secretary in cooperation with the non-Federal project sponsor and in consultation with the Task Force; and

(II) consider the conceptual framework specified in the report entitled "Conceptual Plan for the Central and Southern Florida Project Restudy", published by the Commission and approved by the Governor.

(B) SUBMISSION- Not later than July 1, 1999, the secretary shall--

(i) complete the feasibility phase of the Central and Southern Florida Project comprehensive review study as authorized by section 309(l) of the Water Resources Development Act of 1992 (106 Stat. 4844), and by 2 resolutions of the Committee on Public Works and Transportation of the House of Representatives, dated September 24, 1992; and

(ii) submit to Congress the plan developed under subparagraph (A)(i) consisting of a feasibility report and a programmatic environmental impact statement covering the proposed Federal action set forth in the plan.

(C) ADDITIONAL STUDIES AND ANALYSES - Notwithstanding the completion of the feasibility report under subparagraph (B), the Secretary shall continue to conduct such studies and analyses as are necessary, consistent with subparagraph (A)(i).

(2) USE OF EXISTING AUTHORITY FOR UNCONSTRUCTED PROJECT FEATURES- The Secretary shall design and construct any features of the Central and Southern Florida Project that are authorized on the date of the enactment of this Act or that may be implemented in accordance with the Secretary's authority to modify an authorized project, including features authorized under sections 315 and 316, with funds that are otherwise available, if the Secretary determines that the design and construction--

(A) will accelerate the restoration, preservation, and protection of the South Florida ecosystem;

(B) will be generally consistent with the conceptual framework described in paragraph (1)(A)(ii)(II); and

(C) will be compatible with the overall authorized purposes of the Central and Southern Florida Project.

(3) CRITICAL RESTORATION PROJECTS -

(A) IN GENERAL - In addition to the activities described in paragraphs (1) and (2), if the Secretary, in cooperation with the non-Federal project sponsor and the Task Force, determines that a restoration project for the South Florida ecosystem will produce independent, immediate, and substantial restoration, preservation, and protection benefits, and will be generally consistent with the conceptual framework described in paragraph (1)(A)(ii)(II), the Secretary shall proceed expeditiously with the implementation of the restoration project.

(B) INITIATION OF PROJECTS - After September 30, 1999, no new projects may be initiated under subparagraph (A).

(C) AUTHORIZATION OF APPROPRIATIONS -

(i) IN GENERAL - There is authorized to be appropriated to the Department of the Army to pay the Federal share of the cost of carrying out projects under subparagraph (A) $75,000,000 for the period consisting of fiscal years 1997 through 1999.

(ii) FEDERAL SHARE - The Federal share of the cost of carrying out any 1 project under subparagraph (A) shall be not more than $25,000,000.

(4) GENERAL PROVISIONS -

(A) WATER QUALITY - In carrying out activities described in this subsection and sections 315 and 316, the Secretary--

(i) shall take into account the protection of water quality by considering applicable State water quality standards; and

(ii) may include in projects such features as are necessary to provide water to restore, preserve, and protect the South Florida ecosystem.

(B) COMPLIANCE WITH APPLICABLE LAW - In carrying out the activities described in this subsection and subsection (c), the Secretary shall comply with any applicable Federal law, including the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) and the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.).

(C) PUBLIC PARTICIPATION - In developing the Comprehensive Plan under paragraph (1) and carrying out the activities described in this

subsection and subsection (c), the Secretary shall provide for public review and comment on the activities in accordance with applicable Federal law.

(c) INTEGRATION OF OTHER ACTIVITIES -

(1) IN GENERAL - In carrying out activities described in subsection (b), the Secretary shall integrate such activities with ongoing Federal and State projects and activities, including--

(A) the project for the ecosystem restoration of the Kissimmee River, Florida, authorized by section 101 of the Water Resources Development Act of 1992 (106 Stat. 4802);

(B) the project for modifications to improve water deliveries into Everglades National Park authorized by section 104 of the Everglades National Park Protection and Expansion Act of 1989 (16 U.S.C. 410r-8);

(C) activities under the Florida Keys National Marine Sanctuary and Protection Act (16 U.S.C. 1433 note; 104 Stat. 3089); and

(D) the Everglades Construction Project of the State of Florida.

(2) STATUTORY CONSTRUCTION -

(A) EXISTING AUTHORITY - Except as otherwise expressly provided in this section, nothing in this section affects any authority in effect on the date of the enactment of this Act, or any requirement of the authority, relating to participation in restoration activities in the South Florida ecosystem, including the projects and activities specified in paragraph (1), by--

(i) the Department of the Interior;

(ii) the Department of Commerce;

(iii) the Department of the Army;

(iv) the Environmental Protection Agency;

(v) the Department of Agriculture;

(vi) the State of Florida; and

(vii) the South Florida Water Management District.

(B) NEW AUTHORITY - Nothing in this section confers any new regulatory authority on any Federal or non-Federal entity that carries out any activity authorized by this section.

(d) JUSTIFICATION -

(1) IN GENERAL - Notwithstanding section 209 of the Flood Control Act of 1970 (42 U.S.C. 1962-2) or any other provision of law, in carrying out the activities to restore, preserve, and protect the South Florida ecosystem described in subsection (b), the Secretary may determine that the activities--

(A) are justified by the environmental benefits derived by the South Florida ecosystem in general and the everglades and Florida Bay in particular; and

(B) shall not need further economic justification if the Secretary determines that the activities are cost-effective.

(2) APPLICABILITY- Paragraph (1) shall not apply to any separable element intended to produce benefits that are predominantly unrelated to the restoration, preservation, and protection of the South Florida ecosystem.

(e) COST SHARING -

(1) IN GENERAL - Except as provided in sections 315 and 316 and paragraph (2), the non-Federal share of the cost of activities described in subsection (b) shall be 50 percent.

(2) WATER QUALITY FEATURES -

(A) IN GENERAL - Except as provided in subparagraph (B), the non-Federal share of the cost of project features to improve water quality described in subsection (b) shall be 100 percent.

(B) EXCEPTION -

(i) IN GENERAL - Subject to clause (ii), if the Secretary determines that a project feature to improve water quality is essential to Everglades restoration, the non-Federal share of the cost of the feature shall be 50 percent.

(ii) APPLICABILITY - Clause (I) shall not apply to any feature of the Everglades Construction Project of the State of Florida.

(3) OPERATION AND MAINTENANCE - The operation and maintenance of projects carried out under this section shall be a non-Federal responsibility.

(4) CREDIT - Regardless of the date of acquisition, the value of lands or interests in land acquired by non-Federal interests for any activity described in subsection (b) shall be included in the total cost of the activity and credited against the non-Federal share of the cost of the activity. Such value shall be determined by the Secretary."

On December 11, 2000, the Water Resources Development Act of 2000 was signed which authorized a framework and guide for modifications to the C&SF project to restore the south Florida ecosystem and to provide for the other water-related needs of the region. Specifically, Section 601 pertains to the Comprehensive Everglades Restoration and provides as follows:

TITLE VI--COMPREHENSIVE EVERGLADES RESTORATION

SEC. 601. COMPREHENSIVE EVERGLADES RESTORATION PLAN.

(a) DEFINITIONS- In this section, the following definitions apply:

(1) CENTRAL AND SOUTHERN FLORIDA PROJECT-

(A) IN GENERAL - The term `Central and Southern Florida Project' means the project for Central and Southern Florida authorized under the heading `CENTRAL AND SOUTHERN FLORIDA' in section 203 of the Flood Control Act of 1948 (62 Stat. 1176).

(B) INCLUSION - The term `Central and Southern Florida Project' includes any modification to the project authorized by this section or any other provision of law.

(2) GOVERNOR- The term `Governor' means the Governor of the State of Florida.

(3) NATURAL SYSTEM -

(A) IN GENERAL - The term `natural system' means all land and water managed by the Federal Government or the State within the South Florida ecosystem.

(B) INCLUSIONS - The term `natural system' includes--

(i) water conservation areas;

(ii) sovereign submerged land;

(iii) Everglades National Park;

(iv) Biscayne National Park;

(v) Big Cypress National Preserve;

(vi) other Federal or State (including a political subdivision of a State) land that is designated and managed for conservation purposes; and

(vii) any tribal land that is designated and managed for conservation purposes, as approved by the tribe.

(4) PLAN - The term `Plan' means the Comprehensive Everglades Restoration Plan contained in the `Final Integrated Feasibility Report and Programmatic Environmental Impact Statement', dated April 1, 1999, as modified by this section.

(5) SOUTH FLORIDA ECOSYSTEM -

(A) IN GENERAL - The term `South Florida ecosystem' means the area consisting of the land and water within the boundary of the South Florida Water Management District in effect on July 1, 1999.

(B) INCLUSIONS - The term `South Florida ecosystem' includes-

(i) the Everglades;

(ii) the Florida Keys; and

(iii) the contiguous near-shore coastal water of South Florida.

(6) STATE - The term `State' means the State of Florida.

(b) COMPREHENSIVE EVERGLADES RESTORATION PLAN -

(1) APPROVAL -

(A) IN GENERAL - Except as modified by this section, the Plan is approved as a framework for modifications and operational changes to the Central and Southern Florida Project that are needed to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection. The Plan shall be implemented to ensure the protection of water quality in, the reduction of the loss of fresh water from, and the improvement of the environment of the South Florida ecosystem and to achieve and maintain the benefits to the natural system and human environment described in the Plan, and required pursuant to this section, for as long as the project is authorized.

(B) INTEGRATION - In carrying out the Plan, the Secretary shall integrate the activities described in subparagraph (A) with ongoing Federal and State projects and activities in accordance with section 528(c) of the Water Resources Development Act of 1996 (110 Stat. 3769). Unless specifically provided herein, nothing in this section shall be construed to modify any existing cost share or responsibility for projects as listed in subsection (c) or (e) of section 528 of the Water Resources Development Act of 1996 (110 Stat. 3769).

(2) SPECIFIC AUTHORIZATIONS -

(A) IN GENERAL -

(i) PROJECTS - The Secretary shall carry out the projects included in the Plan in accordance with subparagraphs (B), (C), (D), and (E).

(ii) CONSIDERATIONS - In carrying out activities described in the Plan, the Secretary shall--

(I) take into account the protection of water quality by considering applicable State water quality standards; and

(II) include such features as the Secretary determines are necessary to ensure that all ground water and surface water discharges from any project feature authorized by this subsection will meet all applicable water quality standards and applicable water quality permitting requirements.

(iii) REVIEW AND COMMENT - In developing the projects authorized under subparagraph (B), the Secretary shall provide for public review and comment in accordance with applicable Federal law.

(B) PILOT PROJECTS - The following pilot projects are authorized for implementation, after review and approval by the Secretary, at a total cost of $69,000,000, with an estimated Federal cost of $34,500,000 and an estimated non-Federal cost of $34,500,000:

(i) Caloosahatchee River (C-43) Basin ASR, at a total cost of $6,000,000, with an estimated Federal cost of $3,000,000 and an estimated non-Federal cost of $3,000,000.

(ii) Lake Belt In-Ground Reservoir Technology, at a total cost of $23,000,000, with an estimated Federal cost of $11,500,000 and an estimated non-Federal cost of $11,500,000.

(iii) L-31N Seepage Management, at a total cost of $10,000,000, with an estimated Federal cost of $5,000,000 and an estimated non-Federal cost of $5,000,000.

(iv) Wastewater Reuse Technology, at a total cost of $30,000,000, with an estimated Federal cost of $15,000,000 and an estimated non-Federal cost of $15,000,000.

(C) INITIAL PROJECTS - The following projects are authorized for implementation, after review and approval by the Secretary, subject to the conditions stated in subparagraph (D), at a total cost of $1,100,918,000, with an estimated Federal cost of $550,459,000 and an estimated non-Federal cost of $550,459,000:

(i) C-44 Basin Storage Reservoir, at a total cost of $112,562,000, with an estimated Federal cost of $56,281,000 and an estimated non-Federal cost of $56,281,000.

(ii) Everglades Agricultural Area Storage Reservoirs--Phase I, at a total cost of $233,408,000, with an estimated Federal cost of $116,704,000 and an estimated non-Federal cost of $116,704,000.

(iii) Site 1 Impoundment, at a total cost of $38,535,000, with an estimated Federal cost of $19,267,500 and an estimated non-Federal cost of $19,267,500.

(iv) Water Conservation Areas 3A/3B Levee Seepage Management, at a total cost of $100,335,000, with an estimated Federal cost of $50,167,500 and an estimated non-Federal cost of $50,167,500.

(v) C-11 Impoundment and Stormwater Treatment Area, at a total cost of $124,837,000, with an estimated Federal cost of $62,418,500 and an estimated non-Federal cost of $62,418,500.

(vi) C-9 Impoundment and Stormwater Treatment Area, at a total cost of $89,146,000, with an estimated Federal cost of $44,573,000 and an estimated non-Federal cost of $44,573,000.

(vii) Taylor Creek/Nubbin Slough Storage and Treatment Area, at a total cost of $104,027,000, with an estimated Federal cost of $52,013,500 and an estimated non-Federal cost of $52,013,500.

(viii) Raise and Bridge East Portion of Tamiami Trail and Fill Miami Canal within Water Conservation Area 3, at a total cost of $26,946,000, with an estimated Federal cost of $13,473,000 and an estimated non-Federal cost of $13,473,000.

(ix) North New River Improvements, at a total cost of $77,087,000, with an estimated Federal cost of $38,543,500 and an estimated non-Federal cost of $38,543,500.

(x) C-111 Spreader Canal, at a total cost of $94,035,000, with an estimated Federal cost of $47,017,500 and an estimated non-Federal cost of $47,017,500.

(xi) Adaptive Assessment and Monitoring Program, at a total cost of $100,000,000, with an estimated Federal cost of $50,000,000 and an estimated non-Federal cost of $50,000,000.

(D) CONDITIONS -

(i) PROJECT IMPLEMENTATION REPORTS - Before implementation of a project described in any of clauses (i) through (x) of subparagraph (C), the Secretary shall review and approve for the project a project implementation report prepared in accordance with subsections (f) and (h).

(ii) SUBMISSION OF REPORT - The Secretary shall submit to the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Environment and Public Works of the Senate the project implementation report required by subsections (f) and (h) for each project under this paragraph (including all relevant data and information on all costs).

(iii) FUNDING CONTINGENT ON APPROVAL - No appropriation shall be made to construct any project under this paragraph if the project implementation report for the project has not been approved by resolutions adopted by the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Environment and Public Works of the Senate.

(iv) MODIFIED WATER DELIVERY - No appropriation shall be made to construct the Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement Project (including component AA, Additional S-345 Structures; component QQ Phase 1, Raise and Bridge East Portion of Tamiami Trail and Fill Miami Canal within WCA 3; component QQ Phase 2, WCA 3 Decompartmentalization and Sheetflow Enhancement; and component SS, North New River Improvements) or the Central Lakebelt Storage Project (including components S and EEE, Central Lake Belt Storage Area) until the completion of the project to improve water deliveries to Everglades National Park authorized by section 104 of the Everglades National Park Protection and Expansion Act of 1989 (16 U.S.C. 410r-8).

(E) MAXIMUM COST OF PROJECTS - Section 902 of the Water Resources Development Act of 1986 (33 U.S.C. 2280) shall apply to each project feature authorized under this subsection.

(c) ADDITIONAL PROGRAM AUTHORITY -

(1) IN GENERAL - To expedite implementation of the Plan, the Secretary may implement modifications to the Central and Southern Florida Project that--

(A) are described in the Plan; and

(B) will produce a substantial benefit to the restoration, preservation and protection of the South Florida ecosystem.

(2) PROJECT IMPLEMENTATION REPORTS - Before implementation of any project feature authorized under this subsection, the Secretary shall review and approve for the project feature a project implementation report prepared in accordance with subsections (f) and (h).

(3) FUNDING -

(A) INDIVIDUAL PROJECT FUNDING -

(i) FEDERAL COST - The total Federal cost of each project carried out under this subsection shall not exceed $12,500,000.

(ii) OVERALL COST - The total cost of each project carried out under this subsection shall not exceed $25,000,000.

(B) AGGREGATE COST - The total cost of all projects carried out under this subsection shall not exceed $206,000,000, with an estimated Federal cost of $103,000,000 and an estimated non-Federal cost of $103,000,000.

(d) AUTHORIZATION OF FUTURE PROJECTS -

(1) IN GENERAL - Except for a project authorized by subsection (b) or (c), any project included in the Plan shall require a specific authorization by Congress.

(2) SUBMISSION OF REPORT - Before seeking congressional authorization for a project under paragraph (1), the Secretary shall submit to Congress--

(A) a description of the project; and

(B) a project implementation report for the project prepared in accordance with subsections (f) and (h).

(e) COST SHARING -

(1) FEDERAL SHARE - The Federal share of the cost of carrying out a project authorized by subsection (b), (c), or (d) shall be 50 percent.

(2) NON-FEDERAL RESPONSIBILITIES - The non-Federal sponsor with respect to a project described in subsection (b), (c), or (d), shall be--

(A) responsible for all land, easements, rights-of-way, and relocations necessary to implement the Plan; and

(B) afforded credit toward the non-Federal share of the cost of carrying out the project in accordance with paragraph (5)(A).

(3) FEDERAL ASSISTANCE -

(A) IN GENERAL - The non-Federal sponsor with respect to a project authorized by subsection (b), (c), or (d) may use Federal funds for the purchase of any land, easement, rights-of-way, or relocation that is necessary to carry out the project if any funds so used are credited toward the Federal share of the cost of the project.

(B) AGRICULTURE FUNDS - Funds provided to the non-Federal sponsor under the Conservation Restoration and Enhancement Program (CREP) and the Wetlands Reserve Program (WRP) for projects in the Plan shall be credited toward the non-Federal share of the cost of the Plan if the Secretary of Agriculture certifies that the funds provided may be used for that purpose. Funds to be credited do not include funds provided under section 390 of the Federal Agriculture Improvement and Reform Act of 1996 (110 Stat. 1022).

(4) OPERATION AND MAINTENANCE - Notwithstanding section 528(e)(3) of the Water Resources Development Act of 1996 (110 Stat. 3770), the non-Federal sponsor shall be responsible for 50 percent of the cost of operation, maintenance, repair, replacement, and rehabilitation activities authorized under this section. Furthermore, the Seminole Tribe of Florida shall be responsible for 50 percent of the cost of operation, maintenance, repair, replacement, and rehabilitation activities for the Big Cypress Seminole Reservation Water Conservation Plan Project.

(5) CREDIT -

(A) IN GENERAL - Notwithstanding section 528(e)(4) of the Water Resources Development Act of 1996 (110 Stat. 3770) and regardless of the date of acquisition, the value of lands or interests in lands and incidental costs for land acquired by a non-Federal sponsor in accordance with a project implementation report for any project included in the Plan and authorized by Congress shall be--

(i) included in the total cost of the project; and

(ii) credited toward the non-Federal share of the cost of the project.

(B) WORK - The Secretary may provide credit, including in-kind credit, toward the non-Federal share for the reasonable cost of any work performed in connection with a study, preconstruction engineering and design, or construction that is necessary for the implementation of the Plan if--

(i)(I) the credit is provided for work completed during the period of design, as defined in a design agreement between the Secretary and the non-Federal sponsor; or

(II) the credit is provided for work completed during the period of construction, as defined in a project cooperation agreement for an authorized project between the Secretary and the non-Federal sponsor;

(ii) the design agreement or the project cooperation agreement prescribes the terms and conditions of the credit; and

(iii) the Secretary determines that the work performed by the non-Federal sponsor is integral to the project.

(C) TREATMENT OF CREDIT BETWEEN PROJECTS - Any credit provided under this paragraph may be carried over between authorized projects in accordance with subparagraph (D).

(D) PERIODIC MONITORING -

(i) IN GENERAL - To ensure that the contributions of the non-Federal sponsor equal 50 percent proportionate share for projects in the Plan, during each 5-year period, beginning with commencement of design of the Plan, the Secretary shall, for each project--

(I) monitor the non-Federal provision of cash, in-kind services, and land; and

(II) manage, to the maximum extent practicable, the requirement of the non-Federal sponsor to provide cash, in-kind services, and land.

(ii) OTHER MONITORING - The Secretary shall conduct monitoring under clause (i) separately for the preconstruction engineering and design phase and the construction phase.

(E) AUDITS - Credit for land (including land value and incidental costs) or work provided under this subsection shall be subject to audit by the Secretary.

(f) EVALUATION OF PROJECTS -

(1) IN GENERAL - Before implementation of a project authorized by subsection (c) or (d) or any of clauses (i) through (x) of subsection (b)(2)(C), the Secretary, in cooperation with the non-Federal sponsor, shall complete, after notice and opportunity for public comment and in accordance with subsection (h), a project implementation report for the project.

(2) PROJECT JUSTIFICATION -

(A) IN GENERAL - Notwithstanding section 209 of the Flood Control Act of 1970 (42 U.S.C. 1962-2) or any other provision of law, in carrying out any activity authorized under this section or any other provision of law to restore, preserve, or protect the South Florida ecosystem, the Secretary may determine that--

(i) the activity is justified by the environmental benefits derived by the South Florida ecosystem; and

(ii) no further economic justification for the activity is required, if the Secretary determines that the activity is cost-effective.

(B) APPLICABILITY - Subparagraph (A) shall not apply to any separable element intended to produce benefits that are predominantly unrelated to the restoration, preservation, and protection of the natural system.

(g) EXCLUSIONS AND LIMITATIONS - The following Plan components are not approved for implementation:

(1) WATER INCLUDED IN THE PLAN -

(A) IN GENERAL - Any project that is designed to implement the capture and use of the approximately 245,000 acre-feet of water described in section 7.7.2 of the Plan shall not be implemented until such time as--

(i) the project-specific feasibility study described in subparagraph (B) on the need for and physical delivery of the approximately 245,000 acre-feet of water, conducted by the Secretary, in cooperation with the non-Federal sponsor, is completed;

(ii) the project is favorably recommended in a final report of the Chief of Engineers; and

(iii) the project is authorized by Act of Congress.

(B) PROJECT-SPECIFIC FEASIBILITY STUDY - The project-specific feasibility study referred to in subparagraph (A) shall include--

(i) a comprehensive analysis of the structural facilities proposed to deliver the approximately 245,000 acre-feet of water to the natural system;

(ii) an assessment of the requirements to divert and treat the water;

(iii) an assessment of delivery alternatives;

(iv) an assessment of the feasibility of delivering the water downstream while maintaining current levels of flood protection to affected property; and

(v) any other assessments that are determined by the Secretary to be necessary to complete the study.

(2) WASTEWATER REUSE -

(A) IN GENERAL - On completion and evaluation of the wastewater reuse pilot project described in subsection (b)(2)(B)(iv), the Secretary, in an appropriately timed 5-year report, shall describe the results of the evaluation of advanced wastewater reuse in meeting, in a cost-effective manner, the requirements of restoration of the natural system.

(B) SUBMISSION - The Secretary shall submit to Congress the report described in subparagraph (A) before congressional authorization for advanced wastewater reuse is sought.

(3) PROJECTS APPROVED WITH LIMITATIONS - The following projects in the Plan are approved for implementation with limitations:

(A) LOXAHATCHEE NATIONAL WILDLIFE REFUGE - The Federal share for land acquisition in the project to enhance existing wetland systems along the Loxahatchee National Wildlife Refuge, including the Stazzulla tract, should be funded through the budget of the Department of the Interior.

(B) SOUTHERN CORKSCREW REGIONAL ECOSYSTEM - The Southern Corkscrew regional ecosystem watershed addition should be accomplished outside the scope of the Plan.

(h) ASSURANCE OF PROJECT BENEFITS -

(1) IN GENERAL - The overarching objective of the Plan is the restoration, preservation, and protection of the South Florida Ecosystem while providing for other water-related needs of the region, including water supply and flood protection. The Plan shall be implemented to

ensure the protection of water quality in, the reduction of the loss of fresh water from, the improvement of the environment of the South Florida Ecosystem and to achieve and maintain the benefits to the natural system and human environment described in the Plan, and required pursuant to this section, for as long as the project is authorized.

(2) AGREEMENT -

(A) IN GENERAL - In order to ensure that water generated by the Plan will be made available for the restoration of the natural system, no appropriations, except for any pilot project described in subsection (b)(2)(B), shall be made for the construction of a project contained in the Plan until the President and the Governor enter into a binding agreement under which the State shall ensure, by regulation or other appropriate means, that water made available by each project in the Plan shall not be permitted for a consumptive use or otherwise made unavailable by the State until such time as sufficient reservations of water for the restoration of the natural system are made under State law in accordance with the project implementation report for that project and consistent with the Plan.

(B) ENFORCEMENT -

(i) IN GENERAL - Any person or entity that is aggrieved by a failure of the United States or any other Federal Government instrumentality or agency, or the Governor or any other officer of a State instrumentality or agency, to comply with any provision of the agreement entered into under subparagraph (A) may bring a civil action in United States district court for an injunction directing the United States or any other Federal Government instrumentality or agency or the Governor or any other officer of a State instrumentality or agency, as the case may be, to comply with the agreement.

(ii) LIMITATIONS ON COMMENCEMENT OF CIVIL ACTION - No civil action may be commenced under clause (i)--

(I) before the date that is 60 days after the Secretary and the Governor receive written notice of a failure to comply with the agreement; or

(II) if the United States has commenced and is diligently prosecuting an action in a court of the United States or a State to redress a failure to comply with the agreement.

(C) TRUST RESPONSIBILITIES - In carrying out his responsibilities under this subsection with respect to the restoration of the South Florida ecosystem, the Secretary of the Interior shall fulfill his obligations to the Indian tribes in South Florida under the Indian trust doctrine as well as other applicable legal obligations.

(3) PROGRAMMATIC REGULATIONS -

(A) ISSUANCE - Not later than 2 years after the date of enactment of this Act, the Secretary shall, after notice and opportunity for public comment, with the concurrence of the Governor and the Secretary of the Interior, and in consultation with the Seminole Tribe of Florida, the Miccosukee Tribe of Indians of Florida, the Administrator of the Environmental Protection Agency, the Secretary of Commerce, and other Federal, State, and local agencies, promulgate programmatic regulations to ensure that the goals and purposes of the Plan are achieved.

(B) CONCURRENCY STATEMENT - The Secretary of the Interior and the Governor shall, not later than 180 days from the end of the public comment period on proposed programmatic regulations, provide the Secretary with a written statement of concurrence or nonconcurrence. A failure to provide a written statement of concurrence or nonconcurrence within such time frame will be deemed as meeting the concurrency requirements of subparagraph (A)(i). A copy of any concurrency or nonconcurrency statements shall be made a part of the administrative record and referenced in the final programmatic regulations. Any nonconcurrency statement shall specifically detail the reason or reasons for the nonconcurrence.

(C) CONTENT OF REGULATIONS -

(i) IN GENERAL - Programmatic regulations promulgated under this paragraph shall establish a process--

(I) for the development of project implementation reports, project cooperation agreements, and operating manuals that ensure that the goals and objectives of the Plan are achieved;

(II) to ensure that new information resulting from changed or unforeseen circumstances, new scientific or technical information or information that is developed through the principles of adaptive management contained in the Plan, or

future authorized changes to the Plan are integrated into the implementation of the Plan; and

(III) to ensure the protection of the natural system consistent with the goals and purposes of the Plan, including the establishment of interim goals to provide a means by which the restoration success of the Plan may be evaluated throughout the implementation process.

(ii) LIMITATION ON APPLICABILITY OF PROGRAMMATIC REGULATIONS - Programmatic regulations promulgated under this paragraph shall expressly prohibit the requirement for concurrence by the Secretary of the Interior or the Governor on project implementation reports, project cooperation agreements, operating manuals for individual projects undertaken in the Plan, and any other documents relating to the development, implementation, and management of individual features of the Plan, unless such concurrence is provided for in other Federal or State laws.

(D) SCHEDULE AND TRANSITION RULE -

(i) IN GENERAL - All project implementation reports approved before the date of promulgation of the programmatic regulations shall be consistent with the Plan.

(ii) PREAMBLE - The preamble of the programmatic regulations shall include a statement concerning the consistency with the programmatic regulations of any project implementation reports that were approved before the date of promulgation of the regulations.

(E) REVIEW OF PROGRAMMATIC REGULATIONS - Whenever necessary to attain Plan goals and purposes, but not less often than every 5 years, the Secretary, in accordance with subparagraph (A), shall review the programmatic regulations promulgated under this paragraph.

(4) PROJECT-SPECIFIC ASSURANCES -

(A) PROJECT IMPLEMENTATION REPORTS -

(i) IN GENERAL - The Secretary and the non-Federal sponsor shall develop project implementation reports in accordance with section 10.3.1 of the Plan.

(ii) COORDINATION - In developing a project implementation report, the Secretary and the non-

Federal sponsor shall coordinate with appropriate Federal, State, tribal, and local governments.

(iii) REQUIREMENTS - A project implementation report shall--

(I) be consistent with the Plan and the programmatic regulations promulgated under paragraph (3);

(II) describe how each of the requirements stated in paragraph (3)(B) is satisfied;

(III) comply with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.);

(IV) identify the appropriate quantity, timing, and distribution of water dedicated and managed for the natural system;

(V) identify the amount of water to be reserved or allocated for the natural system necessary to implement, under State law, subclauses (IV) and (VI);

(VI) comply with applicable water quality standards and applicable water quality permitting requirements under subsection (b)(2)(A)(ii);

(VII) be based on the best available science; and

(VIII) include an analysis concerning the cost-effectiveness and engineering feasibility of the project.

(B) PROJECT COOPERATION AGREEMENTS -

(i) IN GENERAL - The Secretary and the non-Federal sponsor shall execute project cooperation agreements in accordance with section 10 of the Plan.

(ii) CONDITION - The Secretary shall not execute a project cooperation agreement until any reservation or allocation of water for the natural system identified in the project implementation report is executed under State law.

(C) OPERATING MANUALS -

(i) IN GENERAL - The Secretary and the non-Federal sponsor shall develop and issue, for each project or group of projects, an operating manual that is consistent with the water reservation or allocation for the natural system described in the project

implementation report and the project cooperation agreement for the project or group of projects.

(ii) MODIFICATIONS - Any significant modification by the Secretary and the non-Federal sponsor to an operating manual after the operating manual is issued shall only be carried out subject to notice and opportunity for public comment.

(5) SAVINGS CLAUSE -

(A) NO ELIMINATION OR TRANSFER - Until a new source of water supply of comparable quantity and quality as that available on the date of enactment of this Act is available to replace the water to be lost as a result of implementation of the Plan, the Secretary and the non-Federal sponsor shall not eliminate or transfer existing legal sources of water, including those for--

(i) an agricultural or urban water supply;

(ii) allocation or entitlement to the Seminole Indian Tribe of Florida under section 7 of the Seminole Indian Land Claims Settlement Act of 1987 (25 U.S.C. 1772e);

(iii) the Miccosukee Tribe of Indians of Florida;

(iv) water supply for Everglades National Park; or

(v) water supply for fish and wildlife.

(B) MAINTENANCE OF FLOOD PROTECTION - Implementation of the Plan shall not reduce levels of service for flood protection that are--

(i) in existence on the date of enactment of this Act; and

(ii) in accordance with applicable law.

(C) NO EFFECT ON TRIBAL COMPACT - Nothing in this section amends, alters, prevents, or otherwise abrogates rights of the Seminole Indian Tribe of Florida under the compact among the Seminole Tribe of Florida, the State, and the South Florida Water Management District, defining the scope and use of water rights of the Seminole Tribe of Florida, as codified by section 7 of the Seminole Indian Land Claims Settlement Act of 1987 (25 U.S.C. 1772e).

(i) DISPUTE RESOLUTION -

(1) IN GENERAL - The Secretary and the Governor shall within 180 days from the date of enactment of this Act develop an agreement for resolving disputes between the Corps of Engineers and the State associated with the implementation of the Plan. Such agreement shall

establish a mechanism for the timely and efficient resolution of disputes, including--

(A) a preference for the resolution of disputes between the Jacksonville District of the Corps of Engineers and the South Florida Water Management District;

(B) a mechanism for the Jacksonville District of the Corps of Engineers or the South Florida Water Management District to initiate the dispute resolution process for unresolved issues;

(C) the establishment of appropriate timeframes and intermediate steps for the elevation of disputes to the Governor and the Secretary; and

(D) a mechanism for the final resolution of disputes, within 180 days from the date that the dispute resolution process is initiated under subparagraph (B).

(2) CONDITION FOR REPORT APPROVAL - The Secretary shall not approve a project implementation report under this section until the agreement established under this subsection has been executed.

(3) NO EFFECT ON LAW - Nothing in the agreement established under this subsection shall alter or amend any existing Federal or State law, or the responsibility of any party to the agreement to comply with any Federal or State law.

(j) INDEPENDENT SCIENTIFIC REVIEW -

(1) IN GENERAL - The Secretary, the Secretary of the Interior, and the Governor, in consultation with the South Florida Ecosystem Restoration Task Force, shall establish an independent scientific review panel convened by a body, such as the National Academy of Sciences, to review the Plan's progress toward achieving the natural system restoration goals of the Plan.

(2) REPORT - The panel described in paragraph (1) shall produce a biennial report to Congress, the Secretary, the Secretary of the Interior, and the Governor that includes an assessment of ecological indicators and other measures of progress in restoring the ecology of the natural system, based on the Plan.

(k) OUTREACH AND ASSISTANCE -

(1) SMALL BUSINESS CONCERNS OWNED AND OPERATED BY SOCIALLY AND ECONOMICALLY DISADVANTAGED INDIVIDUALS - In executing the Plan, the Secretary shall ensure that small business concerns owned and controlled by socially and economically disadvantaged individuals are provided opportunities to participate under section 15(g) of the Small Business Act (15 U.S.C. 644(g)).

(2) COMMUNITY OUTREACH AND EDUCATION -

(A) IN GENERAL - The Secretary shall ensure that impacts on socially and economically disadvantaged individuals, including individuals with limited English proficiency, and communities are considered during implementation of the Plan, and that such individuals have opportunities to review and comment on its implementation.

(B) PROVISION OF OPPORTUNITIES - The Secretary shall ensure, to the maximum extent practicable, that public outreach and educational opportunities are provided, during implementation of the Plan, to the individuals of South Florida, including individuals with limited English proficiency, and in particular for socially and economically disadvantaged communities.

(l) REPORT TO CONGRESS - Beginning on October 1, 2005, and periodically thereafter until October 1, 2036, the Secretary and the Secretary of the Interior, in consultation with the Environmental Protection Agency, the Department of Commerce, and the State of Florida, shall jointly submit to Congress a report on the implementation of the Plan. Such reports shall be completed not less often than every 5 years. Such reports shall include a description of planning, design, and construction work completed, the amount of funds expended during the period covered by the report (including a detailed analysis of the funds expended for adaptive assessment under subsection (b)(2)(C)(xi)), and the work anticipated over the next 5-year period. In addition, each report shall include--

(1) the determination of each Secretary, and the Administrator of the Environmental Protection Agency, concerning the benefits to the natural system and the human environment achieved as of the date of the report and whether the completed projects of the Plan are being operated in a manner that is consistent with the requirements of subsection (h);

(2) progress toward interim goals established in accordance with subsection (h)(3)(B); and

(3) a review of the activities performed by the Secretary under subsection (k) as they relate to socially and economically disadvantaged individuals and individuals with limited English proficiency.

(m) REPORT ON AQUIFER STORAGE AND RECOVERY PROJECT - Not later than 180 days after the date of enactment of this Act, the Secretary shall transmit to Congress a report containing a determination as to whether the ongoing Biscayne Aquifer Storage and Recovery Program located in Miami-Dade County has a substantial benefit to the restoration, preservation, and protection of the South Florida ecosystem.

(n) FULL DISCLOSURE OF PROPOSED FUNDING -

(1) FUNDING FROM ALL SOURCES - The President, as part of the annual budget of the United States Government, shall display

under the heading `Everglades Restoration' all proposed funding for the Plan for all agency programs.

(2) FUNDING FROM CORPS OF ENGINEERS CIVIL WORKS PROGRAM - The President, as part of the annual budget of the United States Government, shall display under the accounts `Construction, General' and `Operation and Maintenance, General' of the title `Department of Defense--Civil, Department of the Army, Corps of Engineers--Civil', the total proposed funding level for each account for the Plan and the percentage such level represents of the overall levels in such accounts. The President shall also include an assessment of the impact such funding levels for the Plan would have on the budget year and long-term funding levels for the overall Corps of Engineers civil works program.

(o) SURPLUS FEDERAL LANDS - Section 390(f)(2)(A)(i) of the Federal Agriculture Improvement and Reform Act of 1996 (110 Stat. 1023) is amended by inserting after `on or after the date of enactment of this Act' the following: `and before the date of enactment of the Water Resources Development Act of 2000'.

(p) SEVERABILITY - If any provision or remedy provided by this section is found to be unconstitutional or unenforceable by any court of competent jurisdiction, any remaining provisions in this section shall remain valid and enforceable.

D.26.2 EXHIBIT "B"

FLORIDA STATUTES
TITLE XXVIII. NATURAL RESOURCES; CONSERVATION, RECLAMATION, AND USE CHAPTER 373. WATER RESOURCES
PART I. STATE WATER RESOURCE PLAN

373.1501. South Florida Water Management District as local sponsor
(1) As used in this section and s. 373.026(8), the term:
(b) "Department" means the Department of Environmental Protection.
(c) "District" means the South Florida Water Management District.
(f) "Project" means the Central and Southern Florida Project.
(g) "Project Component" means any structural or operational change, resulting from the restudy, to the Central and Southern Florida Project as it existed and was operated as of January 1, 1999.
(h) "Restudy" means the Comprehensive Review Study of the Central and Southern Florida Project, for which federal participation was authorized by the federal Water Resources Development Acts of 1992 and 1996 together with related Congressional resolutions and for which participation by the South Florida Water Management District is authorized by this section. The term includes all actions undertaken pursuant to the aforementioned authorizations which will result in recommendations for modifications or additions to the Central and Southern Florida Project.
(2) The Legislature finds that the restudy is important for restoring the Everglades ecosystem and sustaining the environment, economy, and social wellbeing of South Florida. It is the intent of the Legislature to facilitate and support the restudy through a process concurrent with Federal Government review and Congressional authorization. Nothing in this section is intended in any way to limit federal agencies or Congress in the exercise of their duties and responsibilities. It is further the intent of the Legislature that all project components be implemented through the appropriate processes of this chapter and be consistent with the balanced policies and purposes of this chapter, specifically s. 373.016.
(4) The district is authorized to act as local sponsor of the project for those project features within the district as provided in this subsection and subject to the oversight of the department as further provided in s. 373.026. The district may:
(a) Act as local sponsor for all project features previously authorized by Congress;
(b) Continue data gathering, analysis, research, and design of project components, participate in preconstruction engineering and design documents for project components, and further refine the Comprehensive Plan of the restudy as a guide and framework for identifying other project components;
(c) Construct pilot projects that will assist in determining the feasibility of technology included in the Comprehensive Plan of the restudy; and
(d) Act as local sponsor for project components.
(5) In its role as local sponsor for the project, the district shall comply with its responsibilities under this chapter and implement project components through

appropriate provisions of this chapter. In the development of project components, the district shall:
(a) Analyze and evaluate all needs to be met in a comprehensive manner and consider all applicable water resource issues, including water supply, water quality, flood protection, threatened and endangered species, and other natural system and habitat needs;
(b) Determine with reasonable certainty that all project components are feasible based upon standard engineering practices and technologies and are the most efficient and cost-effective of feasible alternatives or combination of alternatives, consistent with restudy purposes, implementation of project components, and operation of the project; (c) Determine with reasonable certainty that all project components are consistent with applicable law and regulations, and can be permitted and operated as proposed. For purposes of such determination:
1. The district shall convene a pre-application conference with all state and federal agencies with applicable regulatory jurisdiction;
2. State agencies with applicable regulatory jurisdiction shall participate in the pre-application conference and provide information necessary for the district's determination; and
3. The district shall request that federal agencies with applicable regulatory jurisdiction participate in the pre-application conference and provide information necessary for the district's determination;
(d) Consistent with this chapter, the purposes for the restudy provided in the Water Resources Development Act of 1996, and other applicable federal law, provide reasonable assurances that the quantity of water available to existing legal users shall not be diminished by implementation of project components so as to adversely impact existing legal users, that existing levels of service for flood protection will not be diminished outside the geographic area of the project component, and that water management practices will continue to adapt to meet the needs of the restored natural environment.
(e) Ensure that implementation of project components is coordinated with existing utilities and public infrastructure and that impacts to and relocation of existing utility or public infrastructure are minimized.
(6) The department and the district shall expeditiously pursue implementation of project modifications previously authorized by Congress or the Legislature, including the Everglades Construction Project. Project components should complement and should not delay project modifications previously authorized.
(7) Notwithstanding any provision of this section, nothing herein shall be construed to modify or supplant the authority of the district or the department to prevent harm to the water resources as provided in this chapter.
(8) Final agency action with regard to any project component subject to s. 373.026(8)(b) shall be taken by the department. Actions taken by the district pursuant to subsection (5) shall not be considered final agency action. Any petition for formal proceedings filed pursuant to ss. 120.569 and 120.57 shall require a hearing under the summary hearing provisions of s. 120.574, which

shall be mandatory. The final hearing under this section shall be held within 30 days after receipt of the petition by the Division of Administrative Hearings.

APPENDIX E
AGENCY AND PUBLIC COORDINATION

TABLE OF CONTENTS

E.0 ENVIRONMENTAL COMPLIANCE COORDINATION E-1
E.1 COOPERATING AGENCIES E-1
E.2 NATIONAL ENVIRONMENTAL POLICY ACT PUBLIC MEETINGS E-6

E.0 ENVIRONMENTAL COMPLIANCE COORDINATION

E.1 COOPERATING AGENCIES

In accordance with regulations pertaining to the National Environmental Policy Act (NEPA) (Title 40 of the Cod of Federal Regulations [CFR], part 1501.6), the following agencies were formally invited to become a cooperating agency for an Environmental Impact Statement (EIS) on the C-111 Spreader Canal (C-111 SC) Western project:

U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. National Marine Fisheries Service
National Park Service
Florida Fish and Wildlife Conservation Commission
Florida Department of Environmental Protection
U.S. Geological Survey
Miami-Dade Department of Environmental Resources Management

An invitation to become a cooperating agency was sent by letter and an example is attached in this section. Thus far, the U.S. Fish and Wildlife Service (FWS) has formally declined the invitation to become a cooperating agency, but has emphasized continued support for the project. Responses from other agencies have not been received at this time.

Though not officially accepting the invitation as cooperating agencies for the purposes of NEPA, the following state and federal agencies are members of the project development team (PDT) and have contributed to the development of the project implementation report (PIR)/EIS: FWS, National Marine Fisheries Service (NMFS), U.S. Environmental Protection Agency (EPA), Florida Department of Environmental Protection (FDEP), National Park Service (NPS), and Miami-Dade Department of Environmental Resources Management (DERM). These agencies are considered to be partners in Comprehensive Everglades Restoration Plan (CERP) projects.

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT CORPS OF ENGINEERS
P.O. BOX 4970
JACKSONVILLE, FLORIDA 32232-0019

REPLY TO ATTENTION OF

Planning Division
Environmental Branch

NOV 0 8 2007

Mr. Bradley J. Hartman, Director
Florida Fish and Wildlife Conservation Commission
Office of Environmental Services
620 South Meridian Street
Tallahassee, Florida 32399-1600

Dear Mr. Hartman:

In accordance with regulations pertaining to the National Environmental Policy Act (Title 40 of the Code of Federal Regulations, part 1501.6), I am formally inviting your agency to become a cooperating agency for an Environmental Impact Statement (EIS) on the C-111 Spreader Canal project. The goal of the C-111 Spreader Canal project is to redistribute freshwater runoff from the watershed into Florida Bay, away from the canal discharges that exist today and provide a more natural and historic flow through existing and or improved coastal wetlands. The plan formulation for this project focused on providing the proper quality, timing, and distribution of available water to meet the goals, objectives, and purposes for the project as described in the Restudy. Please see the enclosed figure of the C-111 Spreader Canal project study area.

Please note that cooperating agency status involves actions and responsibilities beyond that normally associated with a commenting or permitting agency. We appreciate and acknowledge your participation and cooperation in the project formulation to this point, and look forward to your continued cooperation in the preparation of the Draft Project Implementation Report / Environmental Impact Statement.

The formulation of the project, alternatives, and mitigation have been in accordance with Engineer Regulation ER 1105-2-100 and have fully considered a range of environmental, economic, and social factors. As a cooperating agency, you must fully consider the views, needs, and benefits of competing interests.

No cooperating agency will have "veto" over the selection of the project plan, alternatives, or mitigation measures. Under your status as a commenting agency, you may recommend actions not ultimately adopted or implemented by the lead agency. You may also impose requirements to the extent allowed under your legal authority as a permitting agency. Conflict with the lead agency may be resolved through mediation, placing a dissenting opinion in the EIS, withdrawing your cooperating agency status, or the Lead agency pursuing an EIS without you as a cooperating agency. For additional information see the enclosed "Rights and Responsibilities of Lead and Cooperating Agencies" (Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, Council on Environmental Quality, 1981).

-2-

Please indicate whether you accept this invitation to become a cooperating agency (as described above) within 30 days of the date of this letter. If you have any questions, please contact Brad Tarr at 904-232-3582.

Sincerely,

Marie G. Burns
Acting Chief, Planning Division

Enclosures

United States Department of the Interior

FISH AND WILDLIFE SERVICE
South Florida Ecological Services Office
1339 20th Street
Vero Beach, Florida 32960

December 28, 2008

Stuart J. Appelbaum
Chief, Planning Division
U.S. Army Corps of Engineers
Post Office Box 4970
Jacksonville, Florida 32232-0019

Attention: Brad Tarr

Service Federal Activity Code: 41420-2006-FA-0266
Date Received: November 19, 2007
Project: C-111 Spreader Canal
County: Miami-Dade

Dear Mr. Appelbaum:

Thank you for your letter dated November 8, 2007, in which you formally invited the Fish and Wildlife Service (Service) to become a cooperating agency for an Environmental Impact Statement (EIS) on the C-111 Spreader Canal (C-111SC) Project.

The overall goal of the C-111SC Project is ecological restoration of the Southern Glades and Model Lands including downstream estuaries by improving timing, distribution, quantity, and quality of water deliveries. The project will modify the delivery of water to the Southern Glades and Model Lands to establish sheet flow and hydropatterns that will sustain the historic flora and fauna of these areas; provide more natural sheet flow to Florida Bay by eliminating damaging point source discharges of freshwater through the C-111 Canal to the estuarine systems of Manatee Bay and Barnes Sound; and maintain levels of flood protection for agricultural and urban areas adjacent to the project area. The Western (Phase 1) C-111SC Project Implementation Report (PIR) will focus primarily on improving the quantity, timing, and distribution of water delivered to central Florida Bay via Taylor Slough. The Eastern (Phase 2) C-111SC Project PIR will include more details of the features east of the C-111 Canal and focus on additional improvements in the quantity, quality, timing, and distribution of flows needed to maximize overall restoration of the lower system.

The Service has been fully involved in all aspects of the planning of this project since its inception, including the development of performance measures, formulation of project alternatives, determination of ecological benefits, development of monitoring plans, and other project planning components. We have submitted numerous Planning Aid Letters and Planning Aid Reports in support of this project. The U.S. Army Corps of Engineers, South Florida Water

TAKE PRIDE IN AMERICA

Stuart J. Appelbaum Page 2

Management District, National Park Service, Miami-Dade County Department of Environmental Resource Management, and Service continue planning in a collaborative environment to maximize ecological benefits of the C-111 SC Project while minimizing potential adverse impacts to our valuable natural resources. The biologists and resource managers on this study team have reached consensus on many planning components for the study, but other issues must be addressed through communication at future steps along the process.

Although we intend to continue our work on the study team, the Service declines your invitation to become a cooperating agency for the development of the EIS on this project. We will continue to take a broad system-wide perspective and a balanced approach in our evaluation of the ecological effects of the proposed action. The Service must balance its role as a Project Delivery Team member with its statutory responsibilities to independently review this proposed action under the Fish and Wildlife Coordination Act and Endangered Species Act.

The Service greatly appreciates your efforts in helping to protect the fish and wildlife resources of south Florida. If you have questions regarding this letter, please call Richard Fike at 772-562-3909, extension 262.

Sincerely yours,

Paul Souza
Field Supervisor
South Florida Ecological Services Office

cc:
District, West Palm Beach, Florida (John Shaffer)
NPS, Homestead, Florida (Ed Kearns)
Miami-Dade DERM, Miami, Florida (Dr. Susan Markley)
FWC, Vero Beach, Florida (Dr. Joseph Walsh)
Service, Jacksonville, Florida (Miles Meyer)
Service, Atlanta, Georgia (Jeff Weller)

E.2 NATIONAL ENVIRONMENTAL POLICY ACT PUBLIC MEETINGS

Initial coordination began with the distribution of a scoping letter, dated May 7, 2002, announcing the project and requesting assistance in gathering information to help define issues and concerns to be addressed in a NEPA document. Subsequent to the scoping letter, a Project Management Plan (PMP) public workshop was held on May 22, 2002 at the Miami-Dade Agricultural Center in Miami, Florida. The public workshop, advertised through newspapers, radio news releases and email notices, introduced the project's goals and objectives, and provided opportunities for the public to voice their concerns on an array of project issues. On May 16, 2002 a Notice of Intent to prepare an EIS was published in the Federal Register ([FR] Vol. 67, Number 95).

A number of subsequent meetings open to the public have been held to date. CERP policy is for advance notification of meetings to be posted on the CERP website and digital calendar. The meetings generally include updates and discussion by the PDT, followed by a public comment period. The following is a list of recent public meetings held to date.

Benefits Analysis Workshop	24-25 October 2006
PDT Meeting	26 October 2006
Modeling/Benefits Analysis Workshop	17-18 January 2007
PDT Meeting	15 May 2007
Benefits Analysis Workshop	04-06 June 2007
Benefits Analysis Workshop	25 June 2007
PDT Meeting	21 August 2007
PDT Meeting	21 February 2008
PDT Meeting	12 March 2008
PDT Meeting	08 April 2008
PDT Meeting	20 May 2008
PDT Meeting	18 June 2008
PDT Meeting	22 October 2008

Below is a copy of the scoping letter and related public and agency comments.

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT CORPS OF ENGINEERS
P. O. BOX 4970
JACKSONVILLE, FLORIDA 32232-0019

REPLY TO
ATTENTION OF

Planning Division
Environmental Branch

MAY 07 2002

TO WHOM IT MAY CONCERN:

The U.S. Army Corps of Engineers (Corps), Jacksonville District, is requesting your assistance in gathering information that will help define issues and concerns to be addressed in a National Environmental Policy Act (NEPA) document being prepared for the C-111 Spreader Canal Project. The project is part of the Comprehensive Everglades Restoration Plan (CERP) authorized by the Water Resources Development Act of 2000. The C-111 Canal is the southernmost canal of the Central and Southern Florida Project and is located is southeastern Miami-Dade County, Florida (map enclosed).

The canal functions primarily to provide flood protection and drainage for the agricultural areas to the west and south of Homestead, as well as providing a means to deliver water to Taylor Slough in Everglades National Park. Environmentally detrimental effects have resulted from the construction of the canal, including large scale releases of freshwater to Manatee Bay, disruption and redirection of the natural sheet flow pattern over the marsh, and declining fish catches and productivity in northeastern Florida Bay and Barnes Sound, due to highly variable salinities. The final report of the C&SF Comprehensive Review Study (RESTUDY) recommended implementing the C-111 North Spreader Canal Project, now called simply the C-111 Spreader Canal Project. This project will evaluate alternatives to construct, modify, or remove levees, canals, pumps and water control structures, in order to reestablish a more natural water sheet flow pattern through the Model Lands and Southern Glades to Florida Bay, and may include a storm water treatment area.

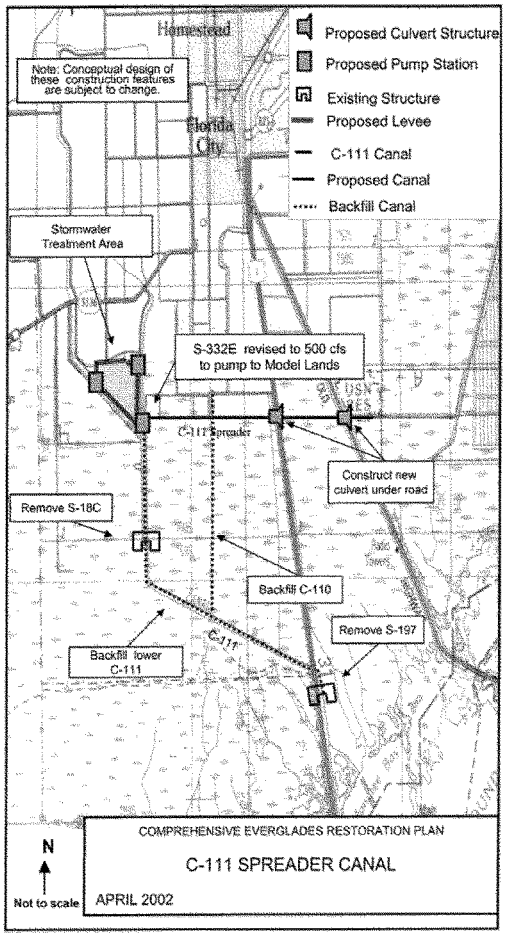
We welcome your views, comments, concerns and information about resources and important features within the area shown as well as any suggested improvements. If you know others who may wish to comment on this activity, please advise them of this request for public comments. Letters of comment or inquiry should be addressed to the attention of Planning Division, Environmental Branch, South Florida Section, and be received by this office within 30 days of the date of this letter. If you

-2-

have any questions, please contact Mrs. Barbara Cintron by telephone at 904-232-1692, or by electronic mail at barbara.b.cintron@saj02.usace.army.mil.

Sincerely,

James C. Duck
Chief, Planning Division


Homestead
Florida City
Note: Conceptual design of these construction features are subject to change.
Proposed Culvert Structure
Proposed Pump Station
Existing Structure
Proposed Levee
C-111 Canal
Proposed Canal
Backfill Canal
Stormwater Treatment Area
S-332E revised to 500 cfs to pump to Model Lands
C-111 Spreader
Construct new culvert under road
Remove S-18C
Backfill C-110
Remove S-197
Backfill lower C-111
C-111
COMPREHENSIVE EVERGLADES RESTORATION PLAN
C-111 SPREADER CANAL
N
Not to scale
APRIL 2002

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

DAVID K. MEEHAN
St. Petersburg

H.A. "HERKY" HUFFMAN
Deltona

JOHN D. ROOD
Jacksonville

QUINTON L. HEDGEPETH, DDS
Miami

EDWIN P. ROBERTS, DC
Pensacola

RODNEY BARRETO
Miami

SANDRA T. KAUPE
Palm Beach

KENNETH D. HADDAD, Executive Director
VICTOR J. HELLER, Assistant Executive Director

BRADLEY J. HARTMAN, DIRECTOR
OFFICE OF ENVIRONMENTAL SERVICES
(850)488-6661 TDD (850)488-9542
FAX (850)922-5679

June 3, 2002

Mr. James C. Duck
Chief, Planning Division
Environmental Branch
U.S. Army Corps of Engineers
P.O. Box 4790
Jacksonville, Florida 32232-0019

Re: Scoping Notice for C-111 Spreader Canal Project, Miami-Dade County

Dear Mr. Duck:

The Office of Environmental Services of the Florida Fish and Wildlife Conservation Commission has received the scoping notice for the referenced project, and offers the following issues and concerns that we would like to see addressed during the development of a Project Implementation Report (PIR).

This project is part of the Everglades Comprehensive Restoration Plan (CERP) authorized by the Water Resources Development Act of 2000. The primary purpose of this project is to expand the benefits of the C-111 General Reevaluation Report, that is currently being finalized by the U.S. Army Corps of Engineers (COE), by extending the previous spreader canal design to reestablish more natural water flow patterns in the Modal Lands east of U.S. 1 and Card Sound Road. Additional proposed features that are intended to improve sheet flow patterns through the Southern Glades and into northeastern Florida Bay include the construction, modification, or removal of levees, canals, pumps, and water control structures.

We have identified the following issues that should be addressed during plan formulation for this project. Due to the overlapping of several project design features of the C-111 Spreader Canal Project with the C-111 General Reevaluation Report Supplement, some of our concerns have previously been conveyed to the COE in a letter to Colonel J. Greg May, dated September 12, 2000 (attached).

1. Potential loss or degradation of Everglades marsh. The tentative location of the proposed stormwater treatment area contains high quality Everglades marl prairie habitat that should be protected. The current alignment of the spreader canal could similarly impact

620 South Meridian Street • Tallahassee • FL • 32399-1600
www.floridaconservation.org

wetlands in the Southern Glades Wildlife and Environmental Area (SGWEA) that would be isolated by the levee to the north of the proposed canal. Given the loss of quality native habitat that has already occurred in the Everglades, we would find it difficult to support any alternative that would result in further loss of native Everglades marsh.

2. Quantity of water available for the project. The quantity of water that will be made available for use by this project in both the near and long terms will need to be identified in order to develop an appropriate structural plan. There will need to be close coordination with the development of the Combined Structural and Operational Plan (CSOP) to ensure that the quantities of water being assumed in modeling runs for the C-111 Spreader Canal are complementary to those made available under CSOP.

3. Water quality. We are concerned about the quality of the greater quantities of water that will presumably be entering the SGWEA, and potential impacts to local flora and fauna. Although we would support the construction of a stormwater treatment area, if needed, to treat the water prior to entering the SGWEA, we recommend that the size of the facility be properly determined and that it's footprint not displace native Everglades wetlands.

4. Modeling concerns. This area lies near the boundary of the South Florida Water Management Model where there is a high degree of uncertainty associated with model predictions, and this area is more topographically heterogeneous that the model assumes for this region. For these reasons, we recommend that a higher resolution "sub-regional" scale model be used during plan formulation for this project. The Regional Simulation Model may be appropriate if a version is available for this area.

5. State and Federally listed species of wildlife. Roseate spoonbills (*Ajaia ajaja*), a species of special concern (SSC), currently use the east-southeast reach of the C-111 as foraging habitat, though this use has steadily decreased in recent years as *Phragmites* ssp., cattails (*Typha* ssp.) and cane grasses have invaded this area. The USFWS has also reported that endangered American crocodiles (*Crocodylus acutus*) have used the tree islands in this area as nesting habitat. The SGWEA provides both forage and nesting habitat for limpkins (*Aramus guarauna*, SSC), and both this bird and the endangered snail kite (*Rostrhamus sociabilis plumbeus*) could benefit as this project creates more natural hydrologic conditions in the area located between the C-111 and C-110 canals. Sub-population D of the endangered Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) inhabits the marsh between the C-111 north-south reach and Aerojet Road within the SGWEA.

6. Recreational resources and facilities. This project could provide considerable enhancements to the recreational value of the SGWEA. Currently, the presence of the C-111 and C-110 create drier than natural conditions in the marsh between them and

prevent airboat access to this marsh. The C-111 canal also prevents sheet flow to the south thus creating unnaturally wetter conditions north of its eastern reach. Saline water intrusions along the C-111 have allowed this area to be invaded by red mangroves.

Because we have specific land and wildlife management responsibilities as managers of the Southern Glades Wildlife and Environmental Area, we reserve the option to submit to you Planning Aid Letters and a Fish and Wildlife Coordination Act report independent of those submitted by the U.S. Department of the Interior. If you have any further questions, please feel free to contact Mr. Tim Towles (772-778-5094) in our Vero Beach office.

Sincerely,

Brian Barnett, for

Bradley J. Hartman, Director
Office of Environmental Services

BJH/DTT
ENV 2-16/5
a\c-111_scopl_spreader-May02.doc
Enclosure
cc: Mr. Jay Slack, USFWS, Vero Beach
Ms. Maureen Finnerty, ENP, Homestead

DADE COUNTY FARM BUREAU

1850 Old Dixie Highway • Homestead, FL 33033 • Telephone (305) 246-5514

May 23, 2002

Mr. Charlie Fales
U. S. Army Corps of Engineers
Jacksonville District
P. O. Box 4970
Jacksonville, Fl 32232-0019

Re: Comments on C-111North Spreader Canal Project, CERP

Dr. Mr. Fales,

These are my comments from the meeting May 22 in Homestead:

1. Why is the plan being altered given the fact that the Mod Waters plan is not executed and you have no way to know that the original plan would work yet, much less have a basis for alteration?

2. The "scope objectives" - why is there no objective to evaluate the impact upon agriculture?

3. I am on the BBRRCT - How have you coordinated your plan with theirs for impact on their wetlands restoration projects on the shore of Biscayne Bay, Card Sound, etc.?

4. How can you determine "Baseline Conditions" are before Mod Waters and C-111 are completed?

5. The project cost is stated at $94,035,000. It describes cost sharing as 50/50 between ACE and SFWMD. Then it lists "other participating agencies" and "Stakeholders." I remind you that one of those "stakeholder groups" is the taxpayers, of which all of you in this room are a part of. In an earlier meeting on this subject I asked the question "for 94 million, will it work?" The answer was "we think so," and, "the models say it will." You will pardon me if I say that those of us in South Dade are a little fed up with the modelers. They have stung us before, at tremendous cost and little result. PLEASE be careful in throwing

Page 2

5. (cont'd) around 94 million dollars. Let's try not to waste any more of my and your money.

In general conversation after the presentation, you solicited open input to the plan - asking if anyone had a better idea, etc. I repeat my response - Very few of us in the audience at these meetings have got the slightest idea or basis up which to challenge you project needs, design or implementation methods. We have to trust you. I repeat, please be careful. Let's not duplicate anymore Kissimmee River ditch fiascos. The planners said we need it, the designers said we need it, everyone said we needed it. Now look what's happening 30 years later at a cost of God only knows how much.

Sincerely,

Dave Friedrichs
Executive Director
Dade County Farm Bureau

cc: David Kaplan, President
Board of Directors

APPENDIX F
PLAN FORMULATION AND EVALUATION

TABLE OF CONTENTS

F.0 PLAN FORMULATION F-1
F.1 INITIAL ARRAY OF ALTERNATIVES F-1
F.2 FROG POND DETENTION AREA ANALYSIS F-58
F.3 ECOLOGICAL EVALUATION F-60
F.4 PHYSICAL FEATURES AND LERR REQUIREMENTS F-67

LIST OF TABLES

Table F-1 Initial Array of Alternatives F-50
Table F-2 Lands and Real Estate Costs for Six Final Alternatives F-69

LIST OF FIGURES

Figure F-1 Alternative Plan 1 (Yellow Book) F-2
Figure F-2 Alternative 2 ..... F-4
Figure F-3 Alternative 3 ..... F-6
Figure F-4 Alternative 4 ..... F-8
Figure F-5 Alternative 5 ..... F-10
Figure F-6 Alternative 6 ..... F-12
Figure F-7 Alternative 7 ..... F-14
Figure F-8 Alternative 8 ..... F-16
Figure F-9 Alternative 9 ..... F-18
Figure F-10 Alternative 10 ..... F-20
Figure F-11 Alternative 11 ..... F-22
Figure F-12 Alternative 12 ..... F-24
Figure F-13 Alternative 13 ..... F-26
Figure F-14 Alternative 14 ..... F-28
Figure F-15 Alternative 15 ..... F-30
Figure F-16 Alternative 16 ..... F-33
Figure F-17 Alternative 17 ..... F-35
Figure F-18 Alternative 18 ..... F-37
Figure F-19 Alternative 19 ..... F-39
Figure F-20 Alternative 20 ..... F-41
Figure F-21 Alternative 21 ..... F-45
Figure F-22 Alternative 22 ..... F-49

F.0 PLAN FORMULATION

F.1 INITIAL ARRAY OF ALTERNATIVES

The original Initial Array of Alternatives, a total of 22, are listed and described as follows:

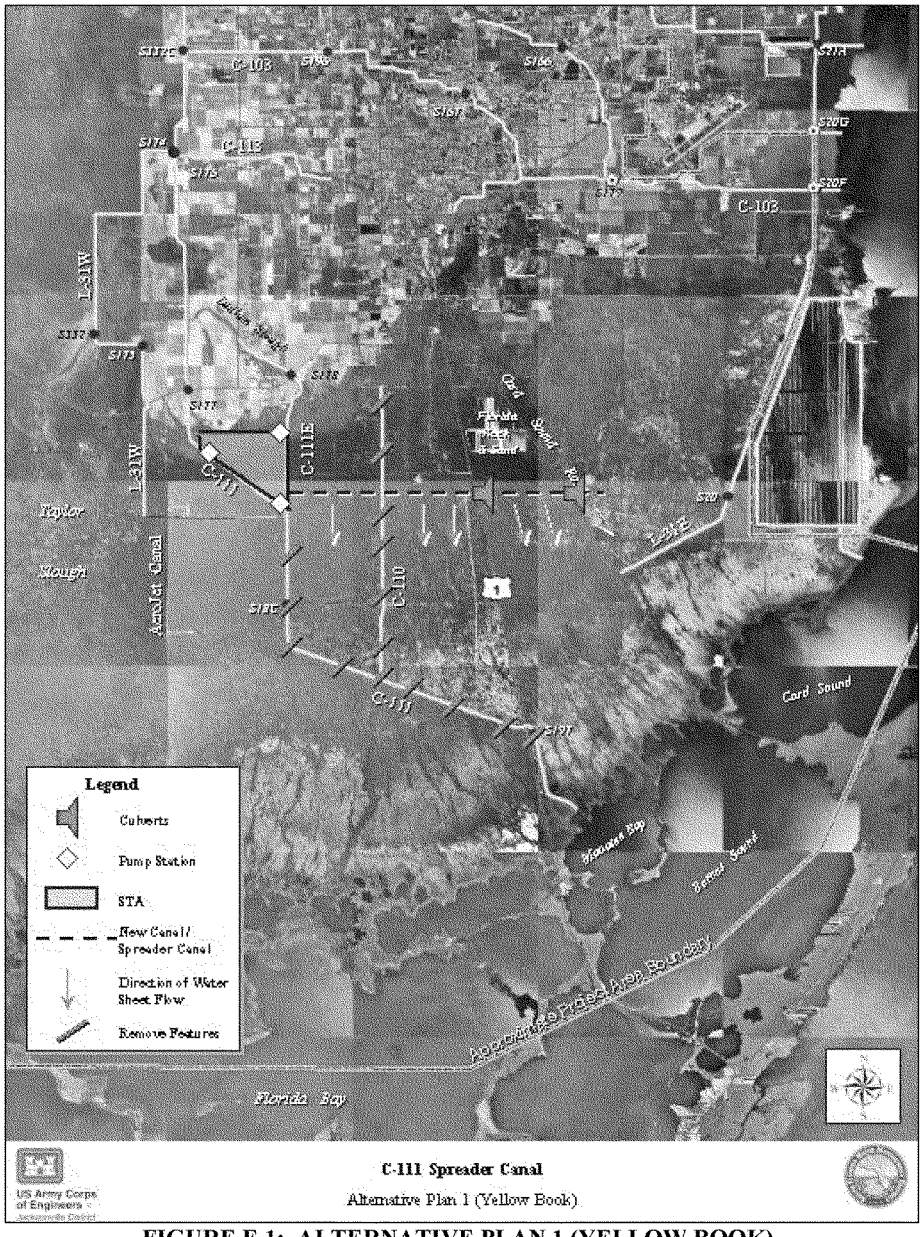


FIGURE F-1: ALTERNATIVE PLAN 1 (YELLOW BOOK)

Yellow Book-Alternative 1 Description

This is the CERP (Yellow Book) alternative. The components include removing S-197, S-18C, backfilling lower C-111, C-110, building an STA in the triangle shown above with three proposed pump stations (S-332E is the bottom right pump station and it would be designed to pump 500 cfs to Model Lands), and constructing new culverts under U.S. Highway 1 and Card Sound Road.

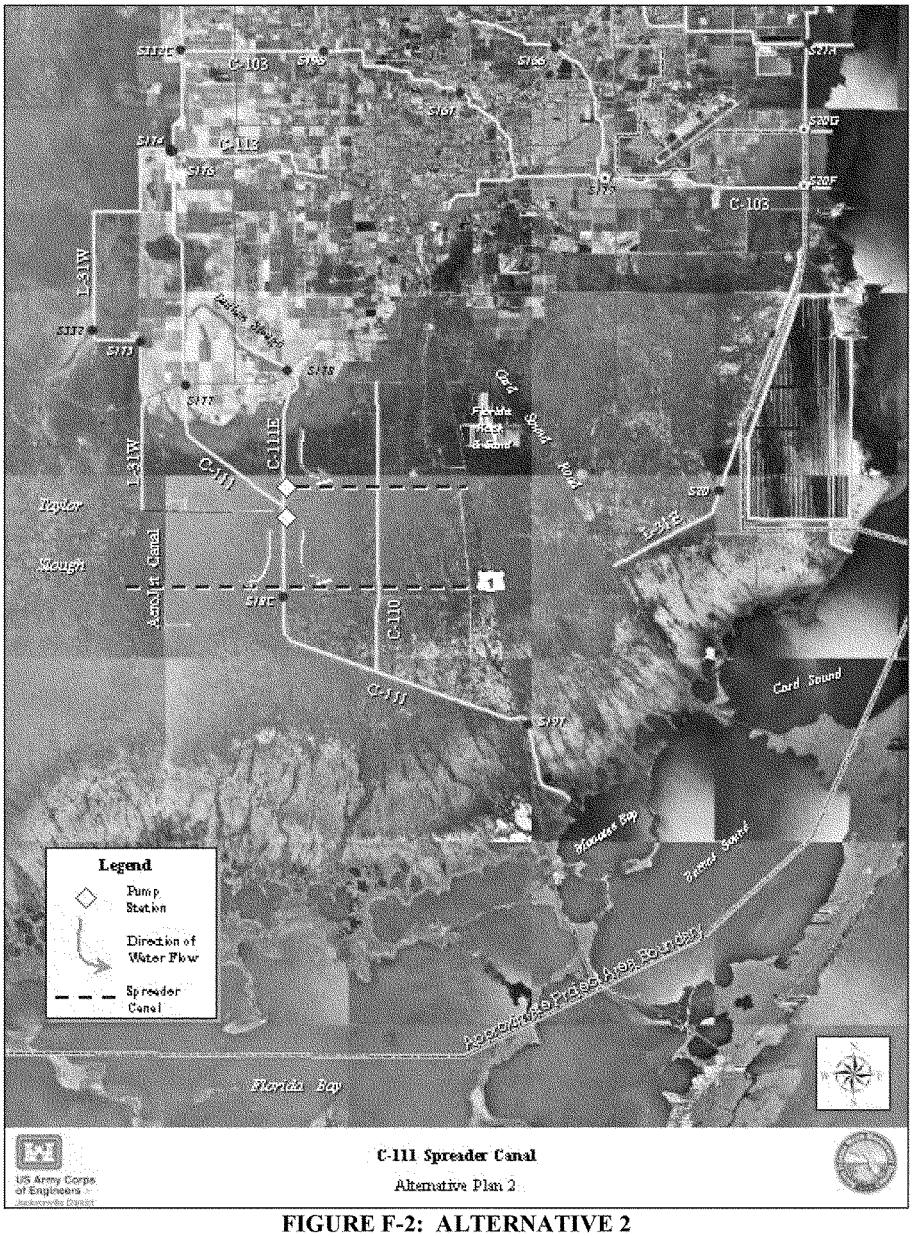


FIGURE F-2: ALTERNATIVE 2

Alternative 2 Description

The capacity of S-176 (currently 1,100 cfs) would be increased. Construct the pump station to 500 cfs as in the approved plan, but construct two spreader canals. One canal would head east as earlier envisioned and the other canal would deliver water first further south and then in an east-west direction towards the Model Lands and Taylor Slough. The second spreader would need another smaller pump structure.

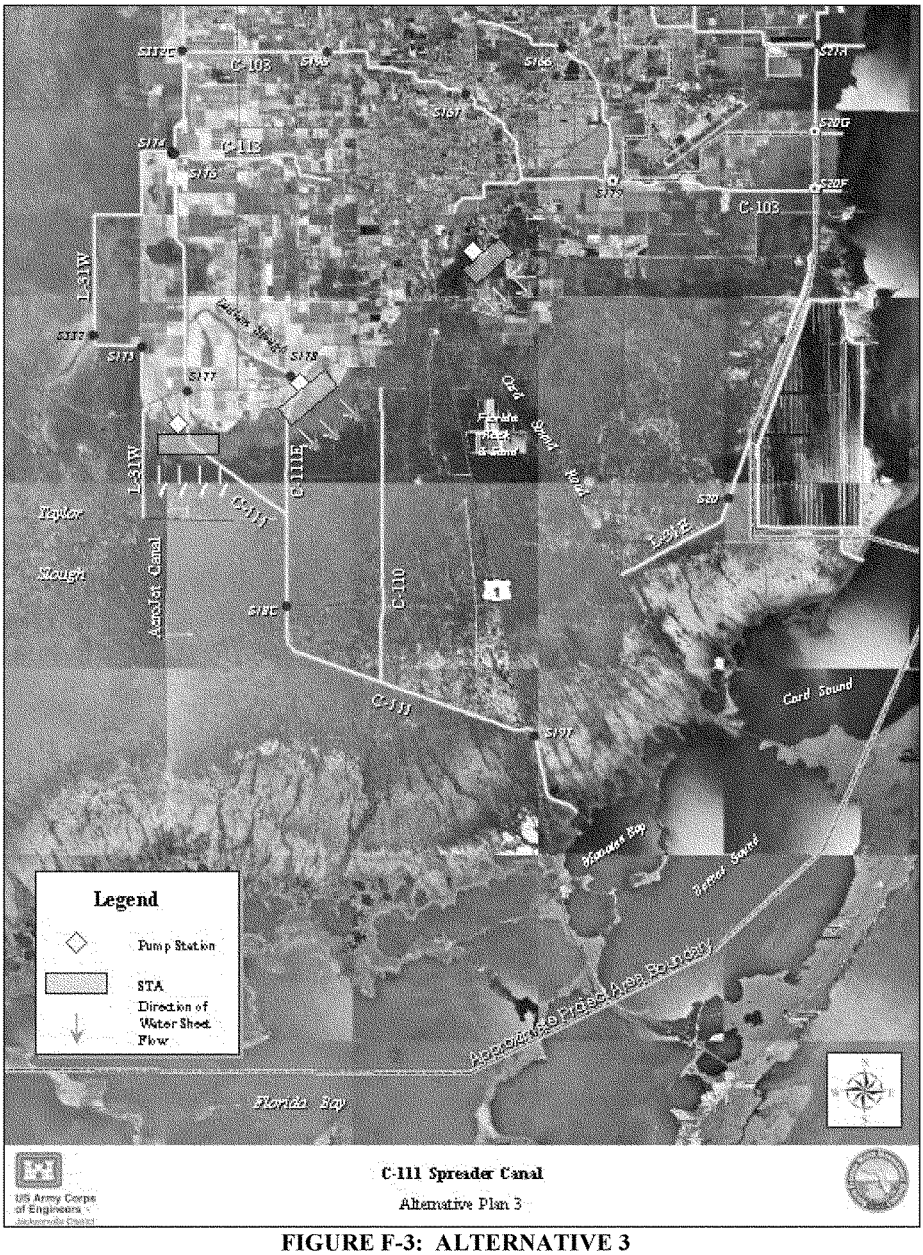


FIGURE F-3: ALTERNATIVE 3

Alternative 3 Description

Two natural sloughs and the one canal (C-111) would serve as three points for introducing water into project lands. Each inflow point would require construction of its own pump structure and its own STA. The most eastern slough would provide a flowway that would also deliver water towards the Florida Power & Light Mitigation Bank area.

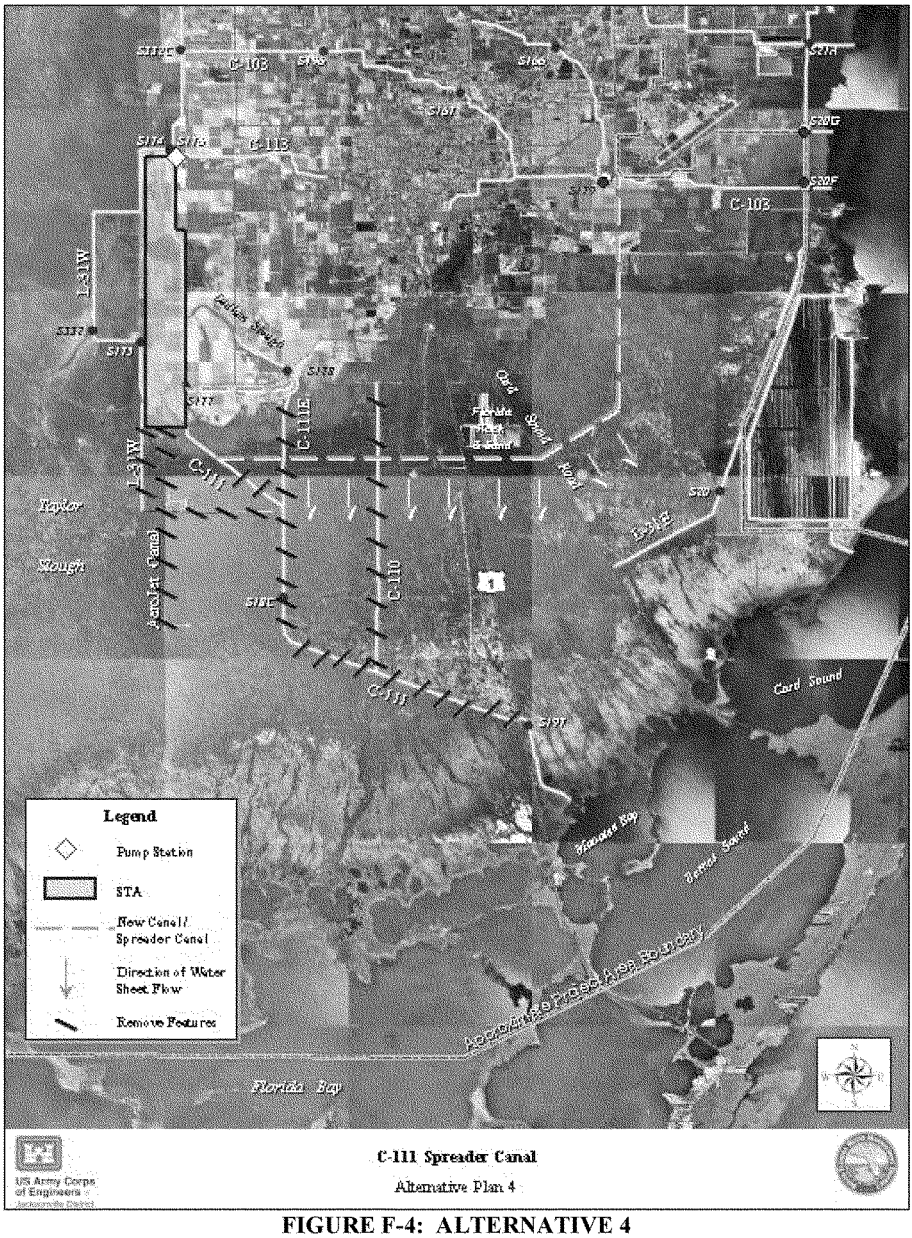


FIGURE F-4: ALTERNATIVE 4

Alternative 4 Description

Increase the capacity of S-176 and construct a pump structure south of S-176 that would pump water westward into a new STA that would be located in the Frog Pond area. Relocate the existing L-31E Canal and levee to the west. Move proposed east-west C-111 Spreader Canal to the north as much as is feasible and extend towards the east to the relocated L-31E Canal. Fill in the lower L-31W and other canals in the project area. Remove the Aerojet Canal and road and restore that area as well.

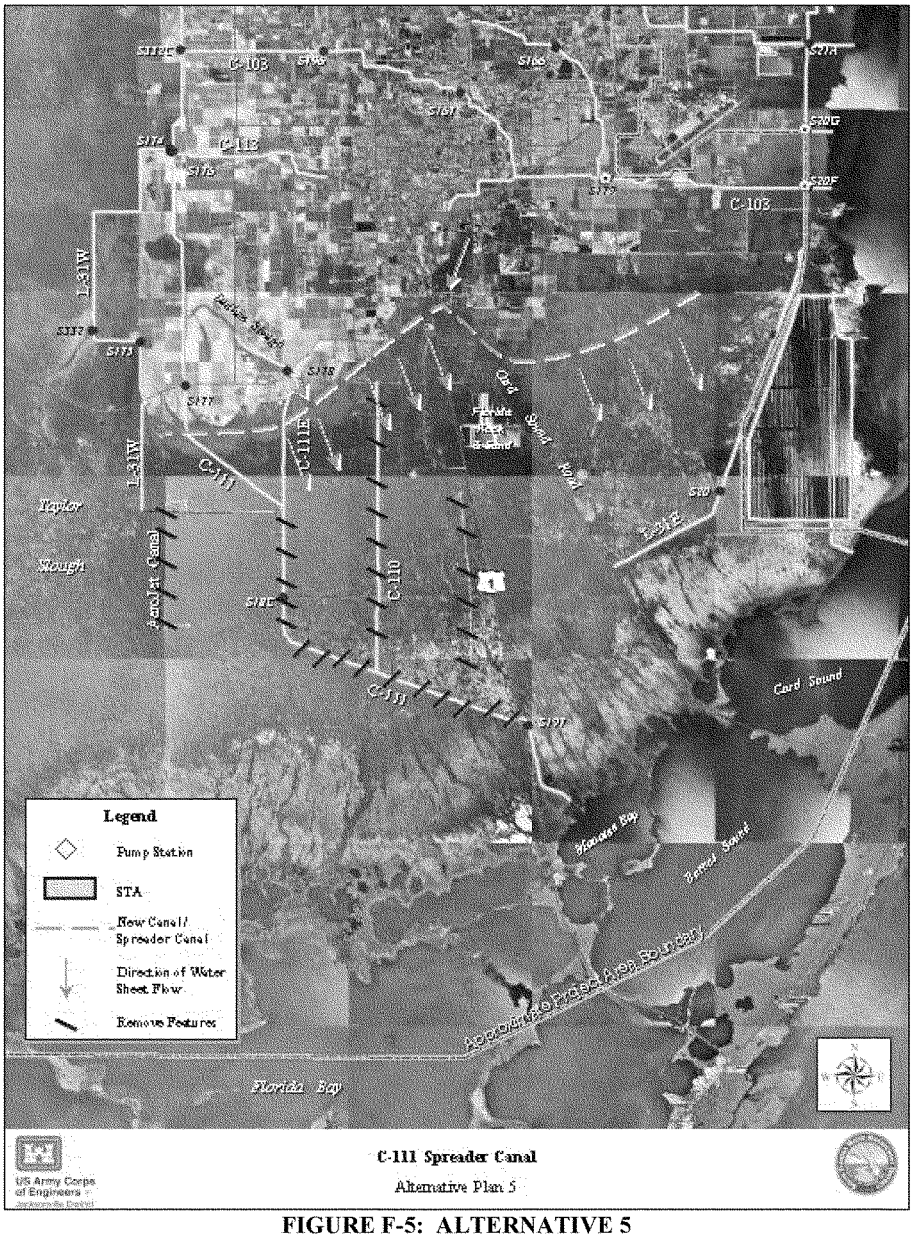


FIGURE F-5: ALTERNATIVE 5

Alternative 5 Description

Use existing natural sloughs and waterways located just to the south of Florida City and Homestead as spreader(s). Water would be delivered using natural flowways from the C-111. A pump structure would siphon water from the northern C-111 and deliver it to an adjacent STA constructed within existing natural flowway. Water would continue to travel along this northernmost natural configuration overflowing to the south and southeast in an arc. Purchase flowage easements as needed. Remove all discontinuities in the Southern Glades and Model Lands.

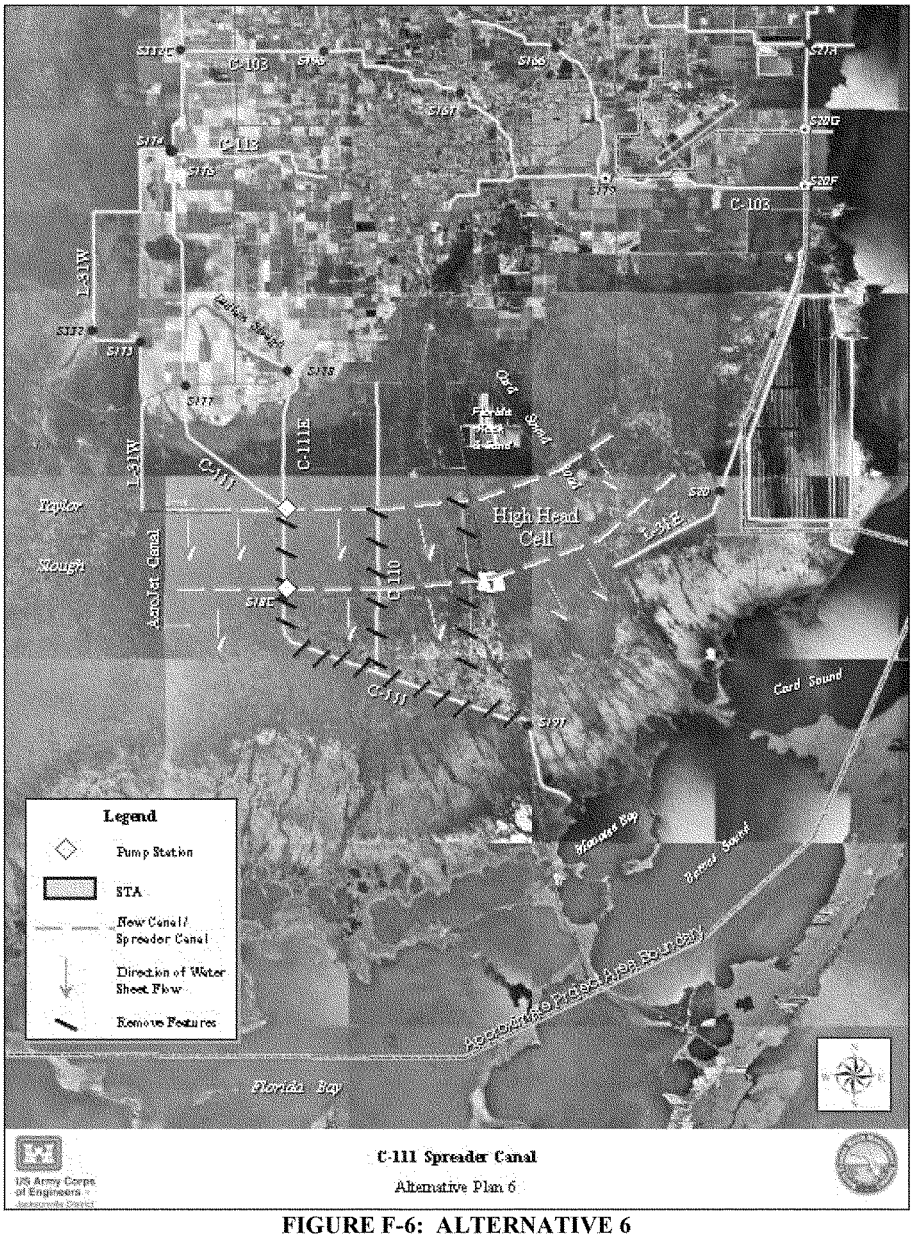


FIGURE F-6: ALTERNATIVE 6

Alternative 6 Description

Construct two parallel spreaders. Instead of a straight line towards the Model Lands as in the approved project, build the spreaders in an arcing pattern so that water is delivered in a southeasterly direction. A separate pump structure for the second spreader and a southern spreader canal would be needed. All discontinuities would be removed.

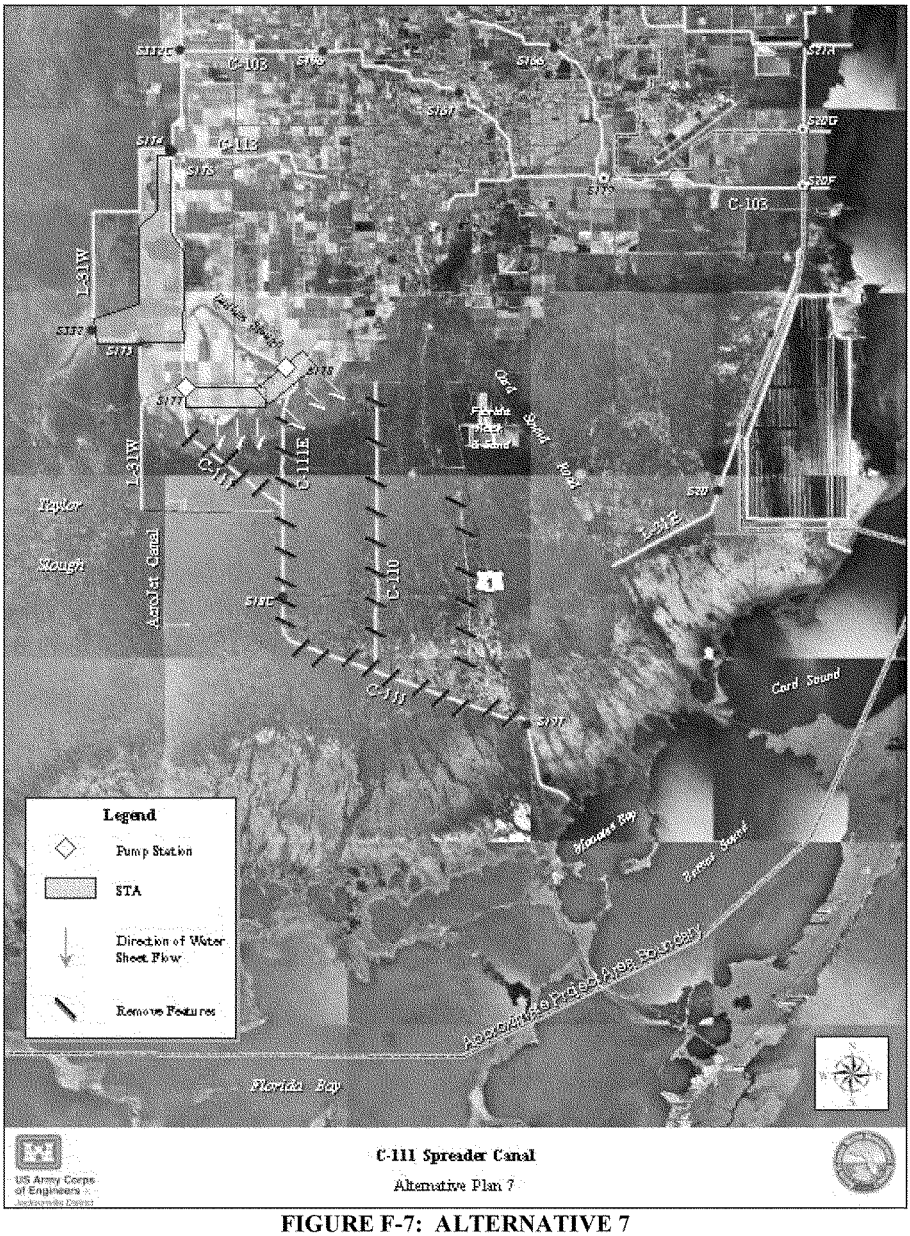


FIGURE F-7: ALTERNATIVE 7

Alternative 7 Description

Enlarge S-176 and construct a pump station at S-177 to discharge into a storage area (reservoir) located within the eastern Frog Pond area. A seepage management feature will be headed to contain this stored water. Also pump water at S-178 into the STA. Seepage control will also be needed on the north side of the STA with the seepage returned to the STA. The new STA will extend east to US1, just south of Florida City. Pump from the proposed Florida City canal into the STA. Spread the discharge from the STA along its south side with larger discharges at old slough locations. Fill in C-111 and C-111E. Remove S-197 and all discontinuities.

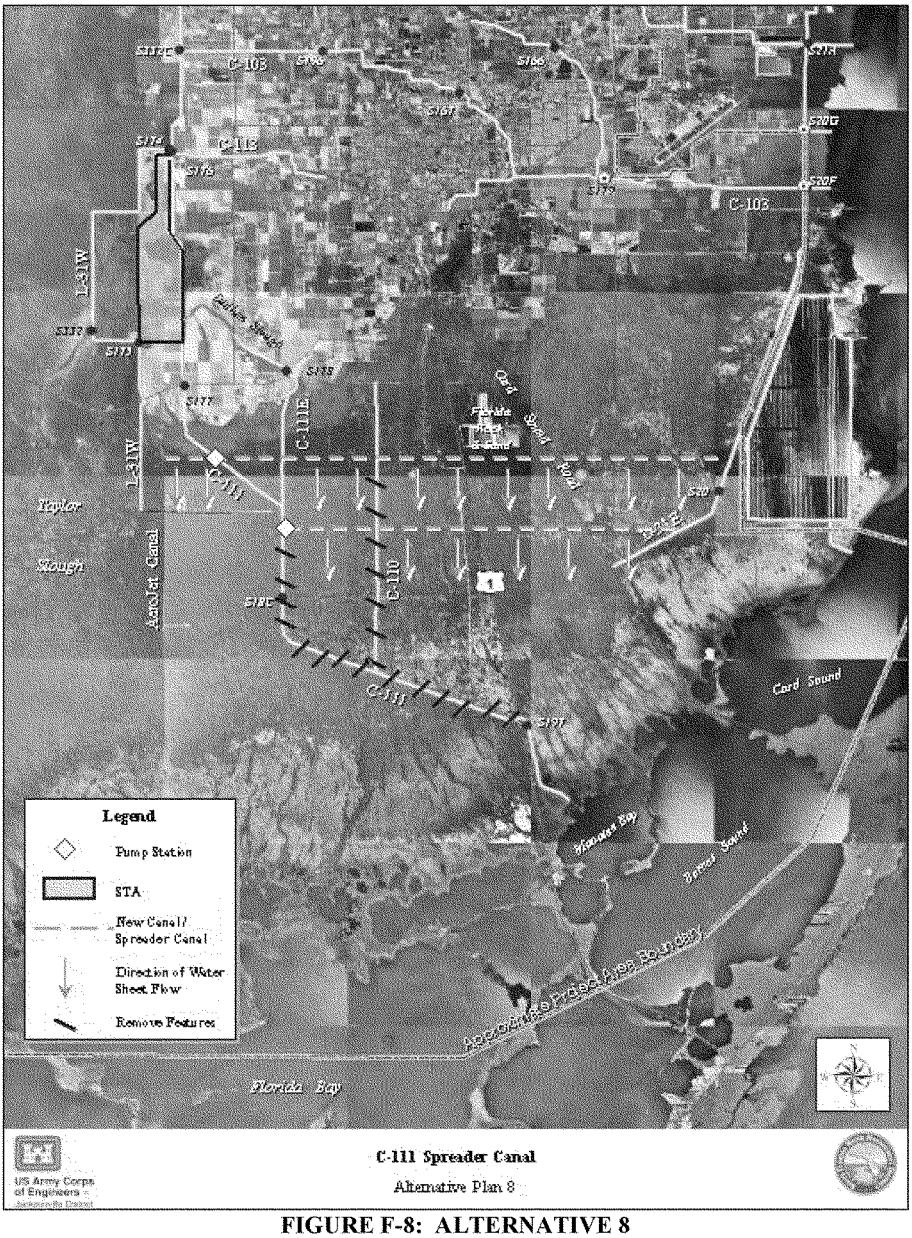


FIGURE F-8: ALTERNATIVE 8

Alternative 8 Description

Construct an STA in the Frog Pond and build two pump structures at the northern bend of the C-111. One structure would pump water directly south and the other would pump water to a north spreader canal that would extend all the way east to L-31E Canal. A second, parallel spreader would be constructed south. C-111 would be shallowed (not filled in) all the way to U.S. Highway 1. Fill in C-110 and remove S-197.

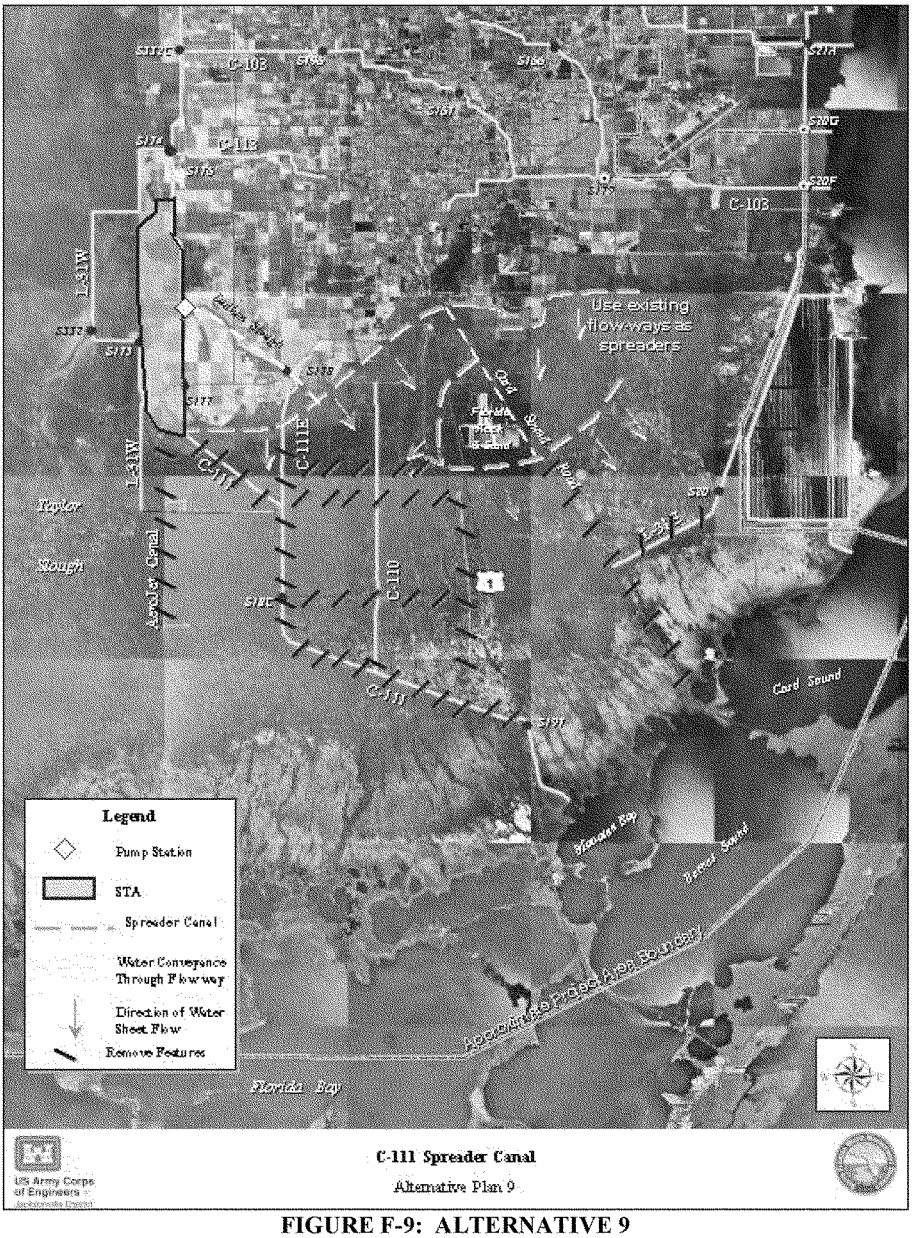


FIGURE F-9: ALTERNATIVE 9

Alternative 9 Description

Construct an STA/reservoir at the Frog Pond. Tie in an existing slough/waterway to the new STA/reservoir using a connector canal and pump structure. This will become a feeder slough that will travel south along its natural flowway to a point where it intersects the southern edge of Florida City/ Homestead at an existing flowway. Another STA may be needed at this juncture. This southern flowway will become the spreader, discharging water along its southern edge in a southeasterly manner. All discontinuities, except for U.S. Highway 1 and Card Sound Road, would be removed. Culverts would be installed under Card Sound Road to allow sheetflow. The existing rock quarry located within the triangle lands would be converted to a second reservoir with its own discharge spreader. U.S. Highway 1 would be converted into a sky bridge with recreational pullouts. L-31E Canal and levee would be removed.

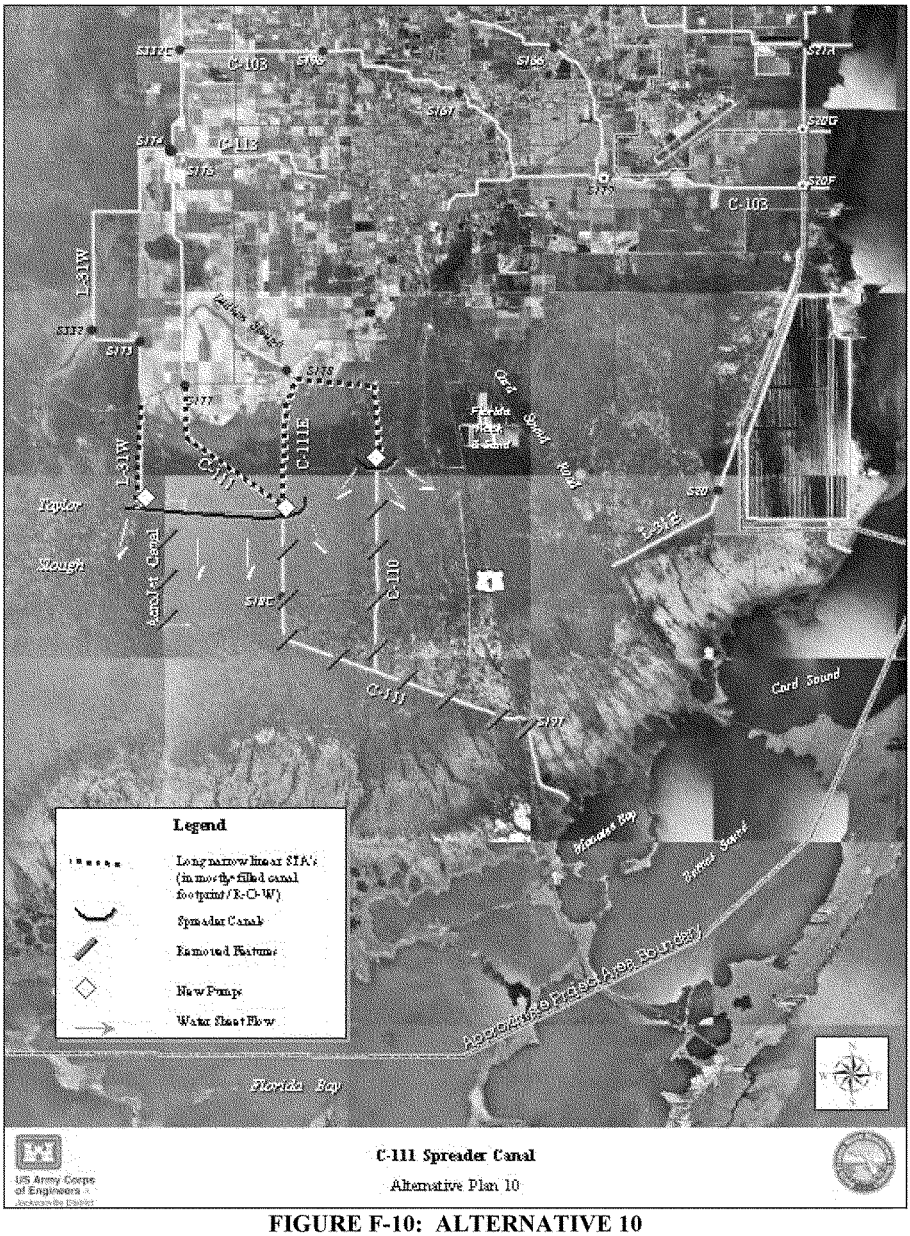


FIGURE F-10: ALTERNATIVE 10

Alternative 10 Description

This plan features STAs located within the footprints of existing water conveyance canals. They would be narrow, but can be about as long as is necessary to perform the desired water quality improvement functions as described in the project objectives. There may need to be some kind of flow-reducing structures within the STAs to prevent water from flowing through too fast, such as weirs or some other kind of obstructions. At the southern ends of the STAs there would be spreader canals, along with their associated adequately sized pumps. The spreader canals would extend in an east-west pattern with arcing ends to allow water to sheetflow through the project area wetlands. An STA similar in dimensions to the others could be constructed between S-178 and the northern end of C-110, if necessary, to help balance amounts of water between the spreader canal serving L-31W, C-111, and C-111E, and the one serving C-110. The canals and water control structures south of the spreader canals would be removed, with the exception of the section of C-111 south of S-197 which is utilized by manatees.

The spreader canals would include seepage control canals/berms on their northern ("upstream") sides, or any other similar features, if necessary to help prevent excessive flooding of adjacent private properties.

South of the spreader canals, the water control structures would be removed and the water conveyance canals would be backfilled or plugged, with the exception of the section of C-111 south of S-197 which is utilized by manatees and can be used for recreational purposes.

As many obstructions to water sheetflow in the project area wetlands (roads, ditches, canals, etc.) as possible would be removed or plugged. A series of culverts/wildlife crossings would be constructed as necessary under U.S. Highway 1, Card Sound Road, Tallahassee Road, and any other roads that cannot be removed to encourage hydrologic exchange and safe wildlife access.

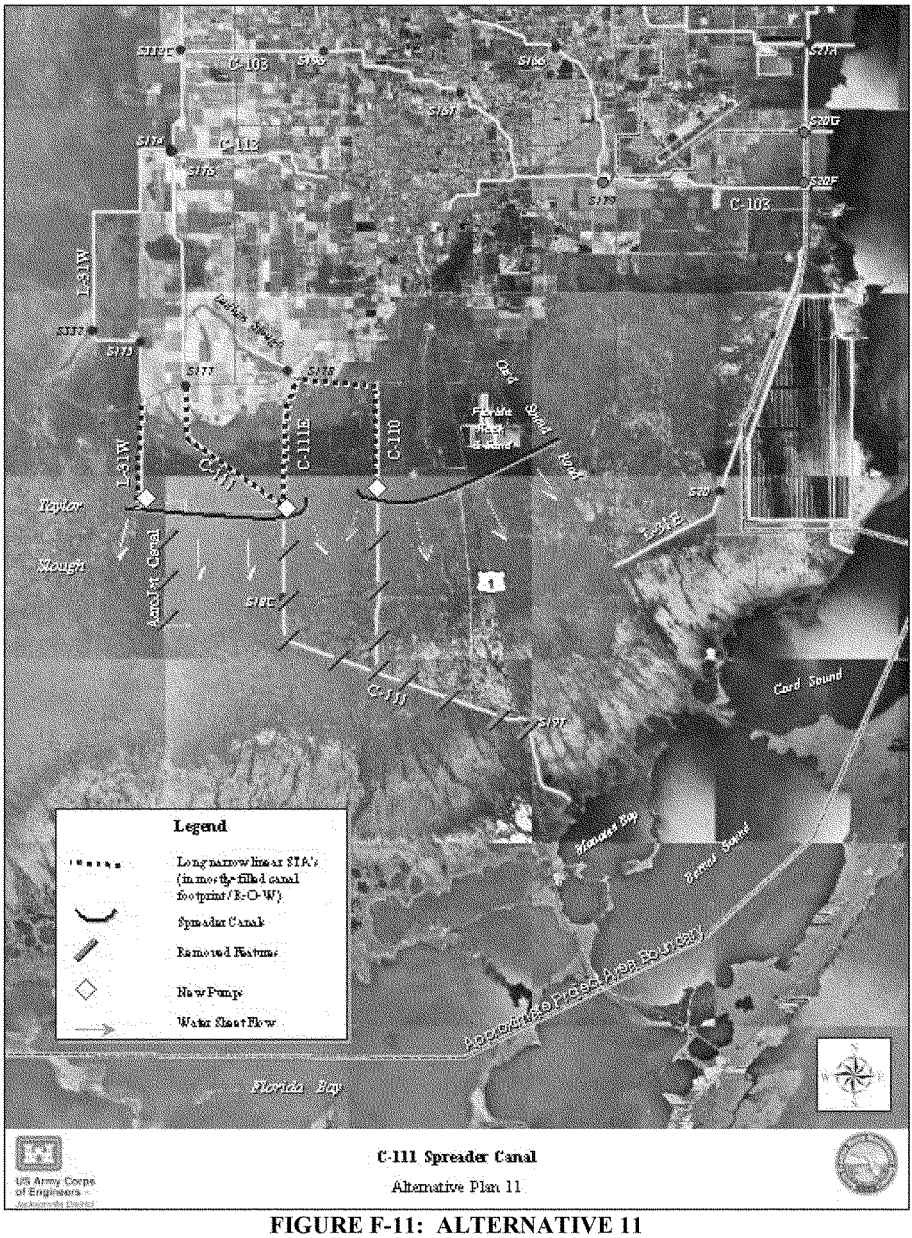


FIGURE F-11: ALTERNATIVE 11

Alternative 11 Description

This plan is the same as Plan 10, above, with the exception of an increased length of the eastern spreader canal, the one serving C-110. This spreader canal would be constructed to extend further to the east, through culverts under U.S. Highway 1 and Card Sound Road, to provide increased water sheet flow to those wetland areas east of U.S. Highway 1. A pump larger than the one used in plan 10 would most likely be necessary to more adequately propel the water the increased distance.

The spreader canals would include seepage control canals/berms on their northern ("upstream") sides, or any other similar features, if necessary to help prevent excessive flooding of adjacent private properties.

South of the spreader canals, the water control structures would be removed and the water conveyance canals would be backfilled or plugged, with the exception of the section of C-111 south of S-197 which is utilized by manatees and can be used for recreational purposes.

As many obstructions to water sheet flow in the project area wetlands (roads, ditches, canals, etc.) as possible would be removed or plugged. A series of culverts/wildlife crossings would be constructed as necessary under U.S. Highway 1, Card Sound Road, Tallahassee Road, and any other roads that cannot be removed to encourage hydrologic exchange and safe wildlife access.

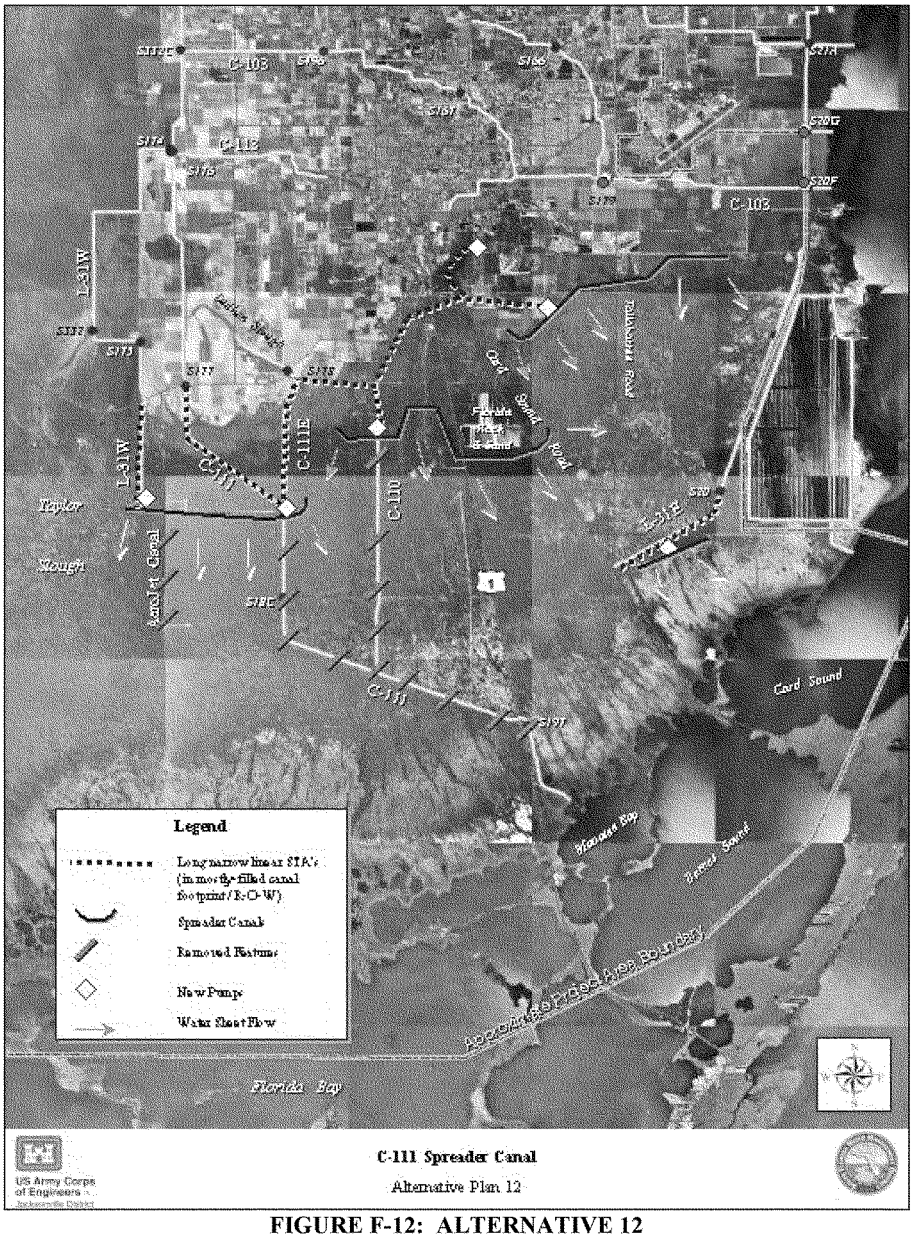


FIGURE F-12: ALTERNATIVE 12

Alternative 12 Description

This plan features STAs located within the footprints of existing water conveyance canals. They would be narrow, but can be about as long as is necessary to perform the desired water quality improvement functions as described in the project objectives. There may need to be some kind of flow reducing structures within the STAs to prevent water from flowing through too fast, such as weirs or some other kind of obstructions. At the southern ends of the STAs, there would be spreader canals, along with their associated adequately sized pumps. The spreader canals would generally extend in an east/west pattern with arcing ends to allow water to sheet-flow through the project area wetlands. An STA similar in dimensions to the others could be constructed between S-178 and the northern end of C-110, if necessary, to help balance amounts of water between the spreader canal serving L-31W, C-111, and C-111E, and the one serving C-110.

STAs similar in dimensions to the others would be constructed from the Long Glade Slough area to the south, and then to the east to a pump structure and spreader canal, which would extend east along natural flow ways as much as possible into the northern Model Lands between Tallahassee Road and the L-31E Canal, and south of C-103 or Florida City canal. Some kind of pump may need to be constructed to draw water from Florida City canal into the STA. Another STA similar in dimensions to the others would be constructed from the northern C-110 terminus to connect with the STA coming from the Long Glade Slough area, described above. Additional pump structures may be necessary to help properly disperse water through the STAs.

The southern portion of L-31E would be transformed into an STA, in a manner similar to the others, and would feature a small spreader canal with associated pump on the south side of the STA.

The spreader canals would include seepage control canals/berms on their northern ("upstream") sides, or any other similar features, if necessary to help prevent excessive flooding of adjacent private properties.

South of the spreader canals, the water control structures would be removed and the water conveyance canals would be backfilled or plugged, with the exception of the section of C-111 south of S-197 which is utilized by manatees and can be used for recreational purposes.

As many obstructions to water sheet flow in the project area wetlands (roads, ditches, canals, etc.) as possible would be removed or plugged. A series of culverts / wildlife crossings would be constructed as necessary under US 1, Card Sound Road, Tallahassee Road, and any other roads that cannot be removed to encourage hydrologic exchange and safe wildlife access.

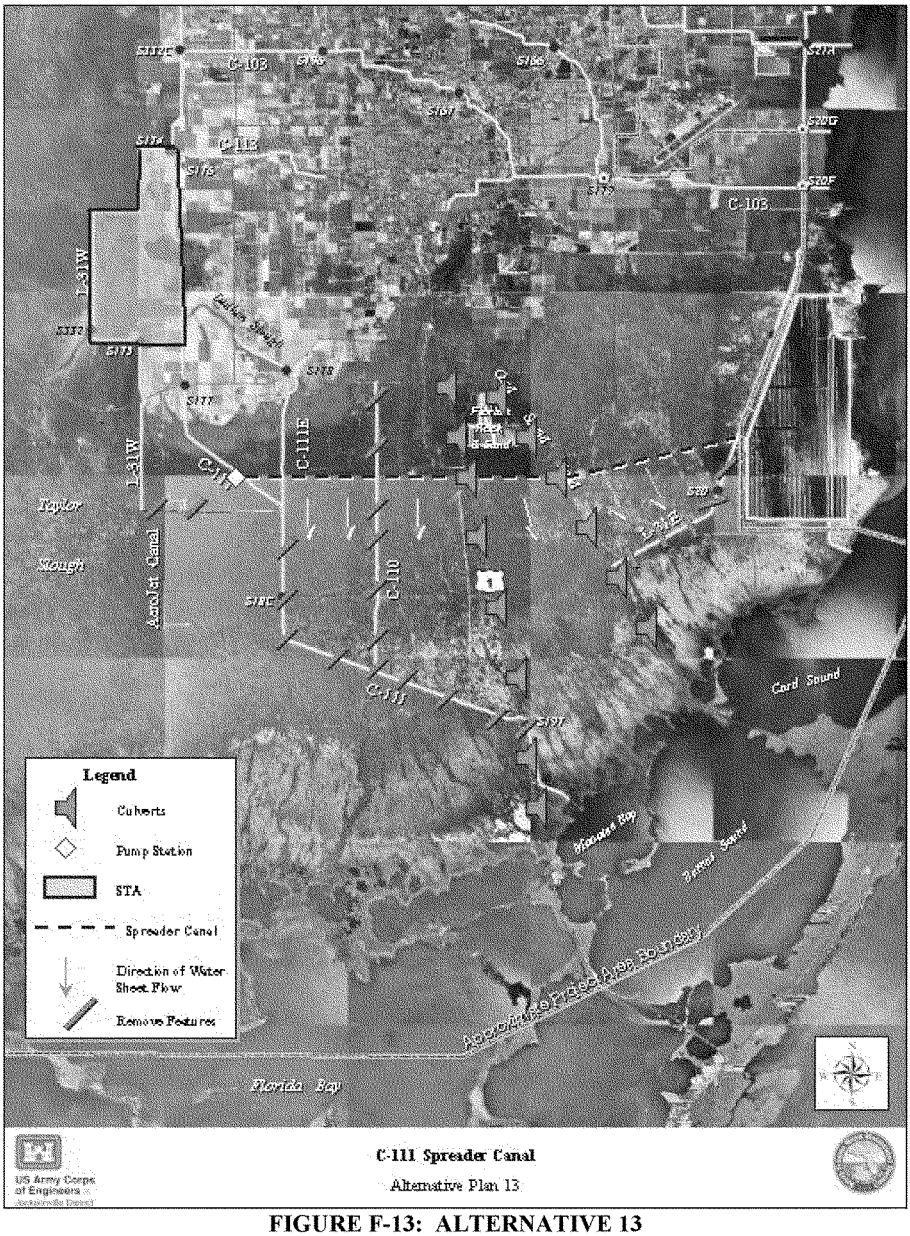


FIGURE F-13: ALTERNATIVE 13

Alternative 13 Description

Management measures:

- Backfill C-111 from triangle area to S-197
  OR, if that's not possible, then
- Shallow C-111 to a maximum depth of 3 feet and create cuts along the canal to promote sheetflow
- Remove S-197
- Build S-332E pump at 1000 cfs
- Backfill C-110
- Construct culverts and animal crossings along US 1 and Card Sound Road
- Construct a spreader canal from C-111 just south of the Florida Rock and Sand quarry going easterly to Card Sound Road, then northeasterly to connect to L-31E. Backfill the southern part of L-31E or shallow to maximum depth of 3 feet and create cuts at regular intervals to promote sheetflow.
- Remove small berms and fill other ditches/borrow canals throughout the project area. Degrade as many associated roads as possible. For those roads needed to remain for land management reasons, culvert the roads at regular intervals to promote sheetflow.
- Construct a STA in the Frog Pond area.

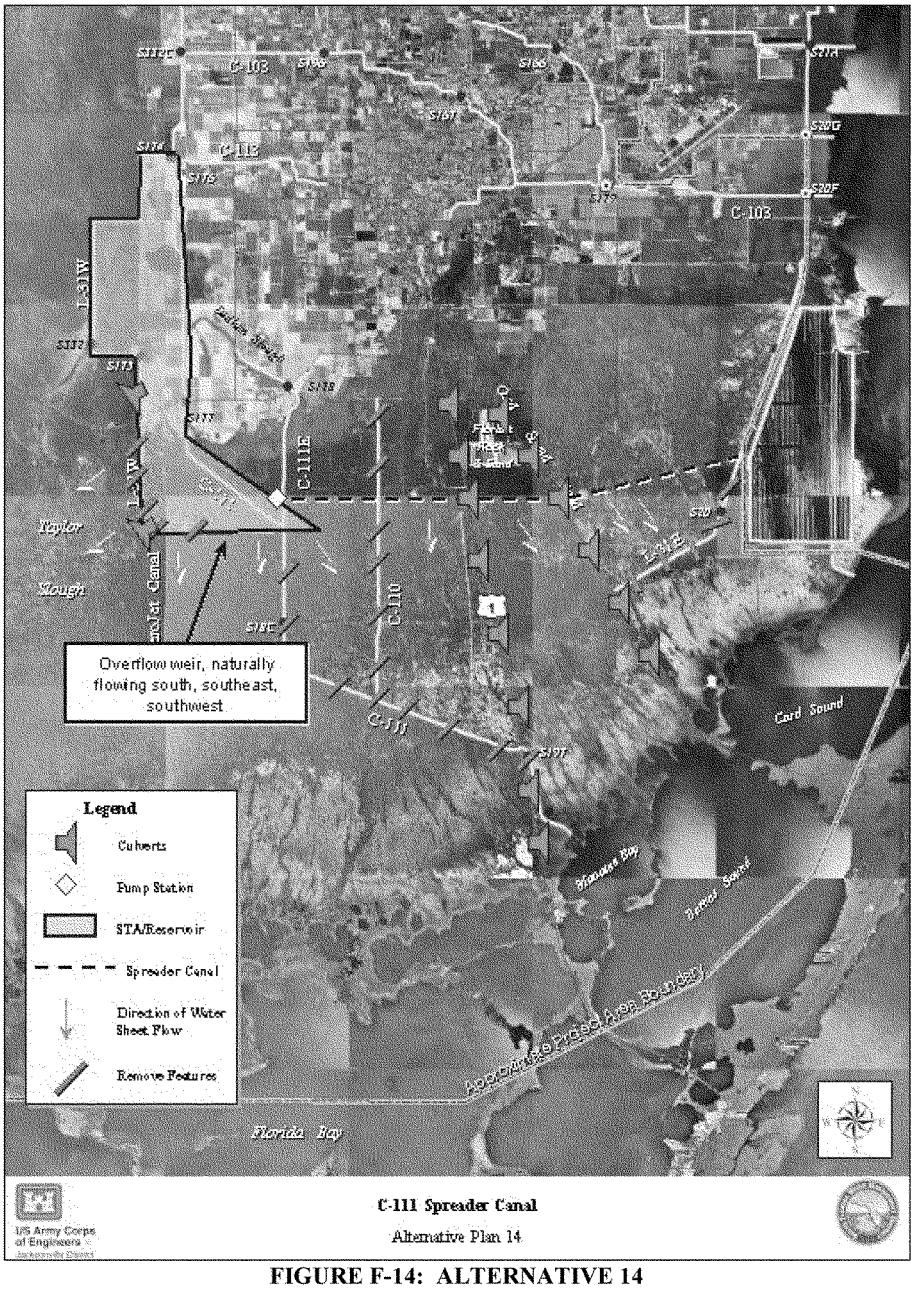


FIGURE F-14: ALTERNATIVE 14

Alternative 14 Description

Large STA that would be pumped into via S-332D and will naturally flow into the STA/Reservoir south and then be pumped using the spreader canal shown above as well as spill naturally at the southern end by constructing a concrete weir. Then, partially fill all the canals, leaving a shallow depth for recreation (i.e. fishing). Also, have culverts located in the project area in U.S. Highway 1 and Card Sound Road.

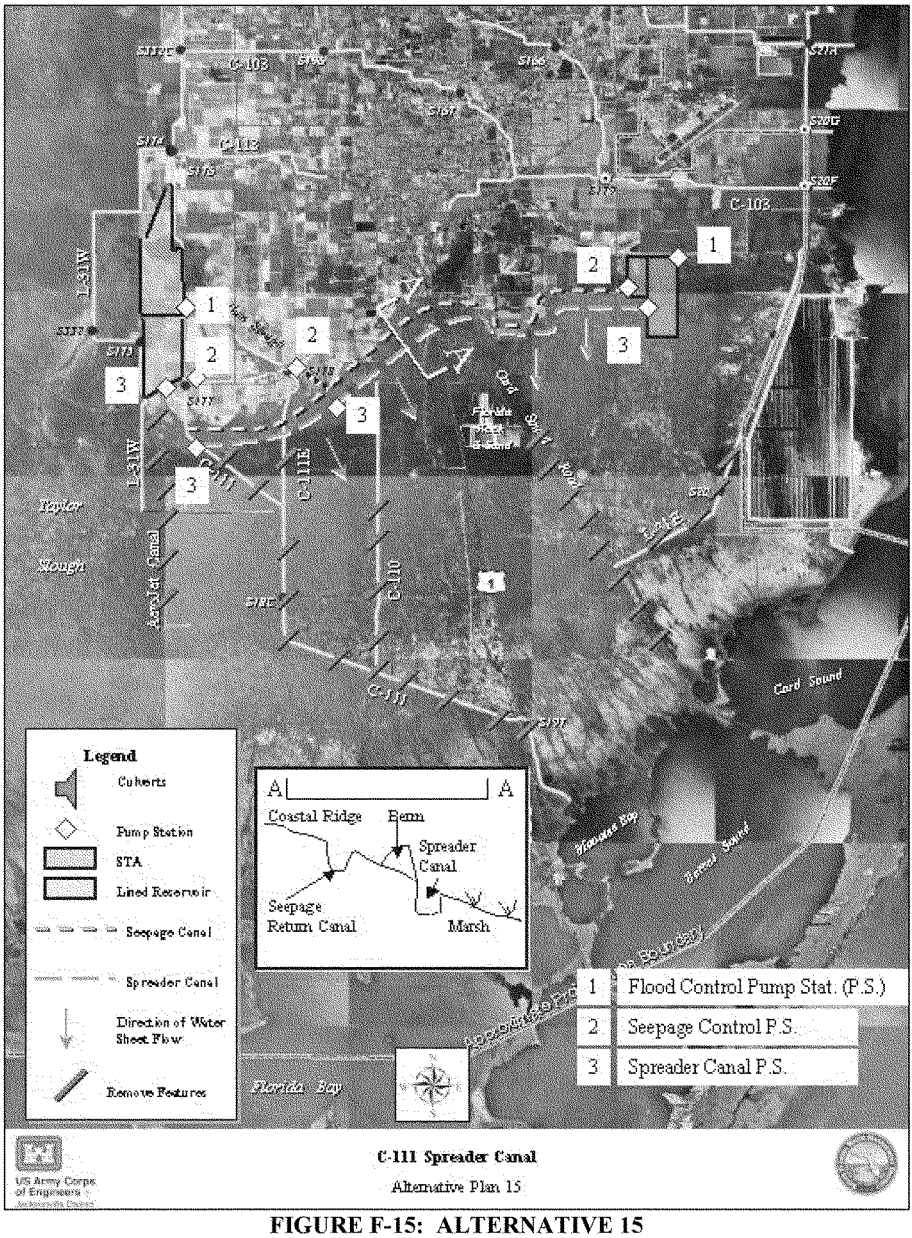


FIGURE F-15: ALTERNATIVE 15

Alternative 15 Description

A lined reservoir built and operated similar to a lake belt reservoir is placed in the northeast part of the Frog Pond.

A STA lined on the east side is placed in the southeast part of the Frog Pond adjacent to the reservoir.

A flood control pump ("1") is located (between S-177 and S176) in the C-111 Canal adjacent to and pumping into the Reservoir.

A STA pump station ("3") discharges water from the south end of the STA into a new canal connecting to the C-111 Canal downstream of the S-177 Structure.

A "steep" topographic gradient exists at the base of the coastal ridge. A Spreader Canal Pump Station is located in the C-111 Canal downstream from the new canal from the STA. This pump station discharges into a Spreader Canal constructed near the base of the coastal ridge. The Spreader Canal continues east and northeast near the base of the coastal ridge passing under US Highway 1 and Card Sound Road and continues east to a pump station ("3") discharging from a STA immediately south and adjacent to the Florida City Canal. The eastern terminus of the Spreader Canal and the location of the eastern STA should be determined by modeling predictions of marsh sheetflow distribution needs. Booster pumps ("3") are located in the Spreader Canal as needed to distribute the water adequately. Culverts in the Spreader Canal deliver more water to historic slough areas than adjacent marsh areas.

A flood control pump station ("1") discharges from the Florida City Canal into the new eastern STA. If additional water is supplied to the project area from the Biscayne Bay Coastal Wetlands Project, distribution of that water can also be made with this pump station.

A seepage collection canal is constructed between the top of the "steep" coastal ridge gradient and the Spreader Canal. This canal collects seepage from the Spreader Canal and higher marsh water levels. On the eastern end, seepage is returned to the STA by a seepage control pump station ("2"). On the western end, a new canal connects to the C-111 Canal upstream from the S-177 Structure and continues east across the C-111E Canal. Seepage control pump stations ("2") are located at the east end of the new canal and at the C-111 Canal to return seepage and flood control water from the C-111E Canal to the C-111 Canal for delivery to the reservoir pump station.

The C-111 and C-111E canals are filled downstream from the Spreader Canal to a point upstream from the existing privately owned marina. The canal is filled to existing grade to eliminate unnatural preferential flow paths and disruptions

to sheetflow. If insufficient material is available, periodic discontinuous sections of the canal remain to provide deepwater habitat. The S-197 Structure is removed.

The L-31E Canal south of the Florida City Canal is removed and its flows are sent to the flood control pump station ("1") discharging from the Florida City Canal into the new eastern STA for distribution through sheetflow to the marsh.

Other discontinuities such as the Aerojet Canal, Card Sound Road Canal, C-110 Canal, unpaved roads, etc, are removed to the maximum extent possible.

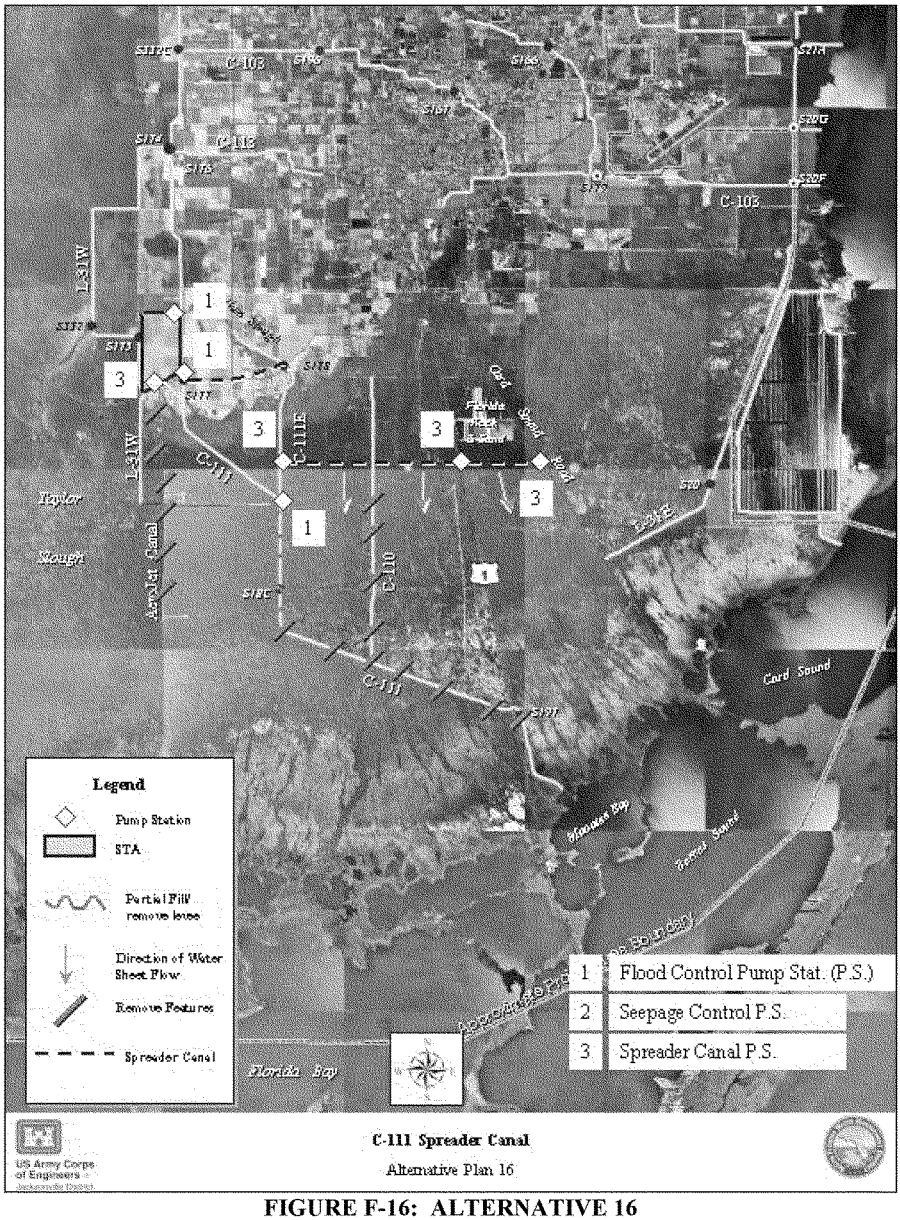


FIGURE F-16: ALTERNATIVE 16

Alternative 16 Description

A STA lined on the north and east side is placed in the southeast part of the Frog Pond adjacent to C-111 Canal. East side lining continues to a point south of the S-177 Structure.

A flood control pump ("1") is located between S-177 and S176 in the C-111 Canal adjacent to and pumping into the STA.

A new canal connects to the C-111 Canal upstream from the S-177 Structure and continues east connecting to the C-111E Canal. A new flood control pump station ("1") is located on the new canal and at the C-111 Canal to move flood control water from the C-111E Canal to the C-111 Canal for delivery to the new flood control pump station discharging to the STA.

A STA pump station ("2") discharges water from the south end of the STA into a new canal connecting to the C-111 Canal downstream of the S-177 Structure.

A Spreader Canal Pump Station ("3") is located in the C-111E Canal upstream from the convergence of the C-111 and C-111E Canals. This pump station discharges into a Spreader Canal constructed along an existing disturbance in the marsh. The Spreader Canal continues east passing under US Highway 1 and Card Sound Road. Booster pumps ("3") are located in the Spreader Canal as needed to distribute the water adequately through the culverts under the highways. A small section of the Card Sound Road Canal distributes water.

Immediately downstream from the convergence of the C-111 and C-111E Canals a new emergency flood control pump station ("1") is constructed in the C-111 Canal. Levees are removed from both sides of the C-111 Canal from the new pump station to the existing S-18C Structure. The levee material is used to gradually shallow the C-111 Canal beginning midway between the new pump station and the existing S-18C Structure until the fill material meets existing grade at the S-18C Structure. Excess material is used for filling downstream as needed.

The existing S-18C Structure is removed and the C-111 Canal is filled downstream from the existing S-18C Structure location to a point upstream from the existing privately owned marina. The canal is filled to existing grade to eliminate unnatural preferential flow paths and disruptions to sheetflow. If insufficient material is available, periodic discontinuous sections of the canal remain to provide deepwater habitat. The S-197 Structure is removed.

Other discontinuities such as the Aerojet Canal, Card Sound Road Canal, C-110 Canal, and unpaved roads, etc, are removed to the maximum extent possible.

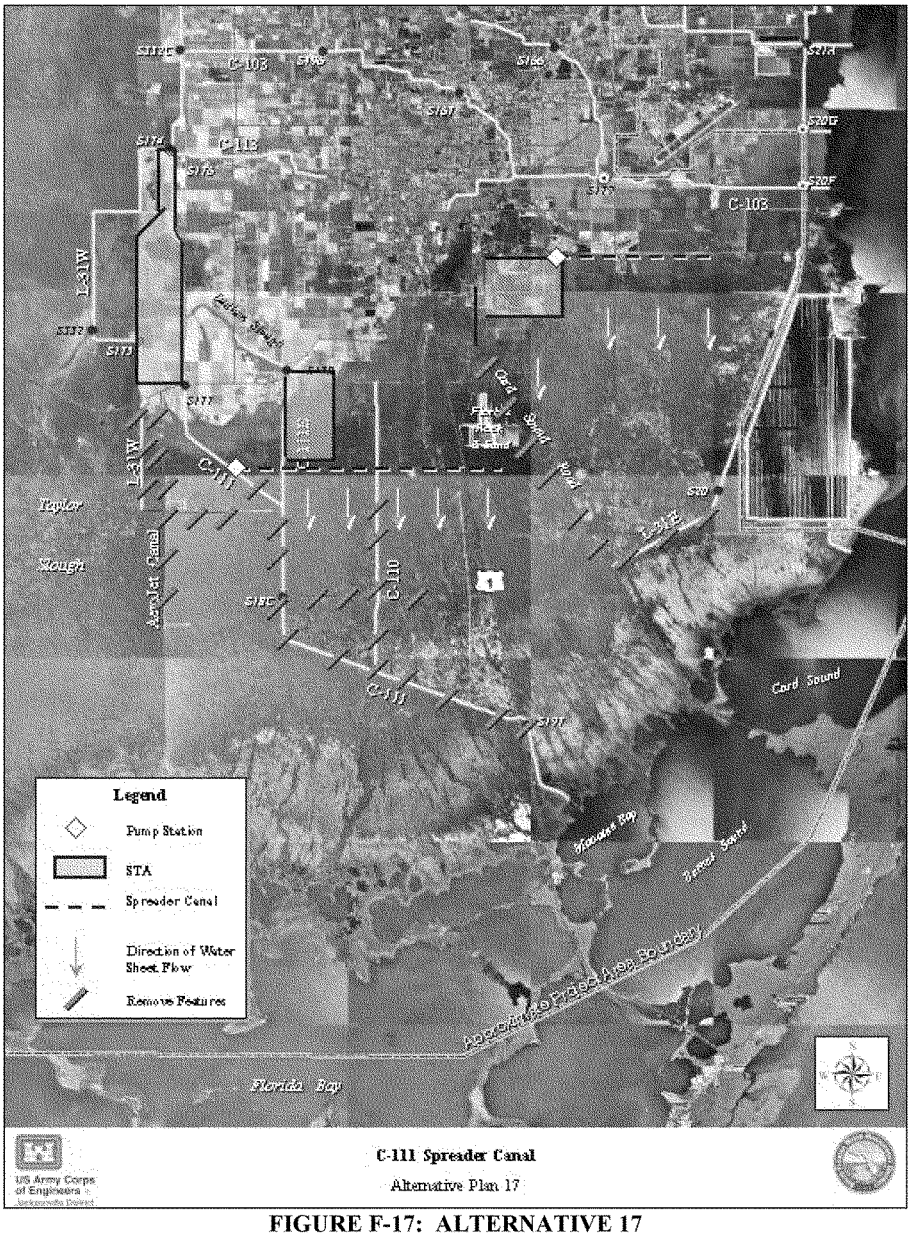


FIGURE F-17: ALTERNATIVE 17

Alternative 17 Description

- Lined reservoir in the northern Frog Pond area adjacent to the S332D detention reservoir. Provides storage and produces a seepage-free head for delivering water to the STA and spreader canal.
- Lower Frog Pond will become an STA for removal of Phosphorus as well as other pollutants (pesticides, heavy metals, etc). STAs should be designed to benefit wildlife whenever possible (see the Service's fish and wildlife enhancement recommendations in the ICU).
- Remove levee and backfill canals with red cross-hatching (includes lower L-31W, Aerojet, lower C-111 and C-111E, C-110, and east-west running roads and agricultural impediments in the Southern Glades). Card Sound Road borrow canal removed and lower L-31E levee and canal filled.
- An STA at Ludlum Slough for treatment of S178 discharge. Should be compartmentalized and east-west levees built within the transitional vegetation zone for Panther crossings.
- S332E pump station should be constructed on the C-111 Canal to pump down a spreader canal which would run along the paved road (should be removed) at the northern boundary of the Southern Glades.
- A third STA and associated pump and distribution canal would be built just south and east of Florida City to collect, treat, and distribute runoff in a southerly direction. This component has also being considered by the Biscayne Bay Coastal Wetlands project.

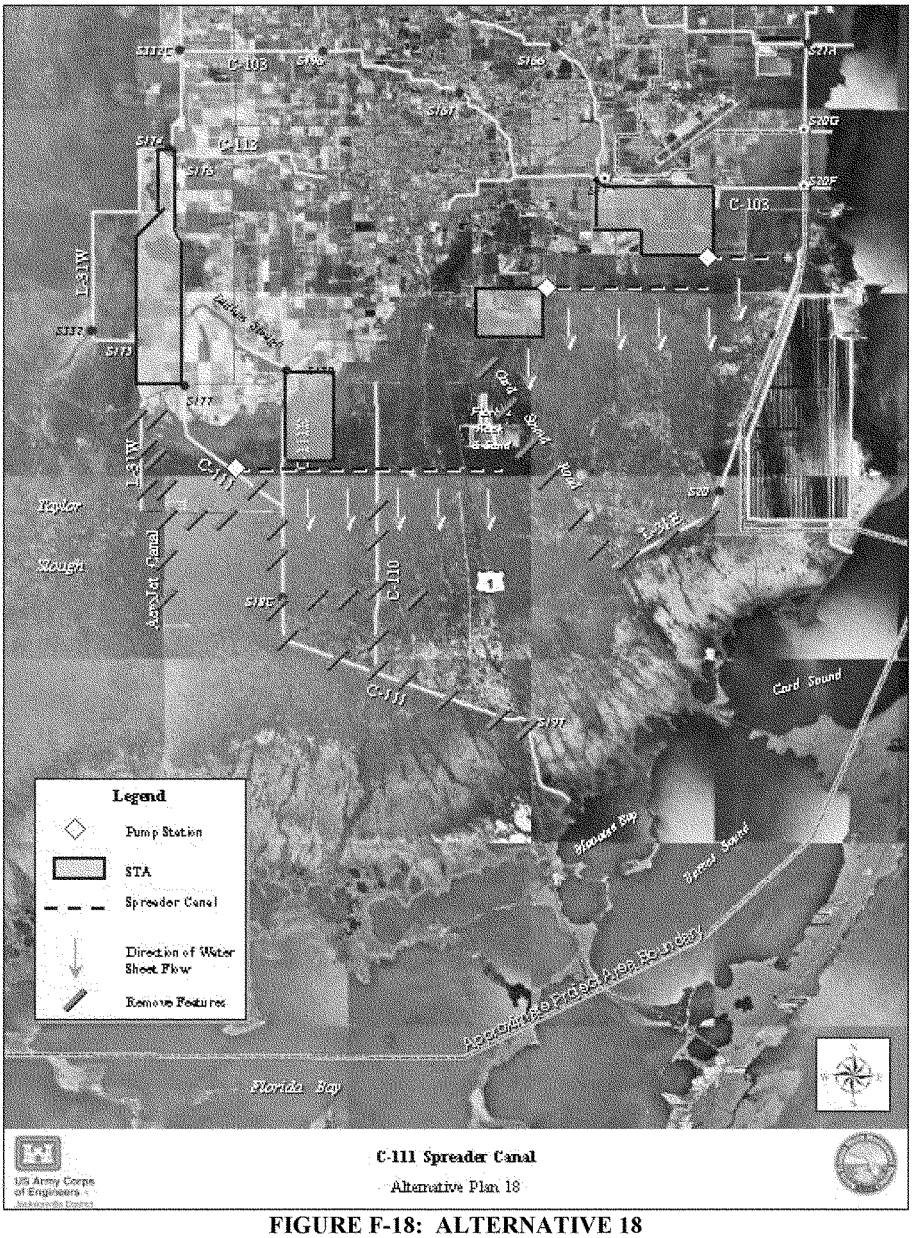


FIGURE F-18: ALTERNATIVE 18

Alternative 18 Description

Utilizes the same components as Alternative 17 except adds a fourth STA/pump/distribution canal in the northeast portion of the project area. This component is also being considered by the BBCW project.

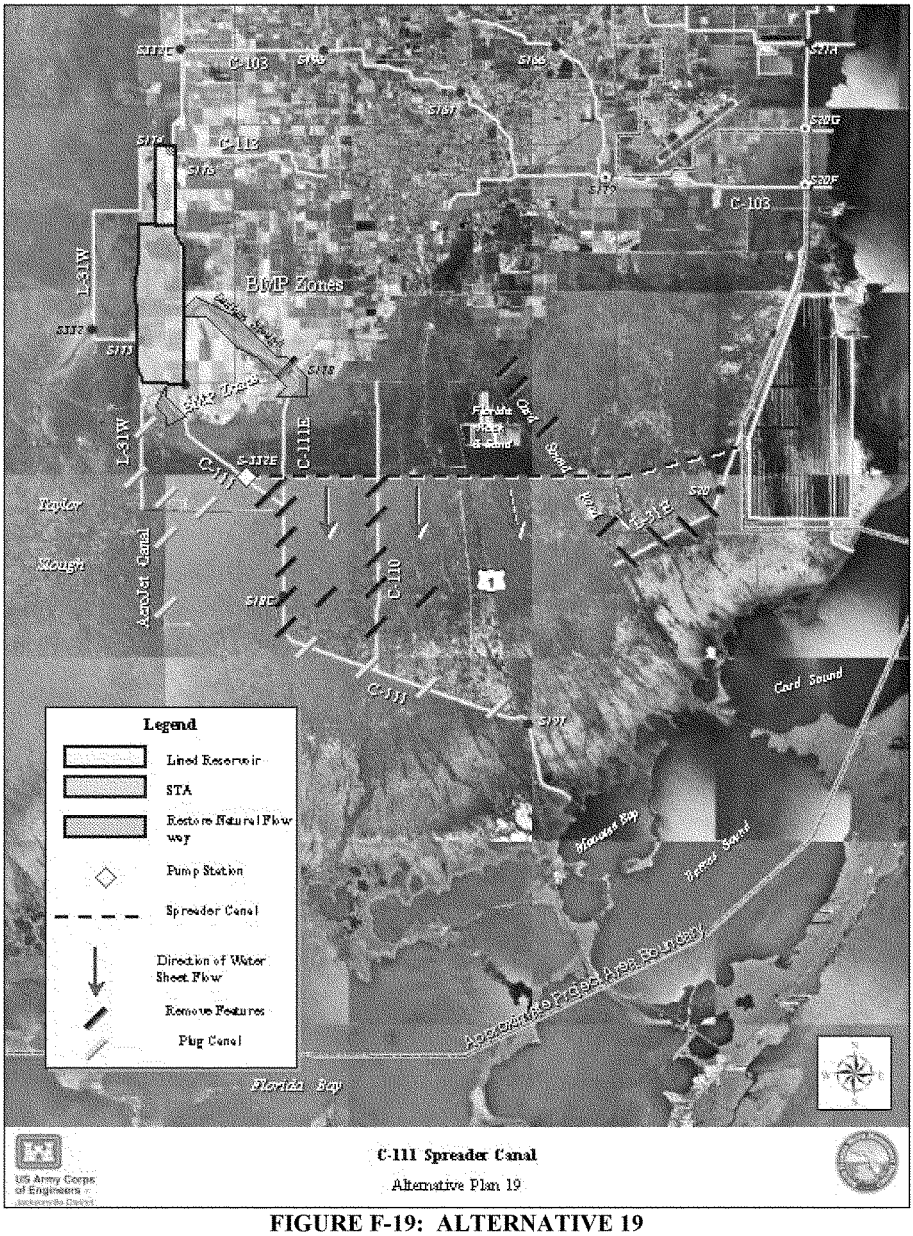


FIGURE F-19: ALTERNATIVE 19

Alternative 19 Description

Utilize the same lined reservoir and STA configuration in the Frog Pond area as in alternatives 17 and 18.

- Natural sloughs located just south of the proposed Frog Pond STA should be restored with littoral shelves included for added treatment capability.
- Similar to above, Ludlum Slough should be restored and even widened if necessary to provide treatment of low quality agricultural run off.
- S178 should be removed.
- Best Management Practices (BMP) should be implemented (or refined if already implemented) for active agricultural practices southwest of Homestead and Florida City. A reduction in harmful pollutants added to the water will ease the burden on STAs and other treatment measures in this area.
- Some canals such as the lower L-31W, Aerojet, and lower C-111 Canal should be plugged and include boat bypasses. This will lower the costs of the project and continue to provide access to the world-class bass fishery located in this area.
- Card Sound Rd. borrow canal north of the L-31E connection would be removed, and the east-west borrow canals in the northern and central parts of the Southern Glades would be filled.

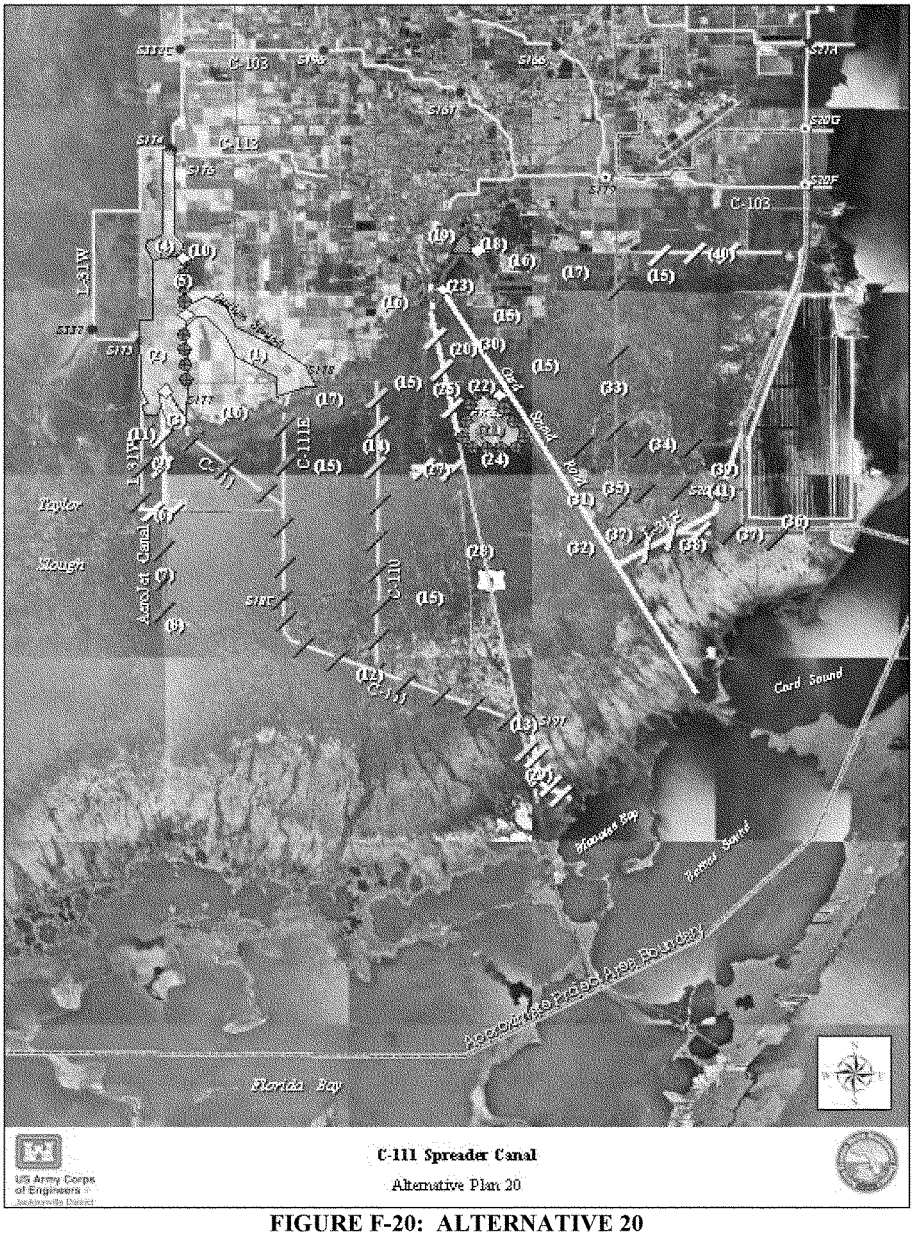


FIGURE F-20: ALTERNATIVE 20

Alternative 20 Description

Features, in no particular order:

1. Ludlam Slough broadened to establish linear flow way with some cleansing functions as emergent vegetation intercepts nutrients, particulates.
2. STA and/or reservoir in south Frog Pond with outflow pumps (diamonds). May need to be lined.
3. Utilize historic flow way to south or Ludlam Slough flow way to introduce water to southern wetlands
4. Frog Pond natural areas (pineland, hammock, pinnacle rock glades) to be preserved
5. ASR wells to supplement storage in Frog Pond
6. Remove Aerojet buildings and remaining access road.
7. Make lower Aerojet road hydrologically invisible–options for screening include road removal, culverts
8. Close/remove Aerojet silo building, remove access road.
9. Make upper Aerojet road hydrologically invisible–culverts preferred due to recreational access issues
10. Inflow pump station with capacity sufficient to remove flood-equivalent volume from C-111 and transfer to reservoir/ASR system for storage
11. Route water from S-175 into Frog Pond reservoir, backfill L-31W south of main ENP road.
12. Backfill C-111 and C-111E south of SR 9336, plus C-110, remove S-18C.
13. Remove S-197 or leave as plug if backfilling C-111 incomplete due to fill availability.
14. Backfill C-110 from SW 424 St to origin at SW 392 St.
15. Remove unneeded small roads, backfill associated borrow ditches except for minimal network retained for land management access.
16. Seepage collector system (collector canal with downstream berm, and intermediate step-up buffer area) to provide flood mitigation for adjacent developed lands.
17. Spreader canal with no (preferred) or very low landward berm extending from Frog Pond reservoir complex along northern boundary of project area to just east of Tallahassee Rd where historic flowways still exist.
18. Small capacity pump at Florida City Canal.
19. Reservoir/STA to pre-treat Florida City Canal water prior to discharge into spreader canal (includes culverts under Palm Drive to reconnect reservoir area with Long Glade slough).
20. Preserve section of Card Sound borrow canal with for use as feeder canal between spreader canal and rock pit reservoir.
21. FRS rock pits converted to sealed (Lake Belt-type) reservoir.
22. Pump station to move water into/out of FRS reservoir.

23. Pump station to move water out of reservoir feeder canal into spreader canal.
24. ASR wells to supplement storage in FRS reservoir.
25. Densify culverts (if necessary) to make US 1 hydrologically invisible under high flow conditions in Long Glade Slough; ensure that (at least) several also serve as wildlife underpasses.
26. Bridge US 1 over seepage collector/spreader canal complex to permit free flow of water in canals and associated buffer area.
27. Make SW 424 St to DJJ facility hydrologically invisible – options for screening include culverts, replacing road with bridge.
28. Densify culverts (if necessary) to make lower US 1 hydrologically invisible under elevated water and higher flow conditions in the region; ensure that historic flowway near MM 115 is reestablished (J. Lorenz comment letter to FDOT); ensure that (at least) several also serve as wildlife underpasses.
29. Retain C-111 below S-197 for recreational access, access to existing South Dade Marina, but culvert on downstream side to restore freshwater flows to coastal wetlands between C-111 and US 1.
30. Bridge north Card Sound Road over slope to Long Glade Slough to permit free flow of water across slope to historic flow way and facilitate recharge of entire flowway when water pumped out of reservoir up to spreader canal.
31. Make lower Card Sound Road hydrologically invisible – options for screening include skybridge with recreational pull-outs, series of bridges, culverts with several designated as wildlife underpasses.
32. Backfill (preferred) or plug Card Sound Canal to eliminate overdrainage and facilitate overland flows.
33. Make Tallahassee Road (SW 137 Ave) hydrologically invisible – options include road removal (preferred), skybridge with limited recreational access pullouts, series of bridges with limited recreational access pullouts
34. Backfill northern Model Lands Canal.
35. Backfill southern Model Lands Canal.
36. Modify S-20 get-away canal as spreader canal to deliver available water to coastal wetlands south and east of Turkey Point cooling canals.
37. Backfill Sea-Dade canal (not needed if FPL Phase 2 proceeds as planned) except on approach to meteorological monitoring tower.
38. Culvert under approach road to meteorological monitoring tower (not needed if FPL Phase 2 proceeds as planned).
39. Culvert (with gates or other means for control) under L-31E between FPL evacuation road and Card Sound Road (not needed if FPL Phase 2 proceeds as planned).
40. Make Palm Drive east of Motorsports Complex hydrologically invisible to reconnect wetlands north and south of road – options for screening include skybridge, multiple bridge sections, and culverts under road.

41. Raise control elevations at S-20 and gated culverts in L-31E up to 0.5 ft. in summer, establish control schedule during fall to bleed down stored water into coastal wetlands during November, December.

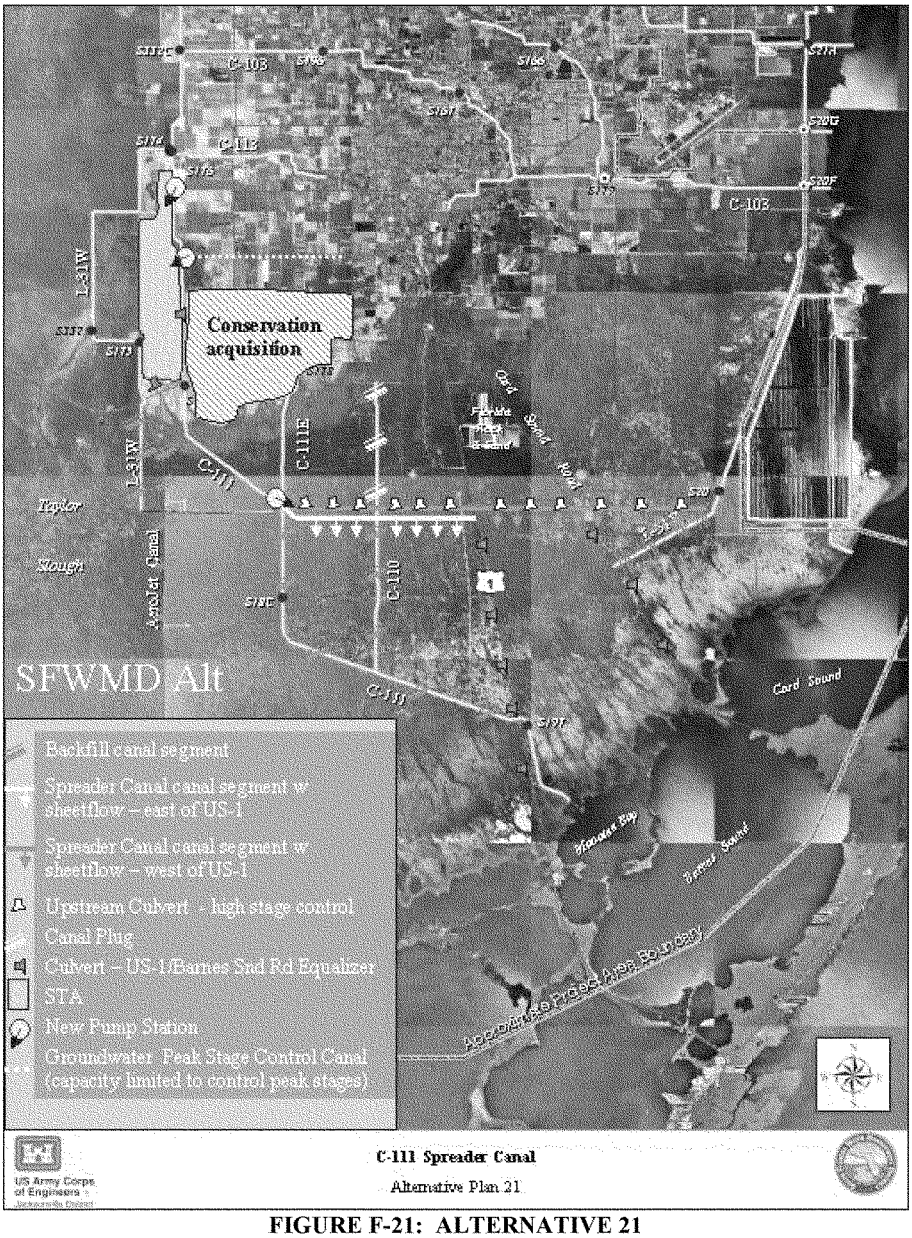


FIGURE F-21: ALTERNATIVE 21

Alternative 21 Description

Frog Pond STA Expansion/Conservation Acquisition–Land not utilized by the Federal C-111 project would be integrated into Spreader Canal Project–STA treatment capacity sized to amount of land removed from agricultural production and placed into conservation to reduce nutrient/pesticide loading from basin. BMPs implemented in remaining basin lands not converted to conservation. Internal STA design would be engineered to meet treatment standards.

New Frog Pond Pump Station/S-332D Integration–water upstream of S-176 is diverted through S-332D for Taylor Slough delivery; water downstream of S-176 diverted into spreader STA for treatment and release to Ludlum Slough or through gravity discharge at the south end STA outlet via a natural drainage flowway into upper C-111 panhandle.

Canal Segment S-176 to S-177–Canal segment operated to promote treatment of remaining C-111E Basin runoff/groundwater not converted to conservation through the new Frog Pond STA facility.

New Spreader Canal Pump Station–provides directional flow control to east/west spreader canals depending on water conditions and marsh hydrology

East/West US-1 Spreader Canals–A separate east/west spreader canal allows water to be preferentially discharged by sheetflow depending on marsh conditions and sources of water volumes

Upstream Culvert Control-Upstream water levels north of the spreader canals are maintained by gated or flap control culverts to prevent over flooding during high rain events

Backfilled/Plug Canals–The Aerojet, L-31West extension below S-175, C-111 Canal below confluence of C-111E and L-31E below S-20 structure are all backfilled. The segment of C-110 north of the new spreader canals is plugged and deep-water habitats retained.

L-31E Backfilled Segment–The east spreader canal is extended to the S-20 structure. The remaining portion of the L-31E Canal and levee is removed. Upstream stage control culverts (gated culverts or flap gates) are placed in the C-111 Spreader Canal east segment to control upstream stages.

S-18C/S-197 Structure Removals–Both structures are removed from active water control.

Groundwater Peak Stage Control Canal and Pump Station–A shallow canal collection system may be needed to control peak groundwater stages upstream of the Ludlum Slough with increased use of this conveyance and higher stages in the STA. The capacity of this collection system would be minimal to reduce peak groundwater stages during high rainfall events. Collected water would be pumped to the Frog Pond STA for treatment and release to Ludlum Slough. Adjusting canal operating stages between S-176 and S-177 may offset the collection capacity.

Until the uncertainty of the flood control and water supply aspects for restoration of this proposed project can be fully evaluated, phased implementation is recommended for critical components as follows.

East Spreader Canal–The east spreader canal and sheetflow segment should be constructed first to accommodate pulse storm flows generated within the C-111 Canal Basin. Excess storm flows can be diverted east of US-1 and Card Sound to rehydrate the existing creeks. The west segment of the spreader canal would not be constructed until a later date.

Upstream Stage Control (East Spreader Canal)-Culverts for upstream stage control would be installed together with the east spreader construction.

Backfill L-31E Canal Segment–The L-31E canal segment below the S-20 structure would be deferred until the C-111 West Spreader Canal segment is constructed.

Gravity Spreader Canal Operation–Water would be discharged by gravity into the east spreader canal segment from the C-111 Canal and controlled by the S-177 structure. A shallow plug or operable gate would be installed in the C-111 Canal downstream from the confluence with the newly constructed C-111East Spreader canal conveyance.

Remaining S-18C/S-197 Canals and Structures–This segment of the canal and structures would remain fully functional until operational experience with the East Spreader Canal and flood control modeling demonstrate that these facilities can be removed as planned. Water flows from the upper C-111 Canal would be split with roughly 50% going to the East Spreader Canal segment and the remaining 50% diverted to the lower C-111 through S-18C. Large rainfall events would be diverted to the East Spreader Canal segment to further reduce or eliminate S-197 discharges during the phased implementation period.

STA Construction and Pump Station–STA construction, the inflow pump station and outlet structures would be accelerated and completed as part of Phase 1

implementation. Water pumped from the canal segment below S-177 would be treated through the STA. Water releases from S-176 could additionally bypass the S-332D structure and be released downstream and pumped through the STA. Discharges from the STA would be split with 75% being diverted to Ludlum Slough and 25% through the southern STA outlet. An additional pump station at Ludlum Slough may be required to achieve the flow distribution.

Conservation Land Acquisition–Acquisition of agricultural lands associated with disproportionately high nutrient loads from the C-111E Basin would be acquired on an accelerated pace. These lands would be converted to conservation to reduce the net export of nutrients out of the basin. Depending on the efficiency of reducing nutrient exports by acquisition, the overall STA requirements may be reduced by a proportionate amount.

Groundwater Peak Stage Control Canal–This component and associated pump station would be deferred until the remaining C-111 Spreader Canal components are constructed and the need has been justified through model assessments.

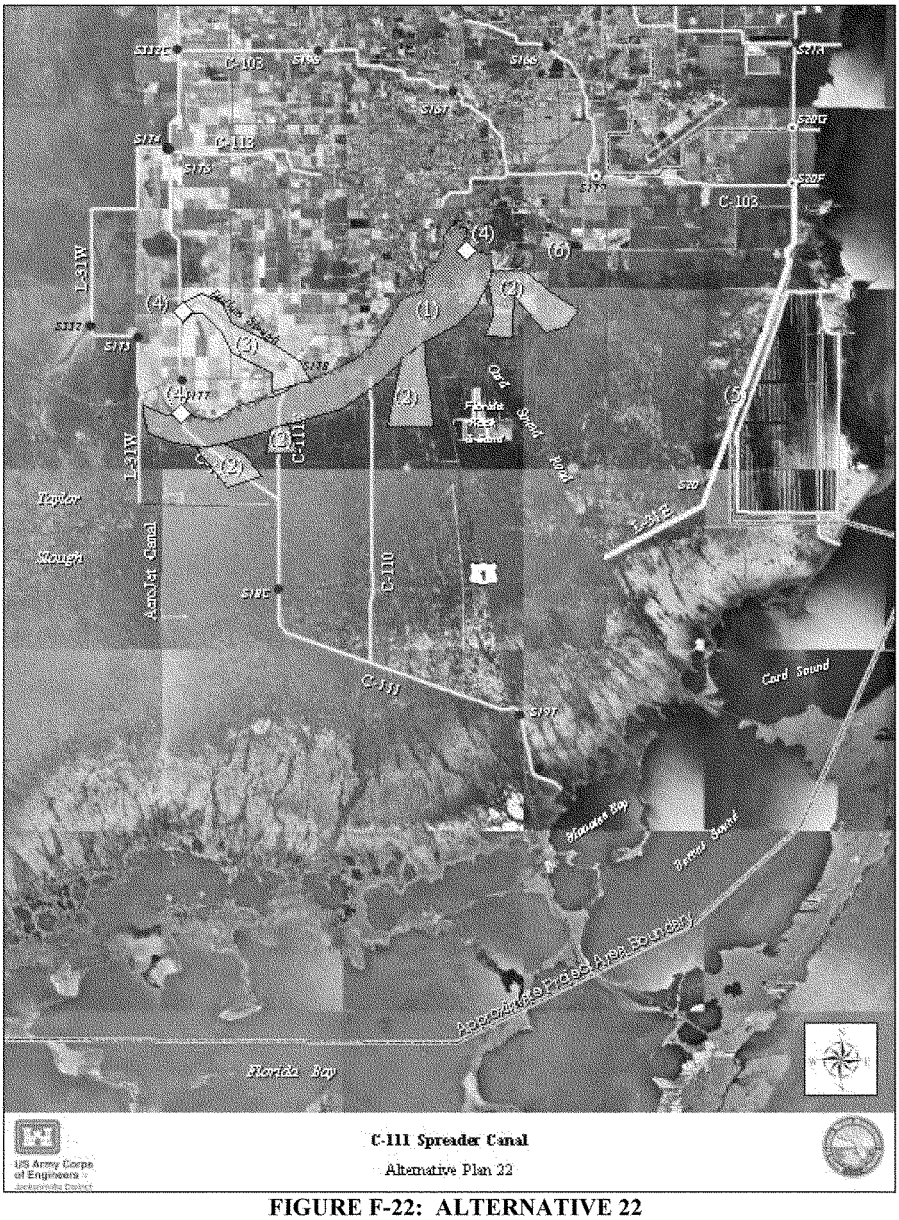


FIGURE F-22: ALTERNATIVE 22

Alternative 22 Description

1. Large STA/reservoir encompassing all impacted wetlands near the boundary of the developed area, plus the Wink Eye Slough.
2. Utilize historic flow ways to introduce water to region from STA. Backfill all primary canals.
3. Ludlam Slough broadened to establish linear flow way with some cleansing functions as emergent vegetation intercepts nutrients, particulates.
4. Pump stations to move available water from adjacent canals to flow ways
5. Shallow L-31E borrow canal to depth no greater than 1 m to restrict habitat suitability for exotic fishes.
6. Seepage collector system (collector canal with downstream berm, and intermediate step-up buffer area) to provide flood mitigation for adjacent developed lands.
7. Other features same as kitchen sink alternative, as appropriate.

TABLE F-1: INITIAL ARRAY OF ALTERNATIVES

Alternative	Description
Alternative 1 (YB)	Removal of S-197, S-18C, backfilling lower C-111, backfilling C-110, STA in the NW triangle of C-111/C-111E convergence, pump stations, culverts under U.S. 1 and Card Sound Road.
Alternative 2	The capacity of S-176 (currently 1,100 cfs) would be increased. Construct the pump station to 500 cfs as in the approved plan, but construct two spreader canals. One canal would head east and the other canal would deliver water first further south and then in an east-west direction towards the Model Lands and Taylor Slough. The second spreader would need another smaller pump structure.
Alternative 3	Two natural sloughs and the one canal (C-111) would serve as three points for introducing water into project lands. Each inflow point would require construction of its own pump structure and its own STA. The most eastern slough would provide a flowway that would also deliver water towards the Florida Power & Light Mitigation Bank area.
Alternative 4	Increase the capacity of S-176. Construct a pump structure south of S-176 that would pump water westward into a new STA that would be located in the Frog Pond area. Relocate the existing L-31E Canal and levee to the west. Move proposed east-west C-111 Spreader Canal to the north as much as is feasible and extend towards the east to the relocated L-31E Canal. Fill in the lower L-31W and other canals in the project area. Remove the Aerojet Canal and road and restore that area as well.
Alternative 5	Use existing natural sloughs and waterways located just to the south of Florida City and Homestead as spreader(s). Water would be delivered using natural flowways from the C-111. A pump structure would siphon water from the northern C-111 and deliver it to an adjacent STA constructed within existing natural flowway. Water would continue to travel along this northernmost natural configuration overflowing to the south and southeast in an arc. Purchase flowage easements as needed. Remove all discontinuities in the Southern Glades and Model Lands.
Alternative 6	Construct two parallel spreaders. Instead of a straight line towards the Model Lands as in the approved project, build the spreaders in an arcing pattern so that water is delivered in a

	southeasterly direction. A separate pump structure for the second spreader. Southern spreader canal would be needed. All discontinuities would be removed.
Alternative 7	Enlarge S-176 and construct a pump station at S-177 to discharge into a storage area (reservoir) located within the eastern Frog Pond area. A seepage management feature will be headed to contain this stored water. Also pump water at S-178 into the STA. Seepage control will also be needed on the north side of the STA with the seepage returned to the STA. The new STA will extend east to US1, just south of Florida City. Pump from the proposed Florida City Canal into the STA. Spread the discharge from the STA along its south side with larger discharges at old slough locations. Fill in C-111 and C-111E. Remove S-197 and all discontinuities.
Alternative 8	Construct an STA in the Frog Pond and build two pump structures at the northern bend of the C-111. One structure would pump water directly south and the other would pump water to a north spreader canal that would extend all the way east to L-31E Canal. A second, parallel spreader would be constructed south. C-111 would be shallowed (not filled in) all the way to U.S. 1. Fill in C-110 and remove S-197.
Alternative 9	Construct an STA/reservoir at the Frog Pond. Tie in an existing slough/waterway to the new STA/reservoir using a connector canal and pump structure. This will become a feeder slough that will travel south along its natural flowway to a point where it intersects the southern edge of Florida City/ Homestead at an existing flowway. Another STA may be needed at this juncture. This southern flowway will become the spreader, discharging water along its southern edge in a southeasterly manner. All discontinuities, except for U.S. Highway 1 and Card Sound Road, would be removed. Culverts would be installed under Card Sound Road to allow sheetflow. The existing rock quarry located within the triangle lands would be converted to a second reservoir with its own discharge spreader. U.S. 1 would be converted into a sky bridge with recreational pullouts. L-31E Canal and levee would be removed.
Alternative 10	STAs located within the footprints of existing water conveyance canals. They would be narrow, but can be about as long as is necessary to perform the desired water quality improvement functions as described in the project objectives. There may need to be some kind of flow-reducing structures within the STAs to prevent water from flowing through too fast, such as weirs or some other kind of obstructions. At the southern ends of the STAs there would be spreader canals, along with their associated adequately sized pumps. The spreader canals would extend in an east-west pattern with arcing ends to allow water to sheetflow through the project area wetlands. An STA similar in dimensions to the others could be constructed between S-178 and the northern end of C-110, if necessary, to help balance amounts of water between the spreader canal serving L-31W, C-111, and C-111E, and the one serving C-110. The canals and water control structures south of the spreader canals would be removed, with the exception of the section of C-111 south of S-197 which is utilized by manatees. The spreader canals would include seepage control canals/berms on their northern ("upstream") sides, or any other similar features, if necessary to help prevent excessive flooding of adjacent private properties. South of the spreader canals, the water control structures would be removed and the water conveyance canals would be backfilled or plugged, with the exception of the section of C-111 south of S-197 which is utilized by manatees and can be used for recreational purposes. As many obstructions to water sheetflow in the project area wetlands (roads, ditches, canals, etc.) as possible would be removed or plugged. A series of culverts / wildlife crossings would be constructed as necessary under U.S. 1, Card Sound Road, Tallahassee Road, and any other roads that cannot be removed to encourage hydrologic exchange and safe wildlife access.
Alternative 11	This plan is the same as plan 10 with the exception of an increased length of the eastern

	spreader canal, the one serving C-110. This spreader canal would be constructed to extend further to the east, through culverts under U.S. 1 and Card Sound Road, to provide increased water sheet flow to those wetland areas east of U.S. 1. A pump larger than the one used in plan 10 would most likely be necessary to more adequately propel the water the increased distance. The spreader canals would include seepage control canals/berms on their northern ("upstream") sides, or any other similar features, if necessary to help prevent excessive flooding of adjacent private properties. South of the spreader canals, the water control structures would be removed and the water conveyance canals would be backfilled or plugged, with the exception of the section of C-111 south of S-197 which is utilized by manatees and can be used for recreational purposes. As many obstructions to water sheet flow in the project area wetlands (roads, ditches, canals, etc.) as possible would be removed or plugged. A series of culverts / wildlife crossings would be constructed as necessary under U.S. 1, Card Sound Road, Tallahassee Road, and any other roads that cannot be removed to encourage hydrologic exchange and safe wildlife access.
Alternative 12	This plan features stormwater treatment areas located within the footprints of existing water conveyance canals. They would be narrow, but can be about as long as is necessary to perform the desired water quality improvement functions as described in the project objectives. There may need to be some kind of flow reducing structures within the STAs to prevent water from flowing through too fast, such as weirs or some other kind of obstructions. At the southern ends of the STAs, there would be spreader canals, along with their associated adequately sized pumps. The spreader canals would generally extend in an east/west pattern with arcing ends to allow water to sheet-flow through the project area wetlands. An STA similar in dimensions to the others could be constructed between S-178 and the northern end of C-110, if necessary, to help balance amounts of water between the spreader canal serving L-31W, C-111, & C-111E, and the one serving C-110. STAs similar in dimensions to the others would be constructed from the Long Glade Slough area to the south, and then to the east to a pump structure and spreader canal, which would extend east along natural flow ways as much as possible into the northern Model Lands between Tallahassee Road and the L-31E Canal, and south of C-103 or Florida City Canal. Some kind of pump may need to be constructed to draw water from Florida City Canal into the STA. Another STA similar in dimensions to the others would be constructed from the northern C-110 terminus to connect with the STA coming from the Long Glade Slough area, described above. Additional pump structures may be necessary to help properly disperse water through the STAs. The southern portion of L-31E would be transformed into an STA, in a manner similar to the others, and would feature a small spreader canal with associated pump on the south side of the STA. The spreader canals would include seepage control canals/berms on their northern ("upstream") sides, or any other similar features, if necessary to help prevent excessive flooding of adjacent private properties. South of the spreader canals, the water control structures would be removed and the water conveyance canals would be backfilled or plugged, with the exception of the section of C-111 south of S-197 which is utilized by manatees and can be used for recreational purposes. As many obstructions to water sheet flow in the project area wetlands (roads, ditches, canals, etc.) as possible would be removed or plugged. A series of culverts / wildlife crossings would be constructed as necessary under US 1, Card Sound Road, Tallahassee Road, and any other roads that cannot be removed to encourage hydrologic exchange and safe wildlife

	access.
Alternative 13	Similar to alternative 19, except this alternative has less features than alternative 19 for reduction of seepage and water quality.
Alternative 14	Large STA that would be pumped into via S-332D and will naturally flow into the STA/reservoir south and then be pumped using the spreader canal as well as spill naturally at the southern end by constructing a concrete weir. Then, partially fill all the canals, leaving a shallow depth for recreation (i.e. fishing). Also, have culverts located in the project area in U.S. 1 and Card Sound Road.
Alternative 15	A lined reservoir built and operated similar to a lake belt reservoir is placed in the northeast part of the Frog Pond. A STA lined on the east side is placed in the southeast part of the Frog Pond adjacent to the reservoir. A flood control pump ("1") is located (between S-177 and S176) in the C-111 Canal adjacent to and pumping into the Reservoir. A STA pump station ("3") discharges water from the south end of the STA into a new canal connecting to the C-111 Canal downstream of the S-177. A "steep" topographic gradient exists at the base of the coastal ridge. A Spreader Canal Pump Station is located in the C-111 Canal downstream from the new canal from the STA. This pump station discharges into a Spreader Canal constructed near the base of the coastal ridge. The Spreader Canal continues east and northeast near the base of the coastal ridge passing under US Highway 1 and Card Sound Road and continues east to a pump station ("3") discharging from a STA immediately south and adjacent to the Florida City Canal. The eastern terminus of the Spreader Canal and the location of the eastern STA should be determined by modeling predictions of marsh sheetflow distribution needs. Booster pumps ("3") are located in the Spreader Canal as needed to distribute the water adequately. Culverts in the Spreader Canal deliver more water to historic slough areas than adjacent marsh areas. A flood control pump station ("1") discharges from the Florida City Canal into the new eastern STA. If additional water is supplied to the project area from the Biscayne Bay Coastal Wetlands project, distribution of that water can also be made with this pump station. A seepage collection canal is constructed between the top of the "steep" coastal ridge gradient and the Spreader Canal. This canal collects seepage from the Spreader Canal and higher marsh water levels. On the eastern end, seepage is returned to the STA by a seepage control pump station ("2"). On the western end, a new canal connects to the C-111 Canal upstream from the S-177 Structure and continues east across the C-111E Canal. Seepage control pump stations ("2") are located at the east end of the new canal and at the C-111 Canal to return seepage and flood control water from the C-111E Canal to the C-111 Canal for delivery to the reservoir pump station. The C-111 and C-111E canals are filled downstream from the Spreader Canal to a point upstream from the existing privately owned marina. The canal is filled to existing grade to eliminate unnatural preferential flow paths and disruptions to sheetflow. If insufficient material is available, periodic discontinuous sections of the canal remain to provide deepwater habitat. The S-197 structure is removed. The L-31E canal south of the Florida City canal is removed and its flows are sent to the flood control pump station ("1") discharging from the Florida City canal into the new eastern STA for distribution through sheetflow to the marsh. Other discontinuities such as the Aerojet Canal, Card Sound Road Canal, C-110, unpaved roads, etc, are removed to the maximum extent possible.
Alternative 16	A STA lined on the north and east side is placed in the southeast part of the Frog Pond adjacent to C-111. East side lining continues to a point south of the S-177. A flood control pump ("1") is located between S-177 and S176 in the C-111 adjacent to and pumping into the STA. A new canal connects to the C-111 upstream from the S-177 and continues east connecting to the C-111E. A new flood control pump station ("1") is located on the new

	canal and at the C-111 to move flood control water from the C-111E to the C-111 for delivery to the new flood control pump station discharging to the STA. A STA pump station ("2") discharges water from the south end of the STA into a new canal connecting to the C-111 downstream of the S-177. A Spreader Canal Pump Station ("3") is located in the C-111E Canal upstream from the convergence of the C-111 and C-111E Canals. This pump station discharges into a Spreader Canal constructed along an existing disturbance in the marsh. The Spreader Canal continues east passing under U.S. 1 and Card Sound Road. Booster pumps ("3") are located in the spreader canal as needed to distribute the water adequately through the culverts under the highways. A small section of the Card Sound Road canal distributes water. Immediately downstream from the convergence of the C-111 and C-111E canals a new emergency flood control pump station ("1") is constructed in the C-111 Canal. Levees are removed from both sides of the C-111 from the new pump station to the existing S-18C. The levee material is used to gradually shallow the C-111 Canal beginning midway between the new pump station and the existing S-18C Structure until the fill material meets existing grade at the S-18C. Excess material is used for filling downstream as needed. The existing S-18C is removed and the C-111 is filled downstream from the existing S-18C location to a point upstream from the existing privately owned marina. The canal is filled to existing grade to eliminate unnatural preferential flow paths and disruptions to sheetflow. If insufficient material is available, periodic discontinuous sections of the canal remain to provide deepwater habitat. The S-197 is removed. Other discontinuities such as the Aerojet Canal, Card Sound Road Canal, C-110, and unpaved roads, etc, are removed to the maximum extent possible.
Alternative 17	Lined reservoir in the northern Frog Pond area adjacent to the S-332D detention reservoir. Provides storage and produces a seepage-free head for delivering water to the STA and spreader canal. Lower Frog Pond will become an STA for removal of phosphorus as well as other pollutants (pesticides, heavy metals, etc). STAs should be designed to benefit wildlife whenever possible (see the Service's fish and wildlife enhancement recommendations in the ICU). Remove levee and backfill canals with red cross-hatching (includes lower L-31W, Aerojet, lower C-111 and C-111E, C-110, and east-west running roads and agricultural impediments in the Southern Glades). Card Sound Road borrow canal removed and lower L-31E levee and canal filled. An STA at Loveland Slough for treatment of S-178 discharge. Should be compartmentalized and east-west levees built within the transitional vegetation zone for panther crossings. S-332E pump station should be constructed on the C-111 to pump down a spreader canal which would run along the paved road (should be removed) at the northern boundary of the Southern Glades. A third STA and associated pump and distribution canal would be built just south and east of Florida City to collect, treat, and distribute runoff in a southerly direction.
Alternative 18	Utilize the same components as Alt 17 except adds a fourth STA/pump/distribution canal in the northeast portion of the project area.
Alternative 19	Utilize the same lined reservoir and STA configuration in the Frog Pond area as in alternatives 17 & 18. Natural sloughs located just south of the proposed Frog Pond STA should be restored with littoral shelves included for added treatment capability. Similar to above, Loveland Slough should be restored and even widened if necessary to

	provide treatment of low quality agricultural run off. S-178 should be removed. Best Management Practices (BMP) should be implemented (or refined if already implemented) for active agricultural practices southwest of Homestead and Florida City. A reduction in harmful pollutants added to the water will ease the burden on STAs and other treatment measures in this area. Some canals such as the lower L-31W, Aerojet, and lower C-111 should be plugged and include boat bypasses. This will lower the costs of the project and continue to provide access to the world-class bass fishery located in this area. Card Sound Road borrow canal north of the L-31E connection would be removed, and the east-west borrow canals in the northern and central parts of the Southern Glades would be filled.
Alternative 20	Features, in no particular order: 1. Loveland Slough broadened to establish linear flow way with some cleansing functions as emergent vegetation intercepts nutrients, particulates. 2. STA and/or reservoir in south Frog Pond with outflow pumps (diamonds). May need to be lined. 3. Utilize historic flow way to south or Loveland Slough flow way to introduce water to southern wetlands 4. Frog Pond natural areas (pineland, hammock, pinnacle rock glades) to be preserved 5. ASR wells to supplement storage in Frog Pond 6. Remove Aerojet buildings and remaining access road. 7. Make lower Aerojet Road hydrologically invisible – options for screening include road removal, culverts. 8. Close/remove Aerojet silo building, remove access road. 9. Make upper Aerojet Road hydrologically invisible – culverts preferred due to recreational access issues. 10. Inflow pump station with capacity sufficient to remove flood-equivalent volume from C-111 and transfer to reservoir/ASR system for storage 11. Route water from S-175 into Frog Pond reservoir, backfill L-31W south of main ENP road. 12. Backfill C-111 and C-111E south of SR 9336, plus C-110, remove S-18C. 13. Remove S-197 or leave as plug if backfilling C-111 incomplete due to fill availability. 14. Backfill C-110 from SW 424 St to origin at SW 392 St. 15. Remove unneeded small roads, backfill associated borrow ditches except for minimal network retained for land management access. 16. Seepage collector system (collector canal with downstream berm, and intermediate step-up buffer area) to provide flood mitigation for adjacent developed lands. 17. Spreader canal with no (preferred) or very low landward berm extending from Frog Pond reservoir complex along northern boundary of project area to just east of Tallahassee Rd where historic flowways still exist. 18. Small capacity pump at Florida City canal. 19. Reservoir/STA to pre-treat Florida City canal water prior to discharge into spreader canal (includes culverts under Palm Drive to reconnect reservoir area with Long Glade slough). 20. Preserve section of Card Sound borrow canal with for use as feeder canal between spreader canal and rock pit reservoir. 21. FRS rock pits converted to sealed (Lake Belt-type) reservoir. 22. Pump station to move water into/out of FRS reservoir. 23. Pump station to move water out of reservoir feeder canal into spreader canal. 24. ASR wells to supplement storage in FRS reservoir. 25. Densify culverts (if necessary) to make US 1 hydrologically invisible under high flow conditions in Long Glade Slough; ensure that (at least) several also serve as wildlife underpasses.

	26. Bridge US 1 over seepage collector/spreader canal complex to permit free flow of water in canals and associated buffer area. 27. Make SW 424 St to DJJ facility hydrologically invisible – options for screening include culverts, replacing road with bridge. 28. Densify culverts (if necessary) to make lower US 1 hydrologically invisible under elevated water and higher flow conditions in the region; ensure that historic flowway near MM 115 is reestablished (J. Lorenz comment letter to FDOT); ensure that (at least) several also serve as wildlife underpasses. 29. Retain C-111 below S-197 for recreational access, access to existing South Dade Marina, but culvert on downstream side to restore freshwater flows to coastal wetlands between C-111 and US 1. 30. Bridge north Card Sound Road over slope to Long Glade Slough to permit free flow of water across slope to historic flow way and facilitate recharge of entire flowway when water pumped out of reservoir up to spreader canal. 31. Make lower Card Sound Road hydrologically invisible – options for screening include skybridge with recreational pull-outs, series of bridges, culverts with several designated as wildlife underpasses. 32. Backfill (preferred) or plug Card Sound Canal to eliminate overdrainage and facilitate overland flows. 33. Make Tallahassee Road (SW 137 Ave) hydrologically invisible – options include road removal (preferred), skybridge with limited recreational access pullouts, series of bridges with limited recreational access pullouts 34. Backfill northern Model Lands Canal. 35. Backfill southern Model Lands Canal. 36. Modify S-20 get-away canal as spreader canal to deliver available water to coastal wetlands south and east of Turkey Point cooling canals. 37. Backfill Sea-Dade canal (not needed if FPL Phase 2 proceeds as planned) except on approach to meteorological monitoring tower. 38. Culvert under approach road to meteorological monitoring tower (not needed if FPL Phase 2 proceeds as planned). 39. Culvert (with gates or other means for control) under L-31E between FPL evacuation road and Card Sound Road (not needed if FPL Phase 2 proceeds as planned). 40. Make Palm Drive east of Motorsports Complex hydrologically invisible to reconnect wetlands north and south of road – options for screening include skybridge, multiple bridge sections, and culverts under road. 41. Raise control elevations at S-20 and gated culverts in L-31E up to 0.5 ft. in summer, establish control schedule during fall to bleed down stored water into coastal wetlands during November, December.
Alternative 21	Frog Pond STA Expansion/Conservation Acquisition – Land not utilized by the Federal C-111 project would be integrated into Spreader Canal Project – STA treatment capacity sized to amount of land removed from agricultural production and placed into conservation to reduce nutrient/pesticide loading from basin. BMPs implemented in remaining basin lands not converted to conservation. Internal STA design would be engineered to meet treatment standards. New Frog Pond Pump Station/S-332D Integration – water upstream of S-176 is diverted through S-332D for Taylor Slough delivery; water downstream of S-176 diverted into spreader STA for treatment and release to Loveland Slough or through gravity discharge at the south end STA outlet via a natural drainage flowway into upper C-111 panhandle. Canal Segment S-176 to S-177 – Canal segment operated to promote treatment of remaining C-111E basin runoff/groundwater not converted to conservation through the new Frog Pond STA facility. New Spreader Canal Pump Station – provides directional flow control to east/west spreader canals depending on water conditions and marsh hydrology East/West US 1 Spreader Canals – A separate east/west spreader canal allows water to be

	preferentially discharged by sheetflow depending on marsh conditions and sources of water volumes Upstream Culvert Control - Upstream water levels north of the spreader canals are maintained by gated or flap control culverts to prevent over flooding during high rain events Backfilled/Plug Canals – The Aerojet, L-31West extension below S-175, C-111 Canal below confluence of C-111E and L-31E below S-20 structure are all backfilled. The segment of C-110 north of the new spreader canals is plugged and deep-water habitats retained. L-31E Backfilled Segment – The east spreader canal is extended to the S-20 structure. The remaining portion of the L-31E Canal and levee is removed. Upstream stage control culverts (gated culverts or flap gates) are placed in the C-111 Spreader Canal east segment to control upstream stages. S-18C/S-197 Structure Removals – Both structures are removed from active water control. Groundwater Peak Stage Control Canal and Pump Station – A shallow canal collection system may be needed to control peak groundwater stages upstream of the Loveland Slough with increased use of this conveyance and higher stages in the STA. The capacity of this collection system would be minimal to reduce peak groundwater stages during high rainfall events. Collected water would be pumped to the Frog Pond STA for treatment and release to Loveland Slough. Adjusting canal operating stages between S-176 and S-177 may offset the collection capacity. Until the uncertainty of the flood control and water supply aspects for restoration of this proposed project can be fully evaluated, phased implementation is recommended for critical components as follows. East Spreader Canal – The east spreader canal and sheetflow segment should be constructed first to accommodate pulse storm flows generated within the C-111 Canal Basin. Excess storm flows can be diverted east of US-1 and Card Sound to rehydrate the existing creeks. The west segment of the spreader canal would not be constructed until a later date. Upstream Stage Control (East Spreader Canal) - Culverts for upstream stage control would be installed together with the east spreader construction. Backfill L-31E Canal Segment – The L-31E canal segment below the S-20 structure would be deferred until the C-111 West Spreader canal segment is constructed. Gravity Spreader Canal Operation – Water would be discharged by gravity into the east spreader canal segment from the C-111 Canal and controlled by the S-177 structure. A shallow plug or operable gate would be installed in the C-111 Canal downstream from the confluence with the newly constructed C-111East Spreader Canal conveyance. Remaining S-18C/S-197 Canals and Structures – This segment of the canal and structures would remain fully functional until operational experience with the East Spreader Canal and flood control modeling demonstrate that these facilities can be removed as planned. Water flows from the upper C-111 Canal would be split with roughly 50% going to the East Spreader Canal segment and the remaining 50% diverted to the lower C-111 through S-18C. Large rainfall events would be diverted to the East Spreader Canal segment to further reduce or eliminate S-197 discharges during the phased implementation period. STA Construction & Pump Station – STA construction, the inflow pump station and outlet structures would be accelerated and completed as part of Phase 1 implementation. Water pumped from the canal segment below S-177 would be treated through the STA. Water releases from S-176 could additionally bypass the S-332D structure and be released downstream and pumped through the STA. Discharges from the STA would be split with 75% being diverted to Loveland Slough and 25% through the southern STA outlet. An additional pump station at Loveland Slough may be required to achieve the flow distribution. Conservation Land Acquisition – Acquisition of agricultural lands associated with

	disproportionately high nutrient loads from the C-111E Basin would be acquired on an accelerated pace. These lands would be converted to conservation to reduce the net export of nutrients out of the basin. Depending on the efficiency of reducing nutrient exports by acquisition, the overall STA requirements may be reduced by a proportionate amount. Groundwater Peak Stage Control Canal – This component and associated pump station would be deferred until the remaining C-111SC components are constructed and the need has been justified through model assessments.
Alternative 22	Large STA/reservoir encompassing all impacted wetlands near the boundary of the developed area, plus the Wink Eye Slough. Utilize historic flow ways to introduce water to region from STA. Backfill all primary canals. Loveland Slough broadened to establish linear flow way with some cleansing functions as emergent vegetation intercepts nutrients, particulates. Pump stations to move available water from adjacent canals to flowways. Shallow L-31E Borrow Canal to depth no greater than 1 m to restrict habitat suitability for exotic fishes. Seepage collector system (collector canal with downstream berm, and intermediate step-up buffer area) to provide flood mitigation for adjacent developed lands. Other features same as alternative 20, as appropriate.

F.2 Frog Pond Detention Area Analysis

Frog Pond Sizing Analysis – For the formulation of the Frog Pond Detention Area (FPDA), different sized configurations (larger and smaller), were both considered. To evaluate the different configurations, multiple lengths (north-south) and widths (east-west) were formulated to arrive at an optimal design. For the FPDA to be effective in creating a hydraulic ridge, the detention area must run continuously north-south in order to block the west-east drainage effects of the C-111 Canal. Any interruptions or open spaces in the detention area would negate its effectiveness by allowing a pass for seepage water to flow out of ENP into the C-111 Canal. Additionally, the detention area must extend far enough to the north and south to prevent seepage from leaking around the poles of the hydraulic ridge. With the parameters for effectiveness and necessary design, an analysis of the area was conducted to determine the appropriate north-south lengths of the FPDA. The analysis focused on avoidance and minimization of any impacts to high quality natural features and adjacent land use while making the detention area extend as far as possible to the north and south. There are environmentally-sensitive lands located in the extreme North of the project site. These lands are non-impacted wetlands that also contain several valuable and distinct tree islands. Avoidance of these lands was a priority for the PDT in the sizing of the proposed FPDA. The northern boundary of the FPDA was sited just to the south of these lands, allowing for these resources to remain in existence. To the extreme south of the proposed FPDA, there is an existing road, Ingraham Highway. Expansion of the FPDA into this area could create severe problems by increasing groundwater levels, which in turn would impact the subgrade of the road. The PDT concluded that

the appropriate alignment of the FPDA in this area would be just north of Ingraham Highway, at a distance far enough to avoid significantly raising groundwater levels in this area. Pursuant to the north-south siting analysis, hydrologic modeling of the alignment demonstrated that a detention area with these parameters was capable of maintaining a proper hydraulic ridge and preventing seepage from ENP into the C-111 Canal.

After making the north-south siting determination for the FPDA, the appropriate east-west alignment was formulated by the PDT. The creation of a hydraulic ridge is heavily dependent on the ability for water that is pumped into the detention area to intersect with groundwater, thereby forming a continuous "wall" from the ground surface to the aquifer below ground. The most effective way to establish surface water contact with the aquifer is directly by excavating the underlying substrate. This method was contemplated and would be similar in nature to the Aerojet Canal feature that is proposed in one alternative; however, the excavation of the site to create this feature could create detrimental, irreversible impacts if modifications were needed for the Eastern PIR. There is no existing canal in the area of the Frog Pond as there is for the Aerojet Canal feature. As such, excavation was not considered and only above-ground detention areas were formulated for the alternatives. The most-effective means to ensure that water pumped into an above-ground detention area intersects with the aquifer would be to provide the maximum amount of surface area for infiltration. As such, different width detention areas were considered, with some bringing the total acreage of the FPDA to over 2,000 acres. Similar to the north-south siting analysis, an analysis was conducted regarding the avoidance and minimization of any impacts to high quality natural features and adjacent land use for the east-west alignment.

To the west of the proposed FPDA are the C-111 South Dade project features and Everglades National Park. Operation of the C-111 South Dade project system was factored into formulation for the proposed project as the currently proposed project and the South Dade project would work in unison as part of the overall restoration plan for the area. As such, none of the FPDA features were proposed to interfere with this area. Additionally, care was taken to avoid any impacts to ENP. The NPS was adamant about the avoidance of any impacts to the National Park system. As such, these features formed the western border of the FPDA. To the east of the proposed FPDA are a series of tree islands. As many of the tree islands in this area have deteriorated due to water management practices or have been leveled due to agricultural activities, avoidance of this limited resource was also a priority for the PDT. Also, engineering analysis demonstrated that by located the FPDA further away from the C-111 Canal, return seepage to the canal was reduced and the FPDA became more effective. As a result of these factors, the eastern perimeter levee for the FPDA was sited just to the west of the tree islands, at a distance far enough

from the C-111 Canal to retain effectiveness of the detention area feature. The final formulation analysis for the sizing of the FPDA resulted a recommendation for a 530-acre above ground infiltrating detention area. After selection of a Recommended Plan along with more detailed design and optimization of the FPDA, the size was increased slightly to 590-acres without impacting any of the aforementioned constraints.

F.3 Ecological Evaluation

The C-111 SC project study area is situated at the southern extent of the CERP study area. As such, the potential functions provided by the C-111 SC project are largely limited to managing seepage from natural areas to drained areas, and detaining/distributing volumes of water made available by upstream water management infrastructure to features of the Project. The C-111 SC project is intended result in the following:

1. Improvements in flow patterns, hydroperiods and ecological connectivity of the Southern Glades, Model Lands and adjacent natural areas.
2. Improvements in habitat, functional quality of existing natural areas and increase spatial extent where practicable.
3. Improvements in native plant and animal species abundance and diversity.
4. Sufficient water for the restoration of the natural system.
5. Elimination of ecologically damaging flows through C-111 to Barnes Sound and Florida Bay.
6. Ecologically compatible water quality consistent with restoration goals and Federal and state requirements applicable to the Southern Glades, Model Lands and Everglades National Park.
7. Recreational opportunities where available and consistent with environmental restoration goals.

As such, the PDT identified CERP RECOVER regional-model performance measures (e.g., Greater Everglades measures 1, 2, and 3; and Southern Estuary measures 1, 3, and 5) that could be refined to characterize the results of finer-resolution hydrologic simulations in a manner consistent with causal relationships characterized by CERP's underlying Conceptual Ecological Models for the Greater Everglades and Southern Estuaries (Wetlands Volume 25, No. 4. The Society of Wetland Scientists, McLean, Virginia.) that can be found via the internet at http://www.evergladesplan.org/pm/recover/cems.aspx (as of 16-November-2007).

Early in the process, the PDT's original formulation and evaluation strategy encountered setbacks when development of the hydrologic model (i.e., WASH-123D) anticipated to be used for multi-year simulations of each alternative was found to be notably behind schedule. At that point, a decision

was made by the Project's sponsoring agencies and the PDT to use an existing model with fewer simulation capabilities (MODBRANCH) that had already been developed to conduct single-year simulations (i.e, three individual single-year simulations representative of "wet," "average," and "dry" conditions) of water management infrastructure in the study area. Because of differences in the simulation periods of record, model simulation capabilities, and model configurations, the PDT adapted its suite of performance measures to fit the framework of the newly-selected model. When the migration from WASH-123D to MODBRANCH occurred, it was recognized by the PDT that long period of record time series would not be available (from MODBRANCH) to allow for computation of event return frequencies or other indicators that rely on multi-year time-series and as such, the PDT would be required to consider the simulations in the context of other CERP-related tools (e.g., of 36-year period of simulation results of compatible South Florida Water Management Model simulations) and exercise some degree of professional judgment when evaluating long-term implications and potential return frequencies of the simulated conditions.

While the formulation process proceeded, continued refinement of the CERP and its individual project elements have yielded simulation results (as recent as November 2007) suggesting that the volumes of water ultimately to be delivered to the project study area could be different from those assumed at the outset and throughout the planning effort. Prior simulations of future-without and future-with CERP conditions exhibited no noteworthy changes in deliveries to the study area, indicating that with or without CERP's other features, deliveries to the study area would be similar. However, recent simulations associated with the planning of the Everglades Agricultural Area A-1 reservoir and other projects indicate an increased likelihood that the volumes of water potentially delivered to/through the study area could be different (potentially larger) than formerly expected. While the significance of the C-111 SC project has repeatedly been reaffirmed by several prior and ongoing studies (e.g., C-111 South Miami-Dade Project, RECOVER's ongoing CERP refinement efforts), the volumes of water potentially available to C-111 SC management measures remain a source of uncertainty and the subject of ongoing investigations and regional planning efforts. In addition to the uncertainties associated with the timing and volumes of water to potentially be made available by upstream projects, questions remain concerning the potential effects of how increased water levels in an area of very low topographic relief might affect the stormwater routing functions of drainage canals located among upstream agricultural and developed areas.

The project's sponsoring agencies and those represented by the PDT have a strong desire to pursue restoration opportunities at the earliest possible opportunity. Therefore, the Project's sponsoring agencies decided that it would be beneficial to implement the project in two phases. The first phase consists of

features that are reasonably certain to allow for improved management of water in the natural areas via reducing the drainage effects of local canals on adjacent wetlands (i.e., western management measures), and several pilot studies that are intended to address critical uncertainties that potentially affect the location, design, and operation of the spreader canal (eastern management measures) that is intended to rehydrate overdrained wetlands of the Southern Glades and Model Lands. Both phases are aligned to independently contribute to a common goal of restoring more natural hydropatterns throughout the study area to provide for more natural timing and distribution of freshwater inputs to Florida Bay.

The first phase of the C-111 SC project consists of largely of management measures in the western portion of the project study area formulated to achieve the following objectives:

Specific Project Objectives Associated with Western Management Measures

i. Improvements in flow patterns, hydroperiods and ecological connectivity of the Southern Glades, Model Lands and adjacent natural areas as quantified via:
   a. Restoration of more natural distribution and timing of freshwater inputs to Florida Bay
   b. Reductions in the influence of the C-111 Canal on hydropatterns of Taylor Slough and adjacent natural areas

ii. Improvements in habitat, functional quality of existing natural areas and increase spatial extent where practicable via:
   a. Reductions in the influence of the C-111 Canal on hydropatterns of Taylor Slough and adjacent natural areas
   b. Restoration of more natural salinity regime at/near Barnes Sound and Florida Bay

iii. Elimination of ecologically damaging flows through C-111 to Barnes Sound and Florida Bay via:
   a. Restoration of more natural distribution and timing of freshwater inputs to Florida Bay
   b. Restoration of more natural salinity regime at/near Barnes Sound and Florida Bay

Due to the refined scope of this initial phase, a sub-set of the PDT's performance measures was selected for the evaluation process. The selected performance measures intended to allow for evaluation of each alternative with respect to the objectives expressed above consist of the following:

- Flow timing and distribution
- Hydroperiods
- Stage-inferred salinities in coastal zones

Evaluation of each alternative (including the "future-without project" condition) with respect to the measures referenced above was conducted using a rainfall-driven "pre-drainage" simulation of the study area as a target condition. The pre-drainage simulation was synthesized via removing all man-made structures form the model domain to provide the PDT with a singular, physically-integrated target that illustrated how the natural landscape would have responded to rainfall during the years of simulation. The pre-drainage simulation also guaranteed that derived hydrologic surrogates for targeted ecological conditions would be compatible with and supportive of one another. For these and other reasons, the PDT elected to use a representative pre-drainage simulation to indicate where and when targeted ecological conditions would occur in a natural landscape in lieu of presupposing the nature and distribution of specified hydrologic conditions in a manner that could have resulted in a set of physically-disjointed and potentially antagonistic set of independent target conditions.

Simulated Conditions

In addition to the referenced pre-drainage condition, a future without-project condition (set in the year 2050, in the absence of all other CERP features) was synthesized to be used as a baseline against which the ecological performance of each alternative would be compared. Because initial regional hydrologic simulations indicated that the C-111 SC study area would likely receive similar deliveries of water from the regional system with or without the remaining CERP projects, the project sponsors and the PDT elected to evaluate each alternative with respect to the future without-project condition as referenced above.

For each of the performance measures, a baseline deviation from the target condition was calculated for wet, average, and dry year scenarios using the pre-drainage condition simulation results as targets, and future without-project condition simulation results as what are estimated to exist in the absence future CERP projects (inclusive of the C-111 SC project).

For every formulated project alternative, wet, average, and dry year scenarios were simulated. For each of the performance measures, a deviation from the target condition was calculated for wet, average, and dry year scenarios using the pre-drainage condition simulation results as targets, and the project alternative results as what are estimated to exist in the future if the alternative is constructed.

Flow Timing and Distribution

The flow timing and distribution performance measure was used as a surrogate for ecological/landscape processes that are affected by water movement (e.g., nutrient redistribution, transport of suspended solids, availability of freshwater, etc.). Because the C-111 SC Western project is intended to allow for improved management of water in the natural areas via reducing the drainage effects of local canals on adjacent wetlands (i.e., Taylor Slough), the PDT was directed to focus on restoring more natural deliveries of water to central Florida Bay via Taylor Slough. In addition to central Florida Bay, Little Madeira Bay and Joe Bay, located at the mouth of Taylor Slough and adjacent to central Florida Bay, are anticipated to benefit from this first-phase objective. The impacts associated with restoring more natural flows to central Florida Bay via Taylor Slough anticipated to directly affect 98,500 acres.

The movement of water in the pre-drainage model was characterized using a series of five flow-transects located upstream of Florida's mainland southern coastline and downstream of where Project features would be located. The five transects were aligned end to end in an east to west orientation, spanning from Taylor Slough (along the western boundary of the study area, just inside the eastern boundary of Everglades National Park), eastward to Florida Power and Light's Turkey Point Power Plant cooling ponds (located along the eastern boundary of the study area, just west of Biscayne Bay). For the wet, average, and dry individual years of simulation, the timing at which water crossed each transect was tabulated/charted as a percentage of the total annual discharge across each transect to "map out" when regional precipitation would have worked its way through the study area. Similarly, the daily discharge of each transect was tabulate/charted as a percentage of total/summed discharge across all five transects to map out where regional precipitation would have worked its way through the study area. The resulting temporal and spatial distributions synthesized from the wet, average, and dry year simulations of the pre-drainage condition served as the target conditions against which the corresponding wet, average, and dry year simulations for each alterative would be compared.

Hydroperiod

The hydroperiod performance measure was used as a surrogate for ecological/landscape processes that are affected by the presence or absence of inundating water levels (e.g., vegetation tolerances to dry or ponded conditions, fire risk potential, etc.). The PDT was directed to focus on restoring more natural deliveries of water to Central Florida Bay via Taylor Slough via reducing the drainage effects of local canals on adjacent wetlands. Due in part to the relatively low degree of topographic relief within the study area, active efforts to reduce the volume of water entering the C-111 Canal from adjacent wetlands, and active efforts to modify hydroperiods near Taylor Slough and adjacent

natural areas, the hydroperiod performance measure was applied to the entire study area as even slight shifts in water levels can result in noteworthy changes in hydroperiods, associated changes in vegetation communities (Hilllsenbeck et al., 1979; Hofstetter and Hilsenbeck, 1980; Ross et al., 2006). The impacts associated with reducing the drainage effects of local canals on Taylor Slough and adjacent natural areas are anticipated to directly affect 129,000 acres.

Wetland hydroperiods and their relative distributions across the study area in the pre-drainage model were characterized using a suite of 25 landscape-scale indicator regions. In contrast to location-specific indicator regions commonly used by other CERP projects to illustrate ecologically-significant hydrologic conditions at a predetermined location, the 25 landscape-scale indicator regions referenced above were formulated by the PDT to allow for a more objective characterization of hydroperiod heterogeneity (and relative abundance) within broad geographic areas defined by common present-day landscape characteristics (i.e., vegetation communities) and longitude. Using generalized 30-day hydroperiod classes/bins (e.g., 0-30, 31-60..., 330-365) the relative abundance of hydroperiods experienced within each indicator region was tabulated/charted as a fraction of the corresponding indicator regions total area in the form of a histogram. The resulting relative abundance distributions synthesized from the wet, average, and dry year simulations of the pre-drainage condition served as the target conditions against which the corresponding wet, average, and dry year simulations for each alterative would be compared.

Near-shore Salinities

The salinity performance measure was used as a surrogate for ecological/landscape processes that are affected by salinity (e.g., osmoregulation). As a result of this first phase's active efforts to decrease the volumes of fresh water drained to tide via the C-111 Canal, and associated efforts to deliver retained water to Central Florida Bay via Taylor Slough, salinities in Little Madeira Bay, Joe Bay, Long Sound, Manatee Bay, and Barnes Sound are anticipated to be affected. As such impacts associated with reducing the drainage effects of local canals on Taylor Slough and adjacent natural areas are anticipated to directly affect 27,500 acres.

It was originally envisioned by the PDT that WASH-123D would be used to directly simulate the responses of coastal salinities to inland precipitation and water management activities. When the decision was made to migrate from WASH-123D to MODBRANCH, it was recognized by the PDT that the capability to directly simulate salinities was compromised. As a result, members of the PDT offered stage-salinity regression equations developed in association with other planning efforts and/or by staff of Everglades Nation Park as a method or permitting salinity-based comparisons among simulations. Site-specific stage-salinity equations were applied to the pre-drainage simulation results to

estimate the wet, average, and dry year salinity time series for (from west to east) Little Madeira Bay, Joe Bay, central Florida Bay, Long Sound, Manatee Bay, and Barnes Sound. Using 5 parts per thousand salinity classes/bins (e.g., 0-5, 6-10... >45), salinity durations were tabulated/charted for each embayment in the form of a histogram. The resulting salinity durations synthesized from the wet, average, and dry year simulations of the pre-drainage condition served as the target conditions against which the corresponding wet, average, and dry year simulations for each alterative would be compared.

Benefits Assessment

Upon completing the simulations for the pre-drainage condition, the without-project condition and each alternative, the performance of each alternative was evaluated using the above-referenced performance measures, and deviation from the target condition was calculated on a scale ranging from infinity (extreme deviation from target condition) to 0.0 (no deviation from target condition). For purposes of converting deviation from target into an index of ecological health, the scaled deviation from target was subtracted from 1.0 (yielding a maximum value of 1.0 and a minimum value of no less than 0.0). The rationale for permitting a deviation from target to exceed 1 is that the conditions can always be "more" different from the target condition, but never "closer" to the target than the target condition.

For each performance measure, the resulting index was multiplied by the acreage likely to be affected by changes in hydrologic conditions characterized by the performance measure to yield a habitat unit estimate specific to the individual performance measure. As one might expect, the pre-drainage condition, exhibiting 0.0 deviation from itself for each performance measure, would exhibit a habitat unit estimate equal to the acreage applicable to the noted performance measure. Identical computations were performed for the baseline condition and each alternative to allow for evaluation of the "lift" provided by each alternative (recognizing that lift can be positive/desirable or negative/undesirable) with respect to each individual performance measure.

The un-weighted average of the habitat units computed for performance measure were then computed for the pre-drainage condition, the 2050 without-project condition, an for each alternative. This yielded a generalized habitat unit score (an average of the three performance measures) for the pre-drainage condition, the 2050 without-project baseline, and each alternative. Because the three performance measures are intended to be representative of generalized ecological health over the entire study area, the generalized habitat unit score for pre-drainage condition, the 2050 without-project baseline, and each alternative were then multiplied by the following factor:

F.4 Physical Features and LERR Requirements

Section 601(h)(5) contains a Savings Clause that provides protection for existing legal sources of water that will be eliminated or transferred due to project implementation and for no significant and adverse reduction in the level of service for flood protection that was in existence on the date of enactment and in accordance with applicable law. Section 601(h)(5) provides:

> *(5) SAVINGS CLAUSE.--*
> *(B) MAINTENANCE OF FLOOD PROTECTION.--Implementation of the Plan shall not reduce levels of service for flood protection that are--*
> *(i) in existence on the date of enactment of this Act; and*
> *(ii) in accordance with applicable law.*

Early in the process, the PDT's original formulation and evaluation strategy encountered setbacks when development of the hydrologic model (i.e., WASH123D) anticipated to be used for multi-year simulations of each alternative was found to be notably behind schedule. At that point, a decision was made by the Project's sponsoring agencies and the PDT to use an existing model with fewer simulation capabilities (MODBRANCH) that had already been developed to conduct single-year simulations (i.e., Three individual single-year simulations representative of "wet", "average" and "dry" conditions) of water management infrastructure in the study area.

The Project's sponsoring agencies and those represented by PDT have a strong desire to pursue restoration opportunities at the earliest possible opportunity. Therefore, the Project's sponsoring agencies decided that it would be beneficial to implement the project in two phases. The first phase consists of features that are reasonably certain to allow for improved management of water in the natural areas via reducing the drainage effects of local canals on adjacent wetlands (i.e., western management measures), and several pilot studies that are intended to address critical uncertainties that potentially affect the location, design, and operation of the spreader canal (eastern management measures) that is intended to rehydrate overdrained wetlands of the Southern Glades and Model Lands. Both phases are aligned to independently contribute to a common goal of restoring more natural hydropatterns throughout the study area to provide for more natural timing and distribution of freshwater inputs to Florida Bay.

There were nine initial alternatives that were modeled as well as the Alternative 7R and the Existing Condition Base

Alternative 1C with a spreader canal
Alternative 1D with a spreader canal
Alternative 2C with a spreader canal

Alternative 2D with a spreader canal
Alternative 3C with a spreader canal
Alternative 3D with a spreader canal
Alternative 4C with a spreader canal
Alternative 4D with a spreader canal
Alternative 6C with a spreader canal

After modeling was completed, an analysis was completed to determine the impacted lands for each of the nine initial alternatives. It was determined that a full blown analysis (comparison of existing condition to each of the alternatives – wet year, dry year, average year) would take a considerable effort and a considerable amount of time. The team working with the geographic information system specialists developed that a formula could be applied to each alternative which would show impacted lands. After the modeling data for each alternative along with the modeling data for existing condition was provided to GIS, the data was used to create maps and data information to determine what lands were impacted by each of the alternatives. The comparisons had to account for changes in hydrology that would be significant enough that land acquisition would be required. The formula ultimately used, compared each alternative in a similar fashion and did not compromise the results. The comparison accounted for both groundwater to agricultural lands and surface water impacts to other land classes.

Data was then provided by GIS that showed the percentage of each individual parcel impacted. Once this data was provided, each parcel or percentage of the parcel was reviewed to determine if only a portion (and what portion) or all of the parcel would have to be acquired. This was done for each alternative independently. Once the analysis was complete, the information was used to develop a real estate cost estimate for each of the nine initial alternatives. For SFWMD owned lands, actual acquisition costs were used. There were a few SFWMD parcels that did not have actual acquisition cost provided, but they were reviewed quickly based on information provided by SFWMD to determine the actual acquisition costs.

The amount of SFWMD owned lands in each of the alternatives produced the variance in total estimated real estate costs. If more privately owned lands had to be acquired for the alternative, the cost increased substantially.

After evaluation of these initial nine alternatives, six new alternatives were modeled and the same formula and method of analysis that was to the nine initial alternatives was use to produce the required/impacted acres and the total estimated real estate costs. None of the six new alternatives contained a spreader canal. Federal and local sponsor leadership directed the PDT to develop a two-phased, two PIR approach that would incorporate some of the principles of the National Academy of Science's (NAS) approach to IAR. Based

on this direction a Final Array of Alternatives was developed. ***TABLE F-2*** provides the acreage impacted and the estimated real estate costs of this Final Array of Alternatives.

TABLE F-2: LANDS AND REAL ESTATE COSTS FOR SIX FINAL ALTERNATIVES

ALTERNATIVE	REQUIRED/IMPACTED ACRES	TOTAL ESTIMATED REAL ESTATE COST
1C No SC	864.97	$43,721,100
1D No SC	8,301.69	$53,196,080
2DShort No SC	11,564.65	$47,657,472
2D Long No SC	12,197.88	40,553,136
3D No SC	11,411.22	$44,849,470
6D No SC	5,612.73	$25,299,210

The MODBRANCH model was used as part of the C-111 Spreader Canal (C-111 SC) PIR1 study to estimate the flooding impacts of the alternatives. For the six final alternatives, designated as Alternatives 1C, 1D, 2D Short, 2D Long, 3D, and 6D, each alternative was modeled and compared to the Existing Condition Base. The MODBRANCH model and the final alternatives are described in more detail in **Appendix A, Engineering, Section A.10.** MODBRANCH is a hybrid code that couples MODFLOW, a three-dimensional groundwater flow model with Branch, a one-dimensional canal routing model. **Figure A-20, in Appendix A** shows the model domain (blue line) superimposed on an aerial photograph of the area. Major canals are shown in red. This figure illustrates the complexity of the area. Land elevations vary from the high Atlantic Ridge to the low Everglades. Land use varies from urban to suburban to agricultural to wilderness. Both, ground water and overland flow are simulated by the MODFLOW part of MODBRANCH. MODFLOW is a pseudo-three-dimensional, finite difference, ground water model (McDonald and Harbaugh, 1988). This model requires defining a model "grid" of specified numbers of rows, columns, and layers. The width of each row or column is determined by required resolution in specific areas. The model grid is shown in **Figure A-21, in Appendix A** with major canals superimposed. The model is bounded by the Biscayne Bay to the east; Florida Bay to the south; and, the Gulf of Mexico to the west. The northern boundary is roughly 2 miles north and parallel to the following canals: C-6, L-30, L-67C and L-29. The model grid is

made up of 239 rows, 259 columns, and 5 layers. The grid resolution varies horizontally from a minimum of 207 feet to a maximum of 5000 feet. Levees are defined by using the horizontal flow barrier package of MODFLOW. The U.S. Army Corps of Engineers, Jacksonville District, made additional model refinements and extended the model domain which was used in previous studies. The savings clause/takings analyses require using the ECB configuration. Various Performance Measures were developed for the flood impacts. Normal hydroperiods used for ecological impacts are based on the number of days in a year that the stage is above the ground. However, for flood impact analysis, hydroperiods are computed as the number of days within a specified season that the water depth exceeds a specified value. The data are divided into two seasons (wet and dry) and eleven depth values are used (+/-2.0, +/-1.5, +/-1.0, +/-0.5, +/-0.25, 0.0 ft). A second flood impact Performance Measure is the longest single duration water is above a stage that is specified between 0 and 24" below the ground, in increments of 2". This Performance Measure is useful in determination of impacts on various crops. Both types of data were provided for each cell to allow further post-processing using GIS packages.

After modeling was completed, an analysis was started to determine the impacted lands for each of the six final alternatives. The Office of Counsel team member working with the geographic information system specialists determined that a formula could be written and applied to each alternative which would show impacted lands. After the modeling data for each alternative along with the modeling data for the Existing Condition Base was provided to GIS, they used the data to create extensive spreadsheets, maps, and data information for review by Office of Counsel to determine what lands were impacted by each of the alternatives. The comparisons had to account for changes in hydrology that would be significant enough that land acquisition would be required. The formula ultimately used would have to compare each alternative in a similar fashion and would not compromise the results. The comparison would have to account for both groundwater and surface water impacts to different land classes.

Once this data was provided by GIS, each parcel or percentage of the parcel was reviewed to determine if only a portion (and what portion) or all of the parcel would have to be acquired. This was done for each alternative independently. Once the analysis was complete, the information was provided to Real Estate Division to provide a cost estimate for each of the final alternatives.

The impacted lands for each alternative were initially analyzed and computed based on the compilation of the following three criteria:

Criteria 1: Non-Agricultural Lands (40days+30 percent)

Alternative Annual Hydroperiod (at surface) is greater than 40 days longer than Existing Condition Base (ECB) run and this value is greater than 30

percent longer than ECB for any of the three years (Average year, Dry year, Wet year)

Criteria 2: Agricultural Lands for Dry Season (Any increase of Hydroperiod at-.5ft)

Alternative Dry Season Hydroperiod (at -.5ft) is greater than 5 days longer than ECB Dry Season Hydroperiod (at -.5ft) for any of the three years (Average year, Dry year, Wet year)

Criteria 3: Agricultural Lands for Wet Season (30days+20 percent)

Alternative Wet Season Hydroperiod (at -.5ft) is greater than 30 days longer than ECB wet season Hydroperiod (at -.5ft) AND this value is greater than 20 percent longer than ECB for any of the three years (Average year, Dry year, Wet year)

Extensive Spreadsheet Data was then provided by GIS that showed the hydrologic changes for each of the "impacted grid cells", including impacts in each year; impacts in the wet seasons of each year; impacts in the dry season of each year; and the percentage of each individual parcel impacted. For the non-agricultural lands, a more detailed analysis was conducted to determine if the impacts were significant. For instance, if the Existing Condition had no shown hydroperiod but for the alternative there was a 40 day increase in hydroperiod across the entire year which would be a 30 percent increase, the lands impacted by this increase were screened out. This was applied to each alternative. Non-agricultural land impacts had to be significant to remain "impacted". There was also a separate data spreadsheet developed for the agricultural lands for each alternative, which showed the hydroperiod differences in the Dry Season and Wet Season between each alternative and the Existing Condition Base for each of the years analyzed (Dry Year 1989, Average Year 1978 and Wet Year 1995). An analysis was then conducted for the agricultural lands to determine what were significant and adverse conditions warranting acquisition of a real estate interest. Any increase in any Dry Season (November through April) of over 5 days was considered as requiring acquisition of a real estate interest (Criteria 2 above). For the Wet Seasons, the increase had to meet not only Criteria 3 above, but it had to increase the entire hydro-period to greater than 80 days. Once all this data was analyzed each parcel or percentage of the parcel was reviewed to determine if only a portion (and what portion) or all of the parcel would have to be acquired. Once the analysis was complete, the information was provided to Real Estate Division to provide a cost estimate.

The lands belonging to the Everglades National Park were not valued. The lands in the Frog Pond area were approved for acquisition under the C-111 South Dade project in the 1994 General Design Memorandum and will be provided as an item of local cooperation under that project. Therefore the real

estate cost for lands required for each Alternative within the Frog Pond were not included under the C-111 Spreader Canal project real estate costs.

APPENDIX G
ECONOMIC AND SOCIAL CONSIDERATIONS

TABLE OF CONTENTS

G.0 APPENDIX G G-1
G.1 ECONOMIC AND SOCIAL CONSIDERATIONS G-1
G.1.1 Introduction G-1
G.1.2 Elements of the Socio-economic Investigation G-2
G.1.2.1 Socio-economic Profile of the Study Area G-2
G.1.2.2 Anticipated Effects of Alternative Plans on the National Economic Development Account G-2
G.1.2.3 Evaluation of Project Costs G-2
G.1.2.4 Regional Economic Development Effects G-3
G.1.2.5 Other Social Effects G-3
G.1.3 Methodology G-3
G.1.3.1 Without-Plan and With-Plan Conditions G-3
G.1.3.2 Economic Analysis Methodology G-4
G.2 POPULATION AND ECONOMY G-7
G.2.1 Overview G-7
G.2.2 Economic and Social Well–Being Problems and Opportunities G-7
G.2.3 Land Use G-8
G.2.4 General G-10
G.2.5 Population G-11
G.2.5.1 Population: Historic Trends and Existing Condition G-11
G.2.5.2 Population: Projections G-13
G.2.6 Economy G-15
G.2.7 Agriculture Economy G-16
G.3 MUNICIPAL AND INDUSTRIAL WATER DEMAND G-17
G.3.1 Agricultural Water Demands G-22
G.4 FLOOD DAMAGE REDUCTION IMPACTS G-23
G.5 RECREATION G-23
G.5.1.1 Regional Recreation Demand G-27
G.5.2 National Recreation Trends G-28
G.5.2.1 National Survey of Recreation and the Environment G-28
G.5.2.2 National Survey of Fishing, Hunting, and Wildlife Recreation G-29
G.5.2.3 State Tourism Trends G-32
G.5.2.4 Potential Changes in Value of Recreation G-33
G.6 COST EFFECTIVE/INCREMENTAL COST ANALYSIS G-33
G.6.1 Average Annual Costs G-34
G.6.2 Ecological Evaluation G-35
G.6.2.1 Average Annual Benefits G-36
G.6.3 Cost Effectiveness Analysis G-37
G.6.4 Incremental Cost Analysis G-39
G.6.4.1 Summary of Cost Effective/Incremental Cost Analysis G-40
G.7 REGIONAL ECONOMIC IMPACTS G-40
G.7.1 Overview G-40
G.7.2 Methodology G-41
G.7.2.1 Real Estate and Effects of Other Land Acquisitions G-41
G.7.3 IMPLAN Regional Economic Effects Results G-42

G.8 OTHER SOCIAL EFFECTS G-42
G.8.1 Overview G-42
G.8.2 Potential Urban and Community Impacts G-43
G.8.2.1 Employment G-45
G.8.2.2 Output G-45
G.8.2.3 Total Gross Regional Product G-45
G.8.2.4 Comparison of Plans' Economic Impact to Overall Economic Activity G-46
G.8.2.5 Other Social Effects G-46
G.8.3 Overall Regional Economic Impact Conclusions G-47
G.9 ENVIRONMENTAL JUSTICE G-48
G.10 REFERENCES G-49

LIST OF TABLES

Table G-1 Land Uses in Miami-Dade County, 2006 ..... G-9
Table G-2 C-111 Study Area Census Tracts, 2000 ..... G-12
Table G-3 Population Estimates, 2000-2050 ..... G-14
Table G-4 Study Area Population Rates of Growth 2000-2050 ..... G-14
Table G-5 Study Area Population Growth 2000-2050 ..... G-14
Table G-6 Economic Indicators in Study Area G-16
Table G-7 USGS Total Water Use, for Selected Counties, 2000, Excluding Mining and Power Generation (In mgd) G-18
Table G-8 Estimated 2050 Service Area 3 Conservation Adjusted, Most Likely Population Scenario (mgd) G-21
Table G-9 Counties Within Scorp Planning Regions Potentially Affected by Alternative Restoration Plans G-25
Table G-10 Regional Outdoor Recreation Facilities G-26
Table G-11 Demand and Facility Needs (1997 and 2010) G-27
Table G-12 Participation Rates for Selected Recreational Activities by U.S. Population 16 Years or Older, 2005 ..... G-29
Table G-13 Total United States Wildlife-Related Recreation Participation and Expenditures, 2006 ..... G-30
Table G-14 Participants in Wildlife-Related Recreation in Florida, 2006 ..... G-31
Table G-15 Total Wildlife-Related Activities in Florida, 2006 ..... G-32
Table G-16 Costs Used in Cost Effectiveness for Plan Selection G-35
Table G-17 Average Annual Habitat Unit Lift for Selected Alternatives G-37
Table G-18 Final Array of Alternative Utilized in The C-111SC G-38
Table G-19 Final Array of Alternative Utilized in The C-111SC Best Buy Analysis G-39
Table G-20 Results of Incremental Cost Analysis: Best Buy Plans Arrayed by Increasing Output by Increasing Output for Combined Habitat (All Plans) G-40
Table G-21 Results of CE/ICA G-40
Table G-22 Direct, Indirect and Induced Impacts on Employee Compensation As A Result .... of Implan Model Runs (2006 Dollars) G-42
Table G-23 Direct, Indirect and Induced Impacts on Regional Output As A Result of ..... Implan Model Runs (2006 Dollars) G-42

Table G-24 Direct, Indirect and Induced Impacts on Employment As A Result of Implan Model Runs (2006 Dollars) G-42
Table G-25 2005 C-111SC (2006) Socio-Economic Vulnerability Profile G-44
Table G-26 Comparison of Plans' Economic Impact To Overall Economic Activity G-46

LIST OF FIGURES

Figure G-1 Map of C-111 Spreader Canal Study Area G-10
Figure G-2 Census Tract Map of C-111 Study Area G-12
Figure G-3 Distribution of U.S. Geological Survey Estimated G-19
Figure G-4 Distribution of U.S. Geological Survey Estimated G-19
Figure G-5 Distribution of Total Conservation-Adjusted Municipal and Industerial Water Use, by Service Area, 2000 and 2050, Most-Likely Population Scenario G-21
Figure G-6 Service Area 3, Most-Likely Population Scenario Municipal and Industrial Conservation–Adjusted Forecast, by Water Use Sector G-22
Figure G-7 C-111 Spreader Canal Alternative Plans–CE/ICA Run G-39

G.0 APPENDIX G

G.1 ECONOMIC AND SOCIAL CONSIDERATIONS

G.1.1 Introduction

The C-111 Spreader Canal (C-111 SC) Western project's Recommended Plan is an integral component of the south Florida ecosystem improvement efforts that together make up the overall Comprehensive Everglades Restoration Plan (CERP). This appendix presents the socio-economic issues related to the C-111 SC Western project implementation.

The primary effects of the project are the costs of implementation (National Economic Development [NED] cost), and the environmental benefits (i.e. ecosystem restoration and improvements). These costs and benefits are incorporated into a Cost Effectiveness/Incremental Cost Analysis (CE/ICA) which is a main tool used in the socio-economic evaluation of an environmental restoration project.

The primary effects of the project include the costs of implementation as well as the ecosystem restoration and improvement benefits. Project implementation costs are monetarily expressed in terms of the net national project cost (NED costs). Project costs have regional impacts as expenditures on the project within the regional economy that could cause changes in local and regional earnings, sales, and employment. While the costs of implementation are expressed in traditional monetary terms, ecosystem improvement, the most significant beneficial effect of the project is not expressed in monetary terms. Ecosystem improvement is expressed in terms of National Ecosystem Restoration benefits in accordance with U.S. Army Corps of Engineers (USACE) policy. For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the federal objective shall be selected.

The potential economic impacts of the alternative restoration plans are secondary consequences of the environmental improvements and hydrologic changes that are expected to result from the proposed structural and operational modifications to the project study area. These projected impacts are contingent upon the successful implementation and operation of restoration plans and subsequent outputs and therefore, subject to the uncertainties inherent in ecosystem restoration activities. Due to the challenges inherent in quantifying National Ecosystem Restoration (NER) effects or benefits, quantifying the resulting NED impact is also a challenge. Nonetheless, there are methods for evaluating the economic efficiencies of producing these alternative restoration plans.

In order to evaluate the economic efficiencies of the span of project alternatives, an analysis of the NED costs and NER benefits of each alternative is undertaken.

Specifically, a CE/ICA is utilized to determine the alternatives that provided the least unit cost per unit of benefits.

This appendix is responsible for considering a variety of social conditions relevant to the project. These social conditions are intricately interconnected with the economics of the project. They include elements such as population, water demand, recreation, environmental justice, and a variety of other considerations.

G.1.2 Elements of the Socio-economic Investigation

This investigation assesses the economic effects of the alternative ecosystem restoration plans formulated in the feasibility phase of the C-111 SC Western project. The economic evaluation of the alternative restoration plans includes five principal elements:

G.1.2.1 Socio-economic Profile of the Study Area

This profile includes population and economic forecasts for the region, as well as projections of future water demand.

G.1.2.2 Anticipated Effects of Alternative Plans on the National Economic Development Account

Alternative plans could result in positive or negative effects on net national economic efficiency due to project-induced impacts on the following economic activities in south Florida:

- Agricultural water supply
- Municipal and industrial (M&I) water supply
- Flooding potential
- Recreation
- Commercial and recreational fishing

G.1.2.3 Evaluation of Project Costs

Project costs include all expenditures required to implement the alternative plans. The federal government and the State of Florida would share these costs. C-111 SC Western project costs include those for initial construction; lands; relocations; rights of way; rehabilitation, replacement, and repair; and operations and maintenance (O&M) (including the costs of post-construction monitoring and adaptive management).

G.1.2.4 Regional Economic Development Effects

The potential Regional Economic Development (RED) effects of the Selected Alternative Plan (SAP) include changes in income, employment, or economic output of the region.

G.1.2.5 Other Social Effects

The potential social effects of the SAP include effects on minority, elderly, and disadvantaged groups, population displacement, and effects on community cohesion.

The economic analysis for the C-111 SC Western project was conducted in a manner consistent with Federal Statutes and U.S. Army Corps of Engineers (USACE) policy. Procedures for estimating NED and RED effects are specified in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (U.S. Water Resources Council, 10 May 1983), Engineering Regulation (ER) 1105-2-100 (22 April 2000), and other USACE guidance.

The potential economic impacts of the alternative restoration plans are secondary consequences of the environmental improvements and hydrologic changes that are expected to result from the proposed structural and operational modifications to the C-111 SC Western project study area. These projected impacts are contingent upon the successful implementation and operation of restoration plans and subsequent outputs and therefore, subject to the uncertainties inherent in those ecosystem restoration activities. Due to the challenges inherent in quantifying NER benefits, quantifying the resulting NED benefit is also a challenge. Nonetheless, there are methods for evaluating the economic efficiencies of alternative restoration plans.

G.1.3 Methodology

A number of factors were considered prior to developing the methodologies used to evaluate the economic effects of the alternative restoration plans. These factors include: available analytical tools, economic theory, federal policy, obtainable data, and time and budgetary constraints. These factors are discussed below.

G.1.3.1 Without-Plan and With-Plan Conditions

Proper definition of the without-plan and with-plan conditions is critical to the planning process. The without-plan condition is the most likely condition expected to exist in the future in the absence of a proposed project. The future without plan condition is the benchmark against which alternative future with-plans are evaluated. National and regional socio-economic parameters considered include income, employment, population and other aggregate projections such as land use trends, water supply and water demand. Comparisons of conditions with the

implementation of alternative plans to future without-plan conditions were performed to identify the beneficial and adverse effects of the proposed plans. Depending on the alternative and the type of economic impact changes resulting from implementation of a restoration plan, it may be desirable or undesirable when compared to the future without-plan condition. For example, alternatives that include modifications to the current system to provide additional water storage areas may result in fewer economic losses associated with agricultural (irrigation) water shortages. This would be a desirable ancillary benefit of restoration.

G.1.3.2 Economic Analysis Methodology

Consistent with USACE guidance, neither a traditional benefit-cost ratio nor a net NED analysis is required for NER plans. For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the federal objective shall be selected. The methodologies used to conduct economic analysis studies for the project were based on a combination of factors, including: economic theory, USACE's ecosystem restoration and economic evaluation policies, and the characteristics of methodologies used by economists to value ecosystem benefits. For this study, the alternative restoration plans were compared using information in monetary and non-monetary units. The economic analysis of the C-111 SC alternative restoration plans include: (1) the NED costs (in monetary terms), (2) the anticipated environmental benefits resulting from restoration measures (in non-monetary terms), (3) the NED benefits and impacts attributable to the following: agricultural water supply, municipal and industrial (M&I) water supply, commercial navigation, recreation, and commercial fishing (in monetary and non-monetary terms) and (4) the positive and adverse regional economic effects (RED) and social effects resulting from project implementation.

This section of the report addresses the above items. The economic basis for making policy decisions about whether to invest public funds in ecosystem restoration for the C-111 SC Western project is comparing monetary costs and non-monetary benefits in order to determine whether the expenditure is justified and to select the plan which minimizes the cost of obtaining ecosystem benefits. The costs of ecosystem restoration projects include: initial construction costs; major rehabilitation and repair costs; O&M costs; post construction monitoring costs; and adverse NED effects. Typically, these costs can be expressed in monetary (i.e., dollar) terms.

The principal challenge of ecosystem restoration economics is estimating the value of restoration benefits. The primary purpose of each alternative plan is ecosystem restoration. The benefits of ecosystem restoration are usually expressed by ecologists in non-monetary units, such as acres of specific habitat created, indices of biological productivity associated with habitat improvement, or increased abundance and/or diversity of particular species of plants or animals. For decision-making purposes, it would be desirable to express ecosystem restoration

benefits in monetary terms, in order to compare them with project costs. Expressing the costs and benefits of alternatives in a common, monetary metric would facilitate selection of the best restoration plan for a given site. However, calculating the monetary value of environmental amenities is both difficult and controversial. Environmental amenities are public goods that are generally not exchanged in the marketplace. For marketable commodities (i.e., items that people buy and sell), the demand and prices paid for these goods can be used as "proxies" for determining their value to consumers. In the absence of data on consumers' expenditures for environmental amenities, resource economists have attempted to develop techniques that can be used to estimate their value using indirect indicators of consumers' "willingness to pay" for ecosystem restoration. For goods and services that are not purchased in the marketplace, non-market valuation approaches must be used to infer their value to the public. There are direct and indirect use values for these goods and services. Use values refer to the value consumers obtain from using a good that is related to an environmental amenity. For example, recreational fishermen obtain direct use value from the freshwater fisheries. The fishermen also obtain indirect use values from the ecosystem, since it provides ecological functions that contribute to the productivity of the fisheries. Use values can be either consumptive or non-consumptive. Consumptive use values refer to the cases for which the good is consumed by the user and is no longer available to others, such as waterfowl hunting. Non-consumptive use values refer to the value obtained by a user in cases for which the good remains to be used by others in the future, such as catch-and-release fishing or bird watching. It is reasonable to expect that the alternative restoration plans will generate additional use values to the public. Non-market activities that would benefit from restoration plans include recreational fishing, subsistence activities, and a variety of eco-tourism related activities (e.g., bird watching, hiking and canoeing).

Non-use values include the values the public obtains from simply knowing that the good or resource is available, even if they have not used it previously. Individuals may value a good simply from knowing it exists (existence value) or because they may want to have the opportunity to use it at some future time (option value). Again, it is reasonable to expect that the alternative restoration plans will generate additional non-use values to the public. The tremendous interest in and support for ecosystem restoration, not just in south Florida but throughout the country (and the world), is an indication that a broad segment of society values the ecosystem, even though most have never experienced the area first hand.

Theoretically, it should be possible to determine the value of restoring the C-111 Basin ecosystem by asking people what they would be willing to pay for different levels and types of restoration projects, or by observing what they spend on ancillary costs (e.g., travel, subsistence, equipment) when they engage in these non-market experiences. Economists have developed a variety of techniques to estimate society's willingness to pay for these types of non-marketable environmental

amenities. These economic valuation techniques include market-based, surrogate market, and non-market methodologies (Freeman, 1993). Market-based approaches estimate the value of environmental resources using information generated in the marketplace. These approaches include changes in factors of production, valuation of complimentary goods and services, defensive expenditures, and market valuation of the next best alternative. Surrogate-market techniques estimate value based on preferences revealed in surrogate markets. These techniques include the travel cost method and hedonic valuation. The contingent valuation method (CVM) is the most widely accepted non-market valuation methodology. CVM is perceived as the most effective technique to determine society's willingness to pay for environmental protection and/or restoration and is the only technique able to estimate non-use (i.e., option and existence) values. This method is based on carefully designed surveys that solicit respondent's willingness to pay for a specific environmental resource in a given condition. The survey is intended to reveal both users' and non-users' willingness to pay for the resource.

Unfortunately, these surrogate-market techniques, including CVM, have significant shortcomings that lead to concerns about their reliability and validity. They are especially problematic in cases for which respondents are unfamiliar with the environmental amenity, when the issue is controversial, or where it generates strong reactions, based on ethical, rather than economic motivations. Most importantly for the C-111 SC effort, the reliability and validity of these techniques are especially questionable in situations in which the actual changes that would result from the restoration efforts are difficult to precisely describe or visualize. Finally, stated preference methods, such as CVM, can be expensive to implement, especially when multiple alternatives are being evaluated.

As specified in USACE's ecosystem restoration policy (EC 1105-2-210: Ecosystem Restoration in the Civil Works Program), ecosystem restoration projects are not subject to traditional benefit-cost analyses. An ecosystem restoration proposal must still be justified by comparing the monetary costs and non-monetary benefits of restoring degraded ecosystems. USACE ecosystem restoration evaluation procedures focus on the non-monetary benefits of restoration, comparing these benefits to monetary costs using CE/ICA procedures.

The sections that follow evaluate the economic impacts of the alternative restoration plans. ***Section G.2*** develops a socio-economic profile for the region, and ***Section G.3*** contains the water demand forecasts for the region. The following sections develop the basis for critical physical and socio-economic effects of the future conditions, with-plan and without-plan. The costs and the incremental analysis of the alternative plans are presented in ***Section G.6***. The regional economic effects and other social effects (OSE) of the alternative plans are explored in ***Sections G.9 and G.10*** respectively.

G.2 POPULATION AND ECONOMY

G.2.1 Overview

The people who live in the study area, and the economic activity, in which they are engaged, comprise important components of the area's total environment. In addition to the direct use of this data for the water use projections and OSE mentioned above, residents of the study area represent the socio-economic environment for the other impact topics of flooding, water use shortages, fishing, recreation, and navigation.

Any course of action forthcoming from this study will have effects throughout an economic system as well as the natural ecosystem(s), the health and sustenance of which are the impetus for this investigation. The economic system is connected with the natural ecosystem and in general is ultimately dependent upon it for survival. This connection is especially strong in the study area.

Adverse changes in the health and condition of the natural system can cause severe negative impacts on the economic system, particularly in the study area for this feasibility study. Conversely, in this study area, beneficial changes to the natural system are expected to have a strong positive effect on the economic system. It is significant, therefore, to describe and understand the general economic and social environment within which such changes could take place. Although the main focus of economic impact evaluation efforts undertaken for this study has been to describe the economic impacts and benefits of alternatives being considered for implementation, describing the broader context for these evaluation efforts is also necessary and important.

G.2.2 Economic and Social Well–Being Problems and Opportunities

In the 1940s the Central and Southern Florida Flood Control project (C&SF project) provided flood protection and an available supply of drinking water to the south Florida region. These provisions contributed to a major surge in population of the region. The population has grown from approximately 900,000 as reported in 1950 to a population of over 5.5 million in 1995. By the year 2050, the population of south Florida is projected to grow to 11.6 million. The increased growth in population can be attributed to an inflow of retirees and immigrants; not as a result of high birth rates for this area. The coastal areas in these counties have become highly urbanized. As a result, this urbanization has caused development to move westward into areas that were once agricultural or natural.

The Governor's Commission for a Sustainable South Florida identified agriculture and tourism as "critical industries" for maintaining the economy in the southern part of the state. A rapidly expanding human population demanding more developable lands and advancing agricultural development now threatens the

relatively pristine natural areas. The tourism industry is also dependent upon the region's ability to sustain its economy and its quality of life through management of its resources. Agriculture and tourism depend on a system that can provide vital water supply needs and flood protection.

Competition for regional water resources has intensified with the increase in population and agriculture industry growth. This places a strain on existing resources, which will eventually surpass the readily available sources. When the needs of the natural system are then factored in, demands become greater and conflicts among competing water users would become even more severe. While most people recognize the need for a healthy ecosystem to support the region's economy and jobs, many people are concerned that restoration projects would displace farms and other businesses, limit development, reduce available water supply and reduce job opportunities. By contrast, continued degradation of the south Florida ecosystem would adversely affect the tourism and recreational industry that are important to the regional economy.

G.2.3 Land Use

The existing land use within the study boundaries varies from preserve lands to agriculture and industrial urban uses. A large portion of south Florida remains natural, although much of it is disturbed land. The dominant natural features are the federally protected Everglades National Park (ENP) and Biscayne National Park, along with Biscayne and Florida Bay and remnant freshwater and coastal wetland and upland systems within and adjacent to the developed areas along the coast. Generally, urban development is concentrated along the lower east coast of Miami-Dade County.

Although there remains substantial agricultural acreage in southwestern Miami-Dade County (62,000 acres), rapid population growth and land development practices have resulted in notable western and southern urban sprawl; the predominant land use is single-family residential. The once significant rural population in the western areas of Miami-Dade County is rapidly evolving into an urbanized makeup in population. A breakdown of the overall land uses in Miami-Dade County is included on the following table.

TABLE G-1: LAND USES IN MIAMI-DADE COUNTY, 2006

Land Use	Area (sq mi)	Percentage
Environmental Protection*	660,104	53%
Urban Development	274,005	22%
Water Conservation	211,731	17%
Agriculture	62,274	5%
Vacant/Private	37,364	3%
Total Land Area	1,245,478	100%
*Includes government-owned lands		

The existing use of the land that is being purchased primarily consists of mixed open land with agriculture, degraded wetlands and fallow fields. Card Sound Road borders the study area on the east (with one minor exception) and the ENP borders the study area on the west and south. Much of the southwest border of the project area is adjacent to Little Card Sound and Manatee Bay, adjacent to Barnes Sound. The northern boundary of the study area is just south of Florida City and the City of Homestead. Actual canal placement could range anywhere from just south of Florida City to a track parallel or nearly parallel to Southwest 424th Street. Inside of this uncertain area is a major industrial site as well as many privately owned agricultural, commercial and residential parcels.

The Turkey Point Nuclear Power Plant is located on the shoreline east of the C-111 SC Western project area. Some water used in the reactor is piped in from the Miami-Dade municipal water supply. A separate supply of water that cools the turbine steam supply for reuse comes from a unique, closed system of 36 interconnected canals totaling over 168 miles on length. This power plant is an integral part of the power supplied to Miami-Dade County, providing energy to over 450,000 homes (FP&L Website).

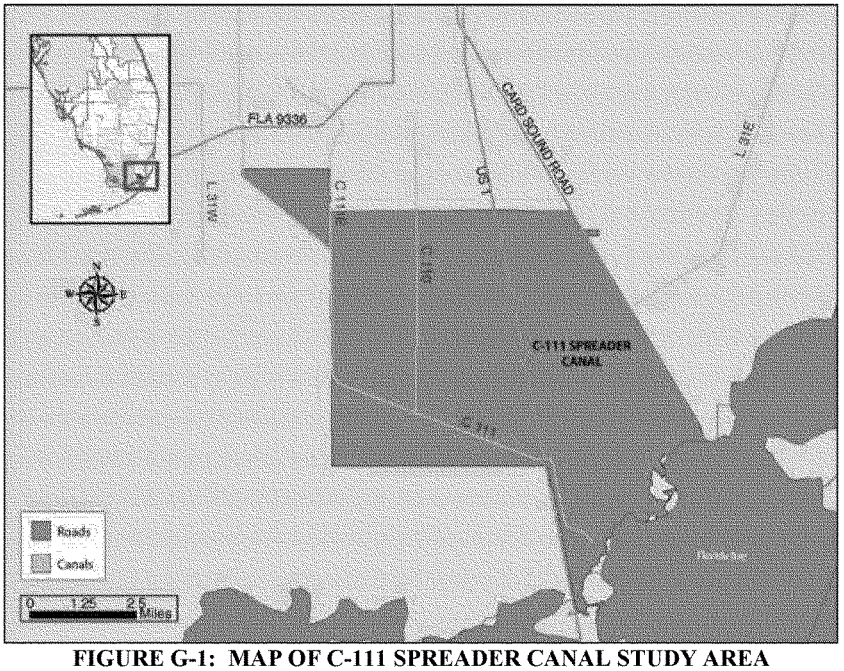


FIGURE G-1: MAP OF C-111 SPREADER CANAL STUDY AREA

G.2.4 General

Socio-economic and demographic data for the three-county south Florida area indicate higher than average income when compared to the rest of the state and nation, and much greater economic and population growth than for the rest of the nation. Additional characteristics of the study area include a strong service sector, fishing, tourism, and recreation. Florida's economy is generally characterized by strong wholesale and retail trade, government and service sectors. Florida's warm weather and extensive coastline attract vacationers and other visitors and helps to make the State a significant retirement destination for people from all over the country. Easily developed land, accessible water supply, abundant natural resources, and the aesthetic beauty of the region are the fundamental building blocks of the local economy. Relative to the national economy, the manufacturing sector has played less of a role in Florida, including the study area. However, high technology manufacturing has begun to emerge as a significant sector in the State over the last decade.

G.2.5 Population

This section includes a description of the local economy and demographics of the study area. This descriptive information provides insight into the study area's socio-economic characteristics, and provides part of the basis for different facets of the economic impact evaluation work in the rest of this document

G.2.5.1 Population: Historic Trends and Existing Condition

Describing the demographic characteristics for the project site's census tract, Miami-Dade County, and the State of Florida, helps to provide a basis for understanding the existing socio-economic context in which plan implementation will take place. Some of these characteristics are outlined below.

The C-111 SC Western project site does not coincide exactly with any census tracts but it is contained entirely within two tracts. The tract-level analysis provides an area for which data is available, and is closer to the relatively small sub-county component site footprint. This census tract data provides a blueprint for the surrounding area, not exact characteristics of the project site. The C-111 site has few permanent residents or existing businesses, and most of the owners of the land do not occupy the property and in many instances reside outside of the region, and therefore may not mirror the demographics of the local area residents. The most current information regarding the detailed demographics of the C-111 census tracts was published in 2000. A map of census tracts in the area is provided below. The C-111 study area is contained completely within tracts 114.02 and 114.01.

More recent data are available for the county and state levels, but such data are not comparable with the year 2000 census tract data which is only published on a decennial basis.

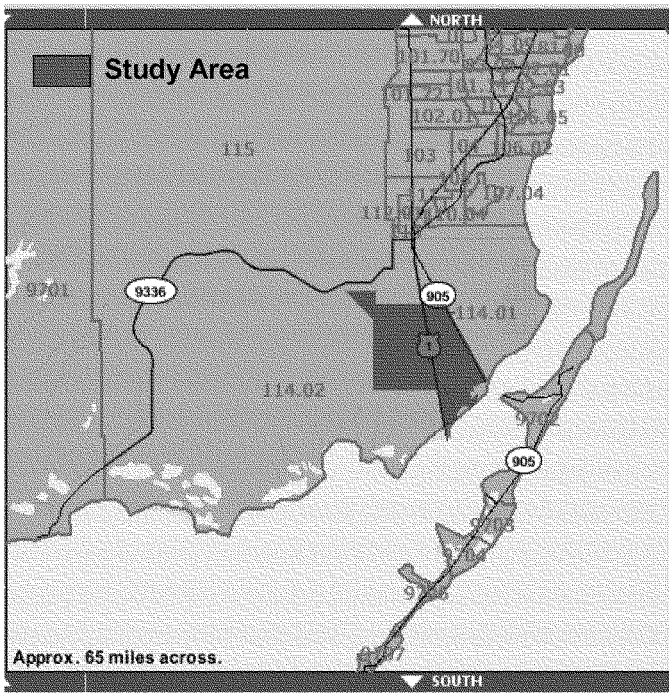


FIGURE G-2: CENSUS TRACT MAP OF C-111 STUDY AREA

TABLE G-2: C-111 STUDY AREA CENSUS TRACTS, 2000

Census Tract	114.02	114.01	Total
Population	10,305	4,330	14,635
Percent below poverty level	40%	9%	24%
White	54%	77%	65%
Black	31%	12%	21%
Some other race	15%	11%	13%
Hispanic origin	47%	31%	39%

Florida:

Population 2000	15,982,378
Change in population, 1990-2000	23.5%
Below poverty level, 1999 estimate	12.5%
White, 2000	78.0%
Black, 2000	14.6%
Other, 2000	7.4%
Hispanic origin, 2000	16.8%

Miami Dade County:

Population 2000	2,253,362
Change in population, 1990-2000	16.3%
Below poverty level, 1999 estimate	18%
White, 2000	69.7%
Black, 2000	20.3%
Other, 2000	10%
Hispanic origin, 2000	57.3%

Population in Miami-Dade County increased 16.3 percent during the period from 1,937,540 in 1990 to 2,253,362 in 2000. The population of Florida and the United States increased 23.5 and 13.1 percent respectively over the same period. Population in Miami-Dade County is expected to increase nearly 70 percent from 2000 to 2050. Despite this population growth, Miami-Dade County will fall short of the projected growth of the south Florida nine-county area, which is projected to grow at 78 percent between 2000 and 2050.

G.2.5.2 Population: Projections

Current statistics demonstrate that countywide, Miami-Dade is characterized by a slower population growth rate than the rest of the State, but a larger population growth than the nation as a whole. However, for lands within and adjacent to Miami-Dade County's Urban Development Boundary near the C-111 study area, growth rates are projected to be much higher.

Miami-Dade County had a 2000 census population of 2,253,362. The population of this county had relatively modest increase of 16.3 percent from 1990 to 2000, although it should be noted that Hurricane Andrew in 1992 had a significant impact on population growth during this period due to mass emigration. The population of Florida and the United States increased 23.5 percent and 13.1 percent respectfully during the same period. The State of Florida added over three million persons from 1990 to 2000, ranking third in the nation in numerical change.

Population in Miami-Dade is expected to increase by almost 1.5 million people from 2000 to 2050. Due to this anticipated population growth, the county is expected to

remain the most populated county in Florida. The dense urban area of the Lower East Coast of Florida has contributed to development pressure and population increases in Miami-Dade County. Miami-Dade County is expected to grow faster than the national trends until at least 2050. Conversion of agricultural and other unimproved lands in southern Miami-Dade County including large areas within the C-111 study area would continue to be fueled in significant part by this population growth.

TABLE G-3 summarizes existing and projected population in Miami-Dade County (2000 figures are from the U.S. Census). The future census estimates to 2030 were based on the University of Florida Bureau of Economic and Business Research (BEBR) projections in *Projections of Florida Population by County, 2001-2030*, dated February 2002. The Miami-Dade County Department of Planning and Zoning developed the long-term projections from 2030-2050. These population projections were calculated for, and accepted by, the Initial CERP Update. ***TABLE G-3*** displays the population rates of growth for each decade from 2000 to 2050. ***TABLE G-4*** indicates the population growth rate of the study area is expected to be lower than that of the State from 2000-2050.

TABLE G-3: POPULATION ESTIMATES, 2000-2050

Population (1,000's)						
	Year					
	2000	2010	2020	2030	2040	2050
Miami-Dade	2,253	2,554	2,862	3,148	3,499	3,811
Share of Florida Total	14.10%	13.54%	13.13%	12.83%	12.90%	12.83%
Florida Total	15,982.40	18,866.70	21,792.60	24,528.60	27,118.70	29,714.50

TABLE G-4: **STUDY AREA POPULATION RATES OF GROWTH 2000-2050**

	Average (% Per year) Population Growth				
	2000-2010	2010-2020	2020-2030	2030-2040	2040-2050
Miami-Dade	1.3%	1.2%	1%	1.1%	0.9%
Florida Total	1.8%	1.55%	1.26%	1.06%	0.96%

TABLE G-5: **STUDY AREA POPULATION GROWTH 2000-2050**

	% Change 2000-2050*
Miami-Dade	70%
Florida	85.9%

* Note: Florida population projections are only published until 2050

G.2.6 Economy

Generally, a strong wholesale and retail trade, government and service sectors characterize Florida's economy. Florida's warm weather and extensive coastline attracts vacationers and other visitors and helps make the state a significant retirement destination for people all over the country. Agricultural production is an important sector of the state's economy, and is especially significant to portions of the study area. Compared to the national economy, the manufacturing sector has played less of a role in Florida, but high technology manufacturing has begun to emerge as a significant sector in the State over the last 15 years.

The three most significant employment sectors in the Miami-Dade economy are administrative support, retail trade and health care and social assistance. In 2002 administrative support employed 127,865 in the county; retail trade in employed 110,975; health care and social assistance employed 110,539. These three top industries paid aggregate 2002 salaries of 2.89 billion, 2.32 billion and 3.74 billion respectively (data from the 2007 economic census has not yet been published).

Homestead Air Reserve Base is a major economic presence in the southeast Miami-Dade region. Since 1994 the Department of Defense has expended approximately $100 million in new construction infrastructure improvements on the base. The military provides an economic boost of $120 million a year for Homestead and Florida City. In 2003 there were 1,776 total personnel at the base with an annual payroll of $84,000,000. The base is a 2,200-acre stand-alone, Air Force Reserve Command-owned and operated installation.

The unemployment rate for Florida is 5.5 percent (2006), while the unemployment rate for Miami-Dade County was 5.8 percent (2006).

As discussed previously, the C-111 study area is encompassed within two census tracts (tract 114.02 west of U.S. Highway 1 and tract 114.02 east of U.S. Highway 1). However, the economic profile of these census tracts is not necessarily representative of the population living within the study area. It is only representative of a population living within relatively close proximity to the study area. The actual population contained within the study area is probably extremely small. The study area does not conform to tract blocks or block groups, thus a more narrow level of analysis was not practical.

Personal per capita income in Florida is $25,297 (2006), but is somewhat lower in Miami-Dade County, at $21,716. The personal per capita income in the study area is lower than the state and county levels, $20,366 in tract 114.01, and $7,911 in tract 114.02 (2000).

Despite having a considerably lower than average per capita income, the study area's median household income is somewhat more comparable to that of the county

and state. The median household income for census tracts 114.01 and 114.02 are $35,430 and $24,306, respectively. These are still significantly lower than the county median household income ($41,237) and the state ($45,495). These numbers suggest greater household size within the study area to account for the increased household income over per capita income.

In 2000 it was reported that 12.6 percent of Florida's population lived below the poverty level, while 6.4 percent of Miami-Dade County were below the poverty level. In tract 114.01, 9.1 percent of individuals were living below poverty level in 2000. In tract 114.02 however, that number was 39.9 percent, considerably higher. Within the tracts that encompass the study area a total of 3,697 individuals live below the poverty level while the state reported 1,952,629 and the county reported 396,995.

These economic indicators can be seen in ***TABLE G-6***, following:

TABLE G-6: **ECONOMIC INDICATORS IN STUDY AREA**

	Florida	Miami-Dade	Tract 114.01	Tract 114.02
Population	15,982,378	2,253,362	4,330	10,305
Unemployment	5.5%	5.8%	6.5%	23.3%
PerCapita Income	$25,297	$21,716	$20,366	$7,911
HH Income (Median)	$45,495	$41,237	$35,430	$24,306
Below Poverty Level	12.6%	6.4%	9.1%	39.9%
White	78.0%	69.7%	77.0%	53.9%
Black	14.6%	20.3%	11.8%	31.0%
Hispanic origin	16.8%	57.3%	31.0%	46.5%

G.2.7 Agriculture Economy

Despite its continued population growth and urban expansion, agriculture in Miami-Dade County remains a valuable industry and employer. In the latest census of agriculture, it is reported that the market value of agricultural products from Florida exceeded six billion dollars per year. Florida ranks number one nationally in sugar cane production and number one in the quantity of all nursery acres. Additionally, Florida ranks number two in fruit, nursery/greenhouse crop and vegetable production. Statewide, agriculture employs 34,800 individuals. There are 1,576 persons employed by agriculture in the county. There are 2,244 farms in the county. The market value of agricultural products sold in Miami-Dade County is 578 million annually.

Because of the temperate climate, Miami-Dade County and south Florida are a major source of traditional vegetables for the rest of the nation during the colder months. Traditional vegetables include pole beans, tomatoes, squash, potatoes, corn, bell peppers and other more common vegetables. For the 2001/2002 growing season, Miami-Dade County produced a traditional/winter vegetable harvest that had an estimated value of over 197 million dollars. Of these crops, the value sold outside Miami-Dade County was over 98 percent. Additionally, Miami–Dade County is the number one producer of nursery/greenhouse crops and the number one producer of sweet potatoes in the state.

Aside from the extended growing season of traditional crops, the climate of south Florida is favorable for the growth of many different tropical fruits. These fruits include lychee, avocado, mango, Persian limes, carambola, mamey sapote, guava, papaya and bananas. Additional smaller yield tropical fruits are harvested as well. In 2001/2002 1,122 farms reported producing fruit in the county. The estimated total value of the yield during that same time period was 35.8 million dollars, with nearly 87 percent sold outside Miami-Dade County.

G.3 MUNICIPAL AND INDUSTRIAL WATER DEMAND

In the study area, surficial aquifers supply the majority of water for urban use. Rainfall is the primary supporter of the agriculture water demand in south Florida and surficial waters (canals, shallow groundwater, and ponds) provide the majority of the irrigation demands in the watershed. Salinity intrusion is becoming a predominant problem for water supply. In the Lower East Coast area, salinity intrusion has resulted from two major causes. The first is the lowering of the ground water table in the area due to drainage and reduced recharge as well as the increased withdrawal of water by pumping. The second reason is the construction of numerous drainage and navigation canals from inland areas to the coastal waters. Currently, water shortages and restrictions are implemented during low rainfall periods or droughts. Sea level rise is likely a third cause.

Municipal and Industrial Water Usage

The U.S. Geological Survey (USGS) estimates annual water withdrawals for Florida at the county-level every five years. The most recent publication of findings was entitled *Water Withdrawals, Use, Discharge, and Trends in Florida, 2000.* Water use estimates for 2005 were not published at the time of this analysis. Water use estimates for 2000 for the nine counties included in this analysis were obtained from the USGS. These uses are distributed as public-supply and self-supply domestic (residential), commercial, industrial, government, and recreational water use estimates, along with unaccounted-for water loss estimates. ***TABLE G-7*** presents the USGS estimated 2000 water use for the nine-county area, excluding mining and power generation water use. Total public-supply water use for the region is estimated at 960.51 million gallons a day (mgd), and total M&I water use

is estimated at 1,176.79 mgd. The addition of the 1,901.14 mgd of agricultural water use increases total water demand for the region to 3,077.93 mgd. Agricultural water use accounts for 62 percent of the total use, and all M&I uses accounts for 38 percent (***TABLE G-7***). The county that corresponds to the C-111 study area is Miami Dade, although it is a relatively small footprint within the county. Total water demands are presented in the following table.

TABLE G-7: USGS TOTAL WATER USE, FOR SELECTED COUNTIES, 2000, EXCLUDING MINING AND POWER GENERATION (IN MGD)

NOTE: Recreation self-supply water use includes golf course irrigation.

	Municipal and Industrial							
	Public	Self-Supply				Sub		Grand
County	Supply	Domestic	Commercial	Industrial	Recreation	Total	Agriculture	Total
Broward	258.06	2.11	0.54	0.00	37.00	297.71	4.10	**301.81**
Glades	0.55	0.61	0.04	0.00	0.42	1.62	69.02	**70.64**
Hendry	4.72	1.67	0.21	0.51	1.09	8.20	503.91	**512.11**
Lee	52.37	8.86	0.46	0.09	22.66	84.44	60.51	**144.95**
Martin	18.45	4.20	0.37	2.78	7.88	33.68	140.02	**173.70**
Miami-Dade	377.27	4.85	1.29	0.00	13.39	396.80	110.35	**507.15**
Monroe	17.02	0.08	0.10	0.00	1.85	19.05	0.03	**19.08**
Okeechobee	2.23	1.52	0.36	0.00	0.68	4.79	67.04	**71.83**
Palm Beach	229.84	10.17	0.59	15.81	74.09	330.50	946.16	**1,276.66**
Total	**960.51**	**34.07**	**3.96**	**19.19**	**159.06**	**1,176.79**	**1,901.14**	**3,077.93**

Source: USGS unpublished data, 2002.

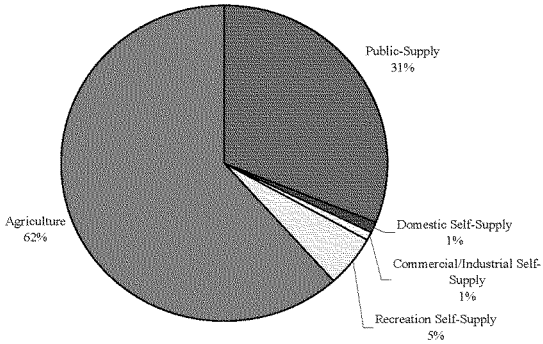


FIGURE G-3: DISTRIBUTION OF U.S. GEOLOGICAL SURVEY ESTIMATED 2000 WATER USE FOR THE NINE-COUNTY

FIGURE G-3 presents the distribution of USGS estimated 2000 total and M&I water use, by county in the Lower East Coast (LEC). Combined, total water use in the four counties of the LEC -- Broward, Miami-Dade, Monroe, and Palm Beach was 2,104.7 MGD, which accounted for 68 percent of the nine-county region. The LEC M&I water use was estimated at 1,044.06 MGD, or 89 percent of the region's total M&I water use.

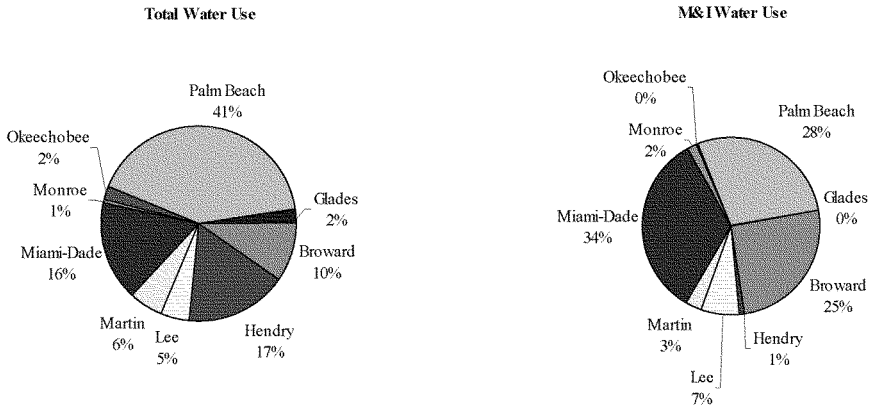


FIGURE G-4: DISTRIBUTION OF U.S. GEOLOGICAL SURVEY ESTIMATED 2000 TOTAL AND M&I WATER USE, BY COUNTY

An M&I forecast is required as input to modeling that will be the basis for planning and optimally designing the C-111 SC Western project. The planning horizon is the year 2050. Water use estimates from the present to 2050 for natural area environmental purposes, agricultural irrigation purposes, M&I use, and other purposes are needed. The results of the IWR-MAIN effort are a set of projections through the year 2050 for M&I use only.

The M&I water use forecasts were developed using the IWR-MAIN Water Demand Management Suite, a computerized water resource planning tool that allows the development of water use forecasts and the evaluation of water conservation programs. The IWR-MAIN software allows water use forecasts to be developed based on existing water use patterns and existing or forecast socioeconomic parameters and then allows the impact of water conservation measures on those water uses to be evaluated. In the Initial CERP Update (ICU), residential water use was forecast using a multiplicative forecast model and nonresidential water use was forecast using a constant use rate model.

The Lower East Coast region M&I water demand forecast is shown in the following table. Figures are derived from the BEBR population and employment projections, and were collected for the 2000 ICU. The section of the ICU that applies to the C-111 study area is Service Area 3, which encompasses Miami-Dade and Monroe counties. Water demand projections estimated for Service Area 3's most likely population scenario, conservation–adjusted water use in 2050 at 505.6 mgd. Service Area 3 is expected to be using one third of the total water demanded in the nine-county ICU region. Due to the exceptionally small rate of growth projected between 2050 and 2060, it is not expected that 2060's water demands would be substantially higher than in 2050, after taking into account strong conservation measures.

The South Florida Water Management District (SFWMD) requires the development of water conservation plans as a prerequisite for water utilities to obtain a water use permit. With the implementation of conservation plans, water demand should change. Most conservation plans incorporate passive water conservation measures that include increasing block rate structures, the required use of ultra-low flow water fixtures on new or renovated construction, restrictions on lawn watering, required use of rain sensors on automatic sprinkler systems, a leak detection program, and public education concerning water conservation measures.

With the increase in population and infrastructure, the demand for water would increase and the shortages and restrictions would become more prominent, leading to both economic and environmental damages. In the Lower East Coast region groundwater is the predominant source of water for M&I uses. This trend is expected to continue in the future. The groundwater levels would continue to decrease, leading to increased shortages of water and increased salinity levels in

wells in the study area. With more persons drawing water and less water available for recharge, migration of the underlying salt wedge leading to increased saltwater intrusion and shortages to wells and well fields would become more prevalent.

TABLE G-8: ESTIMATED 2050 SERVICE AREA 3 CONSERVATION ADJUSTED, MOST LIKELY POPULATION SCENARIO (MGD)

End Use	2000 Demand	2050 Demand
Service Area 3	373.2	586.6

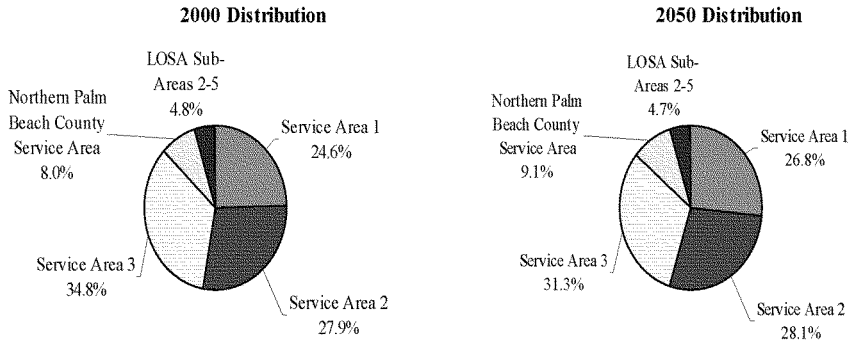


FIGURE G-5: DISTRIBUTION OF TOTAL CONSERVATION-ADJUSTED MUNICIPAL AND INDUSTERIAL WATER USE, BY SERVICE AREA, 2000 AND 2050, MOST-LIKELY POPULATION SCENARIO

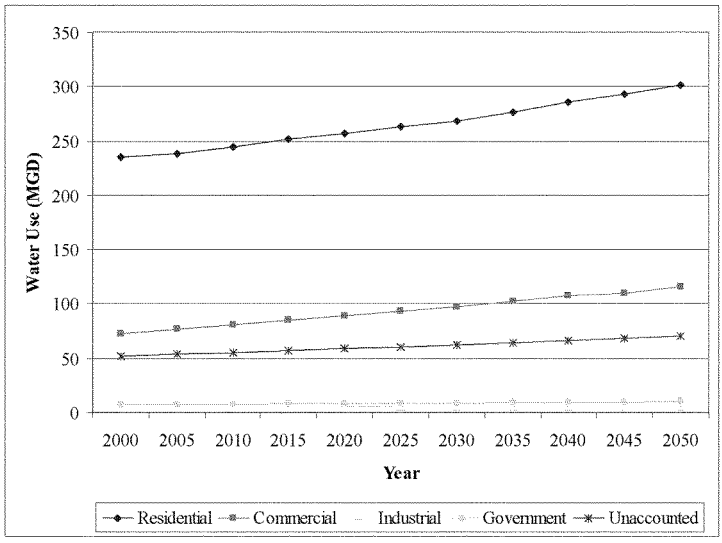


FIGURE G-6: SERVICE AREA 3, MOST-LIKELY POPULATION SCENARIO MUNICIPAL AND INDUSTRIAL CONSERVATION–ADJUSTED FORECAST, BY WATER USE SECTOR

G.3.1 Agricultural Water Demands

Agriculture is a significant irrigated land use of the Lower East Coast region. Agricultural land use represents less than one-quarter of the land use in the service area, and in many areas will be virtually non-existent in the future.

Rainfall is the primary supporter of the agriculture water demand in south Florida approximately 59 inches per year along the Lower East Coast. Surficial waters (canals, shallow groundwater, and ponds) provide the majority of the irrigation demands in the watershed. Unfortunately surficial supplies are inadequate at some time nearly every year. During droughts, agricultural water users have higher irrigation water demands; however, water supplies are usually at their lowest levels during droughts. Consequently, water shortage management policies are implemented which restricts use of water so that agricultural water users do not always receive as much water as they need. This can lead to reduced crop yields and economic damages.

The Lower East Coast receives significant groundwater recharge via easterly seepage from the Water Conservation Areas under the north-south levee system; however, during prolonged droughts, significant volumes of water from Lake

Okeechobee can be required by the Lower East Coast to supplement local water supplies and prevent saltwater intrusion into well fields.

G.4 FLOOD DAMAGE REDUCTION IMPACTS

A key design criterion and goal throughout the development of the project components has been that flooding of developed areas will remain the same or improved with the plan implemented as compared to without the plan. No flooding of residential or commercial properties will be caused by implementation of the plan.

G.5 RECREATION

Recreation is a major contributor to the economy. According to the Outdoor Industry Foundation, Active Outdoor Recreation has the following economic benefits:

- Contributes $730 billion annually to the United States' economy
- Supports nearly 6.5 million jobs across the United States
- Generates $88 billion in annual state and national tax revenue
- Provides sustainable growth in rural communities
- Generates $289 billion annually in retail sales and services across the United States
- Touches over eight percent of America's personal consumption expenditures-more than 1 in every 12 dollars circulating in the economy

The report does not take into account non-market benefits, the increased value of land associated with recreation opportunities or economic benefits from environmental consequences of reserving land for recreation opportunities.

This section examines the potential effects of the Recommended Plan on outdoor recreation in the study area. Outdoor recreation in Florida includes many different activities. A common way of differentiating outdoor recreation activities is to classify them based as "user-oriented" or "resource-based" activities. User-oriented activities, such as individual and team sports, are not dependent on any natural resource setting and can be located, space permitting, on any open site. These facilities are provided for the convenience of the user. For example, a basketball court can be added to a playground. Resource-based activities, such as hunting and fishing, depend on the existence and quality of supporting natural or historical resources. The economic value of resource-based recreation is determined by the users' willingness to pay for a recreation occasion. The willingness of current and potential users to pay for resource-based recreation of specific quantity and quality constitutes the demand for that type of recreation. The interaction of demand with the quantity and quality of recreation resources available determines the recreation use or "participation" levels for that resource-based activity. When the quantity or

quality of recreation resources is modified by a project, such as the alternative restoration plans, the change in value of resource-based recreation is based on the difference in the willingness of users to pay under the with- and without-project conditions.

The C-111 SC Western study area provides a unique and extensive natural resource-based recreational resource. The restoration of the ecosystem could potentially have important impacts on the value of outdoor recreation in the study area. The hydrologic changes associated with the alternative restoration plans have been designed to improve the structure and function of the ecosystems. These improvements can be expected to provide resource-based recreational opportunities compatible with the protection of the natural systems. Many tourists and residents recreate in the natural areas surrounding the study area. If the alternative restoration plans improve the ecology of the study area, the quality of the study area related recreation and/or the number of people who participate in study area related recreation could increase as well. Consequently, the value of outdoor recreation in the study area could also substantially increase.

However, precisely estimating the future value of recreation in the study area is problematic, and anticipating the incremental changes in value associated with restoration is even more challenging. There are four principal uncertainties that challenge forecasting the future quantity and quality of outdoor recreation under with- and without project conditions. Perhaps the most important uncertainty concerns the timing and character of the ecological changes that are expected to result from the alternative restoration plans. At this time, the outcomes of the restoration actions cannot be predicted. Consequently, secondary effects, such as associated changes in recreation patterns and the resulting effect on industries supporting recreation (e.g., marine industry) cannot be accurately quantified.

Another uncertainty regarding the future value of recreation is the marketing of tourism and study area related recreation. If the restored ecosystem is used to market tourism and recreation in the study area, the value of recreation could change dramatically relative to the without-project future conditions.

A third uncertainty is the degree to which recreational facilities and recreational access would be developed as part of a restoration plan. Recreation facilities and access, such as visitor centers, scenic overlooks, nature trails, and roads, can greatly affect participation levels.

Finally, there are a variety of economic factors at the national level that can influence tourist and resident recreation demand. These factors include the health of the national economy, levels of disposable income, and the availability and costs of competing recreation opportunities. In 2007 Florida welcomed a total of 84.5 million visitors. However, Florida tourism and its economic implications are

sensitive to national economic and energy policies. "The dynamic nature of the industry causes uncertainty in tourism forecasting, making it difficult to accurately project visitation levels for more than one or two years at a time" (Florida DEP, 2000). As evidence of the challenges of tourism and recreation forecasting, the Florida Tourism and Industry Marketing Corporation limits its tourism forecasts to three years.

The State Comprehensive Outdoor Recreation Plan (SCORP) is the best source of information on recreation demand and supply at the state and regional scales. It divides the state into 11 planning regions, each with clusters of counties. As indicated in ***TABLE G-9***, Region 11 is comprised of Broward, Miami-Dade and Monroe counties.

TABLE G-9: COUNTIES WITHIN SCORP PLANNING REGIONS POTENTIALLY AFFECTED BY ALTERNATIVE RESTORATION PLANS

Region	Counties
Region 11	Broward
	Miami-Dade
	Monroe

Source: Florida Department of Environmental Protection, 2000

The SCORP organizes outdoor recreation in Florida into 47 categories that encompass a variety of recreation activities including team sports (e.g., basketball and baseball), individual sports (e.g., golf and tennis), hunting, fishing, swimming, and boating. ***TABLE G-10*** presents descriptive information on the recreation facilities in SCORP Regions 11 for study area specific recreation categories. These resource-based categories were selected as those that could potentially be affected by the hydrologic changes or ecological changes associated with the alternative restoration plans. This table also includes percentages of the statewide totals for the recreation categories.

TABLE G-10: REGIONAL OUTDOOR RECREATION FACILITIES
REGION 11, 1998

Resource / Facility	Region 11	% of State Total	State Total
Outdoor Recreation Areas	2,080	16%	13,097
Outdoor Recreation Acres	3,038,475	28%	10,850,904
Land Acres	1,831,363	20%	9,077,004
Water Acres	1,207,112	68%	1,773,900
Hunting Acres	871,151	14%	6,168,716
Land Acres	869,573	14%	6,046,955
Water Acres	1,578	1%	121,761
Camping			
RV / Trailer Camp Sites	10,603	8%	138,576
Tent Camp Sites	1,081	11%	10,214
Trails			
Hiking Trails (miles)	277	7%	3,904
Horseback Riding Trails (miles)	91	6%	1,443
Nature Trails (miles)	107	10%	1,043
Freshwater Catwalks	40	5%	748
Boating			
Canoe Trails (miles)	296	11%	2,587
Freshwater Boat Ramp Lanes	235	12%	1,973
Freshwater Marinas	6	1%	511
Freshwater Slips / Moorings	303	3%	11,758
Saltwater Marinas	366	33%	1123
Saltwater Marina Slips	14,470	32%	45,839

Source: Florida Department of Environmental Protection. 2000

G.5.1 Recreation Demand

Profiles of existing and future recreation demand in the study area can be developed by drawing on a variety of information at the national, state, regional, and local levels. In general, the variety of recreational interests in the United States appears to be increasing along with recreational participation rates. As future recreation needs and interests develop, it is important to recognize that participation in specific types of recreational activities is often linked to demographic factors such as age and income. For example, participation in activities requiring vigorous exercise is considerably higher for young people than for senior citizens. However, the elderly population has increasing recreation participation because of the growing awareness of the importance of physical fitness. Participation in most activities is low for those with family incomes below $25,000 per year. Interestingly, participation is also low for those with family incomes greater than $100,000 per

year. Most outdoor recreational activities appear to be enjoyed largely by the middle class, those with family incomes between $25,000 and $75,000 per year.

G.5.1.1 Regional Recreation Demand

Recreation demands were developed for the SCORP through surveys of residents and tourists. The Division of Recreation and Parks conducts periodic surveys of resident and tourist participation in recreation activities to estimate outdoor recreation in Florida. The recreation participation information was derived from the 2000 surveys conducted by the University of Florida, Department of Recreation, Parks, and Tourism. Participation in outdoor recreation activities is expressed in terms of user-occasions, which occur each time an individual participates in a single outdoor recreation activity. The number of user-occasions was calculated for each planning region as well as the entire state by type of activity. Demand was estimated for 1997, 2000, 2005 and 2010 by applying the per capita participation rates to population projections.

TABLE G-11 presents 1997 and projected 2010 demands for the selected recreation activities in SCORP Planning Region 11. This table includes user-occasions as well as facility/resource needs. As part of the without-project conditions, all of the regions are expected to have significant increases in demands for the selected recreation activities with a commensurate need to increase development of the regions' recreation resources and facilities.

TABLE G-11: DEMAND AND FACILITY NEEDS (1997 AND 2010)– SELECTED RECREATION ACTIVITIES (SCORP REGION 11)

Activity	Units	Demand (user-occasions)		Resources / Facility Needs	
		1997	2010	1997	2010
Hunting	Acres	663,841	772,849	79,348	235,427
RV / Trailer Camping	Camp Sites	2,203,445	2,779,565	0	0
Tent Camping	Camp Sites	888,761	1,136,981	10	317
Hiking	Miles	1,282,041	1,672,767	252	413
Horseback Riding	Miles	1,780,575	2,189,849	0	0
Nature Study	Miles	1,456,739	1,988,143	0	0
Canoeing	N/A.	108,405	142,253	N/A.	N/A.

Source: Florida Department of Environmental Protection, 2000.

In sum, the C-111 SC Western study area ecosystems support a significant amount of outdoor recreation in the Lower East Coast of Florida. A significant portion of the expenditures comes from tourists. It is not possible at this time to anticipate precisely how expenditures and consumer surplus associated with C-111 SC Western project study area related recreation would change if restoration occurred.

However, based on the adverse effects related to environmentally damaging releases of waters into the natural ecosystem, it can be concluded that improving the environmental quality of the C-111 SC Western study area ecosystem would substantially support and sustain local recreation-based businesses. Given the potential levels of expenditures and consumer surplus in the future, a small percentage increase in the quantity or quality of C-111 SC Western study area recreation could represent an increase in recreation value.

Local Parks and Recreation

There are no known, significant local parks within the study area.

As development continues in the southern tier of the county and in particular in the area just south of the UDB, there could be pressure to acquire additional park land in order to meet the county's level of service for local park and recreation acres.

G.5.2 National Recreation Trends

National trends in recreation may help to identify potential or expected changes in the demand for Florida recreation as the result of ecosystem restoration. Two recent national surveys of outdoor recreation have particular relevance for this investigation.

G.5.2.1 National Survey of Recreation and the Environment

The Outdoor Industry Foundation of America conducted a National Survey of Recreation and the Environment in 2005. Approximately 4,000 Americans, 16 years old or more, were interviewed in a random sample telephone survey. The respondents provided information regarding their participation in 22 outdoor activities.

TABLE G-12 presents 2005 participation rates for the 22 outdoor activities. Of the selected activities, the four most popular groups of activities were bicycling (38.2%), fishing (34.5%), hiking (34.2%), and camping (30.4%). Over 160 million Americans participated in some sort of human powered outdoor activity in 2005. The survey did not include more passive activities such as walking and site-seeing, such activities have traditionally show very high participation rates.

TABLE G-12: PARTICIPATION RATES FOR SELECTED RECREATIONAL ACTIVITIES BY U.S. POPULATION 16 YEARS OR OLDER, 2005

Activity	Participation (2005)	Population (Millions)
Human Powered Activities - Any Type	72.1%	161.6
Backpacking	6.0%	13.5
Bicycling - Any Type	38.2%	85.6
Bicycling - Paved Road	35.0%	78.5
Bicycling - Mountain Biking	22.3%	50.0
Bicycling - Single Track Dirt	17.4%	39.0
Bicycling - Wide Track Dirt	17.0%	38.1
Bird Watching	7.0%	15.6
Camping - Any Type	30.4%	68.1
Car Camping	23.1%	51.7
Camping (Away from Car)	7.9%	17.7
Climbing with Rope/Harness - Any Type	4.1%	9.2
Climbing - Natural Rock	2.2%	5.0
Climbing - Artificial Wall	3.0%	6.7
Climbing - Ice	0.5%	1.0
Cross-Country/Nordic Skiing	4.5%	10.0
Fishing - Any Type	34.5%	77.3
Fishing (Non-Fly)	33.1%	74.2
Fly Fishing	6.6%	14.7
Hiking	34.2%	76.7
Paddlesports - Any Type	15.3%	34.3
Canoeing	9.3%	20.8
Rafting	4.7%	10.6
Kayaking - Any Type	5.6%	12.6
Kayaking (Non-Whitewater)	5.3%	11.9
Kayaking - Recreation/Sit-on-Tope	4.0%	9.0
Kayaking - Touring/Sea	2.5%	5.6
Kayaking - Whitewater	1.0%	2.2
Snowshoeing	2.4%	5.5
Telemark Skiing	1.6%	3.5
Trail Running	18.0%	40.4

Source: Outdoor Industry Foundation, Outdoor Recreation Participation Study, eighth edition,2006

G.5.2.2 National Survey of Fishing, Hunting, and Wildlife Recreation

The U.S. Fish and Wildlife Service conducted the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation in 2006. As part of this survey, 85,000 anglers and hunters were surveyed and 21,938 were interviewed. Additionally 11,279 wildlife watchers were interviewed. The purpose of the survey was to gather information regarding participation and expenditures for wildlife-related activities, including fishing, hunting, and wildlife watching. National participation and

expenditure data for sportsmen and wildlife watchers are presented in ***TABLE G-13***. The survey revealed that 87.5 million Americans aged 16 or older (40 percent of the adult population) enjoyed some form of wildlife-related recreation in 2006 with total expenditures exceeding $122.3 billion.

Wildlife watching activities primarily included observing, photographing and feeding wildlife for two types of participants: residential and nonresidential. The residential category included those activities that occurred within one mile of the residents' homes, while the non-residential group included those who took trips or outings for the primary purpose of observing, photographing, or feeding wildlife. Based on the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, in 2006 over 71.1 million people in the United States participated in wildlife watching.

TABLE G-13: TOTAL UNITED STATES WILDLIFE-RELATED RECREATION PARTICIPATION AND EXPENDITURES, 2006

Category	Indicator
Total Participants	87.5 million
Total Expenditures	$122.3 billion
Sportspersons	
Total Participants*	33.9 million
Anglers	30.0 million
Hunters	12.5 million
Total Days	737 million
Fishing	517 million
Hunting	220 million
Total Expenditures	$76.7 billion
Fishing	42.0 billion
Hunting	22.9 billion
Unspecified	11.7 billion
Wildlife Watchers	
Total Participants**	71.1 million
Around the home	67.8 million
Away from home	23.0 million
Total Expenditures	$45.7 billion

Source: 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, US Fish & Wildlife Service

The sum of residential and non-residential subcategories does not equal the total due to an overlap in participation.

The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation also contains state-level information on recreation participation and expenditures. In 2006, approximately 5.9 million of Florida's 18.1 million residents (32.6%) participated in wildlife-related recreation with the following distribution: 4.2 million (23.2%) participated in wildlife watching, 2.8 million (15.5%) fished and 236 thousand (1.3%) hunted. These data are summarized on ***TABLE G-14***, below.

TABLE G-14: PARTICIPANTS IN WILDLIFE-RELATED RECREATION IN FLORIDA, 2006

Type	Participants	%
Total	5.9 million	32.6%
Sportspersons		
Total	2.8 million	15.5%
Anglers	2.8 million	15.5%
Hunters	236 thousand	1.3%
Wildlife Watchers		
Total	4.2 million	23.2%
Away from home	1.6 million	8.8%
Around the home	3.3 million	18.2%
(US Residents 16 years old and older)		

Source: 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, US Fish & Wildlife Service

More detailed data, including expenditures, day and other information is included on ***TABLE G-15***, below. Most notable are expenditures in the order of magnitude of billions on fishing and wildlife watching.

TABLE G-15: TOTAL WILDLIFE-RELATED ACTIVITIES IN FLORIDA, 2006

Anglers (Fishing)	2,767,000
Days of fishing	46,311,000
Average days per angler	17
Total expenditures	$4,308,583,000
Trip-related	$1,973,985,000
Equipment and other	$2,334,598,000
Average per angler	$1,536
Average trip expenditure per day	$43
Hunters	236,000
Days of hunting	3,769,000
Average days per hunter	16
Total expenditures	$377,394,000
Trip-related	$155,116,000
Equipment and other	$222,278,000
Average per hunter	$1,442
Average trip expenditure per day	$41
Total Wildlife-Watching Participants	4,240,000
Away-from-home participants	1,560,000
Around-the-home participants	3,274,000
Days of participation away from home	16,551,000
Average days of participation (away from home)	11
Total expenditures	$3,081,496,000
Trip-related	$887,942,000
Equipment and other	$2,193,554,000
Average per participant	$720
Average trip expenditure per day	$54

Source: 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, US Fish & Wildlife Service

G.5.2.3 State Tourism Trends

84.5 million domestic and international visitors to Florida per year comprise a significant portion of the overall demand for outdoor recreation resources in Florida. Their participation in resource-based recreation and their relatively high incomes (compared to resident recreationists) make tourists a significant component of project-related recreation in the study area. The Comprehensive Review Study detailed the importance of tourism on the recreation in Florida.

G.5.2.4 Potential Changes in Value of Recreation

The C-111 SC Western project can support a significant amount of outdoor recreation in the Florida Lower East Coast, with a significant portion of expenditures coming from tourists. Based on the recent adverse effects related to environmental damage of the ecosystem, it may be concluded that improving the environmental quality of the ecosystem would substantially support and sustain local recreation-based businesses. Given the potential levels of expenditures and consumer surplus in the future, a small percentage increase in the quantity or quality of project-related recreation could represent an increase in recreation value.

There are potential recreation resources that would be associated directly with the construction of the impoundment. The uses presently considered compatible with resource protection and passive recreation include: freshwater fishing, horseback riding, hiking, off-road bicycling, wildlife viewing and nature study.

G.6 COST EFFECTIVE/INCREMENTAL COST ANALYSIS

Cost effectiveness and incremental cost analyses (CE/ICA) reveal information about good financial investments given the dollar costs and non-dollar outputs ("benefits") of alternative investment choices for an ecosystem restoration project. This analysis is useful in lending support to identifying the National Ecosystem Restoration (NER) plan. The analyses are conducted in a series of steps that progressively identify alternatives that meet specified criteria and screen-out those that do not. Corps Engineer Regulation 1105-2-100 requires cost effectiveness and incremental cost analyses to support recommendations for ecosystem restoration.

A cost effectiveness analysis is conducted to ensure that least cost alternatives are identified for various levels of environmental output. Cost effectiveness analysis begins with a comparison of the annual costs and annual outputs of alternatives to identify the least cost plan for every level of output considered. Alternative plans are compared to identify those that would produce greater levels of output at equal or lower costs than other alternatives. Next, through incremental cost analysis (ICA), the cost effective alternative plans are compared to successively identify the alternative plans with the least additional cost per additional output that is, the plans that are the most efficient in production of output. The results of these calculations and comparisons of costs and outputs between alternative plans provide a basis for addressing the decision question "Is it worth it?" i.e., are the additional outputs worth the costs incurred to achieve them?

This analysis is based on and follows guidance from the USACE Institute for Water Resources publication, Evaluation of Environmental Investment Procedures Manual, Interim: Cost Effectiveness and Incremental Analyses, May 1995, IWR Report #95-R-1. As per this guidance, CE/ICA analysis compares the alternative plans' average annual costs against the appropriate average annual habitat unit

estimates. The average annual outputs are calculated as the difference between with-plan and without-plan conditions over the period of analysis (through year 2050). The following sections present the average annual costs, average annual benefits and the results of cost effectiveness and incremental cost analysis for the alternative plans.

G.6.1 Average Annual Costs

Data for initial construction/implementation, land acquisition, monitoring, and periodically recurring costs for operation, maintenance, repair, replacement, and rehabilitation (O&MRR&R), have been developed through engineering design and cost estimation, and real estate appraisal efforts. Details of that data development are explained and discussed elsewhere in this report. The main issues requiring economic evaluation attention include equivalent time basis calculations, price levels, and timing of project spending.

For purposes of this report and analysis, NED costs (as defined by Federal and USACE policy), are expressed in October 2009 (FY10) price levels, and are based on costs estimated to be incurred over a 40 year period of analysis. Costs of a plan represent the value of goods and services required to implement and operate and maintain the selected alternative plan.

The following table displays the costs associated with the alternatives. The costs presented in ***TABLE G-16*** are preliminary rough order of magnitude (ROM) estimates and include total initial costs of construction features, real estate, Interest During Construction (IDC), and total average annual costs for each alternative. These costs were used to formulate and evaluate plans to identify the Recommended Plan. The costs for the Recommended Plan were further refined based on additional engineering and environmental evaluations, as noted in the main report and can be found in the MCACES cost estimates The O&M cost is an annual estimate for fully implemented components.

The timing of a plan's costs is important. Construction and other initial implementation for component costs cannot simply be added to periodically recurring costs for project operation, maintenance, and monitoring. Also, construction costs incurred in a given year of the project can not simply be added to construction costs incurred in other years if meaningful and direct comparisons of the costs of the different components are to be made. A common practice of equating sums of money across time with their equivalent at an earlier single point in time is the process known as discounting. Through this mathematical process, which involves the use of an interest rate (or discount rate) officially prescribed by Federal policy for use in water resource planning analysis (4 5/8% at the time of analysis), the cost time stream for the alternative plans were mathematically translated into a equivalent time basis value.

There is some admitted uncertainty as to how the plan, if approved and adopted, would be implemented. It is recognized that the plan would likely be implemented over a considerable period of time, little by little. For purposes of this evaluation, construction costs are assumed to be incurred on an equal monthly basis during the implementation of the alternative plan as defined.

ER 1105-2-100 requires that IDC be computed which represents the opportunity cost of capital incurred during the construction period. Interest was computed for construction and PED costs from the middle of the month in which the expenditures were incurred until the first of the month following the estimated construction completion date. Interest during construction was computed for both real estate and construction costs. Interest during construction was computed for the total real estate cost starting from the month prior to construction commencing.

The cost of a project is the investment incurred up to the beginning of the period of analysis. The investment cost at that time is the sum of construction and other initial cost such as real estate and PED cost plus interest during construction. ***TABLE G-16*** summarizes the total investment cost and total annual equivalent costs of each alternative plan.

TABLE G-16: COSTS USED IN COST EFFECTIVENESS FOR PLAN SELECTION

C-111 SC INVESTMENT COST						
	Alt 1C	Alt 1D	Alt 2DS	Alt 2DL	Alt 3D	ALT 6D
Total Construction (Including PED &S/A)	$44,000,000	$47,000,000	$62,000,000	$64,000,000	$72,000,000	$252,000,000
Construction Schedule (Months)	16	16	22	22	24	36
Real Estate	$47,176,000	$67,280,000	$66,375,000	$66,278,000	$68,519,000	$36,894,000
Certification for IDC (Months)	19	19	25	25	27	39
Total First Cost	$91,176,000	$114,280,000	$128,375,000	$130,278,000	$140,519,000	$288,894,000
IDC Construction	$1,350,000	$1,450,000	$2,640,000	$2,730,000	$3,360,000	$64,628,397
IDC Real Estate	$3,500,000	$4,990,000	$6,560,000	$6,546,352	$7,340,000	$5,840,000
TOTAL INVESTMENT	$96,026,000	$120,720,000	$137,575,000	$139,554,352	$151,219,000	$359,362,397
O&M	$706,000	$953,000	$1,201,000	$1,213,000	$1,381,000	$264,000
Period of Analysis	40	40	40	40	40	40
Annualization	$5,312,000	$6,680,000	$7,610,000	$7,720,000	$8,360,000	$19,880,000
Average Annual Cost	$6,018,000	$7,633,000	$8,811,000	$8,933,000	$9,741,000	$20,144,000

G.6.2 Ecological Evaluation

In practice, USACE ecosystem restoration studies typically measure the ecosystem benefits of alternative plans in terms of physical dimensions (number of acres of wetlands, for example), or population counts (number of wading birds, for example), or various habitat-based scores (habitat units based on the FWS's Habitat

Evaluation Procedures, or "HEP", for example). This study uses habitat units that represent the ecological lift achieved by each alternative. In accordance with policy, the economic analysis of environmental restoration projects does not use monetary benefits when comparing alternative plans. Rather, environmentally quantified benefits are used.

Habitat units are basically the product of acreage and a Habitat Suitability Index (HSI). The HSI is scaled from 0 to 1, with 1 being a pristine acre. The with-project and without-project habitat units are calculated and the difference between the two is known as the habitat unit lift. This habitat unit lift is the primary benefit used by economists in the CE/ICA to determine best buys and cost-effectiveness among possible alternative plans.

A more thorough discussion of the habitat unit evaluation is located in Appendix C and a detailed description of the project features can be located in Appendix F.

G.6.2.1 Average Annual Benefits

CE/ICA requires a comparison of average annual costs and average annual benefits. The average annual outputs were calculated as the difference between with-plan and without-plan conditions over the period of analysis (through year 2050). The period of analysis for benefit amortization that was utilized is 40 years. The base year, or the first year benefits begin to accrue, is in 2010. The average annual habitat unit lift is calculated as subtracting the future without project habitat units from the future with project habitat units for each year and averaging over the life of the project, which in this case is 40 years. Note that the output values shown reflect the differences between without project and with project on an average annual basis (i.e., ecological "lift" provided by each of the alternatives).

The analysis of ecological response times for large, diverse ecosystems is extremely difficult to calculate. For example, when analyzing an estuarine system, certain attributes would have to be examined when predicting the response to changes in salinity. Oysters may provide responses within a year of salinity change towards normal conditions. Seagrasses would normally respond quickly, but these responses are difficult to measure since there would be relocation of certain populations in response to specific currents and salinity concentrations. Small invertebrate and fish species should respond quickly; however, large vertebrate species would take longer to increase as they take longer to mature and reach reproductive ages.

The same difficulty occurs in the examination of freshwater systems. Different attributes, such as sawgrass marshes, periphyton mats, and bayheads respond differently in time to changes in hydroperiods and hydropatterns. Sawgrass marshes are in intense competition with other grasses, sedges and freshwater marsh species. Changes in the content of certain species could occur fairly rapidly

in certain areas; however, the competition of populations and/or communities in others areas could take a much greater amount of time for species, populations and communities to become established. As such, the team took a linear approach to predict ecological response time for the three combined Performance Measures for both future without and future with project conditions. The ecological response time was estimated to be 10 years until full impact was realized.

The average annual habitat unit lift can be seen in ***TABLE G-17*** below.

TABLE G-17: AVERAGE ANNUAL HABITAT UNIT LIFT FOR SELECTED ALTERNATIVES

	Habitat Units (HU)	Average Annual HU Lift
Existing Condition (2010)	159,087	
Future Without (2050)	155,202	
Alternative 1C	150,674	-3921
Alternative 1D	152,427	-2402
Alternative 2DS	164,755	8271
Alternative 2DL	162,911	6675
Alternative 3D	162,758	6543
Alternative 6D	164,678	8205

G.6.3 Cost Effectiveness Analysis

Cost effectiveness analysis begins with a comparison of the annual costs and annual outputs of alternatives to identify the least cost plan for every level of output considered. Alternative plans are compared to identify those that would produce greater levels of output at equal or lower costs than other alternative plans. The three criteria for cost effectiveness screening:

1. The same output level could be produced by another plan at less cost;
2. A larger output level could be produced at the same cost; or
3. A larger output level could be produced at less cost.

The CE process involves arraying alternatives by increasing costs with their corresponding output. ***TABLE G-18*** displays the final array of alternative utilized in the C-111SC cost effectiveness analysis.

The lowest cost plan with positive output was identified as the first cost effective plan, in this case Alternative 2DS. The next plan (Alternative 2DL) was then compared against this plan. Since Alternative 2DS contains greater output than Alternative 2DL, this plan was not identified as cost effective. The remaining plans were then be evaluated against this plan and so on. As can be seen from this analysis only one plan (Alternative 2DS) was identified as cost effective.

TABLE G-18: FINAL ARRAY OF ALTERNATIVE UTILIZED IN THE C-111SC COST EFFECTIVENESS ANALYSIS

Alternative	Avg. Ann. Cost	Habitat Units	Cost Effective
Alternative 1C	$6,018,000	-3,921	No
Alternative 1D	$7,633,000	-2,402	No
Alternative 2DS	$8,811,000	8,271	Best Buy
Alternative 2DL	$8,933,000	6,675	No
Alternative 3D	$9,741,000	6,543	No
Alternative 6D	$20,144,000	8,205	No

The following graph contains a visual depiction of the cost effectiveness analysis. The graph plots the output of each plan against the cost of each plan.

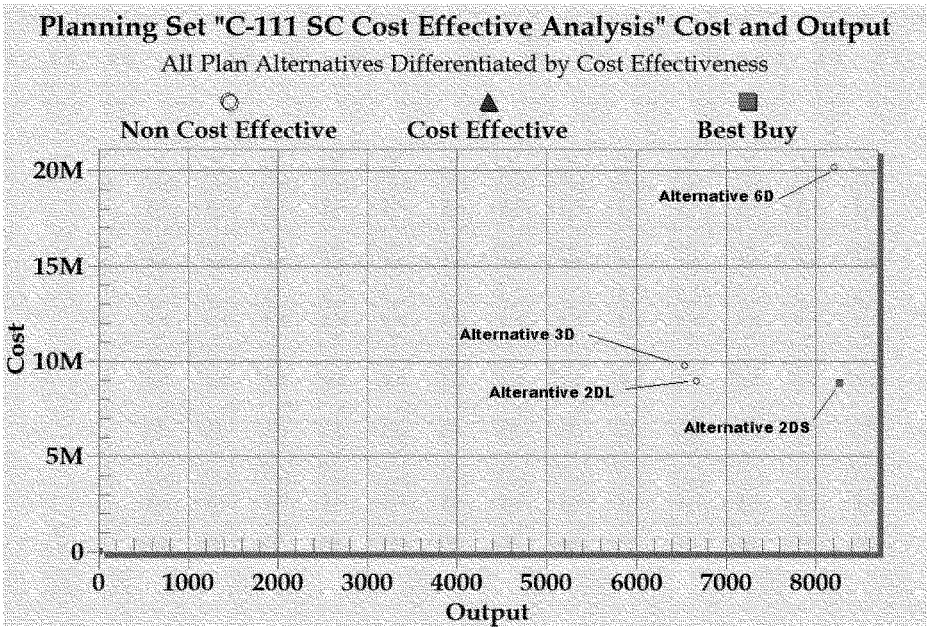


FIGURE G-7: C-111 SPREADER CANAL ALTERNATIVE PLANS–CE/ICA RUN

G.6.4 Incremental Cost Analysis

This section presents the results of incremental cost analysis for the C-111 SC Western project alternative plans for the optimization of the site. From the remaining cost effective alternatives, the plan with the lowest incremental costs per unit of output of all plans is the first best buy plan (Alternative 2DS). For C-111SC only one plan was identified as cost effective alternative.

TABLE G-19: FINAL ARRAY OF ALTERNATIVE UTILIZED IN THE C-111SC BEST BUY ANALYSIS

Alternative	Avg. Ann. Cost	Habitat Units	AAC/Habitat Unit	Cost Effective
Alternative 2DS	$8,811,000	8,271	$1,065	Best Buy

TABLE G-20 shows these results of the incremental cost analysis. The only best buy plan, Alternative 2DS, exhibits an incremental cost of $1,065 per habitat unit, delivering a total of 8,271 average annual habitat units.

TABLE G-20: RESULTS OF INCREMENTAL COST ANALYSIS: BEST BUY PLANS ARRAYED BY INCREASING OUTPUT BY INCREASING OUTPUT FOR COMBINED HABITAT (ALL PLANS)

Alternative	Average Annual Cost	Output	Average Cost Per Output	Incremental Average Annual Cost	Incremental Output	Incremental Cost Per Output
2DS	$8,811,000	8,271	$1,065	$8,811,000	8,271	$1,065

G.6.4.1 Summary of Cost Effective/Incremental Cost Analysis

As can be seen in the following table, Alternatives 2D is both cost effective and a best buy. None of the other alternative are cost effective.

TABLE G-21: RESULTS OF CE/ICA

Alternative 1C	Alternative 1D	Alternative 2DS	Alternative 2DL	Alternative 3D	Alternative 6D
		Cost Effective/ Best Buy			

Alternatives 2DS is identified as a plan of interest and warrant further analysis. Alternative 2DS is recognized as the plan that is most efficient in the production of habitat units.

G.7 REGIONAL ECONOMIC IMPACTS

G.7.1 Overview

This chapter examines the potential effects of the SAP on the RED account. The RED account registers indirect and secondary effects to the region that are expected to result from the direct economic effects of the alternative plans. Direct economic effects represent the impacts of economic stimuli in terms of changes in regional industrial output, earnings, or employment. Indirect economic impacts represent the resultant economic changes in the industries that support and rely upon the industries directly affected by the stimuli. In addition, induced economic impacts are those impacts experienced by all local industries as direct and indirect effects alter household income and ultimately change local household spending patterns.

G.7.2 Methodology

A regional input-output model, *IMPLAN*, was used to estimate the RED effects of the C-111SC Recommended Plan. Regional input-output (I-O) analysis provides the classic tool for tracing economic impacts throughout the regional economy. Based on the region's industrial structure, I-O analysis tracks the expected inter-industry flow of goods and services. For the RED analysis, the regional economy was defined as encompassing Miami-Dade County using *IMPLAN*. Using county-level economic data, which was procured from the software vendor, the model was used to estimate the economic effects of the SAP on wages, employment, and production output (sales). Specifically, *IMPLAN* was employed in a four-part methodology to: (1) describe the study area economy, (2) create economic scenarios, (3) introduce economic changes, and (4) estimate resulting direct, indirect, and induced economic effects.

G.7.2.1 Real Estate and Effects of Other Land Acquisitions

Real estate sales may result in various impacts to the local economy. The sale of land may be regarded as a simple change in which the owner held the value in real estate and now holds an equal value in cash. If the cash is spent locally or reinvested in regional enterprise, then new economic activity might be stimulated in the region and even more funds might be leveraged by the enterprise.

Alternatively, a real estate transaction resulting in a transfer of funds into a regional bank may experience a general economic expansion in the region as supported through the banking multiplier if the funds are invested locally. If, however, there is foreign or corporate land ownership, then the expansionary effects of large transfers of funds may not occur in the study area. A similar result would occur if funds were held in a foreign bank. Additionally, if the land is owned by a governmental agency, then it may just be a land transfer resulting in very little regional economic effect.

Due to the ambiguity of the ultimate use of real estate funds, the expenditures on land were not input into the IMPLAN model. Therefore, the regional impacts of real estate purchases were assumed to be minimal and not calculated. If it were possible to know more about the future use of these funds, expenditures for land, commissions, leases, appraisal fees, title fees, and other administrative activities involved with real estate, those values could be used in the *IMPLAN* analysis or another model. However, even with a higher degree of certainty regarding the future of this knowledge, it is anticipated that the financial inputs would be marginal, and any regional impact model would have significant reliability concerns.

The total construction expenditures are listed in ***TABLE G-16***.

G.7.3 IMPLAN Regional Economic Effects Results

In ***TABLE G-22***, the direct economic effects and aggregated indirect and induced economic effects are presented for the selected alternative plan. RED effects have only been calculated for construction expenditures and not for changes resulting from impacts to navigation, water usage, flood control or real estate expenditures. Economic impacts to total industry output and employee compensation are expected to persist through each year of construction. Wages include salaries, non-wage compensation, and benefits. Employment is measured as the number of jobs, not necessarily full-time equivalents.

TABLE G-22 and ***TABLE G-23*** present the *IMPLAN* output for direct, indirect, and induced impacts of the SAP on employee compensation and regional output (sales), and

TABLE G-24 provides an indicator of the employment effects of the construction expenditures. These impacts account for less than one percent of total economic activity in each of the different output categories.

TABLE G-22: DIRECT, INDIRECT AND INDUCED IMPACTS ON EMPLOYEE COMPENSATION AS A RESULT OF IMPLAN MODEL RUNS (2006 DOLLARS)

	Direct	Indirect	Induced	Total
Alternative 2DS	$26,618,000	$6,588,000	$6,262,000	$39,468,000

TABLE G-23: DIRECT, INDIRECT AND INDUCED IMPACTS ON REGIONAL OUTPUT AS A RESULT OF IMPLAN MODEL RUNS (2006 DOLLARS)

	Direct	Indirect	Induced	Total
Alternative 2DS	$62,000,000	$18,648,000	$20,510,000	$101,158,000

TABLE G-24: DIRECT, INDIRECT AND INDUCED IMPACTS ON EMPLOYMENT AS A RESULT OF IMPLAN MODEL RUNS (2006 DOLLARS)

	Direct	Indirect	Induced	Total
Alternative 2DS	415	165	172	752

G.8 OTHER SOCIAL EFFECTS

G.8.1 Overview

The OSE account considers the effects of alternative plans in areas that are not already contained in the NED and RED accounts. The categories of effects contained within the OSE account include:

- Urban and community impacts
- Life, health, and safety factors
- Displacement

G.8.2 Potential Urban and Community Impacts

An urban and community impact is the principal category of potential OSE impacts associated with the alternative restoration plans. This category of impacts includes effects on income distribution, employment distribution, population distribution and composition, and quality of community life. Some urban and community impacts have previously been addressed in this appendix. For example, regional income effects and fiscal impacts were discussed in the RED analysis. In addition, the impacts of agricultural water supply and M&I water supply were discussed in detail in earlier sections. The OSE assessment of urban and community impacts considers both the potential for exposure to the effects of the alternative restoration plans and the degree of vulnerability to potential impacts. Exposure refers to whether an individual or community is subject to the OSE of the alternative plans. Vulnerability refers to the ability of that individual or community to respond or adjust to those effects.

Potential urban and community impacts of the alternative restoration plans could result from: (1) land acquisition and potential relocation of populations for reservoir and other project construction features, (2) reduced agricultural activity associated with taking the reservoir lands out of cultivation, and (3) construction activity associated with plan implementation. In general, construction activity is considered to have positive impacts. At the local scale, construction and O&M activities associated with the alternative restoration plans can have positive effects to local residents and communities by providing jobs, increasing local wages, increasing local sales, increasing tax revenues and generally benefiting the local economy.

There are a variety of social and economic factors that are important determinants of an individual or community's ability to cope with adversity. One of the most important economic factors in the ability of individuals and groups to respond is the number of employment alternatives available locally. The ability to find another job depends on the education and training of the work force as well as the needs of local economic concerns, such as other farms, agricultural-related services, or some other local business. The socio-economic makeup of the community is also an important consideration of the ability of individuals and the community at large to cope with the adverse effects of large-scale agricultural land conversion. Some groups in society are recognized as having less opportunity to respond to adversity. These groups include ethnic and racial minorities, the elderly, and the poor. ***TABLE G-25*** presents a socio-economic vulnerability profile for the local counties. This profile contains information that indicates the ability of the county population to respond to social and economic adversity. It is important to recognize that the county scale may not accurately reflect the ability of any given community or groups within a

community to accommodate potential changes associated with the alternative restoration plans.

TABLE G-25 contains the 2006 racial/ethnic mix of each county in the study area, as well as population over 65 years of age, unemployment, 2005 per capita income, and the expected changes in employment and income.

The surrounding counties have a wide range of ethnic compositions, proportions of elderly population, unemployment rates, and per capita incomes. These socio-economic characteristics suggest that the rural counties of the study area– those that are expected to provide locations for new storage reservoirs– are areas that are least able to accommodate the associated economic and social effects on local communities. However, in these rural areas the affected populations should be relatively small.

Although the restoration of the estuaries and construction of the reservoir is a unique undertaking, there have been other projects and programs with similar goals and socio-economic contexts. One study conducted by the U.S. Department of the Interior assessed the national and regional economic impacts of not allowing timber harvests in certain old-growth forests in Oregon in order to protect the northern spotted owl. One aspect of this study investigated the re-employment of timber workers who had been displaced by the cessation of local logging activities. Surveys of displaced loggers suggested that they found that 57 percent of displaced workers reported post-displacement wages equal to or above their previous wages. According to the bureau of labor statistics, 92 percent of displaced workers find new jobs within one year, and the remaining eight percent find jobs within two years.

TABLE G-25: 2005 C-111SC (2006) SOCIO-ECONOMIC VULNERABILITY PROFILE

	Asian	White	Black	American Indian	Hispanic	Population Over 65	Unemployment	2005 Per Capita Income**	Percent of Population Below Poverty Level (2004)
Miami-Dade County	1.5%	77%	20%	0.3%	61.3%	14.2%	3.8%	$31,347	17.1%

When running the model, there were five alternatives considered. For each alternative, this analysis estimated the regional impacts of construction costs of the C-111 SC Western project. Therefore, each alternative's regional impact analysis provided Employment, Outputs and Total GRP (Gross Regional Product) estimates for the construction expenditures. Real estate costs were not calculated in the

model due to the complexity and uncertainty in predicting if there are benefits, and if so, how many.

G.8.2.1 Employment

Employment is quantified in terms of years of employment. It is important to note that these are not indefinitely recurring years of employment, but rather single, non-recurring years of employment. While the project will undoubtedly generate some permanent recurring jobs the vast majority of labor will be hired during the actual construction phase only. This can be observed on the tables below by comparing the employment figures for the first four years with those for the following seven years.

G.8.2.2 Output

Output is quantified as total gross sales. This includes all sales that are a direct or indirect result of the project expenditures. Gross sales include the total sales of producers, intermediaries, wholesalers and retailers. While this is a classic indicator of economic activity it is important to remember that this indicator includes 'double counting' of economic activity. That is, the production, distribution and consumption of any given product are counted every time it is sold throughout the chain of production and consumption, even if there is very little actual value added. This is contrasted with total GRP.

G.8.2.3 Total Gross Regional Product

Total GRP is an economic measure of the total returns to the factors of production: land, labor and capital. GRP measures only the total value of end-user products and services. By doing so GRP measures only value-added and avoids double counting products and they move through the production and consumption process.

The regional economic effects for the selected alternative plans are presented on the following tables. RED effects have only been calculated for construction and O&M expenditures and not for changes resulting from impacts to navigation, water usage, flood control or real estate expenditures. Economic impacts to total industry output and employee compensation are expected to persist through each year of construction.

TABLE G-26 shows the 38-year total impacts for the five alternative plans, in millions of 2008 dollars. This is an overall summary of the regional economic impact of the five alternative plans. The table presents economic impacts for Miami-Dade County, the rest of Florida (exclusive of Miami-Dade), and total Florida (inclusive of Miami-Dade), respectively. Since a large proportion of the impact occur during the first two years (the construction period), the two year total impacts are also included on the table.

G.8.2.4 Comparison of Plans' Economic Impact to Overall Economic Activity

These outputs are meaningless, unless there is a relative comparison of what this means for the regional economy. To demonstrate the importance of these effects, the estimations were compared to the county employment and GRP. Data were not available for county-level gross sales output.

TABLE G-26: COMPARISON OF PLANS' ECONOMIC IMPACT TO OVERALL ECONOMIC ACTIVITY

	Current	Plan	Project Impact	%
Employment Years	1,158,801	1-C	1361	0.12%
(38 Year Totals)		1-D	1606	0.14%
		2-D	2288	0.20%
		3-D	2480	0.21%
		6-D	9341	0.81%
Gross Regional Product	$97,200.0	1-C	$165.1	0.17%
(38 Year Totals)		1-D	$199.2	0.20%
(In Millions)		2-D	$278.7	0.29%
		3-D	$300.4	0.31%
		6-D	$922.1	0.95%

It can clearly be seen that the magnitude of the impact of the proposed plans on the overall economy of Miami-Dade County is very small. Only Alternative 6-D of the selected alternative plans' impact would be more than one-third of one percent of the overall Miami-Dade economy. The percentage effect on the overall economy of Florida is so small that it is negligible.

Furthermore, it should be noted that the regional economic impact of the Recommended Plan, Alternative 1-D, is by no means abnormally high. Moreover, these impact will in reality be spread over a 38-year period making the relative importance of their economic impacts in the regional economy that much smaller.

G.8.2.5 Other Social Effects

The Other Social Effects (OSE) account considers the effects of alternative plans in areas that are not already contained in the NED and RED accounts. The categories of effects contained within the OSE account include:

- Urban and community impacts
- Life, health, and safety factors
- Displacement, long-term productivity
- Energy requirements and energy conservation

The C-111 SC Western alternative plans could result in beneficial and adverse OSE within the study area. An urban and community impact is the principal category of potential OSE impacts associated with the alternative restoration plans. This category of impacts includes effects on income distribution, employment distribution, population distribution and composition, and quality of community life.

There are several possible social effects that the C-111 SC Western project could impact. The project has the potential to raise property values in the surrounding area, increase attractiveness to the community, increase recreational opportunities, and improve environmental health such as water and air quality among other impacts. All of these factors could change the surrounding demographics of the community. It may or may not affect Environmental Justice issues.

A major social impact is the change in land available for development. Urban sprawl may have led to this land being used for residential or commercial development. This could reduce the available housing opportunities and possibly raise housing prices. At the same time, since there would be no development on the project site, it could decrease energy demand and improve environmental quality. The footprints of the projects would determine to what extent these impacts could occur.

This project does require a considerably large amount of acres. Despite the large acreage needed, there is currently very little development and population in the immediate project area. Eventually, Miami will probably sprawl towards the project and this could limit available developable land. Any adverse effects social effects will be avoided or mitigated.

G.8.3 Overall Regional Economic Impact Conclusions

All of the selected alternative plans would have some positive effect on employment, gross output and the gross regional product of Miami-Dade County; and to a lesser extent, the State of Florida. The Recommended Plan, (which is the NER plan) will likewise have a positive economic effect on employment, gross output and gross regional product of Miami-Dade County. Moreover any social effects, negligible as they may be, would be entirely positive, improving the quality of life for any affected individuals.

The magnitude of impact, however, is not very large. Based on the analysis and results, it appears that no alternative for C-111 SC Western project, other than Alternative 6-D, would have more than one third of one percent impact on the total regional economy–even less if economic impacts are annualized over a 38-year period as they will actually occur.

G.9 ENVIRONMENTAL JUSTICE

Executive Order (E.O.) 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, requires the federal government to achieve environmental justice by identifying and addressing high, adverse and disproportionate effects of its activities on minority and low-income populations. E.O. 12898, Environmental Justice, states that the proposed action would not result in adverse human health or environmental effects. Any impacts of the action would not be disproportionate towards any minority or low-income population. The activity does not (a) exclude persons from participation in, (b) deny persons the benefits of, or (c) subject persons to discrimination because of their race, color, or national origin. The activity would not impact "subsistence consumption of fish and wildlife." It requires the analysis of information such as the race, national origin, and income level for areas expected to be impacted by environmental actions. It also requires federal agencies to identify the need to ensure the protection of populations relying on subsistence consumption of fish and wildlife, through analysis of information on such consumption patterns, and the communication of associated risks to the public.

Miami-Dade County has a large percentage of people that claim Hispanic origin. Of the 2.25 million residents in the county during the year 2000, over one half are of Hispanic origin. Miami-Dade County also comprises nearly half of the state's Hispanic population. Of the 15,159 population in the study area, 38 percent claim Hispanic roots. Florida's African-American population is 2,333,427, which is 14.5 percent of the State's total population. In Miami-Dade County the African-American population is 457,432, which makes up 20.3 percent of the county's population. The study area has a population that is 21 percent African-American (3,073). The Native-American population of the study area represents less than one percent of the aggregate population of the study area (71 persons).

The C-111 SC Western project would provide benefits to the quality of life by improving the natural environment. The project features of wetland restoration and improved water discharge are by design in locations remote from urban populations such that negative impacts are eliminated for all communities. In public outreach efforts to date, no potential environmental justice issues have been identified.

The project features are located based upon hydrologic characteristics, land availability and inter-connection to existing canals and structures to optimize operations. Furthermore, in the consideration of the project site, urban areas are avoided to eliminate the negative impacts typically associated with site location of large projects. Through "willing seller agreements" a variety of land rights have been or will be acquired that allow the use of land for the resulting improvements to the human quality of life and the intended environmental benefits intended by the impoundment.

These environmental benefits provide quality of life improvements to all people and primarily to people in the communities within the study area. By the nature of design, this operating procedure will maintain if not improve flood damage reduction. This would improve the quality of human life by providing increased wildlife activity; a special bonus for those who appreciate seeing increases in fish and bird populations. This logically translates to the increased benefits in enjoyment, aesthetics, and economics for recreational activities.

G.10 REFERENCES

Bureau of Economic and Business Research, 1997 Florida Statistical Abstract. Tallahassee, Florida. 1997.

Florida Department of Environmental Protection. Outdoor Recreation in Florida, Florida's Statewide Comprehensive Outdoor Recreation Plan. 1994.

Florida Department of Environmental Protection. Outdoor Recreation in Florida, Florida's Statewide Comprehensive Outdoor Recreation Plan. 2000.

Florida Department of Environmental Protection and the Florida Greenways Coordinating Council, Connecting Florida's Communities with Greenways and Trails, September 1998

Florida Tourism Industry Marketing Corporation. 1996 Florida Visitor Study. Tallahassee. 1997.

Milon, J.W. Thunberg, E. A Regional Analysis of Current and Future Florida Resident Participation in Marine Recreational Fishing. Florida Sea Grant Report #112. University of Florida, Gainesville. 1993.

National Parks and Conservation Association. The Economic Importance of National Parks: Effects of the 1995-1996 Government Shutdowns on Selected Park-Dependent Businesses. 1997.

National Park Service. National Park Service Statistical Abstract. 1995.

Outdoor Recreation Coalition of America. Emerging Markets for Outdoor Recreation in the United States. Results of the National Survey of Recreation and the Environment. 1997.

Planning and Management Consultants, Ltd. (PMCL), IWR-MAIN Water Demand Analysis Software User's Manual and System Description, April 1995.

Recreation Roundtable. Outdoor Recreation in America 1997. Prepared by Roper/Starch. Washington, D.C. 1998.

Snyder, G.H. and Davidson, J.M. "Everglades Agriculture: Past, Present, and Future" in Everglades: The Ecosystem and Its Restoration. S.M. Davis and J.C. Ogden (Eds.). (1994): 85-115.

South Florida Water Management District. Draft Documentation for the South Florida Water Management Model. West Palm Beach. 1997a.

South Florida Water Management District. Twenty-Year Evaluation: Economic Impacts from Implementing the Majory Stoneman Douglas Everglades Restoration Act and United States versus SFWMD Settlement Agreement. Hazen and Sawyer. 1993.

South Florida Water Management District. Water Supply Needs and Sources 1990-2010. July, 1992b.

University of Florida, Bureau of Economic Analysis and Business Research, Florida Population Studies.

University of Florida, Bureau of Economic Analysis and Business Research, The Florida Long-Term Economic Forecasat 1995, Volume 2 – State & Counties.

University of Florida, Bureau of Economic Analysis and Business Research, The Florida Long-Term Economic Forecasat 1997, Volume 2 – State & Counties, September 1997.

U.S. Army Corps of Engineers, Water Resources Support Center, Institute For Water Resources, Cost Effectiveness Analysis for Environmental Planning: Nine EASY Steps. IWR Report 94-PS-2, October 1994.

U.S. Army Corps of Engineers, Water Resources Support Center, Institute For Water Resources, Evaluation of Environmental Investments Procedures Manual Interim: Cost Effectiveness and Incremental Cost Analyses. IWR Report #95-R-1, May 1995.

U.S. Army Corps of Engineers, Ecosystem Restoration in the Civil Works Program. (EC 1105-2-210).

U.S. Army Corps of Engineers, Jacksonville District. Central and Southern Florida Reconnaissance Report: Comprehensive Review Study. (Volume I-III). 1994a.

U.S. Army Corps of Engineers, Natural Resources Technical Support Program, Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996, September 1998

U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census, Estimates of Housing Units, Households, Households by Age of Householder, and Persons per Household, 1998.

U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census, Small Area Income and Poverty Estimates, 1997.

U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census, Statistical Abstract of the United States. 1992.

U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis, Regional Economic Analysis Division, County Projections to 2040, 1992.

U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis, Regional Economic Analysis Division, Regional Multipliers: A user Handbook for the Regional Input-Output Modeling System (RIMS II) , 1992

U.S. Congress, Comprehensive Report on Central and Southern Florida for Flood Control and Other Purposes. House Document No. 643. 6 May 1948.

U.S. Department of Labor. Monthly Unemployment Surveys. Bureau of Labor Statistics. July, 1998.

U.S. Fish and Wildlife Service. National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Department of the Interior. 1996.

Van Os, E., Carroll, J.D., and Dunn, J. Creel Census and the Effects of Freshwater, Waddington, D., Boyle, K., and Cooper, J. 1991 Net Economic Value for Bass and Trout Fishing, Deer Hunting, and Wildlife Watching. Report 91-1. U.S. Fish and Wildlife Service.

APPENDIX H
RECREATION PLAN

TABLE OF CONTENTS

H.0 RECREATION PLAN H-1
H.1 AUTHORITY H-1
H.2 INTRODUCTION TO RECREATION PROPOSED FOR THE C-111 SPREADER CANAL H-1
H.2.1 Proposed Recreation Overview H-2
H.2.2 Recreation Facilities Management Overview H-5
H.3 BENEFIT CATEGORIES H-5
H.3.1 Study Area Recreation Background H-5
H.3.2 Existing Recreation Resources H-6
H.4 PROPOSED RECREATION H-7
H.4.1 Trailhead Entrance and Parking H-7
H.4.2 Multi-use Trails H-8
H.5 RECREATION BENEFITS H-8
H.5.1 National Perspective H-8
H.5.2 State of Florida Perspective and Analysis H-13
H.5.3 Regional Perspective and Analysis H-13
H.6 ECONOMIC JUSTIFICATION OF RECREATION H-16
H.7 REFERENCES H-17

LIST OF TABLES

Table H-1 Study Area Population Through 2050 (1,000) H-7
Table H-2 Trailhead Entrance and Parking Proposal Costs H-8
Table H-3 Guidelines For Assigning Points For General Recreation H-10
Table H-4 Conversion of Points to Dollar Values H-12
Table H-5 Most Likely Recreation Participation User Day Projection Scenario H-15
Table H-6 Summary of Recreation Costs and Benefits H-16
Table H-7 Sensitivity Analysis Using Multiple Scenarios H-16

LIST OF FIGURES

Figure H-1 C-111 Spreader Canal Western Project Implementation Report Recreation Conceptual Plan H-4

H.0 RECREATION PLAN

H.1 AUTHORITY

The Comprehensive Everglades Restoration Plan (CERP), authorized by the Water Resources Development Act of 2000 (WRDA 2000), will involve modifying the Central and Southern Florida (C&SF) project, which was constructed with extensive Congressional authorizations from the 1944 Flood Control Act to the WRDA 1996. The Federal Water Project Recreation Act (P.L. 89-72) and the WRDA 1986 (P.L. 99-662) provide guidance for recreation proposals on Federal projects. A specific CERP design guidance was signed on May 12, 2000, in the form of the Department of the Army and South Florida Water Management District (SFWMD) Design Agreement for Everglades and South Florida Ecosystem Restoration Project (SFERR).

Additional authorization and guidance for the proposed ancillary recreation resources development is contained in the CECW-AG, 11 June 1998 Memorandum, Policy Guidance Letter No. 59, Recreation Development at Ecosystem Restoration Projects and EP 1165-2-502. Despite austere budgets and policy requirements, recreational developments can and do contribute to community health and well being (CECW, 1998). The recreation resources that are being proposed as part of the CERP C-111 Spreader Canal (C-111 SC) Western project will comply with the philosophy and inclusion of the CESAD-PD-J 15 SEP 2004 Memorandum, are economically justified, and fall within the ten percent rule.

H.2 INTRODUCTION TO RECREATION PROPOSED FOR THE C-111 SPREADER CANAL

The recreation appendix for the C-111 SC Western project implementation report (PIR) contains a description of the proposed recreation elements and conceptual plan. The objective of the proposed recreation concept is to identify the restoration compatible recreation that is ancillary and complimentary to the proposed project (refer to ***FIGURE H-1).*** The recreation elements proposed are incidental benefits and would not be used in the justification of the recommended plan. Rough Order of Magnitude (ROM) costs have been provided by the SFWMD and have been included in the U.S. Army Corps of Engineers (USACE), Jacksonville District, Microcomputer Aided Cost Engineering System (MCASES) costs. A determination of recreation facility design standards to meet USACE and local building code requirements is underway. The SFWMD would operate and maintain the proposed recreational features. Adjustments may be made to the dollars spent depending on Congressional funding, sponsor budget, and project design. The costs for proposed recreation features would be $165,000. An additional 12 percent for planning, engineering and design (PED),

and an additional eight percent for construction supervision and administration (S&A) bring the estimated total costs for recreation to $198,000.

H.2.1 Proposed Recreation Overview

The C-111 SC Western Project Recommended Plan (Alternative 2DS) would include the following features:

1. 590 Acre Frog Pond Detention Area (FPDA) with a maximum pool depth of 3 feet – includes pump to intercept available water
2. Pump Upstream of S-177 to discharge into the Aerojet Canal and Connector canal between the pump and Aerojet Canal
3. One new operable structure in the lower C-111 Canal
4. Incremental operational changes at S-18C
5. One plug at S-20A
6. Operational changes at S-20
7. 10 plugs in the C-110 Canal
8. Recreational Components
9. Project Monitoring Plan
10. Draft Project Operating Manual
11. OMRR&R

The recreation plan would be incorporated into the first two features, namely the FPDA and the Aerojet Canal. The recreation facilities proposed would include: a trailhead with vehicular parking, traffic controls (entrance gate and fencing), a shade shelter with an interpretive board, and approximately 6.8 miles of designated multi-use levee trails atop impoundment cell levees. An entrance gate and fencing would be used to control access to the trailhead facilities. All levees would provide access for hiking, bike riding, bank fishing, wildlife watching, and environmental interpretation with no associated recreation cost. Filled impoundment levee corners would provide ample areas for visitor to congregate to bird watch, bike, and hike. Hiking and biking use on the levee crowns would not affect the levee crown integrity enough to propose paving or soil cement. Hunting may be proposed based on permit and management coordination with Florida Fish & Wildlife Conservation Commission (FWC). It is envisioned proposed project structures would provide pedestrians access to loop trails around the impoundments on the levees.

Proposed recreation facilities and activities would be ancillary to the proposed C-111 SC Western project and work harmoniously with project purposes. The proposed project recreation facilities would help to fill four Statewide

Comprehensive Outdoor Recreation Plan (SCORP) regional deficits and link with other regional recreation facilities. An example of this concept would be to link the proposed project component recreation sites via greenway or blueway to connect and extend points of destination with federal, state, county and private facilities. An international pool of visitors may be expected at the proposed project recreation facilities.

No additional real estate would be required for the proposed recreation features since all proposed features would be located on project fee title lands. The real estate is to be verified in the ***REAL ESTATE APPENDIX*** of the C-111 SC Western PIR. All recreation features would be compatible with the environmental goals and objectives of the proposed project, and would not detract from the environmental or socioeconomic benefits generated by the proposed project.

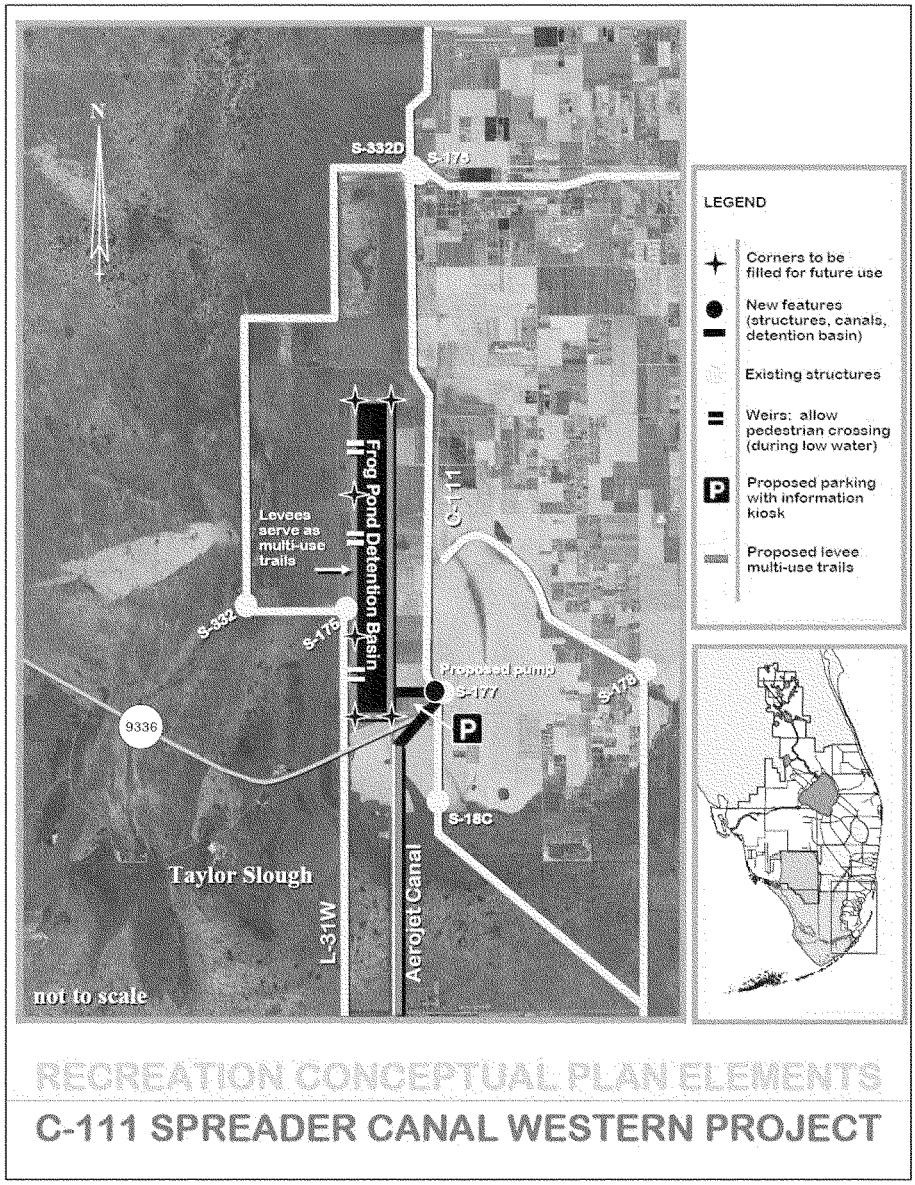


FIGURE H-1: C-111 SPREADER CANAL WESTERN PROJECT IMPLEMENTATION REPORT RECREATION CONCEPTUAL PLAN

H.2.2 Recreation Facilities Management Overview

The SFWMD would be responsible for 100 percent of the recreation operations, maintenance, repair, rehabilitation and replacement (OMRR&R) as outlined in the USACE *Planning Guidance Notebook* (Engineering Regulation [ER] 1105-2-100, Apr 2000, page E-286), the USACE/SFWMD *Design Agreement,* May 2000 and the USACE 29 Sept 2005 OMRR&R Memorandum.

Public access for passive recreation is planned for the proposed restoration project recreation component. Concerns have been expressed regarding the potential unlawful or ecologically harmful affects of passive use within this and other CERP projects. As a result, the SFWMD, through their rulemaking authority, has created Rule 40E-7 F.A.C. The Rule contains enforcement provisions for oversight by wildlife officers or other law enforcement officials to ensure that unlawful or ecologically harmful actions do not occur. The rule has general language applicable to all SFWMD owned lands and several special provisions for different types of land use including recreation. These rules allow the SFWMD to address hours of public access, the ability to allow or prohibit different activities in different areas or at different times, and the overall ability to close public access at any time there are emergencies, pending storms or routine operations and management needs or ongoing protection of the land.

H.3 BENEFIT CATEGORIES

H.3.1 Study Area Recreation Background

The proposed C-111 SC Western project recreation benefit analysis study area includes the counties of Miami-Dade, Broward and Monroe as outlined in the Florida SCORP (SCORP, 2000) Region 11. The SCORP is utilized to identify the recreation baseline for CERP recreation planning. Recreation deficits identified by the SCORP for this region include; bicycle riding, tent camping, hiking, hunting, freshwater beach activities, freshwater fishing and saltwater beach activities. A SCORP statewide needs assessment through 2010 identifies these deficits and the unit need for each recreation element (i.e., miles of trail, number of camp sites). The SCORP deficits for bicycle riding, hiking, freshwater fishing (non-boat) and hunting (managed) activities are considerations for the C-111 SC Western project recreation proposal.

The population growth of south Florida would only add to the calculated existing recreation deficits. The proposed recreation study also typically considers outside study influences from surveys and other documented and respected sources. Population projections per Census 2000 are presented in ***TABLE H-1.***

H.3.2 Existing Recreation Resources

Existing recreational facilities within the SCORP Region 11 provide ideal recreation resources for linkages and bundling with the proposed C-111 SC Western project. Recreation facilities within the C-111 SC Western study area and three-county area include: the Biscayne National Park, Everglades National Park (ENP), Florida Keys National Marine Sanctuary, Crocodile Lake National Wildlife Refuge, five fish management areas, five wildlife management areas, 12 State of Florida greenways and trails projects, 15 State of Florida Parks, 32 Florida Communities Trust Sites and many State of Florida Artificial Reef Program 2000 local projects (SCORP, 2000). The Miami-Dade County website reports 189 parks in the county area (www.miamidade.gov/parks).

Recreation facilities within the more immediate C-111 SC Western project area include: ENP, Glen Garret Park, the Frog Pond Wildlife Management Area, Crocodile Lake National Wildlife Refuge, Canals L-30 and L-31 Fish Management Areas, Southern Glades Wildlife Management Area, A.D. Barnes Park, West Kendall District Park, in addition to approximately 50 other Miami-Dade County parks and greenways. Some of these facilities charge a park entrance fee but most are open to the public free of charge. Additionally, the Florida Fish and Wildlife Conservation Commission (FWC) provide five freshwater boatramps in Miami-Dade, four in Broward and none in Monroe County (www.myfwc.com). Additionally, parts of the C-111 SC Western project area include large tracts of lands managed by public agencies and private companies as parks and mitigation areas to the south and west of the study area.

TABLE H-1: STUDY AREA POPULATION THROUGH 2050 (1,000)

	2000	2010	2020	2030	2040	2050
Broward	1,623	1,931	2,257	2,562	2,745	2,947
% Change		0.91%	0.86%	0.95%	0.90%	0.90%
Miami-Dade	2,253	2,554	2,862	3,480	3,499	3,810
% Change		0.94%	0.89%	0.95%	0.91%	0.92%
Monroe	81	82	84	85.9	88	90
% Change		0.98%	0.97%	0.99%	0.97%	0.97%
Region Totals	3,957	4,567	5,203	6,128	6,332	6,847
Florida	15,982	18,866	21,792	24,528	27,118	29,714
Study Area % of Florida Population	24.7%	24.2%	23.8%	24.9%	23.3%	23.0%
United States	295,531	308,936	335,805	363,584	391,946	419,854
Study Area % of United States Population	1.43%	1.48%	1.54%	1.57%	1.61%	1.64%
Florida growth rate		8.90%	8.58%	9.44%	8.86%	8.98%
US growth rate		0.91%	0.83%	0.79%	0.78%	0.71%

Source: BEBR Projections, US Census (2000)

H.4 PROPOSED RECREATION

H.4.1 Trailhead Entrance and Parking

The main recreation component proposed for the C-111 SC Western project is the entrance trailhead and parking area which will be located at the construction staging area location for the proposed project. The staging area is tentatively planned for the southern area of the project Frog Pond Detention Area. Public access via the construction access road would be finalized once the construction access route is confirmed. The trailhead entrance road and parking would be on the north side of State Road 9336 (Ingraham Highway) between the L-31W Canal and the proposed Frog Pond Detention Area. The trailhead entrance and parking facilities would be in open view as the project lands are accessed from the highway via construction access route. The proposed recreation trailhead area would utilize the former project construction staging area for parking. General parking and paved handicapped parking to include a paved path to an information kiosk/shelter are proposed on the south side of the Cell S Impoundment area. A shade structure, shade trees, entrance gate and fencing would also be located in this area. Equestrian use would be staged in this area and would be allowed on the project lands but restricted on the levees.

The preliminary cost estimate for the entrance and perimeter canal recreation area is estimated at $213,000 as shown in ***TABLE H-2***.

TABLE H-2: TRAILHEAD ENTRANCE AND PARKING PROPOSAL COSTS

Feature	Quantity	Unit Cost	Total Cost
Shade Shelter 10' x 20'	1	$33,000	$33,000
Information Kiosk	1	$23,000	$23,000
Paved Handicapped Parking Area (includes path to shade shelter)	1 Unit	$83,000	$83,000
Park Security Gate	1 Unit	$38,000	$38,000
Fencing	Lump Sum	$18,000	$18,000
Landscaping (Trees)	Lump Sum	$18,000	$18,000
Entrance Trailhead Site Total			**$213,000**

*USACE, Broward County Wildlife Preserve Area November 2006 and SFWMD provided costs. USACE escalated to 2011

H.4.2 Multi-use Trails

Multi-Use Trails would be established on the Levees of the Frog Pond and Aerojet Canal Detention Areas. Public access to the proposed Multi-Use Trails would occur from the above-noted Parking Area. Specific details will be refined once project designs are finalized. Paving the levee crowns is not planned as light recreation uses of walking and biking are not envisioned to degrade the levee crown integrity. Bank fishing would be provided along the Aerojet Canal levees. The FPDA would not be of considerable depth to maintain fish populations for fishing activities. No costs are associated with the designated levee trails. OMRR&R costs would cover trash pickup, mowing and facility repair, rehabilitation and replacement.

H.5 RECREATION BENEFITS

H.5.1 National Perspective

The national economic development (NED) benefit evaluation procedures contained in ER 1105-2-100 (22 Apr 00), Appendix E, Section VII, include three methods of evaluating the beneficial and adverse NED effects of project recreation: travel cost method (TCM), contingent valuation method (CVM), and unit day value (UDV) method.

The unit day value method was selected for estimating recreation benefits for the C-111 SC Western project. When the unit day value method is used for economic evaluations, planners will select a specific value from the range of

values provided annually. Application of the selected value to estimate annual use over the project life, in the context of the future with- and future without project framework of analysis, provides the estimate of recreation benefits.

The future without project condition analysis for the C-111 SC Western project does include some existing recreation value as lands within the project area provide access for biking, hiking, fishing, birdwatching and FWC managed hunts. The future with-project condition would add to this expected value of the recreational activity based on the unit day value method. ***TABLE H-3*** illustrates the method of assigning a point rating to a particular general recreation activity. The table shows the point values assigned based on measurement standards described for the five criteria of activities, facilities, relative scarcity, ease of access, and aesthetic factors.

TABLE H-3: GUIDELINES FOR ASSIGNING POINTS FOR GENERAL RECREATION

Criteria	Judgment factors				
Recreation experience[1] Total Points: 30 Point Value: 13	Two general activities[2] 0-4	Several general activities 5-10	Several general activities: one high quality value activity[3] 11-16	Several general activities; more than one high quality high activity 17-23	Numerous high quality value activities; some general activities 24-30
Availability of opportunity[4] Total Points: 18 Point Value: 6	Several within one hour travel time; a few within 30 minutes travel time 0-3	Several within one hour travel time; none within 30 minutes travel time 4-6	One or two within one hour travel time; none within 45 minutes travel time 7-10	None within one hour travel time 11-14	None within two hour travel time 15-18
Carrying capacity[5] Total Points: 14 Point Value: 8	Minimum facility for development for public health and safety 0-2	Basic facility to conduct activity(ies) 3-5	Adequate facilities to conduct without deterioration of the resource or activity experience 6-8	Optimum facilities to conduct activity at site potential 9-11	Ultimate facilities to achieve intent of selected alternative 12-14
Accessibility Total Points: 18 Point Value: 11	Limited access by any means to site or within site 0-3	Fair access, poor quality roads to site; limited access within site 4-6	Fair access, fair road to site; fair access, good roads within site 7-10	Good access, good roads to site; fair access, good roads within site 11-14	Good access, high standard road to site; good access within site 15-18
Environmental Total Points: 20 Point Value: 8	Low esthetic factors[6] that significantly lower quality[7] 0-2	Average esthetic quality; factors exist that lower quality to minor degree 3-6	Above average esthetic quality; any limiting factors can be reasonably rectified 7-10	High esthetic quality; no factors exist that lower quality 11-15	Outstanding esthetic quality; no factors exist that lower quality 16-20

Point value assignments for ***TABLE H-3*** above are based on Economic Guidance Memorandum (EGM) 09-03. The Criteria and Judgment Factors for General Recreation were used as the basis of the estimated point values for the proposed recreation area. Judgment factors were reviewed after conducting site visits and coordination with local agencies. The following selection factors were used for the criteria outlined in ***TABLE H-3***.

- The C-111 SC Western project proposed recreation plan would provide an area specific, unique recreation opportunity afforded by the project setting and the project levees. The site offers solitude and panoramic views outside a growing metropolitan region, and would provide specific recreation amenities (as outlined in ***TABLE H-3***) for an expanding regional and associated increasing recreation demands. The point value rating is estimated in the middle end of the judgment factor scale because of the general activities that would sustain a regional use in the Miami-Dade County area.

- The availability of opportunity rating is based upon current local recreation facilities near the project area within the proposed recreation resource location. At the high end of the scale are those recreational facilities which are a geographical rarity; these are sites for which there is no close substitute within two hours. For example, two hours of drive time is sufficient for an east west transit across the lower part of Florida. For this study it is assumed that two hours is sufficient to travel approximately 80 miles (non-interstate travel). With the exception of jogging and walking activities and equestrian trails, alternative facilities exist for all other classifications. Scores for this judgment factor are therefore expected to be mid to low scale. With the exception of equestrian activity the proposed recreation resources will provide facilities needed to alleviate both current and projected SCORP Region 11 deficits in those activities.

- The proposed C-111 SC Western project recreation resources carrying capacity point values are estimated to improve with the recreation component construction. The general recreation values are based on the optimum use of the site potential, without overuse of the proposed recreation resources. Water resources and access to them for non-boat fishing, multi-use trail activities and environmental observation comprise a large part of the projected recreation resources use. Peak use is conservatively projected to occur during half of the calendar year.

- The accessibility rating is based upon the availability of local highways, roads and streets in good condition that would provide access to the proposed recreation facilities. A direct and paved road, Ingraham Highway, provides excellent access to the proposed recreation area.

- The environmental quality rating is based upon the existing aesthetic values of the proposed C-111 SC Western project recreation resource facilities, project lands, and the ease of correcting any limiting aesthetic factors. The proposed site would possess outstanding panoramic views,

with optimal views being from the C-111 SC levees of the FPDA and Aerojet Canal to the west during a sunset.

The value of a day of general recreation at the proposed C-111 SC Western project was determined for each project activity using the guidelines for Assigning Points for the General Recreation in ***TABLE H-4***. The points were then converted to dollar values based on the EGM 09-03, Unit Day Values for Recreation, NOV 2008, which is based on ER 1105-2-100.

The Outdoor Recreation Coalition of America noticed the trend of walking and birdwatching increased 42 percent and 155 percent respectively from 1984 survey to the 1995 survey. The U.S. Fish and Wildlife Service (FWS), National Survey of Fishing, Hunting and Wildlife-Associated Recreation shows a 98 percent and 38 percent increase in residential and non-residential wildlife watching respectively in the State of Florida (Yellowbook, 1999). Overall, recreation trends show increased usage of existing facilities and a need to develop new facilities. With ensuing development in the project area, and the increase in population projections for the State of Florida, the study team believes there would be ample use of the proposed recreation facilities.

TABLE H-4 displays the point value conversion to a unit day values in fiscal year 2009 (FY09) dollar amount. The 46 points generated a user day value of $7.27.

TABLE H-4: CONVERSION OF POINTS TO DOLLAR VALUES

General Recreation Point Values	General Recreation Dollar Values
0	$3.52
10	4.26
20	4.71
30	5.39
40	6.73
50	7.63
60	8.30
70	8.75
80	9.65
90	10.32
100	10.77

H.5.2 State of Florida Perspective and Analysis

The State of Florida's Department of Environmental Protection, Division (FDEP) of Recreation and Parks developed the Florida SCORP for 2000. The SCORP was used to obtain state regional recreation participation rates. The SCORP provides recreation user day guidelines for resource based outdoor recreation activities listed in ***TABLE H-5***. These guidelines are based on maximum carrying capacity levels developed by FDEP.

Using the guidelines available from the SCORP, reasonable user rate projections can be determined. Due to the rural project area location and rustic/minimal recreation features planned, it was determined that a conservative usage rate would be applied to the justification process. The projected C-111 SC Western project recreation use rates referenced the resource needs and guidelines published by the SCORP, but use rates developed were substantially lower than the SCORP published rates. It is expected that recreation use within the study area would be reduced during reservoir dry periods. The probability that only the two miles on either side of the access points will be used for the multi-use trail was factored into the recreation use scenario.

In many areas, even where water bodies are accessible, they are unusable due to the lack of facilities. As previously noted, the regional level needs assessments in this plan (SCORP) are not capable of identifying local needs. Nonetheless, it is well known that there is a need to fund development of access facilities such as kayak access, docks, catwalks and piers, as well as support facilities such as bathhouses, restrooms, and parking areas. Federal, state and local governments should work together to fund construction of these facilities in all areas where there is sufficient access to water bodies suitable for recreation (SCORP, 2000).

H.5.3 Regional Perspective and Analysis

The current SCORP indicates regional recreation demands not met for the year 2010 for four activities associated with the proposed C-111 SC Western recreation project. In the current or existing without project condition miles of hiking, biking, bank fishing and hunting are needed to fill projected regional demand. Analysis of supply and demand within Region 11 indicates that future demand for equestrian trails will overcome supply sometime between 2010 and 2015.

The use guidelines for designated bicycle, hiking, bank fishing, hunting and nature study were based on carrying capacity guidelines adopted by the SCORP and used by the state park system (***TABLE H-5***). The C-111 SC Western Storage Reservoir consists of approximately 6.8 miles of multi-use levee trails atop the impoundment cells and adjacent to the Aerojet Canal. A balanced mix of ecosystem compatible recreation use and facilities are proposed for the C-111

SC Western project. No restrooms are provided due to the high probability of vandalism and subsequent high OMRR&R costs. The proposed recreation would help to fill existing and projected SCORP 2000 recreation deficits for Region 11.

TABLE H-5: MOST LIKELY RECREATION PARTICIPATION USER DAY PROJECTION SCENARIO

Activity	Units Provided	SCORP Maximum Area Requirements	SCORP Turn over Rates	SCORP Capacity Guidelines	SCORP Region 11 Resource Needs (2010)		C-111 SC Projected Expected Users
					User Occasions	Units	
Bicycling Hiking	6.8 MI (4 utilized)	10-20 users per MI	4/day	40-80 users per MI per day	16,675,164	4 miles 4 miles	10 10
Nature Study	55.6 MI (4 utilized)	5-20 groups per MI	4/day	40-160 users per MI of trail/day	1,058,861	4 miles	10
Managed Hunting	667 AC	90 AC/ hunter	2/day	45 ACs/day	N/A	667 ac	5
Bank Fishing	500 LF of Bank	10 LF of bank per person	2/day	5 LF of bank user per day	1,678,705	500 LF	5
General Recreation Total							40 users per day

Key:

† = signifies conservative user rates developed between by the USACE and SFWMD recreation planning point of contacts after SCORP review
AC acres
LF linear feet
MI mile

H.6 ECONOMIC JUSTIFICATION OF RECREATION

The justification for incurring additional project costs for the inclusion of recreation features is derived by utilizing a benefit to cost ratio. The tangible economic justification of the proposed project can be found by comparing the equivalent average annual costs with the estimated equivalent average annual benefits, which would be realized over the period of analysis. These recreation benefits and costs are provided in ***TABLE H-6***.

ER 1105-2-100 (The Planning Guidance Notebook) provides economic evaluation procedures to be used in all federal water resources planning studies. The ER guidelines were used in preparing this cost analysis. The federally mandated project evaluation interest rate of 4 1/8 percent, an economic period of analysis of 40 years and current prices were used to evaluate economic feasibility.

TABLE H-6: SUMMARY OF RECREATION COSTS AND BENEFITS

Investment Costs	
Recreation Construction Costs	**$213,000**
PED & S/A (20%)	$43,000
Total Recreation Construction	**$256,000**
Construction Duration	12 months
Interest During Construction Costs	$10,000
Total Recreation Investment	**$266,000**
Average Annual Costs	
Interest and Amortization of Initial Investment	$20,000
OMRR&R	$25,000
Total Average Annual Costs	$45,000
Average Annual Benefits	$122,000
Net Annual Benefits	$77,000
Benefit – Cost Ratio	2.7

Recreation Benefits reflect 2009 unit day values from EGM, 09-02

TABLE H-7: SENSITIVITY ANALYSIS USING MULTIPLE SCENARIOS

Scenario	Annual Users	Daily Users	Annual Benefit
Most Likely	16,425	46	$86,000.00
Worst Case	5,110	15	$39,803.00
SCORP Guidelines	19,412,730	53,185	$141,129,056.00

A sensitivity analysis was performed to check expected benefits and provide additional justification for proposed recreation features. SCORP expected benefits are provided for comparison with the proposed C-111 SC Western project recreation benefits. This economic analysis suggests there would be ample benefits to conservatively justify the proposed recreation facility construction for the C-111 SC Western project.

H.7 REFERENCES

Bureau of Economic and Business Research (BEBR), UF, Bureau of Economic and Business Research, Warrington College of Business. *Florida Statistical Abstract 2004* 38 (2004).

Design Agreement Between The Department of the Army and South Florida Water Management District for the Design of Elements of the Comprehensive Plan for the Everglades and South Florida Ecosystem Restoration Project (12 MAY 2000).

Florida Fish and Wildlife Conservation Commission, "Boating Access to the South Region Counties", http://myfwc.com/boating/access/ramps/so-ramps.html#180> (12 FEB. 2007).

Florida Fish and Wildlife Conservation Commission, Boat Access Need Letter (23 FEB 2007).

Personal Communication: Jerry Krenz, Everglades Recreation Program Manager, South Florida Water Management District, 26 JUL 2007.

Personal Communication: LuAnne McVickers, PhD, PE, Acceler8 Project Manager, South Florida Water Management District, 22 FEB 2006.

Personal Communication: Patricia Evans, Planning Consultant, Division of Recreation and Parks, Department of Environmental Protection, 14 FEB 2007.

Personal Communication: Jon Fury, Florida Fish & Wildlife Conservation Commission, 20 FEB 2007.

Public Law (PL) 78–534. Flood Control Act of 1944, Washington, D.C .

PL 89-72. The Federal Water Project Recreation Act of 1965, Washington, D.C.

PL 99-662. Water Resources Development Act (WRDA) of 1986, Washington, D.C.

PL 104-303. Water Resources Development Act of 1996, Washington, D.C.

PL 106-541. Water Resources Development Act of 2000, Washington, D.C.

SFWMD, A8 Website, C-111 SC Project, https://my.sfwmd.gov/

South Florida Water Management District (SFWMD), Public Access Rule 40E-7, Florida Administrative Code, Tallahassee, FL (FEB 2007).

State of Florida, Department of Environmental Protection, Division of Recreation and Parks, Outdoor Recreation in Florida-2000: Florida's Statewide Comprehensive Outdoor Recreation Plan, Tallahassee, FL (SCORP, 2000).

USACE, Central and Southern Florida Study (Yellow Book, 1999), Jacksonville District, Jacksonville, FL.

USACE, (CESAD-PDD-J). Multi-Purpose Project Memorandum, Atlanta, GA (15 SEP. 2004).

USACE, (CESAD-PDD-J). OMRR&R Memorandum, Atlanta, GA (29 SEP 2005).

USACE, (CESAD-PDD-J), Recreation Authority Memorandum, Atlanta, GA (26 JAN 2007).

USACE, Civil Works, Water Resources Policies and Authorities (CECW-A), Economic Guidance Memorandum (EGM) 09-03, Unit Day Values for Recreation Fiscal Year 2007, Washington, D.C. (NOV 2007).

USACE, Ecosystem Restoration - Supporting Policy Information Engineer Pamphlet (EP) No. 1165-2-502, Washington, D.C. (SEP 1999).

USACE, Civil Works, Policy Division (CECW-AG), Policy Guidance Letter (PGL) No. 59, Recreation Development at Ecosystem Restoration Projects. Memo (JUN 1998).

USACE, Planning Guidance Notebook, ER 1135-2-100 (APR 2000). Washington, D.C.

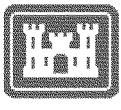
USACE, Design of Recreation Areas and Facilities-Access and Circulation (DEC 1982). Washington, D.C.

USACE/SFWMD, Comprehensive Everglades Restoration Plan, Master Recreation Plan, Public Involvement Summary Report, (Jan 2007).

U.S. Census Bureau. "State and County Quick Facts." 28 June 2006, <http://quickfacts.census.gov/qfd/states/12/12093.html> (2005).

U.S. Department of Commerce, Population Projections Program, Population Division, (NP-D1-A) Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100 28 July 2006, <http://www.census.gov/population/projections/nation/detail/d2041_50.pdf> (13 Jan. 2000).

UF GeoPlan Center, Florida 2060; A Population Distribution Scenario for the State of Florida (Aug 2006), Gainesville, FL.



US Army Corps
of Engineers®

Jacksonville District

South Florida Water
Management District