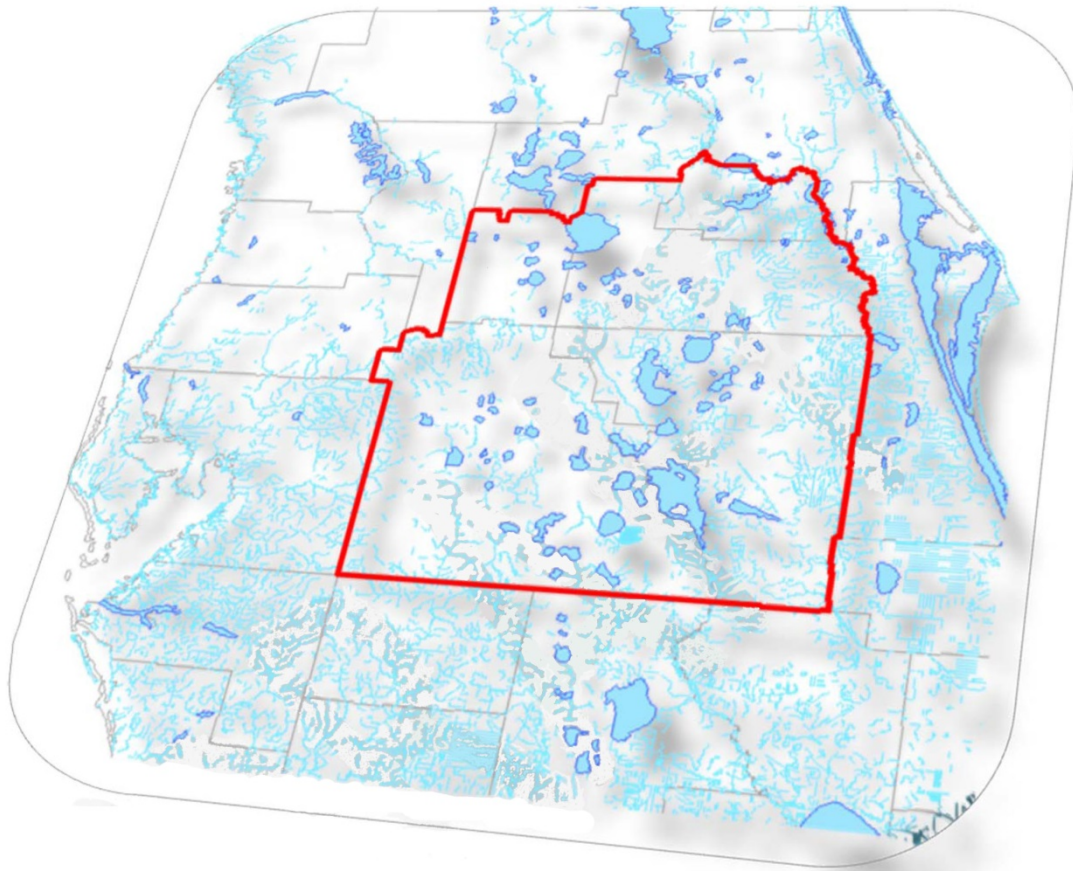


# Development of Environmental Measures for Assessing Effects of Water Level Changes on Lakes and Wetlands in the Central Florida Water Initiative Area

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**Central Florida Water Initiative's Environmental Measures Team**

**Final Report November, 2013**

**Attachments A-H**



*Environmental Measures Team Final Report*

*Attachment A –*

*Land Development Index (LDI) and Cross-Walk of Florida  
Land Use Cover and Classification System (FLUCCS) Codes to  
LDI Values*

*November, 2013*



## Attachment A – Land Development Index (LDI)

Tony Janicki, Ph.D.

Janicki Environmental, Inc.

### Land Use and the Land Development Index

The Land Development Index (LDI) (Brown et al. 2003) was estimated for each of the EMT study sites using land use data and a development intensity measure derived from energy use per unit area. The LDI is an estimate of the potential impacts from human-dominated activities that are experienced by ecological systems within those watersheds.

Initially, each of the wetland sites was overlain on the ECFT model grid. Then, the land uses (i.e., FLUCCS codes) within the ECFT model grid were identified and the contributing areas enumerated. Each of the land uses was assigned an LDI coefficient (**Table A-1**). The overall LDI ranking was calculated as an area weighted average. Using the GIS, total area and percent of total area occupied by each of the land uses were determined and then the LDI was calculated as follows:

$$LDI_{Total} = \sum \%LU_i * LDI_i$$

Where:  $LDI_{total}$  = LDI ranking for wetland site,  $\%LU_i$  = percent of the total area of influence in land use  $i$ , and  $LDI_i$  = landscape development intensity coefficient for land use  $i$ .

**Table A-1 .Land Development Index coefficients for each land use classification (source: Brown, 2003).**

Natural System	1.0	Single Family Residential (medium density)	7.47
Natural Open Water	1.0	Single Family Residential (high density)	7.55
Pine Plantation	1.58	Mobile Home (medium density)	7.70
Low Intensity Recreational/Open Space	1.83	Highway (2 lane)	7.81
Woodland Pasture	2.02	Low Density Commercial	8.00
Pasture (without livestock)	2.77	Institutional	8.07
Low Intensity Pasture (with livestock)	3.41	Highway (4 lane)	8.28
Citrus	3.68	Mobile Home (high density)	8.29
High Intensity Pasture (with livestock)	3.74	Industrial	8.32
Row Crops	4.54	Multi-family Residential (low rise)	8.66
Single Family Residential (low density)	6.79	High Intensity Commercial	9.18
High Intensity Recreational/Open Space	6.92	Multi-family Residential (high rise)	9.19
High Intensity Agriculture (dairy farm)	7.00	Central Business District (Average 2 stories)	9.42
		Central Business District (Average 4 stories)	10.00

The three water management districts with jurisdictions in the CFCA each maintain land use geospatial databases according to the Florida Land Use Cover Classification System (FLUCCS) established in 1971 by the Florida Department of Transportation with continued mapping by all five Water Management Districts and the Florida Department of Environmental Protection. Databases from the three WMDs were obtained and combined to create a single land use map of the CFWI study area. The extent of major land use types was determined for 1995 and 2009, and a comparison of land use changes between these years was calculated (see **Figure 3** in the main report).

## Cross-Walk Of Florida Land Use Cover and Classification System (FLUCCS) To Land Development Index (LDI) Values

Table A-2. FLUCCS Codes and Corresponding LDI Values used in EMT Analyses

FLUCCS	Description	LDI
1000	Urban and Built-up	7.39
1009	Mobile home units any density	6.79
1100	Residential, Low Density <Less than two dwelling units per acre>	6.79
1110	Low density residential - fixed single family units	6.79
1120	Low density residential - mobile home units	6.79
1130	Low Density Residential - Mixed Units <Fixed and mobile home units>	6.79
1140	Ranchettes - fixed single family units	6.79
1150	Ranchettes - mobile units	6.79
1160	Ranchettes - mixed units	6.79
1180	Rural residential	6.79
1190	Low density under construction	6.79
1200	Residential, Medium Density <Two - five dwelling units per acre>	7.59
1210	Medium density residential - fixed single family units	7.59
1220	Medium density residential - mobile home units	7.59
1230	Medium Density Residential - Mixed Units <Fixed and mobile home units>	7.59
1290	Medium density under construction	7.59
1300	Residential, high density	8.66
1310	High Density Residential - Fixed Single Family Units <Si or more	7.99
1320	High Density Residential - Mobile Home Units <Si or more	7.99
1330	Multiple Dwelling Units - Low Rise <Two stories or less>	8.66
1340	Multiple Dwelling Units - High Rise <Three stories or more>	9.19
1350	High Density Residential - Mixed Units <Fixed and mobile home units>	7.99
1390	High density under construction	7.99
1400	Commercial and Services	8
1410	Retail Sales and Services	8
1411	Shopping center	9.18
1420	Wholesale Sales and Services <excluding warehouses associated with	8
1423	Junk yard	9.18
1424	Farmers market	8
1430	Professional services	8
1440	Cultural and Entertainment	8.07
1443	Open air theater	8.07
1450	Tourist services	8
1452	Motel	8
1453	Travel trailer park	8
1454	Campground	4.09
1460	Oil and Gas Storage	8

1470	Mixed Commercial and Services	9.42
1480	Cemeteries	4.09
1490	Commercial and Services Under Construction	8
1500	Industrial	8.32
1510	Food processing	8.32
1513	Seafood processing	8.32
1514	Meat packing facility	8.32
1515	Poultry and/or egg processing	8.32
1516	Grain and legume processing	8.32
1520	Timber processing	8.32
1521	Sawmill	8.32
1522	Plywood and veneer mill	8.32
1523	Pulp and paper mill	8.32
1526	Log home prefabrication	8.32
1527	Woodyard	8.32
1530	Mineral processing	8.32
1532	Phosphate processing	8.32
1533	Limerock processing	8.32
1535	Heavy minerals processing	8.32
1540	Oil and Gas Processing	8.32
1544	Liquified gases	8.32
1545	Asphalt plant	8.32
1550	Other light industrial	8.32
1551	Boat building and repair	8.32
1552	Electronics	8.32
1554	Aircraft building and repair	8.32
1556	Mobile home manufacturer	8.32
1560	Other heavy industrial	8.32
1561	Ship Building and Repair	8.32
1562	Prestressed concrete plants	8.32
1564	Cement plant	8.32
1565	Plastic pipe plant	8.32
1570	Chemical processing plants	8.32
1580	Industrial	8.32
1590	Industrial under construction	8.32
1600	Extractive	8.32
1610	Strip mines	8.32
1611	Clays	8.32
1612	Peat	8.32
1613	Heavy mineral mine	8.32
1614	Phosphate mine	8.32
1620	Sand and Gravel Pits	8.32
1630	Rock quarries	8.32

1631	Limerock quarry	8.32
1632	Dolomite quarry	8.32
1633	Phosphate	8.32
1640	Oil and Gas Fields	8.32
1650	Reclaimed land	8.32
1660	Holding ponds	8.32
1670	Inactive Strip Mines/Rock Quarries or holding ponds	8.32
1700	Institutional	8.07
1710	Educational facilities	8.07
1720	Religious	8.07
1730	Military	8.07
1736	National guard installation	8.07
1740	Medical and Health Care	8.07
1741	Hospital	8.07
1742	Nursing home	8.07
1750	Governmental	8.07
1756	Maintenance yard	8.07
1760	Correctional facilities	8.07
1761	State prison	8.07
1765	Municipal prison	8.07
1770	Other institutional facilities	8.07
1780	Commercial child care	8.07
1790	Institutional under construction	8.07
1800	Recreational	4.09
1810	Swimming beach	4.09
1820	Golf courses	6.92
1830	Race tracks	6.92
1831	Automobile racing track	6.92
1832	Horse racing track	6.92
1833	Dog racing track	6.92
1840	Marinas and Fish Camps	6.92
1850	Parks and Zoos	4.09
1851	City park	4.09
1852	Zoo	6.92
1860	Community recreational facilities	4.09
1870	Stadiums	6.92
1880	Historical sites	8.07
1890	Under Construction or Other Recreational Facilities	4.09
1900	Open land	1.85
1910	Undeveloped urban land	1.85
1920	Inactive development land	1.85
1923	Inactive development land nonforested	1.85
1924	Inactive development land forested	1.85



1930	Urban Land in Transition Without Positive Indicators of Intended Activity	1.85
1940	Other open land	1.85
2000	Agriculture	3.88
2100	Pastures and Fields	3.51
2110	Improved pastures	3.51
2120	Unimproved pastures	2.06
2130	Woodland pastures	2.06
2140	Row crops	4.63
2141	Potatoes and Cabbage	4.63
2150	Field crops	4.63
2156	Field crops - sugar cane	4.63
2160	Mixed crops	4.63
2200	Tree crops	4.06
2210	Citrus groves	4.06
2220	Fruit orchards	4.06
2221	Peaches	4.06
2224	Blueberries	4.06
2230	Other groves	1
2231	Pecans	1
2240	Abandoned tree crops	1
2300	Feeding operations	1
2310	Cattle feeding operations	1
2320	Poultry feeding operations	1
2330	Swine feeding operations	1
2400	Nurseries and Vineyards	1
2410	Tree nurseries	1
2420	Sod farms	1
2430	Ornamental nurseries	1
2431	Shade ferns	1
2432	Hammock ferns	1
2440	Vineyards	1.58
2450	Floriculture	1.58
2460	Timber nursery	1.58
2500	Specialty farms	1.58
2510	Horse farms	1.58
2520	Dairies	1.58
2530	Kennels	1
2540	Aquaculture	1
2550	Tropical fish farms	1
2590	Other specialty farms	1
2600	Other open lands	1
2610	Fallow cropland	1
2620	Old field	1

3000	Rangeland	4.09
3100	Herbaceous	4.09
3200	Shrub and Brushland	4.09
3210	Palmetto prairies	4.09
3220	Coastal scrub	4.09
3290	Other Shrubs and Brush	1
3300	Mixed rangeland	1
4000	Upland forests	1
4100	Upland coniferous forests	1
4110	Pine Flatwoods or Mesic Flatwoods	1
4119	Pine flatwoods - melaleuca infested	1
4120	Longleaf Pine-Xeric Oak or Longleaf Sandhill	1
4130	Sand Pine or Sand Pine Scrub	1
4140	Pine - mesic oak	1
4190	Hunting plantation woodlands	1
4200	Upland hardwood forests	1
4210	Oak sandhill	1
4220	Brazilian pepper	1
4230	Oak - pine - hickory	1
4240	Melaleuca	1
4250	Temperate hardwood	1
4260	Tropical hardwoods	1
4270	Live oak	1
4271	Oak - cabbage palm forest	1
4280	Cabbage palm	1
4290	Wax myrtle - willow	1
4300	Upland hardwood forests continued	1
4310	Beech - magnolia	1
4320	Oak scrub	1
4330	Western everglades hardwoods	1
4340	Hardwood - conifer mixed	1
4350	Dead trees	1
4370	Australian pine	1
4380	Mixed hardwoods	1
4390	Maritime hammock	1
4400	Tree plantations	1.58
4410	Pine plantations	1.58
4420	Hardwood plantations	1.58
4430	Forest regeneration	1.58
4440	Experimental tree plots	1.58
4450	Seed tree plantations	1.58
5000	Water	1
5100	Streams and Waterways	1

		1
5120	Streams and Waterways	1
5200	Lakes	1
5210	Lakes larger than 500 acres (202 hectares)	1
5220	Lakes Larger Than 100 Acres (40 Hectares), but Less Than 500 Acres	1
5230	Lakes Larger Than 10 Acres (4 Hectares), but Less Than 100 Acres	1
5240	Lakes Less Than 10 Acres (4 hectares) Which are Dominant Features	1
5300	Reservoirs	4.09
5310	Reservoirs larger than 500 acres (202 hectares)	4.09
5320	Reservoirs Larger Than 100 Acres (40 Hectares), but Less Than 500 Acres	4.09
5330	Reservoirs Larger Than 10 Acres (4 Hectares), but Less Than 100 Acres	4.09
5340	Reservoirs less than 10 Acres (4 Hectares) which are dominant features	4.09
5400	Bays and Estuaries	1
5410	Embayment Opening into the Gulf of Mexico or the Atlantic Ocean	1
5420	Embayment Not Opening into the Gulf of Mexico or the Atlantic Ocean	1
5430	Enclosed salt water Ponds within salt marsh	1
5500	Major springs	1
5600	Slough waters	1
5720	Gulf of Mexico	1
6000	Wetlands	1
6100	Wetland hardwood forests	1
6110	Bay swamps	1
6111	Bayhead	1
6120	Mangrove swamps	1
6130	Gum swamps	1
6140	Shrub swamps	1
6150	Bottomland hardwood forest	1
6160	Inland Ponds and Sloughs	1
6170	Mixed wetland hardwoods	1
6171	Mixed wetland hardwoods - willows	1
6172	Mixed wetland hardwoods - mixed shrubs	1
6180	Cabbage palm savanna	1
6191	Wet melaleuca	1
6200	Wetland coniferous forests	1
6210	Cypress	1
6215	Cypress - domes/heads	1
6216	Cypress - mixed hardwoods	1
6218	Cypress - melaleuca infested	1
6219	Cypress - with Wet Prairies	1
6220	Wet flatwoods	1
6230	Atlantic white cedar	1
6240	Cypress - pine - cabbage palm	1
6250	Wet pinelands hydric pine	1

6300	Wetland mixed forest	1
6310	Hydric hammock	1
6320	Tidal swamp	1
6400	Vegetated Non-forested Wetlands	1
6410	Freshwater marshes	1
6411	Freshwater marshes - sawgrass	1
6412	Freshwater marshes - cattail	1
6420	Salt marshes	1
6430	Wet prairies	1
6439	Wet Prairies - with Pine	1
6440	Emergent aquatic vegetation	1
6450	Submergent aquatic vegetation	1
6451	Hydrilla	1
6460	Mixed scrub-shrub wetland	1
6500	Non-vegetated	1
6510	Salt barrens	1
6520	Intertidal areas	1
6530	Inland shores/ephemeral ponds	1
6540	Oyster bars	1
6600	Cut over Wetlands	1.58
6900	Wetland scrub	1
7000	Barren land	1
7100	Beaches	1
7200	Sand other than beaches	1
7300	Exposed rock	1
7310	Exposed Rock with Marsh Grasses	1
7400	Disturbed lands	4.09
7410	Rural Land in Transition Without Positive Indicators of Intended Activity	4.09
7420	Borrow areas	4.09
7430	Spoil areas	4.09
7440	Fill areas	4.09
7450	Burned areas	1
7470	Dikes and Levees	4.09
7500	Riverine sandbars	1
8000	Transportation, Communication and Utilities	8.05
8100	Transportation	7.81
8110	Airports	8.28
8111	Commercial airport	8.28
8112	General aviation	8.28
8113	Private airport	8.28
8115	Grass airport	8.28
8120	Railroads	7.81
8130	Bus and Truck Terminals	8.28

8132	Bus terminal	8.28
8133	Truck terminal	8.28
8140	Roads and Highways	8.28
8141	Limited access highway (interstate)	8.28
8142	Divided highway (federal-state)	8.28
8143	Two lane highway	7.81
8147	Transportation corridor	7.81
8150	Port facilities	8.28
8160	Canals and Locks	8.28
8170	Oil, Water, or Gas Long Distance Transmission Line	8.28
8180	Auto parking facilities (highway rest areas)	8.28
8190	Transportation facilities under construction	8.28
8191	Highways	8.28
8192	Railroads	8.28
8200	Communications	8.32
8210	Transmission towers	8.32
8220	Communication facilities	8.32
8290	Communication facilities under construction	8.32
8300	Utilities	8.32
8310	Electrical power facilities	10
8311	Thermal (coal-fired) electrical power generating plant	10
8315	Electrical power substation	10
8320	Electrical power transmission lines	1.85
8330	Water supply plants	8.32
8340	Sewage treatment	8.32
8350	Solid waste disposal	8.32
8390	Utilities under construction	8.32
9000	Special classifications	1
9100	Vegetative	1
9110	Sea grass	1



*Environmental Measures Team Final Report*

*Attachment B*

*CFCA/CFWI Wetland Data Collection Methodology*

*Contractor Statement of Work,*

*Location of Study Area*

*Key Used to Determine Abundance Index Values*

*Wetland Assessment Form and Description of Entries,*

*FLUCCS Codes Used in This Study*

*List of Hydrologic Indicators,*

*Protected Species List*

*November, 2013*





## **STATEMENT OF WORK**

### **WETLAND RESOURCE ASSESSMENT OF THE CENTRAL FLORIDA COORDINATION AREA**

#### **1.0 BACKGROUND**

The Regulatory Working Group (RWG) and the Environmental Assessment Subgroup (EAS) teams comprised of three water management districts (WMDs) have identified a need to do a regional assessment of wetland conditions in the Central Florida Coordination Area (CFCA) due to a rapidly increasing urbanization and growing demands in groundwater use. Initial assessments of wetland monitoring sites in Osceola and Orange Counties were conducted in 2007 and 2008 by the South Florida Water Management District (SFWMD). Results from that effort concluded that some wetlands in the region appeared to be under stress from hydrologic and other factors. The initial assessments indicated that there is a need to expand the assessment effort to better understand the extent, magnitude and source of impacts to wetland resources (including lake littoral zones) in this area. In 2008, environmental consultants were hired to conduct wetland assessments in the CFCA area, under the guidance of the EAS. It has been determined that additional services of these contractors will be required to do follow-up wetland assessments.

#### **2.0 OBJECTIVES**

The overall objective of this scope of work is to outline the tasks to be performed by the environmental consultant (Contractor), which is to collect vegetation and hydrologic data from wetland assessment sites within the CFCA (Figure 1). Survey data will be collected from previously established sites and at new sites that will be identified as part of this effort. This information will be used by the RWG and EAS to evaluate the general condition of wetlands in this area. The collected information will be used to determine the extent and type of vegetative changes that may have occurred as the result of consumptive use withdrawals and other factors.

#### **3.0 SCOPE OF WORK**

This scope of work includes three (3) project tasks as follows:

- Task 1. Collection of Wetland Assessment Data
- Task 2. Electronic Data Storage, Work Summary and Final Report
- Task 3. Final Data Report and Project Close Out

## **4.0 WORK BREAKDOWN STRUCTURE**

### **Task 1. Collection of Wetland Assessment Data**

#### **Task 1.1 Conduct Assessments of Wetland Sites in Study Area**

The Contract Manager (SFWMD) will identify wetland sites within Lake, Orange, Osceola, Polk and Seminole Counties (Figure 1) for the Contractor to visit and complete the tasks identified below.

At each of the wetland sites identified by the Contract Manager, the Contractor shall compile a comprehensive plant species list by providing both scientific and common names for each plant species and record the abundance value for each species, as determined by the key shown in Table 1. This information shall be recorded on field data sheets, an example of which shall be provided by the Contract Manager.

Additional observations that shall be recorded by the Contractor include, but shall not be limited to: 1) approximate number and species (if discernable) of observed tree falls, 2) observed soil subsidence, oxidation or fissures in organic soils, 3) other observed indicators of hydrologic conditions, including but not limited to, height above ground elevation that lichen lines or water lines of adventitious roots occur, 4) observed encroachment of upland or non-native vegetation, and 5) FLUCCS wetland type. Contractor shall refer to field assessment worksheet (to be provided by the Contract Manager) for a comprehensive listing of observations and data to be recorded.

#### **Task 1.2 Photo Documentation of each Wetland**

The Contractor shall provide a minimum of 4 digital (minimum of 5.0 megapixels) photographs of each wetland site evaluated from the wetland edge. The Contractor shall be responsible for providing all digital photographs and providing a description of where the photograph was taken within the wetland and the direction the photograph was taken.

**Task 1 Deliverables:** *Collection of wetland assessment data and electronic-format photos at monitoring sites shall be conducted by the Contractor at specific site locations that will be provided by the Contract Manager before initiation of the field work. Data is to be recorded on field sheets, a sample of which shall be provided by the Contract Manager.*

**Task 1 Deliverable Due Date:** *At the end of each month, the Contractor shall provide the Contract Manager with electronic copies of field data sheets and field photos for each wetland assessed in the month. Collection of field data at identified assessment sites shall be completed no later than (DATE), unless an extension is requested by the South Florida Water Management District.*

**Task 2. Electronic Data Storage, Work Summary and Final Report****Task 2.1. Compile Field Data in Electronic Format**

All field data, including observations and vegetation parameter measurements, will be entered into an MS Excel workbook. Entries will be verified for accuracy. Photographs will be compiled into an electronic format, with each file uniquely identifiable by site name.

**Task 2.2 Summary of Work**

A brief summary of work completed will be compiled, including a write up of work performed in the field (including methods), site locations, general site characteristics and results.

**Task 2.3 Final Report**

A final report that includes the work summary, methods, descriptions of monitoring sites, data tables and data summaries for each wetland site evaluated (as described in Task 1.1 above) will be compiled, with electronic copies of all site photographs, and submitted at the end of the contract term. This document shall be in MS Word format. The Contractor will also provide paper copies of all field notes and data sheets.

**Task 2 Deliverables:** *Electronic copies of all field data and a final report (in a MS Word file) that includes a work summary, description of methods, site locations and site descriptions, data tables, and summaries for each wetland site evaluated (as described in Task 1.1 above) will be compiled. All photographs from each wetland shall be provided in a digital format (e.g., jpg, tif, etc.). Electronic file format must be compatible with MS Office software-(Microsoft XP platform preferred) and recorded on CD-ROM.*

**Task 2 Deliverable Due Date:** *Compilation of field data and final report, both paper and electronic versions, shall be completed by (DATE) unless an extension is requested by the South Florida Water Management District. A minimum of 4 (four) copies each of the paper and electronic formats shall be provided.*

**Task 3. Data Reporting and Project Close Out****Task 3.1 Receipt of Deliverables and Project Close Out**

The project shall be completed before (DATE) unless the Contract Manager requests or grants a time extension.

Four copies each of paper and electronic versions of field data and the final report, will be delivered to the Contract Manager by (DATE). The final product will only be described as complete and acceptable when the deliverables have been received and approved by the Contract Manager. When the project has been deemed complete and acceptable, payment in full will be made to the Contractor.

## 5.0 PERFORMANCE

The Contractor's performance for this work order will be evaluated at the following frequencies:

1. At the end of each month that work was conducted an billed
2. Final: (DATE)
3. Additional evaluations as determined by the Contract Manager

## 6.0 HARDWARE, SOFTWARE, TRAVEL AND LOGISTICS

To be provided by the Contractor

## 7.0 PAYMENT AND DELIVERABLE SCHEDULE

The Contractor may invoice the South Florida Water Management District at the end of each month of the contract; final billing shall be no later than 21 days after Contract Manager's approval of the final deliverable. All invoices shall indicate the number of hours worked per task, times the Contractor's hourly rate within the not-to-exceed amount as shown below for Fiscal Year 20\_\_ (FY20\_\_). A summary deliverable and payment schedule for each task associated with this project is set forth below. All deliverables submitted hereunder are subject to review, comment and approval by the RWG and/or EAS teams. All deliverables shall be submitted to the Contract Manager. The Contract Manager will determine the successful completion of each task. Comments shall be incorporated by the Contractor into revised deliverables for final RWG and/or EAS team approval. All documents must be well written and clearly understood by RWG and/or EAS team reviewers. The Contractor agrees to verbally report the status of work to the Contract Manager and EAS team, beyond what is outlined as a specific task, upon Contract Manager or EAS team request.

<b>Fiscal Year</b>	<b>Task</b>	<b>Deliverable</b>	<b>Due Date</b>	<b>Amount*</b>
FY__	Task 1	Conduct Wetland Assessments	Date	\$_____
FY__	Task 2	Electronic Data Storage, Data Verification, Work Summary and Final Report Compiled	Date	\$_____
FY__	Task 3	Deliverables Received by CFCA's Contract Manager and Project Close Out	Date	\$_____
<b>Total Not-to-Exceed Amount</b>				<b>\$</b>

\*All costs shown are not to exceed amounts.

**8.0 BUDGET SUMMARY**

*FY 20*\_\_ \$\_\_\_\_\_

**Work Order Total Not-to-Exceed Amount** \$\_\_\_\_\_

All costs shown are not to exceed amounts

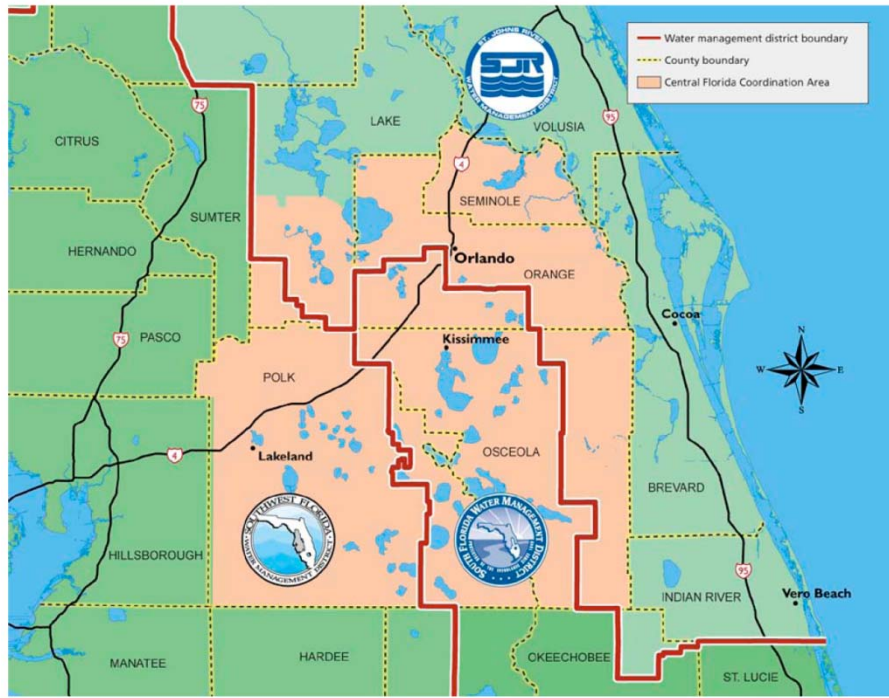
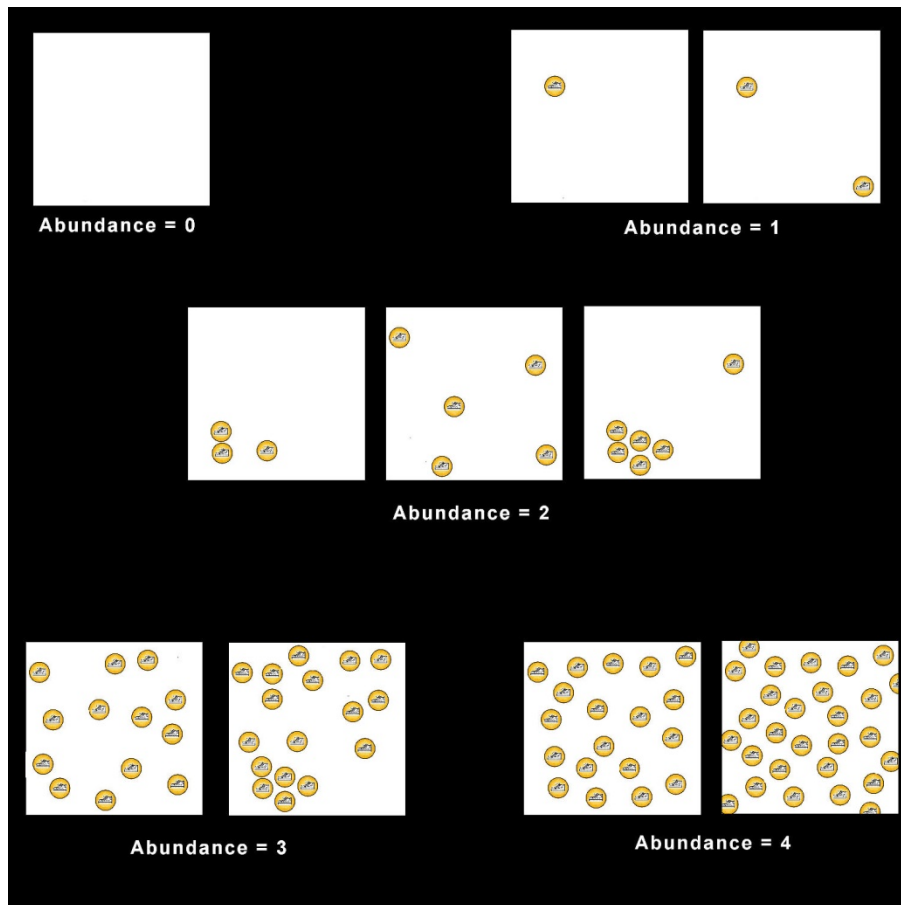


Figure 1. Location of Central Florida Coordination Area.

**Table 1. Dichotomous Key used to Determine Abundance Index Value for the Semiquantitative Survey Method**

<i>Description of Species Population Density</i>	<i>Abundance Index</i>
1a. Species not present.....	0
1b. Species present.	
2a. Two or less individuals; rare.....	1
2b. More than two individuals.	
3a. Highly abundant or dense population (>75% cover), a dominant component of the plant community.....	4
3b. Species not a dominant component of the plant community.	
4a. Sparse; widespread and of low density or restricted to localized populations.....	2
4b. Common; widespread and of moderate density but not a dominant component of the plant community (<50% cover).....	3



**WETLAND ASSESSMENT FIELD FORM – CFCA**

Revised 10-14-08

**Date & Time:** \_\_\_\_\_ **Evaluators:** \_\_\_\_\_  
**Site Name/ID:** \_\_\_\_\_ **County:** \_\_\_\_\_ **District<sup>1</sup>** \_\_\_\_\_  
**GPS Coordinates or Lat/Lon:** \_\_\_\_\_  
**Site Access Info & Location Notes:** \_\_\_\_\_  
 \_\_\_\_\_  
**# of Photos Taken** \_\_\_\_\_ **& Description:** \_\_\_\_\_

<sup>1</sup> SFWMD, SWFWMD or SJRWMD

**Wetland Characteristics**

**Lacustrine:** (A) Littoral \_\_\_\_\_ (B) Floodplain \_\_\_\_\_  
**Palustrine:** (A) Isolated \_\_\_\_\_ (B) Interconnected \_\_\_\_\_ (C) Seepage Slope \_\_\_\_\_ (D) Sandhill \_\_\_\_\_  
**Riverine (Stream)** (A) Shore \_\_\_\_\_ (B) Floodplain \_\_\_\_\_  
**Spring:** \_\_\_\_\_ Run Width \_\_\_\_\_ Depth \_\_\_\_\_  
**Topographic Relief** in Evaluation Area: Relatively Flat (0-2') \_\_\_\_\_ Moderate Relief (3-5') \_\_\_\_\_  
 Extreme Relief (>5 feet) \_\_\_\_\_ Approx. Max Elev. Difference \_\_\_\_\_

**General Wetland Characteristics**

**Listed Wildlife Species:** \_\_\_\_\_  
**Vegetation Zonation:** Well-Defined \_\_\_\_\_ Somewhat Defined \_\_\_\_\_ Poorly-Defined \_\_\_\_\_  
**Zones Present:** Transitional Zone \_\_\_\_\_ Outer Deep Zone \_\_\_\_\_ Deep Zone \_\_\_\_\_  
**Vegetation Communities Present** (% of Total Wetland) \_\_\_\_\_  
 \_\_\_\_\_

**Community 1 (Wettest)** \_\_\_\_\_  
**Dominant spp.: Groundcover:** \_\_\_\_\_  
**Shrub Layer** \_\_\_\_\_  
**Canopy** \_\_\_\_\_

**Soil Condition** \_\_\_\_\_  
*Circle all that apply:* Soil type (sand/mineral, peat, muck, hydric), inundated, moist, dry, subsidence (give measured depth), fissures (measured give depth)

**Water Table Depth** (+ surface water, - subsurface) \_\_\_\_\_ **Mean Pool:** \_\_\_\_\_  
**Max Pool Depth:** \_\_\_\_\_ **Historical High Depth** \_\_\_\_\_  
**Hurricane High Depth** \_\_\_\_\_

*Circle hydrologic indicators present:* distinct or indistinct moss collars, elevated lichen or stain lines, pine edge, adventitious roots, buttressed tree trunks, algal mats, water marks, adventitious roots, rafted debris, crayfish chimneys, etc. Historic Pool Indicators include hydrologic indicators list above plus saw palmetto line, cypress inflection points and other structures (docks, pilings, etc.). Hurricane-related exceptionally high water lines should not be considered.



**Habitat Condition:** \_\_\_\_\_

*Circle those present:* health (excellent, good, fair, poor), invasive species, invading species, fire scars, tree falls, exposed roots, dead or dying plants, premature leaf falls, discolored foliage, evidence of logging, cattle, trash, algae (also see Indicators of Environmental Harm List)

**Community 2** \_\_\_\_\_

**Dominant spp.: Groundcover:** \_\_\_\_\_

**Shrub Layer** \_\_\_\_\_

**Canopy** \_\_\_\_\_

**Soil Condition** \_\_\_\_\_

*Circle all that apply:* Soil type (sand/mineral, peat, muck, hydric), inundated, moist, dry, subsidence (give measured depth), fissures (measured give depth)

**Water Table Depth** (+ surface water, - subsurface) \_\_\_\_\_

**Habitat Condition:** \_\_\_\_\_

*Circle those present:* health (excellent, good, fair poor), invasive species, invading species, fire scars, tree falls, exposed roots, dead or dying plants, premature leaf falls, discolored foliage, evidence of logging, cattle, trash, algae (also see Indicators of Environmental Harm List)

**Community 3** \_\_\_\_\_

**Dominant spp.: Groundcover:** \_\_\_\_\_

**Shrub Layer** \_\_\_\_\_

**Canopy** \_\_\_\_\_

**Soil Condition** \_\_\_\_\_

*Circle all that apply:* Soil type (sand/mineral, peat, muck, hydric), inundated, moist, dry, subsidence (give measured depth), fissures (measured give depth)

**Water Table Depth** (+ surface water, - subsurface) \_\_\_\_\_

**Habitat Condition:** \_\_\_\_\_

*Circle those present:* health (excellent, good, fair poor), invasive species, invading species, fire scars, tree falls, exposed roots, dead or dying plants, premature leaf falls, discolored foliage, evidence of logging, cattle, trash, algae (also see Indicators of Environmental Harm List)

**Community 4 (Driest)** \_\_\_\_\_

**Dominant spp.: Groundcover:** \_\_\_\_\_

**Shrub Layer** \_\_\_\_\_

**Canopy** \_\_\_\_\_

**Soil Condition** \_\_\_\_\_

Circle all that apply: Soil type (sand/mineral, peat, muck, hydric), inundated, moist, dry, subsidence (give measured depth), fissures (measured give depth)

**Water Table Depth** (+ surface water, - subsurface) \_\_\_\_\_

**Habitat Condition:** \_\_\_\_\_

Circle those present: health (excellent, good, fair poor), invasive species, invading species, fire scars, tree falls, exposed roots, dead or dying plants, premature leaf falls, discolored foliage, evidence of logging (also see Indicators of Environmental Harm List)

**Wetland Alterations**

**Drainage Alteration in Wetland** N\_\_\_ | Y\_\_\_, describe: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

**Drainage Alteration of Surrounding Lands** N\_\_\_ | Y\_\_\_, Approx. Distance: \_\_\_\_\_

Describe: \_\_\_\_\_

\_\_\_\_\_

Circle those present: Ditches, swales, canals, drainage wells, pump stations, stormwater culverts, adjacent retention ponds, urban/buildings, borrow pits

**Stormwater Inflows:** N\_\_\_ | Y\_\_\_, describe type and impacts: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

**ADDITIONAL NOTES AND COMMENTS**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
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\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Guidance Document for Collection of Field Assessment Data in the Central Florida Coordination Area (CFCA)**

June 4, 2010

***Date & Time of Assessment***

Please enter the date and time that the field crew arrived at the site and initiated the field assessment.

***Evaluators***

Enter the consulting firm's acronym and initials of field crew who conducted the wetland assessment.

***Site Name/ID***

Enter the unique site identifier (provided by the Water Management District) and the name of the water body or wetland, if there is one.

***GPS Coordinates or Lat/Long***

Record the Lat/Long or GPS coordinates in decimal degrees (with projection type) on the field assessment sheet.

***Site Access Info & Location Notes***

Provide information that will help those who wish to revisit the site with sufficiently details of how to access the wetland. Include the name of major nearby road(s), approximate distance traveled by foot to wetland, name of tract or development that wetland is located in (if there is one), note if wetland is on private property and permission of landowner is required, etc.

***Photography of Wetland Assessment Site***

Multiple photos of each assessment site are to be taken. These will provide an overall view of the wetland. The direction of the photograph should be indicated on the photograph or stated in the documentation that will be submitted. Additional photos of indicators noted on the field assessment sheet (such as subsidence, fissures, exposed roots, adventitious roots, invasion of upland species, etc.) are to be taken. Each photograph taken of an indicator shall include a measuring device adjacent to the indicator, and shall have the appropriate label inserted into the photograph to clearly label the indicator and its position in the image.

**Wetland Characteristics*****Topographic Relief***

This entry describes the topo relief within the wetland or lake rather than within the surrounding landscape. Max elevation may need to be determined by a measuring staff and laser level.

**General Wetland Characteristics*****Listed Wildlife Species***

Please refer to the Florida Fish and Wildlife Conservation Commission's threatened and endangered species list (provided).

**Vegetation Zonation**

This is a determination of how distinct the different vegetation community types (e.g., hydric pine, wet prairie, emergent marsh, deep marsh) are from each other along a hydrologic gradient.

"Well Defined" = Vegetation community types along the hydrologic gradient are differentiated by characteristic species which are confined to a respective zone in a clearly defined and well articulated step-wise transition.

"Somewhat Defined" = Vegetation community types along the hydrologic gradient are differentiated by characteristic species, but a clearly defined and well articulated step-wise transition is lacking and overlapping of adjacent communities is apparent.

"Poorly-Defined" = Vegetation along the hydrologic gradient is vaguely grouped into species that are characteristic of a particular hydrologic regime; intermingling of species with different affinities for wetness (e.g., facultative upland and obligate).

**Wetland Information****Community 1 (etc.)**

FLUCCS code names (to Level 3) and numeric codes are to be used.

**Dominant Spp.: Groundcover, Shrub and Canopy**

The most abundant 4 species present in each of these vegetation layers are to be recorded.

"Ground Cover" = all herbaceous and woody vegetation <1m in height.

"Shrubs" = sub-canopy species or woody stems >1m in height and <6cm dbh (1-4").

"Tree" = canopy species or woody plants ≥6m in height and ≥6cm dbh (greater than 4").

Provide a complete species list of all plants at the wetland assessment site.

**Soil Condition****Soil Type**

Soil at the wetland assessment site shall be examined for organic and mineral (sand, silt, clay) content. If an organic layer is present, measure and record the depth, in inches, from the ground surface to a mineral layer. Do not include surface duff or leaf litter in the measurement.

**Soil Subsidence**

The magnitude of any soil subsidence shall be measured relative to field indicators (such as exposed roots) and recorded on the field assessment sheet as depth in inches from original to current ground surface. Representative photographs must be taken of any soil subsidence identified at the site adjacent to a measuring stick for reference.

**Soil Fissures**

The depth, in inches, of soil fissures (cracks), relative to the soil surface shall be measured and recorded on the field assessment sheet. Representative photographs must be taken of any soil fissures identified at the site (use a measuring stick for reference).

**Water Table Depth**

Record the mean depth of water in the community as a positive value. If surface water is absent, dig a hole to determine the depth, in inches) to the water table from ground surface. Record this number as a negative value.

**Mean, Maximum and Hurricane High Pool Depths**

The field assessment sheet will provide the evaluators with a list of water level indicators. Record the maximum and mean pool depths, in inches, on the field assessment sheet. Representative photographs must be taken of any water level indicators identified at the site. Field indicators listed on the field assessment sheet should provide the evaluator with sufficient evidence for the maximum and mean pool depths. These should be measured in units of inches.

The historic pool elevation of a wetland should not be confused with the relic hydrologic indicators that still exist from the 2004 hurricane season or from the recent extremely high water levels from tropical storm Faye. Many of the indicators that have been observed include a secondary set of elevated lichen lines, stain lines and adventitious roots that are above the typical seasonal high water elevation (max pool) and normal pool elevations. In determining the historic pool elevation it is more accurate to use consistent long-term indicators such as inflection points on older cypress trees, distinct upland vegetation lines (such as saw palmetto or live oak fringes), relic docks or pilings, etc. Photographs of these indicators should be taken adjacent to a measuring stick for reference.

**Habitat Condition**

Provide a qualitative description of the wetland's condition and circle all observed stress factors listed in the footnote. If a stress factor is not listed, add it to the qualitative description. If a stress factor is not mentioned in the qualitative description or is not circled in the footnote list, it is assumed to not be present.

"Invasive Species" = either native or non-native species that have known invasive habits; examples include *Ludwigia peruviana* and *Typha latifolia*. Note if they are present only on the wetland fringe or in the interior as well. Several representative photographs should be taken which shows invasive species observed at the site.

"Invading Species" = the invasion of "dryer" species moving into the wetland. This can include upland species moving into the wetland or species that would normally be seen on the wetland edge moving into the deeper portion of the wetland. Examples include *Pinus elliottii* invading wet prairie, red maple moving into a cypress dominated system, blackberry (*Rubis spp*, poison ivy (*Toxicodendron radicans*), pokeweed (*Phytolacca americana*), and dog fennel (*Eupatorium capillifolium*) encroaching into a wetland. Note if they are present only on the wetland fringe or in the interior as well. Representative photographs must be taken of any invading species observed at the site.

It is important to appropriately describe the age (woody vegetation) and number or percent cover of these species. For instance, if canopy species are invading a marsh wetland, describe their age class, and number of invading i.e., 12 *Pinus elliottii* saplings; 3 *Pinus elliottii* trees.

Example: *Typha latifolia* equal approximately 30% of the remaining 70% desirable ground cover species = 100% Record as: 30% *Typha latifolia*

"Tree Fall" = approximate % or numbers of tree falls that appear to be abnormally high, list species affected in the qualitative description. Representative photographs must be taken of any tree falls identified at the site.

"Exposed Roots" = obvious signs of exposed roots at the base of trees and/or shrubs that seem to indicate that the soil has receded, report measured height (in.). Representative photographs

must be taken which shows exposed roots identified at the site taken adjacent to a measuring stick for reference.

“Dead or Dying Plants, Premature Leaf Falls, Discolored Foliage, Stunted Growth” = plants that are stressed to the point of dying or impaired growth; if from prolonged desiccation or disease, note this, the species, and the approximate % or number in the qualitative description. This descriptor does not include effects of normal seasonal senescence (perennials) or completion or life cycles (annuals). This indicator of harm should not be circled if the dead vegetation is associated with the normal seasonal diebacks associated with frost or freezes. Representative photographs must be taken of any dead, dying, or hydrologically stressed plants identified at the site.

Other Stress Indicators – See Indicators of Harm List (provided)

***Attachments:***  
***Abundance Index Key and Graphic***  
***Indicators of Environmental Harm List***  
***FLUCCS codes***

***Recommended Field Equipment:***  
***Pocket Rod or Large Tape Measure***  
***Soil Probe***  
***Survey Measuring Rod***  
***Laser Level***

## 2004-2005 SFWMD FLUCCS CODES

(Categories not found in central Florida wetlands are omitted)

### 3000 UPLAND NONFORESTED

- 3100 Herbaceous (Dry Prairie)
- 3200 Upland Shrub and Brush land
  - 3210 Palmetto Prairies
  - 3220 Coastal Shrub
  - 3230 Abandoned Groves
- 3300 Mixed Rangeland

### 4000 UPLAND FORESTS

- 4100 Upland Coniferous Forests
  - 4110 Pine Flatwoods
  - 4120 Longleaf Pine - Xeric Oak
  - 4130 Sand Pine
  - 4140 Pine - Mesic Oak
- 4200 Upland Hardwood Forests
  - 4210 Xeric Oak
  - 4220 Brazilian Pepper
  - 4240 Melaleuca
  - 4270 Live Oak
  - 4271 Oak - Cabbage Palm Forests
  - 4280 Cabbage Palm
- 4300 Upland Mixed Forests
  - 4340 Upland Mixed Coniferous / Hardwood
  - 4370 Australian Pine
- 4400 Tree Plantations
  - 4410 Coniferous Plantations
  - 4420 Hardwood Plantations
  - 4430 Forest Regeneration Areas

### 5000 WATER

- 5100 Streams and Waterways
  - 5110 Natural River, Stream, Waterway
  - 5120 Channelized Waterways, Canals
- 5200 Lakes
  - 5250 Marshy Lake
- 5300 Reservoirs
- 5600 Slough Waters

## **6000 WETLANDS**

### **6100 Wetland Hardwood Forests**

**6110 Bay Swamps**

**6111 Bay head**

**6170 Mixed Wetland Hardwoods**

**6172 Mixed Shrubs**

**6180 Cabbage Palm Wetland**

**6190 Exotic Wetland Hardwoods**

**6191 Wet Melaleuca**

### **6200 Wetland Coniferous Forests**

**6210 Cypress**

**6215 Cypress- Domes/Heads**

**6216 Cypress - Mixed Hardwoods**

**6240 Cypress - Pine - Cabbage Palm**

**6250 Wet Pinelands Hydric Pine**

**6260 Pine Savannah**

### **6300 Wetland Forested Mixed**

### **6400 Vegetated Non-Forested Wetlands**

**6410 Freshwater Marshes / Graminoid Prairie - Marsh**

**6411 Freshwater Marshes - Saw grass**

**6420 Saltwater Marshes / Halophytic Herbaceous Prairie**

**6430 Wet Prairies**

**6440 Emergent Aquatic Vegetation**

### **6500 Non-Vegetated Wetland**



# Indicators of Environmental Harm

6/18/08

## Vegetation:

1. Shifts and change in plant communities
2. Lack of distinctive zonation
3. Invasion by upland species
4. Presence of nuisance or exotic species
5. Death or stress of wetland tree species
6. Leaning trees
7. Tree Falls
8. Absence of regeneration of wetland species (all strata)
9. Age class differences of trees
10. Inappropriate species
11. Exposed tree roots

## Soils:

1. Loss of organic soil - Oxidation/Subsidence
2. Fissuring of organic soil
3. Loss of organic soil from catastrophic fire events

## Hydrology:

1. Lack of hydrologic indicators
2. Evidence of a reduced hydrologic regime from historic levels
3. Inappropriate hydrologic regime for wetland type
4. Lack of crayfish burrows

# FLORIDA'S ENDANGERED AND THREATENED SPECIES

Updated January 2013

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

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Source: [http://myfwc.com/media/1515251/threatened\\_endangered\\_species.pdf](http://myfwc.com/media/1515251/threatened_endangered_species.pdf)

**NUMERICAL SUMMARY OF SPECIES**

Listed by the State of Florida as Federally-designated Endangered (**FE**), Federally-designated Threatened (**FT**), Federally-designated Threatened because of similarity of appearance [**FT(S/A)**], Federal non-essential experimental population (**FXN**), State-designated Threatened (**ST**), or State Species of Special Concern (**SSC**).

<b>STATUS DESIGNATION</b>	<b>FISH</b>	<b>AMPHIBIANS</b>	<b>REPTILES</b>	<b>BIRDS</b>	<b>MAMMALS</b>	<b>INVERTEBRATES</b>	<b>TOTAL</b>
FE	3	1	4	9	22	8	47
FT	2	1	6	4	1	6	20
FT(S/A)	0	0	1	0	0	3	4
FXN	0	0	0	1	0	0	1
ST	3	0	7	5	3	1	19
SSC	6	4	6	16	6	4	42
<b>TOTAL</b>	<b>14</b>	<b>6</b>	<b>24</b>	<b>35</b>	<b>32</b>	<b>22</b>	<b>133</b>

## FLORIDA'S ENDANGERED AND THREATENED SPECIES OFFICIAL LIST

### VERTEBRATES

#### FISH

Common Name	Scientific Name	Status
Atlantic sturgeon	<i>Acipenser oxyrinchus</i>	FE
Blackmouth shiner	<i>Notropis melanostomus</i>	ST
Bluenose shiner	<i>Pteronotropis welaka</i>	SSC
Crystal darter	<i>Crystallaria asprella</i>	ST
Gulf sturgeon	<i>Acipenser oxyrinchus [=oxyrhynchus] desotoi</i>	FT
Harlequin darter	<i>Etheostoma histrio</i>	SSC
Key silverside	<i>Menidia conchorum</i>	ST
Lake Eustis pupfish	<i>Cyprinodon hubbsi</i>	SSC
Okaloosa darter	<i>Etheostoma okaloosae</i>	FT
Rivulus	<i>Rivulus marmoratus</i>	SSC
Saltmarsh topminnow	<i>Fundulus jenkinsi</i>	SSC
Shortnose sturgeon	<i>Acipenser brevirostrum</i>	FE
Smalltooth sawfish	<i>Pristis pectinate</i>	FE
Southern tessellated darter	<i>Etheostoma olmstedii maculaticeps</i>	SSC

#### AMPHIBIANS

Common Name	Scientific Name	Status
Florida bog frog	<i>Lithobates okaloosae</i>	SSC
Frosted flatwoods salamander	<i>Ambystoma cingulatum</i>	FT
Georgia blind salamander	<i>Haideotriton wallacei</i>	SSC
Gopher frog	<i>Lithobates capito</i>	SSC
Pine barrens treefrog	<i>Hyla andersonii</i>	SSC
Reticulated flatwoods salamander	<i>Ambystoma bishopi</i>	FE

#### REPTILES

Common Name	Scientific Name	Status
Alligator snapping turtle	<i>Macrochelys temminckii</i>	SSC
American alligator	<i>Alligator mississippiensis</i>	FT(S/A)
American crocodile	<i>Crocodylus acutus</i>	FT
Atlantic salt marsh snake	<i>Nerodia clarkii taeniata</i>	FT
Barbour's map turtle	<i>Graptemys barbouri</i>	SSC
Bluetail mole skink	<i>Eumeces egregius lividus</i>	FT

Common Name	Scientific Name	Status
Eastern indigo snake	<i>Drymarchon corais couperi</i>	FT
Florida brownsnake <sup>1</sup>	<i>Storeria victa</i>	ST
Florida Keys mole skink	<i>Eumeces egregius egregius</i>	SSC
Florida pine snake	<i>Pituophis melanoleucus mugitus</i>	SSC
Gopher tortoise	<i>Gopherus polyphemus</i>	ST
Green sea turtle	<i>Chelonia mydas</i>	FE
Hawksbill sea turtle	<i>Eretmochelys imbricata</i>	FE
Kemp's ridley sea turtle	<i>Lepidochelys kempii</i>	FE
Key ringneck snake	<i>Diadophis punctatus acricus</i>	ST
Leatherback sea turtle	<i>Dermochelys coriacea</i>	FE
Loggerhead sea turtle	<i>Caretta caretta</i>	FT
Peninsula ribbon snake <sup>1</sup>	<i>Thamnophis sauritus sackenii</i>	ST
Red rat snake <sup>1</sup>	<i>Elaphe guttata</i>	SSC
Rim rock crowned snake	<i>Tantilla oolitica</i>	ST
Sand skink	<i>Neoseps reynoldsi</i>	FT
Short-tailed snake	<i>Stilosoma extenuatum</i>	ST
Striped mud turtle <sup>1</sup>	<i>Kinosternon baurii</i>	ST
Suwannee cooter	<i>Pseudemys suwanniensis</i>	SSC

## BIRDS

Common Name	Scientific Name	Status
American oystercatcher	<i>Haematopus palliatus</i>	SSC
Audubon's crested caracara	<i>Polyborus plancus audubonii</i>	FT
Bachman's wood warbler	<i>Vermivora bachmanii</i>	FE
Black skimmer	<i>Rynchops niger</i>	SSC
Brown pelican	<i>Pelecanus occidentalis</i>	SSC
Burrowing owl	<i>Athene cunicularia</i>	SSC
Cape Sable seaside sparrow	<i>Ammodramus maritimus mirabilis</i>	FE
Eskimo curlew	<i>Numenius borealis</i>	FE
Everglade snail kite	<i>Rostrhamus sociabilis plumbeus</i>	FE
Florida grasshopper sparrow	<i>Ammodramus savannarum floridanus</i>	FE
Florida sandhill crane	<i>Grus canadensis pratensis</i>	ST
Florida scrub-jay	<i>Aphelocoma coerulescens</i>	FT
Ivory-billed woodpecker	<i>Campephilus principalis</i>	FE
Kirtland's wood warbler (Kirtland's warbler)	<i>Dendroica kirtlandii</i> ( <i>Setophaga kirtlandii</i> )	FE

Common Name	Scientific Name	Status
Least tern	<i>Sterna antillarum</i>	ST
Limpkin	<i>Aramus guarauna</i>	SSC
Little blue heron	<i>Egretta caerulea</i>	SSC
Marian's marsh wren	<i>Cistothorus palustris marianae</i>	SSC
Osprey <sup>2</sup>	<i>Pandion haliaetus</i>	SSC
Piping plover	<i>Charadrius melodus</i>	FT
Red-cockaded woodpecker	<i>Picoides borealis</i>	FE
Reddish egret	<i>Egretta rufescens</i>	SSC
Roseate spoonbill	<i>Platalea ajaja</i>	SSC
Roseate tern	<i>Sterna dougallii dougallii</i>	FT
Scott's seaside sparrow	<i>Ammodramus maritimus peninsulae</i>	SSC
Snowy egret	<i>Egretta thula</i>	SSC
Snowy plover	<i>Charadrius nivosus</i> ( <i>Charadrius alexandrinus</i> )	ST
Southeastern American kestrel	<i>Falco sparverius paulus</i>	ST
Tricolored heron	<i>Egretta tricolor</i>	SSC
Wakulla seaside sparrow	<i>Ammodramus maritimus juncicola</i>	SSC
White-crowned pigeon	<i>Patagioenas leucocephala</i>	ST
Whooping crane	<i>Grus americana</i>	FXN
White ibis	<i>Eudocimus albus</i>	SSC
Worthington's marsh wren	<i>Cistothorus palustris griseus</i>	SSC
Wood stork	<i>Mycteria americana</i>	FE

### MAMMALS

Common Name	Scientific Name	Status
Anastasia Island beach mouse	<i>Peromyscus polionotus phasma</i>	FE
Big Cypress fox squirrel	<i>Sciurus niger avicennia</i>	ST
Caribbean monk seal	<i>Monachus tropicalis</i>	FE
Choctawhatchee beach mouse	<i>Peromyscus polionotus allophrys</i>	FE
Eastern chipmunk	<i>Tamias striatus</i>	SSC
Everglades mink	<i>Neovison vison evergladensis</i>	ST
Finback whale	<i>Balaenoptera physalus</i>	FE
Florida bonneted (mastiff) bat	<i>Eumops [=glaucinus] floridanus</i>	ST
Florida mouse	<i>Peromyscus floridanus</i>	SSC
Florida panther	<i>Puma [=Felis] concolor coryi</i>	FE

Common Name	Scientific Name	Status
Florida salt marsh vole	<i>Microtus pennsylvanicus dukecampbelli</i>	FE
Gray bat	<i>Myotis grisescens</i>	FE
Gray wolf	<i>Canis lupus</i>	FE
Homosassa shrew	<i>Sorex longirostris eonis</i>	SSC
Humpback whale	<i>Megaptera novaeangliae</i>	FE
Indiana bat	<i>Myotis sodalis</i>	FE
Key deer	<i>Odocoileus virginianus clavium</i>	FE
Key Largo cotton mouse	<i>Peromyscus gossypinus allapaticola</i>	FE
Key Largo woodrat	<i>Neotoma floridana smalli</i>	FE
Lower Keys rabbit	<i>Sylvilagus palustris hefneri</i>	FE
North Atlantic right whale	<i>Eubalaena glacialis</i>	FE
Perdido Key beach mouse	<i>Peromyscus polionotus trissyllepsis</i>	FE
Red wolf	<i>Canis rufus</i>	FE
Rice rat	<i>Oryzomys palustris natator</i>	FE <sup>1</sup>
Sanibel Island rice rat	<i>Oryzomys palustris sanibeli</i>	SSC
Sei whale	<i>Balaenoptera borealis</i>	FE
Sherman's fox squirrel	<i>Sciurus niger shermani</i>	SSC
Sherman's short-tailed shrew	<i>Blarina [=carolinensis] shermani</i>	SSC
Southeastern beach mouse	<i>Peromyscus polionotus niveiventris</i>	FT
Sperm whale	<i>Physeter catodon [=macrocephalus]</i>	FE
St. Andrew beach mouse	<i>Peromyscus polionotus peninsularis</i>	FE
West Indian manatee (Florida manatee)	<i>Trichechus manatus</i> ( <i>Trichechus manatus latirostris</i> )	FE

**INVERTEBRATES****CORALS**

Common Name	Scientific Name	Status
Elkhorn coral	<i>Acropora palmata</i>	FT
Pillar coral	<i>Dendrogyra cylindricus</i>	ST
Staghorn coral	<i>Acropora cervicornis</i>	FT

**CRUSTACEANS**

Common Name	Scientific Name	Status
Black Creek crayfish (Spotted royal crayfish)	<i>Procambarus pictus</i>	SSC

Common Name	Scientific Name	Status
Panama City crayfish	<i>Procambarus econfinae</i>	SSC
Santa Fe Cave crayfish	<i>Procambarus erythrops</i>	SSC
Squirrel Chimney Cave shrimp	<i>Palaemonetes cummingi</i>	FT

### INSECTS

Common Name	Scientific Name	Status
American burying beetle	<i>Nicrophorus americanus</i>	FE
Cassius blue butterfly	<i>Leptotes cassius theonus</i>	FT(S/A)
Ceraunus blue butterfly	<i>Hemiargus ceraunus antibubastus</i>	FT(S/A)
Miami blue butterfly	<i>Cyclargus thomasi bethunebakeri</i>	FE
Nickerbean blue butterfly	<i>Cyclargus ammon</i>	FT(S/A)
Schaus' swallowtail butterfly	<i>Heraclides aristodemus ponceanus</i>	FE

### MOLLUSKS

Common Name	Scientific Name	Status
Chipola slabshell (mussel)	<i>Elliptio chipolaensis</i>	FT
Fat threeridge (mussel)	<i>Amblema neislerii</i>	FE
Florida treesnail	<i>Liguus fasciatus</i>	SSC
Gulf moccasinshell (mussel)	<i>Medionidus penicillatus</i>	FE
Ochlockonee moccasinshell (mussel)	<i>Medionidus simpsonianus</i>	FE
Oval pigtoe (mussel)	<i>Pleurobema pyriforme</i>	FE
Purple bankclimber (mussel)	<i>Elliptoideus sloatianus</i>	FT
Shinyrayed pocketbook (mussel)	<i>Lampsilis subangulata</i>	FE
Stock Island tree snail	<i>Orthalicus reses [not incl. nesodryas]</i>	FT



## KEY TO ABBREVIATIONS AND NOTATIONS

### List Abbreviations

FWC =	Florida Fish and Wildlife Conservation Commission
FE =	Federally-designated Endangered
FT =	Federally-designated Threatened
FXN =	Federally-designated Threatened Nonessential Experimental Population
FT(S/A) =	Federally-designated Threatened species due to similarity of appearance
ST =	State-designated Threatened
SSC =	State Species of Special Concern

### List Notations

- <sup>1</sup> Lower keys population only.
- <sup>2</sup> Monroe County population only.

**SPECIES ADDED, REVISED, OR REMOVED SINCE 2010**

The Florida black bear was removed from Florida's Endangered and Threatened Species List on August 23, 2012 after approval by the Commission at the June 2012 Commission meeting. A new Florida Black Bear Management Plan was also approved at this meeting.

The Miami blue butterfly was emergency listed as Endangered by the U.S. Fish and Wildlife Service on August 10, 2011. On April 6, 2012, the Miami blue was officially listed as Endangered by the U.S. Fish and Wildlife Service. Effective September 9, 2012 the FWC listed the Miami blue butterfly as Federally-designated Endangered on Florida's Endangered and Threatened Species List.

The Cassius blue butterfly, ceraunus blue butterfly, and nickerbean blue butterfly were emergency listed as Threatened Due to Similarity of Appearance to the Miami blue by the U.S. Fish and Wildlife Service on August 10, 2011. On April 6, 2012, these three species were officially listed as Threatened Due to Similarity of Appearance to the Miami blue by the U.S. Fish and Wildlife Service. These three species were listed on Florida's Endangered and Threatened Species List as Federally-designated Threatened by Similarity of Appearance to the Miami blue butterfly effective September 9, 2012, and as such only the following prohibitions apply to these three species:

- a. Incidental take, that is, take that results from, but is not a purpose of, carrying out an otherwise lawful activity will not apply to cassius blue butterfly, ceraunus blue butterfly, and nickerbean blue butterfly.
- b. Collection of the cassius blue butterfly, ceraunus blue butterfly, and nickerbean blue butterfly is prohibited in coastal counties south of Interstate 4 and extending to the boundaries of the State of Florida at the endpoints of Interstate 4 at Tampa and Daytona Beach. Specifically, such activities are prohibited in the following counties: Brevard, Broward, Charlotte, Collier, De Soto, Hillsborough, Indian River, Lee, Manatee, Pinellas, Sarasota, St. Lucie, Martin, Miami-Dade, Monroe, Palm Beach, and Volusia

The Okaloosa darter was reclassified by the U.S. Fish and Wildlife Service on effective May 2, 2011 from Endangered to Threatened. A special rule under Section 4d of the Endangered Species Act was also adopted that allows Eglin Air Force Base to continue activities with a reduced regulatory burden and will provide a net benefit to the Okaloosa darter.

*Environmental Measures Team Final Report*

*Attachment C – Soils Studies*

*November, 2013*



## Attachment C – Soils Studies at EMT Wetland Sites

Christina Uranowski, SWFWMD; Travis Richardson, SJRWMD; Gregory Sawka, Southeast Soil & Environmental Service, Inc.

### Introduction

Hydric soils are soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. These conditions result in specific soil morphologies, which are defined in Field Indicators of Hydric Soils in the United States (USDA, NRCS 2010). Hydric soils are generally characterized by the accumulation of organic matter or by the presence of redoximorphic features that result from the reduction and translocation of iron or manganese.

Accumulation of organic matter typically occurs in wetlands where frequent saturation or inundation (and associated anaerobic conditions) result in lower decomposition rates. The accumulation of organic matter is a slow process, due to the multiple factors and processes involved, and can take more than 100 years to form 1” of muck. The same amount of muck can be lost in a single year through oxidation when organic soils are drained.

Redoximorphic features near the soil surface also typically occur within wetlands because this soil morphology will only form in anaerobic conditions. Iron and manganese are immobile in aerobic conditions, but mobile in anaerobic conditions. Under anaerobic conditions iron and manganese are removed from some areas and concentrate in others resulting in the depletions and concentrations characteristic of redoximorphic features.

Accumulation of organic matter and formation of redoximorphic features are directly related to hydrology and, therefore, are a critical component to consider when assessing the hydrology of a wetland system.

### Subsequent Soil Studies

A complete hydric soils assessment was completed for 44 wetlands investigated for the CFWI. This process was initiated by assessing the data needs and developing a field data sheet (**Figure C-1**) with input from the CFWI EMT, an independent soil scientist, and a SJRWMD soil scientist. The field data sheet was created to facilitate consistency between the two field data collection teams and ensure that all necessary data was collected. Each site was then researched to obtain elevations and datums for known benchmarks or staff gages and aerial imagery and other maps were reviewed to identify potential field sites. In general, field sites were established on public lands in areas with unaltered soils and relatively short distances between the wetland and adjacent uplands.

Soil Field Data Sheet							
Location (ID and Lat/Long):					Date:		
Personnel:							
Check Soil Pit Type:			Photos:		Description		
Historic Edge Pit (w/descriptions)							
Current Edge Pit							
HNH Pit							
Landward extent of muck, histosol, etc. HIS							
Horizon	Depth (in.)	Texture	Matrix Color (moist)	Mottles (% and color)	Diffuse (Y/N)	Redox Features (% and color)	Diffuse (Y/N)
Notes:							
Hydric Soil Indicator(s)		Depth Met (in.)	Measured Ground Elevation	BM desc:			
				BM location (lat/long):			
				BM elev:			
				BM datum:			
Estimated Seasonal High Saturation			Measured Ground Elevation				
Observed Seasonal High Water Indicators (lichen lines, buttress inflection, base of Lyonia root crowns, waterward edge of saw palmetto, base			Measured Elevation of Indicator(s)	<b>Critical Data:</b> 1. Landward extent of hydric soil indicators 2. Landward extent of histosol, histic epipedon, & muck presence (if present) 3. Observed Seasonal high water elevation (e.g. lichen lines, adventitious roots, etc.) 4. Soil description at historic wetland edge (base on topo, veg, and reasonable scientific judgement) 5. Soil description at current wetland edge (62-340) if different from historic. Describe observed vegetation, soils and other evidence based on reasonable scientific judgment.			
1. Altered or unaltered soil condition - describe				2. Are the indicators consistent with the wetland type?			

Figure C-1. Sample of the field data sheet for collecting soils information

The two field data collection teams completed joint assessments on Lake Rosalie and Big Gum Lake as a calibration exercise. Soils were described at the historic wetland/upland edge, the current upland/wetland edge (if different from historic), the hydric/non-hydric soil boundary, the landward

extent of muck, landward extent of histic epipedon (8" of organic soil), and landward extent of histosols (16" of organic soil). The landward extent of other hydric soil indicators were also described at some locations, but was not required. Hydric soil indicators (see below) were observed at the 44 wetlands and lakes investigated. Soil descriptions followed standard USDA, NRCS procedures (Schoeneberger et. al. 2012) for describing and sampling soils that includes the depth, color, texture, and other pertinent characteristic of each soil horizon. Ground elevations were determined at the location of each soil pit.

The two field data collection teams assessed indicators of seasonal high water, composition of vegetative communities, and the observed soils to determine if the hydrology suggested by each of these components was consistent. If inconsistencies or alterations were observed these were documented on the field sheets.

## Select Hydric Soil Field Indicators

*A7. 5 cm Mucky Mineral. For use in LRRs P, T, U, and Z. A mucky modified mineral surface layer 5 cm (2 in) or more thick starting within 15 cm (6 in) of the soil surface.*

**5 cm Mucky Mineral User Notes:** *Mucky* is a USDA texture modifier for mineral soil. The organic carbon content is at least 5 percent and ranges to as high as 18 percent. The percentage requirement is dependent upon the clay content of the soil; the higher the clay content, the higher the organic carbon requirement. An example is mucky fine sand that has at least 5 percent organic carbon, but not more than about 12 percent organic carbon. Another example is mucky sandy loam that has at least 7 percent organic carbon, but not more than about 14 percent organic carbon. See the glossary for the definition of mucky modified mineral texture.

*A8. Muck Presence. For use in LRRs U, V, and Z. A layer of muck that has a value 3 or less and chroma 1 or less within 15 cm (6 in) of the soil surface.*

**Muck Presence User Notes:** The presence of muck of any thickness within 15 cm (6 in) is the only requirement. Normally this expression of anaerobiosis is at the soil surface; however, it may occur at any depth within 15 cm (6 in). Muck is sapric soil material with at least 12 to 18 percent organic carbon. Organic soil material is called muck (sapric soil material) if virtually all of the material has under-gone sufficient decomposition such that plant parts cannot be identified. Hemic (mucky peat) and fibric (peat) soil materials do not qualify. To determine if muck is present, first remove loose leaves, needles, bark, and other easily identified plant remains. This is sometimes called a leaf/root mat. Then examine for decomposed organic soil material. Generally, muck is black and has a greasy feel; sand grains should not be evident. Hydric soil indicator determinations are made below the leaf or root mat; however, root mats that meet the definition of hemic or fibric soil material are included in the decision-making process for Mucky Peat, Peat, Organic Bodies, or Histic Indicators.

*S5. Sandy Redox. For use in all LRRs except V, W, X, and Y. A layer starting within 15 cm (6 in) of the soil surface that is at least 10 cm (4 in) thick and has a matrix with 60 percent or more chroma 2 or less with 2 percent or more distinct or prominent redox concentrations as soft masses and/or pore linings.*

**Sandy Redox User Notes:** Distinct and prominent are defined in the glossary. Redox concentrations include iron and manganese masses (reddish mottles) and pore linings (Vepraskas, 1994). Included within this concept of redox concentrations are iron/manganese bodies as soft masses with diffuse boundaries. Common (2 to less than 20 percent) or many (20 percent or more) redox concentrations are

required (USDA, NRCS, 2002). If the soil is saturated at the time of sampling, it may be necessary to let it dry to a moist condition for redox features to become visible.

*S6. Stripped Matrix.* For use in all LRRs except V, W, X, and Y. A layer starting within 15 cm (6 in) of the soil surface in which iron/manganese oxides and/or organic matter have been stripped from the matrix exposing the primary base color of soil materials. The stripped areas and translocated oxides and/or organic matter form a diffuse splotchy pattern of two or more colors. The stripped zones are 10 percent or more of the volume; they are rounded and approximately 1 to 3 cm (0.5 to 1 in) in diameter.

**Stripped Matrix User Notes:** This indicator includes the indicator previously named *polychromatic matrix* as well as the term *streaking*. Common to many areas of stripped (unmasked) soil materials are required. The stripped areas are typically 1 to 3 cm (0.5 to 1 in) in size but may be larger or smaller. Commonly the stripped areas have a value of 5 or more and chroma of 1 and/or 2 and the unstripped areas have chroma of 3 and/or 4. The matrix (predominant color) may not have the material with chroma of 3 and/or 4. The mobilization and translocation of oxides and/or organic matter is the important process and should result in splotchy masked and unmasked soil areas. This may be a difficult pattern to recognize and is more evident when a horizontal slice is observed.

*S7. Dark Surface.* For use in LRRs N, P, R, S, T, U, V, and Z. A layer 10 cm (4 in) or more thick starting within the upper 15 cm (6 in) of the soil surface with a matrix value 3 or less and chroma 1 or less. At least 70 percent of the visible soil particles must be covered, coated, or similarly masked with organic material. The matrix color of the layer immediately below the dark layer must have chroma 2 or less.

**Dark Surface User Notes:** The organic carbon content of this indicator is slightly less than required for mucky. An undisturbed sample must be observed. A 10X or 15X hand lens is an excellent tool to aid this decision. Many wet soils have a ratio of about 50 percent soil particles that are covered or coated with organic matter and about 50 percent uncoated or uncovered soil particles, giving the soil a salt and pepper appearance. Where the percent of coverage is less than 70 percent, a Dark Surface indicator is not present

#### Field Soil Study Results

Field Study results are summarized in Table C-1 in terms of defining elevations of the wetland edge. Additional work by the EMT determined whether systems were stressed or hydrologically altered (see main document). Analyses of historical hydrologic data were used to determine p80 values.



Table C-1. Data from the 44 CFWI EMT Class 1 Wetlands. Soils studies were used to determine the edge reference elevation for each site. Hydrologic analyses provided the p80 values. Additional studies were conducted by the EMT to determine whether sites were hydrologically stressed (see main report).

No.	Site Name	CFCA ID	Physio-Region	P80 (2006-2011) (ft. NGVD 29)	Edge Reference Elevation (ft. NGVD 29)	θ (ft.)	Stressed	Hydro Altered
1	Unnamed Cypress	SJ-LA	Plain	69.26	70.44	1.18	No	No
2	Green Swamp Marsh #304	SW-LI	Plain	92.64	93.90	1.26	No	No
3	Green Swamp #1, #298	SW-LM	Plain	98.43	100.60	2.17	No	No
4	City of Cocoa, Well 9T	SJ-LL	Plain	71.38	74.14	2.76	No	No
5	Walker Ranch - WR9	SF-XZ	Plain	65.57	68.34	2.77	No	No
6	Green Swamp 7	SW-AA	Plain	103.19	106.37	3.18	No	No
7	Walker Ranch - WR6	SF-LB	Plain	61.00	64.47	3.47	No	No
8	Green Swamp #5, #302	SW-LK	Plain	95.28	98.80	3.52	No	No
9	Walker Ranch - WR11	SF-LA	Plain	63.79	67.68	3.89	No	No
10	Green Swamp #6, #303	SW-LJ	Plain	94.07	98.10	4.03	No	No
11	Cypress Creek #199, W17	SW-LE	Plain	63.34	64.95	1.61	Yes	No
12	Tibet Butler - TB2***	SF-YK	Plain	98.72	102.63	3.91	Yes	No
13	Lake Gem	SJ-AJ	Plain	48.74	53.39	4.65	Yes	Yes
14	Cypress Creek #221, W33	SW-LH	Plain	65.92	70.79	4.87	Yes	No
15	Boggy Marsh	SJ-LC	Plain	113.82	118.82	5.00	Yes	No
16	Island Lake - 2774	SJ-LH	Plain	81.86	87.49	5.63	Yes	No
17	Cypress Creek #190 "E" Marsh	SW-LF	Plain	65.09	72.03	6.94	Yes	No
18	Cypress Creek #223 "B" W46	SW-LG	Plain	60.87	68.93	8.06	Yes	No
19	Lake Leonore (Patrick)	SW-QH	Ridge	85.08	86.23	1.15	No	No
20	Lake Annie (Highlands)	SW-QE	Ridge	109.95	111.49	1.54	No	No
21	Gator Lake	SW-QD	Ridge	129.89	131.80	1.91	No	No
22	Lake Apthorpe	SW-QF	Ridge	68.93	71.28	2.35	No	Yes
23	Lake Van*	SW-QK	Ridge	131.08	134.32	3.24	No	No
24	Lake Streety	SW-QJ	Ridge	103.21	105.95	2.74	No	No
25	Bonnet Lake	SW-QB	Ridge	89.29	92.04	2.75	No	No
26	Parks Lake	SW-QO	Ridge	99.83	102.81	2.98	No	No
27	Surveyors Lake	SW-QH	Ridge	130.30	133.36	3.06	No	No
28	Lake Garfield*	SW-JJ	Ridge	101.39	105.53	4.14	No	Yes
29	Hopkins Prairie	SJ-LD	Ridge	23.71	27.50	3.79	No	No
30	Johns Lake*	SJ-QB	Ridge	93.39	97.4	4.03	No	No
31	Buck Lake (Highlands)	SW-QC	Ridge	89.87	95.05	5.18	No	No
32	Lake Placid	SW-QI	Ridge	89.44	94.91	5.47	No	No
33	Trout Lake*	SJ-QC	Ridge	90.59	97.60	7.01	No	No
34	Polecat Lake	SW-QM	Ridge	139.50	144.37	4.87	Yes	No**
35	Lake Louisa*	SJ-LJ	Ridge	92.41	97.29	4.88	Yes	No
36	Big Gum Lake	SW-QA	Ridge	89.96	95.95	5.99	Yes	Yes
37	Crooked Lake	SW-QQ	Ridge	115.12	121.29	6.17	Yes	Yes*
38	Lake Apshawa	SJ-LF	Ridge	81.13	87.65	6.52	Yes	No
39	Church Lake	SJ-QA	Ridge	82.66	90.37	7.71	Yes	Yes*
40	Unnamed Wetland	SJ-LB	Ridge	61.41	69.37	7.96	Yes	No
41	Lake Wales	SW-MM	Ridge	102.65	111.35	8.70	Yes	No
42	Long Lake*	SJ-QD	Ridge	58.43	68.81	10.38	Yes	No
43	Lake Avalon	SJ-LE	Ridge	86.30	96.68	10.38	Yes	No
44	Lake Walker	SW-QL	Ridge	137.36	150.28	12.92	Yes	No**

\*ERE and θ values were modified to values shown in the table per subsequent staff discussions.

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*Environmental Measures Team Final Report*

*Attachment D –  
Literature Review to Support EMT Tasks*

*November, 2013*



## Attachment D - Literature Review to Support EMT Tasks

Joel VanArman, South Florida Water Management District

Shirley Denton, Cardno-ENTRIX, Inc.

### Introduction

The Environmental Measures Team (EMT), as part of the Central Florida Water Initiative (CFWI) was tasked with reviewing previous environmental assessments conducted within the region, performing additional assessments of wetlands, and other related work needed to support determination of sustainable groundwater withdrawals in the CFWI. As part of this effort, the team initiated a review of relevant published scientific literature.

The purpose of this review was to assist in determining whether the methods and tools used and developed by the EMT are appropriate and suitable for their purpose and consistent with methods and tools used in other similar studies from Florida and elsewhere. This was not intended to be a detailed review of the literature, but rather a targeted survey to determine the extent to which existing scientific studies provided support for the “critical assumptions” that were the basis for the EMT investigations and analyses. These assumptions were as follows:

1. Wetland ecology is a function of hydrology, past conditions, and non-hydrological changes (such as land use changes in the watershed and availability of native and non-native species for colonization) and other factors that affect wetland structure, species composition and ecosystem functions.
2. Wetland vegetation and soils largely respond in predictable ways to changes in hydrology, regardless of the cause of the change. Responses to change may vary depending on system type.
3. Non-hydrological changes can also alter wetland condition and need to be considered in any assessment of wetland condition relative to hydrology.
4. The time duration over which hydrologic (and other) stresses are applied to a wetland affects the extent to which changes to wetland vegetation and soils are apparent.
5. The extent to which changes to the Upper Floridan Aquifer or surficial aquifer system are translated into changes to surface feature hydrology varies with physiography and underlying geology.

Several other literature reviews have been conducted in recent years related to these topics. Results of these reviews were incorporated. Emphasis was placed on identifying other more recent studies that may not have been included in the prior literature reviews.

### Scope, Method and Approach

Two types of wetland systems were the major focus of this investigation. Lacustrine wetlands occupy shallow areas of lakes, along the perimeter or on the edges of islands. Palustrine wetlands include all freshwater, non-tidal wetlands that are substantially covered with emergent vegetation--trees, shrubs, moss, etc. The review mostly excluded studies of brackish or saltwater wetlands, riverine wetlands

(floodplains), wetlands located on seepage slopes, and extensive, interconnected wetland systems such as strands.

Scientific studies conducted to determine effects of reduced water levels in lakes and wetlands were the primary focus. Reduced water levels may occur periodically due to low rainfall conditions during the dry season or droughts. Drawdowns may also occur suddenly as the result of substrate collapse and sinkhole formation or less rapidly due to drainage, water withdrawals for human use or surface water management practices. In addition to water level reductions that occur naturally or incidentally due to human activities, periodic drawdowns are sometimes employed for effective lake or wetland management, or to facilitate mining or construction activities on adjacent lands.

In wetlands, reductions in water levels may result in migration of wetland plant community zones down slope to a lower elevation, leading to degradation or loss of the existing wetland and potential for the conversion of open lakes to wetlands. Even though some wetlands are destroyed and some new wetlands are created, the net result may be a net loss in areal extent of wetlands, a change in abundance and distribution of species, and a loss, shift or reduction of wetland functions and benefits, especially while the system is adjusting to the new water regime. The resulting disturbance may favor the influx or expansion of both native and non-native nuisance species. In lakes, water level reductions may lead to an expansion of the littoral zone and submerged vegetation into areas that were formerly open water. These problems can be exacerbated by water level stabilization and increased influx of nutrients. Changes in wetland hydroperiod (frequency and duration of minimum, maximum and intermediate water levels) can lead to dramatic changes in the composition and distribution of plant communities, soil characteristics and habitat.

Most wetland studies focus on the plant communities. Plants are the basis of the wetland food chain and provide both nutrition and habitat for associated animal communities. Major wetland types (e.g. prairies, marshes, swamps) are usually named primarily on the basis of their associated plant species assemblages and key environmental factors. Within a given geographic region such as Central Florida, the species composition of the wetlands in similar physiographic and hydrologic settings tends to be similar. A "plains" marsh on inorganic soils in the eastern part of the region will typically contain plants that are similar to those found in a plains marsh on inorganic soil in the western part of the region. Exceptions occur with respect to a plant species that may have very specialized habitat or reproductive requirements.

The presence and abundance of macroinvertebrates and small fishes are often studied, since they can be seasonally abundant in shallow wetlands or occur year-round in systems that remain hydrated. Many types of macroinvertebrates have fairly specific requirements in terms of food sources, substrate and seasonal reproductive and larval development requirements, but have widespread distribution wherever these conditions occur. Some amphibians have very specific requirements for water presence during their breeding seasons and adequate time for tadpoles to mature into adults, sometimes coupled with a need for the wetland to dry down to eliminate predators (fish). Because of this specificity, certain species of vertebrates and invertebrates are useful as "indicators." Some species are indicators of polluted or disturbed conditions, while others are found only in undisturbed or pristine environments.

By contrast, populations of larger animals such as birds and mammals can show extreme variations spatially, seasonally and from year-to-year. This can be especially true of migratory and/or threatened or endangered species. Birds, for example, may be very abundant in a particular lake or wetland one year and then absent the next year. Since these species are more difficult to observe and measure, there is much less literature available concerning the use of wetlands by birds and mammals.

In addition to their ecological impacts on lake wetlands, reduced water levels also affect navigation, recreation, fisheries, aesthetics, water quality and aquatic weed population dynamics. Studies of such factors were also noted in the literature review. These considerations have been used when establishing Minimum Flow and Level criteria (as outlined in Ch 373.042 F.S.) for water bodies, especially systems surrounded by development. The reviewers also looked for studies that employed innovative ways to sample or analyze data and/or determine stress or harm based on statistical characteristics of populations

Most of the literature search was conducted in the period from November 2012 to January 2013. The following databases were queried to conduct this review:

- Google Scholar, <http://www.google.com/intl/en/scholar/about.html>
- Palm Beach Atlantic University, West Palm Beach, FL <http://www.pba.edu/the-warren-library>
- University of Florida Wetlands Center in Gainesville, <http://www.cfw.ufl.edu/publications.shtml>
- The University of Florida/IFAS Center for Aquatic and Invasive Plants (APIRS) database, <http://plants.ifas.ufl.edu/APIRS/>
- South Florida Water Management District library facilities and publications, [http://www.sfwmd.gov/portal/pls/portal/portal\\_apps.repository\\_lib\\_pkg.repository\\_browse](http://www.sfwmd.gov/portal/pls/portal/portal_apps.repository_lib_pkg.repository_browse)
- St Johns River Water Management District reports, <http://floridaswater.com/technicalreports/> and <http://www.sjrwmd.com/minimumflowsandlevels/>,
- Southwest Florida Water Management District, <http://www.swfwmd.state.fl.us/documents/> and [http://www.swfwmd.state.fl.us/projects/mfl/mfl\\_reports.php](http://www.swfwmd.state.fl.us/projects/mfl/mfl_reports.php), Science Direct, <http://www.info.sciverse.com/sciencedirect>
- Proquest, <http://www.proquest.com/en-US/access/connect.shtml>
- Florida geological Society Publications, <http://www.dep.state.fl.us/geology/publications/listofpubs.htm>
- National Academy of Sciences Publications <http://dels.nas.edu/>
- United States Geological Survey (USGS) Florida Water Science Center, <http://fl.water.usgs.gov/publications/bibliography/bibliography.html>
- Association of State Wetland Managers (ASWM) <http://www.aswm.org/wetland-science/wetland-science/825-publicationsreports>

EMT team members developed several lists of key words and concepts that were used as the basis for document database queries:

- Aquifer-lake interaction
- Aquifer-wetland interaction
- Biodiversity change hydroperiod reduction
- Cypress growth rates hydroperiod reduction
- Cypress root rot hydroperiod

- Drawdown/drought/reduced water level and hydroperiod effects on wetlands and lake littoral zones
- Fish reproduction effects of lake area and littoral shelf
- Lake area reduction – effects on aesthetic acceptability or recreational use
- Effects of hydrologic changes on Wetland species diseases and growth rates
- Effects of water levels on dissolved oxygen concentrations in lakes and wetlands
- Lake littoral shelf or wetland/marsh area effect on plant or animal biodiversity
- Lake or wetland drawdown
- Lake or Wetland hydrology
- Lake or wetland relationship to aquifer or groundwater levels
- Lake or wetland/marsh animal (fish, birds, macro-invertebrates, amphibians) habitats reduced water levels
- Marsh species hydroperiod reduction
- Modeling lake or wetland response to water levels
- Plant or animal stress, damage or harm due to lake or wetland drawdown
- Soil oxidation, loss, subsidence due to decreased water levels
- Soil subsidence relationship to saturation and duration of inundation
- Water level regulation of lakes or wetlands
- Wetland water level or hydroperiod reduction effects nutrient cycling
- Wetland water level or hydroperiod reduction effects on plants or animals
- Wetland/Lake Statistical analysis of hydrology related to biota

## Results

### Types of Studies

A large number of literature citations (> 10,000) were initially identified that relate to the subject matter. Efforts were made to reduce and refine the search parameters and to place priority on studies that seemed to be most relevant to the EMT efforts and for which physical copies or electronic versions of the study could be obtained with available resources.

Emphasis was placed on the following types of investigations, although some additional studies that seemed particularly relevant or interesting were included:

- Studies conducted in the last 20 years (1992-2013), and especially in the last seven years (2005-2013).
- Studies conducted over multiple systems, watershed or regions as well as site-specific investigations
- Studies conducted in the southern United States, especially central and southern Florida and studies conducted on similar geological settings such as coastal plains as opposed to temperate prairies, mountainous or arid regions, etc.
- Studies conducted in palustrine and lacustrine wetlands rather than riverine, seepage-driven and coastal wetland systems, which were generally excluded.

**Table D-1** provides a summary of the investigations. A total of 367 citations from the selected literature were compiled in a simple spreadsheet database and categorized by date, author, system type (wetland, lake, other), and study type (hydrology, vegetation, invertebrates, groundwater, water quality, modeling, etc.). Electronic copies of most of these papers are compiled in a separate archive.



Of the total number of citations examined, more than half represented studies conducted in Florida. More than half of the studies were conducted in palustrine wetlands. More than 100 additional studies were conducted in lacustrine wetlands or a mixture of both palustrine and lacustrine wetlands. Approximately 20% of the studies were conducted in association with the Minimum Flows and Levels programs of the water management districts. The Florida studies were considered to be the most relevant, since they most informed the methods developed by the EMT. Studies from other areas were generally less useful because they have different species of plants and animals as well as different climate and hydrology, topography, soils and geology, and deal with somewhat different water management issues than are typically encountered in Central Florida.

**Table D-1. References Related to Wetlands Compiled for the EMT Literature Review**

Area or Topic Studied	No. of References	Area or Topic Studied	No. of References
<b>By Resource</b>		<b>By Topic*</b>	
Estuary	4	Minimum Flows and Levels	52
Flatwoods	4	Macroinvertebrates	5
Groundwater studies	7	Methods	20
Lakes	65	Models and modeling studies	36
Lakes/Streams	1	Hydrology	100
Lakes/wetlands	47	Monitoring	3
Misc	23	Indicators	24
River	14	Management	20
Springs/Streams	3	Indexes	4
Soil	4	Land use	3
Wetlands	195	Agriculture	2
<b>By Resource Sub Total</b>	<b>367</b>	Classification	10
<b>Geographic Distribution</b>		Distribution	8
Florida site specific	76	Hurricane Effects	6
Florida Multiple sites	15	Climate Effects	13
Florida Subregional	44	Fire Effects	5
Florida regional	50	Soils	3
Florida Statewide	35	Water supply	7
<b>Florida Sub Total</b>	<b>220</b>	water quality	7
Georgia	3	Water supply	7
South Carolina	4	Statistics	3
New Jersey	2	Other	29
Tennessee	2	<b>TOTAL</b>	<b>367</b>
North Carolina, North Dakota, Rhode Island, Texas, Minnesota, Pennsylvania, Michigan, 1 ea.	7		
Southeastern US Region	5		
Prairie US Region	1		
Great lakes Region	25		
Western US region	1		
China	5		
Other	11		
USA	22		
Global	6		
General	53		
<b>Other Areas Subtotal</b>	<b>147</b>		

Nevertheless, some of these less obviously relevant studies provided additional insight into new or emerging issues, and methods that may be potentially useful for application in the CFWI region.

### Support for EMT Critical Assumptions and Approaches

Results of the search were analyzed to determine the extent to which existing scientific studies provide support for the six “critical assumptions” (see above) of the EMT investigations and analyses.

### Conditions that affect wetland ecology

Wetland ecology is a function of hydrology, past conditions, and non-hydrological changes (such as land use changes in the watershed and availability of native and non-native species for colonization) that

affect wetland species composition and function. Most of the wetland studies reviewed were based on this same or similar assumptions, which may or may not have been explicitly stated, so there is excellent support in the literature for this assumption (for instance, Lentz and Dunson, 2006; Gregory, et al., 2006; Brown and Vivas, 2005).

#### **Wetlands may change over time in response to changes in climate regime**

A number of studies indicate that wetlands that exist in Florida today have been shaped by many cycles of natural climate change, including periods of warmer temperatures, glaciation and a wide range of sea-level fluctuation. The distribution, extent and species composition of wetlands are natural occurrences and the species that live in Florida today represent communities that have evolved, adapted, and/or been selected for these conditions (Gaiser et al., 2009; Bernhardt and Willard, 2009).

Wetlands respond to short-term extreme events. Extreme events whose effects are often localized and of short duration, such as hurricanes, tornadoes, fires, floods and freezes impact Florida's wetlands (see for example Wade et al., 1980, Brandt and Ewel, 1989; Lovelace and McPherson, 1997; Deng et al., 2010). The damage caused by these events can sometimes persist for a long time, especially if they alter overall hydrologic conditions (Smith et al., 2009; Morton and Barras, 2011; Farris et al., 2007). However, climatic stressors and extreme events are a normal part of wetland ecology (e.g., decadal wet and dry cycles, periodic drought, fire or freezes) and are essential for maintaining wetland health (Frederickson, 1991; Shipley and Parent, 1991). The importance of periodic extremes has been emphasized in the lake and stream MFL methods of the SJRWMD (Neubauer et al., 2008).

#### **Wetlands respond to hydrologic change**

Wetland vegetation and soils largely respond in predictable ways to changes in hydrology, regardless of the cause of the change. The nature of the may vary depending on system type (for instance, Palanisamy and Chui, 2012; Webb et al., 2012; Lee, 2002).

#### **Wetlands respond to global-scale phenomena and climate change**

Hydrologic conditions vary over long periods that reflect changes in global-scale phenomena, including solar activity, changes in orbital distance from the sun, global temperature cycles, changing sea levels and major oceanic currents (IPCC, 2001). These changes may act over periods of decades or longer. Atmospheric temperatures and hydrologic conditions are affected by cyclic, multi-year or multi-decadal global weather phenomena such as the Atlantic Multidecadal Oscillation (AMO) (Kelly and Gore, 2008) the El-Niño – Southern Oscillation (ENSO) (Donders et al., 2005) and others (Obeysekera et al., 2011), and by changes in the chemical composition of the atmosphere (IPCC, 2007), and by global events such as large volcanic eruptions (Neely et al., 2013).

#### **Time Required for wetlands to respond to changing conditions**

The time duration over which hydrologic (and other) stresses are applied to a wetland affects the extent to which changes to wetland vegetation and soils are apparent (for instance, Odland and Moral, 2002; Smith et al., 2008; Wilcox, 2004; Busch et al., 1998; SFWMD, 2000; Rochow, 1985). The species composition of a mature swamp canopy may not change for decades or longer after hydrologic conditions change. However, composition of the understory may change rapidly and dramatically as aquatic species disappear, seeds of wetland species fail to germinate and terrestrial species invade the

system (David, 1996; Armentano et al., 2006). Unnaturally dry conditions, which lead to desiccation of organic soils and proliferation of inappropriate understory vegetation, may eventually lead to complete loss of the swamp by tree collapse and more frequent fires (SFWMD, 2000). Rates of change and dependencies on hydrological regime have been estimated for some factors, such as soil subsidence (Stephen and Johnson, 1951; Shih et al., 1998); but are less well known for others.

#### **Wetland relationships to groundwater**

The extents to which changes to the Upper Floridan aquifer or surficial aquifer system are translated into changes to surface feature hydrology vary with physiography and variations in the underlying geology, including sinkhole formation. (for instance Sacks, 2002; Sanderson and Cooper, 2008; Tobias et al., 2001; SFWMD, 1995; SWFWMD, 1999; Swancar and Lee, 2003; Swancar et al., 2000; Sun et al., 2006; Whitman et al., 1999)

#### **Other Issues and Concerns Related to Wetland Values and Impacts**

In addition, we also looked for support for other methodological decisions, approaches selected, wetland values and impacts assessed during the study, including the development of the wetland classification scheme; stress determination; statistical approaches, water quality considerations and wetland-associated animal communities.

#### **Strengths and weaknesses of modeling applied to wetlands**

Modeling of current and future hydrology is a useful tool, but model limitations and the nature of the output provided to the EMT limit how the tool can appropriately be applied. For the regional-scale model developed for the CFWI, the EMT chose to use a probabilistic approach. This type of approach has been demonstrated in several other studies (Wilcox and Xie, 2007; 2008; Nilsson et al., 2013) to be effective and appropriate.

#### **GIS and modeling approaches**

Many studies applied GIS tools at various points in their investigations as a means to organize and compile data and visually represent wetland features obtained from aerial photography, remote sensing, land use studies, ground surveys and other sources of information (for instance Williams and Lyon, 1997; Dronova et al., 2011; Kinser and Minno, 1995; Dunn et al., 2008; Cole and Korfmacher, 2010; Wilcox et al., 2008). Aerial photography and satellite imagery combined with soil survey data can provide a basis for estimating the boundaries and extent of major wetlands, but ground-truthing is needed to determine species composition, hydration, the degree to which connections exist to adjacent lakes or wetlands, more subtle features that might indicate stress or harm, whether the system has been hydrologically altered by land use changes, construction or drainage activities.

GIS tools are often used as a means to organize and present data for planning and decision-making and for input to, and representation of, output data from modeling studies, by using the capability to overlay multiple data sets such as soil, water quality, water depth, land use, etc. GIS tools also provide a basis for Landscape modeling – the applications of GIS and modeling tools to predict wetland/vegetation changes in response to changes in hydrology, water quality, etc. over large areas (for example deAngelis, 1998; Zhang et al., 2011)..

Conceptual models can provide a useful planning tool for organizing information related to a wetland and identifying what is known from what is unknown about ecosystem dynamics, stressors, etc. (for example, Pyzoha et al., 2008; Ogden et al., 2005).

Mathematical models were used in 35 of the studies reviewed, primarily to predict hydrologic conditions and system responses. Models are often the tools of choice for studies that cover large areas or in cases where multiple scenarios need to be evaluated. This has become a common practice for analyses of future impacts caused by circumstances ranging from surface and groundwater withdrawals, construction of drainage and flood control projects, to assessment of potential effects of climate change (for example, Fan and Miguez-Macho 2011; Lee, 2005).

There appears to be widespread acceptance in the science and engineering communities that despite the limitations of models to represent real-world conditions, and the uncertainty of such predictions, models provide a highly useful and practical means to conduct these types of assessments (for example, Bengston and Padmanabhan, 1999; Loftin et al., 1990; USACE and SFWMD, 1999)..

The assumptions and limitations of any modeling approach need to be clearly stated and understood by decision-makers. When using models as the basis for planning, it is typically emphasized that actions need to be implemented in an adaptive management context that includes monitoring and periodic review to verify hydrologic model predictions, verify resource response over time, and modify plans or designs to eliminate or compensate for unforeseen impacts (allowable withdrawals or structural features) in the future if wetland degradation becomes apparent. (for example, Manno et al., 2008; Richards et al., 2010; Yin and Yang, 2012; RECOVER, 2010; SFWMD and USACE 2011).

Groundwater-surface water linked models have generally been used for site specific evaluations, such as to simulate the effects of well field withdrawals, etc. rather than across large regions. Models are used in this context to represent surface water-groundwater interactions and relationship to evapotranspiration, rainfall, runoff, streamflow, seepage, drawdowns and other environmental factors (Reynolds and Spruill, 1995; Lopez et al., 1999; Schmutz and Willis, 2004; Merritt, 2001; Cheng and Anderson, 2003; Bradley, 2002; Wilcox and Xie, 2007; Hudon et al., 2006).

Output from hydrologic models has been used extensively in water resource planning to generate future hydrologic regimes as a basis to predict impacts on wetlands, for example to support development of Minimum Flows and Levels criteria (Kinser et al. 2003; SJRWMD, 2004; Ellison 2007) as well as to simulate transpiration effects (Liu et al., 1998; Sun et al., 1998; Lu et al., 2009). There are also some examples using models to simulate responses of animal communities, notably birds (Desgranges et al. 2006; Bolduc and Alton, 2008, fish (niekand 2006) and overall productivity (Grant et al. 2012). More broadly-based, ecosystem-level, modeling examples include eco-response models (Limnotech, 2005; Chiu et al., 2011) and Landscape Models (deAngelis et al., 1998; Fitz and Paudel, 2012).

#### **Classification of wetlands.**

A number of studies develop or apply classification schemes as a means to place wetlands into logical groups. Such groupings help to simplify the analysis by not having to consider each wetland individually. The classification scheme generally considers some combination of geography, landscape position, geomorphology, hydro pattern, climate, physical/chemical variables, and biogeographic processes

(Doherty et al., 2000a). Classification systems are typically developed by compiling or synthesizing data from the literature or from studies of individual systems and attempting to organize the data based on common features, such as dominant plant species (cypress swamps, sawgrass marshes), combined hydrologic and plant features (wet prairies, sloughs) nutrient status (oligotrophic lakes) water source (spring fed lakes, floodplains) etc.

Thus there are systems that are used globally (RAMSAR, 2006; Lehner and Doll, 2004), nationwide (Cowardin et al., 1979; Tiner, 2013), at the state level (FNAI, 2010; FDOT, 1999; Doherty et al., 2000; Lane et al, 2000) and at regional or subregional levels (Brinson, 1993; Wilcox, 2005; see review by Dunn, 2005). The nature of the classification system often depends on the diversity and uniqueness of the resources in the area, the likely changes or impacts that need to be assessed and the scale of the project, and specific project goals and accuracy needs.

A number of authors have recognized the relationship between groundwater-fed and surface water fed systems as a distinguishing characteristic of wetlands (Bertrand et al., 2011; Almendinger, 1990; Harvey and McCormick, 2009; Skaggs et al., 2005) generally with respect to systems that receive direct groundwater seepage. Sensitivity to water level reductions in most wetland systems is based on vegetation type and soil conditions, especially in areas where there is no apparent hydrologic separation of the wetland from underlying aquifers (Shaw and Huffman, 1998). A major feature of concern to the CFWI study is the nature and degree of connection between lakes or wetlands and underlying surficial and deep aquifer systems, which were used as one of the bases for the classification system used in this study.

#### **Assessing wetland response to hydrologic changes**

A number of investigators have discussed the issue of assessing the “health” or condition of a wetland and making a determination of whether the system is experiencing stress or damage (USEPA, 2008; Pederson, 1998). Stress is generally perceived to occur when characteristics of the wetland change, but before the system has adjusted to the new environmental regime to the extent that the initial regime is no longer recognized. The most notable changes generally consist of shifts in the distribution or abundance of major plant species, changes in soil composition and structures, or changes in hydrology. Other, more subtle changes can also be monitored that provide prior indications of existing or pending impacts.

**Vegetation.** Various methods to assess changes in wetlands that have been used by the water management districts are discussed by Dunn, 2005. The kinds of changes that occur in vegetation communities include changes in dominant species, shifts from species that prefer wetter conditions to plants that prefer drier conditions (Black and Black, 1989) and changes in the location of species or features that indicate water level elevations (Carr et al., 2006)

**Soils.** Changes in soil conditions that occur in response to water level changes include soil oxidation and loss, sometimes leading to increased risk of fire and falling trees (Stephens and Stewart, 1977; Reddy et al. 2006; SFWMD, 2000; SFWMD 1999).

**Hydrology.** Apparent changes in hydrology are also used as indicators of changes in the condition of wetlands, whether or not other effects have become apparent (Miao et al., 2009; Pelczar, 2011). In a

number of studies, changes in water levels due to declines in groundwater levels have been perceived as the primary factor causing changes to occur in wetlands (Mortellaro et al., 1995; Odland and del Moral, 2002). Even apparently small changes in average water depth and hydroperiod have been associated with changes in vegetation communities in natural wetlands (Dunn, 2005; Shaw and Huffman, 1996; SFWMD, 1995). Indicators have been developed and applied to infer recent hydrological conditions and whether changes are occurring, or have occurred, in the past (e.g. Carr et al., 2006). Some have been used to quantitatively determine surface water inundation requirements for wetland protection (Neubauer et al., 2008).

**Other Factors.** Other factors used as indicators include microbial communities (Sims et al., 2013) sugar content of cypress trees (Bacchus et al., 2000), carbon isotopes (Anderson et al., 2005), effects on birds breeding and nesting success (Brazner et al., 2007; Petersen and Niemi, 2007; Emery et al., 2009) changes in fish populations and abundance (Hoyer et al., 2006; Slater and Hall, 2010; Walsh et al., 2009; Ciborowski et al., 2009) and changes to macroinvertebrate communities (Carly et al., 2012; Silver et al., 2012).

A number of studies have developed indexes that combine a variety of different observed features to with the intent to characterize overall condition for wetlands (Reiss, 2005a,b; Reiss, 2006; Lane et al., 2003; Brazner et al., 2007; Wilcox et al., 2002) and lakes (Gerritsen et al., 2000, Fore et al., 2007; Wilson and Bayley, 2007; Grabas et al., 2012; SWFWMD and Tampa Bay Water, 1995).

#### Wetland relationships to water quality

Wetlands have a significant capacity to provide water quality treatment for surface water runoff and wastewater (Schiffer, 1989; Zahina et al., 2001; Dierberg and Brezonik, 1985; Bulc et al., 2009; Brandt and Ewel, 1989), and many systems within the CFWI area have become hydrologically altered to receive discharge from adjacent development or from Rapid Infiltration Basin systems (RIBs). Wetlands also release nutrients into the water column when vegetation dies back during dry periods or droughts, or after fires occur.

Changes in wetland water depths and hydroperiod can affect water quality conditions, including temperature, oxygen saturation and nutrient cycling, as well as rates of soil accretion and loss of organic materials by oxidation. Water quality in Florida wetlands changes continually depending on predominant water source and biological activity (Haag and Lee, 2010). Generally, lower water levels in wetlands will result in higher temperatures, which lead to lower concentrations of dissolved oxygen in the remaining water and which, depending on temperature, may result in stress conditions for many aquatic species (Reiss et al., 2009). An increased proportion of groundwater contribution results in lower levels of dissolved oxygen (Phelps et al., 1996); however, in areas where groundwater is recharged rapidly by rainfall, DO in groundwater may be high (up to 7.3 ml/l per Adamski and Knowles, 1998). Groundwater is typically low in nutrients in non-agricultural, non-urban areas (Adamski and Knowles (1998). However, for urban areas with high connectivity to the aquifer system, groundwater may be higher in nutrients, especially nitrogen, and discharge to wetlands may result in higher nutrient levels, especially nitrogen (Phelps et al., 1996 for the Winter Park Chain of Lakes). Increased groundwater inflow in areas with limestone aquifers may also result in increased water clarity and

higher concentration of calcium carbonate (Metz and Sachs, 2002) as well as increased hardness, pH and alkalinity (Lee et al., 2009; Harvey and McCormick, 2009.)

Nutrient enrichment can accelerate the natural processes of eutrophication and peat formation. In subtropical systems this may be balanced by increased oxidation of organic materials (Reddy et al., 2007). Cypress swamps and other wetlands are used for advanced treatment of wastewater in a number of sites throughout Florida (Brandt and Ewel, 1989), and wetlands are frequently used for stormwater retention and treatment. Long-term changes may occur from such practices that may be detrimental not only to the general condition of the wetland ecosystem but also to its long-term effectiveness as a treatment system (Elder, 1988).

Plant species composition of wetlands can change as a function of water quality parameters such as hardness (mineral content), pH and alkalinity. Increase in mineralization is associated with changes in the composition of emergent marsh wet prairies and submerged aquatic vegetation and periphyton communities (Lee et al., 2009; Harvey and McCormick, 2009). Lentz-Cipollini and Dunson (2006) demonstrated that differences in water quality between surface water and subsurface water sources affect wetland species composition and quality in seasonal ponds.

Release of nutrients from wetlands due to disturbance, dry conditions or fires can lead to periodic degradation of water quality in receiving lakes, rivers or wetlands (Galloway et al., 1999; White et al., 2008, Smith et al., 2001; Neary et al., 2008, Wright, 2013). These issues are of particular concern within wetlands that are managed for agriculture or as Stormwater Treatment Areas, where periodic drying, removal or discing of soil and plants may be a component of the management plan (Moustafa et al., 2012; Gesch et al., 2007)

#### **Animal communities.**

Animal populations and communities also respond over different time periods to changes in their environment. Macroinvertebrates and small fishes may complete several life cycles each year and thus tend to respond within weeks or months to changes in their environment, but stable and consistent communities of these organisms may take several years to form. Larger fishes may take two or more years to reach sexual maturity. Stable populations may require six years or more to form (SFWMD, 2006). Fish depend on seasonal availability of wetlands for spawning and to provide food and protection for larvae and juveniles. Many of the larger reptiles, birds and mammals seek out areas that meet their seasonal or annual habitat, feeding and reproductive requirements (Limnotech, 2005; Bolduc and Afton, 2008). Emery et al. (2009) found that birds seemed to be preferentially attracted to large lakes and that different bird species utilized different plant communities in the littoral zone. Successful feeding, reproduction and survival of many wading birds is often a reflection of seasonal timing, duration and extent of water level drawdowns (Bolduc and Afton, 2008)

Changes in hydrologic or water quality conditions within a wetland can lead to changes in habitat conditions and change the balance among food sources, prey and predator relationships in animal communities (Wilcox and Meeker, 1992). The population dynamics of macroinvertebrate communities are studied as means to assess habitat (wetland) quality and health (Sharma and Rawat, 2009), duration of wetland hydration (Silver et al., 2012) and especially water quality (Water and Air Research, 2000). Leslie et al. (1977) studied the effects of wetland drying on macroinvertebrate populations in pond

cypress wetlands. Amphibians – notably frogs, tadpoles and salamanders depend on seasonal availability of water for egg laying and larval survival and the availability of insect larvae and adults as food sources (Surdick, 2005). Other examples studies of macroinvertebrate populations in wetlands include work by Hayworth (2000) in cypress forests, Sharma & Rawat (2009) in the Central Himalayas and Brazner et al. (2007) in the Great Lakes.



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*Environmental Measures Team Final Report*

*Attachment E –  
Development of the EMT Wetland Classification System*

*November, 2013*



## **Attachment E – DEVELOPMENT OF THE EMT WETLAND CLASSIFICATION SYSTEM**

Christina Uranowski, SWFWMD

Shirley Denton, Cardno ENTRIX

### **Introduction**

An ecohydrological classification was developed to associate wetlands sampled during the CFWI studies with their hydrology. The intent was to group and separate the broad range of wetland vegetation types into their most common functional criteria in order to reduce hydrologic variability. The methodology is designed to identify groups of wetlands that function similarly based on major criteria including the dominant water source (seepage, connection with the surficial aquifer, overland flow, stream flow), hydrodynamics (vertical, unidirectional, horizontal, bidirectional), geomorphic landform, position in the landscape (depressional, flat, slope, fringe) as well as the landscape setting of mesic or xeric and therefore, are the major factors driving wetland hydrology (Brinson, 1993).

The methodology is similar to methods used in recent wetland assessment studies that adopted or advocated a multi-level classification approach suited for specific applications (Fennessy et al., 2007; Stein et al., 2009). The purpose was to quantifiably evaluate the ecological condition of wetlands using methods that would be sensitive enough to help evaluate the effects of groundwater change in major physiographic settings.

### **Review of Existing Classification Systems**

The EMT initially reviewed existing wetland classifications to determine if any was appropriate for use, and a series of pros and cons was developed for each. The systems reviewed included the Florida Land Use, Cover and Forms Classification (FDOT, 1999), the Florida Natural Areas Inventory, 2010, Cowardin, 1979), and a SWFWMD ecohydrologic classification (Uranowski, 2012). The pros and cons of each were considered, and a modified version of the SWFWMD ecohydrologic classification was accepted for the CFWI effort. The classification systems were summarized with pros and cons as follows:

#### **Florida Land Use Cover and Forms Classification (FDOT, 1999):**

##### **Pros:**

Readily available – GIS layers are available for all water management districts.

##### **Cons:**

There is no direct relationship to hydrology.

This is a canopy cover classification. Using this classification system, two wetlands with dramatically different hydrology can be classified identically. Two obvious examples are (1) deep riverine cypress swamps -- deep water wetlands with variable hydroperiods that receive water during extreme events from overbank river flows,; and (2) isolated cypress domes which receive their water predominantly from local rainfall and the surficial aquifer.

Alternatively, evergreen hardwood-dominated wetlands (baygalls and bayswamps), which may exist as raised islands in larger isolated or semi-isolated wetlands (bayheads) or on seepage slopes on the sites

and near the foot of ridges (baygalls), have the same FLUCFCS classification (611). FLUCFCS classifications are also not stable and therefore a system can vary in classification with time. For instance, if classified during a drought, a lake may be mapped as a marsh. Lastly, a system may be mapped as many systems. For instance, a lake with a cypress fringe may be mapped as two or more systems simply due to a narrow band of cypress trees occurring along an edge.

### Florida Natural Areas Inventory (FNAI, 2010)

#### Pros:

There is a defined relationship with landscape setting (physiography), hydrology, and vegetative cover.

#### Cons:

There is no existing detailed GIS layer that covers the entire CFWI.

The system is overly complicated relative to the needs of the EMT analysis.

### Cowardin, 1979

#### Pros:

Simple. Used by the US Army Corps of Engineers and National Wetlands Inventory.

National Wetlands Inventory maps exist as GIS layers.

#### Cons:

The system is very generalized and there is inadequate information contained within the system to reliably categorized many of the mapped wetland types by hydrology or physiography.

Hydrology is very generalized and relates more to duration of hydration than to water source or pattern of inundation.

### SWFWMD Ecohydrologic Classification (Uranowski, 2012)

#### Pros:

Based on major drivers of wetland functions including connectivity, dominant water source (seepage, connection with the surficial aquifer, overland flow, stream flow), hydrodynamics (vertical, unidirectional, horizontal, bidirectional) and position in the landscape (depressional, flat, slope, fringe) as well as the landscape setting of mesic or xeric.

Based on compiled data from more than 250 wetlands over a period of 4 years in central peninsular Florida

#### Cons:

No GIS coverage in existence

### EMT-Selected Classification Scheme

The EMT considered patterns of hydrological fluctuation across the landscape and correlated these patterns with landscape position and wetland type as documented in the wetland literature (e.g., Brinson, 1993). The group also recognized that the data available for analysis does not equally or equivalently cover wetlands in all landscape settings, and that different types of wetlands may



demonstrate different patterns of inundation and saturation. The classification was hierarchical and proceeded as follows:

- The wetlands were divided into two major groups. The first group consisted of wetlands receiving water from groundwater, overland flow, and rainfall only. The second consisted of wetlands which receive a major component of their water from upstream wetlands.
- The first group was then subdivided into finer groups based on physiographic setting, landscape position, soils, size, depth (lake vs. shallow wetland), and existence of an outfall (seepage swamps).
- The second group was subdivided into riverine systems, defined as systems with channels, and connected systems lacking channels.

This classification was consistent with functional classifications developed by Brinson (1993) and with the SWFWMD classification (Uranowski, 2012). A diagram of the classification system is shown in Figure E-1.

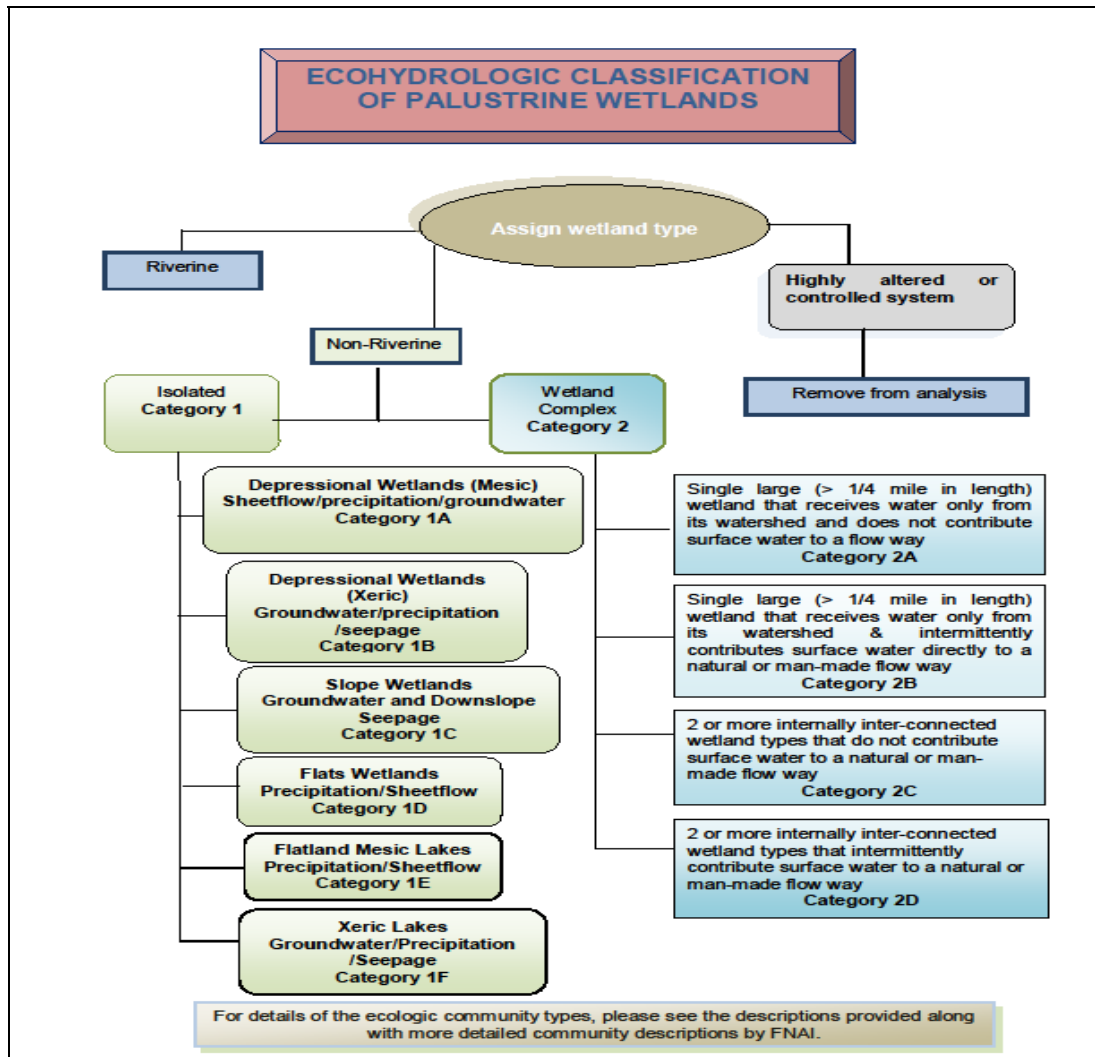


Figure E-1. Wetlands classification system developed by the EMT for use in the CFWI.

The selected terminology was derived from the SWFWMD ecohydrologic classification based on a desire to apply the system using GIS.

In application, the system used the water management district FLUCFCS shape files to identify wetland areas. It also used physiographic provinces as a guide, but used USDA soils shape files to identify local setting based on soil types, since those were ground-truthed at the time of classification and were available at a level of detail more suited to the EMT application than the more generalized physiographic province shape files. A shape file of wetlands connected along mapped streams was used as the basis for identifying floodplains. The non-riverine FLUCFCS polygons were assessed in the context of adjacent polygons, combined with adjacent polygons when appropriate, and then assessed on the basis of size, shape, and dominant FLUCFCS in a guided classification. This classification was then reviewed for major misclassifications and corrected when appropriate based on aerial photointerpretation. Typical corrections included reconnection of slough and floodplain systems which were severed in the FLUCFCS by roads, water-filled former mines that had been classified by FLUCFCS as lakes, stormwater systems mapped as wetlands and wetlands mapped as stormwater systems. Specific identification factors are discussed with each of the classified wetland types. The identified types were defined as follows:

### **Depressional Wetlands (Mesic) (Type 1A).**

These wetland types, mainly located in “plains” physiographic settings”, historically often described as a “flatwoods landscape”. The dominant water source of these wetland types are precipitation and sheetflow. The wetlands typically interact with the surficial aquifer and at various times may lose water to or gain water from that aquifer. At least some studies have shown these wetlands to most often function as recharge wetlands for the surficial aquifer (Lee et al. 2009, Sun et al. 1995), but recharge rates are generally smaller than those for depressional wetlands in xeric (“ridge and upland”) physiographic settings. These wetland types, especially cypress domes can be sub-classified hydrologically according to the hydro-geologic settings determined by Watson et al. (1990) as: shallow depressions, shallow depressions with solution features and relict sinkhole type systems or ecologically as dome swamps and depression marshes (FNAI 2010) or tupelo or mixed wetland forest (FDOT 1999).

Variations include cypress domes, dome swamps, cypress marsh (marsh surrounded by a ring of cypress), depression marsh, basin marsh, and basin swamp. Multiple cover types are common within any one wetland, often in concentric rings that relate to depth. In GIS, these systems were recognized as having a perimeter/area ratio less than 2 coupled with a level III FLUCFCS of 621, 611, 643, 641, 613, 617, or combinations thereof, plus either being in a “plains” physiographic province and being surrounded by uplands with soils that are poorly to moderately well drained (i.e., not well or excessively well drained) soils (this latter handles the case where small areas of mesic flatlands with historic flatwoods interspersed with wetlands are embedded in areas that are generally “xeric” in character. Floodplains were excluded. Following classification with GIS, these systems were review using aerial photography. It was apparent that these are best considered to be isolated or semi-isolated with any connections consisting of ditches or un-mapped flats wetlands. In undisturbed settings with natural upland communities and lack of significant agriculture, these systems are typically unditched and any connections consist of flats wetlands. Where agriculture is present, most connections are ditches, and review of the landscape suggests that the wetlands are generally smaller than those historically present. Sometimes they are minor residuals, often consisting of soft-rush marsh. Review of aerial photography suggests that large systems (basin swamps) are typically at least occasionally connected to other systems either via wet flatlands or via ditches.

### Depressional Wetlands (Xeric) (Type 1B).

These wetland types are located predominantly in physiographic provinces described as “ridge” or upland” and in high recharge areas variously classified as xeric pine, xeric hammock, sandhill and scrub landscape settings by FNAI (2010) or FLUCFCS 421, 412, or 413. This landscape setting exhibits very dry, deep well-drained hills of sand that support xeric-adapted vegetation (FNAI 2010). Most are believed to have a relatively direct connection to the surficial or Floridan aquifer (Watson et al. 1990). Using the hydrogeologic definitions of Watson et al. (1990), these wetlands are mainly those with solution features or relict sinkhole type systems. These wetlands do not always exhibit the common indicators of moderately long term standing water (cypress buttresses, hummock formation, restriction of *Lyonia lucida* roots and *Myrica cerifera* roots to hummocks, sharp palmetto line, etc.) and therefore may require differentiation of edges based on soil characteristics or less distinct indicators such as absence of upland trees within the wetland limits. The distinction between these xeric depressional wetlands and xeric lakes is predominantly size and a depth normally consistent with a permanent or semi-permanent open water pool.

In GIS, these systems are typically mapped as marshes (641), sometimes with shrub marsh or wet prairie (643) on the fringes. They are not in floodplains and they are in either ridge or upland physiographic provinces (they may also occur in pockets on uplands/ridges, i.e., surrounding soils characterized as well or excessively well drained soils, or in plains provinces, but this is not common). No shape restrictions were placed on these wetlands, though there are some located in obvious, round sink holes.

### Slope Wetlands (Type 1C).

These systems are defined as “Seepage Wetlands” by FNAI (2010), that are sloped with a high moisture level maintained by seepage from the underlying aquifer. The primary water source is the surficial aquifer (though obviously aquifer levels are driven by rainfall, and some overland flow and direct rainfall are received by these wetlands). A key distinction is that the water is moving through the wetland, not standing in pools. These wetlands are located at the edges of floodplains and in headwaters where and are characterized by long hydroperiods where the water is slightly above to slightly below the land surface. There is always some form of drain, though it may vary from a headwater stream to a downslope floodplain, lake, or open sink. These wetlands may not always exhibit the characteristic wetland edge indicators that are generally evident in flatwoods landscapes; therefore a baygall forest may have a moss collar to the ground, for instance, and may be perfectly healthy as long as the water table is high. Baygalls are often characterized by deep muck soils. A baygall may be replaced by a wet flatwoods if the peaty soil has been oxidized or removed (FNAI 1990), and some areas of low flatwoods may take on baygall characteristics if natural fire is removed.

Slope wetlands were difficult to identify in GIS as the FLUCFCS 611 code (bay swamp) has been applied to any wetland area with an evergreen hardwood canopy. GIS identification was done in two steps. First any FLUCFCS 611 code was considered to be a candidate. If it was not located in an area where seepage was possible (such as in islands out in the middle of larger swamps or marshes), they were considered not to be slope wetlands. If they were located in areas where slope wetlands could occur (edges of larger systems, entire wetlands with outfalls, they were reviewed on aerial photography and most were accepted as baygalls, the most typical slope wetland type in the CFWI. Wetlands mapped as floodplain edges and upper reaches of stream systems were inspected for bays (which had not been mapped as such in FLUCFCS), and relatively large areas were identified along the eastern edge of the Lake Wales Ridge (Reedy Creek and Lake Marian Creek systems) especially. Areas known to be seepage systems but with non-bay canopies (often highly disturbed areas with residual bay vegetation overrun with grape vines) were included as slope wetlands. The aerial photographic inspection was backed up by on-the-

ground knowledge. It is probable that the area of slope wetlands was under-mapped, but that most unmapped slope wetlands are likely highly disturbed.

### **Flats Wetlands (Type 1D).**

Variants of this classification located within the CFWI include wet flatwoods, wet prairies, prairie-hammock areas near the St. Johns River, and a variety of disturbed, wet settings. Flats wetlands are defined by FNAI (1990) as occurring on relatively flat, poorly drained soils that are typically underlain by an organic hardpan or clay lens. Broad areas of hydric hammock occur along the eastern edge of the CFWI along the St. Johns River floodplain. Slash pines can invade wet prairies during drought conditions or when fire is excluded, when this occurs, wet prairies become wet flatwoods (P. Elliott, personal communication, March 9, 2011). FNAI subtypes include wet flatwoods, wet prairie (savannah), and hydric hammock.

It was apparent that most of these systems were not well delineated in the available GIS layers. An inspection of current aerial photography shows that most were either included within larger mesic depressional wetlands, typically as shallow connectors between the larger wetlands, or were included in the surrounding uplands, usually identified as flatwoods. Hydric hammocks along the St. Johns River were identified. Areas of wet pasture were sometimes given this designation, but the majority of areas that would have met this categorization were not mapped in the base wetland areas. Some areas were assigned this classification during QA/QC of the coverage, but no such areas were included in the study sites. Due to the spotty coverage with almost all (that were mapped) occurring along the St. Johns River, these flats wetlands were excluded from consideration.

### **Flatland Mesic Lakes (Type 1E).**

Flatland lakes are defined as lakes in physiographic provinces defined as “flatlands” or “plains”. These generally shallow lakes (a lake being defined as having a permanent open center 6 ft or more deep), often surrounded by a ring of cypress. They are similar in origin to mesic depressional wetlands, but deeper and typically larger in area. Some have muck layers in the bottom. Some likely formed as interdunal lakes, but most are likely located in single-to-multiple relic sinkholes. Relative to “ridge” or “upland” province lakes, they are typically low fluctuation lakes.

Flatland Mesic lakes were identified in the GIS as having a level 2 FLUCFCS code of 500, 520, or 530, being isolated (not in a floodplain or obvious flow-way) and being in a “plains” physiographic province. Based on the GIS analysis, there are relatively few flatland mesic lakes, and based on review of their locations and aerial photography, these lakes may intergrade into xeric lakes, especially those located in “upland” physiographic provinces. Most flatland mesic lakes were inspected using aerial photography. Most ultimately turned out to be man-made features, mostly mines, and were re-classified accordingly.

### **Xeric Lakes (Type 1F).**

Xeric Lakes are defined as lakes in “ridge” or “upland” physiographic provinces. They are wide fluctuation lakes that in most ways are deeper systems otherwise similar to xeric depressional wetlands. Most are located in obvious old sink hole features and are nearly round, though large ones are often located in multiple sinkholes and may have shallower connections between the sinks within them. Few have cypress fringes (most of those that do are in “upland” physiographic provinces). Most are large enough to be named lakes. Most isolated lakes (versus flow-through lakes) in the CFWI were classified as xeric lakes. Xeric Lakes were identified in the GIS as having a level 2 FLUCFCS code of 500, 520, or 530, being isolated (not in a floodplain or obvious flow-way) and being in an “ridge” or “upland” physiographic province. Depending on the water level at the time of mapping, many include FLUCFCS 641, 644, and 643 polygons.

Xeric lakes were reviewed using the most currently available aerial photography. A few were man-made (mines) but most appeared to be natural. It was apparent from looking at photography from multiple years that there is no clear-cut distinction between xeric lakes and xeric depressional marshes in the FLUCFCS mapping. The classification used is based on the dominant FLUCFCS.

This category was used for wetlands with obvious connectivity to other wetlands and drainages.

### **Wetland Complex Category (Type 2).**

This category was used for wetlands with obvious connectivity to other wetlands and drainages to the extent that inflows (including overland flow, inflows from other wetlands, rainfall) and outflows to other wetlands and or/floodplains are major contributors to the wetland hydrology. Other wetland complexes are large and may include several types of connected wetlands that receives water from the watershed but does not contribute flow to other systems. These types of complexes may themselves flow similar to FNAI described Strands. Wetland complexes are not the uppermost systems in a drainage basin, but they may also be systems with natural incised channels (they may also have been ditched). They may also include wetlands that ultimately drain into lakes or large wetlands in closed basins, but are not themselves closed. Interconnected Wetlands were not restricted to physiographic province as these receive a major component of their water from more upslope systems. On the upslope end, these wetlands are fed by some combination of other interconnected wetlands, semi-isolated xeric setting lakes and wetlands, semi-isolated mesic depressional wetlands, and baygalls. On the downslope end, they feed other interconnected wetlands and floodplains. Some would feed wetlands or lakes in basins that have no surface outfall.

Interconnected Wetlands were identified in GIS as having a high perimeter to acreage ratio, having FLUCFCS 621, 617, 615, 630, 643 and/or 643. Floodplains were excluded. The GIS classification was reviewed using aerial photography looking specifically for connections. This review was needed as large, elongated natural wetlands are often broken in the land use classification at roads, railroads, and other man-made features, and sometimes the breaks cause small "pieces" that would sometimes be classified as isolated based only on the GIS. These pieces were re-assembled reclassified manually. These wetlands were also inspected for potential inclusion of seepage areas which were reclassified as seepage when observed.

### **Riverine.**

Riverine, floodplain wetlands were considered to be those areas mapped as floodplains on the basis of wetland polygons being contiguous or continuous with mapped streams. With the exception of small areas remapped based on aerial interpretation (slope wetlands on areas known to be well above flood level), these areas were left unchanged. They include forested floodplains, floodplain marshes, and lakes. They generally terminate at the upper end at the closes break (usually a road) above which the stream channel was not mapped. Above the region of mapped stream channel, these systems are mapped as Interconnected Wetlands (Type 2).

### **Anthropogenic.**

Anthropogenic systems were excluded from classification. Some of these were classified as marshes and shrub swamps by the FLUCFCS system. Upon review with aerial photography, numerous stormwater ponds, swales, mines, borrow pits, ditches, cattle ponds, and similar features were reclassified and excluded from analysis. Some of these systems undoubtedly have some wetland function, but there is no reason to suspect that they would function like a natural wetland. In urban areas, most mapped "wetlands" an acre or less in size are actually surface water management systems (stormwater and/or water quality management or drainage ditches) of some form. In agricultural areas, most rectangular

features are human created. It is a widely held assumption that flowing floodplain wetlands are more difficult to use in the assessment of groundwater withdrawals in opposition to those wetlands that are more isolated in nature and therefore have a stronger connection to the effects of groundwater withdrawal. The CFWI EMT did not include floodplain wetlands in the analysis.

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*Environmental Measures Team Final Report*

*Attachment F –*

*Statistical Analyses to Discriminate between Stressed  
and Non-Stressed Wetlands and Determine Whether EMT  
Wetlands are a Representative Sample of CFWI Wetlands*

*November, 2013*





## **Attachment F. Statistical Analyses to Discriminate between Stressed and Non-Stressed Wetlands and Determine Whether EMT Wetlands are a Representative Sample of CFWI Wetlands**

Tony Janicki, Ph.D.

Janicki Environmental, Inc.

### **Objective**

The St. Johns River, Southwest Florida, and South Florida water management districts collectively conducted a survey of more than 400 wetlands within the CFWI area. The data collected included a series of variables that took on values of “Yes” or “No”. These variables are generally accepted as indicators of wetland stress. As discussed above, these data along with examination of a series of historical photos were used to identify a wetland as being either “stressed” or “non-stressed”.

The objective of this analysis was to examine the wetland EMT variables and the hydrologic characteristics to identify those variables and water surface elevations (WSE) that best discriminate stressed from non-stressed wetlands.

### **Methods**

The primary method used to identify those variables and characteristics that best discriminate stressed from non-stressed wetlands was changepoint analysis. Changepoint methods are rapidly evolving from simple data mining tools to predictive models using advanced statistical algorithms to evaluate conditional probabilities in the stressor-response relationships. Collectively referred to as “Decision Trees”, this methodology provides an intuitive and easily conveyed approach to identify threshold responses to environmental stressors that may be used in the development of protective water quality or water quantity standards. The classification version of the conditional inference tree methodology (Hothorn et al., 2006) was used as one line of evidence for identifying potential stressors as well as threshold values for WSE in wetlands resulting in stressed conditions within the wetland. Conditional inference trees are a form of regression tree analysis (RTA) that has been successfully used to assist in many environmental issues including the development of numeric nutrient criteria (e.g., Soranno et al., 2008). The approach is based on recursive partitioning. The partitioning process iteratively searches for a point in the stressors variable which maximizes the difference in the response values between two groups of response data. No *a priori* threshold is specified. The classification tree approach defines the breakpoint as that which minimizes the misclassification bias between groups. The point in the stressor variable at which the p value is minimized, after adjustment for multiple comparisons, is assigned as the breakpoint defining the split of the of the response variable into 2 groups. Once the first split is made the process continues to test for subsequent splits that are conditional on the first split. Hence, the term “conditional inference” or “conditional probability analysis” that has been popularized recently by the USEPA as a potential approach for establishing numeric nutrient criteria.

Conditional inference trees embed tree-structured regression models into a well-defined theory of conditional inference procedures (Hothorn et al., 2006). This class of regression trees is applicable to all kinds of regression problems, including nominal, ordinal, numeric, censored as well as multivariate response variables and arbitrary measurement scales of the covariates.

The EMT variable analysis was conceptually similar to the use of a dichotomous key with the major difference being that the nodes (i.e., decision points) are probability distributions. This analysis answers

the question: what EMT variables (or combination) best predict an outcome (e.g., characterization of a wetland as “stressed”).

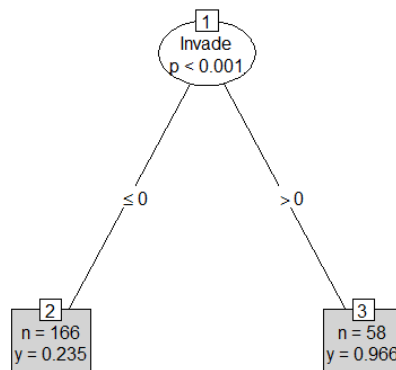
For the WSE analysis, the classification tree approach was selected to identify the distributional statistics of WSE and the specific threshold value of that distributional statistic that maximizes the classification success of sites as either stressed or unstressed. The results suggest that the difference between the wetland edge and the 80<sup>th</sup> percentile of WSE (i.e., WE-P80) was the best choice to discriminate between stressed and unstressed sites, and furthermore, that a threshold value of 3.398 was the best “changepoint” to discriminate between stressed and unstressed sites. Sites with WE-P80 values greater than 3.398 had an 81% chance of being classified as “stressed” while those sites with lower values had only an 8% chance of being classified as stressed.

## Results

The EMT variables examined included the following:

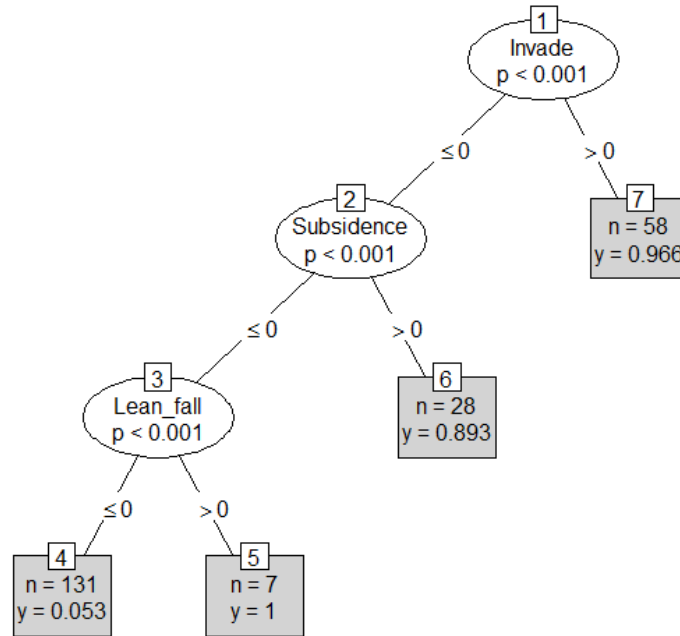
- Soil subsidence,
- Soil fissures,
- Exposed roots,
- Successional stage,
- Leaning/falling trees,
- Dead/dying trees,
- Percent native vegetation,
- Confoundedness, and
- Basin alteration.

As shown in Figure 1, the primary EMT variable that best discriminated between stressed and non-stressed wetlands was invading species. In **Figure F-1**, Y=the probability of being stressed and therefore, if the invading species variable is positive (i.e., invading species were found) there is a 96% probability of being stressed.



**Figure F-1. Results of EMT variable changepoint analysis on wetland classification indicating stressed wetland condition.**

The full decision tree model is shown in **Figure F-2**. This model identifies that after accounting for the effect of invading species subsidence and leaning/falling trees further improved the discrimination of stressed from non-stressed wetlands.



**Figure F-2. Results of full model of the EMT variable changepoint analysis on wetland classification indicating stressed wetland condition.**

The WSE variables used in these analyses included the following:

- wetland edge,
- P5,
- P50,
- P80,
- wetland edge – P5,
- wetland edge – P50, and
- wetland edge – P80.

For this analysis, the classification tree approach identified the distributional statistics of WSE and the specific threshold value of that distributional statistic that maximizes the classification success of wetlands as either stressed or unstressed. The results suggest that the difference between the wetland edge and the 80<sup>th</sup> percentile of WSE (i.e., WE-P80) was the best choice to discriminate between stressed and unstressed sites. Furthermore, a threshold value of 3.398 was the best “changepoint” to discriminate between stressed and unstressed sites (**Figure F-3**). Wetlands with WE-P80 values greater than 3.398 had an 81% chance of being classified as “stressed” while those sites with lower values had only an 8% chance of being classified as stressed.

### Representativeness of Wetland Sites to the Entire CFWI

The spatial characteristics of the subset of wetland sites being used by the EMT for stress probability assessment were examined based on regional GIS coverage data to determine whether they were statistically similar to all wetlands within the CFWI. **Table F-1** presents a summary of the distributions of wetland areas, perimeters, and the ratio of the square root of the area to the perimeter (varea/perimeter) for the isolated wetlands within the Plains and Ridge areas within the CFWI. **Table F-2** presents similar data for the Class I, Class II, and Class III wetlands within the CFWI.

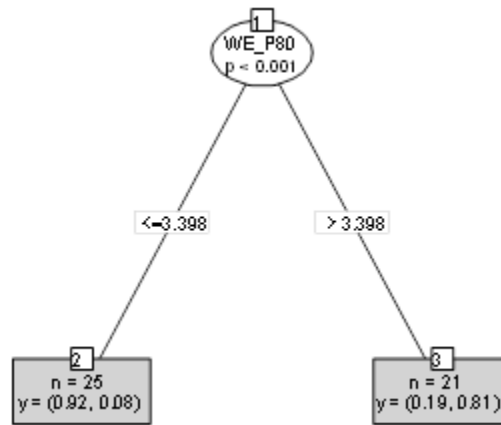


Figure F-3. Results of changepoint analysis of the WSE distributions on wetland classification indicating stressed wetland condition.

Table F-1. Percentage distribution of physical wetland characteristic by wetland group.

Group	Cumulative Percentage Statistic						
	5%	10%	25%	50%	75%	90%	95%
<b>Area (acres)</b>							
Plains Isolated	0.3	0.47	0.91	1.99	4.59	11.12	19.34
Ridge Isolated	0.26	0.41	0.94	2.59	8.11	26.42	55.86
<b>Varea/perimeter</b>							
Plains Isolated	0.16	0.17	0.21	0.24	0.27	0.27	0.28
Ridge Isolated	0.12	0.14	0.19	0.23	0.26	0.27	0.28
<b>Perimeter (ft)</b>							
Plains Isolated	456	563	806	1224	2048	3575	5101
Ridge Isolated	427	541	858	1529	3005	6117	9965

Table F-2. Percentage distribution of physical wetland characteristic by wetland knowledge class.

Group	Cumulative Percentage Statistic						
	5%	10%	25%	50%	75%	90%	95%
<b>Area (acres)</b>							
Class I	1.45	3.39	6.54	111.54	299.45	607.98	2184.72
Class II	1.05	1.68	3.86	11.15	31.99	86.83	156.66
Class III	0.29	0.46	0.91	2.05	4.89	12.47	22.91
<b>Varea/perimeter</b>							
Class I	0.07	0.10	0.14	0.25	0.26	0.27	0.27
Class II	0.09	0.12	0.17	0.22	0.26	0.27	0.28
Class III	0.15	0.17	0.20	0.24	0.27	0.27	0.28
<b>Perimeter (ft)</b>							
Class I	922	1408	2067	11063	24471	30135	139826
Class II	822	1048	1625	3601	6432	15410	24530
Class III	450	558	809	1252	2147	3860	5670

The first notable observation is that the distributions of wetland perimeters across Ridge and Plains wetlands and across knowledge classes are very similar. In terms of wetland area, Ridge wetlands tend to be somewhat greater than those in the Plains region. With respect to wetland area, as expected the Class I wetlands tend to be greater than both of the other knowledge class wetlands, while the distributions of wetland area in these latter two classes are much more similar.

The third physical characteristic of the wetlands examined, the ratio of the square root of the area ( $\sqrt{\text{area}}$ ) to the wetland perimeter, is a unit-less characteristic that describes the geometry of a wetland. More convoluted perimeters will result in lower ratios than those with a simpler boundary or outline. The distributions of the  $\sqrt{\text{area}}$ /perimeter are generally similar in the Ridge and Plains wetlands, except in the upper portions of the distributions (>90%) where the Plains wetlands tend to display a more complex geometry than the isolated wetlands within the Ridge region. As seen with the other physical wetland characteristics, the distribution of the  $\sqrt{\text{area}}$ /perimeter characteristic is greatest in the knowledge Class III wetlands.

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*Environmental Measures Team Final Report*

*Attachment G –  
Hydrologic Analysis: Methodology Summary*

*November, 2013*





## Attachment G - Hydrologic Analysis: Methodology Summary

James Bays, CH2MHILL;

David MacIntyre, P.E., D.WRE, Parsons Brinkerhoff;

Shirley Denton, Ph.D., Cardno Entrix;

John Zahina-Ramos, Ph.D., South Florida Water Management District

### Introduction

As a component of the Central Florida Water Initiative (CFWI) project, the Environmental Measures Team (EMT) comprised of District and utility representatives and consultants was assembled and assigned two objectives: 1) evaluate current environmental conditions of wetlands and surface waters in the CFWI area, and develop quantitative relationships of environmental conditions to hydrologic conditions using appropriate scientific methods; and 2) apply the quantitative assessment relationships to hydrologic model output. Beginning in 2011, regular meetings were initiated to characterize and quantify the hydrologic characteristics of water bodies in the CFWI area in relation to environmental stress classification.

With the input of EMT members, a study was proposed to confirm the applicability of the wetland database for evaluating current environmental conditions in the CFWI area, and to develop a set of quantitative assessment relationships. Five tasks were agreed upon, as listed below, with all results to be summarized in a final report:

- Task 1. Selection and study of a subset of wetlands for combined ecological and hydrological assessment.
- Task 2. Quantitative statistical characterization of the EMT data set.
- Task 3. Quantitative statistical analysis of the ecological data within the EMT data set.
- Task 4. Hydrological analysis of the subset of wetlands.
- Task 5. Development of statistical interrelationships between wetland ecological and hydrological conditions.

The outcome of the study was expected to be a set of quantitative relationships that would ultimately be tested for use as constraints on the CFWI area groundwater flow model developed by the US Geological Survey and updated by the CFWI HAT.

This Attachment summarizes the methodology and presents an overview of results of Task 4, Hydrologic Analysis. The data base comprising the basis for analysis within this document underwent a series of modifications through a continuing process of analysis between initial data collection in September 2011 through final data set development and analysis in early 2013. The primary authors of this Attachment gratefully acknowledge and appreciate the combined input and technical comment and review received from the EMT members during the course of study.

### Methods

Most of the wetland sites in the EMT database do not have an associated record of water levels that can be used to characterize the hydrology of the wetland. Therefore a preliminary list of sites selected for this study was developed in August-September 2011 through the collective input of the EMT, with a goal of identifying water bodies with water level records (e.g., piezometer, staff gage) and ecological (e.g., transect) data. Most of the study sites are distributed throughout the CFWI within SJRWMD, SFWMD, and SWFWMD boundaries, but twelve sites outside the CFWI were added in order to expand the sample

size of sites which had both ecological and hydroperiod data. Within this distribution, sites are located within most of the component physiographic regions.

Cumulatively, a total of 44 lakes and wetlands were selected based upon availability of historic water level data and the location and ecological condition of each site. Of this total, 24 were classified as ridge and 20 as plains.

Most sites had been visited previously by teams of District scientists in 2006 and 2007 during initial Central Florida Coordination Area (CFCA) activities. An environmental assessment was performed at each using the Districts' methodology. An essential component to the field analysis included identification and elevation survey of the wetland edge of a lake or wetland. This indicator is a historic descriptor of an elevation where water remains long enough to preclude establishment of upland species and below which there are predictable vegetation adaptations to flooding and development of specific wetland soil indicators. This elevation is persistent over long time periods, and therefore provides a basis of normalizing water level data between widely different types of systems. Common wetland edge indicators utilized included the uppermost elevation of hydric soils, and where they exist, long-term vegetative indicators. Sites exhibiting trends consistent with long-term lowering of water levels with associated vegetative change and organic soil loss were classified by EMT members as stressed. This classification was drawn from a review of the site environmental data, a review of available historical photographs, and review of available hydrologic data. Some sites were classified as "substantially hydrologically altered (SHA)", where physical changes to the wetland or its basin have altered its surface water hydrology sufficiently to create a water regime inconsistent with the historic hydrologic regime.

A key variable used to classify the different sites was classification as depressional marshes or lakes in mesic or xeric settings, using the classification method described in **Attachment E** of this report. The occurrence of a site in a sandhill ridge or otherwise xeric soil type has been shown to yield a hydrologic relationship to underlying aquifers different than in the floodplains, flatwoods, or other physiographic regions. Through a process of continued review, the initial list of 34 sites developed in 2011 was further augmented with an additional 10 lakes and wetlands assembled primarily from the ridge physiographic region to create a more balanced data set.

**Table G-1** shows each site characterized by their CFWI ID, waterbody type, classification of stress, classification of confoundedness, physiographic setting, water level data period of record (POR) P80, and wetland edge elevation. New sites were assigned IDs to be consistent with the prior method of CFCA wetland identification, and the remainder of the sites already had IDs from the CFCA data base.

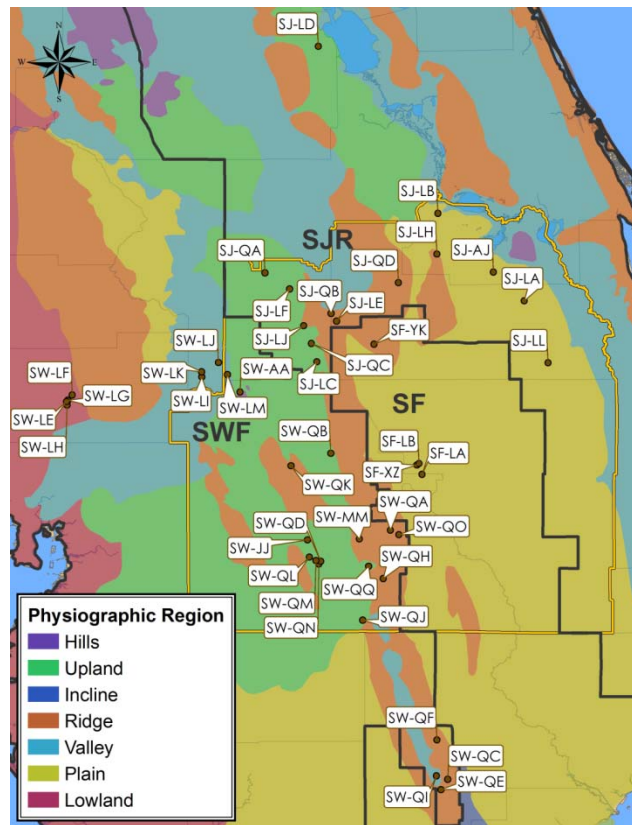
**Figure G-1** shows the location of the study sites superimposed on available GIS coverage of physiographic regions. For the purpose of this analysis, stations were grouped as ridge or plains depending on their site-specific xeric or mesic attributes. As a result, the ridge and plains wetland physiographic type designations are strongly correlated to the more generalized ridge and plains physiographic province designations, but do not match them perfectly.

## Data Sources

Because the study lakes and wetlands are distributed across central Florida, multiple data sources were accessed to obtain available historic stage data information. Sources included the Orlando Utilities Commission (OUC), the City of Cocoa, Seminole County, Orange County, SFWMD DBHYDRO database, SFWMD Water Management Information System (WMIS), the Water Atlas website, USGS National Water Information System, and the SJRWMD Hydrologic Data Search.

Table G-1. Site Identification and Characterization

Site Identifier	Site Name	CFCA ID	Physio-Region	P80 (2006-2011) (ft NGVD 29)	Edge Reference Elevation (ft NGVD 29)	Stressed?	Confounded?
61	Unnamed Cypress	SJ-LA	Plain	69.26	70.44	No	No
146	Green Swamp Marsh #304	SW-LI	Plain	92.64	93.90	No	No
161	Green Swamp #1, #298	SW-LM	Plain	98.43	100.6	No	No
111	City of Cocoa, Well 9T	SJ-LL	Plain	71.38	74.14	No	No
31	Walker Ranch - WR9	SF-XZ	Plain	65.57	68.34	No	No
116	Green Swamp 7	SW-AA	Plain	103.19	106.37	No	No
6	Walker Ranch - WR6	SF-LB	Plain	61.65	64.47	No	No
156	Green Swamp #5, #302	SW-LK	Plain	95.28	98.80	No	No
1	Walker Ranch - WR11	SF-LA	Plain	64.11	67.68	No	No
151	Green Swamp #6, #303	SW-LJ	Plain	94.07	98.10	No	No
126	Cypress Creek #199, W17	SW-LE	Plain	63.34	64.95	Yes	No
36	Tibet Butler - TB2	SF-YK	Plain	98.72	102.63	Yes	No
51	Lake Gem	SJ-AJ	Plain	48.74	53.39	Yes	Yes
141	Cypress Creek #211, W33	SW-LH	Plain	65.92	70.79	Yes	No
71	Boggy Marsh	SJ-LC	Plain	113.82	118.82	Yes	No
96	Island Lake - 2774	SJ-LH	Plain	81.86	87.49	Yes	No
131	Cypress Creek #190 "E" Marsh	SW-LF	Plain	65.09	72.03	Yes	No
136	Cypress Creek #223 "B" W46	SW-LG	Plain	60.87	68.93	Yes	No
216	Lake Leonore (Patrick)	SW-QH	Ridge	85.08	86.23	No	No
191	Lake Annie (Highlands)	SW-QE	Ridge	109.95	111.49	No	No
211	Gator Lake	SW-QD	Ridge	129.89	131.8	No	No
256	Lake Apthorpe	SW-QF	Ridge	68.93	71.28	No	Yes
246	Lake Van	SW-QK	Ridge	131.08	134.32	No	No
236	Lake Streety	SW-QJ	Ridge	103.21	105.95	No	No
201	Bonnet Lake	SW-QB	Ridge	89.29	92.04	No	No
221	Parks Lake	SW-QO	Ridge	99.83	102.81	No	No
241	Surveyors Lake	SW-QN	Ridge	130.30	133.36	No	No
121	Lake Garfield	SW-JJ	Ridge	101.39	105.53	No	Yes
76	Hopkins Prairie	SJ-LD	Ridge	23.71	27.50	No	No
181	Johns Lake	SJ-QB	Ridge	93.39	97.42	No	No
206	Buck Lake (Highlands)	SW-QC	Ridge	89.87	95.05	No	No
226	Lake Placid	SW-QI	Ridge	89.44	94.91	No	No
186	Trout Lake	SJ-QC	Ridge	90.59	97.60	No	No
231	Polecat Lake	SW-QM	Ridge	139.50	144.37	Yes	No (recovered)
106	Lake Louisa	SJ-LJ	Ridge	92.41	97.29	Yes	No
196	Big Gum Lake	SW-QA	Ridge	89.96	95.95	Yes	Yes
171	Crooked Lake	SW-QQ	Ridge	115.12	121.29	Yes	Yes / Regulated
86	Lake Apshawa	SJ-LF	Ridge	81.13	87.65	Yes	No
176	Church Lake	SJ-QA	Ridge	82.66	90.37	Yes	Yes
66	Unnamed Wetland	SJ-LB	Ridge	61.41	69.37	Yes	No
166	Lake Wales	SW-MM	Ridge	102.65	111.35	Yes	No
56	Long Lake	SJ-QD	Ridge	58.43	68.81	Yes	No
81	Lake Avalon	SJ-LE	Ridge	86.30	96.68	Yes	No
251	Lake Walker	SW-QL	Ridge	137.36	150.28	Yes	No (recovered)



**Figure G-1. EMT Wetland Hydrologic Analysis Study Site Locations.** Base map coverage of physiographic regions as defined in White, W.A. (1970). *The Geomorphology of the Florida Peninsula, Florida Geological Survey Bulletin 5. Tallahassee FL.*

The period of 1991-2011 was defined as the target time frame for analysis to meet several objectives: 1) a time period to overlap most of the CFWI model assessment period (1996-2008), thereby allowing direct comparisons to simulated aquifer levels calibrated under the same rainfall conditions; 2) a duration sufficiently long to include the dry (1999-2001) and the wet (2004-2005) years; and 3) to allow the use of wetland water elevation data collected more recently through water use permit monitoring. The initial analysis of water levels was performed using all available data for the period 1991-2011. Within this two-decade target period, however, it was found that relatively few sites had sufficient data to support a 20-year frequency analysis of water levels, and that a shorter period of record was capable of providing reasonably similar P80 water level estimates. The minimum POR in the data set was six years. Prior analyses in the northern Tampa Bay area indicated that six years would be an appropriate minimum length to capture a wet and dry rainfall cycle. However, the hydroperiod for relatively infrequently flooded wetlands can be expected to require a longer period of time to capture the full range of water level fluctuations. Ultimately, the 6-year period from 2006 through 2011 was chosen because it appeared to provide the best compromise between providing a small sample of wetlands with P80 elevations based on a

longer period of record or a significantly larger sample of wetlands with P80 elevations based on a shorter period of record. Since the P80 elevation estimate varies somewhat based on the period of

record, and this variation tends to be more significant for shorter periods of record, it was considered important to select a consistent period of record for all the locations that were included in the final assessment of relationships between ecological conditions and water levels

### Data Analysis

Graphical analysis was utilized to show the percentage of time a measured stage was equaled or exceeded and is referred to here as the Cumulative Frequency Distribution (CFD). In order to compare hydroperiod characteristics across the sites, the CFDs were calculated and summarized relative to wetland edge elevation. If a given stage value is exceeded by only five observations out of 100, it would have a corresponding label of P05. Similarly, if a certain stage is exceeded 90 observations out of 100 water level measurements, it would be labeled as P90. The P50 corresponds to the median value in the data set.

**Table G-2** summarizes CFD percentile data relative to the wetland edge grouped into four major categories: stressed plains, unstressed plains, stressed ridge and unstressed ridge. Sample means and estimates of the 90%, 95%, and 99% confidence intervals of the population are provided for each group.

### Results

#### Water Level Trends and Seasonality

**Figure G-2** presents the water level POR for all of the water bodies in this study. These data are shown as hydrographs of water elevation data on the same vertical scale to illustrate the range of topographic elevations incorporated into the data set, and the relative range in water level fluctuation between water bodies. Analyses summarized below utilized only the six-year period from 2006-2011.

**Table G-2. Wetland Stage Exceedance Values Relative To The Wetland Edge Elevation, Six-Year Data Analysis Period, 2006 Through 2011.**  
Means and estimated population confidence intervals are summarized by stress and physiographic type category.

CFCA ID	Site Name	Class	County	SHA?	WMD Basin	P10	P20	P30	P40	P50	P60	P70	P80	P90
<b>Unstressed Plains – 10 Sites</b>														
SJ-LA	Unnamed Cypress	Wetland	Orange	No	St. Johns	-0.31	-0.44	-0.49	-0.59	-0.68	-0.82	-0.93	-1.18	-1.41
SW-LI	Green Swamp Marsh #304	Wetland	Polk	No	Southwest	-0.43	-0.52	-0.60	-0.72	-0.80	-1.01	-1.09	-1.26	-1.54
SW-LM	Green Swamp #1, #298	Wetland	Polk	No	Southwest	-0.38	-0.46	-0.61	-0.80	-1.00	-1.23	-1.60	-2.17	-3.56
SJ-LL	City of Cocoa, Well 9T	Wetland	Orange	No	St. Johns	-0.55	-0.79	-0.88	-1.18	-1.68	-1.84	-2.14	-2.76	-3.17
SF-XZ	Walker Ranch - WR9	Wetland	Osceola	No	South	-0.15	-0.63	-0.95	-1.25	-1.78	-2.20	-2.63	-2.77	-2.93
SW-AA	Green Swamp 7	Wetland	Polk	No	Southwest	-0.27	-0.37	-0.55	-0.66	-0.87	-1.20	-2.36	-3.18	-4.18
SF-LB	Walker Ranch - WR6	Wetland	Osceola	No	South	-0.22	-0.63	-0.79	-1.19	-1.63	-2.04	-2.53	-2.82	-3.57
SW-LK	Green Swamp #5, #302	Wetland	Polk	No	Southwest	-0.06	-0.17	-0.46	-0.85	-1.21	-1.75	-3.11	-3.52	-4.53
SF-LA	Walker Ranch - WR11	Wetland	Osceola	No	South	-0.47	-0.63	-0.88	-1.35	-1.95	-2.31	-2.86	-3.57	-3.88
SW-LJ	Green Swamp #6, #303	Wetland	Polk	No	Southwest	-0.33	-0.51	-0.66	-0.89	-1.04	-1.93	-2.95	-4.03	-4.71
					Mean	-0.32	-0.52	-0.69	-0.95	-1.26	-1.63	-2.22	-2.73	-3.35
					+90% CI	0.24	0.27	0.28	0.42	0.71	0.82	1.21	1.49	1.77
					+95% CI	0.28	0.32	0.33	0.50	0.85	0.98	1.43	1.77	2.10
					+99% CI	0.37	0.42	0.43	0.66	1.12	1.29	1.89	2.32	2.77
<b>Stressed Plains – 8 Sites</b>														
SW-LE	Cypress Creek #199, W17	Wetland	Pasco	No	Southwest	-0.88	-1.01	-1.06	-1.16	-1.29	-1.43	-1.55	-1.61	-1.64
SF-YK	Tibet Butler - TB2	Wetland	Orange	No	South	-2.50	-2.80	-2.91	-3.24	-3.31	-3.49	-3.71	-3.91	-4.25
SJ-AJ	Lake Gem	Lake	Seminole	Yes	St. Johns	-3.58	-3.84	-3.95	-4.02	-4.14	-4.24	-4.39	-4.65	-5.13
SW-LH	Cypress Creek #221, W33	Wetland	Pasco	No	Southwest	-0.47	-0.69	-1.08	-1.73	-2.39	-3.09	-3.97	-4.87	-5.68
SJ-LC	Boggy Marsh	Wetland	Lake	No	St. Johns	-1.41	-1.59	-1.86	-2.03	-2.48	-2.95	-4.36	-5.00	-5.34
SJ-LH	Island Lake - 2774	Lake	Seminole	No	St. Johns	-4.46	-4.64	-4.79	-4.96	-5.16	-5.31	-5.47	-5.63	-5.82
SW-LF	Cypress Creek #190 "E" Marsh	Wetland	Pasco	No	Southwest	-3.15	-4.21	-4.99	-5.52	-5.86	-6.17	-6.61	-6.94	-7.79
SW-LG	Cypress Creek #223 "B" W46	Wetland	Pasco	No	Southwest	-4.60	-5.61	-5.86	-6.32	-6.69	-7.12	-7.49	-8.06	-9.20
					Mean	-2.63	-3.05	-3.31	-3.62	-3.91	-4.22	-4.69	-5.08	-5.61
					+90% CI	2.45	2.80	2.87	2.92	2.90	2.89	2.84	2.99	3.48
					+95% CI	2.91	3.32	3.41	3.47	3.45	3.44	3.37	3.55	4.13
					+99% CI	3.83	4.38	4.49	4.57	4.54	4.52	4.43	4.67	5.44
<b>Unstressed Ridge – 15 Sites</b>														
SW-QH	Lake Leonore (Patrick)	Lake	Polk	No	Southwest	-0.48	-0.58	-0.68	-0.76	-0.83	-0.93	-1.03	-1.15	-1.35
SW-QE	Lake Annie	Lake	Highlands	No	Southwest	-1.04	-1.19	-1.24	-1.29	-1.35	-1.39	-1.45	-1.54	-1.65
SW-QD	Gator Lake	Lake	Polk	No	Southwest	-0.53	-0.70	-0.82	-0.92	-1.17	-1.40	-1.73	-1.91	-2.37
SW-QR	Lake Apthorpe	Lake	Highlands	Yes	Southwest	-1.48	-1.66	-1.80	-1.87	-1.97	-2.08	-2.19	-2.35	-2.58
SW-QK	Lake Van	Lake	Polk	No	Southwest	-1.59	-1.77	-1.93	-2.21	-2.42	-2.52	-2.76	-3.24	-3.41
SW-QJ	Lake Streety	Lake	Polk	No	Southwest	-1.05	-1.46	-1.71	-1.85	-2.09	-2.20	-2.42	-2.74	-3.29
SW-QB	Bonnet Lake	Lake	Highlands	No	Southwest	-2.00	-2.27	-2.36	-2.45	-2.52	-2.55	-2.67	-2.75	-2.81
SW-QO	Parks Lake	Lake	Polk	No	Southwest	-1.57	-1.77	-2.01	-2.30	-2.53	-2.64	-2.74	-2.98	-3.24
SW-QH	Surveyors Lake	Lake	Polk	No	Southwest	-1.90	-2.07	-2.18	-2.28	-2.49	-2.68	-2.90	-3.06	-3.43
SW-JJ	Lake Garfield	Lake	Polk	Yes	Southwest	-2.33	-2.68	-2.98	-3.28	-3.45	-3.68	-3.86	-4.14	-4.64
SJ-LD	Hopkins Prairie	Wetland	Marion	No	St. Johns	-0.88	-1.49	-1.77	-2.05	-2.66	-2.99	-3.23	-3.79	-3.97
SJ-QB	Johns Lake	Lake	Polk	No	St. Johns	-0.25	-0.69	-1.17	-1.58	-2.01	-2.48	-3.23	-4.03	-4.71
SW-QC	Buck Lake (Highlands)	Lake	Highlands	No	Southwest	-2.42	-3.16	-3.73	-4.26	-4.43	-4.65	-4.93	-5.18	-5.54
SW-QI	Lake Placid	Lake	Highlands	No	Southwest	-2.88	-3.65	-4.03	-4.47	-4.72	-4.99	-5.23	-5.47	-5.70
SJ-QC	Trout Lake	Lake	Lake	No	St. Johns	-1.26	-3.18	-5.48	-5.79	-6.08	-6.58	-6.68	-7.01	-7.71

Table G-2. Wetland Stage Exceedance Values (Cont.)

CFCA ID	Site Name	Class	County	SHA?	WMD Basin	P10	P20	P30	P40	P50	P60	P70	P80	P90
					Mean	-1.44	-1.89	-2.26	-2.49	-2.71	-2.92	-3.14	-3.42	-3.76
					+90% CI	1.22	1.52	2.09	2.23	2.27	2.40	2.41	2.50	2.68
					+95% CI	1.45	1.80	2.48	2.65	2.69	2.85	2.86	2.97	3.18
					+99% CI	1.91	2.37	3.26	3.49	3.54	3.75	3.76	3.92	4.18
<b>Stressed Ridge – 11 Sites</b>														
SW-QM	Polecat Lake	Lake	Polk	No*	Southwest	-2.66	-2.89	-3.13	-3.37	-3.68	-4.05	-4.36	-4.87	-5.49
SJ-LJ	Lake Louisa	Lake	Lake	No	St. Johns	-1.47	-2.24	-3.34	-3.52	-3.82	-4.26	-4.55	-4.88	-5.04
SW-QA	Big Gum Lake	Lake	Polk	Yes	Southwest	-1.55	-1.94	-2.52	-3.21	-4.27	-5.00	-5.46	-5.99	-6.28
SW-QQ	Crooked Lake	Lake	Polk	Yes**	Southwest	-0.84	-2.68	-3.82	-4.63	-5.20	-5.65	-5.84	-6.17	-6.59
SJ-LF	Lake Apshawa	Lake	Lake	No	St. Johns	-1.55	-3.00	-4.32	-5.57	-5.88	-6.05	-6.21	-6.52	-6.77
SJ-QA	Church Lake	Lake	Lake	Yes	St. Johns	-5.98	-6.83	-7.18	-7.27	-7.32	-7.37	-7.48	-7.71	-7.96
SJ-LB	Unnamed Wetland	Wetland	Seminole	No	St. Johns	-3.59	-4.69	-5.14	-5.63	-6.26	-7.13	-7.66	-7.96	-8.47
SW-MM	Lake Wales	Lake	Lake	No	Southwest	-1.32	-2.61	-5.70	-6.53	-7.17	-7.82	-8.23	-8.70	-8.95
SJ-QD	Long Lake	Lake	Orange	No	St. Johns	-4.32	-4.39	-4.61	-4.81	-4.86	-4.89	-4.96	-5.07	-5.12
SJ-LE	Lake Avalon	Lake	Orange	No	St. Johns	-5.56	-5.95	-6.30	-6.77	-7.32	-7.78	-9.69	-10.38	-11.39
SW-QL	Lake Walker	Lake	Polk	No*	Southwest	-6.55	-8.54	-9.72	-10.44	-11.38	-11.72	-11.98	-12.92	-13.49
					Mean	-3.22	-4.16	-5.07	-5.61	-6.11	-6.52	-6.95	-7.38	-7.78
					+90% CI	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
					+95% CI	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
					+99% CI	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91

\*= recovered; \*\*= regulated

Environmental Measures Team Final Report

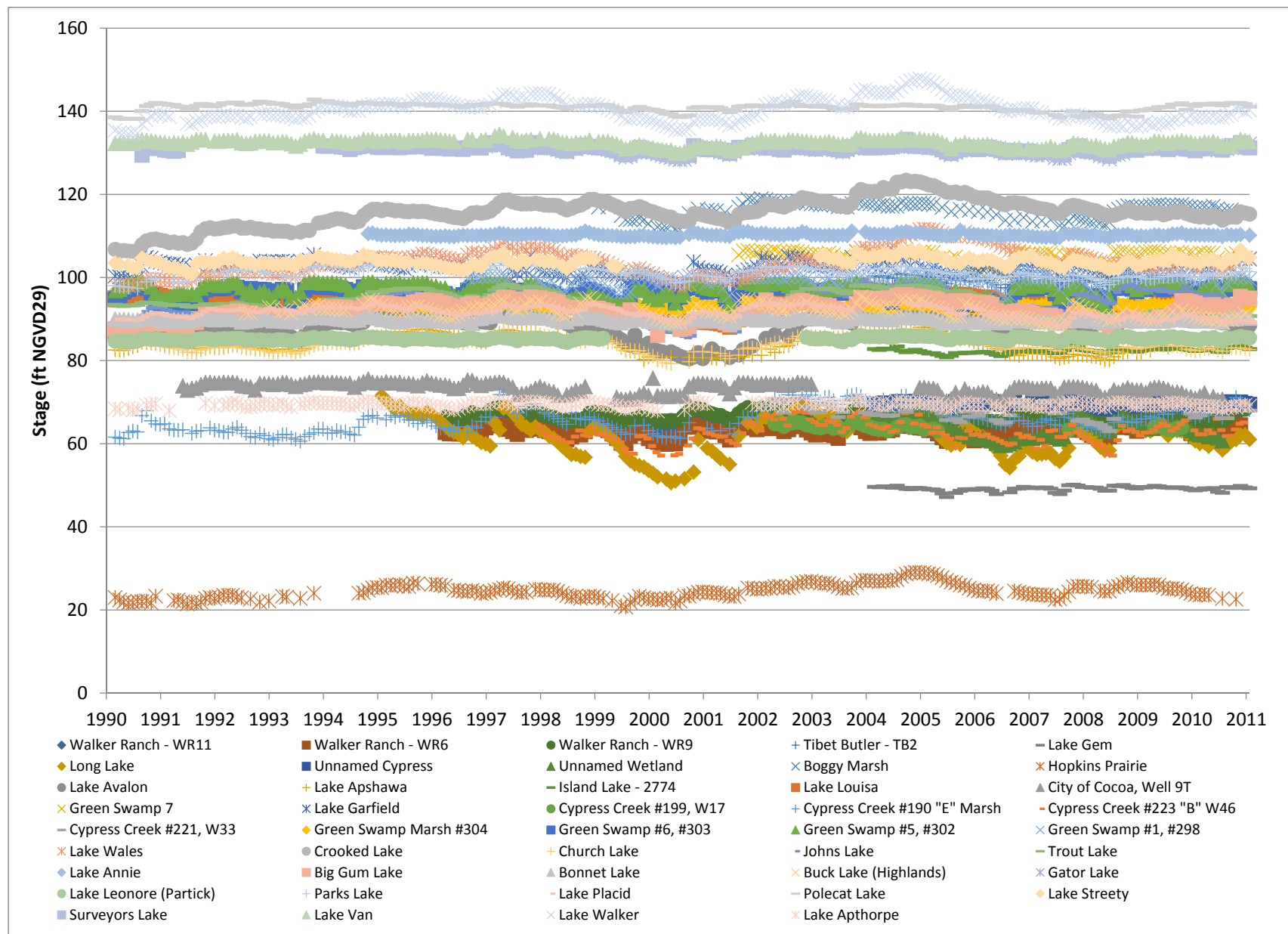


Figure G-2. Hydrographs of site stage records -data are shown for full periods-of-record for each site.



Figures G-3 and G-4 depict the stage level records of selected water bodies representative of typical water level trends in this region. Data shown include the monthly average stage elevation, the wetland edge elevation, and the P05, P50 and P90 stage elevations.

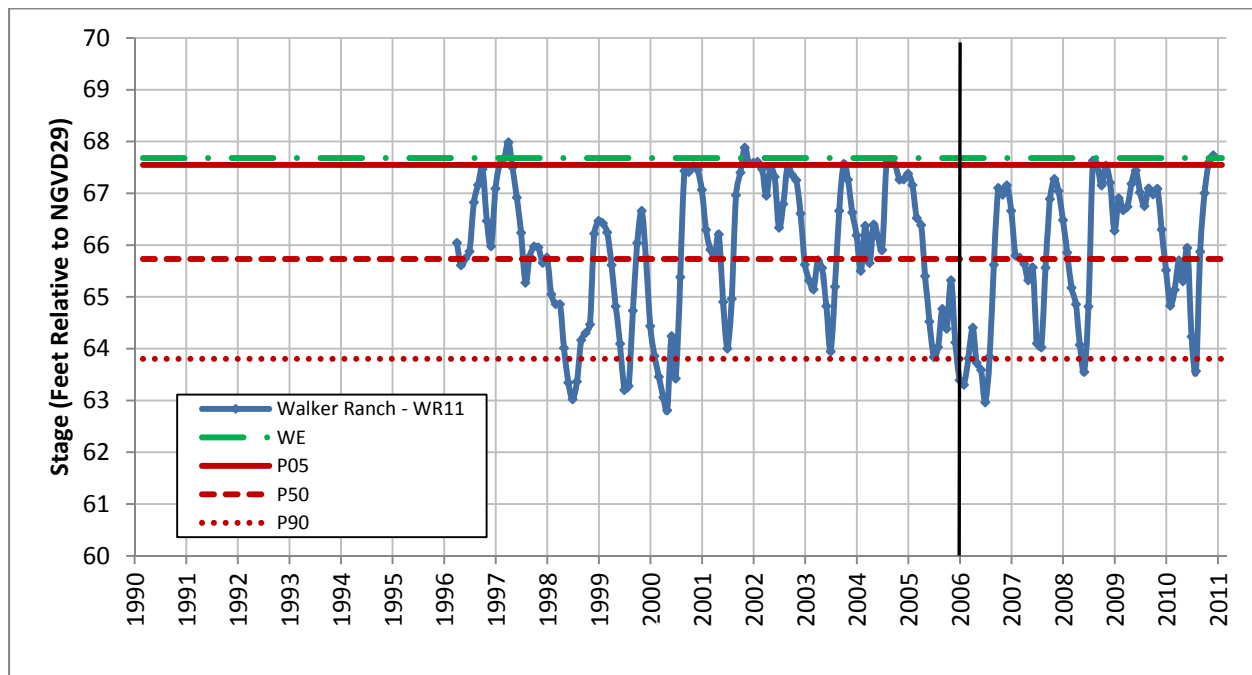


Figure G-3. Walker Ranch WR 11 period of record: an example of plains wetland water level trends. Vertical line delineates start of six-year data analysis period.

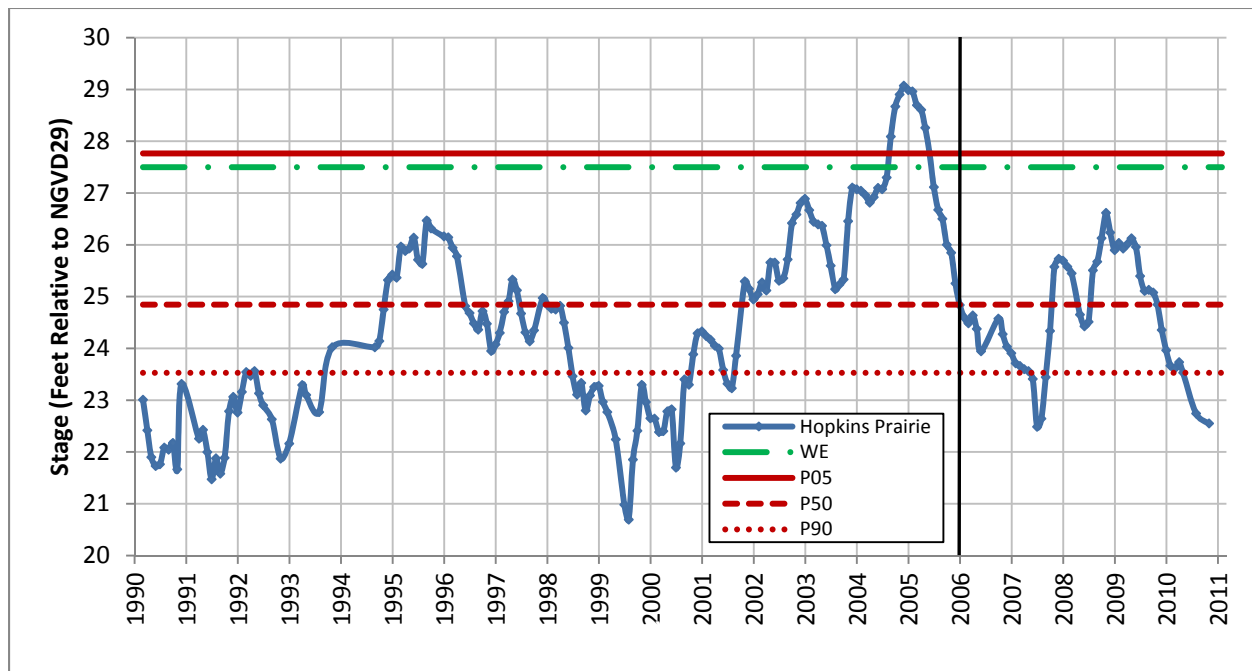


Figure G-4. Hopkins Prairie period of record 1990 through 2011: an example of ridge wetlands water level trends. Vertical line delineates start of data analysis period.

As an unstressed wetland in an undeveloped reserve, with no apparent hydrologic alteration, Walker Ranch WR 11 illustrates the annual cycle of water level variation for a plains type system, with a

generally consistent return to the wetland edge elevation during wet months and years in association with typical seasonal rainfall variation. The ridge type hydrograph is illustrated by Hopkins Prairie, with a greater long-term water level fluctuation range (>8 ft) than the plains (~5 ft), and an inter-annual range in water levels that achieves the wetland edge elevation much less frequently. The beginning of the six-year period of data used for comparison of site water level analysis is shown as a vertical line. The CFDs for Walker Ranch 11 and Hopkins Prairie are provided in **Figures G-5 and G-6**.

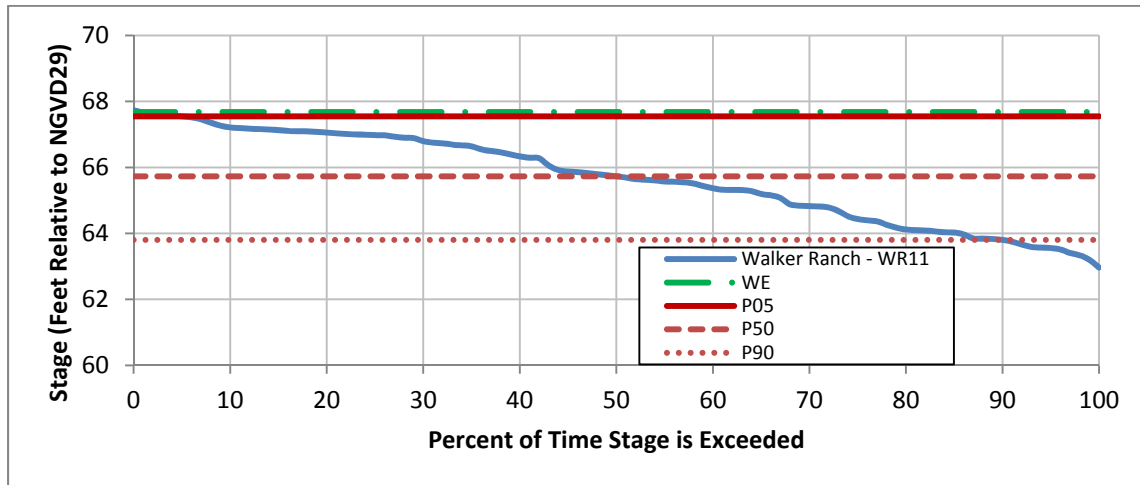


Figure G-5. Cumulative frequency distribution for Walker Ranch 11, Six-year data analysis period . Wetland edge = WE.

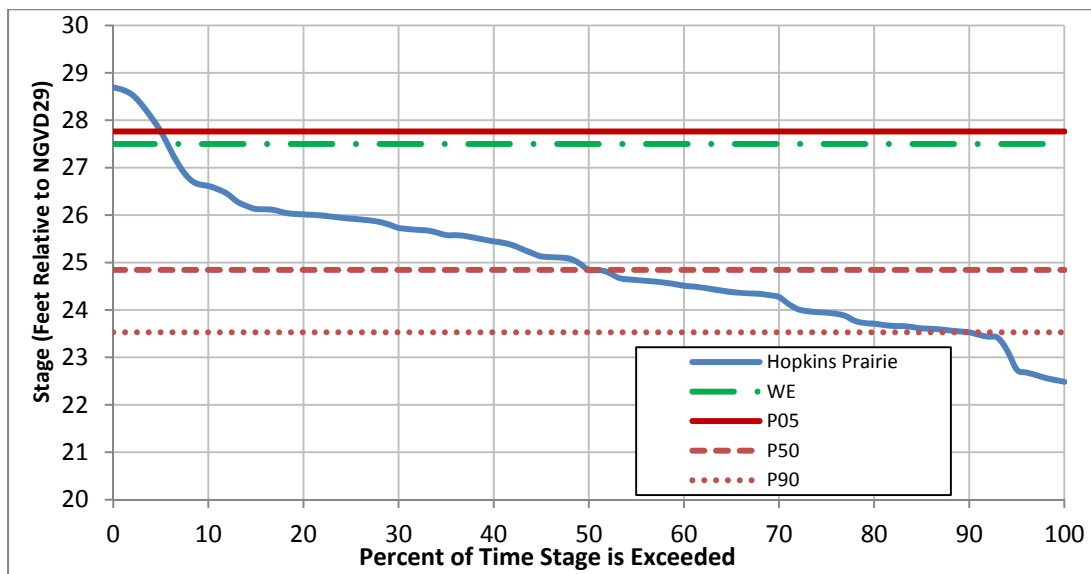


Figure G-6. Cumulative frequency distribution for Hopkins Prairie, six-year data analysis period. Wetland edge = WE.

**Cumulative Frequency Distribution of Water Levels**

Separate CFDs of water levels were prepared for all water bodies and categorized in the ridge and plains physiographic settings to account for regional variation in soils, elevations, and hydrologic characteristics of these settings. **Figures G-7 and G-8** represent the CFDs for unstressed and stressed plains sites, respectively, and include average values for each percentile. The average P10, P50 and P80 for unstressed plains systems are 0.3, 1.3 and 2.7 feet below wetland edge, respectively. For stressed plains systems, the average P10, P50 and P80 values are 2.6, 3.9, and 5.1 feet below the wetland edge, respectively.

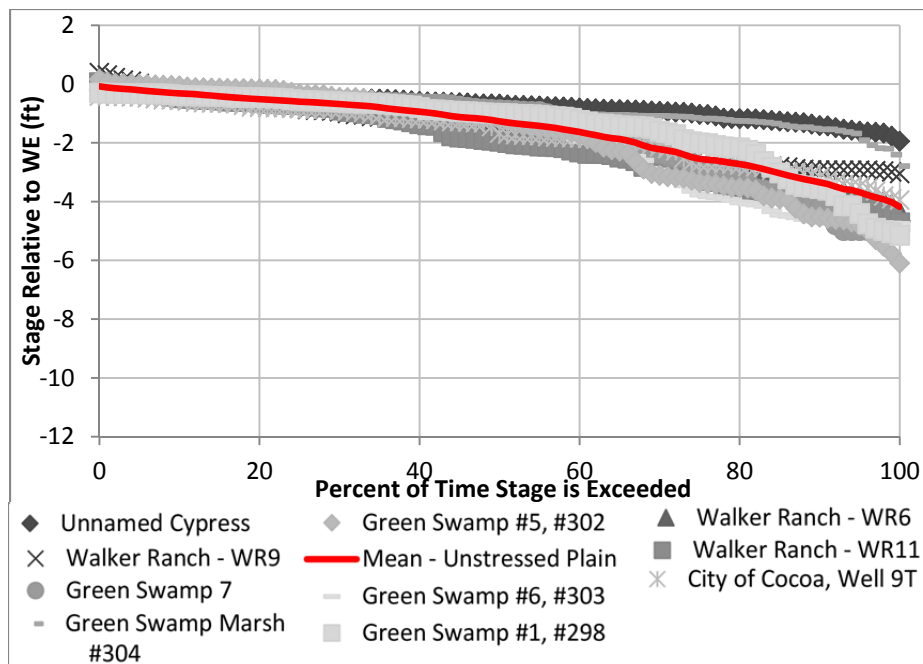


Figure G-7. Unstressed plains physiographic region cumulative frequency distributions. WE = wetland edge; six-year data analysis period 2006 through 2011.

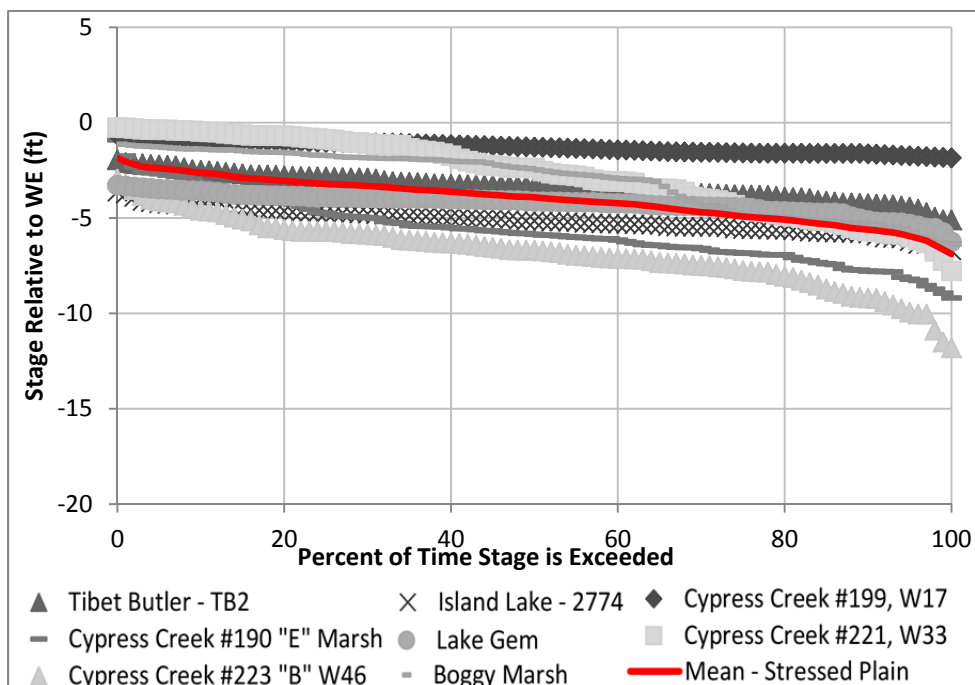


Figure G-8. Stressed plains physiographic region cumulative frequency distribution. Wetland edge = WE; Six year data analysis period 2006 through 2011.

Figures G-9 and G-10 present similar summaries for the ridge category. The average P10, P50 and P80 for unstressed ridge systems are 1.4, 2.7 and 3.4 feet below the wetland edge, respectively. For stressed ridge systems, the average P10, P50 and P80 values are 3.2, 6.1 and 7.4 feet below the wetland edge, respectively. A wide range of variation is apparent around both means across all percentile exceedance values within plains and ridge categories and for stressed and unstressed classes. This difference is

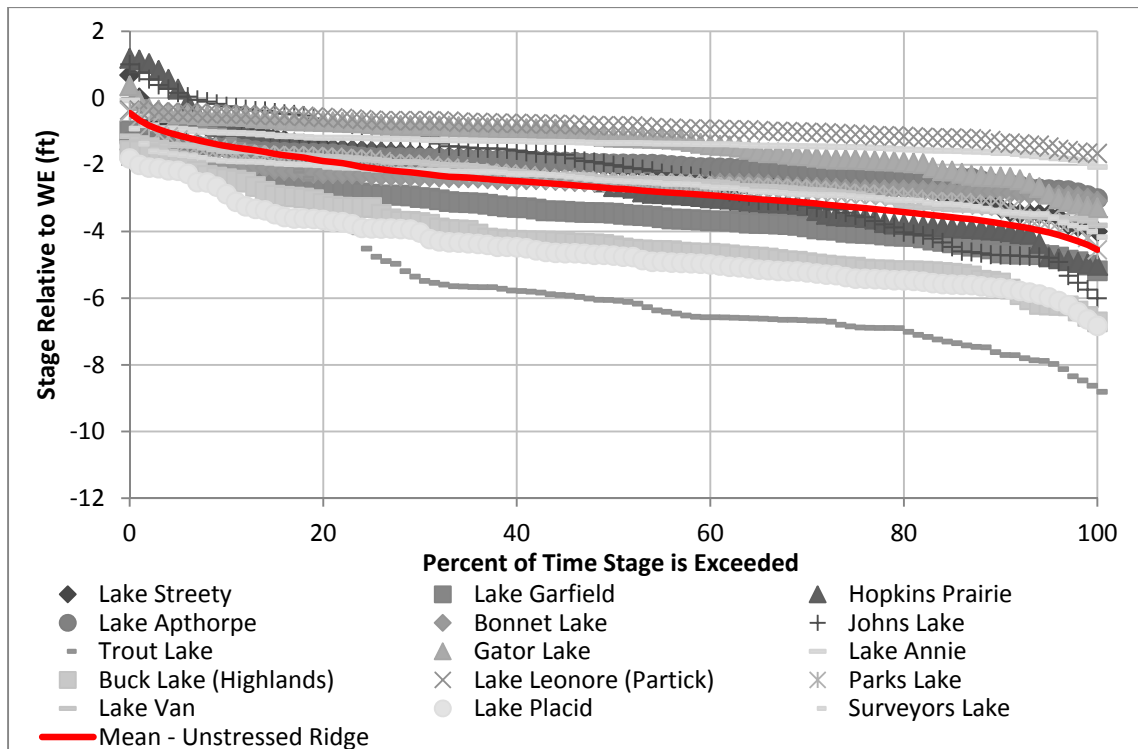


Figure G-9. Unstressed ridge physiographic region cumulative frequency distributions. Wetland wdge = WE; six-year data analysis period 2006 through 2011..

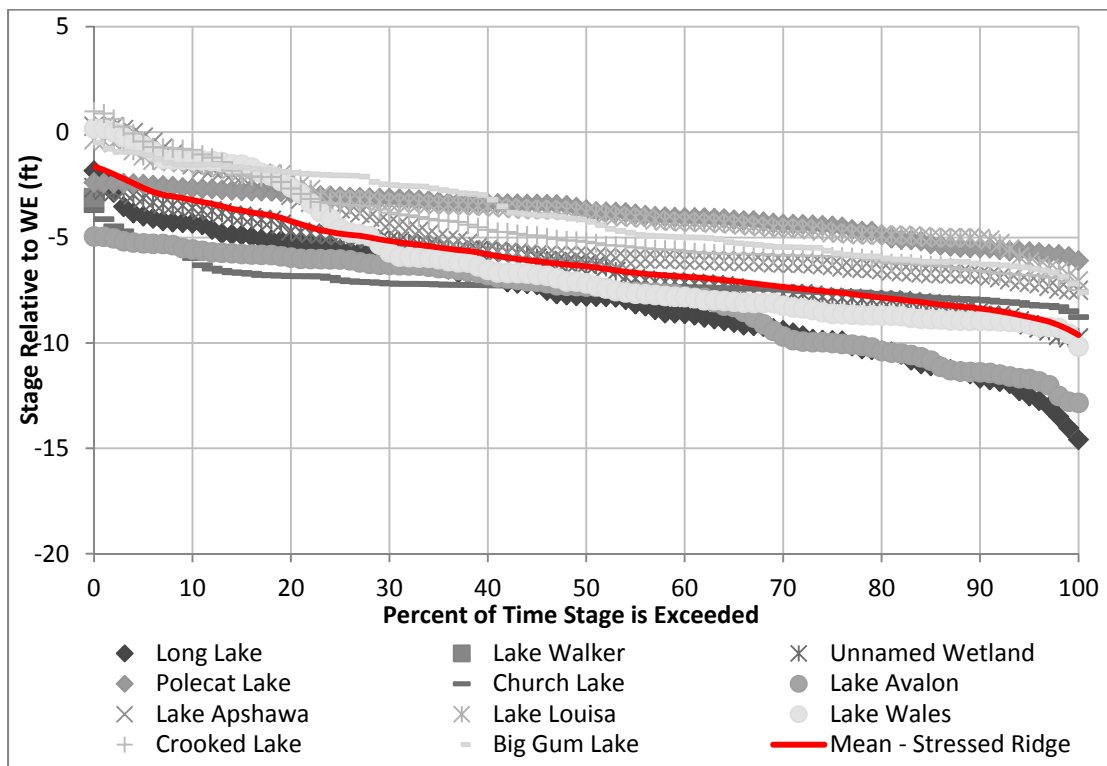


Figure G-10. Stressed ridge physiographic region cumulative frequency distributions. Wetland edge = WE; Six-year data analysis period 2006 through 2011.

attributed to natural variation in wetland type, surface catchment, wetland topographic shape (stage vs. storage volume), and underlying soil and hydrogeologic characteristics, and to the extent of artificial modification. To show the general trend in cumulative water elevations relative to the wetland edge by percentile, mean cumulative frequency distributions for the stressed and unstressed sites are presented in **Figures G-11 and G-12**, respectively.

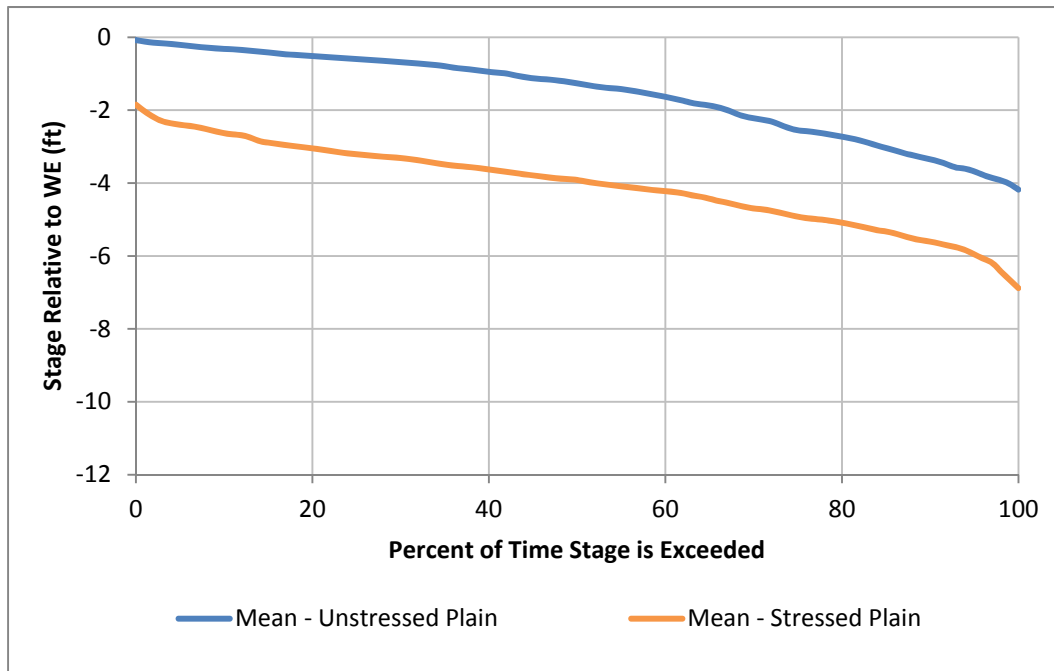


Figure G-11. Plains wetlands average cumulative frequency distributions for stressed and unstressed wetlands. Wetland edge = WE. Six-year data analysis period, 2006 through 2011.

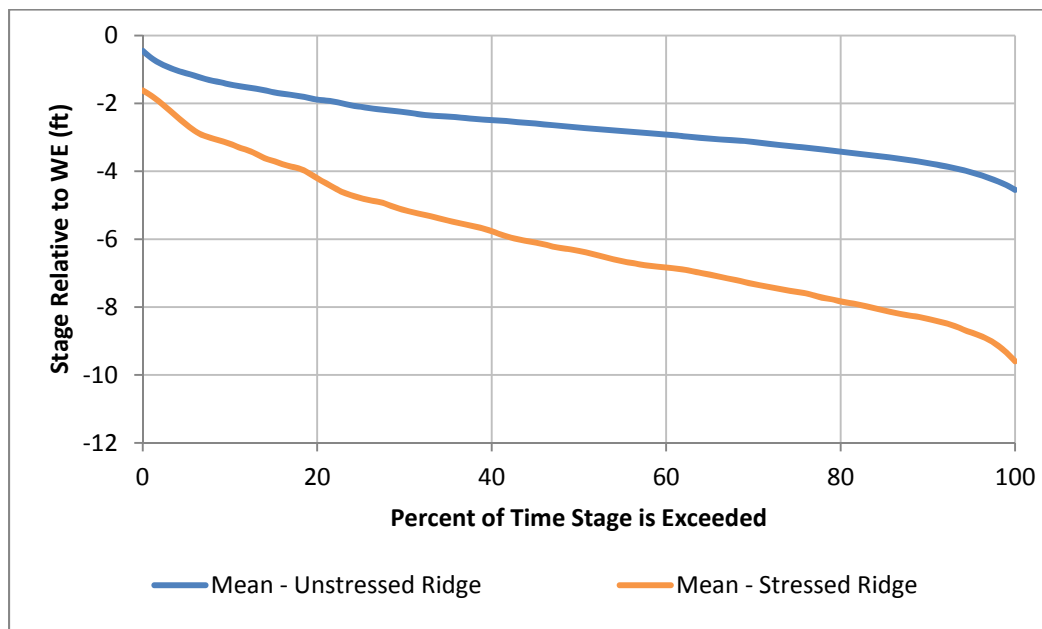


Figure G-12. Ridge wetlands average cumulative frequency distribution for stressed and unstressed wetlands. Wetland edge = WE. Six-year data analysis period, 2006 through 2011.

## Summary

The availability of long-term data sets on wetlands and lakes within the region, coupled with site-specific determination of wetland edge elevations, allowed a preliminary assessment of water elevation ranges associated with hydrologic stress to wetlands and lakes in the CFWI.

Hydrologic records and wetland edge values were assembled for a total of 50 wetlands and lakes. Through analysis and refinement of the data set by the EMT, the final number of lakes and wetlands assessed totaled 44. Of these, 26 lakes and wetlands were categorized as ridge and 18 as plains. While similar data sets from more sites would yield greater information, this sample size was deemed sufficient to establish preliminary relationships for testing and evaluation, within the constraints of time and resources.

Plains and ridge sites differ in that plains-type system exhibit a consistent range and return frequency in water levels that differ from the ridge systems, which appear to have a decadal or greater water level fluctuation influenced by tropical storm-related precipitation.

Through discussion and data analysis by EMT members, P80 percentile values were considered to be most appropriate for characterizing wetland stress for both plains and ridge systems. Based on findings summarized in Attachment E, the P80 was found to be better predictor of stress than P50 and a water level elevation frequently encountered during typical water years, even during relatively brief PORs. A data analysis period comprising the final 6 years of available data was selected for formal characterization of the P80 criterion and risk-based analysis reported elsewhere in this report.

The P80 water level values for plains wetlands averaged 2.7 ft and 5.1 ft below wetland edge for unstressed and stressed sites, respectively. Similarly, values of P80 averaged 3.4 ft and 7.4 ft below wetland edge for unstressed and stressed ridge wetlands, respectively. Considerable variation was observed around these central tendencies. Lower 95% confidence intervals of the population of unstressed wetlands overlapped with upper 95% confidence intervals of stressed wetlands for both plains and ridge categories. As described elsewhere in this report, categorization of probable stress response in wetlands due to altered water levels must be evaluated on a probabilistic basis, given the extent of overlap between the stressed and unstressed populations.

Exceptions were noted during all attempts at categorizing lakes and wetlands into discrete groups, and there will always be a need to evaluate individual water bodies for sensitivity to hydrologic alteration. However, collectively, these values and general findings appear suitable to use in establishing a model estimator for allowable drawdown in surface systems, when coupled with predicted groundwater model output.

*Environmental Measures Team Final Report*

*Attachment H –  
Analysis to Determine Future Change in Wetland Stress*

*November, 2013*





## Attachment H - Development of Probability Functions for Change in Wetland Stress Status Due to Altered Water Levels

David MacIntyre, P.E., D.WRE  
Parsons Brinckerhoff, Inc.

### Introduction

This memo describes the method used to determine the probability that a wetland within the ridge and plains physiographic divisions of the CFWI might change stress status under future hydrologic conditions resulting from changes in water levels within the wetlands induced by future increases or decreases in groundwater withdrawals. A change of wetland stress status can result from changing hydrologic conditions that allow a stressed wetland to become unstressed, or (more commonly) changing hydrologic conditions that cause an unstressed wetland to become stressed.

### Use of a Hydrologic Index for Prediction of Wetland Stress

Work done by the CFWI Environmental Measures Team showed that the probability of hydrologic stress in occurring in wetlands could be related to a hydrologic index,  $\theta$ , which is defined as:

$$\theta = ERE - P80$$

Where:

- EWE* = Wetland Edge Reference Elevation (ft NGVD 29); and
- P80* = The water elevation that is exceeded 80% of the time (ft NGVD 29).

The EMT sorted wetland sites into three broad classes, based on the types of information available at each site, as shown in Table H-1.

Table H-1. Summary of Wetland Data Class Definitions

Wetland Data Class	Data Class Characteristics		
	Wetland Type	Current Stress Condition	Water Level Hydrograph
Class 1	Known	Known	Known
Class 2	Known	Known	Unknown
Class 3	Known	Unknown	Unknown

The EMT identified 44 wetland locations with recent stress status evaluations and sufficient water level data available to calculate a P80 water elevation based on water levels for the period 2006 through 2001. While a longer period of record would have been preferred, we were constrained by the need to find a consistent period in order to calculate consistent P80 values for as many sites as possible. This 6-year period was chosen as the best compromise between longer records on fewer sites vs. shorter records on more numerous sites. These sites were referred to as Class 1 wetland sites, and the methods used to

determine edge reference elevations for the sites are presented in Attachment D. The sites were divided into two types based on their hydro-biological characteristics: plains wetlands and ridge wetlands. For each type, the statistical distribution of the hydrologic index,  $\theta$ , was assessed separately for stressed and unstressed wetland systems. The number of wetlands in each subclass and the calculated means and standard deviations of the  $\theta$  values in each subclass are summarized in Table H-2.

Table H-2. Summary of Class 1 Wetland Hydrologic Index Statistics

	Unstressed Wetlands	Stressed Wetlands
<b>Plains Wetlands</b>	Number of wetlands = 10 Mean value of $\theta$ = 2.82 ft. Standard deviation of $\theta$ = 1.01 ft.	Number of wetlands = 8 Mean value of $\theta$ = 5.08 ft. Standard deviation of $\theta$ = 1.94 ft.
<b>Ridge Wetlands</b>	Number of wetlands = 15 Mean value of $\theta$ = 3.42 ft. Standard deviation of $\theta$ = 1.57 ft.	Number of wetlands = 11 Mean value of $\theta$ = 7.86 ft. Standard deviation of $\theta$ = 2.55 ft.

It was shown that the  $\theta$  value distributions were all reasonably approximated by the normal distribution, and the fitted normal distribution probability density functions are shown in Figures H-1 through H-4.

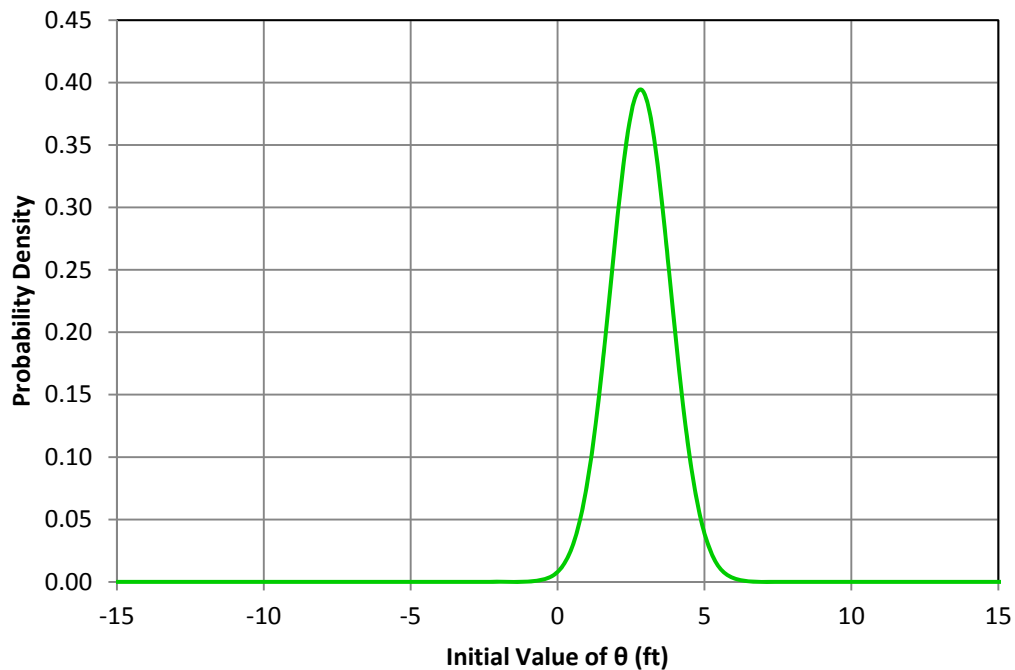


Figure H-1. Unstressed plains wetlands probability density function,  $p_u$

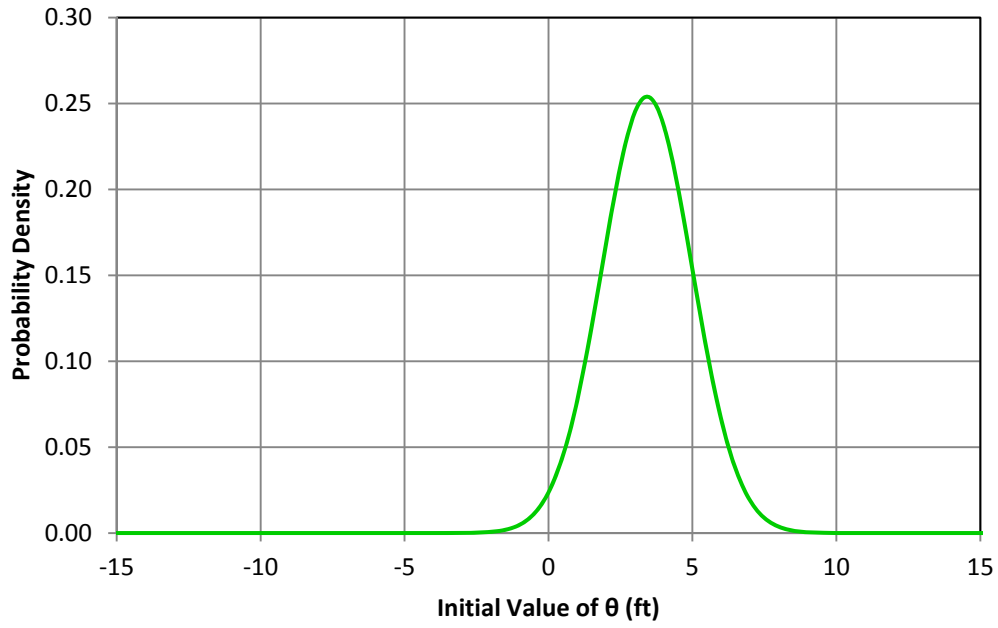


Figure H-2. Unstressed ridge wetlands probability density function,  $p_u$

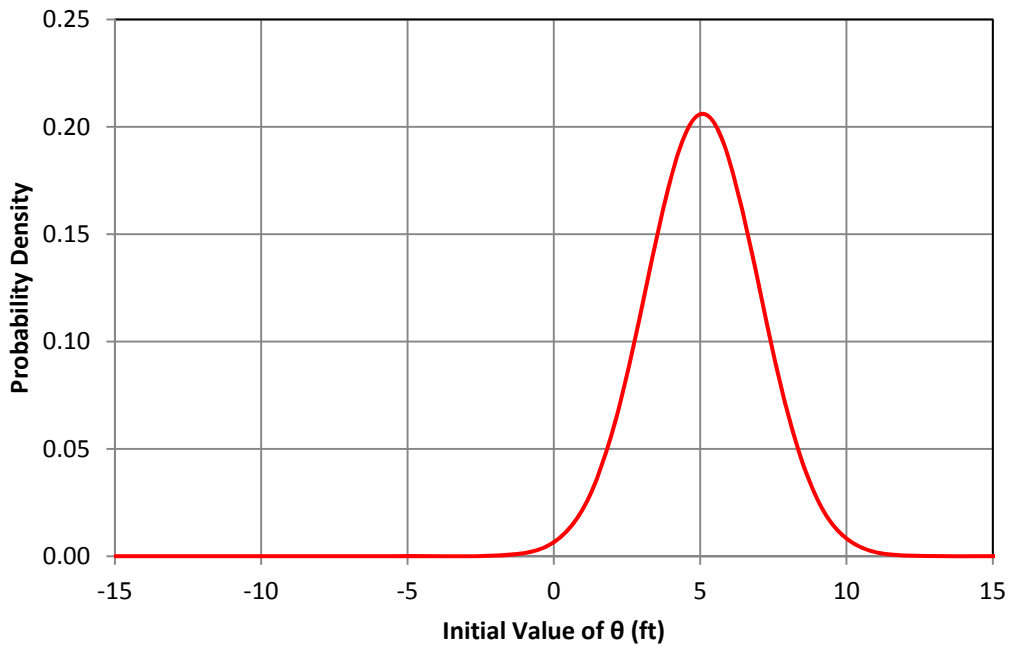
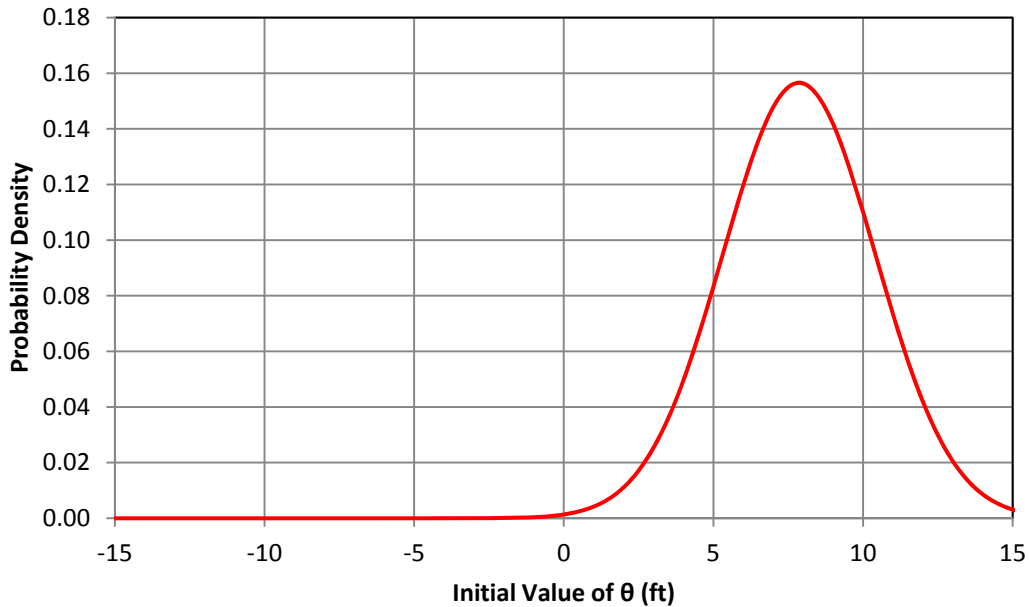


Figure H-3. Stressed plains wetlands probability density function,  $p_s$



**Figure H-4. Stressed ridge wetlands probability density function,  $p_s$**

Using the data from the Class 2 wetlands as a random sample of the relative frequency of occurrence of unstressed and stressed wetland sites. In the field assessment of wetland systems, wetlands were noted as “significantly hydrologically altered” (SHA) if there were obvious alterations that would significantly alter the hydrology that originally gave rise to the wetland system. It was observed that the designation of SHA appeared to have little impact on occurrence of stress in the isolated ridge wetlands, and that the hydroperiod of these systems were generally thought to be more susceptible to groundwater alterations than to the observed surface water alterations, therefore the SHA ridge wetlands were analyzed in the same manner as non-SHA ridge wetlands. In the plains wetland systems it was observed that the designation of SHA was very strongly correlated with stress in wetlands (94% of SHA plains wetlands were stressed, compared to 18% of non-SHA plains wetlands). Assessment of the hydrology of these systems also suggests that their water levels are dominated by surface water effects, and that it is not possible to accurately assess the effects of moderate changes in groundwater elevations on surface water levels in these wetland systems. Therefore SHA plains wetland systems were excluded from the analysis.

After removal of the SHA Plains wetlands, the relative occurrence of stressed and unstressed wetlands in the Class 2 data for the CFWI area is summarized in Table H- 3.

**Table H-3. Summary of Frequency of Stressed and Unstressed Wetlands in CFWI Class 2 Wetland Data Set**

<b>Wetland Type</b>	<b>Not Stressed</b>	<b>Stressed</b>		<b>Not Stressed</b>	<b>Stressed</b>
Plains (non-SHA)	42	9		82%	18%
Ridge (All)	43	28		61%	39%

**Development of Stress Probability functions for Wetlands with Known Initial Conditions**

Using the data from Tables H-1 & H-2, a series of curves was developed to show the probability of causing unstressed plains wetlands to become stressed due to a change in the hydrologic index,  $\theta$ . Probability of stress is shown as a function of the initial value of  $\theta$  and of  $\Delta\theta$ , the amount of future change in the value of  $\theta$ . The function for probability of inducing stress in an initially unstressed wetland is represented as  $\zeta_{u-s}$ . The  $\zeta_{u-s}$  probability curves for negative values of  $\Delta\theta$  (future water levels higher than current water levels) are shown in **Figures H-5 and H-6**, while the  $\zeta_{u-s}$  probability curves for positive values of  $\Delta\theta$  (future water levels lower than current water levels) are shown in **Figure H-7 and H-8**.

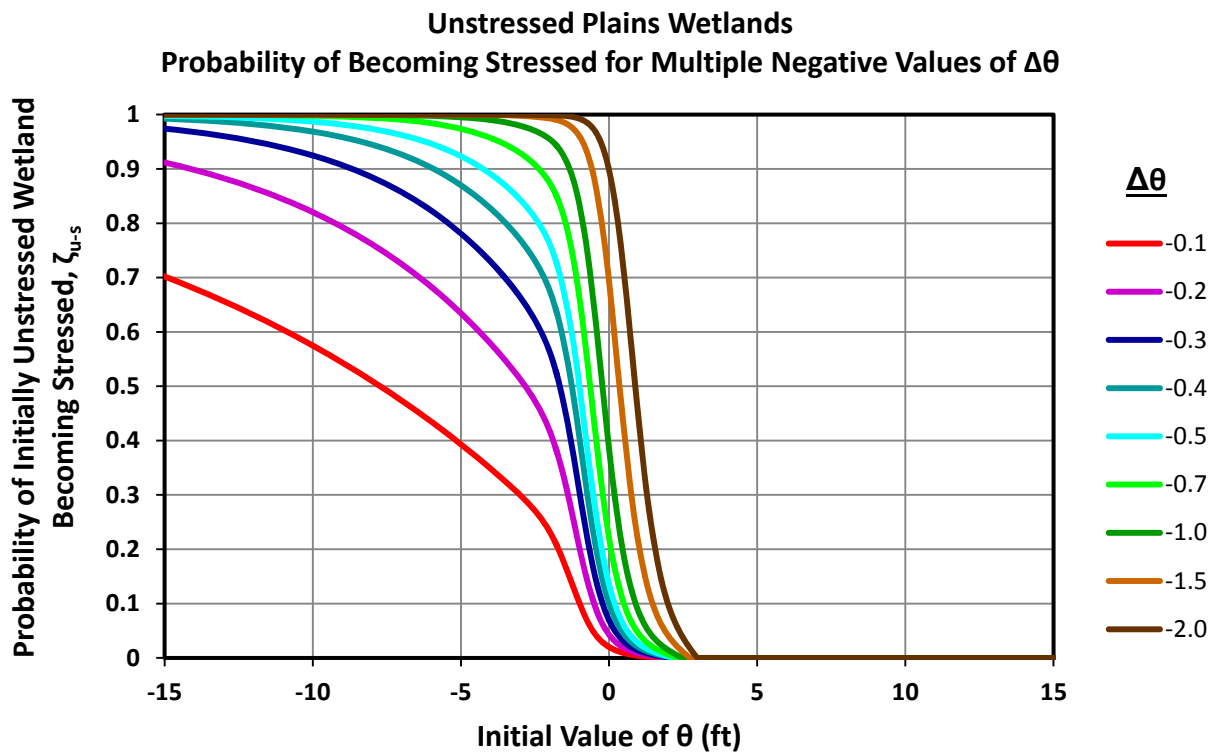


Figure H-5. Unstressed plains wetland probability of becoming stressed for multiple negative values of  $\Delta\theta$ .

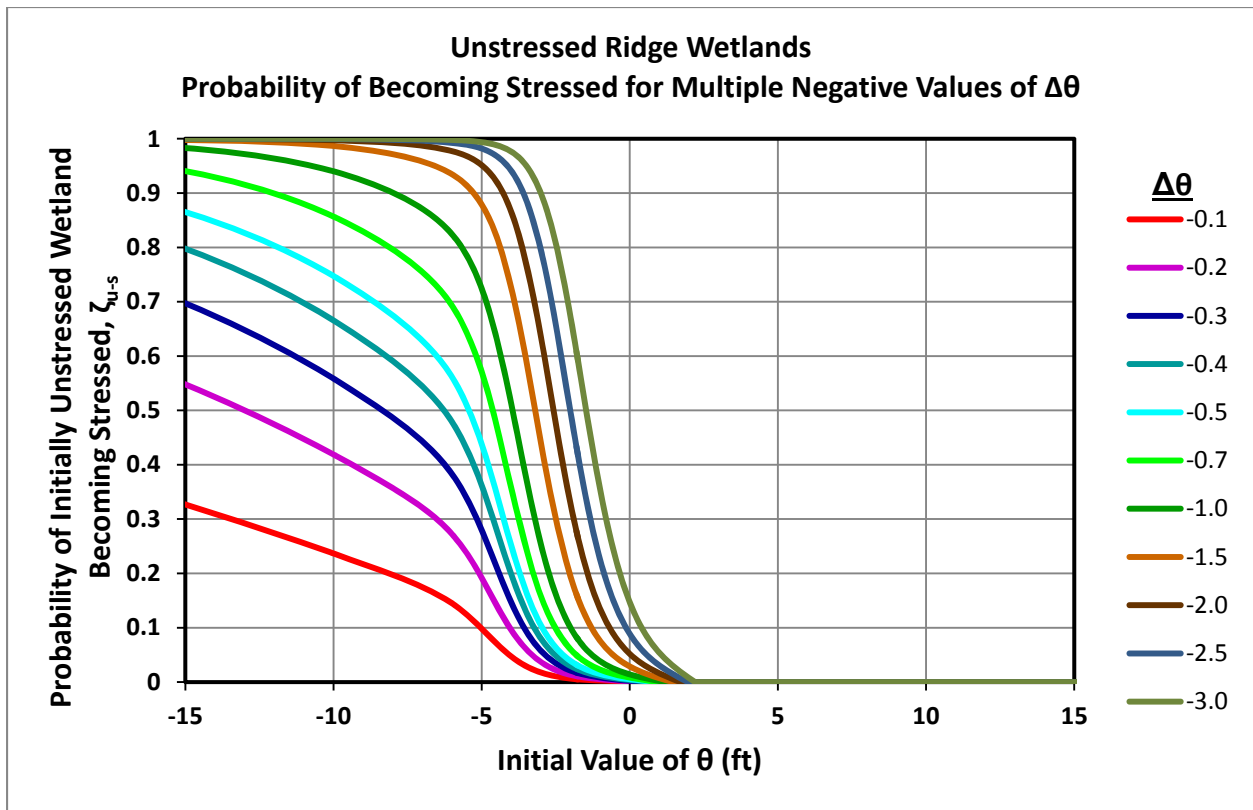


Figure H-6. Stressed ridge wetland probability of becoming stressed for multiple negative values of  $\Delta\theta$ .

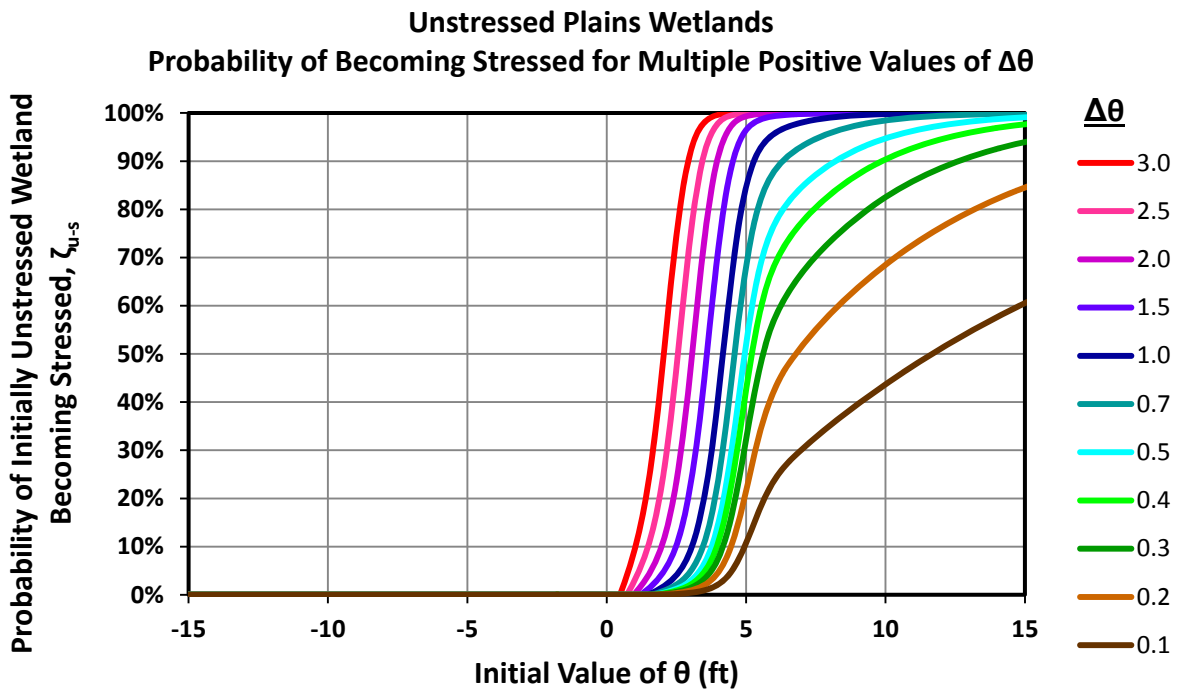


Figure H-7. Unstressed plains wetlands probability of becoming stressed for multiple positive values of  $\Delta\theta$ .

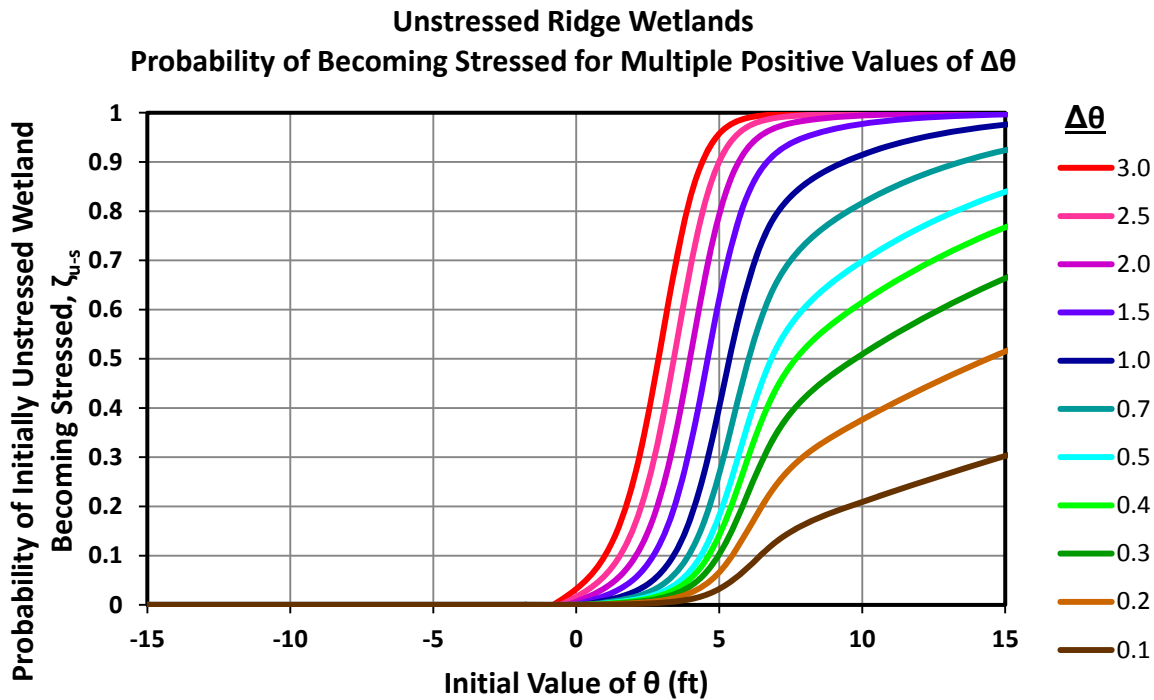


Figure H-8. Unstressed ridge wetlands probability of becoming stressed for multiple positive values of  $\Delta\theta$

Similarly, there are curves in **Figures H-9 through H-12** that show the probability of (eventually) inducing recovery of an initially hydrologically stressed wetlands to an unstressed condition, for negative and positive values of  $\Delta\theta$ , respectively. The function for probability of inducing recovery in an initially stressed wetland is represented as  $\zeta_{s-u}$ .

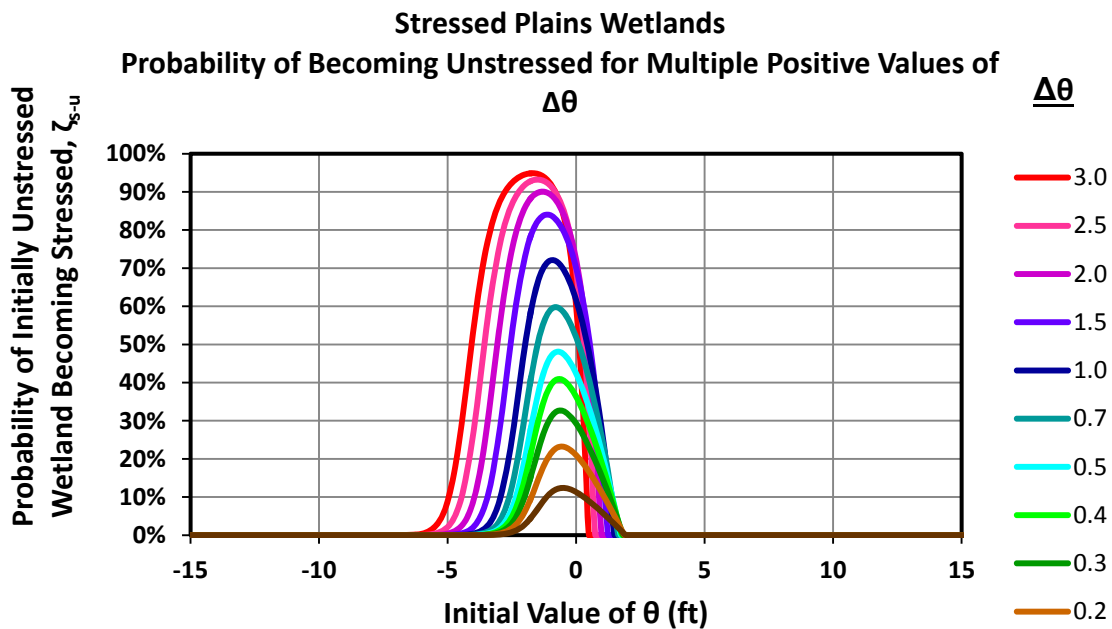


Figure H-9. Stressed plains wetlands probability of becoming unstressed for multiple negative values of  $\Delta\theta$ .

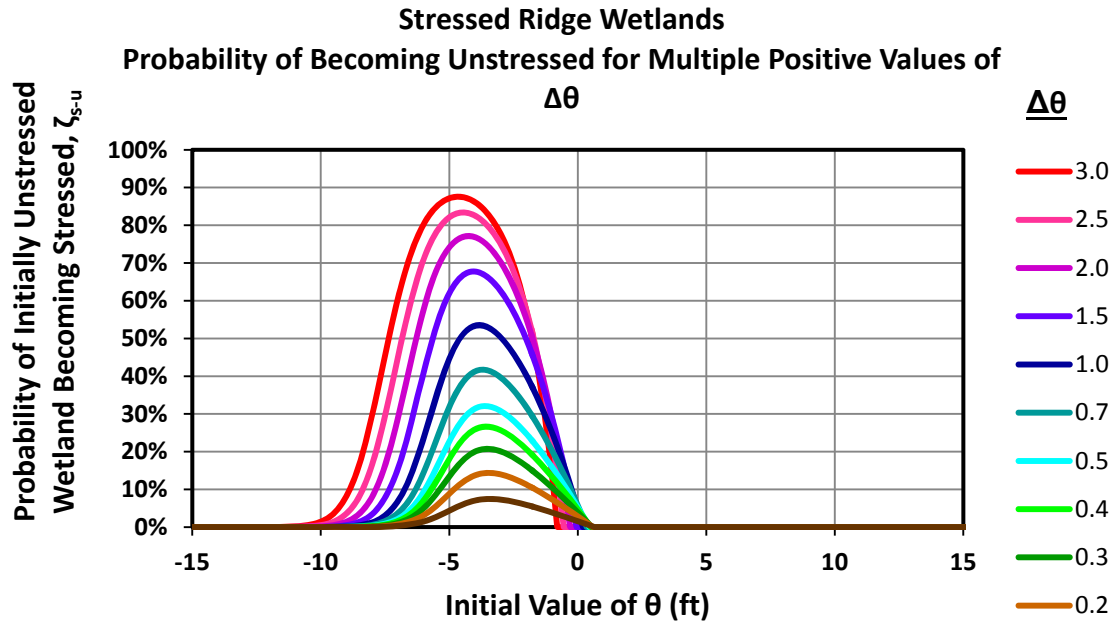


Figure H-10. Stressed ridge wetlands probability of becoming unstressed for multiple negative values of  $\Delta\theta$ .

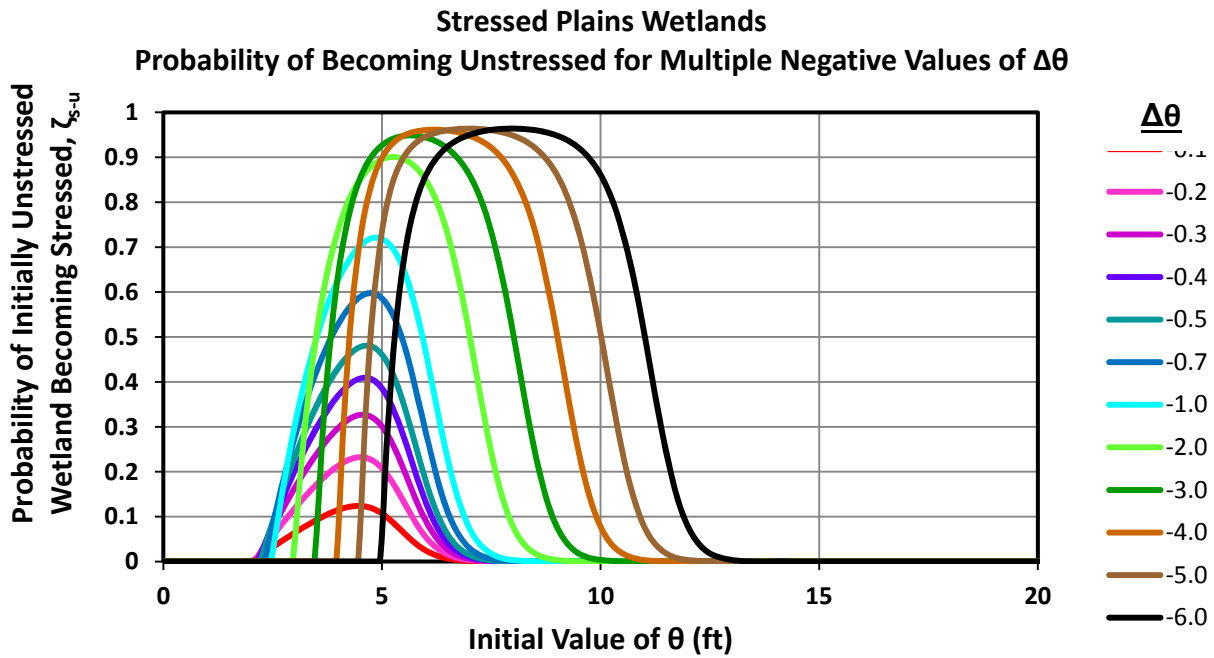


Figure H-11. Stressed plains wetlands probability of becoming unstressed for multiple positive values of  $\Delta\theta$ .



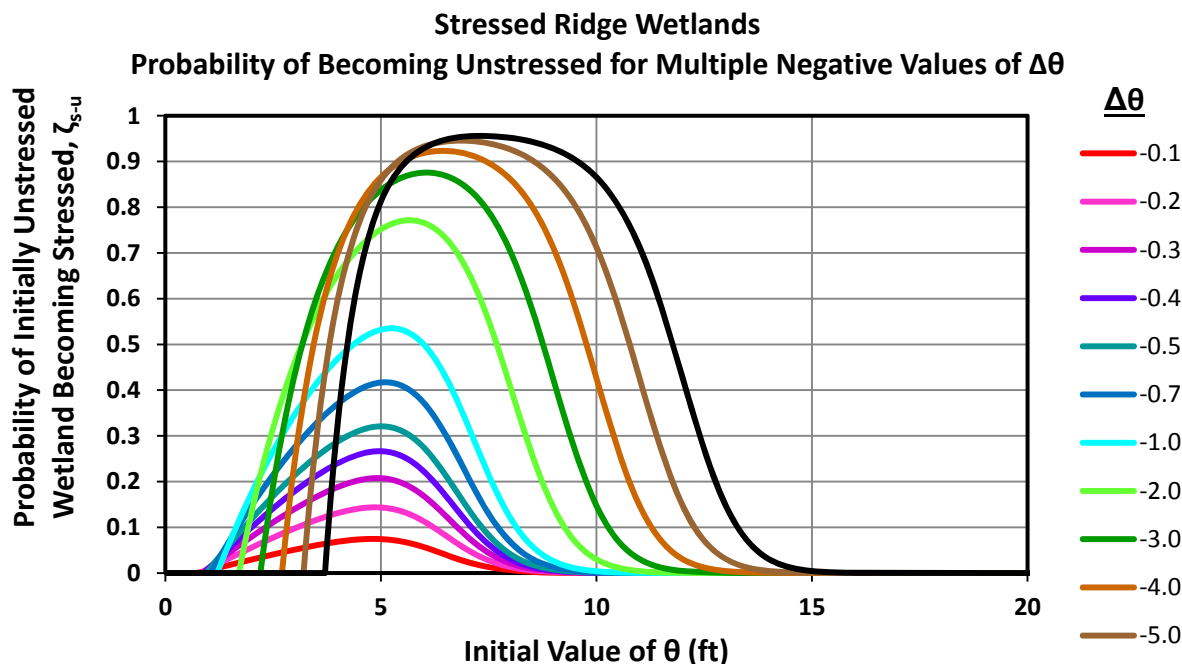


Figure H-12. Stressed ridge wetlands probability of becoming unstressed for multiple positive values of Δθ.

Note that significant probabilities of inducing recovery are obtained by changing an initial  $\theta$  value in a stressed wetland from a relatively extreme high or low value towards the mean  $\theta$  value that’s characteristic of unstressed wetlands. Therefore these recovery (benefit) functions have their highest values within the range of  $\theta$  values that are observed in our data set, and become numerically insignificant as we extrapolate to final condition  $\theta$  values ( $\theta_2 = \theta_1 + \Delta\theta$ ) that lie outside the observed data set.

**Development of Stress Probability functions for Wetlands with Unknown Initial Conditions**

As shown in the figures above, the probability of inducing a stress change is strongly dependent on the initial stress status and the initial hydrologic condition (i.e., the initial  $\theta$  value) of the wetland; this applies to both plains and ridge wetlands, and the creation of both stress and recovery. This dependency is extremely inconvenient because we don’t know these two initial condition values for the overwhelming majority of the wetlands. We are obliged to treat the problem statistically: we can calculate population-weighted average values of  $\zeta_{u-s}$  and  $\zeta_{s-u}$ , and can we estimate the density of initially stressed and unstressed wetlands from our survey sample of wetlands (the Class 2 wetlands). The population-weighted average values of  $\zeta_{u-s}$  and  $\zeta_{s-u}$  are denoted as  $\bar{\zeta}_{u-s}$  and  $\bar{\zeta}_{s-u}$ , respectively, and are calculated as:

$$\bar{\zeta}_{u-s} = \frac{\int_{-\infty}^{\infty} p_u \zeta_{u-s} d\theta}{\int_{-\infty}^{\infty} p_u d\theta}$$

$$\bar{\zeta}_{s-u} = \frac{\int_{-\infty}^{\infty} p_s \zeta_{s-u} d\theta}{\int_{-\infty}^{\infty} p_s d\theta}$$

These two functions allow us to calculate the average probability of inducing a stress change (creating stress or recovery) for any given value of  $\Delta\theta$ . The resulting values of  $\bar{\zeta}_{u-s}$  and  $\bar{\zeta}_{s-u}$  for plains and ridge wetlands are shown as functions of  $\Delta\theta$  in **Figures H-13 and H-14**.

**Population-Weighted  $Z_{u-s}$  for Unstressed Class 2 & Class 3 Wetlands**

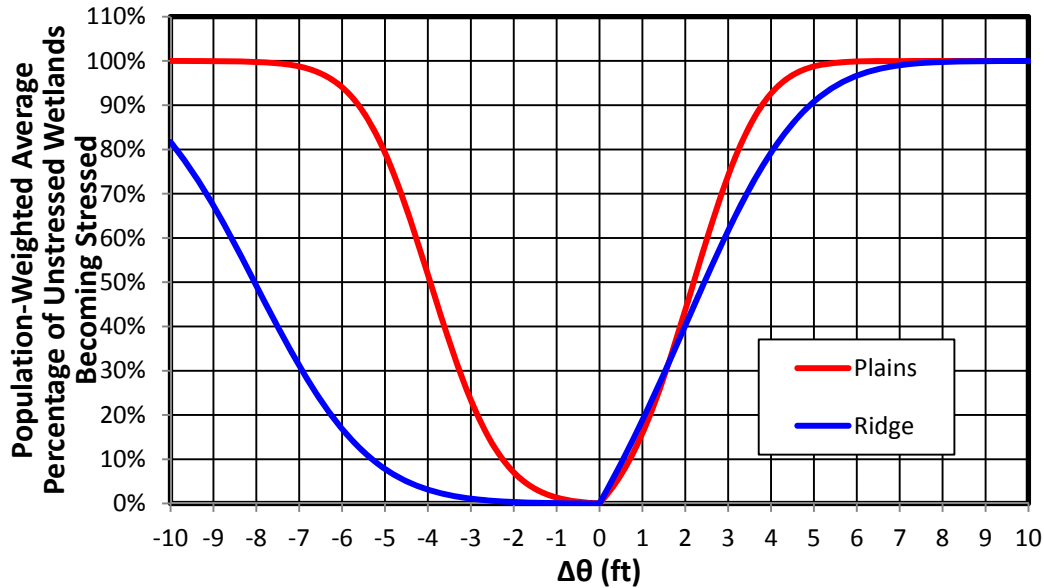


Figure H-13. Population-averaged probabilities of unstressed plains and ridge wetlands becoming stressed, for use with wetlands where the initial condition is unknown.

**Population-Weighted  $Z_{s-u}$  for Stressed Class 2 & Class 3 Wetlands**

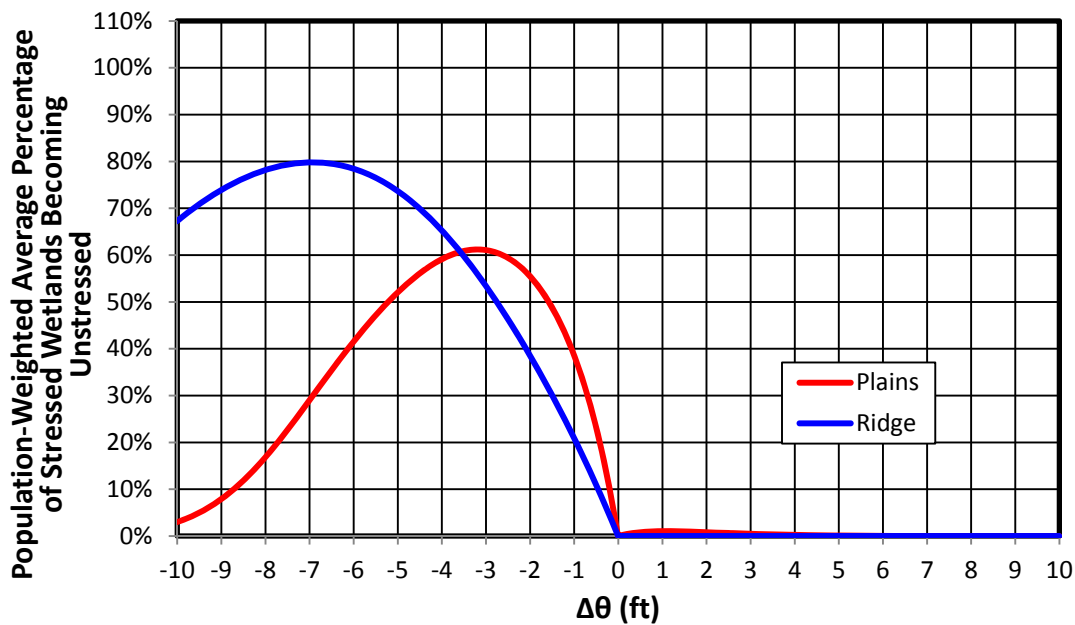


Figure H-14. Population-averaged probabilities of stressed plains and ridge wetlands becoming unstressed, for use with wetlands where the initial condition is unknown.

**Predicted Areas of Wetlands Subject to Change in Stress Status**

From the  $\bar{\zeta}_{u-s}$  and  $\bar{\zeta}_{s-u}$  functions we can calculate a population-weighted average probability of stress change at each wetland location in each cell of the ECFT model, based on the value of  $\Delta\theta$  for that cell.

**The resulting predicted probability of stress status change is extremely unreliable at any individual wetland location or group of wetland locations because the actual local probabilities of stress status change are strongly dependent on the unknown initial conditions of the wetland or group of wetlands.**

The usefulness of this calculation is that the estimated **total** areas of wetlands that will undergo a stress status change can be calculated as:

$$A_{u-s} = \sum_{i=1}^n [(\bar{\zeta}_{u-s})_i \cdot (a_i)]$$

$$A_{s-u} = \sum_{i=1}^n [(\bar{\zeta}_{s-u})_i \cdot (a_i)]$$

Where:

- $A_{u-s}$  = The total area of wetland predicted to change status from unstressed to stressed;
- $A_{s-u}$  = The total area of wetland predicted to change status from stressed to unstressed;
- $i$  = Index counter value for wetland segments in individual ECFT model cells;
- $n$  = The total number of wetland segments in individual ECFT model cells;
- $(\bar{\zeta}_{u-s})_i$  = The population-weighted value of the probability of inducing stress, calculated for wetland segment number "i" based on the predicted value of  $\Delta\theta$  for that type of wetland in that ECFT model cell;
- $(\bar{\zeta}_{s-u})_i$  = The population-weighted value of the probability of inducing recovery from stress, calculated for wetland segment "i" based on the predicted value of  $\Delta\theta$  for that type of wetland in that ECFT model cell; and
- $a_i$  = The area of wetland of specified type (plans/ridge) for wetland segment number "i".

The value of each increment of wetland area subject to a predicted stress status change will likely bear only a weak statistical correlation to the actual area of wetland in that location for which stress will occur. However, so long as the errors in the incremental values of wetland area subject to a predicted stress status change are randomly and independently distributed with a mean value of zero, the **cumulative total** area subject to a predicted stress status change, ( $A_{u-s}$  or  $A_{s-u}$ ) should have relatively small cumulative total error because all the random local increments of error will tend to cancel each other out when summed for large values of "n".

**In general, the appropriate interpretation of any data generated by this process is limited to an observation that the probability of significant contribution to the total area of wetlands subject to stress status change is highest in areas with extensive zones showing higher values of predicted incremental area contributions per cell of wetlands predicted to change stress status.**

From an impact management perspective, management options that will produce more favorable values of  $\Delta\theta_i$ , with corresponding more favorable values of  $\bar{\zeta}_{u-s}$  and  $\bar{\zeta}_{s-u}$ , across such extensive zones are likely to show a beneficial change in the predicted future total value of stressed wetland area. The smaller the total number and area of contiguous affected wetland cells, the less statistically significant the predicted

amount of change, even though individual areas per cell may be relatively large. The challenge is that **unless the total number of wetland cells and the area over which they are located is relatively large, the assumptions of randomly distributed error with zero mean cannot be justified, and the total error in the predicted wetland area subject to stress status change is likely to be relatively large.**

#### **ECFT Water Level Predictor Variables for $\Delta\theta$ in Wetlands**

The value of  $\Delta\theta$  for a wetland is the change of  $\theta$  from some initial condition 1 to some other future condition 2. Since  $\theta = EWE - P80$ , and EWE is a constant value that remains the same for any given wetland, it follows that  $\Delta\theta = \Delta P80$ . In order to predict a  $\Delta\theta$  value, we need to be able to predict a  $\Delta P80$  water level value for the specified wetland.

**Plains Wetlands.** We have previously discussed that for plains wetlands, independent review of hydrologic conditions and review of the ECFT model results both lead us to a conclusion that water levels in the surficial aquifer system (SAS) are generally dominated more by local surface hydrology than by the influence of changes in the underlying Upper Floridan Aquifer (UFA) potentiometric elevation. Therefore our best predictor of long term groundwater-induced changes in plains wetland water levels is the predicted change in SAS water tables at the location of the wetland. Consequently, our best current predictor for  $\Delta\theta$  in wetlands resulting from groundwater alterations is the  $\Delta P80$  water level from reference condition to future condition calculated for the SAS water table in ECFT model cells that contain plains wetland segments.

**Ridge Wetlands.** We have previously speculated that for ridge wetland systems, the localized leakance heterogeneity in the ridge areas might make the potentiometric surface of the UFA a better predictor of long term changes in ridge wetland water levels than the SAS water table. For that reason, results for ridge wetlands are best represented in the form of two alternative assessments of the future predicted areas of stressed ridge wetlands:

1. An extreme worst case based on the assumption that all ridge wetlands are so leaky that their P80 water levels will move on a 1:1 basis with P80 potentiometric levels in the underlying UFA; and
2. A possibly under-conservative case based on the assumption that all ridge wetland P80 water levels will move on a 1:1 basis with P80 water table levels in the underlying SAS.

Initially, it was anticipated that option 1 above, incorporating some average scaling factor,  $C$ , would be the best option; where  $\Delta\theta = \Delta P80_{[\text{ridge wetland}]} = C \cdot \Delta P80_{[\text{UFA}]}$  and  $C < 1$ . On further consideration, it was noted that the SAS water levels used for calibration of the ECFT model in ridge areas tend to be dominated by known lake levels and observations from wells and piezometers that tend to be close to wetlands or water bodies, i.e. in locations where data is most available. Because of this distribution of calibration targets, I suspect that calibrated leakance values in the ridge may be dominated by water levels that are more characteristic of the areas close to lakes and wetlands, and less characteristic of the zones furthest from these features. If so, response of the SAS water levels in the ridge areas of the ECFT model may be a better fit to the leakier depressional areas than was originally anticipated.

On this basis, we suspect that overall, the predicted future areas of stressed wetlands in the ridge areas, based on changes in the SAS water levels, are probably closer to reality than those based on UFA potentiometric elevations. The assumption of a universal 1:1 correspondence between wetland  $\Delta\theta$  values and  $\Delta P80$  potentiometric elevations in the UFA (no scaling factor) seems likely to yield overly conservative estimates.