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MINIMUM LEVELS REEVALUATION FOR COWPEN LAKE PUTNAM COUNTY, FLORIDA

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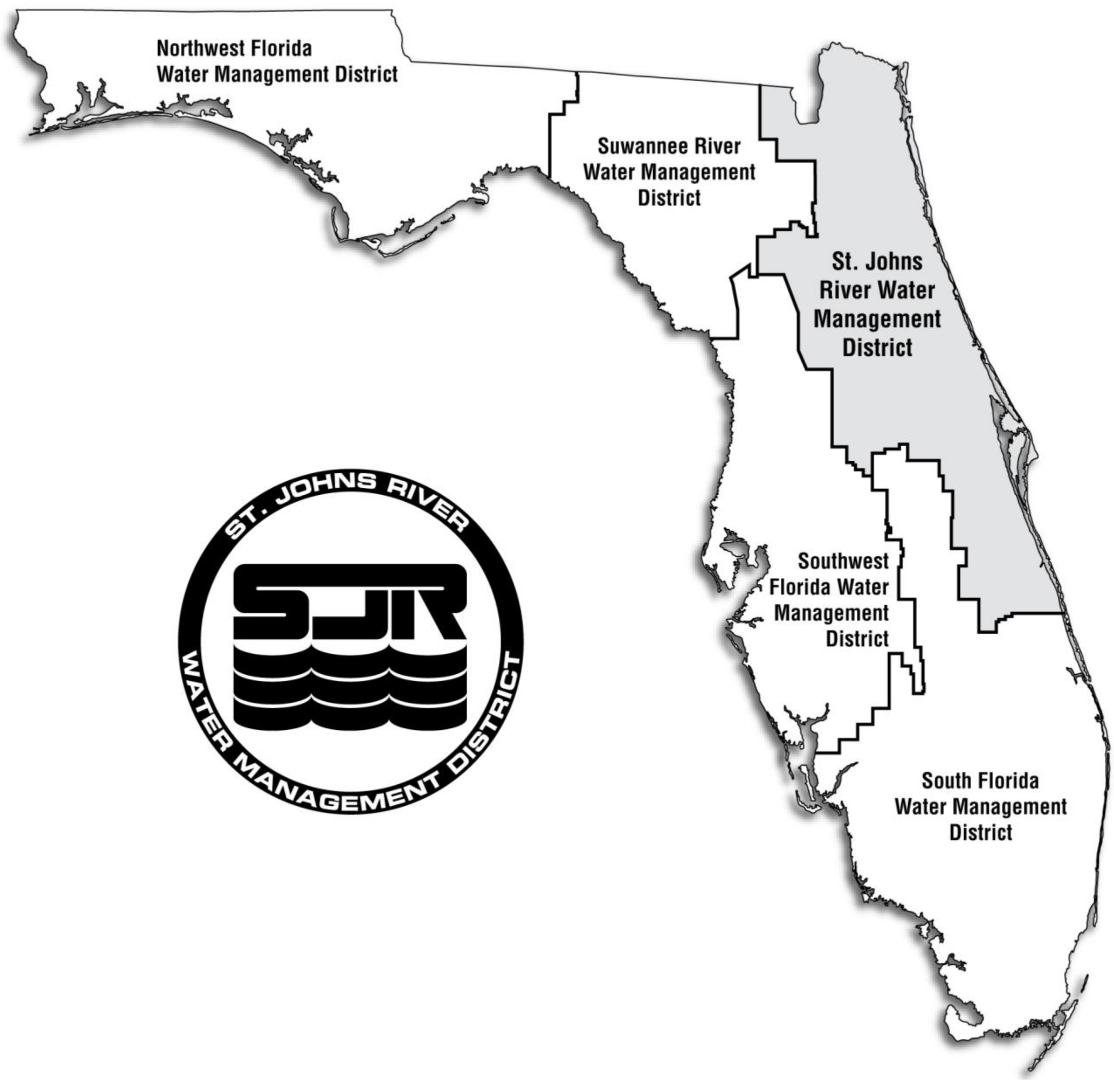
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EXECUTIVE SUMMARY

The St. Johns River Water Management District (SJRWMD) has completed a reevaluation of minimum water levels for Cowpen Lake in Putnam County, Florida, which were originally established in October 1998 (Hall 1997; Appendix A). According to Florida Statute, Minimum Flows and Levels (MFLs) are to be reviewed periodically and revised if necessary (Section 373.0421(3), *Florida Statutes* [*F.S*]). Cowpen Lake 1998 MFLs were selected for reevaluation because the original adopted minimum levels were developed during a short time-frame, using methods that have since been revised and without the availability of long-term hydrologic data or a long-term water budget model. The reevaluation included implementation of updated methods, development of a hydrologic model and analysis of additional long-term hydrologic data to ensure that Cowpen Lake MFLs are based on the most up-to-date methods and criteria (SJRWMD 2006, and Neubauer et al. 2008).

MFLs provide an effective tool to assist in making sound water management decisions that prevent significant adverse impacts due to water withdrawals to the water resources or ecology of the area. MFLs at SJRWMD are established as multiple hydrologic events to protect an ecosystem's natural hydrologic variability and the resources that depend on these seasonal and inter-annual fluctuations. Minimum levels, which are set for lakes, are events with three components: magnitude (elevation in feet), duration (in days) and frequency (in years). These critical events set the limit of available water, beyond which further water withdrawals would be significantly harmful to the ecological structure and/or function, or other beneficial use of a given water body.

The Cowpen Lake reevaluation resulted in a recommendation for three minimum levels (Table ES 1). The recommended Infrequent High (IH) event ensures that the boundary between uplands and wetland (90.8 ft NAVD) will be flooded for a sufficient duration (30-days) and frequency (25-year return interval) to prevent the downhill shift of the upland ecotone and maintain a beneficial mixture of emergent wetland and open water habitat (Table ES 1). The recommended Minimum Average (MA) event ensures that the elevation of deep organic soils (84.0 ft NAVD) are not dried out too often (180-days, with a 1.7 year return interval). This dewatering event will protect wetland soils from oxidation and subsidence, while maintaining the integrity of tree roots, and protecting biogeochemical processes and wetland biota that require long term flooding or saturation. The recommended Frequent Low (FL) level (82.3 ft NAVD, 120-days, with a 2.7 year return interval) is based on maintaining the location of the littoral zone and thus protecting the long-term structure and function of fish and wildlife habitat.

Table ES-1 Adopted and recommended minimum surface water levels for Cowpen Lake, Florida

Minimum Levels Regime	1998 Adopted	2016 Recommended		
	Level (ft NAVD / NGVD)	Level (ft NAVD / NGVD)	Duration (days)	Return Interval (years)
Infrequent high	-	90.8 / 92.0	30	25
Frequent high	88.1 / 89.1	-	-	-
Average	84.5 / 85.7	84.0 / 85.2	180	1.7
Frequent low	83.2 / 84.2	82.3 / 83.5	120	2.7

The SJRWMD is charged with determining the threshold of significant harm caused by water withdrawals, and to separate the effects of groundwater withdrawals from those of climate (i.e., drought) on lake levels. Impact on the Upper Floridan Aquifer (UFA) underneath Cowpen lake due to groundwater withdrawals was estimated using the best available tool, version 3 of the Northeast Florida (NEFv3) regional groundwater model. A drawdown of 2.2 ft was estimated, based on the NEFv3.

The NEFv3 drawdown estimate represents the change in water levels in the UFA beneath Cowpen Lake from a no-pumping condition to the baseline condition. The baseline condition represents a best estimate of current impacted condition, and for the Cowpen Lake MFL is defined as the 2009-pumping condition. This baseline refers to both UFA water levels and lake levels. The baseline condition for UFA water levels incorporates the natural variability of the groundwater level time series, as if impacted by drawdown equal to that caused by 2009 water use. Using a surface water model, the baseline condition UFA water level time series was used to generate the baseline lake level time series for Cowpen Lake.

MFLs status was assessed using frequency analysis (described in detail below) to compare the frequency of critical ecological events under baseline conditions to the frequency of those same events based on the recommended MFLs. Frequency analysis was used to determine the amount of water available for withdrawal (freeboard), defined as feet of drawdown allowable in the UFA. The MFLs for Cowpen Lake are based on critical lake levels, but freeboard is determined based on the amount of change in the UFA that is allowable before the most constraining MFL is no longer achieved.

An MFL is achieved if the freeboard is greater than or equal to zero. If freeboard is less than zero, a water body is in recovery, and requires the development of a recovery strategy. If the MFLs is currently being achieved but is projected to not be achieved within the 20-year planning horizon, then a water body is in “prevention,” and a prevention strategy must be developed. Whether an MFL is being achieved within the planning horizon is determined by comparing the freeboard under baseline conditions to the amount of projected UFA drawdown at the planning horizon. For Cowpen Lake, the projected drawdown at 2035 was estimated using the NEFv3 groundwater model.

Model results and frequency analyses indicate that all three recommended MFLs for Cowpen Lake are currently being achieved under baseline conditions. Freeboards of 0.8 ft., 2.0 ft., and 1.1 ft. were calculated for the IH, MA and FL, respectively. The most constraining MFL is the IH, with a freeboard of 0.8 ft available in the UFA. Based on the best available information, including the NEFv3 groundwater model, the predicted drawdown resulting from projected water use for the 20-year planning horizon is less than 0.8 feet. Therefore, the proposed MFLs for Cowpen Lake are achieved for the 20-year planning horizon.

Cowpen Lake water levels have been low in recent years, which may seem at odds with the current conclusion that the recommended MFLs are being achieved. Based on regional rainfall data, it is thought that recent low water levels at Cowpen Lake are largely driven by the current multi-decadal drought. While the average rainfall for Cowpen Lake is 50.7 inches per year, it is highly variable (29.0 to 73.3 in per year) and many back to back years of below average rainfall occur. Because of its physiographic setting, and variable rainfall, cumulative years of below average rainfall can effectively dry out the landscape surrounding Cowpen Lake, resulting in declining lake levels. From the 1940s to the mid-1970s, there was a cumulative rainfall surplus of approximately 90 inches, leading to relatively high lake levels. From the mid-1970s to the present, there has been a rainfall deficit of approximately 100 inches. This period of landscape drying corresponds to the same period of water level decline at Cowpen Lake. Just as it took many years of cumulative below average rainfall to cause water level declines, it will take many years of above average rainfall to offset this prolonged periods of drought, and return the lake to the high levels seen in the 1970s.

It is assumed that if the essential characteristics of the natural seasonal flooding and drying regimes are maintained, then the basic structure and functions of a given environmental system will be maintained. The recommended MFLs for Cowpen Lake are intended to protect the extent and composition of wetland and aquatic habitat. The SJRWMD concludes that the recommended MFLs, which have been developed primarily for the protection of significant harm to “fish and wildlife habitats and the passage of fish”, will protect all other relevant Rule 62-40.473, *F.A.C.*, environmental values. Because these MFLs protect the structure and function of wetlands and aquatic habitats, other functions and values related to ecological integrity (e.g., nutrient filtration, detrital transport) in Cowpen Lake will likely be protected from significant ecological harm caused by withdrawals, if the IH, MA and FL criteria are protected. In addition, environmental values related to recreational uses (boating, and fishing) will only change a small amount relative to baseline conditions (e.g., dock access changes 5%), and thus are considered protected. Finally, the change in the average (median) lake level between the baseline condition and recommended MFL condition is small (less than 1 foot). Therefore, the recommended hydrologic regime (multiple MFL events) are considered protective of all relevant environmental values for Cowpen Lake.

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ACRONYMS AND ABBREVIATIONS

F.A.C.	Florida Administrative Code
F.S.	Florida Statutes
MFLs	Minimum Flows And Levels
GIS	Geographic Information System
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
POR	Period Of Record
SJRWMD	St. Johns River Water Management District
SWFWMD	Southwest Florida Water Management District
SSURGO	Soil Survey Geographic Database
USGS	U.S. Geological Survey
FNAI	Florida Natural Areas Inventory
HSPF	Hydrologic Simulation Program-Fortran
NEF model	Northeast Florida Groundwater Flow Model
DCIA	Directly Connected Impervious Area
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
NOAA	National Oceanic and Atmospheric Administration
DBH	Diameter at Breast Height
SWIDS	Surface Water Inundation and Dewatering Signatures
IH	Minimum Infrequent High
FH	Minimum Frequent High
MA	Minimum Average
FL	Minimum Frequent Low
IL	Minimum Infrequent Low

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) completed a reevaluation of minimum levels for Cowpen Lake in Putnam County, Florida, which were originally established in October 1998 (Hall 1997; Appendix A). According to Florida Statute, Minimum Flows and Levels (MFLs) are to be reviewed periodically and revised if necessary (Section 373.0421(3), *Florida Statutes* [*F.S*]). Cowpen Lake MFLs were selected for reevaluation because the original adopted minimum levels were developed during a short time-frame, using methods that have since been revised and without the availability of long-term hydrologic data or a long-term water budget model. The reevaluation included implementation of updated methods, development of a hydrologic model and analysis of additional long-term hydrologic data to ensure that Cowpen Lake MFLs are based on the most up-to-date methods and criteria (SJRWMD 2006, and Neubauer et al. 2008). This report describes new field data collection, surface water modeling, and data analyses conducted as part of the reevaluation.

LEGISLATIVE OVERVIEW

SJRWMD establishes minimum flows and levels for priority waterbodies within its boundaries (section 373.042, Florida Statutes [F.S.]). Minimum flows and levels for a given waterbody are the limits "at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (section 373.042, F.S.).

Minimum flows and levels are established using the best information available (section 373.042(1), F.S.), with consideration also given to "changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...," provided that none of those changes or alterations shall allow significant harm caused by withdrawals (section 373.0421(1)(a), F.S.).

The minimum flows and levels section of the State Water Resources Implementation Rule (rule 62-40.473, Florida Administrative Code [F.A.C.]) also requires that "consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology."

Rule 62-40.473, F.A.C., states that minimum flows and levels "should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary, to establish the limit beyond which further withdrawals would be significantly harmful." Waterbodies experience variations in flows and levels that often contribute to significant functions of the system, such as the environmental values listed above.

Current Adopted Minimum Levels

The following levels were adopted in 1998 as part of the original MFLs determination for Cowpen Lake.

Minimum Level Regime	Level (ft NAVD / NGVD)	Level Description	Hydroperiod Category
Frequent high	88.1 / 89.1	*Level corresponds to the average of the mean elevations of the transition zone / wet prairie*	Seasonally flooded
Average	84.5 / 85.7	*Level corresponds to the mean elevation of muck soil minus 0.25 ft*	Typically saturated
Frequent low	83.2 / 84.2	*Level corresponds to the mean elevation of surveyed emergent marsh minus 1.7 ft*	Semi-permanently flooded

SJRWMD MFLs Program Overview

The SJRWMD is engaged in a district-wide effort to develop MFLs for protecting priority surface water bodies, watercourses, associated wetlands, and springs from significant harm caused by water withdrawals. MFLs provide an effective tool for decision-making regarding planning and permitting of surface water or groundwater withdrawals. If a requested withdrawal would cause significant harm to a waterbody, a permit cannot be issued. If a waterbody is not in compliance with an MFLs, or expected not to be in compliance during the 20-year planning horizon due to withdrawals, a recovery or prevention plan must be developed and implemented.

The SJRWMD MFLs program includes environmental assessments, hydrologic modeling, independent scientific peer review, and rule making. A fundamental assumption of the SJRWMD's approach is that alternative hydrologic regimes exist that are lower than historical but will protect the ecological structure and function of priority water bodies, watercourses, associated wetlands, and springs from significant harm caused by water withdrawals.

Significant harm is a function of changes in frequencies of water level and/or flow events of defined magnitude and duration caused by water withdrawals. These changes cause impairment or loss of ecological structure (e.g., permanent downhill shift in plant communities caused by water withdrawals) or function (e.g., insufficient fish reproductive or nursery habitat caused by water withdrawals).

MFLs typically define the frequency of high, intermediate, and low water events necessary to protect relevant water resource values. Three MFLs are usually defined for each system—minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) flows and/or water levels. In some cases, minimum infrequent high (IH) and/or minimum infrequent low (IL) MFLs may also be set (Neubauer et al. 2008). No matter how many MFLs are adopted, the most constraining (i.e., most sensitive to water withdrawal) MFL is used for water supply planning and permitting.

An integral program component is the development of water budget models (Mitsch and Gosselink 1993) that account for precipitation, runoff (i.e., inflows and outflows), evaporation, transpiration, and groundwater volumes. The interactions of these hydrologic components, over time, result in changes to the volume of a surface water system. Volume changes are often measured as changes in stage (i.e., water levels) or flows, which are ecological drivers of structure and function within aquatic and wetland systems. Surface and ground water withdrawals as well as structural alterations in the surface water basin can affect the water budget and the ecology of a system.

The District's MFLs program has changed and continues to improve as new data and technologies become available. That is the case for the Cowpen Lake MFLs reevaluation, which has been developed with the benefit of additional data and new modeling tools. In addition, the 1998 MFLs were established with hydroperiod categories, not based on hydrologic events with discrete return intervals and durations. This change in approach results in minimum levels for Cowpen Lake that are different from, and we feel improved relative to, the original adopted levels.

LAKE SETTING AND DESCRIPTION

Location and Physiographic Setting

Cowpen Lake is located approximately 5 miles east of Hawthorne, Florida (Figure 1, U.S. Geological Survey [USGS] Keuka quadrangle map, scale 1:24,000). It is at the southern end of a physiographic region known as the Interlachen Sand Hills. This sub-district of the Central Lake District has elevations up to 220 feet. The Central Lakes District as a whole is an important recharge area for the Floridan aquifer (Brooks 1982). Lakes of the Interlachen Sand Hills are at or only slightly above the potentiometric level in the limestone aquifer. Thick sand

and gravel deposits provide a direct hydraulic connection to the Floridan aquifer. To the immediate south of Cowpen Lake, the St. Johns Offset sub-district is an ancient river valley partially backfilled with estuarine sediments of reduced permeability (Brooks 1982). This contrast in geology is reflected in the map of recharge rates, which is based on estimates by Boniol et al. (1993; Figure 2). Areas north of Cowpen Lake have generally high recharge rates while areas to the south have medium to low recharge rates. Floodplains along creeks of the area are zones of discharge.

Bathymetry

Cowpen lake has an open water area of about 584 acres at a water level of 88 ft based on the North American Vertical Datum (NAVD). The lake has a closed basin with no channelized surface water inflows or outflows. The basin has a complex morphology comprised of shallow solution basins and submerged ridges (Figure 3). There are four major lake lobes, connected at various elevations (lobes A, B, C, and D). During drought conditions, the four lake lobes can become isolated. The main lake lobe (A) becomes separated from lobes B and D at stages below 81.0 and 80.8 ft NAVD, respectively. Lobes B and C become separated at lake stages below 80.2 ft NAVD. These elevations correspond to the shallowest depths recorded while measuring depth soundings at lake lobe connections. Additional surveying work done in 2016 confirmed that hydraulic controls were at generally the same elevations. The new control elevation between lobes A and B is 80.5 ft NAVD; between lobes A and D it is 80.9 ft NAVD; and between lobes B and C is 79.8 ft NAVD.

The Cowpen Lake bathymetric map (Figure 4) was produced by Florida LAKEWATCH (2005). Depths were taken on June 30, 1998, when the lake water level was 85.46 ft NAVD (86.65 ft NGVD). Data were collected using a small boat with a depth sounder transducer and GPS equipment. Using the lake water level as a base, the data files were converted to points using ArcGIS Display XY Data, converted to DEM using ArcGIS Spatial Analyst Topo to Raster, then converted to contours using Surface Contour tool and later smoothed for consistency. Survey data issues necessitated the manipulation of some data points (i.e. some points were outside of lake edge). The deepest point (22 ft) is located in lobe D (Figure 3). Staff considers the measurements shown in the map to be accurate and representative of current conditions.

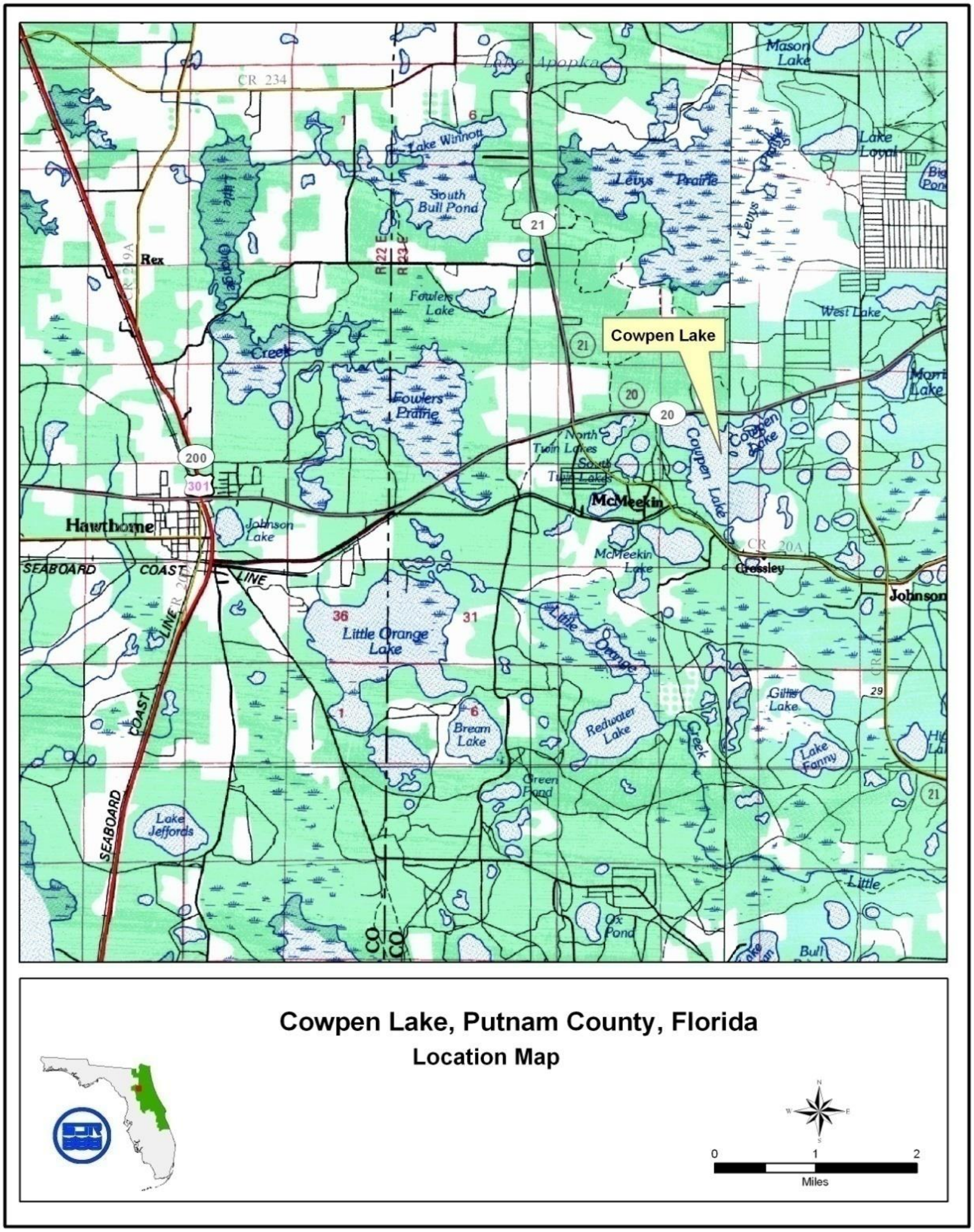


Figure 1. Location map of Cowpen Lake, Putnam County, FL (USGS Keuka Quadrangle)

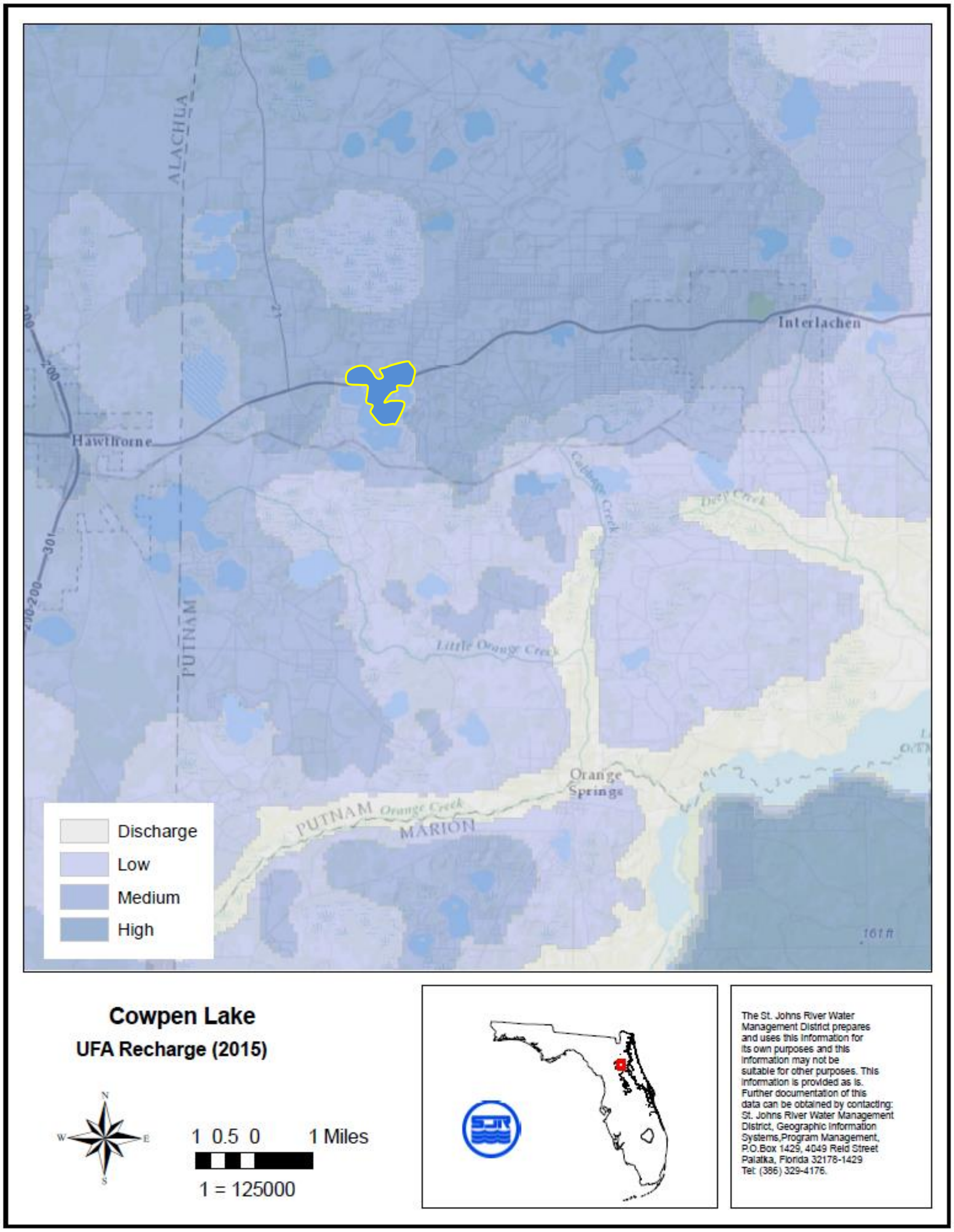


Figure 2. Upper Florida Aquifer recharge map for area around Cowpen Lake, Putnam Co., FL

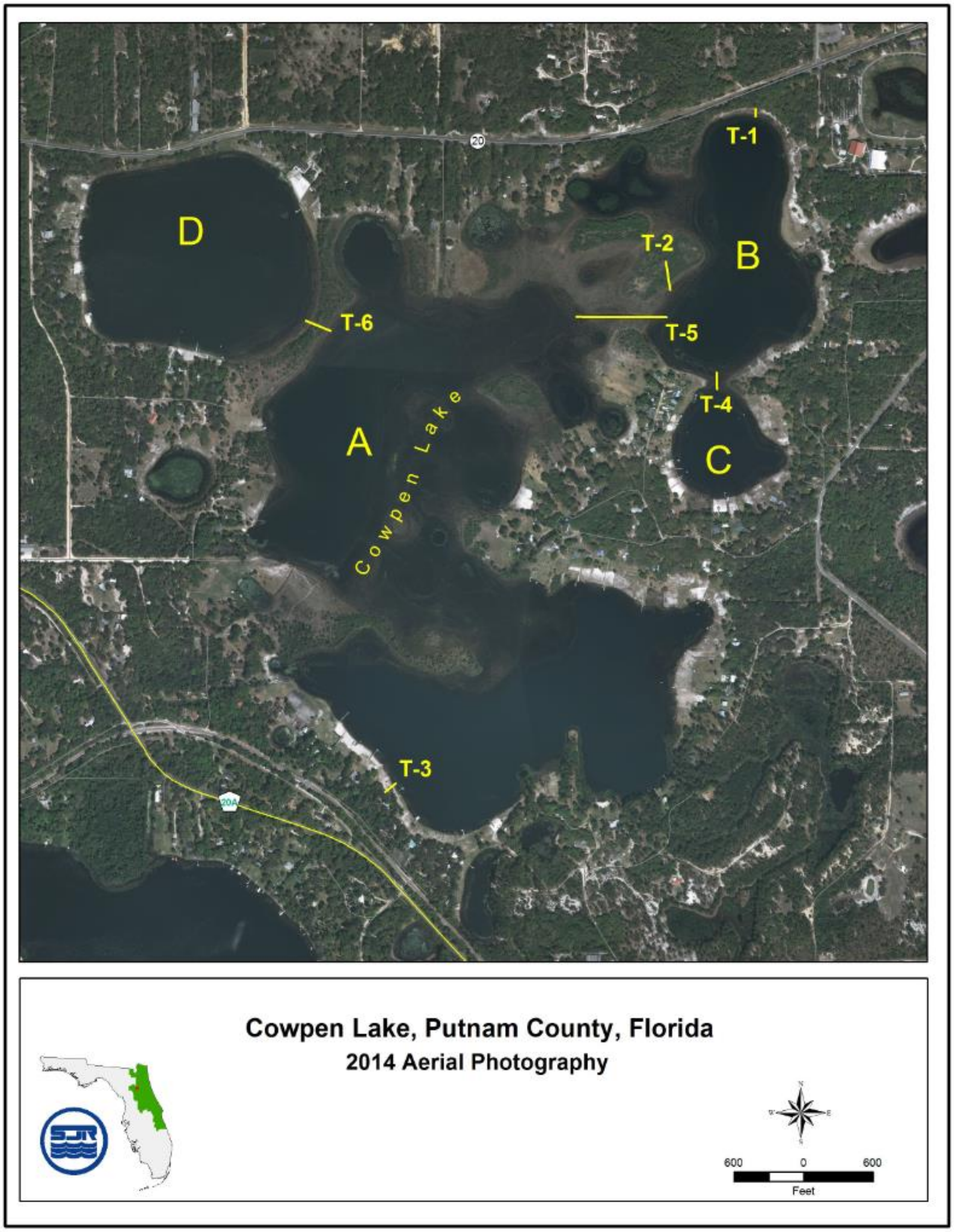


Figure 3. Lake lobes (Lobes A, B, C and D), vegetation transects (T1, T2 and T3) and lobe connections (T4, T5 and T6) for Cowpen Lake, Putnam County, FL

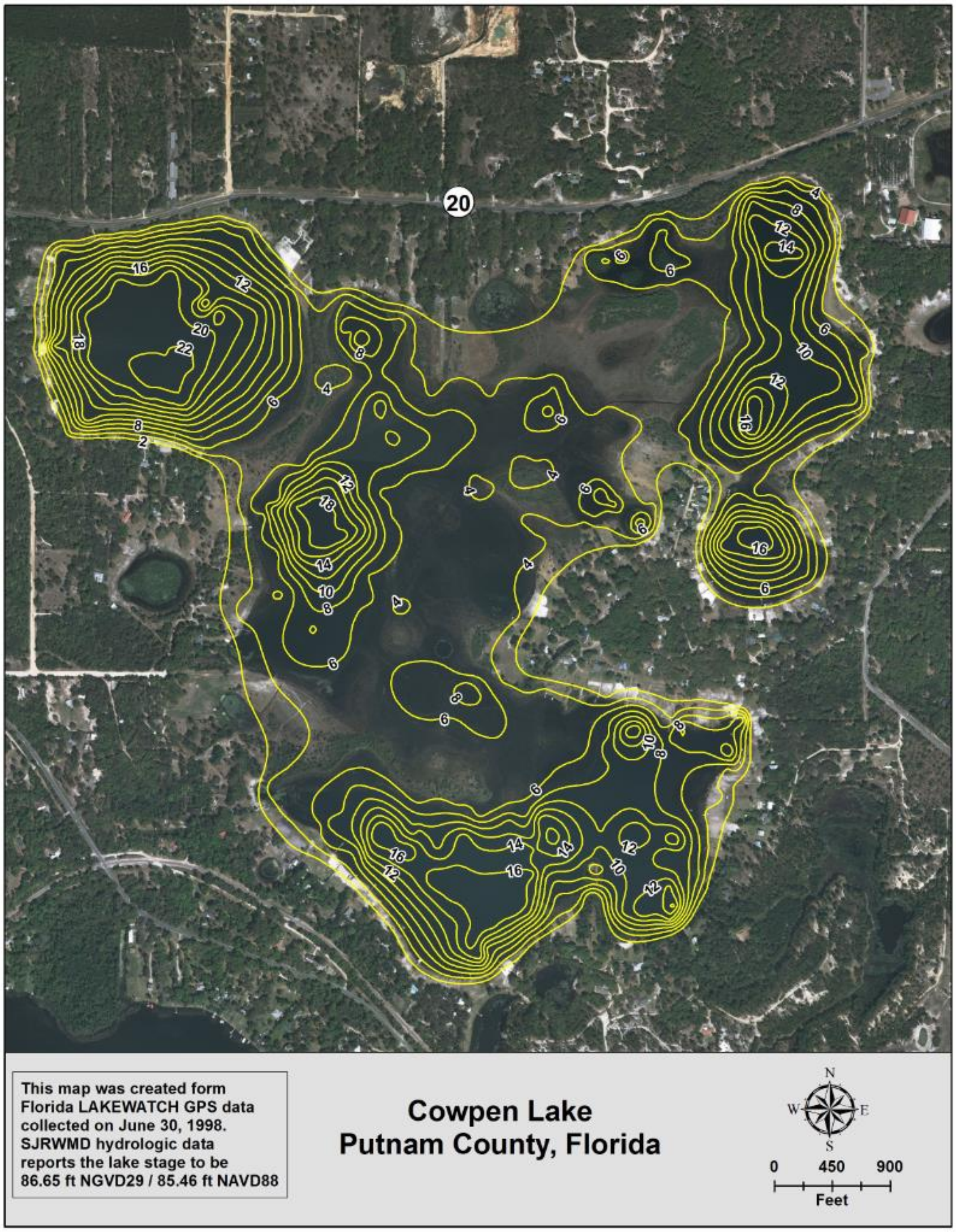


Figure 4. Bathymetric map with four foot contours for Cowpen Lake, Putnam County, FL

Note: this map was created by combining digitized contours from LAKEWATCH (2005) with more recent aerial photography to illustrate recent low water conditions to show lake-lobe separation. These two coverages were not rectified and may show discrepancies. The original map has 4-foot contour intervals and was made when the lake stage was 86.65 ft NGVD.

Land Use Cover

The tributary area of Cowpen Lake is approximately 1,604 acres and includes other small lakes and wetlands. Land use was determined using SJRWMD digital land use coverage data for the year 2009. Figure 5 depicts land use/cover data from 2014; land use/cover did not change significantly between 2009 and 2014. Land use distribution within the Cowpen Lake basin indicates that low density residential is the dominant land use, followed by forested area (Table 1).

Table 2. Land use within the Cowpen Lake drainage basin, Putnam County, Florida, excluding the lake surface area.

Land Use Type	Area (acres)	DCIA (%)	Impervious Area (acres)	Pervious Area (acres)
Low Density Residential	648	5%	32	616
Industrial and Commercial	43	50%	22	22
Mining	6	0%	0	6
Open and barren land	23	0%	0	23
Pasture	31	0%	0	31
Agriculture general	9	0%	0	9
Rangeland	18	0%	0	18
Forest	265	0%	0	265
Water	372	0%	0	0
Wetlands	190	0%	0	139
TOTAL	**1,604**	**3%**	**54**	**1,178**

Hydric Soils

The only hydric soil mapped adjacent to Cowpen Lake was Placid fine sand (Figure 6, SSURGO). This soil type generally occurs around the lake's edge and in some very shallow areas within the lake. The Placid series consists of very deep, very poorly drained, rapidly permeable soils on low flats, depressions, poorly defined drainage ways on uplands, and floodplains on the Lower Coastal Plain. Natural vegetation consists of pond pine, bay, cypress, gum, pickerel weed, and coarse grasses (NRCS 2008). This soil type is not considered a strong criterion and indicator of protection upon which to base an MFL. This is because it is a sand and not a muck, and cannot oxidize and subside because of withdrawals. Also, hydric soil indicators are thought to change slower to the effects of hydrologic changes caused by withdrawals, relative to organic soils. Protecting criteria and indicators that are more sensitive to withdrawals (e.g., organic soils) should protect less sensitive criteria and indicators like this hydric soil. Soil samples collected at various field transects typically varied from the SSURGO map soil classifications due to differences in map scale (see below for field data regarding hydric soils).

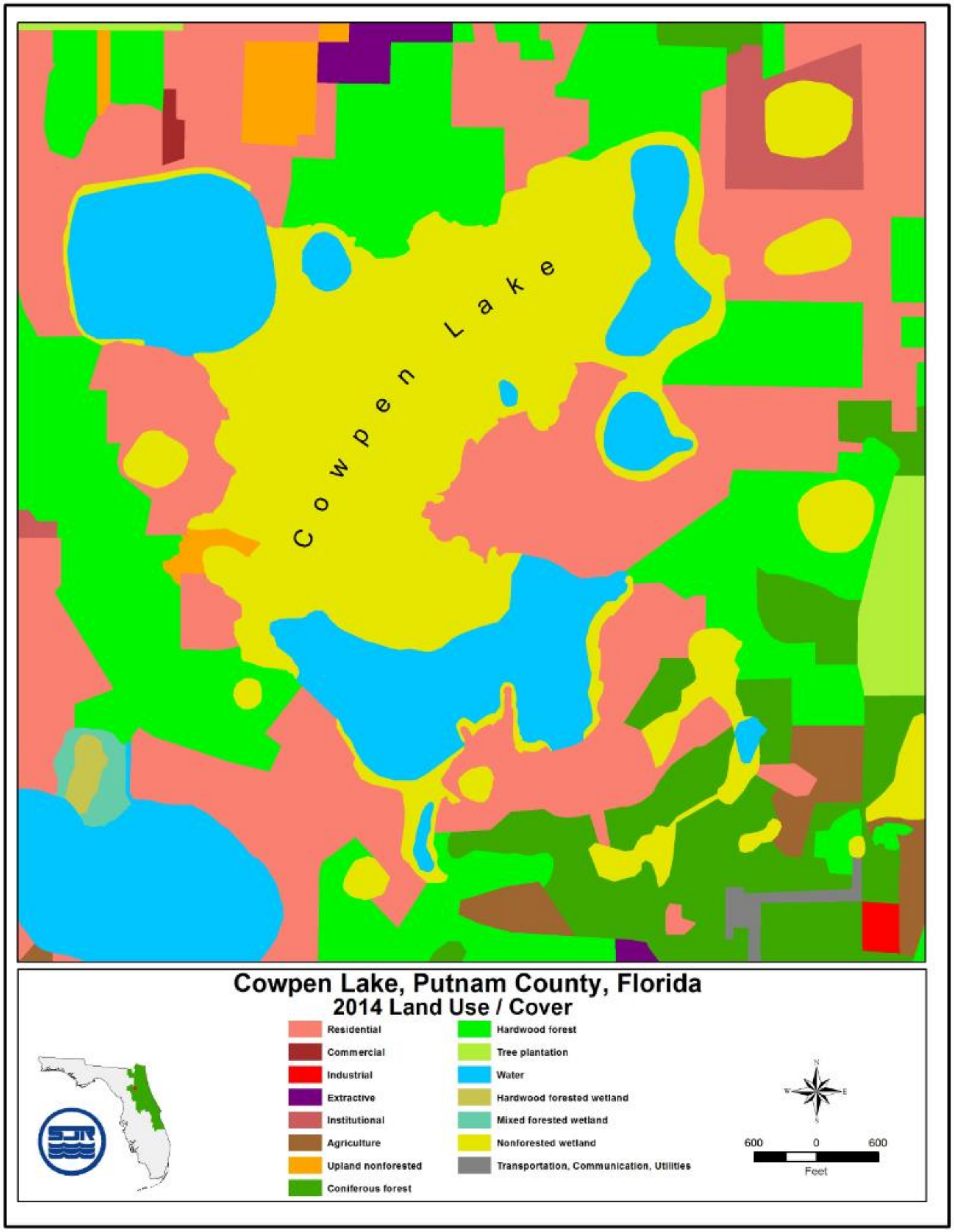


Figure 5. 2014 land use/cover near Cowpen Lake, Putnam County, FL

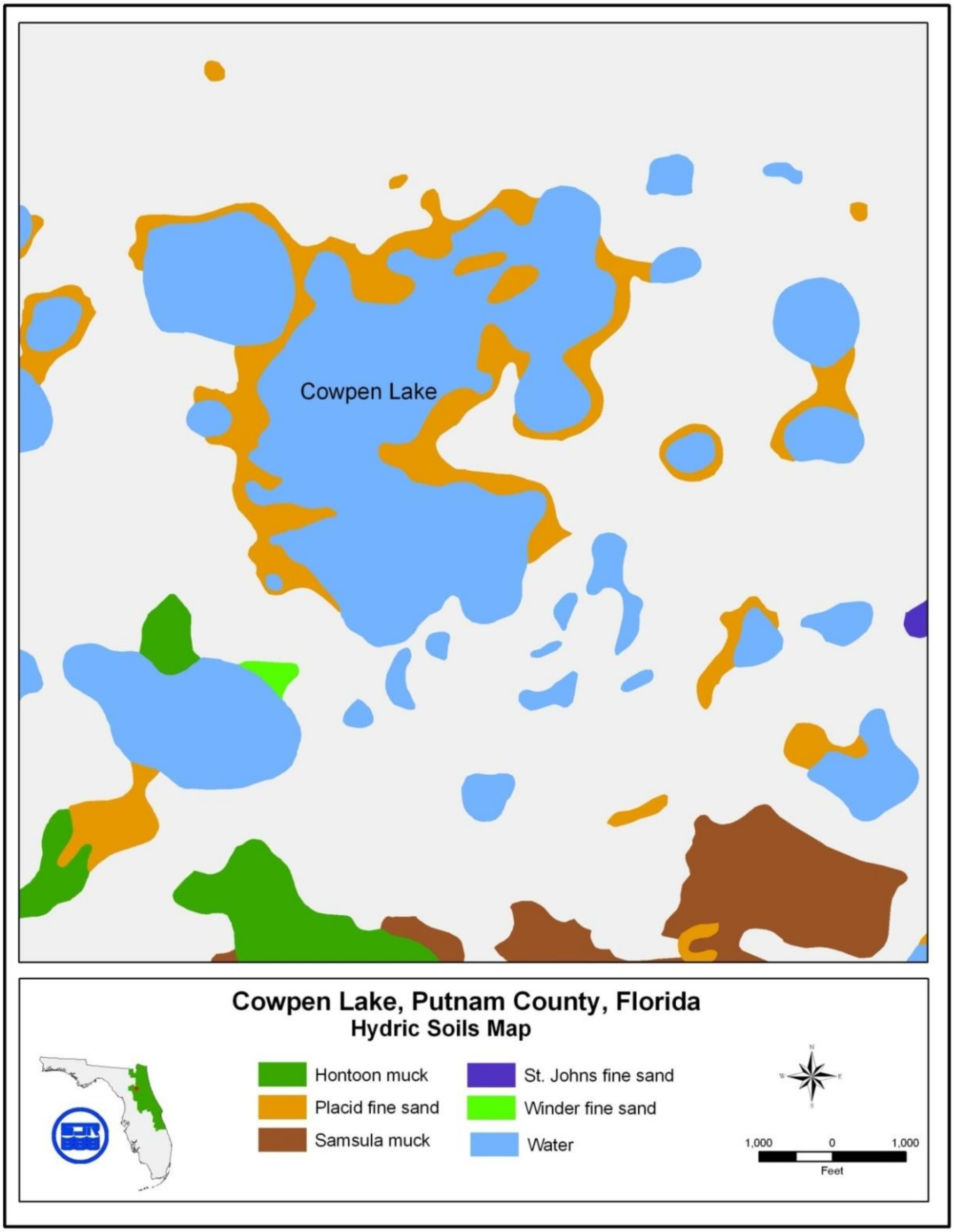


Figure 6. Mapped hydric soils in the vicinity of Cowpen Lake, Putnam Co., FL (SSURGO)

Wetland Vegetation

Based on the SJRWMD Wetland Vegetation Classification System, five wetland communities have been mapped as most common at Cowpen Lake (Figure 7; Kinser 2012). The vegetation and hydroperiod descriptions for deep marsh, shallow marsh, freshwater flats, wet prairie, and transitional shrub communities are summarized in Table 2. More detailed wetland community descriptions are given below, based on field observations.

Table 3. Vegetation and hydroperiod descriptions for wetland communities mapped in the vicinity of Cowpen Lake, Putnam County, FL.

SJRWMD Wetland Community	Vegetation Description	Hydroperiod Description
Deep marsh	Dominated by a mixture of water lilies and deep water emergent species	Semi-permanently and permanently flooded
Shallow marsh	Herbaceous or graminoid communities dominated by species such as sawgrass, maidencane, cattails, pickerel weed, arrowhead, or other grasses and broad leaved herbs	Lengthy seasonal inundation
Freshwater flats	Sandy or muddy sites with less than 33% vegetation cover during the growing season	Occasional or regular inundation
Wet prairie	Community of grasses, sedges, rushes, and herbs typically dominated by sand cordgrass, maidencane, or a mixture of species	Relatively short inundation period but prolonged soil saturation
Transitional shrub	Dominated by transitional shrubby vegetation at upland margins of wetter community types; wax myrtle and groundsel tree	Relatively short inundation period but prolonged soil saturation

Littoral zone is an additional vegetation category used in the original MFLs determination report to describe wetlands subject to long term flooding. Wetland maps of Cowpen Lake (Figure 5 in Appendix A) used the National Wetland Inventory (NWI) classification system (Cowardin et al., 1979) and showed much of the lakebed as L2AB3H (Lacustrine; Littoral; Aquatic bed; Rooted vascular; Permanently flooded). More recent MFLs determinations have discarded this term in favor of more specific plant community terms such as “deep marsh” and “shallow marsh.”

MFLs investigations from 1997 and 2016 have shown that deep and shallow marshes fluctuate spatially and temporally at Cowpen Lake and often intergrade. They often share the same set of species and differ primarily in terms of relative abundance. *Fuirena scirpoidea* (sometimes called "umbrellasedge" but henceforth known in this report simply as *Fuirena*) is a species of the sedge family that is highly characteristic of the littoral zone at Cowpen Lake since it occurs throughout the zone with a high level of abundance. Therefore, we use the more inclusive term "littoral zone" to describe the extensive *Fuirena* marshes that occupy shallow areas of the lakebed.

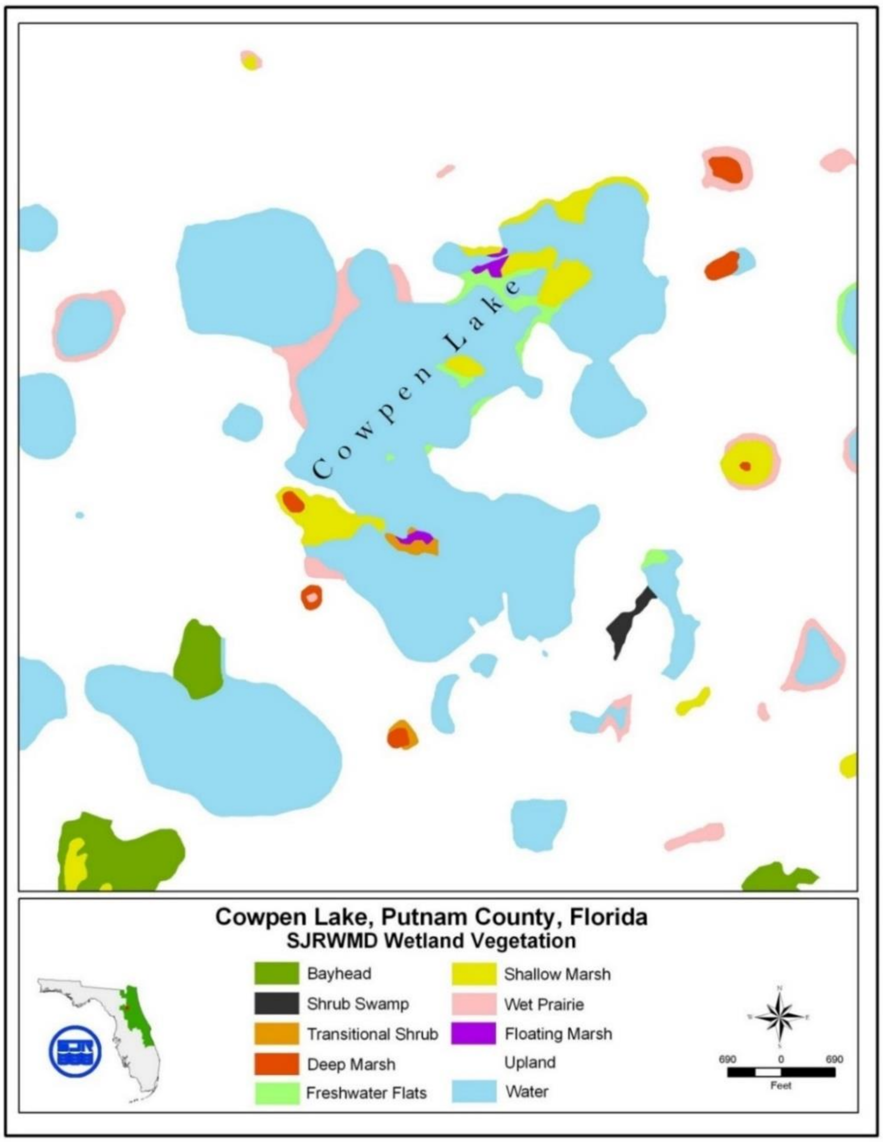


Figure 7. Mapped wetlands in the vicinity of Cowpen Lake, Putnam County, FL, (Kinser 2012)

Hydrology

Water Budget

Based upon SJRWMD's hydrologic lake classification (Epting et al. 2008), Cowpen Lake is an isolated/intermittent ridge lake, with moderate groundwater leakage. It is a closed basin with no channelized surface water inflows or outflows. In 2016, an updated hydrologic simulation program-FORTRAN (HSPF) model was completed. Annual estimates of inflow and outflow volumes were calculated for the model calibration period of 1997 to 2014 (Appendix B). Average total inflows are 1,883 acre-ft; consisting of 397 acre-ft (21%) of total runoff, and 1,486 acre-ft (79%) of direct rainfall. Average total outflows are 1,916 acre-ft; consisting of 1,536 acre-ft (80%) of lake evaporation and 380 acre-ft (20%) of seepage outflow. Average annual change in storage is -33 acre-ft. Recharge to the Floridan aquifer from Cowpen Lake is an estimated 0-4 in. per year (Boniol and Fortich 2005).

Water Level

Stage data for Cowpen Lake are available from 1986-2015 (SJRWMD Water Resource Information). Observations were made daily from July 1986 – August 1999, weekly from August 1999 to July 2014, and then daily from October 10, 2014 to present. Based on the observed lake stage time series, Cowpen Lake has a range of water level fluctuation of about 12.8 ft (Figure 8). The 2016 HSPF model simulated water levels from 1960 - 2014 period of record (POR), indicate that water levels in the 1960s and 1970s were higher than those within the observed record (*see Results and Discussion section below for more details on model results*). A10-inch diameter overflow drainage well located on the north shore of Cowpen Lake is evidence of higher historical water levels (SJRWMD Water Resources Information). The well was constructed by the USGS in 1948 (Appendix B), and the drainage elevation is 92.3 ft NAVD. No record outflow from the well has occurred since the mid-1970s.

Rainfall

Local rainfall data for Cowpen lake is only available for October 1989 to December 2000, with data gaps in the year 2000. Rainfall data from gages near Cowpen Lake were used to develop a regional rainfall time series and hourly rainfall data was developed for the HSPF model using data from these stations (Appendix B). When missing records occurred within these sites, rainfall from the nearest site was used to estimate this missing data. Rainfall stations used are listed below:

Daily Stations

- Gainesville University (1/1/1948-12/31/1963) NOAA
- Gainesville 3WSW (1/1/1954-5/25/1960) NOAA
- Gainesville Airport (5/26/1960-12/31/1969) NOAA
- Gainesville 3WSW (1/1/1970-1/1/1984) NOAA
- Levy's Prairie (1/2/1984-8/23/1989) SJRWMD

- Cowpen Lake (8/24/1989-2/29/2000) SJRWMD
- Long Pond (3/1/2000-5/16/2002) SJRWMD
- Chesser (5/17/2002-Current) SJRWMD

Hourly Stations

- Gainesville Stations
- Gainesville University (1/1/1948-5/31/1957) NOAA
- Gainesville 3WSW (6/1/1957-1/11/1989) NOAA
- Gainesville 11WNW (1/12/1989-8/10/1998) NOAA
- Gainesville Airport (8/11/1998-Current) NOAA

Cowpen Stations

- Levy's Prairie (2/3/1988-8/23/1989) SJRWMD
- Cowpen Lake (8/24/1989-2/29/2000) SJRWMD
- Gainesville Airport (3/1/2000-5/16/2002) NOAA
- Chesser (5/17/2002-Current) SJRWMD

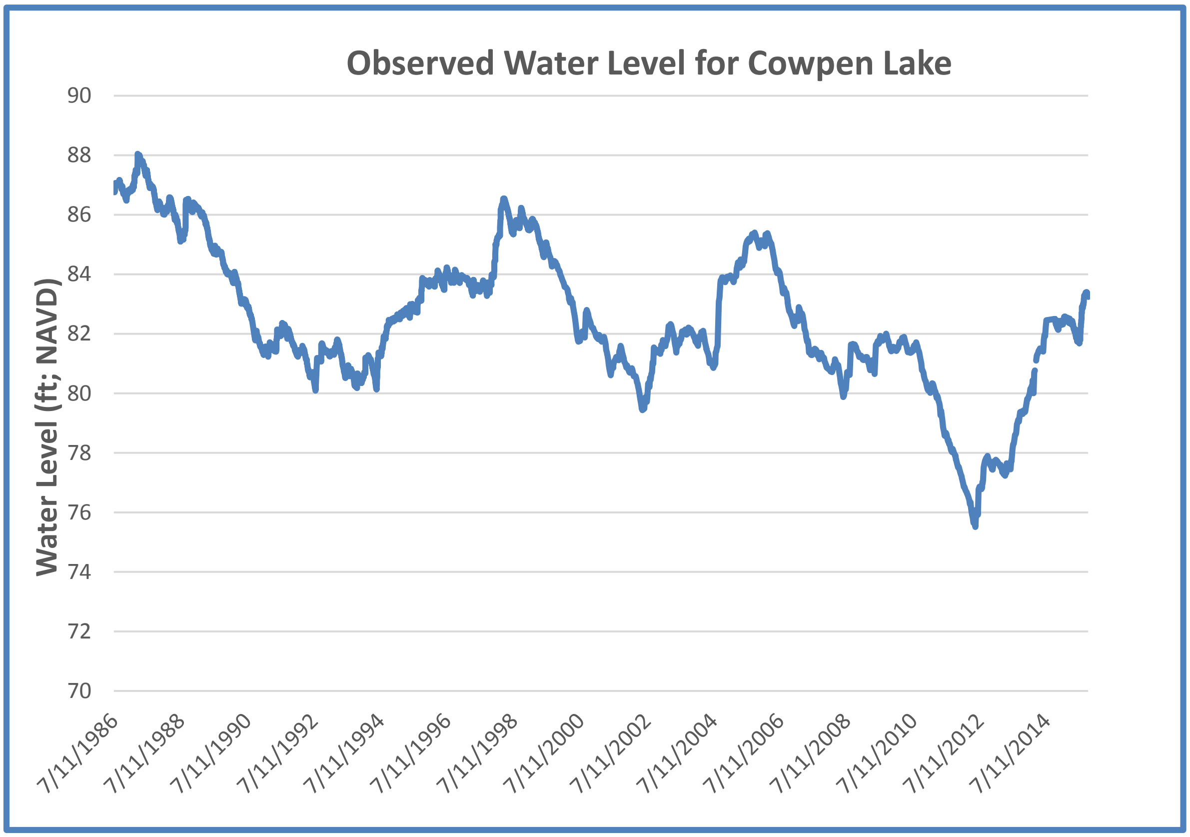


Figure 8. Observed lake stage data (1986-2015) for Cowpen Lake, Putnam County, FL

The average rainfall from 1948 to 2015 is 50.7 inches per year. However, there is a large variance around this mean; rainfall has ranged from 29.0 to 73.3 inches per year (Figure 9).

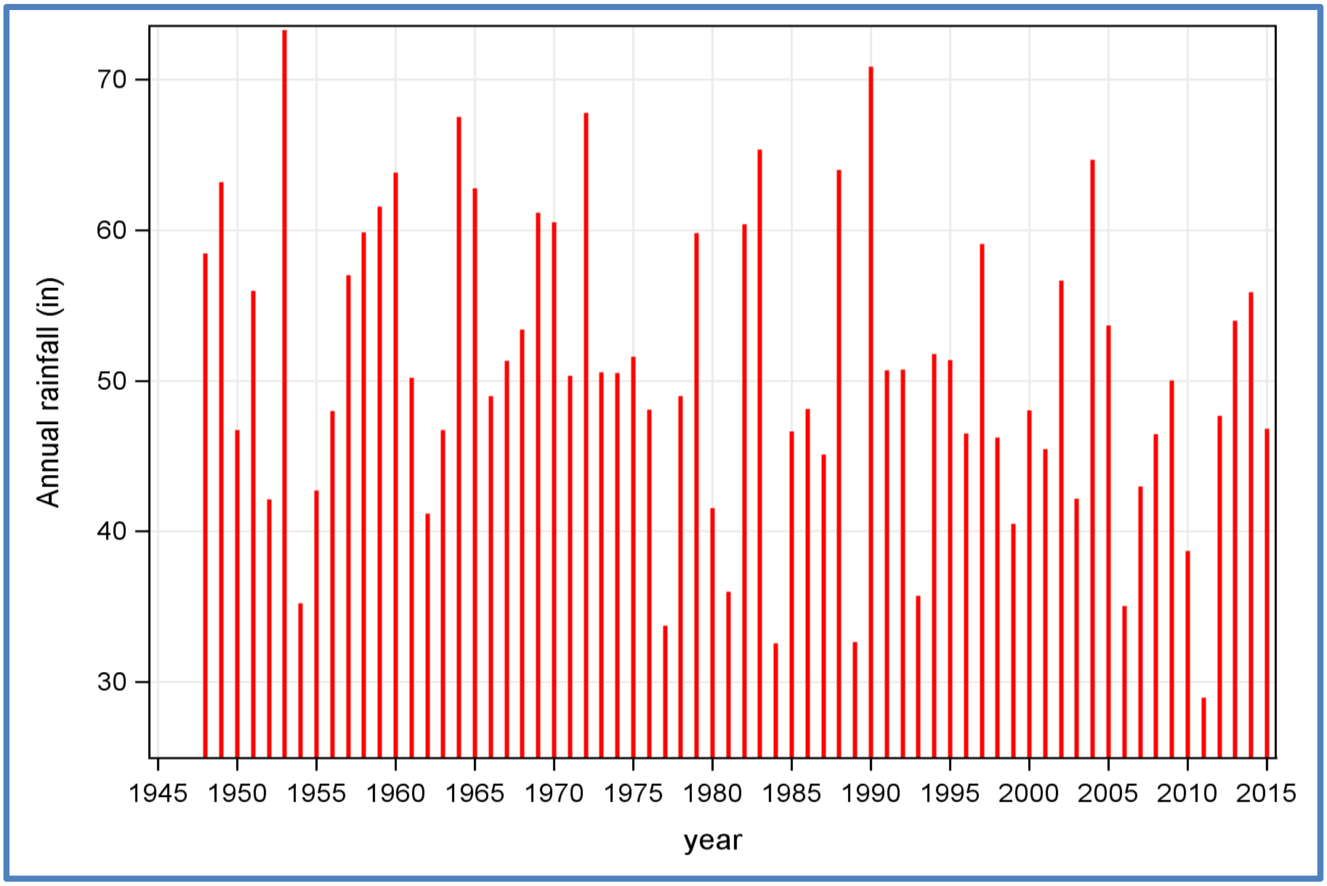


Figure 9. Annual rainfall (1948-2015) for Cowpen Lake, Putnam County, FL

As stated above, Cowpen Lake is located within an area of thick sand deposits (Interlachen Sand Hills), with medium to high recharge rates. Because of this physiographic setting, cumulative (i.e., back to back) years of below mean rainfall will effectively dry out the landscape surrounding Cowpen Lake, as well as lower lake levels. Sandhill lakes, like Cowpen Lake, that are connected to the Upper Floridan Aquifer (UFA) are sensitive to prolonged periods of below average rainfall. The relationship between Cowpen Lake water levels and prolonged periods of below (or above) average rainfall was assessed by comparing lake levels to rainfall deficits and surpluses over time. Figure 10 shows the cumulative departure from mean rainfall (1948 to 2015) versus observed lake levels.

From the 1940s to the mid-1970s, there was a cumulative rainfall surplus of approximately 90 inches. From the mid-1970s to the present, there has been a rainfall deficit of approximately 100 inches. This period of landscape drying corresponds to the same period of water level decline at Cowpen Lake. This analysis suggests that there is close relationship between back-to-back years of below (or above) average rainfall and water levels within Cowpen Lake. This also suggests that it takes many years of above average rainfall to offset prolonged periods of drought for sandhill lakes that are connected to the UFA.

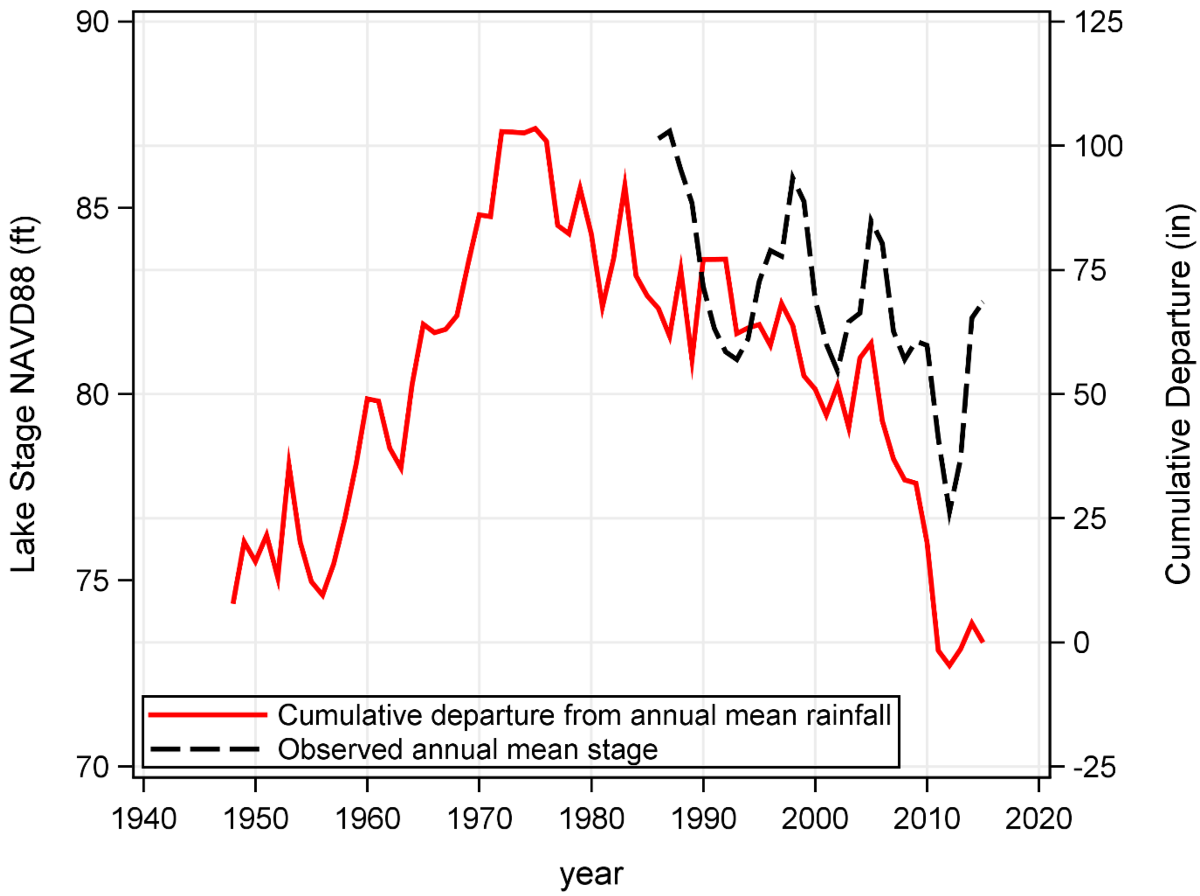


Figure 10. Cumulative departure from mean rainfall for Cowpen Lake, Putnam County, FL

Regional Water Use

Historical groundwater use was compiled for Alachua, Clay, Duval, Putnam and St Johns counties from 1995 to 2015 (Figure 11). These counties were selected because groundwater use in these counties could potentially impact the groundwater levels in the vicinity of Cowpen Lake based on previous groundwater modeling results. Water use data included actual groundwater use reported by consumptive use permit holders and estimated groundwater use for domestic self supply and small agricultural use. As shown in Figure 11, groundwater use in these counties reached at its highest level in 2006 (352 mgd) and has declined about 30% thereafter. The total groundwater use in 2015 was about 235 mgd.

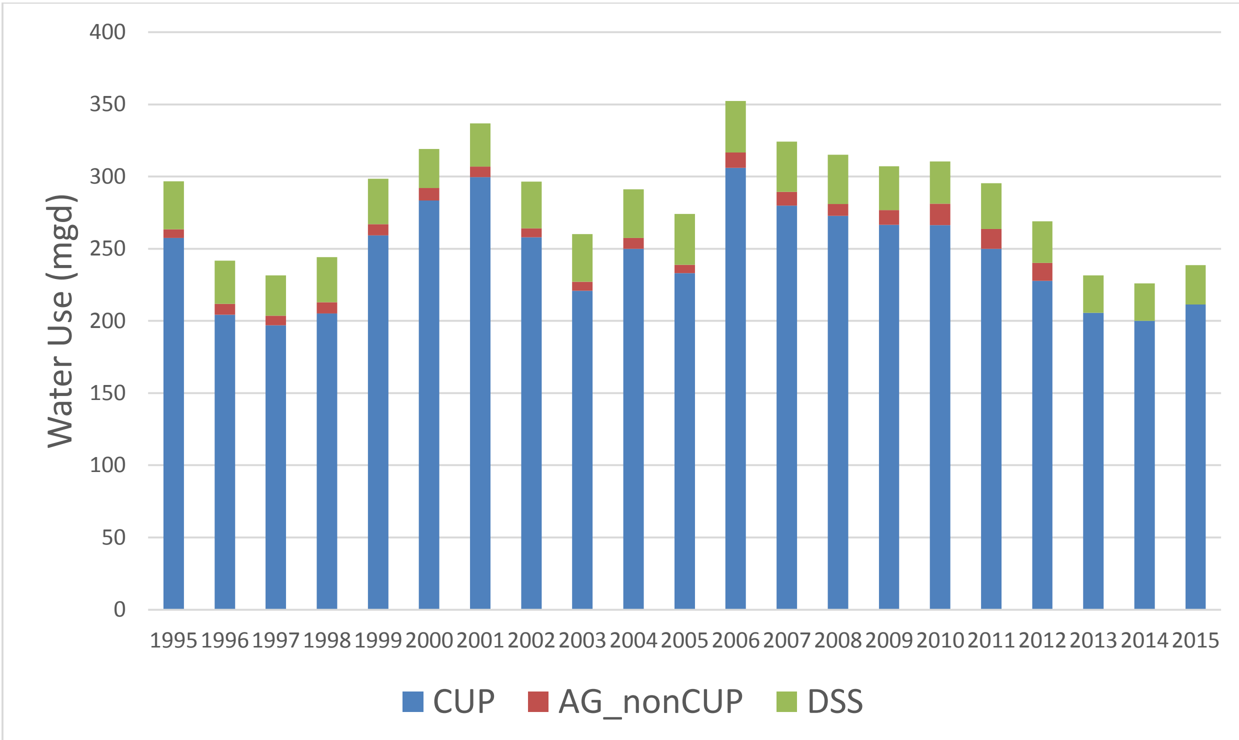


Figure 11. Historical groundwater use (CUP: consumptive use permits; AG_nonCUP: agriculture; and DSS: Domestic self supply) in Alachua, Clay, Duval, Putnam and St Johns Counties

TECHNICAL APPROACH

The SJRWMD MFL approach involves three separate but interrelated analyses of a given priority water body:

- environmental characterization;
- hydrological data analyses; and
- compliance status assessment.

The purpose of these analyses is to answer an overarching question: Is the current hydrologic regime sufficient to protect from significant harm the critical environmental functions and values of a priority water body?

Environmental analyses center on the characterization of ecological attributes and other sensitive beneficial uses of a water body. This typically includes consideration of site-specific field-based ecological and topographical information, empirical data collected at other MFLs sites and supportive information from the scientific literature. Using this information, a determination is made of the most critical environmental features to protect, and of the minimum hydrologic regime (MFL condition) required for their protection.

Hydrological analyses are also conducted to determine the hydrological (flow and/or stage) regime that exists under the current impacted condition (baseline condition). Two key types of information are required to generate this baseline condition. The first is an estimate of the long-term variability in the system, which is represented by long-term flow or stage time series. This provides the long-term frequency distribution of high, low and average conditions for a given water body. This is determined using various types of data analyses, surface water models and groundwater models to general long-term time series (stages, flows, groundwater levels, climate). The second requirement for establishing the baseline condition is a best estimate of current impact due to water withdrawal. This is typically determined using best available groundwater models and water use data.

MFL status is then determined by comparing the MFL condition with the baseline condition. Using frequency analysis, or other methods, the MFL and baseline conditions are compared to determine if there is currently water available for withdrawal (freeboard). An MFL is achieved if the freeboard is greater than or equal to zero. If freeboard is less than zero, a water body is in recovery, and requires the development of a recovery strategy. If the MFLs is currently being achieved but is projected to not be achieved within the 20-year planning horizon, then a water body is in “prevention,” and a prevention strategy must be developed. For lakes, whether the MFL is being achieved within the planning horizon is determined by comparing the freeboard under baseline conditions to the amount of projected UFA drawdown at the planning horizon. For Cowpen Lake, the projected drawdown at 2035 was estimated using the NEFv3 groundwater model.

This section describes the methods used in the MFLs determination process for Cowpen Lake, including field procedures such as site selection and field data collection, data analyses, surface water modeling and consideration of relevant environmental criteria. Further description of the MFLs methods is included in the SJRWMD MFLs methods paper (Neubauer et al. 2008).

EVENT-BASED APPROACH

Hydroperiod is a primary driver of wetland plant distribution and diversity, hydric soils type and location, and to a lesser degree freshwater fauna (Foti et al. 2012, Murray-Hudson et al. 2014). Hydroperiod is often described as the inter-annual and seasonal pattern of water level resulting from the combination of water budget and storage capacity (Welsch et al. 1995). Wetland hydroperiods vary spatially and temporally and consist of multiple components, including: return frequency, duration and magnitude. Native wetland and aquatic communities have adapted to and are structured by this natural variability (Poff et al. 1997, Richter et al. 1997, Murray-Hudson et al. 2014). Therefore, wetland and aquatic species (and hydric soils) require a minimum frequency of critical hydrologic (drying and/or flooding) events for long-term persistence. When viewed as a whole, wetland communities require a range of flooding and drying events to fulfill many different aspects of their life-history requirements (Euliss et al. 2004, Murray-Hudson et al. 2014). Because of the role of hydroperiod in structuring and maintaining wetland and aquatic communities, the SJRWMD MFLs approach is centered around the concept of protecting a minimum number of flooding events or preventing more than a maximum number of drying events for a given ecological system.

Five critical components of hydrological events are typically recognized: return frequency, duration, magnitude, rate of change and timing (Poff et al., 1997). However, because the latter two are thought to be a function of climate, only the first three are a focus of the SJRWMD approach. Magnitude and duration components define the critical ecological events that effect species at an individual level (i.e., individual organisms). The return interval (frequency) of an event is what changes due to climate and/or water withdrawal. Therefore, it is by assessing the effects of water withdrawal on the return interval of MFLs events that a determination is made regarding whether additional water is available. By comparing the frequency of ecologically critical events under, to the allowable frequency of these same events the SJRWMD MFLs method is able to determine the amount of water that is available (or needed for recovery) within a given ecosystem under different withdrawal conditions. The sections presented below on hydrologic modeling and compliance assessment give more details about this process.

Variable flooding and/or drying events are necessary to maintain the extent, composition, and function of wetland and aquatic communities. For example, the long-term maintenance of the maximum extent of a wetland may require an infrequent flooding event, of sufficient duration and frequency, to ensure that upland species do not permanently shift downslope into that wetland. In addition to flooding events, some aspects of wetland ecology (e.g., plant recruitment, soil compaction, nutrient mineralization) are also dependent upon drying events, as long as they do not occur too often. Because hydroperiods vary spatially and temporally (Mitsch and Gosselink 2015), multiple MFLs are typically used to address and protect different portions of a system’s natural hydrologic regime (Neubauer et al. 2008). For many systems SJRWMD sets three MFLs: a minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) flow and/or water level. In some cases (e.g., for sandhill-type lakes) a minimum infrequent high (IH) and/or minimum infrequent low (IL) may also be set. In the case of Cowpen Lake, SJRWMD is recommending an IH, MA and FL. These MFLs were chosen after a comprehensive review and characterization of the soils, wetlands and aquatic fauna which suggested that these three levels were the most sensitive to influence from water withdrawal.

FIELD TRANSECT SITE SELECTION

Most field data at MFLs water bodies are collected along transects. Transects are fixed lines that traverse the floodplain of a waterbody. They usually extend from uplands to open water. Elevation, soil, and vegetation characteristics are sampled in order to assess the influence of surface water flooding on the distribution of soils, vegetation, and other features of interest.

A literature and data search is typically conducted prior to establishing transects. This might include a review of SJRWMD library documents, project record files, the hydrologic database, and SJRWMD Division of Surveying files. The Florida Natural Areas Inventory (FNAI) biodiversity matrix tool (http://www.fnai.org/) is queried for the presence of threatened or endangered species at a site. The goal of the search is to familiarize the investigator with site characteristics, locate important basin features, and assess prospective sampling locations. The following items were used in selecting transect locations:

- Documents from past MFLs investigations
- Aerial photography (existing and historical)
- Remotely sensed vegetation and land use maps
- Soil surveys, maps, and descriptions
- Hydrologic data (hydrographs and stage duration curves)
- Environmental, engineering, or hydrologic reports
- Topographic and bathymetric survey profiles
- On-site natural resource inventories
- Land ownership and access information

The proposed transects should be inspected prior to intensive data collection to confirm the presence of desired features. These features might include:

- representative examples of common wetland communities
- unique or high quality wetlands
- edge of uplands or open water
- hydric soils
- organic soils

FIELD DATA COLLECTION

The original 1998 MFLs determination was based on 1997 field work (Appendix A). A field investigation for the Cowpen Lake MFLs reevaluation was conducted during July and December of 2009. More recent field work was conducted during July and August 2016. Field work conducted in 2009 was also used to develop the recommended infrequent high MFL. This work involved sampling elevations and vegetation data associated with the waterward tree line around the lake. Aerial photographs from the years 1953, 1964, 1984, 1995 and 2005 were examined to determine areas around Cowpen Lake where the location of the waterward treeline was relatively unchanged and undisturbed through time (Appendix C). Examination of aerial photography and numerous site visits in July 2009 indicated that in some areas, a general line of large trees has persisted with very little new downslope establishment on the Cowpen Lake floodplain. On July 20, 2009, tree identification, tree elevations, approximate diameters at breast height (DBH), and Global Positioning System (GPS) locations were determined for 43 large trees at five different relatively unchanged/undisturbed areas along Cowpen Lake's waterward treeline. Elevations were taken at the natural base of the tree as determined by elevation shots off a known Cowpen Lake water level about 100-200 ft away. Tree diameter at breast hight (DBHs) were estimated with a fiberglass survey elevation rod. On December 16, 2009, more trees were inspected in order to supplement the IH elevation data of July 20, 2009. Ten additional large live oaks along the waterward tree line were examined at four new sampling areas using the same methods.

Fieldwork conducted in 2016 involved the characterization of wetland vegetative communities and hydric soil features along three transects (Figure 12). An effort was made to reestablish two of the three original (1997) field transects (T1 and T2), locating the new transects as near as possible to the original lines. A new transect (6A) was located near the original T6 established in 1997, but sampled different features. The original 1997 work involved at T6 involved sampling elevations along a canal that connected lobes "A" and "D", while Transect 6A sampled elevations of the littoral zone in lobe "D" (Figure 3). In January 2016, a survey crew also established elevations for canals connecting lake lobes, as well as dock heights and waterward piling locations.

Soil Sampling Procedures

MFLs field investigations typically involve delineating the extent and types of hydrologically sensitive soil features such as deep organic soils (Histosols and histic epipedons) and hydric indicators (NRCS, 2010). The extent of hydric indicators along transect lines is estimated by close inspection of topographic breaks in conjunction with frequent soil borings. Soil borings along transects typically sample all significant geomorphic features, landscape positions, and plant communities. Permanently flooded areas such as deep marshes are generally not sampled due to difficulty in obtaining samples and frequent lack of hydric indicators in such environments. Soil profile descriptions follow NRCS guidelines (Schoeneberger et al. 2002).

Soil descriptions include the horizon depth, texture, colors, redoximorphic features, presence of roots, and consistence of soil materials.

In 1997, only muck depths were measured along Transect 2 at Cowpen Lake. Muck depths were determined by use of a peat probe, which is a solid rod, about ¼ inch in diameter. The peat probe was pushed through organic layers until firm resistance is met. In 2016 a more detailed characterization of hydric soils at Transect 2 was performed, as detailed above.

Vegetation Sampling Procedures

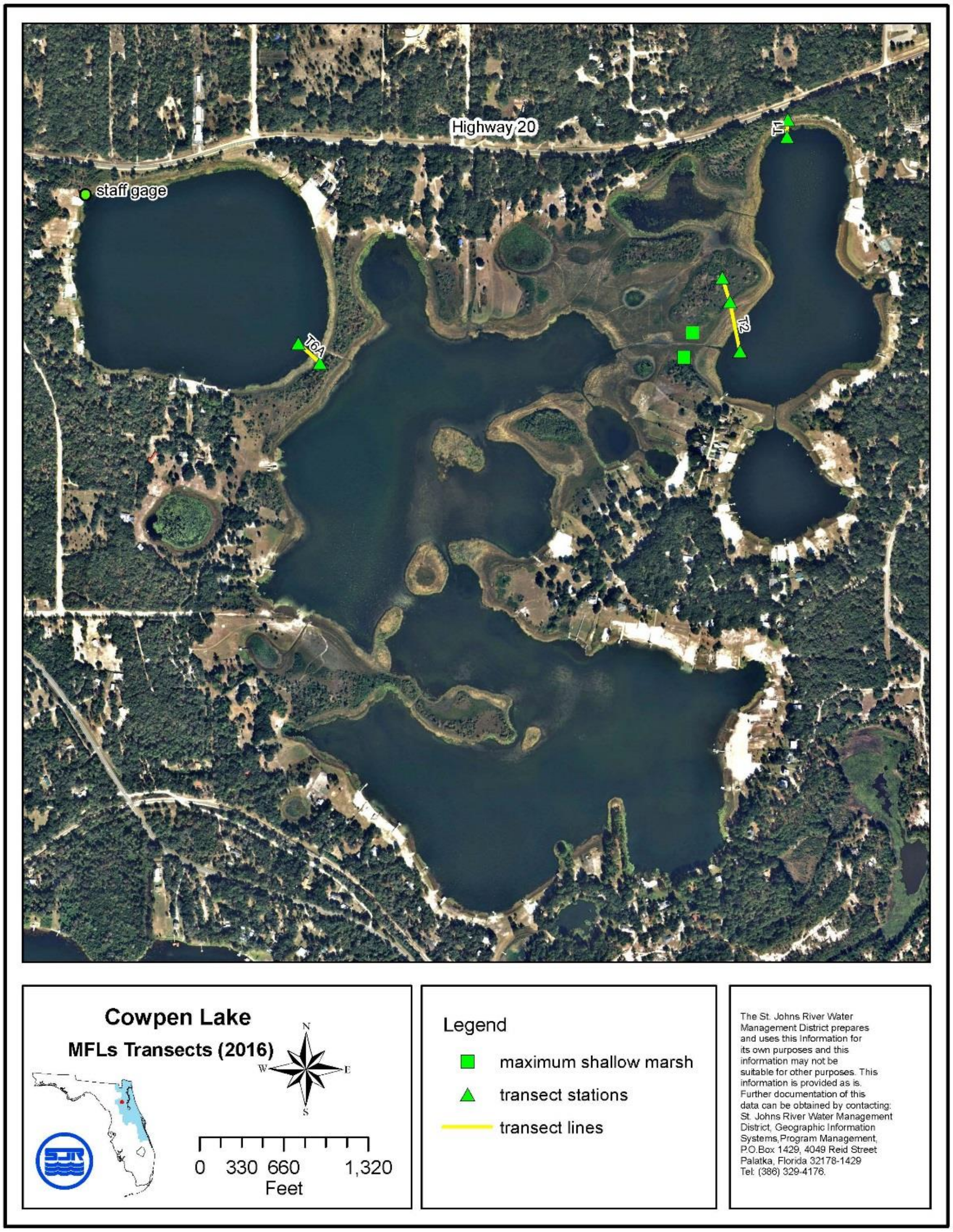
SJRWMD's Wetland Vegetation Classification System (Kinser 2012) was used to standardize the names of wetland plant communities sampled in MFLs fieldwork and in developing reports documenting the MFLs determination.

A technique called line-intercept was used to sample vegetation. This semi-quantitative method involves measuring the lengths of vegetation by plant species that overlap the transect line. Cover intervals are measured to the nearest foot and interval data may be converted to abundance. This technique provides precise data on the distribution of individual species.

The spatial extent of plant communities or transition zones (i.e., ecotones) among plant communities was determined using reasonable scientific judgment. Reasonable scientific judgment involves the ability to collect and analyze information using technical knowledge, personal skills, and experience to serve as a basis for decision making (Gilbert et al. 1995). In this case, such judgment was based upon field observations of relative abundance of dominant plant species, occurrence and distribution of soils and hydric soil indicators, and changes in land slope or elevation along the hydrologic gradient.

VEGETATION AND SOILS DATA ANALYSIS

Data analysis consists of performing basic statistical analyses on the surveyed elevation data generally in an excel spreadsheet. Vegetation and soils information collected along transects are recorded in association with elevation values. Descriptive statistics (e.g., mean, maximum, and minimum values) are calculated for the elevations of the vegetation communities, hydric soil indicators, and other features of interest. Transect elevation data are also graphed to illustrate the elevation profile between the open water and upland community. Locations of vegetation communities along the transect, together with a list of dominant species, soils information, and statistical results, are labeled on graphs.



Author:, Source:I:\ESDATA\RFreese\Cowpen\Cowpen transects_2016.mxd, Time:8/22/2016 2:06:48 PM

Figure 12. 2016 vegetation and soils transects at Cowpen Lake, Putnam County, FL

SURFACE WATER INUNDATION/DEWATERING SIGNATURES (SWIDS)

SWIDS is a technique that uses empirical data to identify protective return interval thresholds for MFLs criteria (Neubauer et al. 2007). Elevation data for soils and wetland vegetation, collected at numerous MFLs waterbodies across the District, are compared with hydroperiod data to calculate flooding and dewatering probabilities for key elevations (e.g., maximum elevation for a given emergent marsh species). Probabilities for continuous exceedance (FH flooding events), continuous non-exceedance (FL dewatering events), and average non-exceedance (MA dewatering events) are produced for a range of durations.

The collective probabilities of events for shared features at several water bodies present a range of tolerance to hydrologic conditions. The dry end of this range suggests a threshold that can be used to define MFLs return intervals. The driest signature (minimum flooding or maximum dewatering probabilities) is the point beyond which return intervals can not shift and still maintain a given ecological criterion. This assumes that the range of signatures is entirely a function of hydrology of the associated water body. However, other variables such as seepage from uplands, fire, disturbance, and colonization history also influence the elevation at which a feature of interest occurs. The following proposed measures address concerns that the SWIDS range accurately represents the actual hydrologic tolerance of a system:

- Select MFLs criteria based on features that are sensitive to surface water hydrology. Long-lived, slow-growing species with specific surface hydrologic requirements during portions of their life cycle (e.g. bald cypress, water lily) are particularly good hydrologic indicators. Select plant community indicators that have a high fidelity to particular hydrologic conditions rather than ones that can result from the interplay of several processes such as seepage and fire.
- Sample size should be large enough to capture the range of variability for the feature of interest. As a rule of thumb, data from at least 10 sites is typically sought.
- Take steps to narrow excessively broad signatures in some SWIDS datasets. This includes examining outliers, excluding sites with obviously altered hydrology, developing subsets of water bodies based on similar hydrologic or geologic characteristics (e.g. lake classification), and examining the consistency of criteria used to delineate communities.
- In recognition of uncertainties in our estimates of flooding/ dewatering probabilities, consider the use of safety margins when setting MFLs return intervals.

It is generally prudent not to use the driest hydrologic signature as a basis for setting MFLs return intervals. Further work is needed to determine a standardized alternative to the driest hydrologic signature. However, there are cases when MFLs return intervals may be based on hydrologic signatures at the edge of the SWIDS dataset. These include systems in which existing conditions are already at or near the driest margin of the dataset. Another example is SWIDS datasets with a very narrow range of signatures and confidence limits that are close to the mean. In these situations, it is necessary to compare the system of interest with each potential reference site to select one with similar characteristics. Potential criteria are: 1) similar extent or quality of the feature of interest, 2) similar physiographic setting of the water body, and 3) absence of obvious hydrologic alterations from the reference site.

HYDROLOGIC MODELING APPROACH

Hydrologic models are used to understand the relative effects of natural variability (e.g., climate) and man-made alterations (e.g., groundwater withdrawal) on a given waterbody. MFLs determinations are based on a concept of maintaining a critical frequency of some ecologically important event (i.e., combination of magnitude and duration). The effects of different water withdrawal or recovery scenarios on these critical events can be evaluated by comparing hydrological statistics derived from surface water model output. Statistical analysis of model output provides a framework to summarize hydrologic characteristics of a given water body. For this type of analysis, the SJRWMD MFLs program uses a statistical method known as frequency analysis.

An HSPF surface water budget model for Cowpen Lake was developed in 2003 and recently revised in 2016 by (Appendix B). The model is calibrated for the period 1997 to 2014, with a long-term simulation period of April 25, 1960 through December 31, 2014. The HSPF model was used to create long-term hydrographs that represent the following two conditions: 1) no-pumping condition; and 2) baseline condition. The purpose for creating these simulated lake stage time series was to compare the recommended MFLs under these different conditions.

No-pumping condition

The no-pumping condition represents the lake stage time series for Cowpen Lake as if there had been no consumptive use of water during the POR. This simulated condition was developed by first creating a no-pumping UFA well time series, which was used to simulate lake level with the HSPF model. UFA well data used in the model came from a nearby well, P-0008. P-0008 well levels were estimated for 1960 to April 1976 based on observed C-120 well levels and P-0464 well levels were used to fill data gaps between 2003 and 2011. See Appendix B for more details on well time series.

The no-pumping condition was created by adding an estimate of impact due to historical pumping (i.e., change in UFA elevation due to pumping) to each year in the observed record. This annual estimate of change in the UFA elevation due to pumping was developed by first estimating historical groundwater pumping from 1930 to present using both historical population and available actual water use in Alachua, Clay, Duval, Putnam and St Johns Counties. These counties were selected because the pumping in these counties have potential for impacting the UFA in the vicinity of Cowpen lake. Next, the relationship between the groundwater pumping and the drawdown at the UFA well P-0008 was developed using version 3.0 of the Northeast Florida Groundwater Flow Model (NEFv3 model). Using the estimated

groundwater pumping from 1930 to present and the relationship between pumping and the UFA drawdown, an estimate of impact at well P-0008 due to historical pumping was determined. Finally, a polynomial trend was generated based on the dataset including the UFA drawdown at P-0008 over time. The polynomial trend was used to develop annual changes in water level due to historical pumping, which were added back to each year of the well time series, to yield a no-pumping well file. This well file was then used in the HSPF model to simulate a no-pumping lake stage time series. The no-pumping condition lake stage time series was used to create the baseline condition.
The NEFv3 drawdown estimate represents the change in water levels in the UFA beneath Cowpen Lake from a no-pumping condition to the baseline condition.

Baseline condition

The baseline condition represents a best estimate of current impacted condition, and for the Cowpen Lake MFL is defined as the 2009-pumping condition. The baseline condition incorporates the natural variability of the groundwater level time series, as if impacted by drawdown equal to that caused by 2009 water use. The baseline year was chosen because it was necessary to use the most current regional groundwater model output available.

The impact on the UFA underneath Cowpen lake from groundwater withdrawals were estimated using the best available tool, the NEFv3 model. Other than water use, all other boundary conditions were held constant at 2009 conditions within the NEFv3. One of the limitations of the NEFv3 model is that its western boundary does not extend far enough to eliminate or minimize boundary effects. Therefore, the influences of pumping beyond the western model boundary on the UFA beneath the lake were not taken into account. If the impact of pumping outside the western model boundary is assumed to be insignificant, the remaining decline in water levels could be assumed to be due to rainfall deficit over the past 40 years or some anthropogenic influences which are not related to pumping. Based on the NEFv3, a 2.2 feet of drawdown was estimated, which represents the change in water levels in the UFA beneath Cowpen Lake from a no-pumping condition to baseline conditions.

The baseline condition lake stage time series was generated by first reducing the no-pumping well level time series by the total estimated impact on the UFA underneath the lake (i.e., 2.2 ft). Next, using a surface water model, the baseline condition UFA water level time series was used to generate the baseline lake level time series for Cowpen Lake. Finally, the frequency of critical ecological flooding and dewatering events under baseline conditions are compared to the recommended MFLs. The difference between these two event frequencies is assessed using frequency analysis to determine the amount of water available for withdrawal. More detail describing this process is presented below.

COMPLIANCE ASSESSMENT

MFLs status was assessed using frequency analysis to compare the frequency of critical ecological events under baseline conditions to the frequency of those same events based on the recommended MFLs. Frequency analysis was used to determine the amount of water available for withdrawal (freeboard), defined as feet of drawdown allowable in the UFA. The MFLs for Cowpen Lake are based on critical lake levels, but freeboard is determined based on the amount of change in the UFA that is allowable before the most constraining MFL is no longer achieved.

An MFL is achieved if the freeboard is greater than or equal to zero. If freeboard is less than zero, a water body is in recovery, and requires the development of a recovery strategy. If the MFLs is currently being achieved but is projected to not be achieved within the 20-year planning horizon, then a water body is in “prevention,” and a prevention strategy must be developed. Whether an MFL is being achieved within the planning horizon is determined by comparing the freeboard under baseline conditions to the amount of projected UFA drawdown at the planning horizon. For Cowpen Lake, the projected drawdown at 2035 was estimated using the NEFv3 groundwater model.

Frequency analysis is used to estimate how often, on average over the long term, a given environmentally important event will occur. Using annual series data (e.g., annual maxima for a specified duration) generated from a stage (or flow) time series (e.g., baseline condition), frequency analysis is used to estimate the probability of a given hydrologic (exceedance or non-exceedance) event happening in any given year. Annual series data are ranked using the Weibull plotting position formula:

$$P(S \geq \hat{S}_m) = \frac{m}{n+1}$$

Ranked data are then graphed on a frequency plot, thus summarizing the stage (or flow) characteristics of the water body. Freeboard or water deficit is determined as follows:

1. Subtract from (or add to) UFA elevations (i.e., well elevations) in the surface water model;
2. Re-run the model to simulate a new lake stage time series; this now represents the baseline plus or minus additional UFA elevation;
3. Conduct frequency analysis and plot new results;
4. Repeat process until MFL event frequency is met;
5. The amount of water added (or subtracted) to UFA elevation represents the amount of water available for consumptive use (i.e., freeboard), or amount of water needed to be recovered (i.e, deficit).

Using the Cowpen Lake HSPF modeled baseline condition stage time series, and the iterative frequency analysis process described above, the recommended MFLs for Cowpen Lake were assessed for current compliance. When new groundwater model results are available, the Cowpen Lake MFL will be reassessed using updated best estimates of current water use.

CONSIDERATION OF ENVIRONMENTAL VALUES PURSUANT TO 62-40.473, *F.A.C.*

Pursuant to section 373.042 and section 373.0421, *F.S.*, SJRWMD considered the following 10 environmental values identified for consideration in rule 62-40.473, *F.A.C.*.

1. Recreation in and on the water—The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include, but are not limited to swimming, scuba diving, water skiing, boating, fishing, and hunting.
2. Fish and wildlife habitat and the passage of fish—Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species; to live, grow, and migrate. These environments include hydrologic magnitudes, frequencies, and durations sufficient to support the life cycles of wetland and wetland-dependent species.
3. Estuarine resources—Coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.
4. Transfer of detrital material—The movement by surface water of loose organic material and associated biota.
5. Maintenance of freshwater storage and supply— The protection of an adequate amount of freshwater for non-consumptive uses and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology.
6. Aesthetic and scenic attributes—Those features of a natural or modified waterscape usually associated with passive uses, such as bird-watching, sightseeing, hiking, photography, contemplation, painting and other forms of relaxation, that usually result in human emotional responses of well-being and contentment.
7. Filtration and absorption of nutrients and other pollutants—The reduction in concentration of nutrients and other pollutants through the process of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.

8. Sediment loads—The transport of inorganic material, suspended in water, which may settle or rise. These processes are often dependent upon the volume and velocity of surface water moving through the system.
9. Water quality—The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a watercourse (lotic) not included in definition number 7 (i.e., nutrients and other pollutants).
10. Navigation—The safe passage of watercraft (e.g., boats and ships), which is dependent upon adequate water depth and channel width.

RESULTS AND DISCUSSION

This section summarizes elevation, soil, and vegetation data in narrative, tabular, and graphic formats and assesses vegetation change relative to the original MFLs data collection work, where possible. During the original Cowpen Lake MFLs determination, three elevation transects were established within the lake basin (Appendix A). A reevaluation of the adopted MA, and FL levels were conducted, along with the addition of a new IH level. The rationale for criteria and recommended minimum levels are presented, along with a discussion of the effect of these levels on maintaining ecological structure and function of wetland and aquatic communities in Cowpen Lake.

FIELD DATA

Upland ecotone data

The primary type of field data collected, in support of the IH determination, was topographic data related to the waterward line of mature trees. Aerial photographs from the 1950s to the present were analyzed, and numerous site visits conducted to determine the location of the upland ecotone, defined as the waterward live oak tree line. This upland ecotone was examined for use as an indicator of protection for an IH level.

On July 20, 2009, tree identification, tree elevations, approximate DBHs, and GPS locations were determined for 43 large trees at five different sampling areas along Cowpen Lake's waterward treeline (Figure 13). Trees included 31 live oak (*Quercus virginiana*), seven sand live oak (*Q. geminata*), four laurel oak (*Q. laurifolia*) and one black cherry (*Prunus* sp.). On December 16, 2009, additional trees were inspected in order to supplement the IH elevation data of July 20, 2009. Ten large live oaks along the waterward tree line were examined at four new sampling locations using the same methods.

Wetland vegetation and hydric soils

Transect Selection

Three transects were selected in 2016 to evaluate hydrologically sensitive vegetation and soil features as a basis for recommended MFLs. Transects 1 and 2 were located as near as possible to Transects 1 and 2 from 1997 and sampled similar features (Figure 12). Transect 6A was located near Transect 6 from 1997 but sampled different features. Transect 6 sampled elevations along a canal that connected Lobes "A" and "D", while Transect 6A sampled elevations of the littoral zone in Lobe "D". In addition, two spot elevations of the shallow marsh – wet prairie boundary were collected in August 2016 from the area near Transect 5.

Transect 1 (2016) North End Lobe "B"

Transect 1 begins at the tree line of a laurel oak dominated woodland and extends 135 feet to the south ending in open water. Transect elevations descend on an even gradient with a relatively steep 11.3 percent slope. Representative photographs, a topographic cross-

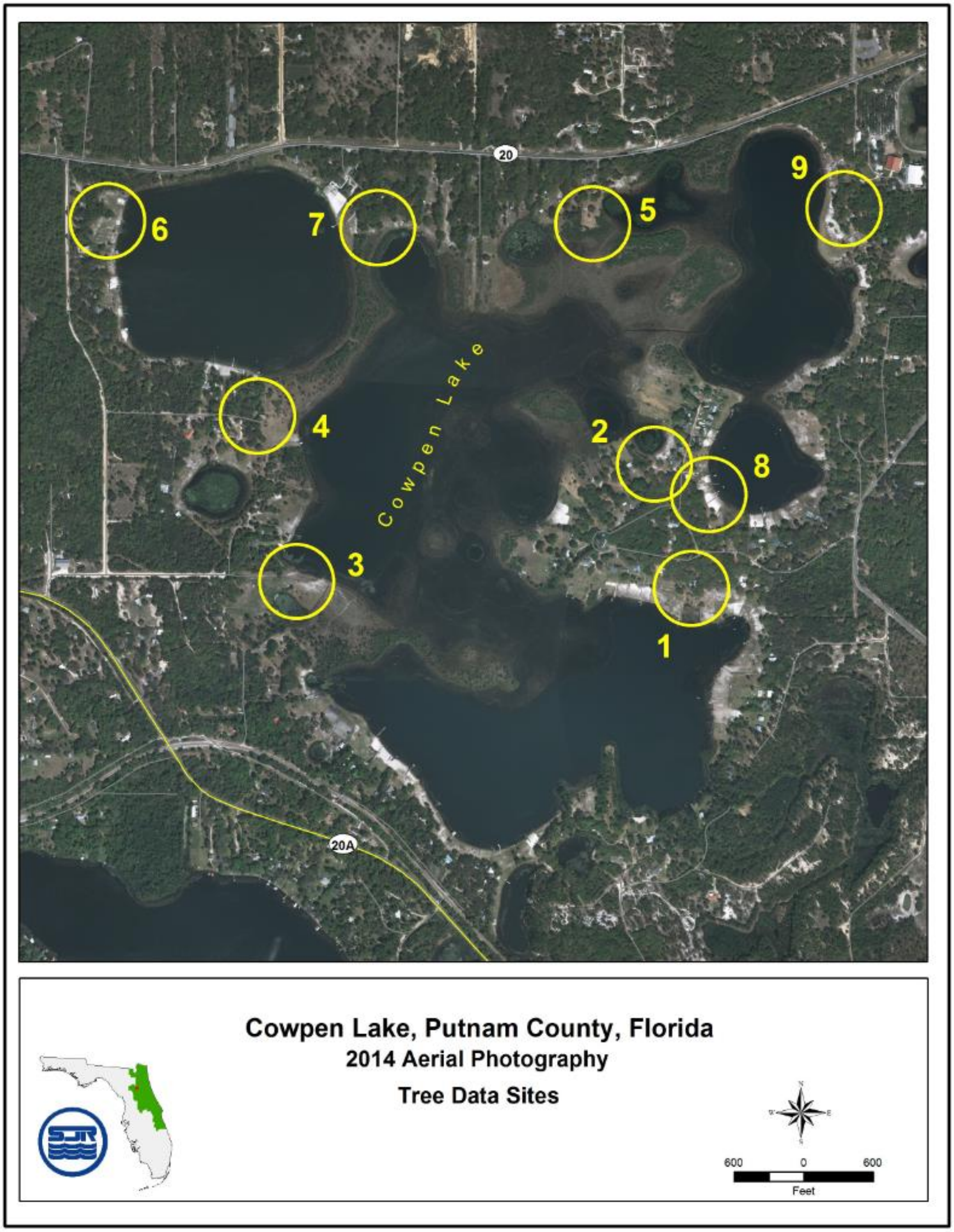


Figure 13. Tree sampling areas at Cowpen Lake, Putnam County, FL

sectional profile and a table with vegetation species and cover estimates are presented in Appendix D. Soil data was not collected at this site.

Vegetation at Transect 1

Upland ecotone (0 to 15 feet) is an herbaceous zone impacted by a jeep trail. Vegetation is mostly facultative or ruderal species such as abundant bahia grass (*Paspalum notatum*), and scattered bluestem (*Andropogon* sp.), persimmon (*Diospyros virginiana*), and milk-pea (*Galactia* sp.).

Wet Prairie (15 to 27 feet) is a diverse, herbaceous zone of mostly hydrophytic species such as abundant redroot (*Lachnanthes caroliniana*), numerous bantam-buttons (*Syngonanthus flavidulus*), and scattered blackberry (*Rubus pensilvanicus*), bluestem, meadow beauty (*Rhexia* sp.), and blue maidencane (*Amphicarpum muhlenbergianum*).

Shallow Marsh (27 to 33 feet) is a narrow band of herbaceous, hydrophytic species such as abundant cutgrass (*Leersia hexandra*), and headed-seedbox (*Ludwigia suffritcosus*), and scattered maidencane (*Panicum hemitomon*). Fuirena rush is present but rare.

Deep Marsh (33 to 100 feet) is a zone of obligate wetland species dominated by water lily (*Nymphaea odorata*) and scattered *Furiena.* Cover estimates of Fuirena may be misleading regarding the prevalence and importance of this species. This is because its vertical, leafless stems produce little cover even when present in great numbers. Other deep marsh species include scattered headed seedbox, and marsh St. Johnswort (*Hypericum fasciculatum*). Submersed species include numerous coontail (Ceratophyllum demersum).

Aquatic Bed (100 to 122 feet) is a very deep zone of numerous waterlily.

Transect 2 (2016) Lobe B

Transect 2 begins near the crest of a rise at the center of an island located in the northeast lobe of the lake. The transect extends 600 feet to the southeast across a wide littoral zone ending in open water. From 0 to 160 feet, the terrain is nearly level. From 160 to 250 feet, there is a gentle (3.9 percent) sideslope to a nearly level bench (0.8 percent slope) from 250 to 380 feet. From 380 to 600 feet, there is a regular, 1.8 percent slope toward open water. Representative photographs, a topographic cross-sectional profile and tables with vegetation and soil data are presented in Appendix D.

Vegetation and Soils at Transect 2

Transitional Shrub (0 to 185 feet) has a sparse, low canopy of scattered wax myrtle (*Myrica cerifera*) and Chinese tallow (*Sapium sebiferum*) and a dense shrub layer entirely dominated by blackberry. Hydric soils occur throughout the community. A8 Muck Presence occurs at stations 40 and 190 at the edges of the community while A2 Histic Epipedon occurs at higher elevations near the center of the community (stations 90 and 160). The estimated extent of deep organic soil, partly based on topographic breaks, is from 50 to 160 feet. Soil organic matter was noticeably dry in July 2016. A2 Histic Epipedon is typified by the Sanibel series at station 90, a very poorly drained, rapidly permeable soil underlain by sand substrate.

<u>Littoral zone transition (185 to 203 feet)</u> is a zone of low, shrubby vegetation along the edge of the island. Abundant wax myrtle and numerous Chinese tallow trees comprise the canopy. Blackberry is numerous in the understory and scattered redroot occurs in the groundcover.

<u>Shallow marsh (203 to 209 feet)</u> is a narrow band of mostly herbaceous vegetation at the upper edge of the littoral zone. Scattered buttonbush are present and the groundcover has numerous torpedo grass (*Panicum repens*), and scattered redroot, and water lily.

<u>Deep Marsh (209 to 580 feet)</u> has abundant water lily and numerous *Fuirena*. Scattered maidencane and torpedo grass are also present. Muck layers are absent from soils of the littoral zone and the hydric indicator at station 220 is S7 Dark Surface.

Transect 6A (2016) Lobe D

Transect 6A begins at the tree line of a maple (*Acer rubrum*) and wax myrtle (*Myrica cerifera*) dominated wetland that occupies a narrow isthmus separating Lobe "D" from the main body of the lake (Lobe "A"). It extends 250 feet to the northwest ending in open water. Transect elevations descend on an even gradient with a gentle 2.8 percent slope. Representative photographs, a topographic cross-sectional profile and a table with vegetation species data and cover estimates are presented in Appendix D. Soil data was not collected at this site.

Vegetation at Transect 6A

<u>Shallow Marsh (0 to 34 feet)</u> has abundant pickerelweed and water shield (*Brasenia schreberi*), numerous water lily, and scattered *Fuirena*.

<u>Deep Marsh (34 to 230 feet)</u> is dominated by water lily with numerous *Fuirena* and scattered water shield.

Comparison of vegetation distributions between 1997 and 2016

The original MFLs report provides information on vegetation distribution at Cowpen Lake in 1997, which includes figures that list the dominant species within defined communities. Table 2 of the original report (Appendix A) also includes a summary of elevations for selected vegetation features and communities. Table 3 compares elevations of wetland vegetation from the 1997 report with those collected in 2016 in order to evaluate vegetation stability.

These data suggest that the minimum elevation of the vegetated littoral zone (as measured by waterward extent of *Fuirena*) has shifted downslope by approximately four feet during the past 19 years as vegetation has encroached into large areas of former open water. This shift downslope corresponds to a period of increased cumulative rainfall deficit. Another large shift in vegetation is the encroachment of young laurel oaks at Transect 1 into areas that were formerly wet prairie, a downward shift in upland edge of approximately three feet. By contrast, the maximum elevation of the littoral zone has been a relatively stable feature that may have shifted downslope by approximately one foot during the past 19 years. The woody vegetation of the Transect 2 transitional shrub communities has also been relatively stable, shifting downslope by approximately 0.8 feet during the past 19 years.

Species composition of wetland communities at Cowpen Lake has also changed between 1997 and 2016. The most notable example is that waterlily, which was not listed as present in 1997, is now one of the most abundant species of the littoral zone.

Table 4. Comparison of elevations (feet NAVD) of wetland vegetation at Cowpen Lake between 1997 and 2016.

Transect	Feature	1997		2016		Conclusions
		station	Elevation (ft; NAVD)	station	Elevation (ft; NAVD)	
1	Littoral (max)	12	83.0	27	82.4[2]	downslope shift 0.6 foot
Various points	Littoral (min)/ ww* *Fuirena*	24 spots	80.2	12 spots	76.3	downslope shift 3.9 feet - *Fuirena* encroachment into open water
1	Wet prairie (max)	60	89.4	0	86.2[1]	downslope shift 3.2 feet - laurel oaks encroaching into wet prairie
1	Wet prairie (mean)	12 to 60	86.0	0 to 27	84.5[1]	downslope shift 1.5 feet
2	Littoral (max)	35	83.5	203	82.4[2]	downslope shift 1.1 feet
2	Trans. shrub (max)	200	85.4	70	84.6	downslope shift 0.8 foot
2	Trans. shrub (mean)	40 to 200	84.8	0 to 200	84.0	downslope shift 0.8 foot
3	Littoral (max)	21	83.4	-	-	-
6A	Littoral (max)	-	-	0	82.2[2]	-
1,2,3,6A (mean)	Littoral (max)	-	83.3	-	82.3	downslope shift 1.0 foot

*waterward
[1] includes elevations of upland ecotone
[2] littoral zone from 2016 includes both shallow and deep marshes

Dock Elevations

Elevations of deck surfaces and the base of waterward pilings were surveyed at 14 docks in January 2016 (Table 4). Surveyed docks at Cowpen Lake were located along the western shoreline of lobes A, C and D and along the eastern shoreline of lobes B and C. The maximum and mean deck elevations were 91.1 and 88.8 ft NAVD, respectively. However, elevations at waterward pilings are more pertinent to evaluating impacts of stage levels on boat usage. The maximum and mean elevations at the waterward pilings of docks were 83.4 and 79.8 ft NAVD, respectively.

Table 5. Maximum, mean and minimum dock elevations (ft, NAVD) at Cowpen Lake

	Maximum elevation (ft. NAVD)	Mean elevation (ft. NAVD)	Minimum elevation (ft. NAVD)
Deck	91.1	88.8	87.6
Waterward piling	83.4	79.8	77.7

Canal Elevations

Elevations were surveyed at 10 to 33 points along the thalweg of three canals that connect the major lobes of Cowpen Lake (Figure 3; Table 5). The survey transects T4, T5 and T6 were used to characterize the canals between lobes B and C, between lobes A and B and between lobes A and D, respectively. The maximum elevations along each canal serve as the control points or water levels below which each pair of lake lobes is hydrologically disconnected. Based on survey data collected in 2016, the main body of the lake (lobe A) is disconnected from lobes B and D at stages below 80.5 and 80.9 ft NAVD, respectively. Lobes B and C become separated at lake stages below 79.8 ft NAVD. These elevations correspond to the shallowest depths recorded while measuring depth soundings at lake lobe connections.

Table 6. Maximum, mean and minimum elevations (ft, NAVD) for canals connecting lobes of Cowpen Lake, Putnam County, FL.

Canal transects	Lake lobes connected	Maximum elevation (ft. NAVD)	Mean elevation (ft. NAVD)	Minimum elevation (ft. NAVD)
T-4	B and C	79.8	79.4	78.9
T-5	A and B	80.5	80.2	79.5
T-6	A and D	80.9	80.2	79.2

RELEVANT ENVIRONMENTAL VALUES

Eight of the 10 environmental values identified in Rule 62-40.473, *F.A.C.*, were deemed relevant for consideration for the Cowpen Lake MFLs reevaluation; these include:

- Recreation in and on the water
- Fish and wildlife habitats and the passage of fish
- Transfer of detrital material
- Maintenance of freshwater storage and supply
- Aesthetic and scenic attributes
- Filtration and absorption of nutrients and other pollutants
- Water quality
- Navigation

Two environmental values were deemed not relevant at Cowpen Lake for the following reasons:

- Estuarine resources—Cowpen Lake is land-locked and has no surface water connection to any estuarine resources.
- Sediment loads—Transport of inorganic materials as bed load is considered relevant only in flowing systems, where riverine fluvial dynamics are critical to the maintenance of geomorphic and ecological function.

The relative sensitivity of environmental values to hydrologic changes was evaluated to determine on which values the Cowpen Lake reevaluation should be based. Criteria used for this screening analysis included risk, importance, and legal constraints (Table 6). The environmental value "*fish and wildlife habitats and the passage of fish*" was considered most sensitive with an overall score of "7." Therefore, all the recommended MFLs in the following section were designed to protect and maintain wetland and wildlife habitats associated with Cowpen Lake.

Table 7. Rule 62-40.473, F.A.C., environmental value decision matrix: Cowpen Lake, FL

Criterion	Level of Resource Risk[1]	Importance of Resource Value[2]	Resource Legal Constraints[3]	Screening Value[4]	Criterion Stage Related? [5]	Criterion Limiting? [6]
Recreation in & on the water	1	2	0	3	Y	N
Fish and wildlife habitats & passage of fish	3	3	1	7	Y	Y
Estuarine resources	0	0	NA[7]	0	N	NA
Transfer of detrital material	2	2	0	4	Y	N
Maintenance of freshwater storage & supply	1	1	0	2	Y	N
Aesthetics & scenic attributes	1	2	0	3	Y	N
Filtration & absorption of nutrients & other pollutants	2	3	0	5	Y	N
Sediment loads	0	0	NA	0	N	NA
Water quality	2	3	0	5	Y	N
Navigation	1	2	0	3	Y	N

Notes:
1. Evaluation of the level to which the resource is at risk. 0 = none, 1 = low, 2 = medium, 3 = high
2. Evaluation of importance of the criterion with respect to resource. 0 = none, 1 = low, 2 = medium, 3 = high
3. Legal constraints on resource, such as endangered species, Outstanding Florida Water, etc. 0 = none, 1 = low, 2 = medium, 3 = high
4. Screening value = sum of columns 1, 2, and 3. Indicates overall importance of criterion to MFLs development.
5. Evaluation as to whether criterion is related to water level in resource. (Y = Yes or N = No)
6. Evaluation as to whether criterion is potentially limiting for MFLs development. (Y = Yes or N = No)
7. NA = not applicable

Minimum Levels Reevaluation for Cowpen Lake

Minimum infrequent high (IH), minimum average (MA), and minimum frequent low (FL) levels are recommended to protect the ecological structure and function of Cowpen Lake. A minimum frequent high (FH) and minimum infrequent low (IL) are not proposed due to a lack of suitable criteria. The rationale and criteria for the three levels are described below.

Minimum Infrequent High (IH) Level – 90.8 ft NAVD, 30-day duration with a 25-year return interval

The goal of the recommended IH flood event for Cowpen Lake is to maintain and protect the extent of wetland and aquatic habitat by maintaining the location of the upland ecotone. The purpose of the IH is to ensure that this ecotone will not shift down slope due to water withdrawals. The infrequent flood event that maintains the upland ecotone also maintains habitat diversity, and the structure and function of downslope wetlands and aquatic resources. Other functions and values of the recommended IH within sandhill lakes include infrequent, but beneficial, surface connection between lake lobes, increased aquifer recharge, detrital transport, nutrient filtration and increased breeding and forage habitat for aquatic and wetland species (CH2M Hill 2005). These high water events are rare and usually associated with wet season rainfall events that occur during or following periods of well above normal precipitation.

The specific indicator of protection for the IH is a high water level at the waterward elevation of the base of mature live oak trees (90.8 ft NAVD). The IH recommends that this elevation be continuously exceeded for a duration of at least 30 days with a 25-year return interval (i.e., at least 4 years per century, on average). The IH shifts the existing frequency distribution of annual maximum 30-day flooding events. However, higher elevations will still be flooded (i.e., exceeded) for 30 consecutive days, albeit, less frequently. Finally, the IH serves as an anchor point for a shift in the return intervals of other durations of flooding (i.e., 1-day to 365-day duration annual maximum frequency curves). Shorter duration flooding events (e.g., 1-day, 7-day, 14-day, and 21-day) will still occur at higher elevations in the landscape, just slightly less frequently, based on the recommended IH.

Elevation

Upland Ecotone

The Florida Unified Wetland Delineation Method designation for live oak is “Upland” (Gilbert et al. 1995). Live oak is a long-lived tree species found in dry to seasonally wet habitats, mostly on sandy soils (Ware 2003). Therefore, large live oak trees are good indicators for the extent of infrequent flooding. Analysis of aerial photography from the 1950s to the present, and numerous site visits revealed the location of a relatively unchanged waterward line of live oaks at Cowpen Lake. The IH elevation component (90.8 ft NAVD) was determined based on this tree line, which is thought to be the mean minimum elevation of live oak trees that became established in the 1940s or 1950s and survived a series of high flood events that occurred at Cowpen Lake from the mid-1960s to mid-1970s (Table 7). The presence of a line of mature oaks at this elevation indicates that areas downslope of this level have historically been subject to inundations sufficient to kill live oaks and other upland plants. The HSPF simulated lake stage time series supports the presence of high floods during the mid-1960s to mid-1970s (Figure 14); these high water events have also been measured at other nearby lakes.

Estimates of tree age for this waterward line of oaks provide some support for a potential establishment date in the 1940s, and survival of floods in the 1970s (Table 7). Tree age was estimated using DBH data and published annual radial growth rates for live oak. The mean DBH of oak tree line (upland ecotone) was 1.9 ft, at the time of sampling (2009). Based on the following information, the annual radial growth rate per year for live oak ranges from about 0.1 in/yr to 0.4 in/yr. The circumference of 217 live oaks was measured in Conway, South Carolina in 1975 and again in 1997 (Keet 2005). Circumference growth averaged approximately 1 ft over the 22 years, yielding a radial growth rate of 0.1 in/yr. The Eastern Native Tree Society (ENTS) reported annual radial growth rates of 0.187 in/yr for a 134 year old tree in Mississippi; 0.212 in/yr over about a 280 years period for the Josephine Stewart Oak in Louisiana; 0.251 in/yr between 1934 and 2007 for the Ruskin Oak in Louisiana; and 0.382 in/yr from 1962 -2007 for two live oaks planted in 1962. The historic Maltby Oak, a large live oak at the Palatka Courthouse about 22 miles east of Cowpen Lake, had an average radial growth rate of 0.21 in/yr from 1854-1979.

Table 8. Elevations and estimated ages of the nine lowest live oak trees measured at upland edge at Cowpen Lake, Putnam County, Florida

Tree ID number	Approx. DBH (ft)	Elevation (ft NAVD)	Estimated Age Years in 2009 (0.15 – 0.20 in/yr radial growth rate)	Estimated Age Years in 1970 (0.15 – 0.20 in/yr radial growth rate)
6-1	1.9	90.0	56 - 76	17 - 37
3B	2.6	91.0	76 - 104	37 - 65
1B	2.4	91.3	70 - 96	31 - 57
9-4	2.1	91.4	62 - 84	23 - 45
5B	1.9	92.0	56 - 76	17 - 37
9-1	1.4	89.6	40 - 56	1 - 17
9-5	1.5	90.5	44 - 60	5 - 21
2B	1.0	90.9	30 - 40	NA - 1
8-3	1.8*	90.9	52 - 72	13 - 33
Mean	**1.9**	**90.8**	**56 - 74**	**17 - 35**

Note: DBH = Diameter at breast height *DBH distorted, tree data not applicable

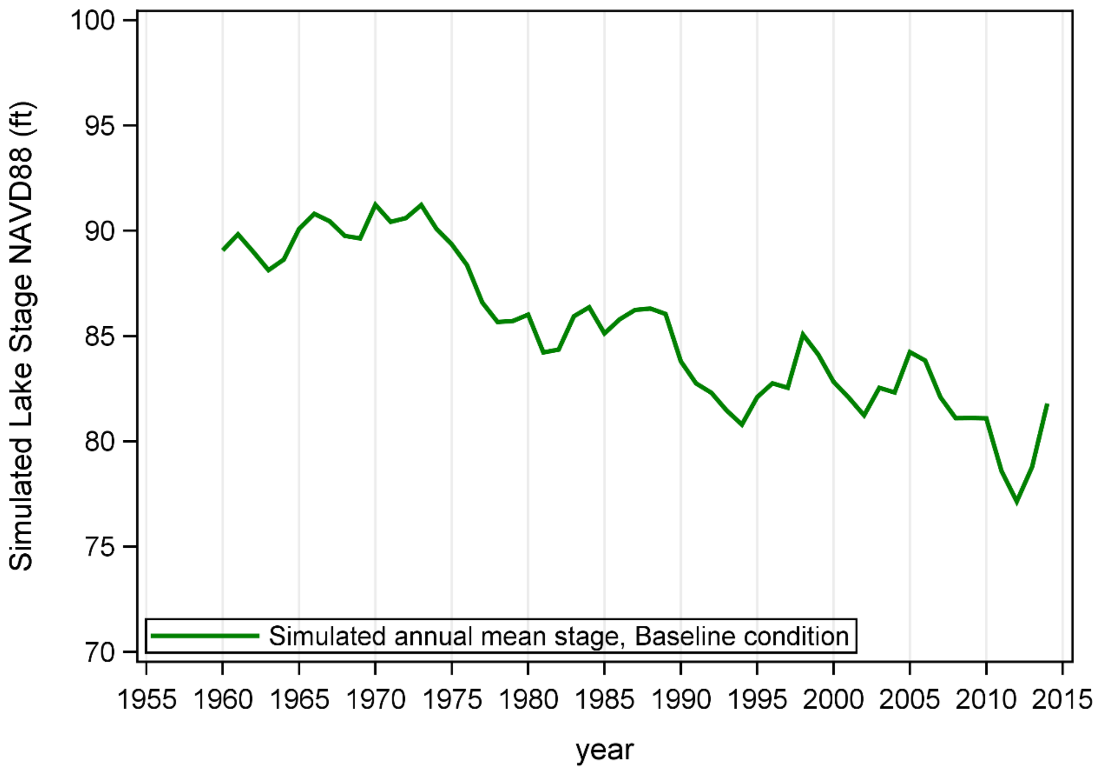


Figure 14 Baseline (2009) condition lake stage time series for Cowpen Lake, FL

Historical aerials suggest that the line of oak trees at 90.8 ft NAVD were present for decades prior to the 1970s, which would have allowed them to survive prolonged inundation. Based on a radial growth rate of 0.20 in/yr, only a few of the trees measured would have been established decades before the large flooding events in the mid-1960s to mid-1970s. If the growth rate was slightly lower (e.g., 0.15 in/yr, as has been documented), all of the trees would have been old enough to survive these high water events. Since exact date of establishment for the waterward line of oaks is unknown and growth rates may have varied depending upon soil fertility, light availability and other factors, the actual age of these trees cannot be determine from DBH data. However, a growth rate of 0.15 to 0.20 in/yr generally supports that these trees were old enough to survive prolonged inundation at the time of very high water levels that persisted from the mid-1960s to mid-1970s (Table 7).

Open Water and Habitat Heterogeneity

The infrequent flooding indicated by the mature live oak line probably plays an important role in maintaining open water. Vegetation data from 2016 shows that the littoral zone has shifted downslope by nearly four feet relative to 1997(Table 3). Water lily, which was not noted in 1997 surveys, is now abundant at lower elevations of the littoral zone. Therefore, MFLs designed to maintain open water at Cowpen Lake must consider flood tolerances of water lily. Data by Caffrey et al. (2006) indicate that the maximum depth of colonization (MDC) for submerged macrophytes in Florida lakes has a mean value of 3.1 meters (10.2 feet). The dataset from this report also lists measured MDC values at numerous lakes similar to Cowpen. These include Como (3.4 m), Emporia (2.9 m), Halfmoon (3.1 m), and Weir (3.0 m). The macrophytes described in this study include hydrilla (*Hydrilla verticellata*), coontail, waternymph (*Najas* sp.), and macrophytic algae (*Chara* sp.). These are all submersed species adapted to low light conditions and their MDC values may be greater than for water lily, which has most of its leaves at or near the water surface. Therefore, the depth of water necessary to damage water lily stands may be less than 10.2 feet. Although water lily produces floating leaves on stems that extend through the water column to the surface, wildlife foraging and other processes frequently damage these stems. If adequate light cannot penetrate to the buds on the plant rhizomes of the lake bottom, then new stems cannot be produced. Furthermore, water lily plants at the maximum elevation of this species typically have short or absent stems.

The proposed IH based on the minimum elevation of the mature oak tree line (90.8 ft NAVD) is also the maximum elevation of water lily plus 8.9 feet. This IH event would stack 8.9, 12.2, and 16.2 feet of water over the maximum, mean, and minimum elevations of water lily, respectively, as measured at Cowpen Lake in 2016 (Table 8). A 30-day flood event of this magnitude would probably devastate mean and minimum elevation stands of water lily while leaving maximum elevation stands relatively unaffected. This event would effectively restore large areas of open water to the lake while leaving a fringe of water lilies at the upper edge of the littoral zone.

Table 9. Elevations of water lily at Cowpen Lake (2016).

Transect	maximum	mean	minimum
1	81.44 (station 33)	77.77	72.46 (station 122)
2	82.10 (station 208)	79.05	76.06 (station 580)
6A	82.16 (station 0)	79.03	75.26 (station 230)
mean	81.9	78.6	74.6

Duration

Upland Ecotone

The recommended duration component of the IH level event is at least 30-days continuously exceeded. Information regarding live oak flood duration tolerances are summarized in Table 9 (Ware 2003). Live oak can tolerate moderately well drained soils but cannot tolerate poorly drained soils. It will withstand only occasional deep inundation. While live oak may withstand flood durations that occur for a cumulative 10 percent of the growing season (Hook, 1984), it probably cannot withstand flood durations that extend to 20 percent (Larson et al, 1981).

Table 10. Summary of scientific literature regarding the waterward extent of live oak (Ware 2003)

Source	End of Live Oak Waterward Extent	Beyond Live Oak Waterward Extent
Hook (1984)	Soils waterlogged for 1-4 weeks usually accounting for 10% of the growing season	Soils waterlogged for about 50 % of the time
Light et al. (1993)	Found end of range in high terraces having approximately 4-10% range of total flooding events per year Soils moderately well drained	Not found in low terraces having approximately 19-33% range of total flooding events per year Soils poorly drained
Larson et al. (1981)	Soil inundation or saturation of 1-2 months during growing season	Soil inundations or saturation during a major part of growing season
Moore (1980)	Thrived in well drained beds	Barely grew in generally poorly drained soils
Vince et al. (1989)	Higher, drier areas of hydric hammocks Withstands occasional inundation	Wetter areas of hydric hammocks Cannot withstand prolonged soil saturation

However, other studies suggest live oak can survive an average annual longest flood duration of 24.2 days (Light et al. 1993). These literature sources suggest that a 30-day flooding duration is the approximate threshold to kill mature oak trees.

Open Water and Habitat Heterogeneity

At the waterward boundary of resident wetlands, a 30-day flood duration at the 90.8 ft NAVD elevation would be sufficiently long to kill species within the aquatic bed. This flood duration would impede photosynthesis and thereby disrupt plant metabolic processes, causing mortality of water lily leaves and stems.

Return Interval

Upland Ecotone

As discussed above, a mean radial growth rate of 0.2 in/yr generally supports a waterward oak line establishment date in the early to mid 1960s. However, live oak growth rate could be up to twice as fast (0.4 in/yr) based on published rates. Considering that the waterward edge of the uplands is often characterized by open sites with higher sunlight, growth rates may be towards the high end of the range. Therefore, live oaks could reach a 2.0 ft DBH within a much shorter period, closer to 20 to 30 years.

Studies suggest that a stand of oaks can become established, having completed the “initiation stage”, within 20 years of a disturbance (Johnson et al. 2002). The growth rate data cited above suggest that live oaks that are 20 to 30 years old years may have a DBH of 1.3 to 2.0 ft. This diameter represents a relatively large tree. Live oaks with a DBH of 2.0 ft can reach heights between 35 and 80 ft tall (Coder 2015). Even at the low end of the range, this represents large, well established trees, at age 30. While analysis of aerial photographs supports generally suggests that the waterward oak line is older than 30 years, it is not know whether the area below this line has been modified by humans. Much of the perimeter of the lake, where oaks were measured, is developed with single family homes. Mowing or other manipulation of vegetation confounds the ability to determine when trees may become established downslope of the current oak line.

However, another related species, laurel oak, was observed growing downslope of the live oak line at Transect 1 in formerly open areas ecotonal to wet prairie. This species grows faster than live oak and has a much shorter life span. Laurel oaks show signs of senescence (e.g. rotting or hollow trunks) by 50 years and do not live longer than 70 years (Gilman and Watson, 1994). Growth and yield data on other oak species (Johnson et al., 2002, pp. 435-436) show that growth in tree height slows substantially by the time oaks reach 12 inches DBH. Laurel oak in Florida are likely to reach this diameter within 25 years and then enter a phase of slower growth marked by increasing girth. This decrease in growth rates marks a transition from a stage when trees are fast growing, metabolically active, and more susceptible to flood driven mortality. Presumably, as growth rates slow they become more resistant to the stresses imposed by flood events. Therefore, flood events at a 25 year return interval will be more effective in maintaining the upland ecotone than would longer return interval events.

Based on live oak growth characteristics, years necessary for stand establishment, and flood frequency necessary to kill faster growing hardwood species associated with live oak (e.g., laurel oak), the infrequent high flood frequency deemed necessary to reset the upland boundary, is at least every 25 years, over the long term.

Open Water and Habitat Heterogeneity

The recommended IH would stack approximately nine feet of water over the maximum elevation of water lily. Because these events are so rare, the SWIDS data set generally does not provide meaningful estimates of their probabilities. However, there are a few exceptions: 30-day floods that stack nine feet of water over the maximum elevation of water lily at Lake Avalon (Orange County, FL) have a probability of 4.04 percent (24.8 year return interval). 30-day floods that stack eight feet of water over the maximum elevation of water lily at Lakes Emporia, Kerr, and Trone have percent probabilities, respectively, of 3.05 (32.8 y RI), 1.63 (61.3 y RI), and 4.47 (22.4 y RI) or an average return interval of approximately 33 years. In order to maintain open water characteristics of Cowpen Lake for significant periods, a return interval of 25 to 33 years is advisable (3 or 4 events per century). This information regarding the maintenance of open water habitat supports the 25-year flood frequency necessary for maintaining the upland ecotone.

Based on frequency analysis from the HSPF model simulation (baseline condition), a 30-day flood event at 90.8 ft NAVD occurs once every 10 years (10 times per century; Figure 15). However, because these autocorrelated high flood events are clustered within a relatively short period their effective frequency is less frequent. In other words, after one large flood event kills vegetation at the upland boundary, the subsequent floods are essentially redundant. As such, the current return interval of the IH is effectively closer to 60 years, rather than 25 years.

This might suggest a return interval closer to 60 years. However, the following sources of uncertainty suggest that a shorter return interval is appropriate. First, there is uncertainty in the future long-term frequency of these large flood events given evidence of non-stationarity trends in climate. Second, the current lake stage time series exhibits the effects of a multi-decadal drought, which has affected the estimated return interval of this flooding event. Finally, drawing conclusions about recruitment of upland species is also confounded by the fact that private landowners manage, to varying extent, the vegetation on the shoreline of Cowpen Lake.

Given these uncertainties related to very long duration return intervals, and given the biologically-based rationales previously discussed that support a 25 year return interval, the more protective return interval was selected.

The dewatering event defined by the recommended IH magnitude and duration occurs under baseline conditions every 10 years on average (i.e., 10 events per century; Figure 15). Therefore, the recommended IH return interval of every 25 years (i.e., 4 events per century) allows 6 fewer 30-day flooding events per 100 years at the 90.8 ft NAVD elevation. The available freeboard, based on a comparison of the baseline and recommended frequency of the IH, is 0.8 ft (Figure 15).

Importance of IH for Wetland Diversity

The upland ecotone is an area that is flooded often enough to kill upland shrubs and trees but not often enough to support hydric soils or hydrophytic vegetation. The uplands surrounding Cowpen Lake typically have well-drained, loamy soils with thick, surficial sand layers (Apopka and Millhopper series). These soils have low fertility but adequate subsoil moisture retention for the establishment of upland shrubs and trees in the periods between large flood events. Infrequent floods are therefore needed to kill these pioneering upland species and maintain the long-term upland boundary.

In addition to resetting the upland boundary of wetlands, large rare flood events also contribute to overall landscape heterogeneity by resetting the waterward boundary of wetlands. By flooding emergent and floating wetland species that have colonized open water during dry periods, high floods help to preserve the extent of open water habitats, over the long term. In addition to promoting higher plant diversity, preservation of open water can also increase the diversity of fish and other aquatic species. Fish are known to prefer an intermediate mixture of open water and littoral habitat (Wiley et al. 1984, Aho et al. 1986, Trebitz and Nibbelink 1996, Miranda and Pugh 2011). A lack of open water can reduce both the abundance and diversity of game fish species (Colle and Shireman 1980, Allen and Tugend 2002, SFWMD 2011). Open water habitats that become colonized by emergent species (e.g., water lily and *Fuirena*) will be reset as open habitat, by infrequent, very deep, flooding events. Maintenance of open water is crucial to protecting both recreational and aesthetic values of Cowpen Lake, thereby preserving property values and economic benefits to the surrounding communities.

In addition to allowing obligate species to extend their distribution into open water habitats, the absence of large floods allows facultative pioneer species to outcompete and thus homogenize the vegetation within some wetland communities. The proposed IH event would disrupt stands of highly competitive facultative species such as laurel oak, blackberry, and Chinese tallow, which would otherwise colonize and eventually dominate wet prairie habitats along the shoreline.

By reshaping the distribution of resident species, at both the high and low boundaries and within wetlands, large infrequent floods act as beneficial disturbance events that prevent community homogenization, and help to maintain spatial and temporal habitat diversity.

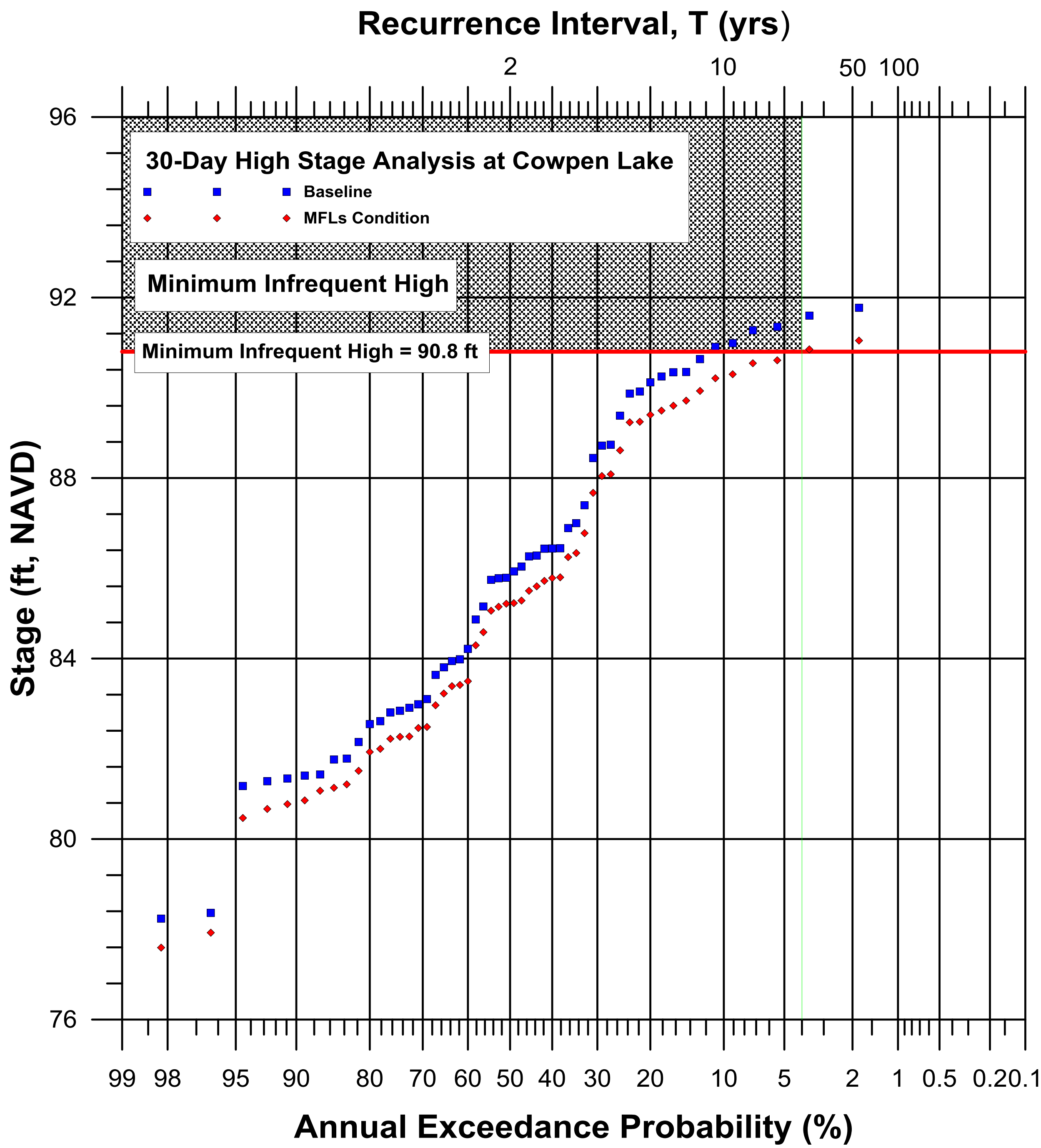


Figure 15. Frequency analysis for Cowpen Lake IH, depicting Baseline condition and MFLs condition.

Minimum Average (MA) Level – 84.0 ft NAVD, 180-day duration, 1.7-year return interval

The goal of the recommended MA is to prevent excessive drying in wetlands during periods of low lake levels and thereby protect deep organic soils from oxidation and subsidence. Soil organic matter is an important component of many wetland soils that maintains integrity of tree roots, supports biogeochemical processes (e.g sequestration of carbon and nutrients, denitrification), and protects wetland biota that require long term flooding or saturation.

The adopted MA at Cowpen Lake was the mean elevation of muck soil at Transect 2 from 1997 minus 0.25 feet. This equaled 85.7 ft NGVD (84.5 ft NAVD) and had an associated hydroperiod category of "typically saturated". The newly recommended MA is based on a similar criterion: the mean elevation of deep organic soils at Transect 2 from 2016 minus 0.3 feet. Specific dewatering durations and event return intervals replace the more general hydroperiod categories.

The reevaluation results in a recommended MA approximately 0.5 feet lower than the adopted MA. The lower elevation may be due to field error in the 1997 delineation of organic soils since the services of a trained soil scientist were not available at that time. It may also be due to slight differences in transect alignment. Finally, there may have been a general lowering of the soil surface elevation due to either oxidative loss of organic soil carbon or a loss of soil buoyancy or volumetric water content.

Elevation to protect organic soils

The average elevation of organic soils at Transect 2 in 2016 (stations 50-160) is 84.3 ft NAVD. Subtracting the 0.3-foot drawdown factor yields the recommended MA elevation of 84.0 ft NAVD. This 0.3-foot factor is based on research in Everglades peat soils (Stephens 1974), which estimated that due to capillary action, long-term average water table drawdown to this level could occur without causing oxidation and subsidence of organic soils. Studies of marshes in the Upper St. Johns River Basin (Brooks and Lowe 1984; Hall 1987) determined that 0.3 foot below the surface of deep organic soils corresponds to a water level exceeded approximately 60% of the time.

Duration to protect organic soils

The recommended average non-exceedance duration of dewatering events at 84.0 ft NAVD is 180 days (i.e., not to exceed this duration for the recommended return interval). This duration maintains long-term saturation of organic soils. In a base line study from Water Conservation Area 3A of the Everglades, Zafke (1983) reported that sawgrass, a species that generally occurs on organic soils, tolerated annual durations of inundation ranging from 15 to 94 percent. Similarly, Sincock (1958) noted that sawgrass in the Upper Basin of the St. Johns River usually occurred where there was annual duration of saturation of 45 percent. These data suggest that organic soils may form under widely ranging durations of saturation. The average of the annual range provided by Zafke (1983) is 54 percent, similar to the 180-day annual duration specified for the MA.

Return Interval to protect organic soils

The recommended return interval for dewatering deep organic soils at Cowpen Lake should not surpass that of deep organic soils from a set of reference sites. The return interval was selected by examining the range of hydrologic signatures for Histosol/ histic epipedon areas in similar lake systems. SWIDS hydrologic signatures for deep organic soils in similar lake systems are shown in Figure 16. They indicate that the driest signature has a mean non-exceedance probability of 0.59 (59 events per 100 years) or a return interval of 1.7 years. This return interval is an estimate of the maximum number of dewatering events that muck soils can sustain.

The driest signature was selected because the hydrologic signatures from this reference set are in relatively close proximity to each other without any obvious outliers. The driest hydrologic signature comes from Davis Lake on the Crescent City-Deland Ridge in Volusia County (Brooks 1982). Davis Lake may have some hydrologic alteration from surface water consumption by nearby ferneries. However, the organic soil signature from South Lake on the Titusville Dunes in Brevard County closely matches it and this lake is relatively unaltered. In addition to the preceding reasons, the use of this driest hydrologic signature in the SWIDS dataset is acceptable because the MA is not the limiting level for Cowpen Lake.

The dewatering event defined by the recommended MA magnitude and duration occurs under baseline conditions every 2 years on average (i.e., 50 events per century; Figure 17). Therefore, the recommended FL return interval of every 1.7 years (i.e., 59 events per century) allows 9 additional continuous 180-day dewatering events per 100 years at the 84.0 ft NAVD elevation. The available freeboard, based on a comparison of the baseline and recommended frequency of the MA, is 2.0 ft (Figure 17).

Importance of MA for Hydric Soils and Wetland Plant Communities

Wetland soils are important in global biogeochemical cycles, particularly as sinks for carbon (Mitsch et al. 2013, Reddy and DeLaune 2008). Frequent anaerobic conditions impede microbial activity and primary production exceeds decomposition. Organic soils gradually accrue as a result. However, when organic soils are drained or otherwise hydrologically altered, aerobic conditions increase microbial activity and decomposition exceeds primary production. Stored soil carbon oxidizes, eventually causing subsidence of the wetland surface. This affects tree root integrity and other aspects of ecosystem structure and function.

Although the presence of organic soils is a function of hydrologic conditions, organic soils have unique physical properties that in turn affect wetland hydrology. Organic soils are very highly porous and may be comprised of > 85 percent pore space (Veery and Boelter 1979). Highly decomposed muck soils, such as those at Cowpen Lake, have mostly very small pores with size distributions and hydraulic conductivities similar to clay (Boelter 1974). Therefore, organic soils hold tremendous volumes of water and release that water very slowly. For example, muck soils in Minnesota that contain 85 percent moisture by volume at saturation still contain 72 percent moisture at 100 cm H_2O suction, the point at which most gravitational drainage ceases (Boelter 1974). Therefore, even brief flooding events can produce extended periods of saturation or near saturation in organic soils and thereby moderate hydrologic extremes.

Soil organic matter in wetlands provides long-term nutrient storage and is a source of mineralizable nutrients for plant growth. Slow release of nutrients occurs at a level sufficient to sustain plant growth within native plant communities. Organic soils also sustain productivity within the larger system by releasing dissolved organic material, which supports downstream (or within lake) aquatic life (Mitsch and Gosselink 2015).

Fine organic soil particles (colloids) have a large surface area with a high density of negatively charged sites. This creates cation exchange capacity (CEC), which regulates release of many plant nutrients (e.g. ammonium-N, K, Ca, Mg) and also affects bioavailability of various metals and toxins deposited in wetlands. Soil humic materials form stable water soluble and insoluble complexes with many metal ions (Reddy and DeLaune 2008). High molecular weight humic acids effectively immobilize most trace and toxic metals through precipitation (Stevenson 1982).

Wetland soils are a medium for denitrification (loss of nitrogen), a process important in maintaining water quality. Suites of anaerobic soil bacteria use nitrate as an alternate electron acceptor to oxygen. In this process, nitrate is reduced to gaseous nitrogen products such as nitrogen gas and nitrous oxide. Wetlands subject to alternating aerobic and anaerobic conditions are highly effective for denitrification because aerobic conditions allow conversion of organic matter to ammonium (ammonification) and ammonium to nitrate (nitrification), which is then subject to denitrification during anaerobic phases (Reddy and DeLaune 2008). However, in permanently waterlogged wetlands or some lake sediments, dissimilatory nitrate reduction may occur, a process that converts nitrate back to ammonium and thereby retains N in the system. (Reddy and DeLaune 2008).

Wetlands can be very productive ecosystems with high rates of primary productivity due in part to the long-term abundance of water and nutrients (Mitsch and Gosselink 2015). In summary, the recommended MA level maintains the following functions:

- Organic Soil Maintenance: Dewatering events do not recur often enough to cause organic soils to oxidize and subside. Carbon sequestration is maintained and adverse impacts to the integrity of tree roots are prevented.

- Biogeochemistry: Soil carbon retains nutrients, and provides exchange sites for sorption of metals and toxins. Alternating periods of aerobic and anaerobic conditions support denitrification, an important water quality function.
- Habitat Quality: Dewatering events maintain long-term saturation and inundation appropriate to wetlands and associated biota at Cowpen Lake.
- Productivity: Productivity of wetland vegetation and other biota adapted to long-term saturation is maintained.

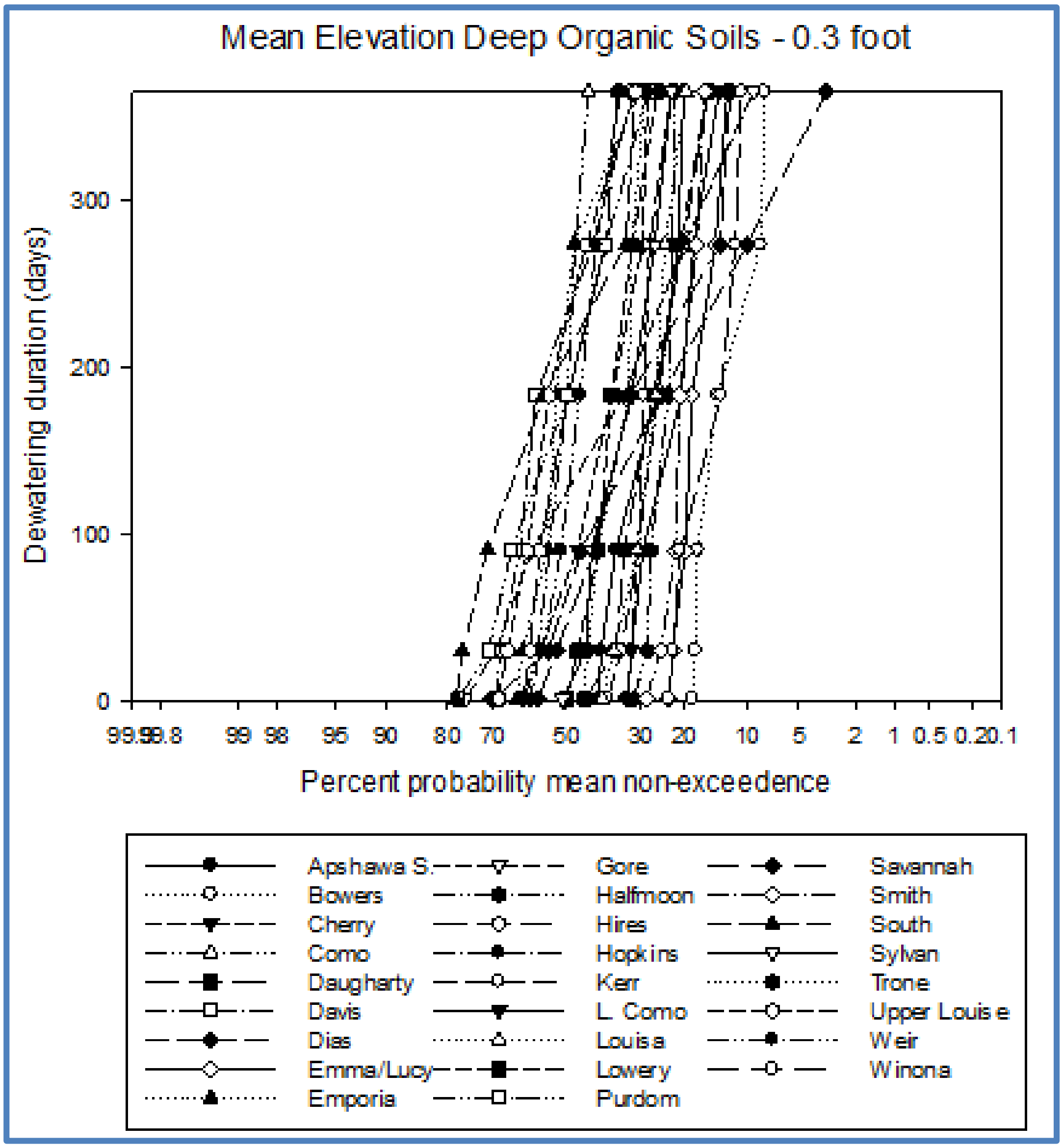


Figure 16. Hydrologic signatures for the non-exceedance probability for deep organic soils showing proposed change in return interval for the MA at Cowpen Lake.

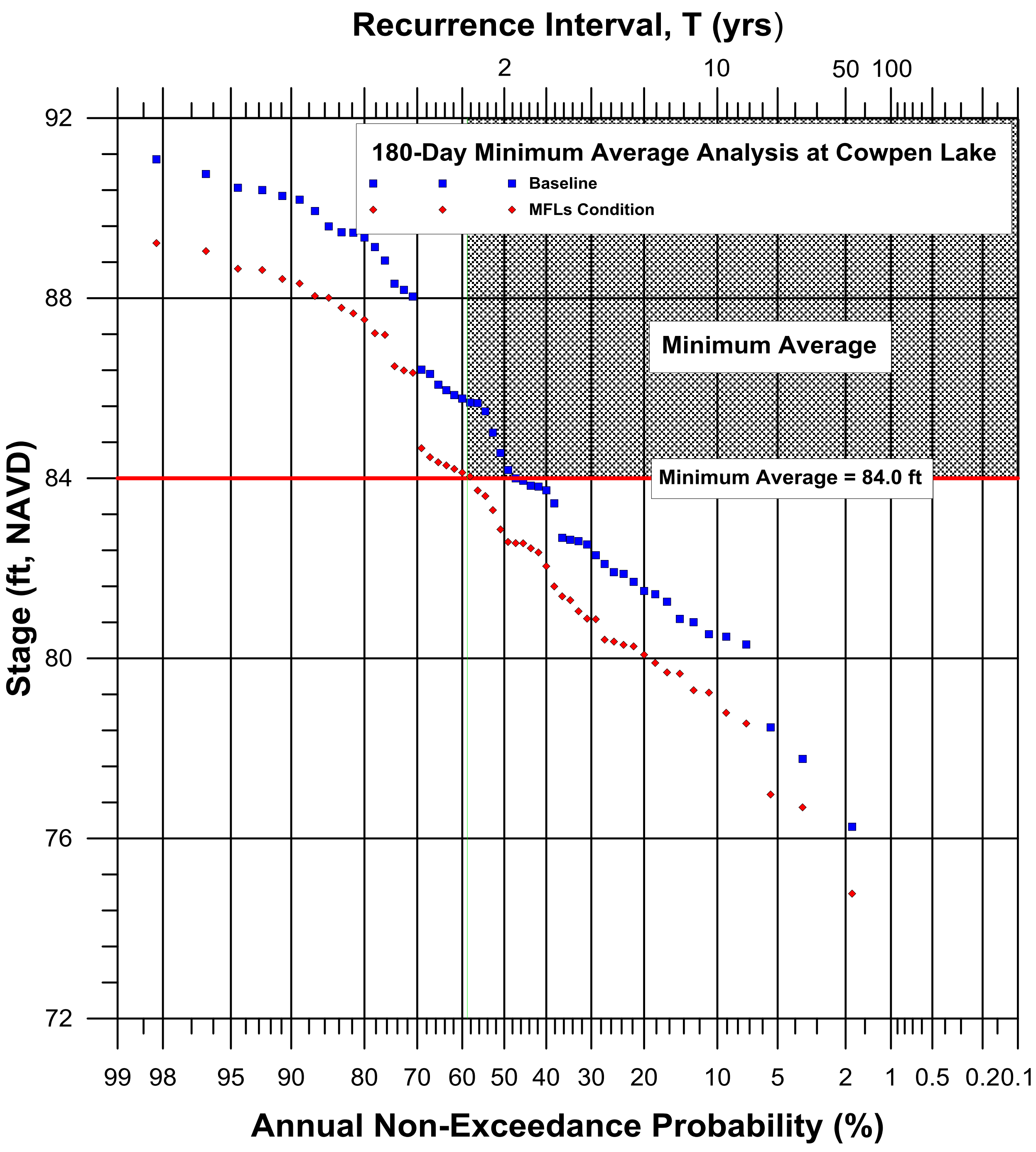


Figure 17. Frequency analysis for Cowpen Lake MA, depicting baseline condition and MFLs condition.

Minimum Frequent Low (FL) – 82.3 ft NAVD, 120-day duration, 2.7-year return interval

The goal of the recommended FL is to maintain the extent of the littoral zone, providing long-term protection of suitable habitat for resident wetland and aquatic species. The littoral zone within a lake is typically defined as the shallow nearshore zone where light penetrates to the bottom, allowing for growth of aquatic macrophytes (Dodds 2002). For the purposes of this report, the littoral zone represents those habitats that are downslope of woody wetland species (e.g., buttonbush, maple) and characterized by emergent and floating aquatic species (i.e., shallow and deep marsh habitats). The recommended FL will prevent a permanent downhill shift in littoral zone vegetation, loss of wetland area, and loss of open water habitat. The recommended FL will maintain long duration flooding of emergent marsh communities (shallow and deep marshes) and aquatic beds while allowing for a minimum number of drying events within wet prairie and transitional shrub communities. By allowing for necessary drying of wet prairie and transitional shrub wetlands, while maintaining the location of deeper emergent marsh habitats, the FL will protect plant community extent and biodiversity while sustaining long-term refuge, forage and reproductive habitat for native fishes, amphibians, reptiles and birds.

The general indicator of protection is maintenance of long-term hydrologic conditions necessary to sustain the littoral zone, a community dominated by *Fuirena* and associated emergent and floating aquatic species. The basis for this general indicator is that the maximum elevation of the littoral zone is currently, and should remain, relatively stable. The purpose of the FL for Cowpen Lake is to ensure that the frequency of low water level events, typically associated with mild droughts, does not increase as a result of water withdrawal to the point where they cause a permanent downhill shift of the littoral zone.

The specific indicator of protection for the FL is the maximum elevation of the littoral zone measured in 2016 at Transects 1, 2, 6A, and at spot elevations near Transect 5. This elevation marks a relatively stable ecotone or interface between the herbaceous vegetation at the edges of the lake bottom and the often woody vegetation of the islands and shorelines.

These specific indicators of protection yield a recommended level of 82.3 ft NAVD. The recommended FL for Cowpen Lake is based on ensuring that this elevation is continuously dewatered for 120 days no more often than once every 2.7 years (i.e., 37 drying events per century, on average). Further rationale for the magnitude, duration and return interval components of the FL are presented below.

Elevation to protect littoral zone

The littoral zone in Cowpen Lake is composed of multiple wetland communities, ranging from seasonally flooded shallow marsh to semipermanently flooded deep marsh and aquatic bed (Appendix D). Shallow marshes are inundated for extended periods (generally greater than one month) during the growing season, while semipermanently flooded wetlands are generally inundated throughout the growing season (FGDC 2013). Both types of communities are located downslope of the maximum elevation of the littoral zone. The maximum elevation of the littoral zone could also be described as the maximum elevation of shallow marsh except that shallow marshes at Cowpen Lake tend to be very narrow, and possibly ephemeral, features that are more of an ecotone to the deep marsh. These features are best described collectively as "littoral zone".

The littoral zone does not include wet prairie or transitional shrub communities, which have long periods of soil saturation but are only briefly inundated. Therefore, the littoral zone boundary at Cowpen Lake often represents the minimum elevation of wet prairie and transitional shrub communities (Appendix D). Elevations of features used to delineate the maximum littoral zone are shown in Table 10.

Table 11. Summary of features used to define maximum elevation of littoral zone.

Transect	Station	Feature	Elevation
1	27	Shallow marsh – wet prairie boundary	82.43
2	203	Shallow marsh – transitional shrub boundary	82.37
5	Mean of 2 spot elevations	Shallow marsh – wet prairie boundary	82.33
6A	0	Shallow marsh – maple swamp boundary	82.16
		Mean elevations	**82.32**

Conventionally, SJRWMD has used the maximum elevation of deep marsh as the specific indicator of protection for a minimum frequent low elevation. However, a comparison of field data collected in 1997 and 2016 suggests that the deep and shallow marshes may shift their distributions but that the collective feature (e.g. littoral zone) is relatively stable. However, there is some uncertainty in these comparisons since the marsh elevations collected in 1997 were based on belt-transect data, whereas current field elevations are based on more detailed line-intercept data and belt-transect data; the latter data are presented in Appendix D. Given this uncertainty, a determination was made to instead base the FL on the maximum elevation of the littoral zone.

There are two primary reasons why basing the FL on the maximum extent of littoral zone is appropriate for Cowpen Lake: 1) importance to resident fish and wildlife; and 2) long-term habitat stability. The first reason for considering the littoral zone as one vegetative and habitat feature (i.e., combining shallow marsh, deep marsh and aquatic bed) is related to shared habitat characteristics for fish and wildlife. The importance of littoral habitats (both shallow and deep marsh habitats) for lake fish communities is well documented (Winfield 2004, Hill and Cichra 2005, Strayer and Findlay 2010). Game fish rely upon deep and shallow marsh habitats to fulfill one or more aspects of their life history (Durocher et al. 1984; Wiley et al. 1984; Hoyer and Canfield 1996; Paukert and Willis 2004). Littoral habitats are also important for resident invertebrates, amphibians, reptiles, mammals and birds (SFWMD 2011). Secondly, littoral zones are structurally complex areas with high autotrophic and heterotrophic production, relative to other areas within a given lake. These areas typically vary in depth, have high plant diversity and provide important forage, reproductive, nursery and refuge habitat for numerous species. Because this complex herbaceous zone is critical to wildlife abundance and diversity, the long-term maintenance of the maximum elevation of the littoral zone is also of critical importance for habitat stability.

At Cowpen Lake, the littoral zone is a herbaceous zone dominated by *Fuirena*, and waterlilies. The relative position of the littoral zone and transitional shrub wetlands through time was analyzed using historical (1953 to present) aerial photography. These aerial photographs support the idea that the lower extent of marsh vegetation has likely shifted into areas that were open water during previous years. They also illustrate the dynamic nature of much of the littoral zone, which expands and contracts over time. However, these photographs also show that certain features are stable over time such as the several islands and the prominent isthmus that separates Lobes “D” and “A”. These wetland features appear to have supported shrubby vegetation throughout this period. The minimum elevations of these features are therefore relatively stable features upon which to base MFLs designed to protect littoral zones.

It is likely that the relative distribution of shallow and deep marsh communities has changed, but that the ecotone between emergent marsh and drier habitats (wet prairie and transitional shrub habitats) has not changed significantly. Because of the importance of the littoral zone as a whole to resident fish and wildlife, the exact relative distribution of shallow marsh, deep marsh and aquatic beds is of reduced importance. It is also worth noting that breaks between seasonally flooded and semipermanently flooded communities can be somewhat subjective in systems with subtle topographic breaks. The species within these communities are distributed along continuous gradients and exist in multiple communities.

Duration to protect littoral zone

The recommended duration component of the FL is 120 days of continuous dewatering days (i.e., not to exceed this duration for the recommended return interval). This duration is associated with the approximate duration of the spring and early summer dry season in central Florida (i.e., mid- February to mid-June). This duration, when combined with the recommended return interval, was chosen to ensure that the frequency of dry periods associated with mild droughts are not increased to point where they cause a shift in Fuirena, which is a species indicator for the littoral zone. The benefits of this dry period, for communities above the maximum elevation of the littoral zone, include soil exposure, compaction and nutrient remineralization. Sufficient drying allows seed germination, seedling establishment and plant growth to occur before wet prairie and shrub habitats are re-flooded.

Return Interval to protect littoral zone

Fuirena is a common emergent species of the littoral zone at Cowpen Lake that was noted in both the 1997 and 2016 MFLs investigations. It generally extends to near the maximum boundary of the shallow marsh but with reduced cover relative to deep marsh. Because the recommended FL is based on the maximum extent of the littoral zone, and because Fuirena is the most characteristic species of the littoral zone, the return interval for the FL is based on the hydrologic requirements of this species. Based on SWIDS data, the driest signature for the maximum elevation of Fuirena has a non-exceedance probability for a 120-day dewatering event of 37% or a return interval of 2.7 years (Figure 18). This driest signature comes from Lakes Como and Banana in Putnam County. These lakes are suitable reference sites for Cowpen Lake since they are located in a similar physiographic region (Crescent City ridge), have a similar range of fluctuation, and are karstic sand hill lakes with a strong Floridan aquifer connection. They also occur in an area of relatively little groundwater use. Therefore, the proposed FL return interval of 2.7 years for 120-day dewatering events should be sufficient to protect the littoral zone at Cowpen Lake. In addition to the preceding reasons, the use of this driest hydrologic signature in the SWIDS dataset is acceptable because the FL is not the limiting level for Cowpen Lake. The dewatering event defined by the recommended FL magnitude and duration occurs under baseline conditions every 3.3 years on average (i.e., 30 events per century; Figure 19). Therefore, the recommended FL return interval of every 2.7 years (i.e., 37 events per century) allows 7 additional continuous 120-day dewatering events per 100 years at the 82.3 ft NAVD elevation. The available freeboard, based on a comparison of the baseline and recommended frequency of the FL, is 1.1 ft (Figure 19).

Importance of FL for Wetland Structure, Function and Biodiversity

Fish community viability

Maintenance of the littoral zone is crucial to the long-term viability of resident fish populations. Cowpen Lake is an oligotrophic, isolated, sandhill lake characterized by low pH and low productivity (Lakewatch 2015). In an isolated lake, one of the most influential factors contributing to fish production, harvest (i.e., number of catchable fish) and overall community viability is recruitment (Haddon 2011). Recruitment is defined as the number of fish, from a given year’s cohort, that contribute to the pool of reproductive or catchable adults (Helfman et al., 2009). Low lake water levels, among other environmental factors, can have a strong influence on fish recruitment and thus overall population dynamics, by negatively affecting nesting success, egg survival, and the survival and growth of larvae and juveniles (Bonvechio and Allen 2005, Helfman et al. 2009, SFWMD 2011).

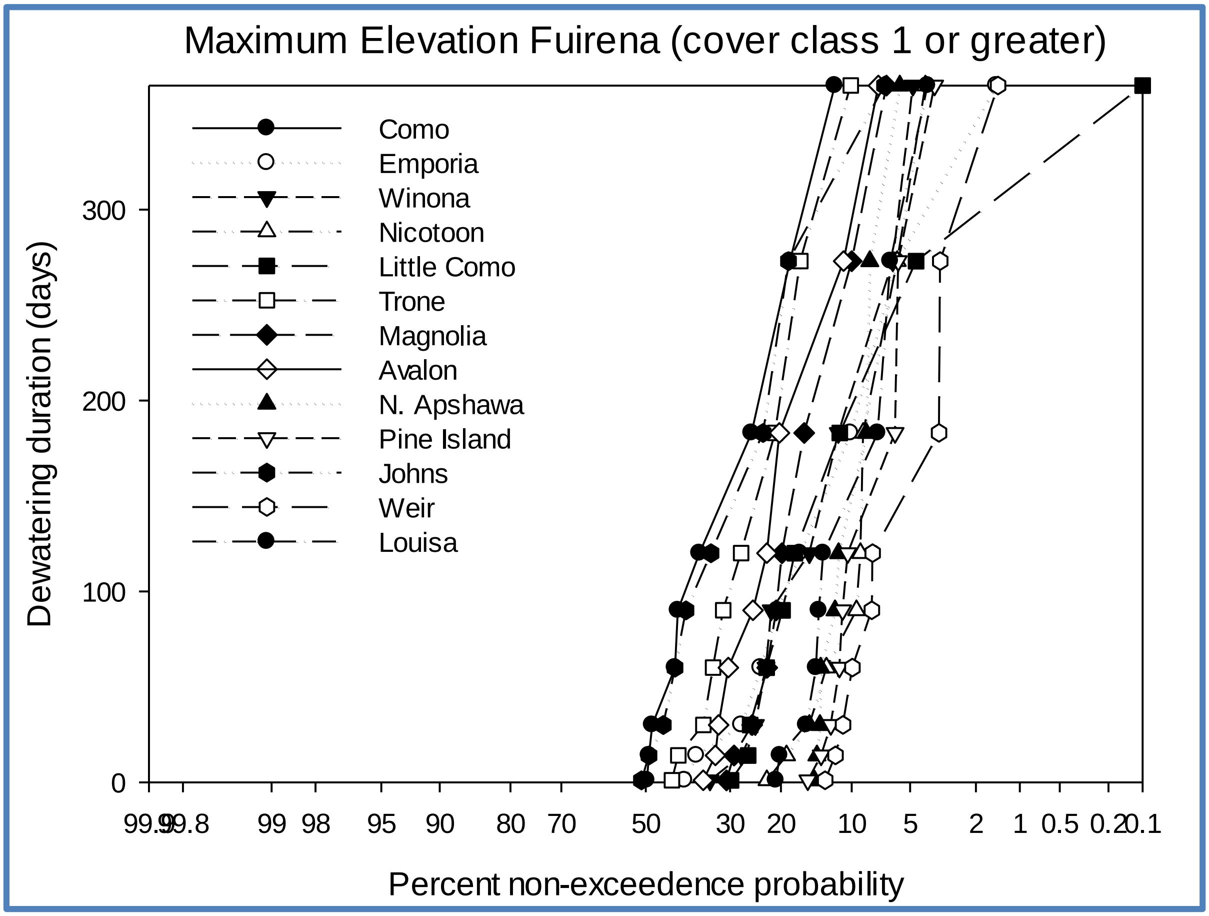


Figure 18. Hydrologic signatures for the non-exceedance probability for rush fuirena (Fuirena scirpoidia) showing proposed change in return interval for the FL at Cowpen Lake.

Fish communities in oligotrophic sandhill lakes in Florida are often dominated by centrarchids (CH2M Hill 2005). Consistent with this general pattern, the dominant sport fish species in Cowpen Lake include largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*) and redear sunfish (*Lepomis microlophus*) (Allen et al. 2002; Kinder 2002; Lakelubbers.com 2016). It is not known if other *Lepomis* spp. (e.g., warmouth [*Lepomis gulosus*]) inhabit the lake. Forage fish, that support the base of production for the fishery at Cowpen Lake, include mosquito fish (*Gambusia* spp.), shiners (*Notropis* spp.) and other small bodied species (Sutherland, personal observations). A significant positive relationship exists between prolonged inundation of littoral habitat, the provision of suitable spawning and rearing habitat, and recruitment of sport fish (Paukert and Willis 2004). Specifically, largemouth bass and sunfish (*Lepomis* spp.) recruitment has been shown to be positively related to high lake levels and inundation of littoral vegetation (Estes and Myers 1996, Bonvechio and Allen 2005, Hill and Cichra 2005, Ozen and Noble 2005).

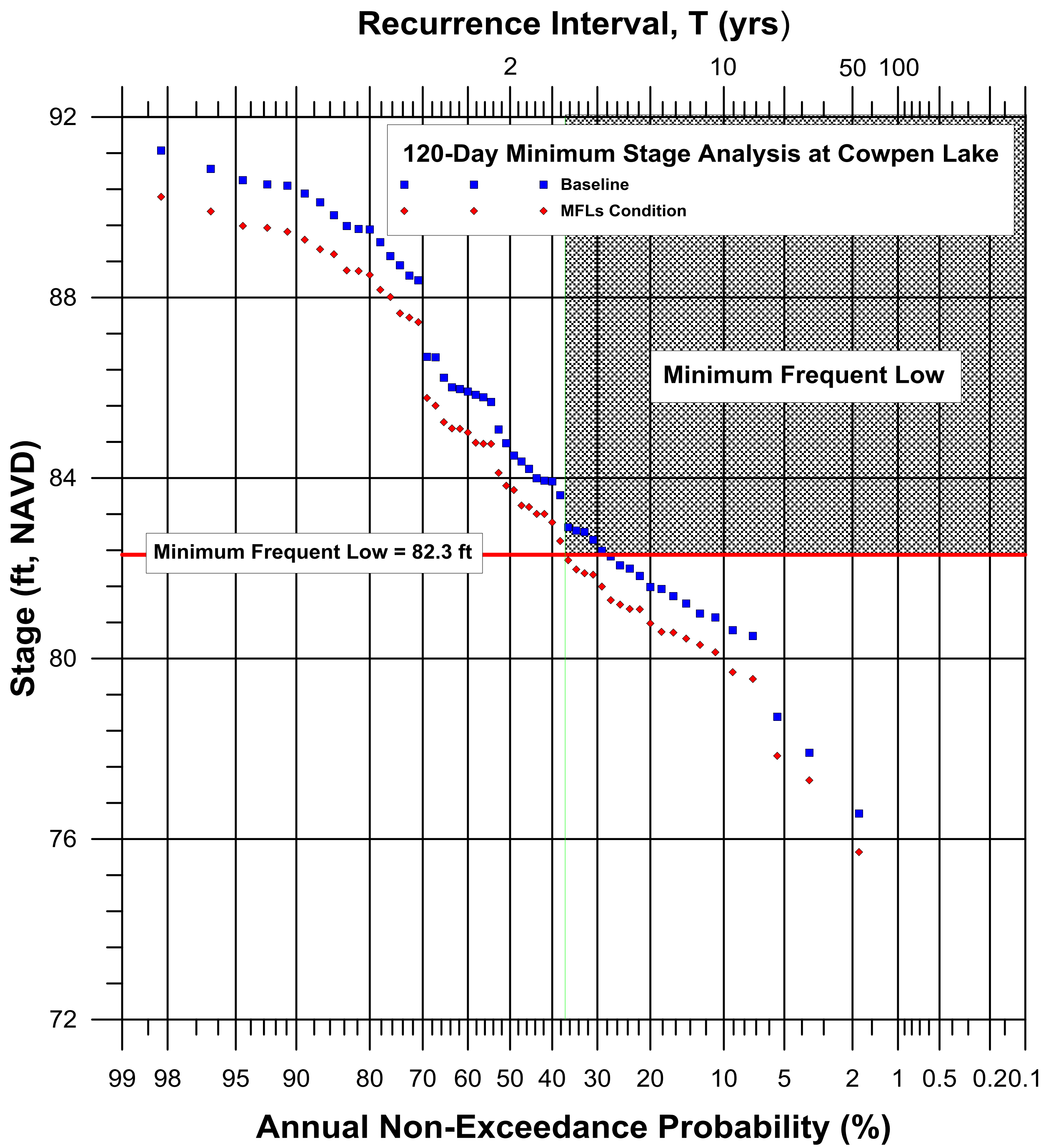


Figure 19. Frequency analysis for Cowpen Lake FL, depicting baseline condition and MFLs condition.

Fish production in Cowpen Lake, as in other oligotrophic sandhill lakes, is modest and fluctuates with long-term water levels (i.e., is positively correlated with water level; Allen Martin, FWC, pers. comm.). Because of natural environmental factors such as low productivity and low pH, fish abundance and diversity at Cowpen Lake is likely less resilient to anthropogenic disturbance, relative to more productive lakes. The maintenance of a hydrologic regime that maintains important fisheries habitat (i.e., the littoral zone) supports the long-term viability of the fish community at Cowpen Lake.

A primary mechanism for the positive relationship between littoral zone inundation and fish community health involves vegetation cover and its positive effect on structural complexity and forage, reproductive, nursery and refuge habitat. Shallow, emergent habitats provides suitable depths for nests, cover that allows game fish young-of-year and small-bodied species to avoid predation, and forage habitat for all species (Bonvechio and Allen 2005, SFWMD 2011). Structural complexity and vegetative cover are directly related to the success of largemouth bass and sunfish populations (Maceina et al. 1995, Hoyer and Canfield 1996, Trebitz and Nibbelink 1996, Paukert and Willis 2004). Largemouth bass recruitment, abundance and biomass are all positively related to extent of littoral vegetation (Durocher et al. 1984, Maceina et al. 1995, Paukert and Willis 2004). Inundation of littoral zone habitats increases largemouth bass year-class strength by providing cover and food resources for juveniles (Bonvechio and Allen 2005). Some studies, however, conclude that in some lakes fish populations (largemouth bass and other species) benefit most from an intermediate coverage of littoral vegetation (i.e., a heterogeneous mix of emergent and open-water habitats is optimal; Allen and Tugend 2002).

Just as high water levels are important for fish, periodic low levels that are related to natural drought are also essential to the maintenance of healthy fish communities (SFWMD 2011). Studies show that occasional drying and rewetting of wetland habitats can spur increased fish production, growth and recruitment (Tugend and Allen 2004, Nagid et al. 2015). Periodic dewatering of wet prairie and shrub wetland habitats at Cowpen Lake will promote increased production of forage and game fish. Inundation of dried, oxidized soil releases nutrients, stimulating primary and secondary food webs (Merritt and Cummins 1984, Kushlan 1990, Gottgens and Crisman 1991). Remineralization of nutrients via aerobic decomposition can promote increased primary production (i.e., algae and plant growth) and secondary production (Estes and Myers 1996, Allen and Tugend 2002). The resulting increase in vegetative structure and basal food resources (i.e., microbial food web) can spur low level secondary production (e.g., invertebrates), and ultimately increase the production of forage fish and larger game fish. While some drying is beneficial, too much can have deleterious effects for both plants and wildlife. In addition to maintaining the extent of the littoral zone, the recommended FL also ensures that periodic drying of habitats upslope from the littoral zone (i.e., wet prairie and transitional shrub wetlands) do not occur too often.

Wildlife forage and refugia

The preservation of shallow habitats within the littoral zone is crucial for wading birds. Wading birds (e.g., egret species, heron species, ibis, bitterns) typically forage in shallow water (0 – 9” for small species; 2 – 14” for larger species; Comiskey et al. 1998, Bancroft et al. 2002). Suitable wading bird forage habitat consists of a heterogeneous mixture of open water and emergent vegetation. The shallow margins of the emergent marshes at Cowpen Lake are dominated by *Fuirena*. These areas are ideal for wading bird prey species (e.g, aquatic insects and crayfish). Areas upslope of the littoral zone are also valuable forage for wading birds. During natural drought periods, declining water level within wet prairie and shrub wetlands will concentrate forage fish, invertebrates and amphibians, allowing birds and mammals to periodically exploit these resources. The recommended FL, based on the upper (shallow) boundary of the littoral zone will ensure the persistence of these important habitats.

Drying of wet prairie and transitional shrub habitats

In addition to protecting the long-term extent of the littoral zone, the recommended FL will also ensure that seasonally flooded communities above this elevation are not dewatered too often. The benefits, to seasonally flooded wetlands, of periodic soil exposure and drying are well known (Mitsch and Gosselink 2015). Wet prairie and shrub wetland species require an exposed or dewatered surface for germination and recruitment (Van der Valk 1981). Naturally occurring drying events enable seeds of emergent wetland plants to germinate from soil seed banks (Kushlan 1990). Exposing wet prairie and transitional shrub habitats for suitable durations maintains the relative abundance of wetland species and increases plant diversity.

CONSIDERATION OF RELEVANT ENVIRONMENTAL VALUES (62-40.473, F.A.C.)

Wetlands are highly productive communities and important habitats for fish, amphibians, wading birds, and other wildlife. Maintenance of a hydrologic regime that will sustain the characteristics, spatial distribution, and areal extent of these communities is key to maintaining fish and wildlife habitat and the ecology of wetlands and aquatic resources. The hydrologic regime defined by the IH, MA and FL MFLs maintain the events that maintain the structure and functions of these wetland systems.

Recreational use was examined by evaluating the exceedance of critical elevations under two scenarios: 1) baseline condition (see above for description), and 2) MFLs condition. The two critical recreation-based elevations examined are related to dock access and lake lobe connectedness as it relates to boat access.

Elevations were surveyed at fourteen docks around the lake and evaluated to determine the potential effects of recommended MFLs on dock access and boating-related activities. The maximum and mean elevations at the waterward pilings of docks were 83.4 and 79.8 ft NAVD, respectively (Table 4). Assuming a 2-foot draft, boats are able to access the average dock at a stage of 81.8 ft NAVD. Under baseline conditions, this lake stage corresponds to an approximate exceedance level of 80%, meaning 80 years per century lake stages are high enough under “current-impacted condition” for residents to access their docks from a boat on the water (Figure 20). Under the most constraining MFL condition, based on the IH, this lake stage corresponds to an approximate exceedance level of 75%. This means that dock access changes only 5% under the conditions set by the recommended MFLs.

Canal elevations were also evaluated to determine the potential effects of recommended MFLs on lake connectedness and recreational uses (e.g., boating, skiing and fishing). Maximum elevations for canals T4, T5 and T6 are 79.8 ft, 80.5 ft and 80.9 ft., respectively. Assuming a 2-foot draft, boats are able to move from the main body of the lake (lobe A) to lobes B and D at stages of 82.5 ft and 82.9 ft NAVD, respectively, and between lobes B and C at a stage of 81.8 ft. NAVD. These stages correspond to exceedance levels of 72%, 65%, and 80% respectively, (Figure 21). Under the most constraining MFL condition, based on the IH, these lake connection control points correspond to the 65%, 62%, and 75% exceedance levels, respectively. Therefore, access from the main body of the lake (lobe A) to the largest, deepest portion (lobe D) only changes, over the long-term, approximately 3%. Access from lobe A to lobe B changes the most (7%) and access between lobes B and C changes approximately 5%.

The change to average lake level was also examined using duration curve analysis (Figure 22). The difference between the baseline condition and the most constraining MFL (IH) condition, was small. The change in the average (median) lake level between the baseline and recommended conditions was less than 1 foot.

For more details on protection of Cowpen Lake environmental values provided by the three recommended MFLs see Appendix E.

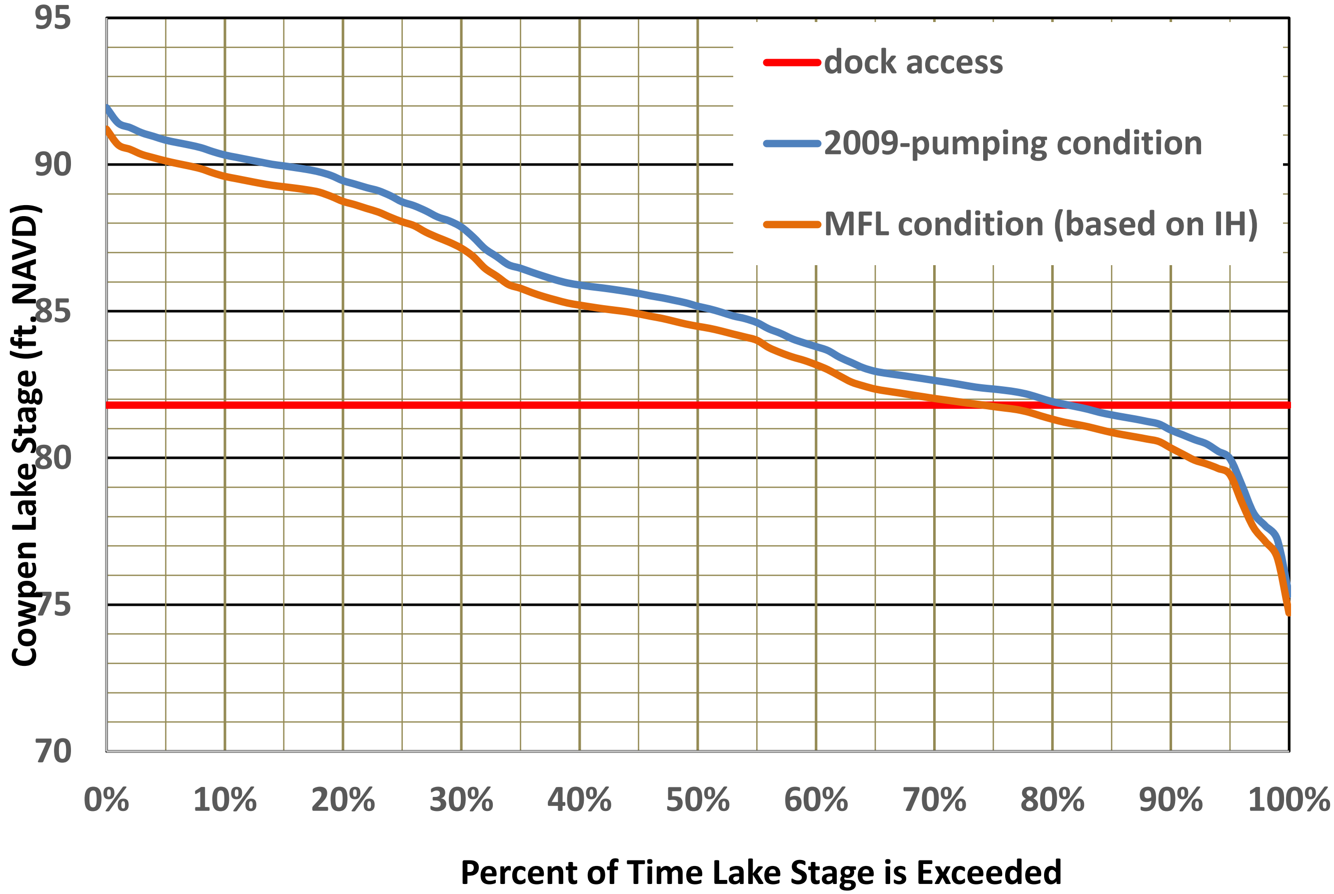


Figure 20. Cowpen Lake stage exceedance curves for baseline condition and MFLs condition (based on the IH), relative to mean waterward dock piling elevation plus 2 ft boat draft (i.e., boat access elevation)

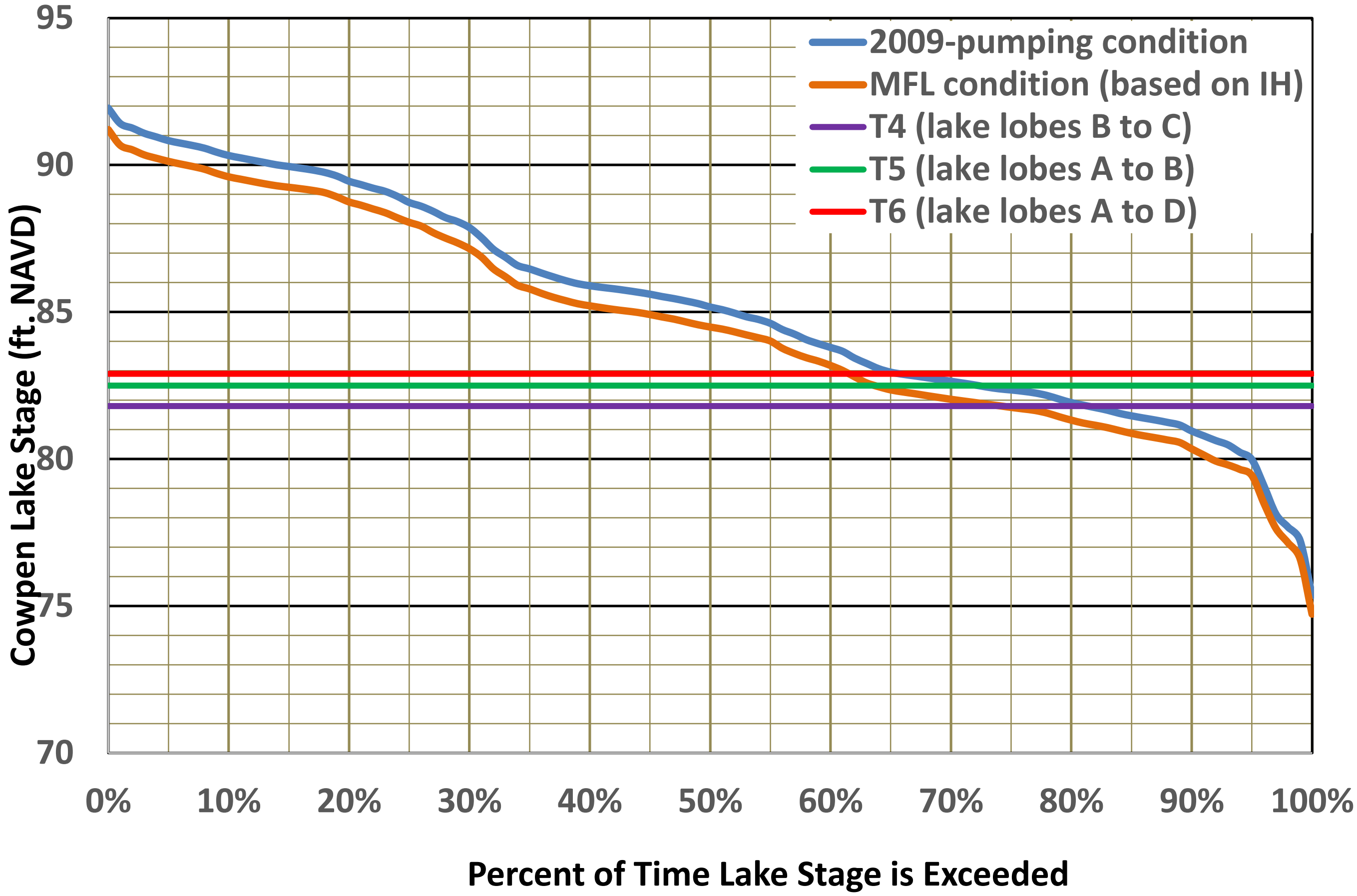


Figure 21. Cowpen Lake stage exceedance curves for baseline condition and MFLs condition (based on the IH), relative to maximum canal elevation plus 2 ft boat draft for transects T4 (lobes B to C), T5 (lobes A to B) and T6 (lobes A to D).

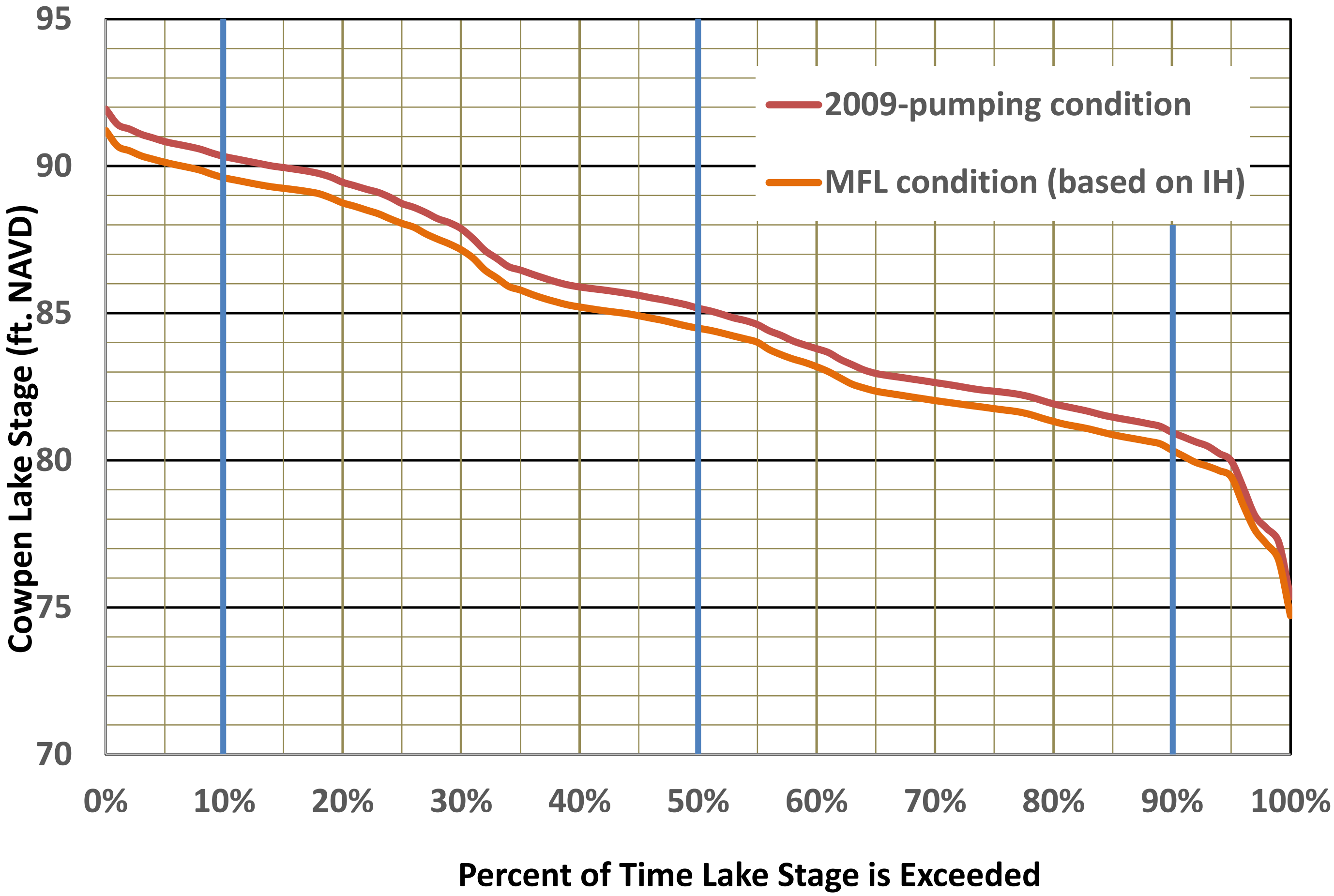


Figure 22. Cowpen Lake stage exceedance curves for baseline condition and MFLs condition (based on the IH), relative to median lake stage (P50), 10th percentile stage (P10) and 90th percentile stage (P90).

CONCLUSIONS AND RECOMMENDATIONS

MFLs were reevaluated for Cowpen Lake using an event based approach. Three levels (IH, MA and FL) based on criteria developed from elevation, soil, and vegetation data collected at the lake in 2009 and 2016 (Table 11) are recommended.

The recommended IH level (90.8 ft NAVD, 30-days, with a 25-year return interval) is based on providing a sufficient number of high water events to prevent the downhill shift of the upland ecotone and loss of open water. The recommended MA level (84.0 ft NAVD, 180-days, with a 1.7 year return interval) is based on ensuring that dewatering events do not occur too often, in order to protect deep organic soils from oxidation and subsidence. This will maintain the integrity of tree roots, and protect biogeochemical processes and wetland biota that require long term flooding or saturation. The recommended FL level (82.3 ft NAVD, 120-days, with a 2.7 year return interval) is based on maintaining the location of the littoral zone and thus protecting the long-term structure and function of fish and wildlife habitat.

Table 12. Adopted and recommended minimum surface water levels for Cowpen Lake, Florida

Minimum Levels Regime	1998 Adopted	2016 Recommended		
	Level (ft NAVD / NGVD)	Level (ft NAVD / NGVD)	Duration (days)	Return Interval (years)
Infrequent high	-	90.8 / 92.0	30	25
Frequent high	88.1 / 89.1	-	-	-
Average	84.5 / 85.7	84.0 / 85.2	180	1.7
Frequent low	83.2 / 84.2	82.3 / 83.5	120	2.7

ft NGVD = feet National Geodetic Vertical Datum 1929
ft NAVD = feet North American Vertical Datum 1988

MFLs status was assessed using frequency analysis (described in detail above) to compare the frequency of critical ecological events under baseline conditions to the frequency of those same events based on the recommended MFLs. The baseline condition represents a best estimate of current impacted condition, and for the Cowpen Lake MFL is defined as the 2009-pumping condition. Impact on the Upper Floridan Aquifer (UFA) underneath Cowpen lake due to groundwater withdrawals was estimated using the best available tool, version 3 of the Northeast Florida (NEFv3) regional groundwater model. The NEFv3 drawdown estimate represents the change in water levels in the UFA beneath Cowpen Lake from a no-pumping condition to the baseline condition. A drawdown of 2.2 ft was estimated, based on the NEFv3.

Frequency analysis was used to determine the amount of water available for withdrawal (freeboard), defined as feet of drawdown allowable in the UFA. The MFLs for Cowpen Lake are based on critical lake levels, but freeboard is determined based on the amount of change in the UFA that is allowable before the most constraining MFL is no longer achieved.

Model results and frequency analyses indicate that all three recommended MFLs for Cowpen Lake are currently being achieved under baseline conditions. Freeboards of 0.8 ft., 2.0 ft., and 1.1 ft. were calculated for the IH, MA and FL, respectively. The most constraining MFL is the IH, with a freeboard of 0.8 ft available in the UFA. Based on the best available information, including the NEFv3 groundwater model, the predicted drawdown resulting from projected water use for the 20-year planning horizon is less than 0.8 feet. Therefore, the proposed MFLs for Cowpen Lake are achieved for the 20-year planning horizon.

It is assumed that if the essential characteristics of the natural seasonal flooding and drying regimes are maintained, then the basic structure and functions of a given environmental system will be maintained. The recommended MFLs for Cowpen Lake are intended to protect the extent and composition of wetland and aquatic habitat. The IH has been developed to maintain the location of the upland ecotone resulting in no permanent down hill encroachment of uplands into the lakebed. The MA has been developed to maintain the saturation of wetland soils and vegetation. The FL has been developed to ensure that long-term maintenance of the littoral zone, the most productive habitat within the lake.

The SJRWMD concludes that the recommended MFLs, which have been developed primarily for the protection of significant harm to “fish and wildlife habitats and the passage of fish”, will protect all other relevant Rule 62-40.473, *F.A.C.*, environmental values. Because these MFLs protect the structure and function of wetlands and aquatic habitats, other functions and values related to ecological integrity (e.g., nutrient filtration, detrital transport) in Cowpen Lake will likely be protected from significant ecological harm caused by withdrawals, if the IH, MA and FL criteria are protected. In addition, environmental values related to recreational uses (boating, and fishing) will only change a small amount relative to baseline conditions (e.g., dock access changes 5%) and thus are considered protected. Finally, the change in the average (median) lake level between the baseline condition and recommended MFL condition is small (less than 1 foot. Therefore, the recommended hydrologic regime (multiple MFL events) are considered protective of all relevant environmental values for Cowpen Lake.

The recommended MFLs presented in this report are preliminary and will not become effective until adopted by the SJRWMD Governing Board as rule, in Rule 40C-8.031, *F.A.C.*

LITERATURE CITED

Adams, L. 1997. "Wetlands." Florida Department of Environmental Protection, Northeast District Office.

Aho, J. M., C. S. Anderson, and J. W. Terrell. 1986. Habitat suitability index models and instream flow suitability curves: redbreast sunfish. U. S. Fish and Wildlife Service Biological Report 82(10.119).

Allen, M. S., and K. Tugend. 2002. Effects of a large-scale habitat enhancement project on habitat quality for age-0 largemouth bass at Lake Kissimmee, Florida. Pages 265-276. In D. Phillipp and M. Ridgeway (eds.) Black Bass: Ecology, Conservation and Management. American Fisheries Society, Bethesda, Maryland.

Annett, C.A. 1998. Hunting behavior of Florida largemouth bass, *Micropterus salmoides floridanus*, in a channelized river. Environmental Biology of Fishes 53:75-87.

Bain, M.B., ed. 1990. *Ecology and Assessment of Warmwater Streams: Workshop Synopsis*. Wash, D.C.: U.S. Fish Wildlife Serv., Biol. Rep. 90(5.44).

Bancroft, G.T., S.D. Jewell, and A.M. Strong. 1990. *Foraging and Nesting Ecology of Herons in the Lower Everglades Relative to Water Conditions*, p. 139. National Audubon Society, Ornithological Research Unit, final report to the South Florida Water Management District, Environmental Sciences Division, West Palm Beach, Fla.

Battelle. 2004. Minimum Flows and Levels in the St. Johns River Water Management District. Sensitivities of "filtration and absorption of nutrients and other pollutants" and "water quality" to alterations in hydrologic regimes. Special Publication SJ2004-SP37.

Boniol, D., and C. Fortich. 2005. *Recharge Areas to the Floridan Aquifer in the St. Johns River Water Management District*, p. 41. Technical Pub. SJ93-5. Supplemental information to Boniol, D., M. Williams, and D. Munch, 1993: Mapping Recharge to the Floridan Aquifer Using a Geographic Information System. Palatka, Fla.: St. Johns River Water Management District.

Boudreau, J., K. Patel, and L. Shearin. 2004. The Effects of Wetland Filtration on the Level of Nitrates Found in Runoff. University of North Carolina at Charlotte.

[CDM] Camp Dresser and McKee Inc. 2003. Model Development for MFL Evaluation of Cowpen Lake, Putnam County. Technical memorandum (unpublished). Prepared for the St. Johns River Water Management District, Palatka, Fla.

CH2M HILL. 2005. *Preliminary Evaluation Criteria in Support of Minimum Flows and Levels for Sandhill Lakes*. Technical Pub. SJ2005-SP7. Palatka, Fla.: St. Johns River Water Management District.

Caffrey, A.J., M.V. Hoyer, and D.E. Canfield. 2006. Factors affecting the maximum depth of colonization by submersed macrophytes in Florida Lakes. University of Florida Institute of Food and Agricultural Sciences. Submitted to Southwest Florida Water Management District, August 3, 2006.

Colle D. E. and J. V. Shireman. 1980. Coefficients of condition for largemouth bass, bluegill, and redear sunfish in hydrilla infested lakes. Transactions of the American Fisheries Society. 109:521-531.

Cuffney, T.F. 1988. Input, Movement and Exchange of Organic Matter Within a Subtropical Coastal Blackwater River-Floodplain System. *Freshwater Biology* 19:305-320.

Daugherty, D.J. and N.G. Smith. 2012. Frequency of Strong Year-Classes: Implications on Fishery Dynamics for Three Life History Strategies of Fishes. North American Journal of Fisheries Management 32(6) DOI: 10.1080/02755947.2012.728177

DeWitt, N. 2004. *The Depostional History of Three Freshwater Lakes in North Central Florida: Brooklyn Lake, Levys Prairie, and Cowpen Lake.* M.S. Thesis, College of Marine Science, University of South Florida.

Durocher, P. P., W. C. Provine, and J. E. Kraai. 1984. Relationship between abundance of largemouth bass and submerged vegetation in Texas Reservoirs. North American Journal of Fisheries Management. 4:84-88.

Enfield, D.B., A.M. Mestas-Nunez, and P.J. Trimble. 2001. The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the continental U.S. Geophysical Research Letters 28(10):2077-2080.

Epting, R.J., C.P. Robison, and R.C. Reddi. 2008. Gauge record hydrologic statistics: indicators for lake classification. Environmental Bioindicators, 3:193-204.

Estes, J. R. and R. A. Myers. 1996. Lower Ocklawaha Basin Fisheries Investigations: Fish Population and Fishery Response to Habitat Change. Final Report. Wallop-Breaux F-55-9. 42 pgs.

Euliss, Ned H. Jr.; LaBaugh, James W.; Fredrickson, Leigh H.; Mushet, David M.; Laubhan, Murray K.; Swanson, George A.; Winter, Thomas C.; Rosenberry, Donald O.; and Nelson, Richard D., "The Wetland Continuum: A Conceptual Framework for Interpreting Biological Studies" (2004). *USGS Northern Prairie Wildlife Research Center.* Paper 269. http://digitalcommons.unl.edu/usgsnpwrc/269

Federal Geographic Data Committee. 2013. Classification of wetlands and deepwater habitats of the United States. FGDC-STD-004-2013. Second Edition. Wetlands Subcommittee, Federal Geographic Data Committee and U.S. Fish and Wildlife Service, Washington, DC.

Finger, T.R., and E.M. Stewart. 1987. Response of Fishes to Flooding Regime in Lowland Hardwood Wetlands. In *Community and Evolutionary Ecology of North American Stream Fishes*, W.J. Matthews and D.C. Heins, eds., p. 86–92. Norman, Okla.: University of Oklahoma Press.

(Florida LAKEWATCH. 2005), http://lakewatch.ifas.ufl.edu/MapList.htm. Accessed June 24, 2009.

Foti, R., M. del Jesus, and I. Rodriguez-Iturbe. 2012. Hydroperiod regime controls the organization of plant species in wetlands. Proceedings of the National Academy of Sciences 109(48): 596 - 600.

Gilbert, K.M., J.D. Tobe, R.W. Cantrell, M.E. Sweeley, and J.R. Cooper. 1995. *The Florida Wetlands Delineation Manual.* Tallahassee: Florida Dept. of Environmental Protection.

Gilman, E.F. and D.G. Watson. 1994. *Quercus laurifolia* Diamond Leaf Oak. US Forest Service. Fact Sheet ST-549

Gottgens, J.F., and T.L. Crisman. 1991. Newnans Lake, Florida: Removal of particulate organic matter and nutrients using a short-term partial drawdown. Lake and Reservoir Management 7(1):53–60.

Guillory, V. 1979. Utilization of an Inundated Floodplain by Mississippi River Fishes. *Florida Scientist* 42(4):222–28.

Haddon, M. 2011. Modelling and Quantitative Methods in Fisheries, Second Edition. CRC Press. 465 pp.

Hall, G. B. 1987. Establishment of minimum surface water requirements for the Greater Lake Washington basin Technical Publication No. SJ87-1 SJRWMD, Palatka, FL.

Hall, G.B. 1997. *Minimum Surface Water Levels Determined for Cowpen Lake, Putnam County.* (Appendix A attached.) Internal memorandum, August 21, 1997.

Hamilton, P. and D. Helsel, 1995. Effects of agriculture on groundwater quality in five regions of the United States. Ground Water 33:217-226.

Hill, J. E., and C. E. Cichra. 2005. Biological Synopsis of Five Selected Florida Centrarchid Fishes with an Emphasis on the Effects of Water Level Fluctuations. Special Publication SJ2005-SP3, St. Johns River Water Management District, Palatka, Florida.

Hook, D. L., 1984. Waterlogging tolerance of lowland tree species of the south. *Southern Journal of Applied Forestry*, Vol. 8, pp. 136 - 149.

Hoyer, M. V., & D. E. Canfield Jr. 1996. Largemouth bass abundance and aquatic vegetation in Florida Lakes: An empirical analysis. Journal of Aquatic Plant Management 34:23-32.

Hoyer, M.V., G.D. Israel, and D.E. Canfield, Jr. 2006. Lake User's Perceptions Regarding Impacts of Lake Water Level on Lake Aesthetics and Recreational Uses. Report submitted to the Ecological Evaluation Section, Resource Conservation and Development Department, Southwest Florida Water Management District, Brooksville, FL.

Huffman, R.T. 1980. *The Relation of Flood Timing and Duration to Variation in Selected Bottomland Hardwood Communities of Southern Arkansas*. Misc. Paper EL-80-4:22. Vicksburg, Miss.: U.S. Army Engineer Waterways Experiment Station.

[JEA Inc.] Jones, Edmunds and Assoc. Inc. 2006 (unpublished). Sandhill Lakes Minimum Flows and Levels: Values, Functions, Criteria, and Thresholds for Establishing and Supporting Minimum Levels. Technical memorandum. Prepared for the St. Johns River Water Management District by Jones, Edmunds and Assoc. Inc., Gainesville, Fla.

Junk, W.J., P.B. Bayley and R.E. Sparks. 1989. The Flood Pulse Concept in River-Floodplain Systems. In Proceedings of the International Large River Symposium, D.P. Dodge, ed. *Can. Spec Publ. Fish. and Aquat. Sci*.

Keet, S. 2005. Live Oaks: The Oldest Citizens of Conway South Carolina. http://www.associatedcontent.com/article/6796/live_oaks_the_oldest_citizens_of_conway.html

Kinder, L. 2002. Flyfisher's guide to freshwater Florida. Wilderness Adventures Press. 444 pp.

Kinser, 2012. Chapter 10- Wetland Vegetation, Appendix 10b, in St Johns River Water Management District Water Supply Impact Study, http://floridawater.com/technicalreports/pdfs/TP/SJ2012-1 Appendix10-B.pdf

Kushlan, J. A. 1990. Freshwater Marshes. Page 341 in R. L. Myers and J. J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

Kushlan, J.A. and M.S. Kushlan. 1979. Observations on Crayfish in the Everglades, Florida. *Crustaceana Suppl*. 5:116–20.

Labaree, J. 1992. *How Greenways Work: A Handbook on Ecology*. Ipswich, MA. 2nd edition.

Lakelubbers LLC. 2016. Website article; no author listed; *http://www.lakelubbers.com/cowpen-lake-1275/*

Larson, J. S., M. S. Bedinger, C. F. Bryan, S. Brown, R. T. Huffman, E. L. Miller, D. G. Rhodes, and B. A. Touchet. 1981. Transition from wetlands to uplands in southeastern bottomland hardwood forests. *Wetlands of bottomland hardwood forests: Proceedings of a workshop on bottomland hardwood forest wetlands of the southeastern United States*. Clark, J. R. and J. Benforado eds. pp. 225-273. Elsevier Scientific Publishing Company.

Light, H.M., M.R. Darst, and J.W. Grubbs. 1998. *Aquatic Habitats in Relation to River Flow in the Apalachicola River Floodplain, Florida.* Professional Paper 1594. Tallahassee, Fla.: U.S. Geological Survey.

Light, H. M., M. R. Darst, M. T. MacLaughlin and S. W. Sprecher. 1993. Hydrology, vegetation, and soils of four north Florida river flood plains with an evaluation of state and federal wetlands determinations. *U. S. Geological Survey. Water Resources Investigation Report 93-4033*. Tallahassee, Florida.

Maceina, M. J., S. J. Rider, and S. T. Szedlmayer. 1995. Density, temporal spawning patterns and growth of age-0 and age-1 largemouth bass in vegetated and unvegetated areas of Lake Guntersville, Alabama. Pages 497-511 in D. H. Secor, J. M. Dean, and S. E. Campana, editors. Recent developments in fish otolith research. University of South Carolina Press, Columbia.

McArthur, J.V. 1989. Aquatic and Terrestrial Linkages: Floodplain Functions. In *Proceedings of the Forested Wetlands of the United States; July 12-14, 1988*, D.D. Hook and L. Russ, eds., p. 107–116. Gen. Tech. Rep. SE-50. Asheville, N.C.: U.S. Forest Service, Southeastern Forest Experiment Station.

McGurk, B., and P.F. Presley. 2002. *Simulation of the Effects of Groundwater Withdrawals on the Floridan Aquifer System in East-Central Florida: Model Expansion and Revision.* Technical Pub. SJ2002-3. Palatka, Fla.: St. Johns River Water Management District.

Merritt, R.W. and K.W. Cummins. 1984. *An Introduction to the Aquatic Insects of North America.* 2nd ed. Dubuque, Iowa: Randal/Hunt Publishing Co.

Miranda, L.E., and L.L. Pugh. 2011. Relationship between vegetation coverage and abundance, size, and diet of juvenile largemouth bass during winter. North American Journal of Fisheries Management 17(3) 601 – 610.

Mitsch, W.J. and J.G. Gosselink. 2015. *Wetlands.* 5th ed. John Wiley and Sons, Inc. Hoboken, New Jersey.

Moore, W. H. 1980. Survival and growth of oaks planted for wildlife in the flatwoods. *U. S. Department of Agriculture Forest Service Research Note SE – 286.* Southeastern Forest Experiment Station. Asheville, North Carolina. U. S. Government Printing Office: 1980-640-190/4531. Region 4.

Murray-Hudson, M. P. Wolski, F. Murray-Hudson, M.T. Brown, and K. Keotshephile. 2014. Disaggregating hydroperiod: components of the seasonal flood pulse as drivers of plant species distribution in floodplains of a tropical wetland. Wetlands 34:927-942.

Neubauer, C.P., G.B. Hall, E.F. Lowe, C.P. Robison, R.B. Hupalo, and L.W. Keenan. 2008. Minimum Flows and Levels Method of the St. Johns River Water Management District, Florida, USA. Environmental Management 42(6): 1101-1114.

[NRCS] 2008. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. Available URL: "http://soils.usda.gov/technical/classification/osd/index.html" [Accessed 10 February 2008]. USDA-NRCS, Lincoln, NE. (Placid series).

Ozen, O. and R.L. Noble. 2005. Relationship between largemouth bass recruitment and water level dynamics in a Puerto Rico reservoir. Lake and Reservoir Management 21(1): 89-95. DOI: 10.1080/07438140509354416

Paukert, C. P. and D. W. Willis. 2004. Fisheries Management and Ecology. 11:345-352.

Phillips, P.J., J.M. Denver, R.J. Shedlock, and P.A. Hamilton, 1993. Effect of forested wetlands on nitrate concentrations in groundwater and surface water on the Delmarva Peninsula. Wetlands 13:75-83.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The Natural Flow Regime—A Paradigm for River Conservation and Restoration. *Bioscience* 47(11):769–84.

Ross, S.T. and J.A. Baker. 1983. The Response of Fishes to Periodic Spring Floods in a Southeastern Stream. *American Midland Naturalist* 109(1):1–14.

Sammons, S.M., M.J. Maceina, and D.G. Partridge. 2003. Changes in behavior, movement, and home ranges of largemouth bass following large-scale Hydrilla removal in Lake Seminole, Georgia. Journal of Aquatic Plant Management 41:31-38.

Schneider, R.L., and R.R. Sharitz. 1986. Seed Bank Dynamics in a Southeastern Riverine Swamp. *American Journal of Botany* 73(7):1022–30.

South Florida Water Management District. 2011. 2011 Interagency Draft Kissimmee Chain of Lakes Long-Term Management Plan. SFWMD.

[SJRWMD] Hydrologic Data Services. St. Johns River Water Management District. Division of Hydrologic Data Services, Palatka, Fla.

SJRWMD. 2006 (draft). Minimum Flows and Levels Methods Manual. G.B. Hall, C.P. Neubauer, and C.P. Robison, eds. St. Johns River Water Management District, Palatka, Fla.

[SSURGO] Soil Survey Geographic Database. Soil Survey Staff, Natural Resources Conservation Service, U. S. Dept. Agriculture. Soil Survey Geographic Database for Orange County, Florida.

Strayer, D.L. and S.E.G. Findlay, 2010. Ecology of freshwater shore zones Aquatic Sciences 72: 127. doi:10.1007/s00027-010-0128-9

Trebitz, A.S. and N. Nibbelink. 1996. Effect of pattern of vegetation removal on growth of bluegill: a simple model. Canadian Journal of Fisheries and Aquatic Sciences 53:1844-1851.

Van der Valk, A.G. 1981. Succession in Wetlands: A Gleasonian Approach. *Ecology* 62:688–96.

Vince, S. W., S. R. Humphrey and R. W. Simons. 1989. *The ecology of hydric hammocks: a community profile.* U. S. Fish Wildl. Serv. Biol. Rep. 85 (7.26). 81 pp.

Ware, C. 2003. Minimum Flows and Levels Plant Ecology Series: Ecological Summaries of Plants Commonly Encountered Duriing Minimum Flows and Levels Determinations. No. 9 *Quercus virginiana* (Live Oak). St. Johns River Water Management District. Palatka, Florida.

Welsch, D.J., D.L. Smart, J.N. Boyer, P. Minken, C. Howard and T.L. McCandless. 1995. Forested Wetlands: Functions, Benefits and the Use of Best Management Practices. NA-PR-01-95. [Radnor, PA:] U.S. Dept. of Agriculture, Forest Service, Northern Area State & Private Forestry

White, W. 1970. *The Geomorphology of the Florida Peninsula*. State of Florida Department of Natural Resources. Bureau of Geology. Geological Bulletin No. 51. Tallahassee, Florida.

Wiley, M. J., R. W. Gorden, S. W. Waite, and T. Powless. 1984. The relationship between aquatic macrophytes and sport fish production in Illinois Ponds: a simple model. North American Journal of Fisheries Management. 4:111-119.

Winfield, I.J. 2004. Fish in the littoral zone: ecology, threats and management. Limnologica – Ecology and Management of Inland Waters 34(1-2): 124-131.

APPENDIX A—1997 COWPEN LAKE MFLS REPORT

MEMORANDUM

DATE: April 21, 1996

TO: Jeff Elledge, P.E., Director
Department of Resource Management

THROUGH: Charles A. Padera, Director
Department of Water Resources

for Edgar F. Lowe, Ph.D., Director
Division of Environmental Sciences

FROM: G. B. (Sonny) Hall, Ph.D., Technical Program Manager
Division of Environmental Sciences

RE: Minimum Surface Water Levels Determined for Cowpen Lake, Putnam County
(Project # 01-43-00-5161-10900)

The purpose of this memorandum is to forward recommended minimum levels determined for Cowpen Lake, Putnam County (Table 1) to the Department of Resource Management. Cowpen Lake was selected for investigation because it is one of the 115 priority lakes identified by the Minimum Flows and Levels Project Plan.

Table 1. Recommended minimum surface water levels for Cowpen Lake, Putnam County. Terminology is defined in 40C-8.021, Florida Administrative Code (F.A.C.).

Minimum Level	Elevation (ft NGVD)	Hydroperiod categories
Minimum Frequent High Level	89.1	Temporarily flooded
Minimum Average Level	85.7	Typically saturated
Minimum Frequent Low Level	84.2	Semipermanently flooded

Cowpen Lake is within the Interlachen Sandhills Physiographic Division of the Central Lakes District (Brooks 1982) in a region of relatively low (0-4 inches/year) aquifer recharge (Boniol et al., 1993). The lake is located approximately 4.9 miles east of Hawthorne, in Putnam County (Figure 1), situated in a landscape of rolling sandhills with rural development.

HYDROLOGY AND LAKE MORPHOMETRY

A record of daily lake levels exists from July 1986 through March 1995 (Figure 2). The mean lake level for the period of record is 84.58 ft NGVD. The lake has fluctuated 8.0 ft with a maximum stage of 89.21 ft NGVD (March 31, 1987), and a minimum stage of 81.24 ft NGVD

(August 2, 1992). The water level was 84.82 ft NGVD on the day that field work for this determination was completed (March 18, 1997). Historical aerial photography indicates that Cowpen Lake has experienced an even greater range of fluctuation than shown in the hydrologic record (Figure 3). Surface waters appear to be well above 92 feet on the 1942 aerial photography. Cowpen Lake has not fully recovered from the record low levels associated with the recent drought.

Cowpen Lake is a closed lake basin with no surface water inflows or outflows. The lake has an open water area of approximately 584 acres when the lake stage is at 89 ft NGVD. There is at least one public access boat ramp on this lake. The lake consists of at least five separate basins (hydrographic map, Figure 1). We examined the physical connections between the four major lake lobes (Figures 1 and 3 [1994]; lobes A, B, C, and D). During drought conditions, the four lake lobes can become isolated. The main lake lobe (A) becomes separated from lobes B and D at stages below 82.0 and 81.8 ft NGVD, respectively. Lobes B and C become separated at lake stages below 81.2 ft NGVD. These elevations correspond to the shallowest depths recorded while depth sounding the connections between the lake lobes.

No surface water consumptive use permits exist on the lake. However, permitted water uses occur from the Floridan aquifer in the uplands within a mile radius of Cowpen Lake (9 wells in Sections 21, 22, 27, and 28, Township 10 South, Range 23 East - personnel communication, Helen Cleveland, Division of Permit Data Services, SJRWMD).

No surface water budget model exists for Cowpen Lake.

Hydric Soils

One hydric soil type was delineated by SCS adjacent to Cowpen Lake. Placid fine sand, depressional (map unit No. 5, Figure 4) has an aerial extent of approximately 151 acres. This soil is very poorly drained, nearly level and occurs in wet depressions of flatwoods and other uplands. The surface layer is typically black and very dark gray fine sand about 14 inches thick over a dark grayish brown fine sand. In most years, the water table is above the soil surface for more than six months. The natural vegetation includes cypress, sweetgum, blackgum, bay, red maple, and wax myrtle. Some areas have marsh vegetation consisting mostly of maidencane, sawgrass and other water tolerant plants (SCS 1990). Included with this soil are small areas of muck soils. We observed such muck layers on shallow islands that form the shallow connections between the lake lobes (see Transect 2, Figure 7).

Wetlands and Littoral Zone Vegetation

Wetlands at Cowpen Lake were classified by the USBS National Wetland Inventory (NWI) as lacustrine, littoral, aquatic bed, rooted vascular, permanently flooded (L2AB3H). These areas are associated with the littoral zone of the lake and the many scattered islands within the lake basin. The open water area of the lake was classified as lacustrine, limnetic, open water, permanently flooded (L1OWH; Figure 5).

Elevation, vegetation, and soil information were collected from three transects. Transect 1 (T1; Figures 1 and 6) was located along the northeast shore of lobe B, and extended from oak hammock, across wet prairie, emergent marshland, to the aquatic bed communities. Transect 2 (T2; Figures 1 and 7) was located on an island which is part of the shallow isthmus that separates lobes A and B during drought conditions. This transect extended from emergent aquatic bed vegetation, and across a maidencane marsh. Transect 3 (T3; Figures 1 and 8) was located on the southwest shore on lobe A, and extended from the lake emergent littoral zone, across emergent marsh and to upland oak hammock. Additional soundings were made at approximately 5-10 ft intervals across the shallow connections between the lobes to determine the hydraulic controls (Transect T4, T5 and T6; Figure 1). Summary elevation data from plant communities, common plant species, and other features are summarized in Table 2. Scientific plant names are provided in Table 3.

Table 2. Spot, mean, maximum, and minimum elevations (ft NGVD) of important features measured at Cowpen Lake.

Location	Feature	n	Mean	Max	Min
Lake	Lake stage record (1986-1995)	2822	84.58	89.21	81.24
Lake	Shallowest elevation between lake lobes B and C	10	80.7	79.9	81.2
Lake	Waterward edge of torpedo grass	4	81.1	81.3	81.0
Lake	Waterward edge of rush fuirena	24	81.4	81.8	80.6
Lake	Shallowest elevation between lake lobes A and D	16	81.5	81.5	81.8
Lake	Shallowest elevation between lake lobes A and B	39	81.7	81.1	82.0
Lake	Water depth at the waterward edge of docks (ft). Values in parentheses are ground elevations.	23	2.3 (82.5)	6.8 (78.0)	0.2 (84.6)
Transect 1	Emergent littoral zone	4	83.4	84.2	82.7
Transect 3	Emergent littoral zone	5	83.9	84.5	83.5
Transect 3	Emergent marsh - seasonal high water zone	10	85.8	87.3	84.5
Transect 2	Emergent marsh - area of muck soils	19	85.9	86.6	84.4
Transect 1	Emergent marsh -seasonal high water zone	10	86.4	88.3	84.2
Transect 3	Wet prairie - transitional zone of historical high water	5	88.9	90.7	87.5
Transect 1	Wet prairie - transitional zone of historical high water	4	89.3	90.6	88.3
Lake	Top of deck elevation	23	92.7	95.6	90.3

Table 3. Plant list from transects and observations at Cowpen Lake, March 18, 1997.

SPECIES	COMMON NAME	DEP
Acer rubrum	red maple	FACW
Amphicarpum muhlenbergianum	blue-maidencane	FACW
Andropogon sp.	bluestem grass	
Centella asiatica	coinwort	FACW
Cladina evansii	deer moss lichen	NA
Eupatorium capillifolium	dog fennel	FAC
Fuirena scirpoidea	rush fuirena	OBL
Galactia sp.	milk-pea	UPL
Gordonia lasianthus	loblolly bay	FACW
Hydrocotyl umbellata	umbrella pennywort	FACW
Hypericum fasciculatum	marsh St. Johnswort	OBL
Ilex glabra	inkberry	UPL
Leersia hexandra	southern cutgrass	OBL
Ludwigia suffruticosa	headed-seedbox	FACW
Lycopodium sp.	clubmoss	FACW
Magnolia virginiana	sweetbay	OBL
Mayaca fluviatilis	bog moss	aquatic
Myrica cerifera	wax myrtle	FAC
Nuphar luteum	spatter-dock	OBL
Nymphoides aquatica	floatingheart	OBL
Opuntia humifusa	prickly-pear cactus	UPL
Panicum hemitomon	maidencane	OBL
Panicum repens	torpedo grass	FACW
Pinus elliottii	slash pine	UPL
Pontederia cordata	pickerelweed	OBL
Quercus laurifolia	laurel oak	FACW
Quercus virginiana	Virginia live oak	UPL
Rubus betulifolius	blackberry	FAC
Sapium sebiferum	chinese tallow-tree	FAC
Smilax glaucescens	greenbrier	UPL
Syngonanthus flavidulus	bantam-buttons	FACW
Vitis rotundifolia	muscadine grape	UPL
Websteria confervoides	water-meal	OBL
Xyris sp.	yelloweye-grass	OBL-FACW

MINIMUM LEVEL DETERMINATIONS

The recommended minimum levels for Cowpen Lake are based on consideration of elevation, vegetation, and soil transects and spot elevation data collected by Division of Environmental Sciences and Division of Surveying staff using the lake water level (determined from benchmark No. TBM 625-20, F.B. 87-79 pg. 1, published elevation 94.217 ft NGVD) as the elevation datum.

The recommended minimum levels are based upon consideration of biological features associated with long-term typical water levels. Three levels with corresponding hydroperiod categories are recommended. A short description of the functions of each level and some of the related data used in the determination follows.

Minimum Frequent High Level

The recommended Minimum Frequent High Level is 89.1 ft. NGVD with an associated hydroperiod category of Temporarily Flooded. This water level corresponds to the average elevation of the transitional zone (wet prairie community) on Transects 1 and 2 (Table 2; Figures 5 and 6). It maintains the spatial extent and functions of the wet prairie and shallow marsh communities and allows sufficient water depths for fish and other aquatic organisms to feed and spawn on the lake floodplain. This lake stage floods the average elevation of the emergent marsh at Transect 2 (85.9 ft NGVD; Table 2) to a depth of 3.2 ft. The emergent littoral zone will be flooded, on average, to a depth of approximately 5.4 ft (83.7 ft NGVD based on average of 3 means), providing cover and foraging habitat along the littoral zone of the lake.

This level provides a broad hydrologic connection among the lake lobes. The emergent marshes along the shallow connections between the lake lobes will be completely inundated to depths of 3 to 4 feet. Water depths at the terminus of docks on Cowpen Lake will average 6.6 feet and the average dock height above the water surface is 3.6 feet at this recommended minimum level. Additionally, this level maintains saturated soil conditions for the transition zone (Figure 5) along the upland edge.

Minimum Average Level

The recommended Minimum Average Level is 85.7 ft. NGVD with an associated hydroperiod category of Typically Saturated. This level and the hydroperiod category approximate a "typical" level that is slightly less than the long-term median water level. It maintains saturated soils throughout the emergent marsh zone, protecting hydric soils and vegetation. This level was calculated by subtracting 0.25 ft from the mean elevation of the muck soil (emergent marsh) on Transect 2 (85.9 ft NGVD; Figure 7). Stephens (1974) demonstrated that oxidation and subsidence of peat soils occurred when the mean elevation of the water table was more than 0.25 feet below the soil surface for extended periods. This criterion has been used within other basins within the District for the protection of hydric soils and vegetation (Hall, 1987).

This level maintains a hydrologic connection among the lake lobes; with 3.7 ft between A and B, 3.9 ft between A and D, and 4.5 ft between B and C. The recommended level would allow passage of large fish between the lake lobes and provides sufficient water depths for refugia, nesting and foraging habitat for aquatic fauna. The littoral zone of rush fuirena, maidencane and cutgrass (mean elevation 83.7 ft NGVD) will be flooded, on average, to depths of 2.1 ft, providing cover and foraging habitat along the littoral zone of the lake. Additionally, the recommended minimum level maintains saturated soil conditions within the emergent wetland zone, inhibiting the invasion of upland species.

Water depths at the terminus of docks on Cowpen Lake will average 3.2 feet and the average dock height above the water surface is 7.0 feet at this recommended minimum level.

Minimum Frequent Low Level

The recommended Minimum Frequent Low Level is 84.2 ft. NGVD with an associated hydroperiod category of Semipermanently Flooded. This level provides important refugia for forage and young-of-the-year fish during mild drought conditions, and recognizes that occasional drawdown conditions are necessary for wetland vegetation zones to experience soil decomposition and seed germination. This level was based on the mean elevation of the surveyed emergent marsh (area of muck soils) on Transect 2 (85.9 ft NGVD) minus 1.7 feet. The Putnam County soil survey describes the typical dry season low water table of many muck soils as less than 10 to 12 inches below the soil surface. A moderate drought is expected to lower the water table more than 1 ft. A lake level of 84.2 ft NGVD results in a water table 1.7 ft below the muck soil surface. We consider this to be a reasonable limit for organic soils during a moderate drought.

A lake level of 84.2 ft NGVD exposes the shallow marsh community (area of muck soils), while maintaining a flooded condition in the emergent littoral zone vegetation (average elevation 83.7 ft NGVD and water depth 0.5 ft). Additionally, this level is 2.8 feet above the average elevation of the waterward extent of rush fuirena (81.4 ft NGVD). The waterward rush fuirena line is a reasonable indicator of drawdown levels that may occur during extreme drought events. Corroborating evidence is the average elevation of the waterward extent of torpedo grass 81.1 ft NGVD (Table 2). Additionally, Great Egrets need water depths less than 0.8 ft and the small herons need water depths less than 0.5 ft to forage efficiently when water levels are receding (Bancroft et al. 1990). Appropriate depths for these wading birds would occur along the ecotones between the emergent marshes and the littoral zone communities.

This level does not result in the separation of any of the major lake lobes. Water depths would exceed 2 ft in the channels connecting the major lobes. Several smaller lobes would become isolated. Historically, lobes A and D and A and B became isolated at this water level. However, the creation of artificial channels for boat passage have allowed for boat and fish passage during moderate droughts. Water depths at the terminus of docks on Cowpen Lake will average 1.7 feet and the average dock height above the water surface is 8.5 feet at this recommended minimum level.

Please call me (x4368), Jane Mace (x4389) or Ric Hupalo (x4338) if you wish to discuss these minimum levels or hydroperiod definitions.

LITERATURE CITED

Bancroft, G.T., S.D. Jewell, and A.M. Strong. 1990. Foraging and nesting ecology of herons in the Lower Everglades relative to water conditions: Final Report to the South Florida Water Management District. National Audubon Society, Ornithological Research Unit. pp. 139.

Brooks, H.K. 1982. Guide to the Physiographic Divisions of Florida; compendium to the map Physiographic Divisions of Florida, 8-5M-82. Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, Fl.

Boniol, D., M. Williams, and D. Munch. 1993. Mapping recharge to the Floridan aquifer using a geographical information system. Technical Publication SJ93-5. St. Johns River Water Management District. 41 pp.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. U.S. Fish and Wildlife Service, Washington, D.C.

Hall, G.B. 1987. Establishment of Minimum Surface Water Requirements for the Greater Lake Washington Basin. Technical Publication No. SJ 87-1, St. Johns River Water Management District, Palatka, FL.

SCS. 1990. Soil Survey of Putnam County, Florida. U.S. Department of Agriculture Soil and Conservation Service.

Stephens, J.C. 1974. Subsidence of organic soils in the Florida Everglades - a review and update. In: Gleason, P.J. (ed.), Environments of South Florida, Memoir 2, Miami Geological Society, Miami, FL.

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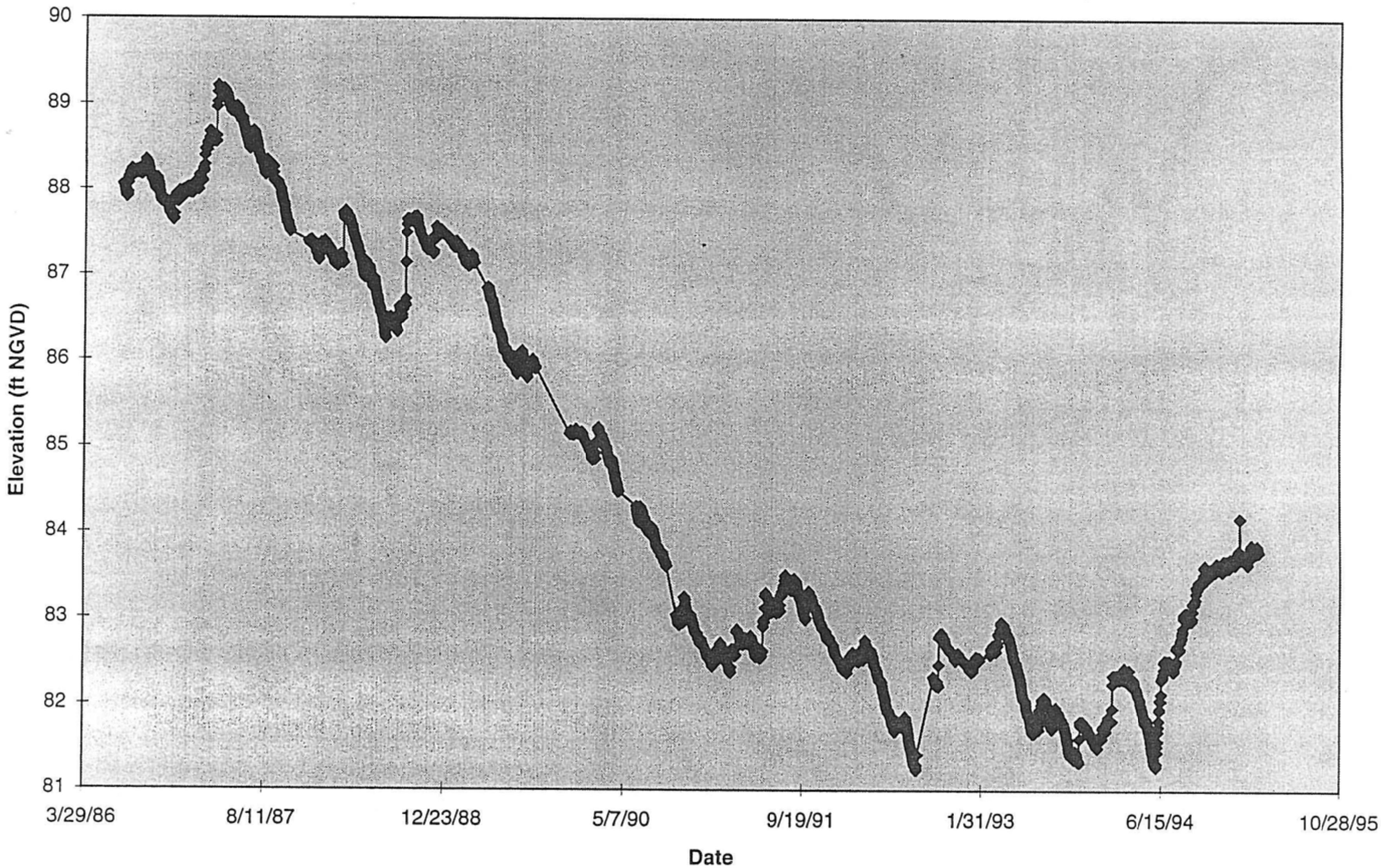
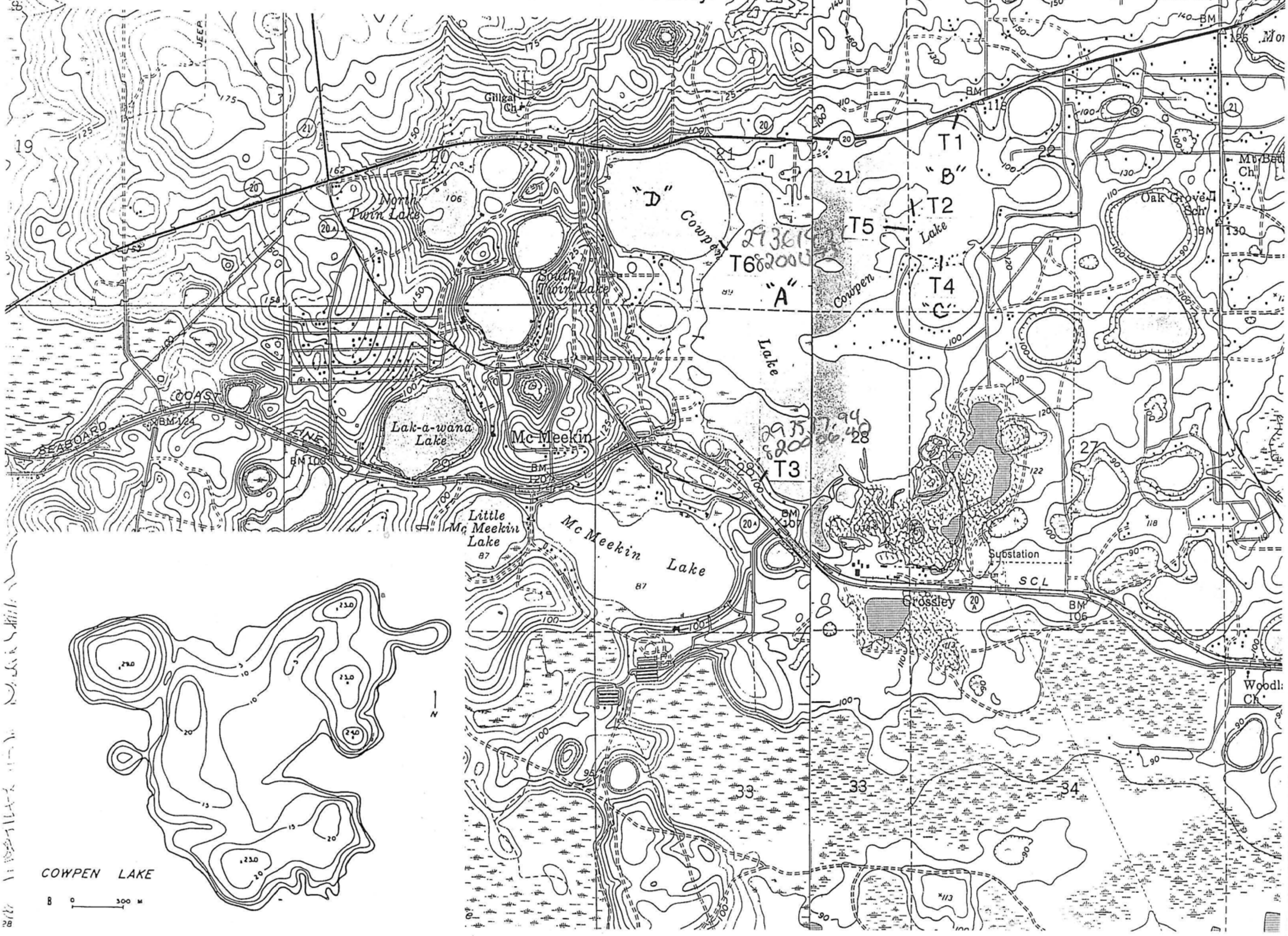
c:	Kathryn Mennella	Hal Wilkening	Tommy Walters	Cliff Neubauer
	Ric Hupalo	Jane Mace	Dave Clapp	Price Robison
	Larry Fayard	Chris Sweazy	Sandy McGee	

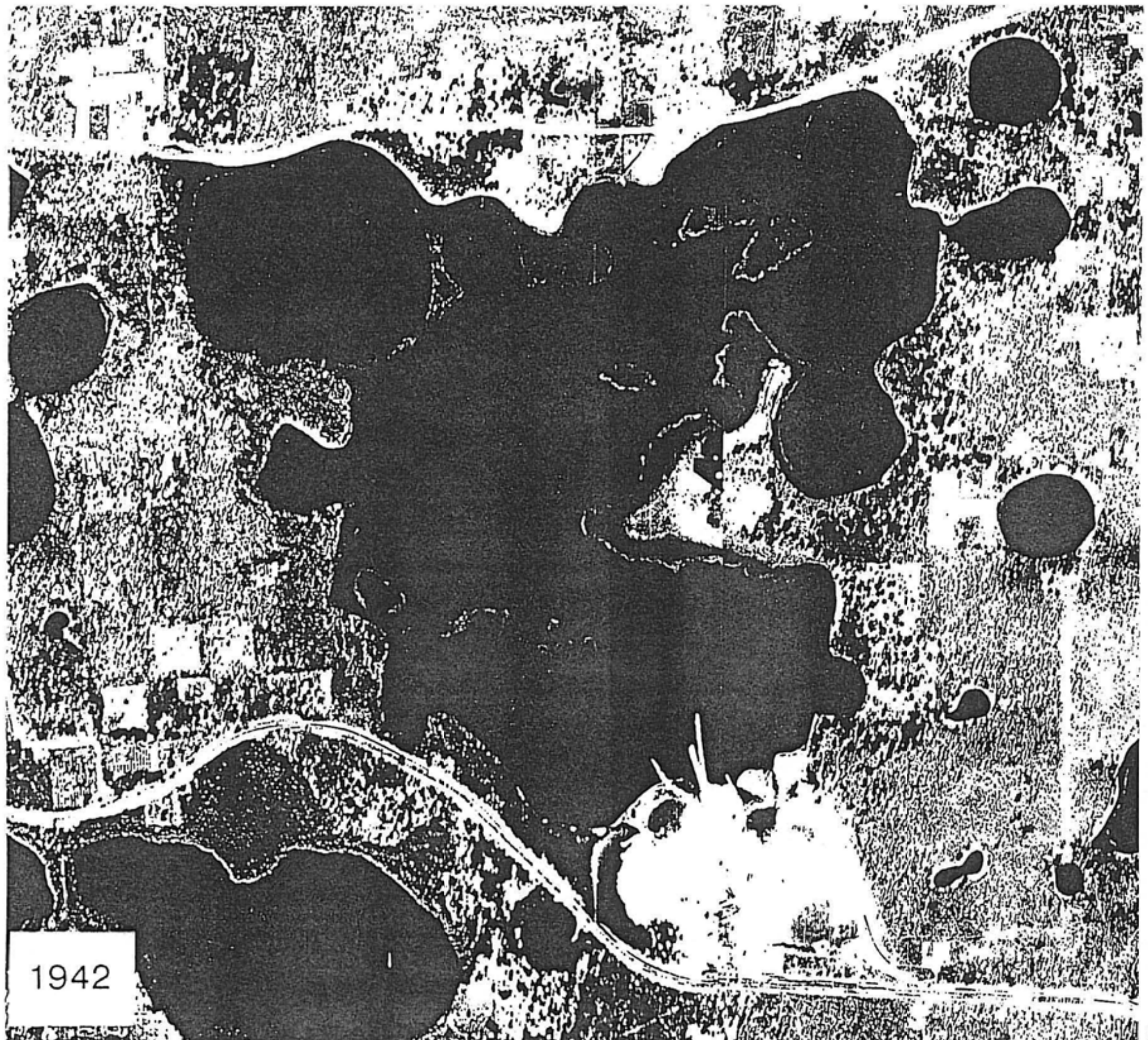
Figure 2. Hydrograph for Cowpen Lake - July 1986 to March 1995.

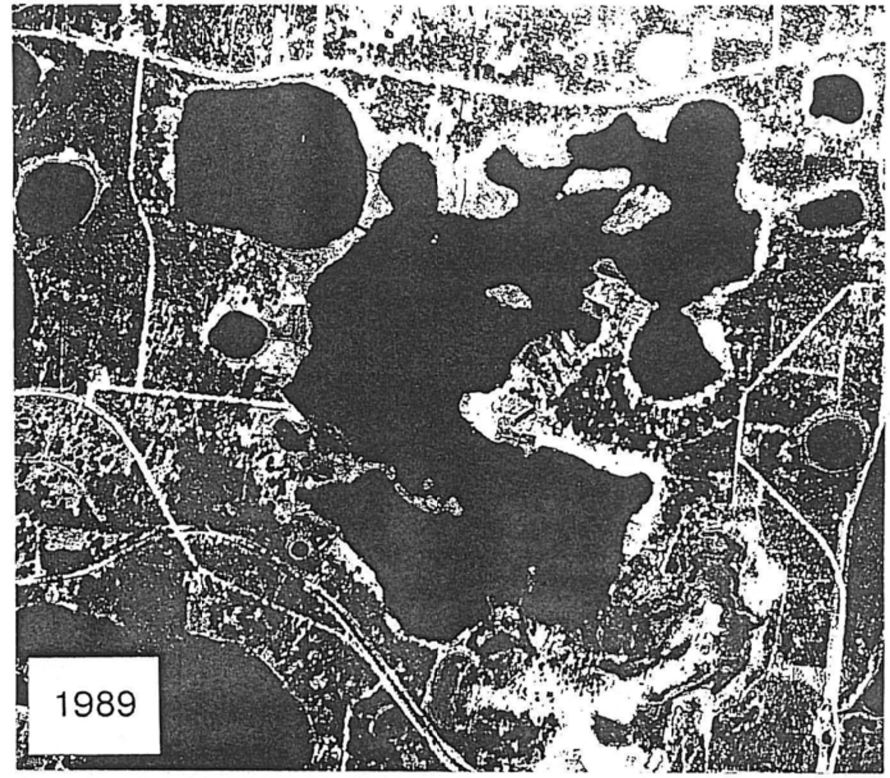


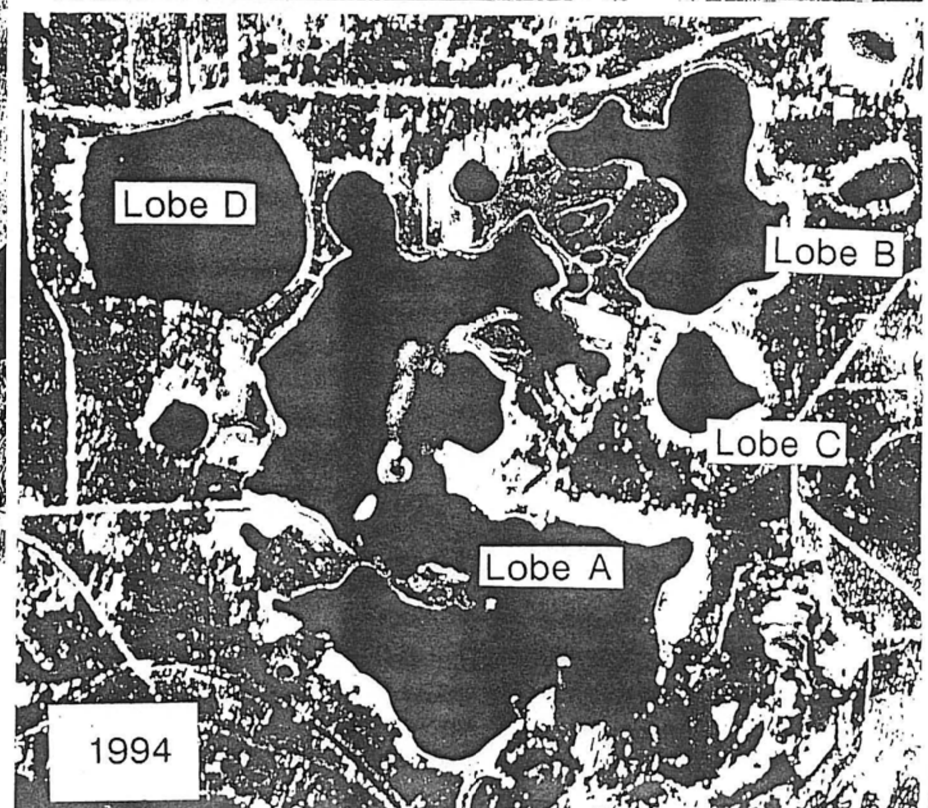
Figu 1. Location map for Cowpen Lake, Putnam County.



F 'e 3. Aerial photographs of Cowpen Lake.







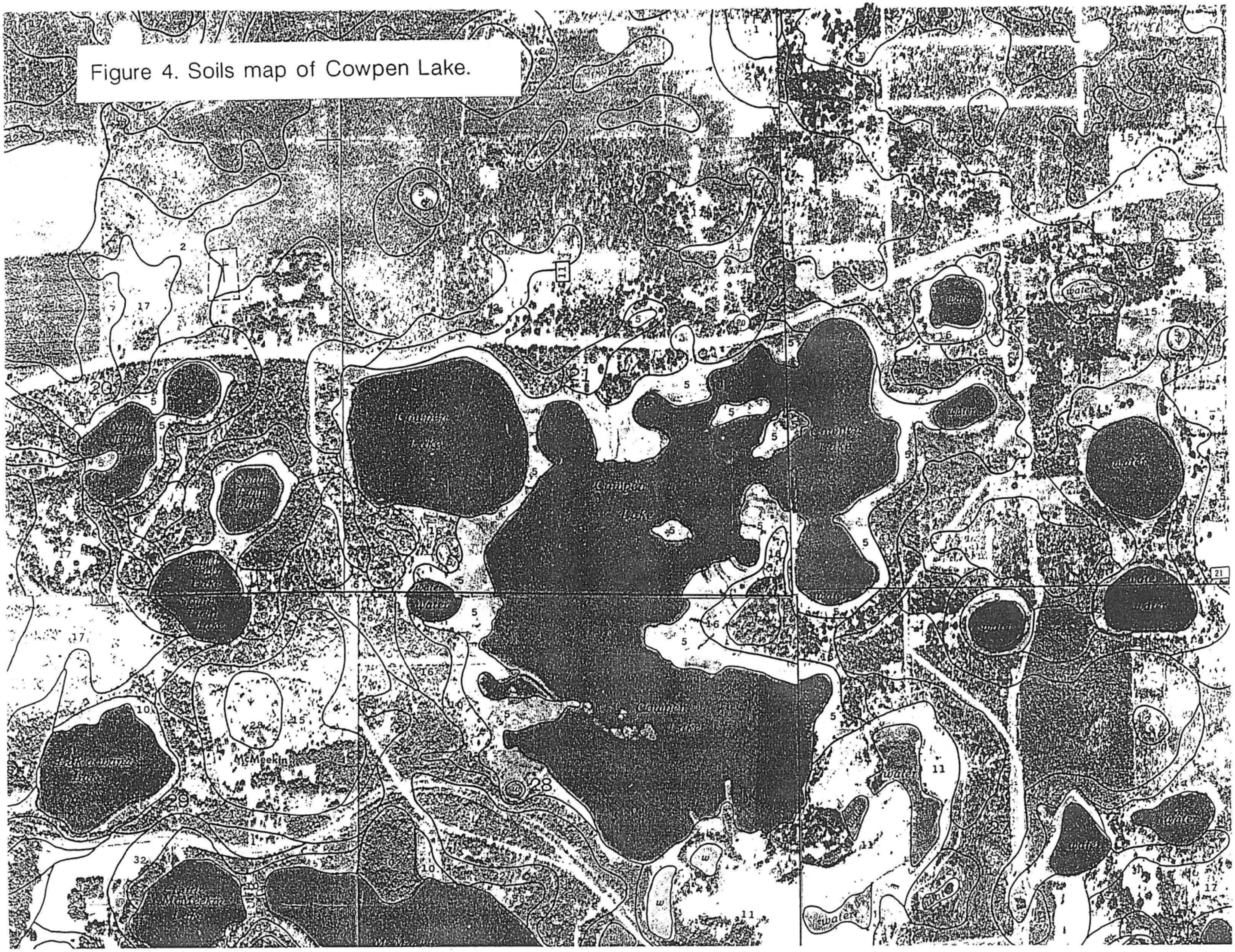


Figure 4. Soils map of Cowpen Lake.

Figure ~~. National Biological Service wetland invento~~ map of Cowpen Lake.

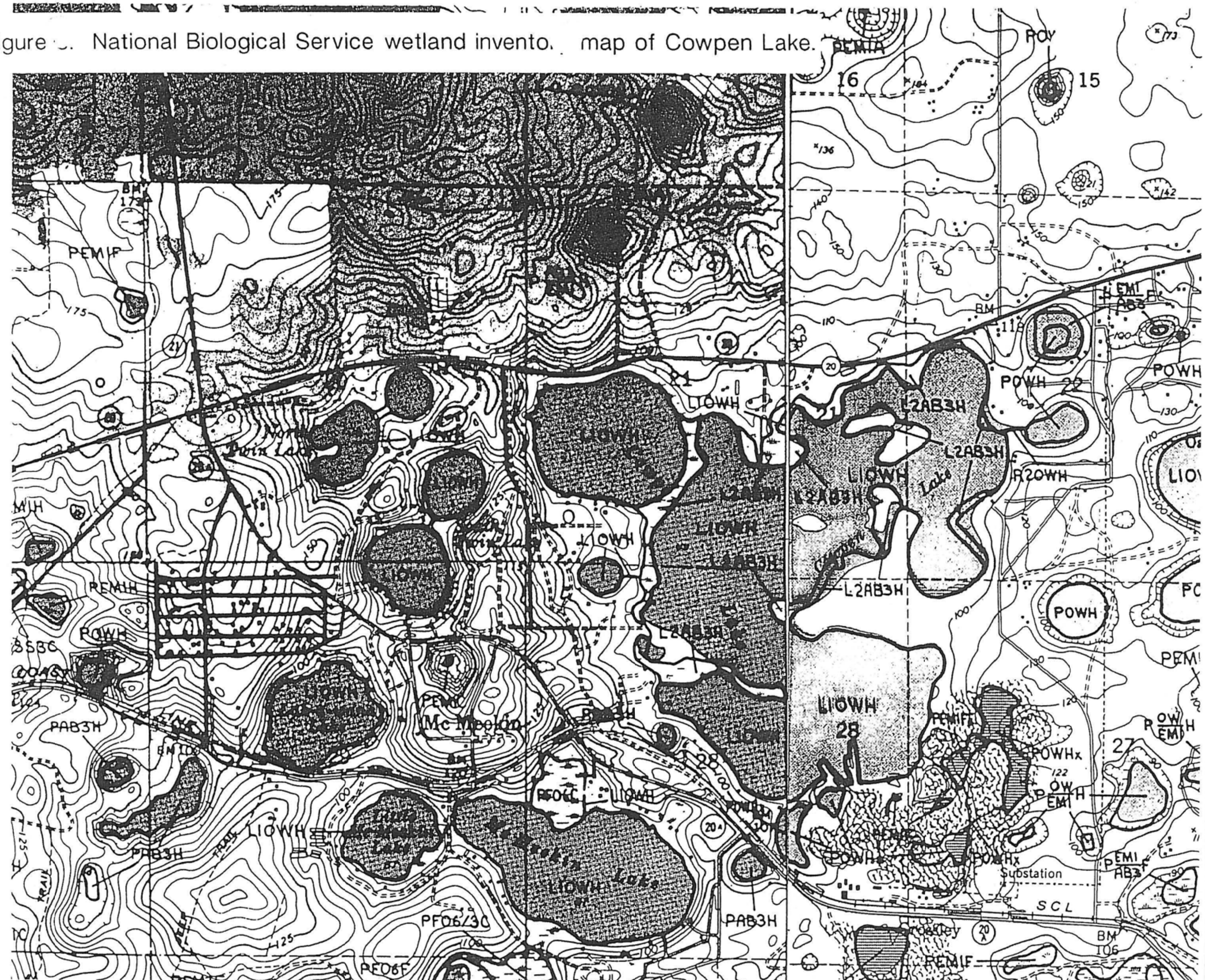


Figure 6. Elevation / vegetation Transect 1 (T1) - Cowpen Lake.

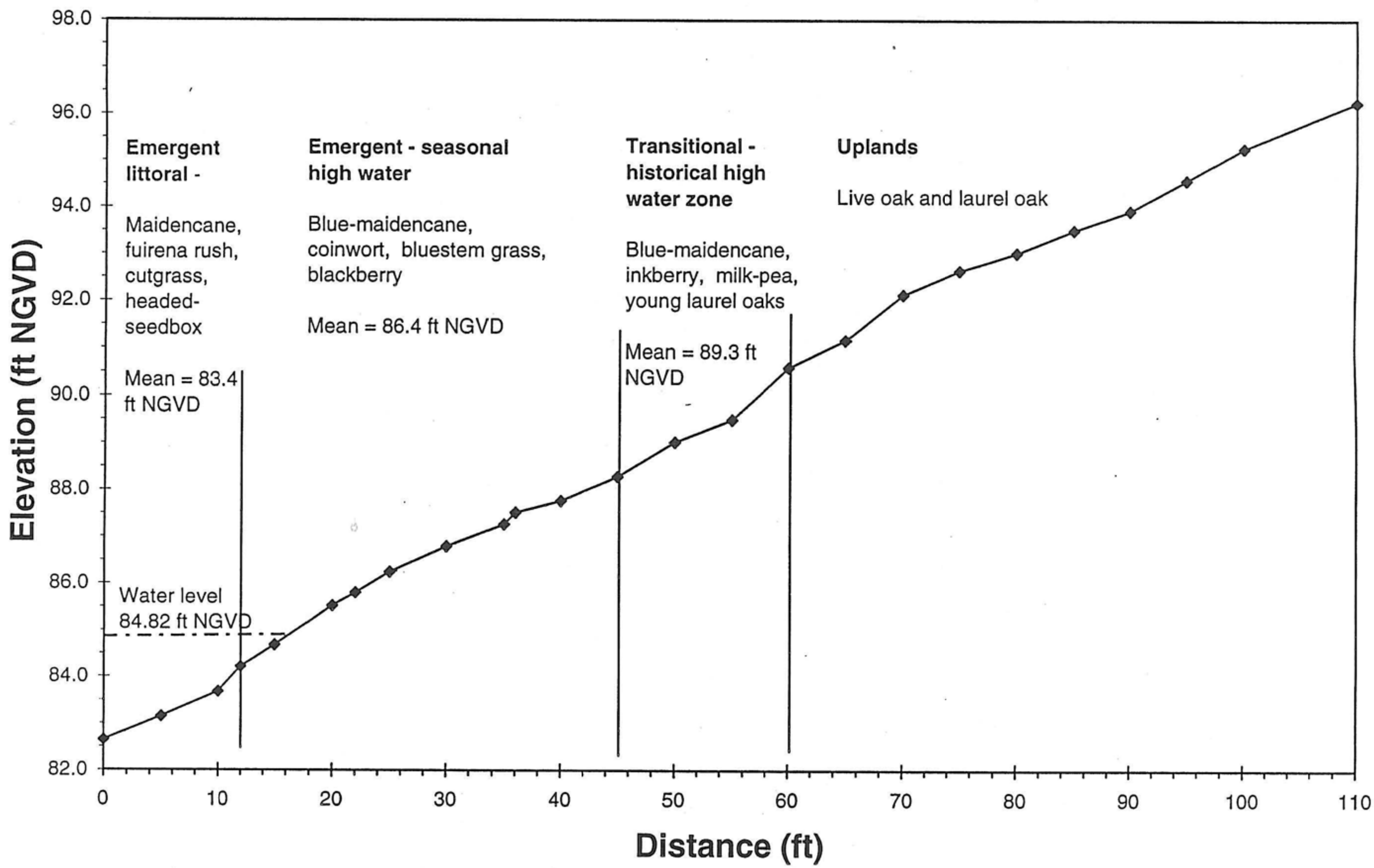


Figure 7. Elevation / vegetation Transect 2 (T2) - Cowpen Lake.

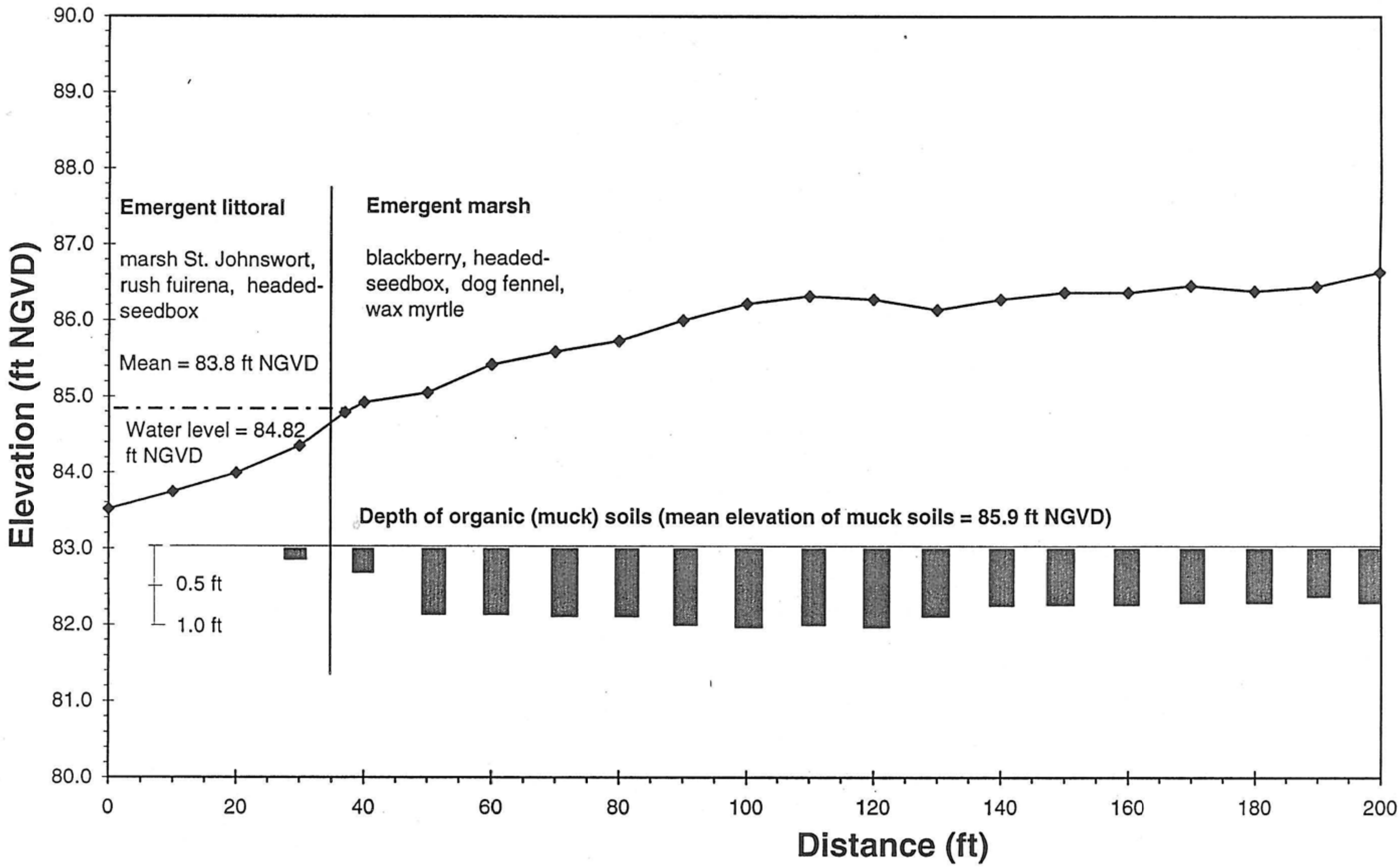
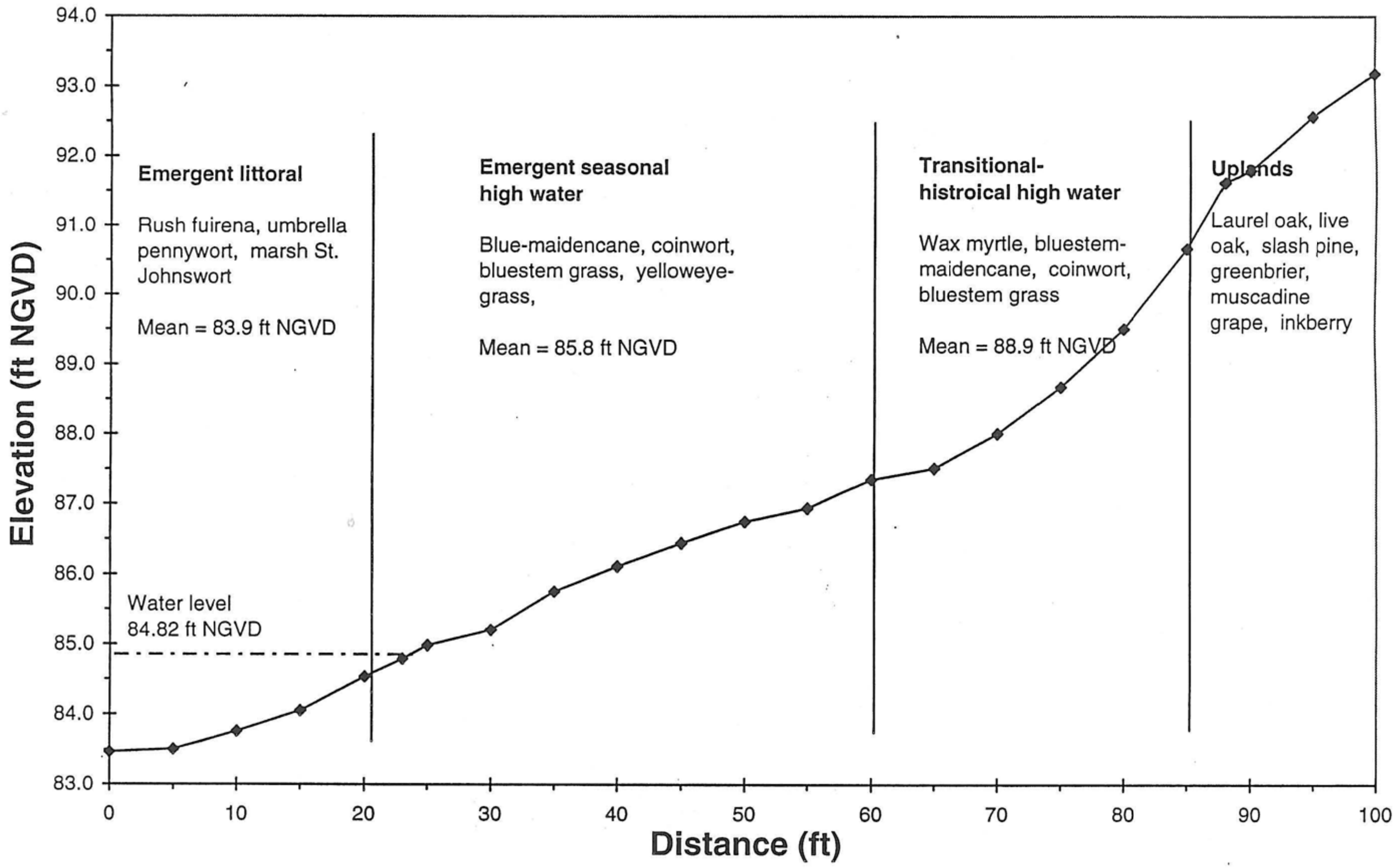


Figure 8. Elevation / vegetation Transect 3 (T3) - Cowpen Lake.



APPENDIX B – CDM SMITH HSPF MODEL REPORT

APPENDIX C—AERIAL PHOTOGRAPHS

COWPEN LAKE AERIAL PHOTOGRAPHY

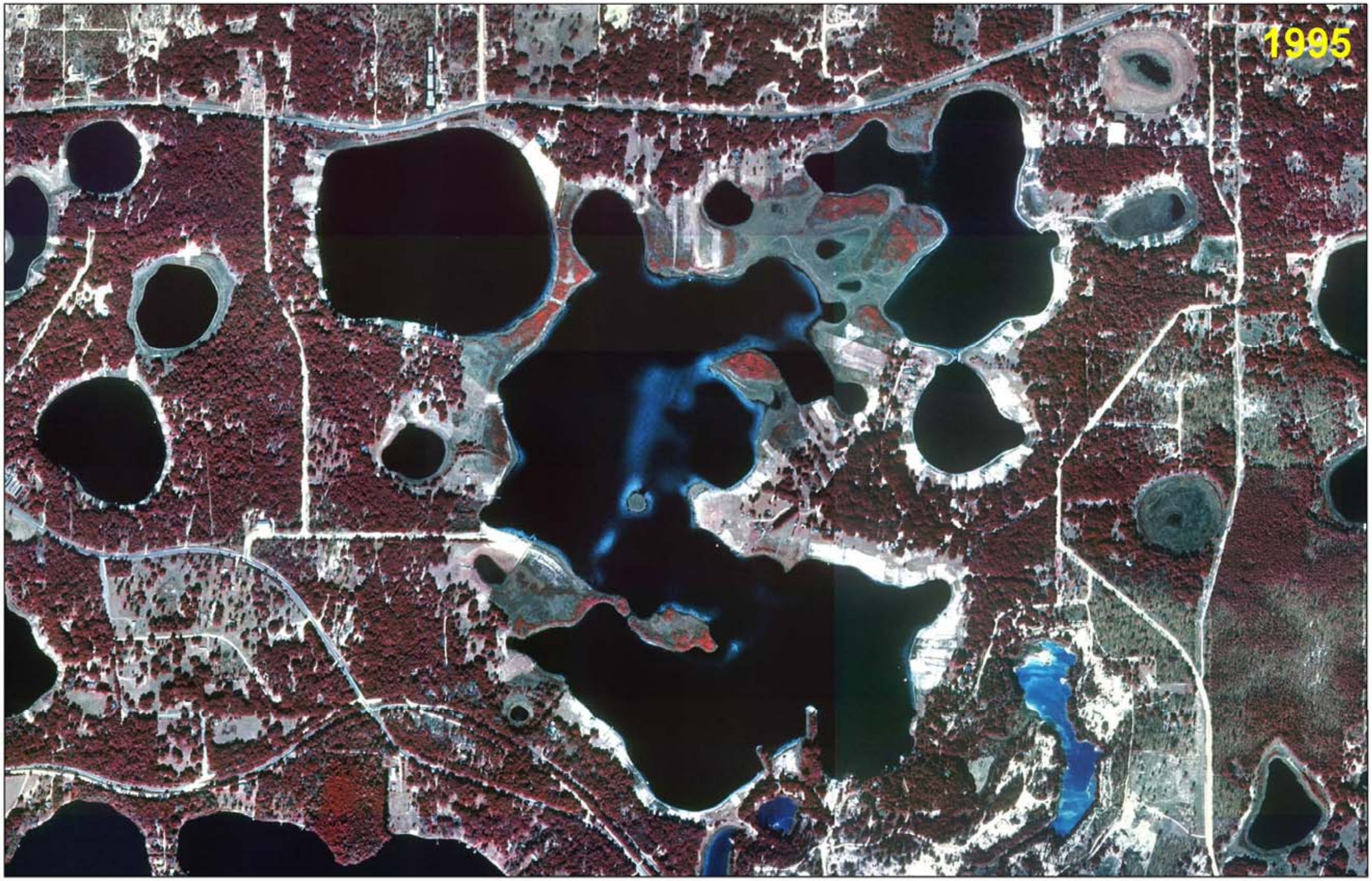
1953

1964


2-8-64
CYZ-2EE-207

1984

1995



2005

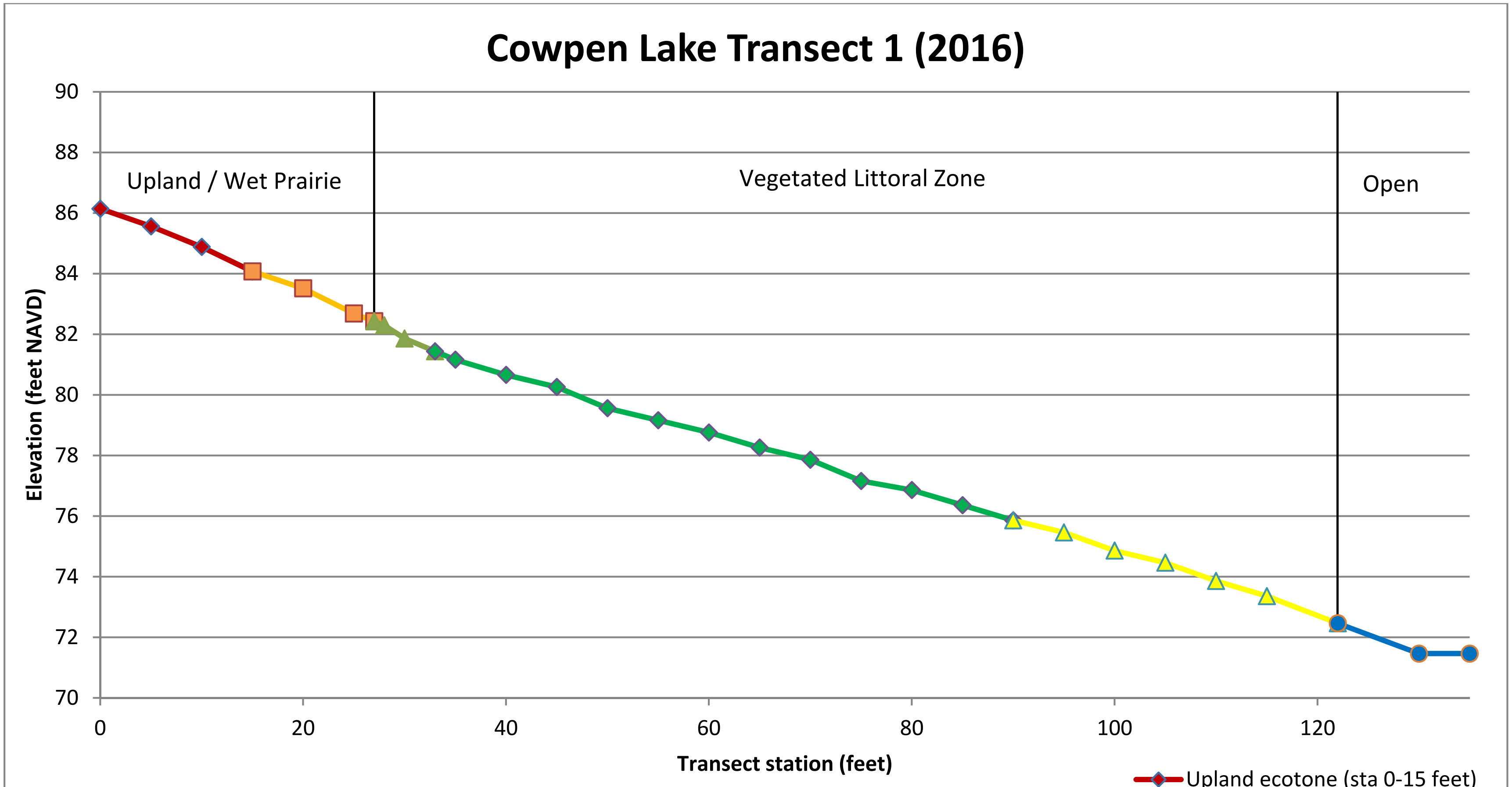
APPENDIX D—FIELD DATA COLLECTION

COWPEN LAKE FIELD TRANSECT PHOTOGRAPHS AND CROSS SECTION PROFILES

TRANSECT 1

Photo 1. Transect 1 station 0: upland ecotone, wet prairie, and littoral zone

Photo 2. Transect 1 station 130: littoral zone (aquatic bed, deep and shallow marshes)



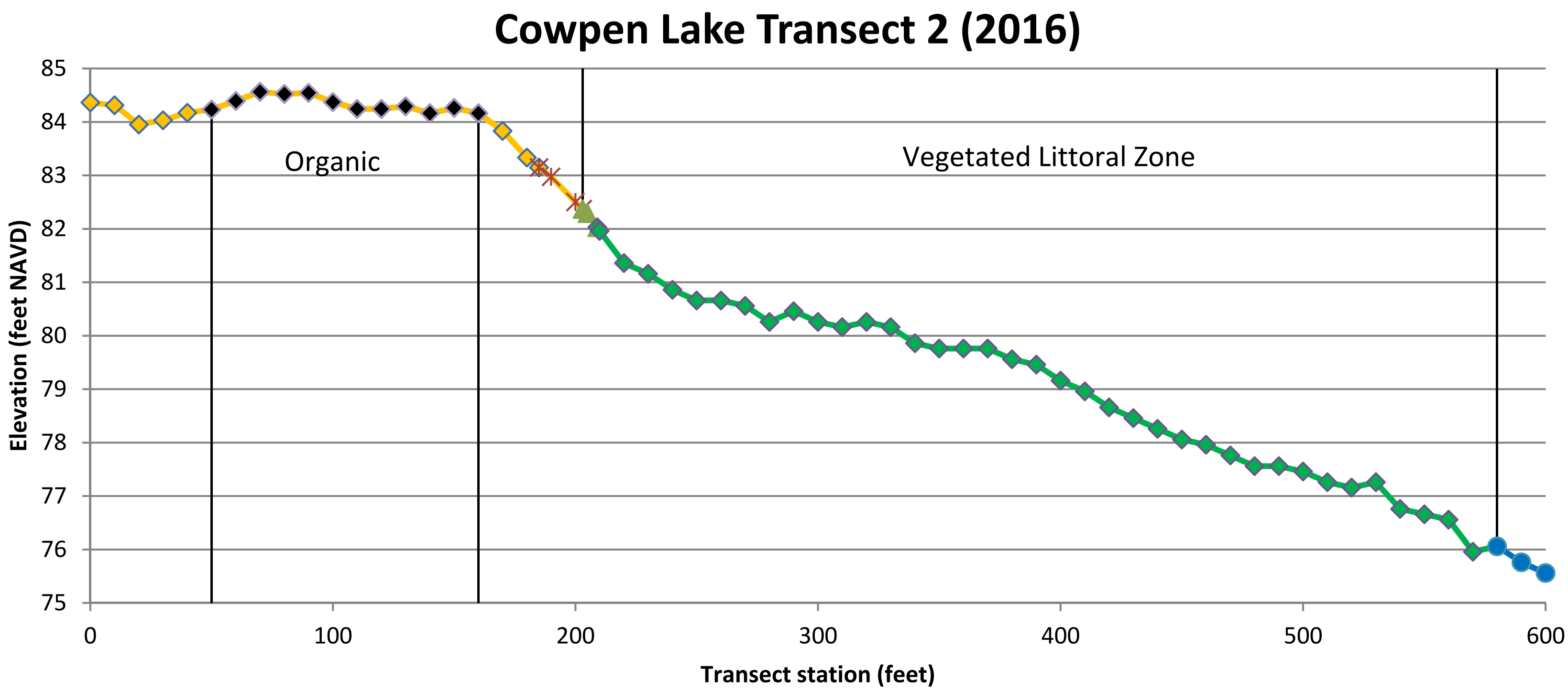
Vegetation Community	station start	station stop	Elevation (ft NAVD) mean	range	max	min	N
Upland Ecotone	0	15	85.17	2.07	86.15	84.08	4
Wet Prairie	15	27	83.34	1.65	84.08	82.43	3
Shallow Marsh	27	33	81.91	0.99	82.43	81.44	3
Deep Marsh	33	91	78.52	5.66	81.44	75.78	12
Aquatic Bed	91	122	74.33	3.32	75.78	72.46	3

Transect 1 cross section profile depicting distribution of vegetation communities

TRANSECT 2

Photo 1. Transect 2 station 580: fuirena-dominated littoral zone and island

Photo 2. Transect 2 station 185: looking waterward towards littoral zone from transitional shrub



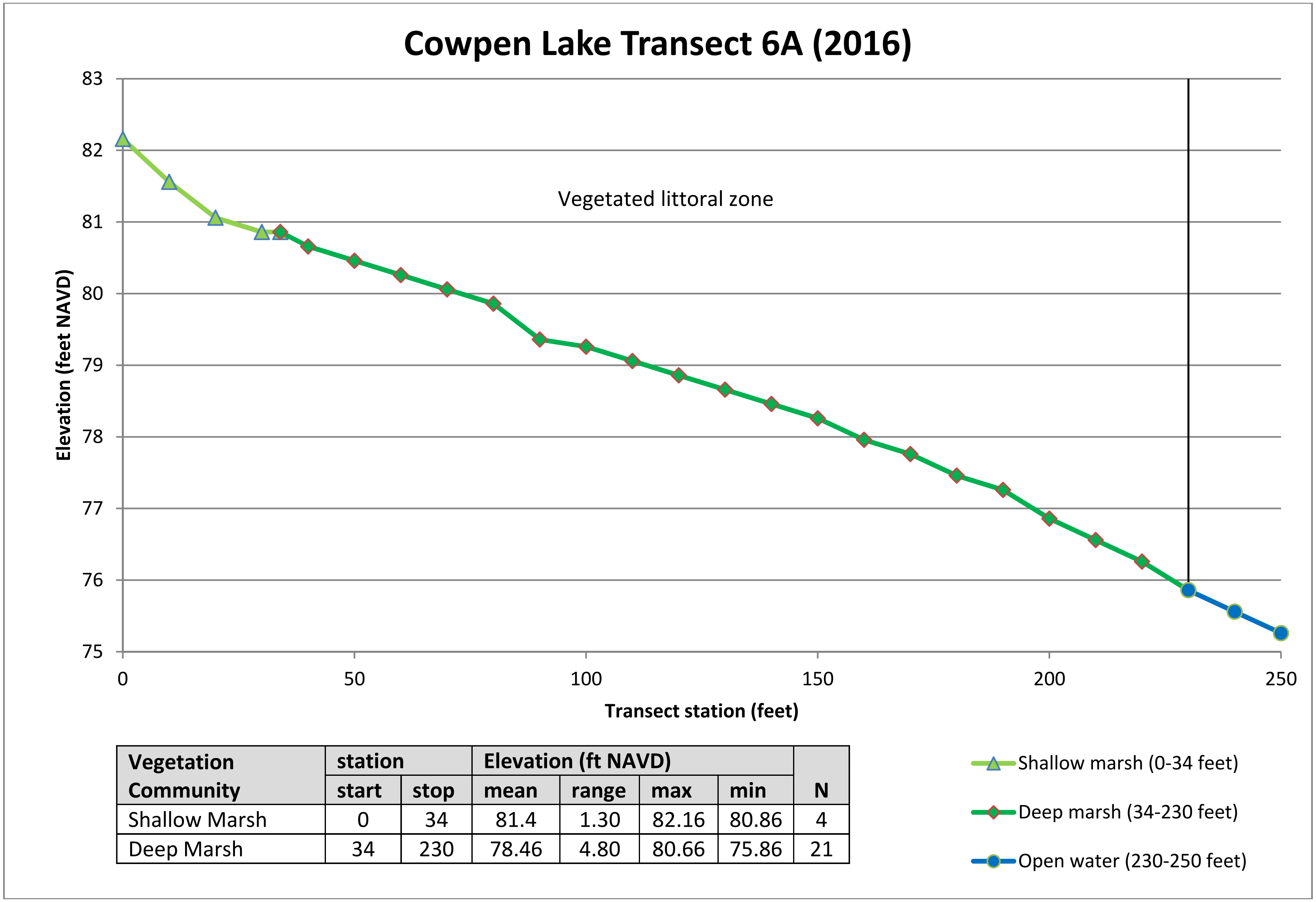
Vegetation community	Station		Elevation (ft NAVD)				N
	start	stop	mean	range	max	min	
Transitional Shrub	0	185	84.16	1.41	84.56	83.15	20
Transition Zone	185	203	82.75	0.78	83.15	82.37	4
Shallow Marsh	203	209	82.2	0.34	82.37	82.03	3
Deep Marsh	209	580	78.96	5.97	82.03	76.06	38
Organic Soils	50	160	84.33	0.40	84.56	84.16	12

Transect 2 cross section profile depicting distribution of organic soils and vegetation communities

TRANSECT 6A

Photo 1. Transect 6A station 0: landward edge littoral zone

Photo 2. Transect 6A station 230: waterward edge littoral zone, facing maple swamp



Vegetation Community	station		Elevation (ft NAVD)				N
	start	stop	mean	range	max	min	
Shallow Marsh	0	34	81.4	1.30	82.16	80.86	4
Deep Marsh	34	230	78.46	4.80	80.66	75.86	21

Transect 6A cross section profile depicting distribution of vegetation communities

COWPEN LAKE BELT TRANSECT (COVER CLASS) VEGETATION DATA (line intercept data not presented)

Transect 1: 2016 Vegetation

		Cover Class Rank by Community Type				
		UP	**WP**	**SM**	**DM**	**AB**
		0-15 ft	**15-27 ft**	**27-33 ft**	**33-91 ft**	**91-122 ft**
Diospyros virginiana	persimmon	0				
Andropogon sp.	bluestem	1	1			
Vitis rotundifolia	grape	1				
Rubus pensilvanicus	blackberry	0	1			
Syngonanthus flavidulus	bantam-buttons		2			
Lachnanthes caroliniana	redroot		3			
Rhexia sp.	meadow beauty		1			
Scleria sp.	nutrush	0				
Paspalum notatum	bahia grass	3				
Galactia elliottii	mild pea	1	0			
Amphicarpum muhlenbergianum	blue maidencane	0	1			
Hypericum fasciculatum	marsh St. Johnswort		0	0	1	
Xyris sp.	yellow eyed grass		0			
Rhynchospora spp.	beaksedge		0			
Panicum hemitomon	maidencane		0	1		
Pluchea sp.	camphorweed			0		
Ludwigia suffruticosa	headed seedbox			3	1	
Leersia hexandra	cutgrass			3	0	
Nymphaea odorata	waterlily				4	2
Polygonum sp.	smartweed			0		
Nymphoides aquatica	floating heart				0	
Pontederia cordata	pickerelweed			0	0	
Fuirena scirpoidea	fuirena rush			0	1	0
Ceratophyllum demersum	coontail				2	2
Utricularia sp.	bladderwort				1	

UP = upland
WP = wet prairie
SM = shallow marsh
DM = deep marsh
AB = aquatic bed

Belt Transect Cover Classes
5: >75% cover (dominant)
4: 50-75% cover (co-dominant)
3: 25-50% cover (abundant)
2: 10-25 % cover (numerous)
1: 1-10% cover (scattered)
0: <1 % cover (rare)

Transect 2: 2016 Vegetation and Soils

		Cover Class Rank by Community Type				
		TS 0-185 ft	TZ 185-203 ft	SM 203-209 ft	DM 209-580 ft	OW 580-600 ft
Rubus pensilvanicus	blackberry	5	2			
Myrica cerifera	wax myrtle	1	3			
Lachnanthes caroliniana	redroot	0	1	1		
Sapium sebiferum	Chinese tallow	1	2			
Cephalanthus occidentalis	buttonbush		0	1		
Triadenum virginicum			0			
Eupatorium capillifolium	dogfennel		0			
Andropogon sp.	bluestem			0		
Nymphaea odorata	waterlily			1	3	
Rhynchospora spp.	beaksedge			0		
Panicum repens	torpedo grass			2	1	
Fuirena scirpoidea	fuirena rush				2	
Panicum hemitomon	maidencane				1	
Pontederia cordata	pickerelweed				0	
Ludwigia suffruticosa	headed seedbox				0	
Brasenia schreberi	water shield				0	

TS = transitional shrub
TZ = transition zone
SM = shallow marsh
DM = deep marsh
OW = open water

Belt Transect Cover Classes
5: >75% cover (dominant)
4: 50-75% cover (co-dominant)
3: 25-50% cover (abundant)
2: 10-25 % cover (numerous)
1: 1-10% cover (scattered)
0: <1 % cover (rare)

Summary of hydric soil characteristics at Cowpen Lake Transect 2 (July 2016)

Station	Hydric Indicator	Muck depth (inches)	Notes
40	A8 Muck Presence	6	Muck layer dry at surface
90	A2 Histic Epipedon	12	Muck layer dry at surface; Sand substrate – Sanibel series (very poorly drained, rapidly permeable)
160	A2 Histic Epipedon	8	Muck layer dry at surface
190	A8 Muck Presence	5	Muck layer dry at surface
220	S7 Dark Surface	0	Site flooded; probably Placid series

Transect 6A: 2016 Vegetation

		Cover Class Rank by Community Type	
		SM	DM
		0-34 ft	34-230 ft
Pontederia cordata	pickerelweed	3	0
Fuirena scirpoidea	fuirena rush	1	2
Nymphaea odorata	waterlily	2	4
Nymphoides aquatica	floating heart		0
Brasenia schreberi	water shield	3	1
Panicum hemitomon	maidencane	0	
Eleocharis sp.	spikerush	0	
Myrica cerifera	wax myrtle	0	
Acer rubrum	red maple	0	

SM = shallow marsh
DM = deep marsh

Belt Transect Cover Classes
5: >75% cover (dominant)
4: 50-75% cover (co-dominant)
3: 25-50% cover (abundant)
2: 10-25 % cover (numerous)
1: 1-10% cover (scattered)
0: <1 % cover (rare)

APPENDIX E—PROTECTION OF RELEVANT ENVIRONMENTAL VALUES - *RULE 62.40.473(1)(A), F.A.C.*

Eight of the 10 environmental values identified in Rule 62-40.473, *F.A.C*., were deemed relevant for consideration for the Cowpen Lake MFLs reevaluation. Protection of these beneficial uses is described below. SJRWMD qualitatively assessed whether the recommended Cowpen Lake MFLs developed to protect “fish and wildlife habitats and passage of fish” were protective of all other relevant environmental values identified in Rule 62-40.473, *F.A.C.* The results of this assessment are listed in Table 9. SJRWMD concludes that the recommended MFLs developed for the protection of significant harm to “fish and wildlife habitats and the passage of fish” will protect all other relevant Rule 62-40.473, *F.A.C.*, environmental values (i.e, all except estuarine resources and sediment loads).

Table 9. Consideration of Rule 62-40.473, *F.A.C.*, environmental values for Cowpen Lake, Florida

Environmental Value	Environmental Value Definition	Criterion of Protection	Discussion	Do Recommended MFLs Protect Environmental Value?
Recreation in and on the water	The active use of water resources and associated natural systems for personal activity and enjoyment.	Hydrologic regime characteristics associated with the water depth necessary to safely operate motorboats and allow water sports activities.	Allows for water sports activities.	Compliance with the three recommended MFLs results in a relatively small change in the long-term ability of resident to access their docks from the water or move from the main body of the lake to other lobes. The benefits to game fish by maintaining the long-term location and diversity of the littoral zone also benefits recreation (i.e., fishing). Therefore, this beneficial use is deemed protected by the recommended MFLs.
Fish & wildlife habitats & the passage of fish	Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species; to live, grow, and migrate.	Hydrologic regime characteristics (high and low stage events) associated with conservation of the floodplain littoral zone/wetland vegetation composition, structure, and function for fish and wildlife habitats.	Fish and wildlife are dependent on local vegetation communities to provide food, cover, and/or nesting sites. Therefore, in order to protect fish and wildlife, it is necessary to protect their associated habitat (i.e., vegetation communities and soils). Water level fluctuations influence the colonization and survival of plants, thereby affecting the species composition and structure of plant communities (Schneider and Sharitz 1986, Kushlan 1990, Huffman 1980) The life cycles of many fishes are related to seasonal water level fluctuations, with flooded areas affecting productivity by providing feeding and spawning habitat and refugia for juveniles (Bain 1990, Poff et al. 1997, Guillory 1979, Ross and Baker 1983, Finger and Stewart 1987). Flooding events redistribute and concentrate organic particulates (Junk et al. 1989), while increasing aquatic vegetation structure as substrates for bacterial and fungal growth, affecting the aquatic faunal food chain (Cuffney 1988). Anaerobic soil conditions within the flooded wetland communities favor hydrophytic vegetation and eliminate upland plant species that have invaded during low water events (CH2M HILL 2005), while increasing vegetative structure available to aquatic organisms (Light et al. 1998). High water events allow the lateral movement of fish and other aquatic organisms between hydrologically connected lake lobes and lakes, as well as onto the floodplain to forage and reproduce. The increased spatial area and vegetation structure provide forage for juveniles and refugia from predators. Low water events allow for the decomposition and/or the compaction of flocculent organic sediments, improving habitat conditions for fish nesting and foraging (Kushlan and Kushlan 1979, Merritt and Cummins 1984). Shallow ponding provides aquatic refugia for fish, amphibians, and small reptiles, creating ideal depths for wading bird forage and concentration of resources in isolated pools (Bancroft et al. 1990, Kushlan 1990). Dewatering events increase the habitats and area available for use by terrestrial fauna, while enabling germination of wetland plant seeds (Kushlan 1990, Van der Valk 1981).	One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. The recommended MFLs for Cowpen Lake were primarily based on the protection of fish and wildlife habitats primarily because of the longer recovery time of fish population compared to other WRVs. A sufficient frequency and duration of high water (flooding) events is provided to preserve the open water area of the lake by preventing a downward shift in the location of the upland ecotone. Also, the fish community is protected by maintaining the long-term location and viability of the littoral zone. Fish and wildlife require access to these habitats and the terrestrial and aquatic passages between them under varying water levels for the continuance of their life cycle and various biological processes (e.g. foraging, reproduction, growth, etc). Compliance with the three recommended MFLs provides for the protection of “fish and wildlife habitats and the passage of fish” for Cowpen Lake . Therefore, this environmental value is considered to be protected.
Estuarine resources	Coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater.	Not applicable	Not applicable	Not applicable
Transfer of detrital material	The movement by surface water of loose organic material and associated biota.	Hydrologic regime characteristics (high and low stages) associated with depth	Detrital material is an important component of the food web in aquatic ecosystems (Mitsch and Gosselink 1993). The ecology of the floodplain and aquatic communities is dependent to a large extent on the events that deliver	Compliance with the recommended Minimum Infrequent High level provides for the protection of flooding events necessary for the transfer of detrital material between

Environmental Value	Environmental Value Definition	Criterion of Protection	Discussion	Do Recommended MFLs Protect Environmental Value?
		and area of inundation necessary for adequate detrital transfer to the water column of the lake.	detrital material to the system. A significant portion of the detrital material transfer occurs during periods of high water events when accumulated detrital materials on the floodplain are detached from the land surface due to buoyancy or turbulence, and moved by currents. Therefore, maintaining the hydrologic regime characteristics in the lake floodplain is essential to the supply and transport of detrital material.	wetland communities in Cowpen Lake. Therefore, the "transfer of detrital material" is considered to be protected.
Maintenance of freshwater storage & supply	The protection of an amount of freshwater supply for permitted users at the time of MFLs determinations.	Permitted surface water and/or groundwater withdrawals.	Maintenance of freshwater storage and supply is assessed by including existing permitted surface and/or groundwater withdrawals in the initial MFLs compliance analysis. SJRWMD uses two modeling tools in this process. A regional groundwater flow model includes any permitted groundwater withdrawals. A lake water budget model includes permitted surface water withdrawals and also accounts for the interaction between the lake and the regional groundwater system. Any projected or planned hydrologic changes for Cowpen Lake would be assessed, from the point of view of MFLs compliance, on top of existing permitted withdrawals.	The definition of "Maintenance of freshwater storage and supply" was recently revised by FDEP from one of protecting existing *consumptive* uses to one of protecting *non-consumptive* storage of water in wetlands and other aquatic systems. The storage of freshwater in all wetland and aquatic habitats within Cowpen Lake is related to all other relevant environmental values. This function/value is protected if other relevant functions/values are protected. Therefore, "maintenance of freshwater storage and supply" is considered to be protected.
Aesthetic & scenic attributes	Those features of a natural or modified waterscape usually associated with passive uses such as bird watching, sightseeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses of well-being and contentment.	Hydrologic regime characteristics (high and low stage events) associated with the preferred stage exceedance range associated with optimal scenic viewing and recreational use.	Southwest Florida Water Management District (SWFWMD) conducted a survey to determine a representative group of lake users' perceptions regarding lake aesthetics and recreational use in relation to lake stage (Hoyer et al. 2006). The results suggested that lake users were willing to accept water level fluctuations between a stage exceedance of 20% to 90%. Outside of this range, lake users felt that lake aesthetics and/or recreational use were impaired.	One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. Compliance with the recommended MFLs provides for the protection of "aesthetic & scenic attributes" for Cowpen Lake
Filtration & absorption of nutrients & other pollutants	The reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.	Hydrologic regime characteristics (high stage events) associated with depth and area of inundation necessary for adequate filtration and absorption of nutrients and other pollutants.	Wetlands serve important functions by filtering and absorbing nutrients from runoff (which typically contains nutrients at concentrations greater than the parent soil), serving as sinks for nutrients deposited from the drainage basin during periods of inundation, and allowing long-term nutrient removal through microbial action (Adams 1997, Boudreau et al. 2004, Labaree 1992). The ability of wetlands to perform these functions depends on cycles of flooding and drying as both anaerobic and aerobic processes are involved (Boudreau et al. 2004). Recognition of the importance of wetlands to the aquatic health of neighboring bodies of water has resulted in the creation or restoration of wetland areas throughout the country. The biogeochemical processing of dissolved constituents is controlled by complex interactions between the rate at which water flows through surface and subsurface flow paths and the rate at which dissolved constituents are processed by methods such as adsorption to sediments or uptake by microorganisms and vegetation (Phillips et al. 1993, Hamilton and Helsel 1995). The conceptual model relevant to the environmental value assessment is that filtration and absorption occur in the pervious soils in the floodplain; hence, the frequency, duration, and return period of overbank flooding are the defining characteristics (Battelle 2004).	Compliance with the recommended Minimum Infrequent High level provides for the protection of flooding events necessary for the "filtration and absorption of nutrients and other pollutants" in Cowpen Lake. Therefore, "filtration and absorption of nutrients and other pollutants" is considered to be protected.
Sediment loads	The transport of inorganic material, suspended in water,	Not applicable	Not applicable	Not applicable

Environmental Value	Environmental Value Definition	Criterion of Protection	Discussion	Do Recommended MFLs Protect Environmental Value?
	which may settle or rise; these processes are often dependent upon the volume and velocity of surface water moving through the system.			
Water quality	The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a watercourse (lotic) not included in “filtration & absorption of nutrients & other pollutants.”	Hydrologic regime characteristics (high and low stage events) necessary to prevent excessive low dissolved oxygen events.	Algal blooms can occur naturally during dry seasons with moderate to severe droughts when water level conditions are low resulting in seasonally elevated water temperatures and elevated concentrations of nutrients. Similarly, algal blooms can occur naturally after the onset of rainy seasons when nutrient loading is high because of runoff from upland and dewatered wetland areas and flushing (e.g., residence time is high when flushing is low) from the lake is low (e.g., an isolated lake). Thus, natural algal blooms can occur following wet or dry season events when conditions for algal growth are favorable. More severe algal blooms can result in low dissolved oxygen (DO) concentrations that may negatively affect aquatic biota (e.g., fish kills). Water withdrawals can increase the number of low water events or decrease the number of high water events per century, on average, and affect the number of low DO events. The time needed for system recovery from natural and human caused low DO events is important to this environmental value assessment.	One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. By maintaining the flooding and dewatering regime at Cowpen Lake, the recommended MFLs also help with the transport and filtration of nutrients which helps to reduce the occurrence of harmful algal blooms. Compliance with the recommended MFLs provides for the protection of “water quality” for Cowpen Lake.
Navigation	The safe passage of watercraft (e.g., boats and ships), which is dependent upon adequate water depth and channel width.	Minimum depth of water necessary for most motorboat safe operation.	Watercraft navigation in most lakes is closely tied to recreation and necessitates adequate draft depths and channel widths for safe boat operation. Allows for navigation between Cowpen Lake lobes during high water periods.	One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. Therefore, the compliance with the recommended MFLs provides for the protection of “navigation” for Cowpen Lake. The lake does not support commercial boating, shipping, or barge traffic. Passage by recreational vessels, canoes, etc. was considered under the “Recreation in and on the water” environmental value.