Technical Publication SJ2018-1

# MINIMUM LEVELS DETERMINATION

# FOR LOCHLOOSA LAKE

# ALACHUA COUNTY, FLORIDA

by

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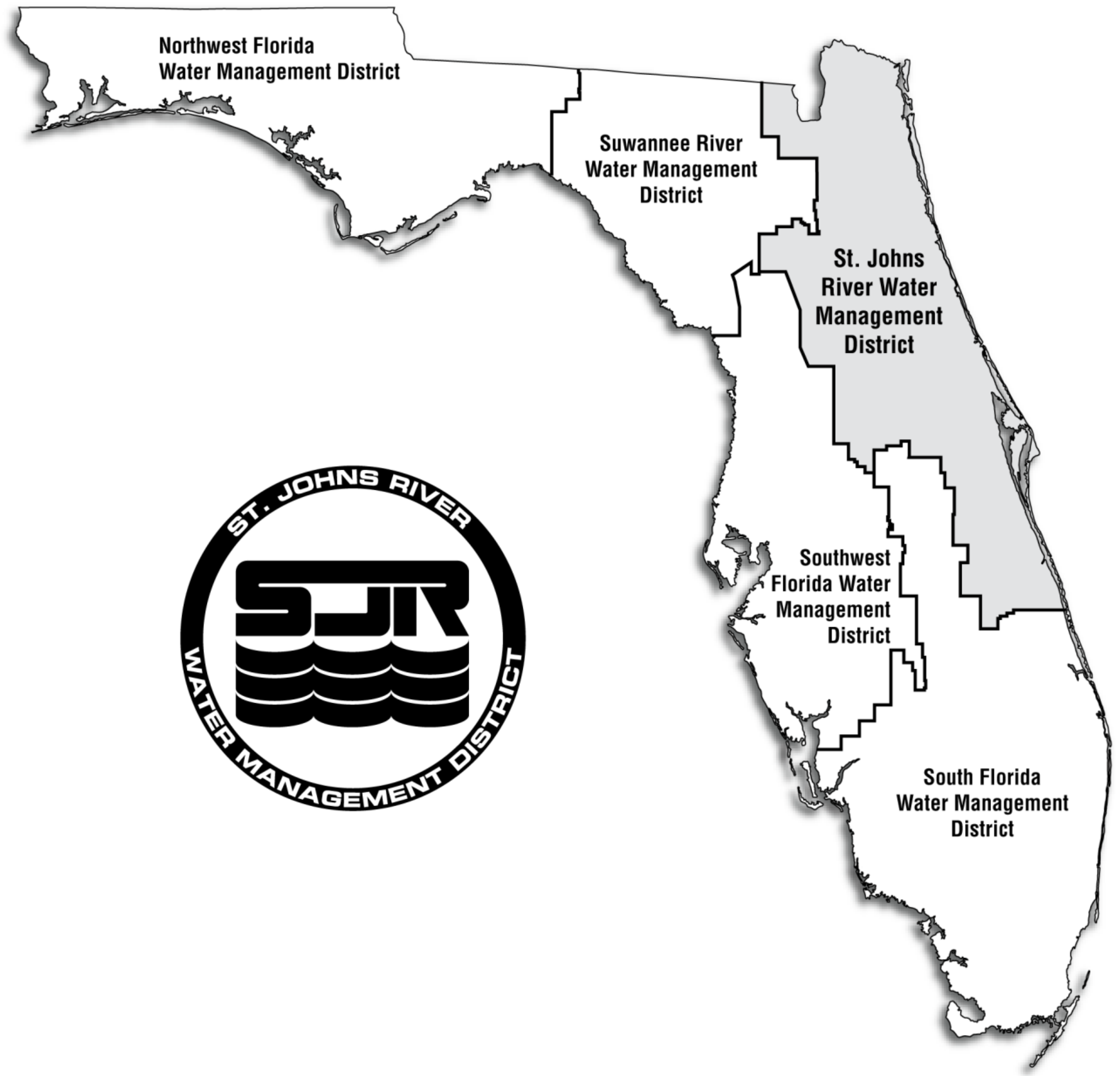
2018




The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the district conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

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# EXECUTIVE SUMMARY

As a part of fulfilling its mission and statutory responsibilities, the St. Johns River Water Management District (SJRWMD) establishes minimum flows and levels (MFLs) for priority waterbodies within its boundaries. MFLs establish a minimum hydrologic regime and define the limits at which further consumptive use withdrawals would be significantly harmful to the water resources or ecology of an area. MFLs are one of many effective tools used by SJRWMD to assist in making sound water management decisions and preventing significant adverse impacts due to water withdrawals.

SJRWMD completed a minimum levels determination for Lochloosa Lake in Alachua County, Florida. Lochloosa Lake was added to the SJRWMD MFLs Priority List because of its regional significance and potential for being impacted due to groundwater pumping. Lochloosa Lake was designated an Outstanding Florida Water in 1987 for its natural attributes and ecological values and the Florida Fish and Wildlife Conservation Commission (FWC) designates Lochloosa Lake as an important Fish Management Area.

As mandated by statute, MFLs are not meant to represent optimal conditions, but rather set the limit to withdrawals, beyond which significant harm will occur. A fundamental assumption of SJRWMD's approach is that an alternative hydrologic regime exist that is lower than historical regime but still protects the environmental functions and values of MFLs waterbodies from significant harm caused by water withdrawals.

A minimum hydrologic regime for Lochloosa Lake encompasses a range of water levels within which the waterbody must fluctuate to protect the inherent ecological structure and function of the system. Four minimum levels were developed to ensure protection of the entire hydrologic regime and are based on protection of 1) floodplain wetlands and associated wildlife habitat values; 2) sandhill crane nesting habitat; 3) organic soils; and 4) deep marsh habitats. The most constraining minimum level is based on protection of sandhill crane nesting habitat and was developed in consultation with FWC.

A minimum median (P50) water level (i.e., water level that must be equal or exceeded 50% of the time, over the long term), is recommended for Lochloosa Lake (Table ES-1). The recommended minimum P50 was calculated from the MFLs condition lake level time series data (1957–2015).

Table ES-1. Recommended Minimum Level for Lochloosa Lake, Alachua County, Florida

| Environmental Criterion | Minimum Median (P50) Lake Level ft. NAVD88 |
|---|---|
| Protection of sandhill crane nesting habitat | 56.5 |

The MFLs condition is a minimum long-term lake level time series, based on the sandhill crane nesting habitat criterion, protected by the recommended minimum P50. This equates to an average allowable lake level reduction of 0.4 ft from the no-pumping condition, over the long term.

Assessment of the MFL indicates that it is met under current-pumping conditions and has a freeboard of 1.3 ft available in the Upper Floridan aquifer (UFA). Projected drawdown due to groundwater pumping in 2035 was estimated as 0.1 feet using the North Florida Southeast Georgia regional groundwater model (NFSEG v1.1). Therefore, the recommended minimum level is achieved for the 20-year planning horizon, and Lochloosa Lake is not in prevention or recovery.

A suite of 10 environmental values, listed in Rule 62-40.473, F.A.C., were considered to ensure that the MFLs condition protects all relevant water resource values (WRVs) for Lochloosa Lake. Based on this analysis, SJRWMD concludes that the recommended minimum level for Lochloosa Lake, which has been developed primarily for the protection from significant harm to “fish and wildlife habitats and the passage of fish,” will also protect all other relevant WRVs, including recreation and other beneficial uses.

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

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# GLOSSARY

**Environmental Criteria:** Specific ecological or human use functions evaluated when setting or assessing an MFL.

**Current-pumping Condition:** A long-term simulated water level (lake or aquifer) timeseries that represents what water levels would be if "current" groundwater pumping was present throughout the entire period of record. The average groundwater pumping over the latest five-year period is used to estimate "current" groundwater pumping.

**Deficit:** The amount of water needed to recover an MFL that is not being achieved. Aquifer deficit, for a lake MFL, is expressed as the amount of recovery (in feet) needed in the Upper Floridan aquifer (UFA).

**Event:** A component of an MFL composed of a magnitude (i.e. water level) and duration.

**Freeboard:** The amount of water available for withdrawal before an MFL is not achieved. Aquifer freeboard, for a lake MFL, is expressed as the allowable drawdown (in feet) in the UFA.

**Frequency Analysis:** a statistical method used to estimate the annual probability of a given hydrological (exceedance or non-exceedance) event; used to assess the current status of an MFL by comparing the frequency of critical hydrological events under current-pumping conditions to the frequency of these events based on recommended minimum levels.

**Hydrologic Regime:** The variation of high and low water levels (or flows) regularly repeated over time within a specified period of record for a specific waterbody.

**Minimum Hydrologic Regime:** A hydrologic regime that is lower than the no-pumping condition, that protects relevant environmental values from significant harm.

**MFLs Condition:** The minimum hydrologic regime necessary to protect a waterbody from significant harm. The MFLs condition represents an allowable change from the no-pumping condition for the entire period of record. It represents a lowering of the no-pumping condition, but only to the degree that still protects a waterbody from significant harm. The MFLs Condition is based upon the minimum flow or level that is most constraining to water withdrawal, for a given waterbody.

**Minimum Flows and Levels (MFL):** The point at which additional withdrawals will result in significant harm to the water resources or the ecology of the area (Sections 373.042 and 373.0421, F.S.).

**Minimum Level:** Each minimum level includes a hydrological event, composed of a magnitude and duration, and a return interval (i.e., the frequency of the event). The five types of minimum levels are as follows:

**Minimum Average:** a minimum surface water level or flow necessary over a long period to maintain the integrity of hydric soils and associated wetland plant communities.

**Minimum Frequent High:** a chronically high surface water level or flow with an associated frequency and duration that allows for inundation of the floodplain at a depth and duration sufficient to maintain wetland functions.

**Minimum Frequent Low:** a chronically low surface water level or flow that generally occurs only during periods of reduced rainfall. Preventing too many such dry events is intended to prevent deleterious effects to the composition and structure of floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs.

**Minimum Infrequent High:** an acutely high surface water level or flow with an associated frequency and duration that is expected to be reached or exceeded during or immediately after periods of high rainfall so as to allow for inundation of a floodplain at a depth and duration sufficient to maintain biota and the exchange of nutrients and detrital material.

**Minimum Infrequent Low:** an acutely low surface water level or flow with an associated frequency and duration which may occur during periods of extreme drought below which there will be a significant negative impact on the biota of the surface water which includes associated wetlands.

**No-pumping Condition:** A long-term simulated (lake or aquifer) timeseries that represents what water levels would be if there were no impact due to groundwater pumping.

**Return Interval:** a component of a minimum level or flow representing the recommended frequency of a minimum hydrological event.

**Threshold:** The allowable change to an environmental criterion, from the no-pumping condition.

# INTRODUCTION

The St. Johns River Water Management District (SJRWMD) completed a minimum levels determination for Lochloosa Lake in Alachua County, Florida. Pursuant to *Florida Statutes* (*F.S.*), SJRWMD is charged with protecting priority waterbodies by developing minimum flows and levels (MFLs). Lochloosa Lake is on the SJRWMD MFLs Priority List and is scheduled for adoption in 2018. It was added to the list because of its regional significance and potential for impact due to pumping. Lochloosa Lake is designated as an Outstanding Florida Water for its natural attributes and ecological values and the Florida Fish and Wildlife Conservation Commission (FWC) designates Lochloosa Lake as an important Fish Management Area. This report describes environmental analyses used to develop protective criteria and minimum levels for Lochloosa Lake. The current and future status assessment of minimum levels is also provided.

## LEGISLATIVE OVERVIEW

SJRWMD establishes MFLs for priority waterbodies within its boundaries (section 373.042, F.S.). MFLs 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.). MFLs 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.*]) requires that "consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology." The environmental values described by the rule include:

1. Recreation in and on the water;
2. Fish and wildlife habitats and the passage of fish;
3. Estuarine resources;
4. Transfer of detrital material;
5. Maintenance of freshwater storage and supply;
6. Aesthetic and scenic attributes;
7. Filtration and absorption of nutrients and other pollutants;
8. Sediment loads;
9. Water quality; and
10. Navigation.

MFLs are used in SJRWMD's regional water supply planning process (Section 373.0361, F.S.), the consumptive use permitting program (Chapter 40C-2, *F.A.C.*), and the environmental resource permitting program (Chapter 62-330, *F.A.C.*).

## SJRWMD MFLs Program Overview

SJRWMD is engaged in a districtwide effort to develop MFLs to protect priority surface waterbodies, 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.

The purpose of setting MFLs is to answer an overarching question: What minimum hydrologic regime is necessary to protect critical environmental functions and values of a priority waterbody, from significant harm due to withdrawals?

As mandated by statute, MFLs are not meant to represent optimal conditions, but rather set the limit to withdrawals, beyond which significant harm will occur. A fundamental assumption of SJRWMD's approach is that alternative hydrologic conditions exist that are lower than historical condition but still protect the environmental functions and values of MFLs waterbodies from significant harm caused by water withdrawals.

Significant harm is a function of changes in frequencies of water level and/or flow events. Hydrologic events are composed of a magnitude and duration. The return interval (frequency) of events is considered the manageable component (Neubauer et al. 2008). MFLs are developed to ensure that changes in return interval due to water withdrawals are not sufficient to cause significant harm, defined as impairment or loss of ecological structure (e.g., permanent downhill shift in plant communities) or function (e.g., insufficient fish reproduction or nursery habitat).

The SJRWMD MFLs approach involves two separate, but interrelated, components: 1) MFLs Determination and 2) MFLs Assessment. The first involves determining a minimum hydrologic regime (e.g., MFLs condition) necessary to protect relevant water resource values. The second involves comparing this MFLs condition to a current-pumping condition to determine the current status of the MFLs. The current-pumping condition could be above or below the MFLs condition. The overall process involves environmental assessments, hydrologic modeling, independent scientific peer review, and rulemaking.

Many SJRWMD MFLs define a protective frequency of high, intermediate, and low hydrologic events (Neubauer et al. 2008). No matter how many MFLs are adopted for a waterbody, the most constraining (i.e., most sensitive to pumping) MFL is always used for water supply planning and permitting. If water levels are below an MFL, or are projected to fall below within 20 years, a district must adopt a recovery or prevention strategy, to prevent MFLs from not being achieved now or in the future. By ensuring that the most sensitive MFL is achieved, assurance is also provided that all other MFLs will be achieved.

# SETTING AND DESCRIPTION

## LOCATION AND PHYSIOGRAPHIC SETTING

Lochloosa Lake is in eastern Alachua County, 3.5 miles southwest of the town of Hawthorne, FL, and is part of the Orange Creek Basin (OCB) (Figure 1). The OCB, a tributary of the Ocklawaha River and ultimately the St. Johns River, is made up of three main surface waterbodies: Lochloosa Lake, Orange Lake, and Newnans Lake. Lochloosa Lake and Orange Lake are designated Outstanding Florida Waters and are known for excellent fishing and important wildlife habitat (SJRWMD 2018).

The Lochloosa Lake subbasin covers an area of 87.4 $mi^2$ and consists of pine flatwoods, rural lands, and streams. The major drainage feature conveying surface runoff for the subbasin is Lochloosa Creek (Adkins and Rao 1995). Several springs, including Magnesia Spring, Iron Spring, and Sulphur Spring also contribute water to the lake (Clark *et al.* 1964; Rosenau *et al.* 1977).

Surface water and groundwater interactions in the OCB are complicated by its underlying geology. The groundwater system consists primarily of two water-bearing units, a surficial aquifer and the Upper Floridan aquifer. Separating the two units is the Hawthorn formation, a low-permeability, confining clay layer (Clark *et al.* 1964; Berndt *et al.* 1998; Schiffer 1998; Lin 2011). The landform physiography of Lochloosa Lake is split between two subdistricts and subdivisions. While the subbasin, as a whole, is in the Ocala Uplift district, the drainage area north of the lake is classified as within the Newnans Lake Basin subdivision of the Northern Peninsula Slopes subdistrict. The main body of Lochloosa Lake is within the Alachua Prairies subdivision of the Northern Peninsula Plains subdistrict (Brooks 1981).

## BATHYMETRY

Lochloosa Lake consists of three distinct areas: the main body of the lake, a smaller portion in the southwest corner referred to as Little Lochloosa Lake, and a broad shallow marsh called the Right Arm Lochloosa Lake (RALL) (Figure 2). The lake has a surface area of 8,494 acres when the lake level is at an average elevation of 56.1 ft NAVD88. The deepest portion of the lake is found in the main body and is approximately 24 ft deep (Figure 3). Little Lochloosa Lake has a maximum depth of approximately 12 ft. The RALL marsh bottom elevations vary little, with an average elevation at 55.5 ft NAVD88 and an elevation range of approximately 0.7 ft (Figure 4). Water depth in the RALL marsh is dependent on Lochloosa Lake water level.

Lochloosa Creek is the major drainage feature of Lochloosa Lake, draining an area of 51 $mi^2$ to the north (Robison et al. 1997). Lochloosa Creek can be intermittent, becoming dry during periods of extended drought. The main outflow of the lake is through Cross Creek to Orange Lake. During periods of low water (below approximately 53.5 ft NAVD88), flow through Cross Creek will cease, isolating and disconnecting Lochloosa Lake from Orange Lake (Clapp and Smith 2015). Under these severe drought conditions Lochloosa Lake maintains water levels from 2 to 5 feet above levels in Orange Lake. When water levels are above 56.6 ft NAVD88 water can also flow eastward through Lochloosa Slough and into Orange Creek (Lasi 1996).

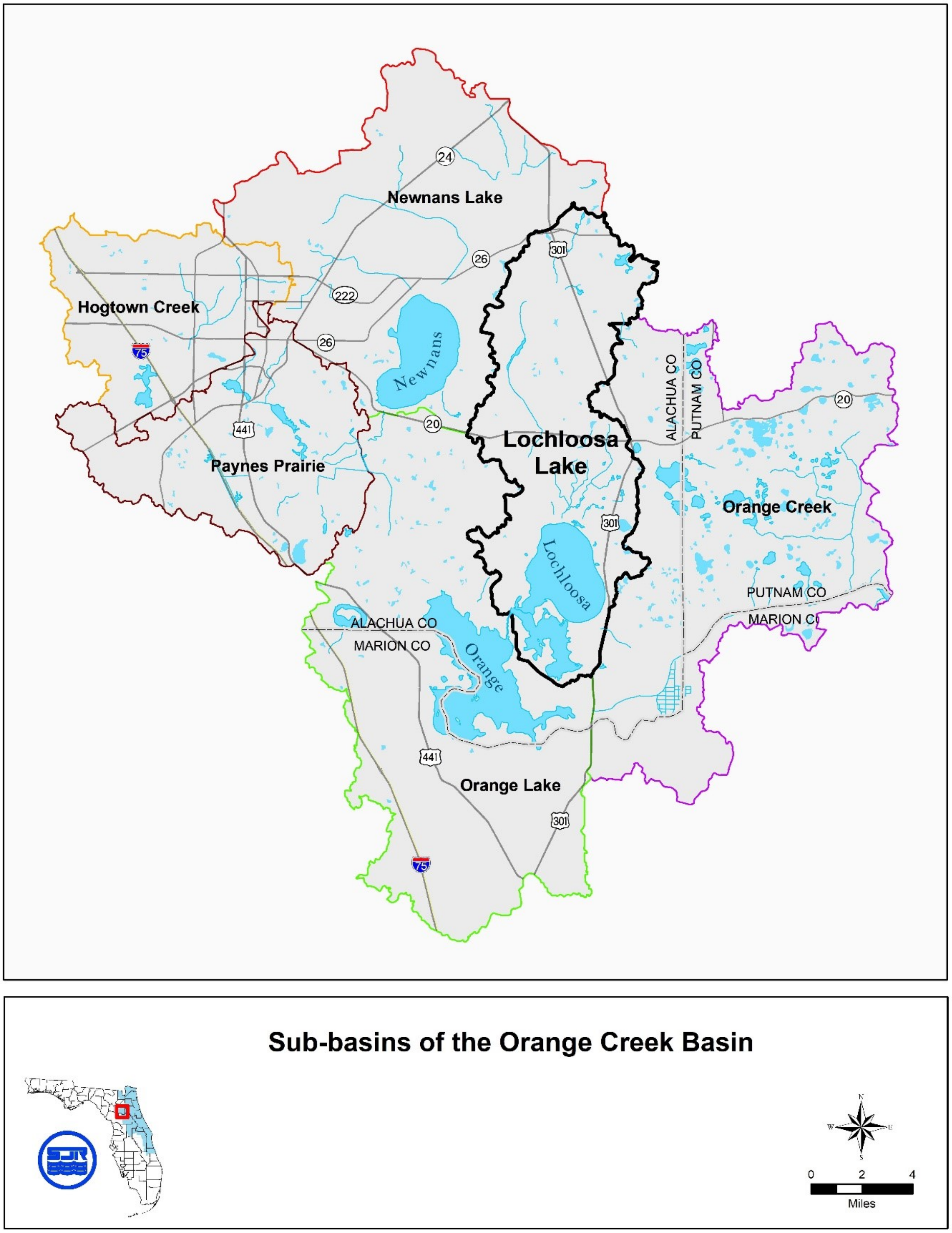


Figure 1. Orange Creek Basin and Lochloosa Lake Sub-basin in Alachua County, Florida

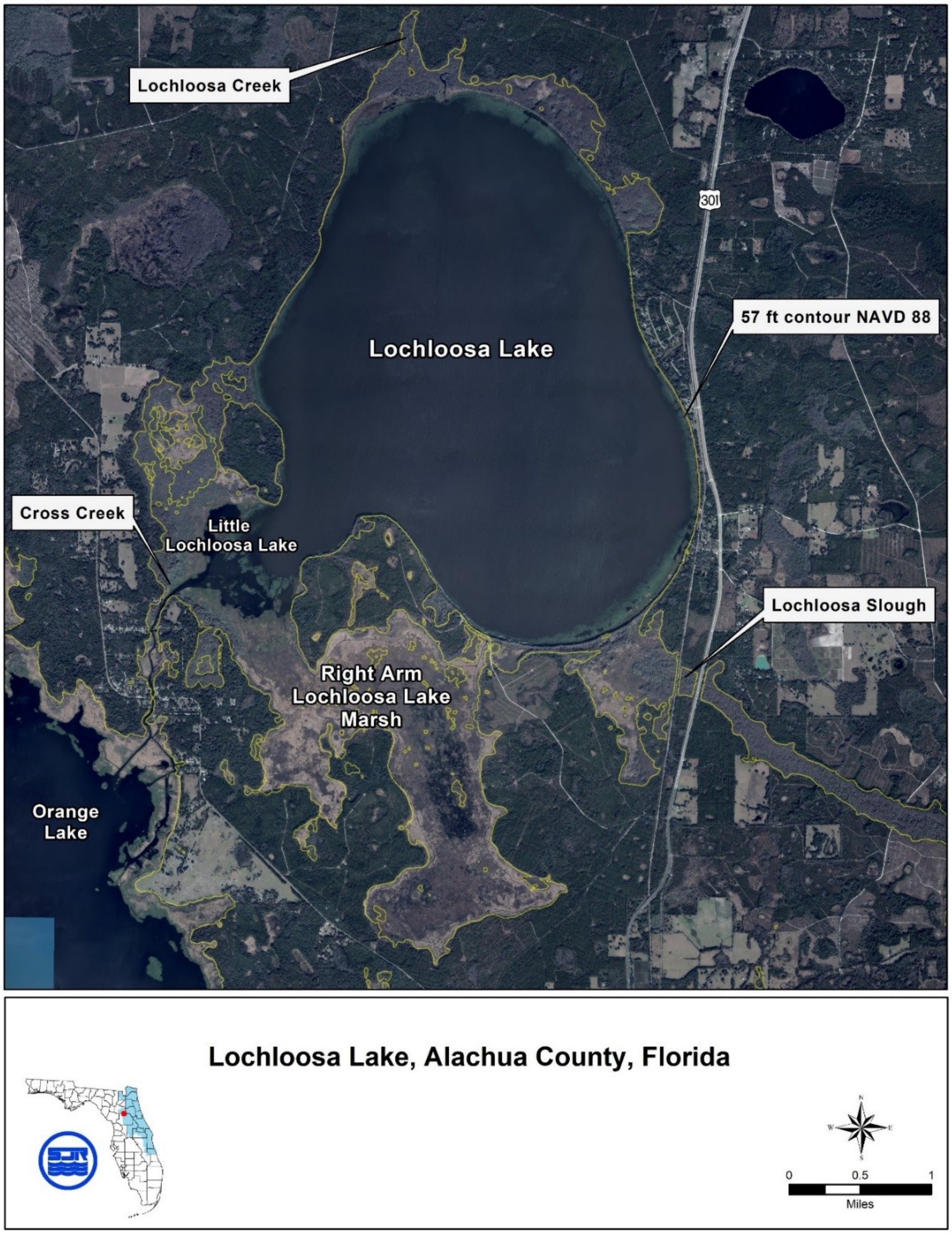


Figure 2. Lochloosa Lake showing distinct portions

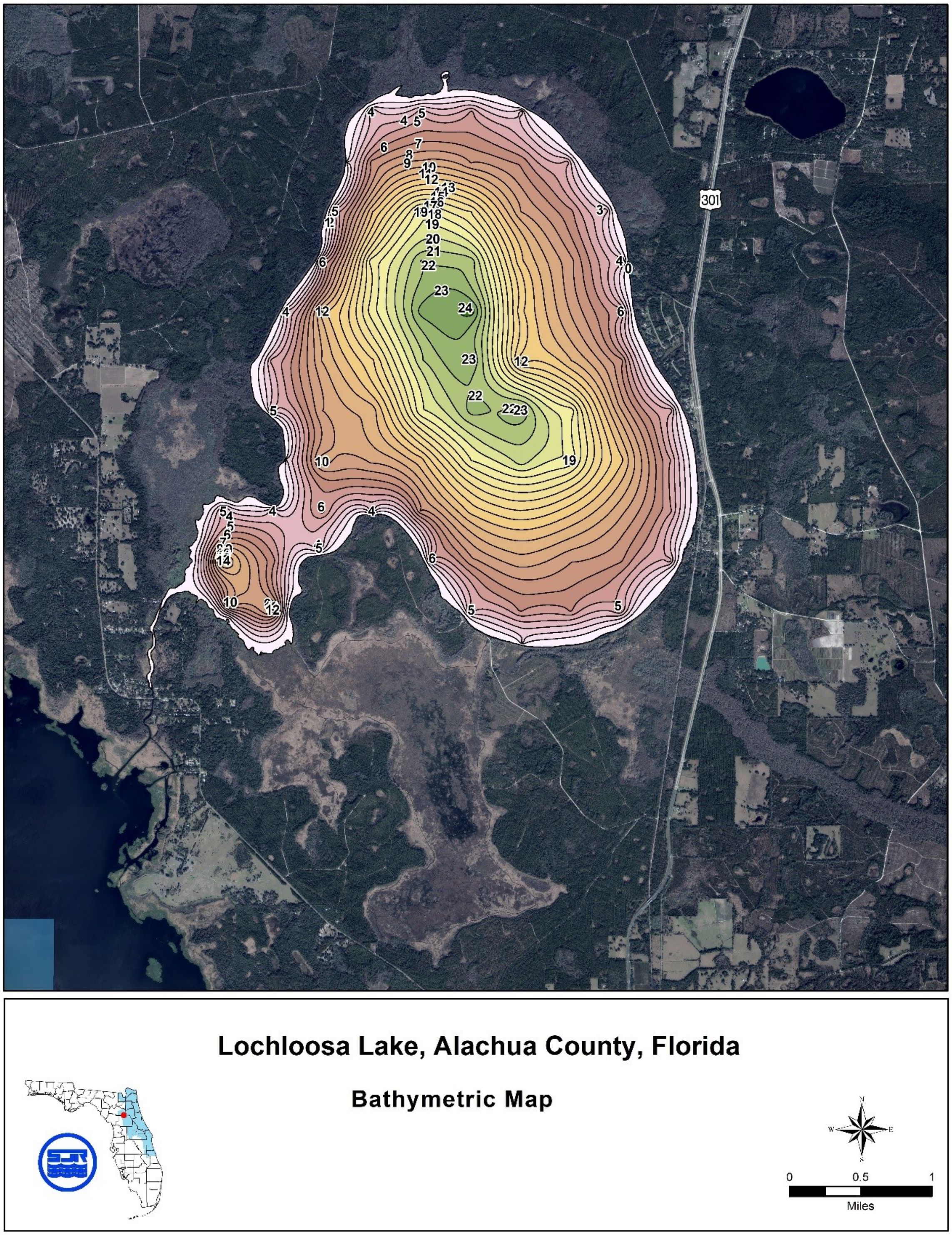


Figure 3. Lochloosa Lake bathymetry

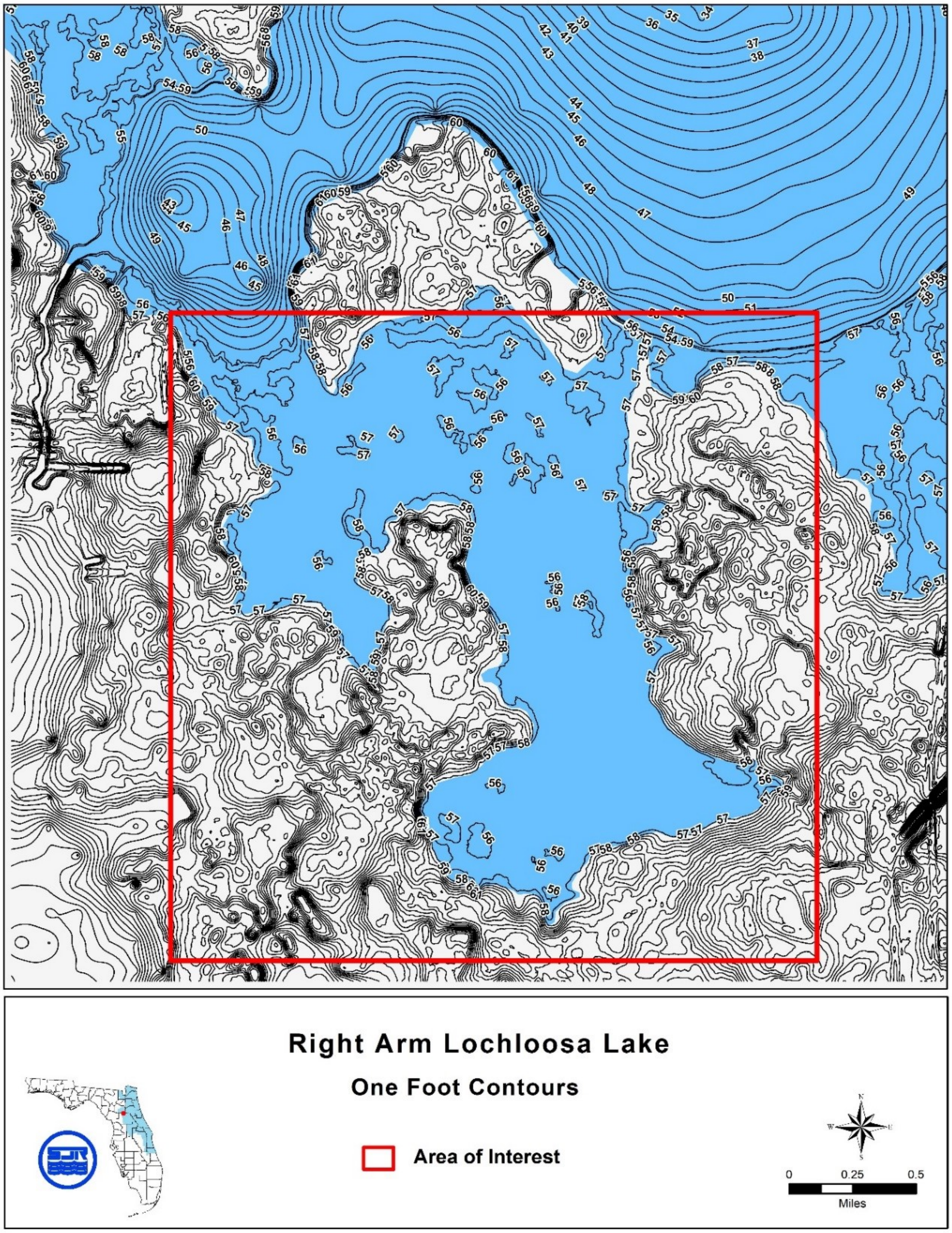


Figure 4. RALL marsh bathymetry

## HYDROLOGY

### Water Level Data

Lake level data for Lochloosa Lake (SJRWMD station 71481615) has been collected from July 1942 to the present (Figure 5). The available data includes relatively good continuous data from 1942 to early 1960s and from 1990 to present and limited sparse data from early 1960s to 1990. The lake is relatively stable with typical fluctuations ranging from 4–5 feet. The long-term annual average lake level is 56.1 ft NAVD88. The maximum observed water level (60.7 ft NAVD88) for Lochloosa Lake was recorded in March 1948. The minimum observed water elevation (51.5 ft NAVD88) for Lochloosa Lake was recorded in April 2012. *(see Appendix B for more details on water level data)*. A summary of water level statistics for Lochloosa Lake is provided in Table 2.

Table 2. Water level (WL) summary statistics for Lochloosa Lake

| Descriptive Statistics | Lochloosa Lake WL |
|---|---|
| Average | 56.1 |
| Median | 56.3 |
| Mode | 57.4 |
| Standard Deviation | 1.6 |
| Range | 9.4 |
| Minimum | 51.3 |
| Maximum | 60.7 |

### Rainfall and Evapotranspiration

Rainfall data were compiled using data from Gainesville stations. Potential evapotranspiration (PET) was computed from temperature data obtained from Gainesville station. Figure 6 shows the annual rainfall data. The long-term annual average rainfall and PET are approximately 50 and 48 inches, respectively (Table 3).

Table 3. Rainfall and PET summary statistics

| Descriptive Statistics | Annual Precipitation (in) | Annual PET (in) |
|---|---|---|
| Average | 50.03 | 48.02 |
| Standard Error | 1.14 | 0.18 |
| Median | 50.23 | 47.95 |
| Standard Deviation | 8.73 | 1.38 |
| Minimum | 33.38 | 45.28 |
| Maximum | 67.80 | 51.42 |

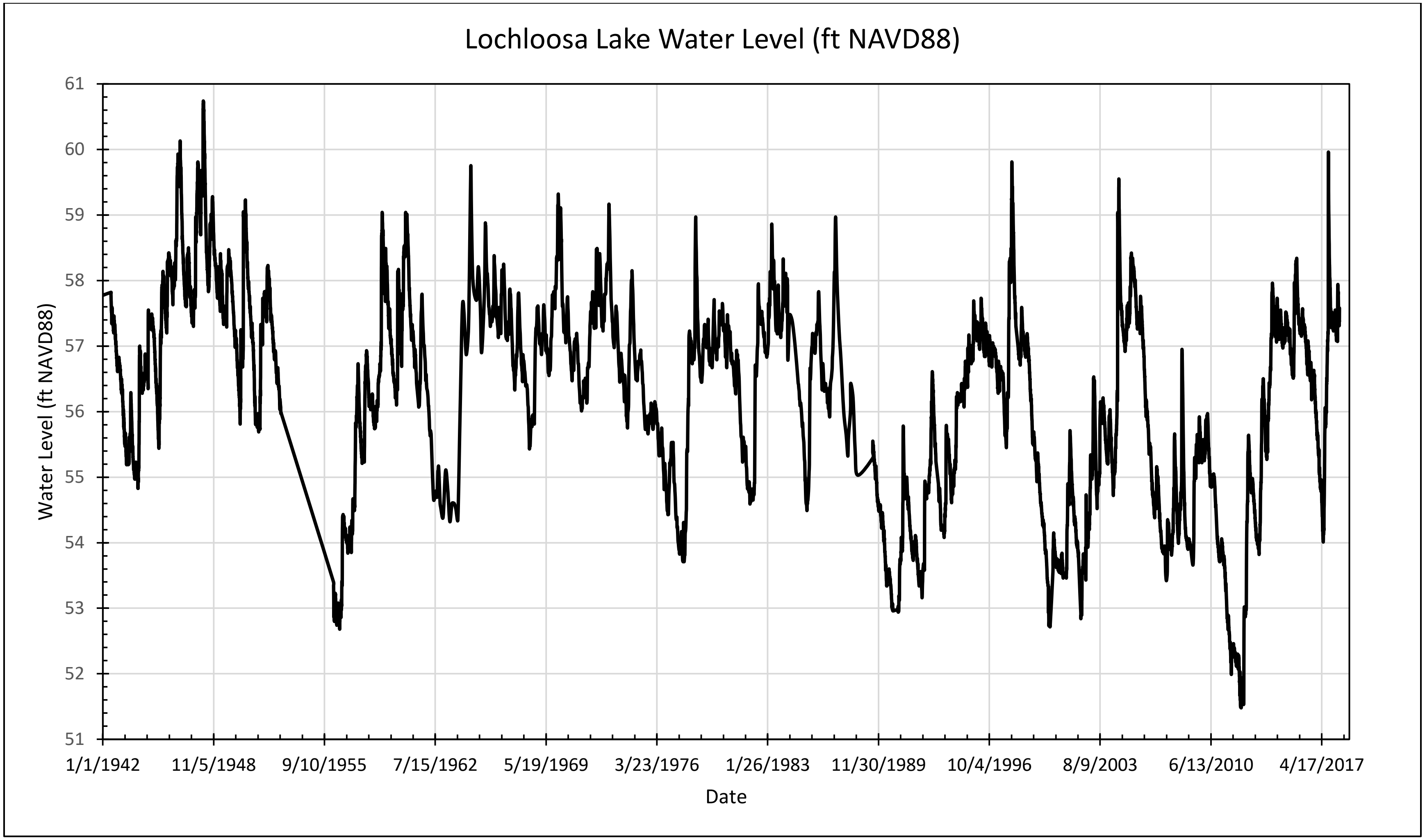


Figure 5. Observed Lochloosa Lake water levels, 1942–2018

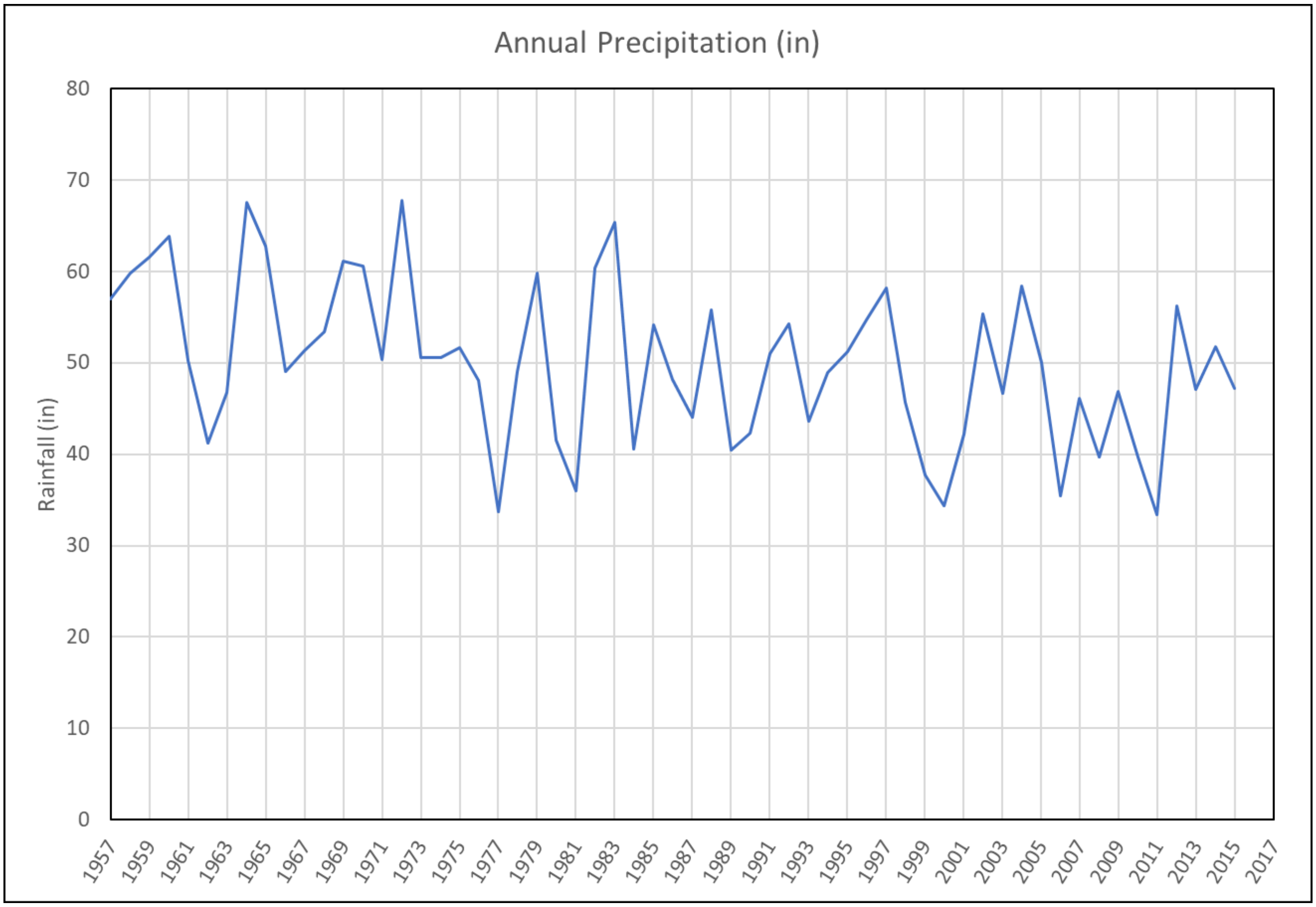


Figure 6. Annual average rainfall, 1957–2015

## SURFACE WATER BASIN CHARACTERISTICS

### Land Use

The Lochloosa Lake watershed remains relatively undeveloped. Land use in the subbasin consists primarily of forest, wetlands, and areas of forest regeneration (Table 4; Figure 7). Impervious land use changes, which include residential, industrial, and mining operations, have occurred on approximately 3,434 ac (6.1%) of the watershed. SJRWMD manages approximately 10,400 ac of forest and wetlands immediately adjoining Lochloosa Lake (Figure 8), as a wildlife conservation area.

### Wetlands

Based on 2014 SJRWMD data, the littoral zone is comprised of submerged aquatic beds (593 ac), deep marsh (155 ac), and floating marsh (102 ac) (Table 5, Figure 9). Shallow marsh vegetation is the most prevalent plant community around the lake, accounting for 1,680 ac of the total wetland acreage. The vast majority (>90%) of the shallow marsh vegetation community is found in the RALL marsh. Forested wetland communities, dominated by hardwood swamp (880 ac) and cypress swamp (209 ac), occur in the northern, western, and southeastern portions of the lake.

Table 4. Land cover in Lochloosa Lake watershed, 2014

| Land Cover | 2014 Land Use (acres) | |
|---|---|---|
| Low Density Residential | 2,378.3 | 4.2% |
| Med Density Residential | 217.1 | 0.4% |
| High Density Residential | 31.1 | 0.1% |
| Industrial | 804.6 | 1.4% |
| Mining | 2.9 | 0.0% |
| Open Land | 151.1 | 0.3% |
| Pasture | 3,630.6 | 6.4% |
| Agriculture | 1,256.7 | 2.2% |
| Agriculture Trees | 740.6 | 1.3% |
| Rangeland | 621.5 | 1.1% |
| Forest | 21,833.5 | 38.6% |
| Water | 5,675.1 | 10.0% |
| Wetlands | 9,103.7 | 16.1% |
| Forest Regeneration | 6,183.5 | 10.9% |
| Wetlands Non Reach | 4,043.7 | 7.0% |
| **Total** | **56,589.5** | **100.0%** |

The seasonal pattern of water level fluctuation is the dominant factor controlling the composition and distribution of wetland communities. This seasonal pattern, known as a system's hydroperiod, is composed of different components, including frequency, duration, magnitude, rate of change and seasonality (Murray-Hudson et al. 2014). Hydroperiod descriptions for the wetland communities found around Lochloosa Lake are presented in Appendix A.

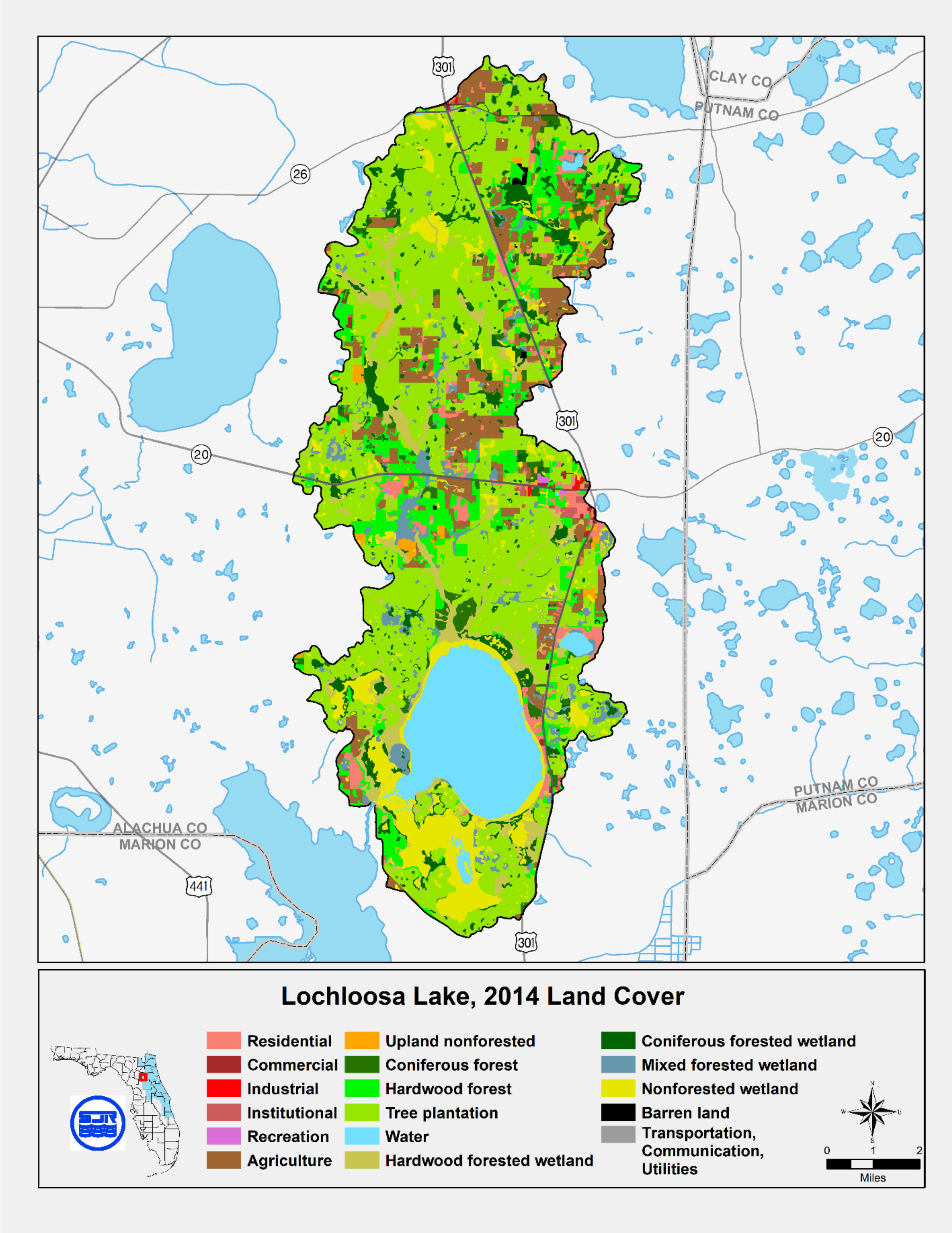


Figure 7. Land cover in the Lochloosa Lake watershed

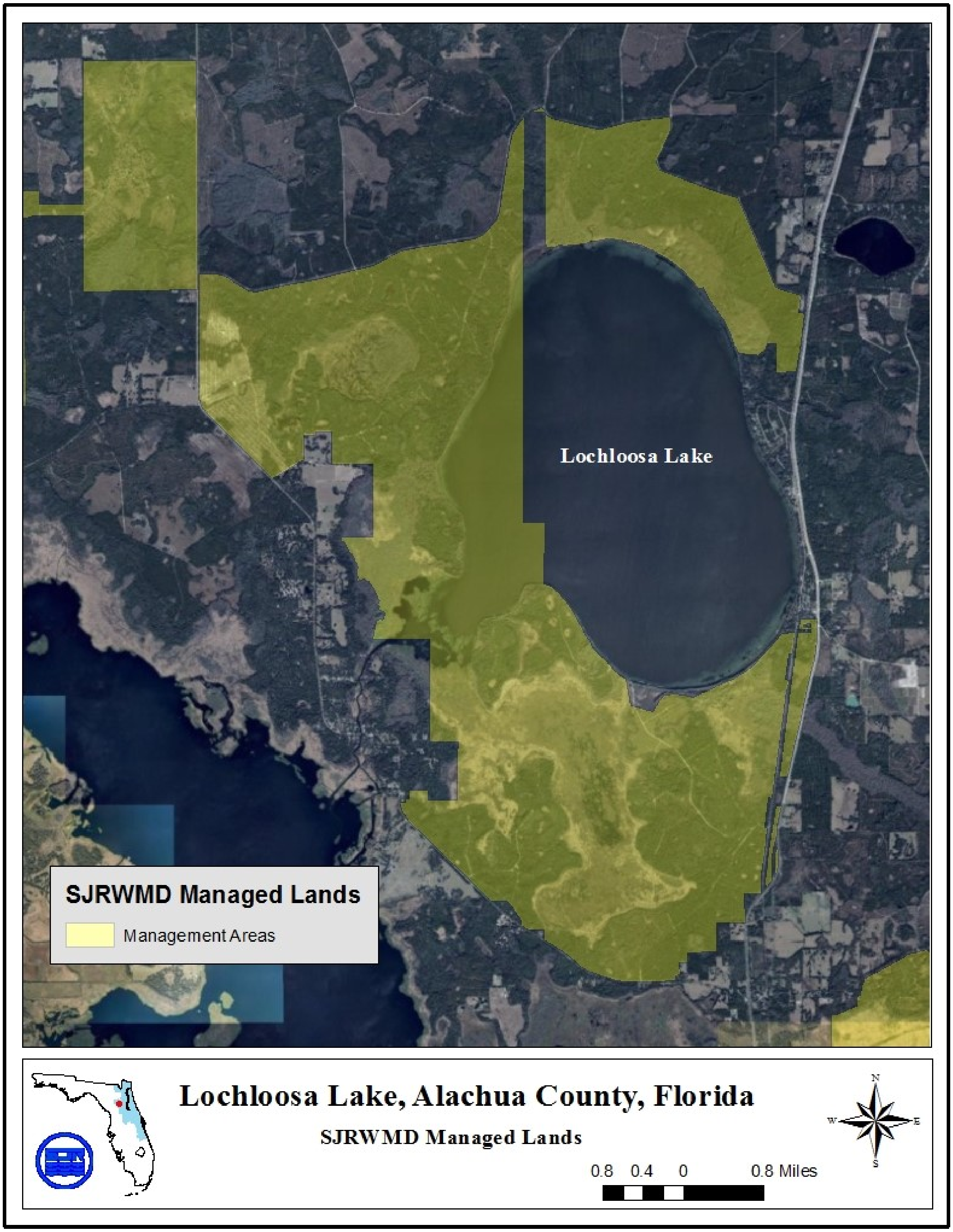


Figure 8. Lochloosa Lake showing land managed by the St. Johns River Water Management District

Table 5. Lochloosa Lake adjacent wetland plant communities by size and ranking

| Wetland Community | Acres | Ranking by Acres |
|---|---|---|
| Shallow marsh | 1680 | 1 |
| Hardwood swamp | 880 | 2 |
| Wet prairie | 555 | 3 |
| Hydric Hammock | 323 | 4 |
| Forested Flatwoods | 263 | 5 |
| Cypress | 209 | 6 |
| Shrub swamp | 176 | 7 |
| Deep marsh | 155 | 8 |
| Transitional shrub | 149 | 9 |
| Floating marsh | 102 | 10 |
| Bayhead; Baygall | 78 | 11 |

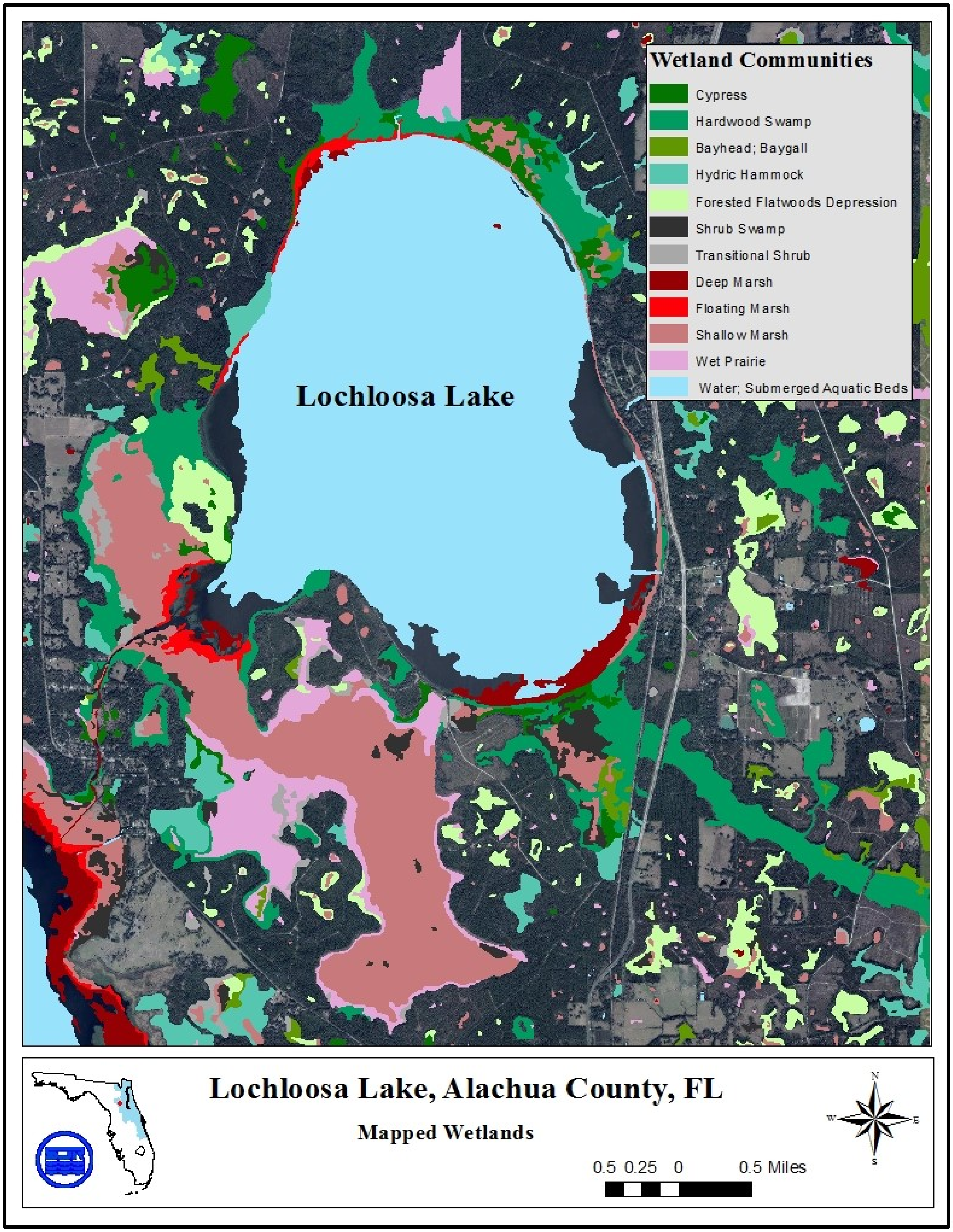


Figure 9. Lochloosa Lake mapped wetlands

## Soils

The soils surrounding Lake Lochloosa are predominantly Spodosols (Figure 10; NRCS Soil Survey Staff, 2017). Histosols, Entisols, Ultisols, Inceptisols, Alfisols, and Mollisols are all also present in proximity to Lake Lochloosa. Observed Spodosol soil series include Pottsburg, Newnan, Wauchula, Pomona, and Myakka. Observed Alfisol series include Emeralda, Wauberg, Popash, Malabar, and Martel. Observed Entisols include Basinger and Candler. Observed Histosols include Samsula and Terra Ceia. Floridana is the only Mollisol and Placid is the only Inceptisol observed near Lake Lochloosa. Observed Ultisols include Pelham and Surrency. Soil drainage varies from somewhat poorly drained to very poorly drained immediately bordering the lake. Drainage improves to excessively well drained through moderately well drained within the areas containing Entisols. Mapped hydric soils were predominantly restricted to observed Mollisols and Histosols (Figure 11; NRCS Soil Survey Staff, 2017), however additional hydric Spodosol and Inceptisols were identified by SJRWMD staff.

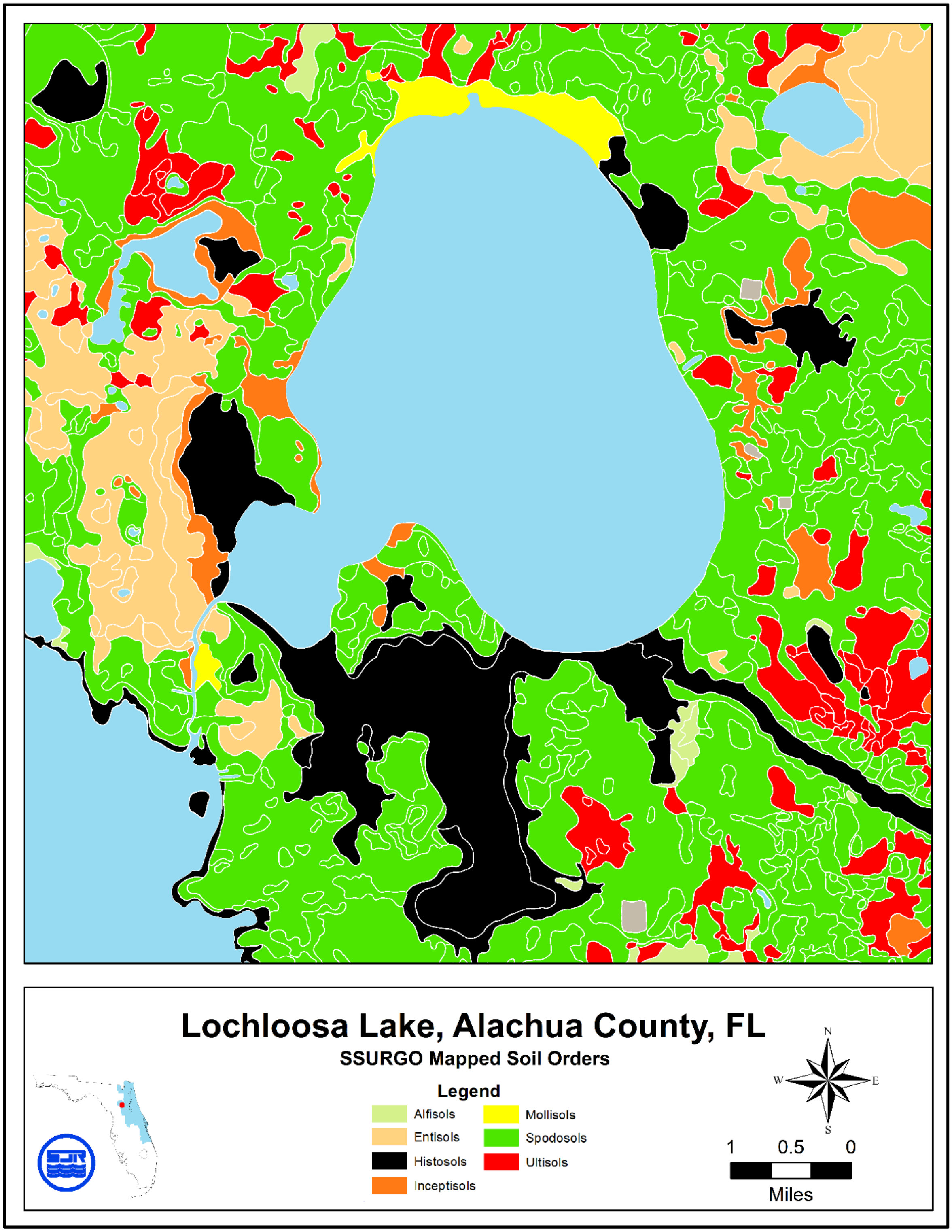


Figure 10. Soil series around Lochloosa Lake according to Soil Survey Geographic Database (NRCS Soil Survey staff, 2017)

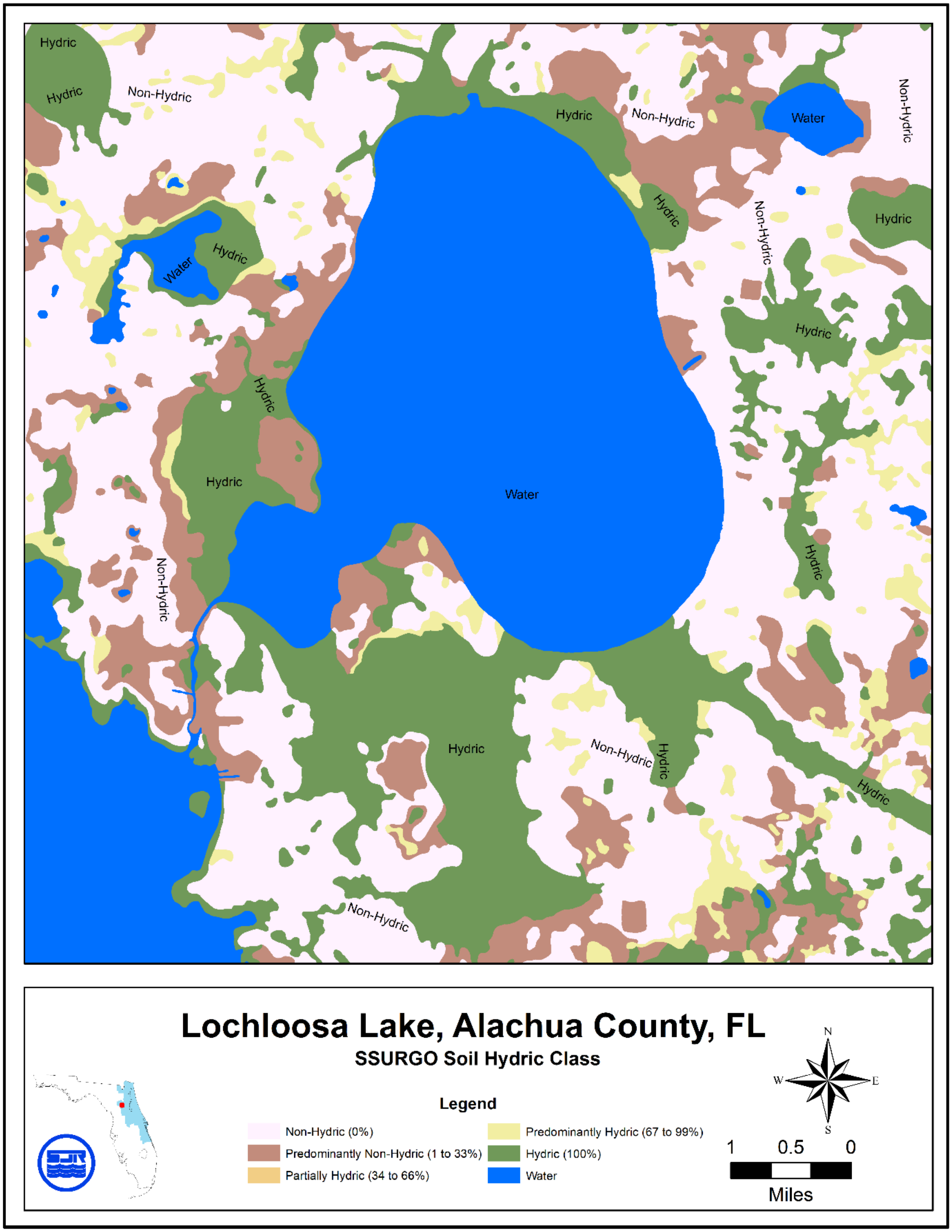


Figure 11. Soil Hydric Class around Lochloosa Lake according to Soil Survey Geographic Database (NRCS Soil Survey Staff, 2017)

## Water Quality

Lochloosa Lake is a hypereutrophic (highly productive) lake. Water quality analyses show elevated concentrations of chlorophyll-a (Chl-a; a measure of phytoplankton biomass), total phosphorus (TP), and total nitrogen (TN) relative to FDEP total maximum daily load (TMDL) target concentrations (Magley 2017) (Table 6).

Trophic State Index (TSI), a measure of water quality based on biological productivity, was calculated for Lochloosa Lake. TSI is considered an indicator of lake health or integrity, and is calculated using TP, TN and Chl-*a* data. Lakes with TSI values less than 60 are rated as "good and fully support uses," and are indicative of good water quality. Values between 60–70 are fair, while values above 70 are considered indicators of poor water quality (Friedemann and Hand 1989). For the available period of record, the Lochloosa Lake average TSI score is 68, which indicates fair water quality. Water quality has no trend in the past three decades as indicated by a regression of TSI over time ($p = 0.20$; Figure 12).

Table 6. Average TN, TP, and Chl-a concentration for Lochloosa Lake and FDEP TMDL targets (both as geometric mean)

| Water quality parameter | Concentration in Lochloosa Lake (Geometric mean;1986 – 2018) | FDEP TMDL Target |
|---|---|---|
| Chl-a (µg/L) | 54 | 38 |
| TP (mg/L) | 0.068 | 0.055 |
| TN (mg/L) | 2.24 | 1.15 |
| TSI | 68 | 60 |

TP is not significantly correlated with Lochloosa Lake water level, while TN, Chl-a, and TSI are all significantly correlated with lake level (Table 7).

Table 7. Correlation between Lochloosa Lake level and TP, TN, Chl-a, and TSI

| Parameter | Person correlation coefficients | P-value |
|---|---|---|
| TP | -0.013 | 0.8467 |
| TN | -0.52 | <0.0001 |
| Chl-a | -0.31 | <0.0001 |
| TSI | -0.38 | <0.0001 |

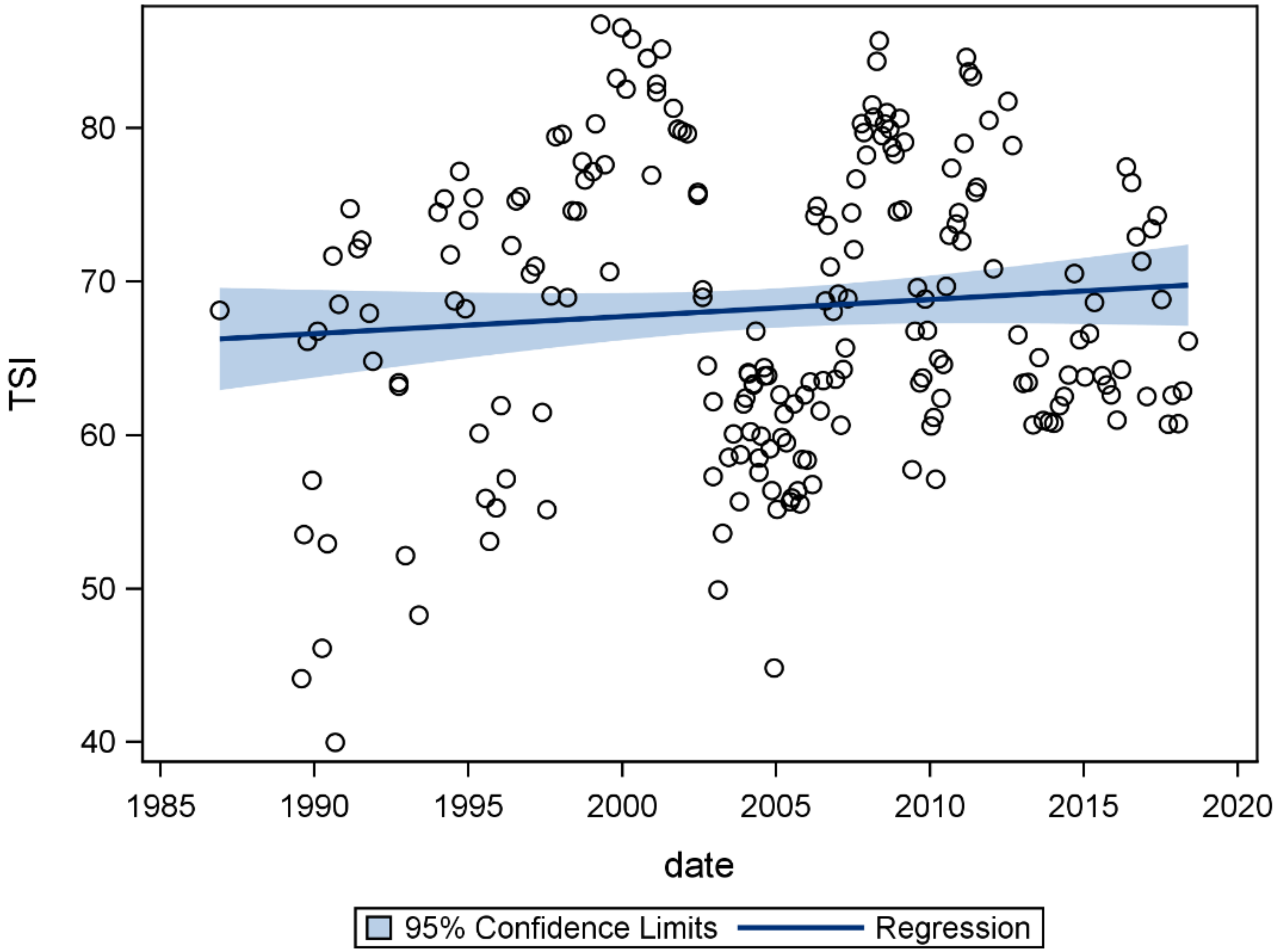


Figure 12. TSI trend from 1986 to 2018 in Lochloosa Lake, Alachua County, Florida

# MFLs Determination

A key component of the MFLs determination is an analysis to determine relevant environmental attributes and beneficial uses for each waterbody. This analysis also involves determining appropriate criteria and thresholds to protect these environmental values. This process typically includes consideration of site-specific field-based ecological data, topographical information, recreational or other environmental data, as well as data collected at other MFLs sites, and supportive information from scientific literature. Using this information, a determination is made of the most important environmental features for a waterbody. Next, appropriate criteria are determined to represent these environmental values and a minimum hydrologic regime (MFLs condition), that ensures their protection, is determined.

The protection of a suite of 10 environmental values, also called Water Resource Values (WRVs), is discussed in the *MFLs Assessment* section. The current and future status of the lake, based on the most constraining criterion, is also presented in the *MFLs Assessment* section. The general approach for determining minimum levels for Lochloosa Lake is presented below, and specific details are provided in Appendix A.

## Environmental Analyses

The environmental analysis for Lochloosa Lake characterized the ecological attributes and other sensitive beneficial uses of the waterbody. This included site-specific field-based ecological and topographical information, empirical data collected at other MFLs sites, and supportive information from the scientific literature.

### Site Selection and Data Collection

Ecological, soils and elevation data for the Lochloosa Lake were collected along transects that extended from uplands to open water. A literature and data search was conducted prior to establishing field transects. Proposed transects were inspected prior to intensive data collection to confirm the presence of desired features, including: representative examples of common wetland communities; unique or high-quality wetlands; edge of uplands or open water; and organic and other hydric soils. Vegetation and soil sampling followed standard field procedures. Detailed information on field transect selection and data collection methods are provided in Appendix A.

### An Event-Based Approach

A waterbody's hydroperiod is the 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). Variable flooding and/or drying events are necessary to maintain the extent, composition, and function of wetland and aquatic communities. Wetland and aquatic species, and hydric soils require a minimum frequency of critical hydrologic (flooding and/or drying) events for long-term persistence.

Event-based MFLs are described with a magnitude component (i.e., water elevation), a duration, and a return interval. The magnitude and duration components define biologically relevant events. The return interval (frequency) of hydrological events is the manageable component (Neubauer et al. 2008). MFLs are developed to ensure that changes in return interval due to water withdrawals are not sufficient to cause significant harm, defined as impairment or loss of ecological structure (e.g., permanent downhill shift in plant communities) or function (e.g., insufficient fish reproduction or nursery habitat).

Quantitative hydrologic probabilities, called Surface Water Inundation and Dewatering Signatures (SWIDS), are used for some waterbodies to determine protective return intervals. SWIDS of vegetation species or communities provide a hydrologic range, with a transition from a drier condition on one side of the range to a wetter condition on the other side. These hydrologic signatures provide an estimate of the shift in return interval of flooding or drying events that can occur before causing significant harm to the species or community in question. More details regarding SWIDS calculations are provided in Appendix A.

Because hydroperiods vary spatially and temporally (Mitsch and Gosselink 2015), multiple events are typically used to protect different portions of a system's hydrologic regime (Neubauer et al. 2008). For many systems, SJRWMD sets three MFLs; minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) water levels. In some cases, a minimum infrequent high (IH) and/or minimum infrequent low (IL) water level may also be set (Figure 13). The FH, MA and FL are typically used for lakes with stable wetland communities and/or organic soils. Because of Lochloosa Lake's small intra-annual water level fluctuation range (2 ft), and the presence of stable wetlands and organic soils, SJRWMD recommends setting FH, MA and FL water levels for this lake.

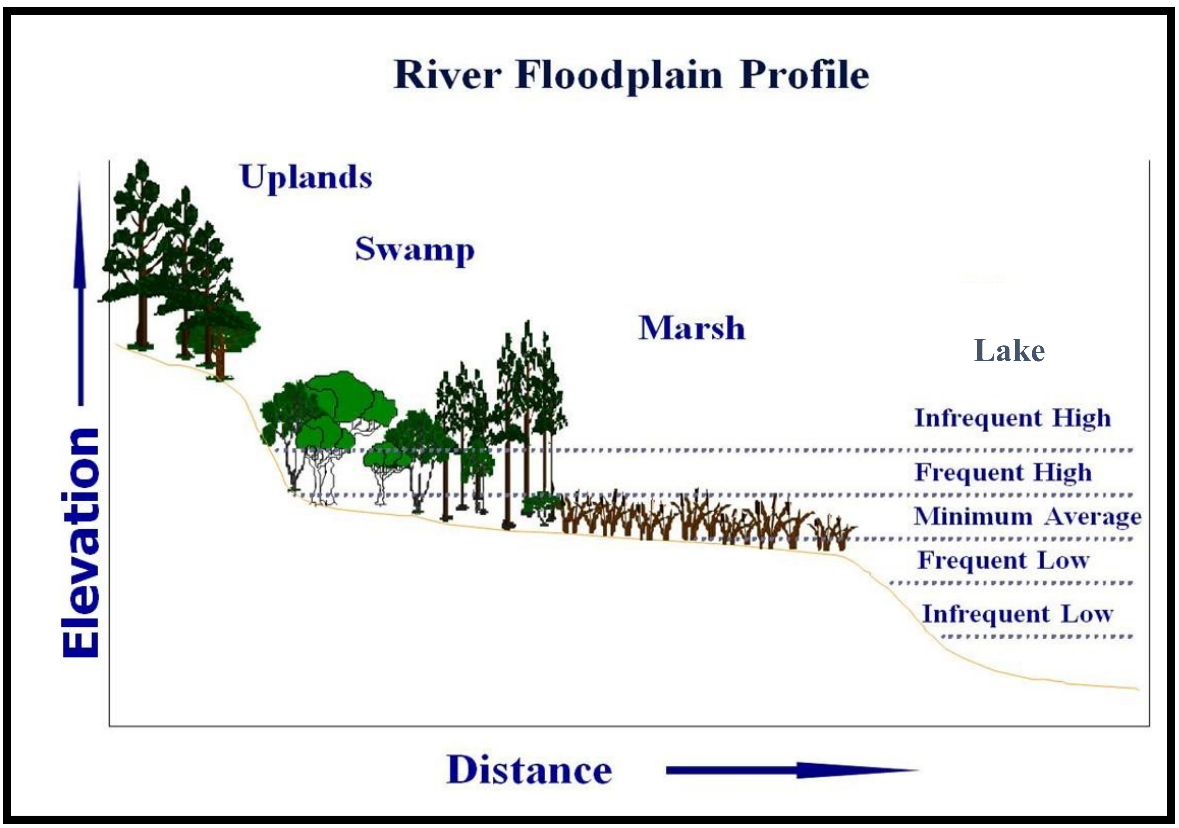


Figure 13. Five potential MFLs developed using SJRWMD's event-based approach

## LOCHLOOSA LAKE MINIMUM LEVELS

Four minimum lake levels were developed for Lochloosa Lake. Three of the minimum levels were determined based on the hydrologic regime necessary to protect wetlands, organic soils, and their ecological functions. The FH-1 is based on providing a sufficient number of flood events to protect floodplain wetlands and associated wildlife habitat values. The MA is designed to prevent an excessive number of drying events, to protect organic soils from oxidation and subsidence and avoid adverse impacts to habitat and water quality. The FL also prevents an excessive number of drying events to protect marsh habitats and associated wildlife values.

In addition to developing the FH-1, MA and FL, SJRWMD also worked with FWC to evaluate environmental criteria necessary to protect important fish and wildlife species and habitats for Lochloosa Lake. Based on these consultations, a second frequent high (FH-2) was determined. The FH-2 is based on the hydrologic regime necessary to protect nesting habitat of the Florida sandhill crane, a state-designated threatened species. The following sections provide a general description of the development of minimum levels for Lochloosa Lake. Specific details are provided in Appendix A.

### Minimum Frequent High

A minimum FH is typically developed to ensure sufficient flooding to maintain seasonally flooded wetland vegetation, hydric soils, and their associated wildlife habitats and biogeochemical processes. Two FH have been developed for Lochloosa Lake (Table 8).

FH-1 is based on maintaining the long-term location, area and ecological functions of hardwood/cypress swamp habitat.

FH-2 is based on maintaining the ecological requirements and critical nesting habitat of the Florida sandhill crane, a state-designated threatened species.

### FH-1

The goal of the FH-1 is to ensure frequent inundation in seasonally flooded wetlands, sufficient to maintain species composition, vegetative structure, and associated ecological functions. Hardwood swamp and cypress swamp are the highest elevation, seasonally flooded wetlands surrounding Lochloosa Lake. These two wetland communities have very similar hydroperiods, with cypress often being a significant component of a hardwood swamp ecosystem (Kinser 2010). Hardwood swamp is frequently a result of natural succession from a cypress swamp in the absence of fire (Conner and Buford 1998). Because of these factors hardwood swamp and cypress swamps surrounding Lochloosa Lake have been grouped together and analyzed as one wetland community type.

The FH-1 magnitude was calculated by averaging the ground elevations of hardwood/cypress swamp communities located along three representative field transects at Lochloosa Lake. The resulting average ground elevation equals 56.8 ft. NAVD. The FH elevation will also provide sufficient water depths for fish and other aquatic organisms to feed and spawn in the hardwood/cypress swamp wetland communities (Guillory 1979; Ross and Baker 1983; Bain 1990; Poff et al. 1997).

The duration component of the FH-1 is a minimum of 30 days continuously flooded at or above the 56.8 ft elevation (described above). Maintaining water levels for the duration at the average hardwood/cypress swamp elevation will promote inundation and/or saturation conditions sufficient to support hydrophytic (i.e., obligate, facultative wet, and facultative) plant species (Mace 2015). This will prevent a permanent downward shift of these important wetland communities.

The FH is typically associated with a seasonally flooded hydroperiod (Rule 40C-8.021(16), *F.A.C.*) "…where surface water is present or the substrate is flooded for brief periods (up to several weeks) approximately every one to two years." The return interval for FH-1 was informed by empirical hydroperiod information collected for other hardwood swamps in SJRWMD. Based on the minimum return interval supported by a SWIDS analysis of 12 SJRWMD lakes with hardwood swamps, the return interval for FH-1 is 2 years. This return interval is meant to maintain the occurrence of high surface water levels, typically during wet seasons of normal or above normal rainfall.

**FH-2**

The FH-2 was developed to protect nesting habitat for the Florida sandhill crane (*Grus canadensis pratensis*), a State-designated Threatened species (FWC 2011). With a low reproductive potential due to small clutch size, low recruitment rate, age at first breeding, and seasonal nesting, the Florida sandhill crane may have limited ability to rebound from natural and man-made disturbances (Dwyer 1990). A continuous loss of suitable sandhill crane habitat over the past several decades has been documented in Florida (Nesbitt and Hatchitt 2008). Florida sandhill cranes prefer to nest in shallow marshes with emergent herbaceous and shrubby species, with an average water depth of 12 in. (Stys 1997; Walkinshaw 1982, Dwyer 1990).

The FH-2 magnitude component is based on the ecological requirements for Florida sandhill crane nesting in the shallow marsh habitats within the RALL marsh (Figure 2). Based on consultation with the FWC, one foot of water depth above average ground elevation is required for Florida sandhill crane nesting. The resulting FH-2 magnitude component is 56.5 ft. NAVD (Appendix A).

The FH-2 duration is based on the seasonal nesting pattern of the Florida sandhill crane, which generally occurs from March to May in north-central Florida (Nesbitt 1988). Based on studies and consultation with the FWC, the duration for the average water level at or above 56.5 ft, during March through May, is 92 days. This is sufficient to maintain the seasonal nesting requirements of the Florida sandhill crane.

Florida sandhill cranes first attempt breeding at a minimum age of 2 to 3 years, with most first-time breeders failing to produce independent young (Gerber et al. 2014). Breeding for pairs that have reached reproductive age is usually attempted annually, although nesting may be delayed or abandoned if conditions are not favorable in a given season (Gerber et al. 2014; Nesbitt 1992). Florida sandhill cranes have the lowest annual recruitment of any species of game birds, with an annual reproductive success of 35%, on average (Drewien et al. 1995; Nesbitt 1992). For these reasons, it is important to maintain adequate conditions for nesting in large nesting habitats such as the RALL marsh. Based on this, and consultation with the FWC, the return interval component is to be two years.

**Minimum Average**

The MA for Lochloosa Lake was developed to protect the long-term location of organic soils while preventing oxidation and subsidence in the floodplain (Table 8). The MA, defined as "…the surface water level…necessary over a long period to maintain the integrity of hydric soils and wetland plant communities" (Rule 40C-8.021(9), F.A.C.), was developed to prevent an excessive number of dewatering events and protect deep organic soils (i.e., ≥8 in. thick organic layer within the top 32 in. of soil) from oxidation and subsidence, preventing adverse impacts to habitat and water quality.

The general indicator of protection for the MA water level is to ensure that organic soils are saturated or inundated frequently enough to maintain soil structure and associated ecological functions. The specific indicator of protection is a water level that equals a 0.3-ft water table drawdown from the average ground surface elevation of deep organic soils surveyed at Lochloosa Lake (for more details *see* Appendix A).

The MA magnitude component was determined based on the average elevation of deep organic soils surveyed at Lochloosa Lake. The resulting elevation is 55.9 ft. NAVD. This elevation corresponds to the average elevation of deep organic soils (56.2 ft. NAVD) minus a water table drawdown of 0.3-ft. (see Appendix A for details).

The duration for the average non-exceedance water level for the MA is 180 days. This will ensure that drying events do not occur too often, and thus will maintain adequate saturation of deep organic soils on Lochloosa Lake. Wetland soils are a medium for denitrification, a process important in maintaining aquatic/wetland water quality. The periodic, short duration alternating aerobic/anaerobic conditions will ensure effective nitrification (the conversion of ammonium to nitrate), which is then subject to denitrification, while the combination of inundation and dewatering will maintain wetland communities (Payne 1981; Reddy and DeLaune 2008; see Appendix A for more details).

As noted, the MA is a dewatering event that usually occurs for a long duration with short return intervals, corresponding to a water level that typically occurs during normal dry seasons. The MA is associated with the "typically saturated" hydroperiod defined below:

> …where for extended periods of the year the water level should saturate or inundate. This results in saturated substrates for periods of one-half year or more during non-flooding periods of typical years. Water levels causing inundation are expected to occur fifty to sixty per cent of the time over a long-term period of record. This water level is expected to have a recurrence interval, on the average, of one or two years over a long-term period of record (Rule 40C-8.021(19), F.A.C.).

Based on this description of drying events that typically occur within this part of central Florida, the return interval for the Lochloosa Lake MA is 1.7 years (59 times in 100 years). This return interval is also supported by SWIDS data of the average elevation of deep organic soils minus 0.3 ft. (Neubauer et al. 2004; Neubauer et al. 2007, draft), which is based on hydroperiods analyzed at 21 unique locations (Mace 2015; Appendix A). The MA allows for a small change relative to the existing hydrologic condition but is expected to prevent permanent loss of deep organic soils due to oxidation or subsidence in the floodplains of Lochloosa Lake.

**Minimum Frequent Low**

An FL was developed for Lochloosa Lake, based on protecting the long-term location and area of deep marsh habitats and maintaining adequate water depth for game fish reproduction and habitat. The FL for Lochloosa Lake was developed to prevent an excessive number of drying events, with the goal of protecting marsh habitats and their associated ecological functions and values (Table 8). The FL also maintains an appropriate water table level in floodplain soils during periodic droughts (See Appendix A for details).

The FL level is defined in Rule 40C-8.021(10), *F.A.C.*, which states, "…a chronically low surface water level…that generally occurs only during periods of reduced rainfall. This level is intended to prevent deleterious effects to the composition and structure of floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs."

The goal of the FL is to avoid excessive floodplain drawdown while simultaneously allowing seed germination and growth of wetland plants, maintaining the extent of deep marsh habitat, and ensuring adequate open water area. The general indicator of protection is to prohibit excessive floodplain drawdown to maintain species composition, vegetative structure, and ecological functions of seasonally flooded wetland plant communities and deep marsh habitats.

The FL magnitude component is based on the average maximum elevation of deep marsh communities surveyed along three representative vegetation transects around the lake. The resulting elevation is 53.4 ft. NAVD. The FL will allow for periodic dewatering of the floodplain facilitating seed germination and maintenance of emergent and shallow marsh vegetation communities while protecting deep marsh habitats from extended periods of drying.

The duration component of the FL is a minimum of 120 days for this continuously non-exceeded drying event. This duration will maintain the ecological integrity of deep marsh habitats, while also allowing for seed germination and providing adequate time for regeneration and growth of shallow marsh wetland plants to a height able to survive the next flood event (Ware 2003).

The FL return interval for Lochloosa Lake is once every five years on average. A five-year return interval is supported by SWIDS data for the maximum elevation of *Nymphaceae* species (i.e. spatterdock and water lily), common deep marsh plant species, which is based on hydroperiods analyzed at 16 unique locations (Appendix A). This return interval allows for a minimum change from existing hydrologic conditions, while ensuring floodplain water level fluctuations are maintained within the normal range for Lochloosa Lake. The FL return interval is expected to prevent a permanent downhill shift of shallow marsh plant communities or a permanent net loss of Lochloosa Lake deep marsh and open water habitats (Mace 2014).

Table 8. Environmental criteria and minimum levels for Lochloosa Lake, Alachua County, Florida

| Minimum Levels | Environmental criteria | Minimum Level Components | | |
|---|---|---|---|---|
| | | Level (ft NAVD88) | Duration (days) | Return Interval (years) |
| FH - 1 | Hardwood/cypress swamp communities | 56.8 | 30 | 2 |
| FH - 2 | Sandhill crane nesting | 56.5 | 92 | 2 |
| MA | Organic soils | 55.9 | 180 | 1.7 |
| FL | Shallow marsh vegetation recruitment/protection of deep marsh habitat | 53.4 | 120 | 5 |

# MFLs Assessment

As described above, MFLs are not meant to represent optimal conditions, but rather set the limit to withdrawals, beyond which significant harm would occur. A fundamental assumption of SJRWMD's approach is that alternative hydrologic regimes exist that are lower than historical regimes but still protect the environmental functions and values of waterbodies from significant harm caused by water withdrawals. The MFLs determination component (previously described) involves defining a minimum hydrologic regime (MFLs condition) necessary to protect relevant water resource values.

The MFLs assessment component compares the MFLs condition with the current hydrologic regime (current-pumping condition) to assess whether the MFLs are being achieved under the current-pumping condition, and to determine if there is water available for withdrawal (freeboard), or necessary for recovery (deficit). If any of the MFLs are not being achieved under the current-pumping condition, indicating a deficit of water, a recovery plan is necessary. If the MFLs are currently being achieved, but a deficit is projected within the 20-year planning horizon, a prevention plan is needed.

## Hydrological Analyses

Assessing the MFL status of waterbodies requires substantial hydrological analysis. Several steps were involved in performing the hydrologic analysis for the Lochloosa Lakes MFLs assessment, including:

1. Review of available data for compiling long-term datasets;
2. Historical groundwater pumping impact assessment;
3. Development of lake level datasets representing no-pumping and current-pumping conditions.

<u>Long-term Lake Levels</u>

Available water level data were discussed previously in the *Hydrology* subsection under the *Setting and Description* section. Because minimum levels established for Lochloosa Lake are based on event-based approach associated with return periods, MFL assessment requires frequency analysis of lake levels. Due to the presence of short- and long-term climatic cycles (e.g. El Nino Southern and Atlantic Multidecadal Oscillations), the frequencies of lake levels could be significantly different in wet periods such as in 1960s than dry periods such as in 2000s. Thus, it is important to perform frequency analysis using long-term lake levels so that short- and long-term variations in lake levels can be captured.

Although observed long-term lake levels are available, the data is discontinuous and especially sparse between 1960 and 1990 (Figure 5) To build a continuous daily long-term lake levels and simulate the influence of the Upper Floridan aquifer on lake levels, a surface water model was developed (CDM Smith, 2018; *see Appendix E for model report*). Using the surface water model, daily long-term lake levels were simulated.

<u>Development of No-pumping and Current-pumping Lake Levels</u>

Lochloosa Lake MFL assessment includes assessment of MFLs under current and future groundwater pumping conditions. The current status assessment of Lochloosa Lake MFLs is based on long-term lake level dataset representative of current-pumping condition. The current-pumping condition lake levels represent a reference hydrologic condition of the lakes in which the impact from regional groundwater pumping on the lakes is constant from 1957 to 2015 at a rate of current-pumping impact. Current-pumping impact is defined as the impact due to the averaged groundwater pumping from 2011 to 2015. Groundwater pumping, used to calculate the current-pumping condition, was averaged over five years so that it is more representative of the most recent average groundwater demand condition. The years 2016 and 2017 were not included because regional pumping data were not available at the time of this analysis.

Assuming climatic conditions such as rainfall, and other conditions present from 1957 to 2015 are repeated over the next 58 years, the current-pumping condition lake levels would reflect the future condition of the lake levels if the current-pumping condition does not change. SJRWMD's understanding of possible future climatic conditions is limited and there are significant uncertainties in global climate model predictions. More importantly, MFLs are established to prevent the lake from being significantly harmed by only groundwater pumping. Therefore, using historical conditions to generate current-pumping condition lake levels is reasonable.

The surface water model was utilized to simulate current-pumping condition lake levels. The interaction between the lake and the UFA was simulated by setting the UFA levels as boundary condition in the surface water model. Thus, the impact of groundwater pumping on the UFA levels near the lake was estimated first. North Florida Southeast Georgia regional groundwater model version 1.1 (NFSEG v1.1) was used for the groundwater pumping impact assessment (Durden, at al., 2018). The details of this analysis are described in Appendix B.

The observed UFA levels used in the surface water model was adjusted by removing the effect of estimated impact from historical pumping, called no-pumping condition UFA levels. To generate current-pumping condition UFA levels, the impacts from current-pumping (average 2011-2015 pumping) were subtracted from the no-pumping condition UFA levels from 1957 to 2015. The no-pumping and current-pumping Lochloosa lake levels were simulated by inputting the no-pumping and current-pumping UFA levels into the surface water model, respectively.

Figures 14 shows both no-pumping and current-pumping conditions lake levels for Lochloosa lake. As shown in the figure, the simulated current-pumping condition lake levels are not much different than the simulated existing-condition lake levels. This is mainly because the connectivity of the UFA to the lake is limited and the impact of the current regional groundwater pumping on the UFA near the lake is relatively low (0.8 ft, on average).

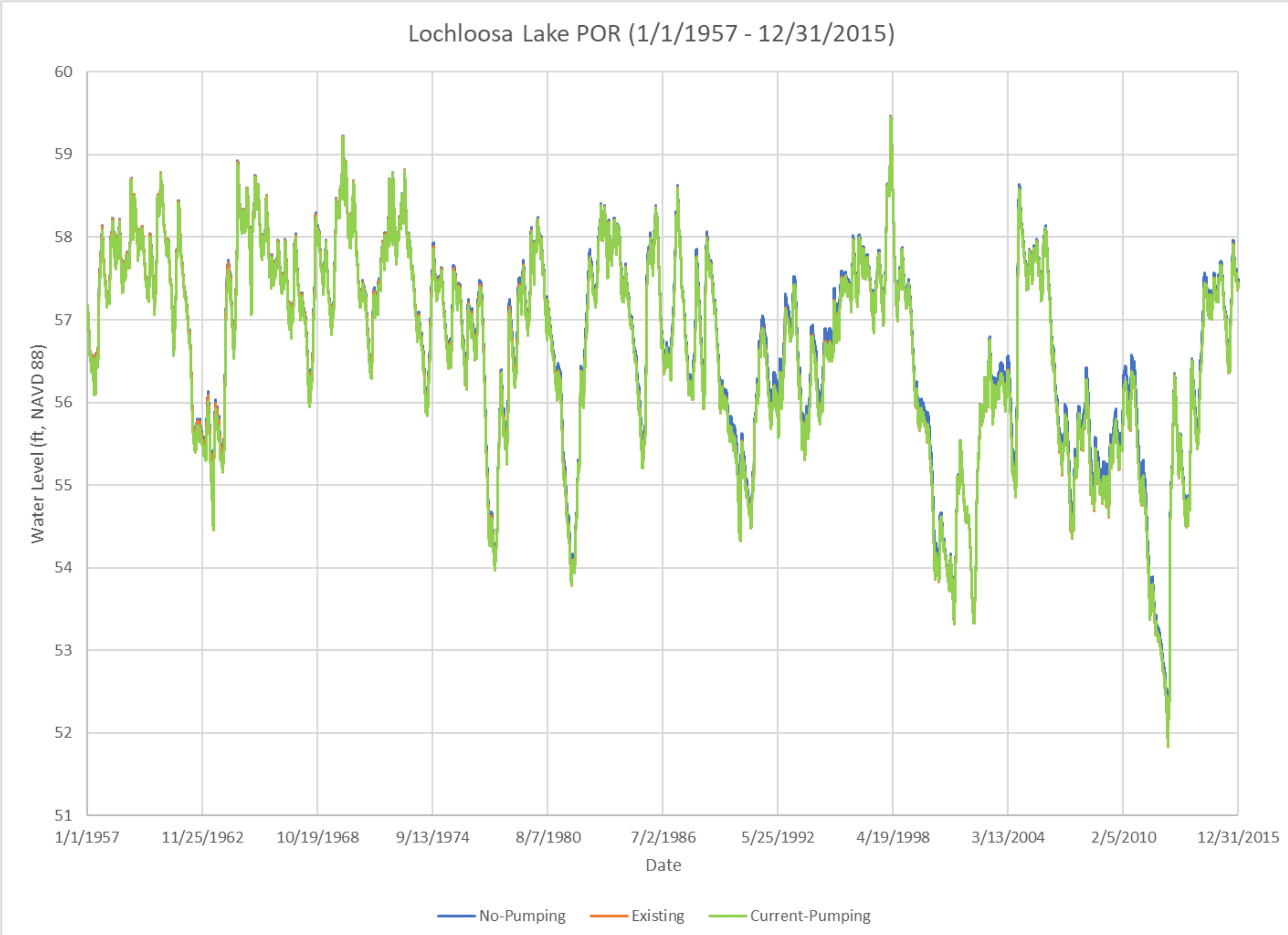


Figure 14. The estimated no-pumping and current-pumping condition levels for Lochloosa Lake, Alachua County, Florida

## CURRENT STATUS

Current MFLs status for Lochloosa Lake was assessed for each of the minimum levels described above (Table 8 in *Determination* section). MFLs status was assessed by comparing the frequency of an MFLs defined hydrologic event (defined with specific lake level and duration components) to the frequency of the same hydrologic event occurs under the current-pumping condition. The frequency of an MFLs defined hydrologic event occurs under the current-pumping condition was calculated based on annual series data. See Appendix C for details regarding frequency analyses used to assess the status of minimum levels.

**Minimum Frequent High-1**

Frequency analysis results show that under current-pumping conditions the FH-1 flooding event occurs 67 years out of 100 years on average (1.5-year return interval) compared to the MFLs frequency of 50 years per 100 years on average (2-years return interval; Table 9; Appendix C). The current-pumping condition exceeds this MFLs frequency, resulting in a freeboard of 6.4 feet in the UFA.

**Minimum Frequent High-2**

The assessment of the FH-2 was generally the same as for the other levels, except that a partial frequency analysis was performed using water level data from March 1 to May 31 for each year in the POR. This was done to calculate the annual probability exceedance of average lake level during the sandhill crane nesting season.

Frequency analysis results show that under the current-pumping conditions the FH-2 flooding event occurs 59 years out of 100 years on average (1.7-year return interval; Table 9; Appendix C). The minimum frequency of the FH-2 flooding event is 50 years per 100 years on average (2-year return interval). The current-pumping condition exceeds this minimum requirement, and results in a freeboard of 1.3 feet in the UFA.

**Minimum Average**

Frequency analysis results show that under current-pumping conditions the MA drying event occurs 36 years out of 100 years on average (2.8-year return interval; Table 9; Appendix C). The maximum frequency of the MA drying event is 59 years out of 100 years on average (1.7-year return interval). The current-pumping condition does not exceed this, and results in a freeboard of 3.1 feet in the UFA.

**Minimum Frequent Low**

Frequency analysis results show that under current-pumping conditions the FL drying event occurs 3 years out of 100 years on average (37-year return interval; Table 9; Appendix C). The maximum frequency of the FL drying event is 20 years out of 100 years on average (5-year return interval). The current-pumping condition does not exceed this, and results in a freeboard of >10 feet in the UFA.

Table 9. MFLs criteria and aquifer freeboard for Lochloosa Lake, Alachua County, Florida

| MFLs | Environmental Criteria | Minimum Level Components | | | | UFA freeboard (ft) |
|---|---|---|---|---|---|---|
| | | Level (ft NAVD88) | Duration (days) | MFL Condition Return Interval (years) | Current-pumping Condition Return Interval (years) | |
| Frequent High 1 (FH-1) | Hardwood/cypress swamp communities / associated wildlife values | 56.8 | 30 | 2 | 1.5 | 6.4 |
| Frequent High 2 (FH-2) | Sandhill crane nesting | 56.5 | 92 | 2 | 1.7 | 1.3 |
| Minimum Average (MA) | Organic soils | 55.9 | 180 | 1.7 | 2.8 | 3.1 |
| Frequent Low (FL) | Shallow and deep marsh communities / associated wildlife values | 53.4 | 120 | 5 | 37 | >10 |

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. By ensuring that the most sensitive MFL is achieved, assurance is also provided that all other MFLs will be achieved.

The most sensitive environmental criterion for Lochloosa Lake is the FH-2, which was based on sandhill crane nesting, and has a UFA freeboard of 1.3 ft (Table 9). Therefore, Lochloosa Lake's minimum levels are currently being achieved.

## Future / Projected Status

If the MFLs are currently being achieved but are projected to not be achieved within the 20-year planning horizon, then a waterbody is in "prevention," and a prevention strategy must be developed. Whether MFLs for a waterbody are being achieved within the planning horizon is determined by comparing the freeboard of the most constraining MFL to the amount of projected UFA drawdown at the planning horizon. For Lochloosa Lake, the projected UFA drawdown at the planning horizon was estimated using NFSEG v1.1. The predicted drawdown resulting from projected water use for the 20-year planning horizon is 0.1 feet (i.e., less than the 1.3 ft of UFA freeboard). Therefore, the MFLs are achieved for the 20-year planning horizon, and Lochloosa Lake is not in prevention or recovery.

## CONSIDERATION OF ENVIRONMENTAL VALUES UNDER 62-40.473, F.A.C.

Pursuant to Sections 373.042 and 373.0421, F.S., SJRWMD considered the following 10 environmental values (also called water resource values [WRVs]) identified in rule 62-40.473, F.A.C..

1. Recreation in and on the water
2. Fish and wildlife habitats and the passage of fish
3. Estuarine resources
4. Transfer of detrital material
5. Maintenance of freshwater storage and supply
6. Aesthetic and scenic attributes
7. Filtration and absorption of nutrients and other pollutants
8. Sediment loads
9. Water quality
10. Navigation

## MFLS CONDITION

The determination of whether each WRV is protected was based on whether there was a significant change, from the no-pumping to the MFL condition, for specific criteria evaluated for each WRV. The MFLs condition represents the minimum hydrologic regime necessary to protect all the minimum levels (i.e., it is based on the most constraining level for Lochloosa Lake). As stated above, the most constraining minimum level for Lochloosa Lake is the FH-2, based on protecting Florida sandhill crane nesting habitat within the RALL. The MFLs condition, defined by the FH-2, equates to an average allowable lake level reduction of 0.4 ft from the no-pumping condition, over the long term (Figure 15).

The MFLs condition exceedance curve was created and compared to the no-pumping condition exceedance curve, to help assess whether all relevant WRVs are protected (Figure 16). The MFLs condition and no-pumping exceedance curves were created using the respective daily lake level time series. The no-pumping condition time series was simulated using the Lochloosa Lake HSPF/SWMM model, with the no-pumping groundwater level time series as an input (see Appendix B for details). The MFL condition lake level time series was simulated by lowering groundwater levels incrementally in the HSPF/SWMM model until the model produced a lake level time series that just meets (but does not trip) the most constraining MFL (FH-2).

A significant harm threshold of 15% was used as the maximum allowable change, for a specific WRV, between the MFLs condition and the no-pumping condition. A threshold of 15% reduction in exceedance of critical elevations has been peer reviewed numerous times and has been the basis for numerous adopted MFLs within Florida (Munson and Delfino 2007).

The WRVs assessment results indicate that all eight WRVs, that are relevant to the environmental functions and values for Lochloosa Lake, are protected by the MFLs (Table 10). WRVs 3 and 8 are not applicable to Lochloosa Lake and thus were not considered in this assessment. See Appendix D for specific details regarding the assessment of each WRV.

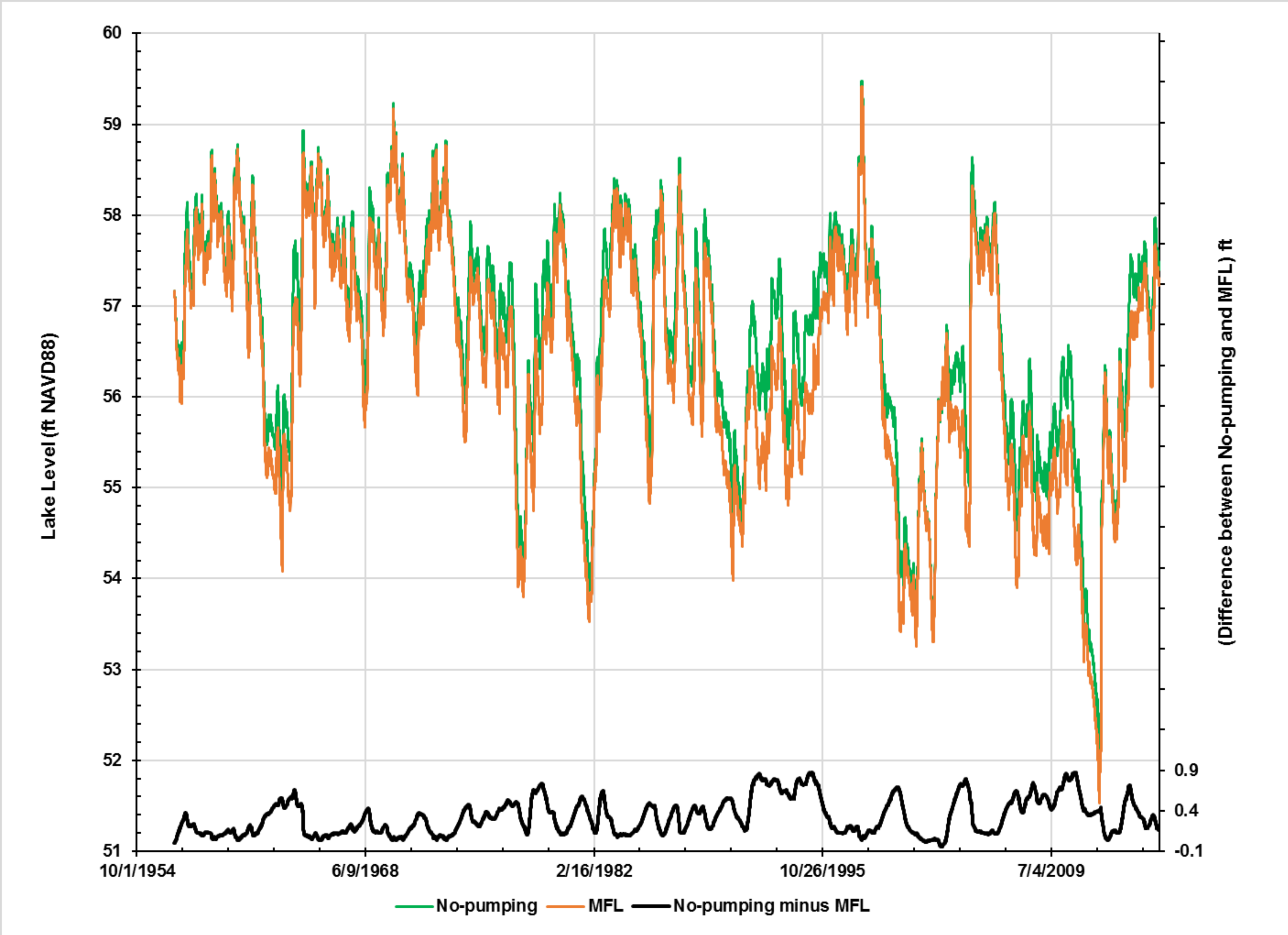


Figure 15. Model simulated lake levels for no-pumping and MFLs conditions and their differences for Lochloosa Lake, Alachua County, Florida

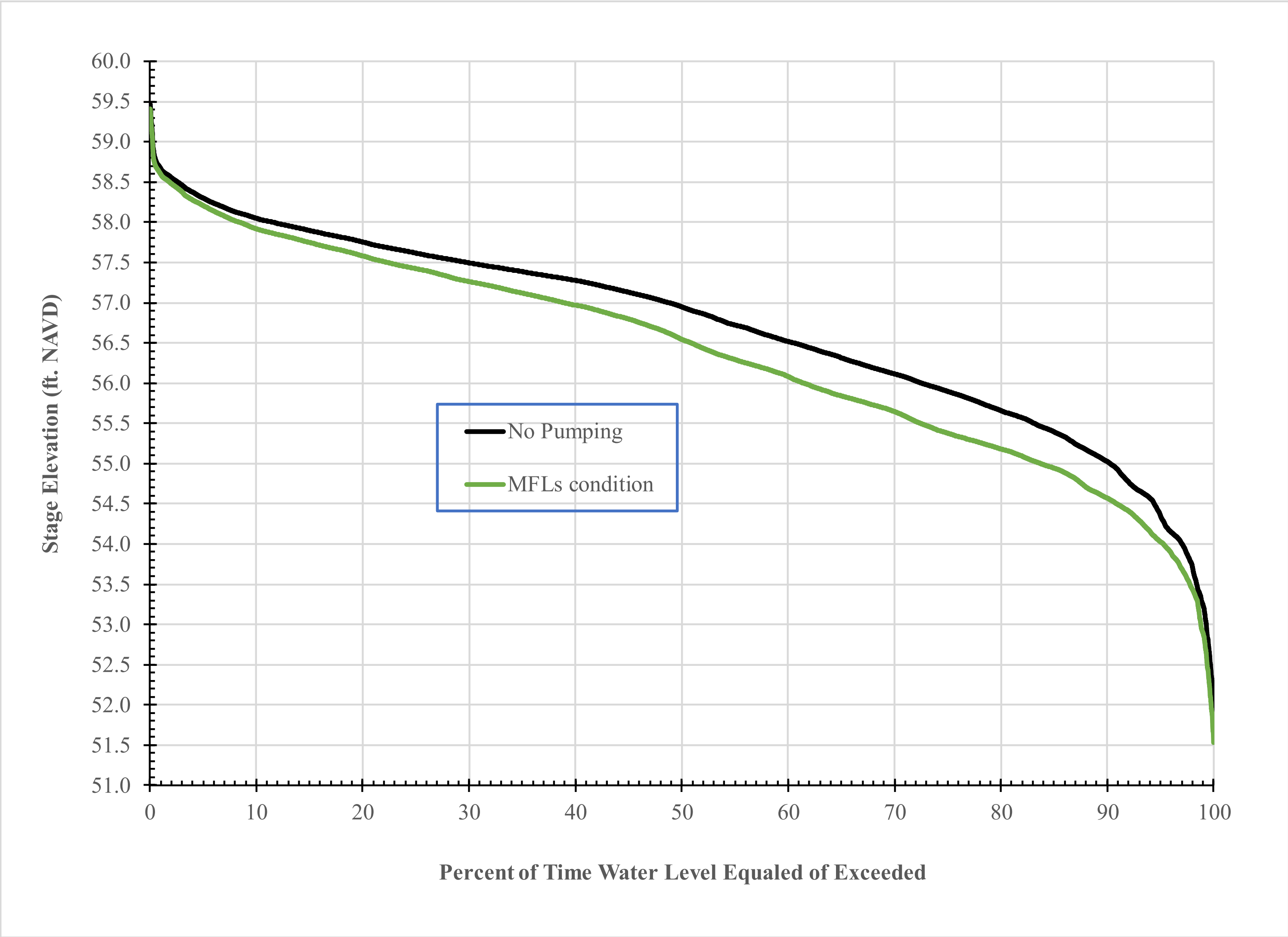


Figure 16. No-pumping condition and MFLs condition exceedance curves for Lochloosa Lake, Alachua County, Florida

Table 10. Representative environmental values/functions of WRVs and percent reduction in their values under the MFLs relative to the no-pumping condition. See Appendix D for WRVs assessment details

| WRV | Representative values or functions | Allowable change from no-pumping | Change under MFLs condition | Protected by the MFLs (Yes/No) |
|---|---|---|---|---|
| Recreation in and on the water | Dock access | 15% reduction in exceedance of critical elevation | 5% reduction in dock access | Yes |
| | Boat ramps access | 15% reduction in exceedance of critical elevation | 0% and 9% reduction in access from two boat ramps | Yes |
| Fish and wildlife habitats and the passage of fish | Fish passage through Cross Creek | 15% reduction in exceedance of critical elevation | 2% reduction in fish passage for large-bodied fish in Cross Creek | Yes |
| | Largemouth bass nesting habitat | 15% reduction in exceedance of critical elevation | 5% reduction in exceedance of lake level required for largemouth bass spawning in deep marshes | Yes |
| | Wading bird nesting habitat | 15% reduction in exceedance of critical elevation | 15% reduction in exceedance of lake level required for wading birds nesting in shallow marshes | Yes |
| Transfer of detrital material | The movement of loose organic material and debris and associated decomposing biota | 15% reduction in frequency of flooding event needed for detritus transport | 7% reduction in frequency of flooding event needed for detritus transport | Yes |
| Aesthetic and scenic attributes | Visual setting around the lake | 15% reduction in open water viewing at median lake level | 3% reduction in open water viewing at median lake level | Yes |
| Filtration and absorption of nutrients and other pollutants | The process of absorption and filtration | 15% reduction in frequency of flooding event to protect nutrient/pollutant filtration | 7% reduction in frequency of flooding event to protect nutrient/pollutant filtration | Yes |
| Water quality | Good water quality standard | 15% increase in exceedance of TSI score of 70: indicator of poor water quality | 8% increase in frequency of TSI scores above 70. | Yes |
| Navigation | Boat passage in Cross Creek | 15% reduction in exceedance of critical elevation | 5% reduction in exceedance of boat passage elevation in Cross Creek | Yes |

# CONCLUSIONS AND RECOMMENDATIONS

Minimum levels were developed for Lochloosa Lake using a hydrologic event-based approach. A premise of the MFLs determination is that by maintaining the lake's natural flooding and drying characteristics, the basic structure and functions of the ecosystem will also be maintained. SJRWMD investigated multiple ecological and human-use criteria and used a multiple-level method to ensure that all relevant environmental values and beneficial uses are protected.

Four minimum lake levels were developed for Lochloosa Lake. Multiple levels are typically developed because different ecological and human-use values require the protection of different portions of a system's hydrologic regime. For Lochloosa Lake, two frequent high (FH) lake levels were developed, as well as a minimum average (MA) and frequent low (FL; Table 9).

The first, FH-1, is based on providing a sufficient number of flood events to protect floodplain wetlands and associated wildlife habitat values. These flood events also promote filtration and absorption of nutrients and other pollutants on the floodplain. SJRWMD staff worked with FWC to develop FH-2, which included an evaluation of environmental criteria necessary to protect important fish and wildlife species and habitats for Lochloosa Lake. The FH-2 is based on the hydrologic regime necessary to protect the nesting habitat of the Florida sandhill crane, a state-designated threatened species. The Minimum Average (MA) is designed to prevent an excessive number of drying events to protect organic soils from oxidation and subsidence, and to avoid adverse impacts to habitat and water quality. The Frequent Low (FL) is designed to prevent an excessive number of drying events to protect marsh habitats and associated wildlife values as well as maintaining an appropriate water-table level in floodplain soils during periodic droughts.

## RECOMMENDED MINIMUM LEVEL

A minimum median (P50) water level (i.e., water level that must be exceeded 50% of the time, over the long term), is recommended for Lochloosa Lake (Table 11). The recommended minimum P50 was calculated from the MFLs condition lake level time series data (1957- 2015; Figure 17). As described above, the MFLs condition lake level time series and exceedance curve were created by lowering groundwater levels incrementally in the Lochloosa Lake HSPF/SWMM model until it produced a lake level time series that just meets (but does not trip) the most constraining MFL (FH-2: minimum level developed to protect sandhill crane habitat; Table 9).

The recommended P50 protects Lochloosa Lake's hydrologic regime (i.e., natural water level variability). The MFLs condition equates to an average allowable lake level reduction of 0.4 ft from the no-pumping condition, over the long term (Figures 15 and 16). The use of adaptive management to ensure the protection of Lochloosa Lake's hydrologic regime is described below.

MFLs status was assessed using frequency analysis for each of the four minimum levels developed for Lochloosa Lake (Table 9). This involved comparing the frequency of each MFL hydrologic event (defined with specific lake level and duration components) to the frequency of the same hydrologic event under the current-pumping condition (See Appendix

C for details). The current-pumping condition is defined as the average pumping condition between 2011and 2015. The MFLs assessment indicates that all four minimum levels are met (Table 9) and the most constraining (FH-2) has a freeboard of 1.3 ft available in the UFA.

Table 11. Recommended Minimum Median (P50) Level for Lochloosa Lake, Alachua County, Florida

| Environmental Criterion | Minimum Median (P50) Lake Level ft. NAVD88 |
|---|---|
| Protection of sandhill crane nesting habitat | 56.5 |

A suite of 10 environmental values, listed in Rule 62-40.473, F.A.C., were considered to ensure that the MFLs condition protects all relevant water resource values (WRVs) for Lochloosa Lake (Appendix D). Based on this analysis, SJRWMD concludes that the recommended minimum level for Lochloosa Lake, which has been developed primarily for the protection from significant harm to “fish and wildlife habitats and the passage of fish,” will also protect all other relevant WRVs, including recreation and other beneficial uses.

The recommended minimum level for Lochloosa Lake presented in this report is preliminary and will not become effective until adopted by the SJRWMD Governing Board, as directed in Rule 40C-8.031, F.A.C.

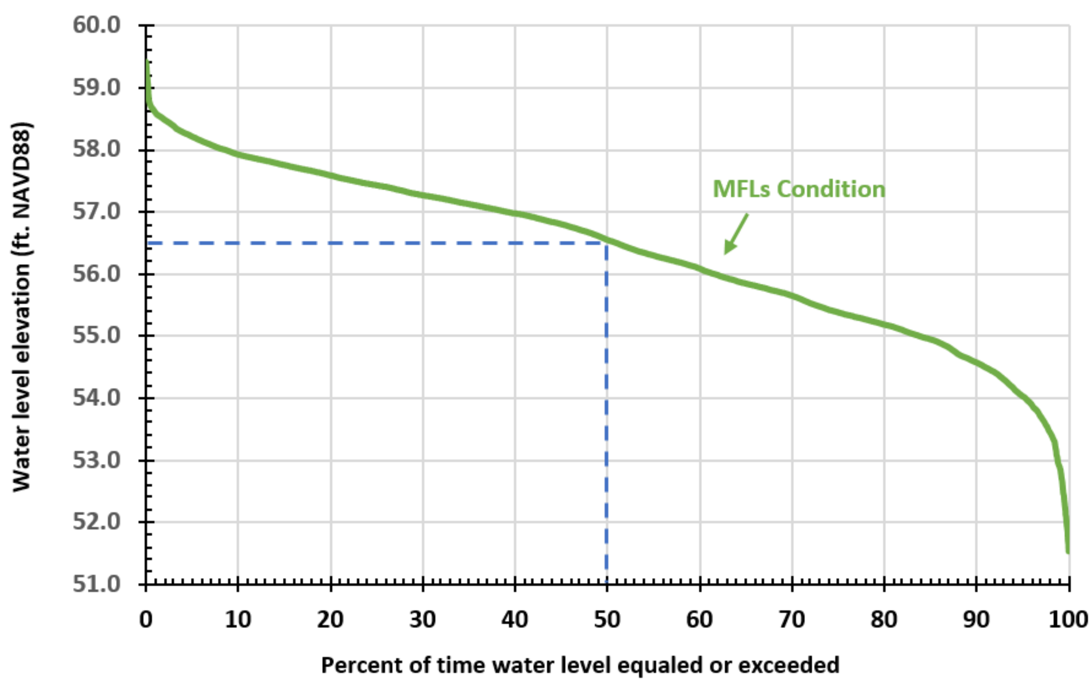


Figure 17. MFLs condition exceedance probability curve based on most constraining minimum level. Dashed line indicates the recommended minimum P50 elevation for Lochloosa Lake, Alachua County, Florida

Projected drawdown due to groundwater pumping in 2035 was estimated as 0.1 feet using the NFSEG v1.1. Therefore, the recommended MFLs are achieved for the 20-year planning horizon, and Lochloosa Lake is not in prevention or recovery.

## ONGOING STATUS / ADAPTIVE MANAGEMENT

A screening level analysis, incorporating changes in rainfall trends and uncertainty, will be performed to ensure that the adopted minimum level continues to be met over the long term. This analysis will be performed approximately every five years. MFL status will also be monitored periodically by reviewing multiple exceedance curve percentiles, updated with post 2015 observed water levels. If these fall below the corresponding MFLs condition percentiles (minus standard error), this may trigger a more detailed analysis to determine whether the change in lake levels is caused by groundwater pumping or rainfall, and whether a further evaluation of the MFLs is necessary.

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# APPENDIX A— ENVIRONMENTAL ANALYSES, METHODS AND DATA

## A.1 ENVIRONMENTAL ANALYSES

MFLs determinations incorporate biological and topographical information collected in the field with stage data, hydrologic models, wetlands, soils, and land ownership data from GIS coverages, aerial photography, and scientific literature. SJRWMD's MFLs methodology provides a process for incorporating these factors to generate a minimum hydrologic regime. This section describes the environmental methods, analyses and assumptions used in the MFLs determination process for Lochloosa Lake, including field procedures such as site selection, field data collection, and data analyses. Vegetation, soils, and elevation data were analyzed in conjunction with data from a hydrologic model (*see Appendix B for details of hydrological analyses; see Appendix E for model report*) and scientific literature in order to develop a minimum hydrologic regime that protects the ecological structure and function of Lochloosa Lake. Additional MFLs methodology descriptions can be found in SJRWMD's draft *Minimum Flows and Levels Methods Manual* (Hall et al. 2006, draft) and MFLs methods paper (Neubauer et al. 2008).

### Field Methods

#### Field Site Selection

Field site selection began with a site history survey and a literature and data search. All pertinent information was compiled from SJRWMD library documents, project record files, the hydrologic database, and SJRWMD Surveying Services files. The Florida Natural Areas Inventory (FNAI) biodiversity matrix tool (http://www.fnai.org/) was queried for the presence of threatened or endangered species at potential sites. The goal of the search was to familiarize staff with site characteristics, locate important basin features, and assess prospective sampling locations. The types of information included:

- On-site and regional vegetation surveys and maps
- Aerial photography (existing and historical)
- Remote sensing (e.g., vegetation, land use) and topographic maps
- Soil surveys, maps, and soil descriptions
- Hydrologic data (hydrographs and stage duration curves)
- Environmental, engineering, and hydrologic reports
- Topographic survey profiles
- Occurrence records of rare and endangered flora and fauna

The field investigation at Lochloosa Lake for the recommended minimum levels described in this document occurred in 2017 and 2018. All the previously identified types of information were considered in the selection of field transect sites at Lochloosa Lake.

#### Transect Site Selection

Many factors were considered in the selection of field transects sites. Transects are fixed sample lines across a river, lake, or wetland floodplain, and they typically extend from open water to uplands. Elevation, soils, and vegetation data are collected along each transect to characterize the distribution of soils and plant communities.

Data compiled during the site selection process were reviewed to familiarize staff with site characteristics, locate important basin features that needed to be evaluated, and assess prospective field transect locations. Potential transect locations at Lochloosa Lake were initially identified from maps of wetlands, soils, topography, and landownership. Specific transect site selection goals included:

- Establishing transects at sites where multiple wetland communities of the most commonly occurring types were traversed
- Selecting multiple transect locations with common wetland communities among them
- Establishing transects that traverse unique wetland communities
- Establish transects at locations where earlier MFLs field data were collected

These goals help to ensure ecosystem protection of both commonly occurring and unique wetland ecosystems at Lochloosa Lake. Transect characteristics were subsequently field-verified to ensure that prospective locations contained representative wetland communities, hydric soils, and reasonable upland access. Specific transect locations were chosen because they met the transect selection criteria for the lake, as a whole, and were the best candidate locations for each section of the lake (i.e. north, west, and south). These transects are good representations of the wetland communities found around the undeveloped portions of Lochloosa Lake. Individual transects are describe below in the *Results and Discussion* section.

**Field Data Collection**

Field data collection procedures involved collecting elevation, soils, and vegetation data along fixed lines, or transects, across a hydrologic gradient (i.e., from uplands to open water). Transects were established in areas where there are changes in vegetation and soils and the hydrologic gradient was marked (Hall et al. 2006, draft). The main purpose in using transects in these situations, where the change in vegetation and soils is clearly directional, was to describe maximum variations over the shortest distances in the minimum time (Kent and Coker 1992).

<u>Site Survey</u>

Once a transect was established at Lochloosa Lake, vegetation was trimmed to allow a line-of-sight along the length of the transect. A measuring tape was then laid out along the transect. Elevation measurements were surveyed at regular intervals on the ground along the length of the transect using a rod and transit, recorded to the nearest hundredth of a foot. At Lochloosa Lake, the elevation gradient decreased where uplands transition to hardwood swamps and the vegetation communities vary in extent among the three transects. Elevations were recorded at 10-ft intervals along each transect. Additional elevations were measured including obvious elevation changes, vegetation community changes, and soil changes. Elevation data were also collected at non-transect sites (e.g., at boat ramps, docks and tributaries).

Elevations are calculated relative to a datum associated with established benchmarks near each transect. SJRWMD uses the North American Vertical Datum 1988 (NAVD) as its standard datum.

Latitude and longitude data were also collected using a global positioning system (GPS) receiver at selected points along the length of each transect. These data are used to create accurate maps of transect locations, locate specific features along the transects, and facilitate recovering transect locations in the future.

Vegetation Sampling Procedures

SJRWMD has wetland maps developed from aerial photography using a unique wetland vegetation classification system based on plant associations. Plant associations are groupings of vegetation of relatively consistent species composition, uniform physiognomy, and a distribution characteristic of a particular habitat (Barbour et al. 1999). For the MFLs program, plant associations are termed "communities." SJRWMD's Wetland Vegetation Classification System (Kinser 2012) was used to standardize the names of wetland plant communities. Community boundaries are spatial localities where the degree of change in species composition is greatest (Fagan et al. 2003). In some instances, intermediate habitats (ecotones) termed "transition zones" were assigned when community boundaries exhibited characteristics of more than one adjoining community.

The spatial extent of plant communities, or transition zones among plant communities, was determined using reasonable scientific judgement. 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.

Plant communities and transition zones were delineated along a specialized line transect called a belt transect, which is a transect line of varying width (belt width). It is essentially a widening of the line transect to form a long, thin, rectangular plot divided into smaller sampling areas called quadrats that correspond to the spatial extent of plant communities or transitions between plant communities. The belt transect width varies depending on the type of plant community to be sampled (Hall et al. 2006, draft). For example, a belt width of 10 ft. (5 ft. on each side of the transect line) is used for sampling herbaceous plant communities of a floodplain marsh. However, a belt width of 50 ft. (25 ft. on each side of the line) is necessary to adequately characterize a forested community (e.g., hardwood swamp) (Figure 1).

Plants were identified, and the percent cover of plant species was estimated if they occurred within the established belt width for the plant community under evaluation (quadrat). Percent cover is defined as the vertical projection of the crown or shoot area of a plant to the ground surface, expressed as a percentage of the quadrat area (Barbour et al. 1999).

Percent cover, as a measure of plant distribution, is often considered as being of greater ecological significance than density, largely because percent cover gives a better measure of plant biomass than the number of individuals. The canopies of the plants inside the quadrat will often overlap, so the total percent cover of plants in a single quadrat will frequently sum to more than 100%. (Hall et al. 2006, draft). Percent cover was estimated visually using cover classes (ranges of percent cover). The cover class and percent cover ranges are a variant of the Daubenmire method (Mueller-Dombois and Ellenberg 1974) and summarized in SJRWMD's draft *Minimum Flows and Levels Methods Manual* (Hall et al. 2006, draft). MFLs cover class scale (with descriptors) is based on a Braun-Blanquet cover abundance scale (Barbour et al. 1999):

- 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)

Another vegetation sampling technique used in the MFLs program is line-intercept. This semi-quantitative method involves measuring the length (i.e., longitudinal location along the transect) of each individual plant that overlaps the transect line. All individual plants that intercept the transect line are identified to species or lowest possible taxon. This technique provides precise data on the distribution of individual species. Line-intercept measures detailed vegetation distribution before community boundaries are assigned.

Line-intercept interval data, plant species, plant communities, and percent cover data were recorded on field vegetation data sheets. The data sheets are formatted to facilitate data collection in the field and for computer transcription.

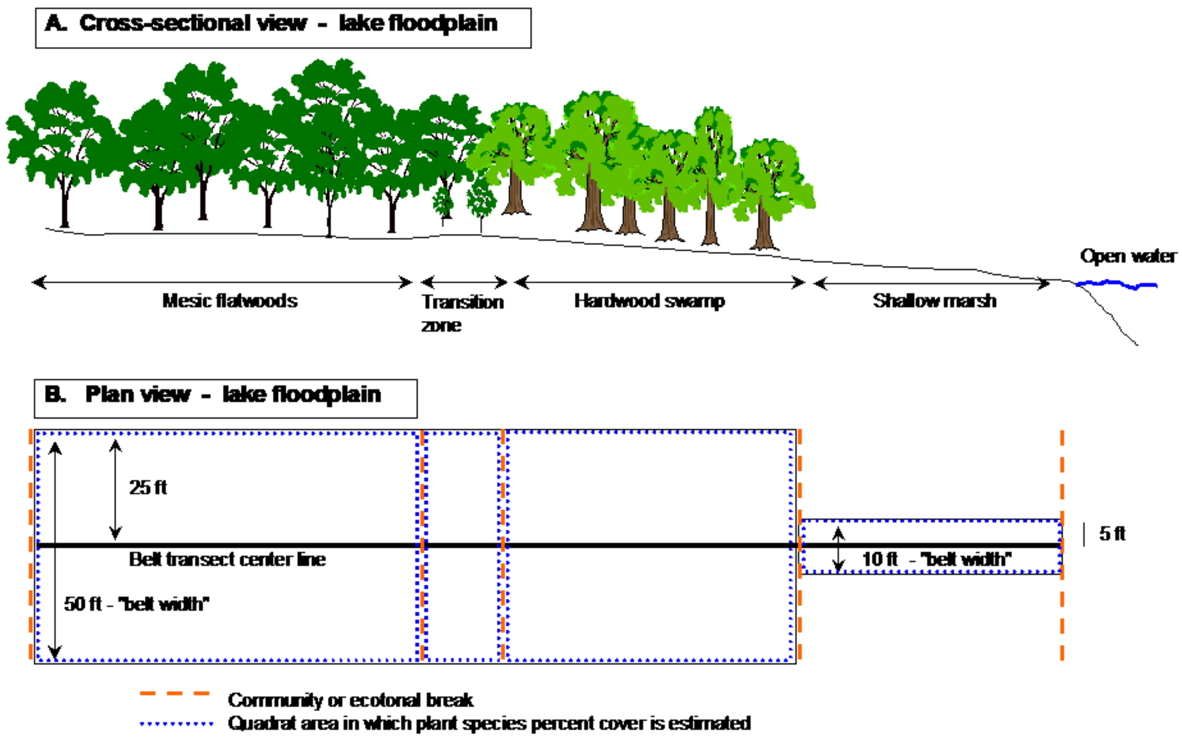


Figure 1. Belt transect through forested and herbaceous plant communities

## Soil Sampling Procedures

The primary soil criteria in the MFLs determination are the presence and depth of organic soils (Histosols and histic epipedons), as well as the extent of hydric soil indicators (HI) observed along field transects (USDA NRCS 2017; Hall et al. 2006, draft). Taxonomic keys are used to determine classification of selected soil pedons (Soil Survey staff 1999). A soil pedon is the smallest sample of one kind of soil sufficient to represent the nature and arrangement of horizons and key features. Pedon classifications can be queried from the NRCS website of official series descriptions allowing for the selection of an appropriate soil series.

A variant of a soil series may be assigned if the pedon fits the taxonomic classification but has some feature that is out of range for the series criteria. A taxadjunct of a soil series may be assigned if the pedon does not fit some part of the taxonomic classification of a soil series but is otherwise similar in morphology and can be expected to have the same properties as the named series. Soil series designations are useful in MFLs determinations when applying NRCS soil hydrologic data.

Soil borings were taken at various points along transects to 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. Soil profile descriptions follow NRCS guidelines (Schoeneberger et al. 2002). Soil descriptions include the horizon depth, texture, color, redoximorphic features, presence of roots, and consistence of soil materials.

The procedure to document hydric soils includes:

- Removing all loose leaf-matter, needles, bark, and other easily identified plant parts to expose the soil surface, digging a hole and describing the soil profile to a depth of at least 20 in., and, using a completed soil description, specifying which hydric soil indicators have been matched
- Performing deeper examination of the soil where field indicators are not easily see within 20 in. of the soil surface (It is always recommended that soils be excavated and described as deep as necessary to make reliable interpretations and classification)
- Paying particular attention to changes in microtopography over short distances, since small elevation changes may result in repetitive sequences of hydric/nonhydric soils and the delineation of individual areas of hydric and nonhydric soils may be difficult (Hurt et al. 1998)

## An 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 interval, 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).

Wetland and aquatic species, and hydric soils require a minimum frequency of critical hydrologic (drying and/or flooding) events for long-term persistence. 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 interval, 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 of an event is what changes due to climate and/or water withdrawal. Therefore, by assessing the effects of water withdrawal on the return interval of MFLs events a determination is made regarding whether additional water is available. By comparing the frequency of ecologically critical events, 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.

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 return interval, 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) (Figure 2). 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 (Figure 3). In some cases (e.g., for sandhill-type lakes) a minimum infrequent high (IH) and/or minimum infrequent low (IL) may also be set. After a comprehensive review and characterization of the soils, wetlands and aquatic fauna, SJRWMD recommends setting two FHs, a MA and FL for Lochloosa Lake.

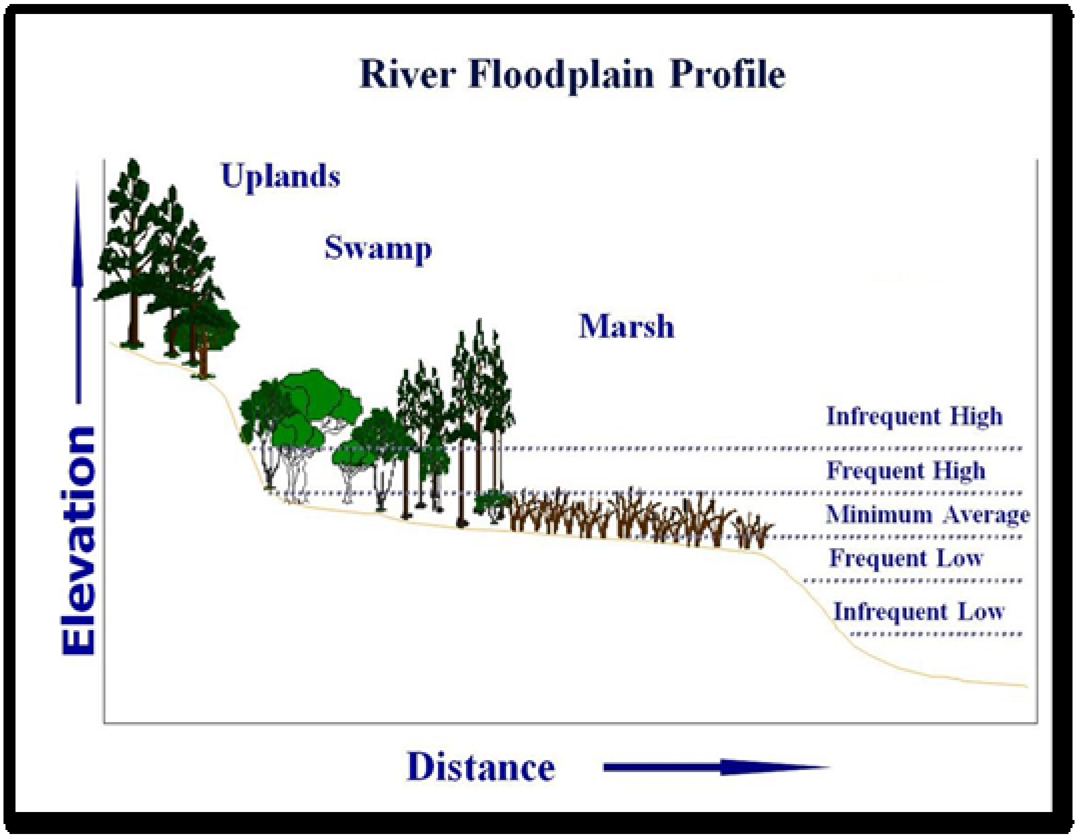


Figure 2. SJRWMD's Event-based approach criteria

**Surface Water Inundation/Dewatering Signatures (SWIDS)**

MFLs have three primary components: magnitude, duration, and return interval. Magnitude and duration define biologically relevant events. The return interval of an event is the manageable component (Neubauer et al. 2008). For example, if a 30-day flooding event of the maximum elevation of shallow marsh has an annual probability of exceedance of 33%, then the event is interpreted as occurring 33 times in 100 years or a 3-year return interval. Such statistics are long-term averages and recorded durations and return intervals of events may vary widely. A return interval may be decreased in the case of flooding events or increased in the case of dewatering events until some threshold is reached where an important ecological process or function is impaired. One of the techniques used to identify these thresholds is known as "Surface Water Inundation/Dewatering Signatures" (SWIDS) (Neubauer et al. 2007). The collection of SWIDS from a set of similar waterbodies provides a range of hydrologic conditions that support an ecologic feature of interest. SWIDS provides a guide for the maximum change in return intervals (with durations held constant) that might occur and still maintain the system. However, they must be used with caution since there can be other variables that maintain the feature of interest besides stage of the waterbody (e.g. seepage from uplands, fire, disturbance history).

SWIDS are derived from frequency analysis of long-term simulated stage data of waterbodies within SJRWMD. Hydroperiod tables for each waterbody include probabilities of specific key elevations being continuously exceeded (flooding events) or continuously not exceeded (dewatering events) over a range of durations. The former are typically used to evaluate return intervals for the FH while the latter are typically used to evaluate return intervals for the FL. Average non-exceedance probabilities are typically used to evaluate return intervals for the MA. Key elevations may be maximum, average or minimum elevations for particular wetland plant communities, common wetland species, and hydric soil indicators.

Boxplots are a simple graphical tool to show the shape of the data distribution, its location of central tendency, and variability. They are one way to evaluate the acceptable range in return intervals. Figure 3 displays the "five-number summary" (Krishnamurty et al., 1995). These five numbers consist of the 1) minimum data value; 2) the first quartile, which sets the limit of the lowest 25% of the data; 3) the median (50$^{th}$ percentile); 4) fourth quartile, which sets the limit of the highest 25% of the data; and 5) the maximum data value. The length of the "box" is the "inter-quartile range," the difference between the 75$^{th}$ and 25$^{th}$ percentiles. Fifty percent of the data values occur within the inter-quartile range. The horizontal line extending from the box to the left, called a "whisker," represents the largest 25% of data values. This whisker extends to the maximum data value. The "whisker" extending from the box to the right represents the smallest 25% of data values. This whisker extends to the minimum data value. The vertical line inside the "box" marks the median of the data values.

A boxplot schematic for flooding event probabilities is shown in Figure 3(b). In this case, drier conditions are shown to the right of the median, terminating with the driest community included in the study, and wetter conditions are shown to the left of the median, terminating in the wettest community included in the study. A boxplot schematic for dewatering event probabilities is shown in Figure 3(c). In this case, wetter conditions are shown to the right of the median, terminating in the wettest community included in the study, and drier conditions are shown to the left of the median, terminating in the driest community included in the study. Shifts in return intervals that maintain the MFLs condition within the same or an adjacent quartile of the box plot as the current-pumping condition can be proposed with greater confidence that the resource will be protected than can a shift that crosses multiple quartiles.

Another approach to refining SWIDS is to limit the set of reference waterbodies to those that are hydrologically similar to the MFLs waterbody. A lake classification study was undertaken to distinguish hydrologic groupings of lakes by principal components analysis (Epting et al. 2008). Most of the hydrologic variation was attributed to two factors: stage range and rise/fall symmetry. Some SWIDS diagrams use common symbols for lakes within the same group. These numbered, color-coded categories correspond to the following eight lake clusters:

1. High range, below average symmetry
2. Moderate range, below average symmetry

3. High range, above average symmetry
4. High range, average symmetry
5. Low range, below average symmetry
6. Low range, above average symmetry
7. Very high range, below average symmetry

Further investigations are being undertaken at SJRWMD to use additional variables to distinguish natural groupings of lakes.

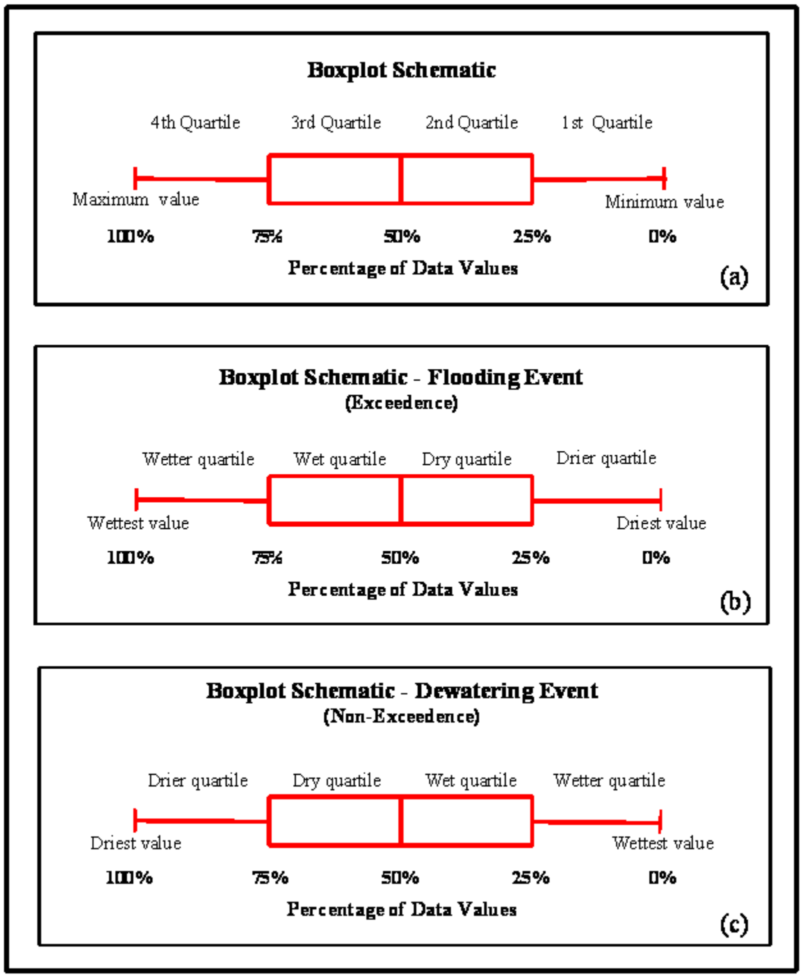


Figure 3. Boxplot schematics (a) General boxplot; (b) Flooding (exceedance) event boxplot; (c) Dewatering (non-exceedance) event boxplot

## 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, transition zones, soil hydric 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 and compiled in tables.

## CONSIDERATION OF ENVIRONMENTAL VALUES IDENTIFIED IN RULE 62-40.473, F.A.C.

Pursuant to Section 373.042 and Section 373.0421, F.S., SJRWMD identifies the environmental value or values most sensitive to long-term changes in the hydrology of each MFLs waterbody. SJRWMD then typically defines the minimum number of flood events and maximum number of dewatering events that would still protect the most sensitive environmental value or values. For example, for waterbodies for which the most sensitive environmental values is fish and wildlife habitat and the passage of fish, recommended MFLs would reflect the number of flooding or dewatering events that allow for no net loss of wetlands. Protecting the most sensitive environmental value or values for each waterbody provides the best opportunity to establish MFLs protective of all the applicable environmental values identified in Rule 62-40.473, *F.A.C.*

SJRWMD uses the following working definitions when considering these 10 environmental values:

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. Analysis of this value focuses on whether the proposed MFLs protect the capacity of wetlands, surface waters, or the aquifer to store and supply water for non-consumptive uses and environmental values.
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.
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 waterbody (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. The basis for proposed minimum levels at Lochloosa Lake are presented along with an evaluation of the roles that these levels are expected to have in maintaining the ecological functions of the lake and its associated communities.

### Lochloosa Lake Mapped Wetland Community Data

Lochloosa Lake has a surface area of approximately 5,624 ac, consisting of 4,780 ac of open water and 850 ac of littoral zone. The littoral zone is comprised of a mix of submerged aquatic beds (593 ac), deep marsh (155 ac), and floating marsh (102 ac) (Figure 4). Shallow marsh vegetation is the most prevalent plant community around the lake, accounting for 1,680ac of the total wetland acreage (Table 1). The majority of the shallow marsh vegetation community (>90%) is found in the southern portion of the lake in an area called the Right Arm Lochloosa Lake (RALL) marsh. Forested wetland communities, dominated by hardwood swamp (880 ac) and cypress swamp (209 ac), occur in the northern, western, and southeastern portions of the lake. Wetland vegetation communities and hydroperiod descriptions for Lochloosa Lake are provided in Table 2.

### Field Data

Vegetation, soils and elevation data were collected along three transects at Lochloosa Lake (Figure 5; Table 3). Field work was conducted in 2017 and 2018. Transect elevations were surveyed in the spring of 2017 followed by vegetation sampling in the summer and early fall of 2017. Some field work continued into the winter of 2017 and concluded in the spring of 2018. Field work during the summer of 2017 was complicated by heavy rainfall, followed by Hurricane Irma on September 10, 2017. Flooding caused by record summer precipitation inundated wetlands surrounding Lochloosa Lake, making vegetation and soils data collection difficult. Soil analysis was performed when possible but was prevented in the lower elevations of the hardwood/cypress swamp due to standing water.

#### Transect 1 (North)

Transect 1 is located on the north bank of Lochloosa Lake and extends 1,550 feet, following a slight arc, into open water. Its location was chosen to characterize the hydric hammock, hardwood swamp, and marsh communities on the north shore near the mouth of Lochloosa Creek (see Figure 6; Tables 4 and 5).

Mapped vegetation, based on remote sensing techniques and vegetation community designations by SJRWMD, show that Transect 1 should begin in a hydric hammock area, followed by a small portion of wet prairie, and proceeding to traverse a hardwood swamp that extends to the bank of Lochloosa Lake (Figure 6). A small width of deep marsh is mapped. The following describes field collected vegetation and soils data at Transect 1 (North).

Vegetation at Transect 1 (North)

From 0 to 170 ft, the transect begins in a small upland zone with abundant laurel oak (*Q. laurifolia*), numerous live oak (*Q. virginiana*), and scattered cabbage palm (*Sabal palmetto*) in the canopy and numerous, but disbursed, patches of saw palmetto (*Serenoa repens*) and scattered wax myrtle (*Myrica cerifera*) in the shrub layer (Figure 7; Table 4 and Table 5). After the first 170 ft of gently sloping upland, a hydric hammock community develops from 170 to 260 ft. The hydric hammock community is still dominated by laurel oak and scattered live oak but scattered slash pine (*Pinus elliottii*), sweetgum (*Liquidambar styraciflua*), and the first bald cypress (*Taxodium distichum*) is now present in the overstory and swamp tupelo (*Nyssa sylvatica* var. *biflora*) seedlings and slender woodoats (*Chasmanthium laxum* var. *sessiliflorum*) are found on the forest floor. A transition zone extends downslope from the hydric hammock community. This transition zone, from 260 to 300 ft, blends features of its upslope hydric hammock and the downslope hardwood swamp. The transition zone is dominated by cabbage palm (both mature and immature), numerous bald cypress, and scattered American elm (*Ulmus americana*) and laurel oak in the canopy. Numerous wax myrtle, scattered swamp tupelo, and scattered bald cypress seedlings occupied the understory.

Between the 290 ft station and the 310 ft. station an abrupt elevation drop of over 0.5 ft occurs. A "station" is synonymous with the transect distance. A clear differentiation from the transition zone into a well-defined hardwood swamp occurs at the 310 ft station (photo Figure 8). The hardwood swamp community continues waterward for 705 ft and is dominated by mature bald cypress with abundant swamp tupelo in the canopy and abundant buttonbush (*Cephalanthus occidentalis*), red maple (*Acer rubrum*), numerous wax myrtle, and scattered immature Carolina ash (*Fraxinus caroliniana*), dahoon holly (*Ilex cassine*), and immature cabbage palm in the understory. Dominating the hardwood swamp community forest floor is savannah panicum (*Panicum gymnocarpon*), sometimes in continuous patches running for hundreds of feet. Numerous lizard's tail (*Saururus cernuus*), scattered alligatorweed (*Alternanthera philoxeroides*) and pickerelweed (*Pontederia cordata*) also made up a significant portion of the forest ground cover. Witchgrass (*Dichanthelium commutatum*), blue flag iris (*Iris virginica*), and swamp dock (*Rumex verticillatus*) was present but in rare amounts. From station 940 to station 1005 a distinct wave berm creates a substantial elevation change between the hardwood swamp and the open water. Numerous buttonbush and scattered saw palmetto were present on the wave berm.

The waterward side of the wave berm demarks the lake edge. At transect station 1005 the slope increases substantially, dropping 3.05 ft in elevation over a distance of 75 ft. In this zone, a dominant monoculture of maidencane (*Panicum hemitomon*) was the only vegetation species found. The maidencane monoculture continued until station 1060. At the 1060 station, a floating vegetation community comprised of smartweed (*Polygonum* spp.), primrose (*Ludwigia peruviana*), sedges (*Carex* spp.), and swamp dock covered the water's surface, effectively preventing a distinct vegetation community break between the transitional, near-shore maidencane community and the deep marsh. However, a distinct change in slope occurred at station 1070, that when combined with historic lake stage data, allowed the demarcation of the start of the deep marsh community. The deep marsh community, from station 1070 to station 1550, consisted of maidencane and spatterdock (*Nuphar advena*). Maidencane was found diffusely in the shallowest parts of the deep marsh and could have been almost entirely associated more with the floating vegetation community than as true, rooted deep marsh vegetation. Patches of floating vegetation comprised the surface of portions of the deep marsh. In areas that floating vegetation was not present, spatterdock was dominant.

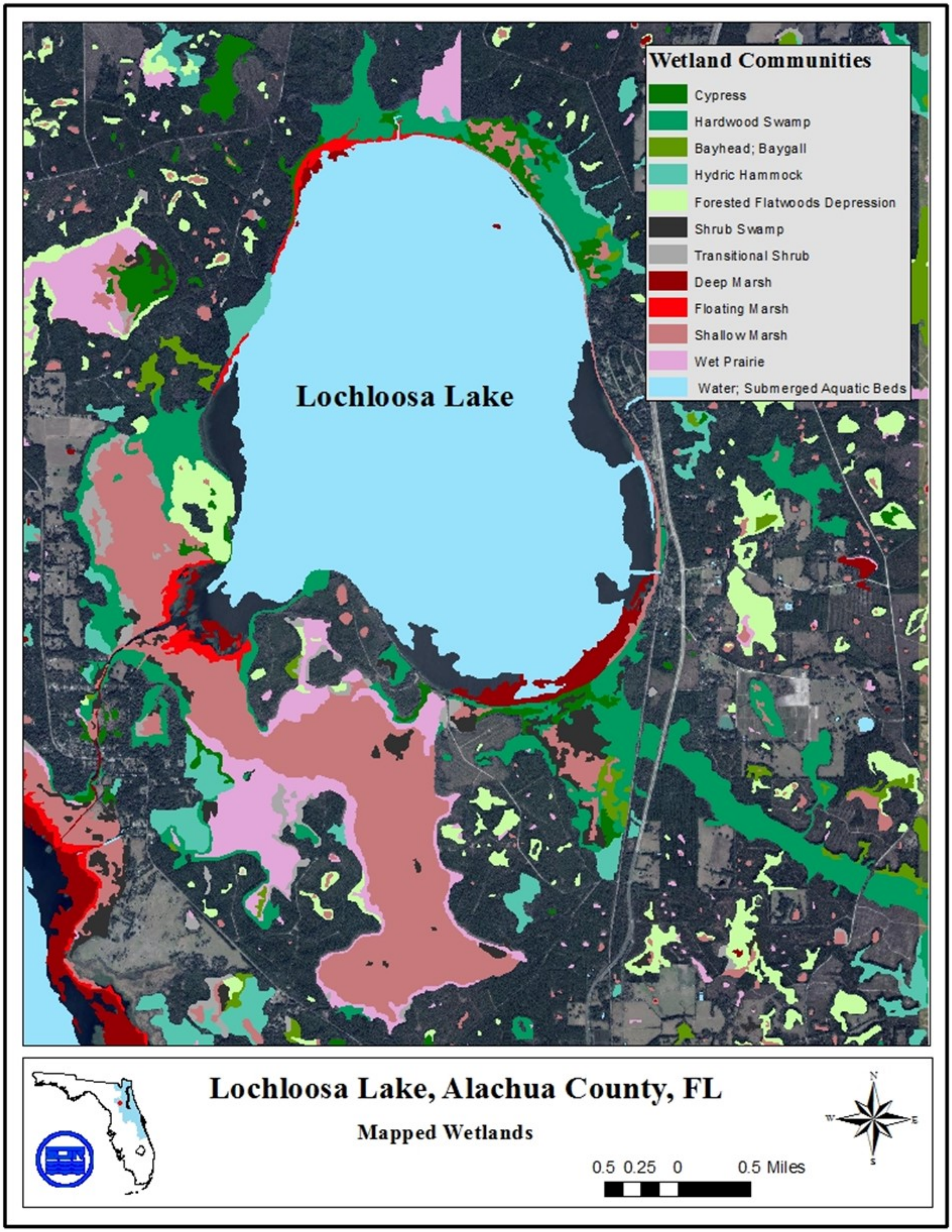


Figure 4. Lochloosa Lake mapped wetland plant communities

Table 1. Lochloosa Lake wetland communities by size

| Wetland Community | Acres | Ranking by Acres |
|---|---|---|
| Shallow marsh | 1680 | 1 |
| Hardwood swamp | 880 | 2 |
| Submerged aquatic beds | 593 | 3 |
| Wet prairie | 555 | 4 |
| Hydric Hammock | 323 | 5 |
| Forested Flatwoods | 263 | 6 |
| Cypress | 209 | 7 |
| Shrub swamp | 176 | 8 |
| Deep marsh | 155 | 9 |
| Transitional shrub | 149 | 10 |
| Floating marsh | 102 | 11 |
| Bayhead; Baygall | 78 | 12 |

Table 2. Wetland vegetation community types, description, and hydroperiod adjacent to Lochloosa Lake

| SJRWMD Wetland Community | Vegetation Description | Hydroperiod Description |
|---|---|---|
| Cypress | Forested wetlands dominated by bald cypress or pond cypress (*Taxodium distichum* or *T. ascendens*) | Flooded annually for periods of long duration – typically 4 to 8 months in any given year |
| Hardwood Swamp | Forested wetlands dominated by one or more deciduous hardwood species typically including black gum, red maple, water ash, water elm, and willows. Cypress often a significant component | Subject to annual, seasonal periods of prolonged flooding |
| Bayhead | Forested wetlands dominated by one or more species of broadleaved, evergreen bay trees (*Gordonia lasianthus*, *Persea palustris*, or *Magnolia virginica*) | Soils usually organic and nearly constantly saturated as well as being at least occasionally flooded |
| Hydric Hammock | Forested systems dominated by a mixture of broadleaved evergreen and deciduous tree species | Seldom inundated but with saturated soils during much of the year |
| Forested Flatwoods Depression | Typically pond cypress, pine, deciduous hardwood, bay, or cabbage palm dominated communities occupying shallow depressions in mesic flatwood sites | Soils usually sandy and subject to brief (1 – 2 months) seasonal inundation or prolonged soil saturation |
| Shrub Swamp | Dominated by willows, buttonbush, or similar appearing vegetation | Hydrology similar to that of cypress, hardwood swamp, or shallow marsh communities |
| Transitional Shrub | Dominated by transitional shrubby vegetation at upland margins of wetter community types or on clear cut hydric sites | Inundated for a relatively short duration each year, but with prolonged soil saturation |

| | | |
|---|---|---|
| Deep Marsh | Deep water wetlands dominated by a mixture of water lilies and deep water emergent species | Semi-permanently to permanently flooded |
| Floating Marsh | Communities of free-floating plants (such as water hyacinth, water lettuce, or duckweed) or floating mats of rhizomatous species (such as alligator weed or various grasses and sedges) | Typically floating above water surface but may periodically strand on ground during periods of low water level |
| Shallow Marsh | Herbaceous or graminoid communities dominated by species such as sawgrass, maidencane, cattails, pickerel weed, arrowhead, or other grasses and broadleaved herbs | Often on organic soils that are subject to lengthy seasonal inundation |
| Wet Prairie | Communities of grasses, sedges, rushes, and herbs typically dominated by sand cordgrass, maidencane, or a mixture of species | Usually on mineral soils that are inundated for a relatively short duration each year, but with prolonged soil saturation |


Figure 5. Lochloosa Lake transect locations

Table 3. Field transect locations with coordinates and dates of field work

| Transect | Latitude/Longitude | Date of Fieldwork |
|---|---|---|
| Transect 1 (North) Station: 0 | 29° 33’ 00.77” N/-82° 07’ 35.46” W | Start: August 2017 |
| Transect 1 (North) Station: 1550 | 29° 32’ 43.34” N/-82° 07’ 48.01” W | End: October 2017 |
| Transect 2 (West) Station: 0 | 29° 31’ 13.99” N/-82° 09’ 21.65” W | Start: July 2017 |
| Transect 2 (West) Station: 1120 | 29° 31’ 10.22” N/-82° 09’ 06.86” W | End: October 2017 |
| Transect 3 (South) Station: 0 | 29° 29’ 27.31” N/-82° 07’ 06.45” W | Start: August 2017 |
| Transect 3 (South) Station: 930 | 29° 29’ 35.67” N/-82° 07’ 06.99” W | End: January 2018 |

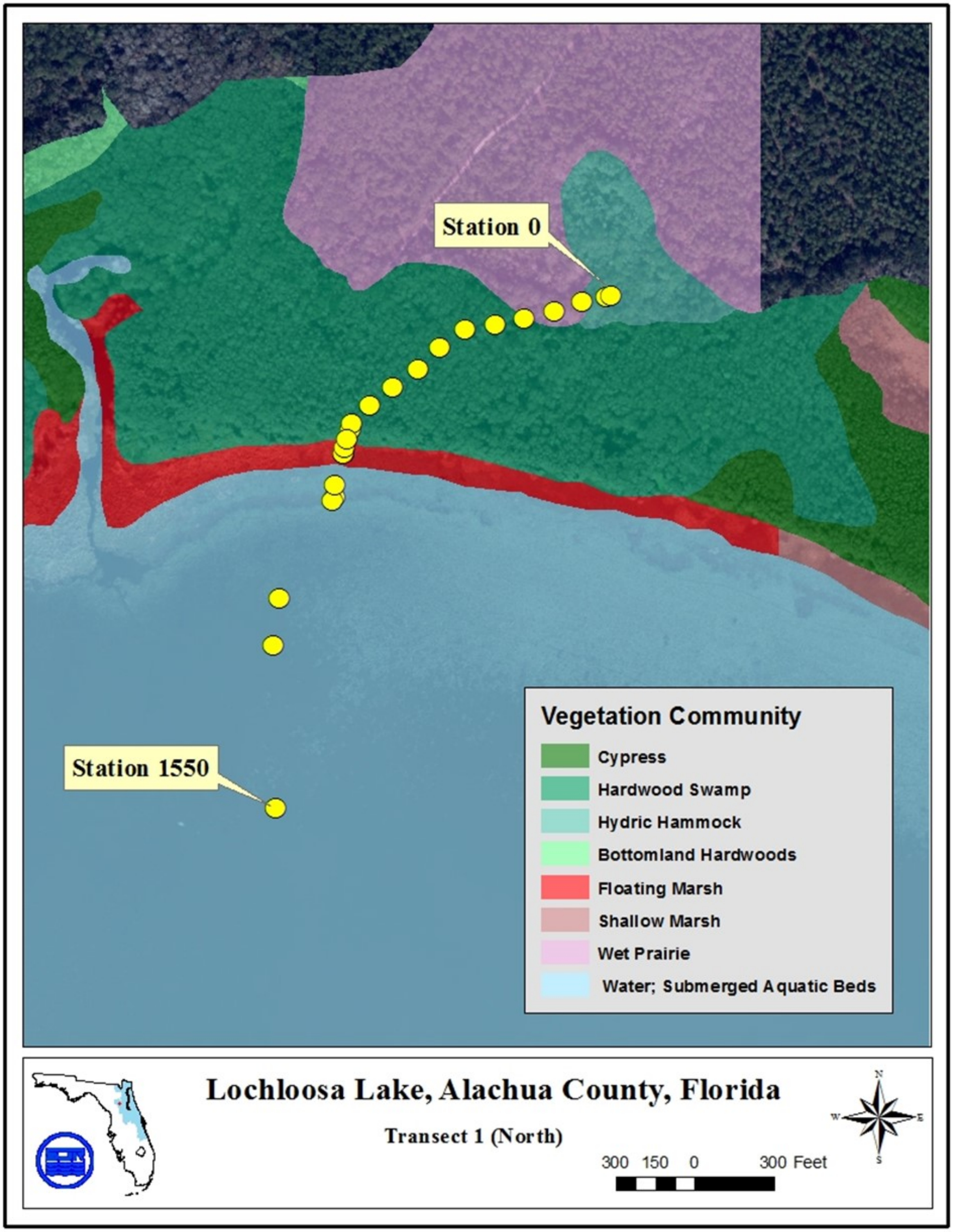


Figure 6. Transect 1 (North) mapped wetland plant communities, Lochloosa Lake

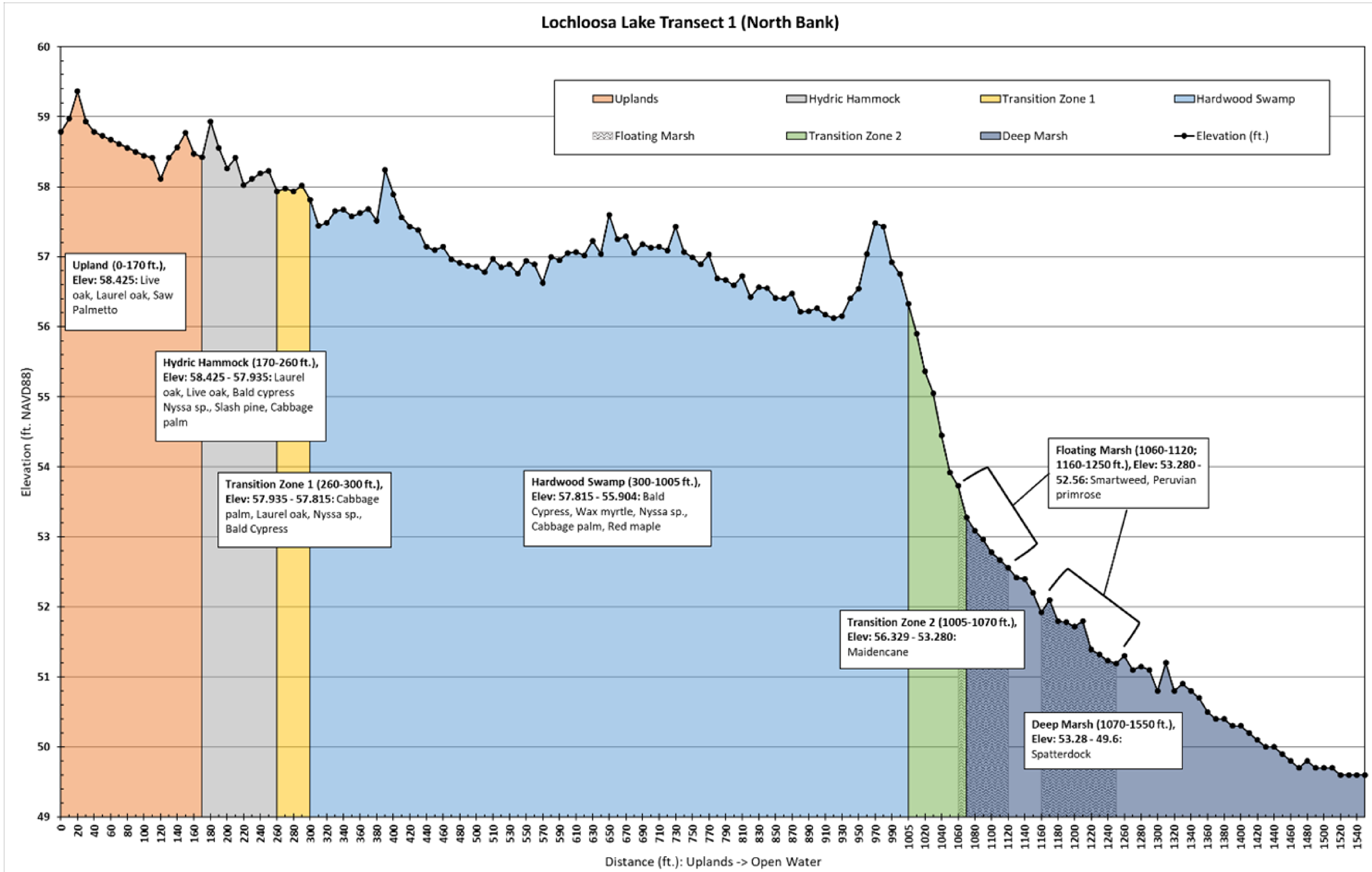


Figure 7. Transect 1 (North) topography and plant communities, Lochloosa Lake

Figure 8. Transect 1 (North) at station 310 looking downslope, Lochloosa Lake

Table 4. Transect 1 (North) vegetation community elevation statistics, Lochloosa Lake

| Vegetation community | Station Distance (ft) | Elevation (ft NAVD)* | | | | **N |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | |
| Upland | 0-170 | 58.6 | 58.6 | 58.1 | 59.4 | 18 |
| Hydric hammock | 170-260 | 58.3 | 58.2 | 57.9 | 58.9 | 10 |
| Transitional | 260-300 | 57.9 | 57.8 | 57.8 | 58.0 | 5 |
| Hardwood swamp | 300-1005 | 57.0 | 57.0 | 56.1 | 58.2 | 73 |
| Transitional marsh | 1005-1070 | 54.8 | 54.8 | 53.3 | 56.3 | 8 |
| Deep marsh | 1070-1550 | 51.0 | 50.9 | 49.6 | 53.3 | 49 |

* ft NAVD = feet North American Vertical Datum 1988

**N = the number of elevation readings surveyed in each vegetation or soil community

## Table 5. Transect 1 (North) belt transect vegetation species and cover class

| Scientific Name | Common Name | Vegetation Community[2] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Name** | **UP** | **HH** | **TRZ1** | **HS** | **TRZ2** | **DM** |
| | | **Start (ft)** | **0** | **170** | **260** | **300** | **1005** | **1070** |
| | | **Stop (ft)** | **170** | **260** | **300** | **1005** | **1070** | **1550** |
| | | **FWDM Code[1]** | **Plant Species Cover Estimates[3]** | | | | | |
| *Acer rubrum* | Red maple | FACW | | | | 3 | | |
| *Alternanthera philoxeroides* | Alligator weed | OBL | | | | 1 | | |
| *Campsis radicans* | Trumpet vine | - | | | 1 | | | |
| *Carex* spp. | Sedge | FACW | | | | | | 3[4] |
| *Cephalanthus occidentalis* | Buttonbush | OBL | | | | 2 | | |
| *Chasmanthium sessiliflorum* | Woodoats | FAC | 1 | 2 | 1 | | | |
| *Dichanthelium commutatum* | Variable witchgrass | - | | | | 0 | | |
| *Eleocharis baldwinii* | Spikerush | OBL | | 2 | | | | |
| *Fraxinus caroliniana* | Carolina ash | OBL | | | | 1 | | |
| *Ilex cassine* var. *cassine* | Dahoon | OBL | | | | 1 | | |
| *Ilex cassine* var. *myrtifolia* | Myrtle dahoon | - | 1 | | | | | |
| *Iris* spp. | Iris | OBL | | | | 0 | | |
| *Juncus effusus* | Soft rush | OBL | 0 | | | | | |
| *Liquidambar styraciflua* | Sweetgum | FACW | | 1 | | 0 | | |
| *Ludwigia peruviana* | Primrose | OBL | | | | | | 2[4] |
| *Myrica cerifera* | Wax myrtle | FAC | 1 | 1 | 2 | 2 | | |
| *Nuphar advena* | Spatterdock | OBL | | | | | | 4 |
| *Nyssa sylvatica* var. *biflora* | Swamp tupelo | OBL | 1 | 1 | 1 | 3 | | |
| *Panicum gymnocarpon* | Savannah panicum | OBL | | | | 4 | | |
| *Panicum hemitomon* | Maidencane | OBL | | | | 1 | 5 | 1 |
| *Pinus elliotii* | Slash pine | - | | 1 | | | | |
| *Polygonum* spp. | Smartweed | OBL | | | | | | 2[4] |
| *Pontederia cordata* | Pickerelweed | OBL | | | | 1 | | |
| *Quercus laurifolia* | Laurel oak | FACW | 3 | 4 | 1 | 0 | | |
| *Quercus virginiana* | Live oak | - | 2 | 1 | | | | |
| *Rumex verticillatus* | Swamp dock | FACW | | | | 0 | | 1[4] |
| *Sabal palmetto* (immature) | Cabbage palm | FAC | | 1 | 4 | 1 | | |
| *Sabal palmetto* (mature) | Cabbage palm | FAC | 1 | | 1 | | | |
| *Sagittaria lancifolia* | Lanceleaf arrowhead | OBL | | | | 0 | | |
| *Saururus cernuus* | Lizard’s tail | OBL | | | | 2 | | |
| *Serenoa repens* | Saw palmetto | - | 2 | | | 0 | | |
| *Taxodium distichum* | Bald cypress | OBL | | 1 | 2 | 5 | | |
| *Toxicodendron radicans* | Poison ivy | - | | | | 0 | | |
| *Ulmus americana* | American elm | FACW | | | 1 | | | |

1 FWMD code indicator categories established in The Florida Wetlands Delineation Manual (Gilbert et al. 1995):

UPL = Upland plants that occur rarely in wetlands but occur almost always in uplands

FAC = Facultative plants with similar likelihood of occurring in both wetlands and uplands

FACW = Facultative wet plants that typically exhibit their maximum cover in areas subject to surface water flooding and/or soil saturation but may also occur in uplands

OBL = Obligate plants that are found or achieve their greatest abundance in an area, which is subject to surface water flooding and/or soil saturation; rarely uplands

2 Plant community abbreviations:

Up = Uplands (stations 0-170)

HH = Hydric hammock (stations 170-260)

TRZ1 = Transition zone #1 (stations 260-300)

HS = Hardwood swamp (stations 300-1005)

TRZ2 = Transition zone #2 (stations 1005-1070)

DM = Deep marsh (stations 1070-1550)

3 Plant Species Cover Estimates: Areal extent of vegetation species along transect within a given community where 0 = <1% (rare); 1 = 1-10% (scattered); 2 = 11-25% (numerous); 3 = 26-50% (abundant); 4 = 51-75% (codominant); 5 = >75% (dominant)

4 Floating vegetation

Soils at Transect 1 (North)

Transect 1 (North) soils were sampled on October 30, 2017. Samples were limited due to excessive flooding along the transect. Transects were inundated due to record high summer rainfall and precipitation from Hurricane Irma in September 2017. Attempts to continue sampling at later dates were abandoned due to continued high lake levels.

Mapped soils at Transect 1 (North) indicate the transect begins in a non-hydric soil type (Figure 9). The transect quickly enters a hydric soil type within roughly 50 ft from the point that station 0 is located.

Detailed profile descriptions were made at select stations along the transect. Samples were taken at stations 0, 41, 110, and 200 to identify hydric soil indicators and/or depth of muck (Table 6). Soil series found along Transect 1 (North) were Anclote and Pomona, respectively. The hydric soil indicators identified at Transect 1 (North) were mucky mineral (A7), dark surface (S7), thin dark surface (S9), and hydrogen sulfide (A4). The following describes the two soil series and four hydric indicators found at Lochloosa Lake Transect 1 (North):

Soil Series:

**Anclote** (Sandy siliceous, hyperthermic Typic Endoaquolls)
The Anclote series consists of very deep, poorly drained, rapidly permeable soils in depressions, poorly defined drainage ways, and flood plains in the Southern Florida Flatwoods (MLRA 155), South Central Florida Ridge (MLRA 154), Florida Everglades and Associated Areas (156A) and Southern Florida Lowlands (MLRA 156B). They formed in thick beds of sandy marine sediments. Near the type location, the mean annual temperature ranges from 68 to 75 degrees F, and the mean annual precipitation ranges from 47 to 56 inches. Slopes range from 0 to 2%.

**Pomona** (Sandy, siliceous, hyperthermic Ultic Alaquods)
The Pomona series consists of very deep, poorly and very poorly drained soils that formed in sandy and loamy marine sediments. Pomona soils are on flats and flatwoods on marine terraces. The mean annual temperature is about 72 degrees F and the mean annual precipitation is about 55 inches. Slopes range from 0 to 2%.

Hydric Indicators:

**Hydrogen Sulfide (A4)**
A hydrogen sulfide odor starting at a depth of ≤30cm (12 in) from the soils surface.

**5 cm Mucky Mineral (A7)**

A layer of mucky modified mineral soil material 5 cm (2 in) or more thick, starting at a depth ≤15 cm (6 in) from the soil surface.

**Dark Surface (S7)**
A layer 10 cm (4 in) or more thickness, starting at a depth less than or equal to the upper 15 cm (6 in) from the soil surface, with a matrix value of 3 or less and chroma of 1 or less. At least 70% of the visible soil particles must be masked with organic material, viewed through a 10x or 15x lens. Observed without a hand lens, the particles appear to be close to 100% masked. The matrix color of the layer directly below the dark layer must have the same colors as those described above or any color that has chroma of 2 or less.

**Thin Dark Surface (S9)**
A layer 5 cm (2 in) or more thick, starting at a depth of ≤15 cm (6 in) from the soil surface, with a value of 3 or less and chroma of 1 or less. At least 70% of the visible soil particles must be masked with organic material, viewed through a 10x or 15x hand lens. Observed without a hand lens, the particles appear to be close to 100% masked. This layer is underlain by a layer or layers with value of 4 or less and chroma of 1 or less to a depth of 30 cm (12 in) or to the spodic horizon, whichever is less.

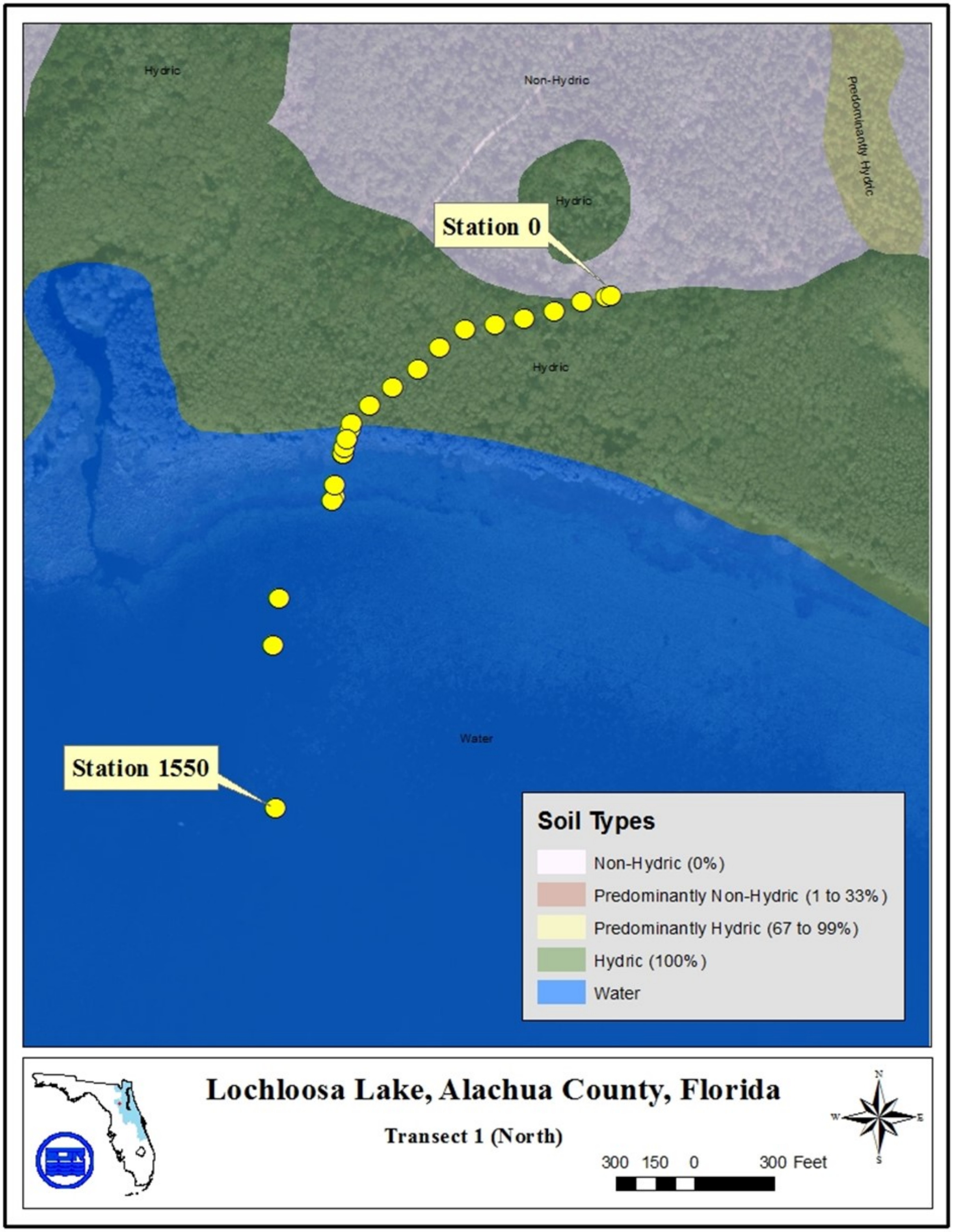


Figure 9. Transect 1 (North) mapped soil types, Lochloosa Lake

Table 6. Transect 1 (North) soil sample descriptions, Lochloosa Lake

| Station | Depth | Horizon | Color | Texture | Notes |
|---|---|---|---|---|---|
| 0 | 0-3” | A1 | 2.5YR 3/2 | Mucky sand | 100% masked, common fine roots |
| | 3-5.5” | A2 | 50% 2.5YR 3/2<br>50% 10YR 3/1 | Mucky sand | 70% masked |
| | 5.5-42” | Cg1 | 10YR 4/1 | Sand | |
| | 42”+ | Cg2 | 10YR 7/2 | Sand | |
| | Hydric Indicator: A7 | | | | |
| | Soil Series: Anclote | | | | |
| 41 | 0-2” | A1 | 7.5TR 2.5/2 | Mucky sand | 100% masked, many coarse roots |
| | 2-6” | A2 | 10YR 3/1 | Mucky sand | 70% masked |
| | 6-9” | A | 10YR 2/1 | Sand | 60% masked |
| | 9-18” | E | 10YR 4/1 | Sand | |
| | 18-30” | Bh1 | 10YR 3/3 | Sand | Sulphur smell |
| | 30”+ | Bh2 | 10YR 3/4 | Sand | |
| | Hydric Indicators: A7, S7, S9 | | | | |
| | Soil Series: Pomona | | | | |
| 110 | 0-3” | A1 | 2.5YR 3/2 | Mucky sand | 70% masked, common fine roots |
| | 3-9” | A2 | 10YR 2/1 | Mucky sand | 70% masked |
| | 9-23” | E1 | 10YR 3/1 | Sand | 10% masked |
| | 23-32” | E2 | 10YR 3/3 | Sand | |
| | 32-37” | Bh1 | 7.5YR 4/3 | Sand | |
| | 37-39” | Bh2 | 7.5YR 5/3 | Sand | |
| | 39”+ | E’ | 7.5YR 6/3 | Sand | |
| | Hydric Indicators: A7, A4, S9 | | | | |
| | Soil Series: Pomona | | | | |
| 200 | 0-3” | A1 | 7.5YR 3/2.5 | Mucky sand | 100% masked |
| | 3-7” | A2 | 10YR 2/1 | Mucky sand | 70% masked |
| | 7-13” | A3 | 10YR 3/1 | Sand | 10% masked |
| | 13-15” | Btg | 10YR 7/2 | Sandy clay | |
| | 15-23” | E1 | 10YR 5/1 | Sand | |
| | 23-45” | E2 | 10YR 7/1 | Sand | |
| | 45-49” | Bh1 | 10YR 3/3.5 | Sand | |
| | 49”+ | Bh2 | 10YR 8/3 | Sand | |
| | Hydric Indicators: A7, S9 | | | | |
| | Soil Series: Pomona | | | | |

### Transect 2 (West)

Transect 2 is located on the west bank of Lochloosa Lake and extends 1120 feet, following a easterly direction, into open water (Figure 10). Its location was chosen to characterize the hydric hammock, hardwood swamp, and marsh communities on the west shore of Lochloosa Lake.

Mapped vegetation, based on remote sensing techniques and vegetation community designations by SJRWMD, show that Transect 2 should begin in an upland area followed by a hardwood swamp that extends to the bank of Lochloosa Lake. No deep marsh communities were mapped using the remote sensing. The following describes field collected vegetation and soils data at Transect 2 (West).

Vegetation at Transect 2 (West)

This transect begins in a small upland community located at the end of a Jeep trail. The upland extended from station 0 to station 40 and was covered in a canopy of numerous laurel oak (*Q. laurifolia*), slash pine (*P. elliottii*), and sweetgum (*L. styraciflua*) (Figure 11; Table 7 and 8). Abundant saw palmetto (*S. repens*) and fetterbush (*Lyonia lucida*), as well as scattered maleberry (*L. ligustrina*), highbush blueberry (*Vaccinium corymbosum*), and a rare dahoon holly (*I. cassine*) seedling made up the understory shrub layer. Two herbaceous graminoids, jungle rice (*Echinochloa colona*) and beakrush (*Rhyncospora harperi*), were found in the groundcover, but only in rare numbers.

A hydric hammock community, between stations 40 and 115, was located downslope of the upland. Laurel oak and slash pine were still numerous in this community but numerous swamp tupelo (*N. sylvatica* var. *biflora*) and scattered bald cypress (*T. distichum*) and sweetbay (*Persea palustris*) were also present in the canopy. The shrub layer contained maleberry and wax myrtle (*M. cerifera*) in scattered amounts. Dahoon holly was also present in rare amounts. Ground cover in the hydric hammock was primarily scattered witchgrass (*D. commutatum* and *D.* spp.) with rare amounts of spikerush (*E. baldwinii*), lizard's tail (*S. cernuus*), gamagrass (*Tripsacum dactyloides*), and water oak (*Quercus nigra*) seedlings.

Starting at station 115, and continuing to station 495, was a hardwood swamp community (photo Figure 12). The 380 ft. length of hardwood swamp habitat was dominated by bald cypress with abundant swamp tupelo and scattered sweetgum and Carolina ash (*F. caroliniana*) in the canopy. The understory shrub species consisted of abundant numbers of young red maple (*A. rubrum*), numerous false nettle (*Boehmeria cylindrica*) individuals, and scattered buttonbush (*C. occidentalis*) and fetterbush. Ground cover was mostly comprised of numerous amounts of pennywort (*Hydrocotyle* sp.) and redroot flatsedge (*Cyperus erythrorhizos*) with scattered amounts of lizard's tail, bulrush (*Schoenoplectus americanus*), and dahoon holly seedlings. A number of other herbaceous forbs and graminoids comprised the ground cover layer in scattered and rare amounts (*see* Table 8). From station 450 to station 495 a distinct wave berm was present.

Waterward of station 495, an abrupt increase in slope distinguished a transitional marsh that marked the edge of the Lochloosa Lake shore. An elevation change of over 3 ft. occurred within a span of just 35 ft. This transitional marsh was dominated by maidencane (*P. hemitomon*). Just waterward of the wave berm and within this transitional marsh, numerous bald cypress, buttonbush, and rattle-bush (*Sesbania herbacea*) were rooted. A significant amount of unrooted, floating vegetation consisting of abundant pickerelweed (*P. cordata*) and smartweed (*Polygonum* sp.), as well as numerous primrose (*L. peruviana*), occupied a large portion of the transitional marsh.

Within the floating vegetation, a distinct community break into a deep marsh habitat was delineated based on a change in vegetation, slope change in the lake bed and the historic stage data of Lochloosa Lake. At this location, substantial amounts of floating smartweed, pickerelweed, primrose, and flatsedge (*Cyperus* sp.) were still present. Rare amounts of amaranth (*Amaranthus* sp.) and water-hyacinth (*Eichhornia crassipes*) were also accounted for. Just beyond the matt of floating vegetation was abundant rooted spatterdock (*N. advena*) and numerous maidencane. Other species present, although in rare quantities, were waterlily (*Nymphaea* sp.) and cattail (*Typha* sp.)

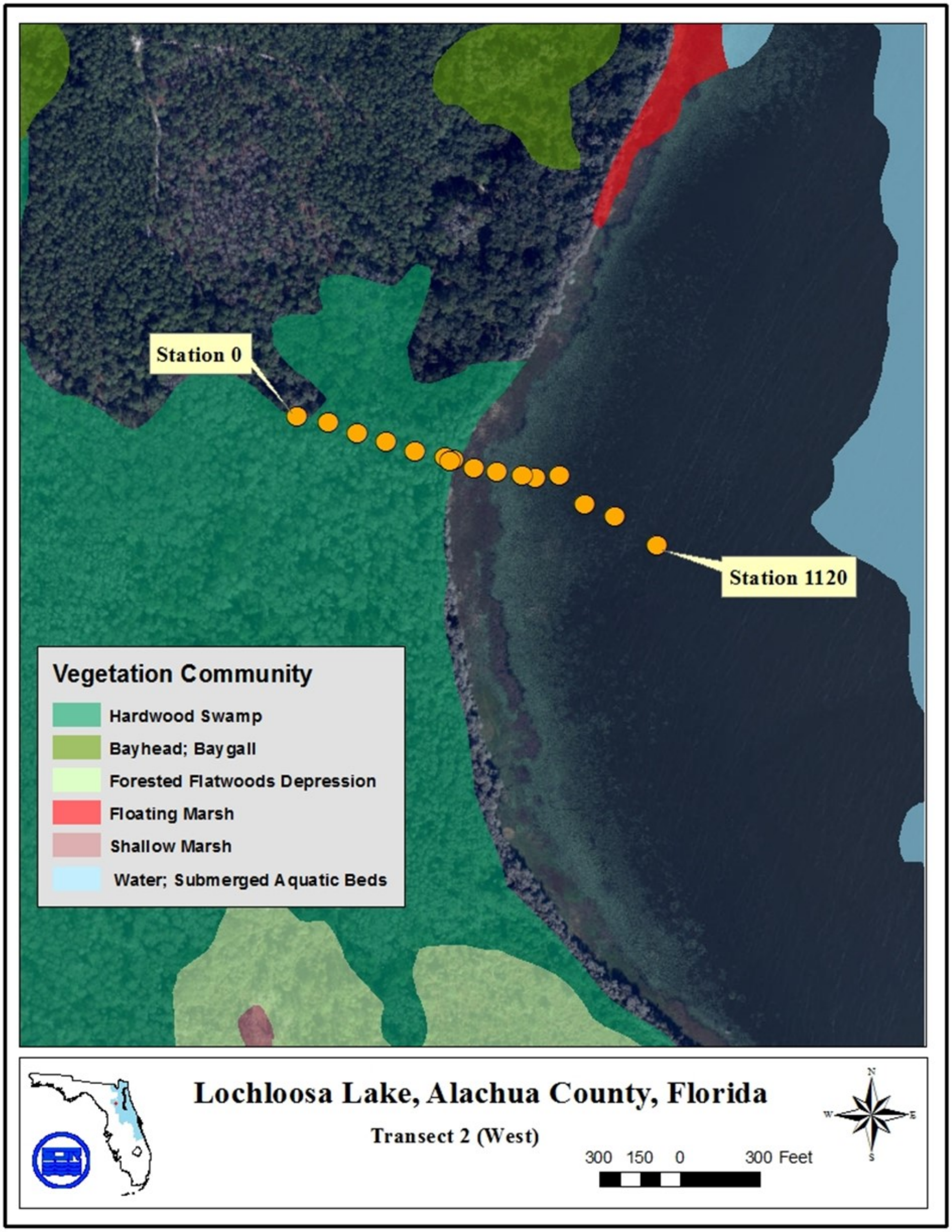


Figure 10. Transect 2 (West) mapped wetland plant communities, Lochloosa Lake

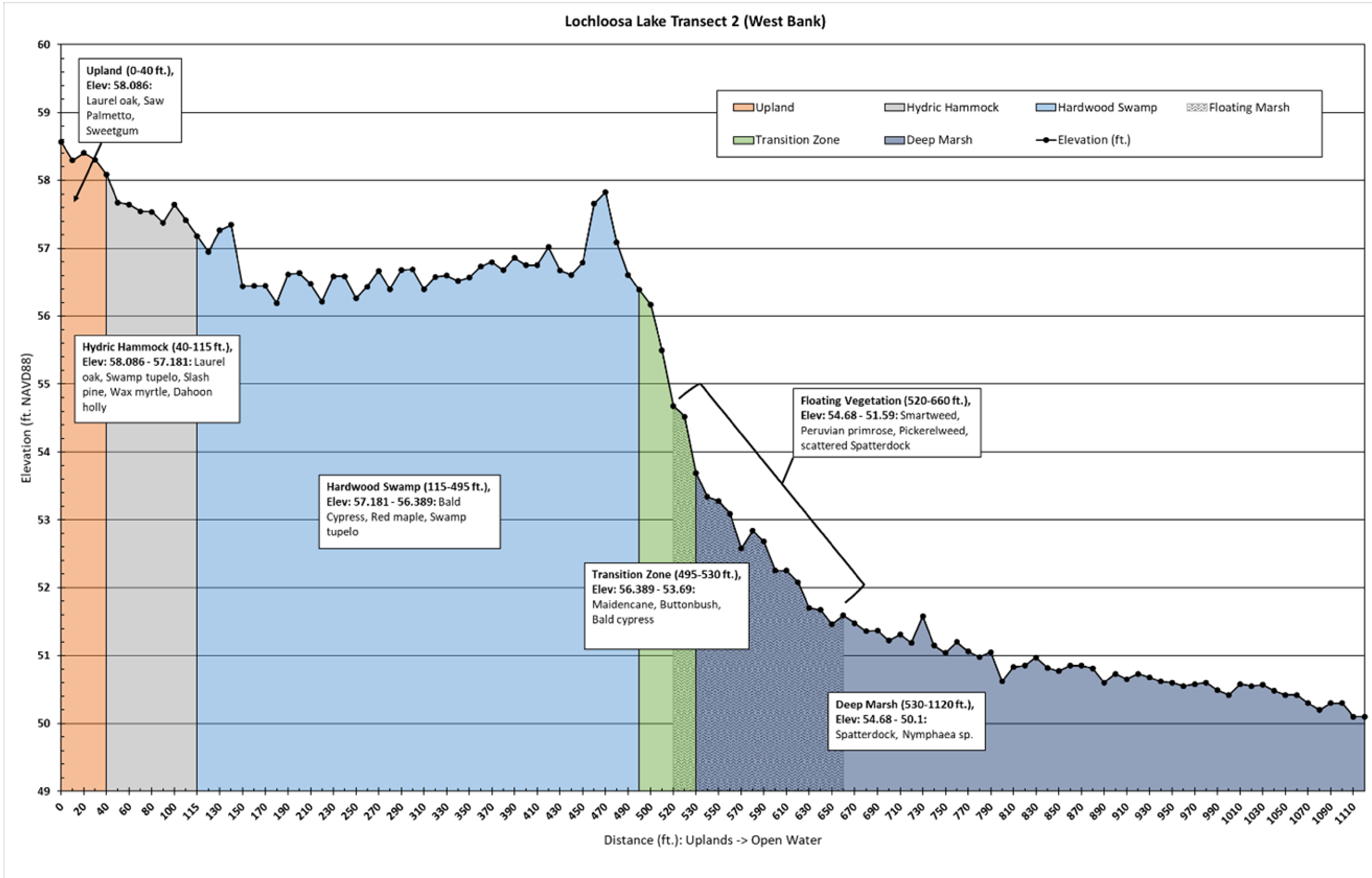


Figure 11. Transect 2 (West) topography and plant communities, Lochloosa Lake

Figure 12. Transect 2 (West) hardwood swamp station 230 looking downslope, Lochloosa Lake

Table 7. Transect 2 (West) vegetation community elevations statistics, Lochloosa Lake

| Vegetation community | Station Distance (ft) | Elevation (ft NAVD)* | | | | **N |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | |
| Upland | 0-40 | 58.3 | 58.3 | 58.1 | 58.6 | 5 |
| Hydric hammock | 40-115 | 57.6 | 57.5 | 57.2 | 58.1 | 9 |
| Hardwood swamp | 115-495 | 56.7 | 56.6 | 56.2 | 57.8 | 40 |
| Transitional marsh | 495-530 | 55.2 | 55.1 | 53.7 | 56.4 | 6 |
| Deep marsh | 530-1120 | 51.2 | 50.9 | 50.1 | 53.7 | 60 |

* ft NAVD = feet North American Vertical Datum 1988

**N = the number of elevation readings surveyed in each vegetation or soil community

Table 8. Transect 2 (West) belt transect vegetation species and cover class, Lochloosa Lake

| Scientific Name | Common Name | Vegetation Community[2] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Name | UP | HH | HS | TRZ | DM |
| | | Start (ft) | 0 | 40 | 115 | 495 | 530 |
| | | Stop (ft) | 40 | 115 | 495 | 530 | 1120 |
| | | FWDM Code[1] | Plant Species Cover Estimates[3] | | | | |
| *Acer rubrum* | Red maple | FACW | | | 3 | | |
| *Alternanthera philoxeroides* | Alligator weed | OBL | | | 1 | | |
| *Amaranthus* spp. | Amaranth | OBL | | | | | 0[4] |
| *Axonopus furcatus* | Carpetgrass | FAC | | | 0 | | |
| *Boehmeria cylindrica* | False-nettle | OBL | | | 2 | | |
| *Carex* spp. | Sedge | OBL | | | 1 | | |
| *Cephalanthus occidentalis* | Buttonbush | OBL | | | 1 | 2 | |
| *Cyperus erythrorhizos* | Redroot flatsedge | OBL | | | 2 | | |
| *Cyperus* spp. | Flatsedge | OBL | | | | | 1[4] |
| *Dichanthelium commutatum* | Variable witchgrass | - | | | 1 | | |
| *Dichanthelium* spp. | Witchgrass | - | 1 | 1 | 1 | | |
| *Echinochloa colona* | Jungle rice | FACW | 0 | | | | |
| *Echinochloa walteri* | Cockspur | FACW | | | | 0 | |
| *Eichhornia crassipes* | Water hyacinth | - | | | | | 0[4] |
| *Eleocharis baldwinii* | Spikerush | OBL | | 0 | 1 | | |
| *Fraxinus caroliniana* | Carolina ash | OBL | | | 1 | | |
| *Hydrocotyle* spp. | Pennywort | FACW | | | 2 | | |
| *Ilex cassine* | Dahoon holly | OBL | 0 | 0 | 1 | | |
| *Leersia virginica* | Whitegrass | OBL | | | 1 | | |
| *Liquidambar styraciflua* | Sweetgum | FACW | 2 | | 1 | | |
| *Ludwigia peruviana* | Primrose | OBL | | | | 2[4] | 1[4] |
| *Lycopus rubellus* | Taperleaf water horehound | OBL | | | 0 | | |
| *Lyonia ligustrina* | Maleberry | FAC | 1 | 1 | | | |
| *Lyonia lucida* | Fetter-bush | FACW | 3 | | 1 | | |
| *Myrica cerifera* | Wax myrtle | FAC | | 1 | | | |
| *Nuphar advena* | Spatterdock | OBL | | | | | 5 |
| *Nymphaea spp.* | Water-lily | OBL | | | | | 1 |
| *Nyssa sylvatica* var. *biflora* | Swamp tupelo | OBL | | 2 | 3 | | |
| *Panicum gymnocarpon* | Savannah panicum | OBL | | | | 3 | |
| *Panicum hemitomon* | Maidencane | OBL | | | 0 | 5 | 2 |
| *Paspalum* spp. | Paspalum | FACW | | | 1 | | |
| *Persea palustris* | Swamp bay | OBL | | 1 | | | |
| *Pinus elliotii* | Slash pine | - | 2 | 2 | | | |
| *Polygonum* spp. | Smartweed | OBL | | | | 3[4] | 2[4] |
| *Pontederia cordata* | Pickerelweed | OBL | | | | 3[4] | 1[4] |
| *Quercus laurifolia* | Laurel oak | FACW | 2 | 2 | | | |
| *Quercus nigra* | Water oak | FACW | | 0 | | | |
| *Rhynchospora harperi* | Harper's beakrush | OBL | 0 | | | | |
| *Saururus cernuus* | Lizard's tail | OBL | | 0 | 1 | | |
| *Schoenoplectus americanus* | American bulrush | OBL | | | 1 | | |
| *Serenoa repens* | Saw palmetto | - | 3 | | | | |
| *Sesbania herbacea* | Rattle-bush | FAC | | | | 2 | |
| *Smilax* spp. | Greenbrier | - | | 0 | | | |
| *Taxodium distichum* | Bald cypress | OBL | | 1 | 4 | 2 | |
| *Thelypteris palustris* | Marsh fern | FACW | | | 0 | | |
| *Triadenum virginicum* | St. John's wort | OBL | | | 0 | | |
| *Tripsacum dactyloides* | Eastern gamagrass | FAC | | 0 | | | |
| *Typha* spp. | Cattail | OBL | | | | | 1 |
| *Vaccinium corymbosum* | Highbush blueberry | FACW | 1 | | | | |
| *Vitis rotundifolia* | Muscadine | - | 1 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Woodwardia virginica* | Chainfern | FACW | 0 | 1 | 0 | | |

1 FWMD code indicator categories established in The Florida Wetlands Delineation Manual (Gilbert et al. 1995):

UPL = Upland plants that occur rarely in wetlands but occur almost always in uplands

FAC = Facultative plants with similar likelihood of occurring in both wetlands and uplands

FACW = Facultative wet plants that typically exhibit their maximum cover in areas subject to surface water flooding and/or soil saturation but may also occur in uplands

OBL = Obligate plants that are found or achieve their greatest abundance in an area, which is subject to surface water flooding and/or soil saturation; rarely uplands

2 Plant community abbreviations:

Up = Uplands (stations 0-40)

HH = Hydric hammock (stations 40-115)

HS = Hardwood swamp (stations 115-495)

TRZ = Transition zone (stations 495-530)

DM = Deep marsh (stations 530-1120)

3 Plant Species Cover Estimates: Areal extent of vegetation species along transect within a given community where 0 = <1% (rare); 1 = 1-10% (scattered); 2 = 11-25% (numerous); 3 = 26-50% (abundant); 4 = 51-75% (codominant); 5 = >75% (dominant)

4 Floating vegetation

Soils at Transect 2 (West)

Transect 2 (West) soils were sampled on September 7, 2017. Samples were limited due to excessive flooding along the transect. Transects were inundated due to record high summer rainfall and precipitation from Hurricane Irma in September 2017. Attempts to continue sampling at later dates were abandoned due to continued high lake levels.

Mapped soils at Transect 2 (West) indicate the transect begins in a predominantly non-hydric soil type (Figure 13). The transect quickly enters a hydric soil type within roughly 30 ft from the point that station 0 is located. The discrimination between the mapped and sampled soils hydric status may be due to the resolution of the mapped soil GIS layer.

Detailed profile descriptions were made at select stations along the transect. A sample was taken at station 34 to identify hydric soil indicators and/or depth of muck (Table 9). Soil series found along Transect 2 (West) was Placid, respectively. The hydric soil indicator identified at Transect 2 (West) was mucky mineral (A7). The following describes the soil series and hydric indicator found at Lochloosa Lake Transect 2 (West):

Soil Series:

**Placid** (Sandy, siliceous, hyperthermic Typic Humaquepts)
The Placid series consists of very deep, very poorly drained, rapidly permeable soils on low flats, depressions, poorly defined drainageways on uplands, and flood plains on the lower Coastal Plain. They formed in sandy marine sediments. Near the type location, the mean annual temperature is about 72 degrees F, and the mean mean annual precipitation is about 55 inches. Slopes range from 0 to 2%.

Hydric Indicators:

**5 cm Mucky Mineral (A7)**
A layer of mucky modified mineral soil material 5 cm (2 in) or more thick, starting at a depth ≤15 cm (6 in) from the soil surface.

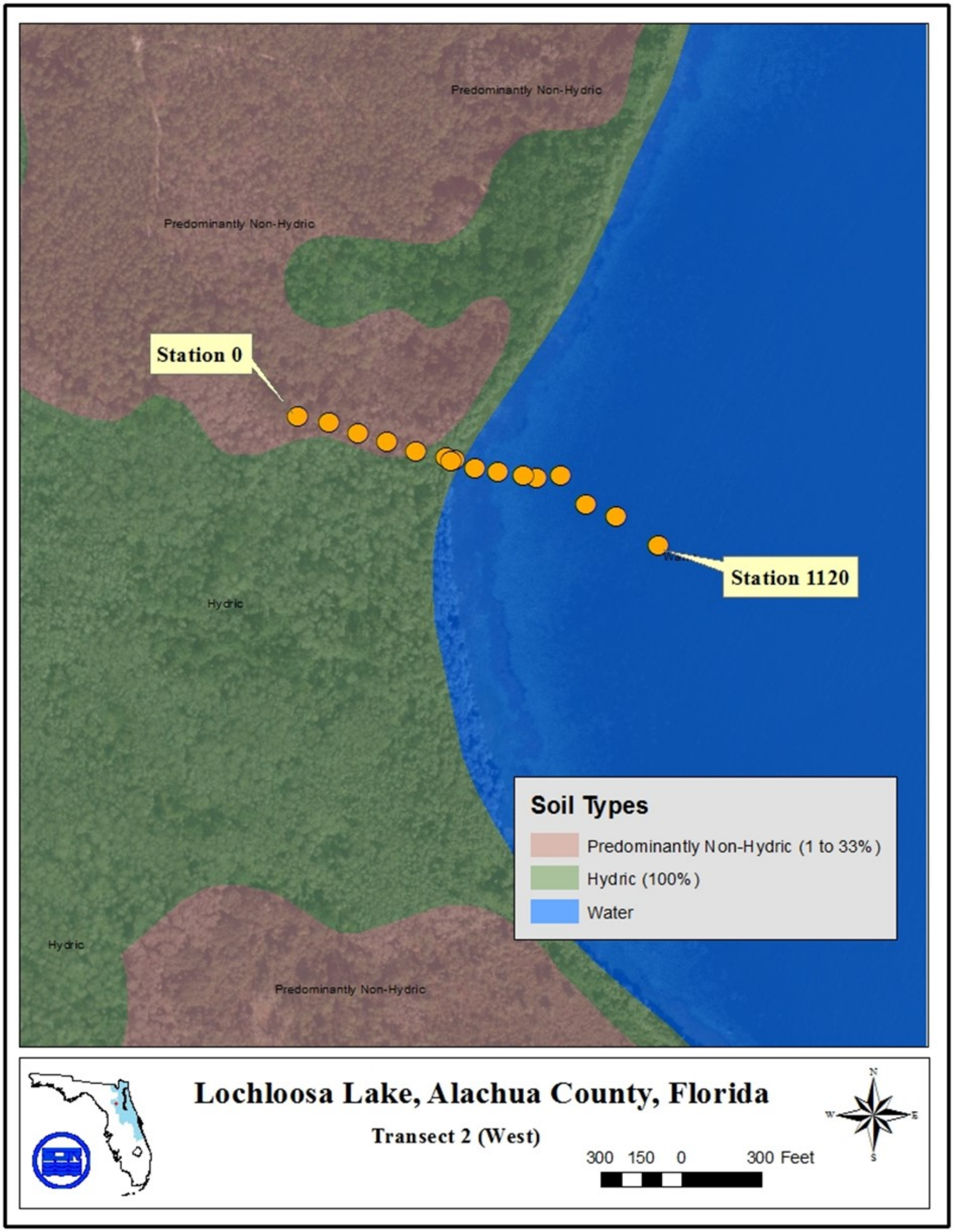


Figure 13. Transect 2 (West) mapped soil types, Lochloosa Lake

Table 9. Transect 2 (West) soil sample descriptions, Lochloosa Lake

| Station | Depth | Horizon | Color | Texture | Notes |
|---|---|---|---|---|---|
| 34 | -5-0” | Oi | 10YR 2/2 | Mucky peat | |
| | 0-8” | A1 | 10YR 2/1 | Mucky sand | 70% masked |
| | 8-19” | A2 | 10YR 4/4 | Sand | |
| | 19-26” | C1 | 10YR 6/2 | Coarse sand | |
| | 26-35” | C2 | 10YR 3/1 | Coarse sand | |
| | 35-39” | C3 | 10YR 4/1 | Coarse sand | |
| | 39”+ | C4 | 10YR 7/1 | Coarse sand | |
| | Hydric Indicators: A7 | | | | |
| | Soil Series: Placid | | | | |

**Transect 3 (South)**

Transect 3 is located on the south bank of Lochloosa Lake and extends 930 feet, following a northerly direction, into open water (Figure 14). Its location was chosen to characterize the cypress swamp, hardwood swamp, and marsh communities on the south shore of Lochloosa Lake.

Mapped vegetation, based on remote sensing techniques and vegetation community designations by SJRWMD, show that Transect 3 should begin in an upland area followed by a cypress swamp community and continuing into a hardwood swamp that extends to the bank of Lochloosa Lake. An extensive deep marsh community is mapped using the remote sensing. The following describes field collected vegetation and soils data at Transect 3 (South).

Vegetation at Transect 3 (South)

This transect began in an upland community dominated by live oak (*Q. virginiana*) with an understory of mature and immature cabbage palm (*S. palmetto*) from station 0 to station 30 (Figure 15; Table 10 and 11). Ground cover in the upland community consisted of numerous witchgrass (*D. commutatum*) and rare pockets of Virginia chain fern (*Woodwardia virginica*).

Between stations 30 and 160 a hydric hammock community was present. In the canopy, live oak and bald cypress (*T. distichum*) were numerous with a scattered amount of swamp bay (*P. palustris*), slash pine (*P. elliottii*), and immature cabbage palm. The shrub layer consisted of a dense patch of blackberry (*Rubus* sp.) and scattered amounts of wax myrtle (*M. cerifera*) and false-willow (*Baccharis angustifolia*). A rare amount of sweetbay (*Magnolia virginiana*) was also present in the shrub layer. Ground cover in the hydric hammock consisted primarily of an abundant amount of Virginia chain fern and numerous amounts of witchgrass and lizard’s tail (*S. cernuus*). Scattered on the hydric hammock floor was royal fern (*Osmunda regalis*) and soft rushes (*Juncus effuses*). Scattered and rare amounts of other species were also present (see Table 11).

Down slope of the hydric hammock a cypress swamp occurred from stations 160 to the lakes edge at station 420. Bald cypress was the only dominant species in the canopy. The shrub layer consisted of a mix of abundant amounts of water hemlock (*Cicuta maculata*) as well as numerous amount of false nettle (*B. cylindrica*), canna (*Canna flacida*), lizard's tail, and Virginia chain fern. Scattered amounts of cabbage palm and buttonbush (*C. occidentalis*) was also present in the shrub layer. Ground cover species consisted mostly of numerous amounts of pennywort (*Hydrocotyle umbellate*) and scattered amounts of alligatorweed (*A. philoxeroides*), broomsedge (*Andropogon virginicus*), iris (*Iris* sp.), pickerelweed (*P. cordata*), and soft rush, among others. A distinct wave berm was located at the final 50 ft of cypress swamp.

On the waterward side of the wave berm a steep transition into the lake occurred from station 420 and ending at station 470. In this transition marsh, some rooted bald cypress, buttonbush, maidencane (*P. hemitomon*) and a rare lanceleaf arrowhead (*S. lancifolia*) was present. But, the majority of the vegetation was flooting and not rooted in the lake bottom (photo Figure 16). The floating vegetation was comprised of mats containing abundant amounts of smartweed (*Polygonum* sp.), and primrose (*L. peruviana*), numerous amounts of pennywort (*Hydrocotyle* sp.), and scattered amounts of pickerelweed and Savannah panicum (*P. gymnocarpon*).

The start of a deep marsh vegetation community was designated where rooted spatterdock (*N. advena*) began. Although dense mats of floating vegetation was still present, individual spatterdock were found starting at station 470. Scattered spatterdock existed within the floating primrose and smartweed mats until station 540. At station 540, the floating mats were no longer present and spatterdock was the sole dominant species in the deep marsh vegetation community. Spatterdock was prolific until station 930, at which point only open water continued (photo Figure 17).

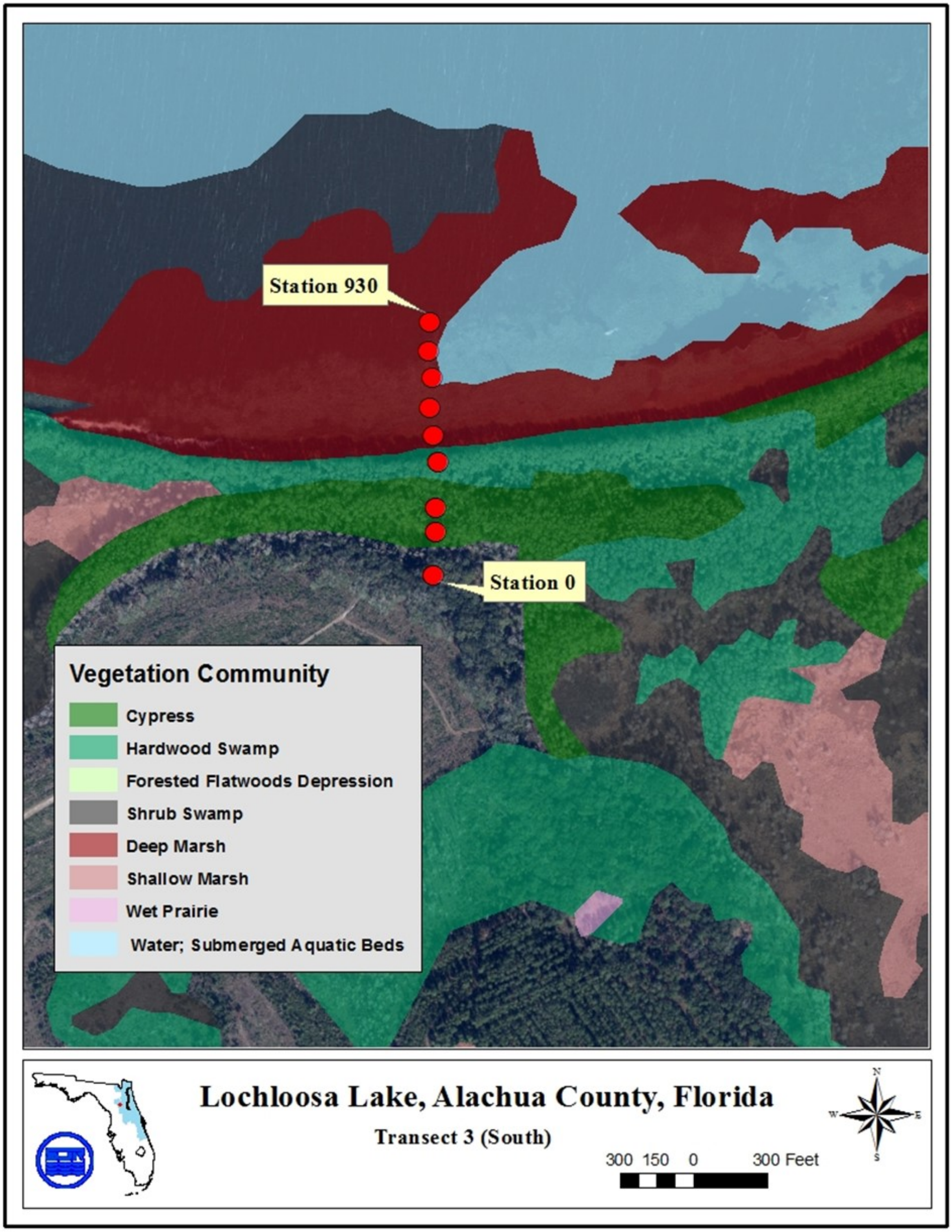


Figure 14. Transect 3 (South) mapped wetland plant communities, Lochloosa Lake

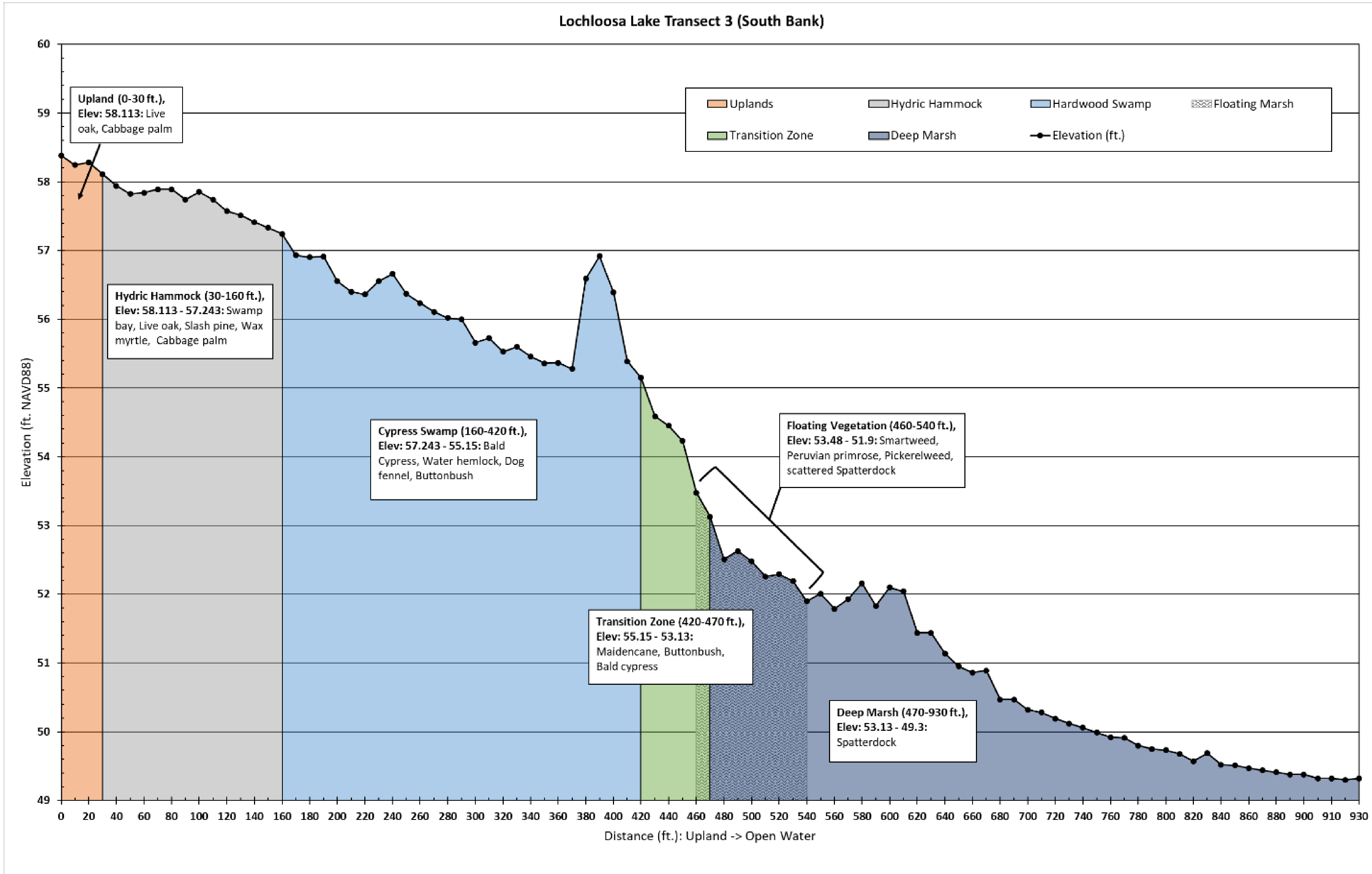


Figure 15. Transect 3 (South) topography and plant communities, Lochloosa Lake

Figure 16. Transect 3 (south) floating marsh habitat looking out into deep marsh habitat, Lochloosa Lake

Figure 17. Transect 3 (south) break between open water and deep marsh habitat, Lochloosa Lake

Table 10. Transect 3 (South) vegetation community elevation statistics, Lochloosa Lake

| Vegetation community | Station Distance (ft) | Elevation (ft NAVD)* | | | | **N |
|---|---|---|---|---|---|---|
| | | Mean | Median | Minimum | Maximum | |
| Uplands | 0-30 | 58.3 | 58.3 | 58.1 | 58.4 | 4 |
| Hydric hammock | 30-160 | 57.7 | 57.8 | 57.2 | 58.1 | 14 |
| Cypress swamp | 160-420 | 56.1 | 56.2 | 55.2 | 57.2 | 27 |
| Transitional marsh | 420-470 | 54.2 | 54.3 | 53.1 | 55.2 | 6 |
| Deep marsh | 470-930 | 50.7 | 50.3 | 49.3 | 53.1 | 48 |

* ft NAVD = feet North American Vertical Datum 1988

**N = the number of elevation readings surveyed in each vegetation or soil community

Table 11. Transect 3 (South) belt transect vegetation species and cover class

| Scientific Name | Common Name | Vegetation Community | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Name** | **UP** | **HH** | **CS** | **TRZ** | **DM** |
| | | **Start (ft)** | **0** | **30** | **160** | **420** | **470** |
| | | **Stop (ft)** | **30** | **160** | **420** | **470** | **930** |
| | | **FWDM Code[1]** | **Plant Species Cover Estimates[2]** | | | | |
| *Alternanthera philoxeroides* | Alligator weed | OBL | | | 1 | | |
| *Andropogon virginicus* | Broomsedge | FAC | | 0 | 1 | | |
| *Baccharis angustifolia* | Falsewillow | OBL | | 1 | | | |
| *Boehmeria cylindrica* | False nettle | OBL | | | 2 | | |
| *Canna flaccida* | Canna | OBL | | | 2 | | |
| *Cephalanthus occidentalis* | Buttonbush | OBL | | | 1 | 1 | |
| *Cicuta maculata* | Water-hemlock | OBL | | | 3 | | |
| *Cyperus croceus* | Baldwin's flatsedge | FAC | | 0 | | | |
| *Dichanthelium commutatum* | Variable witchgrass | - | 2 | 2 | 0 | | |
| *Diodia virginana* | Button-weed | FACW | | | 0 | | |
| *Echinochloa colona* | Jungle rice | FACW | | 0 | | | |
| *Eleocharis baldwinii* | Spikerush | OBL | | 1 | 0 | | |
| *Erechtites hieraciifolia* | Fireweed | FAC | | 0 | 0 | | |
| *Eupatorium* spp. | Thoroughwort | FAC | | 1 | 0 | | |
| *Hydrocotyle* spp. | Pennywort | FACW | | | | 2[3] | 1[3] |
| *Hydrocotyle umbellata* | Pennywort | FACW | | 1 | 2 | | |
| *Hypericum hypericoides* | St. Andrew's cross | FAC | | 1 | 0 | | |
| *Iris* spp. | Iris | OBL | | | 1 | | |
| *Juncus effusus* | Soft rush | OBL | | 1 | 1 | | |
| *Leersia virginica* | Whitegrass | OBL | | 0 | | | |
| *Ludwigia peruviana* | Primrose | OBL | | | | 3[3] | 1[3] |
| *Magnolia virginiana* | Sweetbay | OBL | | 0 | | | |
| *Myrica cerifera* | Wax myrtle | FAC | | 1 | | | |
| *Nuphar advena* | Spatterdock | OBL | | | | | 5 |
| *Nyssa sylvatica* var. *biflora* | Swamp tupelo | OBL | | 0 | | | |
| *Osmunda regalis* | Royal fern | OBL | | 1 | | | |
| *Panicum gymnocarpon* | Savannah panicum | OBL | | 0 | 1 | 1[3] | 1[3] |
| *Panicum hemitomon* | Maidencane | OBL | | | | 1 | |
| *Panicum* spp. | Panicum | - | | | | | |
| *Paspalum* spp. | Paspalum | FACW | | 0 | | | |
| *Persea palustris* | Swamp bay | OBL | | 1 | | | |
| *Pinus elliottii* | Slash pine | - | | 1 | | | |
| *Pluchea* spp. | Camphor-weed | FACW | | | | | |
| *Polygonum* spp. | Smartweed | OBL | | | | 3[3] | 1[3] |
| *Pontederia cordata* | Pickerelweed | OBL | | | 1 | 1[3] | |
| *Quercus virginiana* | Live oak | - | 5 | 2 | | | |
| *Rubus* spp. | Blackberry | FAC | | 2 | | | |
| *Rumex verticillatus* | Swamp dock | FACW | | | 0 | | |
| *Sabal palmetto* (immature) | Sabal palm | FAC | 3 | 1 | 1 | | |
| *Sabal palmetto* (mature) | Sabal palm | FAC | 3 | | | | |
| *Sagittaria lancifolia* | Lanceleaf arrowhead | OBL | | | | 0 | |
| *Saururus cernuus* | Lizard's tail | OBL | | 2 | 2 | | |
| *Taxodium distichum* | Bald cypress | OBL | | 2 | 5 | 3 | |
| *Teucrium canadense* | American germander | FACW | | 1 | 0 | | |
| *Woodwardia virginica* | Virginia chain fern | FACW | 0 | 3 | 2 | | |

1 FWMD code indicator categories established in The Florida Wetlands Delineation Manual (Gilbert et al. 1995):

UPL = Upland plants that occur rarely in wetlands but occur almost always in uplands

FAC = Facultative plants with similar likelihood of occurring in both wetlands and uplands

FACW = Facultative wet plants that typically exhibit their maximum cover in areas subject to surface water flooding and/or soil saturation but may also occur in uplands

OBL = Obligate plants that are found or achieve their greatest abundance in an area, which is subject to surface water flooding and/or soil saturation; rarely uplands

2 Plant community abbreviations:

Up = Uplands (stations 0-30)
HH = Hydric hammock (stations 30-160)
CS = Cypress swamp (stations 160-420)
TRZ = Transition zone (stations 420-470)
DM = Deep marsh (stations 470-930)

3 Plant Species Cover Estimates: Areal extent of vegetation species along transect within a given community where 0 = <1% (rare); 1 = 1-10% (scattered); 2 = 11-25% (numerous); 3 = 26-50% (abundant); 4 = 51-75% (codominant); 5 = >75% (dominant)

4 Floating vegetation

Soils at Transect 3 (South)

Transect 3 (South) soils were sampled on January 11, 2018. Samples were limited due to excessive flooding along the transect. Transects were inundated due to record high summer rainfall and precipitation from Hurricane Irma in September 2017. Attempts to continue sampling at later dates were abandoned due to continued high lake levels.

Mapped soils at Transect 3 (South) indicate the transect begins in a predominantly hydric soil type (Figure 18). The transect quickly enters a hydric soil type within roughly 10 ft from the point that station 0 is located.

Detailed profile descriptions were made at select stations along the transect. Samples were taken at stations 10, 50, and 140 to identify hydric soil indicators and/or depth of muck (Table 12). Soil series found along Transect 3 (South) were Wesconnett and Mascotte, respectively. The hydric soil indicators identified at Transect 3 (South) were mucky mineral (A7), dark surface (S7), and thin dark surface (S9). The following describes the two soil series and three hydric indicators found at Lochloosa Lake Transect 3 (South):

Soil Series:

**Wesconnett** (Sandy, siliceous, thermic Typic Alaquads)
The Wesconnett series consists of very deep, very poorly drained sandy soils that formed in sandy deposits on marine terraces. These soils are in depressions and on flood plains. Slope ranges from 0 to 2%.

**Mascotte** (Sandy over loamy, siliceous, active, thermic Ultic Alaquods)
The Mascotte series consists of very deep, poorly and very poorly drained, moderately slowly permeable soils on areas of flats, depressions, and on low stream terraces of the lower Coastal Plain. They formed in sandy and loamy marine sediments. Near the type location, the mean annual temperature is about 68 degrees F, and the mean annual precipitation is about 55 inches. Slopes range from 0 to 2%.

Hydric Indicators:

**5 cm Mucky Mineral (A7)**

A layer of mucky modified mineral soil material 5 cm (2 in) or more thick, starting at a depth ≤15 cm (6 in) from the soil surface.

**Dark Surface (S7)**
A layer 10 cm (4 in) or more thick, starting at a depth less than or equal to the upper 15 cm (6 in) from the soil surface, with a matrix value of 3 or less and chroma of 1 or less. At least 70% of the visible soil particles must be masked with organic material, viewed through a 10x or 15x lens. Observed without a hand lens, the particles appear to be close to 100% masked. The matrix color of the layer directly below the dark layer must have the same colors as those described above or any color that has chroma of 2 or less.

**Thin Dark Surface (S9)**
A layer 5 cm (2 in) or more thick, starting at a depth of ≤15 cm (6 in) from the soil surface, with a value of 3 or less and chroma of 1 or less. At least 70% of the visible soil particles must be masked with organic material, viewed through a 10x or 15x hand lens. Observed without a hand lens, the particles appear to be close to 100% masked. This layer is underlain by a layer or layers with value of 4 or less and chroma of 1 or less to a depth of 30 cm (12 in) or to the spodic horizon, whichever is less.

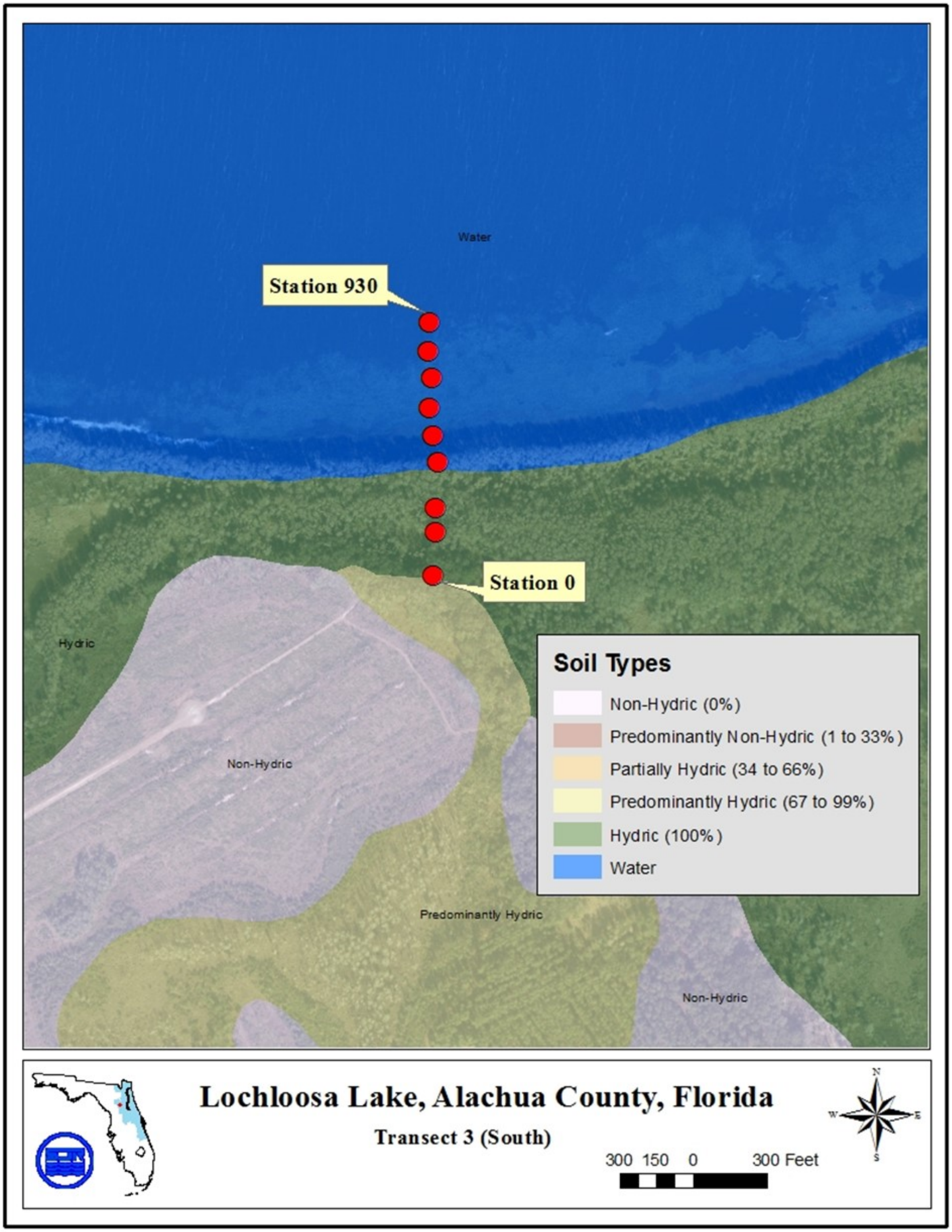


Figure 18. Transect 3 (South) mapped soil types, Lochloosa Lake

Table 12. Transect 3 (South) soil sample descriptions

| Station | Depth | Horizon | Color | Texture | Notes |
|---|---|---|---|---|---|
| 10 | 0-1" | A1 | 10YR 2/2 | Mucky sand | 80% masked |
| | 1-3" | A2 | 2.5/N | Mucky loamy sand | 70% masked |
| | 3-26" | Bh1 | 3/N | Coarse sand | |
| | 26-36" | Bh2 | 10YR 3/2 | Coarse sand | |
| | 36"+ | Bh3 | 10YR 3/3 | Very coarse sand | |
| | Hydric Indicators: A7 | | | | |
| | Soil Series: Wesconnett | | | | |
| 50 | 0-4" | A1 | 10YR 2/2 | Mucky sand | 90% masked |
| | 4-10" | A2 | 50% 2.5/N, 50% 3/N | Mucky sand/sand | 20% masked |
| | 10-46" | Bh1 | 3/N | Coarse sand | |
| | 46"+ | Bh2 | 10YR 3/3 | Coarse sand | |
| | Hydric Indicators: A7 | | | | |
| | Soil Series: Wesconnett | | | | |
| 140 | 0-6.5" | A1 | 2.5/N | Mucky sand | 80% masked |
| | 6.5-28" | E | 4/N | Coarse sand | 10% masked |
| | 28-43" | Bh1 | 3/N | Coarse sand | |
| | 43"+ | Bh2 | 10YR 5/1 | Coarse sand | |
| | Hydric Indicators: A7, S7, S9 | | | | |
| | Soil Series: Mascotte | | | | |

**Transect Data Summary**

Vegetation data surrounding Lochloosa Lake were averaged between transects to create an overall lake condition. Elevations were averaged for each vegetation community (Table 13).

Table 13. Vegetation community elevation statistics at all transects, Lochloosa Lake

| Vegetation Community | Elevation (ft NAVD)* | | | | **N |
|---|---|---|---|---|---|
| | Mean | Median | Minimum | Maximum | |
| Upland | 58.5 | 58.5 | 58.1 | 59.4 | 27 |
| Hydric Hammock | 57.9 | 57.8 | 57.2 | 58.9 | 33 |
| Transitional | 57.9 | 57.9 | 57.8 | 58.0 | 5 |
| Hardwood/Cypress swamp | 56.8 | 56.7 | 55.2 | 58.2 | 140 |
| Transitional marsh | 54.7 | 54.6 | 53.1 | 56.4 | 20 |
| Deep marsh | 51.0 | 50.8 | 49.3 | 53.7 | 157 |

* ft NAVD = feet North American Vertical Datum 1988

**N = the number of elevation readings surveyed in each vegetation or soil community

**Right Arm Lochloosa Lake Marsh Elevations**

The RALL marsh was surveyed to provide precise elevations of wetland plant communities (Figure 19; Table 14). Plant communities were ground truthed and compared to mapped vegetation communities. A variety of communities were sampled to develop an average elevation of the RALL marsh. The average elevation was found to be 55.45 ft NAVD.

Table 14. RALL marsh elevation and vegetation survey results

| Ground Shot | Elevation (ft NAVD88) | Vegetation Community Designation | |
|---|---|---|---|
| | | Remote Sensing | Ground Truthed |
| 1 | 55.87 | Mixed shallow marsh | Flag shallow marsh |
| 2 | 55.26 | Mixed shallow marsh | Mixed shallow marsh |
| 3 | 55.84 | Tall linear-leaved shallow marsh | Mixed shrub swamp |
| 4 | 55.43 | Maidencane shallow marsh | Maidencane shallow marsh |
| 5 | 55.39 | Maidencane shallow marsh | Maidencane shallow marsh |
| 6 | 55.58 | Mixed shallow marsh | Mixed shallow marsh |
| 7 | 55.6 | Tall linear-leaved shallow marsh | Tall linear-leaved shallow marsh |
| 8 | 55.4 | Mixed shallow marsh | Floating-leaved deep marsh |
| 9 | 54.71 | Maidencane shallow marsh | Tall linear-leaved shallow marsh |
| 10 | 55.77 | Mixed shallow marsh | Mixed shallow marsh |
| 11 | 55.32 | Mixed shallow marsh | Mixed shallow marsh |
| 12 | 55.41 | Mixed shallow marsh | Tall linear-leaved shallow marsh |
| 13 | 55.12 | Maidencane shallow marsh | Mixed shallow marsh |
| 14 | 55.69 | Tall linear-leaved shallow marsh | Flag shallow marsh |
| 15 | 55.55 | Mixed shallow marsh | Mixed shallow marsh |
| 16 | 55.48 | Tall linear-leaved shallow marsh | Flag shallow marsh |
| 17 | 55.71 | Flag shallow marsh | Flag shallow marsh |
| 18 | 55.18 | Mixed shallow marsh | Flag shallow marsh |
| 19 | 55.37 | Mixed shallow marsh | Flag shallow marsh |
| 20 | 55.41 | Maidencane shallow marsh | Mixed shallow marsh |
| **Average Elevation** | **55.45** | | |

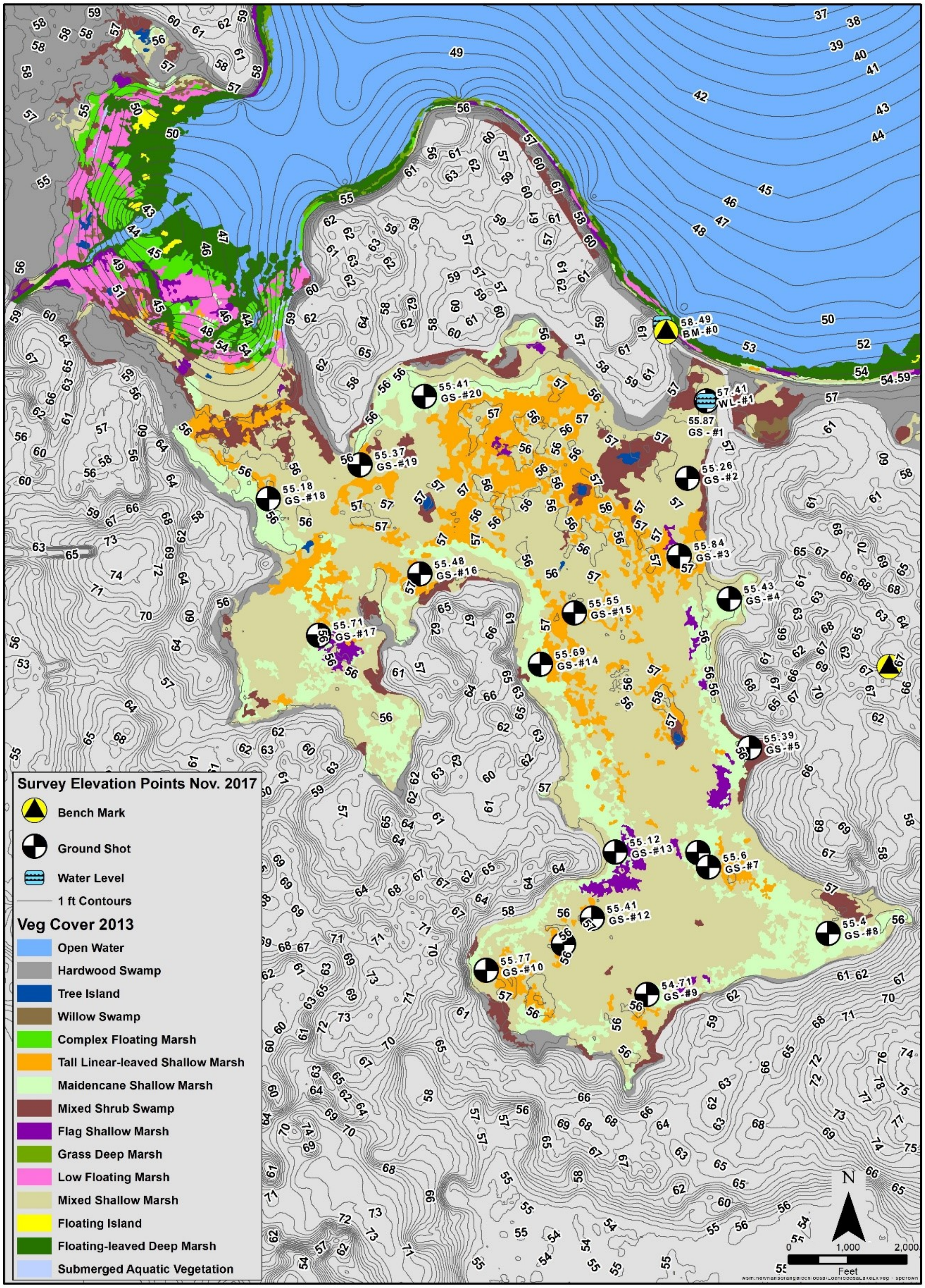


Figure 19. RALL marsh elevation and vegetation survey locations, Lochloosa Lake

**Dock, Boat Ramps, and Cross Creek Channel Elevation**

Elevations of the base of waterward pilings for private and public docks and the base of boat ramps were surveyed in early 2018 (Figure 20; Table 15). In total, seventeen private dock piling bases were surveyed. On Lochloosa Lake, private docks are only located on the eastern shore. One dock was surveyed at the upmost portion of Cross Creek, in an area that maintains a water surface that is equal in elevation to the water surface of Lochloosa Lake. The average waterward dock piling elevations for these sites was 52.7 ft NAVD. The docks chosen for this survey were those that either had a moored boat at the time of survey or had a well-defined path leading through the deep marsh into open water. This path was assumed to indicate that the dock was currently being used as a mooring location.

Two boat ramps exist on Lochloosa Lake. The first is a public boat ramp located at Lochloosa Lake Park in the community of Lochloosa. This boat ramp was surveyed and had an end-of-ramp elevation of 49.2 ft NAVD. The second boat ramp was the private ramp located at the Lochloosa Harbor RV Park. Its end-of-ramp elevation was 53.5 ft NAVD.

The depth of Cross Creek is important for fish and boat passage between Lochloosa and Orange lakes. Measured lake elevations indicate that Lochloosa Lake is higher in elevation the majority of the time (>77%) lake elevations for both lakes were recorded for the same day (Figure 21; Table 16). On days that records for both lake elevations are available, the average height of Lochloosa Lake is 0.69 ft above the height of Orange Lake. Conversely, on the days records indicate Orange Lake was higher than Lochloosa Lake the average height favored Orange Lake by only 0.14 ft. Therefore, Cross Creek depths that allow for fish and boat passage are predominantly dictated by Lochloosa Lake elevation.

Cross Creek was spot surveyed to investigate if a change to channel morphology occurred following Hurricane Irma on September 10, 2017. The single point was surveyed at the location that measured the most shallow water depth during a previous Cross Creek cross-section survey (*see* Figure 20). The spot check resulted in an elevation of 52.8 ft NAVD. The previous Cross Creek cross-section surveyed found this same location to have an elevation of 52.7 ft NAVD (Figure 22 and 23; Table 17). This small difference in elevation was determined to not be significant, indicating that little geomorphological changes occurred to Cross Creek following the high Lochloosa Lake water levels associated with heavy rain falls and Hurricane Irma during the summer and fall of 2017.

Cross Creek was surveyed to determine the channel morphology and water depths. The survey found that the minimal water depth of 0.83 ft occurred at a thalweg elevation of 52.69 ft NAVD. Water depths are determined by Lochloosa Lake and Cross Creek water levels.

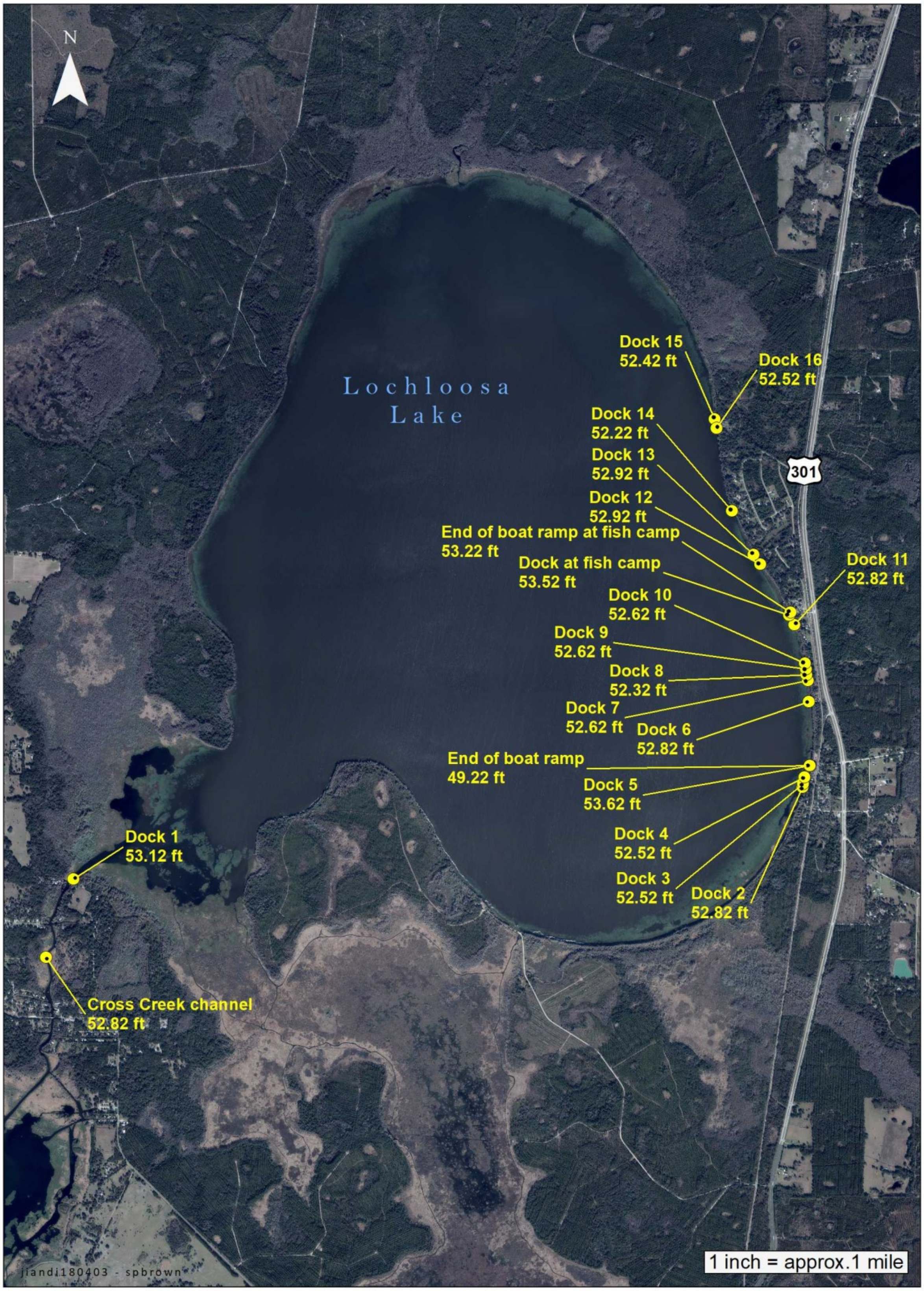


Figure 20. Lochloosa Lake private dock, private and public boat ramps, and Cross Creek elevation survey

Table 15. Lochloosa Lake private dock, private and public boat ramps, and Cross Creek channel elevation survey results

| Survey Type | Number | Elevation (ft NAVD88) |
|---|---|---|
| Private Dock | 1 | 53.1 |
| | 2 | 52.8 |
| | 3 | 52.5 |
| | 4 | 52.5 |
| | 5 | 53.6 |
| | 6 | 52.8 |
| | 7 | 52.6 |
| | 8 | 52.3 |
| | 9 | 52.6 |
| | 10 | 52.6 |
| | 11 | 52.8 |
| | 12 | 52.9 |
| | 13 | 52.9 |
| | 14 | 52.2 |
| | 15 | 52.4 |
| | 16 | 52.5 |
| | Fish Camp Dock | 53.5 |
| | **Average** | **52.7** |
| Private Boat Ramp | - | 53.2 |
| Public Boat Ramp | - | 49.2 |
| Cross Creek Channel | - | 52.8 |

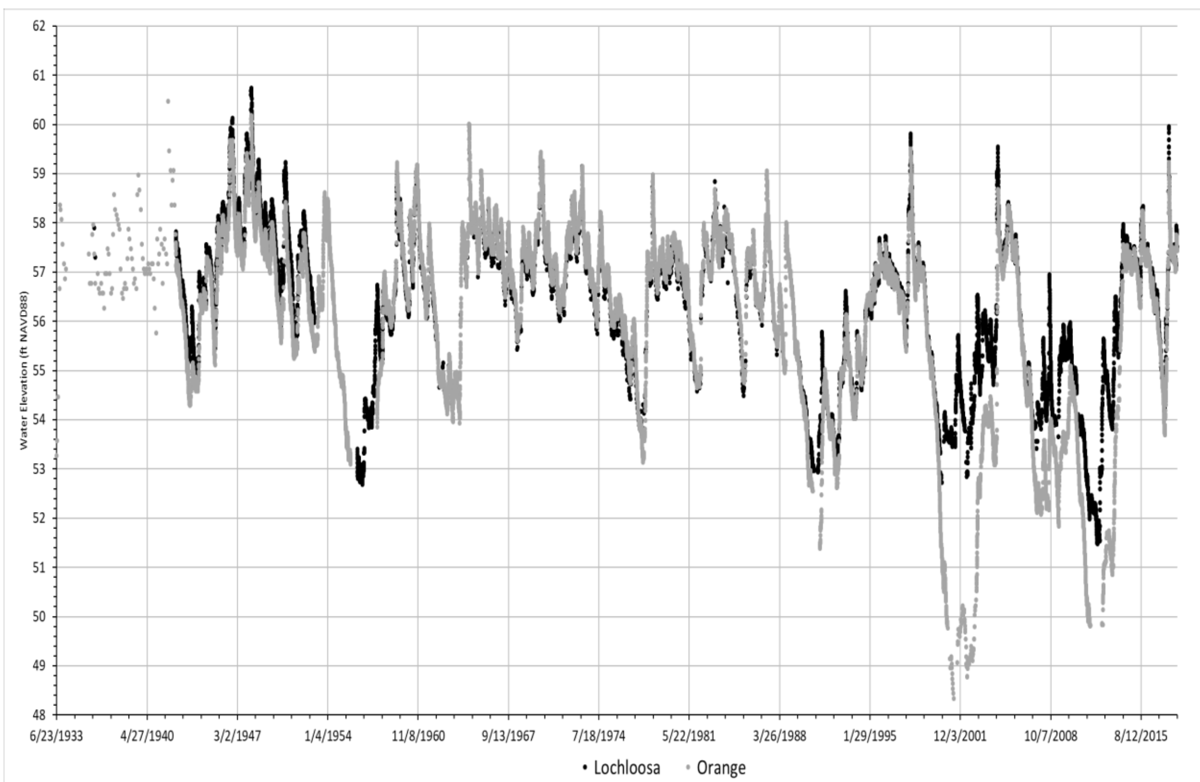

Figure 21. Lochloosa and Orange lakes measured daily stage elevation, 1933 to 2018

Table 16. Lochloosa and Orange lakes measured daily stage elevation statistics, 1993 to 2018

| Statistic | Lochloosa | Orange | Elevations Equal |
|---|---|---|---|
| Number of days lake elevation higher | 11426 | 3129 | 193 |
| Percent of measurements lake is higher (%) | 77.5 | 21.2 | 1.3 |
| Average water level when lake elevation higher (ft) | 0.69 | 0.14 | |
| Median water level when lake elevation higher (ft) | 0.33 | 0.14 | |
| Maximum height above other lake when water elevation higher (ft) | 6.00 | 1.18 | |

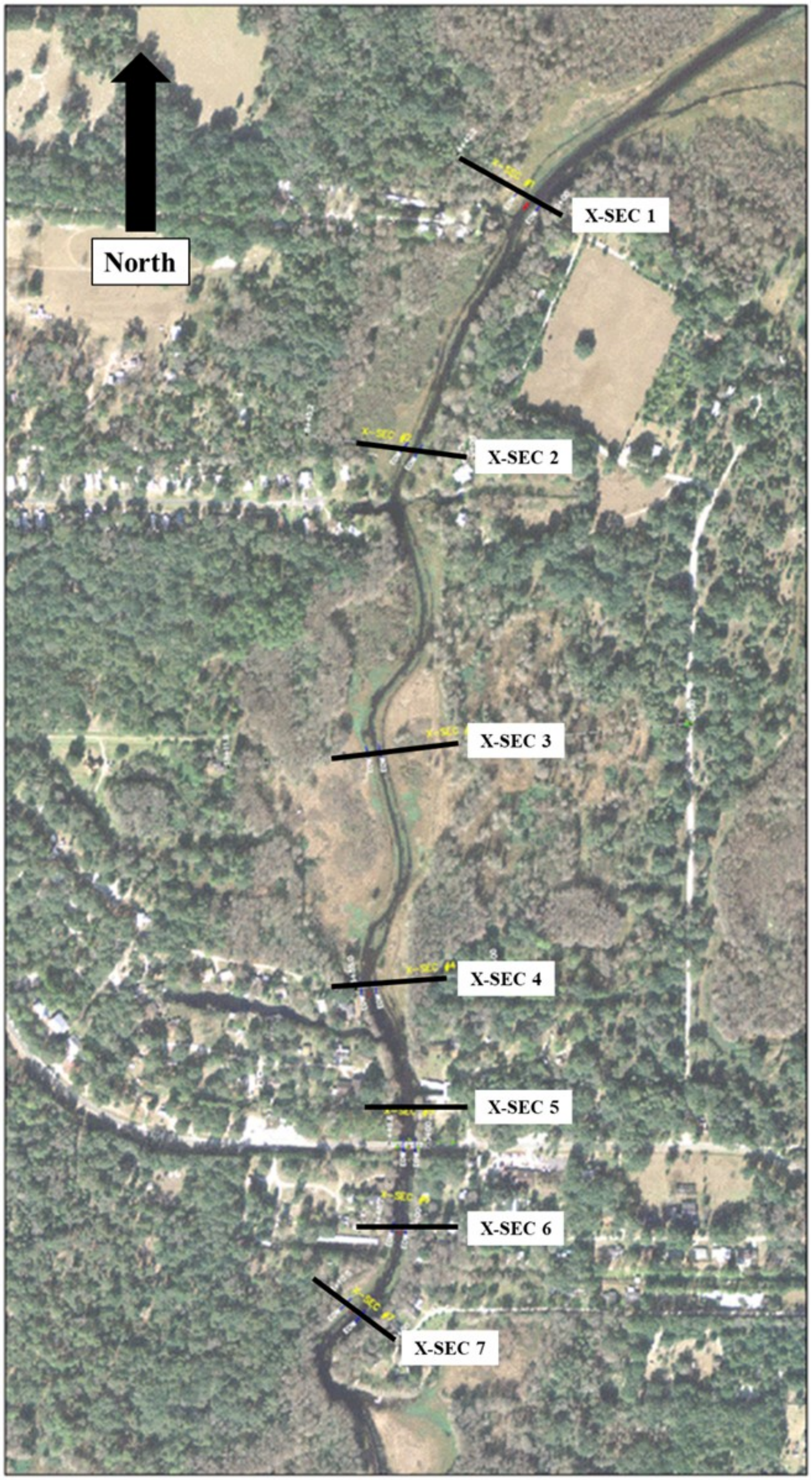

Figure 22. Cross Creek cross section survey

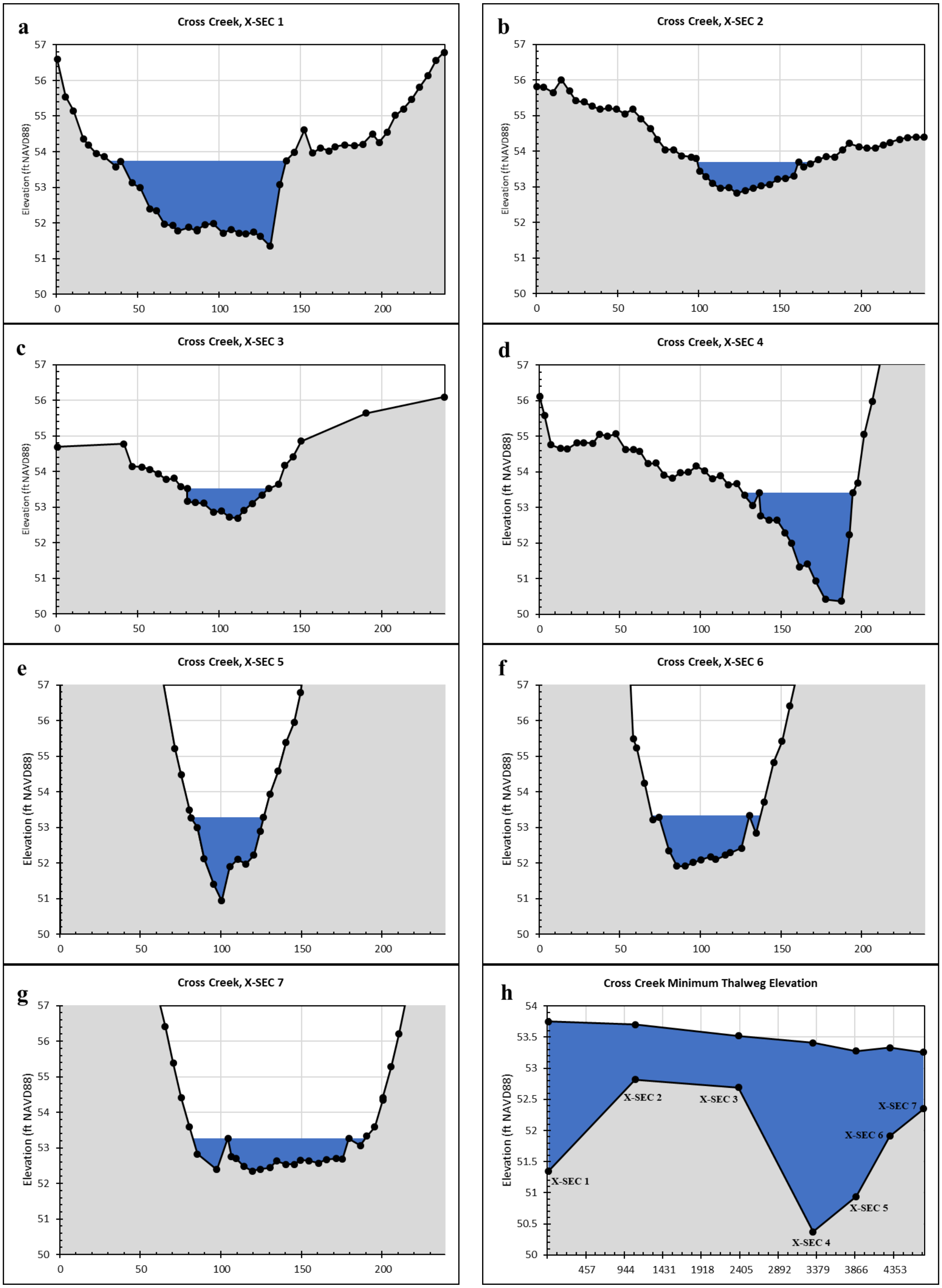


Figure 23. Cross Creek cross section survey (a-g) and longitudinal thalweg-surface water elevation profile (h). *Note: Vertical and horizontal axis not to scale

Table 17. Cross Creek cross section survey results

| Cross Section (x-sec) | Elevation (ft NAVD88) | | Water Depth |
|---|---|---|---|
| | Minimum Thalweg | Water Surface | |
| 1 | 51.35 | 53.75 | 2.40 |
| 2 | 52.82 | 53.70 | 0.88 |
| 3 | 52.69 | 53.52 | 0.83 |
| 4 | 50.37 | 53.41 | 3.04 |
| 5 | 50.94 | 53.28 | 2.34 |
| 6 | 51.91 | 53.33 | 1.42 |
| 7 | 52.35 | 53.26 | 0.91 |

## MINIMUM LEVELS DETERMINATION

Recommended minimum levels for Lochloosa Lake are based on the concept that if the essential characteristics of the natural flooding and drying regime are maintained, then the basic structure and functions of the environmental system will be maintained. Two minimum frequent high (FH-1, FH-2), a minimum average (MA), and a minimum frequent low (FL) are recommended for Lochloosa Lake to protect ecological functions. Three recommended minimum level are based primarily on elevation, soil, and vegetation community data collected in the Lochloosa Lake floodplain. A fourth minimum level is based on the seasonal ecological requirements of Florida sandhill crane nesting.

Environmental criteria used to develop minimum levels vary among waterbodies, depending on the specific level being determined, and the type of wetlands or wildlife habitat at a waterbody. Standardized procedures were followed for setting each level at Lochloosa Lake, and were based on methods detailed in the draft Minimum Flows and Levels Methods Manual (Hall et al. 2006, draft) and the MFLs method paper (Neubauer et al. 2008). The fourth recommended minimum level, which protects Florida sandhill crane nesting habitat, was developed in cooperation with Florida Fish and Wildlife Conservation Commission (FWC) biologists.

### Recommended Minimum Levels for Lochloosa Lake

Two minimum frequent high (FH-1, FH-2), a minimum average (MA), and a minimum frequent low (FL) are recommended for Lochloosa Lake to protect ecological functions. The criteria and rationale for specific components of the four recommended minimum levels are described below.

**Minimum Frequent High 1 (FH-1)** – 56.8 ft NAVD, 30-day duration, 2-year return interval

The role of the FH-1 protection is to maintain:

*"…a chronically high surface water level or flow with an associated frequency and duration that allows for inundation of the floodplain at a depth and duration sufficient to maintain wetland functions." (Rule 40C-8.021(7), F.A.C.).*

The FH typically maintains the hydrology of seasonally flooded wetlands. Seasonal high water levels, occurring in systems with unaltered hydrology, provide for out-of-bank flooding of adjacent wetlands at a duration and return interval sufficient to support important ecological processes (Hill et al. 1991). Levels equal to the FH level typically occur for at least 30 continuous days in the growing season, at least every 2 to 3 years, on average. Aquatic biota relies on inundation of the floodplain for habitat and the exchange of nutrients and organic matter (McArthur 1989). Flooding of wetlands and upland fringes redistributes and concentrates organic particulates across the floodplain (Junk et al. 1989).

The goal of protection for the recommended FH level for Lochloosa Lake (56.8 ft NAVD, 30-day duration, 2-year return interval) is focused on the most sensitive environmental value, "fish and wildlife habitats and the passage of fish". This environmental value can be protected by maintaining the location of the ecotone between the highest seasonally flooded wetlands and the transitional communities located at higher elevations of the floodplain. The highest elevation seasonally flooded wetlands on Lochloosa Lake are hardwood and cypress swamps. The FH level serves to prevent a permanent downhill shift in these communities and a consequent loss in the areal extent of hardwood and cypress swamps. That is, withdrawals should not cause a net downhill shift of seasonally flooded wetland, resulting in a loss of lake area. The location of seasonally flooded wetlands is maintained by frequent flooding events at a specified ground elevation. This elevation must be continuously exceeded for a sufficient duration to kill upland or hydric hammock plant species that grow downslope during periods of low water levels.

The general indicator of protection is that the gradient of wetland communities across the lake floodplain be saturated or inundated frequently enough to maintain the wetland species composition, vegetative structure, and associated ecological functions associated with the seasonally flooded wetland communities. This corresponds to a continuous high-water level event typically associated with extended periods of normal or above-normal rainfall.

The specific indicator of protection is a high-water level that corresponds to the average ground elevation of hardwood/cypress swamp surrounding Lochloosa Lake measured at three transects (56.8 ft NAVD) (Table 18). This elevation provides saturation in transitional wetland communities and hardwood swamps located at higher floodplain elevations and complete inundation at the lower elevations of hardwood/cypress swamps and all other lower elevation wetland communities at Lochloosa Lake.

The recommended FH level for Lochloosa Lake represents a high-water event with a sufficient period of soil saturation or inundation that recurs often enough to maintain the species composition and vegetative structural development of the seasonally flooded wetland communities and the characteristics and ecological functions of the hydric soils in the Lochloosa Lake floodplain.

Table 18. Hardwood and cypress swamp ground elevations, Lochloosa Lake

| Transect | Vegetation Community | Station Distance (ft) | Average Elevation (ft NAVD) | *N |
|---|---|---|---|---|
| Transect 1 (North) | Hardwood swamp | 300-1005 | 57.0 | 73 |
| Transect 2 (West) | Hardwood swamp | 115-495 | 56.7 | 40 |
| Transect 3 (South) | Cypress swamp | 160-420 | 56.1 | 27 |
| **Average Hardwood/cypress swamp Elevation** | | | **56.8** | 140 |

*N = the number of elevation readings surveyed in each vegetation community

FH-1 Magnitude Component

The FH magnitude (water level) was calculated as the average ground elevation of the highest elevation seasonally flooded wetland (hardwood/cypress swamp) communities sampled at three transects surrounding Lochloosa Lake (see Table 18). The rationale for the specific indicator of protection for the FH level at Lochloosa Lake is based on studies indicating that hardwood and cypress swamps are typically seasonally flooded (Mitsch and Gosselink 2015; Ewel 1990; Monk 1968). The following sections discuss the major ecological functions provided by the recommended FH elevation component of 56.8 ft NAVD. The discussion is organized according to the following major topic areas:

- Maintenance of Hardwood Swamp Vegetation Composition and Structure
- Maintenance of Fish and Wildlife Habitat

*Maintenance of Hardwood Swamp Vegetation Composition and Structure*. The inundation of the Lochloosa Lake hardwood and cypress swamp communities to an elevation of 56.8 ft NAVD will promote inundation and/or saturation conditions sufficient to support hydrophytic (i.e., obligate, facultative wet, and facultative) plant species within the Lochloosa Lake hardwood/cypress swamps and adjacent wetlands. An appropriate normal high water level is also necessary to conserve the nature and ecological functions (e.g., denitrification) of the hydric soils within the floodplain wetland communities (Hill et al. 1991).

Swamps are naturally subjected to high water table levels, soil saturation, and periodic and/or continuous flooding at various times of the year. The relative duration and level of flooding plays a key and often critical role in the occurrence and growth rate of tree species and other plants from seed germination, early seedling growth and survival, and later tree growth. The resulting anaerobic soil condition within the wetland communities favors hydrophytic vegetation, tolerant of longer periods of soil saturation and flooding, and mortality of young upland (flood-intolerant) plant species that may have become established during low water events (CH2M HILL 2005). Seedlings of different species exhibit different levels or tolerance to soil saturation or shallow flooding. Water tupelo (*Nyssa aquatica*), ash (*Fraxinus* sp.), and willow are very tolerant while oaks, American elm (*Ulmus americana*), sweetgum (*Liquidambar styraciflua*), and hackberry (*Celtis occidentalis*) are intolerant (Hosner and Boyce 1962; McAlpine 1961). These flood tolerant characteristics in seedlings are often the factor determining occurrence of a given species at a given site.

Soil inundation sets in motion a variety of physical, chemical, and biological processes that alter the capacity of soils to support plant growth (Gill 1970). Soil inundation/saturation induced physiological dysfunctions in plants include the depletion of soil oxygen in the roots, which eventually shuts down respiration in root cells. As respiration ceases, water and ion uptake is inhibited by changing membrane permeabilities in the root cells, affecting movement of both water and ions, and by reducing the amount of energy available for membrane transport, affecting primarily ion movement (Wharton et al. 1982). The inability of flood-intolerant species to absorb and use water and nutrients leads to foliar water deficits, stomatal closure, and reduced gas exchange. Consequently, transpiration and photosynthesis rates are slowed, cellular synthesis requiring unavailable nutrients is curtailed, and overall plant growth is impeded. The plants literally die of dehydration in standing water (Wharton et al. 1982).

Major soil chemical changes due to wetland inundation/saturation include decrease in or depletion of oxygen, accumulation of carbon dioxide, increased solubility of mineral substances, reduction of iron and manganese, and anaerobic decomposition of organic matter (Ponnamperuma 1972, 1984). In addition, many potential toxic compounds accumulate in flooded soils. Some of these compounds (e.g., sulfides, carbon dioxide, soluble iron, and manganese) are produced in waterlogged soils (Kozlowski 1997). Other compounds (e.g., ethanol, acetaldehyde, and cyanogenic compounds) are produced by roots (Rowe and Catlin 1971). Observations suggest that mature, vigorous individuals suffer less flooding damage than either seedlings or over-mature specimens of the same species. Species differ remarkably in their resistance to flooding (Gill 1970).

The hardwood and cypress swamps at Lochloosa Lake are mature wetland communities located downslope from a transition community. Obligate and facultative wet plants (*see* Tables 5, 8, and 11) were prevalent within these transects. Frequent flooding to the average elevation of hardwood swamp at Transect 1 (stations 300-1005; 57.0 ft NAVD) and Transect 2 (stations 115-495; 56.7 ft NAVD) and the cypress swamp at Transect 3 (stations 160-420; 56.1 ft NAVD) should maintain the organic soils and plant community structure and composition if flooding occurs for at least 30 continuous days in the growing season with a return interval of at least every 2 years, as provided by the recommended FH level of 56.8 ft NAVD.

*Maintenance of Fish and Wildlife Habitat*. The inundation of the Lochloosa Lake hardwood and cypress swamp communities to an elevation of 56.8 ft NAVD expands the aquatic habitat, providing sufficient water depths for fish and other aquatic organisms to feed and spawn on the lake floodplain. Surface water connections to the floodplain are important to animal productivity and fecundity (Bain 1990; Poff et al. 1997). The life cycles of many fish are related to seasonal water level fluctuations, particularly the annual flood pattern (Guillory 1979). The floodplain provides feeding and spawning habitat (Guillory 1979; Ross and Baker 1983), refugia for juvenile fishes (Finger and Stewart 1987), and sources of food for many organisms (Brown et al. 1979; Wharton and Brinson 1979, McArthur 1989). Inundation periods encompassing peak spawning periods can potentially enhance fish diversity and production (Knight et al. 1991). Large areas of the floodplain are inundated when water levels increase, and the amount of vegetative structure available to aquatic organisms increases (Light et al. 1998). High primary and secondary productivity result because of nutrient pulses from floodwaters and the decomposition of dead litter and other inundated allochthonous materials (Crow and McDonald 1978; Wharton et al. 1982, Junk et al. 1989). The FH water level may be exceeded during wet years and may not occur during dry years; most aquatic fauna are adapted to year-to-year variation of the natural hydrologic regime. However, MFLs should result in defining the minimum number of flooding events and maximum number of dewatering events to safeguard this and other protection criteria.

<u>FH-1 Duration Component</u>

The recommended FH-1 level duration component (30-day continuous inundation) is based on the fact that seasonally flooded hardwood and cypress swamps are typically inundated for 1 to 2 months during the growing season (Mitsch and Gosselink 1993). A 30-day continuous flooding event represents a sufficient period of soil saturation or inundation needed to protect the structure and functions of seasonally flooded wetland plant communities (Hill et al. 1991). The life cycles of many fishes are related to seasonal water level fluctuations, particularly annual flood patterns (Guillory 1979). Several months of flooding should be provided to ensure fish access to the floodplain and ensure nesting success (Knight et al. 1991). The 30-day flooding duration at the target elevation of 56.8 ft NAVD will result in lower hardwood and cypress swamp elevations experiencing longer flooding conditions as the rise and recession of water to the target elevation exceeds the 30-day duration. Therefore, the 30-day duration allows the majority of the floodplain habitat at Lochloosa Lake to be used by fish and other aquatic fauna to feed, reproduce, and/or use the available floodplain habitat for refuge.

In addition, the 30-day flooding duration is sufficient to cause the mortality of young upland plant species that have become established in the hardwood and cypress swamps during low water events, maintaining the hydrophytic structure and diversity (Ahlgren and Hansen 1957; Menges and Marks 2008). Research shows that abundant hypertrophied lenticels and adventitious roots develop in loblolly pine (*Pinus taeda*) and pond pine (*Pinus serotina*) after 30 continuous days of anaerobic conditions (Topa and McLeod 1986).

The 30-day flooding duration roughly corresponds to the durations of saturation that defines the upper boundaries of many wetlands. From a regulatory standpoint, the U.S. Army Corps of Engineers (USACE) uses durations of saturation between 5% and 12.5% of the growing season in most years as the standard in their wetland delineation manual (USACE 1987). Given the year-round growing season in Florida, this corresponds to durations of 18 to 46 days. However, the National Research Council (NRC 1995) has recommended a shorter duration hydroperiod to define wetland hydrology: saturation within 1 ft of the soil surface for a duration of 2 weeks (14 days) or more during the growing season in most years. This shorter duration hydroperiod may approximate the hydrology of the transitional wetland communities located upslope of the hardwood and cypress swamps along much of the Lochloosa Lake floodplain.

FH-1 Return Interval Component

The FH defines a high surface water level that typically occurs during wet seasons with periods of normal or above-normal rainfall. These flooding events usually occur for short durations with relatively short return intervals between flooding events. The FH is typically associated with the seasonally flooded hydroperiod category (Rule 40C-8.021(16), F.A.C.) "…where surface water is present or the substrate is flooded for brief periods (up to several weeks) approximately every one to two years."

The recommended return interval for the FH-1 is 2 years and is supported by the current SWIDS analysis of 12 lakes with hardwood swamps in SJRWMD (Figure 24; unpublished data, method according to Neubauer et al. 2004; Neubauer et al. 2007, draft). Based on these results, FH level events are estimated to reoccur at least 1 in every 3 years for 30 or more consecutive days, on average. The recommended duration and return interval allows flooding to occur at a similar frequency and duration to the hydrologic signature of the 12 lakes studied. This illustrates that application of this criterion allows for hydrologic change while maintaining a natural signature that is within the hydrologic range for the hardwood swamp communities and associated floodplain structures and functions specific to Lochloosa Lake.

Recommended Frequent High 1 (FH-1) Level

The recommended FH-1 level for Lochloosa Lake is a high water level event at 56.8 ft NAVD (Table 19) with an associated 30-day mean exceedance (flooding) duration at a return interval of at least once every 2 years (50 flooding events per century), on average. See *Appendix C* for details regarding current and future status assessment of minimum levels.

Table 19. Recommended Frequent High 1 (FH-1) levels for Lochloosa Lake, Alachua County, Florida

| Minimum Level | Level (ft NAVD88) | Duration (days) | Return Interval (years) |
|---|---|---|---|
| Frequent High 1 | 56.8 | 30 | 2 |

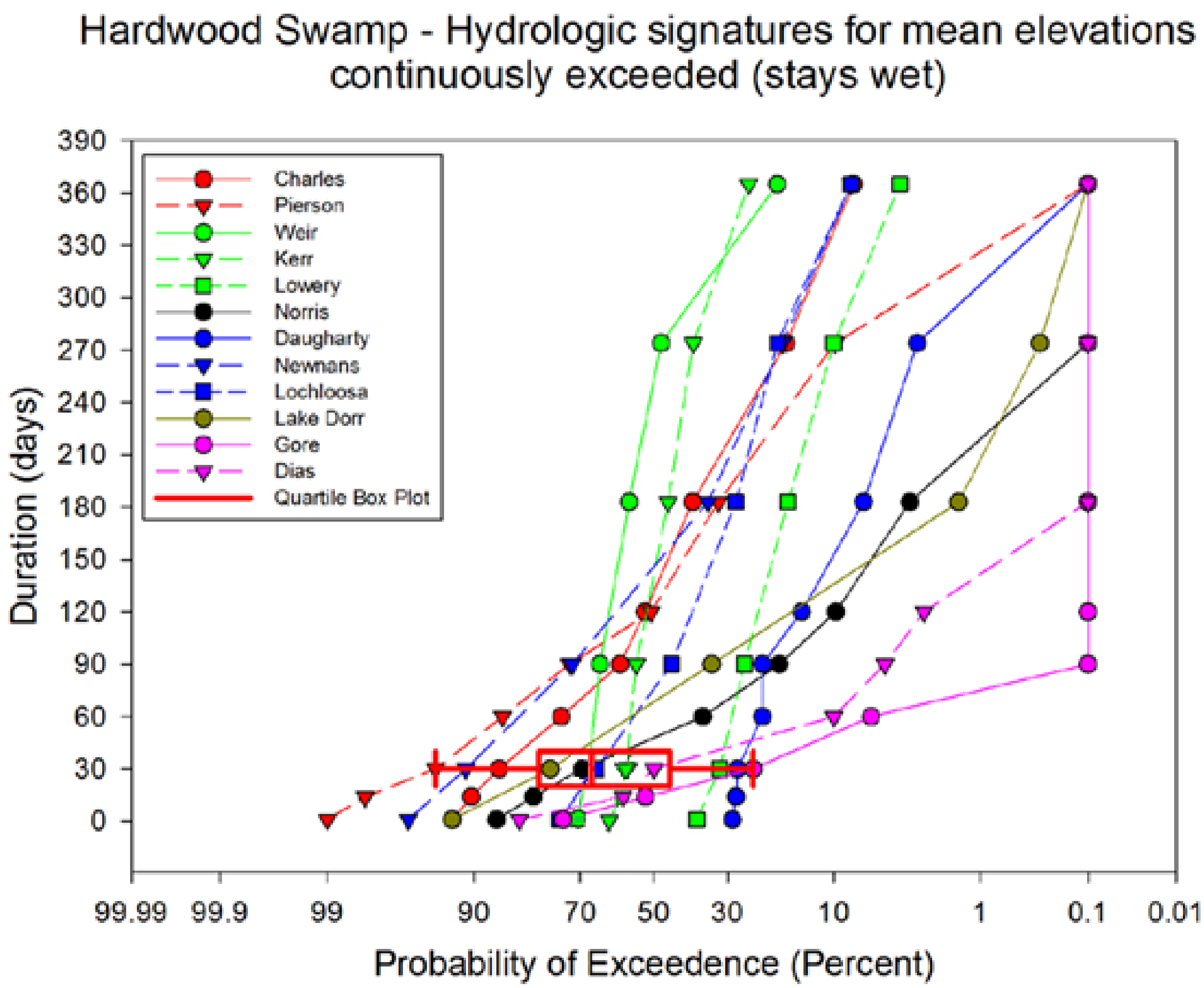


Figure 24. SWIDS plot of the distribution of hydrologic signatures for the annual average exceedance elevation for selected durations of 12 lakes with hardwood swamps

**Minimum Frequent High 2 (FH-2)** – 56.5 ft NAVD, 92-day (March to May) duration, 2-year return interval

A second Frequent High MFLs (FH-2) criterion was developed for the State-designated Threatened Florida sandhill crane (*Grus canadensis pratensis*) (FWC 2011). The goal of the FH-2 is to protect nesting habitat for the Florida sandhill crane. With a low reproductive potential due to small clutch size, low recruitment rate, age at first breeding, and seasonal nesting the sandhill crane may have limited ability to rebound from natural and man-made disturbances (Dwyer 1990). A continuous loss of suitable crane habitat over the past several decades has been documented in Florida (Nesbitt and Hatchitt 2008). Human-altered areas resulted in nesting success well below that of native areas (FNAI 2001). The RALL marsh is important nesting habitat due to the marsh's size, nearly level topography, proliferation of preferred shallow marsh wetland plant communities, and lack of anthropogenic disturbance. Preferred emergent herbaceous and shrubby species including *P. cordata*, *P. hemitomon*, *Lachnanthes caroliniana*, *Nymphaea ordorata*, *Fiurena scirpoidea*, *C. occidentalis*, and *Ludwigia leptocarpa* (Dwyer 1990). A majority of these plant species occur throughout the RALL marsh.

The criterion of protection for the recommended FH-2 is Florida sandhill crane nesting habitat. The general indicator of protection of the FH-2 is water levels within the RALL marsh at depths necessary for successful sandhill crane nesting and that those depth occur, on average, on a bi-yearly interval. The specific indicator of protection of the FH-2 is a minimum of 1 ft, on average, water depth within the RALL marsh during the seasonal nesting period of the Florida Sandhill crane (March-May).

The FH-2 event for the Florida sandhill crane on Lochloosa Lake includes a magnitude component (i.e., elevation) that corresponds to the average elevation, plus 1 ft. of water depth, of the RALL marsh habitats, a duration component of 92 days (March to May) and a return interval of 2 years. This ecological threshold represents a sufficient period of water depths that occur often enough to maintain the RALL marsh as an adequate habitat for Florida sandhill crane nesting.

<u>FH-2 Magnitude Component</u>

The magnitude component was calculated based on the ecological requirements of Florida sandhill crane nesting and the average elevation of the RALL marsh (*see* Figure 19; Table 14). Sandhill cranes prefer to nest in emergent herbaceous and shrubby species shallow marshes with water depths, on average, of 12 in. (Stys 1997; Walkinshaw 1982, Dwyer 1990). Surveys of Right Arm Lochloosa Lake determined the average marsh bottom elevation to be 55.5 ft. NAVD. Adding the additional 1 ft. of water depth required for sandhill crane nesting resulted in a FH-2 magnitude component of 56.5 ft. NAVD.

<u>FH-2 Duration Component</u>

The FH-2 duration was determined from the seasonal nesting pattern of the Florida sandhill crane. Sandhill crane nesting season occurs from roughly March to May in north-central Florida. Nesbitt (1988) found a mean egg laying start date of March 12 and the latest egg laying date of May 22. Mean incubation periods for Sandhill crane were 30 days (Gerber et al. 2014; Nesbitt 1988; Drewien 1973). Based on consultation with FWC, the recommended duration is 92 days (March to May), to reflect the seasonal requirements of nesting.

<u>FH-2 Return Interval Component</u>

Sandhill cranes first attempt breeding at a minimum age of 2 to 3 years, with most first-time breeders failing to produce independent young (Gerber et al. 2014). Breeding for pairs that have reached reproductive age is usually attempted annually, although nesting may be delayed or abandoned if conditions are not favorable that season (Gerber et al. 2014; Nesbitt 1992). Sandhill cranes have the lowest annual recruitment of any species of game birds, with an annual reproductive success of 35%, on average (Drewien et al. 1995; Nesbitt 1992). Lifetime reproductive success is estimated at 1.86 young for any adult, and 2.70 for an adult that had bred successfully before (Nesbitt 1992). For these reasons, adequate conditions for nesting must be maintained in the RALL marsh often enough that a successful nesting maintains Florida sandhill crane populations long-term. Based on consultation with FWC, the recommended FH-2 return interval is 2 years.

Recommended Frequent High 2 (FH-2) Level

The recommended FH-2 level for Lochloosa Lake is a high water level event at 56.5 ft NAVD (Table 20) with an associated 92-day mean exceedance (flooded) duration at a return interval at least every 2 years (i.e., 50 flooding events per century), on average. See *Appendix C* for details regarding current and future status assessment of minimum levels.

The assessment of the FH-2 was generally the same as for the other levels, except that a partial frequency analysis was performed using water level data from March 1 to May 31 for each year in the POR. This was done to calculate the annual probability exceedance of average lake level during the sandhill crane nesting season.

Table 20. Recommended Frequent High 2 (FH-2) levels for Lochloosa Lake, Alachua County, Florida

| Minimum Level | Level (ft NAVD88) | Duration (days) | Return Interval (years) |
|---|---|---|---|
| Frequent High 2 | 56.5 | 92 | 2 |

**Minimum Average (MA)** – 55.9 ft NAVD, 180-day duration, 1.7-year return interval

MA is defined as "…the surface water level or flow necessary over a long period to maintain the integrity of hydric soils and wetland plant communities." (Rule 40C-8.021(9), F.A.C.).

The goal of the recommended MA is to prevent excessive drying of deep organic soils of the floodplain, which could cause their oxidation and subsidence and other adverse environmental impacts. Soil organic matter is an important component of many wetland soils that maintains the 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 purpose of the recommended MA for Lochloosa Lake is to protect the deep organic soils (i.e., ≥8 in. thick organic layer within the top 32 in. of the soil) located in the hardwood swamps from oxidation and subsidence. The MA level approximates a typical lake stage (i.e., elevation component) that is slightly less than the long-term median stage. The MA level corresponds to a low water level event typically associated with the dry season of typical years.

The general indicator of protection for the MA is that deep organic soils across the lake floodplain be saturated or inundated (i.e., shallow ponding) frequently enough to maintain soil structure and associated ecological functions, such as nutrient assimilation and denitrification. At the MA level, soils may be exposed during non-flooding periods during typical years, but the substrate usually remains saturated and loss of organic soils is prevented. The MA level corresponds to a water level that is expected to recur, on average, every 1 to 2 years for approximately 6 months during the dry season (Rule 40C-8.021(19), F.A.C.).

The specific indicator of protection is a water level that equals a 0.3-ft water table drawdown from the average ground surface elevation of the deep organic soils surveyed at Transect 3 (stations 170-370). Achieving the specific indicator of protection at an appropriate duration and frequency should maintain hydrologic conditions that protect the deep organic soils within the seasonally flooded wetlands from oxidation and subsidence.

The recommended MA level for Lochloosa Lake is a low water level event at 55.9 ft NAVD with an associated 180-day mean non-exceedance (dewatered) duration at a return interval no more often than once every 1.7 years, on average. This ecological threshold represents a sufficient period of soil saturation or inundation that recurs often enough to maintain the structure and ecological functions of seasonally flooded organic soils.

<u>MA Magnitude Component</u>

The MA elevation of 55.9 ft NAVD was calculated by estimating the average elevations of deep organic soils minus 0.3 foot from Transect 3 on the south shore of Lochloosa Lake. Estimations were used due to high water levels experienced during the summer and fall of 2017 and the winter, spring and summer of 2018. Heavy summer rains in 2017, followed by heavy precipitation from Hurricane Irma on September 10, 2017, caused deep flooding in the floodplain. Water levels did not recede by the following spring or summer (2018), therefore accurate sampling of organic soils was not possible. Instead, samples were collected when possible and estimations of downslope organic soils depth were calculated based on mapped soil types and plotted projects of organic soil thickness (Figure 25).

The depth of a histic epipedon (8-16 in. thick surface organic horizon) was estimated to begin at station 162 at an elevation of 57.2 ft NAVD. Three soil samples were completed on Transect 3 at stations 10, 50, and 140. Increasing organic soil thickness was found at each location. Histic epipedon was assumed to continue downslope to the base of the wave berm (station 370) (Figure 26). The average elevation from station 162 to station 370 was 56.2 ft NAVD. Subtracting 0.3 ft from the average histic epipedon elevation resulted in a MA magnitude of 55.9 ft NAVD.

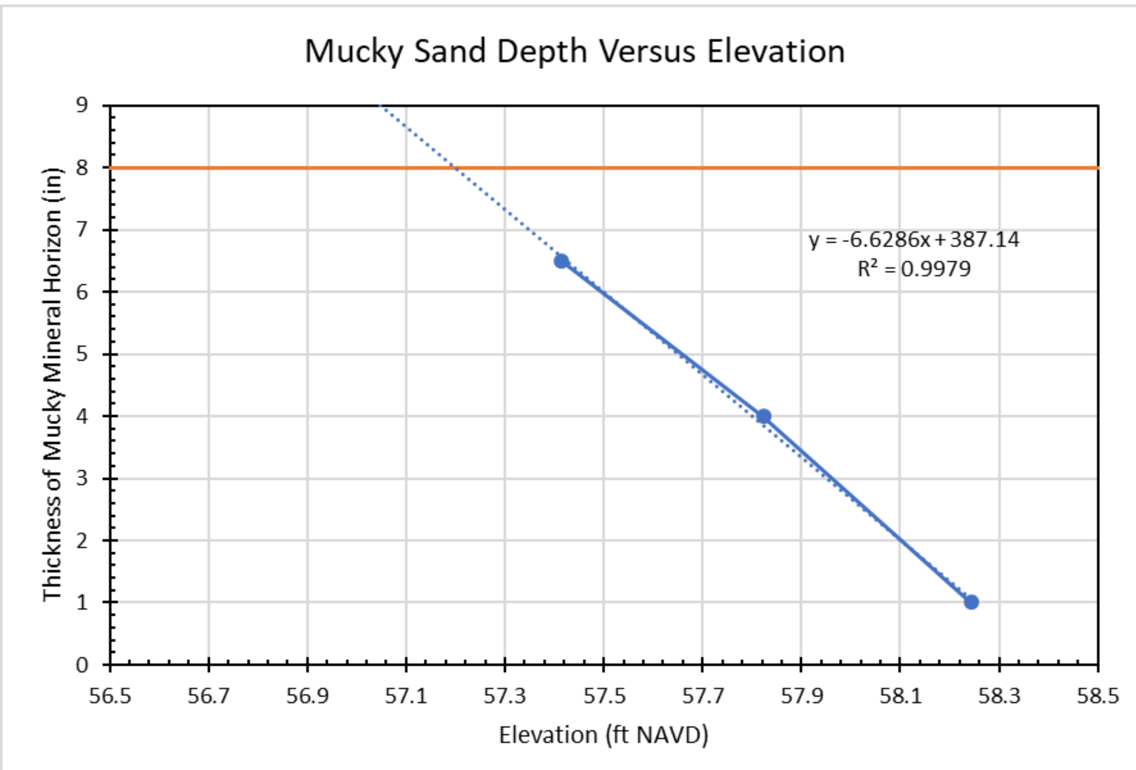


Figure 25. Organic soil depth vs. elevation at Transect 3 (South), Lochloosa Lake

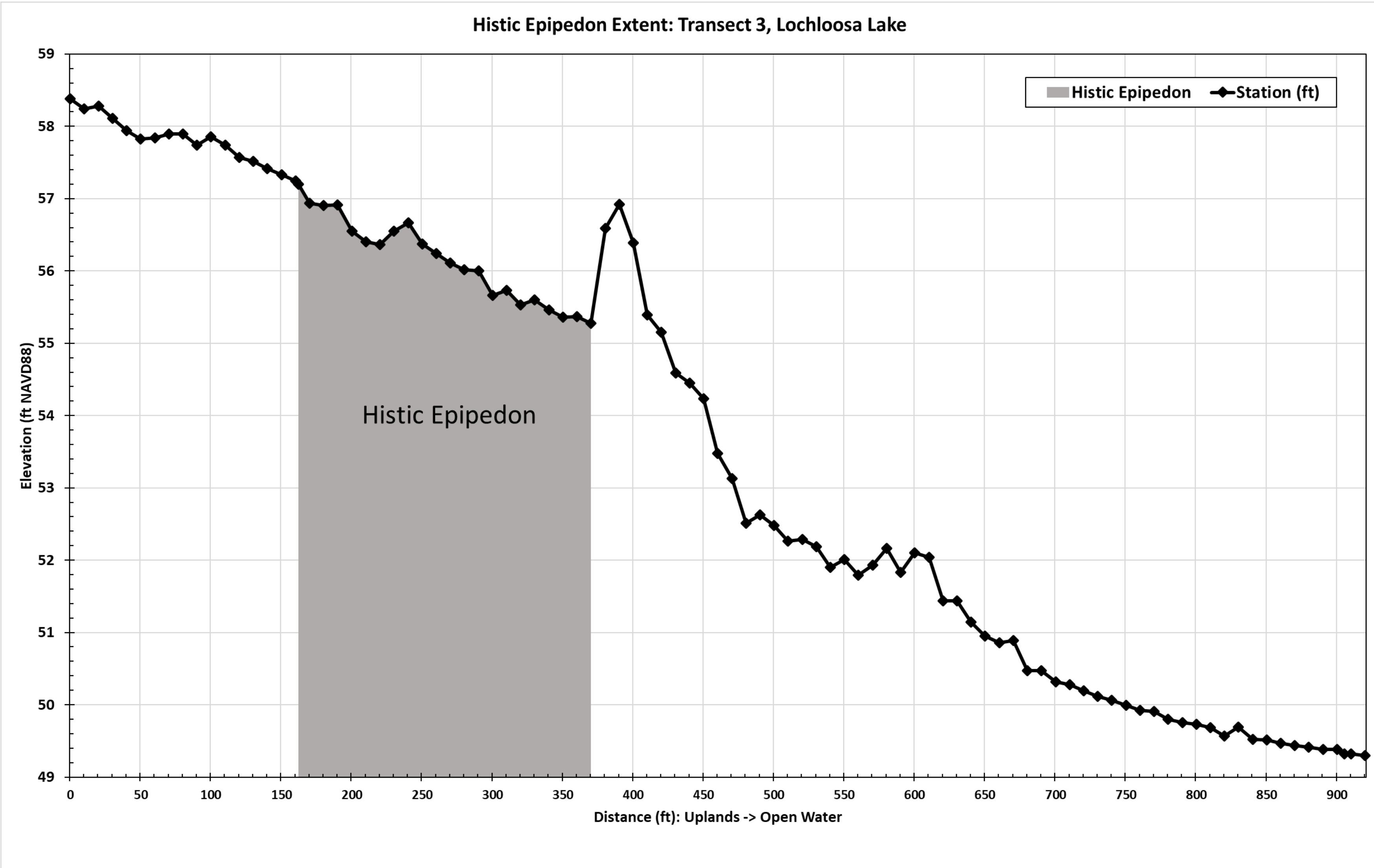


Figure 26. Histic epipedon (organic soil) extent at Transect 3 (South), Lochloosa Lake

Wetlands soils play an important role in global biogeochemical cycles, particularly as reservoirs of carbon (Mitsch and Gosselink 2015). Of particular concern is the decomposition of soil organic matter (loss of soil carbon) that occurs when wetland soils are drained or sufficiently hydrologically altered, resulting in a lowered wetland surface elevations (i.e., subsidence). Soil subsidence is a function of two processes termed primary and secondary subsidence (Stephens 1984; Ewing and Vepraskas 2006). Primary subsidence results from loss of soil buoyancy provided by soil pore water. Once pore water leaves the soil, the support it provided to the overlying soil particles is lost. When air fills these pore spaces, the soil compacts under its own weight. Secondary subsidence is caused by the direct oxidation of the soil organic carbon to inorganic carbon, which may be lost to the atmosphere as carbon dioxide and methane emissions (Ewing and Vepraskas 2006; Parent et al. 1977). In addition, aerobic soil decomposition can also lead to the release of inorganic nutrients (e.g., nitrogen and phosphorus), metals, and toxic materials that might otherwise remain sequestered in the soil under flooded (anaerobic) conditions (Reddy and DeLaune 2008; Osborne et al. 2011).

Soil organic matter in wetlands provides long-term nutrient storage for plant growth. Accumulation of soil organic carbon is a function of the balance between primary productivity and decomposition. When wetland primary productivity exceeds decomposition and erosion rates, soil organic matter accumulates by the stratified buildup of partially decomposed plant remains (Reddy and DeLaune 2008). Soil organic matter produces dissolved organic carbon to support aquatic systems. It is also a source of exchange capacity for cations in soils, and the large surface area of organic colloids present in organic soils plays an important role in the bioavailability of various metals and toxins in wetlands (Reddy and DeLaune 2008).

An appropriate mean non-exceedance water level event is necessary to conserve the hydric nature and the ecological functions of the floodplain organic soils. The presence of deep organic soils are indicative of long-term soil saturation or inundation (Hurt and Vasilas 2010). Stephens (1974) reported that the oxidation and subsidence of Everglades peat soils occurred when the long-term average elevation of the water table was greater than 0.3 ft. below the soil surface. The 0.3-ft organic soil drawdown criterion is also supported by studies in organic soils in the Blue Cypress Water Management area in the Upper St. Johns River Basin (Reddy et al. 2006). Field and laboratory experiments suggested that the top 0.3 ft is the most reactive (i.e., labile) soil area with respect to microbial oxidation. Therefore, this layer of reactive soil is most susceptible to oxidation and requires protection (Reddy et al. 2006). Where deep organic soils are observed, a 0.3-ft organic soil water table drawdown criterion is typically employed when developing the MA level (Mace 2006, 2007).

An important factor to be considered in the protection of organic soils from oxidation is the action of the capillary fringe. The capillary fringe is the subsurface soil layer in which groundwater is wicked up from a water table by capillary action to fill pores in the soil, contributing to saturation of soils and anaerobic conditions above the water table elevation

(Ponnamperuma 1972; Reddy et al. 2006). Soil scientists locate the capillary fringe by measuring the redox potentials in soils. Low redox potentials (200 to -400 millivolts [mV]) are associated with reduced, anaerobic submerged soils; aerobic soils have redox potentials of about 300 to 800 mV (Ponnamperuma 1972). Reddy et al. (2006) measured redox potentials in situ in organic soils of the upper St. Johns River marsh, as well as in soil cores subjected to lowered water tables in the laboratory. The capillary fringe extended +5 to +10 centimeters (cm; 0.2 to 0.3 ft) above the static water level. Deeper water table depths (e.g., -30 cm [-1 ft]) had the greatest rise (+10 cm [0.3 ft]) in the capillary fringe (Reddy et al. 2006). Thus, the action of the capillary fringe could significantly affect the rates of organic soil oxidation and, therefore, reduce the net oxidation during seasonal drawdowns (Reddy et al. 2006).

The recommended MA level of 55.9 ft NAVD at Lochloosa Lake provides saturated soil conditions across the majority of the lake floodplain where deep organic soils were sampled. Additionally, shallow ponding will occur in the shrub swamps, providing aquatic refugia for numerous small fish, amphibians, and small reptiles. Aquatic habitats connected to the open water of Lochloosa Lake are of crucial importance to fishes and invertebrates of the floodplain.

MA Duration Component

The hydrologic regime defined by the 180-day mean non-exceedance duration will typically allow for numerous, short duration alternating aerobic/anaerobic conditions of the organic soil surface elevation. Field and laboratory experiments in organic soils of the Upper St. Johns River Basin indicated that shorter duration dewatering (alternating aerobic and anaerobic conditions) events are less likely to result in oxidation of organic matter, probably due to the wicking action of the capillary fringe in these soils (Reddy et al. 2006). Additionally, wetland soils are a medium for denitrification, a process important in maintaining aquatic/wetland water quality. The denitrification process is most effective in wetlands that are subject to alternating aerobic and anaerobic conditions because the aerobic conditions allow conversion of ammonium to nitrate (nitrification), which is then subject to denitrification (Payne 1981; Reddy and DeLaune 2008).

The 180-day mean non-exceedance duration will also maintain wetland communities by a combination of inundation and dewatering. Studies of marshes in the Upper St. Johns River Basin (Brooks and Lowe 1984; Hall 1987) determined that the elevation corresponding to the 0.3 ft organic soil water table drawdown criterion had a hydroperiod of approximately 219 days. Studies of the Wekiva River system found this hydrologic condition can also be expressed as the low stage occurring on average every 2 years (i.e., 50 events per century) with a duration of less than or equal to 180 days (Hupalo et al. 1994).

In a baseline 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% (approximately 55 to 343 days, respectively). Similarly, Sincock (1958) noted that sawgrass in the Upper St. Johns River

Basin usually occurred where there was an annual duration of saturation of 45% (approximately 164 days). 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%, approximately equal to the 180-day annual duration specified for the MA level at Lochloosa Lake.

MA Return Interval Component

The MA event defines a low surface water level and/or flow that usually occurs during normal dry seasons. These dewatering events typically occur for long durations with short return intervals between dewatering events. Such low water events are important to protect deep muck soils from losses caused by oxidation and subsidence. The MA is usually associated with the typically saturated hydroperiod category defined below:

> …where for extended periods of the year the water level should saturate or inundate. This results in saturated substrates for periods of one-half year or more during non-flooding periods of typical years. Water levels causing inundation are expected to occur fifty to sixty per cent of the time over a long term period of record. This water level is expected to have a recurrence interval, on the average, of one or two years over a long term period of record. Obligate wetland plant species are expected to be predominate near this water level. (Rule 40C-8.021(19), F.A.C.).

The recommended return interval of 1.7 years is supported by the current SWIDS analysis of the mean elevation of deep organic soils minus 0.3 ft at 21 locations (Figure 27). The 59% annual average non-exceedance probability occurs on the SWIDS graph in the "1st quartile"—the driest value for the 180-day duration—for the 21 deep organic soils analyzed (see Figure 27). This illustrates that application of the 0.3 ft drawdown criterion in organic soils allows for the maximum hydrologic change at Lochloosa Lake while preventing subsidence and oxidation of organic soil material.

The recommended MA return interval allows for some hydrologic change from the existing hydrologic conditions while maintaining a natural hydrologic signature that is within the hydrologic range for the mean elevation of deep organic soils that should protect organic soils at Lochloosa Lake from oxidation and subsidence. The return interval for the MA event is expected to protect organic substrates and/or the structure and functions of emergent wetland plant communities by causing dewatering but maintaining saturated conditions. The MA return interval is not expected to cause permanent loss of deep organic soils due to oxidation or subsidence in the floodplains at Lochloosa Lake.

Recommended Minimum Average (MA) Level

The recommended MA level for Lochloosa Lake is a low water level event at 55.9 ft NAVD (Table 21) with an associated 180-day mean non-exceedance (dewatered) duration at a return interval no more often than once every 1.7 years (i.e., 59 dewatering events per century), on average. See *Appendix C* for details regarding current and future status assessment of minimum levels.

Table 21. Recommended Minimum Average (MA) levels for Lochloosa Lake, Alachua County, Florida

| Minimum Level | Level (ft NAVD88) | Duration (days) | Return Interval (years) |
|---|---|---|---|
| Minimum Average | 55.9 | 180 | 1.7 |

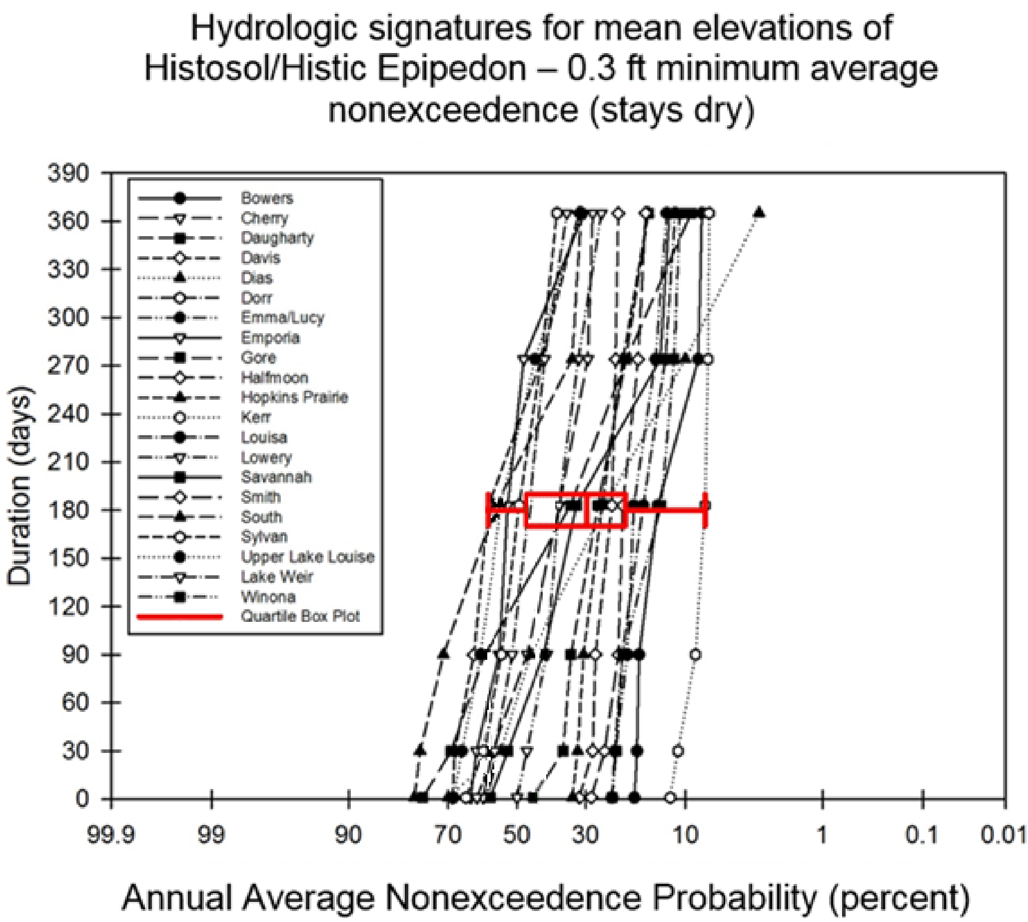


Figure 27. SWIDS plot of the distribution of hydrologic signatures for the annual average non-exceedance elevation for selected durations of deep organic soils minus 0.3 ft sampled on 21 lakes

**Minimum Frequent Low (FL)** – 53.4 ft NAVD, 120-day duration, 5-year return interval

FL is defined as "...a chronically low surface water level that generally occurs only during periods of reduced rainfall. This level is intended to prevent deleterious effects to the composition and structure of floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs" (Rule 40C-8.021(10), F.A.C.).

The goal of the recommended FL level/flow is to prevent excessive drying of the floodplain and associated vegetation, maintaining the extent of deep marsh habitat, and ensuring adequate open water area. Periodic drawdowns are beneficial because they allow regeneration of wetland plants, enhance nutrient cycling, and allow utilization of the floodplain by upland fauna. However, these drawdowns should not occur so frequently that the extent of the marsh ecotone or natural range of water table fluctuations are disrupted.

The general indicator of protection is a low water level in the lake that maintains marsh ecotones and a natural fluctuation range of floodplain water tables. The FL is typically associated with the "semi-permanently flooded" hydroperiod category (Rule 40C-8.021(17), F.A.C.), such that "[w]hen surface water is absent the water table is usually near the land surface… this water level is near the lower elevation that supports emergent marsh or floating vegetation and peat substrates, or other highly organic hydric substrates." These low water level events occur during moderate droughts. Groundwater withdrawals should not increase the number of these low water events beyond the return interval threshold of the FL.

The specific indicator of protection is a low water level at the maximum elevation of spatterdock (*N. advena*) beds at Lochloosa Lake's transects. Spatterdock is a floating-leaved species characteristic of deep marshes. Marsh transition zones along the edge of Lochloosa Lake are protected from excessive dewatering since the indicator of protection water level would allow occasional dewatering of emergent marsh vegetation such as pickerelweed and lanceleaf arrowhead while ensuring long-term inundation of floating-leaved vegetation such as spatterdock.

The specific indicator of protection yields a recommended level of 53.4 ft NAVD. This level is continuously dewatered for 120 days no more often than once every 5 years (i.e., 20 drying events per century, on average).

<u>FL Magnitude Component</u>

The FL elevation of 53.4 ft NAVD was calculated by averaging the maximum elevations of deep marsh habitat from three transects surveyed on Lochloosa Lake (Table 22). The maximum elevation of deep marsh is a typical FL criterion, and distinguishes between frequently dewatered wetlands, such as shallow marshes, and wetlands that stay inundated for very long periods, such as hardwood swamp. Infrequent dewatering selects for flora such as water lilies and the related spatterdock species (family: Nymphaceae), which can germinate under water (Gerritsen and Greening 1989). Protection of deep marsh vegetation is important since the dense vegetation and extended inundation provide important refugia for fish. This FL criterion maintains the long-term ecotone between deep marsh and shallow marsh, thereby preventing downhill shift in species and loss of open water. Table 22 shows the maximum elevations of deep marsh features collected at three transects.

Table 22. Maximum elevation of deep marsh habitats surveyed at three transects on Lochloosa Lake, Alachua County, Florida

| Transect | Maximum Elevation Deep Marsh (ft NAVD88) |
|---|---|
| Transect 1 (North) | 53.3 |
| Transect 2 (West) | 53.7 |
| Transect 3 (South) | 53.1 |
| **Average** | **53.4** |

FL Duration Component

The recommended 120-day continuous non-exceedance duration corresponds to the length of a normal dry season period (i.e., mid-February through mid-June; ~ four months) in north central Florida between the end of winter rains and the start of the summer rainy season. This duration allows seed germination of wetland plants, which generally require saturated but not inundated substrates (Kushlan 1990). This duration also allows time for seedlings to grow sufficiently tall to survive subsequent flooding (Ware 2003). For example, cypress trees have rigorous hydrologic seed germination and seedling establishment requirements. Cypress seeds will not germinate under water and seedlings can be killed by submergence (Demaree 1932; Watson 1983; Ware 2003). Additionally, these low water events enable wading birds to feed over the entire floodplain and allow access to the floodplain resources by wildlife species that usually inhabit upland plant communities (Harris and Gosselink 1990).

FL Return Interval Component

The SWIDS dataset for the maximum elevation of spatterdock and water lily at 16 sites was the basis for the recommended 5-year FL return interval (Figure 28). Although not based on the driest signature, a five-year return interval does occur within the driest quartile of hydrologic signatures. This quartile represents a cluster of dewatering signatures from four waterbodies in central Florida (The Savannah, Big Lake, Johns Lake, and Hires Lake). By using species-based SWIDS some of the uncertainty, about whether similar systems with similar communities are being compared, is removed. This SWIDS analysis allows comparison of the same species with the same physiological tolerances. Further, much of the data for SWIDS was collected pre-2000, prior to some of the unusually severe droughts/ hydrologic perturbations. This SWIDS analysis provides an estimate of the maximum frequency of dewatering that this vegetation feature and associated functions can sustain.

Recommended Frequent Low (FL) Level

The recommended FL level for Lochloosa Lake is a low water level event at 53.4 ft NAVD (Table 23) with an associated 120-day mean non-exceedance (dewatered) duration at a return interval no more often than once every 5 years (i.e., 20 dewatering events per century), on average. See *Appendix C* for details regarding current and future status assessment of minimum levels.

Table 23. Recommended Frequent Low (FL) levels for Lochloosa Lake, Alachua County, Florida

| Minimum Level | Level (ft NAVD88) | Duration (days) | Return Interval (years) |
|---|---|---|---|
| Frequent Low | 53.4 | 120 | 5 |

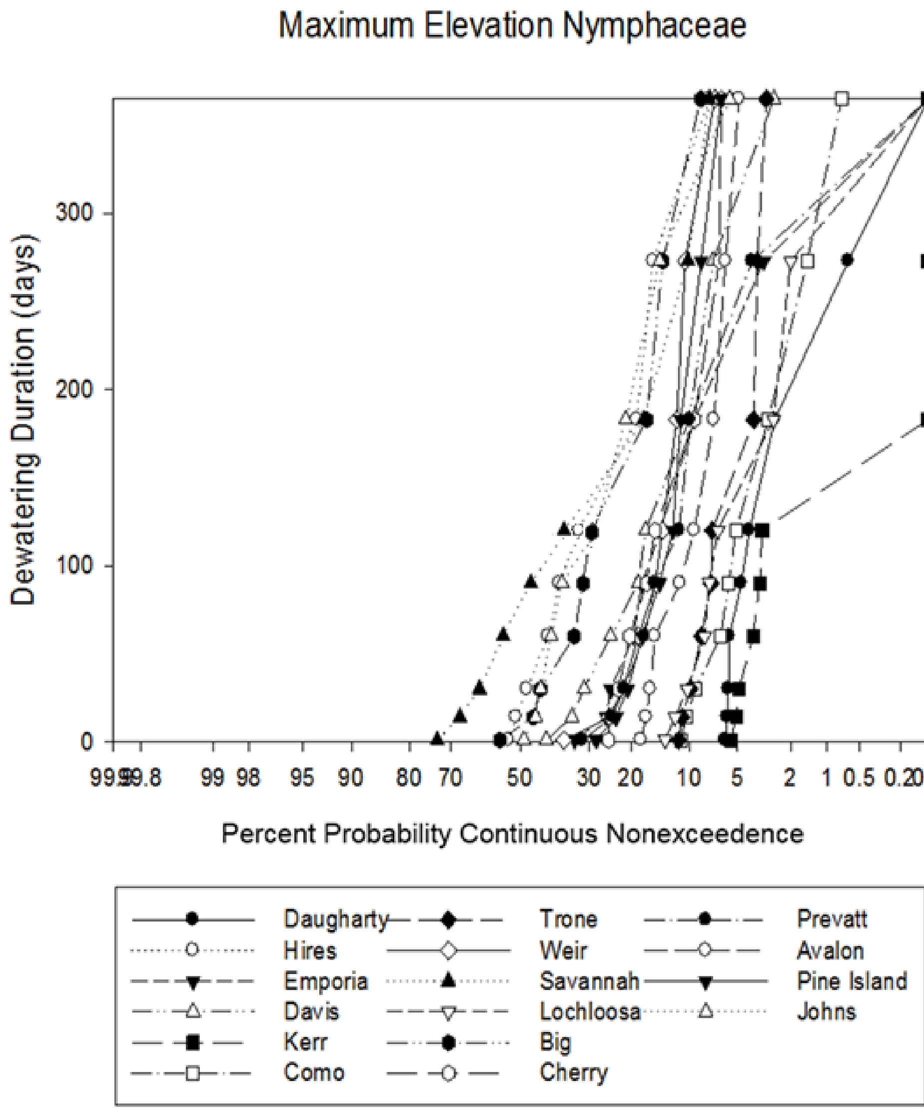


Figure 28. SWIDS plot of the distribution of hydrologic signatures for the annual average non-exceedance elevation for selected durations of the maximum elevation deep marsh species (Nymphaceae) sampled on 16 lakes

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# APPENDIX B — HYDROLOGICAL ANALYSES

## INTRODUCTION

In addition to extensive work conducted to understand the ecological structure and function, and most sensitive environmental values of priority waterbodies, assessing the status of minimum flows and levels (MFLs) requires substantial hydrological analysis. Several steps were involved in performing the hydrologic analysis, including:

1. Review of available data for compiling long-term datasets;
2. Historical groundwater pumping impact assessment;
3. Development of lake level datasets representing no-pumping and current-pumping conditions; and
4. Estimating available water (freeboard or deficit).

Figure B-1 shows the flowchart for the hydrologic analysis. This document describes the first three steps and associated results. Appendix C includes the description of the last step.

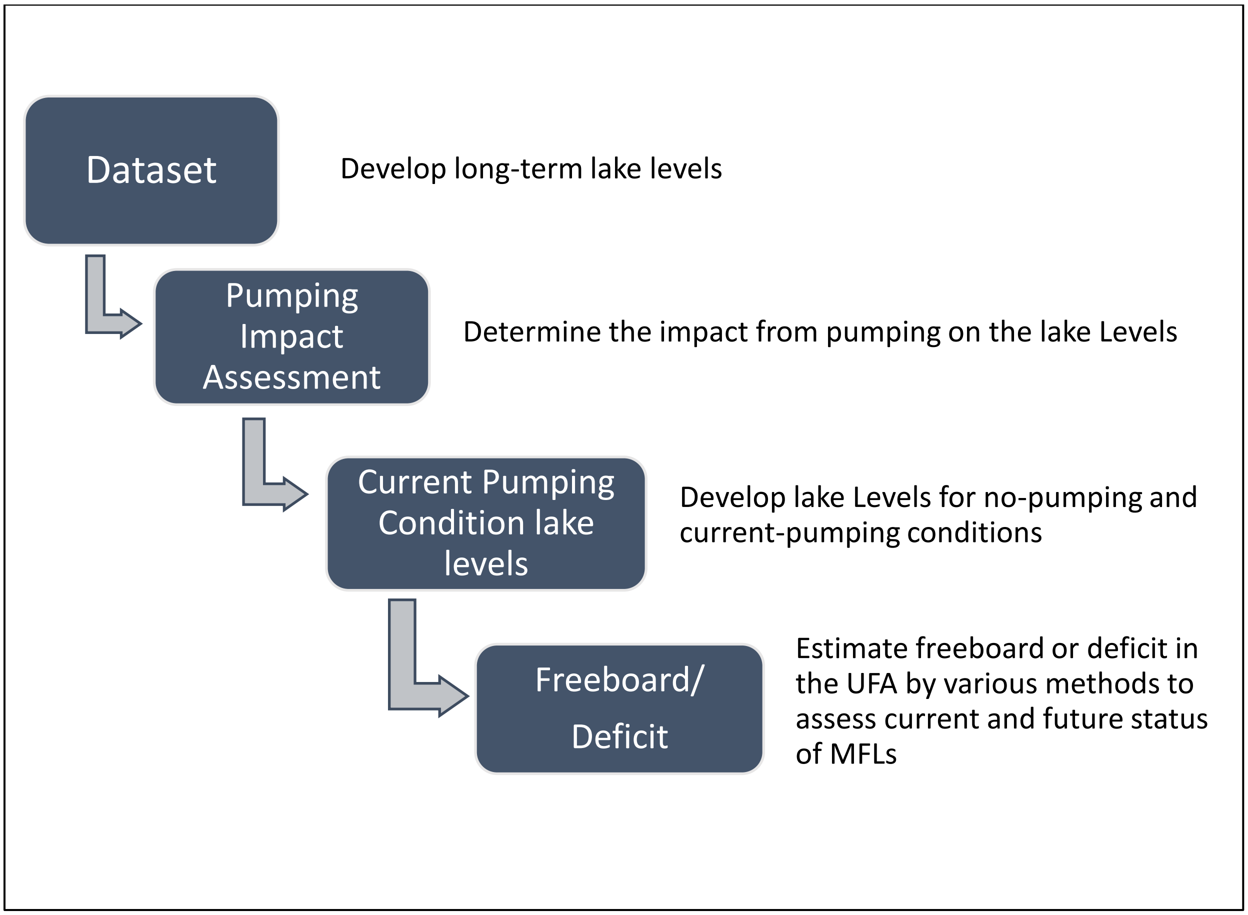


Figure 1. Flowchart for Hydrologic Analysis Process

## BACKGROUND

Lochloosa Lake is a large lake (8,900 acres) in eastern Alachua County, 3.5 miles southwest of Hawthorne, FL. Along with Newnans and Orange lakes as well as Paynes Prairie, they are the major waterbodies within the 600-square-mile Orange Creek Basin (OCB) (Figure B-1).

The St. Johns River Water Management District (SJRWMD) previously developed HSPF models covering the OCB as part of the Water Supply Impact Study (WSIS, 2012). Subsequently, SJRWMD contracted with CDM Smith to update the HSPF models and develop a linkage with the EPA Storm Water Management Model (SWMM) hydraulic model of the basin (CDM Smith, 2018; Appendix E). The linked HSPF/SWMM models were calibrated from 2006 to 2016, verified for a period of record between 1996 and 2005 and then used to develop lake level datasets representing no-pumping and current-pumping conditions for MFL status assessments.

Because minimum levels proposed for Lochloosa Lake are based on an event-based approach associated with return periods (e.g., the recommended minimum frequent low level should be achieved once every five years, on average), MFL assessment requires frequency analysis of lake levels. Due to the presence of short- and long-term climatic cycles (e.g. El Nino Southern and Atlantic Multidecadal Oscillations), the frequencies of lake levels could be significantly different in wet periods such as in 1960s than dry periods such as in 2000s. Thus, it is important to perform frequency analysis using long-term lake levels so that the effect of short- and long-term climatic variations on lake levels can be captured.

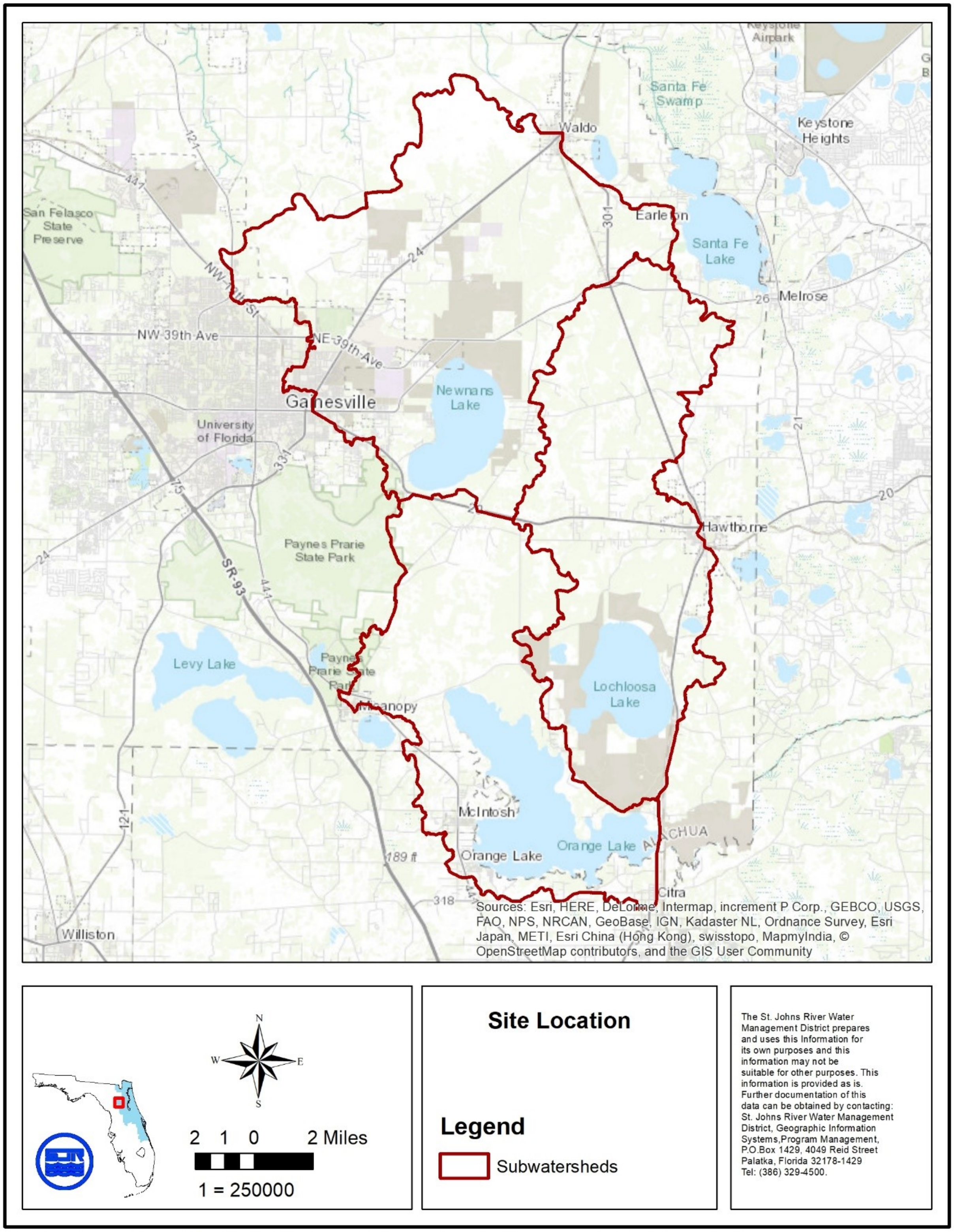


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Figure B-1. Site location map

# REVIEW OF AVAILABLE DATA

## Rainfall and Potential Evapotranspiration (PET)

Rainfall data were compiled using data from several Gainesville stations. Table B-1 shows a list of the rainfall stations.

Table B-1: Rainfall stations used in Lochloosa model

| Rainfall Station Name, ID | Collection Agency | Period Used |
|---|---|---|
| **Gainesville University, 083316** | NOAA | 1897 - 1953 |
| **Gainesville 3WSW, 083321** | NOAA | 1954 - 5/1960 |
| **Gainesville AP, 083326** | NOAA | 6/1960 - 1969 |
| **Gainesville 3WSW, 083321** | NOAA | 1970 - 1/1984 |
| **Gainesville AP, 083326** | NOAA | 2/1984 - 2015 |

PET was computed with temperature data obtained from Gainesville stations using Hargraves-Samani (1985) method. The Hargraves-Samani method was scaled with a coefficient to GOES Priestly-Taylor evaporation estimate (WSIS, 2012). The coefficient is obtained by regressing Hargraves-Samani PET against Priestly-Taylor PET. The PET coefficient of Gainesville Airport is 0.8431. Figure B-2 shows the annual rainfall and PET data and descriptive statistics are presented in Table B-2.

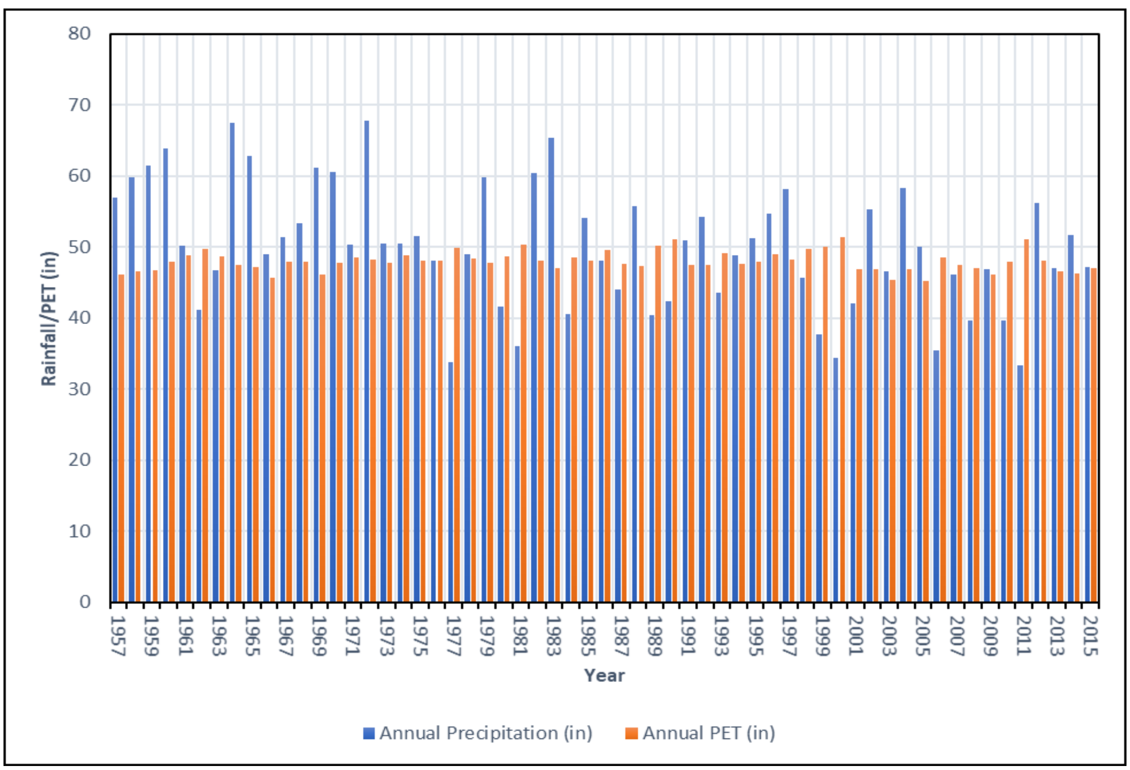


Figure B-2. Annual average rainfall and PET

Table B-2. Summary Statistics of the annual Precipitation and PET

| Statistical Parameter | Annual Precipitation (in) | Annual PET (in) |
|---|---|---|
| **Mean** | 50.03 | 48.02 |
| **Standard Error** | 1.14 | 0.18 |
| **Median** | 50.23 | 47.95 |
| **Standard Deviation** | 8.73 | 1.38 |
| **Minimum** | 33.38 | 45.28 |
| **Maximum** | 67.80 | 51.42 |

## Lake Levels

The water level data for all lakes were retrieved from the SJRWMD database (Table B-3). Figure B-3 shows the number of available water level data per year for Lochloosa Lake. Figure B-4 shows water levels of Lochloosa, Orange and Newnans lakes.

Table B-3. Summary of available water level data

| Station | SJRWMD Station Number | Period of Record | Comment |
|---|---|---|---|
| **Lochloosa Lake at Hawthorne** | 71481615 | 7/1/1942 – Present* | Daily or Monthly |
| **Orange Lake at Boardman** | 02611465 | 6/23/1933 – 6/30/1942<br>7/1/1942 - Present | Random or Monthly<br>Daily |
| **Newnans Lake Baker at Gainesville** | 04831007 | 4/30/1936 – 9/30/1945<br>11/2/1945 – 12/31/1952<br>7/1/1957 - Present | Monthly<br>Random (3-4 day)<br>Daily |

*Only two measurements were recorded in 1936

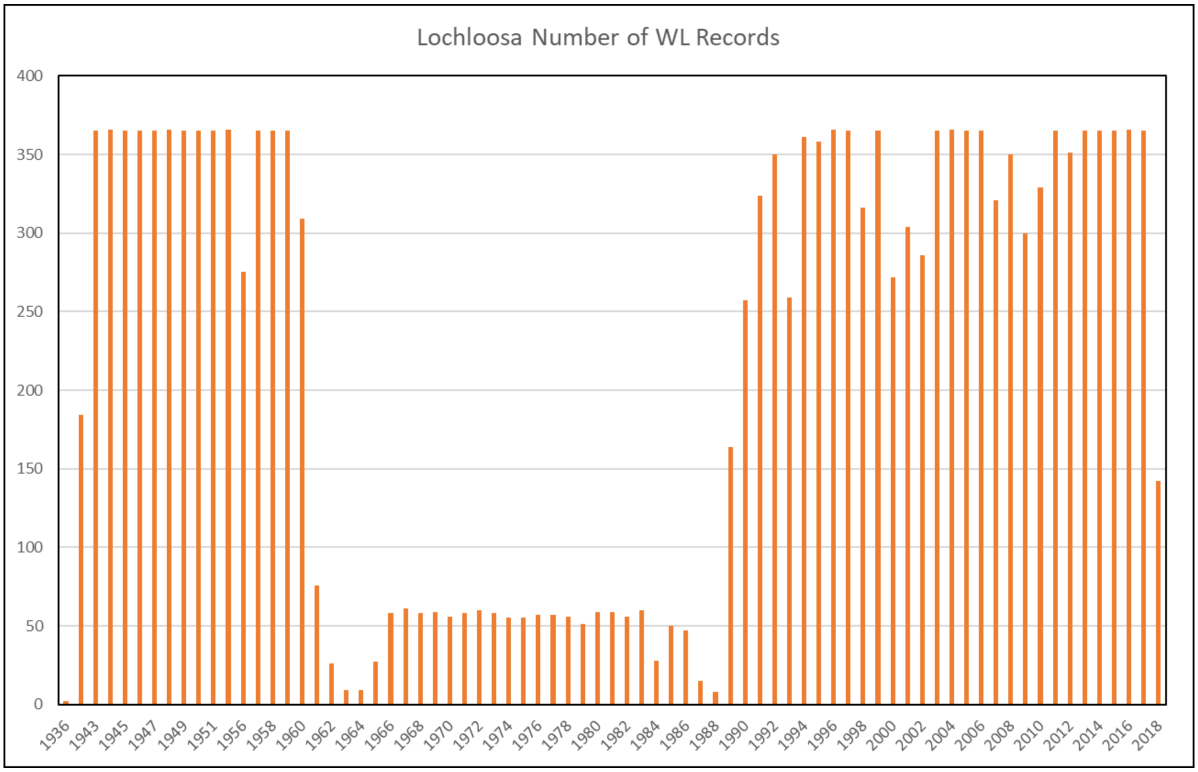


Figure B-3. Number of available water level records per year for Lochloosa Lake

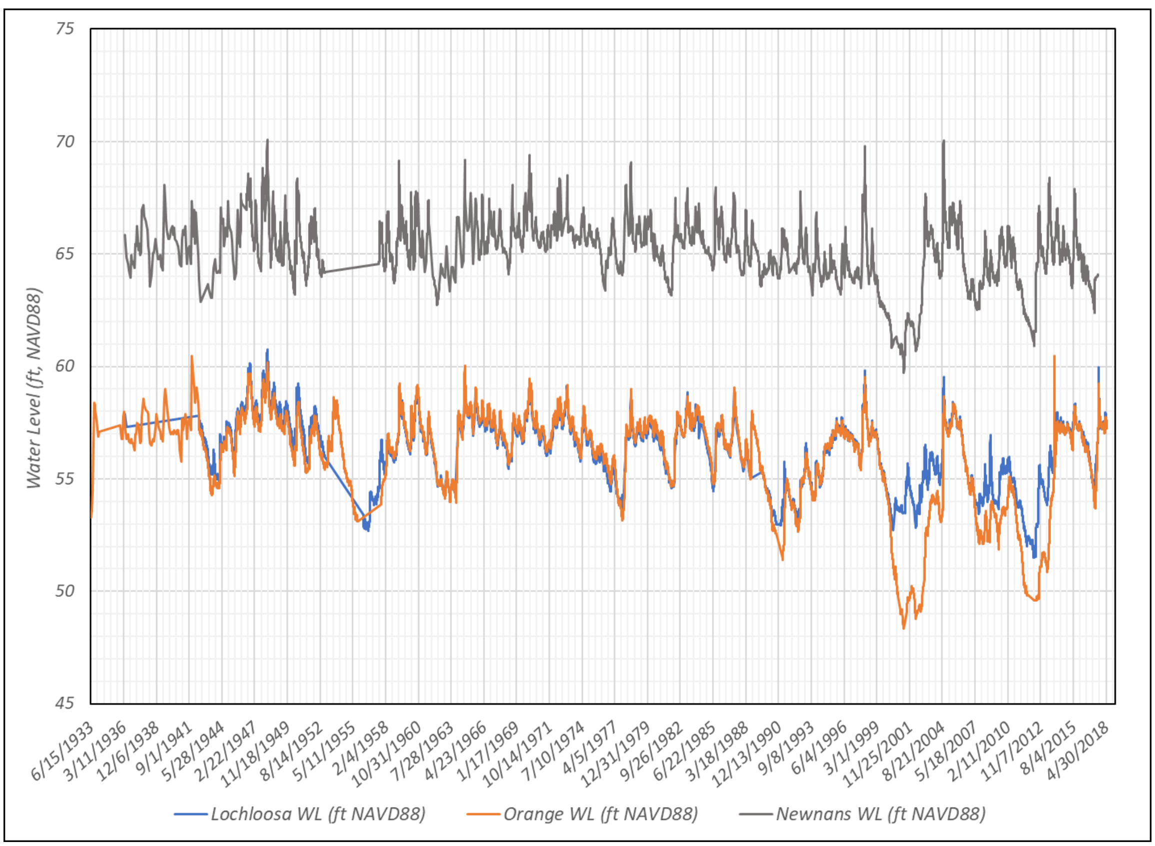


Figure B-4. Water Levels in Lakes Lochloosa, Orange and Newnans

Lochloosa Lake levels are very similar to Orange Lake levels except for extreme dry periods after 2000 (e.g. 2001 and 2011). This could be mainly because the lowest recorded groundwater levels near these lakes were observed in 2001 and 2012. Because Orange Lake is highly connected to the UFA through sinkholes, it declined much more than Lochloosa Lake during these extreme dry periods. Newnans Lake has a water level pattern similar to Lochloosa and Orange lakes but is higher by approximately 9 feet on average. A summary of water level statistics for all lakes is provided in Table B-4.

Table B-4. Water level (WL) summary statistics for Lochloosa, Orange and Newnans Lakes; elevations in feet, NAVD88

| Descriptive Statistics | Lochloosa WL | Orange WL | Newnans WL |
|---|---|---|---|
| **Mean** | 56.1 | 56.1 | 64.9 |
| **Median** | 56.3 | 56.7 | 64.9 |
| **Standard Deviation** | 1.7 | 1.9 | 1.4 |
| **Range** | 9.3 | 12.1 | 10.4 |
| **Minimum** | 51.5 | 48.4 | 59.7 |
| **Maximum** | 60.7 | 60.5 | 70.1 |
| **Count** | 16638 | 25228 | 9673 |

## Groundwater Levels

A number of Upper Floridan aquifer (UFA) wells were used in the analysis (Figure B-5). The A-0420 (Lybass well), A-0071 (Hawthorne well), and M-0367 (Huff well) in Table B-5 were used to compute the exchange of flows between the UFA and Newnans, Lochloosa, and Orange lakes, respectively, in the HSPF/SWMM model developed for evaluation of MFLs (CDM Smith, 2018; Appendix E)

As discussed in the model report, for Newnans Lake, A-0420 was selected based on proximity to the lake and the long period of record. Although A-0973 (Bill Holblack well) is closer to the Newnans Lake than A-0420, it does not have a long period of record, only from August 2014 to present. Thus, water levels at A-0420 were adjusted downward by 5.5 feet to reflect historical differences between the water levels at the A-0420 well and A-0973 well.

For Lochloosa Lake, A-0071 was selected based on the length of the period of record. Although A-0421 (Lochloosa well) and A-0725 are closer to Lochloosa Lake than A-0071, they do not have long period of records, only from 1999 or 2005 to present, respectively. Thus, A-0071 water levels adjusted downward by 14.5 feet to reflect historical differences between the A-0071 water level and the average of A-0421 and A-0725 water levels.

The water levels at M-0367 Huff were used without any adjustment for Orange Lake. The HSPF/SWMM model report (CDM Smith, 2018; Appendix E) includes more detail discussion on these wells. Figure B-6 shows the water levels of the wells.

Table B-5. Upper Floridan Wells and the Data Period of record.

| Station | Station Name | Period of Record |
|---|---|---|
| **A-0071** | Hawthorne Tower Deep at Hawthorn | 07/24/1985 – Current |
| **A-0420** | Lybass at Phifer | 04/30/1975 – Current |
| **M-0367** | Huff Well at McIntosh | 11/30/1995 – Current |

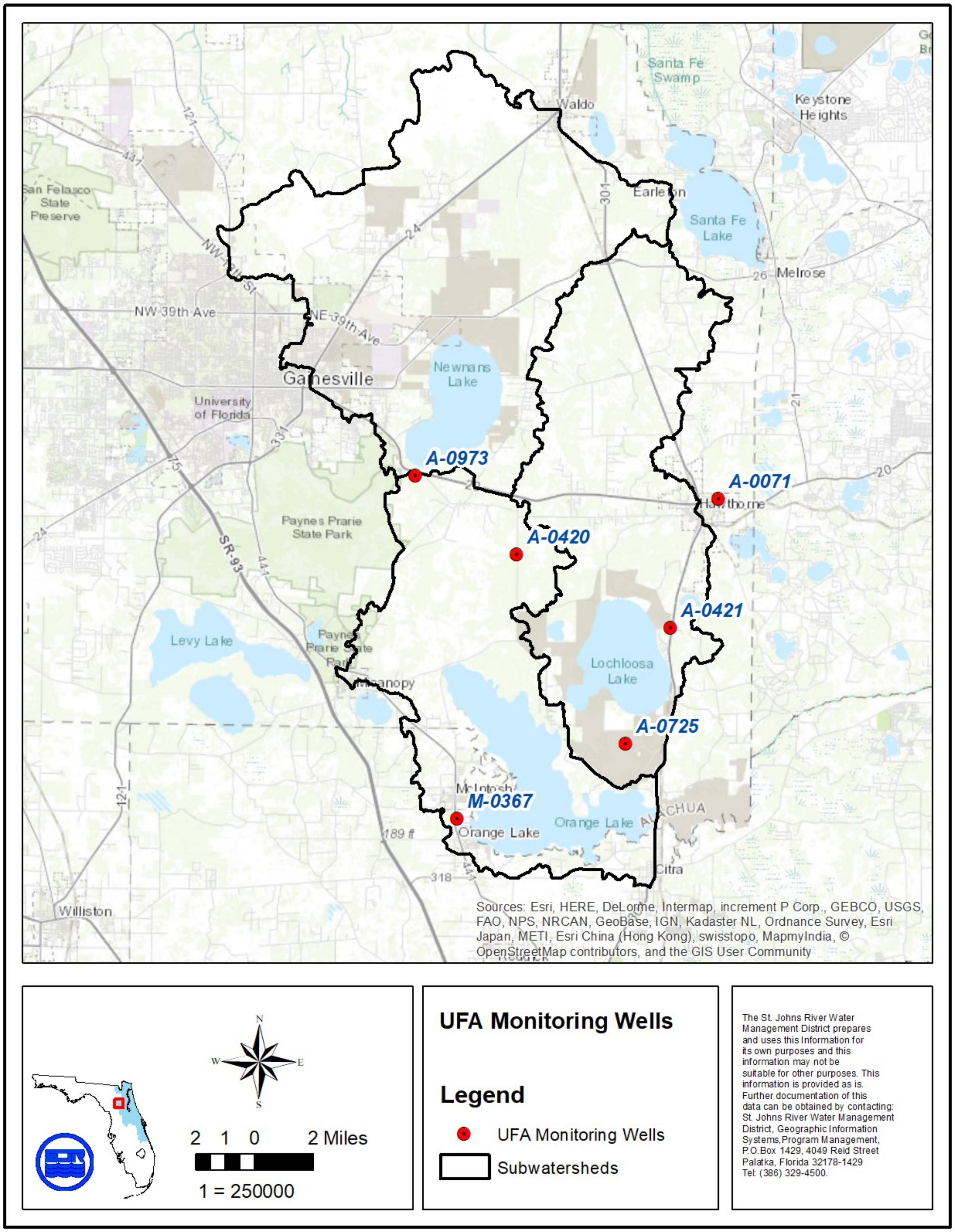


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Figure B-5. Upper Floridan aquifer wells in the basin.

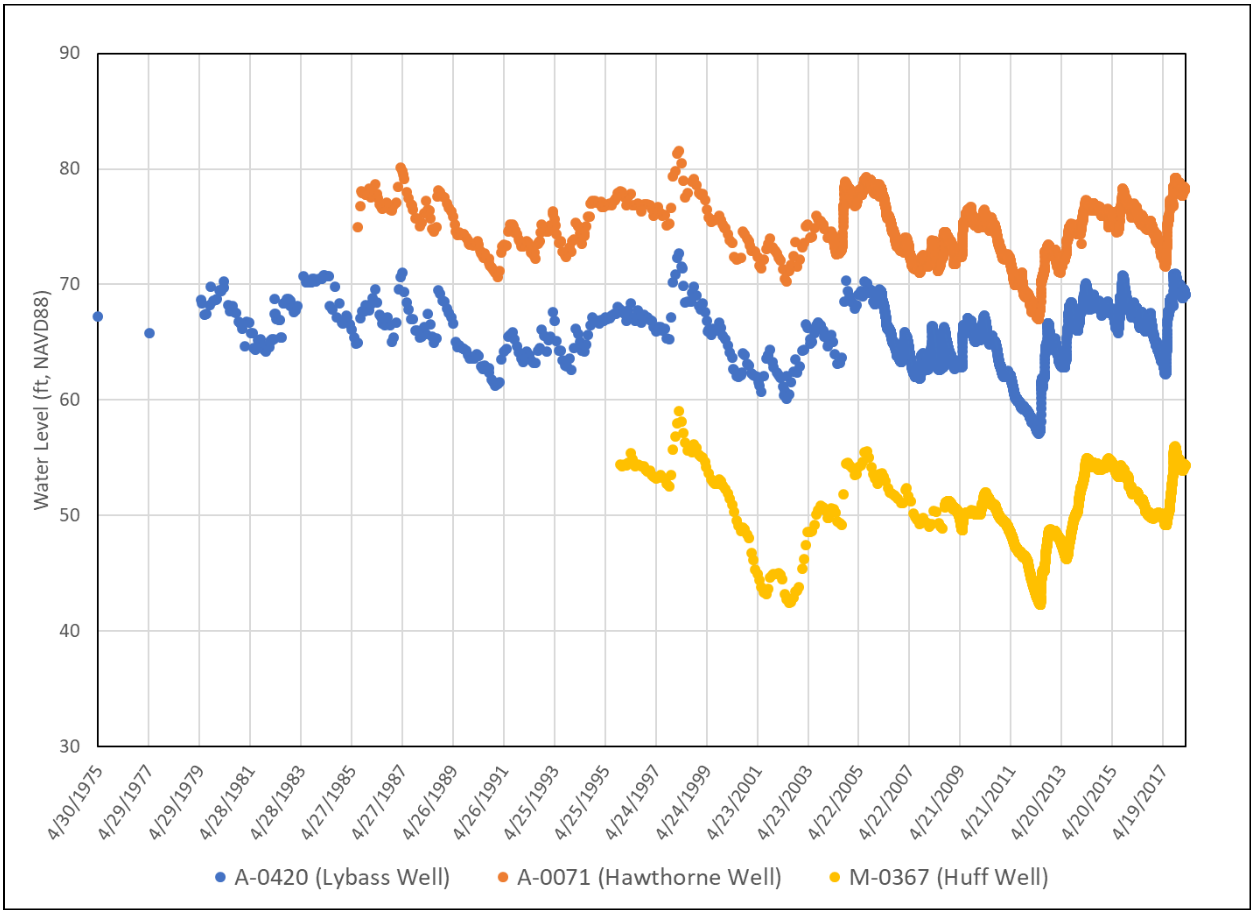



Figure B-6. Groundwater levels

## LOCHLOOSA LAKE LONG-TERM SIMULATIONS

MFL analysis requires long-term lake levels to capture the effect of short- and long-term climatic variations on lake levels. Although observed long-term lake levels are available, the data is discontinuous and especially sparse between 1960 and 1990 (Figure B-3). The HSPF/SWMM model (CDM Smith, 2018; Appendix E) was used to estimate long-term lake levels using long-term rainfall and PET (previously described) as well as long-term groundwater levels. Groundwater level data from three monitoring wells (A-0420, A-0071, and M-0367) were used with some adjustments to compute the exchange of flows between the UFA and Newnans, Lochloosa, and Orange lakes in the model. Thus, the groundwater levels of these wells were extended back to 1957 for long-term model simulations.

### Long-term Groundwater Levels

Among all three wells, A-0420 well has the longest observed data starting from 4/30/1975 (Figure B-5). All the wells have similar hydrographs, indicating a strong correlation among themselves. Initially, A-0420 well was used to extend the period of record of the other wells since it has the longest period of record. Regression analysis was used to correlate A-0420 well with the other two wells (Figures B-7 and B-8). The regressions show a strong relationship between A-0420 with the other wells. The coefficient of determination, $R^2$, is 0.74 for the correlation with M-0367 well and 0.93 for the correlation with A-0071 well. The A-0420 well's missing data were filled linearly before using it to extend the period of record of the other wells back to 4/30/1975.

The period of record for water level data at Lochloosa Lake begins in 1957 and was used to further extend the times series data at all three wells. As shown in Figure B-9, Lochloosa Lake levels correlate strongly with levels of the wells. Regression equations were developed relating Lochloosa Lake levels with levels of each of the three wells (Figures B-10 to B-12). The extended period of record data of the wells is shown in Figure B-13.

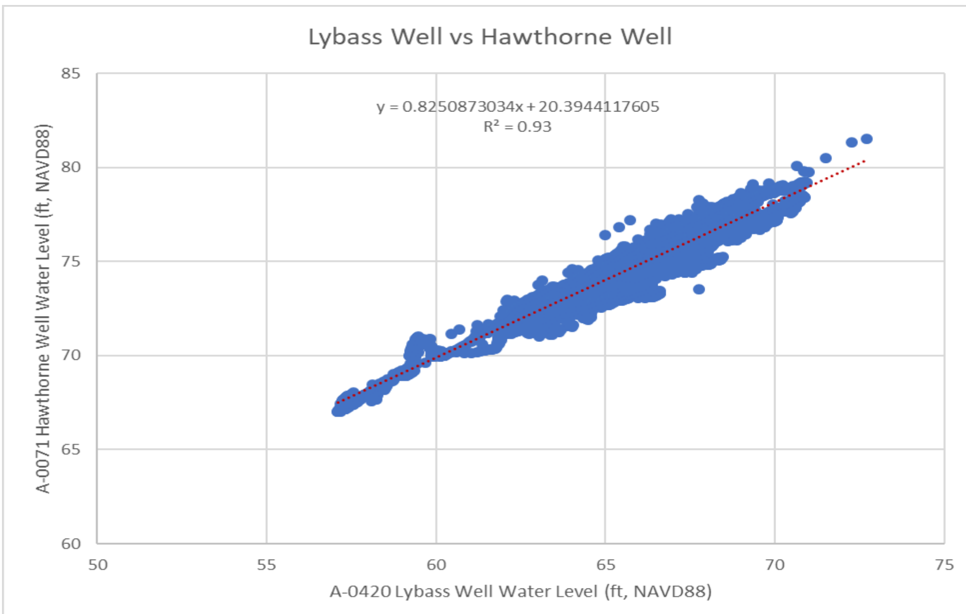



Figure B-7. Regression relationship between observed data at A-0420 and A-0071 wells.

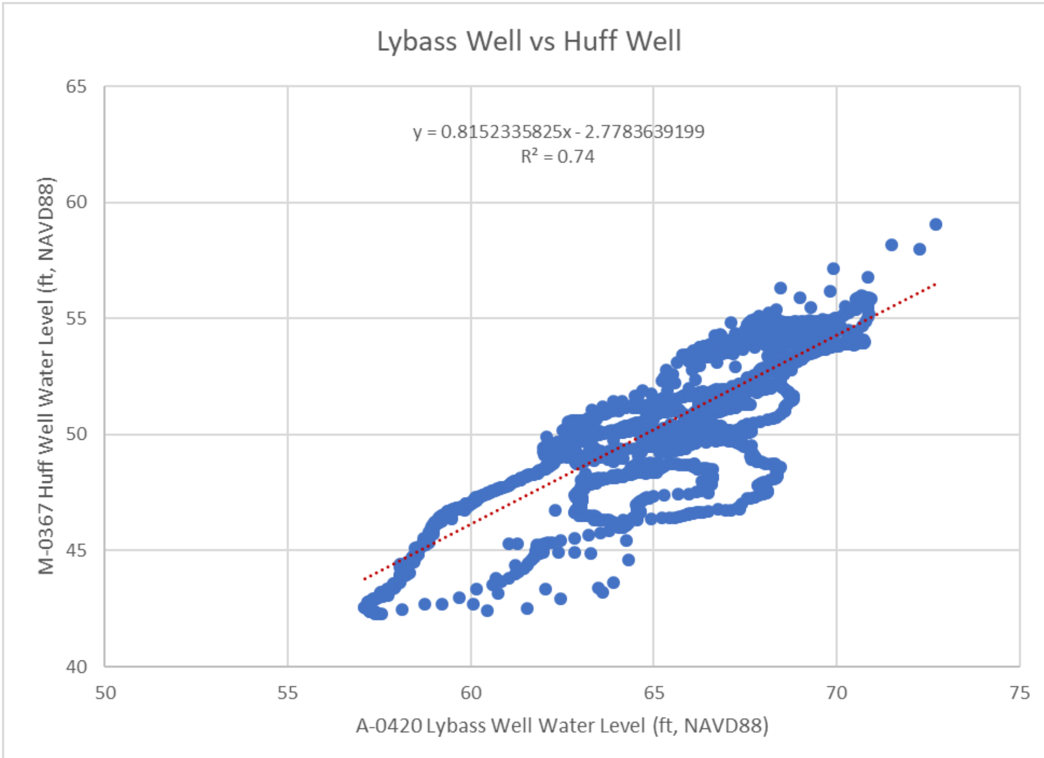



Figure B-8. Regression relationship between observed data at A-0420 and M-0367 wells.

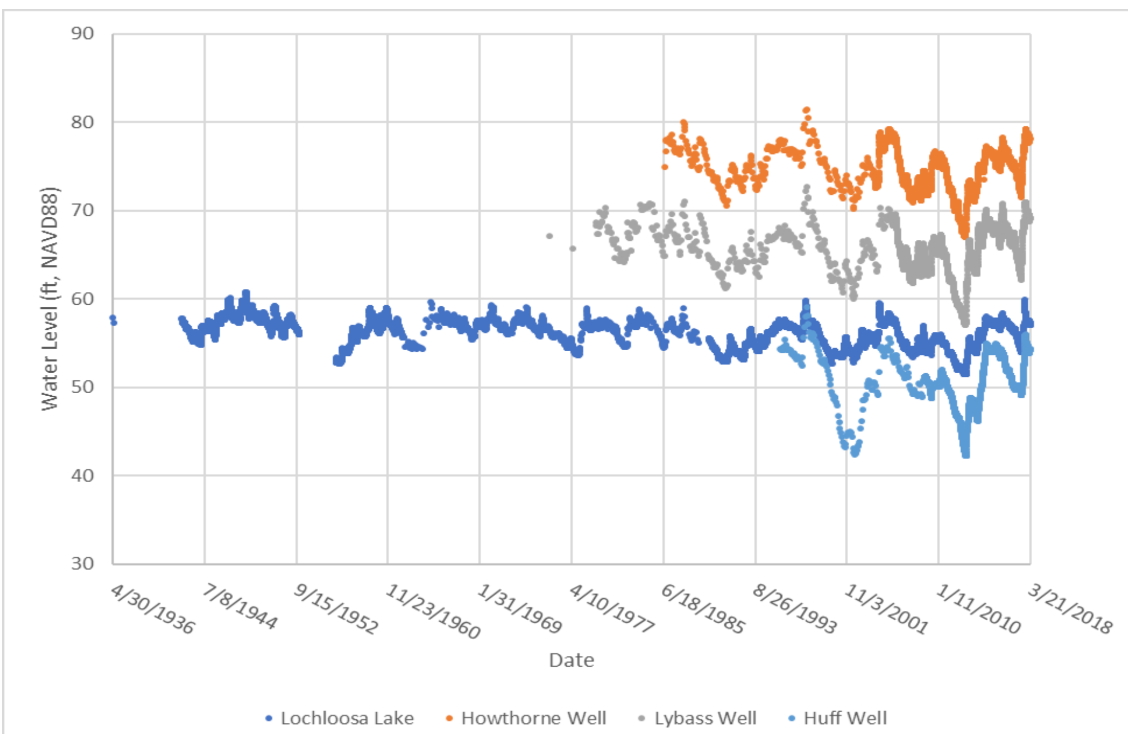



Figure B-9. Lochloosa Lake water levels and groundwater levels for A-0071 (Hawthorne), A-0420 (Lybass), and M-0367 (Huff) wells.

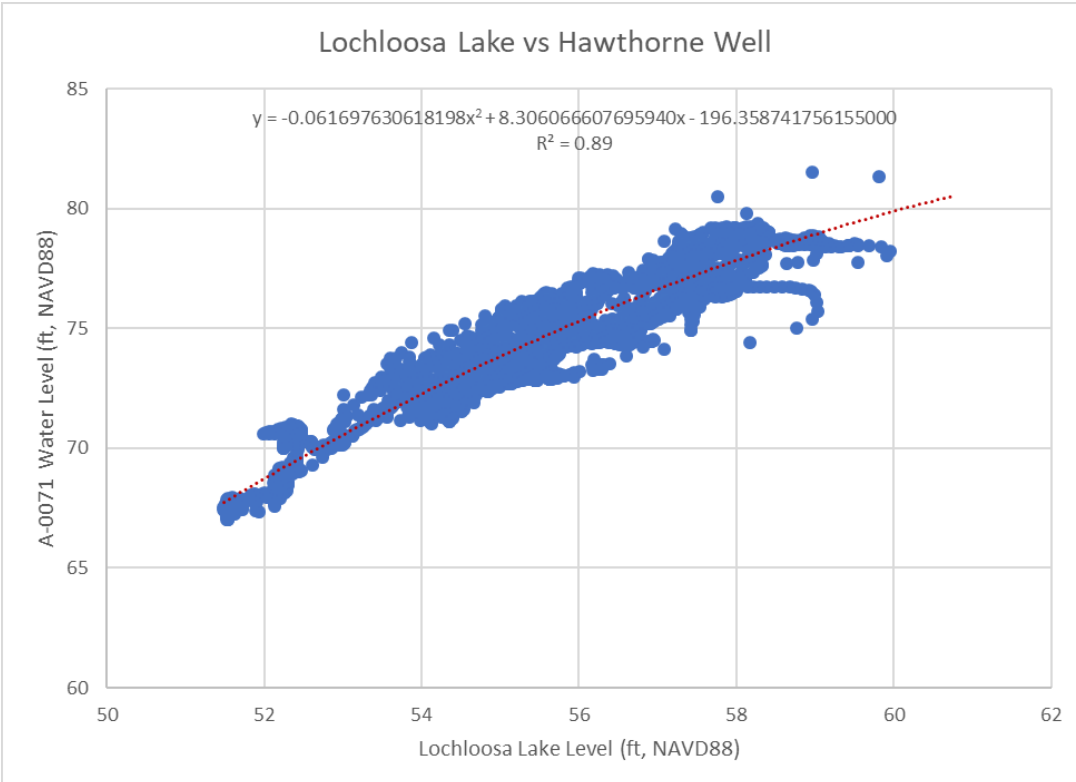



Figure B-10. Regression relationship between Lochloosa Lake and A-0071 water levels.

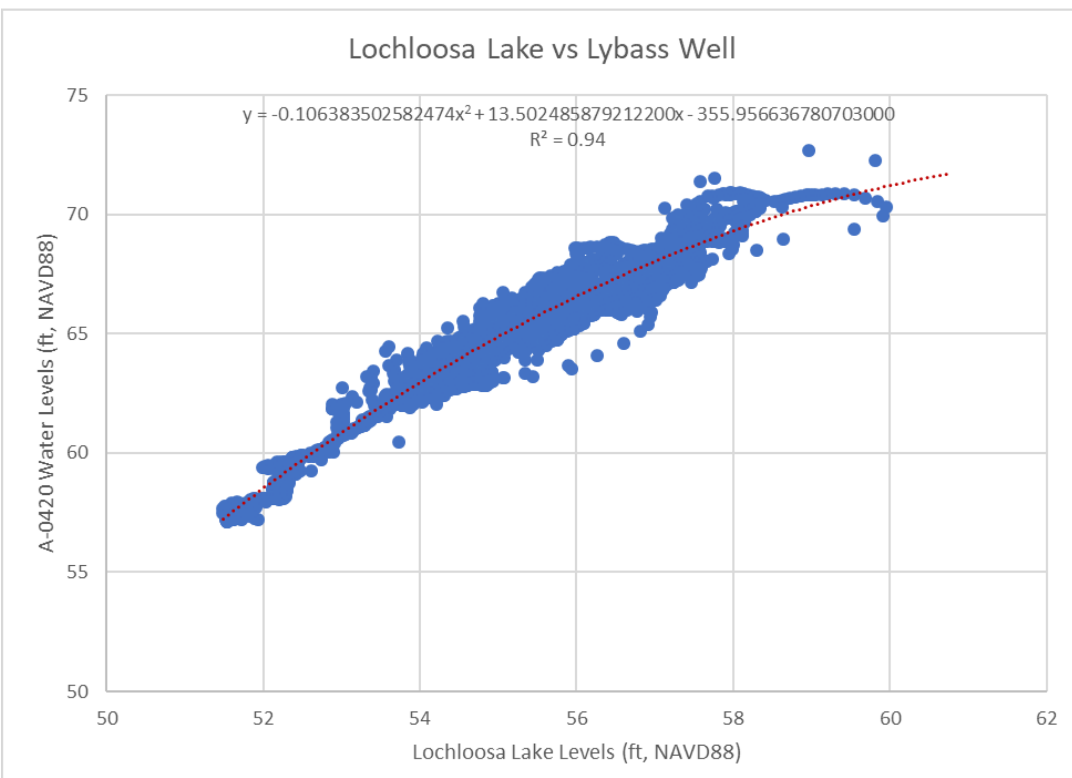



Figure B-11. Regression relationship between Lochloosa Lake and A-0420 water levels.

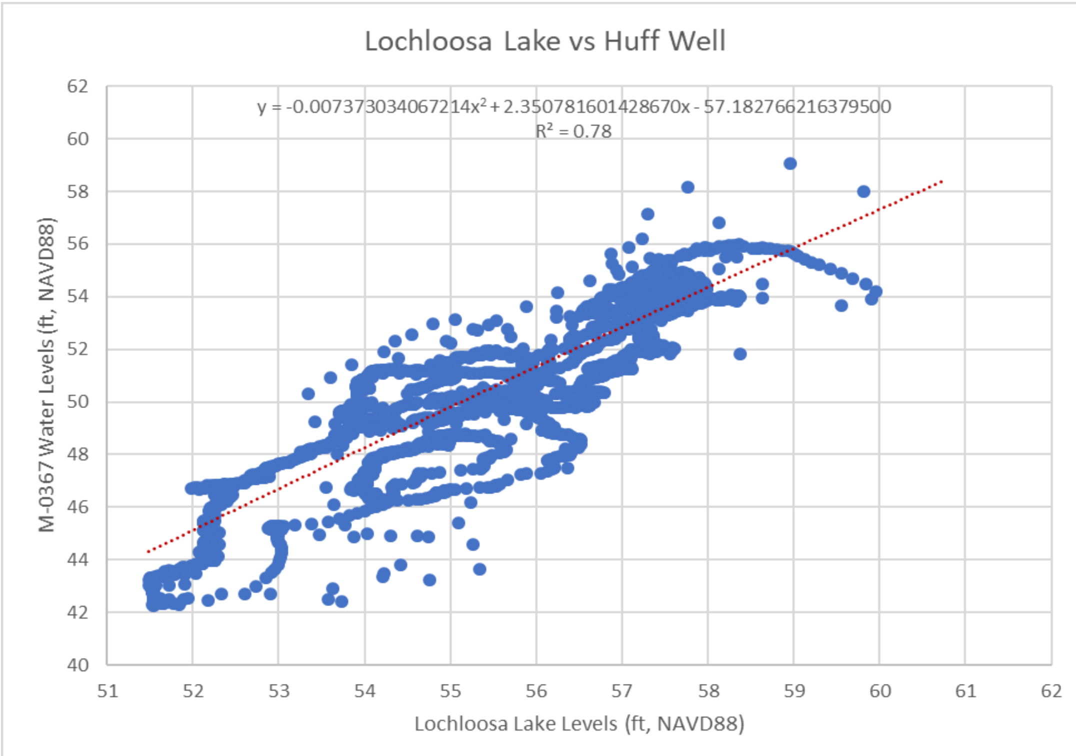



Figure B-12. Regression relationship between Lochloosa Lake and M-0367 water levels.

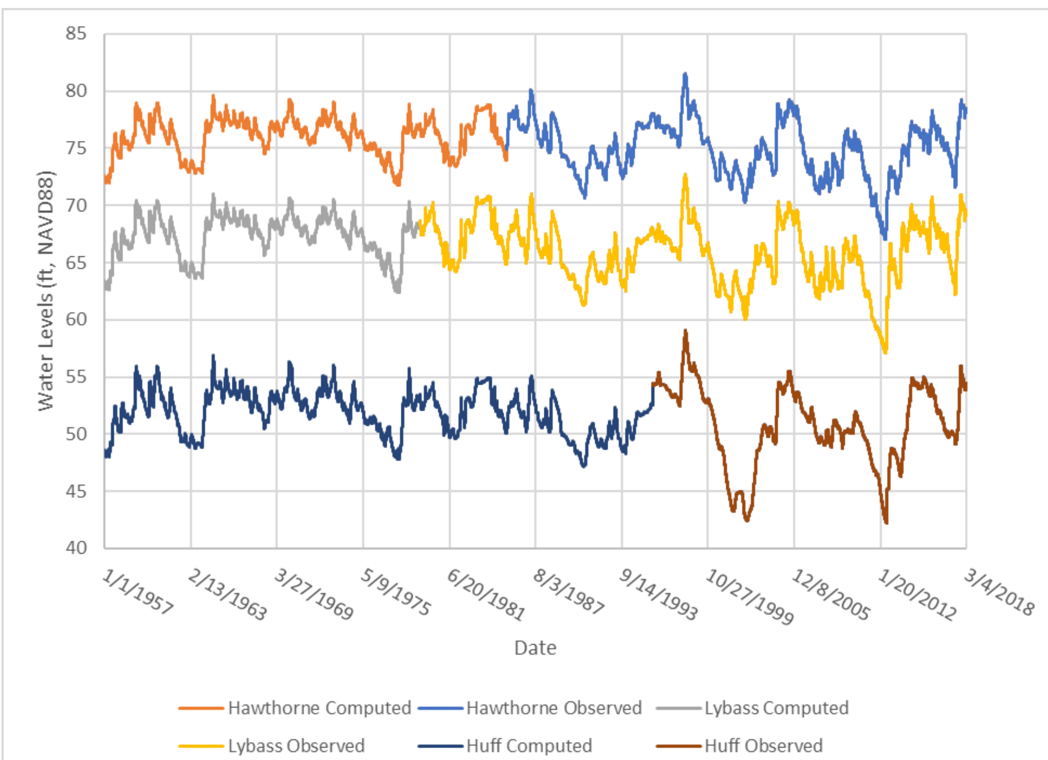



Figure B-13. Extended water levels at the A-0071 (Hawthorne), A-0420 (Lybass), and M-0367 (Huff) wells.

**Historical Long-term Lake Levels**

The HSPF/SWMM model was used to perform long-term simulations from 1/1/1957 to 12/31/2015 using the rainfall, PET, and long-term groundwater levels previously described. Figure B-14 presents the long-term hydrographs of simulated and observed levels at Lochloosa Lake.

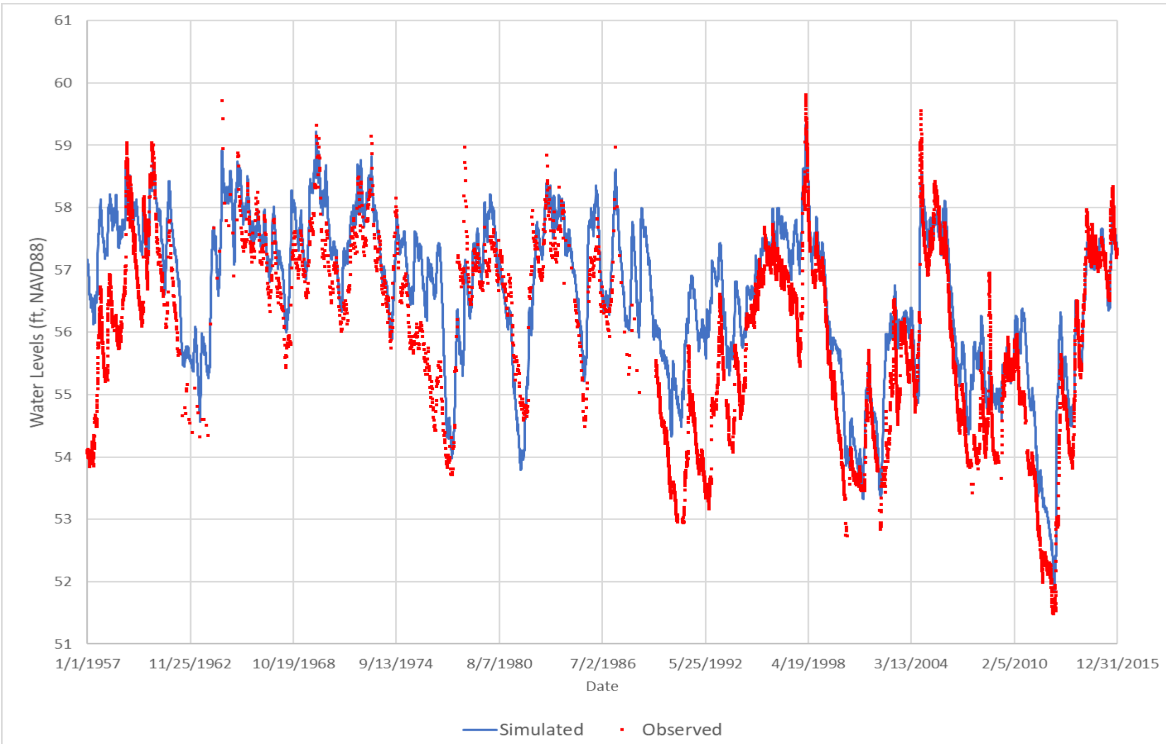



Figure B-14. Comparisons of simulated and observed long-term Lochloosa Lake Levels (ft, NAVD88).

A list of goodness-of-fit statistics are provided for long-term simulations in Table B-6. Overall, the model performed reasonably well in simulating the long-term lake levels considering model was calibrated to only a relatively short period from 2006 to 2016.

Table B-6. Goodness-of-fit statistics of long-termsSimulations

| Statistics | Value |
|---|---|
| **Mean Error (feet)** | 0.73 |
| **Mean Absolute Error (feet)** | 0.81 |
| **RMSE (Root Mean Square Error) (feet)** | 1.03 |
| **R (Pearson Correlation Coefficient)** | 0.89 |
| **$R^2$ (Coefficient of Determination)** | 0.79 |
| **PBIAS (Percent Bias)** | 0.01 |
| **NSE (Nash-Sutcliff Efficiency)** | 0.56 |

## DEVELOPMENT OF NO-PUMPING AND CURRENT-PUMPING LAKE LEVELS

The current and future status of minimum levels developed for Lochloosa Lake needed to be assessed. The objective of the current status assessment is to determine whether the Lochloosa Lake minimum levels are being achieved under the current pumping condition. Because of our limited understanding of possible future climatic conditions and difficulties in predicting future lake levels using global climate model forecasts, historical lake levels were considered to be the best available data and were adjusted for groundwater pumping impact to assess the current status of minimum levels.

The adjustment of historical lake levels requires considering the effect of current groundwater pumping on lake levels not only for the recent years but also for the entire period-of record (from 1957 to 2015). Two sets of adjusted lake levels were developed – no-pumping condition and current-pumping condition lake levels. The no-pumping condition lake levels constitute a reference hydrologic condition in which lakes were not under the influence of any groundwater pumping from 1957 to 2015. The current-pumping condition lake levels represent a reference hydrologic condition in which lakes were under the influence of current groundwater pumping constantly from 1957 to 2015. Current groundwater pumping is defined as the average groundwater pumping from 2011 to 2015. An average of the past five years of groundwater pumping was used to calculate the current-pumping condition so that it is more representative of the most recent average groundwater demand condition. The years 2016 and 2017 were not included because regional pumping data were not available at the time of this analysis.

Figure B-15 show the process for developing lake levels for no-pumping and current-pumping conditions.

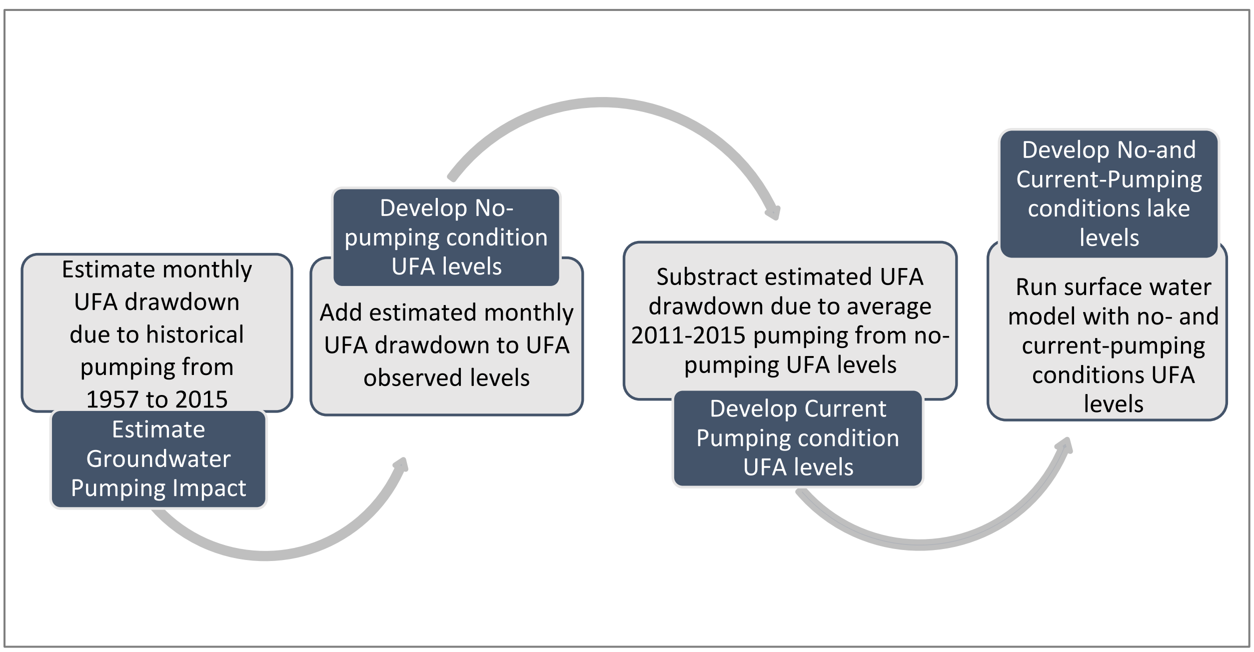



Figure B-15 Process for developing no-pumping and current-pumping condition lake levels

HSPF/SWMM model was used to develop no-pumping and current-pumping condition lake levels. To simulate no-pumping and current-pumping condition lake levels, no-pumping and current-pumping groundwater levels near lakes were required. As previously discussed, water level data from three groundwater monitoring wells were used with some adjustments to compute the exchange of flows between the UFA and Newnans, Lochloosa, and Orange lakes in the model.

The first step in developing the current-pumping condition groundwater levels is to develop the no-pumping condition groundwater level dataset. This dataset was developed by adding an estimate of impact due to historical pumping (i.e., the UFA drawdown due to pumping) to the observed record. The current-pumping condition groundwater level dataset was developed by subtracting an estimate of impact due to current pumping (average groundwater pumping from 2011–2015) from the no-pumping groundwater levels. No-pumping and current-pumping condition groundwater levels were later input into the surface water model to simulate no-pumping and current-pumping condition lake levels.

## Historical Groundwater Pumping Impact Assessment

### Groundwater Use

Figure B-16 shows the UFA potentiometric contours for September 2015 (the latest available data in the SJRWMD database) and possible groundwater flow paths near lakes drawn perpendicular to potentiometric contours. Based on a review of possible groundwater flow paths near lakes, it was determined that Newnans Lake could potentially be impacted by the pumping in Alachua County, Orange Lake could potentially be impacted by the pumping in Alachua and Marion counties, and Lochloosa Lake could potentially be impacted by the pumping in all three counties.

Therefore, to estimate the impact on groundwater levels from pumping, monthly groundwater use data was compiled for Alachua, Putnam and Marion counties from 1957 to 2015 (Figure B-17). The pumping in 2016 and 2017 was not included because complete datasets of 2016 and 2017 pumping were not available at the time of analysis.

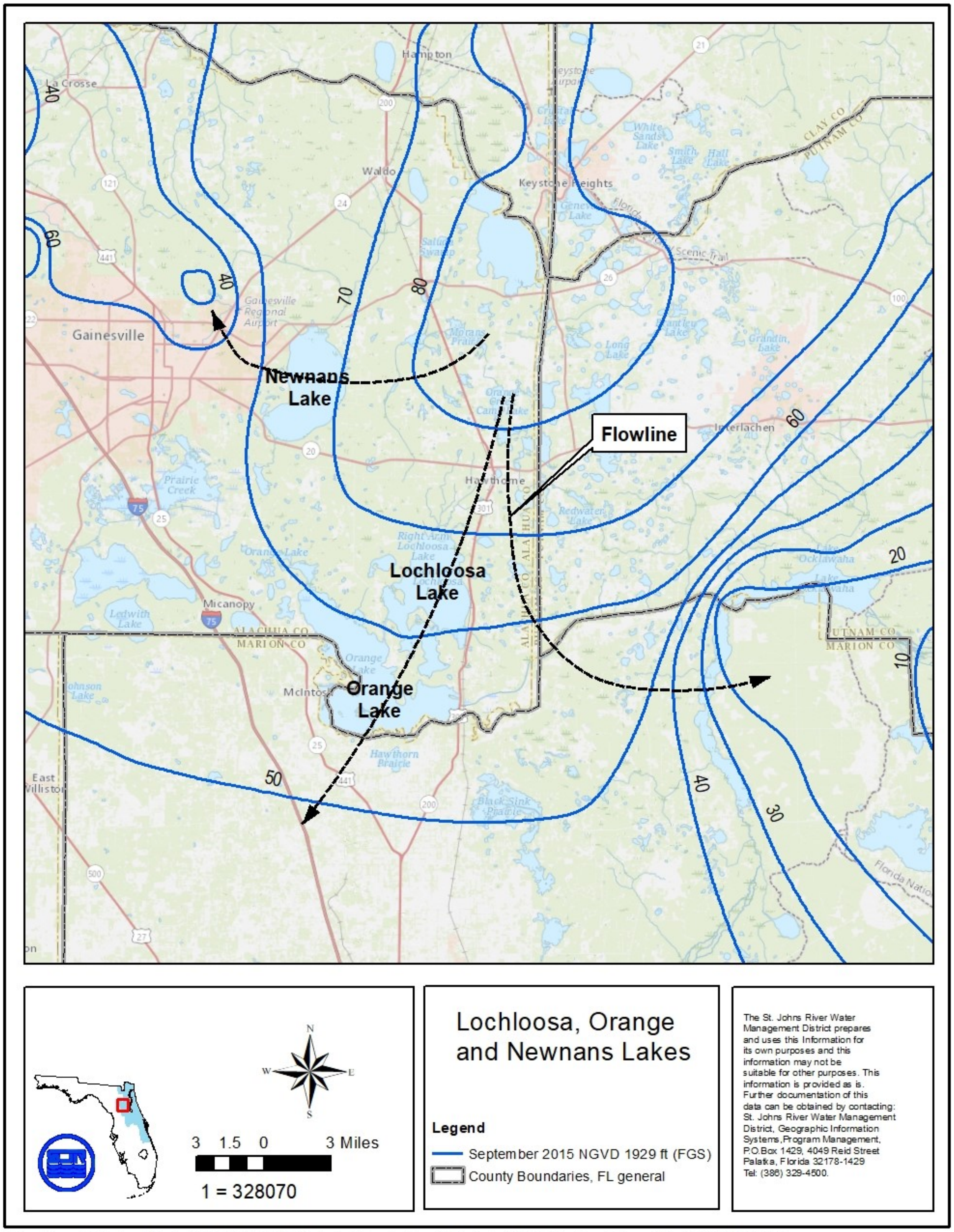
The groundwater pumping data was estimated from 1957 to 2015 using the data available from different sources. The pumping data from 1995 to 2015 are from the SJRWMD historical water use database with actual monthly use and station-level details. The data from 1965 to 1995 are based on the United States Geological Service (USGS) published county-level water use (available every five years starting in 1965) and the annual SJRWMD county-level Annual Water Use Survey (AWUS), starting in 1978. Using these two sources, the water use data was aggregated to the county for every five years and some years in between from 1965. Any missing years for each county were estimated using an exponential growth assumption to create a complete aggregate table. If the USGS and AWUS estimates do not match, the published AWUS data were used. To estimate annual groundwater use by county for the period before 1965, per capita groundwater use was estimated for each county. Multiplying the 1965 per capita water use by the historic county-level population from U.S.

Census, the annual groundwater uses by county were estimated for the period before 1965. The U.S. Census data is reported in 10-year intervals. An exponential growth was assumed to estimate the annual population between 10-year intervals.

To disaggregate the annual data to monthly groundwater use, the average monthly proportions by county, estimated from the monthly SJRWMD database from 1995 to 2015, were applied to the annual data.

It should also be noted that the groundwater pumping within three counties was only used as a proxy to understand the variation of regional groundwater pumping from 1957 to 2015. The impact of groundwater pumping on lake levels was assessed based on all groundwater pumping within the groundwater model domain (described further below).

As shown in Figure B-17, the total groundwater use in these counties reached its highest in 2006 (174 mgd) and has declined more than 25% after 2006. The average total groundwater use in these counties over the past five years (2011–2015) is approximately 136 mgd, which is similar to groundwater use in the late 1970s.




Author:, Source:U:\Water Supply Planning\ResEvalMdlg\MFLs\03_MFL_Systems\OrangeLochloosa\3_HydroAnalysis\4_Analysis\LochloosaReview.mxd, Time:5/29/2018 3:48:16 PM

Figure B-16. UFA potentiometric contours and possible flow paths.

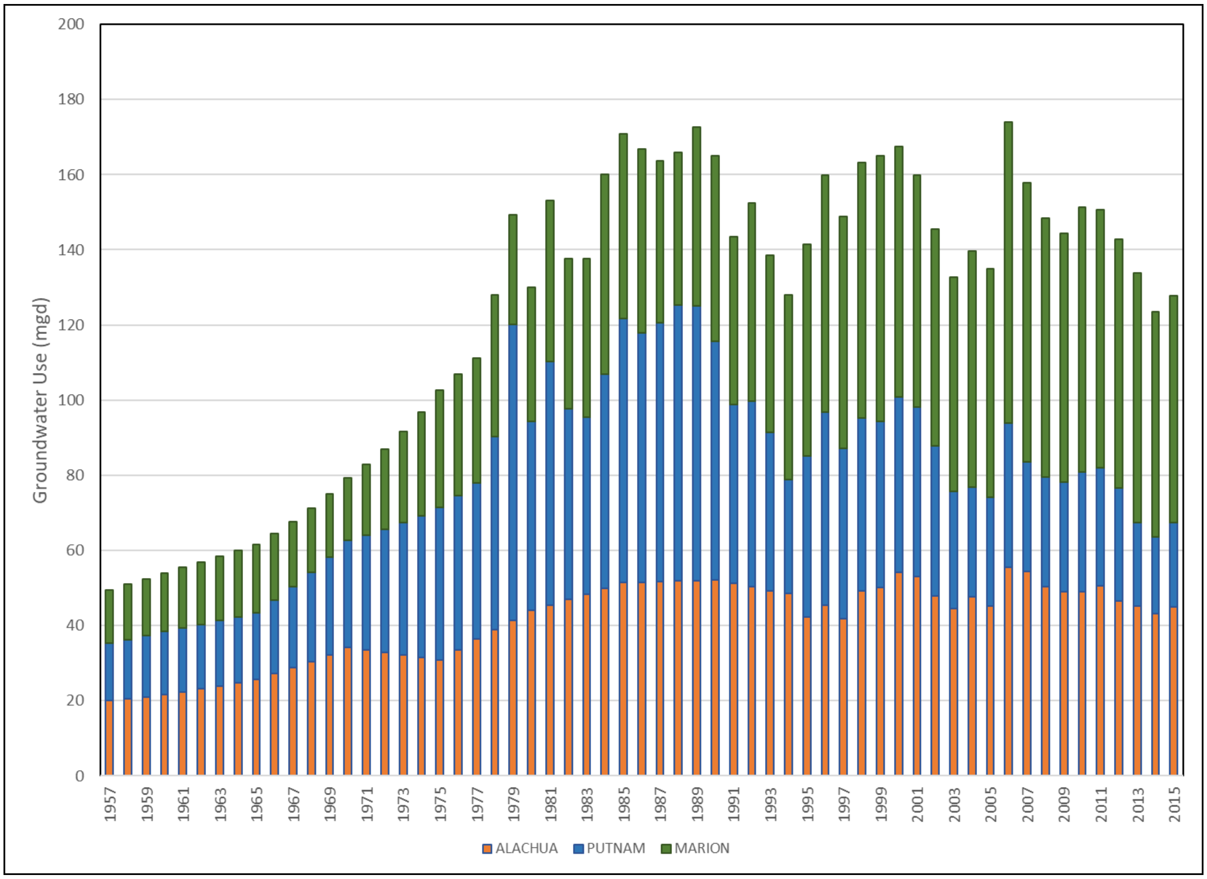
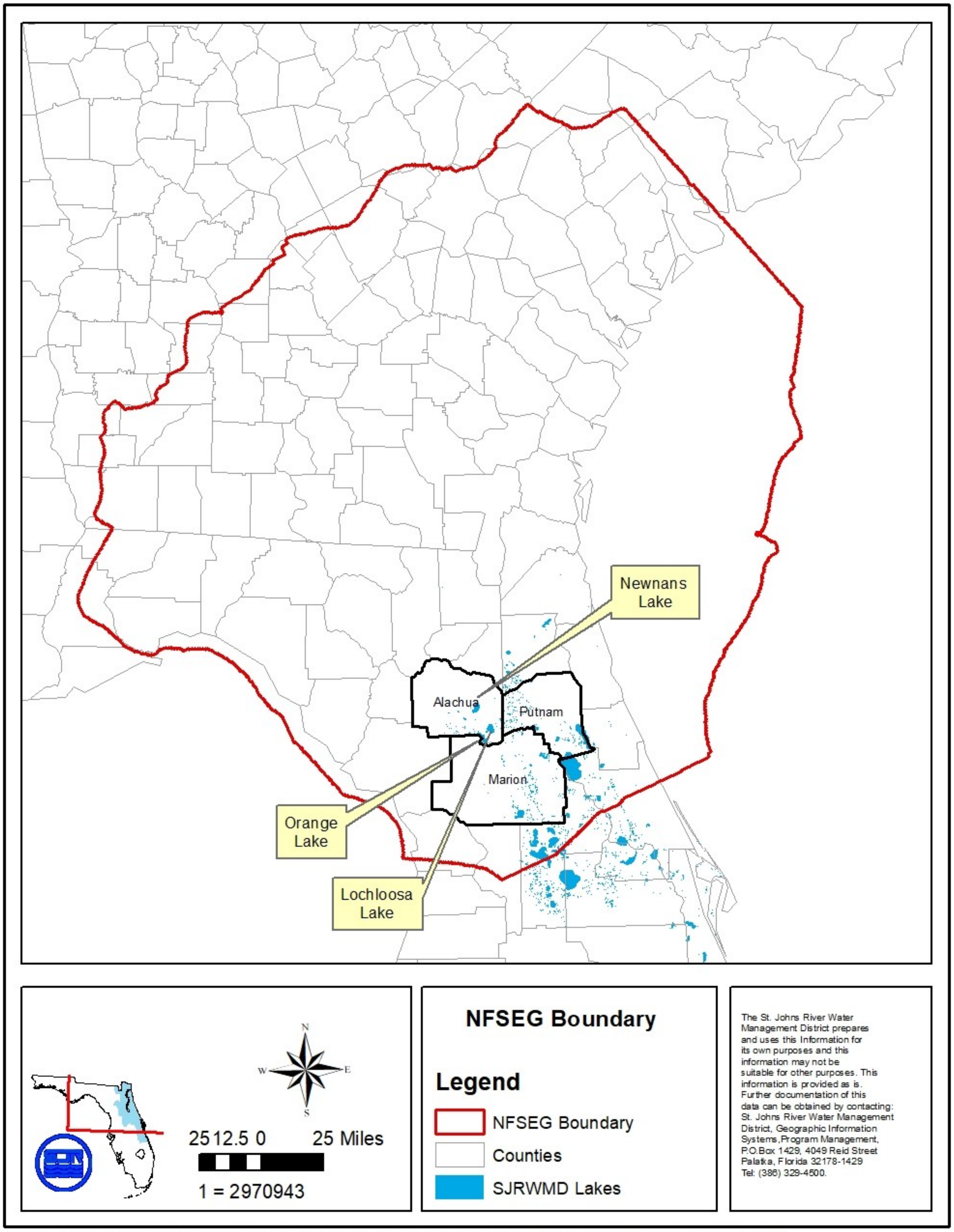



Figure B-17. Estimated historical groundwater uses in Alachua, Marion and Putnam counties

## Groundwater Modeling

North Florida Southeast Georgia regional groundwater model version 1.1 (NFSEG v1.1) was used for the groundwater pumping impact assessment (Durden, at al., 2018). NFSEG v1.1 is a steady-state model which was calibrated to match average water levels and flows in 2001 and 2009. Figure B-18 shows the boundary of NFSEG model and the three counties used in the groundwater pumping impact assessment.




Author:, Source:U:\Water Supply Planning\ResEvalMdlg\MFLs\03_MFL_Systems\OrangeLochloosa\3_HydroAnalysis\4_Analysis\LochloosaNFSEG.mxd, Time:5/31/2018 2:37:11 PM

Figure B-18. Boundaries of NFSEG model and Alachua, Marion and Putnam counties

**Estimated historical impact on groundwater levels**

An estimate of drawdowns resulting from regional pumping from 1957 to 2015 on a monthly time step is needed for the no-pumping simulations. Because NFSEG v1.1 is a steady-state model and was not designed to simulate monthly simulations over a long-time period (i.e from 1957 to 2015), to overcome the limitations of the NFSEG v1.1, a methodology was developed to estimate the impact of regional pumping on groundwater levels for every month from 1957 to 2015. The methodology includes developing a relationship between groundwater pumping and the UFA drawdown underneath the lakes using the NFSEG model. To develop the relationship, the following model simulations were performed so that a wide range of pumping conditions can be included in the regression analysis.

- 2001 no-pumping
- 2001 pumping
- 2009 no-pumping
- 2009 pumping
- 2009 pumping reduced by 50%
- 2009 pumping reduced by 75%
- 2009 pumping increased by 25%

The no-pumping simulations were used to estimate the UFA drawdowns near lakes at each pumping scenario. For example, the UFA drawdown near a lake was calculated by subtracting the simulated groundwater level near the lake under 2009 pumping condition from the simulated groundwater level near the lake under 2009 no-pumping condition. Figures B-19 through B-21 show the regression plots for Lochloosa, Orange and Newnans respectively.

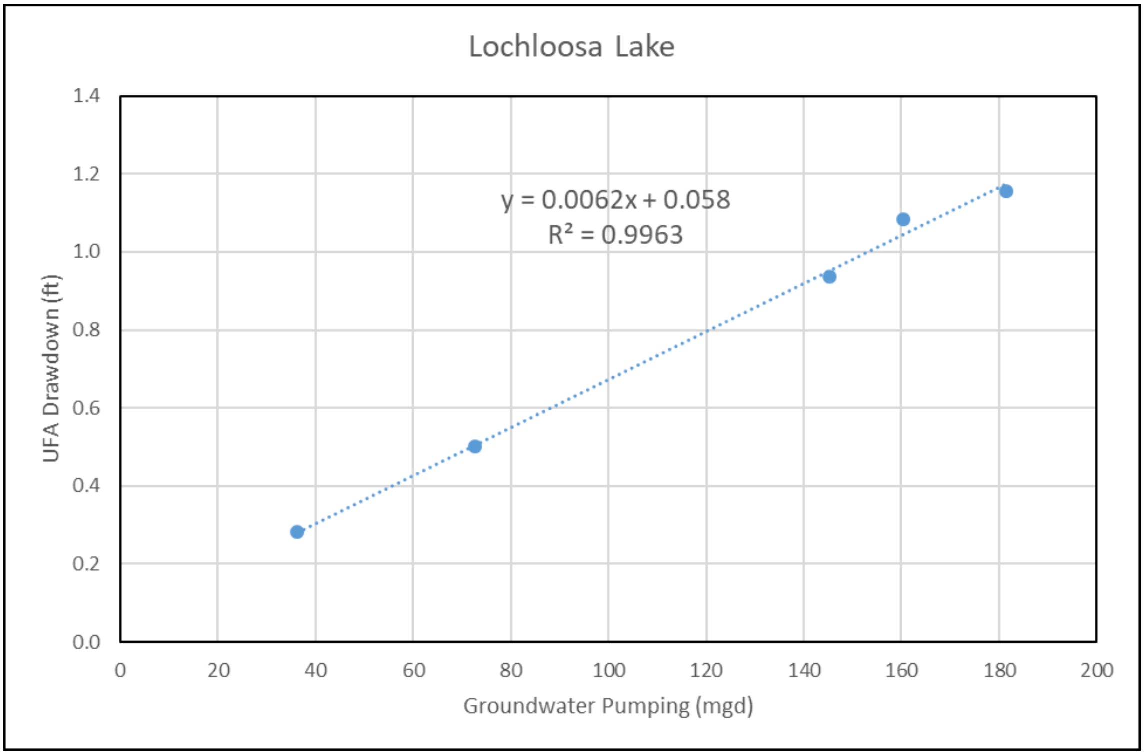



Figure B-19. Relationship between UFA drawdown near Lochloosa Lake and groundwater pumping in Alachua, Putnam and Marion counties

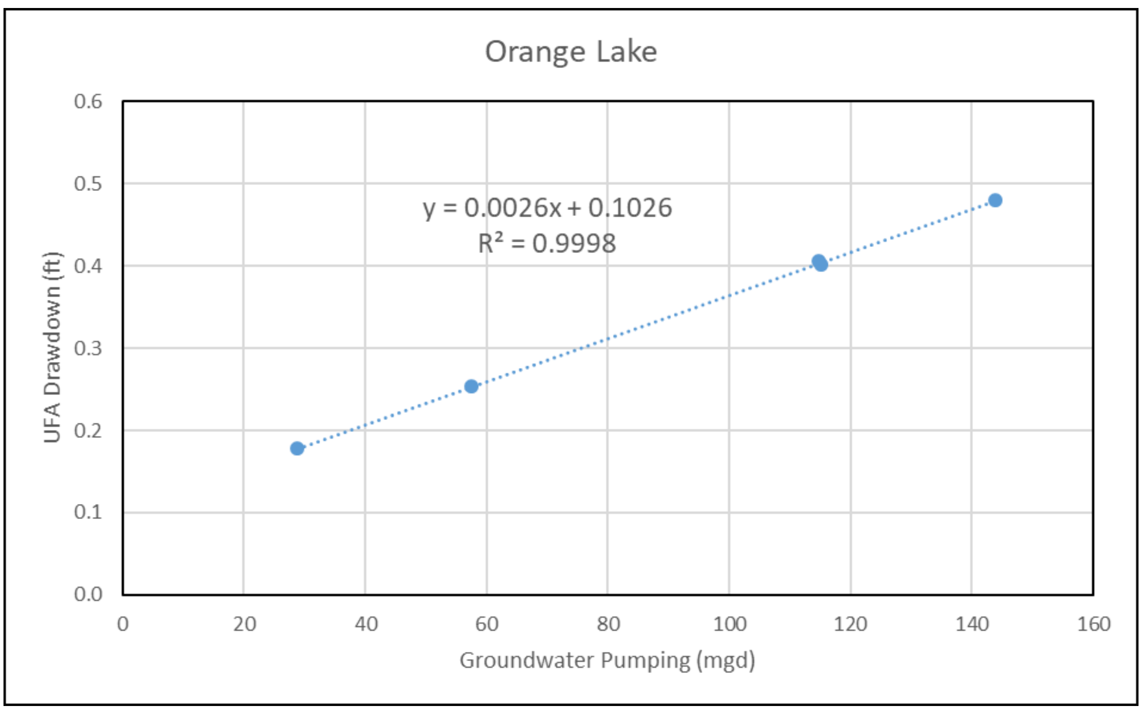



Figure B-20. Relationship between UFA drawdown near Orange Lake and groundwater pumping in Alachua and Marion counties

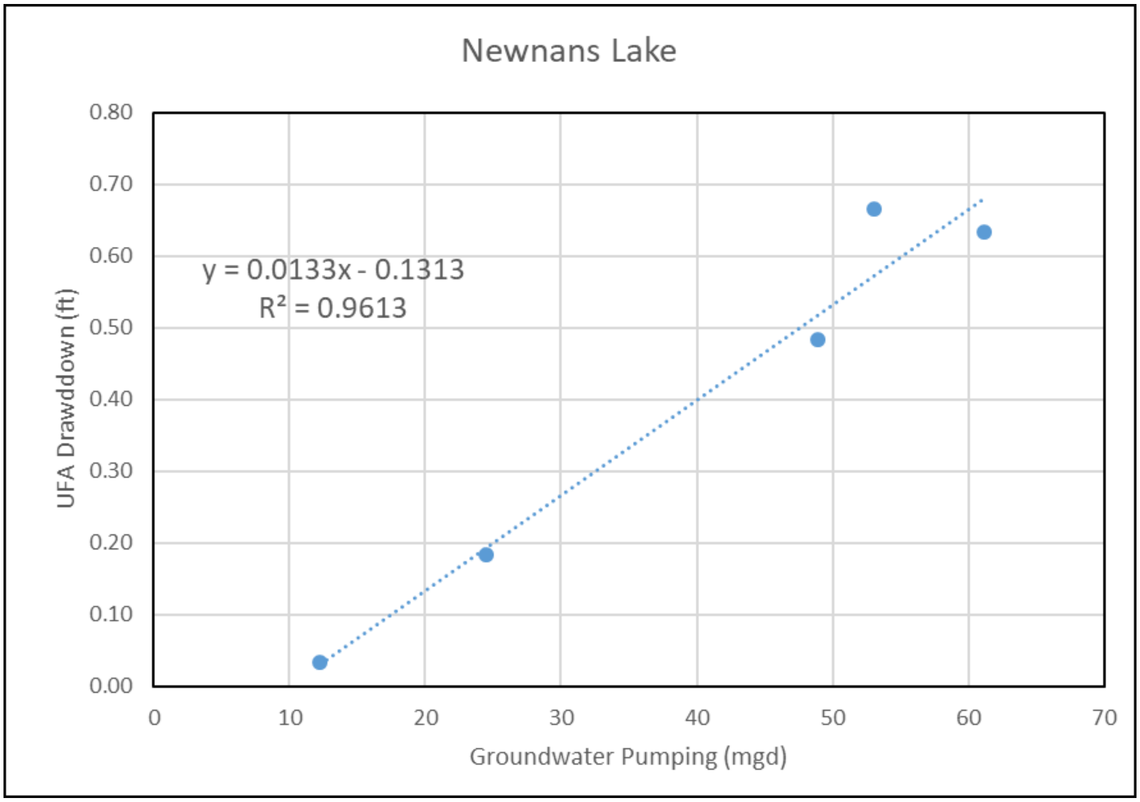



Figure B-21. Relationship between UFA drawdown near Newnans Lake and groundwater pumping in Alachua County

A strong linear relationship exists between UFA drawdown near Lochloosa Lake and groundwater pumping (Figure 19). However, a non-linear relationship exists between UFA drawdowns near Orange and Newnans Lakes and groundwater pumping. This may be because Orange and Newnans lakes are more connected to the UFA than Lochloosa Lake. In addition, nearby recharge features such as Kanapaha injection wells and Alachua sink might influence Orange and Newnans lakes more than Lochloosa Lakes because of their proximity to these lakes.

Using the linear and logarithmic functions shown in Figures B-19 through B-21 and the estimated historical pumping in the designated county or counties (Figure B-17), monthly UFA drawdown at each lake due to historical pumping was estimated (Figure B-22). It should be noted that the groundwater pumping in three counties were considered only as proxy to develop the relationship and capture the variation of regional pumping over time. The NFSEGv1.1 groundwater model simulations included pumping for the entire model domain.

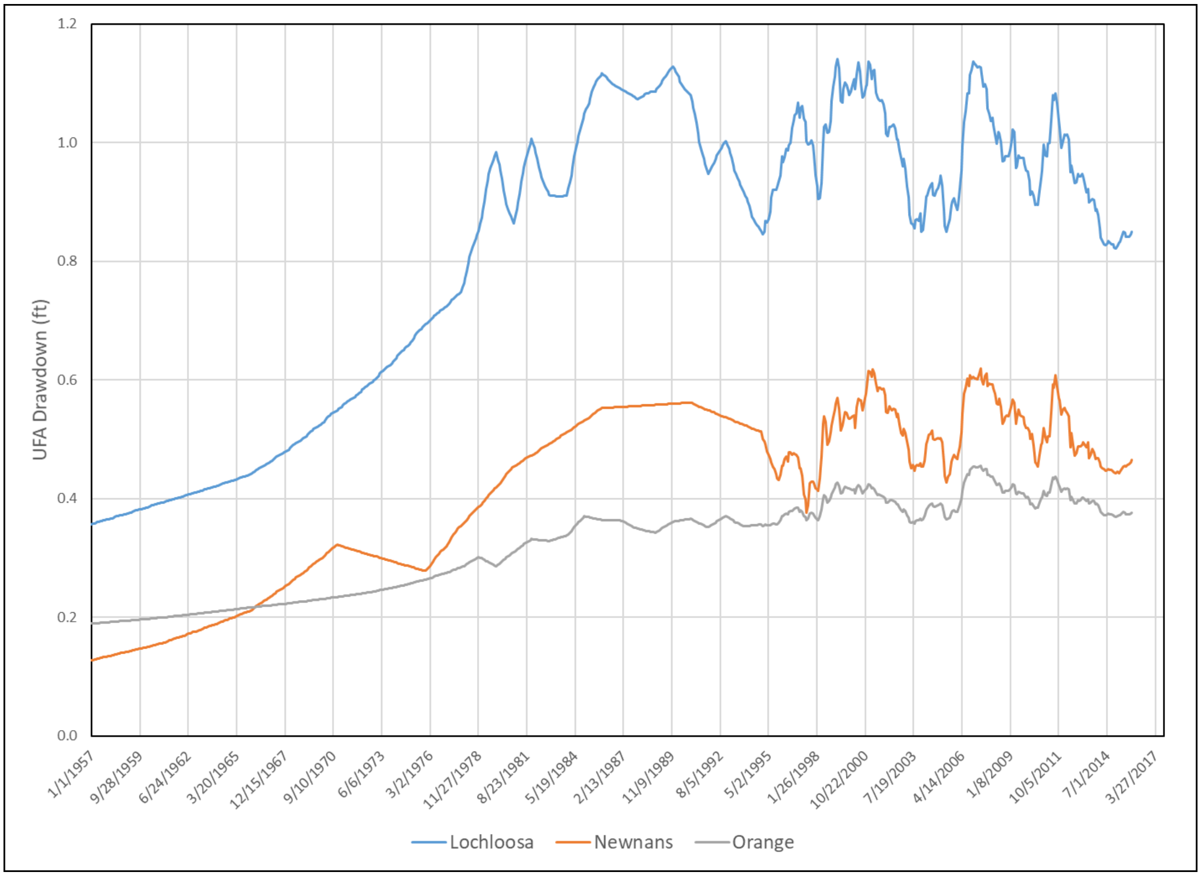



Figure B-22. Estimated impact of pumping on UFA levels near Lochloosa, Orange and Newnans lakes

### No-pumping condition groundwater levels

The impacts from pumping as shown in Figure B-22 were added to the monthly means of the observed groundwater level data to create no-pumping condition groundwater level datasets for Lochloosa, Orange and Newnans lakes. The monthly datasets were later disaggregated into daily groundwater levels by linear interpolation.

### Current-pumping condition groundwater levels

To generate current-pumping condition groundwater levels, the impacts from the average 2011–2015 pumping were subtracted from the no-pumping condition groundwater levels. Figures B-23 and B-25 show both no-pumping and current-pumping conditions groundwater levels for Lochloosa, Newnans, and Orange lakes, respectively. The monthly datasets were later disaggregated into daily lake levels by linear interpolation.

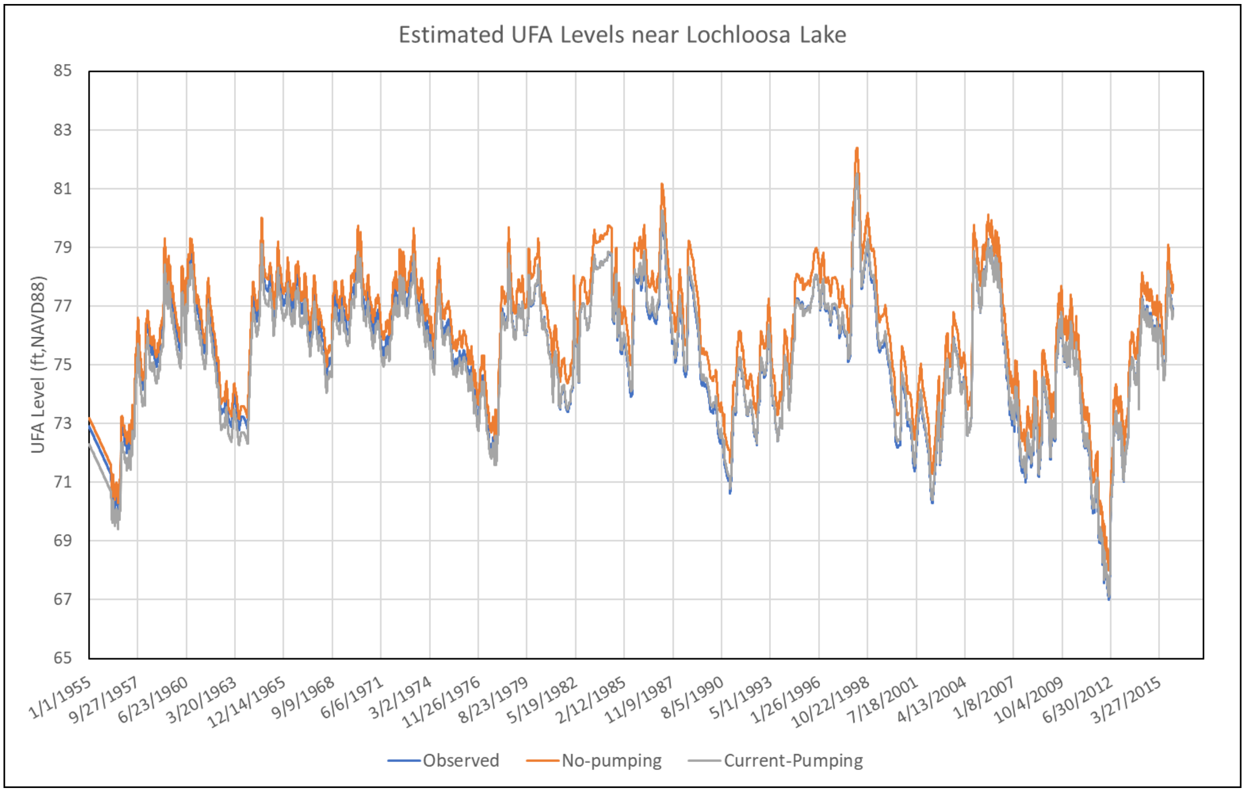



Figure B-23. Estimated no-pumping and current-pumping UFA levels near Lochloosa Lake

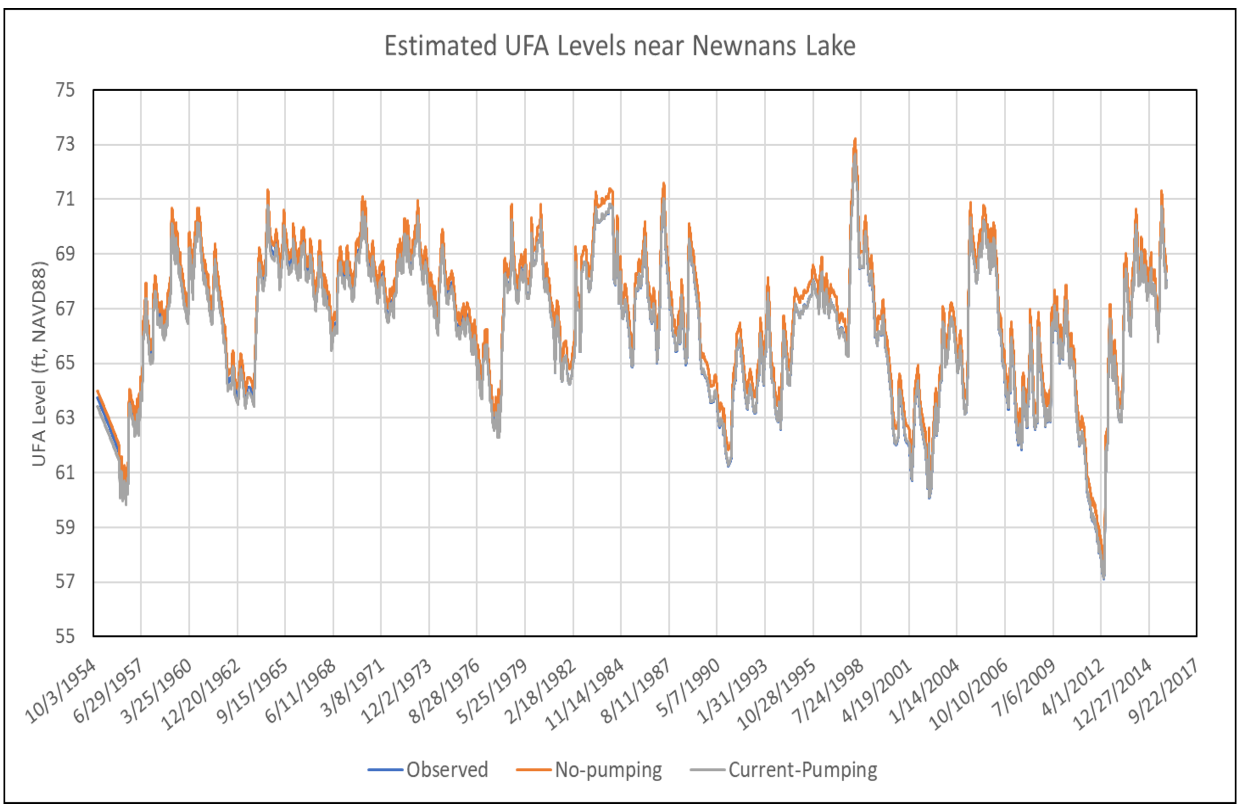



Figure B-24. Estimated no-pumping and current-pumping UFA levels near Newnans Lake

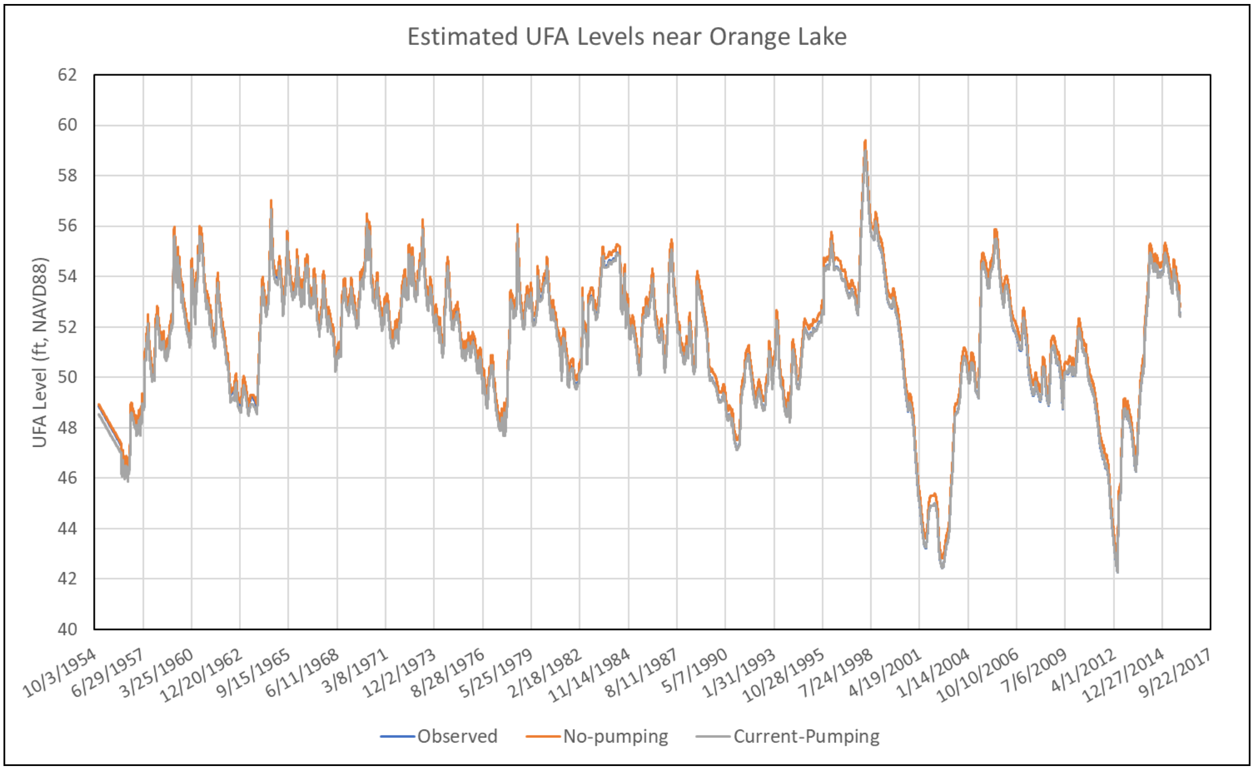



Figure B-25. Estimated no-pumping and current-pumping UFA levels near Orange Lake

## Lake Level Datasets for MFL Analysis

The no-pumping and current-pumping Lochloosa Lake levels were simulated by inputting the no-pumping and current-pumping groundwater levels (Figures B-23 through B-25) to HSPF/SWMM model.

Figures B-26 shows both no-pumping and current-pumping conditions lake levels for Lochloosa Lake. The monthly datasets were later disaggregated into daily lake levels by linear interpolation. Table B-7 show the descriptive statistics of existing, no-pumping and current-pumping condition lake levels.

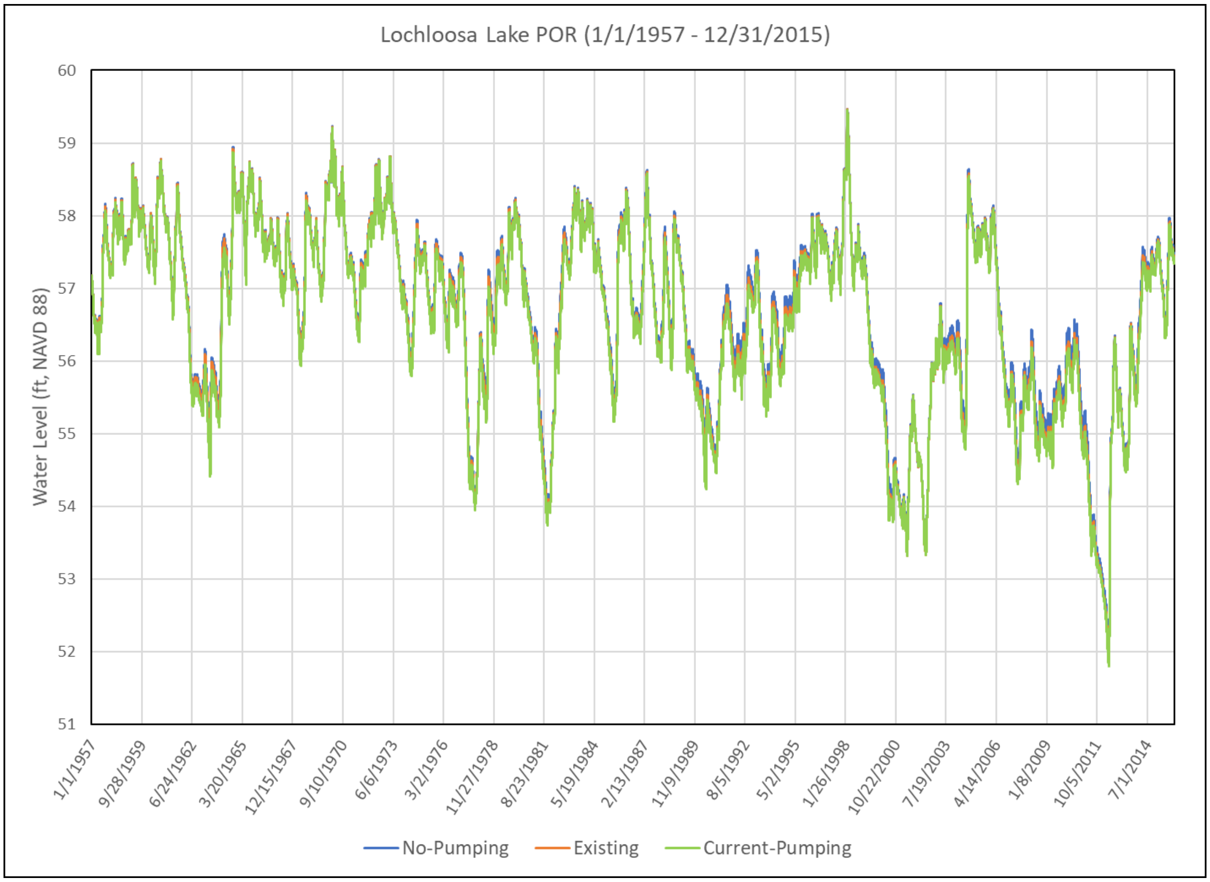



Figure B-26. The estimated no-pumping and current-pumping condition levels for Lochloosa Lake

Table B-7. Descriptive statistics of simulated Lochloosa Lake stages

| Statistical Parameter | No-pumping condition lake level (ft, NAVD88) | Existing condition lake level (ft, NAVD88) | Current-pumping condition lake level (ft, NAVD88) |
|---|---|---|---|
| **Mean** | 56.69 | 56.63 | 56.58 |
| **Standard Error** | 0.01 | 0.01 | 0.01 |
| **Median** | 56.95 | 56.88 | 56.83 |
| **Standard Deviation** | 1.23 | 1.26 | 1.27 |
| **Minimum** | 51.94 | 51.84 | 51.81 |
| **Maximum** | 59.47 | 59.46 | 59.45 |

The current-pumping condition lake levels represent a reference hydrologic condition of the lakes in which the total regional groundwater pumping impacting the lakes is constant from 1957 to 2015 at a rate of averaged pumping from 2011 to 2015. Assuming climatic, rainfall, and other conditions present from 1957 to 2015 are repeated over the next 58 years, the current-pumping condition lake levels would reflect the future condition of the lake levels if the average regional groundwater pumping does not change from 2011–2015 condition.

Because of our limited understanding of possible future climatic conditions and uncertainties in global climate model predictions, using historical conditions to generate current-pumping condition lake levels is reasonable. Therefore, the no-pumping and current-pumping condition lake level datasets shown in Figure B-26 were used to assess the MFLs at Lochloosa Lake.

## LITERATURE CITED


CDM Smith, 2018. Lochloosa, Orange and Newnans Lakes Hydrologic Evaluation (See Appendix E)

Durden et al., 2018. North Florida Southeast Georgia Groundwater Model v1.1 Report (Draft)

WSIS, 2012. SJRWMD Water Supply Impact Study. Technical Publication SJ2012-1

# APPENDIX C — MFLS STATUS ASSESSMENT

## CURRENT AND FUTURE STATUS ASSESSMENT AND UFA FREEBOARD CALCULATION

Frequency analysis was used to 1) assess the current status of all four recommended MFLs, 2) determine Upper Floridan aquifer (UFA) freeboards for each minimum level and 3) assess the future status of all four recommended MFLs. The following sections describe all three analyses.

### Current Status Assessment

Current status was assessed for all four minimum levels developed for Lochloosa Lake (see *MFLs Determination* section of the main report for details on minimum levels) by performing frequency analysis of the lake levels under current-pumping condition. The development of current-pumping condition lake levels is described in Appendix B. The frequency of each minimum levels was determined based on the allowable probability of exceedance (flooding) events (FH-1 and FH-2) or non-exceedance (drying) events (FL and MA) calculated using annual series data. The following describes the frequency analysis method and results for assessing each of the four MFLs developed for Lochloosa Lake.

#### Status assessment for FH-1

Calculating the probability of exceedance of the FH-1 involved the following three steps:

1. Determine the annual maximum elevation continuously exceeded for the specified duration (30 days) for each water year. The water year for flooding events is from June 1 to May 31.
2. Rank annual maximums from step 1 in descending order.
3. Use Weibull plotting position formula to calculate the probability of exceedance.

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

where $P(S \geq \hat{S}_m)$ = probability of S equaling or exceeding $\hat{S}_m$

m = rank of event

n = number of water years

Under the current-pumping condition, the frequency of the FH-1 flooding event (56.8 feet, duration of 30 days) has a probability of 67% (1.5-year return interval) compared to a probability of 50% (2-year return interval) for the MFLs condition. The MFLs condition would allow 17 fewer flooding events per 100 years relative to the current-pumping condition. Therefore, the current status of the FH-1is that the minimum level is achieved (Table 1 and Figure 1).

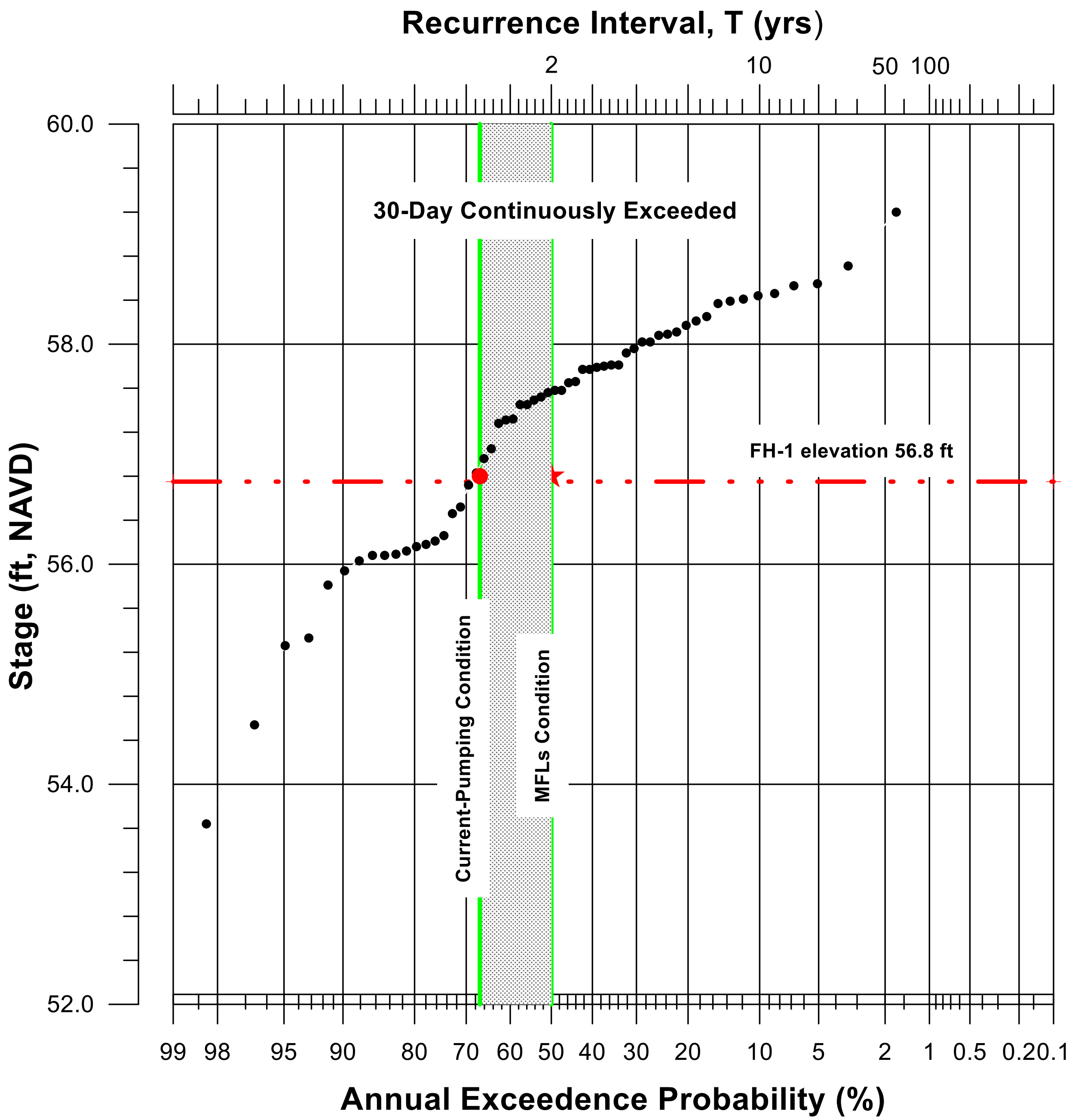



Figure 1. Exceedance probability (bottom axis) and return interval (top axis) of FH-1 for current-pumping (left green line) and MFLs (right green line) conditions. The data plotted (black dots) represent the maximum elevation continuously exceeded for 30 days, for each year in the period of record. The position of the red dot shows the exceedance probability (67%) and return interval (1.5 year) of the FH-1 event, under the current-pumping condition. The position of red star shows the exceedance probability (50%) and return interval (2 years) recommended for the FH-1 event. The dashed red line represents the magnitude component (lake level) for the recommended minimum level.

**Status assessment for FH-2**

Calculating the probability of exceedance of the FH-2 involved the following three steps:

1. Determine the average elevation for the period March 1 to May 31 for each year. In this calculation, only the data between March 1 to May 31 period were used in the frequency analysis. This period corresponds to the sandhill crane nesting season that is the basis for the FH-2. By using the partial data instead of the whole data set, it improves the accuracy of the frequency of the FH-2 defined event for the current-pumping condition.
2. Rank the March 1 to May 31 annually averages from step 1 in descending order.
3. Use Weibull plotting position formula to calculate the probability of exceedance.

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

where $P(S \geq \hat{S}_m)$ = probability of S equaling or exceeding $\hat{S}_m$

m = rank of event

n = number of water years

Under the current-pumping condition, the frequency of the FH-2 flooding event (average of 56.5 feet during March 1 to May 31 period) has a probability of 59% (1.7-year return interval) compared to a probability of 50% (2-year return interval) for the MFLs condition. The MFLs condition would allow 9 fewer flooding events per 100 years relative to the current-pumping condition. Therefore, the current status of the FH-2 is that the minimum level is achieved (Table 1 and Figure 2).

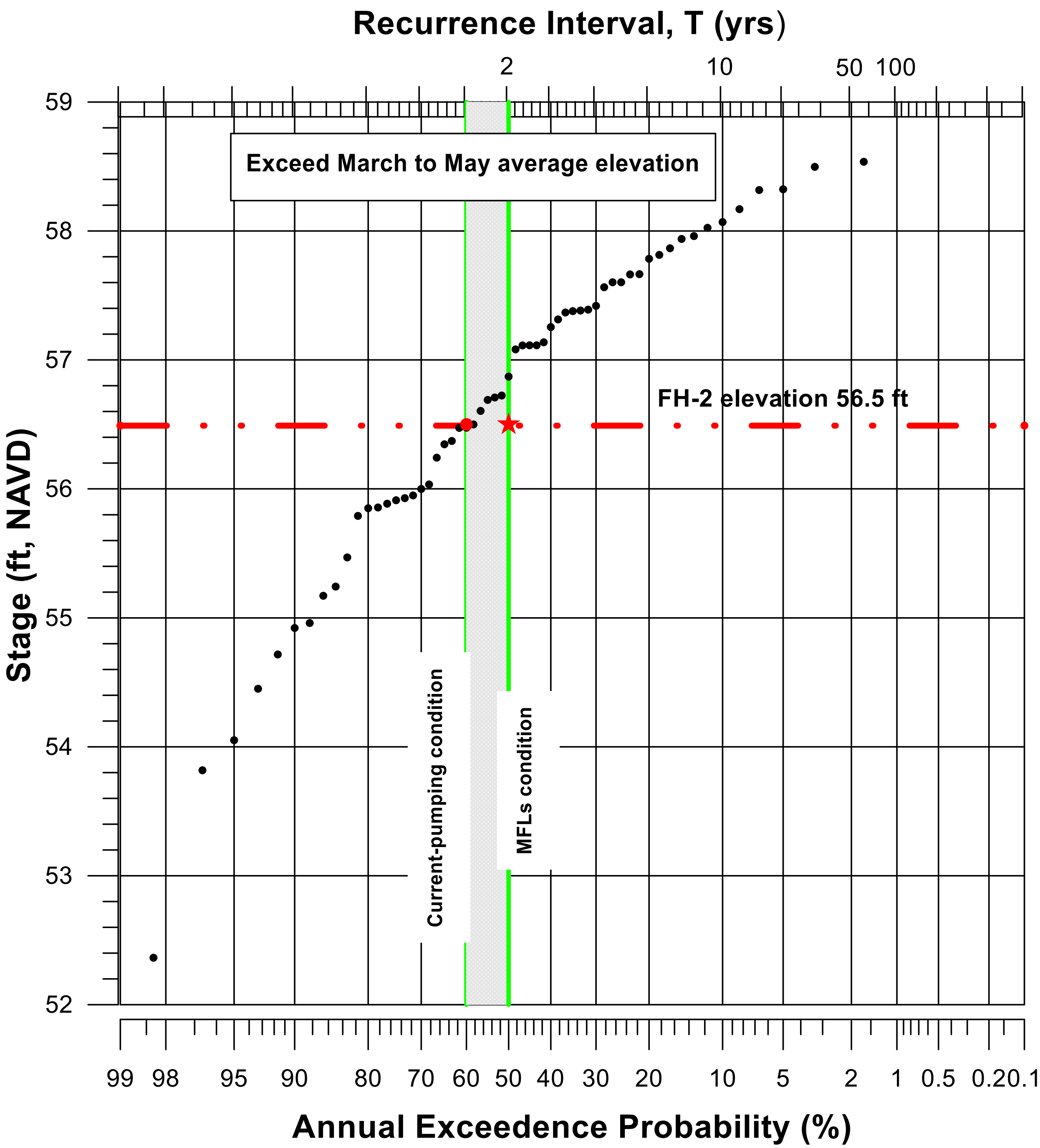



Figure 2. Exceedance probability (bottom axis) and return interval (top axis) of FH-2 for current-pumping (left green line) and MFLs (right green line) conditions. The data plotted (black dots) represent the minimum value for a mean lake level from March 1 to May 31, for each year in the period of record. The position of the red dot shows the exceedance probability (59%) and return interval (1.7 years) of the FH-2 event, under the current-pumping condition. The position of red star shows the exceedance probability (50%) and return interval (2 years) recommended for the FH-2 event. The dashed red line represents the magnitude component (lake level) for the recommended minimum level.

**Status assessment for MA**

Calculating the probability of non-exceedance of the MA involved the following three steps:

1. Determine the annual minimum average elevation not exceeded for the specified duration (180 days) for each water year. The water year for a non-exceedance event is October 1 to September 30.
2. Rank annual minimum averages from step 1 in descending order.
3. Use Weibull plotting position formula to calculate the probability of non-exceedance.

$$P(S < \hat{S}_m) = 1 - \left(\frac{m}{n+1}\right)$$

where $P(S \geq \hat{S}_m)$ = probability of S not exceeding $\hat{S}_m$

m = rank of event

n = number of water years

Under the current-pumping condition, the frequency of the MA drying event (55.9 feet, duration of 180 days) has a probability of 36% (2.8-year return interval) compared to a probability of 59% (1.7-year return interval) for the MFLs condition. The MFLs condition would allow 23 more drying events per 100 years relative to the current-pumping condition. Therefore, the current status of the MA is that this minimum level is achieved (Table 1 and Figure 3).

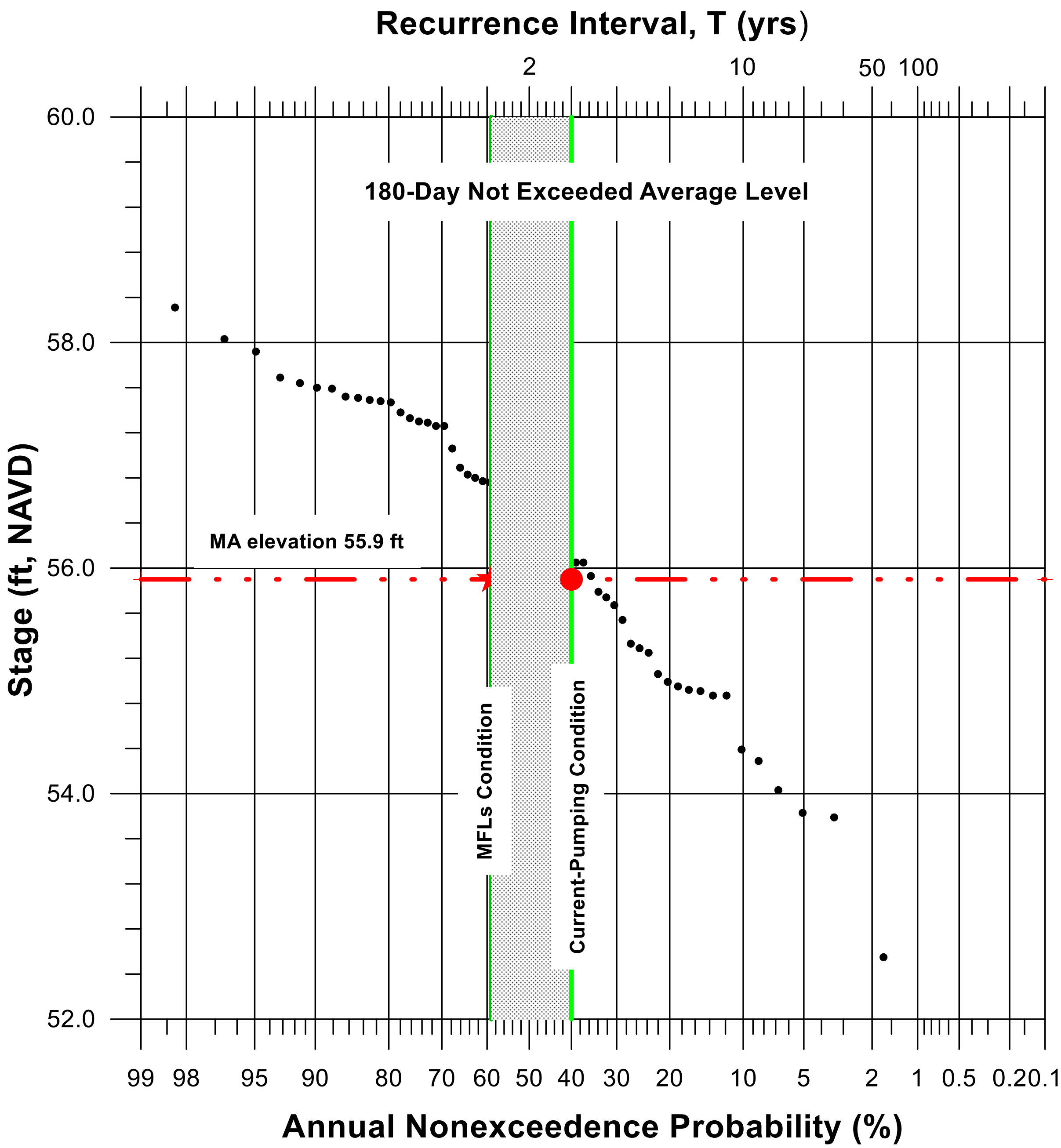



Figure 3. Exceedance probability (bottom axis) and return interval (top axis) of MA for current-pumping (left green line) and MFLs (right green line) conditions. The data plotted (black dots) represent the minimum value for a mean lake level for a duration of 180-days, for each year in the period of record. The position of the red dot shows the exceedance probability (36%) and return interval (2.8 years) of the MA event, under the current-pumping condition. The position of red star shows the exceedance probability (59%) and return interval (1.7 years) recommended for the MA event. The dashed red line represents the magnitude component (lake level) for the recommended minimum level.

**Status assessment for FL**

Calculating the probability of non-exceedance of the FL involved the following three steps:

1. Determine the annual minimum elevation continuously not exceeded for the specified duration (120 days) for each water year. The water year for a non-exceedance event is October 1 to September 30.
2. Rank annual minimums from step 1 in descending order.
3. Use Weibull plotting position formula to calculate the probability of non-exceedance.

$$P(S < \hat{S}_m) = 1 - \left(\frac{m}{n+1}\right)$$

where $P(S \geq \hat{S}_m)$ = probability of S not exceeding $\hat{S}_m$

m = rank of event

n = number of water years

Under the current-pumping condition, the frequency of the FL drying event (53.4 feet, duration of 120 days) has a probability of 2.7% (37-year return interval) compared to a frequency of 20% (5-year return interval) for the MFLs condition. The MFLs condition would allow 17 more drying events per 100 years relative to the current-pumping condition. Therefore, the current status of the FL is that this minimum level is achieved (Table 1 and Figure 4).

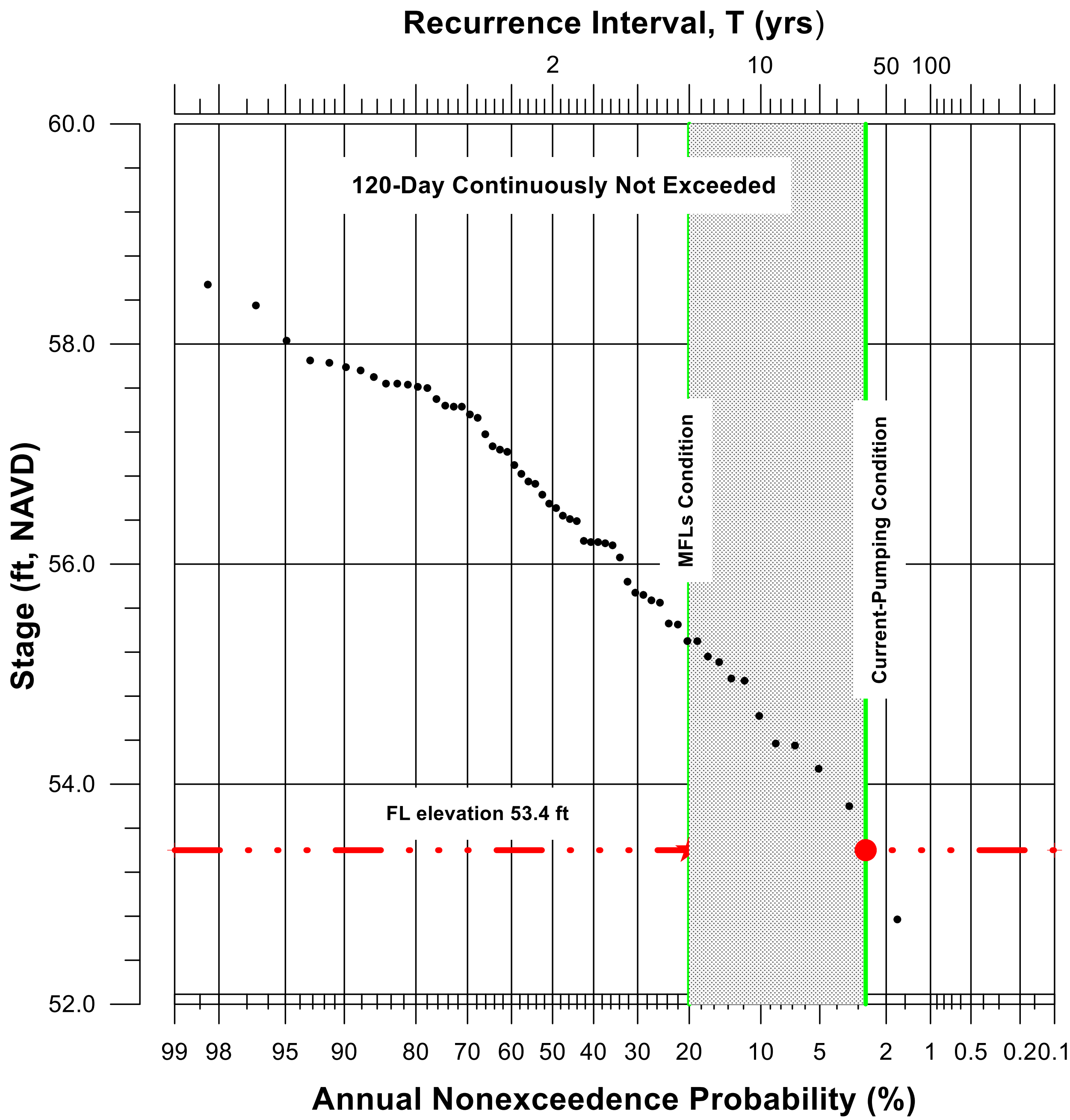



Figure 4. Exceedance probability (bottom axis) and return interval (top axis) of FL for current-pumping (left green line) and MFLs (right green line) conditions. The data plotted (black dots) represent an event which is defined as the lake level not exceeded continuously for 120 days, for each year in the period of record. The position of the red dot shows the exceedance probability (2.7%) and return interval (37 year) of the FL event, under the current-pumping condition. The position of red star shows the exceedance probability (20%) and return interval (5 year) recommended for the FL event. The dashed red line represents the magnitude component (lake level) for the recommended minimum level.

Table 1. Frequency of the four recommended MFLs under current-pumping and MFLs conditions for Lochloosa Lake, Alachua County, Florida

| Recommended MFLs | Environmental Criteria | Frequency of the MFLs event (years per 100-years) | | Difference in number of events between MFLs and current-pumping conditions* |
|---|---|---|---|---|
| | | MFLs Condition | Current-pumping condition | |
| Frequent High 1 (FH-1) | Hardwood/cypress swamp communities / associated wildlife values | 50 | 67 | 17* |
| Frequent High 2 (FH-2) | Sandhill crane nesting | 50 | 59 | 9* |
| Minimum Average (MA) | Organic soils | 59 | 36 | 23** |
| Frequent Low (FL) | Shallow and deep marsh communities / associated wildlife values | 20 | 37 | 17** |

* Represents a decrease in flooding (exceedance) events

**Represents an increase in drying (non-exceedance) events

## UFA Freeboard/Deficit Calculation

Frequency analysis was also used to determine whether there is water available for withdrawal (freeboard) or whether water is needed to recover the UFA (deficit). Freeboard is defined as a UFA reduction (ft) that is allowable before the most constraining MFL is no longer achieved.

Freeboard or deficit calculation involves the following steps:

1. UFA elevations (i.e., water levels at an UFA well) in the surface water model are increased or decreased by small increments (depending on Weibull plot results);

2. Surface water model is run iteratively after each change to UFA elevations, to simulate a new lake stage time series;

3. Frequency analysis and Weibull plotting is repeated;

4. Steps 1 through 3 are repeated until MFL is just 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).

UFA freeboard for each of the four MFLs developed for Lochloosa Lake are presented in Table 2. The FH-2 is the most constraining MFLs since it allows the smallest reduction in UFA level.

Table 2. UFA freeboard for the four MFLs developed for Lochloosa Lake, Alachua County, Florida

| MFLs | Environmental Criteria | UFA freeboard (ft) |
|---|---|---|
| Frequent High 1 (FH-1) | Hardwood/cypress swamp communities / associated wildlife values | 6.4 |
| Frequent High 2 (FH-2) | Sandhill crane nesting | 1.3 |
| Minimum Average (MA) | Organic soils | 3.1 |
| Frequent Low (FL) | Shallow and deep marsh communities / associated wildlife values | >10 |

**Future/Projected Status**

A future status assessment of all minimum levels for Lochloosa Lake was conducted to determine if they are met under projected pumping for the 20-year planning horizon. If the MFLs are currently being achieved but are projected to not be achieved within the 20-year planning horizon, then a waterbody is in “prevention,” and a prevention strategy must be developed.

Whether MFLs for a waterbody are being achieved within the planning horizon is determined by comparing the frequency analysis results (i.e., freeboard) for the most constraining MFL (FH-2) to the amount of projected UFA drawdown at the planning horizon. For Lochloosa Lake, the projected UFA drawdown at the planning horizon was estimated using NFSEG v1.1. The predicted drawdown resulting from projected water use for the 20-year planning horizon is 0.1 feet, which is less than the 1.3 ft of UFA freeboard. Therefore, the MFLs are achieved for the 20-year planning horizon, and Lochloosa Lake is not in prevention or recovery.

# APPENDIX D —WATER RESOURCE VALUE (WRV) ASSESSMENT

Pursuant to Sections 373.042 and 373.0421, F.S., SJRWMD considered the following 10 environmental values (also called water resource values [WRVs]) identified in rule 62-40.473, F.A.C..

1. Recreation in and on the water
2. Fish and wildlife habitats and the passage of fish
3. Estuarine resources
4. Transfer of detrital material
5. Maintenance of freshwater storage and supply
6. Aesthetic and scenic attributes
7. Filtration and absorption of nutrients and other pollutants
8. Sediment loads
9. Water quality
10. Navigation

The determination of whether each WRV is protected was based on whether there was a significant change, from the no-pumping to MFL condition, for specific criteria evaluated for each WRV. For each WRV, a significant harm threshold of 15% was used as the allowable reduction from the no-pumping condition. A 15% threshold for allowable reduction in exceedance of critical elevations, related to both recreation and wildlife habitat, has been used by other water management districts (e.g., SRWMD MFLs for the Lower Santa Fe and Ichetucknee rivers and priority springs; and numerous SWFWMD MFLs). This threshold has been peer reviewed numerous times and has been the basis for numerous adopted MFLs within Florida (Munson and Delfino 2007). No-pumping and MFLs conditions exceedance curves were created to help assess whether relevant environmental values are protected by the recommended MFLs (Figure 1). The exceedance curves were created using no-pumping and MFLs conditions daily lake stage time series respectively. The no-pumping condition time series was simulated using the Lochloosa Lake HSPF/SWMM model, with the no-pumping groundwater level time series as an input (see Appendix B for details). The MFL condition lake stage time series was simulated by lowering groundwater levels incrementally in the HSPF/SWMM model until the model produced a lake level time series that just meets (but does not trip) the most constraining MFL (FH-2).

WRVs 3 and 8 are not applicable to Lochloosa Lake and thus were not considered as part of this assessment.

## 1. Recreation in and on the water

The purpose of this environmental value is to protect, from significant change due to water withdrawal, the active use of water resources and associated natural systems for personal activity and enjoyment. Lochloosa Lake supports various legal recreational activities, such as, boating, fishing, alligator and frog hunting and others. However, the most popular recreational activity on Lochloosa Lake is fishing from boats. FWC designates Lochloosa Lake as a Fish Management Area and it is listed as one of the top waterbodies in Florida for warmouth (*Lepomis gulosus* ), and black crappie (*Pomoxis nigromaculatus*) fishing (http://myfwc.com/fishing/freshwater/sites-forecast/crappie/). Therefore, recreational boat access to the lake is used as the representative function to be protected for this WRV.

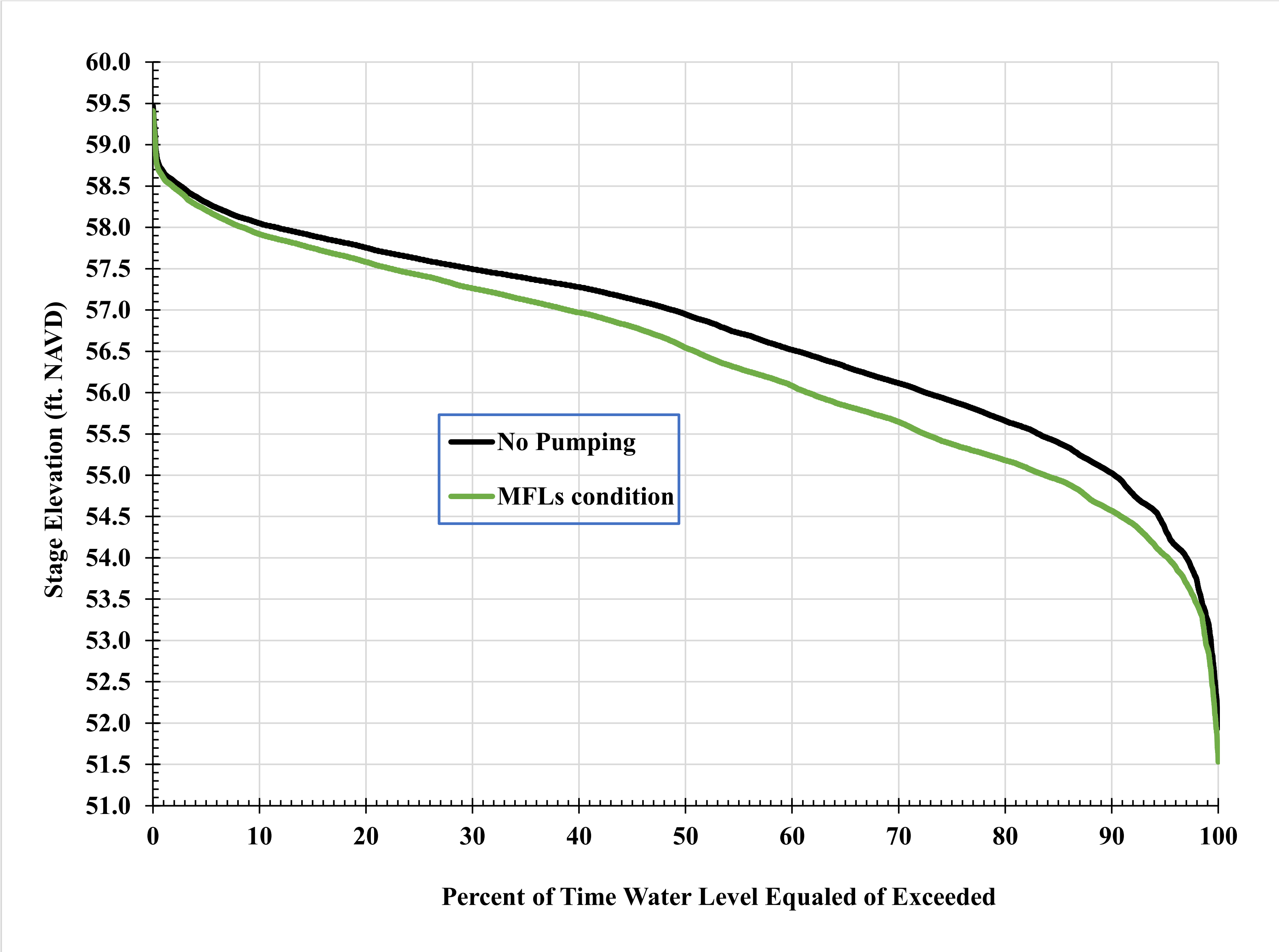



Figure 1. No-pumping condition and MFLs condition exceedance curves for Lochloosa Lake, Alachua County, Florida

To determine whether this WRV is protected by the recommended MFLs, the frequency of exceedance for four important lake levels for boating were compared between MFLs and no-pumping conditions. Exceedance of elevations related to access from boat ramps and docks and for safe boat passage in Cross Creek was evaluated to determine if there was a 15% reduction under the MFLs condition relative to the no-pumping condition.

Two popular boat ramps, accessed from U.S. Highway 301, provide access to Lochloosa lake (Figure 2). A public boat ramp is located in the town of Lochloosa, and a private boat ramp is located at Lochloosa Harbor Fish Camp just north of the town of Lochloosa. In addition, there are approximately 50 private docks located around the lake. SJRWMD staff surveyed lake bottom elevations for both boat ramps and for 16 private docks around the lake. The majority of private docks are located on the east side of the lake and the variation in elevations is small (Figure 2). Because many docks were in disrepair at the time of evaluation, the only docks surveyed were those with a moored boat. Most of the boats used for recreational activities on this lake are 20 ft or less in length (personal communication with FWC staff), and the typical draft is approximately 2 ft for boats less than 20 ft long (http://www.selway-fisher.com/Mc2130.htm; Georgia Boating Safety Course/Get Certified Online/boat-ed.com). To account for the typical boat draft and ensure access at boat ramps and docks, 2 ft was added to the waterward boat ramp elevation and to the mean waterward lake bottom elevation of 16 private docks to represent the minimum accessible lake elevation (minimum access elevation) from those locations.

Cross Creek is an important waterway, used by the public to travel between Lochloosa Lake and Orange Lake. Numerous homes with docks are also located along Cross Creek. The effect of recommended MFLs on boat travel in Cross Creek was evaluated by determining the change in exceedance of a critical high-spot elevation, from the no pumping to MFLs condition. This minimum boat passage elevation at Cross Creek was based on seven cross sections surveyed in July 2007 (See Appendix A for detailed survey data). At the shallowest part along Cross Creek, the creek bottom elevation is 52.7 ft NAVD. Adding a 2 ft boat draft to this critical high spot elevation yields the minimum boat passage elevation of 54.7 ft for Cross Creek. Minimum elevations for boat access and passage at the two boat ramps and at Cross Creek, and the mean minimum boat access elevation of 16 docks are summarized in Table 1.

Results indicate that the reductions in exceedance of all four critical elevations related to recreation were less than 15% under the MFLs condition relative to the no-pumping condition (Table 1 and Figure 3). Based on these results, this environmental value is considered protected by the recommended minimum hydrologic regime (i.e., the MFLs condition).

Table 1. Minimum boat access/passage elevation at boat ramps, docks, and at Cross Creek, and the percent reduction in exceedance over these elevations comparing the no-pumping and MFLs conditions

| | Minimum access elevation (ft, NAVD88) | Number of days per year that exceeds the min. access elevation (day/year) | | Percent reduction in exceedance of boat access/passage elevations under MFLs condition relative to no-pumping condition (%) |
|---|---|---|---|---|
| | | No-pumping | MFL | |
| Public boat ramp | 51.2 | 365 | 365 | 0 |
| Private Docks | 54.7 | 338 | 332 | 5 |
| Cross Creek | 54.7 | 338 | 332 | 5 |
| RV park boat ramp | 55.2 | 320 | 290 | 9 |

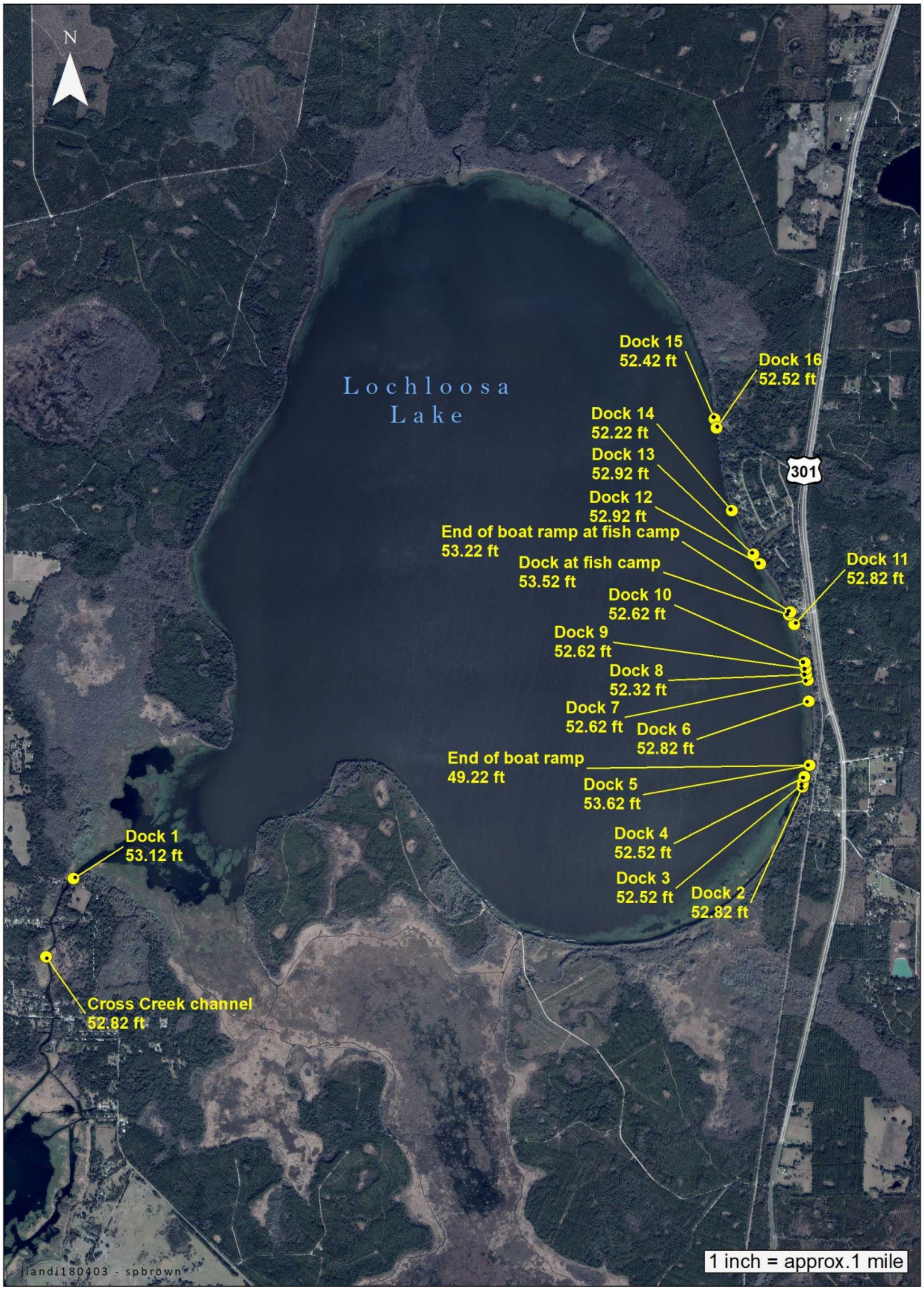



Figure 2. Location and elevations of two boat ramps and 16 docks at Lochloosa Lake

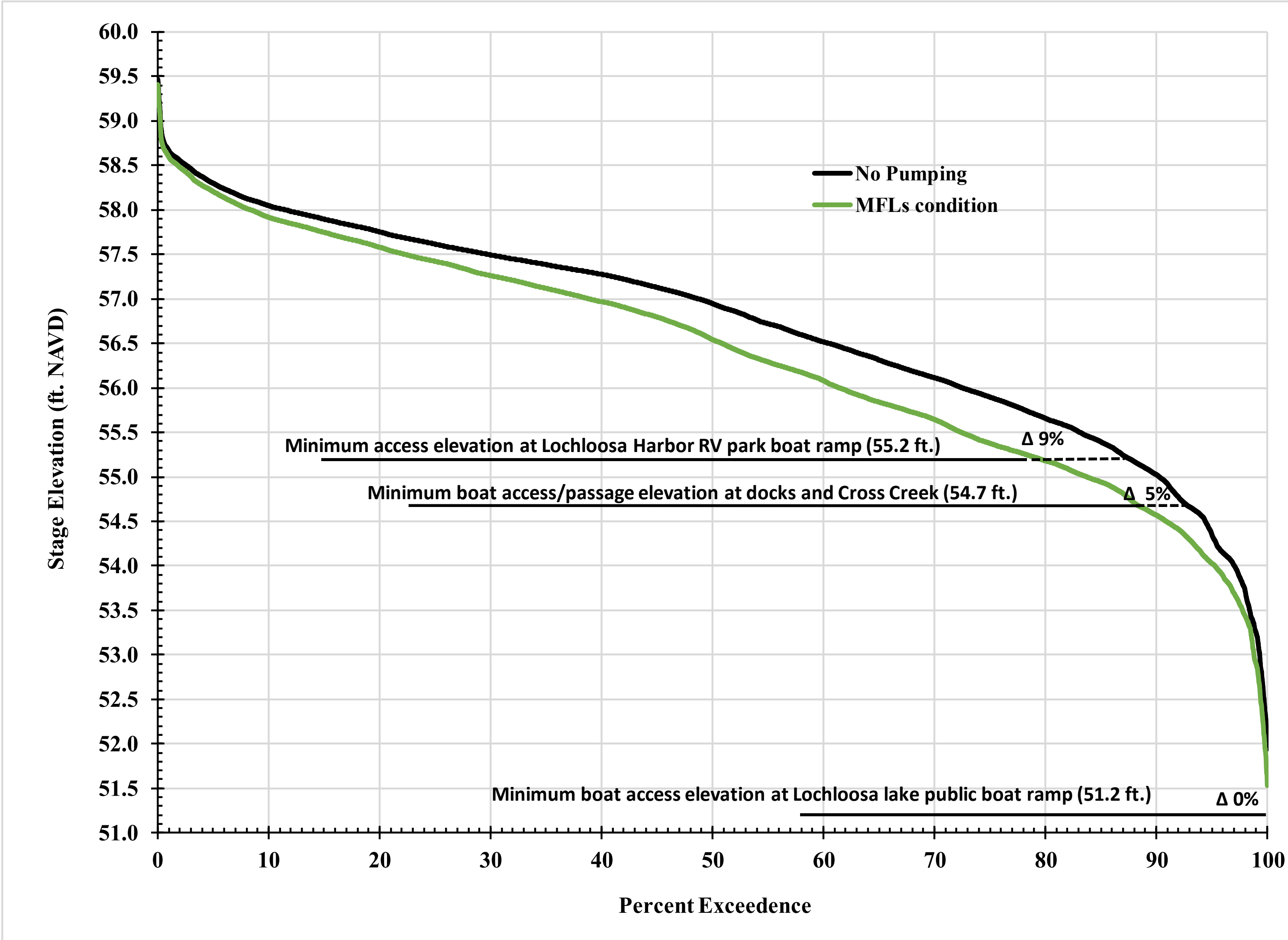



Figure 3. Minimum boat access/passage elevation at boat ramps, docks, and at Cross Creek, and percent exceedance at minimum boat access/passage elevations under no-pumping and MFLs conditions

## 2. Fish and wildlife habitat and the passage of fish

The purpose of this environmental value is to protect, from significant change due to water withdrawal, aquatic and wetland environments required by fish and wildlife. Minimum hydrologic requirements necessary to support the life cycles of aquatic, wetland and wetland-dependent species were considered in multiple ways.

The most constraining recommended minimum lake level for Lochloosa Lake is based on maintaining sandhill crane nesting habitat (see *MFLs Determination* section). This metric is the most sensitive to withdrawal, of the numerous fish and wildlife criteria evaluated by SJRWMD staff and was based on consultation with FWC. The other three recommended minimum levels (FH, MA and FL) are designed to protect hardwood swamp and deep marsh wetland communities, and organic soils. Because they are less constraining than the recommended sandhill crane metric, fish and wildlife that utilize/inhabit wetland communities at Lochloosa Lake are considered protected under the recommended MFLs Condition.

In an effort to examine the potential effect of the MFLs condition on other important fish and wildlife values not captured in the MFLs determination, the difference in exceedance between the no-pumping and MFLs conditions was evaluated for critical lake levels important for key fish and wildlife species and habitats. Based on recommendations by FWC, critical elevations for protecting several regionally significant fish and wildlife species were evaluated. These elevations are relevant to (1) water depth necessary to protect wading bird nesting in shallow marsh habitats, (2) water depth necessary to protect fish passage in Cross Creek, and (3) water depth necessary to protect largemouth bass (*Micropterus salmoides*) spawning habitat within deep marsh habitats (Table 2).

<u>Critical elevation for protecting wading bird nesting habitat within the RALL marsh– 56.2 ft. NAVD</u>

The Right Arm Lochloosa Lake (RALL) consists of approximately 1,500 acres of shallow marsh habitats. Its diverse vegetation community provides high quality habitat for many wildlife species including wading birds, waterfowl, and herpetofauna (reptiles and amphibians). Wading bird is a generic term, that includes a diverse group of birds utilizing aquatic habitats and adjacent forested wetland habitats. Most wading birds that use the RALL marsh are in the avian order Ciconiiformes and families Ardeidae (herons, egrets, and their allies), Threskiornithidae (ibises and spoonbills), and Ciconiidae (storks). Shallow marsh habitat is important for foraging and loafing of Ciconiiformes wading birds and provides nesting and foraging habitat for cranes, rails and gallinules. High quality foraging habitat should improve foraging success rates, which ultimately would result in higher nestling survivorship and fledging rates when coupled with available nesting substrate. Waterfowl, such as wood ducks and dabbling ducks also utilize shallow marsh for forage and cover. Herpetofauna including a variety of frogs, salamanders, turtles, snakes, and alligators, including primarily terrestrial species that forage and/or breed in the shallow marsh habitat.

There are four vegetation communities within the RALL marsh, including mixed shrub swamp, tall linear-leaved shallow marsh, mixed shallow marsh, and herbaceous marsh dominated by *Panicum hemitomon* (maidencane). The average elevation of shallow marsh habitat in the RALL marsh is 55.5 ft. To protect wading bird nesting habitat water must be present under nesting colonies at sufficient levels to deter predation, and FWC scientists recommended water depths ranges from 0.2 ft. – 0.7 ft. The lake stage elevation of 56.2 ft., which is the mean elevation of RALL (55.5 ft) plus 0.7 ft, was determined as a critical elevation for protecting wading bird nesting habitat.

Lake levels exceed the 56.2 ft level (the critical elevation for wading bird nesting) 210 days per year under the MFL condition, compared to 247 days per year under the no-pumping condition, resulting in a difference of 37 days per year. This 37-day difference equals a 15% loss in temporal exceedance of the critical elevation under the MFLs condition, relative to the no-pumping condition. Because the reduction is not more than 15%, this environmental value is considered protected under the MFLs condition (Table 2 and Figure 4).

<u>Critical elevation for protecting fish passage in Cross Creek – 54.3 ft. NAVD</u>

A critical fish passage depth was determined based on previous studies. Much of the early work on fish passage depths is related to Salmonid species in cold-water systems. Thompson (1972) developed minimum depth criteria (0.6 – 0.8 feet) for salmon passage in cold-water rivers. A minimum water depth criterion of 1.6 feet was used to protect the passage of large fish (largemouth bass, gar, and catfish) in the MFL developed for the St. Johns River between SR 528 and SR 46 (HSW 2007). As stated above, Cross Creek is an important waterway that connects Lochloosa Lake and Orange Lake. In addition to providing a connection for boaters, Cross Creek also provides an important connection for fish and wildlife. At the shallowest section of Cross Creek, the creek bottom elevation is 52.7 ft. NAVD. A water depth of 1.6 ft. at this shallowest section should ensure fish passage between the two lakes. As such, an elevation of 54.3 ft. (52.7 ft. plus 1.6 ft.) was determined as the critical elevation for protecting fish passage between Lochloosa and Orange lakes.

Lochloosa Lake exceeds the 54.3 ft elevation 339 days per year under the MFLs condition, compared to 347 days per year under the no-pumping condition, with a difference of 8 days per year. This equates to a 2% reduction in exceedance and number of days accessible for fish passage under the MFLs condition. Since the reduction is less than 15%, this environmental value is considered protected under the MFLs condition(Table 2 and Figure 4).

<u>Critical elevation for protecting largemouth bass spawning habitat - 54.7 ft. NAVD</u>

Within Lochloosa Lake, game fish spawning habitat is limited by wide-spread, unconsolidated organic matter on the lake bottom. While largemouth bass, and other game fish, typically use firm substrate for spawning, in Lochloosa Lake the prefer spawning substrate is vegetation (FWC staff pers. comm.). Spatterdock, knotgrass, maidencane, and smartweed stalks are the preferred substrate for largemouth bass nest sites in Lochloosa Lake.

Based on consultation with FWC, an average water depth of 3.1 ft. is recommended for protecting largemouth bass nesting habitat in deep marshes. This recommended water depth is also consistent with largemouth bass nesting sites reported for other waterbodies within Florida (Strong et al. 2010). At Lochloosa Lake, the average elevation for *Nuphar* dominated deep marsh is 51.6 ft NAVD. As such, an elevation of 54.7 ft. (51.6 ft. plus 3.1 ft) was determined as the critical elevation for protecting largemouth bass nesting habitat.

Lochloosa Lake levels exceed the largemouth bass critical elevation 322 days per year under the MFL condition, compared to 338 days per year under the no-pumping condition, with a difference of16 days per year. This equates to a 5% loss in bass spawning habitat relative to the no-pumping condition (Table 2).

The reduction in exceedance of all fish and wildlife-related critical elevations was less than or equal to 15% under the MFLs condition relative to the no-pumping condition (Table X). Therefore, this WRV is considered protected under the MFLs condition (Table 2 and Figure 4).

Table 2. Lochloosa Lake elevations important to resident fish and wildlife species, and the percent reduction in exceedance over these important elevations comparing the no-pumping and MFLs conditions

| **Habitat** | **Important elevation (ft. NAVD88)** | **Number of days per year exceeds the important elevation (day/year)** | | **Percent reduction in exceedance of fish and wildlife critical elevations under MFLs condition relative to no-pumping condition (%)** |
|---|---|---|---|---|
| | | **No-pumping** | **MFL** | |
| Wading bird nesting | 56.2 | 247 | 210 | 15 |
| Fish passage | 54.3 | 347 | 339 | 2 |
| Largemouth bass nesting | 54.7 | 338 | 332 | 6 |

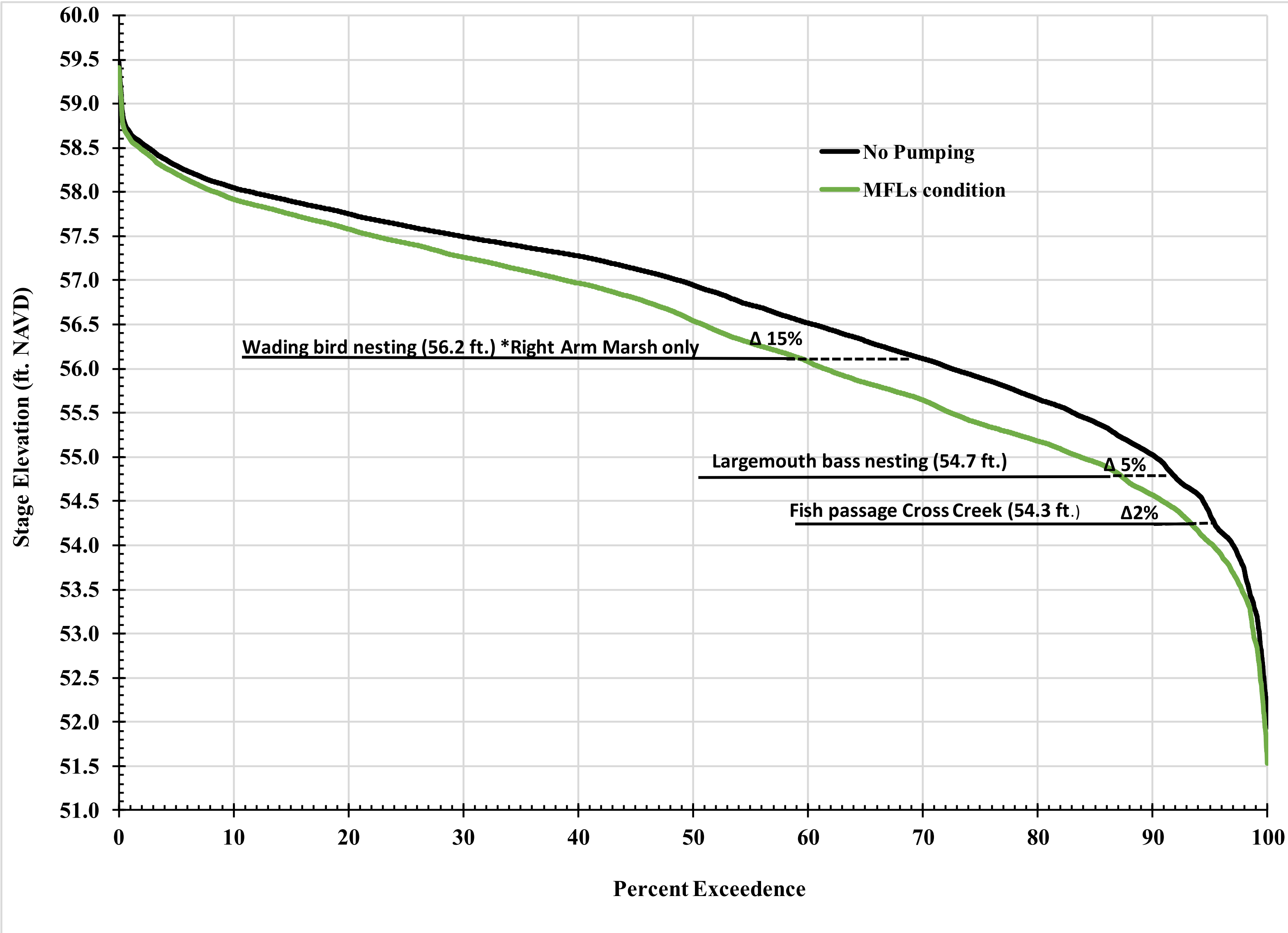



Figure 2. Percent exceedance at three critical elevations for fish and wildlife under the no-pumping and MFLs conditions

## 3. Estuarine resources

The purpose of this environmental value is to protect, from significant change due to water withdrawal, coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets freshwater. These resources are not affected by the recommended minimum hydrologic regime at Lochloosa Lake, and therefore this environmental value was not evaluated.

## 4. Transfer of detrital material

The purpose of this environmental value is to protect, from significant change due to water withdrawal, the production and movement of particulate organic matter and its associated fauna that form the base of invertebrate and fish food webs.

Detrital material is an important component of aquatic food webs (Mitsch and Gosselink 2015). Wetland communities, such as hardwood swamp and shallow marsh, are importance sources of detrital material for the Lochloosa Lake system. For this analysis, the transport of detritus is defined as the movement by water of loose organic material and debris and associated decomposing biota. The organic particles consist of decomposing vegetation, including leaves and wood, processed by microbes (e.g., bacteria and fungus).

A significant portion of detrital transfer occurs during periods of high water, when accumulated detrital materials in floodplain wetlands are transported to aquatic habitats. Therefore, maintaining the hydrologic regime (with characteristic high and low water levels) of floodplain wetland habitat is essential to the supply and transport of detrital material.

The highest elevation seasonally flooded wetlands at Lochloosa Lake are hardwood swamps. The mean elevation of hardwood swamps, based on field surveys, was used as the threshold stage for evaluating the effect of the MFLs condition on the transport of detrital material from the floodplain at Lochloosa Lake. This corresponds to the elevation used for the recommended minimum Frequent High (minimum elevation equals 56.8 ft NAVD)

A ≥30-day duration is recommended for the minimum Frequent High, to protect hardwood swamp habitat. It is reasonable to assume that a flooding duration sufficient to protect hardwood swamp habitat would also provide for adequate detrital transfer between seasonally flooded and aquatic habitats. It is also important to note that while the mean hardwood swamp elevation is flooded for 30 days, all higher elevations will also continue to be flooded, just at a slightly smaller duration than under the no-pumping conditions.

To determine whether this WRV is protected by the recommended MFLs, the exceedance at the critical elevation (described above) was compared under no-pumping and MFLs conditions (Table 3). This comparison shows that there is a small (7%) reduction in the exceedance of a 30-day flooding event under the MFLs condition, relative to the no pumping condition. This small change in exceedance is not considered significant. Therefore, detrital transport at Lochloosa Lake is considered protected under the recommended MFLs hydrologic regime.

Table 3. Frequency analysis of critical elevation for transferring detrital material

| Metric | Threshold elevation (ft NAVD) | Duration (days) | No-pumping | MFLs | Difference |
|---|---|---|---|---|---|
| | | | Number of years per 100 years threshold elevation continuously exceeded | | |
| Hardwood swamp | 56.8 | 30 | 70 | 63 | 7 |

5. **Maintenance of freshwater storage and supply**

The purpose of this environmental value is to protect, from significant change due to water withdrawal, an adequate amount of freshwater for non-consumptive uses and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology. This environmental value encompasses all other environmental values identified in Rule 62-40.473 F.A.C.. Because the overall purpose of the MFL is protect environmental resources, and other non-consumptive beneficial uses while also providing for consumptive uses, this environmental value is considered protected if the remaining relevant values are protected.

6. **Aesthetic and scenic attributes**

The purpose of this environmental value is to protect, from significant change due to water withdrawal, those features of a waterbody typically associated with passive uses, such as bird-watching, sightseeing, hiking, photography, contemplation, painting and other forms of relaxation.

Given the lack of statutory or other guidance, this WRV was evaluated based on the change to the area of open water habitat at the median (P50) water level, resulting from the recommended MFLs hydrologic regime. Extent of open water habitat (acres) at the P50 water level was compared between the no pumping and MFLs condition.

The long-term median lake level is 56.95 ft and 56.54 ft for the no-pumping and MFLs condition, respectively. The lake stage-area relationship developed for the Lochloosa Lake hydrologic and water quality model was used to determine the difference in surface area between these two elevations (Figure 5; Clapp and Smith 2015).

The P50 lake surface area under the MFL condition is approximately 263 acres less than under the no-pumping condition. This corresponds to an approximate 2.9% reduction in area at long-term median lake level (Table 4). This small reduction on open water would have an insignificant impact on aesthetics and scenic attributes, and therefore, this WRV is considered protected by the recommended MFLs hydrologic regime.

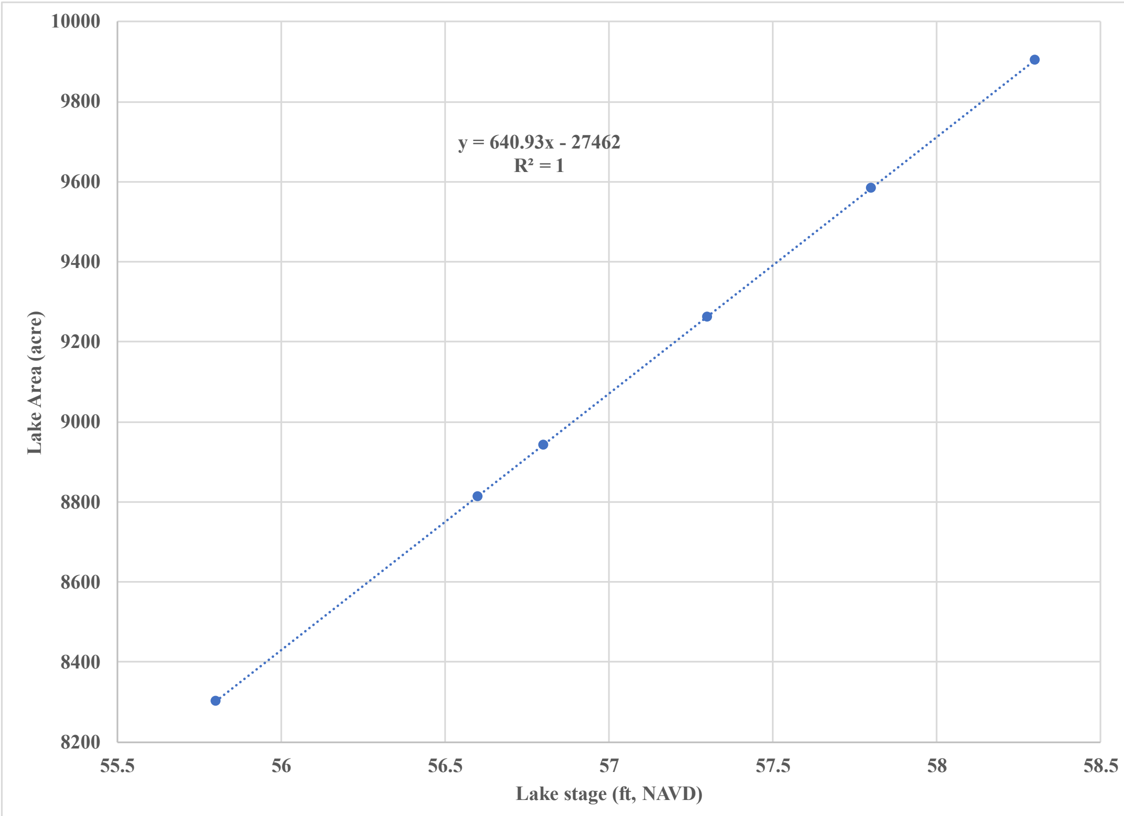



Figure 3. Relationship between lake level and surface area at Lochloosa Lake

Table 1. Lake area at median stage elevation and percent change between the no-pumping and MFLs conditions

| Hydrologic condition | Median stage (ft, NAVD) | Lake area at median stage (acres) | Area change between no-pumping and MFL at P50 (acres) | Percent change in lake area between no-pumping and MFLs conditions at P50 (%) |
|---|---|---|---|---|
| No-pumping | 56.95 | 9039 | 263 | 2.9% |
| MFL | 56.54 | 8776 | | |

7. **Filtration and absorption of nutrients and other pollutants**

The purpose of this environmental value is to protect, from significant change due to water withdrawal, the ability of a waterbody to mitigate the negative effects of elevated 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 are processed by associated organisms.

Wetlands serve important ecosystem functions by filtering and absorbing nutrients and other pollutants from surface water runoff, serving as sinks for nutrients deposited from the drainage basin during periods of inundation, and allowing long-term removal through sedimentation, plant uptake, and microbial action (Adams 1997, Labaree 1992, Boudreau et al. 2004). 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). Such functions are expected to occur in the wetlands surrounding Lochloosa Lake. Conversely, excessive reduction of saturation of wetland soils may reduce filtration and absorption of pollutants by marsh habitat, and enhance solubility of nutrients, leading to nutrient fluxes during reflooding (Harris *et al*., 1995, Olila *et al*., 1997, White *et al*., 2004).

More than 3,000 acres of hardwood swamp, shallow marsh and deep marsh surround Lochloosa Lake. These wetland communities promote the key nutrient dynamics discussed above. The flooding and dewatering events maintained by the recommended MFLs (see *Determination* section) provide protection for these important functions. The assessment of whether this WRV is protected by the proposed MFLs for Lochloosa Lake is assessed by comparing the change in frequency of both flooding and drying events, between the MFLs and no-pumping conditions. This analysis shows a small (7) reduction in the number of annual flooding events, per 100 years, in seasonally flooded wetlands. There is an even smaller (0.6) difference in the number of annual drying (non-exceedance) events between the MFLs and no pumping conditions (Table 5).

This small reduction in the exceedance of the average hardwood swamp elevation and slight increase in the frequency of exposure of the minimum shallow marsh elevation is not considered significant. Based on this small change, the pollutant filtration and absorption functions of Lochloosa Lake are considered protected under the recommended MFLs hydrologic regime.

Table 2. Frequency analysis of threshold elevations for pollutant filtration and absorption for Lochloosa Lake

| Metric | Threshold elevation (ft NAVD) | Duration (days) | No-pumping | MFLs | Difference |
|---|---|---|---|---|---|
| | | | Number of years per 100 years threshold elevation continuously exceeded | | |
| Hardwood swamp elevation | 56.8 | 30 | 70 | 63 | 7 |
| Minimum shallow marsh elevation | 53.4 | 120 | 2.6 | 3.2 | 0.6 |

## 8. Sediment loads

The purpose of this environmental value is to protect, from significant change due to water withdrawal, the ability of a system to transport inorganic sediment. This resource is not affected by the recommended minimum hydrologic regime at Lochloosa Lake, and therefore this environmental value was not evaluated.

## 9. Water quality

The purpose of this environmental value is to protect, from significant change due to water withdrawal, the ambient chemical and physical properties of a waterbody. Excessive nutrient concentrations, and associated changes to trophic state (e.g., increased algal production) are the primary water quality issues in Lochloosa Lake. Lochloosa Lake is a hypereutrophic (highly productive) lake with mean Chl-a, TP and TN concentrations of 0.055 mg/L, 0.068 mg/L, and 1.89 mg/L, respectively. Tropic State Index (TSI) is a measure of water quality calculated using Chl-a, TP, and TN, with values above 70 considered poor water quality, and values 60 or below considered good water quality (Friedemann and Hand 1989). There is a positive, but not statistically significant, trend in TSI values at Lochloosa Lake. The long-term TSI average is 68, which is considered indicative of fair water quality (Figure 6).

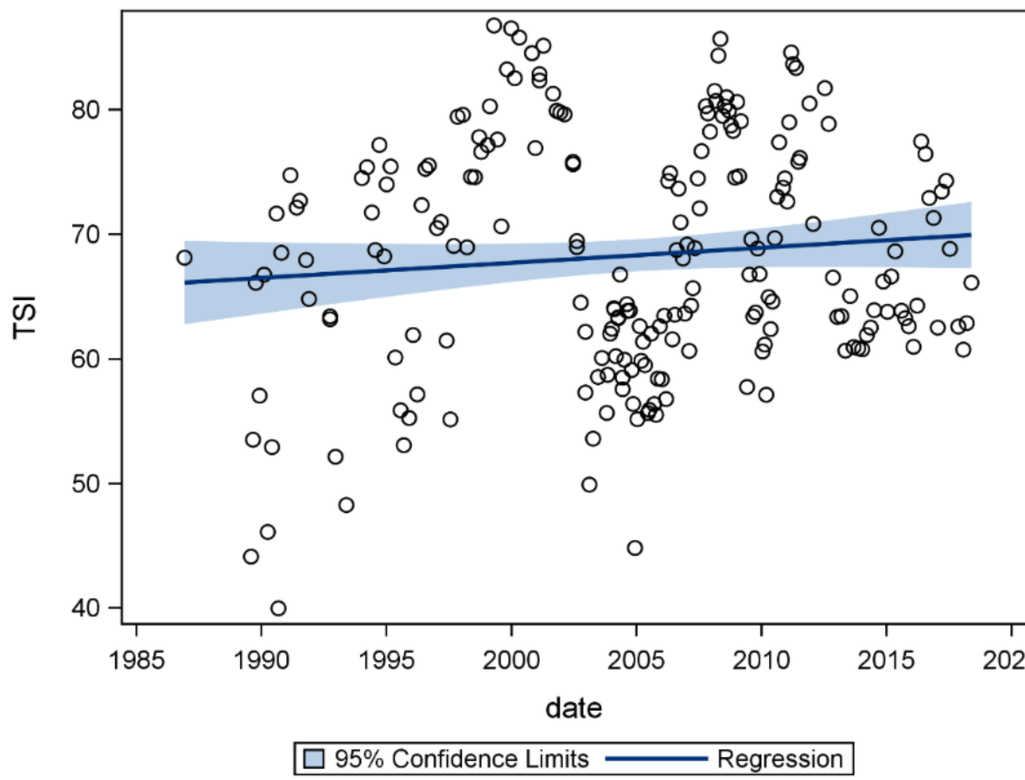



Figure 6. Lochloosa Lake TSI from 1986 to 2018

The major cause of water quality deterioration in Lochloosa Lake is excessive nutrient loading from the watershed. In 2017, FDEP adopted TMDLs for Lochloosa Lake, with restoration target concentrations for TP and TN of 0.055 mg/L and 1.15 mg/L, respectively (Magley 2017). To achieve these restoration targets, FDEP recommends reductions in external (i.e., watershed) and internal loading of TP and TN by 41% and 59%, respectively. These goals are being addressed and implemented through FDEP's Basin Management Plan.

Phosphorus (P) is an essential element for all life forms. However, an excessive concentration of P is the most common cause of eutrophication in Florida freshwater lakes

(Kratzer and Brezonik 1984), and is negatively correlated with water level in many Florida lakes. At Lochloosa Lake, however, P concentration is not correlated to lake level (Figure 7). This suggests that lake level reduction would not have a significant effect on TP concentration Lochloosa Lake.

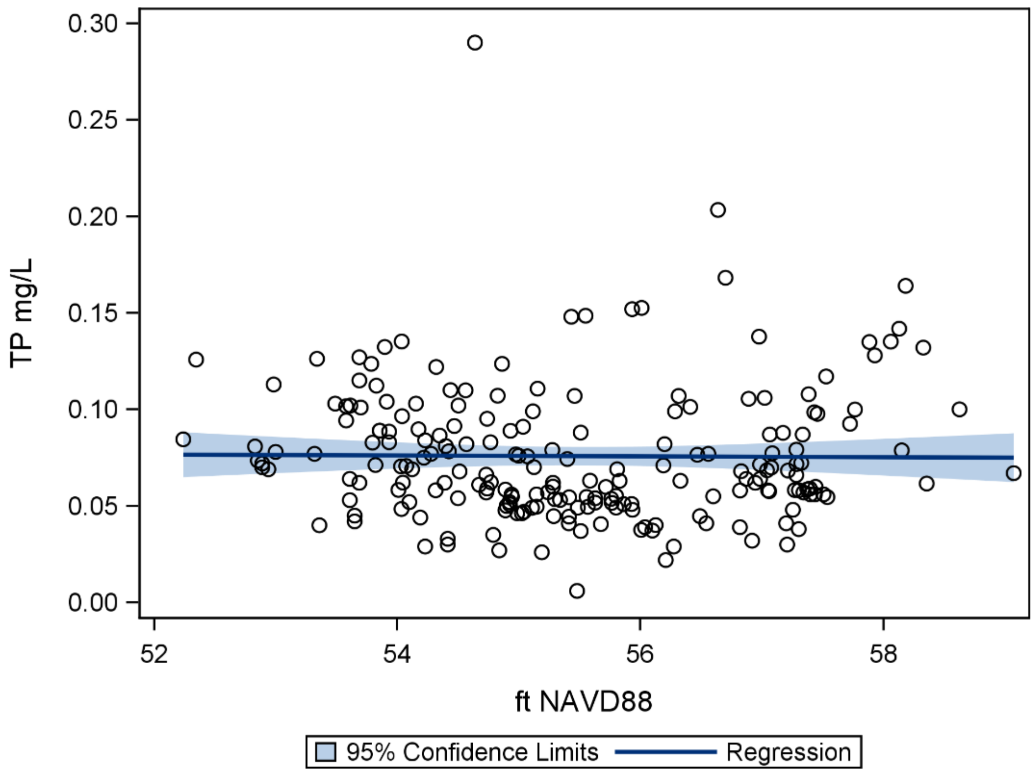



Figure 7. Regression between TP and Lochloosa Lake stage

To evaluate whether this WRV is protected by the recommended MFLs, the change in exceedance between the no-pumping and MFLs conditions were evaluated for TSI values that exceed the poor water quality threshold of 70. It is assumed that this WRVs is protected under the no-pumping hydrologic regime with a long term median lake level of 56.95 ft NAVD. It is also assumed that this WRV is protected if there is a small change in the frequency of threshold violations (TSI>70) between no pumping and MFLs conditions.

Logistic regression was used to evaluate the relationship between lake level and TSI value, because the latter (response variable) is binary (i.e., it either exceeds 70 or does not). Figure 8 and Table 6 present the logistic regression plot and associated parameter estimates for the logistic regression model that compares the relationship between lake level and TSI values that exceed 70. Using the model estimates in Table 6, at stage 56.95 ft (the long term no-pumping median), the probability of having a TSI value that exceeds 70 is 31%. At the recommended MFLs median elevation of 56.54 ft, the probability of having a TSI value that exceeds 70 is 39% (Figure 8). The difference between these two scenarios is 8%, which represents a small increase in the probability of exceeding the poor water quality threshold.

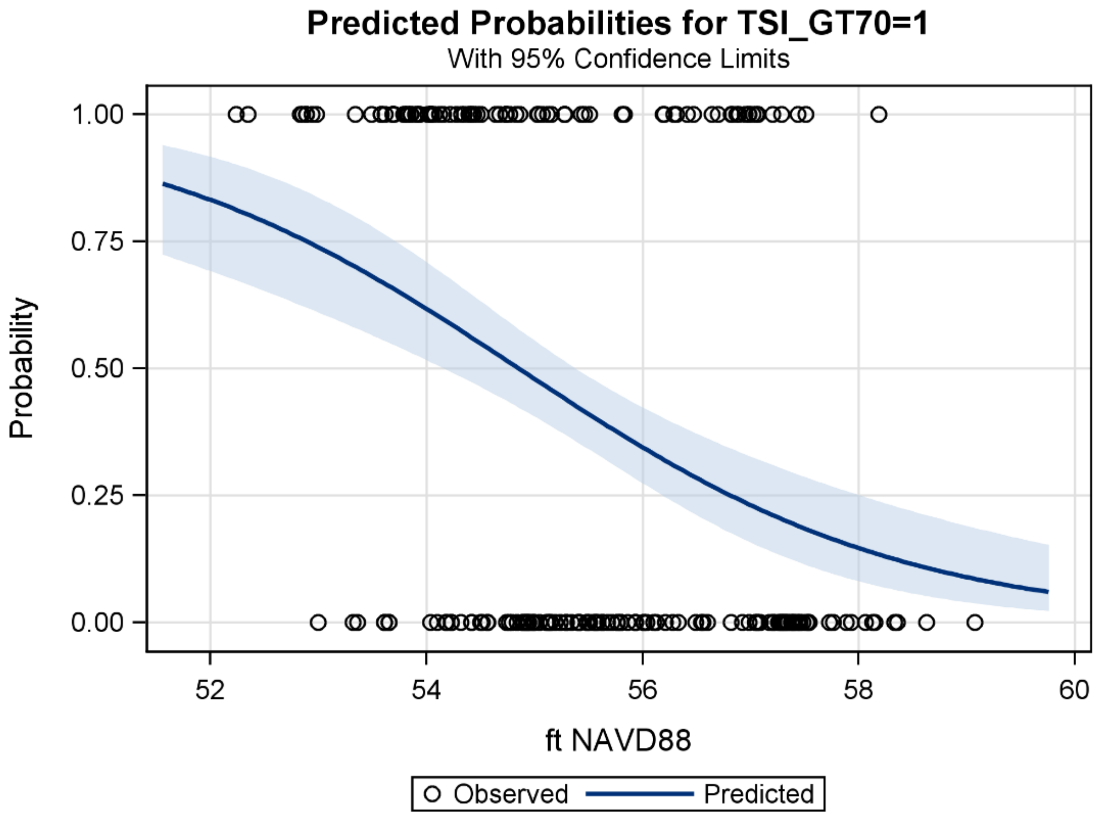



Figure 8. Logistic regression plot between lake stage and probability that TSI value exceeds 70

Table 6. Parameter estimates of the logistic regression model for estimating the probability of TSI exceeding 70 at a given stage

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr>ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 30.7185 | 6.2661 | 24.03 | <0.0001 |
| Stage (NAVD88) | 1 | -0.56 | 0.1133 | 24.45 | <0.0001 |

In addition to using the TSI for evaluating whether this WRV is protected by the MFLs, the probability of exceeding the TMDL targets of Chl-a, and TN was compared between no-pumping and MFLs conditions. Chl-a and TN are negatively correlated with lake stage (Figures 9 and 10). The Chl-a TMDL target is 0.038 mg/L and TN target is 1.15 mg/L (Magley 2017).

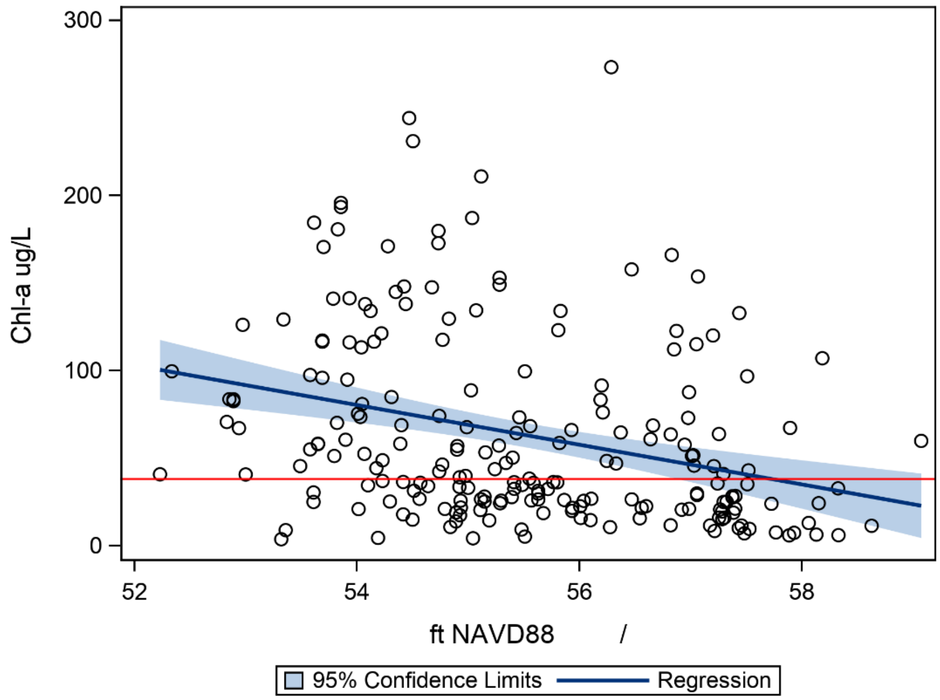



Figure 9. Regression between Chl-a and Lochloosa Lake stage. Red line is the Chl-a TMDL target of 0.038 mg/L.

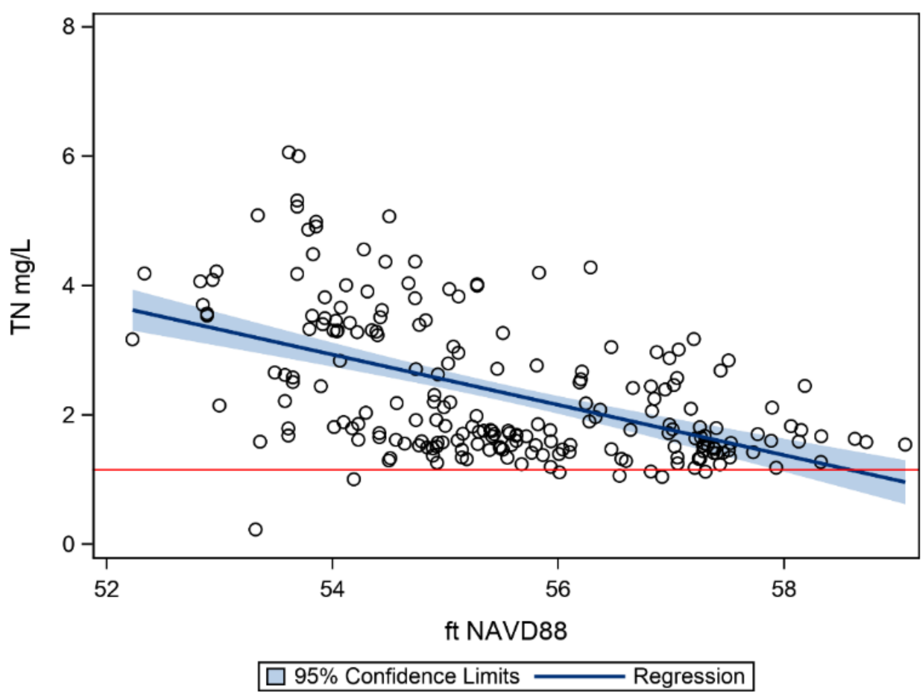



Figure 10. Regression between TN and Lochloosa Lake stage. Red line is the TMDL target concentration 1.15 mg/L.

Logistic regression was used to estimate the probability of Chl-a concentration exceeds the target value of 0.038 mg/L at median lake stage of no-pumping and MFLs conditions. Chl-a is treated as a binary variable (i. e., it either exceeds 0.038 or does not). The probability of exceeding the Chl-a concentration target is 37% and 42% at the median lake stage of no-pumping (56.95 ft) and MFLs (56.54 ft) conditions respectively (Table 7 and Figure 11). The difference between these two scenarios is 5% which represents a small increase in the probability of exceeding the Chl-a TMDL target concentration threshold.

Table 7. Parameter estimates of the logistic regression model for estimating the probability of Chl-a exceeding 0.038 mg/L at a given stage

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr>ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 27.4455 | 5.9389 | 21.36 | <0.0001 |
| Stage (NAVD88) | 1 | -0.4909 | 0.1068 | 21.11 | <0.0001 |

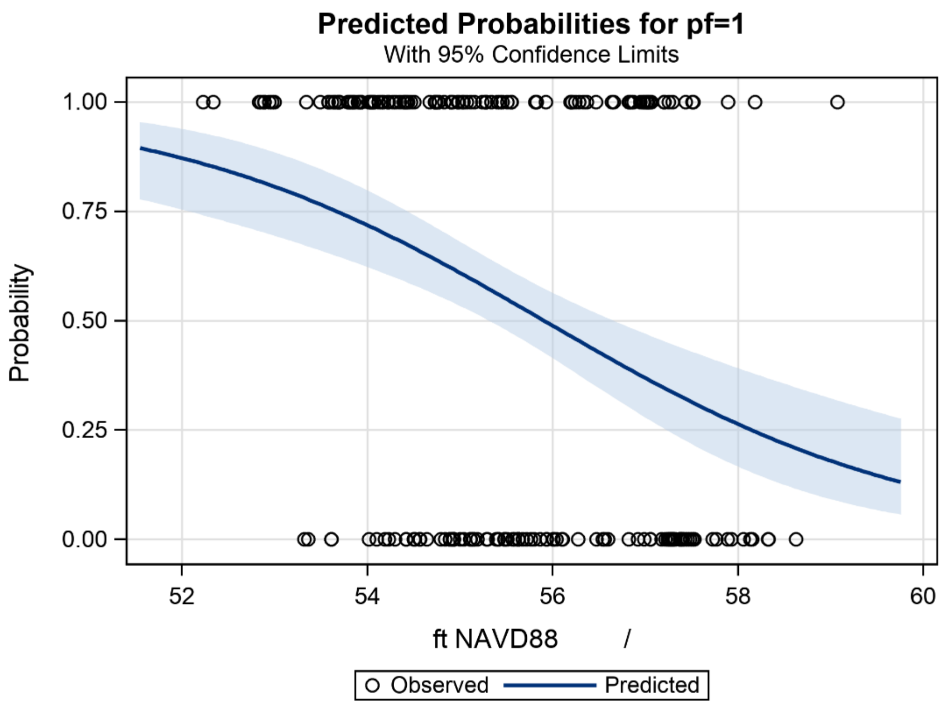



Figure 11. Probability of Chl-a exceeds 0.038 mg/L TMDL target at different lake levels.

The probability of exceeding 1.15 mg/L TN TMDL target threshold is statistically the same at the no-pumping median stage relative to MFLs median stage (Figure 12).

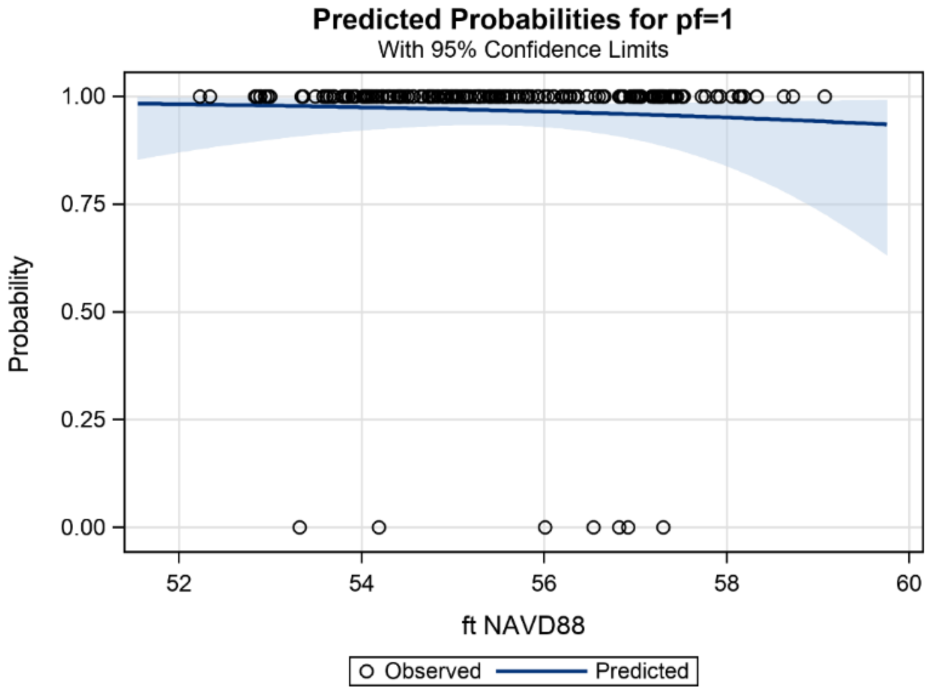



Figure 12. Probability of TN exceeds 1.15 mg/L TMDL target at different lake levels

In summary, this WRV is considered protected under the recommended MFL hydrologic regime, because (1) the increase in probability of exceeding the poor water quality threshold (TSI 70) and Chl-a TMDL target (0.038 mg/L) threshold under the MFLs condition, relative to the no pumping condition, is very small; (2) there is no change in the probability of TN exceeding the TMDL target of 1.15 mg/L, between the two conditions; and (3) there is no significant relationship between TP and lake level.

## 10. Navigation

The primary navigation of Lochloosa Lake is by recreational boaters. As such, this WRV is addressed under WRV-1, “Recreation in and on the water.”

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# Lochloosa, Orange and Newnans Lakes Hydrologic Evaluation

## St. Johns River Water Management District

Contract #27776
Work Order #18

January 2018

CDM Smith

# Lochloosa, Orange and Newnans Lakes Hydrological Evaluation Executive Summary

This executive summary and attached documents summarize the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. under Work Order #18 of Contract #27776. The work order included five tasks (A through D, plus F). This final report, which consists of an executive summary and attachments that reflect work from other tasks, is Task F. (Note: Task E was an optional task that was not funded or executed.)

## Background

A hydrologic model was previously developed by the SJRWMD for the study area. The model consists of two separate HSPF models: one covering Newnans Lake and its tributary area, and the second covering Lochloosa Lake and Orange Lake, and the tributary area to those lakes. The modeled outflow from Newnans Lake in the first model was used as inflow to the second model.

The District requested assistance from CDM Smith with hydrologic modeling in support of the evaluation of Minimum Flows and Levels (MFLs) for Lochloosa Lake. Specifically, CDM Smith updated the HSPF models; developed an EPA Stormwater Management Model (SWMM) hydraulic model of the lakes and channels connecting the lakes; developed a linkage between the calculated HSPF hydrologic flows and the SWMM hydraulic network; calibrated the models; and validated the models.

## Data Review

Task A involved the review of data required for the HSPF and SWMM model development and simulation. Details are included in **Appendix A**, which summarizes the data review.

CDM Smith reviewed data provided by the District, which included the following:

- Hourly rainfall records
- Evapotranspiration data
- Lochloosa, Orange and Newnans Lakes stage data
- Groundwater elevations from existing observation wells
- Tributary area, topographic, and hydrographic data
- Recharge data
- Land use data
- Soils data

- Lake bathymetry
- Geometry of channels connecting the lakes

The data provided were considered sufficient to develop a model that could be used to evaluate long-term lake stages and achievement of established MFLs.

Through the data evaluation and discussion with District staff, the well (or wells) used as the Upper Florida aquifer (UFA) elevation were changed from the current HSPF model. For Newnans Lake, well A-0420 was selected based on proximity to the lake and long period of record. The A-0420 time series was adjusted downward by 5.5 feet, to reflect historical differences between the values at the A-0420 well and a well (A-0973) which is closer to the lake. For Lochloosa Lake, well A-0071 was selected based on period of record, with the time series values adjusted downward by 14.5 feet, to reflect historical differences between the values at A-0071 and wells A-0421 and A-0725, which are close to the lake. Well M-0367 values were selected for Orange Lake, rather than well M-0063 which was used in the original HSPF model but is located further away from the lake.

## HSPF Model Update

Task B involved the use of data acquired in Task A to update the HSPF model of the lakes and associated tributary area. This task focused primarily on the refinement of land use distribution, seepage from the lake to the Upper Floridan aquifer, and generation of time series flows to be used as input to the SWMM hydraulics. Details are included in **Appendix B**, which summarizes the model update.

Specific refinements included the following:

- **Vertical datum.** All lake stage and well elevation input, and lake stage model output, are now in the NAVD 88 vertical datum.
- **Land use**. The 2009 land use provided by the District was used to define the distribution of land use within the lake contributing area. The land use data were categorized into 13 land use types, consistent with the existing HSPF model. Values of percent imperviousness by land use category were maintained from the existing HSPF model.
- **Lake Flow Interaction with UFA**. As discussed above, the wells used to evaluate the potential for lake interaction with the UFA were changed from the original model. Consequently, the lake seepage coefficients which are used to simulate the flow exchange between the lakes and the UFA also needed to be adjusted. Initial values were established so that the flow exchange was roughly similar to that generated with the original HSPF model, and were later adjusted as part of the calibration process.
- **Time Series Flows for SWMM**. The HSPF models were modified to generate output time series data that would be used as input for the SWMM hydraulics model. A total of 10 flow time series were developed, which included three flow time series directly to the lakes, three tributaries to the main streams connecting the three lakes, and four flow time series that reflected the land-based inflows direct to the main streams. Inflows to the three lakes


CDM Smith

included all upstream watershed inflow plus direct rainfall on the lake surface calculated by HSPF, but did not include flow interaction between lake and UFA, or evaporation from the lake surface, which was simulated in SWMM.

## SWMM Model Development

Task C involved the use of data acquired in Task A to establish a SWMM hydraulics model of the three lakes and connecting stream segments. Details are included in **Appendix C**, which summarizes the model development.

Specifics of the model development included the following:

- **General model setup.** The SWMM represents the system as a series of nodes (junctions) and links (conduits). The lakes are represented as storage junctions. Junctions were generally established at points representing inflow load points, location of significant cross-section geometry change, and location of bridges/culverts. The nodes were then connected via links that reflect available shapefile coverage of the stream and canals.

- **Channel Cross-Sectional Geometry.** Available survey data, supplemented with data from the Digital Elevation Model (DEM) for the study area, were used to establish the open channel and overbank cross-sectional geometry. A limited comparison of survey data and elevation data from the DEM suggests that the DEM data are similar to the survey data, and furthermore appear to provide a good representation of both the channel and overbank areas. Survey data were mainly available along Cross Creek (between Lochloosa Lake and Orange Lake) and in the vicinity of the discharge from Camps Canal to Paynes Prairie.

- **Lake Evaporation**. The storage nodes representing the three lakes were assigned an evaporation time series used to quantify the evaporative water loss from the lakes. The time series was identical to that used by HSPF.

- **Lake Flow Interaction with UFA**. As discussed above, the wells used to evaluate the potential for lake interaction with the UFA were changed from the original model. Consequently, the lake seepage coefficients that are used to simulate the flow exchange between the lakes and the UFA also needed to be adjusted. Initial values were established so that the flow exchange was roughly similar to that generated with the original HSPF model, and were later adjusted as part of the calibration process.

  SWMM accounted for the exchange by establishing pumps in the model. For Newnans Lake, a single pump was assigned to account for water loss from the lake to the UFA. For Lochloosa Lake, two pumps were considered: one for water loss from the lake to the UFA, and the other for flow to the lake from the UFA (which is the usual condition). Orange Lake also included two pumps, to reflect the fact that seepage tends to be higher at higher lake stages when connectivity through an existing sinkhole is more effective. Consequently, the two pumps have different assigned pumping rates.

- **Lake Depth/Area Relationship**. For all lakes, the bottom elevation and the relationship between lake depth and area was taken directly from HSPF.

- **Outfalls.** SWMM includes three surface water outfalls: (1) the discharge to Paynes Prairie from Camps Canal, (2) the discharge from Lochloosa Lake to Lochloosa Slough, and (3) the weir outfall at the downstream end of Orange Lake. Discharge to Paynes Prairie is governed by a rating curve based on relationship between estimated flows to Paynes Prairie (difference between gage flows at Camps Canal and Prairie Creek) and stages at Camps Canal. The Lochloosa Slough discharge is governed by a rating curve provided by the District, and the Orange Lake discharge is governed by the rating curve established in the HSPF model FTABLE for Orange Lake.

## Model Calibration and Validation

Task D involved the calibration of the HSPF and SWMM models. Details are included in **Appendix D**, which summarizes the model calibration effort.

After discussion with the District, CDM Smith selected the period of 2006 through 2016 as an appropriate calibration period for the models. This period features the best and most complete set of model input and calibration data (e.g., streamflow gages, lake stages, local groundwater well data), and is a recent period that is representative of the model land use conditions.

HSPF calibration focused on agreement between gage flows and modeled flows at various gage locations in the study area, as well as modeled and measured lake stages. The initial model results using the previously-developed hydrologic input parameters of the existing model did not result in good agreement between measured and modeled flows at several gages in the study area. PEST was used to develop hydrologic parameters that resulted in a better match between modeled and measured streamflows.

SWMM calibration focused on the adjustment of channel roughness for the flow routing between lakes, and the adjustment of the pump curves representing the exchange between the UFA and the lakes.

The results of the model for the calibration period were compared to observed lake stages, according to the criteria established in previous MFL modeling studies. The calibrated model resulted in Nash-Sutcliffe scores of 0.83 and 0.82 for Lochloosa and Orange Lakes, respectively. The Nash-Sutcliffe score for Newnans Lake was 0.77. This is lower than target values that were applied in some previous MFL modeling studies (0.85 to 0.90).

As an additional evaluation, SWMM was applied for the calibration period using gage data to characterize the inflows, rather than HSPF results. With the gage inflows, the Nash-Sutcliffe scores for Lochloosa and Orange Lakes were 0.92 and 0.94, respectively. This suggests that better agreement between gage flows and modeled flows, whether due to refined hydrologic model parameters, hydrologic routing, and/or local rainfall, would result in better results.

The calibrated model was tested further through model application to a separate validation period of 1996 through 2005. The model still did a good job of matching the observed lake stages during the validation period. The Nash-Sutcliffe scores for Lochloosa and Orange Lakes were very similar to the calibration (0.80 and 0.83, respectively).

## Summary

An updated HSPF hydrologic model and new SWMM hydraulic model of Lochloosa, Orange and Newnans Lakes and associated tributary area have been developed. The models were calibrated based on model results and observed streamflow and lake stages for the period of 2006 through 2016, and validated for the period of 1996 through 2005. The model performs well at reproducing observed lake stages during dry and wet periods, and is considered appropriate for long-term model simulation in support of MFL analyses.

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# Appendix A

# Task A Letter Report

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August 4, 2017 (updated January 31, 2018)

Dr. Xiaoqing Huang
St. Johns River Water Management District
PO Box 1429
4049 Reid St.
Palatka, FL 32178

Subject: Lochloosa, Orange and Newnans Lake MFL Evaluation – Task A: Data Review

Dear Dr. Huang:

This letter summarizes the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. (CDM Smith) in Task A of the Lochloosa, Orange, and Newnans Lakes Minimum Flows and Levels (MFL) Evaluation, under Work Order #18 of contract #27776. Task A involves the review of data required for the HSPF and SWMM model development and simulation. HSPF models have previously been developed by the District and were updated for this study. A SWMM model routing flows between the lakes was developed for this study.

## Review of Data Provided by the District

CDM Smith reviewed the data provided by the District, which included the following:

- **Hourly rainfall records.** The District provided time series of rainfall data from 1897 through 2016 in a WDM (Watershed Data Management) file, which listed Gainesville Airport as the location of the data. CDM Smith reviewed the period from 1948 to 2016 (corresponding to the period of evapotranspiration data), and found that the average and range of the annual values (**Table 1**) appeared reasonable.

**Table 1. Annual Totals and Statistics for Precipitation and Potential Evapotranspiration**

| Year | Annual Precipitation (in) | Annual ET (in) |
|---|---|---|
| 1948 | 58.0 | 50.0 |
| 1949 | 63.2 | 51.3 |
| 1950 | 46.7 | 52.3 |
| 1951 | 56.0 | 51.3 |
| 1952 | 42.1 | 51.4 |
| 1953 | 73.3 | 48.7 |
| 1954 | 35.2 | 50.7 |
| 1955 | 42.7 | 51.9 |
| 1956 | 48.0 | 50.7 |
| 1957 | 57.0 | 48.9 |
| 1958 | 60.9 | 48.9 |
| 1959 | 60.5 | 49.4 |
| 1960 | 64.0 | 49.5 |
| 1961 | 50.1 | 50.2 |
| 1962 | 41.2 | 50.3 |
| 1963 | 46.7 | 49.2 |
| 1964 | 67.5 | 48.8 |
| 1965 | 62.8 | 49.0 |
| 1966 | 49.0 | 47.0 |
| 1967 | 51.4 | 49.7 |
| 1968 | 53.4 | 48.9 |
| 1969 | 61.7 | 46.9 |
| 1970 | 60.0 | 50.4 |
| 1971 | 50.6 | 51.3 |
| 1972 | 67.6 | 51.0 |
| 1973 | 50.6 | 50.5 |
| 1974 | 50.5 | 51.7 |
| 1975 | 51.6 | 51.0 |
| 1976 | 48.2 | 50.8 |
| 1977 | 33.7 | 52.4 |
| 1978 | 50.4 | 51.0 |
| 1979 | 58.5 | 50.4 |
| 1980 | 41.6 | 51.2 |
| 1981 | 36.0 | 53.0 |
| 1982 | 60.4 | 51.0 |
| 1983 | 65.3 | 49.4 |
| 1984 | 40.6 | 48.6 |
| 1985 | 54.4 | 47.5 |
| 1986 | 48.0 | 48.3 |
| 1987 | 43.9 | 48.2 |
| 1988 | 55.8 | 48.0 |
| 1989 | 41.1 | 49.4 |
| 1990 | 41.7 | 50.7 |
| 1991 | 51.0 | 47.2 |
| 1992 | 54.3 | 45.8 |
| 1993 | 44.9 | 48.5 |
| 1994 | 47.6 | 47.5 |
| 1995 | 52.0 | 48.2 |
| 1996 | 53.9 | 49.1 |
| 1997 | 58.2 | 48.9 |
| 1998 | 45.6 | 50.5 |
| 1999 | 37.8 | 50.7 |
| 2000 | 34.4 | 51.6 |
| 2001 | 42.1 | 49.7 |
| 2002 | 55.3 | 49.4 |
| 2003 | 46.6 | 48.0 |
| 2004 | 58.4 | 49.6 |
| 2005 | 50.0 | 47.9 |
| 2006 | 36.1 | 51.3 |
| 2007 | 45.4 | 50.3 |
| 2008 | 39.7 | 49.8 |
| 2009 | 47.7 | 48.9 |
| 2010 | 38.9 | 50.5 |
| 2011 | 33.4 | 53.8 |
| 2012 | 56.2 | 51.0 |
| 2013 | 47.9 | 49.5 |
| 2014 | 50.9 | 48.8 |
| 2015 | 47.3 | 49.7 |
| 2016 | 41.9 | 51.6 |
| **Minimum** | 33.4 | 45.8 |
| **Mean** | 50.1 | 49.8 |
| **Maximum** | 73.3 | 53.8 |

- **Evapotranspiration data.** The District provided time series of potential evapotranspiration (PET) data from 1948 through 2016 in a WDM (Watershed Data Management) file, which listed Gainesville Airport as the location of the data. The PET data were calculated on a daily basis using maximum and minimum air temperature using the Hargreaves equation, and then disaggregated to hourly values using WDMUtil. An e-mail from District staff indicated that the time series values should be adjusted by a factor of 0.8431 for use in the HSPF model. The average and range of the annual values (corresponding to the simulation period), including the adjustment factor (**Table 1**), appeared reasonable.

- **Lochloosa, Orange and Newnans Lake Stage Data.** The District provided daily time series of stage data for six stations. **Table 2** summarizes the period of data availability for each station. Stages were rounded to the nearest 0.1 ft for reporting.

**Table 2. Data Availability for Stage Data**

| Station | Station Name | Time Period |
|---|---|---|
| 71481615 | Lochloosa Lake at Hawthorne | 04/1936 – 05/2017 |
| 02601462 | Orange Lake Outlet at Citra | 05/1933 – 05/2017 |
| 02611465 | Orange Lake at Boardman | 06/1933 – 05/2017 |
| 04831007 | Newnans Lake Baker at Gainesville | 04/1936 – 04/2017 |
| 19274284 | Cross Creek on CR325 at Gainesville | 03/2005 – 05/2017 |
| 08631958 | Prairie Creek at Gainesville | 08/1978 – 05/2017 |
| 02320630 | Lake Alto near Waldo | 01/1976 – 12/2016 |

**Figure 1** displays the lake stage data and the annual rainfall and averaged annual PET values (with PET adjusted using the factor described earlier), for years that are expected to be modeled for calibration and validation.

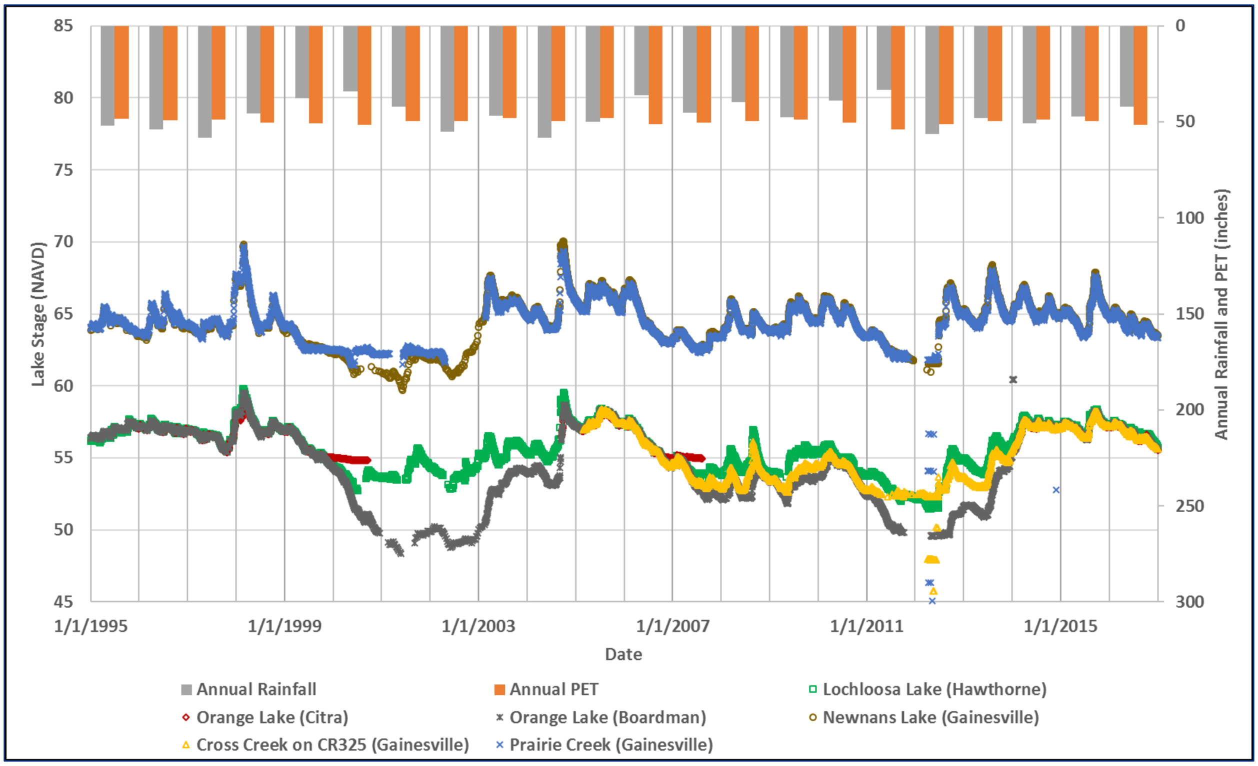


**Figure 1**
**Historical Stage Data for Lochloosa, Orange and Newnans Lakes**

The rainfall and lake stage data seem to be consistent, with lake stages rising in response to higher rainfall years and dropping in lower rainfall years. The lowest measured lake stages are in 2001, after 4 years (1998-2001) of rainfall that is below average and is exceeded by the PET. The highest lake stages are in 1998 and 2004, which reflect the fact that previous years, 1995 through 1997, 2002, and 2004, show above average rainfall in excess of the PET. There is provisional data in 2012 and 2014 that appear to be outliers and will be excluded from the calibration.

- **Flow Gage Data**. The District provided daily time series of flow data for 14 stations. **Table 3** summarizes the period of data availability for each station.

**Table 3. Data Availability for Flow Data**

| Station | Station Name | Time Period |
|---|---|---|
| 01950193 | Hatchet Creek at Fairbanks | 06/1995–7/2009 |
| 02850235 | Bee Tree Creek at Orange Heights | 03/1999–05/2017 |
| 14342633 | Hatchet Creek at Gainesville | 03/1948–05/2017 |
| 01920187 | Little Hatchet Creek at Gainesville | 05/1995–09/198 |
| 02840233 | North Branch Little Hatchet Creek | 10/1998–05/2017 |
| 19244274 | Lake Forest Creek at Kincaid Hills on CR329B | 01/2005–05/2017 |
| 08631958 | Prairie Creek at Gainesville | 01/1947–05/2017 |
| 01930189 | Lochloosa Creek at Grove Park | 06/1995–10/2011 |
| 19234272 | Lochloosa Creek South at Grove Park | 12/2004–05/2017 |
| 19274284 | Cross Creek on CR325 at Gainesville | 05/2005–05/2017 |
| 08661963 | Camps Canal at Rochelle | 03/1948–05/2017 |
| 10882632 | Camps Canal Diversion at Micanopy | 03/1992–08/2013 |
| 19974721 | River Styx Nr Micanopy | 12/2005–05/2017 |
| 02601462 | Orange Lake Outlet at Citra | 10/1946–05/2017 |

- **Groundwater elevations from existing observation wells.** The District provided time series data of Upper Floridan well levels for 12 wells, including A-0071, A-0420, A-0421, A-0725, A-0750, A-0973, M-0052, M-0063, M-0367, M-0443, M-0527, and P-0008. **Table 4** summarizes the period of data availability for each station. **Figure 2** displays the location of the stations with groundwater level data.

**Table 4. Data Availability for Well Data**

| Station | Station Name | Time Period |
|---|---|---|
| A-0071 | Hawthorne Tower Deep at Hawthorn | 07/1985–05/2017 |
| A-0420 | Lybass at Phifer | 04/1975–05/2017 |
| A-0421 | Lochloosa Well at Hawthorne | 11/2005–05/2017 |
| A-0725 | Orange Lake Weather Station | 01/1999–05/2017 |
| A-0750 | Paynes Prairie Buffalo Pasture at Micanopy | 02/2007–05/2017 |
| A-0973 | Bill Holblack FAS | 08/2014–10/2016 |
| M-0052 | Ft McCoy Tower UFA | 04/1985–05/2017 |
| M-0063 | Sparr Replacement FA | 02/1980–02/2017 |
| M-0367 | Huff Well at McIntosh | 11/1995–05/2017 |
| M-0443 | Citra Ranch at Citra | 07/2000–05/2017 |
| M-0527 | CR 316 at Reddick FA | 06/2009–05/2017 |
| P-0008 | Chesser at Interlachen FA | 04/1976–05/2017 |

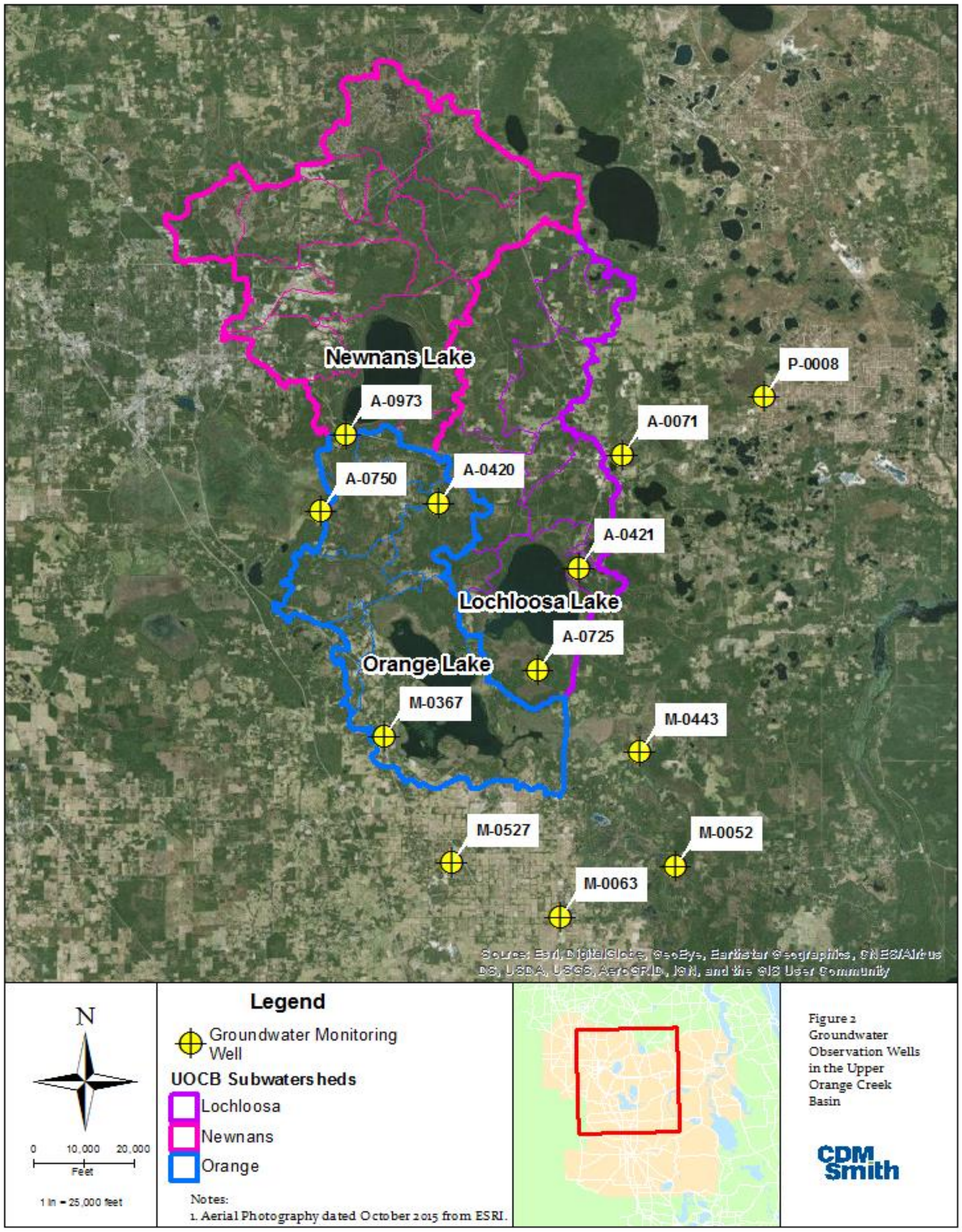


**Figure 2**
**Location of Groundwater Observation Wells in Upper Orange Creek Basin (UOCB)**

The previous HSPF models used Sparr well (M-0063) for the Orange & Newnans Lake model, and the Hawthorne well (A-0421) for the Lochloosa model. Data are available for both wells through the anticipated calibration period (2006–2016); however, data at the Hawthorne well for the anticipated validation period (1995–2005) would be limited to synthesized data developed previously by SJRWMD.

- **Tributary area, topographic, and hydrographic data.** The District provided the Upper Orange Creek Basin delineation that includes the immediate Lochloosa, Orange, and Newnans Lake tributary areas as well as areas west, east, and south of the lakes. **Figure 3** illustrates the topography in the Upper Orange Creek Basin.

- **Recharge data.** CDM Smith also obtained the latest Floridan aquifer recharge map from the District. The map is illustrated on **Figure 4**, and **Table 5** summarizes the percentage of the basin that falls under each recharge category.

- **Land use data.** The digital land use coverage for 2009 available on the District's website was used. Additional land use coverage, which includes the land areas contributing to non-riparian wetlands, was provided by the District.

  **Figure 5** illustrates the land cover in the Upper Orange Creek Basin, and **Table 6** summarizes the percentage of the basin that falls under each land use category. The updated land use will be used by CDM Smith to develop the model hydrology input such as impervious acreage, and acreage and associated hydrologic parameter values for various pervious land covers (e.g., residential, forest, pasture). The land use will be subdivided into the 13 standard land use categories that have been used for HSPF modeling by the District.

- **Soils.** The District provided digital soil coverage. **Figure 6** illustrates the soils in the Upper Orange Creek Basin, and **Table 7** summarizes the percentage of the basin that fall under each hydrologic soils group. The basin is 13.9 percent water, and this is not included in Table 7. Hydrologic parameters such as INFILT (index to infiltration) will be established accordingly in the HSPF model. It is anticipated that surface runoff from pervious land areas will be limited, and most of the inflow to the lake will be either surficial groundwater inflow or direct rainfall on the lake surface.

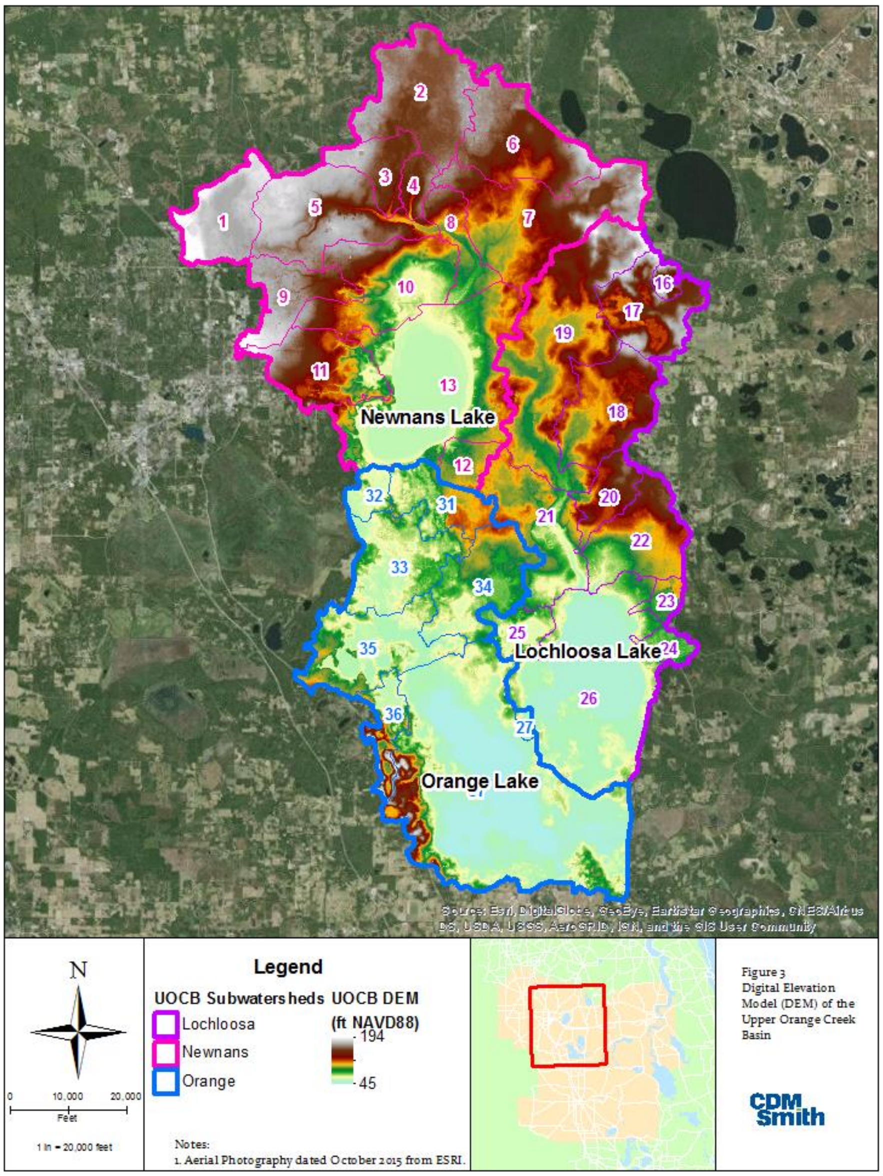


**Figure 3**
**Topographic Map of Upper Orange Creek Basin**

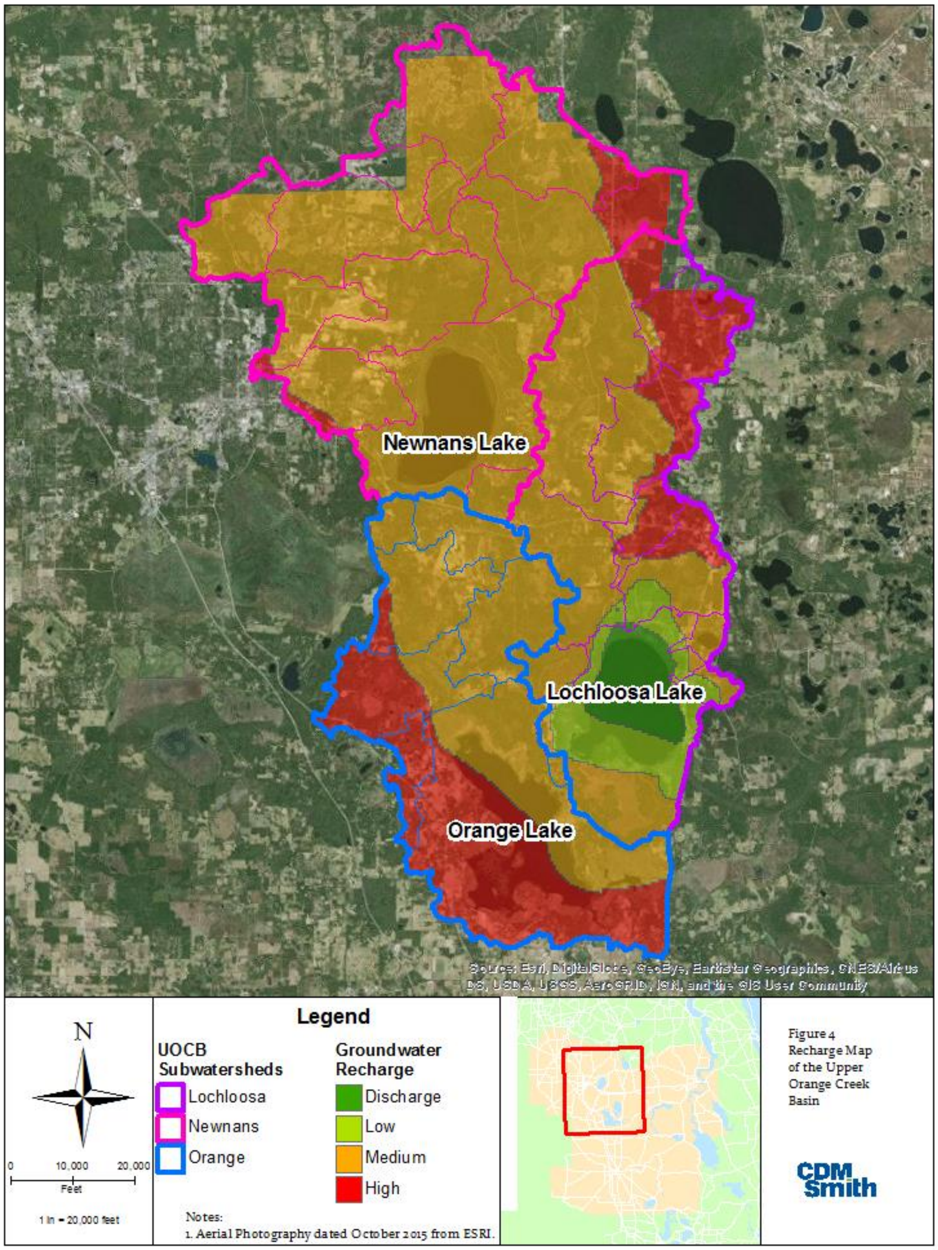


**Figure 4**
**Recharge Map of Upper Orange Creek Basin**

**Table 5. Percentage of Upper Orange Creek Basin in each Recharge Category**

| Recharge Classification | Percentage of Basin |
|---|---|
| Discharge | 2.7 |
| Low (1-5 in/year) | 4.5 |
| Medium (5-10 in/year) | 70.8 |
| High (10-15 in/year) | 22.0 |

**Table 6. Percentage of Upper Orange Creek Basin in each Land Use Category**

| Land Use Classification | Percentage of Basin |
|---|---|
| 1 - Low Density Residential | 2.4% |
| 2 - Medium Density Residential | 1.1% |
| 3 - High Density Residential | 0.2% |
| 4 - Industrial and Commercial | 2.6% |
| 5 - Mining | 0.1% |
| 6 - Open Land and Barren Land | 0.6% |
| 7 - Pasture | 5.8% |
| 8 - Agriculture General | 2.0% |
| 9 - Agriculture Tree Crops | 0.6% |
| 10 - Rangeland | 2.3% |
| 11 - Forest | 46.9% |
| 12 - Water | 9.7% |
| 13 - Wetlands | 17.0% |
| 15 – Non-riparian Wetlands | 8.5% |

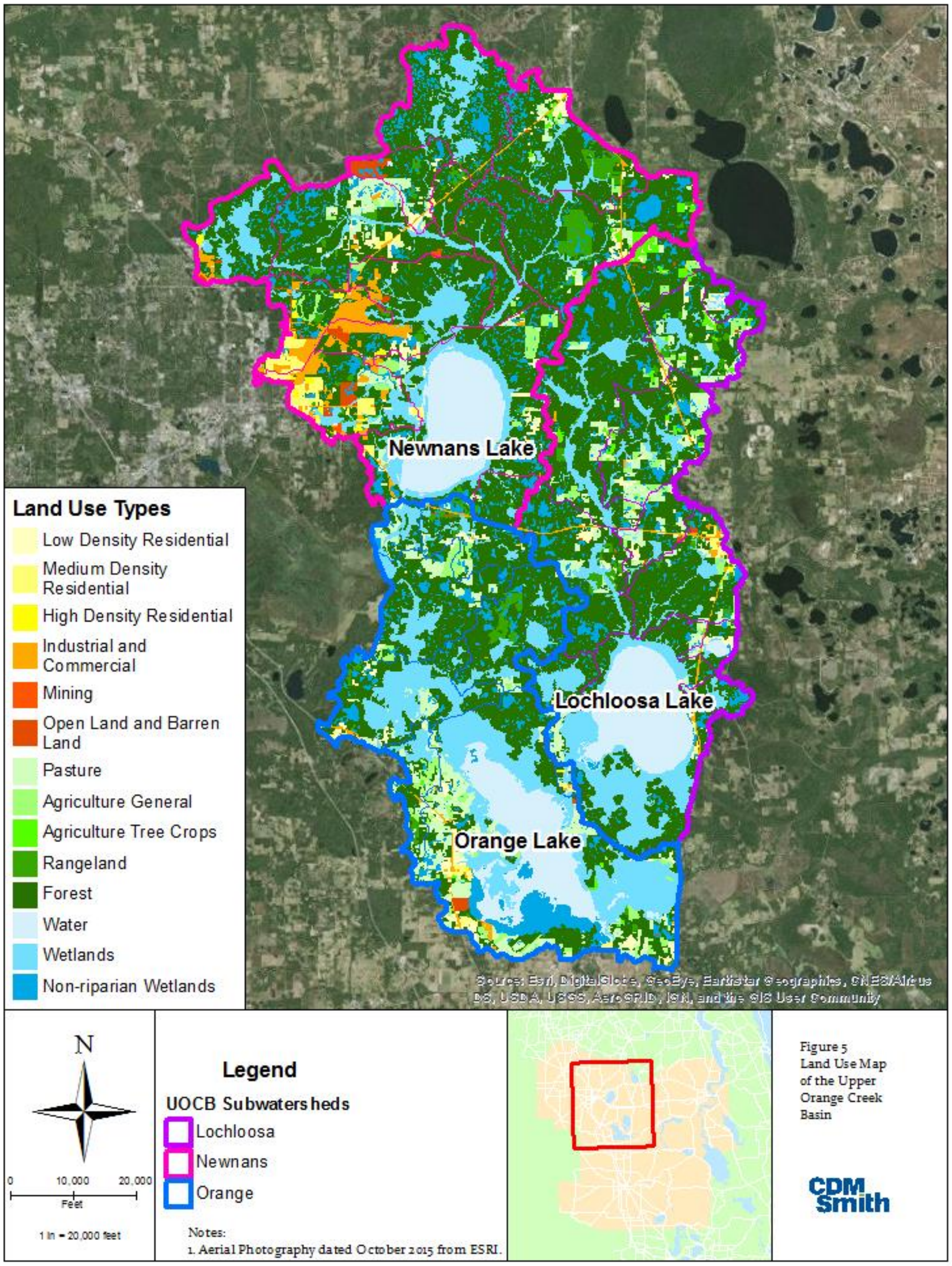


**Figure 5**
**Land Use Map of Upper Orange Creek Basin**

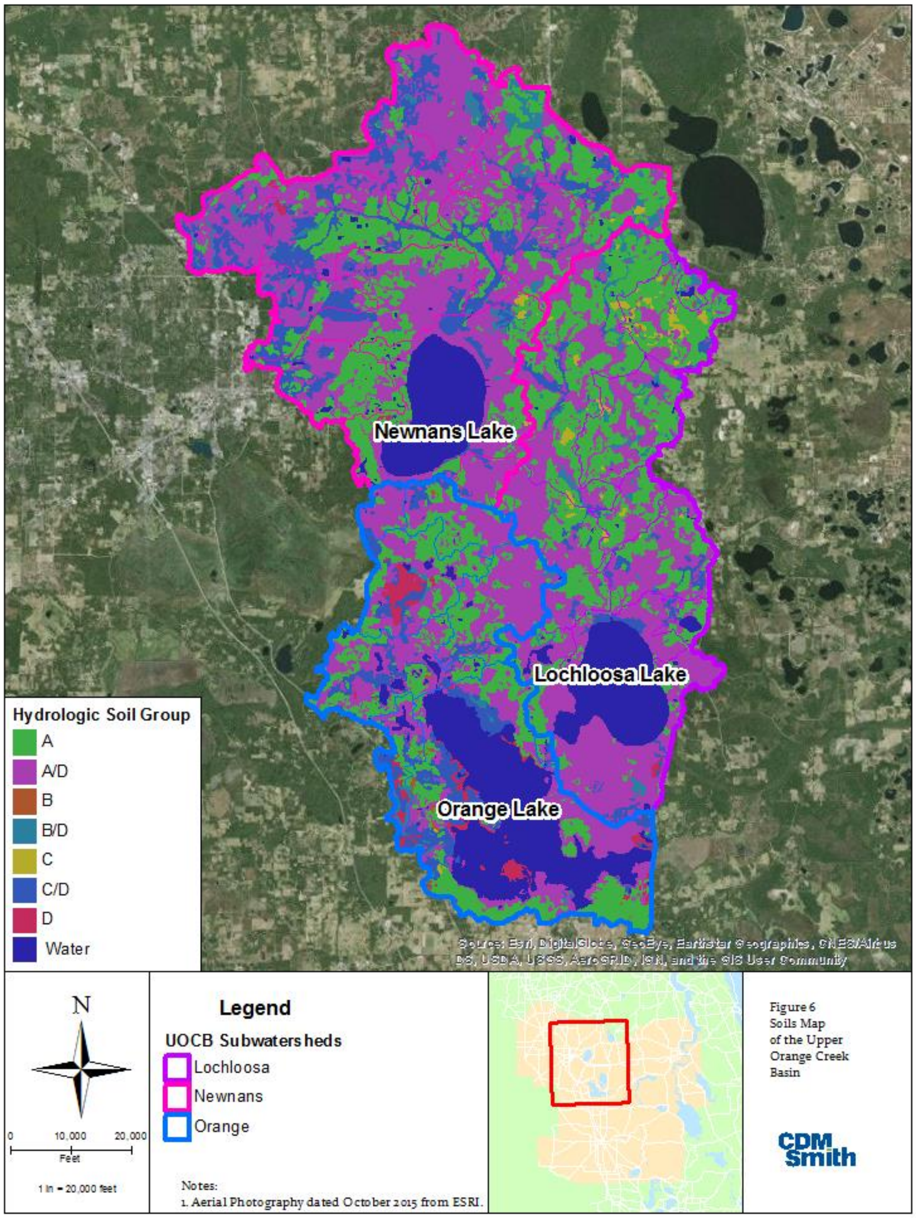


**Figure 6**
**Soils Map of Upper Orange Creek Basin**

**Table 7. Percentage of Upper Orange Creek Basin in each Soils Category**

| Hydrologic Soils Group | Percentage of Basin |
|---|---|
| A | 31.1% |
| A/D | 39.5% |
| B | 0.2% |
| B/D | 2.6% |
| C | 0.7% |
| C/D | 10.8% |
| D | 1.2% |

- **Lake Bathymetry.** The existing HSPF models include FTABLES that define the depth-surface area-storage volume-outflow relationships for the three lakes.

- **SWMM model inputs.** There were several data sets provided that will assist in the development of the SWMM component of the model. Surveyed cross sections as well as bridge details for a section of Cross Creek were provided and will assist in the development of that portion of the SWMM. Survey data were also provided for the structure moving flow from Camps Canal to Paynes Prairie. In addition to District provided survey data, the DEM that was provided ("OCB_DEM_170720") is appropriate to extract cross sections for the SWMM channel; an example is provided on **Figure 7**. The "FTABLES" provided in the HSPF input file for the study lakes were used to define their volume in SWMM.

- **Discharge to Bee Tree Creek headwaters under Highway 301**. This information was provided by the District as a timeseries for input to the HSPF model.

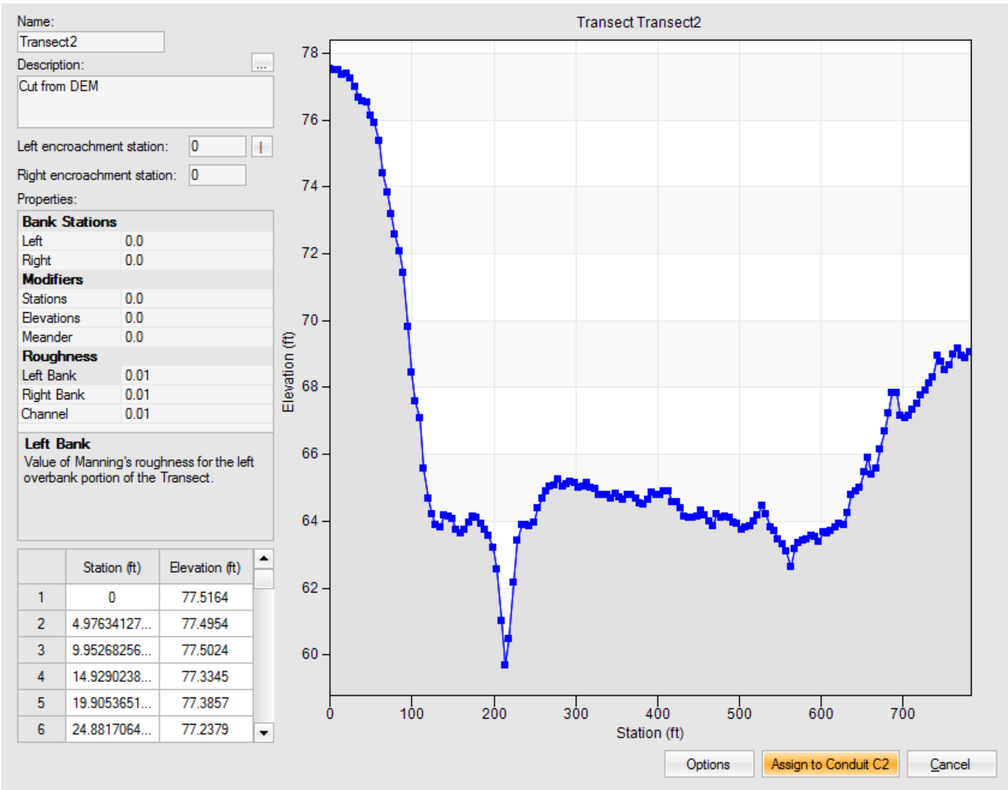


**Figure 7**
**Example SWMM Transect Developed from DEM**

## Modeling Approach

In this study, hydrologic results generated by HSPF were loaded to a SWMM hydraulic model that routes flows between Newnans, Lochloosa, and Orange Lakes. Based on a review of the HSPF model for Orange and Lochloosa Lakes, the output from HSPF was loaded to SWMM at 10 locations, which are summarized in **Table 8** and illustrated on **Figure 8**.

**Table 8. Linkage Points between HSPF and SWMM**

| Linkage Point ID | Waterbody | HSPF Flow |
|---|---|---|
| 1 | Prairie Creek | Total Inflow to Newnans Lake (RCHRES 13) + Direct Rainfall |
| 2 | Prairie Creek | Outflow from Newnans Lake Tributary Reach (RCHRES 31) |
| 3 | Prairie Creek | Inflow from PERLNDs 721-735, IMPLND 721-724 (Basin 32) |
| 4 | Camps Canal | Inflow from PERLNDs 741-755, IMPLND 741-744 (Basin 33) |
| 5 | River Styx | Inflow from PERLNDs 781-795, IMPLND 781-784 (Basin 35) |
| 6 | River Styx | Outflow from Coleman Cemetery Bog Reach (RCHRES 34) |
| 7 | Orange Lake | Outflow from Fish Prairie Reach (RCHRES 36) |
| 8 | Orange Lake | Inflow from PERLNDs 821-835, IMPLND 821-824 (Basin 37) + Direct Rainfall |
| 9 | Lochloosa | Total inflow to Lochloosa Lake (RCHRES 26) + Direct Rainfall |
| 10 | Cross Creek | Inflow from PERLNDs 621-635, IMPLND 621-624 (Basin 27) |

A PLTGEN text output file was produced for each of the flow locations listed in Table 8.

For the development of the linked input to SWMM, the application *SWMMInterfacer.exe* was applied. This application was developed by CDM Smith to read PLTGEN files and create an input file that can be read by SWMM as input. Required input for the application is the name of the text file that lists all the PLTGEN files that should be included, and the name of the text file for the SWMM flow input file.

As an example, **Figure 9** shows an input file that lists one PLTGEN file (which happens to be the Newnans Lake surface outflow generated by running the existing District model for the Newnans Lake watershed). **Figure 10** shows an abbreviated version of the PLTGEN file. The PLTGEN file was created by HSPF so that the SWMM model node ID (in this example A200) is what appears in the first column of the PLTGEN output file.

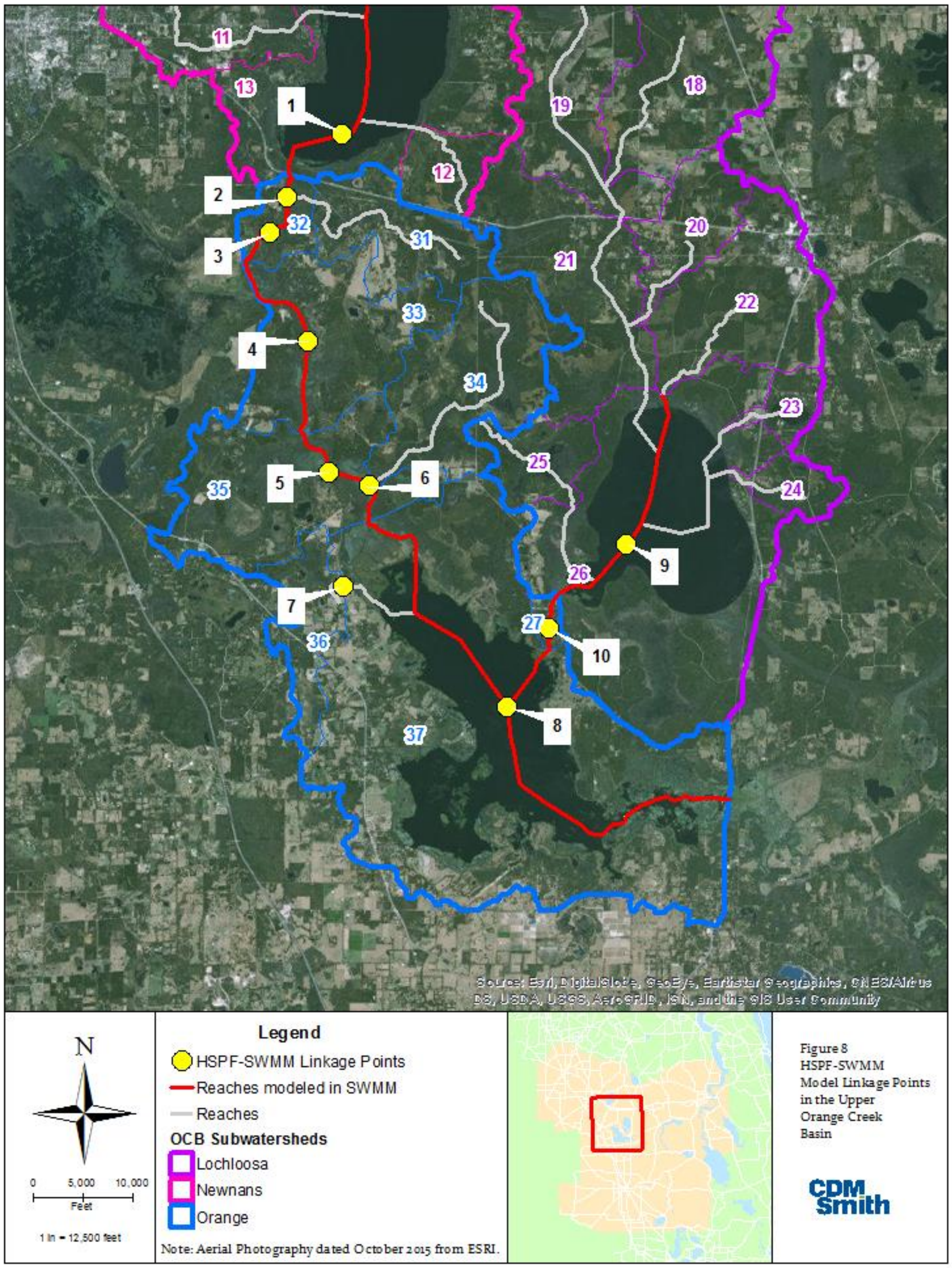


**Figure 8**
**Location of Linkage Points between HSPF and SWMM**

```
; Instruction file for HSPF to SWMM conversion program
; List of textfiles created by HSPF for transfer to SWMM
[Files]
A200.TXT
```

**Figure 9**
**Example PLTGEN File List Input for Linkage Application**

```
A200 HSPF FILE FOR DRIVING SEPARATE PLOT PROGRAM
A200 Time interval:   60 mins          Last month in printout year: 12
A200 No. of curves plotted:  Point-valued:  1   Mean-valued:  0   Total  1
A200 Label flag:  0          Pivl:    1          Idelt:   60
A200 Plot title:   A200
A200 Y-axis label: Simulated Flow (cfs)
A200 Scale info:  Ymin:   0.0000             Threshold:-0.10000E+31
A200              Ymax:   2000.0
A200              Time:   20.000     intervals/inch
A200 Data for each curve (Point-valued first, then mean-valued):
A200 Label                     LINTYP     INTEQ    COLCOD      TRAN   TRANCOD
A200 Simulated Flow                 0         1         1      AVER         2
A200
A200
A200
A200
A200
A200
A200
A200
A200
A200 Time series (pt-valued, then mean-valued):
A200
A200 Date/time                         Values
A200
A200  1974 12 31 24  0  29.60000
A200  1975  1  1  1  0  29.84655
A200  1975  1  1  2  0  30.02337
A200  1975  1  1  3  0  30.05808
A200  1975  1  1  4  0  30.08919
A200  1975  1  1  5  0  30.11715
A200  1975  1  1  6  0  30.14242
A200  1975  1  1  7  0  30.16458
A200  1975  1  1  8  0  30.16958
A200  1975  1  1  9  0  30.15788
A200  1975  1  1 10  0  30.13789
A200  1975  1  1 11  0  30.11676
```

**Figure 10**
**Example PLTGEN Output File Format**

An abbreviated output file from the application example is shown on **Figure 11**. As formatted in Figure 10, the file can be read by SWMM by specifying that file for inflows. This is done at the SWMM data screen depicted on **Figure 12**.

```
SWMM5
SWMMInterfacer-HSPF via orange_list.inp.
3600.
1
FLOW CFS
  1
A200
Node      Year Mon Day Hr  Min Sec FLOW
A200      1975 01  01  01  00  00     29.8465
A200      1975 01  01  02  00  00     30.0234
A200      1975 01  01  03  00  00     30.0581
A200      1975 01  01  04  00  00     30.0892
A200      1975 01  01  05  00  00     30.1171
A200      1975 01  01  06  00  00     30.1424
A200      1975 01  01  07  00  00     30.1646
A200      1975 01  01  08  00  00     30.1696
A200      1975 01  01  09  00  00     30.1579
A200      1975 01  01  10  00  00     30.1379
A200      1975 01  01  11  00  00     30.1168
A200      1975 01  01  12  00  00     30.0946
A200      1975 01  01  13  00  00     30.0715
A200      1975 01  01  14  00  00     30.0476
A200      1975 01  01  15  00  00     30.0301
A200      1975 01  01  16  00  00     30.0273
A200      1975 01  01  17  00  00     30.0395
A200      1975 01  01  18  00  00     30.0523
A200      1975 01  01  19  00  00     30.0647
A200      1975 01  01  20  00  00     30.0768
A200      1975 01  01  21  00  00     30.0885
A200      1975 01  01  22  00  00     30.1000
A200      1975 01  01  23  00  00     30.1111
A200      1975 01  01  24  00  00     30.1221
A200      1975 01  02  01  00  00     30.1328
A200      1975 01  02  02  00  00     30.1433
A200      1975 01  02  03  00  00     30.1537
A200      1975 01  02  04  00  00     30.1639
A200      1975 01  02  05  00  00     30.1740
```

**Figure 11**
**Example Application Output File Format (for Input to SWMM)**

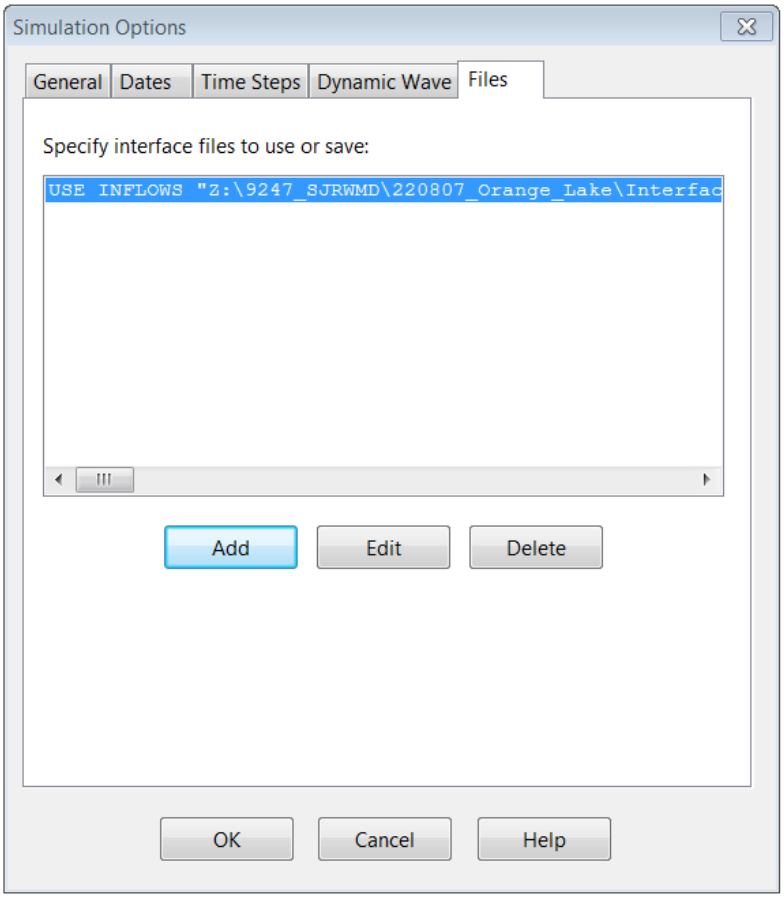


**Figure 12**
**Linking the Application Output File in the SWMM Input Dataset**

As discussed earlier HSPF flows were loaded to SWMM at a total of 10 locations. The "list" file included 10 PLTGEN output file names, and all 10 time series inflows included in the single SWMM inflow file.

Please call me at (904) 527-6706 or e-mail me at wagnerra@cdmsmith.com if you have any questions, comments, or require further information.

Sincerely,

Richard A. Wagner

Richard Wagner, P.E., D.WRE
Principal Water Resources Engineer
CDM Smith Inc.

cc: File
Shayne Wood, CDM Smith
Joanne Chamberlain, SJRWMD
Andrew Sutherland, SJRWMD
Fatih Gordu, SJRWMD

# Appendix B

# Task B Letter Report

CDM Smith

8381 Dix Ellis Trail, Suite 400
Jacksonville, Florida 32256
tel: 904 731-7109

September 12, 2017 (updated January 31, 2018)

Dr. Xiaoqing Huang
St. Johns River Water Management District
PO Box 1429
4049 Reid St.
Palatka, FL 32178

Subject: Lochloosa, Orange and Newnans Lake MFL Evaluation – Task B: HSPF Model Update

Dear Dr. Huang:

This letter summarizes the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. in Task B of the Lochloosa, Orange and Newnans Lakes Minimum Flows and Levels (MFL) Evaluation, under Work Order #18 of Contract #27776. Task B involves using the Task A data to update the previously developed HSPF models of Newnans Lake and Lochloosa Lake/Orange Lake for the current MFL analysis.

CDM Smith created an updated HSPF model that includes the following features specified by the District in the project scope:

- **Vertical datum.** The stage correction parameter (STCOR, which represents the elevation at zero depth in Newnans, Lochloosa, and Orange lakes (i.e., the "bottom" of the lake) was reduced by 1.2 feet to account for the difference between NAVD and NGVD. This is based on the difference between observed lake stages that are reported in both NAVD and NGVD units on the District hydrologic data website. In addition, all lake stage inputs to the model were converted to NAVD. In the Lochloosa/Orange Lake HSPF model, two special actions were updated to account for the stage correction: Cross Creek special action determining which column of the FTABLE (RCHRES 26) is used for flow; and Orange Lake (RCHRES 37) special action that changes the lake seepage coefficient as a function of stage. Consequently, all lake stage model output will be in NAVD as required by the scope.

- **Land use**. The 2009 land use provided by the District (shown on **Figure 1**) was used to define the distribution of land use within the lake contributing area. The land use data were categorized into 14 land use types as directed in the scope, based on the 13 land use classifications and a designation between riparian and non-riparian wetlands developed by the District. **Tables 1 through 3** present the distribution of land use in the current model for the Newnans Lake tributary area, Lochloosa Lake tributary area, and Orange Lake tributary area, respectively.

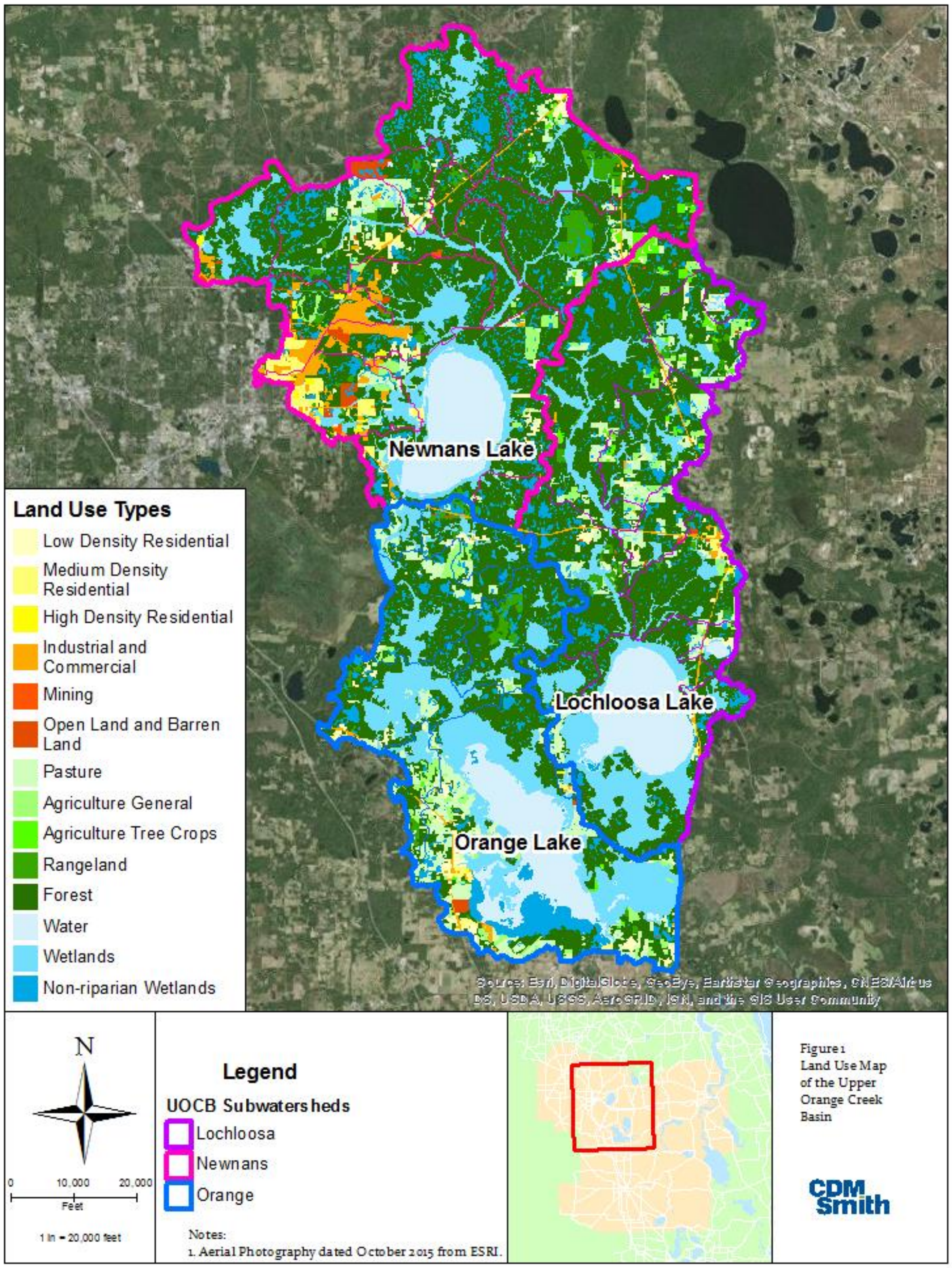


**Figure 1**
**Land Use in Upper Orange Creek Basin (UOCB) Study Area**

**Table 1. Land Use Distribution in Newnans Lake Tributary Area**

| Land Use Type | Area (acres) | DCIA (%) | Impervious Acres | Pervious Acres | % to Non-riparian Wetlands | |
|---|---|---|---|---|---|---|
| | | | | | Updated Model | Previous Model |
| Low Density Residential | 1,645 | 5% | 82 | 1,563 | 43% | 42% |
| Medium Density | 1,517 | 15% | 228 | 1,289 | 35% | 23% |
| High Density Residential | 351 | 35% | 123 | 228 | 23% | 9% |
| Industrial and | 3,423 | 50% | 1,711 | 1,711 | 44% | 33% |
| Mining | 91 | 0% | 0 | 91 | 18% | 10% |
| Open Land and Barren | 895 | 0% | 0 | 895 | 42% | 56% |
| Pasture | 2,243 | 0% | 0 | 2,243 | 52% | 57% |
| Agriculture General | 963 | 0% | 0 | 963 | 72% | 48% |
| Agriculture Tree Crops | 296 | 0% | 0 | 296 | 47% | 44% |
| Rangeland | 2,274 | 0% | 0 | 2,274 | 49% | 63% |
| Forest[1] | 37,911 | 0% | 0 | 37,911 | 56% | 54% |
| Water | 5,818 | 0% | 0 | 0 | 0% | 0% |
| Wetlands | 9,370 | 0% | 0 | 9,370 | 0% | 0% |
| Non-riparian Wetlands | 6,721 | 0% | 0 | 6,721 | 100% | 100% |
| TOTAL[2] | 73,516 | 3% | 2,144 | 65,554 | 47% | 46% |

[1]Forest includes Forest Regeneration classification in previous model
[2]Sum of pervious and impervious acres does not equal total area because acres of water are not included.

**Table 2. Land Use Distribution in Lochloosa Lake Tributary Area**

| Land Use Type | Area (acres) | DCIA (%) | Impervious Acres | Pervious Acres | % to Non-riparian Wetlands | |
|---|---|---|---|---|---|---|
| | | | | | Updated Model | Previous Model |
| Low Density | 1,275 | 5% | 64 | 1,211 | 52% | 46% |
| Medium Density | 165 | 15% | 25 | 141 | 56% | 21% |
| High Density | 18 | 35% | 6 | 12 | 77% | 11% |
| Industrial and | 788 | 50% | 394 | 394 | 52% | 36% |
| Mining | 3 | 0% | 0 | 3 | 85% | 24% |
| Open Land and Barren | 93 | 0% | 0 | 93 | 70% | 46% |
| Pasture | 3,350 | 0% | 0 | 3,350 | 53% | 61% |
| Agriculture General | 1,186 | 0% | 0 | 1,186 | 74% | 47% |
| Agriculture Tree Crops | 739 | 0% | 0 | 739 | 66% | 51% |
| Rangeland | 984 | 0% | 0 | 984 | 35% | 49% |
| Forest[1] | 28,975 | 0% | 0 | 28,975 | 55% | 50% |
| Water | 5,668 | 0% | 0 | 0 | 1% | 0% |
| Wetlands | 9,122 | 0% | 0 | 9,122 | 0% | 0% |
| Non-riparian Wetlands | 3,938 | 0% | 0 | 3,938 | 100% | 100% |

| Land Use Type | Area (acres) | DCIA (%) | Impervious Acres | Pervious Acres | % to Non-riparian Wetlands | |
|---|---|---|---|---|---|---|
| | | | | | Updated Model | Previous Model |
| TOTAL[2] | 56,305 | 1% | 489 | 50,148 | 44% | 40% |

[1]Forest includes Forest Regeneration classification in previous model
[2]Sum of pervious and impervious acres does not equal total area because acres of water are not included.

**Table 3. Land Use Distribution in Orange Lake Tributary Area**

| Land Use Type | Area (acres) | DCIA (%) | Impervious Acres | Pervious Acres | % to Non-riparian Wetlands | |
|---|---|---|---|---|---|---|
| | | | | | Updated Model | Previous Model |
| Low Density | 1,357 | 5% | 68 | 1,289 | 35% | 31% |
| Medium Density | 391 | 15% | 59 | 333 | 43% | 19% |
| High Density | 18 | 35% | 6 | 12 | 7% | 0% |
| Industrial and | 487 | 50% | 243 | 243 | 47% | 24% |
| Mining | 0 | 0% | 0 | 0 | 0% | 0% |
| Open Land and Barren | 161 | 0% | 0 | 161 | 80% | 26% |
| Pasture | 4,961 | 0% | 0 | 4,961 | 45% | 33% |
| Agriculture General | 1,535 | 0% | 0 | 1,535 | 37% | 35% |
| Agriculture Tree Crops | 89 | 0% | 0 | 89 | 17% | 15% |
| Rangeland | 910 | 0% | 0 | 910 | 54% | 43% |
| Forest[1] | 17,818 | 0% | 0 | 17,818 | 51% | 40% |
| Water | 6,078 | 0% | 0 | 0 | 9% | 0% |
| Wetlands | 12,257 | 0% | 0 | 12,257 | 0% | 0% |
| Non-riparian Wetlands | 4,625 | 0% | 0 | 4,625 | 100% | 100% |
| TOTAL[2] | 50,687 | 1% | 376 | 44,233 | 37% | 26% |

[1]Forest includes Forest Regeneration classification in previous model
[2]Sum of pervious and impervious acres does not equal total area because acres of water are not included.

For the Newnans Lake, Lochloosa Lake, and Orange Lake tributary areas, the “water” land use category is explicitly modeled by the reaches (RCHRES) representing the lakes, and the variability in land area for riparian land uses around the lake (e.g., wetlands) is addressed using Special Actions developed by the District in the previous models. These were updated according to the 2009 land use, as were the multiplication factors associated with non-riparian wetlands in the MASS-LINK block.

- **Groundwater recharge.** Based on review of the latest District recharge map (shown on **Figure 2**), the Newnans Lake basin is primarily categorized as a “medium” recharge area (5–10 inches per year), with a small area in the east categorized as a “high” recharge area (10–15 inches per year). This suggests that the hydrologic modeling should consider a moderate value of the parameter DEEPFR (fraction of water passing from the lower soil zone that is directed to deep recharge rather than to active groundwater that discharges as baseflow). The Lochloosa Lake basin is primarily “medium” recharge with some “high” recharge in the northeast, areas of “low” recharge surrounding the lake, and areas of “discharge” underneath the lake itself. The Orange Lake basin is about evenly split between “medium” and “high” recharge potential, and therefore may not contribute significant groundwater flow to the lake as compared to Newnans and Lochloosa, and will be assigned a higher value of DEEPFR than these basins. Exchange between the lakes and the Floridan (discussed in a separate bullet point below) will also be evaluated for consistency with the expected recharge/discharge, which would include moderate recharge from Newnans Lake, high recharge from Orange Lake (particularly when the lake is high enough to lose water through the sinkhole in the southwest part of the lake), and discharge to Lochloosa Lake from the aquifer.

- **Lake seepage.** The seepage from Newnans, Lochloosa, and Orange Lakes to the Floridan aquifer is simulated in a similar manner as the calculations done in the previous HSPF models. In the models, the seepage is calculated based on the head differential between the lake water surface elevation calculated by HSPF and the time series of well water levels, and a multiplier reflecting the conductivity. A variable coefficient was used in the case of Orange Lake, considering that the sinkhole connectivity with the Floridan is reduced when the Orange Lake water level is low.

  For Newnans Lake, the well adjacent to the lake (A-0973) has only 2 years of data, whereas well A-0420 has sufficient data for calibration and validation (**Figure 3**). The data from the A-0420 well, adjusted downward by 5.5 feet, matches the observed values at A-0973 very well. Thus, the adjusted A-0420 well data were used (**Figure 4**).

  For Lochloosa Lake, A-0071 has sufficient data for calibration and validation. These data were adjusted downward when calculating the exchange with the Upper Floridan, to reflect data from the wells closer to the lake (A-0421 and A-0725; Figure 3). The data from the A-0071 well were adjusted downward by 14.5 feet, which is the difference between the average at A-0071 (73.7) and the average of the two other well averages (64.6 at A-0421, 53.7 at A-0725). **Figure 5** shows Lochloosa lake stage, along with data from the three wells and the “A-0071 adjustment.”

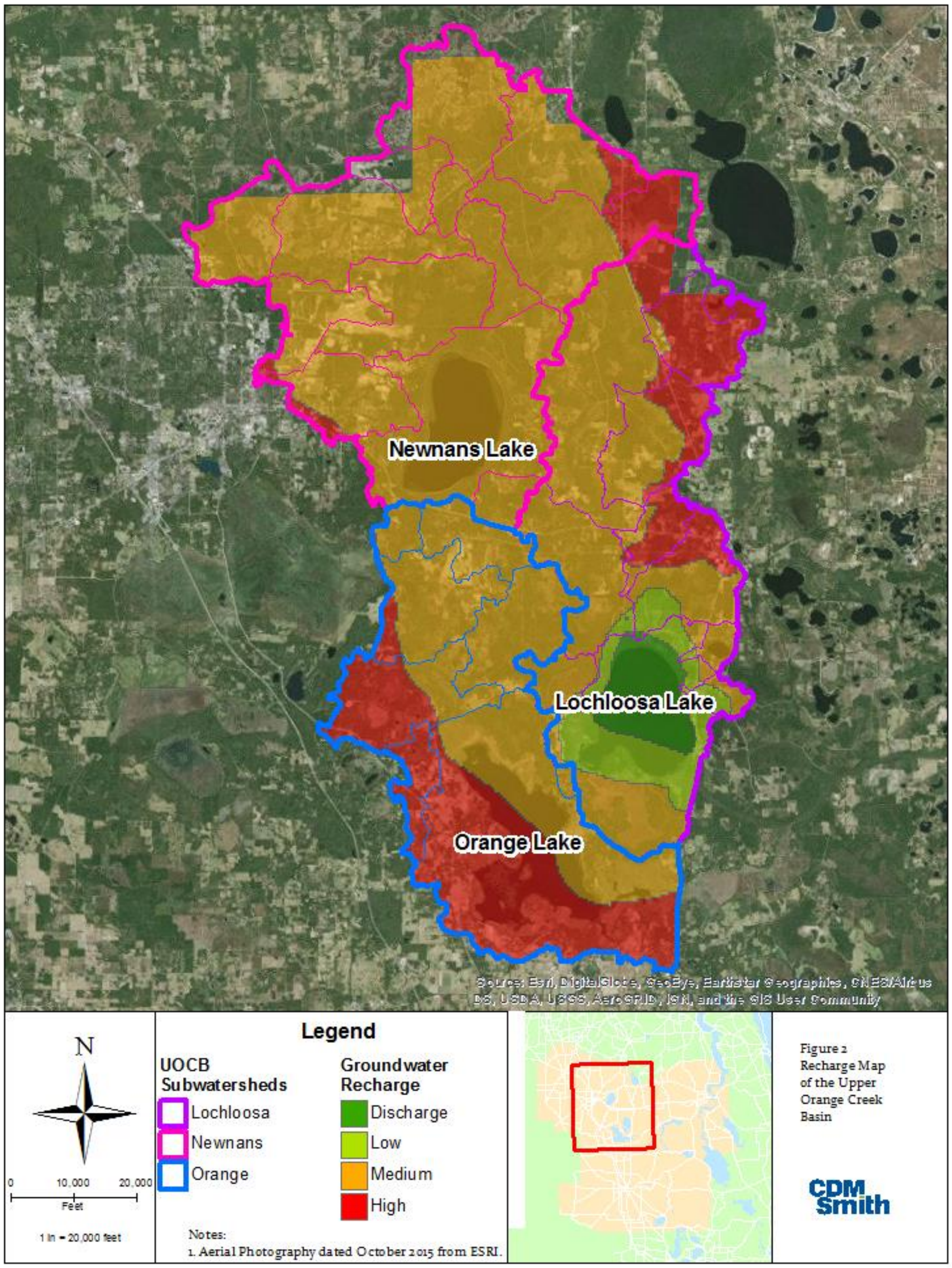


**Figure 2**
**Recharge in Upper Orange Creek Basin (UOCB) Study Area**

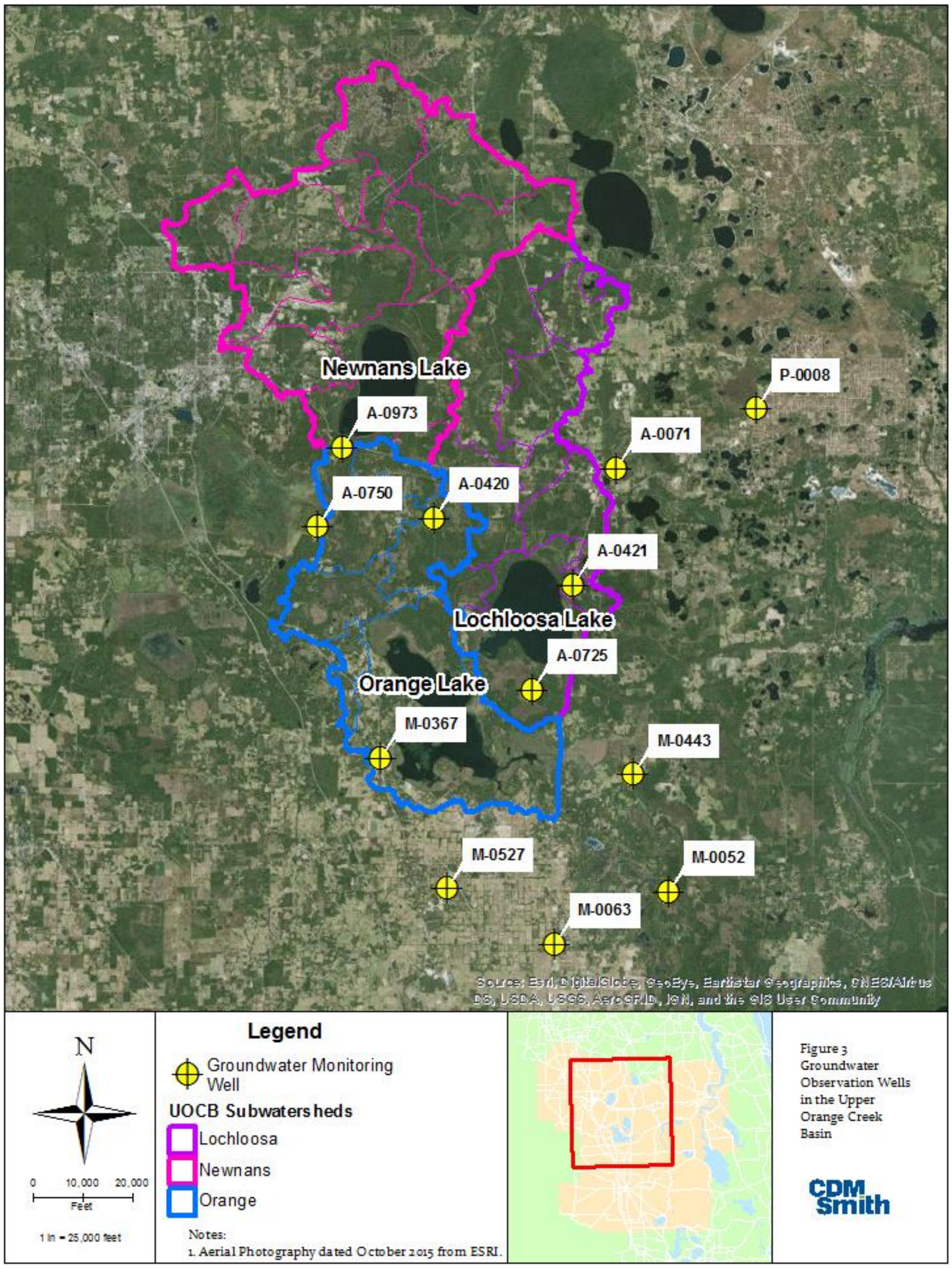


**Figure 3**
**Location of Groundwater Observation Wells in Upper Orange Creek Basin (UOCB)**

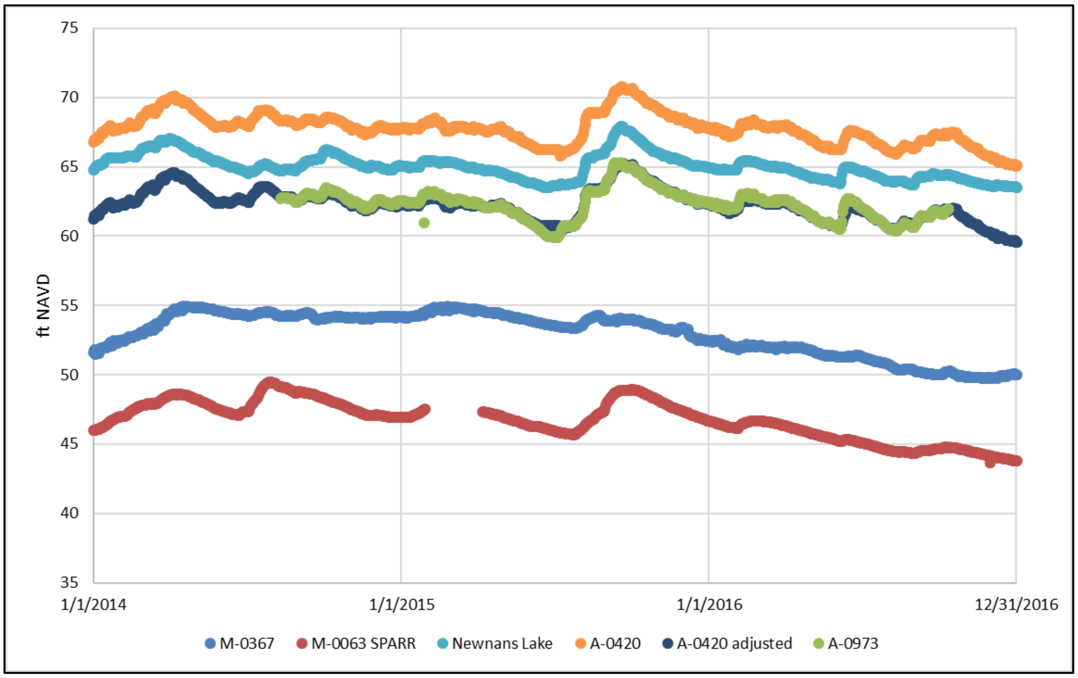


**Figure 4**
**Comparison of Groundwater Levels for Newnans Lake**

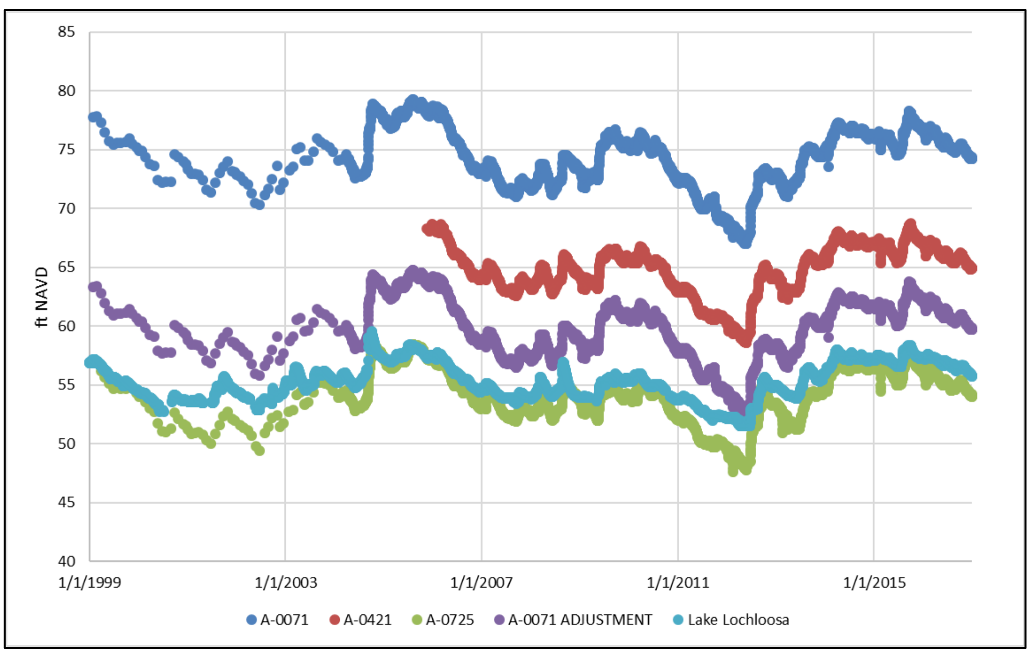


**Figure 5**
**Comparison of Groundwater Levels for Lochloosa Lake**

For Orange Lake, well M-0367 is close to the lake, and has sufficient data for calibration and validation (Figure 3).

The multiplier values used to calculate the flow exchange with the Upper Floridan were considered in HSPF as part of the calibration and validation, which focused primarily on the calculation of appropriate hydrologic flows from the watersheds to the hydraulic system including the lakes. A reasonable set of coefficients was established in HSPF so that HSPF can determine reasonable estimates of direct rainfall on the lakes, as well as reasonable estimates of discharge from the upstream lakes (Newnans and Lochloosa) to the downstream lake (Orange). The SWMM hydraulic model was used to calculate the exchange with the Floridan aquifer, using multiplier values that are similar to those used in HSPF.

- **Lake surface area.** The contributing area of riparian wetlands will vary over time as the lake surface area changes. The District established this relationship using Special Actions that were applied in the previous HSPF models. In the Special Action, the contributing riparian area is calculated as the total area of water surface plus riparian area, minus the lake surface area calculated by HSPF.

- **Land-based watershed flows**. CDM Smith defined linkage points between the HSPF and SWMM models, and modified the HSPF model to save flows from these linkage points for input into the SWMM model. Linkage points are summarized in **Table 4** and displayed on **Figure 6**.

**Table 4. Linkage Points between HSPF and SWMM**

| Linkage Point ID | Waterbody | HSPF Flow |
|---|---|---|
| 1 | Newnans Lake | Total Inflow to Newnans Lake (RCHRES 13) + Direct Rainfall |
| 2 | Prairie Creek | Outflow from Newnans Lake Tributary Reach (RCHRES 31) |
| 3 | Prairie Creek | Inflow from PERLNDs 721-735, IMPLND 721-724 (Basin 32) |
| 4 | Camps Canal | Inflow from PERLNDs 741-755, IMPLND 741-744 (Basin 33) |
| 5 | River Styx | Inflow from PERLNDs 781-795, IMPLND 781-784 (Basin 35) |
| 6 | River Styx | Outflow from Coleman Cemetery Bog Reach (RCHRES 34) |
| 7 | Orange Lake | Outflow from Fish Prairie Reach (RCHRES 36) |
| 8 | Orange Lake | Inflow from PERLNDs 821-835, IMPLND 821-824 (Basin 37) + Direct Rainfall |
| 9 | Lochloosa Lake | Total inflow to Lochloosa Lake (RCHRES 26) + Direct Rainfall |
| 10 | Cross Creek | Inflow from PERLNDs 621-635, IMPLND 621-624 (Basin 27) |

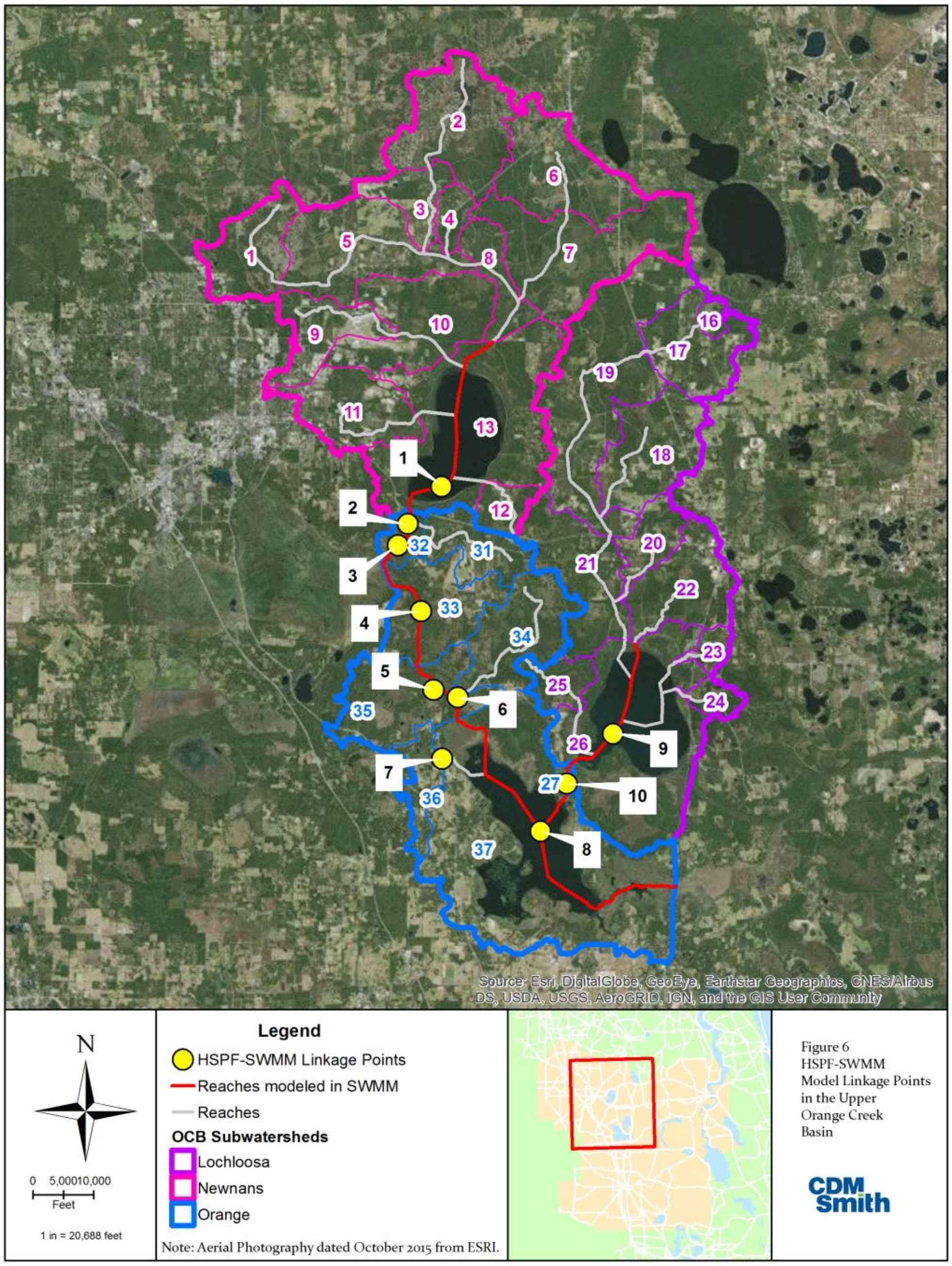


**Figure 6**
**Location of Linkage Points between HSPF and SWMM**

In summary, CDM Smith updated HSPF models for Newnans Lake and Lochloosa Lake/Orange Lake and their tributary areas. Updates included conversion to NAVD, land use distribution, initial establishment of lake and pervious land area recharge to the Floridan aquifer that are consistent with the most recent District recharge mapping, and export of land-based flows for input into a SWMM hydraulic model.

Please call me at (904) 527-6706, or e-mail me at wagnerra@cdmsmith.com if you have any questions, comments, or require further information.

Sincerely,

Richard Wagner, P.E., D.WRE
Principal Water Resources Engineer
CDM Smith Inc.

cc: File
Shayne Wood, CDM Smith
Joanne Chamberlain, SJRWMD
Andrew Sutherland, SJRWMD

# Appendix C

# Task C Letter Report

8381 Dix Ellis Trail, Suite 400
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September 22, 2017 (updated January 31, 2018)

Dr. Xiaoqing Huang
St. Johns River Water Management District
PO Box 1429
4049 Reid St.
Palatka, FL 32178

Subject: Lochloosa, Orange, and Newnans Lakes SWMM Development

Dear Dr. Huang:

This letter summarizes the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. in Task C of the Lochloosa, Orange, and Newnans Lakes Minimum Flows and Levels (MFL) Evaluation, under Work Order #18 of Contract #27776. Task C involves the development of the Stormwater Management Model (SWMM) of Newnans, Lochloosa, and Orange Lakes for the current MFL analysis. This work builds upon our two previous letter reports on data, and HSPF model refinement. The SWMM will be used in conjunction with the updated HSPF model for calibration.

## Introduction

A SWMM was developed to provide a fully dynamic representation of the surface water routing system for the HSPF model for the Newnans, Orange, and Lochloosa Lakes system. This model uses the hydrological results from the HSPF model as input. The flows are routed from Newnans Lake in the northernmost portion of the system downstream to the outfall weirs at the downstream side of both Orange Lake and Lochloosa Lake.

**Figure 1** provides a representation of the SWMM indicating both the entire model schematic, the locations at which HSPF inflow hydrographs are loaded into the system, as well as the location of the monitoring wells used to represent the Upper Floridan aquifer (UFA) boundary condition.

The following sections will provide additional details of the system and input parameters.

## Model Connectivity

Various data were available from SJRWMD, either provided directly from the modeling team or available for download on the District website. To obtain a general indication of the connectivity of this system, ESRI's online aerials were used in conjunction with the "Hydro_Streams_and_Canals_24K" polyline shapefile. These two data sources were further augmented by the digital elevation model (DEM "OCB_DEM_170720.tif") provided by the District modeling team.

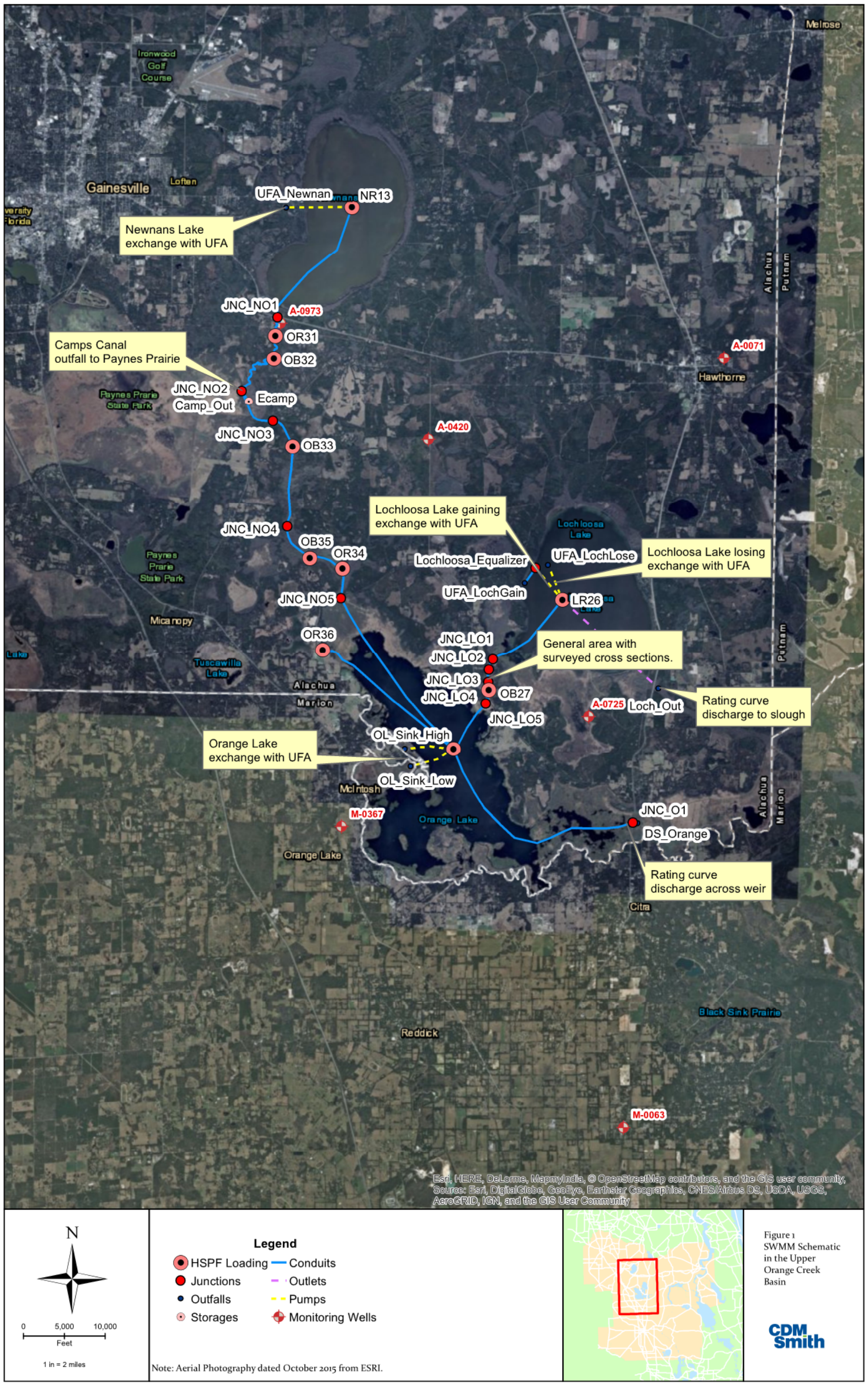


**Figure 1**
**SWMM Schematic in the Upper Orange Creek Basin**

Storage unit nodes (i.e., depth/area nodes) placement occurred at the three modeled lakes, as well as an offline depressional area northeast of Camps Canal. Junction placement occurred along the channel alignments at coincident locations of HSPF hydrograph introduction, locations of significant channel cross section change, and at locations of bridges/culverts. Typically, bridges along the main alignment were not explicitly modeled due to a lack of survey information, as well as the assumption that their capacity would be adequate for most simulation; that is, they would not constrict conveyance significantly.

Once the nodes were placed, they were connected via channel links. Typically, the shallow wide sloughs were modeled as conveyance features; that is, the available storage was included in the cross section associated with the channel segment, rather than additional storage units. There is one exception: a storage node is located east of Camps Canal, in the general vicinity of the culverts to Paynes Prairie. In reviewing the topography, it appeared there was significant, largely off-line storage in this location. This storage unit is connected to Camps Canal via an overflow channel, located at the lowest point along the northeastern top of bank. This channel allows positive and negative flow. Refer to Figure 1 for the model schematic. Shape files for the modeled features are included with the model input file.

As noted in the introduction, flow time series from the HSPF simulation were used as inflows at various locations in the SWMM. For reference, **Figure 2** provides the overall HSPF model schematic, including HSPF subbasins and reaches. At these locations, the junction or storage unit naming convention was consistent with the HSPF model. This ensured that the HSPF results were loaded at the correct location in the SWMM. Other junctions/conduits in the SWMM are named sequentially from Newnans Lake to Orange Lake (junctions = "JNC_NOx" and channels – "CH_NOx" where "x" is an incremental number increasing downstream) and from Lochloosa Lake to Orange Lake (junctions = "JNC_LOx" and channels – "CH_LOx" where "x" is an incremental number increasing downstream). Several other features have more descriptive naming, e.g., "Out_2_Paynes," which is the rating curve that conveys flow from Camps Canal to Paynes Prairie.

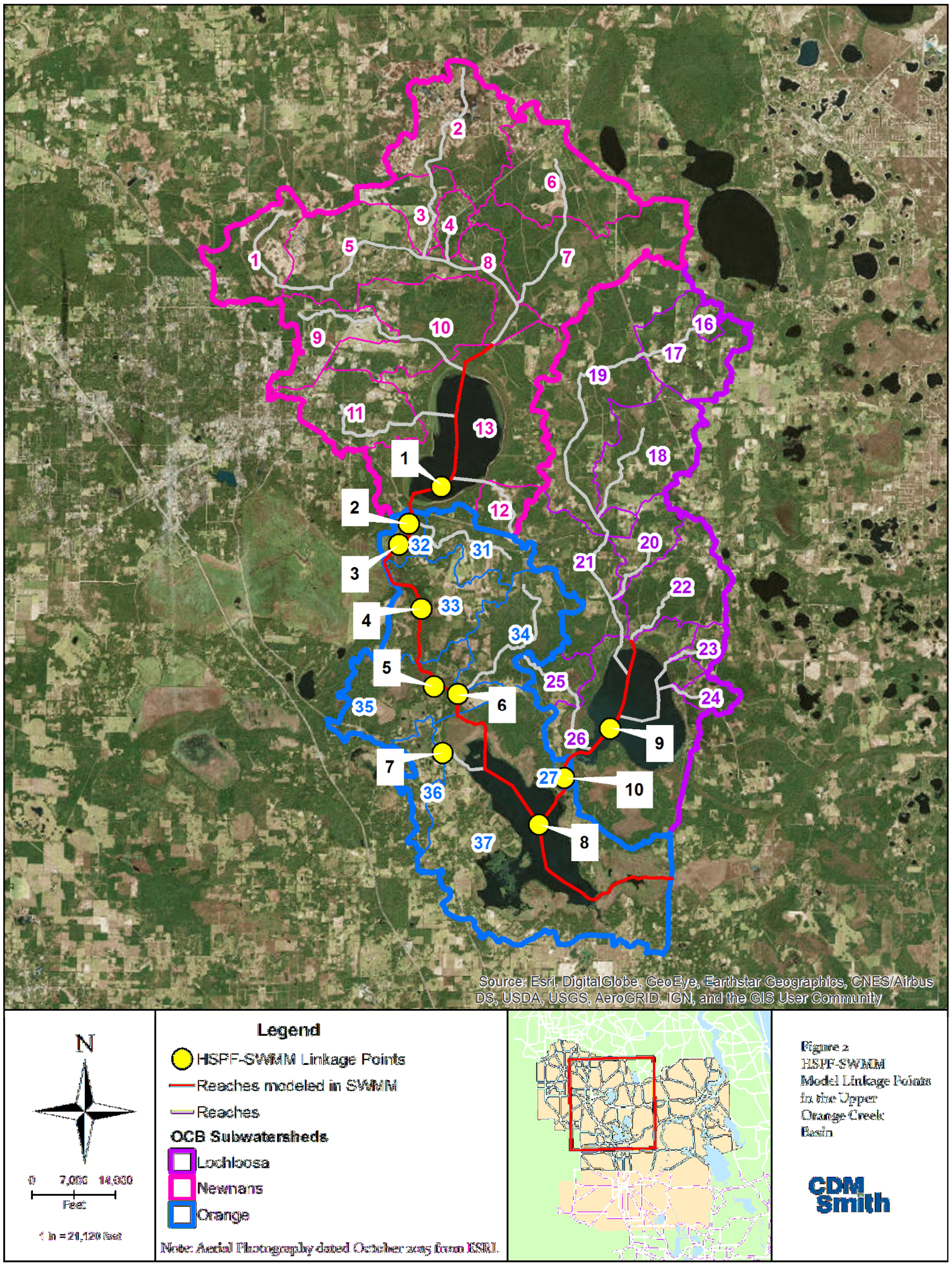


**Figure 2**
**Location of Linkage Points between HSPF and SWMM**

**Table 1** provides the SWMM location that receives the HSPF output.

**Table 1. HSPF Inflows to SWMM**

| Linkage Point ID (SWMM Node ID) | Waterbody | HSPF Flow |
|---|---|---|
| 1 (NR13) | Newnans Lake | Total Inflow to Newnans Lake (RCHRES 13) + Direct Rainfall |
| 2 (OR31) | Prairie Creek | Outflow from Newnans Lake Tributary Reach (RCHRES 31) |
| 3 (OB32) | Prairie Creek | Inflow from PERLNDs 721-735, IMPLND 721-724 (Basin 32) |
| 4 (OB33) | Camps Canal | Inflow from PERLNDs 741-755, IMPLND 741-744 (Basin 33) |
| 5 (OB35) | River Styx | Inflow from PERLNDs 781-795, IMPLND 781-784 (Basin 35) |
| 6 (OR34) | River Styx | Outflow from Coleman Cemetery Bog Reach (RCHRES 34) |
| 7 (OR36) | Orange Lake | Outflow from Fish Prairie Reach (RCHRES 36) |
| 8 (OB37) | Orange Lake | Inflow from PERLNDs 821-835, IMPLND 821-824 (Basin 37) + Direct Rainfall |
| 9 (LR26) | Lochloosa Lake | Total inflow to Lochloosa Lake (RCHRES 26) + Direct Rainfall |
| 10 (OB27) | Cross Creek | Inflow from PERLNDs 621-635, IMPLND 621-624 (Basin 27) |

## Cross Sections

Channel cross sections were extracted from the digital elevation model (DEM). In general, it appears that the topographic data were collected during a relatively dry period, as most of the channel cross sections appear to represent the full channel shape. There is no horizontal line at the bottom of the extracted cross section that would indicate water was present when the topographic data were collected.

A comparison was made between the surveyed cross sections provided by the District with the DEM derived cross sections. **Figure 3** shows a comparison between the HEC-RAS cross section at mile 6.26 of Cross Creek (between Lochloosa and Orange Lakes) compared to the cross section extracted from the DEM. Typically, the DEM-derived cross sections are similar in shape. It was determined, from the spreadsheet that was provided ("Appendix.xlsx"), that the vertical datum of the surveyed cross sections was NGVD. Thus, for the comparison, a vertical shift was applied (-1.2 ft) to convert these elevations to NAVD. With the correction, the two cross sections are very similar. For this limited area (between Lochloosa and Orange Lakes - see Figure 1), the surveyed cross sections are used in the model. This area is noted on Figure 1.

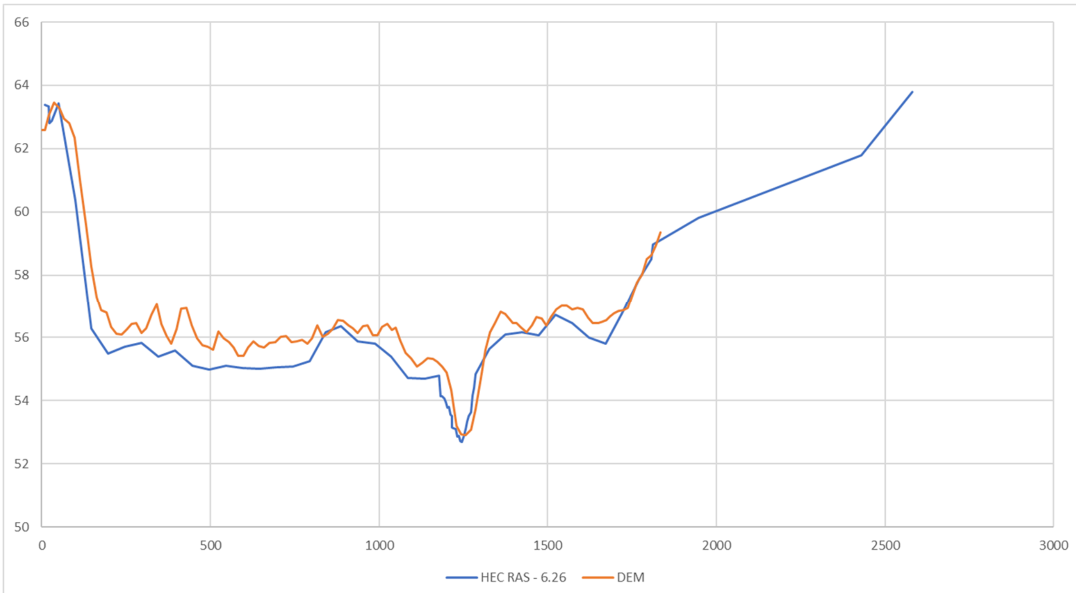


**Figure 3**
**Select Comparison of Provided Cross Sections with DEM Extracted**

It is also noted that the HEC-RAS model of Cross Creek used a Manning's roughness coefficient of 0.02 to 0.08 for the incised channel and 0.3 for the overbank areas. These were initially used globally in the SWMM. The Manning's coefficients were used as a calibration factor and the final values vary 0.05 to 0.15 for the incised channel to 0.15 to 0.45 for the overbank areas.

To have a more robust representation of the culvert crossing to Paynes Prairie, as well as Camps Canal, the District provided survey for both the set of culverts, as well as a representative cross section of the canal. This surveyed cross section was used near the connection to Paynes Prairie. Other than this cross section, and the RAS cross sections in Cross Creek, all other cross sections in the model are derived from the DEM. **Table 2** lists the channel IDs, cross section IDs, and the source of the data.

**Table 2. Channel/Cross Section Data Source**

| Channel ID | Cross Section ID | Source (RAS/DEM) |
|---|---|---|
| CH_NO1 | Transect_NO1 | DEM |
| CH_NO2 | Transect_NO2 | DEM |
| CH_NO3 | Transect_NO3 | DEM |
| CH_NO4 | Transect_NO4 | DEM |
| CH_NO5 | SJRWMD_transect1 | Survey |
| CH_NO6 | Transect_NO6 | DEM |
| CH_NO7 | Transect_NO7 | DEM |
| CH_NO8 | Transect_NO8 | DEM |
| CH_NO9 | Transect_NO9 | DEM |
| CH_NO10 | Transect_NO10 | DEM |
| CH_NO11 | Transect_NO11 | DEM |
| CH_OrangeIn | Transect_O1 | DEM |
| CH_LO1 | Transect_LO1 | DEM |
| CH_LO2 | RAS_7.55 | Cross Creek RAS |
| CH_LO3 | RAS_6.26 | Cross Creek RAS |
| CH_LO4 | RAS_5.27 | Cross Creek RAS |
| CH_LO5 | Bridge_Cross_Canal | Cross Creek RAS |
| CH_LO6 | RAS_3.74 | Cross Creek RAS |
| CH_LO7 | Transect_LO7 | DEM |
| CH_Orange_Out | Transect_Orange_Out | DEM |
| CH_Camp_Stor | Transect_CampE | DEM |

## Storage Volumes

The appropriate FTABLES from the District HSPF models were used for the three main lakes (Newnans, Orange, and Lochloosa). It was necessary to convert the STCOR parameter (invert) of the lake from the HSPF file from NGVD to NAVD. Based upon a comparison of District stage data, it appears that a shift of -1.2 feet is appropriate for this datum correction.

As mentioned previously, a storage junction was defined east of Camps Canal to account for overflow from Camps Canal. The depth/area data was extracted from the DEM using an ArcGIS tool for an appropriately sized area.

## Evaporation

The District's provided potential evaporation time series, adjusted with the District-provided coefficient of 0.843, was used in the SWMM simulation. As the adjustment coefficient was already included in the evaporation time series, 100 percent of the input evaporation was applied at each of the lakes and storage nodes in the SWMM.

## UFA Connectivity

Direct connections to the UFA were established for each of the three lakes in the model domain using pumps. The parameters included in the HSPF model were used to define the connection in the SWMM. More specifically, each lake in the HSPF model had a "K-value" defined. This value is a coefficient that is applied to the difference in head between the calculated lake level and the measured UFA level (hereafter referred to as the "delta head"). The product of the delta head and the coefficient is an estimate of flow (in cubic feet per second [cfs]) either into or out of a lake.

Prior to incorporating UFA connectivity in the SWMM, a comparison of the measured lake level to the appropriate UFA level was made to estimate the range of delta heads. The product of the delta head (minimum and maximum) and the K-value was calculated, which resulted in a range of flow rates. The delta head/flow rate pairs were used to define a pump curve in the SWMM. There are some additional specific variations associated with each of the lakes, that will be addressed in the subsequent subsections. Figure 1 includes the location of the monitoring wells mentioned in the subsequent sections.

Generalizing, Orange and Newnans Lakes lose water to the UFA; Lochloosa Lake typically gains water from the UFA. However, there is the potential, in droughts, that Lochloosa Lake could also lose water to the UFA. A different modeling scheme is considered for losing and gaining. The following sections provide an overview of how the connections were modeled in SWMM.

## Orange Lake

There is a sinkhole located in the southwest quadrant of this lake. When the lake level is above a specific elevation (previously defined in the District HSPF model at 50 feet NAVD), the lake and UFA are highly connected. When the water level is below this elevation, connection between lake and UFA is less effective. Consequently, Two "K-values" were defined: a lower value (for lake level below 50 feet NAVD) and a higher value (for lake levels at or above 50 feet NAVD).

The stage records for the surface water level at Orange Lake (gauge 02611465) were compared to UFA levels (monitoring well: M-0367). Based on this comparison, the delta heads ranged from a minimum of approximately 1 to a maximum of approximately 7 feet (see **Figure 4**).

The K values (and associated SWMM pump curve values) were modified as part of the calibration, due both to the change in well time series used to calculate the interaction between the lake and the Floridan aquifer as well as to better match the surface water levels. The original HSPF modeling had used the time series associated with well M-0063, which is located approximately 7 miles to the southeast of Orange Lake. In the current study, well M-0367, which is immediately adjacent (<1 mile) to the west of the lake is being used. Both HSPF and SWMM will use this time series.

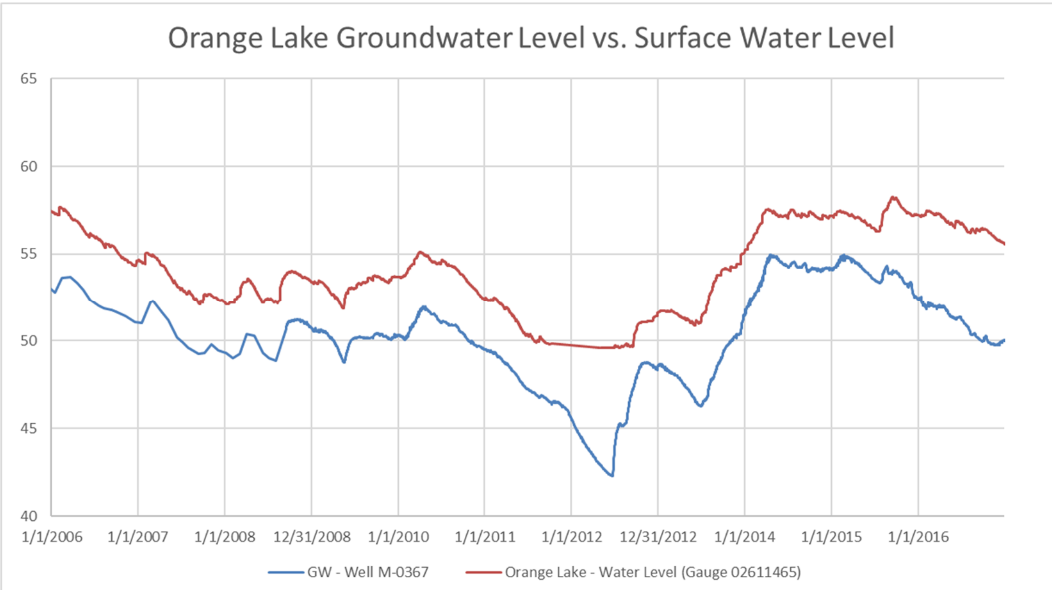


**Figure 4**
**Comparison of Orange Lake Water Level with Nearby UFA Elevation**

Pumps in SWMM are defined as being able to move water from a lower to a higher head. A SWMM type 3 pump (delta head/flow) cannot pump water from a higher elevation to a lower elevation, so it was necessary to adjust both the UFA time series and the delta heads to have the pump operate. This was done by adjusting both the time series and the delta head in the pump curve upwards by 100 feet. A time varying stage boundary condition ("outfall") was defined in the SWMM and the adjusted UFA time series (M-0367) was associated with it. A SWMM pump was defined between the lake and the outfall with the defined relationship between delta head and flow used as the pump curve.

The final calibrated maximum flow rates were 32.7 cfs for lower seepage and 163.4 cfs in times of higher seepage, at a delta head of 10 feet. These relate to K values of 3.27 $ft^2$/sec and 16.34 $ft^2$/sec respectively.

Another requirement for modeling the connection at Orange Lake was to ensure that when the simulated lake level was equal to or greater than 50.1 feet NAVD, the higher flow was used, and when the simulated lake level was less than 50.1 feet NAVD, the lower flow was used. This was done by control rules in the SWMM. These rules apply more sophisticated control to the modeled pumps in SWMM. The following are the rules that were defined:

RULE P1

IF NODE OB37 HEAD >= 50.1

THEN PUMP P_High STATUS = ON

AND PUMP P_Low STATUS = OFF

PRIORITY 1

RULE P2

IF NODE OB37 HEAD < 50.1

THEN PUMP P_High STATUS = OFF

AND PUMP P_Low STATUS = ON

PRIORITY 1

## Lochloosa Lake

In the HSPF model, well A-0071 was used for calibration at Lochloosa Lake. This well was chosen because it had a long period of record (ideal for calibration), and was reasonably close to the lake. However, under closer inspection, the UFA levels in this time series were significantly different compared with wells closer to Lochloosa Lake (A-0421 and A-0725). The A-0071 time series was adjusted 14.5 feet lower, which is the difference between the average level at A-0071 (73.7) and the average of the 2 other well level averages (64.6 at A-0421, 53.7 at A-0725).

To estimate the range of flows, it was necessary to determine the delta head between lake level and UFA level for the calibration period. The stage records for the surface water level at Lochloosa Lake (gauge 71481615) were compared to UFA levels (adjusted monitoring well: A-0071). Based on this comparison, the delta heads ranged from a low of 0 feet up to approximately 9 feet (see **Figure 5**). It is noted that the delta head is always negative, that is this is a gaining lake for the entire calibration period, however it was indicated that there may be periods when the delta head is positive, i.e. Lochloosa Lake would be losing to the UFA. The flow was calculated for this range of heads.

To ensure separation between the measured UFA time series and the simulated lake water level (for lake gaining), 40 feet were subtracted from the UFA time series as well as the delta head. A separate outfall/pump configuration was set up for instances when the lake would be losing to the aquifer, in this case the UFA time series and losing pump configuration had 40 feet added.

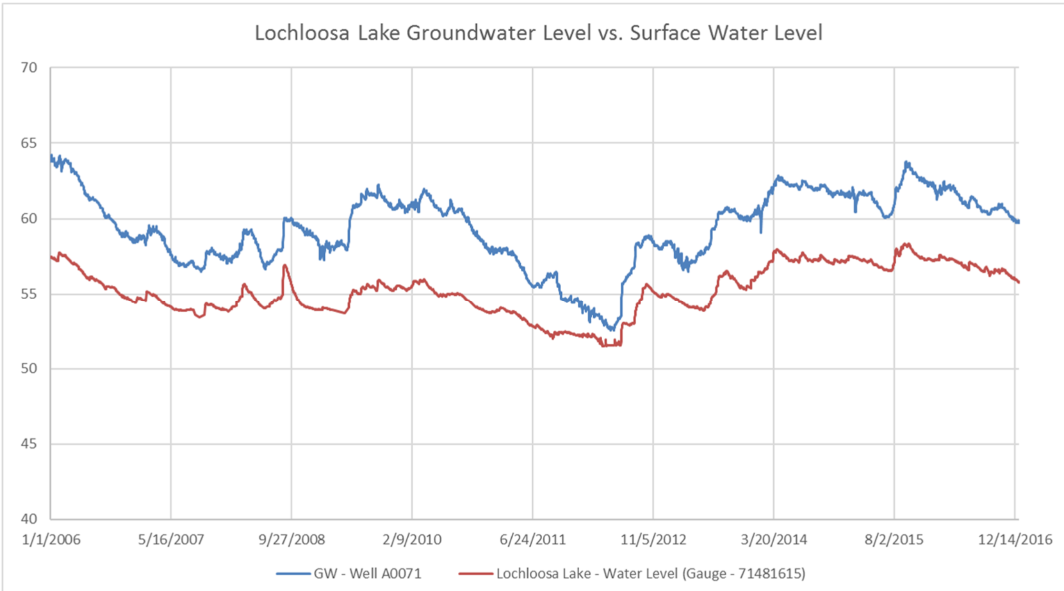


**Figure 5**
**Comparison of Lochloosa Lake Water Level with Nearby UFA Elevation**

The K-value (and associated SWMM pump curve values) were modified as part of the calibration. The final flow rate for the pump curve was set at 6.1 cfs for a delta head of 10 feet, which is equivalent to a K-value of 0.61.

## Newnans Lake

There is a well A-0973 that is relatively close to Newnans Lake; however, it only has 2 years of data. There is another well reasonably close, A-0420, that has an adequate period of record for calibration and validation. However, there was an obvious shift, with the closer well (A-0973) being approximately 5.5 feet lower than A-0420. The time series at A-0420 was adjusted by subtracting 5.5 feet and was used to determine the delta head and flow.

To estimate the range of flows, it was necessary to determine the delta head between lake level and UFA level for the calibration period. The stage records for the surface water level at Newnans Lake (gauge 04831007) were compared to UFA levels (adjusted monitoring well: A-0420). Based on this comparison, the delta heads ranged to approximately 10 feet (see **Figure 6**). The flow was calculated for a range of heads from 0 to 10 feet.

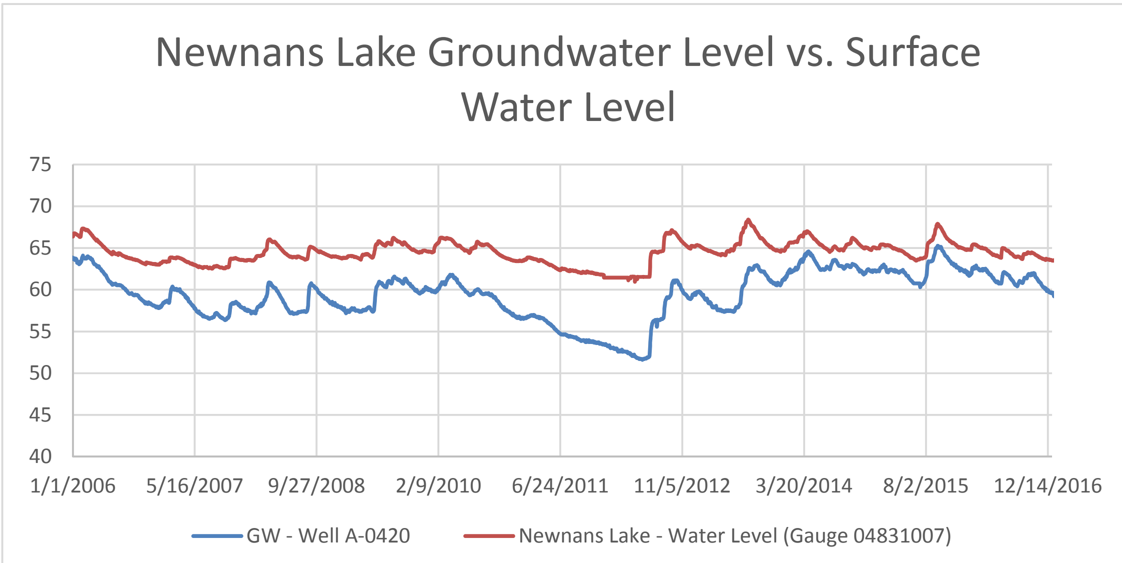


**Figure 6**
**Comparison of Newnans Lake Water Level with Nearby UFA Elevation**

Based upon the time series of surface water and groundwater levels, it appears that Newnans Lake consistently loses water to the UFA. Similar to Orange Lake, it was necessary to adjust both the UFA time series and the delta heads in order to have the pump work. This was done by adjusting both the time series and the delta head in the pump curve upwards by 100 feet. This adjusted UFA elevation was associated with an outfall node, and a pump was defined between the lake storage unit (NR13) and the outfall using a curve defined by a series of delta heads between 0 and 10 feet.

It should be noted that the K values (and associated SWMM pump curve values) were modified as part of the calibration, due to the change in well time series used to calculate the interaction between the lake and the Floridan aquifer. Previous HSPF modeling had used well M-0063, which on average has elevations that are about 19 feet lower than Newnans Lake. In contrast, SWMM will use the adjusted data from well A-0420. The calibrated K-value was 1.37.

## Outfalls

There are three surface water outfalls in the model: at Camps Canal to Paynes Prairie, from Lochloosa Lake to the slough located to the east, and the flow out of Orange Lake across the weir to the east. In all cases, these outfalls are associated with free boundary conditions. Following are discussions of each outfall location.

## Camps Canal to Paynes Prairie

The connection from Camps Canal to Paynes Prairie is a rating curve that discharges to a free outfall boundary condition. The initial rating curve was developed based on comparison of available stage data and estimated flows to Paynes Prairie (estimated as difference between

Camps Canal and Prairie Creek gage flows). This rating curve was extended during calibration/validation, as there were several instances in the validation period when the end of the rating curve was reached and a constant flow (reflecting the highest point on the rating curve) occurred.

## Lochloosa Lake to Slough

When Lochloosa Lake gets to a specific elevation (56.6 feet NAVD), flow will start to enter the slough located southeast of the lake. SJRWMD staff provided a United States Geological Survey (USGS) rating curve (lochslough.rt - STATION NUMBER 02242500 LOCHLOOSA SLOUGH NR LOCHLOOSA, FLA.) that was incorporated into the SWMM. This rating curve estimates the flow into the slough based upon simulated lake level.

## Orange Lake to Slough

The main outfall from the lake system being modeled is located at a weir that is at the southwestern side of Orange Lake. When Orange Lake gets to a specific elevation (55.8 feet NAVD), flow begins to overtop the weir and flow east in a slough system. The FTABLE in the HSPF model was used to estimate the flow over the Orange Lake weir based upon simulated lake level.

Sincerely,

Doug Moulton, P.E.
Water Resources Engineer
CDM Smith Inc.

cc: File
Shayne Wood, CDM Smith
Joanne Chamberlain, SJRWMD
Andrew Sutherland, SJRWMD

# Appendix D

# Task D Letter Report

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November 27, 2017 (updated January 31, 2018)

Dr. Xiaoqing Huang
St. Johns River Water Management District
PO Box 1429
4049 Reid St.
Palatka, FL 32178

Subject: Lochloosa, Orange and Newnans Lake MFL Evaluation – Task D: Model Calibration

Dear Dr. Huang:

This letter summarizes the work completed for the St. Johns River Water Management District (District) by CDM Smith Inc. (CDM Smith) in Task D of the Lochloosa, Orange, and Newnans Lakes Minimum Flows and Levels (MFL) Evaluation, under Work Order #18 of Contract #27776. Task D involves the calibration of the HSPF/SWMM models of Newnans Lake, Lochloosa Lake, and Orange Lake for the current MFL analysis. This work builds upon our three previous letter reports on data, HSPF model refinement, and SWMM model development.

## Model Calibration Period

CDM Smith recommends the period of 2006 through 2016 as the most appropriate calibration period for the HSPF models. This period features the following:

- **Best calibration data.** This period includes flow records at multiple gages within the tributary area to the three lakes. The Hatchet Creek and Lochloosa Creek gages during this period are located further downstream and reflect additional tributary area (i.e., flow comparisons at these gages include a larger part of the watershed).

- **Variety of meteorological conditions**. The calibration period includes 11 years of simulation, which includes years of dry, average, and wet conditions. The wettest year is 2012 (56.2 inches) and the driest year is 2011 (33.4 inches). The overall mean for these years is 44.1 inches.

- **More recent period that is considered consistent with current land use and lake seepage conditions.** The model (based on 2009 land use data) is most representative of conditions in the tributary area after the early 2000s.

For the calibration period of 2006 through 2016, the average annual rainfall of 44.1 inches is somewhat lower than the long-term average of 50.1 inches for the years 1948 through 2016. The average annual PET during the period is 50.5 inches per year, slightly greater than the long-term annual average of 49.8 inches per year.

## HSPF Model Modifications during Calibration

The refined HSPF model from Task B was run for the calibration period, and the tributary area flow results were initially compared to gage data at several locations. At the Hatchet Creek gage 14342633, the Nash-Sutcliffe score for daily flow comparison was 0.37, and the average modeled flow was 21.6 cubic feet per second (cfs) compared to the observed average flow of 27.6 cfs. At the Lochloosa Creek South gage 19234272, the Nash-Sutcliffe score for daily flow comparison was -0.12, and the average modeled flow was 8.6 cfs compared to the observed average flow of 14.4 cfs.

An analysis using PEST was conducted to develop alternative hydrologic parameter values. At the Hatchet Creek gage, the PEST hydrologic parameters improved the Nash-Sutcliffe score for daily flow comparison from 0.37 to 0.43, and the average modeled flow was 25.7 cfs compared to the observed average flow of 27.6 cfs. At the Lochloosa Creek South gage, the PEST hydrologic parameters improved the Nash-Sutcliffe score for daily flow comparison from -0.12 to 0.39, and the average modeled flow was 14.2 cfs compared to the observed average flow of 14.4 cfs.

After review of initial modeling results with SJRWMD, additional PEST analyses were conducted for other parts of the study area. For the incremental tributary area between the Lochloosa Creek South gage and Lochloosa Lake, PEST was applied, using the gaged Lochloosa Creek South flows as a headwater input and gaged Cross Creek flows as a time series outflow from the lake, The PEST analysis considered the comparison of gaged and modeled lake stages during the calibration period. For the incremental tributary area between Newnans Lake and Orange Lake, PEST was applied, using the gaged Prairie Creek flows as a headwater input, and compared gage flows to modeled flows at the River Styx gage.

**Table 1** compares the original hydrologic parameters to the values determined using PEST based on flow comparisons at the Hatchet Creek gage, and **Table 2** compares the original hydrologic parameters to the values determined using PEST based on flow comparisons at the Lochloosa Creek, Cross Creek, and River Styx gages. Whereas the original hydrologic parameter values in some cases show a substantial difference in value between the Newnans watershed and the Lochloosa/Orange watershed, and even in different parts of the Newnans watershed, the newer PEST values tend to show more consistency across the watersheds.

Though the statistical results appear to be better with the refined parameters, the somewhat low Nash-Sutcliffe scores suggest differences between measured and modeled flows, which are likely to result in some differences between modeled and observed lake stages. Further improvement of the hydrologic flow modeling could potentially require more detailed review of model inputs such as rainfall data, which is beyond the scope of the current analysis.

The resulting average flows for the calibration period are summarized in **Table 3**. In general, the modeled flows are slightly lower on average than the gage flows. This may be due in part to higher gage flows that could reflect values above the established rating curve (i.e., high recorded flow may exceed the actual flow).

**Table 1. Hydrologic Parameter Input Values in Newnans Lake HSPF Model**

| Hydrologic Parameter | Land Cover | Original Newnans RCH 1-5 | Original Newnans RCH 6-7 | Original Newnans RCH 8,10,12,13 | Original Newnans RCH 9,11 | Refined Newnans RCH 1-13 |
|---|---|---|---|---|---|---|
| LZSN | Non-wetland | 5.0 – 10.0 | 4.2 – 8.4 | 5.0 – 10.0 | 5.0 – 10.0 | 5.0 – 10.0 |
| | Wetland | 0.5 | 2.0 | 0.5 | 0.5 | 1.0 |
| INFILT | Non-wetland | 0.06 – 0.09 | 0.04 – 0.06 | 0.05 – 0.08 | 0.38 – 0.57 | 0.77 – 0.94 |
| | Wetland | 0.001 | 0.020 | 0.001 | 0.001 | 0.001 |
| AGWRC | All | 0.954 | 0.926 | 0.995 | 0.990 | 0.900 |
| DEEPFR | All | 0.150 | 0.150 | 0.150 | 0.648 | 0.014 |
| BASETP | All | 0.011 | 0.028 | 0.031 | 0.001 | 0.150 |
| AGWETP | Non-wetland | 0.200 | 0.200 | 0.026 | 0.001 | 0.09 |
| | Wetland | 0.700 | 0.700 | 0.690 | 0.700 | 1.00 |
| UZSN | Non-wetland | 0.07 – 0.10 | 0.43 – 0.62 | 0.47 – 0.67 | 0.07 – 0.10 | 0.6 – 1.0 |
| | Wetland | 0.01 | 0.10 | 0.01 | 0.01 | 0.18 |
| INTFW | Non-wetland | 0.001 | 0.001 | 0.375 | 0.100 | 0.271 |
| | Wetland | 0 | 0 | 0 | 0 | 0 |
| IRC | All | 0.600 | 0.600 | 0.599 | 0.697 | 0.500 |
| LZETP | Non-wetland | 0.34 – 0.69 | 0.43 – 0.85 | 0.33 – 0.66 | 0.43 – 0.85 | 0.30 – 0.70 |
| | Wetland | 1.10 | 1.10 | 0.90 | 0.90 | 0.80 |

**Table 2. Hydrologic Parameter Input Values in Lochloosa and Orange Lakes HSPF Model**

| Hydrologic Parameter | Land Cover | Original Lochloosa RCH 16-19 | Original Lochloosa RCH 20-27, Orange 31-37 | Refined Lochloosa RCH 16-21 | Refined Orange RCH 31-36 | Refined Lochloosa and Orange RCH 22-27, 37 |
|---|---|---|---|---|---|---|
| LZSN | Non-wetland | 5.0 – 10.0 | 1.0 – 2.0 | 5.0 – 10.0 | 5.0 – 10.0 | 5.0 – 10.0 |
| | Wetland | 2.0 | 2.0 | 1.26 | 1.00 | 1.50 |
| INFILT | Non-wetland | 0.14 – 0.21 | 0.05 – 0.08 | 0.82 – 1.00 | 0.82 – 1.00 | 0.82 – 1.00 |
| | Wetland | 0.002 | 0.040 | 0.001 | 0.001 | 0.001 |
| AGWRC | All | 0.900 | 0.998 | 0.946 | 0.998 | 0.946 |
| DEEPFR | All | 0.287 | 0.579 | 0.457 | 0.001 | 0.004 |
| BASETP | All | 0.019 | 0.001 | 0.023 | 0.030 | 0.001 |
| AGWETP | Non-wetland | 0.200 | 0.100 | 0.006 | 0.200 | 0.012 |
| | Wetland | 0.700 | 0.252 | 0.209 | 0.200 | 0.200 |
| UZSN | Non-wetland | 0.47 – 0.67 | 1.27 – 1.82 | 0.6 – 1.0 | 0.6 – 1.2 | 0.6 – 1.2 |
| | Wetland | 0.01 | 0.10 | 0.04 | 0.04 | 0.18 |
| INTFW | Non-wetland | 0.001 | 0.001 | 0.375 | 0.100 | 0.271 |
| | Wetland | 0 | 0 | 0 | 0 | 0 |
| IRC | All | 0.600 | 0.600 | 0.500 | 0.697 | 0.576 |
| LZETP | Non-wetland | 0.43 – 0.85 | 0.43 – 0.85 | 0.30 – 0.70 | 0.29 – 0.67 | 0.26 – 0.60 |
| | Wetland | 1.10 | 0.90 | 0.80 | 0.80 | 0.90 |

**Table 3. Average Gage and Model Flows during Calibration Period**

| Location | Start Date | End Date | Model | Average Flow (cfs) | |
|---|---|---|---|---|---|
| | | | | Gage | Model |
| Hatchet Creek | 1/1/2006 | 12/31/2016 | HSPF | 25.7 | 27.6 |
| Prairie Creek | 1/1/2006 | 12/31/2016 | HSPF | 44.9 | 39.9 |
| Camps Canal | 1/1/2006 | 12/31/2016 | SWMM | 18.0 | 17.3 |
| River Styx | 8/1/2006 | 12/31/2016 | SWMM | 24.4 | 22.8 |
| Lochloosa Creek South | 1/1/2006 | 12/31/2016 | HSPF | 14.4 | 14.2 |
| Cross Creek | 10/1/2006 | 12/31/2016 | SWMM | 33.4 | 27.1 |

Several additional modifications were made after the review of initial modeling results. These include the following:

- The HSPF FTABLE accounting for Lochloosa Lake outflow to Cross Creek was modified to be more representative of the hydraulic routing in SWMM. The original FTABLE included three columns of Lochloosa Lake water depth and corresponding lake outflow, which were based on three tailwater elevations in Orange Lake. A Special Action then determined which column (or interpolation between columns) would be an appropriate estimate of lake outflow. In the modified HSPF, the outflow was computed in a new

Special Action based on the Lochloosa Lake elevation and the difference in stage between Lochloosa and Orange Lakes. Output from SWMM was used to establish the stage/flow relationships that were incorporated into the new Special Action.

- The land cover data for the Orange Creek basin (37) was revised so that it was more consistent with the original model. Review of the updated model indicated that the area assigned to non-riparian wetland was much greater in the updated model, and that some area considered non-riparian would be inundated if the Orange Lake water level was high enough (so perhaps should be considered riparian). SJRWMD was provided with a spreadsheet illustrating how the land use adjustments were made.

## SWMM Lake Bathymetry and Seepage Outflow (or Inflow)

The bathymetry of the three lakes modeled in SWMM was taken directly from the HSPF models for the lake system, which were adjusted in the HSPF models so that the resultant stage calculations were in feet NAVD 88.

In SWMM, lake seepage is represented by one or more pumps connected to the lakes. As in the original HSPF models, the groundwater exchange is calculated as a function of the head differential between the lake stage and the well elevation, and a coefficient that is established through model calibration.

For each of the three lakes, there is at least one pump that simulates seepage from the lake to the Upper Floridan aquifer (UFA). This is a Type 3 pump, which discharges at a rate based on the head differential between the SWMM node being pumped and the node receiving the pumped water. For this pump, the node receiving the water is an outfall node with an assigned stage time series reflecting the UFA stages at the lake. The actual UFA time series was adjusted upward by an arbitrary amount (100 feet for Newnans and Orange Lakes, 40 feet for Lochloosa Lake) so that the pump would move water from the lake (lower water level) to the outfall node (higher water level). For example, if the actual head differential between the lake surface and the UFA was 10 feet, SWMM would see a head difference of 90 feet, and the pump curve at a head differential of 90 feet would reflect the expected seepage for an actual head differential of 10 feet.

For Lochloosa Lake, there is a second pump that is designed to simulate the much more common occurrence of the UFA contributing flow into Lochloosa Lake rather than losing water. (Note: the lake is always receiving water from the UFA during the calibration period, but the lake could conceivably lose water in very dry conditions.) In this case, the pump is conveying water from a node that is connected to an outfall, and in turn this outfall has an assigned stage time series reflecting the UFA levels at the lake. The stage time series this time has been adjusted downward by 40 feet, so pumping will go from the node to the lake.

Orange Lake also has a second pump, which reflects the fact that exchange at lower lake stages will not be as significant because the lake level has dropped to a point at which the connection between the lake and the UFA is less effective. SWMM includes Control Rules that determine which pump (high seepage or low seepage) is active based on lake stage.

During the calibration period, the following exchanges between the lakes and the UFA were modeled in SWMM:

- Newnans Lake: 1.0 – 11.7 cfs from lake to UFA (average 5.7 cfs)
- Lochloosa Lake: 0.4 – 4.4 cfs from UFA to lake (average 2.6 cfs)
- Orange Lake: 1 – 101 cfs from lake to UFA (average 57 cfs)

## SWMM Flow to Paynes Prairie

Efforts were made to explicitly simulate the culverts that carry flow from Camps Canal west to Paynes Prairie, which would require the establishment of a tailwater time series. Insufficient data were available to establish the tailwater time series, so the diversion of flow westward was simulated in SWMM using a rating curve. The rating curve establishes the flow through the culverts as a function of the stage at the culvert location. The rating curve was developed much like the flow split in the HSPF model, assuming that the difference in flow between the Prairie Creek flow gage and Camps Canal gage reflected the quantity of culvert flow, and that the stage at the culverts was similar to the stage at the downstream Camps Canal gage.

**Figure 1** shows the rating curve used in SWMM. In the figure, a depth of zero corresponds to a stage of 57 feet NAVD 88. The rating curve extends up to a depth of 6.9 feet (stage of 63.9 feet NAVD 88), which was sufficient to handle all flows and stages encountered in the calibration and validation periods.

Using the SWMM results, the paired values of modeled flow in Camps Canal upstream of the culverts and modeled discharge to Paynes Prairie was plotted against historical flow data, as shown on **Figure 2**. The original figure included historical data prior to 2006, and was provided by SJRWMD. Later historical data, and the SWMM results, were added by CDM Smith. The results show that SWMM is discharging flows to Paynes Prairie in a manner consistent with the historical data.

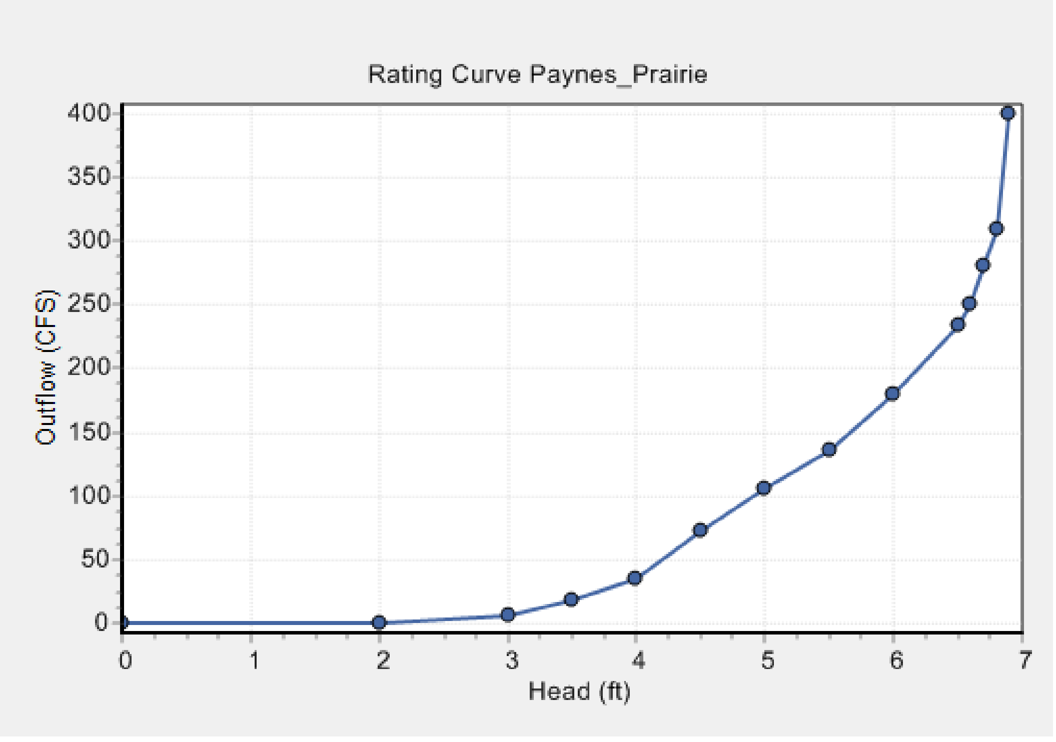


**Figure 1**
**Rating Curve for Paynes Prairie Diversion**

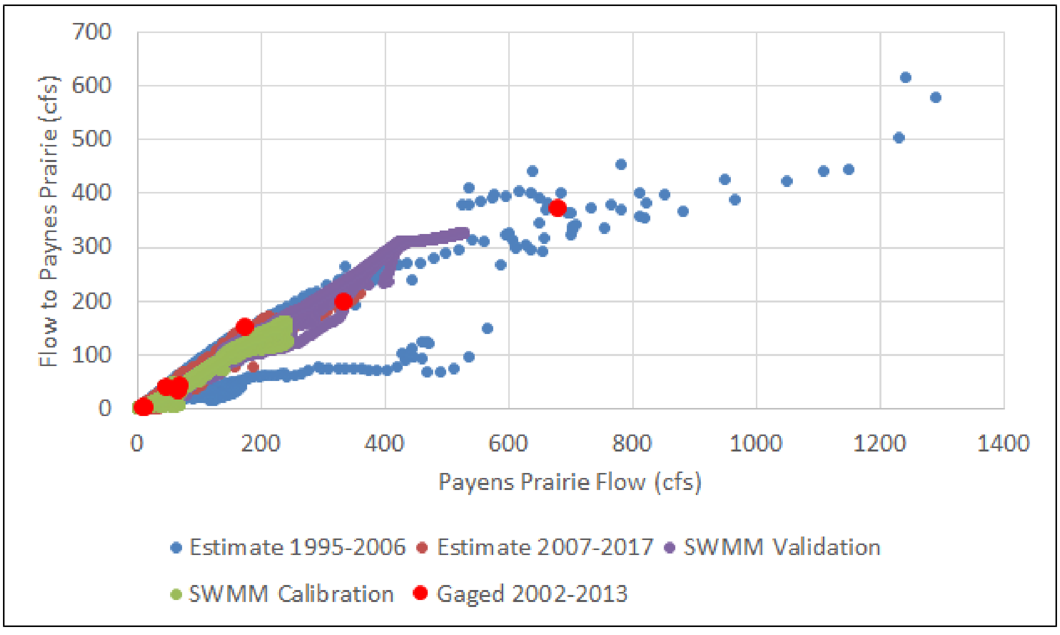


**Figure 2**
**Relationship between Prairie Creek Flow and Flow to Paynes Prairie**

## Other SWMM Rating Curves

Rating curves are also applied at several other locations. These include the Lochloosa Slough discharge from Lochloosa Lake eastward (i.e., not contributing flow downstream to Orange Lake), and the Orange Lake outfall. Both rating curves are consistent with the HSPF model FTABLES.

## SWMM Calibration Overview

Using the inflow hydrographs provided by HSPF, SWMM accounted for the routing of flows through the stream network between the three lakes, and lake processes including surface evaporation and exchange with the UFA.

For the routing of flows between the lakes, the establishment of the channel roughness coefficient was based on comparisons of observed and modeled stages, in some cases using observed flow and stage data as input. For example, the evaluation of Cross Creek between Lochloosa Lake and Orange Lake was based on isolating that section of the model, assigning observed Lake Orange stages as a tailwater boundary condition, and then adjusting the Cross Creek routing coefficients to achieve a good match with the stages in Lochloosa Lake. Similarly, the channel between the Camps Canal and Orange Lake was evaluated using measured flows in Camps Canal as a headwater condition and observed Orange Lake stages as a tailwater condition, and comparing the modeled stages at the Camps Canal gage to the stages modeled in SWMM. The values developed in the smaller models were then used in the full model.

The initial roughness values used for all channels was 0.02 to 0.08 for channel and 0.30 for overbank. For Cross Creek, the calibration resulted in higher values (0.15 channel, 0.45 overbank), which seem high based on limited observation of the stream. However, the lower values could not replicate stages in Lochloosa Lake without using these higher values. The values of 0.05 for channel and 0.15 for overbank produced reasonable results for the Prairie Creek, Camps Canal, and River Styx reaches.

Lake stage calibration also included consideration of the exchange with the UFA. The pump curves were adjusted as necessary to achieve the best fit between the observed and simulated lake stages, and were consistent with the seepage coefficients used in the HSPF models providing the hydrologic flows to SWMM.

## Calibration Model Results

**Figures 3 and 4** present the observed and modeled stage time series and frequency-exceedance relationship for Newnans Lake during the years 2006 through 2016. The results indicate that the model is doing a very good job of simulating lake stages and replicating high and low lake stages during the simulation period.

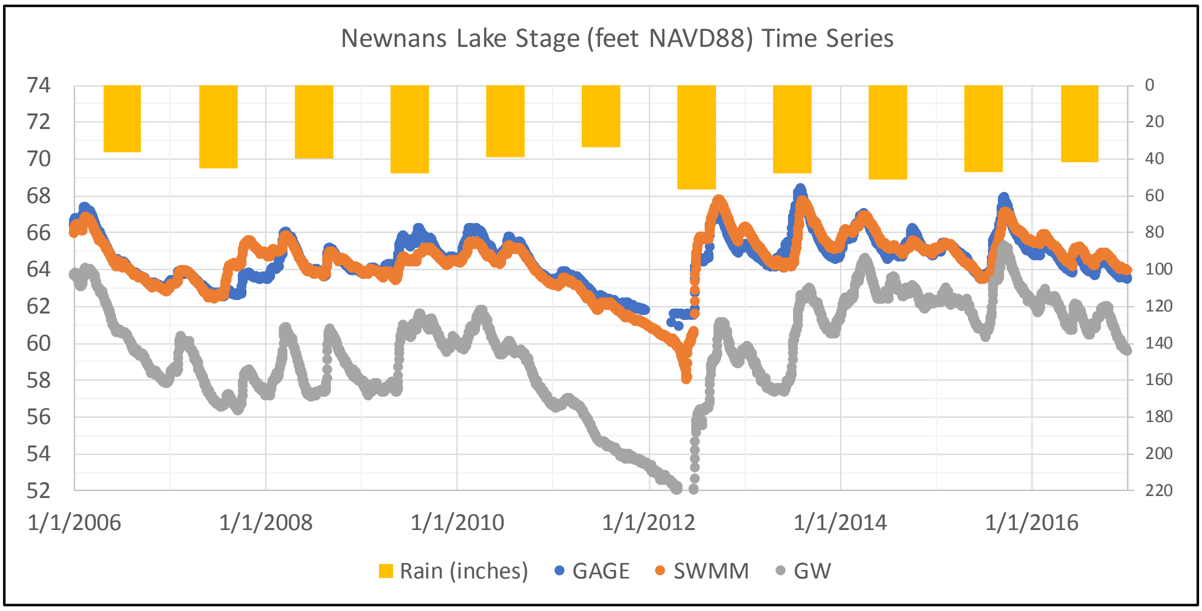


**Figure 3**
**Comparison of Observed and Modeled Stage Time Series in Newnans Lake for Calibration Period**

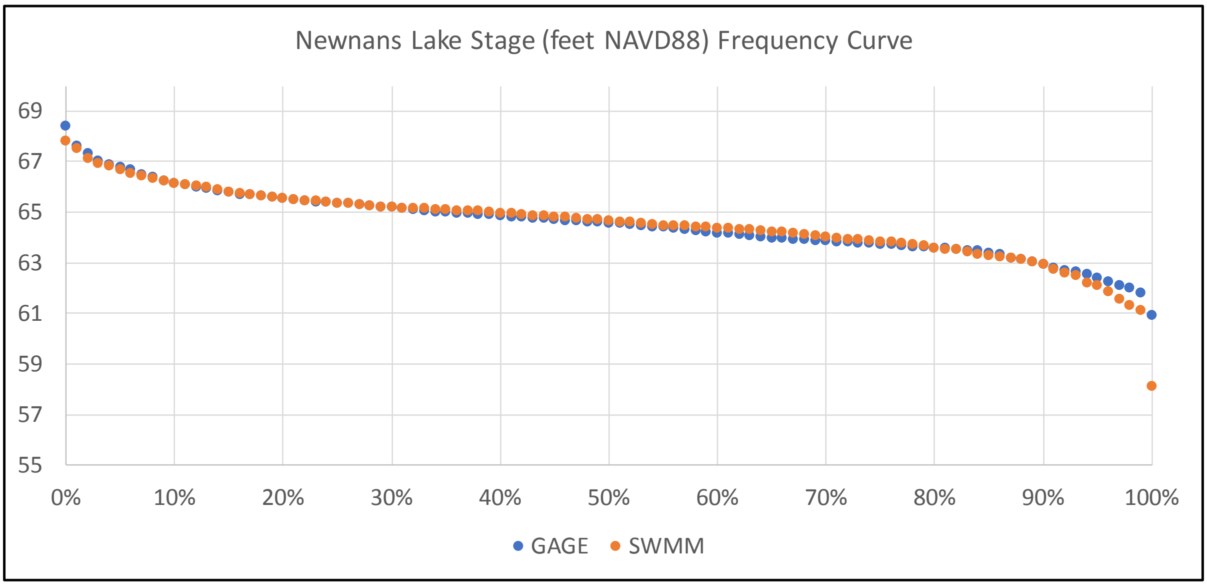


**Figure 4**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Newnans Lake for Calibration Period**

Calculations were performed to determine the Nash-Sutcliffe score for the simulation period. The calculation uses the following equation:

(1) $NS = 1 - [\sum (S_o - S_m)^2 / \sum (S_o - S_{bar})^2]$,

where

$S_o$ = observed lake stage (feet NAVD 88),

$S_m$ = modeled lake stage (feet NAVD 88), and

$S_{bar}$ = average observed lake stage (feet NAVD 88).

Based on differences between the observed lake stages and mean observed lake stage during the calibration period (64.55 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.77.

The differences between the observed and modeled lake stages were also evaluated to determine the percentage of time that the absolute difference between the observed and modeled stages was 0.50 foot or less. The results indicated that 70 percent of the paired data were within 0.5 foot. The average absolute error of the lake stage is 0.43 foot.

The calibration period water budget for Newnans Lake is presented in **Table 4**. Total inflow, lake seepage, and lake surface discharge come directly from the SWMM output. The change in volume value was calculated based on the SWMM depth-area table and the initial and final modeled lake stages. Evaporation is calculated so that the inflow and outflow values sum to zero.

**Table 4. Calibration Period Water Budget for Newnans Lake**

| Lake Inflows | Average Flow (cfs) |
|---|---|
| Total Inflow (Upstream Watershed + Direct Rainfall) | 79.9 |
| Evaporation | -35.0 |
| Lake Seepage to Floridan Aquifer | -5.6 |
| Lake Surface Discharge | -38.8 |
| Change in Volume | -0.5 |

The table indicates that the average inflow to the lake during the calibration period is 79.9 cfs. Considering that the average annual rainfall during the period is 44.1 inches per year compared to 50.5 inches per year average for lake evaporation, the direct rainfall on the lake surface is estimated to be 30.6 cfs, which is about 38 percent of the total inflow. Inflow from the watershed would account for the remaining 62 percent. Lake surface discharge accounts for most of water loss from the lake, followed by evaporation.

**Figures 5 and 6** present the observed and modeled stage time series and frequency-exceedance relationship for Lochloosa Lake during the years 2006 through 2016. The results indicate that the model is doing a good job of simulating lake stages, though the lake appears to show a higher variability in stages (i.e., SWMM modeled stages appear a bit lower than observed data during periods of high stages and higher than observed stages when the observed stages are low). Based on differences between the observed lake stages and mean observed lake stage during the calibration period (55.40 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.83. The results indicated that 64 percent of the paired data were within 0.5 foot. The average absolute error of the lake stage is 0.49 feet.

The calibration period water budget for Lochloosa Lake is presented in **Table 5**. Total inflow, lake seepage, and lake surface discharge come directly from the SWMM output. The change in volume value was calculated based on the SWMM depth-area table and the initial and final modeled lake stages. Evaporation is calculated so that the inflow and outflow values sum to zero.

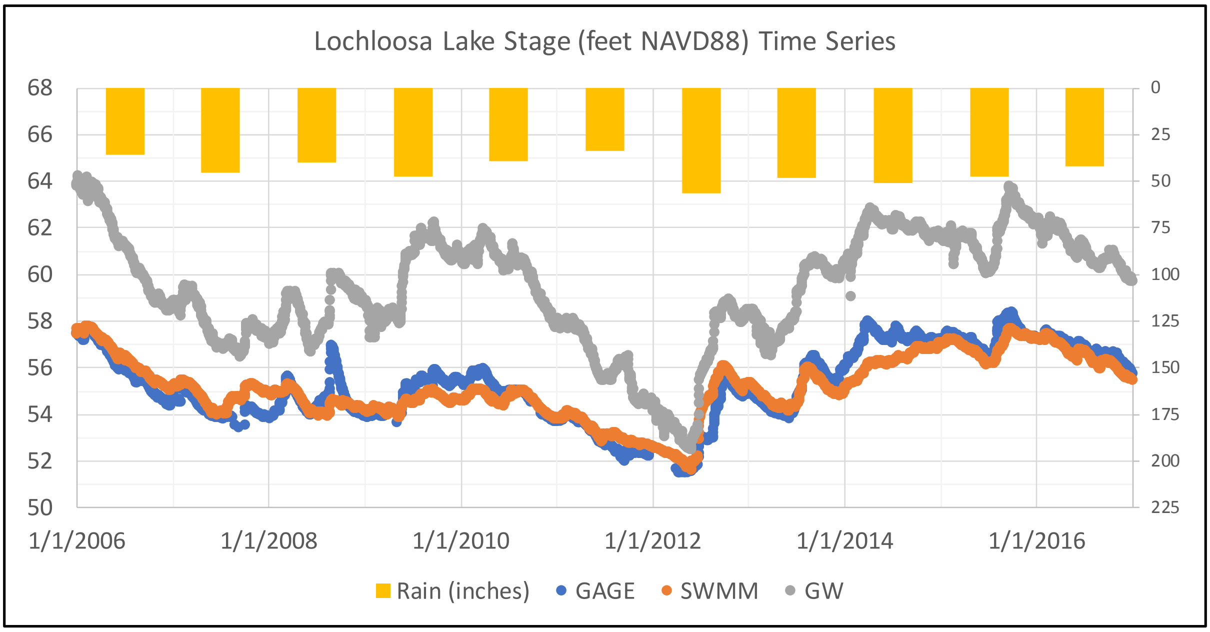


**Figure 5**
**Comparison of Observed and Modeled Stage Time Series in Lochloosa Lake for Calibration Period**

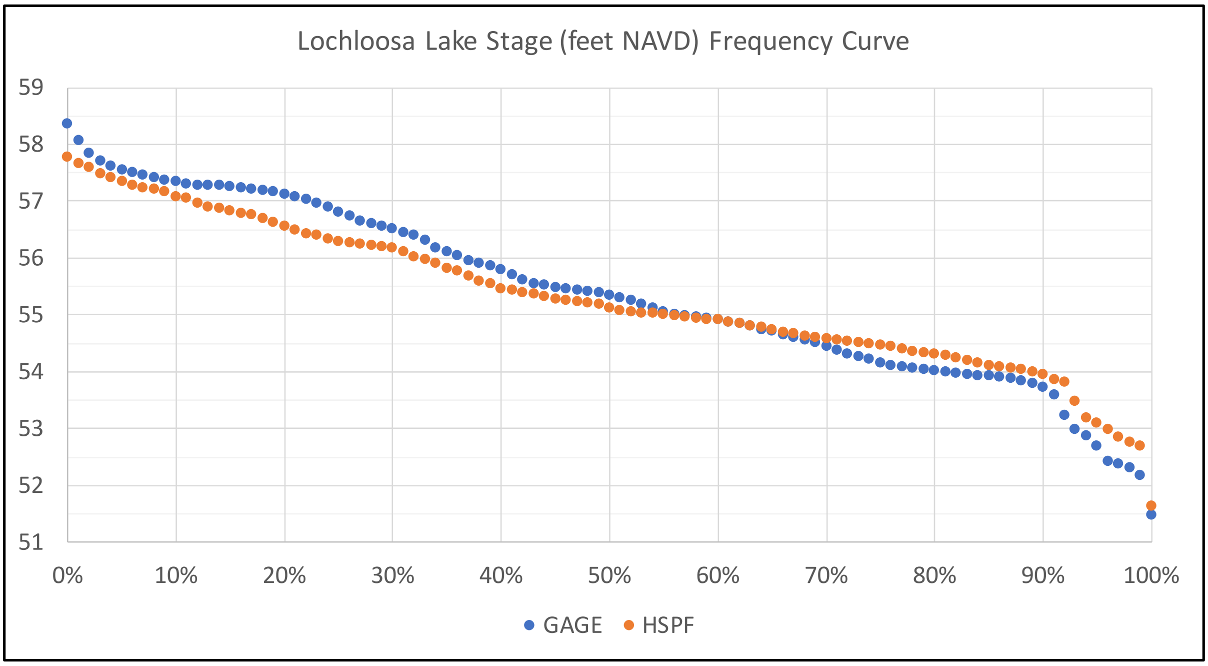


**Figure 6**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Lochloosa Lake for Calibration Period**

The table indicates that the average inflow to the lake during the calibration period is 67 cfs. Considering that the average annual rainfall during the period is 44.1 inches per year compared to 50.5 inches per year average for lake evaporation, the direct rainfall on the lake surface is estimated to be 34.0 cfs, which is about 50 percent of the total inflow (considering the watershed, direct rainfall, and UFA inflows). Inflow from the watershed and UFA inflow would account for 46 percent and 4 percent of the inflow, respectively. Evaporation accounts for most of water loss from the lake, followed by outflow via Cross Creek.

**Table 5. Calibration Period Water Budget for Lochloosa Lake**

| Lake Inflows | Average Flow (cfs) |
|---|---|
| Total Inflow (Upstream Watershed + Direct Rainfall) | 66.8 |
| Lake Inflow from Floridan Aquifer | 2.6 |
| Evaporation | -38.9 |
| Cross Creek Discharge | -27.5 |
| Lochloosa Slough Discharge | -0.8 |
| Change in Volume | -2.2 |

**Figures 7 and 8** present the observed and modeled stage time series and frequency-exceedance relationship for Orange Lake during the years 2006 through 2016. The results indicate that the model is doing a good job of simulating lake stages, though the lake appears to show a higher variability in stages (i.e., SWMM modeled stages appear a bit lower than observed data during periods of high stages, and higher than observed stages when the observed stages are low). Based on differences between the observed lake stages and mean observed lake stage during the calibration period (54.35 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.82. The results indicated that 56 percent of the paired data were within 0.5 foot. The average absolute error of the lake stage is 0.65 foot.

The calibration period water budget for Orange Lake is presented in **Table 6**. Total inflow, lake seepage, and lake surface discharge come directly from the SWMM output. The change in volume value was calculated based on the SWMM depth-area table and the initial and final modeled lake stages. Evaporation is calculated so that the inflow and outflow values sum to zero.

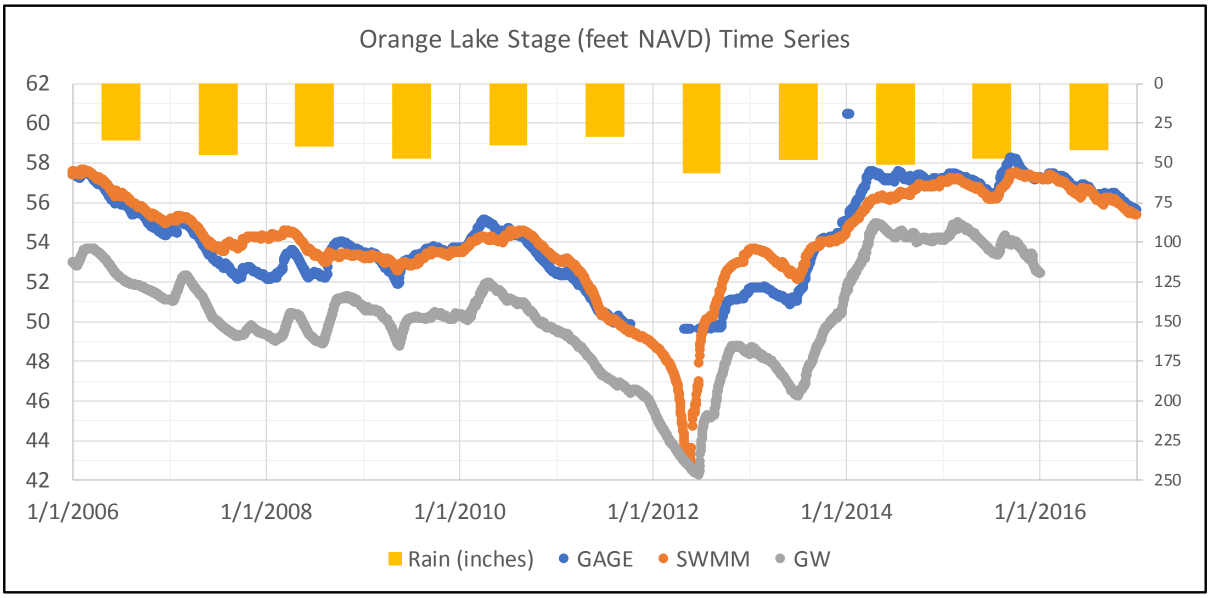


**Figure 7**
**Comparison of Observed and Modeled Stage Time Series in Orange Lake for Calibration Period**

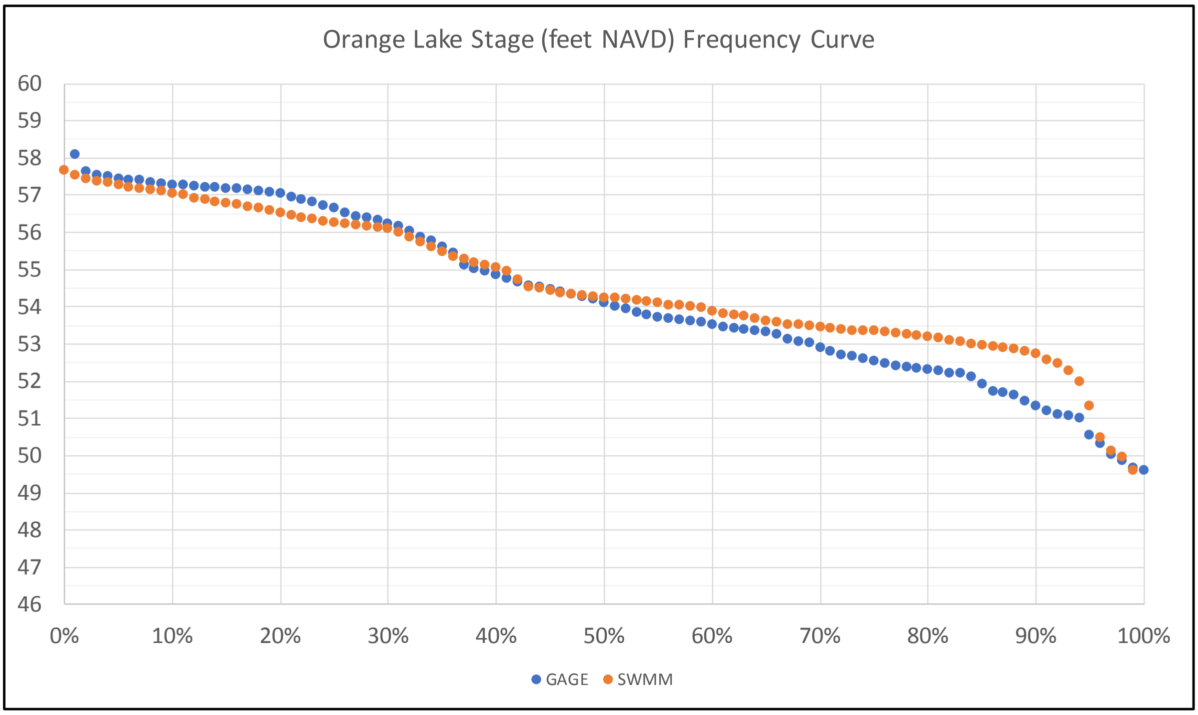


**Figure 8**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Orange Lake for Calibration Period**

The table indicates that the average inflow to the lake during the calibration period is 120 cfs. Considering that the average annual rainfall during the period is 44.1 inches per year compared to 50.5 inches per year average for lake evaporation, the direct rainfall on the lake surface is estimated to be 47.7 cfs, which is about 40 percent of the total inflow. Lake outflow to the UFA accounts for most of the water loss from the lake, followed by evaporation.

**Table 6. Calibration Period Water Budget for Orange Lake**

| Lake Inflows | Average Flow (cfs) |
|---|---|
| Total Inflow (Upstream Watershed + Direct Rainfall) | 120.0 |
| Evaporation | -54.7 |
| Lake Outflow to Floridan Aquifer | -56.9 |
| Lake Surface Discharge | -5.0 |
| Change in Volume | -3.5 |

For all three lakes, the water budget is generally consistent with the estimated values presented in the *Orange Creek Basin SWIM Plan* (SJRWMD, 2011). The exception is the split of Orange Lake discharge between the surface outfall and the seepage to the UFA. The SWIM plan estimated an annual combined outflow of 58 cfs which is slightly less than the total 61.9 cfs in Table 6, but the estimated split in the SWIM plan was 36 cfs to the UFA and 22 cfs for the lake surface discharge.

## Calibration Model with Gaged Inflows

After reviewing the initial modeling results, the SWMM calibration model was run with hydrologic input based on gage data. For the Newnans Lake tributary area, land-based inflows were assigned based on available flow gages (Hatchet Creek, North Branch Little Hatchet Creek, and Lake Forest Creek) and extension of the gage flows to the ungaged area upstream of Newnans Lake. For the incremental tributary area to Lochloosa Lake and Orange Lake, the Lochloosa Creek South gage flows were used to account for the gaged area and were also applied to ungaged areas, based on the relative acreage of gaged and ungaged areas. For all three lakes, the direct rainfall on the lake surface was calculated using the observed lake stage, daily rainfall, and the lake stage-surface area relationship from the HSPF FTABLE.

**Figures 9 through 14** present the observed and modeled stage time series and frequency-exceedance relationship for the three lakes using gaged inflows. Using the gaged inflows resulted in a better agreement between modeled and observed lake stages. The Nash-Sutcliffe scores for Lochloosa and Orange Lakes increased to 0.92 and 0.94, respectively.

These results suggested that SWMM as calibrated was capable of appropriately calculating lake stages, provided that the hydrologic input from HSPF was representative of actual watershed flows. This is the reason that additional PEST analyses were done, as described earlier.

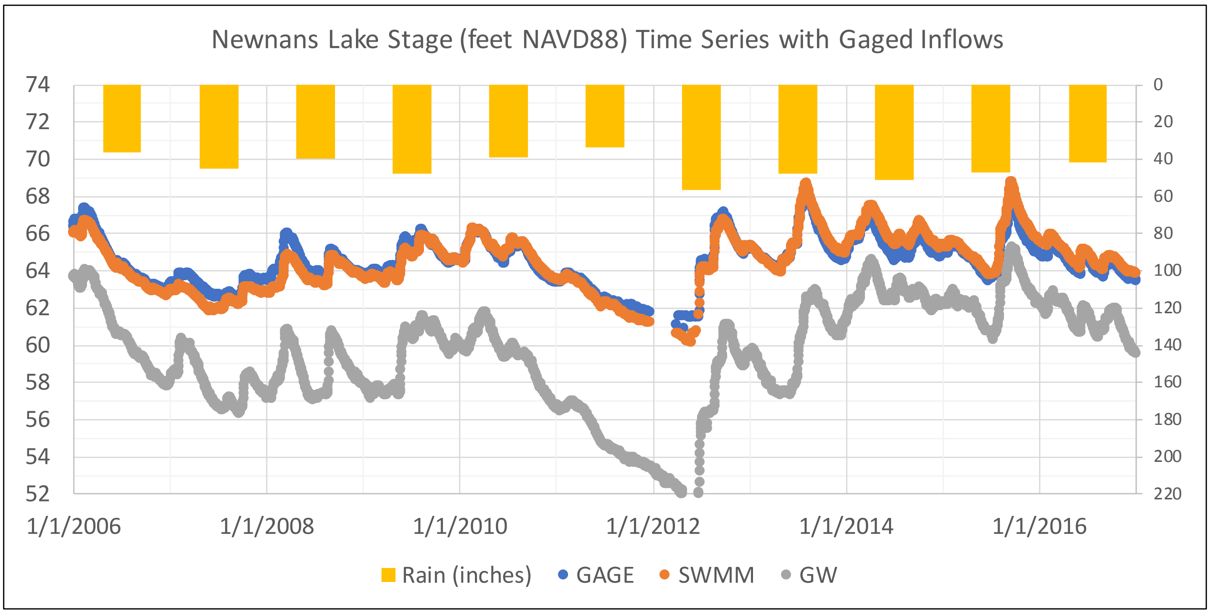


**Figure 9**
**Comparison of Observed and Modeled Stage Time Series in Newnans Lake using Gaged Inflows for Calibration Period**

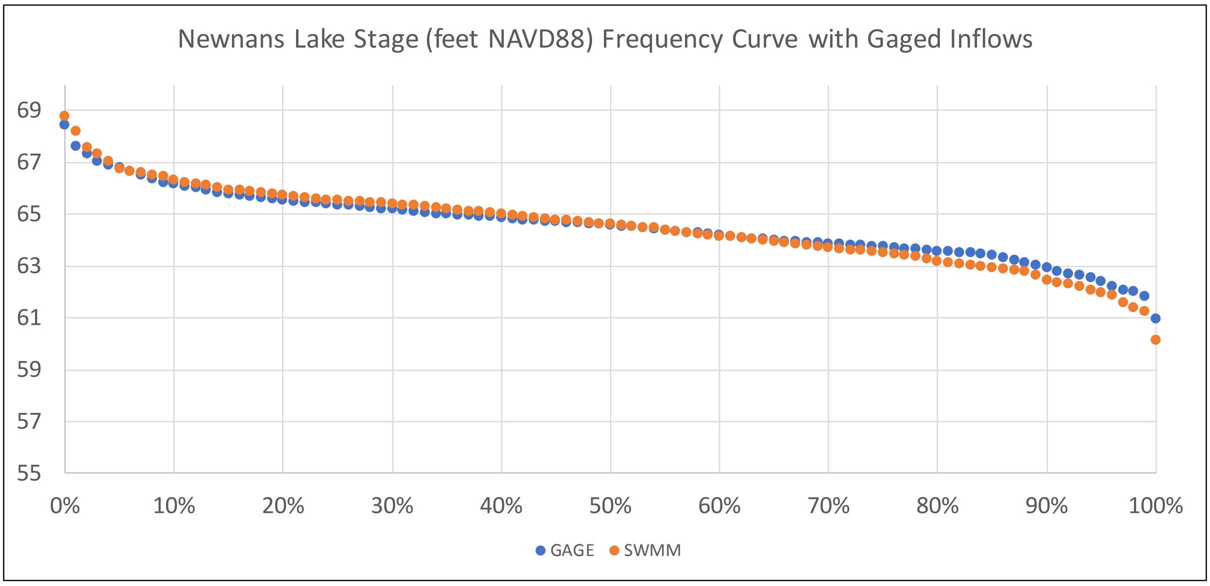


**Figure 10**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Newnans Lake using Gaged Inflows for Calibration Period**

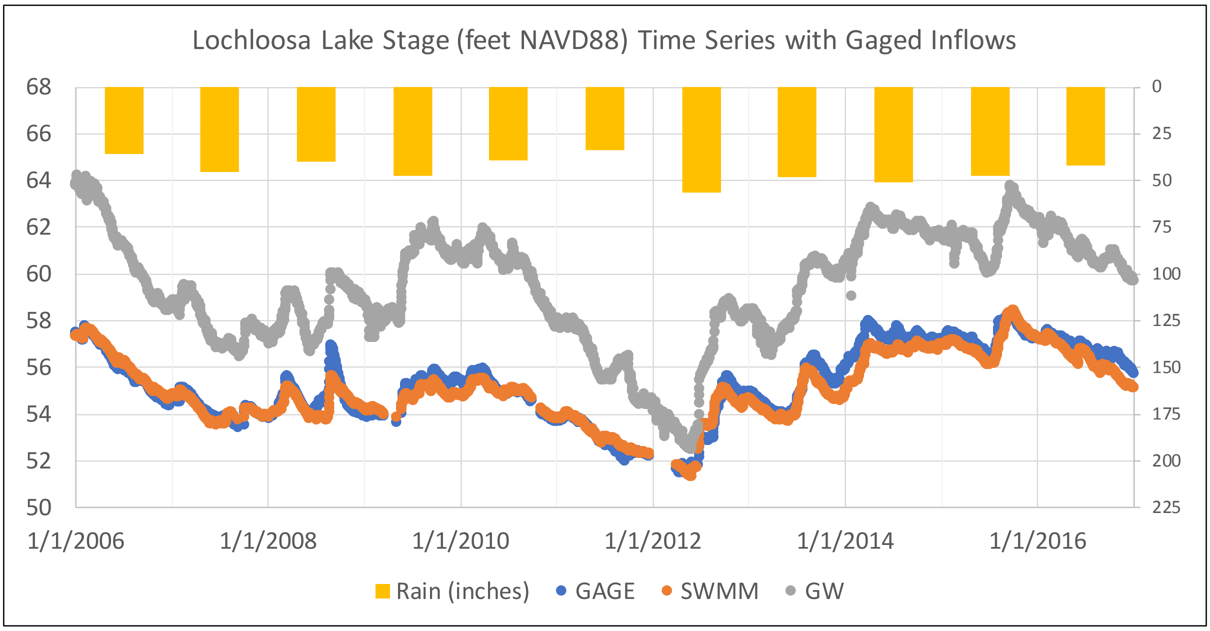


**Figure 11**
**Comparison of Observed and Modeled Stage Time Series in Lochloosa Lake using Gaged Inflows for Calibration Period**

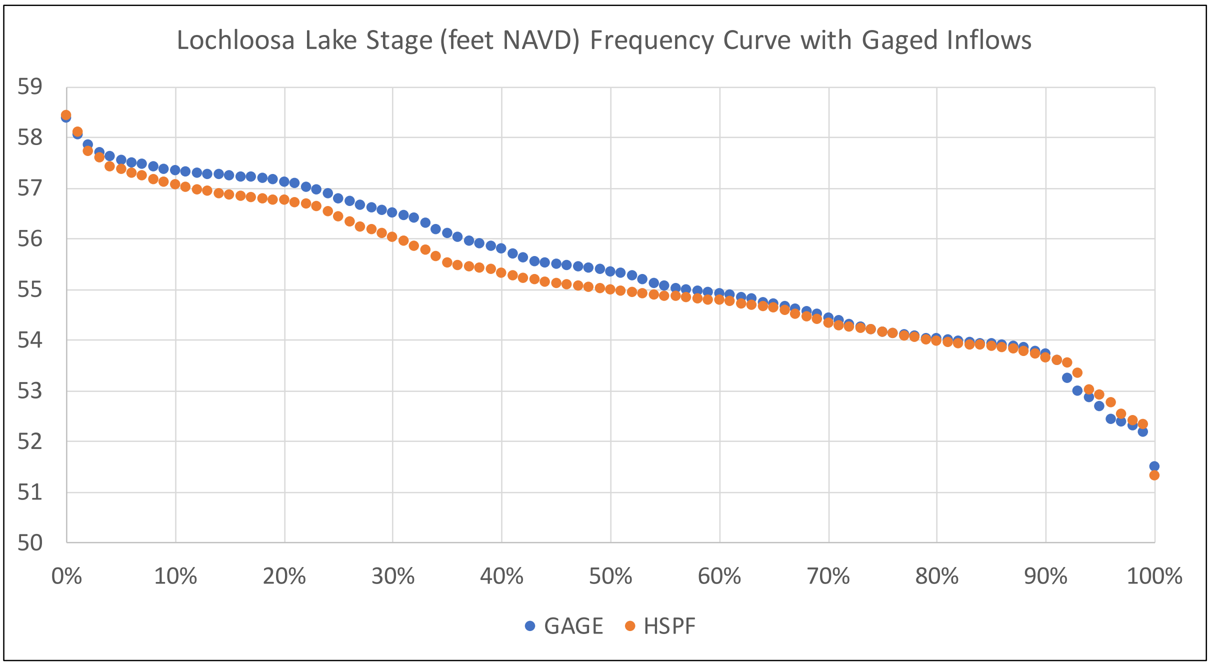


**Figure 12**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Lochloosa Lake using Gaged Inflows for Calibration Period**

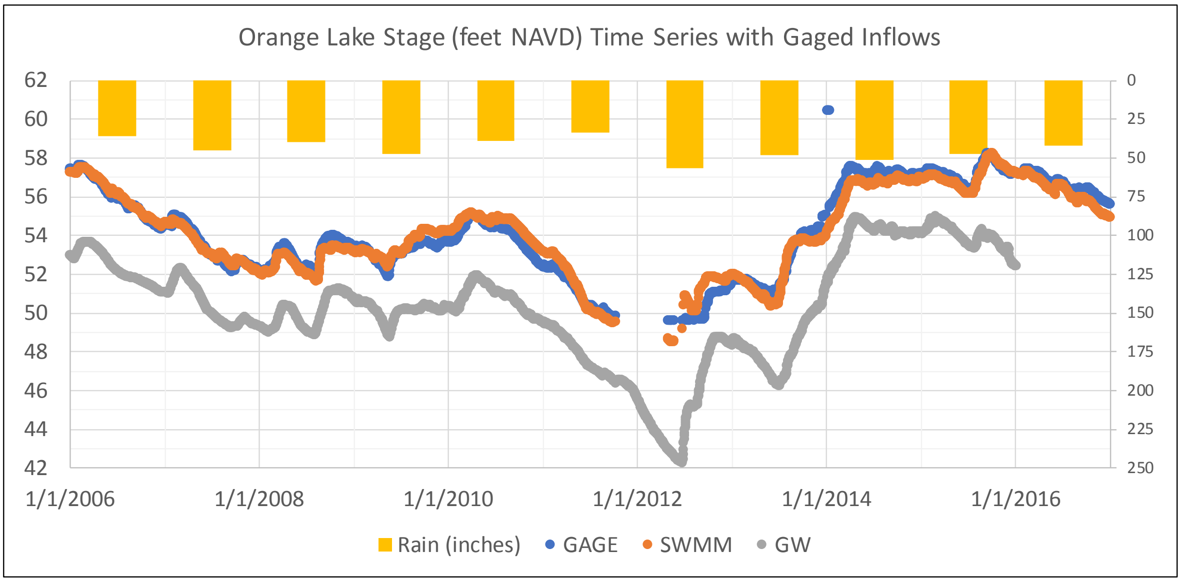


**Figure 13**
**Comparison of Observed and Modeled Stage Time Series in Orange Lake using Gaged Inflows for Calibration Period**

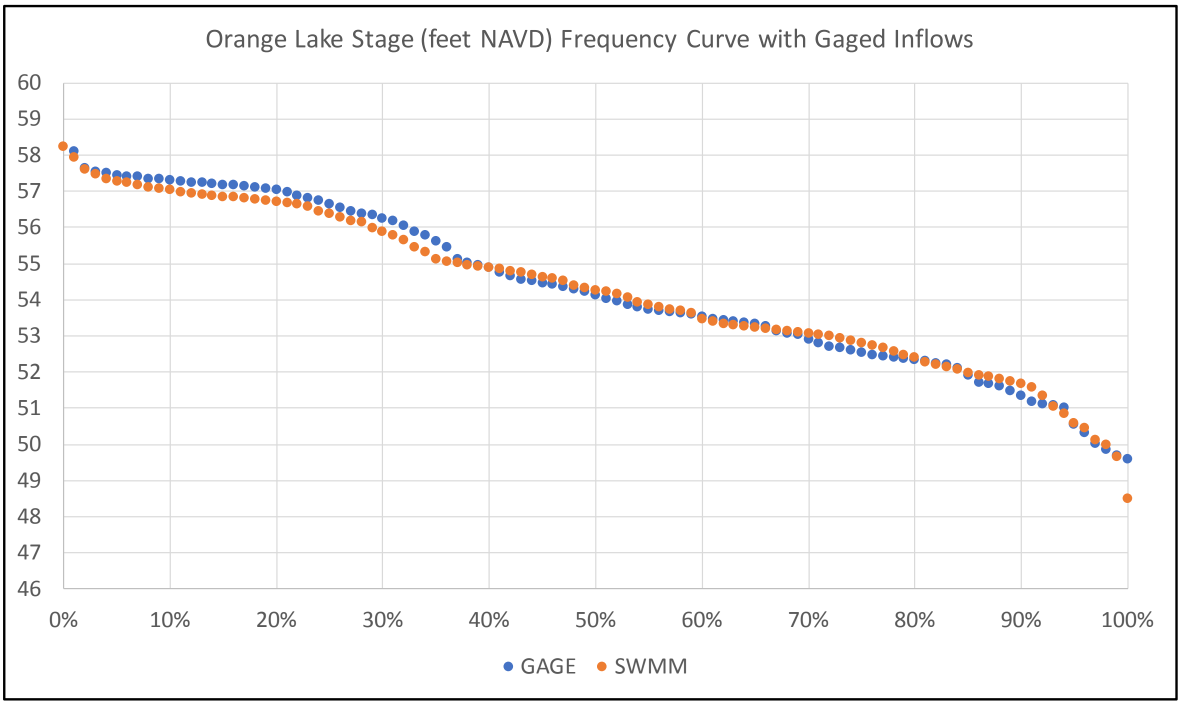


**Figure 14**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Orange Lake using Gaged Inflows for Calibration Period**

## Validation Model Results

The calibrated model was applied for the years 1996 through 2005 as a validation period. The comparison between observed and modeled stages is presented below.

**Figures 15 and 16** present the observed and modeled stage time series and frequency-exceedance relationship for Newnans Lake during the validation period. The results indicate that the model is still doing a good job of simulating lake stages, thought the modeled stages are generally higher than observed stages when observed stages are relatively low.

Based on differences between the observed lake stages and mean observed lake stage during the validation period (64.76 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.72, which is somewhat lower than the calibration value of 0.77.

The differences between the observed and modeled lake stages were also evaluated to determine the percentage of time that the absolute difference between the observed and modeled stages was 0.50 foot or less. The results indicated that 36 percent of the paired data were within 0.5 foot. The average absolute error in modeled lake stages is 0.80 foot.

**Figures 17 and 18** present the observed and modeled stage time series and frequency-exceedance relationship for Lochloosa Lake during the validation period. The results indicate that the model is doing a good job of simulating lake stages, perhaps better than during the calibration period.

Based on differences between the observed lake stages and mean observed lake stage during the validation period (55.96 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.80, which is slightly lower than the calibration value of 0.83.

The differences between the observed and modeled lake stages were also evaluated to determine the percentage of time that the absolute difference between the observed and modeled stages was 0.50 foot or less. The results indicated that 58 percent of the paired data were within 0.5 foot. The average absolute error in modeled lake stages is 0.53 foot.

**Figures 19 and 20** present the observed and modeled stage time series and frequency-exceedance relationship for Orange Lake during the validation period. The results indicate that the model is doing a good job of simulating lake stages, perhaps better than during the calibration period. The frequency curve suggests that the model stages are generally higher than observed at relatively low observed lake stages.

Based on differences between the observed lake stages and mean observed lake stage during the validation period (55.40 feet NAVD 88), and differences between the observed and modeled lake stages, the calculated Nash-Sutcliffe score is 0.83, which is very similar to the calibration value of 0.82.

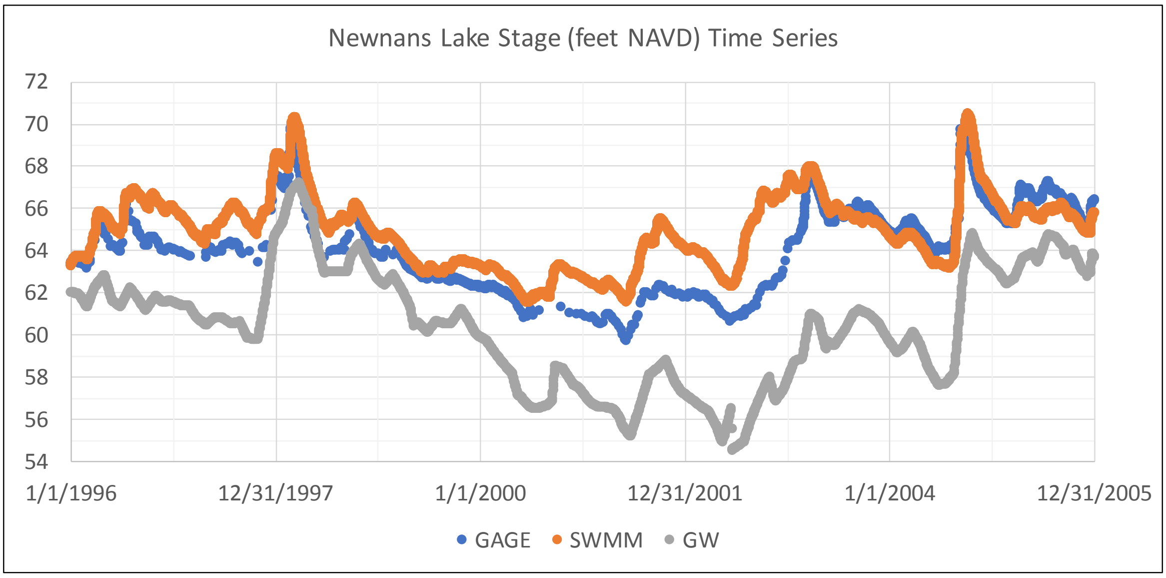


**Figure 15**
**Comparison of Observed and Modeled Stage Time Series in Newnans Lake for Validation Period**

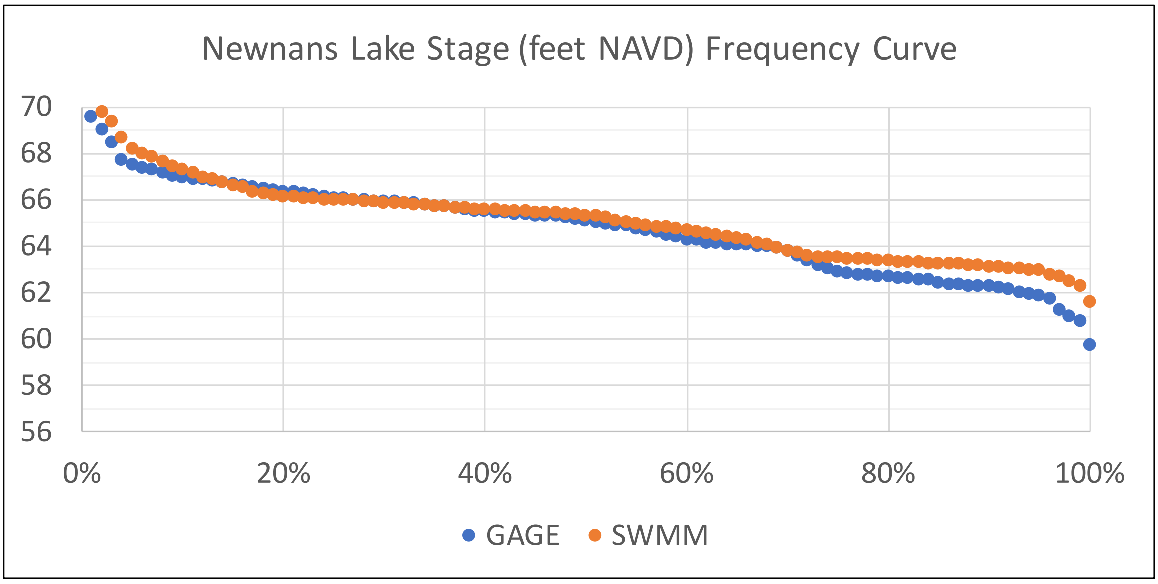


**Figure 16**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Newnans Lake for Validation Period**

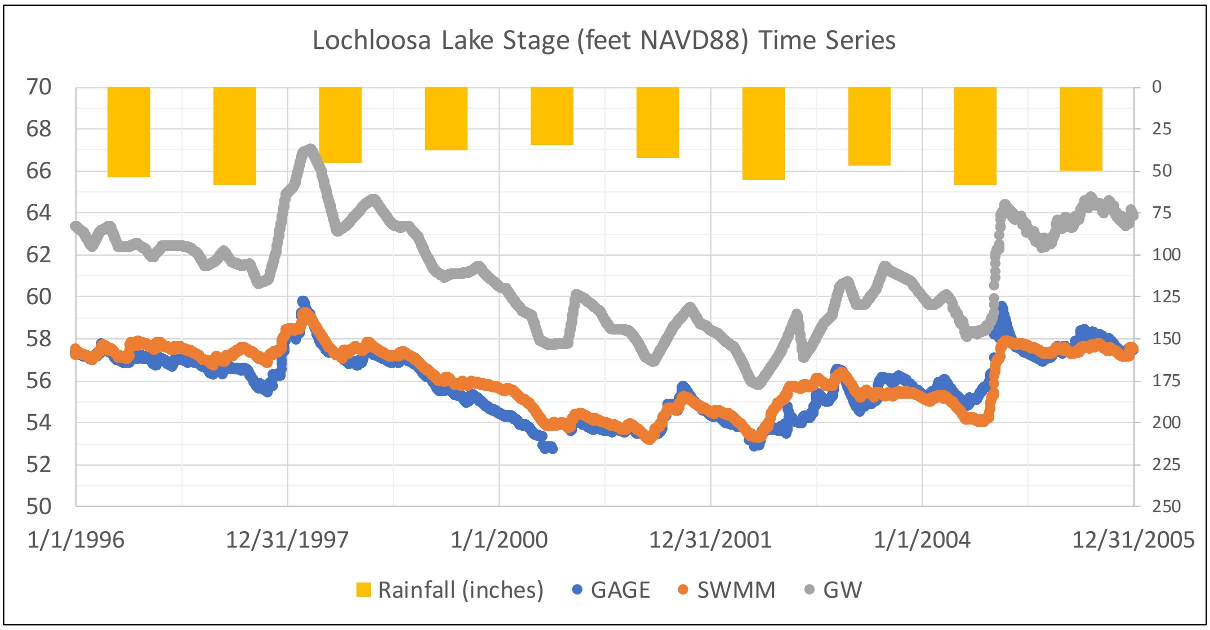


**Figure 17**
**Comparison of Observed and Modeled Stage Time Series in Lochloosa Lake for Validation Period**

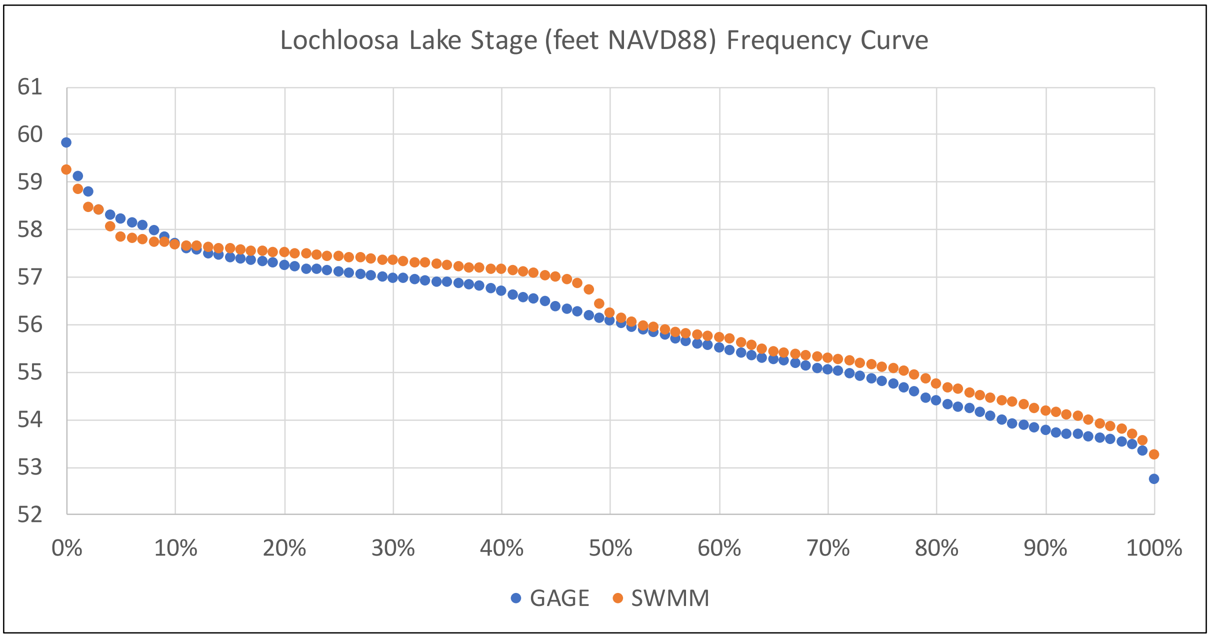


**Figure 18**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Lochloosa Lake for Validation Period**

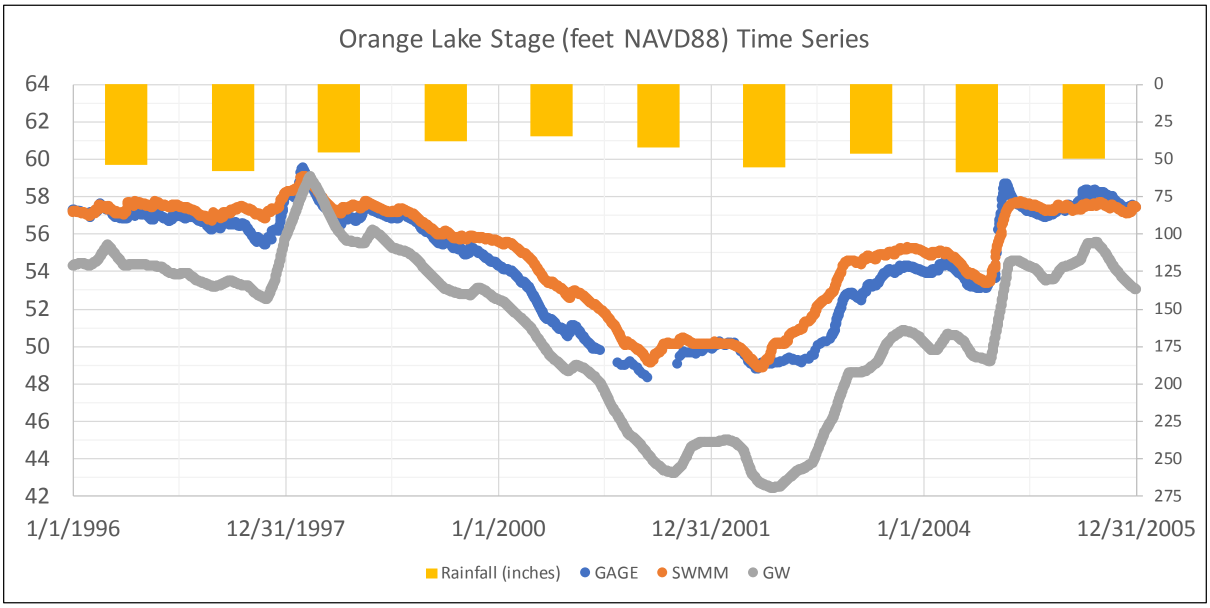


**Figure 19**
**Comparison of Observed and Modeled Stage Time Series in Orange Lake for Validation Period**

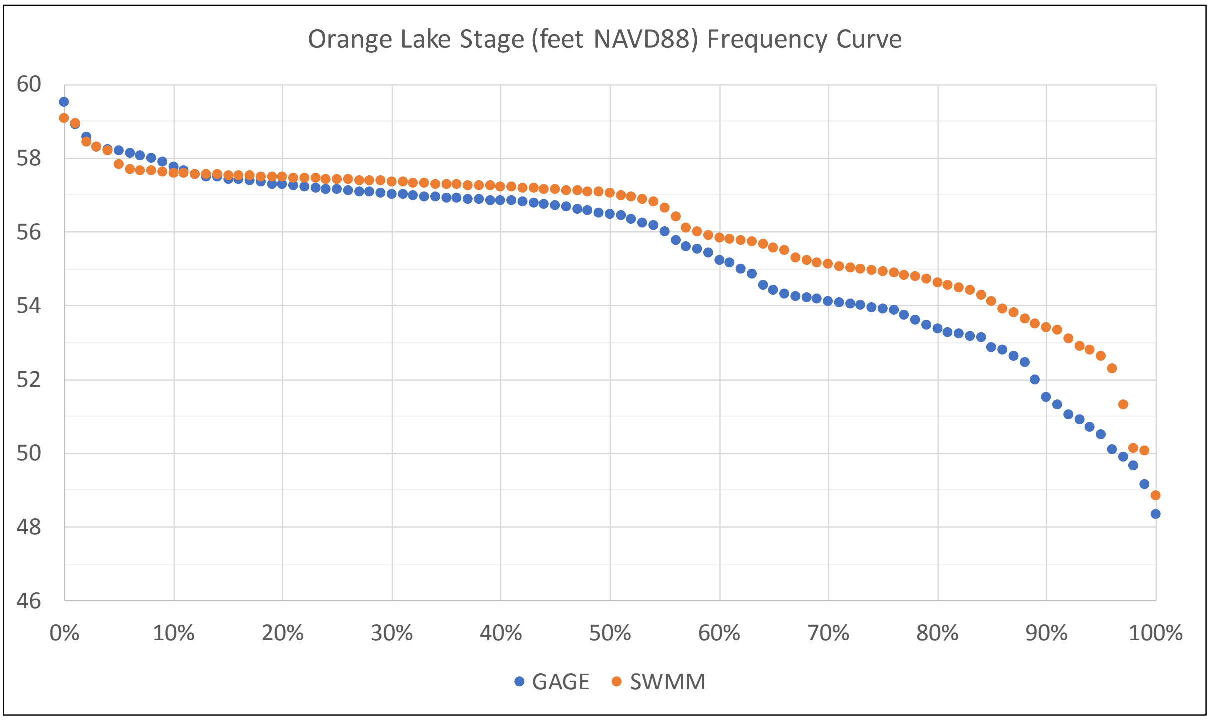


**Figure 20**
**Comparison of Observed and Modeled Stage Frequency-Exceedance in Orange Lake for Validation Period**

## Discussion of Model Results

For the calibration, the model does a good job of following the trends of increasing and decreasing lake stages. However, the modeled stages in Lochloosa and Orange Lakes appear to be less variable (i.e., modeled stages tend to be lower than observed when observed stages are high; modeled stages tend to be higher than observed stages when observed stages are low). The validation results are similar to the calibration period results.

The results do not achieve goals that have been used in several previous MFL modeling studies (e.g., modeled stages within 0.5 foot of measured stage at least 85 percent of the time; Nash-Sutcliffe of 0.90 or greater). This is due to the limited match between modeled and measured flows in the watershed, which could be due to multiple factors. Even with PEST analyses of various parts of the watershed, the agreement between modeled streamflows and gage flows was limited. It is possible that the input rainfall is not always representative of the rainfall that fell on the watersheds.

## Summary

CDM Smith developed a calibration model for Newnans, Lochloosa, and Orange Lakes, evaluating the years 2006 through 2016. Model calibration considered comparison of measured and modeled flows at selected gages in the study area, and then lake stages using graphical and statistical methods. The overall hydrologic flow results were improved with the refinement of hydrologic parameters, but it is possible that model inputs (e.g., rainfall data, hydrologic parameter values) are not always producing modeled flows that agree with the observed gage flow values. The lake modeling resulted in stages that generally replicate increasing and decreasing trends in lake stage, and the range of lake stage values measured during the calibration period.

The calibrated model was then applied to a validation period of 1996 through 2005. The results for this analysis also generally replicated the increasing and decreasing trends in lake stage, and the range of lake stage values measured during the period.

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Sincerely,

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