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MINIMUM LEVELS DETERMINATION

FOR LAKE BUTLER,

VOLUSIA COUNTY, FLORIDA

by

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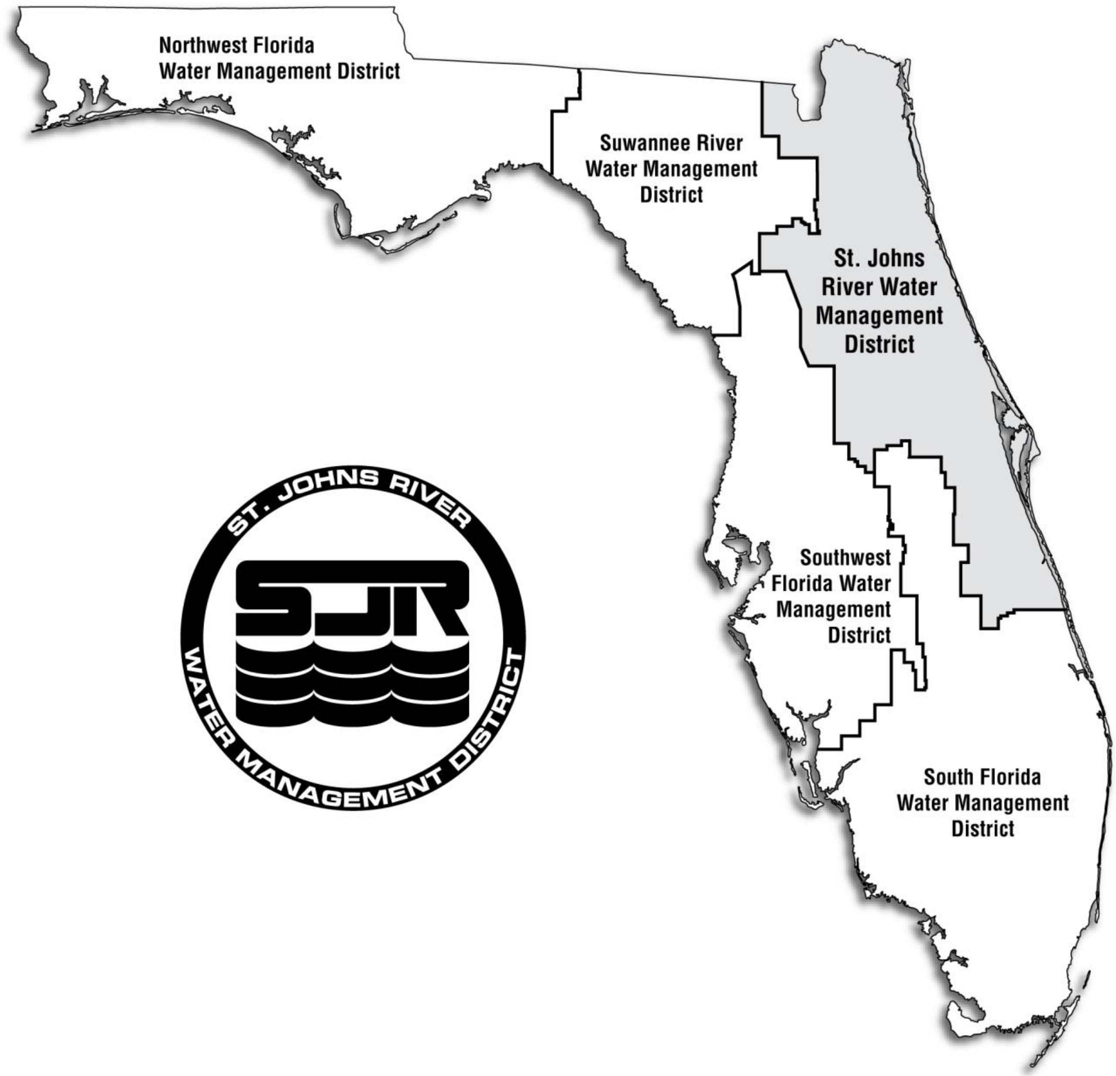

The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage 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 water bodies 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.

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 exists that is lower than historical regime but still protects the environmental functions and values of MFL water bodies from significant harm caused by water withdrawals.

SJRWMD completed a minimum levels determination for Lake Butler in Volusia County, Florida. Lake Butler is part of the Theresa chain of lakes system located within an SJRWMD water resources caution area. Lake Butler is on the MFLs Priority Water Body List and Schedule, and as such, minimum levels are being established for this lake system pursuant to Section 373.042(3), *Florida Statutes* (F.S.).

SJRWMD lake MFLs typically include Frequent High, Minimum Average and Frequent Low events (with specific target levels, durations and return intervals) that are based on protecting stable wetland communities and organic soils (Neubauer et al. 2008). However, the types of stable wetland communities and organic soils utilized to determine these events are not present at Lake Butler. Therefore, instead of the usual MFL event criteria, SJRWMD developed an infrequent flooding criterion (a minimum Infrequent High; IH) consisting of a 30-day duration and a 25-year return interval to maintain the long-term location of the boundary between uplands and wetlands. The minimum IH for Lake Butler was determined to be 24.1 feet NAVD88.

While the IH protects the long-term wetland/upland boundary, preliminary modeling indicated that the IH (located at a high elevation) is relatively insensitive to groundwater withdrawals and would therefore not be protective of other environmental functions and values associated with lower elevations. To ensure protection of these other environmental functions from significant harm, six other metrics were developed for Lake Butler. Five fish and wildlife habitat metrics were developed, based on ensuring no more than a 15% reduction in habitat area from the pre-withdrawal condition. Finally, a lake lobe connectivity metric was developed, based on allowing no more than a 15% reduction in temporal exceedance of a boat passage elevation from the pre-withdrawal condition.

MFLs status was assessed by comparing the minimum hydrologic regime necessary to protect each of the seven environmental criteria developed for Lake Butler with the hydrologic regime under the current-pumping condition. For this analysis, the current-pumping condition for Lake Butler is defined as the average pumping condition between

2014 and 2018. The MFLs assessment indicates that all seven minimum environmental criteria are protected under the current-pumping condition and the most constraining (lake lobe connectivity metric) has a freeboard of 0.1 ft available in the Upper Floridan aquifer (UFA). The projected UFA drawdown at the 20-year planning horizon was estimated for Lake Butler using the SJRWMD 2015 Volusia groundwater model (Williams, 2006). The predicted drawdown resulting from projected water use for the 20-year planning horizon is greater than the available water (i.e., 0.1 ft of freeboard), therefore, the Lake Butler MFLs are in prevention and a prevention strategy must be developed concurrently with the MFLs.

A minimum median (P50) water level (i.e., water level that must be exceeded 50% of the time, over the long term) is the recommended MFL for Lake Butler, and is based on the lake lobe connectivity metric (i.e., most constraining metric with a UFA freeboard of 0.1 ft). The recommended minimum P50 (20.1 ft NAVD88; Table E-1) was calculated from the MFLs condition exceedance curve. The MFLs curve which was derived using the Lake Butler surface water model to simulate aquifer drawdown that resulted in a 15% reduction in exceedance, relative to the no-pumping condition, of the most constraining lake lobe connection elevation (20.4 ft NAVD88).

Table E-1. Recommended Minimum Median (P50) Level for Lake Butler, Volusia County, Florida

Environmental Criterion	Minimum Median (P50) Lake Level (ft, NAVD88)
Lake Lobe Connectivity	20.1

In addition to protecting all seven of the primary environmental criteria assessed, the MFLs condition was also tested against a subset of relevant water resource values (WRVs). The results of this analysis suggest that the MFLs condition protects all relevant WRVs for Lake Butler. Further, the minimum hydrologic regime for three WRVs was very similar to the MFLs condition. The MFLs condition, based on lake lobe connectivity, resulted in a 14.0%, 13.6% and 13.2% reduction in average canoeable area, average emergent marsh habitat area and average gamefish habitat area, respectively. These results provide a weight of evidence for the appropriateness of the recommended MFLs for Lake Butler.

SJRWMD concludes that the recommended minimum median level for Lake Butler will protect all relevant Rule 62-40.473, *F.A.C.*, environmental values. These recommended MFLs are preliminary and will not become effective until adopted by the SJRWMD Governing Board, as directed in Rule 40C-8.031, *F.A.C.*

A screening level analysis, which incorporates change in rainfall trend and uncertainty, will be performed to monitor the status of the adopted minimum level for Lake Butler. This analysis will be performed approximately every five years, as well as when permit applications are considered that may impact the MFL. If the screening level analysis shows that MFLs are being met based on the rainfall-adjusted levels, then no further actions are required beyond continued monitoring. If the analysis shows that MFLs are not being met or are trending toward not being met based on the rainfall-adjusted levels, SJRWMD will conduct a cause-and-effect analysis to independently evaluate the potential impacts of various stressors on the MFLs water body.

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GLOSSARY

Acoustic Doppler Profiling (ADP): Bathymetric data collection method that uses sound waves to measure depth and/or velocity. A Hydrosurveyor™ device and software were used to collects bathymetric data as part of a hydrographic survey of Lake Butler.

Atlantic Multidecadal Oscillation (AMO): Long-term variability of the sea surface temperature occurring in the North Atlantic Ocean, including cool and warm phases with an estimated quasi-cycle period of 60-80 years. These changes are natural and have been occurring for at least the last 1,000 years.

Current-pumping Condition Levels: A long-term simulated water level (lake or aquifer) time series that represents what water levels would be if "current" groundwater pumping was present throughout the entire period of record. The average groundwater pumping available 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).

Digital Elevation Model (DEM): Arrays of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator (UTM) projection or to a geographic coordinate system. The grid cells are spaced at regular intervals along south to north profiles that are ordered from west to east.

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

El Nino Southern Oscillations (ENSO): periodic departures from expected sea surface temperatures (SSTs) in the equatorial Pacific Ocean, ranging from about three to seven years. These warmer or cooler than normal ocean temperatures can affect weather patterns around the world by influencing high- and low-pressure systems, winds, and precipitation.

EPA Stormwater Management Model (SWMM): a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas.

Event: A component of an MFL composed of a magnitude 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: A timeseries of water levels (or flows) within a specified period of record for a specific water body. Water levels (or flows) typically vary over time, and this variation is an important component of the regime, maintaining critical environmental functions and values.

Minimum Hydrologic Regime: A hydrologic regime with an average level (or flow) that is lower than the no-pumping condition, that protects relevant environmental values from significant harm.

MFLs Condition: The MFLs Condition is a specific "minimum hydrologic regime" (see definition above) that is based on the most constraining MFLs metric and is necessary to protect a water body 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 water body from significant harm. The MFLs Condition is based upon the minimum flow or level that is most constraining to water withdrawal, for a given water body.

Minimum Flows and Levels (MFL): Environmental flows or levels expressed as hydrological statistics, based on the most constraining environmental value, that defines 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 (e.g., Minimum Infrequent High, Minimum Average, or other MFL) is a hydrological event, composed of a magnitude and duration, and a return interval.

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

Pacific Decadal Oscillation (PDO): a long-lived El Niño-like pattern of Pacific climate variability with an estimated quasi-cycle period of 20-30 years.

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 Lake Butler in Volusia County, Florida. Pursuant to section 373.042(1), *Florida Statutes* (*F.S.*), SJRWMD is charged with protecting priority water bodies by developing minimum flows and levels (MFLs). Lake Butler is on the SJRWMD MFLs Priority List and is scheduled for adoption in 2020. Lake Butler was added to the Priority List because of the potential for impact due to pumping. This report describes environmental and hydrological analyses used to develop protective criteria and minimum levels for Lake Butler. The current and future status assessment of minimum levels is also provided.

LEGISLATIVE OVERVIEW

SJRWMD establishes minimum flows and levels for priority water bodies within its boundaries pursuant to section 373.042 (3), F.S. Minimum flows and/or levels for a given water body are limits “at which further withdrawals would be significantly harmful to the water resources or ecology of the area” (section 373.042(1)(a), F.S.). Minimum flows and/or levels are established using the best information available (section 373.042(1), F.S.), with consideration also given to “changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...,” provided that none of those changes or alterations shall allow significant harm caused by withdrawals (section 373.0421(1)(a), F.S.).

The minimum flows and levels section of the State Water Resources Implementation Rule (rule 62-40.473, Florida Administrative Code (F.A.C.) also requires that “consideration shall be given to natural seasonal fluctuations in water flows or levels, 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.

As part of the MFLs Determination process (see below), each of the 10 environmental values are evaluated to determine their relevance to a given priority water body. Specific criteria are developed for those that are relevant for a given system.

MFLs are used in SJRWMD's regional water supply planning process (Section 373.709, 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 for protecting priority surface water bodies, watercourses, associated wetlands, and springs from significant harm caused by water withdrawals. MFLs provide an effective tool for decision-making regarding planning and permitting of surface water or groundwater withdrawals.

The purpose of setting MFLs is to answer an overarching question: What hydrologic regime is needed to protect critical environmental functions and values of a priority water body from significant harm due to withdrawal?

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 regimes exist for a specific water body that are lower than the pre-withdrawal historical regime but will protect the environmental functions and values of priority water bodies from significant harm caused by water withdrawals.

The SJRWMD MFLs approach involves two separate but interrelated components: 1) MFLs Determination; and 2) MFLs Assessment. The overall approach involves environmental assessments, hydrologic modeling, independent scientific peer review, and rulemaking.

The Determination involves conducting field data collection, using scientific literature and professional judgement to select and evaluate environmental values and determine the MFLs condition, which is the minimum hydrologic regime necessary to protect these values.

The Assessment involves comparing the MFLs condition to a current-pumping condition to determine the current status of the MFLs. The Assessment also involves comparing the MFLs condition to relevant water resource values, per rule 62-40.473, F.A.C. Finally, the assessment involves evaluating the effect of future pumping on the MFLs condition.

If a water body does not meet its MFLs or is projected to not meet its MFLs within 20 years, the system is said to be in Recovery or Prevention, respectively. If either is true, a district must adopt a strategy concurrent with the MFL to ensure the MFLs will be achieved.

Many SJRWMD MFLs define a protective frequency of high, intermediate, and low hydrologic events (Neubauer et al. 2008). However, for some priority water bodies, for which an event-based approach is not appropriate, a protective minimum hydrologic regime is established based on a percentage of change allowable from a more natural (no-pumping) condition. The goal of either approach is to identify relevant environmental metrics that are sensitive to water withdrawal, and through their assessment determine the amount of water that is available before significant harm occurs to the metrics and system. The assessment identifies available water (freeboard) or water to be recovered (deficit).

No matter how environmental thresholds are set, or how many MFLs are adopted for a water body, the most constraining 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 concurrent with the MFL to ensure the MFLs will be achieved.

SETTING AND DESCRIPTION

LOCATION AND PHYSIOGRAPHIC SETTING

Lake Butler is located in the city of Deltona in Volusia County (Figure 1). It is part of the Theresa chain of lakes which also includes Lake Dupont, Angela Lake, Elizabeth Lake, Lake Theresa, Louise Lake, and Lake Doyle.

Lake Butler is in the Crescent City-Deland Ridge Sub-district of the Central Lakes District. This physiographic region consists of thick sandy soils with Plio-Pleistocene sand and shell resting directly upon the Floridan aquifer (Brooks 1982). The Central Lakes District is characterized by sandhill karst with solution basins (Brooks 1982).

This region has active collapsed sinkhole development and is a principle recharge area of the Floridan aquifer (Brooks 1982; Boniol and Fortich 2005). At low water levels, the multiple lobes of Lake Butler are disconnected and act as separate sinkhole lakes. At higher water levels, the lobes are hydrologically connected and function as a lake system, or chain-of-lakes. Figure 2 depicts approximate lake lobe boundaries in overlain on aerials of different years, to show how lake lobe connections change with fluctuating water level.

Lake Butler is a typical sandhill lake, characterized by sinkhole features and located in a landscape that contains deep sandy soils and lacks an accumulation of organic material. Sandhill upland lakes are typically shallow, rounded solution depressions found in sandy upland communities (FNAI and FDNR 1990). The open water tends to be permanent, but levels may fluctuate dramatically with complete drying during extreme drought. The substrate is usually sand with minimal organic deposits that may increase with depth. The water is usually clear, circumneutral to slightly acidic, and moderately soft, with a variable mineral content. These lakes are seldom eutrophic unless artificially fertilized through human activity (FNAI and FDNR 1990).

While other lakes in the Theresa chain have experienced major landscape alterations, Lake Butler has experienced fewer impacts from regional land development, partially due to larger parcel sizes. As opposed to other lakes in the City of Deltona, several small remnant natural areas remain around Lake Butler. Lake Butler lies within a water resource caution area (WRCA) (SJRWMD 2020). WRCAs are areas where existing and reasonably anticipated sources of water and conservation efforts may not be adequate (1) to supply water for all existing legal uses and reasonably anticipated future needs and (2) to sustain the water resources and related natural systems.

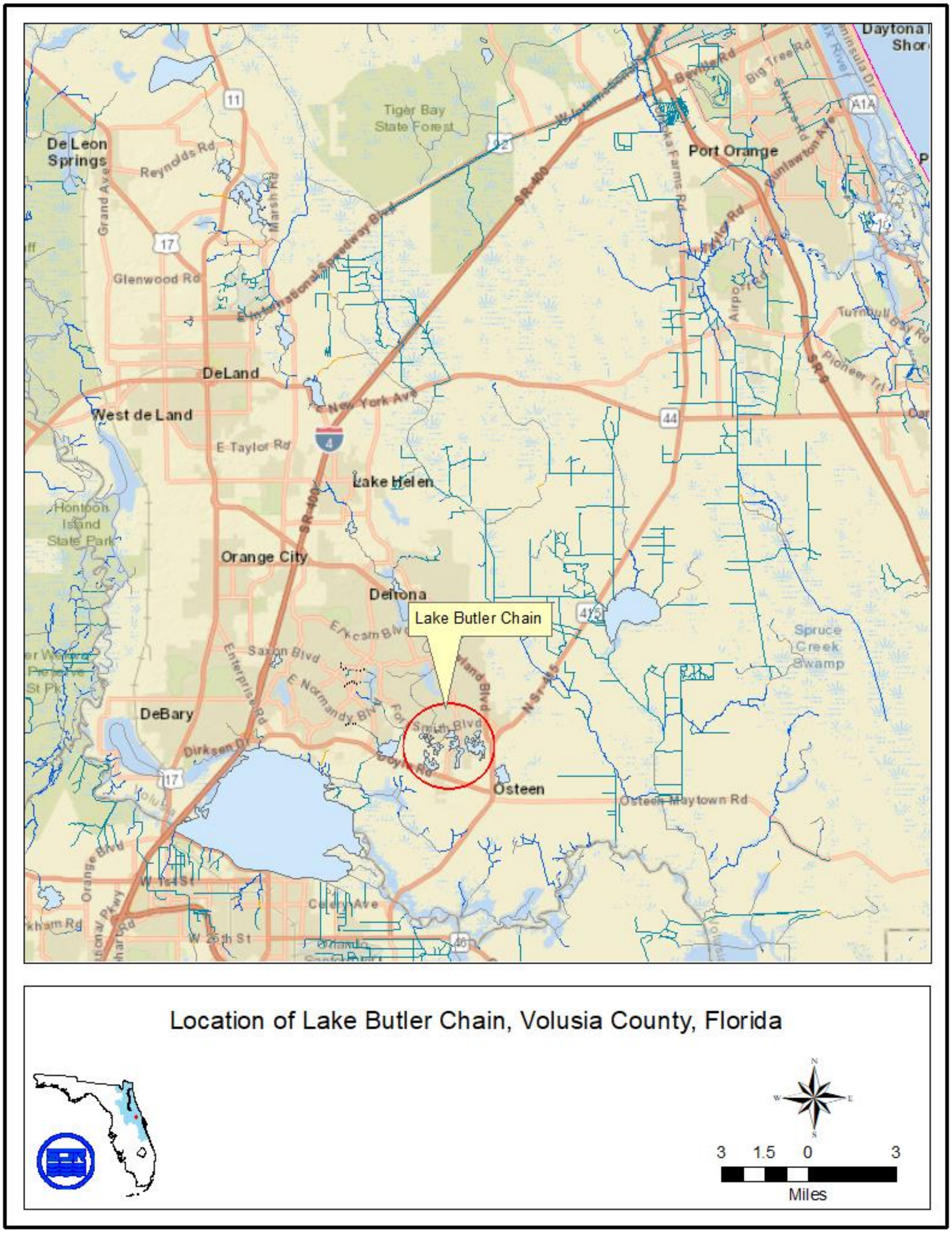

Figure 1. Lake Butler in city of Deltona, Volusia County, Florida.

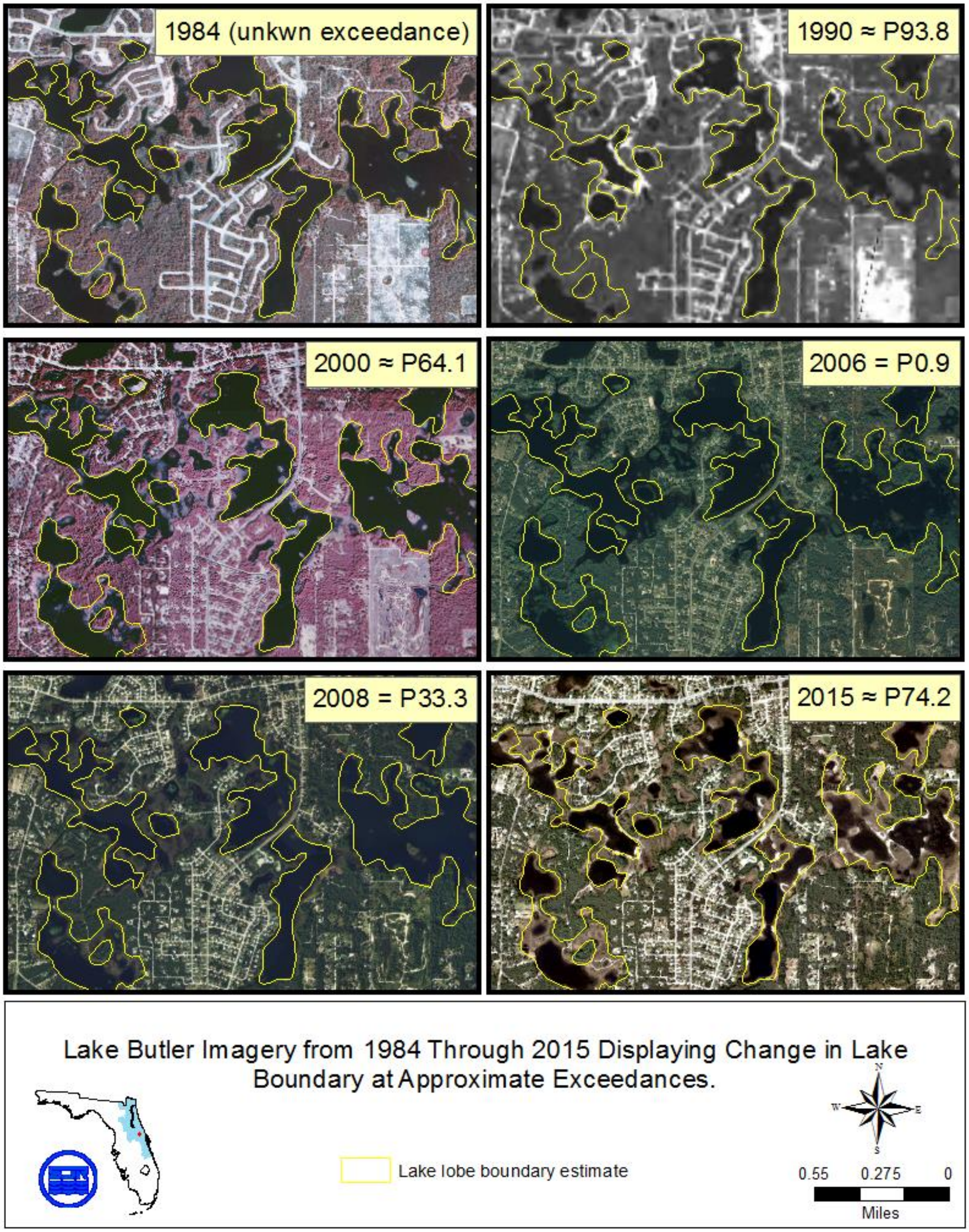

Figure 2. Approximate lake lobe boundaries (polygons) for Lake Butler, overlain on aerial photographs from different years, showing fluctuating water levels and lobe connections.

Bathymetry

Elevation data were collected along numerous transects (Figure 3) and were used along with light detection and ranging (LIDAR), acoustic doppler profiler (ADP), and aerial photography-derived data to develop a digital elevation model (DEM) for Lake Butler. These bathymetry data are presented as a map of the resulting digital elevation model data (Figure 4).

Lake Butler consists of five lobes that are connected at an elevation of 20.9 ft NAVD88 (exceedance of 43.4). These lobes have been connected roughly 43.4% of the time since 1948. Additional important major lobe connections occur at 20.8, 19.4, and 18.7 ft NAVD and correspond to exceedances of 44.7, 59.0, and 64.1 respectively. The surface area for all Lake Butler lobes is approximately 296 acres at a stage of 20.9 ft NAVD88. The deepest portion of Lake Butler is approximately 7.5 ft NAVD88. Water depths vary between 17.6 ft and 3.6 ft deep for the deepest lobe, based on the observed period of record (POR) from 1990-2018. Lake sections and lobes have complex morphologies comprised of shallow solution basins and submerged ridges. Consequently, water depths and lake area varies significantly over time within Lake Butler.

Some Lake Butler lobe connections have been artificially augmented and channelized. High water levels within this system have caused residential and roadway flooding in the past.

Hydrology

Water Level Data

As of June 2020, water level readings (SJRWMD station 03390378) were available for Lake Butler from 1990-2019 (Figure 5). Data were collected three times a year from 2016–2019, quarterly from 2014-2015, and daily (with some gaps in the record) from 1990–2013. For access to the data used in these analysis please refer to the SJRWMD hydrologic data portal: http://webapub.sjrwmd.com/agws10/hdsnew/map.html.

The POR for observed water level data (1990–2019) includes periods of high-water levels and major droughts (Figure 5). From 1990 to 2019, Lake Butler fluctuated 13.0 ft, with an average stage of 18.7 ft NAVD88 and a median stage of 19.6 ft NAVD88 as determined from 283 average monthly observations. The maximum and minimum stage elevations during the POR are 24.4 and 11.4 ft NAVD88, respectively. Descriptive statistics for Lake Butler water level data are presented below (Table 1).

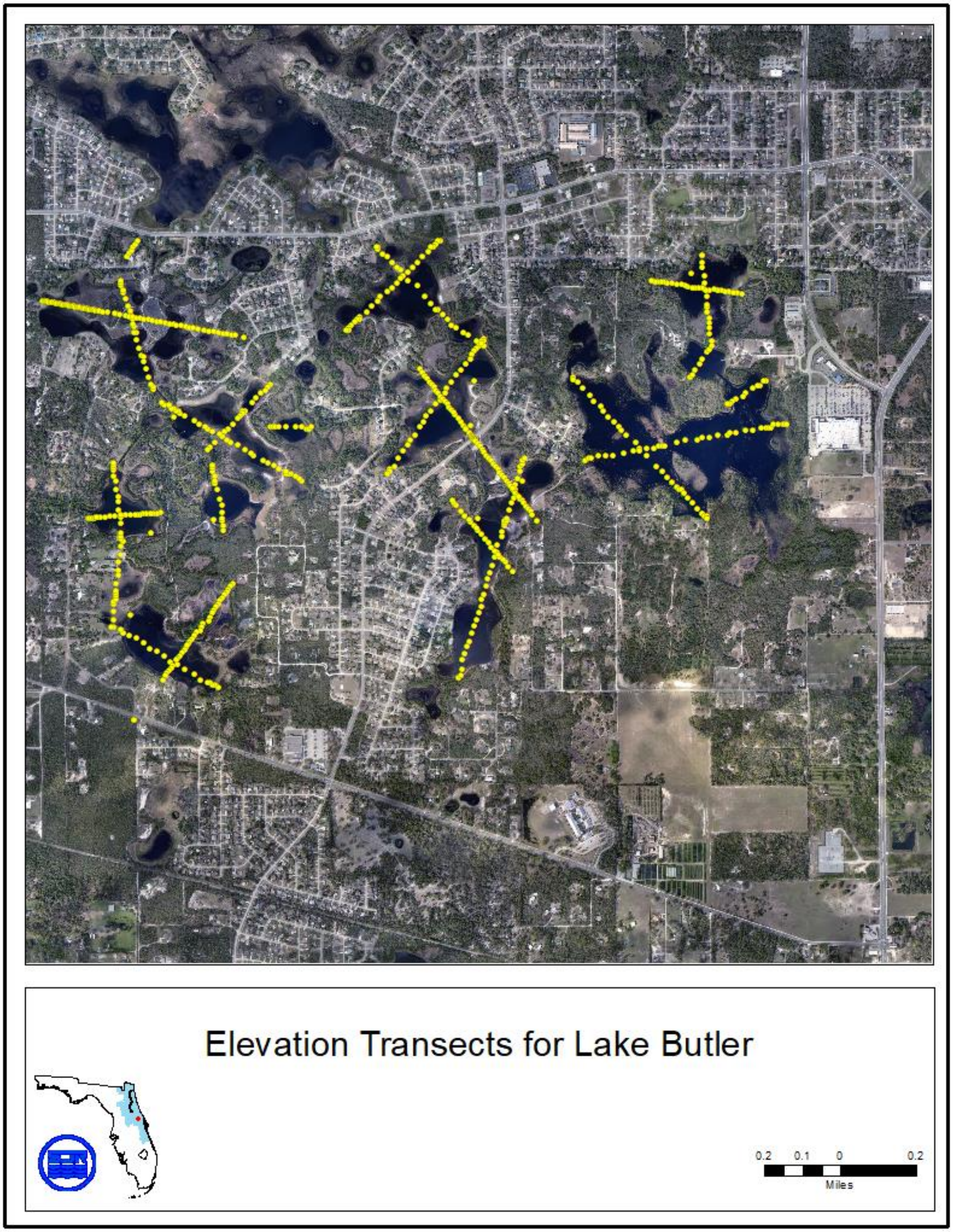

Figure 3. Elevation transect locations for Lake Butler, Volusia County, Florida

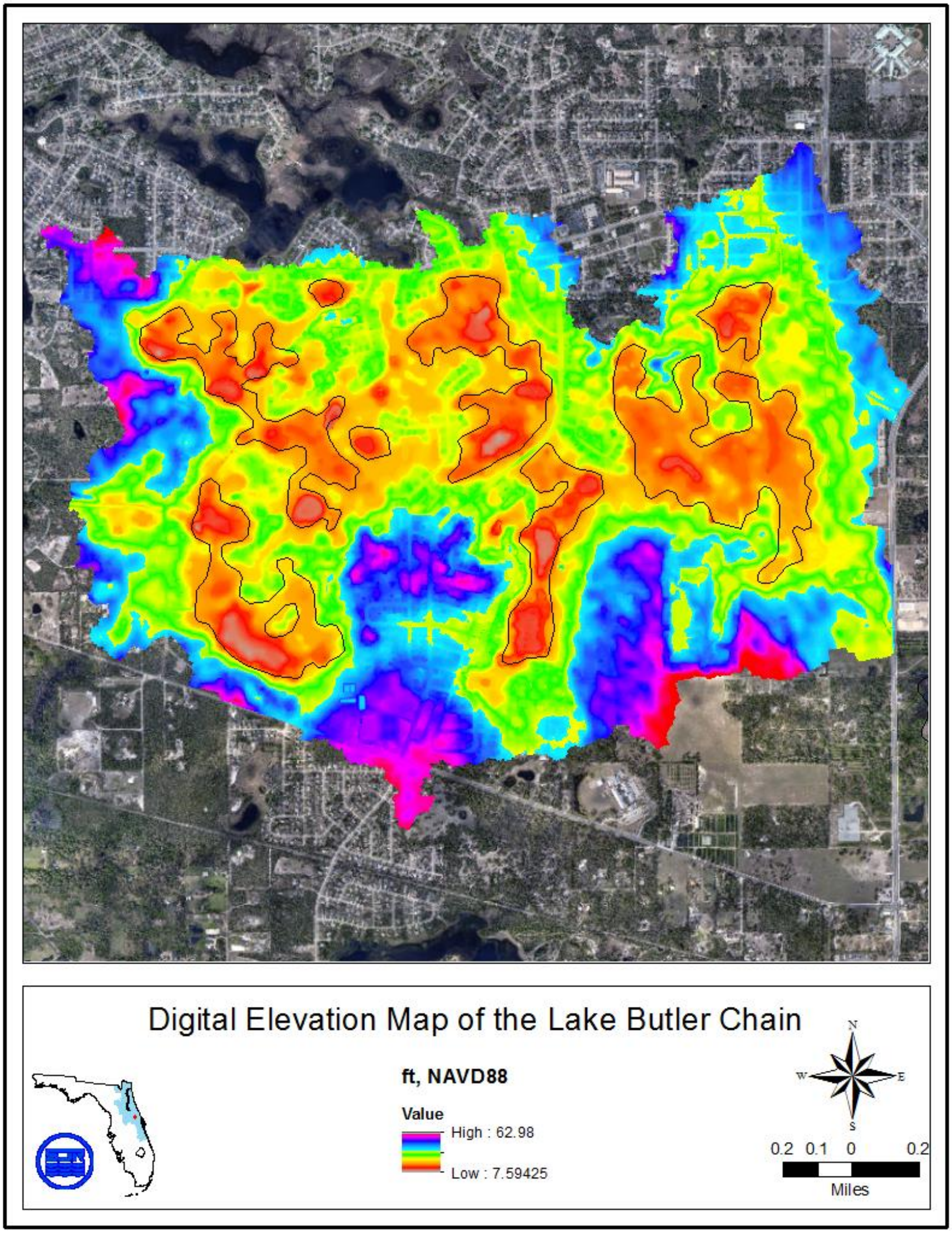

Figure 4. Digital elevation model data for Lake Butler, Volusia County, Florida

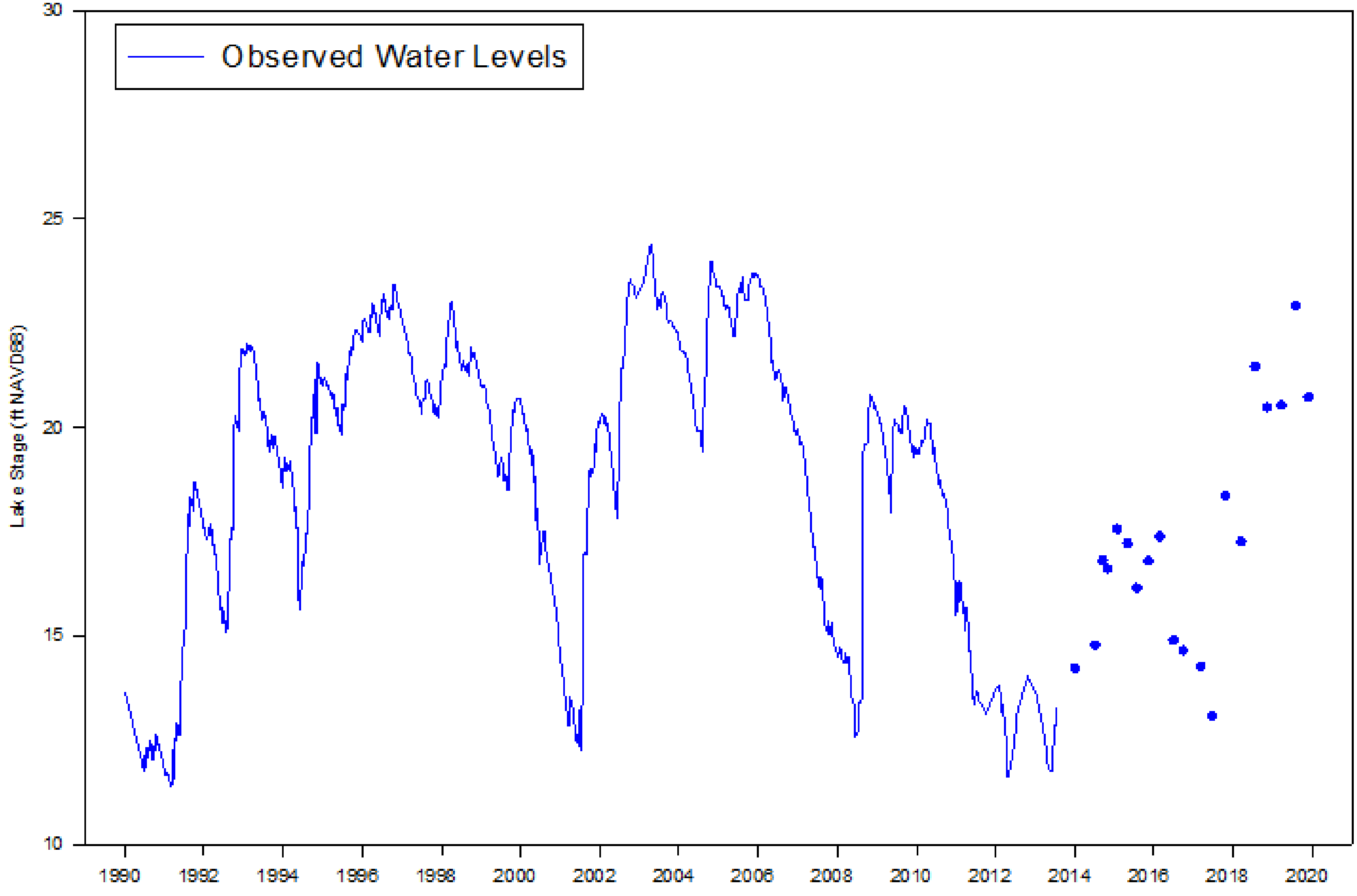

Figure 5. Lake Butler water level hydrograph (1990-2019)

Table 1. Summary statistics for Lake Butler water level data (SJRWMD station 03390378; 1990-2019)

Hydrologic Statistic	Lake Butler Water Level Surface Elevation (ft NAVD)
Mean	18.7
Median	19.6
Standard Deviation	3.4
Range	13.0
Minimum	11.4
Maximum	24.4

Rainfall

A composite hourly rainfall timeseries (1/1/1948 to 12/31/2018) was developed for the Lake Butler surface water model, based on numerous rainfall stations and both rain gauge and NEXRAD rainfall data (Figure 6). Minimum and maximum rainfall over this POR was 26.5 in/yr and 74.1 in/yr, respectively, with a mean rainfall of 50.6 in/yr. Potential evapotranspiration (PET) was also estimated for the simulated POR, and ranged from 48.3 in/yr to 54.7 in/yr, with a mean of 51.6 in/yr. (Figure 6; *see Appendix B for more details on rainfall and PET for Lake Butler*).

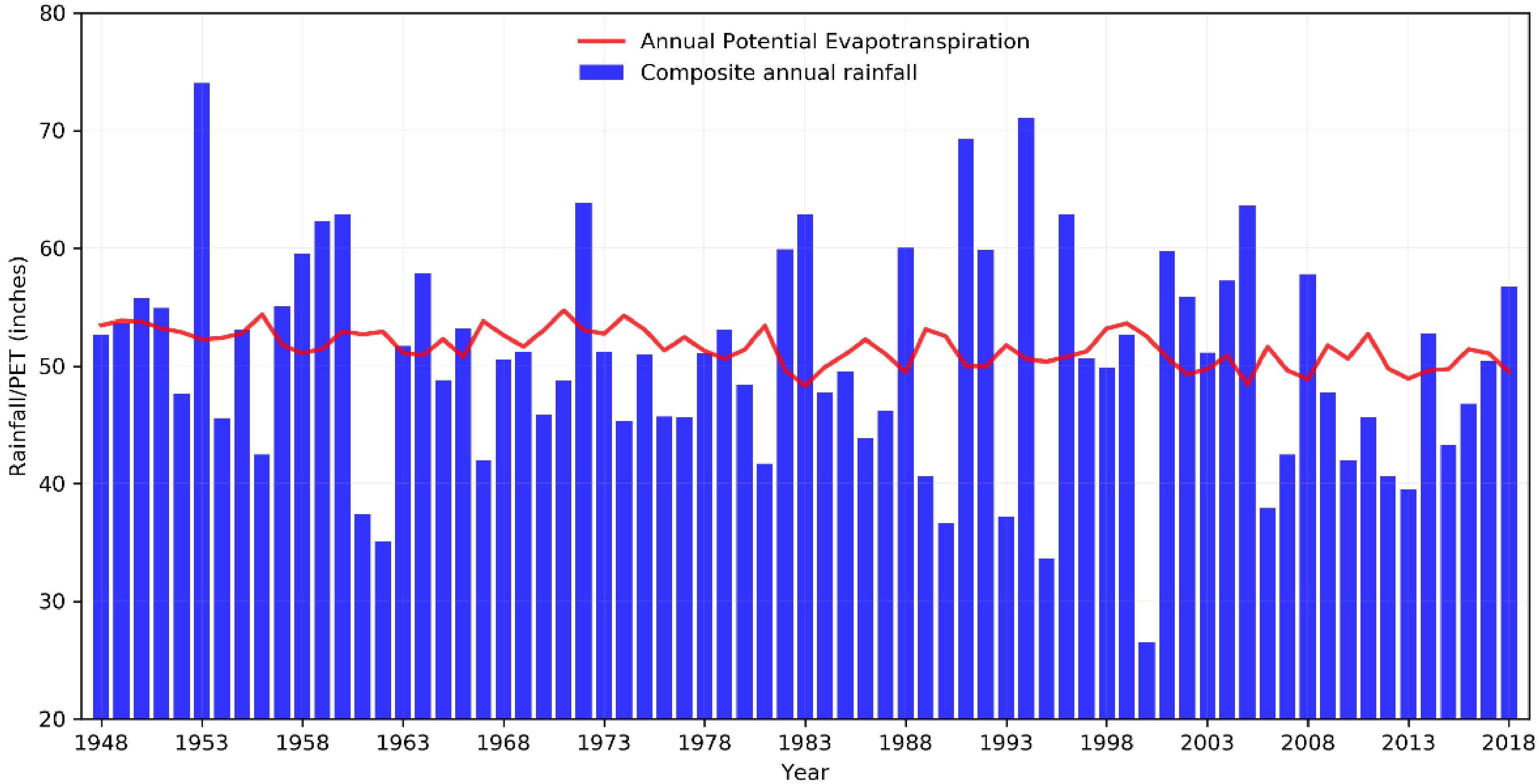

Figure 6. Composite annual rainfall and PET for Lake Butler, Volusia County, Florida.

Water Level Fluctuations

No significant long-term trend was detected in the observed available lake levels from 1990 to 2019. However, significant short-term fluctuations have been observed in lake levels throughout the period-of-record. The lake levels have declined and rebounded as much as 12 ft since 1990 (Figure 5). These significant fluctuations are most likely because Lake Butler receives significant surface flows from the upstream lakes and the surrounding urbanized areas causing lake level increases in short time periods during wet periods and loses water to downstream lakes and groundwater causing rapid water level decline during dry periods due to its sandhill ad sinkhole nature. It sits in the Penholoway Terrace, with lithology that consists of a thin layer of sand overlaying punctured limestone. This geological setting facilitating rapid recharge to the aquifer can facilitate a rapid decline in lake stage.

Figure 7 shows Standardized Precipitation Index (SPI), a NOAA drought index used to characterize and quantify meteorological drought for a given period of time. The SPI index shows timing of wet and dry periods which may explain some of the fluctuations in the observed lake levels. For example, the relatively low levels in the 2011–2017 period (Figure 5) seems to coincide with the dry period shown in Figure 7.

According to the Florida Climate Institute, climatic cycles, such as El Nino Southern Oscillations (ENSO), Atlantic Multidecadal Oscillation (AMO), and the Pacific Decadal Oscillation (PDO), have the strongest influence on Florida's climate variability (Kirtman et al., 2017). These climatic cycles most likely play an important role on lake level fluctuations as well.

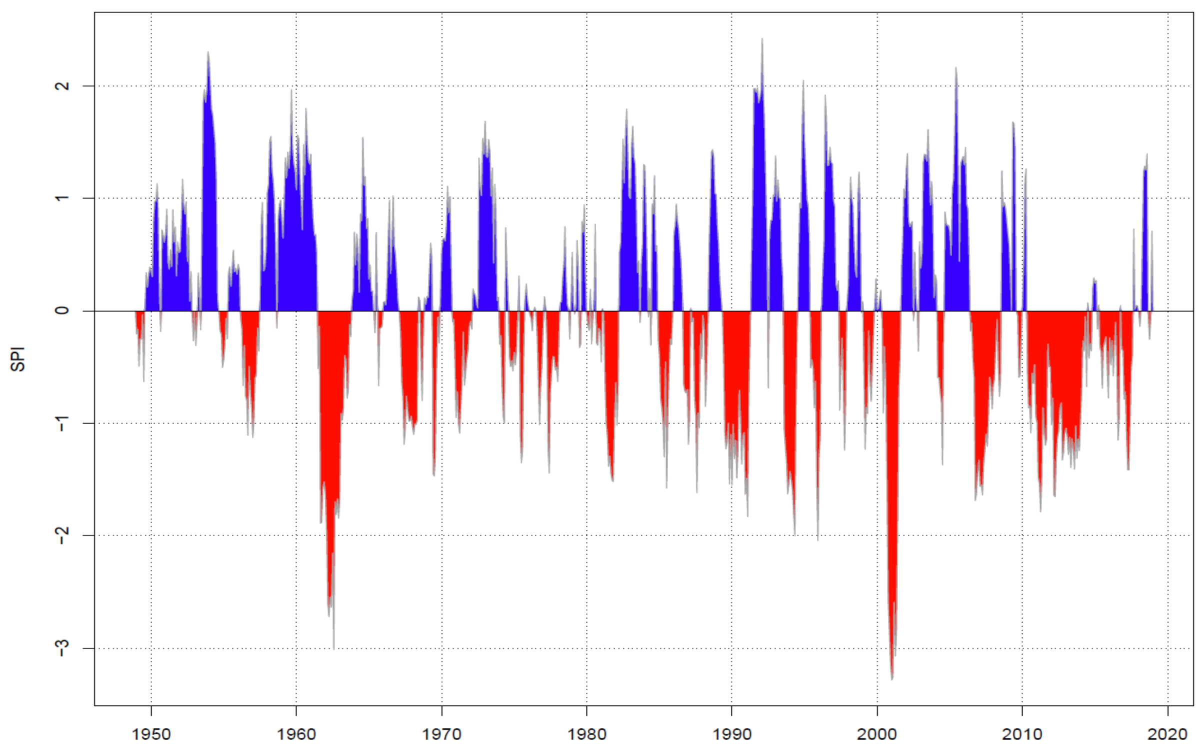

Figure 7. 12-month SPI based on composite rainfall data (1948-2018) at Lake Butler, Volusia County

Historical Groundwater Use

MFLs are established to set the limit at which further withdrawal of groundwater (or surface water) would be significantly harmful to water resources. To estimate the impact on Lake Butler water levels from pumping, monthly groundwater use data for the period 1948 to 2018 was compiled for a truncated 10-mile buffer zone (see Appendix B).

Groundwater use, within the 10-mile zone around Lake Butler, has increased since 1948, peaking in May 2002 at approximately 37 mgd (Figure 8). Pumping has remained relatively constant in more recent years, with average monthly groundwater at approximately 22 mgd for the period 2014 to 2018. During this five-year period UFA drawdown has averaged approximately 1.75 ft, based on an impact assessment conducted using the Volusia groundwater model (Williams 2006; *see Appendix B for detailed groundwater impact analysis*).

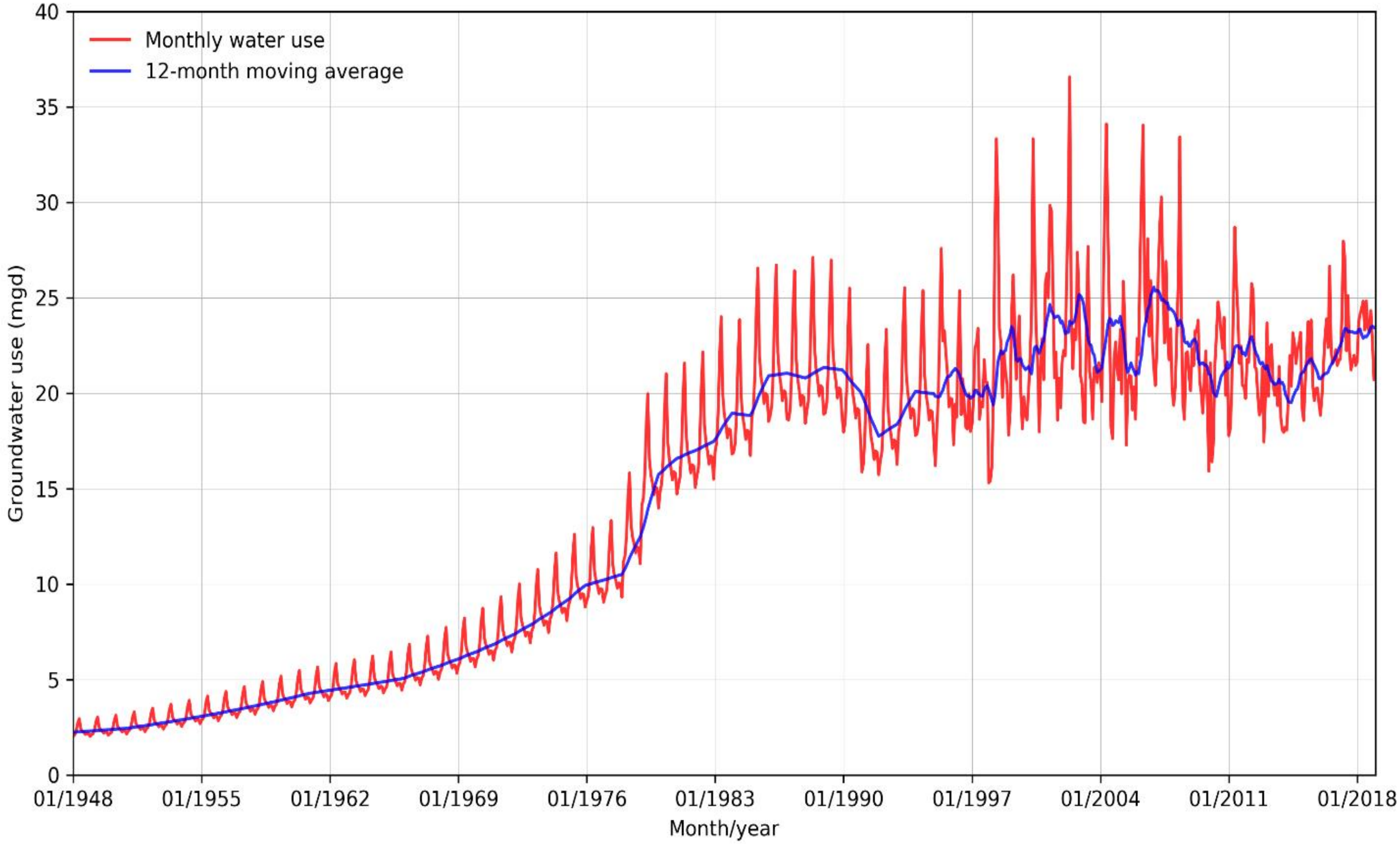

Figure 8. Estimated historical monthly groundwater uses and 12-month moving average within 10-mile buffer zone around Lake Butler, Volusia County, Florida

SURFACE WATER BASIN CHARACTERISTICS

Land Use

The Lake Butler watershed has undergone significant urbanization, with the dominant land use consisting primarily of residential development (31.8%) followed by hardwood forest (15.8%) (Figure 9 and Table 2). Impervious land uses, which include residential, industrial, institutional and commercial, occur on approximately 37.1% (968 acres) of the basin.

Wetlands

Based on the SJRWMD GIS database, wetland communities in the vicinity of Lake Butler are comprised of wet prairie (159 acres), shallow marsh (29 acres), shrub bog (2 acres), shrub swamp (4 acres), and transitional swamp (4 acres), based on the SJRWMD Wetlands Classification System (Kinser 1996, Kinser et al., 2012; Table 3, Figure 10). Wet prairie is the dominant community, comprising 38.5% of wetlands and 6.1% of the basin (Table 3). Based on localized staff data collected on multiple dates, most wetland species at Lake Butler appear to migrate up- and down-slope, corresponding with high or low water conditions, respectively. Detailed vegetation community data are presented in Appendix A.

The two genera, *Pinus* and *Nymphaea*, seem to exemplify this migration and respond to lake stage. The two have been observed alive within proximity to each other at Lake Butler and require drastically different hydrology to survive. *Nymphaea* was observed at different elevations in 2004, 2009, and 2018 (Appendix A). Immature *Pinus* spp. were also observed dying, in some instances after inundation for over two years. The Lake Butler system seems to be in a perpetual state of ecological succession.

Hydric Soils

The development of hydric soils and hydric soil indicators is related to biogeochemical processes that occur in inundated soils. Hydric soils are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part (USDA Soil Conservation Service 1987). Hydric soil indicators are often confounding on sandhill lakes due to the presence of ephemeral wetland plant communities (Kizza and Richardson, 2007). Hydric soils data collected in 2004 showed that stripped matrix was the most common hydric feature surrounding Lake Butler, and occurred at an elevation of 23.8 ft NAVD88 (*see Appendix A for more details*).

Four soil series that meet the hydric soil criteria for Volusia County are mapped adjacent to the Theresa system: Immokalee, Myakka, Placid, and Samsula (USDA NRCS 2007, FAESS 2000, USDA SCS 1980). Only two of these hydric soil series were observed adjacent to Lake Butler: Immokalee and Myakka (Appendix A). The Samsula and Myakka soil series meet the hydric soil criteria for saturation and ponding, whereas the Immokalee and Placid soil series meet the hydric soil criteria for saturation (FAESS 2000). Approximately 49.3% (1,284 acres) of the basin surrounding Lake Butler are mapped as “non-hydric” (Figure 11; Table 4) of the basin (SSURGO, 2017).

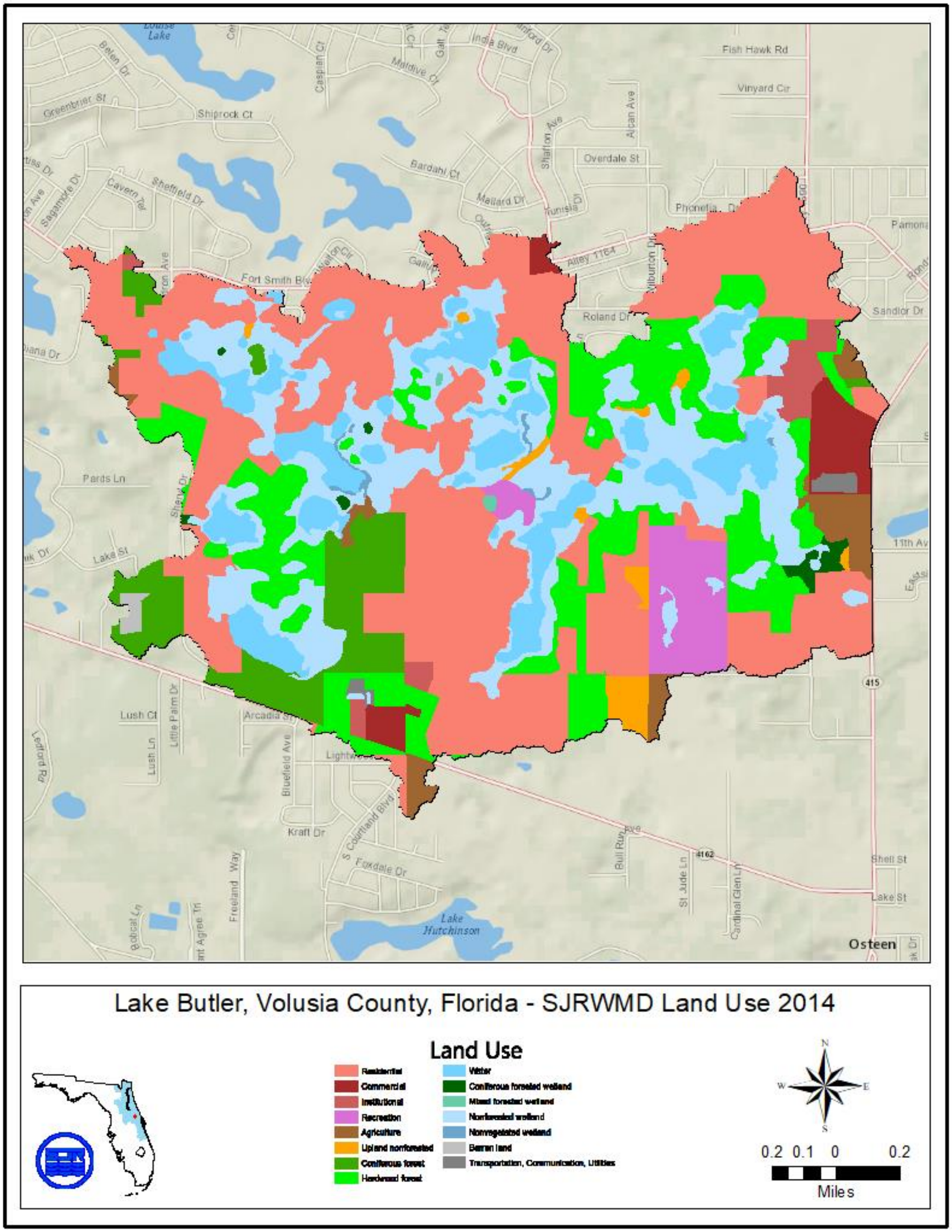

Figure 9. Land use surrounding Lake Butler, Volusia County, Florida; SJRWMD 2014

Table 2. Land Use within the Lake Butler Basin

Land Use	Acres	Percent of Basin
Residential	829	31.8
Commercial	63	2.4
Industrial	42	1.6
Institutional	34	1.3
Recreational	73	2.8
Agricultural	175	6.7
Upland Non-Forested	33	1.3
Coniferous Forest	360	13.8
Hardwood Forest	413	15.8
Water	193	7.4
Coniferous Forested Wetland	13	0.5
Mixed Forested Wetland	2	0.1
Nonforested Wetland	360	13.8
Non-Vegetated Wetland	5	0.2
Barren Land	6	0.2
Transportation, Communication, Utilities	7	0.3
Total	2,606	100

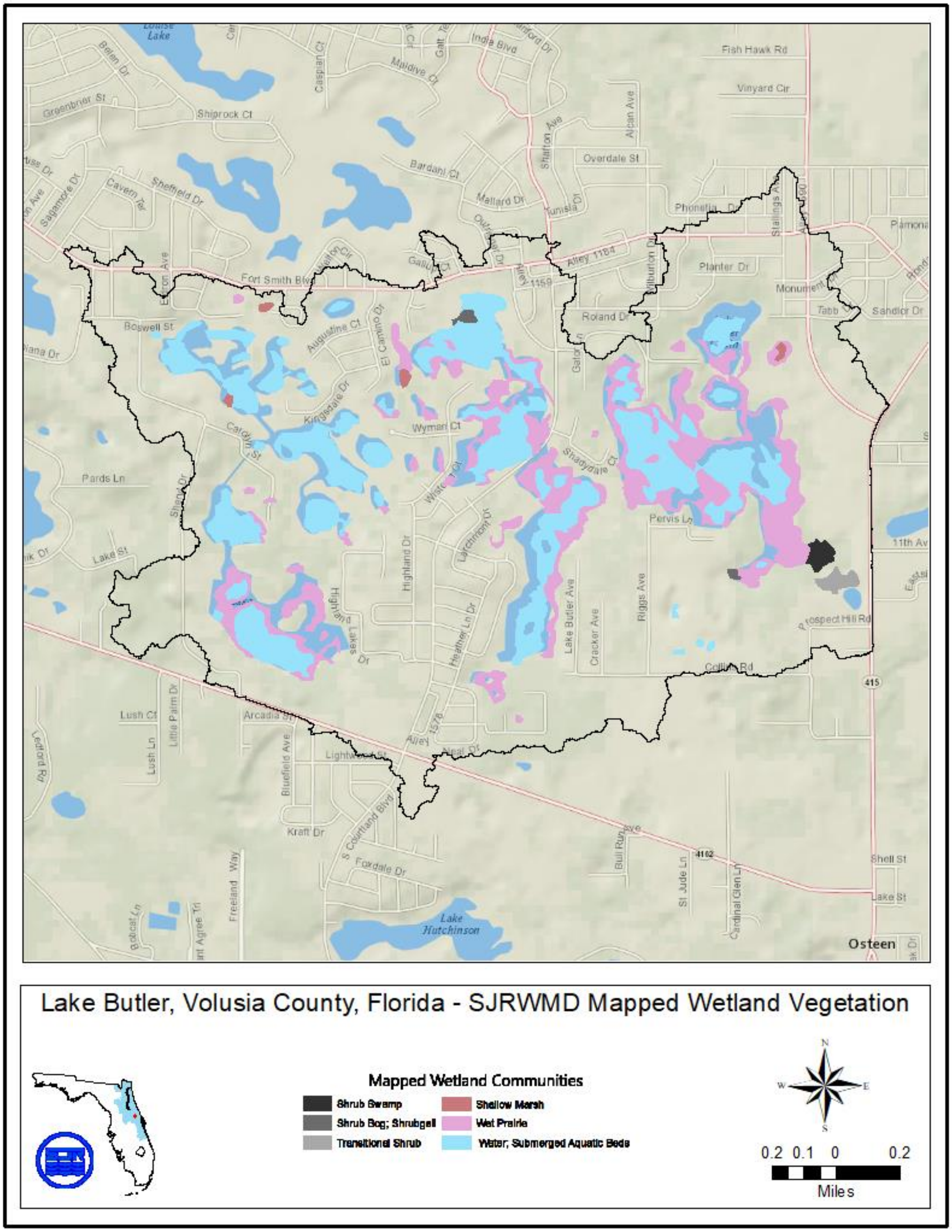

Figure 10. Mapped vegetation communities for Lake Butler, Volusia County, Florida; SJRWMD 2014

Table 3. Wetland Vegetation Communities present within the Lake Butler Basin

Wetland Community	Acres	Percentage of Basin	Percentage of Wetland Coverage
Water; Submerged Aquatic Beds	216	8.3	52.2
Wet Prairie	159	6.1	38.5
Shallow Marsh	29	1.1	6.9
Shrub Bog: Shrubgall	2	0.1	0.5
Shrub Swamp	4	0.1	0.9
Transitional Swamp	4	0.2	1.0
Total	413	15.9	100.0

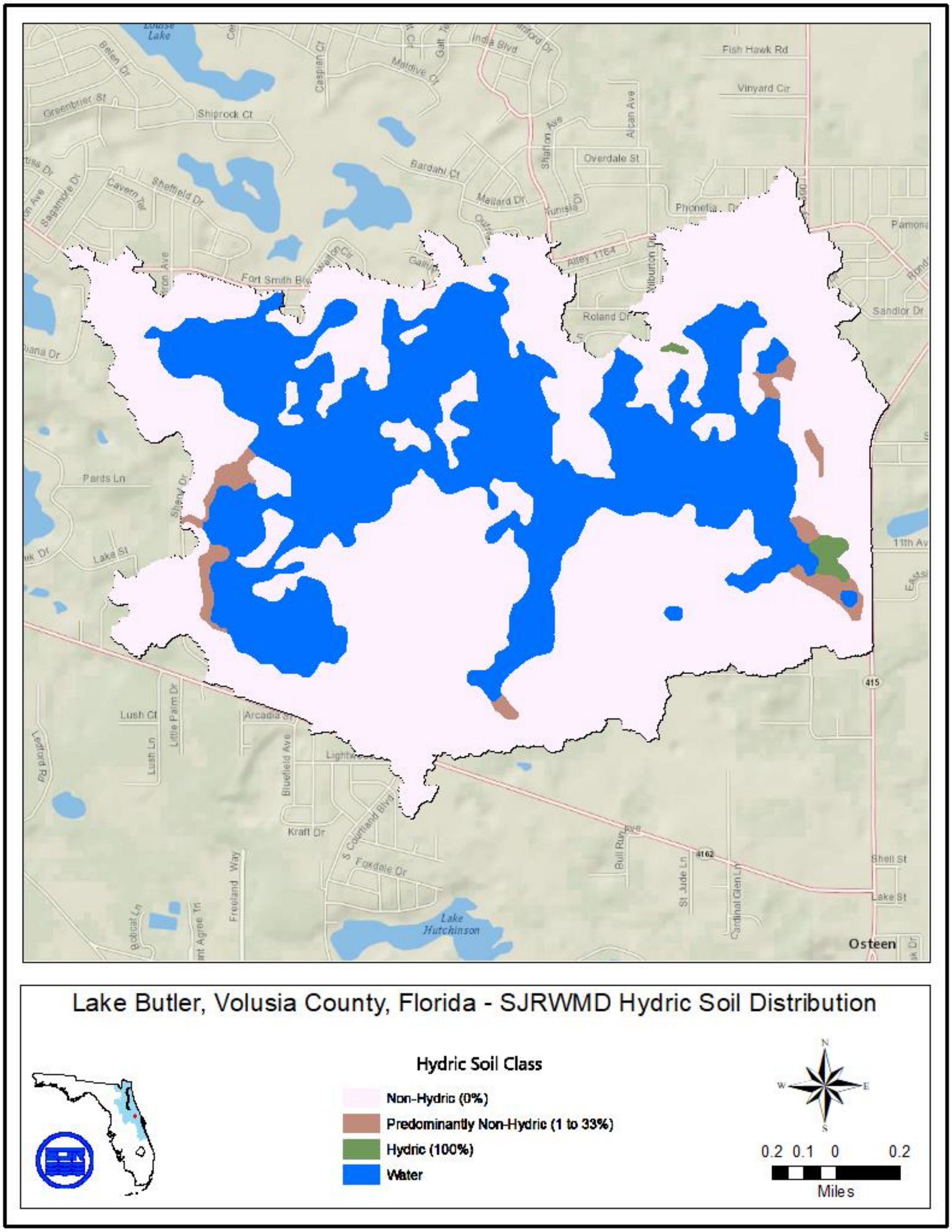

Figure 11. Hydric soils at Lake Butler, Volusia County, Florida; SSURGO 2017

Table 4. Hydric soil distribution in the Lake Butler Basin

Hydric Soil Class	Acres	Percentage of Basin (excluding water)
Non-Hydric	1284	96.6
Predominantly Non-Hydric	37	2.8
Hydric	9	0.7
Total	1330	100

Water Quality

Very few water quality data are available for Lake Butler. Lakewatch conducted limited water quality sampling from March 1999 to November 2005 at nearby Lake Theresa (Lakewatch 2005). A summary of 2005 Lakewatch data, from 75 sampling months, are presented below (Table 5). Water quality data for Lake Butler, collected in July 2003, was reported in the Florida Atlas of Lakes (Florida Water Atlas 2015; Table 6). Water quality parameter values, typical of lakes within the Crescent City-Deland Ridge physiographic region (which includes Lake Butler), are presented in Table 7. Due to limited data availability no conclusions can be made regarding water quality and MFLs.

Table 5. Summary of available Lakewatch water quality data for Lake Theresa chain (n=75; source: Lakewatch 2005)

Parameter	Minimum	Average	Maximum
Total Phosphorus (µg/l)	7	12	20*
Total Nitrogen (µg/l)	220	544	910*
Total Chlorophyll (µg/l)	2	7	28*
Secchi depth (ft)	1.3	4.6	8.7

*Exceeds Florida's Dept. of Environmental Protection Numeric Nutrient Standard (2013)

Table 6. Summary of Lake Butler water quality data from 7/22/2003 sampling event (source: Florida WaterAtlas 2015)

Parameter	Range	Sample Size
Dissolved oxygen (DO)	0.82 – 4.98 mg/l	4
Nitrogen	794.00 – 794.00 ug/l	2
pH	5.52 – 5.69	4
Phosphorus as P	16.00 – 16.00 ug/l	2
Secchi disk depth	2.62 – 2.62 ft	2
Temperature, water	79.32 – 86.54 deg F	4
Total Suspended Solids (TSS)	4.00 – 4.00 mg/l	2
Trophic State Index: Florida DEP	45.00 – 45.00	2
Turbidity	1.20 – 1.20 NTU	2

Table 7. Typical water quality data of lakes within the Crescent City-Deland Ridge subdivision (Griffith et al., 1997)

Mean Value	pH (lab) n=29	Total Alkalinity (mg/l) n=29	Conductivity (µS/cm @ 25° C) n = 29	Total Phosphorus (µg/l) n = 51	Total Nitrogen (µg/l) n = 50	Chlorophyll_a (µg/l) n = 50	Color (pcu) n=28	Secchi (m) n=46
minimum	4.2	0.0	52	0.1	118	1	1	0.4
25th %	5.7	1.3	74	7.0	453	3	16	1.6
median	6.8	11.0	144	12.0	632	5	31	2.2
75th %	7.1	16.7	167	16.0	825	7	56	2.7
maximum	7.8	40.7	349	124.0	1300	38	296	5.7

HYDROLOGIC ANALYSIS

In addition to the work conducted to determine the most relevant environmental criteria for priority water bodies, another critical step is to assess whether these criteria are protected under current withdrawal conditions. This part of the process requires substantial hydrological analysis. The following steps were involved in performing the hydrological analysis used for the Lake Butler MFLs assessment:

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).

The first three steps are summarized in this section and the last step is summarized in the MFL assessment section. The details of the hydrologic analysis are provided in Appendix B.

Long-term Lake Levels

The Lake Butler MFLs determination and assessment require long-term lake level data. to better capture the effect of short- and long-term climatic variations, versus water withdrawal, on lake levels. However, observed long-term lake levels were not available for Lake Butler before 1/4/1990 (Figure B-10; Appendix B). In addition, available water level data were discontinuous and sparse for some of the POR (Figure B-10; Appendix B). Available water level data are discussed in the *Hydrology* subsection under the *Setting and Description* section, and details are in Appendix B.

Because of the lack of a long-term observed record, long-term lake level simulation is needed to develop the no- and current-pumping conditions lake levels. 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 (The Storm Water Management Model [SWMM]) model) was developed (Jones Edmunds, 2018) and later updated (Appendix B). Long-term lake levels were simulated by the SWMM model using long-term rainfall, PET, boundary lake levels, and groundwater levels data (Appendix B).

Development of No-pumping and Current-pumping Lake Levels

The MFLs determination for Lake Butler involved the development of a long-term water level time series that is representative of a no-pumping condition. The no-pumping condition lake levels constitute a reference hydrologic condition in which lakes were under no influence of groundwater pumping since 1948.

The MFLs assessment for Lake Butler involved the development of a long-term water level time series that is representative of a current-pumping condition. The current-pumping condition lake levels constitute a reference hydrologic condition in which lakes were under the influence of current groundwater pumping since 1948.

Development of the no- and current-pumping condition lake level timeseries is discussed briefly below. The role of the no- and current-pumping condition timeseries in the MFLs determination and assessment is discussed in the MFLs Determination and Assessment sections and in Appendix B.

The adjustment of historical lake levels to develop no- and current-pumping condition lake levels requires considering the effect of groundwater pumping on lake levels not only for the recent years but also for the entire period of record (from 1948 to 2018). Assuming the present climatic, rainfall, and other conditions of the period from 1948 to 2018 are representative of the conditions over the next 71 years, the current-pumping condition lake levels reflect the future condition of the lake levels if the average regional groundwater pumping does not change from that experienced during the period 2014 to 2018. Because of 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 deemed reasonable.

The Lake Butler SWMM model was utilized to simulate no-pumping and 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 model. Thus, the impact of groundwater pumping on the UFA levels near the lake was estimated first. The SJRWMD Volusia groundwater model was used for the groundwater pumping impact assessment.

The UFA levels used in the surface water model were adjusted by removing the effect of estimated impact from historical pumping, to create a timeseries of no-pumping condition UFA levels. To generate current-pumping condition UFA levels, the impacts from current pumping were subtracted from the no-pumping condition UFA levels from 1948 to 2018. An average of a recent five-year period (from 2014 to 2018) of groundwater pumping was used to calculate the current-pumping condition; an average of five years is used because it is more representative of the recent average groundwater demand. The no-pumping and current-pumping Lake Butler levels were simulated by inputting the no-pumping and current-pumping UFA levels into the surface water model, respectively (Figure 12). Note that the Figure 12 POR starts in 1949. This is because a one-year model spin-up period was used to improve the initial conditions (e.g. soil moisture, lake levels) of the system within the model. Because of this, assessments of environmental criteria (described below) were performed using simulated lake levels with a POR of 1949 to 2018. The details of these analyses and graphs of no-pumping and current-pumping condition UFA and lake levels are in Appendix B.

Long-term lake level time series were also expressed as exceedance probabilities to facilitate the MFLs determination (e.g., to determine a 15% reduction from no-pumping exceedance of lake lobe connection metric). Exceedance probabilities for Lake Butler were defined as the percent of time a specified level will be equaled or exceeded over the period of record. Lake Butler exceedance probability curves for the observed and no-pumping condition timeseries are presented in Figure 13. A description of hydrologic analyses performed for Lake Butler is included in Appendix B.

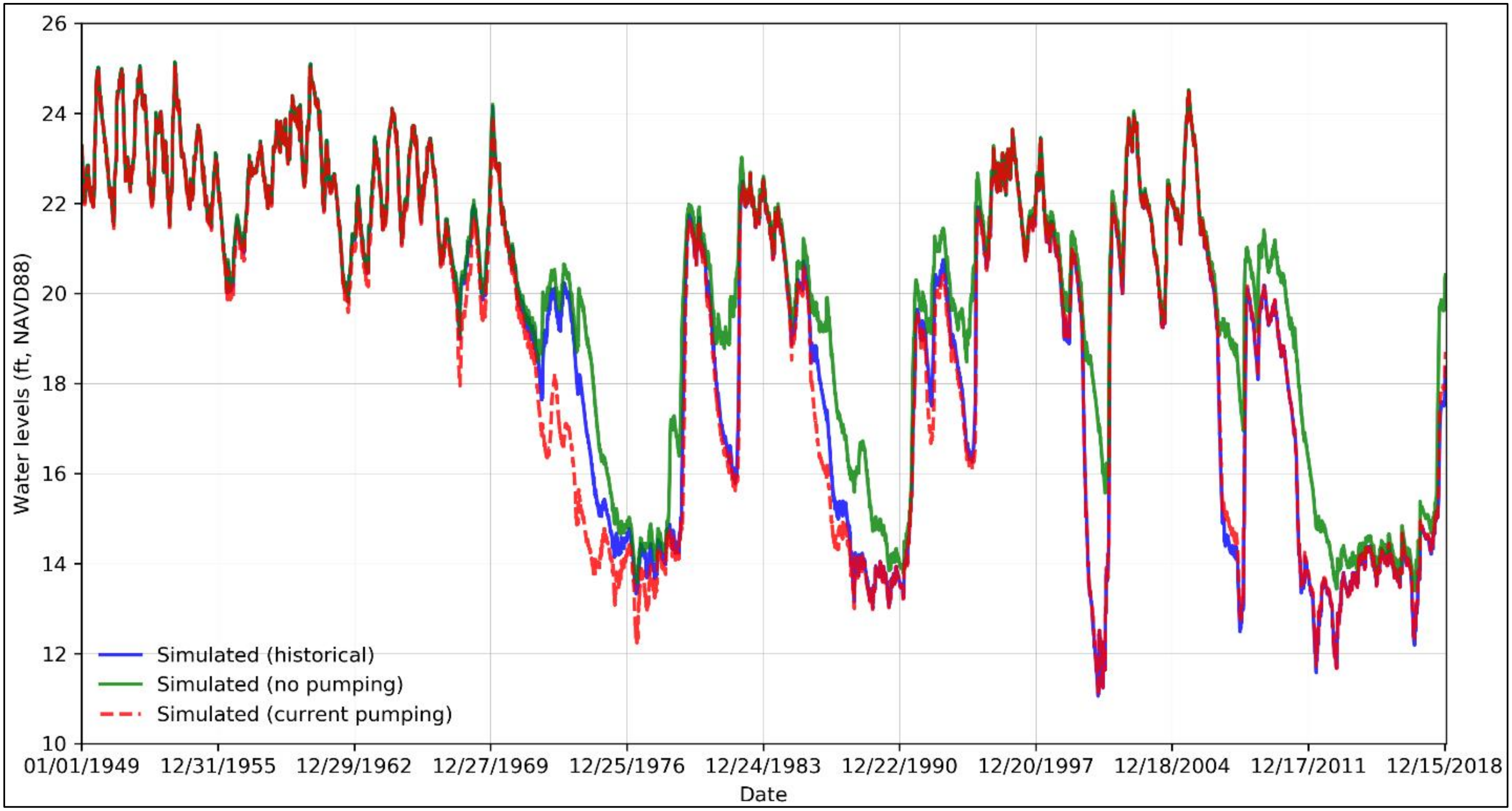

Figure 12. Simulated historical, no-pumping and current-pumping condition lake levels for Lake Butler, Volusia County, Florida.

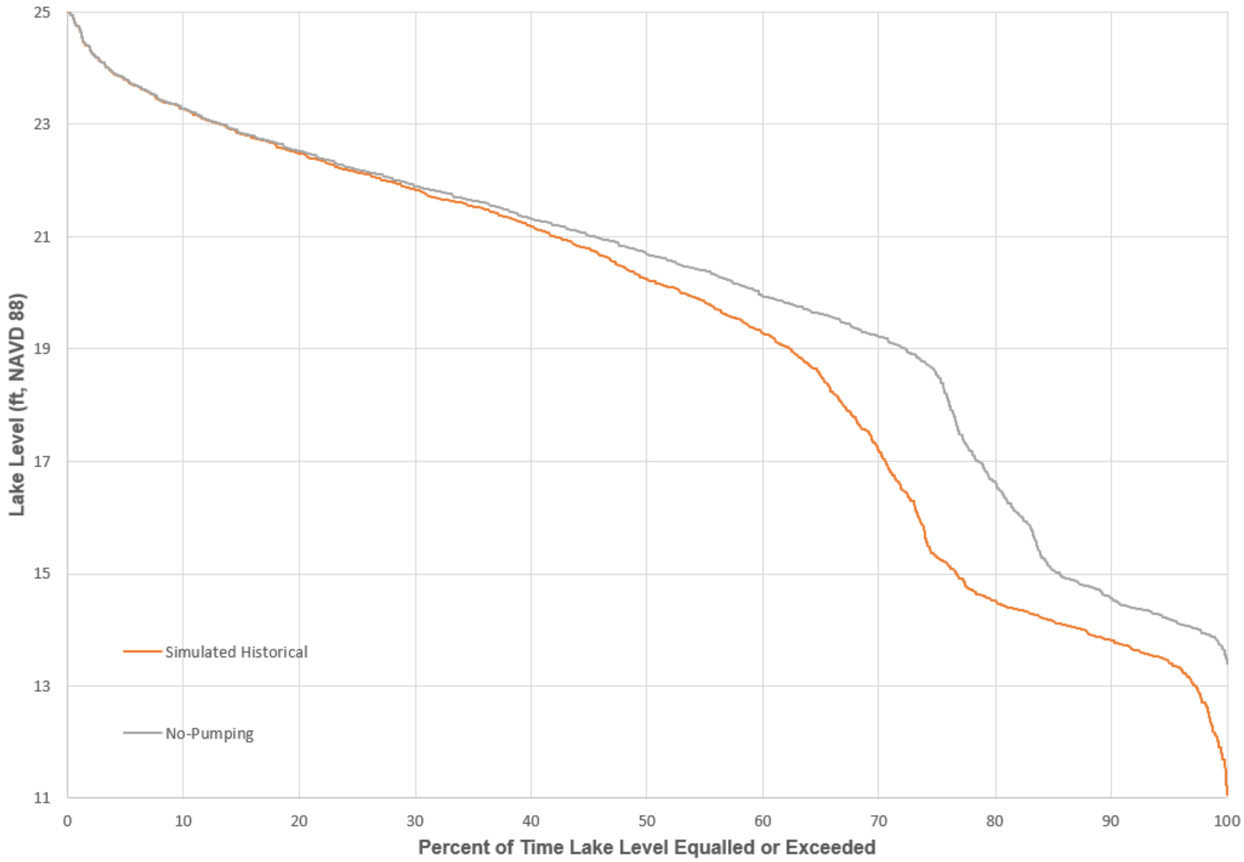

Figure 13. Percent exceedance curves for Lake Butler simulated historical and no-pumping condition lake levels.

MFLs DETERMINATION

The MFLs determination for Lake Butler involved both hydrological and environmental analyses. The *Hydrological Analyses* section above provides a brief description of modeling and data analyses used to develop long-term lake level time series, which were used to develop minimum lake levels for the system (*see Appendix B for more details on hydrological analyses*).

The *Environmental Analyses* section below provides a brief description of environmental criteria evaluated for Lake Butler. Criteria descriptions, methods and results are presented, including the calculation of minimum lake levels based on each criterion. Environmental criteria were chosen based on their potential to protect non-consumptive environmental values and beneficial uses, as mandated by Rule 62-40.473, F.A.C.

The protection of other environmental values, also called Water Resource Values (WRVs), is discussed further in the *MFLs Assessment* section; details of the WRVs assessment are also located in Appendix D.

ENVIRONMENTAL ANALYSES

A critical part of the MFLs determination process is to determine relevant environmental attributes (e.g., fish and wildlife habitat) and beneficial uses (e.g., recreational value) for each water body, and then to determine 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, appropriate criteria to represent them, and a minimum hydrologic regime (MFLs condition) that ensures their protection.

Because of the history of using event-based criteria (e.g., Minimum Frequent High, etc.) to develop MFLs at SJRWMD, the environmental analysis and criteria development typically starts with investigating if event-based are appropriate for a given system. As described above, Lake Butler is a sandhill lake, and is characterized by large water level fluctuations and a lack of stable wetlands and organic soils. Wetland and organic soil locations have shifted over time as a result of large fluctuations in water levels.

Therefore, MFLs for Lake Butler require an approach that moves beyond the use of stable wetlands criteria, for establishing protective minimum levels. While not being able to use event-based criteria developed to maintain stable wetlands and soils, other event-based metrics were investigated, including the Minimum Infrequent High described below.

After investigating the possibility of using the district’s standard event-based criteria, other criteria were then explored. This included using a new approach developed for other highly fluctuating sandhill lakes, using what is referred to as the “hydroperiod tool”. Evaluating the effects of water level decline on fish and wildlife habitat and recreation, using the hydroperiod tool, was the second step in the environmental analysis.

Finally, because of the lobed, sinkhole nature of Lake Butler, and because of the importance of recreation at this lake, a lake lobe connectivity metric was investigated. For other lakes with more motorboat traffic, a larger water depth offset has been used. At Lake Butler, a 20-ft offset was used because the dominant recreation is canoeing and kayaking (based on staff observations and discussions with local homeowners).

West versus East Lake Butler

Initially, environmental criteria were evaluated for the multiple lobes that comprise Lake Butler (Figure 14). However, due to the following factors, the MFLs determination and assessment was only carried out for criteria measured on western side of Lake Butler:

- Lake Butler divides into two main areas at water levels below 19.4 ft NAVD88; East and west sides of the lake are divided by Courtland Boulevard;
- Water level data has only been collected for the west side of the lake (SJRWMD station 03390378; data is lacking for lake lobes east of Courtland Boulevard; and
- Based on data availability, the Lake Butler surface water model was calibrated using water level data collected on the west side of the lake.

For these reasons, the following sections describing environmental criteria development and assessment are for metrics measured on the western side of Lake Butler (i.e., lobes 1, 2, 3, and the western portion of lobe 4; Figure 14). An implicit assumption with this approach is that the minimum hydrologic regime developed based on assessment of criteria on the west side, will protect the entire lake. In future, if data are available for the east side of the lake, the environmental assessment will be updated to include both sides of the lake.

Criteria and Thresholds for Lake Butler

Little has been published on environmentally protective lake levels, relative to the large body of literature available on protective flows for rivers and streams (Tharme 2003, Arthington 2012, Gleeson and Richter 2017). The majority of published studies on lake level thresholds are associated with determining the effects of reservoir regulation alternatives on recreational uses (Cordell and Bergstrom 1993, Hanson et al., 2002) and economic valuations (e.g., home and property values; Allen et al., 2010, Dickes and Crouch 2015). Some of these studies allow very large water level reductions from full pool (e.g., reducing reservoir storage by 69%; Shang 2013), while other lake studies suggest a less dramatic reduction (Hoyer and Canfield 1994, Emery et al., 2009).

Multiple environmental criteria were evaluated to ensure that protective minimum levels are set at Lake Butler. Criteria were chosen based on their potential to protect non-consumptive environmental values and beneficial uses (also called WRVs), whose consideration is mandated by Rule 62-40.473, F.A.C. These criteria include:

1. Event-Based Metrics: Two minimum levels, based on SJRWMD’s conventional event-based method, were developed:

    a. Minimum Infrequent High: An infrequent flood event criterion was developed, based on preventing a downward shift in the upland boundary at Lake Butler;

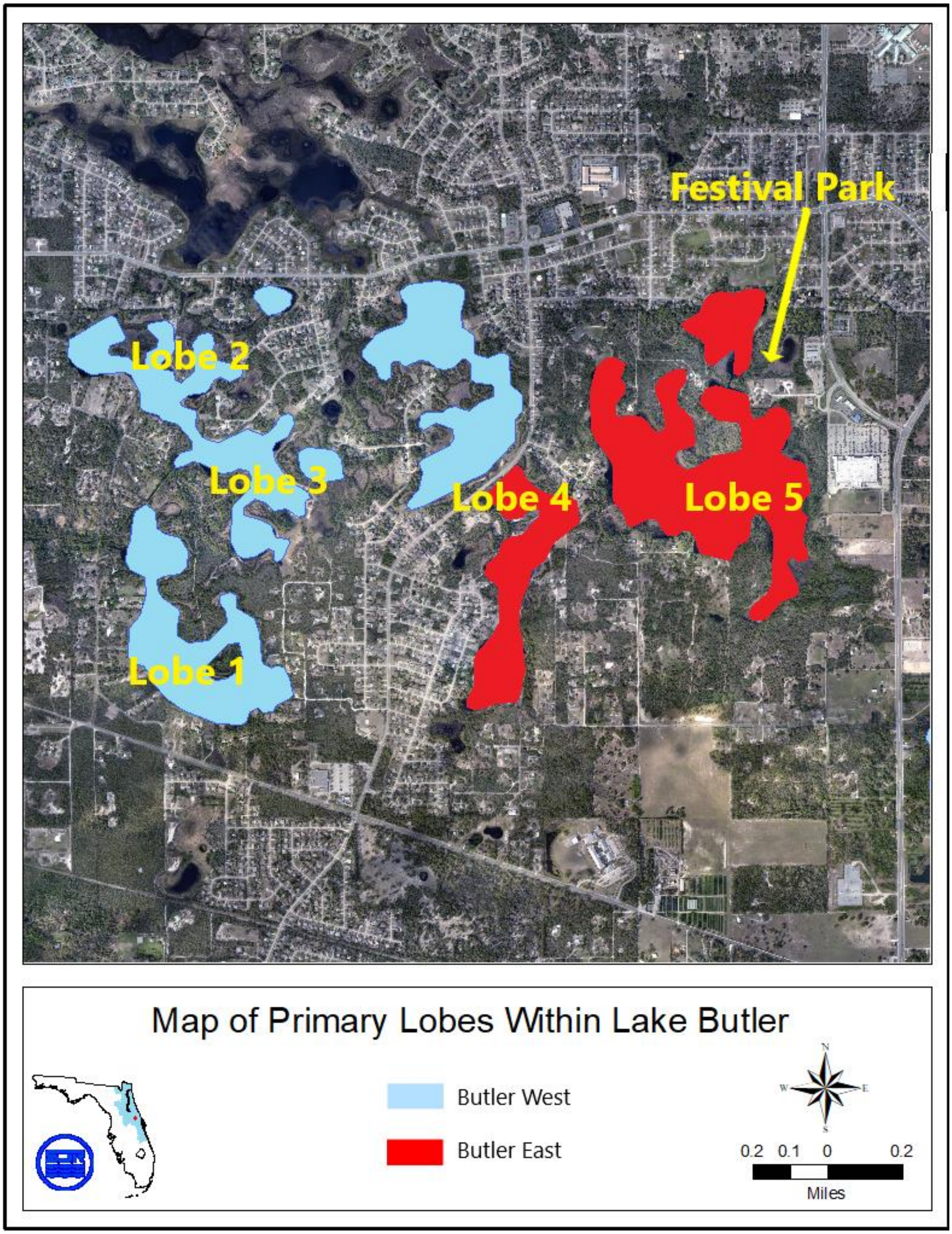

Figure 14. Map of primary lobes within Lake Butler

   b. Minimum Infrequent Low: An infrequent drought event criterion was developed, based on maintaining deep marsh habitat at Lake Butler;

2. Lake Lobe Connectivity: A criterion based on maintaining minimum water depths for passage between lake lobes was evaluated; and

3. Hydroperiod Tool Metrics: The effect of water level decline on aerial extent of fish and wildlife habitats was evaluated using a GIS-based hydroperiod tool.

Event-Based Metrics

SJRWMD lake MFLs typically include Frequent High, Minimum Average, and Frequent Low events (with specific target levels, durations, and return intervals) that are based on protecting a minimum number of flooding events or preventing more than a maximum number of drying events, to protect stable wetland communities and organic soils (Neubauer et al. 2008). Given the absence of stable wetlands and organic soils at Lake Butler, an event-based approach was used to develop a different type of metric, with the aim of protecting this sandhill lake. This effort resulted in an infrequent flooding criterion – a minimum Infrequent High (IH) – intended to prevent a downhill shift in the upland/wetland boundary, and a minimum Infrequent Low (IL) intended to maintain the location of deep marsh communities at Lake Butler.

Minimum Infrequent High

The general indicator of protection for the IH is a high-water level that must be flooded for a sufficiently long duration to kill upland plant species that grow down slope during periods of less extreme high-water levels, preventing permanent encroachment by upland woody vegetation into lower elevation wetland communities. The upland ecotone should not permanently shift down slope if withdrawals do not reduce the number of infrequent flooding events beyond the specified return interval of the IH event. These high-water level events are usually associated with wet season rainfall events that occur during or following periods of well above normal precipitation.

The specific indicator of protection is a high-water level that corresponds to the average waterward elevation of uplands (24.1 ft NAVD88) that is continuously exceeded for a duration of 30 days with a 25-year return interval (Table 8). This elevation was derived from the elevations of mature oak and pine trees observed in the Lake Butler chain and adjacent lakes that are connected at higher stages. While immature pine and oak may be present lower elevations, this is due to the low frequency of inundation that allows for germination and growth of upland species but not recruitment. For a more detailed discussion of the infrequent high and data used to derive the elevation of 24.1 see Appendix A. The recommended duration component is based on flooding upland species while maintaining the location of the upland/wetland boundary. The recommended duration is sufficient to kill all upland species that become established downslope of the upland boundary. The return interval of 25 years is associated with a flood frequency necessary to kill pine trees and faster growing hardwood species and deemed necessary to periodically reset the upland boundary. The observed POR and boundary elevation of immature versus mature pine and oak was also used as supporting evidence for the IH return interval.

Table 8. Minimum Infrequent High for Lake Butler, Volusia County, Florida

Minimum Level	Level (ft, NAVD88)	Duration (days)	Return Interval (years)
Infrequent High	24.1	30	25

Minimum Infrequent Low

The general indicator of protection for the infrequent low (IL) is a low water level that protects deep marsh by limiting the dewatering of low elevations, while conserving the structure and composition of floodplain soils and flora. The IL level represents a low water event that generally occurs during extreme droughts or extended periods of well below normal rainfall and results in ecological benefits for dewatered wetlands. The IL level event will allow water lilies or other deep marsh plant species to perpetuate at lower elevations and to recolonize upper elevations during higher water levels.

The specific indicator of protection is a low water level that corresponds to the average maximum elevation of established white water lily (plants with > 1 ft diameter leaves; 16.7 ft NAVD88) with a continuous non-exceedance duration of 180 days and a return interval of 20 years (Table 9).

Due to the ephemeral nature of the marsh habitat in Lake Butler, district staff observed that the maximum elevation of the deep marsh was located at markedly different elevations over a little more than a decade. The dynamic nature of the marsh location confounds the setting of an IL for this system. Setting an IL when water levels are very low could lead to an MFL that does not protect from significant harm over the entire POR. Conversely, setting an IL based on high water levels could lead to an MFL that is too constraining. Therefore, the IL was not assessed or used to set a minimum level at Lake Butler.

Table 9. Minimum Infrequent Low for Lake Butler, Volusia County, Florida

Minimum Level	Level (ft, NAVD88)	Duration (days)	Return Interval (years)
Infrequent Low	16.7	180	20

Further, preliminary modeling results indicated that the high elevation associated with the IH event developed for Lake Butler is relatively insensitive to groundwater withdrawal. High water levels (i.e., near the upland ecotone) are driven more by infrequent storm events than by changes in UFA levels. Preliminary analyses suggested that the IH is potentially not protective of lower lake elevations and would therefore not be protective of other environmental functions and values associated with lower elevations.

In addition, preliminary modeling indicated that the IL developed for Lake Butler could not be met under a no-pumping condition. Because of these issues with both event-based metrics, additional environmental criteria were evaluated to ensure that important environmental values and beneficial uses are protected. These additional environmental criteria are described below.

Lake Lobe Connectivity

The purpose of this criterion is to prevent a significant change, due to water withdrawal and relative to historical conditions, to minimum depths that allow for passage between lake lobes at Lake Butler. This metric is intended to maintain recreational (e.g., canoe/kayak passage) as well as ecological (e.g., fish passage) functions and values. This metric is based on the minimum water depth required for lake lobe connectivity to which an offset is added to provide sufficient depth for boating of other forms of recreation.

Lake Butler supports various recreational activities, such as fishing, kayaking, canoeing and small motor craft boating. The most popular recreational activity on Lake Butler is kayaking/canoeing (based on SJRWMD staff communications with residents), however some residents also use small jon boats (≤ 16 ft; Figure 15). Recreational value at Lake Butler is linked to the ability to canoe and kayak and therefore is dramatically reduced when lake lobes are disconnected. Lake Butler consists of many lobes and the number of lobes varies with water level. Five primary lobes were identified for use when developing the lake lobe connectivity metric (Figure 16). A minimum boat passage elevation was calculated by adding an offset to lake lobe connection elevations (i.e., the highest elevation surveyed along each flow way that connects two lake lobes). The offset (20”) was chosen based in part on a 2004 environmental value assessment conducted on the St. Johns River that reported the draft of small flat bottomed jon boats of 16 ft or less to be usually 1.5 ft or less (HSW 2004). As stated above, the majority of watercraft used at Lake Butler are small and have small draft/depth requirements. The boat depth suggested by the HSW study is also consistent with an FDEP study that suggests that a minimum of 20” water depth is required for protecting bottom vegetation damage from paddling and boat prop actions. This study was conducted to determine the likelihood of “paddle gouging” of submerged vegetation within the Wekiva River basin by canoeists and boat propellers (FDEP 1990). The chosen minimum paddling depth (20”) for the Lake Butler MFL is also consistent with canoe paddling depths used by Suwanee River Water Management District in MFL determinations. Further, the most common recreational activities at Lake Butler (e.g. canoeing, kayaking, fishing, etc.) typically require at least 20” of water for safe operation. For these reasons, an offset of 20” was chosen.

This depth was added to lake lobe connection elevations to determine minimum boat passage elevations. In other words, adding 20” to the highest elevation between each pair of lobes determines the minimum passage elevation between the lobes for recreational boats (small jon boats, kayaks, and canoes). Due to a lack of water level data on the eastern side of Lake Butler, and the other reasons discussed above, connections between eastern lobes of Lake Butler were not evaluated. In addition, the flow-way between lobes L1 (Lake Doyle) and L3 was not accessible at the time of survey, and therefore this connection is not being evaluated. Lobe connection elevations and minimum boat passage elevations are presented in Table 10.

Figure 15. A small jon boat and a canoe on a dock at Lake Butler, Volusia County.

Figure 16. Lake Butler lobes identified for developing lobe connectivity criterion

Table 10. Highest ground elevation and minimum lake elevation for boat passage between selected lobes

Lobe Connection	Highest ground elevation between lobes (ft, NAVD88)	Minimum boat passage elevation (ft, NAVD88)
L2 – L3	18.7	20.4
L3 – L4	20.8	22.5

A 15% threshold was used as the allowable reduction in exceedance of the minimum boat passage elevation. Therefore, the amount of time this elevation is exceeded under no-pumping condition can be reduced by a maximum of 15% over the long-term. After determining minimum boat passage elevations, the next step involved determining their temporal exceedance under the no-pumping condition. Next, the MFL condition was calculated by shifting the time exceeded under the no-pumping condition by 15%.

Two minimum boat passage elevations were examined: the elevation between lobes L2 and L3, and the elevation between lobes L3 and L4 (Figure 16; Table 10). The no-pumping condition exceedance percentiles are 55.5% and 21.2%, respectively for these two connection elevations (Table 11). The MFLs condition equals a 15% reduction in exceedance of the connection elevation, relative to the no-pumping condition. Thus, the MFLs condition (i.e. minimum) exceedance the minimum boat passage elevation between L2 and L3 equals 47.2% (i.e., 55.5% *85%) and equals 18% (i.e., 21.2% *85%) between L3 and L4 (Table 11).

Table 11. Exceedance percentiles at minimum lake lobe connectivity elevations for no-pumping and MFLs condition for Lake Butler.

Connection between Lobes	Minimum Lake Lobe Connectivity elevation (ft, NAVD88)	No-pumping condition exceeding percentile	MFLs condition exceeding percentile
L2 – L3	20.4	55.5	47.2
L3 – L4	22.5	21.2	18.0

Hydroperiod Tool Metrics

Per Rule 62-40.473, *F.A.C.*, water management districts are directed to consider a suite of environmental values when setting MFLs. One of these environmental values is "*fish and wildlife habitats and the passage of fish*". Typically, SJRWMD evaluates fish and wildlife habitat through event-based metrics that are developed to maintain the long-term persistence and integrity of wetland communities. As discussed above, the event-based metrics typically used are not appropriate for this dynamic system.

Therefore, a new approach, using a Geographic Information System (GIS) tool, referred to as the “hydroperiod tool” (see below for details), was developed to evaluate the effects of withdrawal on fish and wildlife habitat area. The hydroperiod tool was also used to evaluate a “canoeable area,” to assess the effects of water level decline on *“recreation in and on the water,”* another environmental value listed in 62-40.473, F.A.C.

Fish and Wildlife Habitat

Five fish and wildlife habitats, representing different components of the Lake Butler nearshore environment, were evaluated. Each habitat is defined by the area of the lake that has a specific depth range (see below). Habitat areas were estimated based on a stage/area curve developed using the hydroperiod tool. This customized tool was developed, with the South Florida Water Management District (SFWMD), to work with ESRI’s ArcMap© and functions primarily with raster (grid-based) representations of a specific environment. Elevation values from a digital elevation model (DEM or land elevation) are subtracted from an interpolated water surface elevation on a grid cell by grid cell basis, producing a new raster surface containing elevation or depth of water for each grid cell (Figure 17). The hydroperiod tool was used to assess the relationship between stage and habitat quantity (area of a specified depth). Undulating lake bathymetry can lead to a variable relationship between habitat and stage. With the hydroperiod tool, the effect of bathymetry and water level reduction on habitat area is quantifiable.

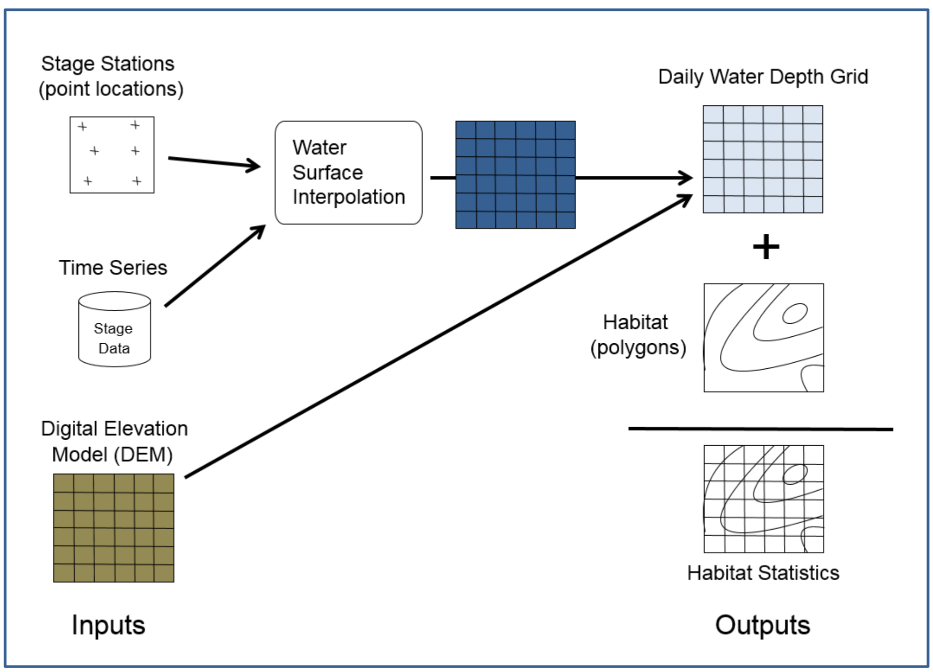

Figure 17. Conceptual diagram of the Hydroperiod tool used to estimate lake area and habitat area.

Lake Butler lacks stable wetlands yet harbors valuable wetland plant and animal communities that are worth protecting. Large water level fluctuations in Lake Butler have resulted in perpetual movement of marsh and upland communities with the occasional temporary extirpation of marsh communities. This conclusion is based on SJRWMD staff observations of current wetland locations relative to surveyed wetland locations during 2004, 2009, 2018. As wetlands move downslope during periods of drought, their areal coverage (e.g. total acreage) and habitat volume also change. Changes in the extent of nearshore habitat is related to the combined effect of changing water level and specific lake bathymetry. For example, if "habitat" is defined as all portions of the lake with depths ranging from 1 to 2 ft, the areal extent of this habitat will vary with water level and be a function of lake shape and slope. The extent of some habitats may be minimal at high elevations, if banks are steep, and may be extensive at lower elevations that are characterized by low slope (e.g., if there is a large flat shelf or lake bottom).

Impact threshold

The significant harm threshold used for hydroperiod tool metrics is a 15% change in areal extent (acreage) of habitat, relative to the no-pumping condition over the simulated model period of 1948-2018. A 15% reduction of habitat availability has been used by other water management districts as a significant harm threshold for MFLs (Munson and Delfino 2007). This threshold has been peer reviewed numerous times and has been the basis for numerous adopted MFLs (see SWFWMD MFLs for Crystal River, Gum Slough, Chassahowitzka River, and Homosassa River, among others). While many MFLs using this threshold are for flowing systems, a 15% reduction in habitat has also been used as a critical threshold for lakes (Hoyer and Canfield 1994, Leeper et al., 2001, Emery et al., 2009). This threshold is also within the range (10 to 33%) of percent allowable change documented in other studies (Munson and Delfino 2007).

Average habitat area

Average habitat area was calculated for each metric, for each day in the POR, using the stage/habitat area relationship derived from the hydroperiod tool and the simulated water surface elevations for the no-pumping condition. Figure 18 depicts the stage/habitat area curve (i.e., hydroperiod tool output data) for the emergent marsh metric, where habitat is defined as the lake area with depths ranging from 0 to 6 ft (*see below for more details about this metric*).

The MFLs condition for hydroperiod tool habitat metrics equals a 15% reduction in average habitat area under the no-pumping condition (i.e., habitat area averaged across the entire no-pumping condition lake level timeseries). Assessment of habitat metrics is then simply the comparison of the average habitat area under no-pumping condition to the average habitat area under the current-pumping condition (*see MFLs Assessment for more details*).

Nearshore habitats

The nearshore environment (littoral zone) within Lake Butler provides habitat for numerous native fish and wildlife species, including game fishes and wading birds (SJRWMD staff observations). The shallow littoral zone fringing the lake provides valuable habitat for various life stages including refugia and forage habitat for aquatic invertebrates, gamefish juveniles and small-bodied fishes. These areas also provide important reproductive habitat for fish, amphibians and reptiles, forage habitat for wading birds, and nesting habitat for the Florida sandhill crane (*Grus canadensis pratensis*).

Five habitats were defined for this analysis. Habitats are areas within the nearshore environment with specific depth ranges and are based on water level requirements of plant and animal species known to inhabit these areas in Lake Butler (Figure 19; SJRWMD staff observations). These habitats were chosen to ensure that multiple portions of the nearshore environment were evaluated, in case one or more was particularly sensitive to water level change. Each habitat described below was evaluated using the hydroperiod tool to determine the amount of water level decline associated with a 15% reduction in habitat extent.

Emergent Marsh Habitat

The littoral zone at Lake Butler consists mainly of deep marsh habitats, with occasional woody wetland shrubs (e.g., buttonbush, *Cephalanthus occidentalis*). Deep marsh habitats are dominated by white water-lily (*Nymphae odorata*), with occasional maidencane (*Panicum hemitomon*), torpedo grass (*Panicum Repens*), fringe rush (*Fuirena scirpoidea*), St. John's wort (Hypericum fasciculatum), arrowhead (*sagittaria* sp.), redroot (*Lachnanthes caroliniana*), pennywort (*Hydrocotyle* sp.), primrose willow (*Ludwigia suffruticosa*), and frog's bit (*Limnobium spongia*). Emergent marsh generally extends from the edge of the shore to approximately 6 feet deep. A maximum depth of 6 ft was used based on the known depth ranges for species inhabiting these communities (e.g., maidencane, and water lily). Based on this, the emergent marsh habitat depth range used for this analysis is 0 to 6 ft.

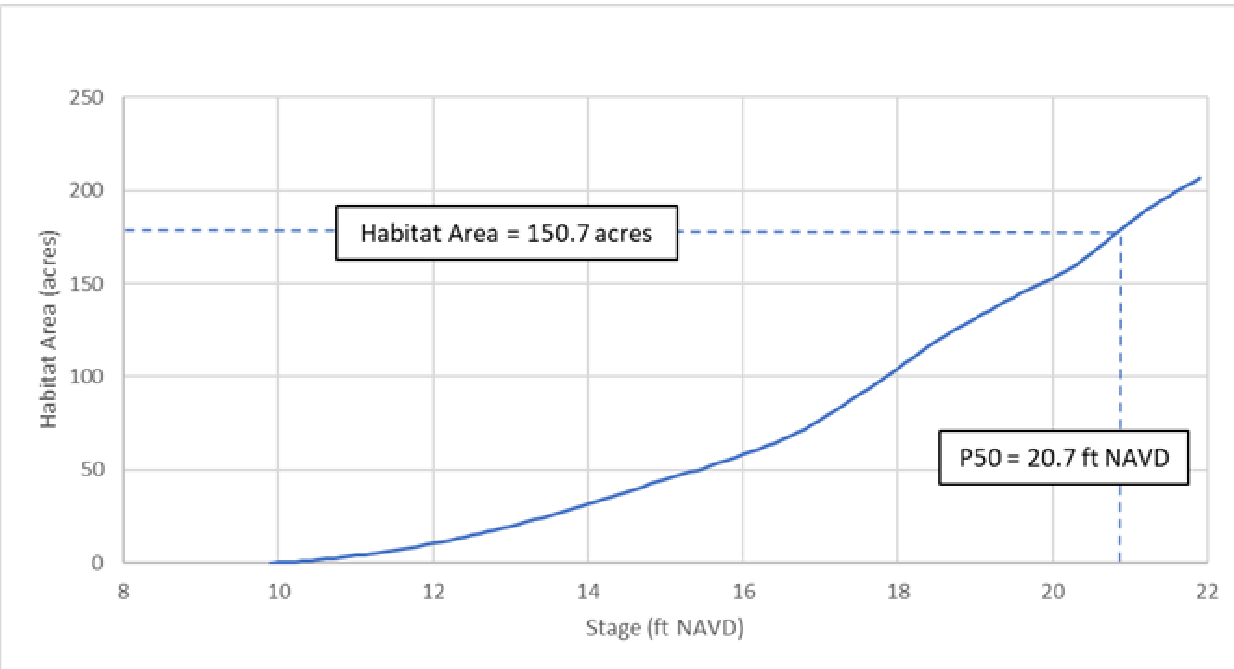

Figure 18. Example of hydroperiod tool output; stage/habitat area (acres) for emergent marsh (0-6ft depth) for Lake Butler, Volusia County, Florida.

Game Fish Spawning Habitat

Similar to other oligotrophic systems, Lake Butler is likely characterized by low fish production. However, largemouth bass (*Micropterus salmoides*) are present in Lake Butler, along with bluegill (*Lepomis macrochirus*) and other bream species (SJRWMD staff observations [Figure 20]). The purpose of this habitat metric is to prevent significant harm to game fish spawning habitat, due to withdrawal. Largemouth bass and other lake game fish (e.g., *Lepomis spp.*) typically construct their nests in shallow water in close proximity to emergent vegetation. While the range of nest depths for largemouth bass can vary from less than one foot to over 10 feet, the average depth is typically 1 to 4 feet (Stuber et al., 1982, Bruno et al., 1990, Hill and Cichra 2005, Strong et al., 2010). Therefore, the depth range used for this habitat metric – game fish spawning habitat – equals 1 to 4 feet.

This depth range will also provide important refuge habitat for small forage fish that form the base of production for game fish, birds and other wildlife in the lake chain. Forage fish found in the system may include mosquito fish (*Gambusia spp.*), shiners (*Notropis spp.*), golden topminnow (*Fundulus chrysotus*), killifish (*Fundulus spp.*) and other small bodied species (SJRWMD staff observations). Shallow marshes provide important refugia and forage habitat for these small fish, as well as for game fish (largemouth bass, bluegill, etc.) young-of-the-year.

These small-bodied fish seek refuge from larger fish, birds and other predators, among the shallow marsh vegetation. Habitat depths of 1 to 4 feet will provide protection for this important component of the aquatic community in Lake Butler.

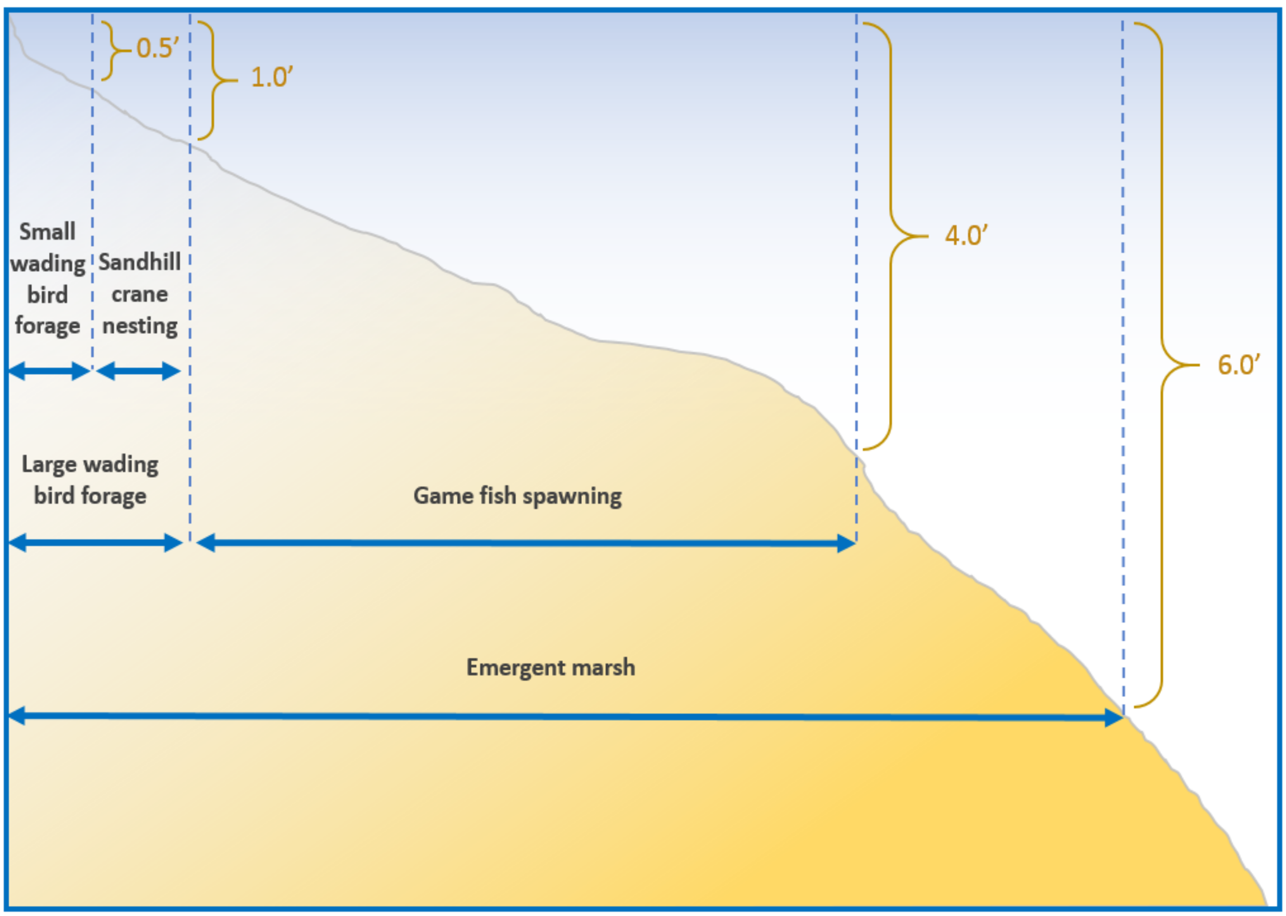

Figure 19. Nearshore habitat depth ranges used in hydroperiod tool-based metrics.

Figure 20. Fisherman holding largemouth bass at Festival Park on Lake Butler, Volusia County, Florida

Large Wading Bird Habitat

Water depth is a critical component of wading bird habitat (Bancroft et al., 2002, Pierce and Gawlik, 2010, Lantz et al., 2011). Forage success of long-legged wading bird species (e.g., great egret, great blue heron) can be constrained by their leg length (Powell 1987), and typically forage in vegetation in water less than or equal to ~10–12” (Kushlan 1979, Kushlan et al., 1985, Bancroft et al., 1990). Therefore, the depth range used, to prevent a significant shift in forage habitat for large wading birds, is 0 to 1 foot.

Small Wading Bird Habitat

Short-legged wading birds (little blue heron, snowy egret, ibis, etc) require shallower habitat (~0.5 ft) for suitable foraging (Kushlan 1979, Kushlan et al., 1985). The depth range used, to prevent significant change to forage habitat for small wading birds, is 0 to 0.5 ft.

Sandhill Crane Nesting Habitat

The Florida sandhill crane typically nests in shallow herbaceous wetlands, dominated by maidencane, pickerelweed, rush and/or smartweed (*Polygonum spp*.; Stys 1997). The shallow maidencane marshes at Lake Butler provide nesting and forage habitat for sandhill cranes and other birds. Sandhill cranes have been observed in shallow maidencane marsh habitats throughout Lake Butler, along with nests in the large emergent marshes (Figure 21). Average

Figure 21. Sandhill Crane turning eggs at a nest on Lake Butler

water depths for suitable sandhill crane nesting ranges from approximately 0.5 to 1 ft (Stys 1997). This is the depth range used for evaluation of this habitat metric.

Recreation In and On the Water

In addition to evaluating the effects of water level decline on fish and wildlife habitat area, the hydroperiod tool was also used to evaluate recreational values. One of the primary forms of recreation in or on the water at Lake Butler is canoeing and kayaking.

<u>Canoeable Area</u>

The hydroperiod tool was used to evaluate the effect of water level decline (over the long term, relative to the no-pumping condition), using the same method developed for evaluating fish and wildlife habitat. For this analysis, canoeable area is defined as lake area (in acres) with a depth of 20” or greater, based on guidelines set by the Florida DEP (FDEP 1990). See below for assessment of this environmental value.

Hydroperiod Tool Metrics Results

Fish and Wildlife habitat

Habitat area for all five fish and wildlife metrics increased with stage, with emergent marsh having the greatest relationship (i.e., highest slope; Figure 22). Habitat area data were smoothed using local regression (LOESS; 10 ft window), to minimize noise in the dataset which may be due to uncertainty in bathymetry data as well as uncertainty related to Lake Butler splitting into smaller lobes at certain elevations. Due to the bathymetry of the lake, the relationship between lake stage and habitat shows some small increases associated with decreasing stage, but the overall trend for all metrics is positive. Habitat area for the no-pumping condition and MFLs condition (i.e., 15% reduction in average NP area), for each metric is presented in Table 12.

Canoeable Area

Similar to the five fish and wildlife habitat metrics, the canoeable area for Lake Butler (i.e., the area of the lake deep enough to canoe or kayak; 20” or greater) also increased with lake stage (Figure 22). The average canoeable area for Lake Butler under the no-pumping condition was 135.4 acres (Table 12). Therefore, the MFLs condition for the canoeable area metric, which represents a 15% reduction in the no-pumping condition area, equals 115.1 acres (Table 12).

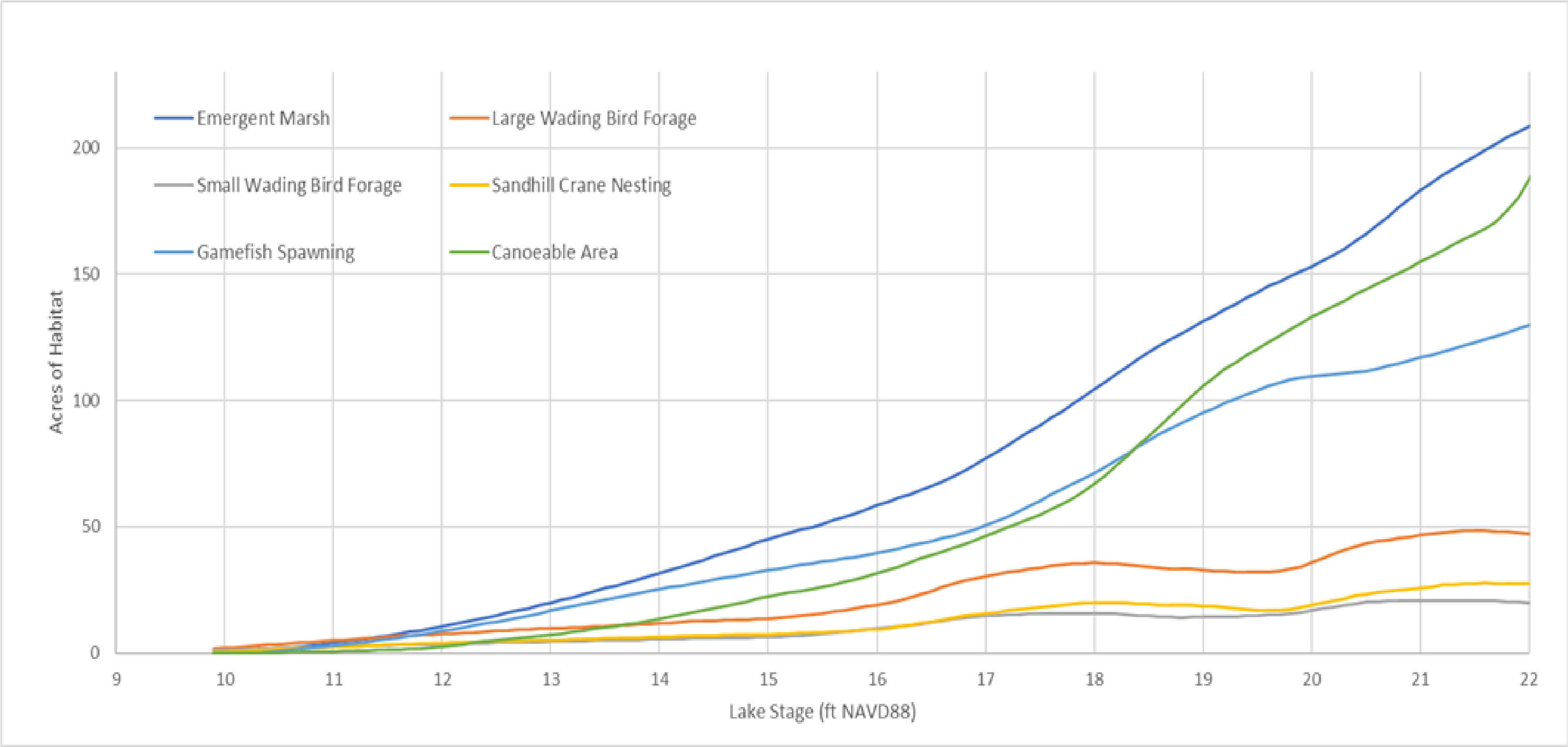

Figure 22. Hydroperiod tool output data showing stage versus habitat area for five fish and wildlife metrics used for Lake Butler, Volusia County, Florida

Table 12. Average acreage for fish and wildlife habitat and canoeable area, under no-pumping (NP) condition and MFLs condition; MFLs condition equals a 15% reduction in NP condition habitat area; areas based on hydroperiod tool

Fish and wildlife habitat metric	**Habitat acreage (averaged over entire POR; acres)**	
	NP	MFL
Emergent marsh habitat	150.7	128.1
Large wading bird forage habitat	35.3	30.0
Small wading bird forage habitat	15.4	13.1
Sandhill crane nesting habitat	19.7	16.7
Game fish spawning habitat	103.8	88.2
Canoeable area	135.4	115.1

MFLs Determination Summary

The MFLs condition for environmental criteria used for the Lake Butler MFLs determination are summarized in Table 13. This list represents those criteria that were chosen from the numerous metrics evaluated. The assessment of environmental criteria (i.e., whether they are being met currently and in the future) is discussed below in the *MFLs Assessment* section.

Table 13. MFL criteria summary for Lake Butler, Volusia County, Florida

<table>
<tr><th>Environmental Criterion</th><th>Environmental/ Recreational value protected</th><th colspan="4">MFLs Condition</th></tr>
<tr><td rowspan="2">Minimum Infrequent High</td><td rowspan="2">Upland/wetland boundary</td><td colspan="2">Level (ft, NAVD88)</td><td>Duration (days)</td><td>Return Interval (years)</td></tr>
<tr><td colspan="2">24.1</td><td>30</td><td>25</td></tr>
<tr><td rowspan="2">Minimum Emergent Marsh habitat reduction</td><td rowspan="2">Fish and wildlife habitat</td><td colspan="4">15% reduction in average habitat over entire period of record</td></tr>
<tr><td colspan="2">NP = 150.7 acres</td><td colspan="2">MFL = 128.1 acres</td></tr>
<tr><td rowspan="2">Large Wading Bird Forage habitat reduction</td><td rowspan="2">Fish and wildlife habitat</td><td colspan="4">15% reduction in average habitat over entire period of record</td></tr>
<tr><td colspan="2">NP = 35.3 acres</td><td colspan="2">MFL = 30.0 acres</td></tr>
<tr><td rowspan="2">Small Wading Bird Forage habitat reduction</td><td rowspan="2">Fish and wildlife habitat</td><td colspan="4">15% reduction in average habitat over entire period of record</td></tr>
<tr><td colspan="2">NP 15.4 =acres</td><td colspan="2">MFL = 13.1 acres</td></tr>
<tr><td rowspan="2">Sandhill Crane Nesting habitat reduction</td><td rowspan="2">Fish and wildlife habitat</td><td colspan="4">15% reduction in average habitat over entire period of record</td></tr>
<tr><td colspan="2">NP = 19.7 acres</td><td colspan="2">MFL = 16.7 acres</td></tr>
<tr><td rowspan="2">Game Fish Spawning habitat reduction</td><td rowspan="2">Fish and wildlife habitat</td><td colspan="4">15% reduction in average habitat over entire period of record</td></tr>
<tr><td colspan="2">NP = 103.8 acres</td><td colspan="2">MFL = 88.2 acres</td></tr>
<tr><td rowspan="3">Lake Lobe Connectivity (LLC)</td><td rowspan="3">Recreation: boating / fishing</td><td colspan="2">LLC elevation (ft, NAVD88)</td><td>No-pumping LLC elevation percentile</td><td>MFLs condition percentile</td></tr>
<tr><td>L2 to L3</td><td>20.4</td><td>55.5</td><td>47.2</td></tr>
<tr><td>L3 to L4</td><td>22.5</td><td>21.2</td><td>18.0</td></tr>
<tr><td rowspan="2">Canoeable Area</td><td rowspan="2">Recreation</td><td colspan="4">15% reduction in average habitat over entire period of record</td></tr>
<tr><td colspan="2">NP = 134.5 acres</td><td colspan="2">MFL = 115.1 acres</td></tr>
</table>

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 water bodies from significant harm caused by water withdrawals. The MFLs determination component (described above) involves defining a minimum hydrologic regime (MFLs condition) necessary to protect relevant water resource values.

The MFLs assessment component compares the MFLs condition (for each metric) 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 criteria are not being protected under the current-pumping condition, indicating a deficit of water, a recovery plan is necessary. If an MFLs criterion is currently being met (i.e., protected), but a deficit is projected within the 20-year planning horizon, a prevention plan is needed.

A summary of the development of the current-pumping condition lake levels was previously provided in Hydrological Analyses section and more details can be found in Appendix B.

Current and future Status Assessment and UFA Freeboard Calculation

MFLs status was assessed for each environmental criterion by comparing the MFLs condition (i.e., the minimum hydrologic regime necessary to protect a criterion) with the current impacted condition, called the current-pumping condition. The MFLs and current-pumping conditions are compared to determine if there is currently water available for withdrawal (freeboard), or if recovery is necessary (deficit). MFLs are considered to be currently achieved if the freeboard is greater than or equal to zero. If there is currently a deficit of water, a water body is in recovery. If a deficit is projected within the 20-year planning horizon the water body is in prevention; the future status assessment is described below.

Current Status

Current status was assessed for the final suite of environmental criteria selected as part of the MFLs determination process (Table 13). The MFLs and current-pumping conditions were compared, resulting in a freeboard or deficit for each environmental metric. Freeboards/deficits were then compared to determine the most constraining environmental metric for Lake Butler. The following briefly summarizes the calculation of freeboard/deficit for each environmental metric.

Event Based Metric

One event-based metric, an infrequent high (IH) was assessed for Lake Butler (*see MFLs Determination section for more details*). Based on the frequency analysis (Appendix C Figure C-1) the Lake Butler IH, with a duration of 30 days and a return interval of 25 years, is achieved under the current pumping condition. Under the current-pumping condition, the IH event (24.1 feet, duration of 30 days) has an exceedance probability of 10% (9.6-year return interval) compared to the recommended exceedance probability of 4% (25-year return interval) for the MFLs condition. Under current-pumping conditions the elevation exceeded at the recommended MFL frequency is approximately 24.9 ft NAVD88. When compared to the IH elevation (24.1 ft), the difference yields a lake freeboard of approximately 0.8 ft. UFA freeboard is greater than 0.5 ft (i.e., this metric is still met when aquifer levels are reduced by 0.5 ft in the surface water model). The highest UFA drawdown simulated was 0.5 ft because it equals the projected 20-year planning horizon pumping impact (i.e., this metric was still met at the planning horizon pumping projection, and is therefore not in prevention; *see Appendix C for details on UFA freeboard calculation*).

Hydroperiod Tool Metrics

The SJRWMD GIS-based hydroperiod tool was used to evaluate the effect of water level decline on the following criteria:

- Emergent marsh habitat area;
- Game fish spawning habitat area;
- Large wading bird habitat area;
- Small wading bird habitat area;
- Sandhill crane nesting habitat area; and
- Canoeable area

For each metric, area was calculated at 0.1 ft intervals for the no-pumping lake level timeseries, using stage/habitat area output from the hydroperiod tool. Current status was assessed by comparing the percent reduction of average metric area (i.e., averaged across the entire POR) under the current-pumping condition, relative to the no-pumping condition. Metrics that exhibited less than or equal to a 15% reduction in average area, relative to the no-pumping condition, are described as meeting the MFL.

Based on this comparison, all five fish and wildlife habitat metrics and the canoeable area were met under the current-pumping condition, and therefore they are not in recovery (Table 14). To determine the UFA freeboard for each habitat metric, the current-pumping lake level timeseries was iteratively reduced using the surface water model until the average habitat area for each metric was reduced by 15%, relative to the no-pumping condition (*see Appendix C for details*). The canoeable area metric is the most constraining hydroperiod tool metric, with a UFA freeboard of 0.2 ft (Table 14). The emergent marsh metric is the most constraining fish and wildlife habitat, with a UFA freeboard of 0.3 ft (Table 14).

Lake Lobe Connectivity

Current status of the lake lobe connectivity metrics was assessed by comparing the percent exceedance at critical lobe connection elevations under the current-pumping condition and the MFLs condition. The MFLs condition for this metric is defined as a 15% reduction of exceedance (i.e., number of days over the POR) of critical lake lobe connectivity elevations relative to no-pumping condition. If the percent exceedance of a critical elevation is greater under the current-pumping condition than the MFL conditions, this metric is currently met (i.e., it is not in recovery and there is positive UFA freeboard).

Table 14. Average acreage of the five habitats of the MFL and current pumping condition for Lake Butler, Volusia County, Florida

Fish and wildlife habitat metric	Habitat area (acres)			
	MFLs Condition	CP Condition	MFLs – CP	UFA freeboard (ft)
Emergent marsh habitat	128.1	131.3	3.2	0.3
Large wading bird forage habitat	88.2	91.3	3.1	0.4
Small wading bird forage habitat	30	31.5	1.5	0.5
Sandhill crane nesting habitat	13.1	13.7	0.6	0.5
Game fish spawning habitat	16.7	17.7	1	0.5
Canoeable area	115.1	116.5	1.4	0.2

The percent exceedance at both critical lake lobe connectivity elevations is greater under the current-pumping condition than under the MFLs-condition for both of lake lobe connection elevations (i.e., these metrics are not in recovery; Table 15). UFA freeboard analysis shows that the lake lobe connection between lobes L2 and L3 is more constraining (0.1 ft) than the connection between lobes L3 and L4 (0.2 ft; Table 15; *see Appendix C for details of UFA freeboard calculations*).

Table 15. MFLs-condition and current-pumping condition exceedance percentiles for minimum lake lobe connection elevations for Lake Butler.

Lake lobe connection	Minimum lake lobe connection elevation (ft NAVD 88)	MFLs-condition exceedance percentile	Current-pumping condition exceedance percentile	UFA freeboard (ft)
L2 – L3	20.4	47.2	47.4	0.1
L3 – L4	22.5	18.0	19.9	0.2

Future / Projected Status

The status assessment for Lake Butler show that all metrics evaluated have positive UFA freeboard, and therefore this water body is not in recovery (Table 16). If the MFLs are currently being achieved but are projected to not be achieved within the 20-year planning horizon, then a water body is in "prevention," and a prevention strategy must be developed concurrently with the MFLs. Whether MFLs are being achieved within the planning horizon is determined by comparing the UFA freeboard of the most constraining environmental criterion to the amount of projected UFA drawdown at the planning horizon. The most constraining criterion for Lake Butler is the lake lobe connectivity metric, with 0.1 ft of UFA freeboard (Table 16).

The projected UFA drawdown at the 20-year planning horizon was estimated for Lake Butler using the SJRWMD 2015 Volusia groundwater model. The predicted UFA drawdown resulting from projected water use for the 20-year planning horizon is 0.5 feet. Because this is greater than the available water (i.e., 0.1 ft of UFA freeboard), the Lake Butler MFLs are in prevention and a prevention strategy must be developed with the MFLs.

Table 16. UFA freeboards for environmental criteria developed for Lake Butler, Volusia County, Florida

Environmental Criterion	UFA freeboard (ft)
Minimum Infrequent High	> 0.5
Emergent Marsh (0-6ft)	0.3
Gamefish Spawning (0-4ft)	0.5
Large Wading Bird Foraging Habitat (0-1ft)	0.4
Small Wading Bird Foraging Habitat (0-0.5ft)	0.5
Sandhill Crane Nesting Habitat (0.5-1ft)	0.5
Canoeable Area (≥ 20 in. deep)	0.2
Minimum Lake Lobe Connectivity (L3-L4)	0.2
Minimum Lake Lobe Connectivity (L2-L3)	0.1

WATER RESOURCE VALUES

Consideration of Environmental Values Under 62-40.473, F.A.C.

Pursuant to Sections 373.042 and 373.0421, F.S., SJRWMD considered whether the recommended MFLs protect relevant environmental values (also called water resource values [WRVs]) among the following 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; and
10. Navigation.

MFLS CONDITION

The determination of whether a WRV is protected is 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 environmental criteria identified in the MFLs determination (i.e., it is based on the most constraining criterion for Lake Butler). The most constraining criterion, with a UFA freeboard of 0.1 ft, is the lake lobe connectivity metric designed to protect recreational uses at Lake Butler.

An exceedance curve was created based on the MFLs-condition lake level timeseries. This was compared to the no-pumping condition exceedance curve, to help assess whether all relevant WRVs are protected (Figures 23 and 24). The MFLs condition and no-pumping exceedance curves were created using the respective daily lake level time series. The MFL condition lake level time series was simulated by lowering groundwater levels incrementally in the SWMM model until the model produced a lake level time series that just meets (but does not trip) the most constraining environmental criterion (i.e., the lake lobe connectivity metric).

A significant change 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).

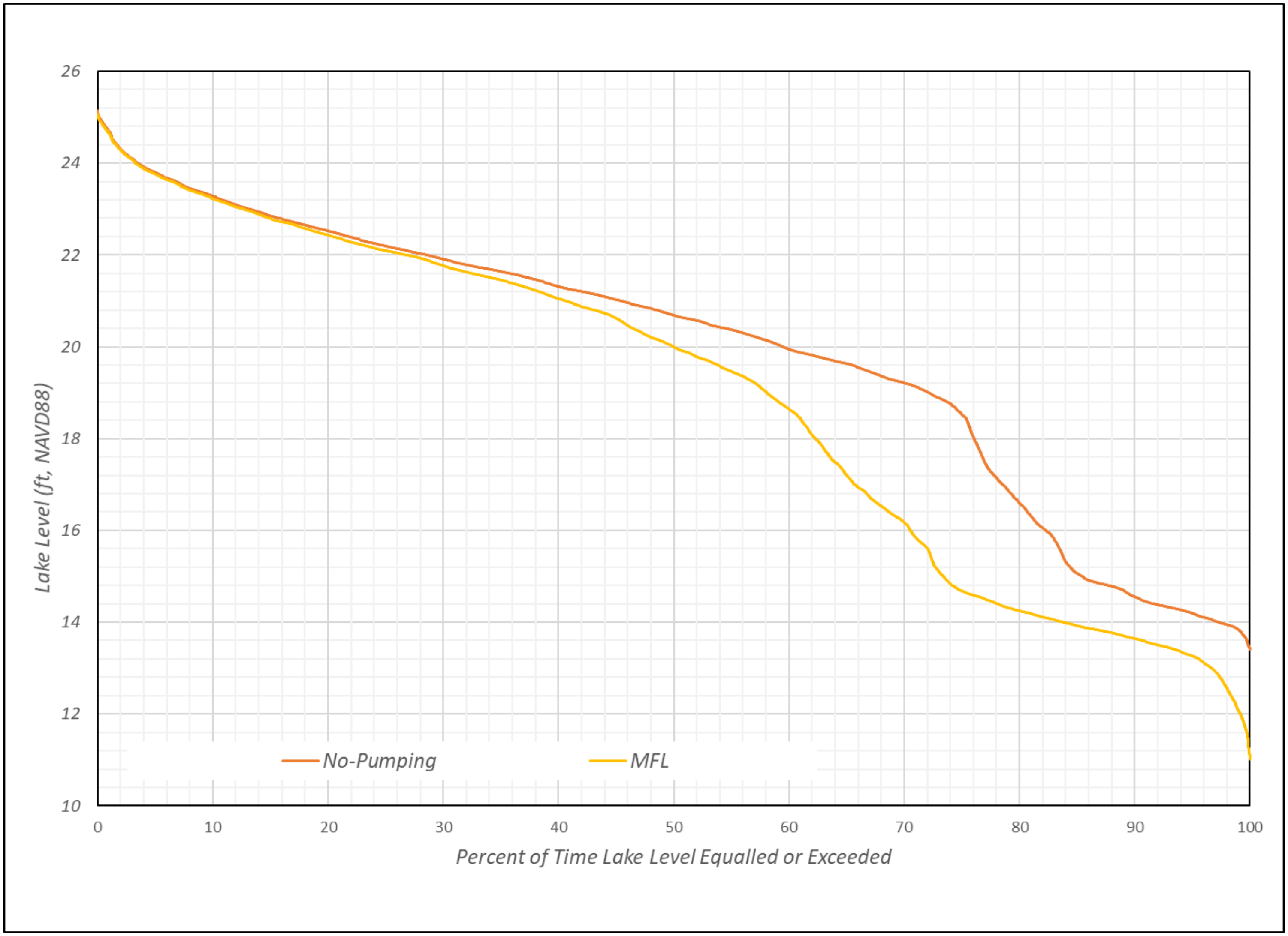

Figure 23. No-pumping condition and MFLs condition exceedance curves for Lake Butler

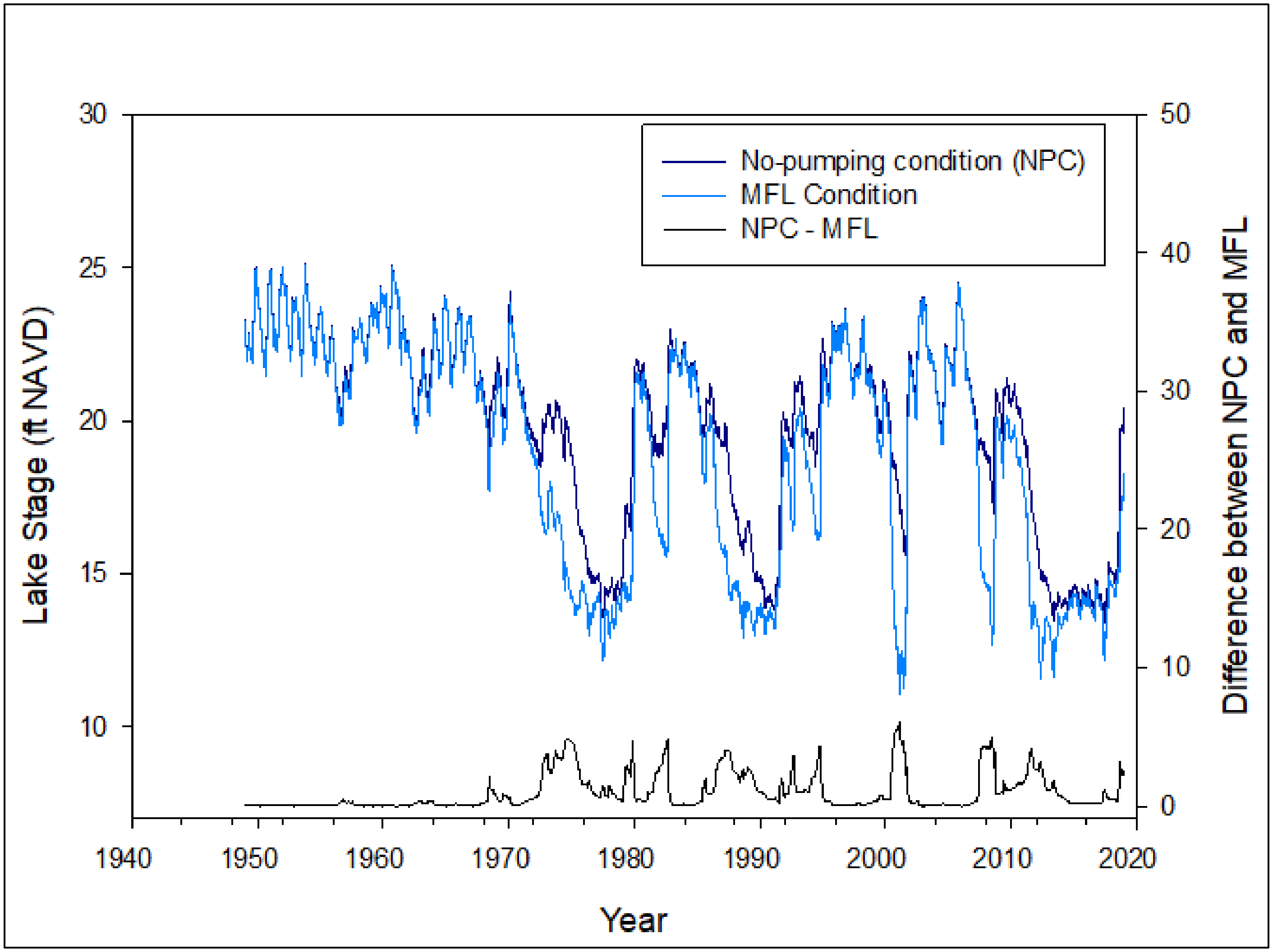

Figure 24. Model simulated lake levels under no-pumping, and MFLs condition for Lake Butler; also presented is the difference between no-pumping and MFLs conditions (NPC – MFL) over for the simulated POR

The following environmental values were determined not relevant to Lake Butler and thus were not considered as part of this assessment:

- Estuarine resources (WRV3): This environmental value is not relevant because the lake is land-locked, while the overflow structure is sealed and has no surface water connection to any estuarine resources. Therefore, WRV-3 was not considered in this evaluation;

- Sediment loads (WRV8): Transport of inorganic materials as bed load is considered relevant only in flowing systems, where riverine fluvial dynamics are critical to maintenance of geomorphic features (i.e. bed forms and the floodplain) and their associated ecological communities. Lakes serve as sinks instead of sources of sediment load, and therefore WRV-8 was not considered in this evaluation;

- Water quality (WRV9): Sufficient data were not available for evaluating the relationship between lake stage and water quality. Water quality samples were collected by the district on July 22, 2003. Due to the lack of water quality data, WRV-9 was not considered in this evaluation.

Seven WRVs were considered relevant to the environmental functions and values of Lake Butler and have sufficient data for the assessment (Table 17). All seven WRVs evaluated are considered protected by the MFLs condition (Table 14; *see Appendix D for details regarding the assessment of each WRV*).

Table 17. Percent reduction in exceedance, allowable under no-pumping and MFLs conditions, for critical elevations associated with relevant WRVs at Lake Butler, Volusia County, Florida

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	Canoeable area	15% reduction in area	14.0% reduction in canoeable area	Yes
	Lake Lobe Connectivity	15% reduction of exceedance of critical lake lobe connectivity	8.3%	Yes
Fish and wildlife habitats and the passage of fish	Emergent marsh habitat	15% reduction in area	13.6% reduction in area of emergent marsh habitat	Yes
	Gamefish habitat	15% reduction in area	13.2% reduction in area of game fish habitat	Yes
	Small wading bird habitat	15% reduction in area	11.7% reduction in area of small wading bird habitat	Yes
	Large wading bird habitat	15% reduction in area	11.3% reduction in area of large wading bird habitat	Yes
	Sandhill crane habitat	15% reduction in area	12.2% reduction in area of sandhill crane habitat	Yes
Transfer of detrital material	The movement of loose organic material and debris and associated decomposing biota	15% reduction in f mean marsh area	13.6% reduction in mean marsh area	Yes
Aesthetic and scenic attributes	Visual setting around the lake	15% reduction in average lake area	13% reduction in reduction of average lake area	Yes
Filtration and absorption of nutrients and other pollutants	The process of absorption and filtration	15% reduction in mean marsh area	13.6% reduction in mean marsh area	Yes

Maintenance of freshwater storage and supply	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	Yes
Navigation	This environmental value is defined as the safe passage of watercraft (e.g., boats and ships), which is dependent upon adequate water depth and width. There is no commercial boat traffic on the Lake Butler. The primary navigation of Lake Butler is by recreational boaters, which is addressed under WRV1, “Recreation in and on the water.”	Yes

CONCLUSIONS AND RECOMMENDATIONS

MFLs were developed for Lake Butler based on the analysis of numerous environmental criteria. A premise of the MFLs determination is that by identifying all relevant environmental values, and protecting the most sensitive (i.e., most constraining), that the basic structure and functions of the ecosystem will also be maintained. SJRWMD investigated multiple ecological and human-use criteria and assessed the effects of current and future pumping on these criteria to ensure that all relevant environmental values and beneficial uses are protected.

Seven environmental criteria were assessed for Lake Butler. Multiple criteria are typically developed and assessed because different ecological and human-use values require the protection of different portions of a system's hydrologic regime. For Lake Butler, one infrequent high (IH) level, five fish and habitat metrics, and one minimum lake lobe connectivity metric were developed and assessed. The IH is based on providing inundation that is frequent enough to prevent the downslope movement of upland species into the lake. The five fish and wildlife habitat metrics are based on ensuring no more than a 15% reduction in habitat area, relative to the no-pumping condition. These habitats include emergent marsh (0-6 ft depth), large wading bird forage (0-1 ft depth), small wading bird forage (0-0.5 ft depth), sandhill crane nesting habitat (0.5-1 ft depth), and game fish spawning (1-4 ft depth). The lake lobe connectivity metric is based on allowing no more than a 15% reduction in exceedance, relative to the no-pumping condition, of a boat (and fish) passage elevation. This elevation was derived by adding a canoe paddle depth offset of 20" to the highest elevation present in important lake lobe connections. This metric was the most sensitive (i.e., had the smallest UFA freeboard) of all metrics assessed.

RECOMMENDED MINIMUM LEVEL

MFLs status was assessed by comparing the minimum hydrologic regime necessary to protect each of the seven environmental criteria developed for Lake Butler with the hydrologic regime under the current-pumping condition (*see Appendix C for details*). The current-pumping condition is defined as the average pumping condition between 2014 and 2018. The MFLs assessment indicates that all seven environmental criteria are protected under the current-pumping condition, and therefore Lake Butler is not in recovery. The most constraining (lake lobe connectivity metric) has a UFA freeboard of 0.1 ft.

The projected UFA drawdown at the 20-year planning horizon was estimated for Lake Butler using the SJRWMD 2015 Volusia groundwater model. The predicted UFA drawdown resulting from projected water use for the 20-year planning horizon is 0.5 feet. Because this is greater than the available water (i.e., 0.1 ft of UFA freeboard), the Lake Butler MFLs are in prevention and a prevention strategy must be developed concurrently with the MFLs.

A minimum median (P50) water level is the recommended MFL for Lake Butler, and is based on the lake lobe connectivity metric (i.e., most constraining metric with a UFA freeboard of 0.1 ft; Table 18). The recommended minimum P50 (20.1 ft NAVD88) was calculated from the MFLs condition lake level timeseries data (Figure 25). The MFLs condition curve was derived using the Lake Butler surface water model to simulate aquifer drawdown that resulted in a 15% reduction in exceedance, relative to the no-pumping condition, of the most constraining lake lobe connection elevation (20.4 ft NAVD88).

In addition to protecting all seven of the primary environmental criteria assessed, the MFLs condition was also tested against a subset of relevant environmental values listed in Rule 62-40.473, F.A.C. The results of this analysis suggest that the MFLs condition protects all relevant WRVs for Lake Butler. Further, the minimum hydrologic regime (i.e., 15% reduction, relative to the no-pumping condition) for three WRVs was very similar to the MFLs condition. The MFLs condition, based on lake lobe connectivity, resulted in a 14.0%, 13.6% and 13.2% reduction in average canoeable area, average emergent marsh habitat area and average game fish habitat area, respectively. These results provide a weight of evidence for the appropriateness of the recommended MFLs for Lake Butler.

The information presented in this report, including the recommended minimum P50 for Lake Butler, is preliminary and will not become effective until adopted by the SJRWMD Governing Board, as directed in Rule 40C-8.031, F.A.C.

Table 18. Recommended Minimum Median (P50) Lake Level for Lake Butler

Environmental Criterion	Minimum Median (P50) Lake Level (ft, NAVD88)
Lake Lobe Connectivity	20.1

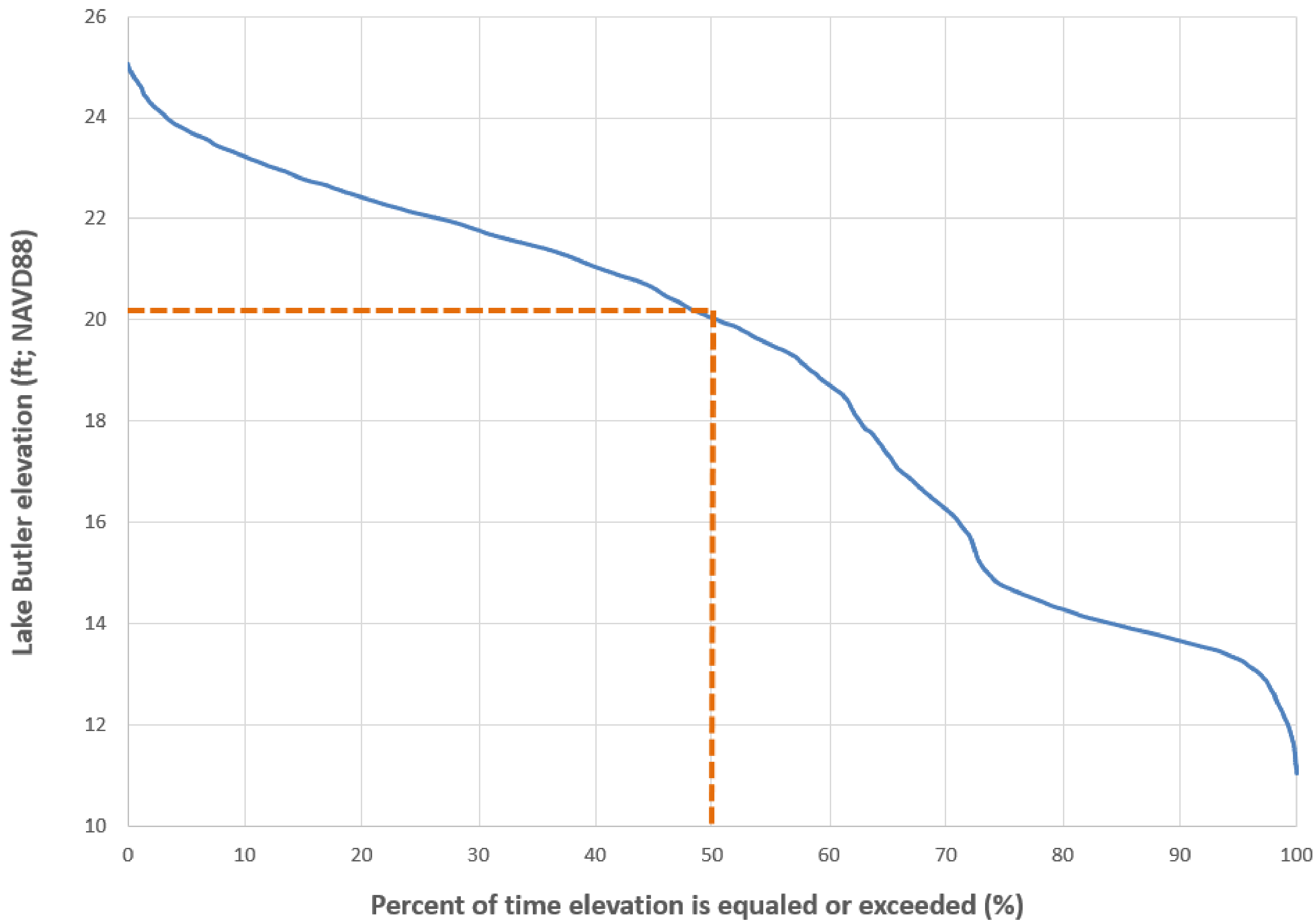

Figure 25. MFLs condition percent exceedance curve based on most constraining environmental criterion. Dashed lines indicate the recommended minimum P50 elevation for Lake Butler

ONGOING STATUS / ADAPTIVE MANAGEMENT

Given data, modeling and other ecohydrological analysis uncertainties, it is prudent to test implicit assumptions made as part of setting and assessing MFLs. SJRWMD implements an adaptive management strategy to address continuing challenges and uncertainties in ecohydrological data and tools. This screening level analysis, which incorporates changes in rainfall trends and uncertainty, will be performed to monitor the status of the adopted minimum P50 for Lake Butler. This analysis will be performed approximately every five years, as well as when permit applications are considered that may impact the MFL. MFL status will also be monitored periodically by reviewing multiple exceedance curve percentiles, updated with post current-pumping condition (i.e., 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. If the screening level analysis shows that MFLs are being met based on the rainfall-adjusted levels, then no further actions are required beyond continued monitoring. If the analysis shows that MFLs are not being met or are trending toward not being met based on the rainfall-adjusted levels, SJRWMD will conduct a cause-and-effect analysis to independently evaluate the potential impacts of various stressors on the MFLs water body.

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