Revised Minimum and Guidance Levels for Lake Jackson and Little Lake Jackson in Highlands County, Florida

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Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District

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Cover: Oblique aerial photograph of Lake Jackson and Little Lake Jackson, August 1999.

Contents

Introduction

Reevaluation of Minimum Flows and Levels

This report describes the development of revised minimum levels for Lake Jackson and Little Lake Jackson in Highlands County, Florida. These revised levels were developed based on the reevaluation of minimum and guidance levels approved by the Southwest Florida Water Management District (District) Governing Board in March 2006 and subsequently adopted into District rules. The revised minimum and guidance levels represent necessary revisions to the currently adopted levels.

Lake Jackson and Little Lake Jackson were selected for reevaluation based on development of modeling tools used to simulate natural water level fluctuations in lake basins that were not available when the currently adopted minimum levels for the lake were developed. Adopted levels for Lake Jackson and Little Lake Jackson were also reevaluated to support ongoing District assessment of minimum flows and levels and the need for additional recovery in the Southern Water Use Caution Area (SWUCA), a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Minimum Flows and Levels Program Overview

Legal Directives

Section 373.042, Florida Statutes (F.S.), directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels (MFLs) for lakes, wetlands, rivers and aquifers. Section 373.042(1)(a), F.S., states that "[t]he minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Section 373.042(1)(b), F.S., defines the minimum water level of an aquifer or surface water body as "…the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." MFLs are established and used by the Southwest Florida Water Management District (SWFWMD or District) for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction and use of surface water management systems.

Established MFLs are key components of resource protection, recovery and regulatory compliance, as Section 373.0421(2) F.S., requires the development of a recovery or prevention strategy for water bodies "[i]f the existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level established pursuant to S. 373.042." Section 373.0421(2)(a), F.S., requires that recovery or prevention strategies be developed to: "(a) [a]chieve recovery to the established minimum flow or level as soon as practicable; or (b) [p]revent the existing flow or level from falling below the established minimum flow or level." Periodic reevaluation and, as necessary, revision of established minimum flows and levels are required by Section 373.0421(3), F.S.

Minimum flows and levels are to be established based upon the best information available, and when appropriate, may be calculated to reflect seasonal variations (Section 373.042(1), F.S.). Also, establishment of MFLs is to involve consideration of, and at the governing board or department's discretion, may provide for the protection of nonconsumptive uses (Section 373.042(1), F.S.). Consideration must also be 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…", with the requirement that these considerations shall not allow significant harm caused by withdrawals (Section 373.0421(1)(a), F.S.). Sections 373.042 and 373.0421 provide additional information regarding the prioritization and scheduling of minimum flows and levels, the independent scientific review of scientific or technical data, methodologies, models and scientific and technical assumptions employed in each model used to establish a minimum flow or level, and exclusions that may be considered when identifying the need for MFLs establishment.

The Florida Water Resource Implementation Rule, specifically Rule 62-40.473, Florida Administrative Code (F.A.C.), provides additional guidance for the establishment of MFLs, requiring that "…consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic and wetlands ecology, including: a) Recreation in and on the water; b) Fish and wildlife habitats and the passage of fish; c) estuarine resources; d) Transfer of detrital material; e) Maintenance of freshwater storage and supply; f) Aesthetic and scenic attributes; g) Filtration and absorption of nutrients and other pollutants; h) Sediment loads; i) Water quality; and j) Navigation."

Rule 62-40.473, F.A.C., also indicates that "[m]inimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area as provided in Section 373.042(1), F.S." It further notes that, "…a minimum flow or level need not be expressed as multiple flows or levels if other resource protection tools, such as reservations implemented to protect fish and wildlife or public health and safety, that provide equivalent or greater protection of the hydrologic regime of the water body, are developed and adopted in coordination with the minimum flow or level." The rule also includes provision addressing: protection of MFLs during the construction and operation of water resource projects; the issuance of permits pursuant to Section 373.086 and Parts II and IV of Chapter 373, F.S.; water shortage declarations; development of recovery or prevention strategies, development and updates to a minimum flow and level priority list and schedule, and peer review for MFLs establishment.

Development of Minimum Lake Levels in the Southwest Florida Water Management District

Programmatic Description and Major Assumptions

Since the enactment of the Florida Water Resources Act of 1972 (Chapter 373, F.S.), in which the legislative directive to establish MFLs originated, and following subsequent modifications to this directive and adoption of relevant requirements in the Water Resource Implementation Rule, the District has actively pursued the adoption, i.e., establishment of MFLs for priority water bodies. The District implements established MFLs primarily through its water supply planning, water use permitting and environmental resource permitting programs, and through the funding of water resource and water supply development projects that are part of a recovery or prevention strategy. The District's MFLs program addresses all relevant requirements expressed in the Florida Water Resources Act and the Water Resource Implementation Rule.

A substantial portion of the District's organizational resources has been dedicated to its MFLs Program, which logistically addresses six major tasks: 1) development and reassessment of methods for establishing MFLs; 2) adoption of MFLs for priority water bodies (including the prioritization of water bodies and facilitation of public and independent scientific review of revised MFLs and methods used for their development); 3) monitoring and MFLs status assessments, i.e., compliance evaluations; 4) development and implementation of recovery strategies; 5) MFLs compliance reporting; and 6) ongoing support for minimum flow and level regulatory concerns and prevention strategies. Many of these tasks are discussed or addressed in this revised minimum levels report; additional information on all tasks associated with the District's MFLs Program is summarized by Hancock *et al.* (2010).

The District's MFLs Program is implemented based on three fundamental assumptions. First, it is assumed that many water resource values and associated features are dependent upon and affected by long-term hydrology and/or changes in long-term hydrology. Second, it is assumed that relationships between some of these variables can be quantified and used to develop significant harm thresholds or criteria that are useful for establishing MFLs. Third, the approach assumes that alternative hydrologic regimes may exist that differ from non-withdrawal impacted conditions but are sufficient to protect water resources and the ecology of these resources from significant harm.

Support for these assumptions is provided by a large body of published scientific work addressing relationships between hydrology, ecology and human-use values associated with water resources (e.g., see reviews and syntheses by Postel and Richter 2003, Wantzen *et al.* 2008, Poff *et al.* 2010, Poff and Zimmerman 2010). This information has been used by the District and other water management districts within the state to identify significant harm thresholds or criteria supporting development of MFLs for hundreds of water bodies, as summarized in the numerous publications associated with these efforts (e.g., SFWMD 2000, 2006, Flannery *et al*. 2002, SRWMD 2004, 2005, Neubauer *et al.* 2008, Mace 2009).

About the assumption associated with alternative hydrologic regimes, consider a historic condition for an unaltered river or lake system with no local groundwater or surface water withdrawal impacts. A new hydrologic regime for the system would be associated with each increase in water use, from small withdrawals that have no measurable effect on the historic regime to large withdrawals that could substantially alter the regime. A threshold hydrologic regime may exist that is lower or less than the historic regime, but which protects the water resources and ecology of the system from significant harm. This threshold regime could conceptually allow for water withdrawals, while protecting the water resources and ecology of the area. Thus, MFLs may represent minimum acceptable rather than historic or potentially optimal hydrologic conditions.

Consideration of Changes and Structural Alterations and Environmental Values

When establishing MFLs, the District considers "…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…" in accordance with Section 373.0421(1)(a), F.S. Also, as required by statute, the District does not establish MFLs that would allow significant harm caused by withdrawals when considering the changes, alterations and their associated effects and constraints. These considerations are based on review and analysis of best available information, such as water level records, environmental and construction permit information, water control structure and drainage alteration histories, and observation of current site conditions.

When establishing, reviewing or implementing MFLs, considerations of changes and structural alterations may be used to:

- adjust measured flow or water level historical records to account for existing changes/alterations;
- model or simulate flow or water level records that reflect long-term conditions that would be expected based on existing changes/alterations and in the absence of measurable withdrawal impacts;
- develop or identify significant harm standards, thresholds and other criteria;
- aid in the characterization or classification of lake types or classes based on the changes/alterations;
- evaluate the status of water bodies with revised or established MFLs (i.e., determine whether the flow and/or water level are below, or are projected to fall below the applicable minimum flow or level); and
- support development of lake guidance levels (described in the following paragraph).

The District has developed specific methodologies for establishing minimum flows or levels for lakes, wetlands, rivers, estuaries and aquifers, subjected the methodologies to independent, scientific peer-review, and incorporated the methods for some system types, including lakes, into its Water Level and Rates of Flow Rule (Chapter 40D-8, F.A.C.). The rule also provides for the establishment of Guidance Levels for lakes, which serve as advisory information for the District, lakeshore residents and local governments, or to aid in the management or control of adjustable water level structures.

Information regarding the development of adopted methods for establishing minimum and guidance lake levels is included in Southwest Florida Water Management District (1999a, b) and Leeper *et al.* (2001). Additional information relevant to developing lake levels is presented by Schultz et al. (2004), Carr and Rochow (2004), Caffrey *et al.* (2006, 2007), Carr *et al.* (2006), Hancock (2006), Hoyer *et al*. (2006), Leeper (2006), Hancock (2006, 2007) and Emery *et al.* (2009). Independent scientific peer-review findings regarding the lake level methods are summarized by Bedient *et al.* (1999), Dierberg and Wagner (2001) and Wagner and Dierberg (2006).

For lakes, methods have been developed for establishing Minimum Levels for systems with fringing cypress-dominated wetlands greater than 0.5 acre in size, and for those without fringing cypress wetlands. Lakes with fringing cypress wetlands where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands are classified as Category 1 Lakes. Lakes with fringing cypress wetlands that have been structurally altered such that lake water levels do not rise to levels expected to fully maintain the integrity of the wetlands are classified as Category 2 Lakes. Lakes with less than 0.5 acre of fringing cypress wetlands are classified as Category 3 Lakes.

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria are used to develop recommend minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. The Cypress Standard is 1.8 feet below the normal pool elevation. For Category 3 lakes, six significant change standards are typically developed. Other available information, including potential changes in the coverage of herbaceous wetland and submersed aquatic plants is also considered when establishing minimum levels for Category 3 Lakes. The standards and other available information are associated with the environmental values identified for consideration in Rule 62-40.473, F.A.C., when establishing MFLs (Table 1). The specific standards and other information evaluated to support development of revised minimum levels for Lake Jackson and Little Lake Jackson are provided in subsequent sections of this report. More general information on the standards and other information used for consideration when developing minimum lake levels is available in the documents identified in the preceding sub-section of this report.

Table 1: Environmental values identified in the state Water Resource Implementation Rule for consideration when establishing minimum flows and levels and associated significant change standards and other information used by the District for consideration of the environmental values.

Environmental Value	Associated Significant Change Standards and Other Information for Consideration
Recreation in and on the water	Basin Connectivity Standard, Recreation/Ski Standard, Aesthetics Standard, Species Richness Standard, Dock-Use Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Fish and wildlife habitats and the passage of fish	Cypress Standard, Wetland Offset, Basin Connectivity Standard, Species Richness Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Estuarine resources	NA[1]
Transfer of detrital material	Cypress Standard, Wetland Offset, Basin Connectivity Standard, Lake Mixing Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Maintenance of freshwater storage and supply	NA[2]
Aesthetic and scenic attributes	Cypress Standard, Dock-Use Standard, Wetland Offset, Aesthetics Standard, Species Richness Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Filtration and absorption of nutrients and other pollutants	Cypress Standard Wetland Offset Lake Mixing Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Sediment loads	NA[1]
Water quality	Cypress Standard, Wetland Offset, Lake Mixing Standard, Dock-Use Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Navigation	Basin Connectivity Standard, Submersed Aquatic Macrophyte Information

NA[1] = Not applicable for consideration for most priority lakes;
NA[2] = Environmental value is addressed generally by development of minimum levels based on appropriate significant change standards and other information and use of minimum levels in District permitting programs

Lake Classification
Lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. Those with fringing cypress wetlands greater than 0.5 acre in size where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands (i.e. the Historic P50 is equal to or higher than an elevation 1.8 feet below the Normal Pool elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acre in size that have been structurally altered such that the Historic P50 elevation is more than 1.8 feet below the Normal Pool elevation are classified as Category 2 Lakes. Lakes without fringing cypress wetlands or with cypress wetlands less than 0.5 acre in size are classified as Category 3 Lakes.

According to (Chapter 40D-8.624, F.A.C.), Lake Jackson and Little Lake Jackson meet the classification as Category 3 lakes, with less than 0.5 acre of fringing cypress wetlands. The standards associated with category 3 lakes described below will also be developed in a subsequent section of this report.

Lake-specific significant change standards and other available information are developed for establishing Minimum Levels for Category 3 Lakes. The standards are used to identify thresholds for preventing significant harm to cultural and natural system values associated with lakes in accordance with guidance provided in the Florida Water Resources Implementation Rule (Chapter 62-40.473, F.A.C.). Other information taken into consideration includes potential changes in the coverage of herbaceous wetland vegetation and aquatic plants.

The Recreation/Ski Standard is developed to identify the lowest elevation within the lake basin that will contain an area suitable for safe water skiing. The standard is based on the lowest elevation (the Ski Elevation) within the basin that can contain a 5-foot deep ski corridor delineated as a circular area with a radius of 418 feet, or a rectangular ski corridor 200 feet in width and 2,000 feet in length, and use of Historic lake stage data or region-specific reference lake water regime statistics where Historic lake data are not available.

The Dock-Use Standard is developed to provide for sufficient water depth at the end of existing docks to permit mooring of boats and prevent adverse impacts to bottom-dwelling plants and animals caused by boat operation. The standard is based on the elevation of lake sediments at the end of existing docks, a two-foot water depth for boat mooring, and use of Historic lake stage data or region-specific reference lake water regime statistics.

The Wetland Offset Elevation is developed to protect lake fringing non-cypress wetlands. Based on the rationale used to develop the Cypress Wetland Standard for Category 1 and 2 lakes (1.8 feet below the Normal Pool elevation), a Wetland Offset Elevation for Category 3 Lakes was developed. Because Hydrologic Indicators of sustained inundation used to determine the Normal Pool elevation usually do not exist on Category 3 Lakes, another datum, in this case the Historic P50 elevation, was used in the development of the Wetland Offset Elevation. Based on an evaluation of the relationship of the Cypress Wetland Standard with the Historic P50 for hydrologically unimpacted cypress wetlands, the Wetland Offset Elevation for Category 3 Lakes was established at an elevation 0.8 feet below the Historic P50 elevation (Hancock, draft report, 2007).

The Aesthetics Standard is developed to protect aesthetic values associated with the inundation of lake basins. The standard is intended to protect aesthetic values associated with the median lake stage from diminishing beyond the values associated with the lake when it is staged at the Low Guidance Level. The Aesthetic Standard is established at the Low Guidance Level. Water levels equal or exceed the standard ninety percent of the time during the Historic period, based on the Historic, composite water level record.

The Species Richness Standard is developed to prevent a decline in the number of bird species that may be expected to occur at or utilize a lake. Based on an empirical relationship between lake surface area and the number of birds expected to occur at a lake, the standard is established at the lowest elevation associated with less than a fifteen percent reduction in lake surface area relative to the lake area at the Historic P50 elevation.

The Basin Connectivity Standard is developed to protect surface water connections between lake basins or among sub-basins within lake basins to allow for movement of aquatic biota, such as fish, and support recreational use of the lake. The standard is based on the elevation of lake sediments at a critical high spot between lake basins or lake sub-basins, identification of water depths sufficient for movement of biota and/or watercraft across the critical high spot, and use of Historic lake stage data or the region-specific Reference Lake Water Regime statistics where Historic lake data are not available.

The Lake Mixing Standard is developed to prevent significant changes in patterns of wind-driven mixing of the lake water column and sediment re-suspension. The standard is established at the highest elevation at or below the Historic P50 elevation where the dynamic ratio (see Bachmann *et al.* 2000) shifts from a value of <0.8 to a value >0.8, or from a value >0.8 to a value of <0.8.

Herbaceous Wetland Information is also taken into consideration to determine the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (i.e., basin area with a water depth of four feet or less) (Butts *et al*. 1997). Similarly, changes in lake stage associated with changes in lake area available for colonization by rooted submersed or floating-leaved macrophytes are also evaluated, based on water transparency values. Using methods described in Caffrey (2006), mean secchi disk depth (SD) is used to calculate the maximum depth of colonization (MDC) for aquatic plants using regression equation $\log(MDC) – 0.66\log(SD) + 0.30$, where all values are represented in meters. The MDC depth is then used to calculate the total acreage at each lake stage that is available for aquatic plant colonization.

Minimum Levels

Two Minimum Levels and two Guidance Levels are typically established for lakes. Upon completion of a public input/review process and, if necessary completion of an independent scientific review, either of which may result in modification of the revised levels, the levels are adopted by the District Governing Board into Chapter 40D-8, F.A.C. Code (see Hancock *et al.* 2010 for more information on the adoption process). The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29), may include the following (refer to Rule 40D-8.624, F.A.C.).

- A **High Guidance Level** that is provided as an advisory guideline for construction of lake shore development, water dependent structures, and operation of water management structures. The High Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ten percent of the time on a long-term basis.

- A **High Minimum Lake Level** is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis.

- A **Minimum Lake Level** that is the elevation that the lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis.

- A **Low Guidance Level** that is provided as an advisory guideline for water dependent structures, information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis.

The District is in the process of converting from use of the NGVD29 datum to use of the North American Vertical Datum of 1988 (NAVD 88). While the NGVD29 datum is used for most elevation values included within this report, in some circumstances, notations are made for elevation data that was collected or reported relative to mean sea level or relative to NAVD88 and converted to elevations relative to NGVD29.

Development of Minimum and Guidance Levels for Lake Jackson and Little Lake Jackson

Lake Setting and Description

Watershed

Lake Jackson and Little Lake Jackson (Figure 1) are located in Highlands County, Florida (Sections 23, 24, 25, and 36, Township 34S, Range 28E; Sections 19, 29, 30, 31, and 32, Township 34S, Range 29E; Section 1, Township 35S, Range 28E, and Section 6, Township 35S, Range 29E) in the Kissimmee River Basin within the Southwest Florida Water Management District.

Within the Kissimmee River primary basin, the lakes are in the Josephine Creek watershed, and have a contributing watershed of 10,287 acres (Figure 2), or approximately 16.1 square miles (BCI Engineers & Scientists, Inc. 2005). The lakes have one main inlet located on the north shore of Lake Jackson, delivering water from Lake Sebring, and one main outlet located on the east side of Little Lake Jackson, which drains south through Jackson Creek to Lake Josephine (Figure 3).

There are currently no surface water withdrawals from the lake permitted by the District. There are, however, several permitted groundwater withdrawals in the lake vicinity.

The “Gazetteer of Florida Lakes” (Florida Board of Conservation 1982) lists the lakes’ area at 3,412 acres at an elevation of 102 ft. A stage-volume relationship generated in support of the minimum levels development calculates the lakes’ area to be 3,396 acres at elevation 102 ft.

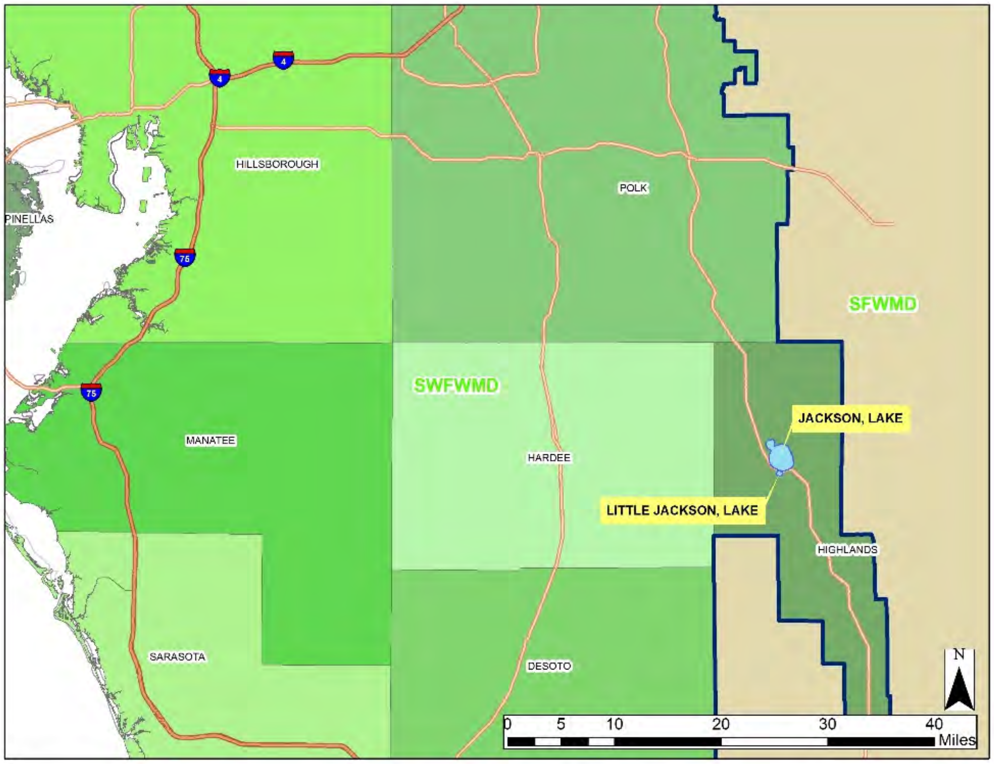

Figure 1: Location of Lake Jackson and Little Lake Jackson in Highlands County, Florida.

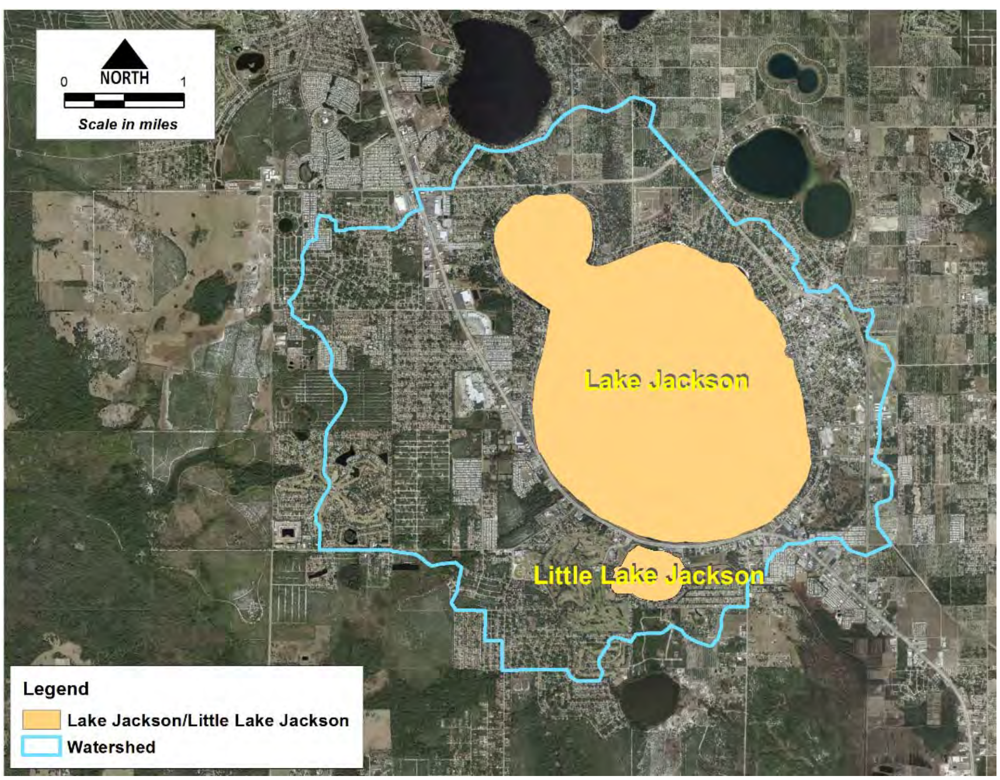

Figure 2: Contributing Watershed Delineation

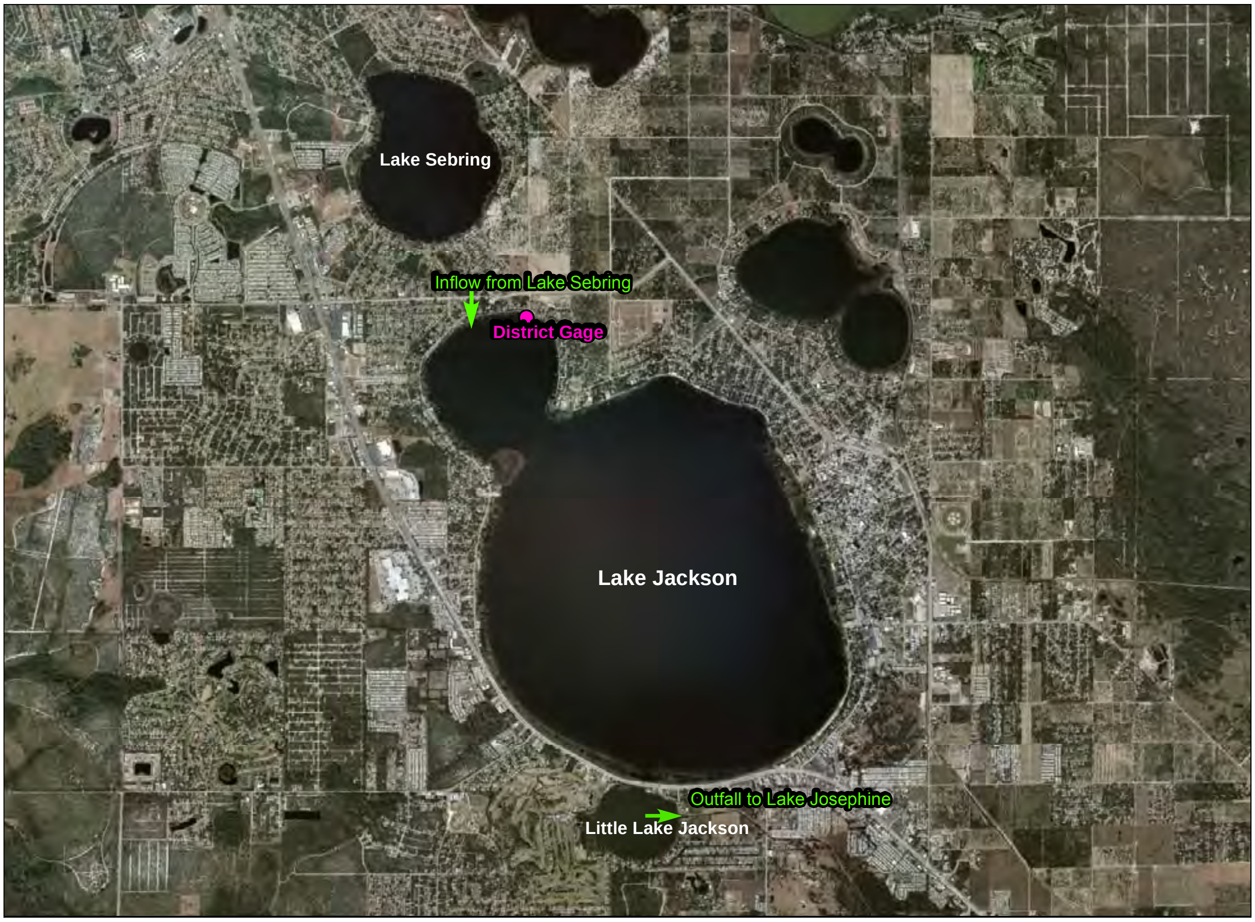

Figure 3: Location of Conveyance Systems and District Gage

Land Use Land Cover

An examination of the 1990 and more current 2011 Florida Land Use, Cover and Forms Classification System (FLUCCS) maps revealed that there has been little change to the landscape (specifically the dominant land forms) in the vicinity during this period (Figure 4 and Figure 5). The area immediately surrounding the lakes on all sides is primarily urban. However, Figure 6 through Figure 11 aerial photography chronicle considerable landscape changes to the immediate lake basin from 1944 through 2015. In 1944 land use to the south and east sides of the lakes consisted of residential and commercial development, and agriculture was on the north side of Lake Jackson. The west side of Lake Jackson was primarily undeveloped. Today, land use has become more urban, replacing much of the agriculture and undeveloped land. As of 2011, the land use within the Lake Jackson and Little Lake Jackson watershed is predominantly urban with some agriculture and wetlands.

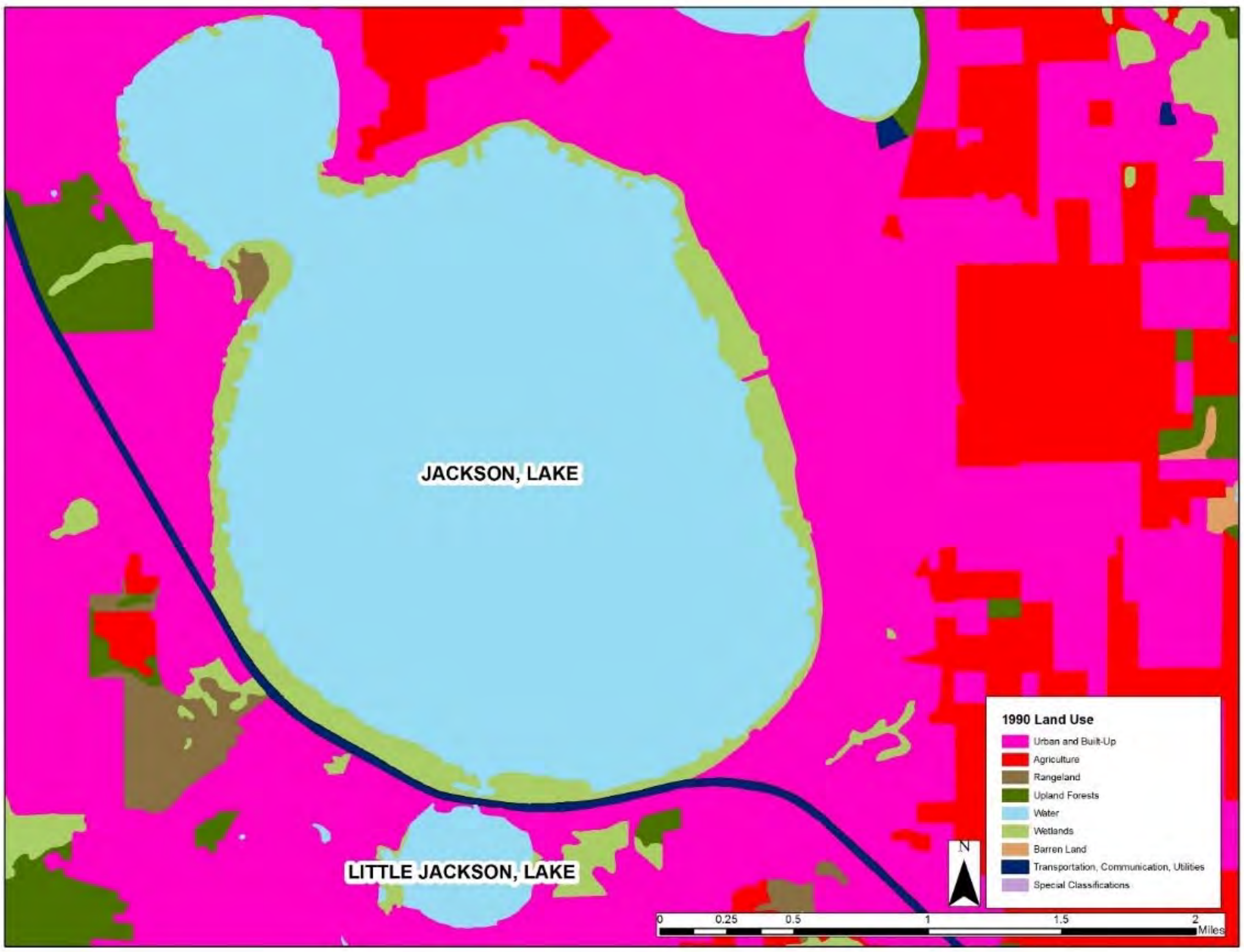

Figure 4: 1990 Land Use Land Cover Map of the Lake Jackson and Little Lake Jackson Vicinity.

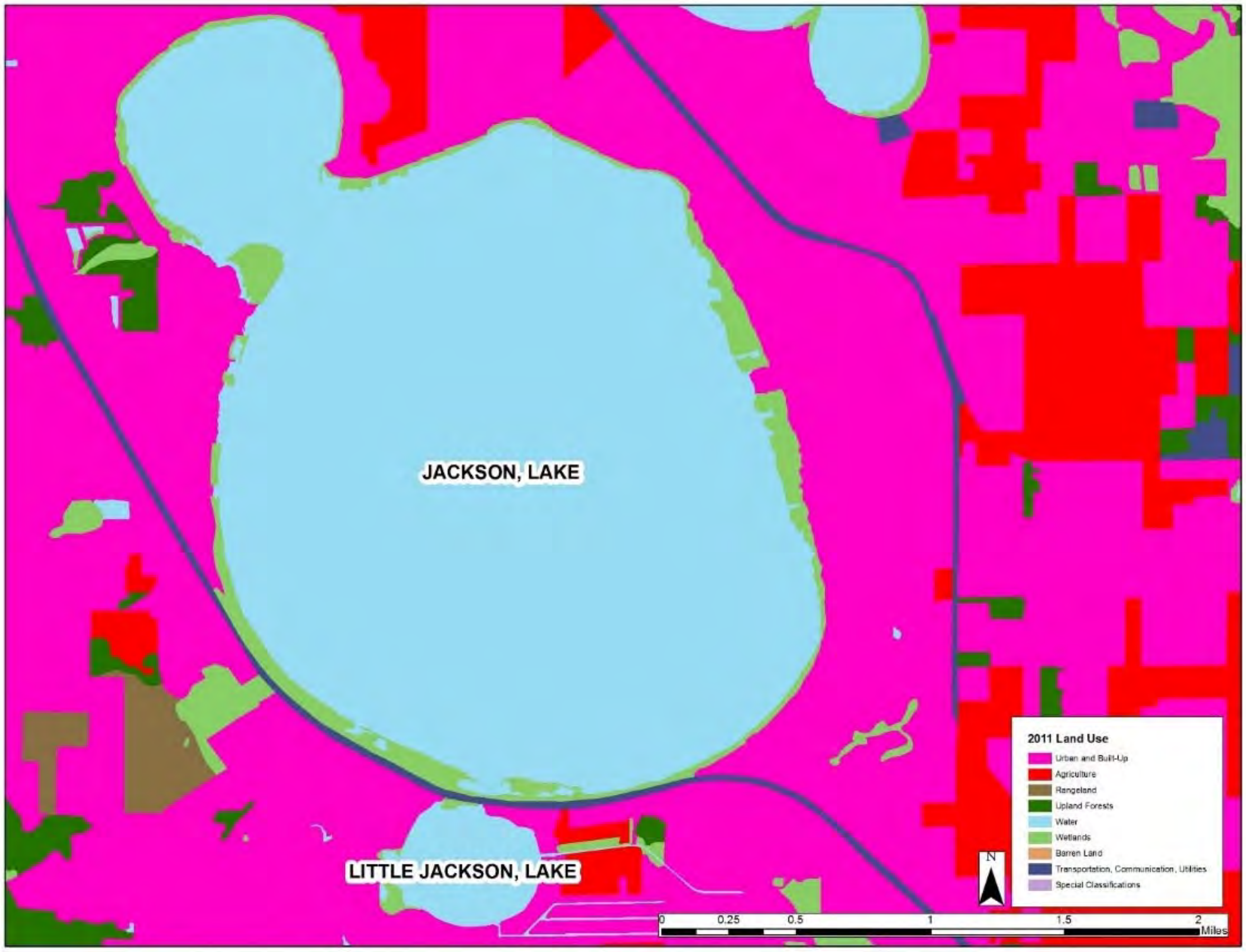

Figure 5: 2011 Land Use Land Cover Map of the Lake Jackson and Little Lake Jackson Vicinity.

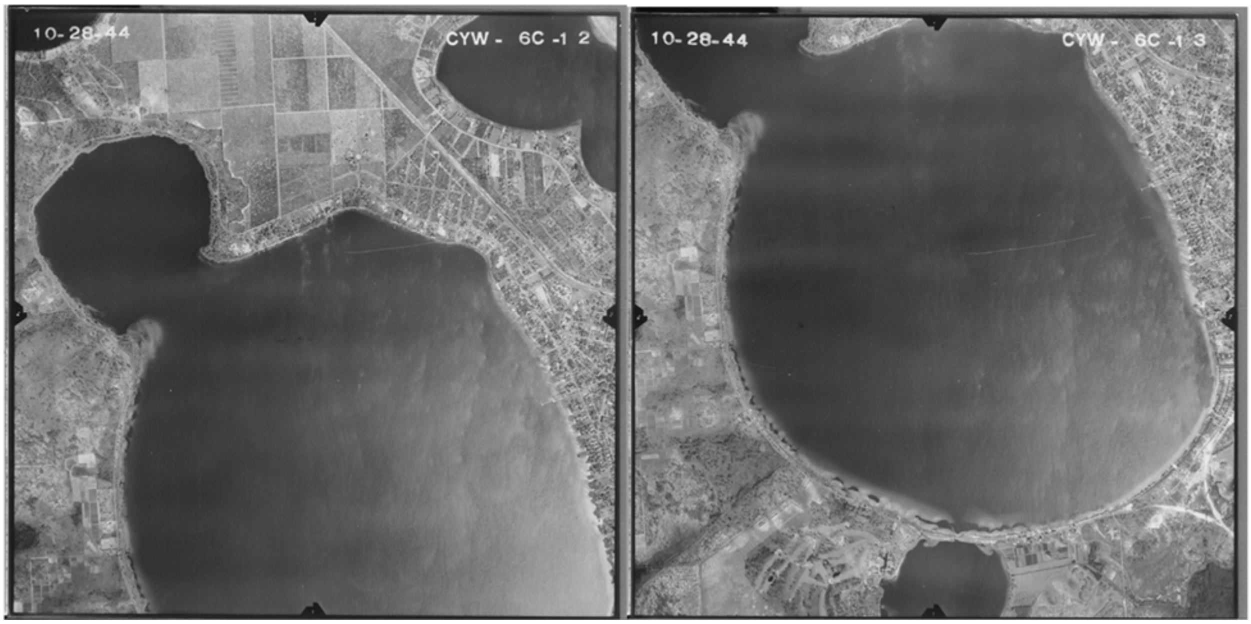

Figure 6: 1944 Aerial Photographs of Lake Jackson and Little Lake Jackson

Figure 7: 1952 Aerial Photographs of Lake Jackson and Little Lake Jackson

Figure 8: 1970 Aerial Photograph of Lake Jackson and Little Lake Jackson

Figure 9: 2004 Aerial Photograph of Lake Jackson and Little Lake Jackson

Figure 10: 2008 Aerial Photograph of Lake Jackson and Little Lake Jackson

Figure 11: 2014 Aerial Photograph of Lake Jackson and Little Lake Jackson

Bathymetry Description and History

One-foot interval bathymetric data gathered from recent field surveys resulted in lake-bottom contour lines from 74 ft. to 109 ft. (Figure 12). These data revealed that the lowest lake bottom contour (74 ft.) is located in a small depression in the southwest area of Lake Jackson. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

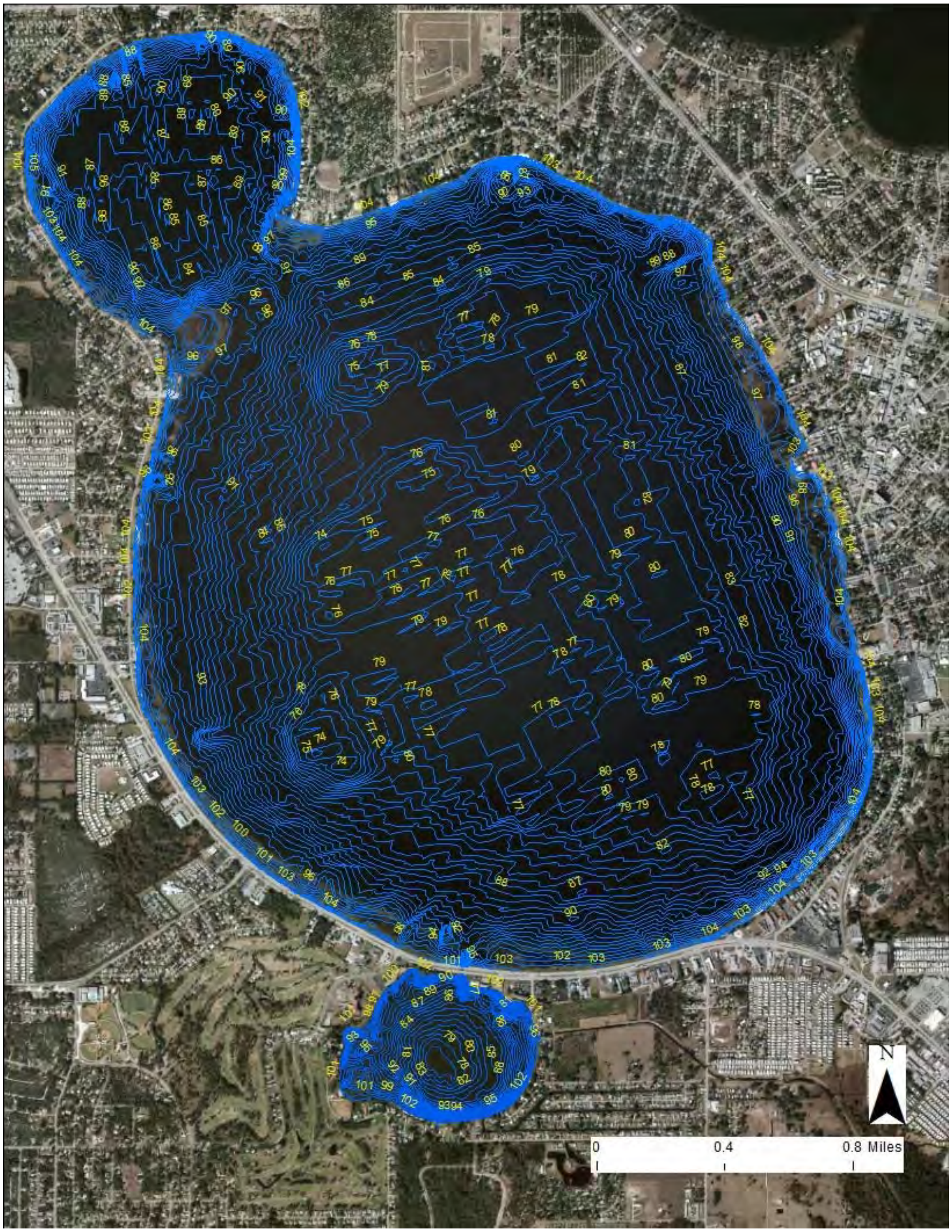

Figure 12: Lake Bottom Contours (ft., NGVD29) on a 2014 Natural Color Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Lake Jackson and Little Lake Jackson from the District's Water Management Information System (SID 23807 and SID 25475) (Figure 13). Data collection began on April 25, 1945 for Lake Jackson and July 1, 1981 for Little Lake Jackson, and continues to be monitored monthly at the time of this report. There was a break in monitoring between October 1975 and October 1979 with no water level records available. The highest lake stage elevation on record is 103.76 ft. and occurred on September 19, 1947. The lowest lake stage elevation on record is 96.47 ft. and occurred on June 16, 2008.

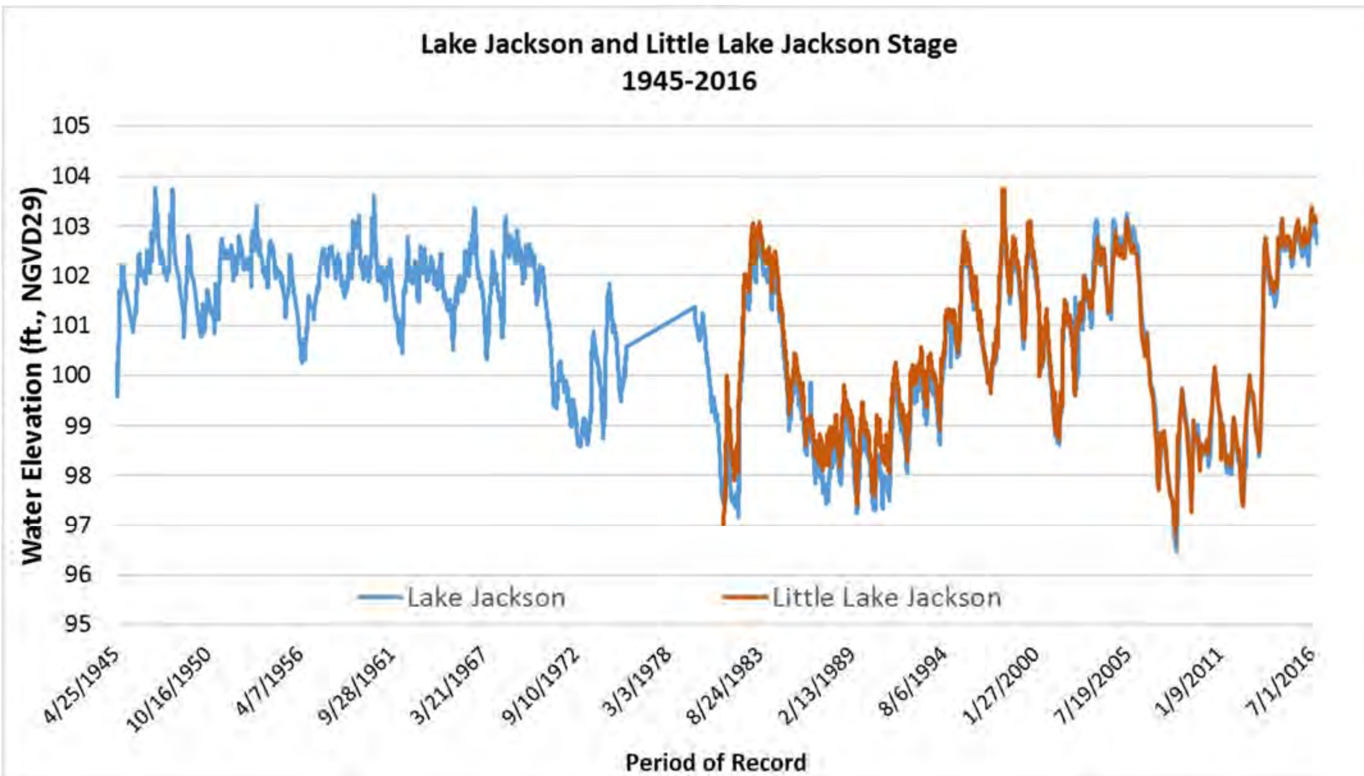

Figure 13: Lake Jackson and Little Lake Jackson Period of Record Water Elevation Data (SID 23807 and 25475)

Historical and Current Management Levels

The District has a long history of water resource protection through the establishment of lake management levels. With the development of the Lake Levels Program in the mid-1970s, the District began establishing management levels based on hydrologic, biological, physical and cultural aspects of lake ecosystems. By 1996, management levels for nearly 400 lakes had been adopted into District rules.

The District Governing Board approved Guidance and Minimum Levels for Lake Jackson and Little Lake Jackson (Table 2) in March 2006, which were subsequently adopted into Chapter 40D-8, Florida Administrative Code, on December 12, 2006, using the methodology for Category 3 Lakes described in SWFWMD (1999a and 1999b).

Table 2: Guidance levels adopted December 2006 for Lake Jackson and Little Lake Jackson

Level	Elevation (ft., NGVD)
Ten Year Flood Guidance Level	104.1
High Guidance Level	102.6
High Minimum Level	102.4
Minimum Level	101.3
Low Guidance Level	100.2

Methods, Results and Discussion

The Minimum and Guidance Levels revised in this report were developed for Lake Jackson and Little Lake Jackson using the methodology for Category 3 lakes described in Chapter 40D-8, F.A.C. Revised levels along with lake surface area for each level are listed in Table 3, along with other information used for development of the revised levels. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

Table 3: Lake Stage Percentiles, Normal Pool and Control Point Elevations, Significant Change Standards, and revised Minimum and Guidance Levels and associated surface areas for Lake Jackson and Little Lake Jackson.

Levels	**Elevation in Feet NGVD 29**	**Lake Area (acres)**
Lake Stage Percentiles		
Historic P10 (1946 to 2013)	103.5	3,427.8
Historic P50 (1946 to 2013)	102.0	3,396.4
Historic P90 (1946 to 2013)	100.7	3,356.3
Normal Pool and Control Point		
Normal Pool	NA	NA
Control Point	102.6	3,408.1
Significant Change Standards		
Recreation/Ski Standard	82.2	1,365.6
Dock-Use Standard	102.5	3,406.1
Wetland Offset Elevation	101.2	3,375.9
Aesthetics Standard	99.9	3,305.1
Species Richness Standard	95.3	2,880.4
Basin Connectivity Standard	97.7	3,056.9
Lake Mixing Standard	102.2	3,400.4
Minimum and Guidance Levels		
High Guidance Level	102.8	3,412.2
High Minimum Lake Level	102.3	3,402.3
Minimum Lake Level	101.2	3,375.9
Low Guidance Level	99.9	3,305.1

NA - not appropriate

Bathymetry

Relationships between lake stage, inundated area, and volume can be used to evaluate expected fluctuations in lake size that may occur in response to climate, other natural factors, and anthropogenic impacts such as structural alterations or water withdrawals. Long term reductions in lake stage and size can be detrimental to many of the environmental values identified in the Water Resource Implementation Rule for consideration when establishing MFLs. Stage-area-volume relationships are therefore useful for developing significant change standards and other information identified in District rules for consideration when developing minimum lake levels. The information is also needed for the development of lake water budget models that estimate the lake's response to rainfall and runoff, outfall or discharge, evaporation, leakance, and groundwater withdrawals.

Stage-area-volume relationships were determined for Lake Jackson and Little Lake Jackson by building and processing a digital elevation model (DEM) of the lake basin and surrounding watershed. Elevations of the lake bottom and land surface elevations were used to build the model through a series of analyses using LP360 (by QCoherent) for ArcGIS, ESRI® ArcMap 10.2 software, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basin with the lake basin morphology to develop one continuous 3D digital elevation model. The 3D digital elevation model is then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the largest size of the lake at its peak or flood stage, and working downward to the base elevation (deepest pools in the lake).

Two elevation data sets were used to develop the terrain model for Lake Jackson and Little Lake Jackson. Light Detection and Ranging Data (LiDAR) was processed with LP360 for ArcGIS and merged with bathymetric data collected with both sonar and mechanical (manual) methods. These data were collected using a LEI HS-WSPK transducer (operating frequency = 192kHz, cone angle = 20) mounted to a boat hull, a Lowrance LMS-350A sonar-based depth finder and the Trimble GPS Pathfinder Pro XR/Mapping System (Pro XR GPS Receiver, Integrated GPS/MSK Beacon Antenna, TDC1 Asset Surveyor and Pathfinder Office software).

The DEM created from the combined elevation data sets was used to develop topographic contours of the lake basin and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments. Selected stage-area-volume results are presented in Figure 14.

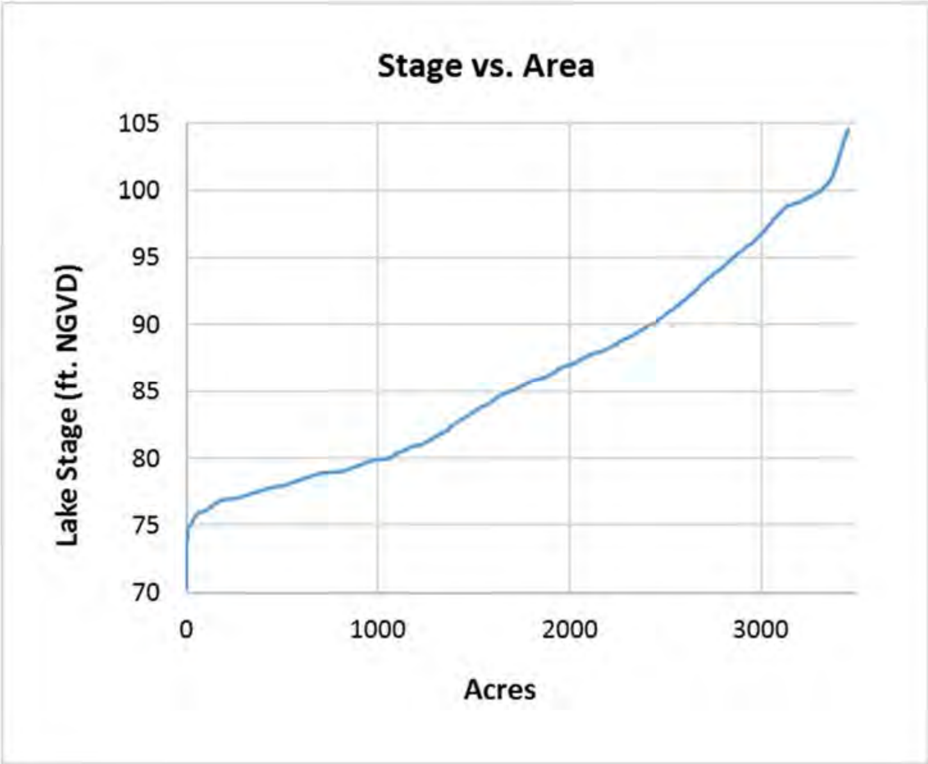

Figure 14: Lake Stage (Ft. NGVD29) to Surface Area (Acres) for Lake Jackson and Little Lake Jackson.

Development of Exceedance Percentiles

A key part of establishing Minimum and Guidance Levels is the development of exceedance percentiles based on Historic water levels (lake stage data). For the purpose of minimum levels determination, lake stage data are categorized as "Historic" for periods when there were no measurable impacts due to water withdrawals, and impacts due to structural alterations were similar to existing conditions. In the context of minimum levels development, "structural alterations" means man's physical alteration of the control point, or highest stable point along the outlet conveyance system of a lake, to the degree that water level fluctuations are affected.

Based on water-use estimates and analysis of lake water levels and regional ground water fluctuations, a modeling approach (Appendix A) was used to estimate Historic lake levels. This approach was considered appropriate for extending the period of record for lake stage values for developing Historic lake stage exceedance percentiles. Development of this stage record was considered necessary for characterization of the range of lake-stage fluctuations that could be expected based on long-term climatic cycles that have been shown to be associated with changes in regional hydrology (Enfield et al. 2001, Basso and Schultz 2003, Kelly 2004).

The initial approach included developing a water budget model which incorporated the effects of precipitation, evaporation, overland flow, and groundwater interactions (Appendix A). Using the results of the water budget model, regression modeling for lake stage predictions was conducted using a linear line of organic correlation statistical model (LOC) (see Helsel and Hirsch 1992). The procedure was used to derive the relationship between daily water surface elevations for Lake Jackson and Little Lake Jackson and composite regional rainfall.

A combination of model data produced a hybrid model which resulted in a 69-year (1946-2015) Historic water level record. Based on this hybrid data, the Historic P10 elevation, i.e., the elevation of the lake water surface equaled or exceeded ten percent of the time, was 103.5 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 102.0 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 100.7 ft. (Figure 15 and Table 3).

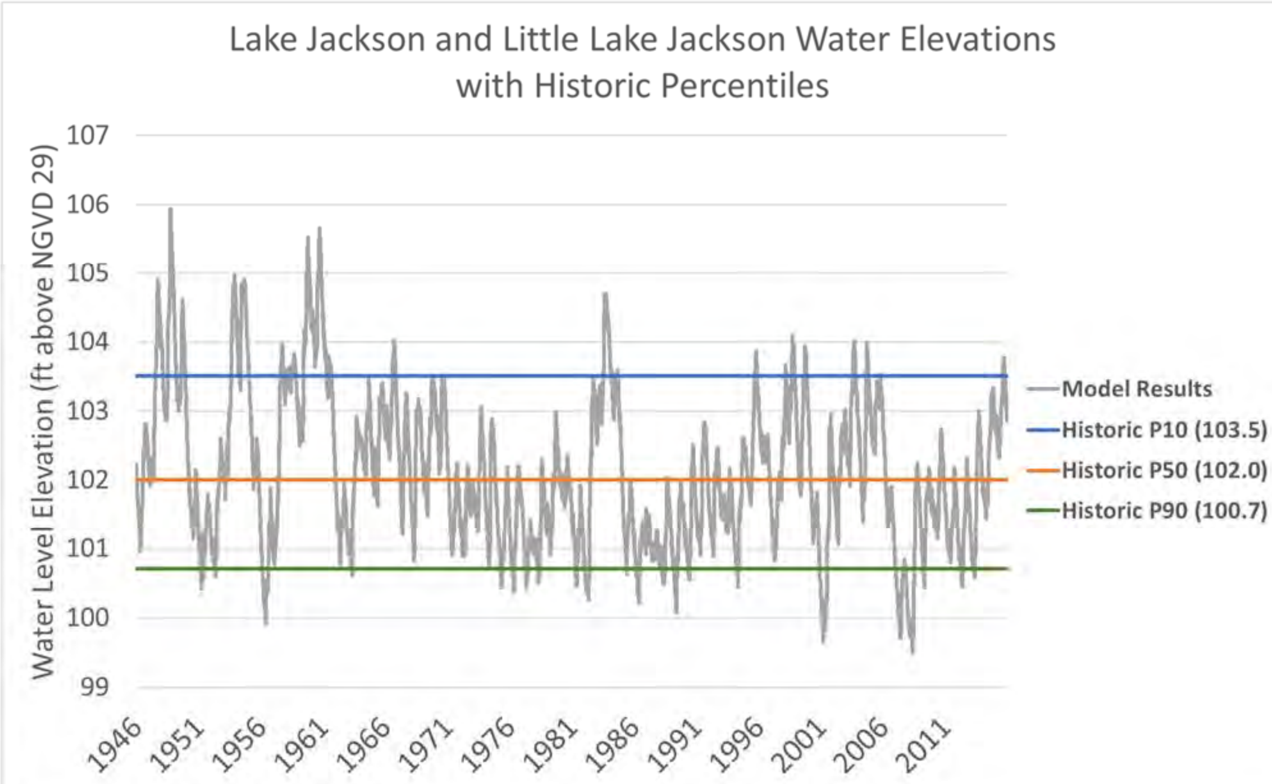

Figure 15: Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

Normal Pool Elevation and Additional Information

The Normal Pool elevation, a reference elevation used for development of minimum lake and wetland levels, is established based on the elevation of hydrologic indicators of sustained inundation. The inflection points (buttress swelling) and moss collars on the trunks of cypress trees have been shown to be reliable biologic indicators of hydrologic Normal Pool (Carr et al. 2006). As Lake Jackson and Little Lake Jackson do not have sufficient cypress trees with adequate hydrologic indicators, a Normal Pool elevation was not determined.

Additional information to consider in establishing Minimum and Guidance Levels are the Control Point elevation and the lowest building floor (slab) elevation within the lake basin (determined by field survey data). The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system that can principally control the lake water level fluctuations at the high end. The control point was established at 102.6 ft., the elevation of the structure at Little Lake Jackson's outlet. The low floor slab, based on survey reports, was established at 105.06 ft.

Revised Guidance Levels

The High Guidance Level is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake, and is established using Historic data if it is available, or is estimated using the Current P10, the Control Point elevation and the Normal Pool elevation. Based on the availability of data developed for Lake Jackson and Little Lake Jackson, the revised High Guidance Level was established at the elevation of the P10 of current water level data (1999-2016), 102.8 ft., which is approximately one foot lower than the highest recorded water level of 103.76 ft. Gauged data indicate that the High Guidance Level has been regularly met or exceeded from 1999 to 2016 (Figure 13).

The Low Guidance Level is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, reference lake water regime statistics. Reference lake water regime statistics are used when adequate Historic or Current data are not available. These statistics represent differences between P10, P50, and P90 lake stage elevations for typical, regional lakes that exhibit little or no impacts associated with water withdrawals, i.e., reference lakes. Reference lake water regime statistics include the RLWR50, RLWR90 and RLWR5090, which are, respectively, median differences between P10 and P50, P10 and P90, and P50 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of Historic data for Lake Jackson and Little Lake Jackson, the revised Low Guidance Level was established at the revised Minimum Lake Level minus the RLWR5090 of 1.3 ft., resulting in an LGL elevation of 99.9 ft. The gaged period of record indicates the lowest water level, recorded in June 2008, was 96.47 ft., which is 3.43 ft. below the revised Low Guidance Level (Figure 13). The most recent record of the water level dropping below the revised Low Guidance Level was in June 2013, with a recorded low level of 98.75 ft.

Significant Change Standards

Category 3 significant change standards were established for Lake Jackson and Little Lake Jackson based on the stage-volume relationship which was developed. These standards include a Recreation/Ski Standard, Dock-Use Standard, Wetland Offset Elevation, Aesthetics Standard, Species Richness Standard, Basin Connectivity Standard, and Lake Mixing Standard. Each was evaluated for minimum levels development for Lake Jackson and Little Lake Jackson and presented in Table 3.

- The **Recreation/Ski Standard** was established at an elevation of 82.2 ft. based on a ski elevation of 81 ft. and the difference between the Historic P50 and P90, plus an additional 5 feet.
- The **Dock-Use Standard** was established at an elevation of 102.5 ft. based on the elevation of lake sediments at the end of 176 docks on the lakes, a two-foot clearance depth, and the difference between the Historic P50 and P90.
- The **Wetland Offset Elevation** was established at 101.2 ft., or 0.8 ft. below the Historic P50 elevation.
- The **Aesthetic-Standard** for was established at the Low Guidance Level elevation of 99.9 ft.
- The **Species Richness Standard** was established at 95.3 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- The **Basin Connectivity Standard** was established at 97.7 ft., based on the addition of 2 feet and the difference between the Historic P50 and P90 to the critical high spot elevation of 94.5 ft. This is the highest bottom elevation where Lake Jackson is connected to Little Lake Jackson.
- The **Lake Mixing Standard** was established at an elevation of 102.2 ft., where the dynamic ratio shifts from a value of less than 0.8 to greater than 0.8, indicating that potential changes in basin susceptibility to wind-induced sediment resuspension would not be of concern for minimum levels development (see Bachmann *et al.* 2000).

Review of changes in potential herbaceous wetland area associated with change in lake stage (Figure 16), and potential changes in area available for aquatic plant colonization (Figure 17) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development. Figure 16 and Figure 17 show that as the lake stage increases, the acres available for herbaceous wetlands (i.e., acres < 4 ft. deep) and aquatic plant colonization (i.e., acres < 10 ft. deep) also increase up to a point, and then begins to decrease as the lake becomes deeper. The changes in the slope of the lines reflect the variation in lake bottom contours and the area which it contains.

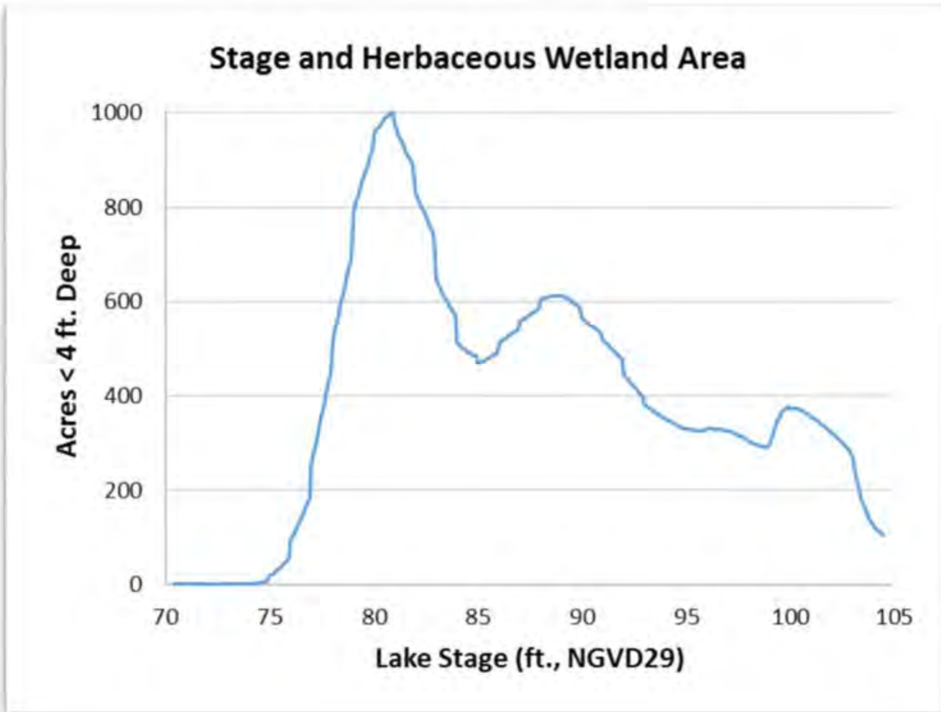

Figure 16: Lake Stage Compared to Available Herbaceous Wetland Area.

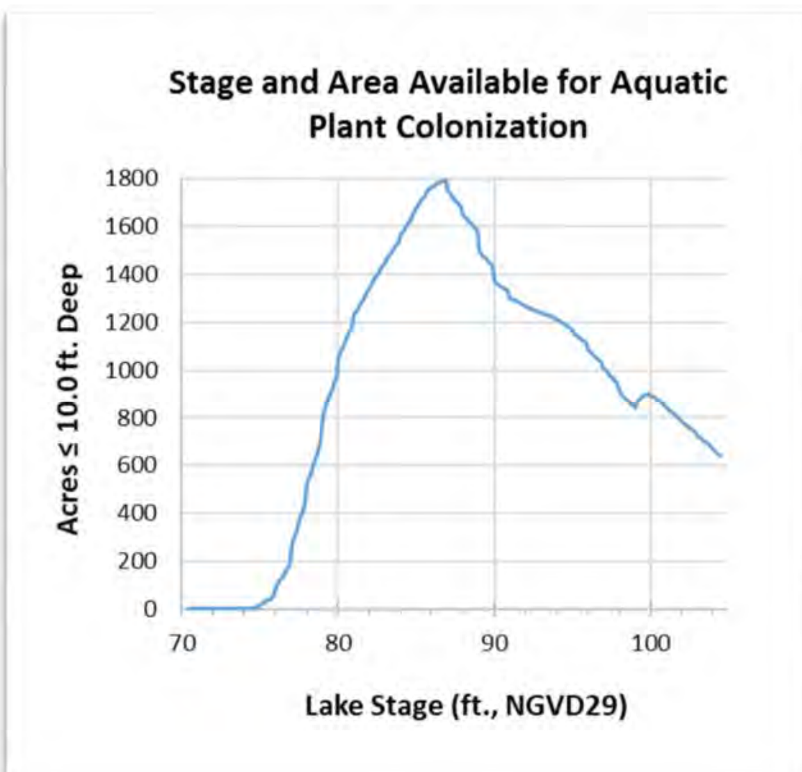

Figure 17: Lake Stage and Area Available for Aquatic Plant Colonization.

Revised Minimum Levels

The High Minimum Lake Level (HMLL) is the elevation that a lake's water levels are ***required*** to equal or exceed ten percent of the time on a long-term basis. For a Category 3 lake, Chapter 40D-8.624, F.A.C. allows for the HMLL to be established using one of two methods. The High Minimum Lake Level can be established at the elevation corresponding to the Minimum Lake Level plus the difference between the Historic P10 and the Historic P50 or alternatively, the revised HMLL is established at the elevation corresponding to the MLL plus the RLWR50 value. Based on the concerns for flooding on the lake, the latter RLWR50 method was used, resulting in a revised HMLL of 102.3 ft. This elevation allows for potential relief from long-term flooding concerns, yet also allows for a relatively natural fluctuation of lakes levels.

The Minimum Lake Level (MLL) is the elevation that a lake's water levels are ***required*** to equal or exceed fifty percent of the time on a long-term basis. For a Category 3 lake, the Minimum Lake Level is established using a process that considers applying professional experience and judgement, and the Standards previously discussed. The revised MLL for Lake Jackson and Little Lake Jackson is established at the Wetland Offset elevation of 101.2 ft.

Revised Minimum and Guidance levels for Lake Jackson and Little Lake Jackson are plotted on the Historic water level record (Figure 18). To illustrate the approximate locations of the lake surface edge when water levels equal the revised Minimum and Guidance levels, the revised levels are imposed on a 2014 natural color aerial photograph in Figure 19.

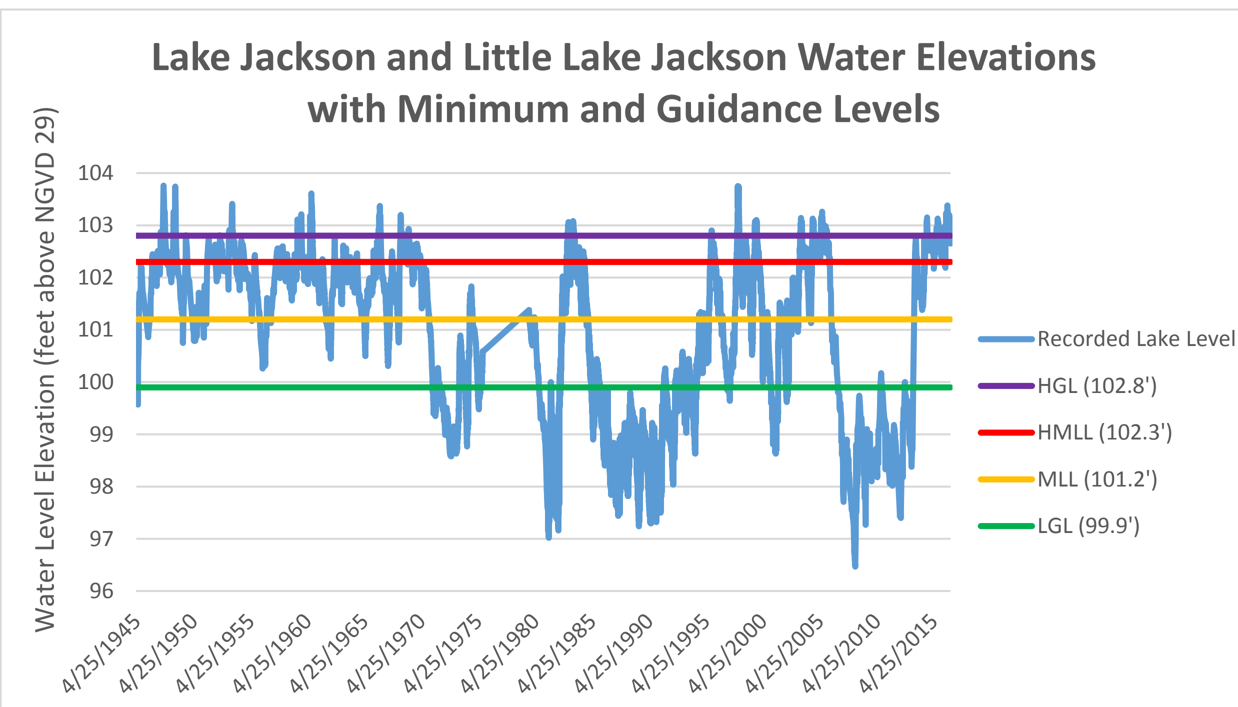

Figure 18: Revised Minimum and Guidance Levels for Lake Jackson and Little Lake Jackson along with model (Historic) water level data from Lake Jackson

Figure 19: Lake Jackson and Little Lake Jackson Minimum and Guidance Level Contour Lines Imposed onto a 2014 Natural Color Aerial Photograph.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida's water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the revised MFLs for Lake Jackson and Little Lake Jackson are presented in both datum standards (Table 4). The datum shift was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum of 1988. The NGVD29 datum conversion to NAVD88 is -1.07 ft. for SID 23807 on Lake Jackson and -1.20 for SID 25475 on Little Lake Jackson.

Table 4: Revised Minimum and Guidance Levels for Lake Jackson and Little Lake Jackson in NGVD29 and NAVD88.

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88 (SID 23807)	Elevation in Feet NAVD88 (SID 25475)
High Guidance Level	102.8	101.7	101.6
High Minimum Lake Level	102.3	101.2	101.1
Minimum Lake Level	101.2	100.1	100.0
Low Guidance Level	99.9	98.8	98.7

Consideration of Environmental Values

The revised minimum levels for Lake Jackson and Little Lake Jackson are protective of relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, F.A.C.). As presented above, when developing minimum lake levels, the District evaluates categorical significant change standards and other available information to identify criteria that are sensitive to long-term changes in hydrology and represent significant harm thresholds. The Wetland Offset Elevation was used for developing revised Minimum Levels for Lake Jackson and Little Lake Jackson based on their classification as Category 3 lakes. This standard is associated with protection of several environmental values identified in Rule 62-40.473, F.A.C., including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, and water quality (Table 1).

In addition, the environmental value of maintenance of freshwater storage and supply is also expected to be protected by the minimum levels based on inclusion of conditions in water use permits that stipulate permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Two environmental values identified in the Water Resource Implementation Rule were not considered relevant to development of revised minimum levels for Lake Jackson and Little Lake Jackson. Estuarine resources were not considered relevant because the lake is not connected to an estuarine resource. Sediment loads were similarly not considered relevant for minimum levels development for the lake, because the transport of sediments as bedload or suspended load is a phenomenon typically associated with flowing water systems.

Comparison of Revised and Currently Adopted Levels

The revised High Guidance Level is 0.2 ft. higher than the previously adopted High Guidance Level, while the Low Guidance Level is 0.3 ft. lower than the previously adopted Low Guidance Level (Table 5). These differences are associated with application of a new modeling approach for characterization of Historic water level fluctuations within the lake, i.e., water level fluctuations that would be expected in the absence of water withdrawal impacts given existing structural conditions, and additional data since the last evaluation.

The revised High Minimum Lake Level for Lake Jackson and Little Lake Jackson is 0.1 ft. lower than the previously adopted High Minimum Lake Level. The revised Minimum Lake Level is also 0.1 ft. lower than the previously adopted Minimum Lake Level (Table 5). These differences are due to the same factors listed for the changes in guidance levels, as well as the MLL being based on the Wetland Offset for this reevaluation. When the last levels were established, the MLL was based on the Dock-Use Standard, which is now calculated to be above the Historic P50, and thus ruled out as the MLL.

The revised Minimum and Guidance Levels identified in this report replace previously adopted levels for Lake Jackson and Little Lake Jackson.

Table 5: Revised Minimum and Guidance Levels for Lake Jackson and Little Lake Jackson compared to currently adopted Minimum and Guidance Levels.

Minimum and Guidance Levels	Revised Elevations (in Feet NGVD29)	Previously Adopted Elevations (in Feet NGVD29)
High Guidance Level	102.8	102.6
High Minimum Lake Level	102.3	102.4
Minimum Lake Level	101.2	101.3
Low Guidance Level	99.9	100.2

Minimum Levels Status Assessment

To assess if the revised Minimum and High Minimum Lake Levels are being met, observed stage data in Lake Jackson and Little Lake Jackson were used to create a long-term record using a Line of Organic Correlation (LOC) model, similar to what was developed for establishing the Minimum Levels (Appendix A). For the status assessment, the lake stage data used to create the LOC must be from a period representing a time when groundwater withdrawals and structural alterations are reasonably stable, and represent current conditions, referred to as the “Current” period. Current stage data observed on Lake Jackson and Little Lake Jackson were determined to be from 1999 through 2015. Using the Current stage data, the LOC model was created. The LOC model resulted in a 69-year long-term water level record (1946-2015).

For the status assessment, cumulative median (P50) and cumulative P10 water elevations were compared to the revised Minimum Lake Level and High Minimum Lake Level to determine if long-term water levels were above the revised levels. Results from these assessments indicate that Lake Jackson and Little Lake Jackson water levels are currently below the Minimum Lake Level and above the High Minimum Lake Level (see Appendix B).

The lake lies within the region of the District covered by an existing recovery strategy for the Southern Water Use Caution Area (Rule 40D80-074, F.A.C.). The District plans to continue regular monitoring of water levels in Lake Jackson and Little Lake Jackson and will also routinely evaluate the status of the lake’s water levels with respect to adopted minimum levels for the lake included in Chapter 40D-8, F.A.C.

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APPENDIX A

Draft Technical Memorandum

November 22, 2016

TO: Mark Hurst, Senior Environmental Scientist, Water Resources Bureau

THROUGH: Jerry L. Mallams, P.G., Manager, Water Resources Bureau

FROM: Jason G. Patterson, Hydrogeologist. Water Resources Bureau
Donald Ellison, P.G., Senior Professional Geologist, Water Resources Bureau
Mark Barcelo, P.E., Chief Professional Engineer, Water Resources Bureau

Subject: Lake Jackson and Little Lake Jackson Water Budget Model, Rainfall Regression Model, and Historic Percentile Estimations

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A. Introduction

Water budget and rainfall regression models were developed to assist the Southwest Florida Water Management District (District) in the assessment of minimum levels for Lake Jackson and Little Lake Jackson, located in northwest Highlands County, within the City of Sebring. A proposed minimum level for the lakes is scheduled to be established in FY 2016. This document will discuss the development of the Lake Jackson and Little Lake Jackson models and use of the models for development of Historic lake stage exceedance percentiles using those models.

B. Background and Setting

Lake Jackson and Little Lake Jackson are located in northwest Highlands County. US Highway 27 is located to the west side of Lake Jackson and follows the lake perimeter along the south side of the lake (Figure 1). An outlet conveyance system connecting Lake Jackson and Little Lake Jackson is located at the southern portion of Lake Jackson and the northern portion of Little Lake Jackson. The outlet is located under US Highway 27. The lake is within the Kissimmee River Basin watershed (Spechler, 2010). Lake Jackson receives surface water inflow via a channel from Lake Sebring, located just north of Lake Jackson. There is significant drainage into the lake from culverts on the northern and western side of the lake. The southern and eastern side of the lake is mostly residential with runoff flowing directly into the lake from the east. There are currently no permitted surface water withdrawals from the lake; however, there are numerous permitted groundwater withdrawals in the vicinity.

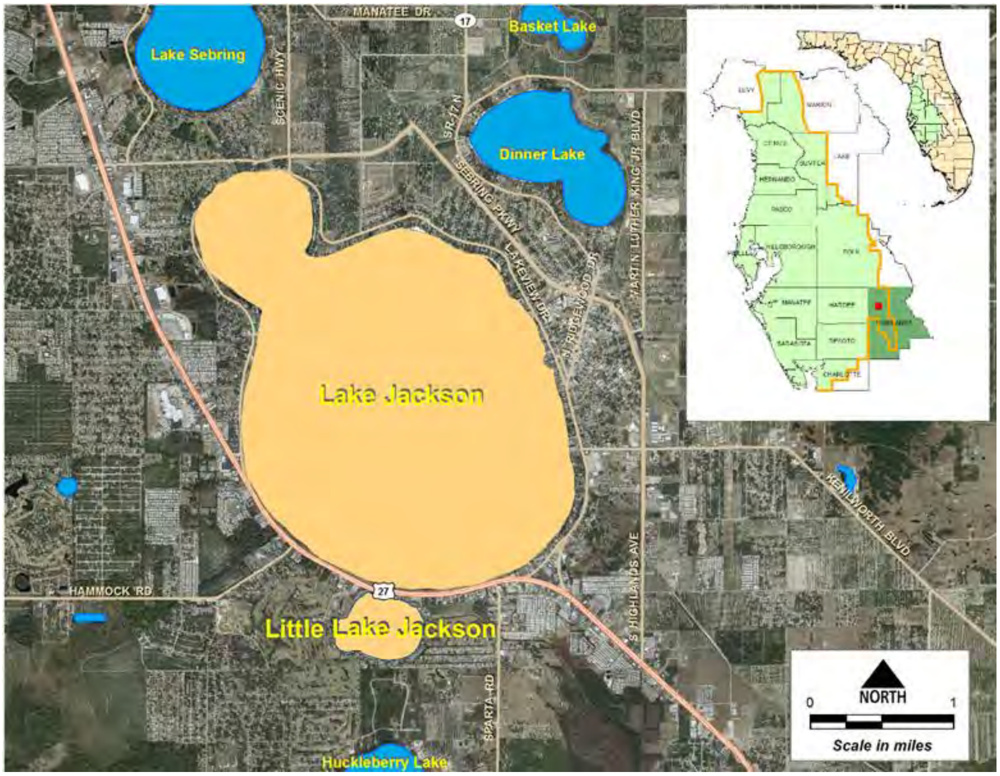


Figure 1. Location of Lake Jackson in Polk County, Florida

Physiography and Hydrogeology

Lake Jackson and Little Lake Jackson are situated in the Intraridge Valley located within a north-south oriented ridge (the Lake Wales Ridge) that is approximately 100 miles long and ranges from four to ten miles wide (Brooks, 1981). The Intraridge Valley is approximately 35 miles long and about 2 miles wide. This valley was formed by the dissolution of the underlying limestone and contains numerous karst features (Spechler, 2010). The area surrounding the lakes is categorized as the Eastern Complex of the Central Ridge subdivision in the Central Lake Physiographic District (Brooks, 1981). It is a sub-region of the Lake Wales Ridge and contains some residual high hills (up to 220 feet) and considerable amounts of Upper Miocene coarse clastics underlying the ridge. Most of the surficial deposits and the relief features are related to Pliocene and Pleistocene beach ridges and paleodunes. Many solution basins, some with large lakes occur on the western margin (Brooks, 1981). The Lake Wales Ridge area is predominantly well-drained and has internal drainage caused by numerous karst features; hence, it is the principal recharge area of the Floridan aquifer. Dissolution of the underlying limestone creates the relief seen in the Lake Wales Ridge. The Lake

Wales Ridge Complex is a remnant of a broader upland that has been eroded and lowered by sea level fluctuations, fluvial erosion, and aeolian redistribution of sediments (Green et al., 2012). Elevations within the immediate watershed range from the south edge of Little Lake Jackson at about 100 feet to 165 feet NGVD29 on the northwest side of the lake. Drainage into the lake is a combination of overland flow, flow through a stormwater drainage system, as well as percolation from the surficial aquifer. The area adjacent to the western side of the lake is categorized as the Carlton Ranch Ridge in the Southwestern Flatwoods District; a linear ridge with thick sands and no karstic features (Brooks, 1981).

Lithology and hydrologic units near Lake Jackson are described by Regional Observation Monitoring Program (ROMP) reports completed by the Southwest Florida Water Management District for ROMP 29A AVPK PZ (SID 670785) and ROMP 29 U FLDN AQ (SID 774267). ROMP 29A AVPK PZ is approximately 1.6 miles east of Lake Jackson and east of the Intraridge Valley on the Lake Wales Ridge. The surficial aquifer at the site consists of undifferentiated sand and clay at a depth of 165 feet below land surface datum (LSD). Between 110 and 165 feet below LSD, the surficial aquifer is within the Peace River Formation, a formation within the Hawthorn Group. From 165 to 371 feet below LSD is the confining Hawthorn Group. At 371 feet below LSD the Suwannee Limestone geologic unit exists and marks the top of the Upper Floridan aquifer (Gates, 2012).

ROMP 29 U FLDN is located approximately 5.9 miles to the southwest of the lake (Figure 3). ROMP 29 is located within the Desoto Plain, west of the Lake Wales Ridge (Brooks, 1981). The surficial aquifer at the site consist of undifferentiated sands and clayey deposits from LSD to 196 feet below LSD. The Hawthorn Group acts as a confining unit and exists at the site from 196 below LSD to 461 feet below LSD. The Hawthorn Group consist of sandy clay, sandstone and calcareous clayey sand. At 461 feet below LSD, the Suwannee Limestone geologic unit marks the top of the Upper Floridan aquifer (Mallams, 2006).

Data

Water level data collection at Lake Jackson began in 1945 and is collected sporadically. During the Water Budget Model period (1999-2015) data collection occurred at the lake at a minimum of once per month. For many months, data collection occurred 4-5 times at the lake. Additionally, water level data collection began in 1981 at Little Lake Jackson and data collection occurred daily until 2005. A median water level difference of 0.1 ft was observed between Lake Jackson and Little Lake Jackson from 1/1/1999 through 2015 indicating the lakes were fluctuating similarly (Figure 2).

ROMP 43XX (SID 25532) was used for the water budget model for Lake Jackson and Little Lake Jackson from 1999 through September 2008. The well is located approximately 6.2 miles north of Lake Jackson. Data at ROMP 43XX was collected hourly with some data gaps. These data gaps were typically less than 7 days and were infilled linearly. In September 2008, data collection began at ROMP 29A (SID 670785). From September 2008 through December 2015, ROMP 29A was used for the water budget model. The well is located approximately 1.6 miles east of the lake (Figure 3 and 4). Data are collected manually at the well twice a month. Data gaps were infilled linearly.

Surficial aquifer monitor wells RIDGE WRAP H-4 (SID 25487) was used to construct the water budget model for Lake Jackson and Little Lake Jackson (Figures 3 and 4). The well is located approximately 1.8 miles southwest of Little Lake Jackson and is located west of the Intraridge Valley on the Lake Wales Ridge. Data for RIDGE WRAP H-4 begin in April 1991 and data collection frequency are monthly. Data gaps were linearly infilled.

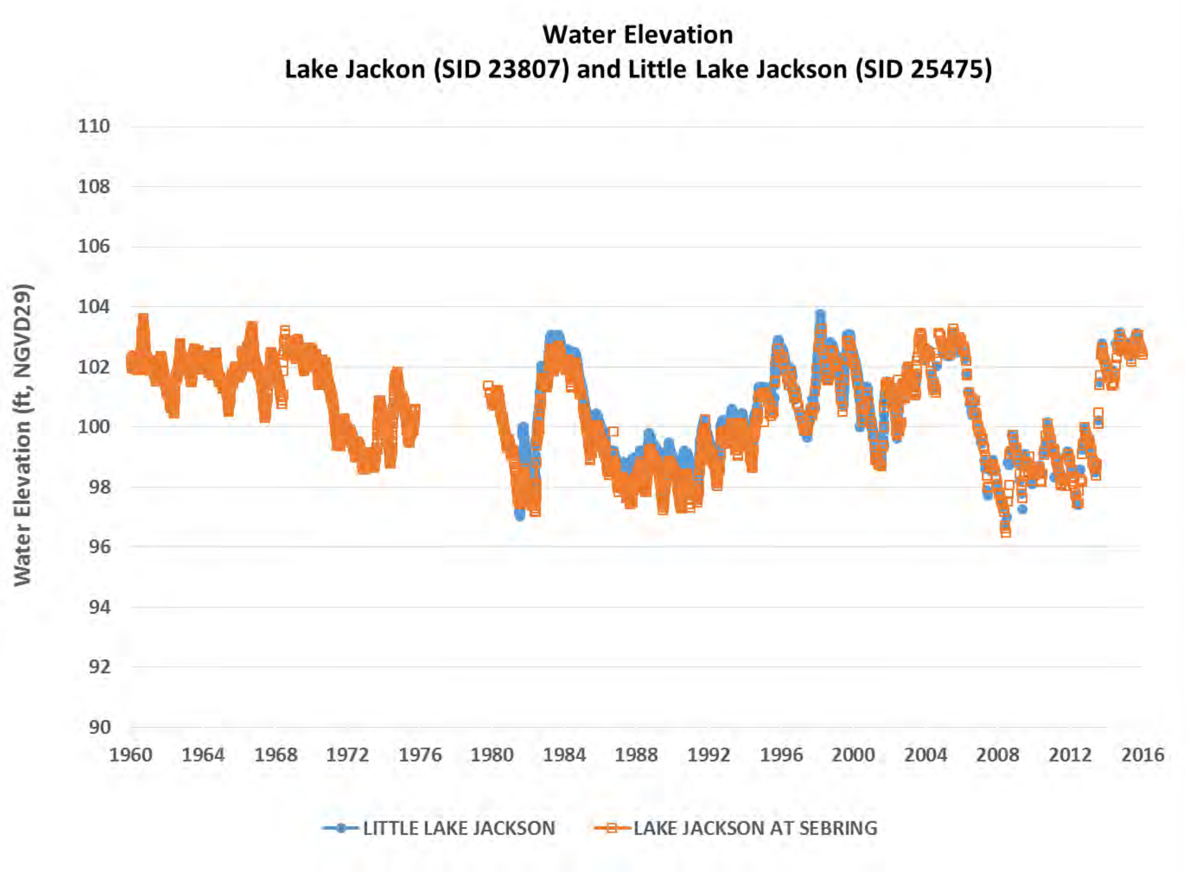


Figure 2. Lake Jackson and Little Lake Jackson Water Levels

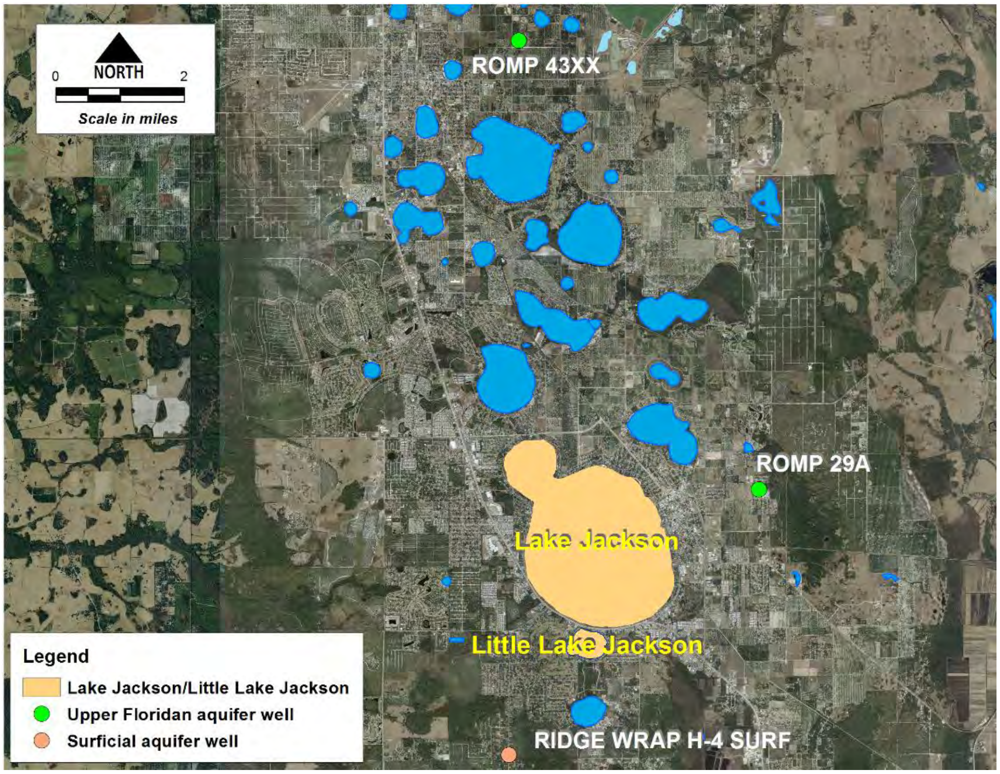


Figure 3. Location of monitoring wells near Lake Jackson and Little Lake Jackson

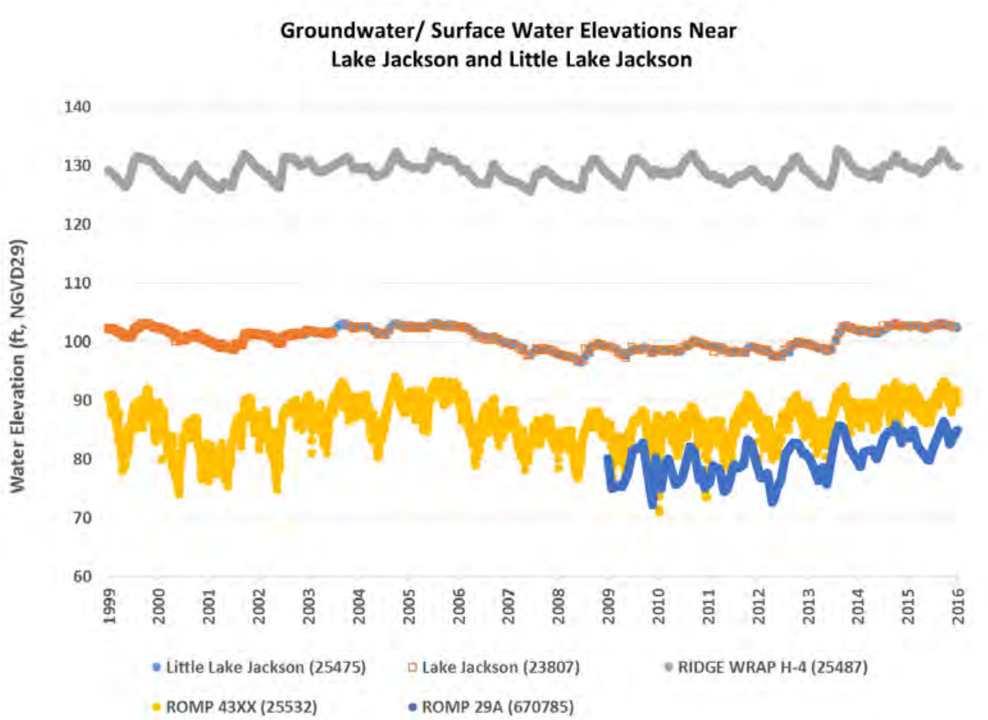
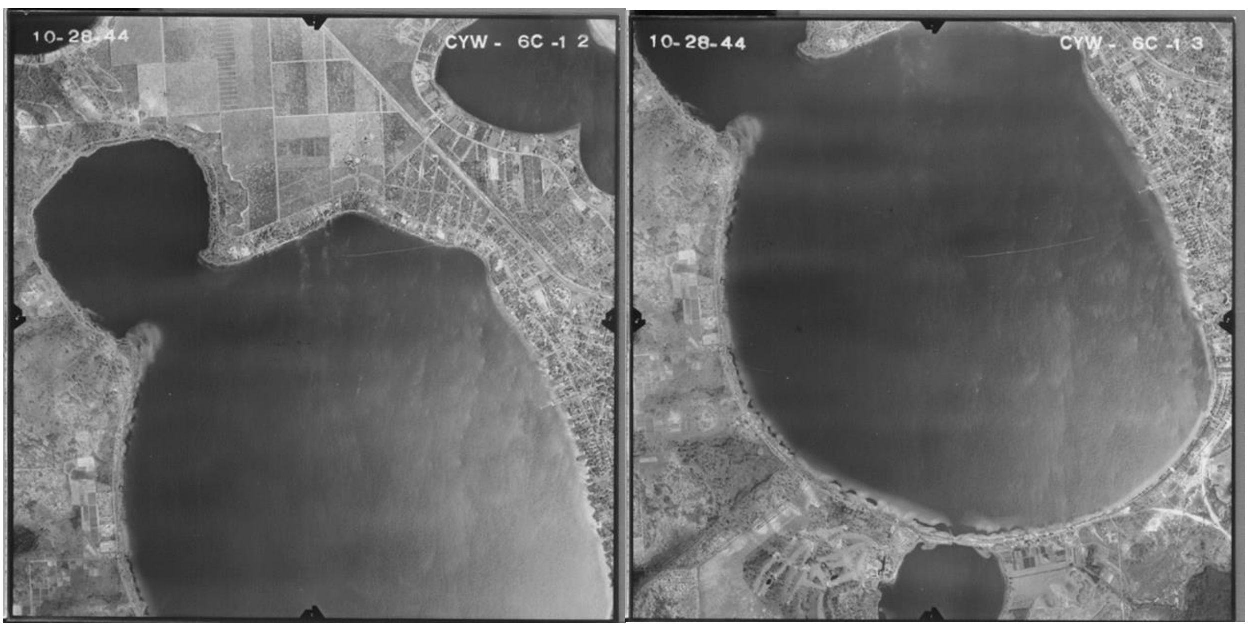


Figure 4. Water levels in monitoring wells near Lake Jackson/Little Lake Jackson

Land and Water Use

Land and water use in the area of Lake Jackson and Little Lake Jackson has changed over the years. Figure 5 shows the land use around the lakes in 1944 and Figure 6 shows 2011 land use/land cover with 2012 aerial imagery. Land use to the south and east side of the lakes consisted of residential and commercial development in 1944 and agriculture was at the north side of the lake. The west side of the lake was primarily undeveloped. Today, land use has become more urban, replacing much of the agriculture and undeveloped land. As of 2011, the land use within the Lake Jackson and Little Lake Jackson watershed is predominantly urban with some agriculture and wetlands.

Individual withdrawal point locations near the lakes are shown in Figure 7 and graphs depicting total water use within specified radial distances from a central point within the lake are presented in Figures 8 and 9. The estimated total groundwater use average from 2008 through 2012 within the first mile of the central point is 0.46 million gallons per day (mgd), of which most is for public supply. At three miles, the groundwater use average for the same time period is 5.8 mgd and at six miles from the center point within the lake the groundwater use average is 15.3 mgd.



Northeast portion of Lake Jackson **Southwest portion of Lake Jackson and Little Lake Jackson**

Figure 5. Land use around Lake Jackson and Little Lake Jackson in 1944

Figure 6. Land use/land cover in 2011 shown on 2012 aerial imagery

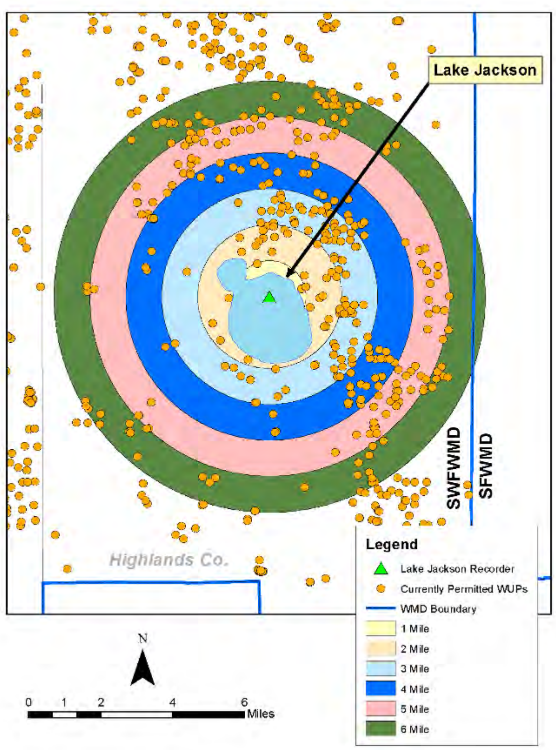


Figure 7. Location of water use permits near Lake Jackson

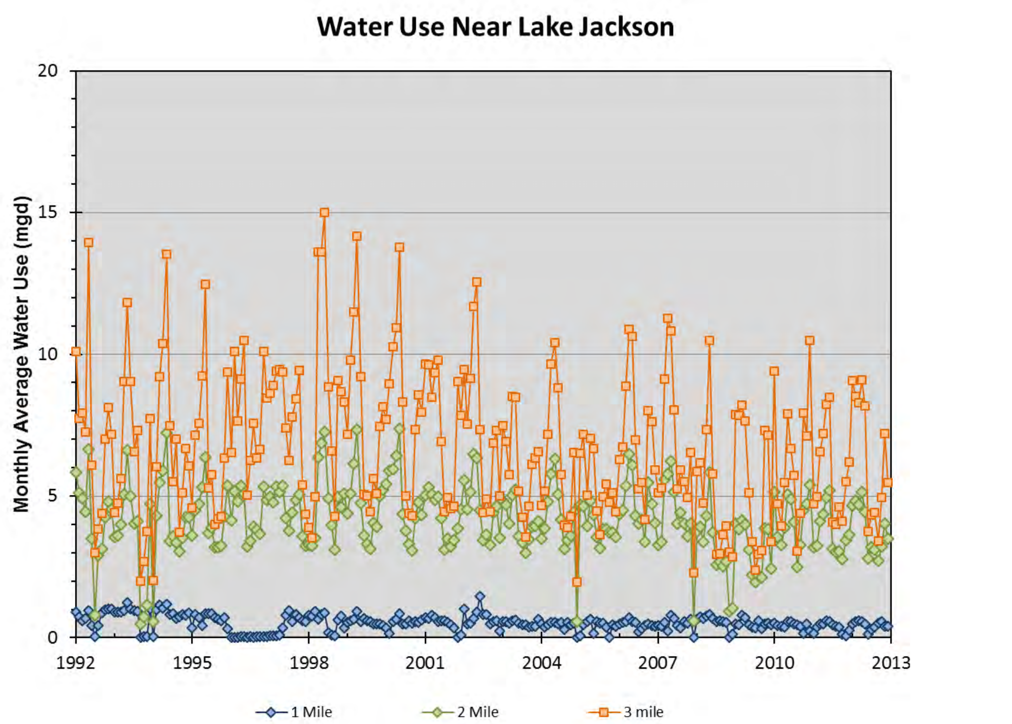


Figure 8. Metered and estimated water use within 1, 2 and 3 miles of Lake Jackson

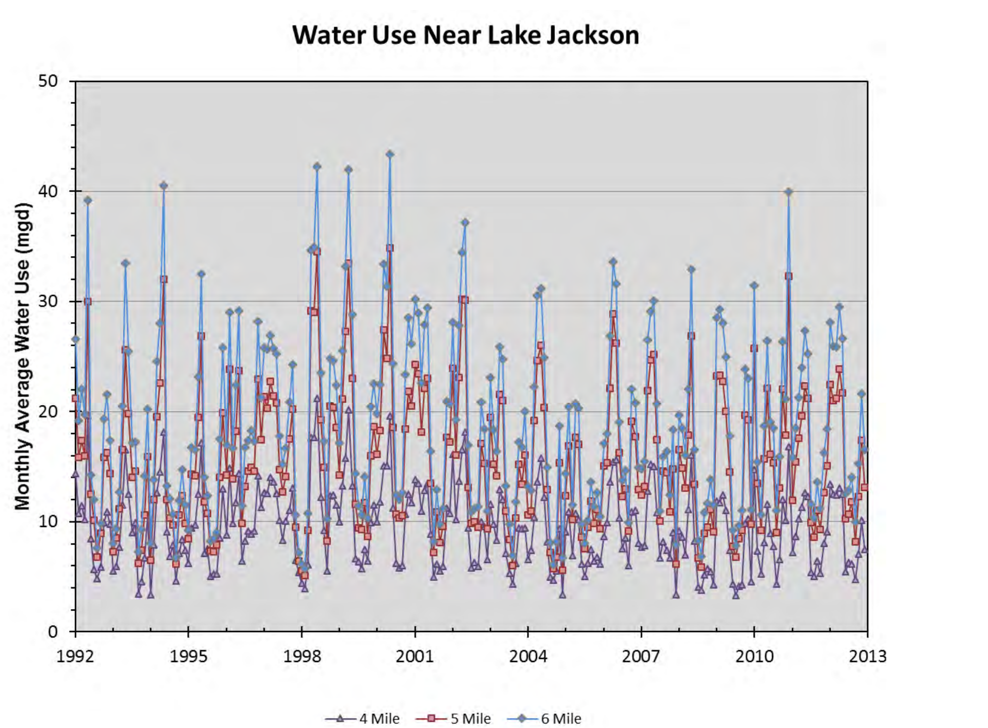


Figure 9. Metered and estimated water use within 4, 5 and 6 miles of Lake Jackson

C. Purpose of Models

Prior to establishment of Minimum Levels, long-term lake stage percentiles are developed to serve as the starting elevations for the determination of the lake's High Minimum Lake Level and the Minimum Lake Level. A critical task in this process is the delineation of a Historic time period. The Historic time period is defined as a period of time when there is little to no groundwater withdrawal impact on the lake, and the lake's structural condition is similar or the same as present day. The existence of data from a Historic time period is significant, since it provides the opportunity to establish strong predictive relationships between rainfall, groundwater withdrawals, and lake stage fluctuation that represent the lake's natural state in the absence of groundwater withdrawals. This relationship can be used to calculate Long-term Historic lake stage exceedance percentiles such as the P10, P50, and P90, which are, respectively, the water levels equaled or exceeded ten, fifty, and ninety percent of the time. If data representative of a Historic time period do not exist, or available Historic time period data is considered too short to represent long-term conditions, then a model is developed to approximate Long-term Historic data.

In the case of Lake Jackson and Little Lake Jackson, withdrawals throughout the area have potentially affected water levels in the lake since the early 1940s. No data from the lakes exist prior to the initiation of groundwater withdrawals. Therefore, the development of a water budget model coupled with a rainfall correlation model of the lake was considered essential for estimating long-term Historic percentiles, accounting for changes in the lake's drainage system, and simulating effects of changing groundwater withdrawal rates.

D. Water Budget Model Overview

The Lake Jackson and Little Lake Jackson water budget model is a spreadsheet-based tool that includes natural hydrologic processes and engineered alterations acting on the control volume of the lake. The control volume consists of the free water surface within the lake extending down to the elevation of the greatest lake depth. Using LiDAR and bathymetry data, a stage-volume curve was derived for the lake that produced a unique lake stage for any total water volume within the control volume.

The hydrologic processes in the water budget model include:

a. Rainfall and evaporation
b. Overland flow
c. Inflow and discharge via channels
d. Flow from and to the surficial aquifer

e. Flow from and to the Upper Floridan aquifer

The water budget model uses a daily time step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels. The water budget model for Lake Jackson and Little Lake Jackson was calibrated for the period from 1999 to 2015. This period provides a balance for utilizing available data for all components of the water budget and the desire to develop a long-term water level record.

E. Water Budget Model Components

Lake Stage/Volume

Lake stage-area and stage-volume estimates were determined by building a terrain model of the lake and surrounding watersheds. Lake bottom elevations and land surface elevations were used to build the model with LP360 (by QCoherent) for ArcGIS, ESRI's ArcMap 10.2 the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basin with the underlying lake basin morphology to develop one continuous three-dimensional (3D) digital elevation model. The 3D digital elevation model was then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the extent of the lake at its flood stage and working downward to the lowest elevation within the basin.

Precipitation

After a review of several rain gages in the area, rainfall data from ROMP 43X rainfall gage, Avon Park National Weather Service (NWS) gage, and NEXRAD (Next Generation Weather Radar) was used for the water budget model (Figure 10).

Data for ROMP 43X rainfall gage was used from January 1999 through December 2006. Missing daily rainfall totals were infilled using the Avon Park NWS gage. In a few cases where both above-mentioned rainfall gages were missing daily data, the Wauchula rainfall gage was used.

For the period January 2007 through December 31, 2015, an average of data from 12 NEXRAD pixels coinciding with the lake were used for the LOC model. NEXRAD is a network of 160 high-resolution Doppler weather radars controlled by the NWS, Air Force Weather Agency, and Federal Aviation Administration. Use of the NEXRAD data, rather than the more distant rain gages, resulted in an improved water budget model calibration.

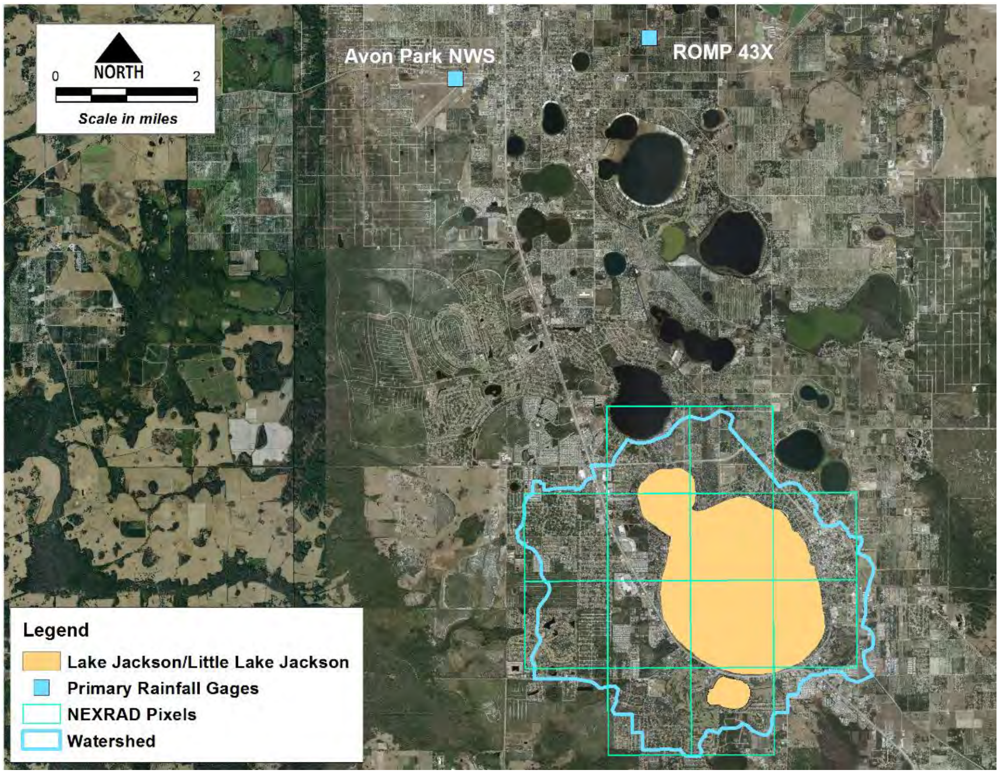


Figure 10. Rainfall Gages and NEXRAD grids assessed in the Lake Jackson water budget model

Lake Evaporation

Lake evaporation was estimated through use of monthly energy budget evaporation data collected by the U.S. Geological Survey (USGS) at Lake Starr in Polk County (Swancar et al., 2000) (Figure 11). Lake Starr is located approximately 31 miles to the north of Lake Jackson. The data were collected from August of 1996 through July of 2011. Monthly Lake Starr evaporation data were used in the water budget model when available, and monthly averages for the period of record were used for those months when Lake Starr evaporation data were not available.

Jacobs (2007) produced daily potential evapotranspiration (PET) estimates on a 2-square kilometer grid for the entire state of Florida. The estimates began in 1995, and are updated annually. These estimates, available from the USGS, were calculated through the use of solar radiation data measured by a Geostationary Operational Environmental Satellite (GOES). Because PET is equal to lake evaporation over open water areas, using the values derived from the grid nodes over the modeled lake was considered. A decision was made to instead use the Lake Starr evaporation data since the GOES data nodes typically include both upland and lake estimates, with no clear way of subdividing the two. It was thought that using the daily PET estimates based on the GOES data would increase model error more than using the Lake Starr data directly.

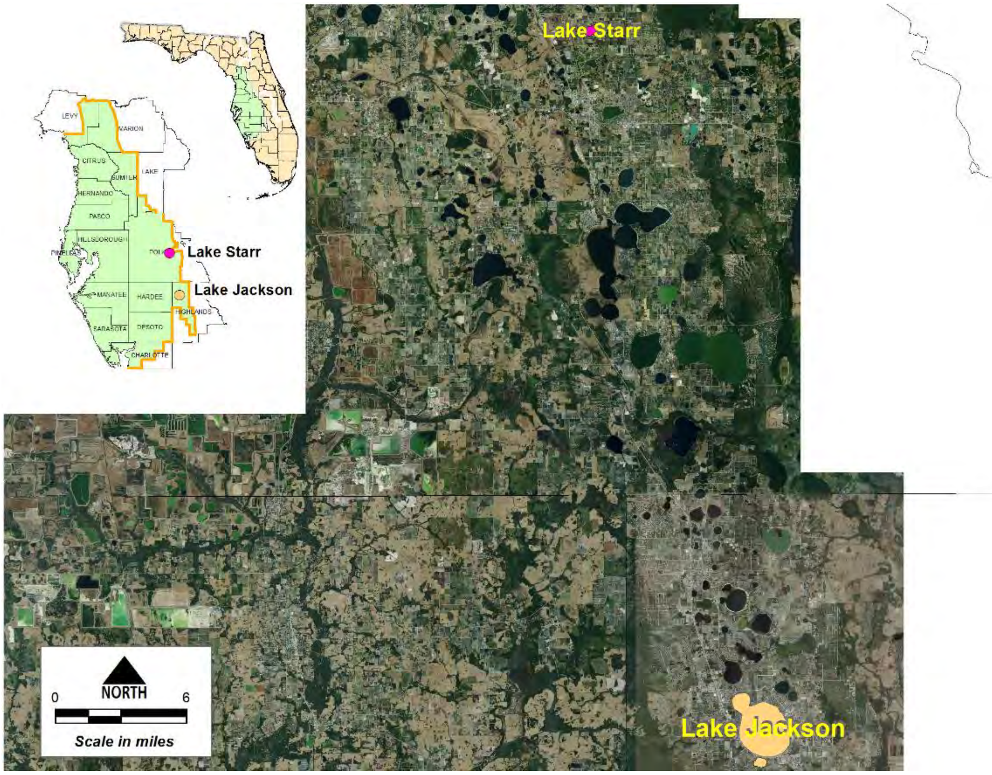


Figure 11. Location of Lake Jackson and Lake Starr

Overland Flow

The water budget model was set up to estimate overland flow via a modified version of the U.S. Department of Agriculture, Soil Conservation Service (SCS) Curve Number method (SCS, 1972), and via directly connected impervious area calculations. The free water area of the lake was subtracted from the total watershed area at each time step to estimate the watershed area contributing to surface runoff. The directly connected impervious area (DCIA) is subtracted from the watershed area for the SCS calculation, and then added to the lake water budget separately. Additionally, the curve number (CN) chosen for the watershed of the lake only represents the portion of the watershed not accounted for with DCIA.

The modified SCS method was described and suggested for use in Florida by CH2M HILL (2003), and has been used in several other analyses. The modification adds a fourth category of antecedent moisture condition (AMC) to the original SCS method (SCS, 1972) to account for Florida's frequent rainfall events.

The lake is located in the Intraridge Valley within the Lake Wales Ridge. Land elevations are higher on each side of the lake with exception to the southern portion of the lake. Several slightly varying estimates of watershed boundaries have been performed in the past for different modeling efforts in the area. One of the most recent set of estimates was developed as part of an effort to evaluate the City of Sebring watershed (BCI, 2005). These watershed area values were adopted for the Lake Jackson and Little Lake Jackson model (Table 1) after an independent check confirming that they are reasonable for modeling purposes (Figure 12).

The DCIA and SCS CNs used for the direct overland flow portion of the watershed are listed in Table 1. The soils in the immediate lake watershed are mostly “A/D” and “A” soils. The land use within the lake watershed is mostly medium/high density residential. A curve number (model calibration parameter) of 63 was used in the model and was considered reasonable given the local soil types, land use types and hydrologic conditions. The DCIA parameter was used in addition to the curve number parameter to account for connected impervious areas that provide direct runoff to the lake through storm water systems. There are several directly connected drains for street and residential storm water. It was estimated that 25 percent of the watershed (model calibration parameter) is directly connected impervious area, which was considered reasonable given current land use types.

Table 1. Model inputs for the Lake Jackson water budget model

Input Variable	Value
Overland Flow Watershed Size (acres)	10,287
SCS CN for watershed	63
Percent Directly Connected Area	25%
Upper Floridan Aquifer Monitor Well Used	ROMP 43XX and ROMP 29A
Surficial Aquifer Monitor Well Used	Ridge WRAP H-4 Surficial
Upper Floridan Aquifer Leakance Coefficient (ft/day/ft)	0.0003
Surficial Aquifer Leakance Coefficient (ft/day/ft)	0.0013
Outflow K	0.035
Outflow Invert (ft NGVD 29)	102.6
Inflow K	0.015
Inflow Invert (ft NGVD 29)	106.5

Figure 12. The Lake Jackson/Little Lake Jackson watershed

Inflow and Discharge via Channels from Outside Watersheds

Inflow and outflow via channels from the watershed or to the watershed (hence referred to as "channel flow") occur and are incorporated into the water budget model for Lake Jackson and Little Lake Jackson. Channel inflow occurs at Lake Jackson from Lake Sebring, located north of Lake Jackson. The inflow structure to Lake Jackson is a fixed sheet pile structure. The top elevation of the structure is 108.2 feet NGVD29. There is a 6-foot notch on the structure where channel inflow occurs. The elevation of the notch is 106.5 feet NGVD29. As-built information regarding the Sebring-to-Jackson structure was provided by Highlands County.

Channel outflow occurs at a concrete sharp crested weir located at the southeast portion of Little Lake Jackson. The weir is 30 feet wide and the control elevation is 102.6 feet NGVD29 (AIM, 2016).

Flow from and into the surficial aquifer and Upper Floridan aquifer

Water exchange between Lake Jackson and Little Lake Jackson and the underlying aquifers is estimated using a vertical leakance coefficient and the head difference between the lake and the aquifer levels. For each day of the simulation period, surficial aquifer and Upper Floridan aquifer leakage volumes were calculated independently. Leakance coefficients for each aquifer were then determined through calibration.

ROMP 43XX and ROMP 29A Avon Park PZ Upper Floridan Monitor Well

The ROMP 43XX Upper Floridan aquifer well and ROMP 29A Avon Park PZ well were used to represent the Upper Floridan aquifer potentiometric surface at the lake (Figures 3 and 4). During the water budget model calibration period data was collected hourly at the ROMP 43XX Upper Floridan aquifer well. The well was used until September 2008 when data collection began at ROMP 29A Avon Park PZ well on a bi-monthly basis. Missing data for both wells were infilled linearly. The ROMP 43XX Upper Floridan aquifer well is located approximately 6.2 miles north of Lake Jackson and the ROMP 29A Avon Park PZ well is located approximately 1.6 miles to the east. Due to the distances from the wells to the lake, an offset was subtracted to the data collected at the well. The offset for the ROMP 43XX well was 10.5 feet and the offset for the ROMP 29A well was 4.5 ft. The offsets were calculated by averaging the potentiometric surfaces in the Upper Floridan aquifer at the well and lake and taking the difference of the averages. The potentiometric surfaces were generated by the United States Geological Survey (USGS) on a biannual schedule of May and September in order to represent the wet and dry condition for each year. The USGS created potentiometric surfaces within the District annually from 2000 to 2011. Since the water budget model for Lake Jackson extends back to 1999, each of the given May and September potentiometric surface maps were used to calculate the offset.

RIDGE WRAP H-4 Surficial Aquifer Monitor Wells

The RIDGE WRAP H-4 surficial aquifer monitor well data are monthly. The well is located approximately 1.8 miles south of Little Lake Jackson along the western portion of the Lake Wales Ridge (Figures 3 and 4). Due to the distance of the well to the lake, an offset of 27.7 feet was applied to the well. The offset was calculated by averaging the monthly water levels at the well and the lake and taking a difference of the averages. Data collection at this well begin in April 1991. Linear infilling was used to infill missing data to create daily values needed for the water budget model.

F. Water Budget Model Calibration

The primary reason for the development of the water budget model was to estimate Historic lake stage exceedance percentiles that could be used to support development of Minimum and Guidance Levels for the lake. Model calibration was therefore focused on matching long-term percentiles based on measured water levels, rather than short-term high and low levels. Model calibration statistics that are reported are based on comparison of pairs of daily measured and modeled water levels.

Figure 13 presents the calibration results of the model. Table 2 presents a comparison of the percentiles of the measured data versus the model results. Table 3 presents the modeled water budget components for the calibration period.

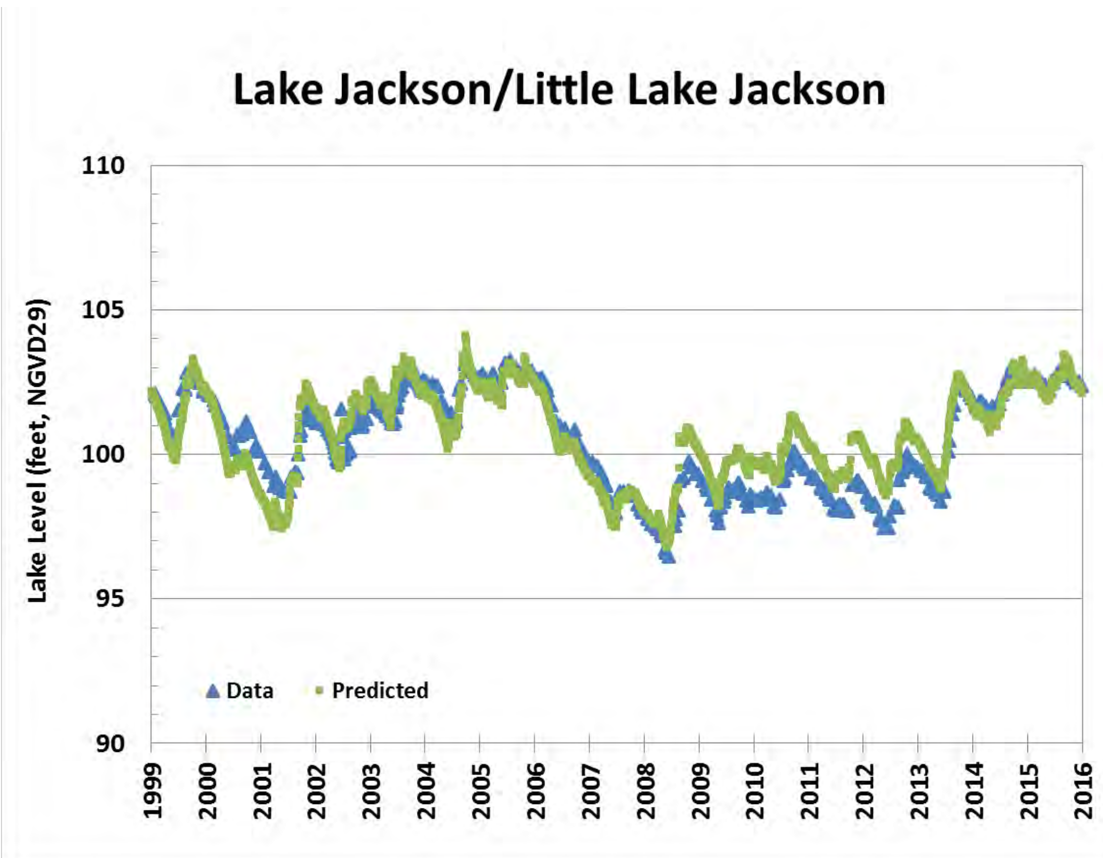


Figure 13. Modeled water levels predicted for the calibrated Lake Jackson and Little Lake Jackson water budget (Predicted) and measured levels used for the model calibration (Data)

Table 2. Comparison of percentiles of measured lake level data compared to calibration percentiles from the model (all in feet NGVD 29)

	Data	Model
P10	102.7	102.7
P50	101.1	101.1
P90	98.3	98.8

Table 3. Lake Jackson Water Budget (2006-2015)

Inflows	Rainfall	Surficial Aquifer Ground-water Inflow	Floridan Aquifer Ground-water Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
In/yr	49.9	4.6	0.0	7.4	26.4	4.4	92.6
%	53.9	4.9	0.0	7.9	28.4	4.8	*100.0
Outflows	Evap-oration	Surficial Aquifer Ground-water Outflow	Floridan Aquifer Ground-water Outflow			Outflow via channel	Total
In/yr	58.1	1.1	28.1			5.4	92.6
%	62.7	1.2	30.3			5.8	*100.0

* Percentage in columns do not add to 100% in this table due to rounding to tenths of a foot.

G. Water Budget Model Calibration Discussion

Based on visual inspection of Figure 13 the model appears to be reasonably well calibrated. There are a few periods when the peaks or lows in the modeled hydrograph are slightly higher or lower than the measured values, and these differences contributed to minor differences between the modeled and measured percentiles associated with the P90 percentile. Data limitations in the extreme ranges of the topography/bathymetry used to develop stage-volume estimates may also have contributed to the percentile difference.

A review of Table 2 shows no differences in medians (P50) and the P10 percentile between the data and model for the lake. The difference in measured and water budget model predicted P90 percentiles is 0.5 (with model being higher for both). This minor difference could be attributed to inaccuracies in rainfall estimates caused by the distance between rainfall gages and the lake during certain time periods or data collection frequency or issues.

The water budget model results are presented in terms of inches per year over the average lake area for the period of the model run, which can be difficult to comprehend at first. For example, runoff for the entire watershed is applied to the smaller lake area, which makes the value appear high until the differences in application area are considered. Leakage rates (and leakance coefficients), as another example, represent conditions below the lake base only, and may not be representative of the entire watershed. Professional judgement and decisions were used to match the modeled lake levels with observed data and arrive at the ultimate goal of developing a calibrated model. Even though data gaps as well as uncertainties in the values of model parameters have caused some differences between the model and observed data, the model is reasonably well calibrated and can be used to estimate the long term historic percentiles.

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the Lake Jackson and Little lake Jackson water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. When a relationship between withdrawal rates and Upper Floridan aquifer potentiometric levels can be established, the effect of changes in groundwater withdrawals can be estimated by adjusting Upper Floridan aquifer levels in the model.

Determining the amount of Upper Florida Aquifer drawdown that has occurred due to groundwater withdrawals involved the use of a regional groundwater model and analysis of water level data. The East-Central Florida Transient (ECFT) groundwater model (Sepulveda, et al., 2012 and CFWI, 2014) was used to quantify changes in water levels in response to changes in groundwater withdrawals. This was accomplished using a series of model runs whereby recent withdrawals and irrigation amounts were reduced by 25 percent, 50 percent, and 75 percent. This approach enabled the model to be used within the range of withdrawals that were used during the calibration phase. For the reassessment of minimum levels, the reduced pumping scenarios used a Reference Condition as a basis for comparing model reduction scenarios. The Reference Condition was based on the amount of groundwater withdrawals needed to meet the demands for water that existed as of 2005. Pumping amounts for each year and month of the 12 year transient model run were varied according to rainfall that occurred during each month. As a result of the model scenarios it was estimated that modeled groundwater withdrawals have lowered Upper Floridan aquifer water levels about 6.5 feet beneath Lake Jackson.

Because there are no Upper Floridan wells in the immediate area of Lake Jackson, the assessment focused on changes occurring at the Lake Alfred Deep well near Lake Alfred, Coley Deep, ROMP 60 and the ROMP 73 sites. Water levels for the ROMP 73 well were extended back to the 1950s using available data from the other well sites. One issue associated with this type of analysis is that the water level data do not extend back in time when pumping was zero, whereas the change represented by the model reflects a period of no pumping. Average annual water level changes represented by the data were based on comparison of recent (1990 to 2014) levels to the period prior to and including 1960. For the Lake Alfred well, model results were 2.2 feet compared to 2.9 feet when looking at the data and for the Coley Deep well, the model indicated 7.4 feet compared to a change of 9.2 feet when looking at the data. These results are generally consistent, especially considering the data shows slightly more change which is likely due to the differences in rainfall recharge between the two periods that is not represented in the model. Results for the ROMP 60 and ROMP 73 well sites were less certain and likely influenced by their locations relative to model boundaries.

For use in the water budget model, it was recommended that 6.5 feet of drawdown be used (Barcelo, 2016). This accounts for increases in pumping amounts that have occurred within one mile of the lake during and beyond the period used for the model. Given the diverse and dispersed nature of groundwater withdrawals affecting the lake, it was difficult to determine a multi-period correction for groundwater impacts.

With respect to the surficial aquifer, the relationship between the Leakance coefficient and the ratio of surficial aquifer to Upper Florida aquifer drawdowns established for previous modeling efforts was used. From the water budget model, the Leakance coefficient was 0.0003 feet/day/feet which resulted in a ratio of surficial to Upper Floridan drawdown of 0.37. The calculated recovery in the surficial aquifer is 2.4 feet as determined by the product of the ratio (0.37) and the estimated Upper Floridan aquifer recovery amount (6.5 feet).

Figure 14 presents the results of the calibrated water budget model for Lake Jackson and Little Lake Jackson with and without the effects of groundwater withdrawals. Table 4 presents the percentiles based on the model output.

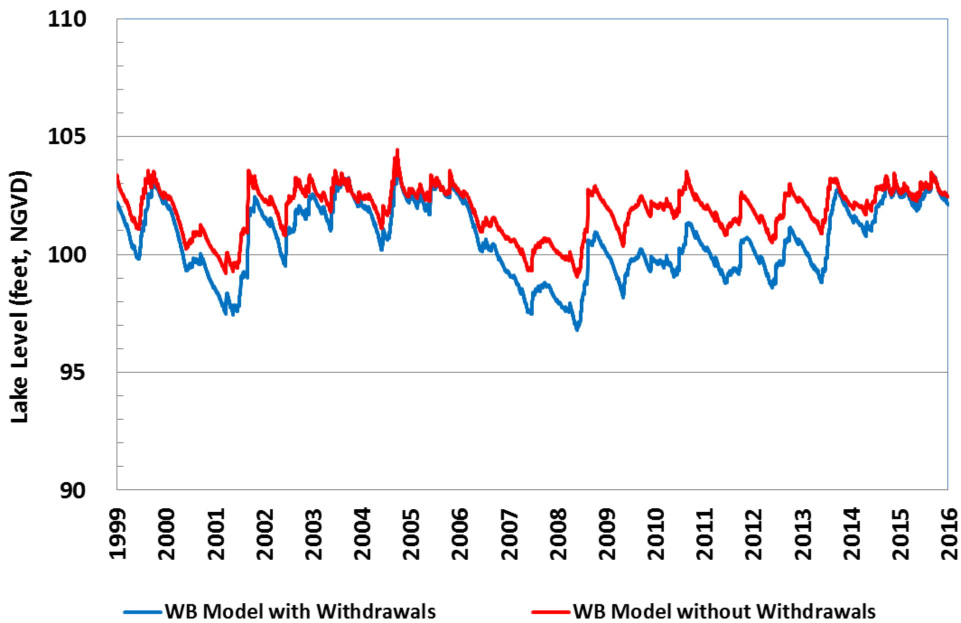


Figure 14. Calibrated Water Budget Model for Lake Jackson and Little Lake Jackson with and without the effects of withdrawals

Table 4. Historical lake level percentiles determined using the water budget model (feet NGVD 29)

Percentile	Elevation
P10	103.0
P50	102.3
P90	100.6

J. Rainfall Regression Model

In an effort to extend the period of record of water levels used to determine the Historic percentiles to be used in the development of the Minimum Levels, a line of organic correlation (LOC) was performed using the results of the water budget model and long-term rainfall data. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. By using this technique, the limited years of calibrated model water levels can be projected back to create a simulated data set representing over 60 years of lake levels, based on the relationship between modeled water levels and actual rainfall.

In this application, the simulated lake water levels representing Historic conditions were correlated with long-term rainfall data. For the rainfall regression analysis, additional representative rainfall records were added to the rainfall data used in the water budget model (1999-2015), extending the rainfall record back to 1946. The record consisted of daily rainfall measurements from the Avon Park 2 W NWS rain gage from January 1946 through 1997. The ROMP 43X rain gage was used from 1997 through 2007. Both rain gages are located approximately six miles north of Lake Jackson. An average of NEXRAD data over the immediate watershed was used from January 2007 through 2015. Locations of rainfall gages and NEXRAD data used are shown on Figure 10. The Wauchula NWS rain gage to the west of the lake was used to fill in a few missing data points where both the Avon Park and ROMP 43X gages were missing data.

Rainfall data were correlated to lake water level data by applying a linear inverse weighted sum to the rainfall. The weighted sum gives higher weight to more recent rainfall and less weight to rainfall in the past. In this application, weighted sums varying from 6 months to 10 years were separately used, the results were compared, and the weighted rainfall series with the highest coefficient of determination (R^2) was chosen as the best model.

The goal of this step in the analysis is to develop an LOC model that simulates Long-term water levels under the current structural conditions and without the effects of groundwater pumping. The water budget model results used in the LOC model were limited to a period of relatively consistent groundwater impacts from 1999 to 2016. For this assessment, the final 2-year weighted model had the highest coefficient of determination, with R^2 of 0.89. The results are presented in Figure 15.

In an attempt to produce Historic percentiles that apply significant weight to the results of the water budget models, the rainfall LOC results for the period of the water budget model are replaced with the water budget model results. Therefore, the LOC rainfall model results are used for the period of 1946 through 1998, while the water budget results are used for the period of 1999 through 2015. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Table 5. Note that the difference between the P10, P50, and P90 percentiles from the water budget model (Table 4) and those from the hybrid rainfall model (Table 5) for Lake Jackson are 0.6 and 0.1 for the P10 and P90, respectively (with the hybrid model being higher) and 0.3 for the P50 (with the water budget model being higher).

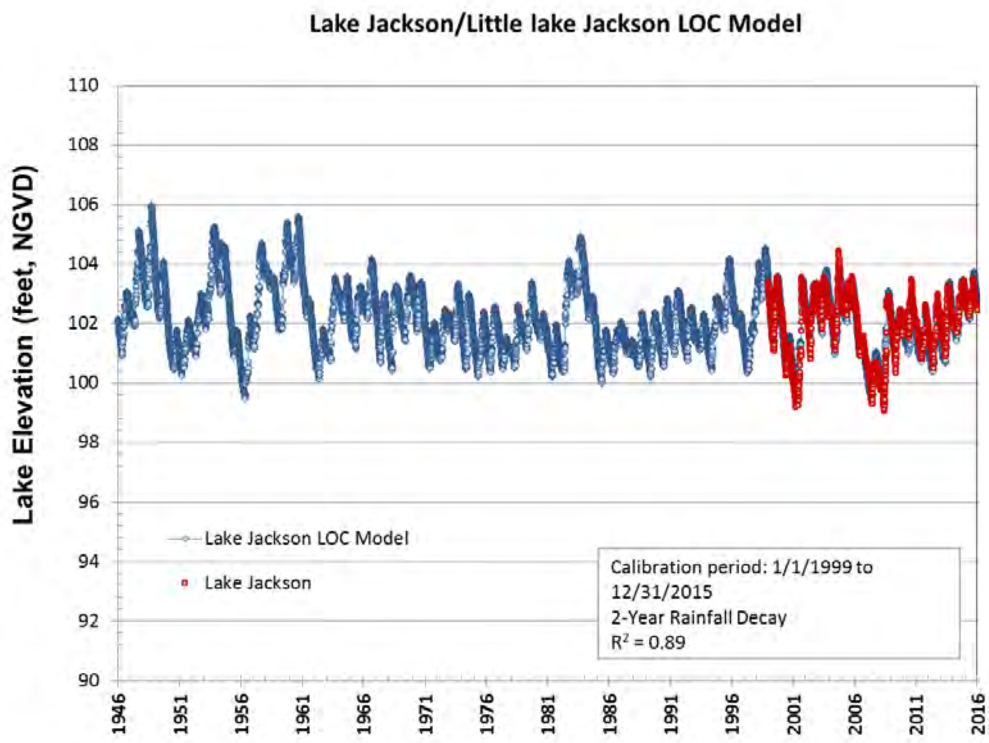


Figure 15. LOC model results for Lake Jackson and Little Lake Jackson

Table 5. Historic percentiles as estimated using the hybrid model from 1946 to 2015 (feet NGVD 29).

Percentile	Lake Jackson
P10	103.5
P50	102.0
P90	100.7

J. Conclusions

Based on the model results and the available data, the Lake Jackson water budget and LOC rainfall models are useful tools for assessing long-term percentiles in the lake. Based on the same information, lake stage exceedance percentiles developed through use of the models appear to be reasonable estimates for Historic conditions.

K. References

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Appendix B

Draft Technical Memorandum

November 17, 2016

TO: Jerry L. Mallams, P.G., Manager, Water Resources Bureau

FROM: Jason G. Patterson, Hydrogeologist, Water Resources Bureau
Mark Hurst, Senior Environmental Scientist, Water Resources Bureau

Subject: Lake Jackson and Little Lake Jackson Initial Minimum Levels Status Assessment

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A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Lake Jackson and Little Lake Jackson and is proposing revised minimum levels for both lakes, in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the revised minimum levels is provided by Patterson and Ellison (2016) and Hurst and others (2016).

Section 373.0421, F.S. requires that a recovery or prevention strategy be developed for all water bodies that are found to be below their minimum flows or levels, or are projected to fall below the minimum flows or levels within 20 years. In the case of Lakes and other waterbodies with established minimum flows or levels in the Southern Water Use Caution Area (SWUCA), an applicable regional recovery strategy, referred to as the SWUCA Recovery Strategy, has been developed and adopted into District rules (Rule 40D-80.074, F.A.C.). One of the goals of the SWUCA Recovery Strategy is to achieve recovery of minimum flow and level water bodies such as Lake Jackson and Little Lake Jackson. This document provides information and analyses to be considered for evaluating the status of the revised minimum levels proposed for Lake Jackson and Little Lake Jackson and any recovery that may be necessary for the lake.

B. Background

Lake Jackson and Little Lake Jackson are located in northwest Highlands County. Lake Jackson is located east of US Highway 27 and is connected to Little Lake Jackson via a canal located on the south side of Lake Jackson under U.S. Highway 27 (Figure 1). The lakes are within the Peace River Basin.

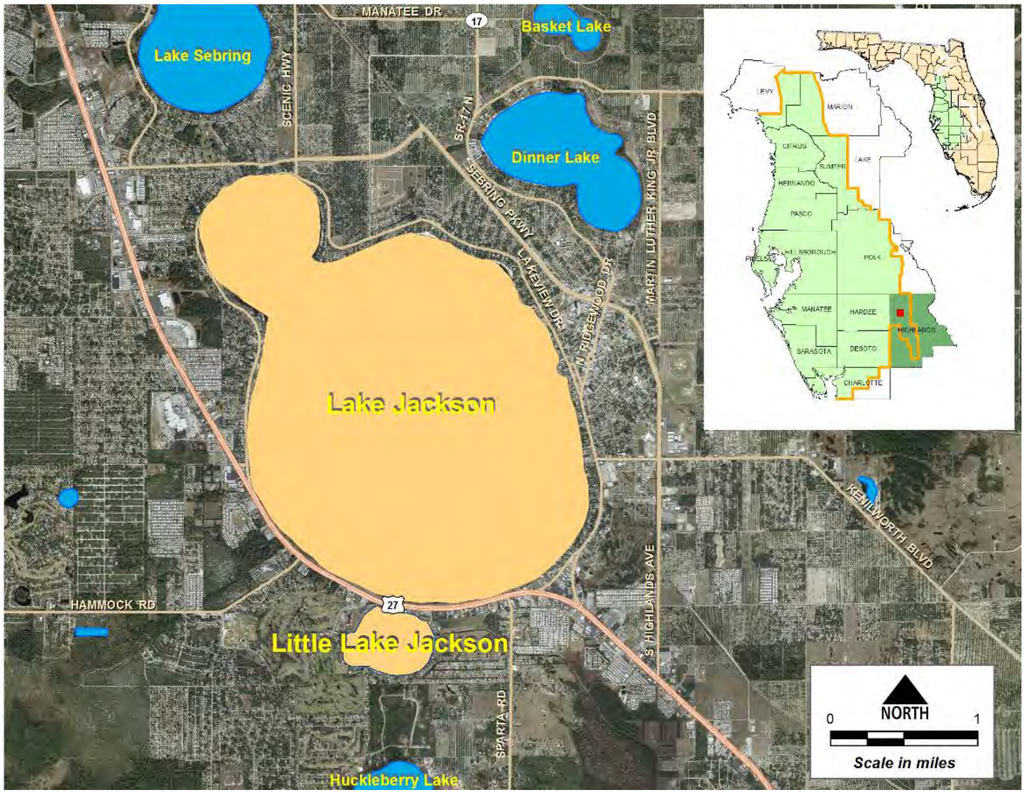

Figure 1. Location of Lake Jackson and Little Lake Jackson, Highlands County, Florida

C. Minimum Levels Proposed for Lake Jackson and Little Lake Jackson

Minimum levels proposed for Lake Jackson and Little Lake Jackson are presented in Table 1 and discussed in more detail by Hurst and others (2015). Minimum levels represent long-term conditions that if achieved, are expected to protect water resources and the ecology of the area from significant harm that may result from water withdrawals. The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. The Minimum Lake Level therefore represents the required 50th percentile (P50) of long-term water levels, while the High Minimum Lake Level represents the required 10^{th} percentile (P10) of long-term water levels. To determine the status of minimum levels for Lake Jackson or minimum flows and levels for any other water body, long-term data or model results must be used.

Table 1. Proposed Minimum Levels for Lake Jackson.

Proposed Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	102.3
Minimum Lake Level	101.2

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Lakes Jackson and Little Jackson from 1999 through 2015, which was determined to represent the "Current" period. The Current period represents a recent "Long-term" period when hydrologic stresses (including groundwater withdrawals) and structural alterations are reasonably stable. For both lakes, structural alterations near the lake occurred in 1998 and have affected the water table at the lake. It is anticipated that the structural alterations will remain stable, and therefore 1999 through 2015 are considered to represent the "Current" period. "Long-term" is defined as a period that has been subjected to the full range of rainfall variability that can be expected in the future. As demonstrated in Patterson and Ellison (2016), groundwater withdrawals during this period were relatively consistent. To create a data set that can reasonably be considered to be "Long-term", a line of organic correlation (LOC) analysis was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used to develop the minimum levels for Lake Jackson and Little Lake Jackson (Patterson and Ellison, 2016). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing over 60 years of lake levels, based on the current relationship between lake water levels and actual rainfall.

The same rainfall data set used for setting the minimum levels for Lake Jackson and Little Lake Jackson was used for the status assessment. The best resulting correlation for the LOC model created with measured data was the 4-year weighted period, with a coefficient of determination of 0.82. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the same percentiles calculated directly from the measured lake level data for Lakes Jackson and Little

Jackson for the period from 1999 through 2015. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 17 years, rather than the longer-term rainfall conditions represented in the 1946 to 2015 LOC model simulations.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 1999 to 2015 data, and the revised minimum levels proposed for Lake Jackson and Little Lake Jackson.

Percentile	**Lake Stage/LOC Model Current Withdrawal Scenario Results** Elevation in feet NGVD 29	**1999 to 2015 Data** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	103.8	102.7	102.3
P50	100.9	101.1	101.2

A comparison of the LOC model with the minimum levels proposed for Lake Jackson indicates that the Long-term P10 is 1.5 feet above the proposed High Minimum Lake Level, and the Long-term P50 is 0.3 feet lower than the proposed Minimum Lake Level. The P10 elevation derived directly from the 1999 through2015 lake data is 0.4 feet above the proposed High Minimum Lake Level and the P50 elevation is 0.1 feet below the proposed Minimum Lake Level. Differences in rainfall between the shorter 1999 to 2015 period and the longer 1946 to 2015 period used for the LOC modeling analyses likely contribute to the differences between derived and measured lake stage exceedance percentiles. Additionally, differences between actual withdrawal rates and those used in the models may have contributed to some of the differences in the percentiles.

E. Conclusions

Based on the information presented in this memorandum, it is concluded that Lake Jackson and Little Lake Jackson water levels are currently below the Minimum Lake Level, and above the High Minimum Lake Level proposed for the lake. These conclusions are supported by comparison of percentiles derived from LOC modeled lake stage data with the proposed minimum levels.

Minimum flow and level status assessments are completed on an annual basis by the District and on a five-year basis as part of the regional water supply planning process.

F. References

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