Revised Minimum and Guidance Levels Based on Reevaluation of Levels Adopted for Lake Lotela in Highlands County, Florida

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Resource Evaluation Section
Water Resources Bureau
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Cover: Photograph of Lake Lotela, 1999 (Southwest Florida Water Management District files).

Contents

Introduction

Reevaluation of Minimum Flows and Levels

This report describes the development of revised minimum and guidance levels for Lake Lotela 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 previously adopted levels.

Lake Lotela was 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 previously adopted minimum levels for the lake were developed. Adopted levels for Lake Lotela 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.

Following Board approval on November 13, 2016, the revised levels became effective on April 20, 2017.

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 proposed 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 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).

With regard to 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 proposed 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 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 Lotela 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 (HP50), or the 50th percentile of historic data, 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 Lotela meets the classification as a Category 3 lake, 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 <u>Recreation/Ski Standard</u> 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 <u>Dock-Use Standard</u> 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 <u>Wetland Offset Elevation</u> 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) – 0.66log(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. (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 Lotela

Lake Setting and Description

Watershed

Lake Lotela (Figure 1) is located in Highlands County, Florida (Sections 25, 26, 35, 36, Township 33S, Range 28E) in the Peace River Basin within the Southwest Florida Water Management District.

Within the Peace River primary basin, the lake is in the Carter Creek watershed (Figure 2), and has a contributing watershed of 12.2 square miles (Florida Board of Conservation 1969). The lake has one main inlet along the western shore, delivering water from Lake Lelia, and one main outlet along the southeastern shore draining to Little Bonnet Lake (Figure 3). A second outlet, located along the northeast shore also drains Lake Lotela to a common canal to Little Bonnet Lake 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 1969, Shafer et al. 1986) lists the lake’s area at 802 acres at an elevation of 106 ft. A stage-volume relationship generated in support of minimum levels development also estimates the lake’s area to be 803 acres at the same elevation.

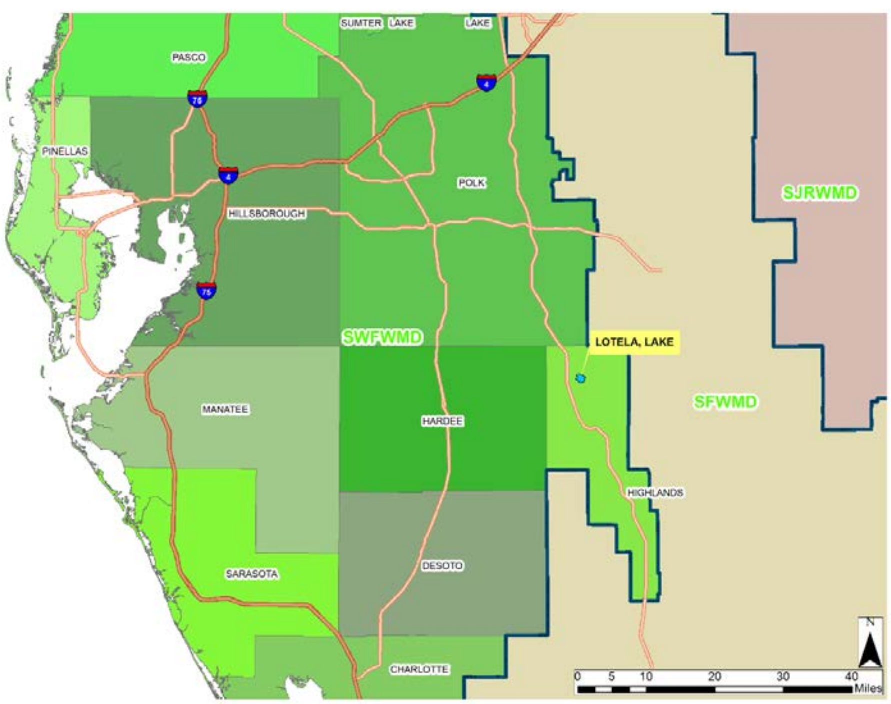

Figure 1: Location of Lake Lotela in Highlands County, Florida.

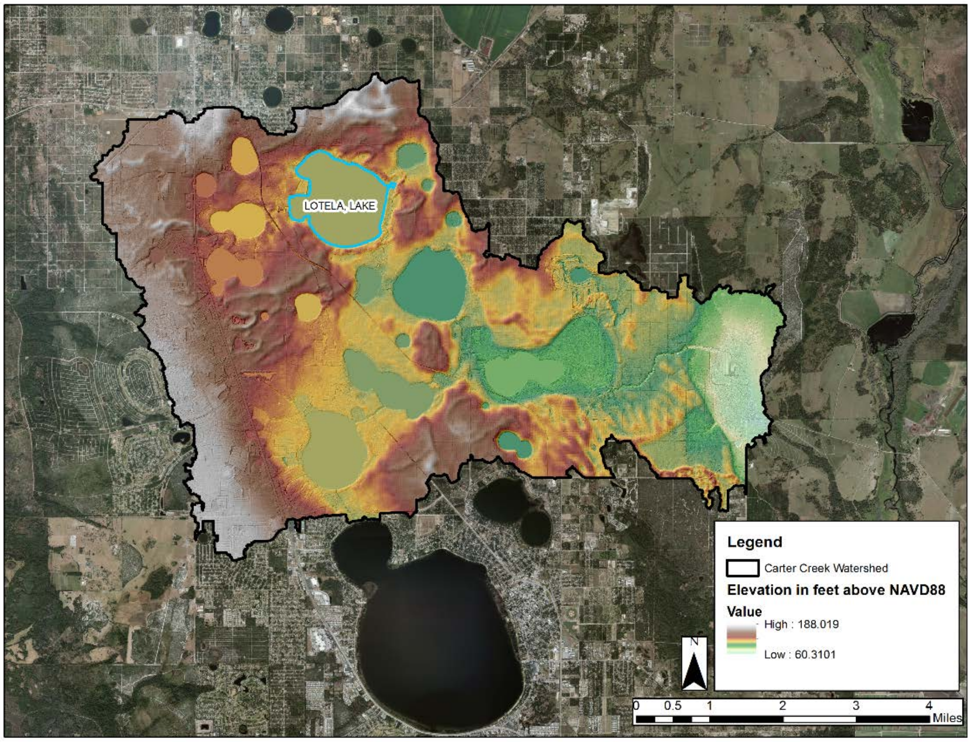

Figure 2: Watershed Delineation and Topography.

Figure 3: Location of Conveyance Systems and District Gages.

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 lake on all sides is primarily residential. There is also extensive crop land (orange groves) surrounding the lake. The southeast corner of the lake has been developed into a golf course, and there is a power plant located between the two coves on the western shore. A field reconnaissance in April 2016 indicated that this habitat along the lake shore was comprised primarily of *Panicum repens,* with some *Shinus* and *Typha* along the western shore*.* Figure 6 through Figure 11 aerial photography chronicles landscape changes to the immediate lake basin from 1944 through 2015.

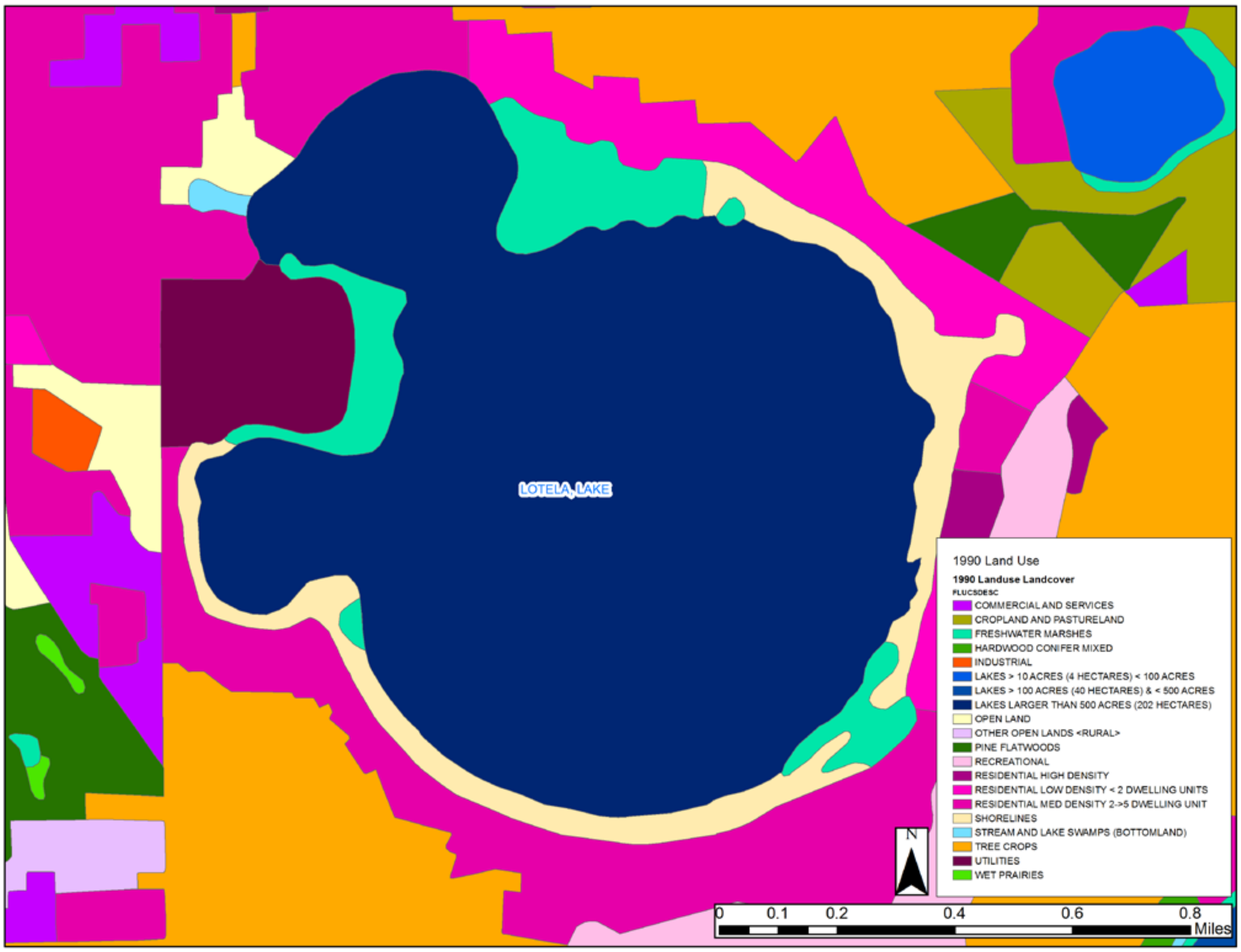

Figure 4: 1990 Land Use Land Cover Map of the Lake Lotela Vicinity.

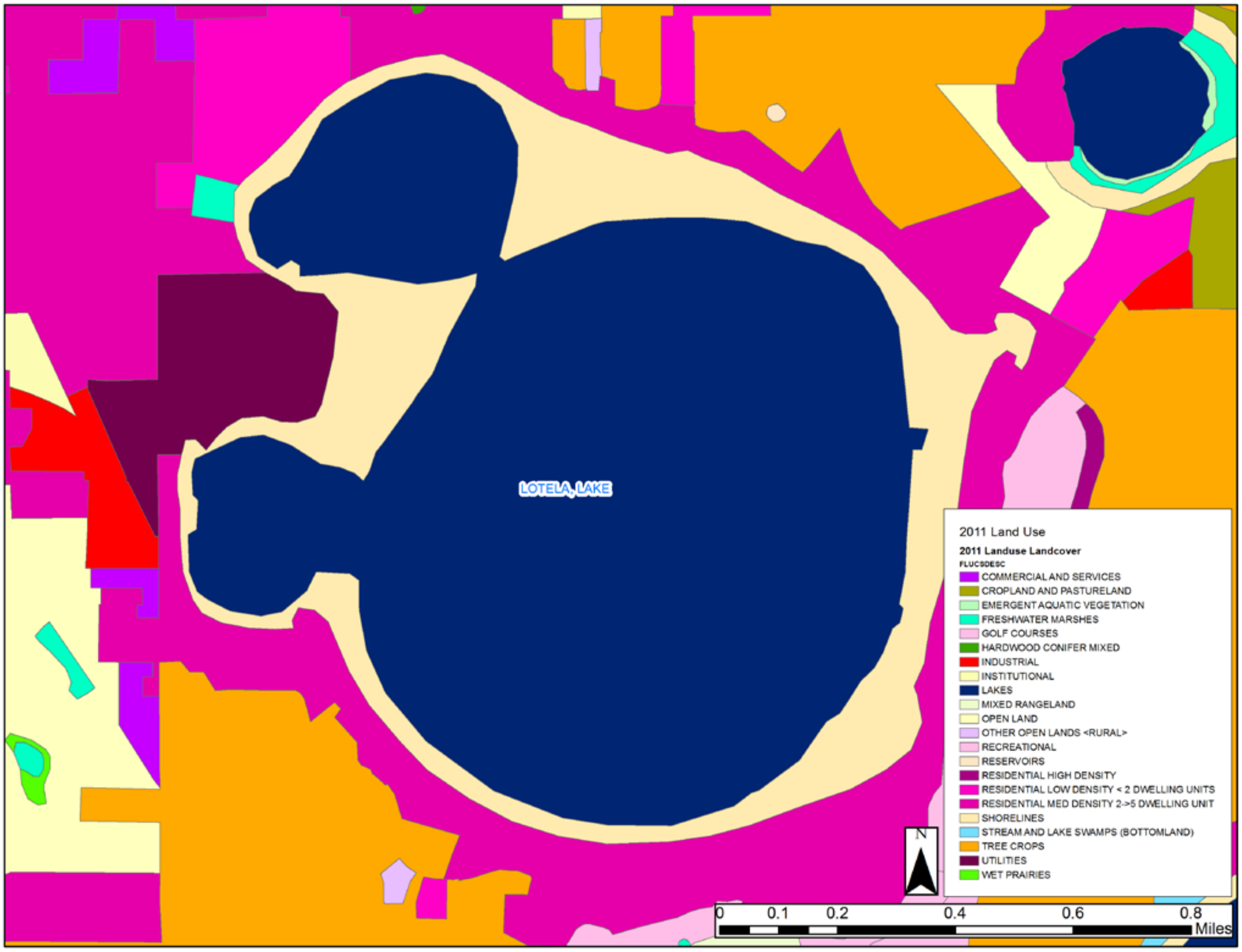

Figure 5: 2011 Land Use Land Cover Map of the Lake Lotela Vicinity.

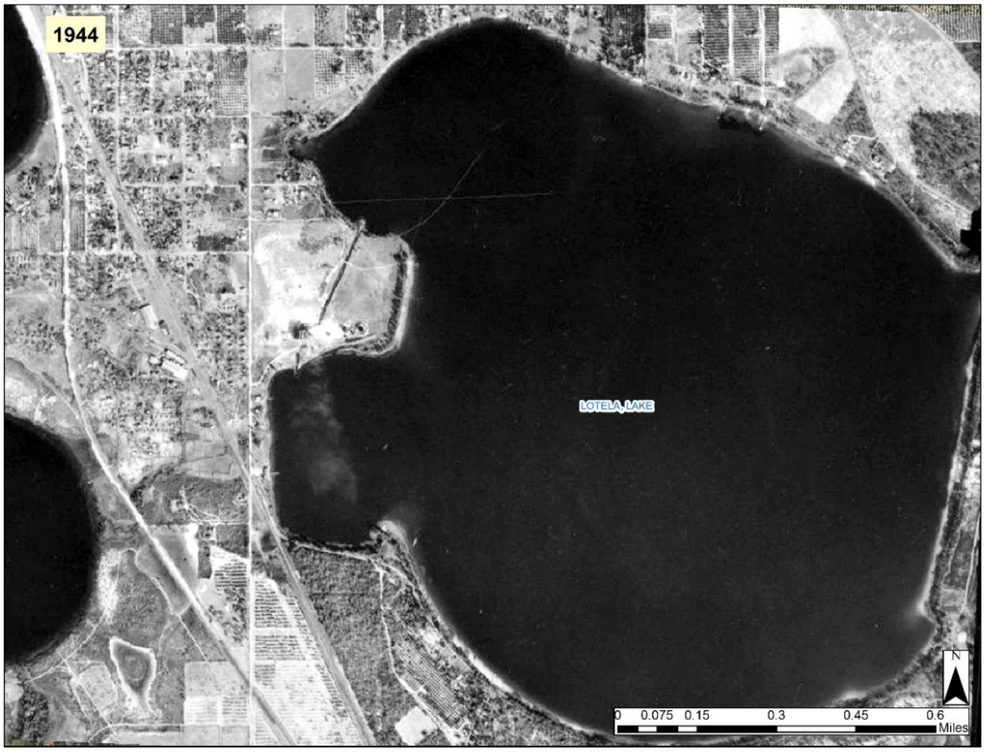

Figure 6: 1944 Aerial Photograph of Lake Lotela

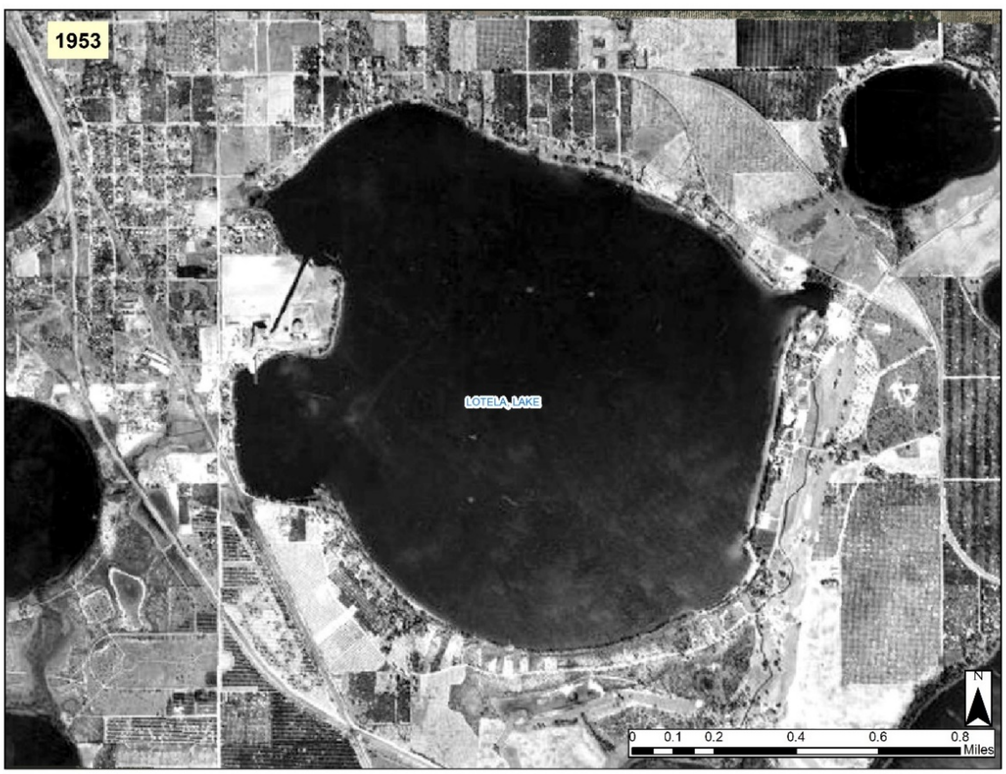

Figure 7: 1953 Aerial Photograph of Lake Lotela

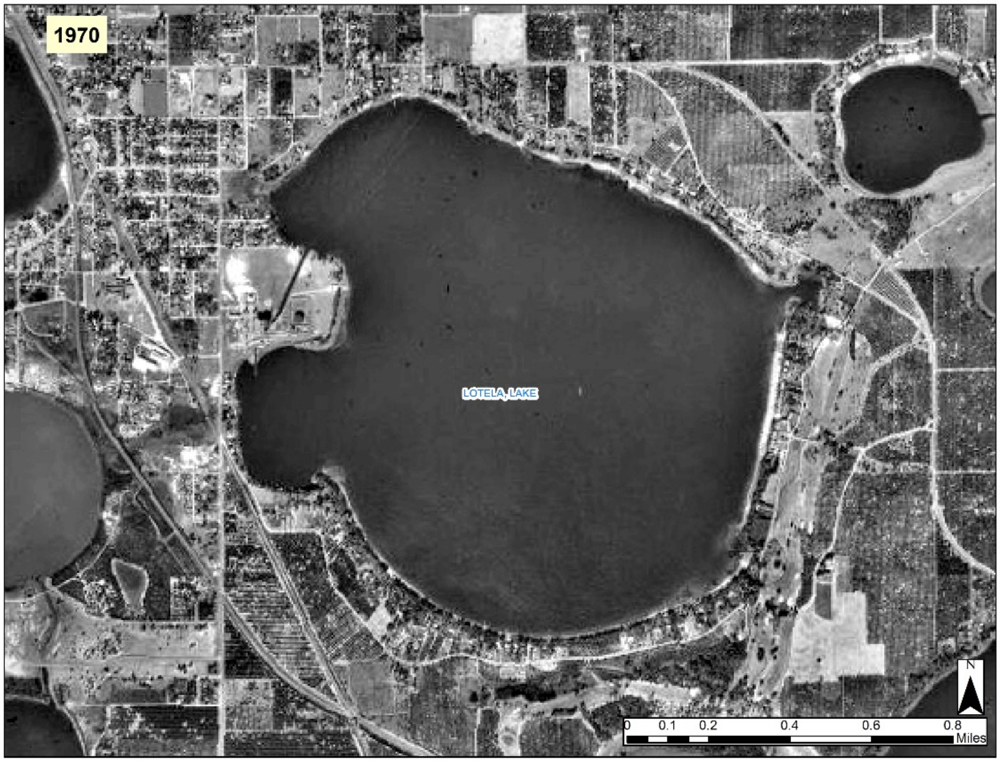

Figure 8: 1970 Aerial Photograph of Lake Lotela

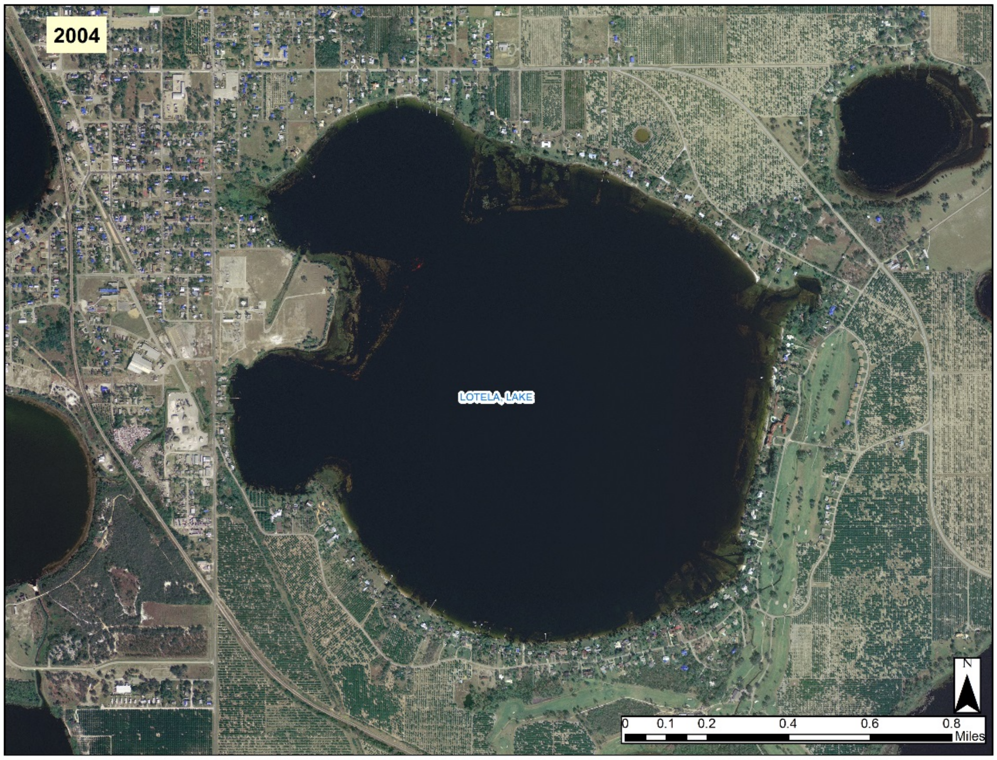

Figure 9: 2004 Aerial Photograph of Lake Lotela

Figure 10: 2008 Aerial Photograph of Lake Lotela

Figure 11: 2015 Aerial Photograph of Lake Lotela

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 three small holes in the southwest corner of the lake. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

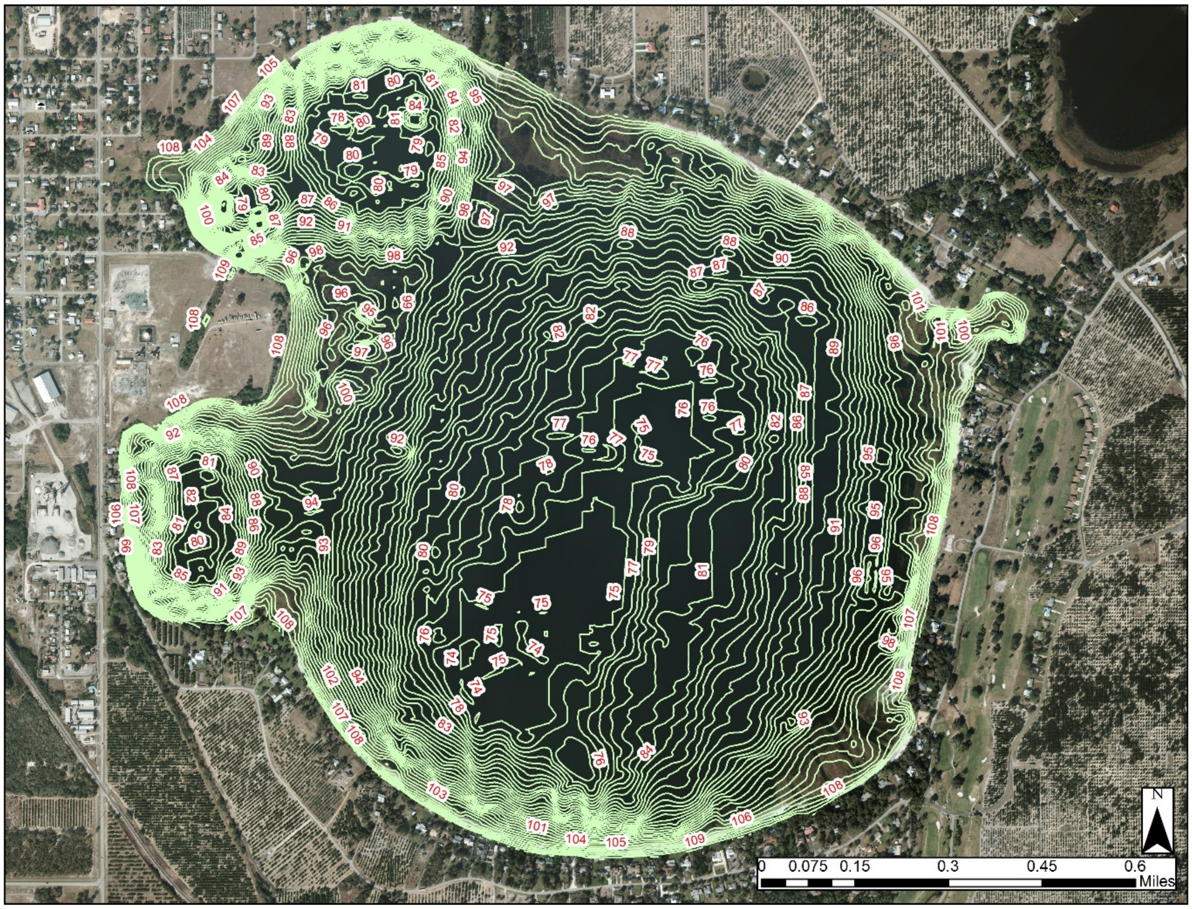

Figure 12: Lake Bottom Contours (ft., NGVD29) on a 2014 Natural Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Lake Lotela from the District's Water Management Information System (SID 25521) (Figure 13). Data collection began on September 8, 1950 and continues to be monitored on a monthly basis 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 was 109.38 ft. and occurred on July 25, 1954. The lowest lake stage elevation on record was 96.63 ft. and occurred on June 16, 2008.

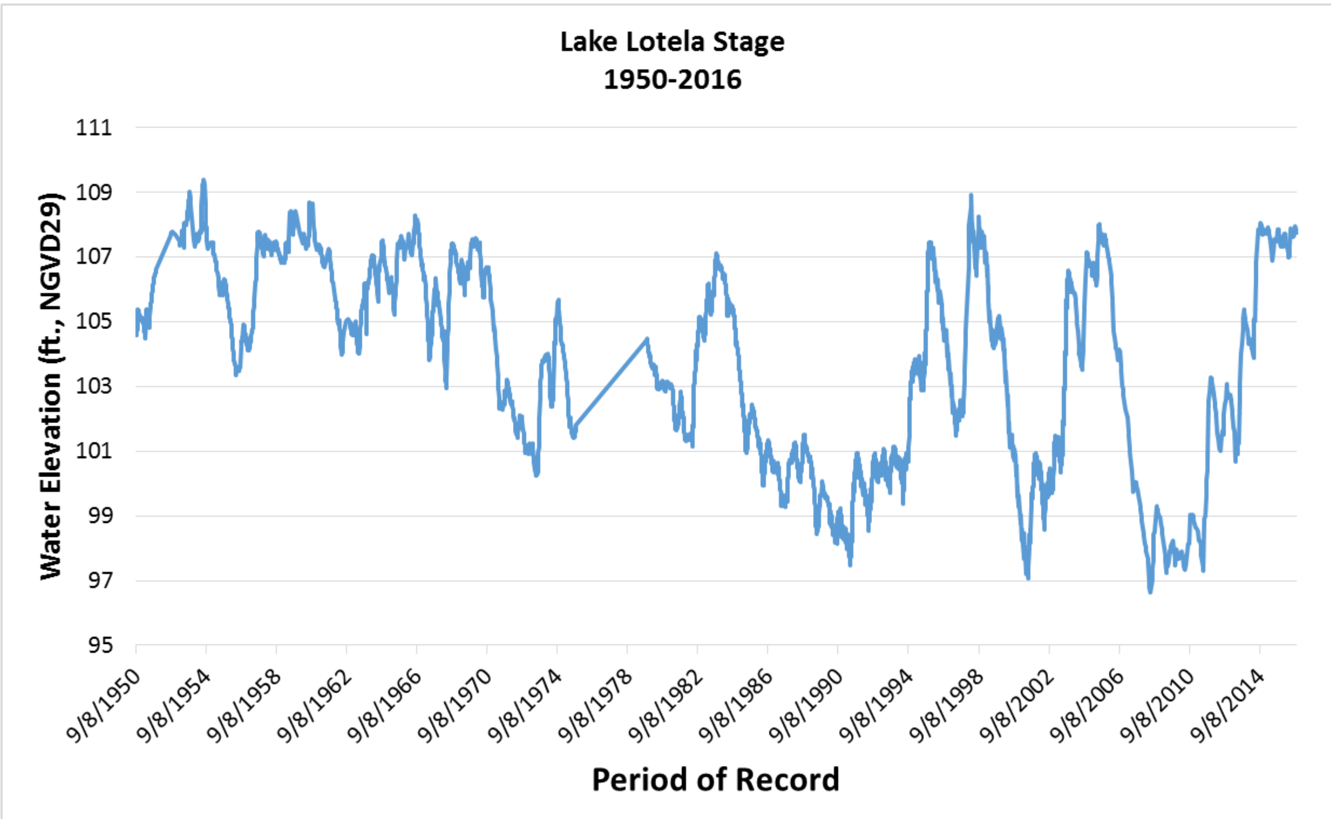

Figure 13: Lake Lotela Period of Record Water Elevation Data (SID 25521)

Historic 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 Lotela (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). Revised levels (Table 3) have since been incorporated into rule and have replaced those listed in Table 2.

Table 2: Guidance levels adopted December 2006 for Lake Lotela

Level	Elevation (ft., NGVD)
Ten Year Flood Guidance Level	108.5
High Guidance Level	107.5
High Minimum Level	106.8
Minimum Level	105.7
Low Guidance Level	105.0

Methods, Results and Discussion

The Minimum and Guidance Levels revised in this report were developed for Lake Lotela 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, and Significant Change Standards, revised Minimum and Guidance Levels associated surface areas for Lake Lotela.

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Historic P10 (1946 to 2013)	109.1	868
Historic P50 (1946 to 2013)	105.8	799
Historic P90 (1946 to 2013)	102.0	735
Revised Normal Pool and Control Point		
Normal Pool	NA	NA
Control Point	107.5	834
Significant Change Standards		
Recreation/Ski Standard	82.3	261
Dock-Use Standard	106.4	810
Wetland Offset Elevation	105.0	786
Aesthetics Standard	102.0	735
Species Richness Standard	99.4	681
Basin Connectivity Standard	98.3	654
Lake Mixing Standard	83.1	280
Revised Minimum and Guidance Levels		
High Guidance Level	109.1	868
High Minimum Lake Level	106.1	805
Minimum Lake Level	105.0	786
Low Guidance Level	102.0	735

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 Lotela 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 Lotela. 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.

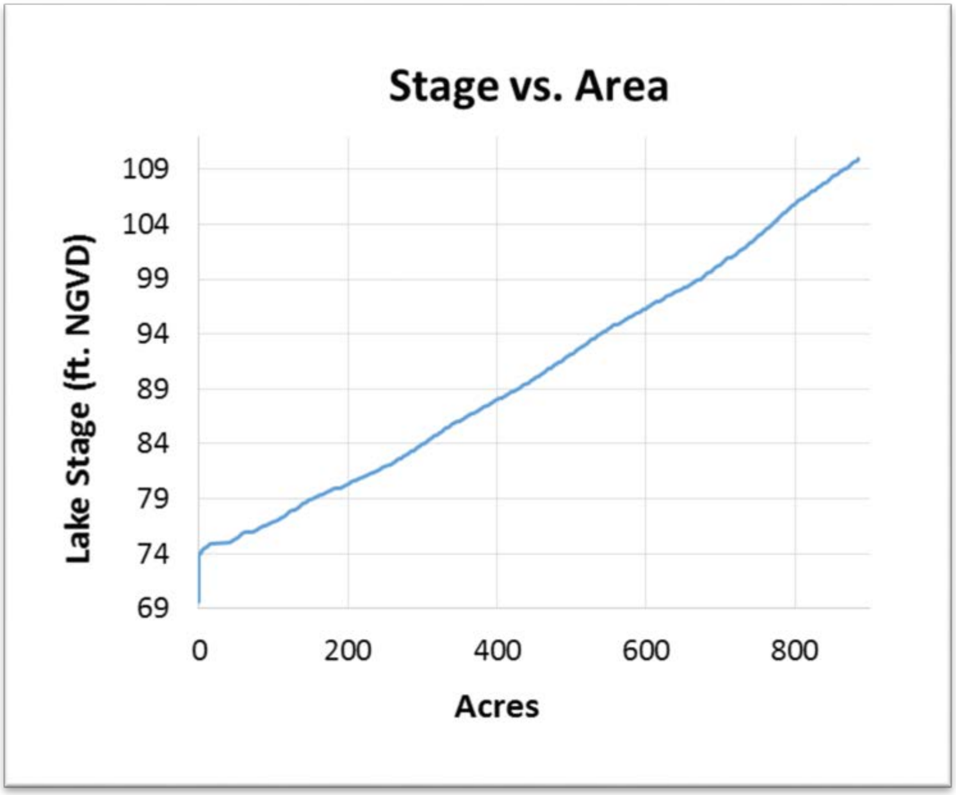

Figure 14: Lake Stage (Ft. NGVD29) to Surface Area (Acres).

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 Lotela 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 108.9 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 105.8 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 102.2 ft. (Figure 15 and Table 3).

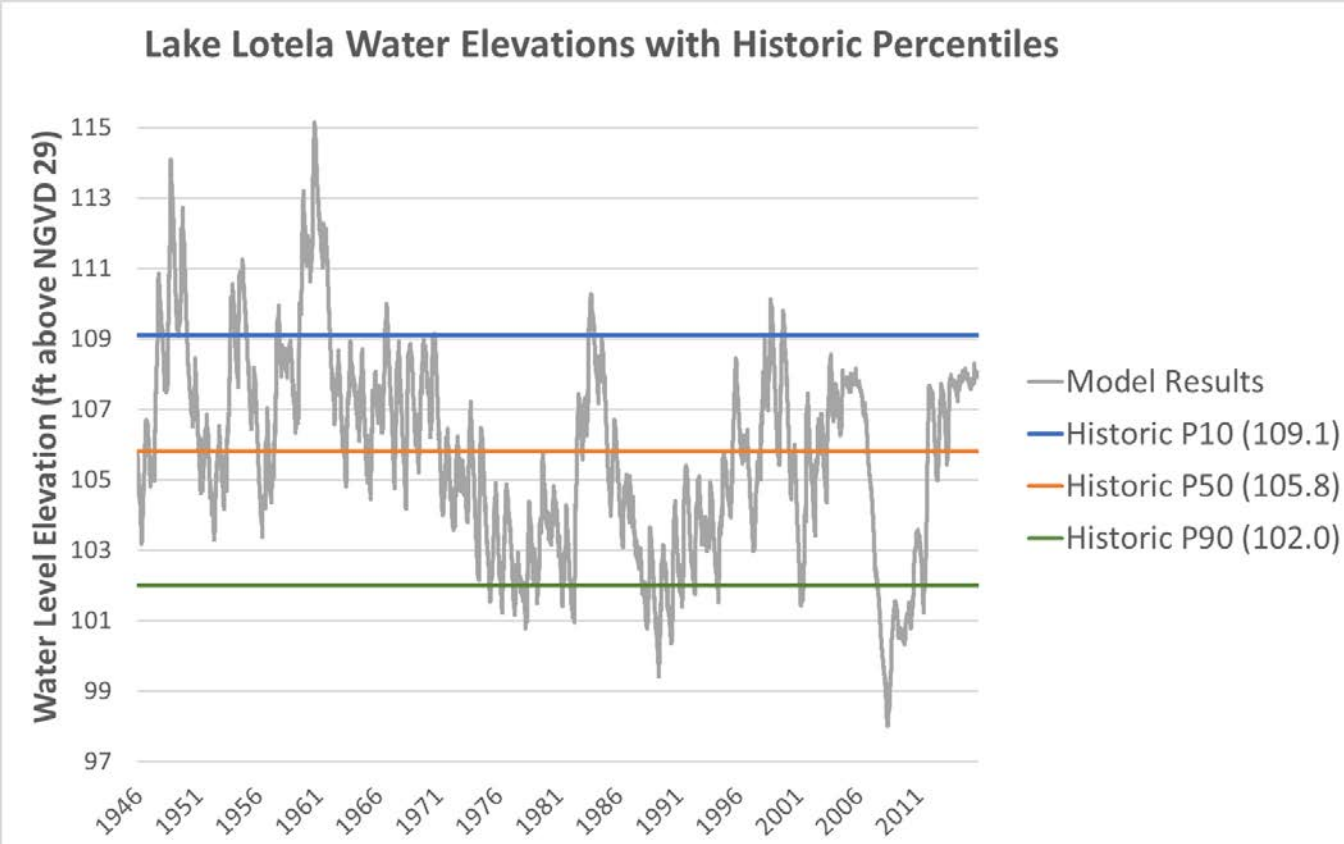

Figure 15: Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

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 Lotela does 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 107.5 ft., the elevation of a structure at the lake's outlet. The low floor slab, based on survey reports, was established at 110.01 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 Historic data developed for Lake Lotela, the revised High Guidance Level was established at the Historic P10 elevation, 109.1 ft. Gauged data indicate that the High Guidance Level has been exceeded a few times in the past, primarily in the spring and summer of 1954. The highest peak was 109.38 ft. in July 1954 (Figure 13, Figure 18).

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 Lotela, the revised Low Guidance Level was established at the Historic P90 elevation, 102.0 ft. The gaged period of record indicates the lowest recorded elevation was 96.63 ft., below the low guidance level, in June 2008 (Figure 13). The most recent record of the water level dropping below the low guidance level was in June of 2013, with a recorded level of 101.23 ft.

Significant Change Standards

Category 3 significant change standards were established for Lake Lotela 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 Lotela and presented in Table 3.

- The **Recreation/Ski Standard** was established at an elevation of 82.3 ft. based on a ski elevation of 81 ft. and the RLWR5090 of 1.3 ft.
- The **Dock-Use Standard** was established at an elevation of 106.4 ft. based on the elevation of lake sediments at the end of 24 docks on the lake, a 2 ft. clearance depth, and the RLWR5090.
- The **Wetland Offset Elevation** was established at 105.0 ft., or 0.8 ft. below the historic P50 elevation.
- The **Aesthetic-Standard** for Lake Lotela was established at the Low Guidance Level elevation of 102.0 ft.
- The **Species Richness Standard** was established at 99.4 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- The **Basin Connectivity Standard** was established at 98.3 ft., based on the addition of 2 ft. plus the RLWR5090 (1.3 ft.) to the critical high spot elevation of 95 ft. This is the highest elevation where the northwest basin of Lake Lotela is connected to the remainder of the lake.
- The **Lake Mixing Standard** was established at an elevation of 83.1 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 (acres < 4 ft.) and aquatic plant colonization (acres < 8ft.) also increase up until a point, and then begin to decrease as the lake becomes deeper. The changes in the slope of the lines reflects the variation in lake bottom contours and the area which it contains.

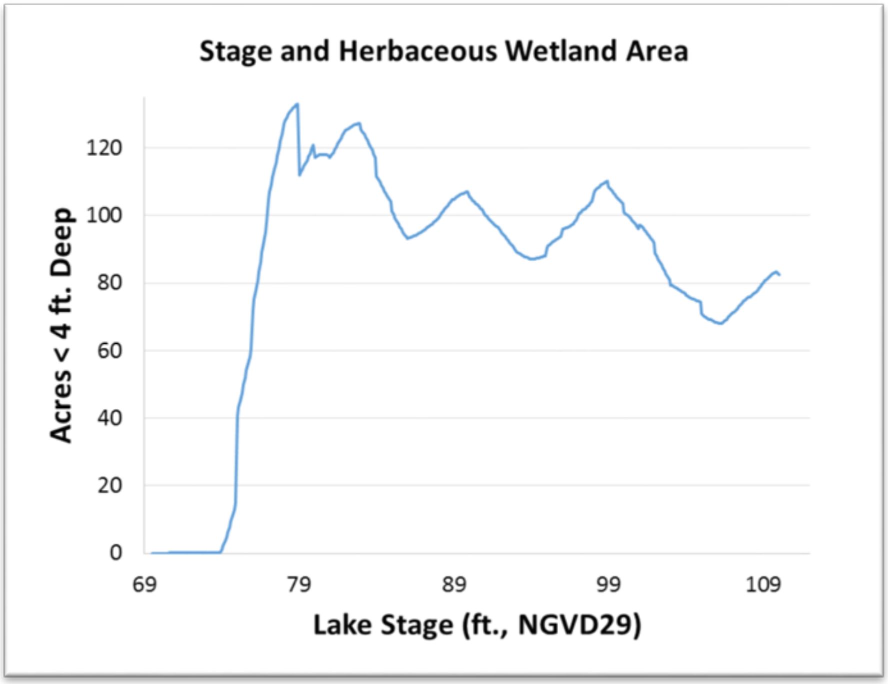

Figure 16: Lake Stage Compared to Available Herbaceous Wetland Area.

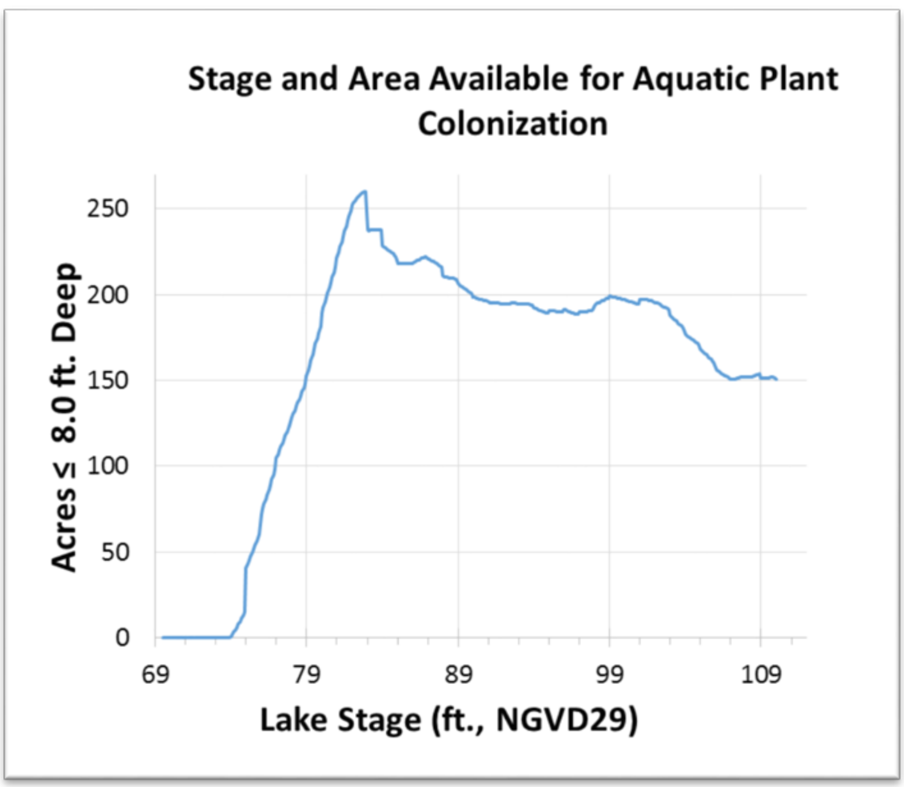

Figure 17: Lake Stage and Area Available for Aquatic Plant Colonization.

Revised Minimum Levels

The 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 listed. The revised MLL for Lake Lotela is established at the Wetland Offset elevation of 105.0 ft.

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 is established at the elevation corresponding to the Minimum Lake Level plus the difference between the Historic P10 and the Historic P50 or alternatively, the HMLL is established at the elevation corresponding to the MLL plus the RLWR value. Based on the concerns for flooding on the lake, the latter RLWR method was used, resulting in a revised HMLL of 106.1 ft. This elevation allows for potential relief from long-term flooding concerns, yet also allows for a relatively natural fluctuation of lakes levels.

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

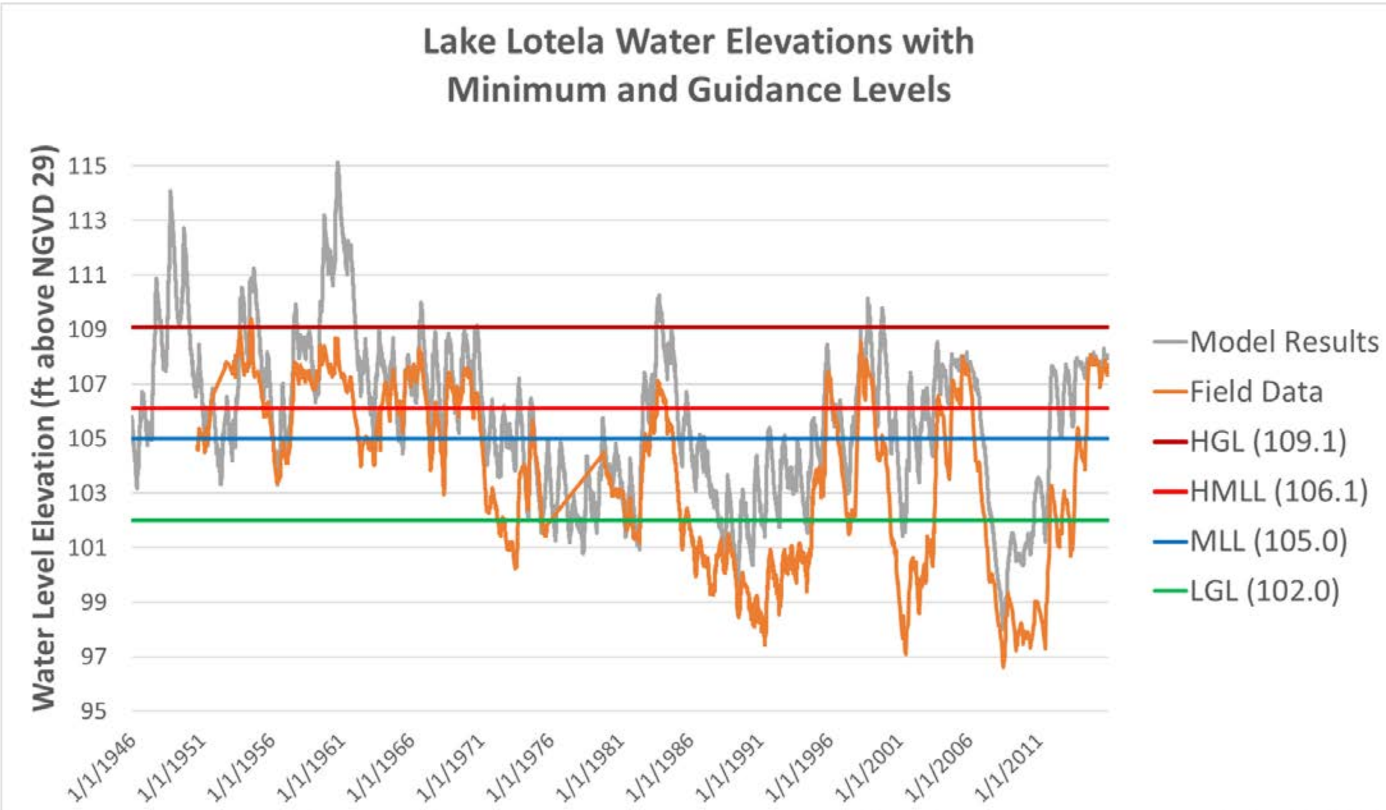

Figure 18: Historic water levels used to calculate the Revised Minimum and Guidance Levels along with field collected water level data, Guidance, and Minimum lake levels for Lake Lotela.

Figure 19: Lake Lotela Revised 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 Lotela 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 on 1988. The NGVD29 datum conversion to NAVD88 is -0.98 ft. for SID 25521 on Lake Lotela.

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

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88
High Guidance Level	109.1	108.1
High Minimum Lake Level	106.1	105.1
Minimum Lake Level	105.0	104.0
Low Guidance Level	102.0	101.0

Consideration of Environmental Values

The revised minimum levels for Lake Lotela 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 Lotela based on its classification as a Category 3 lake. 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 minimum levels for Lake Lotela. 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 Previously Adopted Levels

The revised High Guidance Level is 1.6 ft. higher than the previously adopted High Guidance Level, while the Low Guidance Level is 3.0 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 Lotela is 0.7 ft. lower than the previously adopted High Minimum Lake Level. The revised Minimum Lake Level is 0.7 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 during this evaluation. When the previous levels were established, the MLL was based on the dock standard, which is now calculated to be above the Historic P50, and thus ruled out as the MLL.

Table 5: Revised Minimum and Guidance Levels for Lake Lotela compared to previously adopted Minimum and Guidance Levels.

Minimum and Guidance Levels	Revised Elevation (in Feet NGVD29)	Previously Adopted Elevation (in Feet NGVD29)
High Guidance Level	109.1	107.5
High Minimum Lake Level	106.1	106.8
Minimum Lake Level	105.0	105.7
Low Guidance Level	102.0	105.0

Minimum Levels Status Assessment

To assess if the revised Minimum and High Minimum Lake Levels are being met, observed stage data in Lake Lotela 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 Lotela was determined to be from 2004 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 levels. Results from these assessments indicate that Lake Lotela water levels are currently below the revised Minimum Lake Level and above the revised 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 Lotela 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

Technical Memorandum

6/2/2017

TO: Donna Campbell, Environmental Scientist, Water Resources Bureau

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

FROM: Donald L. Ellison, P.G., Senior Hydrogeologist, Water Resources Bureau

Subject: Lake Lotela and Lake Letta Water Budget Models, Rainfall Correlation Models, and Historic Percentile Estimations

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A. Introduction

Water budget and rainfall correlation models were developed to assist the Southwest Florida Water Management District (District) in the reassessment of minimum and guidance levels for Lake Lotela and Lake Letta, located in northwest Highlands County. This document will discuss the development of the hydrologic analysis and models used for development of Historic lake stage exceedance percentiles for each lake.

B. Background and Setting

Lakes Lotela and Letta are bordered on the west side by the city of Avon Park and on east by State Road 17 (Figure 1). The area is comprised of low to medium density residential lots, open land and citrus groves (Figure 2). Both lakes are located in the Carter Creek watershed (Figure 3). Drainage into the lake is a combination of overland flow, flow through drainage swales and conveyance systems, and groundwater inflow from the surficial aquifer. Surface water inflow to each lake occurs as overland flow from each lake's small drainage basin, and also channel inflow originating from Lake Glenada, which flows down the chain of lakes to Lake Lelia, Lake Lotela, Lake Little Bonnet and finally to Lake Letta (Figure 4). Though withdrawals from the lake occur for lawn irrigation, there are no permitted surface water withdrawals from the lakes. There are numerous permitted groundwater withdrawals in the vicinity of the lake.

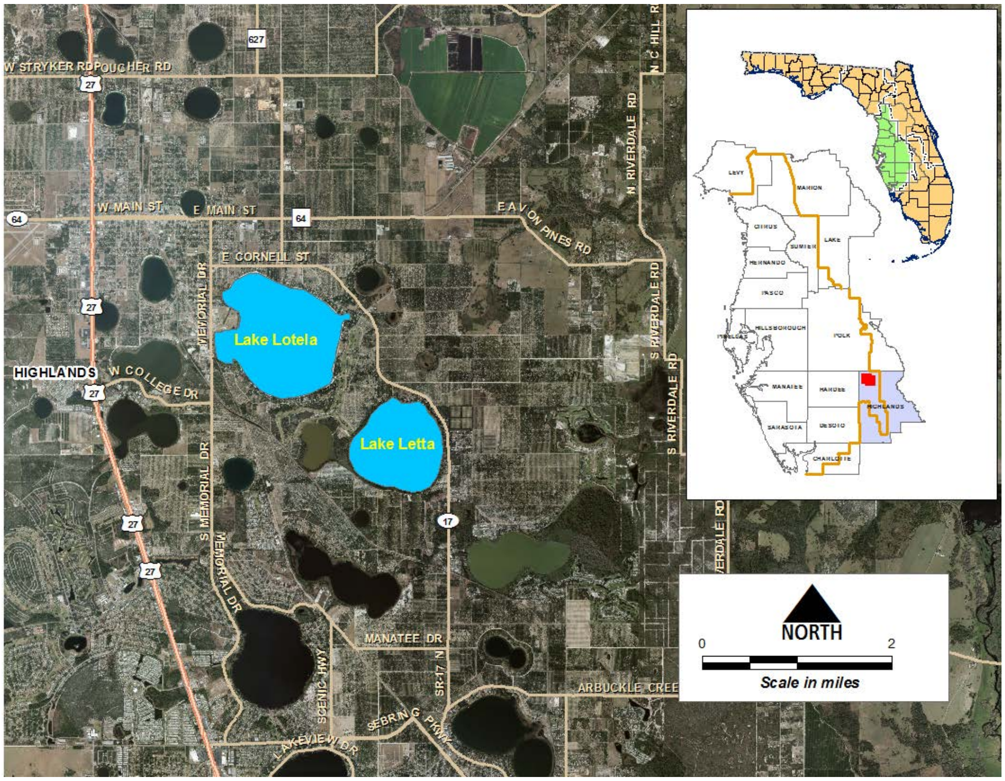

Figure 1. Location of Lake Lotela and Lake Letta in Highlands County, Florida.

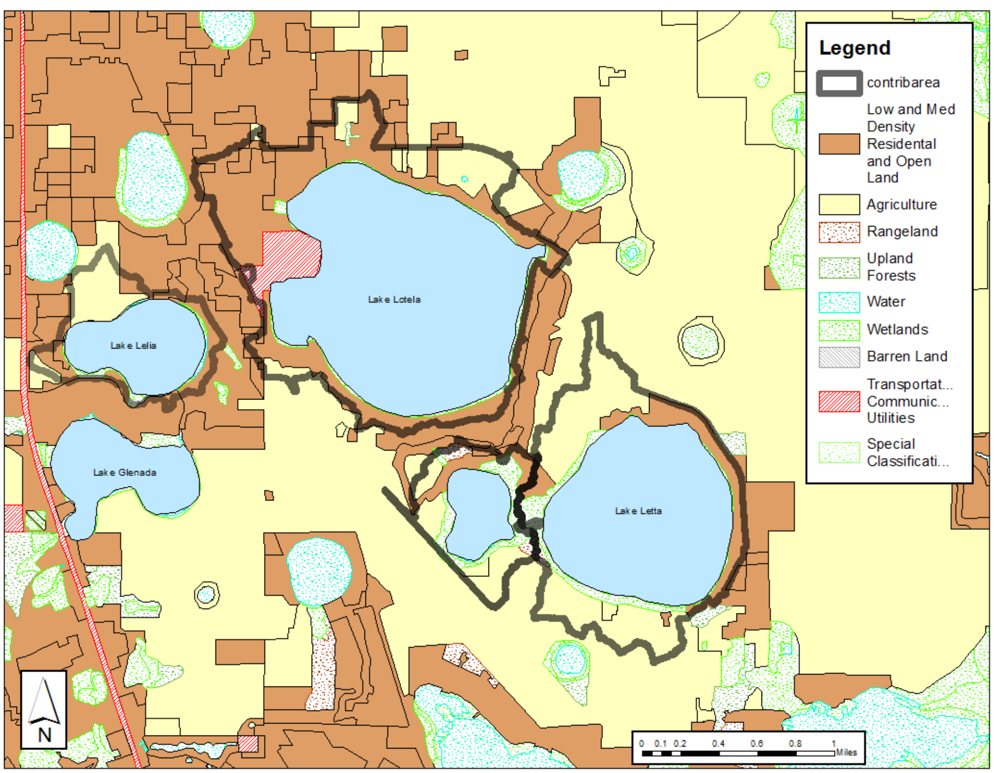

Figure 2. Land use adjacent to Lake Lotela and Lake Letta.

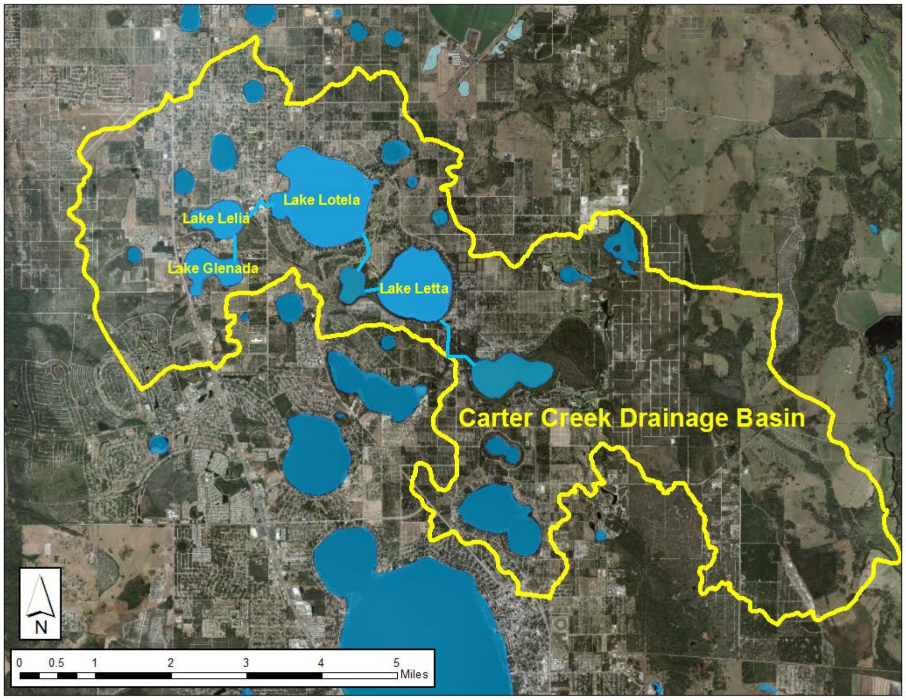

Figure 3. Carter Creek Drainage Basin and drainage pathways between lakes contributing flow to Lake Lotela and Lake Letta.

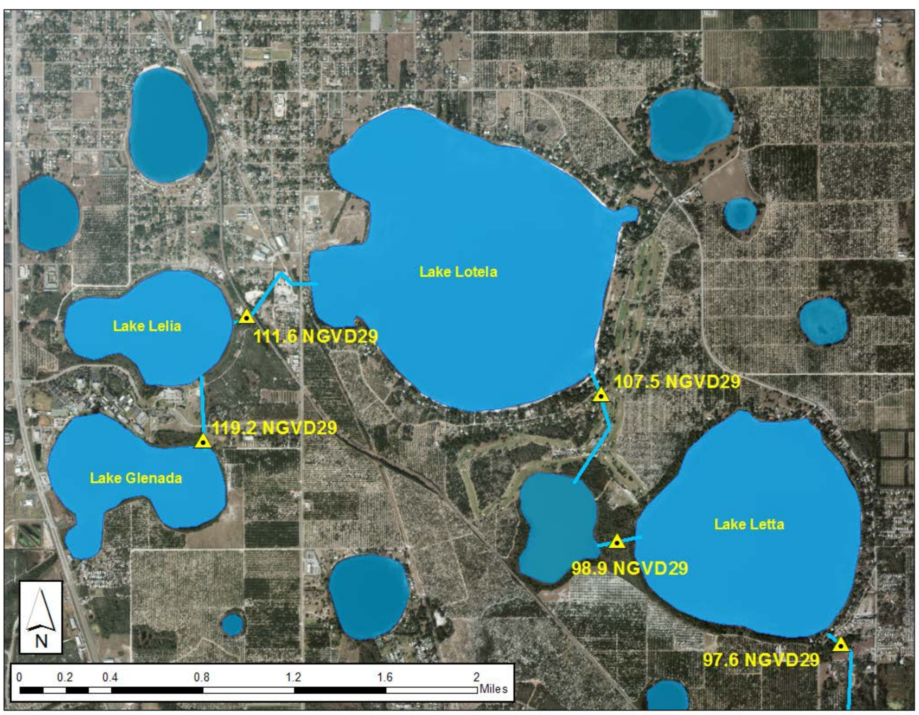

Figure 4. Drainage pathways between lakes and control elevations between the lakes.

Physiography and Hydrogeology

The generalized physiography as detailed in Spechler, 2010 is shown in (Figure 5). The prominent features most relevant to this study are the Lake Wales Ridge and the Intra Ridge Valley. The Lake Wales Ridge, evidenced by wave-cut terraces paralleling the current shoreline, suggests that this feature was formed by wave actions during periods of higher sea level (Spechler, 2010).

Figure 6 presents a zoomed in view of the Lake Wales Ridge showing the position of Lake Lotela and Lake Letta in the Intra ridge Valley. Altitudes on the Lake Wales Ridge are the highest in the county, with a range of 60 to 210 feet above NGVD29. Contrastingly, elevations within the Intra Ridge Valley range from 50 to > 106 feet above NGVD29. The Intra Ridge Valley maintains a width of about 2 miles, and is thought to have been formed by the dissolution of limestone in the underlying materials and contains many karst features (Spechler, 2010).

The hydrogeology of Highlands County has been described by others, but most recently by Spechler in 2010. The system consists of a thick sequence of sedimentary rocks that include sands, clays and carbonates (Spechler, 2010). The lithostratigraphic units form a layered sequence of aquifers and confining units, with three hydrogeologic units of interest present within the county:

- The surficial aquifer
- The Intermediate Aquifer System/Intermediate Confining Unit (IAS/ICU)
- The Floridan aquifer system

The surficial aquifer is approximately 200 ft. thick and is the upper most water bearing unit. The surficial aquifer is quite transmissive in this area, although it is not used for large-scale water supply.

Just below the surficial aquifer lies the IAS/ICU, which can restrict the movement of water between the surficial and Floridan aquifer system. The Floridan aquifer system consists of the Upper Floridan and Lower Floridan aquifers which are separated by the middle confining units I, II, and/or VI (Miller, 1986).

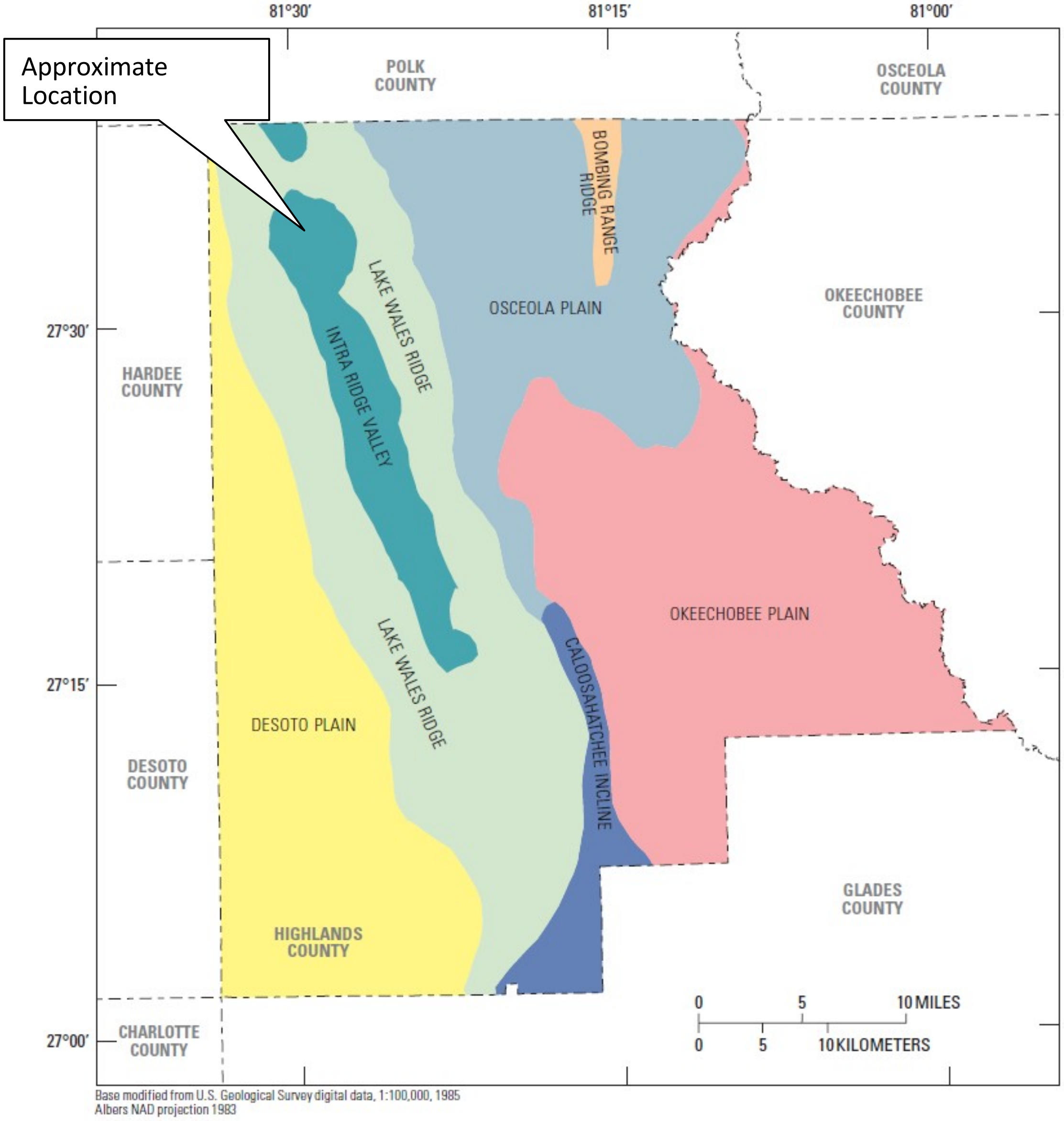

Figure 5. Generalized Physiography of Highlands County (After: Spechler 2010).

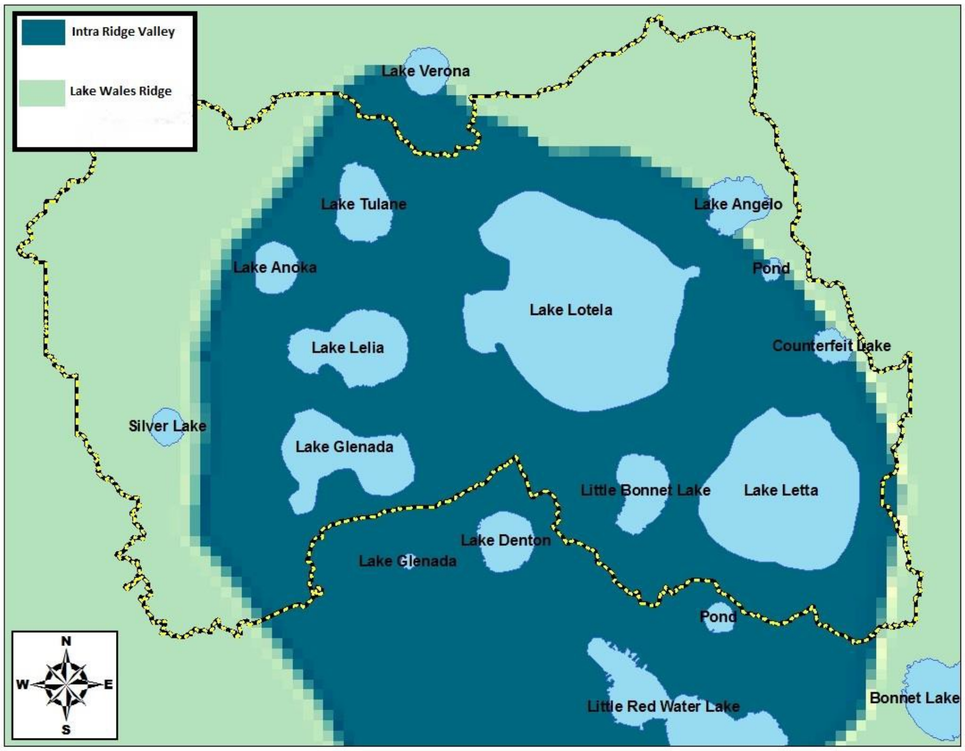

Figure 6. Location of the lakes in the Intra-Ridge Valley. (After: Spechler 2010).

Data

Regular water level data collection beginning dates, and summary of data collection frequencies, are presented in Table 1. The Upper Floridan aquifer monitor well used in this analysis is the ROMP 43xx well (SID 25532), with nearly regular daily data collection beginning in June 1982. The surficial well used was ROMP 43xx surficial (SID 25529) which consists of weekly to monthly data starting in March 1995. Well locations are presented in Figure 7. Hydrographs for each lake are presented in Figure 8.

Table 1. Period of records for lakes Glenada, Lelia, Lotela, Little Bonnet and Letta.

Lake	Site Identification Number (SID)	Period of Record	Summary of Frequency
Glenada	25512	March 1977	Sporadic Weekly and Monthly
Lelia	25518	June 1981	Sporadic Weekly and Monthly
Lotela	25521	September 1950	Sporadic Weekly and Monthly
Little Bonnet	25511	June 1981	Sporadic Weekly and Monthly
Letta	23798	June 1951	Sporadic Weekly and Monthly

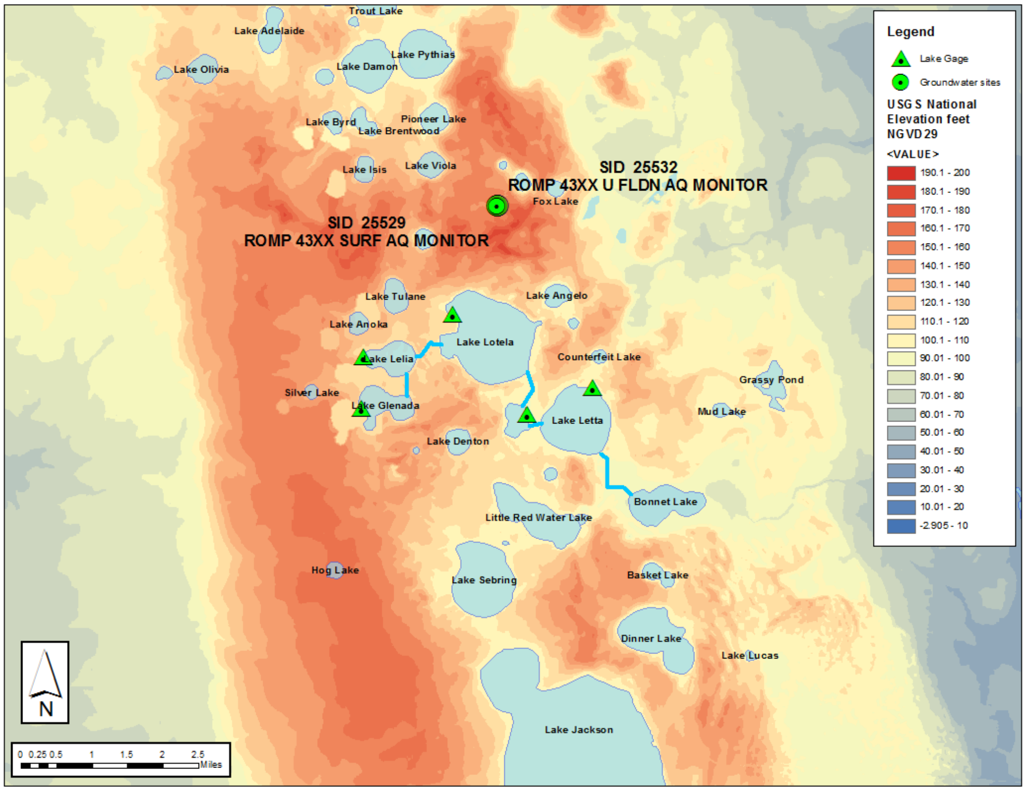

Figure 7. Monitoring wells and lake gage locations.

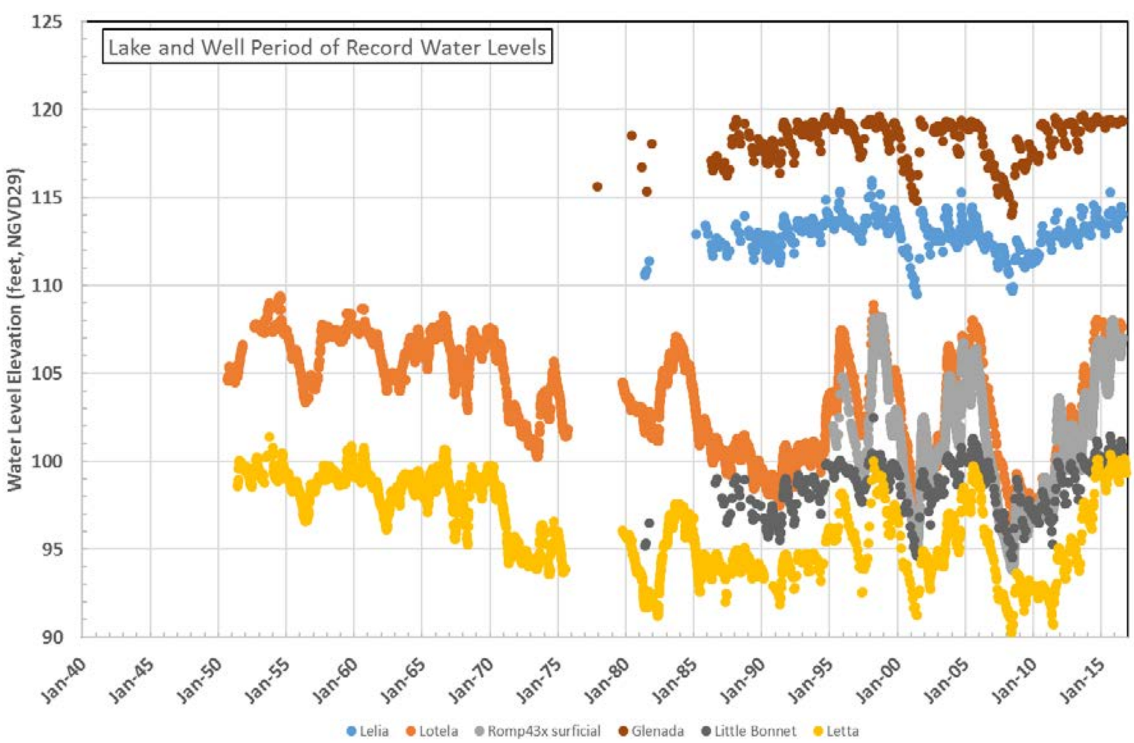

Figure 8. Hydrographs for lakes Glenada, Lelia, Lotela, Little Bonnet and Letta.

Water Use

Detailed water use near Lake Lotela and Lake Letta was obtained from the District's annual estimated water use report. Estimated water use reports are available starting in 1992 and are current through 2012 (SWFWMD 2013). The water use data included in these reports are primarily from the District Water Use Permitting (WUP) database in the Water Management Information System (WMIS). The water quantity data is derived from metered withdrawal points and from estimates applied to unmetered withdrawal points. Population data is based on population numbers given by public supply permittees on the Public Supply Annual Report (PSAR) forms and functional BEBR population data. About 81 percent of the water use in this report is based on directly metered withdrawals. Since the total water use contains an element of estimation, the annual report is referred to as the "Estimated Water Use Report."

Individual withdrawal point locations near the lakes are shown in Figure 9 and graphs depicting total water use within specified radial distances from a central point within the lake are presented in Figures 10 and 11. Water use within the first mile of the central point is close to zero, since a large percentage of this region is occupied by the lake. Water use for the area within two miles of the central point is generally between 2 and 5 mgd fairly consistently through time. At three miles, the water use ranges generally between 5 to 15 mgd with an average around 10 mgd and an occasional peak between 15 mgd and 25 mgd. At four, five and six miles the water use is similar, and typically ranges from 10 to 30 mgd with occasional peaks as near 60 mgd.

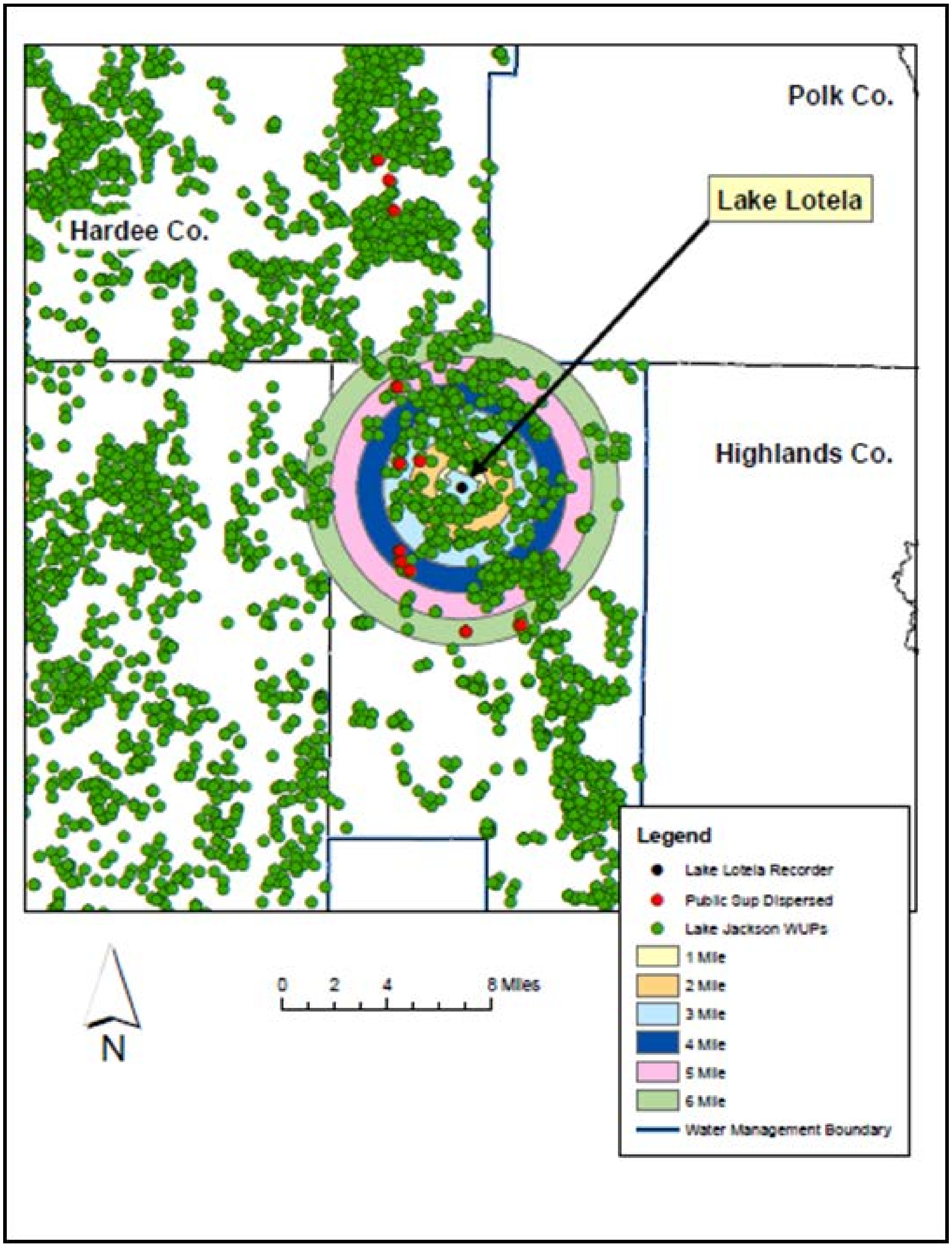

Figure 9. Location of water use permits.

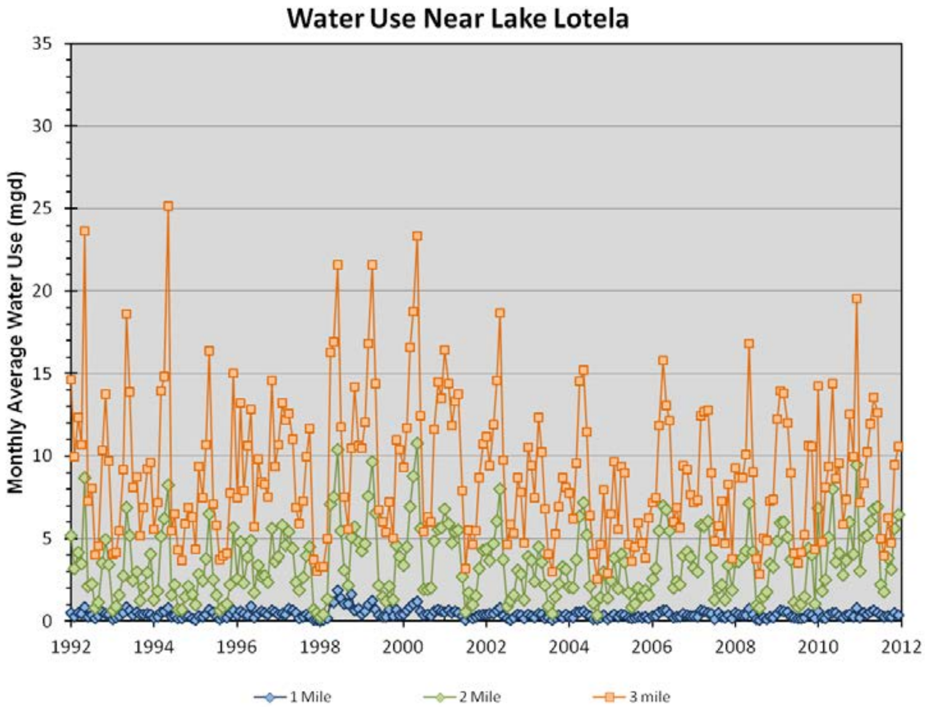

Figure 10. Metered and estimated water use within 1, 2 and 3 miles of Lake Lotela.

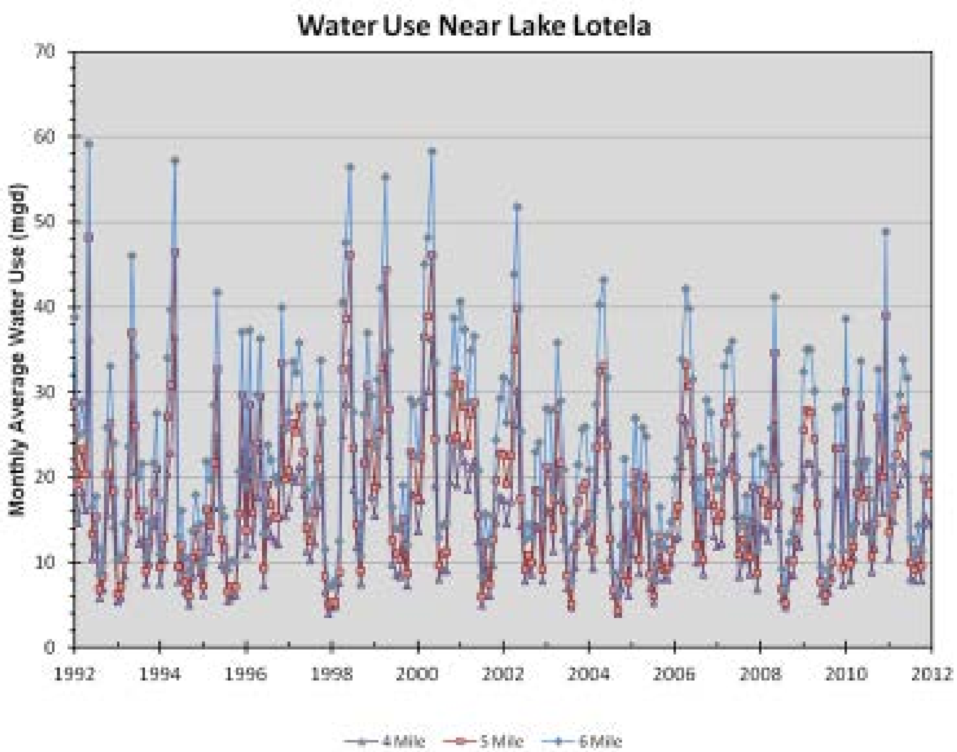

Figure 11. Metered and estimated water use within 4, 5 and 6 miles of Lake Lo**tela**.

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 (HML) and the Minimum Lake Level (MLL). 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 then 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 does 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 lakes Lotela and Letta, withdrawals throughout the area have potentially affected water levels in the lakes since the early 1960s. Therefore, the development of a water budget model coupled with a rainfall correlation model for the lake was used to estimate 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 budget model is a spreadsheet-based tool that includes natural hydrologic processes and engineered alterations acting on the control volume of each lake. The control volume consists of the free water surface within the lake extending down to the elevation of the greatest lake depth. 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 model include:

a. Rainfall and evaporation
b. Overland flow
c. Inflow and discharge via channels
d. Flow from and into the surficial aquifer
e. Flow from and into 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 Lake Lotela model is calibrated from 2004 through 2015 and the Lake Letta model is calibrated from 2010 through 2015.

The calibration periods for both lakes are delineated by recent modifications to the drainage systems between the lakes.

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. The lake stage and stage volume relationship from the original model was not changed.

Precipitation

The period of record daily data from the ROMP 43x rain gage located 1.2 miles north of Lake Lotela was used for the 1997 through 2015 period (Figure 12). The Avon Park 2w rain gage, located 2.2 miles west of the lakes was used for the remainder of the model period back to January 1,1946 (Figure 12). The Wachula rain gage to the west was used to fill in a few missing data points where both the Avon Park and ROMP 43x gages were missing data.

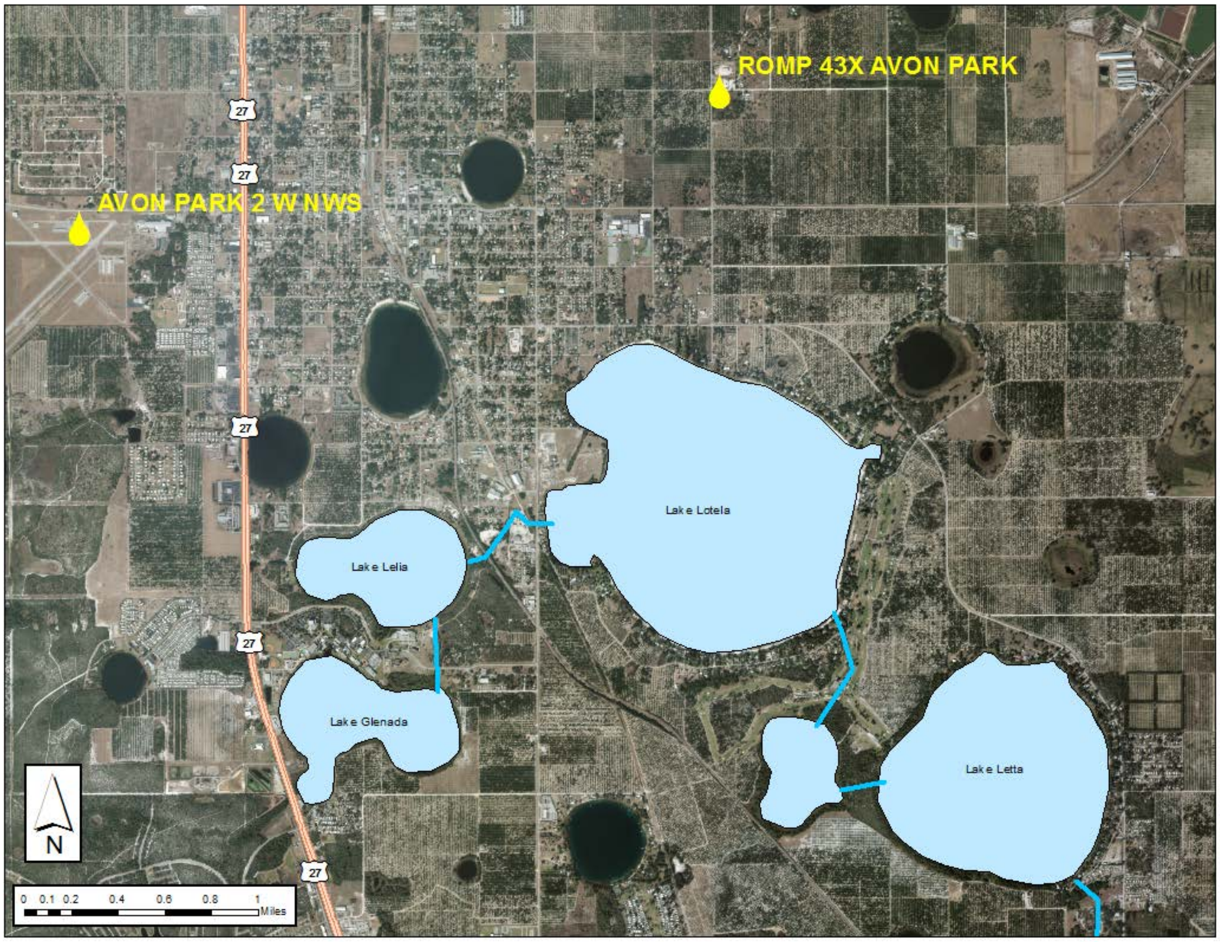

Figure 12. Rain gages used in the water budget model.

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 and others, 2000) (Figure 13). The data was 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.

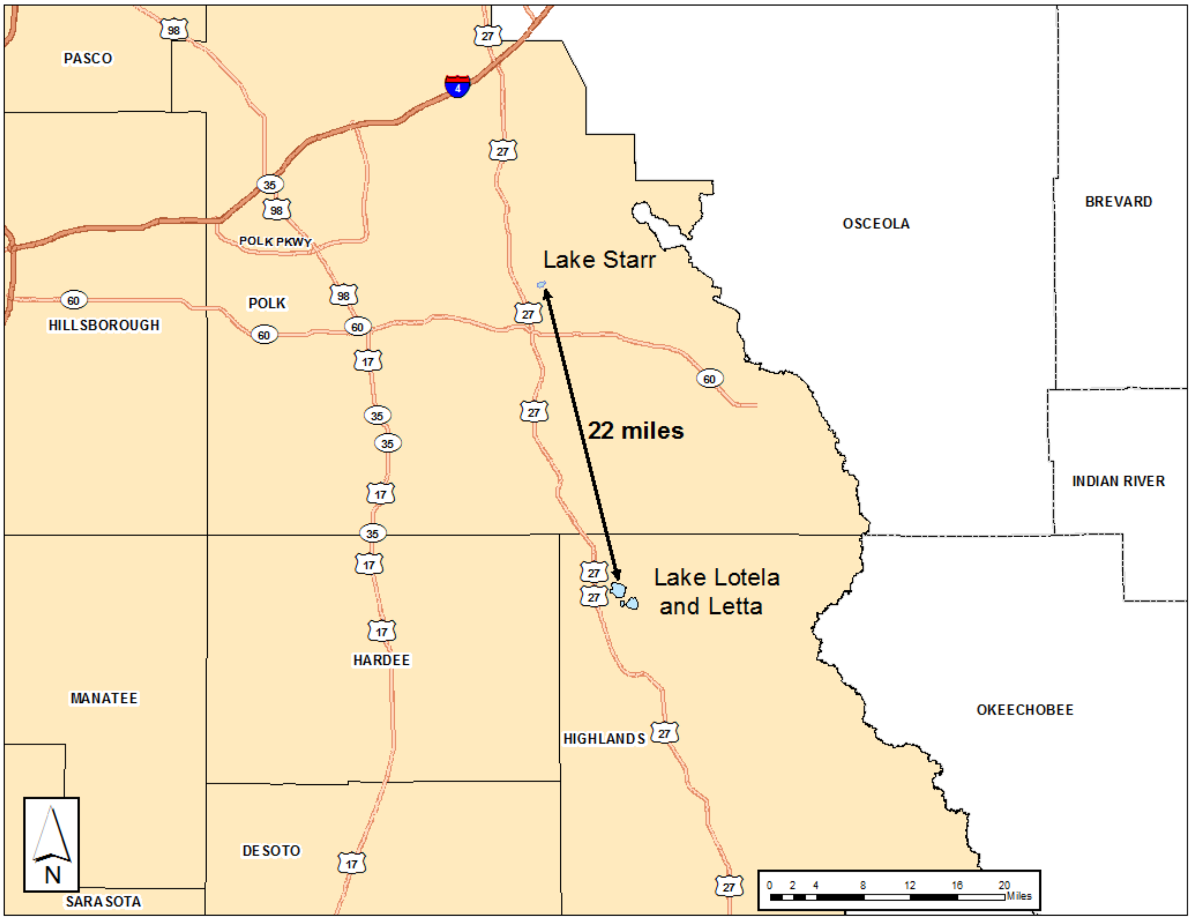

Figure 13. Location of Lake Starr ET data collection site north of Lakes Lotela and Letta.

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 surface 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 DCIA percent area and SCS curve number used for direct overland flow portion of the watershed for each lake are listed in Tables 2, 5, 8, and 11. The soils in the area of the lakes are mostly A with a few small areas of A/D. (Figure 14). Land use within the contributing areas to the lakes is comprised of open land, agricultural areas and low to medium density residential areas so the DCIA of the watershed was set to zero.

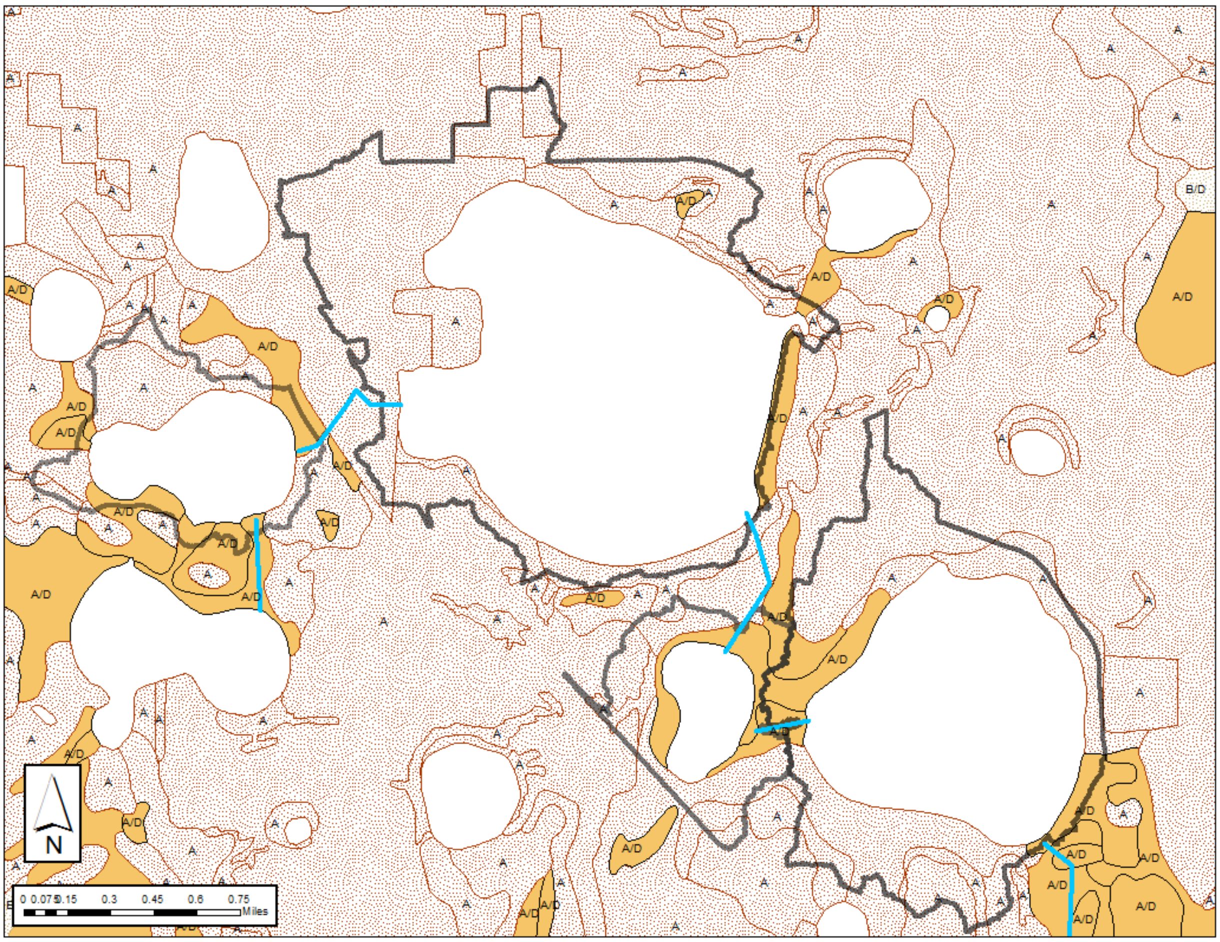

Figure 14. Soil types within the lakes contributing areas.

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 models for Lelia, Lotela, Little Bonnet and Letta. Channel flow originates in Lake Glenada which then flows to Lelia, Lotela, Little Bonnet and finally Lake Letta. To estimate flow into or out of each lake, the predicted elevation of the lake from the previous day is compared to the controlling elevation. If this value is a positive number, the difference is multiplied by the current area of the lake and either the “inflow coefficient” or “outflow coefficient.” The coefficient represents a measure of channel and structure efficiency, and produces a rough estimate of volume lost or gained for each lake. This volume is then subtracted from the current estimate of volume.

Individual water budget models were developed for Lakes Lelia, Lotela, Little Bonnet and Letta. Channel inflow from Glenada to Lelia was established by using Lake Glenada measured water levels and the outlet elevation (119.2 ft. NGVD29) between the two lakes. Channel inflow from Lake Lelia to Lake Lotela used measured water levels from Lelia and the outlet elevation (111.62 ft. NGVD29) between the two lakes. Channel inflow from Lotela to Little Bonnet used the measured water levels from Lotela and the outlet elevation (107.48 ft. NGVD29) between the two lakes. Lake Letta inflow was established by using the measured water levels from Little Bonnet and the outlet elevation (98.91 ft. NGVD29) between the two lakes. Each model was used to remove the impacts from groundwater withdrawals and produce a new water level series for each lake reflective of the higher elevations and thus increase channel out/in flow. The unimpacted water levels series was then used in each lake. A water budget model wasn’t developed for Lake Glenada and water levels were adjusted slightly (0.2 ft.) to represent the non-impacted conditions.

Flow from and into the surficial aquifer and Upper Floridan aquifer

Water exchange between each lake and the underlying aquifers is estimated using a leakance coefficient and the head difference between the lake and the aquifer levels. For each time step, surficial aquifer and Upper Floridan aquifer leakage volumes were calculated independently. Leakance coefficients for each aquifer were determined through calibration.

ROMP 43xx Floridan aquifer monitoring well and surficial aquifer well, located 1.2 miles north of Lake Lotela, were used to represent the Upper Floridan aquifer and surficial aquifer water levels used in the water budget models (Figure 15). ROMP 43xx Floridan aquifer well data starts in 1983 and extends to present day. The surficial well starts in 1995 and extends to present day. Data frequency for both wells is a mixture of nearly complete daily readings with some short week long breaks mixed in. A simple approach was used to fill in missing data by using the last recorded data value until a new value was recorded. The head difference between the two wells is approximately 15 feet and ranges from 9 to 25 feet between 2004 and 2015 (Figure 16).

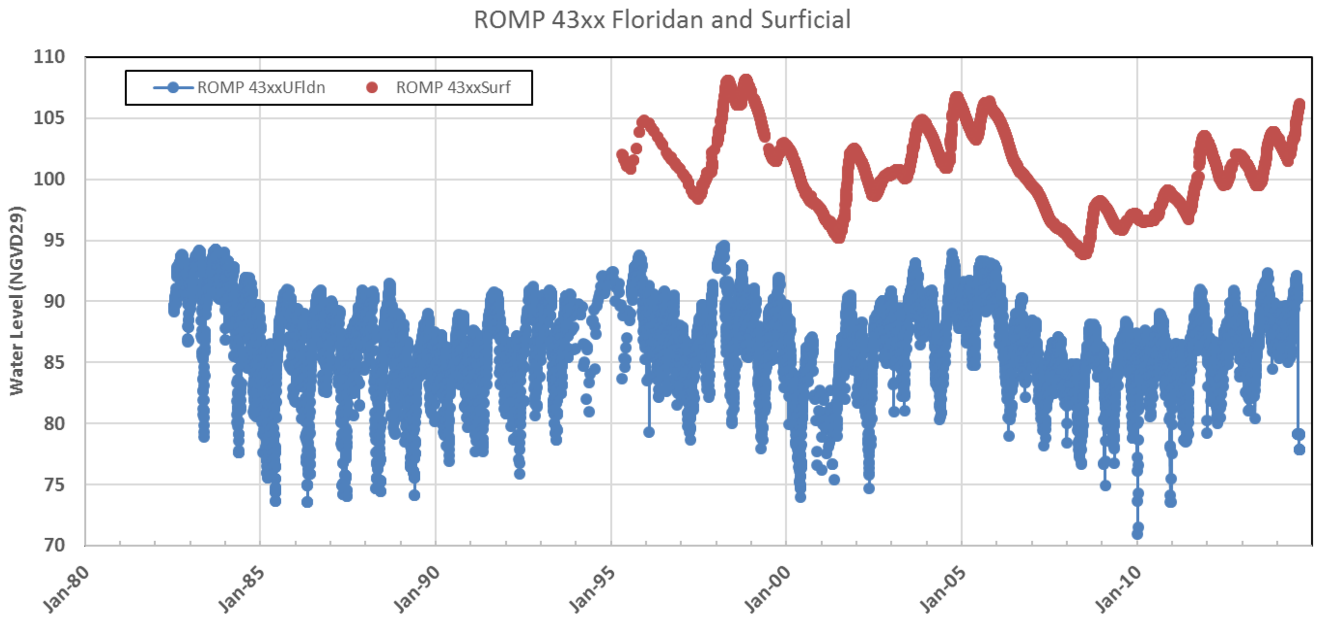

Figure 15. Monitoring well water levels used in the water budget models for each Lake (Lelia, Lotela, Little Bonnet and Letta).

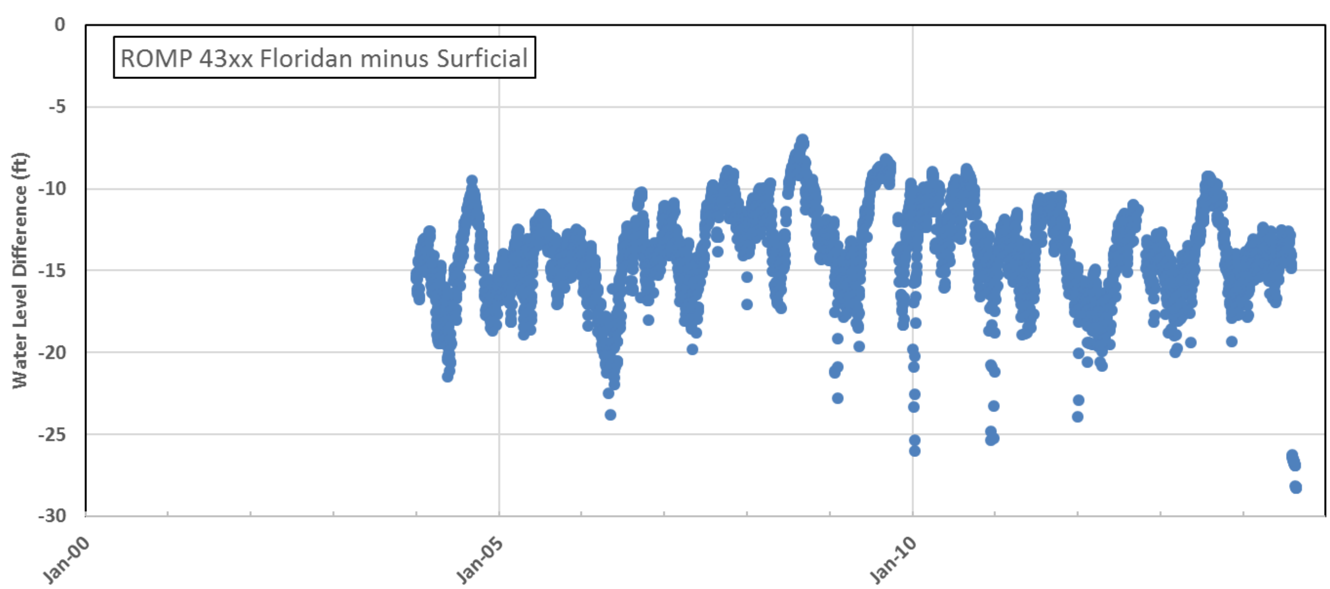

Figure 16. Head difference between 43xx Floridan well and 43xx Surficial well.

F. Water Budget Model Approach

The primary reason for the development of the water budget models is to estimate Historic lake stage exceedance percentiles that could be used to support development of Minimum and Guidance Levels for Lakes Lotela and Letta. Model calibration was therefore focused on matching long-term percentiles based on measured water levels, rather than short-term high and low levels.

Measured data from each lake were used for comparison with modeled water levels. Daily values are generated from the models, but only measured lake data points were used for the calibration.

Figures 17 through 20 present the calibration results for Lelia, Lotela, Little Bonnet and Letta models. Tables 3, 6, 9 and 12 present a comparison of the percentiles of the measured data versus the model results. Tables 2, 5, 8 and 11 present the model inputs for each lake water budget model calibration. Tables 4, 7, 10 and 13 presents the modeled water budget components for lake water budget model calibration.

Table 2. Model Inputs for the Lake Lelia water budget model.

Input Variable	Input Value
Overland Flow Watershed Size (acres)	293
SCS CN of watershed	55
Percent Directly Connected	0
FL Monitor Well Used	ROMP 43xx
Surf. Aq. Monitor Well(s) Used	ROMP43xx
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.0063
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.0004
Outflow K	0.039
Outflow Invert (ft NGVD29)	111.62
Inflow K	0.4
Inflow Invert (ft NGVD29)	119.2

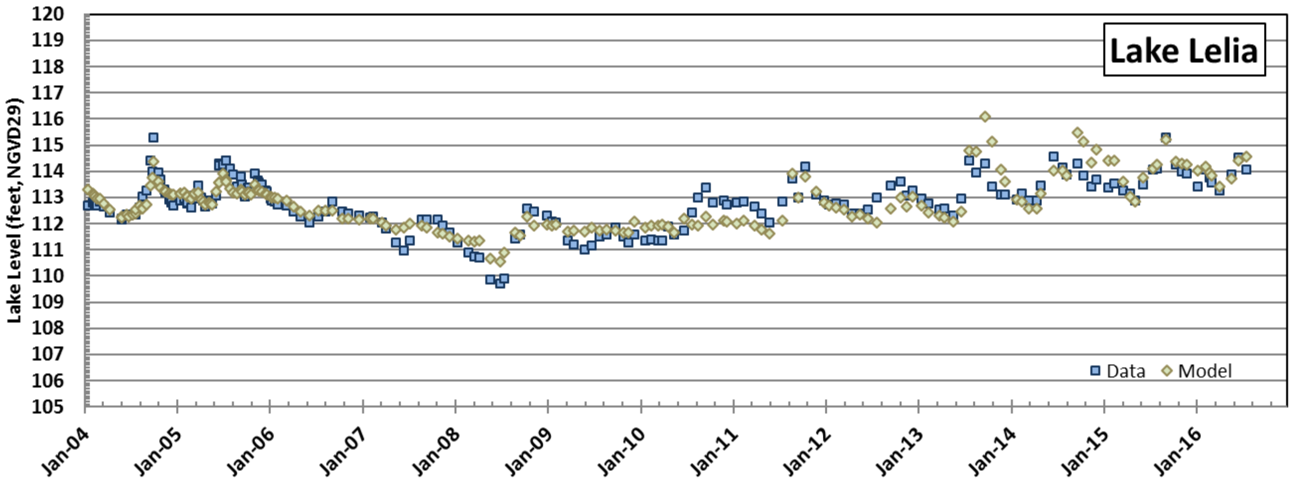

Figure 17. Modeled water levels predicted for Lake Lelia in the calibrated water budget model (Model) and measured levels used for the model calibration (Data).

Table 3. Comparison of percentiles (January 1, 2004 through 2015) of measured lake level data compared to calibration percentiles from the Lake Lelia water budget model (all in feet NGVD29).

	Lake Lelia Data	Lake Lelia Model
P10	114.1	114.1
P50	112.9	112.8
P90	111.4	111.7

Table 4. Lake Lelia Model Water Budget (January 1, 2004 through 2015)

Inflows	Rainfall	SURF GW Inflow	FL GW Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	47.4	185.1	0.0	2.4	0.0	60.5	295.3
Percentage	16.1	62.7	0.0	0.8	0.0	20.5	100
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**			**Outflow via channel**	**Total**
Inches/year	59.0	0.0	51.0			185.0	294.88
Percentage	20.0	0.0	17.3			62.7	100.0

Table 5. Model Inputs for the Lake Lotela water budget model.

Input Variable	Input Value
Overland Flow Watershed Size (acres)	1334
SCS CN of watershed	30
Percent Directly Connected	0
FL Monitor Well Used	ROMP 43xx
Surf. Aq. Monitor Well(s) Used	ROMP 43xx
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.01
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.00019
Outflow K	0.2
Outflow Invert (ft NGVD29)	107.48
Inflow K	0.013
Inflow Invert (ft NGVD29)	111.62

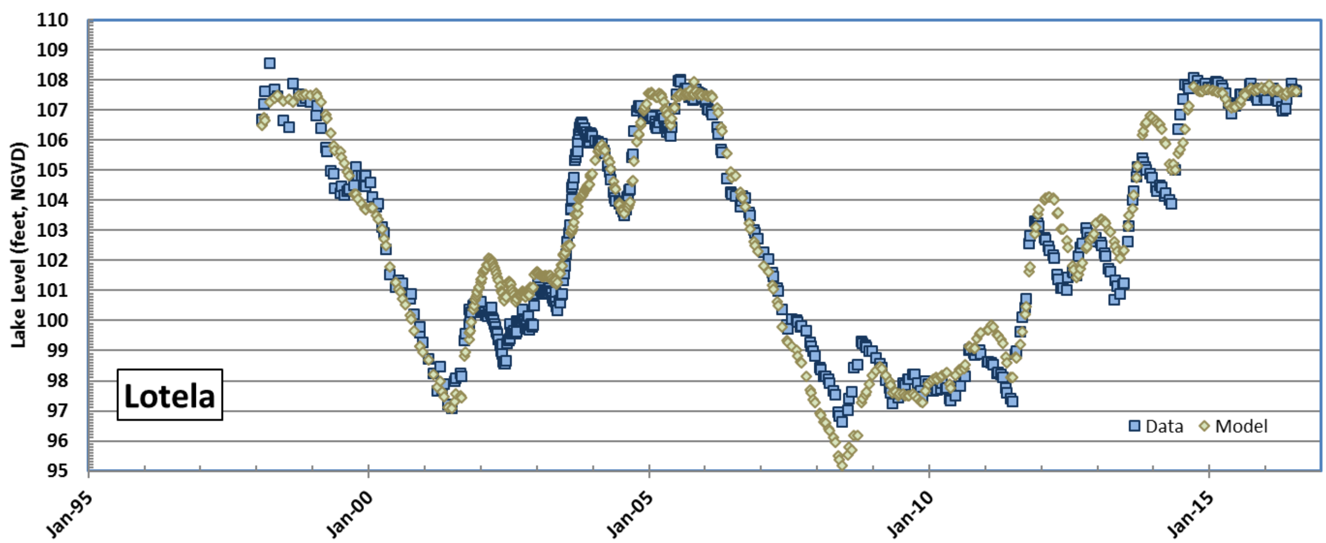

Figure 18. Modeled water levels predicted for Lake Lotela in the calibrated water budget model (Model) and measured levels used for the model calibration (Data).

Table 6. Comparison of percentiles (January 1, 2004 through 2015) of measured lake level data compared to calibration percentiles from the Lake Lotela water budget model (all in feet NGVD29).

	Lake Lotela Data	Lake Lotela Model
P10	107.6	107.6
P50	104.0	104.0
P90	97.8	97.6

Table 7. Lake Lotela Model Water Budget (January 1, 2004 through 2015)

Inflows	Rainfall	SURF GW Inflow	FL GW Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	47.4	8.7	0.0	0.2	0.0	63.7	119.9
Percentage	39.6	7.2	0.0	0.2	0.0	53.1	100
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**			**Outflow via channel**	**Total**
Inches/year	59.0	30.3	13.2			14.3	116.8
Percentage	50.5	25.9	11.3			12.3	100.0

Table 8. Model Inputs for the Lake Little Bonnet water budget model.

Input Variable	Input Value
Overland Flow Watershed Size (acres)	233
SCS CN of watershed	50
Percent Directly Connected	0
FL Monitor Well Used	ROMP43xx
Surf. Aq. Monitor Well(s) Used	ROMP 43xx
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.019
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.00001
Outflow K	0.07
Outflow Invert (ft NGVD29)	98.91
Inflow K	0.2
Inflow Invert (ft NGVD29)	107.48

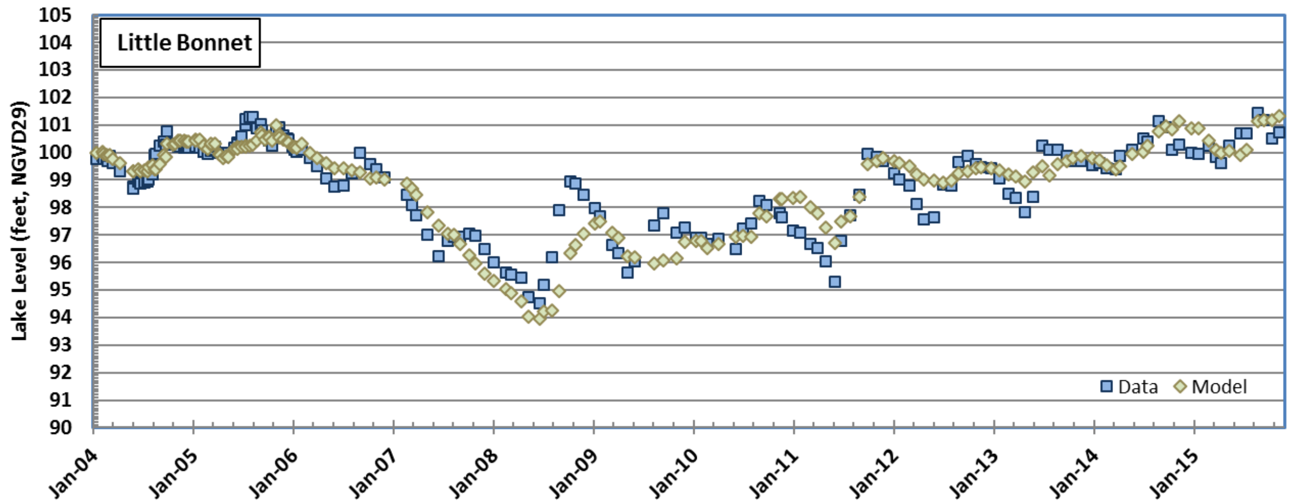

Figure 19. Modeled water levels predicted for Lake Little Bonnet in the calibrated water budget model (Model) and measured levels used for the model calibration (Data).

Table 9. Comparison of percentiles (January 1, 2004 through 2015) of measured lake level data compared to calibration percentiles from the Lake Little Bonnet water budget model (all in feet NGVD29).

	Lake Little Bonnet Data	Lake Little Bonnet Model
P10	100.7	100.9
P50	99.7	99.6
P90	96.7	96.6

Table 10. Lake Little Bonnet Model Water Budget (January 1, 2004 through 2015)

Inflows	Rainfall	SURF GW Inflow	FL GW Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	47.4	171.5	0.0	3.9	0.0	28.6	251.4
Percentage	18.9	68.2	0.0	1.5	0.0	11.4	100
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**			**Outflow via channel**	**Total**
Inches/year	59.0	4.0	0.7			186.7	250.5
Percentage	23.6	1.6	0.3			74.5	100.0

Table 11. Model Inputs for the Lake Letta water budget model.

Input Variable	Input Value
Overland Flow Watershed Size (acres)	826
SCS CN of watershed	40
Percent Directly Connected	0
FL Monitor Well Used	ROMP43xx
Surf. Aq. Monitor Well(s) Used	ROMP43xx
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.001
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.00045
Outflow K	0.014
Outflow Invert (ft NGVD29)	97.56
Inflow K	0.018
Inflow Invert (ft NGVD29)	98.91

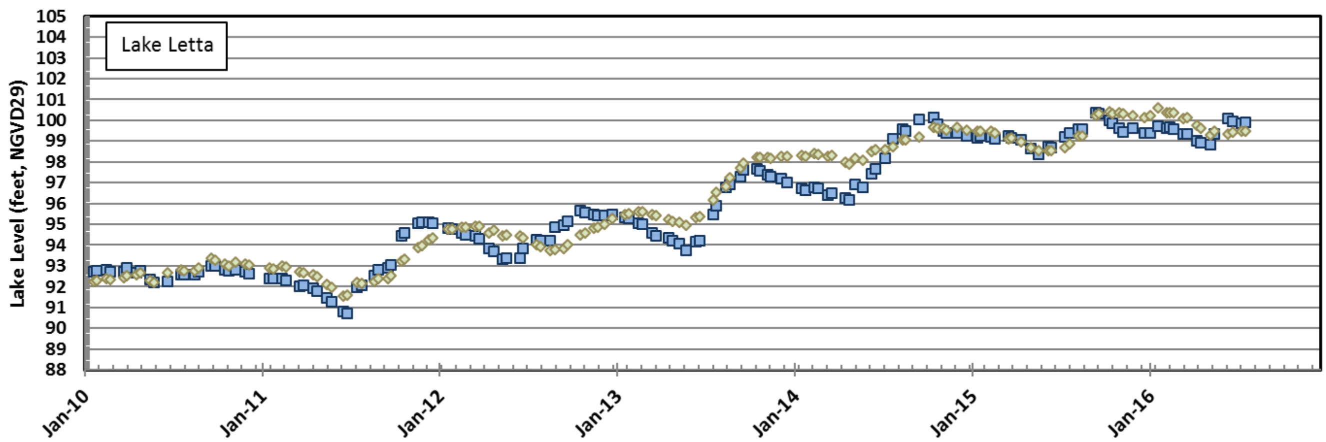

Figure 20. Modeled water levels predicted for Lake Letta in the calibrated water budget model (Model) and measured levels used for the model calibration (Data).

Table 12. Comparison of percentiles (January 1, 2004 through 2015) of measured lake level data compared to calibration percentiles from the Lake Letta water budget model (all in feet NGVD29).

	Lake Letta Data	Lake Letta Model
P10	99.6	99.7
P50	95.4	95.5
P90	92.4	92.5

Table 13. Lake Letta Model Water Budget (January 1, 2004 through 2015)

Inflows	Rainfall	SURF GW Inflow	FL GW Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	48.2	38.5	0.0	0.9	0.0	48.5	136.1
Percentage	35.4	28.3	0.0	0.7	0.0	35.6	100
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**			**Outflow via channel**	**Total**
Inches/year	58.3	0.0	28.6			33.5	120.3
Percentage	48.4	0.0	23.7			27.8	100.0

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 17 through 20, the models appear to be reasonably well calibrated. There are a few periods when the peaks in the modeled hydrograph are higher or lower than the measured values, and these differences contributed to minor differences between the modeled and measured percentiles associated with higher and lower lake levels, i.e., the P10 and P90 percentiles.

A review of tables 3, 6, 9 and 12 shows that the differences in median percentiles (P50) is 0.1 feet or less; 0.2 feet difference or less in the P10 percentile for all lakes; and 0.3 feet difference in the P90 percentile between the data and model for all the lakes.

The water budget component values in the model can be difficult to judge since they are expressed as inches per year over the average lake area for the period of the model run. Leakage rates (and leakance coefficients), for example, represent conditions below the lake only, and may be very different than those values expected in the general area. Runoff also represents a volume over the average lake area, and when the resulting values are divided by the watershed area, they actually represent fairly low runoff rates. Lakes Lelia and Little Bonnet are relatively small; thus, values in the water budget table will tend to be larger due to the division of the flux by a smaller area.

H. **Historic Water Budget Model Scenario**

Groundwater withdrawals are not directly included in the lake water budget models, 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. Based on the model scenarios it was estimated that modeled groundwater withdrawals have lowered Upper Floridan aquifer water levels about 8.8, 7.8, 7.4 and 6.0 feet beneath lakes Lelia, Lotela, Little Bonnet and Letta, respectively.

During evaluation of the reduced pumping scenarios, an assessment of long-term changes in water levels was also conducted to verify model results. The evaluation focused on water levels in the ROMP 43xx Upper Floridan aquifer well located 2 miles north of Lake Lotela. This was done using water level data averaged over different periods, for example annual and monthly, and single months such as September, May and December. For each regression analysis, the regression parameters were determined. These parameters were then used to estimate water levels for the period available for the respective independent well levels at Coley Deep. For the regression analyses, estimate of long-term changes in groundwater levels is 6.7 feet of drawdown at the ROMP 43xx site which verifies the drawdown of 6.8 feet obtained from the ECFT model. Based on this, verification drawdown results from the ECFT model were used at each lake. With respect to the surficial aquifer, the relationship between the leakance coefficient and the ratio of surficial aquifer to Upper Floridan aquifer drawdowns established for previous modeling efforts was used. From the water budget models, the leakance coefficient were 0.00045, 0.0002, 0.00001 and 0.00045 feet/day/feet for Lelia, Lotela, Little Bonnet and Letta, respectively. These values resulted in ratios of surficial to Upper Floridan drawdown from 0.33 to 0.005. The resulting recovery in the surficial aquifer was then estimated as the product of this ratio and the estimated Upper Floridan aquifer recovery amount of 2.9, 2.3, 0.04 and 2.0 feet at Lelia, Lotela, Little Bonnet and Letta, respectively.

Figures 21 through 24 present the results of the calibrated water budget models for each lake with and without the effects of groundwater withdrawals. Table 14 presents the percentiles based on model output.

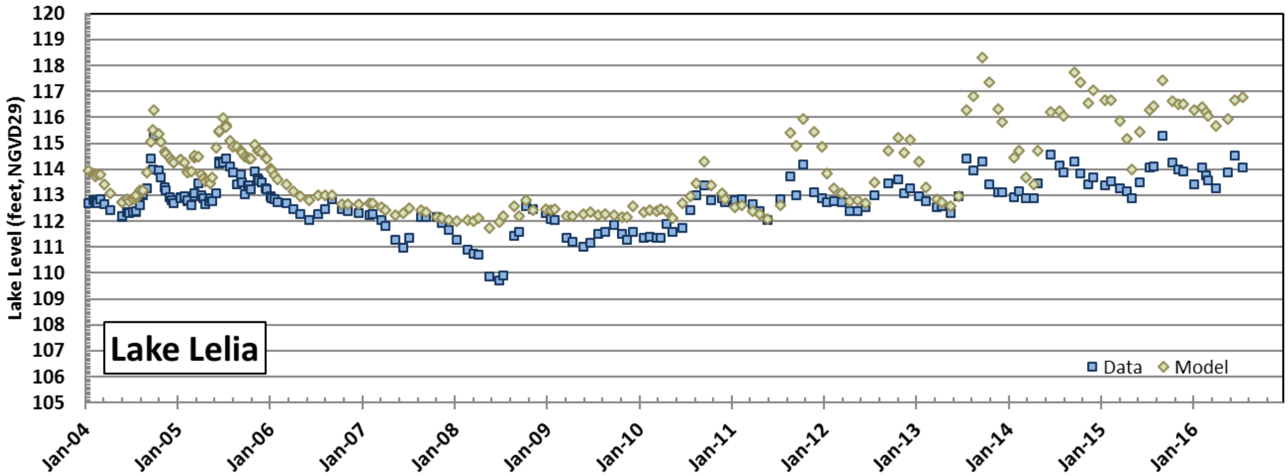

Figure 21. Calibrated Water Budget Model for Lake Lelia without the effects of withdrawals and observed data.

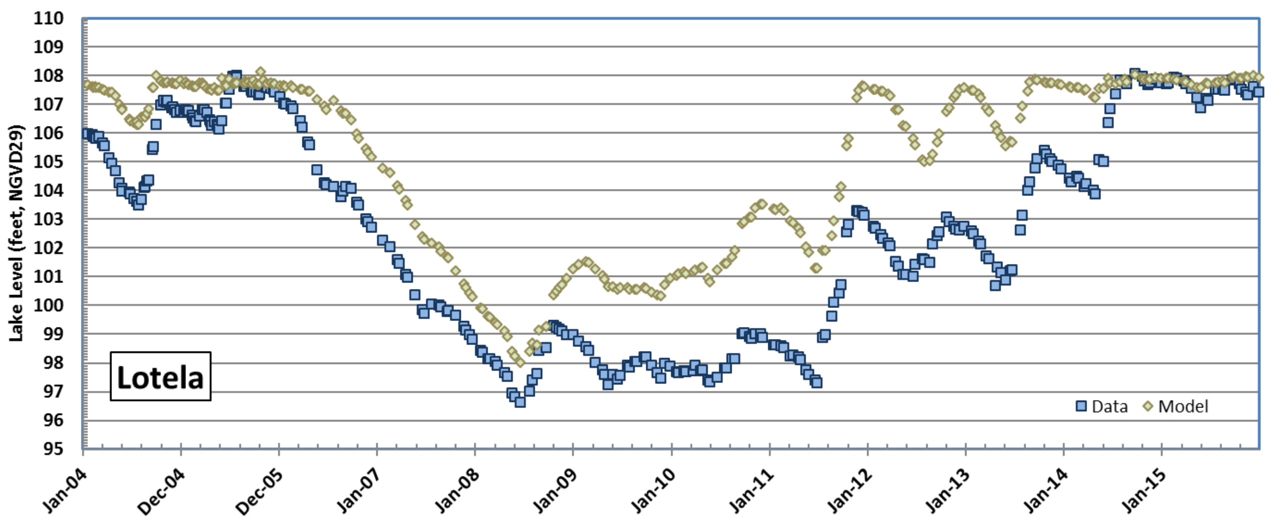

Figure 22. Calibrated Water Budget Model for Lake Lotela without the effects of withdrawals and observed data.

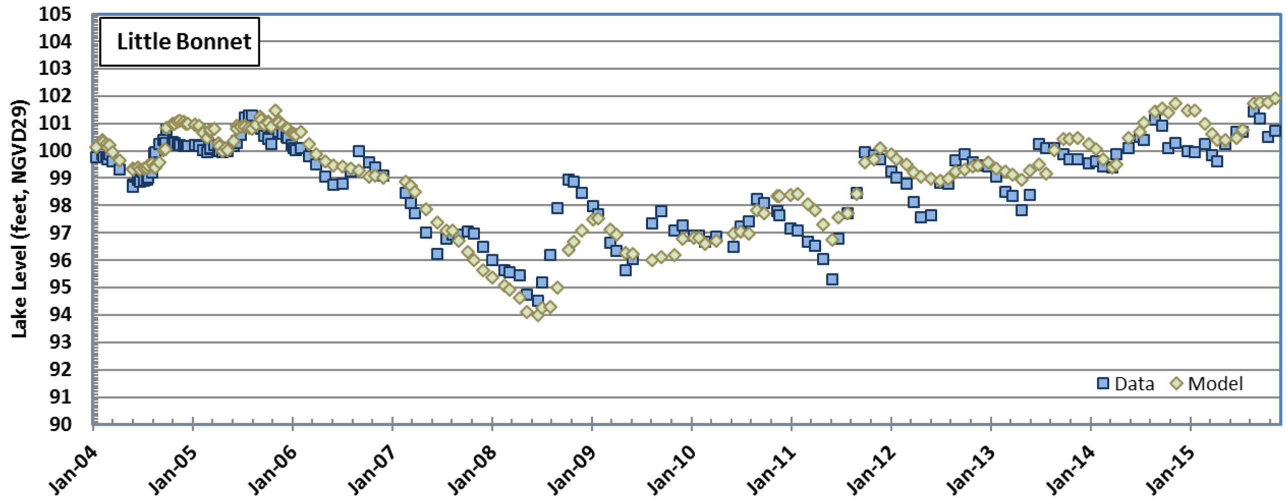

Figure 23. Calibrated Water Budget Model for Little Bonnet Lake without the effects of withdrawals and observed data.

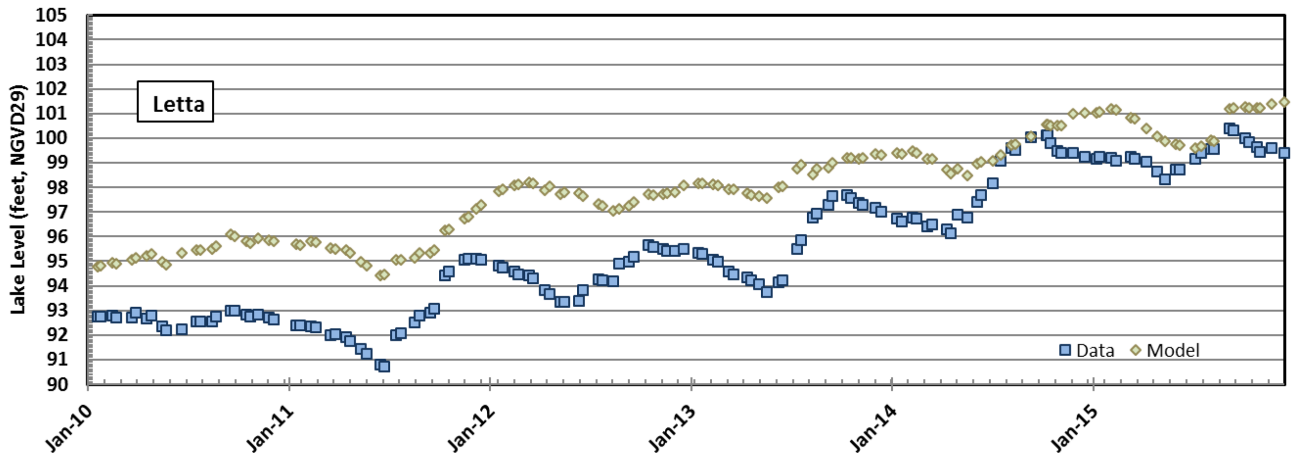

Figure 24. Calibrated Water Budget Model for Lake Letta without the effects of withdrawals and observed data.

Table 14. Historic percentiles as estimated using the lake water budget models (all in feet NGVD29).

Percentile	Lake Lelia (2004 through 2015)	Lake Lotela (2004 through 2015)	Little Bonnet (2004 through 2015)	Lake Letta (2010 through 2015)
P10	116.3	107.87	101.1	101.2
P50	113.9	107.29	99.7	98.2
P90	110.4	100.64	96.7	95.3

I. Rainfall Correlation Model

In an effort to extend the period of record of the 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 Historic water budget model and long-term rainfall. 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, 1997). 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.

Rainfall is 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 are separately used, and the results are compared, with the correlation with the highest correlation coefficient (R^2) chosen as the best model.

For lakes Lotela and Letta rainfall was correlated to each of the water budget model results for the entire calibration period used in each water budget model, and the results from 1946 through 2015 (70 years) were produced. For Lake Lotela, the 6-year weighted model had the highest correlation coefficient, with an R^2 of 0.85. The results are presented in Figure 25. For Lake Letta, the 8-year weighted model had the highest correlation coefficient, with an R^2 of 0.85. The results are presented in Figure 26.

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 for Lotela are used for the period of 1946 to 2004 , while the water budget results are used for the period of 2004 through 2015. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Table 15. The same process was used for Lake Letta using LOC results from 1946 to 2010 and water budget model results from 2010 through 2015 (Table 16).

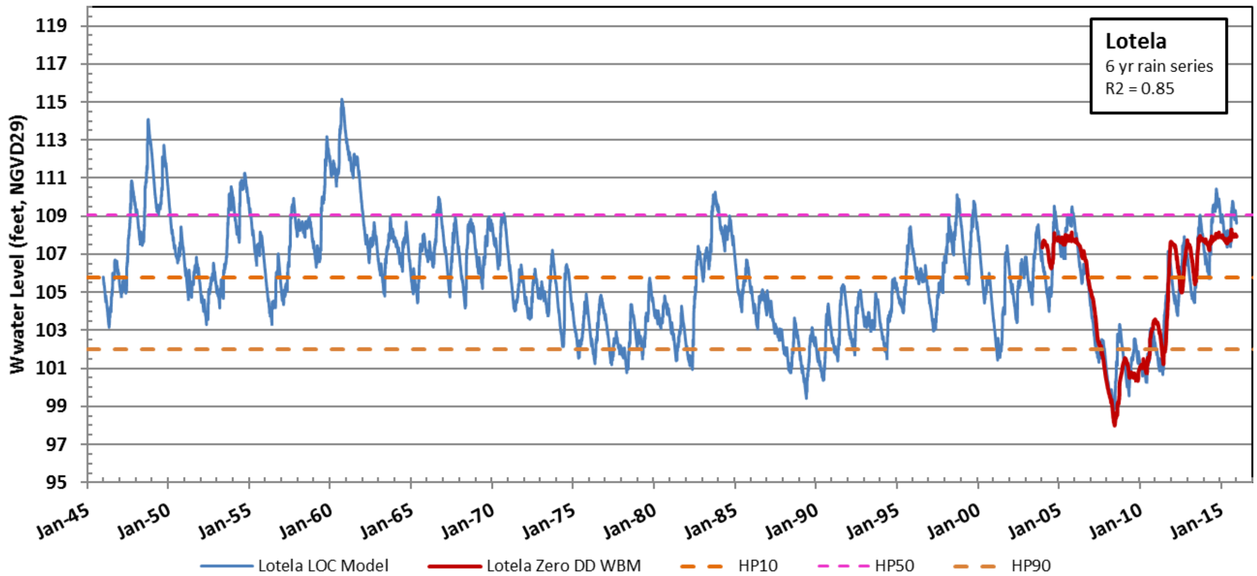

Figure 25. LOC Historic model results for Lake Lotela.

Table 15. Historic percentiles for Lake Lotela as estimated using the hybrid model from 1946 through 2015 (feet NGVD 29).

Percentile	Lake Lotela
P10	109.1
P50	105.8
P90	102.0

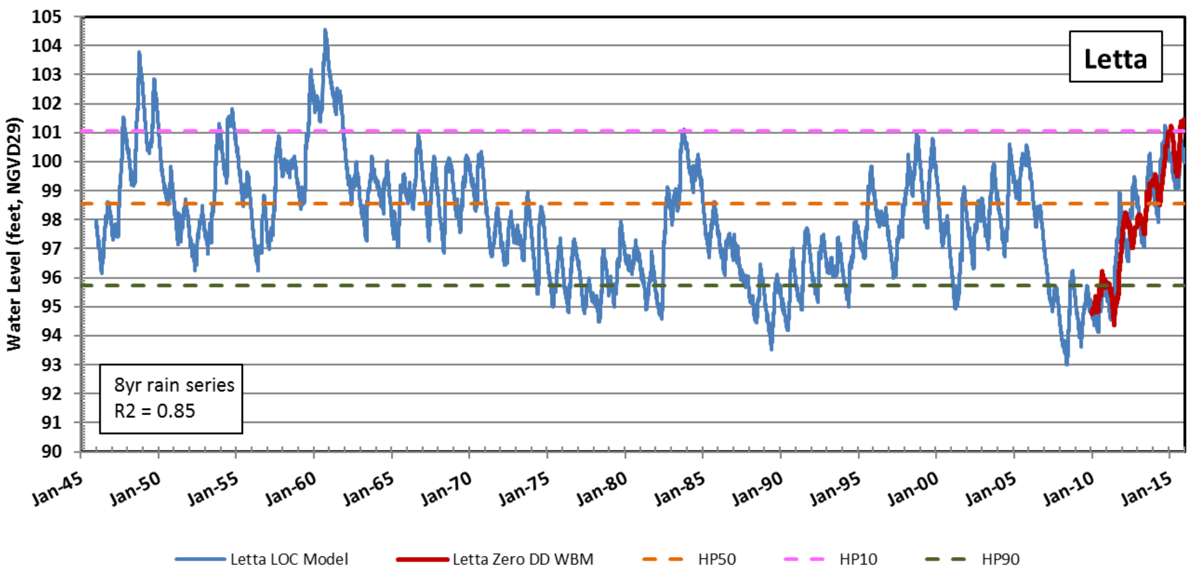

Figure 26. LOC model results for Lake Letta.

Table 16. Historic percentiles for Lake Letta as estimated using the hybrid model from 1946 through 2015 (feet NGVD 29).

Percentile	Lake Letta
P10	101.1
P50	98.5
P90	95.7

J. Conclusions

Based on the model results and the available data, the Lake Lotela and Lake Letta 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 of Historic conditions.

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APPENDIX B

Draft Technical Memorandum

June 6, 2017

TO: Jerry L. Mallams, P.G., Manager, Resource Evaluation Section

FROM: Donald L. Ellison, P.G., Senior Hydrogeologist, Water Resources Bureau

Subject: Lake Lotela 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 Lotela and has revised minimum levels for the lake, in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the revised minimum levels is provided by Ellison (2017) and Campbell and others (2017).

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 Lake Lotela 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 Lotela. This document provides information and analyses to be considered for evaluating the status of the revised minimum levels for Lake Lotela and any recovery that may be necessary for the lake.

B. Background

Lake Lotela is bordered on the west side by the city of Avon Park and on east by State Road 17 (Figure 1). The lake is located in the Intra Ridge Valley of Lake Wales Ridge and is within the Carter Creek watershed.

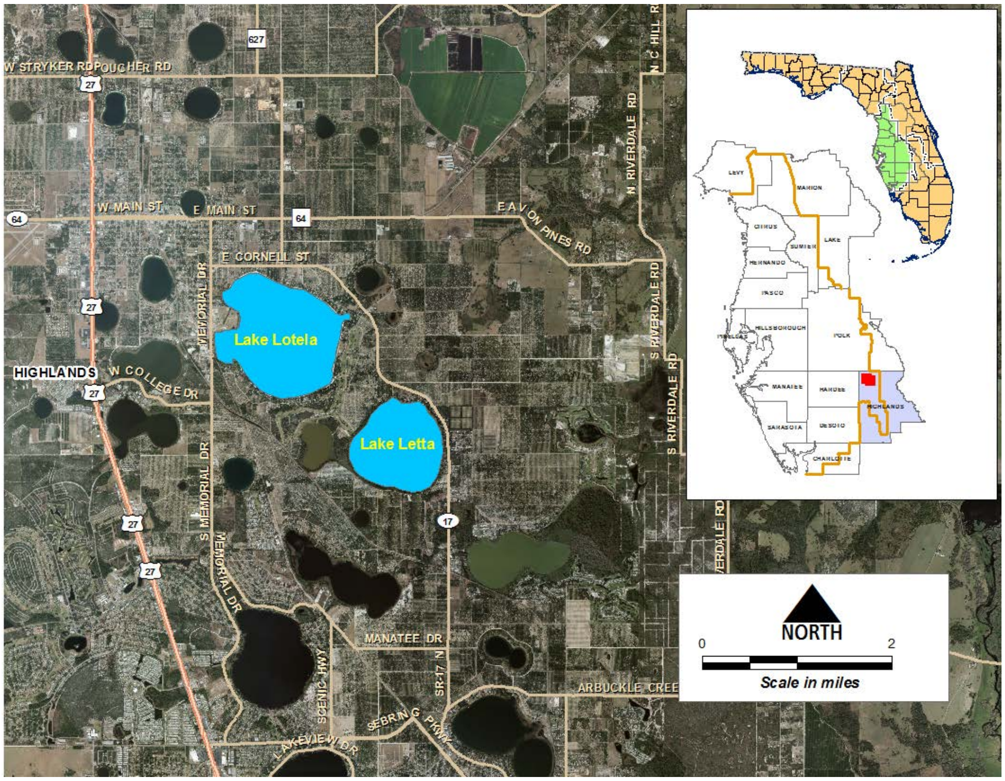

Figure 1. Location of Lake Lotela and Lake Letta in Highlands County, Florida.

C. Revised Minimum Levels for Lake Lotela

Revised minimum levels for Lake Lotela are presented in Table 1 and discussed in more detail by Campbell and others (2017). 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 10th percentile (P10) of long-term water levels. To determine the status of minimum levels for Lake Lotela or minimum flows and levels for any other water body, long-term data or model results must be used.

Table 1. Revised Minimum Levels for Lake Lotela.

Revised Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	106.1
Minimum Lake Level	105.0

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Lake Lotela from 2004 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. "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 Ellison (2017), groundwater withdrawals during this period were relatively consistent. To create a data set that can reasonably be considered to be "Long-term," a rainfall regression model, using the line of organic correlation (LOC), was developed using 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 Lotela (Campbell, 2017). 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 Lotela was used for the status assessment. The best resulting correlation for the LOC model created with measured data was the 8-year weighted period, with a coefficient of determination of 0.94. The LOC model was then modified to create an LOC/hybrid model by replacing modeled data with actual measured data for the period 2004 through 2015. The resulting lake stage exceedance percentiles are presented in Table 2.

Table 2. Comparison of lake stage exceedance percentiles for Lake Lotela.

Percentile	Status: Long-term LOC/Hybrid Model Calibrated to Current Conditions[a] (feet NGVD 29)	Revised Minimum Levels (feet NGVD 29)
P10	108.7	106.1
P50	104.1	105.0

[a]Values represent percentiles for the period 1946 to 2015. LOC calibrated using actual data from 2004 through 2015.

A comparison of the LOC/hybrid model with the revised minimum levels for Lake Lotela indicates the Long-term P10 is 2.6 feet higher than the revised High Minimum Lake Level, and the Long-term P50 is 0.9 feet lower than the revised Minimum Lake Level.

Conclusions

Based on the information presented in this memorandum, it is concluded that Lake Lotela water levels are currently above the revised High Minimum Lake Level and below the revised Minimum Lake Level for the lake. These conclusions are supported by comparison of percentiles derived from LOC modeled lake stage data with the revised 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. In addition, Lake Lotela is included in the Recovery Strategy for the Southern Water Use Caution Area Recovery Strategy (40D-80.074, F.A.C). Therefore, the analyses outlined in this document will be reassessed by the District as part of this plan.

E. References

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