Minimum and Guidance Levels for Lake Alice in Hillsborough County, Florida

October 20, 2017

Resource Evaluation Section
Water Resources Bureau
Southwest Florida
Water Management District

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Cover: 1997 aerial photograph of Lake Alice, (Southwest Florida Water Management District files).

Contents

Introduction

Reevaluation of Minimum Flows and Levels

This report describes the development of minimum levels for Lake Alice in Hillsborough County, Florida. These levels were developed based on the reevaluation of minimum and guidance levels approved by the Southwest Florida Water Management District (District) Governing Board in October 1998 and subsequently adopted into District rules. The minimum and guidance levels represent necessary revisions to the currently adopted levels.

Lake Alice 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 currently adopted minimum levels for the lake were developed. Adopted levels for Lake Alice were also reevaluated to support ongoing District assessment of minimum flows and levels and the need for additional recovery in the Northern Tampa Bay Water Use Caution Area (NTB WUCA), a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Minimum Flows and Levels Program Overview

Legal Directives

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

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

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

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

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

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

Programmatic Description and Major Assumptions

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

A substantial portion of the District's organizational resources has been dedicated to its MFLs Program, which logistically addresses six major tasks: 1) development and reassessment of methods for establishing MFLs; 2) adoption of MFLs for priority water bodies (including the prioritization of water bodies and facilitation of public and independent scientific review of 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 revised minimum levels report; additional information on all tasks associated with the District's MFLs Program is summarized by Hancock *et al.* (2010).

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

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

Regarding 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 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, 2007), Hoyer *et al*. (2006), Leeper (2006), 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 recommended minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. 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 proposed minimum levels for Lake Alice 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 from the Water Resource Implementation Rule (62-40.473, F.A.C.), and the Significant Change Standards (and other information) associated with each that are considered when establishing minimum flows and levels.

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 base on appropriate significant change standards and other information and use of minimum levels in District permitting programs

Lake Classification

Lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. Those with fringing cypress wetlands greater than 0.5 acre in size where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands (i.e. the Historic P50 is equal to or higher than an elevation 1.8 feet below the Normal Pool elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acre in size that have been structurally altered such that the Historic P50 elevation is more than 1.8 feet below the Normal Pool elevation are classified as Category 2 Lakes. Lakes without fringing cypress wetlands or with cypress wetlands less than 0.5 acre in size are classified as Category 3 Lakes. According to Rule 40D-8.624, F.A.C., Lake Alice meets the classification as a Category 3 lake.

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 Resource Implementation Rule (62-40.473, F.A.C.). Other information taken into consideration includes potential changes in the coverage of herbaceous wetland vegetation and aquatic plants.

Although potential changes in the coverage of herbaceous wetland vegetation and aquatic plants associated with use of the standards is taken into consideration in the development of Minimum Levels, there is no significant change standard to determine a threshold for preventing significant harm to fringing non-cypress wetlands. Based on the Cypress Wetland Standard for Category 1 Lakes, however, a Wetland Offset Elevation was developed for Category 3 Lakes to provide protection for non-cypress fringing wetlands.

The **Wetland Offset** Elevation is developed to protect lake fringing non-cypress wetlands. Based on the rationale used to develop the Cypress Wetland Standard for Category 1 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 un-impacted cypress wetlands, the Wetland Offset Elevation for Category 3 Lakes was established at an elevation 0.8 feet below the Historic P50 elevation (Hancock, 2007).

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.

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

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 RLWR statistics where Historic lake data are not available.

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 water elevation associated with less than a fifteen percent reduction in lake surface area relative to the lake area at the Historic P50 elevation.

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 **Recreation/Ski** Standard is developed to identify the lowest elevation within the lake basin that will contain an area suitable for safe water skiing. The standard is based on the lowest elevation within the basin that can contain a 5-foot deep ski area (the Ski Elevation) delineated as a circle 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 RLWR statistics where Historic lake data are not available.

In addition, **Herbaceous Wetland Information** is 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 or less feet). 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.

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 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** that 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 primary 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 Alice

Lake Setting and Description

Watershed

Lake Alice is located in Northwest Hillsborough County (Section 16, Township 27 South, Range 17 East) and within the Brooker Creek Watershed (Figure 1 & Figure 2). The drainage basin area of Lake Alice is 301 acres (Appendix A).

Surface water inflow to Lake Alice occurs as overland flow and minor runoff in the neighborhood. Discharge from Lake Alice leading to Lake Taylor can occur on the western shore of the lake via an open ditch and a 36-inch corrugated metal pipe under Spencer Road (Figure 3). As part of developing MFLs for Lake Alice, a comprehensive topopgraphic survey was conducted by District staff on July 27, 2017. This survey identified the elevations of the lowest roads and buildings adjacent to the lake. The elevations of the outflow conveyance system leading to Lake Taylor were also determined. The lowest finished floor and lake side structure (out building) on Lake Alice are at 43.90 ft. and 43.98 ft., respectively.

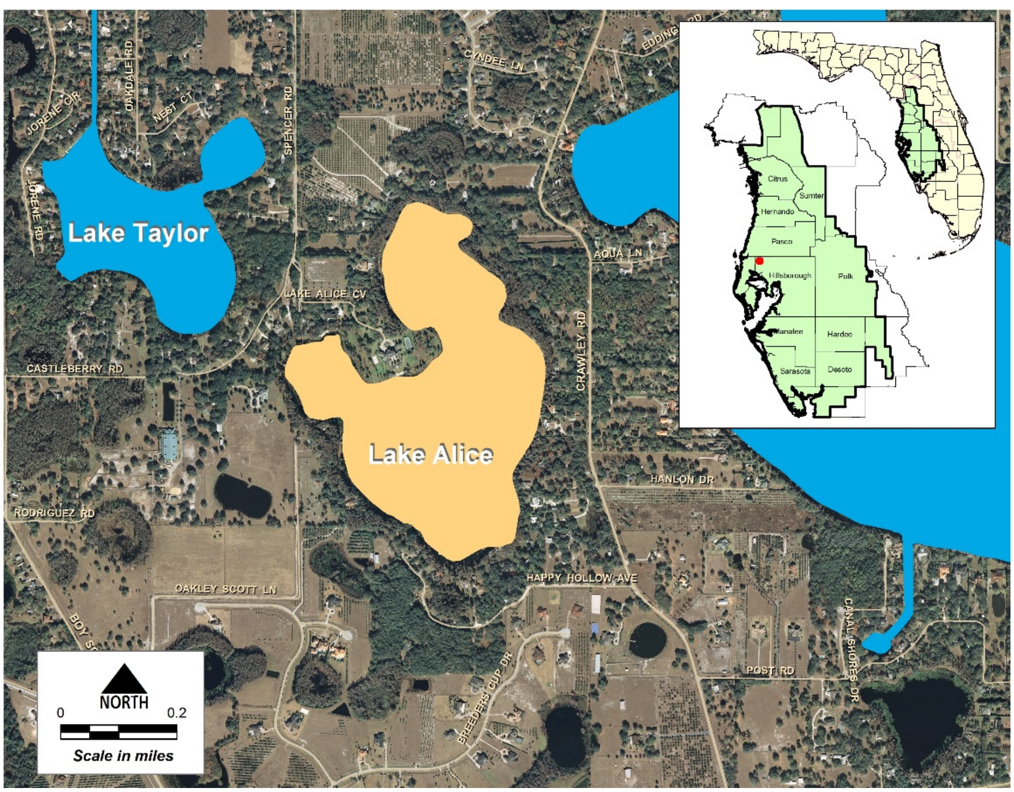

Figure 1. Location of Lake Alice in Hillsborough County, Florida.

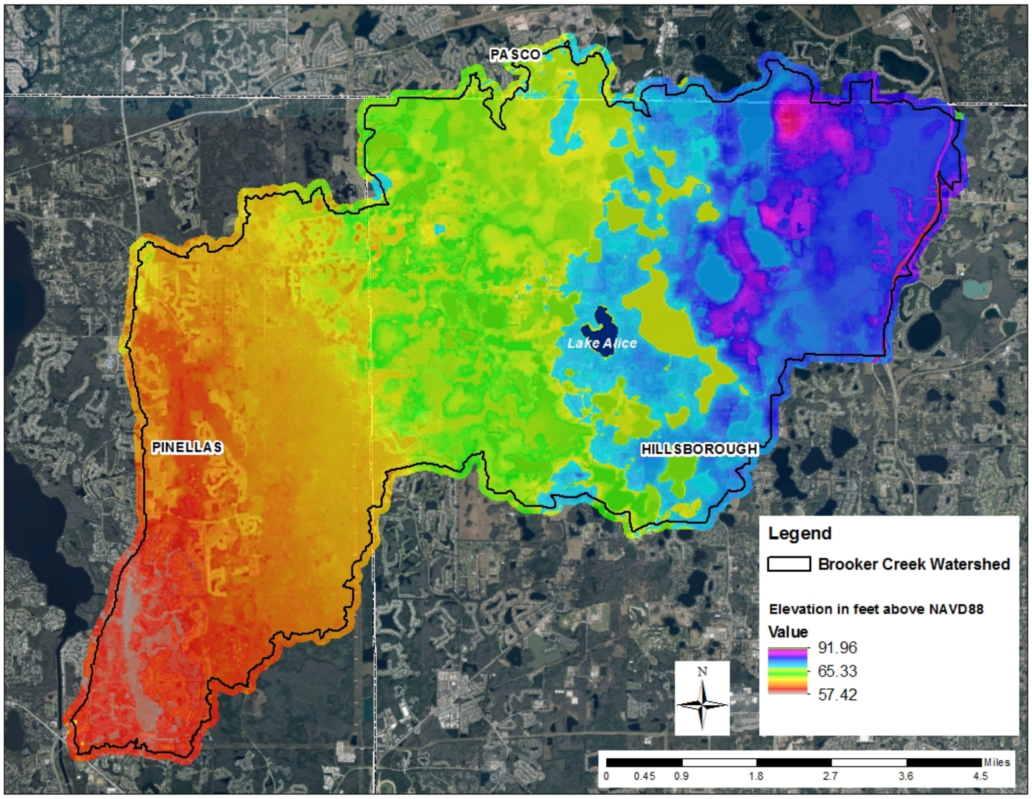

Figure 2. Brooker Creek Watershed Delineation and Topography.

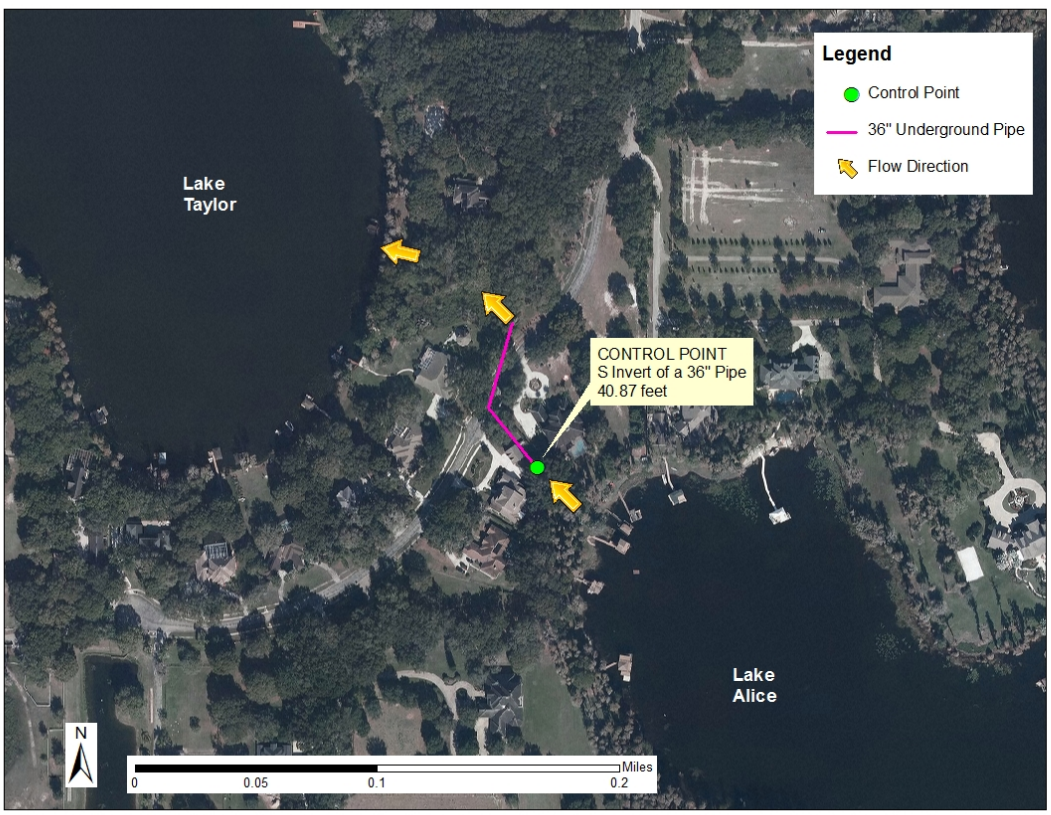

Figure 3. Lake Alice Outflow Conveyance System.

Site Specific Details

Lake Alice is located between the Cosme-Odessa and the Eldridge-Wilde Wellfields, two of Tampa Bay Water public water supply production facilities in service since 1930 and 1956, respectively. They are the oldest public supply wellfields in the District. Therefore, Lake Alice and adjacent lakes have likely been subjected to the effects of groundwater withdrawals longer than any other lakes in the District. Total withdrawals at Cosme-Odessa steadily climbed to as much as 20 million gallons per day (mgd) in 1962/1963, but recent withdrawal rates at the wellfield have typically averaged approximately 7 mgd. Total withdrawals at Eldridge-Wilde often spiked near 40 mgd during the 1970-1990s, but recent withdrawal rates at the wellfield have roughly averaged approximately 15 mgd.

Land form physiology or morphology of the nature or structure of the underlying geology in the region is primarily silty sand overlying limestone. The area surrounding the lake was characterized as the Odessa Flats subdivision of the Tampa Plain in the Ocala Uplift Physiographic District (Brooks 1981), and was described as a poorly dissected low sandy plain overlying Tampa Limestone. As part of the Florida Department of Environmental Protection's Lake Bioassessment/Regionalization Initiative, the area has been identified as the Keystone Lakes region, and described as well-drained, sandy upland with numerous slightly acidic, clear-water lakes with low nutrient levels (Griffith et al. 1997). Romie (2000) characterized the lake as a clear, soft water, oligo-mesotrophic lake, with low concentrations of phosphorus and with generally good water quality based on the Florida Trophic State Index.

Land Use Land Cover

An examination of the 1950, 1990 and most current 2011 Florida Land Use, Cover and Forms Classification System (FLUCCS) maps revealed that there have been considerably changes to the landscape in the vicinity during this period; specifically, the dominant land forms. The land surrounding Lake Alice in 1950 was primarily agriculture (crop and pastureland), upland forests (pine flatwoods) and pre-development open land (Figure 4). Dominant land use in 1990 was residential, open land, and citrus groves (Figure 5). By 2011, the lake was surrounded almost exclusively by residential development with a small remnant of pasture and citrus groves (Figure 6). Aerial photography chronicles landscape changes to the immediate lake basin from 1938 to the 1970’s (Figures 7 through 11).

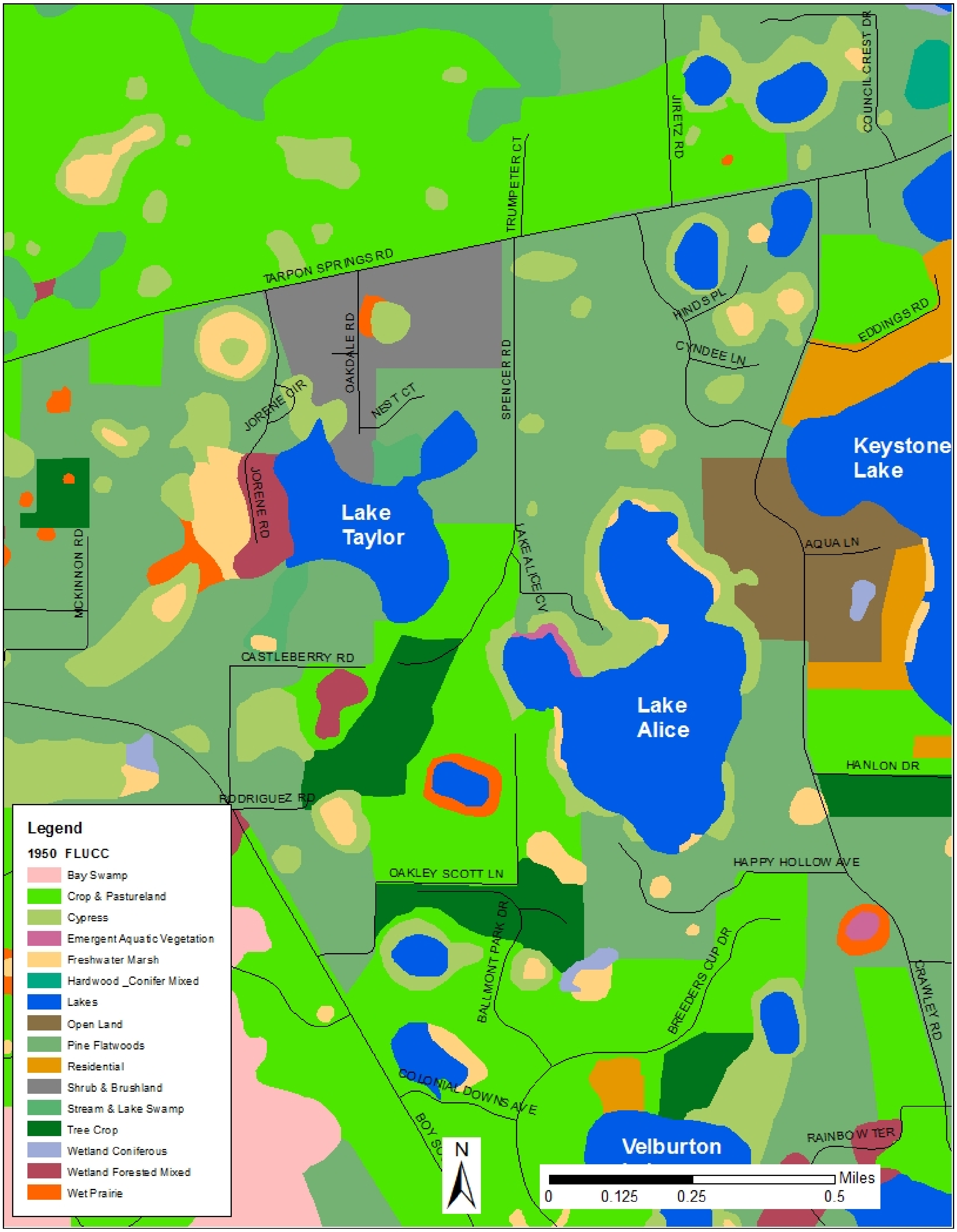

Figure 4. 1950 Land Use Land Cover Map of the Lake Alice Vicinity.

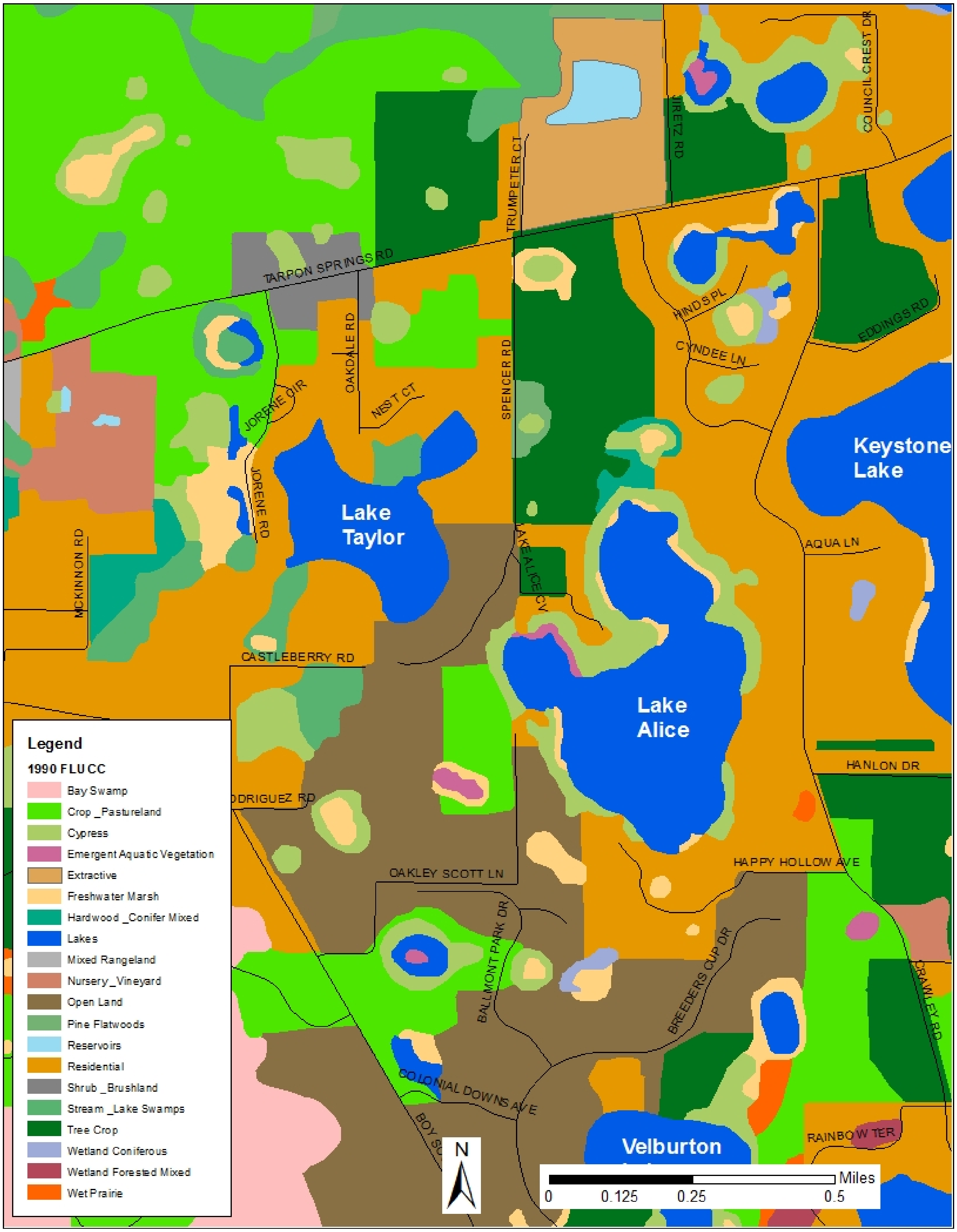

Figure 5. 1990 Land Use Land Cover Map of the Lake Alice Vicinity.

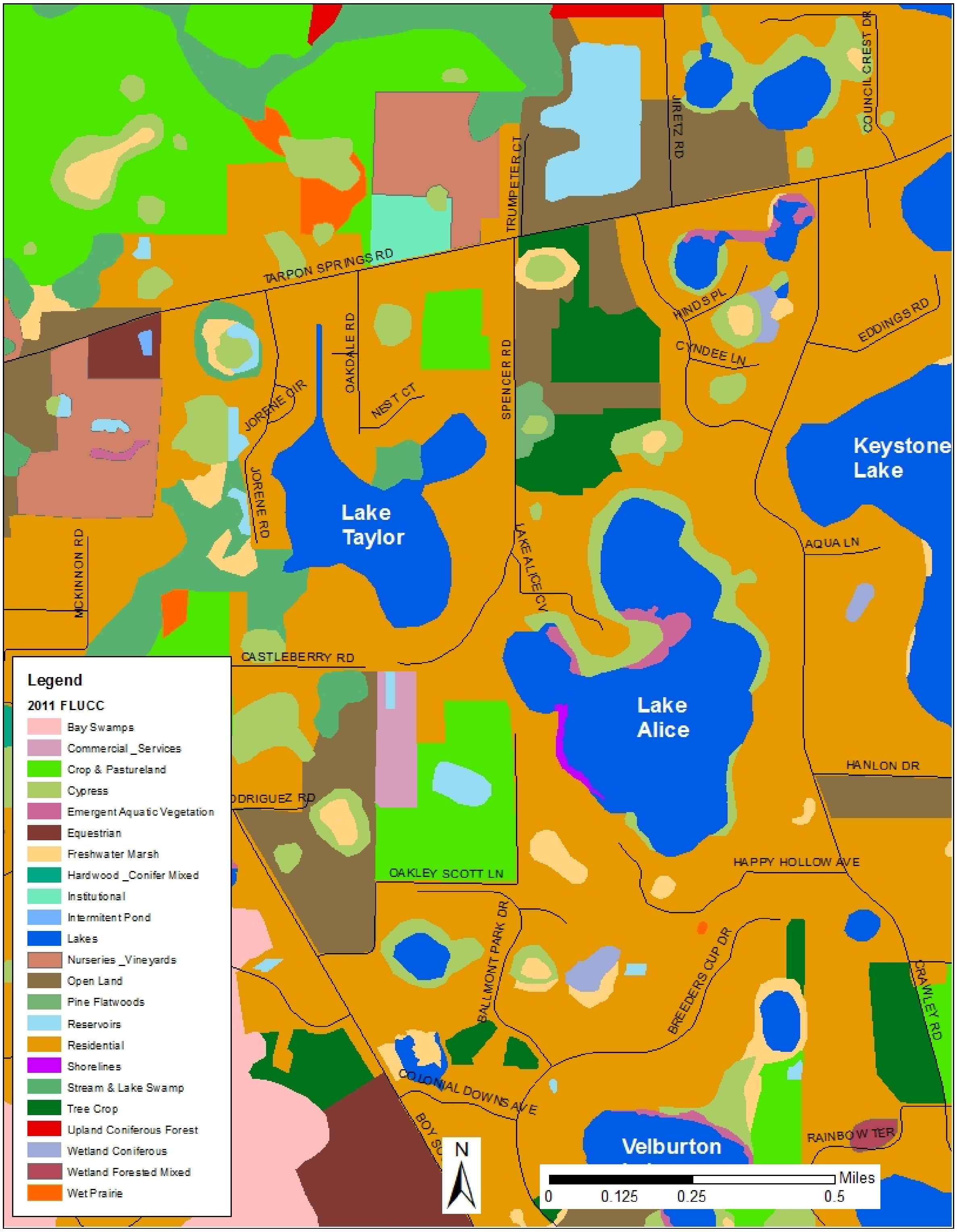

Figure 6. 2011 Land Use Land Cover Map of the Lake Alice Vicinity.

Figure 7. 1938 Aerial Photograph of Lake Alice.

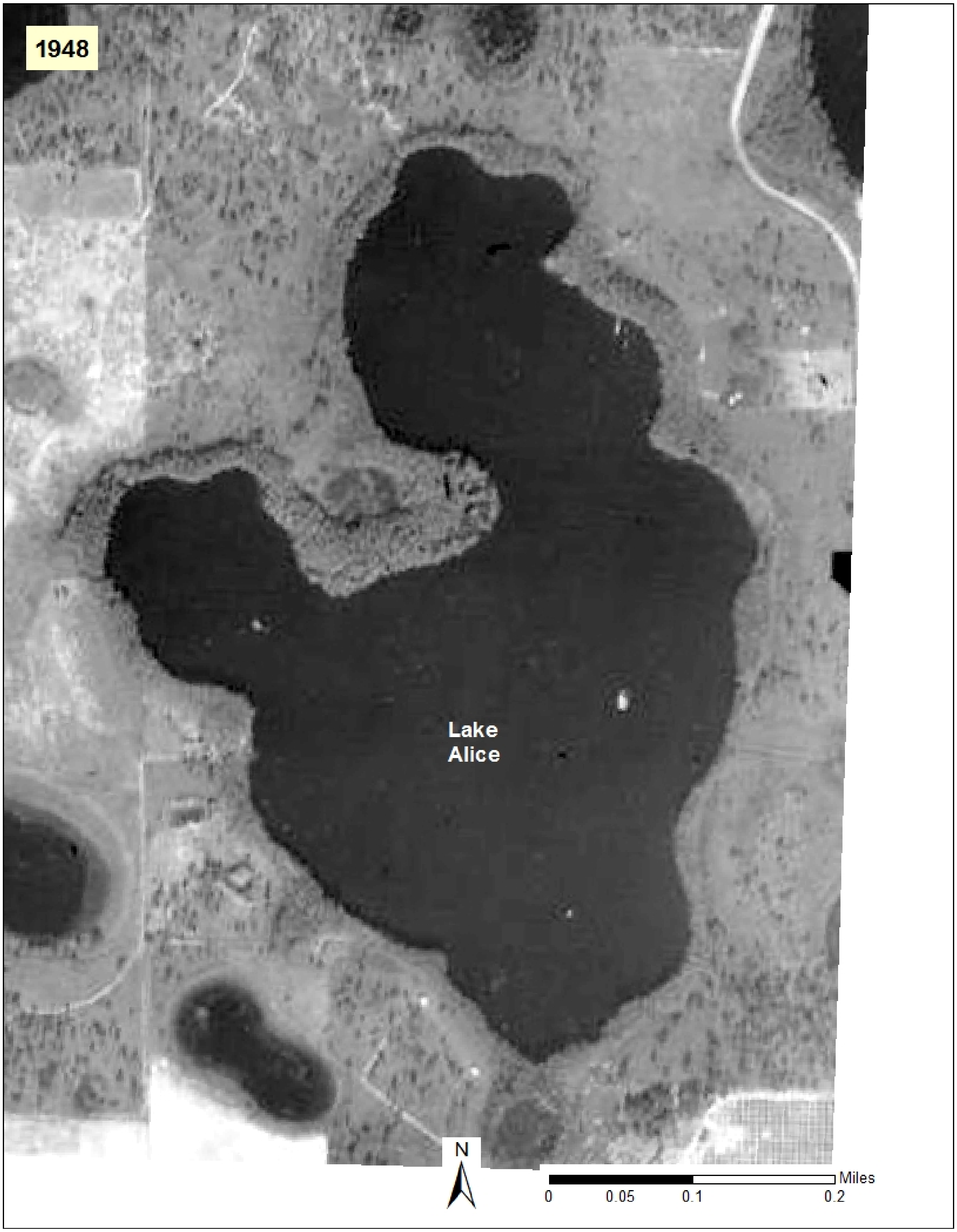

Figure 8. 1948 Aerial Photograph of Lake Alice.

Figure 9. 1957 Aerial Photograph of Lake Alice.

Figure 10. 1968 Aerial Photograph of Lake Alice.

Figure 11. 1970's Aerial Photograph of Lake Alice.

Bathymetry Description and History

One-foot interval bathymetric data gathered from recent field surveys resulted in lake-bottom contour elevations from approximately 11 ft. to 40 ft. (Figure 12). These data revealed that the lowest lake bottom contour (11.2 ft.) is located in a small "hole" in the western part of the lake about 100 ft. off the shoreline near the outflow ditch. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

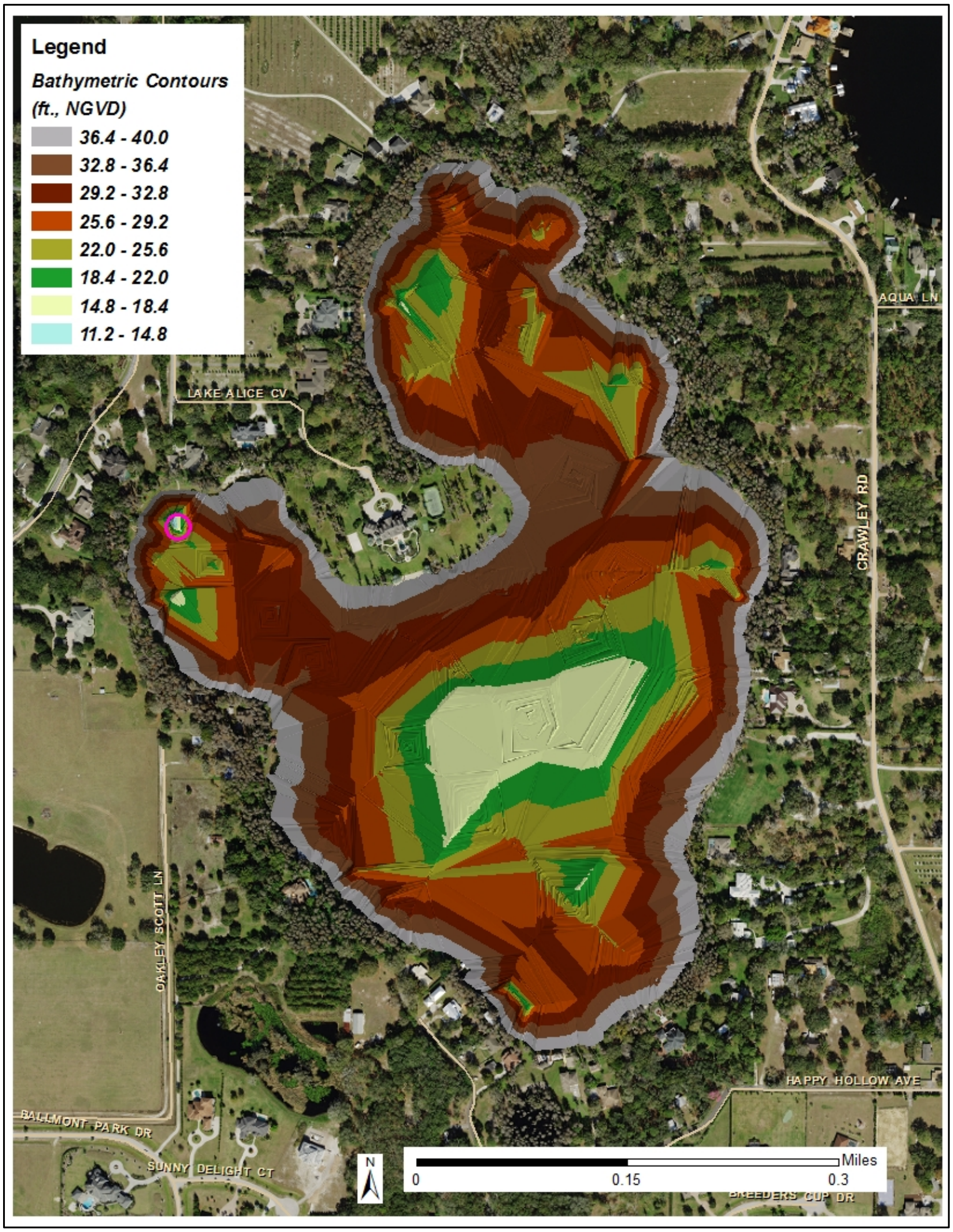

Figure 12. Lake Alice Contours on a 2017 Natural Aerial Photograph.

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Lake Alice from the District's Water Management Information System. The data used in setting the MFLs were collected from a gage on the northern end of the lake (SID 19874) (Figure 13). This gage was recently moved to the southeastern shore where the District continues to monitor the water levels on a monthly basis (Figure 14). Data has been collected since June 25, 1971. The highest lake stage elevation on record was 42.4 ft. and occurred in September 2004 with the water periodically peaking above 41 ft. The lake regularly experienced periods of low water since 1971 (near 36 ft.) with the lowest lake stage elevation on record occurring during a drought at 33.24 ft. (May 29, 2002). An aerial photograph in 1997 exhibits a period of low water (Figure 15) while the historic aerial from 2014 exhibits a period of high water (Figure 16).

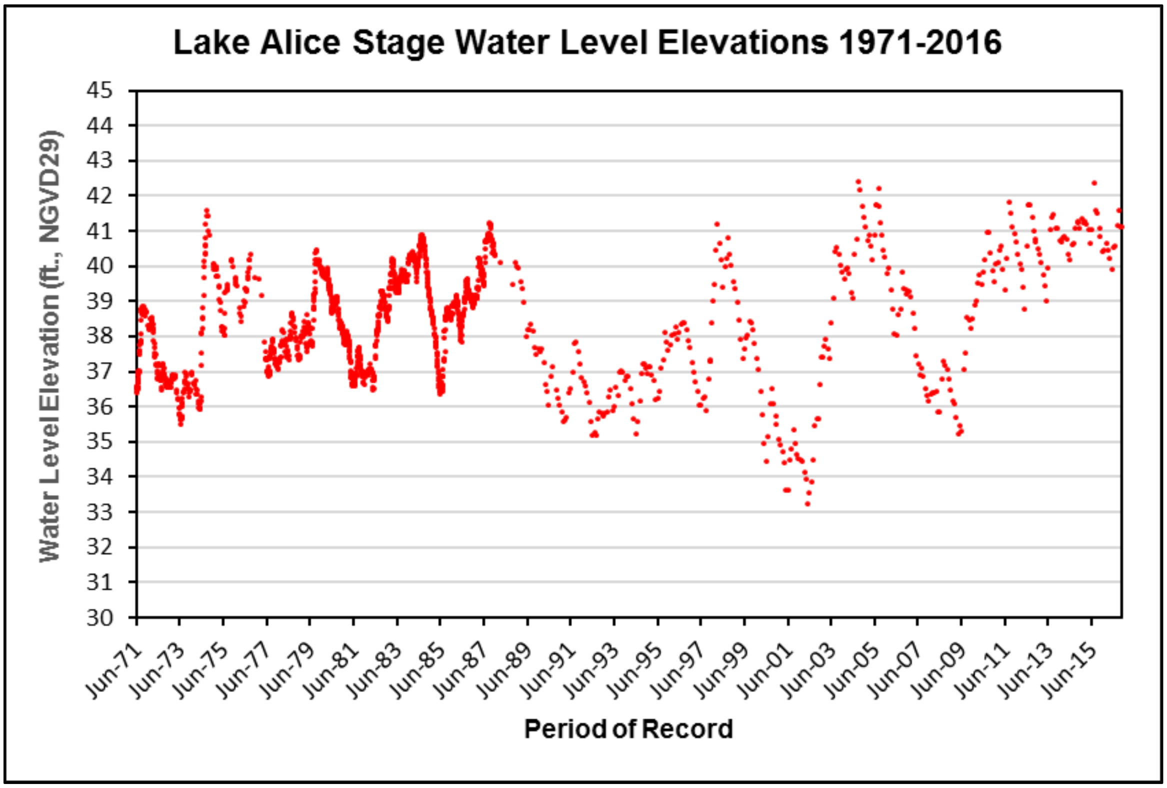

Figure 13. Lake Alice Period of Record Stage Data (SID 19874).

Figure 14. Lake Alice Gauge SID 884744 Currently Located on the Southeastern Shoreline Installed June 2017.

Figure 15. Low Water Levels in 1997 Reveal Shallow Area on North End of Lake Alice (facing SW).

Figure 16. 2014 Aerial Photograph of Lake Alice.

Historical and Current Management Levels

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

The District Governing Board approved Guidance and Minimum levels for Lake Alice (Table 2) which were subsequently adopted into Chapter 40D-8, Florida Administrative Code, in July 2000, using the methodology for Category 2 Lakes described in SWFWMD (1999a and 1999b). The current re-evaluation establishes Minimum and Guidance Levels that replace the levels established in 2000.

Table 2. Guidance Levels Adopted July 2000 for Lake Alice.

Level	Elevation (ft., NGVD)
Ten Year Flood Guidance Level	42.4
High Guidance Level (Control Point)	40.9
High Minimum Level	40.9
Minimum Level	39.9
Low Guidance Level	38.8

Methods, Results and Discussion

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

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

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Historic P10 (1947 to 2016)	41.4	103.4
Historic P50 (1947 to 2016)	39.6	95.8
Historic P90 (1947 to 2016)	37.6	89.4
Normal Pool and Control Point		
Normal Pool	NA	NA
Control Point	40.9	100.9
Significant Change Standards		
Lake Mixing Standard	17.8	5.0
Dock-Use Standard	38.9	93.6
Basin Connectivity Standard	36.0	83.9
Species Richness Standard	35.3	81.1
Aesthetics Standard	37.6	89.4
Recreation/Ski Standard	35.0	79.8
Cypress Standard	NA	NA
Wetland Offset Elevation	38.8	93.3
Other		
Lowest Floor Slab Elevation	43.9	115*
Minimum and Guidance Levels		
High Guidance Level	41.4	103.4
High Minimum Lake Level	40.7	99.8
Minimum Lake Level	38.9	93.6
Low Guidance Level	37.6	89.4

NA - not available; * estimated.

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 Alice 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 10.4.1 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 Alice. 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. A lake stage to surface area graph is presented in Figure 17.

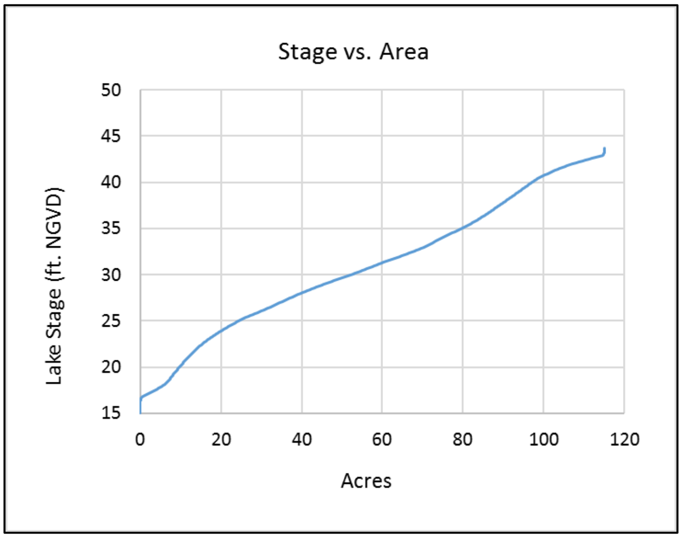

Figure 17. Lake Stage (Ft. NGVD29) to Surface Area (Acres).

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 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). An evaluation of groundwater withdrawal impacts to Lake Alice is available in Appendix C.

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 Alice and composite regional rainfall.

A combination of model data produced a hybrid model which resulted in a 70-year (1947-2016) 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 41.4 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 39.6 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 37.6 ft. (Figure 18 and Table 3).

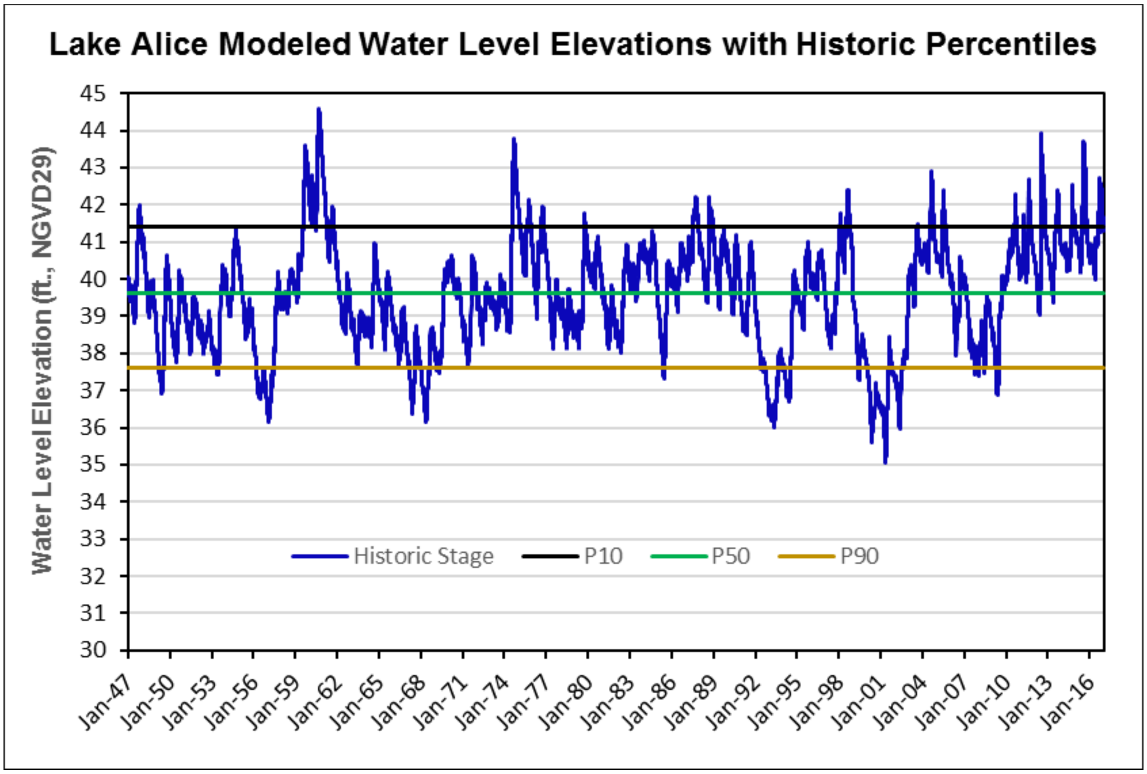

Figure 18. Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

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). A thorough search of hydrologic indicators on Lake Alice was performed. No reliable indicators were found. Seven cypress buttress swelling indicators were measured for the original MFL on the lake in 1998.

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. Based on survey data collected by District staff, it was determined that the highest spot in the outflow conveyance system is the south end of the culvert (elevation 40.9 ft.) located at the end of the ditch leading out of Lake Alice. This culvert runs under Spencer Road and eventually to Lake Taylor. The lowest finished floor elevation on Lake Alice is 43.9 ft.

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 Alice, the High Guidance Level was established at the Historic P10 elevation, 41.4 ft. The High Guidance Level is exceeded several times in the modeled data (Figure 19). For example, the high peaks are in July 2012, September 1974 and September 1960 (43.9, 43.7 and 44.5 ft., respectively). In comparison, gaged period of record levels for the lake (Figure 20) exceeded the High Guidance Level in September 2004 and July 2015 (42.4 ft.).

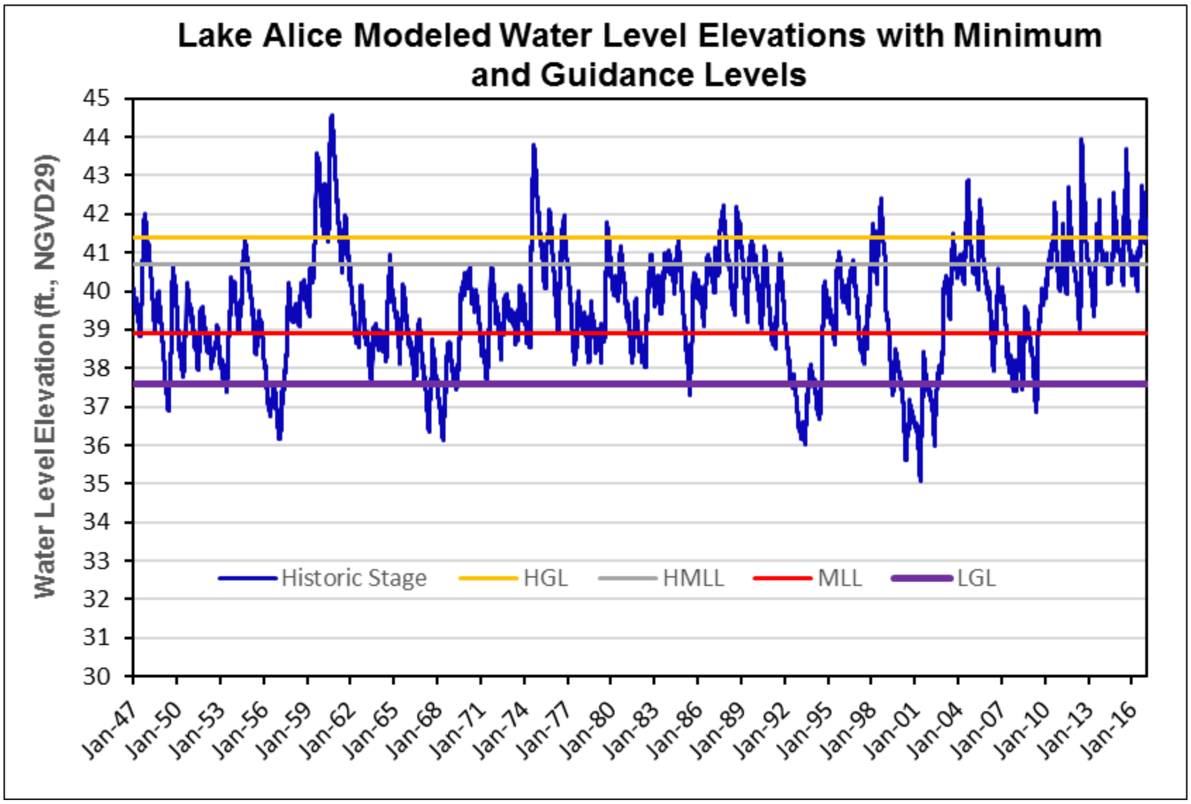

Figure 19. Historic Water Levels (hybrid) used to Calculate the Minimum and Guidance Levels. The Levels Include the High Guidance Levels (HGL), High Minimum Lake Levels (HMLL), Minimum Lake Levels (MLL), and Low Guidance Levels (LGL).

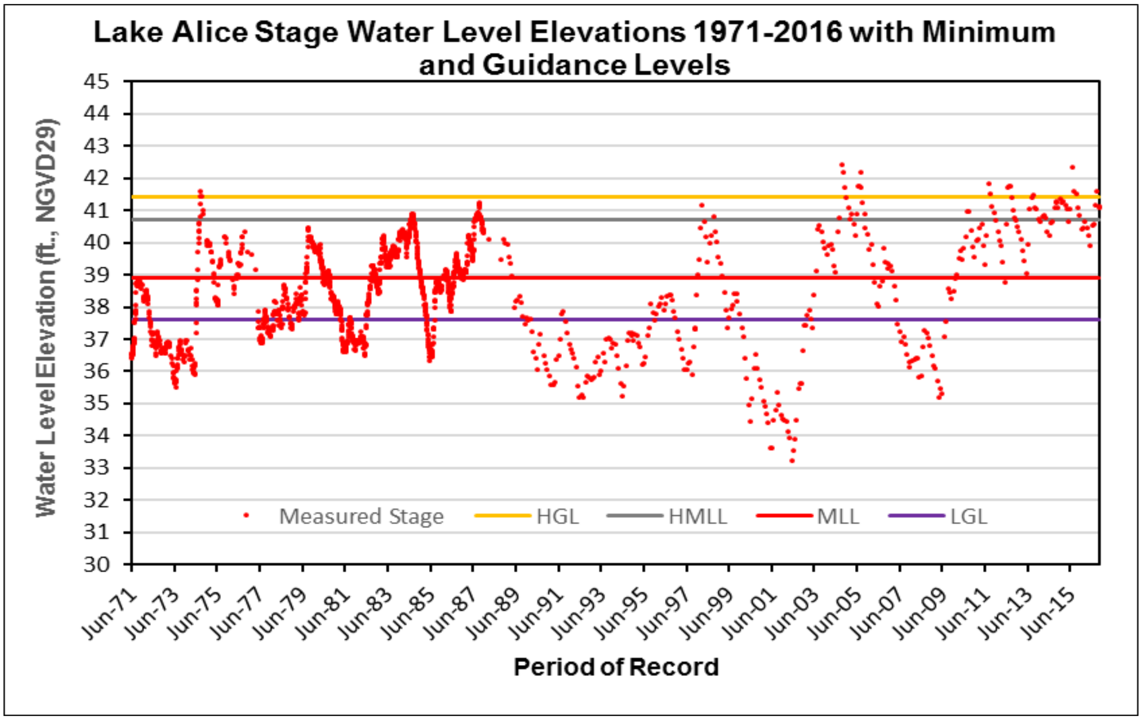

Figure 20. Lake Stage Water Levels (gage) and the High Guidance Levels (HGL), High Minimum Lake Levels (HMLL), Minimum Lake Levels (MLL), and Low Guidance Levels (LGL).

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, RLWR statistics. RLWR 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. Based on the availability of Historic data for Lake Alice, the Low Guidance Level was established at the Historic P90 elevation, 37.6 ft. The gaged period of record indicates the lowest recorded elevation was 33.2 ft., below the Low Guidance Level, in May 2002. (Figure 20).

Significant Change Standards

As mentioned previously in this report, lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. Despite the presence of lake-fringing cypress wetlands of 0.5-acre or more in size within the lake basin, the cypress trees lacked sufficient biological indicators of hydrology (Normal Pool indicators). Therefore, Lake Alice was classified as a Category 3 lake, for this reevaluation.

However, lake-specific Significant Change Standards and other available information are considered for establishing minimum levels. The standards are used to identify thresholds for preventing significant harm to environmental values associated with lakes (refer to Table 1) in accordance with guidance provided in the Florida Water Resource Implementation Rule (62-40.473, F.A.C.). Other information taken into consideration includes potential changes in the coverage of herbaceous wetland vegetation and aquatic plants.

Category 3 Significant Change Standards, including a Lake Mixing Standard, Dock-Use Standard, Basin Connectivity Standard, Species Richness Standard, Herbaceous Wetland Standard, Submerged Aquatic Macrophyte Standard, Aesthetics Standard, and a Recreation/Ski Standard were established for Lake Alice, where appropriate (Each standard was previously defined in the Lake Classification section of this report). Each standard was evaluated for minimum levels development for Lake Alice and presented in Table 3.

- The **Lake Mixing** Standard was established at 17.8 ft. due to the dynamic ratio (basin slope) shifting from <0.8 to >0.8 ft., indicating that potential changes in basin susceptibility to wind-induced sediment re-suspension (see Bachmann *et al.* 2000).
- The **Dock-Use** Standard was established at 38.9 ft. derived from the elevation of lake sediments at the end of 42 docks on the lake.
- The **Basin Connectivity** Standard was set at 36.0 ft. This is the elevation the lake would need to be in order for the lake to create an isolated northern lobe of the lake and not allow for enough clearance for non-powerboat watercraft to pass.
- The **Species Richness** Standard was established at 35.3 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- Review of changes in potential **herbaceous wetland** area associated with change in lake stage (Figure 21), and potential change in area available for **aquatic macrophyte** colonization (Figure 21) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development.
- An **Aesthetic** Standard for Lake Alice was established at the Low Guidance Level elevation of 37.6 ft.
- The **Recreation/Ski** Standard was established at an elevation of 35.0 ft. based on a Ski Elevation of 33.0 ft., plus the difference between the Historic P50 and P90.
- The **Wetland Offset** was calculated to be 38.8 ft.

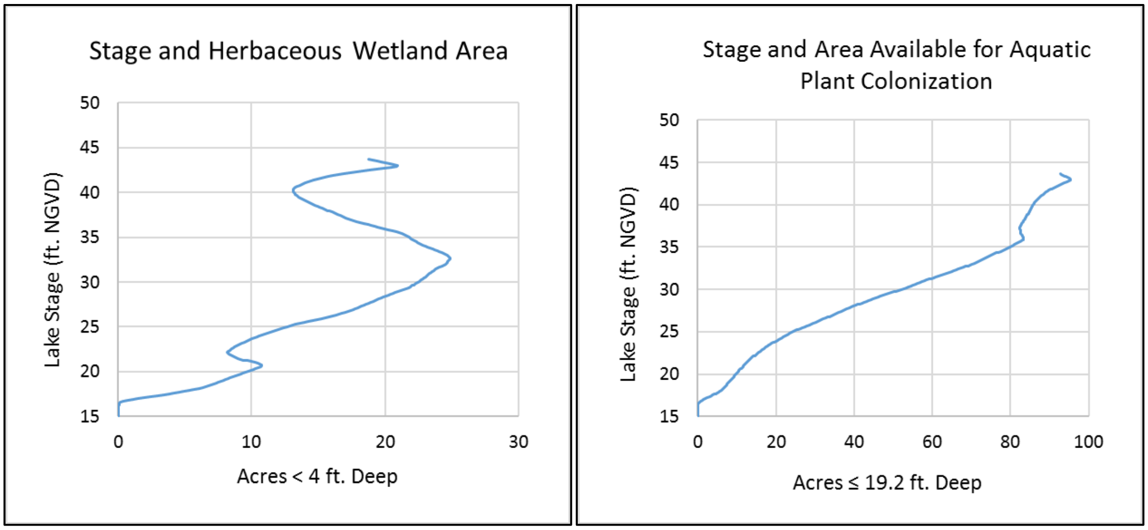

Figure 21. Potential Herbaceous Wetland Area and Area Available for Macrophyte colonization in Lake Alice as a Function of Lake Stage.

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 utilizing a process that considers applying professional experience and judgement, and the seven Standards listed previously. In the case of Lake Alice, the Minimum Lake Level is established at the Dock-Use Standard elevation of 38.9 feet, which is notably nearly equal to the wetland offset (38.8 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, Rule 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. For Lake Alice, the HMLL is established at an elevation 40.7 ft., which is the MLL plus the difference between the Historic P10 and P50.

Minimum and Guidance levels for Lake Alice are plotted on the modeled and stage water level record in Figures 19 and 20. To illustrate the approximate locations of the lake margin when water levels equal the minimum levels, the levels are imposed onto a 2017 natural color photograph in Figure 22.

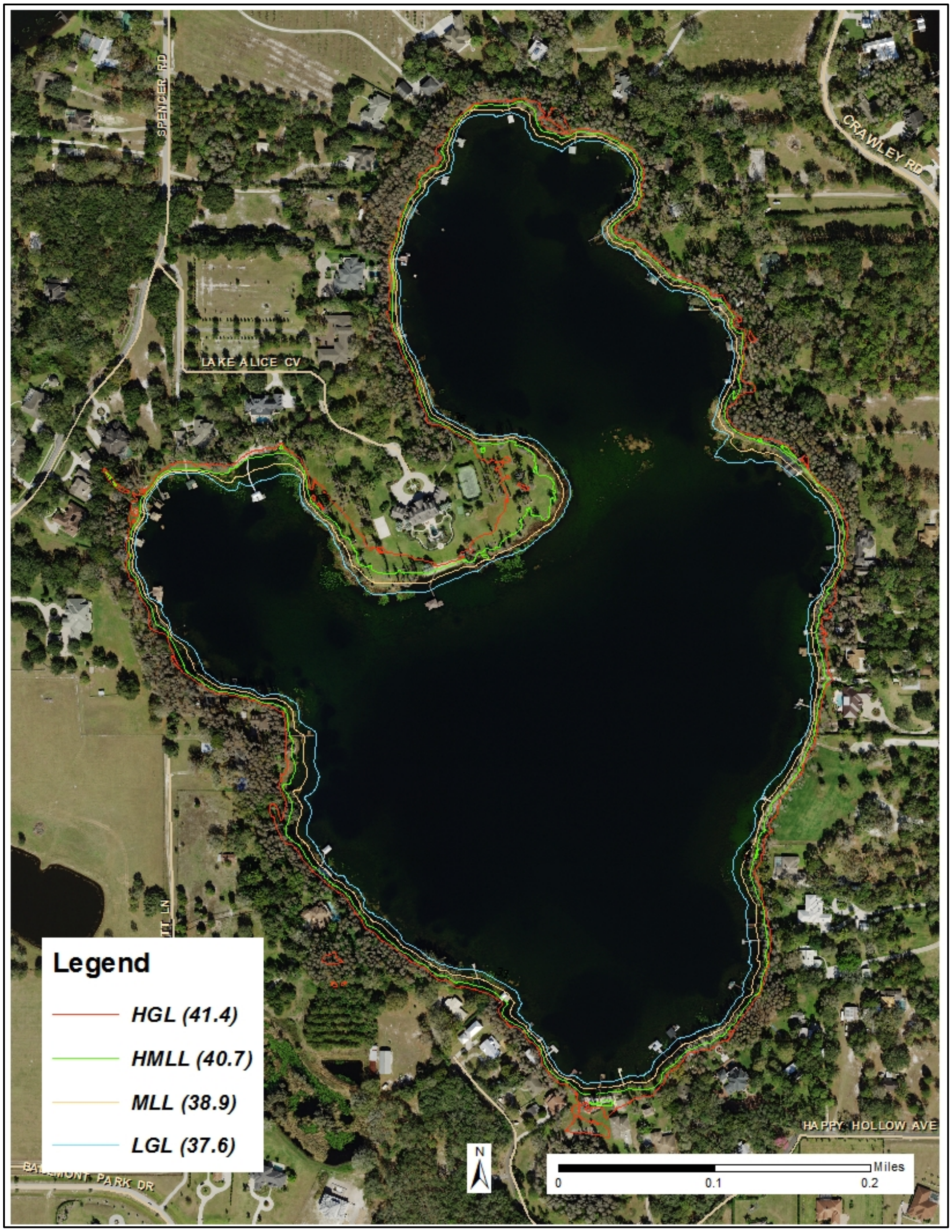

Figure 22. Lake Alice Minimum and Guidance Level Contour Lines Imposed Onto a 2017 Natural Color Aerial Photograph.

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 MFLs for Lake Alice are presented in both datum standards (Table 4). The datum shift was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum of 1988. The NGVD29 datum conversion to NAVD88 is 0.84 feet for SID 19818 on Lake Alice.

Table 4. Minimum and Guidance Levels for Lake Alice in NGVD29 and NAVD88.

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88
High Guidance Level	41.4	40.6
High Minimum Lake Level	40.7	39.9
Minimum Lake Level	38.9	38.1
Low Guidance Level	37.6	36.8

Consideration of Environmental Values

The revised minimum levels for Lake Alice are protective of relevant environmental values identified for consideration in the Water Resource Implementation 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 Dock-Use standard was used for developing revised Minimum Levels for Lake Alice 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: recreation in and on the water, aesthetic and scenic attributes, and water quality (Table 1).

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

Two environmental values identified in the Water Resource Implementation Rule were not considered relevant to development of revised minimum levels for Lake Alice. 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 process typically associated with flowing water systems.

Minimum Levels Status Assessment

To assess if the Minimum and High Minimum Lake Levels are being met, observed stage data in Lake Alice 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 were determined to be from January 2003 through October 2016. Using the Current stage data, the LOC model was created. The LOC model resulted in a 70-year long-term water level record (1946-2016).

For the status assessment, cumulative median (P50) and cumulative P10 water elevations were compared to the 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 Alice water levels are currently above the High Minimum and Minimum Lake Levels (see Appendix B).

The lake is within the region of the District covered by an existing recovery strategy, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area (Rule 40D-80.073, F.A.C.). The District plans to continue regular monitoring of Lake Alice water levels and will also routinely evaluate the status of the lake’s water levels with respect to the adopted minimum levels for the lake included in Chapter 40D-8, F.A.C.

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APPENDIX A

Technical Memorandum

October 6, 2017

TO: Mark K. Hurst, Senior Environmental Scientist, Water Resources Bureau
David C. Carr, Staff Environmental Scientist, Water Resources Bureau

THROUGH: Tamera McBride, P.G, Manager, Resource Evaluation, Water Resources Bureau

FROM: Cortney Cameron, G.I.T., Hydrogeologist, Water Resources Bureau
Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau

Subject: Lake Alice Water Budget Model, Rainfall Correlation Model, 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 levels for Lake Alice in northwest Hillsborough County. Lake Alice currently has adopted minimum levels which are scheduled to be re-assessed in FY 2018. This document will discuss the development of the Lake Alice models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Lake Alice is in northwest Hillsborough County, northwest of the intersection between Crawley Road and Happy Hollow Avenue and southeast of Lake Alice Cove (Figure 1). The lake lies within Brooker Creek watershed that forms part of the larger Tampa Bay watershed (USGS HUC 03100206). Lake Alice has no significant inflow other than overland flow, but discharges to Lake Taylor to the northeast via a reinforced concrete pipe during high flow periods (Figure 2). The topography is very flat, however, and flows are often negligible.

Physiography and Hydrogeology

The area surrounding the lake is categorized as the Land-O-Lakes subdivision of the Tampa Plain in the Ocala Uplift Physiographic District (Brooks, 1981), a region of many lakes on a moderately thick plain of silty sand overlying limestone. The topography is

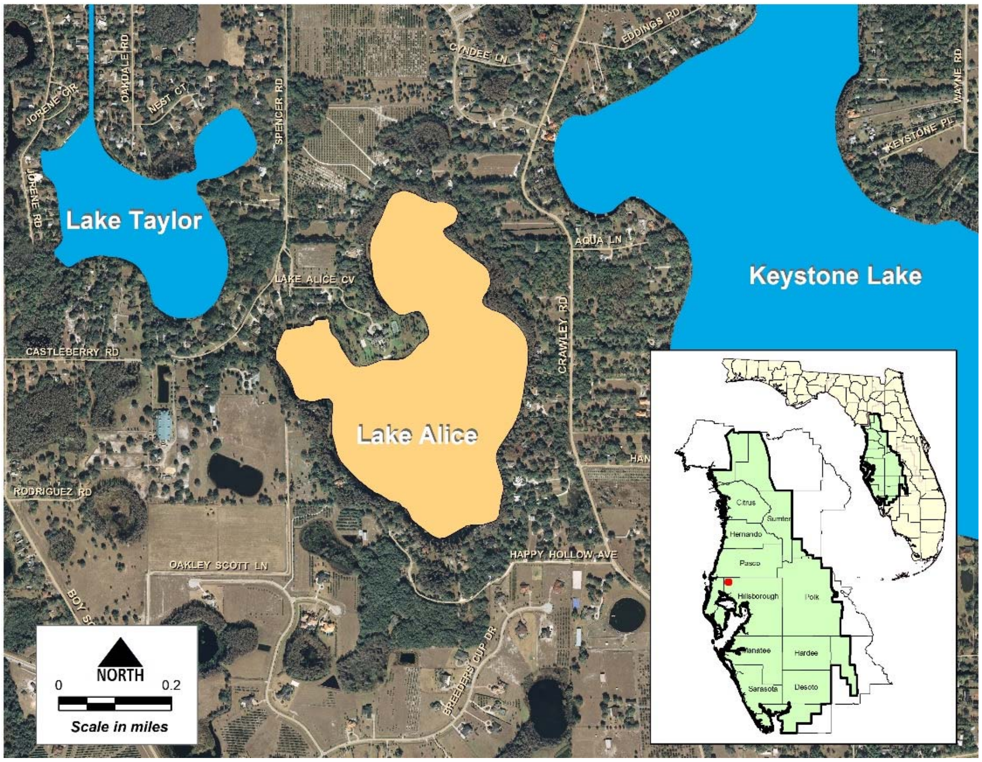

Figure 1. Location of Lake Alice in Hillsborough County, Florida.

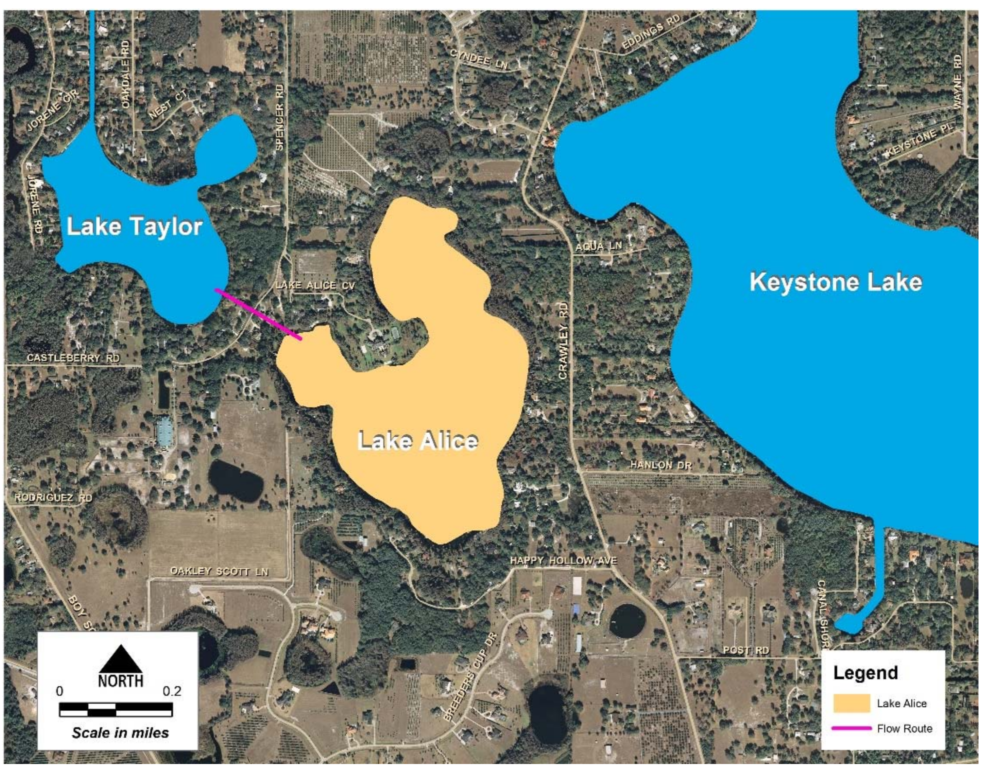

Figure 2. Flow between Lake Alice and Lake Taylor.

very flat, and drainage into the lake is a combination of overland flow and flow through drainage swales and minor conveyance systems.

The hydrogeology of the area includes a sand surficial aquifer; a discontinuous, intermediate clay confining unit; and the thick carbonate Upper Floridan aquifer. In general, the surficial aquifer in the study area is in good hydraulic connection with the underlying Upper Floridan aquifer because the clay confining unit is generally thin, discontinuous, and breeched by numerous karst features. The surficial aquifer is generally ten to thirty feet thick and overlies the limestone of the Upper Floridan aquifer that averages nearly one thousand feet thick in the area (Miller, 1986). In between these two aquifers is the Hawthorn Group clay that varies between a few feet to as much as 25 feet thick. Because the clay unit is breached by buried karst features and has previously been exposed to erosional processes, preferential pathways locally connect the overlying surficial aquifer to the Upper Floridan aquifer resulting in moderate-to-high leakage to the Upper Floridan aquifer (Hancock and Basso, 1996).

Data

The District began collecting water level data at Lake Alice in June 1971 (Figure 3) at a gage on the northeastern lobe. In October 2016, the District lost access to the long-term gage in the lake, but resumed data collection in a new location on the lake in June 2017 (red squares, Figure 3) at a new site on the southeastern shore of the main lobe. The data collection frequency has typically been monthly, although data was often collected at least weekly from June 1971 to September 1974 and June 1977 to December 1987, likely via a volunteer on the lake.

Due to its proximity to Lake Alice, one Upper Floridan (SID 19809) and surficial aquifer (SID 19808) monitor well nest was considered for the analysis (Figure 4). The Lake Alice Floridan and surficial aquifer monitor wells are located less than 650 feet from the lake’s southwestern shore and approximately 0.2 miles from its center. Data are available for these wells back to June 2002 and were collected weekly to monthly through March 2003, at which point it became daily, with gaps during parts of June/July of 2003 and February/March of 2007 and 2013 (Figure 5).

Land and Water Use

Lake Alice is located approximately 3.8 miles to the southeast of the Eldridge Wilde Wellfield and 2.0 miles northwest of the Cosme-Odessa Wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 6). Groundwater withdrawals began at the Cosme-Odessa Wellfield in 1930, and steadily climbed to approximately 21 million gallons per day (mgd) in 1962. The Eldridge Wilde Wellfield

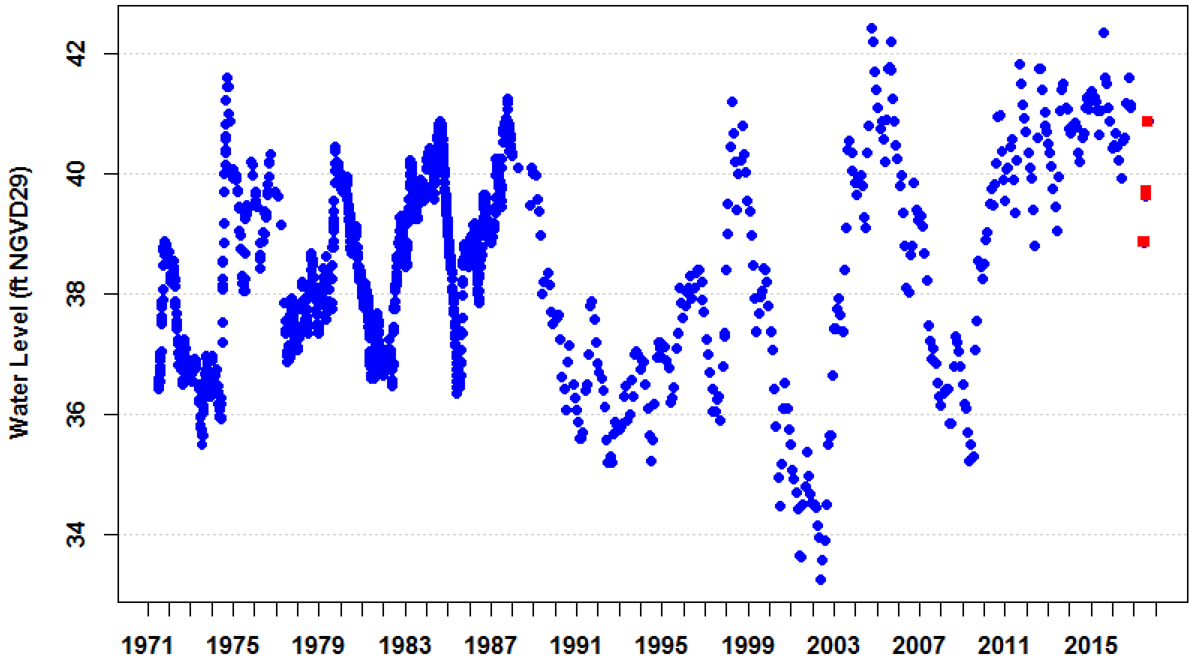

Figure 3. Lake Alice water levels from June 1971 to August 2017.

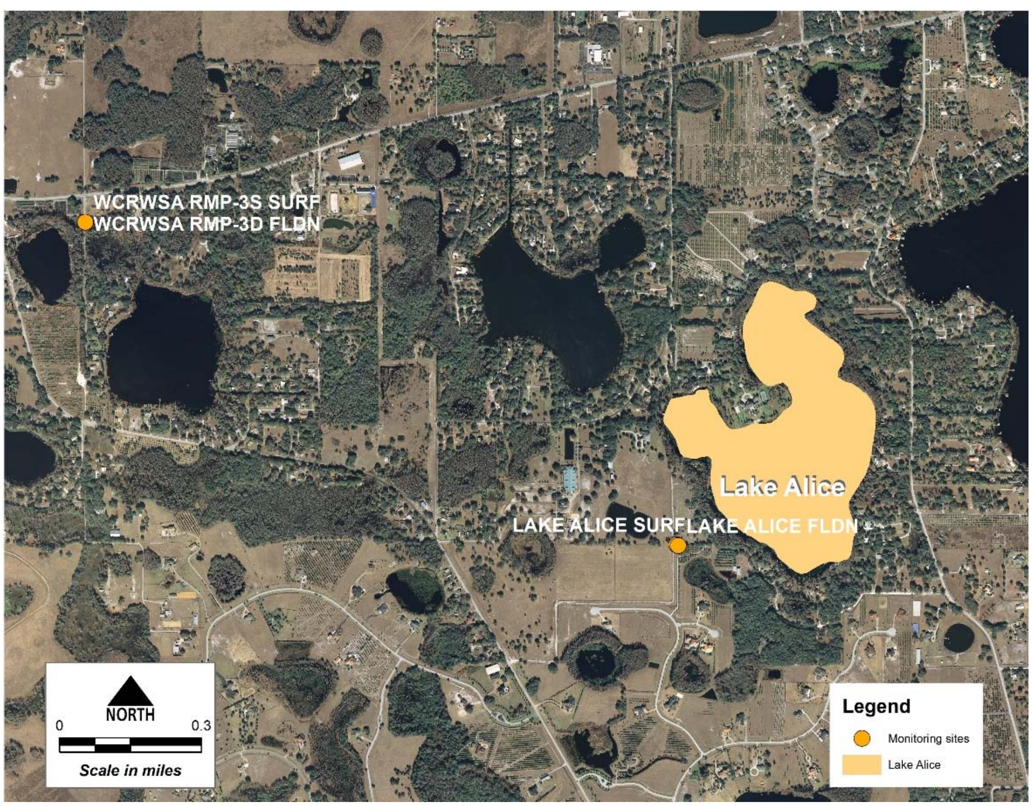

Figure 4. Location of monitor wells near Lake Alice considered for model use.

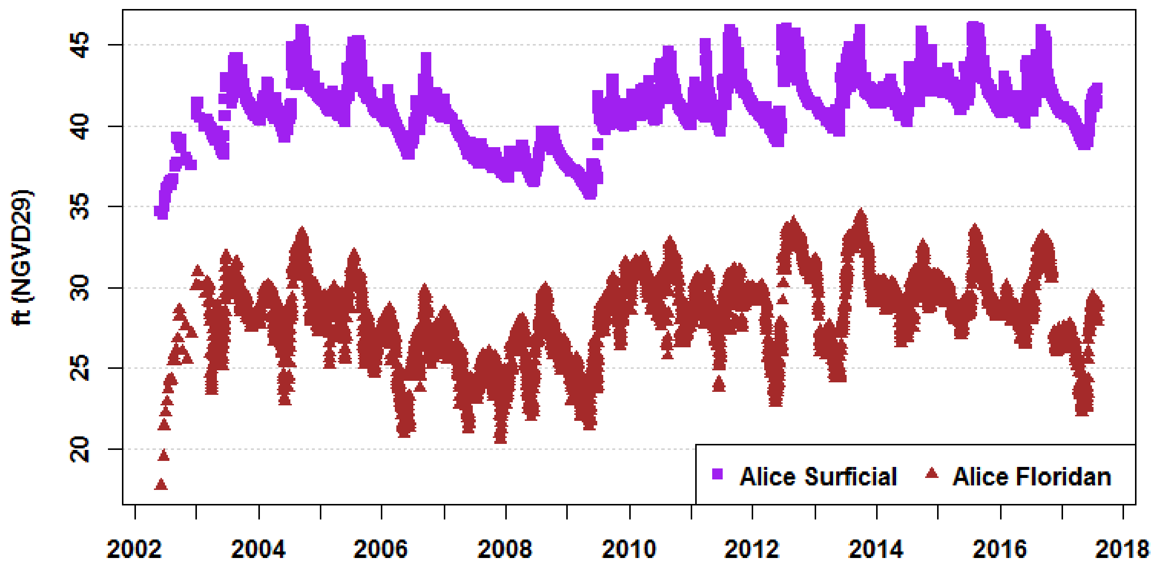

Figure 5. Water levels in the Lake Alice Surficial (green) and Floridan (blue) aquifer monitor wells from June 2002 to August 2017.

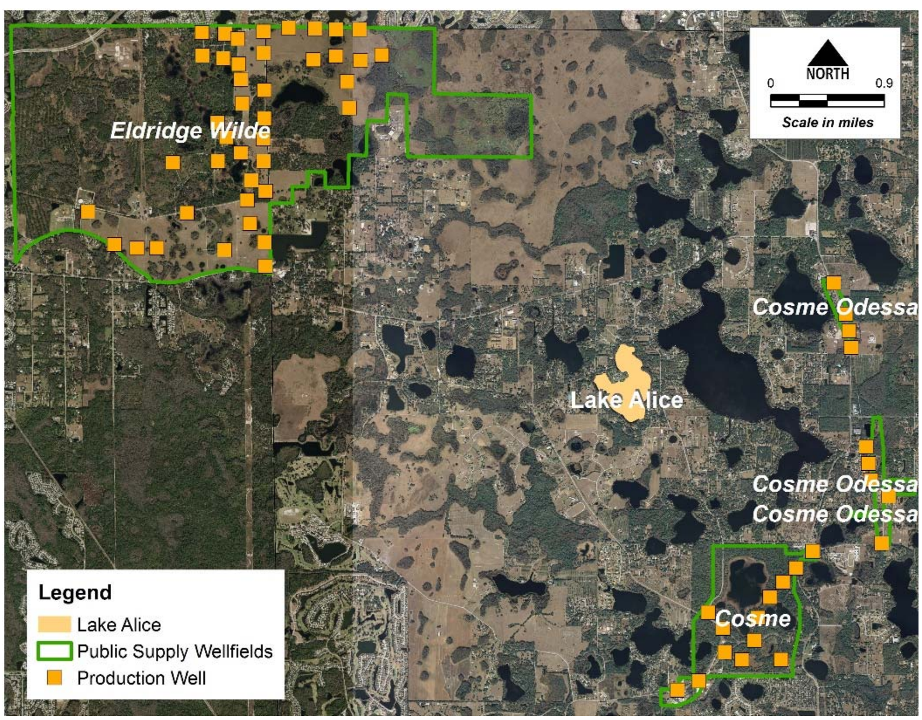

Figure 6. Lake Alice and the Cosme-Odessa and Eldridge Wilde wellfields.

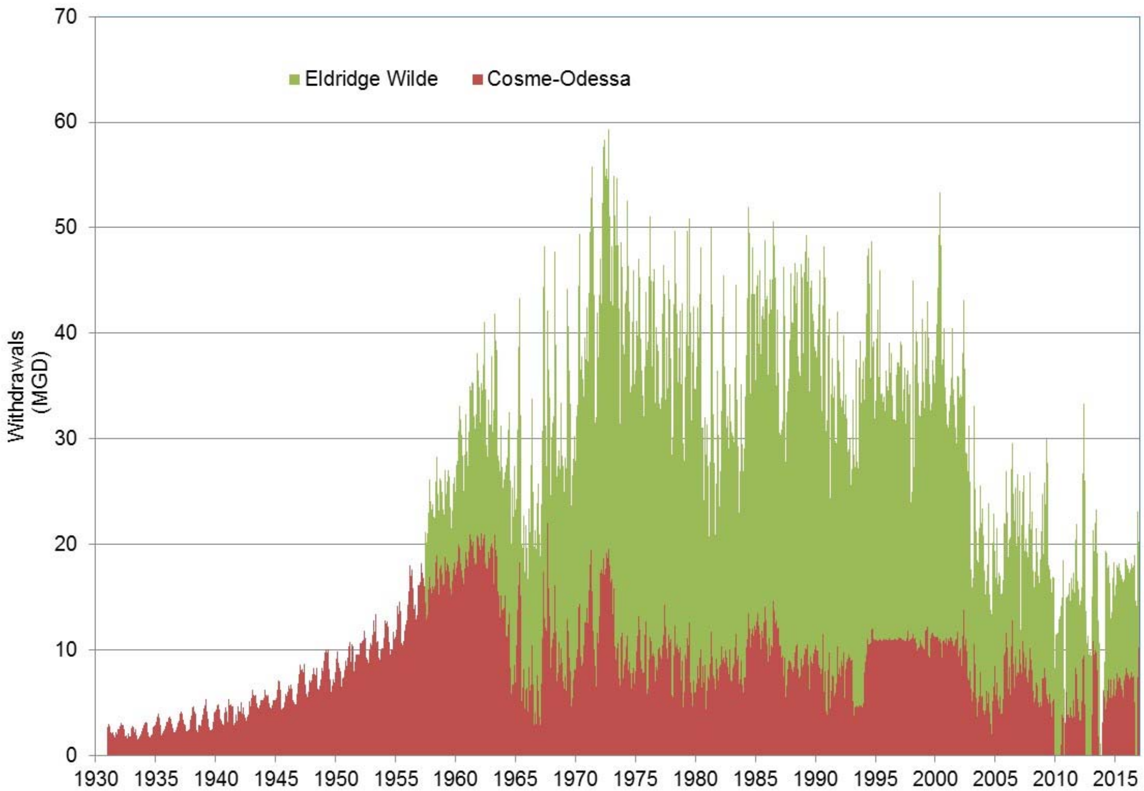

Figure 7. Stacked Cosme-Odessa (red) and Eldridge-Wilde (green) Wellfield withdrawals.

began withdrawing groundwater in 1957, and pumped over 35 mgd in the early 1970s (Figure 7). Combined groundwater withdrawals from the two wellfields peaked at over 52 mgd in the early 1970s. Combined withdrawal rates since 2003 have averaged a little over 18 mgd (less than 13 mgd at the Eldridge Wilde Wellfield, and less than 6 mgd at the Cosme Odessa Wellfield), with several extended periods since 2009 when groundwater withdrawals at the Cosme-Odessa Wellfield were zero.

Water levels in several lakes in Cosme-Odessa and Eldridge Wilde Wellfield areas have dropped significantly since public supply groundwater withdrawals began in the area (Hancock and Basso, 1996). Because Lake Alice water level data collection did not begin until well after the beginning of withdrawals from the wellfields (Figure 3 and 7), the correlation between groundwater withdrawals and lake levels is not easily seen in the early data. Lake recovery during the period of recent reductions in groundwater withdrawals can be seen in Figure 3, but above average rainfall during that period could also account for some of the apparent recovery.

Comparing the 1938, 1968, and 1970s aerial photographs of Lake Alice, lake bottom was exposed along the shores of Lake Alice and Keystone Lake in 1968 and the 1970s

(Figure 8). Depending on exactly when the 1968 and 1970s images were taken, the exposed lake bottom may be due to a combination of low rainfall and groundwater withdrawals from the wellfields.

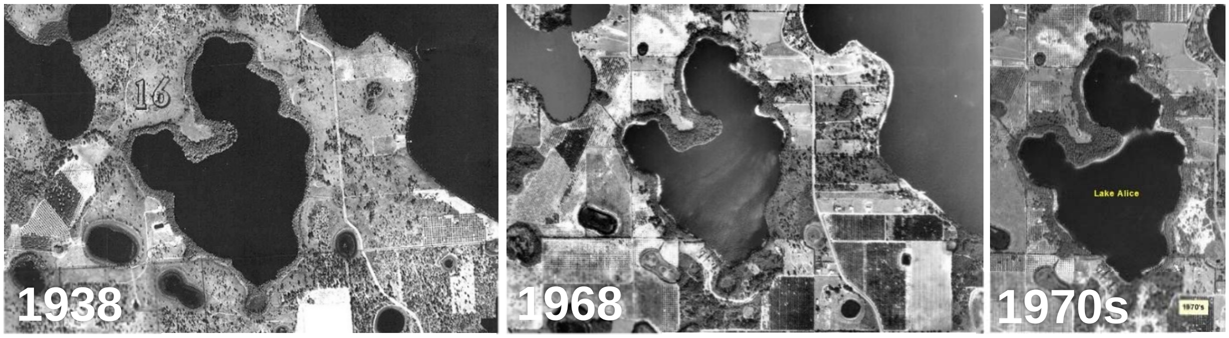

Figure 8. Water level changes in Lake Alice.

The relationship between sinkhole formation or karst activity and hydrologic stress in the northwest Hillsborough County area has been well established and thoroughly discussed (Bredehoeft and others, 1965; Sinclair, 1973 Stewart and Hughes, 1974; Sinclair, 1982; Sinclair and others, 1985; Hancock and Basso, 1996; Metz and Sacks, 2002; and, Metz, 2011). Man-induced or natural hydrologic stress can cause sediments in karst formations to unravel or can lower water levels that support overburden covering voids in the limestone aquifer. This can result in sinkholes that appear on the surface, or can result in changes that occur underground and cannot be seen at the surface. These changes, in turn, can result in pathways for water to connect lakes, wetlands, or the surficial aquifer in general, to the underlying Upper Floridan aquifer. It is thus possible that a change in leakance properties between Lake Alice and the Upper Floridan aquifer (possibly due to karst activity beneath or surrounding the lakes) has occurred.

C. Purpose of Models

Prior to establishment of Minimum Levels, long-term lake stage percentiles are developed to serve as the starting elevations for the determination of the lake's High Minimum Lake Level and the Minimum Lake Level. A critical task in this process is the delineation of a Historic time period. The Historic time period is defined as a period of time when there is little to no groundwater withdrawal impact on the lake, and the lake's structural condition is similar or the same as present day. The existence of data from a Historic time period is significant, since it provides the opportunity to establish strong predictive relationships between rainfall, groundwater withdrawals, and lake stage fluctuation that represent the lake's natural state in the absence of groundwater withdrawals. This relationship can 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 Lake Alice, both the Cosme-Odessa and Eldridge Wilde wellfields have potentially affected water levels since they began operation in 1930 and 1956, respectively; however, impacts are not obvious from the aerial photography prior to 1968. Empirical data are not available to evaluate the potential impacts of the early groundwater withdrawals near the wellfields. Other groundwater withdrawals (including other wellfields) could also affect levels, but the effect of such withdrawals would be smaller and less consistent. Therefore, the development of a water budget model coupled with a rainfall correlation model of the lake was considered essential for estimating long-term Historic percentiles, accounting for any changes in the lake's drainage system, and simulating effects of changing groundwater withdrawal rates.

D. Water Budget Model Overview

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

The hydrologic processes in the water budget model include:

a. Rainfall and evaporation
b. Overland flow
c. Inflow and discharge via channels
d. Flow from and 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 for the lake. The water budget model for Lake Alice is calibrated from June 2002 through October 2016 (lake data was not collected in November and December of 2016). This period provides the best balance of using available data for all parts of the water budget and the desire to develop a long-term water level record.

E. Water Budget Model Components

Lake Stage/Volume

Lake stage area and stage volume estimates were determined by building a terrain model of the lake and surrounding watersheds. Lake bottom elevations and land surface elevations were used to build the model with LP360 (by QCoherent) for ArcGIS, ESRI's ArcMap 10.4.1, 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.

Although bathymetric data of Lake Alice reveal that it is possible for Lake Alice to split into a smaller northeastern lobe and a larger southwestern main lobe when stage falls below ~33-30 ft NVGD 29 (Figure 8), observed lake stages have never fallen below this value (Figure 3). Therefore, the lake was considered as a single unit for the water budget model.

Precipitation

After a review of several rain gages in the area of Lake Alice, a composite of several stations was used for the water budget model. The goal was to use the closest available data to the lake, as long as the data appeared to be high quality (Figure 9). Lake Alice's proximity to Sunset Lake, approximately 1.3 miles (center-to-center) northwest of Lake Alice, results in significant overlap in the rain gages most appropriate for each lake, so rainfall data from the most recent Sunset Lake model was used in the Lake Alice model.

The Sunset Lake (SID 19501) rain gage, located approximately 1.6 miles northwest of Lake Alice, was used from June 2002 to April 2005. For the remainder of the modeled period, rainfall data was used from Island Ford (SID 19487; approximately 1.4 miles northeast of Lake Alice) from May 2005 to December 2015, followed by NEXRAD-derived rainfall data from January to December 2016. NEXRAD (Next Generation Weather Radar) is a network of 160 high-resolution Doppler weather radars controlled by the NWS, Air Force Weather Agency, and Federal Aviation Administration. Several other gages were also used to infill short periods of missing or unusable data, including Crescent Lake (SID 19488; approximately 1.6 miles northeast of Lake Alice), Cosme 18 (a Tampa Bay Water gage; approximately 2.5 miles southeast of Lake Alice) and ROMP TR13-3 Racetrack Road (SID 19498; approximately 5 miles southwest of Lake Alice). Except for the Cosme rain gage and the NEXRAD data, all of the rain gages used are monitored by the District.

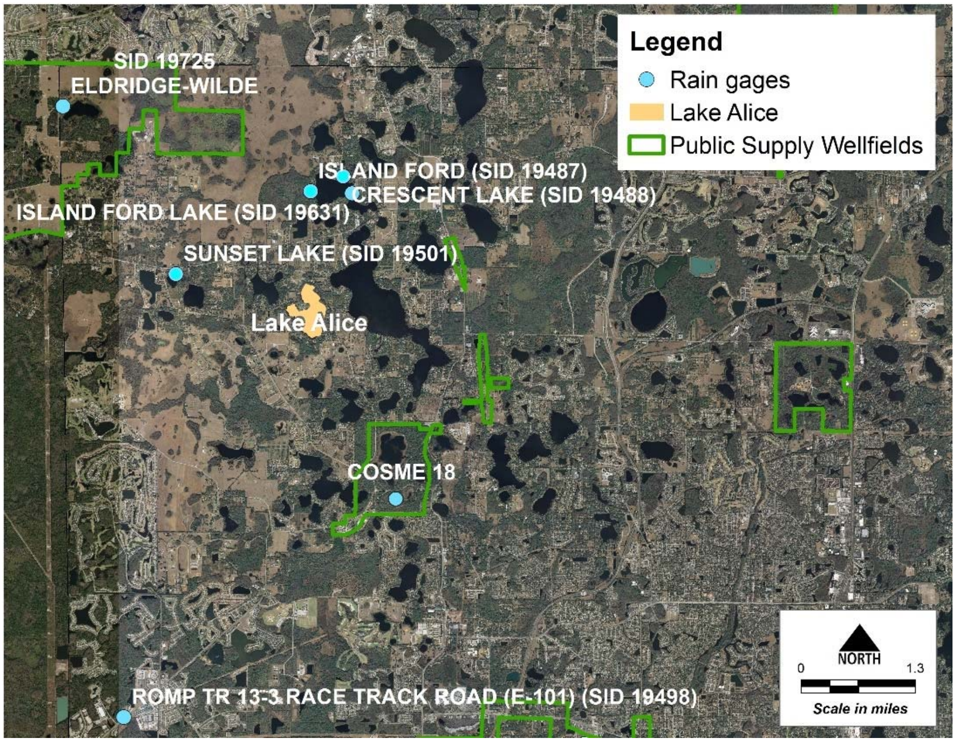

Figure 9. Rain gages used in the Lake Alice water budget model.

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 10). The data was collected from August of 1996 through July of 2011. Monthly Lake Starr evaporation data were used in the Lake Alice 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.

A recent study compared monthly energy budget evaporation data collected from both Lake Starr and Calm Lake (Swancar, 2011, personal communications). Calm Lake is located approximately 0.8 miles (center-to-center) to the northeast of Lake Alice (Figure 10). The assessment concluded that the evaporation rates between the two lakes were nearly identical, with small differences attributed to measurement error and monthly differences in latent heat associated with differences in lake depth.

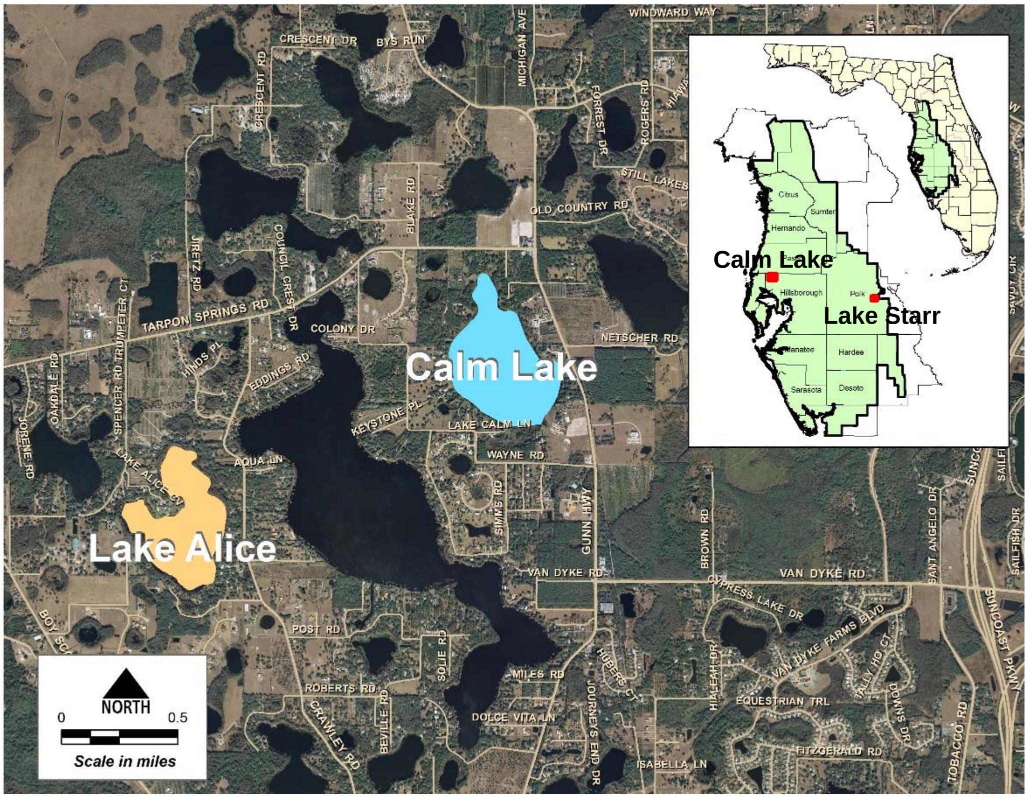

Figure 10. Location of Lakes Alice, Calm and Starr (see map inset).

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

Overland Flow

The water budget model was set up to estimate overland flow via a modified version of the U.S. Department of Agriculture, Soil Conservation Service (SCS) Curve Number method (SCS, 1972), and via directly connected impervious area calculations. The free water area of each 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) was subtracted from the watershed 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 considers the amount of DCIA in the watershed that has been handled separately.

The modified SCS method was 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 topography around Lake Alice is relatively flat, so determining watersheds based on relatively subtle divides can be challenging. Several slightly varying estimates of watershed boundaries have been performed in the past for different modeling efforts in the area. The most recent set of estimates was developed as part of an effort to model the five main watersheds in northwest Hillsborough County for flood assessment purposes (CH2M HILL Engineers, 2016). The watershed area values developed by CH2M HILL were adopted for the Lake Alice model (Table 1) after an independent check confirming that they are reasonable for modeling purposes.

Lake Alice's watershed as used in the model is shown in Figure 11. The entire area of the contributing watersheds is estimated to be approximately 301.2 acres (including the lake).

The DCIA and SCS CN used for the direct overland flow portion of the watershed are listed in Table 1. Curve numbers were difficult to assess. Most of the soils in the area are A/D soils, which means that the characteristics of the soils are highly dependent on how well they are drained. A "D" soil will generally have a higher amount of runoff per quantity of rain than a "A" soil. Because of the proximity of the wellfields to the area being modeled, water levels have been historically lowered by the withdrawals, and soils in the area may have had lower runoff rates (characteristic of "A" soils). Groundwater withdrawals during the period of model calibration were, however, significantly reduced relative to historic withdrawal rates, so the soils in the area may have begun to exhibit runoff properties more characteristic of "D" soils.

For purposes of this model, considering the range of conditions experienced, a CN was used somewhere between the two conditions. No direct discharges to the lake were identified, so the DCIA of the watershed is zero.

Inflow and Discharge via Channels from Outside Watersheds

Inflow and outflow via channels from or to the lake's watershed (i.e. "channel flow") is an important component of the Lake Alice water budget, although the gradients of the channels are relatively flat, and inflows to the lake likely occur only during high rainfall events.

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

Input Variable	Value
Overland Flow Watershed Size (acres)	301.2
SCS CN of watershed	73
Percent Directly Connected	0
FL Monitor Well(s) Used	Lake Alice FLDN
Surf. Aq. Monitor Well(s) Used	Lake Alice SURF
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.002
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.00055
Outflow K	0.022
Outflow Invert (ft NGVD29)	40.9
Inflow K	N/A
Inflow Invert (ft NGVD29)	N/A

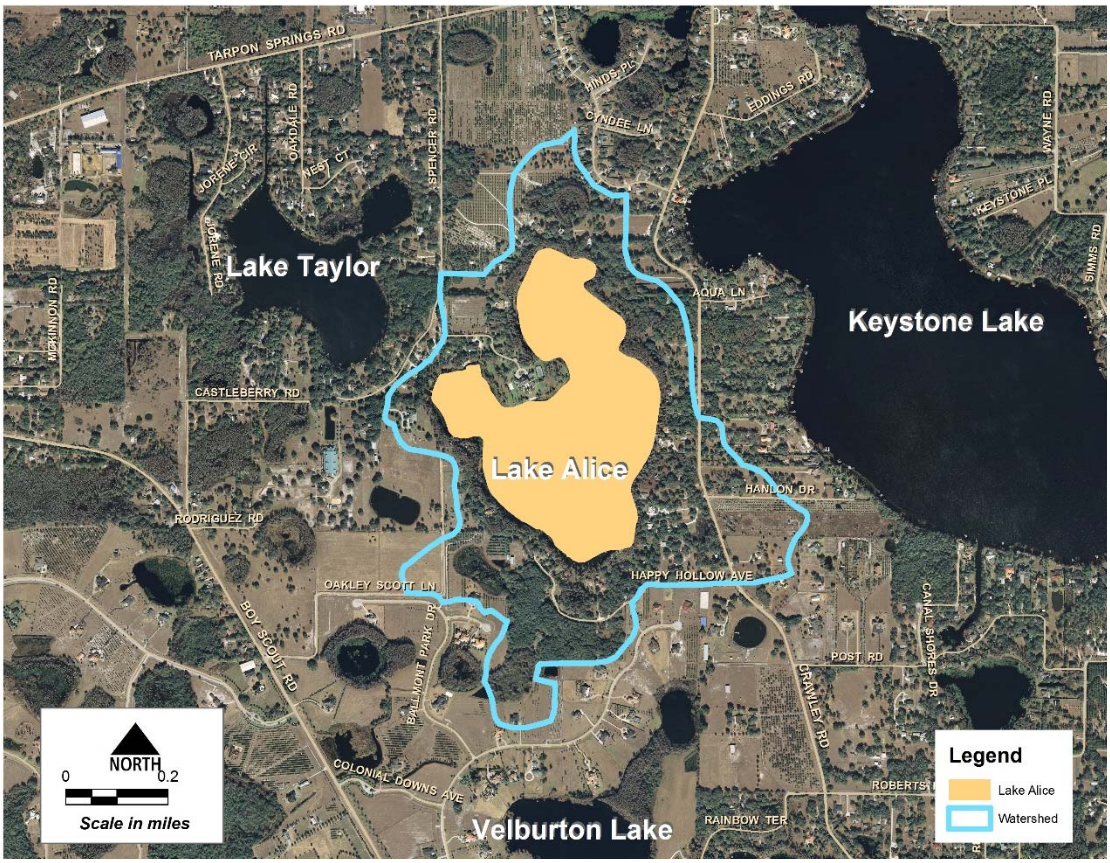

Figure 11. The Lake Alice watershed used in the model.

There is no channel inflow to Lake Alice. To estimate flow out of Lake Alice, the predicted elevation of the lake from the previous day is compared to the controlling elevation. Control elevations were determined based on professional surveying performed in the area. If the lake elevation is above the controlling elevation, the difference is multiplied by the current area of the lake and an "outflow coefficient." The coefficient represents a measure of channel and structure efficiency, and produces a rough estimate of volume lost from the lake. This volume is then subtracted from the current estimate of volume in the lake.

Lake Alice discharges via a ditch exiting the lake from the northwest lobe (Figure 2). The discharge then passes under Spencer Road via a 36-inch reinforced concrete pipe (RCP), and enters another ditch flowing toward Lake Taylor. There is a berm before the flow reaches Lake Taylor, but the low area of the berm is lower than the upstream end of the culvert (as confirmed by survey). Therefore, the southern invert of the 36-inch RCP was determined to be the controlling elevation for the outlet of Lake Alice (surveyed at 40.9 feet NGVD29).

Flow from and into the surficial aquifer and Upper Floridan aquifer

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

The Lake Alice Floridan well (SID 19809) is the closest Upper Floridan aquifer monitor well to Lake Alice, located less than 650 feet from the southwestern shore of Lake Alice (Figures 4 and 5), and was used to represent the potentiometric surface under the lake. An inspection of multiple May and September potentiometric surface maps from District archives over several years representing periods before and after wellfield cutbacks found both the Lake Alice well and Lake Alice to be consistently located along the same potentiometric value, it was concluded that no adjustment of the water levels at the well were needed to represent the potentiometric surface at the lake. Monthly or missing data were infilled using bilinear interpolation.

Similarly, the Lake Alice Surficial well (SID 19808) is the closest surficial aquifer well to Lake Alice (at the same location as the Lake Alice Floridan well), and was used to represent the water table at the lake (Figures 4 and 5). Because topographic elevations around the Lake Alice wells are similar to those around Lake Alice, no adjustment was made to the Lake Alice well data. Again, monthly or missing data were infilled based on the approach used for the Upper Floridan aquifer monitoring wells.

Because the time period of the water budget model is generally limited by the parameter with the shortest period of record, the beginning date of the water budget model is the beginning date of the wells: June 2002. Unfortunately, June 2002 is also the period of record lowest point in the Lake Alice data set (see Figures 3 and 5). The period preceeding June 2002 was one of the driest period of records for many rain stations and lakes in the area. There was a concern with starting the model runs on a record low for Lake Alice, which can bias further analysis. To avoid losing additional valuable data by starting the water budget at a later date, a line of organic correlation regression was performed using a temporal overlap (2002 to 2016) for the Lake Alice and WCRWSA RMP-3 well data (SIDs 19606 and 19608), which are located approximately 1.6 miles northwest of Lake Alice (Figure 4). The results are shown in Figure 12. Lake Alice well levels were estimated using this regression from January 1999 to May 2002, and actual and interpolated Lake Alice well levels were used in the water budget beginning June 2002 onwards. This temporally extended model allowed the model runs to start at lake and well elevations that were closer to average levels, while maintaining maximum use of the data. A similar approach of temporally extending well data using appropriately adjusted nearby wells has previously been applied to other lakes in the area.

F. Water Budget Model Approach

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

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

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

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 13, the model appears to be reasonably well calibrated. The model correlates with observed lake stage data at $R^2 = 0.92$ (df = 220). The mean and median differences of the residuals (observed less predicted values) are -0.06 and 0.01 feet, respectively.

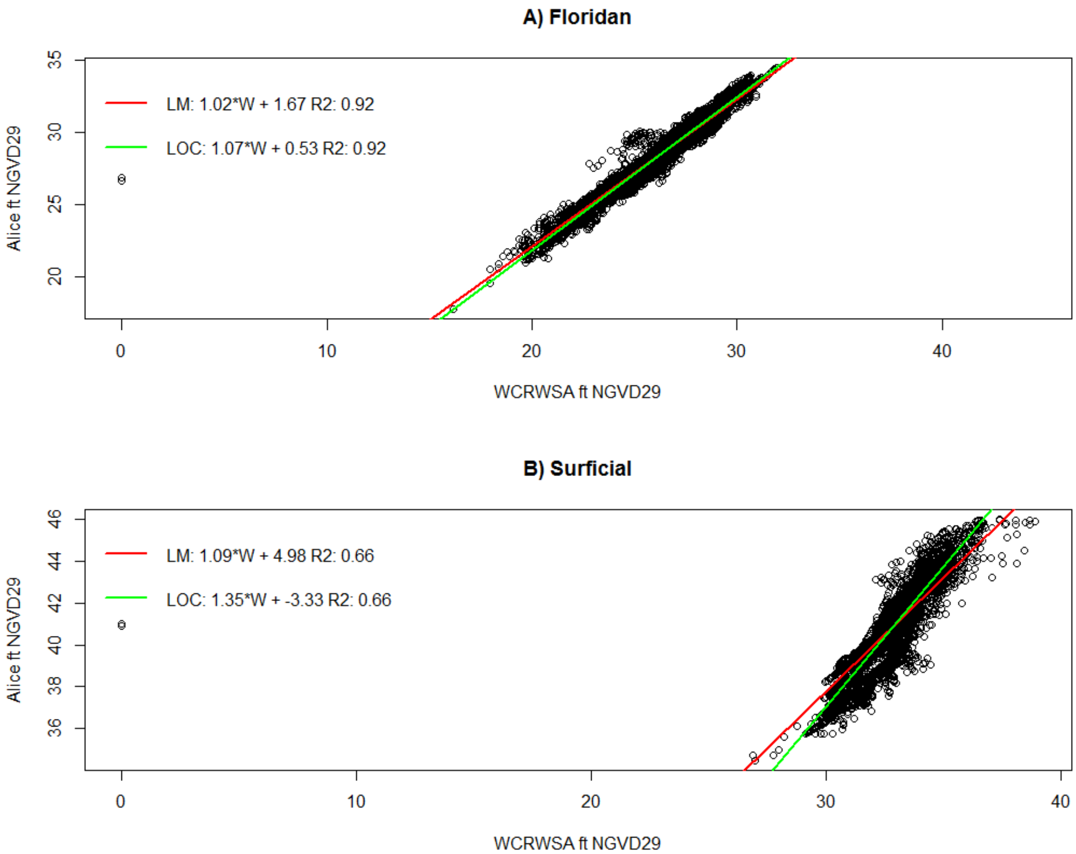

Figure 12. Alice–WCRWSA RMP-3 A) Floridan and B) surficial well level linear (LM) and line of organic correlation (LOC) regressions. The LOC regressions were used to estimated Alice well levels from January 1999 to May 2002.

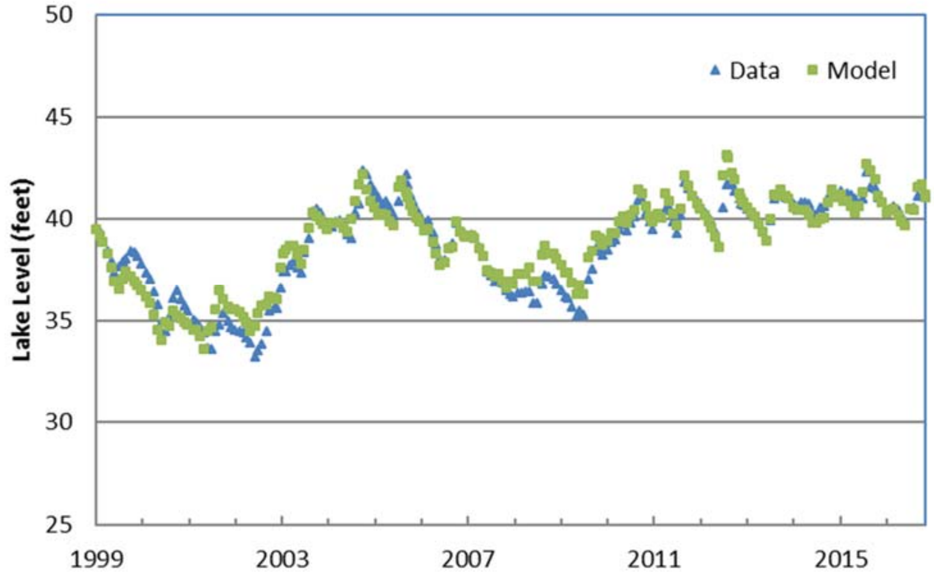

Figure 13. Modeled water levels predicted for the calibrated Lake Alice water budget model (Model; green squares) and measured levels used for the model calibration (Data; blue triangles).

Table 2. Comparison of percentiles of measured lake level data compared to calibration percentiles from the model (all in feet NGVD29).

	Data	Model
P10	41.3	41.3
P50	39.5	39.5
P90	35.2	35.4

Table 3. Lake Alice Water Budget (1999-2016)

Inflows	Rainfall	Surficial Aquifer Groundwater Inflow	Floridan Aquifer Groundwater Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	56.5	12.3	0.0	30.0	0.0	0.0	98.8
Percentage	57.2	12.4	0.0	30.4	0.0	0.0	100.0
Outflows	**Evaporation**	**Surficial Aquifer Groundwater Outflow**	**Floridan Aquifer Groundwater Outflow**			**Outflow via channel**	**Total**
Inches/year	58.5	0.7	28.1			10.7	97.9
Percentage	59.8	0.7	28.7			10.9	100.0

A review of Table 2 shows that the differences for the P10 and P50 percentiles between the data and model for the lake are the same (within 0.1 feet), while the model P90 is 0.2 feet higher. 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. The minimum and maximum differences are -1.73 and 1.52 feet, respectively. Reduced precision in the higher and lower ranges of the stage-volume relationships for the lake may also have contributed to the percentile differences.

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 represent low runoff rates.

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the Lake Alice water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from the Eldridge Wilde and Cosme-Odessa Wellfields are available throughout the period of the calibrated model, so if 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.

The Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013) is an integrated model developed for the northern Tampa Bay area. The INTB model can account for groundwater and surface-water, as well as the interaction between them. The domain of the INTB application includes the Lake Alice area, and represents the most current understanding of the hydrogeologic system in the area.

The INTB was used to determine the drawdown in the surficial aquifer and Upper Floridan aquifer in response to groundwater withdrawals in the area. Drawdown in both aquifers was calculated for two withdrawal rates representing the effects of Tampa Bay Water's regional wellfields before and after cutbacks from approximately 150 mgd to 90 mgd. The pre-cutback period in the model is from 1999 through 2002, while the post-cutback period is 2003 through 2016. The model results allowed the drawdowns associated with all permitted withdrawals to be calculated before and after wellfield cutbacks, assuming changes in all other withdrawals are consistent for the modeled period.

The INTB model was run for each withdrawal scenario from 1996 to 2006 using a daily integration step. Drawdown values in feet were calculated by running the model with and without groundwater withdrawals, and were calculated for each node in the model. The INTB model uses a one-quarter mile grid spacing around the wellfields. Groundwater withdrawal rates from the Eldridge Wilde Wellfield in each scenario were 23.6 mgd and 13.8 mgd, respectively, and 11.0 mgd and 6.2 mgd for the Cosme-Odessa Wellfield, respectively.

Results from the INTB modeling scenarios showed that there is a fairly linear relationship between Upper Floridan aquifer drawdown and withdrawal rates at the wellfields. Because of the leaky nature of the confining unit around Lake Alice, and because the water table in the model is not active, the relationship between groundwater withdrawals in the Upper Floridan and water levels in the surficial aquifer was also of interest. Using the drawdowns determined through the INTB model, the Upper Floridan aquifer and surficial monitor well data in the model can be adjusted to reflect changes in groundwater withdrawals.

To estimate lake levels without the influence of groundwater withdrawals, the Upper Floridan aquifer and surficial aquifer wells in the water budget model were adjusted to represent zero withdrawals. For the 1999 through 2016 water budget model period, two adjustment periods were used to reflect the cutbacks that took place at the Eldridge Wilde and Cosme-Odessa Wellfields. Adjustments to each Upper Floridan aquifer and surficial aquifer well and the associated adjustment periods are found in Table 4.

Table 4. Aquifer water level adjustments to the Lake Alice Model to represent Historic percentiles.

Well	**Adjustment (feet) 1999 through 2002**	**Adjustment (feet) 2003 through October 2016**
Floridan aquifer	7.9	4.0
Surficial aquifer	0.9	0.4

Figure 14 presents measured water level data for the lake along with the model-simulated lake levels in the lake under Historic conditions, i.e. in the absence of groundwater withdrawals with structural alterations similar to current conditions. Table 5 presents the Historic percentiles based on the model output.

Historic normal pool elevations are established for lakes ponds and wetlands to standardize measured water levels and facilitate comparison among wetlands and lakes. The Historic normal pool elevation is commonly used in the design of wetland storm water treatment systems (Southwest Florida Water Management District, 1988). The normal pool can be consistently identified in cypress swamps or cypress-ringed lakes based on similar vertical locations of several indicators of inundation (Hull, et al, 1989; Biological Research Associates, 1996). Historic normal pools have been used as an estimate of the Historic P10 in natural wetlands and lakes, based on observation of many control sites in the northern Tampa Bay area.

Historic normal pool was determined for Lake Alice based on inflection points of adjacent cypress trees. The Historic normal pool for Lake Alice was previously determined to be 43.0 feet NGVD29. While the Historic normal pool and natural P10 in lakes and wetlands in the northern Tampa Bay area may differ by several tenths of a foot in many cases, the model's estimate of the Historic P10 for Lake Alice is significantly lower than the field determined Historic normal pool. Most of this difference is likely because the lake is structurally altered by a culvert and ditch system.

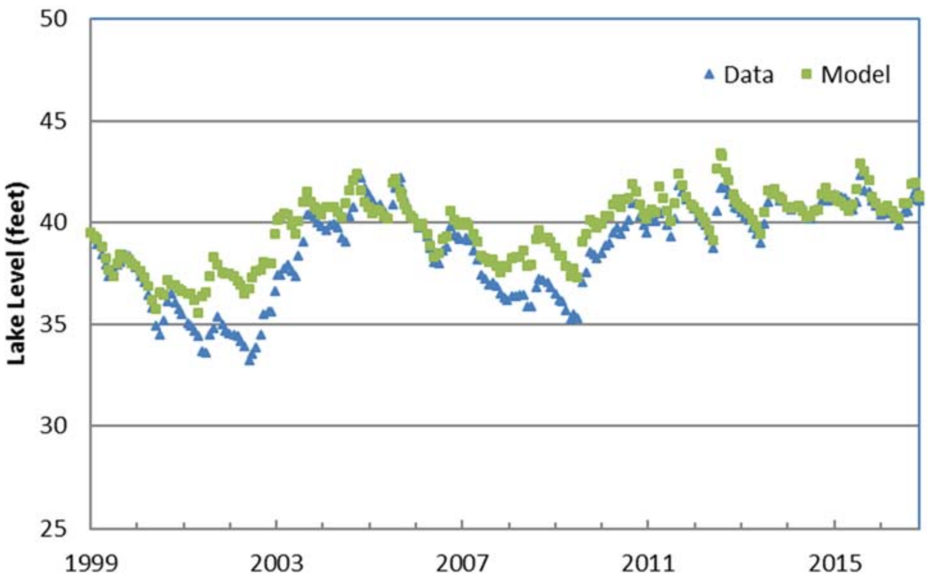

Figure 14. Measured lake levels and Historic water levels predicted with the calibrated Lake Alice model.

Table 5. Historic percentiles estimated using the Lake Alice water budget model (in feet NGVD29).

Percentile	Elevation
P10	41.6
P50	40.2
P90	37.3

I. Rainfall Correlation Model

A line of organic correlation (LOC) was performed using the results of the water budget model and long-term rainfall to extend the data set used to determine the Historic percentiles. These Historic percentiles are considered in development of the Minimum Levels. The LOC is a linear fitting procedure that minimizes errors in both the *x* and *y* directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data.

In this application, the simulated lake water levels representing Historic conditions were correlated with Long-term rainfall. For the correlation, additional representative rainfall records were added to the rainfall records used in the water budget model (1999-2016). Rainfall data from the Island Ford Lake gage (SID 19631), located approximately 1.4 miles northeast of Lake Alice, was used to extend data back to January 1972, and the Cosme rain gage was used to extend the rain data back to 1945. Finally, the St. Leo National Weather Service gage (SID 18901) was used to extend the data back to 1930. Although the St. Leo gage is approximately 25 miles northeast of Lake Alice Lake (Figure 15), it is one of only a few rain gages in the vicinity with data preceding 1945, and in this case, is only used in the first few years of the correlation.

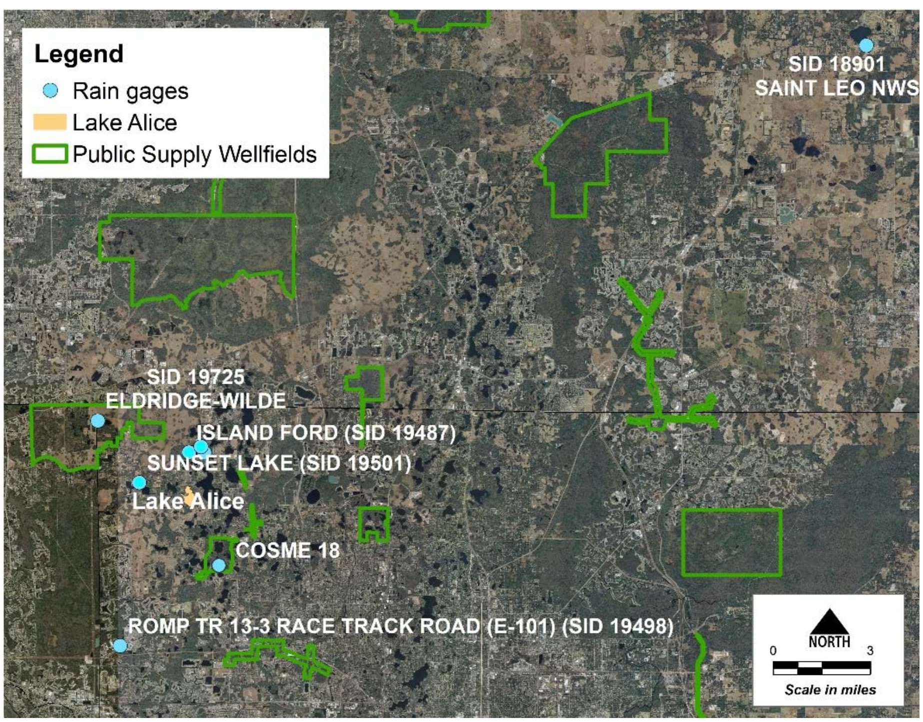

Figure 15. Location of rain stations used for the rainfall correlation model.

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

Rainfall was correlated to the water budget model results for the entire period used in the water budget model (1999-2016), and the results from 1947-2016 (70 years) were produced. For Lake Alice, the 3-year weighted model had the highest correlation coefficient, with an R^2 of 0.70. Previous correlations for lakes in the northern Tampa Bay area have consistently had best correlation coefficients in the 2 to 5-year range. The results are presented in Figure 16.

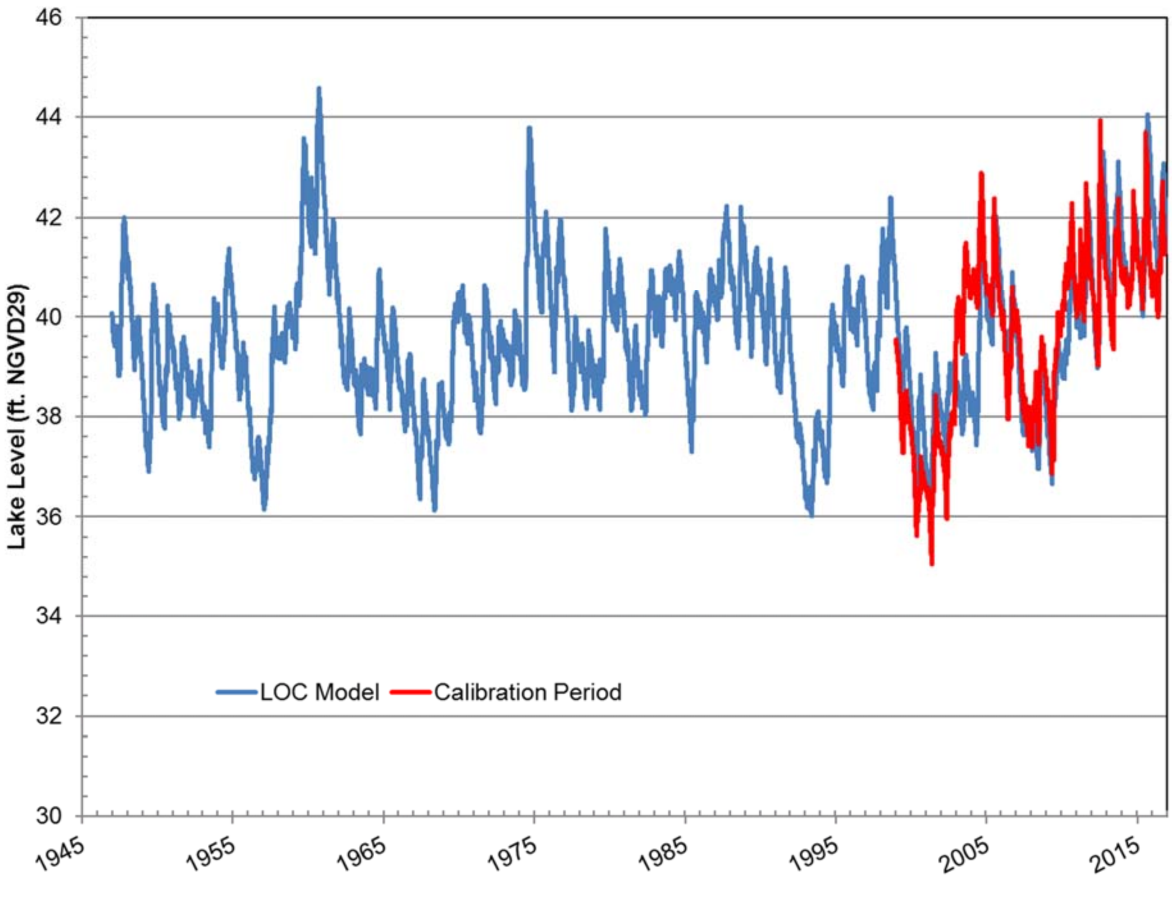

Figure 16. LOC model and water budget results for Lake Alice.

To produce Historic percentiles that apply significant weight to the results of the water budget models, the rainfall LOC results for the period of the water budget model are replaced with the water budget model results. Therefore, the LOC rainfall model results are used for the period of 1946 through 2002 and the end of 2016, while the water budget results are used for the period of 1999 through October 2016. These results are referred to as the "hybrid model." The resulting Historic percentiles for the hybrid model are presented in Table 6. Note that the the P10, P50, and P90 percentiles for the water budget model (Table 5) differ from those of the hybrid rainfall model (Table 6) for Lake Alice by 0.2, 0.6, and 0.3 feet, respectively.

Table 6. Historic percentiles as estimated by the hybrid model from 1946 to 2016 (feet NGVD29).

Percentile	Lake Alice
P10	41.4
P50	39.6
P90	37.6

J. Conclusions

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

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APPENDIX B

Technical Memorandum

October 6, 2017

TO: Tamera S. McBride, P.G., Manager, Resource Evaluation, Water Resources Bureau

FROM: Cortney Cameron, G.I.T., Hydrogeologist, Water Resources Bureau
Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau

Subject: Lake Alice Initial Minimum Levels Status Assessment

A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Lake Alice and is proposing 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 Cameron and Hancock (2017) and Hurst 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 Alice and other waterbodies with established minimum flows or levels in the northern Tampa Bay area, an applicable regional recovery strategy, referred to as the “Comprehensive Plan”, has been developed and adopted into District rules (Rule 40D-80.073, F.A.C.). One of the goals of the Comprehensive Plan is to achieve recovery of minimum flow and level water bodies such as Lake Alice that are in the area affected by the Consolidated Permit wellfields (i.e., the Central System Facilities) operated by Tampa Bay Water. This document provides information and analyses to be considered for evaluating the status (i.e., compliance) of the revised minimum levels proposed for Lake Alice and any recovery that may be necessary for the lake.

B. Background

Lake Alice is in northwest Hillsborough County, northwest of the intersection between Crawley Road and Happy Hollow Avenue and southeast of Lake Alice Cove (Figure 1). The lake lies within Brooker Creek watershed that forms part of the larger Tampa Bay watershed (USGS HUC 03100206). Lake Alice has no significant inflow other than overland flow, but discharges to Lake Taylor to the northeast via a reinforced concrete pipe during high flow periods (Figure 2). The topography is very flat, however, and flows are often negligible.

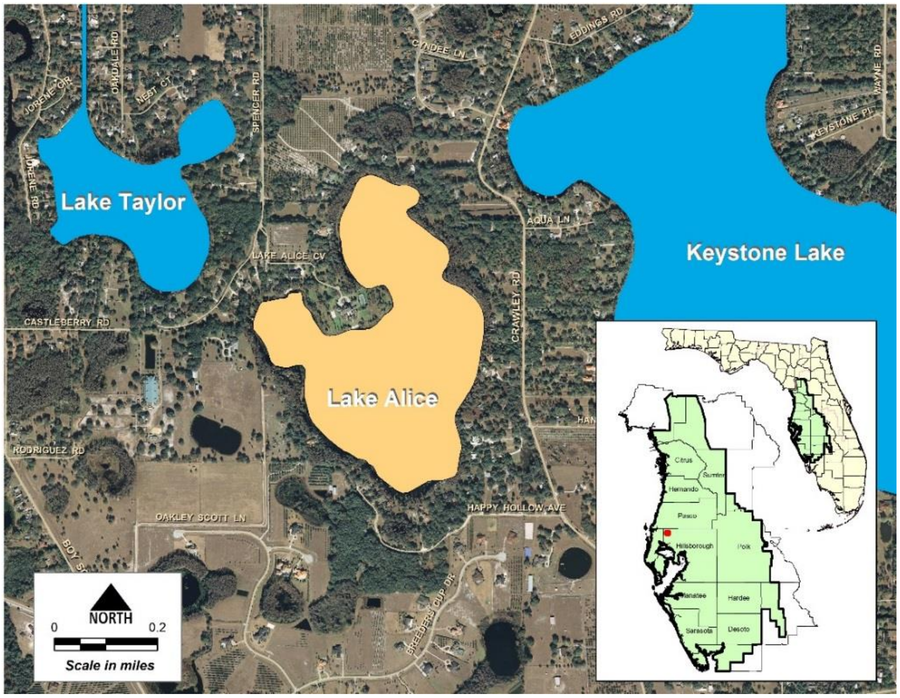

Figure 1. Location of Lake Alice in Hillsborough County, Florida.

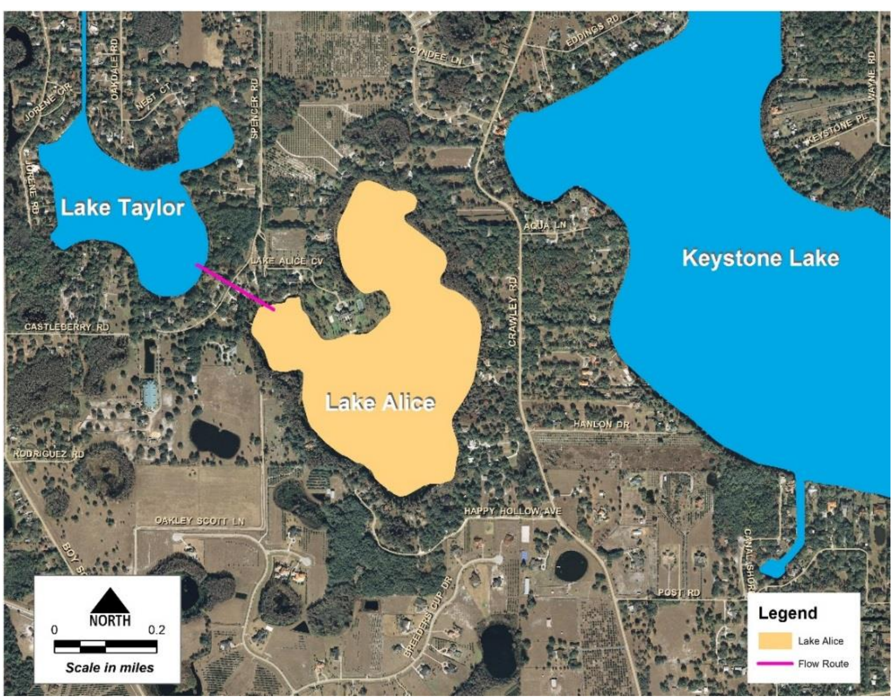

Figure 2. Flow between Lake Alice and Lake Taylor.

Lake Alice is located approximately 3.8 miles to the southeast of the Eldridge Wilde Wellfield and 2.0 miles northwest of the Cosme-Odessa Wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 3). Groundwater withdrawals began at the Cosme-Odessa Wellfield in 1930, and steadily climbed to approximately 21 million gallons per day (mgd) in 1962. The Eldridge Wilde Wellfield began withdrawing groundwater in 1957, and pumped over 35 mgd in the early 1970s (Figure 4). Combined groundwater withdrawals from the two wellfields peaked at over 52 mgd in the early 1970s. Combined withdrawal rates since 2003 have averaged a little over 18 mgd (less than 13 mgd at the Eldridge Wilde Wellfield, and less than 6 mgd at the Cosme Odessa Wellfield), with several extended periods since 2009 when groundwater withdrawals at the Cosme-Odessa Wellfield were zero.

C. Revised Minimum Levels Proposed for Lake Alice

Revised minimum levels proposed for Lake Alice are presented in Table 1 and discussed in more detail by Hurst 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 Alice or minimum flows and levels for any other water body, long-term data or model results must be used.

Table 1. Proposed Minimum Levels for Lake Alice.

Proposed Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	40.7
Minimum Lake Level	38.9

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Lake Alice from January 2003 through October 2016, 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 Cameron and Hancock (2017),

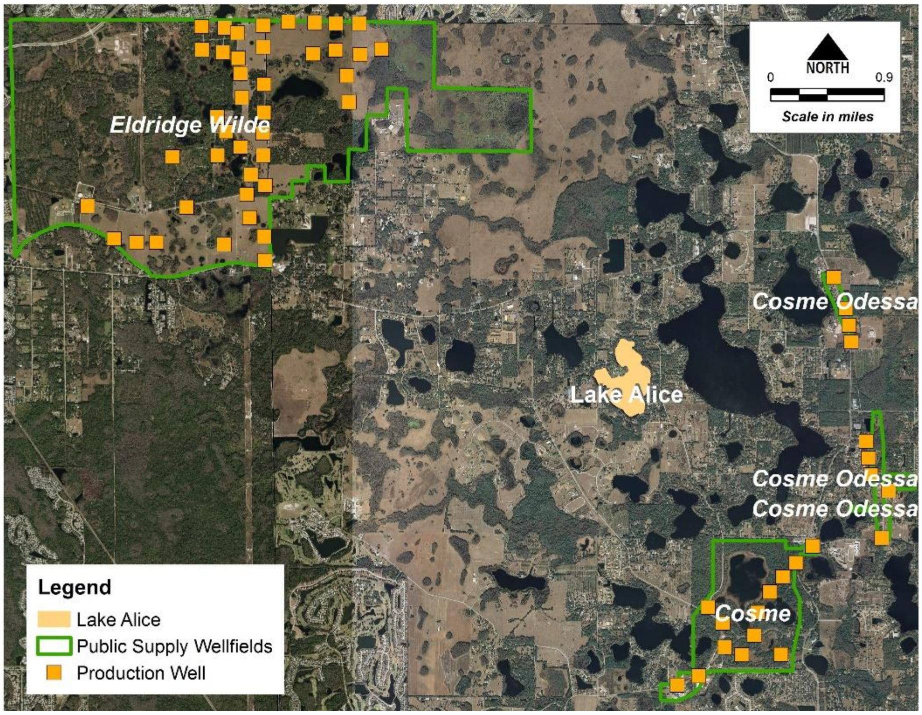

Figure 3. Lake Alice and the Cosme-Odessa and Eldridge Wilde wellfields.

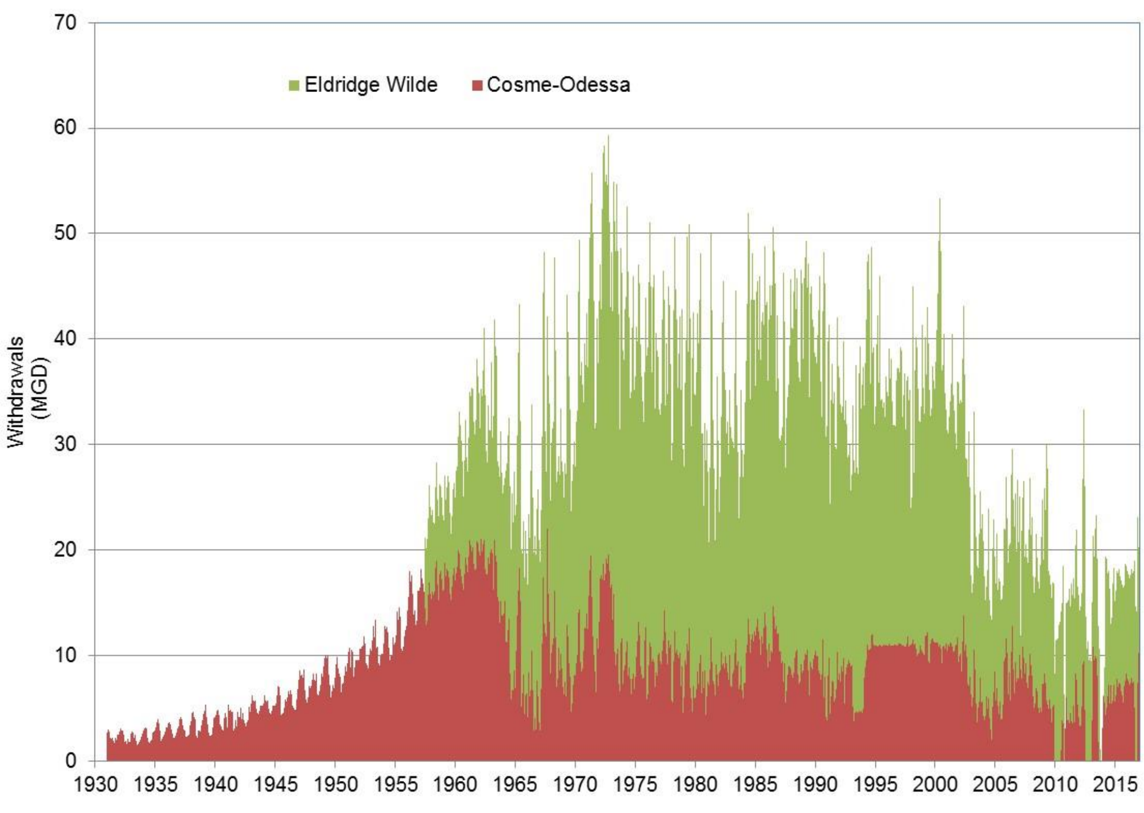

Figure 4. Stacked Cosme-Odessa (red) and Eldridge-Wilde (green) Wellfield withdrawals.

groundwater withdrawals during this period were relatively consistent. To create a data set that can reasonably be considered “Long-term,” a regression analysis using the line of organic correlation (LOC) method was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the *x* and *y* directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used to develop the minimum levels for Lake Alice (Cameron and Hancock, 2017). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing 70 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 Alice was used for the status assessment (Cameron and Hancock, 2017). The best resulting correlation for the LOC model created with measured data (2003-2016) was the 4-year weighted period, with a coefficient of determination of 0.74. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the percentiles calculated directly from the measured lake level data for Lake Alice for the period from 2003 through 2016. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 14 years, rather than the longer-term rainfall conditions represented in the 1947 to 2016 LOC model simulation.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 2003 to 2016 data, and the revised minimum levels proposed for Lake Alice.

Percentile	**Long Term LOC Model Results 1946 to 2016** Elevation in feet NGVD 29*	**Measured Lake Levels for Current Period (2003 to 2016)** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	41.1	41.4	40.7
P50	39.0	40.1	38.9

* LOC model based on Current Period and extended using rainfall for 1947 to 2016

A comparison of the LOC model with the revised minimum levels proposed for Lake Alice indicates that the Long-term P10 is 0.4 feet above the proposed High Minimum Lake Level, and the Long-term P50 is 0.1 feet above the proposed Minimum Lake Level. The P10 elevation derived directly from the 2003 to 2016 measured lake data is 0.7 feet higher than the proposed High Minimum Lake Level, and the P50 elevation is 1.2 feet higher than the proposed Minimum Lake Level. Differences in rainfall between the shorter 2003 to 2016 period and the longer 1947 to 2016 period used for the LOC modeling analyses likely contribute to the differences between derived and measured lake stage exceedance percentiles. Additionally, differences between actual withdrawal rates and those used in the models may have contributed to some of the differences in the percentiles.

E. Conclusions

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

Minimum flow and level status assessments are completed on an annual basis by the District and on a five-year basis as part of the regional water supply planning process. In addition, Lake Alice is included in the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area (40D-80.073, F.A.C). Therefore, the status of Lake Alice will be reassessed by the District and Tampa Bay Water as part of this plan, and as part of Tampa Bay Water's Permit Recovery Assessment Plan (required by Chapter 40D-80, F.A.C. and the Consolidated Permit (No. 20011771.001)). Tampa Bay Water, in cooperation with the District, will assess the specific needs for recovery in Lake Alice and other water bodies affected by groundwater withdrawals from the Central System Facilities. By 2020, if not sooner, an alternative recovery project will be proposed if Lake Alice is found to not be meeting its adopted minimum levels. The draft results of the Permit Recovery Assessment Plan are due to the District by December 31, 2018.

F. References

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APPENDIX C

Technical Memorandum

October 10, 2017

TO: Cortney Cameron, G.I.T., Hydrogeologist, Water Resources Bureau
Mark K. Hurst, Senior Environmental Scientist, Water Resources Bureau
Michael C. Hancock, P.E., Senior Hydrogeologist, Water Resources Bureau

FROM: Jason G. Patterson, Hydrogeologist, Water Resources Bureau

Subject: Evaluation of Groundwater Withdrawal Impacts to Lake Alice

1.0 Introduction

Lake Alice is in northwest Hillsborough County in west-central Florida (Figure 1). Prior to establishment of a Minimum Level (ML), an evaluation of hydrologic changes near the lake is necessary to determine if the water body has been significantly impacted by groundwater withdrawals. The establishment of the ML for Lake Alice is not part of this report. This memorandum describes the hydrogeologic setting near the lake and includes the results of two numerical model scenarios of groundwater withdrawals in the area.

2.0 Hydrogeologic Setting

The hydrogeology of the area includes a surficial sand aquifer system; a discontinuous, intermediate clay confining unit, a thick carbonate Upper Floridan aquifer, a low permeable confining unit and a Lower Floridan aquifer. In general, the surficial aquifer system is in good hydraulic connection with the underlying Upper Floridan aquifer because the clay confining unit is generally thin, discontinuous, and breeched by numerous karst features. The surficial sand aquifer is generally a few tens of feet thick and overlies the limestone of the Upper Floridan aquifer that averages nearly 1,000 feet thick in the area (Miller, 1986). In between these two aquifers is the Hawthorn Group clay that varies between a few feet to as much as 25 feet thick. Because the clay unit is breached by buried karst features and has previously been exposed to erosional processes, preferential pathways locally connect the overlying surficial aquifer to the Upper Floridan aquifer resulting in moderate-to-high leakage to the Upper Floridan aquifer (SWFWMD, 1996). Thus, the Upper Floridan aquifer is defined as a leaky artesian aquifer system.

The base of the Upper Floridan aquifer generally occurs at the first, persistent sequence of evaporitic minerals such as gypsum or anhydrite that occur as nodules or discontinuous thin layers in the carbonate matrix. This low permeability unit is regionally extensive and is generally referred to as middle confining unit II. Underlying the middle confining unit II is the Lower Floridan aquifer (Miller, 1986).

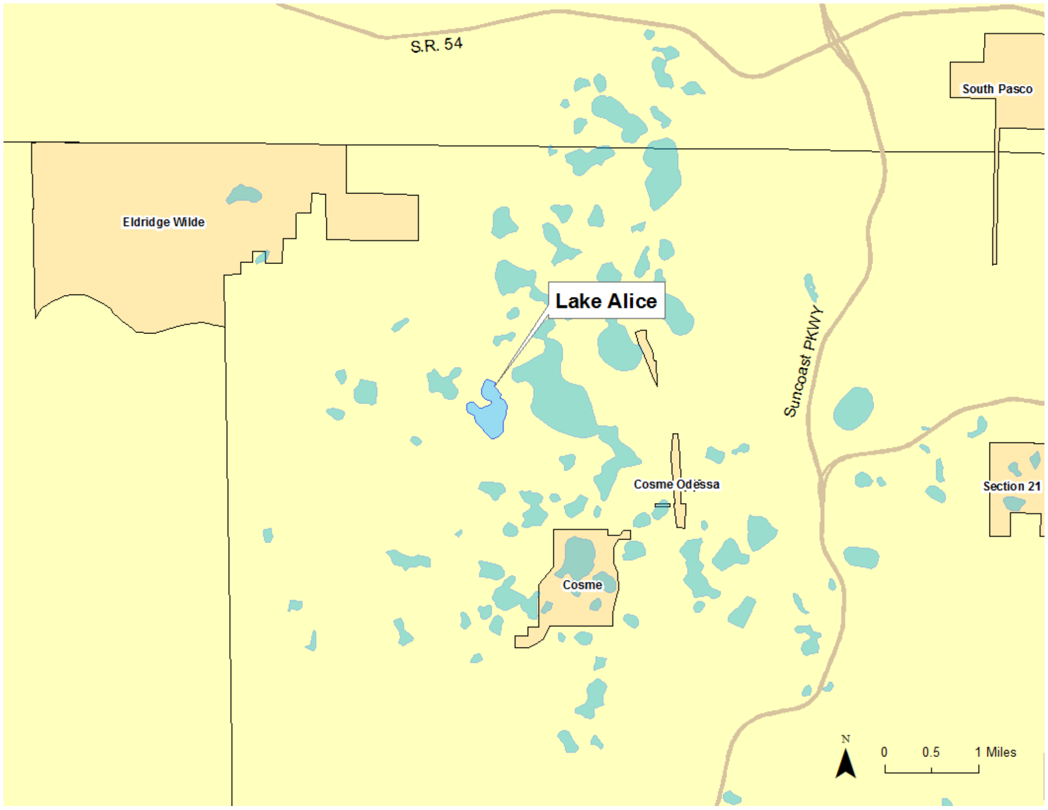

Figure 1. Location of Lake Alice.

3.0 Evaluation of Groundwater Withdrawal Impacts to Lake Alice

Several regional groundwater flow models have included the area around Lake Alice in northwest Hillsborough County. Ryder (1982) simulated the entire extent of the Southwest Florida Water Management District. In 1993, the District completed the Northern Tampa Bay groundwater flow model that covered a 2,000-square mile area of Hillsborough, Pinellas, Pasco, and Hernando Counties (SWFWMD, 1993). In 2002, the USGS simulated the entire Florida peninsula in their Mega Model of regional groundwater flow (Sepulveda, 2002). The most recent and advanced simulation of southern Pasco County and the surrounding area is the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2012). The construction and calibration of this model was part of a cooperative effort between the SWFWMD and Tampa Bay Water (TBW), a regional water utility that operates 11 major wellfields. The Integrated Northern Tampa Bay Model covers a 4,000 square-mile area of the Northern Tampa Bay region (Figure 2).

An integrated model represents the most advanced simulation tool available to the scientific community in water resources investigations. It combines the traditional ground-water flow model with a surface water model and contains an interprocessor code that links both systems. One of the many advantages of an integrated model is that it simulates the entire hydrologic system. It represents the "state-of-art" tool in assessing changes due to rainfall, drainage alterations, and withdrawals.

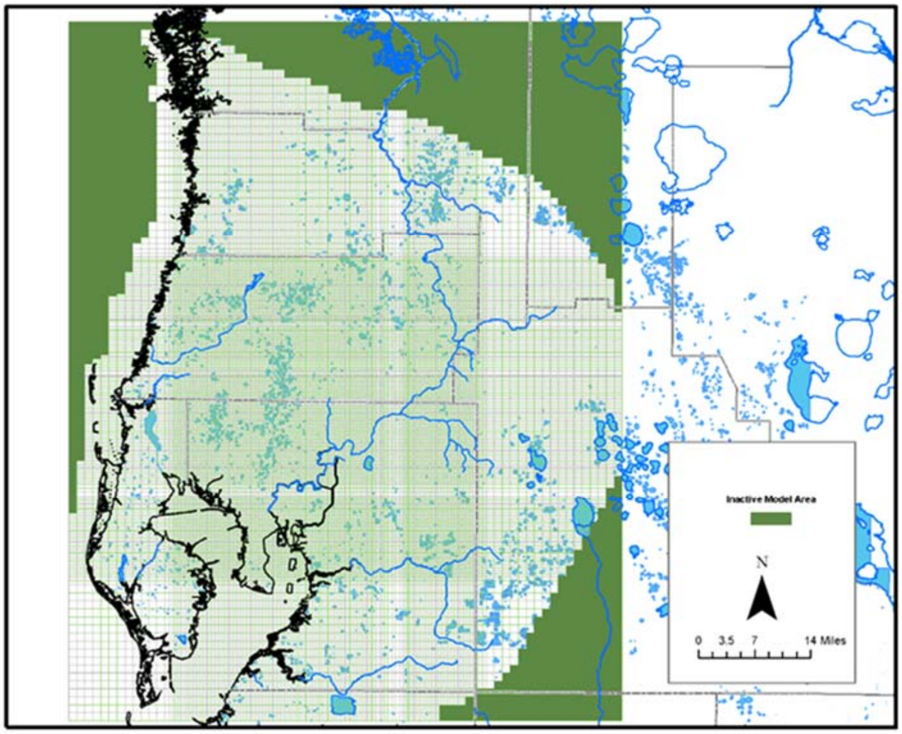

Figure 2. Groundwater grid used in the INTB model

The model code used to run the INTB simulation is called the Integrated Hydrologic Model (IHM) which combines the HSPF surface water code and the MODFLOW ground-water code using interprocessor software. During the INTB development phase, several new enhancements were made to move the code toward a more physically-based simulation. The most important of these enhancements was the partitioning of the surface into seven major land use segments: urban, irrigated land, grass/pasture, forested, open water, wetlands, and mining/other. For each land segment, parameters were applied in the HSPF model consistent with the land cover, depth-to-water table, and slope. Recharge and ET potential were then passed to each underlying MODFLOW grid cell based on an area weighted-average of land segment processes above it. Other new software improvements included a new ET algorithm/hierarchy plus allowing the model code to transiently vary specific yield and vadose zone storages.

The INTB model contains 172 subbasin delineations in HSPF (Figure 3). There is also an extensive data input time series of 15-minute rainfall from 300 stations for the period 1989-1998, a well pumping database that is independent of integration time step (1-7 days), a methodology to incorporate irrigation flux into the model simulation, construction of an approximate 150,000 river cell package that allows simulation of hydrography from major rivers to small isolated wetlands, and GIS-based definition of land cover/topography. An empirical estimation of ET was also developed to constrain model derived ET based on land use and depth-to-water table relationships.

The MODFLOW gridded domain of the INTB contains 207 rows by 183 columns of variable spacing ranging from 0.25 to one mile. The groundwater portion is comprised of three layers:

a surficial aquifer (layer 1), an intermediate confining unit or aquifer (layer 2), and the Upper Floridan aquifer (layer 3). The model simulates leakage between layers in a quasi-3D manner through a leakance coefficient term.

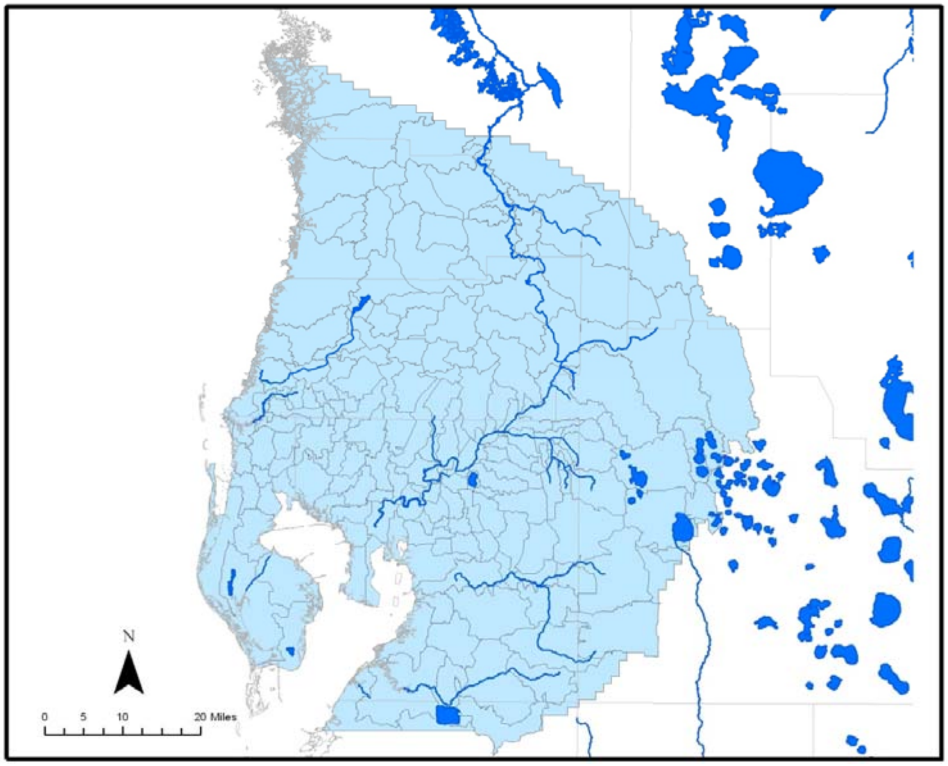

Figure 3. HSPF subbasins in the INTB model.

The INTB model is a regional simulation and has been calibrated to meet global metrics. The model is calibrated using a daily integration step for a transient 10-year period from 1989-1998. A model Verification period from 1999 through 2006 was also added. Model-wide mean error for all wells in both the surficial and Upper Floridan aquifers is less than 0.2 feet during both the calibration and verification periods. Mean absolute error was less than two feet for both the surficial and Upper Floridan aquifer. Total stream flow and spring flow mean error averaged for the model domain is each less than 10 percent. More information summarizing the INTB model calibration can be found in Geurink and Basso (2012).

3.1 INTB Model Scenarios

Three different groundwater withdrawal scenarios were run with the INTB model. The first scenario consisted of simulating all groundwater withdrawn within the model domain from 1989 through 2000. The second scenario consisted of eliminating all pumping in the Central West-Central Florida Groundwater Basin (Figure 4). Total withdrawals within the Central West-Central Florida Groundwater Basin averaged 239.4 mgd during the 1989-2000 period. TBW central wellfield system withdrawals were simulated at their actual withdrawal rates during this period. The third scenario consisted of reducing TBW central wellfield system withdrawals to their mandated recovery quantity of 90 mgd from the 11 central system wellfields. For TBW only, the 2008 pumping distribution was adjusted slightly upward from 86.9 mgd to 90 mgd to match recovery quantities.

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Lake Alice was 0.9 feet, and 7.9 feet in the Upper Floridan aquifer (Figure 5 and 6). Taking the difference in modeled heads from the TBW recovery pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Lake Alice was 0.4 feet and 4.0 feet in the Upper Floridan aquifer (Figure 6 and 7). Table 1 presents the predicted drawdown in the surficial and the Upper Floridan aquifer based on the INTB model results.

Table 1. INTB model results for Lake Alice.

Lake Name	**Predicted Drawdown (feet) in the Surficial Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (feet) in the Surficial Aquifer with TBW Withdrawals reduced to 90 mgd***
Alice	0.9	0.4
Lake Name	**Predicted Drawdown (feet) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (feet) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd***
Alice	7.9	4.0

* Average drawdown from model cells intersecting lake

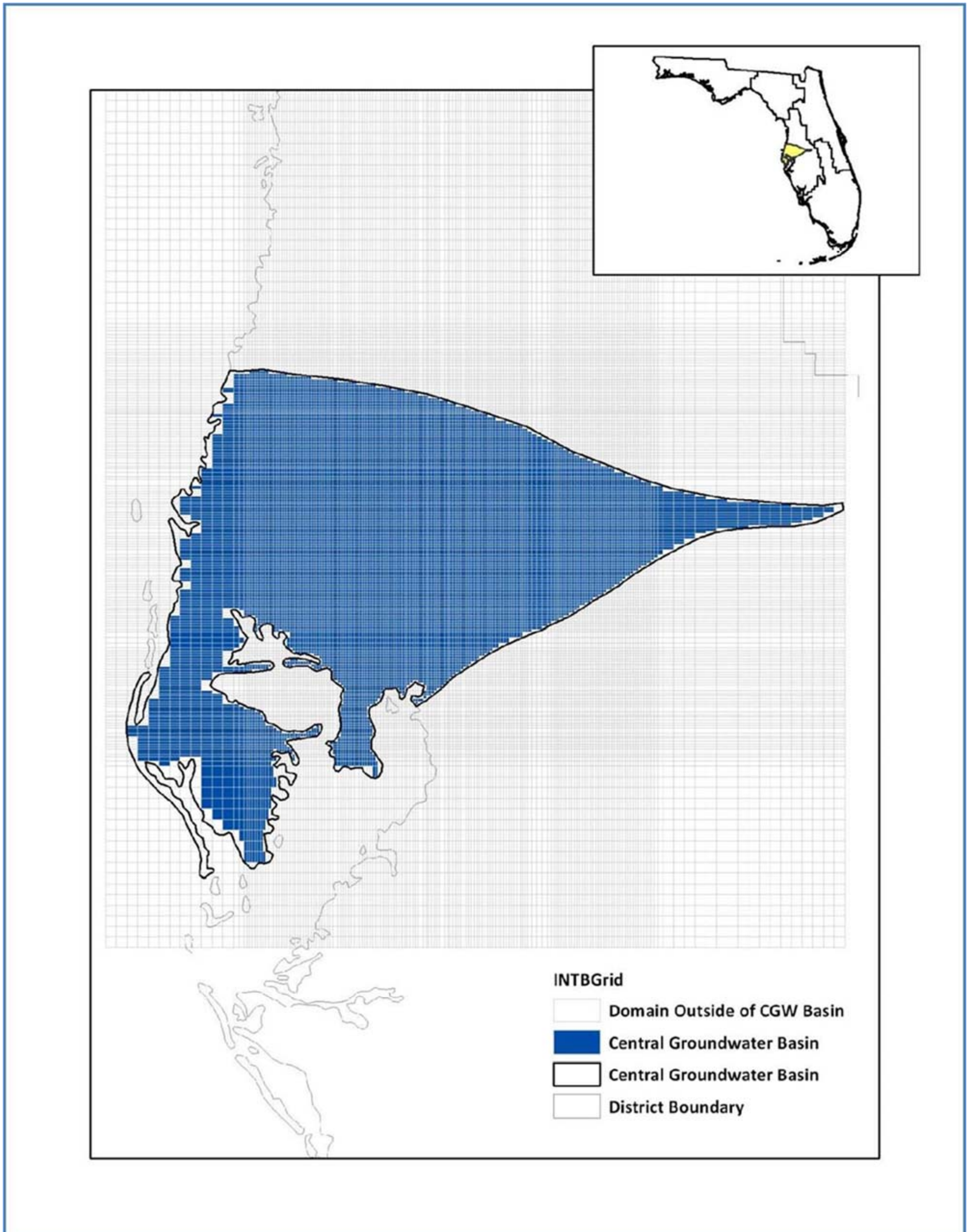

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin

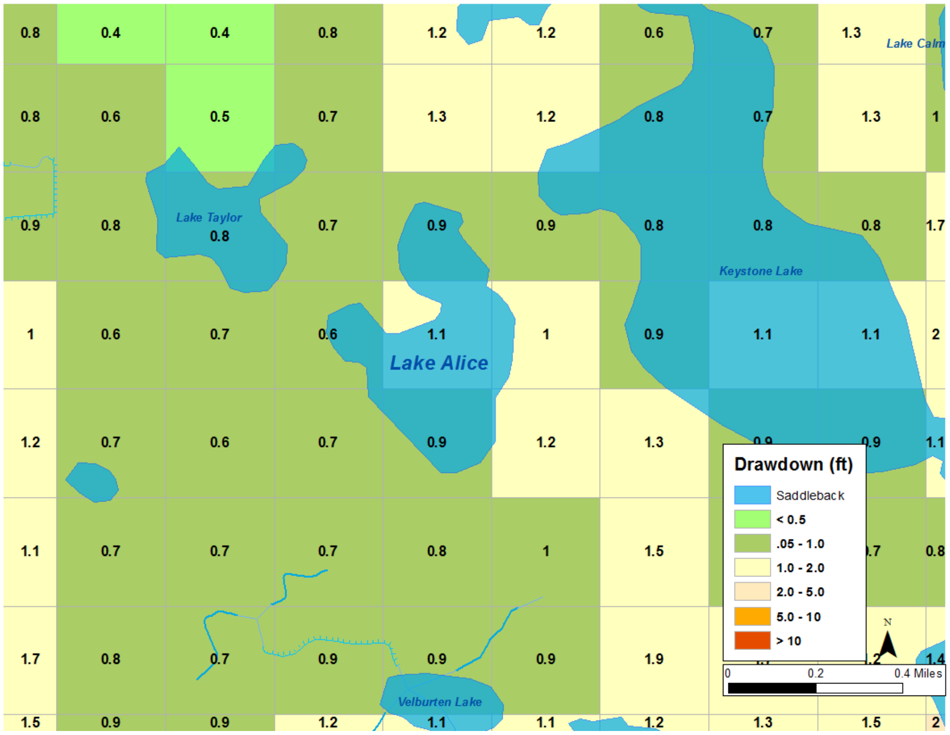

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

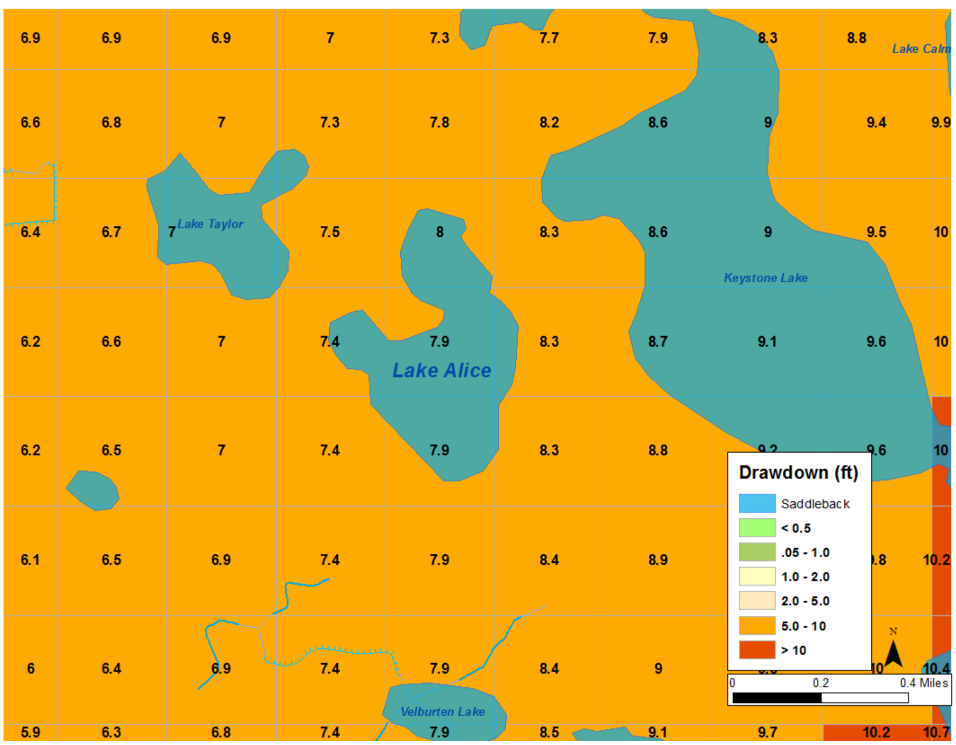

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

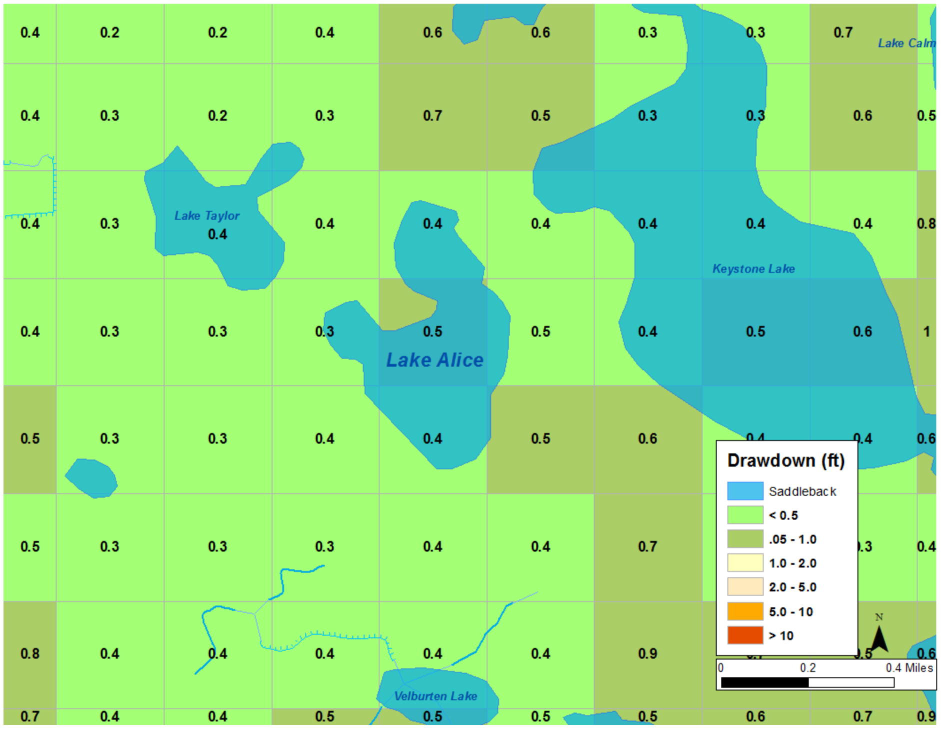

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

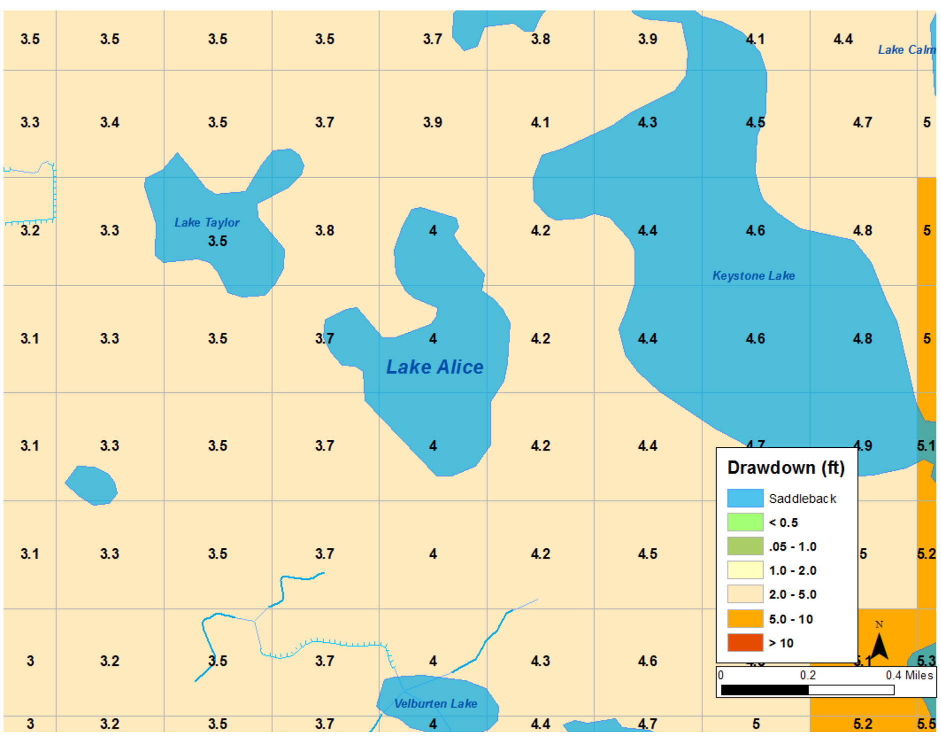

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

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