Revised Minimum and Guidance Levels Based on Reevaluation of Levels Adopted for Church and Echo Lakes in Hillsborough County, Florida

November 14, 2019

DRAFT

Resource Evaluation Section
Water Resources Bureau
Southwest Florida
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Cover: 2017 Aerial Imagery of Church and Echo Lakes (Southwest Florida Water Management District).

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Definitions

Category 1 Lakes	Lakes with lake-fringing cypress swamp(s) greater than 0.5 acre in size where Structural Alterations have not prevented the Historic P50 from equaling or rising above an elevation that is 1.8 feet below the Normal Pool elevation of the cypress swamp(s).
Category 2 Lakes	Lakes with lake-fringing cypress swamp(s) greater than 0.5 acre in size where Structural Alterations have prevented the Historic P50 from equaling or rising above an elevation that Is 1.8 feet below the Normal Pool and the lake fringing cypress swamp(s) remain viable and perform functions beneficial to the lake despite the Structural Alterations.
Category 3 Lakes	Lakes without lake-fringing cypress swamp(s) greater than 0.5 acre in size.
Control Point Elevation	The elevation of the highest stable point along the outlet profile of a surface water conveyance system that principally controls lake water level fluctuations
Current	A recent Long-term period during which Structural Alterations and hydrologic stresses are stable.
District	Southwest Florida Water Management District (SWFWMD)
Dynamic Ratio	The ratio of a lake's surface area (in square kilometers) to the mean depth of the lake (in meters). Used to determine at what water level a lake is susceptible to decreased water quality, i.e., turbidity, due to wave disturbance of bottom sediments.
F.A.C.	Florida Administrative Code

FDEP	Florida Department of Environmental Protection
F.S.	Florida Statutes
Guidance Levels	Water levels determined by the District and used as advisory information for the District, lakeshore residents and local governments, or to aid in the management or control of adjustable structures.
High Guidance Level (HGL)	The expected Historic P10 elevation. Provided as an advisory guideline for the construction of lake shore development, water dependent structures, and operation of water management structures.
High Minimum Lake Level (HMLL)	The elevation that a lake's water levels are required to equal or exceed ten percent of the time on a Long-term basis
Historic	A Long-term period when there are no measurable impacts due to withdrawals, and Structural Alterations are similar to current conditions.
Historic P10	The expected Historic P10 elevation; *I.e.,* the elevation of the water surface of a lake or wetland that is expected to be equaled or exceeded ten percent of the time based on a Long-term period when there are or were no measurable impacts due to withdrawals, and Structural Alterations are similar to current conditions.
Historic P50	The expected Historic P50 elevation; *I.e.,* the elevation of the water surface of a lake or wetland that is expected to be equaled or exceeded fifty percent of the time based on a Long-term period when there are or were no measurable impacts due to withdrawals, and Structural Alterations are similar to current conditions.

Historic P90	The expected Historic P90 elevation; *I.e.,* the elevation of the water surface of a lake or wetland that is expected to be equaled or exceeded ninety percent of the time based on a Long-term period when there are or were no measurable impacts due to withdrawals, and Structural Alterations are similar to current conditions.
Hydrologic Indicators	Biological and physical features, as listed In Section 373.4211(20), Florida Statutes, which are representative or indicative of previous water levels.
Leakance	Relative to groundwater movement, the ratio of the vertical hydrologic conductivity of the confining bed to the thickness of the confining bed (Anderson and Woessner, 2002); a measure of how easily water can pass through a confining unit.
Long-term	An evaluation period utilized to establish minimum flows and levels, to determine compliance with established minimum flows and levels, and to assess withdrawal impacts on established minimum flows and levels, that represents a period which spans the range of hydrologic conditions which can be expected to occur based upon historical records, ranging from high water levels to low water levels. In the context of a predictive model simulation, a Long-term simulation will be insensitive to temporal fluctuations in withdrawal rates and hydrologic conditions, so as to simulate steady-state, average conditions. In the context of an average water level, the average will be based upon the historic expected range and frequency of levels. relative to minimum level establishment and compliance, where there are six years or more of competent data, a minimum of a six-year evaluation period will be used; but the available data and reasonable scientific judgement will dictate whether a longer period is used. Where there are less than six years of competent data, the period used will be dictated by the available data and a determination, based on reasonable scientific

	judgement, that the period is sufficiently representative of Long-term conditions.
Low Guidance Level (LGL)	The expected Historic P90. Provided as an advisory guideline for construction of water dependent structures, information for lakeshore residents, and operation of water management structures.
MFL	Minimum Flows and Levels
Minimum Lake Level (MLL)	The elevation that the lake's water levels are required to equal or exceed fifty percent of the time on a Long-term basis.
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
Normal Pool Elevation	An elevation approximating the P10 (see below) elevation which is determined based on hydrologic indicators of sustained inundation
Not Structurally Altered	Refers to a lake where the control point elevation equals or exceeds the Normal Pool elevation, or the lake has no outlet
P10	The percentile ranking represented by the elevation of the water surface of a lake or wetland that is equaled or exceeded ten percent of the time as determined from a Long-term stage frequency analysis.
P50	The percentile ranking represented by the elevation of the water surface of a lake or wetland that Is equaled or exceeded fifty percent of the time as determined from a Long-term stage frequency analysis.

P90	The percentile ranking represented by the elevation of the water surface of a lake or wetland that Is equaled or exceeded ninety percent of the time as determined from a Long-term stage frequency analysis.
Reference Lakes	Lakes from a defined area which are not measurably impacted by water withdrawals. Reference lakes may be used to develop reference lake statistics, including the RLWR50, RLWR90, and the RLWR5090 (see below).
RLWR50	Reference Lake Water Regime 50. The median difference between the P10 and P50 elevations for reference lakes with historic data and similar hydrogeologic conditions as the lake of concern.
RLWR5090	Reference Lake Water Regime 5090. The median difference between the P50 and P90 elevations for reference lakes with historic data and similar hydrogeologic conditions as the lake of concern.
RLWR90	Reference Lake Water Regime 90. The median difference between the P10 and P90 lake stage elevations for reference lakes with historic data and similar hydrogeologic conditions as the lake of concern
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SWFWMD	Southwest Florida Water Management District

Introduction

Reevaluation of Minimum Flows and Levels

This report describes the development of minimum levels and guidance levels for Church and Echo Lakes 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 2003 and subsequently adopted into District rules. The minimum and guidance levels represent necessary revisions to the currently adopted levels.

Church and Echo Lakes 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 Church and Echo Lakes 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 Minimum Levels report; additional information on all tasks associated with the District's MFLs Program is summarized by Hancock *et al.* (2010).

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

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

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

Consideration of Changes and Structural Alterations and Environmental Values

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

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

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

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

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

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

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria are used to develop minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. The Cypress Standard is 1.8 feet below the normal pool elevation. For Category 3 Lakes, six significant change standards are typically developed. Other available information, including potential changes in the coverage of herbaceous wetland and submersed aquatic plants, is also considered when establishing minimum levels for Category 3 Lakes. The standards and other available information are associated with the environmental values identified for consideration in Rule 62-40.473, F.A.C., when establishing MFLs (Table 1). The specific standards and other information evaluated to support development of minimum levels for Church and Echo Lakes 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 based on appropriate significant change standards and other information and use of minimum levels in District permitting programs

Lake Classification

Lakes are classified as Category 1, 2, or 3 for Minimum Levels development. According to Rule 40D-8.624, F.A.C., Church and Echo Lakes meets the classification as Category 3 Lakes, with less than 0.5 acre of fringing cypress wetlands. The standards associated with Category 3 Lakes described below will also be developed in a subsequent section of this report.

Lake-specific significant change standards and other available information are developed for establishing Minimum Levels for Category 3 Lakes. The standards are used to identify thresholds for preventing significant harm to cultural and natural system values associated with lakes in accordance with guidance provided in the Florida Water 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.

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 corridor delineated as a circular area with a radius of 418 feet, or a rectangular ski corridor 200 feet in width and 2,000 feet in length (the Ski Elevation), and use of Historic lake stage data or region-specific Reference Lake Water Regime statistics where Historic lake data are not available.

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

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

The Aesthetics Standard is developed to protect aesthetic values associated with the inundation of lake basins. The standard is intended to protect aesthetic values associated with the median lake stage from diminishing beyond the values associated with the lake when it is staged at the Low Guidance Level. The Aesthetics Standard is established at the Low Guidance Level.

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

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

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

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

Minimum and Guidance 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 proposed levels, the levels are then 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), 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 most elevation values included within this report, in some circumstances, notations are made for elevation data that was collected or reported relative to mean sea level or relative to NAVD88 and converted to elevations relative to NGVD29
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Development of Minimum and Guidance Levels for Church and Echo Lakes

Lake Setting and Description

Church and Echo Lakes (Figure 1) are located in Hillsborough County, Florida (Sections 27 and 28, Township 27S, Range 17E) in the Northwest Hillsborough Basin within the Southwest Florida Water Management District.

The lakes' watershed (Figure 2) has a drainage area of approximately 0.40 square miles. Church Lake has one inlet along the eastern shore from a small lake, Lake Amelia, which only flows at relatively high water levels (Figure 3). Church Lake has an outlet along the southwest shore into Lake Williams, and Echo Lake discharges to the northwest (Figure 3). The two lakes are connected above elevations of approximately 32.5 ft. NGVD29 through a navigable canal. The lakes have been connected with equalized water levels approximately 80% of the time during their periods of record. There are currently no surface water withdrawals from the lake permitted by the District. There are, however, several permitted groundwater withdrawals in the lake vicinity.

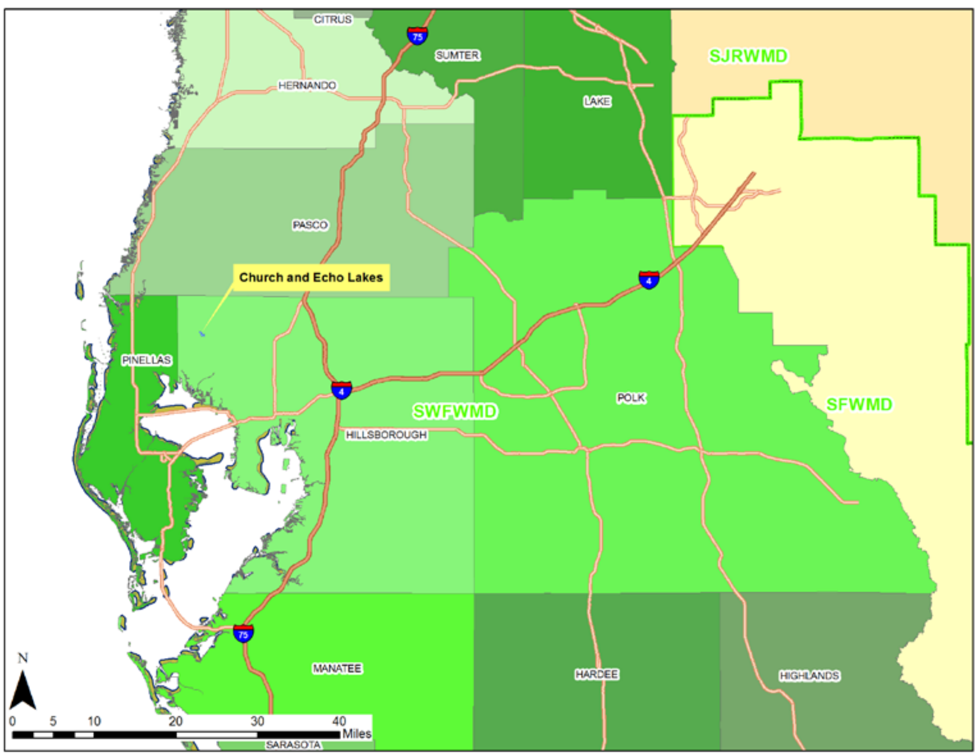

Figure 1: Location of Church and Echo Lakes in Hillsborough County, Florida.

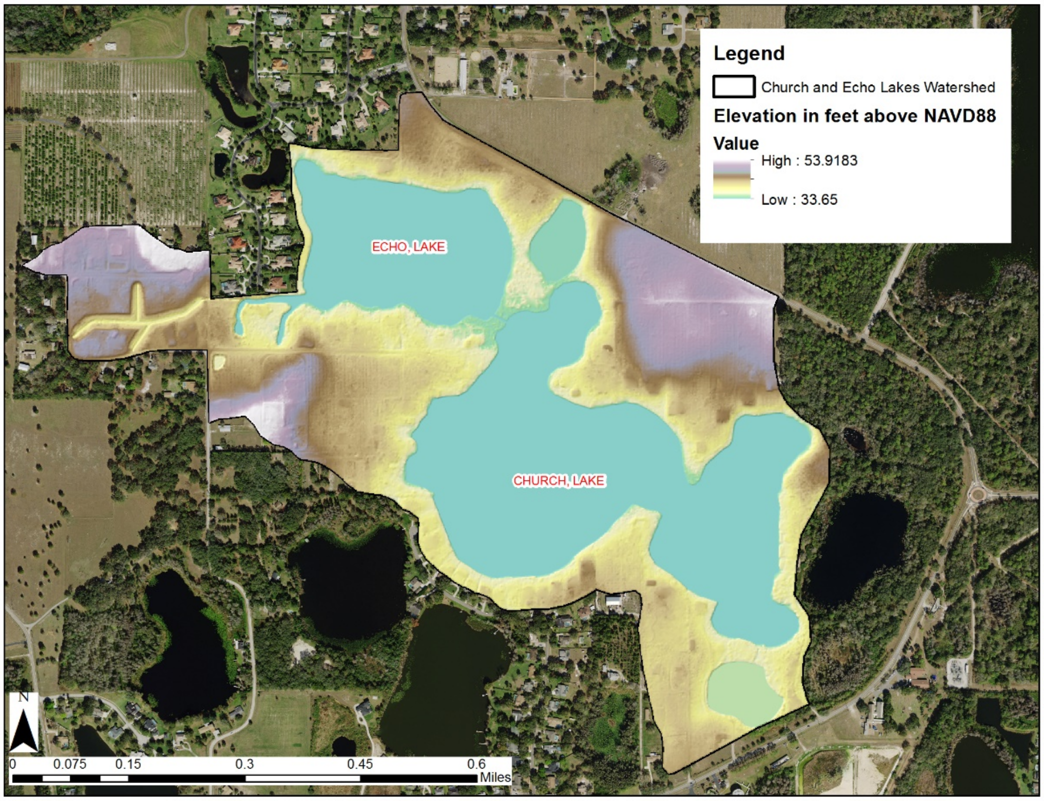

Figure 2: Watershed Delineation and Topography.

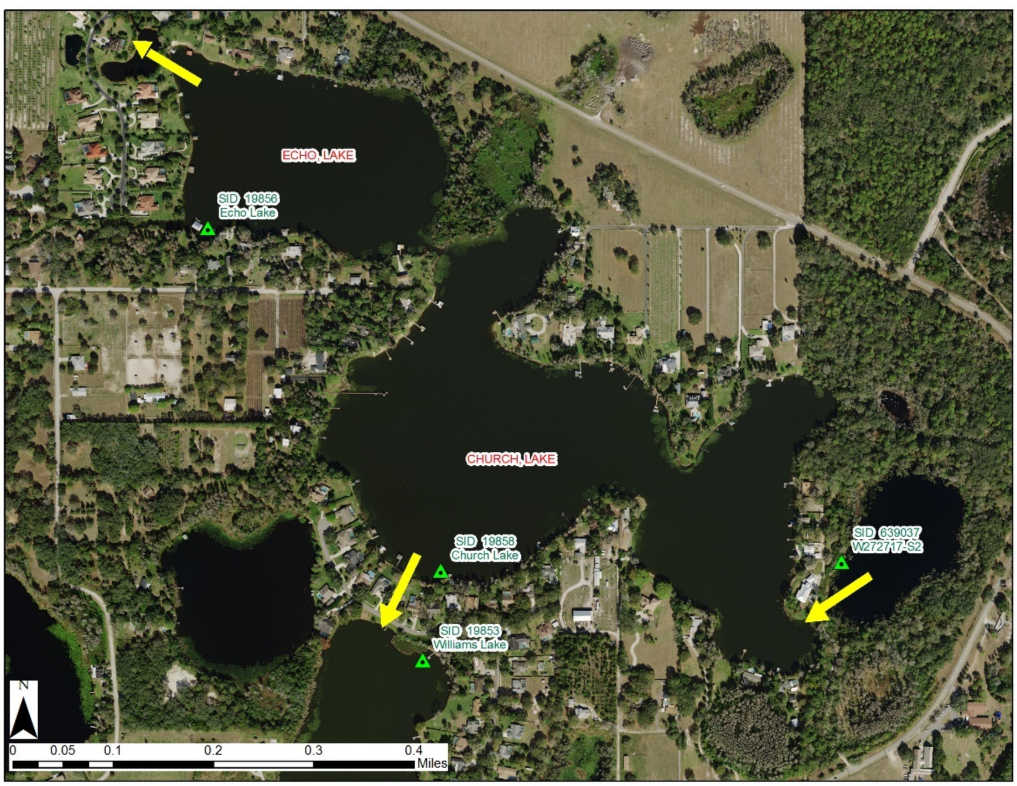

Figure 3: Location of Conveyance Systems and District Gages.

Land Use Land Cover

An examination of the 1950 and more current 2011 Florida Land Use, Cover, and Forms Classification System (FLUCCS) maps revealed that there have been substantial changes to the landscape (specifically the dominant land forms) in the vicinity of the lakes during this period (Figure 4 and Figure 5). In 1950 (Figure 4) the majority of the land surrounding Church and Echo Lakes was classified as crop and pastureland to the North, and either wetland or pine flatwoods to the South. To the Northwest was stream and lake/bay swamps. By 2011 (Figure 5), much of the land use had been replaced with residential lands, and the steam and lake/bay swamps to the Northwest has been disconnected from the lakes primarily by residential lands*.* Figure 6 through Figure 11 aerial photography chronicles landscape changes to the immediate lake basin from 1948 through 2017.

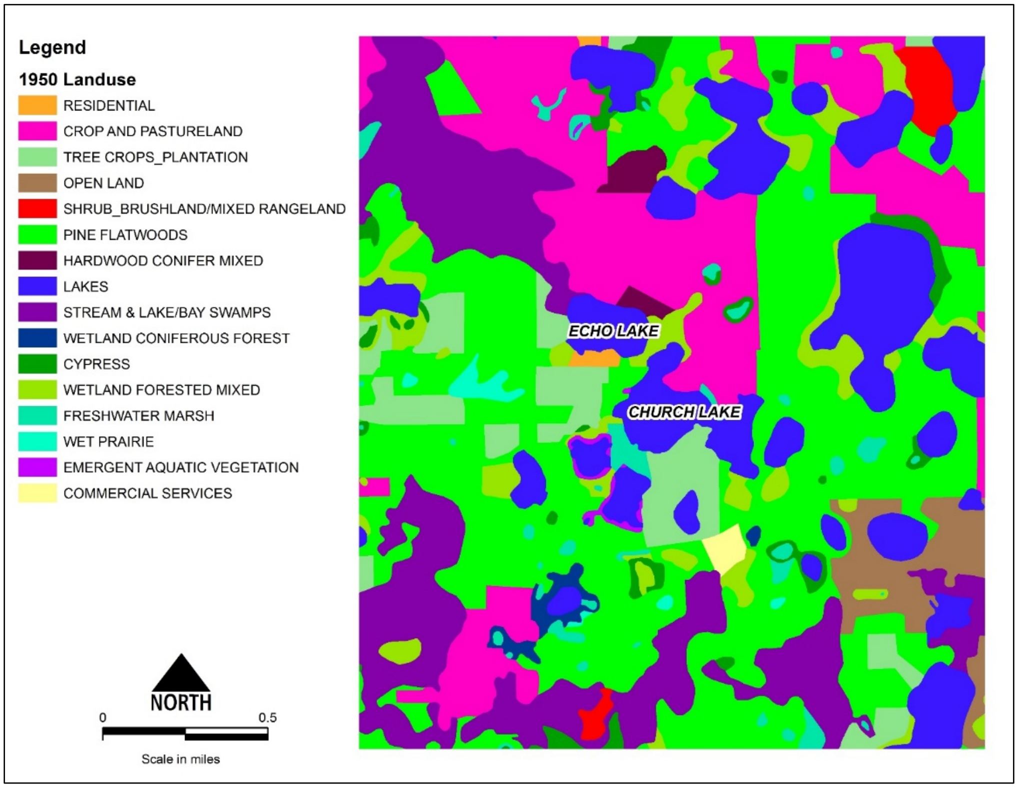

Figure 4: 1950 Land Use Land Cover Map of the Church and Echo Lakes Vicinity.

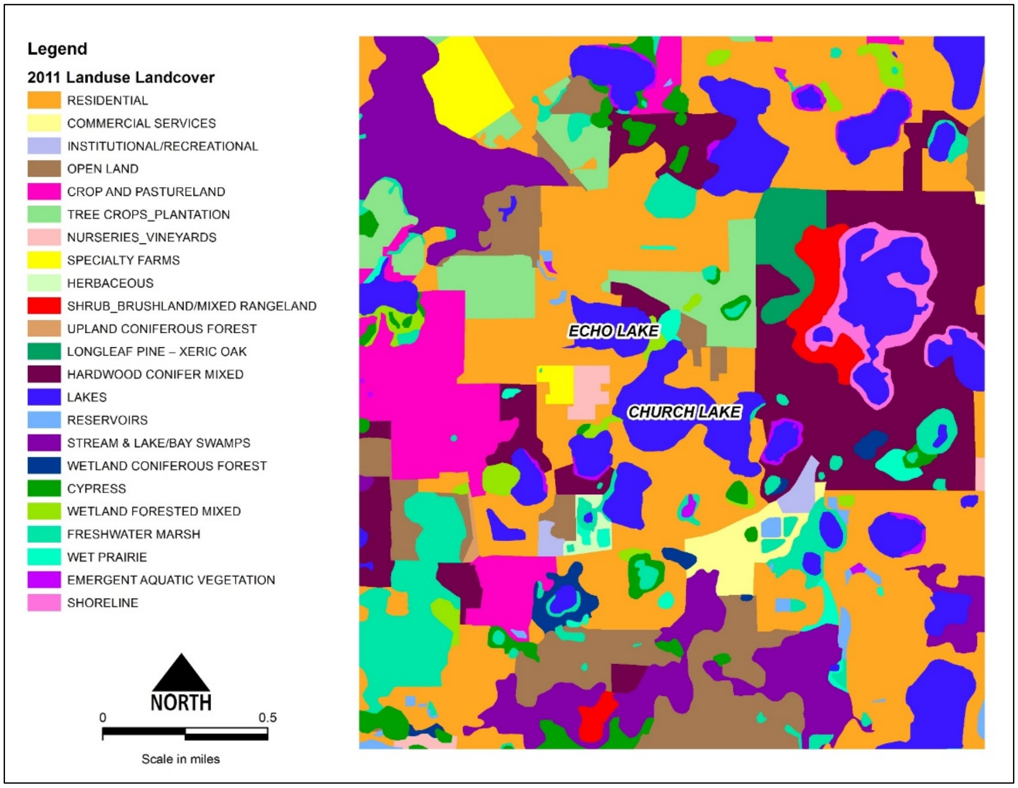

Figure 5: 2011 Land Use Land Cover Map of the Church and Echo Lakes Vicinity.

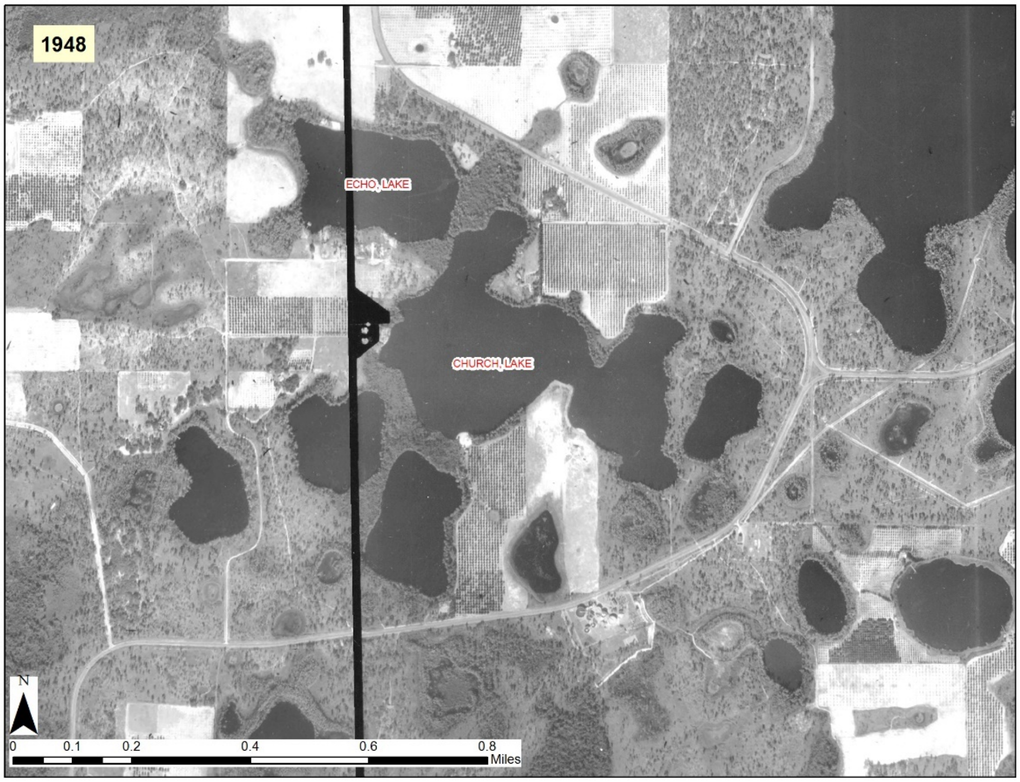

Figure 6: 1948 Aerial Photograph of Church and Echo Lakes

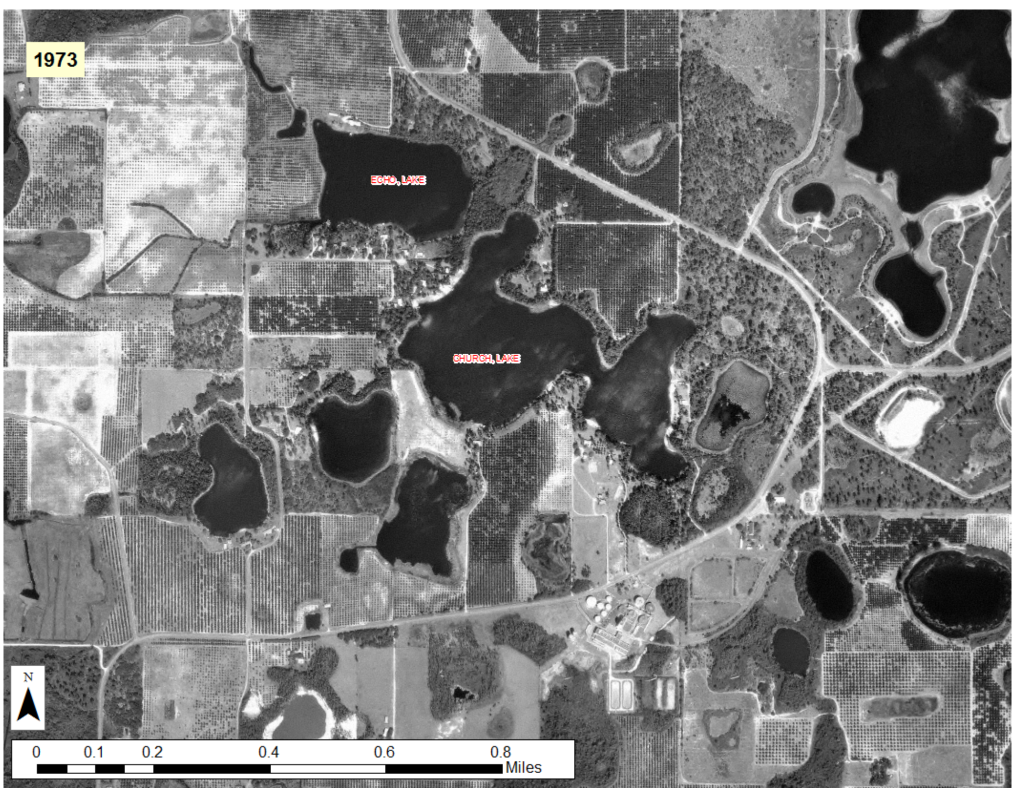

Figure 7: 1973 Aerial Photograph of Church and Echo Lakes

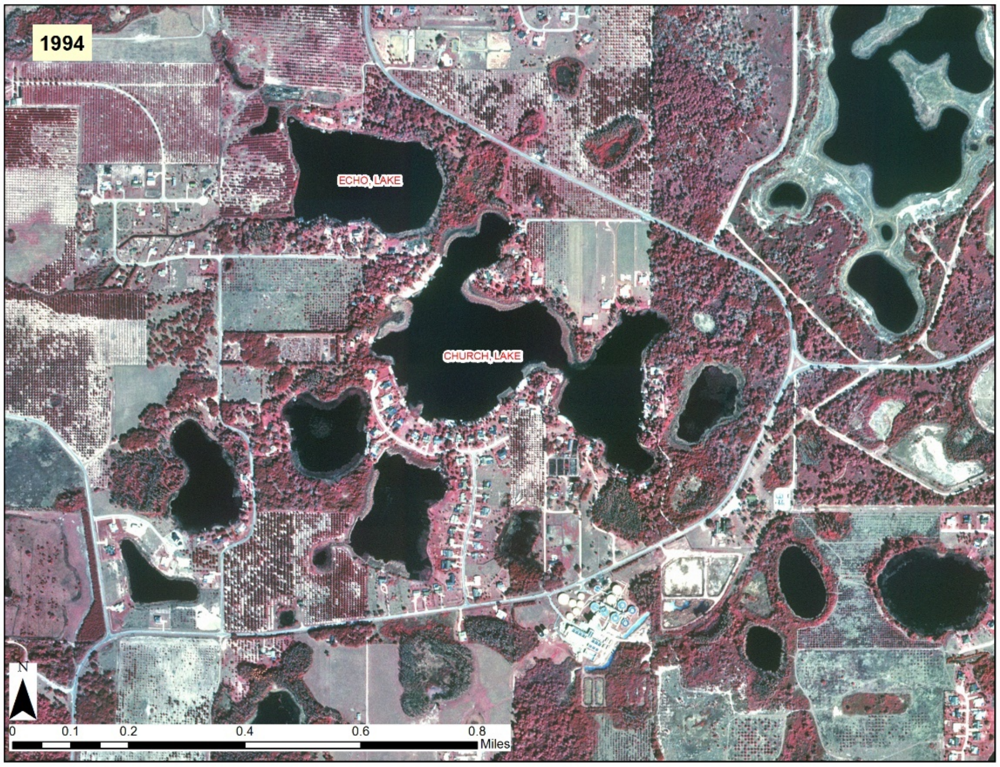

Figure 8: 1994 Color Infrared Aerial Photograph of Church and Echo Lakes

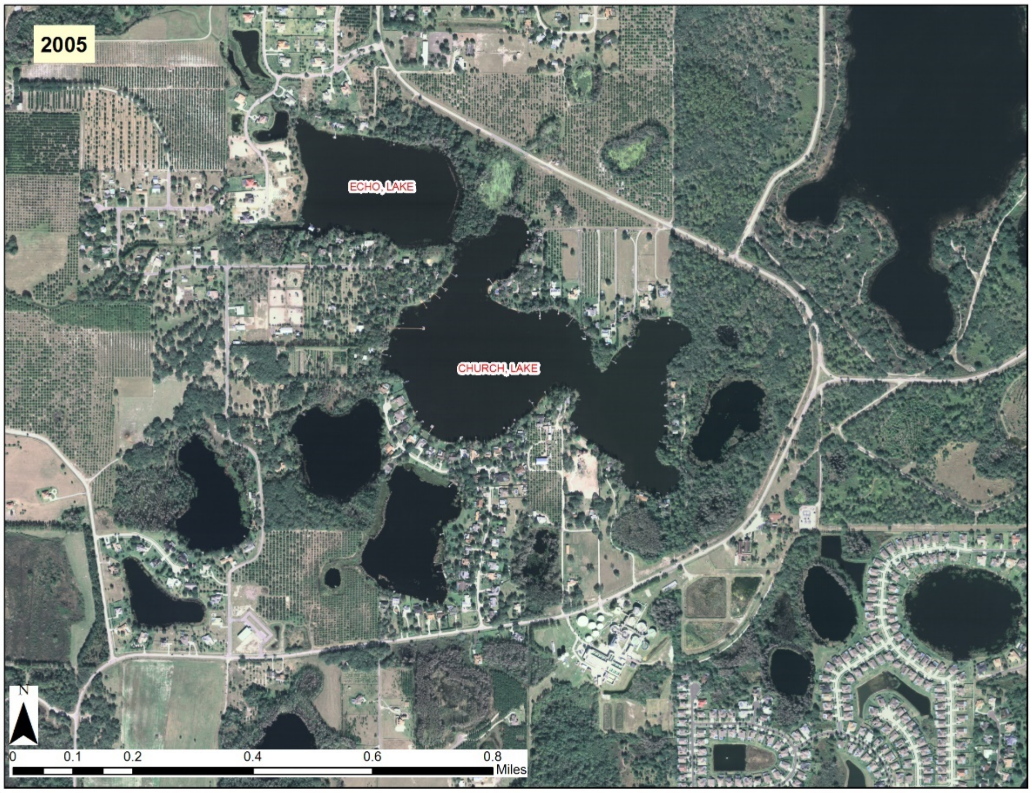

Figure 9: 2005 Aerial Photograph of Church and Echo Lakes

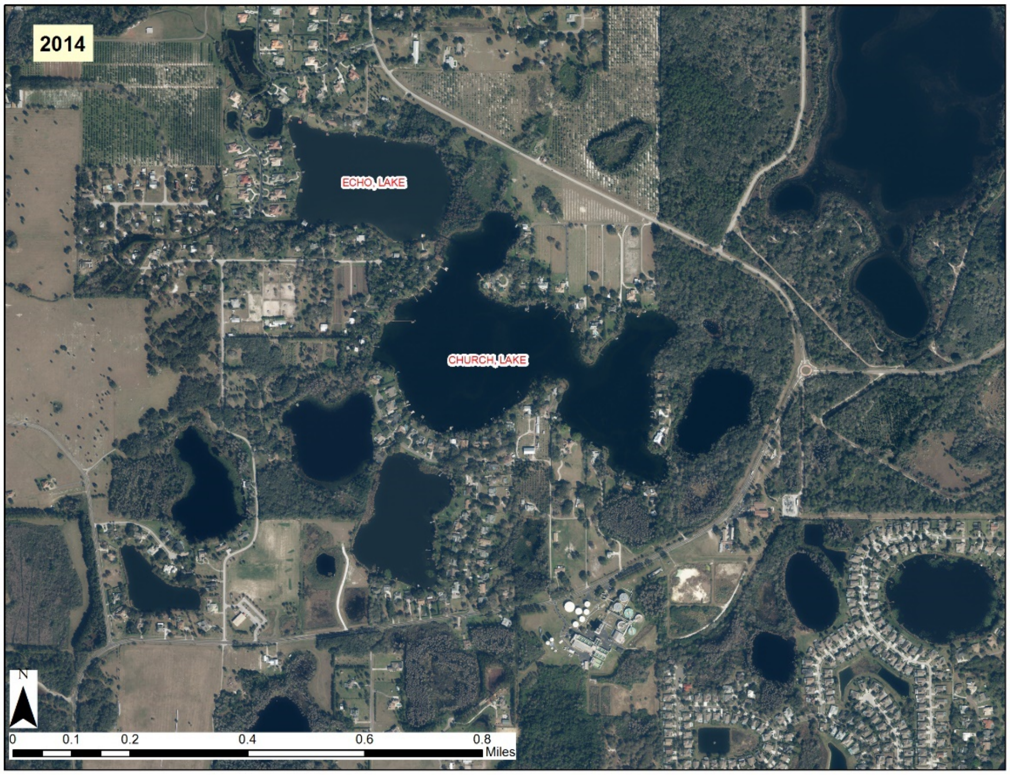

Figure 10: 2014 Aerial Photograph of Church and Echo Lakes

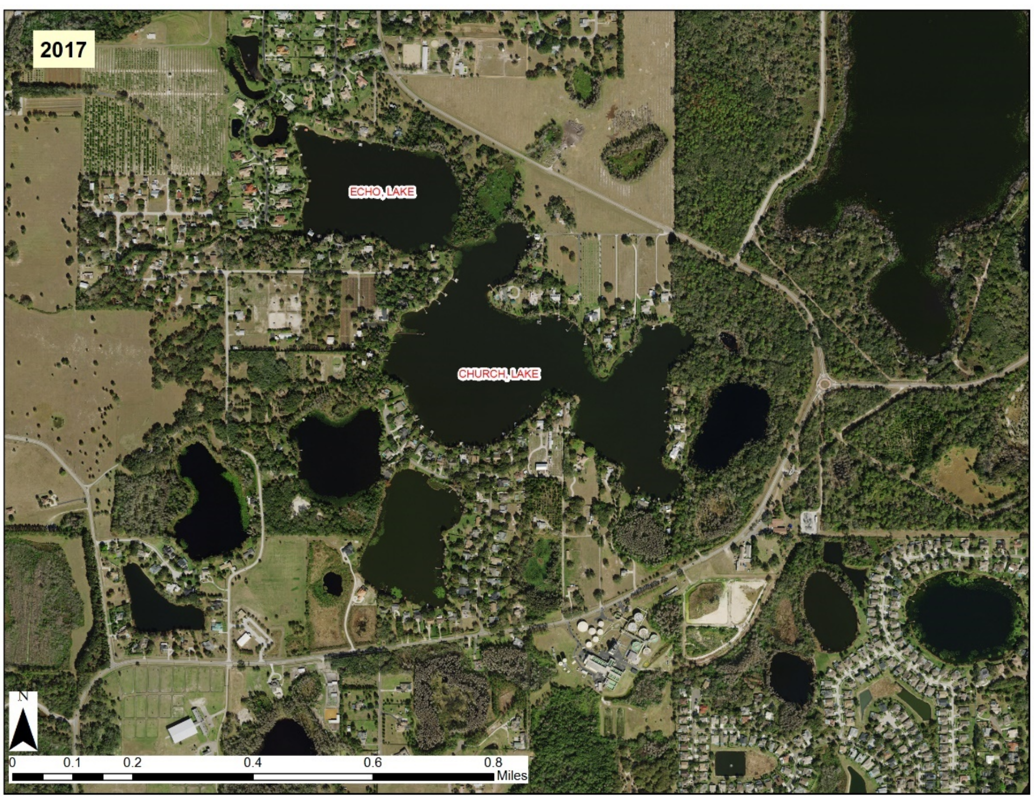

Figure 11: 2017 Aerial Photograph of Church and Echo Lakes

Bathymetry Description and History

One foot interval bathymetric data gathered from recent field surveys resulted in lake-bottom contour lines from 14.8 ft. to 36.8 ft., NGVD29 (Figure 12). These data revealed that the lowest lake bottom contour (14.8 ft. NGVD29), or the deepest part of the lake, is a possible dredge hole located along the eastern shore of Church Lake. The lake's bottom is generally around 21-22 ft. NGVD. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

Figure 12: Lake Bottom Contours (ft., NGVD29) on a 2017 Natural Color Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Church and Echo Lakes from the District's Water Management Information System (SID 19858 & 19856, respectively) (Figure 13). Data collection began on June 13, 1931 from SID 19858 on Church Lake, and on September 5, 1957 from SID 19856 on Echo Lake. There have been a few lapses in data collection from both gauges, including from September 1937 through September 1957 on Church Lake, and from September 1958 through July 1971 on Echo Lake, which was shortly after data collection began. Echo Lake also had a break in data collection from September 1981 through April 1989, and August 1996 through December 2002. Water elevations continue to be monitored on a monthly basis from both SIDs at the time of this report. On September 2, 2014 SID 19858 was adjusted from NGVD29 to NAVD88, with a measured shift of -0.91 ft, and on September 18, 2014 SID 19856 was adjusted from NGVD29 to NAVD88 with a measured shift of -0.88 ft. The highest lake stage elevation on record was 38.6 ft. and occurred on Church Lake on February 22, 1936. The lowest lake stage elevation on record was 27.94 ft. on Church Lake and occurred on May 29, 2002. Despite data missing on Echo Lake, it's likely that water levels would have mirrored Church Lake's extreme high and lows, as the two lakes mirror each other when water level data exists for both.

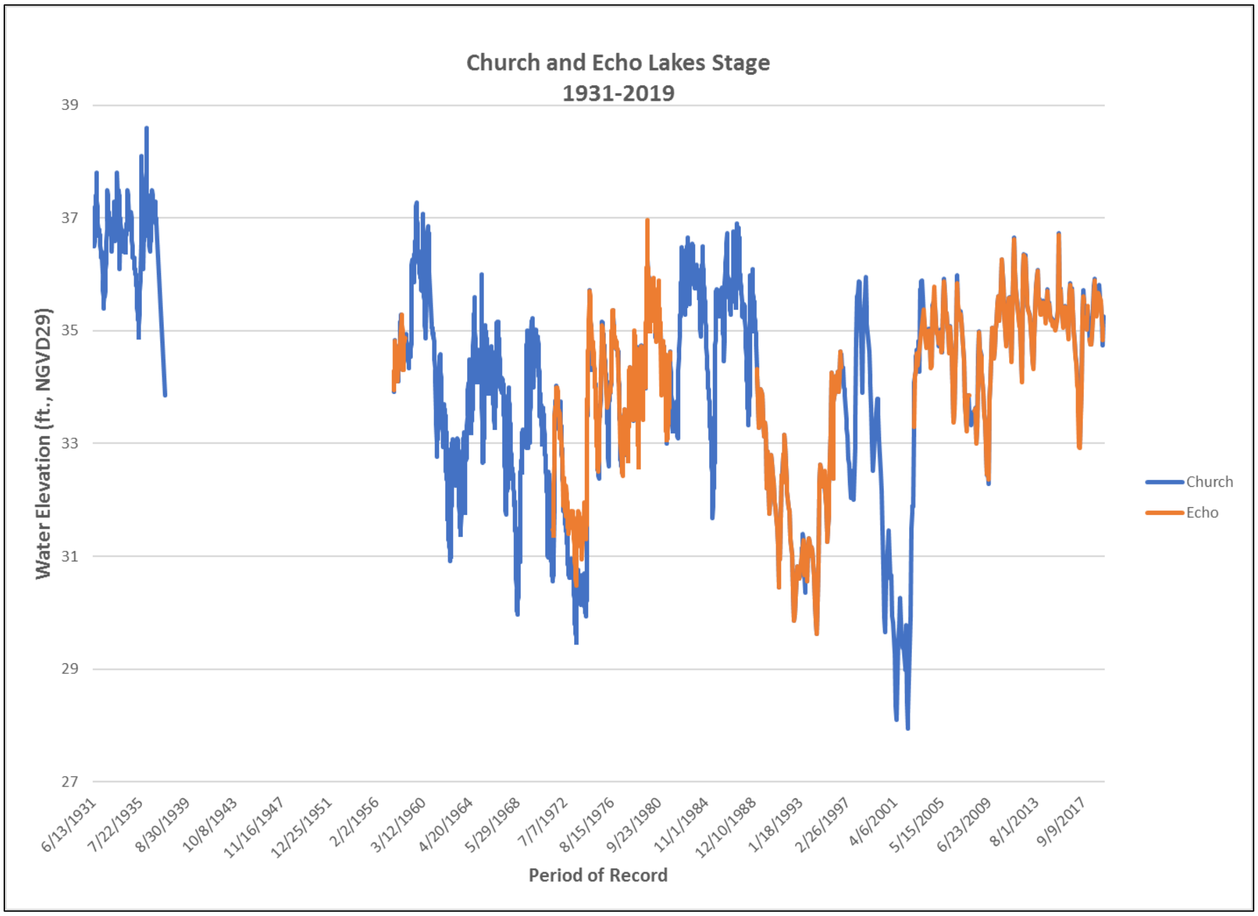

Figure 13: Church and Echo Lakes Period of Record Water Elevation Data (SIDs 19858 and 19856, respectively)

Historic Management Levels

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

The District Governing Board first approved Guidance and Minimum Levels for Church and Echo Lakes (Table 2) in October 2003, which were subsequently adopted into Chapter 40D-8, Florida Administrative Code in January 2004 using the methodology for Category 3 Lakes described in SWFWMD (1999a and 1999b).

Table 2: Minimum and Guidance Levels approved in 2003 for Church and Echo Lakes

Level	Elevation (ft., NGVD)
High Guidance Level	35.64
High Minimum Level	35.64
Minimum Level	34.64
Low Guidance Level	33.54

Methods, Results and Discussion

The Minimum and Guidance Levels in this report were developed for Church and Echo Lakes using the methodology for Category 3 Lakes described in Chapter 40D-8, F.A.C. Levels, Standards, and other information used for development of the levels, are listed in Table 3, along with lake surface area for each level. 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 with associated surface areas for Church and Echo Lakes.

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Historic P10 (1946 to 2018)	36.0	104
Historic P50 (1946 to 2018)	35.2	98
Historic P90 (1946 to 2018)	34.1	92
Normal Pool and Control Point		
Normal Pool	NA	NA
Control Point	35.0	97
Significant Change Standards		
Recreation/Ski Standard	33.9	91
Dock-Use Standard	33.8	90
Wetland Offset Elevation	34.4	94
Aesthetics Standard	34.1	92
Species Richness Standard	32.6	94
Basin Connectivity Standard	35.6	101
Lake Mixing Standard	NA	NA
Minimum and Guidance Levels		
High Guidance Level	36.0	104
High Minimum Lake Level	35.2	98
Minimum Lake Level	34.4	94
Low Guidance Level	34.1	92

NA - not appropriate

Bathymetry

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

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

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

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

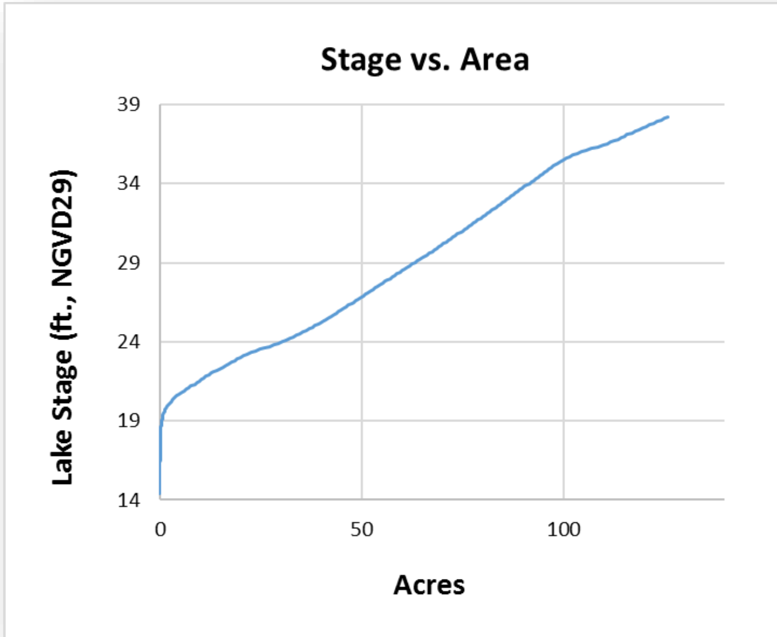

Figure 14: Lake Stage (Ft. NGVD29) to Surface Area (Acres) for Church and Echo Lakes.

Development of Exceedance Percentiles

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

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

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

A combination of model data produced a hybrid model which resulted in a 72-year (1946-2018) 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 36.0 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 35.2 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 34.1 ft. (Figure 15 and Table 3).

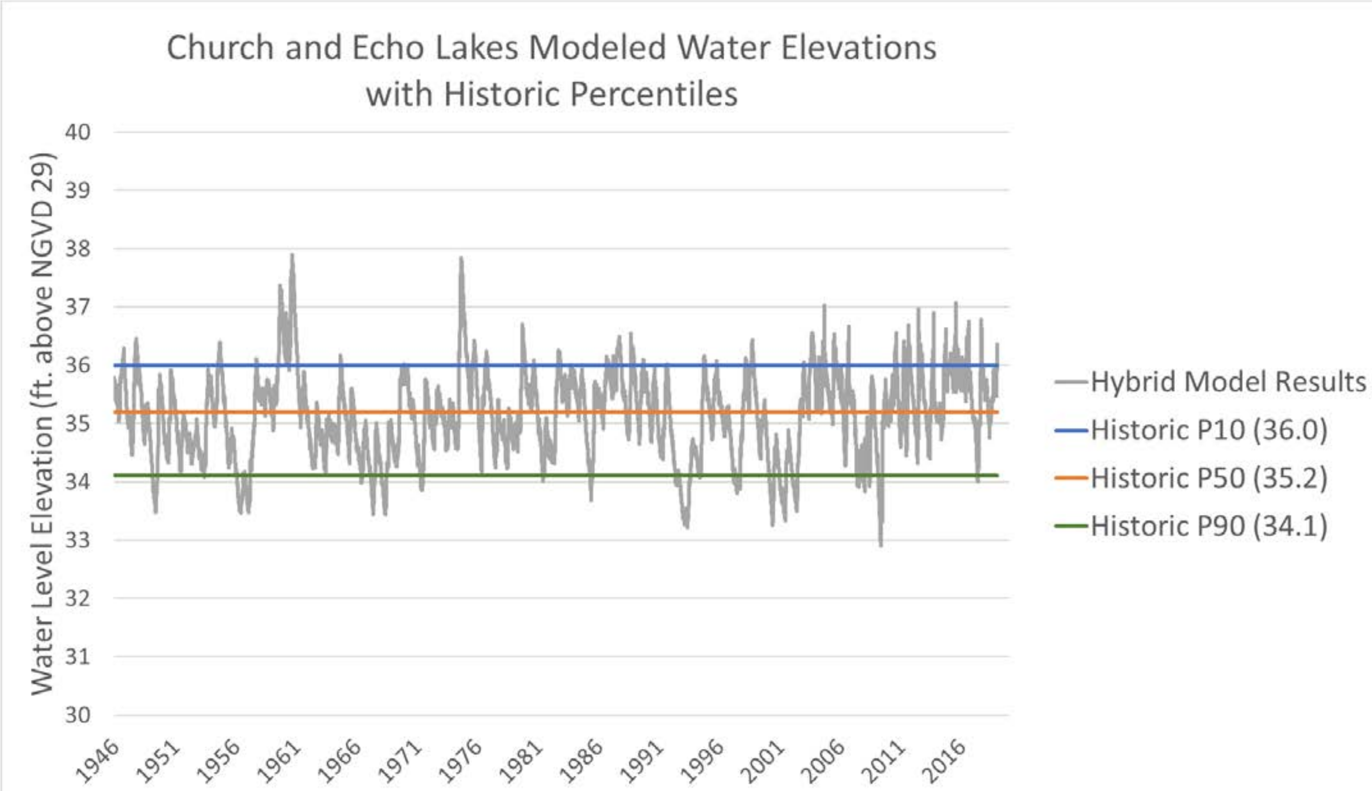

Figure 15: Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

Normal Pool Elevation and Additional Information

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

Additional information to consider in establishing Minimum and Guidance Levels are the Control Point elevation and the lowest building floor (slab) elevation within the lake basin (determined by field survey data). The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system that can principally control the lake water level fluctuations at the high end. The Control Point for Church and Echo Lakes was determined at 35 ft., the elevation of a high point in a stable, maintained ditch at the Echo Lake outlet. The control point of the outflow from Church Lake into Lake Williams was surveyed at 34.7 ft. The low floor slab elevations, based on survey reports, were established at 37.9 ft. on Echo Lake and 38.6 ft. on Church Lake. The low road was 36.9 ft. on Church Lake (Williams Drive) and 38.6 ft. on Echo Lake (McGlamery Road).

Guidance Levels

The High Guidance Level (HGL) 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 Church and Echo Lakes, the High Guidance Level was established at the Historic P10 elevation, 36.0 ft. Recorded data indicate that the highest levels reached were in the 1930’s, with a peak of 38.6 ft. in February 1936.

The Low Guidance Level (LGL) is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, Reference Lake Water Regime (RLWR) statistics. Based on the availability of Historic data for Church and Echo Lakes, the Low Guidance Level was established at the Historic P90 elevation, 34.1 ft. The recorded period of record indicates the lowest lake level elevation was 27.9 ft., below the Low Guidance Level, in May 2002 (Figure 13). The most recent record of the water level dropping below the Low Guidance Level was in December 2008, with a recorded level of 33.9 ft. on both lakes.

Significant Change Standards

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

- The **Recreation/Ski Standard** was established at an elevation of 33.9 ft. based on a ski elevation of 27.8 ft. and the difference between the Historic P50 and P90 of 1.1 ft.
- The **Dock-Use Standard** was established at an elevation of 33.8 ft. based on the elevation of lake sediments at the end of 49 docks on the lake, a 2-ft. clearance depth, and the difference between the Historic P50 and P90 of 1.1 ft.
- The **Wetland Offset Elevation** was established at 34.4 ft., or 0.8 ft. below the historic P50 elevation.
- The **Aesthetic Standard** was established at the Low Guidance Level elevation of 34.1 ft.
- The **Species Richness Standard** was established at 32.6 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- The **Basin Connectivity Standard** was established at an elevation of 35.6 ft. based on a critical high spot elevation of 32.5 ft, the addition of 2 feet, plus the difference between the Historic P50 and P90 of 1.1 ft. This critical high spot is the elevation separating Church Lake from Echo Lake.
- The **Lake Mixing Standard** was not established, as the dynamic ratio does not reach a value of 0.8 (see Bachmann et al. 2000).

Review of changes in potential herbaceous wetland area associated with change in lake stage (Figure 16), and potential changes in area available for aquatic plant colonization (Figure 17) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development. Figure 16 shows that as the lake stage increases, the acres available for herbaceous wetland area (acres < 4 ft.) also increase, up until around 25 ft. NGVD. The acres available for herbaceous wetlands then decrease as the lake becomes deeper and increase again above 35 ft. as the lake stages above the control point at the outlet. Similarly, the area available for aquatic plant colonization (acres < 10.2 ft.) follows the same trend of increasing until a threshold point (Figure 17). The changes in the slope of the lines reflects the variation in lake bottom contours and the area which it contains.

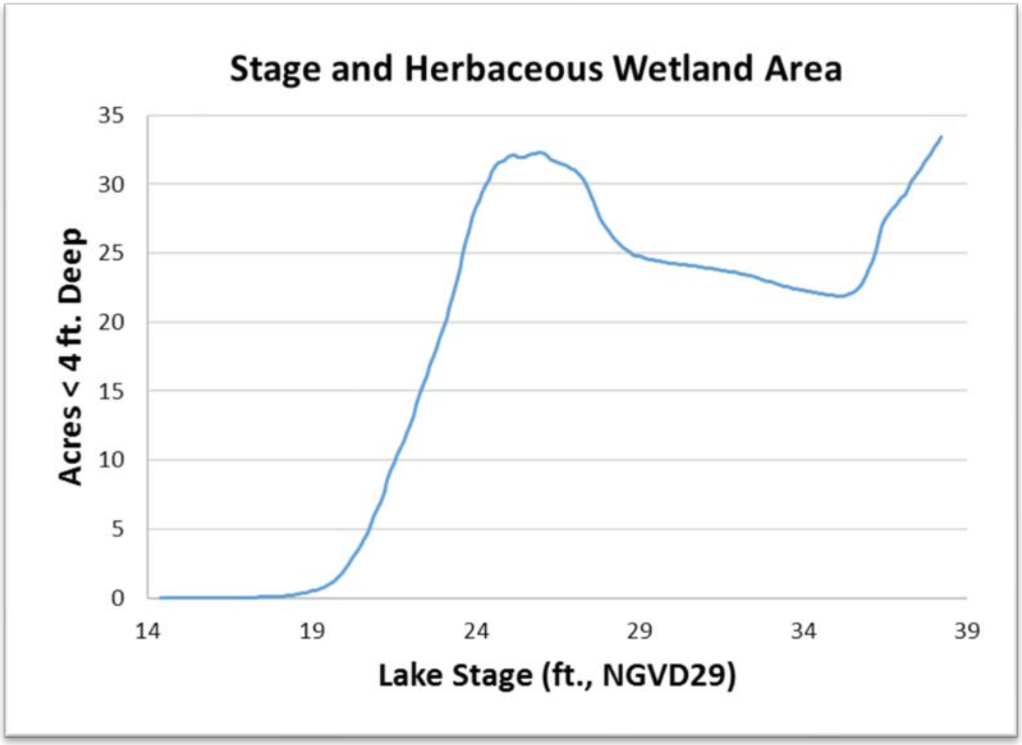

Figure 16: Lake Stage Compared to Available Herbaceous Wetland Area.

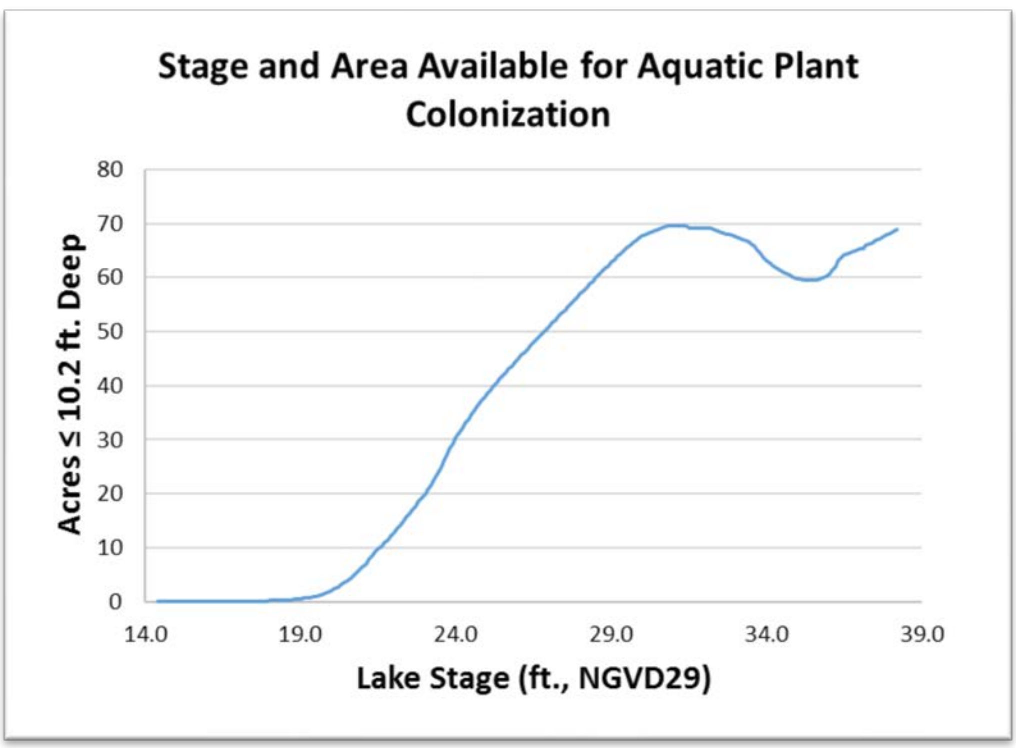

Figure 17: Lake Stage and Area Available for Aquatic Plant Colonization.

Minimum Levels

The Minimum Lake Level (MLL) is the elevation that a lake's water levels are ***required*** to equal or exceed fifty percent of the time on a long-term basis. For a Category 3 Lake, the Minimum Lake Level is established using a process that considers applying professional experience and judgement, and the Standards previously listed. The MLL for Church and Echo Lakes is established at the Wetland Offset elevation of 34.4 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, or alternatively, the HMLL is established at the elevation corresponding to the MLL plus the RLWR value. Due to the availability of Historic percentiles, the HMLL was established using the first method, resulting in a HMLL of 35.2 ft. This elevation accounts for a natural fluctuation of lake levels.

Minimum and Guidance levels for Church and Echo Lakes are plotted on the recorded water level record in Figure 18. 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 aerial photograph in Figure 19.

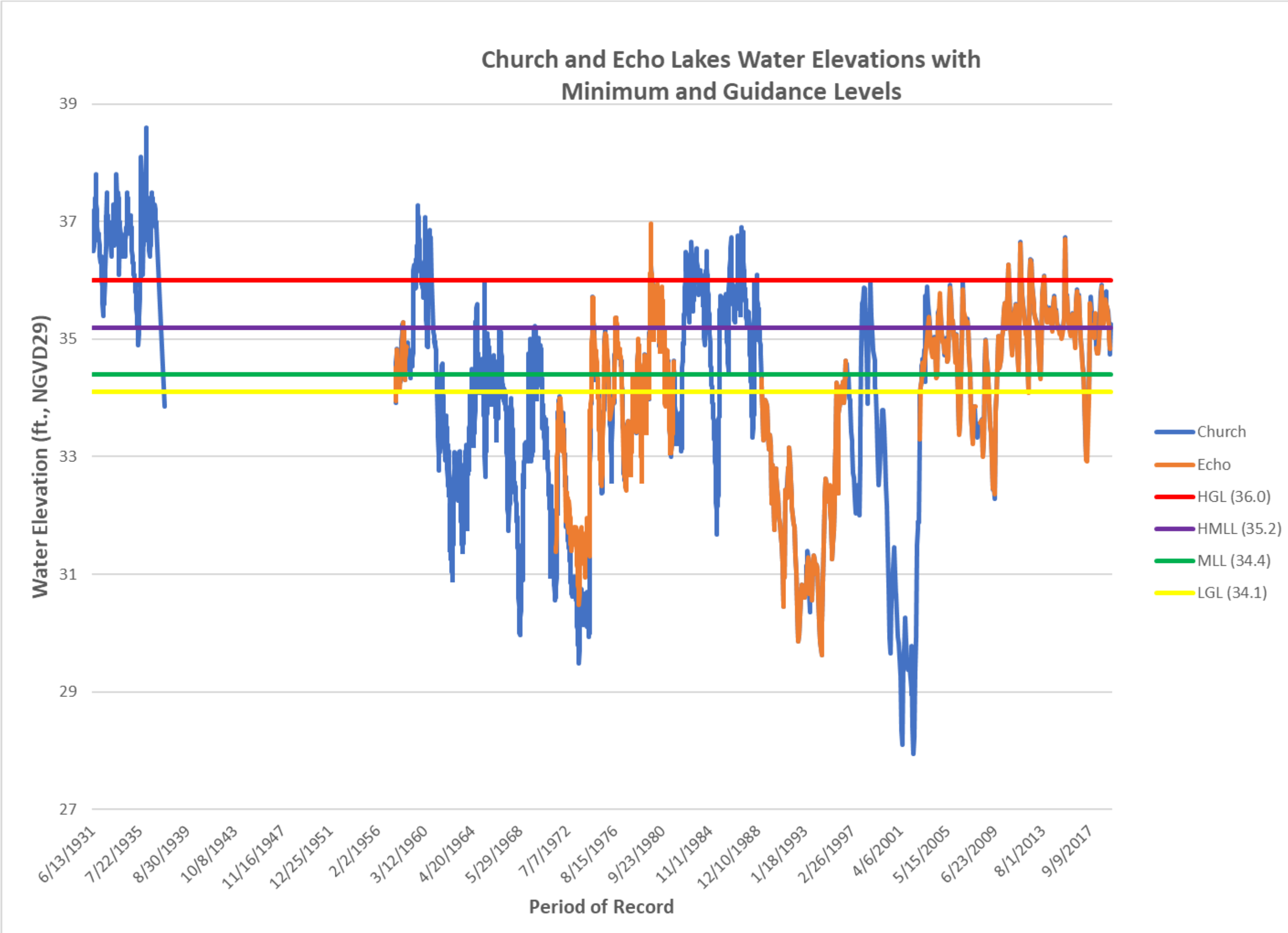

Figure 18: Recorded Water Level Elevations with Guidance and Minimum Lake Levels for Church and Echo Lakes.

Figure 19: Church and Echo Lakes 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 Church and Echo Lakes 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 -0.91 ft. for SID 19858 on Church Lake.

Table 4: Minimum and Guidance Levels for Church and Echo Lakes in NGVD29 and NAVD88.

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88
High Guidance Level	36.0	35.1
High Minimum Lake Level	35.2	34.3
Minimum Lake Level	34.4	33.5
Low Guidance Level	34.1	33.2

Consideration of Environmental Values

The minimum levels for Church and Echo Lakes are protective of relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, F.A.C.). As presented above, when developing Minimum Lake Levels, the District evaluates categorical significant change standards and other available information to identify criteria that are sensitive to long-term changes in hydrology and represent significant harm thresholds.

The Wetland Offset Elevation was used for developing Minimum Levels for Church and Echo Lakes based on its classification as a Category 3 Lake. This standard is associated with protection of several environmental values identified in Rule 62-40.473, F.A.C., including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, and water quality (Table 1).

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

Two environmental values identified in the Water Resource Implementation Rule were not considered relevant to development of minimum levels for Church and Echo Lakes. 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.

Comparison of Revised and Previously Adopted Levels

The High Guidance Level is 0.4 feet higher than the previously adopted High Guidance Level, while the Low Guidance Level is 0.4 feet higher than the previously adopted Low Guidance Level (Table 5). These differences are associated with application of a new modeling approach for characterization of Historic water level fluctuations within the lake, i.e., water level fluctuations that would be expected in the absence of water withdrawal impacts given existing structural conditions, and additional data since the last evaluation.

The High Minimum Lake Level for Church and Echo Lakes is 0.4 ft. lower than the previously adopted High Minimum Lake Level. The Minimum Lake Level is 0.3 feet lower than the previously adopted Minimum Lake Level (Table 5). These differences are due to the same factors discussed above for the changes in the Guidance Levels, as well as the fact that the revised MLL is based on the Wetland Offset elevation for this reevaluation, while the last evaluation set the MLL at the Historic P50.

The Minimum and Guidance Levels identified in this report replace the previously adopted levels for Church and Echo Lakes.

Table 5: Minimum and Guidance Levels for Church and Echo Lakes compared to previously adopted Minimum and Guidance Levels.

Minimum and Guidance Levels	Elevations (in Feet NGVD29)	Previously Adopted Elevations (in Feet NGVD29)
High Guidance Level	36.0	35.6
High Minimum Lake Level	35.2	35.6
Minimum Lake Level	34.4	34.6
Low Guidance Level	34.1	33.5

Minimum Levels Status Assessment

To assess if the Minimum and High Minimum Lake Levels are being met, observed stage data in Church and Echo Lakes were used to create a long-term record using a Line of Organic Correlation (LOC) model, similar to what was developed for establishing the Minimum Levels (Appendix A). For the status assessment, the lake stage data used to create the LOC must be from a period representing a time when groundwater withdrawals and structural alterations are reasonably stable, and represent current conditions, referred to as the “Current” period. Current stage data observed on Church and Echo Lakes were determined to be from 2004 through 2018. Using the Current stage data, the LOC model was created. The LOC model resulted in a 72-year long-term water level record (1946-2018).

For the status assessment, cumulative median (P50) and cumulative P10 water elevations were compared to the Minimum Lake Level and High Minimum Lake Level, respectively, to determine if long-term water levels were above these levels. Results from these assessments indicate that Church and Echo Lakes are meeting both the Minimum Lake Levels and the High Minimum Lake Levels (see Appendix B).

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

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DRAFT APPENDIX A
Technical Memorandum

November 14, 2019

TO: Donna Campbell, Staff Environmental Scientist, Water Resources Bureau

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

FROM: Jason Patterson, Hydrogeologist, Water Resources Bureau
Samantha Smith, Hydrogeologist, Water Resources Bureau

Subject: Church Lake and Echo Lake 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 Church Lake and Echo Lake in northwest Hillsborough County. Church and Echo lakes currently have adopted minimum levels which are scheduled to be re-assessed in FY 2019. This document will discuss the development of the Church and Echo lake models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Church and Echo lakes are in northwest Hillsborough County, west of the Race Track Road and Boy Scout Road roundabout (Figure 1). The lake lies within an Unnamed watershed that forms part of the larger Tampa Bay watershed (USGS HUC 03100206). Church and Echo lakes are connected above elevations of approximately 32.5 ft NGVD29 through a navigable canal at the northern portion of Church Lake and southeastern portion of Echo Lake. Church Lake has one inlet along the eastern shore from Lake Amelia which flows at 36.83 ft NGVD29. Church Lake has one outlet along the southwest shore into Lake Williams, and Echo Lake discharges through a canal into a wetland located to the northwest of the lake (Figure 2).

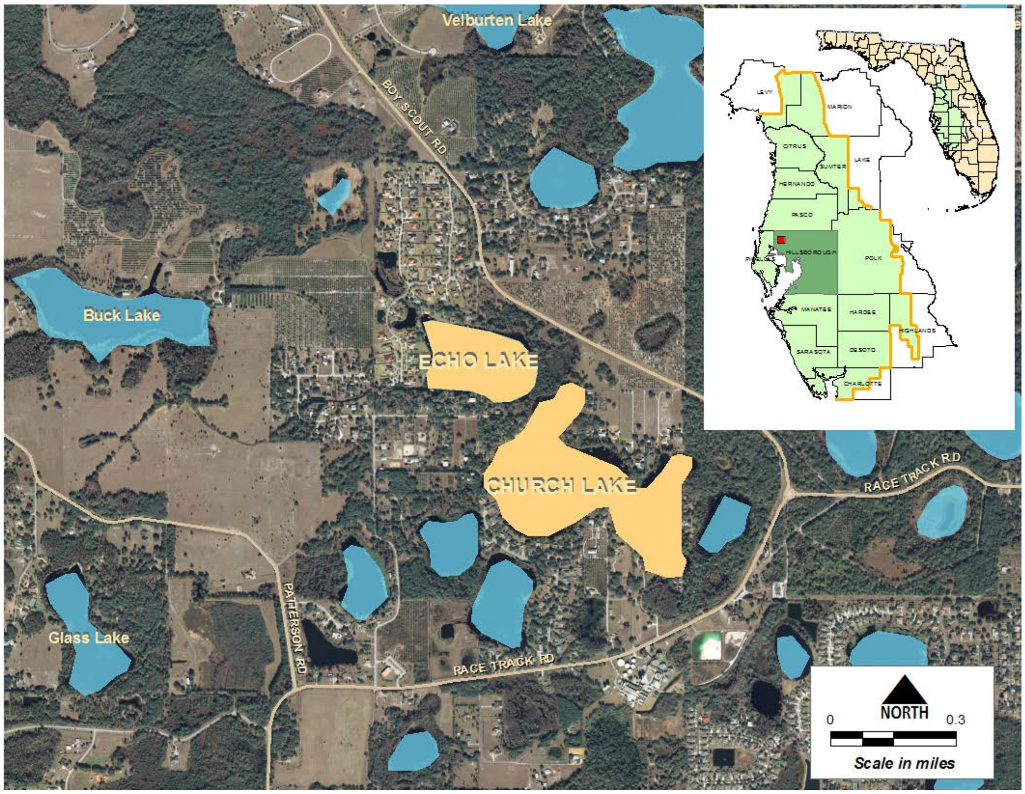

Figure 1. Location of Church and Echo lake in Hillsborough County

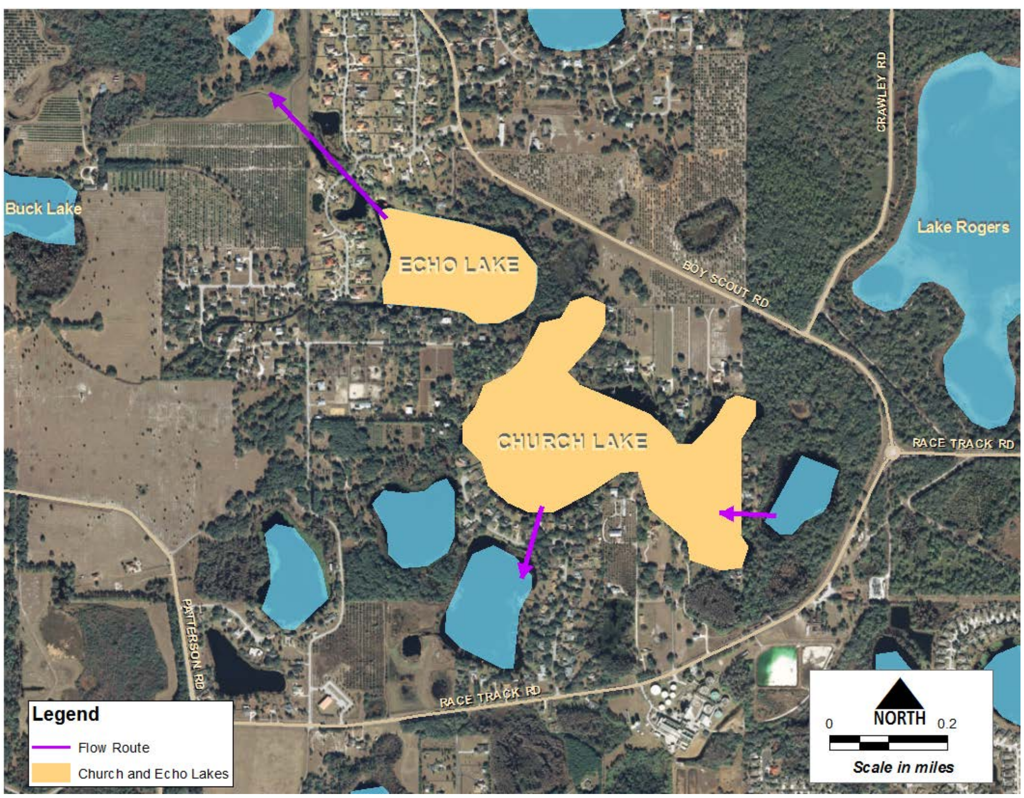

Figure 2. Flow into and out of Church and Echo lake

Physiography and Hydrogeology

The area surrounding the lakes 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 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 Church Lake in June 1931 (Figure 3) at a gage on its western shore (SID 19858) and at Echo Lake in September 1957 (SID 19856). Data collection at each lake continued sporadically with lapses in data collection from both gages until December 2002 when data collection for both lakes changed to monthly. Currently, data collection continues to be collected on a monthly basis from both lake gages. A comparison of lake stage was made between Church and Echo lakes from 1989 through 2018 to ensure lake stages are similar. The maximum water level difference between the lakes on days that had readings for both lakes is 0.1 ft.

In order to calculate stage volume for Church and Echo lakes, A datum shift from NAVD88 to NGVD29 was performed. The datum shift at Church Lake was 0.91 ft and 0.88 ft for Echo Lake. Considering the lake stage volume for Church Lake is larger than that of Echo Lake and the water levels are similar through time, a decision to use the Church Lake gage to represent both lakes' water levels was made.

Two well clusters (Upper Floridan aquifer well and surficial aquifer well) are located approximately 0.5 miles from Church Lake. However, these wells were were not used for water budget purposes due to their close proximity to production wells. Diocese

FLDN (SID 19983) and Diocese Surf (SID 19982) are located roughly 0.7 miles southwest from Church Lake and were used for the analysis (Figure 4). Data are available for these wells from February 1990 to current, and water levels are collected monthly (Figure 5).

Land and Water Use

Land use in the area of Church and Echo lakes has changed over the years. Figure 6 shows the land use around the lakes in 1938 and Figure 7 shows the 2011 land use/land cover with 2011 aerial imagery. According to the 1950 Florida Land Use and Cover Cloassification System (FLUCCS) much of the land use within the watershed consisted of pine flatwoods, crop pastures and tree crops. As for 2011, FLUCCS defines land use within the watershed as predominately low density residential, hardwood conifer mixed and medium density residential.

Church and Echo lakes are located adjacent to the Cosme-Odessa Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 8). Groundwater withdrawals began at the Cosme-Odessa Wellfield in 1930, and steadily climbed to approximately 21 million gallons per day (mgd) in 1962 (Figure 9). Since 2003, Cosme Odessa Wellfield has averaged approximately 6 mgd, with several extended periods since 2009 when groundwater withdrawals were zero.

Water levels in several lakes in the Cosme-Odessa Wellfield areas have dropped significantly since public supply groundwater withdrawals began in the area (Hancock and Basso, 1996). Because Church and Echo lakes water level data collection did not begin until 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.

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 Church and Echo lakes and the Upper Floridan aquifer (possibly due to karst activity beneath or surrounding the lakes) has occurred.

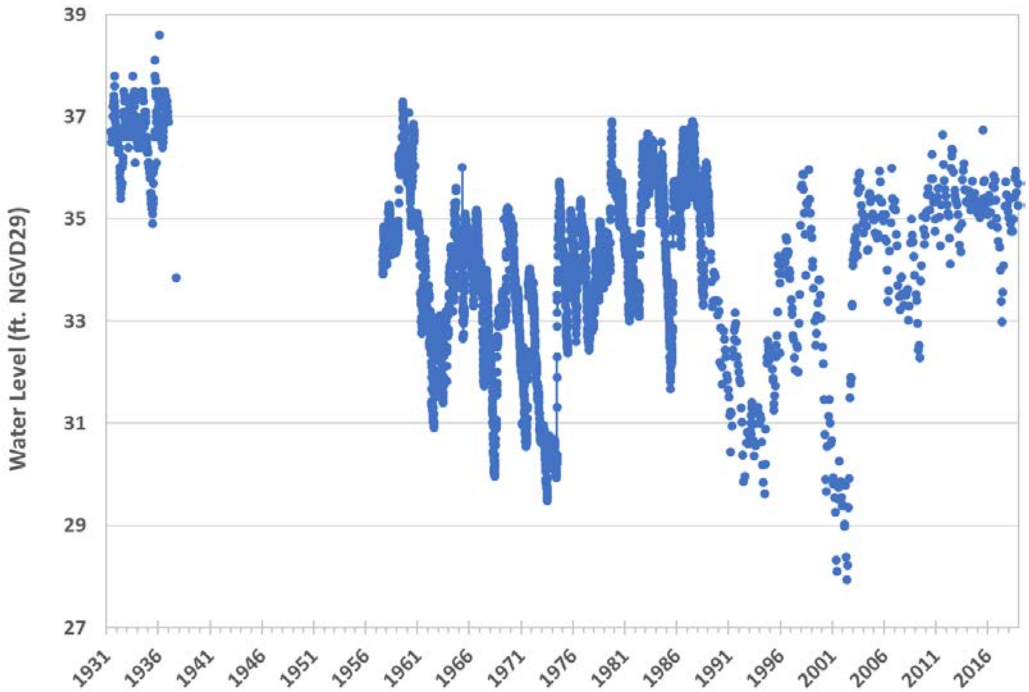

Figure 3. Church Lake water levels from June 1931 to December 2018

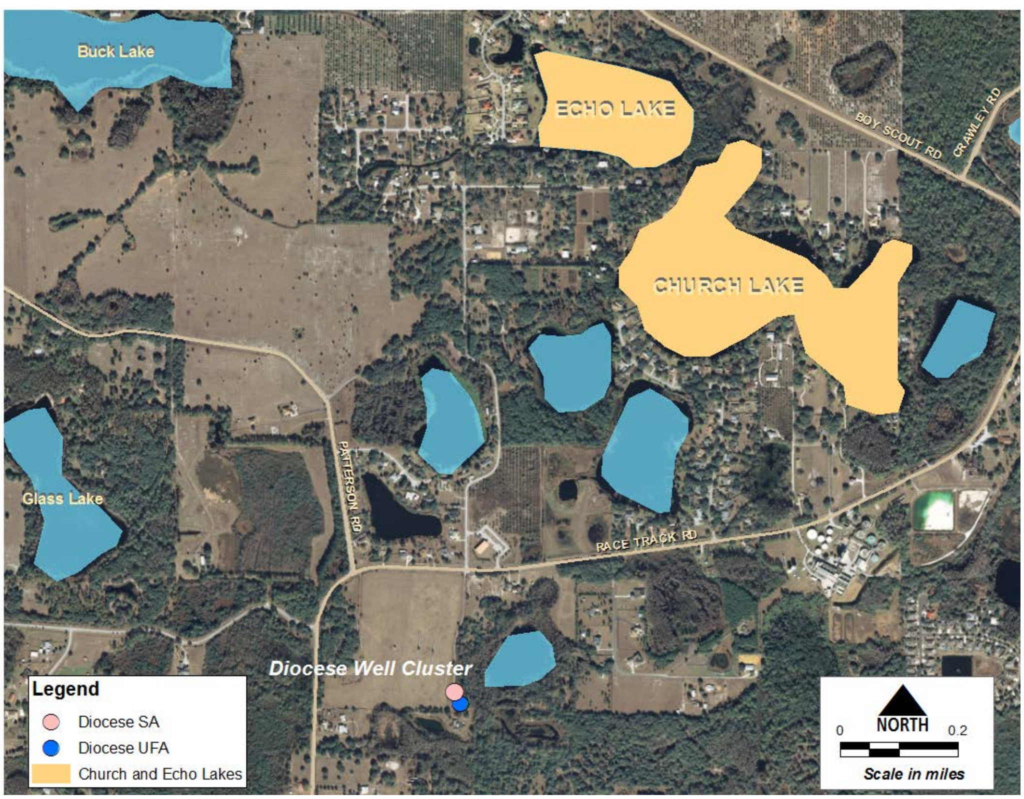

Figure 4. Location of monitor wells near Church and Echo lake used for water budget model

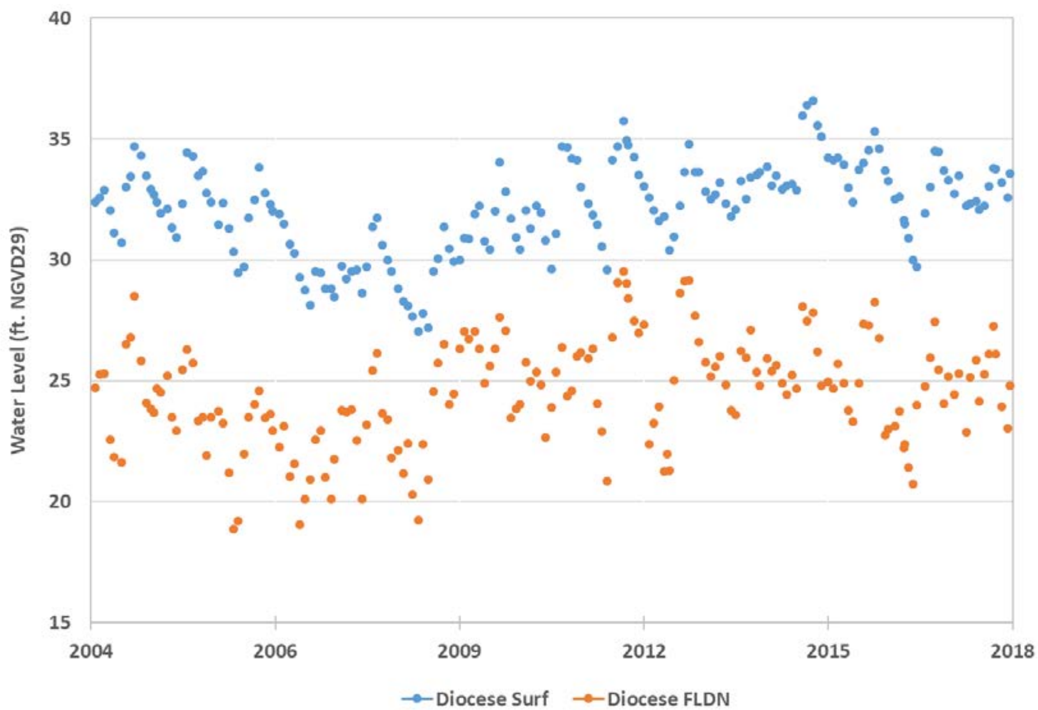

Figure 5. Well water levels used for the Church and Echo water budget model

Figure 6. Land Use around Church and Echo lake in 1938

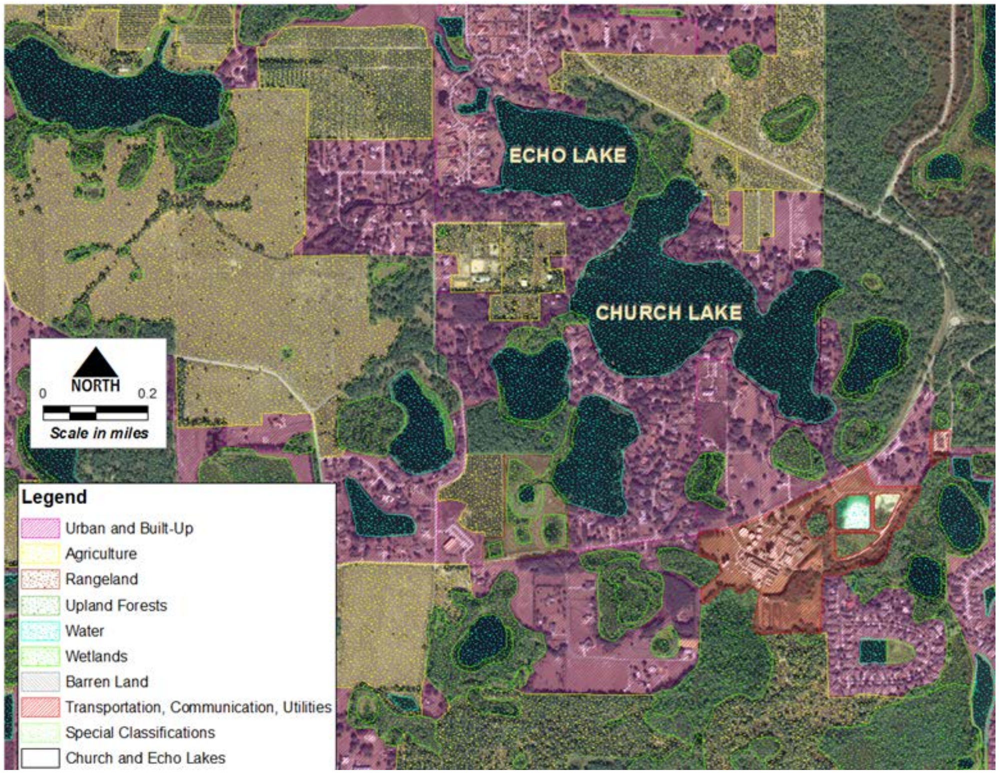

Figure 7. Land Use/land cover in 2011 shown on 2011 aerial imagery

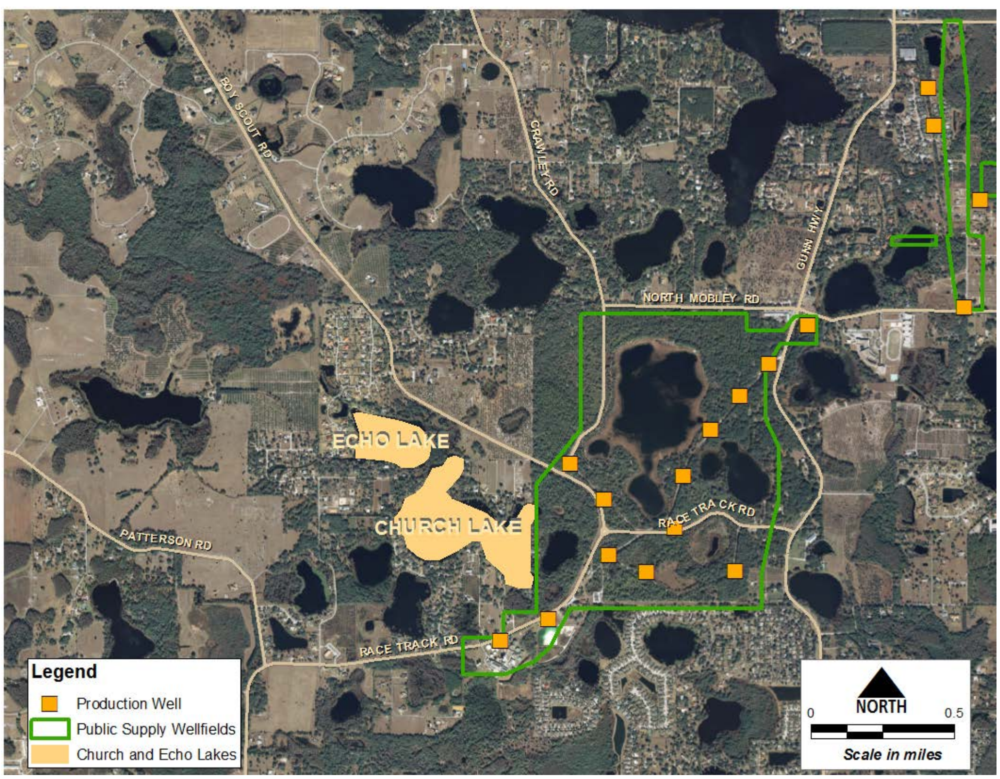

Figure 8. Church and Echo lakes and Eldridge Wilde wellfields.

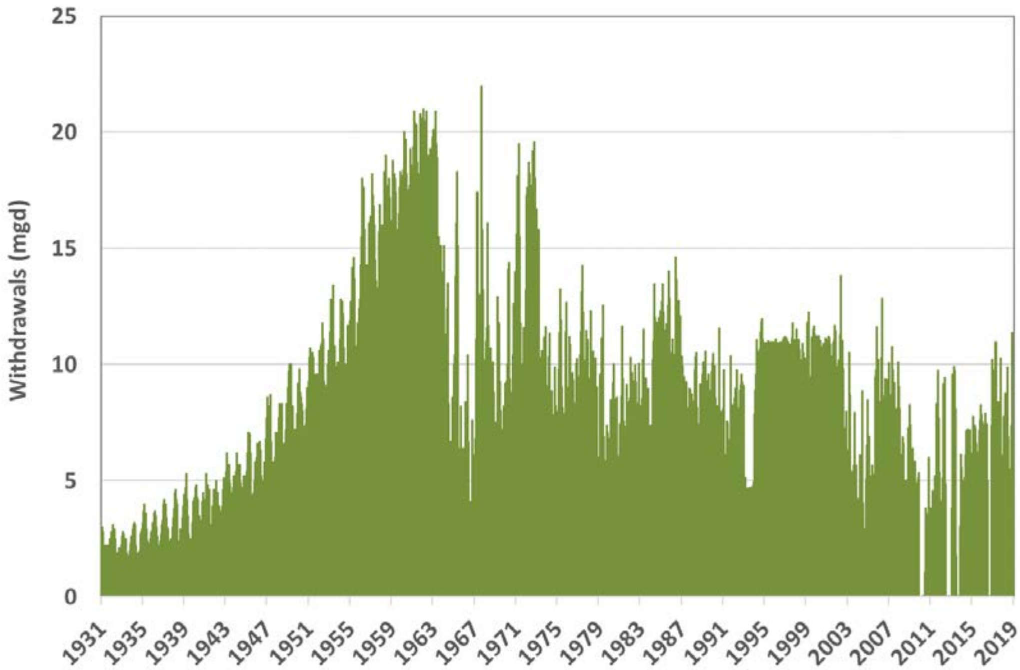

Figure 9. Cosme-Odessa Wellfield withdrawals.

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.

For Church and Echo lakes, Cosme-Odessa wellfield has potentially affected water levels since they began operation in 1930, however, impacts are not obvious from the aerial photography. 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 Church and Echo lakes 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 Church and Echo lakes is calibrated from January 2004 through December 2018. 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.

Precipitation

Data for St Leo NWS (SID 18901) are available for the earliest date necessary to complete the LOC model (January 1930) through present. The St Leo NWS weather station is located approximately 26 miles from Church and Echo lakes and rainfall data was used from St Leo until December 1944. From January 1945 through December 1971, data collected at the Cosme 18 Rainfall gage located 0.9 miles from Church and Echo lakes was used. From January 1971 through 1995, a combination of gages were used; Eldriged Wilde (SID 19725) located roughly 4.8 miles northwest of the lakes, Island Ford lake (SID 19631) located approximately 3 miles north of the lakes, and Crescent Lake (SID 19488) located about 3.2 miles from the lakes. Rainfall data from NEXRAD (Next Generation Weather Radar) Pixels 102216 and 102217 was used for the water budget model (Figure 10). NEXRAD is a network of 160 high-resolution Doppler weather radars controlled by the National Weather Service (NWS), Air Force Weather Agency, and Federal Aviation Administration. NEXRAD data are expected to be available in the future, so they can be used for future status assessments.

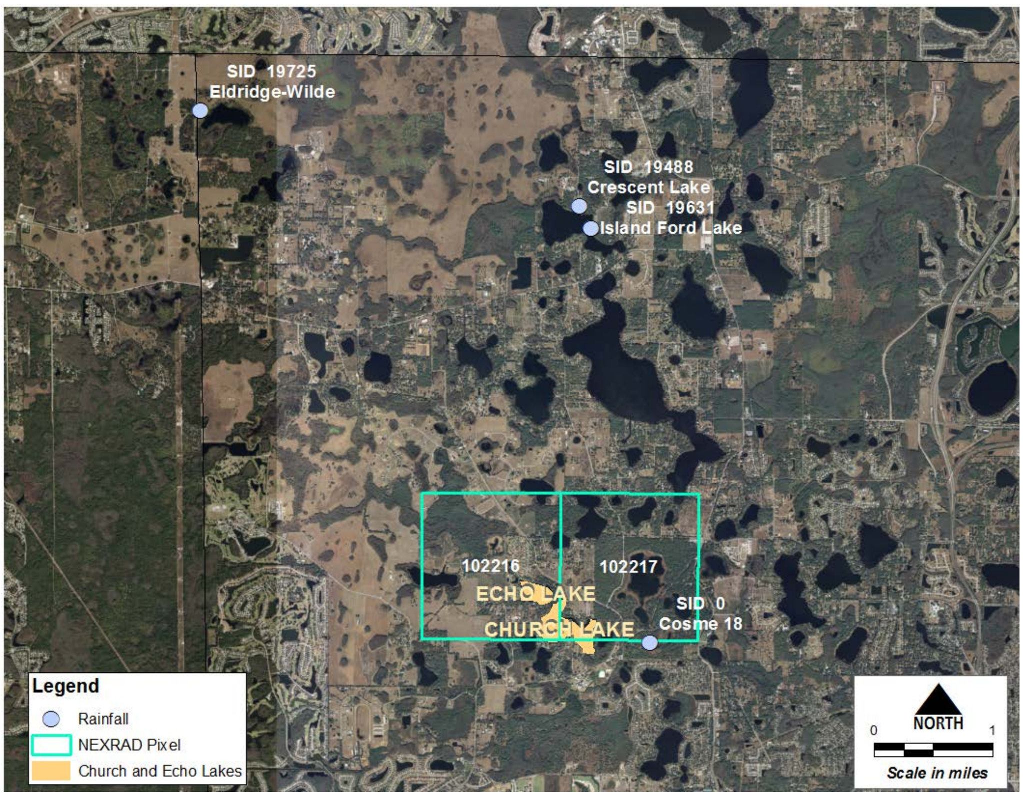

Figure 10. Rain gages used in the Church Lake and Echo Lake water budget model.

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 Church and Echo lakes 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, 2015). Calm Lake is located approximately 2.5 miles to the northeast of Church and Echo lakes (Figure 11). The assessment concluded that the evaporation rates between the two lakes were similar, with small differences attributed to measurement error and monthly differences in latent heat associated with differences in lake depth.

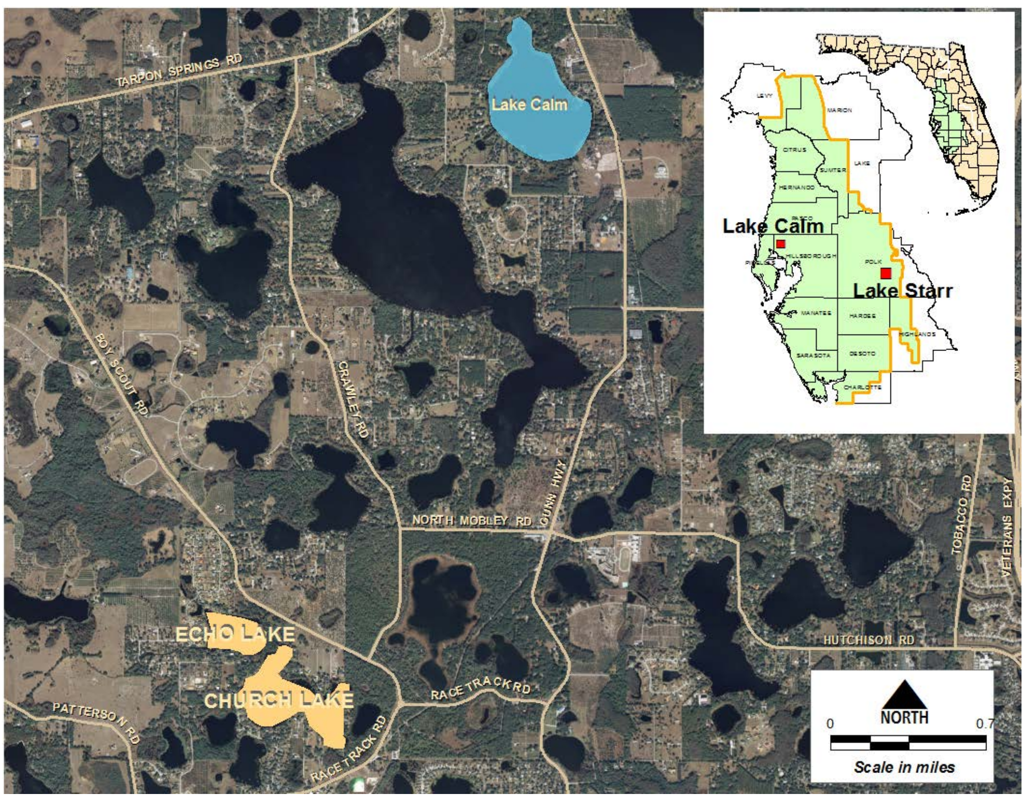

Figure 11. Location of Church and Echo lakes, Calm and Starr (see map inset).

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 DCIA and SCS CN used for the direct overland flow portion of the watershed are listed in Table 1. 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 an "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.

The DCIA parameter was used in addition to the CN parameter to account for connected impervious areas that provide direct runoff to the lake through storm water systems. While only one inflow to the lake, there are directly connected drains for street and residential storm water. It is estimated that 12 percent of the watershed is directly connected impervious area, which was considered reasonable given current land use types.

The topography around Church and Echo lakes 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 Church and Echo lakes model (Table 1) after an independent check confirming that they are reasonable for modeling purposes.

The Church and Echo lakes watershed as used in the model is shown in Figure 12. The entire area of the contributing watersheds is estimated to be approximately 257.5 acres (including the lake).

Table 1. Model inputs for the Church and Echo Lake water budget model.

Input Variable	Value
Overland Flow Watershed Size (acres)	257.5
SCS CN of watershed	78
Percent Directly Connected	0.12
FL Monitor Well(s) Used	Diocese FLDN
Surf. Aq. Monitor Well(s) Used	Diocese SURF
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.0012
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.00029
Outflow K – Echo #1	0.0002
Outflow Invert – Echo #1 (ft NGVD29)	35.0
Outflow K – Echo #2	0.85
Outflow Invert – Echo #2 (ft NGVD29)	36.2
Outflow K – Church	0.0002
Outflow Invert – Church (ft NGVD29)	34.67
Inflow K	0.001
Inflow Invert (ft NGVD29)	36.83

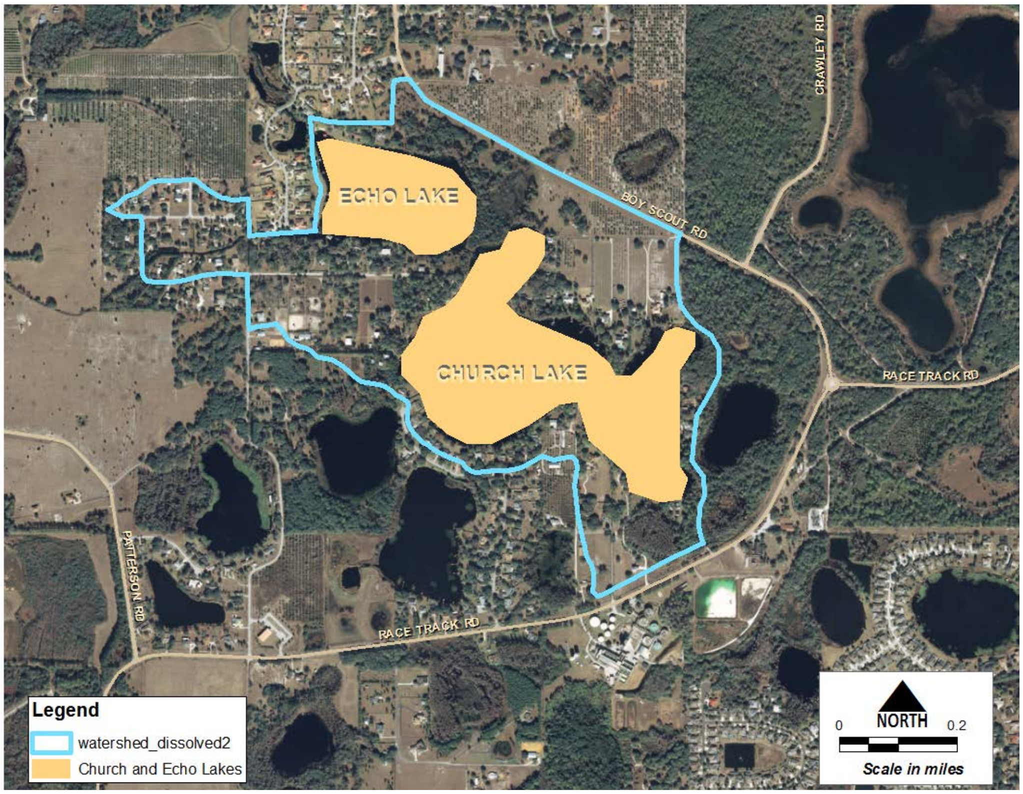

Figure 12. Church and Echo Lake watershed used in the model.

Inflow and Discharge via Channels from Outside Watersheds

Inflows and outflows via channesls and culverts from the watershed, or to the watershed (hence referred to as "channel flow") occur and are incorporated into the water budget model. Channel inflow to Church Lake occur from Lake Amelia located east of Church Lake. Inflows only occur into Church Lake when water levels from Lake Amelia reach 36.83 ft. NGVD29. The inflow occur through a galvanized culvert below an unpaved road.

Church Lake has an outlet along the southwest shore into Lake Williams. The outlet is a concrete culvert beneath Lake Williams Road. The high end of the culvert is on the Church Lake side and was surveyed at 34.67 ft. NGVD29. Echo Lake has an outlet along the north portion of the lake. Outflows occur through a large galvanized culvert located under a privately owned access road. The surveyed elevation for outflow to occur is 35.0 ft. NGVD29. During high flow events, water has been known to flow over the access road. The access road was improved sometime during 2003. The high elevation of the access road along the flow path was surveyed at 36.2 ft. NGVD29.

Flow from and into the surficial aquifer and Upper Floridan aquifer

Water exchange between Church and Echo lakes 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 Diocese FLDN well (SID 19983) is approximately 0.7 miles southwest of the lakes (Figures 4 and 5), and was used to represent the potentiometric surface under the lake. An inspection of May and September potentiometric surface maps from District archives were reviewed for the water budget model time period (2004- 2018) and found that the potentiometric surface beneath Church and Echo Lake to be approximately 1.4 ft higher than the Diocese FLDN well. An adjustment of 1.4 ft to the water levels at the well were needed to represent the potentiometric surface at the lake. Monthly or missing data were infilled using linear interpolation.

Similarly, the Diocese Surf (SID 19982) is approximately 0.7 miles southwest of the lakes (at the same location as the Diocese Floridan well), and was used to represent the water table at the lake (Figures 4 and 5). Topographic elevations around Church and Echo lakes were slightly different than that of the well. An adjustment of 2.0 ft was made to the Diocese Surf well data to represent the surficial aquifer at the lakes. Monthly or missing data were also infilled busing linear interpolation.

F. Water Budget Model Calibration

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

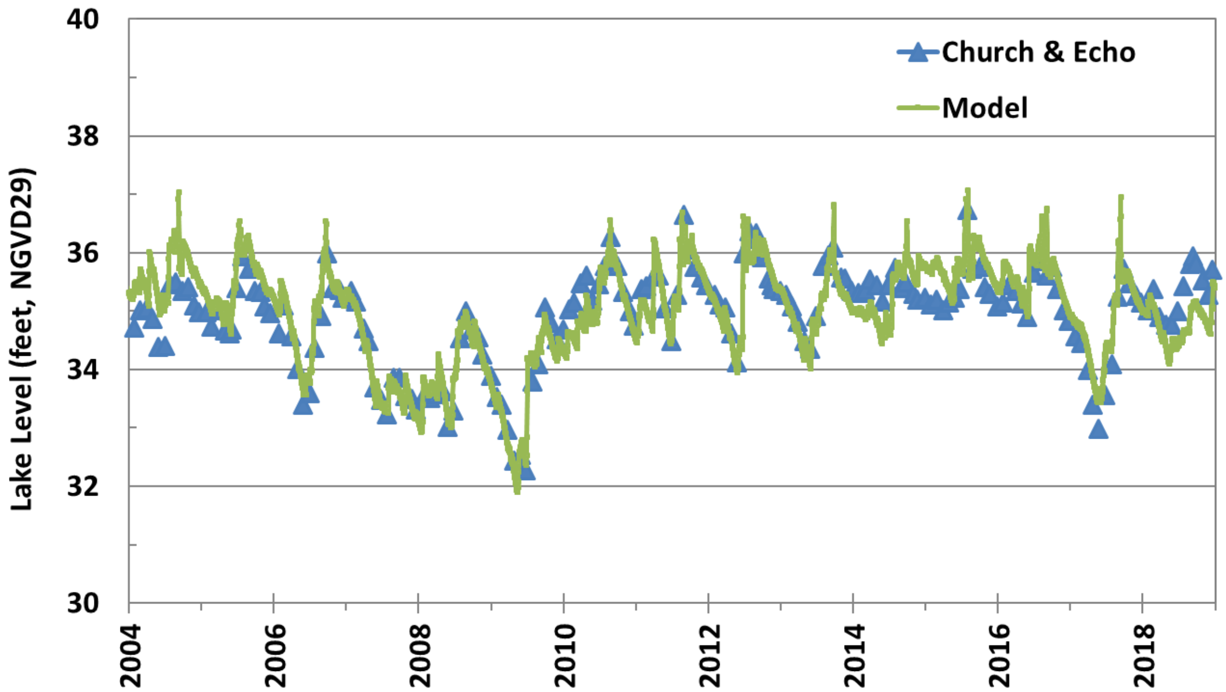

Figure 13. Modeled water levels predicted for the calibrated Church and Echo lakes water budget model and measured levels used for the model calibration

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

	Data	Model
P10	35.8	35.9
P50	35.1	35.1
P90	33.6	33.7

Table 3. Church and Echo lakes Water Budget (2004-2018)

Inflows	Rainfall	Surficial Aquifer Groundwater Inflow	Floridan Aquifer Groundwater Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	57.8	1.1	0.0	20.0	11.5	0.0	90.4
Percentage	64.0	1.2	0.0	22.1	12.7	0.0	100.0
Outflows	**Evap-oration**	**Surficial Aquifer Groundwater Outflow**	**Floridan Aquifer Groundwater Outflow**	**Outflow via channel (Echo)**	**Outflow via channel (Echo)**	**Outflow via channel (Church)**	**Total**
Inches/year	58.5	5.1	11.1	0.5	0.3	13.9	89.4
Percentage	65.4	5.7	12.4	0.5	0.3	15.6	100.0

G. Water Budget Model Calibration Discussion

Based on visual inspection of Figure 13 the model appears to be reasonably well calibrated. There are a few periods when peaks or lows in the modeled hydrograph are slightly higher or lower than the measured values, and these differences contributed to minor differences between the modeled and measured percentiles associated with the P10 and P90 percentile. Data limitations in the extreme ranges of the topography/bathymetry used to develop stage-volume estimates may als have contributed to the percentile differences.

A review of Table 2 shows no differences in medians (P50) between the data and the model for the lake. The differences in measured and water budget model predicted P10 and P90 percentiles is 0.1 feet. This minor difference could be attributed to inaccuracies in rainfall estimates caused by the distance between rainfall gages and the lake during certain time periods or data collection frequency or issues.

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

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the Church and Echo lakes water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from the Cosme-Odessa Wellfield 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 Church and Echo Lake 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 Cosme-Odessa Wellfield in each scenario were 11.0 mgd and 6.2 mgd.

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 Church and Echo Lake, and because the water table in the water budget 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.

The local hydrogeology, observed lake responses to wellfield initiation, and proximity of Church and Echo lakes to the Cosme Odessa wellfield suggest that this wellfield exerts the largest influence on these lakes with respect to drawdowns. Therefore, using the existing INTB model runs (Appendix C), linear models were developed to associate withdrawal rates at the Cosme Odessa wellfield with drawdowns predicted in the Upper Floridan and surficial aquifers (Figure 14). The resulting linear models were used with actual average monthly umping at the Cosme Odessa wellfield (Figure 15) to estimate monthly drawdowns, which were then disaggregated into daily time series assuming a uniform distribution (Figure 16). This approach allows for consideration of the variations in withdrawal rates, and therefore drawdowns, that have occurred throughout time.

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. Figure 17 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 4 presents the Historic percentiles based on the model output.

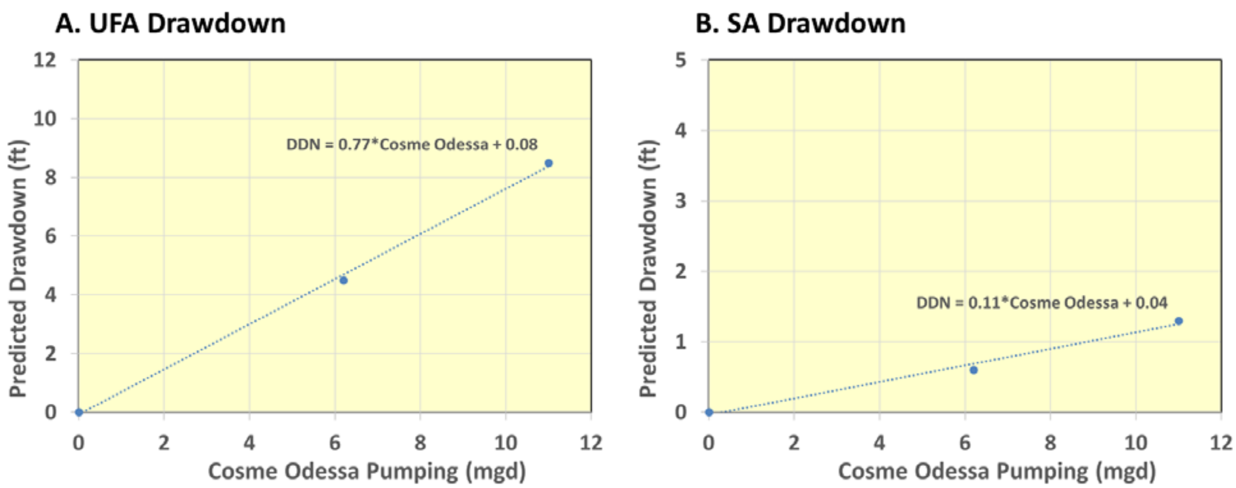

Figure 14. Relationship between average monthly pumping at the Cosme Odessa wellfield (mgd) and lon-term average drawdown predicted by the INTB for A. the Upper Floridan aquifer and B. the surficial aquifer at Church and Echo lakes.

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.

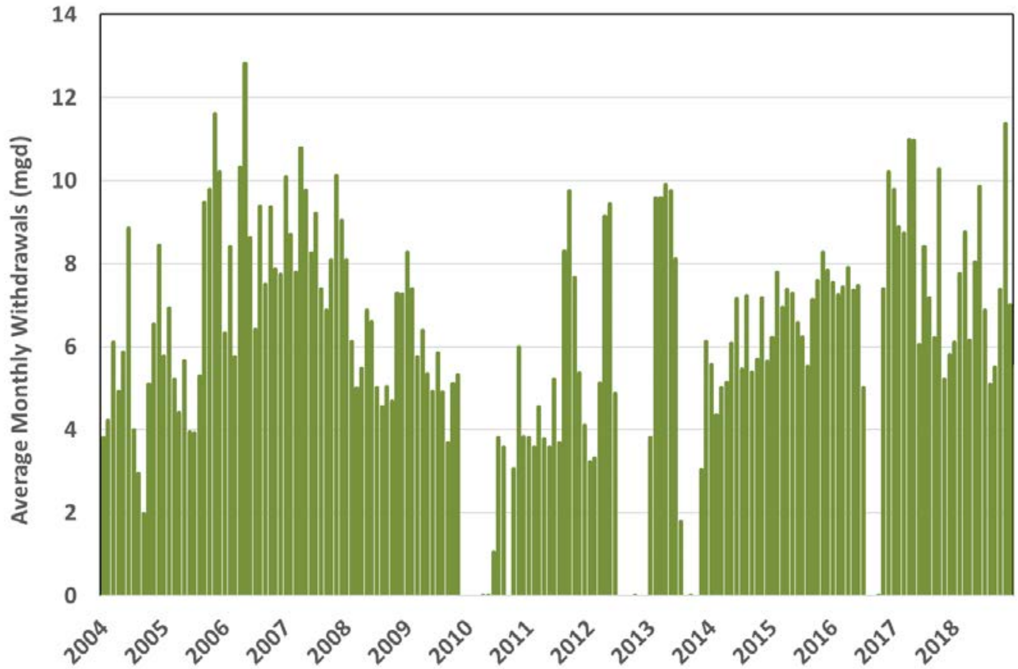

Figure 15. Average monthly pumping at Cosme Odessa wellfield.

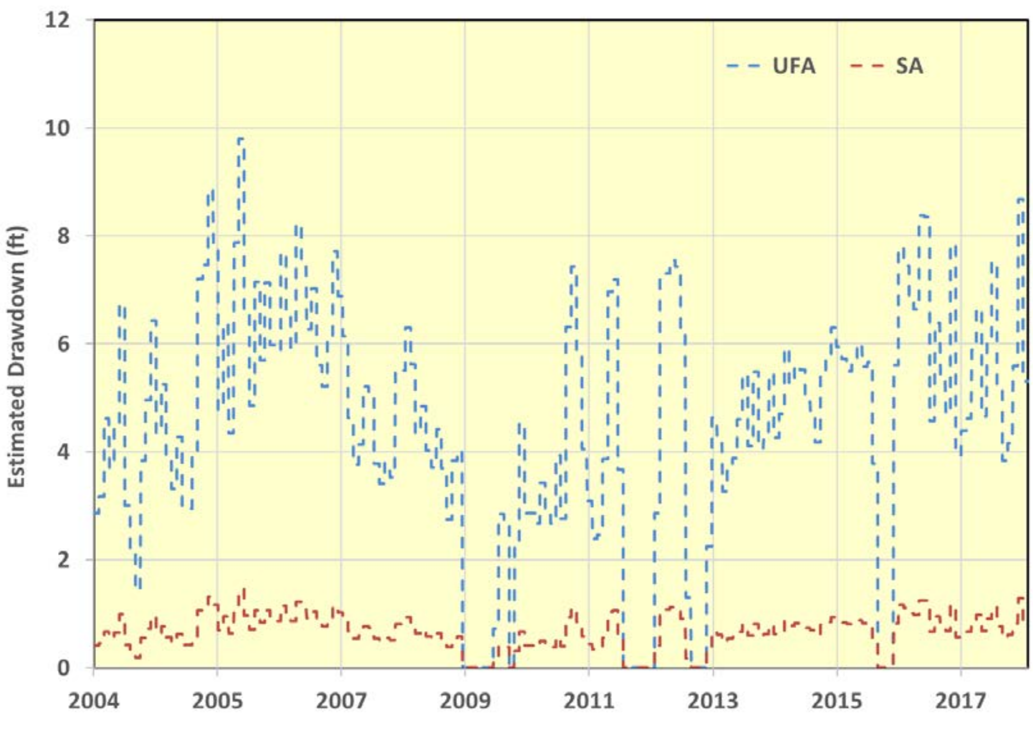

Figure 16. Estimated drawdown at Church and Echo lakes in the Upper Floridan (dashed blue line) and surficial (solid red line) aquifers.

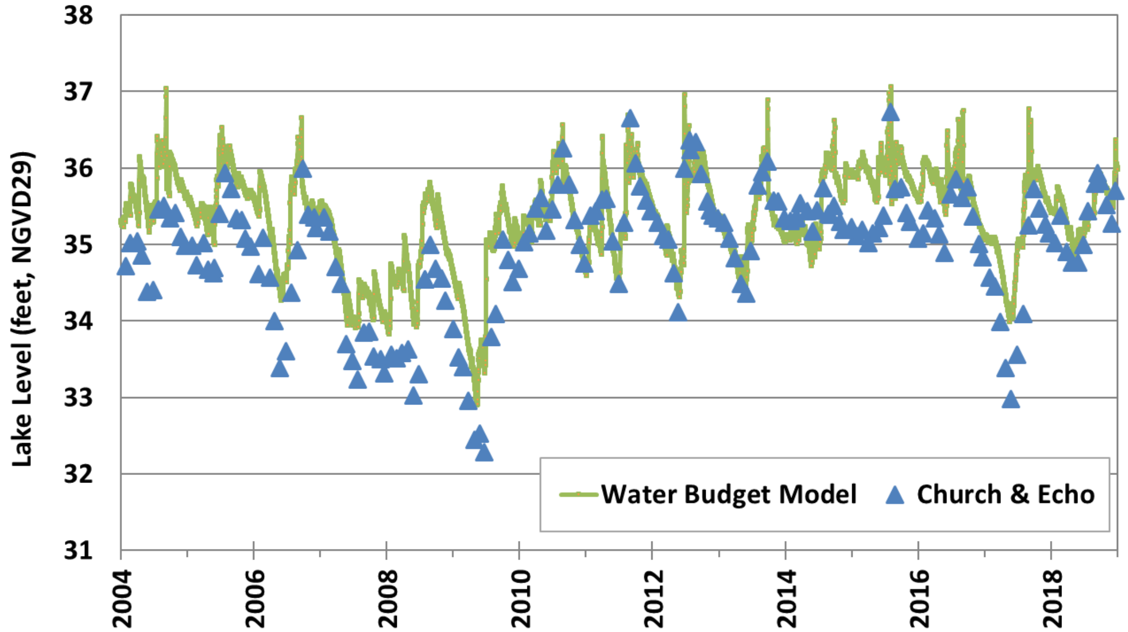

Figure 17. Measured lake levels and Historic water levels predicted with the calibrated Church and Echo Lake model.

Table 4. Historic percentiles estimated using the Church and Echo Lake water budget model (in feet NGVD29).

Percentile	Elevation
P10	36.1
P50	35.4
P90	34.5

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 (2004-2018). Rainfall data from the Island Ford Lake gage (SID 19631), located approximately 3 miles northeast of Church and Echo lakes, Cosme 18 rain gage, located 0.9 miles from the lakes, Eldriged Wilde (SID 19725) located roughly 4.8 miles northwest of the lakes, Crescent Lake (SID 19488), located 3.2 miles from the lakes, and St. Leo NWS gage (SID 18901) was used to extend the data back to 1930. Although the St. Leo gage is approximately 26 miles northeast of Church and Echo lakes (Figure 18), 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. From 1995 through 2018 NEXRAD rainfall was used.

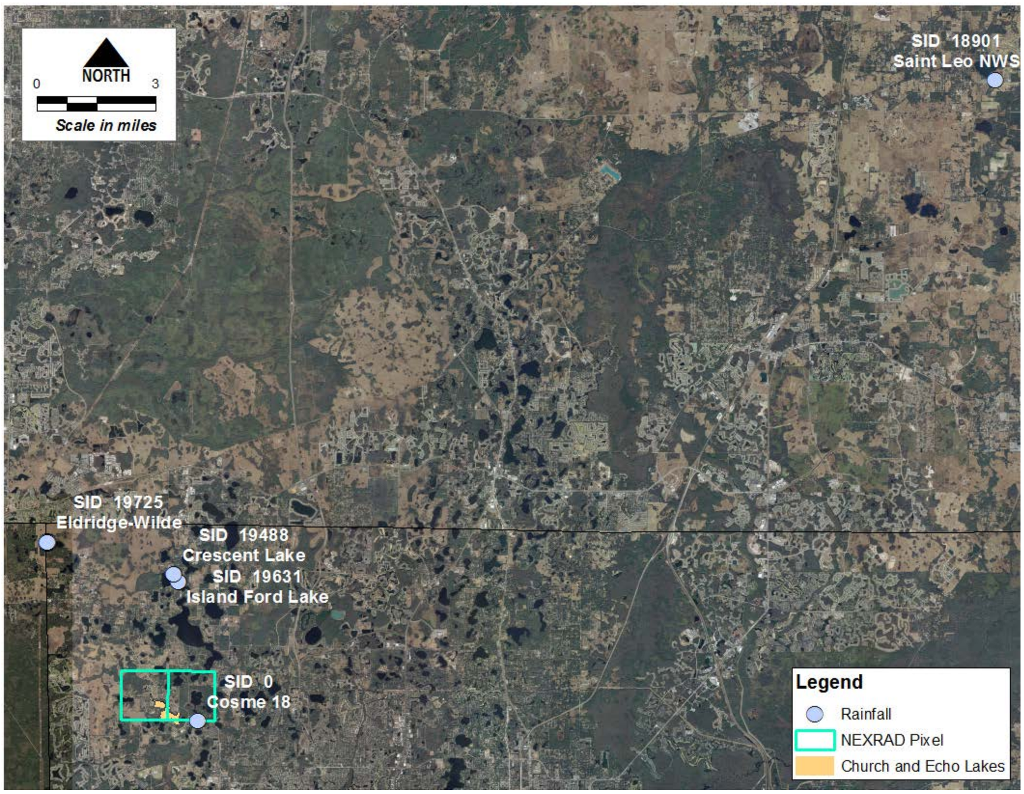

Figure 18. Location of rain stations used for the rainfall correlation model.

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 (2004-2018), and the results from 1947-2018 (72 years) were produced. For Church and Echo lakes, the 2-year weighted model had the highest correlation coefficient, with an R^2 of 0.64. 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 19.

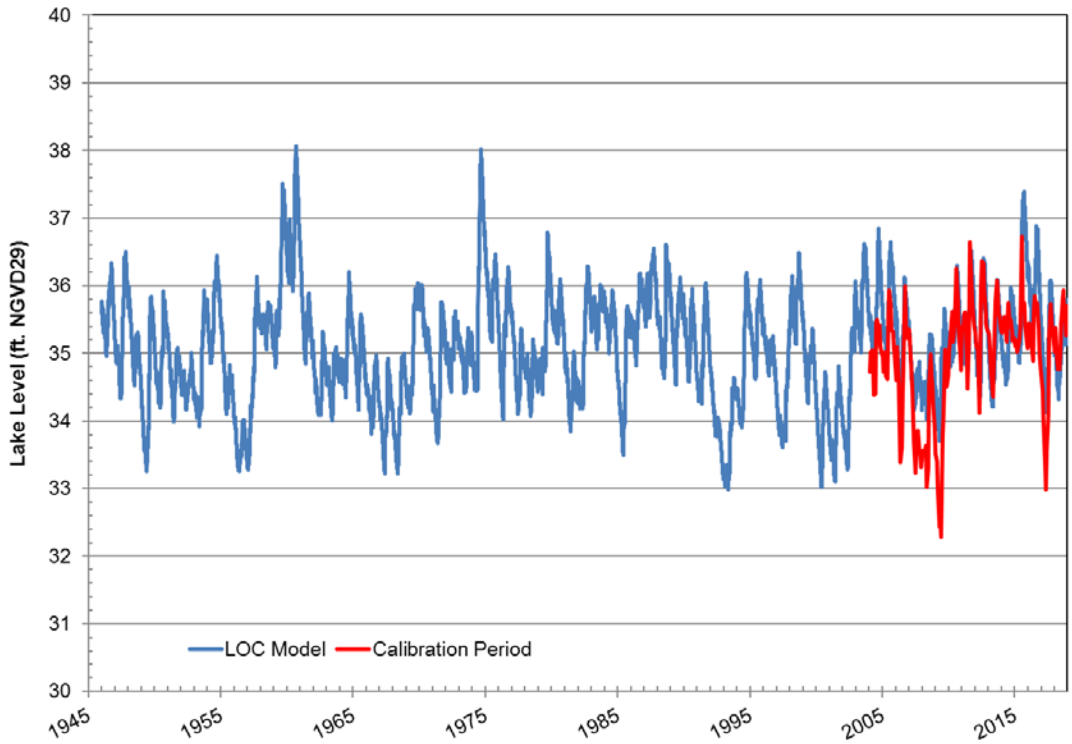

Figure 19. LOC model and water budget results for Church and Echo Lake

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 2004 and the end of 2018, while the water budget results are used for the period of 2004 through 2018. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Table 5. Note that the the P10, P50, and P90 percentiles for the water budget model (Table 5) differ from those of the hybrid rainfall model (Table 6) for Church and Echo lakes by 0.1, 0.2, and 0.4 feet, respectively.

Table 5. Historic percentiles as estimated by the hybrid model from 1946 to 2018 (feet NGVD29).

Percentile	Church and Echo Lakes
P10	36.0
P50	35.2
P90	34.1

J. Conclusions

Based on the model results and the available data, the Church and Echo lake 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

Draft Technical Memorandum

November 14, 2019

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

FROM: Jason G. Patterson, Hydrogeologist, Water Resources Bureau
Don Ellison, P.G., Senior Hydrogeologist, Water Resources Bureau
Donna Campbell, Staff Environmental Scientist, Water Resources Bureau

Subject: Church Lake and Echo Lake Initial Minimum Levels Status Assessment

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A. Introduction

The Southwest Florida Water Management District (District) is adopting minimum levels for Church and Echo lakes in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the minimum levels is provided by Patterson and Ellison (2019) and Campbell and others (2019).

Section 373.0421, F.S. requires that a recovery or prevention strategy be developed for all water bodies that are found to be below their minimum flows or levels, or are projected to fall below the minimum flows or levels within 20 years. In the case of lakes and other waterbodies with established minimum flows or levels in the northern Tapa Bay area, an applicable regional recovery strategy, referred to as the “Comprehensive Plan”, has been developed and adopted into District rule (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 Church and Echo lakes 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 Church and Echo Lakes and any recovery that may be necessary for the lakes.

B. Background

Church and Echo lakes are in northwest Hillsborough County, west of the Race Track Road and Boy Scout Road roundabout (Figure 1). The lake lies within an Unnamed watershed that forms part of the larger Tampa Bay watershed (USGS HUC 03100206). Church and Echo lakes are connected above elevations of approximately 32.5 ft

NGVD29 through a navigable canal at the northern portion of Church Lake and southeastern portion of Echo Lake.

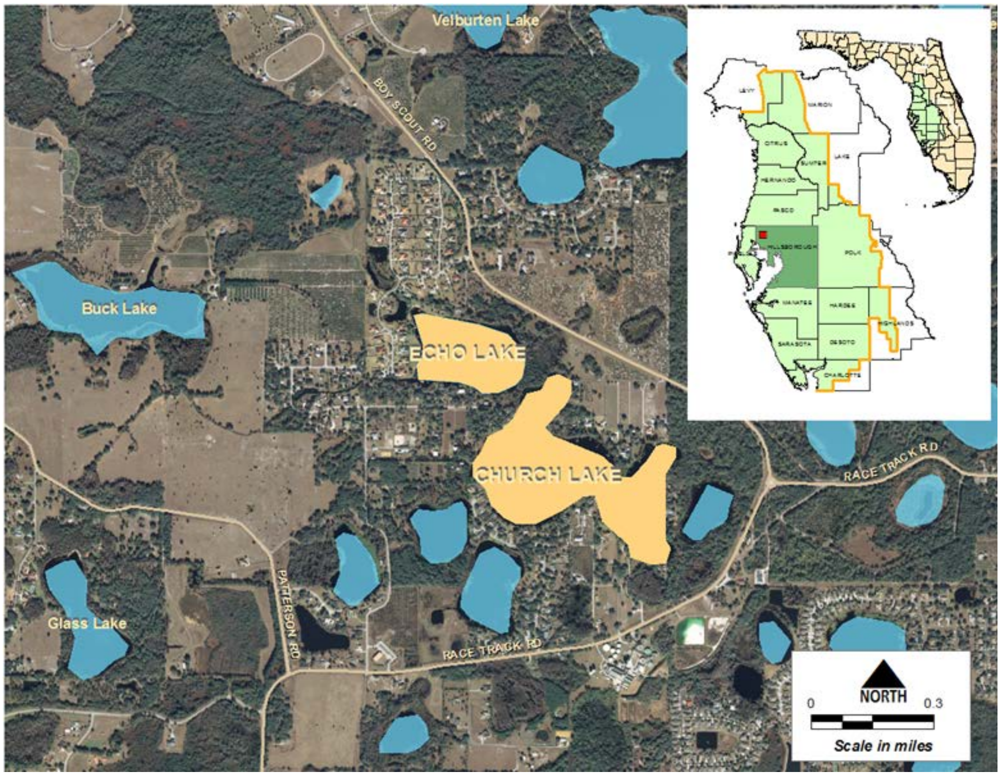

Figure 1. Location of Church and Echo Lakes in Hillsborough County, Florida

C. Minimum Levels Proposed for Church and Echo Lakes

Minimum levels proposed for Church and Echo lakes are presented in Table 1 and discussed in more detail by Campbell and others (2019). Minimum levels represent long-term conditions that if achieved, are expected to protect water resources and the ecology of the area from significant harm that may result from water withdrawals. The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. The Minimum Lake Level therefore represents the required 50th percentile (P50) of long-term water levels, while the High Minimum Lake Level represents the required 10^{th} percentile (P10) of long-term water levels. To determine the status of minimum levels for Church and Echo Lakes, 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 Church and Echo Lakes

Proposed Minimum Levels	Elevation in Feet NGVD 29
High Minimum Lake Level	35.2
Minimum Lake Level	34.4

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Church and Echo lakes from 2004 through 2018, 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. No structural alterations have occurred at the lake and groundwater withdrawals during this period were relatively consistent as demonstrated by Patterson and Ellison (2019). Therefore, 2004 through 2018 are considered to represent the "Current" period". "Long-term" is defined as a period that has been subjected to the full range of rainfall variability that can be expected in the future. To create a data set that can reasonably be considered to be "Long-term", a line of organic correlation (LOC) analysis was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used to develop the minimum levels for Church and Echo lakes (Patterson and Ellison, 2019). By using this technique, the limited years of current lake level data can be projected back to create a simulated data set representing over 60 years of lake levels, based on the current relationship between lake water levels and actual rainfall.

The same rainfall data set used for setting the minimum levels for Church and Echo lakes was used for the status assessment. The best resulting correlation for the LOC model created with measured data was the 2-year weighted period (the best correlation for the LOC analyses created with Historic data to set the Church and Echo lakes MFL was 2 years), with a coefficient of determination of 0.57. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the same percentiles calculated directly from the measured lake level data for Church and Echo lakes for the period from 2004 through 2018. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 15 years, rather than the longer-term rainfall conditions represented in the 1946 through 2018 LOC model simulations.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 2004 through 2018 data, and the minimum levels proposed for Church and Echo lakes

Percentile	**Lake Stage/LOC Model Current Withdrawal Scenario Results** Elevation in feet NGVD 29	**Measured Lake Levels for Current Period (2004 to 2018)** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	35.9	35.7	35.2
P50	34.7	35.1	34.4

A comparison of the LOC model with the minimum levels proposed for Church and Echo lakes indicates that the Long-term P10 is 0.7 feet above the proposed High Minimum Lake Level, and the Long-term P50 is 0.4 feet above the proposed Minimum Lake Level. The P10 elevation derived directly from the 2004 through 2018 lake data is 0.5 feet above the proposed High Minimum Lake Level and the P50 elevation is 0.8 feet above the proposed Minimum Lake Level. Differences in rainfall between the shorter 2004 through 2018 period and the longer 1946 to 2018 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 Church and Echo lakes water levels are currently above the Minimum Lake Level and above the High Minimum Lake Level proposed for the lakes. These conclusions are supported by comparison of percentiles derived from LOC modeled lake stage data with the proposed minimum levels.

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

F. References

Campbell, D., J. Patterson, D. Ellison. 2019. Proposed Minimum and Guidance Levels for Church Lake and Echo Lake in Hillsborough County, Florida. Southwest Florida Water Management District. Brooksville, Florida.

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APPENDIX C

Technical Memorandum

DATE: November 14, 2019

TO: Jason Patterson, Hydrogeologist, Water Resources Bureau
Don Ellison, P.G., Senior Hydrogeologist, Water Resources Bureau

FROM: Cortney Cameron, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Lakes Church and Echo

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1.0 Introduction

Lakes Church and Echo is located in northwest Hillsborough County in west-central Florida (Figure 1). Prior to establishment of a Minimum Level (ML), an evaluation of hydrologic changes in the vicinity of the lake is necessary to determine if the water body has been significantly impacted by groundwater withdrawals. The establishment of the ML for Lakes Church and Echo 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, which are used to estimate drawdown time series used n the Church and Echo lakes water budget model (Appendix A, Section H).

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).

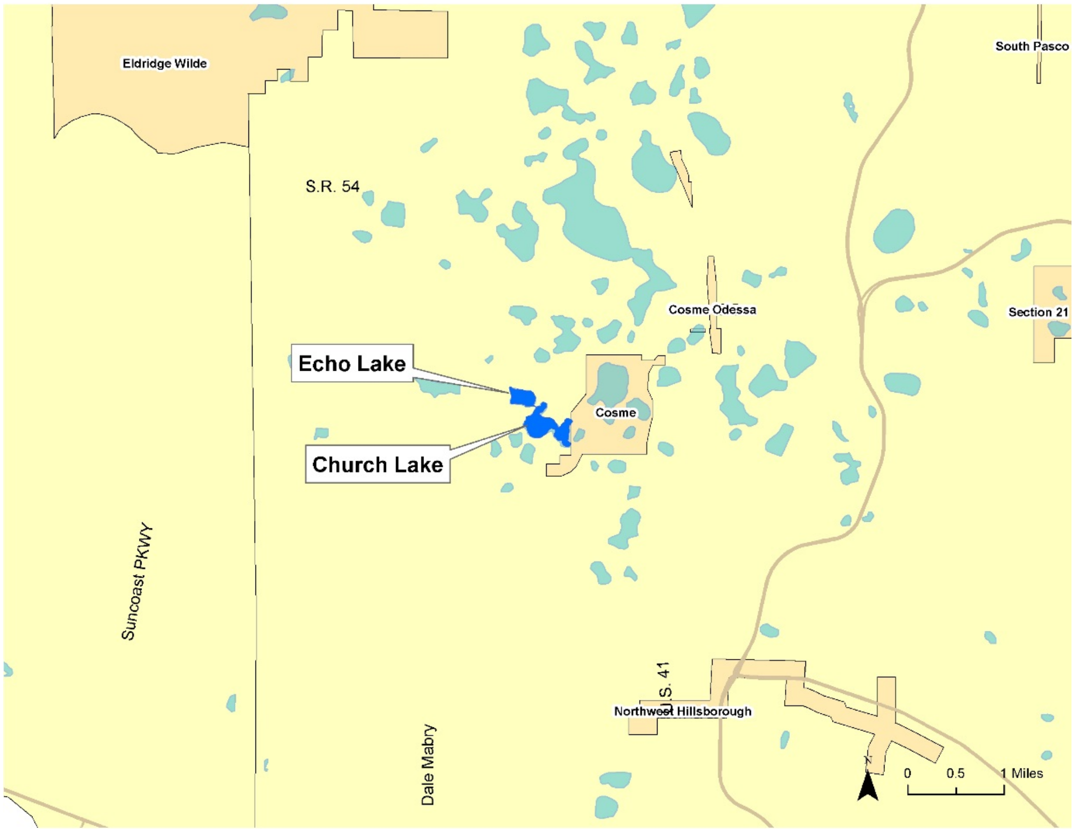

Figure 1. Location of Lakes Church and Echo

3.0 Evaluation of Groundwater Withdrawal Impacts to Lakes Church and Echo

Several regional groundwater flow models have included the area around Lakes Church and Echo 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.

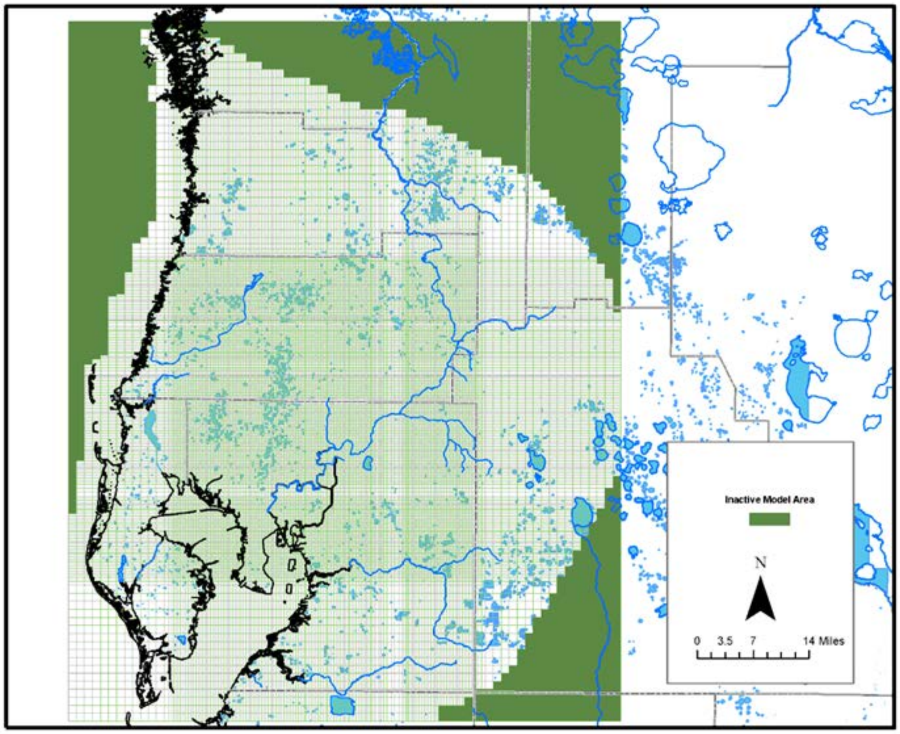

Figure 2. Groundwater grid used in the INTB model

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.

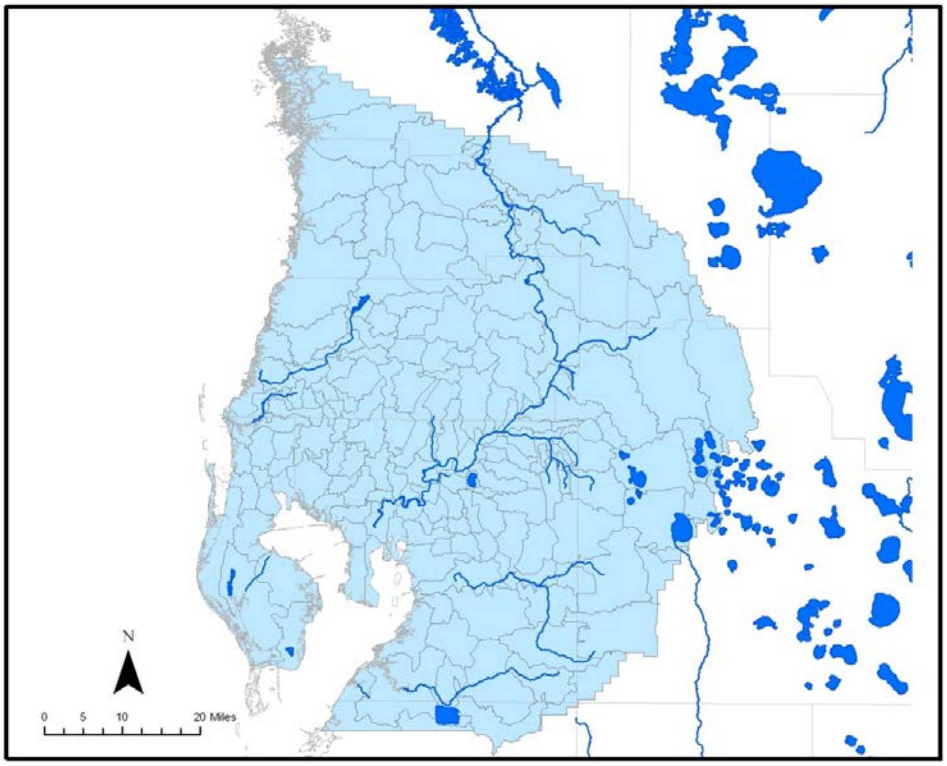

Figure 3. HSPF subbasins in the INTB model

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.

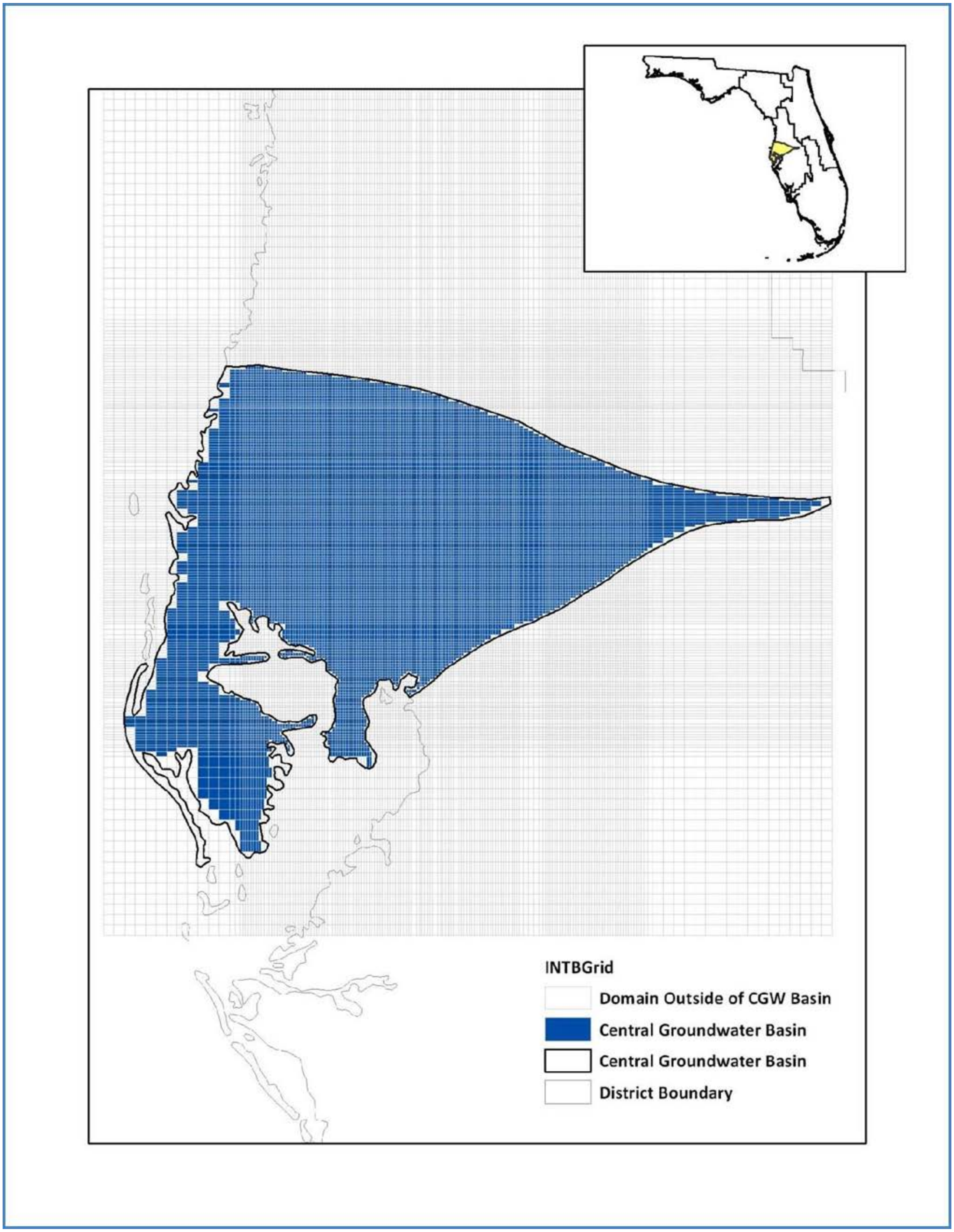

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Lakes Church and Echo was 1.3 ft, and 8.5 ft 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 Lakes Church and Echo was 0.6 ft and 4.5 ft 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.

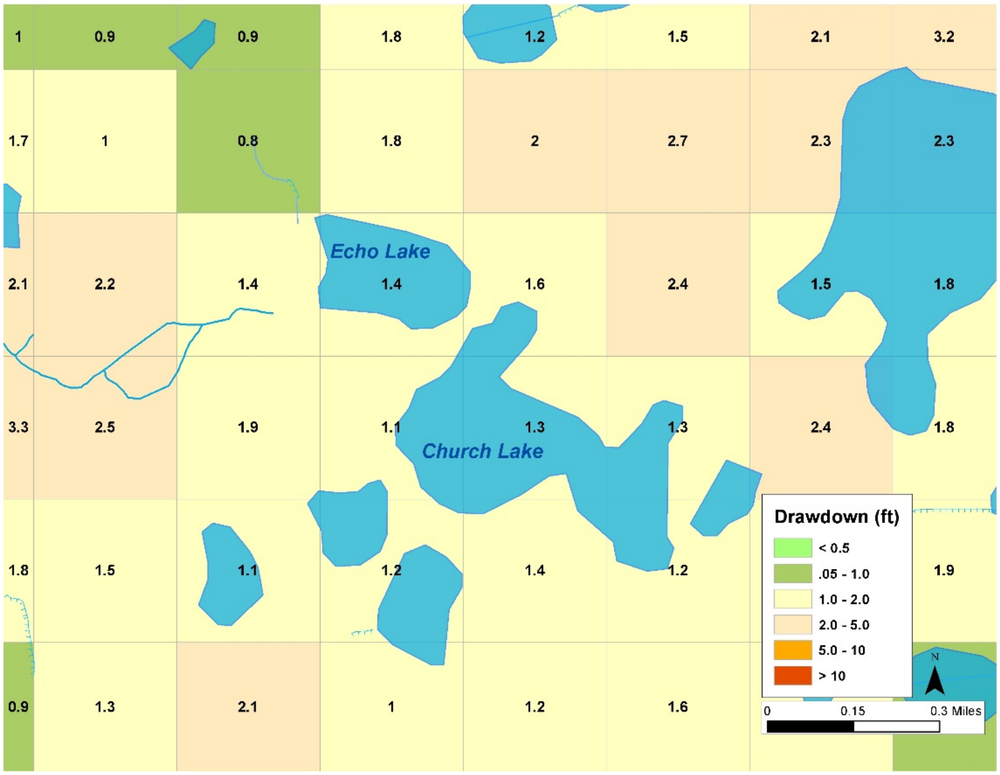

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals

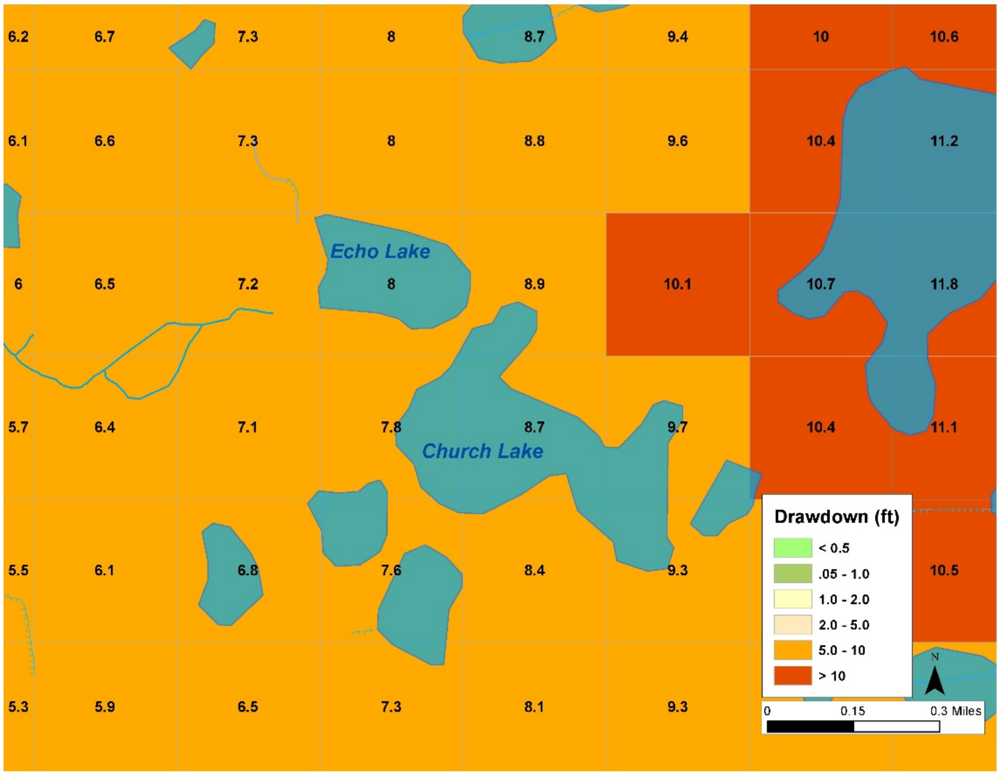

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals

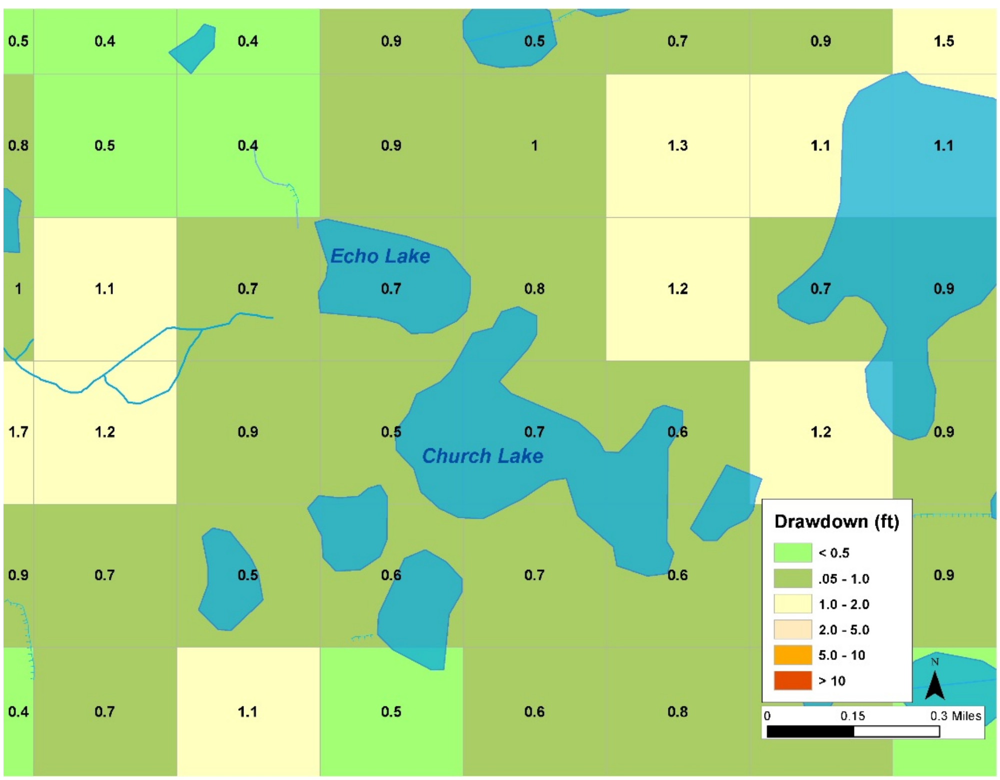

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals

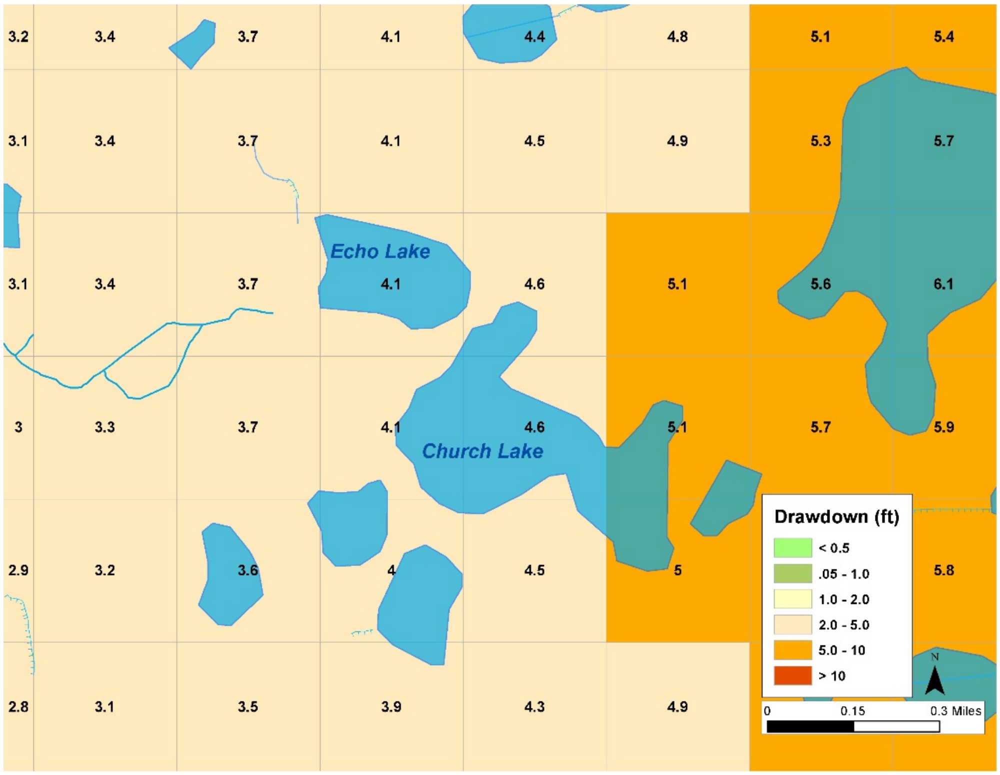

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

Table 1. INTB model results for Lakes Church and Echo

Lake Name	**Predicted Drawdown (ft) in the Surficial Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (ft) in the Surficial Aquifer with TBW Withdrawals reduced to 90 mgd***
Church & Echo	1.3	0.6
Lake Name	**Predicted Drawdown (ft) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (ft) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd***
Church & Echo	8.5	4.5

* Average prorated drawdown from model cells intersecting lake

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