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

July 6, 2020

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Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District

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Cover: January 2018 Lake Linda (SWFWMD staff photograph).

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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, lake shore 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

Executive Summary

The Southwest Florida Water Management District (District) is directed by the Florida Legislature to establish minimum levels for lakes within its jurisdiction. Minimum levels are defined in Section 373.042(1) Florida Statutes as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.” Once adopted into District rules, minimum levels can be used for water supply planning, water use permitting, and environmental resource regulation.

This report identifies minimum levels that were developed as part of a reevaluation of minimum levels currently established for Lake Linda. District Rule (Section 40D-8.624, Florida Administrative Code) establishes the minimum levels for Lake Linda. As part of the reevaluation, recommended minimum levels were developed using the best information available, as required by the Florida Statutes, and were based on all relevant environmental values identified in the Florida Water Resource Implementation Rule (Section 62-40.473, Florida Administrative Code) for consideration when setting minimum levels.

As mandated by statute, Minimum Flows and Levels (MFLs), are not meant to represent optimal conditions, but rather set the limit to withdrawals, beyond which significant harm will occur. A fundamental assumption of the District’s approach is that an alternative hydrologic regime exists that is lower than the historical regime but still protects the environmental functions and values of MFL waterbodies from significant harm caused by water withdrawals.

A minimum hydrologic regime for Lake Linda encompasses a range of water levels within which the waterbody must fluctuate to protect the inherent ecological structure and function of the system. Two minimum water levels were developed to ensure protection of the hydrologic regime. The Minimum Lake Level (MLL) is set at an elevation that the median water level must equal or exceed 50% of the time, over the long term. The High Minimum Lake Level (HMLL) is set at an elevation that the water level must equal or exceeded 10% of the time, over the long term., For Lake Linda, our evaluation resulted in a MLL of 65.0 ft. NGVD29 and a HMLL of 65.6 ft. NGVD29, based on the Aesthetic Standard.

In addition to the minimum levels, a High Guidance Level (HGL) and a Low Guidance Level (LGL) were determined for Lake Linda, and are the levels the lake is *expected* to equal or exceed 10% of the time and 90% of the time, over the long term, respectively. Guidance Levels are provided as an advisory guideline for construction of lake shore development, water dependent structures, and operation of water management structures. For Lake Linda, our evaluation resulted in a HGL of 66.1 ft. NGVD29 and a LGL of 65.0 ft. NGVD29.

Assessment of Lake Linda relative to these minimum levels indicates that the long-term lake water levels are currently above both the Minimum Lake Level and the High Minimum Lake Level, and therefore a recovery strategy is not required at this time. Should the lake fall out of compliance of its levels, the lake lies 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.). Additionally, the District will continue to implement its general, three-pronged prevention strategy that includes monitoring, protective water-use permitting, and regional water supply planning to ensure that the adopted minimum levels for the lake continue to be met. The District will continue to monitor levels in this and other lakes to further our understanding of lakes and to develop and refine our minimum levels methods.

Introduction

Reevaluation of Minimum Flows and Levels

This report describes the development of minimum levels and guidance levels for Lake Linda in Pasco 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 December 2007 and subsequently adopted into District rules February 18, 2008. The minimum and guidance levels represent necessary revisions to the previously adopted levels.

Lake Linda was selected for reevaluation based on development of modeling tools used to simulate natural water level fluctuations in lake basins that were not available when the previously adopted minimum levels for the lake were developed. Adopted levels for Lake Linda 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 Lake Linda 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., Lake Linda meets the classification as a Category 3 lake, with less than 0.5 acre of fringing cypress wetlands. The standards associated with Category 3 lakes described below will also be developed in a subsequent section of this report.

Lake-specific significant change standards and other available information are developed for establishing Minimum Levels for Category 3 Lakes. The standards are used to identify thresholds for preventing significant harm to cultural and natural system values associated with lakes in accordance with guidance provided in the Florida Water 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 $\log(MDC) – 0.66\log(SD) + 0.30$, where all values are represented in meters. The MDC depth is then used to calculate the total acreage at each lake stage that is available for aquatic plant colonization.

Minimum 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.

Note: The information and findings in this report and appendices were only examined to the extent of establishing minimum and guidance levels for Lake Linda.

Development of Minimum and Guidance Levels for Lake Linda

Lake Setting and Description

Lake Linda (Figure 1) is in Pasco County, Florida (Section 26, Township 26, Range 18) in the Upper Rocky Creek drainage basin (United States Geological Survey Hydrologic Unit Classification System), Coastal River Basin watershed within the Southwest Florida Water Management District.

The lake has a single inlet from a culvert under Leonard Road (Figure 2). Lake Linda has one outlet on the north edge of the lake and leads into an extensive stormwater system. 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.

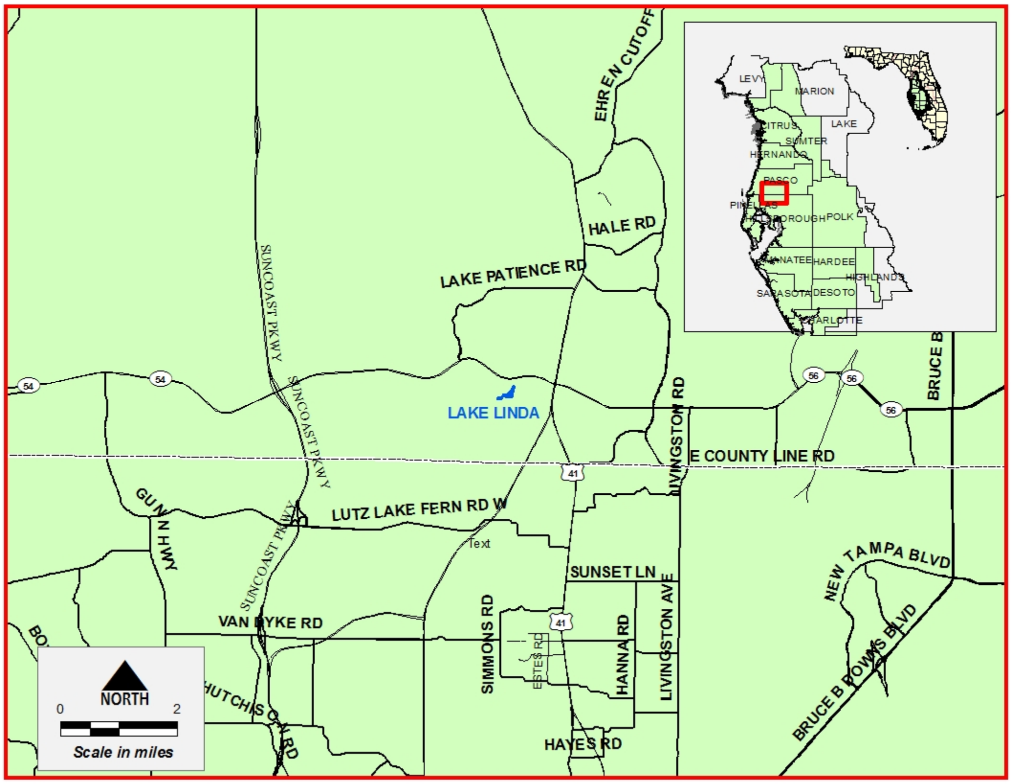

Figure 1: Location of Lake Linda in Pasco County, Florida.

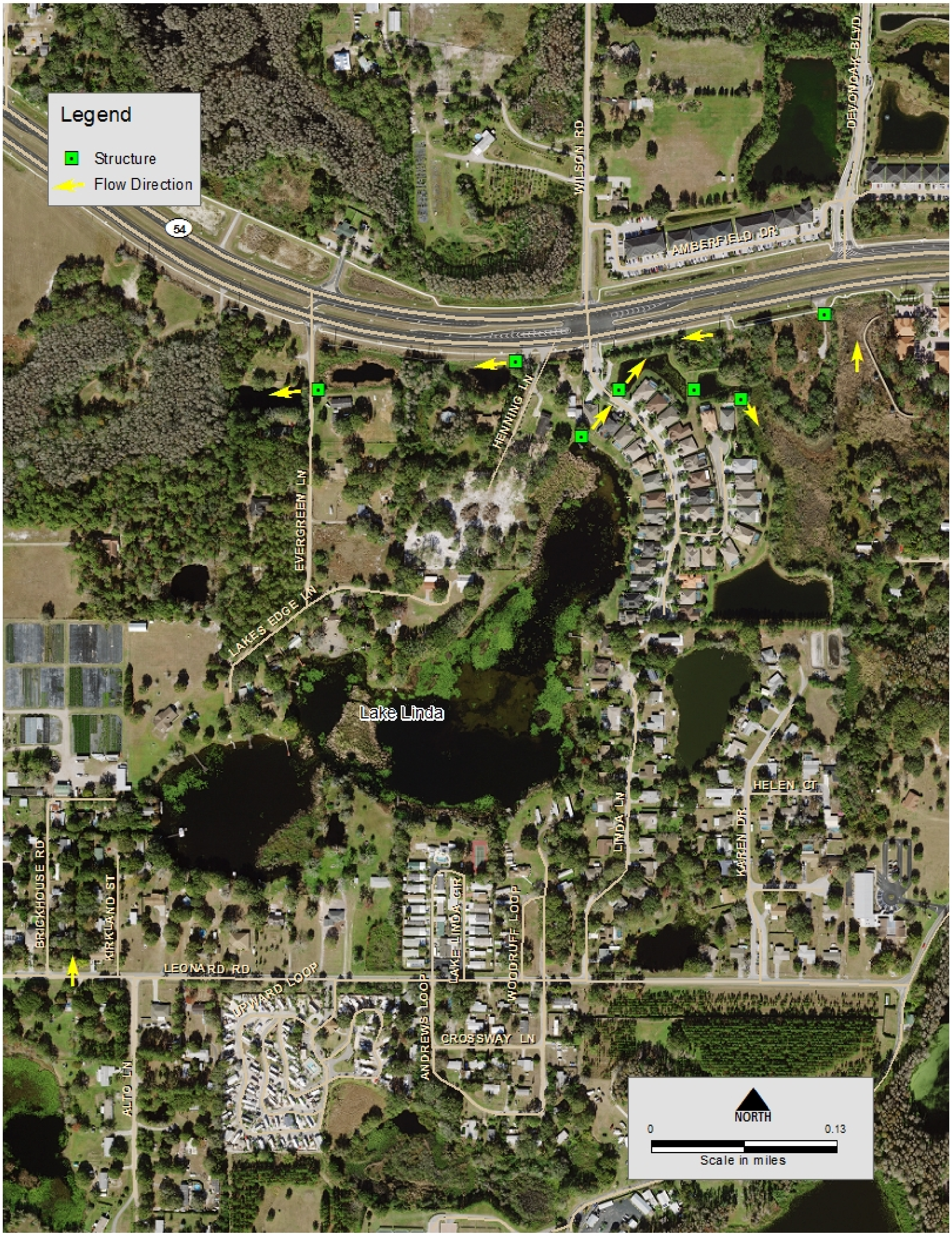

Figure 2: Location of Conveyance Systems.

Land Use Land Cover

An examination of the 1950, 1990 and 2011 Florida Land Use, Cover, and Forms Classification System (FLUCCS) maps (Figures 3 through 5) and aerial photography from 1938 through 2017 (Figures 6 through 12) chronicles landscape changes in the lake's vicinity typical of the northern Tampa Bay area. A large area west of the lake changed from upland coniferous forest/pine flatwoods to citrus between 1948 (Figure 7) and 1950. By 1950 (Figure 3), tree crops (citrus) and pine flatwoods dominated the area with patches of freshwater marshes throughout. Much of the land northwest of the lake was crop and pastureland. By 1990 (Figure 4), most of the area was classified as residential with row crops and crop and pastureland. By 2011 (Figure 5) the area was dominated by residential development.

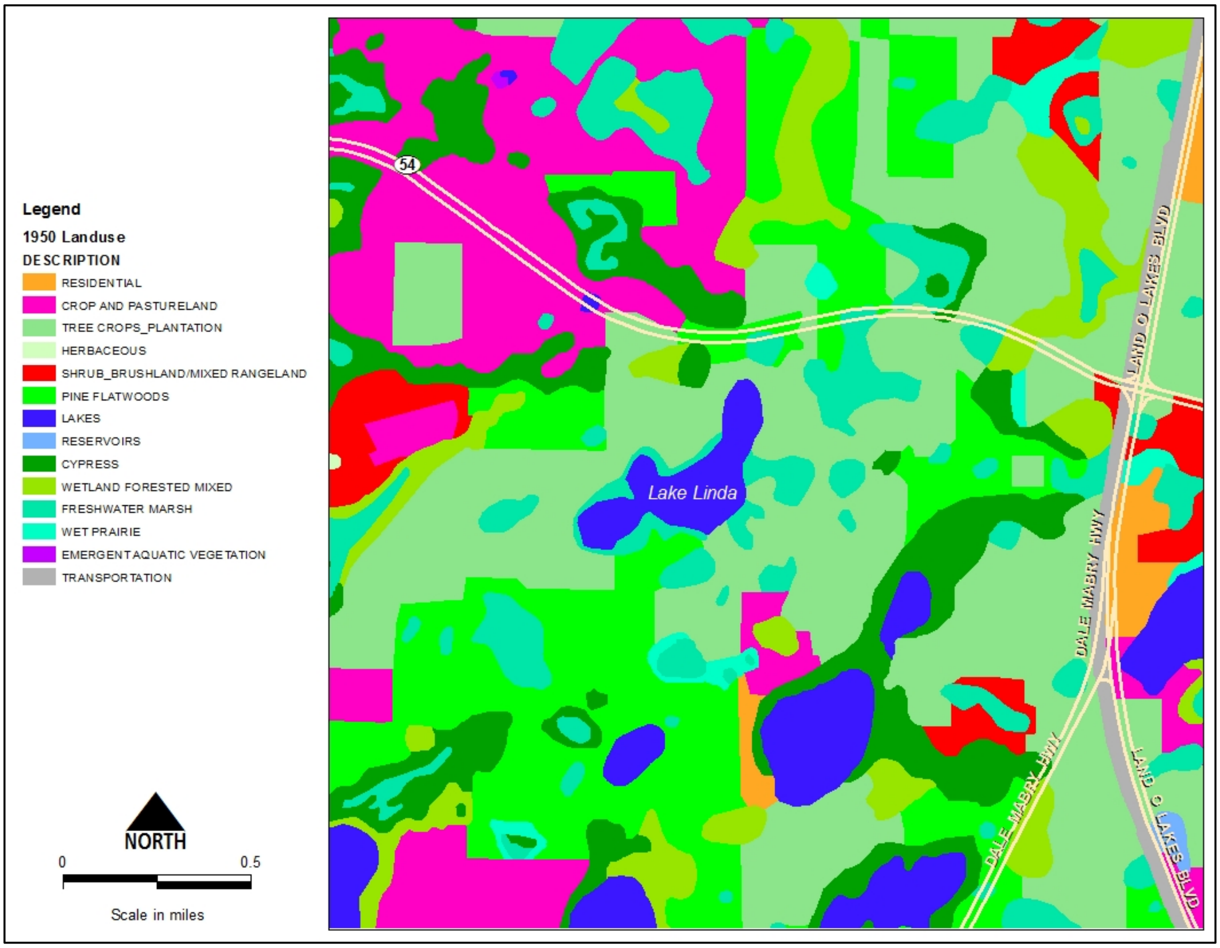

Figure 3: 1950 Land Use Land Cover Map of the Lake Linda Vicinity.

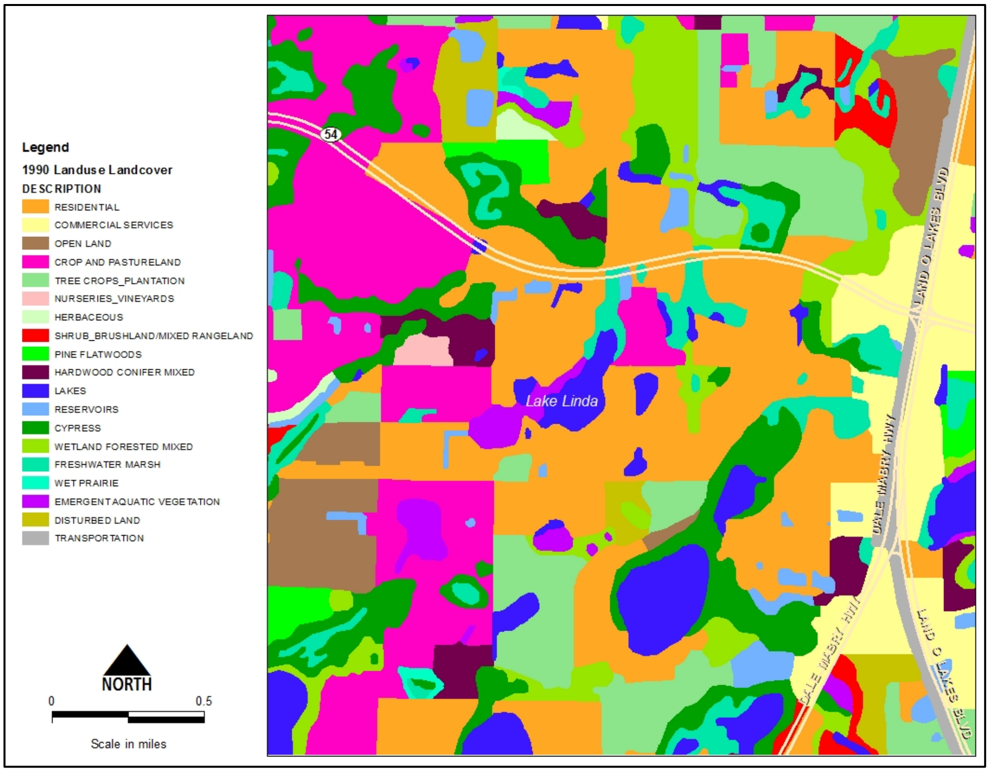

Figure 4: 1990 Land Use Land Cover Map of the Lake Linda Vicinity.

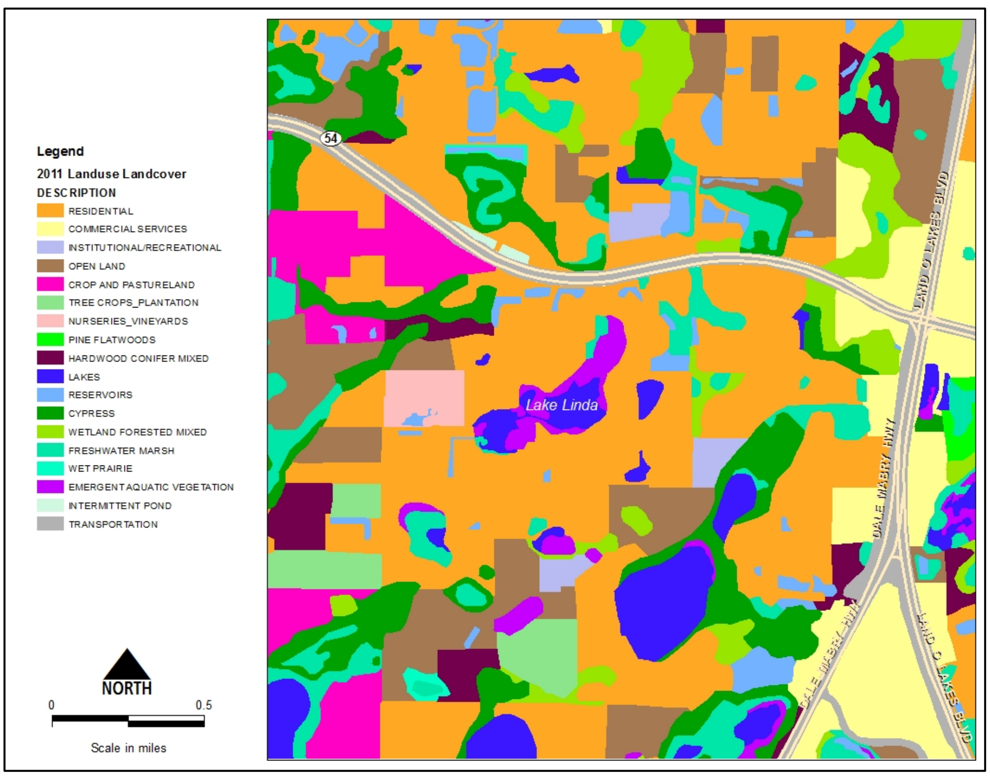

Figure 5: 2011 Land Use Land Cover Map of the Lake Linda Vicinity.

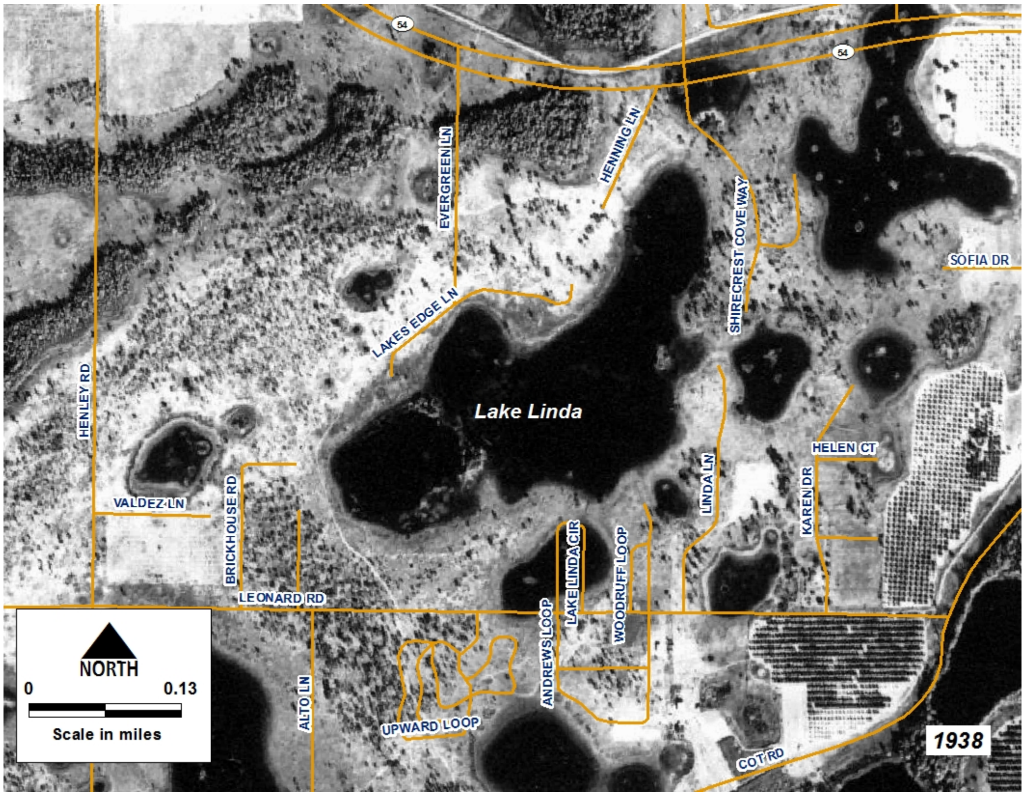

Figure 6: 1938 Aerial Photograph of Lake Linda

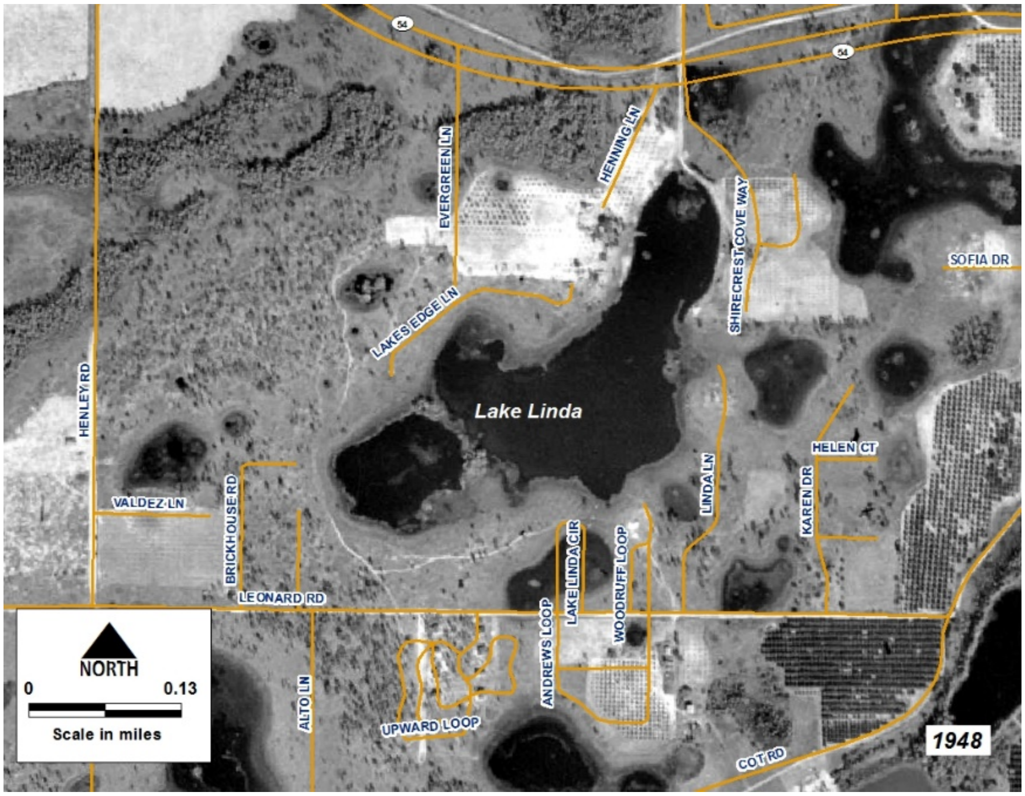

Figure 7: 1948 Aerial Photograph of Lake Linda

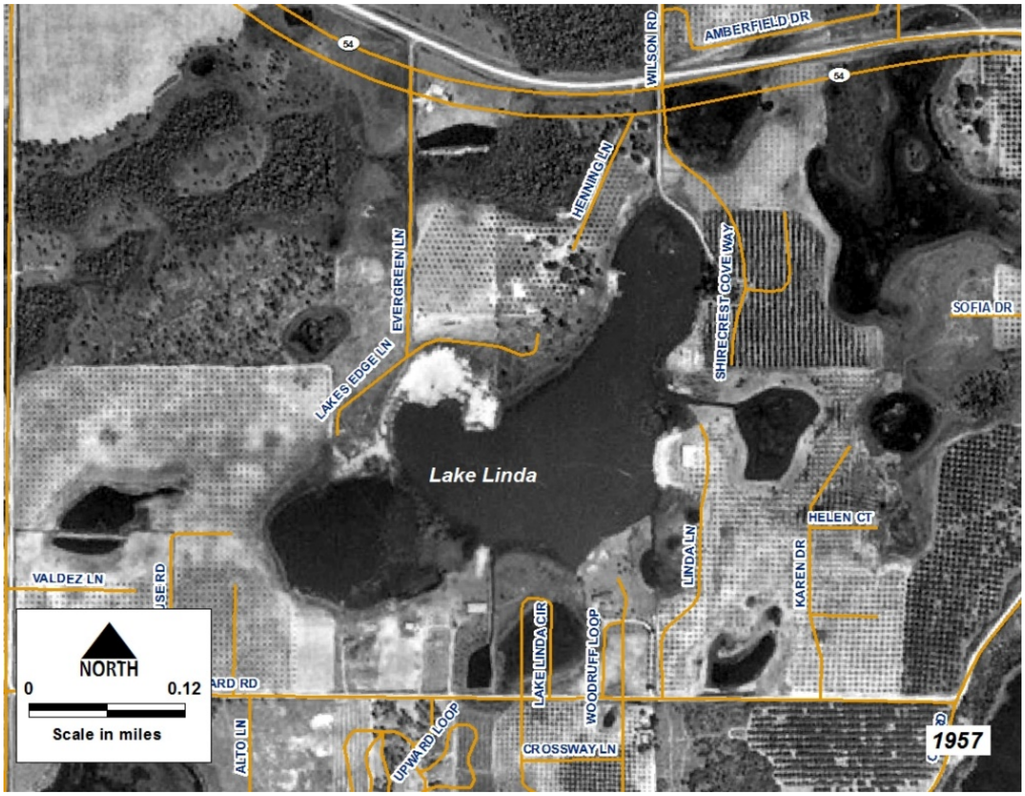

Figure 8: 1957 Aerial Photograph of Lake Linda

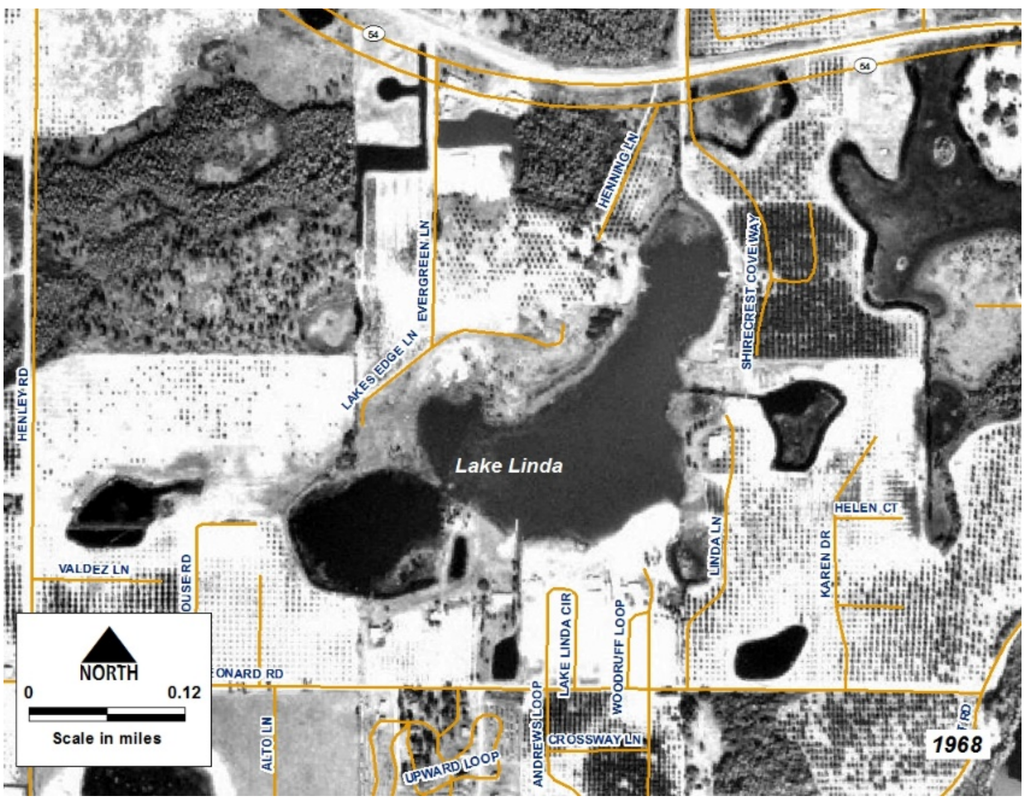

Figure 9: 1968 Aerial Photograph of Lake Linda

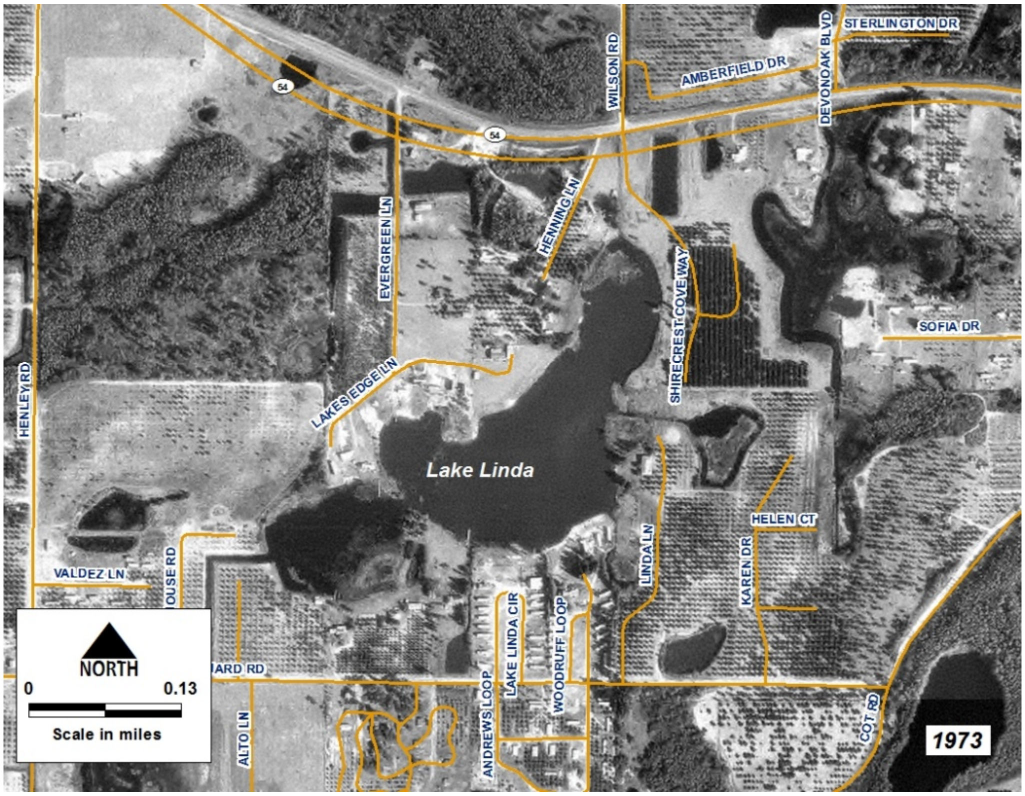

Figure 10: 1973 Aerial Photograph of Lake Linda

Figure 11: 2007 Aerial Photograph of Lake Linda

Figure 12: 2017 Aerial Photograph of Lake Linda

Bathymetry Description and History

One-tenth foot interval bathymetric data gathered from recent field surveys resulted in lake-bottom contour lines from 43.6 ft. to 66.5 ft., NGVD29 (Figure 13). Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

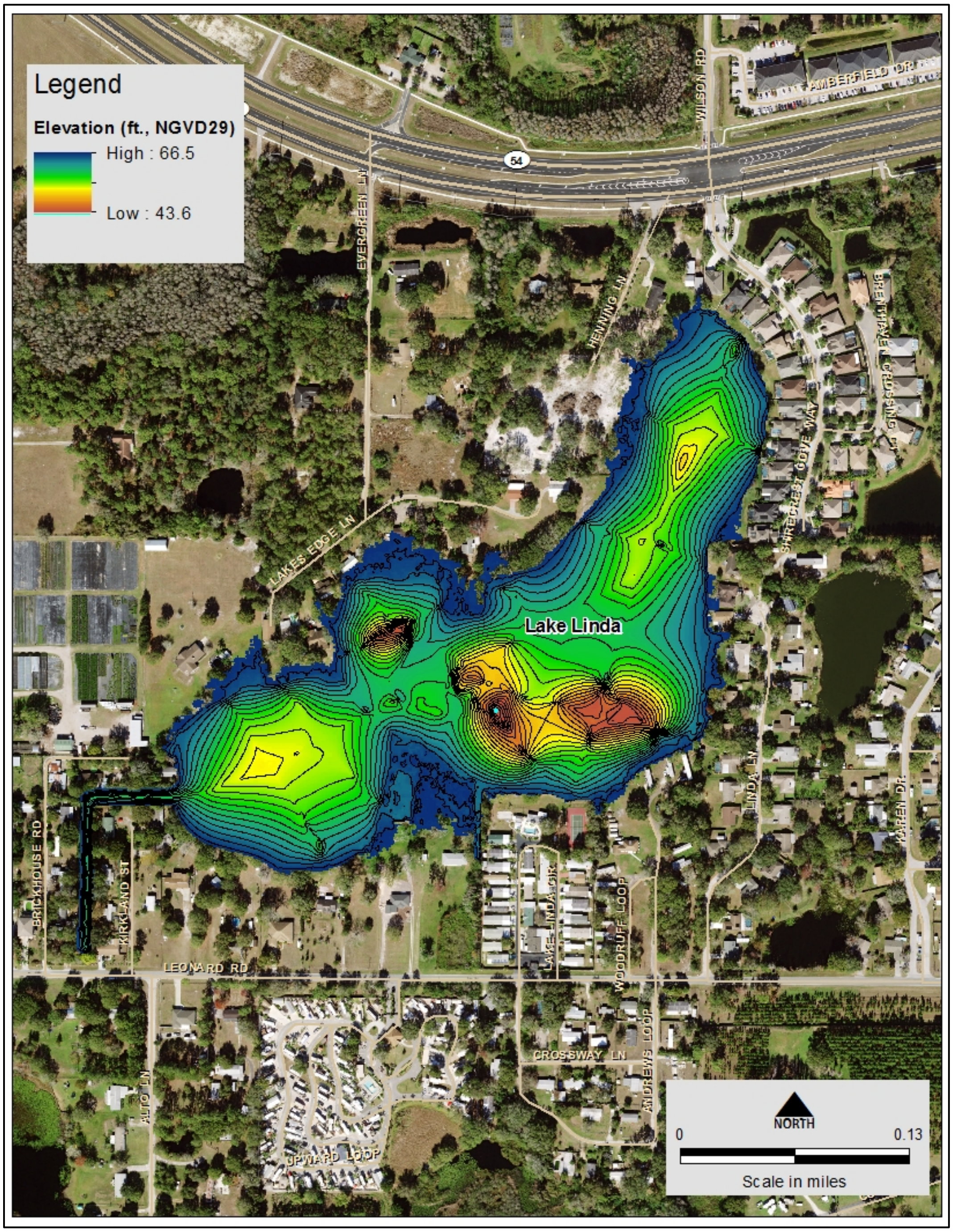

Figure 13: Lake Bottom Contours (black lines; 1 foot intervals) on a 2017 Natural Color Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Lake Linda from the District's Water Management Information System (SID 19122) (Figure 14). Data collection began on October 2, 1969. Water elevations continue to be monitored on a monthly basis at the time of this report. On July 8, 2015 the gauge was adjusted from NGVD29 to NAVD88, with a measured shift of -0.85 ft. The highest lake stage elevation on record was 67.17 ft. and occurred on September 25, 2017. The lowest lake stage elevation on record was 60.07 ft. and occurred on May 21, 2001.

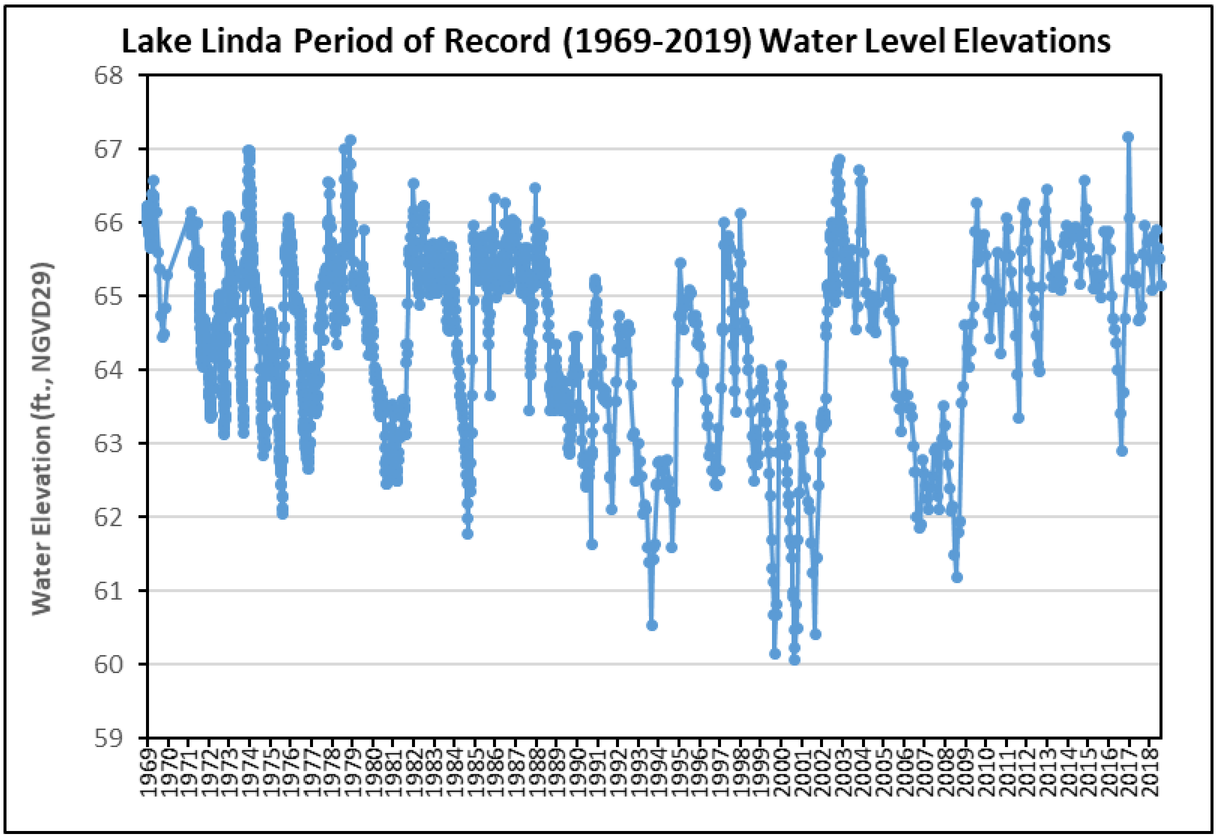

Figure 14: Lake Linda Period of Record Water Elevation Data (SID 19122)

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 Lake Linda (Table 2) in December 2007, which were subsequently adopted into Chapter 40D-8, Florida Administrative Code in February 2008, using the methodology for Category 3 Lakes described in SWFWMD (1999a and 1999b).

Table 2: Minimum and Guidance Levels Adopted February 2008 for Lake Linda

Level	Elevation (ft., NGVD)
High Guidance Level	66.3
High Minimum Level	66.2
Minimum Level	64.7
Low Guidance Level	63.6

Methods, Results and Discussion

The Minimum and Guidance Levels in this report were developed for Lake Linda 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 Lake Linda.

Levels	**Elevation in Feet NGVD 29**	**Lake Area (acres)**
Lake Stage Percentiles		
Historic P10 (1946 to 2018)	66.1	24.8
Historic P50 (1946 to 2018)	65.5	23.4
Historic P90 (1946 to 2018)	65.0	22.3
Normal Pool and Control Point		
Normal Pool	NA	NA
Control Point	65.6	23.6
Significant Change Standards		
Recreation/Ski Standard	NA	NA
Dock-Use Standard	64.2	20.5
Wetland Offset Elevation	64.7	21.6
Aesthetics Standard	65.0	22.3
Species Richness Standard	64.0	20.0
Basin Connectivity Standard	63.7	19.3
Lake Mixing Standard	NA	NA
Minimum and Guidance Levels		
High Guidance Level	66.1	24.8
High Minimum Lake Level	65.6	23.6
Minimum Lake Level	65.0	22.3
Low Guidance Level	65.0	22.3

NA - not appropriate

Bathymetry

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

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

Two elevation data sets were used to develop the terrain model for Lake Linda. 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 15.

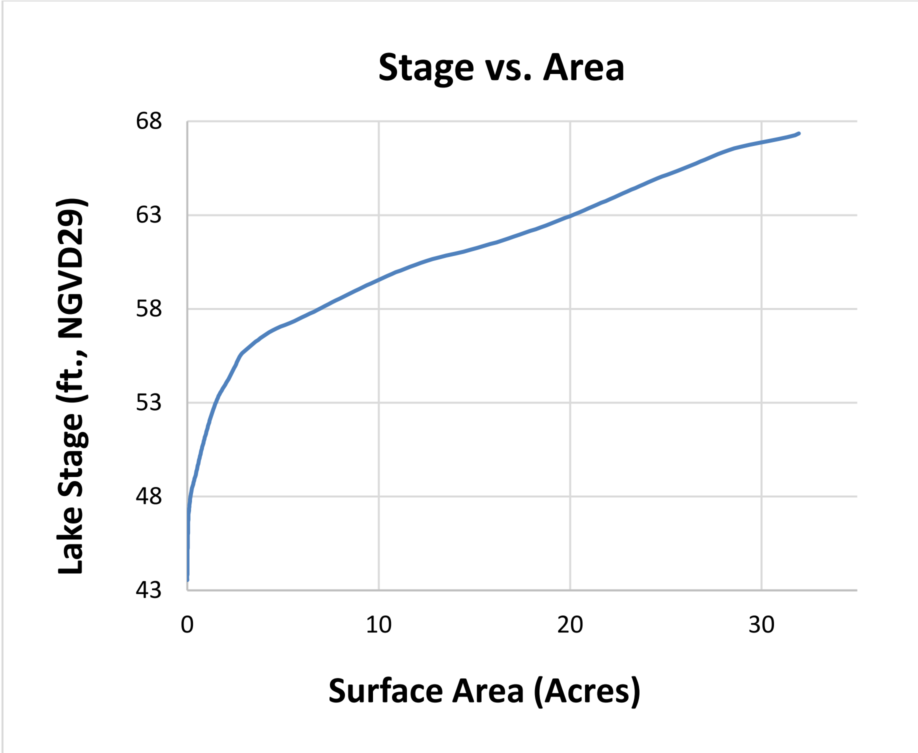

Figure 15: Lake Stage (Ft. NGVD29) to Surface Area (Acres) for Lake Linda.

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, 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 Lake Linda 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 modeled data, the Historic P10 elevation, i.e., the elevation of the lake water surface equaled or exceeded ten percent of the time, was 66.1 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 65.5 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 65.0 ft (Figure 16 and Table 3).

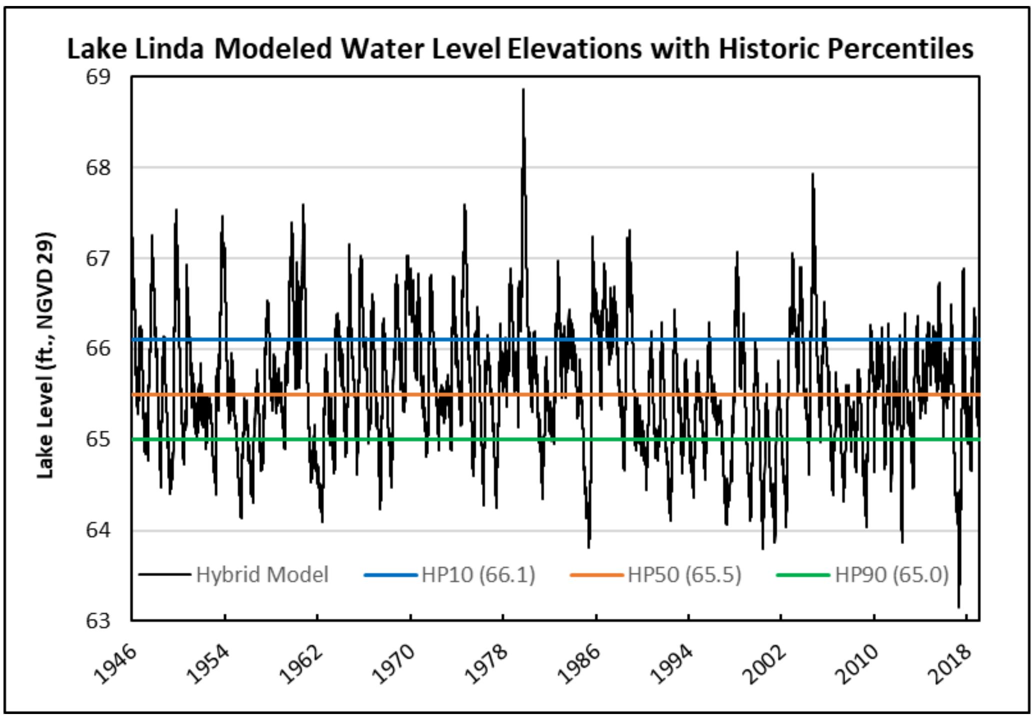

Figure 16: Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

Normal Pool Elevation and Additional Information

The Normal Pool elevation, a reference elevation used for development of minimum lake and wetland levels, is established based on the elevation of hydrologic indicators of sustained inundation. The inflection points (buttress swelling) and moss collars on the trunks of cypress trees have been shown to be reliable biologic indicators of hydrologic Normal Pool (Carr et al. 2006). As Lake Linda does not have a sufficient number of 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 Lake Linda was determined at 65.6 ft., the elevation of the weir structure in the pond adjacent to Shirecrest Cove Way (Figure 2). The low floor slab elevation, based on survey reports, was established at 68.71 ft.

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 Lake Linda, the High Guidance Level was established at the Historic P10 elevation, 66.1 ft. Recorded stage data indicate that the levels peaked above the HGL in the Fall of 1974 and 1979, with a maximum of 67.2 ft. in September 2017 (Figure 16).

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 Lake Linda, the Low Guidance Level was established at the Historic P90 elevation, 65.0 ft. The period of record stage data indicates the lake levels have regularly been below the Low Guidance Level, most notably May/June 2000, 2001, 2002 (Figure 16). The lowest water level on record was 60.1 ft. on May 21, 2001.

Significant Change Standards

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

- The **Recreation/Ski Standard** was not established, since a circular ski corridor with a radius of 418 feet or a rectangular corridor 200 x 2,000 feet was not possible. Thus, Lake Linda is classified as a Non-Ski lake.

- The **Dock-Use Standard** was established at an elevation of 64.2 ft. based on the elevation of lake sediments at the end of 11 docks on the lake, a 2-ft. clearance depth, and the difference between the Historic P50 and P90, of 0.5 ft.
- The **Wetland Offset Elevation** was established at 64.7 ft., or 0.8 ft. below the historic P50 elevation.
- The **Aesthetic Standard** was established at the Low Guidance Level elevation of 65.0 ft.
- The **Species Richness Standard** was established at 64.0 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 63.7 ft. based on a critical high spot elevation of 61.2 ft, the addition of 2 feet, plus the difference between the Historic P50 and P90, of 0.5 ft. This critical high spot is the elevation separating the lake into an oblong “eastern pool”, “western pool” and small “northwestern central pool”.
- 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 17), and potential changes in area available for aquatic plant colonization (Figure 18) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development. Figure 17 shows that as the lake stage increases, the acres available for herbaceous wetland area (acres < 4 ft.) also increase, up until around 64 ft. The acres available for herbaceous wetlands then decrease about 1.5 acres at the lake’s deepest point. The area available for aquatic plant colonization (acres < 10.6 ft.) steadily increases to a maximum available area of 28 acres (Figure 18).

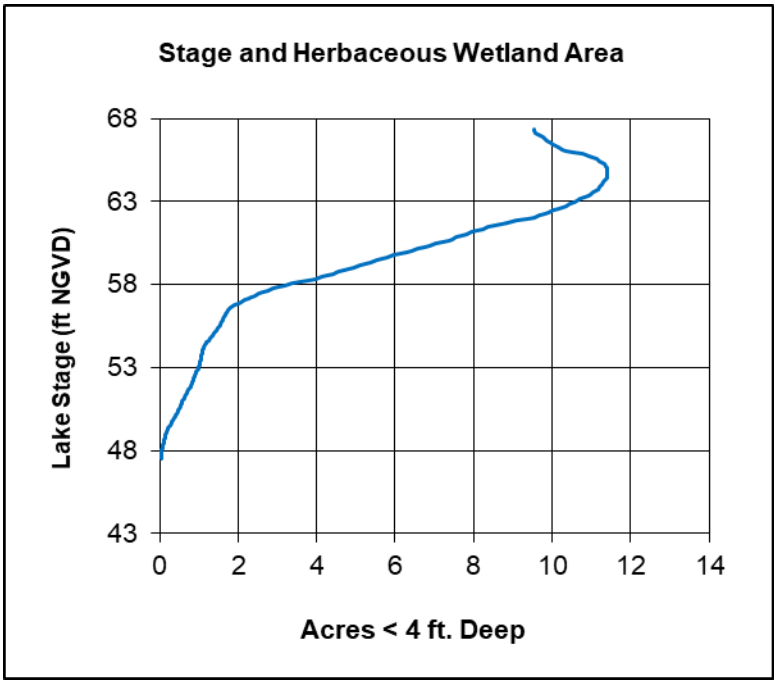

Figure 17: Lake Stage Compared to Available Herbaceous Wetland Area.

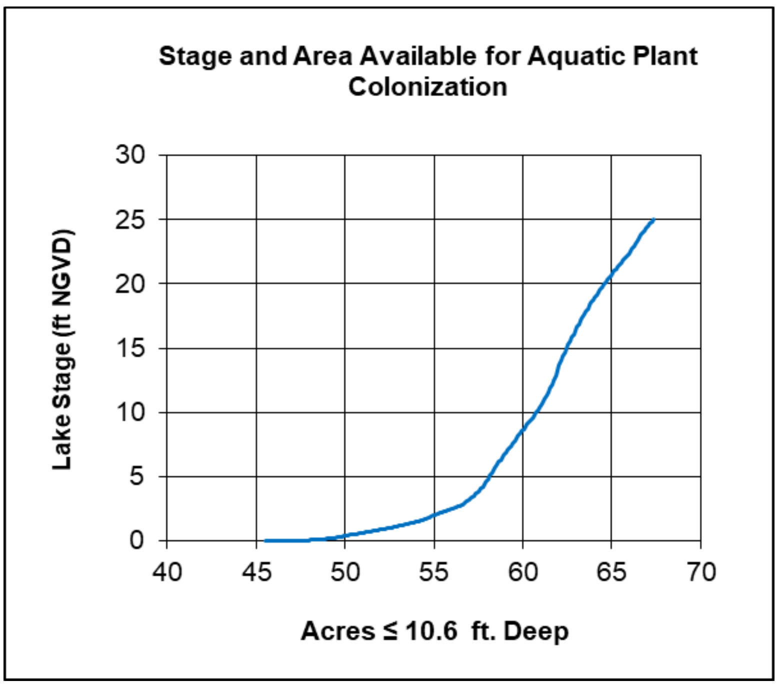

Figure 18: Lake Stage and Area Available for Aquatic Plant Colonization.

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 Lake Linda is established at the Aesthetics standard elevation of 65.0.

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 65.6. This elevation accounts for a natural fluctuation of lake levels.

Minimum and Guidance levels for Lake Linda are plotted on the recorded water level record in Figure 19. 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 20.

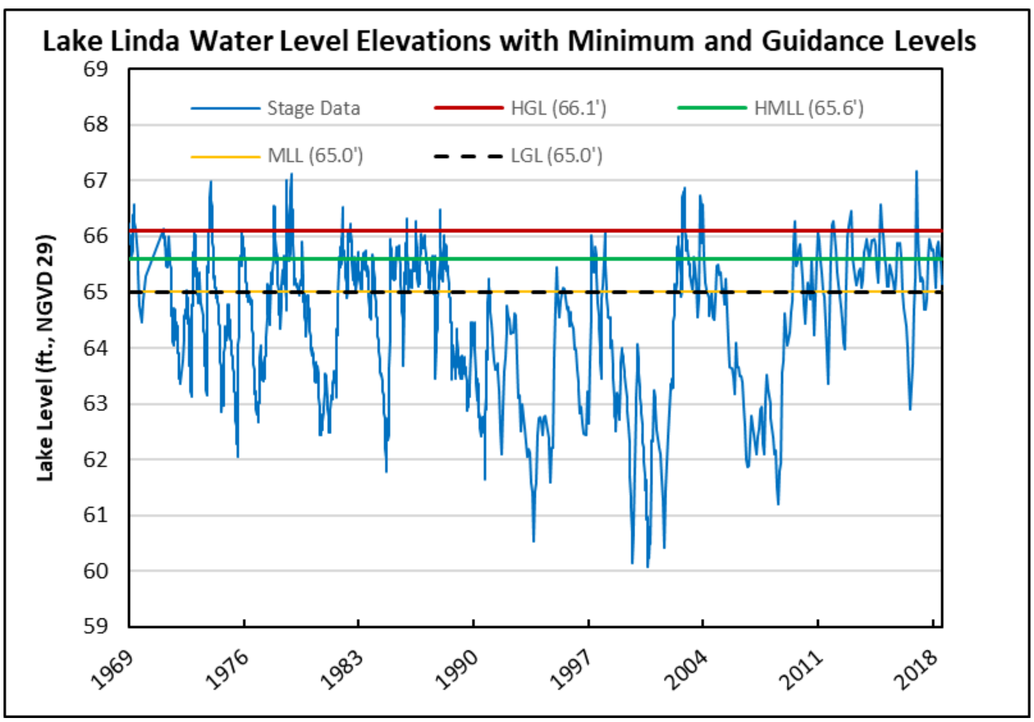

Figure 19: Water Levels and the Minimum and Guidance Levels.

Figure 20: Lake Linda Minimum and Guidance Level Contour Lines Imposed onto a 2017 Natural Color Aerial Photograph.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida's water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the MFLs for Lake Linda 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 -0.85 ft. for SID 19122 on Lake Linda.

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

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88
High Guidance Level	66.1	65.3
High Minimum Lake Level	65.6	64.8
Minimum Lake Level	65.0	64.2
Low Guidance Level	65.0	64.2

Consideration of Environmental Values

The minimum levels for Lake Linda 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 Aesthetics standard elevation was used for developing Minimum Levels for Lake Linda based on its classification as a Category 3 lake. This standard is associated with protection of two environmental values identified in Rule 62-40.473, F.A.C.,: Recreation in and on the water, and aesthetic and scenic attributes. (Table 1). However, since the other standards fall below the aesthetics standard, the MLL is also protective of all the environmental values that are associated with the standards below it.

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

Two environmental values identified in the Water Resource Implementation Rule were not considered relevant to development of minimum levels for Lake Linda. 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 0.2 feet lower than the previously adopted High Guidance Level. The Low Guidance Level is 1.4 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 Lake Linda is 0.6 feet lower than the previously adopted High Minimum Lake Level. The Minimum Lake Level is 0.3 feet higher 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 Aesthetics for this reevaluation. The previously adopted MLL was based on the Basin Connectivity Standard.

The Minimum and Guidance Levels identified in this report replace the previously adopted levels for Lake Linda.

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

Minimum and Guidance Levels	Elevations (in ft. NGVD29)	Previously Adopted Elevations (in ft. NGVD29)
High Guidance Level	66.1	66.3
High Minimum Lake Level	65.6	66.2
Minimum Lake Level	65.0	64.7
Low Guidance Level	65.0	63.6

Minimum Levels Status Assessment

To assess if the Minimum and High Minimum Lake Levels are being met, observed stage data in Lake Linda were used to create a long-term record using a Line of Organic Correlation (LOC) model, similar to what was developed for establishing the Minimum Levels (Appendix A). For the status assessment, the lake stage data used to create the LOC must be from a period representing a time when groundwater withdrawals and structural alterations are reasonably stable, and represent current conditions, referred to as the “Current” period. Current stage data observed on Lake Linda were determined to be from 2010 through 2018. Using the Current stage data, the LOC model was created. The LOC model resulted in a 73-year long-term water level record (1946-2019).

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 Lake Linda water levels are above both the Minimum Lake Levels and the High Minimum Lake Levels (see Appendix B).

The lake lies 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 Lake Linda 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.

Documents Cited and Reviewed

Anderson, M.P., and Woessner, W.W. 2002. Applied Groundwater Modeling Simulation of Flow and Advective Transport. Academic Press. San Diego, California.

Ardaman and Associates, Inc. 2007. Recommended Ten Year Flood Guidance Level and Other Flood Stage Elevations for Lake Linda in Pasco County, Florida. Orlando, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Bachmann, R.W., Hoyer, M.V., and Canfield, D.E. Jr. 2000. The potential for wave disturbance in shallow Florida lakes. Lakes and Reservoir Management 16:281-291.

Basso, R., and Schultz, R. 2003. Long-term variation in rainfall and its effect on Peace River flow in west-central Florida. Southwest Florida Water Management District, Brooksville, Florida.

Bedient, P., Brinson, M., Dierberg, F., Gorelick, S., Jenkins, K., Ross, D., Wagner, K., and Stephenson, D. 1999. Report of the Scientific Peer Review Panel on the data, theories, and methodologies supporting the Minimum Flows and Levels Rule for northern Tampa Bay Area, Florida. Prepared for the Southwest Florida Water Management District, the Environmental Confederation of Southwest Florida, Pasco County, and Tampa Bay Water. Southwest Florida Water Management District. Brooksville, Florida.

Butts, D., Hinton, J. Watson, C., Langeland, K., Hall, D., and Kane, M. 1997 Aquascaping: planting and maintenance. Circular 912, Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, Florida.

Carr, D.W., and Rochow, T.F. 2004. Technical memorandum to file dated April 19, 2004. Subject: comparison of six biological indicators of hydrology in isolated *Taxodium acsendens* domes. Southwest Florida Water Management District. Brooksville, Florida.

Carr, D.W., Leeper, D.A., and Rochow, T.F. 2006. Comparison of Six Biologic Indicators of Hydrology and the Landward Extent of Hydric Soils

Caffrey, A.J., Hoyer, M.V., and Canfield, D.E., Jr. 2006. Factors affecting the maximum depth of colonization by submersed aquatic macrophytes in Florida lakes. University of Florida Institute of Food and Agricultural Sciences Department of Fisheries and Aquatic Sciences. Gainesville, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Caffrey, A.J., Hoyer, M.V., and Canfield, D.E., Jr. 2007. Factors affecting the maximum depth of colonization by submersed aquatic macrophytes in Florida lakes. Lake and Reservoir Management 23:287-297

Dierberg, F.E., and Wagner, K.J. 2001. A review of “A multiple-parameter approach for establishing minimum levels for Category 3 Lakes of the Southwest Florida Water Management District" June 2001 draft by D. Leeper, M. Kelly, A. Munson, and R. Gant. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Emery, S., Martin, D., Sumpter, D., Bowman, R., and Paul, R. 2009. Lake surface area and bird species richness: analysis for minimum flows and levels rule review. University of South Florida Institute for Environmental Studies. Tampa, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida

Enfield, D.B., Mestas-Nunez, A.M., and Trimble, P.J. 2001. The Atlantic multi-Decadal oscillation and its relation to rainfall and river flow in the continental U. S. Geophysical Research Letters 28:2077-2080.

Flannery, M.S., Peebles, E.B., and Montgomery, R.T. 2002. A percent-of-flow approach for Managing reductions in freshwater flows from unimpounded rivers to southwest Florida estuaries. Estuaries 25:1318-1332.

Hancock, M. 2006. Draft memorandum to file, dated April 24, 2006. Subject: a proposed interim method for determining minimum levels in isolated wetlands. Southwest Florida Water Management District. Brooksville, Florida.

Hancock, M. 2007. Recent development in MFL establishment and assessment. Southwest Florida Water Management District, draft 2/22/2007. Brooksville, Florida.

Hancock, M.C., and Basso, R. 1996. Northern Tampa Bay Water Resource Assessment Project: Volume One. Surface-Water/Ground-Water Interrelationships. Southwest Florida Water Management District. Brooksville, Florida.

Hancock, M.C., Leeper, D.A., Barcelo, M.D., and Kelly, M.H. 2010. Minimum flows and levels development, compliance, and reporting in the Southwest Florida Water Management District. Southwest Florida Water Management District. Brooksville, Florida.

Helsel, D. R., and Hirsch, R. M. 1992. Statistical methods in water resources. Studies in Environmental Science 45. Elsevier. New York, New York.

Hoyer, M.V., Israel, G.D., and Canfield, D.E., Jr. 2006. Lake User’s perceptions regarding impacts of lake water level on lake aesthetics and recreational uses. University of Florida Institute of Food and Agricultural Sciences Department of Fisheries and Aquatic Sciences and Department of Agricultural Education and Communication. Gainesville, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Kelly, M. 2004. Florida river flow patterns and the Atlantic Multidecadal Oscillation. Southwest Florida Water Management District. Brooksville, Florida.

Leeper, D. 2006. Proposed methodological revisions regarding consideration of structural alterations for establishing Category 3 Lake minimum levels in the Southwest Florida Water Management District, April 21, 2006 peer-review draft. Southwest Florida Water Management District. Brooksville, Florida.

Leeper, D., Kelly, M., Munson, A., and Gant, R. 2001. A multiple-parameter approach for establishing minimum levels for Category 3 Lakes of the Southwest Florida Water Management District, June14, 2001 draft. Southwest Florida Water Management District, Brooksville, Florida.

Mace, J. 2009. Minimum levels reevaluation: Gore Lake Flagler County, Florida. Technical Publication SJ2009003. St. Johns River Water Management District. Palatka, Florida.

Miller, J.A. 1986. Hydrogeologic framework of the Floridan aquifer system in Florida and parts of Georgia, Alabama, and South Carolina. U.S. Geological Survey Water-Resources Investigations Report.

Neubauer, C.P., Hall, G.B., Lowe, E.F., Robison, C.P., Hupalo, R.B., and Keenan, L.W. 2008. Minimum flows and levels method of the St. Johns River Water Management District, Florida, USA. Environmental Management 42:1101-1114.

Poff N.L., Richter, B., Arthington, A.H., Bunn, S.E., Naiman, R.J., Kendy, E., Acreman, M., Apse, C., Bledsoe, B.P., Freeman, M., Henriksen, J., Jacobson, R.B., Kennen, J., Merritt, D.M., O'Keeffe, J., Olden, J.D., Rogers, K., Tharme, R.E., and Warner, A. 2010. The Ecological Limits of Hydrologic Alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology* 55:147-170.

Poff, N.L., and Zimmerman, K.H. 2010. Ecological responses to altered flow regimes: a literature review to inform science and management of environmental flows. Freshwater Biology 55:194-205.

Postel, S., and Richter, B. 2003. Rivers for life: Managing water for people and nature. Island Press. Washington, D.C.

Schultz, R., Hancock, M., Hood, J., Carr, D.W., and Rochow T. Memorandum of file, dated July 21, 2004. Subject: Use of Biologic Indicators for Establishment of Historic Normal Pool. Southwest Florida Water Management District. Brooksville, Florida.

South Florida Water Management District. 2000. Minimum flows and levels for Lake Okeechobee, the Everglades and the Biscayne aquifer, February 29, 2000 draft. West Palm Beach, Florida.

South Florida Water Management District. 2006. Technical document to support development of minimum levels for Lake Istokpoga, November 2005. West Palm Beach, Florida.

Southwest Florida Water Management District. 1999a. Establishment of minimum levels for Category 1 and Category 2 lakes, *in* Northern Tampa Bay minimum flows and levels white papers: white papers supporting the establishment of minimum flows and levels for isolated cypress wetlands, Category 1 and 2 lakes, seawater intrusion, environmental aquifer levels and Tampa Bypass canal, peer-review final draft, March 19, 1999. Brooksville, Florida.

Southwest Florida Water Management District. 1999b. Establishment of minimum levels in palustrine cypress wetlands, *in* Northern Tampa Bay minimum flows and levels white papers: white papers supporting the establishment of minimum flows and levels for isolated cypress wetlands, Category 1 and 2 lakes, seawater intrusion, environmental aquifer levels and Tampa Bypass canal, peer-review final draft, March 19, 1999. Brooksville, Florida.

Suwannee River Water Management District. 2004. Development of Madison Blue Spring-based MFL technical report. Live Oak, Florida.

Suwannee River Water Management District. 2005. Technical report, MFL establishment for the lower Suwannee River & estuary, Little Fanning, Fanning & Manatee springs. Live Oak, Florida.

Wagner and Dierberg. 2006. A Review of a Multiple-Parameter Approach for Establishing Minimum Levels for Category 3 Lakes of the Southwest Florida Water Management District. SWFWMD, Brooksville, Fl.

Wantzen, K.M., Rothhaupt, K.O., Morti, M. Cantonati, M.G. Toth, L.G., and Fisher, P. (editors). 2008. Ecological effects of water-level fluctuations in lakes. Development in Hydrobiology, Volume 204. Springer Netherlands.

DRAFT APPENDIX A
Technical Memorandum

July 1, 2020

TO: David Carr, Staff Environmental Scientist, Resource Evaluation, Water Resources Bureau

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

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

Jason Patterson, Hydrogeologist, Water Resources Bureau

Samantha Smith, Hydrogeologist, Water Resources Bureau

Subject: Draft Lake Linda Water Budget Model, Rainfall Correlation Model, and Historic Percentile Estimations

A. Introduction

Water budget and rainfall correlation models have been developed with express purpose of assisting the Southwest Florida Water Management District (District) in the reevaluation and assessment of minimum levels for Lake Linda in south-central Pasco County, Florida. The reassessment of minimum levels currently associated with Lake Linda are scheduled for fiscal year 2019 and are further discussed within the parameters of this documentation. Discussion on the development and use of Lake Linda models, as well as the employment of models for the development of historic lake stage exceedance percentiles are additionally discussed in the following literature.

B. Background and Setting

Lake Linda is in south-central Pasco County, within the Land O' Lakes region of west-central Florida. It is bounded by State Road 54 to the north, US Highway 41 to the east, and Dale Mabry Highway to the south-southeast (Figure 1). The lake lies within the Upper Rocky Creek Basin of the Southwest Florida Water Management District, in a sector designated by Brooks (1981) as the Tampa Plain division of the Ocala Uplift Physiographic District. It has further been characterized by its assemblage of small, neutral to slightly alkaline, low to moderate nutrient-enriched, clear-water lakes interspersed within the moderately thick silty-sand deposits that overlie the Tampa Limestone formation (Griffith et al. 1997).

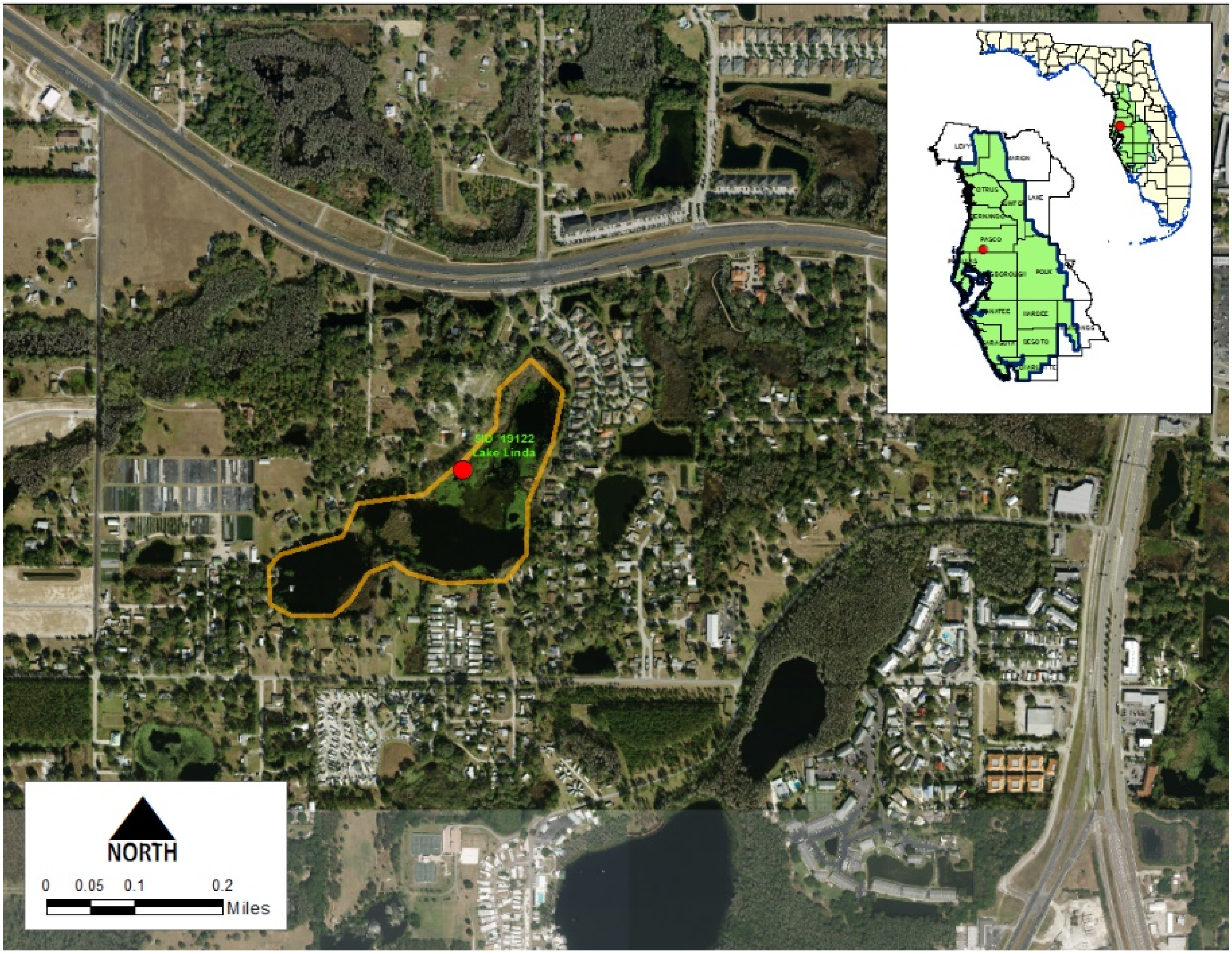

Figure 1. Location of Lake Linda in Pasco County, Florida.

Physiography and Hydrogeology

Topography in the abovementioned region is notably flat, with drainage into the area lakes consisting primarily of a combination of flow moving overland, as well as through drainage swales and secondary conveyance systems (Figure 2).

Figure 2. Approximate flow conveyance path from Lake Linda.

The hydrogeology of the immediate region consists of a surficial sand aquifer that overlies a discontinuous, intermediate clay confining unit. Both upper units are subsequently underlain by a substantially thicker limestone layer that comprises the Upper Floridan aquifer (UFA). The overall thickness of the surficial aquifer ranges between ten and thirty feet, whereas the limestone of the UFA averages nearly one thousand feet of thickness within the immediate region (Miller, 1986). The discontinuous, intermediate clay unit exhibits variable thickness, shifting from as little as a few feet, to as much as 25 feet in some areas. In general, good hydraulic connectivity exists between the uppermost surficial aquifer and the underlying Upper Floridan. This is due to the mostly thin and segmented nature of the intermediate [Hawthorn Group] clay confining unit, and the fact that it is recurrently intruded by karst features. Preferential pathways are created as a result of this, which locally connect the two units, and ultimately result in moderate-to-high leakage into the UFA (Hancock and Basso, 1996).

Situated within the Upper Rocky Creek drainage basin in the Tampa Bay and Coastal Areas watershed (United States Geological Survey Hydrologic Unit Classification System), Lake Linda has a drainage area of approximately 0.13 miles (Ardaman & Associates, Inc., 2007). Along the southern shore, an inlet provides transport into the basin from a wetland positioned between Lake Linda and Como Lake (Figure 2). When the lake water surface elevation surpasses 65.6 feet above the National Geodetic Vertical Datum of 1929 (NGVD), stormwater systems associated with lakeshore development and State Road 54 (SR 54) are in place to provide conveyance of excess water. Multiple water control structures, stormwater ponds and natural wetland areas comprise these systems, and help divert flows toward Camp Lake (Figure 2).

The lake outlet system, in its current state, differs considerably from what it was prior to the widening of SR 54 and the construction of a residential development situated along the northeastern shore in the early 2000s. A 2001 District Survey (Southwest Florida Water Management District, 2001) reports that the controlling elevation for lake discharge at that time was 64.8 feet above NGVD. This was based on a high elevation area within a ditch along the north shore, serving to connect the lake with a borrow pit positioned approximately 175 feet north. A topographic map of the lake basin, generated in support of minimum levels development (Figure 4), exhibits a more than 27-acre expanse of the lake when staged at 66 feet above NGVD. Water surface elevations of the lake currently remain monitored at a District-maintained gauge situated along the northern shore (Figure 4).

<u>Data</u>

The water level data record for Lake Linda extends back to October 1969 and has been continuously recorded and maintained by the District up to present-day (Figure 3). As previously mentioned, the gauge is situated along the north shore, as shown in Figure 4. Early on (1969 up to 1978) data collection occurred on an almost daily or multiple day basis. From 1979 to 2003, data collection typically occurred an average of 2-5 days per month, and from 2004 up to present day, data has been steadily collected on a monthly basis.

The Upper Floridan aquifer monitor well nearest Lake Linda is the Wilson Floridan Well (SID 19429), while the surficial aquifer monitor closest in proximity is Wilson Surf (SID 19429) (Figures 4). In 2000 these wells were relocated and replaced 1,000 feet to the northeast with Wilson Surf Repl (SID 18509) and Wilson Fldn Repl (SID 18508). These monitor wells and their data collection frequency are further discussed in “Flow from and into the surficial aquifer and Upper Floridan aquifer” under Section E of this Appendix.

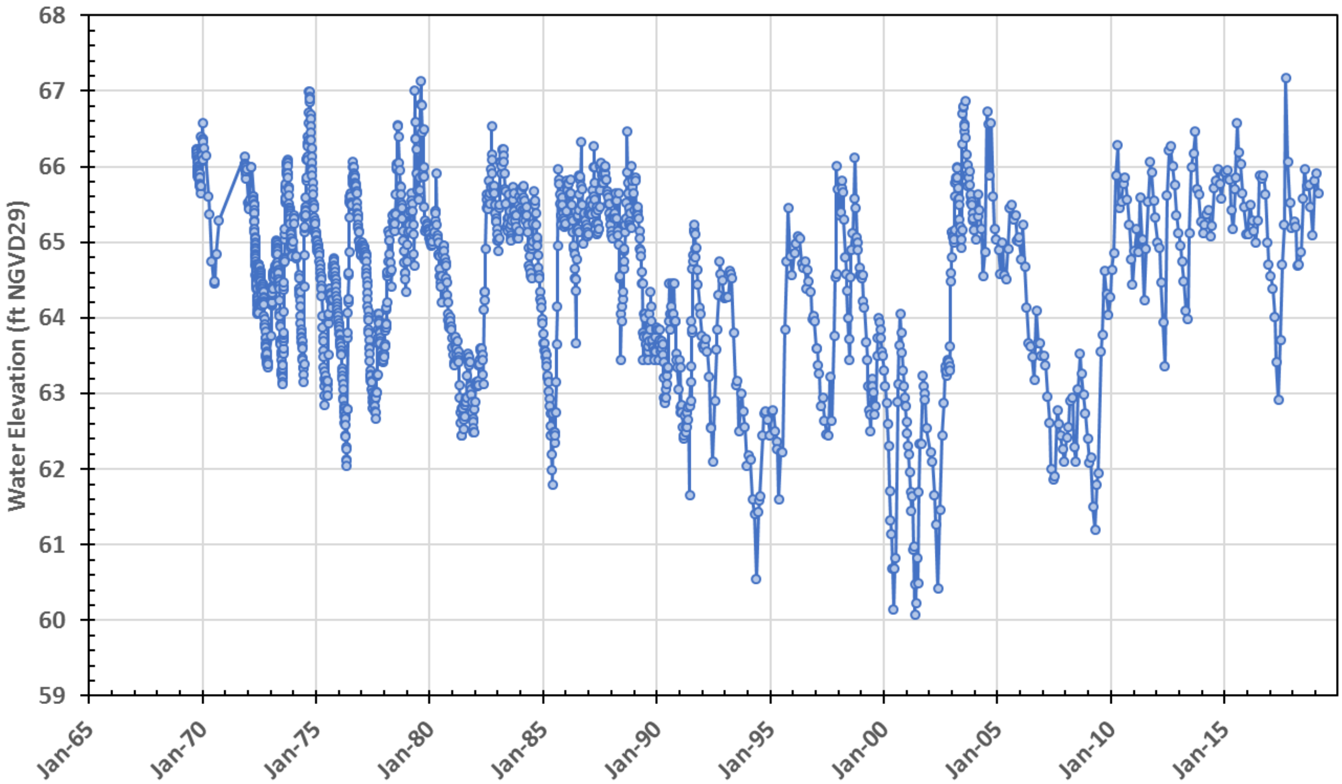

Figure 3. Lake Linda water levels from 1969 to 2019.

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

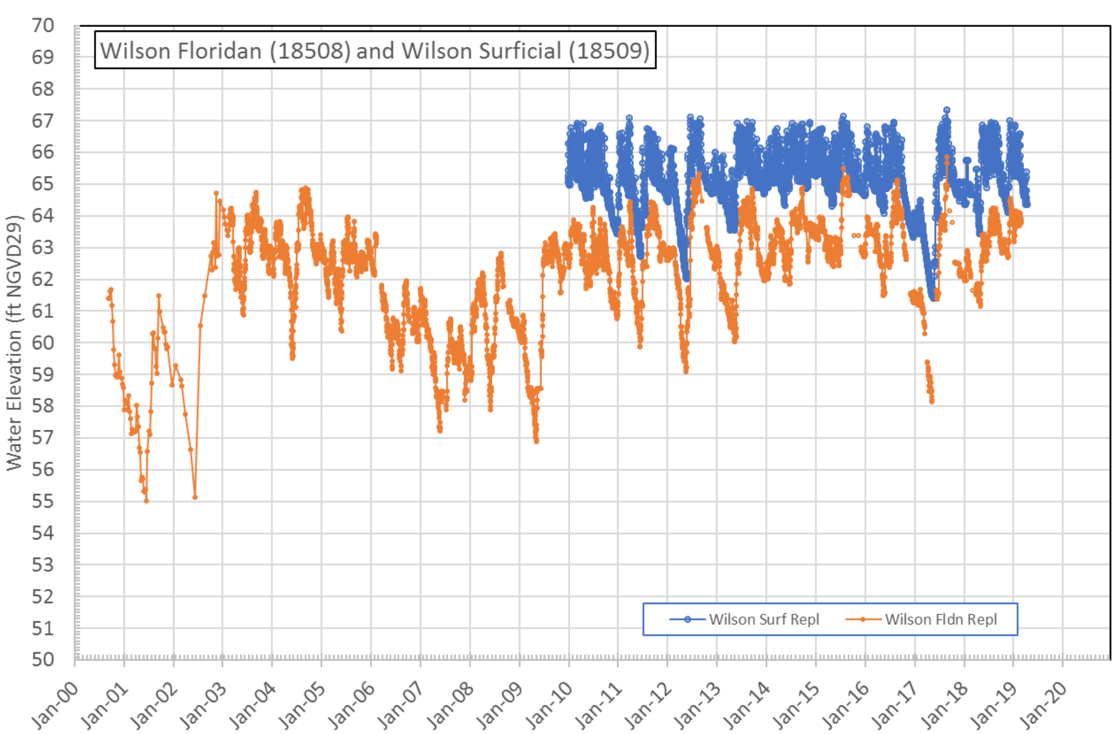

Figure 5. Water levels surficial (Wilson Surficial Replacement) and Upper Floridan aquifer (Wilson Floridan Replacement) monitor wells near Lake Linda.

Land and Water Use

Most of the groundwater use in the area of Lake Linda is for public supply. Lake Linda is located approximately 1.5 miles east of the South Pasco wellfield, and less than 4 miles northeast of the Section 21 wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 6). Groundwater withdrawals began at the Section 21 wellfield in 1963 and steadily climbed to approximately 20 mgd in 1967 (Figure 7). With the development of the South Pasco wellfield in 1973, withdrawal rates at the Section 21 wellfield were reduced to approximately 10 mgd, while withdrawal rates at the South Pasco wellfield quickly rose to 16 to 20 mgd, for a combined withdrawal rate ranging from 20 to 30 mgd in the mid to late 1970s (Figure 7). Combined withdrawal rates since 2005 have ranged from zero to nearly 20 mgd, with several extended periods when one wellfield or the other was shut down completely.

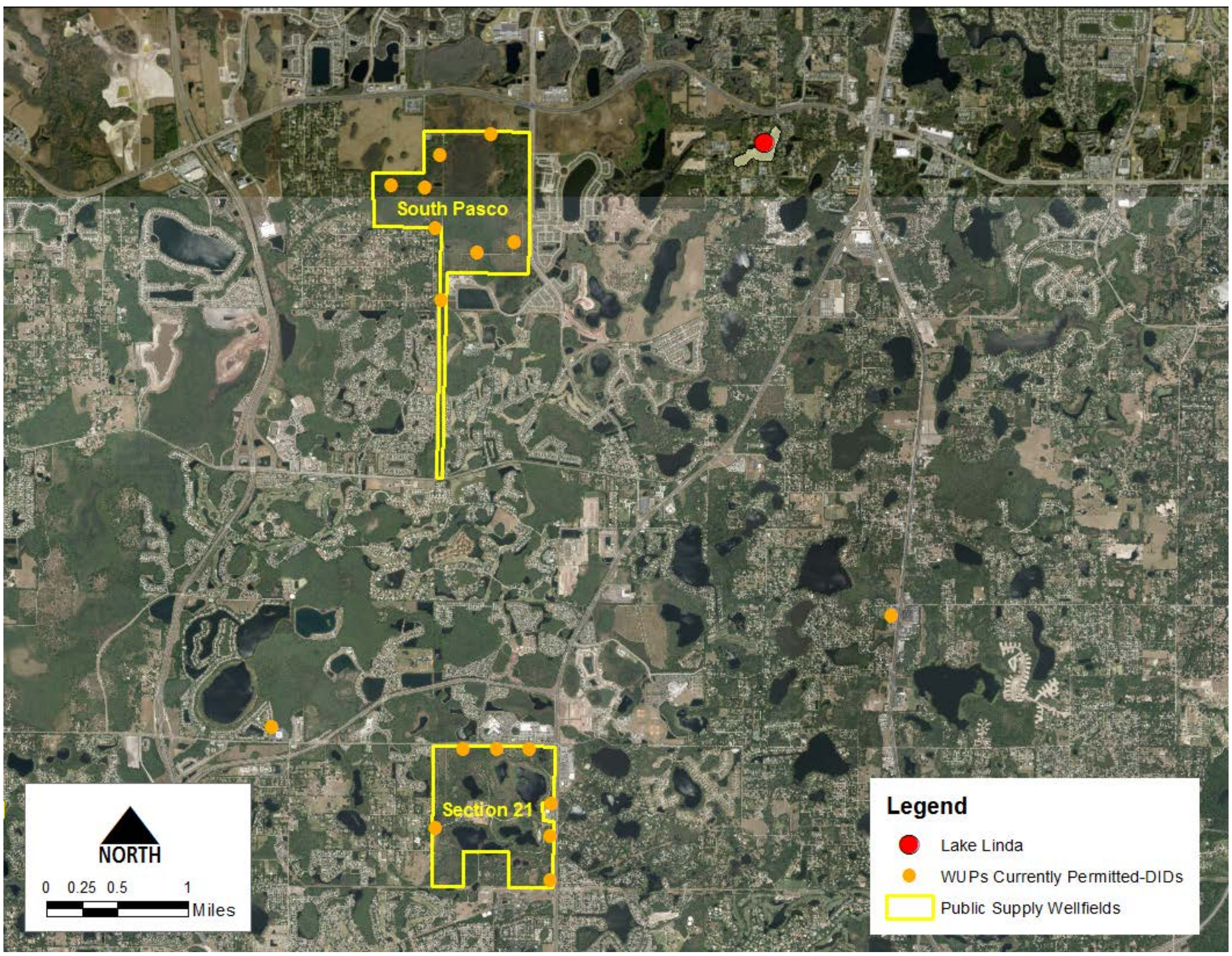

Figure 6. Lake Linda and the South Pasco wellfield.

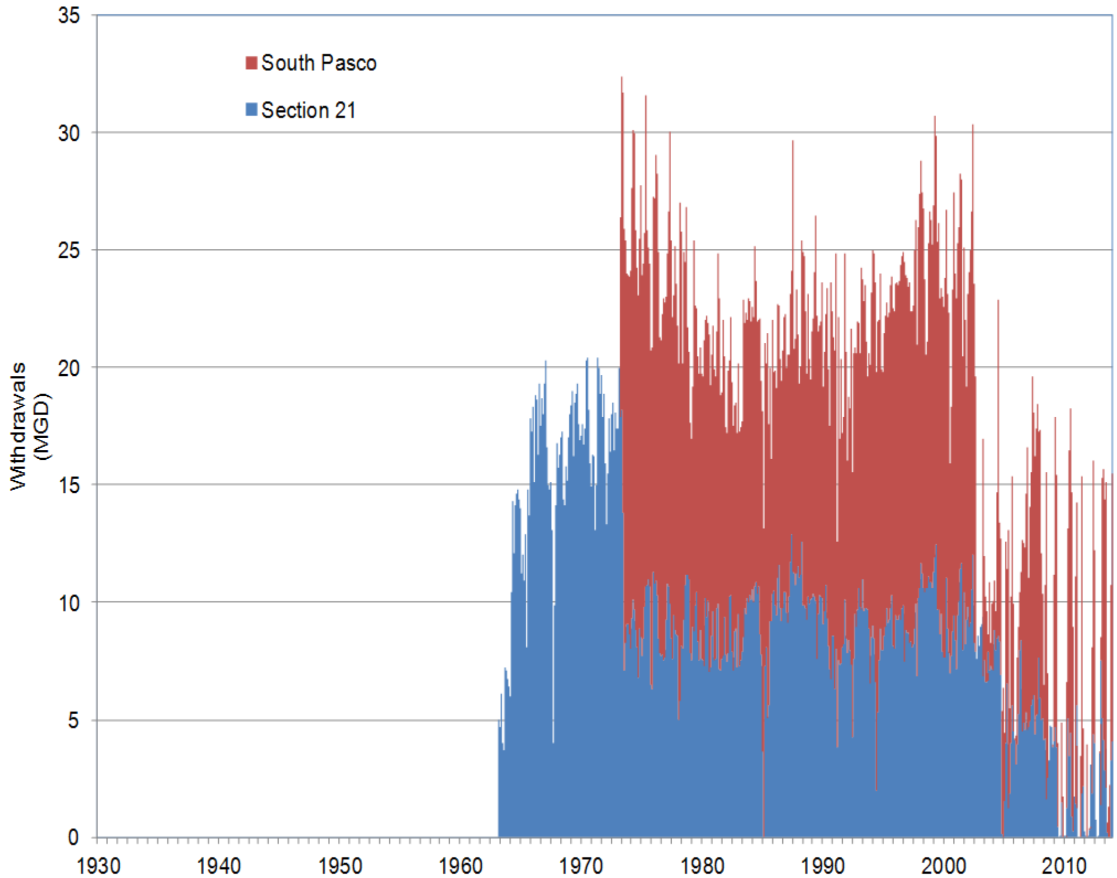

Figure 7. Average monthly withdrawals at the Section 21 and South Pasco wellfields.

C. Purpose of Models

Determination of the High Minimum and Minimum Lake Levels is contingent upon the development of long-term lake stage percentiles, which are utilized as starting elevations. The delineation of a Historic time period is a crucial part of this process. It is technically defined as a period when there is negligible or no groundwater withdrawal impact on the lake, and structurally, when the lake's condition is comparable to or the same as present day. The existence of data from a Historic time period is fundamental in establishing strong predictive relationships between groundwater withdrawal, rainfall, and lake stage fluctuation. These correlations are used to represent the lake's natural state in the absence of groundwater withdrawals, and to calculate long-term Historic lake stage exceedance percentiles. The P10, P50 and P90 percentiles are, respectively, the elevations that the lake water surface equaled or exceeded ten, fifty, and ninety percent of the time. If no Historic time period data is retrievable, or if it is insufficient in terms of representing long-term conditions, a model is developed to approximate the Long-term Historic data.

D. Water Budget Model Overview

The Lake Linda water budget model consists of a spreadsheet tool that incorporates hydrologic processes and engineered alterations that influence the control volume of the lake. The control volume is comprised of everything across and beneath the free water surface, extending down to the deepest elevation of the lake floor. In order to produce a unique lake stage for the total water within the control volume, a stage-volume curve was also derived.

The hydrologic processes included in the water budget model are:

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

A daily time-step is used in the water budget model, to track inputs, outputs and lake volume, with the express purpose of calculating daily lake level estimates. The calibration period for the Lake Linda water budget model ranges from January 2010 to July 1, 2018. The need to develop a reasonable period of water level record, and to provide an efficient balance of usable data for all parts of the water budget, was best served by this selected period. Temporal constraints on data included structural changes to the lake. The model inputs are summarized in Table 1.

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

INPUT VARIABLE	VALUE
Overland Flow Watershed Size (acres)	72.0
SCS CN of Watershed	66
Percent Directly Connected	0.01
Fl. Aq. Monitor Well(s) Used	Wilson Fldn Repl (SID 18508)
Surf. Aq. Monitor Well(s) Used	Wilson Surf Repl (SID 18509)
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.0015
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.012
Outflow with Bricks K	0.16
Outflow Invert #1 with Bricks (ft NGVD29)	65.6
Outflow #2 K	0.16
Outflow Invert #2 (ft NGVD29)	66.5

E. Water Budget Model Components

Lake Stage/Volume

Estimations of lake stage area and stage volume were determined with the development of a terrain model of the lake and proximate watersheds. Utilizing LP360 (by QCoherent) for ArcGIS, ESRI's ArcMap 10.6, the 3D Analyst ArcMap Extension, Python, and XTools Pro, a model was constructed with the lake bottom and land surface elevations. By merging the terrain morphology of the lake drainage basin with that of the underlying lake basin, a single, continuous three-dimensional (3D) digital elevation model (DEM) was created. The 3D DEM was subsequently used to calculate overall lake area, as well as the associated volume of the lake at various elevations. The starting point was the extent of the lake from its flood stage, moving progressively downward to the lowest elevation within the basin.

Precipitation

After thorough review of available rainfall data in the region surrounding Lake Linda, for the selected water budget model period, a combination of the following rain gauges and data were selected: Lake Como (NOAA) rain gauge (SID 19493; approximately 0.63 miles to the south-southwest of Lake Linda), South Pasco (district) rain gauge (SID 22870; approximately 1.73 miles west-northwest), Lutz (District) rain gauge (SID 19629; approximately 1.76 south-southwest), Lake Padgett (District) rain gauge (SID 19431; approximately 1.25 northeast), and NEXRAD data from pixel 104119. Gauges denoted (NOAA) are operated by the National Oceanic and Atmospheric Administration, and those denoted (District) are operated by the District. NEXRAD (Next Generation Weather Rad) is a network of 160 high-resolution Doppler radar stations collaboratively controlled by the National Weather Service, Air Force Weather Agency, and Federal Aviation Administration. The primary objective in selecting data was to utilize what was closest, but also appeared to be of the highest quality available (Figure 8).

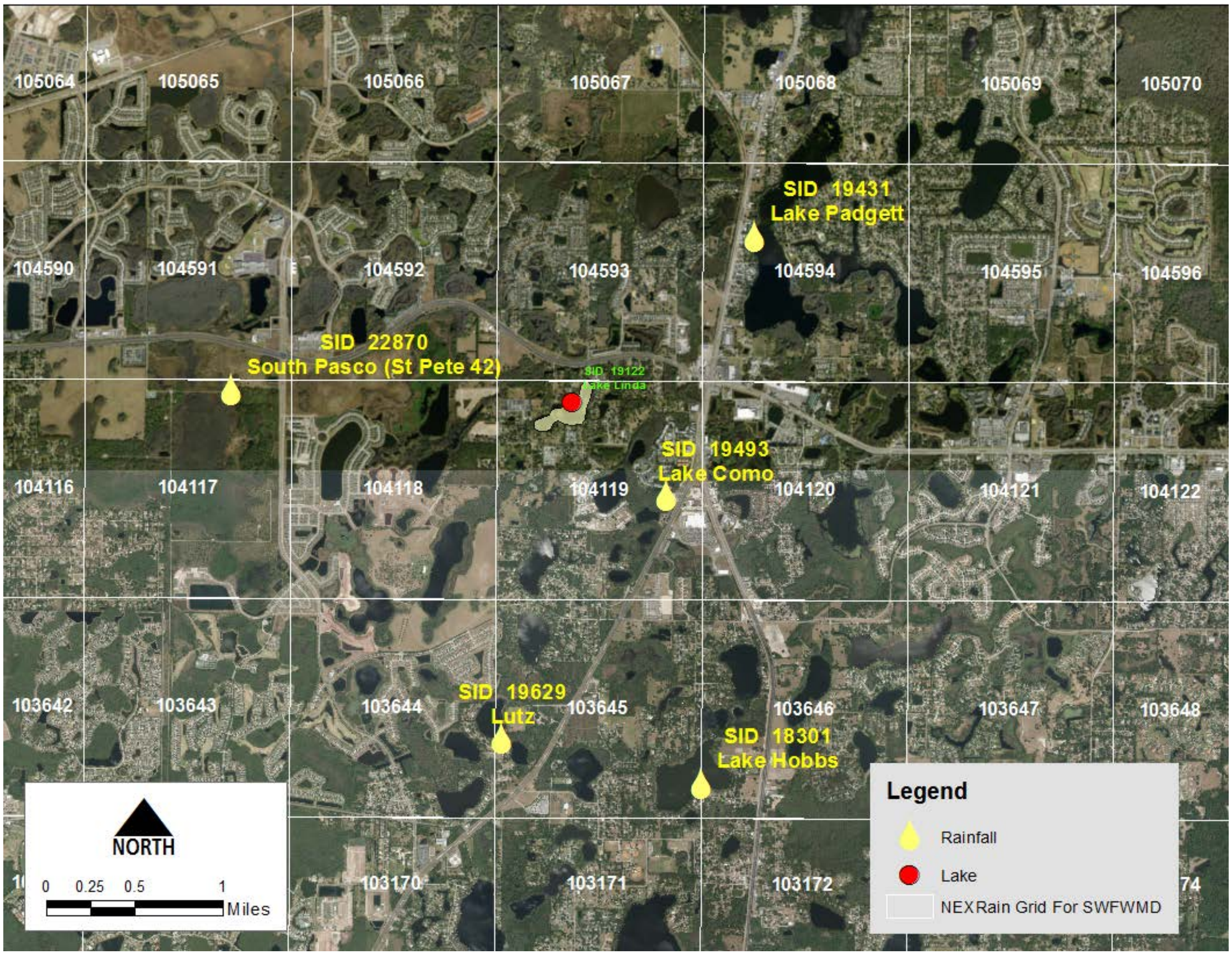

Figure 8. Rain gages and NEXRAD pixel (104119) used in the Lake Linda water budget model.

Lake Evaporation

A database of monthly energy budget data collected by the U.S. Geological Survey (USGS) at Lake Starr in Polk County was used to estimate lake evaporation between August 1996 and July 2011 (Swancar et al., 2000) (Figure 9). These data were used in the Lake Linda water budget model for the abovementioned timeframe, while monthly averages for the overall period of record were used for months that fell outside the window of August 1996 to July 2011.

Evidence of a recent study comparing monthly energy budget evaporation data at both Lake Starr and Calm Lake (Swancar, 2011, personal communications) revealed the conclusion that the evaporation rates at both were nearly indistinguishable. Only minute differences existed, which were most attributed to measurement error and monthly variances in latent heat associated with discrepancies in lake depth. Calm Lake is approximately 7.1 miles (center to center) to the west-southwest of Lake Linda (Figure 9).

In 2007, Jacobs produced daily potential evapotranspiration (PET) estimates across the entire state of Florida, on a 2-square kilometer grid. The calculations were performed using solar radiation data measurements from a Geostationary Operational Environmental Satellite (GOES), commencing in 1995 and continuously updated on an annual basis. The data is accessible through a website maintained by the U.S. Geological Survey. Given that PET is essentially equivalent to lake evaporation over open water areas, there was some consideration given to using derived values from the grid nodes over Lake Linda for the model. Ultimately, using the Lake Starr evaporation data was determined most appropriate, due to GOES data nodes typically including both upland and lake estimates with no clear method of delineation between the two. The presumption was that using the PET estimates could, conversely, increase model error.

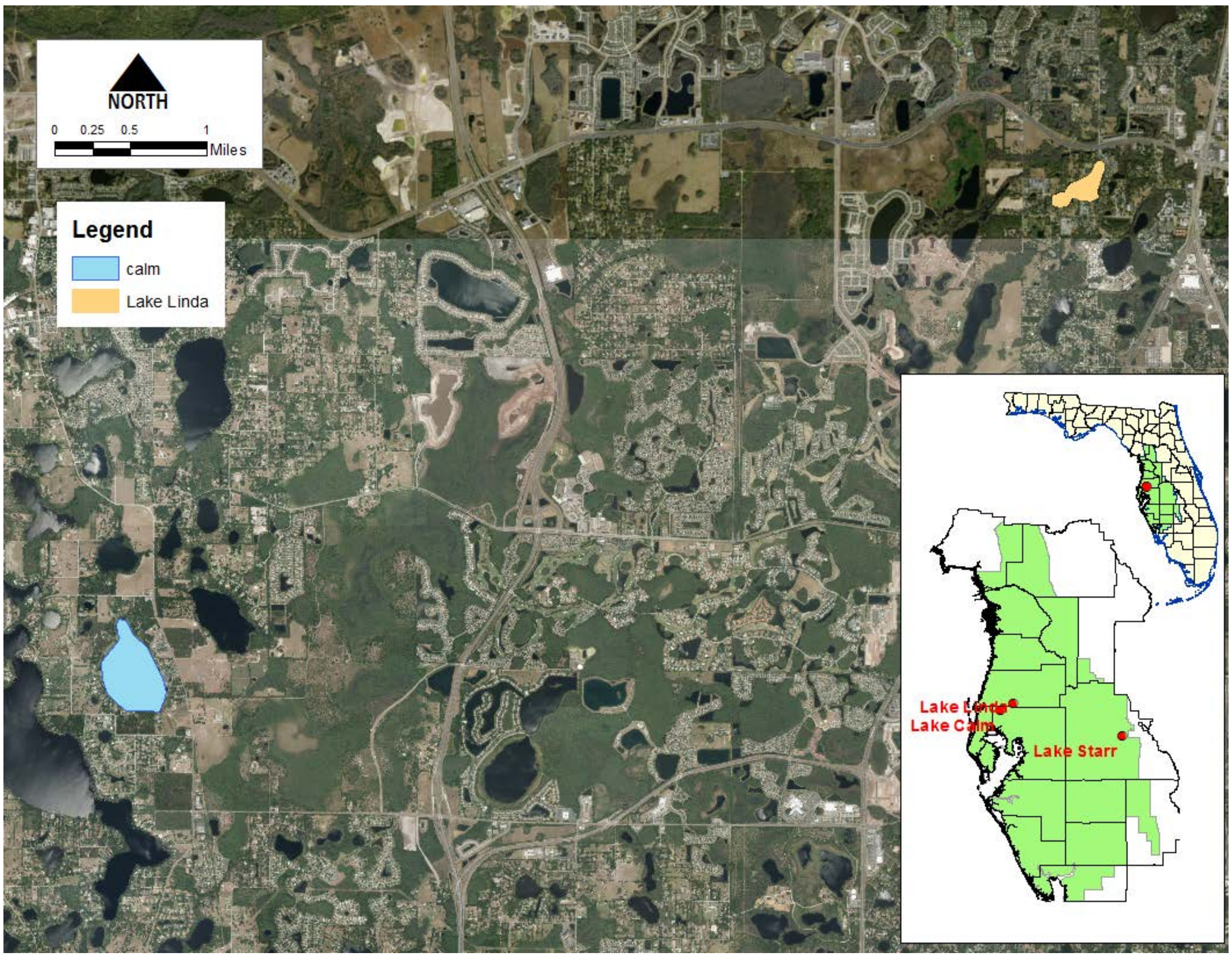

Figure 9. Location of Lakes Calm, Linda and Starr (see map inset).

Overland Flow

Using a modified version of the U.S. Department of Agriculture, Soil Conservation Service (SCS) Curve Number method (SCS, 1972), the water budget model was tailored to estimate overland flow for Lake Linda. In addition to this, directly connected impervious area calculations were also employed. At each individual timestep, the free water area of each lake was subtracted from the total watershed area. This permits an estimate of what portion of the watershed contributes to surface runoff. For the SCS calculation, the directly connected impervious area (DCIA) is subtracted from the watershed. The curve number (CN) selected for the watershed of the modeled lake takes the separately handled amount of DCIA into consideration.

The outlined, modified method was suggested for use in the state of Florida by CH2M HILL (2003) and has since been used in a multitude of other analyses. Modification of the original SCS method (SCS, 1972) adds a fourth category of antecedent moisture condition (AMC), which specifically accounts for Florida's frequency of rainfall events.

Surrounding topography at Lake Linda is relatively flat, making the determination of watersheds on subtle divides somewhat of a challenge. The watershed utilized in the Lake Linda water budget model was estimated in ArcMap and confirmed by Engineering and Watershed Management within the Water Resources Bureau at the District (Figure 10).

Shown in Table 1 are the DCIA and SCS CN used for the direct overland flow portion of the watershed. The assessment of curve numbers is a difficult process given that most of the soils in the area are A/D. This means that their characteristics are highly dependent on how sufficiently they're drained. Typically, a "D" soil exhibits a higher level of runoff per quantity of rain than is observed with an "A" soil. Given the proximity of the modeled area to the regional well-fields, water levels have historically been lowered by the withdrawals, subsequently reducing the soil runoff rates and creating more "A" soil type conditions. In the period of model calibration, however, groundwater withdrawals were significantly reduced as compared to historic withdrawal rates. As a result, the soils in the area may have conversely begun to exhibit runoff properties more characteristic of "D" soils. Most of the watershed is comprised of Basinger, Narcoossee, Myakka fine sands and Quartzipsamments. The soils are predominately are A/D classification with a limited amount of A and B classifications.

Given the range of conditions associated with the model area, a CN was chosen lying somewhere between the two. Direct discharges were observed as negligible, so the DCIA of the watershed was set at 1.0 percent.

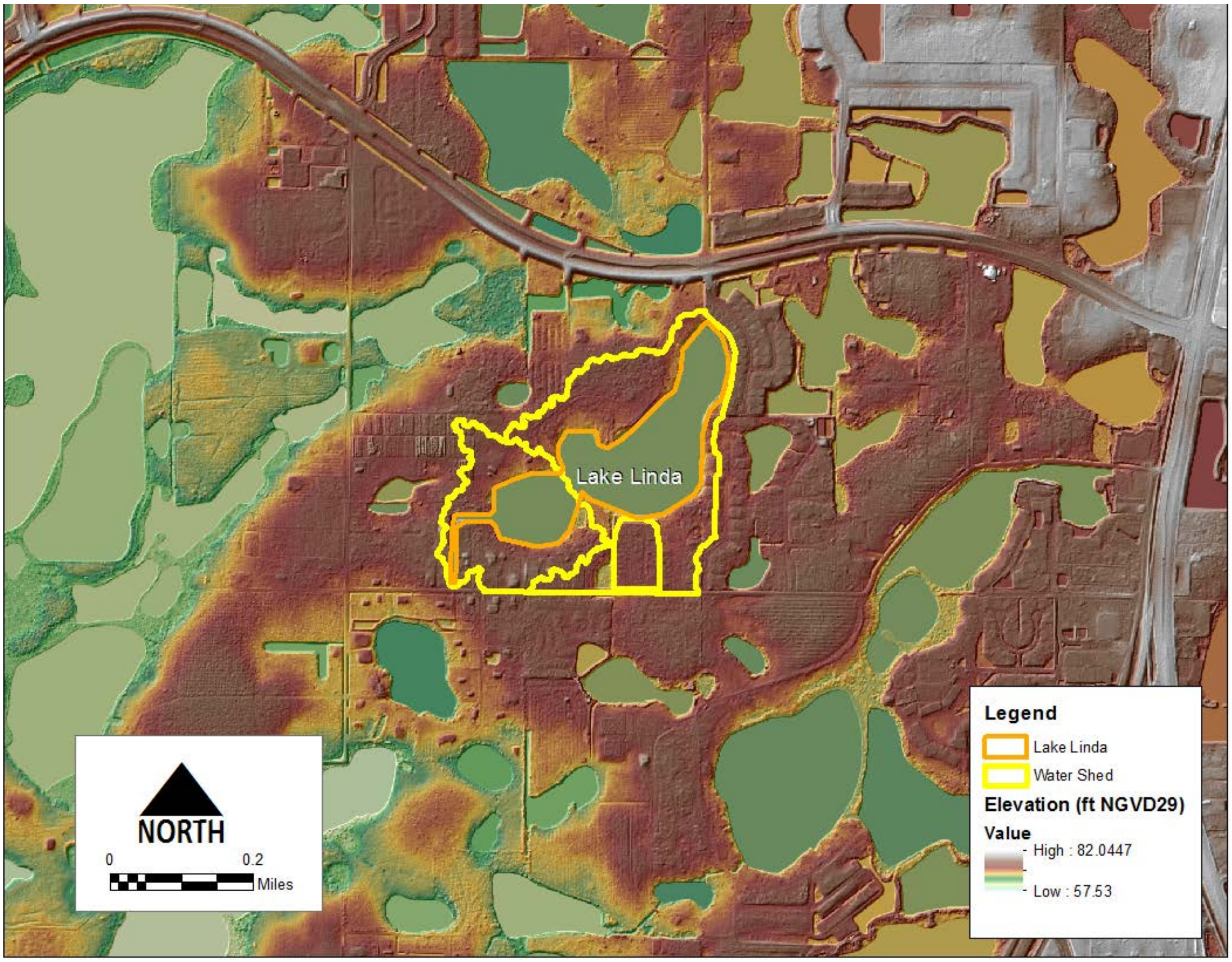

Figure 10. Watershed of Lake Linda as used in the water budget model.

Inflow and Discharge via Channels from Outside Watersheds

A highly significant component of the water budget for many southern Pasco County lakes is inflow/outflow via channels to or from the watershed. This is a necessary consideration, despite the relatively flat gradients of the channels, and inflows typically only occurring during high rainfall events. The development of minimum and guidance levels is partially dependent on basin classification. Open basin lakes are systems that either connect to or are a part of an ordered surface water conveyance system (i.e., they have inlets or outlets that facilitate the conveyance of surface water). Closed basin lakes, on the contrary, are not part of an ordered conveyance system. Based on Lake Linda's outfall structure – and the conveyance of water from the north shore to stormwater systems that drain toward Camp Lake, it has been classified as an open basin lake. Inflow to the lake was assumed to be negligible and wasn't incorporated into the water budget model.

In 2004, a single-family residential development (Environmental Resource Permit 23232) was completed modifications to the outlet structure for Lake Linda were made in the same timeframe. The structure was upgraded and conveyance properties may have been improved, thus the water budget model developed utilized data form 2010 on to preform model calibration to ensure effects from the recent modifications were fully captured. Based on a survey, the outlet elevation is 65.6 feet NGVD29. Sometime after structure construction was completed someone modified it by adding two layers of brick and mortar to raise the invert. This modification was removed in June 2018 by the HOA in response to a request of the District. The modification appeared to have been in place for a longtime, although the actual modification date is unknown. For the purposes of this model it is assumed the bricked structure was in place up to July 2018 and the model was calibrated to this period using a structure elevation of 66.1 ft NGVD29.

To estimate flow out of Lake Linda in the water budget model, the predicted elevation of the lake from the previous day is compared to the controlling elevation. If the lake elevation is above the controlling elevation, the difference is multiplied by the current area of the lake and an "outflow coefficient." The coefficient represents a measure of channel and structure efficiency and produces a rough estimate of volume lost from the lake. This volume is then subtracted from the current estimate of volume in the lake.

Flow from and into the Surficial Aquifer and Upper Floridan aquifer

The exchange that takes place between Lake Linda and underlying aquifers is approximated using a leakance coefficient, as well as the head difference between the lake and the aquifer levels. At each individual model time step, both Upper Floridan and surficial aquifer leakage volumes were calculated independently. Leakance coefficients for each aquifer were determined in the calibration process.

Upper Florida Aquifer. The Upper Florida aquifer monitor well closest in proximity to Lake Linda with data covering he model calibration period is Wilson Fldn Repl (SID 18508) (Figures 4 and 5). The well is located northeast of the lake which is potentiometrically higher by approximately 2 ft. The 2 ft. downward adjustment of the Wilson well resulted in an improvement in the water budget model calibration and was deemed appropriate for the model. Periods of missing data were infilled by using the last level recorded for half the missing period and the next actual level for the remainder of the missing period.

Surficial aquifer. The surficial aquifer monitor well nearest Lake Linda is the Wilson well (SID 19430)—located approximately 1,000 feet from the northwestern shore of Lake

Linda—for which data begins in December 2004 (Figures 4 and 5). The Wilson surficial well was relocated approximately 1,500 feet from the lake with the Wilson Surficial Replacement Well (SID 18509). The data record for the new well begins in September 2000 covering the entire water budget model calibration period. Throughout the period of record, data collection has typically occurred daily, except for the first three years being weekly. An elevation adjustment of positive 0.5 feet was made to the water levels to account for the higher topographic condition south east of the lake.

F. Water Budget Model Approach

The principle objective in the development of a water budget model is the estimation of Historic lake stage exceedance percentiles, which are used to support the development of Minimum and Guidance Levels for the lake. Model calibration, as such, focuses on matching long-term percentiles based on measured water levels, versus 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.

The calibration results for the model are shown in Figure 11. A comparison of the percentiles of the measured data versus model results can be found in Table 2, whereas Table 3 presents the water budget components utilized for model calibration.

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 11, the model appears to be reasonably well calibrated. A review of Table 2 shows that the P10, P50 and P90 percentiles between the lake data and model are within 0.03 to 0.4 feet. There are periods when the peaks in the modeled hydrograph are higher or lower than the measured values, and these differences contributed to minor differences between the modeled and measured percentiles associated with higher and lower lake levels, i.e., the P10 and P90 percentiles. The minimum and maximum differences (measured minus modeled) are -0.9 and 0.8 feet, respectively

The water budget component values in the model are expressed as inches per year over the average lake area for the period of the model run. Leakage rates (and leakance coefficients), for example, represent conditions below the lake only, and may be very different than those values expected in the general area. Runoff also represents a volume over the average lake area, and when the resulting values are divided by the watershed area, they represent low runoff rates.

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

	Data	Model
P10	66.02	65.98
P50	65.31	65.35
P90	64.45	64.42

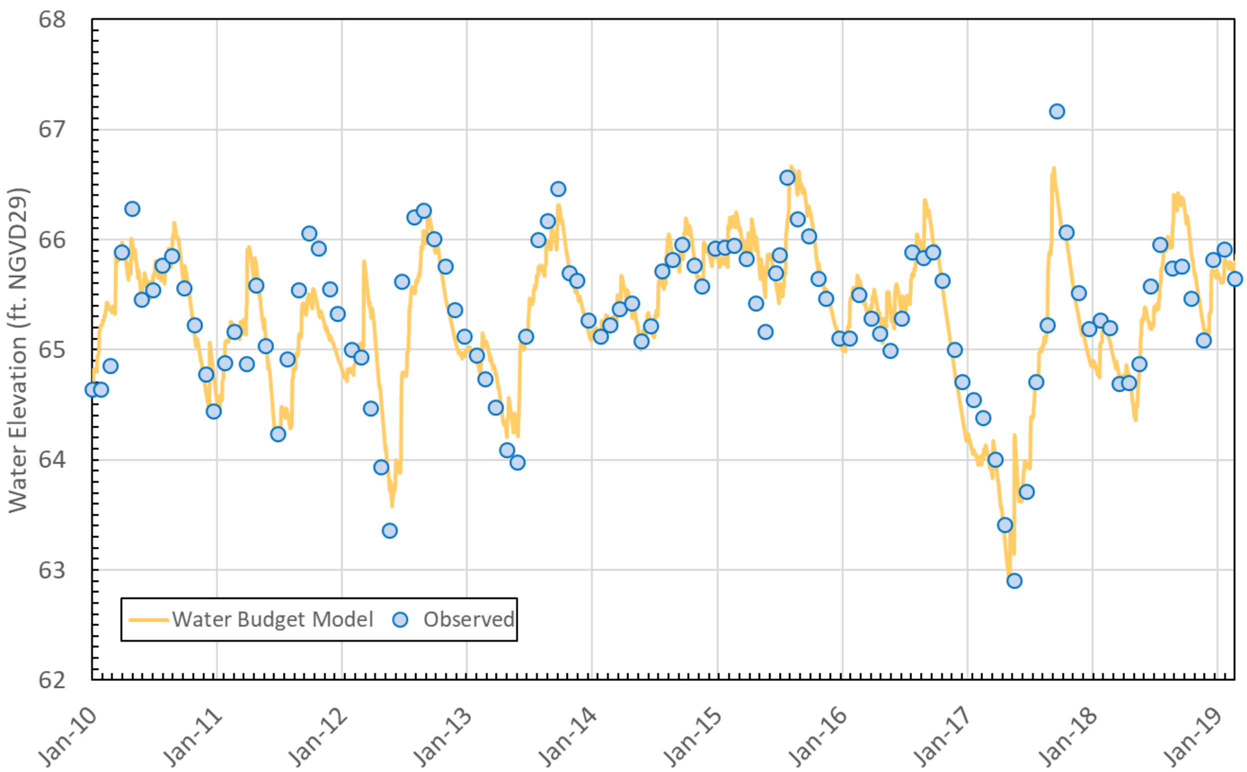

Figure 11. Modeled water levels predicted for the calibrated Lake Linda water budget model and measured levels used for the model calibration.

Table 3. Lake Linda Water Budget (January 2010 to July 1, 2018).

Inflows	Rainfall	Surficial Aquifer Groundwater Inflow	Floridan Aquifer Groundwater Inflow	Runoff	DCIA Runoff	Augmen-tation	Total
Inches/year	55.8	25.8	0.0	14.8	0.5	0.0	94.2
Percentage	57.0	27.4	0.0	15.1	0.5	0.0	100
Outflows	Evaporation	Surficial Aquifer Groundwater Outflow	Floridan Aquifer Groundwater Outflow			Outflow via channel	Total
Inches/year	58.2	6.8	29.3			0.07	95.0
Percentage	61.1	7.2	31.0			0.07	100

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the Lake Linda water budget model but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from regional wellfields are available throughout the period of the calibrated model, so if a relationship between withdrawal rates and Upper Floridan aquifer potentiometric levels can be established, the effect of changes in groundwater withdrawals can be estimated by adjusting Upper Floridan aquifer levels in the model. Since the water table in the model is not active, and because of the leaky nature of the confining unit around Halfmoon Lake, the relationship between groundwater withdrawals in the Upper Floridan and water levels in the surficial aquifer was also of interest.

The Integrated Northern Tampa Bay (INTB) model is an integrated model developed for the northern Tampa Bay area (Geurink and Basso, 2013). 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 Halfmoon Lake area and represents the most current understanding of the hydrogeologic system in the area. Using the drawdowns determined using INTB model scenarios, the Upper Floridan aquifer and surficial monitor well data in the model can be adjusted to reflect changes in groundwater withdrawals.

To estimate lake levels without the influence of groundwater withdrawals, the Upper Floridan aquifer and surficial aquifer wells in the water budget model were adjusted to represent zero withdrawals. Given the time period of the water budget model, a single adjustment period is used, corresponding to the long-term average drawdown after the cutbacks that took place at the South Pasco wellfield. Adjustments to each Upper Floridan aquifer and surficial aquifer well for this period are found in Table 4.

In addition to the drawdown correction, the additional invert height due to the vigilante two brick high with mortar modification was removed from the invert height in the model. The modification was removed in June 2018 per the request of the District.

Table 4. Aquifer water level adjustments to the Lake Linda water budget model to represent Historic percentiles.

Well	Adjustment (feet) 2010 through 2018
Floridan aquifer	1.5
Surficial aquifer	0.8

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

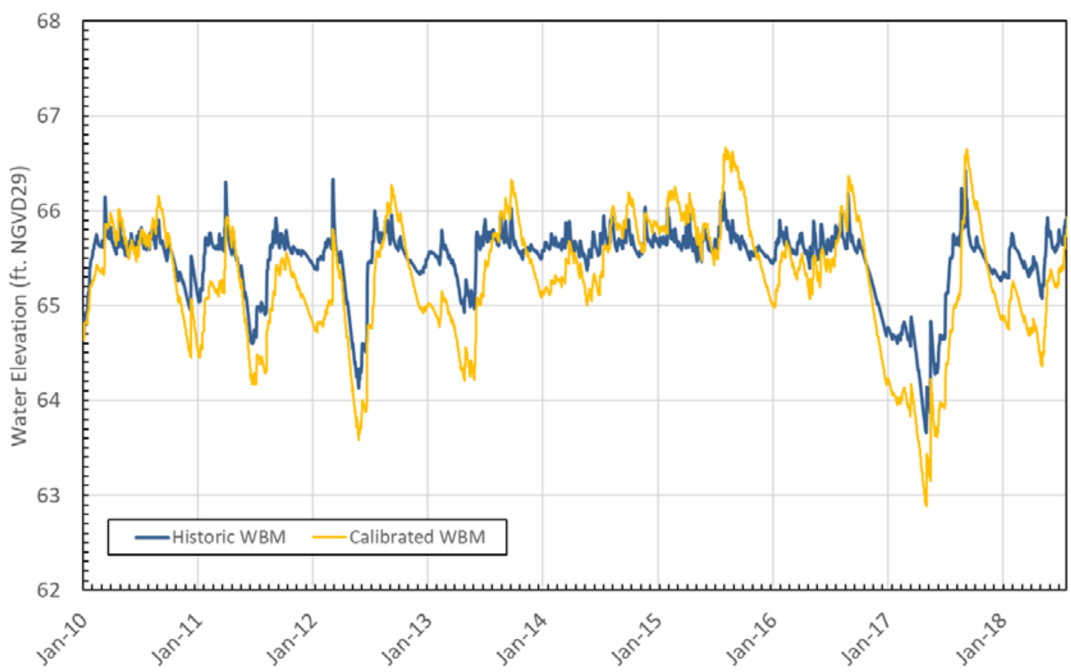

Figure 12. Calibrated Water Budget Model and Historic water levels predicted using the calibrated Lake Linda model adjusted for drawdown.

Table 5. Historic percentiles (in feet NGVD29) estimated using the Lake Linda water budget model (2010 to July 2018).

Percentile	Elevation
P10	65.8
P50	65.6
P90	65.0

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, water budget model simulated lake water levels that represent Historic conditions were correlated with Long-term rainfall data. For the correlation, additional rainfall data were added to those that were utilized in the water budget model creating a rainfall record back to 1936. The rainfall series consists of NEXRAD data back to 1995 (Figure 11), a combination of the Lutz (SID 19629), South Pasco (SID 22870), Lake Padgett (SID 19431) rain gauges back to 1963 and St Leo NWS (SID 18901) gage back to 1936 with minor infilling with the Tarpon Springs gage (SID 22881). The closest gage with data was used and missing data was infilled with the next closest gage.

A linear inverse weighted sum is applied to the rainfall data to correlate it to lake water level. More weight is given to more recent rainfall by the weighted sum, versus less to rainfall in the past. Weighted sums that vary from 6 months to 10 years are utilized separately, the results are compared, and the correlation with the greatest correlation coefficient (R^2) is selected as the best model.

Rainfall was correlated with the water budget model results from 2010 to July 2018 (Figure 13). The daily lake water elevations for Lake Linda, from January 1946 to July 2018, are produced by way of this stage-rainfall relationship. In the case of Lake Linda, the 1-year weighted model has the highest correlation coefficient, with an R2 of 0.34. The results are presented in Figure 16, which gives insight into the lake's predicted behavior without the effects of withdrawals.

To generate Historic percentiles that apply substantial weight to the water budget model results, the rainfall LOC outputs for the period of the water budget model are substituted by the water budget model results. The LOC rainfall model results are, therefore, used for the period of January 1946 through December 2009, while the water budget results are utilized for the period of January 2010 to July 2018. These results comprise what is referred to as the “hybrid model”; the resulting percentiles are presented in Table 6.

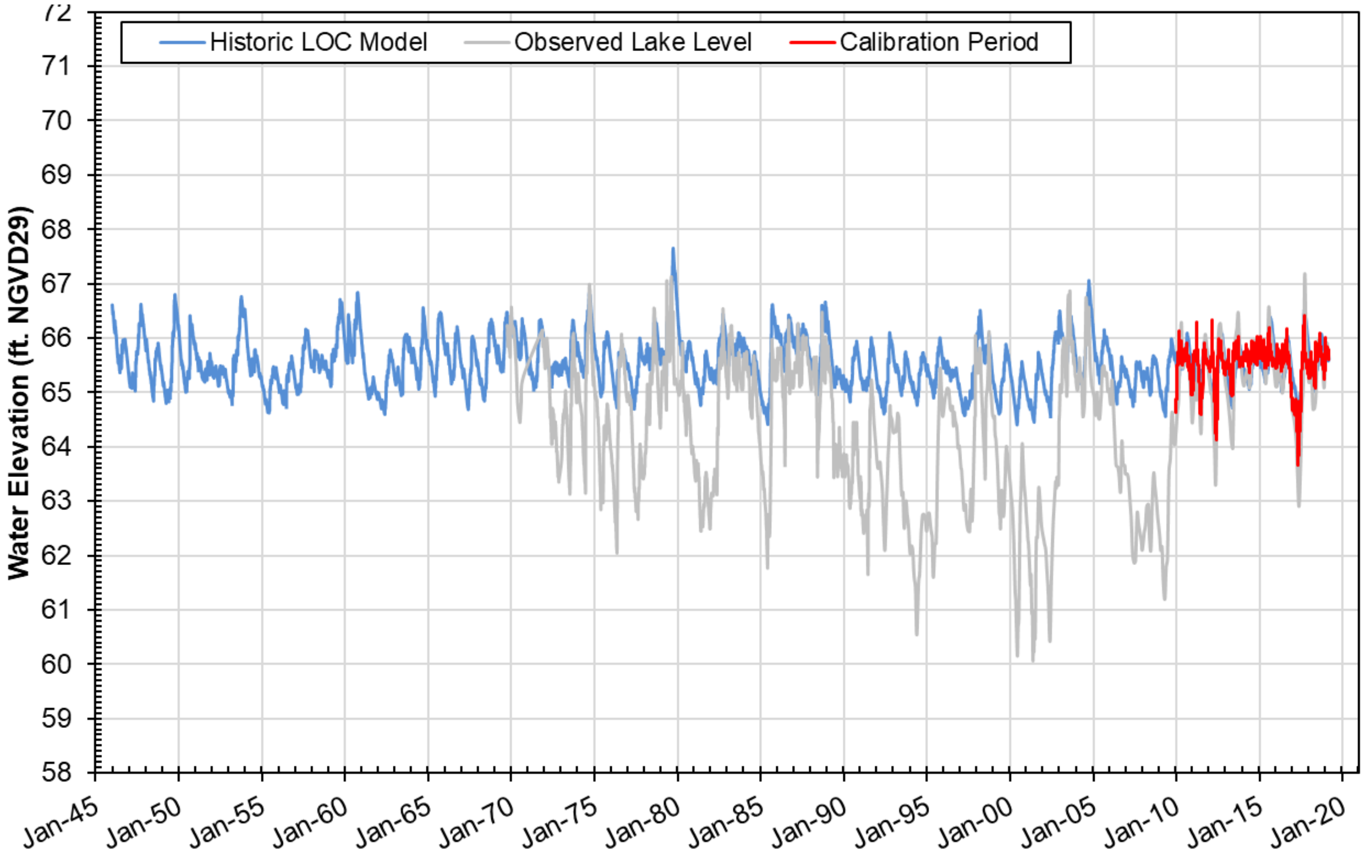

Figure 16. Historic LOC model (blue line), water budget (red line) and observed water level (gray line) for Lake Linda.

Table 6. Historic percentiles as estimated by the hybrid model from January 1946 to July 2018 (feet NGVD29).

Percentile	Lake Linda
P10	66.1
P50	65.5
P90	65.0

J. Conclusions

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

K. References

Biological Research Associates. 1996. Use of lasting indicators of historic inundation patterns in isolated wetlands as reference elevations to determine areal extent and intensity of reduced water levels near areas of groundwater withdrawals. Report submitted to the West Coast Regional Water Supply Authority. November 1996.

Bredehoeft, J.D., I.S. Papadopulos, and J.W. Stewart. 1965. Hydrologic Effects of Ground-Water Pumping in Northwest Hillsborough County, Florida. Open File Report 65001. U.S. Geological Survey.

Brooks, H.K. 1981. Physiographic divisions of Florida: map and guide. Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.

CH2M HILL. 2003. Local Runoff Prediction for the Lower Hillsborough River and Tampa Bypass Canal Watersheds. Draft Technical Memorandum. Prepared for Tampa Bay Water. Clearwater, FL.

CH2M HILL Engineers, Inc. 2016. Hillsborough County Northwest Five Watershed Management Plan Update. Prepared for Hillsborough County and the Southwest Florida Water Management District. October 2016.

Geurink, J.S. and R. Basso. 2013. Development, Calibration, and Evaluation of the Integrated Northern Tampa Bay Hydrologic Model. Prepared for Tampa Bay Water and Southwest Florida Water Management District. March 2013.

Hancock, M.C. and R. Basso. 1996. Northern Tampa Bay Water Resource Assessment Project: Volume One. Surface-Water/Ground-Water Interrelationships. Southwest Florida Water Management District. Brooksville, Florida.

Helsel D.R. and R.M Hirsch. 2002. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations of the United States Geological Survey. Book 4, Hydrologic Analysis and Interpretation. Chapter A3. U.S. Geological Survey.

Hull, H.C., J.M. Post Jr., M. Lopez, and R.G. Perry. 1989. Analysis of water level indicators in wetlands: Implications for the design of surface water management systems. In Wetlands: Concerns and Successes. Proceeding of the American Water Resources Association, Tampa. D. Fisk (ed.), pages 195-204.

Jacobs, J. 2007. Satellite-Based Solar Radiation, Net Radiation, and Potential and Reference Evapotranspiration Estimates over Florida: Task. 4. Calculation of Daily PET and Reference ET from 1995 to 2004. University of New Hampshire.

Metz, P.A and L.A. Sacks. 2002. Comparison of the Hydrogeology and Water Quality of a Ground-Water Augmented Lake with Two Non-Augmented Lakes in Northwest Hillsborough County, Florida. Water-Resources Investigations report 02-4032. U.S. Geological Survey.

Metz, P.A. 2011. Factors that Influence the Hydrologic Recovery of Wetlands in the Northern Tampa Bay Area, Florida. Scientific Investigations Report 2011-5127. U.S. Geological Survey.

Miller, J.A. 1986. Hydrogeologic framework of the Floridan aquifer system in Florida and in parts of Georgia, Alabama, and South Carolina. U.S. Geological Survey Water-Resources Investigations Report.

Sinclair, W.C. 1973. Hydrogeologic Characteristics of the Surficial Aquifer in Northwest Hillsborough County, Florida. Open File Report 73023. U.S. Geological Survey.

Sinclair, W.C. 1982. Sinkhole Development resulting from Ground-Water Withdrawal in the Tampa Area, Florida. Water Resources Investigations 81-50. U.S. Geological Survey.

Sinclair, W.C., J.W. Stewart, R.L. Knutilla, and A.E. Gilboy. 1985. Types, Features, and Occurrence of Sinkholes in the Karst of West-Central, Florida. Water Resources Investigations report 85-4126. U. S. Geological Survey.

Soil Conservation Service. 1972. National Engineering Handbook. August 1972.

Southwest Florida Water Management District. 1988. Basis of Review for Surface Water Permit Applications in the Southwest Florida Water Management District.

Stewart, J.W. and G.H. Hughes. 1974. Hydrologic Consequences of Using Ground Water to Maintain Lake Levels Affected by Water Wells near Tampa, Florida. Open File Report 74006. U.S. Geological Survey.

Swancar, A., T.M. Lee, and T.M. O'Hare. 2000. Hydrogeologic Setting, Water Budget, and Preliminary Analysis of Ground-Water Exchange at Lake Starr, a Seepage Lake in Polk County, Florida. Water-Resources Investigations Report 00-4030. U.S. Geological Survey. Tallahassee, Florida.

DRAFT APPENDIX B

Technical Memorandum

July 1, 2020

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

FROM: Jason Paterson, P.G., Hydrogeologist, Water Resources Bureau
Don Ellison, P.G., Senior Hydrogeologist, Water Resources Bureau

Subject: Draft Lake Linda Initial Minimum Levels Status Assessment

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A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Lake Linda and is proposing revised minimum levels for the lake, in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the revised minimum levels is provided by Ellison and others (2019) and Carr 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 Lake Linda and other waterbodies with established minimum flows or levels in the northern Tampa Bay area, an applicable regional recovery strategy, referred to as the “Comprehensive Plan”, has been developed and adopted into District rules (Rule 40D-80.073, F.A.C.). One of the goals of the Comprehensive Plan is to achieve recovery of minimum flow and level water bodies such as Lake Linda that are in the area affected by the Consolidated Permit wellfields (i.e., the Central System Facilities) operated by Tampa Bay Water. This document provides information and analyses to be considered for evaluating the status (i.e., compliance) of the revised minimum levels proposed for Lake Linda and any recovery that may be necessary for the lake.

B. Background

Lake Linda is in south-central Pasco County, within the Land O’ Lakes region of west-central Florida (Figure 1). The lake lies within the Upper Rocky Creek Basin of the Southwest Florida Water Management District, in a sector designated by Brooks (1981) as the Tampa Plain division of the Ocala Uplift Physiographic District. It has further been characterized by its assemblage of small, neutral to slightly alkaline, low to moderate nutrient-enriched, clear-water lakes interspersed within the moderately thick silty-sand deposits that overlie the Tampa Limestone formation (Griffith et al. 1997). Topography in the abovementioned region is notably flat, with drainage into the area lakes consisting primarily of a combination of flow moving overland, as well as through drainage swales and secondary conveyance systems (Figure 2).

Lake Linda is located approximately 1.5 miles east of the South Pasco wellfield, and less than 4 miles northeast of the Section 21 wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 3). Groundwater withdrawals began at the Section 21 wellfield in 1963 and steadily climbed to approximately 20 mgd in 1967 (Figure 4). With the development of the South Pasco wellfield in 1973, withdrawal rates at the Section 21 wellfield were reduced to approximately 10 mgd, while withdrawal rates at the South Pasco wellfield quickly rose to 16 to 20 mgd, for a combined withdrawal rate ranging from 20 to 30 mgd in the mid to late 1970s. Combined withdrawal rates since 2005 have ranged from zero to nearly 20 mgd, with several extended periods when one wellfield or the other was shut down completely.

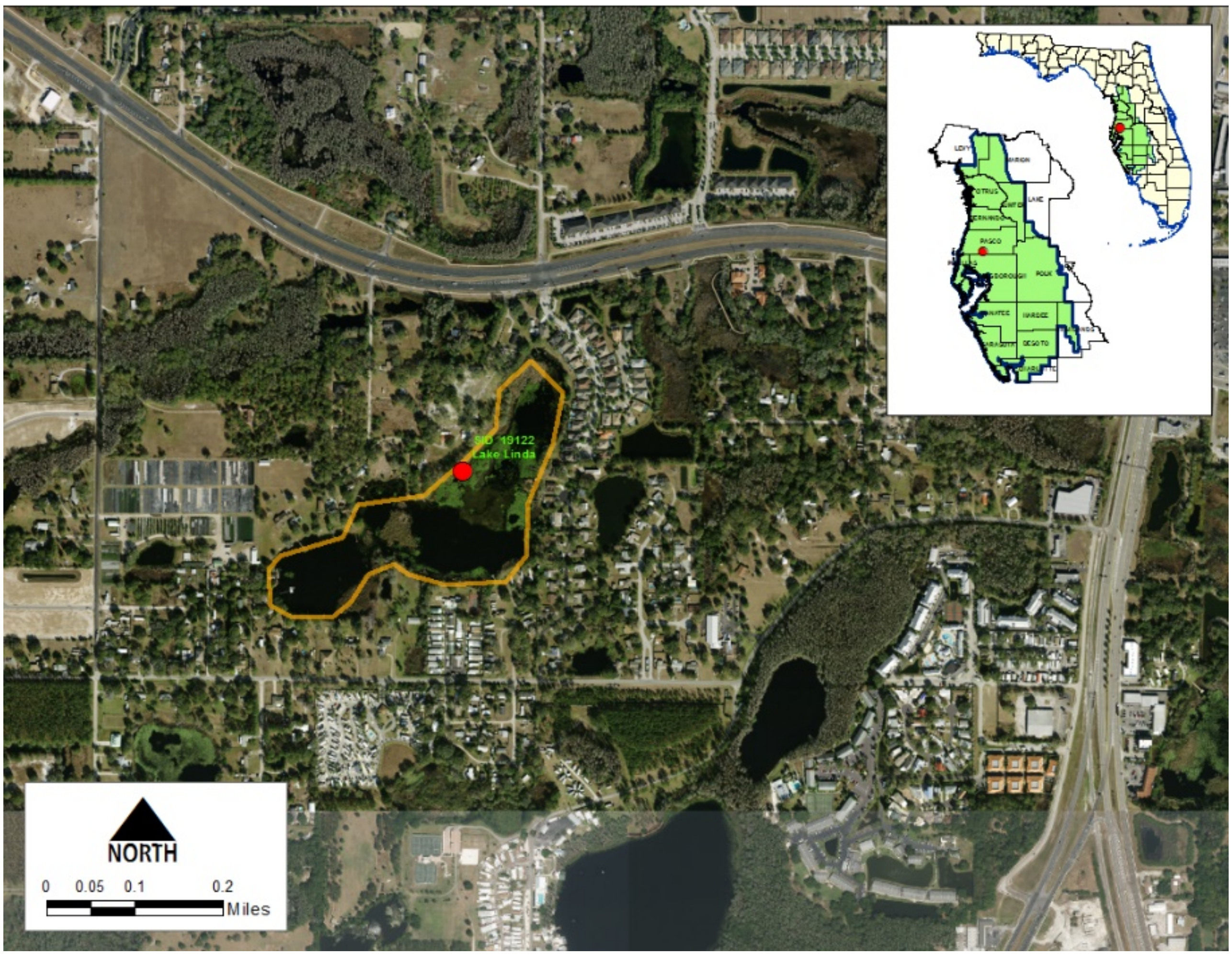

Figure 1. Location of Lake Linda in Hillsborough County, Florida.

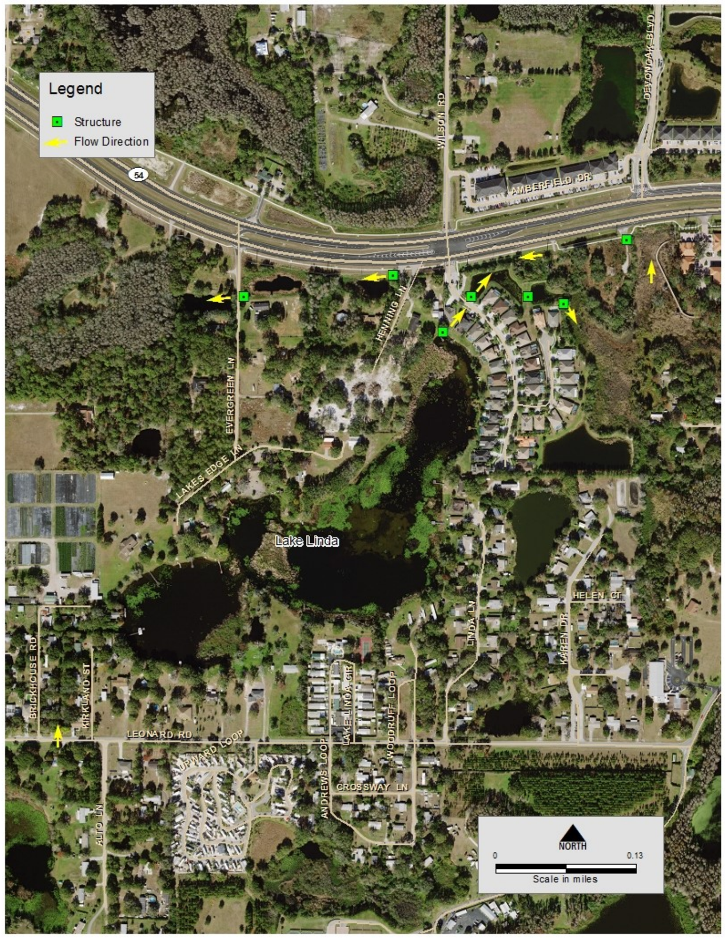

Figure 2. Approximate flow conveyance path from Lake Linda.

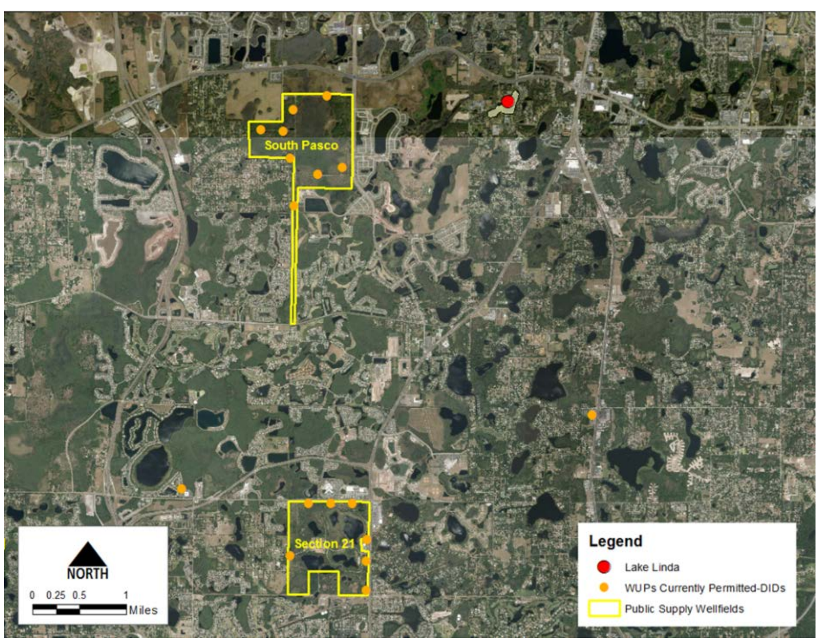

Figure 3. Lake Linda and the South Pasco wellfield.

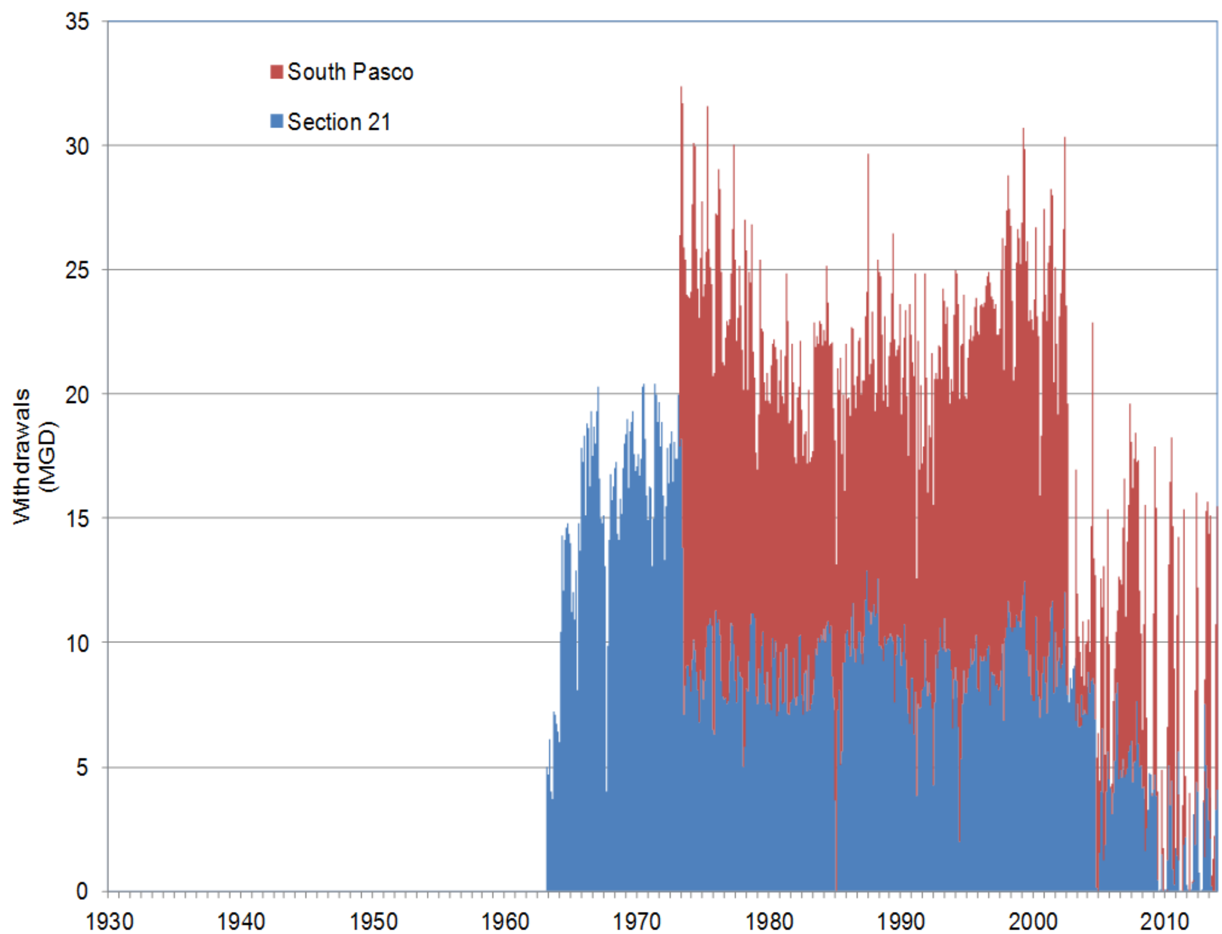

Figure 4. Average monthly withdrawals at the Section 21 wellfield. Horizontal black lines indicate the average production of the time period spanned by the line.

C. Revised Minimum Levels Proposed for Lake Linda

Revised minimum levels proposed for Lake Linda are presented in Table 1 and discussed in more detail by Carr and others (2020). Minimum levels represent long-term conditions that, if achieved, are expected to protect water resources and the ecology of the area from significant harm that may result from water withdrawals. The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. The Minimum Lake Level therefore represents the required 50th percentile (P50) of long-term water levels, while the High Minimum Lake Level represents the required 10^{th} percentile (P10) of long-term water levels. To determine the status of minimum levels for Lake Linda or minimum flows and levels for any other water body, long-term data or model results must be used.

Table 1. Proposed Minimum Levels for Lake Linda.

Proposed Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	65.6
Minimum Lake Level	65.0

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Lake Linda from July 2010 through 2019, which was determined to represent the "Current" period based on the removal of bricks from the outlet structure in 2018. The current period also contains the commencement of cutbacks at the neighboring Section 21 wellfield (Figures 3 and 4). As demonstrated in Ellison and others (2020), groundwater withdrawals during this period were relatively consistent. The Current period represents a recent "Long-term" period when hydrologic stresses (including groundwater withdrawals) and structural alterations are reasonably stable. "Long-term" is defined as a period that has been subjected to the full range of rainfall variability that can be expected in the future. July 2018 is used as the start of the Current period in the following analyses.

To create a data set that can reasonably be considered "Long-term," a regression analysis using the line of organic correlation (LOC) method was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the *x* and *y* directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used to develop the minimum levels for Lake Linda (Ellison and others). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing over 70 years of lake levels, based on the current relationship between lake water levels and actual rainfall.

The same rainfall data set used for setting the minimum levels for Lake Linda was used for the status assessment (Ellison and others, 2019). The best resulting correlation for the LOC model created with measured data (July 2018 to December 2019) was the 1-year weighted period, with a coefficient of determination of 0.5. The results are presented in Figure 6, which displays the lake's predicted behavior under Current withdrawal conditions.

To characterize time error associated with the status model (Cameron et al., 2020), paired points of observed and modeled data from the calibration period were compared to assess the percentages of times that 1) paired modeled and observed data both fall above or below the minimum level (correct prediction), 2) the modeled data fell above the minimum level while paired observed data fell below (overprediction), and 3) the modeled data fell below the minimum level while paired observed data fell above (underprediction). Assuming that the errors from the calibration period are representative of errors for the entire modeled period, this provides an estimate of the error that may be present in the modeled status results. With respect to the MLL, the status model overpredicted 7% of the time and underpredicted 11% of the time, for a net error of -4% of the time. With respect to the HMLL, the status model overpredicted 6% of the time and underpredicted 17% of the time, for a net error of -11% of the time.

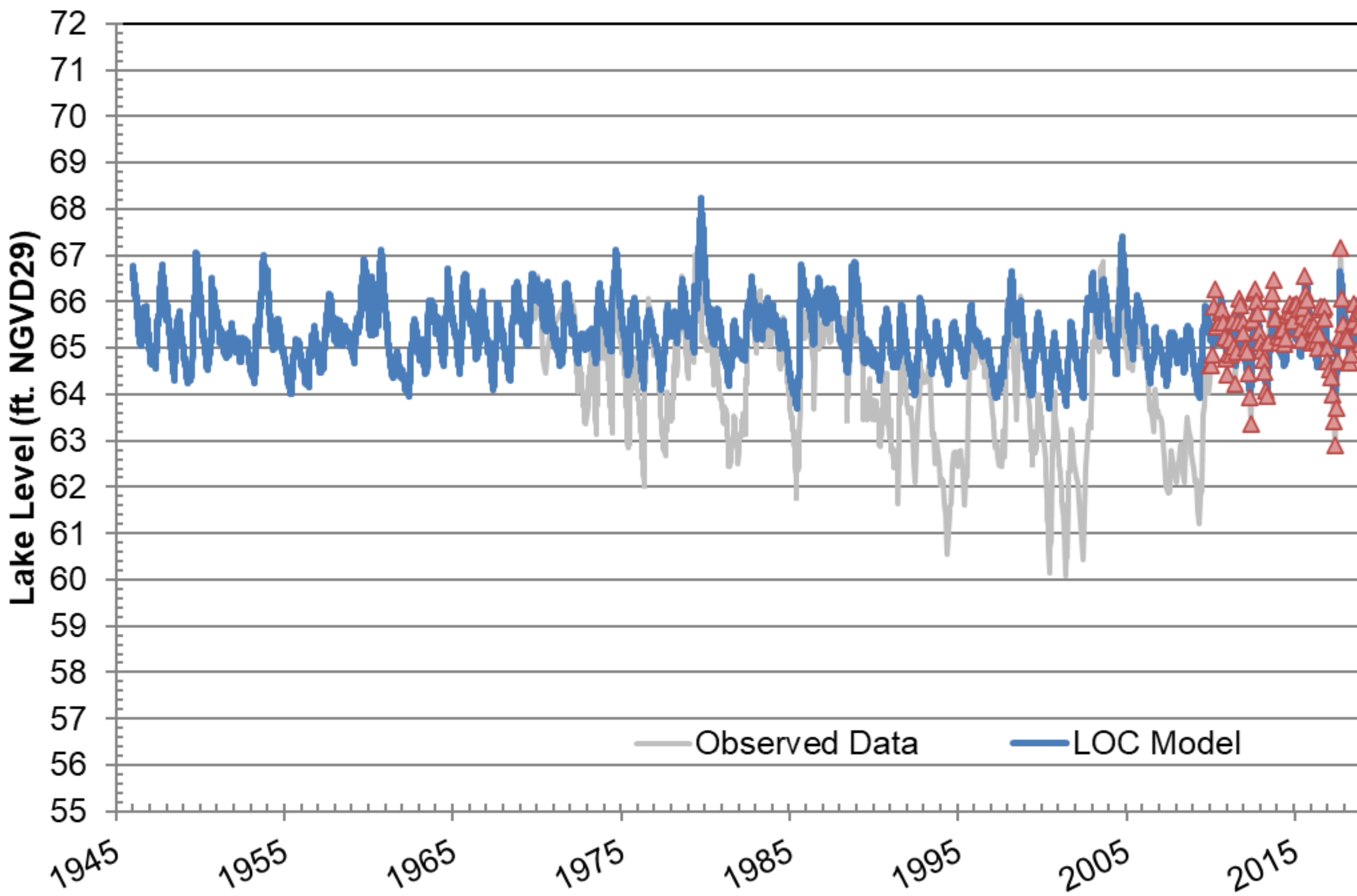

Figure 6. Current LOC model results (blue line), observed current data (red line) and full observed data (gray line) for Lake Linda.

A comparison of the current period LOC model with the revised minimum levels proposed for Lake Linda indicates that the Long-term P10 (66.1 ft NGVD29) is 0.5 feet above the proposed

High Minimum Lake Level, and the Long-term P50 (65.2 ft NGVD29) is 0.2feet above the proposed Minimum Lake Level.

E. Conclusions

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

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

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the January 2010 through December 2018 data, and the revised minimum levels proposed for Lake Linda. All elevations in feet NGVD 29.

Percentile	Proposed Minimum Levels	Long Term LOC Model Results (1946 through 2018)	LOC Model Results – Percentage of Time at or Above Level (1946 through 2018)
P10	65.6	66.1	30%
P50	65.0	65.2	66%

F. References

Cameron, C., Ellison, D., and Hancock, M. 2020. Draft Technical Memorandum to File, Subject: Expanded Summary of the Proposed MLL Status Assessment Error Analysis. Southwest Florida Water Management District. Brooksville, Florida.

Ellison, D.L. and others 2019. Technical Memorandum to D. Carr, Subject: Lake Linda Water Budget Model, Rainfall Correlation Model, and Historic Percentile Estimations. Southwest Florida Water Management District. Brooksville, Florida.

Helsel, D.R. and R.M. Hirsch. 2002. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations of the United States Geological Survey. Book 4, Hydrologic Analysis and Interpretation. Chapter A3. U.S. Geological Survey.

Carr, D., and others. 2019. Proposed Minimum and Guidance Levels for Lake Linda in Hillsborough County, Florida. Southwest Florida Water Management District. Brooksville, Florida.

APPENDIX C

Technical Memorandum

December 17, 2018

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

Jason Patterson, Hydrogeologist, Water Resources Bureau

Samantha Smith, Hydrogeologist, Water Resources Bureau

FROM: Cortney Cameron, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Lake Linda

1.0 Introduction

Lake Linda is located in south-central Pasco 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 Lake Linda is not part of this report. This memorandum describes the hydrogeologic setting near the lake and includes the results of two numerical model scenarios of groundwater withdrawals in the area.

2.0 Hydrogeologic Setting

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

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

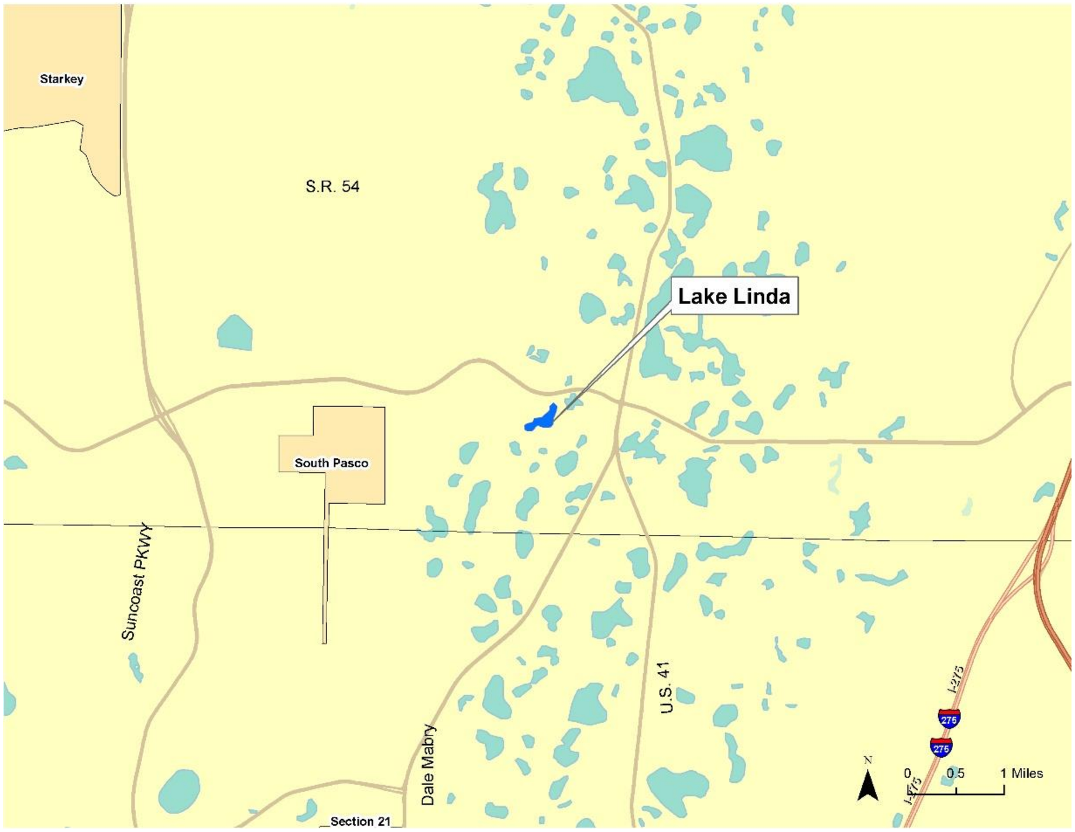

Figure 1. Location of Lake Linda.

3.0 Evaluation of Groundwater Withdrawal Impacts to Lake Linda

Several regional groundwater flow models have included the area around Lake Linda 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.

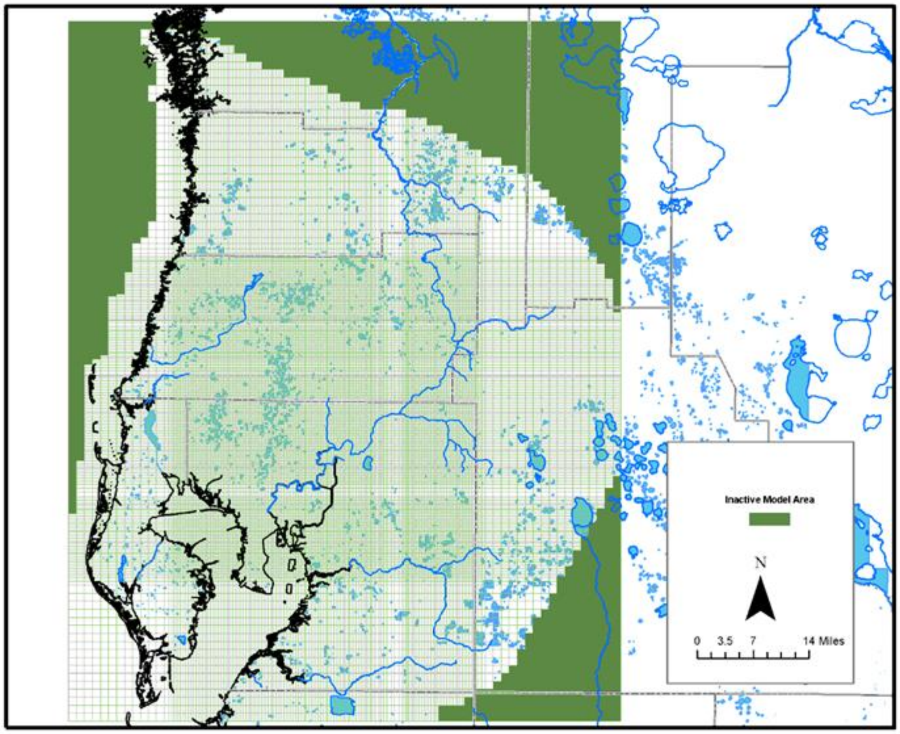

Figure 2. Groundwater grid used in the INTB model

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.

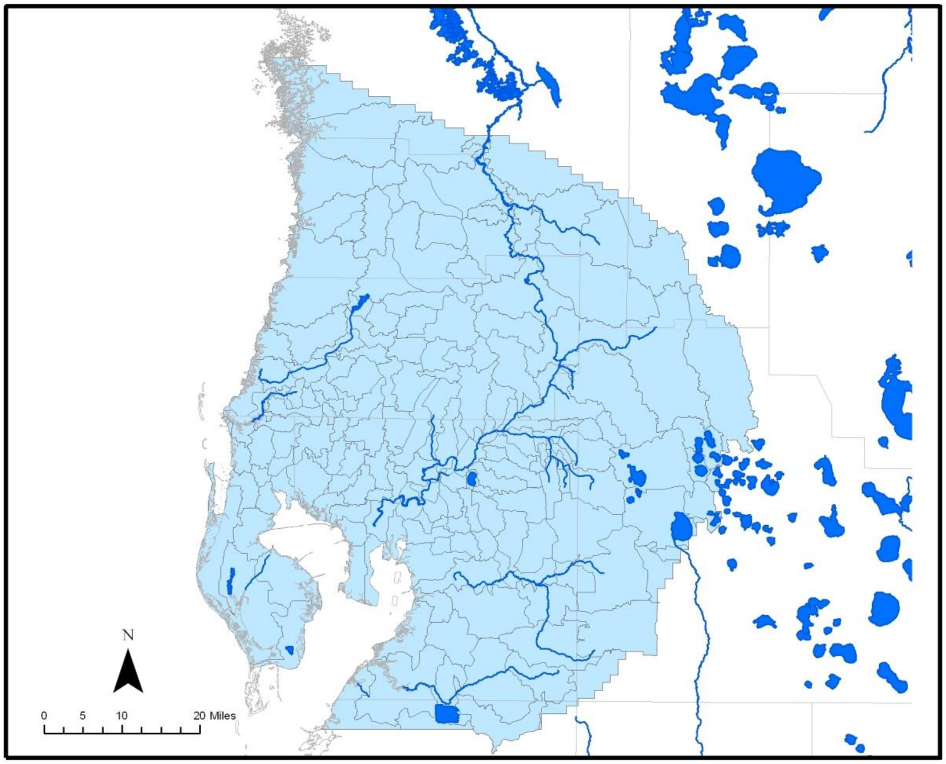

Figure 3. HSPF subbasins in the INTB model.

The INTB model is a regional simulation and has beenc 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.

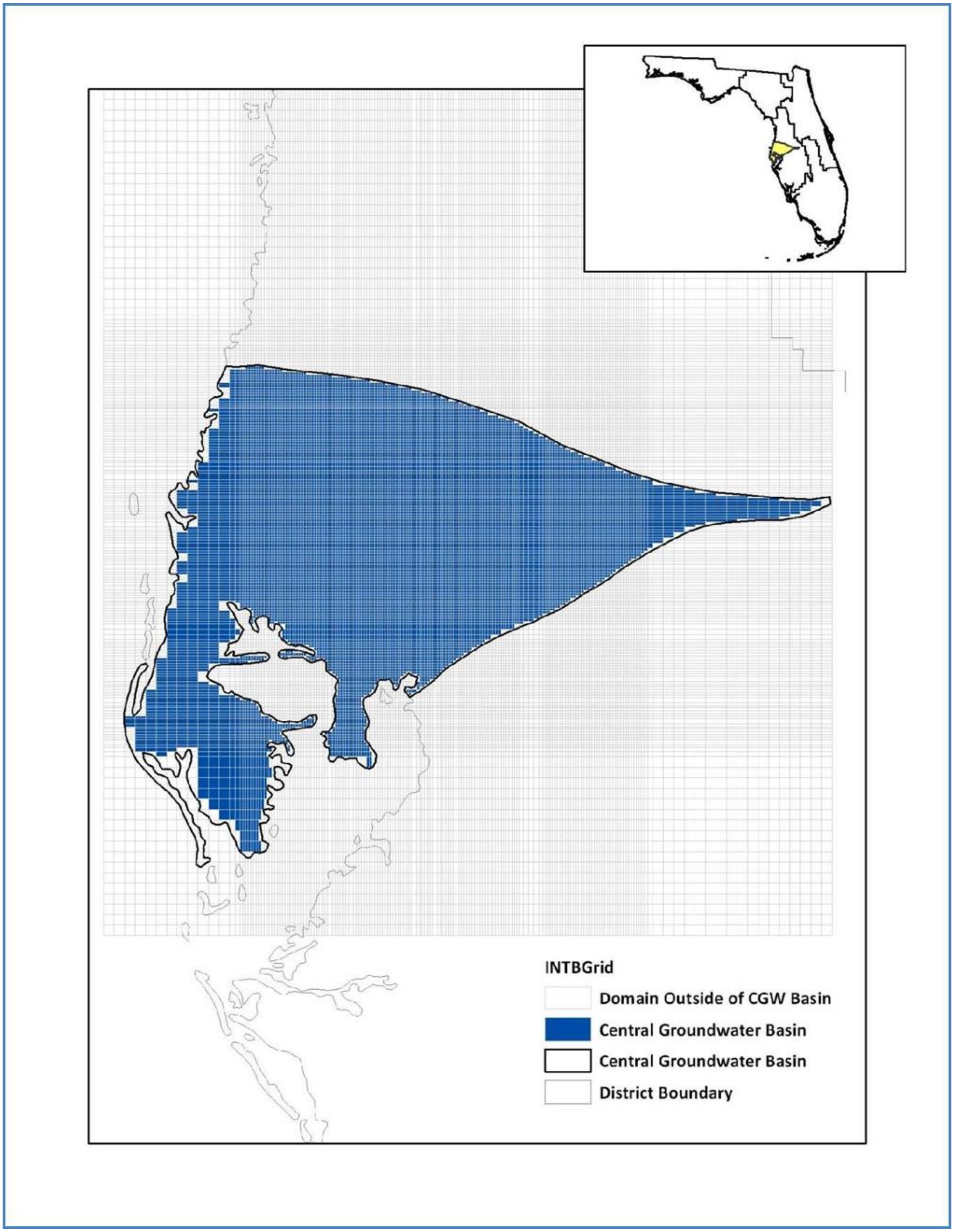

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Lake Linda was 0.9 ft, and 7.9 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 Lake Linda was 0.4 ft and 4.0 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.

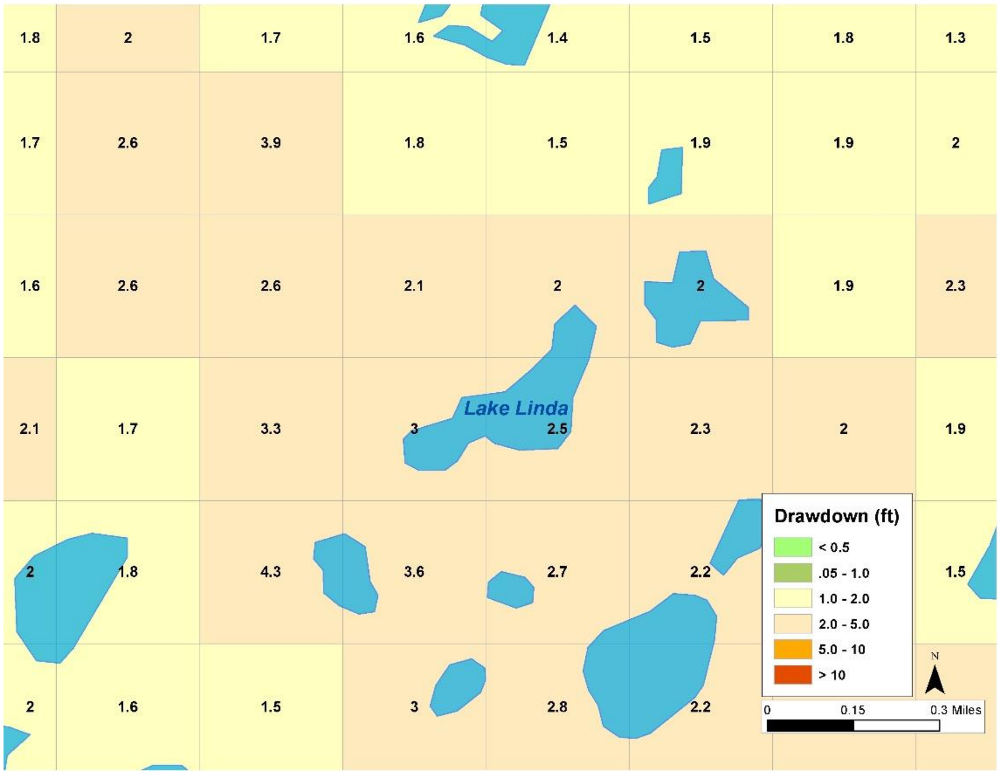

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

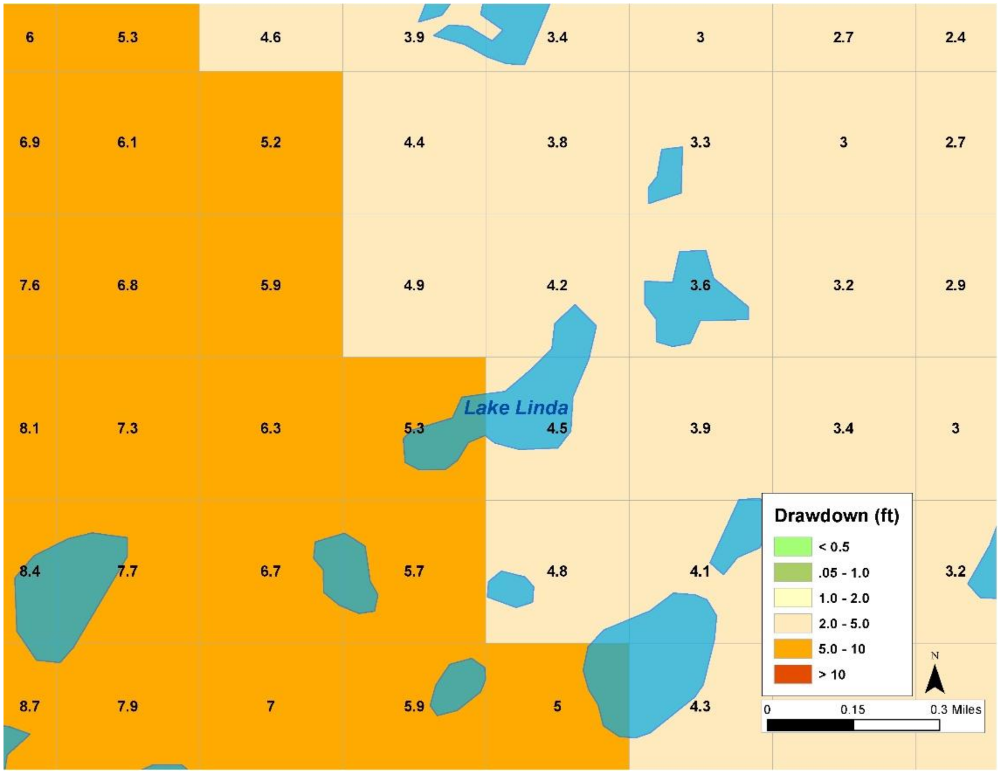

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

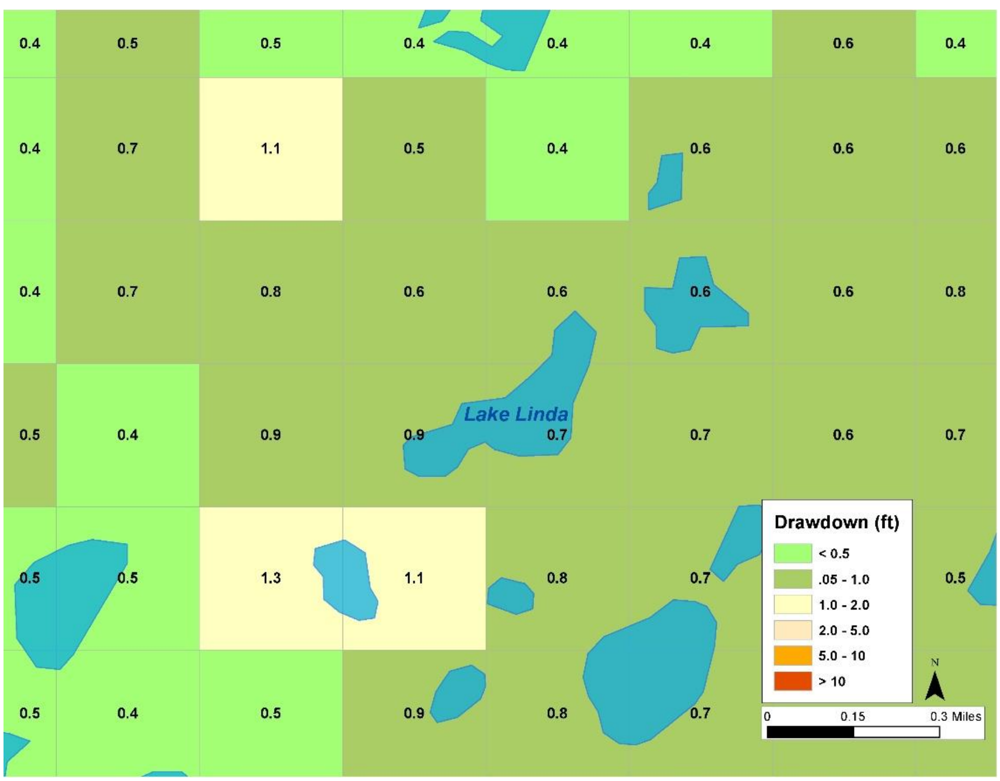

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

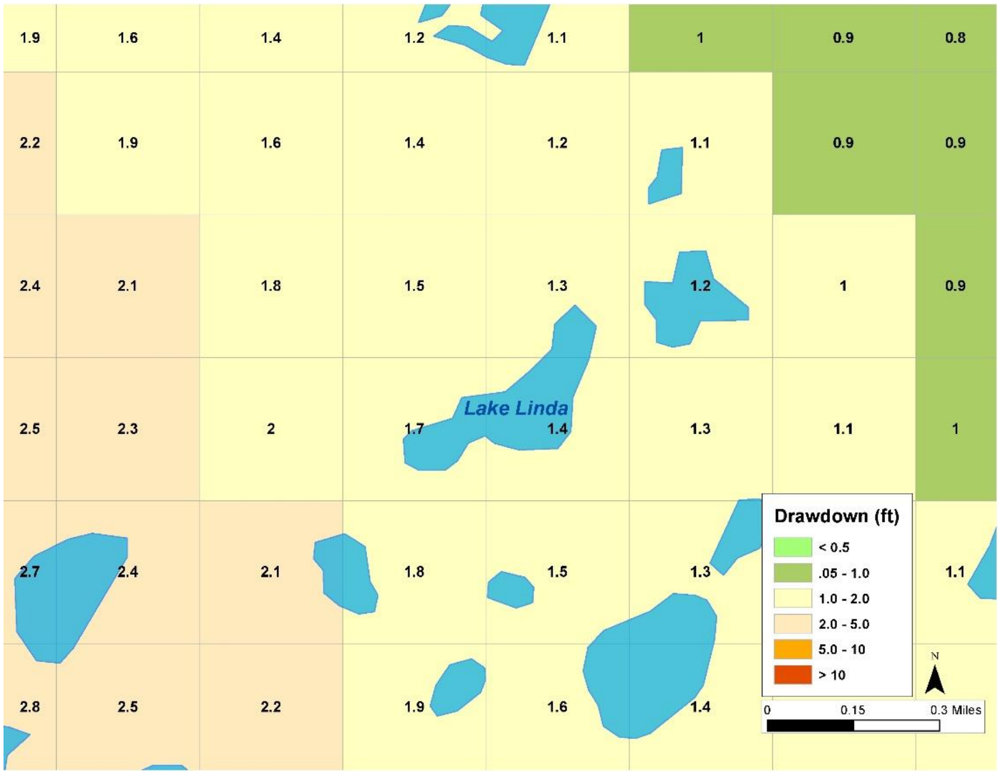

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

Table 1. INTB model results for Lake Linda.

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***
Linda	2.6	0.8
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***
Linda	4.7	1.5

* Average prorated drawdown from model cells intersecting lake

References

Geurink, J., and Basso, R., 2012. Development, Calibration, and Evaluation of the Integrated Northern Tampa Bay Model: An Application of the Integrated Hydrologic Model Simulation Engine, Tampa Bay Water and the Southwest Florida Water Management District.

Miller, J.A. 1986. Hydrogeologic framework of the Floridan aquifer system in Florida and in parts of Georgia, Alabama, and South Caroline: U.S. Geological Survey Water-Resources Investigations Report 84-4135, 69 p.

Ryder, P., 1982. Digital Model of Predevelopment Flow in the Tertiary limestone (Floridan) Aquifer System in West-Central Florida, U.S. Geological Survey Water-Resources Investigations Report 81-54.

Sepulveda, N. 2002. Simulation of Ground-Water Flow in the Intermediate and Floridan Aquifer Systems in Peninsular Florida, U.S. Geological Survey WRI Report 02-4009, 130 p.

Southwest Florida Water Management District, 1993, Computer Model of Ground-water Flow in the Northern Tampa Bay Area, 119 p.