Revised Minimum and Guidance Levels for Deer Lake in Hillsborough County, Florida

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Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District

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Cover: Deer Lake, November 16, 2000 (SWFWMD)

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Introduction

Reevaluation of Minimum Flows and Levels

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

Deer Lake was selected for reevaluation based on development of modeling tools used to simulate natural water level fluctuations in lake basins that were not available when the currently adopted minimum levels for the lake were developed. Adopted levels for Deer Lake 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 proposed minimum levels report; additional information on all tasks associated with the District's MFLs Program is summarized by Hancock *et al.* (2010).

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

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

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

Consideration of Changes and Structural Alterations and Environmental Values

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

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

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

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

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

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

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria are used to develop recommend minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. The Cypress Standard elevation 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 Deer Lake are provided in subsequent sections of this report. More general information on the standards and other information used for consideration when developing minimum lake levels is available in the documents identified in the preceding sub-section of this report.

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

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

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

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

According to Chapter 40D-8.624, F.A.C., Deer Lake meets the classification as a Category 1 Lake. The previously adopted levels for Deer Lake are based on the lake being a Category 2 lake, i.e., the High Minimum Level is equal to the High Guidance Level and the Minimum Level is equal to the Historic median lake level (P50). However, reevaluation of the lake indicates water levels currently rise to an elevation expected to fully maintain the integrity of the fringing cypress wetlands, and is therefore a Category 1 Lake. Although the change standards listed in Rule 40D-8.624(8)(c), F.A.C., are not used to establish Minimum Levels for a Category 1 Lake, for comparison purposes the standards associated with Category 3 lakes are described below and will also be discussed further in a subsequent section of this report.

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

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

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

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

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

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

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

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

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

Minimum Levels

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

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

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

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

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

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

Development of Minimum and Guidance Levels for Deer Lake

Lake Setting and Description

Watershed

Deer Lake (Figure 1) is a 35-acre lake (Dickinson et al, 1982) located in the northern Tampa Bay area in the community of Lutz, Hillsborough County, Florida (Section 1, Township 27S, Range 18E). Deer Lake is part of a chain of lakes called the Deer Group of lakes (Water & Air 1997). The lake chain begins with Deer Lake through a series of natural flow ways to Little Deer, Lake Hobbs, and Little Hobbs and discharges to Lake Cooper (Figure 2). Deer Lake is located approximately 3 miles southeast of the South Pasco Wellfield, and 3 miles northeast of the Section 21 Wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water. Deer Lake is in the Rocky/Brushy Creek watershed.

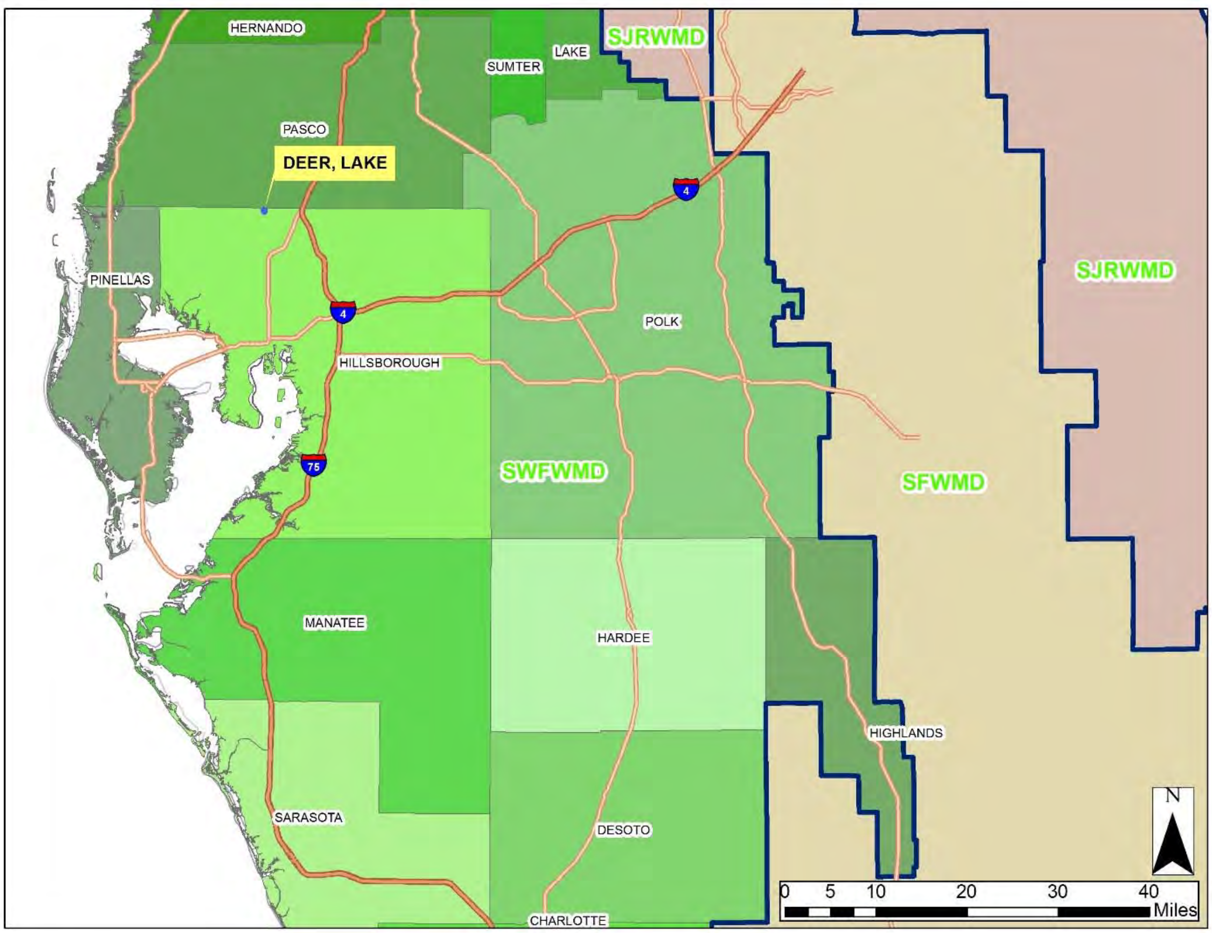

Figure 1: Location of Deer Lake in Hillsborough County, Florida.

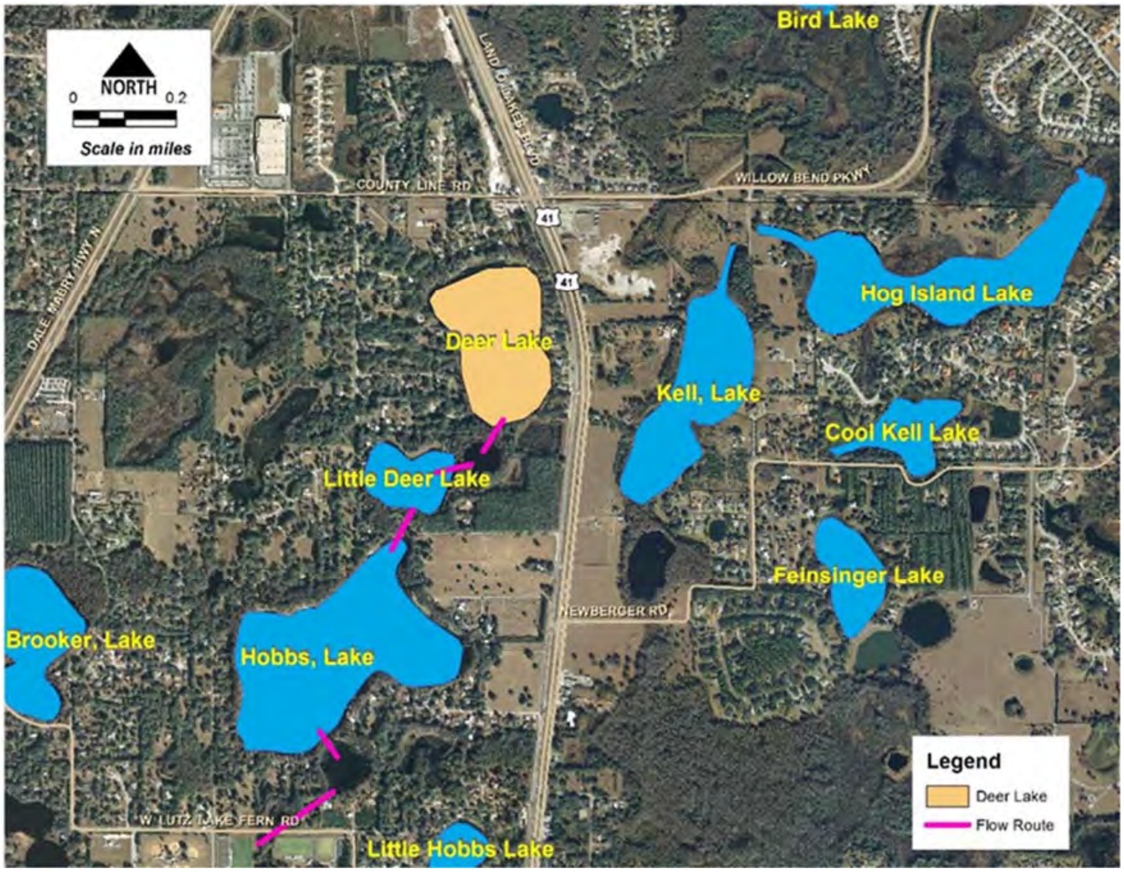

Figure 2. Flow between Deer Lake, Little Deer Lake, and Lake Hobbs.

Land Use Land Cover

An examination of the pre-development (1950, Figure 3) and recent (2011, Figure 4) Florida Land Use, Cover and Forms Classification System (FLUCCS) maps, as well as historic aerial photographs, revealed that there have been considerable changes to the landscape near Deer Lake (Figure 5 through Figure 10). In 1950 and prior, agriculture (i.e., citrus groves and improved pasture), upland forests, and wetlands dominated the area. By 2011, much of the agriculture and upland forests had been converted to urban, e.g., residential, use. Figure 5 through Figure 10 aerial photography chronicles landscape changes to the immediate lake basin from 1938 through 2014.

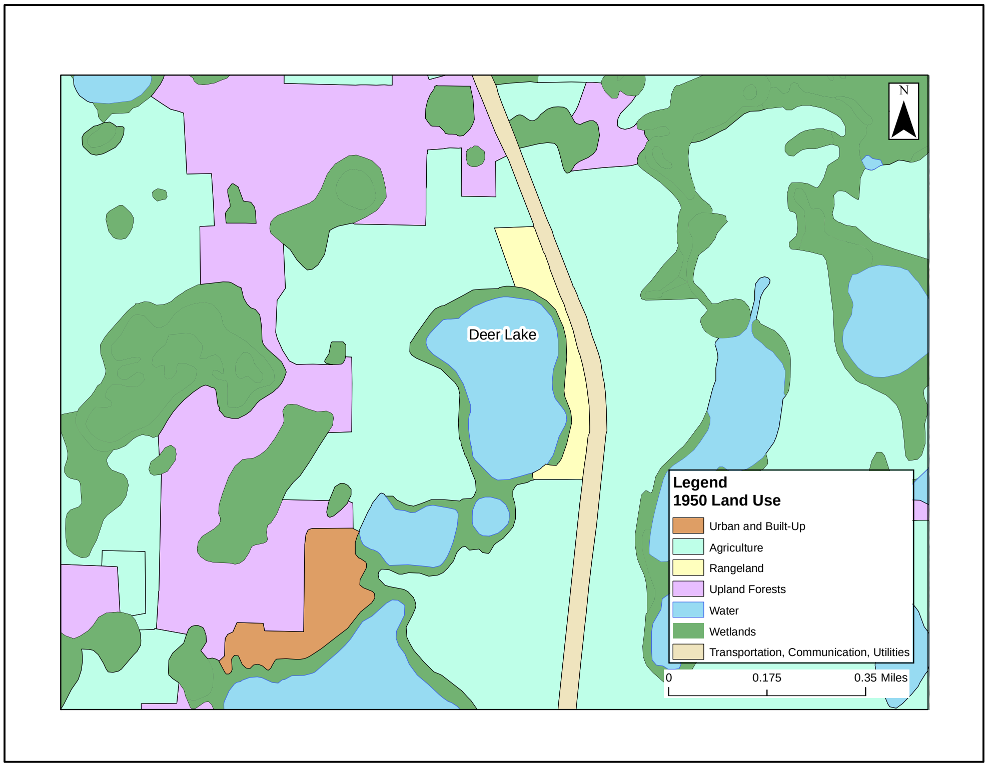

Figure 3: 1950 Land Use-Land Cover in the Deer Lake Vicinity.

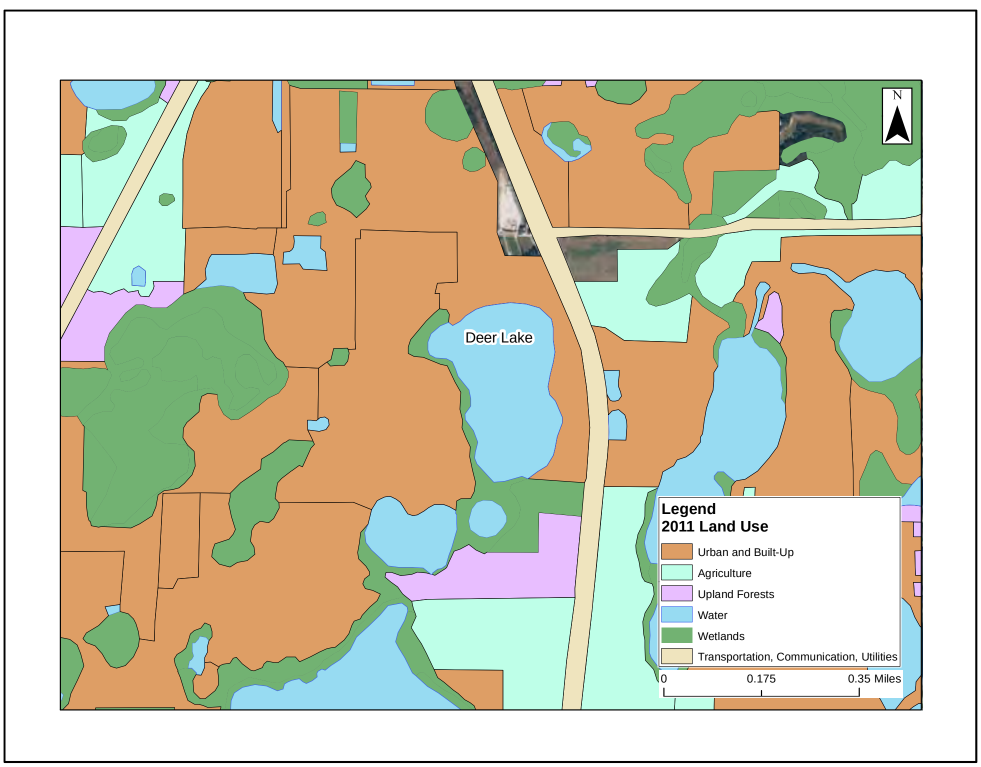

Figure 4: 2011 Land Use-Land Cover in the Deer Lake Vicinity.

Figure 5: 1938 Aerial Photograph of Deer Lake

Figure 6: 1947 Aerial Photograph of Deer Lake

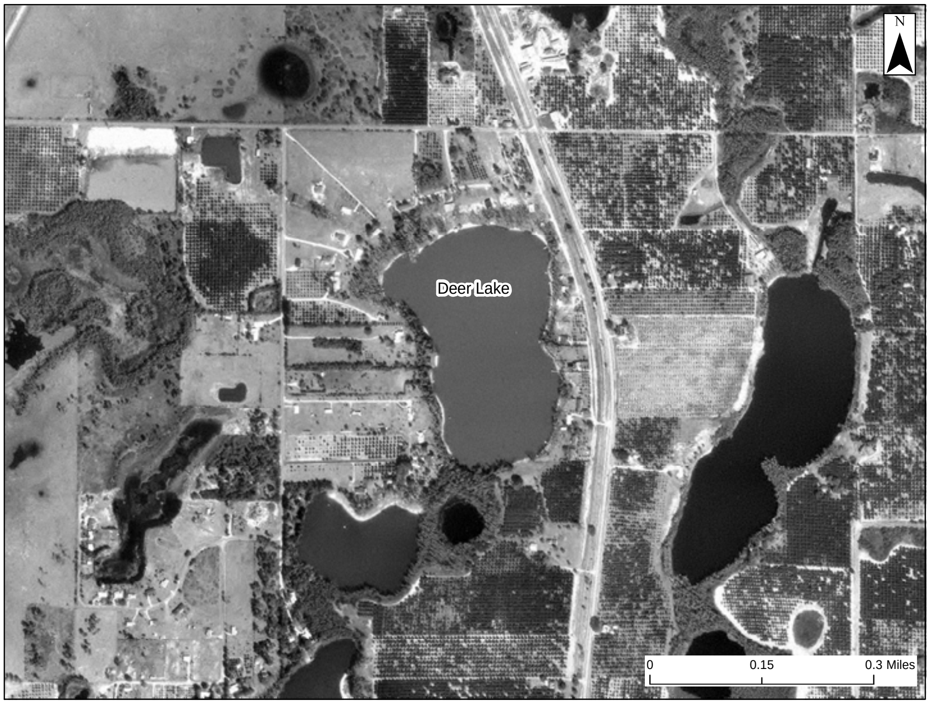

Figure 7: 1970s Aerial Photograph of Deer Lake

Figure 8: 1984 Aerial Photograph of Deer Lake (false-color infra-red)

Figure 9: 2004 Aerial Photograph of Deer Lake

Figure 10: 2014 Aerial Photograph of Deer Lake

Bathymetry Description and History

One-foot interval bathymetric data gathered from recent field surveys resulted in lake-bottom contour lines from 40.6 ft. to 62 ft. (Figure 11). These data revealed that the lowest lake bottom contour (40.6 ft.) is in two separate small depressions in the northeast and southeast areas of the lake. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

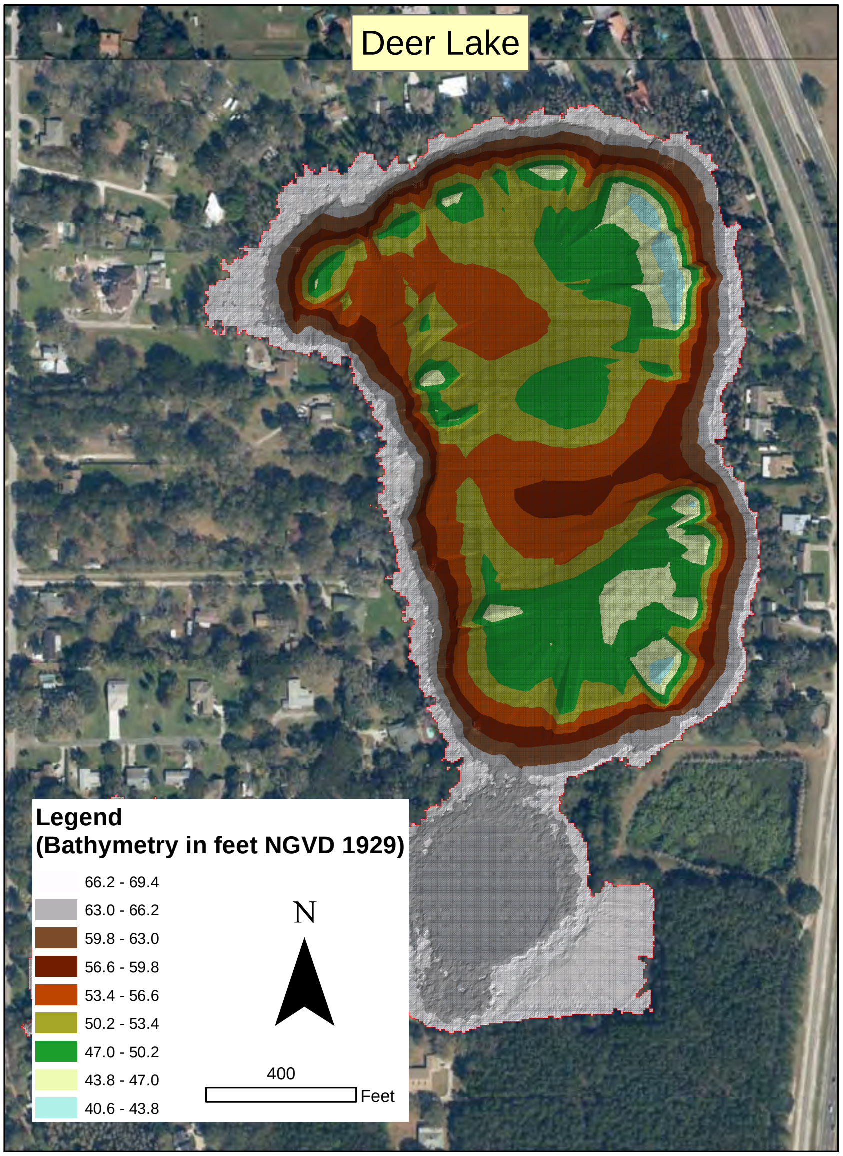

Figure 11: Lake Bottom Contours (ft., NGVD29) on a 2014 Natural Color Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Deer Lake from the District's Water Management Information System (SID 19818) (Figure 12). Data collection began on August 12, 1977, and continues to be monitored monthly at the time of this report. The highest lake stage elevation on record was 67.42 ft. and occurred on December 27, 1997. The lowest lake stage elevation on record was 60.72 ft. and occurred on June 28, 2002.

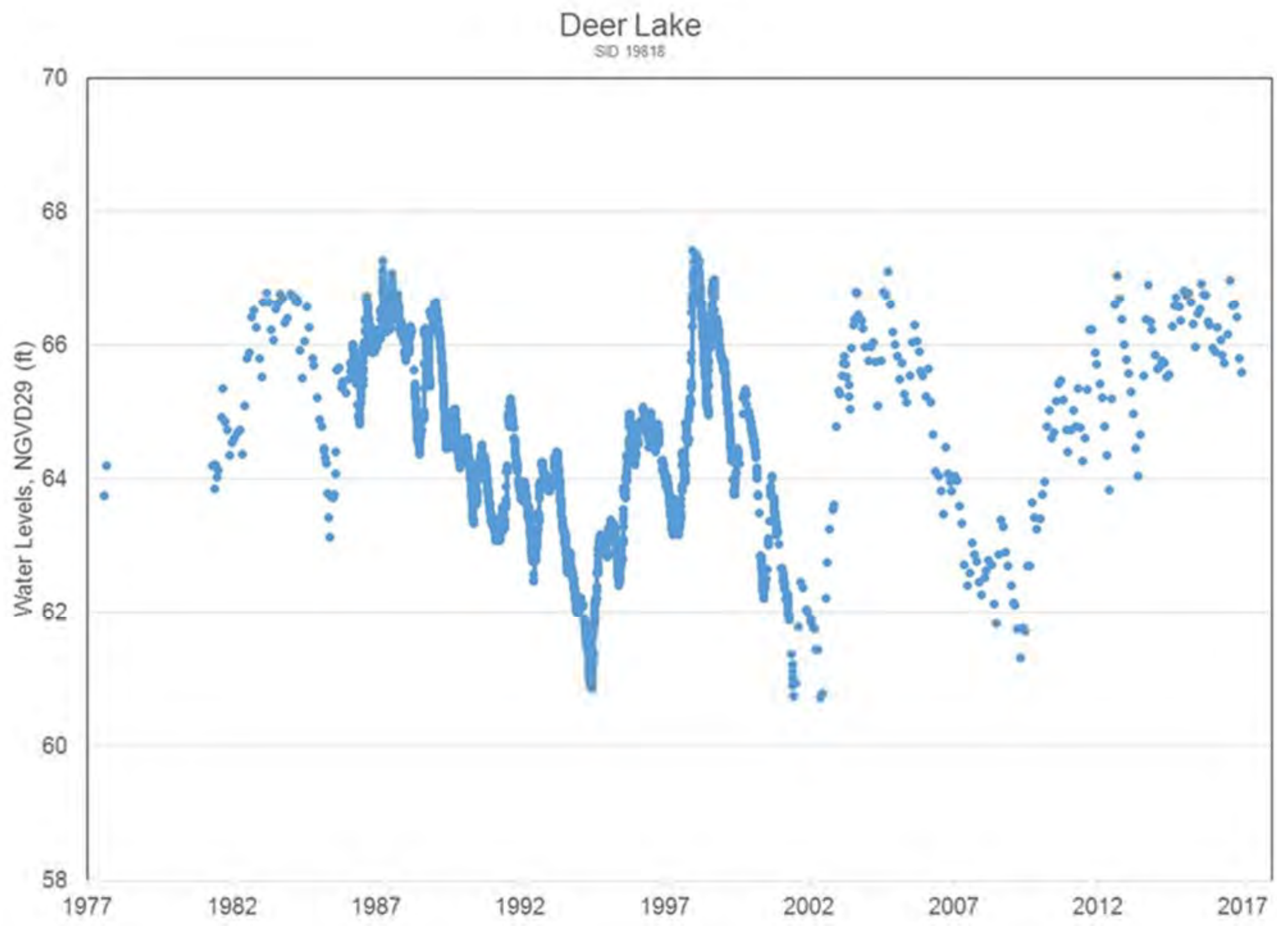

Figure 12: Deer Lake Period of Record Water Elevation Data (SID 19818)

Historical and Current Management Levels

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

The District Governing Board first approved Guidance and Minimum Levels for Deer Lake (Table 2) in October 1998, which were subsequently adopted into Chapter 40D-8, Florida Administrative Code, on July 18, 2000, using the methodology for Category 2 Lakes described in SWFWMD (1999a and 1999b).

Table 2: Minimum and Guidance Levels adopted July 18, 2000 for Deer Lake

Level	Elevation (ft., NGVD)
High Guidance Level	66.5
High Minimum Level	66.5
Minimum Level	65.5
Low Guidance Level	64.4

Methods, Results and Discussion

The Minimum and Guidance Levels in this report were developed for Deer Lake using the methodology for Category 1 lakes described in Chapter 40D-8, F.A.C. The revised levels along with lake surface area for each level are listed in

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.

Table 3, along with other information used for development of the levels. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

Bathymetry

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

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Historic P10 (1946 to 2015)	68.1	63.0
Historic P50 (1946 to 2015)	66.1	52.1
Historic P90 (1946 to 2015)	64.1	33.1
Normal Pool and Control Point		
Normal Pool	66.9	55.8
Control Point	66.0	51.7
Significant Change Standards		
Recreation/Ski Standard	65.0	41.2
Dock-Use Standard	67.1	57.0
Wetland Offset Elevation	65.3	47.6
Aesthetics Standard	64.1	33.1
Species Richness Standard	65.9	51.4
Basin Connectivity Standard	57.8	26.9
Lake Mixing Standard	NA	NA
Minimum and Guidance Levels		
High Guidance Level	67.3	57.8
High Minimum Lake Level	66.5	53.7
Minimum Lake Level	65.1	43.4
Low Guidance Level	64.1	33.1

NA - not applicable

Stage-area-volume relationships were determined for Deer Lake 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 Deer Lake. 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. Stage-area results are presented in Figure 13.

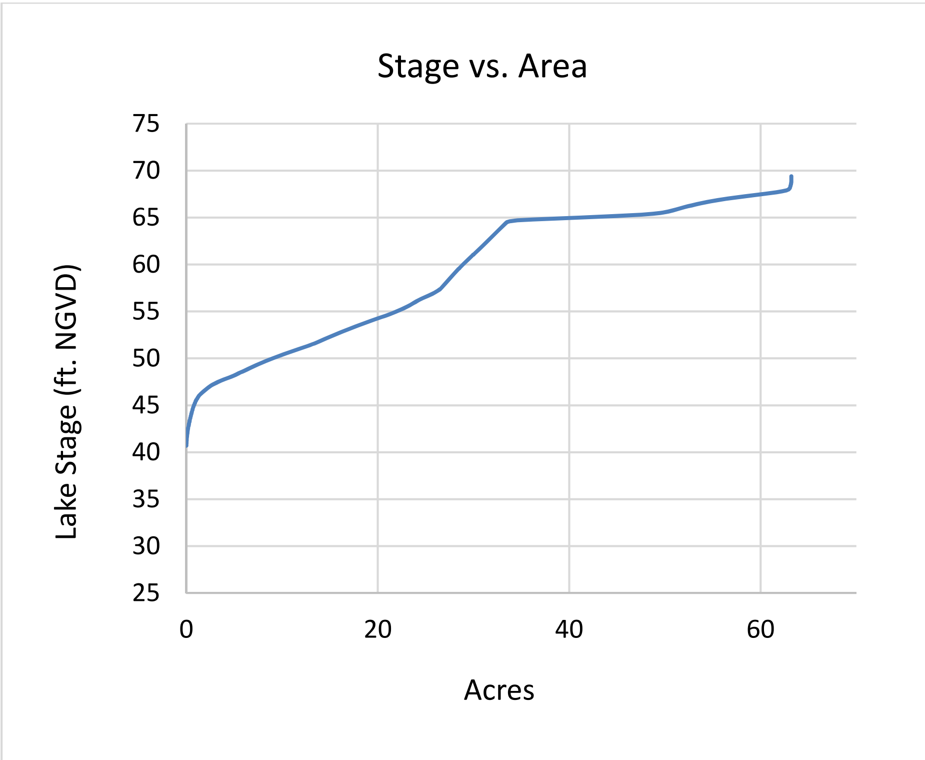

Figure 13: Lake Stage (Ft. NGVD29) to Surface Area (Acres) for Deer Lake.

Development of Exceedance Percentiles

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

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

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

A combination of model data produced a hybrid model which resulted in a 69-year (1946-2015) Historic water level record. Based on this hybrid data, the Historic P10 elevation, i.e., the elevation of the lake water surface equaled or exceeded ten percent of the time, was 68.1 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 66.1 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 64.1 ft. (Table 4 and Figure 14).

Table 4. Historic percentiles as estimated by the hybrid model from 1946 to 2015 (feet NGVD29).

Percentile	Deer Lake
P10	68.1
P50	66.1
P90	64.1

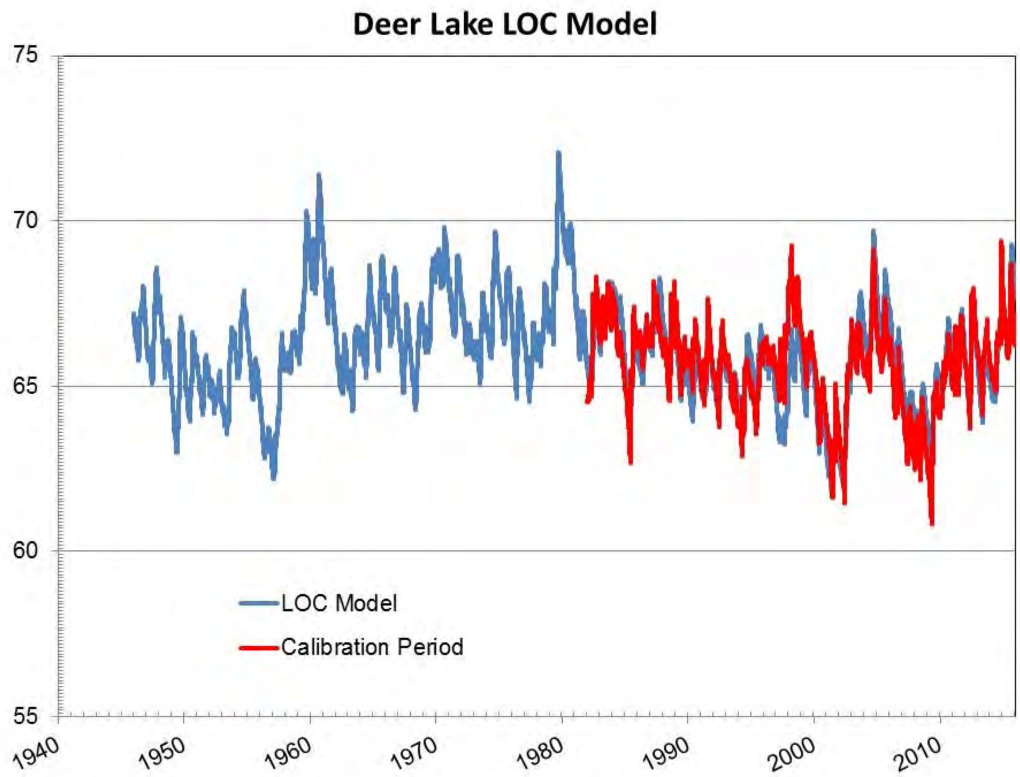

Figure 14: Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

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). Nine good quality examples of cypress buttress swelling where measured on the lake in January 2017 (Table 5). Based on the survey of these biologic indicators, the Normal Pool elevation was established at the median normal pool of 66.9 ft. NGVD 1929.

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 Deer Lake was determined at 66.0 ft., the elevation of a natural high area between Little Lake Deer and Lake Hobbs. The low floor slab, based on survey reports, was established at 70.1 ft.

Table 5. Summary statistics for hydrologic indicators used for establishing Normal Pool elevations for Deer Lake (feet NGVD29).

Summary Statistic	Number (N) or Elevation
N	9
Median	66.9
Mean	66.8
Minimum	66.6
Maximum	67.2

Guidance Levels

The High Guidance Level is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake, and is established using Historic data if it is available, or is estimated using the Current P10, the Control Point elevation, and the Normal Pool elevation. For Deer Lake, the High Guidance Level was established based on an LOC model of the Current P10 water level data (2003-2016), an elevation of 67.2 ft. As stated in Appendix A, this elevation is used rather than the P10 from the LOC “hybrid model”, as the P10 from the hybrid model appears to be inflated. Gaged data indicate that the High Guidance Level was met or exceeded only in December 1997, and February and March 1998; an “El Nino” period. The highest recorded level was 67.42 ft. in December 1997 (Figure 12).

The Low Guidance Level is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, reference lake water regime statistics. Based on the availability of Historic data for Deer Lake, the Low Guidance Level was established at the elevation of 64.1 ft. The gaged period of record indicates the lowest water level recorded, in May 2002, was 60.7 ft., which is 3.4 ft. below the proposed Low Guidance Level (Figure 12). The most recent record of the water level below the proposed Low Guidance Level was in May 2012, with a recorded level of 63.8 ft.

Significant Change Standards

For comparative purposes, Category 3 significant change standards were determined for Deer Lake based on the stage-volume relationship which was developed. These standards include a Recreation/Ski Standard, Dock-Use Standard, Wetland Offset Elevation, Aesthetics Standard, Species Richness Standard, Basin Connectivity Standard, and Lake Mixing Standard.

- The **Recreation/Ski Standard** was established at an elevation of 65.0 ft. based on a ski elevation of 58.0 ft., plus 5 feet and the difference between the Historic P50 and P90.
- The **Dock-Use Standard** was established at an elevation of 67.1 ft. based on the elevation of lake sediments at the end of 27 docks on the lake, a two-foot clearance depth, and the difference between the Historic P50 and P90.
- The **Wetland Offset Elevation** was established at 65.3 ft., or 0.8 ft. below the Historic P50 elevation.
- The **Aesthetic-Standard** was established at the Low Guidance Level elevation of 64.1 ft.
- The **Species Richness Standard** was established at 65.9 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- The **Basin Connectivity Standard** was established at 57.8 ft., based on the addition of 2 feet, plus the difference between the Historic P50 and P90 to the critical high spot elevation of 53.8 ft. This critical high spot is the lowest bottom elevation separating the north and south "pools" of Deer Lake (see Figure 11).
- The **Lake Mixing Standard** was not established, as the dynamic ratio for the lake does not exceed 0.3. The Lake Mixing Standard is established where the dynamic ratio shifts from a value of less than 0.8 to greater than 0.8, indicating that potential changes in basin susceptibility to wind-induced sediment resuspension would not be of concern for minimum levels development (see Bachmann *et al.* 2000).

Review of changes in potential herbaceous wetland area associated with change in lake stage (Figure 15), and potential changes in area available for aquatic plant colonization (Figure 16) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development. Figure 15 and Figure 16 show that as the lake stage increases, the acres available for herbaceous wetlands (i.e., acres < 4 ft. deep) and aquatic plant colonization (i.e., acres </= 10.7 ft. deep) also increase up to a point, and then begin to alternately increase and decrease as the lake becomes deeper. The changes in the slope of the lines reflects the variation in lake bottom contours and the area which it contains.

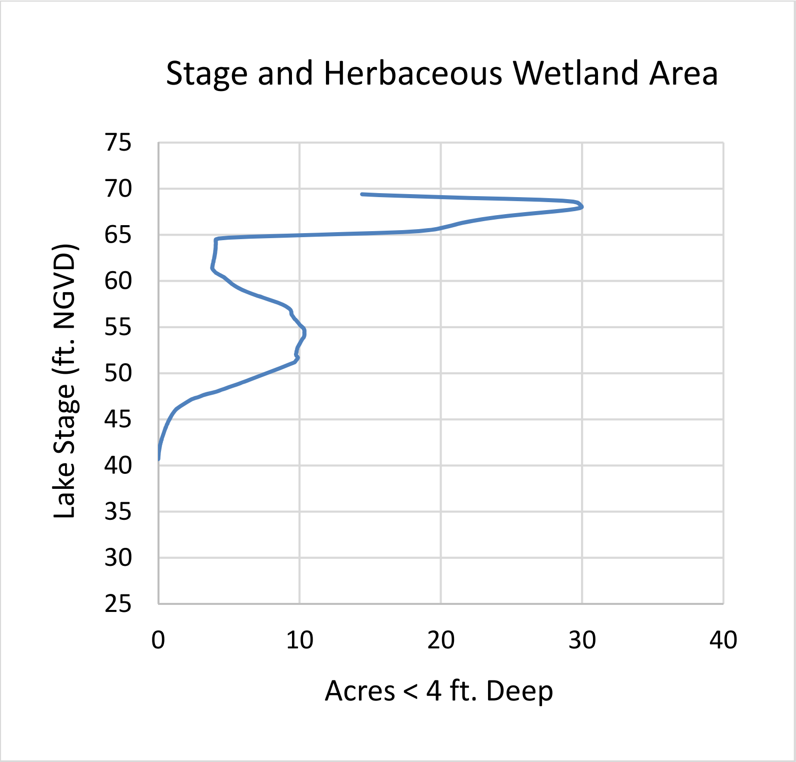

Figure 15: Lake Stage Compared to Available Herbaceous Wetland Area.

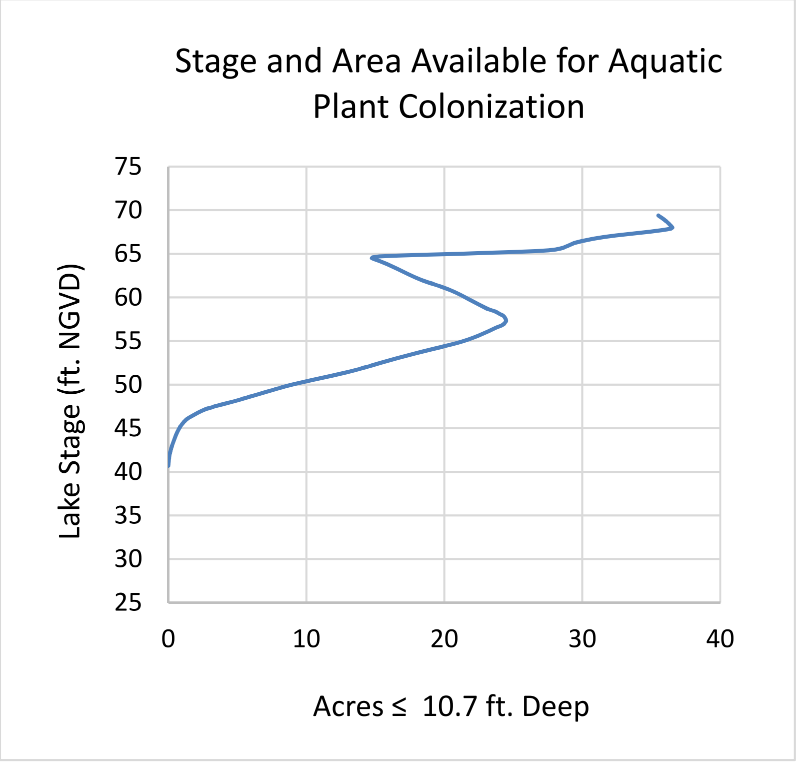

Figure 16: Lake Stage and Area Available for Aquatic Plant Colonization.

Minimum Levels
The High Minimum Lake Level (HMLL) is the elevation that a lake's water levels are ***required*** to equal or exceed ten percent of the time on a long-term basis. For a Category 1 Lake, Chapter 40D-8.624, F.A.C. requires the HMLL to be established at the elevation of the Historic Normal Pool minus 0.4 feet, resulting in a revised HMLL for Deer Lake of 66.5 ft.

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 1 Lake, the Minimum Lake Level is established at the elevation of the Historic Normal Pool minus 1.8 feet. The MLL for Deer Lake is established at an elevation of 65.1 ft.

The Minimum Levels for Deer Lake are plotted on the Historic water level record (Figure 18). To illustrate the approximate locations of the lake margin when water levels equal the Minimum and Guidance Levels, the levels are depicted on a 2014 natural color aerial photograph in Figure 18.

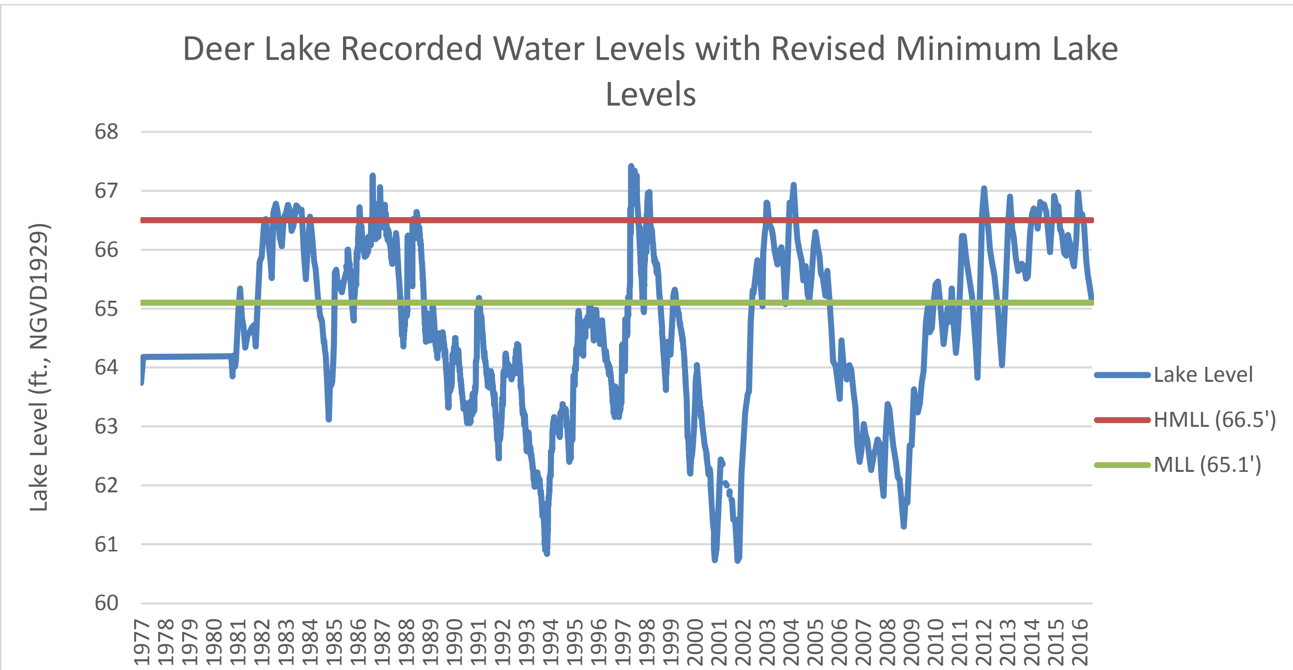

Figure 17: Deer Lake Period of Record Lake Levels with Minimum Levels

Figure 18: Deer Lake Minimum and Guidance Level Contour Lines Imposed on a 2014 Natural Color Aerial Photograph.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida's water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the proposed MFLs for Deer Lake 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 -0.9 ft. for SID 19818 on Deer Lake.

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

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88 (SID 19818)
High Guidance Level	67.2	66.2
High Minimum Lake Level	66.5	65.6
Minimum Lake Level	65.1	64.2
Low Guidance Level	64.1	63.2

Consideration of Environmental Values

The minimum levels for Deer Lake 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.

A Cypress Standard of Historic Normal Pool was identified to support development of minimum levels for Deer Lake based on the occurrence of lake-fringing cypress wetlands of one-half acre or greater in size. The standard is associated with protection of several environmental values identified in the Water Resource Implementation Rule, including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, and water quality (Table 1). Ultimately, the Cypress Standard of Historic Normal Pool was used for developing the minimum levels for Deer Lake based on its classification as a Category 1 Lake. Given this information, the levels are as protective of all relevant environmental values as they can be. In addition, the environmental value, 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 levels.

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

Comparison of Revised and Previously Adopted Levels

The High Guidance Level is 0.7 feet higher than the previously adopted High Guidance Level, while the Low Guidance Level is 0.3 feet lower than the currently 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 Deer Lake is not changed from the previously adopted High Minimum Lake Level. The Minimum Lake Level is 0.4 feet lower than the previously adopted Minimum Lake Level (Table 5). These differences are due to the same factors discussed above for the changes in the Guidance Levels, as well as the fact that the revised MLL is based on the Historic Normal Pool for this reevaluation. The previously adopted MLL was based on the Dock Standard, as the lake was previously considered to be a Category 2 Lake.

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

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

Minimum and Guidance Levels	Elevations (in Feet NGVD29)	Previously Adopted Elevations (in Feet NGVD29)
High Guidance Level	67.2	66.5
High Minimum Lake Level	66.5	66.5
Minimum Lake Level	65.1	65.5
Low Guidance Level	64.1	64.4

Minimum Levels Status Assessment

To assess if the Minimum and High Minimum Lake Levels are being met, observed stage data in Deer Lake 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 Deer Lake were determined to be from 2003 through 2016. Using the Current stage data, the LOC model was created. The LOC model resulted in a 69-year long-term water level record (1946-2015).

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

The lake lies within the region of the District covered by an existing recovery strategy for the Northern Tampa Bay Water Use Caution Area (Rule 40D-80.074, F.A.C.). The District plans to continue regular monitoring of water levels in Deer Lake and will also routinely evaluate the status of the lake’s water levels with respect to adopted minimum levels for the lake included in Chapter 40D-8, F.A.C.

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APPENDIX A

Technical Memorandum

March 7, 2017

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

THROUGH: JP Marchand, P.E., Bureau Chief, Water Resources Bureau

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
Tamera S. McBride, P.G., Senior Prof. Geologist, Water Resources Bureau

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

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A. Introduction

Water budget and rainfall correlation models were developed to assist the Southwest Florida Water Management District (District) in the reassessment of minimum levels for Deer Lake in northwest Hillsborough County. Deer Lake currently has adopted minimum levels which are scheduled to be re-assessed in FY 2017. This document will discuss the development of the Deer Lake models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Deer Lake is in northwest Hillsborough County, on the southwest corner of the intersection of U.S. 41 and County Line Road in Lutz (Figure 1). The lake lies within the Brushy Creek watershed. Brushy Creek is a tributary to Rocky Creek. Deer Lake has no significant inflow other than overland flow, but discharges south via a wetland connection to a small unnamed lake, Little Deer Lake and Lake Hobbs (Figure 2) during high flow periods. The topography is very flat, however, and flows are often negligible.

Physiography and Hydrogeology

The area surrounding the lake is categorized as the Land-O-Lakes subdivision of the Tampa Plain in the Ocala Uplift Physiographic District (Brooks, 1981), a region of many lakes on a moderately thick plain of silty sand overlying limestone. The topography is very flat, and drainage into the lake is a combination of overland flow and flow through drainage swales and minor conveyance systems.

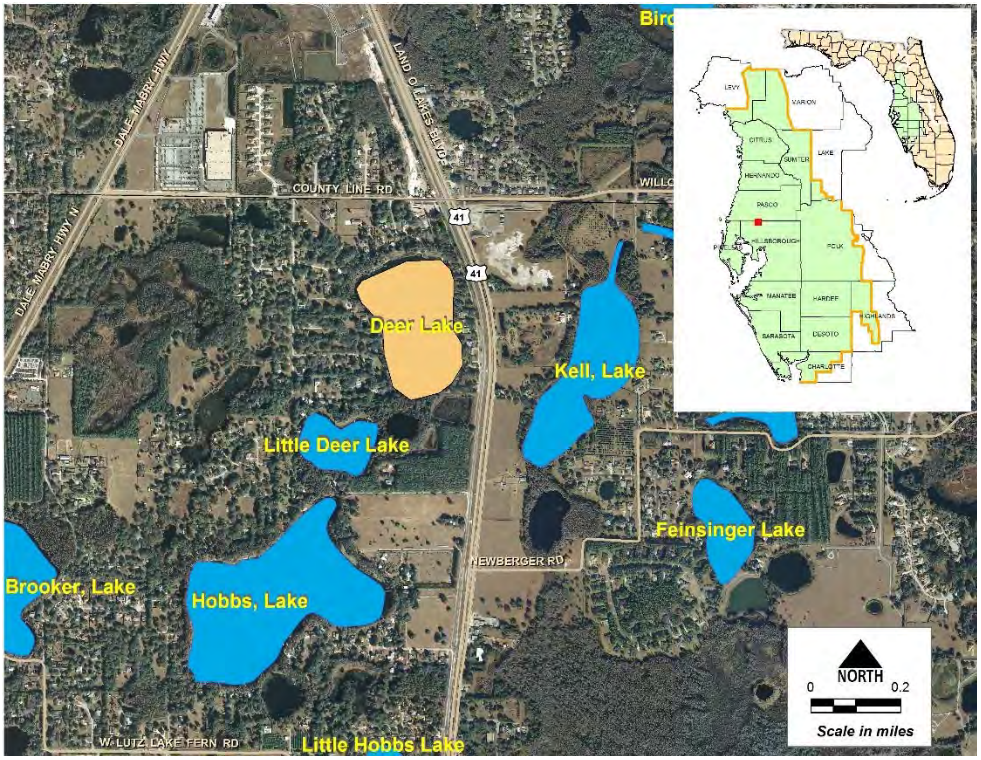

Figure 1. Location of Deer Lake in Hillsborough County, Florida.

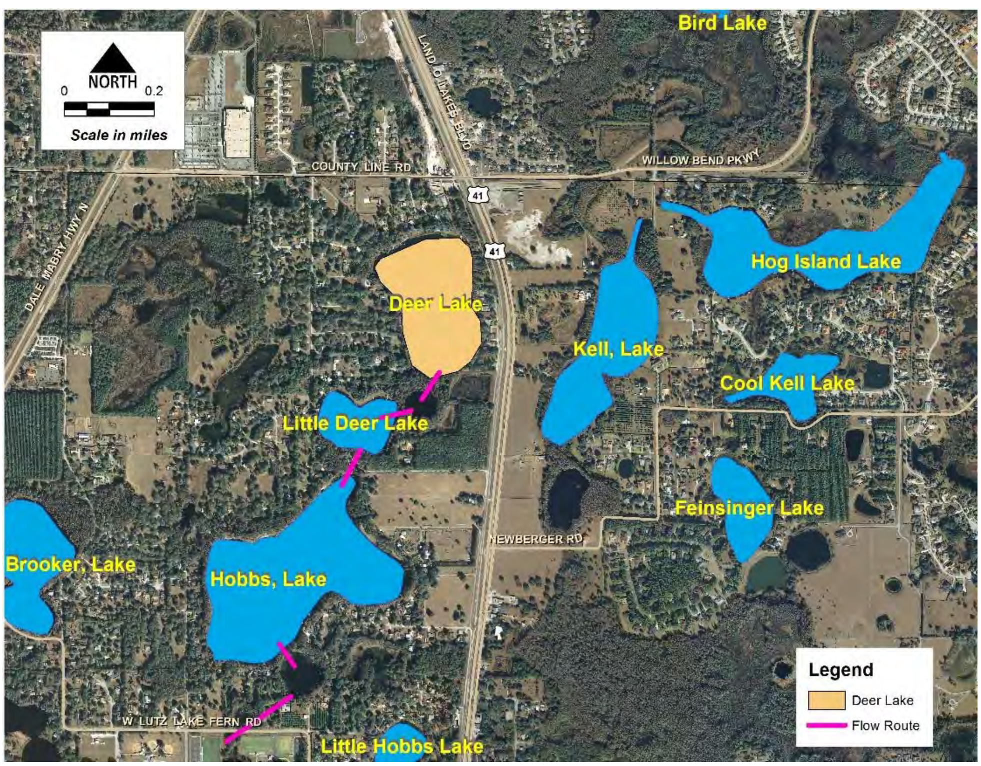

Figure 2. Flow between Deer Lake, Little Deer Lake, and Lake Hobbs.

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

Data

The Southwest Florida Water Management District began collecting water level data at Deer Lake in August of 1977 (Figure 3). The data collection frequency has typically been monthly, although some period of daily data collection has occurred at times, likely via a volunteer on the lake. Three Upper Floridan and surficial aquifer monitor well nests were considered for the analysis (Figure 4). The Newberger Road Floridan and surficial aquifer monitor wells are located approximately 4,400 feet to the southeast of Deer Lake. Monthly data are available for these wells back to July 1989 (Figure 5). The Lutz Park Floridan and surficial aquifer monitor wells are located approximately 1.2 miles to the southwest of Deer Lake. Monthly data are available for these wells back to March 1989 (Figure 6). Water levels from the Debuel Road Deep Floridan aquifer and Debuel Road Shallow surficial aquifer monitor wells have been collected since August 1965, making them two of the longest-term monitor wells in Hillsborough County. The wells are located approximately 2.8 miles to the southeast of Lake Hobbs. The data collection frequency began as weekly, and became daily in the mid-1970s (Figure 7).

Land and Water Use

Deer Lake is located approximately 3 miles southeast of the South Pasco Wellfield, and 3 miles northeast of the Section 21 wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 8). Groundwater withdrawals began at the Section 21 Wellfield in 1963 and steadily climbed to approximately 20 mgd in 1967 (Figure 8). 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.

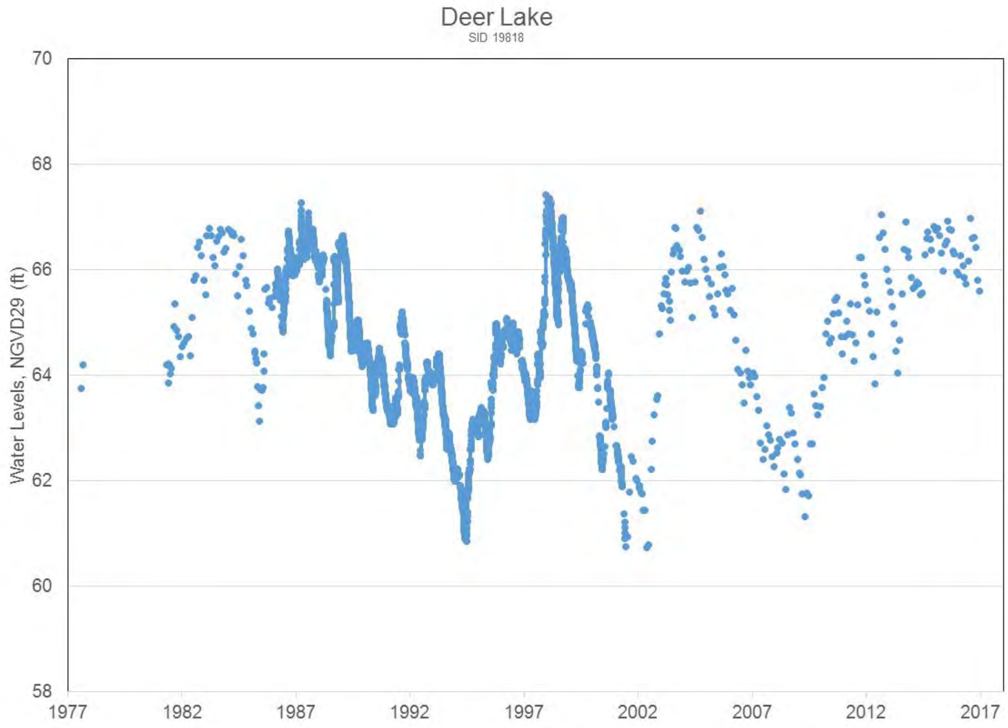

Figure 3. Deer Lake water levels.

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

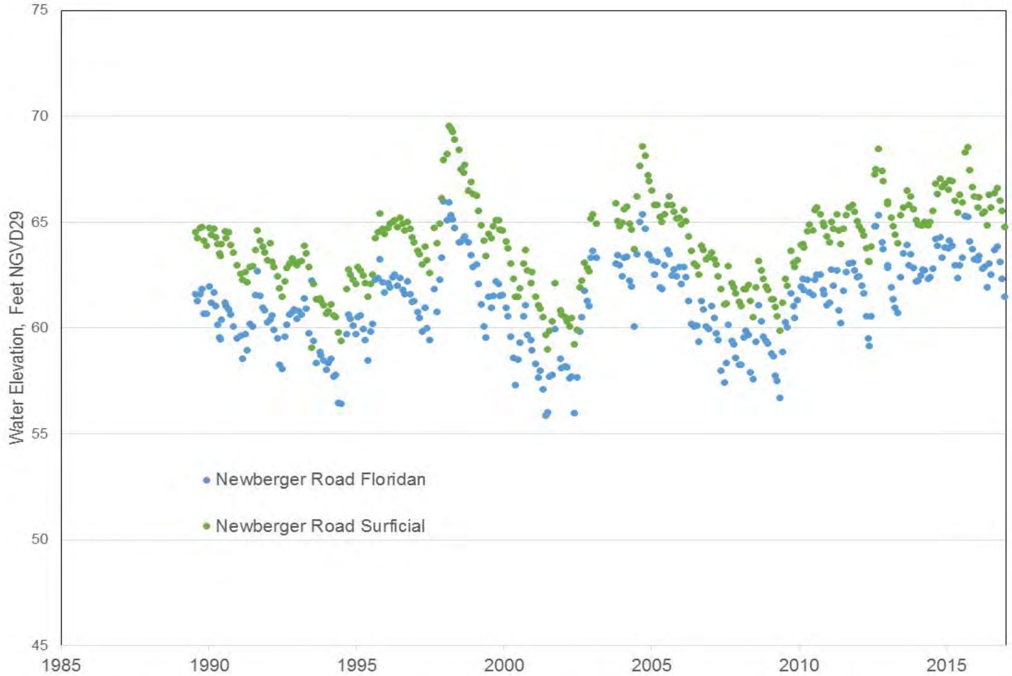

Figure 5. Water levels in the Newberger Road Surficial and Floridan aquifer monitor wells.

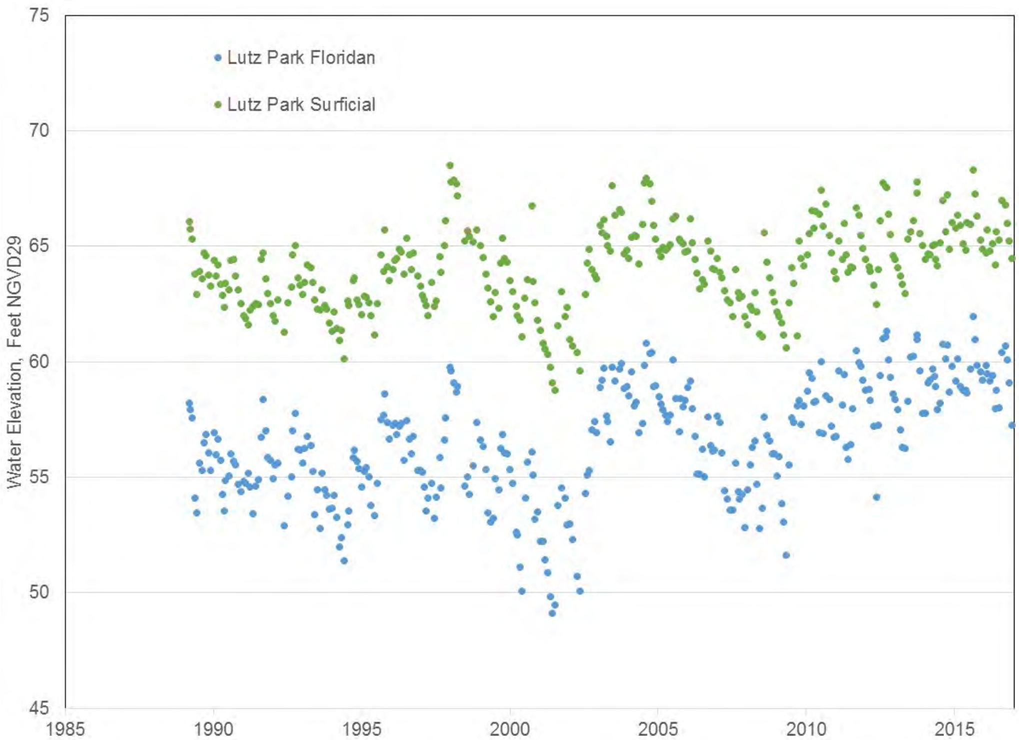

Figure 6. Water levels in the Lutz Park Surficial and Floridan aquifer monitor wells.

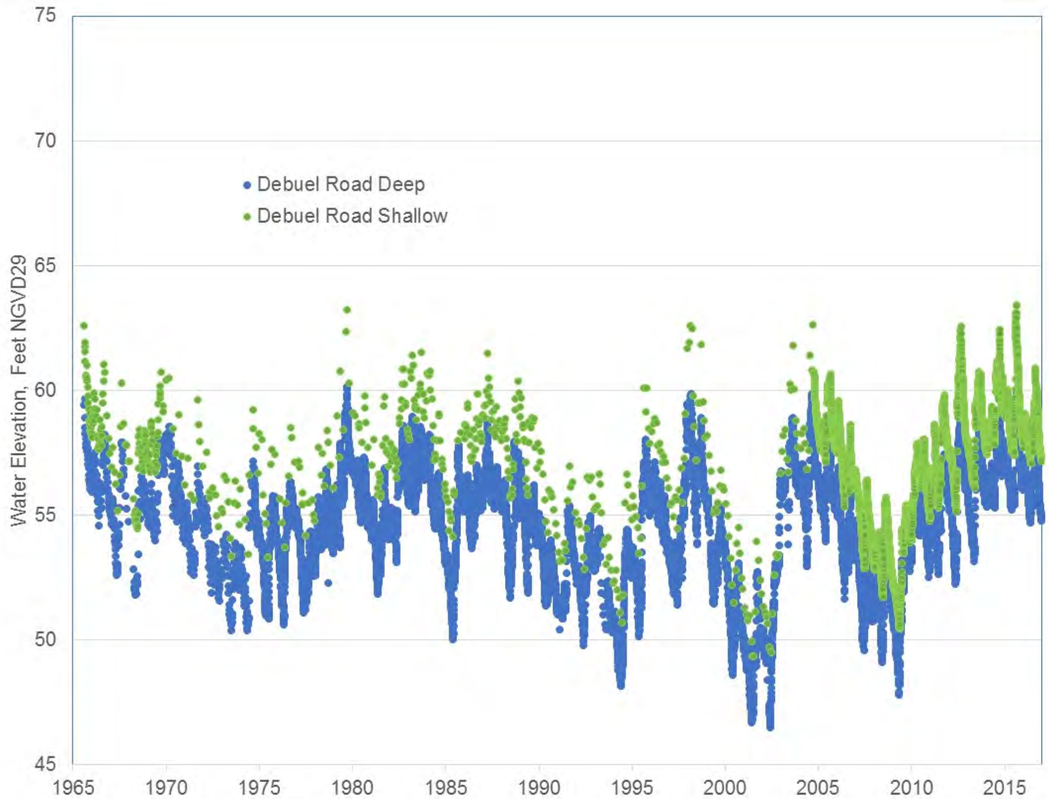

Figure 7. Water levels in the Debuel Road Surficial and Floridan aquifer monitor wells.

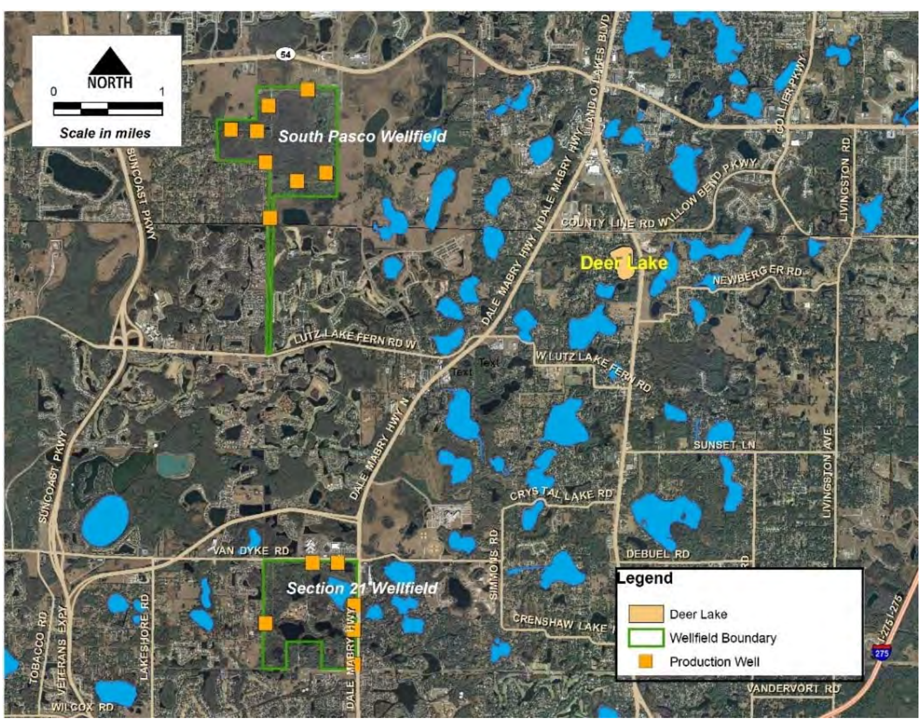

Figure 8. Deer Lake and the Section 21 and South Pasco Wellfields.

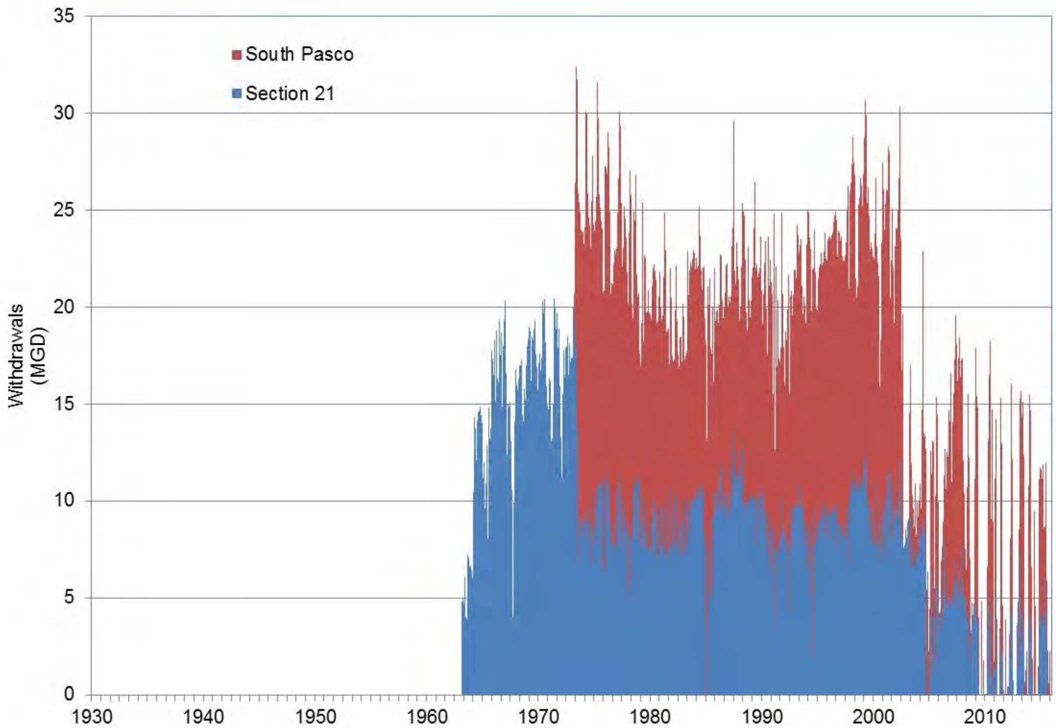

Figure 9. Stacked Section 21 and South Pasco Wellfield withdrawals.

Water levels in many lakes in the area of the South Pasco and Section 21 wellfields have dropped significantly since public supply groundwater withdrawals began in the area (Hancock and Basso, 1996). Because Deer Lake water level data collection did not begin until well after the beginning of withdrawals from the wellfields (Figure 3 and 9), the correlation between groundwater withdrawals and lake levels is not easily seen in the early data. Lake recovery during the period of recent reductions in groundwater withdrawals can be seen in Figure 3, but above average rainfall during that period may account for some of the apparent recovery.

Comparing the 1970s-aerial photograph below with the 1938 aerial, lake bottom is exposed along the shores of both Deer Lake and Little Deer Lake (and some other lakes in the area) in the 1970s aerial (Figure 10). Depending on exactly when the 1970s image was taken, the exposed lake bottom may be due to a combination of low rainfall and groundwater withdrawals from the Section 21 wellfield, or a combination of the Section 21 wellfield and the South Pasco Wellfield. Sinclair (1982) discusses the observed formation of dozens of sinkholes following the initiation of groundwater withdrawals at the Section 21 Wellfield in 1963. Sinkholes were documented as far as several miles away (including several in the Deer Lake area and beyond), and they continued to appear around the wellfield years later. It is possible that a change in

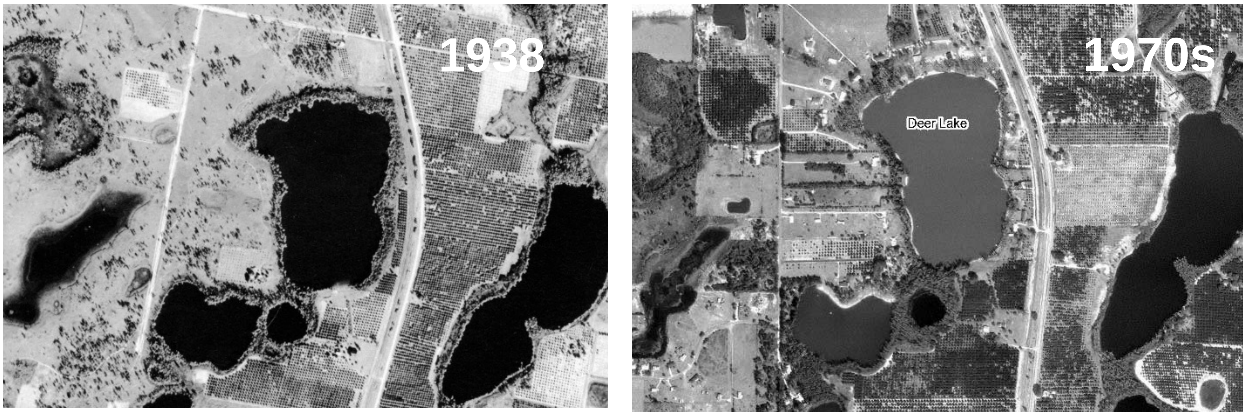

Figure 10. Water level changes in Deer Lake.

leakance properties between Deer Lake and the Upper Floridan aquifer (possibly due to karst activity beneath or surrounding the lakes) has occurred.

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

C. Purpose of Models

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

In the case of Deer Lake, the Section 21 Wellfield has potentially affected lake water levels since early 1963, while the South Pasco Wellfield has potentially affected water level since 1973. Other groundwater withdrawals (including other wellfields) in the area could also affect levels, but the effect of such withdrawals would be much smaller and less consistent. No data from Deer Lake exist prior to the initiation of groundwater withdrawals from the South Pasco and Section 21 Wellfields. Therefore, the development of a water budget model coupled with a rainfall correlation model of the lake was considered essential for estimating long-term Historic percentiles, accounting for any changes in the lake's drainage system, and simulating effects of changing groundwater withdrawal rates.

D. Water Budget Model Overview

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

The hydrologic processes in the water budget model include:

a. Rainfall and evaporation
b. Overland flow
c. Inflow and discharge via channels
d. Flow from and into the surficial aquifer
e. Flow from and into the Upper Floridan aquifer

The water budget model uses a daily time-step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels for the lake. The water budget model for Deer Lake is calibrated from 1982 through 2015. This period provides the best balance of using available data for all parts of the water budget and the desire to develop a long-term water level record.

E. Water Budget Model Components

Lake Stage/Volume

Lake stage area and stage volume estimates were determined by building a terrain model of the lake and surrounding watersheds. Lake bottom elevations and land surface elevations were used to build the model with LP360 (by QCoherent) for ArcGIS, ESRI's ArcMap 10.2.2, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basin with the underlying lake basin morphology to develop one continuous three-dimensional (3D) digital elevation model. The 3D digital elevation model was then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the extent of the lake at its flood stage and working downward to the lowest elevation within the basin.

Precipitation

After a review of several rain gages in the area, a composite of several sources of rainfall data was used for the Deer Lake water budget model (Figure 11). The goal was to use the closest available data to the lake, if the data appeared to be high quality. Rainfall data were collected at a station next to Lake Hobbs (to the south of and closest station to Deer Lake) from January 1, 1986 to August 31, 1995 (Lake Hobbs, SID 18301). Data from the second closest station, Lutz station (SID 19629), is available from 1962 to 1997. Both rainfall stations were maintained by the District. Also available is NEXRAD (Next Generation Weather Radar) derived rainfall data for the lake from 1995 to current. NEXRAD is a network of 160 high-resolution Doppler weather radars controlled by the NWS, Air Force Weather Agency, and Federal Aviation Administration.

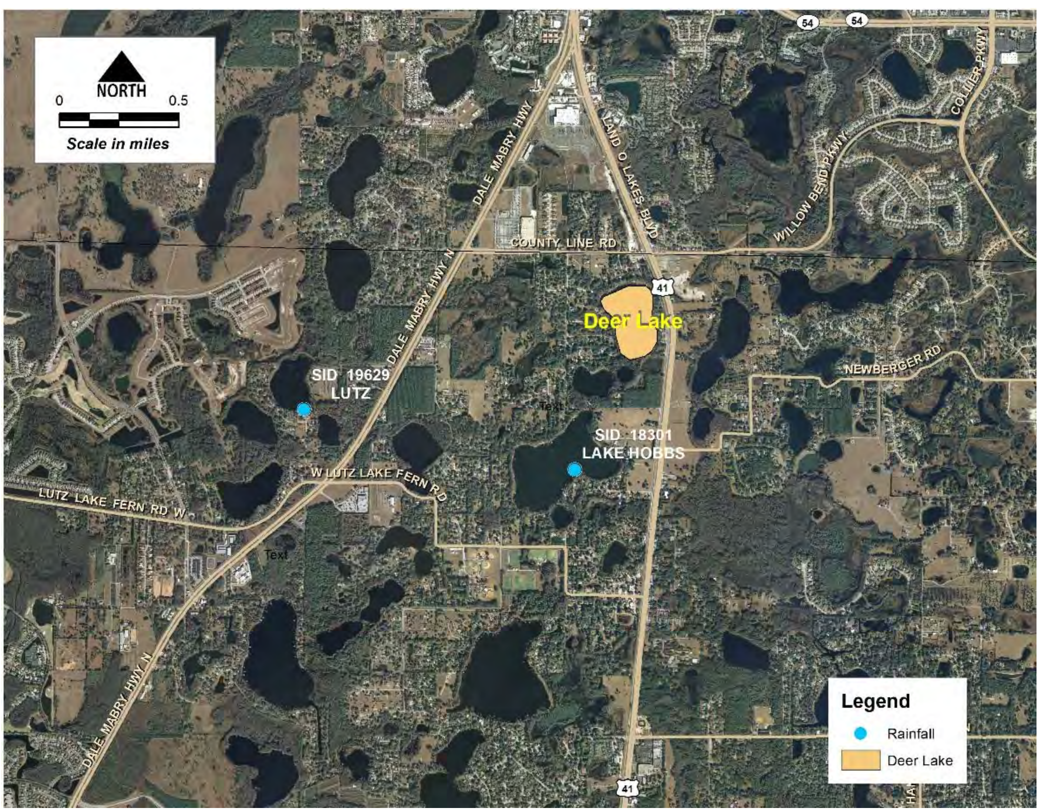

Figure 11. Rain gages used in the Deer Lake water budget model.

After assessment of all available rainfall data, the decision was made to use the Lutz data from January 1982 through December 1985, the Lake Hobbs data from January 1986 through December 1994 (with some missing dates infilled with Lutz data), and the NEXRAD data for the lake from 1995 to 2015.

Lake Evaporation

Lake evaporation was estimated through use of monthly energy budget evaporation data collected by the U.S. Geological Survey (USGS) at Lake Starr in Polk County (Swancar and others, 2000) (Figure 12). The data was collected from August of 1996 through July of 2011. Monthly Lake Starr evaporation data were used in the Deer Lake water budget model when available, and monthly averages for the period of record were used for those months when Lake Starr evaporation data were not available.

A recent study compared monthly energy budget evaporation data collected from both Lake Starr and Calm Lake (Swancar, 2011, personal communications). Calm Lake is located approximately 7 miles to the southwest of Deer Lake (Figure 12). The assessment concluded that the evaporation rates between the two lakes were nearly identical, with small differences attributed to measurement error and monthly differences in latent heat associated with differences in lake depth.

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

Overland Flow

The water budget model was set up to estimate overland flow via a modified version of the U.S. Department of Agriculture, Soil Conservation Service (SCS) Curve Number method (SCS, 1972), and via directly connected impervious area calculations. The free water area of each lake was subtracted from the total watershed area at each time step to estimate the watershed area contributing to surface runoff. The directly connected impervious area (DCIA) was subtracted from the watershed for the SCS calculation, and then added to the lake water budget separately. Additionally, the curve number (CN)

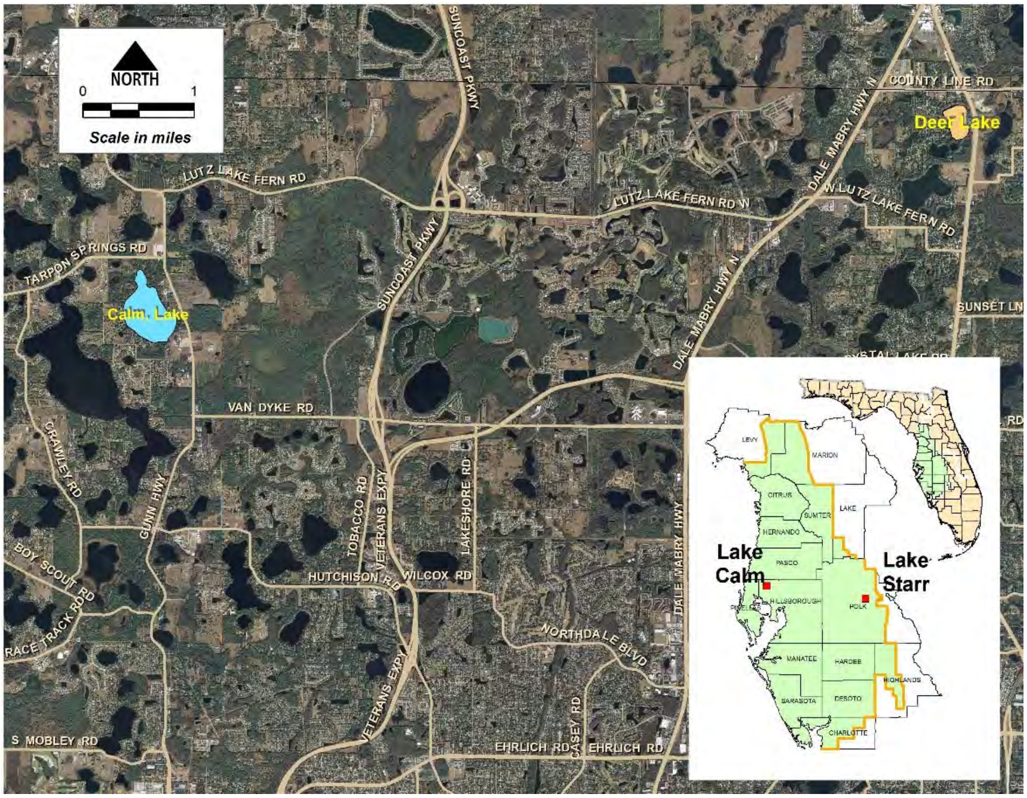

Figure 12. Location of Lakes Deer, Calm and Starr (see map inset).

chosen for the watershed of the lake considers the amount of DCIA in the watershed that has been handled separately.

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

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

Deer Lake’s watershed used in the model is shown in Figure 13. The entire area of the contributing watersheds is estimated to be approximately 250 acres (including the lake), which includes the unnamed lake and Little Deer Lake directly below Deer Lake (for reasons explained in the next section).

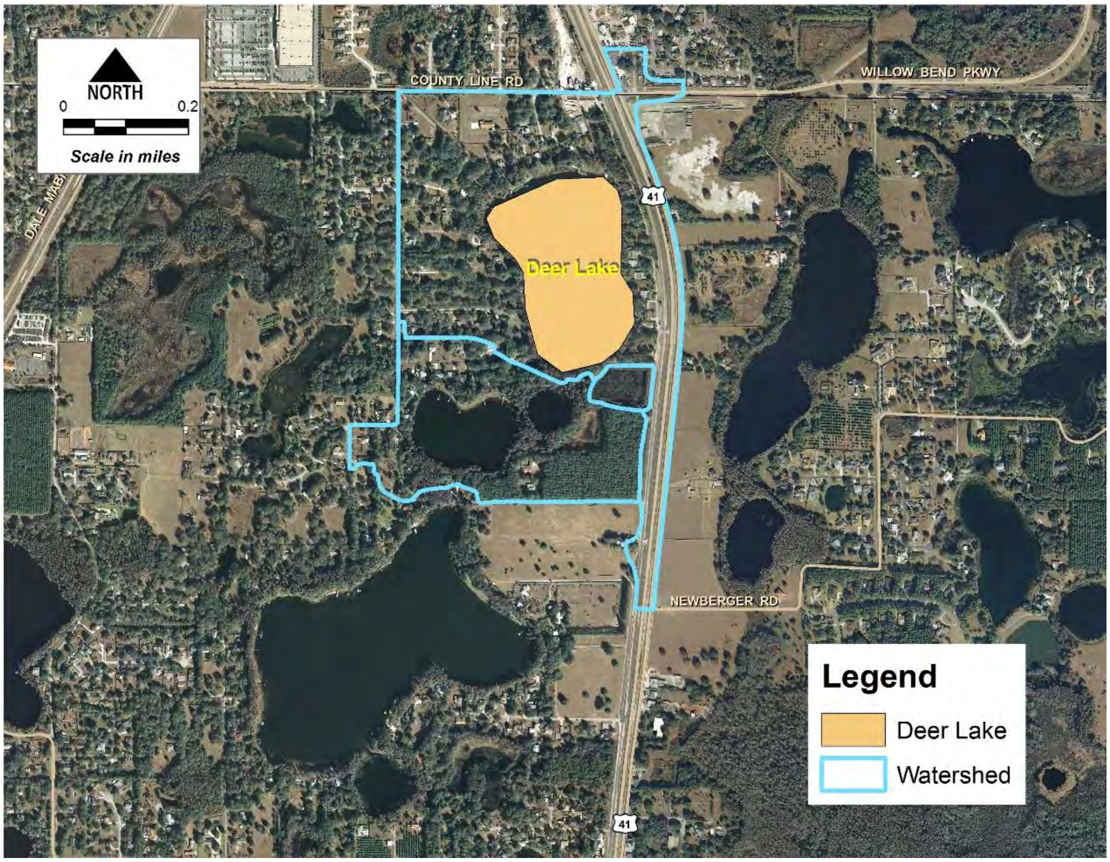

Figure 13. The Deer Lake watershed used in the model.

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

Input Variable	Value
Overland Flow Watershed Size (acres)	250.0
SCS CN of watershed	71
Percent Directly Connected	0
FL Monitor Well Used	Newberger Road Floridan
Surf. Aq. Monitor Well(s) Used	Newberger Road Surficial
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.002
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.0023
Outflow K	0.009
Outflow Invert (ft NGVD29)	66.0
Inflow K	N/A
Inflow Invert (ft NGVD29)	N/A

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

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

Inflow and Discharge via Channels from Outside Watersheds

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

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

A wetland system exists between Deer Lake and Lake Hobbs (with Little Deer Lake and a small unnamed lake in between – Figure 1). A natural high area in wetland between the Little Deer Lake and Lake Hobbs was surveyed at 66.0 feet NGVD29, with all other survey elevations between Deer Lake, the unnamed Lake, and Little Deer Lake being several feet lower, so the wetland between Little Deer Lake and Lake Hobbs is the controlling elevation for Deer Lake (Table 1). For this reason, the unnamed lake and Little Deer Lake are considered part of Deer Lake in this analysis. This elevation was also used as the controlling inlet elevation for the evaluation of the recent reassessment of the Lake Hobbs MFL (Uranowski and others, 2015).

Flow from and into the surficial aquifer and Upper Floridan aquifer

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

The Newberger Road Floridan well is the closest Upper Floridan aquifer monitor well to Deer Lake, located approximately 4,400 feet to the southeast of Deer Lake (Figures 4 and 5), and was used to represent the potentiometric surface under the lake. An inspection of multiple May and September potentiometric surface maps from District archives over several years representing periods before and after wellfield cutbacks found both the Newberger Road well and Deer Lake to be consistently located along the same potentiometric value, it was concluded that no adjustment of the water levels at the well were needed to represent the potentiometric surface at the lake. Missing daily water level values were in-filled using the previously recorded value. Since the Newberger Road Floridan well data does not begin until 1989, the Debuel Road Deep Floridan well was used from 1982 until the beginning of the Newberger Road Floridan well data begins Figures 4 and 7). A similar inspection of potentiometric surface maps found that the potentiometric surface elevation from the Debuel Road Deep Floridan well need to be increased by 5 feet to be equal to the potentiometric surface around Deer Lake. Missing daily water level values were again in-filled using the previously recorded value.

Similarly, the Newberger Road Surficial well is the closest surficial aquifer well to Deer Lake (at the same location as the Newberger Road Floridan well) was used to represent the water table at the lake (Figures 4 and 5). Because topographic elevations around the Newberger wells are similar to those around Deer Lake, no adjustment was made to the Newberger Road well data. As with the Floridan aquifer wells, data from the Debuel Road shallow surficial aquifer well was used for the period before the Newberger Road surficial aquifer well was constructed (Figures 4 and 7). However, because the topographic elevations around the Debuel Road wells is approximately 8 feet low than those around Deer Lake, 8 feet was added to the Debuel Road Shallow water level data. Again, monthly or missing data were in-filled based on the approach used for the Upper Floridan aquifer monitoring wells.

F. Water Budget Model Approach

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

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

Figure 14 presents the calibration results for the model. Table 2 presents a comparison of the percentiles of the measured data versus the model results. Table 3 presents modeled water budget components for the model calibration.

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 14, the model appears to be reasonably well calibrated. There are a few periods when the peaks in the modeled hydrograph are higher or lower than the measured values, and these differences contributed to minor differences between the modeled and measured percentiles associated with higher and lower lake levels, i.e., the P10 and P90 percentiles. Reduced precision in the higher and lower ranges of the stage-volume relationships for the lake may also have contributed to the percentile differences.

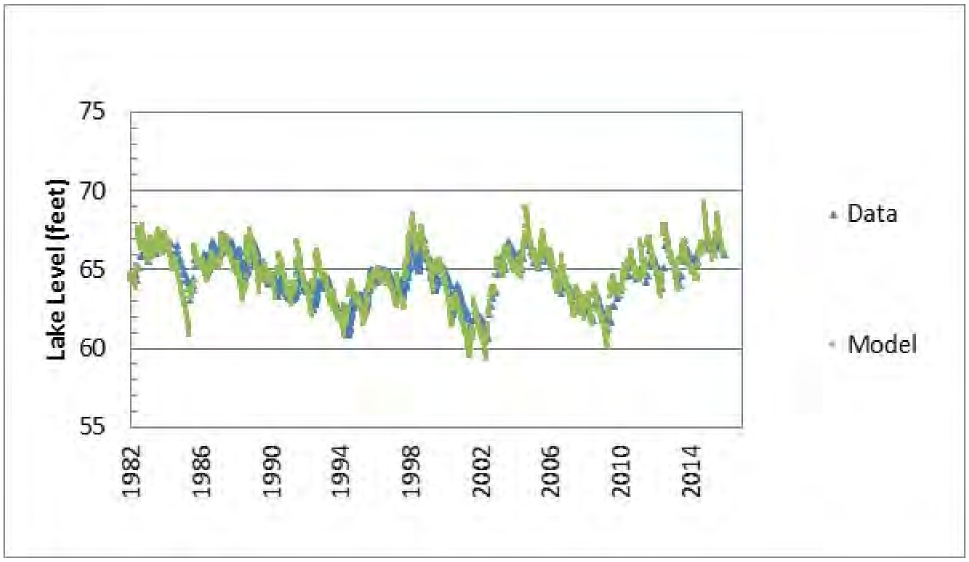

Figure 14. Modeled water levels predicted for the calibrated Deer Lake water budget model (Model) and measured levels used for the model calibration (Data).

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

	Data	Model
P10	66.4	66.4
P50	64.4	64.4
P90	62.6	62.5

Table 3. Deer Lake Water Budget (1982-2015)

Inflows	Rainfall	Surficial Aquifer Groundwater Inflow	Floridan Aquifer Groundwater Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	54.0	3.0	0.0	43.7	0.0	0.0	100.7
Percentage	53.6	3.0	0.0	43.4	0.0	0.0	100.0
Outflows	**Evaporation**	**Surficial Aquifer Groundwater Outflow**	**Floridan Aquifer Groundwater Outflow**			**Outflow via channel**	**Total**
Inches/year	58.1	4.0	36.1			6.3	104.5
Percentage	55.6	3.8	34.6			6.0	100.0

A review of Table 2 shows that the differences in median percentile (P50) and P10 percentiles between the data and model for the lake are the same within 0.1 feet, while the P90 is off by 0.1 feet. Attempts at better calibration of the P90 resulted in larger differences between the medians. Some of the differences at the higher and lower percentiles may be due to less detail in the higher and lower stage-volume relationships.

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

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the Deer Lake water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from the Section 21 and South

Pasco Wellfields are available for the model calibration period, so if a relationship between withdrawal rates and Upper Floridan aquifer potentiometric levels can be established, the effect of changes in groundwater withdrawals can be estimated by adjusting Upper Floridan aquifer levels in the model.

The Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013) is an integrated model developed for the northern Tampa Bay area. The INTB model can account for groundwater and surface-water, as well as the interaction between them. The domain of the INTB application includes the Deer Lake area, and represents the most current understanding of the hydrogeologic system in the area.
The INTB was used to determine the drawdown in the surficial aquifer and Upper Floridan aquifer in response to groundwater withdrawals in the area. Drawdown in both aquifers was calculated for two withdrawal rates representing the effects of Tampa Bay Water's regional wellfields before and after cutbacks from approximately 150 mgd to 90 mgd. The pre-cutback period in the model is from 1974 through 2002, while the post-cutback period is 2003 through 2015. The model results allowed the drawdowns associated with all permitted withdrawals to be calculated before and after wellfield cutbacks, assuming changes in all other withdrawals are consistent for the modeled period.

The INTB model was run for each withdrawal scenario from 1996 to 2006 using a daily integration step. Drawdown values in feet were calculated by running the model with and without groundwater withdrawals, and were calculated for each node in the model. The INTB model uses a one-quarter mile grid spacing around the wellfields. Groundwater withdrawal rates from the Section 21 Wellfield in each scenario were 8.9 mgd and 4.2 mgd, respectively, while groundwater withdrawals from the South Pasco wellfield in each scenario were 14.9 mgd and 4.4 mgd, respectively.

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

To estimate lake levels without the influence of groundwater withdrawals, the Upper Floridan aquifer and surficial aquifer wells in the water budget model were adjusted to represent zero withdrawals. For the 1982 through 2015 water budget model period, two adjustment periods were used to reflect the cutbacks that took place at the Section 21 and South Pasco Wellfields. Adjustments to each Upper Floridan aquifer and surficial aquifer well and the associated adjustment periods are found in Table 4.

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

Well	Adjustment (feet) 1982 through 2002	Adjustment (feet) 2003 through 2015
Floridan aquifer	2.9	1.0
Surficial aquifer	1.8	0.6

Figure 15 presents measured water level data for the lake along with the model-simulated lake levels in the lake under Historic conditions, i.e. in the absence of groundwater withdrawals with structural alterations similar to current conditions. Table 5 presents the Historic percentiles based on the model output.

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

Historic normal pool was determined for Deer Lake based on inflection points of adjacent cypress trees. The Historic normal pool for Deer Lake was determined to be 66.9 feet NGVD29. While the Historic normal pool and natural P10 in lakes and wetlands in the northern Tampa Bay area may differ by several tenths of a foot in many cases, the model's estimate of the Historic P10 for Deer Lake is slightly higher than the field determined Historic normal pool, which may indicate some subsidence may have occurred in the past.

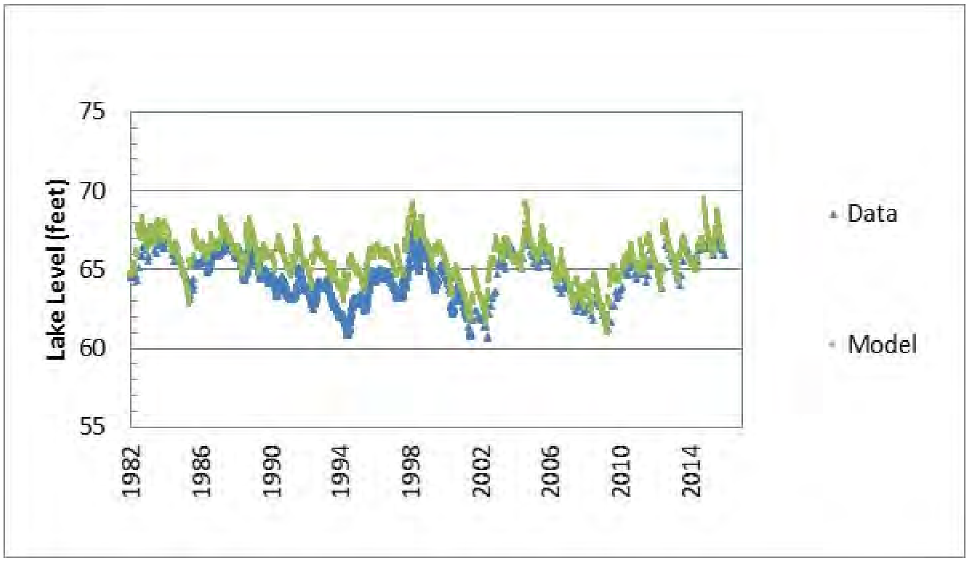

Figure 15. Measured lake levels (Data) and Historic water levels predicted with the calibrated Deer Lake model (Model).

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

Percentile	Elevation
P10	67.2
P50	65.8
P90	64.4

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, 1997). LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data.

In this application, the simulated lake water levels representing Historic conditions were correlated with Long-term rainfall. For the correlation, additional representative rainfall records were added to the rainfall records used in the water budget model (1982-2015). As with the initial water budget model, the goal was to use the closest available data to the lake, if the data appeared to be high quality. Data from the Lutz station (SID 19629) was used from January 1, 1974 to December 31, 1981. Data from the Hanna and Whalen stations were used to fill in missing data points during this period. Data from the Cosme rain gage (located near the Cosme wellfield), which was replaced by the Cosme 18 due to quality control issues, was used to extend the rain data back to 1945 (Figure 16). The quality control issues at the gage reportedly occurred after 1995, and there is no evidence that there were quality control issues at the Cosme gage prior to that time. Therefore, the data used in the LOC model appears to not have been affected by the quality control issues. Finally, rainfall data from the St. Leo gage (Figure 16) were used to extend the data back to 1930. Although the St. Leo gage is approximately 17 miles from Deer Lake, it is one of only a few rain gages in the vicinity with data preceding 1945, and in this case, is only used in the first few years of the correlation.

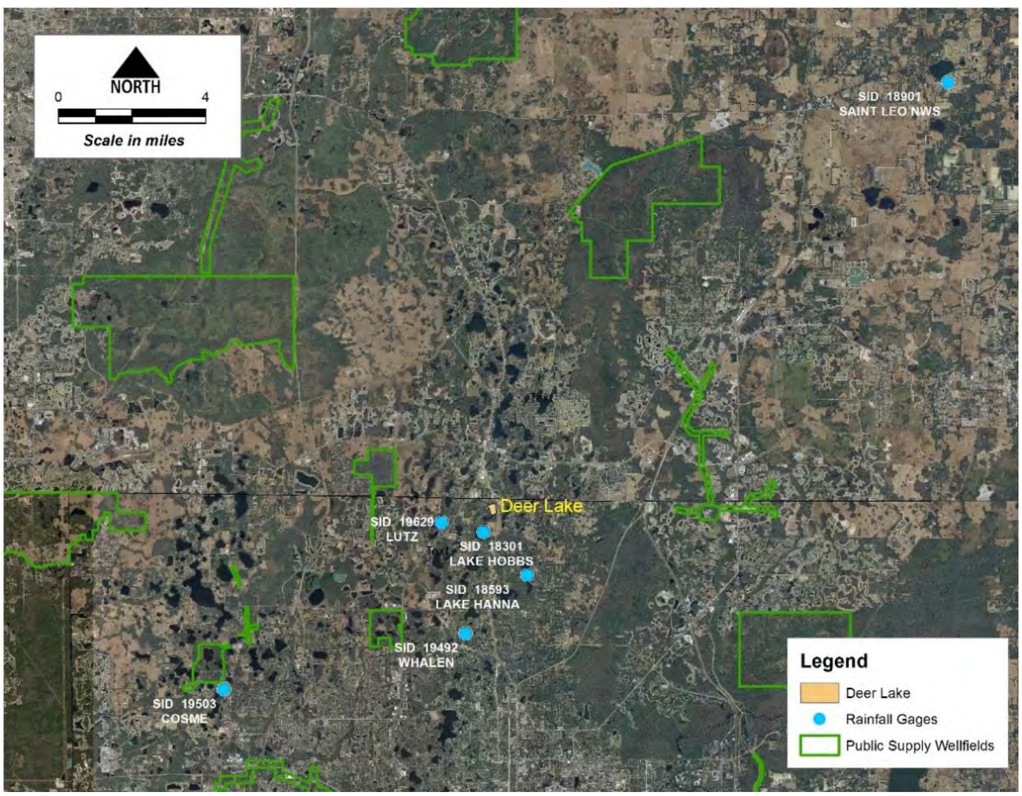

Figure 16. Location of rain stations used for the rainfall correlation model.

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

Rainfall was correlated to the water budget model results for the entire period used in the water budget model (1982-2015), and the results from 1946-2015 (70 years) were produced. For Deer Lake, the 3-year weighted model had the highest correlation coefficient, with an R^2 of 0.70. Previous correlations for lakes in the northern Tampa Bay area have consistently had best correlation coefficients in the 2 to 5-year range. The results are presented in Figure 17.

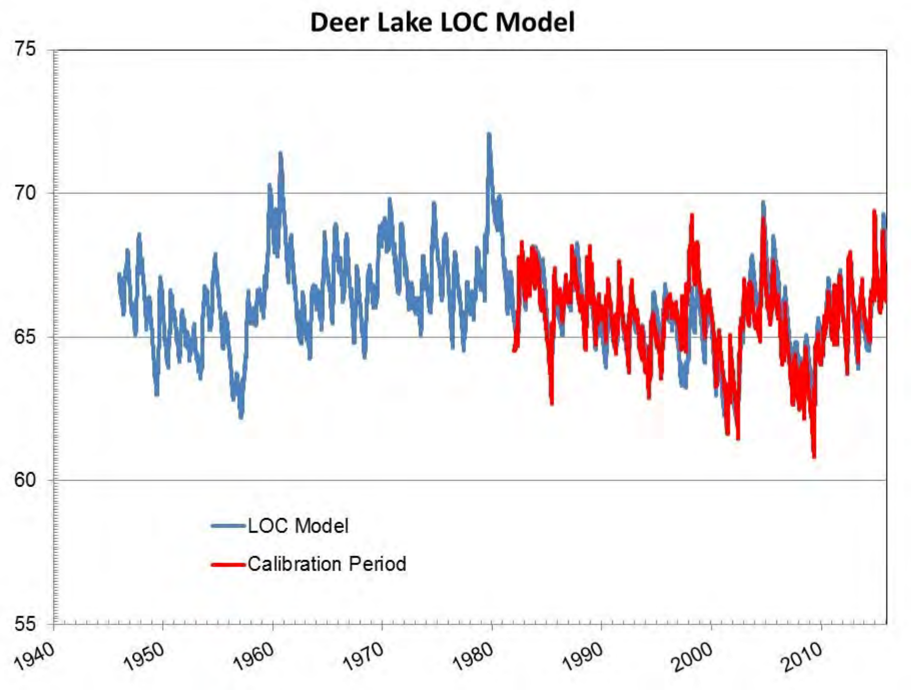

Figure 17. LOC model results for Deer Lake.

To produce Historic percentiles that apply significant weight to the results of the water budget models, the rainfall LOC results for the period of the water budget model are replaced with the water budget model results. Therefore, the LOC rainfall model results are used for the period of 1946-1981, while the water budget results are used for the period of 1982-2015. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Table 6. Note that the difference between the P10, P50, and P90 percentiles from the water budget model (Table 5) and those from the hybrid rainfall model (Table 6) for Deer Lake are 0.9, 0.3, and 0.3 feet, respectively. It does appear that the P10 derived from the LOC model may be inflated due some potentially unrealistic high values prior to the calibration period, which may need to be assessed when the Minimum and Guidance levels are calculated.

Table 6. Historic percentiles as estimated by the hybrid model from 1946 to 2015 (feet NGVD29).

Percentile	Deer Lake
P10	68.1
P50	66.1
P90	64.1

J. Conclusions

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

K. References

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APPENDIX B

Technical Memorandum

March 16, 2017

TO: JP Marchand, P.E., Bureau Chief, Water Resources Bureau

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
Mark K. Hurst, Senior Environmental Scientist, Water Resources Bureau

Subject: Deer Lake Initial Minimum Levels Status Assessment

A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Deer Lake 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 Hancock and McBride (2017) and Hurst and others (2017).

Section 373.0421, F.S. requires that a recovery or prevention strategy be developed for all water bodies that are found to be below their minimum flows or levels, or are projected to fall below the minimum flows or levels within 20 years. In the case of Deer Lake 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 Deer Lake 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 Deer Lake and any recovery that may be necessary for the lake.

B. Background

Deer Lake is in northwest Hillsborough County, on the southwest corner of the intersection of U.S. 41 and County Line Road in Lutz (Figure 1). The lake lies within the Brushy Creek watershed. Brushy Creek is a tributary to Rocky Creek. Deer Lake has no inflow other than overland flow, but discharges south via a wetland connection to a small unnamed lake, Little

Deer Lake and Lake Hobbs (Figure 2) during high flow periods. The topography is very flat, however, and flows are often negligible.

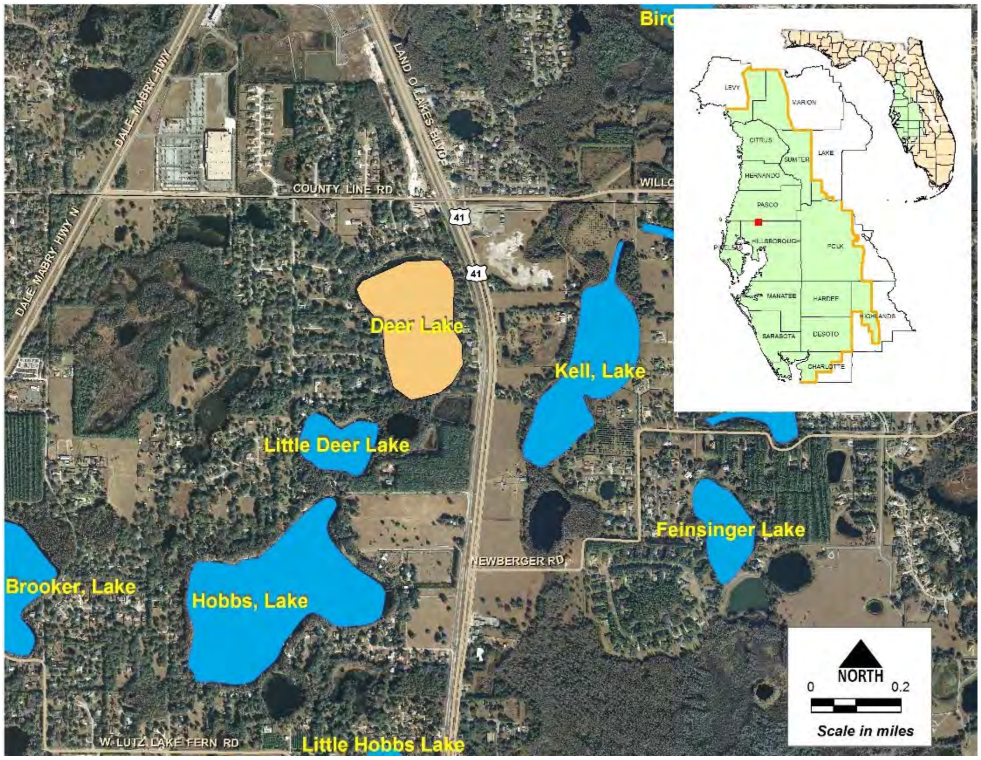

Figure 1. Location of Deer Lake in Hillsborough County, Florida.

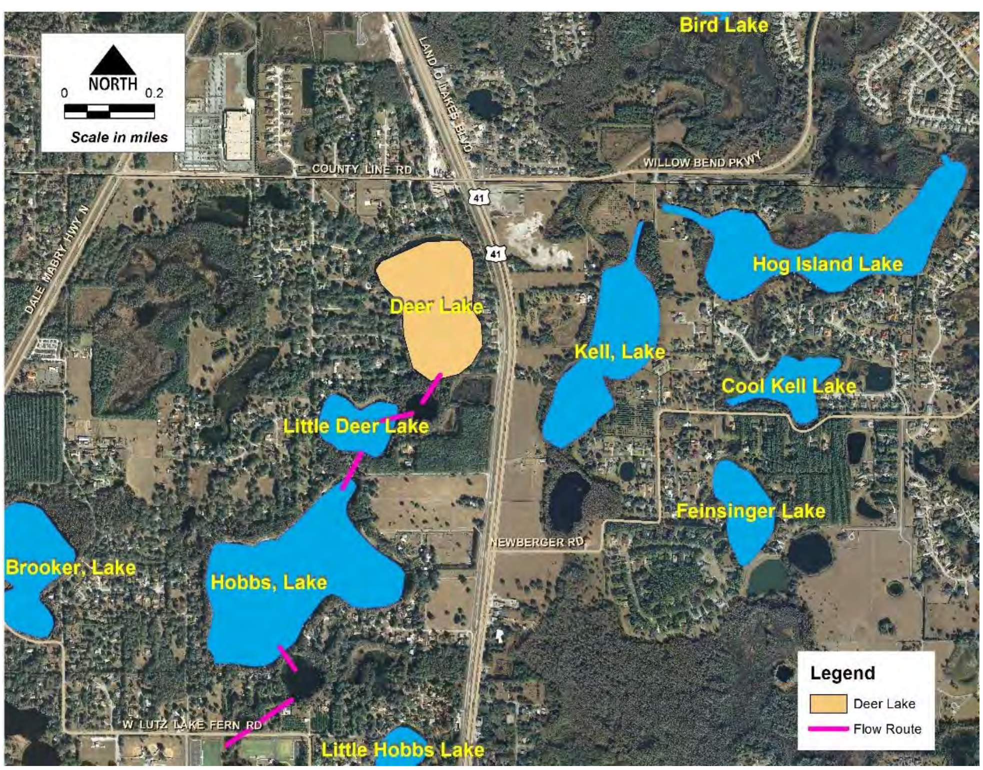

Figure 2. Flow between Deer Lake, Little Deer Lake, and Lake Hobbs.

Deer Lake is located approximately 3 miles southeast of the South Pasco Wellfield, and 3 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.

C. Revised Minimum Levels Proposed for Deer Lake

Revised minimum levels proposed for Deer Lake are presented in Table 1 and discussed in more detail by Hurst and others (2017). Minimum levels represent long-term conditions that, if achieved, are expected to protect water resources and the ecology of the area from significant harm that may result from water withdrawals. The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. The Minimum Lake Level therefore represents the required 50th percentile (P50) of long-term water levels, while the High Minimum Lake Level represents the required 10th percentile (P10) of long-term water levels. To determine the status of minimum levels for Deer Lake 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 Deer Lake.

Proposed Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	66.5
Minimum Lake Level	65.1

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Deer Lake from January 2003 through December 2016, which was determined to represent the “Current” period. The Current period represents a recent “Long-term” period when hydrologic stresses (including groundwater withdrawals) and structural alterations are reasonably stable. “Long-term” is defined as a period that has been subjected to the full range of rainfall variability that can be expected in the future. As demonstrated in Hancock and McBride (2017), groundwater withdrawals during this period were relatively consistent. To create a data set that can

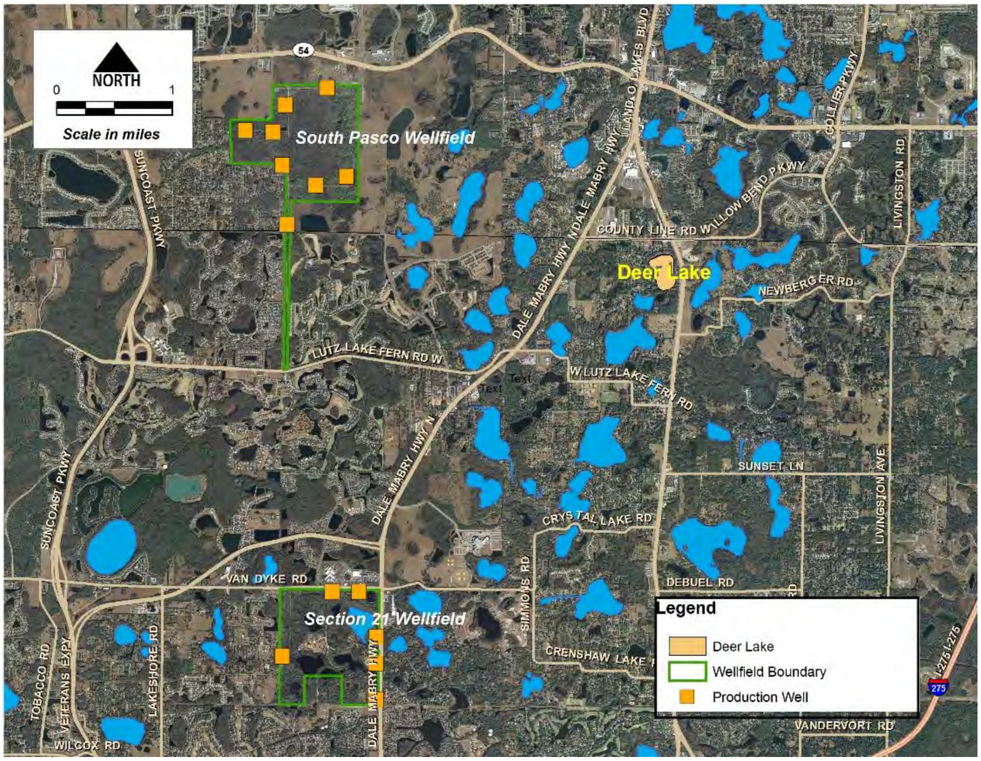

Figure 3. Deer Lake and the Section 21 and South Pasco Wellfields.

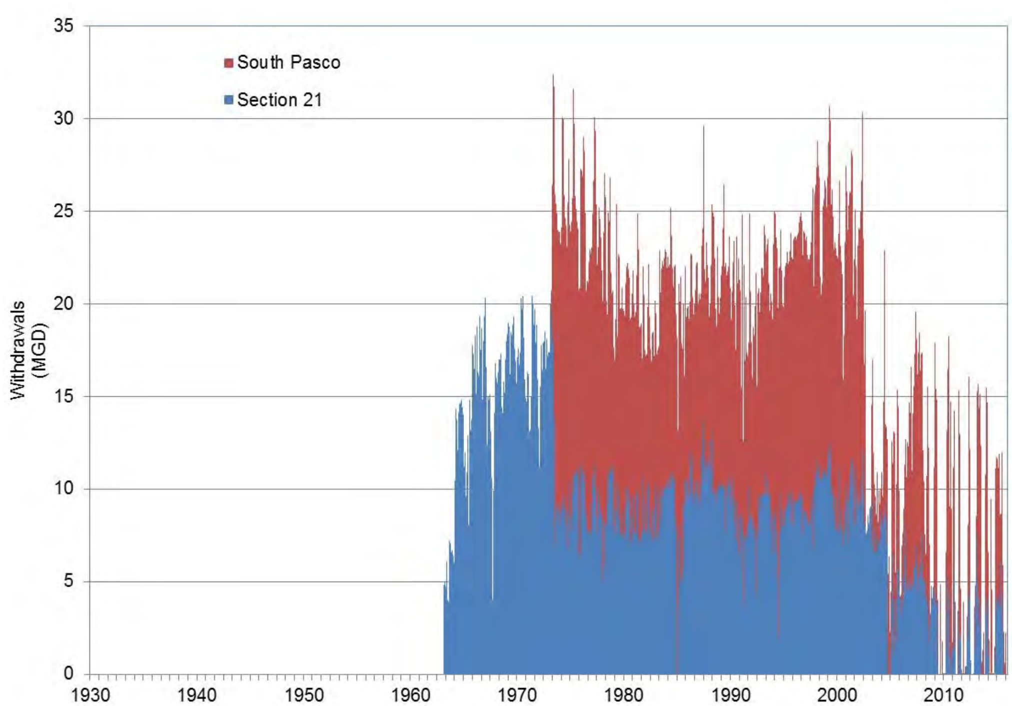

Figure 4. Section 21 and South Pasco Wellfield withdrawals.

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 Deer Lake (Hancock and McBride, 2017). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing over 60 years of lake levels, based on the current relationship between lake water levels and actual rainfall.

The same rainfall data set used for setting the minimum levels for Deer Lake was used for the status assessment, and one more year (2016) of NEXRAD derived rainfall data was added (Hancock and McBride, 2017). The best resulting correlation for the LOC model created with measured data (2003-2016) was the 3-year weighted period, with a coefficient of determination of 0.69. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the percentiles calculated directly from the measured lake level data for Deer Lake for the period from 2003 through 2016. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 11 years, rather than the longer-term rainfall conditions represented in the 1946 to 2016 LOC model simulation.

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

Percentile	**Long Term LOC Model Results 1946 to 2016** Elevation in feet NGVD 29*	**Measured Lake Levels for Current Period (2003 to 2016)** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	67.3	66.6	66.5
P50	65.1	65.5	65.1

* LOC model based on Current Period and extended using rainfall for 1946 to 2016

A comparison of the LOC model with the revised minimum levels proposed for Deer Lake indicates that the Long-term P10 is 0.8 feet above the proposed High Minimum Lake Level, and the Long-term P50 is at the proposed Minimum Lake Level. The P10 elevation derived directly from the 2003 to 2016 measured lake data is 0.1 feet higher than the proposed High Minimum Lake Level, and the P50 elevation is 0.4 feet higher than the proposed Minimum

Lake Level. Differences in rainfall between the shorter 2003 to 2016 period and the longer 1946 to 2016 period used for the LOC modeling analyses likely contribute to the differences between derived and measured lake stage exceedance percentiles. Additionally, differences between actual withdrawal rates and those used in the models may have contributed to some of the differences in the percentiles.

E. Conclusions

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

Minimum flow and level status assessments are completed on an annual basis by the District and on a five-year basis as part of the regional water supply planning process. In addition, Deer Lake 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 Deer Lake 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 Deer Lake 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 Deer Lake is found to not be meeting its adopted minimum levels. The draft results of the Permit Recovery Assessment Plan are due to the District by December 31, 2018.

F. References

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APPENDIX C

Technical Memorandum

February 10, 2017

TO: Michael C. Hancock, P.E., Senior Hydrogeologist, Water Resources Bureau
Mark K. Hurst, Senior Environmental Scientist, Resource Evaluation Bureau
Tamera S. McBride, P.G., Senior Hydrogeologist, Water Resources Bureau

FROM: Jason G. Patterson, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Deer Lake

1.0 Introduction

Deer Lake is in northwest Hillsborough County in west-central Florida (Figure 1). Prior to establishment of a Minimum Level (ML), an evaluation of hydrologic changes near the lake is necessary to determine if the water body has been significantly impacted by groundwater withdrawals. The establishment of the ML for Deer Lake 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 Deer Lake.

3.0 Evaluation of Groundwater Withdrawal Impacts to Deer Lake

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

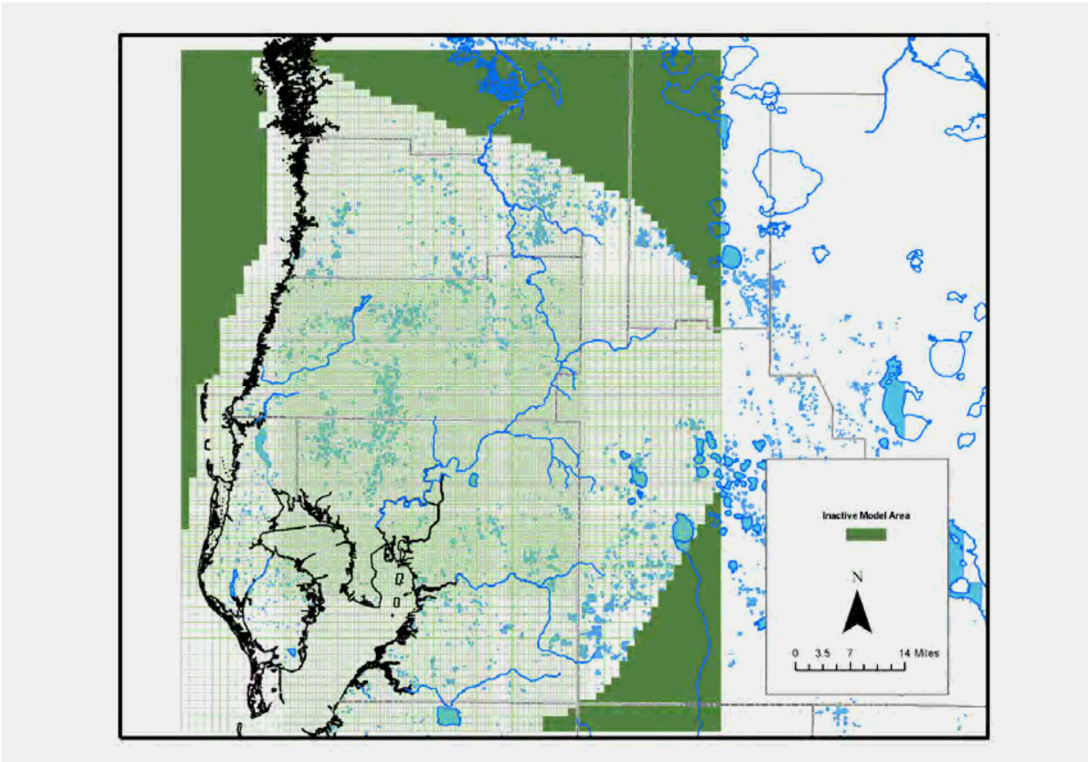

Figure 2. Groundwater grid used in the INTB model

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.

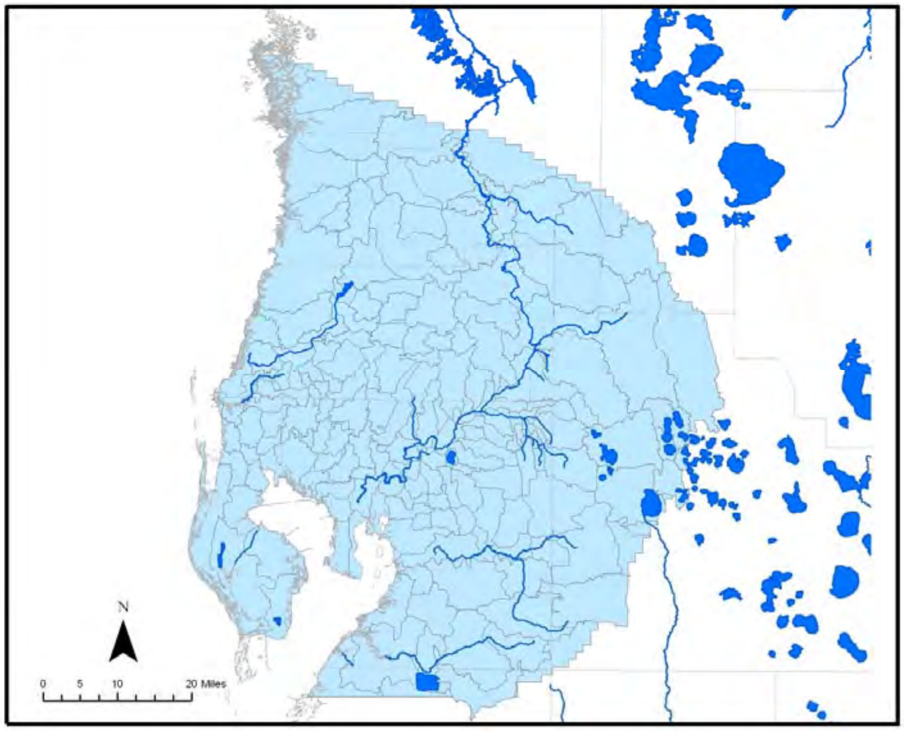

Figure 3. HSPF subbasins in the INTB model.

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.

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

3.1 INTB Model Scenarios

Three different groundwater withdrawal scenarios were run with the INTB model. The first scenario consisted of simulating all groundwater withdrawn within the model domain from 1989 through 2000. The second scenario consisted of eliminating all pumping in the Central West-Central Florida Groundwater Basin (Figure 4). Total withdrawals within the Central West-Central Florida Groundwater Basin averaged 239.4 mgd during the 1989-2000 period. TBW central wellfield system withdrawals were simulated at their actual withdrawal rates during this

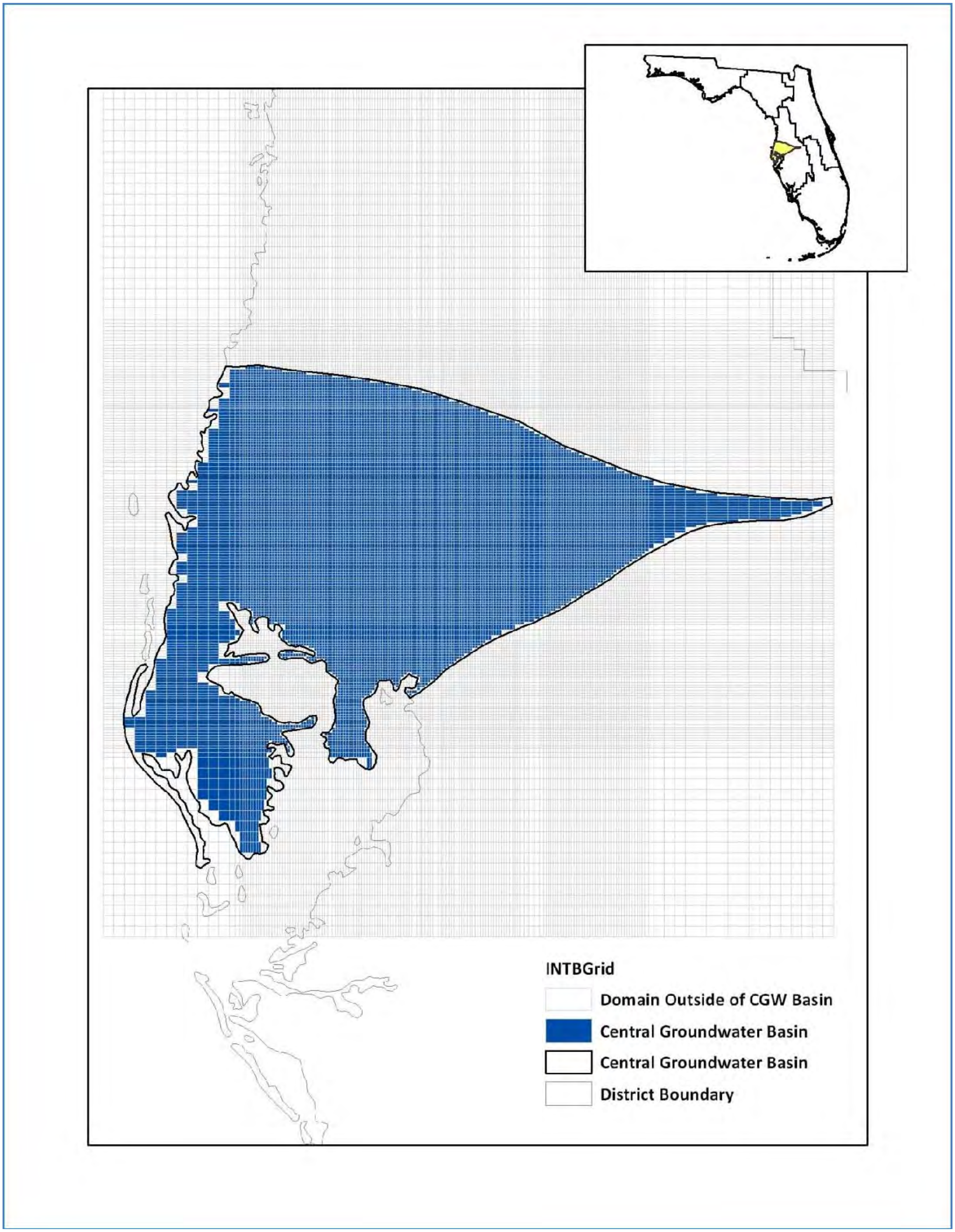

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

period. The third scenario consisted of reducing TBW central wellfield system withdrawals to their mandated recovery quantity of 90 mgd from the 11 central system wellfields. For TBW only, the 2008 pumping distribution was adjusted slightly upward from 86.9 mgd to 90 mgd to match recovery quantities.

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Deer Lake was 1.8 feet, and 2.9 feet in the Upper Floridan aquifer (Figure 5 and 6). Taking the difference in modeled heads from the TBW recovery pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Deer Lake was 0.6 feet and 1.0 feet in the Upper Floridan aquifer (Figure 7 and 8). Table 1 presents the predicted drawdown in the surficial and the Upper Floridan aquifer based on the INTB model results.

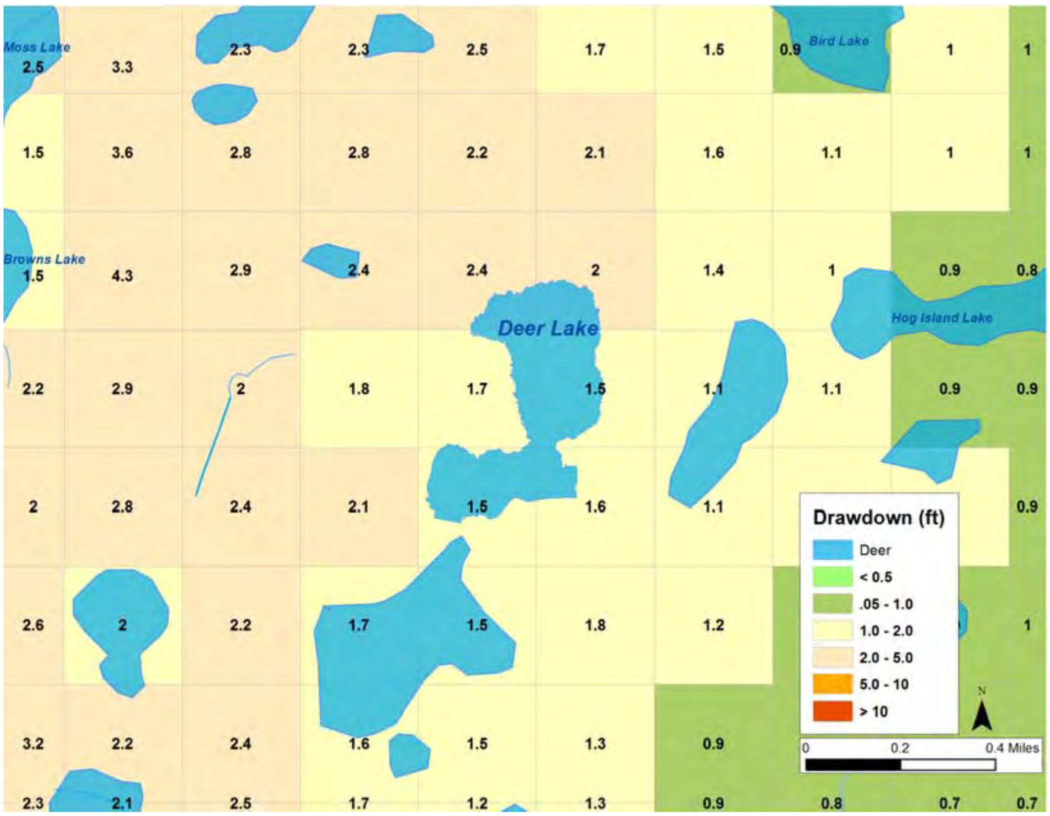

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

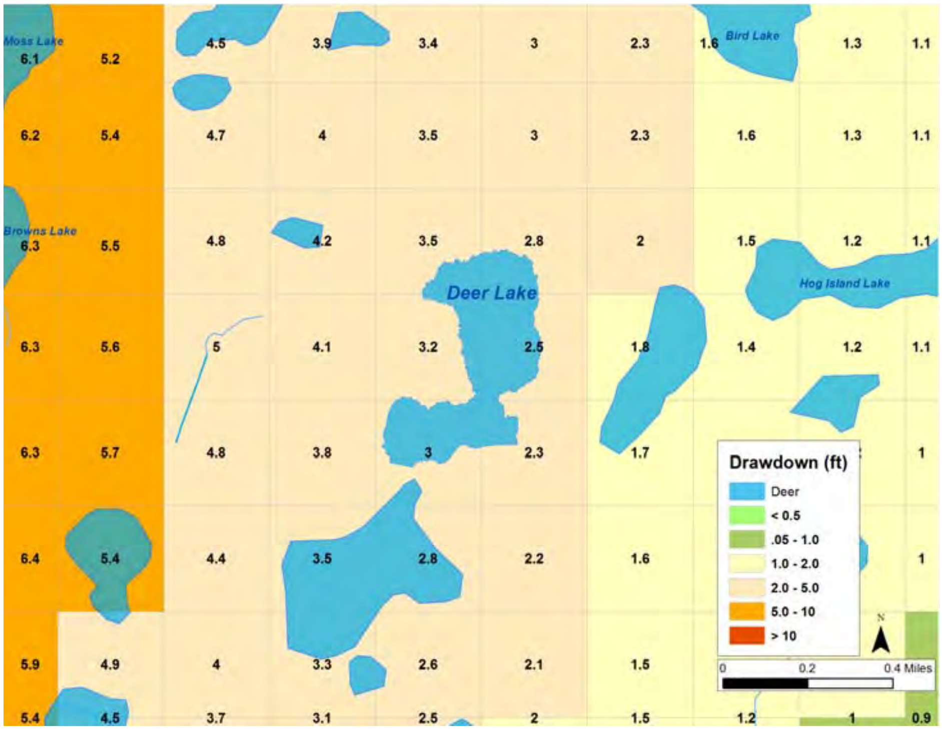

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

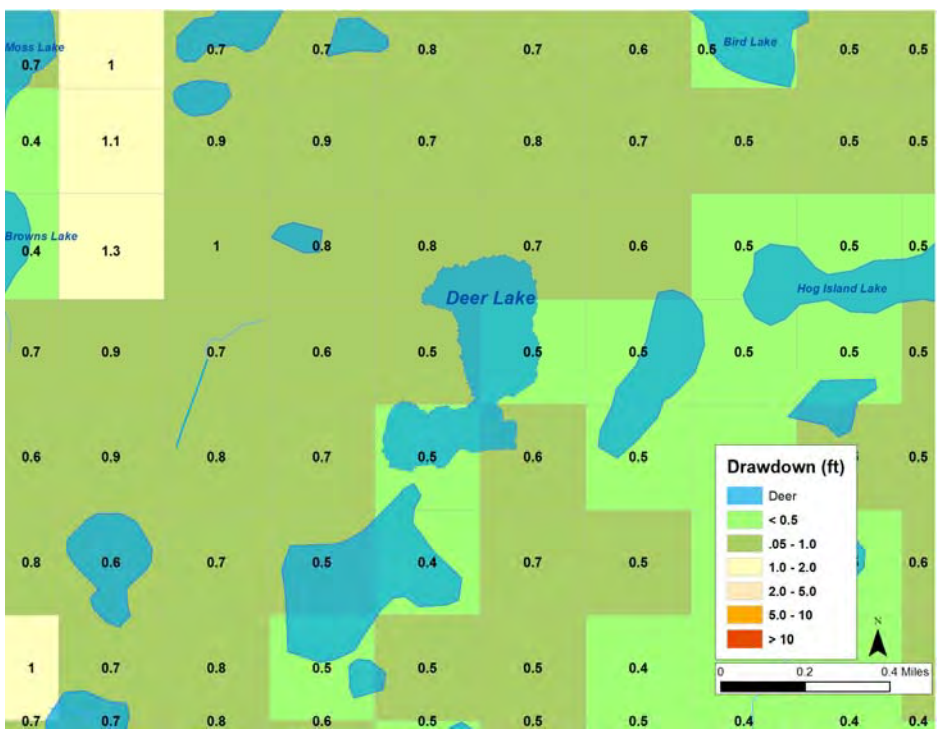

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

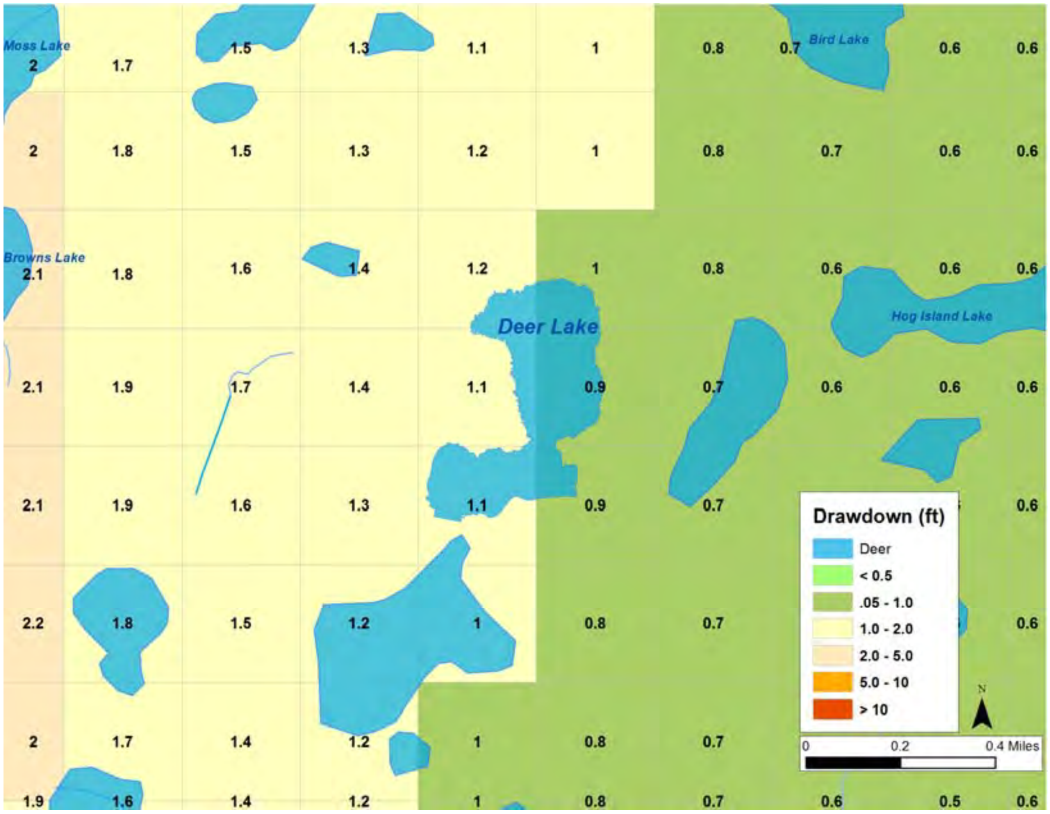

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

Table 1. INTB model results for Deer Lake.

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*
Deer	1.8	0.6
Lake Name	**Predicted Drawdown (ft) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (ft) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd***
Deer	2.9	1.0

* Average drawdown from model cells intersecting lake

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