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

July 7, 2015

Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District

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Cover Page: 2002 aerial photograph of Bird Lake, District archives.

Table of Contents

Executive Summary

This report describes the development of Minimum and Guidance levels for Bird Lake in Hillsborough County, Florida based on reevaluation of levels in Southwest Florida Water Management District rules that became effective in August 2000. Minimum levels are the levels at which further water withdrawals would be significantly harmful to the water resources of the area (Section 373.042(1)(b), F.S.). Adopted minimum levels are used to support water resource planning and permitting activities. Adopted guidance levels are used as advisory guidelines for construction of lakeshore development, water dependent structures, and operation of water management structures.

Section 373.0421(3), F.S., requires the periodic reevaluation and, as needed, the revision of established minimum flows and levels. Bird Lake was selected for reevaluation based on development of modeling tools for simulating lake level fluctuations that were not available when levels currently adopted for the lake were developed. The adopted lake levels were also reevaluated to support ongoing assessments of minimum flows and levels in the northern Tampa Bay Water Use Caution Area, a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Revised Guidance and Minimum Levels for Bird Lake were developed using current District methods for establishing minimum levels for Category 2 Lakes, which are lakes that are not contiguous with at least 0.5 acres of cypress-dominated wetlands. The Minimum Levels were developed with consideration of and are protective of all 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.). The levels are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29) that must be equaled or exceeded specified percentages of time on a long-term basis. Table ES-1 identifies these elevations and includes generic descriptions for the levels in District rules (Rule 40D-8.624, F.A.C). Differences between the current and previously adopted levels are primarily 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.

Based on these results, revision of the previously adopted Guidance and Minimum Levels for Bird Lake was recommended and approved by the District Governing Board. The Minimum and Guidance Levels identified in this report replaces the previously adopted levels for the lake included in District rules.

Based on available measured and modeled water level records, the minimum levels for Bird Lake are not currently being met. Recovery strategies outlined in the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area and the Hillsborough River Recover Strategy (Rule 40D-80.073, F.A.C) will apply for recovery of minimum levels for the lake. Modeling analyses suggest that if recent, lowered groundwater withdrawal rates from the Tampa Bay Water

Central System Facilities that impact the lake's water levels continue, the Minimum Level may be met. Tampa Bay Water, in cooperation with the District, will assess the specific needs for recovery in Bird Lake and other water bodies affected by groundwater withdrawals from the Central System Facilities and by 2020, if not sooner, an alternative recovery project will be proposed if Bird Lake is found to not be meeting its adopted minimum levels.

Table ES-1. Minimum and Guidance Levels for Bird Lake and level descriptions.

Minimum and Guidance Levels	Elevation (feet above NGVD29[a])	Level Descriptions
High Guidance Level	50.0	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.
High Minimum Lake Level	50.0	Elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis.
Minimum Lake Level	48.8	Elevation that the lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis.
Low Guidance Level	47.5	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.

[a] National Geodetic Vertical Datum of 1929

[b] North American Vertical Datum of 1988

Introduction

Reevaluation of Minimum and Guidance Levels

This report describes the development of minimum and guidance levels for Bird Lake in Hillsborough County, Florida. The levels were developed based on the reevaluation of minimum and guidance levels approved by the Southwest Florida Water Management District Governing Board for the lake in October 1998 (see Southwest Florida Water Management District 1999) and adopted into District rules with an effective date of August 7, 2000. The minimum and guidance levels presented in this report represent the needed revisions to the previously adopted levels.

Bird Lake was selected for reevaluation based on development of modeling tools for simulating lake level fluctuations that were not available when the currently adopted levels were developed. The adopted lake levels were also reevaluated to support ongoing assessments of minimum flows and levels in the northern Tampa Bay Water

Use Caution Area, 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." Minimum flows and levels 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), Fla. Stat, 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 MFLs 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 MFLs, 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 setting identifying the need for establishment of MFLs.

The Florida Water Resource Implementation Rule, specifically Rule 62-40.473, Florida Administrative Code (F.A.C.), provides additional guidance for the MFLs establishment, 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.S., 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

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 MFLs status assessments, i.e., compliance evaluations; 4) development and implementation of recovery strategies; 5) MFLs compliance reporting; and 6) ongoing support for minimum flow and level regulatory concerns and prevention strategies. Many of these tasks are discussed or addressed in this minimum levels report for Bird Lake; additional information on all tasks associated with the District's MFL 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 Richer 2003, Wantzen *et al.* 2008, Poff *et al.* 2010, Poff and Zimmerman 2010). This body of knowledge has been used by the District and other water management districts within the state to identify significant harm thresholds or criteria supporting development of MFLs for hundreds of water bodies, as summarized in the numerous publications associated with these efforts (e.g., SFWMD 2000, 2006, Flannery *et al*. 2002, SRWMD 2004, 2005, Neubauer *et al.* 2008, Mace 2009).

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

Consideration of Changes and Structural Alterations and Environmental Values

When establishing MFLs, the District considers "…changes and structural alterations to watersheds, surface waters and aquifers, and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer…" in accordance with Section 373.0421(1)(a), F.S. Also, as required by statute, the District does not establish

MFLs that would allow significant harm caused by withdrawals when considering the changes, alterations and their associated effects and constraints. These considerations are based on review and analysis of best available information, such as water level records, environmental and construction permit information, water control structure and drainage alteration histories, and observation of current site conditions.

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

- adjust measured flow or water level historical records to account for existing changes/alterations;
- model or simulate flow or water level records that reflect long-term conditions that would be expected based on existing changes/alterations and in the absence of measurable withdrawal impacts;
- develop or identify significant harm standards, thresholds and other criteria;
- aid in the characterization or classification of lake types or classes based on the changes/alterations;
- support status assessments for 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 MFLs 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 the SWFWMD (1999a, b) and Leeper *et al.* (2001). Additional information relevant to developing lake levels is presented by Schultz et al. (2005), 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 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 is/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. For Category 3 Lakes, six significant change standards, including a Basin Connectivity Standard, a Recreation/Ski Standard, an Aesthetics Standard, a Species Richness Standard, a Lake Mixing Standard and a Dock-Use Standard 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 minimum flows or levels (Table 1). Descriptions of the specific standards and other information evaluated to support development of minimum levels for Bird Lake are provided in subsequent sections of this report.

Table 1. Environmental values identified in the state Water Resource Implementation Rule for consideration when establishing MFLs, 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 Standard 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 Standard 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 Standard Aesthetics Standard Species Richness Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Filtration and absorption of nutrients and other pollutants	Cypress Standard Wetland Offset Standard Lake Mixing Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Sediment loads	Lake Mixing Standard Cypress Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Water quality	Cypress Standard Wetland Offset Standard Lake Mixing Standard Dock-Use Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Navigation	Basin Connectivity Standard Submersed Aquatic Macrophyte Information

NA[1] = Not applicable for consideration for most priority lakes

NA[2] = Environmental value is addressed generally by development of minimum levels base on appropriate significant change standards and other information and use of minimum levels in District permitting programs

Two Minimum Levels (high minimum lake and minimum lake levels) and two Guidance Levels (high and low guidance levels) are typically established for lakes. The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29), may include the following (refer to Rule 40D-8.624, F.A.C.).

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

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

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

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

The District is in the process of converting from use of the NGVD29 datum to use of the North American Vertical Datum of 1988 (NAVD 88). While the NGVD29 datum is used for 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. All datum conversions were derived using the Corpscon 6.0 software distributed by the United States Army Corps of Engineers.

Data and Analyses Supporting Development of Minimum and Guidance Levels

Lake Setting and Description

Bird Lake (Figure 1) is located in Hillsborough County, Florida (Section 26, Township 27S, Range 18E) in the Sweetwater Creek watershed (22 square miles) within the larger Coastal Old Tampa Bay Watershed estimated at 248 square miles (FDEP, 2001).

According to the "Gazetteer of Florida Lakes" (Dickinson, et., al 1982) Bird Lake is 26 acres in size at an elevation of 50 ft. while a contour map created as part of MFL development delineated the Lake at 33 acres for the same elevation. Land use and land cover within about a mile surrounding Bird Lake showed little change from 1938 to the late-1950s; dominating this area was roughly 40% wetlands (cypress), 30% citrus, and 20% forests (less than 3% residential). By 1990, the same area experienced a 25%, 30%, and 15% reduction of wetlands, groves, and forests, respectively. Residential development had begun by the 1960s and by 1990, grew to dominate the landscape at nearly 70% as is found in recent years (Figure 2).

White (1970) classified the area of west-central Florida containing Bird Lake as the Northern Gulf Coastal Lowlands physiographic region (Figure 3). Brooks (1981) characterized the area surrounding the lake as the Land-O-Lakes subdivision of the Tampa Plain in the Ocala Uplift Physiographic District: a region of numerous lakes on a moderately thick plain of silty sand overlying Tampa Limestone. The soils surrounding the lake are Basinger, Holopaw, and Samsula depressional soils, and Myakka, Zolfo and Seffner fine sands (Hyde *et al.* 1977).

The Florida Department of Environmental Protection's Lake Bioassessment/Regionalization Initiative determined that the region around Bird Lake was one having a high density of typically clear water, neutral to slightly alkaline lake systems with low to moderate nutrient concentration. The initiative further described the region as having sandy upland with poorly drained soils interspersed and once was dominated by longleaf pine and turkey oaks, which were mostly removed for citrus groves (Griffith *et al.* 1997).

Bird Lake receives relatively little surface water flow. A small swale under Indian Mound Road appears to originate in the Avila subdivision and contributes some inflow to the lake (Appendix A) (Figure 2). There is one outlet at the south side of the lake. A canal directs the outflow to Platt Lake through culverts under Lake Magdalene Blvd. A weir about 150 feet upstream of the culverts at one time may have affected the lake levels. However, it is currently in disrepair and serves to at best slow the flow out of the lake. Observations by field personnel in the late 1970's indicate that the weir has long been in disrepair.

In 1979, for the purpose of recreation and aesthetics, the Lake Byrd Improvement Association was issued a permit to augment the lake with water from the Floridan aquifer. Augmentation began in 1980, according to the District permit files. The District issued a water use permit to augment the lake from the west side from a 500-foot deep 8-inch well. The permit was renewed in 1985, 1991 and 1996. The Lake Byrd Improvement Association withdrew its water use permit in 2013, concluding that augmentation was no longer necessary. Lakes that are augmented with groundwater withdrawn from the Floridan aquifer (including Bird Lake) typically experience a shift from low to high calcium-bicarbonate (hardness) concentrations and increase in pH (Brenner et al.).

The hydrogeologic setting of the lake basin includes potential withdrawal impacts (Appendix C), and the above mentioned history of lake augmentation from the Floridan aquifer artificially affected surface water levels. Monthly average water withdrawals from 1992 – 2011 within this three mile radius were 8.7 million gallons per day (mgd). Seventy-nine percent of these withdrawals (6.9 mgd) were from the public supply wells at the Section 21 Wellfield 2-3 miles from the lake (Figure 4).

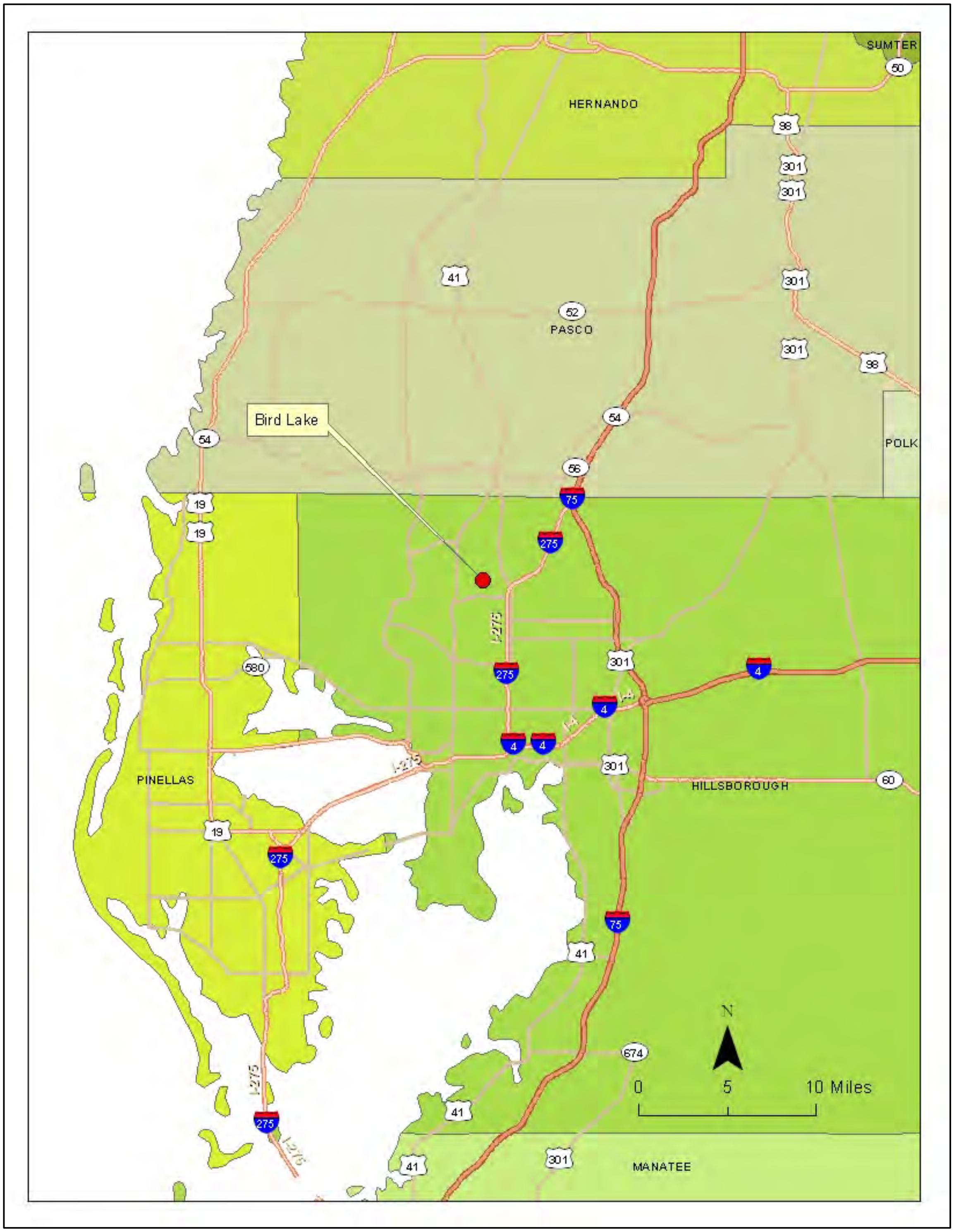

Figure 1. Location of Bird Lake in Hillsborough County, Florida.

Figure 2. 2011 Florida Land Use and Cover Classification features in proximity to Bird Lake overlaying a natural color photograph. The water level gage is located on the northeastern side of the lake. The ditch located on the southern side of the lake serves as the lake outflow.

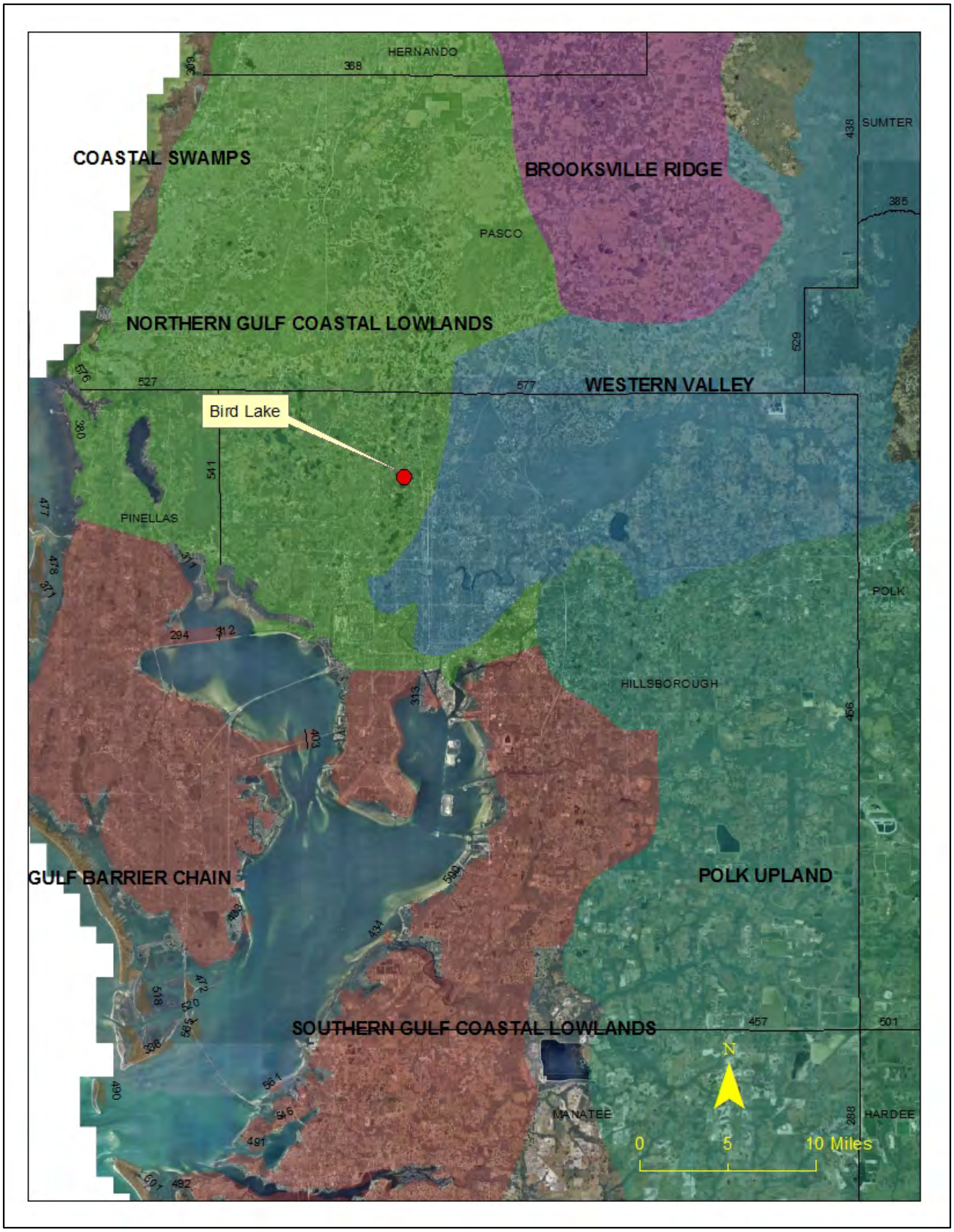

Figure 3. Physiographic regions of the Bird Lake area.

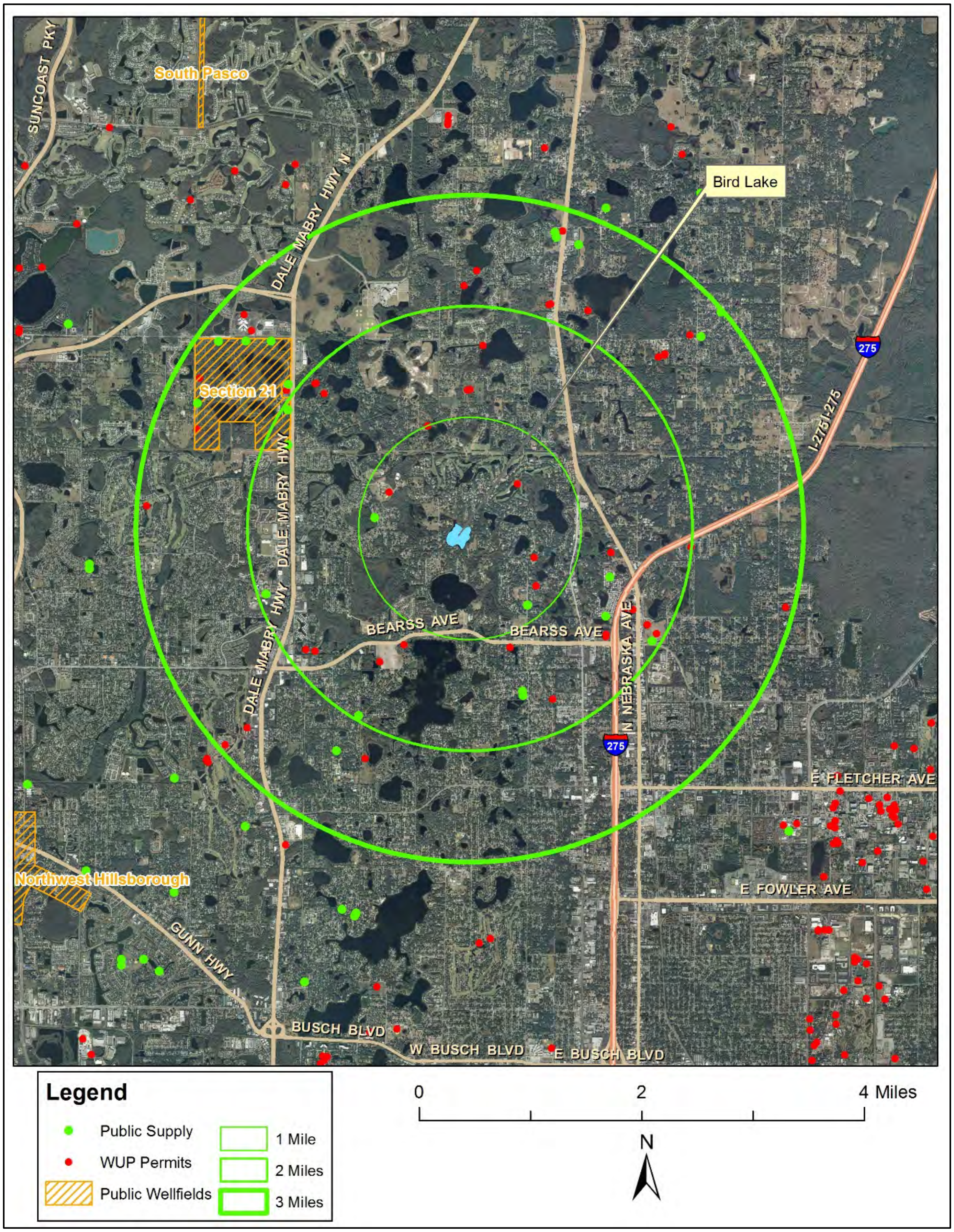

Figure 4. Permitted groundwater withdrawals within a one-three mile radius of Bird Lake.

Currently Adopted Guidance 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 an initiative for establishing lake management levels based on hydrologic, biological, physical and cultural aspects of lake ecosystems. By 1996, management levels for nearly 400 lakes, including Bird Lake, had adopted into the District's Water Levels and Rates of Flow Rules (SWFWMD 1996a).

The previously adopted Minimum and Guidance Levels for Bird Lake (Table 2) were developed using a methodology that differs from the current approach for establishing Minimum and Guidance Levels (SWFWMD 1999a). The levels do not, therefore, necessarily correspond with the levels developed using current methods. The Minimum and Guidance Levels developed using current methods replaces Guidance Levels adopted by the District Governing Board into Chapter 40D-8, F.A.C in 2007. One of the previous management levels, a Ten Year Flood Guidance Level of 53.0 ft., was removed from Chapter 40D-8, when the District Governing Board determined that flood-stage elevations should not be included in the District's Water Levels and Rates of Flow rules.

Table 2. Previously adopted Minimum and Guidance Levels for Bird Lake as listed in Table 8-3 of subsection 40D-8.624, F.A.C.

Minimum and Guidance Levels	**Elevation in Feet NGVD 29**
High Guidance Level	49.6
High Minimum Level	49.6
Minimum Level	48.6
Low Guidance Level	47.5

Annually since 1991, a list of stressed lakes has been developed to support the District's consumptive water use permitting program as referenced in the District's Water Use Permit (WUP) Handbook (Part B) dated May 19, 2014. This reference defines a stressed condition for a lake" as "chronic fluctuation below the normal range of lake level fluctuations".

For those lakes without established management levels, stressed conditions shall be determined on a case-by-case basis through site investigation by District staff during the permit evaluation process. Bird Lake was deemed stressed from 1992 through 1998, using this method prior to management levels being established for Bird Lake (District technical memos). For those lakes with District-established management levels (Bird Lake post-1998), a stressed condition is a chronic fluctuation below the minimum low management level. More recent stressed condition criterion is based on continuous monthly data for the most recent five-year period, with the latest readings being within the past 12 months, and two-thirds of the values are at or below the adopted minimum low management level. Using this method, Bird Lake was stressed from 2002 through 2004, but has not been designated as stressed since (2005 through 2015).

Summary Data Used for Minimum and Guidance Levels Development

Minimum and Guidance Levels for Bird Lake were developed using the methodology for Category 2 Lakes described in Rule 40D-8.624, F.A.C. These levels and additional information are listed in Table 3, along with lake surface areas for each level or feature/standard elevation. Detailed descriptions of the development and use of these data are provided in the subsequent sections of this report.

Lake Stage Data and Exceedance Percentiles

Period of record (POR) lake stage data, *i.e.,* surface water elevations for Bird Lake relative to NGVD 29 were obtained from the District's Water Management Information System (WMIS) data base, Site Identification (SID) number 19793 (Figure 2). Surface water level data have been recorded since April 1977 (Figure 5). Data through 2013 were used for modeling analyses.

Record high water levels were generally above 50 ft. and occurred on nine occasions. The extreme high water level was 51.9 ft. and occurred in September 1998. Record low water levels were generally below 45 ft. and occurred on three occasions; these lows mostly occurred between 2000 and 2002. The extreme low water level was 42 ft. and occurred in June 2001. The extreme high and low water level contour lines are shown on a 2011 aerial photograph (Figure 6). The average horizontal distance from the base (shoreline) of most docks to the record low water level is approximately 81 ft.

For the purpose of Minimum Levels determination, lake stage data are classified as "Historic" for long-term periods when there are no measurable impacts due to water withdrawals, and impacts due to structural alterations are 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. Lake stage data are classified as "Current" when hydrologic stresses due to water withdrawals and structural alterations are stable, and representative of the current situation.

A Long-term Historic lake stage record is a critical step to establish Minimum and Guidance Levels. No measured Historic data are available for Bird Lake because effects from groundwater withdrawals from the nearby Section 21 Wellfield predate the lake level record. A water budget model was therefore developed to simulate Historic water levels for the lake (Appendix A). The LOC model was then used to predict the lake stage for the long-term Historic time period of 1946 to 2013 which resulted in a correlation coefficient of determination (r^2) equal to 0.81. This hybrid water level record (Figure 7) represents Historic conditions.

Table 3. Minimum and Guidance Levels, lake stage exceedance percentiles, normal pool, control point, significant change standards and associated surface areas for Bird Lake.

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Exceedance Percentiles		
Period of Record (POR) P10 (1977 to 2013)	49.7	32.2
Period of Record (POR) P50 (1977 to 2013)	48.0	23.5
Period of Record (POR) P90 (1977 to 2013)	46.1	20.0
Historic P10 (1946 to 2013)	50.0	33.5
Historic P50 (1946 to 2013)	48.8	27.9
Historic P90 (1946 to 2013)	47.5	22.4
Normal Pool and Control Point		
Normal Pool	52.1	44.4
Control Point	48.6	26.2
Low Floor Slab	51.2	39.0
Significant Change Standards		
Cypress Standard	50.3	34.7
Species Richness Standard*	48.1	23.8
Wetland Offset Elevation*	48.0	23.5
Aesthetics Standard*	47.5	22.4
Dock-Use Standard*	50.2	34.3
Basin Connectivity Standard *	NA	NA
Recreation/Ski Standard*	NA	NA
Lake Mixing Standard*	NA	NA
Minimum and Guidance Levels		
High Guidance Level	50.0	33.5
High Minimum Lake Level	50.0	33.5
Minimum Lake Level	48.8	27.9
Low Guidance Level	47.5	22.4

NA - not appropriate.

* Developed for comparative purposes only; not used to establish Minimum Levels

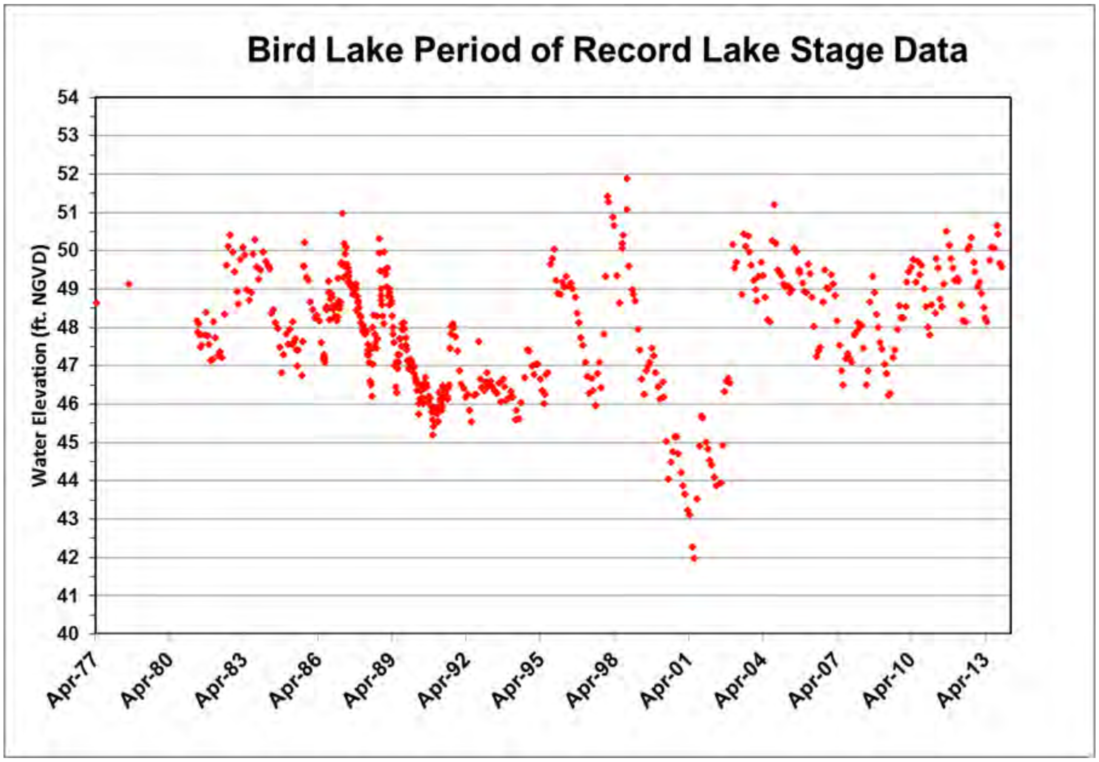

Figure 5. Bird Lake period of record stage data – Apr. 1977 through Dec. 2013.

The modeled hybrid Historic lake stage record was used to calculate Historic P50, and P90 lake stage percentile elevations (Figure 8, Table 3). The Historic P10 was calculated based on an evaluation using data from Platt Lake located adjacent to Bird Lake. Platt Lake has nearly identical percentiles to Bird Lake when concurrent data measurements are compared (Appendix A). Platt Lake also has data pre-dating groundwater withdrawals at Section 21 Wellfield enabling a rainfall regression model to be developed to estimate the long term Historic P10 for Platt and thus for Bird Lake. The Historic P10 elevation, the elevation the lake water surface equaled or exceeded ten percent of the time during the Historic period based on Platt Lake water elevations, was 50.0 ft. The Historic P50 elevation, the elevation the lake water surface equaled or exceeded fifty percent of the time during the Historic period based on the water budget model, was 48.8 ft. The Historic P90 elevation, the elevation the lake water surface equaled or exceeded 90 percent of the time during the Historic period based on the water budget model, was 47.5 ft.

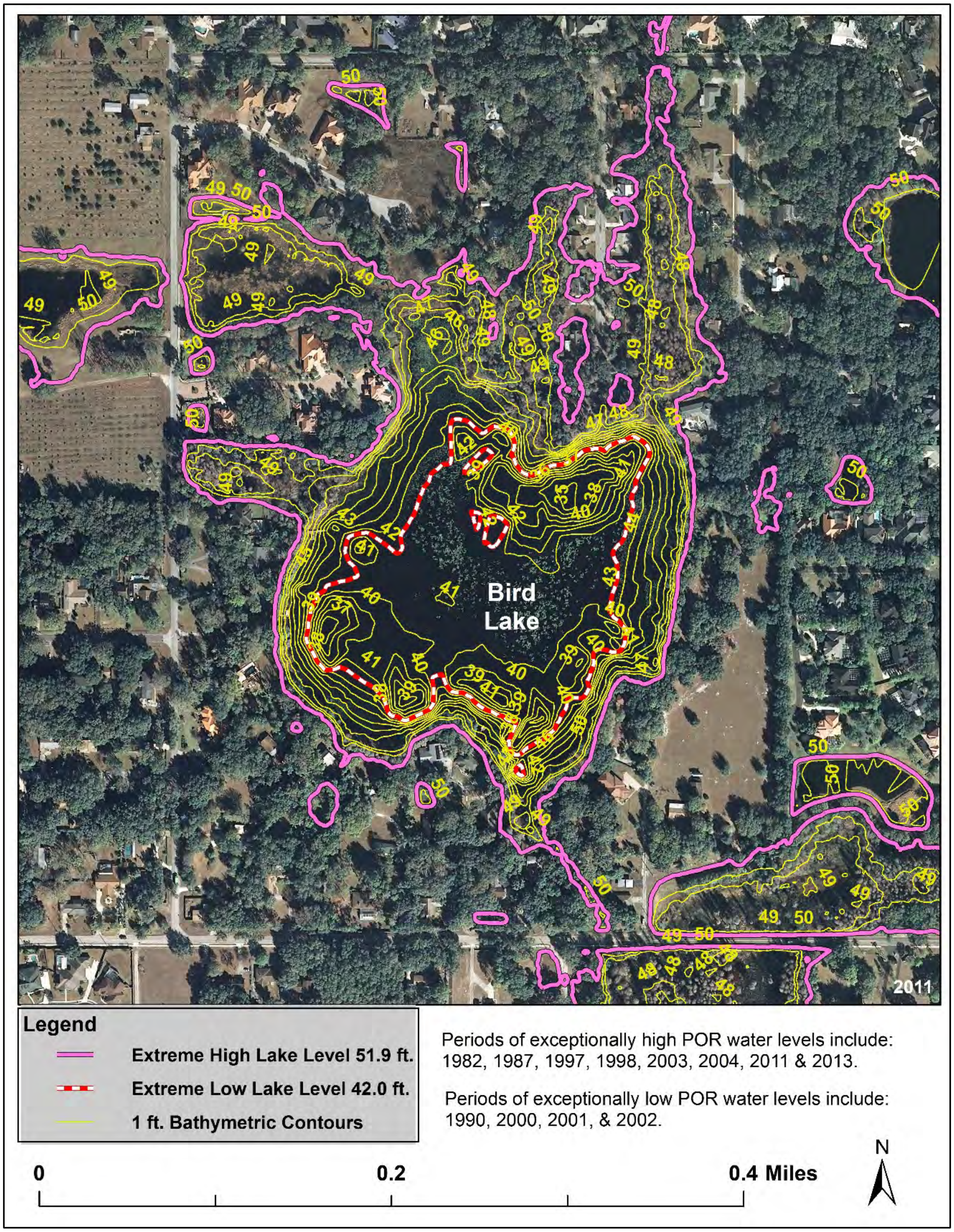

Figure 6. Bathymetric map with POR extreme high and extreme low water level contours for Bird Lake imposed on to a January 2011 aerial imagery.

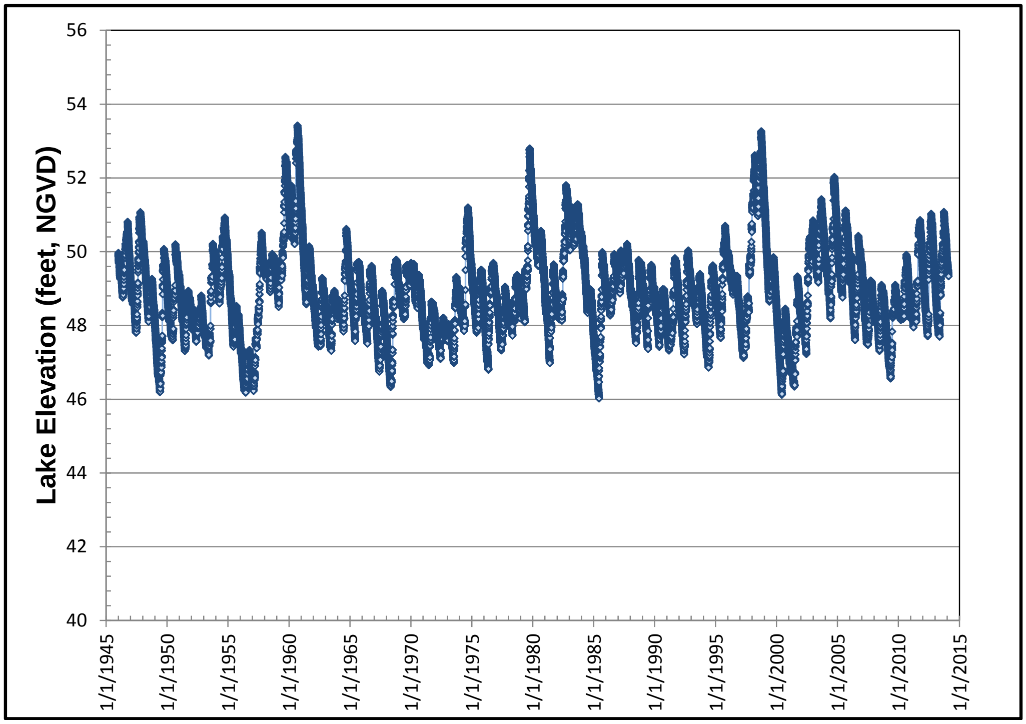

Figure 7. Hybrid model predicted long-term Historic water levels at Bird Lake for a calibration period from November 1988-December 2013 (the water budget model period).

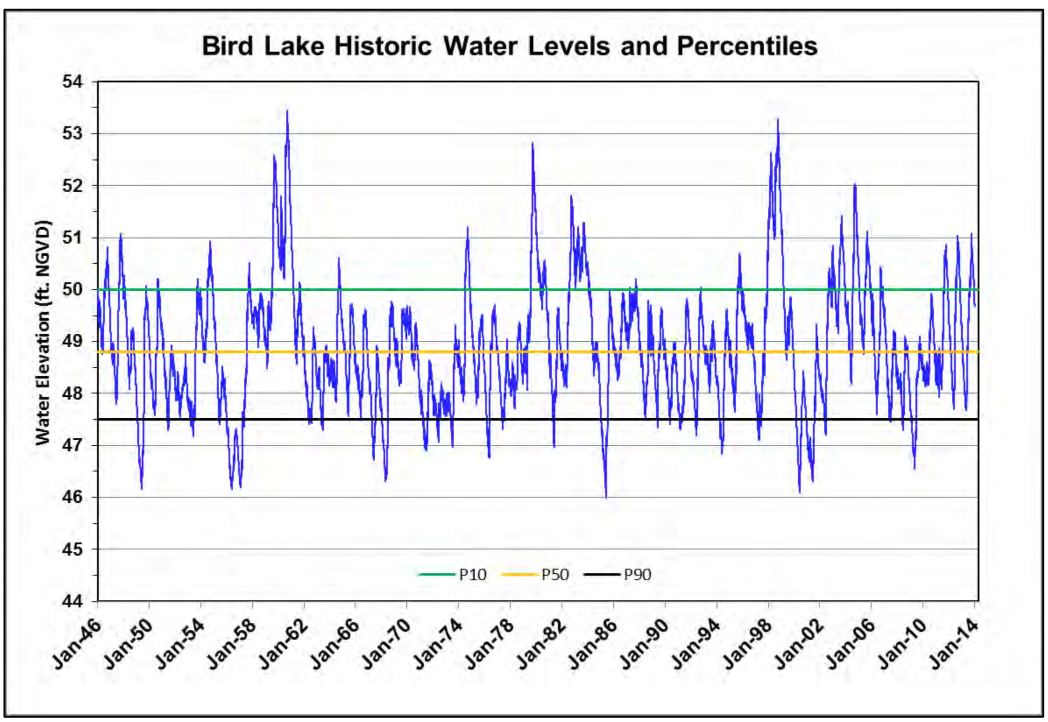

Figure 8. Historic water levels (hybrid results) used to calculate percentile elevations for Bird Lake. Historic P10, P50, and P90 are depicted as horizontal lines.

Normal Pool Elevation, Control Point Elevation and Structural Alteration Status

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 buttress inflection points on the trunks of *Taxodium* sp. have been shown to be reliable biologic indicators of hydrology at an approximation of the historic P10 (Carr, et al. 2006). Seven examples of *Taxodium* sp. buttresses were measured on the lake in March 2013 at various points along the shoreline in the Cypress wetlands adjacent to the lake (see Figure 2). Based on the survey of these biologic indicators, the Normal Pool elevation was established at the median, **52.1 ft**. (Table 5).

Table 5. Summary statistics for hydrologic indicator measurements (elevations buttress inflection points of lakeshore *Taxodium sp*.) used for establishing normal pool elevations for Bird Lake.

N	7
Median	52.1
Mean	52.0
Minimum	51.1
Maximum	52.3

The **Control Point** elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system (*e.g.,* weir, conservation structure, ditch, culvert, or pipe) that is the principal control of water level fluctuations in the lake. In the case of Bird Lake, the outlet conveyance is at the South end of the lake and water flows into Platt Lake. The control point established during development of the originally adopted MFL (**47.1 ft.**) was set at the elevation of the two 4 ft. by 8 ft. culverts that lead under Lake Magdalene Boulevard. The opening of partially collapsed contracted rectangular weir located along the conveyance serves as the new control point at **48.6 ft**.

Structural Alteration Status is determined to support development of Minimum and Guidance Levels and the modeling of Historic lake stage records. In addition to identification of outlet conveyance system modifications, comparison of the Control Point elevation and Normal Pool elevations is typically used to determine if a lake has been structurally altered. If the Control Point elevation is below the Normal Pool, the lake is classified as a structurally altered system. If the Control Point elevation is above the Normal Pool or the lake has no outlet, then the lake is not considered to be structurally altered. Based on the existence of the outflow conveyance system and given that the Normal Pool elevation (52.1 ft.) is higher than the Control point elevation (48.6 ft.), Bird Lake was classified as structurally altered.

Guidance Levels

The **High Guidance Level** 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 expected Historic P10 of the lake and is established using historic lake stage data if it is available, or is estimated using the Current P10, the Control Point, and the Normal Pool elevation. Based on long-term Historic model results, the High Guidance Level for Bird Lake was established at **50.0 ft.** (Figure 9, Table 3). The lowest residential floor slab within the immediate lake basin (51.2 ft.) is 1.2 feet higher than the High Guidance Level.

The **Low Guidance Level** is provided as an advisory guideline for water dependent structures, information for lake shore 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 (P90) 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, which are differences between selected lake stage percentiles for a set of reference lakes. Based on long-term Historic model results, the Low Guidance Level for Bird Lake was established at **47.5 ft.** (Figure 9, Table 3).

Lake Classification

Lakes are classified as Category 1, 2 or 3 for the purpose of Minimum Levels development. Systems with fringing cypress wetlands greater than 0.5 acres in size where water levels regularly 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. Category 2 lakes are also lakes with fringing cypress wetlands greater than 0.5 acres in size, but where structural alterations have prevented the Historic P50 from equaling or rising above an elevation that is equal to an elevation 1.8 ft. below normal pool. Despite the structural alterations the lake-fringing cypress swamp(s) remain viable and perform functions beneficial to the lake. Lakes without fringing cypress wetlands or with less than 0.5 acres of fringing cypress wetlands are classified as Category 3 Lakes. Based on the presence of lake-fringing cypress wetlands of 0.5 acre or more in size within the lake basin, and because the Historic P50 (48.8 ft.) is more than 1.8 ft. below the Normal Pool elevation (52.1 ft.), Bird Lake was classified as a Category 2 lake.

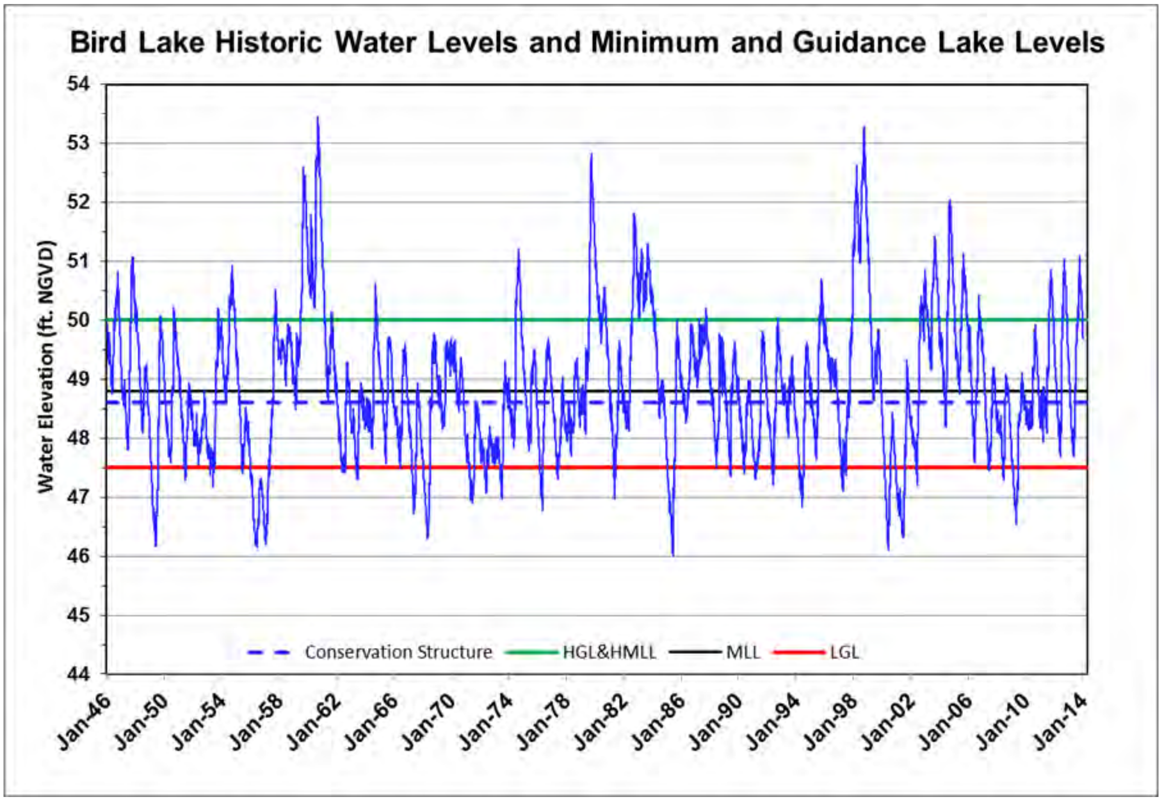

Figure 9. Historic water levels (hybrid results) and Minimum and Guidance Levels for Bird Lake. Levels include the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL), and the Low Guidance Level (LGL).

Significant Change Standards and Other Information for Consideration

Lake-specific significant change standards and other available information are considered for establishing minimum levels. The standards are used to identify thresholds for preventing significant harm to environmental values associated with lakes (refer to Table 1) in accordance with guidance provided in the Florida Water 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.

For Category 1 or 2 Lakes, a significant change standard is established 1.8 feet below the normal pool elevation. This standard identifies a desired median lake stage that if achieved, may be expected to preserve the ecological integrity of lake-fringing wetlands. Although not identified by name in the District's Minimum Flows and Levels rule, the elevation 1.8 feet below normal pool is typically referred to as the **Cypress Standard** in District documents pertaining to minimum levels development. For Bird Lake, the Cypress Standard was established at **50.3 ft.** Based on the Historic water level record for the lake, the standard was equaled or exceeded twelve percent of the time, *i.e.*, the standard elevation corresponds to the Historic P12.

Six significant change standards for Category 3 lakes, including a Dock-Use Standard, a Basin Connectivity Standard, an Aesthetics Standard, a Recreation/Ski Standard, a Species Richness Standard, and a Lake Mixing Standard are developed. These standards identify desired median lake stages that if achieved, are intended to preserve various environmental values (see Table 1). Although Bird Lake is a Category 2 Lake, Category 3 Lake standards were developed for comparative purposes. These standards were not, however, used to establish the Minimum Levels.

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 becoming degraded below 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, which is **47.5 ft.** for Bird Lake. Because the Low Guidance Level was established at the Historic P90 elevation, water levels equaled or exceeded the Aesthetics Standard ninety percent of the time during the Historic period.

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 Florida lakes, the standard is established at the lowest elevation associated with less than a 15 percent reduction in lake surface area relative to the lake area at the Historic P50 elevation. The Species Richness Standard established for Bird Lake is established at **48.1 ft.** (see Figure 10 for a plot of lake stage versus lake surface area).

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 five-foot deep ski corridor delineated as a circular area with a radius of 418 ft., or as used in this case, a rectangular ski area 200 ft. in width and 2,000 ft. in length, and use of historic lake stage data. The Recreation/Ski Standard for safe skiing is not applicable because Bird Lake is too small to accommodate a safe ski corridor (see Leeper *et. al* (2001).

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 clearance water depth value for boat mooring, and use of historic lake stage data. The Dock-Use Standard for Bird Lake was established at **50.2 ft.**, based on the elevation of sediments at the end of ninety percent of the 10 docks within the lake (46.9 ft., Table 6), a two-foot water depth based on use of powerboats in the lake, and the 1.3 ft. difference between the Historic P50 and Historic P90.

Table 6. Summary statistics and elevations associated with docks in Bird Lake based on measurements made by District staff in March 2013. Percentiles (10th, 50th and 90th) represent the percentage of docks at or below the corresponding elevation.

Summery Statistics	Statistics Value (N) or Elevation (feet) of Sediments at Waterward End of Docks	Statistics Value (N) or Elevation (feet) of Dock Platforms
N (number of docks)	10	10
Median	45.5	52.0
10th Percentile (P90)	44.5	50.9
90th Percentile (P10)	46.9	52.8
Maximum	46.9	53.4
Minimum	41.9	50.5

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 lake-use. The standard is based on the elevation of lake sediments at a critical high-spot between lake sub-basins, clearance water depths for movement of aquatic biota or powerboats and other watercraft, and use of historic lake stage data or region-specific reference lake water regime statistics. Lake sub-basins were not identified for Bird Lake therefore a Basin Connectivity Standard was not developed.

The **Lake Mixing Standard** is developed to prevent significant changes in patterns of wind-driven mixing of the lake water column and sediment re-suspension. The standard is established at the highest elevation at or below the Historic P50 elevation where the dynamic ratio (see Bachmann *et al.* 2000) shifts from a value of <0.8 to a value >0.8, or from a value >0.8 to a value of <0.8. The dynamic ratio does not shift across the 0.8 threshold over the range of water levels that may be expected within the basin, therefore, a Lake Mixing Standard was not developed (Figure 10).

Also considered is the elevation at which change in lake stage would result in substantial change in the area available for colonization by **Submersed Aquatic Plants** (i.e., basin area with a water depth of 7.9 ft. or less), based on water clarity values. Review of this stage vs. area data did not indicate that there would be a significant increase or decrease in the area of submersed aquatic plant vegetation associated with use of the applicable standards (refer to Figure 11).

Information pertaining to **Herbaceous Wetlands** in the lake basin is taken under consideration to determine the elevation at which the change in lake stage would result in substantial change in potential wetland area within the lake basin (*i.e*., basin area with a water depth less than or equal to four feet). Although herbaceous wetlands are uncommon within the Bird Lake basin, this additional measure of wetland change was considered for minimum levels development. Hancock 2006 determined that up to a 0.8 ft. decrease (or Wetland Offset) in the Historic P50 elevation (48.0 ft.) would not likely be associated with significant changes in the herbaceous wetlands occurring within lake basins. Review of changes in potential herbaceous wetland area in relation to change in lake stage did not indicate that there would be a significant increase or decrease in the area of herbaceous wetland vegetation associated with use of the applicable significant change standards (Figure 11).

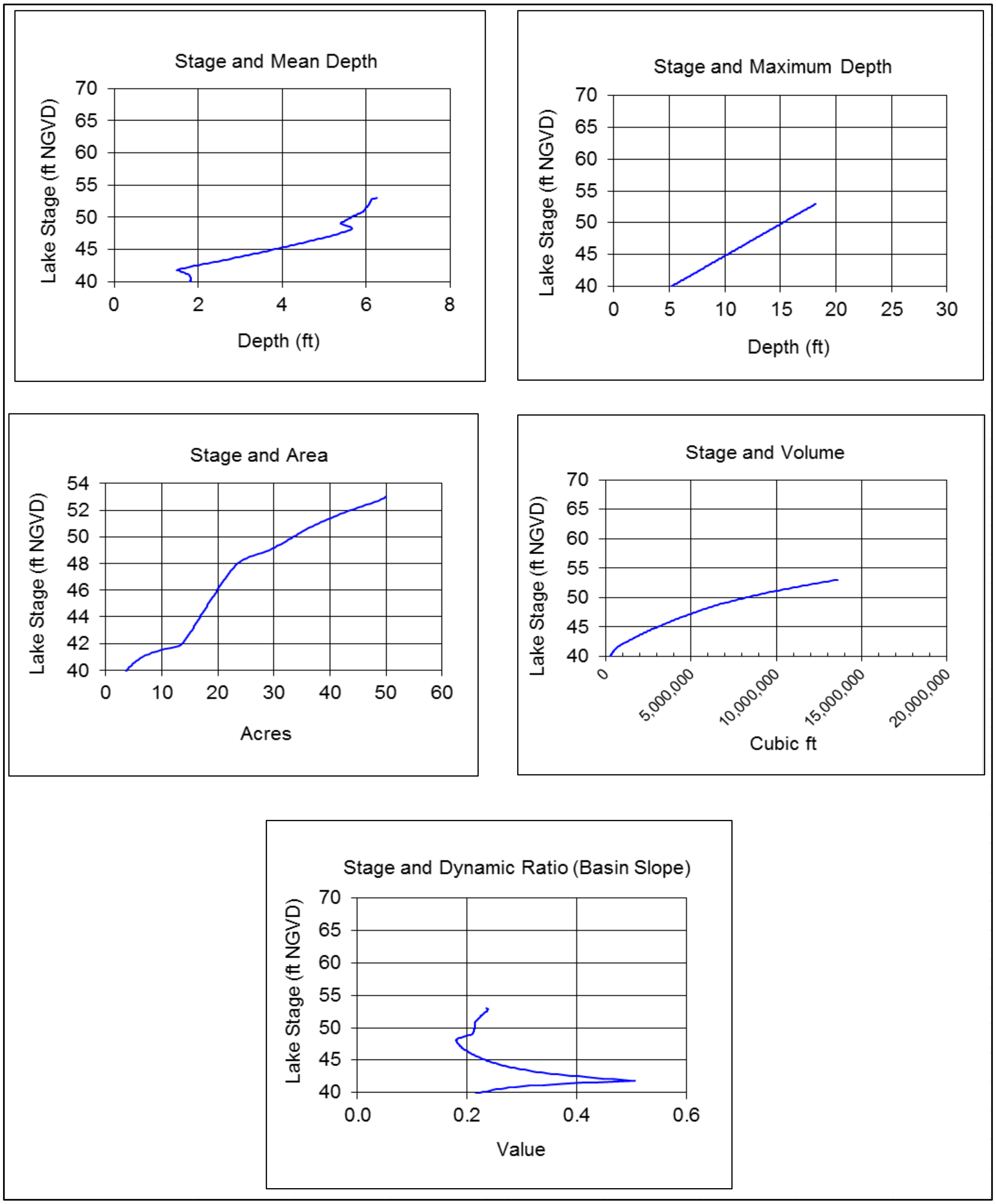

Figure 10. Mean depth, maximum depth, surface area volume, stage volume, and dynamic ratio (basin slope) in feet for Bird Lake.

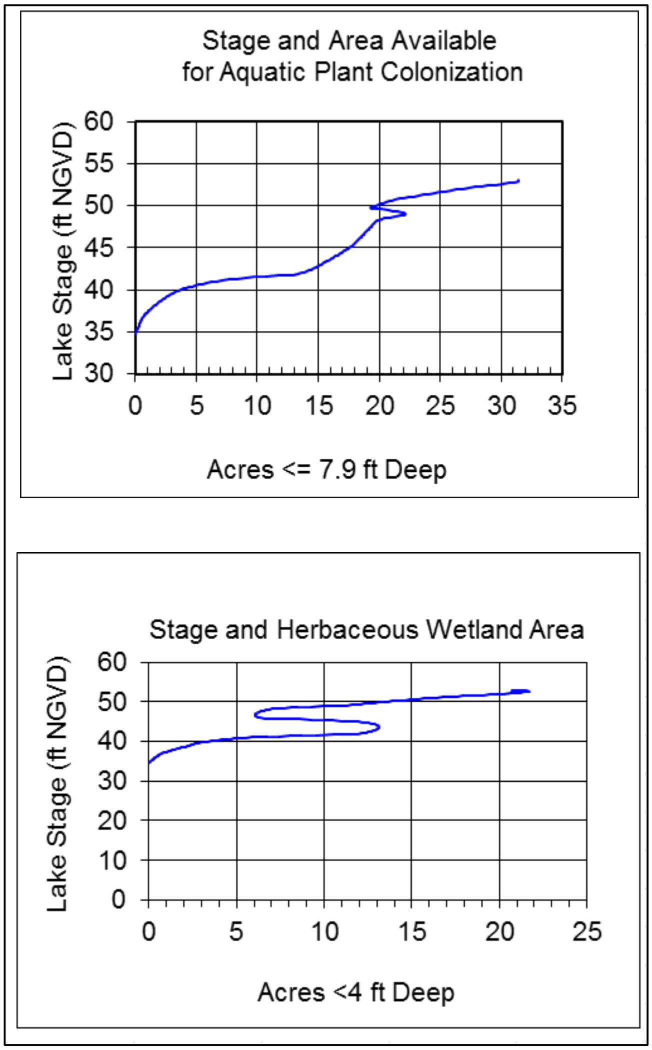

Figure 11. Area available for submersed macrophyte colonization and potential herbaceous wetland area in Bird Lake as a function of lake stage (water surface elevation).

Minimum Levels

Minimum Lake Levels are developed using specific lake-category significant change standards and other available information or unique factors, including: substantial changes in the coverage of herbaceous wetland vegetation and aquatic macrophytes; elevations associated with residential dwellings, roads or other structures; frequent submergence of dock platforms; faunal surveys; aerial photographs; typical uses of lakes (*e.g.,* recreation, aesthetics, navigation, and irrigation); surrounding land-uses; socio-economic effects; and public health, safety and welfare matters. Minimum Levels development is also contingent upon lake classification*, i.e.,* whether a lake is classified as a Category 1, 2 or 3 lake.

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. The Minimum Lake Level is established at the elevation that the lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The Minimum Lake Level for Bird Lake is **48.8 ft**.

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. For Category 2 Lakes, the High Minimum Lake Level is established at the High Guidance Level, which is the expected Historic P10. The High Minimum Lake Level for Bird Lake is therefore established at **50.0 ft**.

The Minimum and Guidance levels for Bird Lake are shown in Figure 9 along with surface water elevations based on historic modeled water levels. The MLL and HMLL levels are also shown as contour lines on historic aerial photographs (Figures 12 – 14). Figure 12 presents a 2011 aerial which illustrates the water level 0.6 ft. lower than the MLL. Figure 13 present a 1982 aerial which illustrates the water level was near the MLL. Figure 14 present a 1938 aerial which illustrates the water level was above the MLL and equal to the HMLL.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida's water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the MFLs for Bird Lake are presented in both datum standards (Table 7). The NGVD29 datum was converted to NAVD88 using the Corpscon conversion of 0.830 ft.

Table 7. Minimum and Guidance Levels for Bird Lake relative to NGVD29 and NAVD88.

Minimum and Guidance Levels	Feet NGVD29	Feet NAVD88
High Guidance Level	50.0	49.2
High Minimum Lake Level	50.0	49.2
Minimum Lake Level	48.8	48.0
Low Guidance Level	47.5	46.7

Consideration of Environmental Values

When developing MFLs, the District evaluates the categorical significant change standards and other available information as presented above. The purpose is to identify criteria that are sensitive to long-term changes in hydrology and represent significant harm thresholds. The Historic P50 elevation was used for developing the Minimum Levels for Bird Lake based on its classification as a Category 2 Lake. This elevation is associated with protection of the environmental values identified in Rule 62-

40.473, F.A.C. (refer to Table 1). The minimum levels for Bird Lake are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing MFLs (see Rule 62-40.473, F.A.C.).

A Cypress Standard was identified to support development of minimum levels for Bird Lake based on the occurrence of lake-fringing cypress wetlands of one-half an acre or greater in size. The standard is associated with protection of several environmental values identified in the 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. Ultimately, the Historic P50 elevation and High Guidance Level/Historic P10 were used for developing the minimum levels for Bird Lake based on existing structural alterations and its classification as a Category 2 Lake. Given that the minimum levels were established using Historic lake stage exceedance percentiles, the levels are as protective of all relevant environmental values as they can be, given the existing structural alterations. 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 that permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Two environmental values identified in Rule 62-40.473, F.A.C., were not considered relevant to development of minimum levels for Bird Lake. Estuarine resources were not considered relevant because the lake is only remotely connected to the estuarine resources associated with the downstream receiving waters of Tampa Bay, and water level fluctuations in the lake are expected to exert little effect on the ecological structure and functions of the bay. 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 associated with flowing water systems.

Assessment of the Bird Lake Minimum Level Condition

The Minimum Lake Level and High Minimum Lake Level were evaluated for compliance using the same predictive models that were used to develop the long-term Historic exceedance percentiles (Appendix B). The models were used to evaluate whether Bird Lake water levels are currently above or below the Minimum Lake Level and High Minimum Lake Level for the lake. Current levels were determined to be below the Minimum Lake Level and High Minimum Lake Level.

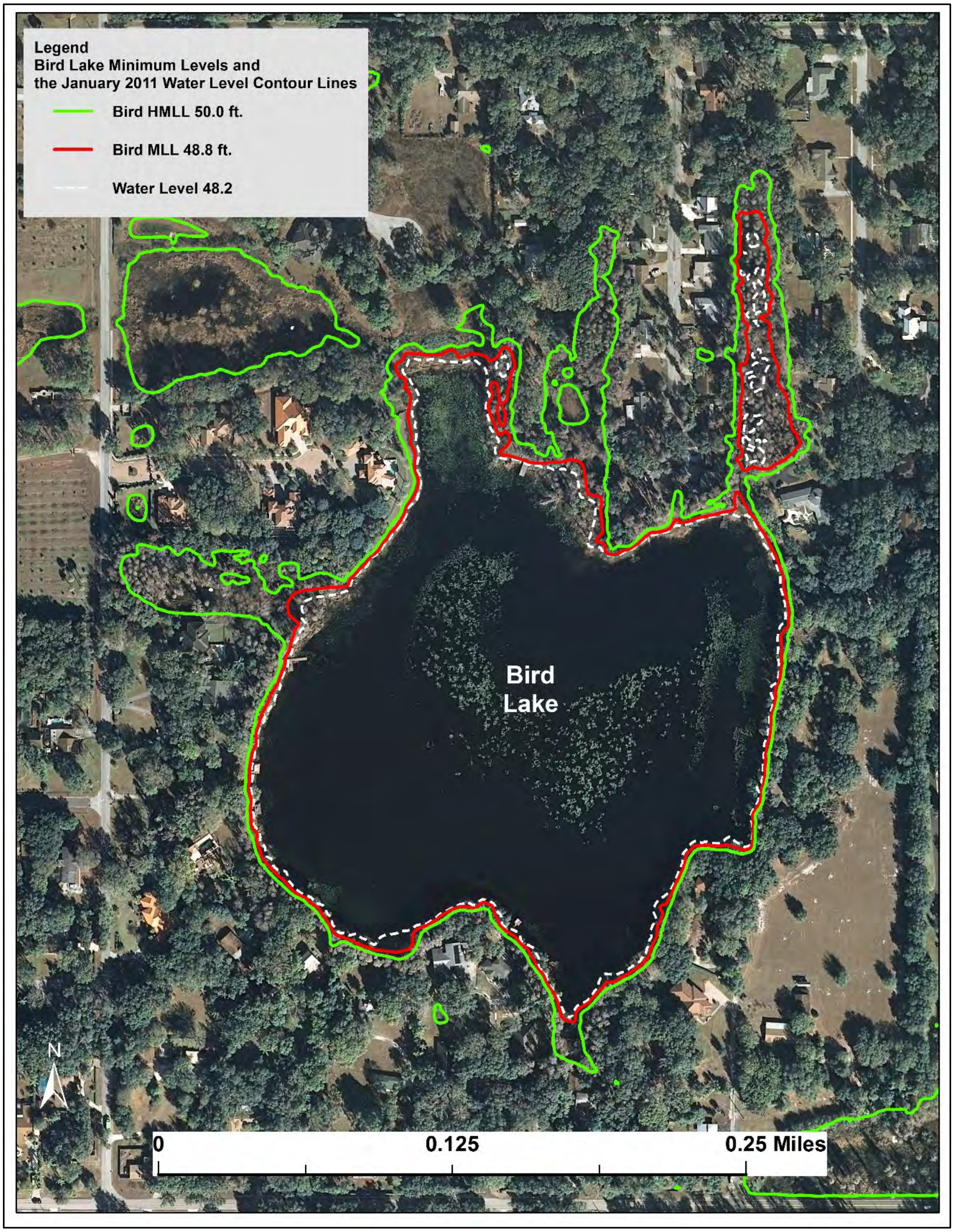

Figure 12. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Bird Lake relative to conditions in January 2011. Lake water level elevation was 48.2 ft. NGVD when the imagery was taken.

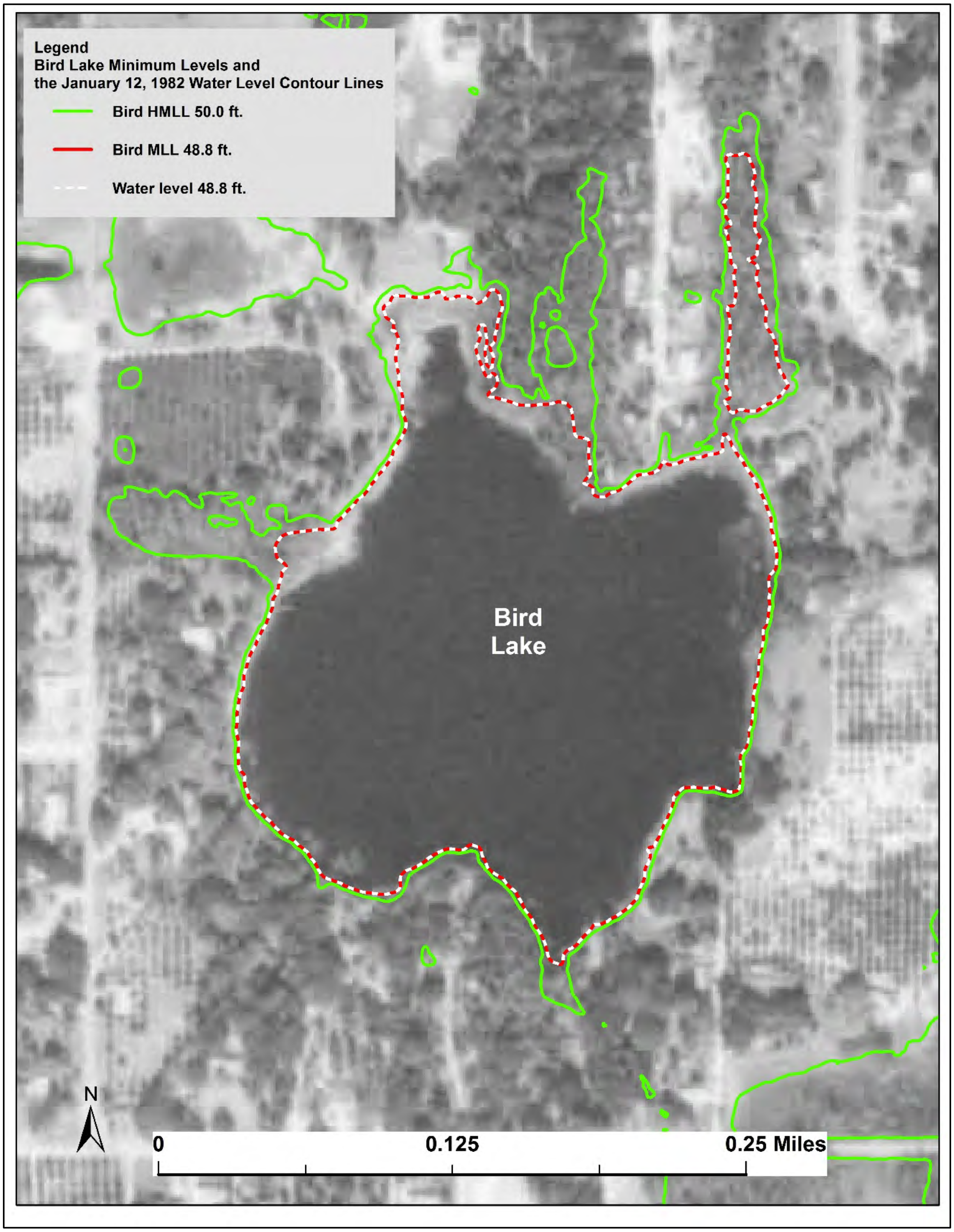

Figure 13. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Bird Lake relative to conditions on January 12, 1982. Lake water level elevation was 48.8 ft. NGVD when the photograph was taken.

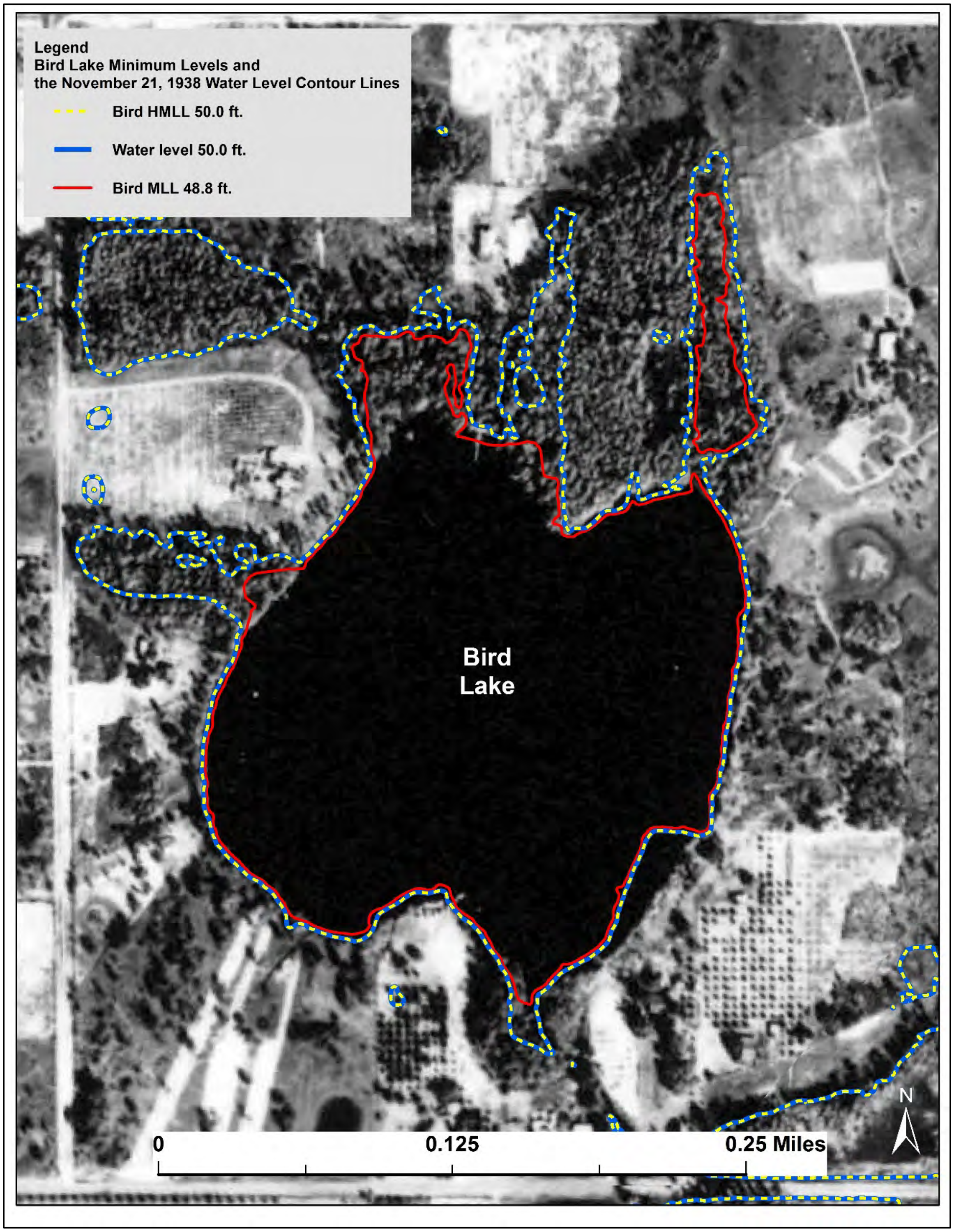

Figure 14. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Bird Lake relative to conditions on November 21, 1938. Lake water level elevation was approximately 50.0 ft. NGVD when the photograph was taken.

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Appendix A

Technical Memorandum
July 7, 2015

TO: David Carr, Staff Environmental Scientist, Water Resources Bureau
THROUGH: Jerry L. Mallams, P.G., Manager, Water Resources Bureau
FROM: Tamera S. McBride, P.G., Hydrogeologist, Water Resources Bureau
Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau

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

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 Bird Lake, in northwest Hillsborough County. Bird Lake currently has adopted minimum levels, which are being re-assessed in FY 2014. This document will discuss the development of the Bird Lake models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Bird Lake is located in Northwest Hillsborough County, north of Lake Magdalene Boulevard between Dale Mabry Highway and North Florida Avenue in Tampa, Florida (Figure 1). The lake is located to the southeast of the Section 21 Wellfield, which is one of eleven regional water supply wellfields operated by Tampa Bay Water.

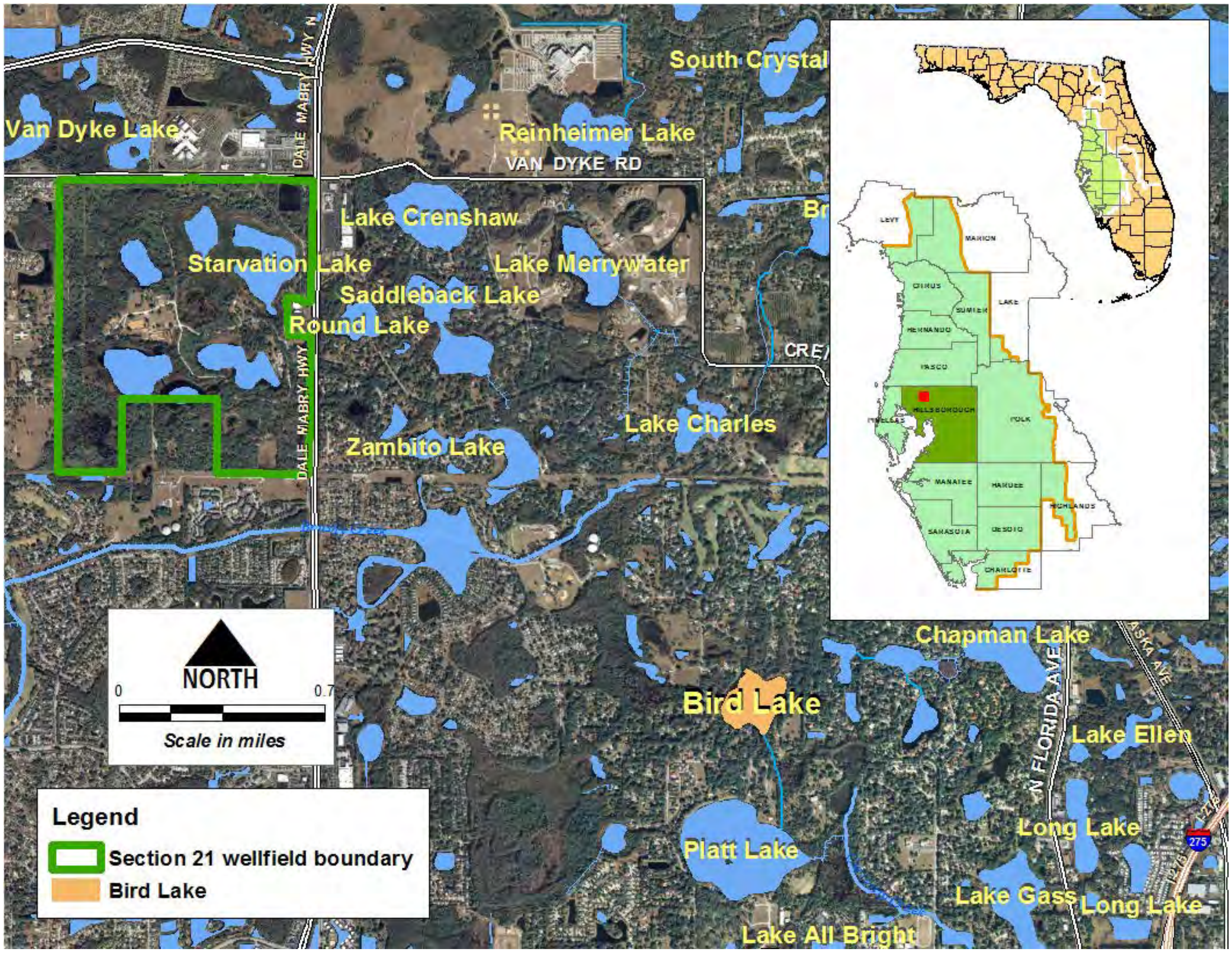

Figure 1. Location of Bird Lake in Hillsborough County, Florida

Bird Lake is within the upper reaches of the Sweetwater Creek watershed. While there is some discharge from Bird Lake via a drainageway into Platt Lake to the south, the lake is somewhat isolated since there is relatively little inflow to the lake. Surface water inflow to Bird Lake occurs as overland flow from the drainage basin immediately surrounding the lake. There is a small swale and culvert under Indian Mound Road to the north and a small wetland to the northwest that appear to be the source of some inflow into the lake; however, based on elevation changes shown in area Light Detection and Ranging Data (LiDAR) coverage, drainage studies (Atkins, 2011), and visual inspection of these features, contributions from these areas were expected to be relatively small and were not specified in the model. In addition, there are no water level data available for these features on which to base inflow contributions from these areas. Discharge from Bird Lake can occur through an open drainageway through a man-made weir south of the lake. The drainageway continues south and then through two 4-foot by 8-foot box culverts under Lake Magdalene Boulevard located south of the weir. It eventually discharges into Platt Lake, directly south of Bird Lake (Figure 2).

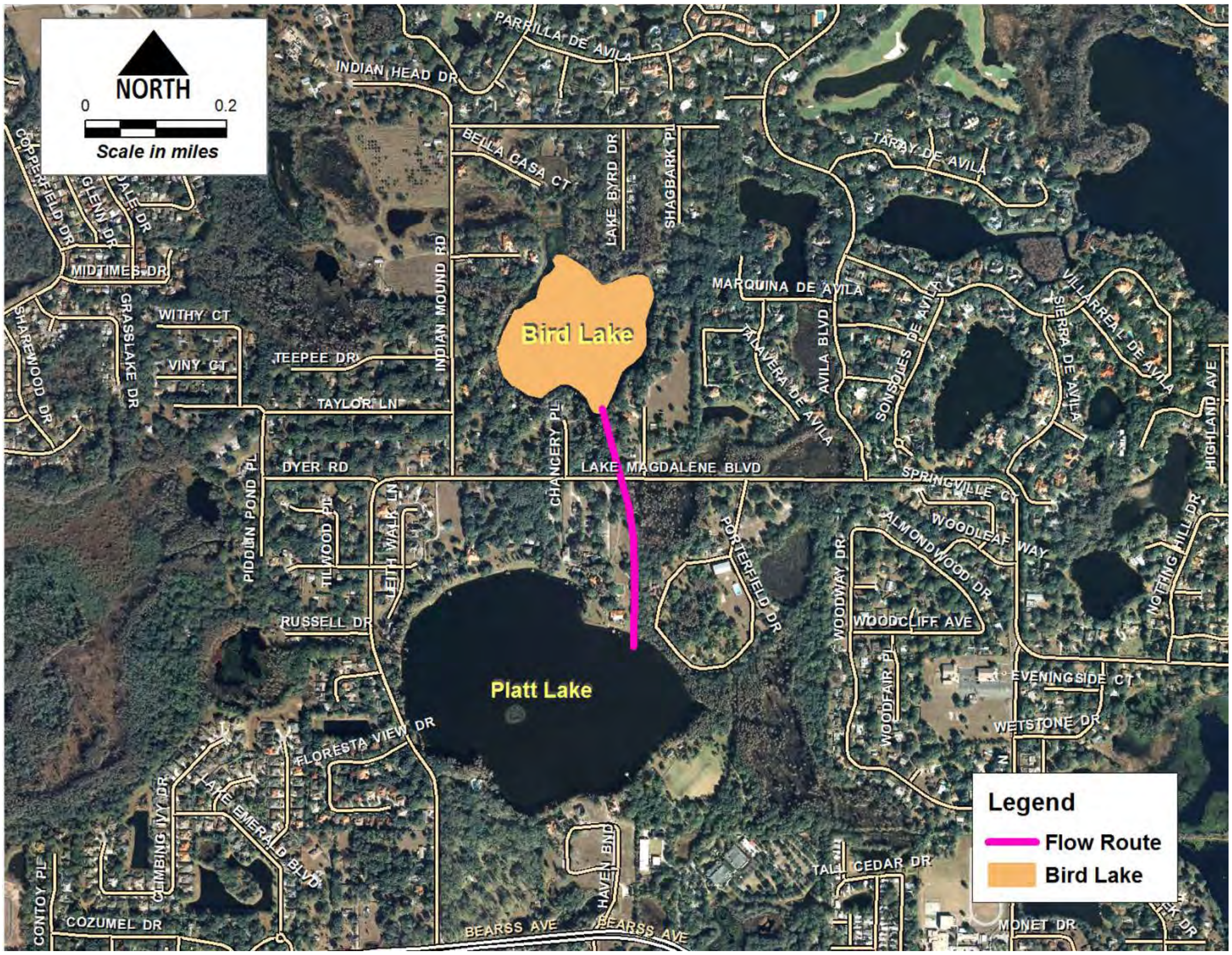

Figure 2. Flow between Bird and Platt Lakes

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 to the lake is a combination of overland flow and flow through drainage swales and minor conveyance systems.

The hydrogeology of the area includes a sand surficial aquifer; a discontinuous, intermediate clay confining unit; and the thick carbonate Upper Floridan aquifer. In general, the surficial aquifer in the study area is relatively connected with the underlying Upper Floridan aquifer because it has been breached by numerous karst features. Consistent with Green and others (2012), lithology data collected by the District shows the surficial aquifer in the vicinity of Bird Lake is generally about 30 to 50 feet thick and overlies the Hawthorn Group clay, which is about 45 to 60 feet thick. However, Hawthorn Group clay thickness is known to be variable and discontinuous in the northern Tampa Bay area where there are karst features (Hancock and Basso, 1996).

District lithology data show the limestone of the Upper Floridan aquifer starts at about 90 feet below land surface and averages nearly one thousand feet thick in the area (Miller, 1986). Connection of the overlying surficial aquifer to the Upper Floridan aquifer results in moderate-to-high leakage to the Upper Floridan aquifer (Hancock and Basso, 1996).

Bird Lake is about 1.6 miles southeast of the Section 21 Wellfield (Figure 3). Groundwater withdrawals began in 1963 and approached production of over 17 million gallons per day (mgd) annual average withdrawal by the mid-1960s and reached over 18 mgd during 1970 (Figure 4). South Pasco Wellfield began production in 1973 while Section 21 Wellfield production was coincidentally reduced to less than 10 mgd annual average withdrawal by 1974. Annual average withdrawal has steadily declined since 1999 to about 5 mgd between 2005 and 2008 and was further reduced to 2 mgd by the end of 2009, which included several months of no withdrawals. Reductions were the result of Tampa Bay Water bringing new water sources online. Of the eleven wellfields that are part of Tampa Bay Water's consolidated permit, the reduction in withdrawals (by percentage) at the Section 21 Wellfield has been significantly larger than reductions at other wellfields, while one wellfield has significantly increased withdrawals. Currently (early 2014), average annual withdrawal at Section 21 Wellfield has remained between less than 1 to 2 mgd, with several intermittent months of no withdrawals.

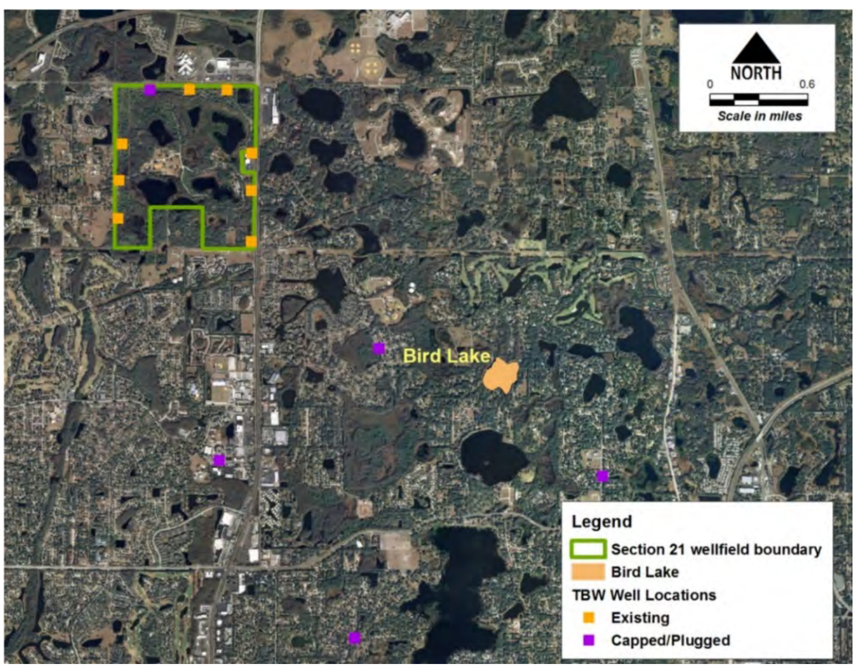

Figure 3. Section 21 Wellfield configuration and other area Tampa Bay Water Consolidated Permit wells

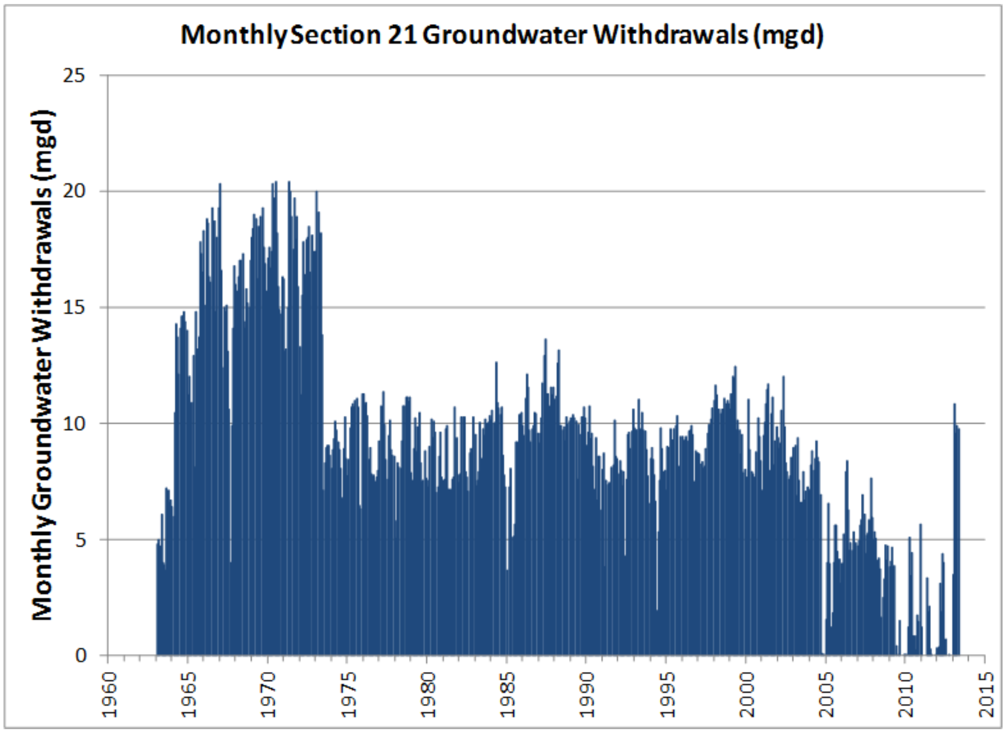

Figure 4. Section 21 Wellfield withdrawals

Water level data collection at Bird Lake began in 1977, but regular data collection did not occur until 1981 (Figure 5). There are no water level data for the lake that predate wellfield withdrawals (wellfield withdrawals began in 1963), and annual average withdrawal rates were nearly 8.5 mgd at the time water level data collection at regular frequency began.

The Buchanan Middle School Upper Floridan aquifer monitor well (District SID 19915), located about 0.9 miles southeast of Bird Lake was used in the water budget model (Figure 6). Water level measurements for this well started in November 1988 (Figure 7).

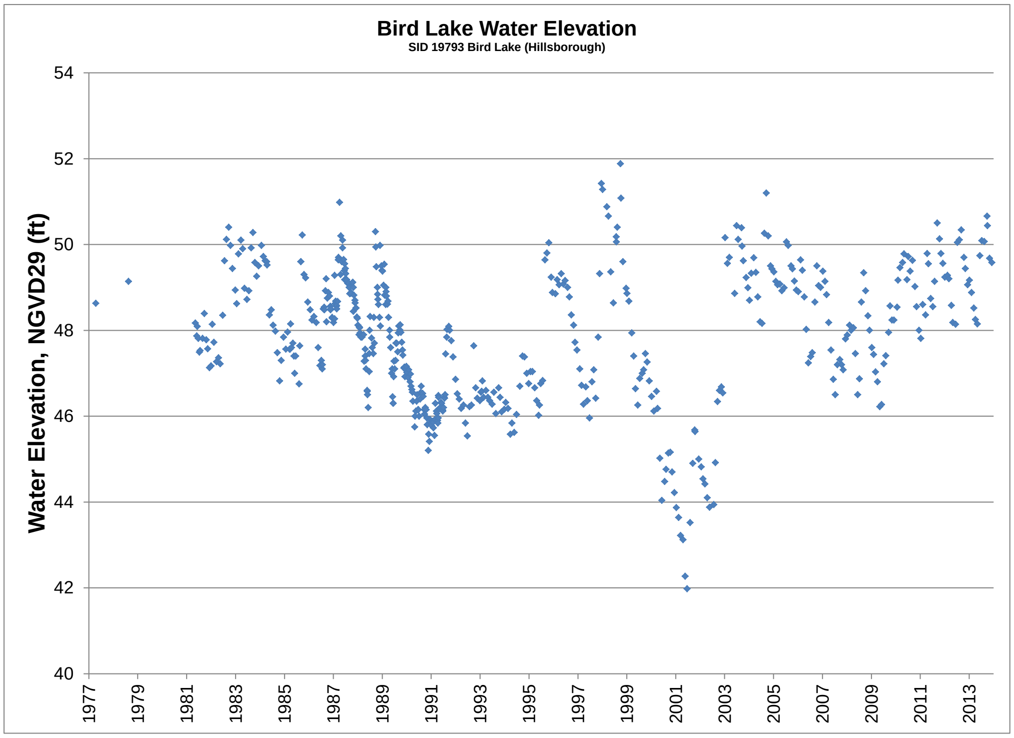

Figure 5. Bird Lake water elevation

Several Upper Floridan aquifer wells in the area were considered for use in the model; however, most did not have a longer period of record with consistent data collection or they were located farther from Bird Lake than the Buchanan Middle School well. One exception is the Berger Deep Upper Floridan aquifer well located about 1.4 miles northwest of Bird Lake; however, the Berger Deep well is located farther from Bird Lake than the Buchannan Middle School well. In addition, the Berger Deep well is also located less than 0.5 miles east of the western boundary of Section 21 Wellfield. Due to proximity to the wellfield, the Berger Deep well was not expected to be as representative of groundwater conditions at Bird Lake, since the well is closer to the Section 21 Wellfield than Bird Lake. The Berger Deep well was expected to be more heavily influenced by the wellfield and not as representative of groundwater conditions at Bird Lake as the Buchanan Middle School well.

The Buchanan Middle School surficial aquifer monitor well (District SID 19916), located about 0.9 miles southeast of Bird Lake and near the Buchanan Middle School Upper Floridan aquifer well, was used in the water budget model (Figure 6). Water level measurements for this well started in October 1988 (Figure 8).

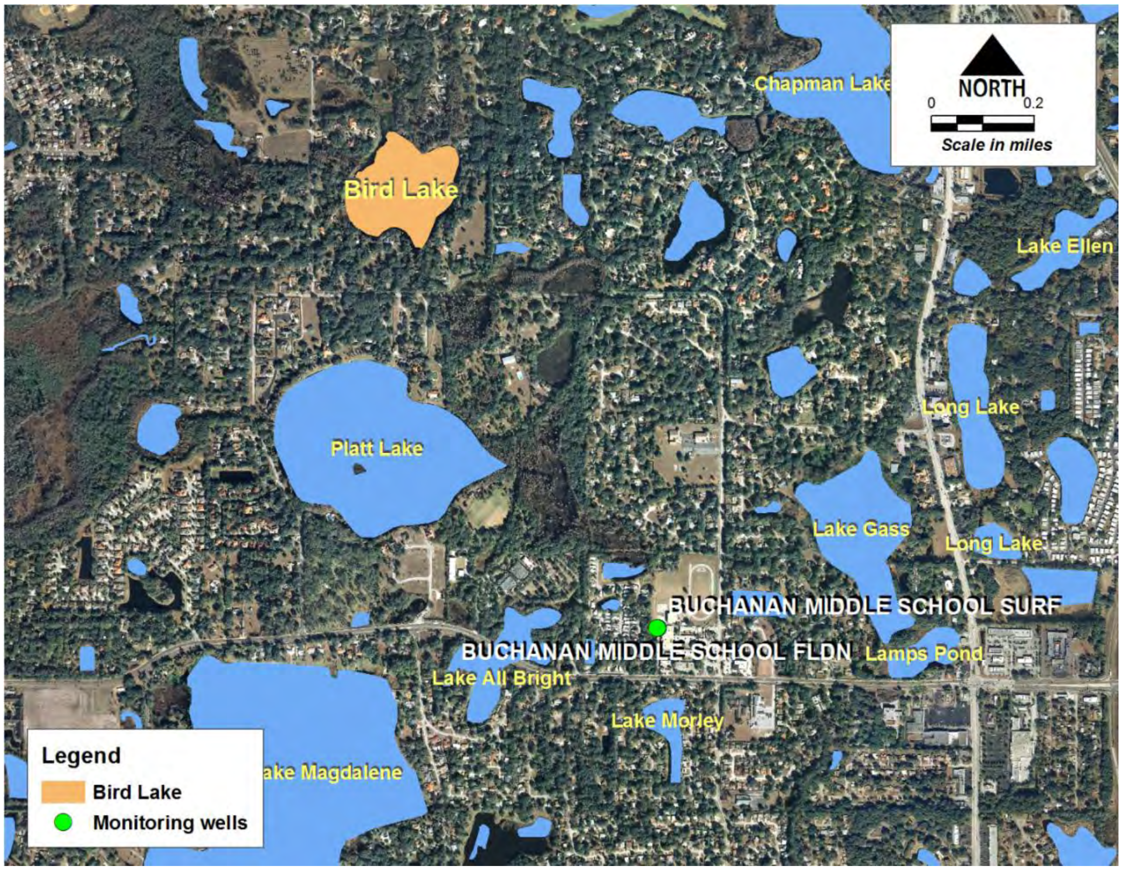

Figure 6. Locations of monitor wells near Bird Lake

Several surficial aquifer wells in the area were considered for use in the model; however, most did not have a longer period of record with consistent data collection or they were located farther from Bird Lake than the Buchanan Middle School well. One exception is the Berger Shallow aquifer well. However, it was not used in the model for the same reasons the Berger Deep well was not used.

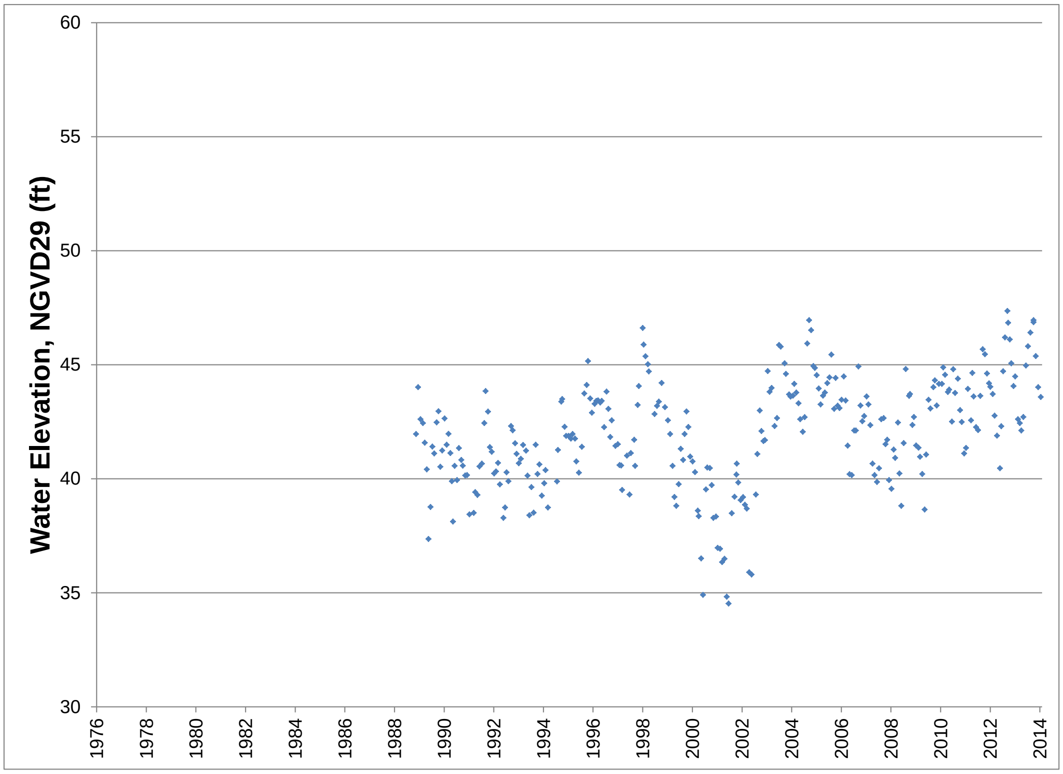

Figure 7. Water levels in Buchanan Middle School Floridan aquifer monitor well (SID 19915)

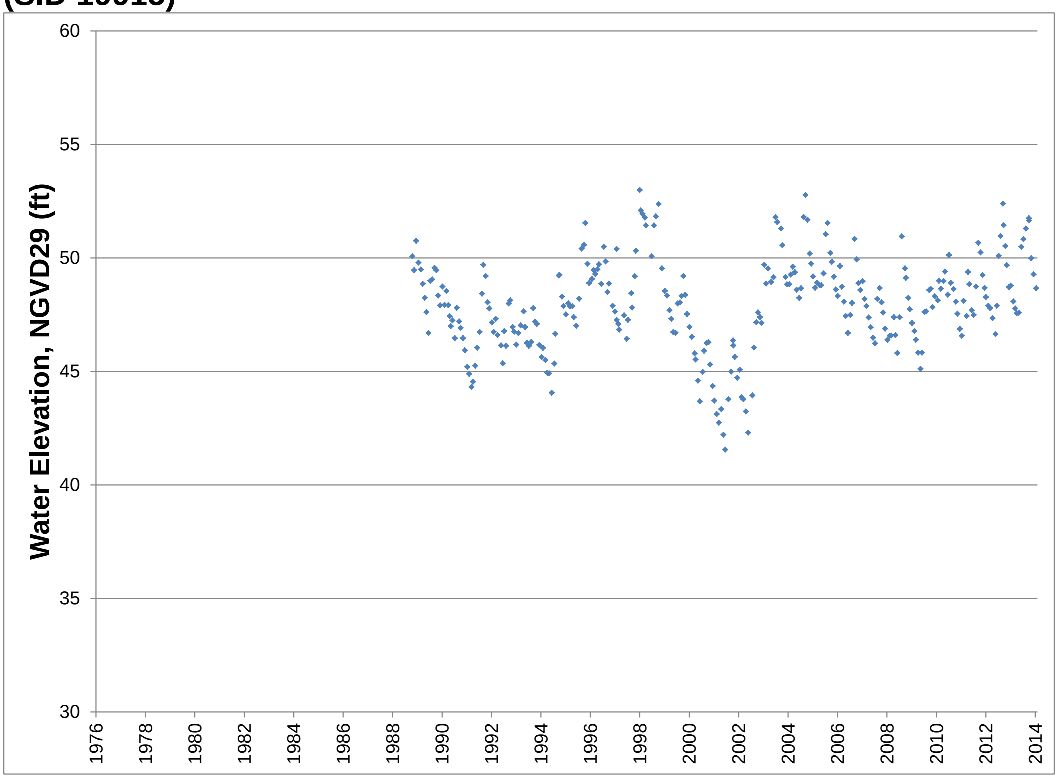

Figure 8. Water levels in Buchanan Middle School surficial well (SID 19916)

Water levels in many lakes in the Section 21 Wellfield area dropped significantly since public supply groundwater withdrawals began (Hancock and Basso, 1996) (Figures 4 and 5, 9 and 10). Because Bird Lake water level data collection did not begin until well after the beginning of withdrawals from the wellfield (Figure 10), the correlation between groundwater withdrawals and lake level cannot be easily seen in the data. Lake recovery during the period of recent reductions in groundwater withdrawals can be seen in Figure 10. A review of aerial photography (Figure 9) shows that signs of lowered lake level after the commencement of groundwater withdrawals in 1963 at the Section 21 Wellfield are somewhat obvious in the 1970 photograph. It should also be noted that the lake was structurally altered since at least the late 1970s (and possibly the 1960s) (Gant, 2014).

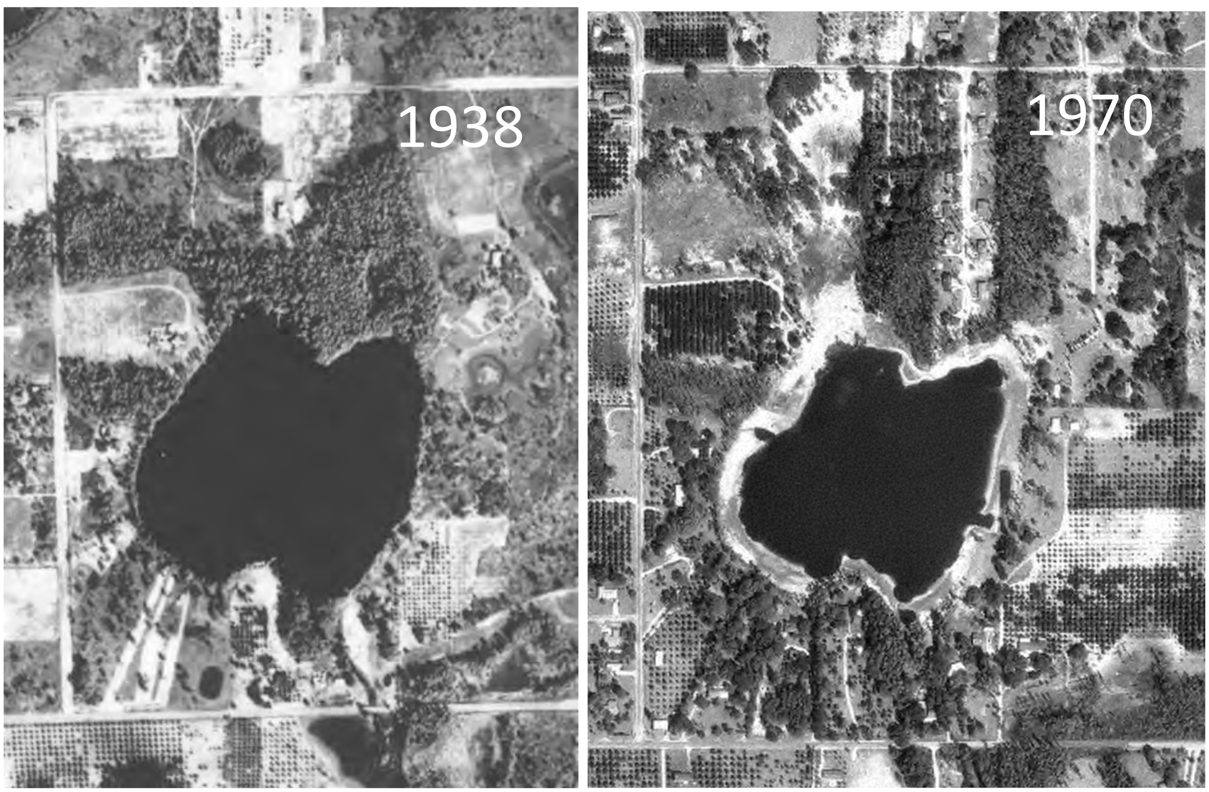

Figure 9. Water level changes in Bird Lake

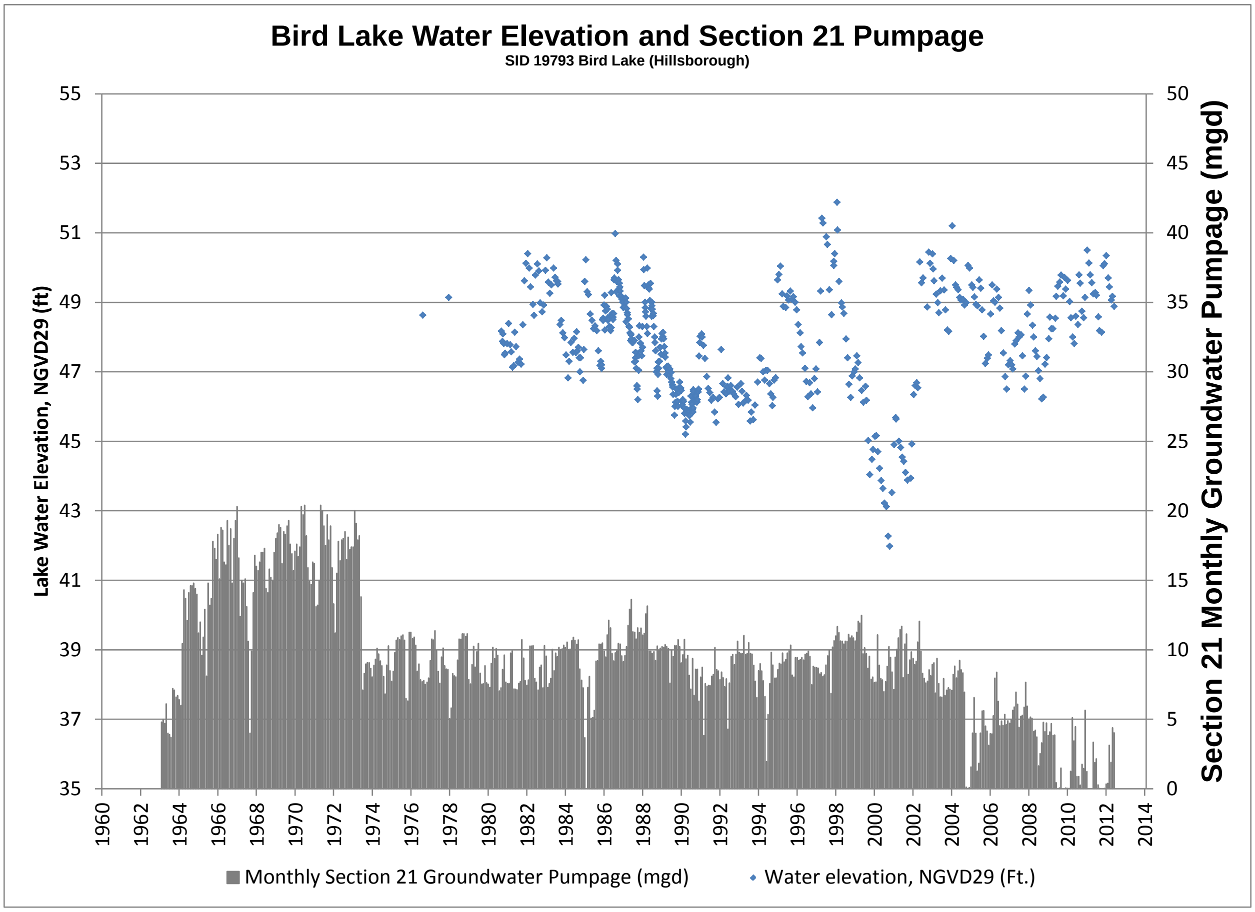

Figure 10. Water levels in Bird Lake and Section 21 Wellfield groundwater withdrawals

A permit to augment Bird Lake with groundwater (WUP 5327, Lake Byrd Improvement Association) was issued in August 1979 and augmentation began in 1980 (Figure 11). According to permittee supplied withdrawal data, groundwater withdrawal from the well for augmentation was heaviest between 1984 and June 1988. Pumping for augmentation was relatively less after June 1988. The last reported augmentation was in June 1997, and the water use permit for augmentation expired in January 2012 and an application to renew it was withdrawn in 2013.

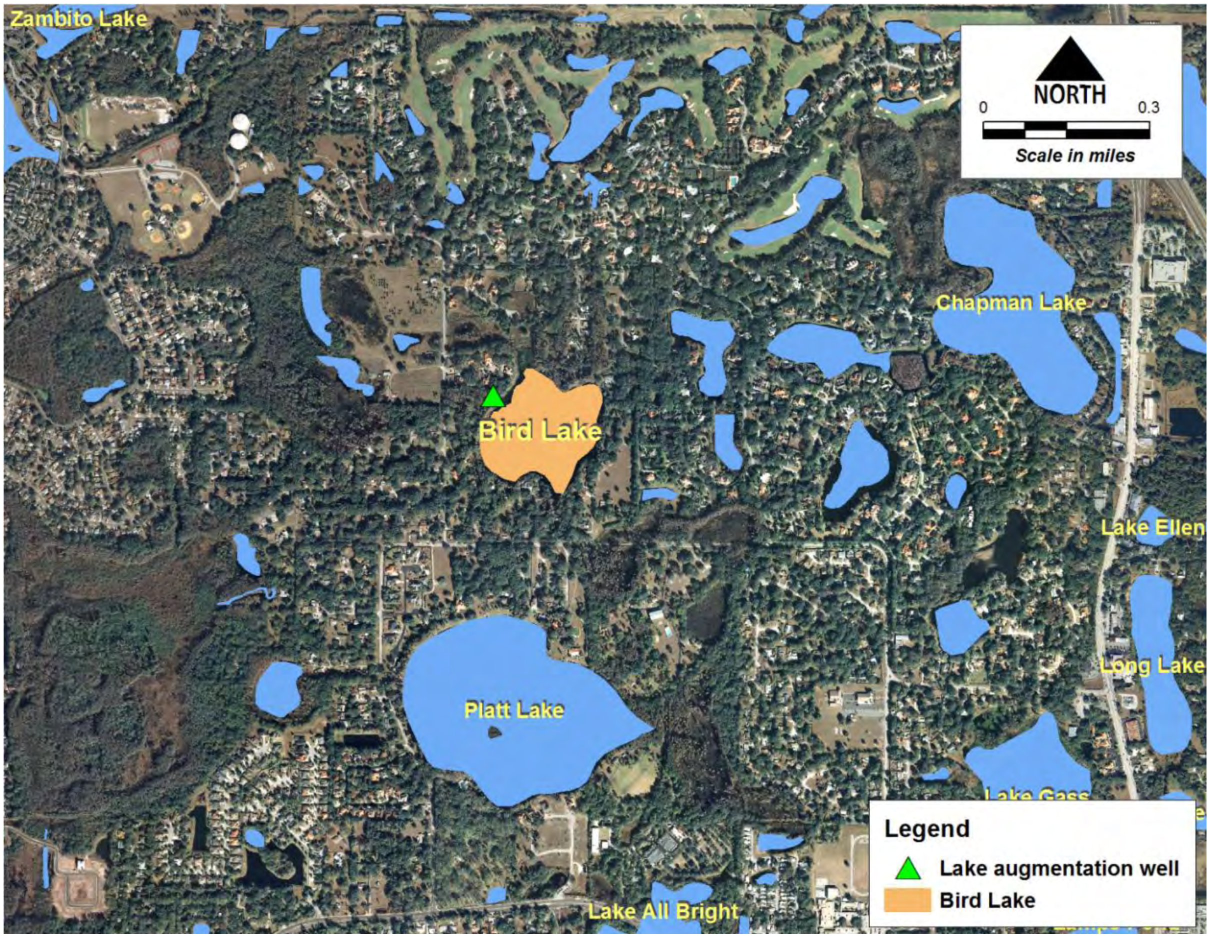

Figure 11. Bird Lake augmentation well location

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 a long-term Historic lake 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 Bird Lake, the Section 21 Wellfield has potentially affected water levels in the lake since early 1963. 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 Bird Lake exist prior to the initiation of groundwater withdrawals from the Section 21 Wellfield. Therefore, the development of a water budget model coupled with a rainfall correlation model of the lake was considered useful for estimating long-term Historic percentiles, accounting for changes in the lake's drainage system, and simulating effects of changing groundwater withdrawal rates.

D. Water Budget Model Overview

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

The hydrologic processes in the water budget model include:

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

The water budget model uses a daily time-step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels for each lake. The water budget model is calibrated from November 1988 to 2013. 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 10.1, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basin with the underlying lake basin morphology to develop one continuous three dimensional (3D) digital elevation model. The 3D digital elevation model was then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the extent of the lake at its flood stage and working downward to the lowest elevation within the basin.

Precipitation

Precipitation gages were selected based on distance from Bird Lake, period of available data, completeness of data series, and ability to calibrate the model. Gages used in the model are shown in Figure 12. To assemble a complete data set for the model period, multiple gages were used, due to varying collection periods for near-by gages. From the start of the model period (November 1988) through 2005, daily data from the District's Whalen gage (SID 19492), located 1.1 miles north-northeast of Bird Lake, was used, and a few missing data points were infilled with data from the District's Crenshaw Lake gage (SID 20005), located 1.8 miles north-northwest of Bird Lake. Data collection at the Whalen and Crenshaw Lake gages ended in 2005, so the data series could not be extended past 2005 with these gages. For the period January 2006 through December 2013 (end of the model period), the composite time series data set for the Tampa Bay Water rain gage RN-NWH-S21 (TBW SID 5), located 1.7 miles northwest of Bird Lake was used. A few missing data points were infilled with the data from the District's Bay Lake gage (SID 19509), located 2.5 miles southwest of the Bird Lake.

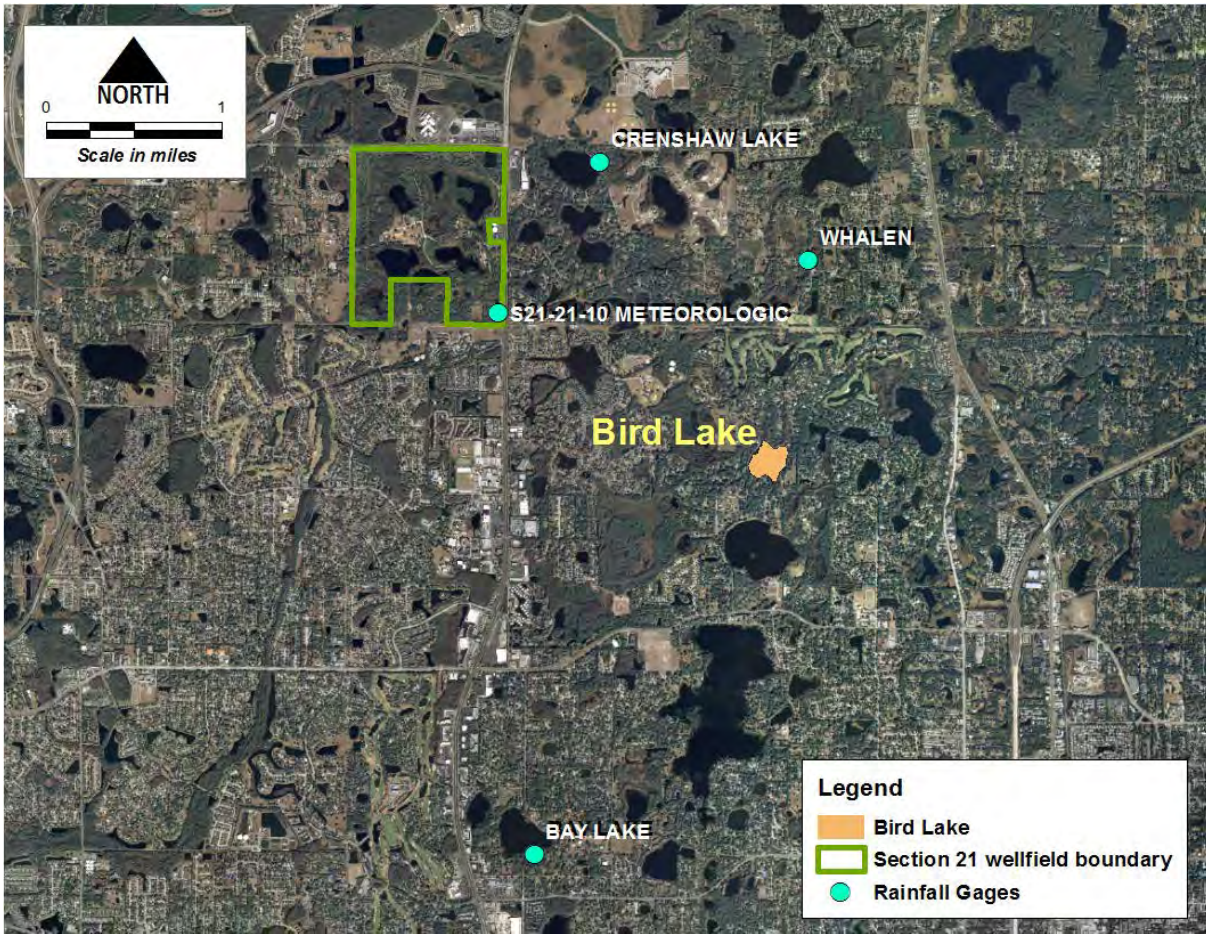

Figure 12. Rain gages used in the water budget model

<u>Lake Evaporation</u>

Lake evaporation was estimated through use of monthly energy budget evaporation data collected by the U.S. Geological Survey (USGS) at Lake Starr in Polk County (Swancar and others, 2000) (Figure 13). The data was collected from August of 1996 through July of 2011. Monthly Lake Starr evaporation data were used in the water budget model when available and monthly averages for the period of record were used for those months in the model when Lake Starr evaporation data were not available.

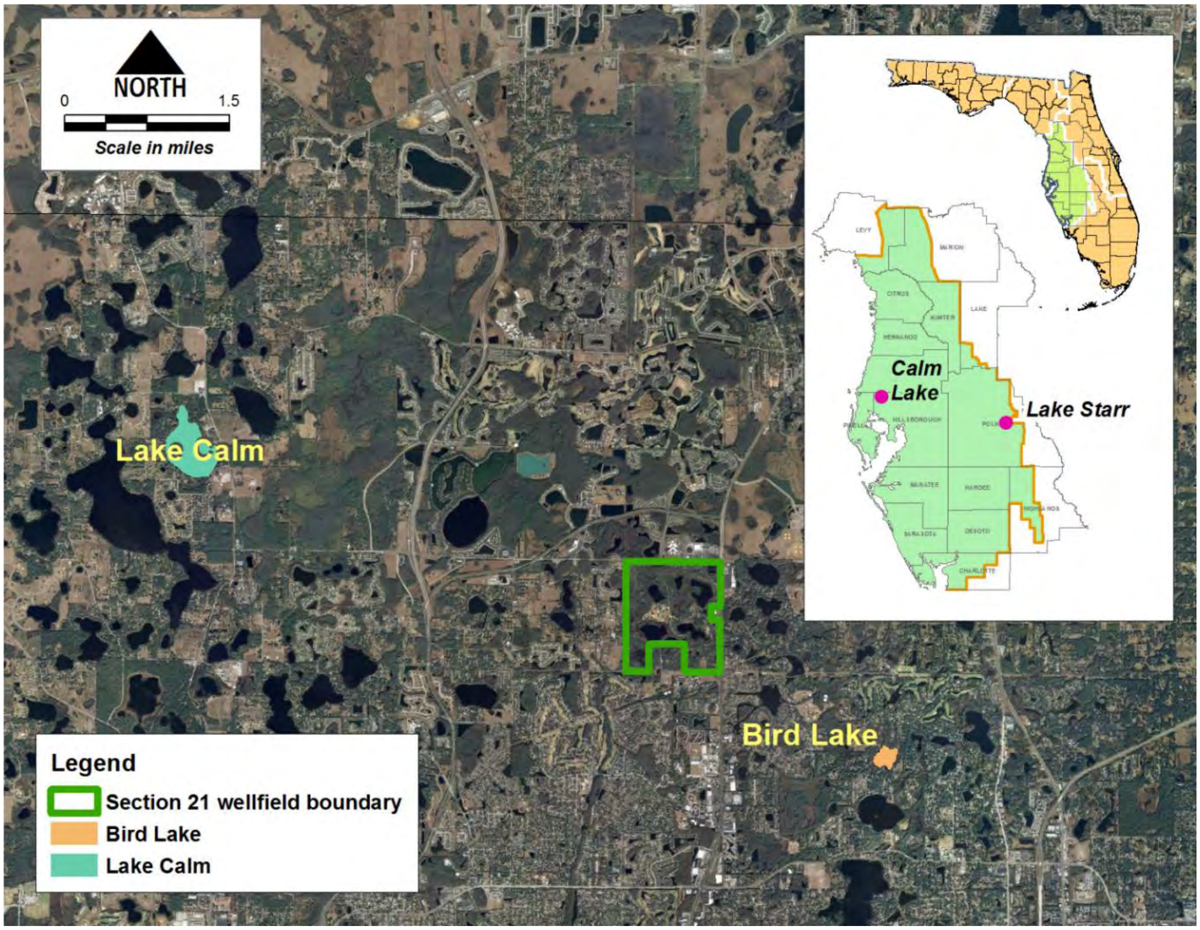

Figure 13. Location of Lakes Starr and Calm

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 6.5 miles northwest of Bird Lake (Figure 13). The assessment concluded that the evaporation rates between the two lakes were nearly the same, 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 began in 1995, and are updated annually. These estimates, available from a website maintained by the USGS, were calculated through the use of 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.

Augmentation withdrawn from the Upper Floridan aquifer

When applicable, augmentation quantities withdrawn from the Upper Floridan aquifer were added to the lake on a daily basis, based on the available metered values reported to the District by the permittee. Because monthly totals are all the permittee is required to report for the permit issued by the District, an assumption was made that the monthly total was distributed evenly each day of the month for which augmentation was reported. The augmentation permit was in place from 1979 through 2012, and pumping was heaviest between 1984 and June 1988, prior to the start of the water budget model.

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) is subtracted from the watershed for the SCS calculation, and then added to the lake water budget separately. Additionally, the curve number (CN) chosen for the watershed of the lake takes into account 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 in the area of 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 Sweetwater Creek watershed for flood assessment purposes (Atkins, 2011). The watershed area values developed by Atkins were adopted for the Bird Lake model (Table 1) after an independent check confirming that they are reasonable for modeling purposes. The watershed is relatively small at 91.4 acres and the topography is relatively flat (Figure 14). Significant flow from the watersheds into the downstream Sweetwater Creek basin occurs only during large rainfall events.

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

	Bird Lake
Overland Flow Watershed Size (acres)	91.4
SCS CN of watershed	79
Percent Directly Connected	0
FL Monitor Well Used	Buchanan Middle School FLDN (District SID 19915)
Surf. Aq. Monitor Well(s) Used	Buchanan Middle School Surf (District SID 19916)
Surf. Aq. Leakance Coefficient (ft./day/ft.)	0.002
Fl. Aq. Leakance Coefficient (ft./day/ft.)	0.0014
Outflow K	0.006
Outflow Invert (ft. NGVD 29)	48.6
Inflow K	N/A
Inflow Invert (ft. NGVD 29)	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. The soils in the area of the lake are C, D, or B/D soils. Group C soils have moderately high runoff potential when thoroughly wet. Group D soils have high runoff potential when thoroughly wet. The B/D soil type 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 “B” soil. Because of the proximity of the wellfields to the area being modeled, water levels have been historically lowered by the withdrawals, and therefore the soils in the area may have had lower runoff rates during that time (characteristic of a “B” soil). Groundwater withdrawals during the period of calibration, however, have recently been significantly reduced relative to historic withdrawal rates, so the soils in the area may have begun to exemplify runoff properties that are more characteristic of “D” soils.

A recent flood model (Atkins, 2011) used a curve number of 89 for the watershed, characteristic of poorly drained soils. For purposes of this model, taking into account the range of conditions experienced, a value of 79 was used. No direct discharges to the lake were identified, so the DCIA of the watershed is zero.

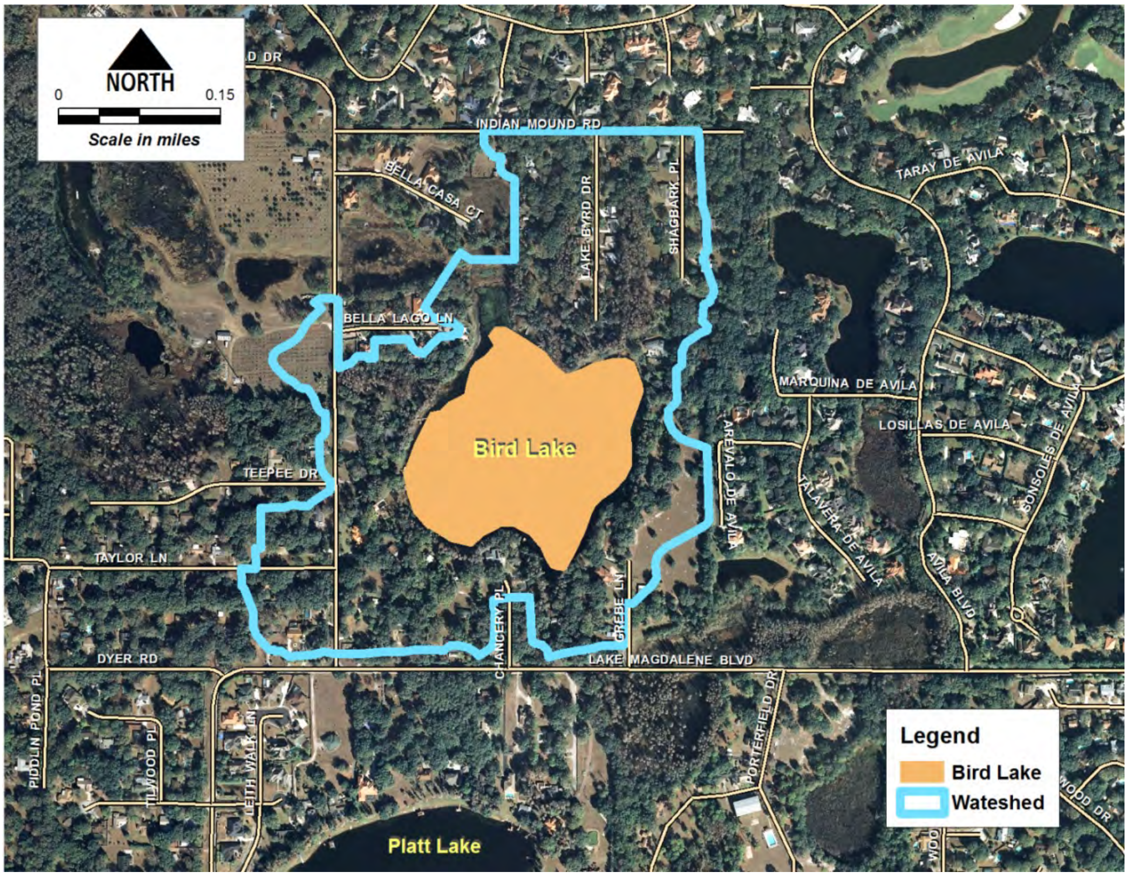

Figure 14. Bird Lake watershed

Inflow and Discharge via Channels from Outside Watersheds

Outflow via a channel from the lake's immediate watershed (hence referred to as "channel flow") is an important component to the Bird Lake water budget, although the gradient of the channel is relatively flat. Lake inflow is likely to occur only during very high rainfall events.

To estimate flow out of the 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.

Outflow occurs on the southern end of Bird Lake through a small three-foot wide weir structure, then through two four-foot by eight-foot box culverts under Lake Magdalene

Boulevard, and then into Platt Lake. The control elevation was measured by a professional survey and determined to be 48.6 feet NGVD 29. The control elevation for the lake is the weir opening between Bird Lake and Lake Magdalene Boulevard.

Flow from and into the surficial aquifer and Upper Floridan aquifer

Water exchange between the lake and the 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 Buchanan Middle School Floridan aquifer monitoring well (District SID 19915) was used to represent the Upper Floridan aquifer. The well period of record begins in November 1988, the beginning of the water budget model. To represent the surficial aquifer, the Buchanan Middle School surficial aquifer monitor well (District SID 19916) was used in the water budget model. Water level measurements for this well started in October 1988, one month prior to the beginning of the water budget model. Data was collected monthly for both of these wells; however, a daily series was necessary to complete the water budget model. A simple approach was used to fill in weekly or monthly data (or missing data) to create daily values by using the last recorded data value.

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. The first water level data collected by the District for Bird Lake was in April 1977, but the collection schedule was irregular for the next several years. Regular monthly data collection by the District began in May 1981 (with some periods of more frequent data collection). Daily values are used in the model, so data was filled-in using the same approach used to fill-in the well data.

Figure 15 shows the calibration results of 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 period.

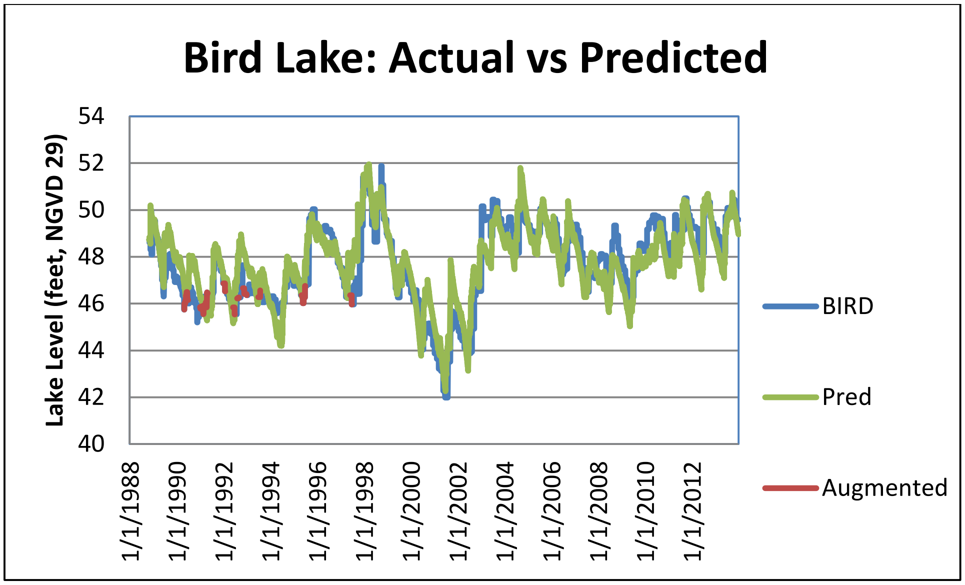

Figure 15. Bird Lake calibration in the water budget model

Table 2. Comparison of percentiles of mearured lake level data to calibration percentiles from the water budget model (all in feet NGVD 29).

	Bird LakeData	Bird Lake Model
P10	49.8	49.8
P50	47.8	47.8
P90	45.6	45.7

Table 3. Bird Lake Water Budget (November 1988-December 2013)

Inflows	Rainfall	Surficial Aquifer Ground-water Inflow	Floridan Aquifer Ground-water Inflow	Runoff	DCIA Runoff	Inflow via channel	Augmen-tation	Total
Inches/year	55.6	3.7	0.0	44.2	0.0	0.0	0.8	104.4
Percentage	53.3	3.6	0.0	42.4	0.0	0.0	0.8	100.0
Outflows	**Evap-oration**	**Surficial Aquifer Ground water Outflow**	**Floridan Aquifer Ground water Outflow**			**Outflow via channel**		**Total**
Inches/year	58.1	2.4	36.5			6.9		104.0
Percentage	55.9	2.4	35.1			6.7		100.0

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 15, the model appears to be reasonably well calibrated. There are a few periods when the peaks or lows 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.

A review of Table 2 shows no difference in median (P50) and P10 percentiles between the data and model. The P90 percentile for Bird Lake is within 0.1 feet. Some of this difference could be due to inaccuracies in rainfall estimates caused by the distance between rainfall gages and the lake during certain time periods or data collection frequency or issues.

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

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the 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 Wellfield 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 water budget 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 has the ability to account for groundwater and surface water, as well as the interaction between them. The domain of the INTB application includes the Bird 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 water budget model is from November 1988 to September 2004, while the post-cutback period is October 2004 to December 2013. 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 with 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 in the area of the wellfields. Groundwater withdrawal rates from the Section 21 Wellfield in each scenario were 8.9 mgd and 4.2 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 in the Bird Lake area, 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 November 1988 to December 2013 water budget model period, two periods of adjustment were used to reflect the cutbacks that took place at the Section 21 Wellfield. Adjustments to each Upper Floridan aquifer and surficial aquifer well and the associated adjustment periods are found in Table 4.

The lake was augmented with groundwater during the model period. Reported augmentation quantities were removed from the model for the scenario runs. This allows the results to represent the hydrology of the lake without man-made effects (with the exception of permanent structures).

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

Well	Adjustment (feet) November 1988 to September 2004	Adjustment (feet) October 2004 to December 2013
Floridan aquifer	4.2	2.4
Surficial aquifer	2.1	1.2

Figure 16 presents measured water level data for the lake along with the model's simulated lake levels under Historic conditions, i.e., in the absence of groundwater withdrawals and augmentation with structural alterations similar to current conditions. Table 5 presents the Historic percentiles based on the model output.

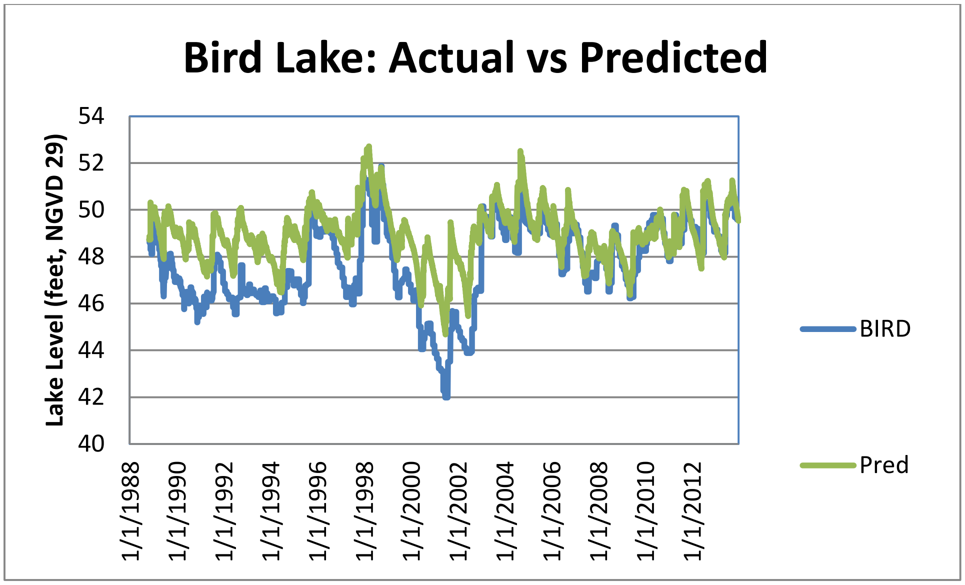

Figure 16. Measured lake levels (Bird) and Historic water levels predicted with the calibrated Bird Lake model (Pred)

Table 5. Historic percentiles estimated by the water budget model (all in feet NGVD 29).

Percentile	Lake Elevation
P10	50.5
P50	48.9
P90	47.5

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 pools were determined based on inflection points of remaining cypress trees. The historic normal pool for Bird Lake is 52.08 feet NGVD 29.

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 water budget model's estimate of the Historic P10 is approximately 1.6 feet lower than the field determined Historic normal pool. The difference is likely caused by the structural alterations of the lake, since Bird Lake's current control point is 3.5 feet lower than the Historic normal pool.

I. Rainfall Correlation Model

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

In this application, the simulated lake water levels representing Historic conditions were correlated with Long-term rainfall. For the correlation, additional representative rainfall records were added to the rainfall records used in the water budget model (November 1988-December 2013). Data from the St. Leo NWS (SID 18901) rain gage was used for the period 1935 to 1945, and a few missing daily data points were filled in with data from the Tarpon Springs Sewage Plant NWS (DID 22881) and Tampa International Airport NWS (DID 19500) rain gages. Data from the "Cosme" rain gage (RNF-197), which was eventually replaced by the Cosme 18 rain gage due to quality control issues, was used for the period 1945 through July 1965. The quality control issues occurred after 1995, and there is no evidence that there were quality control issues at the Cosme gage prior to that time. Rainfall data from the Section 21 Lutz Wellfield gage (SID 19491) was used for the period August 1965 to December 1971. The Crenshaw Lake gage (SID 20005) was used for the period January 1972 to June 1975. The Whalen gage (SID 19492) was used from July 1975 to the start of the water budget model. The rainfall gage locations are shown in Figure 17.

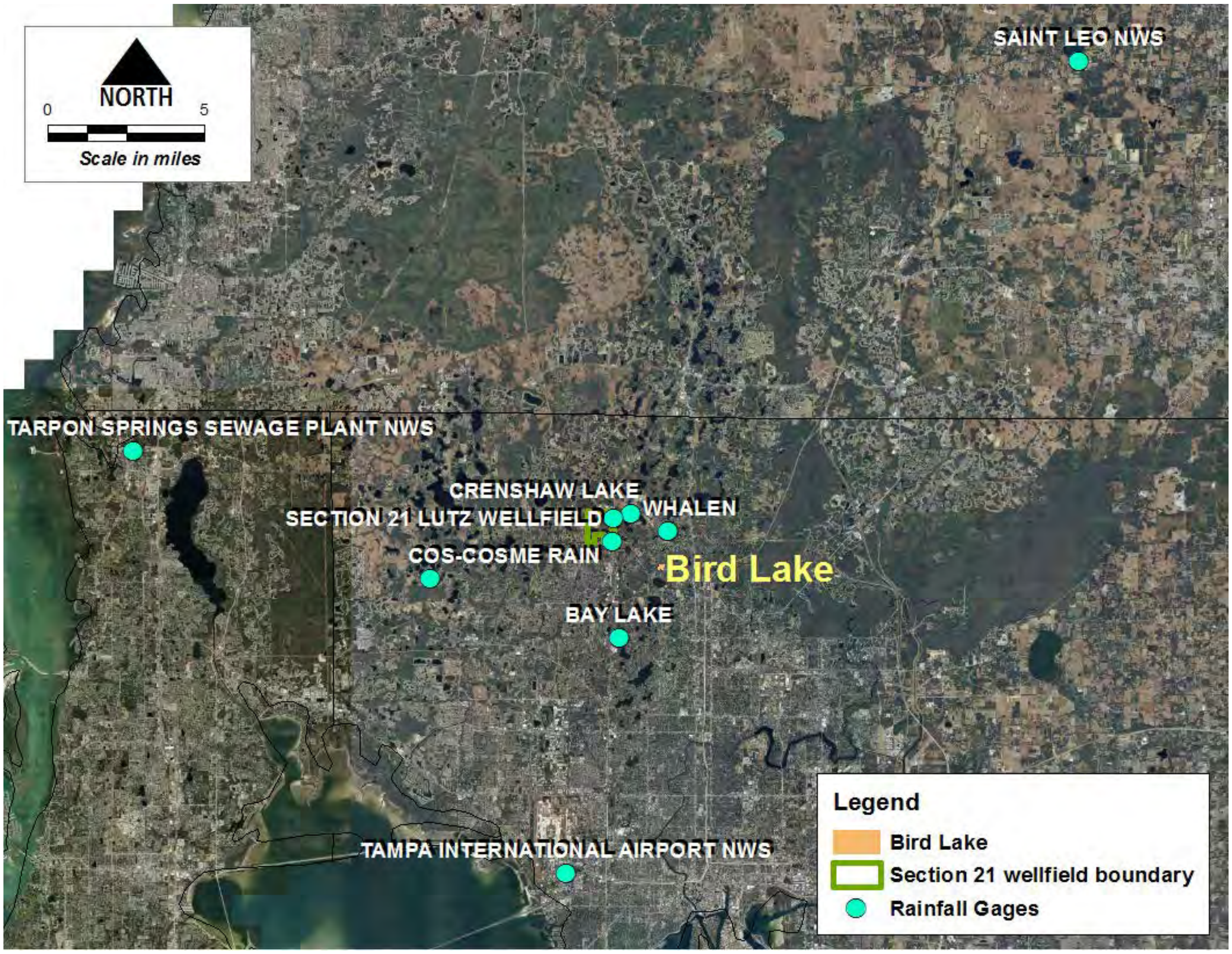

Figure 17. Location of rain stations used for the rainfall correlation model

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 (November 1988-December 2013), and the results from 1946-2013 (68 years) were produced. For Bird Lake, the 2-year weighted model had the highest correlation coefficient, with an R^2 of 0.81. 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 18.

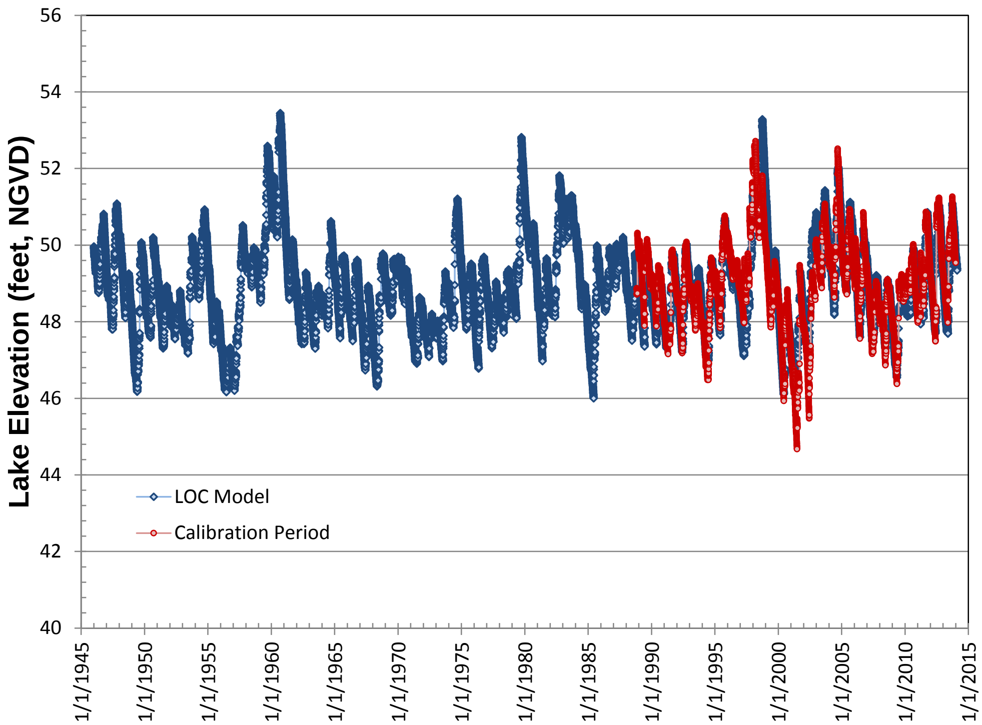

Figure 18. LOC model results for Bird Lake

In an attempt to produce Historic percentiles that apply significant weight to the results of the water budget model, 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-October 1988, while the water budget results are used for the period of November 1988-2013. 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 Bird Lake are 0, 0.1, and 0 feet, respectively. Therefore, there are relatively small changes to the Historic percentiles between the two models.

Table 6. Historic percentiles as estimated by the hybrid model from 1946 to 2013 (all in feet NGVD 29).

Percentile	Bird Lake
P10	50.5
P50	48.8
P90	47.5

J. Conclusions

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

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Technical Memorandum Addendum

July 7, 2015

TO: Tamera McBride, P.G., Senior Hydrogeologist, Water Resources Bureau

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

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

Subject: Bird Lake Historic P10 Review

A. Introduction

Recent long-term historic tenth percentile calculations using a water budget model for Bird Lake (McBride and Hancock, 2015) were reviewed through a comparison to Lake Platt located adjacent to Bird Lake. Bird Lake doesn't have any data pre-dating groundwater withdrawals at the nearby Section 21 wellfield; however, because Platt Lake does, an opportunity exists to investigate a refinement to the historic tenth percentile (HP10) for Bird Lake using Platt Lake data. The historic HP10, representing a long-term 60-year plus un-impacted statistic, is a challenging percentile to estimate due to the infrequent nature of the high lake levels and the interconnection formed between lakes at these high stages. This review looks at other information in the area of Lake Bird to aid in the refinement of the HP10 produced by the water budget model.

Figure 6. Location of Lakes Bird and Platt in Hillsborough County, Florida.

B. Background and Setting

Bird Lake is located in north-east Hillsborough County, approximately 4 miles south of the northern Hillsborough County line and 10 miles east of the western Hillsborough county line (Figure 1). Platt Lake is located approximately 0.1 miles south of Bird Lake and they are connected by a short drainage swale. The two lakes have nearly identical water levels and at times behave as one lake (Figure 2). All elevations in this report are relative to the National Geodetic Vertical Datum of 1929 (NGVD29).

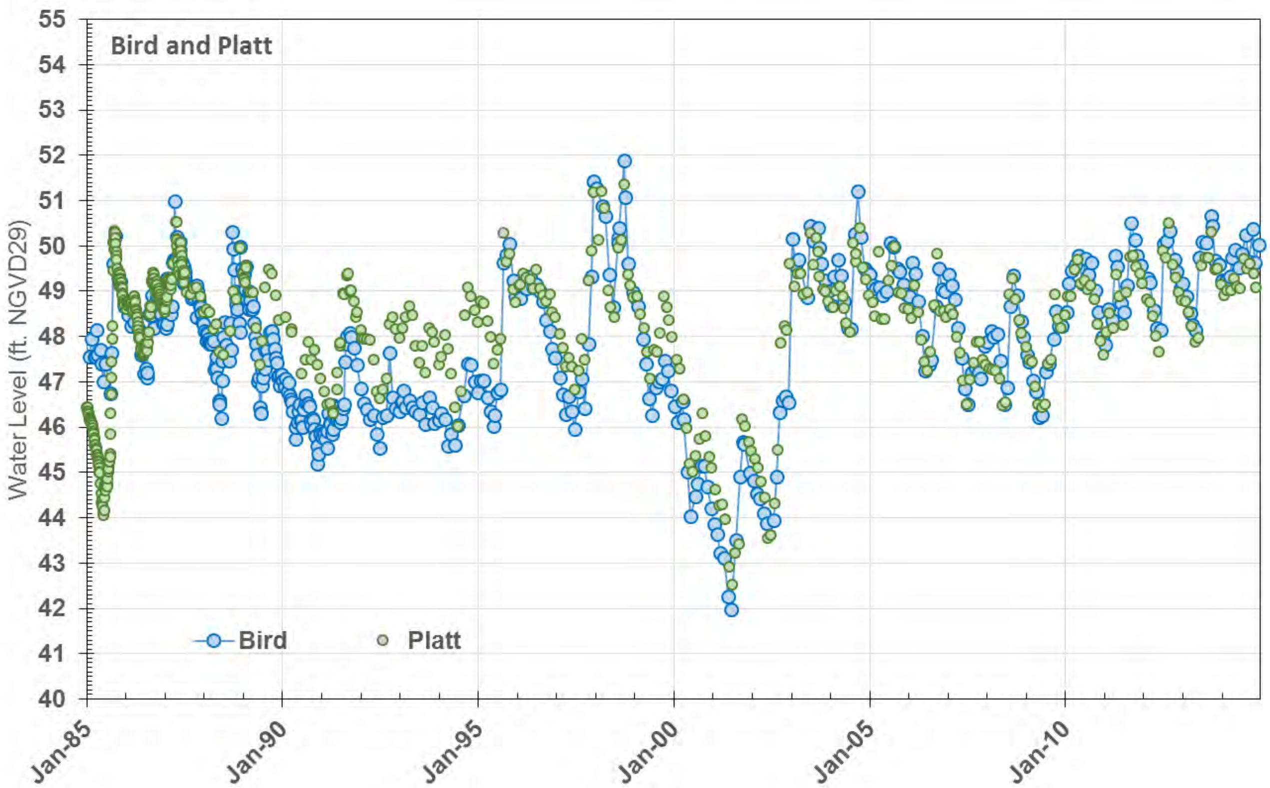

Figure 2. Lakes Bird and Platt Hydrographs.

Lake Bird is located approximately two miles southeast of the Section 21 Wellfield, which is one of the eleven Tampa Bay Water wellfields, collectively referred to as the Central System Facilities. Groundwater withdrawals began at the Section 21 Wellfield in 1963 and incrementally increased to approximately 20 mgd in 1967 (Figure 3). 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 rose to 16 to 20 mgd, for a combined withdrawal rate ranging from 20 to 30 mgd in the mid to late 1970s.

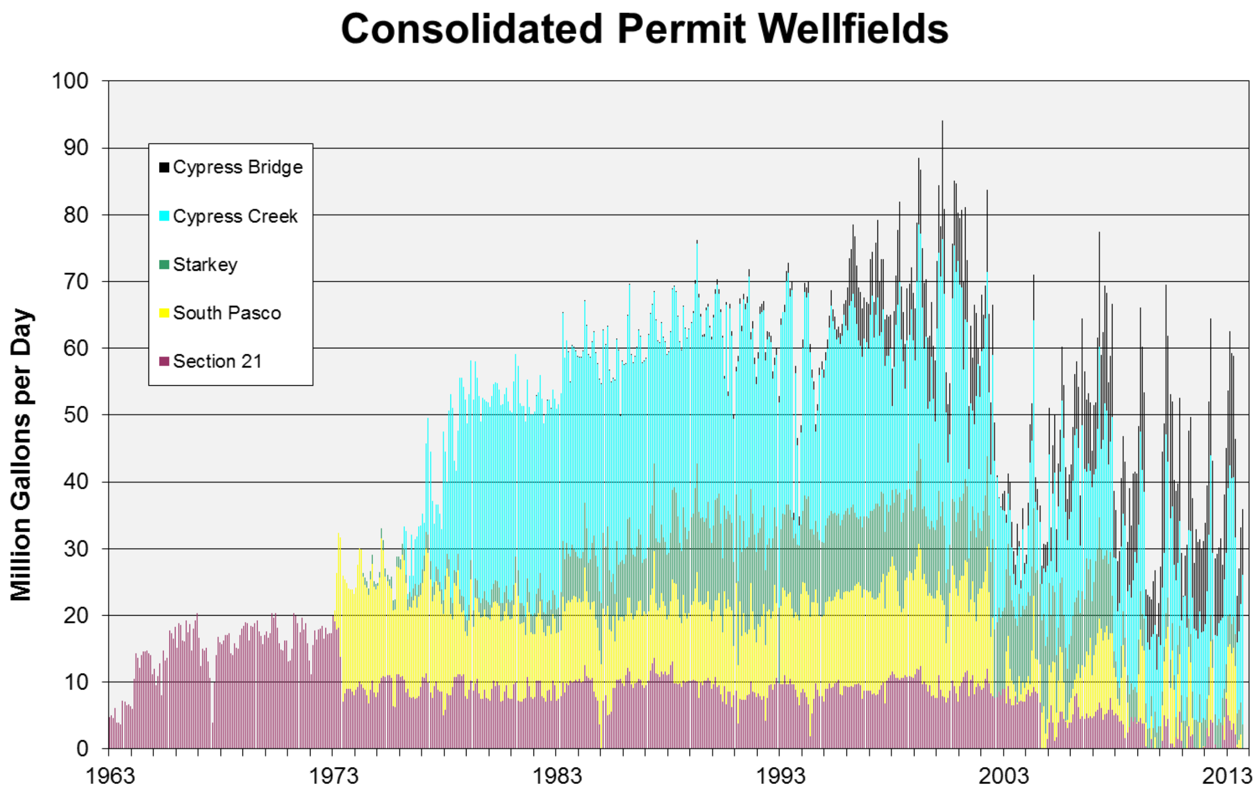

Figure 3. Section 21, South Pasco, Cypress Creek, Starkey and Cypress Bridge wellfield withdrawals.

C. Analysis of Lake Bird Historic Percentiles

Long-term historic percentiles were developed (McBride and Hancock, 2015) using a water budget model calibrated to impacted conditions and adjusted to non-pumping conditions by adjusting Upper Floridan and Surficial aquifer water levels by the Integrated Northern Tampa Bay (INTB) numerical model predicted drawdown.

This memo presents the results of a cross-check of the HP10 calculated by the water budget model through the use of water level data from Platt Lake and a rainfall regression model based on un-impacted Platt Lake data. Bird lake's earliest data starts in 1976 after production at Section 21 began in 1963 and thus the lake levels could be impacted by the withdrawals. Platt Lake's data starts in 1945, pre-dating water withdrawals at Section 21, making it useful in analyzing long-term lake stage percentiles.

When Bird and Platt lakes hydrographs are plotted on one graph they visually appear to be very similar (Figure 2). Comparison of percentiles between 1982 through 2014 using matching measurement dates shows that Platt Lake's measured P10 is slightly higher by 0.045 ft. which is considered to be 0.0 ft. for the purpose of this evaluation.

Because the tenth percentile measured water levels between lakes Bird and Platt are nearly identical, behave similarly and are connected at times and Platt Lake has early data (1946 – 1956) pre-dating groundwater withdrawals, an estimate of the long-term HP10 on Bird Lake using a rainfall regression modeling technique (Ellison 2010) applied to Platt Lake was performed. A Historic time period is a period when there are little to no groundwater withdrawal impacts on the lake, and the lake's structural condition is similar or the same as the present day. In contrast, a Current time period is a recent long-term period during which withdrawals and structural alterations are stable. Data from the Historic period are typically used to establish a statistical relationship (regression) with rainfall. This rainfall regression is then used to extend the available stage record (i.e., develop a 60 year or longer record) for calculation of long-term P10, P50 (median), and P90 lake stage percentiles. The P10, P50 and P90 are, respectively, the water level elevations equaled or exceeded ten, fifty and ninety percent of the time on a long-term basis. The rainfall regression model can then be used to evaluate whether the lake is fluctuating consistently with climate (primarily rainfall) and can also be used for assessing whether minimum levels are being met.

The rainfall regression method involves development of a Line of Organic Correlation (LOC) between lake stage and rainfall. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 1992). The magnitude of the slope of the LOC line is calculated as the ratio of the standard deviations of the x and y variables and its sign, i.e., whether it is positive or negative, determined by the sign (+ or -) of the correlation coefficient (r). The LOC approach, rather than a simple linear regression approach is preferable for the rainfall-regression method since it produces a result that better retains the variance (and therefore retains the "character") of the original data.

Rainfall for the LOC model is correlated to the lake's water level data using inverse linearly-weighted rainfall sums. The weighted-sums ascribe higher weight to more recent rainfall and progressively less weight to rainfall in the past. For the rainfall regression method, weighted sums varying from 6 months to 10 years are used to develop separate models, and the model with the highest coefficient of determination (r^2) is chosen as the best-fit model.

D. Rain Gage Data

Available rain data was inventoried and sorted by distance and period of record to locate the closest rain data to the lake. Consideration was also given to the location of the data sites up gradient of the lake. Table 1 list presents the progression of gauges used and Figure 4 shows the location of the gages. Missing data at the Saint Leo gage was infilled in accordance with methods presented by Aly (2008). The remaining rain gages were fairly complete, but, for few missing data points the nearest gage was used to infill the data set.

Table 1: Rain gages used in the rainfall-regression model.

Site ID	Site Name	Period Of Record Begin	Period Of Record End	Distance from Bird Lake (mi.)
19492	WHALEN	7/1/1975	12/31/2005	1
19493	LUTZ	1/1/1963	6/30/1975	2
18593	HANNA	8/1/2004	Present	3
18901	SAINT LEO NWS	1/1/1935	12/31/62	20

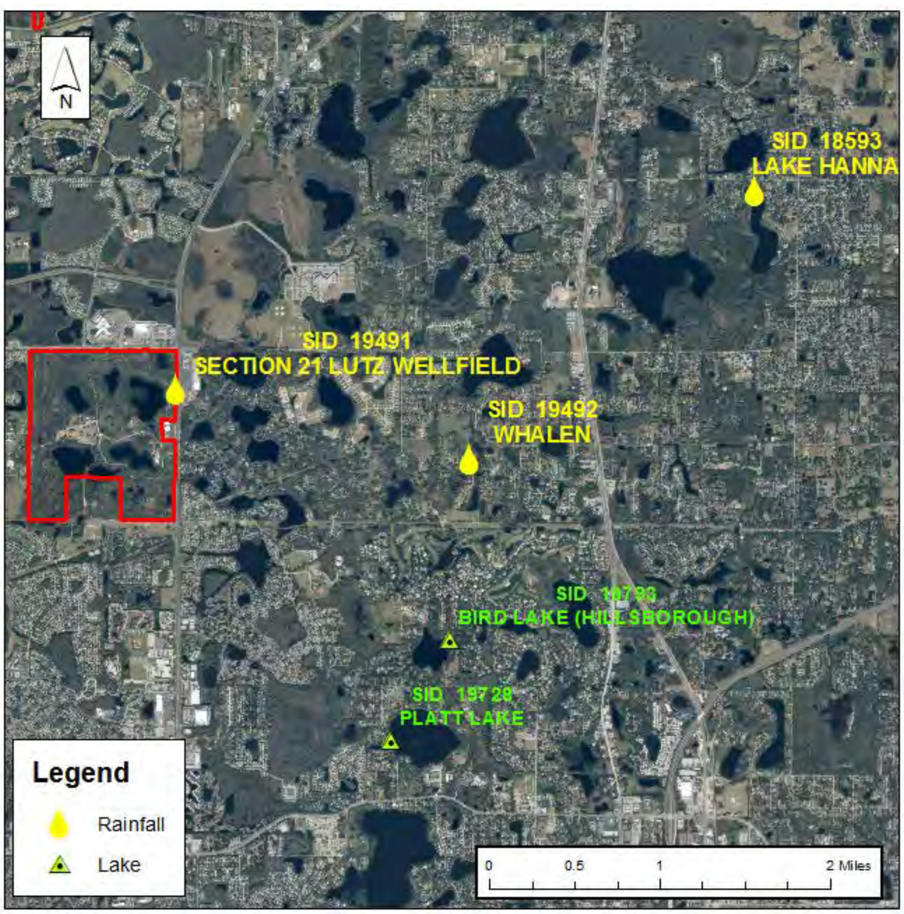

Figure 4. Rain gauge locations used in the rainfall regression models for Platt and Bird Lakes.

E. Platt Lake Rainfall Regression Model and Historic Percentiles

Rainfall regression LOC models were developed using lake stage data and rainfall data from May 1946 through August 1956. Data collected after this period were conservatively excluded from model development to preclude inclusion of records that could reflect potential effects from groundwater withdrawals at the Central System Facilities. The best-fit LOC model for predicting water levels in Platt Lake (Figure 5) was the 6 month rainfall series which exhibited a coefficient of determination (r^2) of 0.42 and may be simplified as:

$$\hat{y}_i = b_0 + sign[r] * b_i * x_i \qquad \text{(Equation 1)}$$

where

$\hat{y}_i =$ *the estimate of lake stage expressed as an elevation in feet above NGVD29*

$b_0 =$ *the y intercept, in this case 47.24 feet above NGVD29*

$b_i =$ *the regression slope; in this case 0.12485*

$sign[r] =$ *the algebrac sign (+ or -) of the correlation coefficient; in this case "+"*

$x_i =$ the *inversely, linearly-weighted one-year cumulative rainfall sum in inches*

A time series plot of actual (i.e., observed) and modeled water levels for the 1946 through 1956 calibration period is shown in Figure 5 and comparison of percentiles for the calibration period are presented in Table 2. The model-derived P10, P50 and P90 percentiles for the calibration period were respectively, 0.1 ft. lower, 0.1 ft. higher and 0.1 ft. higher than the corresponding percentiles for the observed data.

The best-fit LOC model and rainfall records from the rain gages listed in Table 1 were used to estimate long-term historic water levels for Platt Lake for the period from January 1, 1946 through January 30, 2013 (Figure 6). The final historic long-term percentiles for Platt Lake are based on the hybrid set of observed data and modeled data during the calibration period and modeled data for the remaining period (Table 3).

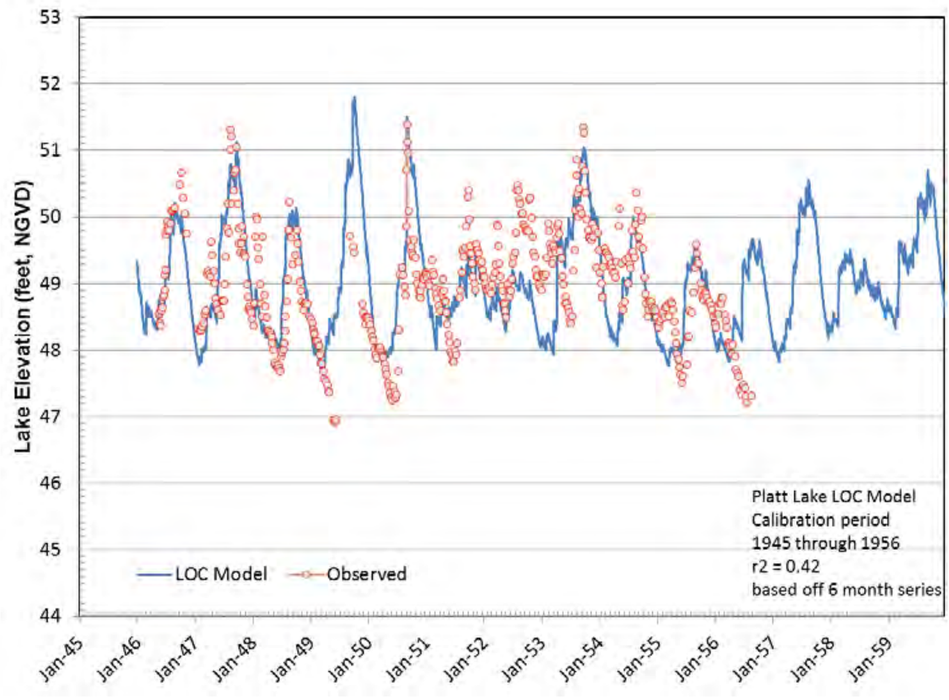

Figure 5. Platt Lake LOC-modeled and actual (i.e., observed) water levels for the calibration period.

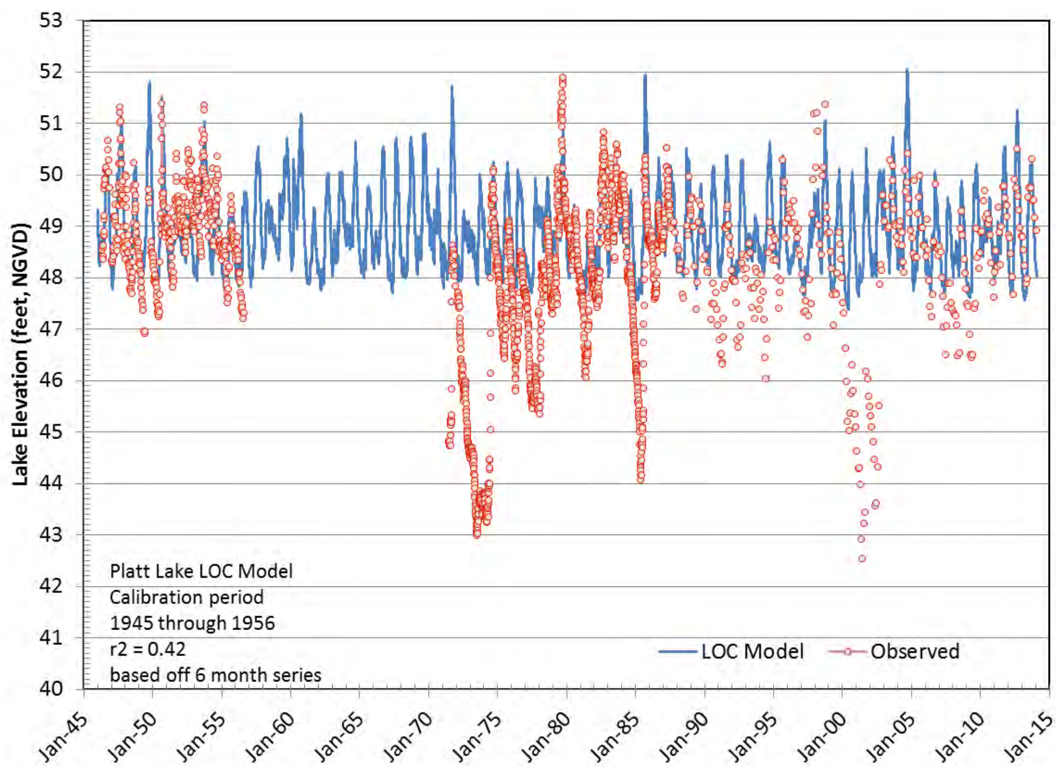

Figure 6. Platt Lake LOC-model predicted and actual (i.e., observed) water levels from January 1, 1946 through January 30, 2013.

Table 2. Comparison of Platt Lake calibration period percentiles.

Calibration 1946 through 1956		
Percentiles*	**Observed**	**Model**
P10	50.0	50.1
P50	48.9	48.8
P90	47.9	48.0

* Percentiles listed include the water surface elevation equaled or exceeded ten (P10), fifty (P50) and ninety (P90) percent of the time

Table 3. Platt Lake Long-term Historic percentiles.

Long-term Historic Percentiles* (1/1/1946 through 1/30/2013)	
Percentiles	
P10	50.0
P50	48.8

* Percentiles listed include the water surface elevation equaled or exceeded ten (P10), and fifty (P50) percent of the time

F. Normal Pool Elevation and Historic Percentiles

A Normal Pool elevation is a datum established to standardize measured water levels, facilitate comparisons among wetlands and lakes, aid in the design of wetland storm water treatment systems (SWFWMD, 1988) and the development of minimum lake and wetland levels (SWFMD 1999a, 1999b). 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).

A Normal Pool of 52.1 and 49.9 feet NGVD29 was determined for Bird and Platt lakes, respectively, based on buttress inflection points of cypress trees along the lake shore and within wetlands contiguous with the lake. A comparison of Platt Lake's long-term HP10 of 50.0 feet from the rainfall regression analysis with the Normal Pool elevation indicates that Platt Lake can reach long-term lake levels associated with establishment of the remaining fringing wetlands. The long-term HP10 for Platt Lake is 0.1 feet higher than its Normal Pool, which is a very close agreement between the two.

Bird and Platt Lake have been shown to be nearly identical; thus, the long-term HP10 from Platt Lake is a reasonable representation of Bird Lakes HP10. Comparison of Bird Lakes HP10 of 50.0 feet is more than 2 feet below Bird Lakes Normal Pool elevation of 52.1 feet indicating that structural alterations to Bird Lake preclude it from reaching the Normal Pool elevation ten percent of the time.

G. Conclusions

Platt Lake and Bird Lake have very similar lake stage tenth percentiles when matching days of measurements are compared. The P10's from the two lakes were within 0.045 feet of each other; thus, Platt Lake can be useful in evaluating long term historic percentiles for Bird Lake. Because Bird Lake's stage data starts after groundwater withdrawals at Section 21 Wellfield began there are no data available to produce a rainfall regression model of un-impacted conditions. However, Platt Lake has early data pre-dating groundwater withdrawals at the Section 21 Wellfield that can be used to develop long-term historic percentiles with the rainfall regression model. Because the two lakes have nearly identical tenth percentiles when concurrent daily measurements are compared, the long-term Historic P10 from the rainfall regression model for Platt Lake is a reasonable representation of Bird Lake.

The rainfall regression model for Platt Lake was developed using data starting in 1946 and ending in 1956 which pre-dates the initiation of groundwater withdrawals in 1963 at Section 21 Wellfield. The rainfall regression model for Platt Lake produced a long-term HP10 of 50.0 feet NGVD29. This is approximately 0.5 feet lower than the HP10 of 50.5 feet produced by the water budget model. The results of the two models show very similar results and are within a reasonable range of each other considering the inherent challenges of modeling high lake levels due to the infrequent occurrence and complexities of interrelationships with other water bodies that interconnect at these high stages. Fortunately, Platt Lake is available to provide insight on the limits of the high lake stage range, and it is recommended that the results of 50.0 feet NGVD29 by the rainfall regression model for Platt be considered for the long-term HP10 for Bird Lake.

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Appendix B
Technical Memorandum

July 7, 2015

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

FROM: Tamera McBride, P.G., Hydrogeologist, Water Resources Bureau
David Carr, Staff Environmental Scientist, Water Resources Bureau

Subject: Bird Lake Initial Minimum Levels Status Assessment

A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Bird 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 McBride and Hancock (2015) and Carr (2015).

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 Bird Lake and other water bodies 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 Bird Lake that are located 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 for Bird Lake and any recovery that may be necessary for the lake.

B. Background

Bird Lake is located in Hillsborough County, north of Lake Magdalene Boulevard between Dale Mabry Highway and North Florida Avenue in Tampa, Florida. The lake is located to the southeast of the Section 21 Wellfield, one of the eleven regional water supply wellfields comprising the Central System Facilities (Figure 1). From 2002 to 2005, a cutback in the withdrawal rates at most Central System Facility wellfields occurred in response to the development of several alternative water supply sources.

As a whole, the wellfields were reduced from approximately 158 million gallons per day (mgd) to 90 mgd, although the timing and amount of reduction at each wellfield was variable. These cutbacks are evident in the withdrawal rates reported for the Section 21 Wellfield (Figures 2 and 3).

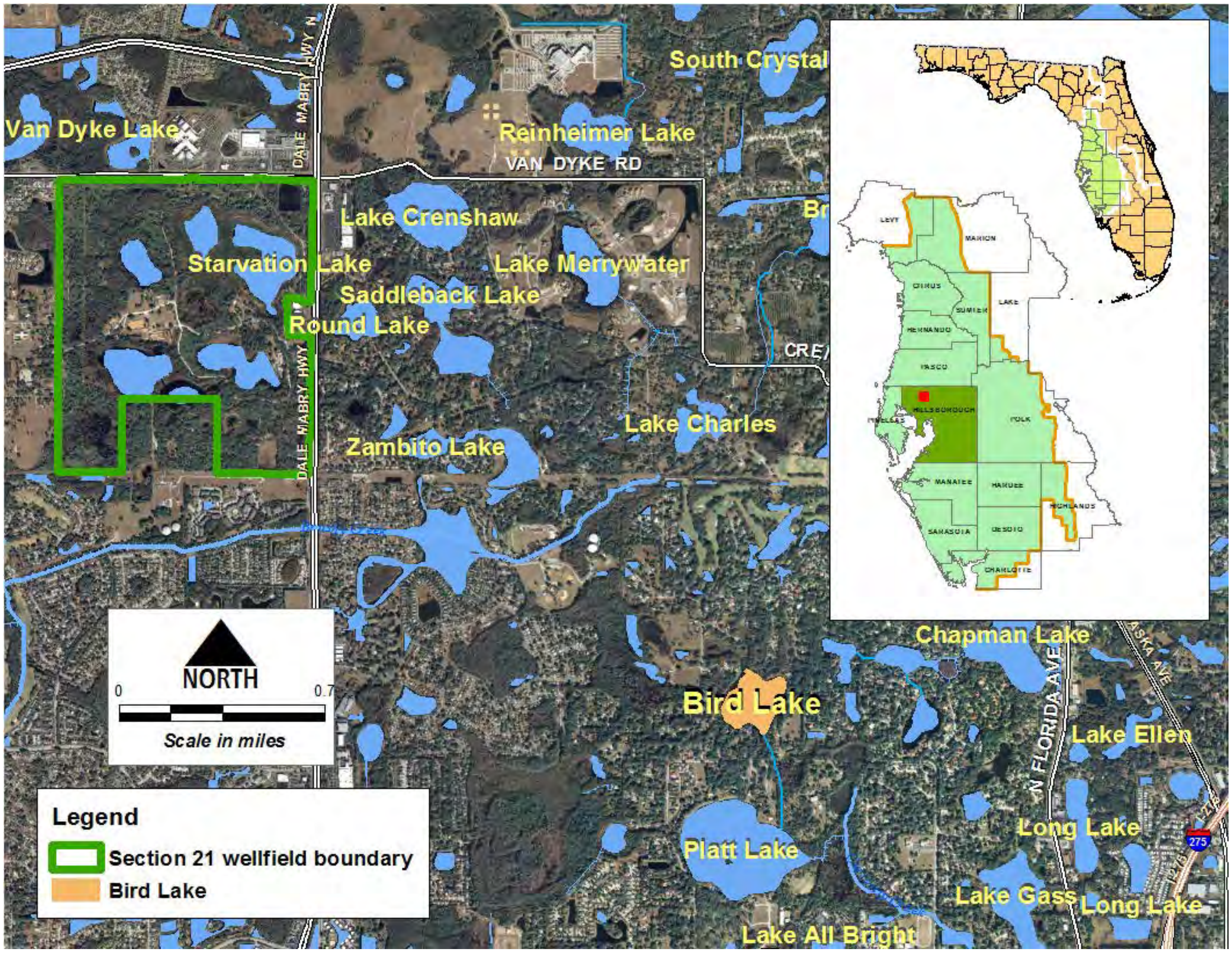

Figure 7. Location of Bird Lake and the Section 21 Wellfield.

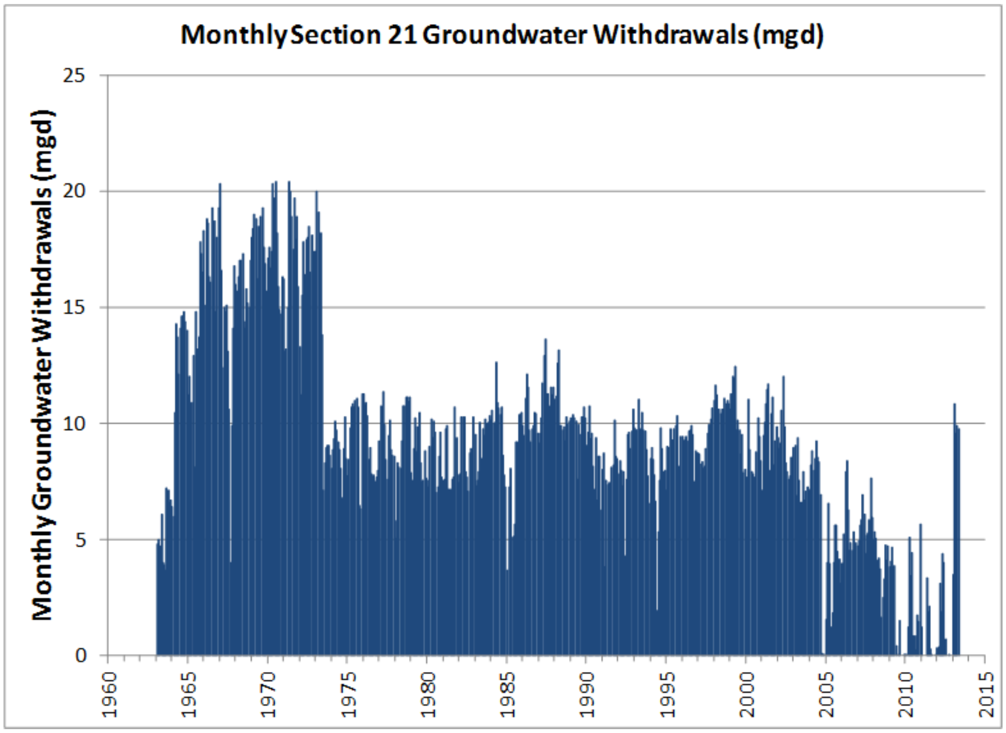

Figure 2. Section 21 Wellfield withdrawals in million gallons per day (MGD).

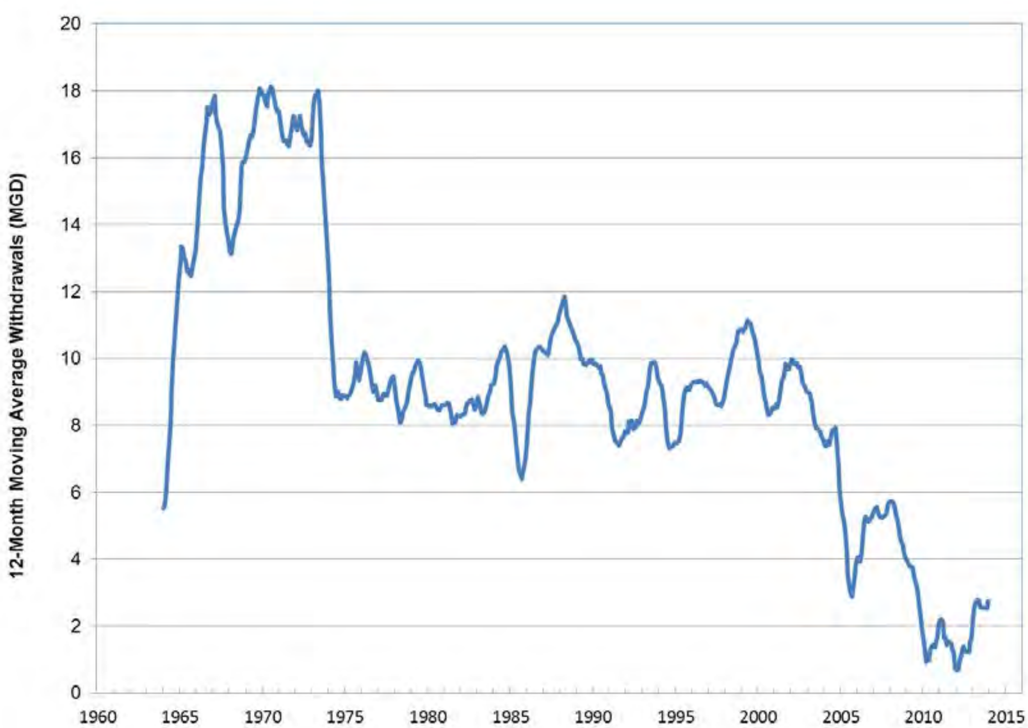

Figure 3. 12-month moving average of Section 21 Wellfield withdrawals in million gallons per day (MGD).

A permit to augment Bird Lake with groundwater (WUP 5327, Lake Byrd Improvement Association) was issued in August 1979 and augmentation began in 1980. According to permittee supplied withdrawal data, groundwater withdrawal from the well for augmentation was heaviest between 1984 and June 1988. Pumping for augmentation was relatively less after June 1988. The last reported augmentation was in June 1997, and the water use permit for augmentation expired in January 2012 and an application to renew it was withdrawn in 2013.

C. Revised Minimum Levels for Bird Lake

Revised minimum levels for Bird Lake are presented in Table 1 and discussed in more detail by Carr (2015). 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 Bird Lake or minimum flows and levels for any other water body, long-term hydrologic data or model results must be used.

Table 1. Revised Minimum Levels for Bird Lake.

Revised Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	50.0
Minimum Lake Level	48.8

D. Status Assessment

Three models were used in this assessment, including the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013), the Bird Lake Water Budget model (McBride and Hancock, 2015), and the Bird Lake Line of Organic Correlation (LOC) model (McBride and Hancock, 2015). Using these models, three approaches were used to assess the status of Bird Lake (described below).

Use of the Integrated Northern Tampa Bay (INTB) Model

The Integrated Northern Tampa Bay (INTB) model was used in the development of the minimum levels (McBride and Hancock, 2015) and in this MFL status assessment to estimate drawdowns in the surficial and Upper Floridan aquifers in response to various rates of groundwater withdrawals. All INTB model simulations were performed for an 11-year period corresponding to conditions from 1996 through 2006 using a daily integration step. Average pre-cutback wellfield withdrawals for an initial simulation were represented by the actual 1997 distribution and quantity of withdrawals for the eleven Central System Facility wellfields, which represented pre-cutback withdrawal rates. Post-cutback wellfield withdrawals for a second simulation were represented by the actual 2008 distribution and quantities of withdrawals for the eleven Central System Facility wellfields. The 2008 distribution and quantities were considered representative of forecasted long-term average withdrawal conditions for the post-cutback period. These withdrawal distributions and quantities were repeated for each year of the 11-year simulations. All other area withdrawals not associated with the Central System Facilities were included in the simulations, based on their actual quantities and distributions from 1996 through 2006. Results for the two simulations were compared to an 11-year INTB model run with no withdrawals to estimate drawdown. The pre- and post-cutback withdrawal rates used for the Section 21 Wellfield for the two simulations are presented in Table 2. The modeled drawdowns in the surficial aquifer and Upper Floridan aquifer systems in the vicinity of Bird Lake for the two simulations are presented in Table 3.

Table 2. Withdrawal rates used for pre- and post-cutback withdrawal INTB simulations.

Wellfield	Pre-cutback Withdrawal Rate (MGD)	Post-cutback Withdrawal Rate (MGD)
Section 21	8.9	4.2

MGD = million gallons per day

Table 3. Resulting drawdown at Bird Lake from pre- and post-cutback withdrawal INTB simulations.

Well	Pre-Cutback Drawdown (feet) November 1988 to September 2004	Post-Cutback Drawdown (feet) October 2004 to December 2013
Floridan aquifer	4.2	2.4
Surficial aquifer	2.1	1.2

Use of the Bird Lake Water Budget and Line of Organic Correlation (LOC) Models

The Bird Lake Water Budget and LOC models were created as part of the development of the revised minimum levels for Bird Lake. The Bird Lake Water Budget model (McBride and Hancock, 2015) is a spreadsheet-based tool that includes natural hydrologic processes and engineered alterations acting on the control volume of the lake. The water budget model uses a daily time-step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels. The water budget model for Bird Lake was calibrated from November 1988 through 2013. This period provided the best balance between using available data for all parts of the water budget and the desire to model a long-term period. The calibrated model can be used to assess the effect of changes in the various water budget components on lake water levels.
The Bird Lake LOC model (McBride and Hancock, 2015) was developed to extend the period of record of the water levels produced by various simulations of the water budget model. The LOC model 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). An LOC model is a preferred method for developing long-term water level records, since it results in predictions that retain the variance (and therefore best retains the "character") of the original data. Through this process, rainfall is correlated with the water budget model results, and long-term lake levels were then estimated using long-term rainfall data. In this application, lake levels are simulated using rainfall data collected in the region back to 1946, allowing assessment of a relatively long period that takes into account lake level variability caused by a variation in rainfall conditions.

Bird Lake Status Assessment

First Approach

The first lake status assessment approach involved three steps, including: 1) adjusting the Upper Floridan and surficial aquifer levels in the Bird Lake Water Budget model to represent expected long-term post-cutback average wellfield withdrawal rates, 2) use of the LOC model to estimate lake levels associated with the withdrawal rates over a long period of time, and 3) development of a composite or “hybrid” long-term water level (i.e., stage) record based on output from the water budget and LOC models.

For the first step in the analysis, the water budget model was run for the November 1, 1988 to 2013 period based on drawdown in the Upper Floridan aquifer associated with the post-cutback wellfield withdrawal rates estimated with the INTB model. Because there is no active water use permit for augmentation permit for Bird Lake, the analysis was performed without the historic augmentation quantities. These interim results are provided in Table 4. Next, these results were correlated with rainfall through the LOC model to develop a 68-year stage record (1946 through 2013) to represent lake levels subjected to the post-cutback withdrawal rates. This analysis was done using the water budget model scenario without augmentation. The correlation lag-period with the best correlation coefficient was 2 years (the best correlation performed in the LOC developed to set the minimum levels was 2 years). The correlation coefficient for the 2-year lag was 0.80. Finally, to apply significant weight to the period of the water budget model results, the LOC lake stage values for the period of the water budget simulation were replaced with the results of the water budget simulation. The LOC rainfall model results were therefore used for the period from 1946 through October 31, 1988, while the water budget model results were used for the period from November 1, 1988 through 2013. The resulting composite lake stage series is referred to as the Bird Lake “hybrid” results. Lake stage exceedance percentiles calculated from these results are provided in Table 5. The results of this analysis are compared to the revised Minimum Levels for Bird Lake in Table 6.

Table 4. Lake stage exceedance percentiles for Bird Lake derived using the Bird Lake Water Budget Model. Percentiles include lake stage values equaled or exceeded ten (P10), fifty (P50) and ninety (P90) percent of the time.

Percentile	**Water Budget Model Post-Cutback Wellfield Withdrawal Scenario Results without Augmentation** Elevation in feet NGVD 29
P10	50.0
P50	48.2
P90	46.4

Table 5. Lake stage exceedance percentiles for Bird Lake based on the Bird Lake hybrid results.

Percentile	**Water Budget/LOC Model Hybrid Post-Cutback Wellfield Withdrawal Scenario Results without Augmentation** Elevation in feet NGVD 29
P10	49.9
P50	48.0
P90	46.4

Differences in exceedance percentiles presented in Tables 4 and 5 are likely attributable to differences in rainfall between the 1946-2013 period used to derive the Bird Lake hybrid model results and the November 1, 1988-2013 period used to develop the Bird Lake Water Budget model results.

Table 6. Comparison of hybrid lake stage exceedance percentiles from the models and the revised minimum levels for Bird Lake. Percentiles are described in Table 4.

Percentile	**Water Budget/LOC Model Hybrid Post-Cutback Wellfield Withdrawal Scenario Results without Augmentation** Elevation in feet NGVD 29	**Revised Minimum Levels** Elevation in feet NGVD 29
P10	49.9	50.0
P50	48.0	48.8

Second Approach

The second lake status assessment approach involved using actual lake stage data for Bird Lake from October 2004 through December 2013 (representing the period of wellfield cutbacks) to develop an LOC model, combining the LOC and lake stage data into a hybrid result, and comparing the hybrid results to the revised minimum levels. This analysis was intended for development of a long-term model (1946-2013) based on measured lake levels. The model was calibrated to the post-cutback period (2005-2013), which integrated effects of withdrawal rates that occurred during this period, rather than pre-cutback withdrawal rates, which were higher. Note also that any augmentation of the lake during this period would also be reflected in the lake data, but records show that the last *reported* augmentation was in June 1997, outside of the 2005-2013 period.

The best resulting correlation was for the 2-year weighted period, with a correlation coefficient of 0.63. As before, “hybrid” results were created by replacing the rainfall LOC results with the actual Bird Lake data for the period of October 2004 to December 2013. However, because the measured data was recorded on a monthly, rather than a daily basis, the calculated stage exceedance percentiles from the direct LOC results and the “hybrid” results were similar. The resulting stage exceedance percentiles are presented in Table 7.

Table 7. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC hybrid results and the revised minimum levels for Bird Lake.

Percentile	**Lake Stage/LOC Model Hybrid Post-Cutback Wellfield Withdrawal Scenario Results** Elevation in feet NGVD 29	**Revised Minimum Levels** Elevation in feet NGVD 29
P10	50.1	50.0
P50	48.5	48.8

Third Approach

The third approach involved a comparison of lake stage exceedance percentiles based directly on measured lake level data for Bird Lake for the period from October 2004 through December 2013 with the revised minimum levels. No models were used for this approach. A limitation of this analysis 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 2013 LOC model simulations. As with the second approach, the data would reflect any augmentation that had taken place, but as noted previously, there was no augmentation during this time period. Results for the third approach are presented in Table 8.

Table 8. Comparison of lake stage exceedance percentiles derived from measured water level records at Bird Lake from October 2004 through December 2013 (post cutback) and the revised minimum levels for the lake.

Percentile	**October 2004 to December 2013 Data** Elevation in feet NGVD 29	**Revised Minimum Levels** Elevation in feet NGVD 29
P10	50.0	50.0
P50	48.9	48.8

Discussion

Table 9 is a summary of the results of all three approaches.

Table 9. Comparison of lake stage exceedance percentiles derived from each approach compared to the revised minimum levels for the lake.

Percentile	**Approach 1[a]** Elevation in feet NGVD 29	**Approach 2[b]** Elevation in feet NGVD 29	**Approach 3[c]** Elevation in feet NGVD 29	**Revised Minimum Levels** Elevation in feet NGVD 29
P10	49.9	50.1	50.0	50.0
P50	48.0	48.5	48.9	48.8

[a] Water budget/LOC hybrid model post-cutback wellfield withdrawal scenario results
[b] Lake stage/LOC hybrid model results based on post-cutback data
[c] Measured lake stage results based on post-cutback data

A comparison of the water budget/LOC hybrid results (Approach 1) with the revised minimum levels for Bird Lake indicates that the hybrid long-term P10 without augmentation is 0.1 feet lower than the revised High Minimum Lake Level. The hybrid long-term P50 without augmentation is 0.8 feet lower than the revised Minimum Lake Level.

The P10 for the second MFL status assessment approach is 0.1 foot higher than the revised High Minimum Level, while the P50 is 0.3 feet lower than the revised Minimum Lake Level. The P10 and P50 for Approach 2 are higher than Approach 1.

The P10 elevation derived from the third approach was equal to the revised High Minimum Lake Level, and the P50 elevation was 0.1 feet higher than the revised Minimum Lake Level. Differences in rainfall between the shorter October 2004 to December 2013 period and the longer (1946 to 2013) period used for the LOC modeling analyses likely contribute to the differences in derived lake stage exceedance percentiles as compared to the first two approaches. Additionally, differences between actual withdrawal rates and those used in the models likely contributed to the differences. While the actual average withdrawals from the Section 21 Wellfield from October 2004 through December 2013 were approximately 3.0 mgd (compared to the 4.2 mgd used in the ITNB model), the average withdrawals from the Section 21 Wellfield for the past 5 years (2009 through 2013) were only 1.8 mgd.

E. Conclusions

Based on the information presented in this memorandum, it is concluded that Bird Lake water levels are currently below the revised Minimum Lake Level and revised High Minimum Lake Level for the lake. These conclusions are supported by comparison of long-term modeled lake stage exceedance percentiles with the revised minimum levels. The modeling analyses were based on expected post-cutback withdrawal rates from the Central System Facilities. Other analyses presented show that if more recent low withdrawal rates continue, the revised Minimum Level for the lake may be met.

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, Bird 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 analyses outlined in this document for Bird 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 Bird 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 if Bird 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.

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Appendix C
Technical Memorandum

July 7, 2015

TO: Keith Kolasa, Senior Environmental Scientist, Resource Evaluation Section

FROM: Jason Patterson, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Bird Lake

1.0 Introduction

Bird Lake is located in northwest Hillsborough County in west-central Florida (Figure 1). Prior to establishment of a Minimum Level (ML), an evaluation of hydrologic changes in the vicinity of the lake is necessary to determine if the water body has been significantly impacted by groundwater withdrawals. The establishment of the ML for Bird 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 (Miller, 1986).

3.0 Evaluation of Groundwater Withdrawal Impacts to Bird Lake

A number of regional groundwater flow models have included the area around Bird 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).

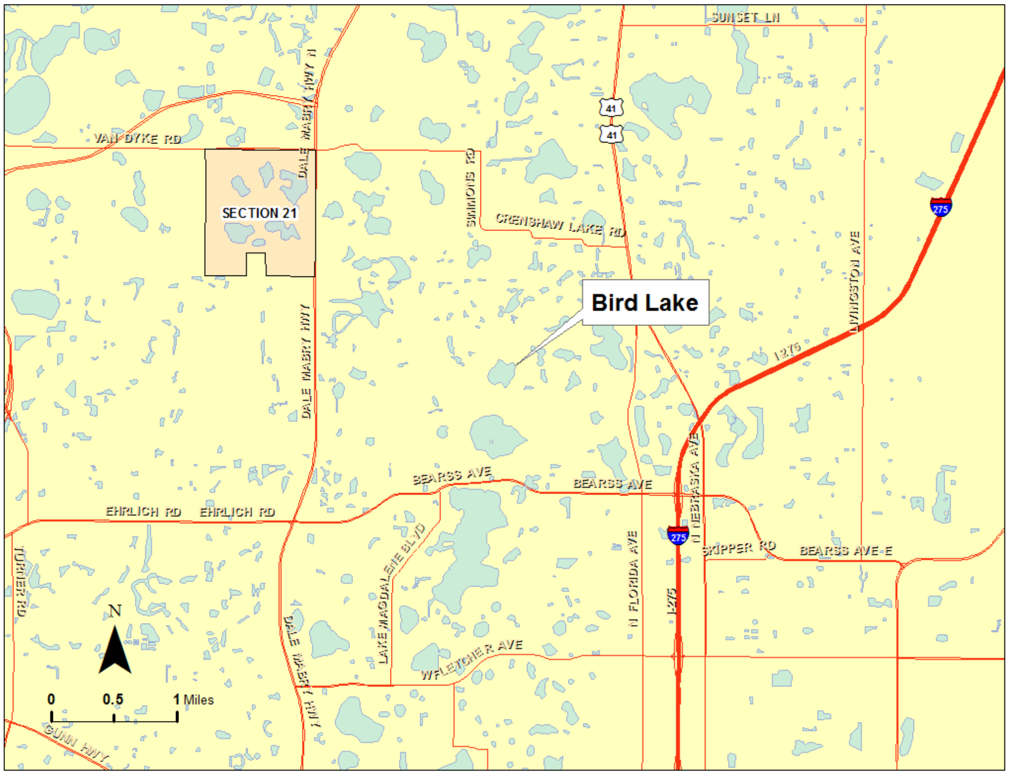

Figure 8. Location of Bird Lake.

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.

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 from

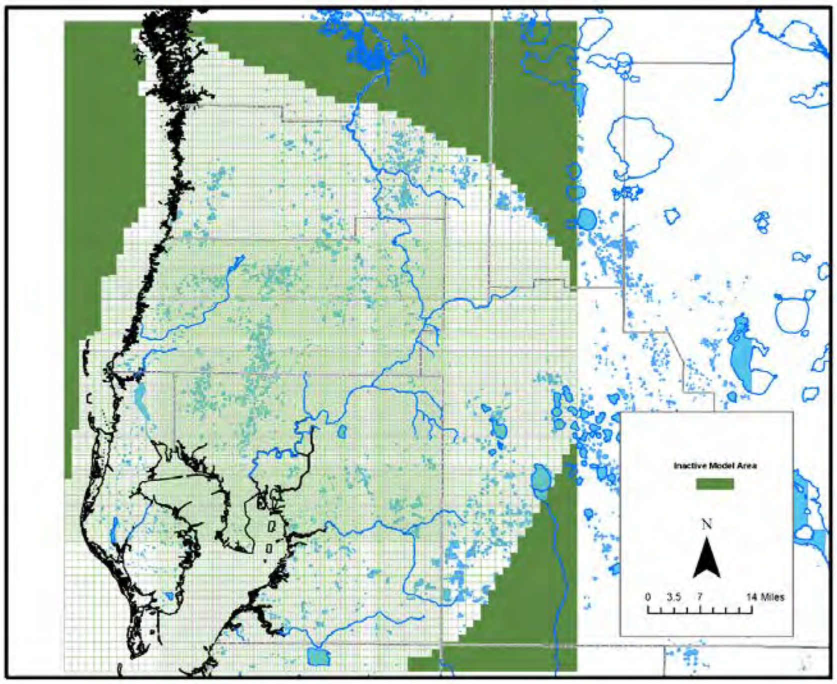

Figure 2. Groundwater grid used in the INTB model

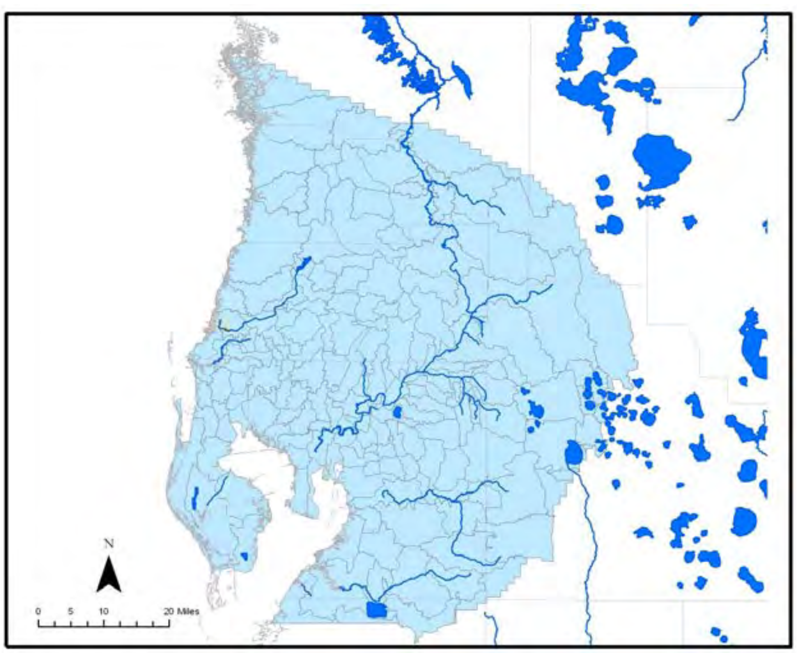

Figure 3. HSPF subbasins in the INTB model.

major rivers to small isolated wetlands, and GIS-based definition of land cover/topography. An empirical estimation of ET was also developed to constrain model derived ET based on land use and depth-to-water table relationships.

The MODFLOW gridded domain of the INTB contains 207 rows by 183 columns of variable spacing ranging from 0.25 to one mile. The groundwater portion is comprised of three layers: a surficial aquifer (layer 1), an intermediate confining unit or aquifer (layer 2), and the Upper Floridan aquifer (layer 3). The model simulates leakage between layers in a quasi-3D manner through a leakance coefficient term.

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 has recently been added. Model-wide mean error for all wells in both the surficial and Upper Floridan aquifers is less than 0.2 feet during both the calibration and verification periods. Mean absolute error was less than two feet for both the surficial and Upper Floridan aquifer. Total stream flow and spring flow mean error averaged for the model domain is each less than 10 percent. More information summarizing the INTB model calibration can be found in Geurink and Basso (2012).

3.1 INTB Model Scenarios

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

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Bird Lake was 2.6 ft. and 4.6 ft. in the Upper Floridan (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 Bird Lake was 1.3 ft. and 2.5 ft. in the Upper Floridan aquifer (Figure 6 and 7). Table 1 presents the predicted drawdown in the surficial aquifer based on the INTB model results.

Table 1. INTB model results for Bird 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***
Bird	2.6	1.3
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***
Bird	4.6	2.5

* Average drawdown from model cells intersecting lake

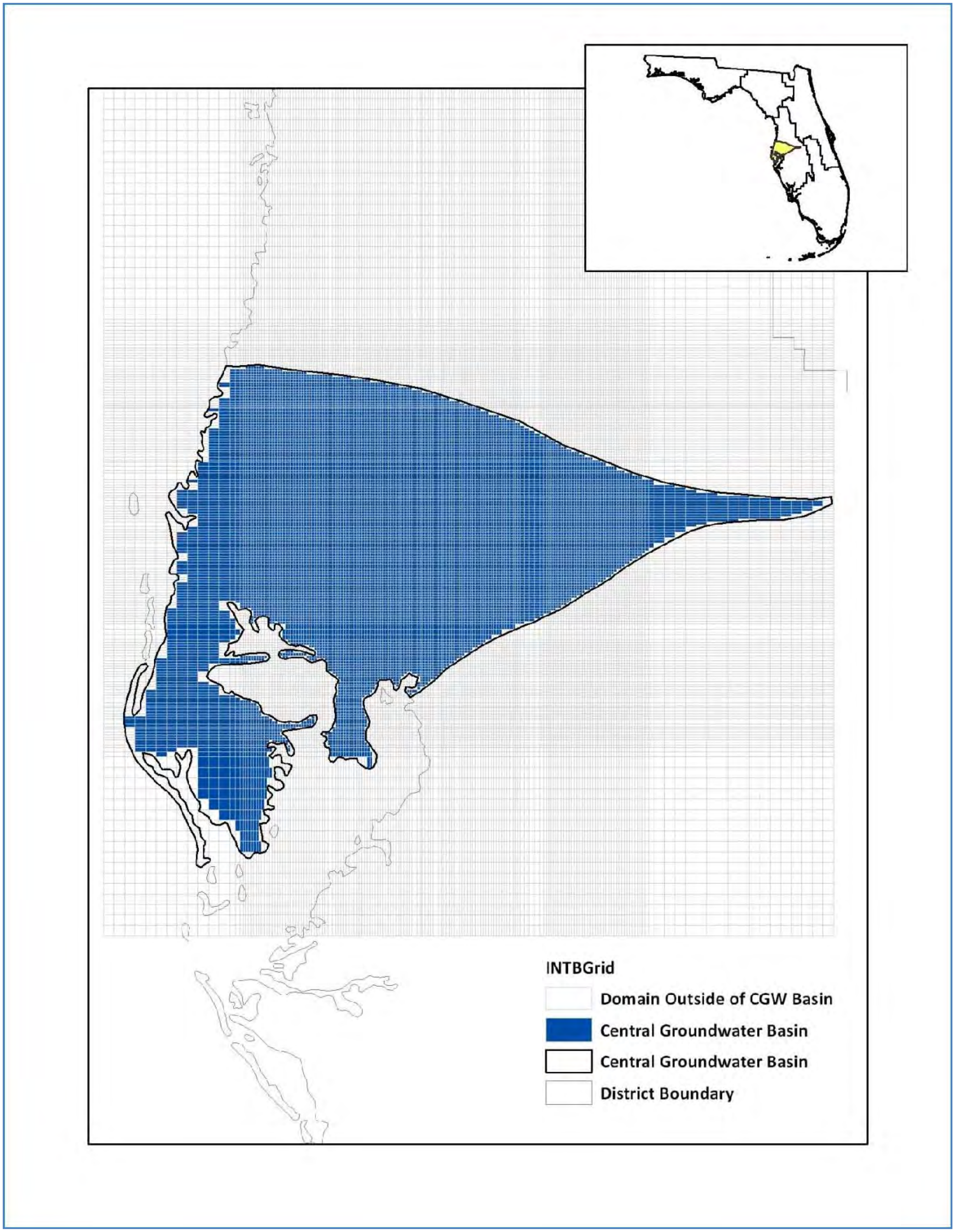

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

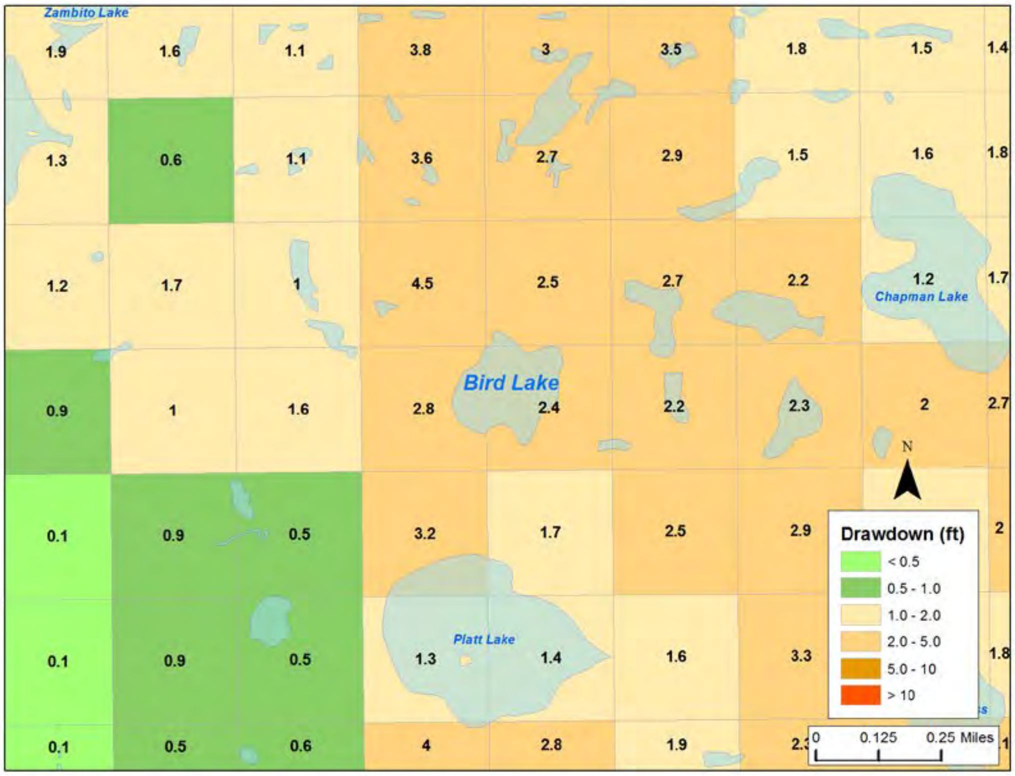

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

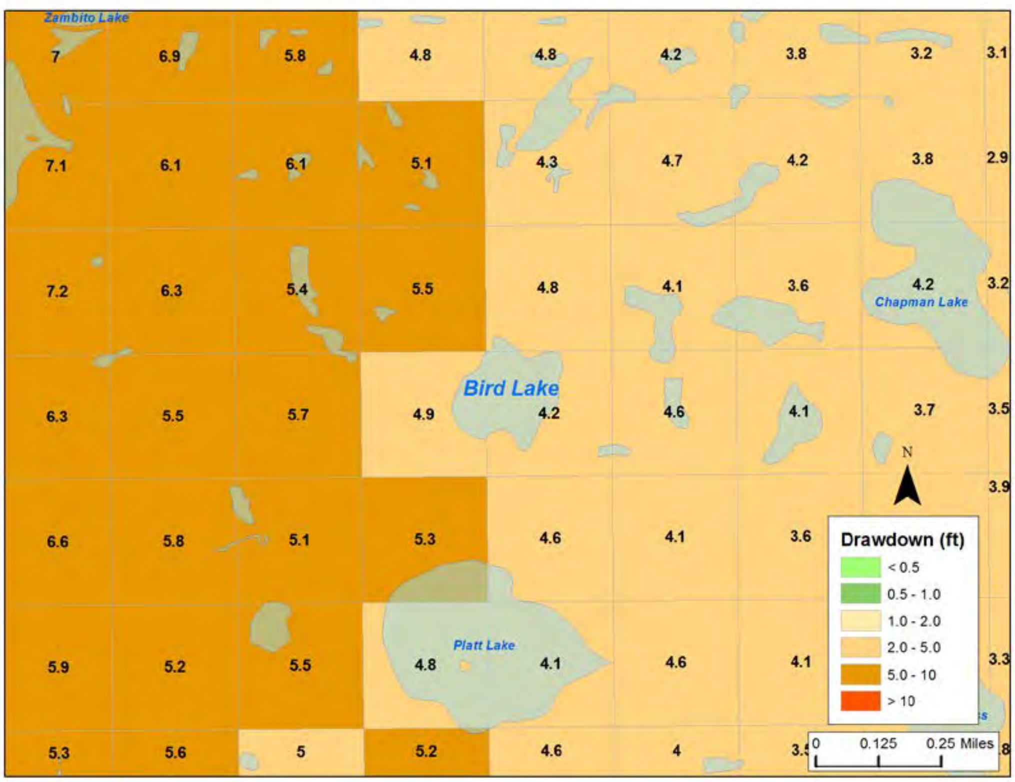

Figure 5. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

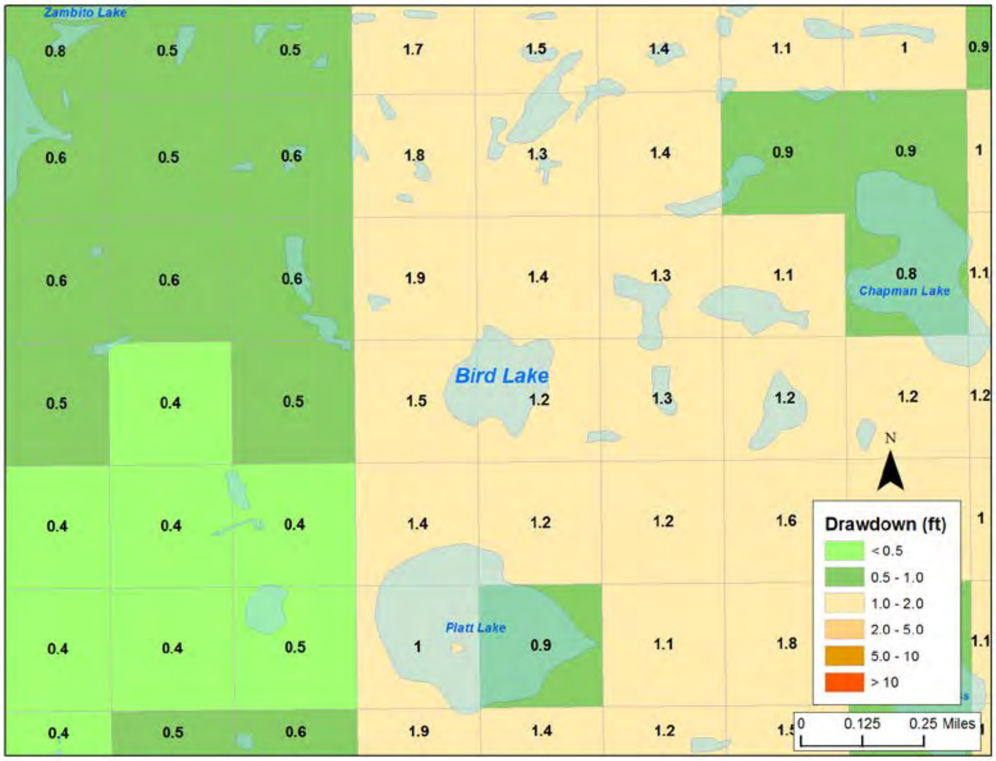

Figure 6. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

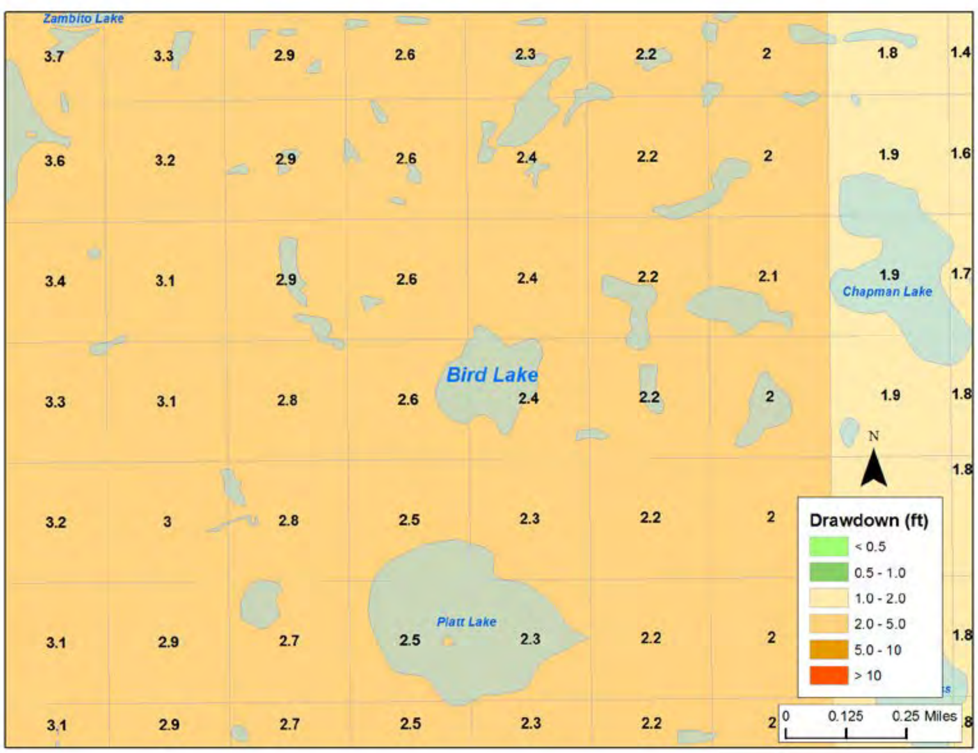

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

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