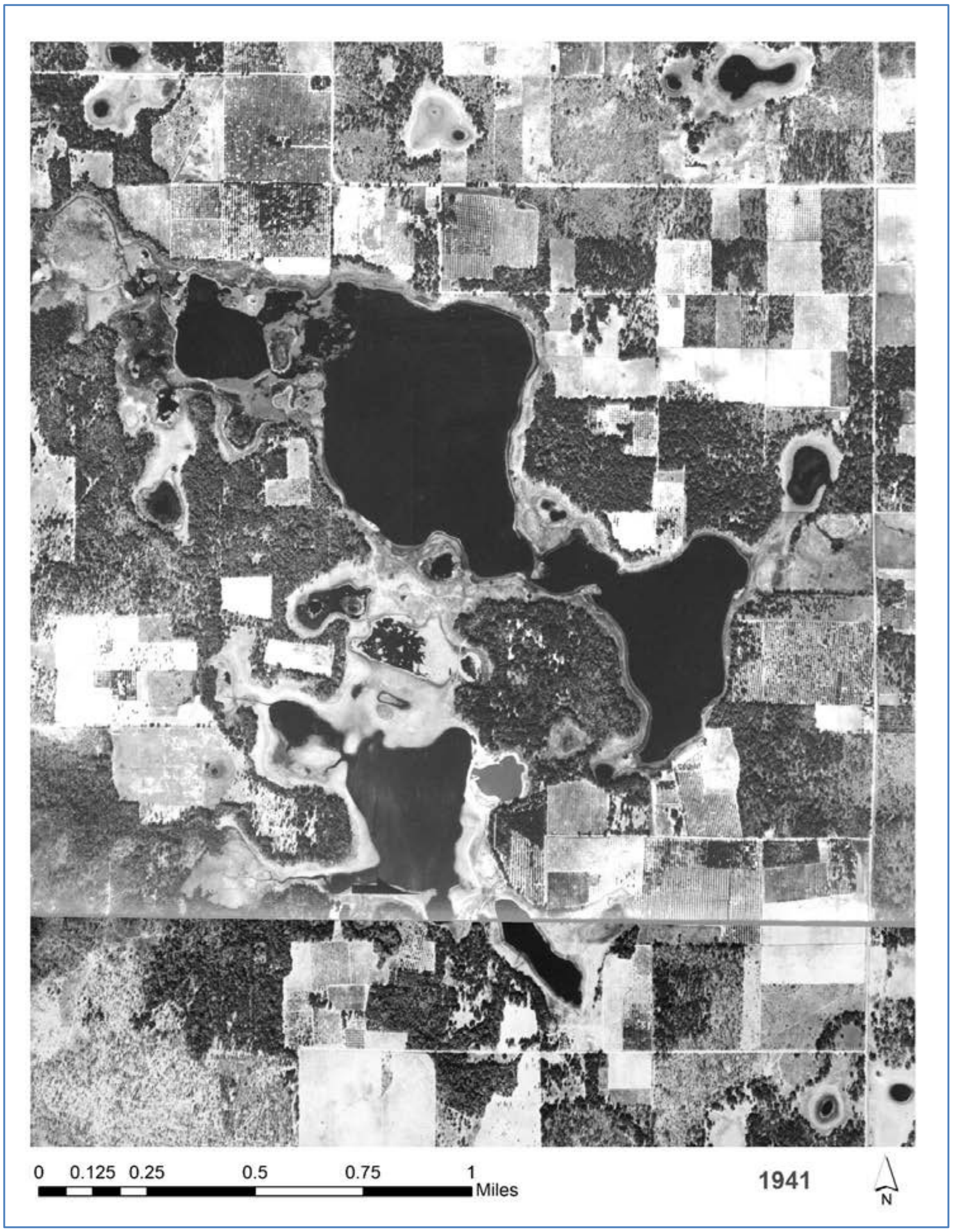
Revised Minimum and Guidance Levels for Lakes Buddy and Pasadena in Pasco County, Florida



January 16, 2018

Resource Evaluation Section
Water Resources Bureau

Southwest Florida Water Management District

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Executive Summary

This report describes the development of Minimum and Guidance levels for Lakes Buddy and Pasadena in Pasco County, Florida based on reevaluation of levels in Southwest Florida Water Management District rules that became effective in February 2017. 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.). Minimum levels are used to support water resource planning and permitting activities. 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. Lakes Buddy and Pasadena were 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 these 2 lakes were developed using current District methods for establishing minimum levels for Category 3 Lakes. The proposed 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 proposed 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 revised 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 currently adopted Guidance and Minimum Levels for Lakes Buddy and Pasadena was recommended. Subsequently, the District Governing Board approved the revised Minimum and Guidance Levels identified in this report and replaced the previously adopted levels for the lake included in District rules.

Based on available measured and modeled water level records, the revised minimum levels for Lakes Buddy and Pasadena are being met. If levels are not met in the future 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.

Table ES-1. Revised Minimum and Guidance Levels for Lakes Buddy and Pasadena and level descriptions.

Minimum and Guidance Levels	Elevation (feet above NGVD29)	Level Descriptions
High Guidance Level	93.3	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	92.5	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	87.6	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	85.0	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.

	High Guidance Level	High Minimum Level	Minimum Lake Level	Low Guidance Level
NGVD 29[a]	93.3	92.5	87.6	85.0
NAVD 88[b]	92.4	91.6	86.7	84.1

[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 Lakes Buddy and Pasadena in Pasco 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 April 2004 (see Southwest Florida Water Management District 1999) and adopted into District rules with an effective date of December 2004. The revised minimum and guidance levels represent needed revisions to the currently adopted levels.

These two connected lakes were 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 "the 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 "if the existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level established pursuant to S. 373.042." Section 373.0421(2)(a), F.S., requires that recovery or prevention strategies be developed to: "(a) achieve recovery to the established minimum flow or level as soon as practicable; or (b) prevent 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 "minimum 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 373.86 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 Lake Pasadena and Buddy 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).

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

Consideration of Changes and Structural Alterations and Environmental Values

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

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

- adjust measured flow or water level historical records to account for existing changes/alterations;
- model or simulate flow or water level records that reflect long-term conditions that would be expected based on existing changes/alterations and in the absence of measurable withdrawal impacts;
- develop or identify significant harm standards, thresholds and other criteria;
- aid in the characterization or classification of lake types or classes based on the changes/alterations;
- 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 Lakes Buddy and Pasadena 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 - Not applicable for consideration for most priority lakes
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 - 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
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

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. The datum shift from NAVD88 to NGVD29 (see Table ES -1 and Table 7) was determined by actual surveys in the field at the location of the lake level gauge and was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum on 1988. The shift or conversion determined for Lakes Buddy and Pasadena was 0.87 ft.

Data and Analyses Supporting Development of Minimum and Guidance Levels

Lake Setting and Description

Lakes Buddy and Pasadena are located (Figure 1) in Pasco County, Florida (Sections 8, 9, 16 and 17 Township 25 South, Range 21 East) in the Hillsborough River Basin of the Southwest Florida Water Management District (Figure 1). The area surrounding the lakes is categorized as the Dade City Hills subdivision of the Ocala Uplift Physiographic District (Brooks 1981). The subdivision is a region of internally drained, high sand hills (Brooks 1981). As part of the Florida Department of Environmental Protection’s Lake Bioassessment/Regionalization Initiative, the area has been identified as the Southern

Brooksville Ridge lake region and described as an area of neutral to alkaline, mesotrophic or meso-eutrophic lakes (Griffith *et al.* 1997).

Uplands adjacent to Lake Pasadena and Buddy Lake have, for the most part, been cleared of native vegetation and are used for residential development, citrus production, or livestock grazing (Figure 2). Public access to the lake is available at a private boat ramp site located on the north shore of Lake Pasadena.

Lake Pasadena and Lake Buddy are identified as internally drained by the U.S. Geological Survey, and collectively have a drainage area of 4.6 square miles (SWFWMD 1996). There are no major inlets to the lakes, although the greater lake basin, which contains both lakes, includes areas north of Clinton Avenue (County Road 52A) and west of that may drain to Lake Pasadena (Figure 2). Extensive wetland areas occur throughout the basin, including the region between Lake Pasadena and Buddy Lake. Although Lake Pasadena and Buddy Lake basin does not contain cypress-dominated wetlands the basin does include extensive marsh and littoral wetland areas. These are dominated by maidencane (*Panicum hemitomon*), torpedo grass (*Panicum repens*), cattail (*Typha* sp.), spatterdock (*Nuphar luteum*), smartweed (*Polygynum* sp.), water lily (Nymphaea sp.), water pennywort (*Hydrocotyle* sp.), pickerelweed (*Pontederia cordata*), primrose willow (*Ludwigia* sp), and willow (*Salix* sp.) occur throughout the basin.

This inter-lake wetland area is inundated when the water surface in the basin exceeds 91-92 ft. above the National Geodetic Vertical Datum of 1929 (NGVD). A shallow ditch breaches the remains of a low-lying berm that bisects the inter-lake wetland area. Although the lakes are typically internally drained, surface outflow from the southeast corner of Buddy Lake may occur when water level in the lake system exceeds 99.9 ft. above NGVD. Anecdotal accounts indicate that this last occurred in 1960.

The United States Geological Survey (USGS) 1960 1:24,000, 7.5 Minute Series (Topographic) Dade City Quadrangle map shows a lake surface elevation of 93 ft. above NGVD for both Lake Pasadena and Buddy Lake. The "Gazetteer of Florida Lakes" (Florida Board of Conservation 1969, Shafer *et al.* 1986) lists areas of 373 acres and 90 acres for Lake Pasadena and Lake Buddy, respectively, at an elevation of 93 ft. above mean sea level. Based on a topographic map of the basin generated in support of minimum levels development (Figure 3), the lakes have a combined surface area of 764 acres at an elevation of 93 ft. above NGVD. Data used for production of the topographic map were obtained from both field surveys of the lake bottom conducted in 2003, and LiDAR land surface elevation data collected in 2004.

Currently, there are no surface water withdrawal from the lake system permitted by the District; however, there are also numerous ground water withdrawals in the region (Figure 4). Monthly average water withdrawals from 1992 – 2012 within a two-mile radius were 1.6 million gallons per day gallons, and within a three-mile radius were 3.6 million gallons per day (mgd) (Figure 4) (Appendix C).

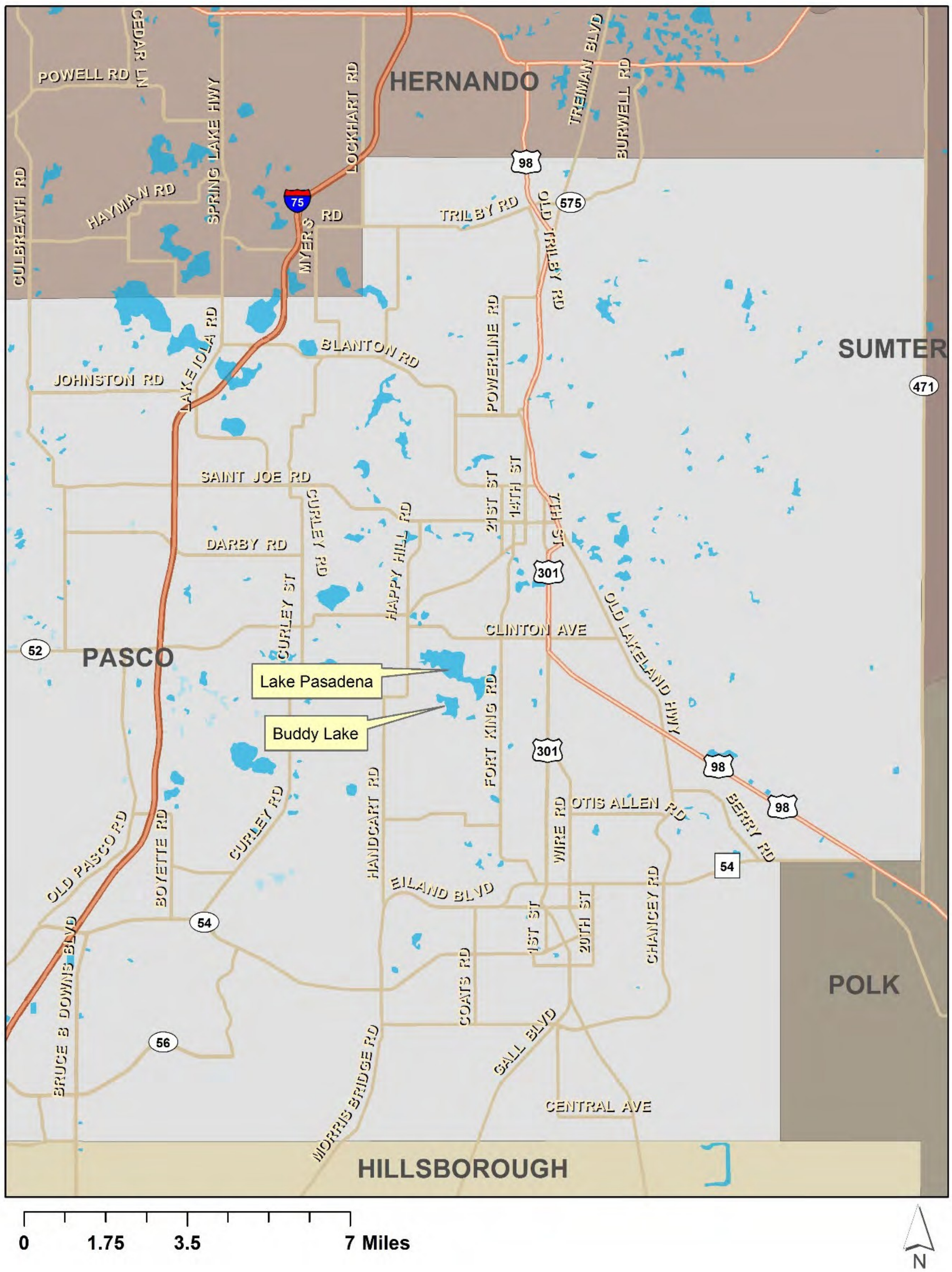


Figure 1. Location of Lakes Buddy and Pasadena in Pasco County, Florida

Figure 2. Location of water level gage, drainage conveyance (inlet and outlet), and connection between lake basins.

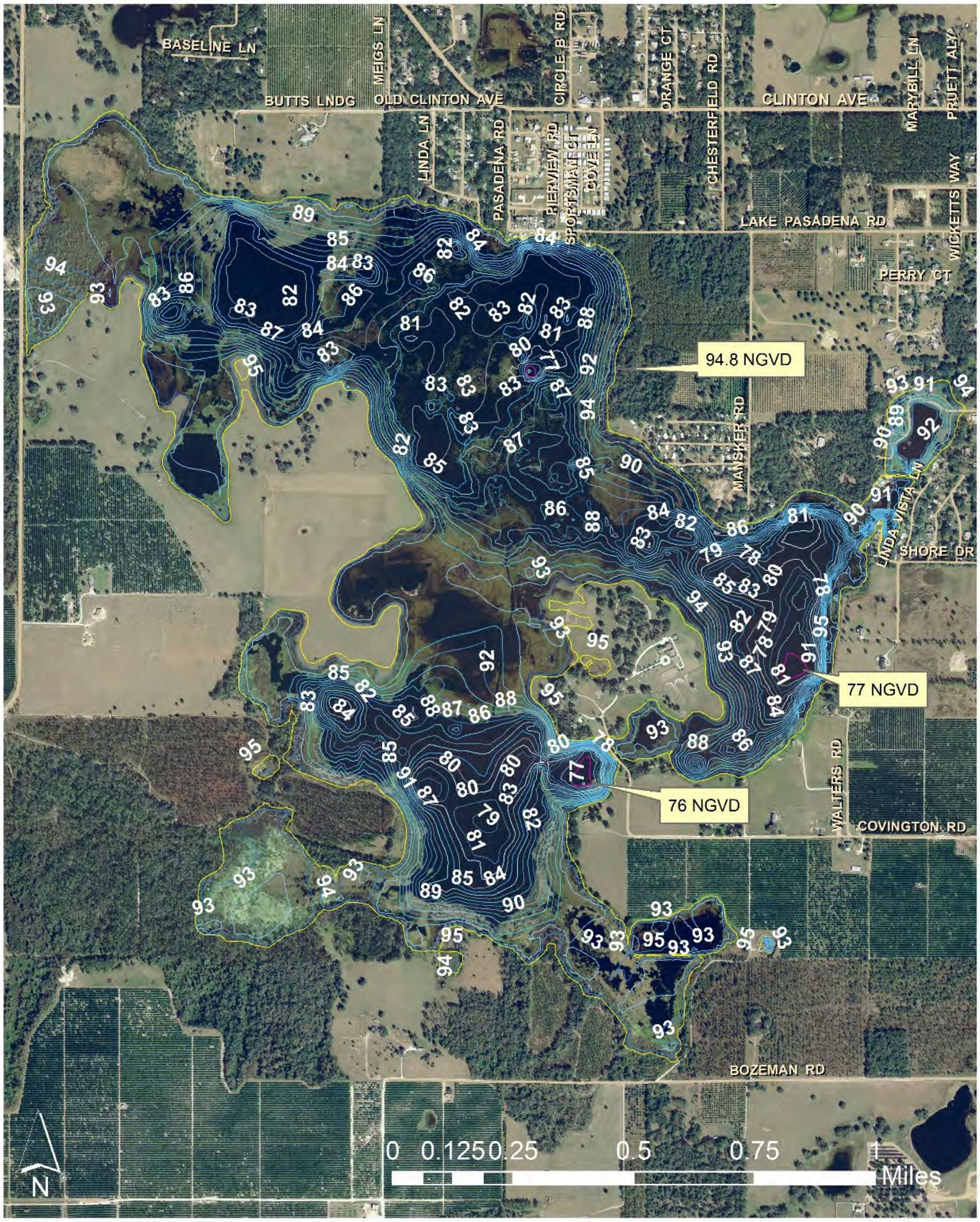


Figure 3. One-foot contour lines within the Lake Pasadena and Buddy Lake basins in Pasco County, Florida with elevations of deepest locations and lake basin perimeter noted.

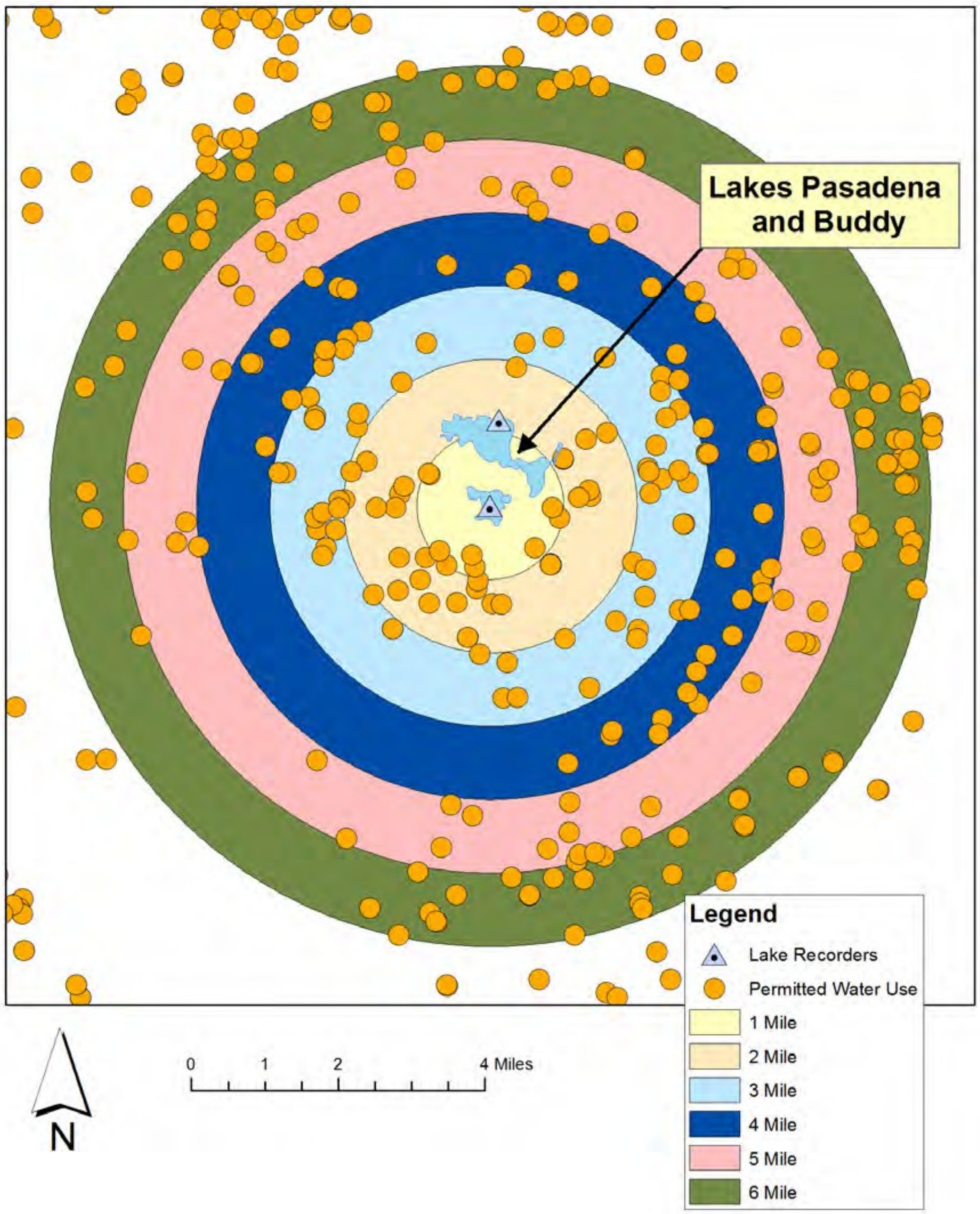


Figure 4. Permitted groundwater withdrawals within a one-six mile radius of Lakes Buddy and Pasadena.

Previously Adopted Minimum and 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 Lakes Buddy and Pasadena, had adopted into the District's Water Levels and Rates of Flow Rules (SWFWMD 1996a).

Based on work conducted in the 1980s (see SWFWMD 1996a), the District adopted management levels, including minimum and flood levels, for Lakes Buddy and Pasadena in November 1989 (Table 2) and incorporated the levels into its Water Levels and Rates of Flow Rules (Chapter 40D-8, F.A.C.). As part of the work leading to the adoption of management levels, a Maximum Desirable Level of 94.00 feet above mean sea level was also developed for the lake, but was not adopted by rule.

Based on changes to sections of the Florida Statutes that address minimum flows and levels in 1996 and 1997, and the development of new approaches for establishing MFLs, District Water Levels and Rates of Flow rules were modified in 2004. The modifications included incorporation of rule language addressing MFLs development and the renaming of established levels as Guidance Levels, as indicated for Lakes Buddy and Pasadena in Table 2. Subsequent revisions to District rules incorporated additional rule language associated with developing minimum lake levels.

Based on the approaches for establishing MFLs developed in the late 1990s and early 2000s, the District adopted recommended Guidance and Minimum Levels for Lakes Buddy and Pasadena (Leeper 2003) into its Water Levels and Rates of Flow rules in September 2004 (Table 3), and removed the previously adopted management levels for the lake from District rules. A Ten-Year Flood Guidance Level of 97.2 ft. above NGVD that was adopted for the lake along with the other levels in September 2004 was subsequently removed from Chapter 40D-8, F.A.C., in 2007, when the Governing Board determined that flood-stage elevations should not be included in the District's Water Levels and Rates of Flow rules.

The previously adopted Minimum and Guidance Levels for Lakes Buddy and Pasadena (Table 3) 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 revised Minimum and Guidance Levels developed using current methods replaced existing levels into Chapter 40D-8, F.A.C.

Ongoing development of methods for establishing MFLs has led the District to develop revised Minimum and Guidance Levels for these two lakes, as outlined in this report. Because the previously adopted Minimum and Guidance Levels were developed using methods that differ from those now in use, they do not necessarily correspond with the revised levels presented in this report.

Table 2. Initial adopted management and Guidance Levels for Lakes Buddy and Pasadena.

Management Levels (as originally adopted)	Guidance Levels [a]	Elevation (feet above Mean Sea Level)
Ten (10) Year Flood Warning Level	Ten Year Flood Guidance Level	97.2
Minimum Flood Level	High Level	94.5
Minimum Low Management Level	Low Level	91.5
Minimum Extreme Low Management Level	Extreme Low Level	90.0

[a] Adopted management levels within District rules were renamed as Guidance Levels in 2000.

Table 3. Previously Adopted Minimum and Guidance Levels for Lakes Buddy and Pasadena as listed in Table 8-2 of subsection 40D-8.624, F.A.C.

Minimum and Guidance Levels	Elevation in Feet NGVD 29
High Guidance Level	93.7
High Minimum Level	93.7
Minimum Level	87.3
Low Guidance Level	83.9

Methods, Results, and Discussion

Summary Data Used for Revised Minimum and Guidance Levels Development

Revised Minimum and Guidance Levels for Buddy Lake and Lake Pasadena were developed using the methodology for Category 3 Lakes described in Rule 40D-8.624, F.A.C. Revised 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.

Table 4. Revised Minimum and Guidance Levels, lake stage exceedance percentiles, normal pool, control point, significant change standards and associated surface areas for Lakes Buddy and Pasadena.

Levels	**Elevation in Feet NGVD 29**	**Lake Area (acres)**
Lake Stage Percentiles		
Current P10 (1984 to 2015)	93.6	827
Current P50 (1984 to 2015)	87.4	375
Current P90 (1984 to 2015)	84.0	228
Historic P10 (1946 to 2015)	93.3	796
Historic P50 (1946 to 2015)	88.4	413
Historic P90 (1946 to 2015)	85.0	270
Normal Pool and Control Point		
Low Road	99.9	NA
Low Floor Slab	96.4	1009
Normal Pool	NA	NA
Control Point	NA	NA
Significant Change Standards		
Basin Connectivity Standard	96.4	1009
Dock-Use Standard	94.4	887
Wetland Offset Elevation	87.6	383
Species Richness Standard	86.8	351
Aesthetics Standard	85.0	270
Lake Mixing Standard	NA	NA
Recreation/Ski Standard	NA	NA
Minimum and Guidance Levels		
High Guidance Level	93.3	796
High Minimum Lake Level	92.5	613
Minimum Lake Level	87.6	383
Low Guidance Level	85.0	270

Bathymetry

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

Stage-area-volume relationships were determined for the combined lake basins by building and processing a digital elevation model (DEM) of the lake basin and surrounding watershed. Lake bottom elevations and land surface elevations were used to build the model through a series of analyses using LP360 (by QCoherent) for ArcGIS, ESRI® ArcMap 10.2.2 software, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basin with the lake basin morphology to develop one continuous 3D digital elevation model. The 3D digital elevation model is then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the largest size of the lake at its peak or flood stage, and working downward to the base elevation (deepest pools in the lake).

Two elevation data sets were used to develop the terrain model for Lakes Buddy and Pasadena. Light Detection and Ranging Data (LiDAR) was processed with LP360 for ArcGIS and merged with bathymetric data collected with both sonar and mechanical (manual methods). Manual methods involved surveying the elevation through standard methods using a known nearby benchmark elevation. Sonar lake bottom elevations were determined using a Lowrance LMS-350A sonar-based depth finder equipped with a LEI HS-WSPK transducer (operating frequency = 192kHz, cone angle = 20) mounted to a boat hull, and integrated with a Trimble GPS Pathfinder Pro XR/Mapping System (Pro XR GPS Receiver, Integrated GPS/MSK Beacon Antenna, TDC1 Asset Surveyor and Pathfinder Office software).

The DEM created from the combined elevation data sets was used to develop topographic contours of the lake basin (Figure 3) and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments (selected stage-area-volume results are presented in Figure 10).

Lake Stage Data and Development of Exceedance Percentiles

Period of record (POR) lake stage data, *i.e.,* surface water elevations for Lakes Buddy and Pasadena relative to NGVD 29 were obtained from the District's Water Management Information System (WMIS) data base, Site Identification (SID) number 18867 (Figure 2). Surface water level data have been recorded since February 1984 (Figure 5). Data through 2015 were used for modeling analyses.

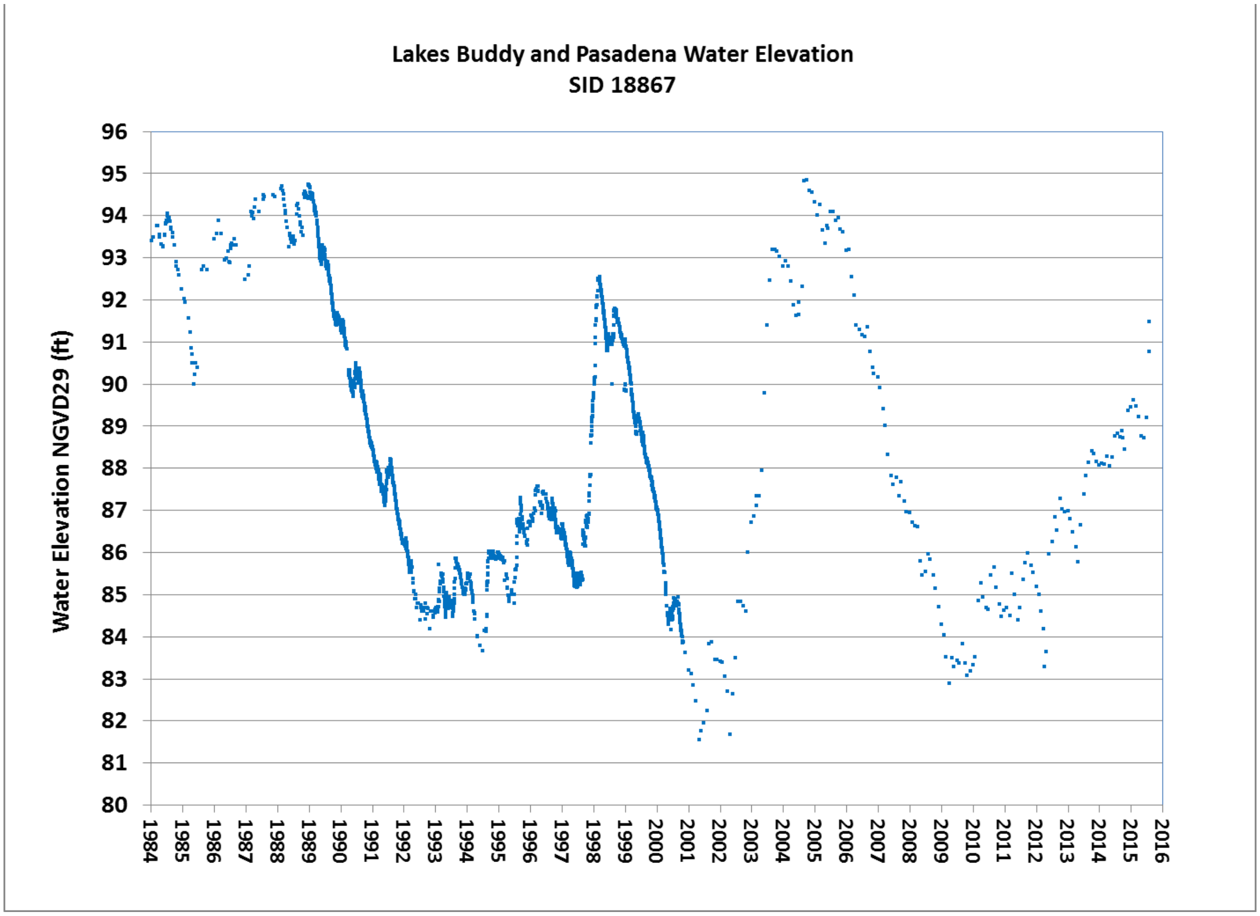


Figure 5. Water level data for Lakes Buddy and Pasadena – 1984 through 2015.

The period of record (POR) high water level was 94.86 ft. (NGVD 29) as observed in October 2004 during the 2004 hurricane season. Similarly, the lake level reached 94.72 ft. in January 1989. The POR low water level was 81.56 NGVD 29, as observed in May 18, 2001. The approximate contour lines of the POR high is shown in Figure 6.

For 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 are representative of the current situation.

A Long-term Historic lake stage record is critical for establishing Minimum and Guidance Levels. Although the original MFL developed for Lakes Buddy and Pasadena (Leeper 2004) classified the entire period of record lake stage data as Historic, specific information was not available at that time regarding the estimated drawdown in the surficial and Upper Floridan aquifer in response to groundwater withdrawals near Lakes Buddy and Pasadena. This information is now available using the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013) with the results of the model showing an average predicted drawdown of 0.0 ft. in the surficial aquifer near these lake basins from 1989-2000 and 0.0 ft. from 2000 forward (Patterson 2014), indicating no measurable impacts due to regional groundwater withdrawals.

Although the period of record of lake stage data (1984 to 2015) for Lakes Buddy and Pasadena could be classified as the Historic data, it was determined that a longer period would better characterize historic water level fluctuation within the basin. A longer period was developed by using a predictive lake stage model in this case the Rainfall Line of Organic Correlation (LOC) (Ellison 2012). The method relates local rain gage data to historic lake stage data to produce a regression model that predicts lake stage based on past rainfall amounts. The procedure uses a linear inverse time weighted rainfall sums to establish the relationship. Models produced with this method are extended back in time to 1946 to produce a 60-year non-impacted lake stage record that serves as the basis for establishing historic lake-stage exceedance percentiles. A sixty-year period was considered sufficient for incorporating the range of lake stage fluctuations that would be expected based on long-term climatic cycles that have been shown to be associated with changes in regional hydrology (Enfield et al. 2001, Basso and Schultz 2003).

The development of the rainfall correlation model involved an inventory of rainfall stations sorted by distance to Lakes Buddy and Pasadena and by period of record. A description of model methods including the specific rainfall gauges selected is provided by Ellison (2015). The resulting lake level rainfall model had a correlation coefficient of determination (r^2) equal to 0.93 based on use of a six-year linear decay series of daily rainfall values. A comparison of the modeled lake stage (1946 to 2015) to the observed lake stage (1984 to 2015) is shown in Figure 7.

The modeled Historic lake stage record was used to calculate Historic P10, P50, and P90 lake stage exceedance percentile elevations (Figure 8, Table 4). The Historic P10 elevation, the elevation the lake water surface equaled or exceeded ten percent of the time during the Historic period based was 93.3 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 88.4 ft. The Historic P90 elevation, the elevation the lake water surface equaled or exceeded 90 percent of the time during the Historic period was 85.0 ft.

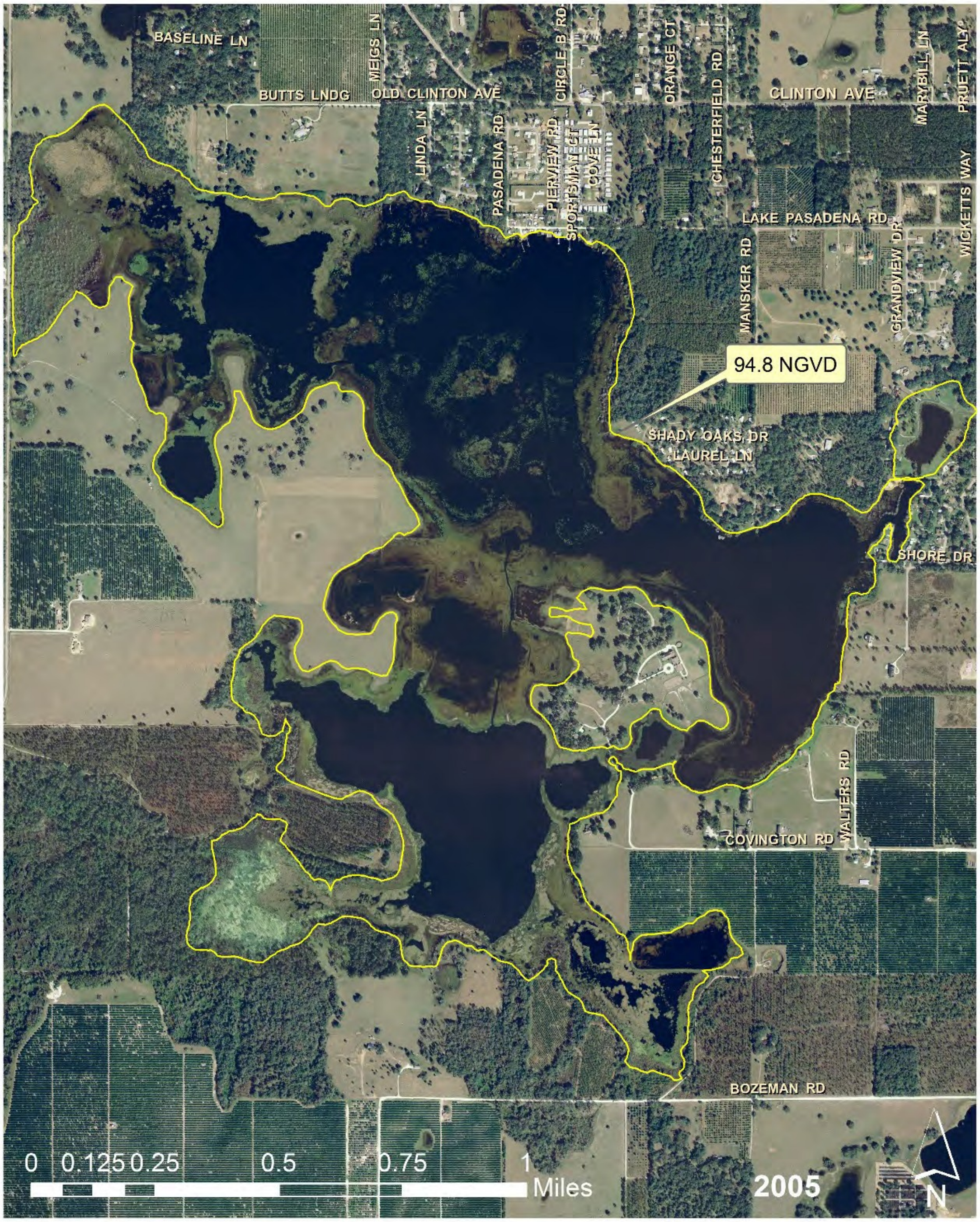


Figure 6. Approximate contour of the POR high level recorded for Lakes Buddy and Pasadena imposed on 2005 (February) aerial imagery. The high level of 94.86 NGVD 29 was recorded on October 25, 2004. The lowest level recorded was (81.56 NGVD 29).

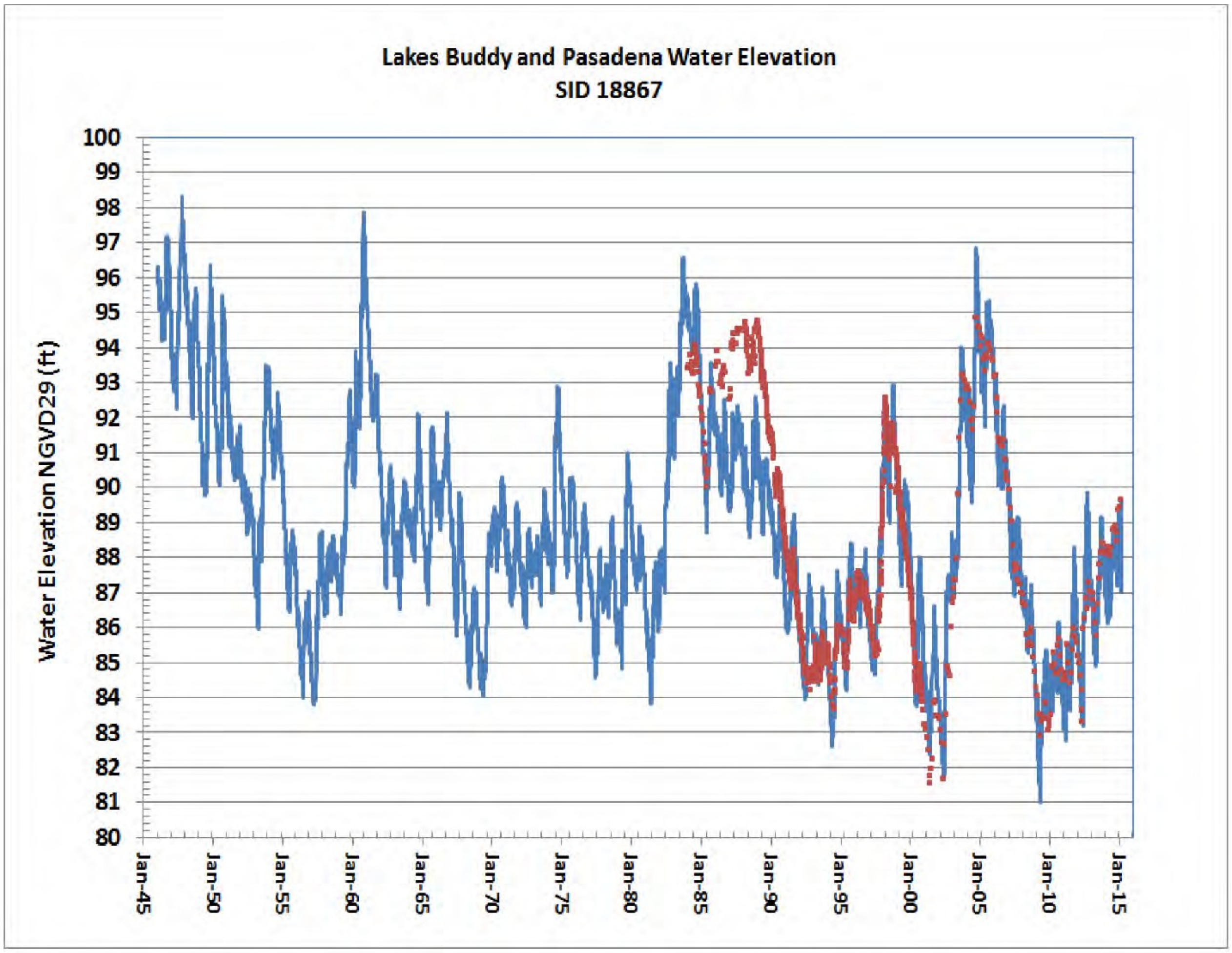


Figure 7. Observed and predicted long-term Historic water levels at Lakes Buddy and Pasadena for a calibration period from November 1988-December 2013 (water budget model period).

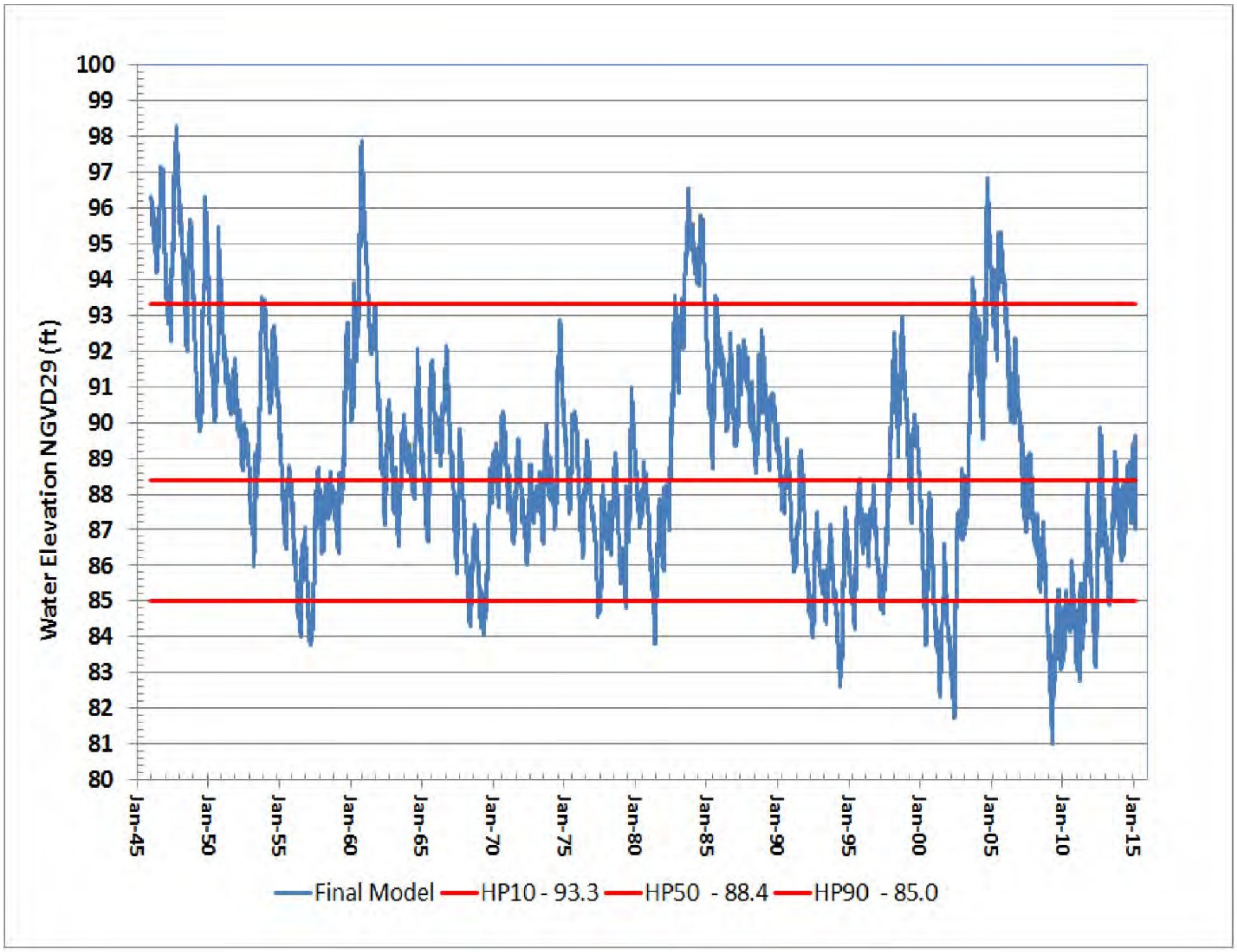


Figure 8. Historic water levels (hybrid results) used to calculate percentile elevations for Lakes Buddy and Pasadena. Historic P10, P50, and P90 are depicted as horizontal lines.

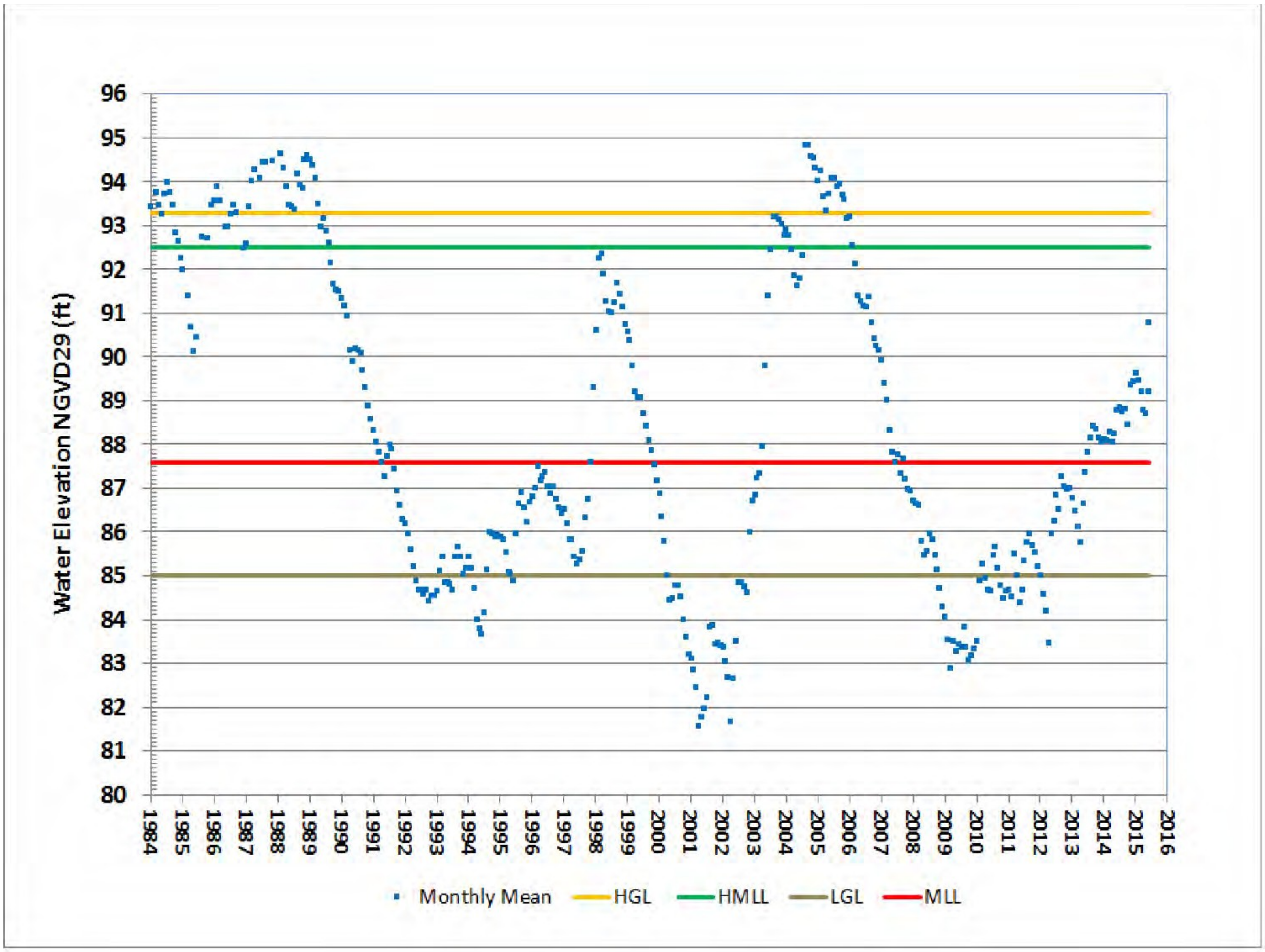


Figure 9. Observed monthly water levels and revised Minimum and Guidance Levels for Lakes Buddy and Pasadena. Revised levels include the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL), and the Low Guidance Level (LGL).

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. A Normal Pool elevation (Table 3) was not established for Lake Pasadena or Buddy Lake. Reliable Hydrologic Indicators of high water levels were not observed. Citrus trees were planted at relatively low elevations within the basins, although not as low as the lowest floor slab. Based on available lake-stage data, the Florida Department of Environmental Protection has recommended that an elevation of

93.5 ft. above NGVD may be used as a provisional approximation of the ordinary high water line for Lake Pasadena (Maddox 1997).

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. Because Lake Pasadena and Buddy Lake are typically internally drained, a control point elevation was not established for the lake system. A low spot along Bozeman Road, at an elevation of 99.9 ft. above NGVD, was identified as a potential high-stage discharge site for the lake system (see Figure 2). Because the lake basins are internally drained these lakes are not considered to be structurally altered.

Revised 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 Lake Pasadena and Buddy Lake is established at **93.3 ft.** (Figure 9 and 12, Table 4). The lowest residential floor slab within the immediate lake basin (96.4 ft.) is 3.1 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 is established at **85.0 ft**. (Figure 9 and 12, Table 4).

Lake Classification

Lakes are classified as Category 1, 2, or 3 for Minimum Levels development. Systems with fringing cypress wetlands greater than 0.5 acres in size are classified as either as Category 1 or 2 lakes as described in Rule 40D-8.624, F.A.C. 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 absence of lake-fringing cypress wetlands of 0.5 acre or more in size within the lake basin, Lake Pasadena and Buddy Lake are classified as a Category 3 lakes.

Significant Change Standards and Other Information for Consideration

Lake-specific significant change standards and other available information are considered for establishing minimum levels for Category 3 Lakes. 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.

Seven 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, a Lake Mixing Standard, and a Wetland Offset Standard are developed. These standards identify desired median lake stages that if achieved, are intended to preserve various environmental values (see Table 1).

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. The Basin Connectivity Standard was established at 96.4 ft., based on the elevation that ensures connectivity between Lake Pasadena and Buddy Lake (91.0 ft. above NGVD), a 2-ft clearance values for use of powerboats on the lake, and the difference between the Historic P50 and Historic P90 elevations (3.4 ft.). Based on the Historic water level record for the lake, the standard was equaled or exceeded 1.2 percent of the time. The elevation exceeds the highest lake elevation recorded for the lake during the period of record (1984-2015) and is not applicable as a management level since it is equivalent to the elevation of the low slab.

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 was established at 94.4 ft. above NGVD, based on the elevation of sediments at the end of 90% of the 10 docks within the basin (89.0 ft. above NGVD, Table 5), a clearance value of 2-ft. based on use of powerboats in the lake, and the difference between the Historic P50 and Historic P90 elevations (3.4 ft.). Based on the Historic water level record for the lake, the standard was equaled or exceeded 6.7 percent of the time, *i.e*., the standard elevation corresponds to the Historic P6.7. This standard is not appropriate for the establishment of the minimum level since it above the elevation of both the Historic and Current P10.

Table 5. Summary statistics and elevations associated with docks (n=10) in Lakes Buddy and Pasadena based on measurements made by District staff in April 2003. Exceedance percentiles (P10, P50, P90) represent elevations exceeded by 10, 50 and 90 percent of the docks.

Summery Statistics	Elevation of Sediments at Waterward End of Docks (feet as NGVD 29)	Elevation of Dock Platforms (feet as NGVD 29)
90th Percentile (P10)	89.0	97.1
Median or 50th Percentile	87.9	95.5
10th Percentile (P90)	84.9	92.3
Maximum	89.5	98.0
Minimum	83.4	90.8

Because herbaceous wetlands are common within the Lake Pasadena and Buddy Lake basins, the Wetland Offset Standard was applied. Based on a review (Hancock 2006) of the development of minimum level methods for cypress-dominated wetlands, it was determined that up to an 0.8 foot decrease (or Wetland Offset) in the Historic P50 elevation would not likely be associated with significant changes in the herbaceous wetlands occurring within lake basins. A Wetland Offset elevation of 87.6 ft. was therefore established by subtracting 0.8 feet from the Historic P50 elevation (88.4 ft.). The wetland offset elevation was equaled or exceeded 62.5 percent of the time during the Historic period and therefore corresponds to the Historic P62.5.

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 for Lakes Pasadena and Buddy is established at **86.8 ft.** (see Figure 10 for a plot of lake stage versus lake surface area). The Species Richness Standard was equaled or exceeded 74.2 percent of the time during the Historic period and therefore corresponds to the Historic P74.2.

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 **85.0 ft.** for Lakes Buddy and Pasadena. Because the Low Guidance Level was established at the Historic P90 elevation, water levels equaled or exceeded the Aesthetics Standard 90 percent of the time during the Historic period.

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. Due to the irregular morphology (numerous small pools) of these two interconnected lake basins the dynamic ratio shift across the 0.8 threshold occurred at four elevations 92.5, 89.9, 78.9, and 76.3 (ft. above NGVD 29) (see Figure 10). A single Lake Mixing Standard could not be determined for this lake system.

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 was not determined for due to the extensive stands of aquatic macrophytes in Lake Pasadena and Buddy Lake that would be expected to limit recreational skiing within the basins.

Information on herbaceous wetlands is taken into consideration when determining the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (*i.e*., basin area with a water depth of four or less feet). Similarly, changes in lake stage associated with changes in lake area available for colonization by rooted submersed or floating-leaved macrophytes are also evaluated, based on water transparency values (*i.e*., basin area with a water depth of 9.2 feet or less).

Review of changes in potential herbaceous wetland area in relation to change in lake stage relative to the wetland area of the Historic P50 did not indicate that there would be a significant increase or decrease in herbaceous wetland vegetation associated with use of the applicable significant change standards below the Historic P50 which includes the Wetland Offset Standard (37.5 ft.), the Species Richness Standard, and the Aesthetics Standard (36.3 ft.) (Figure 11). Review of changes in area available for submersed aquatic plant colonization relative to the area available at the Historic P50 change in lake stage also did not indicate that there would be a significant increase or decrease in the area of submersed aquatic plant vegetation at the elevation of the Wetland Offset Standard or Aesthetics standard; however, a significant increase (19 percent) would occur at the Species Richness Standard (86.8 ft.) (Figure 11).

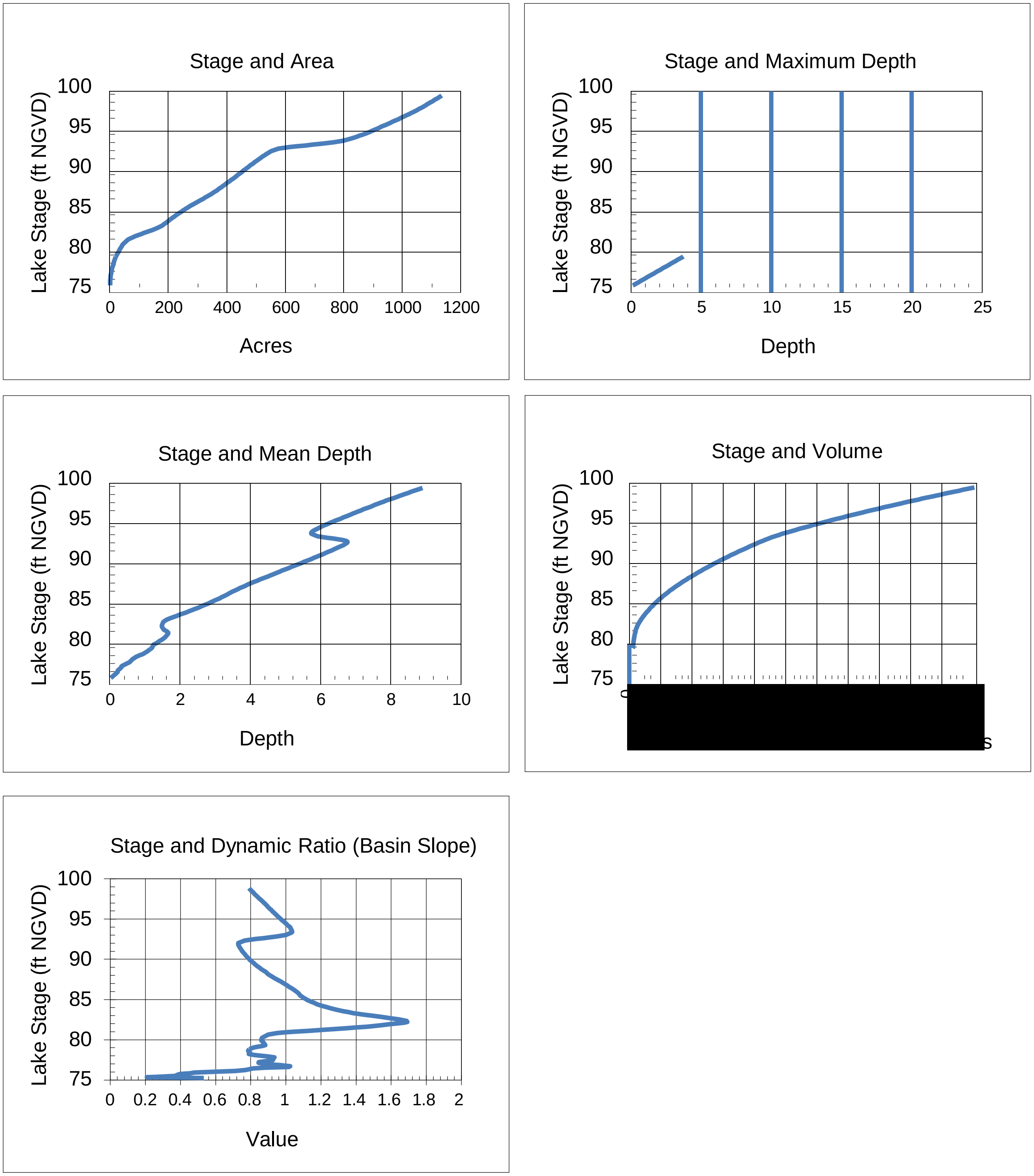
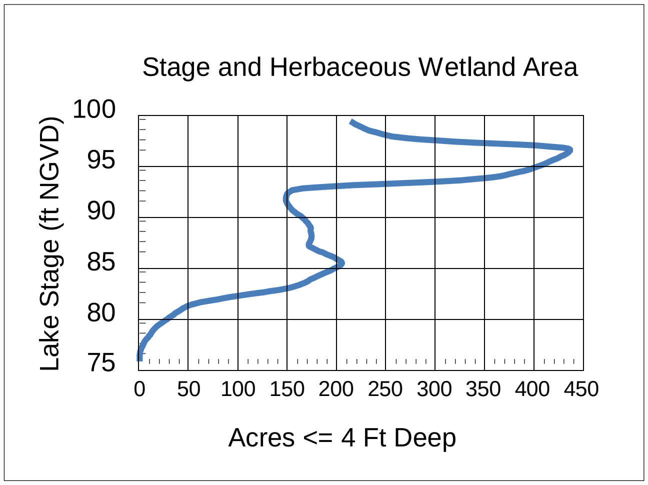


Figure 10. Mean depth, maximum depth, surface area volume, stage volume, and dynamic ratio (basin slope) in feet for Lakes Buddy and Pasadena.



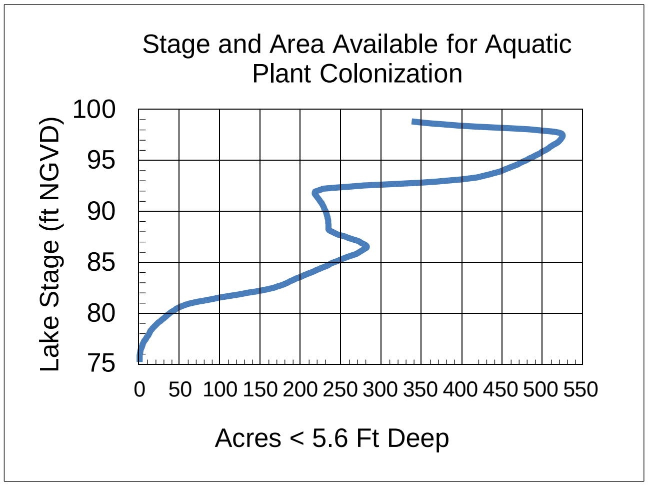


Figure 11. Area available for submersed macrophyte colonization and potential herbaceous wetland area of Lakes Buddy and Pasadena as a function of lake stage (water surface elevation).

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. For Category 3 Lakes, the Minimum Lake Level is typically established at the elevation corresponding to the most conservative significant change standard, *i.e*., the standard with the highest elevation, except where that elevation is above the Historic P50 elevation, in which case, the Minimum Lake Level is established at the Historic P50 elevation. Because all appropriate significant change standards were below the Historic P50 elevation, the Minimum Level for Lakes Buddy and Pasadena is established at 87.6 NGVD 29, the elevation corresponding to the Wetland Offset Standard (Figures 9 and 13). The Minimum Lake Level was equaled or exceeded 62.5 percent of the time, based on the Historic, composite water level record and corresponds to the Historic P62.5. This level is expected to afford protection to the natural system and human-use values associated with the identified significant change standards and also provide protection for wetlands occurring within the basin. The Minimum Lake Level for Lake Pasadena and Buddy Lake is **87.6 ft**.

The **High Minimum Lake Level (HMLL)** is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. For Category 3 lakes, the High Minimum Lake Level is developed using the Minimum Lake Level, Historic data or reference lake water regime statistics. If Historic Data are available, the High Minimum Lake Level is established at an elevation corresponding to the Minimum Lake Level plus the difference between the Historic P10 and Historic P50. If Historic data are not available, the High Minimum Lake Level is set at an elevation corresponding to the Minimum Lake Level plus the region-specific RLWR50. Based on the availability of long term modeled Historic data for Lakes Buddy and Pasadena, the High Minimum Lake Level is established at 92.5 NGVD 29 (Figures 9 and 13), by adding the difference between the Historic P50 and Historic P10 (4.9 feet) to the Minimum Lake Level (87.6 NGVD 29). The High Minimum Lake Level at 92.5 NGVD 29 equaled or exceeded 13.8 percent of the time, based on the long term modeled Historic water level record, and corresponds to the Historic P13.8. The proposed High Minimum Lake Level for Lakes Buddy and Pasadena is therefore established at **92.5 ft**.

The Minimum and Guidance levels for Lakes Buddy and Pasadena are shown in Figure 9 along with lake stage elevation. The levels are also shown plotted as approximate contour lines on the 2005 aerial imagery (Figures 12 and 13). The Minimum Level is also plotted on the 1941 historical imagery as a reference to historical conditions (Figure 14).

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 Lakes Buddy and Pasadena MFLs are presented in both datum standards (Table 7). The datum shift from NAVD88 to NGVD29 was determined by actual surveys in the field at the location of the lake level gauge and was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum on 1988. The shift or conversion determined for Lakes Buddy and Pasadena was 0.870 ft.

Table 7. Minimum and Guidance Levels for Lakes Buddy and Pasadena relative to both NGVD29 and NAVD88.

Minimum and Guidance Levels	Feet NGVD29	Feet NAVD88
High Guidance Level	93.3	92.4
High Minimum Lake Level	92.5	91.6
Minimum Lake Level	87.6	86.7
Low Guidance Level	85.0	84.1

Consideration of Environmental Values

The minimum levels for Lake Pasadena and Buddy 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.). 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 Wetland Offset Standard determined the Minimum Levels for Lakes Buddy and Pasadena based on their classification as Category 3 Lakes.

The Wetland Offset Standard is associated with protection of several environmental values identified in Rule 62-40.473, F.A.C., including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, sediment loads and water quality (refer to Table 1).

Two additional environmental values identified in Rule 62-40.473, F.A.C., are also protected by the minimum levels for these two lakes. The environmental value, recreation in and on the water, is associated with the Aesthetic Standard for the lake. This standard is associated with an elevation lower than the Wetland Offset Standard elevation (85.0 NGVD vs 87.6 NGVD) indicating that it achieves a higher frequency than the Wetland Offset Standard. The environmental value, maintenance of freshwater storage and supply is protected by the minimum levels based on the relatively modest potential changes in storage associated with the minimum flows hydrologic regime as compared to the non-withdrawal impacted historic condition. Maintenance of freshwater 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 the minimum flows and levels.

Two environmental values identified in Rule 62-40.473, F.A.C., were not considered relevant to the development of minimum levels for Lakes Buddy and Pasadena. Estuarine resources are not considered relevant because the lakes are not directly connected to the estuarine resources associated with the waters of Tampa Bay. Sediment loads are similarly not considered relevant for minimum levels development, because the transport of sediments as bedload or suspended load is a phenomenon associated with flowing water systems.

Assessment of the Minimum Level Status

The Minimum Lake Level and High Minimum Lake Level for Lakes Buddy and Pasadena are assessed to determine if lake levels are fluctuating relative to both these levels in an appropriate manner (Appendix A). The methods include using the prediction interval of the rainfall regression model developed to model the Historic data; and evaluating the cumulative median relative to the minimum level (Appendix B). Both methods indicate that the lakes are at or above the Minimum Low Level of 87.6 NGVD 29 and High Minimum Level of 92.5 NGVD 29.

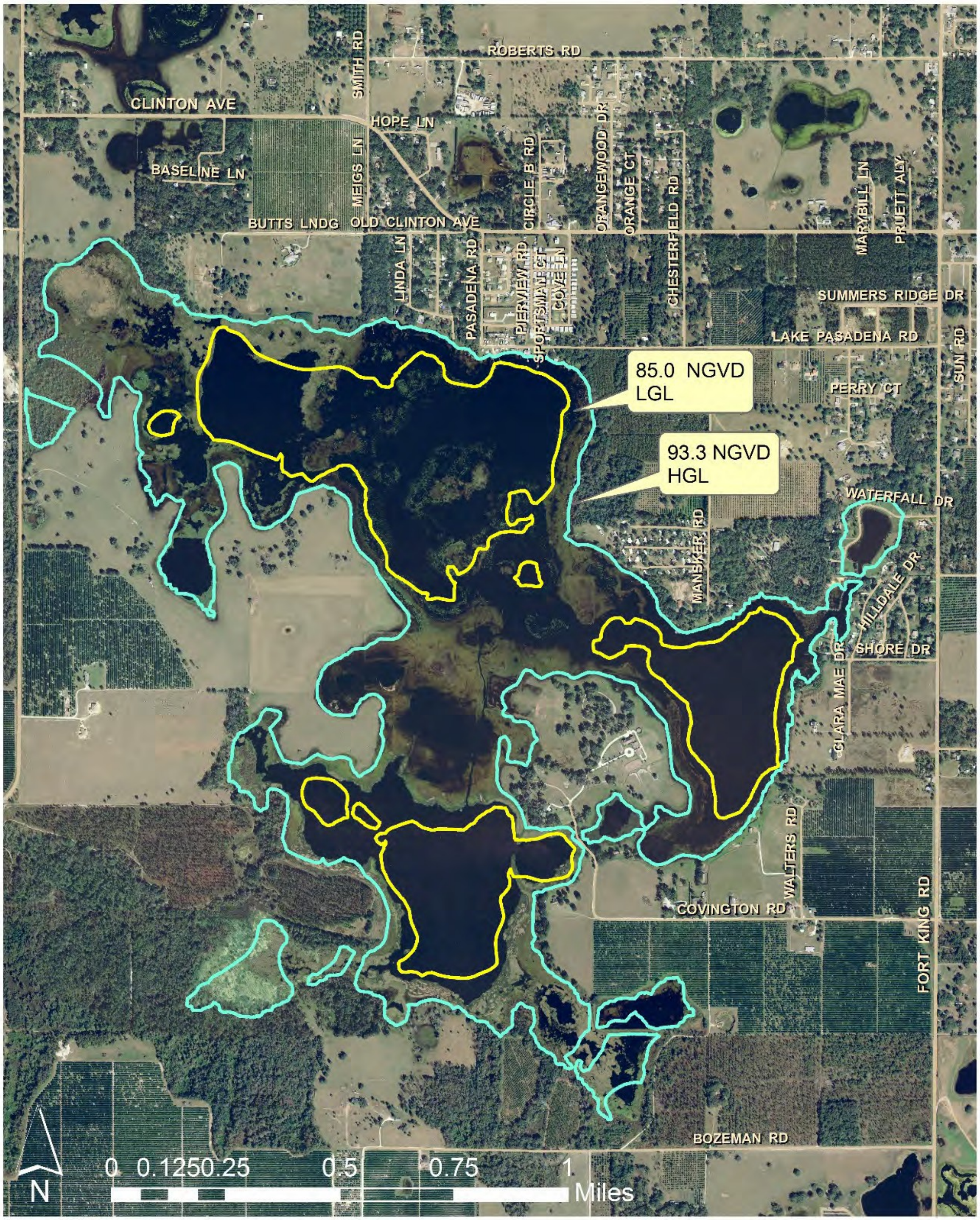


Figure 12. Approximate location of water level (i.e., shoreline) associated with the Low Guidance Level (LGL) and High Guidance Level (HGL) for Pasadena Lake and Lake Buddy relative to conditions during February 2005.

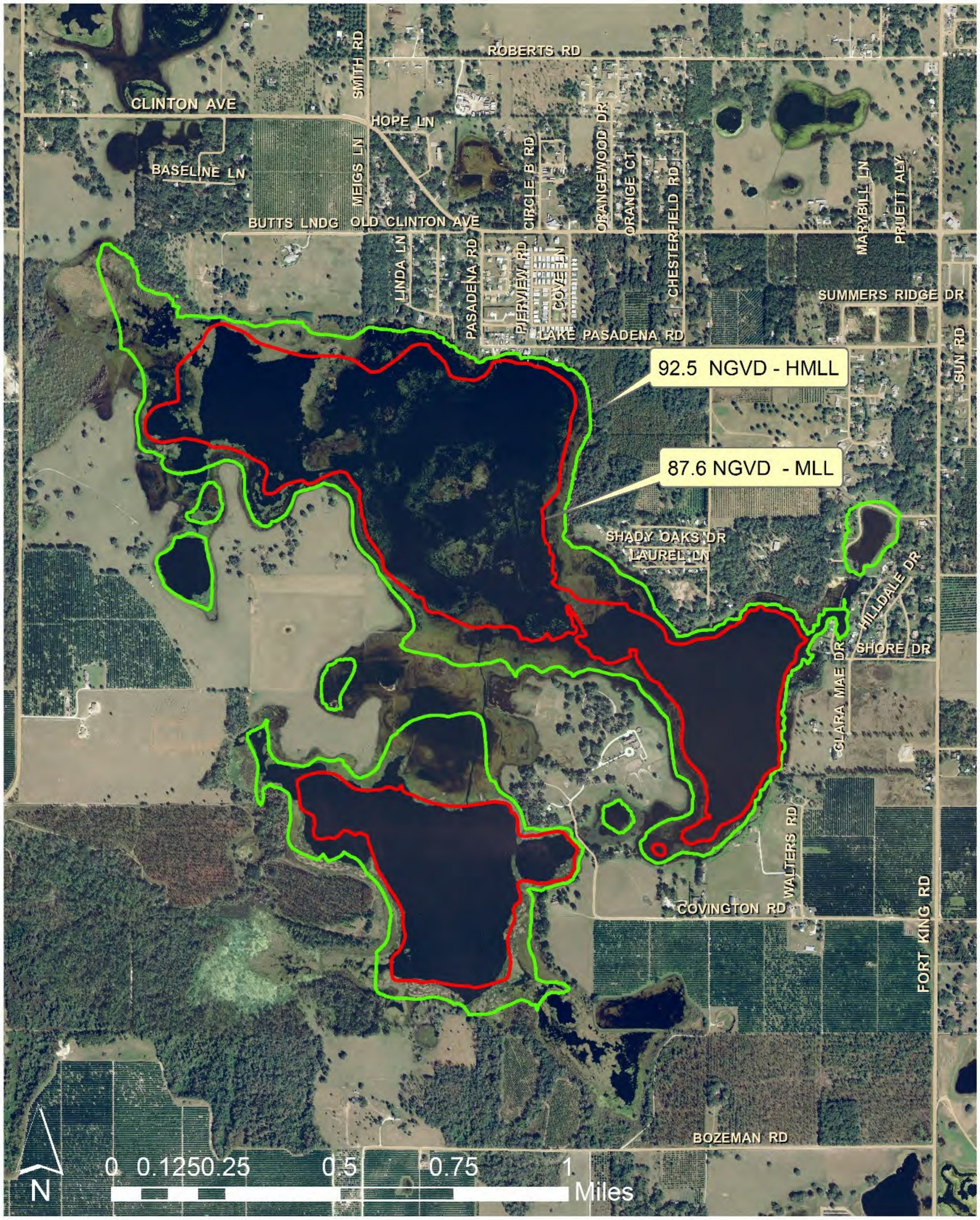


Figure 13. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Lake Pasadena and Buddy Lake relative to conditions in February 2005.

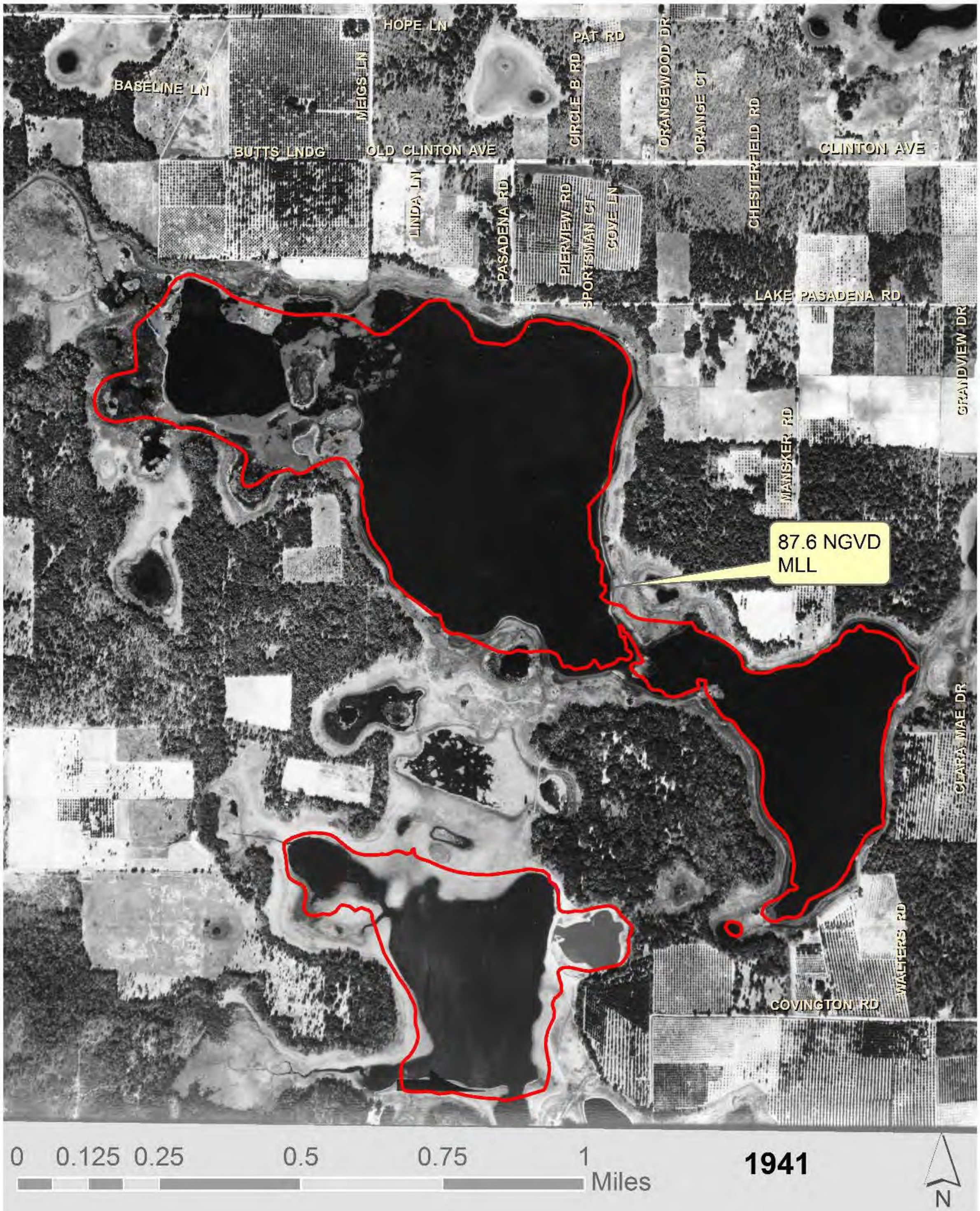


Figure 14. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) for Lakes Buddy and Pasadena relative to conditions in 1941.

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Appendix A

Technical Memorandum

October 12, 2015

TO: Keith Kolasa, Senior Environmental Scientist, 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: Lake Pasadena and Buddy Hydrogeology, Rainfall Regression Model, Historic Percentile Estimations and Assessment of Minimum Levels Status

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A. Introduction

A rainfall regression model was developed to assist the Southwest Florida Water Management District (District or SWFWMD) in the establishment of minimum and guidance levels for lake's Pasadena and Buddy, located in east-central Pasco County (Figure 1). This document discusses development of the model, hydrogeologic evaluations used to support model development, derivation of lake stage percentiles used to develop levels for the lake, and minimum level status assessments (i.e., whether long-term water levels in the lake are above currently and projected to stay above the minimum levels, i.e., whether the levels are being met and may be expected to be met for the next twenty years.

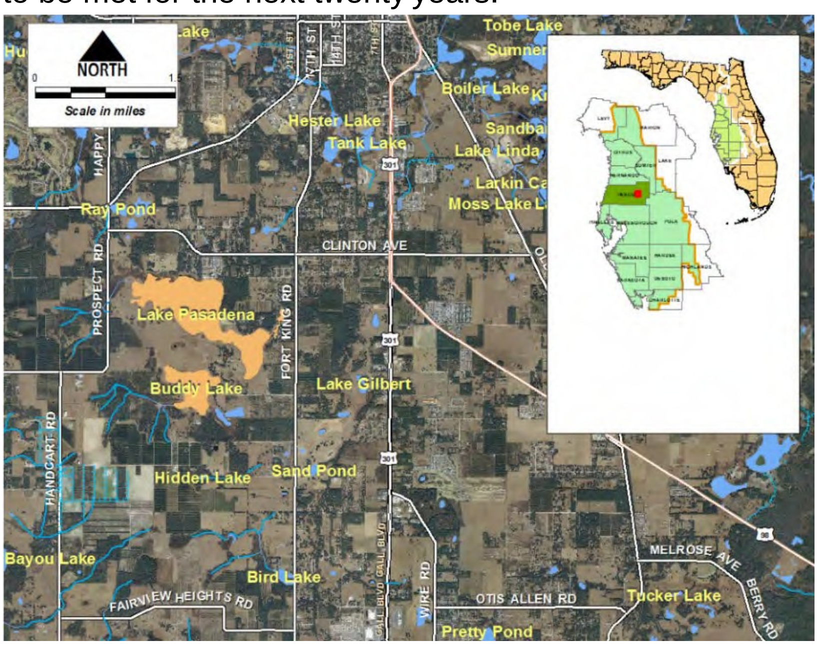

Figure 1. Location of Lake Pasadena and Buddy in east-central Pasco County, Florida.

B. Background and Setting

Lakes Pasadena and Buddy are in east-central Pasco County, approximately 10 miles north of the southern Pasco County line (Figure 1). The lakes are in a non-contributing basin within the larger Hillsborough River watershed (Figures 2 and 3). White (1970) classified the physiographic area as the Brooksville Ridge physiographic region (Figure 4). Brooks (1981) categorize the area as the Dade City Hills and describes it as **"**a spectacular ridge of high hills dissected from Upper Miocene sand and silty sand. Drainage is downward to the Floridan aquifer and solution is now the dominant process influencing the landscape. Deep weathering has produced thick sand soils. Many hills are above 200 feet in elevation; one reaches 301 feet" (Figure 5).

The Brooksville Ridge physiographic area consists of numerous hills and depressions with relatively thick confinement. Where the clay-rich soils are thick, there is limited dissolution of the underlying limestone leading to an undulating ridge and valley system with land surface elevations often exceeding 150 ft. NGVD. Numerous, localized, hydraulically "perched" lakes and shallow aquifers exist because of the generally thick clay confinement between the surface and the underlying UFA with hydraulic head differences varying from 20 to more than 100 feet. Sprinkled within the hydrogeologic province are localized karst "windows", which provide a source of high recharge to the underlying UFA.

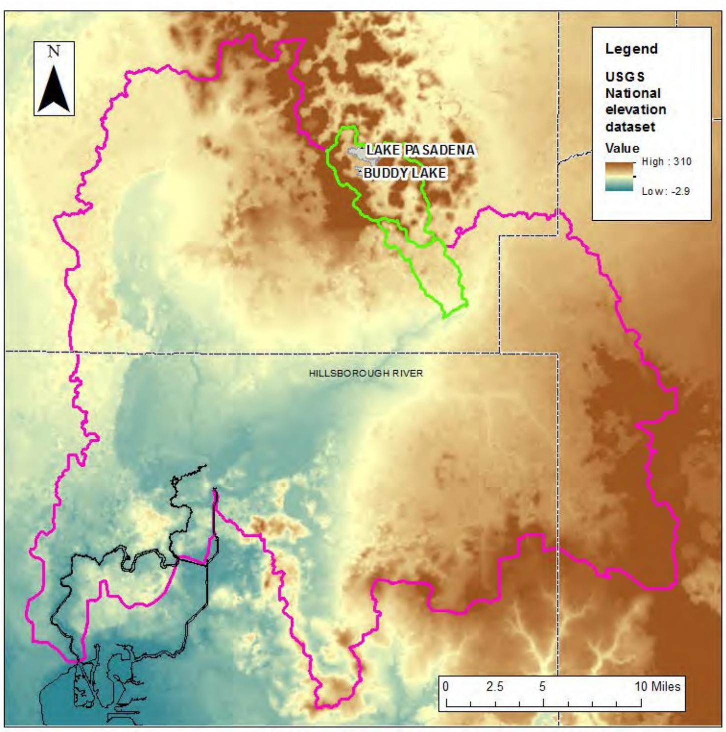

Figure 2. Watershed delineation and topography.

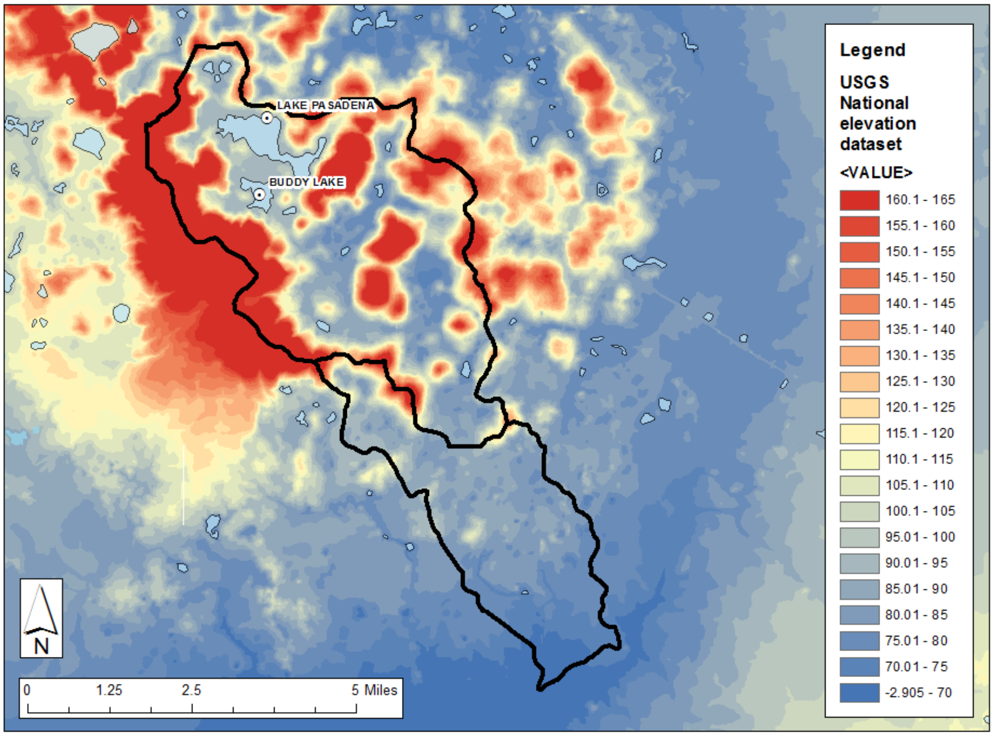

Figure 3. Drainage Basin delineation and topography.

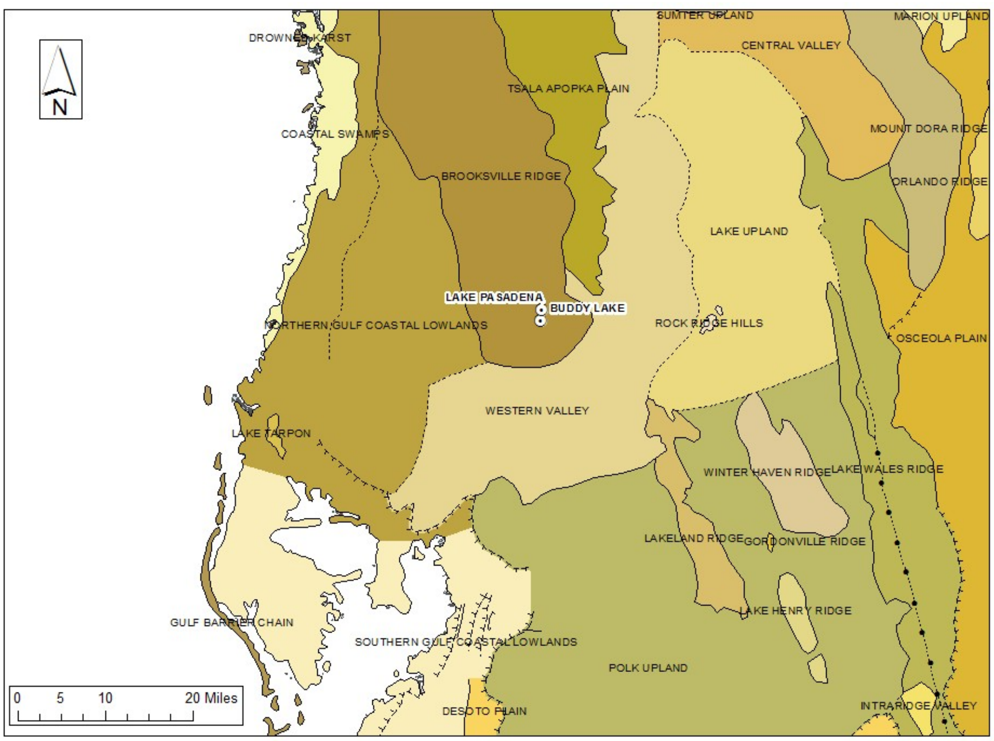

Figure 4. Physiographic Provinces (White, 1970) and topography.

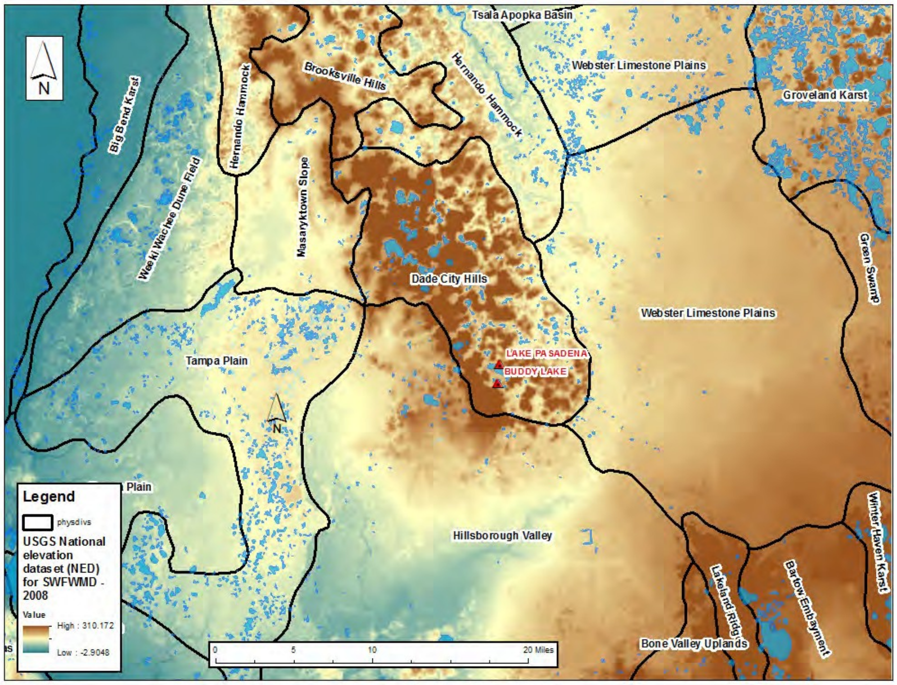

Figure 5. Physiographic Provinces (Brooks, 1981) and topography.

Lithologic information along the Brooksville Ridge generally shows a relatively thin layer of sand (average 11 feet thick) overlying rather thick clays (varying from 34 to 72 feet in thickness). A distinct water table usually exists within the surficial sand but may only be present during the summer rainy season or extremely wet periods (Basso, 2009). The ROMP well nest BR-3 (Figure 6) is representative of this hydrogeologic regime with an approximate average hydraulic head difference between the surficial and Upper Floridan aquifers of 27 feet (Figure 7). In general, the larger the hydraulic head difference, the greater confinement of the system. The lakes that straddle the clay-rich soils of the Brooksville Ridge are generally hydraulically "perched" or separated from the underlying UFA. Thick clays beneath the lakes form a relatively impermeable barrier which support these perennial systems. If the lakes were in hydraulic connection with the UFA, their water levels would closely approximate the potentiometric surface elevation of the Upper Floridan.

Soil Boring and well construction logs from drilling activity in the area of the lake (Figure 8) describe a sequence of fine sand, clay, clay and limestone, followed by limestone, which may be layered with clay beds. The sand thickness averaged 15 ft. and was observed at one location to be as thick as 90 feet. The clay was averaged 42 ft. with an observed maximum of 110 ft. Clayey limestone thickness averaged 34 ft. with a maximum of 110 ft. observed at one location. The combined clay and clayey limestone thickness averaged 74 feet with a maximum of 165 observed at one site. Information from the drillers logs was compiled to produce a generalized interpretation of the geologic conditions is presented in a cross-section (Figures 8 and 9).

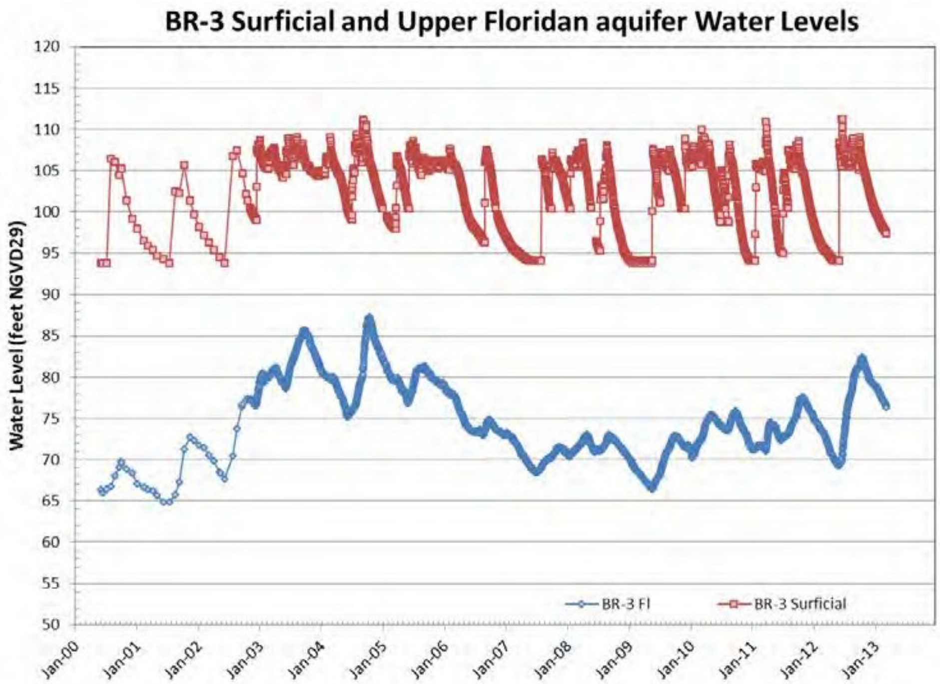

Figure 6. Water levels in BR-3 Surficial and Upper Floridan wells.

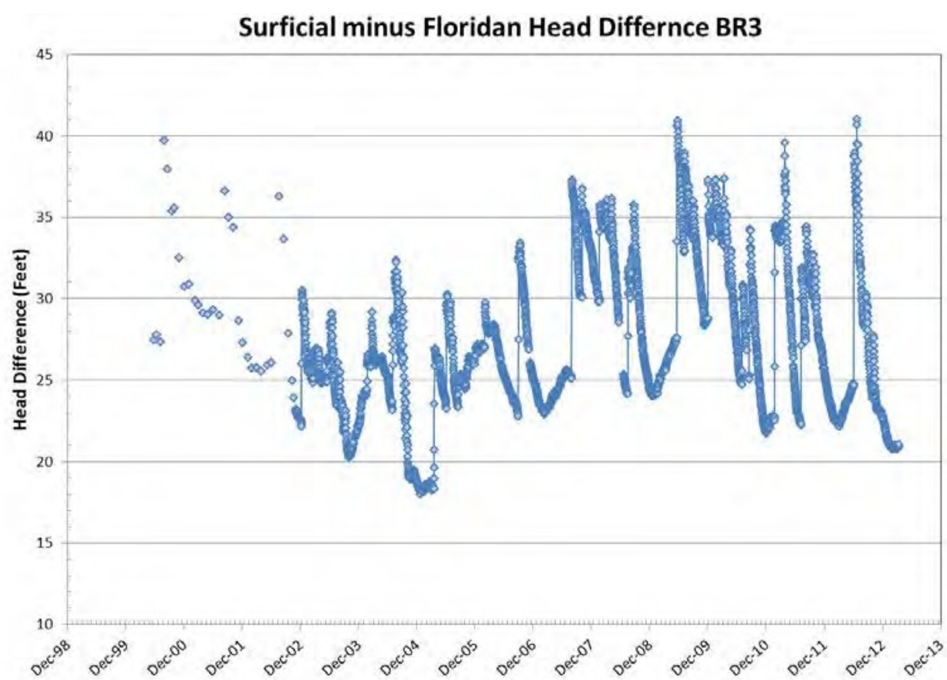

Figure 7. Water levels in BR-3 Surficial and Upper Floridan wells.

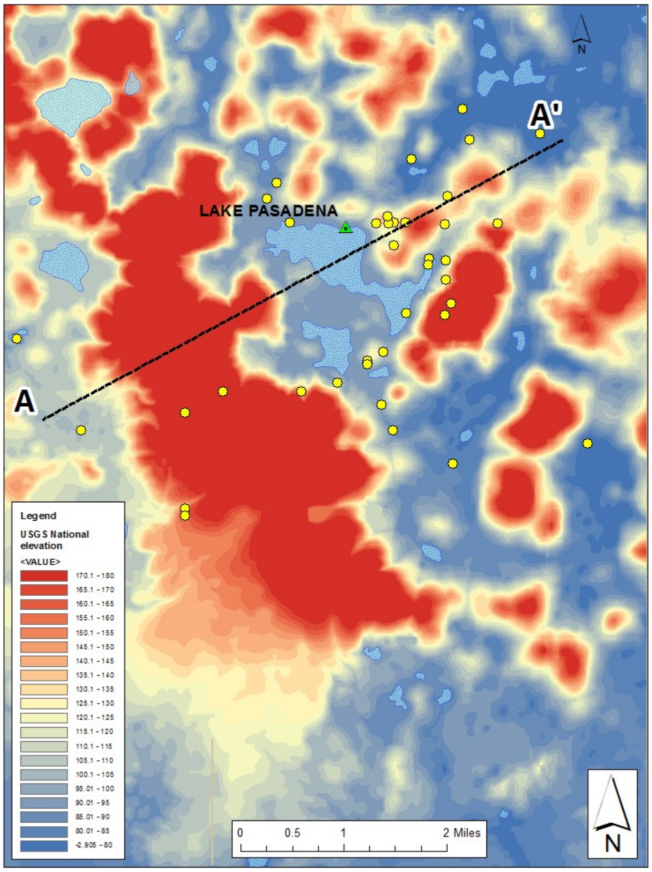

Figure 8. Location of well construction logs and alignment of the generalized cross-section (Figure 8).

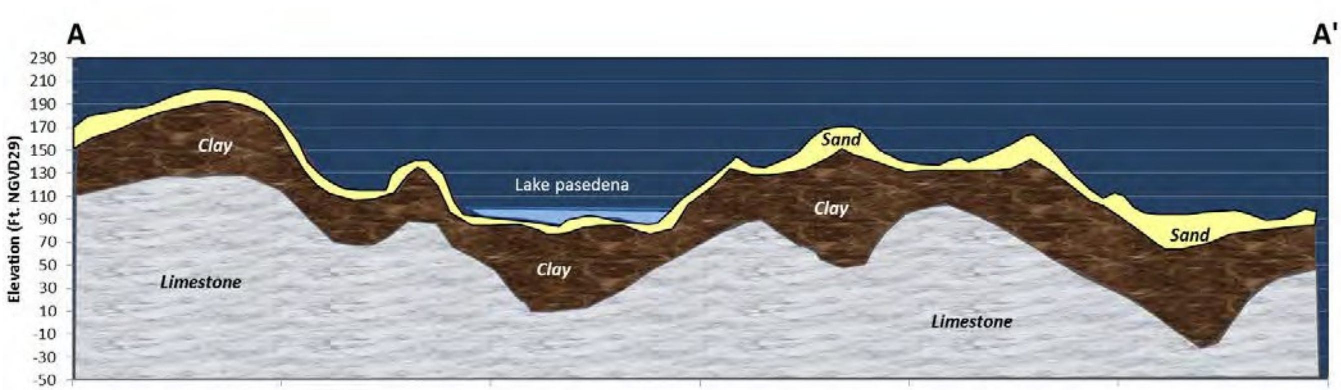

Figure 9. Generalized cross-section through Lake Pasadena.

Lakes Pasadena and Buddy are approximately 9 miles northeast of the Cypress Creek Wellfields and Cypress Bridge dispersed wellfields. These wellfields are part of the eleven regional water supply wellfields collectively referred to as the Central System Facilities that are operated by Tampa Bay Water (TBW) (Figure 10). Groundwater withdrawals began at the Section 21 Wellfield in 1963 and incrementally increased to approximately 20 mgd in 1967 (Figure 11). 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 11). Cypress Creek Wellfield withdrawals began in 1976 and operated at approximately 30 mgd prior to cutbacks. Cypress Bridge Wellfield withdrawals were initiated in 1982 at a less than 1 mgd and increased to approximately 10 mgd. Combined withdrawal rates since 2005 have ranged from zero to nearly 90 mgd, with several extended periods when individual wellfields were shut down.

Total estimated water use in the area inclusive of other uses such as agriculture and domestic supply wells is presented as sums for radial distances from the approximate center of the lake in Figures 12 through 14. Estimated and metered water use are available from 1994 through 2012.

Changes to surficial and Upper Floridan aquifer levels in the vicinity of Lake Pasadena and Buddy were evaluated (Patterson, 2015) using the Integrated Northern Tampa Bay Model developed by Geurink and Basso (2013). Pumping and non-pumping model scenarios were performed for the period starting in 1989 and ending in 2000. Total withdrawals within the Central West-Central Florida Groundwater Basin, within which Lakes Pasadena and Buddy lie, averaged 239.4 mgd during the 1989-2000 period. A third scenario, consisting of reducing TBW central wellfield system withdrawals to their mandated recover quantity of 90 mgd from the 11 central wellfields was also evaluated. Based on the difference in simulated heads from the 1989-2000 pumping and non-pumping model runs, the average predicted drawdown in the surficial and Upper Floridan aquifers near Lake Padgett were 0.0 ft. and 0.3 ft., respectively. Based on the difference in modeled heads from the TBW recovery pumping and the non-pumping scenarios, the average predicted drawdown near the lake was 0.0 ft. in the surficial aquifer and 0.1 ft. in the Upper Floridan aquifer.

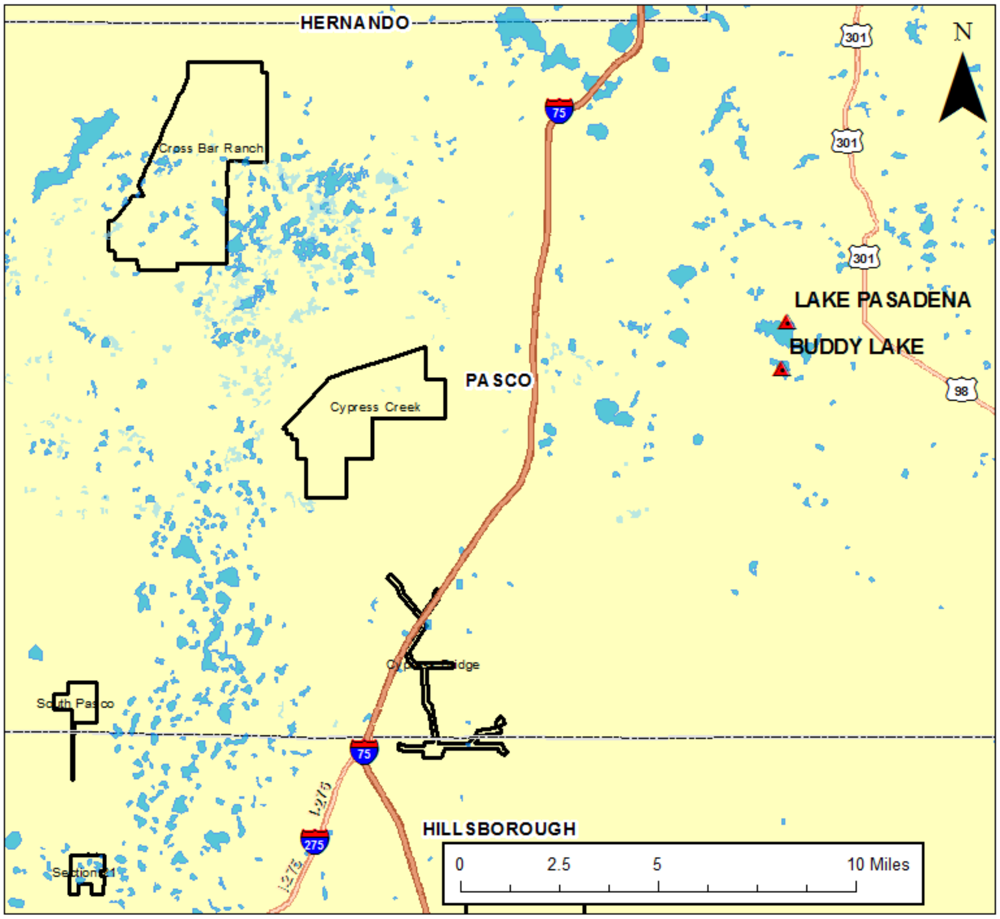

Figure 10. Lakes Buddy and Pasadena and the central system wellfields.

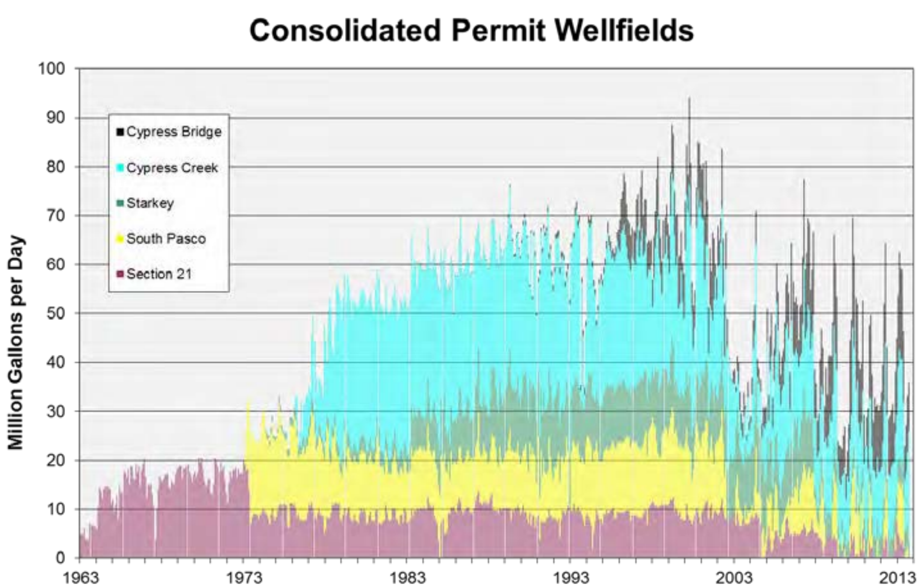

Figure 11. Section 21, South Pasco, Cypress Creek, Starkey and Cypress Bridge wellfield withdrawals.

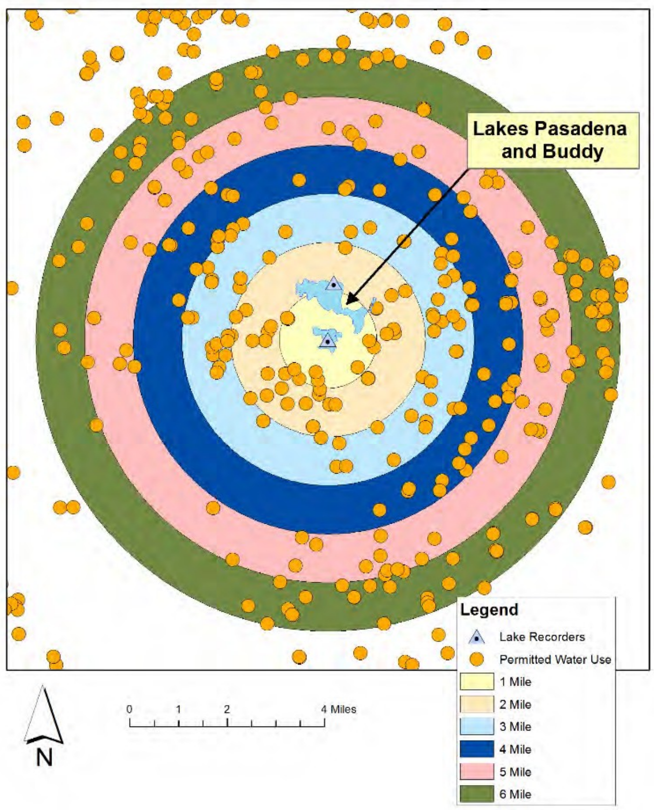

Figure 12. Location of withdrawals near lakes Pasadena and Buddy.

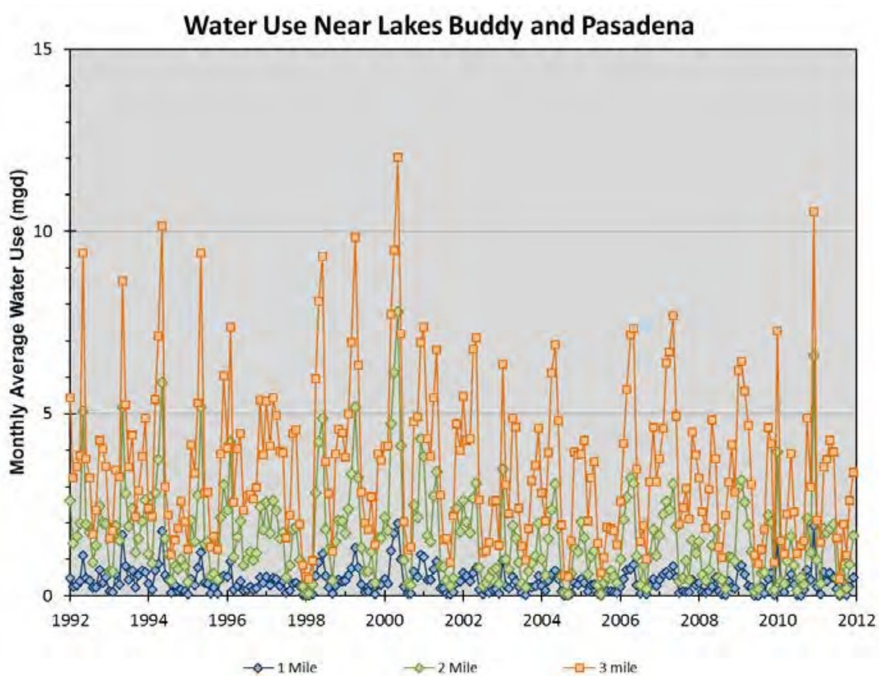

Figure 13. Metered and estimated water use within 1, 2 and 3 miles of lakes Pasadena and Buddy.

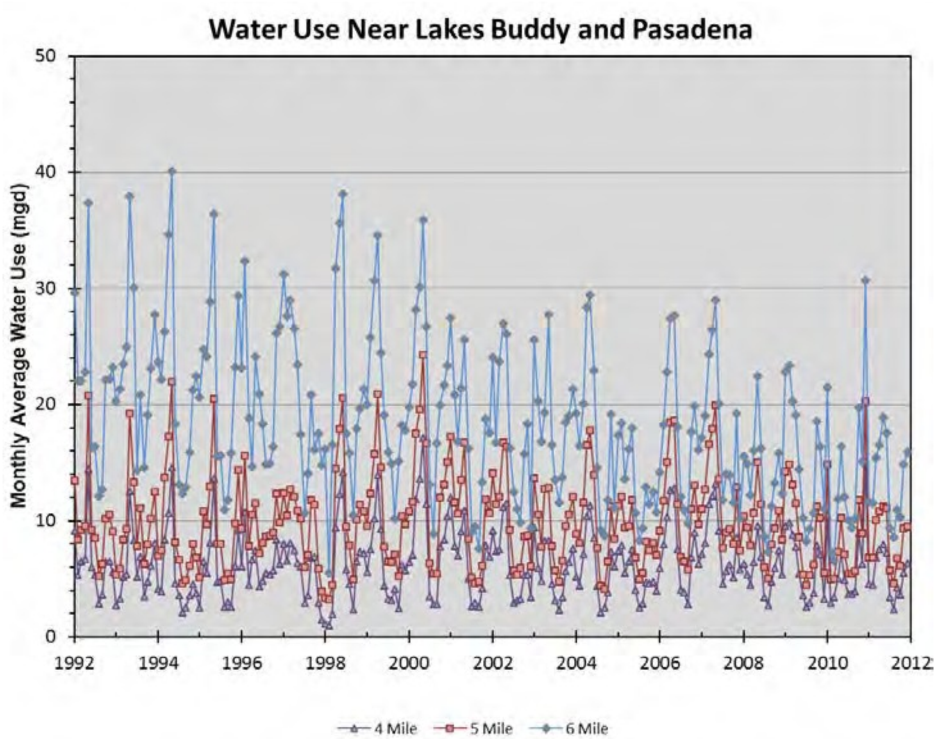

Figure 14. Metered and estimated water use within 4, 5 and 6 miles of lakes Pasadena and Buddy. Note that y-axis scale differs from that shown in Figure 8.

Rainfall Regression Long-Term Historic Lake Percentile Estimation

The procedure to establish minimum and guidance levels for lakes is based on long-term lake stage percentiles. In the absence of a long-term water level data, a rainfall based regression model may be constructed and used to model lake stage fluctuations and create a long-term water level record. A first step in developing a rainfall regression model is the delineation of “Historic” and “Current” time periods. 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. To identify Historic and Current time periods, an evaluation of hydrologic changes in the vicinity of the lake is completed to determine if the water body has been significantly impacted by groundwater withdrawals. Examples of hydrological changes that are reviewed include drainage modifications, dredging, filling and modifications to the lake outlets.

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.

This memorandum describes the hydrogeologic setting near lakes Buddy and Pasadena, delineation of a Historic period, development of rainfall regression models and selection of a best-fit model for the lake, and assessment of the current and future lake levels with respect to minimum levels for the lake.

The rainfall regression method (Ellison 2010) 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 lake 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.

Lake Buddy and Pasadena Water Level Data and Identification of Historic Data

Period of record (POR) lake stage data, *i.e.,* surface water elevations for Lakes Buddy and Pasadena relative to NGVD 29 were obtained from the District's Water Management Information System (WMIS) data base, Site Identification (SID) number 18867 (Figure 15). Surface water level data have been recorded since February 1984. The period of record water level data for Lake Buddy and Pasadena are classified as Historic due to the perched nature of the lakes (hydraulically separated from the Upper Floridan aquifer).

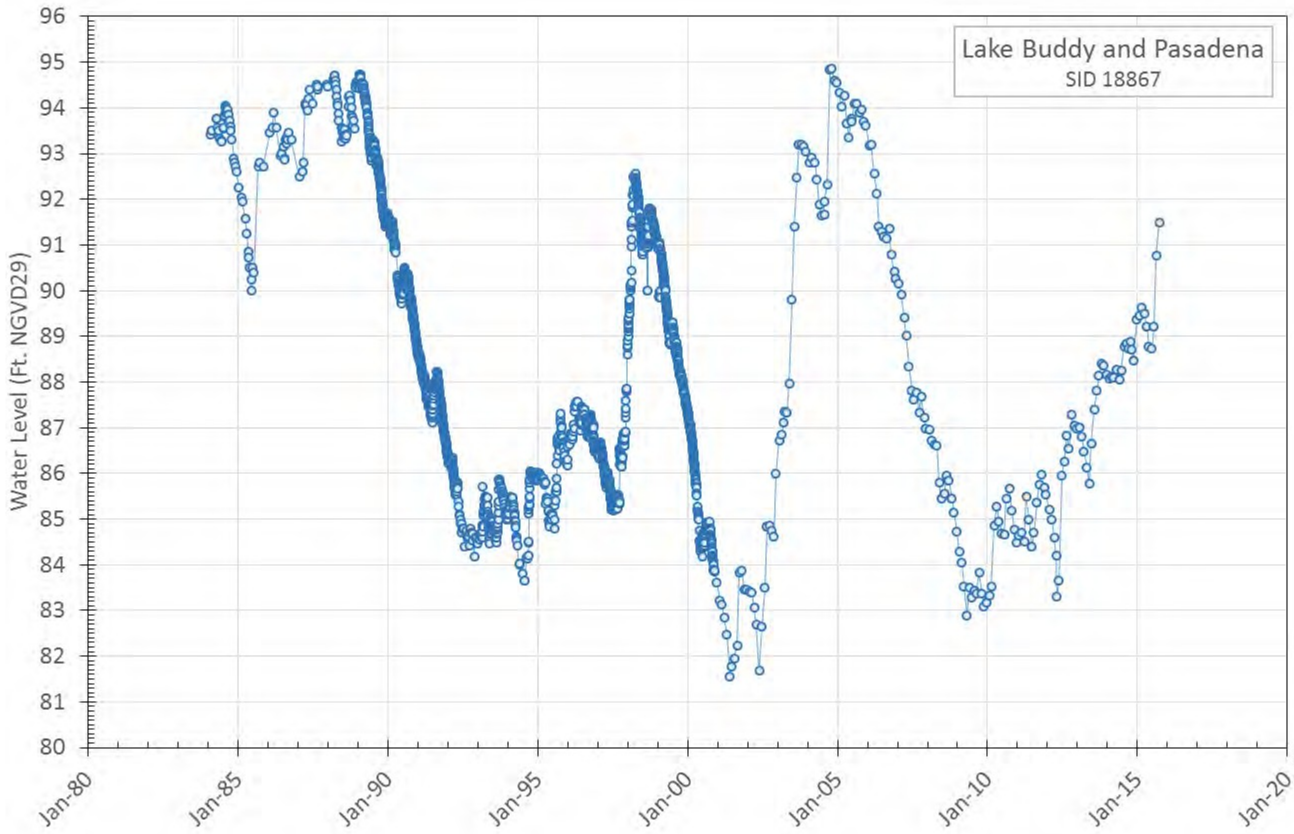

Figure 15. Lakes Buddy and Pasadena water level data (SID 18867).

Rain Gauge Data

Available rain gage data were inventoried and sorted by distance from Lake Buddy and Pasadena and by their period of record (POR) to locate the closest rain data to the lake for compilation of a long-term rainfall record that could be used to develop rainfall regression LOC models to predict long-term lake levels. Daily records starting in the year 1901 are available from the St. Leo National Weather Service (SID 18901) station located within two miles of the lakes (Figure 16). Missing days of data were infilled by Aly (2008) using interpolation methods.

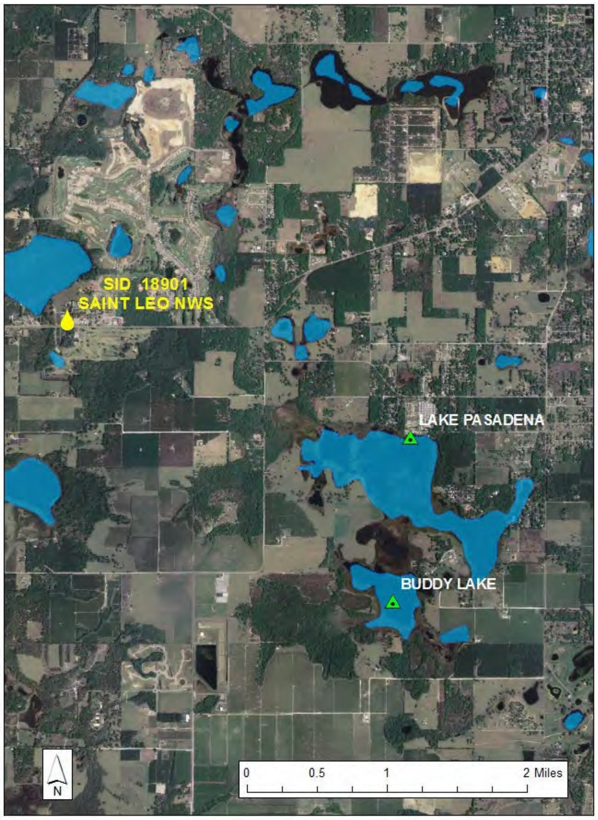

Figure 16. Rain gauge location used in the rainfall regression models for Lakes Buddy and Pasadena.

Lake Padgett Rainfall Regression Model and Historic Percentiles

Rainfall regression LOC models were developed using lake stage data and rainfall data from January 1, 2003 to February 28, 2015. This period corresponds to the cutbacks made by TBW at Cypress Creek and Cross Bar. This is the period of lowest pumping during the lake stage POR. The best-fit LOC model for predicting water levels in Lake Buddy and Pasadena (Figure 17) exhibited a coefficient of determination (r^2) of 0.93 and may be simplified as:

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

where

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

b_0 = *the y intercept, in this case 50.62 feet above NGVD29*

b_i = *the regression slope; in this case 0.2325*

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

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

The residuals and a time series plot of actual (i.e., observed) and modeled water levels for the 2003-2015 calibration period are shown in figures 16 and 17, respectively. A comparison of measured and modeled percentiles for the calibration period is presented in Table 1. The model-derived P10 and P90 percentiles for the calibration period were the same as the data. The model derived P50 was 0.8 ft. higher than the corresponding percentiles for the observed data.

The best-fit LOC model and rainfall records from the St. Leo rain gage were used to estimate water levels for Lake Pasadena/Buddy for the period from January 1, 1946 through February 28, 2015 (Figure 19). Model-predicted water levels match actual, i.e., observed period of record data reasonably well, indicating that the lake water levels fluctuate mostly in response to rainfall and impacts from groundwater withdrawals are minimal for most of the record.

Because the model produced a close match with the observed data throughout the period of record, Long-term percentiles were developed as a composite of observed data and modeled data that was used to infill data gaps. Historic long-term percentiles for Lake Pasadena/Buddy based on the hybrid set of modeled and observed records are presented in Table 2.

Comparison of Lake Pasadena/Buddy Historic Percentiles to Hydrologic Indicators

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 (Southwest Florida Water Management District 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 elevation was not established for Lake Pasadena or Buddy Lake. Reliable Hydrologic Indicators of high water levels were not observed. Based on available lake-stage data, the Florida Department of Environmental Protection has recommended that an elevation of 93.5 ft. above NGVD may be used as a provisional approximation of the ordinary high water line for Lake Pasadena (Maddox 1997). The model produced a similar lake Historic P10 of 93.6 ft. above NGVD.

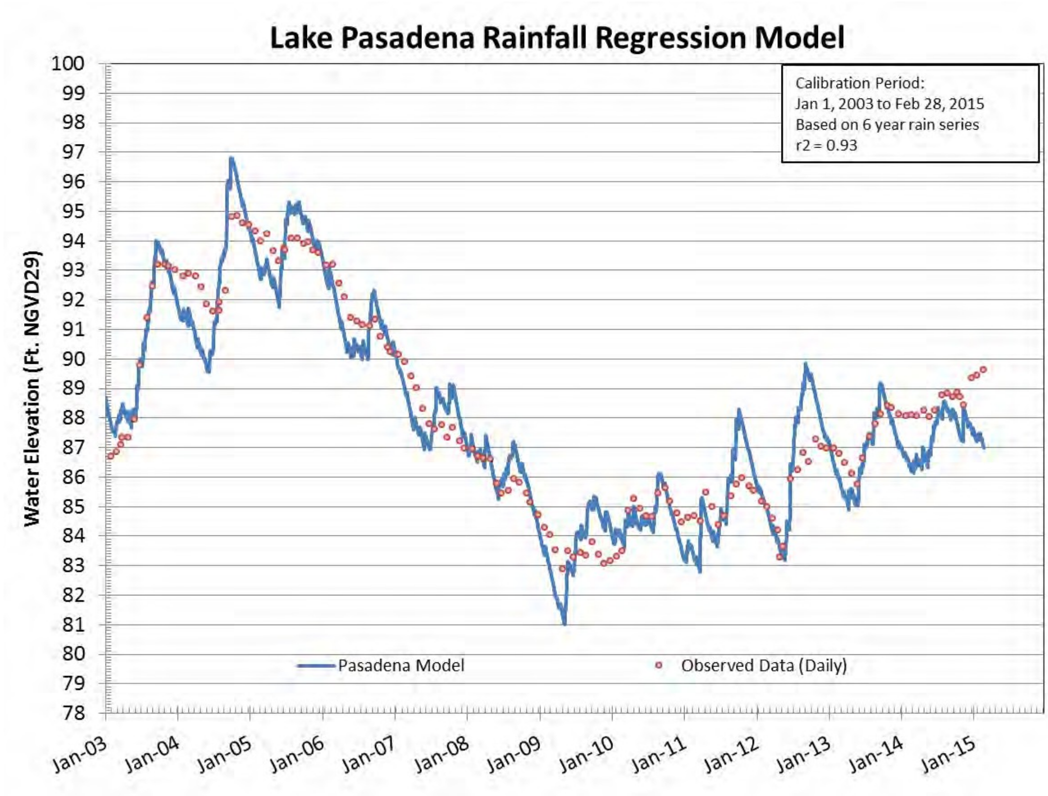

Figure 17. Lake Pasadena LOC-modeled and actual (i.e., observed) water levels for the calibration period.

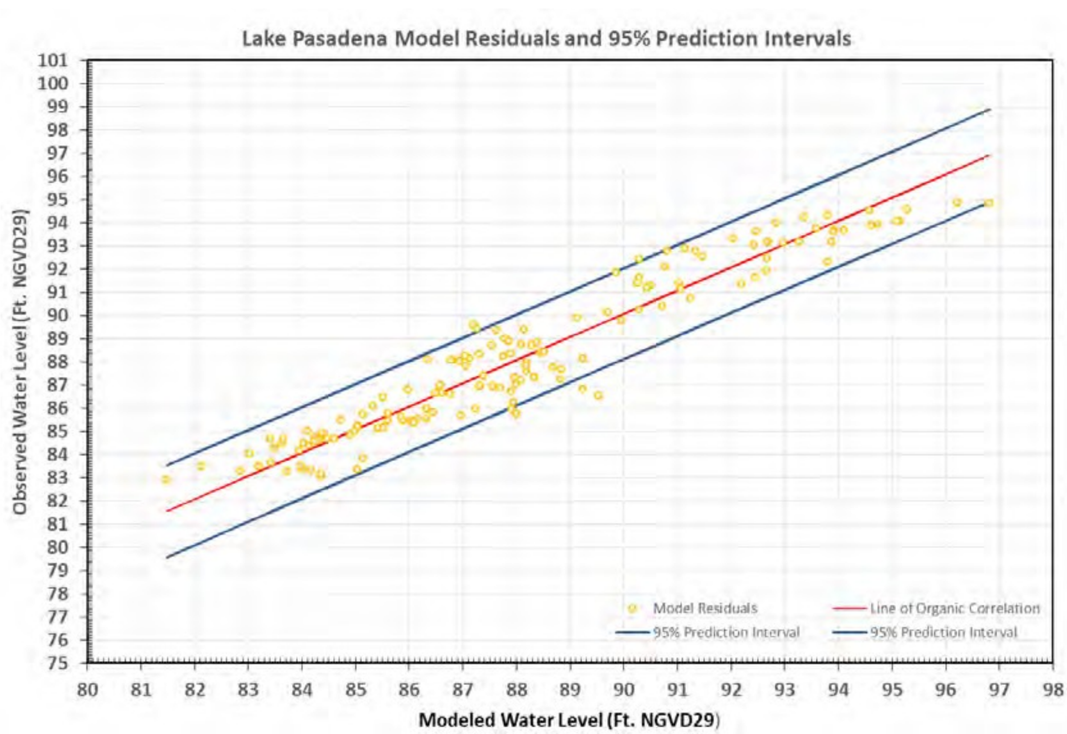

Figure 18. Lake Pasadena Line of Organic Correlation (LOC) model results and 95% prediction intervals.

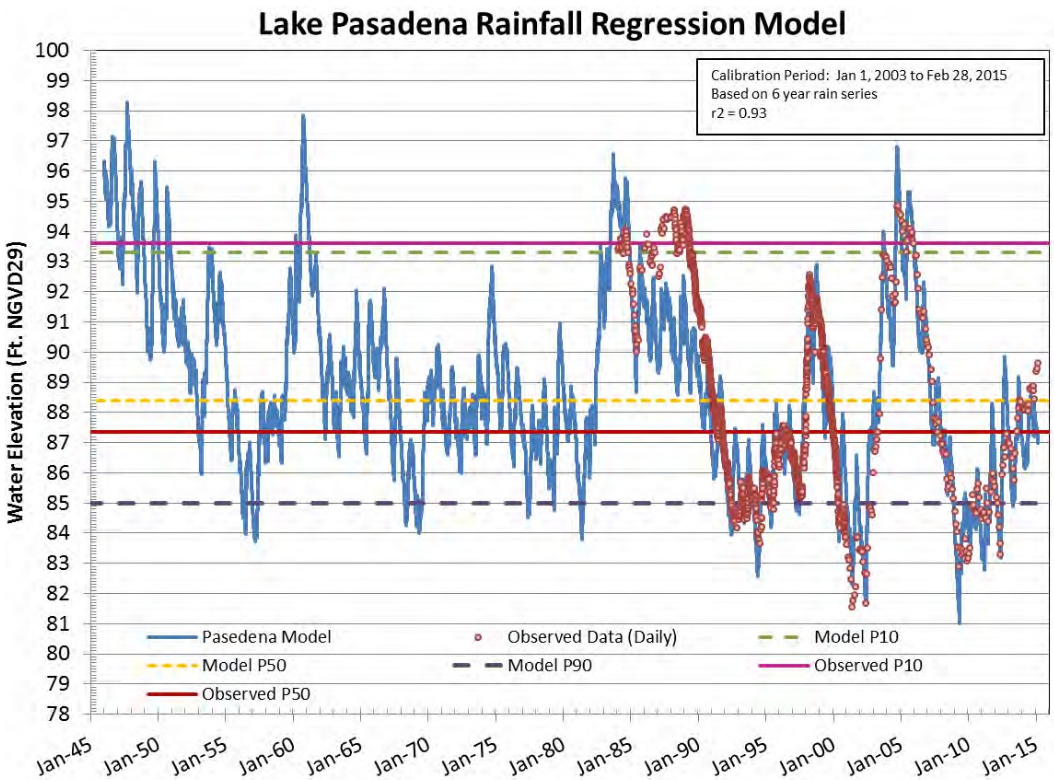

Figure 19. Lake Pasadena LOC-model predicted and actual (i.e., observed) water levels for period from January 1, 1946 through February 28, 2015.

Table 1. Comparison of lakes Pasadena and Buddy calibration period percentiles.

Calibration Jan 2003 through Feb 28, 2014		
Percentiles*	**Observed**	**Model**
P10	93.67	93.64
P50	87.04	87.85
P90	83.96	83.96

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

Table 2. Lake Pasadena/Buddy Long-term Historic percentiles.

Lake Pasadena/Buddy Long-term Historic Percentiles* (1/1/1946 through 2/28/2014)	
Percentiles	
P10	93.3
P50	88.4
P90	85.0

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

Assessment of Minimum Level Status

The goal of a minimum levels status assessment is to determine if lake levels are fluctuating in accordance with criteria associated with these levels, i.e., to determine whether or not the minimum levels are being met. In addition to use of a rainfall regression model and/or other types of models, the process includes comparison of long-term water levels with adopted levels, review of periodic groundwater modeling updates, and, if necessary, investigation of other factors that could help explain lake level fluctuations.

An assessment method used for evaluating the Minimum Lake Level (MLL) involves modification of an LOC model and associated prediction intervals based on elevations associated with the Historic P50 and the MLL. For this process, the intercept for the LOC model and prediction intervals are decreased in elevation based on the difference between the Historic P50 and the MLL (Figure 20). These modified, shifted lines represent a defined range of lake levels that would be expected to meet the MLL while exhibiting variation expected due to changes in rainfall.

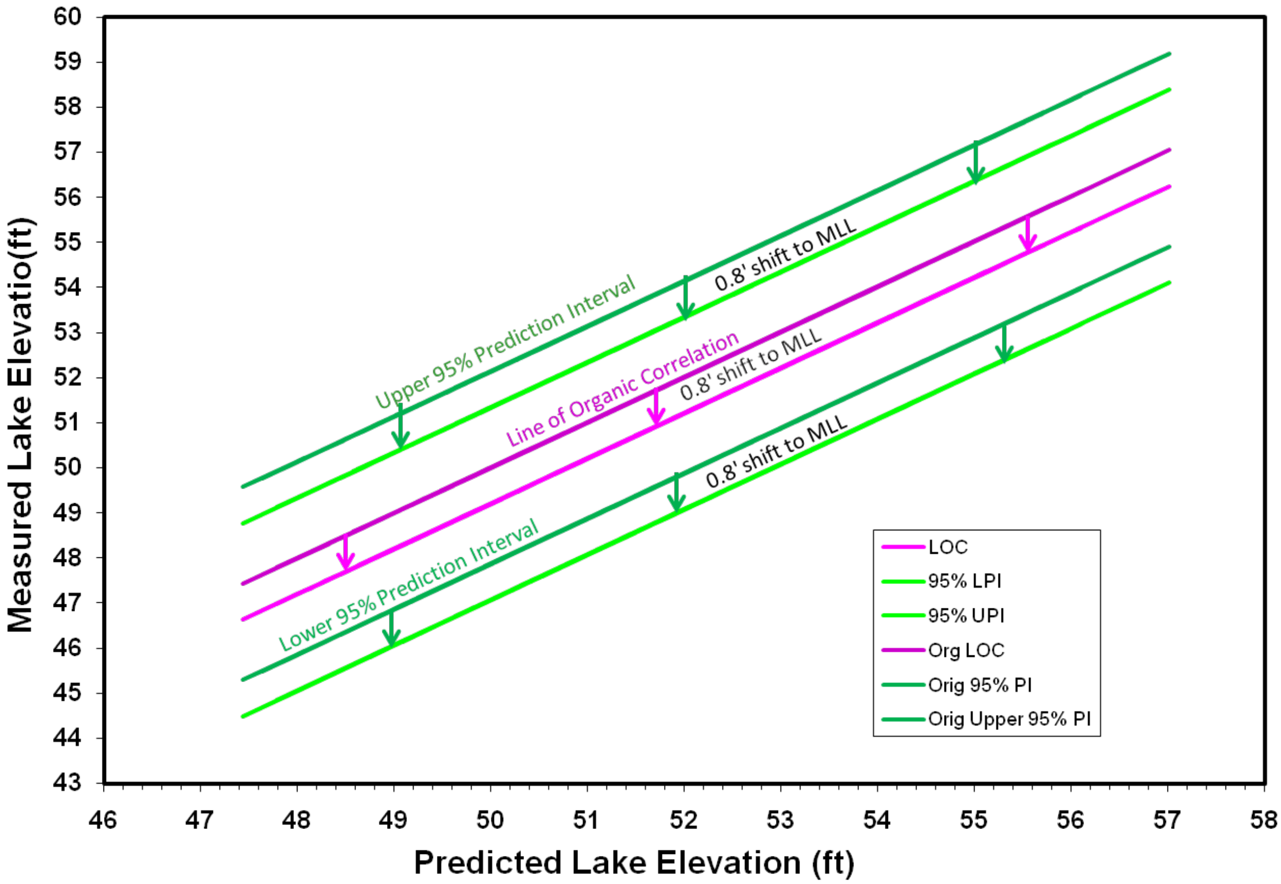

Figure 20. Example of the shifts to the prediction interval and LOC lines to reflect the MLL.

Prediction intervals for an LOC model are calculated for alpha equal to 0.025 (single tail) using the following equation (Helsel and Hirsch, 1992):

$$\hat{y} - ts\sqrt{1 + \frac{1}{n} + \frac{(x_0 - \bar{x})^2}{SS_x}}\ ,\ \hat{y} + ts\sqrt{1 + \frac{1}{n} + \frac{(x_0 - \bar{x})^2}{SS_x}} \qquad \text{(Equation 2)}$$

where

$\hat{y} = b_0 + ssss[r] * b_i * x_i$ *the estimate of y given x_i* (refer to Equation 1)

$t = \frac{\hat{y} - \mu_0}{s/\sqrt{n}}$ *students t distribution*

$s = \sqrt{s^2}$ *standard error of the regression*

$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$ *mean x*

$SS_x = \sum_{i=1}^{n} (x_i - \bar{x}_i) = \sum_{i=1}^{n} x_i^2 - s(\bar{x})^2$ *sums of squares*

The LOC model can also be used to update predicted daily or monthly lake levels which are then combined in an assessment plot along with a shifted LOC and prediction intervals to identify the number of predicted daily or monthly points that plot below the lower 95% prediction interval. For a 95% prediction interval it is expected that 2.5% of the points will plot below the lower prediction interval. However, such a strict interpretation may not be appropriate for MLL status assessments due to the variability in rainfall and the complexities in representing areal rainfall totals with point measurement taken at a gage site. Because of these and other factors such as limitations imposed on calibration to short time periods that may not include the entire range of water levels (extreme highs and record lows), the expected number of predicted water level values that may plot below the 95% prediction interval is doubled, to 5%. The occurrence of more than 5% of the predicted water level values below the lower prediction interval would suggest the lake is lower than can be accounted for based solely on rainfall, and may be affected by changes resulting from groundwater withdrawals or other factor(s).

The MLL for lake Pasadena/Buddy (87.6 feet above NGVD29) is 0.8 feet lower than the modeled Historic P50. For assessment of the MLL status, the intercept of the LOC and prediction intervals were therefore shifted down 0.8 feet. Plotted regression model results versus observed levels for Lake Pasadena/Buddy since January 2010 lie mostly near the top of or above the shifted upper prediction interval (Figure 21), indicating the MLL is being met.

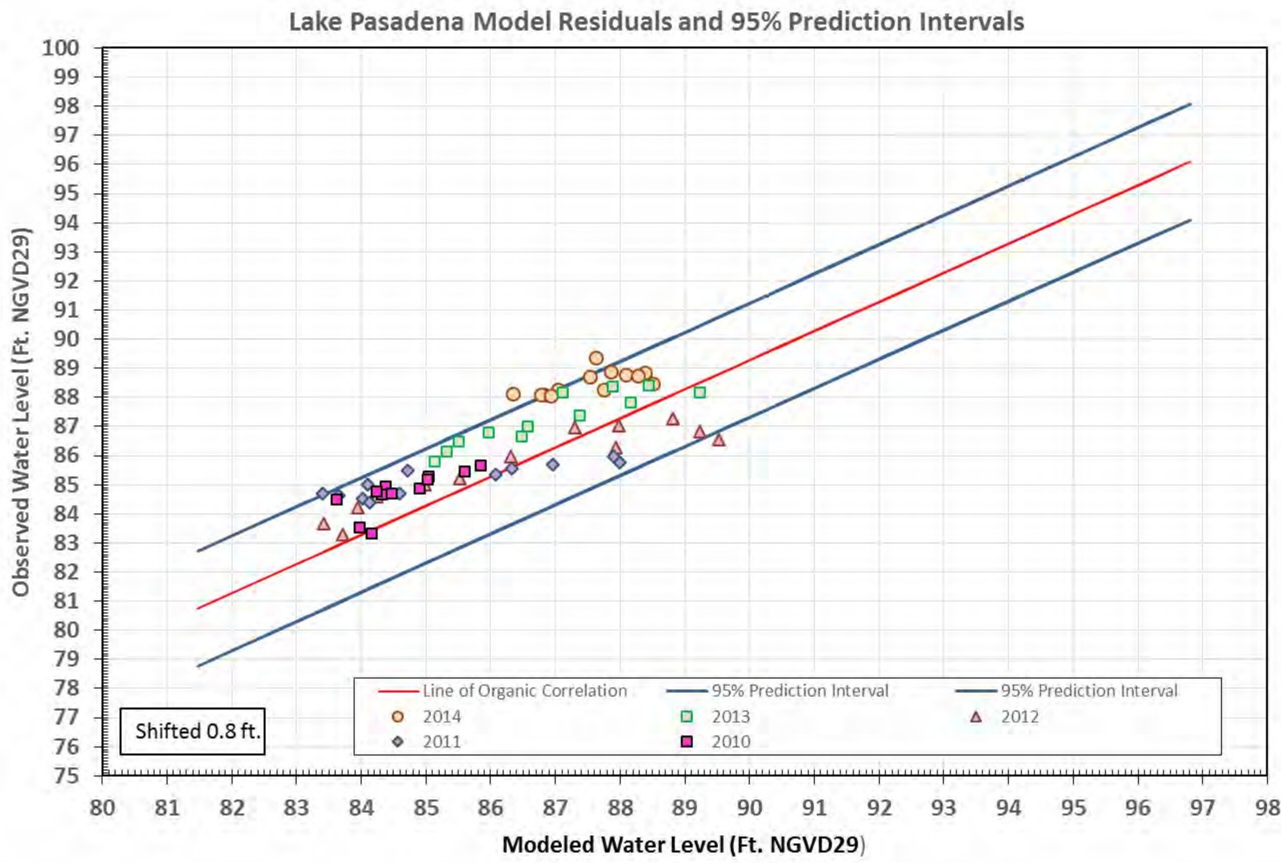

Figure 21. Lake Padgett MLL assessment prediction intervals and model versus observed data since 2007.

Use of observed lake data provides an empirical method for assessing whether the MLL and High Minimum Lake Level (HMLL) are being met. The MLL and HMLL represent long-term exceedance percentiles for the P50 and P10, respectively; so full assessment of the MLL and HMLL with actual percentiles requires data from a long period of record.

Assessment of the MLL and HMLL for Lake Pasadena and Buddy using the record starting in 1984 allows for evaluation of the lake relative to the history of withdrawals in the area which have been variable through time. The cumulative median and cumulative P10 ended with values above the MLL and HMLL, respectively (Figure 22). Because lakes are perched above the Upper Floridan aquifer the High Minimum Lake Level and Minimum Lake Level are also expected to be met for the next 20 year planning period.

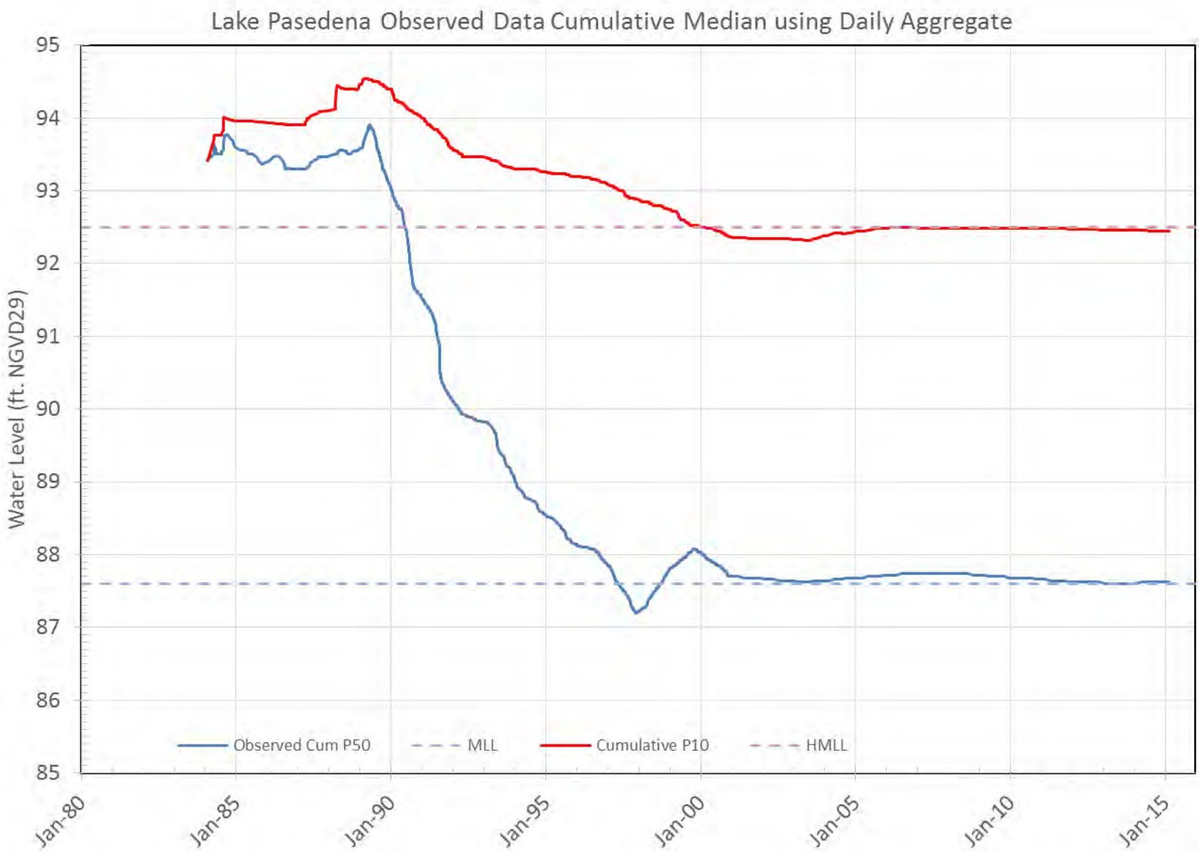

Figure 21. Lake Padgett observed data cumulative median (horizontal red line) and cumulative P10 (horizontal blue line)water levels starting in 1984 compared to the MLL of 87.6 and 92.5 feet, NGVD29 (horizontal red line).

Conclusions

Lakes Pasadena and Buddy are perched lakes (hydraulically separated from the Upper Floridan aquifer) located on the Brooksville Ridge and the period of record water levels represent Historic data. Impact to the lakes water levels from water use from the Upper Floridan aquifer is not a factor in these lakes. Direct withdrawals from the lakes or occurrence of sink holes could influence the lake levels. There are no documented direct withdrawals from the lake. There are no structural alterations to the lake and the lake has a natural high outlet.

Long-term water levels for lakes Pasadena and Buddy were simulated using a rainfall regression technique. A best-fit LOC rainfall regression model was calibrated to water level data from January 2003 through February 28, 2014 using weighted six-year cumulative rainfall sums in inches. Model-predicted water levels closely approximated observed water levels, indicating that Lake Pasadena and Buddy water level fluctuations are consistent with expectations based on variation in rainfall.

The long-term Historic P50 of 88.4 feet NGVD and the Historic P10 of 93.3 feet NGVD developed using model-predicted and observed water levels was used in conjunction with the wetland offset to develop the MLL and HMLL of 87.6 and 92.5 feet NGVD, respectively (Kolasa, 2015).

Assessment of observed lakes Pasadena and Buddy water levels relative to the minimum levels indicates the lake is at the two levels and is in good status. Because the lakes are perched (hydraulically separated from the Upper Floridan aquifer), the MLL and HMLL are expected to be met in the future.

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APPENDIX B

Technical Memorandum

October 15, 2015

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

FROM: Jason Patterson, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Lakes Buddy and Pasadena

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1.0 Introduction

Buddy and Pasadena Lake are located in east-central Pasco County in west-central Florida (Figure 1). Prior to establishment of a Minimum Level (ML), an evaluation of hydrologic changes in the vicinity of the lake is necessary to determine if the water body has been significantly impacted by groundwater withdrawals. The establishment of the ML for Buddy and Pasadena Lakes are not part of this report. This memorandum describes the hydrogeologic setting near the lakes 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 Buddy and Pasadena Lakes

A number of regional groundwater flow models have included the area around Buddy and Pasadena Lake in east-central Pasco 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

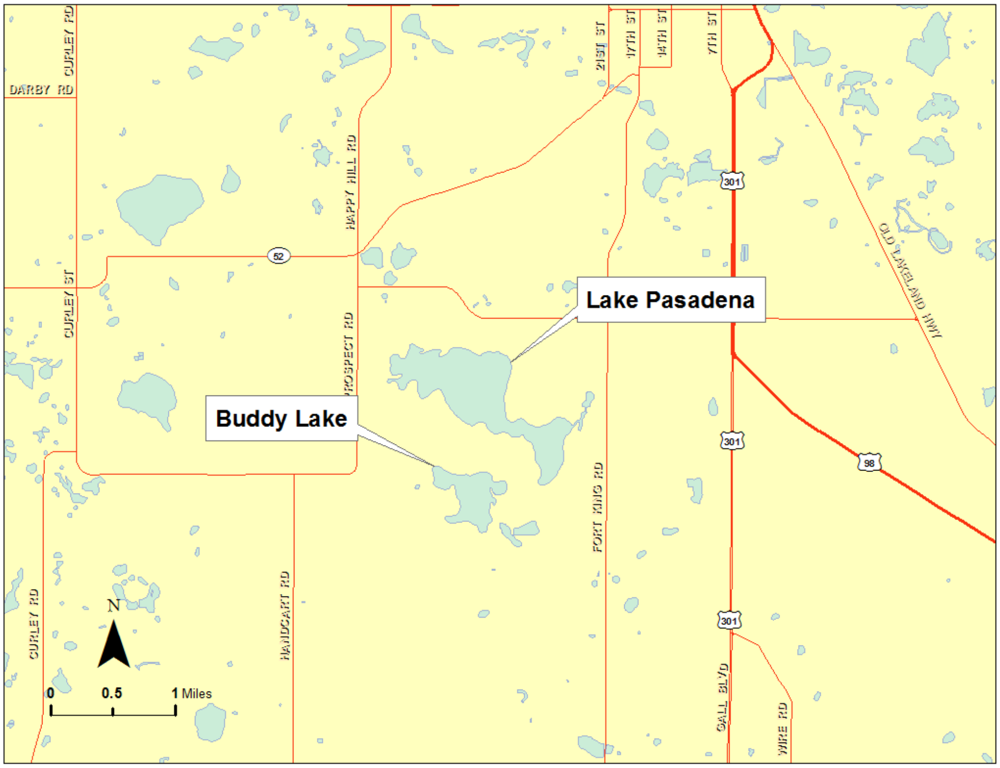

Figure 3. Location of Buddy and Pasadena Lake.

wellfields. The Integrated Northern Tampa Bay Model covers a 4,000 square-mile area of the Northern Tampa Bay region (Figure 2).

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

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

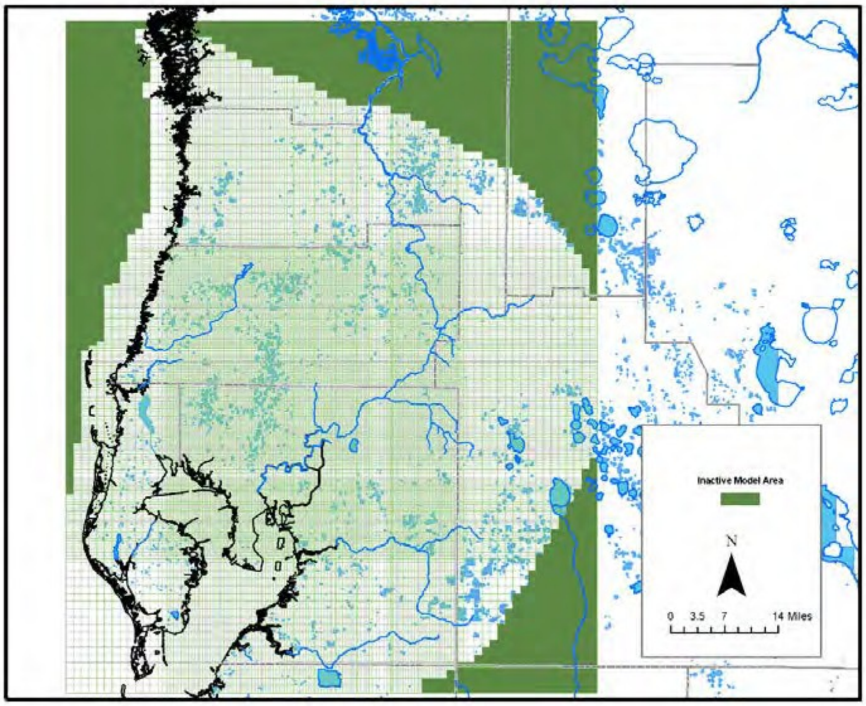

Figure 2. Groundwater grid used in the INTB model

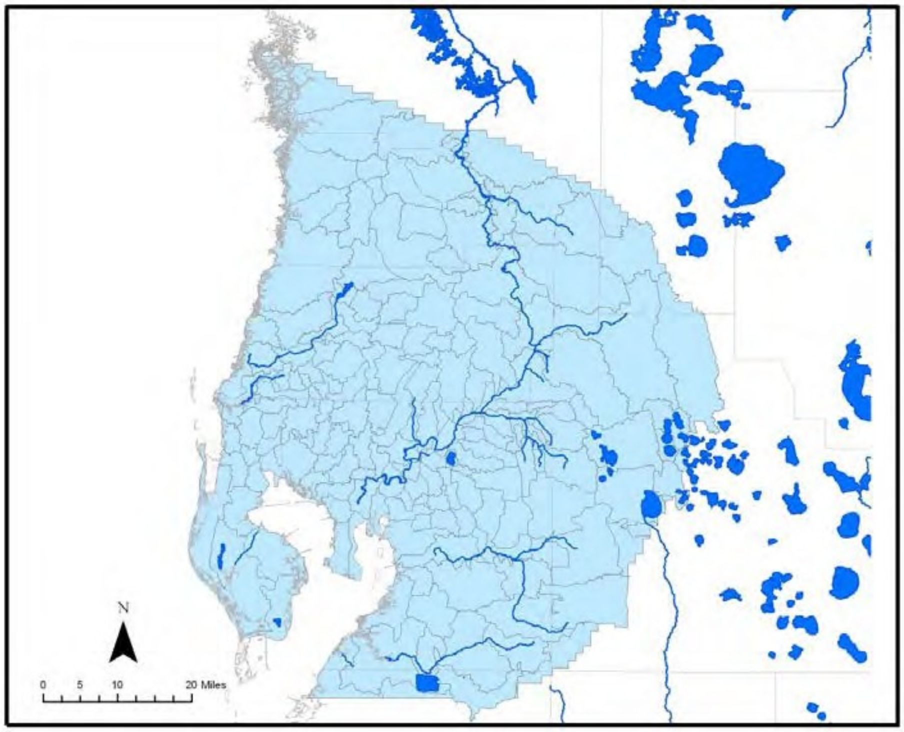

Figure 3. HSPF Subbasins in the INTB model.

flux into the model simulation, construction of an approximate 150,000 river cell package that allows simulation of hydrography from major rivers to small isolated wetlands, and GIS-based definition of land cover/topography. An empirical estimation of ET was also developed to constrain model derived ET based on land use and depth-to-water table relationships.

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

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 Buddy and Pasadena Lake was 0.0 ft and 0.3 ft near both lakes in the Upper Floridan aquifer (Figure 5 and 6). Taking the difference in modeled heads from the TBW recovery pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Buddy and Pasadena Lake was 0.0 ft and 0.1 ft in the Upper Floridan near both lakes (Figure 7 and 8). Table 1 presents the predicted drawdown in the surficial aquifer based on the INTB model results.

Table 1. INTB model results for Buddy and Pasadena 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***
Buddy	0.0	0.0
Pasadena	0.0	0.0
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***
Buddy	0.3	0.1
Pasadena	0.3	0.1

* Average drawdown from model cells intersecting lake