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

September 27, 2017

Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District

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Cover: 2014 Natural Color Imagery of Lake Juanita, (Southwest Florida Water Management District files).

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Introduction

Reevaluation of Minimum Flows and Levels

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

Lake Juanita was selected for reevaluation based on development of modeling tools used to simulate natural water level fluctuations in lake basins that were not available when the previously adopted minimum levels for the lake were developed. Previously adopted levels for Lake Juanita were also reevaluated to support ongoing District assessment of minimum flows and levels and the need for additional recovery in the Northern Tampa Bay Water Use Caution Area (NTB WUCA), a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Following Governing Board approval on September 27, 2016, the revised levels became effective on March 22, 2017.

Minimum Flows and Levels Program Overview

Legal Directives

Section 373.042, Florida Statutes (F.S.), directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels (MFLs) for lakes, wetlands, rivers and aquifers. Section 373.042(1)(a), F.S., states that "[t]he minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Section 373.042(1)(b), F.S., defines the minimum water level of an aquifer or surface water body as "…the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." MFLs are established and used by the Southwest Florida Water Management District (SWFWMD or District) for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction and use of surface water management systems.

Established MFLs are key components of resource protection, recovery and regulatory compliance, as Section 373.0421(2) F.S., requires the development of a recovery or prevention strategy for water bodies "[i]f the existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level established pursuant to S. 373.042." Section 373.0421(2)(a), F.S., requires that recovery or prevention strategies be developed to: "(a) [a]chieve recovery to the established minimum flow or level as soon as practicable; or (b) [p]revent the existing flow or level from falling below the established minimum flow or level." Periodic reevaluation and, as necessary, revision of established minimum flows and levels are required by Section 373.0421(3), F.S.

Minimum flows and levels are to be established based upon the best information available, and when appropriate, may be calculated to reflect seasonal variations (Section 373.042(1), F.S.). Also, establishment of MFLs is to involve consideration of, and at the governing board or department's discretion, may provide for the protection of nonconsumptive uses (Section 373.042(1), F.S.). Consideration must also be given to "…changes and structural alterations to watersheds, surface waters and aquifers, and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer…", with the requirement that these considerations shall not allow significant harm caused by withdrawals (Section 373.0421(1)(a), F.S.). Sections 373.042 and 373.0421 provide additional information regarding the prioritization and scheduling of minimum flows and levels, the independent scientific review of scientific or technical data, methodologies, models and scientific and technical assumptions employed in each model used to establish a minimum flow or level, and exclusions that may be considered when identifying the need for MFLs establishment.

The Florida Water Resource Implementation Rule, specifically Rule 62-40.473, Florida Administrative Code (F.A.C.), provides additional guidance for the establishment of MFLs, requiring that "…consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic and wetlands ecology, including: a) Recreation in and on the water; b) Fish and wildlife habitats and the passage of fish; c) estuarine resources; d) Transfer of detrital material; e) Maintenance of freshwater storage and supply; f) Aesthetic and scenic attributes; g) Filtration and absorption of nutrients and other pollutants; h) Sediment loads; i) Water quality; and j) Navigation."

Rule 62-40.473, F.A.C., also indicates that "[m]inimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area as provided in Section 373.042(1), F.S." It further notes that, "…a minimum flow or level need not be expressed as multiple flows or levels if other resource protection tools, such as reservations implemented to protect fish and wildlife or public health and safety, that provide equivalent or greater protection of the hydrologic regime of the water body, are developed and adopted in coordination with the minimum flow or level." The rule also includes provision addressing: protection of MFLs during the construction and operation of water resource projects; the issuance of permits pursuant to Section 373.086 and Parts II and IV of Chapter 373, F.S.; water shortage declarations; development of recovery or prevention strategies, development and updates to a minimum flow and level priority list and schedule, and peer review for MFLs establishment.

Development of Minimum Lake Levels in the Southwest Florida Water Management District

Programmatic Description and Major Assumptions

Since the enactment of the Florida Water Resources Act of 1972 (Chapter 373, F.S.), in which the legislative directive to establish MFLs originated, and following subsequent modifications to this directive and adoption of relevant requirements in the Water Resource Implementation Rule, the District has actively pursued the adoption, i.e., establishment of MFLs for priority water bodies. The District implements established MFLs primarily through its water supply planning, water use permitting and environmental resource permitting programs, and through the funding of water resource and water supply development projects that are part of a recovery or prevention strategy. The District's MFLs program addresses all relevant requirements expressed in the Florida Water Resources Act and the Water Resource Implementation Rule.

A substantial portion of the District's organizational resources has been dedicated to its MFLs Program, which logistically addresses six major tasks: 1) development and reassessment of methods for establishing MFLs; 2) adoption of MFLs for priority water bodies (including the prioritization of water bodies and facilitation of public and independent scientific review of proposed MFLs and methods used for their development); 3) monitoring and MFLs status assessments, i.e., compliance evaluations; 4) development and implementation of recovery strategies; 5) MFLs compliance reporting; and 6) ongoing support for minimum flow and level regulatory concerns and prevention strategies. Many of these tasks are discussed or addressed in this minimum levels report; additional information on all tasks associated with the District's MFLs Program is summarized by Hancock *et al.* (2010).

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

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

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

Consideration of Changes and Structural Alterations and Environmental Values

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

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

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

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

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

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

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria are used to develop minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. For Category 3 lakes, six significant change standards are typically developed. Other available information, including potential changes in the coverage of herbaceous wetland and submersed aquatic plants is also considered when establishing minimum levels for Category 3 Lakes. The standards and other available information are associated with the environmental values identified for consideration in Rule 62-40.473, F.A.C., when establishing MFLs (Table 1). The specific standards and other information evaluated to support development of revised minimum levels for Lake Juanita are provided in subsequent sections of this report. More general information on the standards and other information used for consideration when developing minimum lake levels is available in the documents identified in the preceding sub-section of this report.

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

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

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

Lake Classification

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

According to Chapter 40D-8.624, F.A.C., Lake Juanita meets the classification as a Category 2 lake: For comparison purposes, the standards associated with Category 3 lakes described below will be developed in a subsequent section of this report.

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

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

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

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

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

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

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

Herbaceous Wetland Information is taken into consideration to determine the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (i.e., basin area with a water depth of four 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. Using methods described in Caffrey (2006), mean secchi disk depth (SD) is used to calculate the maximum depth of colonization (MDC) for aquatic plants using regression equation log(MDC) – 0.66log(SD) + 0.30, where all values are represented in meters. The MDC depth is then used to calculate the total acreage at each lake stage that is available for aquatic plant colonization.

Although potential changes in the coverage of herbaceous wetland vegetation and aquatic plants associated with use of the standards is taken into consideration in the development of Minimum Levels, there is no significant change standard to determine a threshold for preventing significant harm to fringing non-cypress wetlands. Based on the Cypress Wetland Standard for Category 1 and 2 lakes, however, a Wetland Offset Elevation was developed for Category 3 Lakes to provide protection for non-cypress fringing wetlands.

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

Minimum Levels

Two Minimum Levels and two Guidance Levels are typically established for lakes. Upon completion of a public input/review process and, if necessary completion of an independent scientific review, either of which may result in modification of the revised levels, the levels are adopted by the District Governing Board into Chapter 40D-8, F.A.C. (see Hancock *et al.* 2010 for more information on the adoption process). The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29), 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 (Table 5).

Development of Minimum and Guidance Levels for Lake Juanita

Lake Setting and Description

Watershed

Lake Juanita is located in Northwest Hillsborough County (Section 22, Township 27 South, Range 17 East) and within the Brooker Creek Watershed (Figure 1 & Figure 2). The lake has a drainage basin area of 148.5 acres (Figure 3).

Surface water inflow to Lake Juanita occurs as overland flow from the lake's small drainage basin, and as overflow from Lake Eva and a series of wetlands to the northwest. Discharge from Lake Juanita can occur on the western shore of the lake via a series of open ditches and culverts passing under Crawley Road and into Rainbow Lake (Figure 4). Refer to Appendix A for details.

The lowest finished floor elevation on Lake Juanita is a residence with an elevation of 43.75 NAVD88 (44.71 NGVD29). The lowest lake side structure on Lake Juanita is a wooden dock with an elevation of 40.85 NAVD88 (41.81 NGVD29). These elevations are from the survey, dated 12/18/2013.

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

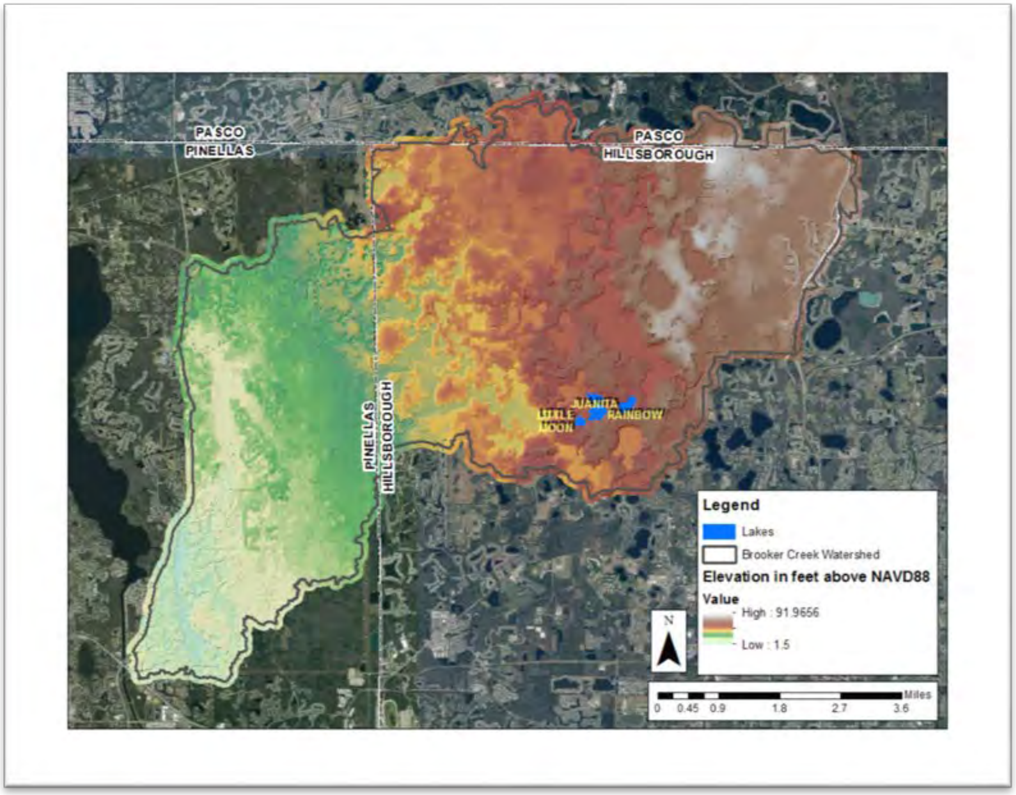

Figure 2. Brooker Creek Watershed Delineation and Topography.

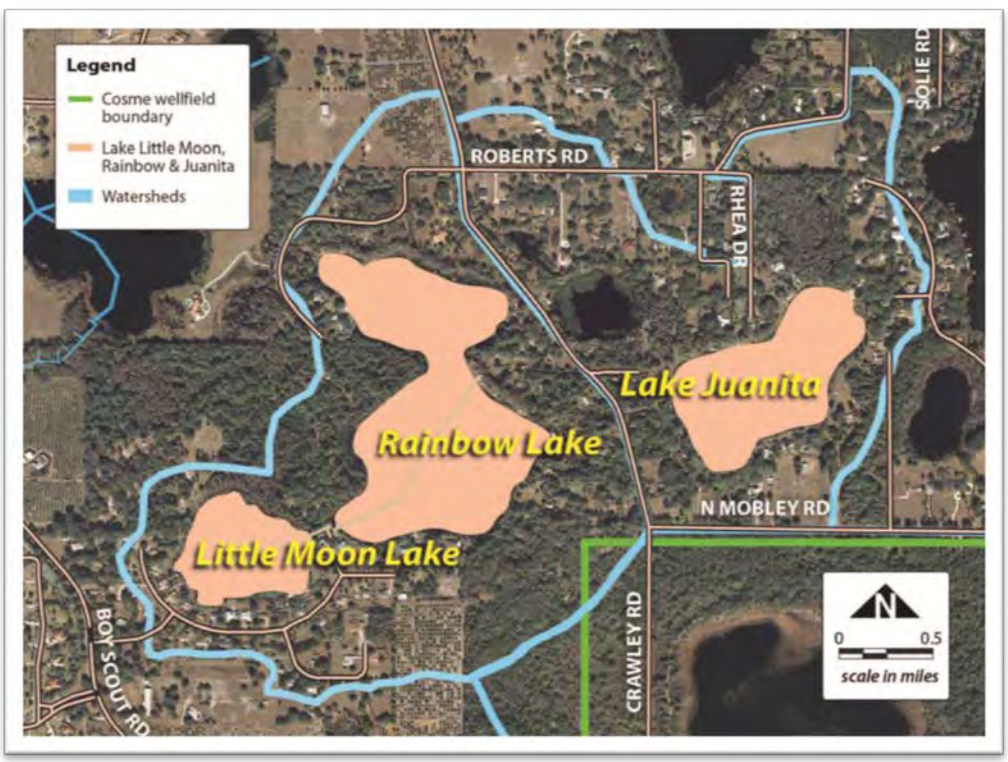

Figure 3. Drainage Basin for Lakes Juanita, Rainbow, and Little Moon.

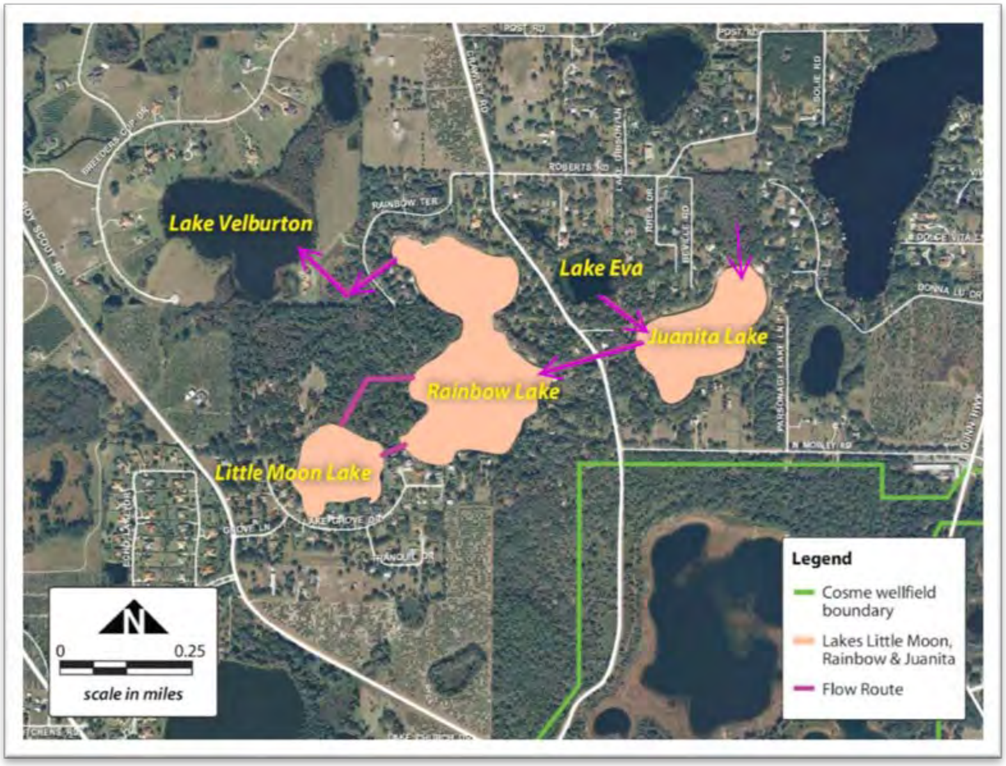

Figure 4. In-flow and Out-flow from Lake Juanita.

Site Specific Details

Lake Juanita is located just north of the Cosme Wellfield, a Tampa Bay Water public water supply production facility that has been in service since 1930 (the oldest public supply wellfield in the District). Therefore, Lake Juanita and other adjacent lakes have been subjected to the effects of groundwater withdrawals longer than any other lakes in the District. Monthly withdrawals steadily climbed to as much as 21 million gallons per day (mgd) in 1962, but current withdrawal rates at the wellfield have typically been an annual average of 6mgd.

Land Use Land Cover

An examination of the 1950 and 2011 Florida Land Use, Cover and Forms Classification System (FLUCCS) maps revealed that there have been considerable changes to the landscape in the vicinity during this period; specifically, the dominant land forms. Land use in 1950 was primarily agriculture and upland forests (Figure 5). By 2011, much of the agriculture and upland forest had been replaced by urban land uses (Figure 6). Aerial photography chronicles landscape changes to the immediate lake basin from 1938 to 1984; (Figures 7 through 10).

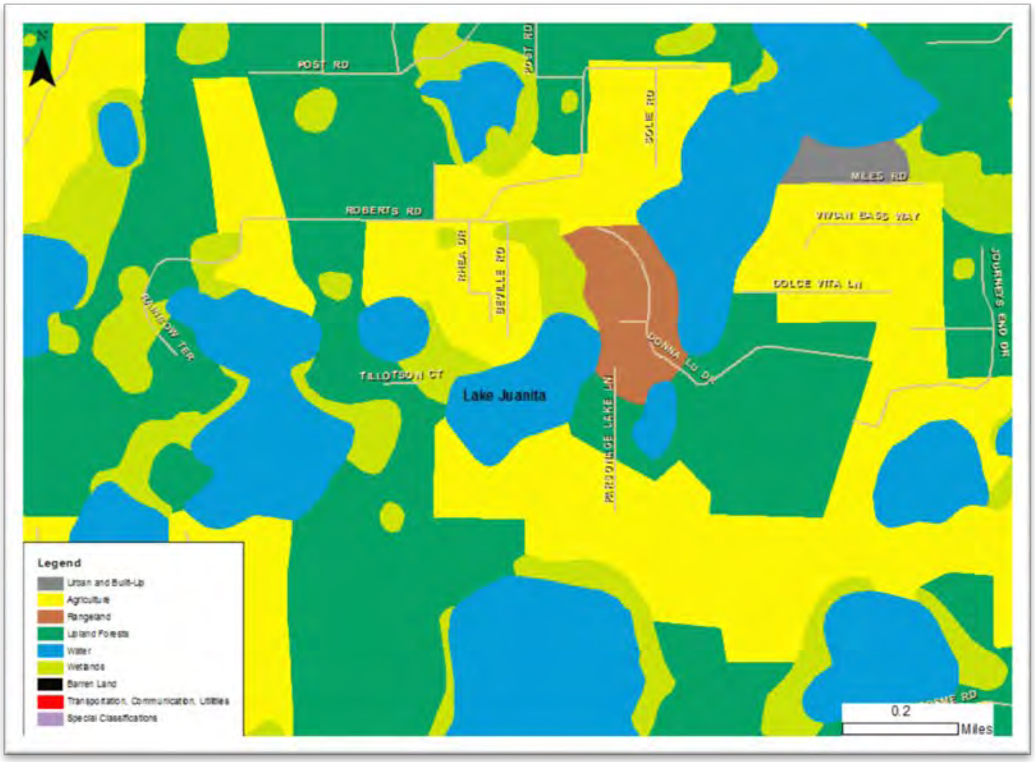

Figure 5. 1950 Land Use Land Cover Map of the Lake Juanita Vicinity.

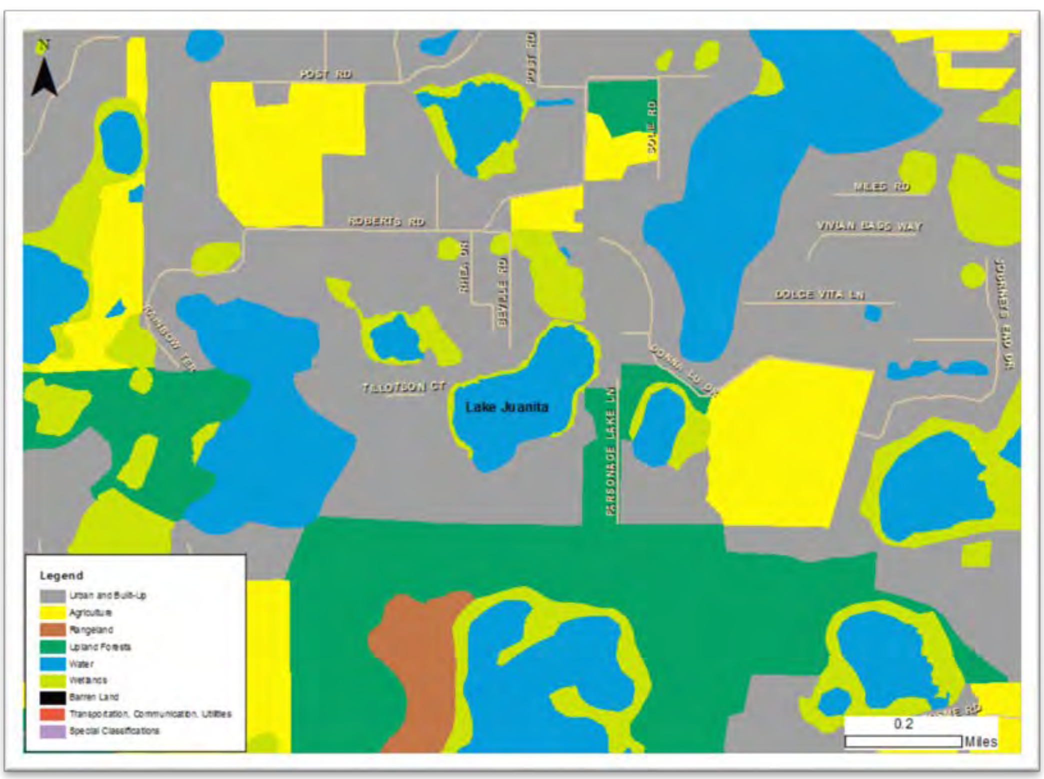

Figure 6. 2011 Land Use Land Cover Map of the Lake Juanita Vicinity.

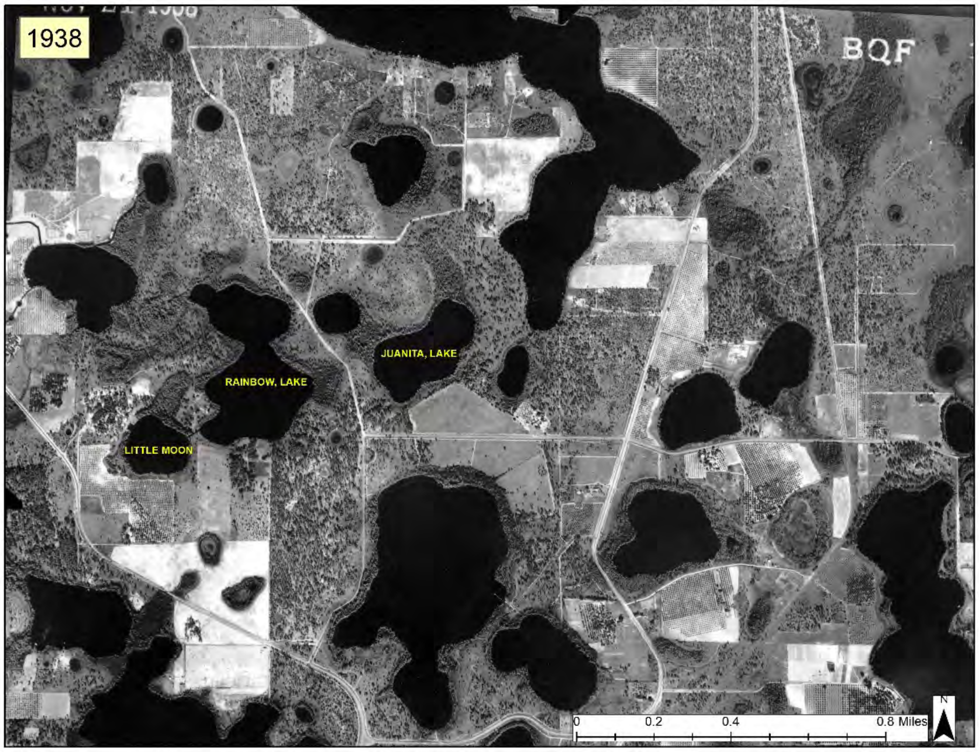

Figure 7. 1938 Aerial Photograph of Lake Juanita.

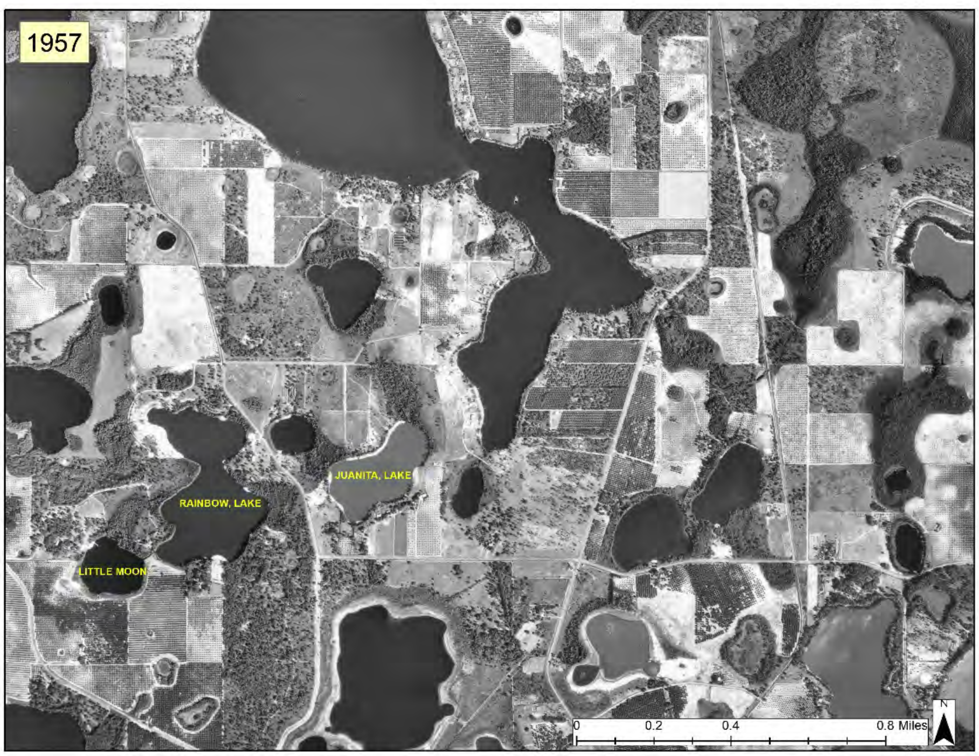

Figure 8. 1957 Aerial Photograph of Lake Juanita.

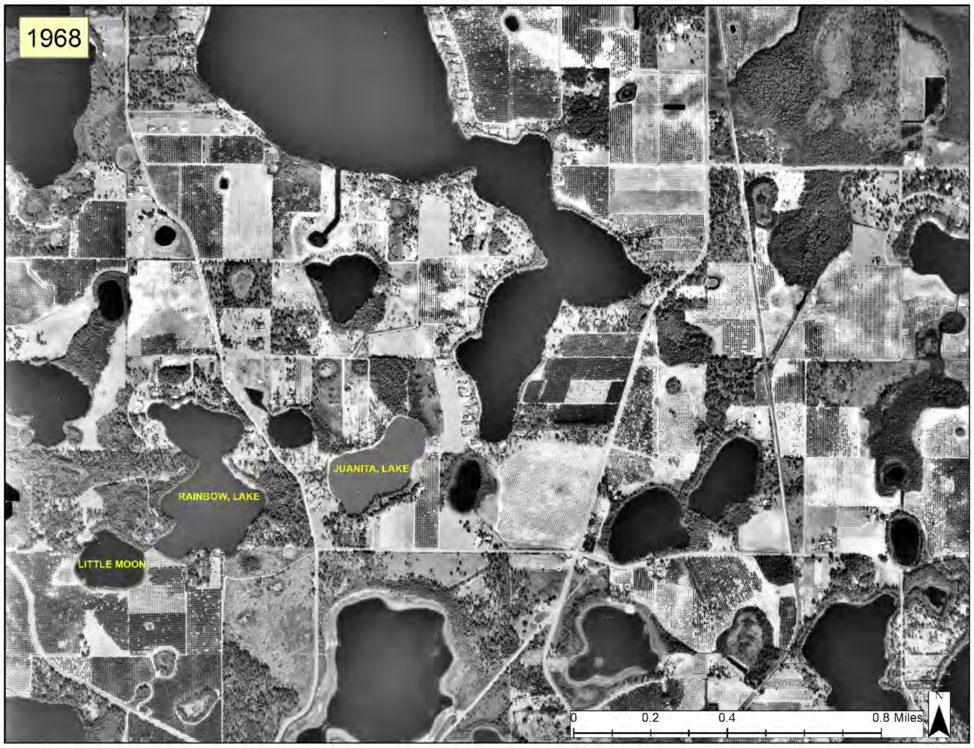

Figure 9. 1968 Aerial Photograph of Lake Juanita.

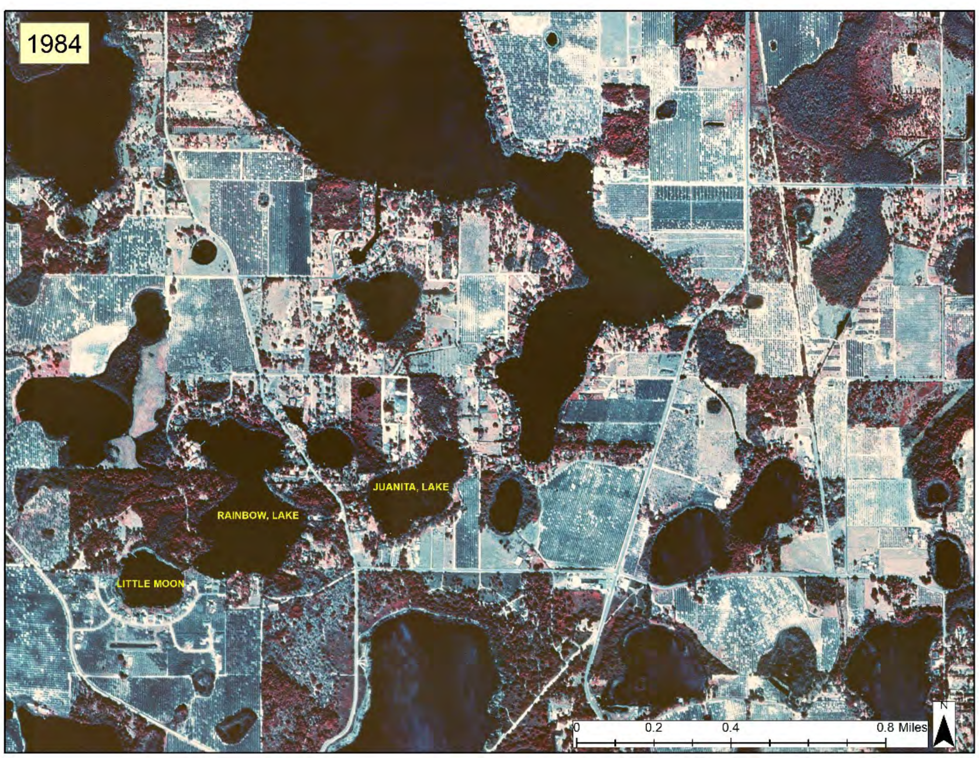

Figure 10. 1984 Aerial Photograph of Lake Juanita.

Bathymetry Description and History

One foot interval bathymetric data gathered from field surveys resulted in lake-bottom contour lines from 21 ft. to 43 ft. (Figure 11). These data revealed that the lowest lake bottom contour (21 ft.) is located in a small area on the western edge of the lake, and at the highest elevation (43 ft.) would include the northern wetlands, Lake Eva to the northwest, and would be connected to Rainbow Lake. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

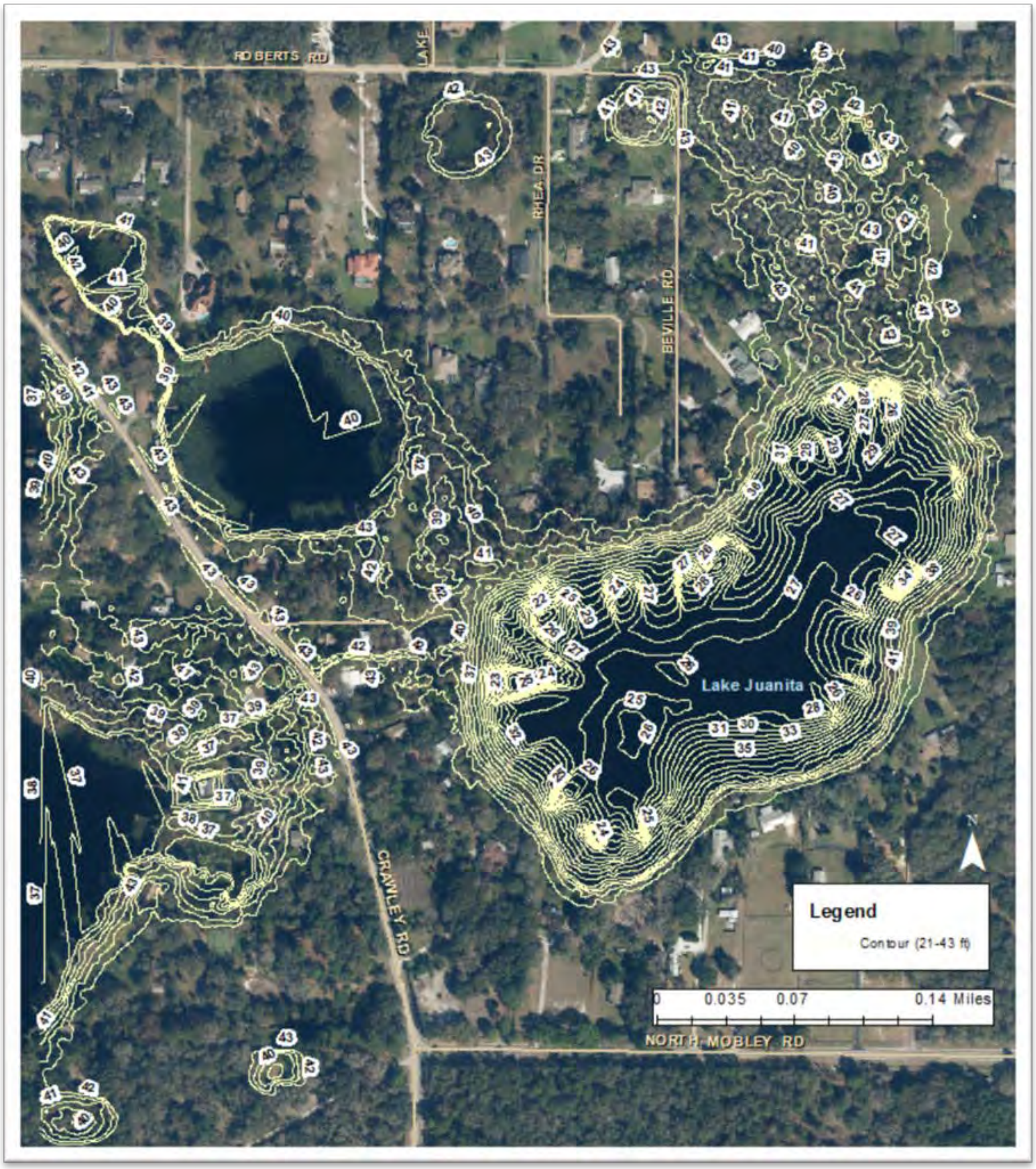

Figure 11. Lake Juanita Contours on a 2014 Natural Aerial Photograph.

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Lake Juanita from the District's Water Management Information System (SID 827848, SID 827032, and SID 19806) (Figures 12 and 13). The District continues to monitor the water levels on a monthly basis. Data has been collected since July 7, 1971. The highest lake stage elevation on record was 43.24 ft. and occurred on September 27, 1978. The lowest lake stage elevation on record was 32.09 ft. and occurred on May 28, 2002. Figure 14 shows the wet (1984) and dry (1994) historic aerial photographs of Lake Juanita.

Figure 12. Lake Juanita Gauge SID 19806 on May 13, 2009.

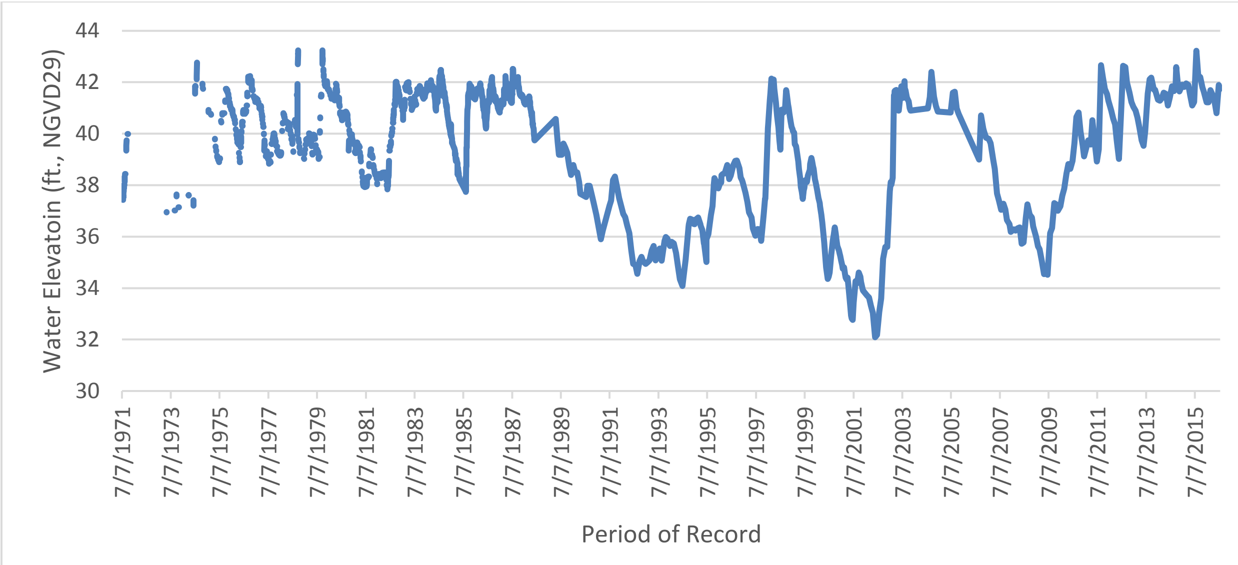

Figure 13. Lake Juanita Period of Record Stage Data (SID 827848, SID 827032, & SID 19806).

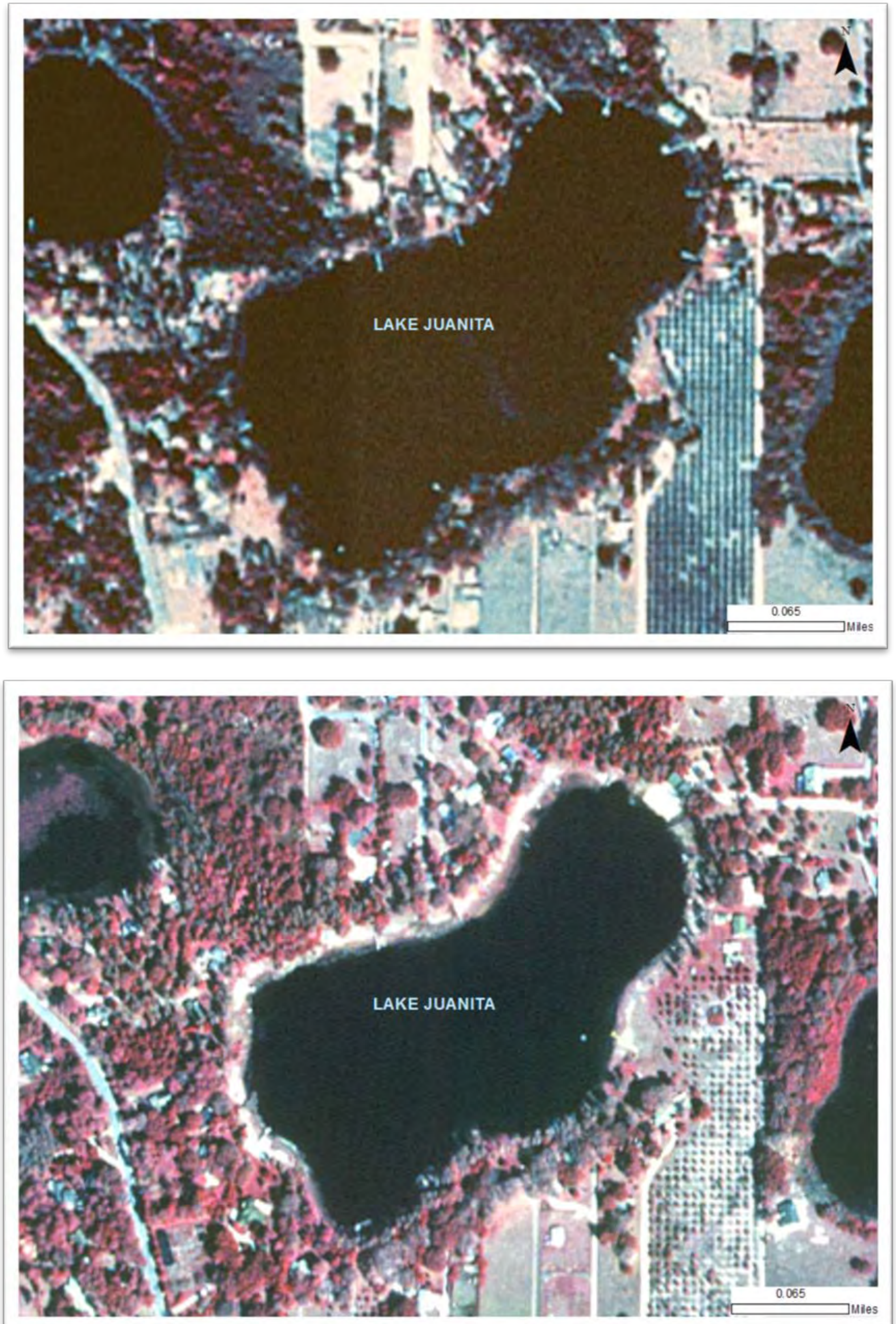

Figure 14. Wet (1984) and Dry (1994) Historic Aerial Photographs of Lake Juanita.

Historical Management Levels

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

The District Governing Board approved Guidance and Minimum levels for Lake Juanita (Table 2) and subsequently were adopted into Chapter 40D-8, Florida Administrative Code in July 2000 using the methodology for Category 2 Lakes described in SWFWMD (1999a and 1999b). Revised levels (Table 3) have since been incorporated into rule and have replaced those listed below in Table 2.

Table 2. Guidance levels adopted July 2000 for Lake Juanita:

Level	Elevation (ft., NGVD)
Ten Year Flood Guidance Level	43.8
High Guidance Level (P10)	41.7
High Minimum Level	41.7
Minimum Level	40.7
Low Guidance Level	39.6

Methods, Results and Discussion

The revised Minimum and Guidance Levels in this report were developed for Lake Juanita using the methodology for Category 2 lakes described in Chapter 40D-8, F.A.C. The levels, along with lake surface area for each level, are listed in Table 3 along with other information used for development of the revised levels. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

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

Levels	**Elevation in Feet NGVD 29**	**Lake Area (acres)**
Lake Stage Percentiles		
Historic P10 (1946 to 2013)	41.8	38.2
Historic P50 (1946 to 2013)	40.3	25.9
Historic P90 (1946 to 2013)	38.8	22.7
Revised Normal Pool and Control Point		
Normal Pool	43.5	>47.6
Control Point	41.2	34.0
Significant Change Standards		
Lake Mixing Standard*	21.3	0.001
Dock-Use Standard*	41.0	32.5
Basin Connectivity Standard *	43.5	>47.6
Species Richness Standard*	38.3	22.1
Aesthetics Standard*	38.8	22.7
Recreation/Ski Standard*	N/A	N/A
Cypress Standard	41.7	37.6
Wetland Offset Elevation*	39.5	23.6
Other		
Lowest Floor Slab Elevation	44.7	>47.6
Revised Minimum and Guidance Levels		
High Guidance Level	41.8	38.2
High Minimum Lake Level	41.8	38.2
Minimum Lake Level	40.3	25.9
Low Guidance Level	38.8	22.7

N/A - not appropriate; * Developed for comparative purposes only; not used to establish Minimum Levels

Bathymetry

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

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

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

The DEM created from the combined elevation data sets was used to develop topographic contours of the lake basin and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments (selected stage-area-volume results are presented in Figure 15).

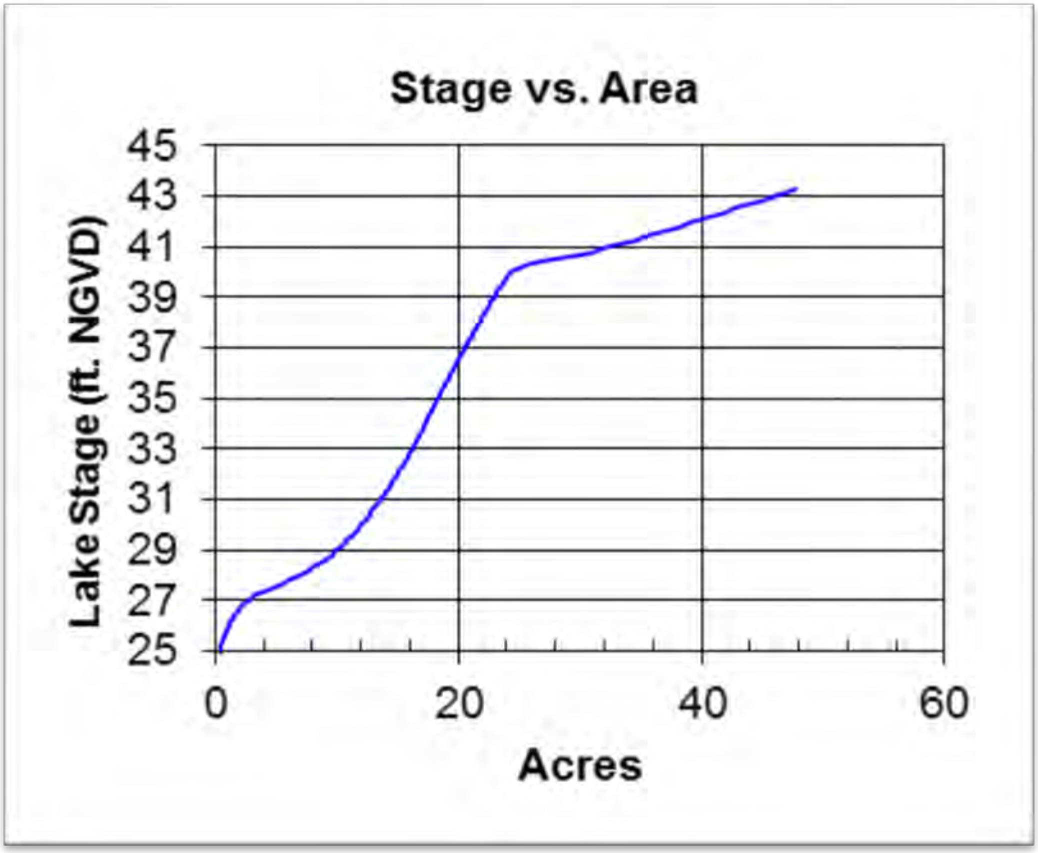

Figure 15. Lake Stage (Ft. NGVD29) to Surface Area (Acres).

Development of Exceedance Percentiles

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

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

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

A combination of model data produced a hybrid model which resulted in a 68 year (1946-2013) Historic water level record. Based on this hybrid data, the Historic P10 elevation, i.e., the elevation of the lake water surface equaled or exceeded ten percent of the time, was 41.8 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 40.3 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 38.8 ft. (Figure 16 and Table 3).

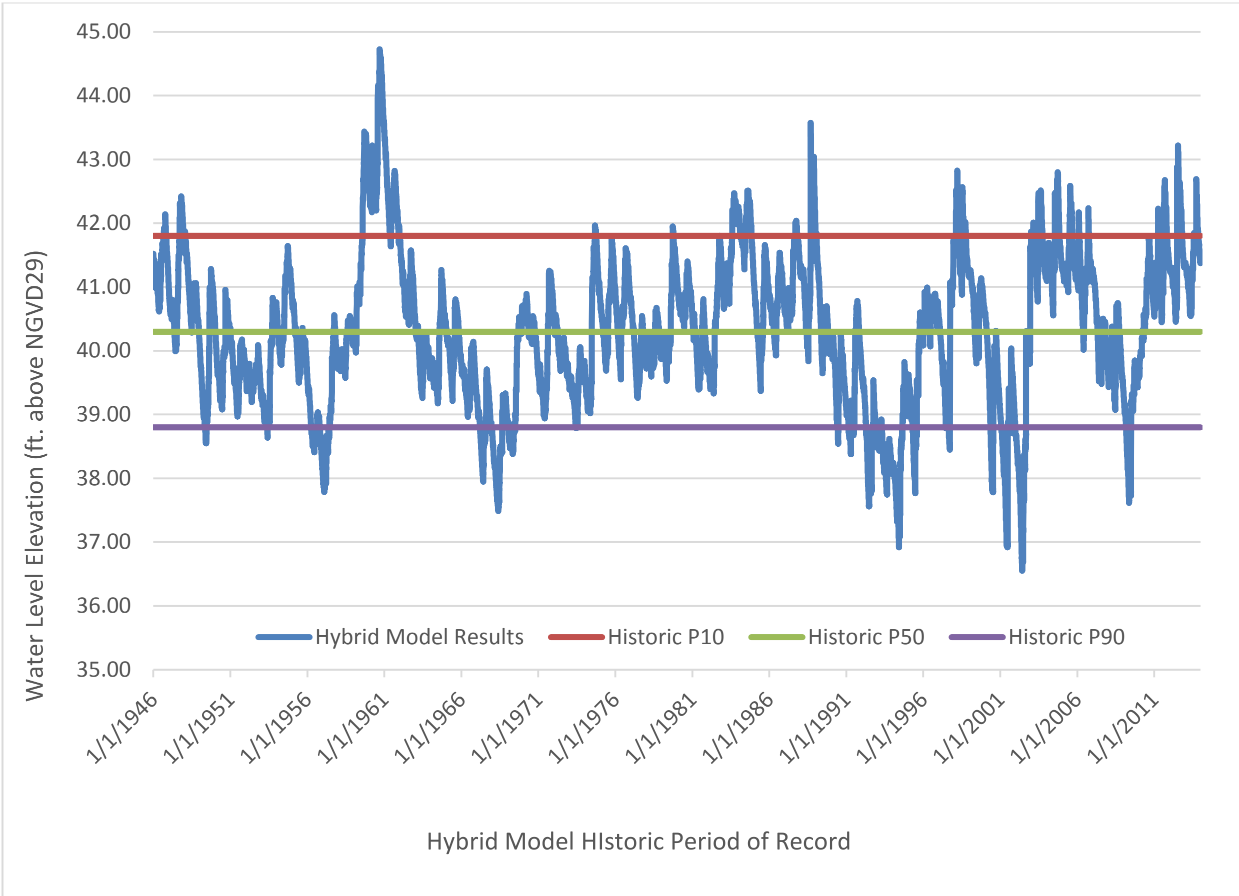

Figure 16. Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

Normal Pool Elevation and Additional Information

The Normal Pool elevation, a reference elevation used for development of minimum lake and wetland levels, is established based on the elevation of hydrologic indicators of sustained inundation. The inflection points (buttress swelling) and moss collars on the trunks of cypress trees have been shown to be reliable biologic indicators of hydrologic Normal Pool (Carr, et al. 2006). Five cypress trees were measured for buttress swelling on the lake in March 2013 (Table 4). Based on the survey of these biologic indicators, the Normal Pool elevation was established at 43.5 ft. The likely reason for the large spread in the field derived HNP indicators is variable subsidence around the lake; this may result in a calculated HNP that is low, but it is based on the best available information. Also, Lake Juanita is a Category 2 lake and thus, the rule requires we use our best estimate of HNP.

Table 4. Summary statistics for 2016 hydrologic indicator measurements used for establishing normal pool elevations for Lake Juanita.

Summary Statistic	Number (N) or Elevation
N	5
Median	43.5
Mean	43.4
Maximum	43.8
Minimum	43.1
Range	0.7

Additional information to consider in establishing Minimum and Guidance Levels are the Control Point elevation and the lowest building floor (slab) elevation within the lake basin (determined by field survey data). The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system that can control the lake water level fluctuations at the high end. Based on survey data, it was determined that the highest spot in the outflow conveyance system is in the ditch at the west side of the lake and serves as the control point at 41.2 ft. The lowest finished floor elevation on Lake Juanita is at an elevation of 44.71 NGVD29 (43.75 NAVD88).

Revised Guidance Levels

The High Guidance Level is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake, and is established using Historic data if it is available, or is estimated using the Current P10, the Control Point elevation and the Normal Pool elevation. Based on the availability of Historic data developed for Lake Juanita, the revised High Guidance Level was established at the Historic P10 elevation, 41.8 ft. The High Guidance Level has been exceeded several times; for example, the highest recorded level for the lake was a maximum level of 43.24 ft. in September 1978. (Figure 12).

The Low Guidance Level is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, reference lake water regime statistics. Reference lake water regime statistics are used when adequate Historic or Current data are not available. Based on the availability of Historic data for Lake Juanita, the revised Low Guidance Level was established at the Historic P90 elevation, 38.8 ft. The gaged period of record indicates the lowest recorded elevation was 32.09 ft., below the Low Guidance Level, in May 2002. (Figure 12).

Significant Change Standards

Category 3 significant change standards including a Lake Mixing Standard, Dock-Use Standard, Basin Connectivity Standard, Species Richness Standard, Aesthetics Standard, Recreation/Ski Standard, and area available for herbaceous wetlands and submerged aquatic macrophytes were established or considered for Lake Juanita, where appropriate. Each standard was previously defined in the Lake Classification section of this report. Each standard was evaluated for minimum levels development for Lake Juanita and presented in Table 3.

- The Mixing Standard was established at 21.3 ft. due to the dynamic ratio (basin slope) shifting from <0.8 to >0.8 ft., indicating that potential changes in basin susceptibility to wind-induced sediment re-suspension.
- The Dock-Use Standard was established at 41.0 ft., considering a two foot draft at the ends of the docks.
- The Basin Connectivity Standard was set at 43.5 ft.; this is the elevation the lake would need to rise to in order to be connected to Lake Eva to the northwest and allowing for enough clearance for non-powerboat water crafts to pass.
- The Species Richness Standard was established at 38.3 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- The Aesthetic-Standard for Lake Juanita was established at the Low Guidance Level elevation of 38.8 ft.
- The Recreation/Ski Standard was not applicable as the area of the lake does not provide an adequate sized ski corridor.
- The Wetland Offset was calculated to be 39.5 ft.
- Review of changes in potential herbaceous wetland area associated with change in lake stage (Figure 17), and potential change in area available for aquatic macrophyte colonization (Figure 18) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development.

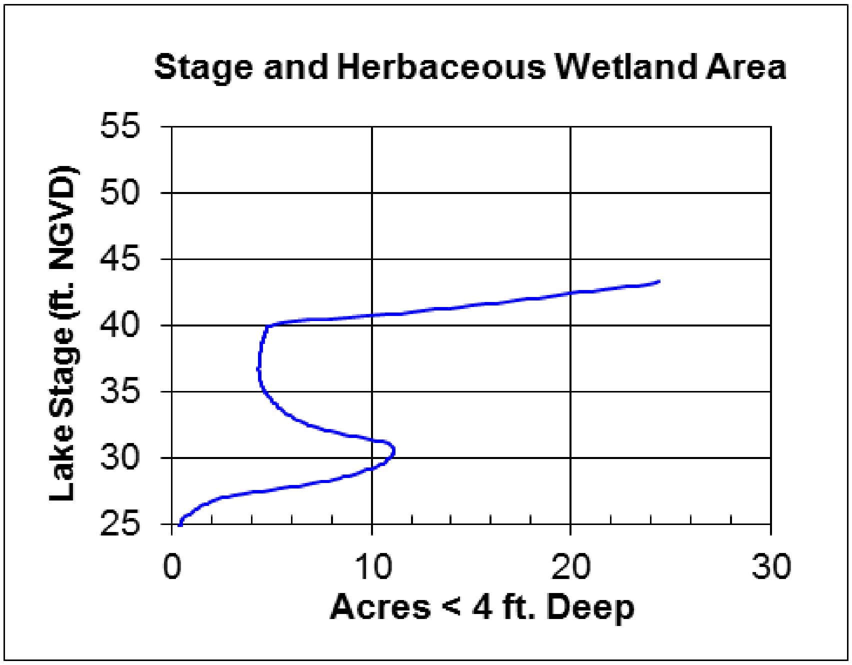

Figure 17. Lake Stage Compared to Available Herbaceous Wetland Area.

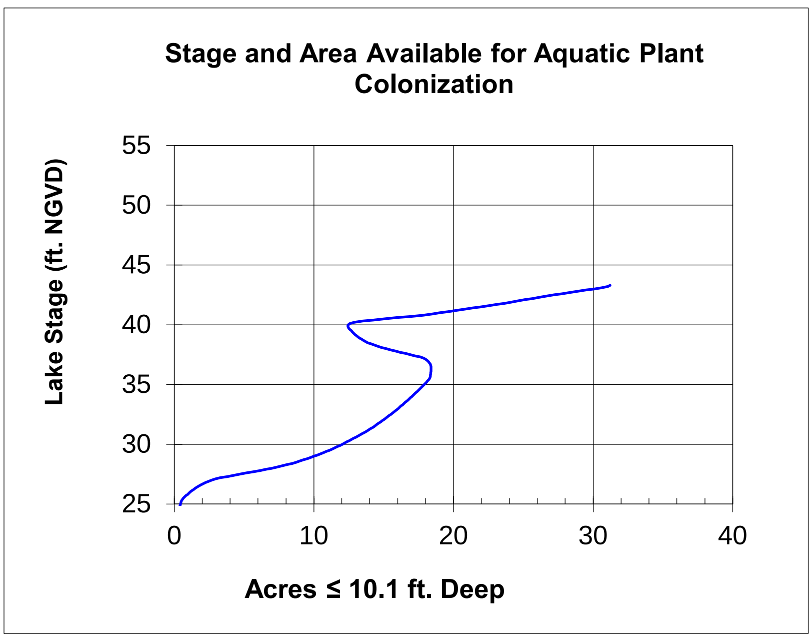

Figure 18. Lake Stage and Area Available for Aquatic Plant Colonization.

Revised Minimum Levels

The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. For a Category 2 lake, the Minimum Lake Level is established at median (P50) of the Historic water level. In the case of Lake Juanita, the revised minimum level is 40.3 ft.

The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. For a Category 2 lake, the High Minimum Lake Level is established at the High Guidance Level (P10). Therefore, the revised High Minimum Lake Level for Lake Juanita is established at 41.8 ft.

Revised Minimum and Guidance levels for Lake Juanita are plotted on the Historic water level record Figure 19. To illustrate the approximate locations of the lake margin when water levels equal the revised minimum levels, the levels are imposed onto a 2014 natural color aerial photograph in Figure 20.

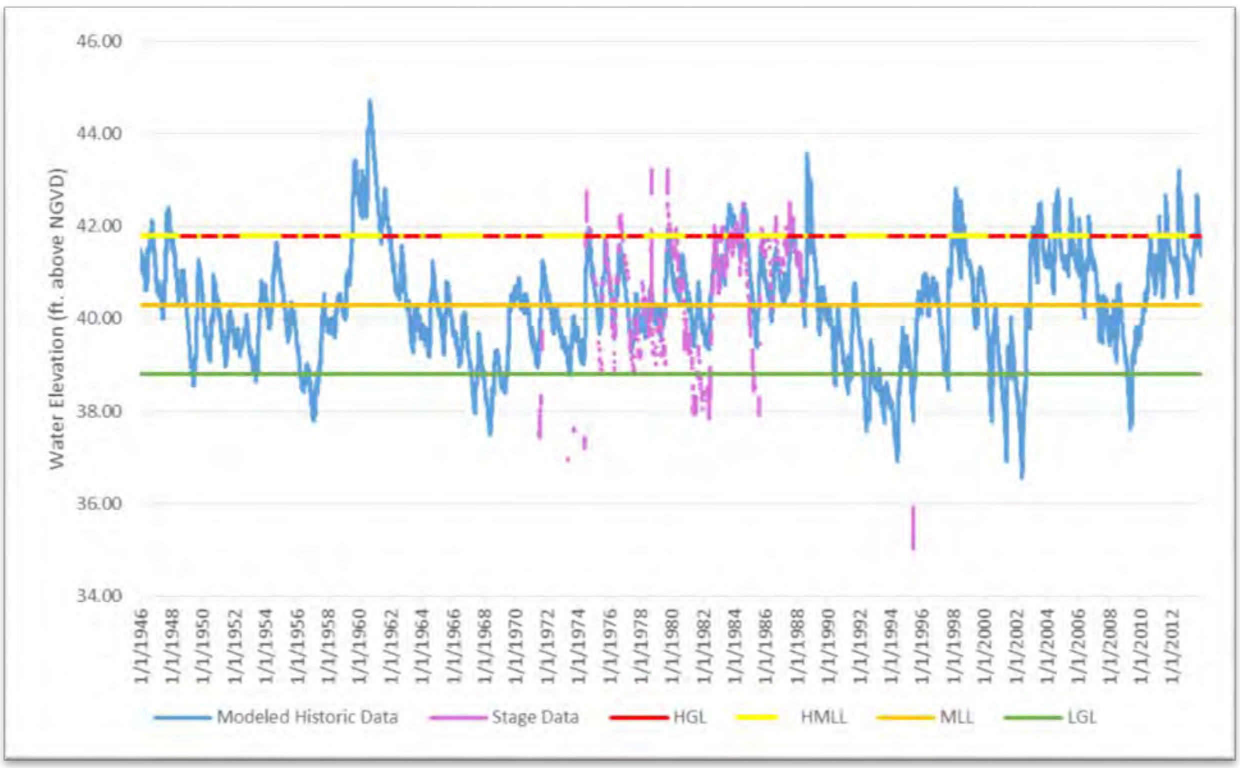

Figure 19. Historic water levels (hybrid) used to calculate the Revised Minimum and Guidance Levels. The revised levels include the High Guidance Levels (HGL), High Minimum Lake Levels (HMLL), Minimum Lake Levels (MLL), and Low Guidance Levels (LGL).

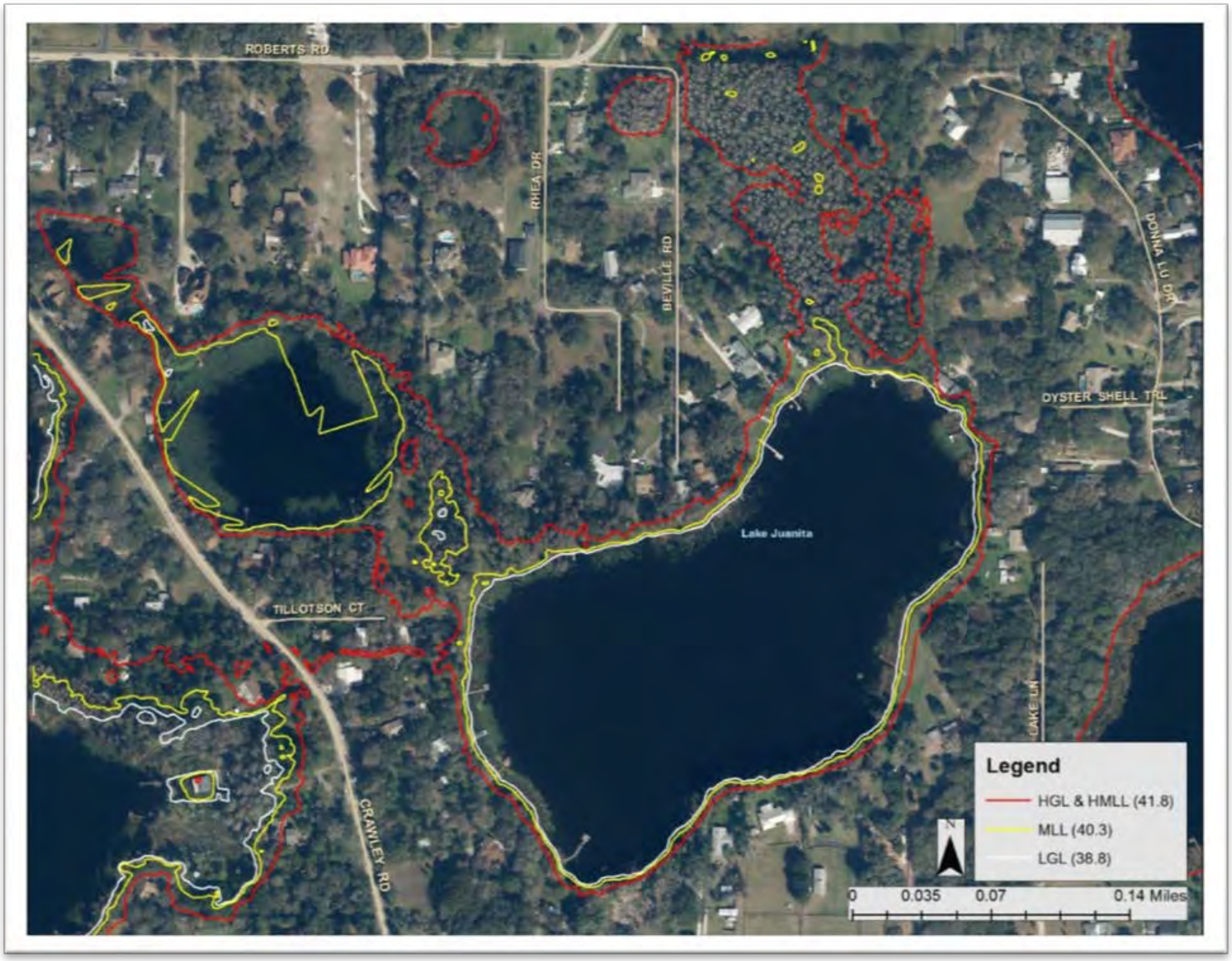

Figure 20. Lake Juanita Minimum and Guidance Level Contour Lines Imposed Onto a 2014 Natural Color Aerial Photograph.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida’s water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the revised MFLs for Lake Juanita are presented in both datum standards (Table 5). The datum shift was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum on 1988. The NGVD29 datum conversion to NAVD88 at gage SID 19806 is -0.93 ft., installed August 20, 1982.

Table 5. Revised Minimum and Guidance Levels for Lake Juanita in NGVD29 and NAVD88.

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88 (-0.93 ft.)
High Guidance Level	41.8	40.9
High Minimum Lake Level	41.8	40.9
Minimum Lake Level	40.3	39.4
Low Guidance Level	38.8	37.9

Consideration of Environmental Values

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

The Minimum Lake Level for Category 2 lakes shall be established at the Historic P50 elevation, as such, the revised MLL for Lake Juanita is at 40.3 ft. Given this information, the levels are as protective of all relevant environmental values as they can be, as identified in the Water Resource Implementation Rule, including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, and water quality (Table 1). In addition, the environmental value, maintenance of freshwater storage and supply is also expected to be protected by the minimum levels based on inclusion of conditions in water use permits that stipulate that permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Comparison of the Revised and Previously Adopted Levels

The revised High Guidance Level is 0.1 ft. higher than the previously adopted guidance level and the revised Low Guidance Level is 0.8 lower than the previously adopted guidance level for Lake Juanita (Table 6). These differences are associated with application of a new modeling approach for characterization of Historic water level fluctuations within the lake, i.e., water level fluctuations that would be expected in the absence of water withdrawal impacts given existing structural conditions. It may also be due to differences in the control elevation.

The revised High Minimum Lake Level for Lake Juanita is 0.1 ft. higher than the previously adopted High Minimum Lake Level (Table 6). The revised Minimum Lake Level is 0.4 ft. lower than the previously adopted Minimum Lake Level (Table 6). These differences are primarily due to including additional Normal Pool elevations and water level data and due to the revised Control Point elevation (refer to Appendix A for further details).

Table 6. Previously Adopted and Revised Minimum and Guidance levels for Lake Juanita

Level	Previously Adopted Elevation (ft., NGVD)	Revised Elevation (Ft., NGVD)
High Guidance Level (P10)	41.7	41.8
High Minimum Level	41.7	41.8
Minimum Level	40.7	40.3
Low Guidance Level	39.6	38.8

Minimum Levels Status Assessment

To assess whether the revised Minimum and High Minimum Lake Levels are being met, observed stage data in Lake Juanita were used to create a long-term record using a Line of Organic Correlation (LOC) model, similar to what was developed for establishing the Minimum Levels (Appendix A). For the status assessment, the lake stage data used to create the LOC must be from a period representing a time when groundwater withdrawals and structural alterations are reasonably stable, referred to as the "Current" period. Current stage data observed on Lake Juanita were determined to be from 2002 through 2015. Using the current stage data, the LOC model was created. Utilizing rainfall data in the LOC model resulted in a 68 year long-term water level record (1946-2015).

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

The lake lies within the region of the District covered by an existing recovery strategy, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution (Rule 40D80-073, F.A.C.). The District plans to continue regular monitoring of water levels in Lake Juanita and will also routinely evaluate the status of the lake's water levels with respect to adopted minimum levels for the lake included in Chapter 40D-8, F.A.C.

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APPENDIX A

Technical Memorandum

July 28, 2016

TO: Jaime Swindasz, Staff Environmental Scientist, Water Resources Bureau

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

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau

Subject: Lakes Juanita/Rainbow/Little Moon Water Budget Models, Rainfall Correlation Models, and Historic Lake Stage Exceedance Percentiles

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A. Introduction

Water budget and rainfall correlation models were developed to assist the Southwest Florida Water Management District (District) in the reassessment of minimum levels for Lakes Juanita, Rainbow, and Little Moon in northwest Hillsborough County. All three lakes currently have adopted minimum levels which are schedule for re-assessed in FY 2014. This document will discuss the development of the Lakes Juanita, Rainbow, and Little Moon models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Lakes Juanita, Rainbow, and Little Moon are located in northwest Hillsborough County, west of Gunn Highway in Odessa (Figure 1). Lake Juanita is located north of North Mobley Road and to the east of Crawley Road. Rainbow Lake is located across Crawley Road from Lake Juanita, while Little Moon Lake is located to the southwest of Rainbow Lake. All three lakes are located to the immediate north and northwest of the Cosme-Odessa wellfield, which is one of eleven regional water supply wellfields operated by Tampa Bay Water.

All three lakes are within the Brooker Creek watershed, although the lakes are relatively isolated, and there are long stretches of time when no discharge occurs from the lakes. Surface water inflow to Lake Juanita occurs as overland flow from the lake's small drainage basin, as overflow from a large wetland to the north, or from Lake Eva and a series of wetlands to the northwest (Figure 2). For purposes of modeling, the wetlands and Lake Eva are considered as part of Lake Juanita, and are included in the

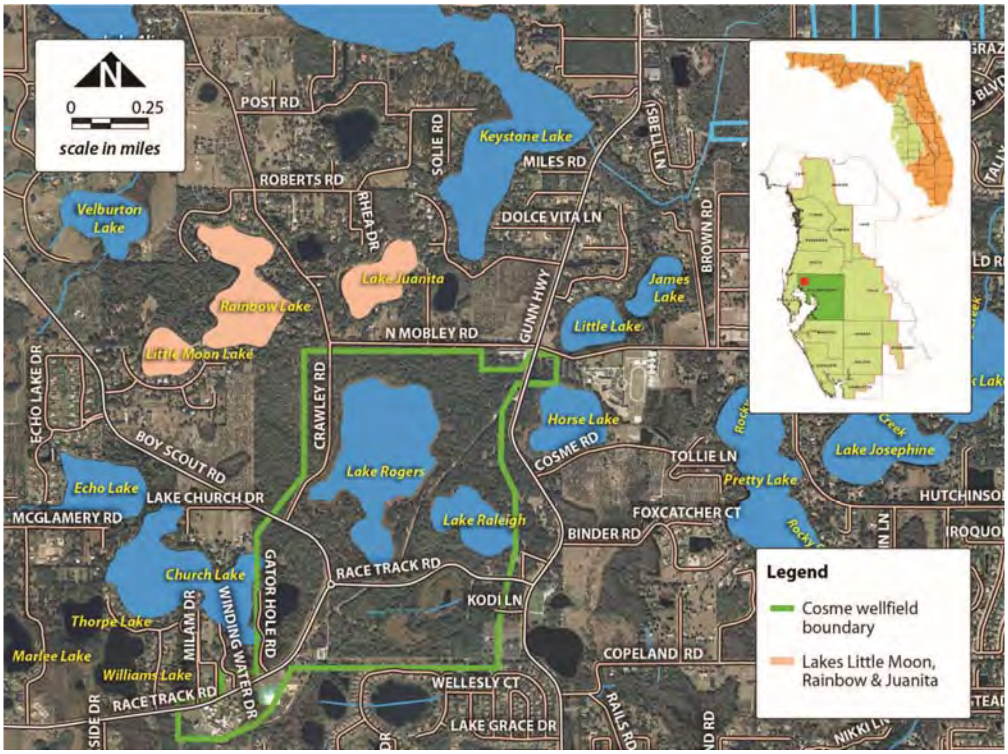

Figure 1. Location of Juanita, Rainbow, and Little Moon Lakes in Hillsborough County, Florida.

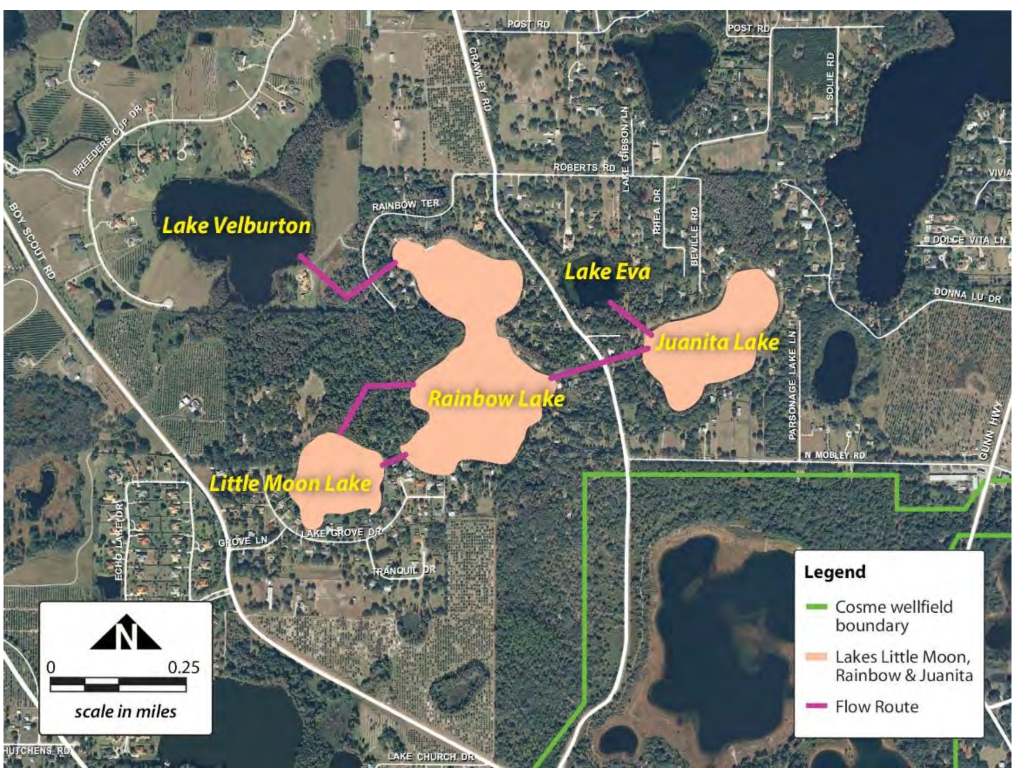

Figure 2. Flow between Juanita, Rainbow, and Little Moon Lakes.

stage/volume information in the model. Discharge from Lake Juanita can occur on the western shore of the lake via a series of open ditches and culverts passing under Crawley Road and into Rainbow Lake. Discharge from Rainbow Lake can occur on the northern shore of the lake through a series of culverts and open ditches to Lake Velburton. One of these culverts was replaced in approximately 2010, so the new specifications of the culvert required re-surveying and consideration in the modeling. Equalized flow can also occur between Little Moon Lake and Rainbow Lake via a canal, or through a wetland north of the canal (Figure 2).

Physiography and Hydrogeology

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

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

Data

Water level data collection began in 1971 for Lakes Juanita and Rainbow, and 1991 in Little Moon Lake. The frequency of data collection at each of the lakes has been inconsistent over the years (Figures 3, 4, and 5). There are no water level data for these three lakes that predate wellfield withdrawals (wellfield withdrawals began over 40 years prior), and withdrawal rates were approximately 10 mgd at the time water level data collection began.

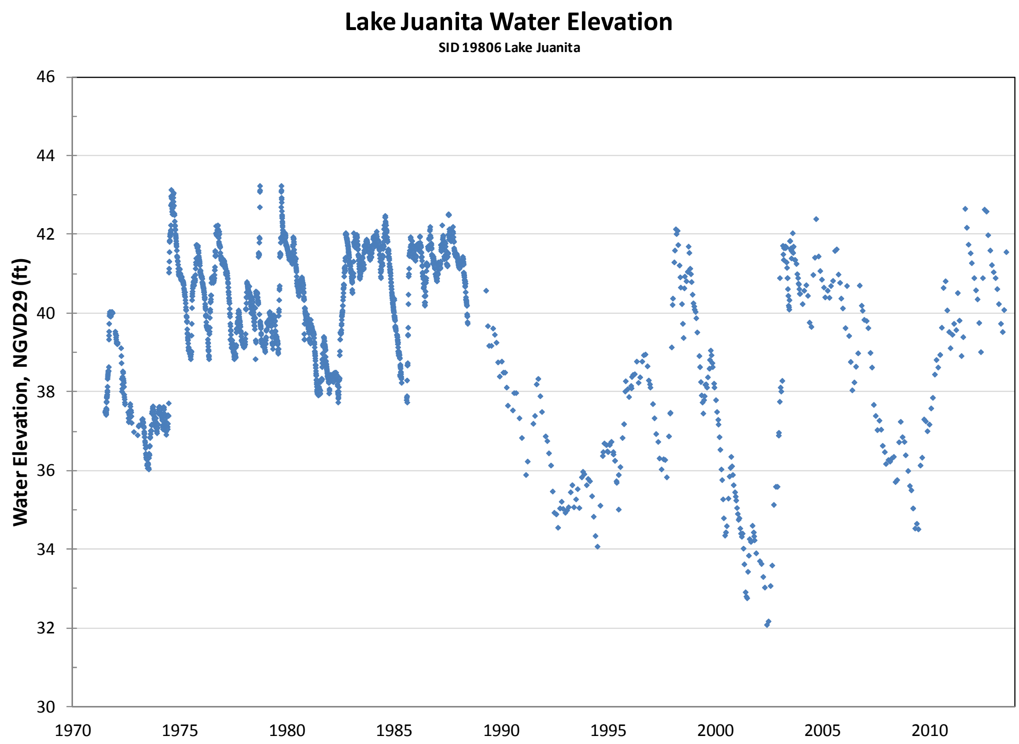

Figure 3. Lake Juanita water levels.

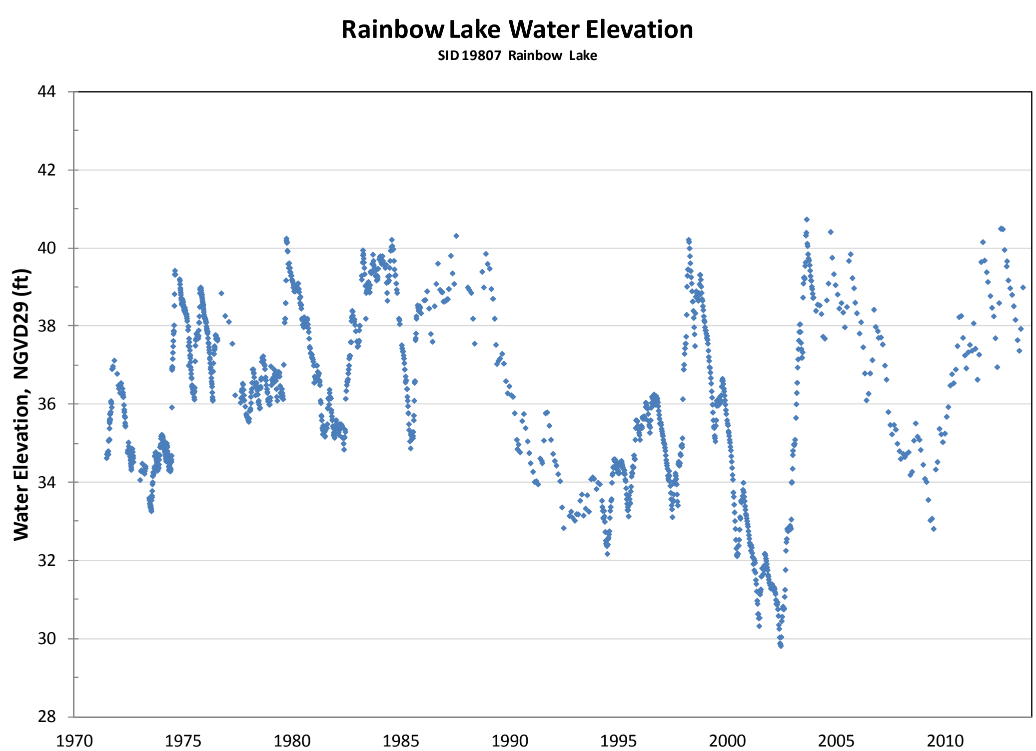

Figure 4. Rainbow Lake water levels.

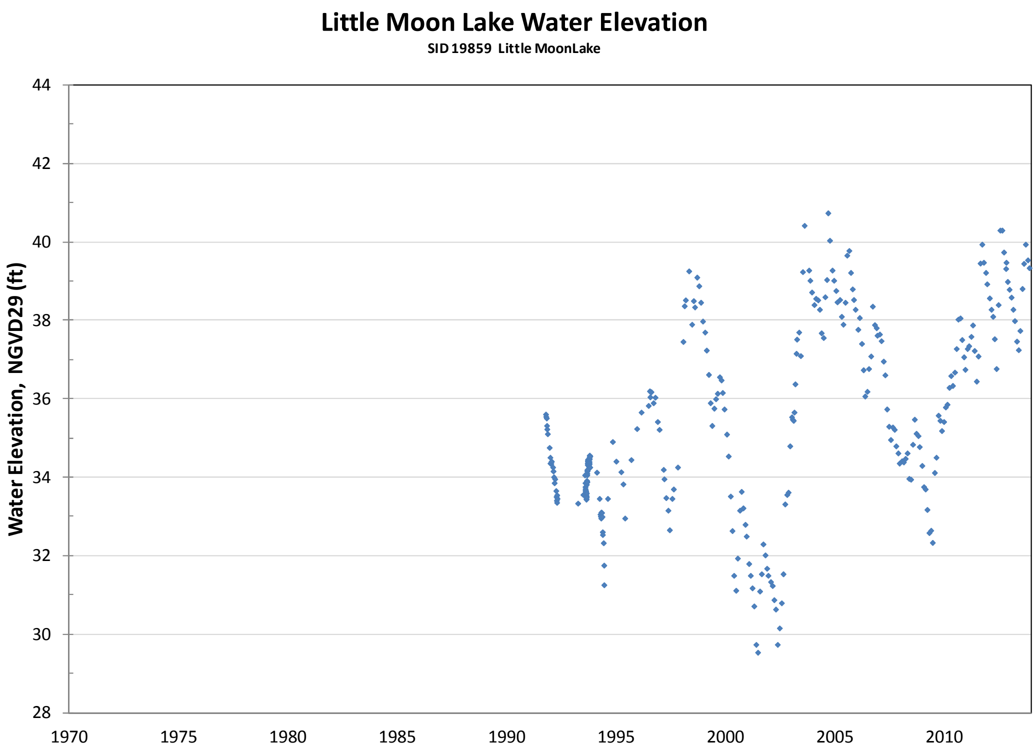

Figure 5. Little Moon Lake water levels.

Water levels from Upper Floridan aquifer monitor wells to the east and south of the lakes exist for the same period of record. One well, James 11, is located approximately one mile to the east of Lake Juanita, but through examination of various interpolated potentiometric surface maps prepared by the United States Geologic Survey (USGS), the well falls approximately along the same potentiometric contour as the lakes (Figure 6). Also, through examination of potentiometric drawdown results from the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013), The Upper Floridan aquifer in the area of both the lakes and the James 11 well appears to have experienced very similar drawdowns over time. Data from the James 11 well has a period of record reaching back to 1965 (Figure 7).

Several surficial aquifer monitor wells exist in the area. Three wells were assessed for modeling the three lakes: Horse Lake surficial, James 10 surficial, and Lake Rogers surficial (all monitored by Tampa Bay Water – James 10 is also monitored by the District) (Figure 8). The period of record of James 10 begins in 1965, while the other two wells begin in the mid-1990s.

Figure 6. Locations of monitor wells near Lakes Juanita, Rainbow, and Little Moon.

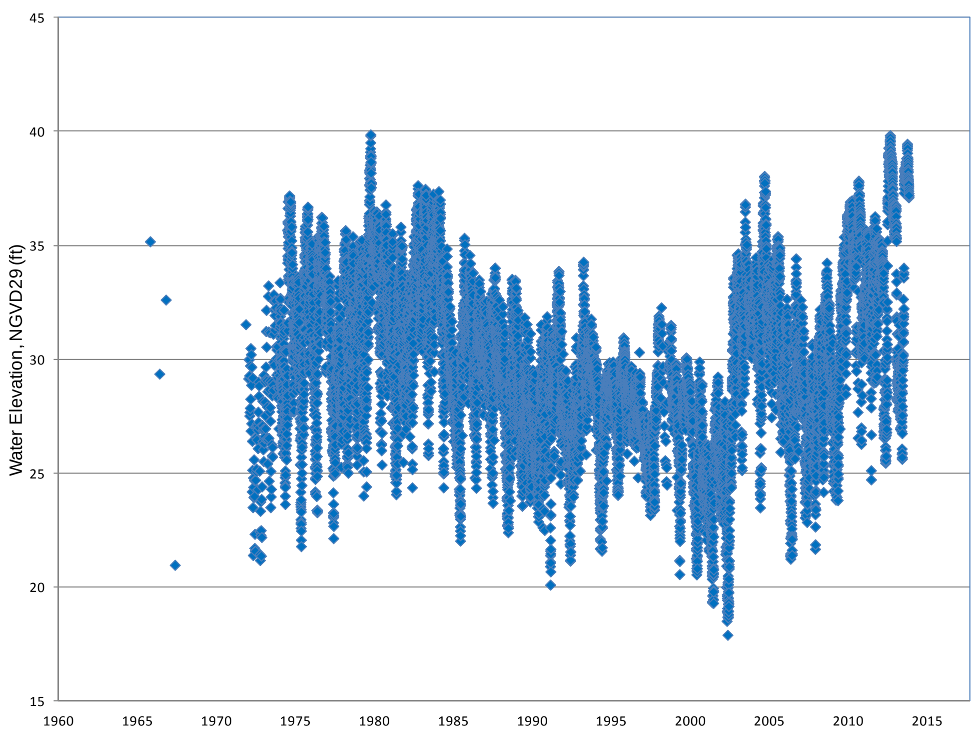

Figure 7. Water levels in James 11 Floridan aquifer monitor well.

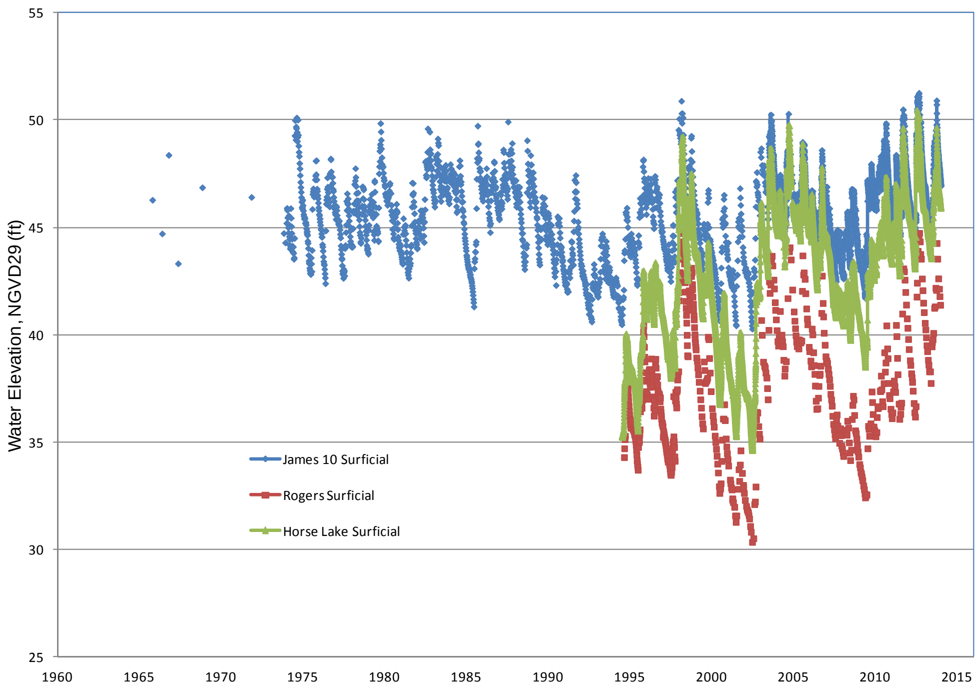

Figure 8. Water levels in James 10, Lake Rogers and Horse Lake surficial wells.

__Land and Water Use__

Juanita, Rainbow, and Little Moon Lakes are unique in that they are located adjacent to the Cosme-Odessa Wellfield, which is the oldest public supply wellfield in the District. Therefore, these and adjacent lakes have been subjected to the effects of groundwater withdrawals longer than any other lakes in the District. The wellfield consists of the original wellfield constructed in 1930 (on approximately 1.1 square miles of property), as well as a linear wellfield spanning approximately 2 miles to the north along Gunn Highway (Figure 9). The original wellfield began supplying water to the City of St. Petersburg in 1930, while withdrawals along the linear expansion began in the mid-1950s. Monthly withdrawals steadily climbed to as much as 21 million gallons per day (mgd) in 1962 (Figure 10). By the 1970s, the development of the Section 21 Wellfield, also in northwest Hillsborough County to the east of the Cosme-Odessa Wellfield, allowed withdrawals at the Cosme-Odessa Wellfield to be reduced to 12 mgd on annual average. Current withdrawal rates at the wellfield have typically averaged approximately 6 mgd on annual average.

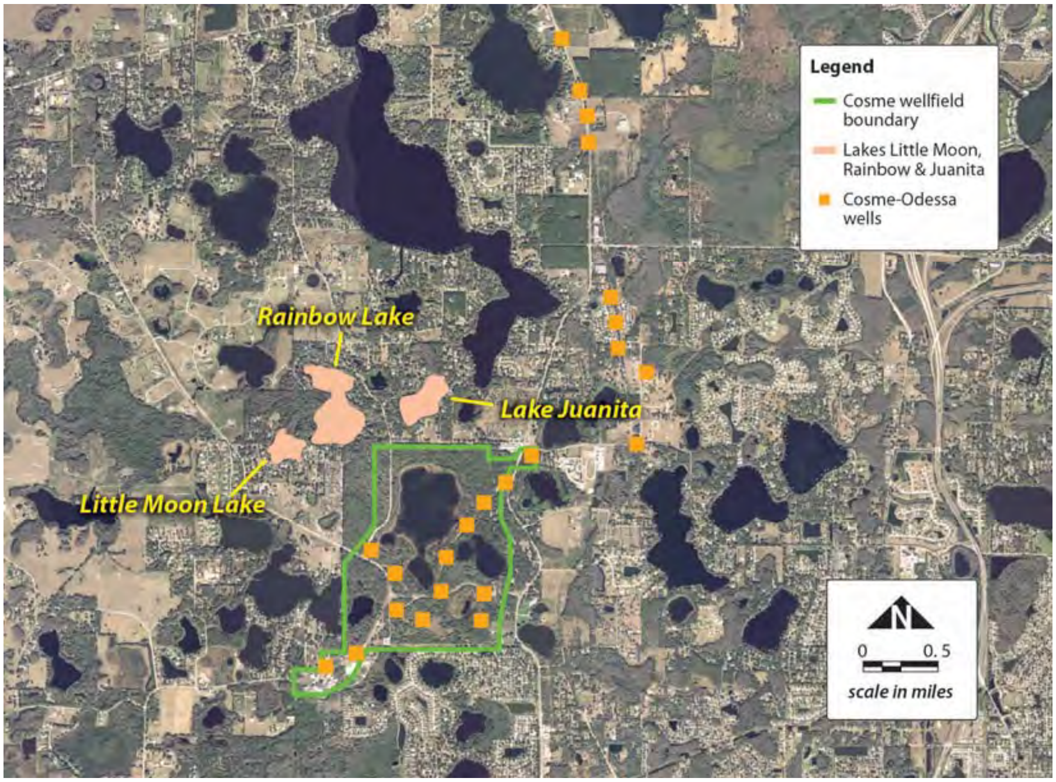

Figure 9. Cosme-Odessa Wellfield configuration.

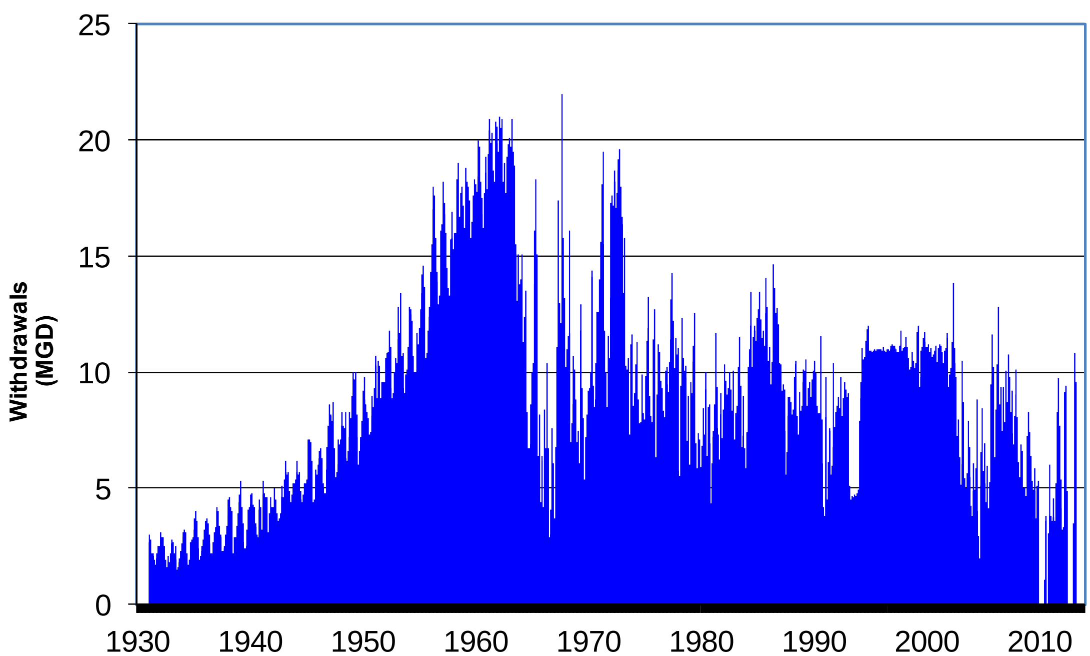

Figure 10. Cosme-Odessa Wellfield withdrawals.

It is apparent that water levels in the lakes in and near the Cosme-Odessa wellfield have dropped significantly since groundwater withdrawals began (Figures 3 through 5 and Figures 10 through 12), based on field indicators of historic normal pool (an elevation of biologic indicators representing approximately P10 conditions) and the longer historic records of nearby Lakes Rogers, Raleigh, and Horse (Hancock and McBride, 2013). Although all three lakes have also been structurally altered since the wellfield withdrawals began, water levels in the lakes have fluctuated in correlation with the underlying Floridan aquifer, which in turn has fluctuated with the groundwater withdrawals from the wellfield (Figures 11 and 12). Note, however, that Lakes Juanita, Rainbow, and Little Moon do not appear to be as affected by the wellfield withdrawals as the lakes to the south (Hancock and McBride, 2013).

During an El Niño event in 2002/2003, high water flows from nearby Pretty Lake were transferred via pumps, temporary pipelines, and existing channels to Lakes Horse, Raleigh, and Rogers, and then to Lakes Juanita, Rainbow, and Little Moon (Figure 13). Water had been transferred from Lake Pretty to the first three lakes in a prior El Niño event (1997/1998). Both of these transfers are described in “Lake Pretty Water Transfer Project” (Southwest Florida Water Management District, 2003). During the period that water was transferred to Lakes Juanita, Rainbow and Little Moon (February 21, 2003 to May 9, 2003), water was transferred from Pretty Lake to Lake Horse. A pump at Lake Horse transferred water under Gunn Highway to the ditch that leads to Lake Raleigh. From Lake Raleigh, a third pump transferred water to Lake Rogers, while a third pump transferred water from Lake Rogers to Lake Juanita. Water then flowed by gravity to Rainbow and Little Moon Lake. Although withdrawal quantities were not metered for each event, it is estimated that about 450 million gallons of water were transferred from Pretty Lake to the other lakes during this event.

Water withdrawals upstream of an operable water conservation structure on Pretty Lake were strictly limited to a small percentage of the structure overflow, so no lowering of Pretty Lake below target water levels occurred due to the water transfers. Strict target levels in each receiving lake were used to determine when to stop inflows and begin outflows. Because lake levels in some lakes were much lower prior to water transfers, and the size of each lake varies considerably, some lakes received significantly larger volumes of water than others. It is estimated that Lakes Juanita, Rainbow and Little Moon received much less water than the upstream lakes. It should be noted that significant rainfall during the pumping events also contributed to lake recovery.

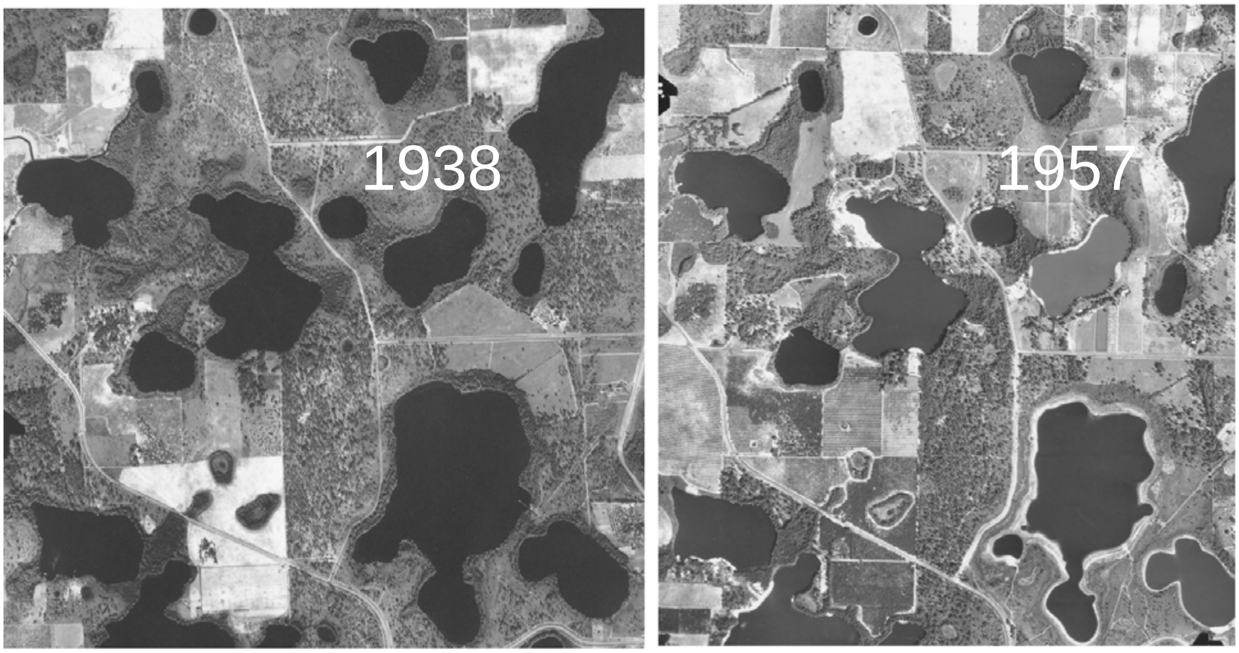

Figure 11. Water level changes in Lakes Juanita, Rainbow, and Little Moon

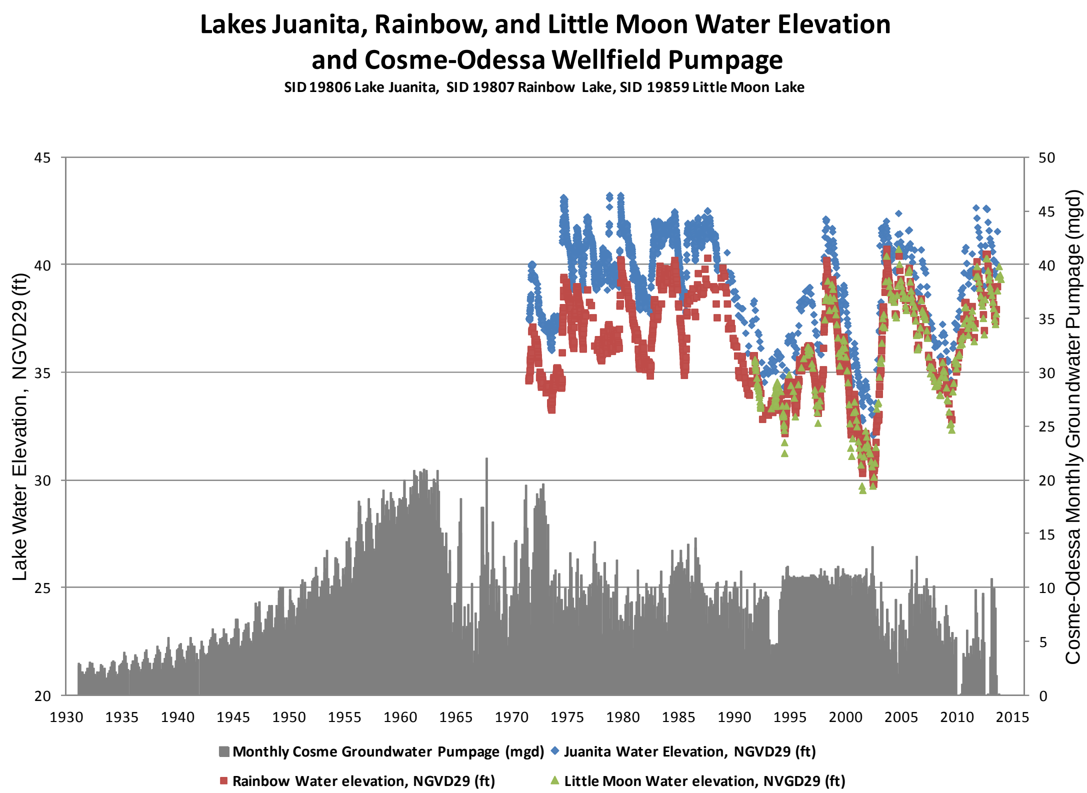

Figure 12. Water levels in Lakes Juanita, Rainbow, and Little Moon and Cosme-Odessa Wellfield withdrawals.

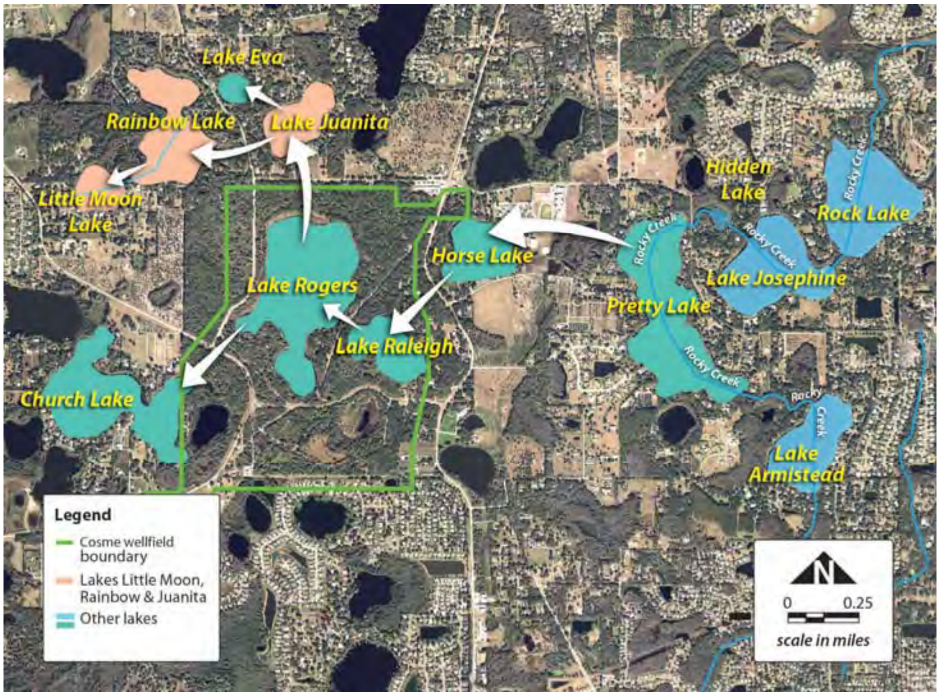

Figure 13. Water transfers in 1997/1998 and 2002/2003

C. Purpose of Models

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

In the case of Lakes Juanita, Rainbow, and Little Moon, because the wellfield has affected water levels in the lakes since before the beginning of data collection, no

Historic data exist for these lakes. The development of a water budget model coupled with a rainfall correlation model for these lakes was considered essential for estimating long-term Historic percentiles, accounting for changes in the lakes' drainage systems, and simulating the effects of changing groundwater withdrawal rates.

D. Water Budget Model Overview

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

The hydrologic processes in the water budget model include:

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

The water budget model uses a daily time-step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels for each lake. The water budget model is calibrated from 1988 to 2013. This period also provides the best balance of using available data for all parts of the water budget and the desire to develop a long-term water level record.

E. Water Budget Model Components

Lake Stage/Volume

Lake stage area and stage volume estimates were determined by building a terrain model of the lakes and surrounding watersheds. Lake bottom elevations and land surface elevations were used to build the model with LP360 (by QCoherent) for ArcGIS, ESRI's ArcMap 10.1, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basins with the underlying basin morphology of each lake to develop one continuous three-dimensional (3D) digital elevation model. The 3D digital elevation models were then used to calculate areas of each lake and the associated volume of each lake at different elevations, starting at the extent of the lakes at their flood stage and working downward to the lowest elevation within the basins.

Precipitation

Because these lakes are located directly to the north of Lakes Horse, Raleigh and Rogers, for which a similar model was recently created, the same rainfall data assembled for those lakes was used for this model. Daily data from the ROMP TR 13-3 Race Track Road (E-101) and Cosme 18 rain gages were used to represent precipitation over the area of the three lakes (Figure 14). The Race Track Road gage is maintained by the District, while the Cosme 18 gage is maintained by Tampa Bay Water. The Cosme 18 gage, located on the southern end of the wellfield property, is a replacement for a previous gage that was reported to have quality issues. Therefore, the Race Track Road gage, located approximately 3 miles to the southwest of the wellfield, was used for the beginning of the model period (January 1, 1988) until June 3, 2003, while the Cosme 18 gage is used from June 4, 2003 through the end of the calibration period (December 31, 2013). The Lake Crescent gage, maintained by the District, and located approximately 3 miles to the north of the wellfield property, was used to fill in a few missing data points in the rainfall data set.

Lake Evaporation

Lake evaporation was estimated through use of monthly energy budget evaporation data collected by the U.S. Geological Survey (USGS) at Lake Starr in Polk County (Swancar and others, 2000) (Figure 15). The data was collected from August of 1996 through July of 2011. Monthly Lake Starr evaporation data were used in the water budget model when available, and monthly averages for the period of record were used for those months in the water budget model when Lake Starr evaporation data were not available.

A recent study compared monthly energy budget evaporation data collected from both Lake Starr and Calm Lake (Swancar, , personal communications). Calm Lake is located less than 2 miles to the north of Lakes Juanita, Rainbow, and Little Moon (Figure 15). The assessment concluded that the evaporation rates between the two lakes were nearly identical, with small differences attributed to measurement error and monthly differences in latent heat associated with differences in lake depth.

Jacobs (2007) produced daily potential evapotranspiration (PET) estimates on a 2-square kilometer grid for the entire state of Florida. The estimates begin in 1995, and are updated annually. These estimates, available from a website maintained by the USGS, were calculated through the use of solar radiation data measured by a Geostationary Operational Environmental Satellite (GOES). Because PET is equal to lake evaporation over open water areas, using the values derived from the grid nodes

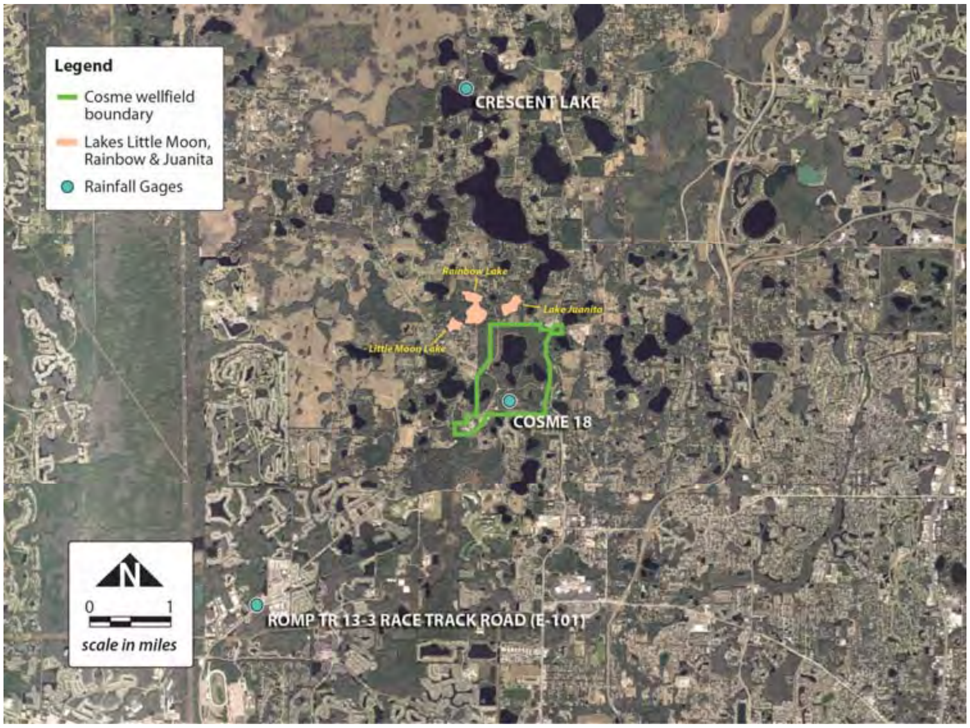

Figure 14. Rain gages used in the water budget models.

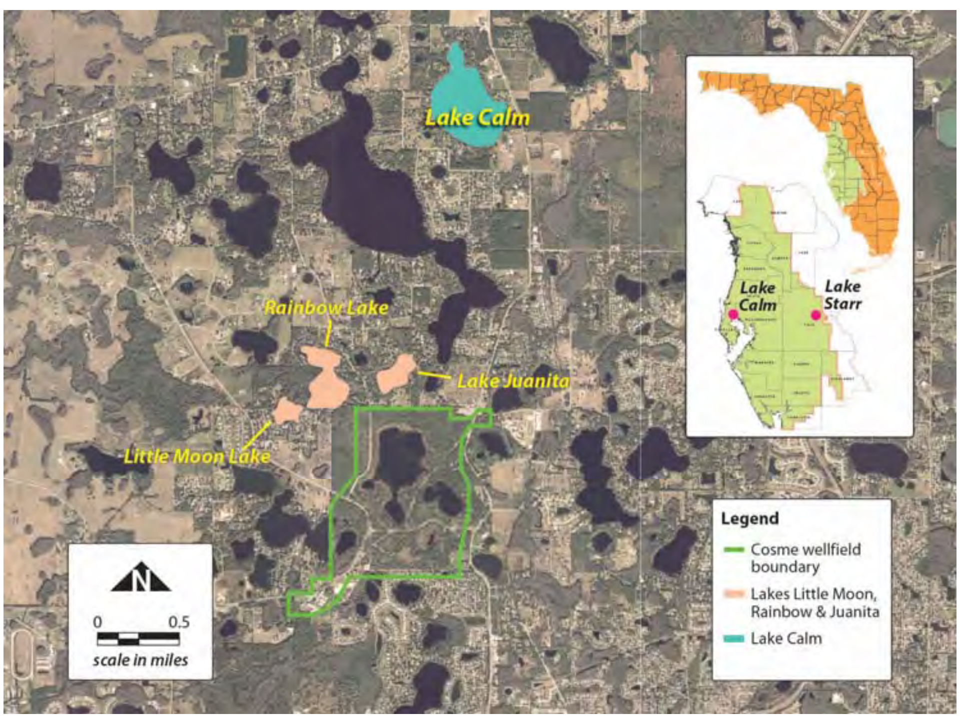

Figure 15. Location of Lakes Juanita, Rainbow, and Little Moon, Calm, and Starr (see map inset).

over the modeled lakes was considered. A decision was made to use the Lake Starr data since the GOES data nodes typically include both upland and lake estimates, with no clear way of subdividing the two. It was thought that using the daily PET estimates based on GOES data would introduce more error than using the Lake Starr data directly.

Overland Flow

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

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

The topography in the area of the three lakes is relatively flat, so determining watersheds based on relatively subtle divides can be challenging. Several slightly varying estimates of watershed boundaries have been performed in the past for different modeling efforts in the area. The most recent estimates were performed as part of an effort to model the Brooker Creek watershed for flood assessment purposes (PBS&J, 2006). The watershed area values developed by PBD&J were adopted for the water budget model for Lakes Juanita, Rainbow, and Little Moon (Table 1) after an independent check confirming that they are reasonable for modeling purposes.

The watersheds for each lake are relatively small 148.5 and 207.8 acres for Lake Juanita and combined Rainbow and Little Moon Lakes, respectively (Figure 16). The watersheds are relatively flat, and significant flow from these watersheds into the remainder of the Brooker Creek basin occurs only during large rainfall events.

The DCIA and SCS CN used for the direct overland flow portion of the watersheds for each lake is listed in Table 1. Curve numbers were difficult to assess. Most of the soils in the area are a B/D or C/D soil, which means that the characteristics of the soils are highly dependent on how well they are drained. A “D” soil will generally have a higher amount of runoff per quantity of rain than a “B” or “C” soil. Because of the proximity of the wellfield to the area being modeled, water levels have been historically lowered by

Table 1. Model Inputs

Input Variable	Juanita	Rainbow/Little Moon
Overland Flow Watershed Size (acres)	148.5	207.8
SCS CN of watershed	70	70
Percent Directly Connected	0	0
FL Monitor Well Used	James 11	James 11
Surf. Aq. Monitor Well(s) Used	Horse Lake Surf	Horse Lake Surf
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.002	0.002
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.0004	0.0022
Outflow K (pre 2010)	0.02	0.07
Outflow Invert (ft NGVD29) (pre 2010)	41.2	39.1
Outflow K (since 2010)	0.02	0.07
Outflow Invert (ft NGVD29) (since 2010)	41.2	38.6
Inflow K	N/A	0.02
Inflow Invert (ft NGVD29)	N/A	41.1

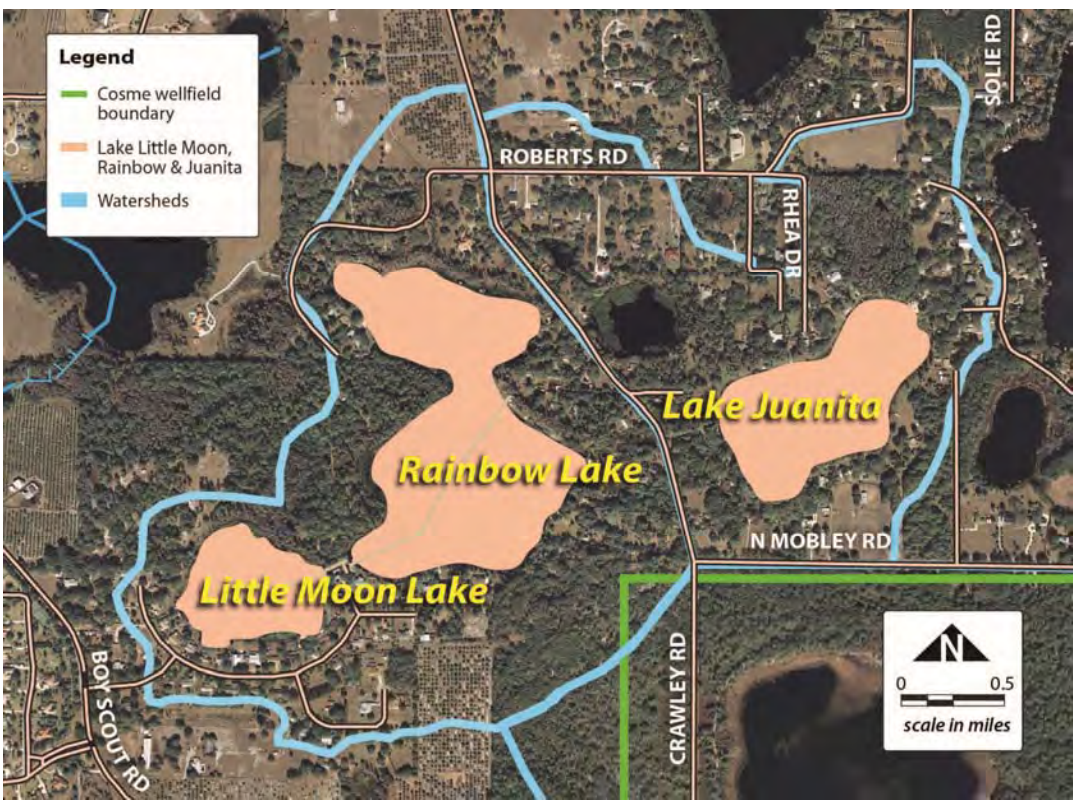

Figure 16. Watersheds of Lakes Juanita, Rainbow, and Little Moon.

the withdrawals, and therefore the soils in the area may have had lower runoff rates during that time (characteristic of a “B” or “C” soil).

The groundwater withdrawals during the period of calibration, however, have been significantly reduced, so the soils in the area may have begun to exemplify runoff properties that are more characteristic of “D” soils. A previous water budget model of these lakes (Berryman & Henigar, Inc., 2005) used CN values in the range of 55 to 60, which would be characteristic of a well-drained soil. A recent flood model developed for the District (PBS&J, 2006) used values for the watersheds of these lakes in the 83-89 range, characteristic of poorly drained soils. For purposes of this model, taking into account the range of conditions experienced, a compromise of 70 was used. No direct discharges to the lakes were identified, so the DCIA of each watershed is zero.

Inflow and Discharge via Channels from Outside Watersheds

Inflow and outflow via channels from or to outside lake’s watershed (i.e., channel flow) is a relatively small component of the water budgets in each of the three lakes since water levels rarely reach elevations that allow discharge. Because the channel flow component is small, and detailed surveys and dimensions of structures and channels were not available, a simplified approach was used.

To estimate flow out of each lake, the predicted elevation of the lake from the previous day is compared to the controlling elevation. Control elevations were determined based on professional surveying performed in the area. If the lake elevation is above the controlling elevation, the difference is multiplied by the current area of the lake and an “outflow coefficient.” The coefficient represents a measure of channel and structure efficiency, and produces a rough estimate of volume lost from the lake. This volume is then subtracted from the current estimate of volume. To estimate flow into each lake, the same approach was applied, using data and information from a donating water body to determine availability of water.

Lake Juanita has no significant channels draining into the lake, but does have an approximately 10 acre forested wetland to the north that flows into the lake during high rainfall periods, as well a similar lake and wetland system (Lake Eva) that flows into the lake from the northwest. For modeling purposes, all of these systems were considered part of the lake. There is a ditch where water can outflow from Lake Juanita on the west end of the lake. Water flows though the ditch passes under a local road though a 28 inch metal pipe, and through a 26 inch by 38 inch elliptical reinforced concrete pipe under Crawley Road. The control elevation of the lake is a reasonably stable high point in the ditch (41.2 feet NGVD) before the Crawley Road culvert (40.5 feet NGVD). From Crawley Road, a ditch runs approximately 500 feet to Rainbow Lake (entering the lake on the southwest end of the lake). In the model, the outflow calculated for Lake Juanita becomes the inflow for Rainbow Lake (hence connecting the model for Lake Juanita with the model for the Rainbow/Little Moon Lake system). Because the outflow generated from the Lake Juanita model affects the results of the Rainbow/Little Moon Lake, both were calibrated together.

Little Moon Lake and Rainbow Lake are connected via a ditch on the southwest end of Rainbow Lake and the east side of Little Moon Lake. The two water bodies are also connected via a forested wetland flow system to the north of the ditch. There is no other discharge from Little Moon Lake. Discharge from Rainbow Lake occurs via a ditch and culvert system through wetlands on the north end of the lake to Lake Velburton. The control elevation prior to 2010 for Rainbow Lake was determined to be the south end of the culvert leading into Lake Velburton at 39.1 feet NGVD29. In approximately 2010 one of the culverts was replaced, and a concrete weir was added. A professional survey of the new weir demonstrated that the new control elevation is currently 38.6 feet NGVD29. The model was developed to include both elevations (pre and since 2010), as well as individual outflow coefficient.

The connection between Little Moon Lake and Rainbow Lake becomes dry at 36.1 feet NGVD. For purposes of the model, Little Moon Lake was modeled as part of Rainbow Lake until water levels fall below 36.1 feet. At that point, the volume of Little Moon Lake is separated from Rainbow Lake's volume.

Flow from and into the surficial aquifer and Upper Floridan aquifer

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

The James 11 Floridan aquifer monitoring well (Figure 8), located approximately one mile to the east of Lake Juanita, was used to represent the Upper Floridan aquifer for all three lakes. The well has a long period of record of data that extends well before the calibration period of the model. A simple approach was used to fill in missing data by using the last recorded data value until a new value was recorded.

To represent the surficial aquifer, the Horse Lake surficial aquifer monitor well was used. The Lake Rogers surficial aquifer monitor well was considered for use in the model, especially since it is physically closer to both lakes. However, because it is closer to the center of groundwater withdrawals, it has been subjected to significantly more drawdown than the Horse Lake well (as assessed through modeling efforts). Assessments have shown that the area of the Horse Lake well and the lakes have experienced similar drawdown effects, making the Horse Lake well a better representation of conditions in the area of the lakes.

The data for the Horse Lake surficial aquifer monitor well exists as daily, with only a few small gaps. Because the period of record of the well only extends back to 1994, adjusted data from the James 10 surficial aquifer monitor well was used back to 1988. Because the topography is relative flat in the area, ground elevations at each well are within a foot or two of each other, so no adjustments to the James 10 surficial aquifer monitor well data were made. Also, through examination of surficial aquifer drawdown results from the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013), both the lakes and both wells appear to have experienced very similar average drawdowns (within one foot) over time. However, there is an estimated difference of approximately three feet in the topography between the lakes and the Horse Lake well, so the entire data set was adjusted down by three feet for use in the model.

F. Water Budget Model Approach

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

Measured data from all three lakes were used for comparison with modeled water levels. Water level data from Lake Juanita and Rainbow Lake has been collected monthly since 1971 (with some periods of more frequent data collection), while water level at Little Moon Lake has been collected monthly since late 1991. Daily values are generated from the model, but only actual lake data points are used for the calibration.

Attempts to determine a reasonably accurate time series of augmentation rates during the two water transfer events were not successful, so the augmentation quantities could not be included in the model. Therefore, it was decided to remove the augmentation period from the calibration statistics. The effects of the augmentation events would be expected to affect lake levels during the period of augmentation, but also would be expected to affect lake levels for some period after the augmentation ceased. For purposes of calibration, the post-augmentation data was not used until the peak in the hydrograph after the end of augmentation was reached. For the first event, the period from February 21, 2003 through September 1, 2003 was excluded.

Figures 17 and 18 present the calibration results of the two models. Table 2 presents a comparison of the percentiles of the measured data versus the model results. Tables 3 and 4 present the modeled water budget components for the model calibration period of each lake.

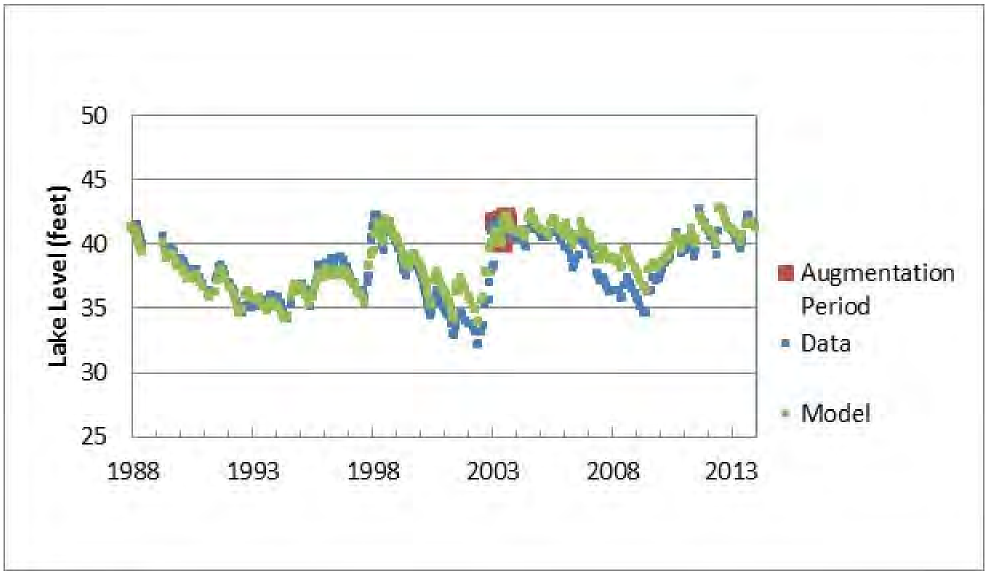

Figure 17. Modeled water levels predicted for the calibrated Lake Juanita water budget model (Model) and measured levels used for the model calibration (Data).

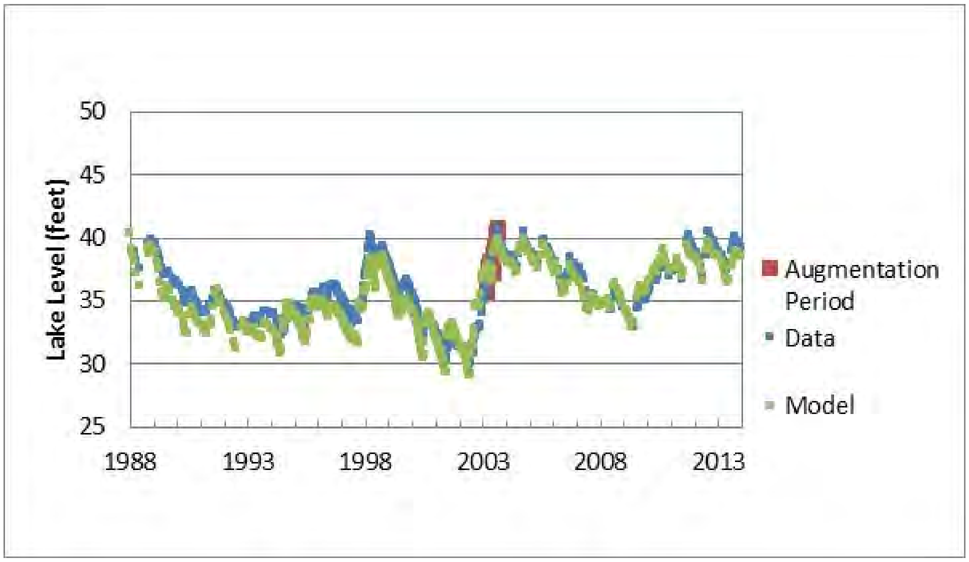

Figure 18. Modeled water levels predicted for the calibrated Rainbow/Little Moon Lake water budget model (Model) and measured levels used for the model calibration (Data).

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

	Lake Juanita Data	Lake Juanita Model	Rainbow/Little Moon Lake Data	Rainbow/Little Moon Lake Model
P10	41.3	41.3	38.9	38.6
P50	38.5	38.5	35.0	35.0
P90	34.9	35.5	31.9	32.2

Table 3. Lake Juanita Water Budget (1988-2013)

Inflows	Rainfall	Surficial Aquifer Groundwater Inflow	Floridan Aquifer Groundwater Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	53.7	6.7	0.0	24.2	0.0	0.0	84.6
Percentage	63.6	7.8	0.0	28.6	0.0	0.0	100.0
Outflows	**Evaporation**	**Surficial Aquifer Groundwater Outflow**	**Floridan Aquifer Groundwater Outflow**			**Outflow via channel**	**Total**
Inches/year	58.1	3.6	17.2			5.7	84.6
Percentage	68.7	4.2	20.3			6.8	100.0

Table 4. Rainbow/Little Moon Lake Water Budget (1988-2013)

Inflows	Rainfall	Surficial Aquifer Groundwater Inflow	Floridan Aquifer Groundwater Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	53.7	31.6	0.0	33.5	0.0	5.7	124.6
Percentage	43.2	25.3	0.0	26.9	0.0	4.6	100.0
Outflows	**Evaporation**	**Surficial Aquifer Groundwater Outflow**	**Floridan Aquifer Groundwater Outflow**			**Outflow via channel**	**Total**
Inches/year	58.1	0.0	58.9			8.4	125.4
Percentage	46.3	0.0	46.9			6.8	100.0

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figures 17 and 18, the calibration of the model appears to be reasonable. For both lakes, there are a few periods when the peaks in the modeled hydrographs are a bit high or low. Some of the differences at the higher and lower percentiles may be due to less detail in the higher and lower stage-volume relationships. Very little differences are seen during the periods affected by augmentation, which may imply that the actually quantities diverted to the lakes was small compared to the amount of rainfall that was received during the same period.

A review of Table 2 shows that the differences in P50 (median) percentiles between the data and model for each lake are within 0.1 feet, as are the P90 percentiles for Lake Juanita. The P10 percentile difference between the data and the lake is 0.3 feet. While the P90 percentile for Rainbow Lake is within 0.3 feet, the P90 percentile for Lake Juanita is off by 0.6 feet. Some of this difference may be due to less detail in the lower stage-volume relationships, inaccuracies in rainfall estimates, and differences in structure outlets.

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

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the Lakes Juanita, Rainbow and Little Moon water budget models, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from the Cosme-Odessa wellfield are available for the model calibration period, so if a relationship between withdrawal rates and Upper Floridan aquifer potentiometric levels can be established, the effect of changes in groundwater withdrawals can be estimated by adjusting Upper Floridan aquifer levels in the models.

The Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013) is an integrated model developed for the northern Tampa Bay area. The INTB model has the ability to account for groundwater and surface-water, as well as the interaction between them. The domain of the INTB application includes the Cosme-Odessa wellfield area, and represents the most current understanding of the hydrogeologic system in the area. The INTB was used to determine the drawdown in the surficial aquifer and Upper Floridan aquifer in response to groundwater withdrawals in the area. Drawdown in both aquifers was calculated for two withdrawal rates representing the effects of Tampa Bay Water's regional wellfields before and after cutbacks from approximately 150 mgd to 90 mgd. The pre-cutback period in the model is from 1988 through 2002, while the post-cutback period is 2003 to current. The model results allowed the drawdowns associated with all permitted withdrawals to be calculated before and after wellfield cutbacks, assuming changes in all other withdrawals are consistent for the modeled period.

The INTB model was run for each withdrawal scenario from 1996 to 2006 using a daily integration step. Drawdown values in feet were calculated by running the model with and without groundwater withdrawals, and were calculated for each node in the model. The INTB model uses a one-quarter mile grid spacing in the area of the wellfields. Groundwater withdrawal rates from the Cosme-Odessa Wellfield in each scenario were 11 mgd and 6.2 mgd, respectively.

Results from the INTB modeling scenarios showed that there is a fairly linear relationship between Upper Floridan aquifer drawdown and withdrawal rates at the Cosme-Odessa wellfield, with one mgd of groundwater withdrawals resulting in approximately one foot of Upper Floridan aquifer drawdown. This relationship was consistent in the area of the three lakes. Because of the leaky nature of the confining unit in the area of the lakes, and because the water table in the water budget model is also not active, the relationship between groundwater withdrawals in the Upper Floridan and water levels in the surficial was also of interest. The same scenarios described above showed that for one mgd of groundwater withdrawals results in approximately 0.2 feet of drawdown in the water table, which was also consistent throughout the area of the three lakes. Using the drawdowns determined through the INTB model, the Upper Floridan aquifer and surficial monitor well data in the model can be adjusted to reflect changes in groundwater withdrawals.

To estimate lake levels without the influence of groundwater withdrawals, the Upper Floridan aquifer and surficial aquifer wells in the water budget model were adjusted to represent zero withdrawals. For the 1988 to 2013 water budget model period, two periods of adjustment were used to reflect the cutbacks that took place at the Cosme-Odessa wellfield.   The adjustments to each Upper Floridan aquifer and surficial aquifer well are found in Table 5.

Table 5. Aquifer water level adjustments to the water budget model to represent Historic percentiles

Well	Adjustment (feet) 1988 to 2002	Adjustment (feet) 2003 to 2013
Juanita (Floridan aquifer)	10.1	5.2
Juanita (surficial aquifer)	2.0	0.9
Rainbow/Little Moon (Floridan aquifer)	8.9	4.6
Rainbow/Little Moon (surficial aquifer)	1.3	0.6

Figures 19 and 20 present measured water level data for each lake along with the model-simulated lake levels in the lake under Historic condition, i.e., in the absence of groundwater withdrawals with structural alterations similar to current conditions. Table 6 presents the Historic Percentiles based on the model output.

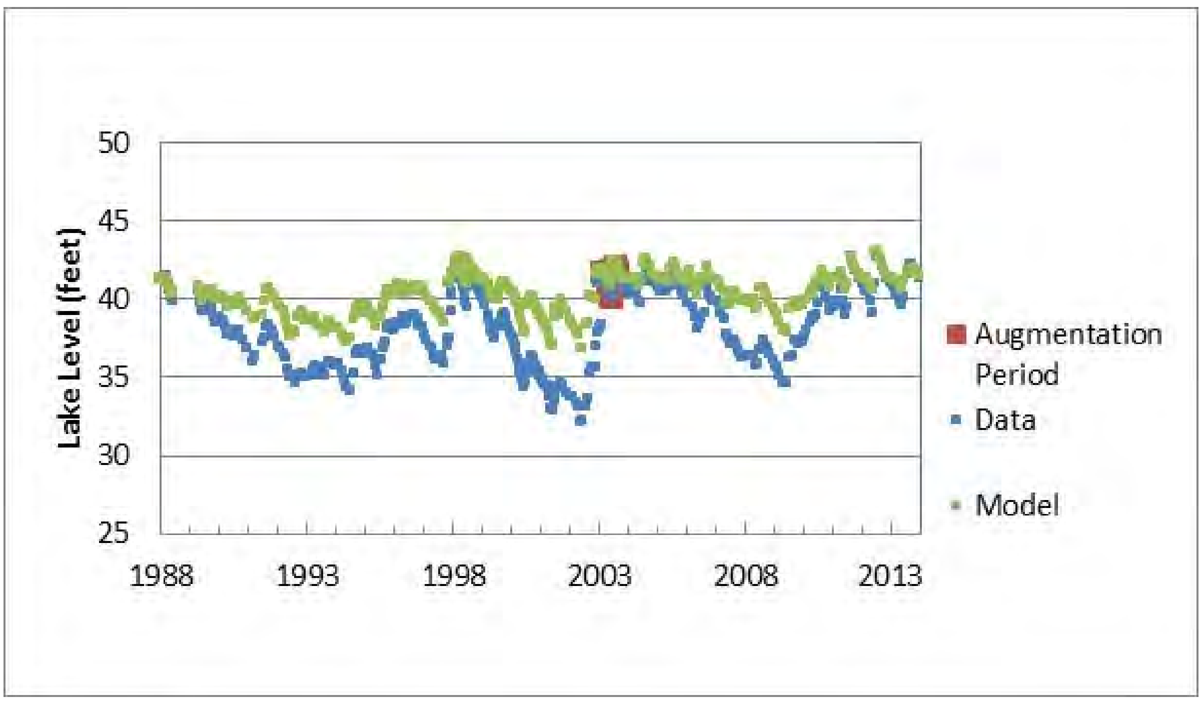

Figure 19. Historic percentile scenario for Lake Juanita

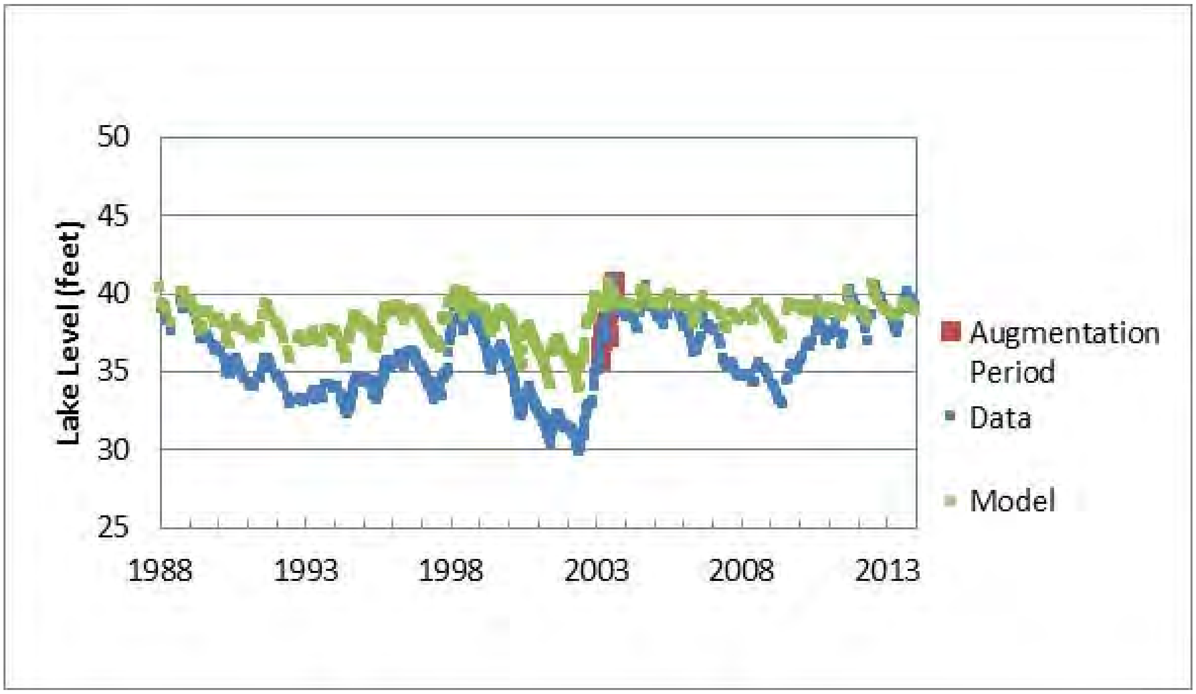

Figure 20. Historic percentile scenario for Rainbow/Little Moon

Table 6. Historic percentiles as estimated by the water budget model (all in feet NGVD).

Percentile	Lake Juanita	Rainbow Lake
P10	41.7	39.4
P50	40.3	38.6
P90	38.4	36.7

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

Historic normal pools were determined on all three lakes based on inflection points of remaining cypress trees. The Historic normal pools of each lake are shown in Table 7. While the Historic normal pool and natural P10 in lakes and wetlands in the northern Tampa Bay area may differ by several tenths of a foot in many cases, the P10 of the model's estimates for Lake Juanita is 1.8 feet lower than the estimated Historic normal pool elevation for the lake. The difference is likely caused by the structural alterations of the lake, since Lakes Juanita's control point is 2.4 feet lower than its Historic normal pool. Rainbow and Little Moon's P10 is 0.6 feet below the estimated Historic normal pool. While the control structure for Lakes Rainbow and Little Moon is over 2 feet lower than the lakes' Historic normal pool, the inefficiency of the discharge system may not have a large effect on the lake, and the discharge from Lake Juanita may help to offset any losses to the discharge system.

Table 7. Field determined Historic normal pool for Lakes Juanita, Rainbow, and Little Moon

Lake	Historic Normal Pool (feet NGVD)
Juanita	43.5
Rainbow	40.0
Little Moon	40.0

I. Rainfall Correlation Model

In an effort to extend the period of record of the water levels used to determine the Historic Percentiles to be used in the development of the lakes' Minimum Levels, a line of organic correlation (LOC) was performed using the results of the water budget model and long-term rainfall. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 1997). LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data.

In this application, the simulated lake water levels representing Historic conditions were correlated with Long-term rainfall. For the correlation, additional representative rainfall records were added to the rainfall records used in the water budget model (1988-2013). Rainfall from the existing Cosme 18 rain gage (Figure 14) was used to extend the data through 2013. Data from the "Cosme" rain gage, which was replaced by the Cosme 18 due to quality control issues, was used to extend the rain data back to 1945. The quality control issues at the gage reported occurred after 1995, and there is no evidence that there were quality control issues at the Cosme gage prior to that time. Finally, rainfall data from the St. Leo gage (Figure 21) were used to extend the data back to 1930. Although the St. Leo gage is approximately 26 miles from Lakes Juanita and Rainbow, it is one of only a few rain gages in the vicinity with data preceding 1945, and in this case, is only used in the first few years of the correlation.

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

Rainfall was correlated to the water budget model results for the entire period used in the water budget model (1988-2013), and the results from 1946-2013 (68 years) were produced. For both lakes, the 4-year weighted model had the highest correlation coefficient. The R^2 for each lake was of 0.71 and 0.72, respectively. Previous correlations for lakes in the northern Tampa Bay area have consistently had best correlation coefficients in the 2 to 5 year range. The results are presented in Figures 22 and 23.

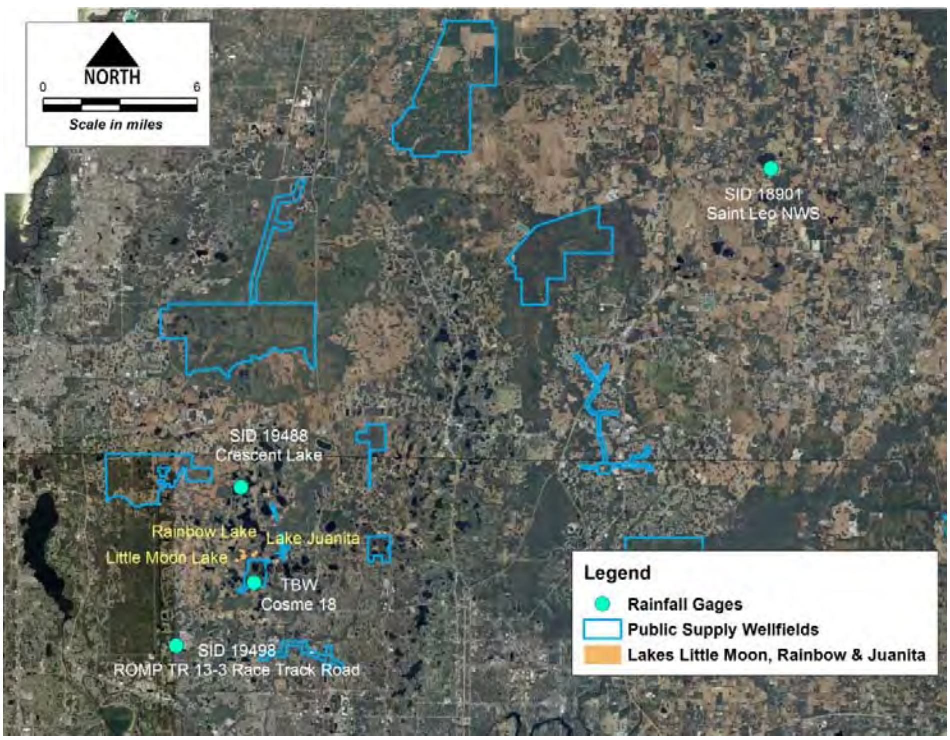

Figure 21. Location of rain stations used for the rainfall correlation model.

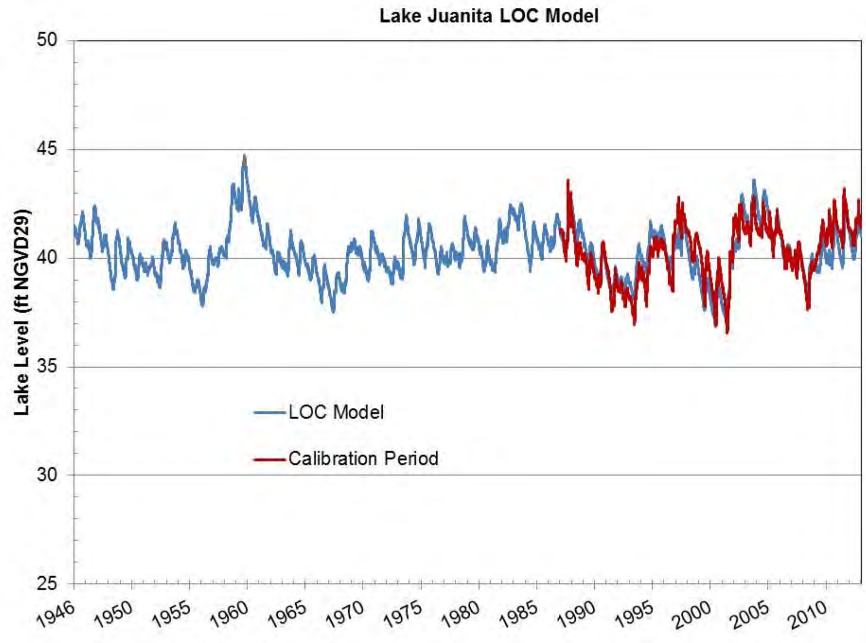

Figure 22. LOC model results for Lake Juanita.

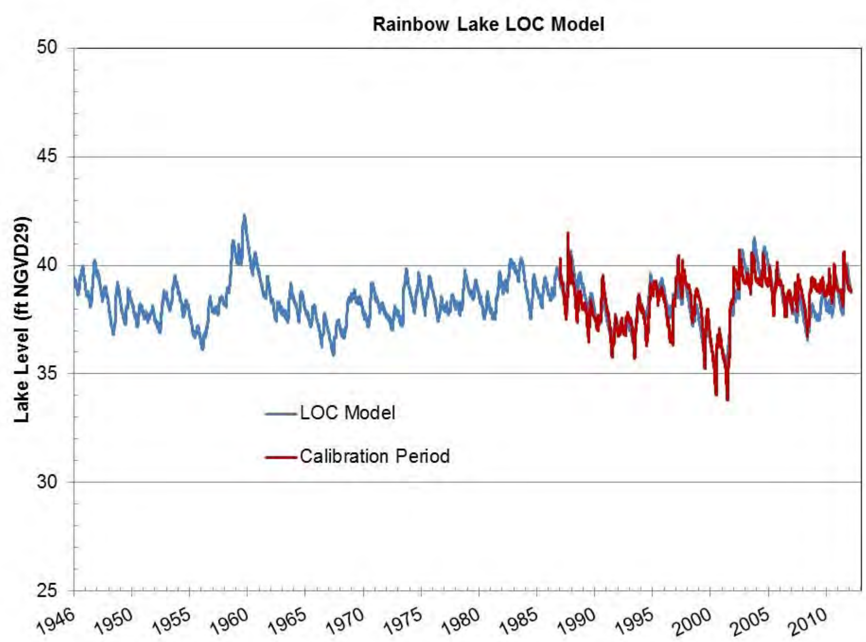

Figure 23. LOC model results for Rainbow Lake.

In an attempt to produce Historic percentiles that apply significant weight to the results of the water budget models, the rainfall LOC results for the period of the water budget model are replaced with the water budget model results. Therefore, the LOC rainfall model results are used for the period of 1946-1987, while the water budget results are used for the period of 1988-2013. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Table 8. Note that the difference between the P10, P50, and P90 percentiles from the water budget model (Table 6) and those from the hybrid rainfall model (Table 8) for Lake Juanita are 0.1, 0.0, and 0.4 feet, respectively. The difference between the P10, P50, and P90 percentiles from the water budget model (Table 6) and those from the hybrid rainfall model (Table 8) for Rainbow Lake are 0.2, 0.2, and 0.3 feet, respectively. Therefore, there are relatively small changes to the Historic percentiles between the two models for both lakes.

Table 8. Historic percentiles as estimated by the hybrid model from 1946 to 2013 (feet NGVD29).

Percentile	Lake Juanita	Rainbow Lake
P10	41.8	39.6
P50	40.3	38.4
P90	38.8	37.0

J. Conclusions

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

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APPENDIX B

Technical Memorandum

July 28, 2016

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

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
Jaime A. Swindasz, Staff Environmental Scientist, Water Resources Bureaus

Subject: Lake Juanita Initial Minimum Levels Status Assessment

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A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Lake Juanita and is proposing revised minimum levels for the lake, in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the revised minimum levels is provided by Hancock (2016) and Swindasz and others (2016).

Section 373.0421, F.S. requires that a recovery or prevention strategy be developed for all water bodies that are found to be below their minimum flows or levels, or are projected to fall below the minimum flows or levels within 20 years. In the case of Lake Juanita and other waterbodies with established minimum flows or levels in the northern Tampa Bay area, an applicable regional recovery strategy, referred to as the "Comprehensive Plan", has been developed and adopted into District rules (Rule 40D-80.073, F.A.C.). One of the goals of the Comprehensive Plan is to achieve recovery of minimum flow and level water bodies such as Lake Juanita that are located in the area affected by the Consolidated Permit wellfields (i.e., the Central System Facilities) operated by Tampa Bay Water. This document provides information and analyses to be considered for evaluating the status (i.e., compliance) of the revised minimum levels proposed for Lake Juanita and any recovery that may be necessary for the lake.

B. Background

Lake Juanita is located in northwest Hillsborough County, north of North Mobley Road and to the east of Crawley Road (Figure 1). The lake is also located to the immediate north and northwest of the Cosme-Odessa wellfield, which is one of eleven regional water supply wellfields operated by Tampa Bay Water. The wellfield property is owned by the City of St.

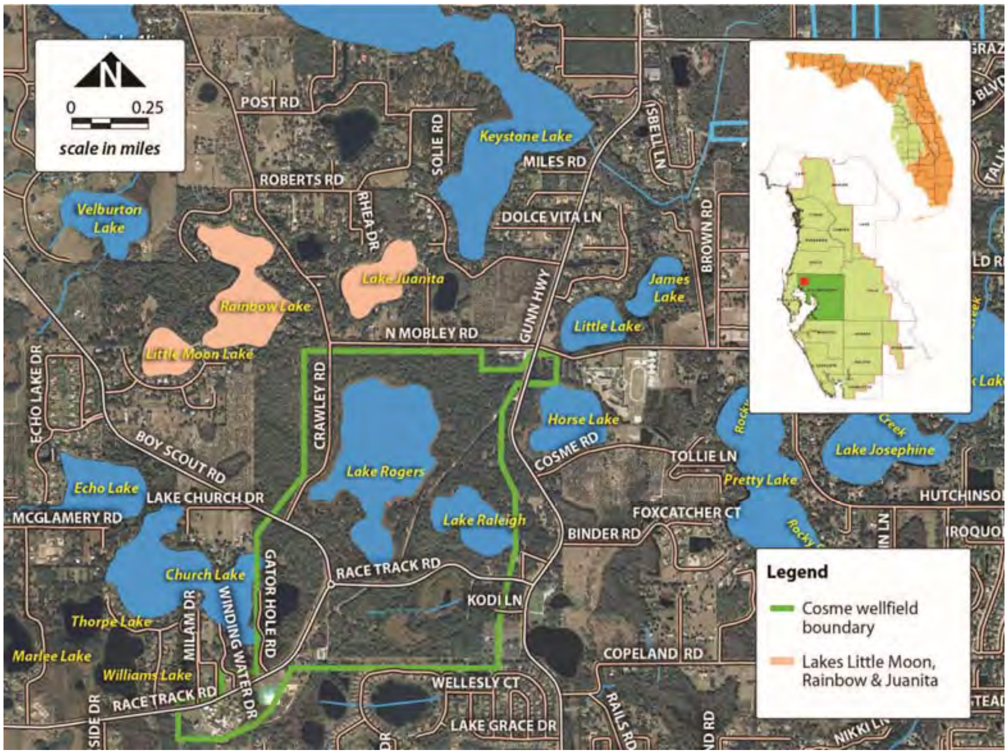

Figure 1. Location of Lake Juanita in Hillsborough County, Florida.

Petersburg, although the Hillsborough County Parks and Recreation Department maintains the wellfield land as a county park (Lake Rogers Park).

Lake Juanita lies within the Brooker Creek watershed, although the lake is relatively isolated, and there are long stretches of time when no discharge occurs from the lake. Surface water inflow to Lake Juanita occurs as overland flow from the lake's small drainage basin, as overflow from a large wetland to the north, or from Lake Eva and a series of wetlands to the northwest (Figure 2). For purposes of modeling, the wetlands and Lake Eva are considered as part of Lake Juanita, and are included in the stage/volume information in the model. Discharge from Lake Juanita can occur on the western shore of the lake via a series of open ditches and culverts passing under Crawley Road and into Rainbow Lake.

Lake Juanita and other neighboring lakes are unique in that they are located in or adjacent to the Cosme-Odessa Wellfield, the oldest public supply wellfield in the District. Therefore, Lake Juanita and adjacent lakes have been subjected to the effects of groundwater withdrawals longer than any other lakes in the District. The wellfield consists of the original Cosme wellfield constructed in 1930 (on approximately 1.1 square miles of property), as well as a linear Odessa wellfield spanning approximately 2 miles to the north along Gunn Highway (Figure 3). The original wellfield began supplying water to the City of St. Petersburg in 1930, while withdrawals along the linear expansion began in the early 1950s. Monthly withdrawals steadily

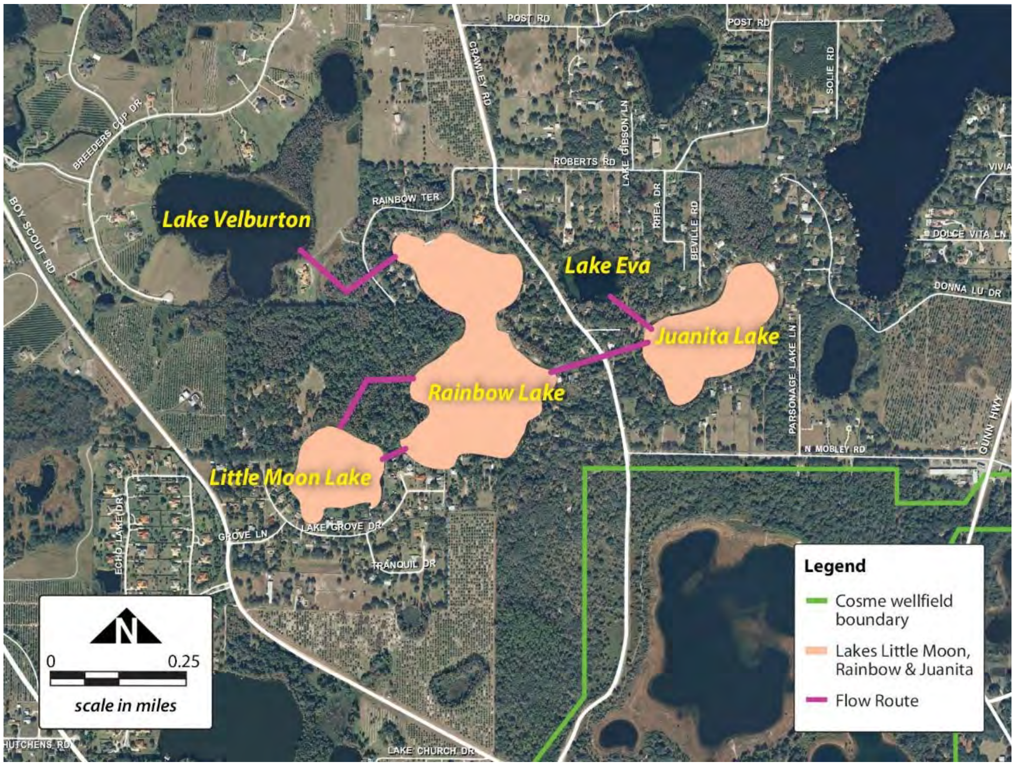

Figure 2. Flow between Juanita, Rainbow, and Little Moon Lakes.

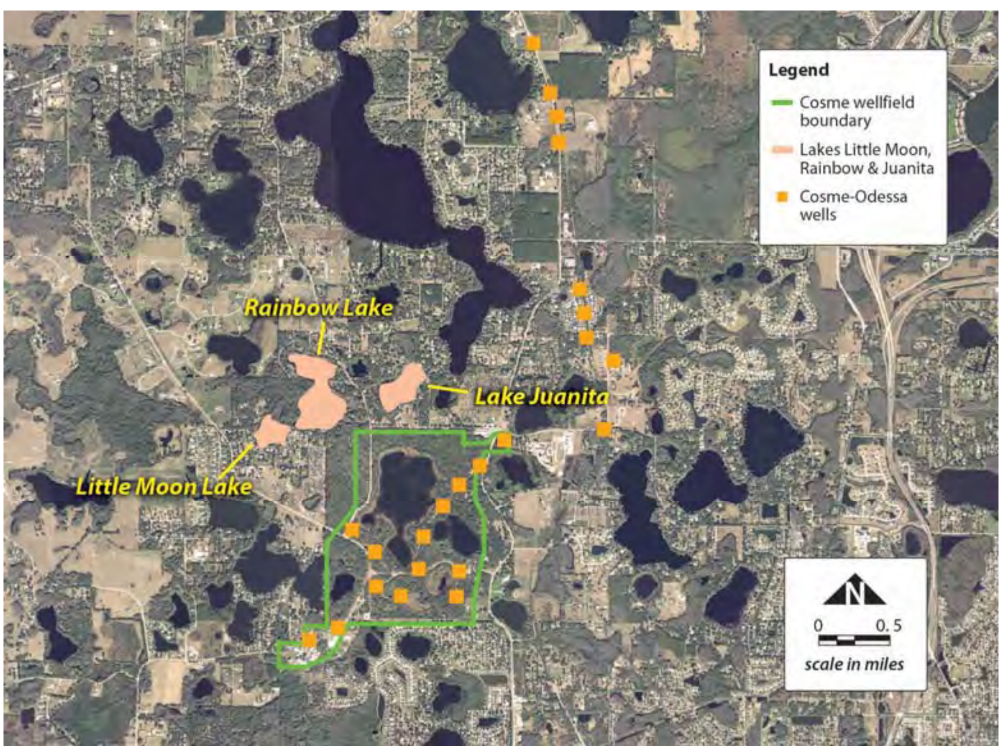

Figure 3. Cosme-Odessa Wellfield configuration.

climbed to as much as 21 million gallons per day (mgd) in 1962 (Figure 4). By the 1970s, the development of the Section 21 Wellfield, also in Northwest Hillsborough County to the east of the Cosme-Odessa Wellfield, allowed withdrawals at the Cosme-Odessa Wellfield to be reduced to about 12 mgd on annual average. Withdrawal rates during the Current period at the wellfield typically average approximately 6 mgd on annual average.

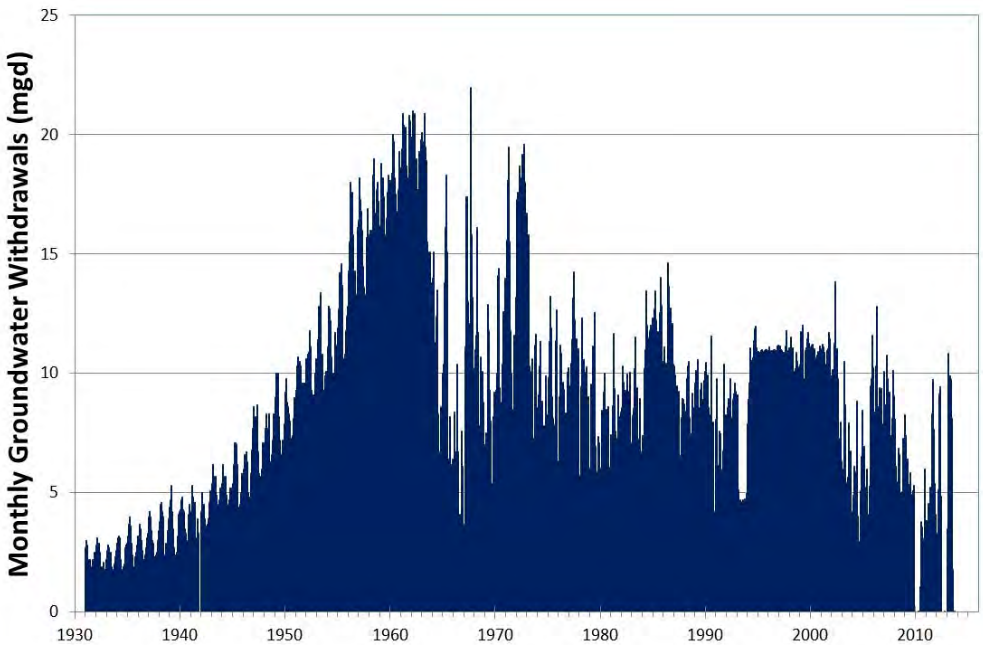

Figure 4. Cosme-Odessa Wellfield withdrawals

C. Revised Minimum Levels Proposed for Lake Juanita

Revised minimum levels proposed for Lake Juanita are presented in Table 1 and discussed in more detail by Swindasz and others (2016). Minimum levels represent long-term conditions that, if achieved, are expected to protect water resources and the ecology of the area from significant harm that may result from water withdrawals. The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. The Minimum Lake Level therefore represents the required 50th percentile (P50) of long-term water levels, while the High Minimum Lake Level represents the required 10^{th} percentile (P10) of long-term water levels. To determine the status of minimum levels for Lake Juanita or minimum flows and levels for any other water body, long-term data or model results must be used.

Table 1. Proposed Minimum Levels for Lake Juanita.

Proposed Minimum Levels	Elevation in Feet NGVD 29
High Minimum Lake Level	41.8
Minimum Lake Level	40.3

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Lake Juanita from August 2002 through 2015, which was determined to represent the "Current" period. The Current period represents a recent "Long-term" period when hydrologic stresses (including groundwater withdrawals) and structural alterations are reasonably stable. "Long-term" is defined as a period that has been subjected to the full range of rainfall variability that can be expected in the future. As demonstrated in Hancock (2016), groundwater withdrawals during this period were relatively consistent. To create a data set that can reasonably be considered to be "Long-term", a regression analysis using the line of organic correlation (LOC) method was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used to develop the minimum levels for Lake Juanita (Hancock, 2016). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing over 60 years of lake levels, based on the current relationship between lake water levels and actual rainfall.

The same rainfall data set used for setting the minimum levels for Lake Juanita was used for the status assessment (Hancock, 2016), although it was updated through 2015. The best resulting correlation for the LOC model created with measured data (August 2002-2015) was the 4-year weighted period, with a coefficient of determination of 0.56. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the percentiles calculated directly from the measured lake level data for Lake Juanita for the period from August 2002 through 2015. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 13 years, rather than the longer-term rainfall conditions represented in the 1946 to 2015 LOC model simulation.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the August 2002 to 2015 data, and the revised minimum levels proposed for Lake Juanita.

Percentile	**Long Term LOC Model Results 1946 to 2015** Elevation in feet NGVD 29*	**Measured Lake Levels for Current Period (August 2002 to 2015)** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	41.6	41.9	41.8
P50	38.6	40.9	40.3

* LOC model based on Current Period and extended using rainfall for 1946 to 2015

A comparison of the LOC model with the revised minimum levels proposed for Lake Juanita indicates that the Long-term P10 is 0.2 feet lower than the proposed High Minimum Lake Level, and the Long-term P50 1.7 feet lower than the proposed Minimum Lake Level. The P10 elevation derived directly from the August 2002 to 2015 measured lake data is 0.1 feet higher than the proposed High Minimum Lake Level, and the P50 elevation is 0.6 feet higher than the proposed Minimum Lake Level. Differences in rainfall between the shorter 2002 to 2015 period and the longer 1946 to 2015 period used for the LOC modeling analyses likely contribute to the differences between derived and measured lake stage exceedance percentiles. Additionally, differences between actual withdrawal rates and those used in the models may have contributed to some of the differences in the percentiles.

E. Conclusions

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

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

F. References

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APPENDIX C

Technical Memorandum

August 11, 2016

TO: Jaime Swindasz, Staff Environmental Scientist, Water Resources Bureau

FROM: Jason Patterson, Hydrogeologist, Water Resources Bureau

Subject: Evaluation of Groundwater Withdrawal Impacts to Lake Juanita

1.0 Introduction

Lake Juanita is located in northwest Hillsborough County in west-central Florida (Figure 1). Prior to establishment of a Minimum Level (ML), an evaluation of hydrologic changes in the vicinity of the lake is necessary to determine if the water body has been significantly impacted by groundwater withdrawals. The establishment of the ML for Lake Juanita is not part of this report. This memorandum describes the hydrogeologic setting near the lake and includes the results of two numerical model scenarios of groundwater withdrawals in the area.

2.0 Hydrogeologic Setting

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

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

3.0 Evaluation of Groundwater Withdrawal Impacts to Lake Juanita

A number of regional groundwater flow models have included the area around Lake Juanita in northwest Hillsborough County. Ryder (1982) simulated the entire extent of the Southwest Florida Water Management District. In 1993, the District completed the Northern Tampa Bay groundwater flow model that covered a 2,000 square mile area of Hillsborough, Pinellas, Pasco, and Hernando Counties (SWFWMD, 1993). In 2002, the USGS simulated the entire Florida peninsula in their Mega Model of regional groundwater flow (Sepulveda, 2002). The most recent and advanced simulation of southern Pasco County and the surrounding area is the Integrated Northern Tampa Bay (INTB) model (Geurink

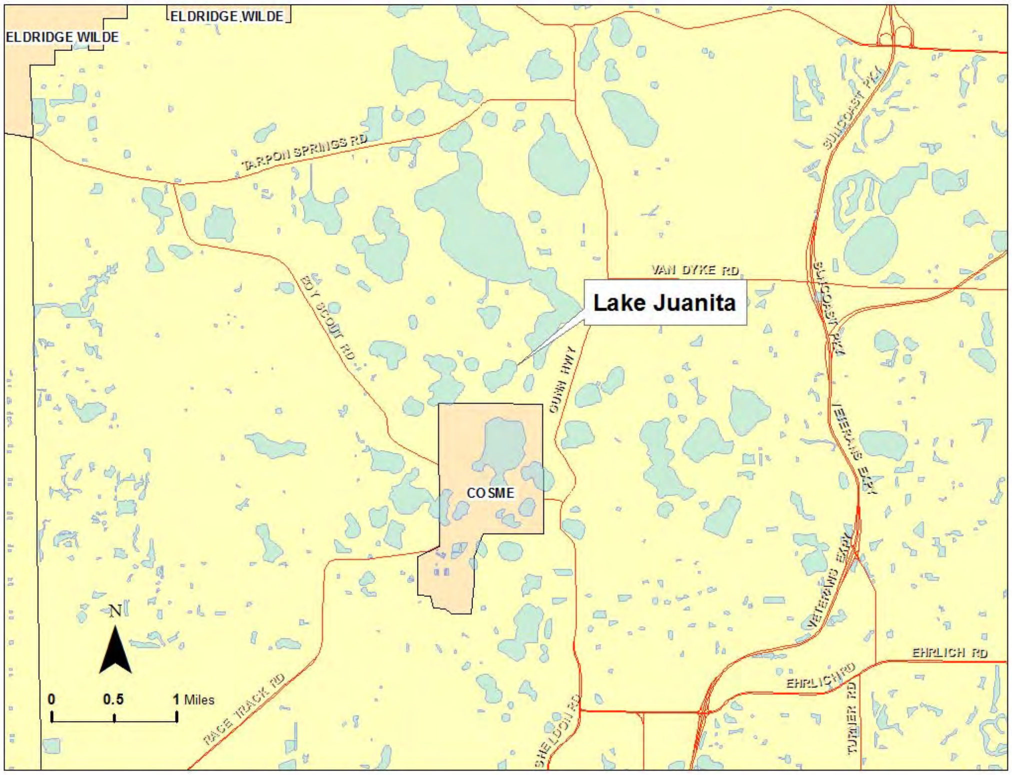

Figure 1. Location of Lake Juanita.

and Basso, 2012). The construction and calibration of this model was part of a cooperative effort between the SWFWMD and Tampa Bay Water (TBW), a regional water utility that operates 11 major wellfields. The Integrated Northern Tampa Bay Model covers a 4,000 square-mile area of the Northern Tampa Bay region (Figure 2).

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

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

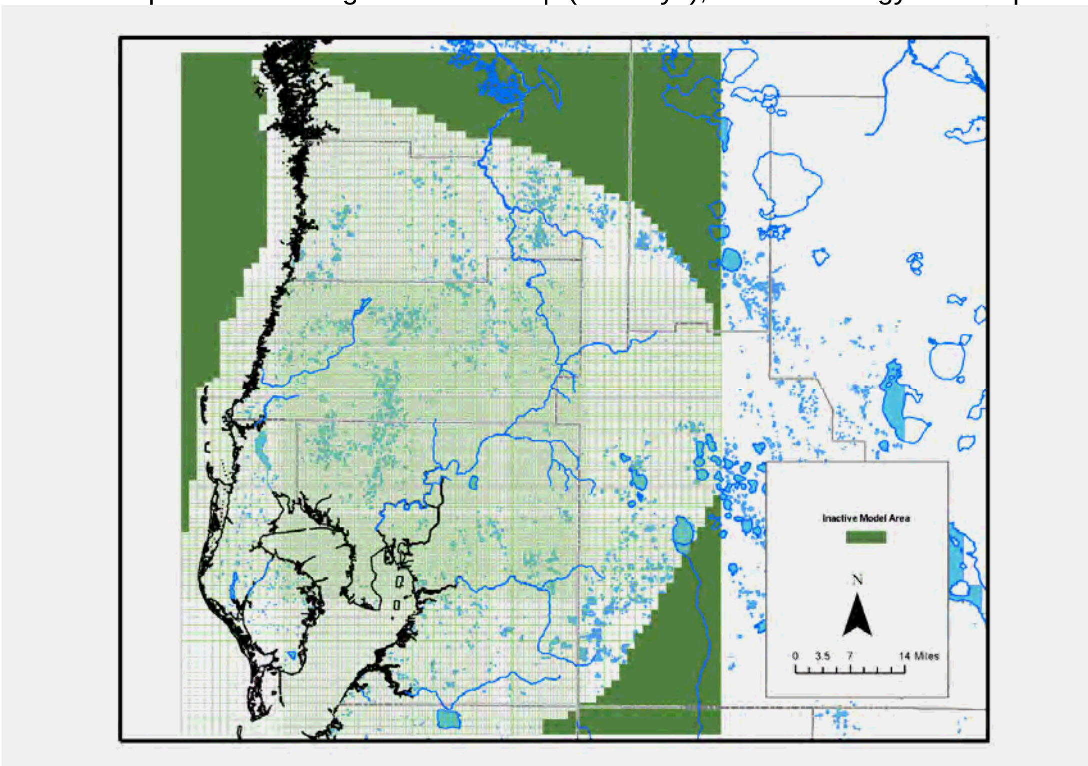

Figure 2. Groundwater grid used in the INTB model

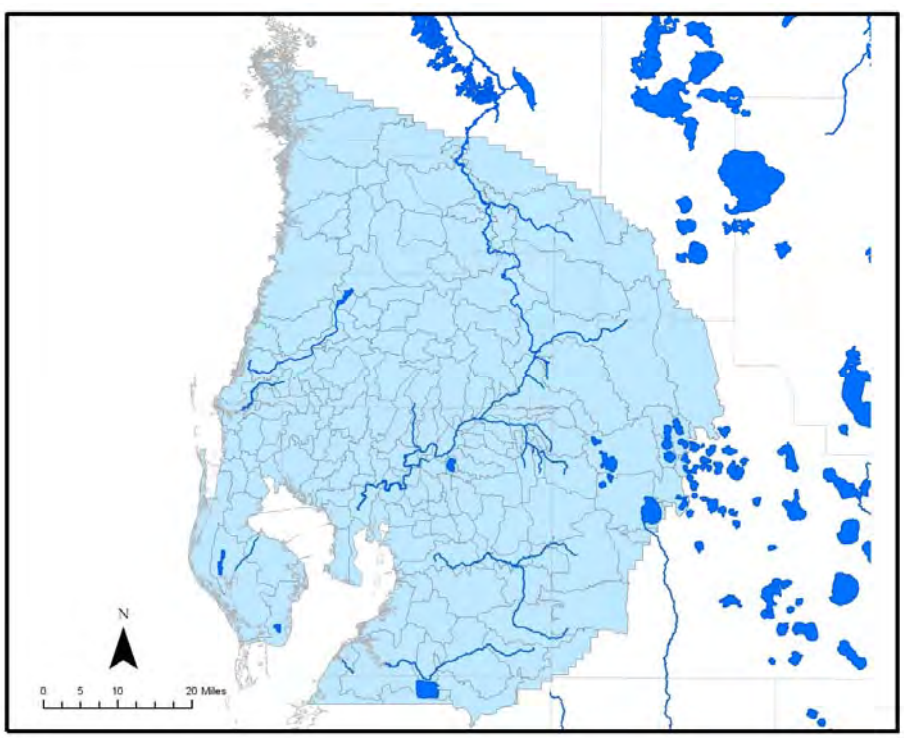

Figure 3. HSPF subbasins in the INTB model.

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 Lake Juanita was 2.0 ft and 10.1 ft in the Upper Floridan aquifer (Figure 5 and 6). Taking the difference in modeled heads from the TBW recovery pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Lake Juanita was 0.9 ft and 5.2 ft in the Upper Floridan aquifer (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 Lake Juanita.

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***
Juanita	2.0	0.9
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***
Juanita	10.1	5.2

* Average drawdown from model cells intersecting lake

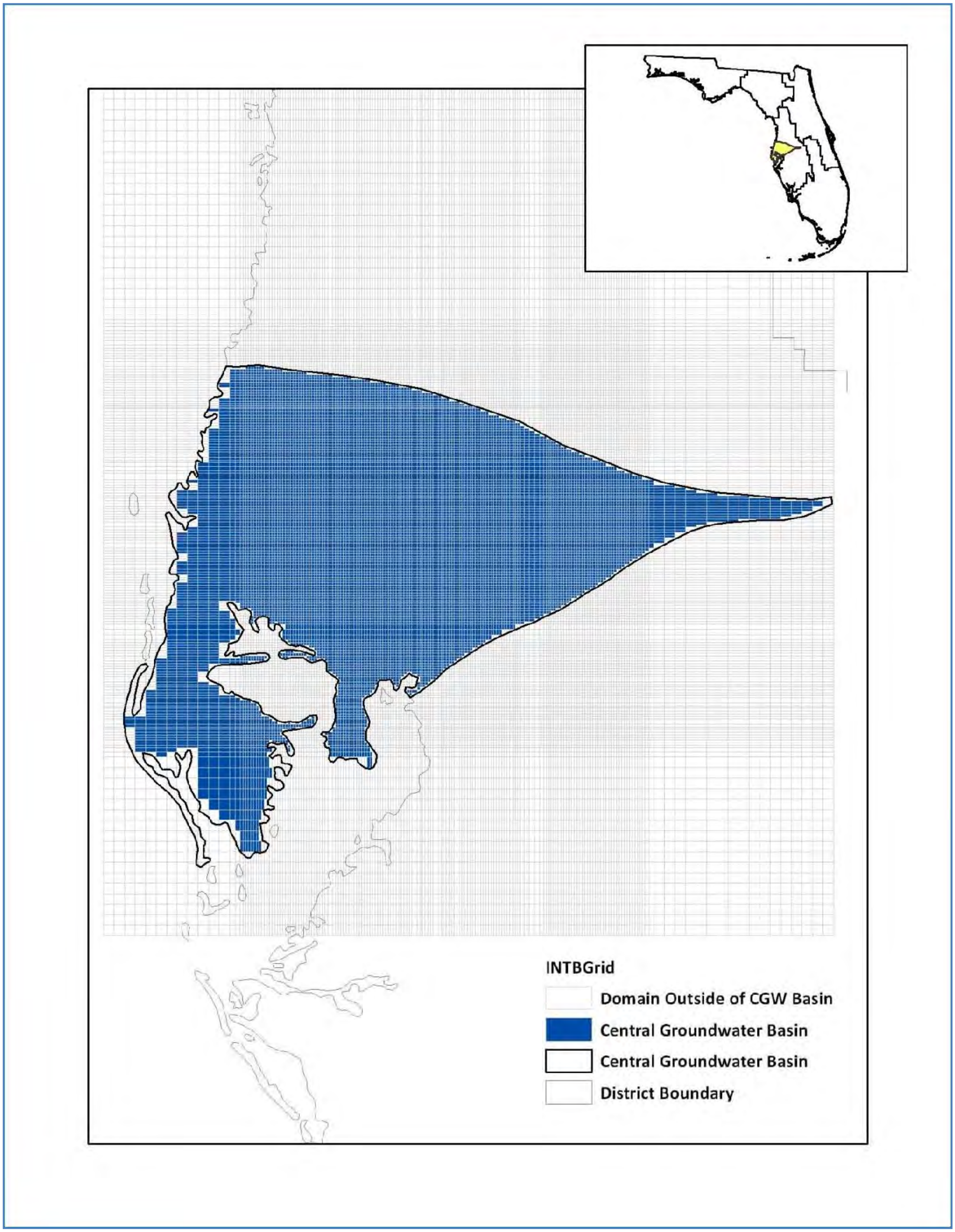

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

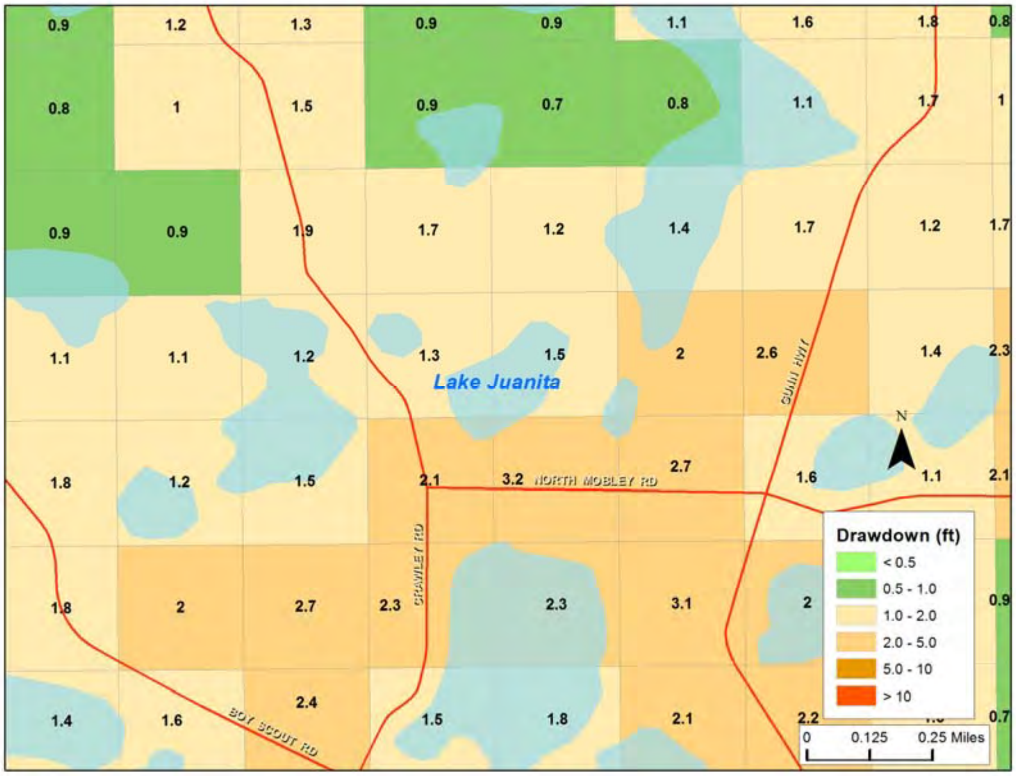

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

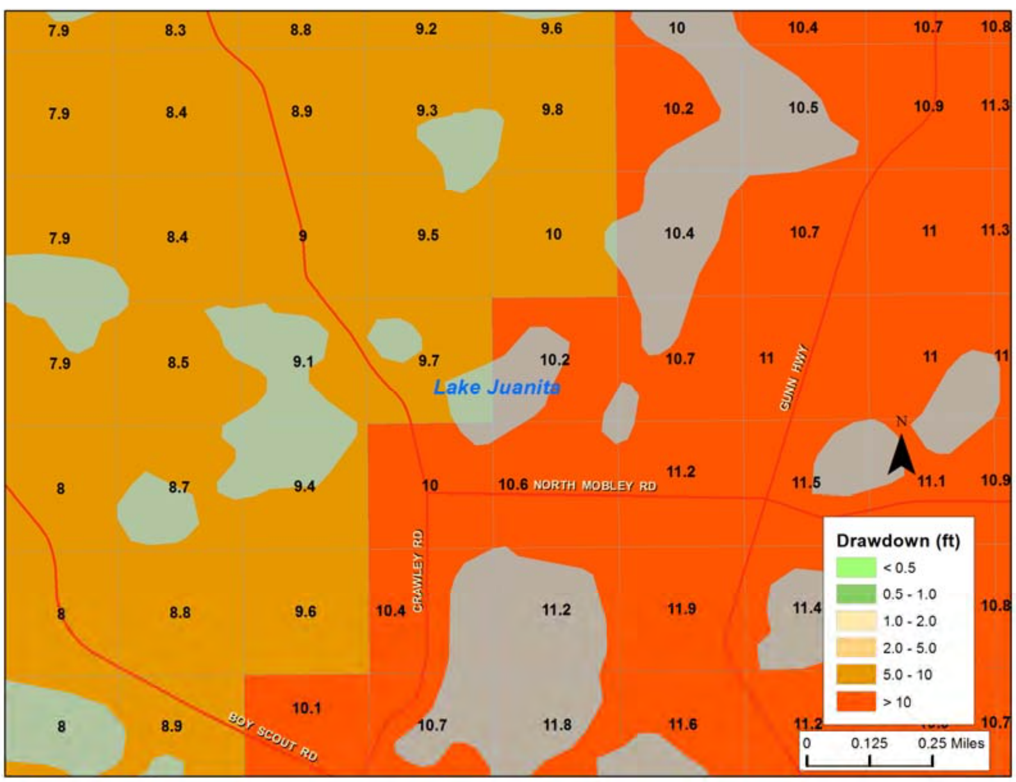

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

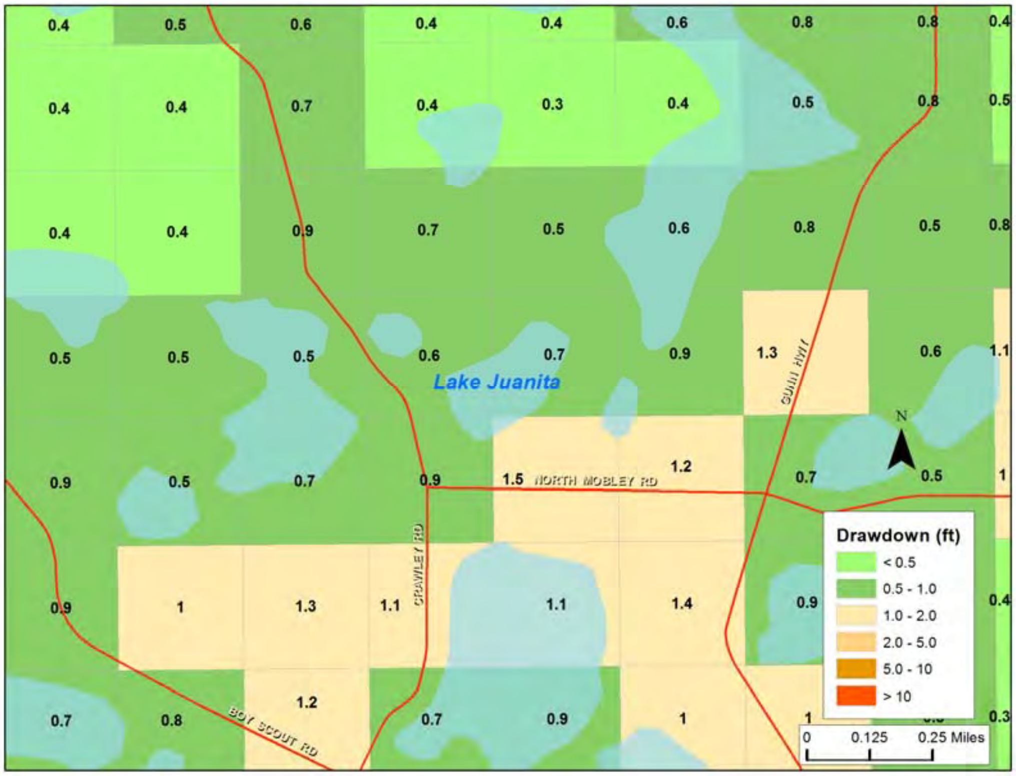

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

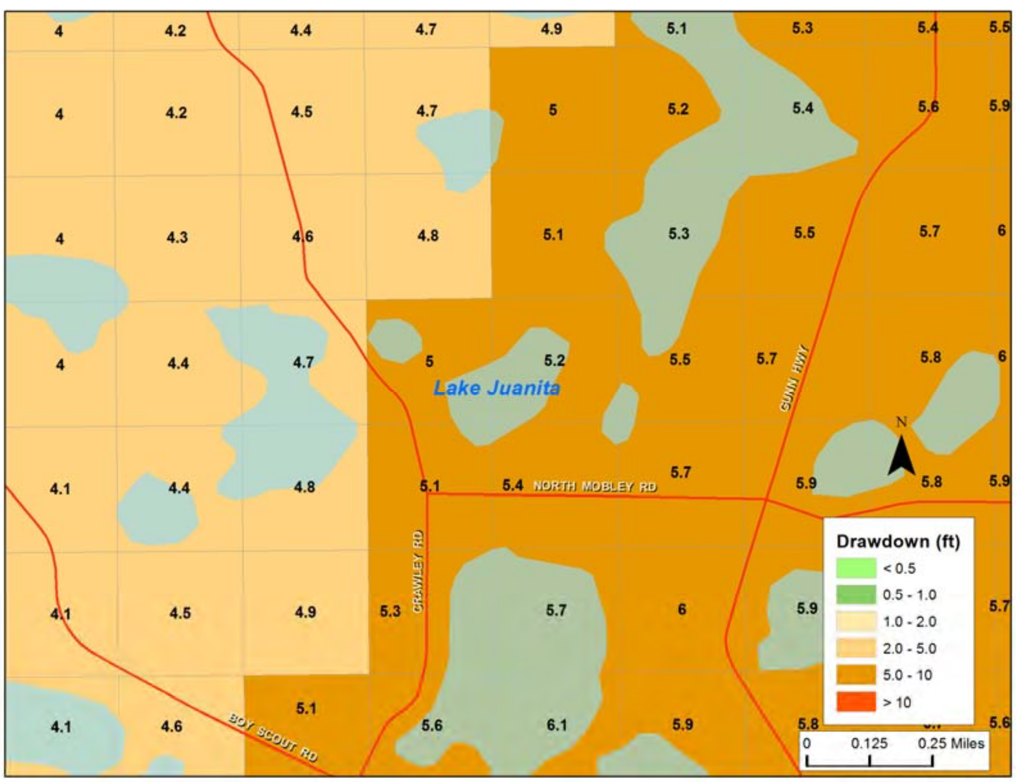

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

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