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

May 25, 2017

Resource Evaluation Section
Water Resources Bureau
Southwest Florida
Water Management District

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Cover: 2002 Aerial photograph of Sunset Lake, (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 Sunset Lake in Hillsborough County, Florida. These revised levels (Table 1) were developed using peer-reviewed methods for establishing lake levels within the Southwest Florida Water Management District (District) and are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, Florida Administrative Code [F.A.C.]). Following a public input process, the minimum and guidance levels were approved by the District Governing Board in August 2016 and subsequently adopted into the rule in January 2017. Rulemaking for these levels also included removal of previously adopted guidance levels for the lake from the rules.

**Table 1. Revised Minimum and Guidance Levels for Sunset Lake in NAVD88.**

| Minimum and Guidance Levels | Elevation in Feet NGVD29 | Elevation in Feet NAVD88 |
|---|---|---|
| High Guidance Level | 33.6 | 32.8 |
| High Minimum Lake Level | 33.6 | 32.8 |
| Minimum Lake Level | 32.3 | 31.5 |
| Low Guidance Level | 31.1 | 30.3 |

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

## Minimum Flows and Levels Program Overview

### *Legal Directives*

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

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

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

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

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

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

### *Programmatic Description and Major Assumptions*

Since the enactment of the Florida Water Resources Act of 1972 (Chapter 373, F.S.), in which the legislative directive to establish MFLs originated, and following subsequent modifications to this directive and adoption of relevant requirements in the Water Resource Implementation Rule, the District has actively pursued the adoption, i.e., establishment of MFLs for priority water bodies. The District implements established MFLs primarily through its water supply planning, water use permitting and environmental resource permitting programs, and through the funding of water resource and water supply development projects that are part of a recovery or prevention strategy. The District's MFLs program addresses all relevant requirements expressed in the Florida Water Resources Act and the Water Resource Implementation Rule.
A substantial portion of the District's organizational resources has been dedicated to its MFLs Program, which logistically addresses six major tasks: 1) development and reassessment of methods for establishing MFLs; 2) adoption of MFLs for priority water bodies (including the prioritization of water bodies and facilitation of public and independent scientific review of proposed MFLs and methods used for their development); 3) monitoring and MFLs status assessments, i.e., compliance evaluations; 4) development and implementation of recovery strategies; 5) MFLs compliance reporting; and 6) ongoing support for minimum flow and level regulatory concerns and prevention strategies. Many of these tasks are discussed or addressed in this revised minimum levels report; additional information on all tasks associated with the District's MFLs Program.

The District's MFLs Program is implemented based on a 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), Hoyer *et al*. (2006), Leeper (2006), Hancock (2006, 2007) and Emery *et al.* (2009). Independent scientific peer-review findings regarding the lake level methods are summarized by Bedient *et al.* (1999), Dierberg and Wagner (2001) and Wagner and Dierberg (2006).

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

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria are used to develop recommended 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 2). The specific standards and other information evaluated to support development of revised minimum levels for Sunset Lake are provided in subsequent sections of this report. More general information on the standards and other information used for consideration when developing minimum lake levels is available in the documents identified in the preceding sub-section of this report.

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. Code (see Hancock *et al.* 2010 for more information on the adoption process). The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29), may include the following (refer to Rule 40D-8.624, F.A.C.).

- A **High Guidance Level** (HGL) 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** (HMLL) 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** (MLL) 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** (LGL) 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). In some circumstances, notations are made for elevation data that was collected or reported relative to mean sea level or relative to NAVD88 and converted to elevations relative to NGVD29. All datum conversions were derived from surveyed measurements. The NGVD to NAVD measuring point shift is -0.78 ft. All elevation values presented in this report are reported in the NGVD29 datum.

**Table 2. 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<br>Wetland Offset<br>Lake Mixing Standard<br>Herbaceous Wetland Information<br>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 lakes including Sunset Lake;
NA[2] = Environmental value is addressed generally by development of minimum levels base on appropriate significant change standards and other information and use of minimum levels in District permitting programs

### *Lake Classification*

Lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. According to (Chapter 40D-8.624, F.A.C.) Sunset Lake meets the classification as a Category 2 lake: one that “has fringing cypress wetlands greater than 0.5 acres in size where structural alterations have prevented the Historic P50 from equaling or rising above an elevation that is equal to an elevation that is equal to an elevation that is 1.8 ft. below normal pool…”. The Historic P50 for Sunset (32.3 ft.) is lower than 1.8 feet below the Normal Pool elevation (32.7 ft.). For comparison purposes, the standards associated with category 3 lakes described below will be developed in a subsequent section of this report.

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

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

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

The 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.

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.

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

The 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.

# Lake Setting and Description

## General Lake Setting

Sunset Lake (Figure 1) is a 37 acre lake (FBC 1969) at elevation 30 ft. located in the Keystone community in the northern Tampa Bay area of unincorporated Hillsborough County, Florida (Section S17, Township 27S, Range 17E).  Residential development along the lakeshore encompasses nearly 75 percent of the lake edge. The remaining shoreline is comprised of forested swamps. There is no public access to the lake.

Land form physiology or morphology of the nature or structure of the underlying geology in the region is primarily silty sand overlying limestone. The area surrounding the lake was characterized as the Odessa Flats subdivision of the Tampa Plain in the Ocala Uplift Physiographic District (Brooks 1981), and was described as a poorly dissected low sandy plain overlying Tampa Limestone. As part of the Florida Department of Environmental Protection's Lake Bioassessment/Regionalization Initiative, the area has been identified as Keystone Lakes region, and described as well-drained, sandy upland with numerous slightly acidic, clear-water lakes with low nutrient levels (Griffith *et al.* 1997).  Romie (2000) characterized the lake as colored, soft water, meso-eutrophic lake with generally good water quality based on the Florida Trophic State Index.

## Bathymetry and Basin/Watershed Description and History

Romie (2000) listed the lake area was 37 acres at an elevation of 35 ft. One foot interval bathymetric data gathered from recent field surveys resulted in lake-bottom contour lines to 35 ft. (Figure 2). At the ten-year flood guidance levels established in 1998 (35 ft., Table 3), the lake surface area is 69 acres based on recent stage volume data calculated in support of minimum levels development. These data revealed that the lowest lake bottom contour (14.8 ft.) located in a rectangular hole on the western area of the lake is the deepest area at nearly 20 ft. deep. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

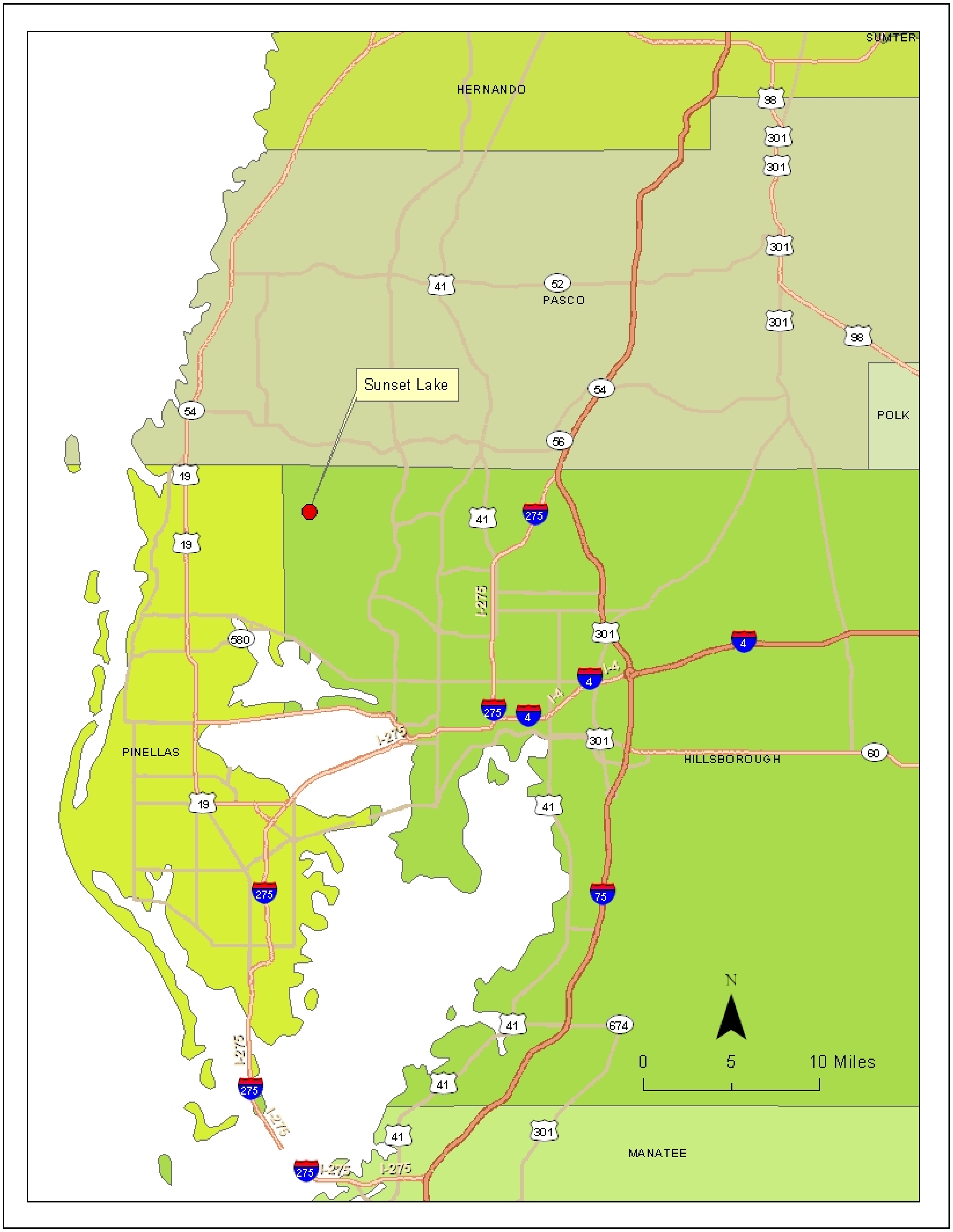


**Figure 1. Sunset Lake Location Map.**

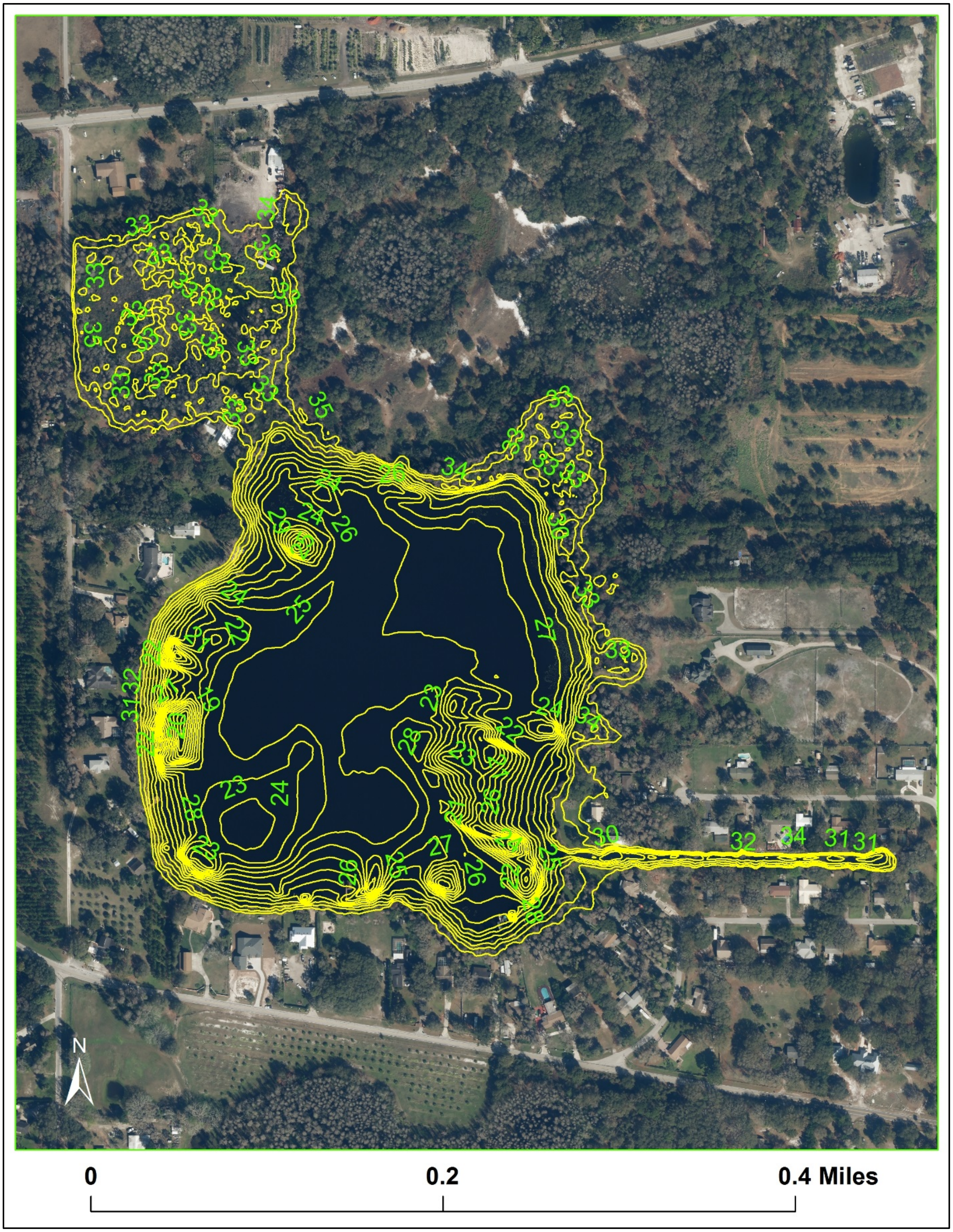


**Figure 2. Lake Bottom Contours on a 2014 Natural Aerial Photograph**

**Table 3. Previously adopted guidance levels and associated surface areas for Sunset Lake.**

| Level | Elevation (ft., NGVD) | Total Lake Area (acres) |
|---|---|---|
| Ten Year Flood Guidance Level | 35.0 | 68.6 |
| High Guidance Level | 34.8 | 66.6 |
| High Minimum Level | 34.4 | 63.1 |
| Minimum Level | 33.0 | 53.0 |
| Low Guidance Level | 32.7 | 47.6 |

Sunset Lake is located within the 338 square Coastal Old Tampa Bay Watershed. Surface water conveyance systems consist of a single main inflow into and outflow from the lake (Figure 3). The lake receives water from a forested wetland via a drainage ditch and culvert under Belmack Boulevard E. and into the canal (Figures 4 & 5). Water leaves the lake via a culvert under Burrell Rd. (elevation 30.7 ft.) that leads to Lake Jackson (aka Brown Lake) (Figures 6).

A culvert in the ditch on the northwest side of Lake Jackson leading to a ditch along Boy Scout Rd. serves as the control point for both lakes (Figures 7 & 8). In the report for the original MFL on Lake Sunset (SWFWMD 1999a), a culvert invert in the ditch between Lake Jackson (aka Lake Brown) and Boy Scout Road was used as the control point (CP) for Sunset Lake, which had a reported elevation of 35.1 ft. This value was derived from a survey that was done at the time. The report documenting the MFL established for Lake Jackson (Leeper 2004) reported the elevation of the presumably same culvert to be 32.1 ft. seemingly in conflict with the elevation reported in the 1999 Sunset Lake report. The same survey reported an elevation of a high point in the ditch near the culvert to be 32.4 ft., which was chosen as the CP for Lake Jackson. Re-survey of the outlet ditch was conducted as part of this Sunset re-evaluation in August 2014 and reported two identical high points in the ditch (32.5 ft.) (Figure 9), and the elevation of the (presumably) same culvert from the original 1999 report to be 32.0 feet NGVD. These results were consistent with the 2004 survey. Both high points in the ditch are susceptible to soil erosion and ditch maintenance such as dredging that will likely change over time. Therefore, the culvert elevation was chosen as the CP elevation (32.0 ft.) mainly because the culvert invert is a stable elevation.

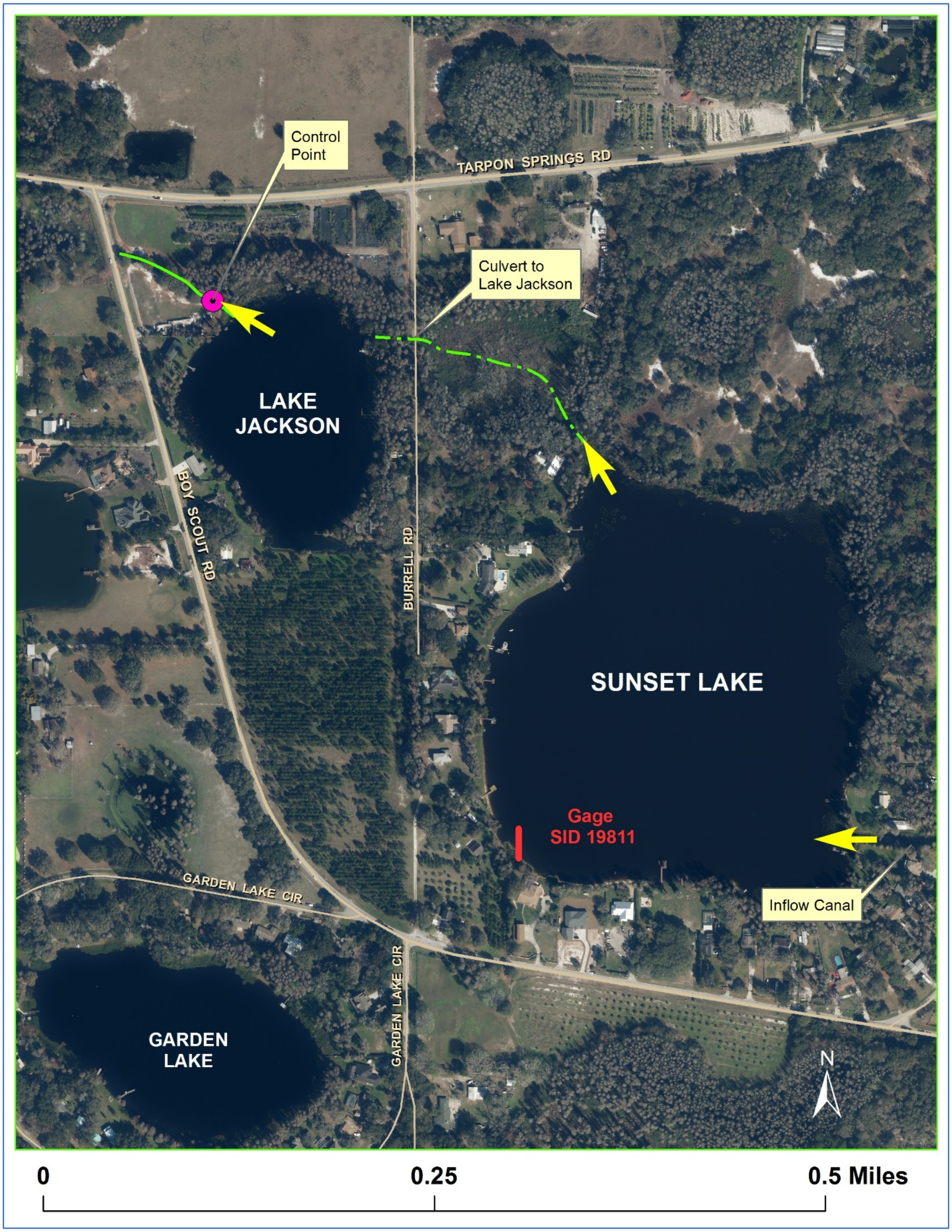


**Figure 3. Location of Inflow and Outflow Conveyance Systems and District Gage and Control Point imposed onto a 2014 Natural Color Photograph.**

**Figure 4. Inflow ditch on west side of Belmack Blvd. E.**

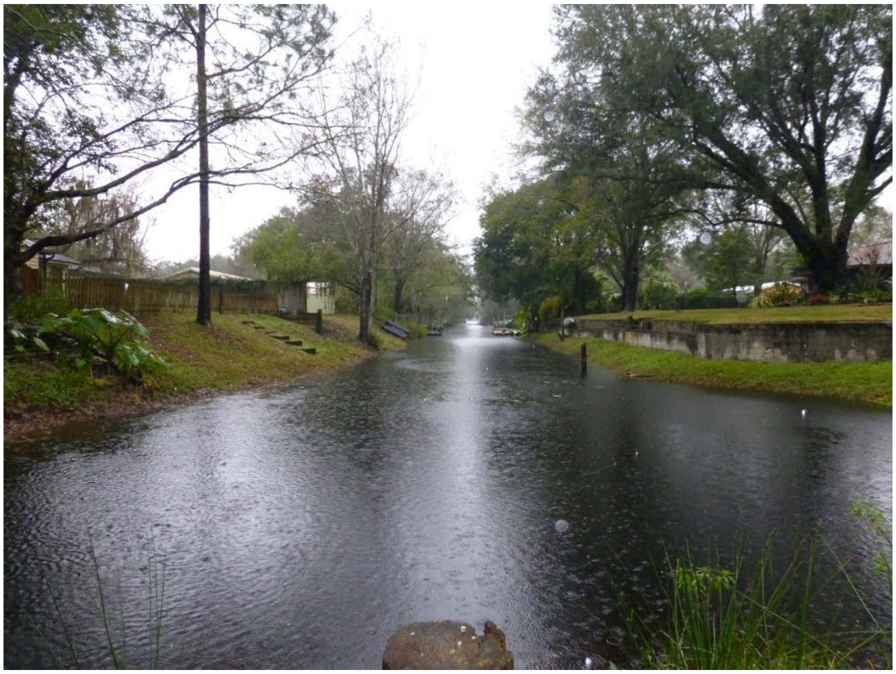

**Figure 5. End of Inflow canal into Sunset Lake.**

**Figure 6. View from Burrell Rd. into Lake Jackson**

**Figure 7. Outflow ditch leaving Lake Jackson.**

**Figure 8. Road and culvert as part of Lake Jackson outflow ditch.**

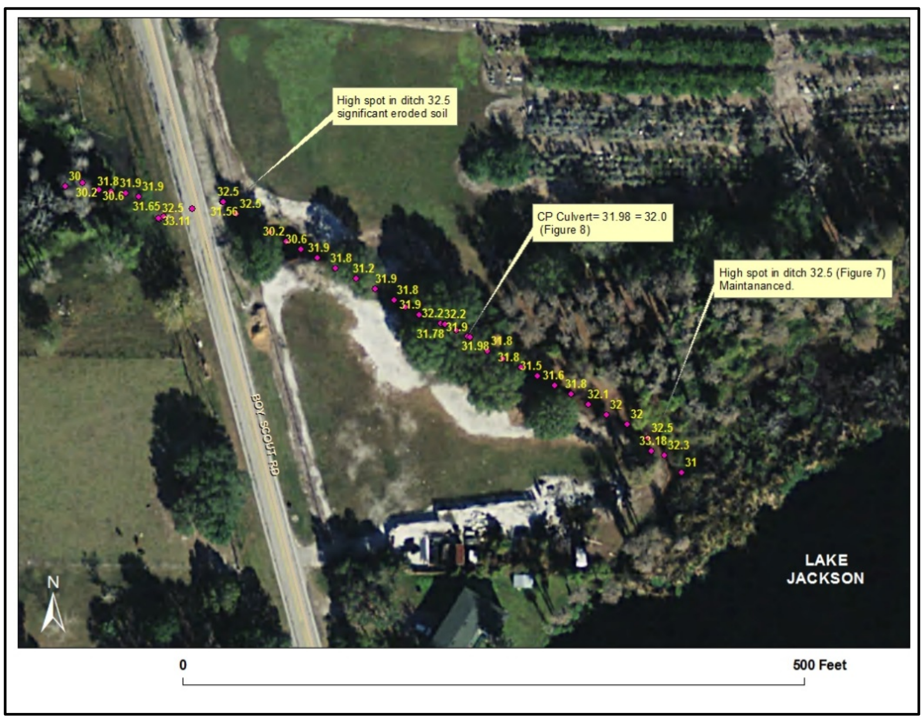


**Figure 9. Outflow ditch leaving Lake Jackson.**

An examination of the 1950 and more current 2011 Florida Land Use, Cover and Forms Classification System (FLUCCS) maps revealed that there has been considerable changes to the landscape in the vicinity during this period. Specifically, the dominant land forms. Land use in 1950 was primarily shrub and brushland (*Serenoa repens, Ilex glabra, Myrica cerifera,* and open areas of upland grasses), pine flatwoods (a thin canopy of *Pinus elliottii, Pinus palustris* with a shrub and brushland understory), and agriculture (*Paspalum notatum pasture,* citrus groves). By 2011, the landscape shifted to mostly residential development (Figure 10). Aerial photography chronicles landscape changes to the immediate lake basin from 1938 to the present (Figures 11 and 12).

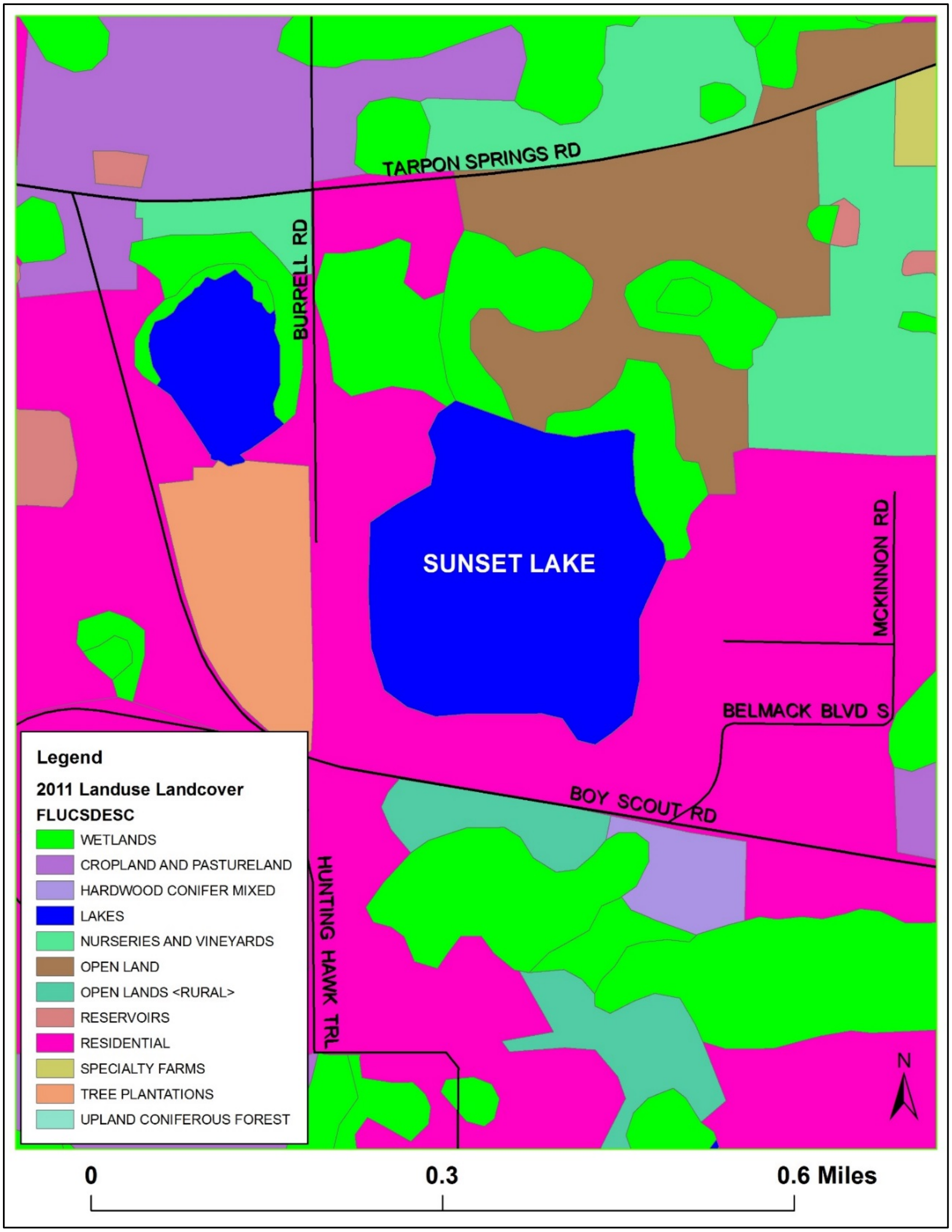


**Figure 10. 2011 Land Use Land Cover Map of the Sunset Lake Vicinity.**

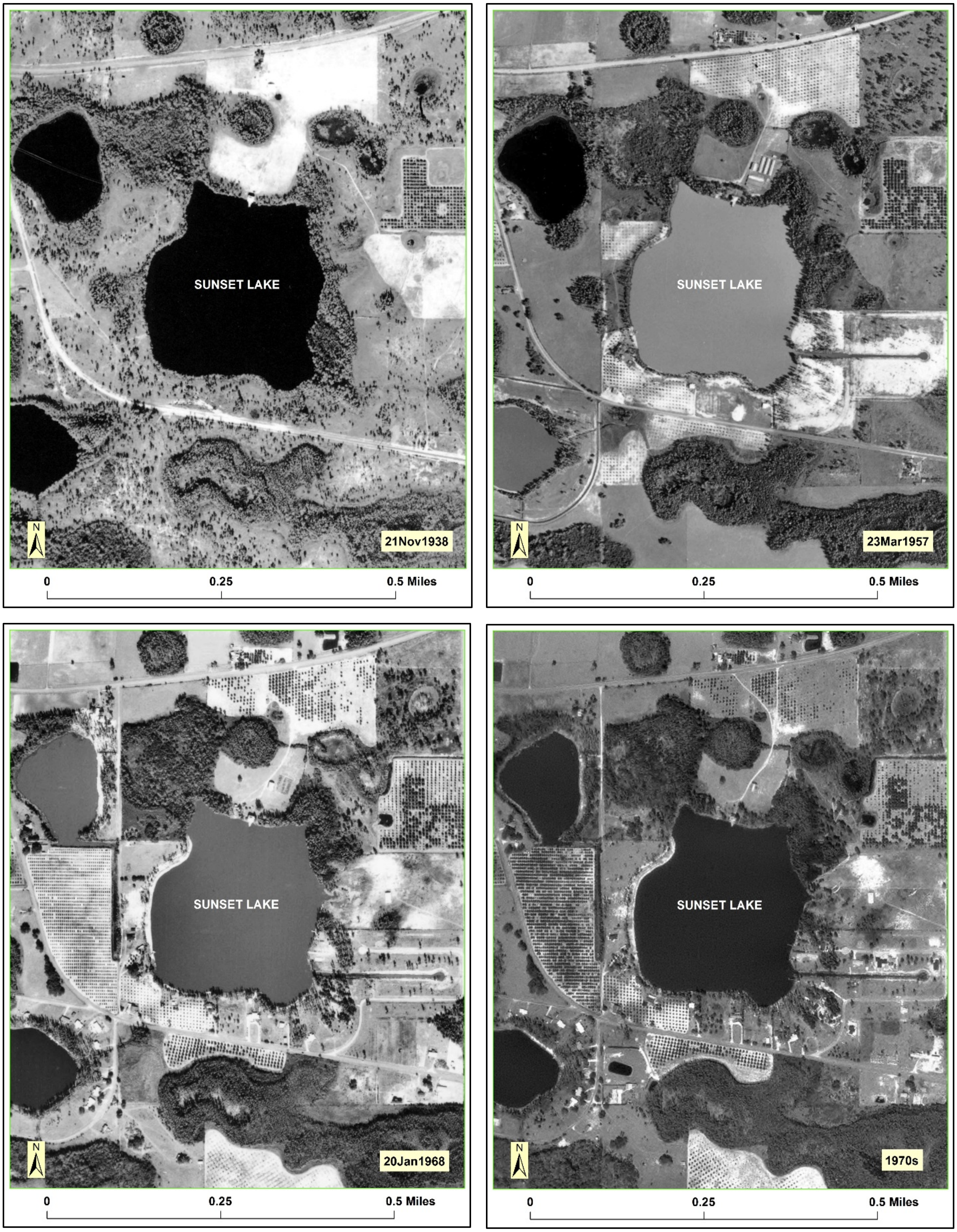


**Figure 11. 1938, 1957, 1968 and 1970s Aerial Photographs of Sunset Lake.**

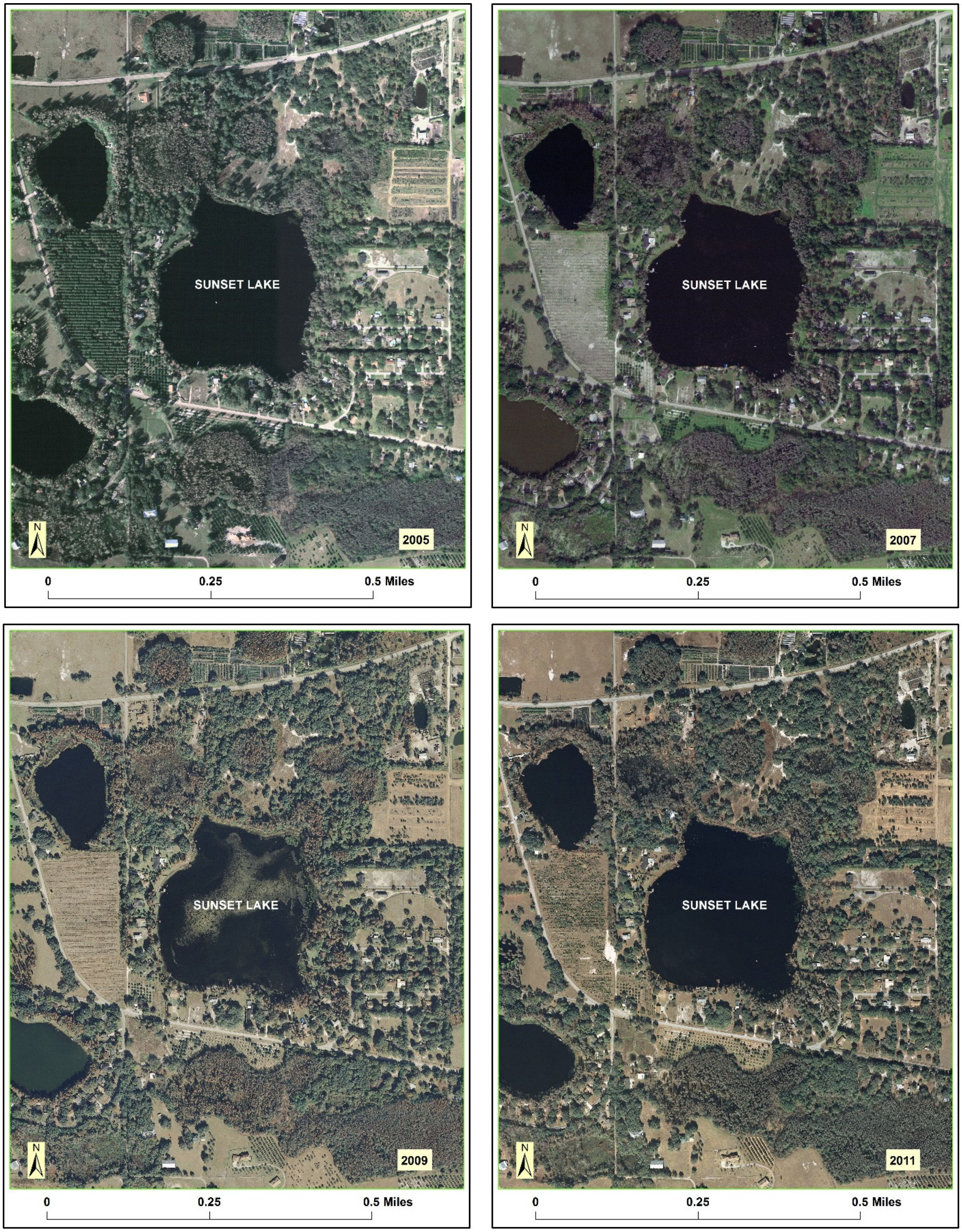


**Figure 12. 2005, 2007, 2009 and 2011 Aerial Photographs of Sunset Lake.**

# Hydrology and MFLs Development

## Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations collected, are available for Sunset Lake from the District Water Management Information System (SID 19811) (Figures 3 and 13). The District continues to monitor the water levels on a monthly basis. Data has been collected since July 10, 1972. The highest lake stage elevation on record was 35.8 ft. and occurred on September 13, 2004 in response to rainfall associated with hurricanes Charley, Frances, Ivan and Jeanne. The lowest lake stage elevation on record was 29.0 ft. and occurred on May 30, 2001 following a 1999-2001 period of extended drought.

## Historical Management Levels and Previous Minimum and Guidance Levels Development

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.

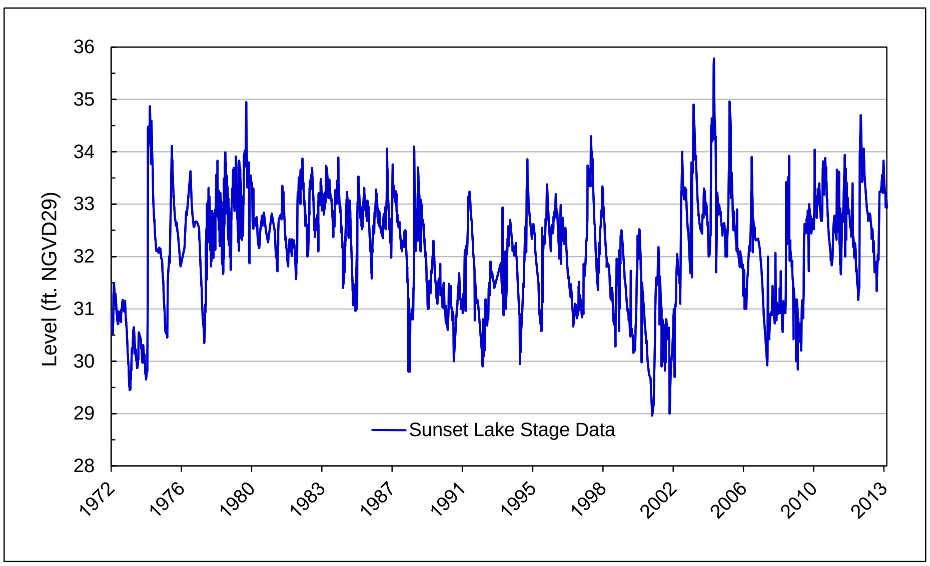


**Figure 13. Sunset Lake Period of Record Stage Data (WMIS SID 19811).**

Based on work conducted in 1988 (see SWFWMD 1996), the District Governing Board adopted management levels (currently referred to as Guidance Levels) into Chapter 40D-8, Florida Administrative Code for Sunset Lake in 1988 (Table 3). These previously adopted management levels for Sunset Lake were replaced by Minimum and Guidance Levels in February 2017 using the methodology for Category 2 Lakes described in Leeper *et al.* (2001), in accordance with modifications outlined by Dierberg and Wagner (2001). The currently adopted Minimum and Guidance Levels, along with area values for each water level are listed in Table 4.

# Methods, Results and Discussion

## Summary of Data and Analyses Supporting Development of the Revised Minimum and Guidance Levels

The revised Minimum and Guidance Levels in this report were developed for Sunset Lake using the methodology for Category 2 lakes described in Chapter 40D-8, F.A.C. Revised levels along with lake surface area for each level are listed in Table 4 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 4. Lake Stage Percentiles, Normal Pool and Control Point Elevations, and Significant Change Standards, Revised Minimum and Guidance Levels associated surface areas for Sunset Lake.**

| Levels | Elevation in Feet NGVD 29 | Lake Area (acres) |
|---|---|---|
| Lake Stage Percentiles | | |
| Historic P10 (1946 to 2013) | 33.6 | 58 |
| Historic P50 (1946 to 2013) | 32.3 | 46 |
| Historic P90 (1946 to 2013) | 31.1 | 43 |
| Normal Pool and Control Point | | |
| Normal Pool | 34.5 | 64 |
| Control Point | 32.0 | 45 |
| Significant Change Standards | | |
| Lake Mixing Standard* | NA | NA |
| Dock-Use Standard* | 33.0 | 53 |
| Basin Connectivity Standard * | NA | NA |
| Species Richness Standard* | 30.7 | 42 |
| Aesthetics Standard* | 31.1 | 43 |
| Recreation/Ski Standard* | 33.5 | 58 |
| Wetland Offset Elevation* | 31.5 | 44 |
| Minimum and Guidance Levels | | |
| High Guidance Level | 33.6 | 58 |
| High Minimum Lake Level | 33.6 | 58 |
| Minimum Lake Level | 32.3 | 46 |
| Low Guidance Level | 31.1 | 43 |

NA - 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 Sunset Lake by building and processing a digital elevation model (DEM) of the lake basin and surrounding watershed. Elevations of the lake bottom and land surface elevations were used to build the model through a series of analyses using LP360 (by QCoherent) for ArcGIS, ESRI® ArcMap 10.2 software, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involved 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 was then used to calculate area of the lake and the associated volume of the lake at different elevations, starting with 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 Sunset Lake. Light Detection and Ranging Data (LiDAR) was processed with LP360 for ArcGIS and merged with bathymetric data collected with both sonar and mechanical (manual) methods. A LEI HS-WSPK transducer (operating frequency = 192kHz, cone angle = 20) mounted to a boat hull was used, as well as 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 14).

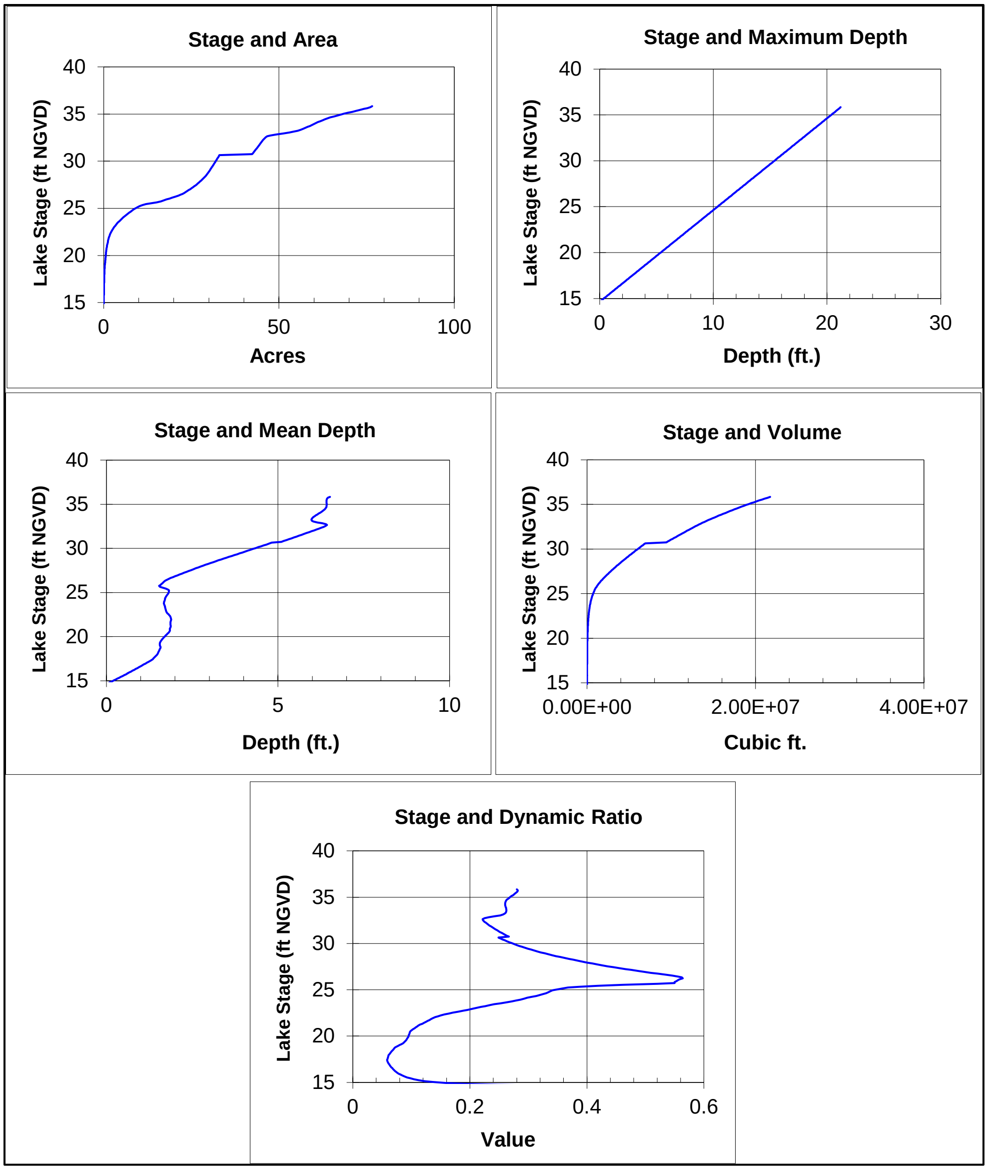


**Figure 14. Surface area, volume, mean depth, maximum depth and dynamic ratio (basin slope) as a function of lake stage.**

## Classification of Lake Stage Data and 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 a water budget model which incorporated the effects of precipitation, evaporation, overland flow, and groundwater interactions (Appendix A). Using the results of the water budget model, regression modeling for lake stage predictions was conducted using a linear line of organic correlation statistical model (LOC) (see Helsel and Hirsch 1992). The procedure was used to derive the relationship between daily water surface elevations for Sunset Lake 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, or the elevation of the lake water surface equaled or exceeded ten percent of the time, was 33.6 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 32.3 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 31.1 ft. (Figure 15 and Table 4).

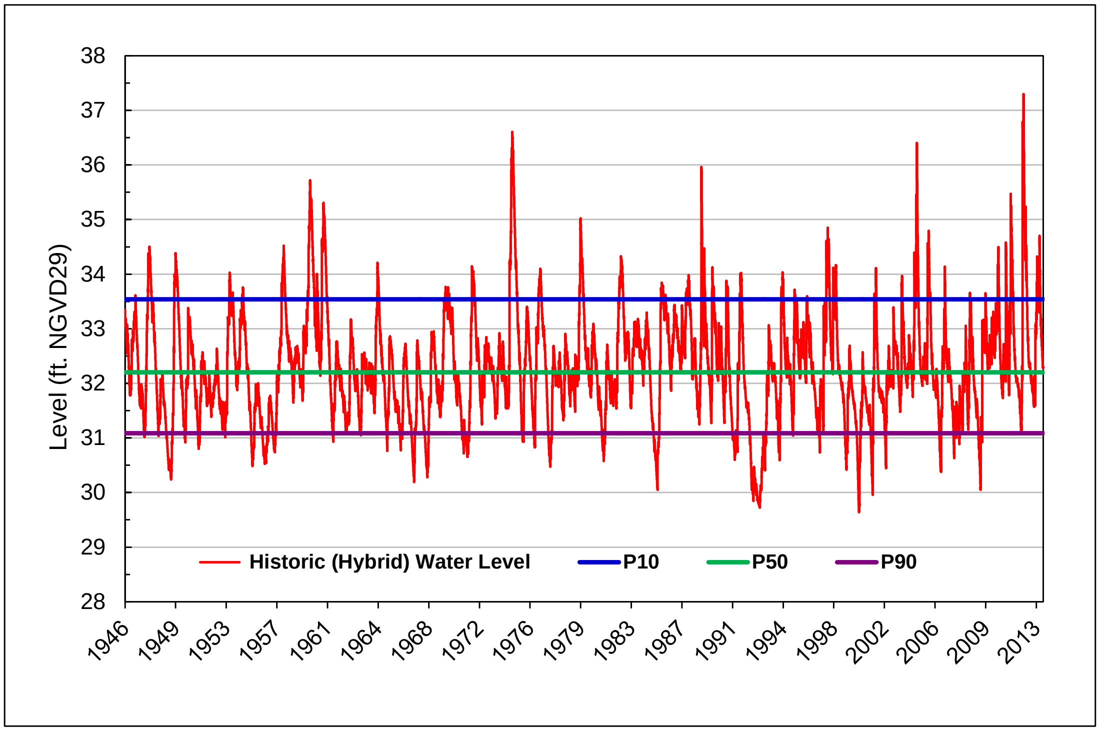


**Figure 15. Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.**

## 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). Ten good quality examples of cypress buttress swelling where measured on the lake in August 2013 (Table 5). The spread between the minimum and maximum buttress elevations (1.7 ft.) is greater than most lakes in the Northern Tampa Bay area, though not without precedence. This spread is likely due to subsidence that has occurred in the past. Based on the survey of these biologic indicators, the Normal Pool elevation was established at 34.5 ft.

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

| Summary Statistic | Number (N) or Elevation |
|---|---|
| N | 10 |
| Median | 34.5 |
| Mean | 34.4 |
| Minimum | 33.6 |
| Maximum | 35.3 |

Additional information to consider in establishing Minimum and Guidance Levels are the Control Point elevation and the lowest building floor (slab) elevation within the lake basin (determined by field survey data). The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system that can principally control the lake water level fluctuations at the high end. The highest fixed spot in the outflow conveyance system is the culvert in the ditch at the NW corner of Lake Jackson serves as the control point at 32.0 ft. The low floor slab elevation was determined by field survey as 37.6 ft., which is 4.0 ft. higher than the HGL and 1.8 ft. higher than the highest period of record stage elevation. The low floor slab was not considered in establishing the Minimum and Guidance Levels.

## 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 Sunset Lake, the revised High Guidance Level was established at the Historic P10 elevation, 33.6 ft. The High Guidance Level has been exceeded several times in the Historic data. For example, the highest peak was 37.3 ft. in July 2012. In comparison, gaged period of record levels for the lake exceeded the High Guidance Level regularly with a maximum level of 35.8 ft. in September 2004. (Figure 13).

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. These statistics represent differences between P10, P50 and P90 lake stage elevations for typical, regional lakes that exhibit little or no impacts associated with water withdrawals, i.e., reference lakes. Reference lake water regime statistics include the RLWR50, RLWR90 and RLWR5090, which are, respectively, median differences between P10 and P50, P50 and P90, and P10 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of Historic data for Sunset Lake, the revised Low Guidance Level was established at the Historic P90 elevation, 31.1 ft.

## Significant Change Standards

Category 3 significant change standards, including a Lake Mixing Standard, Dock-Use Standard, Basin Connectivity Standard, Species Richness Standard, Herbaceous Wetland Standard, Submerged Aquatic Macrophyte Standard, Aesthetics Standard, and a Recreation/Ski Standard were established for Sunset Lake where appropriate. Each standard was previously defined in the Lake Classification section of this report. Each were evaluated for minimum levels development for Sunset Lake and presented in Table 4.

The Mixing Standard was not established because the data did not shift as the rule requires, indicating that potential changes in basin susceptibility to wind-induced sediment re-suspension would not be of concern for minimum levels development. The Dock-Use Standard was established at 33.0 ft., derived from the elevation of lake sediments at the end of 16 docks on the lake (Table 6). The Basin Connectivity Standard was not applicable and was not established because historical aerial photography and lake bathymetry revealed that the lake is one continuous basin. The Species Richness Standard was established at 30.7 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation. An Aesthetic-Standard for Sunset Lake was established at the Low Guidance Level elevation of 31.1 ft. The Recreation/Ski Standard was calculated at 33.5 ft. based on a ski elevation of 32.3 ft. that contained a suitable area and depth for safe water skiing.

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 (Figure 16).

**Table 6. Summary statistics and elevations associated with docks in Sunset Lake based on measurements made by District staff in March 2013. Exceedance percentiles (P10, P50, and P90) represent elevations exceeded by 10, 50 and 90 percent of the docks.**

| Summery Statistics | Statistics Value (N) or Elevation (feet) of Sediments at Waterward End of Docks | Statistics Value (N) or Elevation (feet) of Dock Platforms |
|---|---|---|
| N (number of docks) | 16 | 16 |
| 10th Percentile (P90) | 26.1 | 33.2 |
| Median or 50th Percentile | 28.2 | 34.6 |
| 90th Percentile (P10) | 29.8 | 35.7 |
| Maximum | 32.2 | 35.8 |
| Minimum | 24.7 | 32.5 |

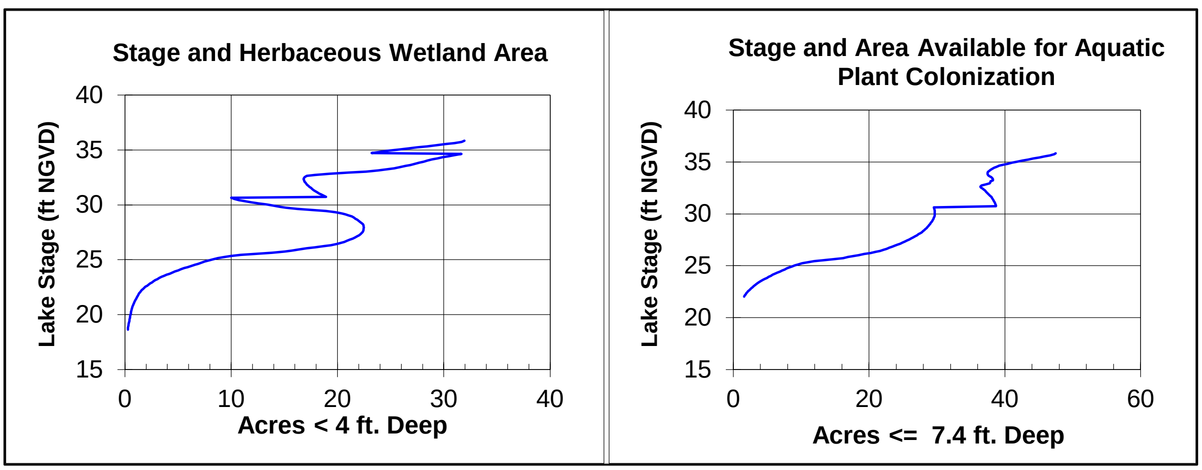


**Figure 16. Potential herbaceous wetland area and area available for macrophyte colonization in Sunset Lake as a function of lake stage.**

## 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 the median (P50) of the Historic water level. In the case of Sunset Lake, the revised minimum level is 32.3 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 Sunset Lake is established at 33.6 ft.

Revised Minimum and Guidance levels for Sunset Lake are plotted on the Historic water level record (Figure 17). To illustrate the approximate locations of the lake margin when water levels equal the revised minimum levels, revised levels are imposed onto a 2014 natural color photograph in Figure 18a & b.

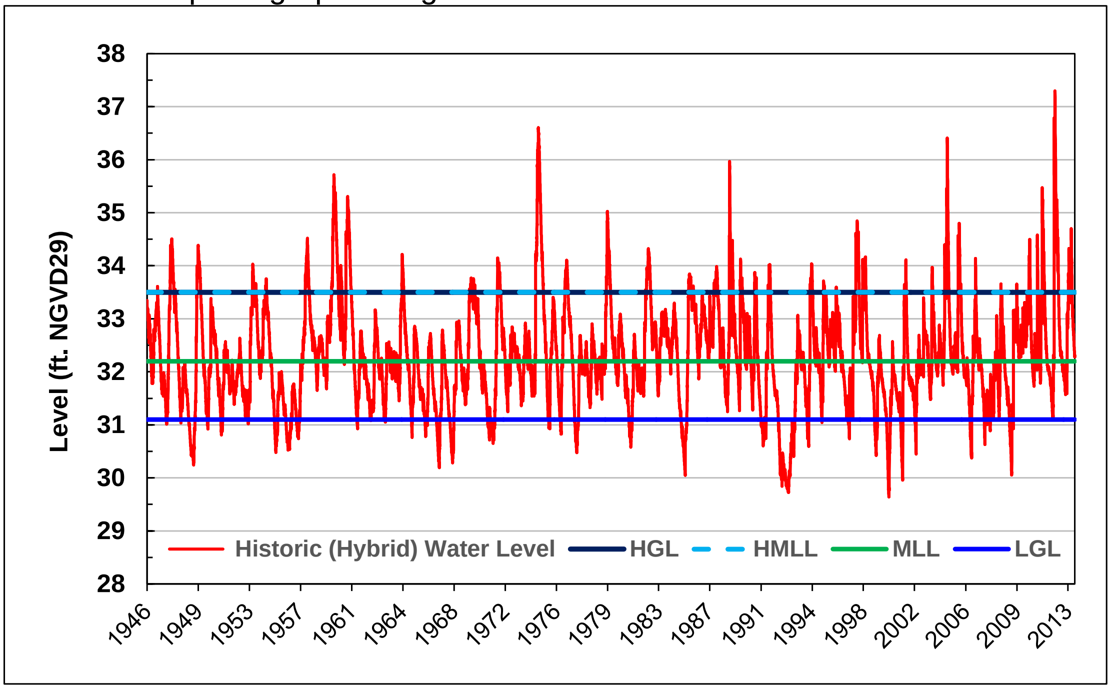


**Figure 17. Historic water levels (hybrid) used to calculate the revised Minimum and Guidance Levels. The revised levels include the High Guidance Levels (HGL), High Minimum Lake Levels (HMLL), Minimum Lake Levels (MLL), and Low Guidance Levels (LGL).**

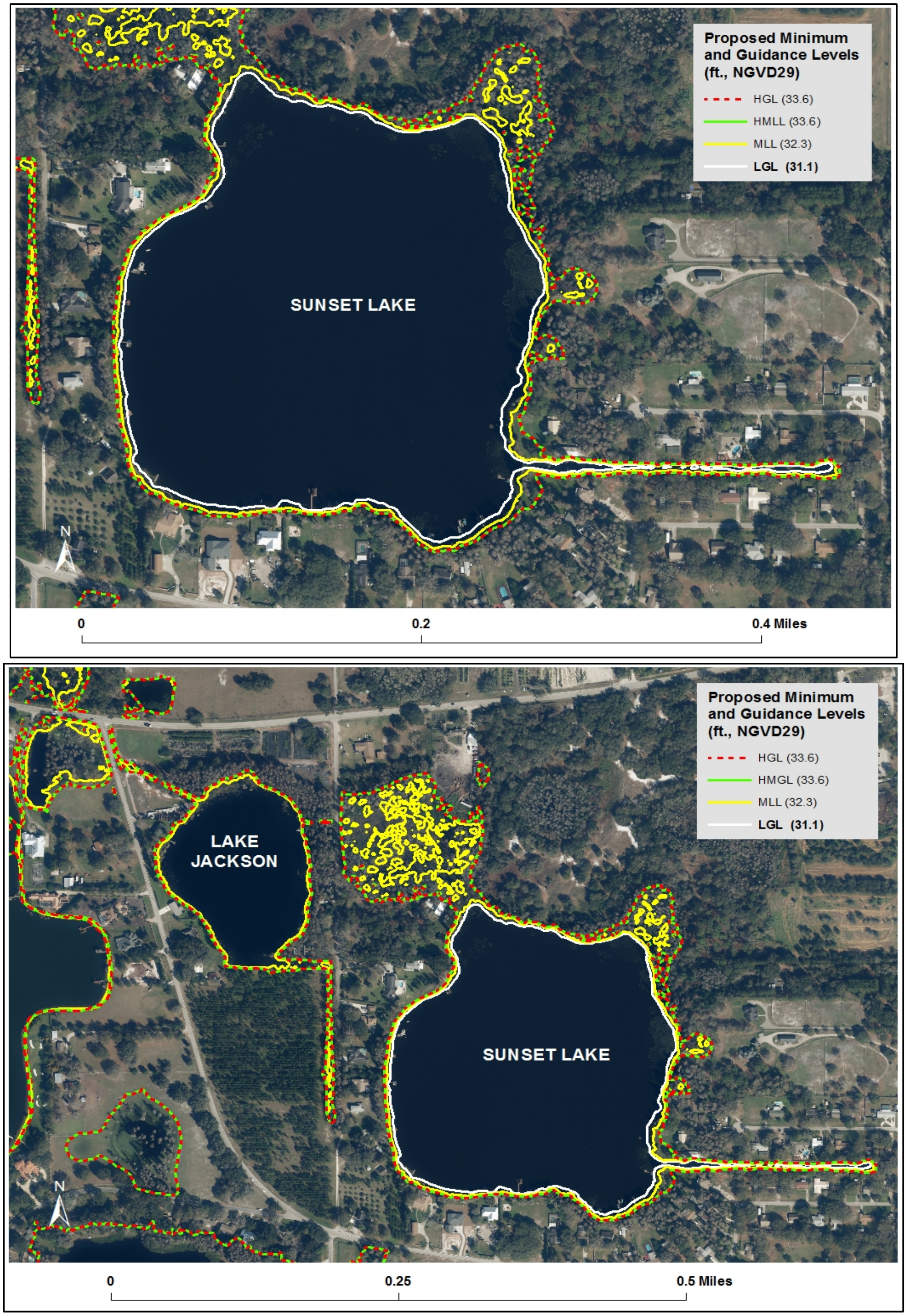


**Figure 18 a & b. Sunset Lake Minimum and Guidance Level Contour Lines Imposed Onto a 2014 Natural Color Aerial Photograph presented in two scales. 17a is a close up of Sunset; 17b included Lake Jackson.**

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 Sunset Lake are presented in both datum standards (Table 1). 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 is -0.78 ft. for Sunset Lake.

# Consideration of Environmental Values

The revised minimum levels for Sunset Lake are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing MFLs (see Rule 62-40.473, F.A.C.). When developing MFLs, the District evaluates the categorical significant change standards and other available information as presented above. The purpose is to identify criteria that are sensitive to long-term changes in hydrology and represent significant harm thresholds. The Historic P50 elevation and High Guidance Level/Historic P10 were used for developing the minimum levels for Sunset Lake based on existing structural alterations and its classification as a Category 2 Lake. Given that the minimum levels were established using Historic lake stage exceedance percentiles, the levels are as protective of all relevant environmental values as they can be, given the existing structural alterations (culvert serving as the control point). 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 Revised and Previously Adopted Levels

The revised High Guidance Level and Low Guidance Level for Sunset Lake are respectively, 1.2 ft. and 1.6 ft. lower than the previously adopted guidance levels. 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.

The revised High Minimum Lake Level for Sunset Lake is 0.8 ft. lower than the previously adopted High Minimum Lake Level. The revised Minimum Lake Level is 0.7 ft. lower than the previously adopted Minimum Lake Level. These differences are primarily due to the differences in the water level data and the control point elevation used in Minimum and Guidance Level development.

# Minimum Levels Status Assessment

The previous Minimum Lake Level for Sunset Lake were assessed to determine if lake levels are fluctuating relative to both these levels in an appropriate manner (Appendix B). The models were used to evaluate whether Sunset Lake water levels are currently above or below the revised Minimum Lake and revised High Minimum Lake Level for the lake. Previous levels were determined to be at the revised Minimum Lake Level and above the revised High Minimum Lake Level.

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

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# APPENDIX A

**Technical Memorandum**

May 11, 2016

TO: David Carr, 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
Tamera S. McBride, P.G., Hydrogeologist, Water Resources Bureau

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

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## A. Introduction

Water budget and rainfall correlation models were developed to assist the Southwest Florida Water Management District (District) in the reassessment of minimum levels in Sunset Lake, located in northwest Hillsborough County. Sunset Lake currently has adopted minimum levels which are scheduled to be re-assessed in FY 2016. This document will discuss the development of the Sunset Lake models, as well as the development of the Historic percentiles using the models.

## B. Background and Setting

Sunset Lake is located in northwest Hillsborough County between Tarpon Springs Road and Boy Scout Road, and east of Burrell Road (Figure 1). The lake lies within the Brooker Creek watershed. There are limited inflows to Sunset Lake from Lake Taylor via a weir and wetland system to the east, while discharge from Sunset Lake occurs via a wetland system on the northwest shore of the lake, through a ditch and culvert system under Burrell Road, and into Lake Jackson (Figure 2).

*Physiography and Hydrogeology*

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

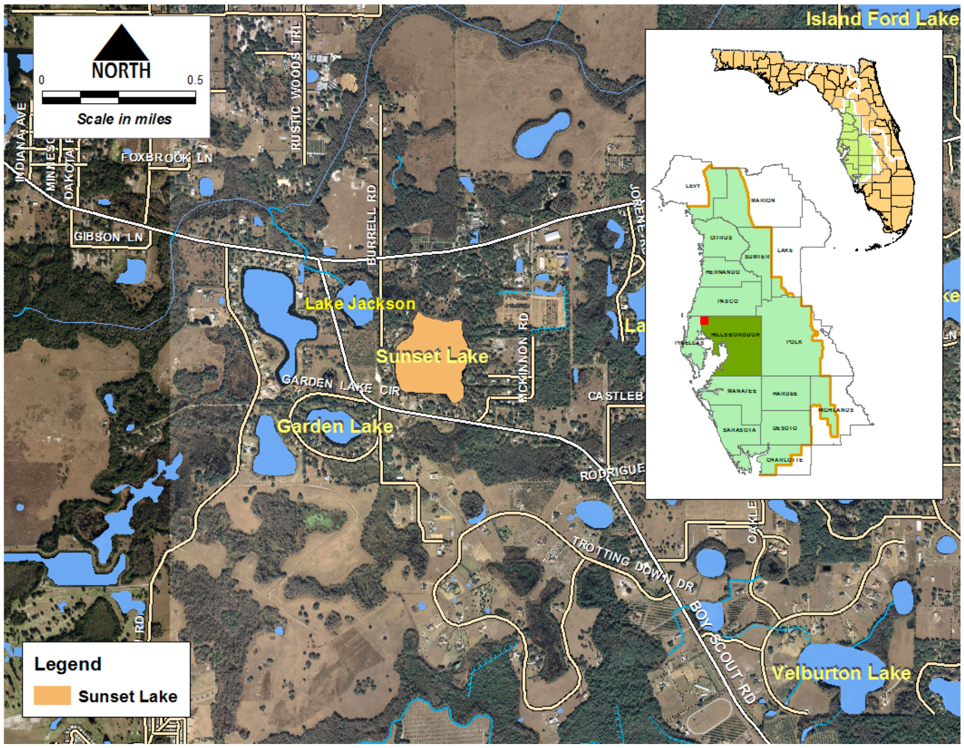


Figure 1. Location of Sunset Lake in Hillsborough County, Florida.

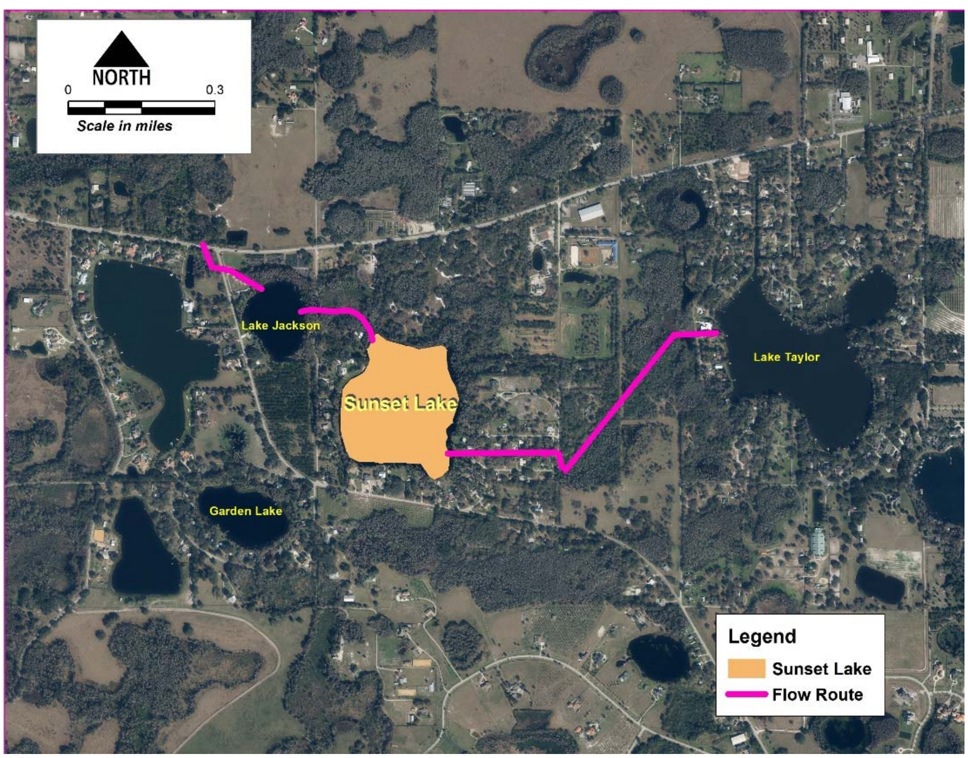


Figure 2. Flow between Lakes Taylor, Sunset, and Jackson.

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 at Sunset Lake began in July 1972 (Figure 3). Data collection frequency has occurred weekly to monthly in the early part of the record (by the United States Geological Survey (USGS) and the District), and has been consistently monthly since February of 1996. Water level data are currently collected by the District.

Water levels from the WCRWSA RMP-3 Floridan aquifer and surficial aquifer monitor wells are available beginning in June 1987 (Figures 4 and 5), and are collected by Tampa Bay Water as a requirement of their consumptive use permit for the regional wellfield withdrawals. The wells are located approximately 930 feet northwest of Sunset Lake. The data collection frequency at both wells began as weekly, but became daily in October 1987 for the Upper Floridan aquifer monitor well, and February 1999 for the surficial aquifer monitor well.

*Land and Water Use*

Sunset Lake is located approximately 2 miles to the southeast of the Eldridge Wilde Wellfield, and 2.5 miles northwest of the Cosme-Odessa Wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 6). Groundwater withdrawals began at the Cosme-Odessa Wellfield in 1930, and steadily climbed to approximately 21 million gallons per day (mgd) in 1962. The Eldridge Wilde Wellfield began withdrawing groundwater in 1957, and pumped over 35 mgd in the early 1970s (Figure 7). Combined groundwater withdrawals from the two wellfields peaked at over 52 mgd in the early 1970s. Combined withdrawal rates since 2003 have averaged a little over 18 mgd (less than 13 mgd at the Eldridge Wilde Wellfield, and less than 6 mgd at the Cosme Odessa Wellfield), with several extended periods since 2009 when groundwater withdrawals at the Cosme-Odessa Wellfield were zero.

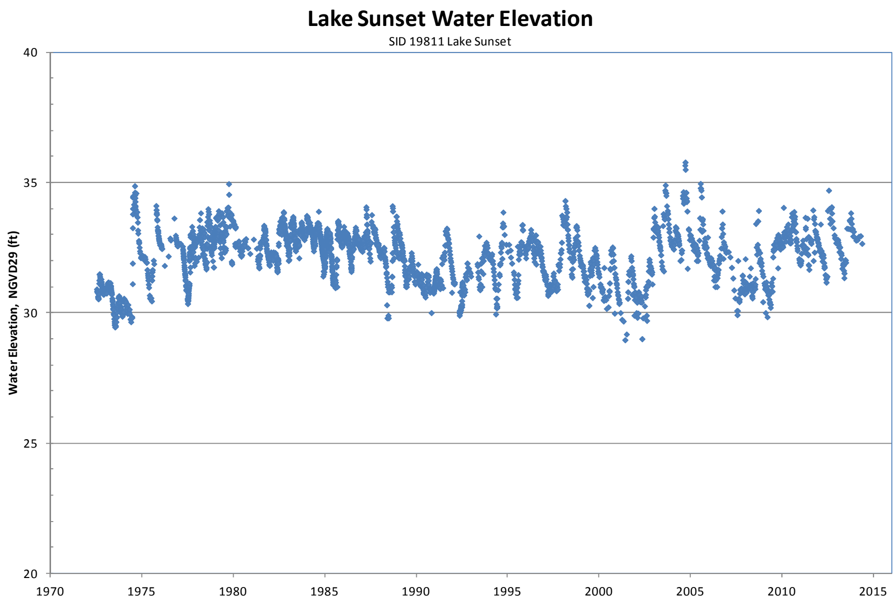


Figure 3. Sunset Lake water levels.

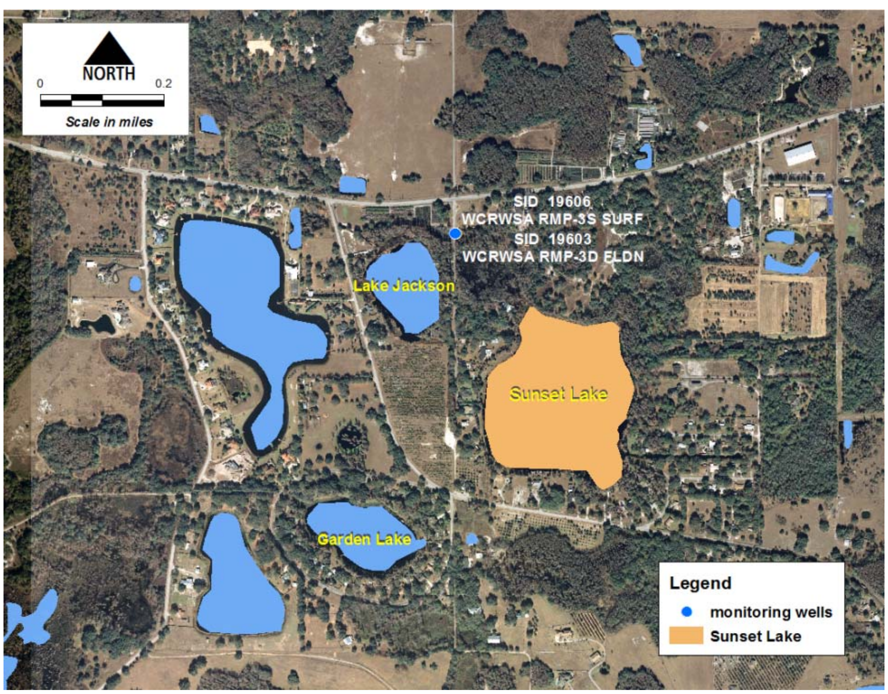


Figure 4. Location of the WCRWSA RMP-3 monitor wells near Sunset Lake.

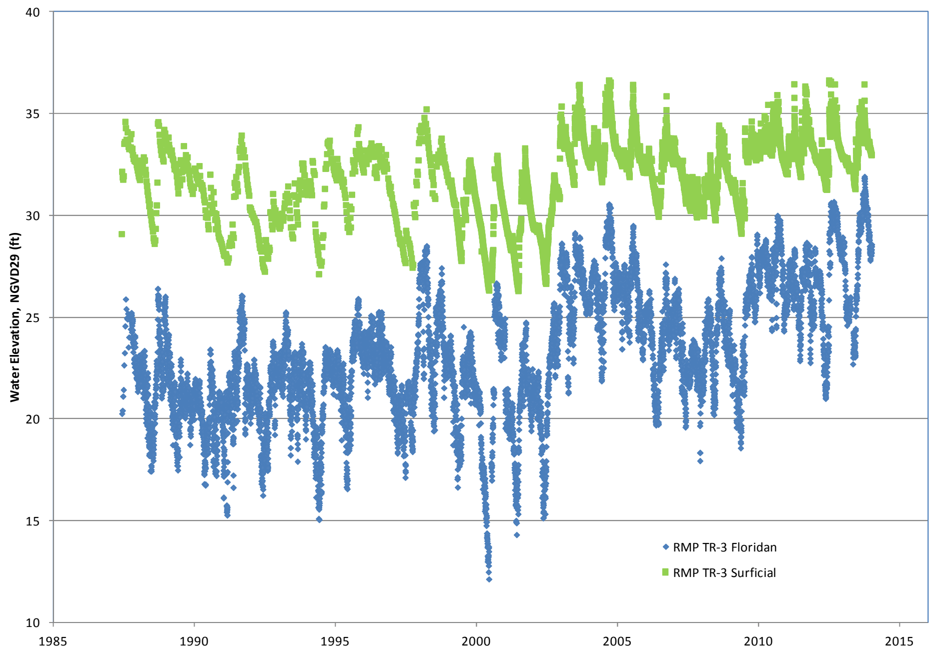


Figure 5. Water levels in the WCRWSA RMP-3 Surficial and Upper Floridan aquifer monitor wells.

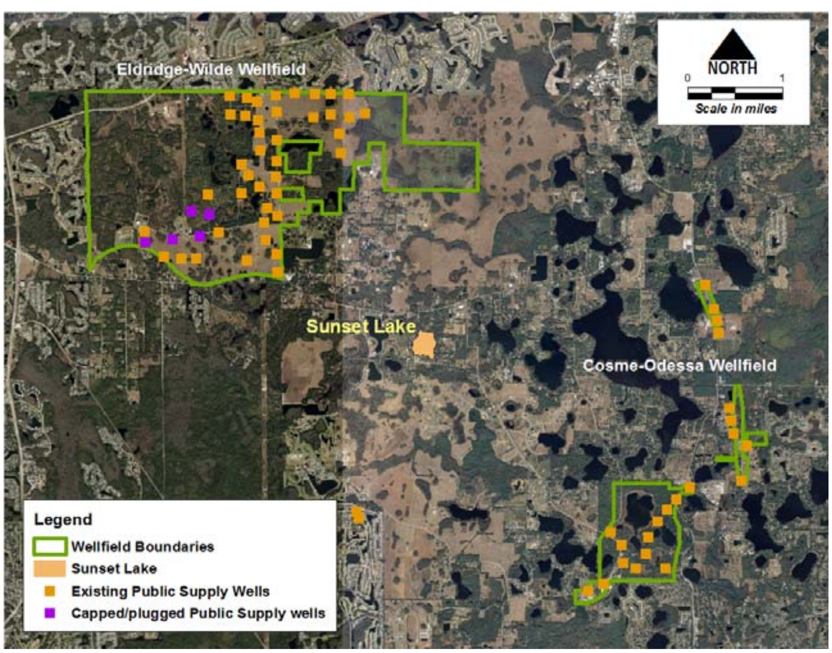


Figure 6. Sunset Lake and the Cosme-Odessa Eldridge Wilde wellfields.

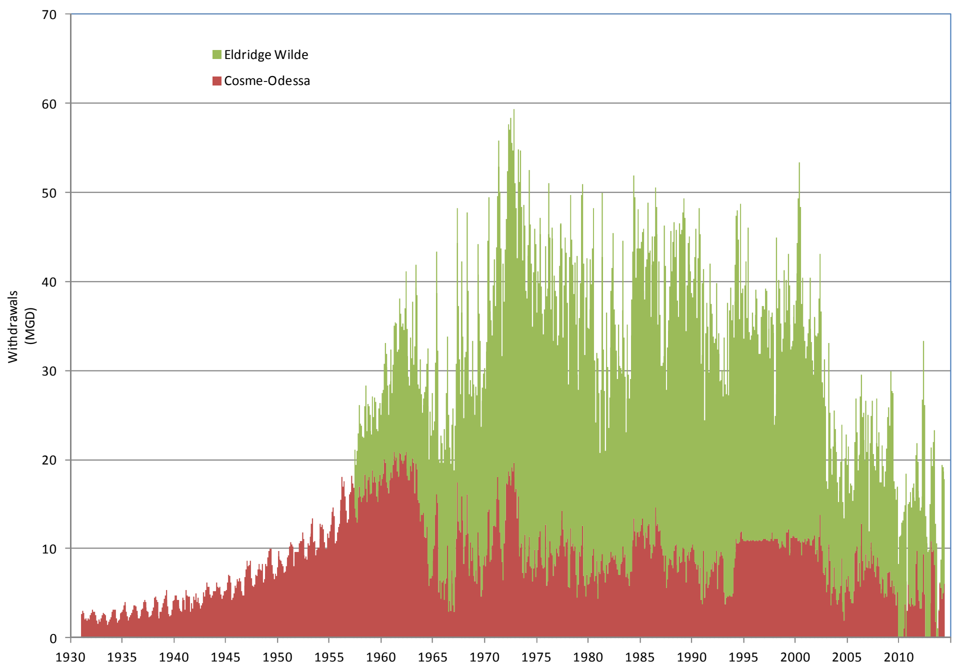


Figure 7. Stacked Cosme-Odessa and Eldridge Wilde wellfield withdrawals

Water levels in several lakes in the Cosme-Odessa and Eldridge Wilde Wellfield areas dropped significantly since public supply groundwater withdrawals began (Hancock and Basso, 1996). Because Sunset Lake water level data collection did not begin until long after the beginning of withdrawals from the wellfields (Figure 8), declines in lake water levels that may have been caused by increased ground-water withdrawals prior to 1972 cannot be observed in the available data, but a recovery in water levels can be observed in the lake levels beginning around 2003/2004, and both aquifers around the same time in Figure 5. This was a period of high rainfall that corresponded with reductions in groundwater withdrawals. A review of 1957 aerial photography (Figure 9) shows no obvious visible signs of lowered lake levels after the commencement of groundwater withdrawals at the Eldridge Wilde Wellfield in 1957, but lowered lake levels are somewhat obvious in the 1968 photograph as shown by the exposed sandy shoreline.

In 1977, due to concerns of low lake levels, the District issued a permit to Pinellas County (who operated the Eldridge Wilde Wellfield at the time) to begin augmenting Sunset Lake with water withdrawn from the Upper Floridan aquifer (along with nearby lakes Garden and Jackson). The permit has been renewed several times since 1977, and was last renewed in 2001 at 325,000 gpd annual average and 1,010,000 gpd maximum monthly (to be used for all three lakes). Metering of withdrawals has occurred since 1988. Prior to the current permit, groundwater withdrawals used for augmenting the lakes were often reported as a total for all three lakes; therefore, the amount of

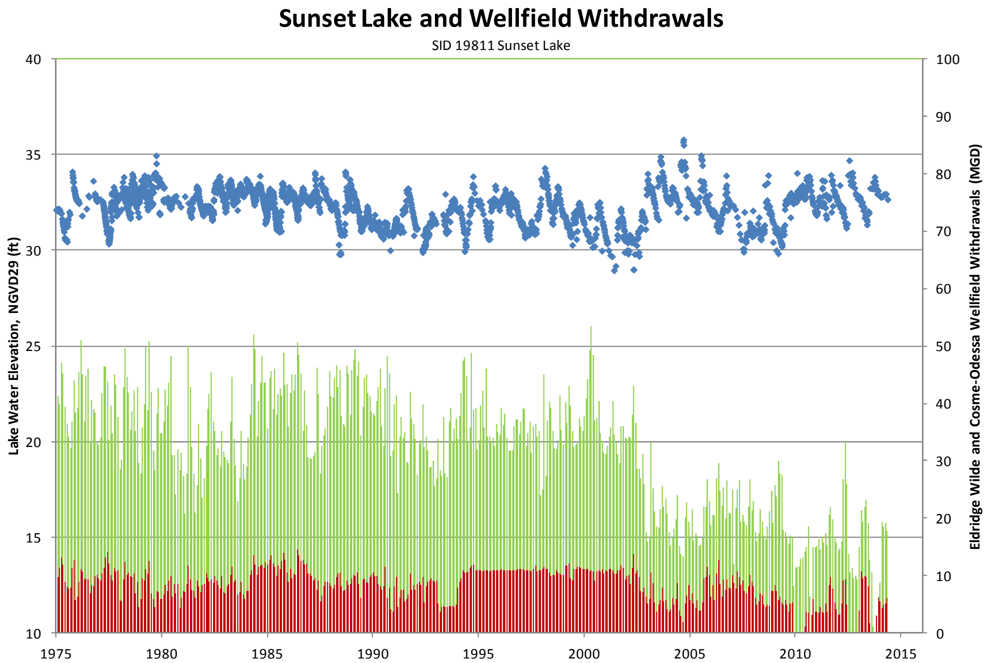


Figure 8. Water levels in Sunset Lake and combined groundwater withdrawals at the Cosme-Odessa and Eldridge Wilde wellfields.


Figure 9. Water level changes in Sunset Lake.

water put into individual lakes is not apparent from the District records. However, from a review of the data that was broken out by lake, it appears that most of the water was put into Lakes Sunset and Garden. Figure 10 presents the permittee reported groundwater withdrawals for Lake Sunset augmentation. It can be seen in the figure that augmentation has decreased significantly in recent years.

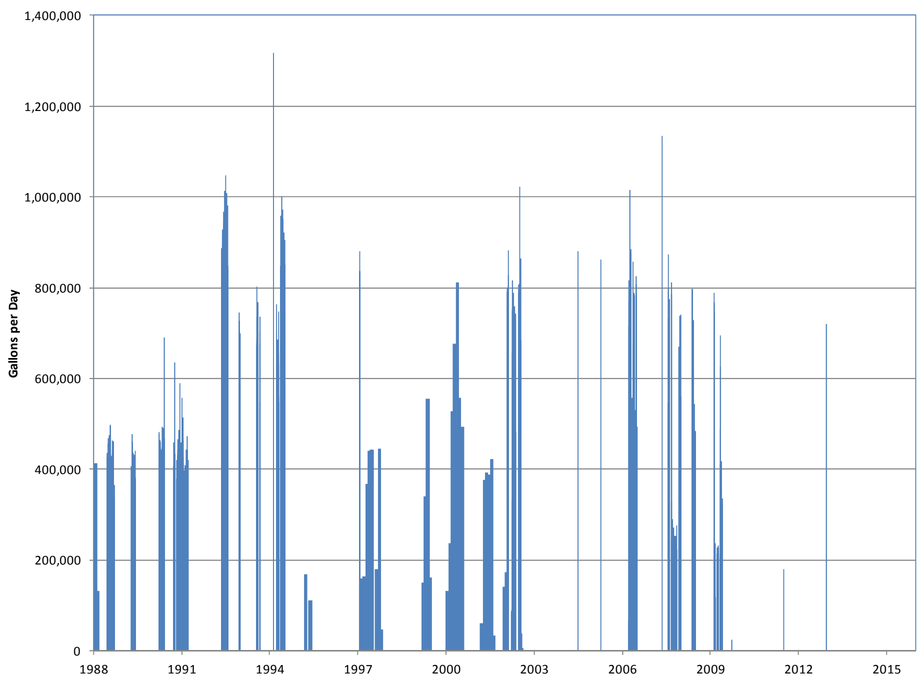


Figure 10. Reported augmentation withdrawals used in model.

## C. Purpose of Models

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

In the case of Sunset Lake, both the Cosme-Odessa and Eldridge Wilde wellfields have potentially affected water levels since they began operation in 1956 and 1930, respectively; however, impacts are not obvious from the aerial photography prior to 1968. Empirical data are not available to evaluate the potential impacts of the early groundwater withdrawals near the wellfields. Other groundwater withdrawals (including other wellfields) could also affect levels, but the effect of such withdrawals would be smaller and less consistent. The development of a water budget model coupled with a rainfall correlation model for the lake was considered essential for estimating long-term Historic percentiles, accounting for changes in the lake's drainage system, and simulating effects of changing groundwater withdrawal rates.

## D. Water Budget Model Overview

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

The hydrologic processes in the water budget model include:

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

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

## E. Water Budget Model Components

*Lake Stage/Volume*

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

*Precipitation*

After a review of several rain gages in the area of Sunset Lake, a composite of several stations was used for the water budget model. The goal was to use the closest available data to the lake, as long as the data appeared to be high quality (Figure 11). With one exception, all rain gages used are monitored by the District. A rain gage was located on the north shore of Sunset Lake (SID 19501) with data from January 1998 through April 2005. Rainfall data from several other gages was used for the remainder of the modeled period: Island Ford Lake gage (SID 19631) - January 1988 to September 1990, Eldridge Wilde (SID 19725) – October 1990 to June 1992 and December 1992 to March 1993, Island Ford (SID 19487) – June 1992 to December 1992, April 1993 to December 1997, and May 2005 to December 2013. Several other gages were used to infill short periods of missing or unusable data also, including Crescent Lake (SID 19488), Cosme-18 (a Tampa Bay Water gage) and ROMP TR13-3 Racetrack Road (SID 19498).

*Lake Evaporation*

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

A recent study compared monthly energy budget evaporation data collected from both Lake Starr and Calm Lake (Swancar, 2011, personal communications). Calm Lake is located less than 3 miles to the east of Sunset Lake (Figure 12). The assessment concluded that the evaporation rates between the two lakes were nearly identical, with small differences attributed to measurement error and monthly differences in latent heat associated with differences in lake depth.

Jacobs (2007) produced daily potential evapotranspiration (PET) estimates on a 2-square kilometer grid for the entire state of Florida. The estimates began in 1995, and are updated annually. These estimates, available from a website maintained by the

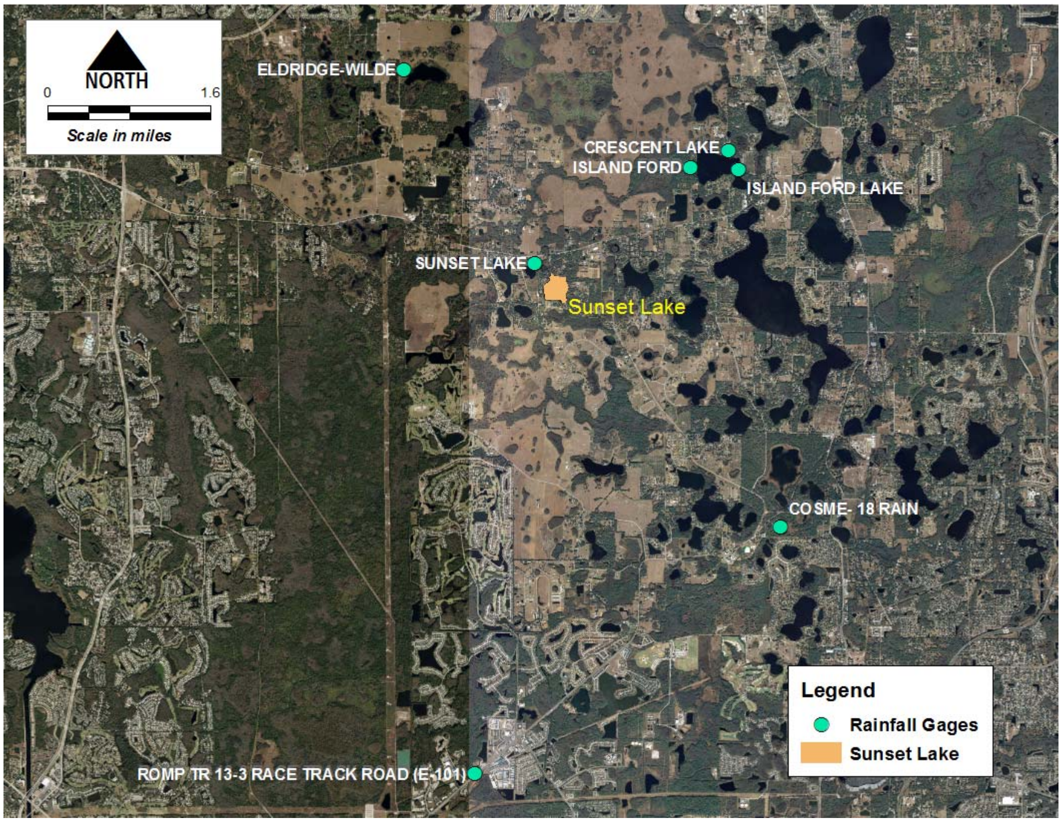


Figure 11. Rain gages used in the Sunset Lake water budget model.

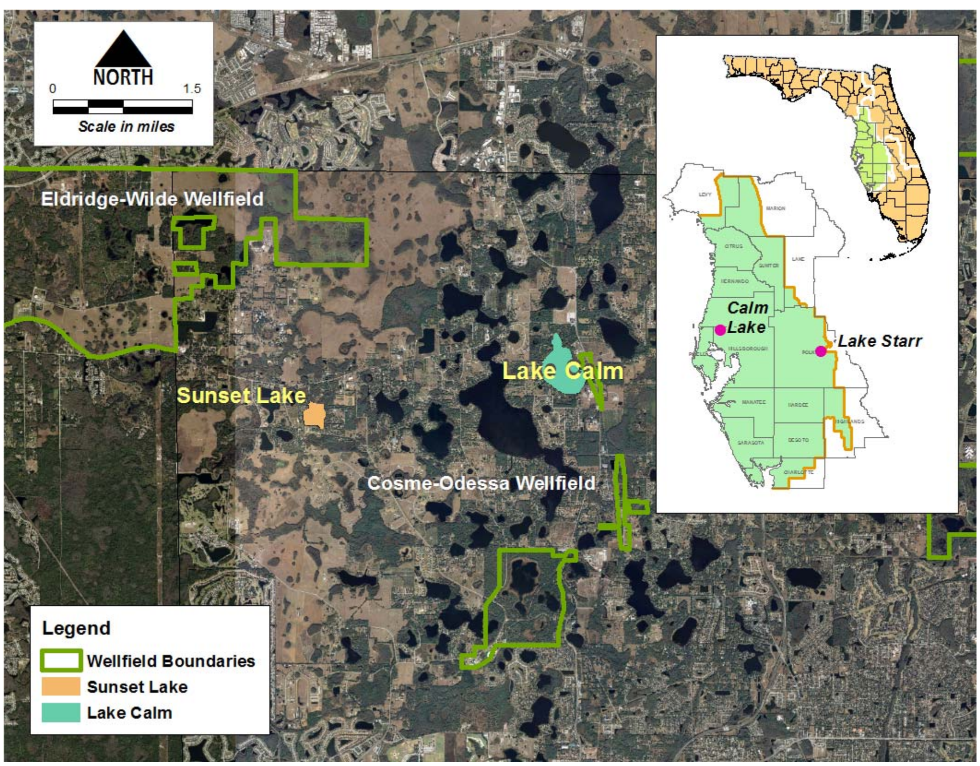


Figure 12. Location of Sunset Lake, Lake Calm and Lake Starr (see map inset).

USGS, were calculated through the use of solar radiation data measured by a Geostationary Operational Environmental Satellite (GOES). Because PET is equal to lake evaporation over open water areas, using the values derived from the grid nodes over the modeled lake was considered. A decision was made to instead use the Lake Starr evaporation data since the GOES data nodes typically include both upland and lake estimates, with no clear way of subdividing the two. It was thought that using the daily PET estimates based on GOES data would increase model error more than using the Lake Starr data directly.

*Augmentation withdrawn from the Upper Floridan aquifer*

When applicable, augmentation quantities withdrawn from the Upper Floridan aquifer were added to the lake on a daily basis, based on the available reported values (Figure 10). As discussed earlier, only totals for all three lakes are often reported prior to 2001. Because much of the water used appears to augment to Sunset Lake when quantities are assigned to a specific lake, unless otherwise documented, all augmentation quantities were assigned to Sunset Lake. Additionally, because monthly totals are often the only records that exist (particularly prior to the most recent permit), an assumption was made that the monthly total was distributed evenly each day of the month for which augmentation was reported. When daily groundwater withdrawals were reported, daily augmentation quantities were used.

*Overland Flow*

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

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

The topography in the area of Sunset Lake is relatively flat, so determining watersheds based on relatively subtle divides can be challenging. Several slightly varying estimates of watershed boundaries have been performed in the past for different modeling efforts in the area. One of the most recent estimates was performed as part of an effort to model the Brooker Creek watershed for flood assessment purposes (PBSJ, 2006). The watershed area values developed by PBSJ were adopted for the Sunset Lake model (Table 1) after an independent check confirming that they were reasonable for modeling purposes. Sunset Lake has an immediate watershed from which it receives direct overland flow (approximately 136.6 acres.

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

Table 1. Model Inputs for the Sunset Lake model, using all unassigned augmentation.

| Input Variable | Value |
|---|---|
| | |
| Overland Flow Watershed Size (acres) | 136.6 |
| SCS CN of watershed | 75 |
| Percent Directly Connected | 0.1 |
| FL Aq. Monitor Well Used | WCRWSA RMP-3 Floridan |
| Surf. Aq. Monitor Well Used | WCRWSA RMP-3 Surficial |
| Surf. Aq. Leakance Coefficient (ft/day/ft) | 0.002 |
| Fl. Aq. Leakance Coefficient (ft/day/ft) | 0.00085 |
| Outflow K | 0.009 |
| Outflow Invert (ft NGVD29) | 32.0 |
| Inflow K | 0.0001 |
| Inflow Invert (ft NGVD29) | 37.7 |

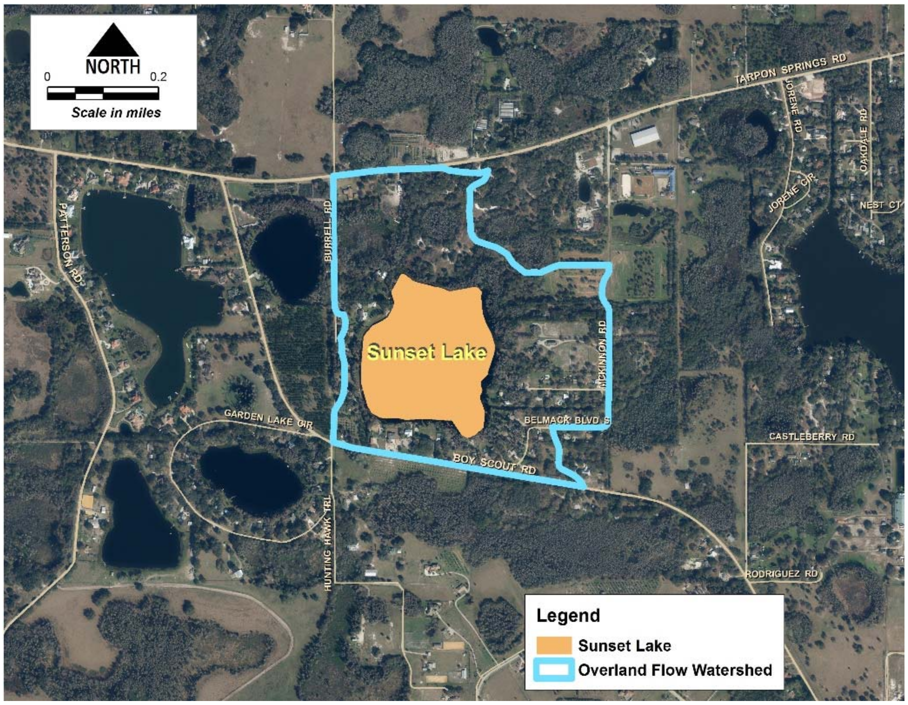


Figure 13. Direct overland flow portion of the Sunset Lake watershed.

For purposes of this model, taking into account the range of conditions experienced, a compromise was used for the CN. Additionally, approximately 10 percent of the watershed drains directly to an excavated canal on the southeast side of the lake, so the DCIA of the watershed was set to 0.1.

*Inflow and Discharge via Channels from Outside Watersheds*

Inflow and discharge via channels from or to the lake's watershed (i.e. "channel flow") can be important components of a lake's water budget. In the case of Lake Sunset, the inflow and discharge gradients of the channels are relatively flat, and inflows to the lake appear to occur only during high rainfall events.

To estimate flow out of Sunset Lake, the predicted elevation of the lake from the previous day is compared to the controlling elevation. Control elevations were determined based on professional surveying performed in the area. If the lake elevation is above the controlling elevation, the difference is multiplied by the current area of the lake and an "outflow coefficient." The coefficient represents a measure of channel and structure efficiency, and produces a rough estimate of volume lost from the lake. This volume is then subtracted from the current estimate of volume in the lake. Inflow from Lake Taylor to Sunset Lake was done similarly using the elevation of the control structure on Lake Taylor.

Discharge from Sunset Lake occurs via a ditch and wetland system on the northern side of the lake. While the high point of the culvert under Burrell Road is 30.7 feet NGVD 29, a higher elevation in a culvert within the outflow ditch from Lake Jackson (before the flow passes through a third culvert under Boy Scout Road) is higher at 32.0 feet NGVD 29 (Figure 2). A high point in the outfall ditch in front of the Boy Scout Road culvert was surveyed to be 32.5 feet NGVD, but it was considered to be a buildup of silt, and not considered permanent. Therefore, the control elevation for both Lake Sunset and Lake Jackson is the same.

Inflow to Lake Sunset can occur on the southeast shore of Sunset Lake. Discharge from Lake Taylor (to the east) occurs through a concrete weir, and then through a wetland and ditch system with significant storage, and finally into a canal on the southeast shore of Sunset Lake (Figure 2). The weir elevation on Lake Taylor was surveyed at 37.7 feet NGVD 29.

*Flow from and into the surficial aquifer and Upper Floridan aquifer*

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

The WCRWSA RMP-3 Floridan well is the closest Upper Floridan aquifer monitor well to Sunset Lake, and was used to represent the potentiometric surface at the lake (Figure 6). The WCRWSA RMP-3 surficial aquifer monitor well was used to represent the water table elevation near the lake (Figures 6 and 7). Since no significant differences in topography exist between the lake and wells, no adjustments to the water levels were made for modeling purposes. Missing daily water level values were in-filled using the previously recorded value.

## F. Water Budget Model Calibration

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

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

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

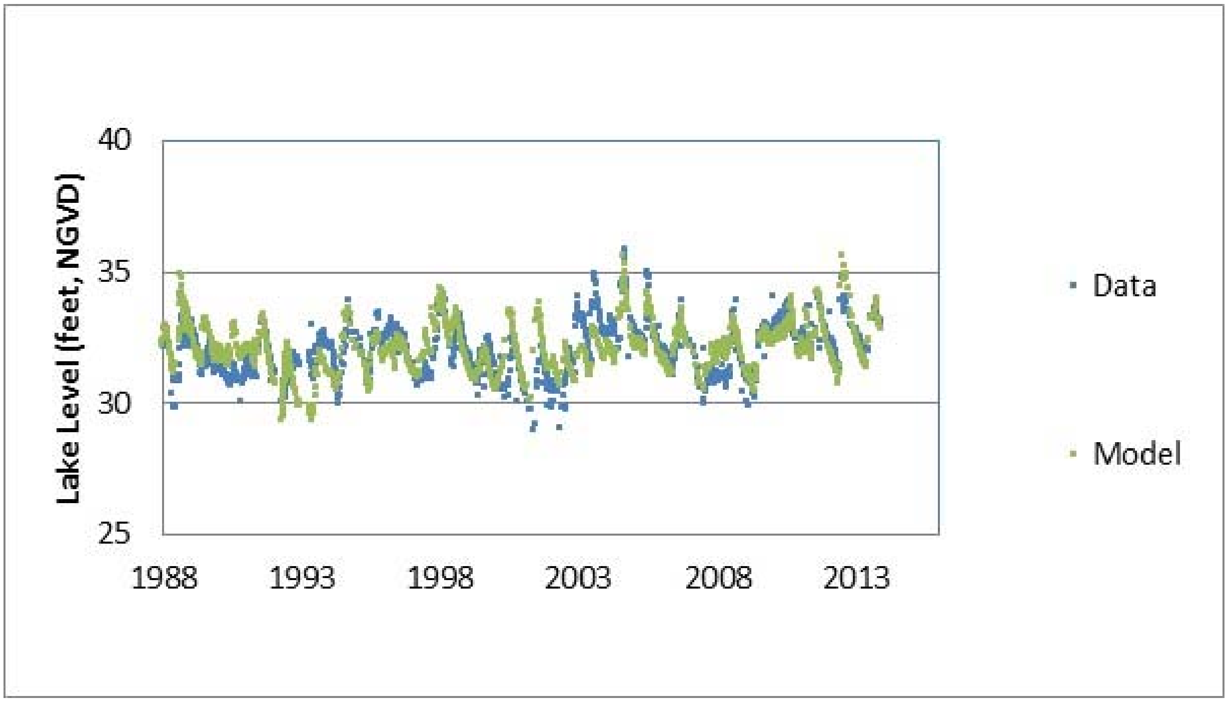


Figure 14. Modeled water levels predicted for the calibrated Sunset Lake water budget model (Model) and measured levels used for the model calibration (Data).

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

| | Data | Model |
|---|---|---|
| P10 | 33.2 | 33.2 |
| P50 | 31.9 | 31.9 |
| P90 | 30.7 | 31.0 |

### G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 14, the model appears to be reasonably well calibrated. There are a few periods in the early part of the calibration period when the modeled values are significantly lower than the data. A review of the model inputs shows little or no augmentation values in the model during those periods, which may mean that the augmentation was actually much higher during those periods than documented in the records. However, the calibration of the more recent period appears better, perhaps due to better record keeping.  Overall, the calibration statistics are very reasonable.

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

| Inflows | Rainfall | Surficial Aquifer Groundwater Inflow | Upper Floridan Aquifer Groundwater Inflow | Runoff | DCIA | Aug. | Inflow via channel | Total |
|---|---|---|---|---|---|---|---|---|
| Inches/year | 54.3 | 3.2 | 0.0 | 21.3 | 10.7 | 22.4 | 0.1 | 112.0 |
| Percentage | 48.5 | 2.9 | 0.0 | 19.0 | 9.5 | 20.0 | 0.1 | 100.0 |
| **Outflows** | **Evap.** | **Surficial Aquifer Groundwater Outflow** | **Upper Floridan Aquifer Groundwater Outflow** | | | | **Outflow via channel** | **Total** |
| Inches/year | 58.1 | 6.2 | 32.5 | | | | 15.0 | 111.8 |
| Percentage | 52.0 | 5.5 | 29.1 | | | | 13.4 | 100.0 |

A review of Table 2 shows that there is no difference between the P10 and P50 of the model and the data, and the P90 percentiles of the model and the data differ within 0.3 feet.  Some of the difference at the P90 percentile may be due to less detail in the lower stage-volume relationships, or inaccuracies in rainfall estimates.

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 Sunset Lake water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer.  Metered groundwater withdrawal rates from the Eldridge Wilde and Cosme-Odessa Wellfields are available throughout the period of the calibrated model, so if a relationship between withdrawal rates and Upper Floridan aquifer potentiometric levels can be established, the effect of changes in groundwater withdrawals can be estimated by adjusting Upper Floridan aquifer levels in the model.

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 Sunset Lake area, and represents the most current understanding of the hydrogeologic system in the area.

The INTB was used to determine the drawdown in the surficial aquifer and Upper Floridan aquifer in response to groundwater withdrawals in the area. Drawdown in both aquifers was calculated for two withdrawal rates representing the effects of Tampa Bay Water’s regional wellfields before and after cutbacks from approximately 150 mgd to 90 mgd. The pre-cutback period in the model is from 1988 through 2002, while the post-cutback period is 2003 through 2013. The model results allowed the drawdowns associated with all permitted withdrawals to be calculated before and after wellfield cutbacks, assuming 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 Eldridge Wilde Wellfield in each scenario were 23.6 mgd and 13.8 mgd, respectively, and 11.0 mgd and 6.2 mgd for the Cosme-Odessa Wellfield, respectively.

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

To estimate lake levels without the influence of groundwater withdrawals, the Upper Floridan aquifer and surficial aquifer wells in the water budget model were adjusted to represent zero withdrawals. For the 1988 to 2013 water budget model period, two adjustment periods were used to reflect the withdrawal reductions that took place at the Eldridge Wilde and Cosme-Odessa Wellfields. Adjustments to each Upper Floridan aquifer and surficial aquifer well and associated adjustment periods are found in Table 4.

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

| Well | Adjustment (feet) 1988 to 2002 | Adjustment (feet) 2003 to 2013 |
|---|---|---|
| Upper Floridan aquifer | 6.0 | 3.0 |
| Surficial aquifer | 2.2 | 1.0 |

Additionally, because Sunset Lake has experienced a significant amount of augmentation during the modeled period, the augmentation was removed from the model. This allows the results to represent the hydrology of the lake with no man-made effects (with the exception of permanent structures).

Figure 15 presents measured water level data for the 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 5 presents the Historic percentiles based on the model output.

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

Historic normal pools were determined for Sunset Lake based on inflection points of remaining cypress trees. The Historic normal pool for Sunset Lake was determined to be 34.5 feet NGVD. While the Historic normal pool and natural P10 in lakes and wetlands in the northern Tampa Bay area may differ by several tenths of a foot in many cases, the model's estimate of the Historic P10 for Sunset Lake is approximately one foot lower than the field determined Historic normal pool. The difference is likely caused by the structural alterations of the lake, since the control point (a man-made ditch) is 2.5 feet lower than the Historic normal pool.

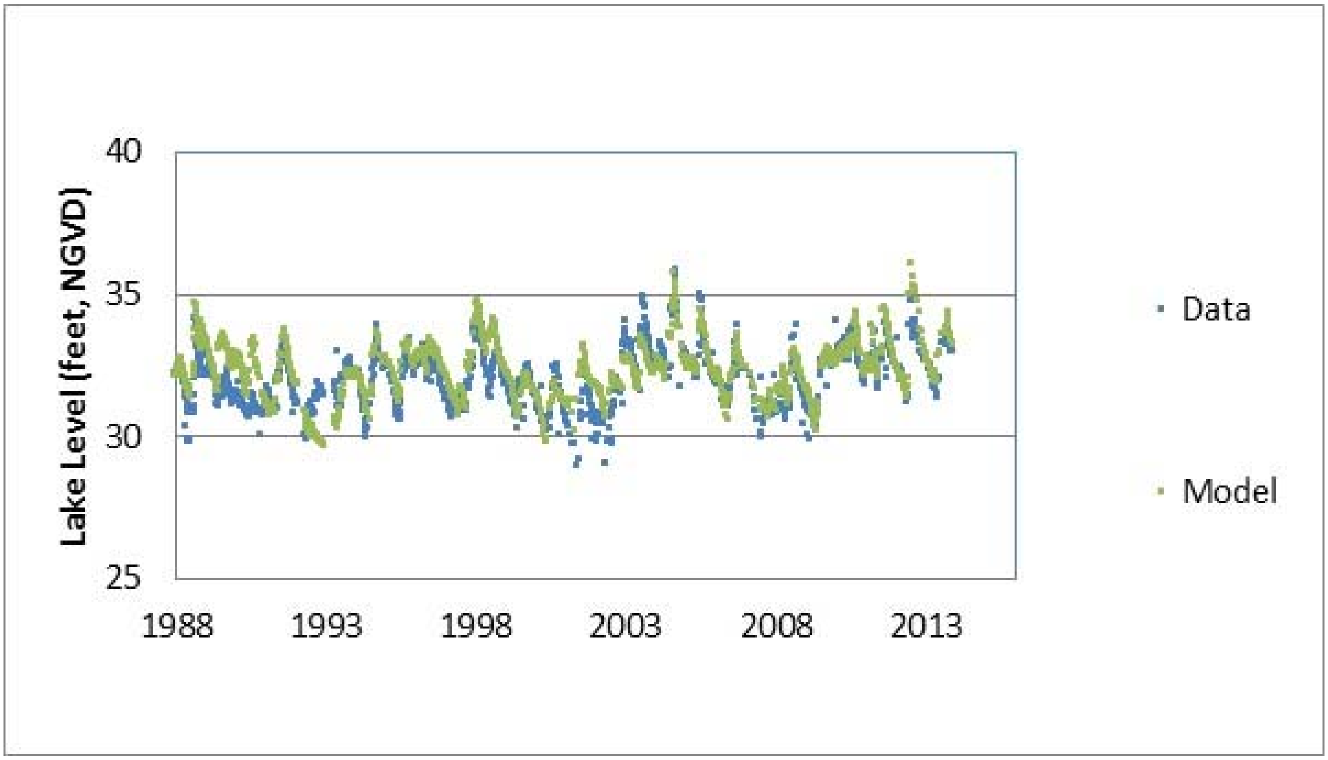


Figure 15. Measured lake levels (Data) and Historic water levels predicted with the calibrated Sunset Lake model (Model).

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

| Percentile | Elevation |
|---|---|
| P10 | 33.4 |
| P50 | 32.2 |
| P90 | 30.9 |

### I. Rainfall Correlation Model

In an effort to extend the period of record of the water levels used to determine the Historic Percentiles to be used in the development of the Minimum Levels, a line of organic correlation (LOC) was performed using the results of the water budget model and long-term rainfall. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 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 data from the Island Ford Lake gage (SID 19631) was used to extend data back to January 1972, and the Cosme rain gage (maintained by Tampa Bay Water and located on the Cosme wellfield) was used to extend the rain data back to 1945. Finally, rainfall data from the St. Leo National Weather Service gage (SID 18901) (Figure 16) were used to extend the data back to 1930. Although the St. Leo gage is approximately 26 miles from Sunset Lake, it is one of only a few rain gages in the vicinity with data preceding 1945, and in this case, is only used in the first few years of the correlation.

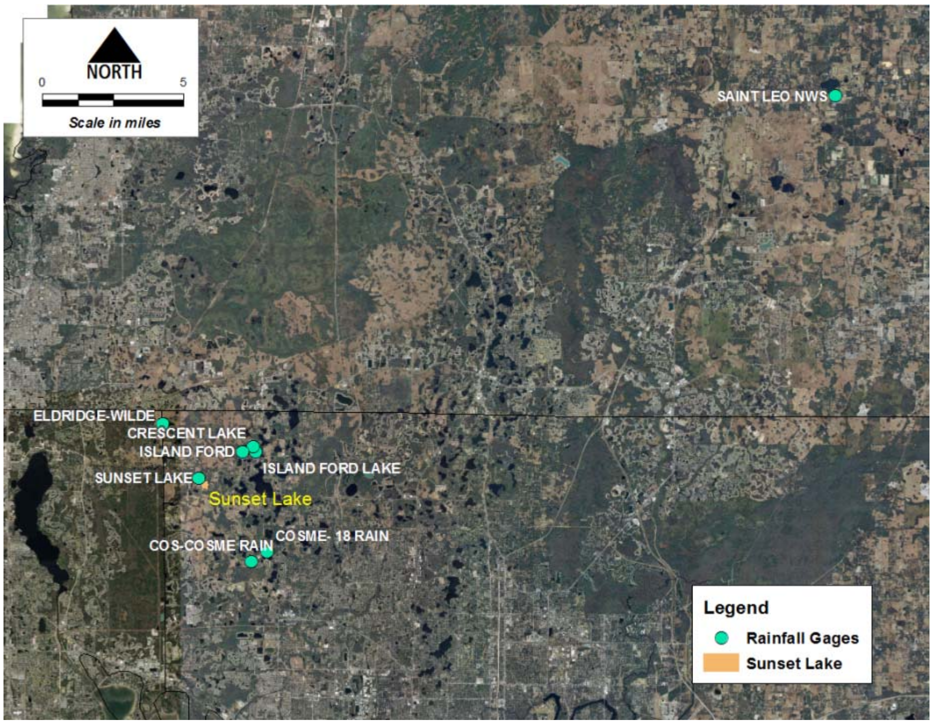


Figure 16. Location of rain stations used for the rainfall correlation model.

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

Rainfall was correlated to the water budget model results for the entire period used in the water budget model (1988-2013), and the results from 1946-2013 (68 years) were produced. For Sunset Lake, the 1-year weighted model had the highest correlation coefficient, with an $R^2$ of 0.84. Previous correlations for lakes in the northern Tampa Bay area have consistently had best correlation coefficients in the 2 to 5 year range, so a 1-year weight is somewhat unusual.  Experimentation was performed using various rainfall gages to represent the rainfall for both models, but the 1-year weight was the best correlation each time, and the resulting Historic percentiles were identical.  The results are presented in Figure 17.

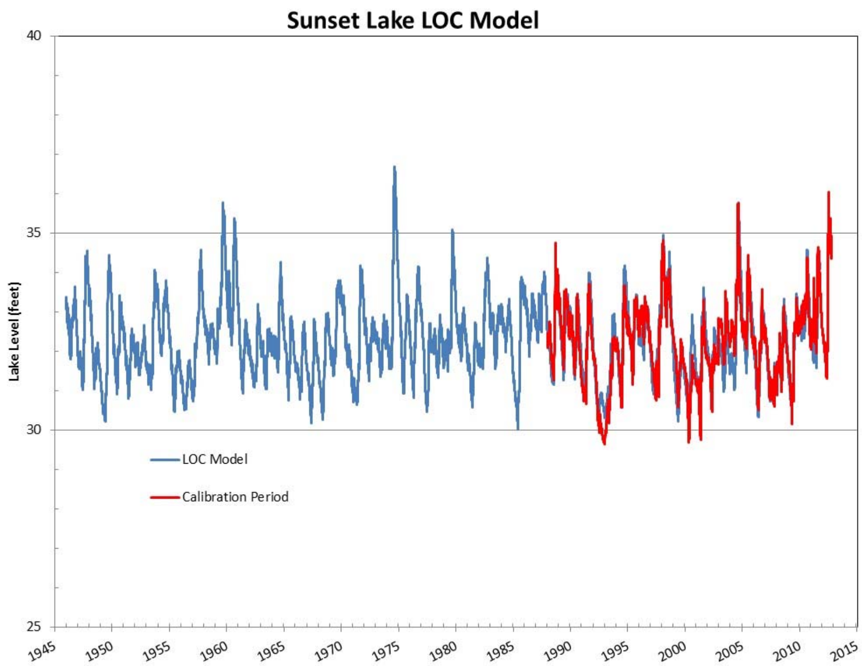


Figure 17.  LOC model results for Sunset Lake.

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 6.  Note that the difference between the P10, P50, and P90 percentiles from the water budget model (Table 5) and those from the hybrid rainfall model (Table 6) for Sunset Lake are 0.2, 0.1, and 0.2 feet, respectively. Therefore, there are relatively small differences in the Historic percentiles between the two models.

Table 6. Historic percentiles as estimated by the hybrid model from 1946 to 2013 (all in feet NGVD29).

| Percentile | Sunset Lake |
|---|---|
| P10 | 33.6 |
| P50 | 32.3 |
| P90 | 31.1 |

## J. Conclusions

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

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# APPENDIX B

**Technical Memorandum**

May 11, 2016

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

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
David Carr, Staff Environmental Scientist, Water Resources Bureau

**Subject: Sunset Lake Initial Minimum Levels Status Assessment**

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## A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Sunset Lake and is proposing revised minimum levels for the lake, in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the revised minimum levels is provided by Hancock and McBride (2016) and Carr 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 Sunset Lake and other waterbodies with established minimum flows or levels in the northern Tampa Bay area, an applicable regional recovery strategy, referred to as the “Comprehensive Plan”, has been developed and adopted into District rules (Rule 40D-80.073, F.A.C.). One of the goals of the Comprehensive Plan is to achieve recovery of minimum flow and level water bodies such as Sunset Lake that are located in the area affected by the Consolidated Permit wellfields (i.e., the Central System Facilities) operated by Tampa Bay Water. This document provides information and analyses to be considered for evaluating the status (i.e., compliance) of the revised minimum levels proposed for Sunset Lake and any recovery that may be necessary for the lake.

## B. Background

Sunset Lake is located in northwest Hillsborough County between Tarpon Springs Road and Boy Scout Road, and east of Burrell Road (Figure 1). The lake lies within the Brooker Creek watershed. Sunset Lake is located approximately 2 miles to the southeast of the Eldridge Wilde Wellfield, and 2.5 miles northwest of the Cosme-Odessa Wellfield, two of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 2).

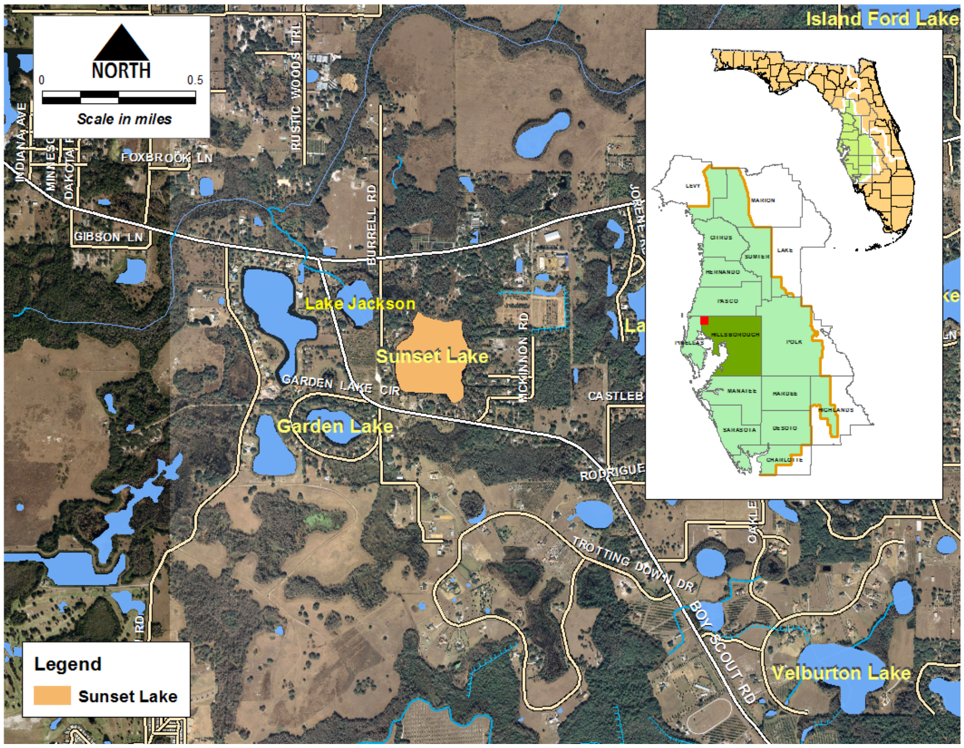


Figure 1. Location of Sunset Lake in Hillsborough County, Florida.

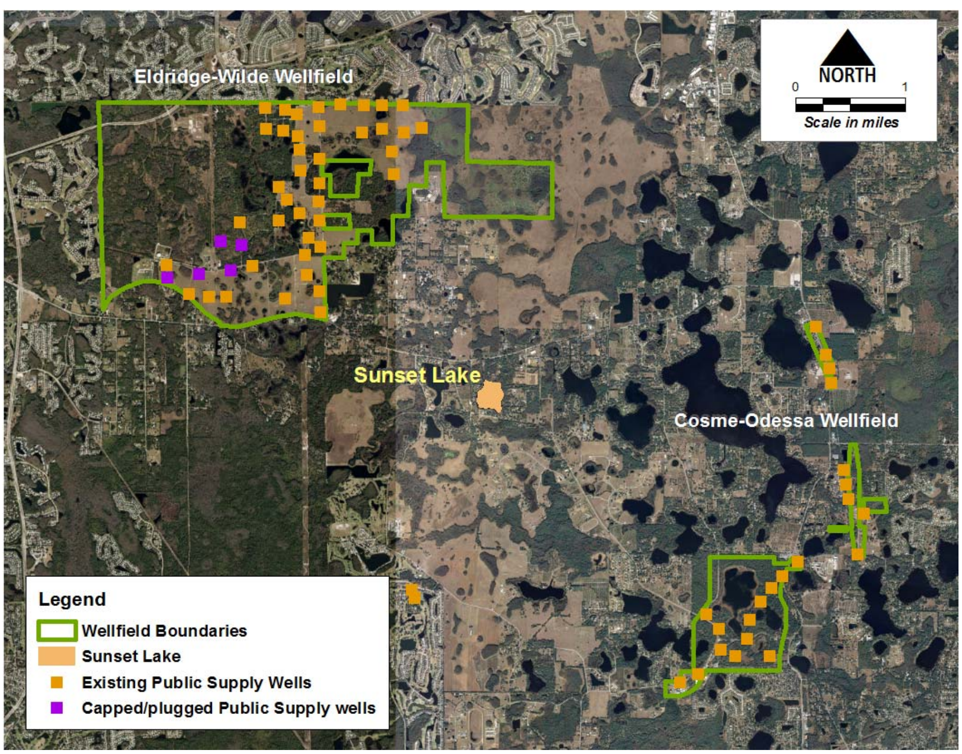


Figure 2. Sunset Lake, the Cosme-Odessa Wellfield and the Eldridge Wilde Wellfields.

Groundwater withdrawals at both wellfields since 1975 are presented in Figure 3. Withdrawals began at the Cosme-Odessa Wellfield in 1930, steadily climbed to approximately 21 million gallons per day (mgd) in 1962, and then were reduced to approximately 10 mgd in the mid-1970s. The Eldridge Wilde Wellfield began withdrawing groundwater in 1957, and pumped over 35 mgd in the early 1970s. Combined groundwater withdrawals from the two wellfields peaked at over 52 mgd in the early 1970s. Combined withdrawal rates since 2003 have averaged a little over 18 mgd (less than 13 mgd at the Eldridge Wilde Wellfield, and less than 6 mgd at the Cosme-Odessa Wellfield), with several extended periods since 2009 when the Cosme-Odessa Wellfield was shut down completely. Monthly withdrawals at both wellfields have been highly variable since 2003.

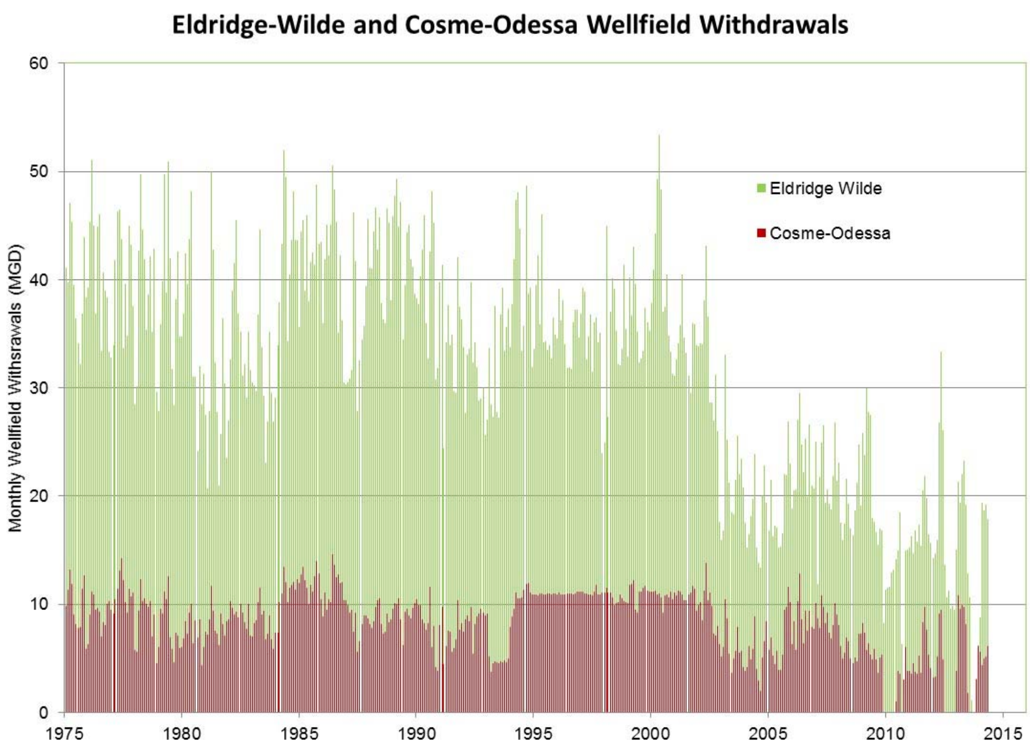


Figure 3. Combined groundwater withdrawals at the Cosme-Odessa and Eldridge Wilde wellfields since 1975.

In 1977, due to concerns of low lake levels, the District issued a permit to Pinellas County (who operated the Eldridge Wilde Wellfield at the time) to begin augmenting the lake with water withdrawn from the Floridan aquifer (along with nearby Lakes Garden and Jackson). The permit has been renewed several times since 1977, and was last renewed in 2001 at 325,000 gpd annual average and 1,010,000 gpd maximum monthly (to be used for all three lakes), and required metering of withdrawals. Prior to the current permit, groundwater withdrawals used for augmenting the lakes were often reported as a total for all three lakes; therefore, the amount of water put into individual lakes is not apparent from the District records. However, from a review of the data that was broken out by lake, it appears that most of the water was put into Lakes Sunset and Garden. Figure 4 presents the permittee reported groundwater withdrawals for Lake Sunset augmentation. It can be seen in the figure that augmentation has decreased significantly in recent years.

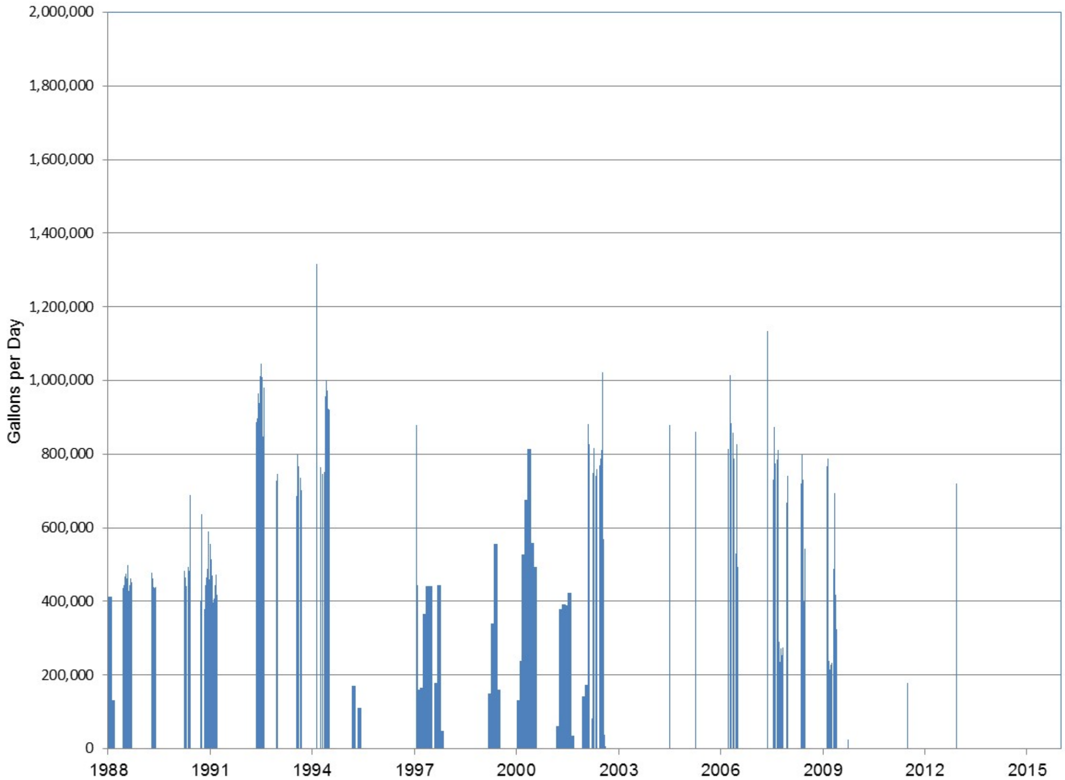


Figure 4. Reported augmentation withdrawals at Sunset Lake.

## C. Revised Minimum Levels Proposed for Sunset Lake

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

Table 1. Proposed Minimum Levels for Sunset Lake.

| Proposed Minimum Levels | **Elevation in Feet** NGVD 29 |
|---|---|
| High Minimum Lake Level | 33.6 |
| Minimum Lake Level | 32.3 |

## D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Sunset Lake from 2003 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 and McBride (2016), groundwater withdrawals during this period were relatively consistent. To create a data set that can reasonably be considered to be “Long-term”, a line of organic correlation (LOC) analysis 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 Sunset Lake (Hancock and McBride, 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 Sunset Lake was used for the status assessment (Hancock and McBride, 2016). The best resulting correlation for the LOC model created with measured data was the 1-year weighted period, with a coefficient of determination of 0.53. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the same percentiles calculated directly from the measured lake level data for Sunset Lake for the period from 2003 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 simulations.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 2003 to 2015 data, and the revised minimum levels proposed for Sunset Lake.

| Percentile | **Lake Stage/LOC Model Current Withdrawal Scenario Results** Elevation in feet NGVD 29 | **2003 to 2015 Data** Elevation in feet NGVD 29 | **Proposed Minimum Levels** Elevation in feet NGVD 29 |
|---|---|---|---|
| P10 | 33.7 | 33.7 | 33.6 |
| P50 | 32.3 | 32.6 | 32.3 |

A comparison of the LOC model with the revised minimum levels proposed for Sunset Lake indicates that the Long-term P10 is 0.1 feet above the proposed High Minimum Lake Level, and P50 is the same (within 0.1 feet) as the proposed Minimum Lake Level. The P10 elevation derived directly from the 2003 to 2015 lake data is 0.1 feet higher than the proposed High Minimum Lake Level, and the P50 elevation is 0.3 feet higher than the proposed Minimum Lake Level. Differences in rainfall between the shorter 2003 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 Sunset Lake water levels are at the revised Minimum Lake Level and above the revised High Minimum Lake Level proposed for the lake. These conclusions are supported by comparison of percentiles derived from Long-term LOC modeled lake stage data with the proposed minimum levels.

Minimum flow and level status assessments are completed on an annual basis by the District and on a five-year basis as part of the regional water supply planning process. In addition, Sunset Lake is included in the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area (40D-80.073, F.A.C). Therefore, the analyses outlined in this document for Sunset Lake will be reassessed by the District and Tampa Bay Water as part of this plan, and as part of Tampa Bay Water's Permit Recovery Assessment Plan (required by Chapter 40D-80, F.A.C. and the Consolidated Permit (No. 20011771.001)). Tampa Bay Water, in cooperation with the District, will assess the specific needs for recovery in Sunset Lake and other water bodies affected by groundwater withdrawals from the Central System Facilities. By 2020, if not sooner, an alternative recovery project will be proposed if Sunset Lake is found to not be meeting its adopted m1inimum 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**

July 17, 2016

TO: David Carr, Staff Environmental Scientist, Resource Evaluation Section

FROM: Jason Patterson, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Sunset Lake

## 1.0 Introduction

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

## 2.0 Hydrogeologic Setting

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

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

## 3.0 Evaluation of Groundwater Withdrawal Impacts to Sunset Lake

A number of regional groundwater flow models have included the area around Sunset Lake in northwest Hillsborough County. Ryder (1982) simulated the entire extent of the Southwest Florida Water Management District. In 1993, the District completed the Northern Tampa Bay groundwater flow model that covered a 2,000 square mile area of Hillsborough, Pinellas, Pasco, and Hernando Counties

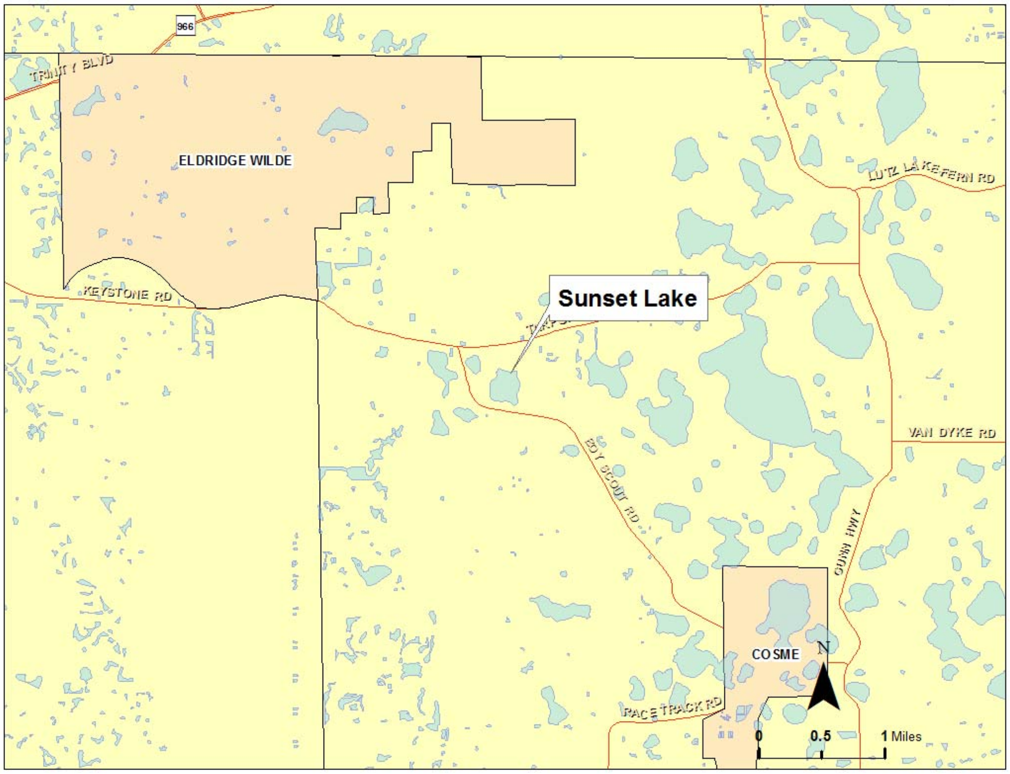


Figure 1. Location of Sunset Lake.

(SWFWMD, 1993). In 2002, the USGS simulated the entire Florida peninsula in their Mega Model of regional groundwater flow (Sepulveda, 2002). The most recent and advanced simulation of southern Pasco County and the surrounding area is the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013). 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.

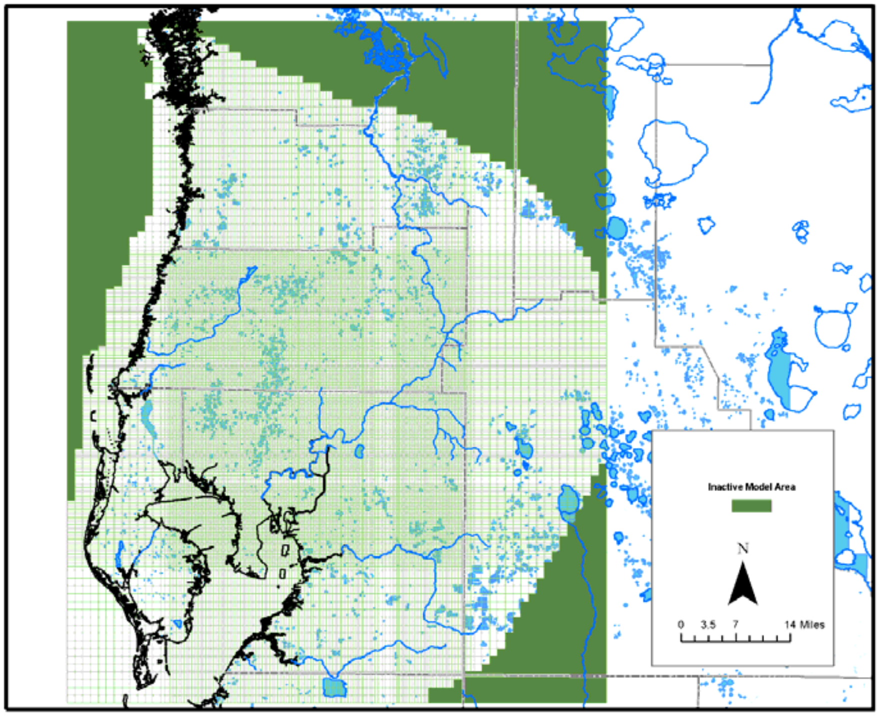


Figure 2. Groundwater grid used in the INTB model

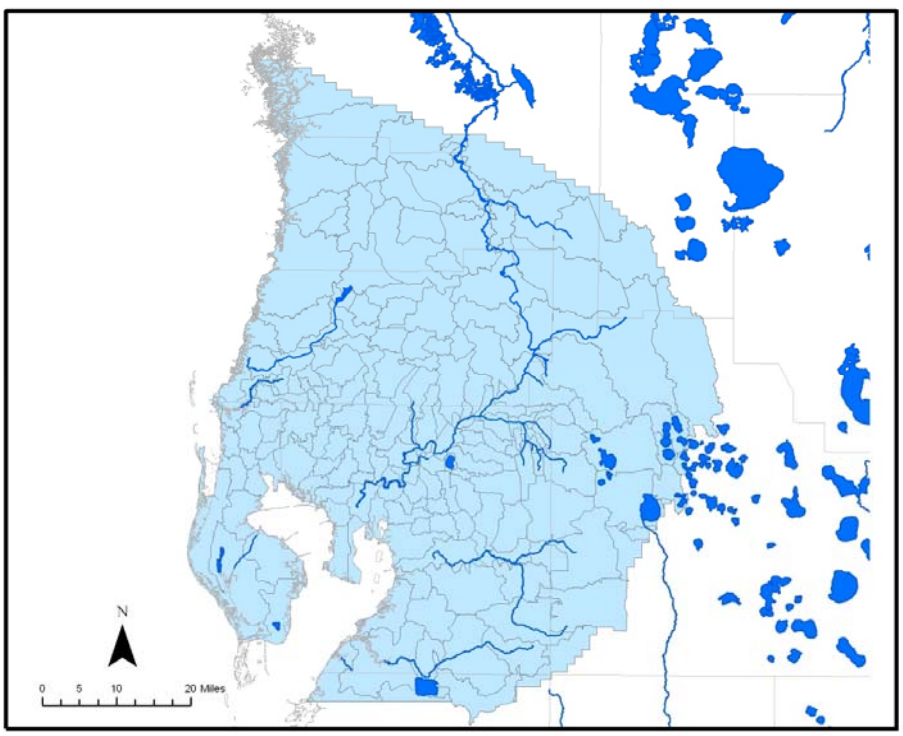


Figure 3. HSPF subbasins in the INTB model.

The INTB model contains 172 subbasin delineations in HSPF (Figure 3). There is also an extensive data input time series of 15-minute rainfall from 300 stations for the period 1989-1998, a well pumping database that is independent of integration time step (1-7 days), a methodology to incorporate irrigation flux into the model simulation, construction of an approximate 150,000 river cell package that allows simulation of hydrography from major rivers to small isolated wetlands, and GIS-based definition of land cover/topography. An empirical estimation of ET was also developed to constrain model derived ET based on land use and depth-to-water table relationships.

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

The INTB model is a regional simulation and has been calibrated to meet global metrics. The model is calibrated using a daily integration step for a transient 10-year period from 1989-1998. A model Verification period from 1999 through 2006 was also added. Model-wide mean error for all wells in both the surficial and Upper Floridan aquifers is less than 0.2 feet during both the calibration and verification periods. Mean absolute error was less than two feet for both the surficial and Upper Floridan aquifer. Total stream flow and spring flow mean error averaged for the model domain is each less than 10 percent. More information summarizing the INTB model calibration can be found in Geurink and Basso (2013).

### 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 Sunset Lake was 2.2 ft, and 6.0 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 Sunset Lake was 1.0 ft and 3.0 ft in the Upper Floridan aquifer (Figure 7 and 8). Table 1 presents the predicted drawdown in the surficial and the Upper Floridan aquifer based on the INTB model results.

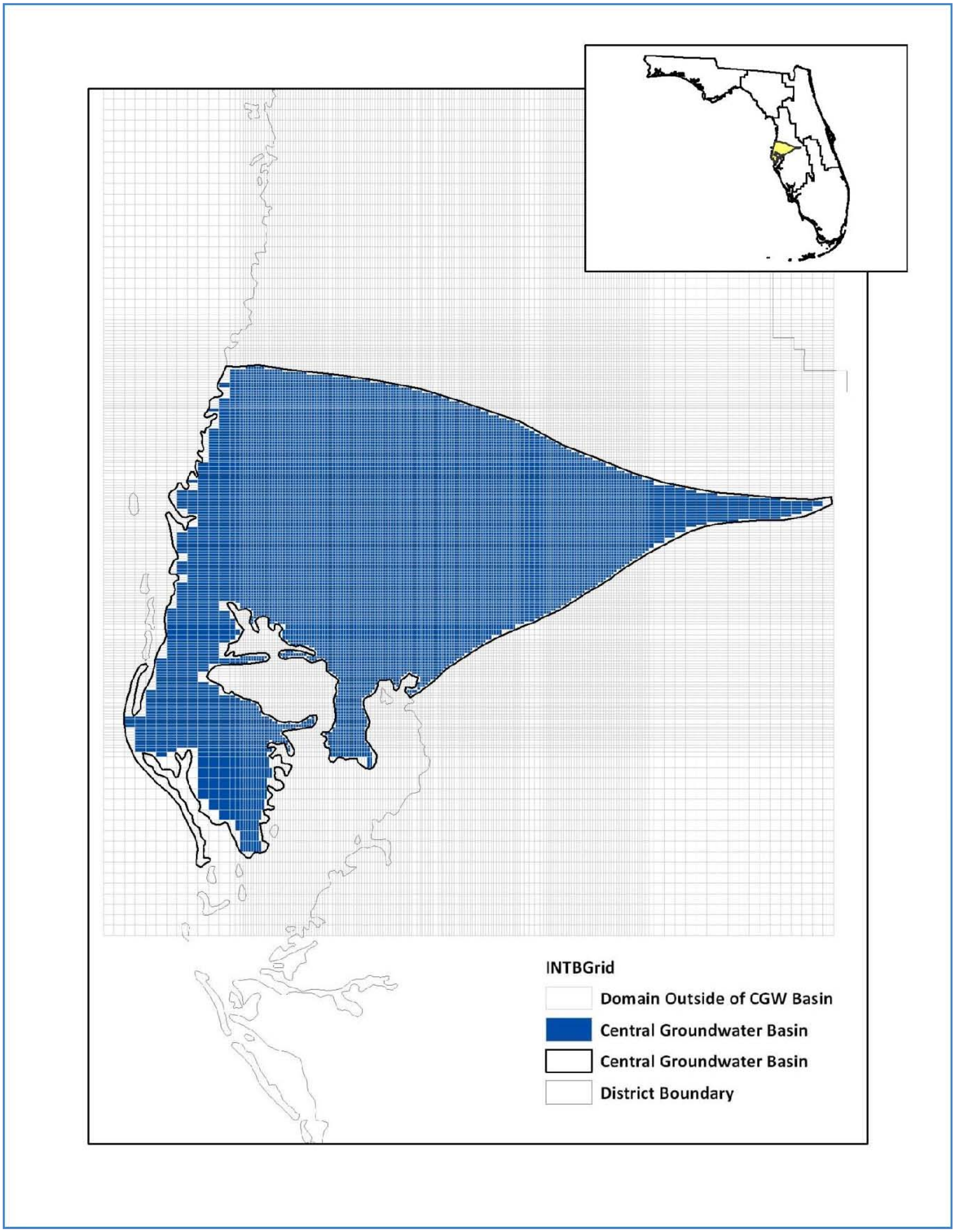


Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

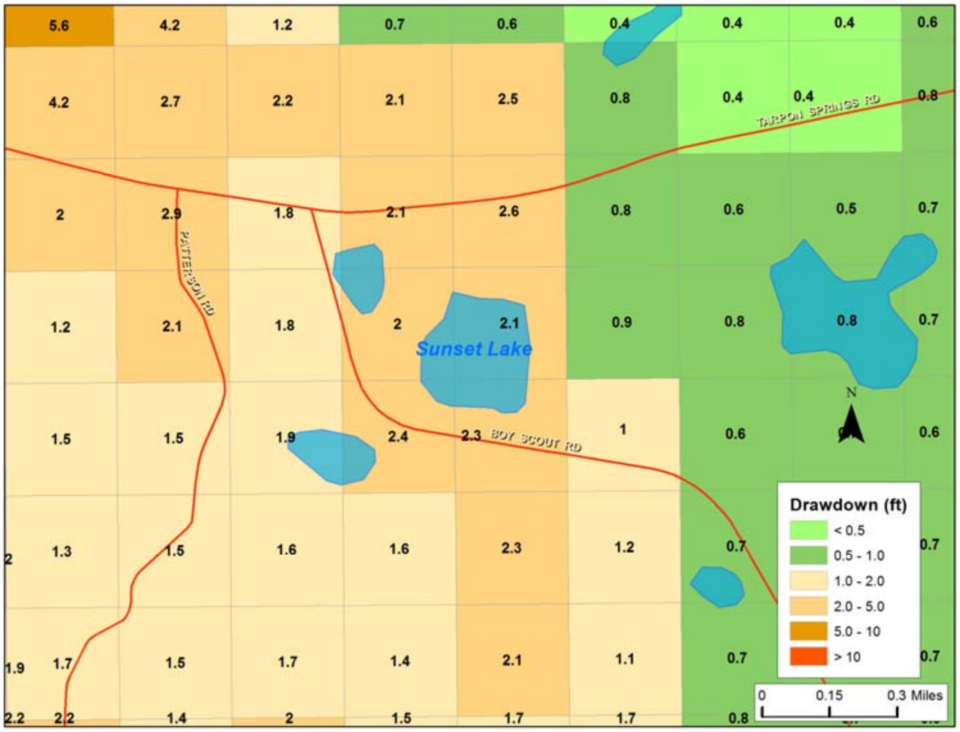


Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

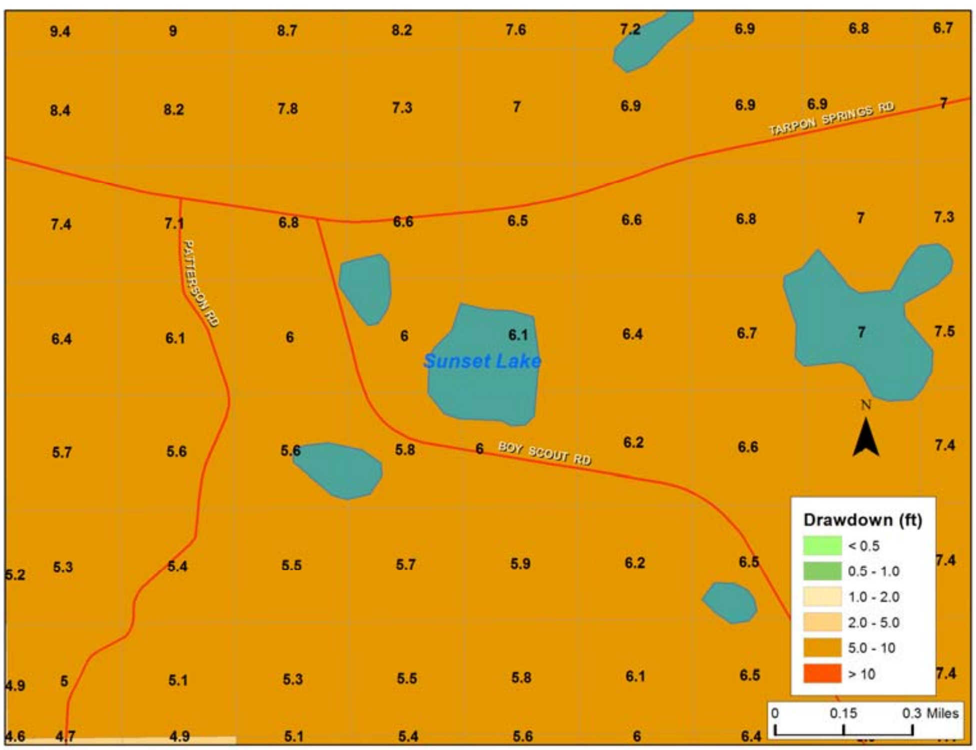


Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

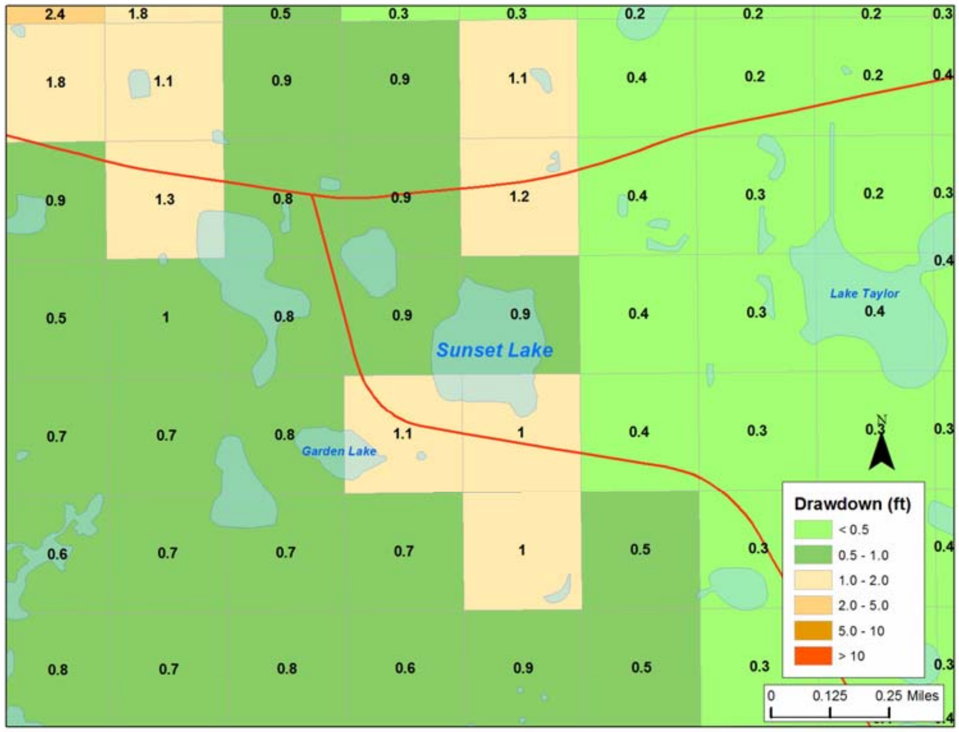


Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

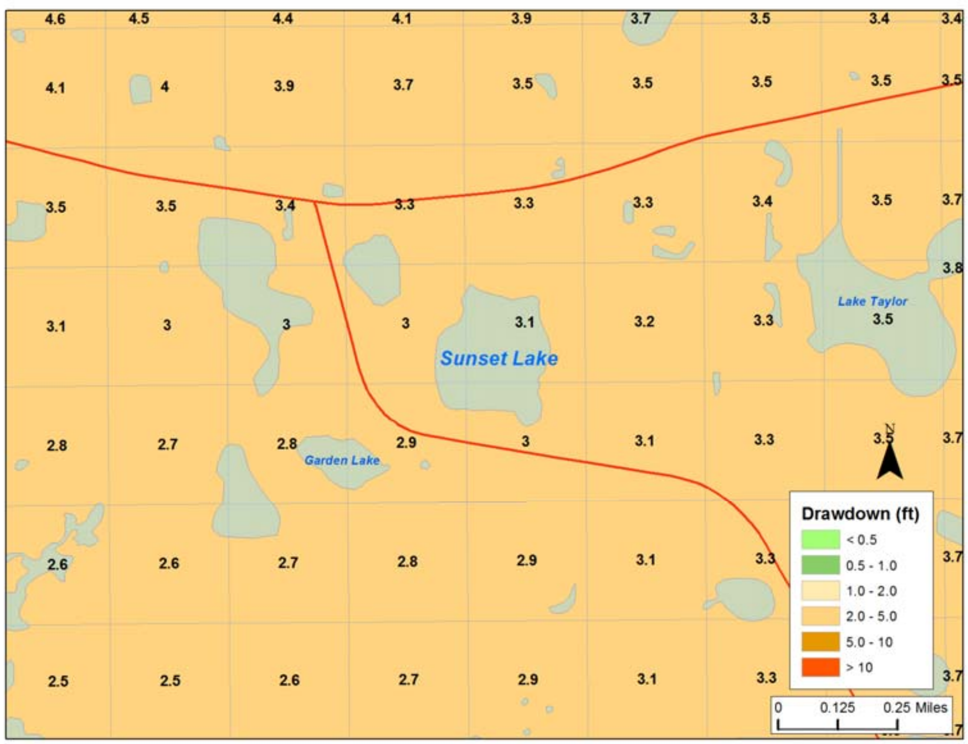


Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

Table 1. INTB model results for Sunset Lake.

| Lake Name | Predicted Drawdown (ft) in the Surficial Aquifer due to 1989-2000 Withdrawals* | Predicted Drawdown (ft) in the Surficial Aquifer with TBW Withdrawals reduced to 90 mgd* |
|---|---|---|
| Sunset | 2.2 | 1.0 |
| **Lake Name** | **Predicted Drawdown (ft) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals*** | **Predicted Drawdown (ft) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd*** |
| Sunset | 6.0 | 3.0 |

* Average drawdown from model cells intersecting lake

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