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

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Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District

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Cover: Aerial photographs of Lake Merrywater, 1998 and 2000 (Southwest Florida Water Management District files).

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Introduction

Reevaluation of Minimum Flows and Levels

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

Lake Merrywater 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. Adopted levels for Lake Merrywater were also reevaluated to support ongoing District assessment of minimum flows and levels and the need for additional recovery in the Northern Tampa Bay Water Use Caution Area (NTB WUCA), a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Following Governing Board approval on October 25, 2016, the revised levels became effective on March 2, 2017.

Minimum Flows and Levels Program Overview

Legal Directives

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

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

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

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

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

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

Programmatic Description and Major Assumptions

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

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

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

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

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

Consideration of Changes and Structural Alterations and Environmental Values

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

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

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

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

Information regarding the development of adopted methods for establishing minimum and guidance lake levels is included in Southwest Florida Water Management District (1999a, b) and Leeper *et al.* (2001). Additional information relevant to developing lake levels is presented by Schultz et al. (2004), Carr and Rochow (2004), Caffrey *et al.* (2006, 2007), Carr *et al.* (2006), Hancock (2006), 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 minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. The Cypress Standard is 1.8 feet below the normal pool elevation. For Category 3 lakes, six significant change standards are typically developed. Other available information, including potential changes in the coverage of herbaceous wetland and submersed aquatic plants is also considered when establishing minimum levels for Category 3 Lakes. The standards and other available information are associated with the environmental values identified for consideration in Rule 62-40.473, F.A.C., when establishing MFLs (Table 1). The specific standards and other information evaluated to support development of revised minimum levels for Lake Merrywater are provided in subsequent sections of this report. More general information on the standards and other information used for consideration when developing minimum lake levels is available in the documents identified in the preceding sub-section of this report.

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

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

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

Lake Classification

Lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. Those with fringing cypress wetlands greater than 0.5 acre in size where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands (i.e. the Historic P50 (HP50), or the 50th percentile from historic data, is equal to or higher than an elevation 1.8 feet below the Normal Pool elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acre in size that have been structurally altered such that the Historic P50 elevation is more than 1.8 feet below the Normal Pool elevation are classified as Category 2 Lakes. Lakes without fringing cypress wetlands or with cypress wetlands less than 0.5 acre in size are classified as Category 3 Lakes.

According to Chapter 40D-8.624, F.A.C., Lake Merrywater meets the classification as a Category 1 lake. The Historic P50 for Merrywater (56.0 ft.) is equal to 1.8 feet below the Historic Normal Pool elevation. The previously adopted levels for Lake Merrywater are based on the lake being a Category 2 lake. The change from Category 2 to Category 1 is due to an updated Normal Pool elevation, based on additional field data, and an updated Historic P50 elevation based on new modelling approaches rather than utilizing the Reference Lake Water Regime (RLWR). The previously used Historic Normal Pool and P50 elevations resulted in the P50 falling below the Cypress Standard, making it a Category 2 lake, while the current data puts the Cypress Standard equal to the HP50 elevation as described above. For comparison purposes, the standards associated with Category 3 Lakes described below will also be developed in a subsequent section of this report.

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

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

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

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

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

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

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

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

Minimum Levels

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

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

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

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

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

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

Development of Minimum and Guidance Levels for Lake Merrywater

Lake Setting and Description

Watershed

Lake Merrywater (Figure 1) is a 26-acre lake (FBC 1969) located in the northern Tampa Bay area in Lutz, Hillsborough County, Florida (Section 22, Township 27S, Range 18E). Lake Merrywater is located less than a mile due east of the Section 21 Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water. Lake Merrywater is located in the Rocky/Brushy Creek watershed (Figure 2).

Surface water conveyance systems consist of a single main inflow into and outflow from the lake, as well as a small inflow from a wetland conservation area on the southwestern shore (Figure 3). The inflow (Figure 4) receives water from Reinheimer Lake over two broad-crested rectangular weirs. The outflow conveyance system consists of four culverts on the southeast side of the lake (Figure 5) that lead to three broad-crested rectangular weirs (Figure 6) that serve as the lake's control point. There is no public access to the lake and the Home Owners Association does not allow powerboats to operate in the lake or docks to be constructed along the shore.

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

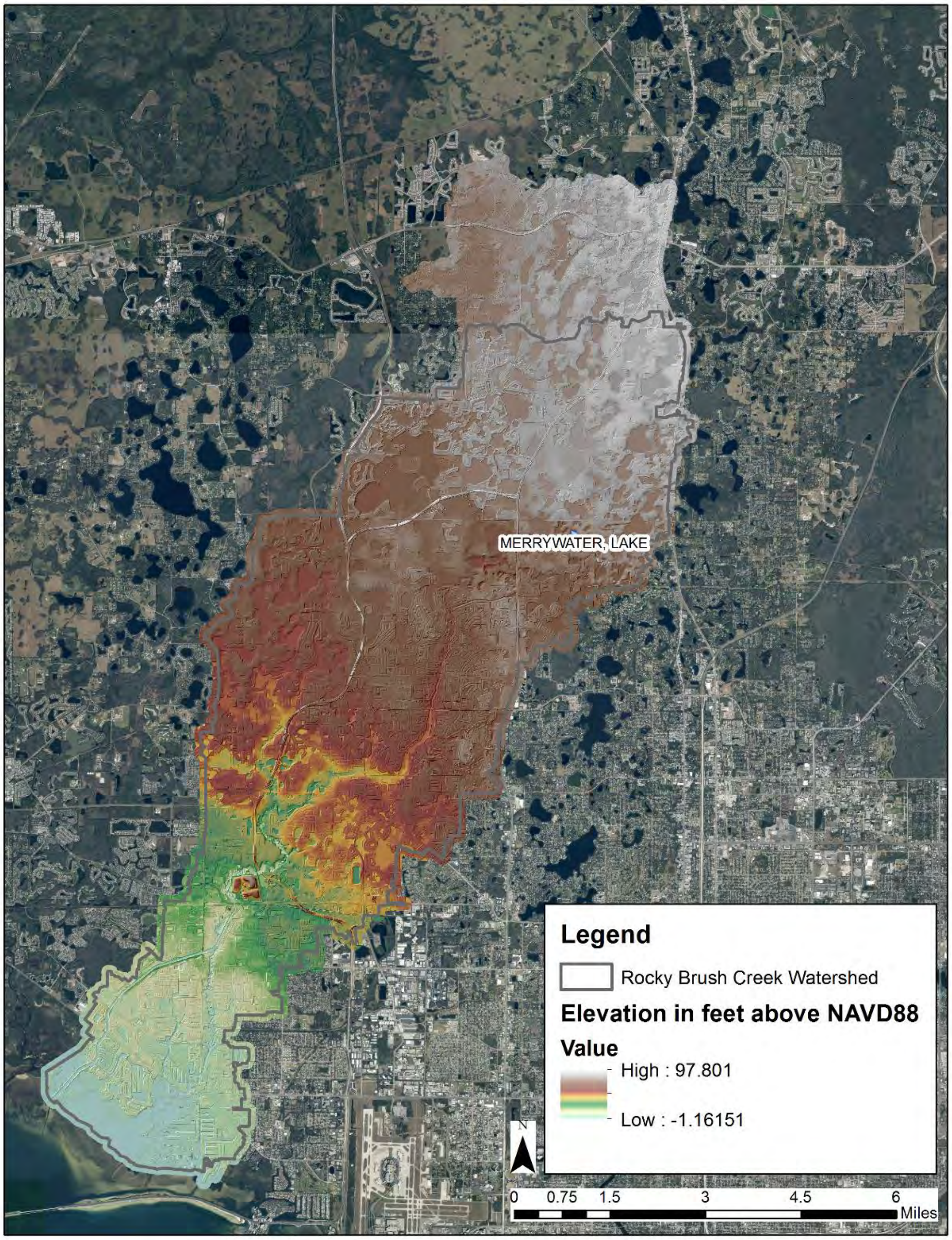

Figure 2: Watershed Delineation and Topography.

Figure 3: Location of Conveyance Systems and District Gages.

Figure 4: Two inflow weirs receive water from Reinheimer Lake under Van Dyke Road.

Figure 5: Four 60”X38” culverts under Merrywater Drive serve as outflow from the lake.


Figure 6: Three outflow weirs that serve as the control point out of the lake.

Site/Basin Specific Details

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, but in the area of Lake Merrywater is typically much thinner or absent. 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).

Land Use Land Cover

An examination of the pre-development (1950) and current (2011) Florida Land Use, Cover and Forms Classification System (FLUCCS) maps, as well as historic aerial photographs, revealed that there have been considerable changes to the landscape in the vicinity (Figure 8 - Figure 14). In 1950, 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 pastureland (primarily *Paspalum notatum*) dominated the area (Figure 7). This vegetation is typical of the Myakka fine sands present. By 2011, the landscape was split between residential and open urban lands (transitioning into residential) (Figure 8). Figure 9 through Figure 14 aerial photography chronicles landscape changes to the immediate lake basin from 1938 through 2014.

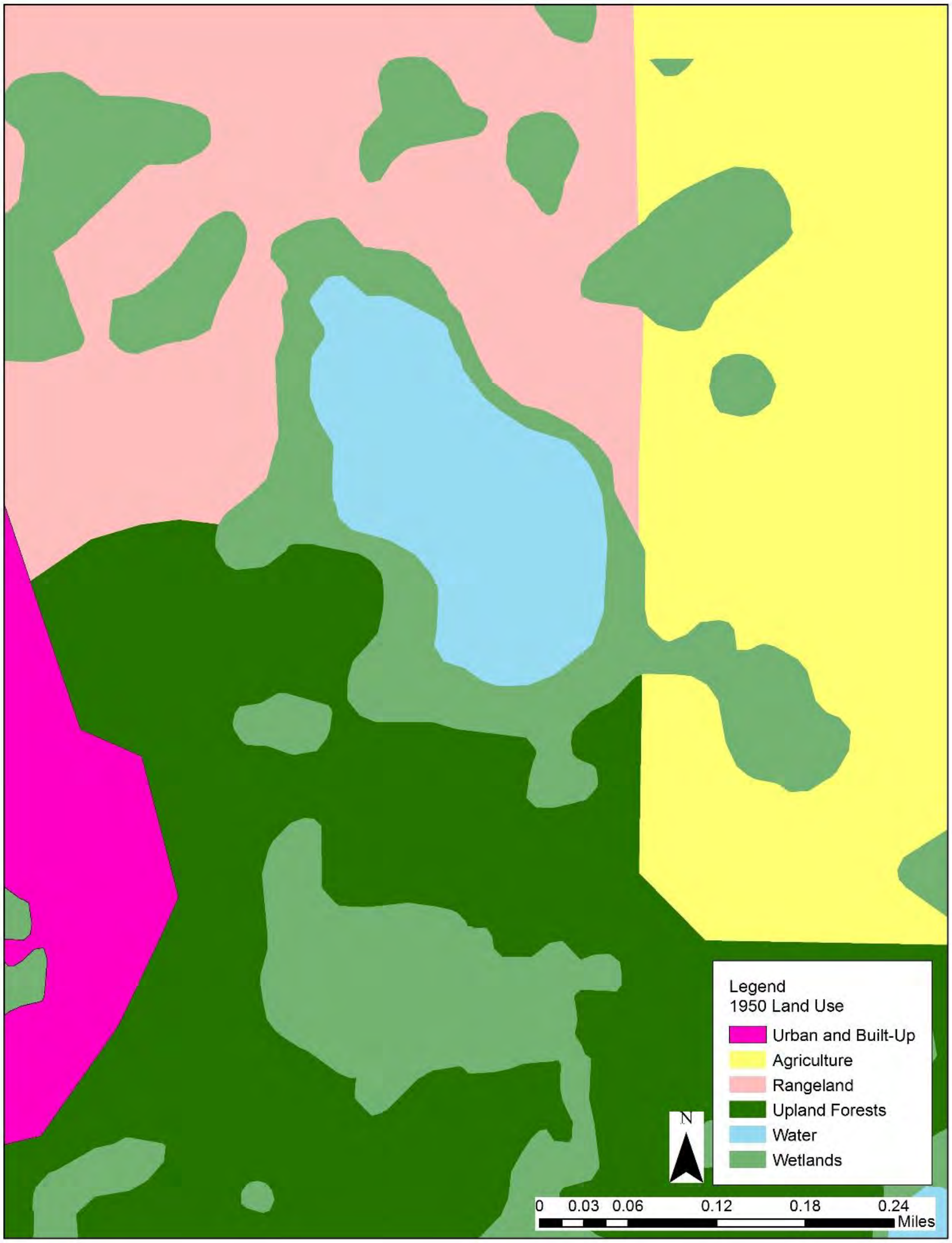

Figure 7: 1950 Land Use Land Cover Map of the Lake Merrywater Vicinity.

Figure 8: 2011 Land Use Land Cover Map of the Lake Merrywater Vicinity.

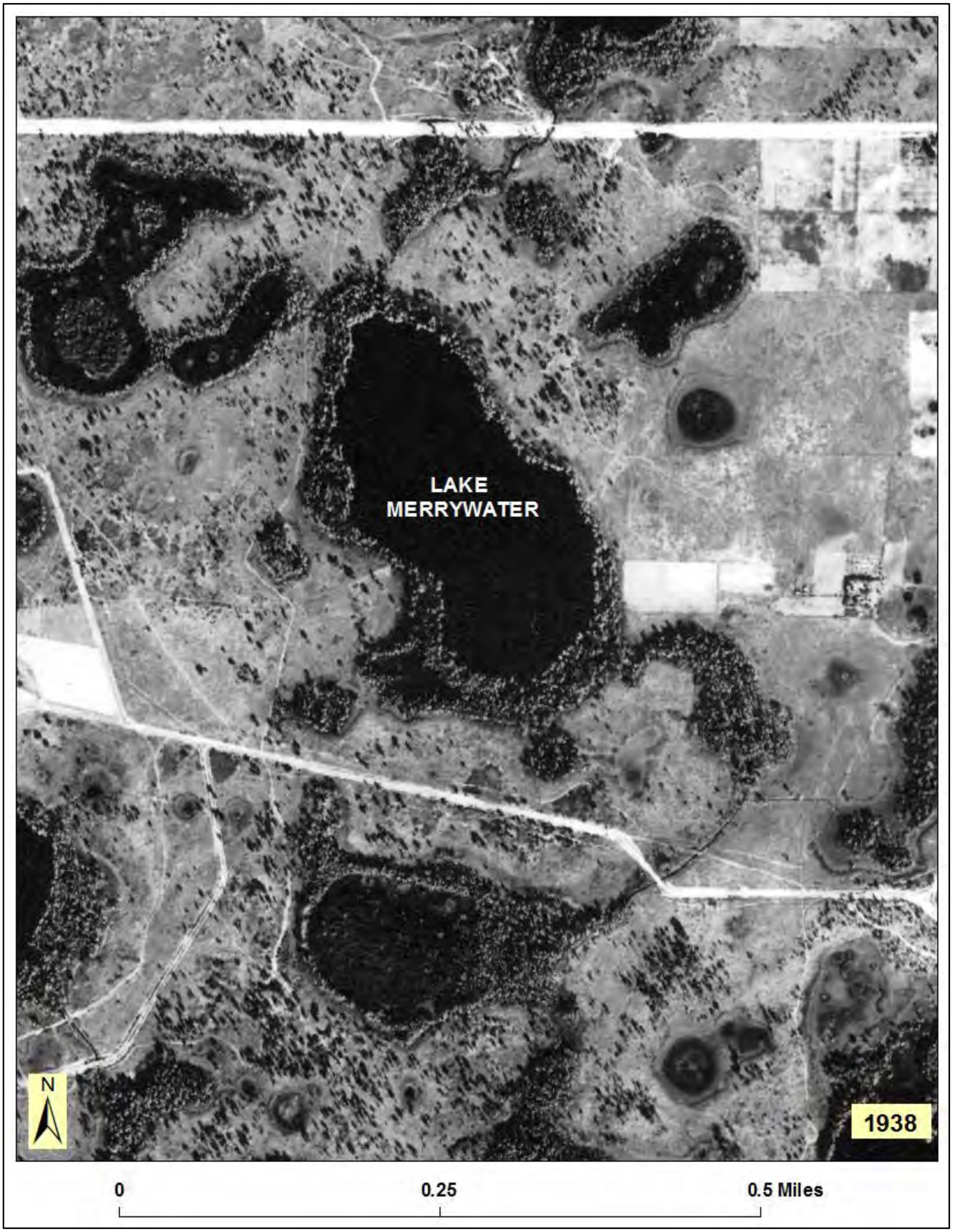

Figure 9: 1938 Aerial Photograph of Lake Merrywater

Figure 10: 1970s Aerial Photograph of Lake Merrywater

Figure 11: 2006 Aerial Photograph of Lake Merrywater

Figure 12: 2007 Aerial Photograph of Lake Merrywater

Figure 13: 2010 Aerial Photograph of Lake Merrywater

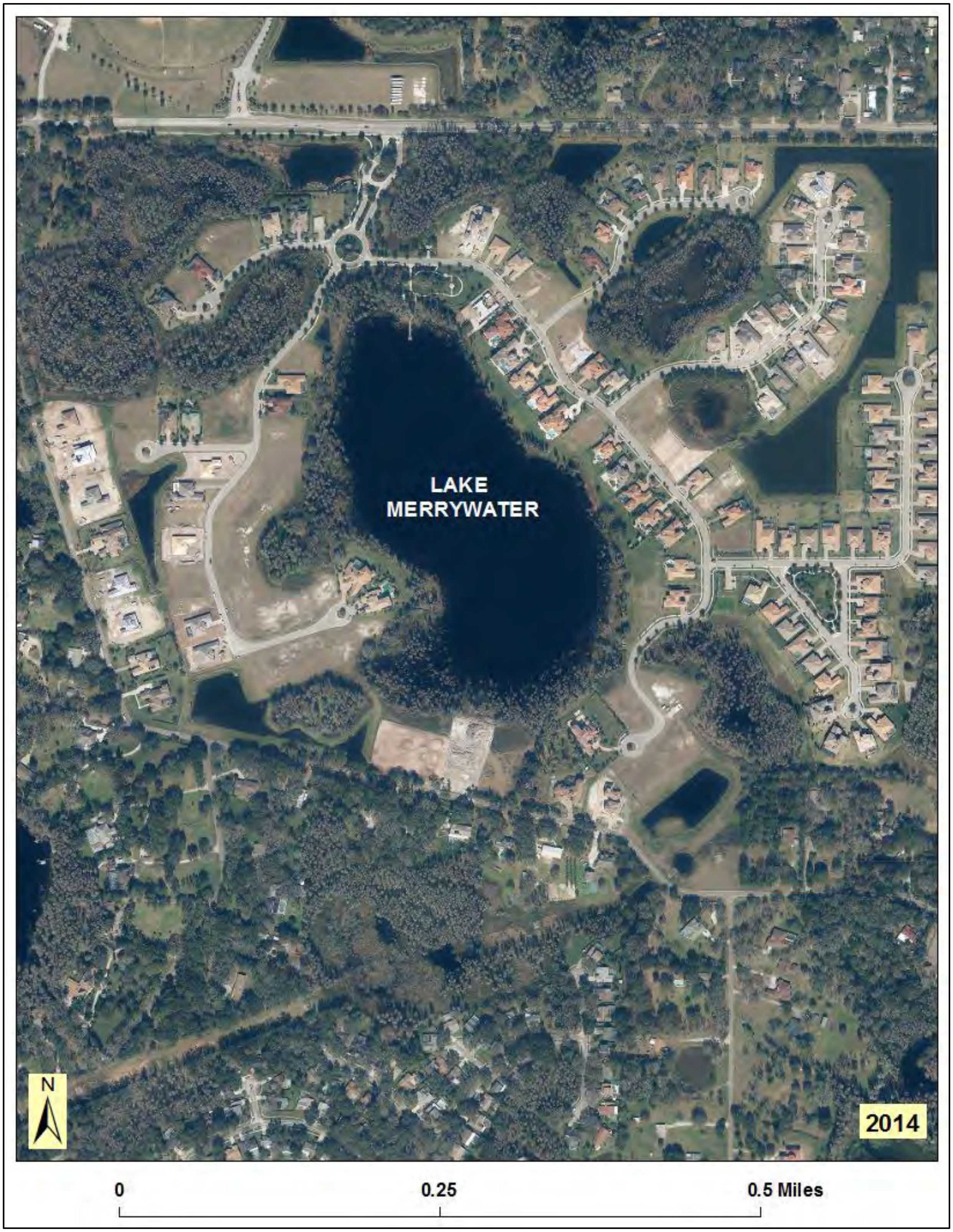

Figure 14: 2014 Aerial Photograph of Lake Merrywater

Bathymetry Description and History

One-foot interval bathymetric data gathered from field surveys resulted in lake-bottom contour lines from 41 ft. to 57 ft. (Figure 15). These data revealed that the lowest lake bottom contour (41 ft.) is located in two spots at the northern tip of the lake, approximately 115 ft. and 250 ft. past the end of the dock. The highest elevation (57 ft.) would include the main lake basin as well as wetland areas to the northwest of the lake and to the southeast of the lake (Figure 15). Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

Figure 15: Lake Bottom Contours (ft., NGVD29) on a 2014 Natural Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations, are available for Lake Merrywater from the District's Water Management Information System (SID 19841 and SID 825768) (Figure 16). Data collection began on October 11, 1977 from staff gauge SID 19841. In April 2007, the gauge was replaced with a new one (SID 825768) on the north end of the lake, which continues to be monitored on a monthly basis at the time of this report. The highest lake stage elevation on record was 58.41 ft. and occurred on August 4, 2015. The lowest lake stage elevation on record was 45.71 ft. and occurred on June 27, 2001 following a 1999-2001 period of extended drought.

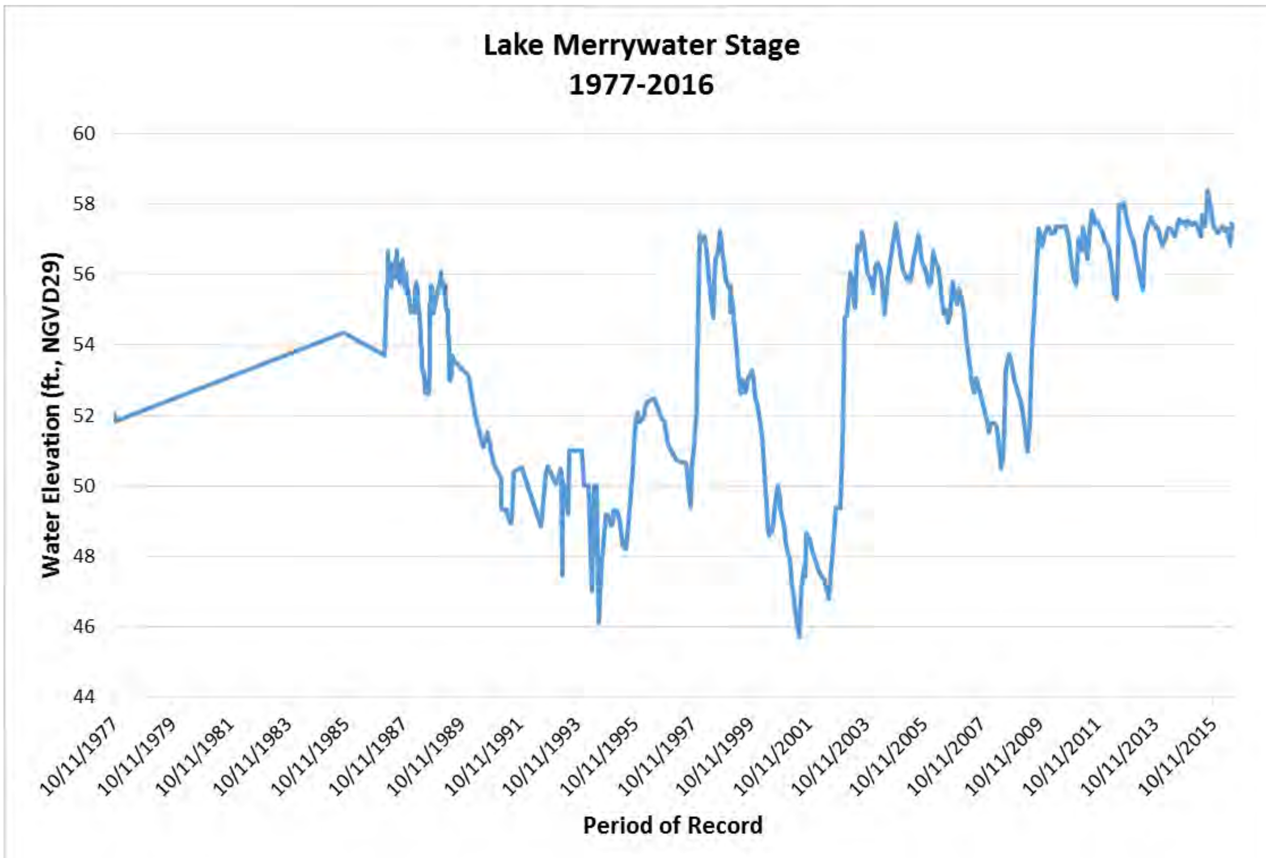

Figure 16: Lake Merrywater Period of Record Water Elevation Data (SID 19841 & 825768).

Historical Management Levels

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

The District Governing Board approved Guidance and Minimum levels for Lake Merrywater (Table 2) in October 1998, which were subsequently adopted into Chapter 40D-8, Florida Administrative Code on July 18, 2000 using the methodology for Category 2 Lakes described in SWFWMD (1999a and 1999b). Revised levels (Table 3) have since been incorporated into rule and have replaced those listed in Table 2.

Table 2. Guidance levels adopted July 2000 for Lake Merrywater

Level	Elevation (ft., NGVD)
Ten Year Flood Guidance Level	58.0
High Guidance Level	55.8
High Minimum Level	55.8
Minimum Level	54.8
Low Guidance Level	53.7

Methods, Results and Discussion

Revised Minimum and Guidance Levels were developed for Lake Merrywater using the methodology for Category 1 lakes described in Chapter 40D-8, F.A.C. The levels along with lake surface area for each level are listed in Table 3 along with other information used for development of the revised levels. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

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

Levels	**Elevation in Feet NGVD 29**	**Lake Area (acres)**
Lake Stage Percentiles		
Historic P10 (1946 to 2013)	57.4	34.7
Historic P50 (1946 to 2013)	56.0	29.7
Historic P90 (1946 to 2013)	54.3	25.7
Revised Normal Pool and Control Point		
Normal Pool	57.8	36.7
Control Point	57.2	33.7
Significant Change Standards		
Recreation/Ski Standard*	NA	NA
Dock-Use Standard*	NA	NA
Wetland Offset Elevation*	55.2	27.6
Aesthetics Standard*	54.3	25.7
Species Richness Standard*	54.0	25.1
Basin Connectivity Standard*	51.2	18.9
Lake Mixing Standard*	NA	NA
Revised Minimum and Guidance Levels		
High Guidance Level	57.4	34.7
High Minimum Lake Level	57.4	34.7
Minimum Lake Level	56.0	29.7
Low Guidance Level	54.3	25.7

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

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

The DEM created from the combined elevation data sets was used to develop topographic contours of the lake basin and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments. Selected stage-area-volume results are presented in Figure 17.

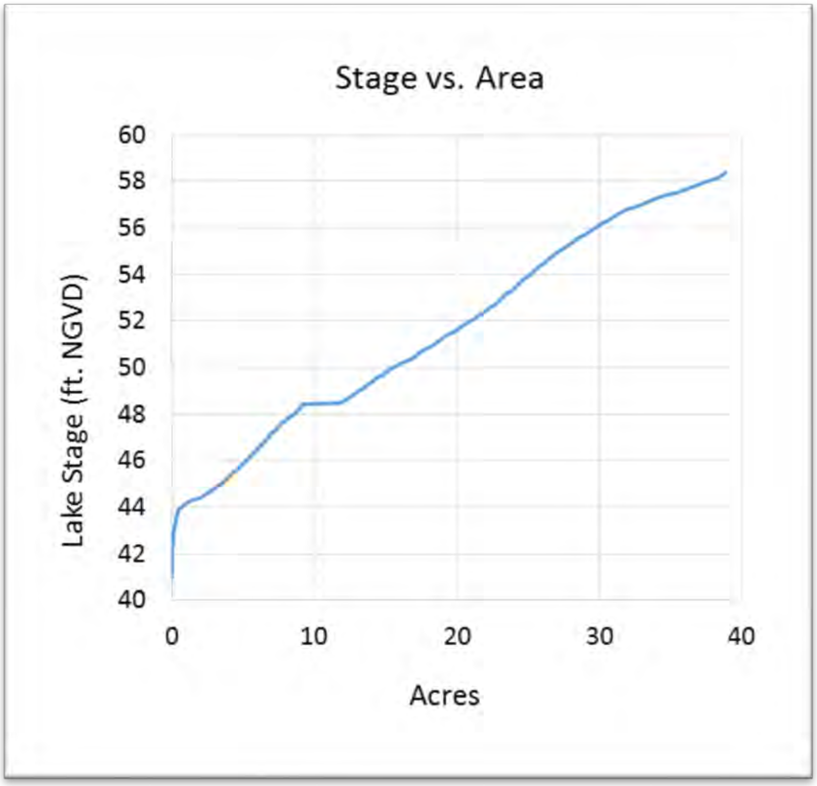

Figure 17: Lake Stage (Ft. NGVD29) to Surface Area (Acres).

Development of Exceedance Percentiles

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

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

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

A combination of model data produced a hybrid model which resulted in a 69-year (1946-2015) Historic water level record. Based on this hybrid data, the Historic P10 elevation, i.e., the elevation of the lake water surface equaled or exceeded ten percent of the time, was 57.4 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 56.0 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 54.3 ft. (Figure 18 and Table 3).

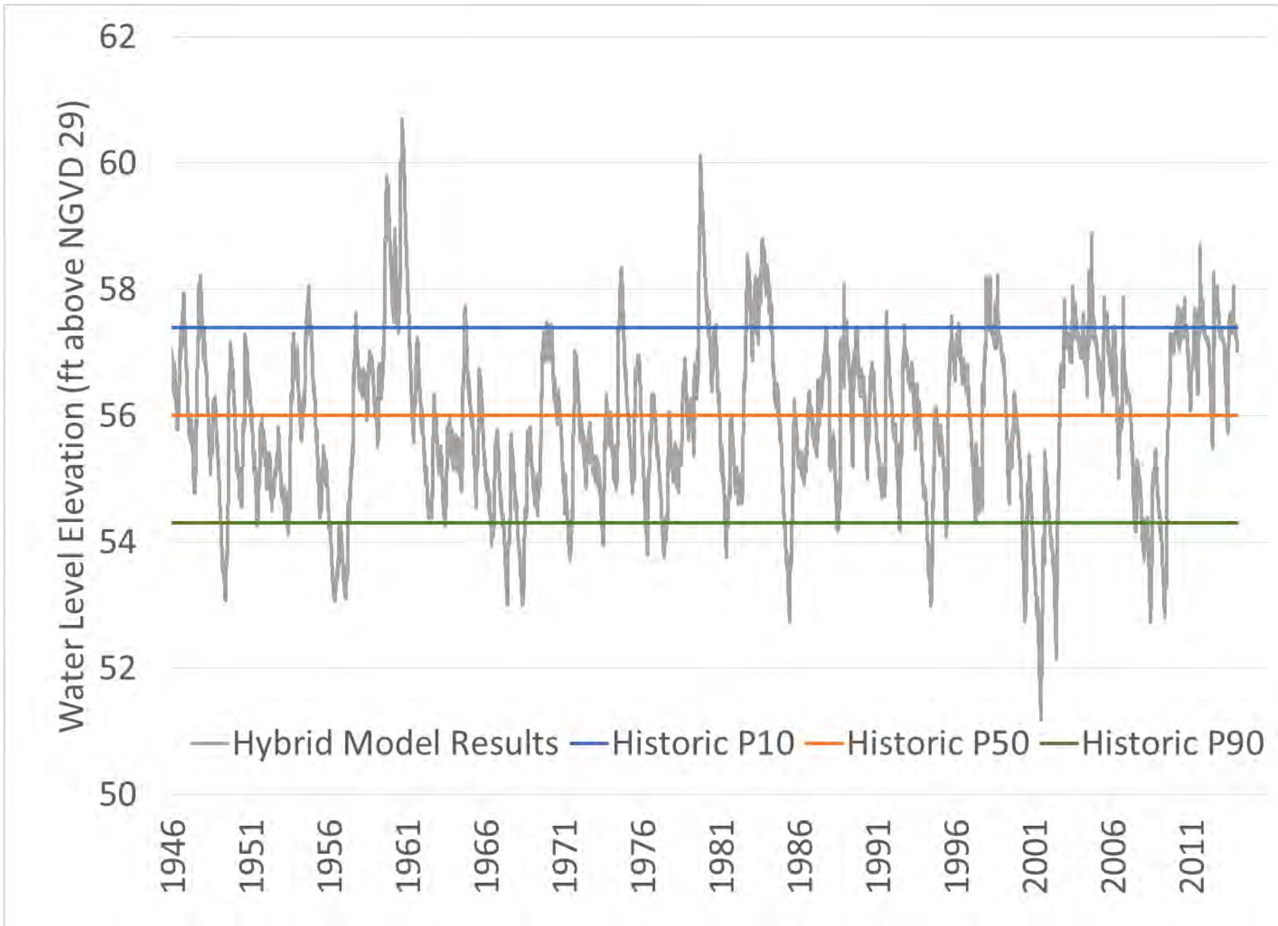

Figure 18: Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

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 Historic normal pool was determined for Lake Merrywater based on the 2013 measurements of the elevation of cypress tree buttressing (n=7) and the elevation of moss collar formation on cypress trees (n=3), and was determined to be 57.8 feet NGVD29 (Table 4). 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). This normal pool is 0.7 ft. lower than the normal pool calculated for the 1999 report (58.5ft.). The original normal pool calculation was based on only 3 data points, while this calculation is more robust with 10 data points. Note that there is substantial subsidence and soil loss around Lake Merrywater, which could result in lower than expected normal pool indicators.

Table 4. Summary statistics for 2013 hydrologic indicator measurements used for establishing normal pool elevations for Lake Merrywater.

Summary Statistic	Number (N) or Elevation
N	10
Median	57.8
Mean	57.8
Minimum	57.7
Maximum	57.9

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. A group of three broad-crested rectangular weir structures serve as the control point at 57.2 ft. (Figure 6). The previously adopted MFLs for Lake Merrywater used a control point elevation of 55.53 ft., based on the highest point in the outflow ditch from the lake. However, survey reports and field reconnaissance for re-evaluation have confirmed that the weirs are the true control point. All of the houses located around Lake Merrywater were newer construction at the time of this report, and were all located at high elevations compared to the lake. For this reason, a low floor slab elevation was not considered or applicable.

Revised Guidance Levels

The High Guidance Level is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake, and is established using Historic data if it is available, or is estimated using the Current P10, the Control Point elevation and the Normal Pool elevation. Based on the availability of Historic data developed for Lake Merrywater, the revised High Guidance Level was established at the Historic P10 elevation, 57.4 ft. Gauged data indicate that the High Guidance Level has been exceeded a few times in the past, primarily between 2011 and 2015. The highest peak was 58.41 ft. in August 2015.

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, P10 and P90, and P50 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of Historic data for Lake Merrywater, the revised Low Guidance Level was established at the Historic P90 elevation, 54.3 ft. The gaged period of record indicates the lowest recorded elevation was 45.71 ft., below the low guidance level, in June 2001 (Figure 16). The most recent record of the water level dropping below the low guidance level was in July of 2009, with a recorded level of 53.85 ft.

Significant Change Standards

For comparison purposes, Category 3 significant change standards were established for Lake Merrywater based on the stage-volume relationship which was developed. These standards include a Recreation/Ski Standard, Dock-Use Standard, Wetland Offset Elevation, Aesthetics Standard, Species Richness Standard, Basin Connectivity Standard, and Lake Mixing Standard. Each was evaluated for minimum levels development for Lake Merrywater and presented in Table 3.

- The **Recreation/Ski Standard** was not established due to the Home Owner's Association restriction of no power boats allowed on the lake.
- The **Dock-Use Standard** was not established because there is only one dock on the lake which is an insufficient number of docks to develop a standard.
- The **Wetland Offset Elevation** was established at 55.2 ft., or 0.8 ft. below the historic P50 elevation.
- An **Aesthetic-Standard** for Lake Merrywater was established at the Low Guidance Level elevation of 54.3 ft.
- The **Species Richness Standard** was established a 54.1 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- The **Basin Connectivity Standard** was established at 51.2 ft., based on the addition of 1 ft. plus the difference between the Historic P50 and P90 elevations (1.7 ft.) to the critical high spot elevation of 48.5 ft. This is the highest elevation where the north and south basins of Lake Merrywater are connected.
- The **Lake Mixing Standard** was not established, as the dynamic ratio does not reach a value of 0.8 (see Bachmann *et al.* 2000).

Review of changes in potential herbaceous wetland area associated with change in lake stage (Figure 19), and potential changes in area available for aquatic plant colonization (Figure 20) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development. Figure 19 shows that as the lake stage increases, the acres available for herbaceous wetland area also increase, up until around 52 ft. NGVD. The acres available for herbaceous wetlands then decrease as the lake becomes deeper before spilling over into nearby wetland areas. Around 56 ft. NGVD the wetland to the northwest of Lake Merrywater (Figure 15) is then included in the stage volume calculations, which is why the acreage increases again. Similarly, the area available for aquatic plant colonization generally increases as lake stage increases as well (Figure 20). The changes in the slope of the line reflect the variation in lake bottom contours and the area which it contains.

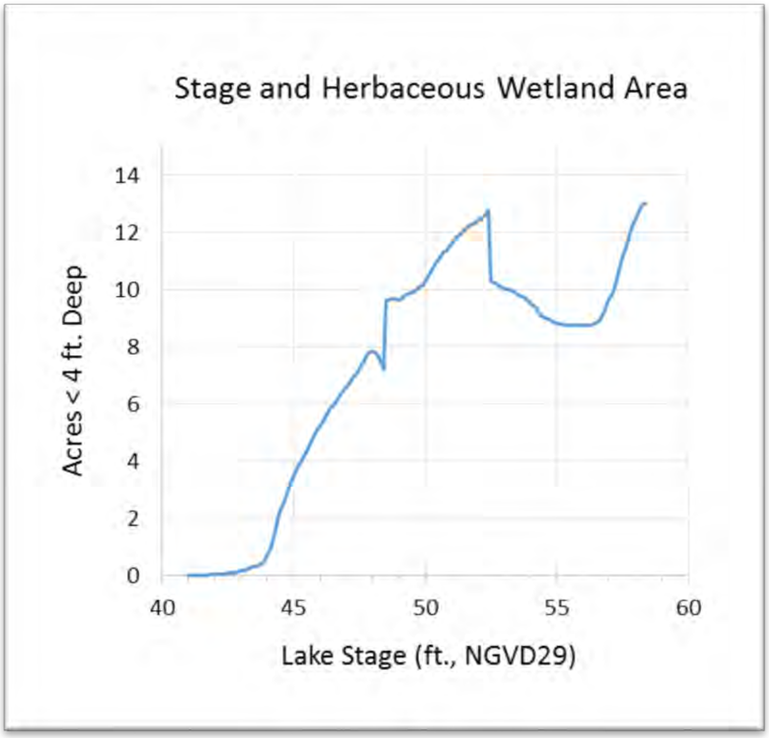

Figure 19: Lake Stage Compared to Available Herbaceous Wetland Area.

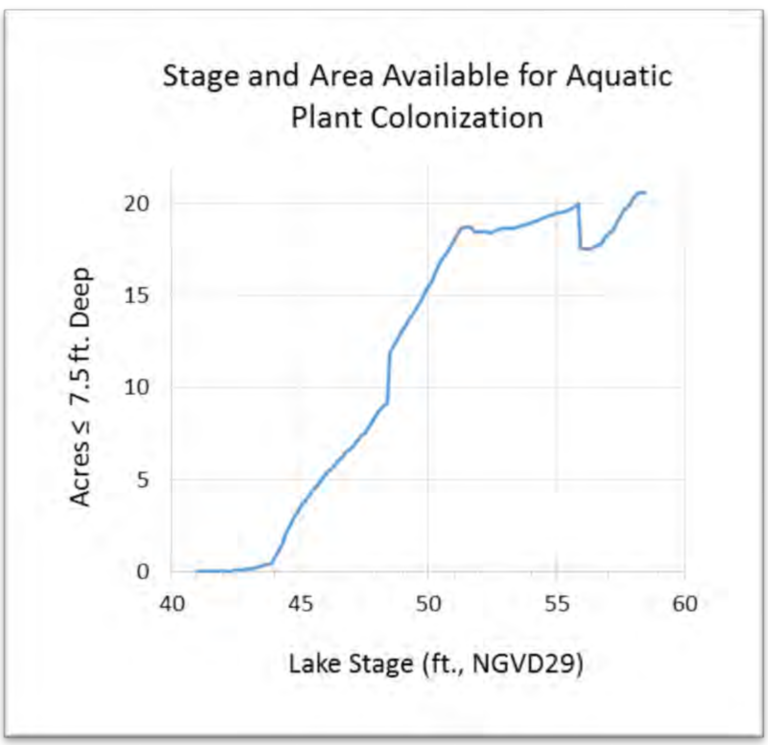

Figure 20: Lake Stage and Area Available for Aquatic Plant Colonization.

Revised Minimum Levels

The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. For a Category 1 lake, the Minimum Lake Level is established at 1.8 ft. below the historic normal pool elevation. In the case of Lake Merrywater, the revised minimum level is 56.0 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 1 lake, the High Minimum Lake Level is established at 0.4 ft. below the historic normal pool elevation. Therefore, the revised High Minimum Lake Level for Lake Merrywater is established at 57.4 ft.

Revised Minimum and Guidance levels for Lake Merrywater are plotted on the Historic water level record as well as actual water level elevations collected in the field (Figure 21). To illustrate the approximate locations of the lake margin when water levels equal the revised minimum levels, the levels are imposed onto a 2014 natural color aerial photograph in Figure 22.

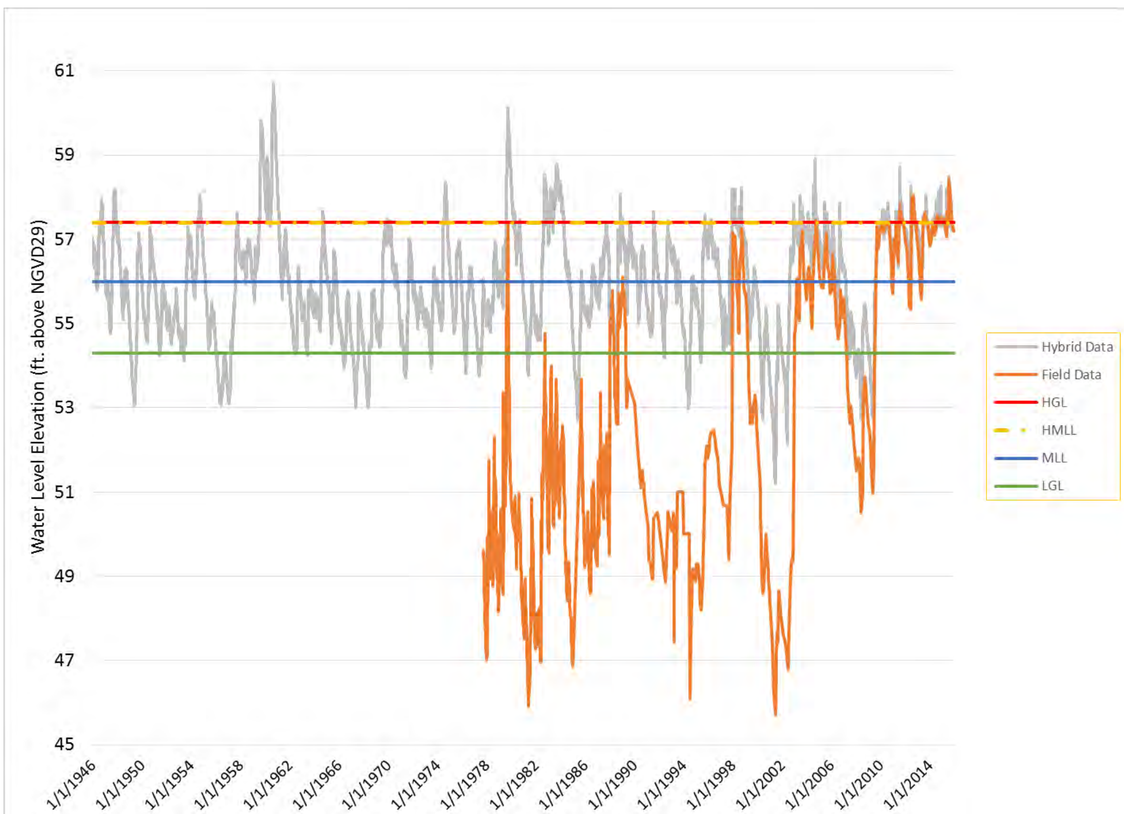

Figure 21: Historic water levels (hybrid) used to calculate the Revised Minimum and Guidance Levels along with field collected water level data, High Guidance Level (HGL. 57.4 ft.), High Minimum Lake Level (HMLL, 57.4 ft.), Minimum Lake Level (MLL, 56.0 ft.), and Low Guidance Level (LGL, 54.3 ft.).

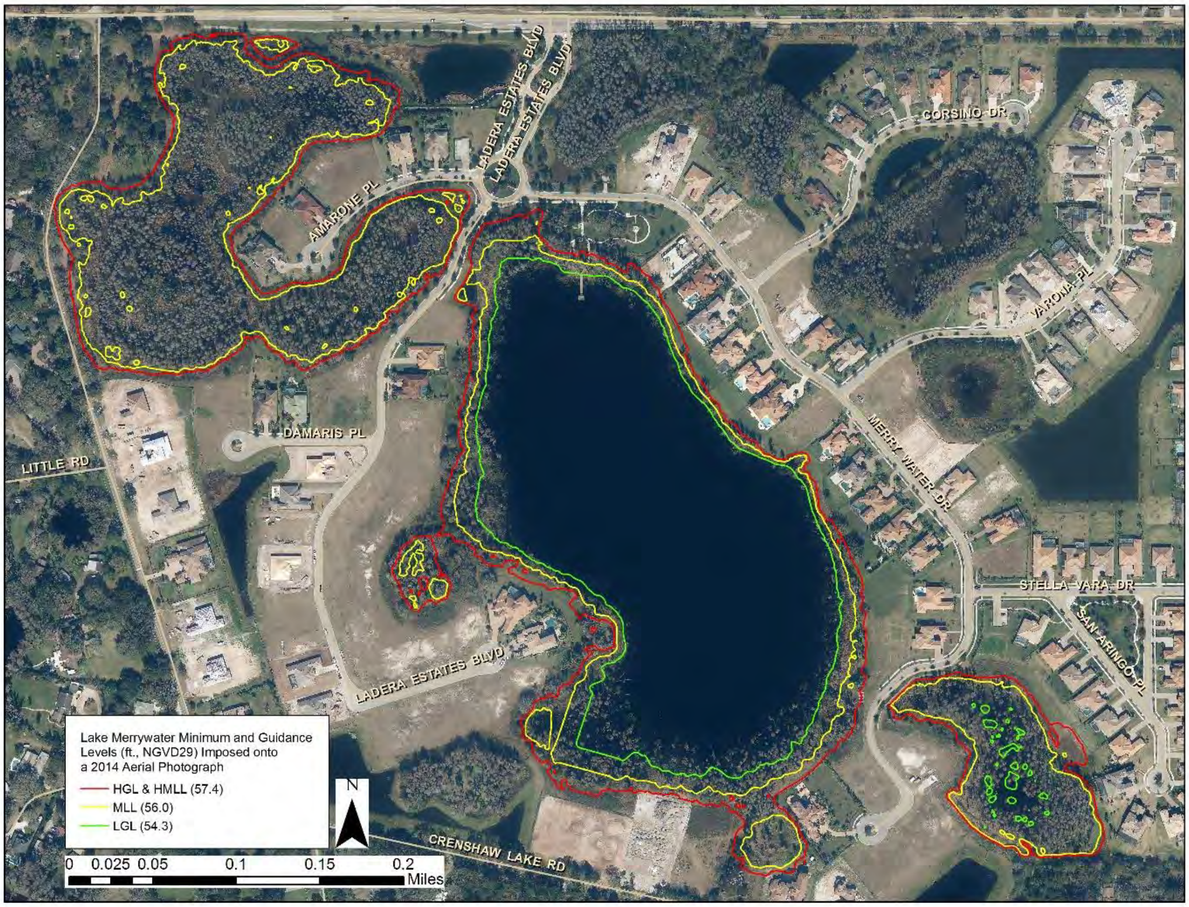

Figure 22: Lake Merrywater Revised Minimum and Guidance Level Contour Lines Imposed onto a 2014 Natural Color Aerial Photograph.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida's water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the revised MFLs for Lake Merrywater are presented in both datum standards (Table 5). The datum shift was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum of 1988. The NGVD29 datum conversion to NAVD88 is -0.83 ft. for SID 825768 on Lake Merrywater.

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

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88
High Guidance Level	57.4	56.57
High Minimum Lake Level	57.4	56.57
Minimum Lake Level	56.0	55.17
Low Guidance Level	54.3	53.47

Consideration of Environmental Values

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

A Cypress Standard (1.8 ft. below the historic normal pool elevation) was identified to support development of minimum levels for Lake Merrywater based on its classification as a Category 1 lake. The standard is associated with protection of several environmental values identified in the Water Resource Implementation Rule, including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, and water quality (Table 1). Given this information, the levels are as protective of all relevant environmental values as they can be.

In addition, the environmental value, maintenance of freshwater storage and supply is also expected to be protected by the minimum levels based on inclusion of conditions in water use permits that stipulate permitted withdrawals will not lead to violation of adopted minimum flows and levels.

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

Comparison of the Revised and Previously Adopted Levels

The revised High Guidance Level is 1.6 ft. higher than the previously adopted High Guidance Level, while the Low Guidance Level is 0.6 ft. higher than the previously adopted Low Guidance Level (Table 6). These differences are due to the higher control point being used in the current assessment, as well as the 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 Lake Merrywater is 1.6 ft. higher than the previously adopted High Minimum Lake Level. The revised Minimum Lake Level is 1.2 ft. higher than the previously adopted Minimum Lake Level (Table 6). These differences are due to the same factors listed for the increases in the guidance levels.

Table 6. Revised Minimum and Guidance Levels for Lake Merrywater compared to previously adopted Minimum and Guidance Levels.

Minimum and Guidance Levels	Revised Elevation (in Feet NGVD29)	Previously Adopted Elevation (in Feet NGVD29)
High Guidance Level	57.4	55.8
High Minimum Lake Level	57.4	55.8
Minimum Lake Level	56.0	54.8
Low Guidance Level	54.3	53.7

Minimum Levels Status Assessment

To assess if the revised Minimum and High Minimum Lake Levels are being met, observed stage data in Lake Merrywater were used to create a long-term record using a Line of Organic Correlation (LOC) model, similar to what was developed for establishing the Minimum Levels (Appendix A). For the status assessment, the lake stage data used to create the LOC must be from a period representing a time when groundwater withdrawals and structural alterations are reasonably stable, and represent current conditions, referred to as the "Current" period. Current stage data observed on Lake Merrywater were determined to be from 2005 through 2015. Using the Current stage data, the LOC model was created. The LOC model resulted in a 69-year long-term water level record (1946-2015).

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

The lake lies within the region of the District covered by an existing recovery strategy, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution (Rule 40D80-073, F.A.C.). The District plans to continue regular monitoring of water levels in Lake Merrywater 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

October 11, 2016

TO: Donna Campbell, 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: Lake Merrywater Water Budget Model, Rainfall Correlation Model, and Historic Percentile Estimations

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A. Introduction

Water budget and rainfall correlation models were developed to assist the Southwest Florida Water Management District (District) in the reassessment of minimum levels for Lake Merrywater in northwest Hillsborough County. Lake Merrywater currently has adopted minimum levels which are scheduled to be re-assessed in FY 2016. This document will discuss the development of the Lake Merrywater models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Lake Merrywater is located in northwest Hillsborough County, approximately 0.8 miles east of Dale Mabry Highway and immediately south of Van Dyke Road in Lutz (Figure 1). The lake lies within the Brushy Creek watershed. Brushy Creek is a tributary to Rocky Creek. Surface-water inflow from Reinheimer Lake to the north (Figure 2) occurs during high flow periods, although the topography is very flat, and flows are often negligible. Discharge from Lake Merrywater occurs via a culvert and ditch system to the beginning of the Interceptor Canal. The Interceptor Canal was constructed in 1960 as a flood control system, diverting floodwater from the upper Sweetwater Creek watershed into the Rocky/Brushy Creek watershed (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

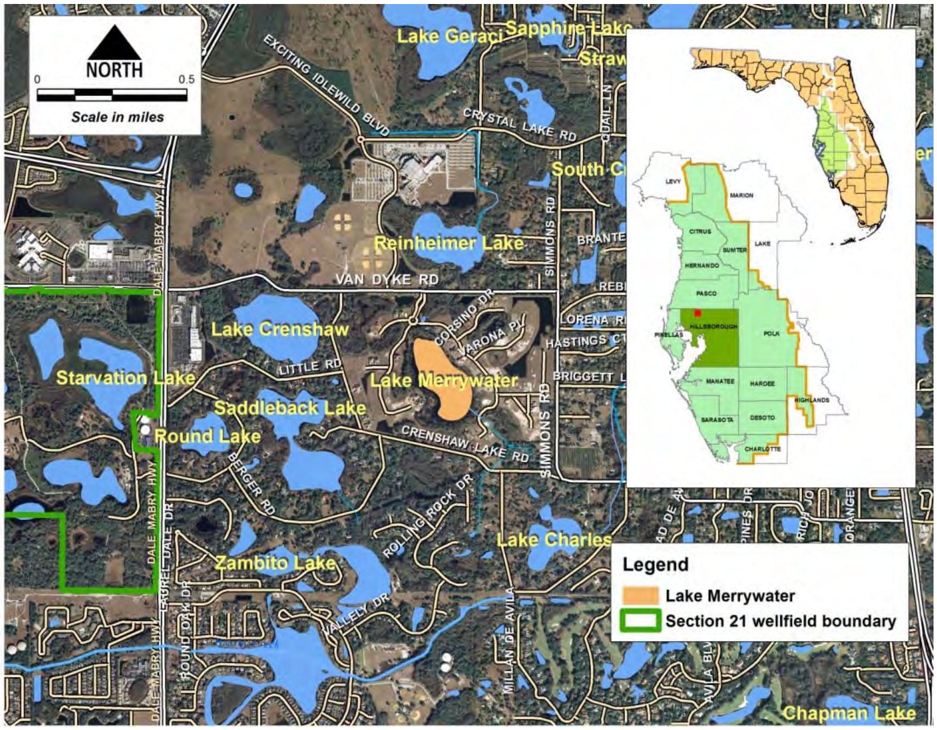

Figure 1. Location of Lake Merrywater in Hillsborough County, Florida.

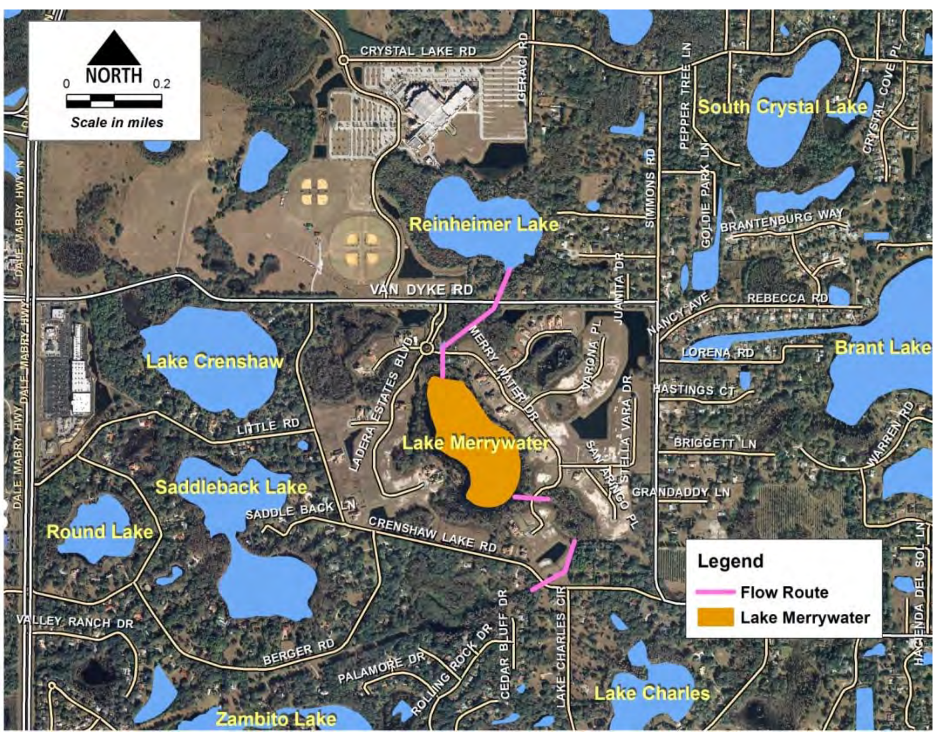

Figure 2. Flow between Reinheimer Lake and Lake Merrywater through wetland to Interceptor Canal.

very flat, and drainage in to the lake is a combination of overland flow and flow through drainage swales and minor flow systems.

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

Data

Water level data collection by the District at Lake Merrywater began in early 1987, with a couple of data points earlier (in 1977 and 1985, Figure 3). Data collection frequency occurred weekly in the early part of the record, and has been monthly since approximately 1991.

Water levels from the Berger Deep Floridan aquifer and Berger Shallow surficial aquifer monitor wells are available beginning in May 1965 and June 1973, respectively (Figures 4 and 5). The wells are located approximately 3,000 feet to the southwest of Lake Merrywater. The data for the Upper Floridan aquifer well are available as weekly at the beginning of the period of record, and become daily in 1974. The available data for the surficial aquifer well are mostly as monthly data. Data from the Van Dyke Shallow near Lutz surficial aquifer monitor well are available since October 1964. This well is located approximately 2,000 feet to the northwest of Lake Merrywater (Figure 4). Weekly data are available from this well at the beginning of the period of record, and become daily in 1974 (Figure 6).

Land and Water Use

Lake Merrywater is located less than a mile due east of the Section 21 Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 7). Groundwater withdrawals began at the Section 21 Wellfield in 1963, with monthly withdrawals steadily climbing to nearly 15 million gallons per day (mgd) in 1964 and to over 20 mgd on annual average in 1967 (Figure 8). With the development of the South Pasco Wellfield in 1973, withdrawal rates at the Section 21 Wellfield were reduced to

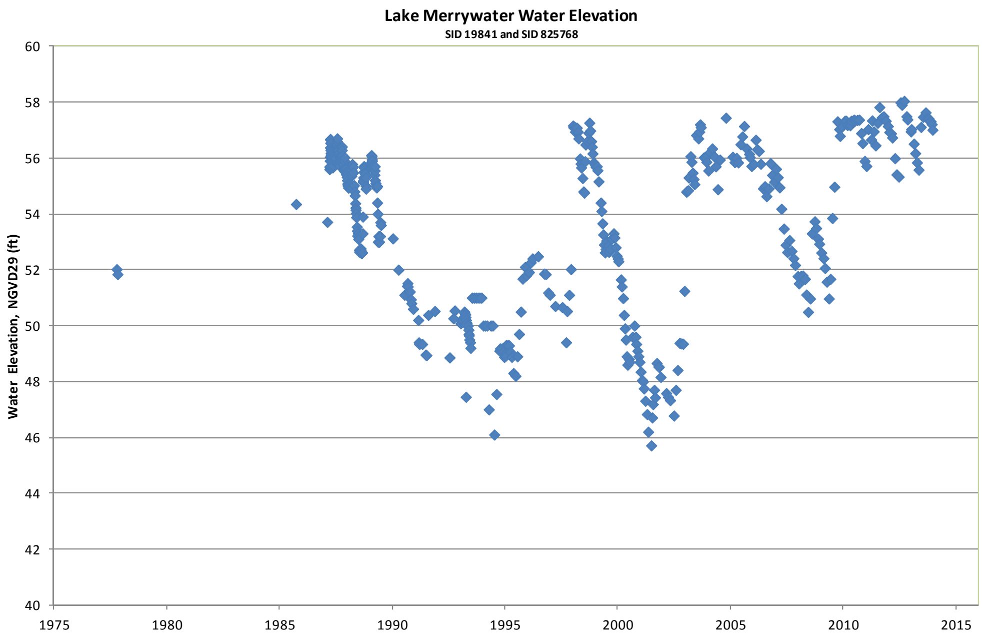

Figure 3. Lake Merrywater water levels.

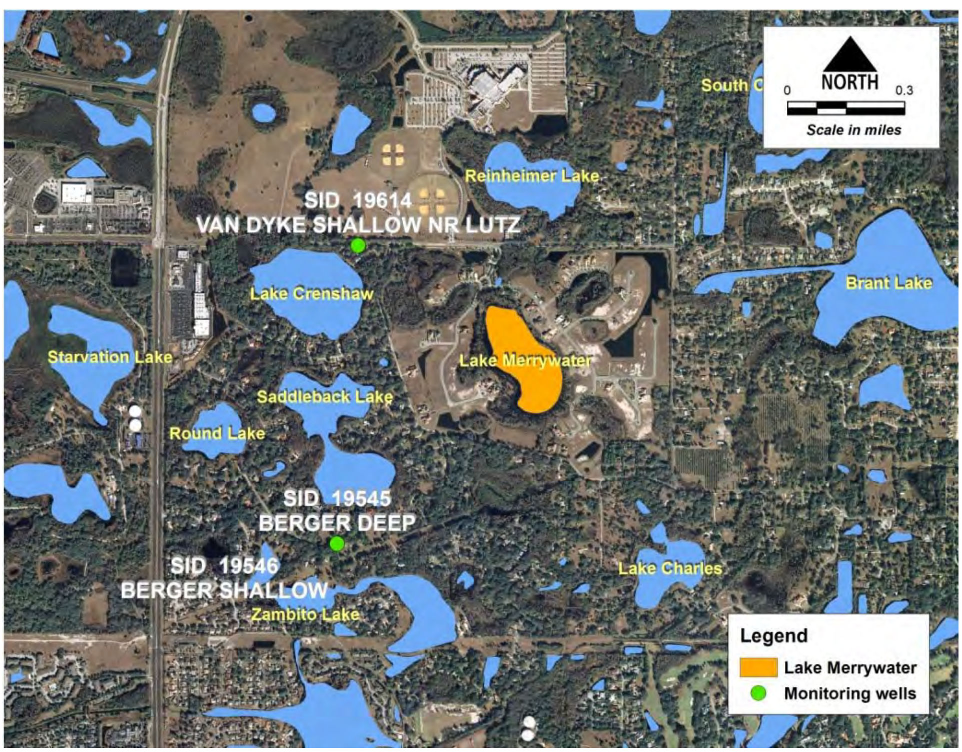

Figure 4. Location of monitor wells near Lake Merrywater.

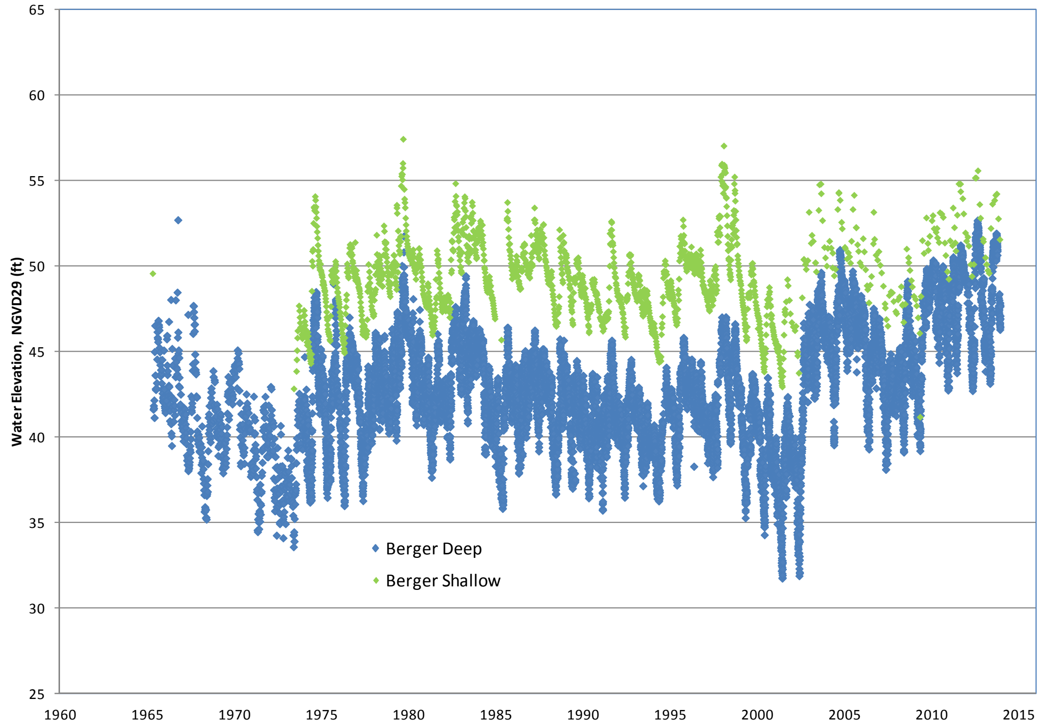

Figure 5. Water levels in the Berger Surficial and Floridan aquifer monitor wells.

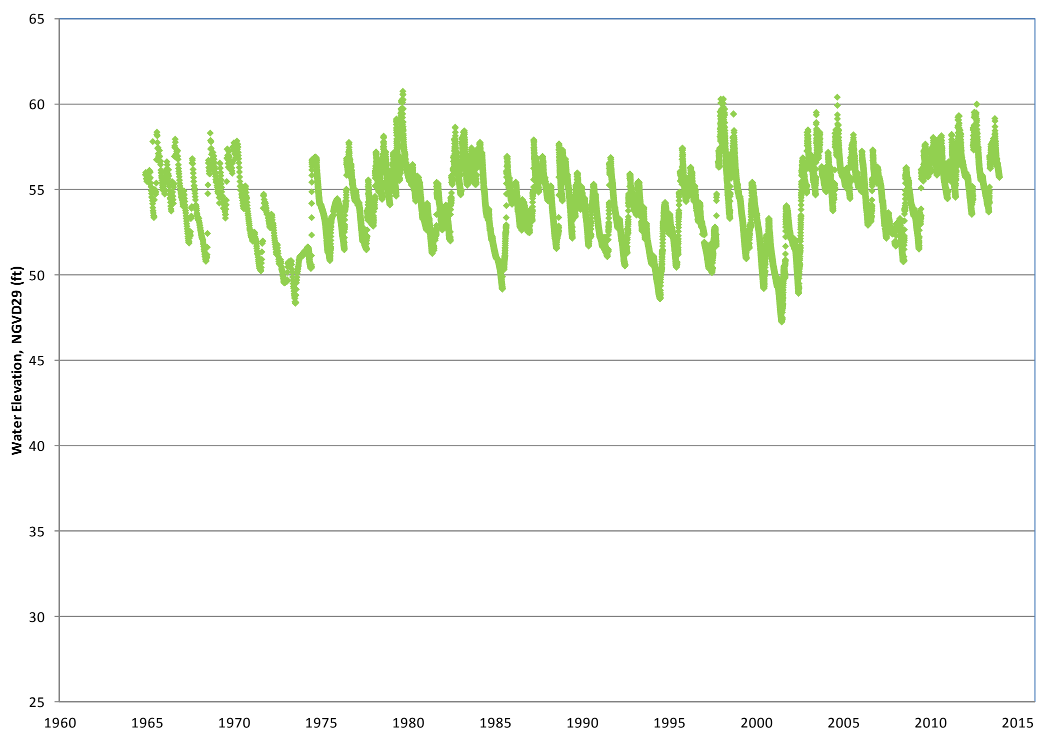

Figure 6. Water levels in the Van Dyke Shallow surficial aquifer monitor well.

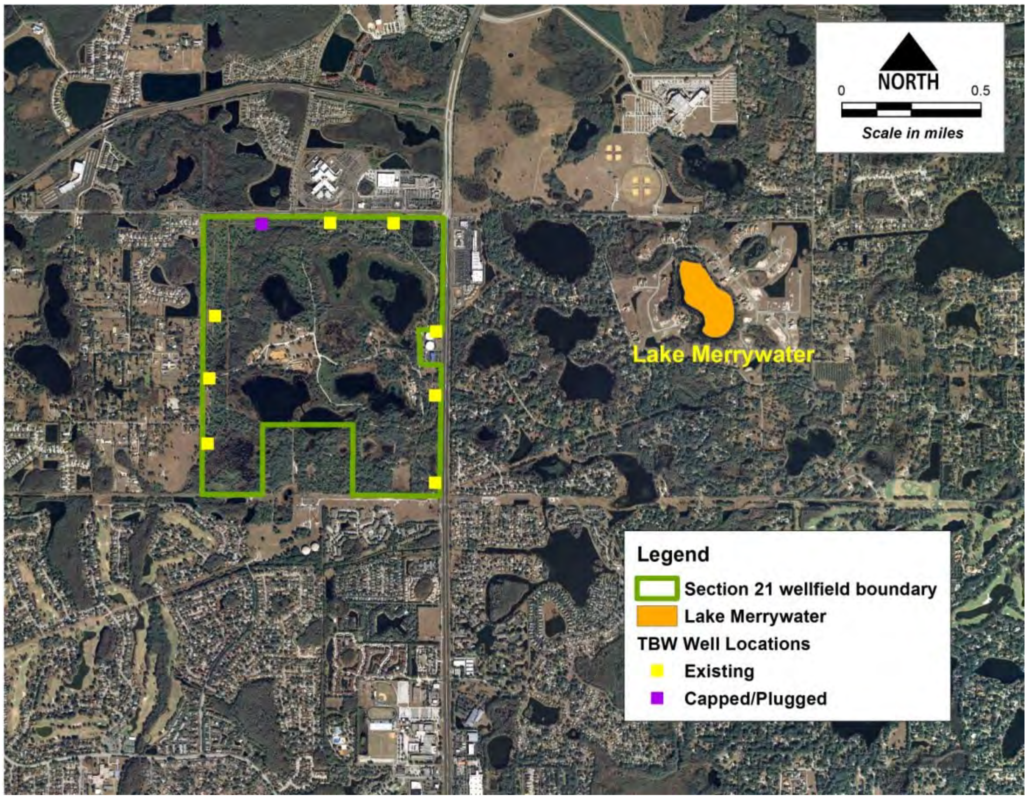

Figure 7. Lake Merrywater and the Section 21 Wellfield.

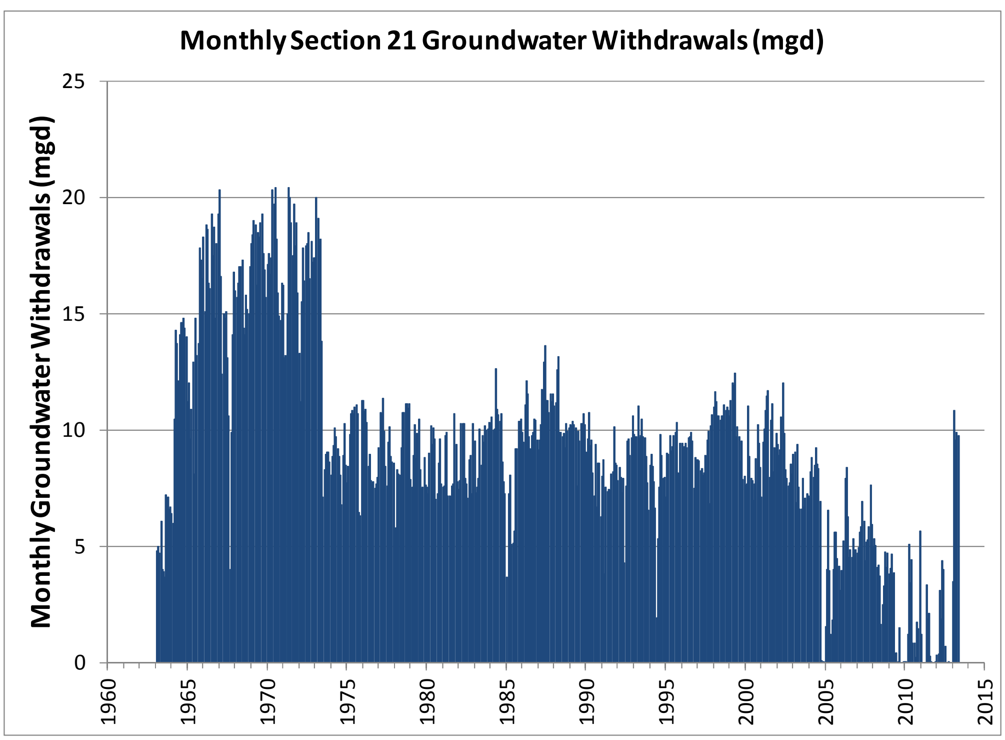

Figure 8. Section 21 Wellfield withdrawals.

approximately 10 mgd on annual average. Withdrawal rates since 2005 have averaged a little over 3 mgd on annual average, with several extended periods with no groundwater withdrawals.

Water levels in many lakes in the Section 21 wellfield area dropped significantly since public supply groundwater withdrawals began (Hancock and Basso, 1996). Because Lake Merrywater water level data collection did not begin until well after the beginning of withdrawals from the wellfield (Figures 9 and 10), the correlation between ground-water withdrawals and lake level cannot be easily made from the comparison of data. Lake recovery during the period of recent reductions in groundwater withdrawals can be seen in Figure 10. A review of aerial photography (Figure 9) shows that signs of lowered lake level after the commencement of groundwater withdrawals at the Section 21wellfield are not obvious in the 1968 photograph, but signs of exposed lake bottom are clear in the photo taken in the 1970s (exact date unknown). Sinclair (1982) discusses the observed formation of dozens of sinkholes following the initiation of groundwater withdrawals at the Section 21 Wellfield. Withdrawals at the Section 21 Wellfield began in 1963. Sinkholes were documented as far as several miles away (including several in the Lake Merrywater area and beyond), and they continued to appear around the wellfield years later. It is possible that a change in leakance properties between Lake Merrywater and the Upper Floridan aquifer (possibly due to karst activity beneath or surrounding the lakes) has occurred that has not reversed since that time.

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

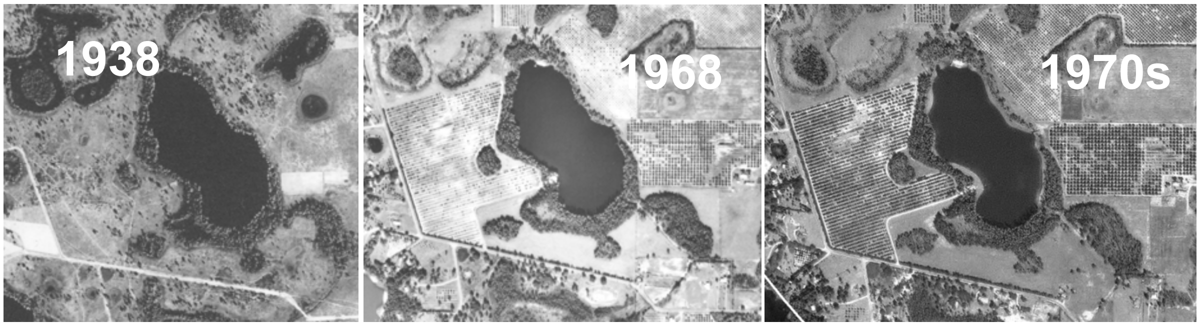

Figure 9. Water level changes in Lake Merrywater.

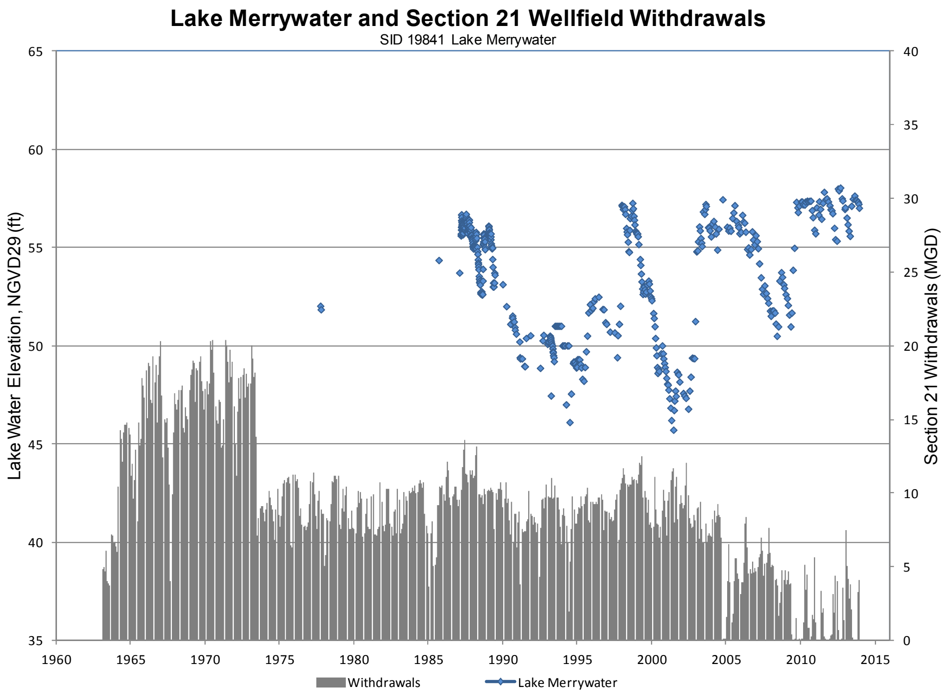

Figure 10. Water levels in Lake Merrywater and Groundwater Withdrawals at the Section 21 wellfield.

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 measured 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 Lake Merrywater, the Section 21 Wellfield has potentially affected lake water levels in the lake since early 1963. Other groundwater withdrawals (including other wellfields) in the area could also have affected levels, but the effect of such withdrawals would be smaller and less consistent. No data from Lake Merrywater exists prior to the commencement of groundwater withdrawals from the Section 21 Wellfield. Therefore, 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 Lake Merrywater 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 Lake Merrywater water budget model include:

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

The water budget model uses a daily time-step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels for the lake. The water budget model for Lake Merrywater is calibrated from 1988 to 2011. This period provides the best balance of using available data for all parts of the water budget and the desire to develop a long-term water level record.

E. Water Budget Model Components

Lake Stage/Volume

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

In the case of Lake Merrywater, the lake is known to divide into two basins at very low lake levels. Therefore, the lake stage area is divided into two basins below 48.5 feet, and only the stage area of the southern pool is used in the model (the location of the staff gage until very recently).

Precipitation

After a review of several rain gages in the area, a composite of several stations was used for the Lake Merrywater water budget model (Figure 11). The goal was to use the closest available data to the lake, as long as the data appeared to be high quality. The Crenshaw Lake rainfall gage (SID 20005), located about 1,800 feet to the northwest of the lake, has measurements starting at the beginning of the model period (January 1, 1988) through May 30, 2005. The Whalen gage (SID 19492), located approximately 3,800 feet to the southeast of the lake, also has data available through 2005 (when the gage was terminated). The St. Pete Jackson 26A gage (SID 19550), located approximately 1.5 miles to the west of the lake, has data available through current, but was not ultimately used for this analysis. All of these rainfall stations are maintained by the District. Also available is NEXRAD (Next Generation Weather Radar) derived rainfall data for the lake from 1995 to current. NEXRAD is a network of 160 high-resolution Doppler weather radars controlled by the NWS, Air Force Weather Agency, and Federal Aviation Administration.

After assessment of all available rainfall data, there was a concern with quality of the later years of the Crenshaw Lake gage when compared to the other gages. The decision was made to use the Crenshaw Lake data for the model from 1988 to 1994, and the average of two NEXRAD pixels that overlay the lake from 1995 to 2015. The Whalen gage was used to infill missing data at the Crenshaw Lake gage.

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 Lake Merrywater water budget model when available, and monthly averages for the period of record were used for those months when Lake Starr evaporation data were not available.

A recent study compared monthly energy budget evaporation data collected from both Lake Starr and Calm Lake (Swancar, 2011, personal communications). Calm Lake is located approximately 5.5 miles to the northwest of Lake Merrywater (Figure 12). The assessment concluded that the evaporation rates between the two lakes were essentially the same, with small differences attributed to measurement error and monthly differences in latent heat associated with differences in lake depth.

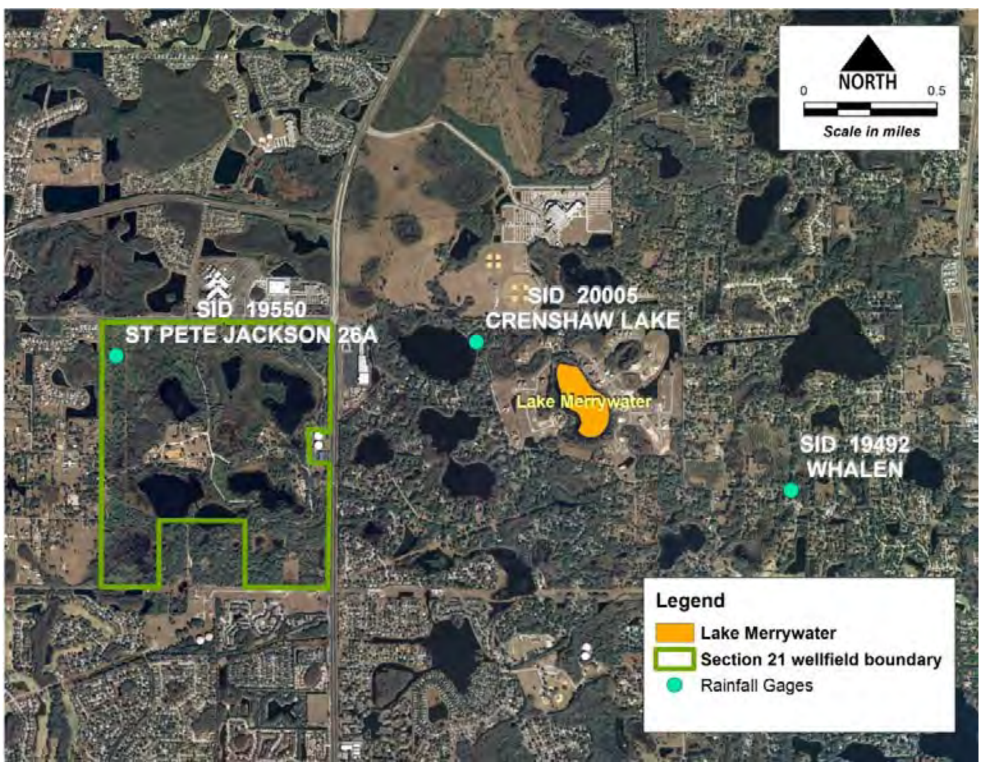

Figure 11. Rain gages considered in the Lake Merrywater water budget model.

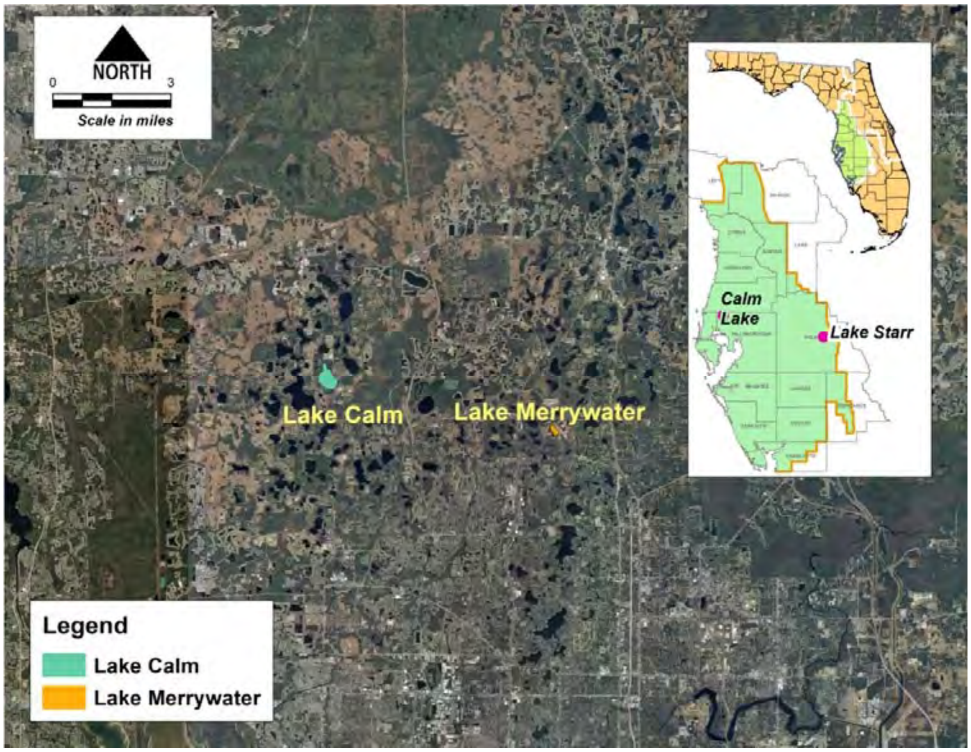

Figure 12. Location of Lakes Merrywater, Calm and Starr (see map inset).

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

<u>Overland Flow</u>

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

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

The topography in the area of Lake Merrywater 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 Rocky Creek watershed for flood assessment purposes (Parsons, 2010). The watershed acreage developed by Parsons was adopted for the Lake Merrywater model (Table 1) after an independent check confirming that it was reasonable for modeling purposes.

Lake Merrywater has an immediate watershed from which it receives overland flow, and a contributing watershed to the north from which it can receive channel flow from Reinheimer Lake (Figures 2 and 13). The entire area of the contributing watershed includes much of the northern section of the Rocky/Brushy Creek watershed, while the area of direct overland flow watershed is approximately 101.6 acres (including the lake).

Because Lake Merrywater has an overland flow basin and contributing basins, it can be modeled as one large basin using the modified SCS method, or by modeling the overland flow portion of the contributing basin using the modified SCS method, and modeling the contributing basin using lake stage at Reinheimer Lake and a control elevation. Both approaches were evaluated, but the latter was chosen since it was felt that modeling the lake using both channel and overland flow was more realistic, and would allow the model to be used to evaluate effects of variations in structure alterations to assist with potential recovery project assessments.

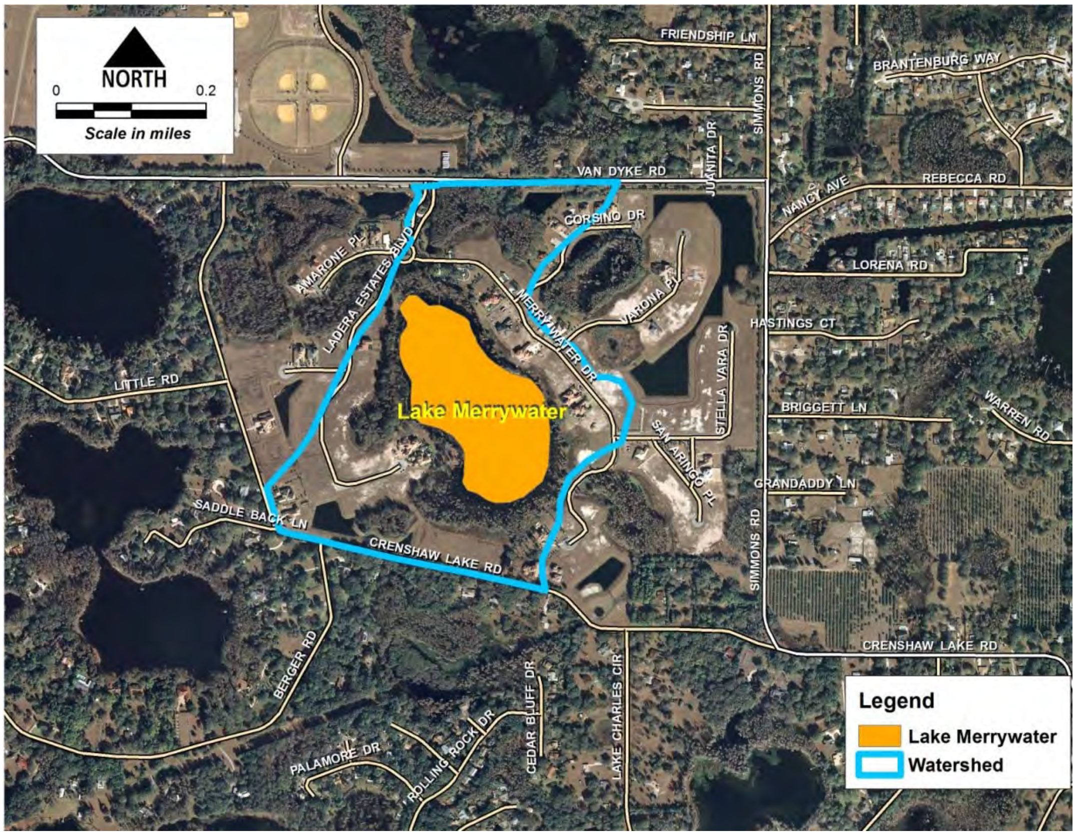

Figure 13. Direct overland flow portion of the Lake Merrywater watershed.

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

For purposes of this model, taking into account the range of conditions experienced, a compromise was used for the CN. No direct discharges from impervious areas to the lake were identified, so the DCIA of the watershed is zero.

Table 1. Model Inputs for the Lake Merrywater water budget model.

Input Variable	Value
Overland Flow Watershed Size (acres)	101.6
SCS CN of watershed	79
Percent Directly Connected	0
FL Monitor Well Used	Berger Deep Floridan
Surf. Aq. Monitor Well(s) Used	Van Dyke Shallow
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.002
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.001
Outflow K	0.3
Outflow Invert (ft NGVD29)	57.2 ft NGVD
Inflow K	0.1
Inflow Invert (ft NGVD29)	58.8 ft NGVD

Inflow and Discharge Via Channels from Outside Watersheds

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

To estimate flow out of Lake Merrywater, 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. To estimate flow into the lake, the same approach was applied. Monthly lake stage data from Reinheimer Lake (infilled to daily) was included in the model, and the elevation of Reinheimer Lake each day was compared to the controlling elevation of a weir in the ditch system from Reinheimer Lake which discharges to Lake Merrywater. If the Lake Reinheimer elevation is above the controlling elevation, the difference is multiplied by the current area of Lake Merrywater and an outflow coefficient. The resulting volume is then added to the current estimate of volume in Lake Merrywater.

Discharge from Lake Reinheimer flows through a vegetated ditch and wetland system, under Van Dyke Road, and eventually into Lake Merrywater (Figure 2). A weir in a small pond within the ditch system (built recently as part of surface water management system for a new development built around Lake Merrywater) was determined to be the controlling elevation for the inflow to Lake Merrywater (weir crest at 58.8 feet NGVD).

Discharge from the lake occurs through a culvert, pond, ditch, and weir system on the southeast shore of Lake Merrywater (Figure 2). Some of this system was rebuilt as part of the new development. Discharge flows under a subdivision road via four large culverts (38 by 60 inch RCP), through a natural forest wetland, and then to a ditch system. A weir structure in the wetland's discharge ditch was determined to be the controlling elevation for Lake Merrywater via professional survey (57.2 feet NGVD).

Flow from and into the surficial aquifer and Upper Floridan aquifer

Water exchange between Lake Merrywater 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 Berger Deep well is the closest Upper Floridan aquifer monitor well to Lake Merrywater, and was used to represent the potentiometric surface at the lake. Because the potentiometric surface is relatively steep toward the Section 21 wellfield (Figure 3), three feet were added to the water level data from the Berger Deep well to compensate for the fact that the well is approximately 3,000 feet closer to the wellfield than is the lake. Three feet was determined by examining potentiometric surface maps of the area, and interpolating between ten foot contour lines. The Van Dyke Shallow surficial aquifer monitor well was used to represent the water table elevation near the lake, since the well is located very close to the lake (Figure 6). The Van Dyke well has daily data available for the entire period of the model, and a simple approach was used to fill in the few missing data by using the last recorded data value until a new value was recorded.

F. Water Budget Model Approach

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

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

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

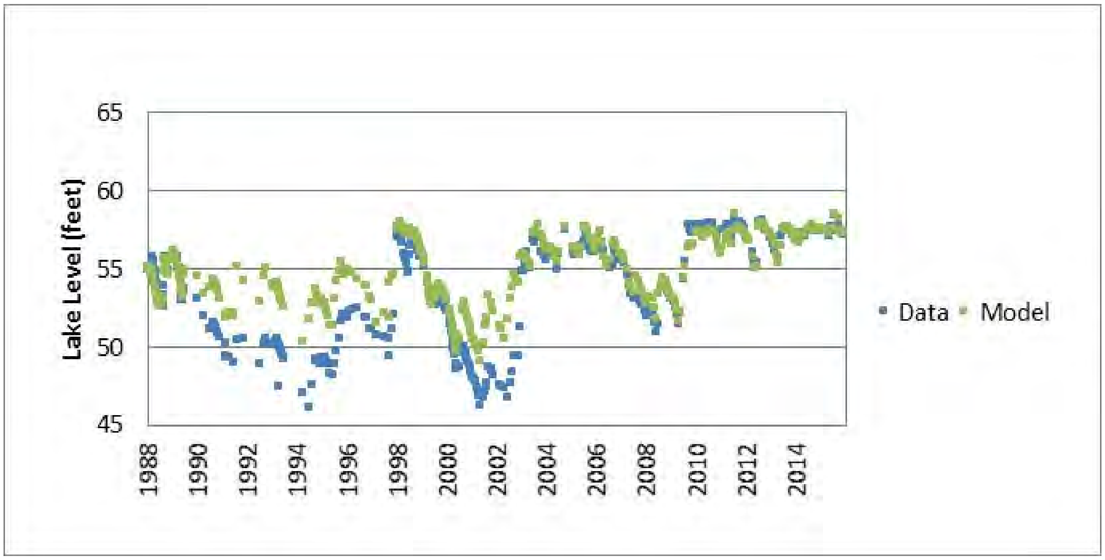

Figure 14. Modeled water levels predicted for the calibrated Lake Merrywater water budget model (Model) and measured levels used for the model calibration (Data).

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

	Data	Model
P10	57.3	57.3
P50	54.8	54.8
P90	49.1	52.1

Table 3. Lake Merrywater Water Budget (1988-2015)

Inflows	Rainfall	Surficial Aquifer Groundwater Inflow	Floridan Aquifer Groundwater Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
Inches/year	53.7	1.8	0.0	45.2	0.0	52.3	153.0
Percentage	35.1	1.1	0.0	29.6	0.0	34.2	100.0
Outflows	**Evaporation**	**Surficial Aquifer Groundwater Outflow**	**Floridan Aquifer Groundwater Outflow**			**Outflow via channel**	**Total**
Inches/year	58.1	5.0	35.5			53.5	152.1
Percentage	38.2	3.2	23.4			35.2	100.0

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 14, the model appear to be reasonably well calibrated, although the results for the beginning of the calibration period are not as successful as the later part of the calibration period. While the model was calibrated primarily for the P50 and P10 (thus both the model and data have the same P50 and P10 within one-tenth of a foot), the model is high at the P90.

A review of Table 2 shows that the differences in the P90 percentiles is 3.0 feet. Attempts at better calibration of the P90 resulted in larger differences between the medians. Some of the differences at the lower percentiles may be due to less detail in the lower stage-volume relationships, or, potentially, a change in effective leakance values at different elevations. The differences between the P90 of the data and the P90 of the model should be taken into account in the minimum level assessment.

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 Lake Merrywater water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from the Section 21 Wellfield are available 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 Lake Merrywater 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 2004, while the post-cutback period is 2005 through 2015. The model results allowed the drawdowns associated with all permitted withdrawals to be calculated before and after wellfield cutbacks, assuming changes in all other withdrawals are consistent for the modeled period.

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

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

To estimate lake levels without the influence of groundwater withdrawals, the Upper Floridan aquifer and surficial aquifer wells in the water budget model were adjusted to represent zero withdrawals. For the 1988 to 2015 water budget model period, two periods of adjustment were used to reflect the cutbacks that took place at the Section 21 wellfield. The adjustments to each Upper Floridan aquifer and surficial aquifer well are found in Table 4.

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

Well	Adjustment (feet) 1988 to 2004	Adjustment (feet) 2005 to 2015
Upper Floridan aquifer	6.2	2.5
Surficial aquifer	2.8	0.9

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.

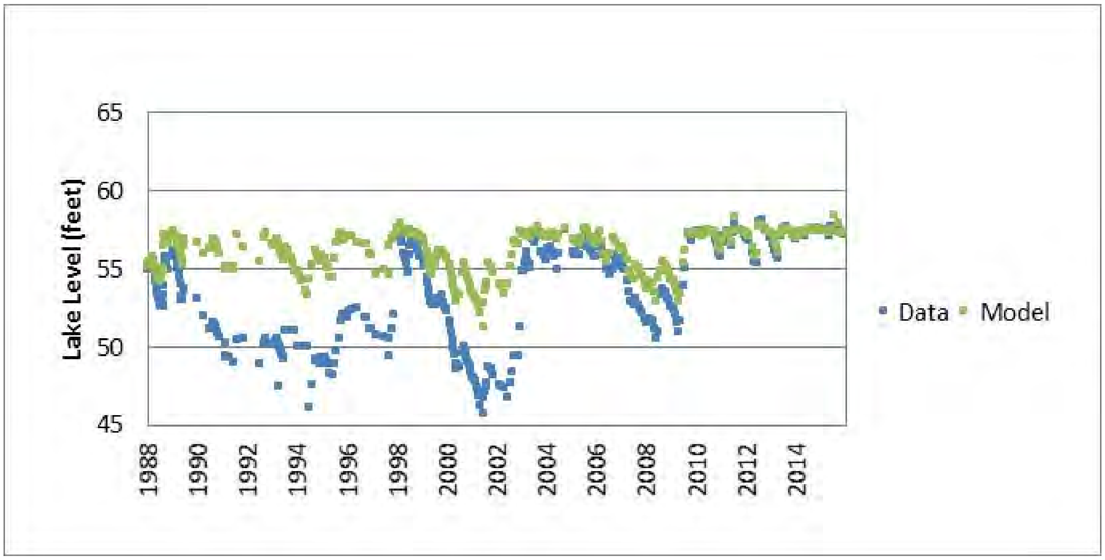

Figure 15. Measured lake levels (Data) and Historic water levels predicted with the calibrated Lake Merrywater model (Model).

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

Percentile	Elevation
P10	57.3
P50	56.5
P90	54.3

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 Lake Merrywater based on inflection points of remaining cypress trees. The Historic normal pool for Lake Merrywater was determined to be 57.8 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 Lake Merrywater is within 0.4 feet of the field determined Historic normal pool. Therefore, in this case, the natural water levels experienced prior to the wellfield establishment may not quite be able to be achieved, likely due structural alterations of the lake's outlet.

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 (1988-2011). NEXRAD rainfall data was used to extend the data through 2015. Data from the Cosme rain gage (located on the Cosme wellfield), which was replaced by the Cosme 18 due to quality control issues, was used to extend the rain data back to 1945. The quality control issues at the gage reported occurred after 1995, and there is no evidence that there were quality control issues at the Cosme gage prior to that time. Finally, rainfall data from the St. Leo gage (Figure 16) were used to extend the data back to 1930. Although the St. Leo gage is approximately 20 miles from Lake Merrywater, 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.

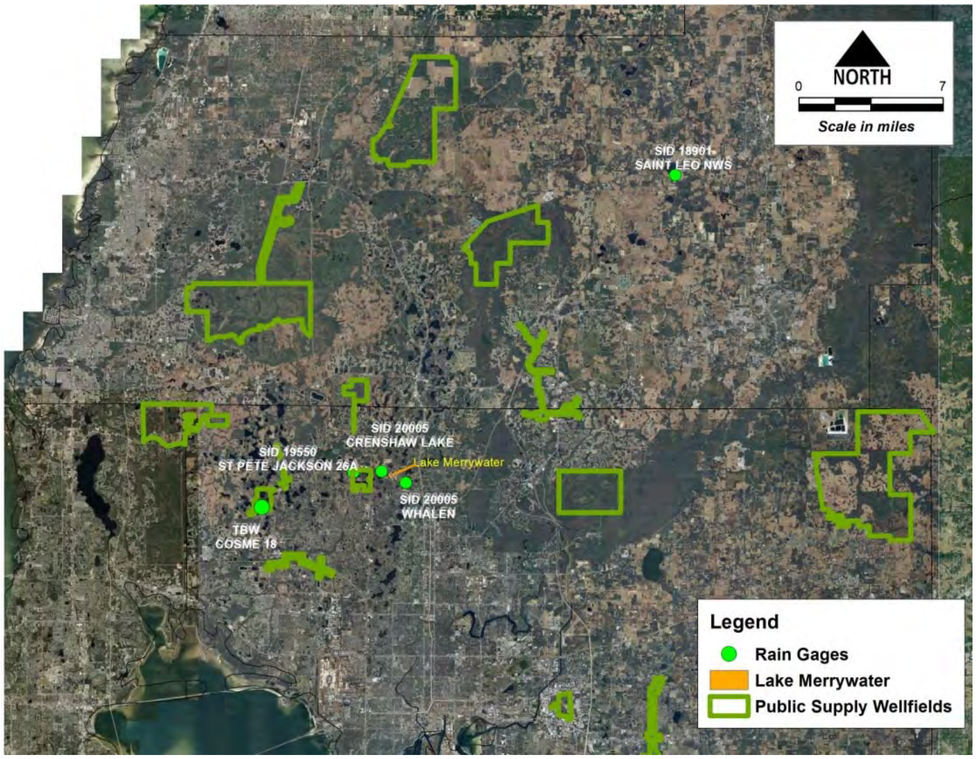

Figure 16. Location of rain stations used for the rainfall correlation model.

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 (1988-2015), and the results from 1946-2015 (69 years) were produced. For Lake Merrywater, the 2-year weighted model had the highest correlation coefficient, with an R^2 of 0.65. Previous correlations for lakes in the northern Tampa Bay area have consistently had best correlation coefficients in the 2 to 5 year range. The results are presented in Figure 17.

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 1988-2015. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Table 8. Note that the difference between the P10, P50, and P90 percentiles from the water budget model (Table 7) and those from the hybrid rainfall model (Table 8) for Lake Merrywater are 0.1, 0.6, and 0.1 feet, respectively.

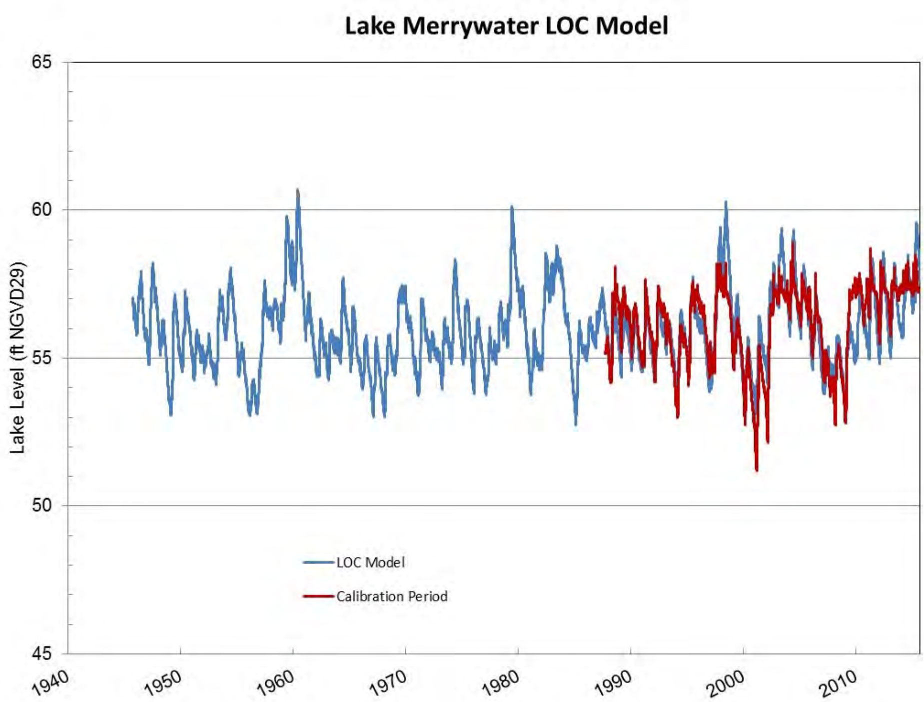

Figure 17. LOC model results for Lake Merrywater.

Table 8. Historic percentiles as estimated by the hybrid model from 1946 to 2015 (feet NGVD29).

Percentile	Lake Merrywater
P10	57.4
P50	56.0
P90	54.3

J. Conclusions

Based on the model results and the available data, the Lake Merrywater 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

October 11, 2016

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

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
Donna Campbell, Environmental Scientist, Water Resources Bureau

Subject: Lake Merrywater Initial Minimum Levels Status Assessment

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A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Lake Merrywater 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 Campbell and others (2016).

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

B. Background

Lake Merrywater is located in northwest Hillsborough County, approximately 0.8 miles east of Dale Mabry Highway and immediately south of Van Dyke Road in Lutz (Figure 1). Lake Merrywater is located less than a mile due east of the Section 21 Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water.

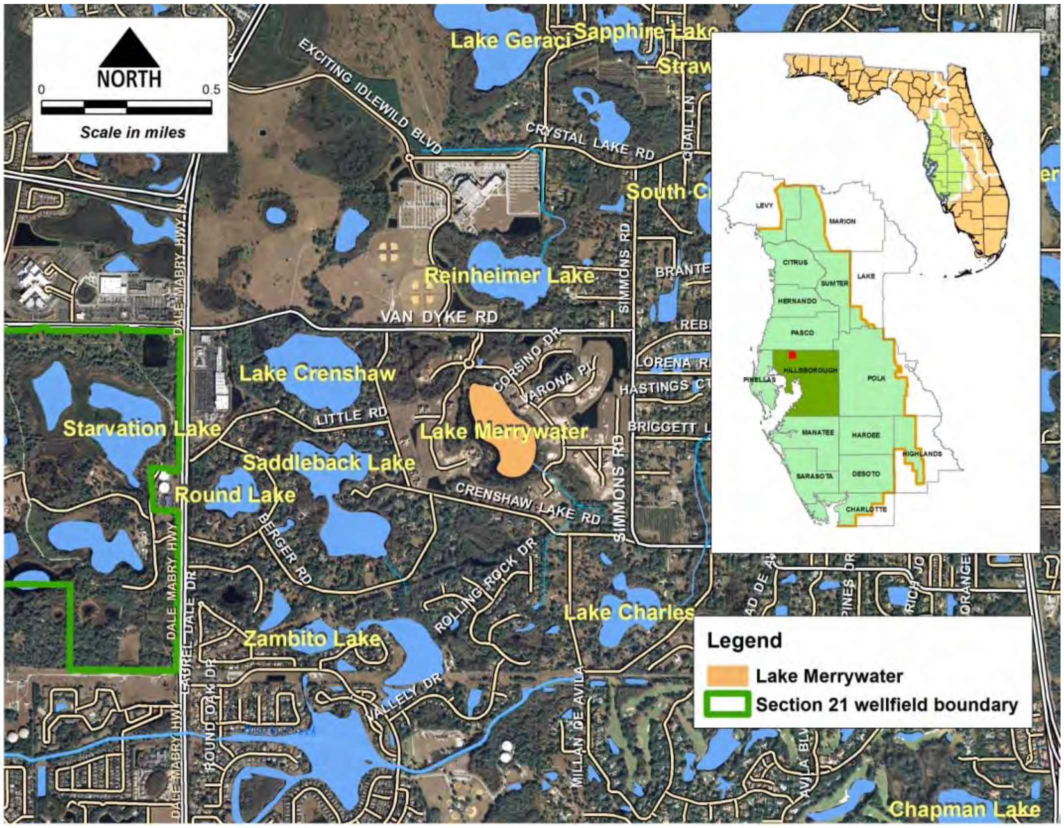

Figure 1. Location of Lake Merrywater in Hillsborough County, Florida.

The lake lies within the Brushy Creek watershed. Brushy Creek is a tributary to Rocky Creek. Surface-water inflow from Reinheimer Lake to the north (Figure 2) occurs during high flow periods, although the topography is very flat, and flows are often negligible. Discharge from Lake Merrywater occurs via a culvert and ditch system to the beginning of the Interceptor Canal. The Interceptor Canal was constructed in 1960 as a flood control system, diverting floodwater from the upper Sweetwater Creek watershed into the Rocky/Brushy Creek watershed (Figure 2).

Lake Merrywater is located less than a mile due east of the Section 21 Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 3). Groundwater withdrawals began at the Section 21 Wellfield in 1963. Monthly average withdrawals steadily climbed to nearly 15 million gallons per day (mgd) in 1964 and to over 20 mgd in 1967 (Figure 4). With the development of the South Pasco Wellfield in 1973, annual average withdrawal rates at the Section 21 Wellfield were reduced to approximately 10 mgd. Monthly withdrawal rates since 2005 have averaged less than 3 mgd, with several extended periods when the wellfield was shut down completely.

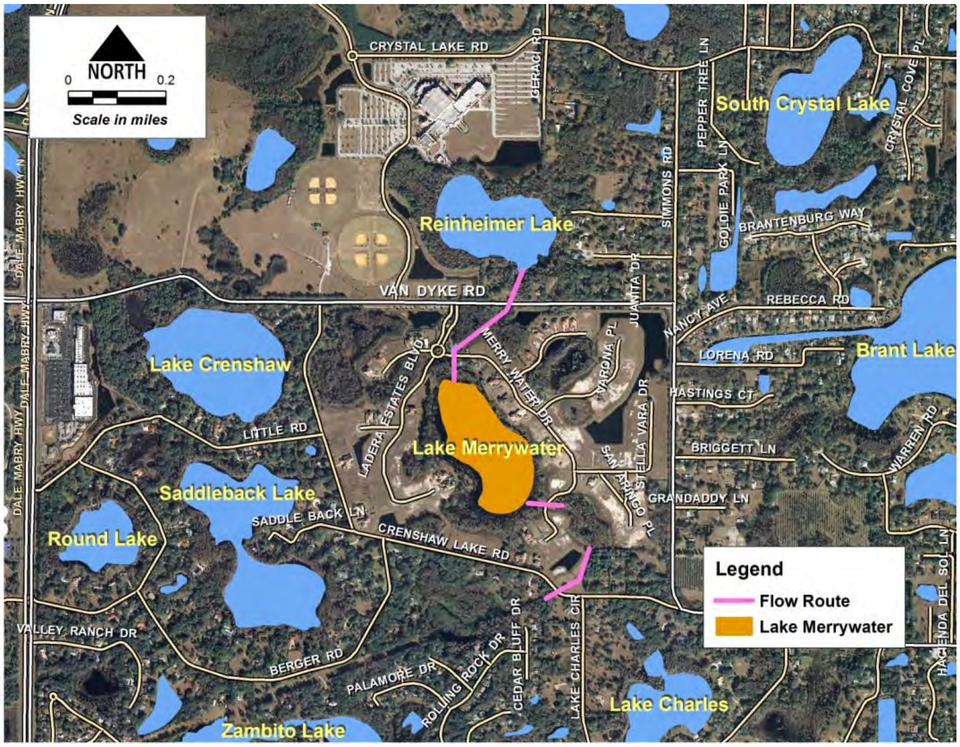

Figure 2. Flow between Reinheimer Lake and Lake Merrywater through wetland to Interceptor Canal.

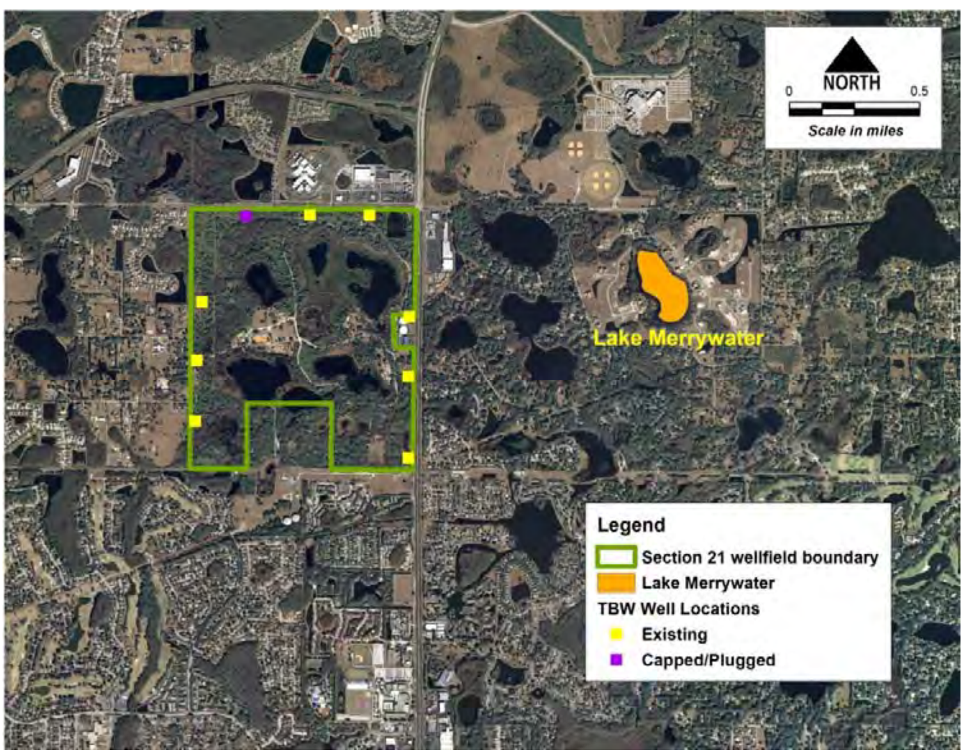

Figure 3. Lake Merrywater and the Section 21 Wellfield.

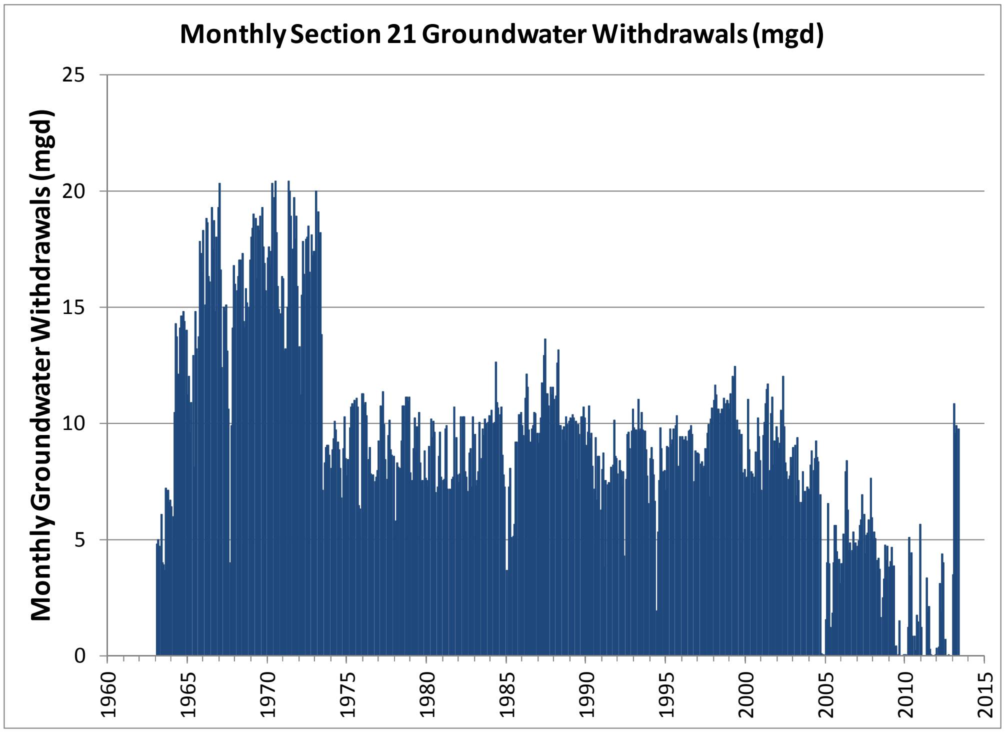

Figure 4. Section 21 Wellfield withdrawals.

C. Revised Minimum Levels Proposed for Lake Merrywater

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

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Lake Merrywater from January 2005 through December 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

Table 1. Proposed Minimum Levels for Lake Merrywater.

Proposed Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	57.4
Minimum Lake Level	56.0

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 regression analysis using the line of organic correlation (LOC) method was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used to develop the minimum levels for Lake Merrywater (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 Lake Merrywater was used for the status assessment (Hancock and McBride, 2016). The best resulting correlation for the LOC model created with measured data (2005-2015) was the 2-year weighted period, with a coefficient of determination of 0.58. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the percentiles calculated directly from the measured lake level data for Lake Merrywater for the period from 2005 through 2015. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 11 years, rather than the longer-term rainfall conditions represented in the 1946 to 2015 LOC model simulation.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 2005 to 2015 data, and the revised minimum levels proposed for Lake Merrywater.

Percentile	**Long Term LOC Model Results 1946 to 2015** Elevation in feet NGVD 29*	**Measured Lake Levels for Current Period (2005 to 2015)** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	58.2	57.5	57.4
P50	55.2	56.8	56.0

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

A comparison of the LOC model with the revised minimum levels proposed for Lake Merrywater indicates that the Long-term P10 is 0.8 feet above the proposed High Minimum Lake Level, and the Long-term P50 is 0.8 feet below the proposed Minimum Lake Level. The P10 elevation derived directly from the 2005 to 2015 measured lake data is 0.1 feet higher than the proposed High Minimum Lake Level, and the P50 elevation is 0.8 feet higher than the proposed Minimum Lake Level. Differences in rainfall between the shorter 2005 to 2015 period and the longer 1946 to 2015 period used for the LOC modeling analyses likely contribute to the differences between derived and measured lake stage exceedance percentiles. Additionally, differences between actual withdrawal rates and those used in the models may have contributed to some of the differences in the percentiles.

E. Conclusions

Based on the information presented in this memorandum, it is concluded that Lake Merrywater water levels are below 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, Lake Merrywater 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 Lake Merrywater will be reassessed by the District and Tampa Bay Water as part of this plan, and as part of Tampa Bay Water's Permit Recovery Assessment Plan (required by Chapter 40D-80, F.A.C. and the Consolidated Permit (No. 20011771.001)). Tampa Bay Water, in cooperation with the District, will assess the specific needs for recovery in Lake Merrywater and other water bodies affected by groundwater withdrawals from the Central System Facilities. By 2020, if not sooner, an alternative recovery project will be proposed if Lake Merrywater is found to not be meeting its adopted minimum levels. The draft results of the Permit Recovery Assessment Plan are due to the District by December 31, 2018.

F. References

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APPENDIX C

Technical Memorandum

August 30, 2016

TO: Donna Campbell, Environmental Scientist, Resource Evaluation Section

FROM: Jason Patterson, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Lake Merrywater

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1.0 Introduction

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

2.0 Hydrogeologic Setting

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

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

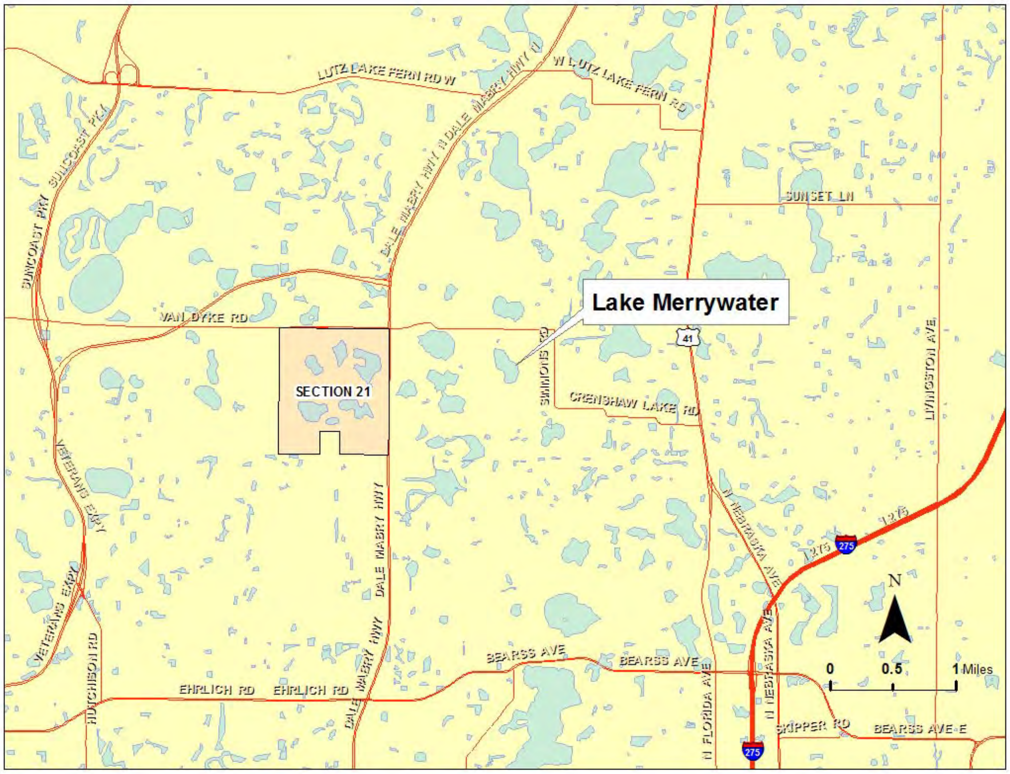

Figure 1. Location of Lake Merrywater.

3.0 Evaluation of Groundwater Withdrawal Impacts to Lake Merrywater

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

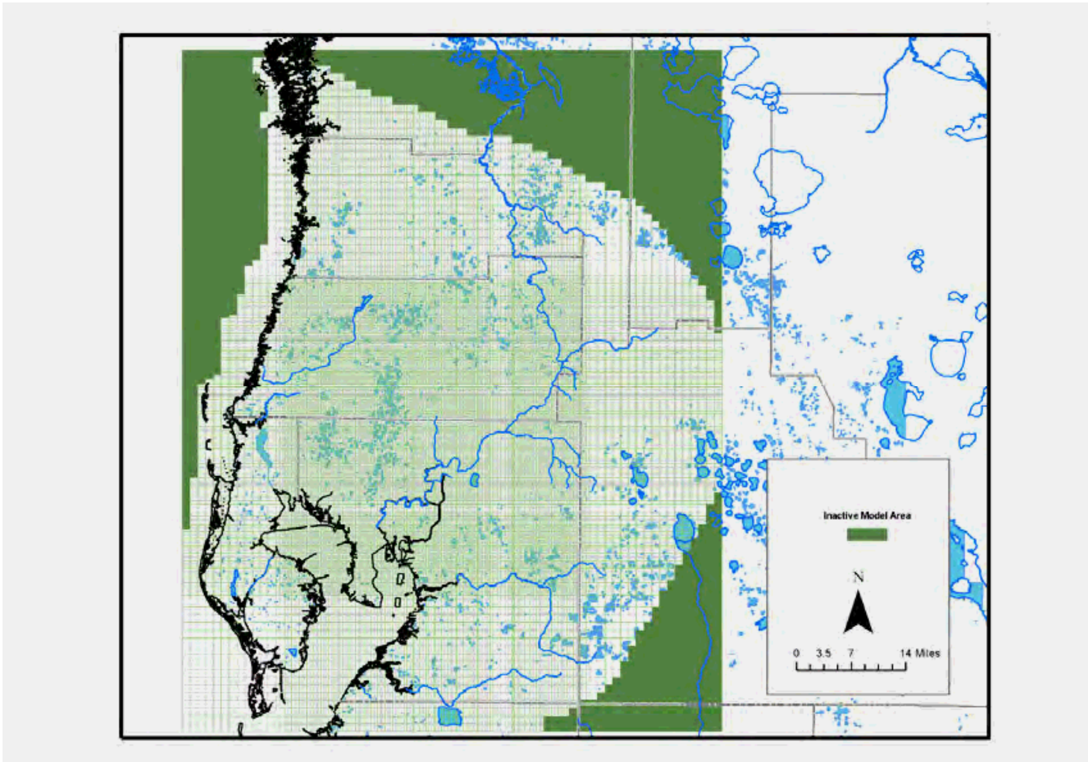

Figure 2. Groundwater grid used in the INTB model

The model code used to run the INTB simulation is called the Integrated Hydrologic Model (IHM) which combines the HSPF surface water code and the MODFLOW ground-water code using interprocessor software. During the INTB development phase, several new enhancements were made to move the code toward a more physically-based simulation. The most important of these enhancements was the partitioning of the surface into seven major land use segments: urban, irrigated land, grass/pasture, forested, open water, wetlands, and mining/other. For each land segment, parameters were applied in the HSPF model consistent with the land cover, depth-to-water table, and slope. Recharge and ET potential were then passed to each underlying MODFLOW grid cell based on an area weighted-average of land segment processes above it. Other new software improvements included a new ET algorithm/hierarchy plus allowing the model code to transiently vary specific yield and vadose zone storages.

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

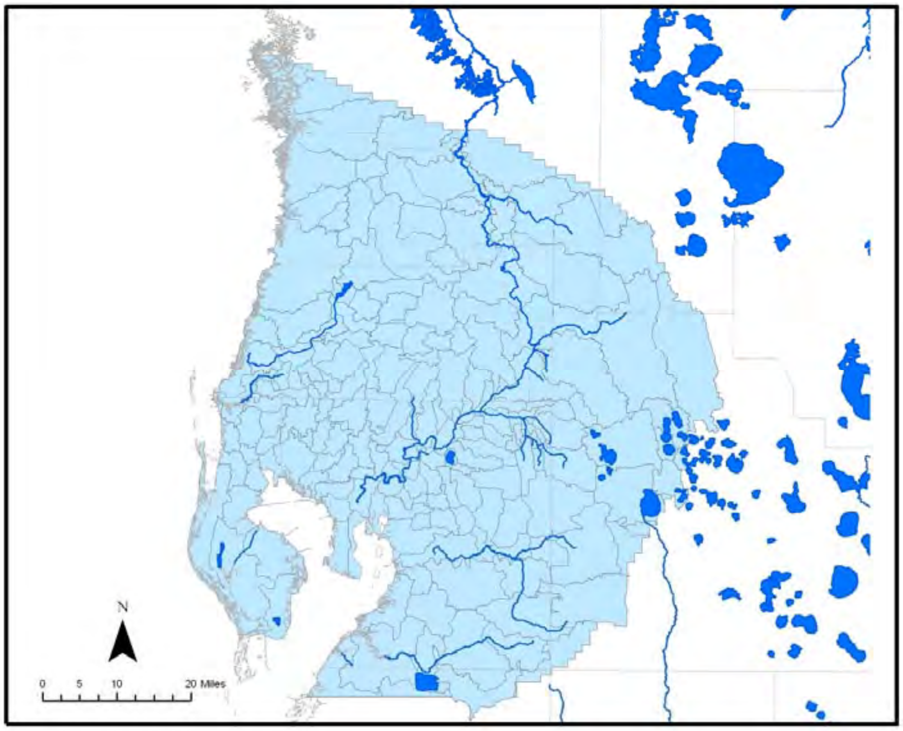

Figure 3. HSPF subbasins in the INTB model.

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

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

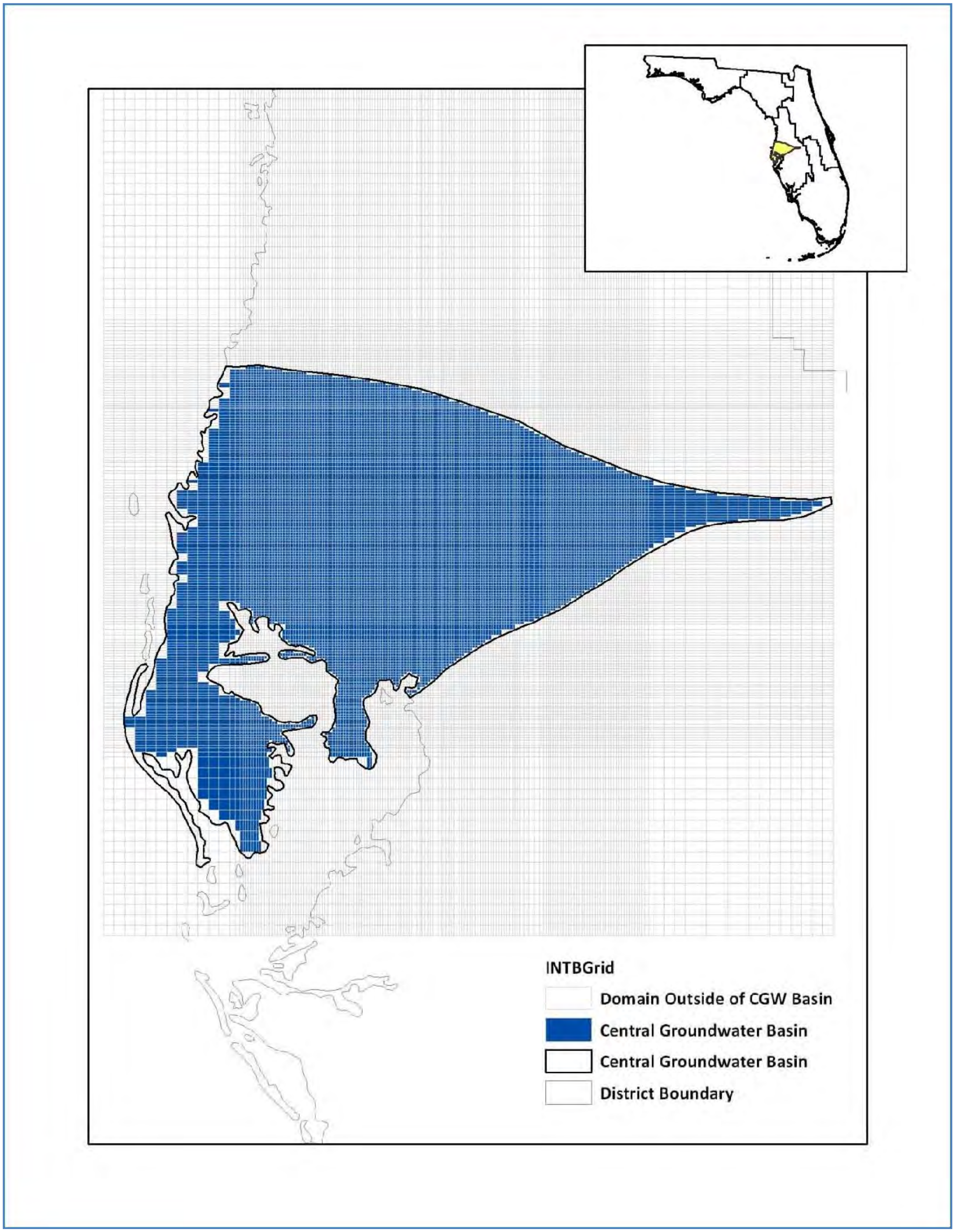

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

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

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Lake Merrywater was 2.5 ft and 6.2 ft in the Upper Floridan aquifer (Figure 5 and 6). Taking the difference in modeled heads from the TBW recovery pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Lake Merrywater was 0.9 ft and 2.8 ft in the Upper Floridan aquifer (Figure 7 and 8). Table 1 presents the predicted drawdown in the surficial aquifer based on the INTB model results.

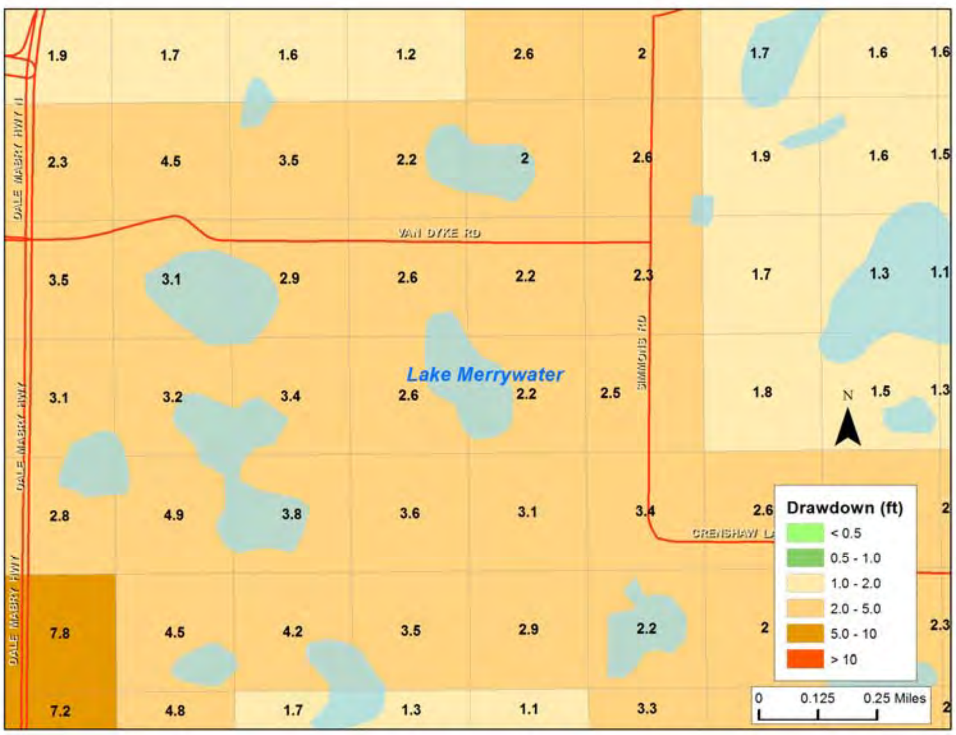

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

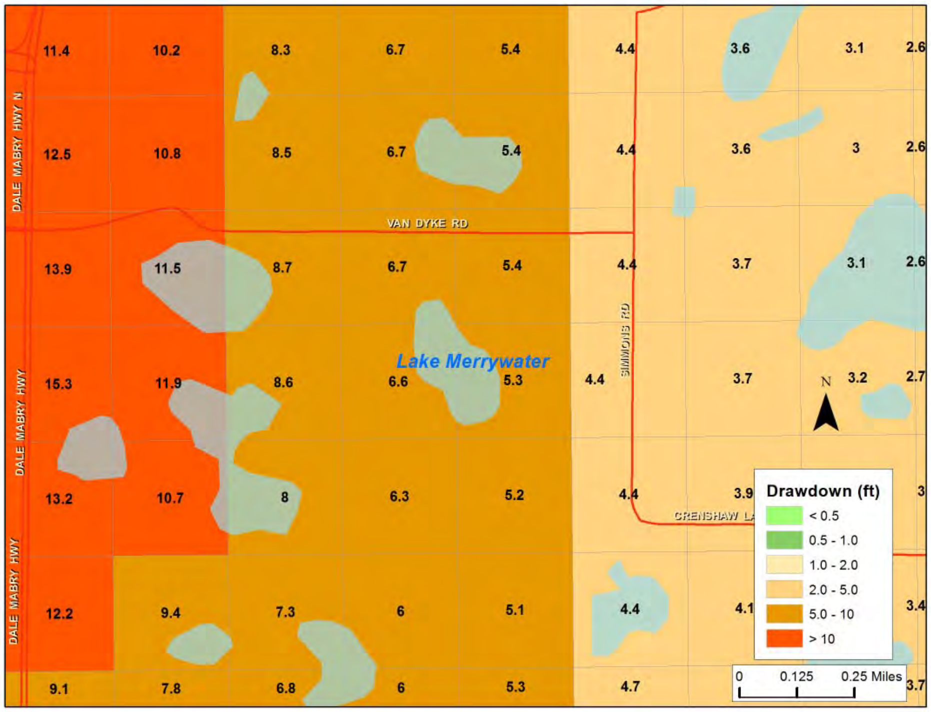

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

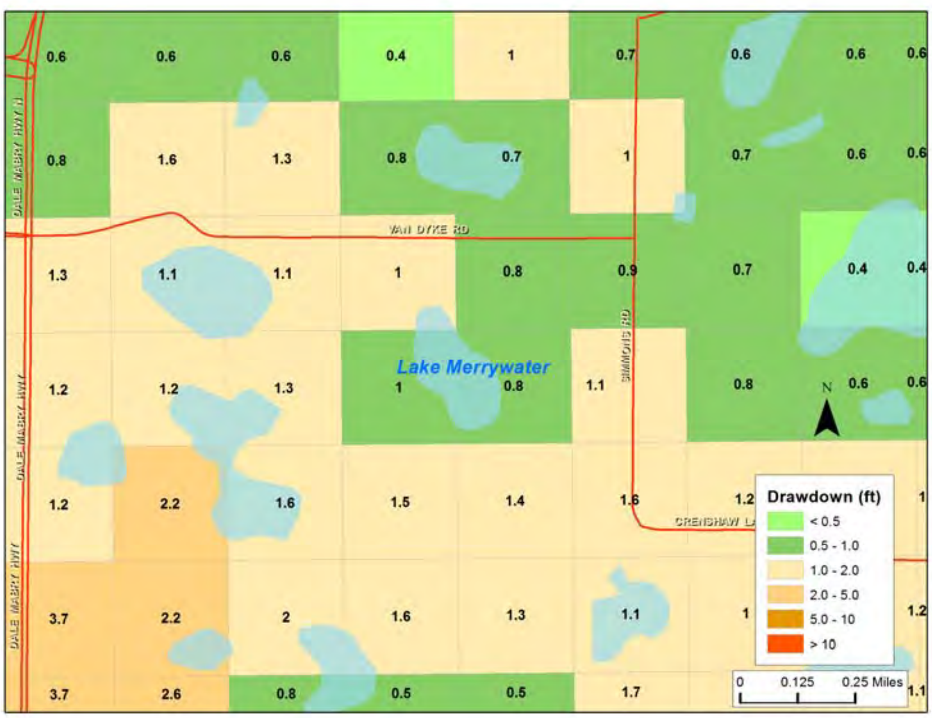

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

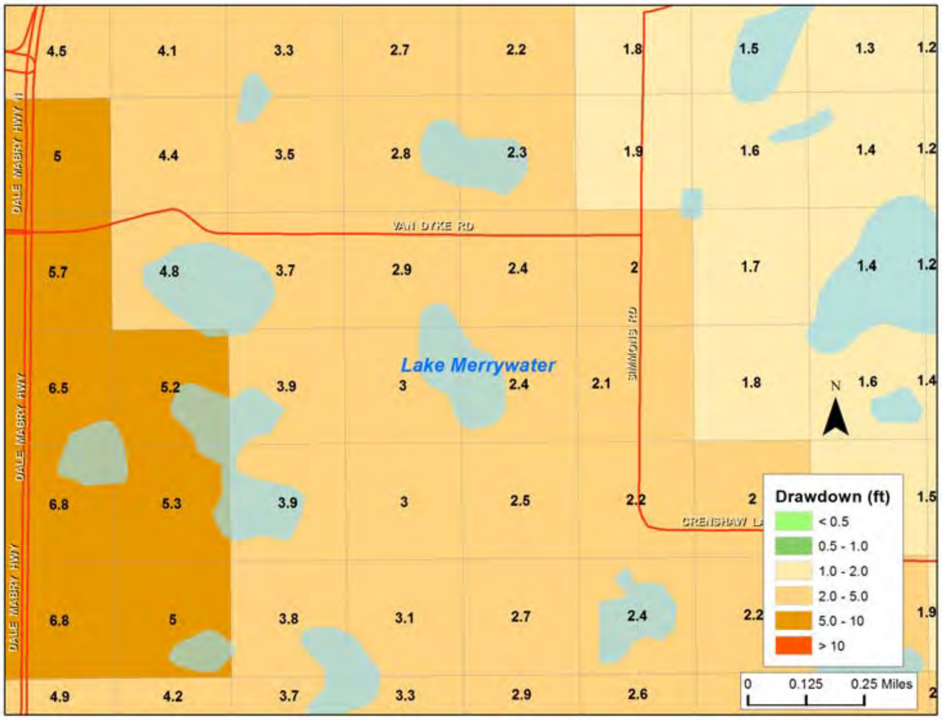

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

Table 1. INTB model results for Lake Merrywater

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*
Merrywater	2.5	0.9
Lake Name	**Predicted Drawdown (ft) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (ft) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd***
Merrywater	6.2	2.8

* Average drawdown from model cells intersecting lake

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