Minimum and Guidance Levels for Lakes Bonable and Tiger in Marion County, Florida

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Resource Evaluation Section
Water Resources Bureau
Southwest Florida
Water Management District

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Cover Page: Comparison between 1957 and 2011 aerial views of Lakes Bonable and Tiger. The 1957 imagery was collected by the United States Department of Agriculture, Soil Conservation Service. The 2011 imagery was collected on January 7th by the District through its Geographical Information Services (GIS) program.

Table of Contents

Page

Title Page 1
Table of Contents 2
Minimum and Guidance Levels for Lakes Bonable and Tiger 3
Data and Analyses Supporting Development of Minimum and Guidance Levels for Lakes Bonable and Tiger 6
- Lake Setting and Description 6
- Currently Adopted Guidance Levels 13
- Summary Data Used for Development of Minimum and Guidance Levels 14
- Lake Stage Data and Exceedance Percentiles 15
- Normal Pool, Control Point Elevation, and Structural Alteration Status 20
- Guidance Levels 20
- Lake Classification 22
- Significant Change Standards and Other Information for Consideration 22

Minimum Levels 28
Compliance Evaluation 29

Documents Cited and Reviewed for Development of Minimum and Guidance Levels for Lakes Bonable and Tiger 37

Minimum and Guidance Levels for Lakes Bonable and Tiger

Section 373.042, Florida Statutes (F.S.) directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels for lakes, wetlands, rivers and aquifers. Section 373.042(1)(a), F.S., states that the minimum flow for a given watercourse "shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area". Section 373.042(1)(b), F.S., defines the minimum level of an aquifer or surface water body as "the level of groundwater in the aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area". Minimum flows and levels are established and used by the Southwest Florida Water Management District (SWFWMD) 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.

Development of minimum flows and levels are key components in supporting resource protection, recovery and regulatory compliance by establishing standards below which significant harm will occur in specific water bodies. Section 373.0421, F.S., requires the development of a recovery or prevention strategy for water bodies if the " existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level." Section 373.0421 (2), F.S., requires that recovery or prevention strategies be developed to: "(a) achieve recovery to the established minimum flow or level as soon as practicable; or (b) prevent the existing flow or level from falling below the established minimum flow or level." Periodic re-evaluation 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 available information with consideration 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 caveat that these considerations shall not allow significant harm caused by withdrawals (Section 373.0421, F.S.). The Florida Water Resources Implementation Rule (Rule 62-40.473, Florida Administrative Code (F.A.C.), provides additional guidance for the establishment of minimum flows and levels, requiring that "consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows, and environmental values associated with coastal, estuarine, aquatic and wetland 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." The Water Resource Implementation Rule also indicates that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond

which further withdrawals would be significantly harmful to the water resources or the ecology of the area".

The Southwest Florida Water Management District has developed specific methodologies for establishing minimum flows or levels for lakes, wetlands, rivers and aquifers, subjected the methodologies to independent, scientific peer-review, and incorporated the methods into Chapter 40D-8, F.A.C. For lakes, methodologies 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 without at least 0.5 acre of fringing cypress wetlands are classified as Category 3 Lakes. Rule 40D-8.624, F.A.C., provides for the establishment of Guidance Levels, 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 provided in Southwest Florida Water Management District (1999a, b), Leeper *et al.* (2001) and Leeper (2006). Peer-review findings regarding the lake level methods are available in Bedient *et al.* (1999), Dierberg and Wagner (2001) and Wagner and Dierberg (2006).

Two Minimum Levels and two Guidance Levels have typically been established for lakes, and upon adoption by the District Governing Board, incorporated into Rule 40D-8.624, F.A.C. The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD), are described below.

- 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 elevation that a lake's water levels are expected to equal or exceed ten 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** 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 **Low Guidance Level** 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.

In accordance with Chapter 40D-8, F.A.C., Minimum and Guidance Levels were developed for Lakes Bonable and Tiger (Table 1), both Category 3 lakes located in Marion County, Florida. The levels were established using best available information, including field data that were obtained specifically for the purpose of minimum levels development. The data and analyses used for development of the levels are described in the remainder of this report. Following a public input process, District staff recommended and the Governing Board approved incorporation of the proposed levels into District Rule, Chapter 40D-8, subsection 40D-8.624, F.A.C., at their October 30, 2012 meeting. Public input included a public workshop held on September 27, 2012 in Dunnellon Florida. Upon approval by the District Governing Board, staff prepared an amendment to subsection 40D-8.624, F.A.C. that establishes Minimum and Guidance levels for Lakes Bonable and Tiger based on current methodologies, replacing the previously adopted management levels established in 1993 (see Table 2). The rule amendment was submitted to the Joint Administrative Procedures Committee and notice was provided to the Governor's Office of Fiscal Accountability and Regulatory Reform (OFARR). The rule amendment and adoption of Minimum and Guidance levels (See Table 1) became effective on February 21, 2013.

All elevation data values shown within this report on graphs, bathymetric maps, and within tables are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD 29). In some circumstances notations are made for data that was collected as North American Vertical Datum of 1988 (NAVD 88) (also as feet) and converted to NGVD 29. All datum conversions were derived using Corpscon 6.0, a computer software program developed by the United States Army Corps of Engineers.

Table 1. Minimum and Guidance Levels for Lakes Bonable and Tiger

Minimum and Guidance Levels	Elevation in Feet
	NGVD 29
High Guidance Level	63.6
High Minimum Lake Level	62.8
Minimum Lake Level	58.3
Low Guidance Level	50.5

Data and Analyses Supporting Development of Minimum and Guidance Levels for Lakes Bonable and Tiger

Lake Setting and Description

Lakes Bonable and Tiger are located northwest of Dunnellon in western Marion County and eastern Levy County (Sections 30, 31, 32 , Township 15 South, Range 18 East; and Section 25, Township 15 South, Range 17 East) (Figure 1). The "Gazetteer of Florida Lakes" (Shafer *et al.* 1986) lists the lake areas of Lake Bonable and Lake Tiger as 211, and 77 acres, respectively.

The lakes are part of the Sand Slough watershed (approximately 32.3 square miles), which drains to Waccasassa River basin overall watershed area. They are located within the Northern Brooksville Ridge lakes region that was identified and mapped as part of the Florida Department of Environmental Protection's Lake Bioassessment /Regionalization Initiative (Griffith *et al.* 1997). Romie (2000) described Lake Bonable as a colored, soft water, meso-eutrophic lake with moderately high concentrations of phosphorus. Lake Tiger was described as a clear to moderately colored, meso-eutrophic lake. The chemical type of water or predominant ionic composition for both lakes was either calcium chloride or sodium sulfate.

The eastern and north surrounding area of the lakes is in the Rainbow Lake Estates, a low density sub-division of Dunnellon. Both lakes are bounded on the western edge by low density residential and agriculture. The lakes discharge into a forested wetland strand located along the southwest shore of Lake Bonable. A constructed berm separates the lake basin from the strand. Flow within the strand continues westward eventually broadening into the expansive cypress wetland strands within the Goethe State Forest (Figure 2). Public access is provided to the lakes through two boat ramps, one on each basin; however, low water has limited use of the boat ramps especially over the past few years.

Lake stage is monitored on both lakes (Figure 3) with the longest period of record available for Lake Tiger. A topographic map of the basin generated in support of minimum levels development indicates Bonable Lake is connected to Lake Tiger by a shallow canal with the lakes becoming connected or forming one basin at water levels greater than 55.2 NGVD. At a high or near full elevation of 63.0 ft NGVD (Figure 4) the two integrated lake basins comprise approximately 284 acres The topographic map (Figure 4) and corresponding depth contour map (Figure 5) show that the lake basins are irregularly shaped with generally flat and gentle sloping bottoms. Only one sinkhole feature is noted on the northwest corner of Lake Tiger. The lakes are shallow with an average depth of 8.6 feet at a lake stage of 63.0 ft (Figure 5).

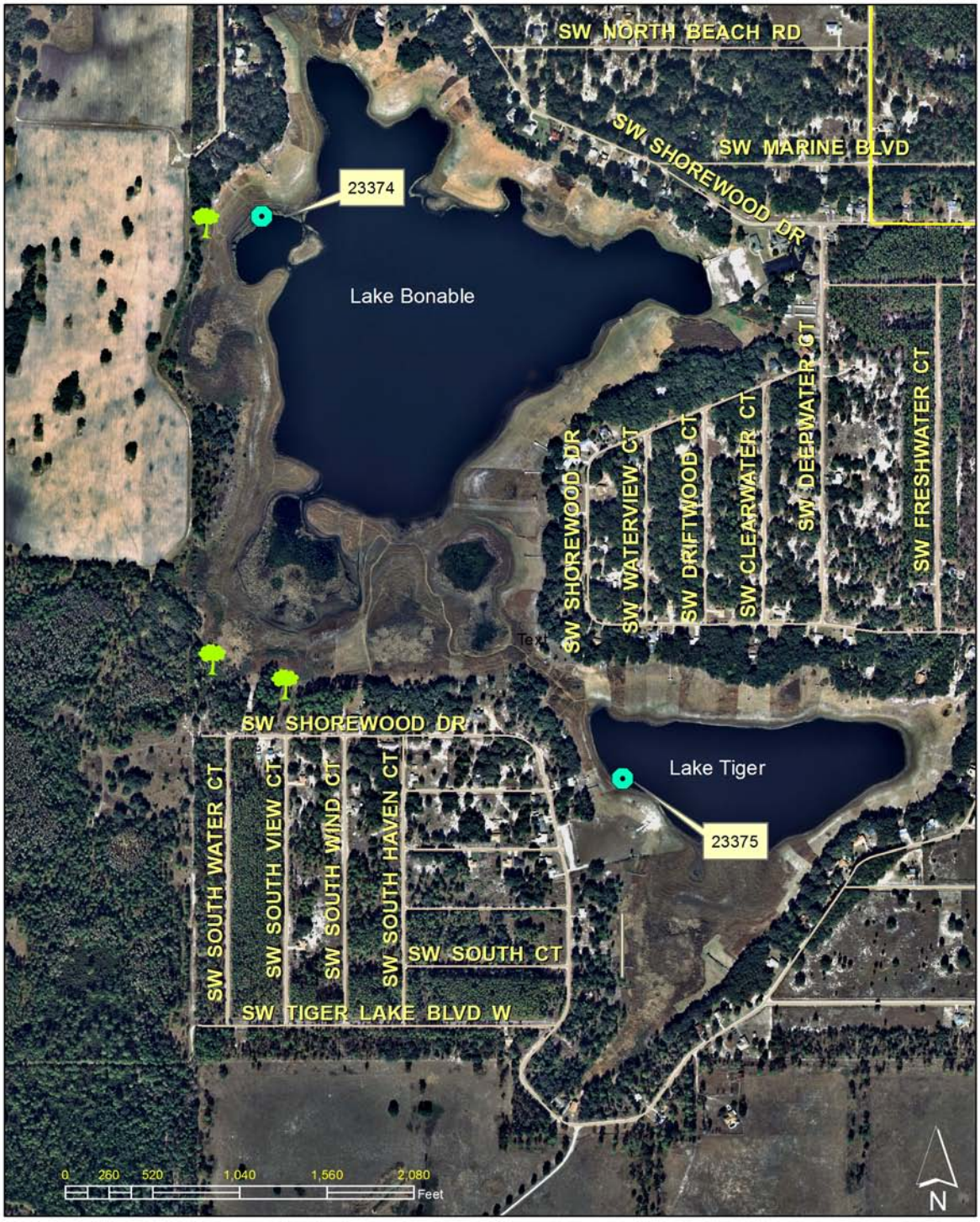
There are no surface water withdrawals from the lake currently permitted by the District. There are no significant withdrawals within the immediate vicinity of the lakes with only five permitted groundwater withdrawals within a two mile radius of the lake (Figure 3).

Within 3 miles of the lake there are nine permitted groundwater withdrawals with 0.15 million gallons per day (mgd) reported as the cumulative average groundwater withdrawn in 2006 (SWFWMD 2011).

Figure 1. General location of Lakes Bonable and Tiger in Marion County, Florida.

Figure 2. Approximate location of berm (top) and ground view of outlet pipe (bottom) located within the berm on Lake Bonable.

Figure 3. Location of vegetative indicators and water level gages at Lakes Bonable and Tiger, WMIS site ID's 23374 and 23375, respectively.



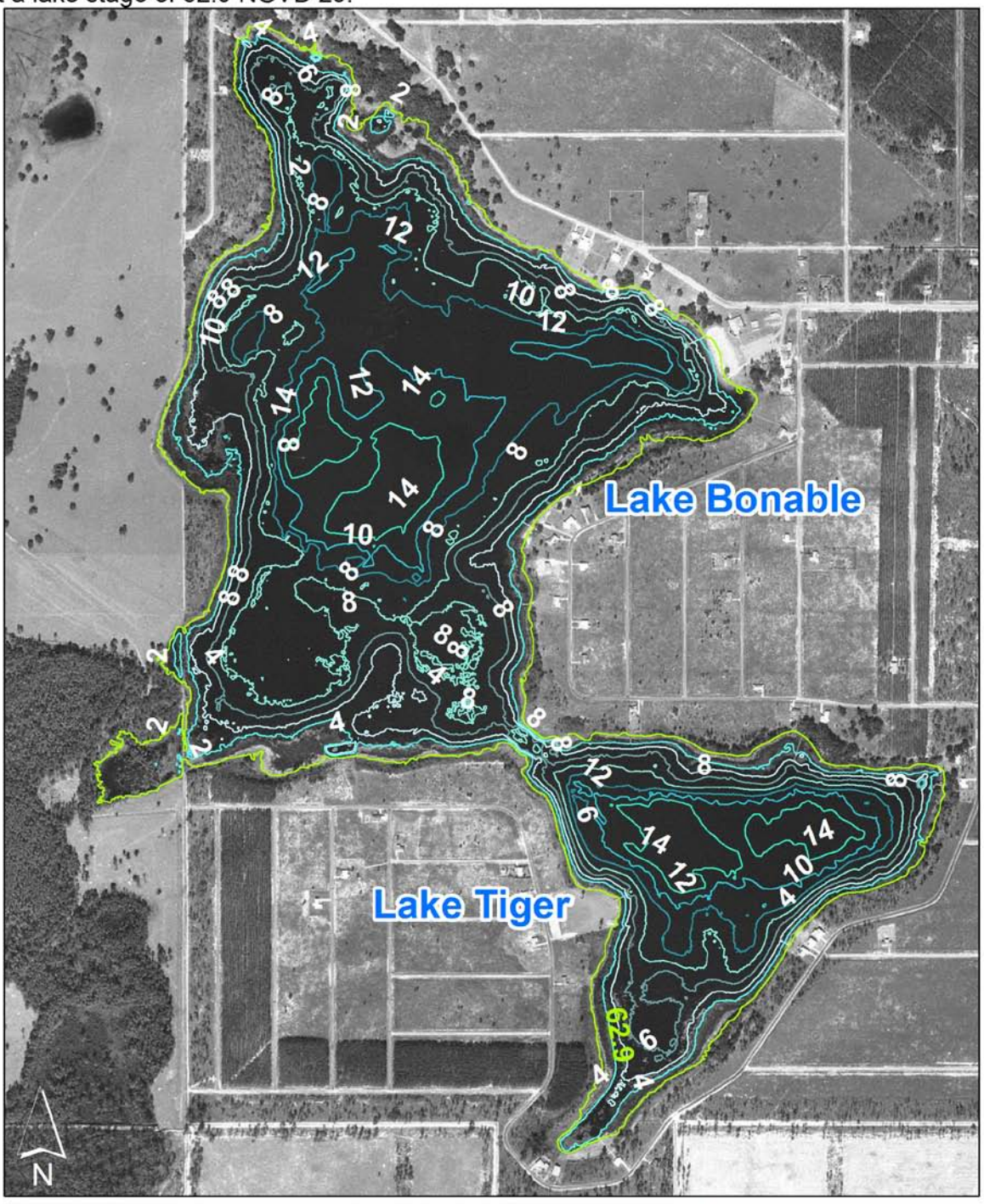
- Approximate location of water level gages. WMIS IDs 23374 (top) and 23375 (bottom)
- Vegetative indicators

Map was prepared using natural color imagery collected on January 7,2011.

Figure 4. Two-foot contour lines within Lakes Bonable and Tiger. Values shown are elevations in feet as NGVD 29.

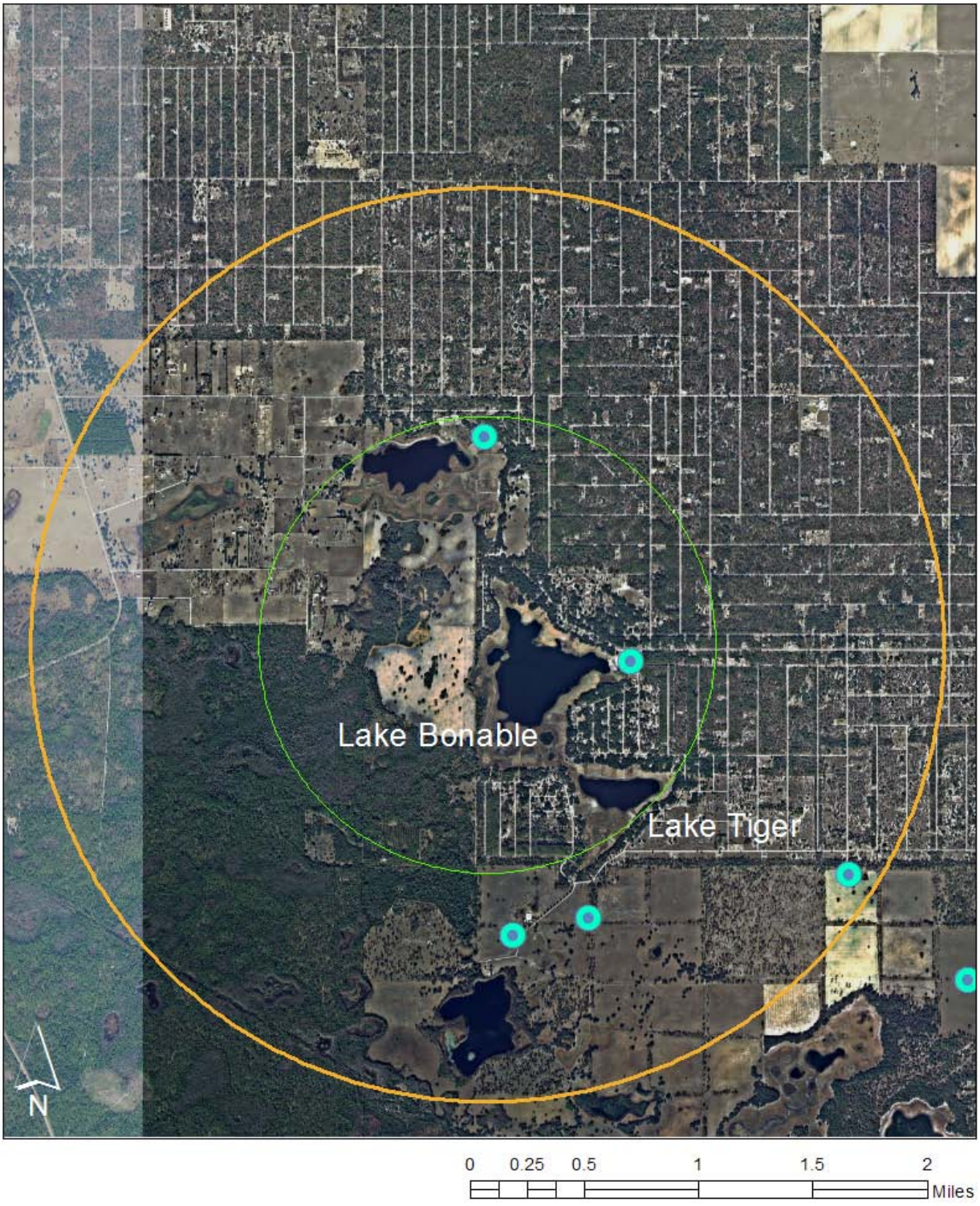
Approximate bottom elevation contours (as ft NGVD 29) within Lakes Bonable and Tiger, Marion County. Contours were prepared using bottom depth data and LiDAR land surface elevation data. Bottom depths were collected by D.C. Johnsons & Associates in June 2006 (File No, 2004-003A02). The background imagery is natural color digital ortho photography collected in January 7, 2011.

Figure 5. Bathymetric map of Lakes Bonable and Tiger showing approximate bottom depths at a lake stage of 62.9 NGVD 29.



General depth (ft) within Lakes Bonable and Tiger, Marion County. Contours were prepared using bottom depth data and LiDAR land surface elevation data. Bottom depths were collected by D.C. Johnsons & Associates in June 2006 (File No. 2004-003A02). The depths shown are based on a high lake stage of 62.9 NGVD. Background imagery was collected in March 1970 by FDOT.

Figure 6. Permitted groundwater withdrawals within a one mile radius and two mile radius of Lakes Bonable and Tiger, Marion County.



Currently Adopted Guidance Levels

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

Based on work conducted in the 1970s (see SWFWMD 1996), the District Governing Board adopted management levels (currently referred to as Guidance Levels) for Lakes Bonable and Tiger in January 1993 (Table 2). A Maximum Desirable Level of 63.50 NGVD was also developed, but was not adopted by the Governing Board. The adopted Guidance Levels and Maximum Desirable Level were developed using a methodology that differs from the current District approach for establishing Minimum and Guidance Levels. The levels do not, therefore, necessarily correspond with levels developed using current methods. Minimum and Guidance Levels developed using current methods will replace existing Guidance Levels upon adoption by the District Governing Board into Chapter 40D-8, F.A.C. One of the management levels, a Ten Year Flood Guidance Level of 65.10 NGVD, was removed from Chapter 40D-8 in 2007, when the District Governing Board determined that flood-stage elevations should not be included in the District's Water Levels and Rates of Flow rules

Annually since 1991, a list of stressed lakes has been developed to support the District's consumptive water use permitting program. Chapter 40D-2, F.A.C., defines a stressed condition for a lake" as "chronic fluctuation below the normal range of lake level fluctuations". For lakes with adopted Guidance Levels, chronic fluctuation below the Low Level is considered a stressed condition. For lakes without adopted levels, evaluation of stressed condition is conducted on a case-by-case basis. Due to prolonged drought conditions in Marion County, Lakes Bonable and Tiger were listed as stressed over the past recent years including 2009, 2010, and 2011 (Gant *et al.* 2009, Gant *et al.* 2010, Gant *et al.* 2011).

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

Guidance Levels	Elevation in Feet
	NGVD 29
Ten Year Flood Guidance Level	65.10
High Level	64.00
Low Level	61.50
Extreme Low Level	59.50

Summary Data Used for Development of Minimum and Guidance Levels

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

Table 3. Minimum and Guidance Levels, lake stage exceedance percentiles, and control point elevations, significant change standards, and associated surface areas for Lakes Bonable and Tiger.

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Period of Record (POR) P10 (1992 to 2012)	60.3	260.4
Period of Record (POR) P50 (1992 to 2012)	57.2	217.5
Period of Record (POR) P90 (1992 to 2012)	50.9	89.3
Historic P10 (1946 to 2012)	63.6	NA
Historic P50 (1946 to 2012)	59.1	244.1
Historic P90 (1946 to 2012)	50.5	83.3
Normal Pool and Control Point		
Normal Pool	63.5	291.0
Control Point	59.1	244.1
Significant Change Standards		
Dock-Use Standard	NA	NA
Basin Connectivity Standard	NA	NA
Recreation/Ski Standard	NA	NA
Wetland Offset Elevation	58.3	233.9
Species Richness Standard	56.7	208.5
Lake Mixing Standard	51.0	90.7
Aesthetics Standard	50.5	83.3
Minimum and Guidance Levels		
High Guidance Level	**63.6**	292.1
High Minimum Lake Level	**62.8**	284.0
Minimum Lake Level	**58.3**	233.9
Low Guidance Level	**50.5**	83.3

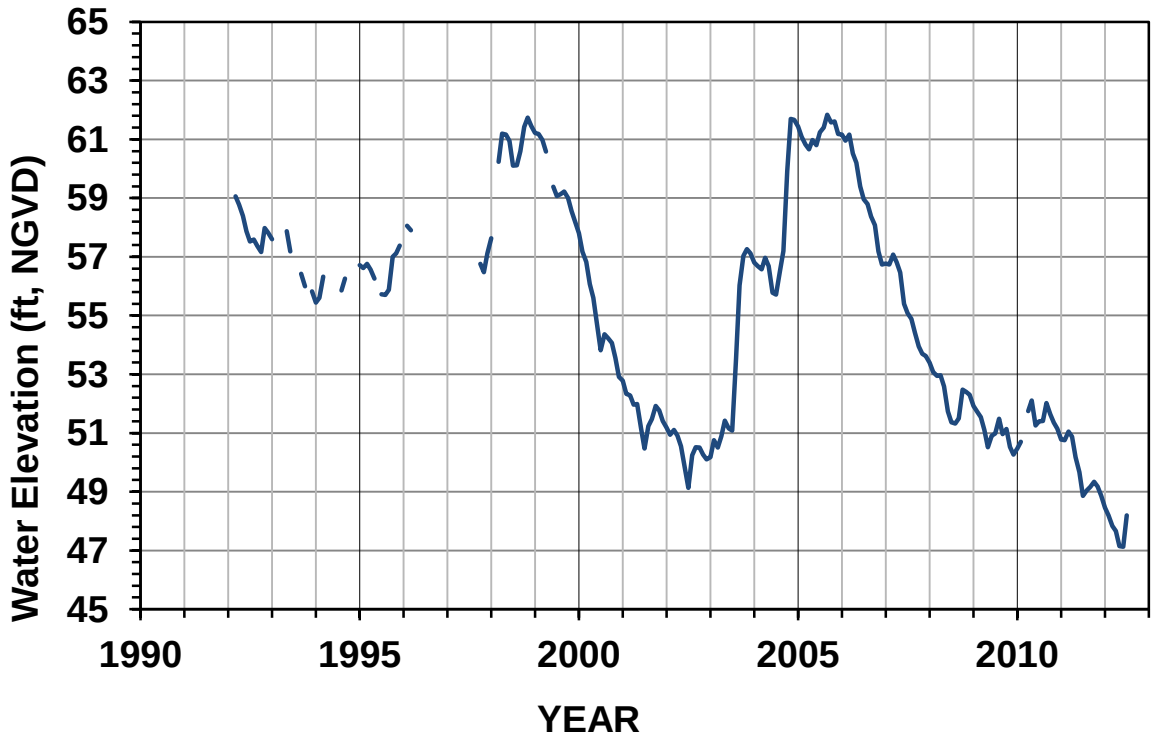
NA = not appropriate;

Lake Stage Data and Exceedance Percentiles

Lake stage data, *i.e.,* surface water elevations for Lakes Bonable and Tiger relative to NGVD 29 were obtained from the District's Water Management Information System (WMIS) data base (Site Identification Number 23374 and 23375 respectively). There is a twenty year period of record for lake stage data on Lake Tiger (WMIS ID 23375) with the period of record (POR) extending from February 1992 through present day (Figure 7, see Figure 3 for the location of the SWFWMD lake water level gage). Lake stage data has been collected on Lake Bonable for a significantly shorter period of time and as a result of the data limitations, the analyses described within this report focus on the stage data from Lake Tiger.

Lake stage data has been recorded for Lake Tiger on a monthly basis and recorded in the District's WMIS data base and graph of the data is shown in Figure 7. The highest surface water elevation for the lake recorded for Lake Tiger was 61.84 NGVD 29 occurring in August 2005 after the 2004 hurricane series that brought heavy rainfall to central Florida. Similar high stages were recorded in October 1998 during the well known "El Niño" event. The lowest surface water elevation of 47.13 NGVD 29 occurred recently during May 29, 2012. A low stage of 49.1 NGVD 29 also occurred during June 2002. Based on the most recent level of 48.8 NGVD recorded on August 24, 2012, the lake stage has increased by 1.7 feet from its POR low as the result of heavy rainfall that occurred during Tropical Storm Debby.

Figure 7. Monthly mean surface water elevations (NGVD 29) through June 2012 for Lake Tiger, SWFWMD WMIS site ID 23375.



For the purpose of Minimum Levels determination, lake stage data are classified 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. Lake stage data are classified as "Current" for periods when there were measurable, stable impacts due to water withdrawals, and impacts due to structural alterations were stable. A hydrologic analysis (SWFWMD 2011, draft report) completed for Lakes Bonable and Tiger indicated that the lake was determined to be have no measureable impacts due to regional groundwater withdrawals. The results of the analysis indicated that lake stage data for the period of record (1992 to 2012) for Lake Tiger could be classified as Historic (Figure 9). As previously stated the lake stage data for Lake Tiger was selected to represent water level for both lakes due its longer period or record.

Although the period of record of lake stage data (1992 to 2012) for Lake Tiger could be classified as the Historic data, it was determined that a longer period would better characterize historic water level fluctuation within the basin. A longer period was developed by using a predictive lake stage model in this case the Rainfall Line of Organic Correlation (LOC)(Ellison et al. 2011). The method relates local rain gage data to historic lake stage data to produce a regression model that predicts lake stage based on past rainfall amounts. The procedure uses a linear inverse time weighted rainfall sums to establish the relationship. Models produced with this method are extended back in time to 1946 to produce a 60-year non-impacted lake stage record that serves as the basis for establishing historic lake-stage exceedance percentiles. A sixty year period was considered sufficient for incorporating the range of lake stage fluctuations that would be expected based on long-term climatic cycles that have been shown to be associated with changes in regional hydrology (Enfield et al. 2001, Basso and Schultz 2003).

To produce the model a composite rainfall data set was developed for the time period of 1946 to 2012 using data from five rainfall data collection sites. The rain gage sites included the following: Cedar Key, Dunnellon Tower, Inglis Lock, Inglis 3E NWS, Lebanon Tower, Rainbow Springs, Romeo, and Usher (WMIS Site ID’s 26292, 22997, 22959, 22958, 26291, 23323, 22977, 26387). The resulting lake level rainfall model had a correlation coefficient of determination (r^2) equal to 0.674 based on use of a five-year linear decay series of daily rainfall values. The model was then applied to predict the lake stage for the long term Historic time period of the 1946 to 2012 (Figure 9a). A comparison of the modeled lake stage to the observed lake stage is shown in Figure 9b for the period of record (1992-2012).

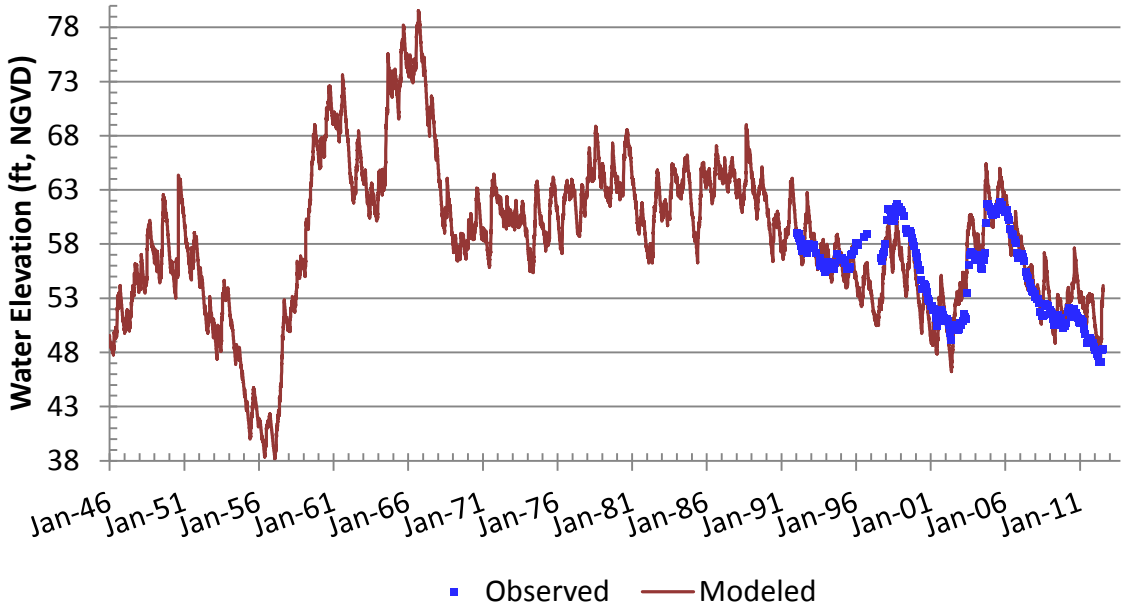
The modeled long term Historic lake stage (1946 to 2012) was then combined with the measured or period of lake stage (1992 to 2012) to provide a final composite long term Historic lake stage (Figure 10). Because the model predicts levels well in excess of the normal pool indicators observed around the lake (primarily at the saw palmetto edge) the model results were trimmed at the normal elevation (63.6 NGVD 29). The trimmed

model values are shown in white on Figure 10. This composite data long term Historic data trimmed at 63.6 NGVD was the final data set used to calculate the **Historic P10, P50, and P90** lake stage percentile elevations.

The **Historic P10** elevation, the elevation the lake water surface equaled or exceeded ten percent of the time during the historic period, was **63.6 NGVD 29.** The **Historic P50** elevation, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was **59.1 NGVD 29.** The **Historic P90** elevation, the elevation the lake water surface equaled or exceeded 90 percent of the time during the historic period, was **50.5 NGVD 29.**

Figure 9: **a**. Modeled long term **Historic** lake stage (as daily, see red line) from 1946 to 2012 and observed lake stage (as daily, see blue points) from 1992 to 2012 for Lake Tiger. **b.** Modeled daily lake stage and observed (as daily) for period of record (1992 to 2012).

9a.



9b.

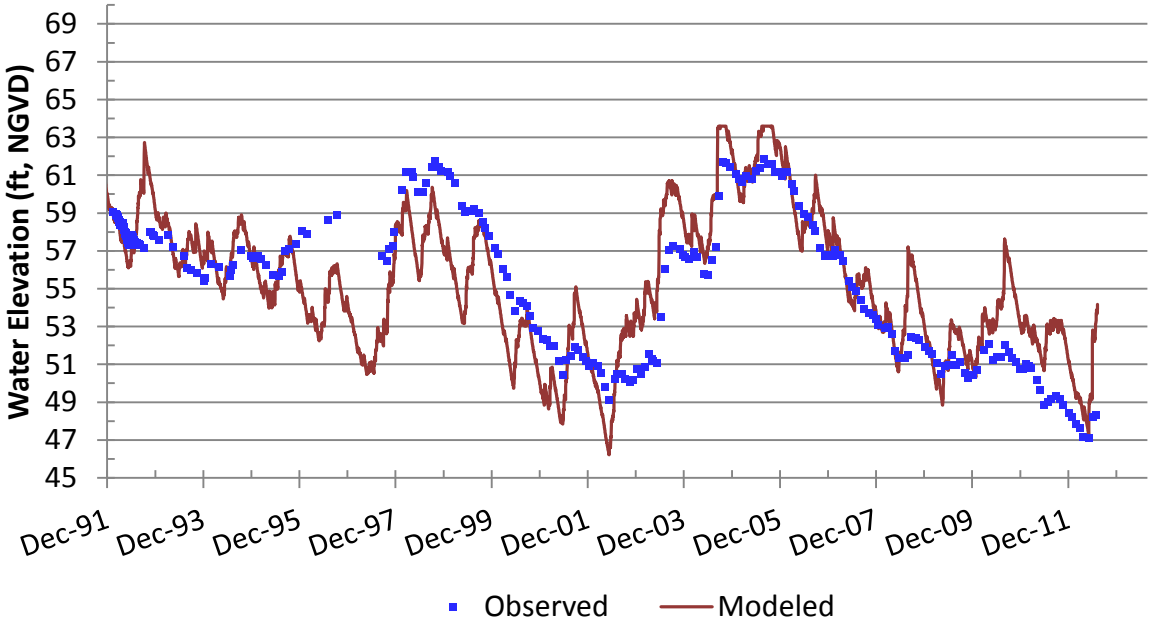
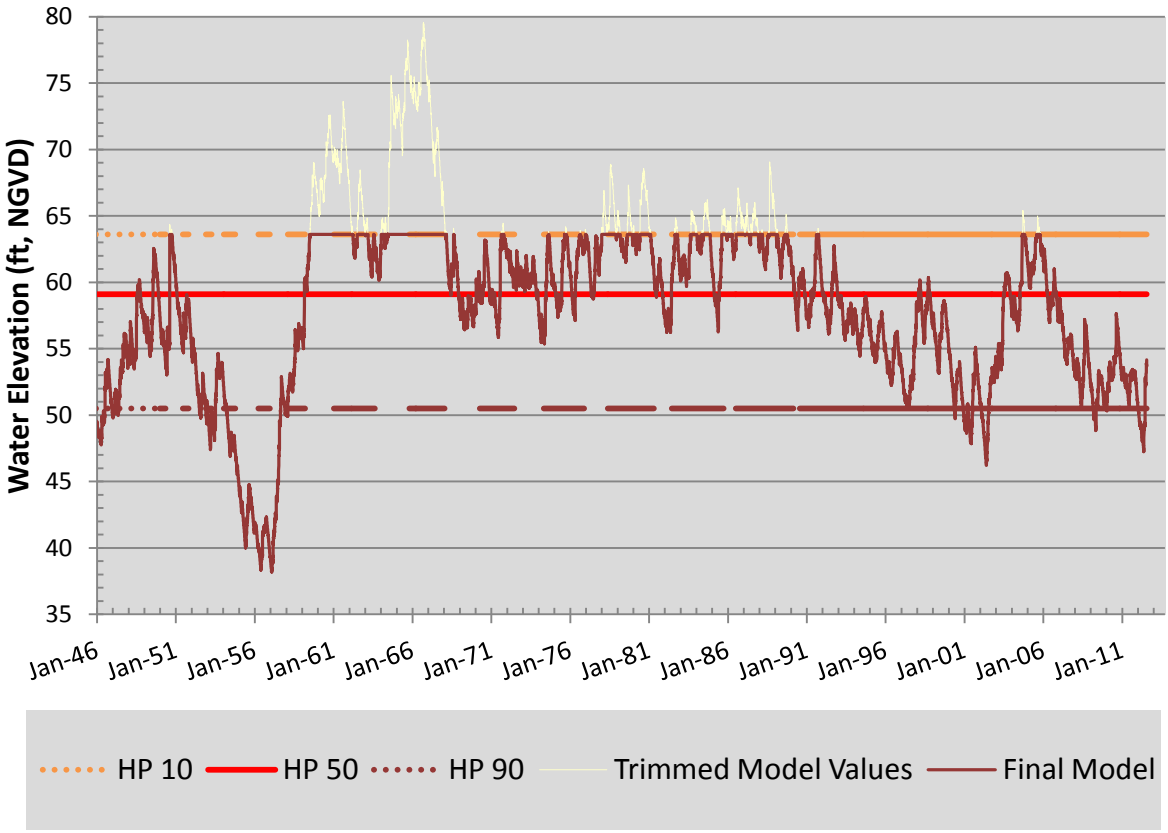


Figure 10. Modeled long term Historic lake stage and measured lake stage (both as daily) used to calculate the Historic P10, P50, and P90 lake stage percentile elevations for Lakes Bonable and Tiger from January 1946 through July 2012. The long term Historic P10, P50, and P90 are depicted as horizontal solid and dotted lines. White line represents trimmed modeled lake stage based on the normal pool elevation (63.5 NGVD 29).



Normal Pool Elevation, Control Point Elevation and Structural Alteration Status

The **Normal Pool** elevation, a reference elevation used for development of minimum lake and wetland levels, is established based on the elevation of Hydrologic Indicators of sustained inundation. For development of Minimum Lake Levels, the Normal pool elevation is considered an approximation of the Historic P10. Based on ground elevations at the base of saw palmetto (*Serenoa repens*) along the lakeshore (Table 5, see Figures 3 and 13), the Normal Pool elevation was established at 63.54 feet above NGVD. Cypress trees (*Taxodium* sp.) are also used as indicators of normal pool, specifically the buttress inflection point. Several cypress trees were observed along the southwest shore of Lake Bonable near the outfall. Although inflection points were not observed for these trees, elevations were measured at the base on the trees with a median elevation established at 61.3 feet above NGVD. Although this elevation does not represent normal pool it provides supplemental information for expected inundation elevations below the Historic P10.

The **Control Point** elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system (*e.g.,* weir, ditch, culvert, or pipe) that is the principal control of water level fluctuations in the lake. The outfall for Lakes Bonable and Tiger is located within a man-made berm that separates the lake basins from the wetland slough system located on the central western shore. Based on review of historical imagery the berm appears to have been constructed between 1957 and 1963. A breach in the berm that occurred during a period of high flows forms the low spot in the berm. It's likely that the berm was breached during the high stages that occurred during the El Nino event in 1998. Based on elevation data collected by professional surveyors during the topographic assessment of the watershed (Xynides 2006), the elevation of the base of the cut in the berm is 59.1 NGVD (see Figure 2). An 18 inch culvert lies at the bottom of the breach in the berm and it is evident that high flows eroded the bank, creating a 6 to 8 foot channel around the culvert. The historical vertical placement of the culvert within the berm and elevation is unknown.

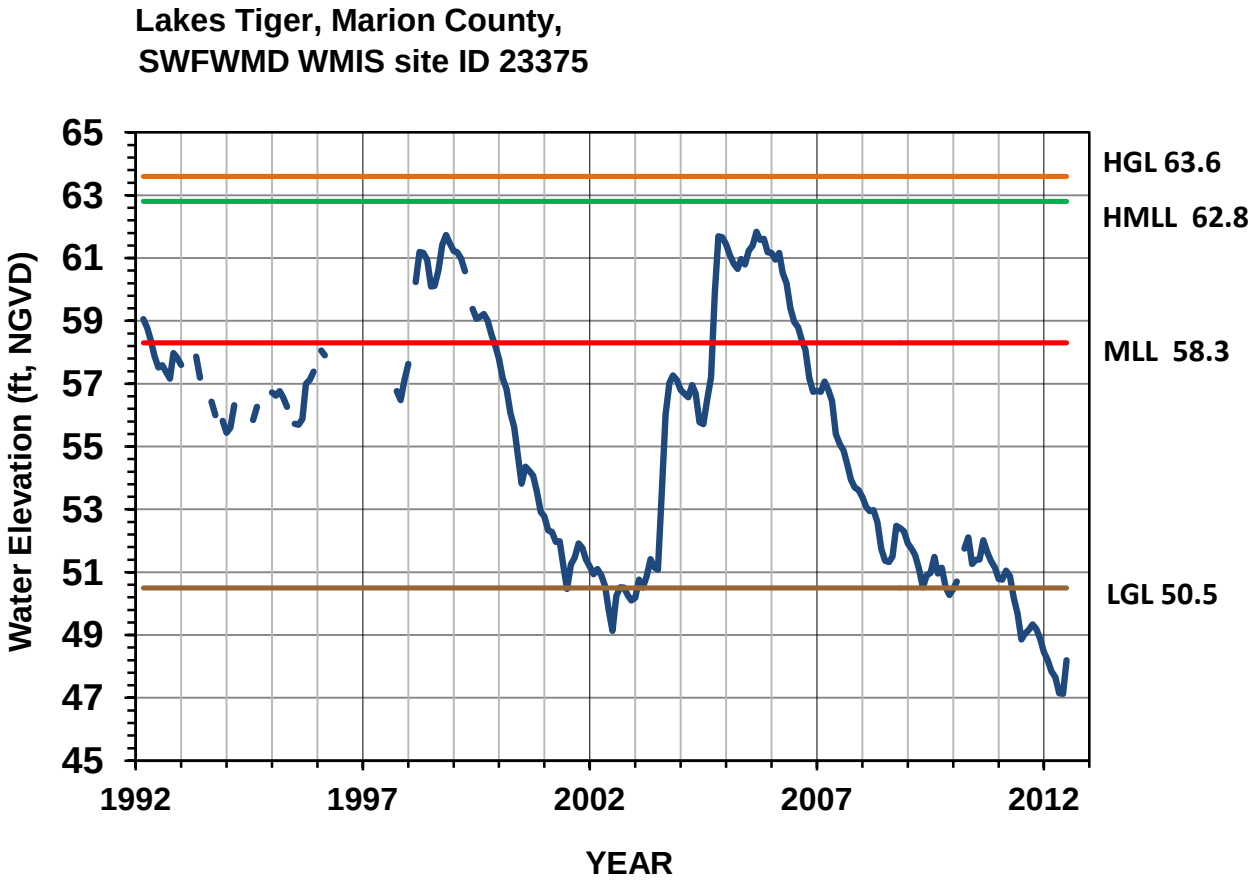
Structural Alteration Status is determined to support development of Minimum and Guidance Levels. Because of known modifications (berm) to the outlet Lakes Bonable and Tiger are considered to be Structurally Altered.

Guidance Levels

The **High Guidance Level** is provided as an advisory guideline for construction of lake-shore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake and is established using historic lake stage data if it is available, or is estimated using the Current P10, the control point, and the normal pool elevation. Based on the availability of the modeled long term Historic data record for Lake Tiger, the High Guidance Level for both lakes was established at **63.6 NGVD 29** (Figure 11).

The **Low Guidance Level** is provided as an advisory guideline for water dependent structures, information for lake shore residents, and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time (P90) on a long-term basis. The level is established using Historic or Current lake stage data, and in some cases, the Reference Lake Water Regime (RLWR) statistics. Based on the availability of the long term modeled Historic data set for Lake Tiger, the Low Guidance Level for both lakes was established at **50.5 NGVD 29** (Figure 11, Table 3).

Figure 11. Mean monthly lake stage for Lake Tiger of the period of record; and Minimum and Guidance Levels for Lakes Bonable and Tiger (as NGVD 29). Levels include the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL), and the Low Guidance Level (LGL).



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 acres in size where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands (*i.e.*, the Historic P50 is equal to or higher than an elevation 1.8 feet below the Normal Pool elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acres 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 acres in size are classified as Category 3 Lakes. Because Lakes Bonable and Tiger do not have fringing cypress wetlands, they are classified as a **Category 3 Lake.**

Significant Change Standards and Other Information for Consideration

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 (Rule 62-40.473, F.A.C.). Other information taken into consideration includes potential changes in the coverage of herbaceous wetland vegetation and aquatic plants.

Six significant change standards are developed for Category 3 Lakes, including a Dock-Use Standard, a Basin Connectivity Standard, a Recreation/Ski Standard, a Species Richness Standard, Aesthetics Standard, and a Lake Mixing Standard. A Wetland Offset Elevation is also developed and used along with the significant change standards to identify desired median lake stage elevations that if achieved, are intended to preserve various natural system and human-use lake values.

The **Dock-Use Standard** is developed to provide for sufficient water depth at the end of existing docks to permit mooring of boats and prevent adverse impacts to bottom-dwelling plants and animals caused by boat operation. The standard is based on the elevation of lake sediments at the end of existing docks, a clearance value for boat mooring, and use of Historic lake stage data or region-specific reference lake water regime statistics. The Dock-Use Standard for Lakes Bonable and Tiger was established at 70.3 feet above NGVD, based on the elevation of sediments at the end of ninety percent of the 34 docks within the lake (59.7 feet above NGVD, Table 4), a two-foot water depth based on use of powerboats in the lake, and the 8.6 foot difference between the Historic P50 and Historic P90. The sediment elevations were measured in May of 2011 with a corresponding water level of 50.1 NGVD.

The **Basin Connectivity Standard** is developed to protect surface water connections between lake basins or among sub-basins within lake basins to allow for movement of

aquatic biota, such as fish, and support recreational lake-use. The standard is based on the elevation of lake sediments at a critical high-spot between lake basins or lake, clearance values for movement of aquatic biota or powerboats and other watercraft, and use of Historic lake stage data or region-specific reference lake water regime statistics.

A review of historical aerial imagery for years 1940, 1949, and 1957 indicates that a natural connection existed between the two lake basins (see Figures 18 and 19). A shallow canal was later dredged through the connection sometime between 1957 and 1963 to increase navigation between the basins during lower stages. A review of bathymetric contours created from LiDAR elevation data and spot elevation data for these combined lakes indicated that a critical high spot within the shallow canal is approximately 55.2 NGVD (Figure 12). The Basin Connectivity Standard was established at 65.7 NGVD, based on the sum of the elevation that ensures connectivity (55.2 NGVD as critical high spot), a two foot clearance value for movement of biota and use of powerboats on the lake, and the difference between the Historic P50 and Historic P90 (8.6 ft).

Neither the elevation established for the dock-use standard (70.3) or the connectivity standard (65.7) are practical management levels since potential for flooding of residential structures would occur at these elevations. Both elevations are also greater than the Ten Year Flood Guidance Level of 65.1 NGVD established in 1993 for Lakes Bonable and Tiger (SWFWMD 1996). The Dock-Use Standard and Connectivity Standard were therefore determined as not appropriate for Lakes Bonable and Tiger.

The **Recreation/Ski Standard** is developed to identify the lowest elevation within the lake basin that will contain an area suitable for safe water skiing. The standard is based on the lowest elevation (the Ski Elevation) within the basin that can contain a five-foot deep ski corridor delineated as a circular area with a radius of 418 ft, or a rectangular ski area 200 ft in width and 2,000 ft in length, and use of Historic lake stage data or region-specific reference lake water regime statistics. The Recreation/Ski Standard was established at 64**.**1 ft NGVD, based on the sum of the elevation at which the lake could contain an area suitable for safe skiing (50.5 NGVD + 5 ft) and the difference between the Historic P50 and Historic P90 (8.6 ft). Based on a review of the long term composite Historic water level record for Lakes Bonable and Tiger, the Recreation /Ski Standard elevation of 64.1 falls above the Historic P10 and associated High Guidance Level. The Recreation /Ski Standard is not appropriate in this case.

Based on a review (Hancock 2006) of the development of minimum level methods for cypress-dominated wetlands, it was determined that up to an 0.8 foot decrease (or Wetland Offset) in the Historic P50 elevation would not likely be associated with significant changes in the herbaceous wetlands occurring within lake basins. Because herbaceous wetlands are common within the Lakes Bonable and Tiger basin, the **Wetland Offset** was determined by subtracting 0.8 feet from the Historic P50 elevation. A Wetland Offset elevation of 58.3 NGVD was therefore established for Lakes Bonable and Tiger and was equaled or exceeded 55.2 percent of the time, based on the Historic, composite water level record. The standard elevation therefore corresponds to the

Historic P55.2. Review of changes in potential wetland area in relation to change in lake stage indicated there would not be a substantial increase or decrease in potential wetland area within the lake basin at the Wetland Offset Elevation (27.6% of the lake basin) relative to the potential wetland area at the Historic P50 elevation (25.1% of the lake basin).

The **Species Richness Standard** is developed to prevent a decline in the number of bird species that may be expected to occur at or utilize a lake. Based on an empirical relationship between lake surface area and the number of birds expected to occur at Florida lakes, the standard is established at the lowest elevation associated with less than a 15 percent reduction in lake surface area relative to the lake area at the Historic P50 elevation (see Figure 14) for a plot of lake surface area versus lake stage. For Lakes Bonable and Tiger, the Species Richness Standard was established at 56.7 NGVD 29. The Species Richness Standard was equaled or exceeded 65.5 percent of the time, based on the long term composite Historic water level record. The standard elevation therefore corresponds to the Historic P65.5.

The **Lake Mixing Standard** is developed to prevent significant changes in patterns of wind-driven mixing of the lake water column and sediment resuspension. 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. A shift in the dynamic ratio occurs at an elevation of 51.0 (Figure 14), indicating the elevation at which the lake depth and bottom slope becomes susceptible to resuspension of bottom sediments. The Mixing Standard elevation established at 51.0 NGVD 29 was equaled or exceeded 88.5 percent of the time, based on the term composite Historic water level record. The standard elevation therefore corresponds to the Historic P88.5.

The **Aesthetics Standard** is developed to protect aesthetic values associated with the inundation of lake basins. The standard is intended to protect aesthetic values associated with the median lake stage from becoming degraded below the values associated with the lake when it is staged at the Low Guidance Level. The Aesthetic Standard was established at the Low Guidance Level, which for Lakes Bonable and Tiger is 50.5 NGVD 29. Because the Low Guidance Level was established at the Historic P90 elevation, water levels equaled or exceeded the Aesthetics Standard ninety percent of the time during the Historic long term period (1946 to 2012, Figure 10).

Information on herbaceous wetlands is taken into consideration when determining the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (*i.e*., basin area with a water depth of four or less feet). Similarly, changes in lake stage associated with changes in lake area available for colonization by rooted submersed or floating-leaved macrophytes are also evaluated, based on water transparency values (*i.e*., basin area with a water depth of 5.5 feet or less feet). Review of changes in potential herbaceous wetland area or area

available for submersed aquatic plant colonization in relation to change in lake stage did not indicate that of use of any of the significant change standards would be inappropriate for establishment of the Minimum Lake Level (Figure 15).

Figure 12. Location of critical high spot(s) used to develop the connectivity standard for Lakes Bonable and Tiger, Marion County.

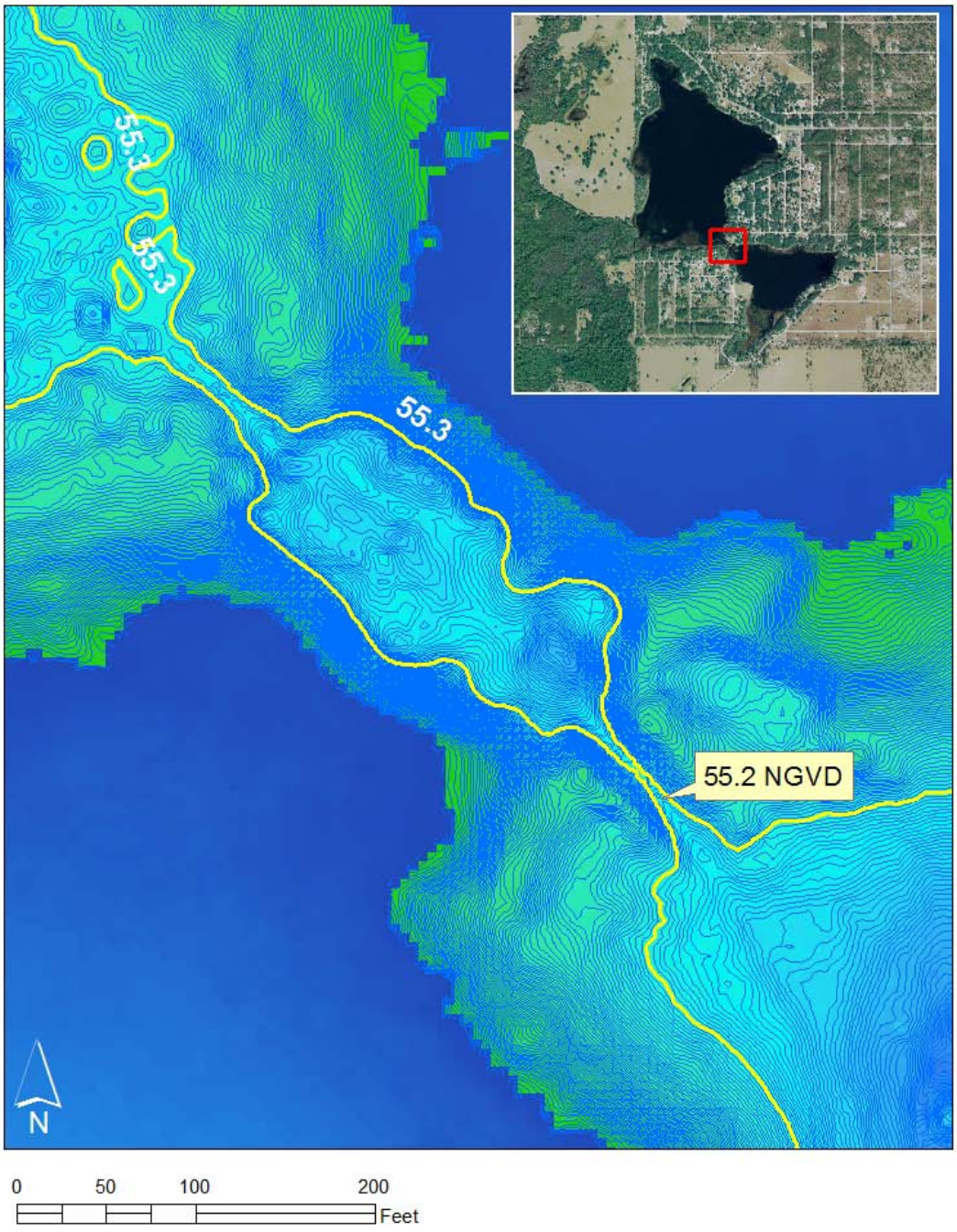


Table 4. Summary statistics and elevations associated with docks in Lakes Bonable and Tiger as based on measurements made by District staff in February 2011. Percentiles (10th, 50th and 90th) represent the percentage of docks at or below the corresponding elevation.

Summary Statistics	Statistic Value (N) or Elevation (feet above NGVD) of Sediments at Waterward End of Docks	Statistic Value (N) or Elevation (feet above NGVD) of Dock Platforms
N (number of docks)	34	34
Median	58.5	64.5
10^{th} Percentile (P90)	54.2	61.2
50^{th} Percentile	58.5	64.5
90^{th} Percentile (P10)	59.7	65.7
Maximum	63.8	66.2
Minimum	52.4	54.8

Table 5. Summary statistics for ground elevations at saw palmetto shrubs (*Serenoa repens,* Figure 13) used to establish the normal pool elevation for Lakes Tiger and Bonable Lake.

Statistic	Statistic Value (N) or Elevation (feet above NGVD)
N	23
Median	63.54
Mean (SD)	63.6 (0.2)
Minimum	63.2
Maximum	64.1

Table 6. Summary statistics for hydrologic indicator measurements elevations of the base of *Taxodium* sp. used for establishing the Normal Pool Elevation for Lakes Bonable and Tiger.

Statistic	Statistic Value (N) or Elevation (feet above NGVD)
N	7
Median	61.3
Mean (Standard Deviation)	61.5 (0.1)
Minimum	60.9
Maximum	62.5

Figure 13. Line of saw palmetto shrubs (*Serenoa repens*) located along northwest shoreline of Lake Bonable (see Figure 3 for location).

Minimum Levels

Minimum Lake Levels are developed using specific lake-category significant change standards and other available information or unique factors, including: substantial changes in the coverage of herbaceous wetland vegetation and aquatic macrophytes; elevations associated with residential dwellings, roads or other structures; frequent submergence of dock platforms; faunal surveys; aerial photographs; typical uses of lakes (*e.g.,* recreation, aesthetics, navigation, and irrigation); surrounding land-uses; socio-economic effects; and public health, safety and welfare matters. Minimum Levels development is also contingent upon lake classification*, i.e.,* whether a lake is classified as a Category 1, 2 or 3 lake. Table 7 provides an overall summary of the environmental and structural elevations that were considered for the development of significant change standards for Lakes Bonable and Tiger, as well as the change standards calculations applied from the District's methodology outlined in Rule 40D-8.624, F.A.C.

The **Minimum Lake Level (MLL)** is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. For Category 3 Lakes, the Minimum Lake Level is typically established at the elevation corresponding to the most conservative significant change standard, *i.e*., the standard with the highest elevation, except where that elevation is above the Historic P50 elevation, in which case, the Minimum Lake Level is established at the Historic P50 elevation. Because all appropriate significant change standards were below the Historic P50 elevation, the Minimum Level for Lakes Bonable and Tiger could be established at 56.7 NGVD 29, the elevation corresponding to the Richness Standard. The Minimum Lake Level was, however, established at the Wetland Offset elevation, 58.3 NGVD 29. (Figures 11, 16, 17, 18, and 19). The Minimum Lake Level was equaled or exceeded 55.2 percent of the time, based on the Historic, composite water level record and corresponds to the Historic P55.2. This level is expected to afford protection to the natural system and human-use values associated with the identified significant change standards and also provide protection for wetlands occurring within the basin.

The **High Minimum Lake Level** (HMLL) is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. For Category 3 lakes, the High Minimum Lake Level is developed using the Minimum Lake Level, Historic data or reference lake water regime statistics. If Historic Data are available, the High Minimum Lake Level is established at an elevation corresponding to the Minimum Lake Level plus the difference between the Historic P10 and Historic P50. If Historic data are not available, the High Minimum Lake Level is set at an elevation corresponding to the Minimum Lake Level plus the region-specific RLWR50. Based on the availability of long term modeled Historic data for Lakes Bonable and Tiger, the High Minimum Lake Level was established at 62.8 NGVD 29 (Figures 11 and 16, 17,18, and 19), by adding the difference between the Historic P50 and Historic P10 (4.5 feet) to the Minimum Lake Level. The High Minimum Lake Level at 62.8 NGVD 29 was equaled or exceeded 27.6 percent of the time, based on the term modeled Historic water level record, and corresponds to the Historic P27.6.

The Minimum and Guidance levels for Lakes Bonable and Tiger are shown in Figure 11 along with monthly mean water surface elevations based on period of record water level measurements. Staging of the lake at Minimum levels (Figure 16, 17, 18, and 19) would not be expected to flood any man-made features within the immediate lake basin. The High Minimum Lake Level (62.8 NGVD 29) is approximately 3.1 feet lower than the lowest residential floor slab (65.9 NGVD 29) within the lake basin (Table 6). The High Minimum Lake Level is also approximately 4.4 ft lower than the lowest spot on the paved roads (67.18 NGVD 29) encircling the lake.

Table 6. Elevations of lake basin features in the immediate Lakes Bonable and Tiger basin (Xynides 2006) as NGVD 29

Lake Basin Features	**Elevation in Feet NGVD 29**
Lowest roadway elevation	**67.18**
Low floor slab – residential	**65.88**

Compliance Evaluation

The Minimum Lake Level and High Minimum Lake Level were evaluated for comparison using same predictive model (Rainfall Line of Organic Correlation) that was used to develop the long term Historic Exceedance percentiles (Ellison 2012). The model is used to evaluate whether the predicted lake stage and observed lake stage fits within the prediction intervals established with the model's calibration window or time period. Lakes Bonable and Tiger were determined to be in compliance for both the Minimum Low Level and High Minimum Level based on rainfall data through July 2012.
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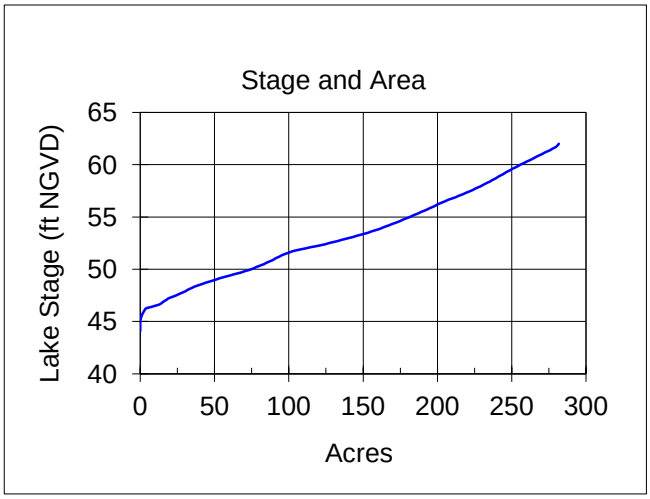
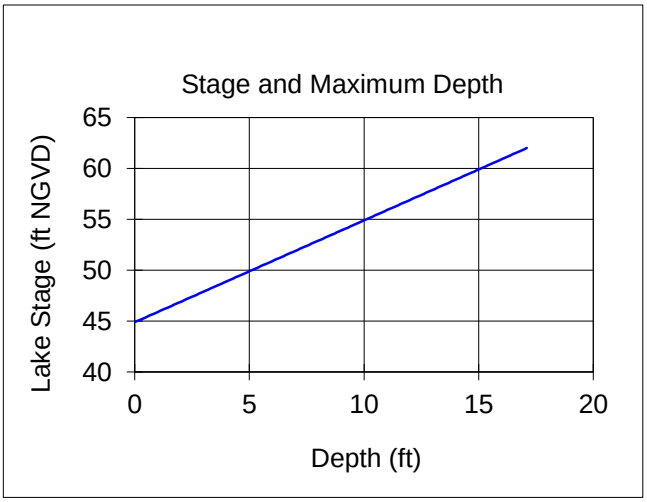
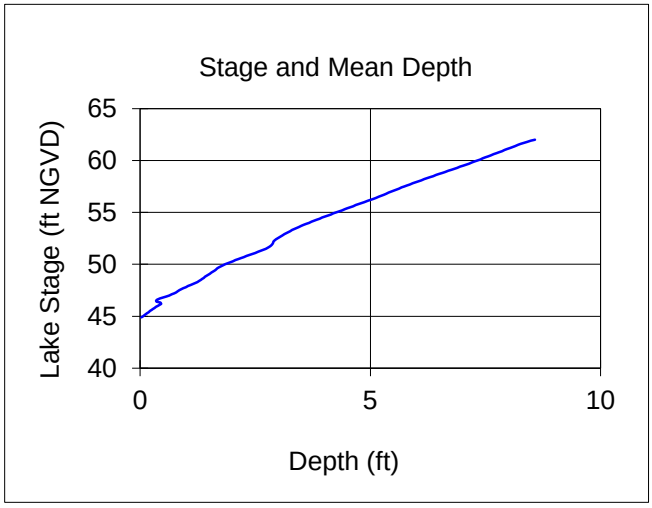
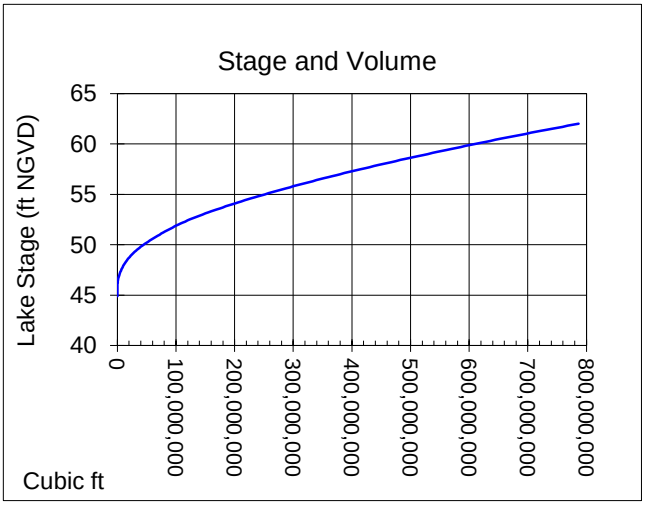
Figure 14. Surface area, maximum depth, mean depth, volume, dynamic ratio (basin slope) in feet above NGVD 29 for Lakes Bonable and Tiger.









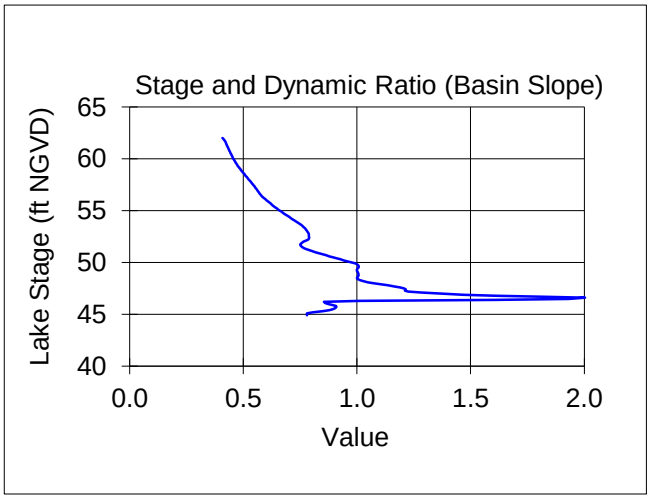
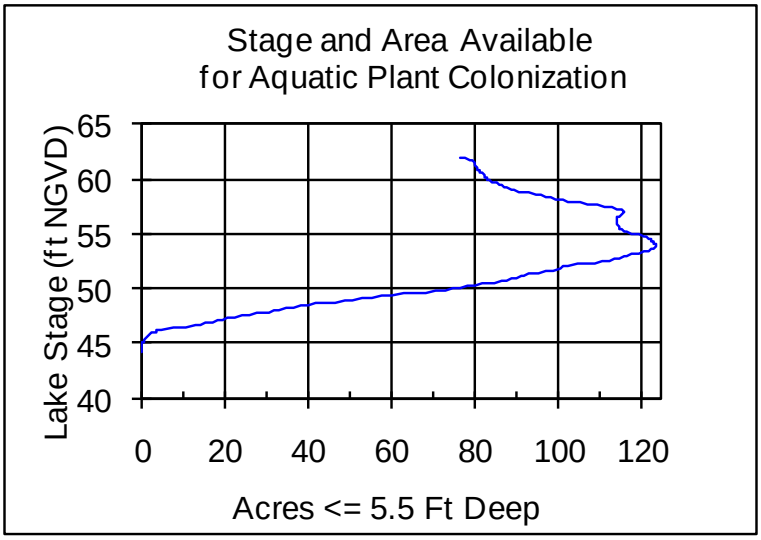


Figure 15. Potential herbaceous wetland area and area available for submersed macrophyte colonization in Lakes Bonable and Tiger as a function of lake stage (water surface elevation).



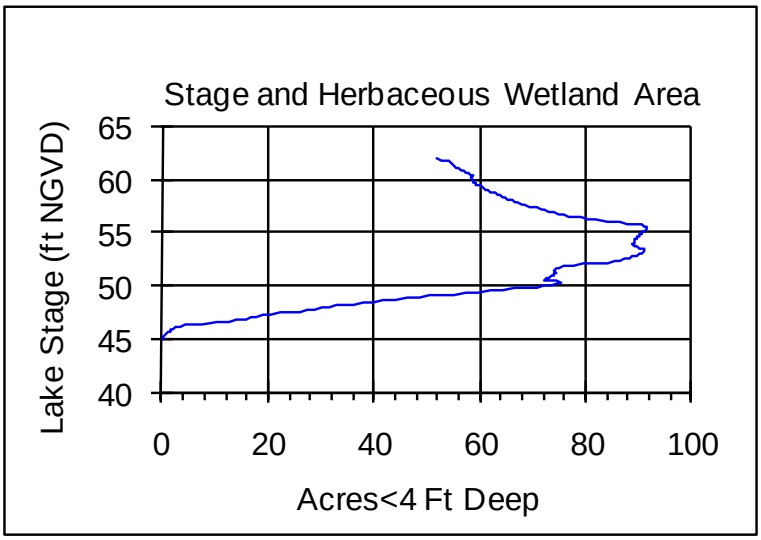


Table 7. Summary of Environmental and Structural Measures, Change Standards, Historic Exceedance Percentiles, and Minimum and Guidance Levels for Lakes Bonable and Tiger, Marion County

	ft NGVD 29
Lake Morphology	
Connection between lakes	55.2
Maximum Lake Depth Bonable	45
Maximum Lake Depth Tiger	45
Structural	
Outfall Pipe and Berm Cut Base	59.1
Top of Berm near Outfall Pipe	63-64
Low Road	66.31
Low Slab	65.88
Bottom at Docks (median)	58.53
Bottom Docks 90th Percentile (or P10)	59.71
Top of Docks (median)	64.51
Indicators	
Palmetto Line South	63.6
Palmetto Line North	63.48
Cypress Trees (West Side)	61.5
Cord Grass Fringe	60.0 – 61.0

Historic Percentiles and Levels (ft NGVD 29)	
HP 10	63.6
HP 50	59.1
HP 90	50.5
HGL	63.6
HMLL	62.8
MLL	58.3 (Wetland Offset)
LGL	50.5

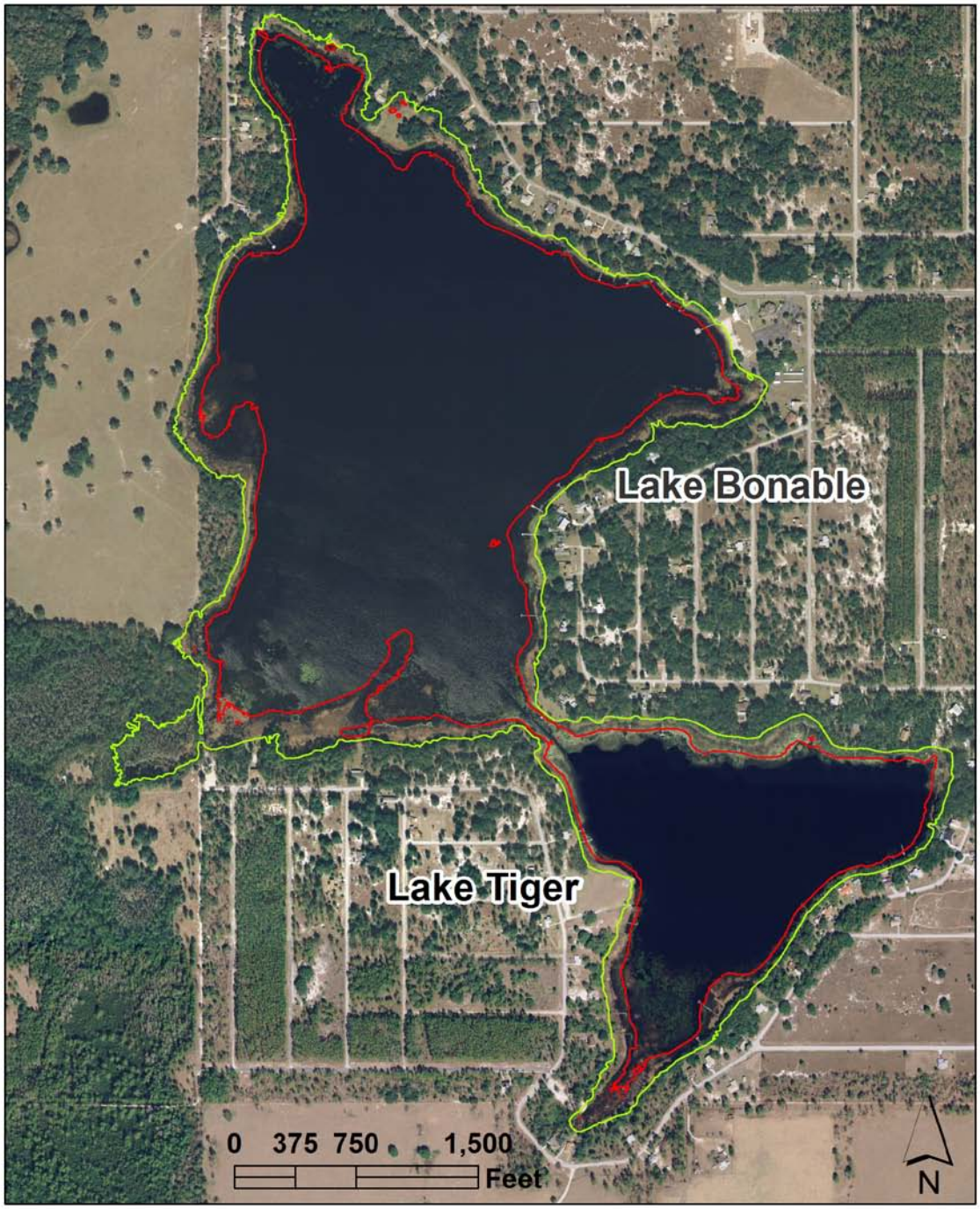
Change Standards and their associated calculations (feet NGVD 29)	
Dock * 59.71 NGVD + 8.6 +2 = 73.1	70.3, > HP50
Connectivity * 55.2 NGVD + 8.6 + 2 = 65.7	65.7, > HP50
Ski * 50.47 NGVD + 5+ 8.6 = 64.1	64.1, > HP50
Wetland Offset HP50 - 0.8	58.3, <HP50
Species Richness	56.7, <HP50
Mixing Standard	51.0, <HP50

*** - Determined to Not Appropriate (NA)**

Figure 16. Recent (January 12, 2011) aerial view of Lakes Bonable and Tiger with contour lines representing the Minimum Lake Level (58.3 NGVD) and High Minimum Lake Level (62.8 NGVD).

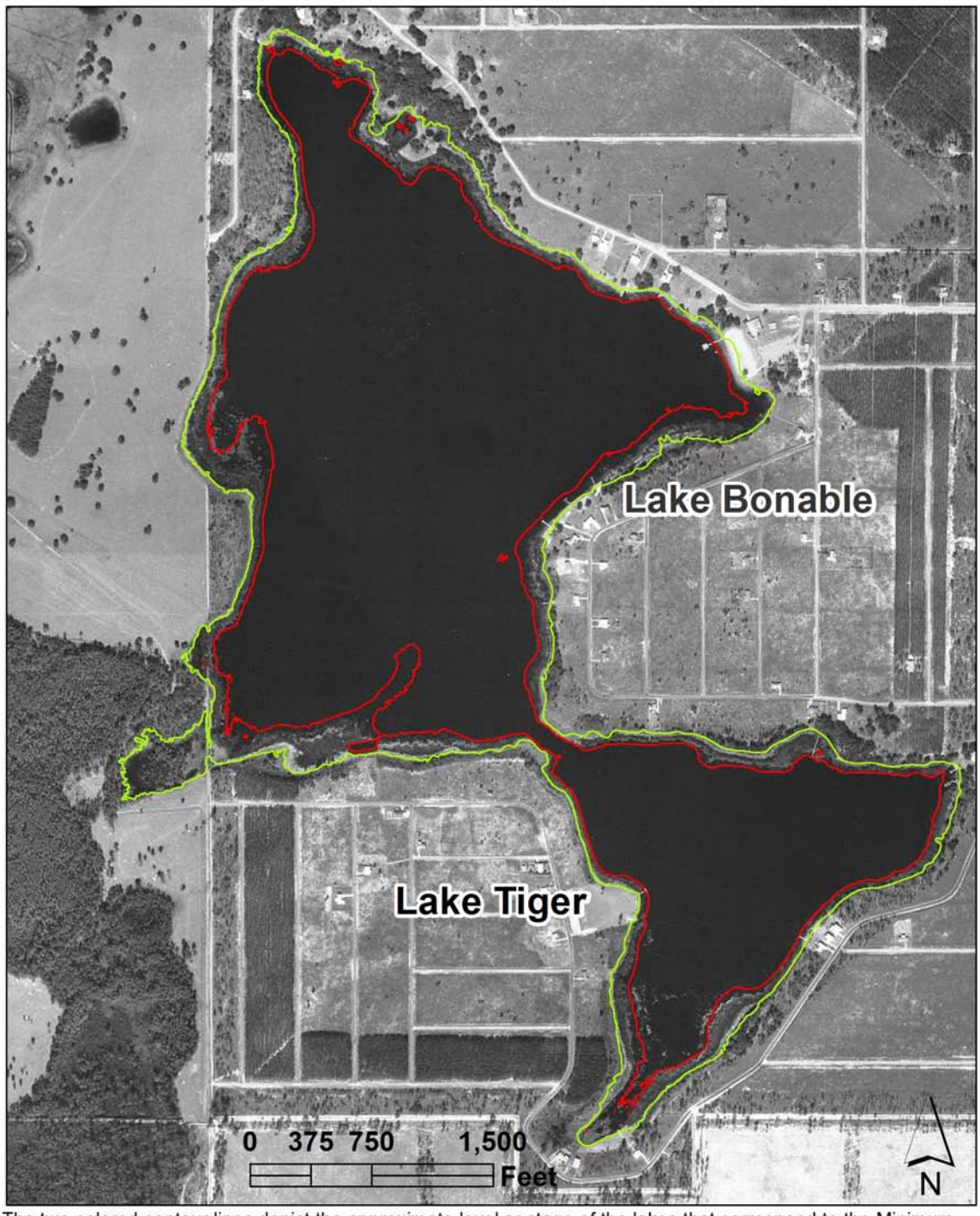
The two colored contour lines depict the approximate level or stage of the lakes that correspond to the Minimum Low Level in red (58.3 NGVD 29), and the High Minimum Level in green (62.8 NGVD 29). Contours were prepared using a combination of LiDAR data and bathymetric data collected with underwater sonar. LiDAR was collected in early 2007 by Earth LLC. Bathymetric data was collected by D.C. Johnson & Associates in October 2006 (File No. 2004-003A02). The background imagery is natural color digital ortho photography collected on January 7, 2011. The lake stage recorded on January 12, 2011 was 50.76 NGVD 29.

Figure 17. 2006 aerial view of Lakes Bonable and Tiger with contour lines representing the Minimum Lake Level (58.3 NGVD) and High Minimum Lake Level (62.8 NGVD).



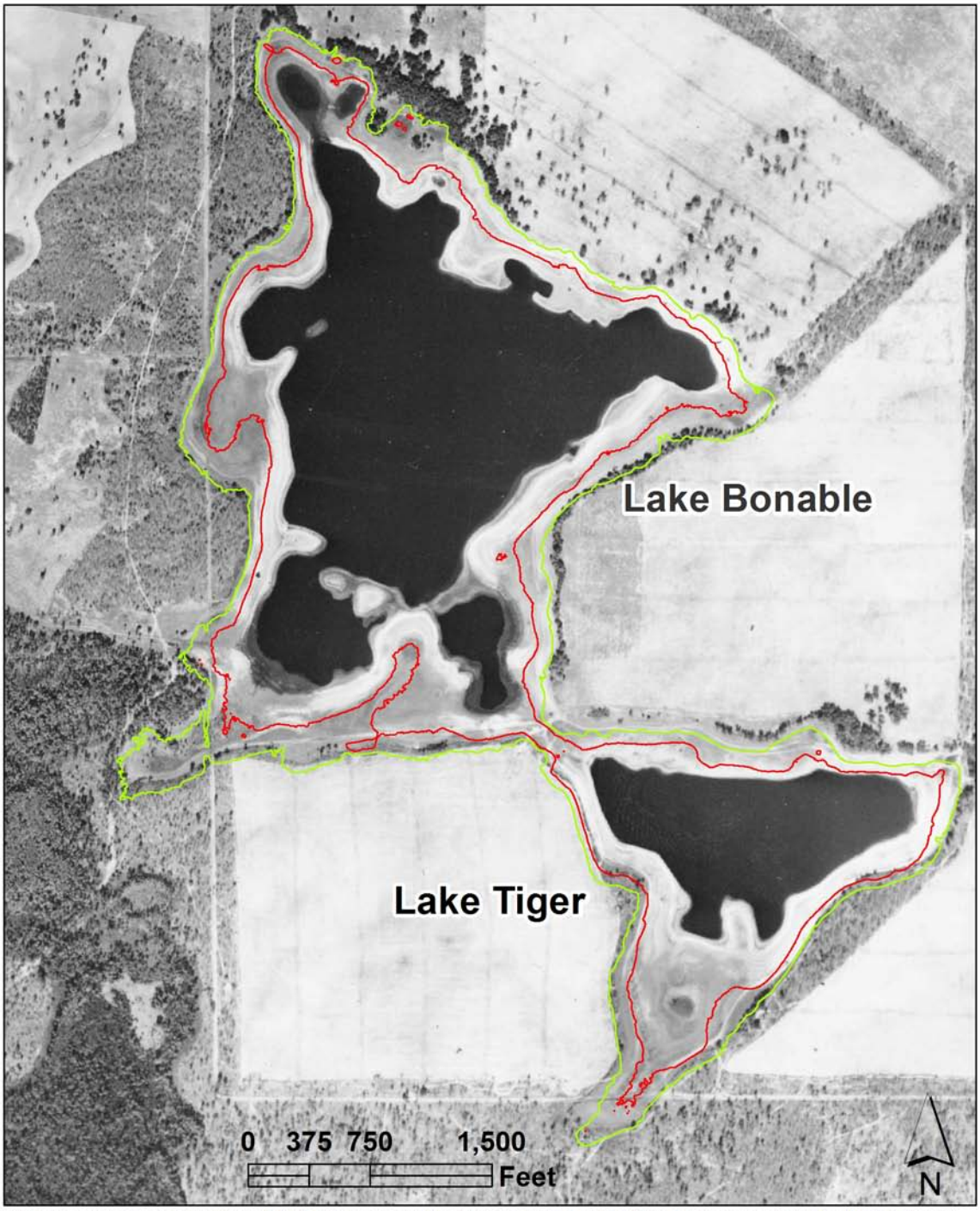
The two colored contour lines depict the approximate level or stage of the lakes that correspond to the Minimum Low Level in red (58.3 NGVD 29), and the High Minimum Level in green (62.8 NGVD 29). Contours were prepared using a combination of LiDAR data and bathymetric data collected with underwater sonar and as spot elevations. LiDAR was collected in early 2007 by Earth LLC. Bathymetric data was collected by D.C. Johnson & Associates in June 2006 (File No. 2004-003A02). The background imagery was collected on February 13, 2006. The lake stage recorded on February 15, 2006 was 61.16 NGVD.

Figure 18. Historical aerial view (January 25, 1970) of Lakes Bonable and Tiger with contour lines representing the Minimum Lake Level (58.3 NGVD) and High Minimum Lake Level (62.8 NGVD).



The two colored contour lines depict the approximate level or stage of the lakes that correspond to the Minimum Low Level in red (58.3 NGVD 29), and the High Minimum Level in green (62.8 NGVD 29). Contours were prepared using a combination of LiDAR data and bathymetric data collected with underwater sonar and as spot elevations. LiDAR was collected in early 2007 by Earth LLC. Bathymetric data was collected by D.C. Johnson & Associates in June 2006 (File No. 2004-003A02). The background imagery was collected on January 25, 1970 by the Florida Department of Transportaiton.

Figure 19. Historical aerial view (February 2, 1957) of Lakes Bonable and Tiger with contour lines representing the Minimum Lake Level (58.3 NGVD) and High Minimum Lake Level (62.8 NGVD).



The two colored contour lines depict the approximate level or stage of the lakes that correspond to the Minimum Low Level in red (58.3 NGVD 29), and the High Minimum Level in green (62.8 NGVD 29). Contours were prepared using a combination of LiDAR data and bathymetric data collected with underwater sonar and as spot elevations. LiDAR was collected in early 2007 by Earth LLC. Bathymetric data was collected by D.C. Johnson & Associates in June 2006 (File No. 2004-003A02). The background imagery was collected on February 2, 1957 by the U.S. Department of Agriculture (University of Florida, 2011).

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