Minimum and Guidance Level for Lake Rogers in Hillsborough County, Florida

October 1, 2013

Resource Evaluation Section
Water Resources Bureau

Southwest Florida
Water Management District

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Cover Page: Views of emergent (littoral) zone within Lake Rogers, November 2012

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Minimum and Guidance Levels for Lake Rogers

Section 373.042, Florida Statutes (Fla.Stat.) 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), Fla.Stat., 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), Fla.Stat., 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 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.

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, Fla.Stat., 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), Fla.Stat, 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), Fla.Stat.

Minimum flows and levels 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, Fla.Stat.). The Florida Water Resources Implementation Rule (Rule 62-40.473, Florida Administrative Code (Fla. Admin. Code), 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 SWFWMD 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, Fla. Admin. Code. 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, Fla. Admin. Code, 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 SWFWMD (1999a, b), Leeper *et al.* (2001) and Leeper (2006). Peer-review findings regarding the lake level methods are available in 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, Fla. Admin. Code. 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, Fla. Admin. Code, Minimum and Guidance Levels were developed for Lake Rogers (Table 1), a Category 3 lake located in Hillsborough 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, Fla.Admin.Code., at their June 25, 2013 meeting. Public input included a public workshop held on May 29, 2013 in Odessa, 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 Lake Rogers based on current methodologies, replacing the previously proposed levels recommended in 2003 (see Table 3). 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 (Table 1) became effective on September 3, 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 (ft NGVD). 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 ft NGVD. All datum conversions were derived using Corpscon 6.0, a software developed by the United States Army Corps of Engineers. In this report all references to elevations will be abbreviated as ft NGVD.

Table 1. Minimum and Guidance Levels for Lake Rogers

Minimum and Guidance Levels	**Elevation**
	ft NGVD
High Guidance Level	39.5
High Minimum Lake Level	38.7
Minimum Lake Level	35.6
Low Guidance Level	34.4

Data and Analyses Supporting Development of Minimum and Guidance Levels for Lake Rogers

Lake Setting and Description

Lake Rogers is located in the Northwest Hillsborough Basin in Hillsborough County, Florida in Section 27, Township 27S, Range 17E (Figure 1). 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. As part of the Florida Department of Environmental Protection's Lake Bioassessment/Regionalization Initiative, the area has been identified as the Keystone Lakes region, and described as an area of numerous slightly acidic, low nutrient, and mostly clear-water lakes (Griffith *et al.* 1997). Lake Rogers lies within the Cosme-Odessa wellfield, which is one of the major water supply wellfields operated by Tampa Bay Water.

The lake is surrounded by a natural buffer of forested land that has remained undeveloped. The area has undergone some clear cutting and logging evident within historical aerial imagery. The Hillsborough County Parks and Recreation Department maintains the area surrounding the lake as a county park (Lake Rogers Park). A recreational trail around the perimeter of the lake provides physical fitness activities and wildlife viewing. There are numerous pavilions located along the trail, two canoe launches, and a lakeshore campsite.

Lake Rogers is an isolated lake with little to no surface water inflow. The lake has a small outlet located on the southwest side of the lake under Race Track Road; however, the lake stage elevation has not met the discharge elevation for any time after 1961.

The Florida Lake Gazetteer (Florida Board of Conservation 1969, Shafer *et al.* 1986) lists the lake area at 93 acres. The United States Geological Survey 1956 (photorevised 1987) 1:24,000 Citrus Park, Fla. quadrangle map indicates a water level elevation of 36 ft above mean sea level. This elevation corresponds to a lake surface area of 87 acres, based on a topographic map of the basin generated in support of minimum levels development (Figure 3). At a high or near full elevation of 40.0 ft NGVD (Figure 3) the lake comprises 100.8 acres.

Data used for production of the topographic map were obtained from Light Detection and Ranging Data (LiDAR) and from bathymetric data collected with both sonar and manual measurements. The bathymetric data was collected by a Florida licensed survey contractor of the District using hydrographic techniques outlined by Army Corp of Engineers, publication EM 1110-2-1003. The topographic map of the basin indicates Lake Rogers is irregularly shaped comprised of three basins, one main basin and two secondary lobes. Overall the lake is shallow with an average depth of 10.9 feet at a lake stage of 40.0 ft NGVD (Figure 3), but has moderately deep pools within the center of main basin with a maximum depth of 26.7 feet. There are a number of sinkhole features (circular depressions or sinks) around the perimeter of the lake. During a recent site visit in November 2012, two small subsidence depressions (3 feet in diameter) were observed along the upward fringe of a sink basin located along the east shore. The depressions appear recent due to steep edges and young pine trees within and around the depressions.

There are no surface water withdrawals from the lake permitted by the District. There are, however, several groundwater withdrawals in the vicinity of the lake, including those associated with the Cosme-Odessa wellfield. Several wells are located in close vicinity to the lake. During the El Niño periods in 1997/1998 and 2002/2003, the lake was augmented with water pumped from Pretty Lake through Horse Lake and Lake Raleigh (Wylupek 2001) to test the feasibility of augmentation with surface water during wet periods.

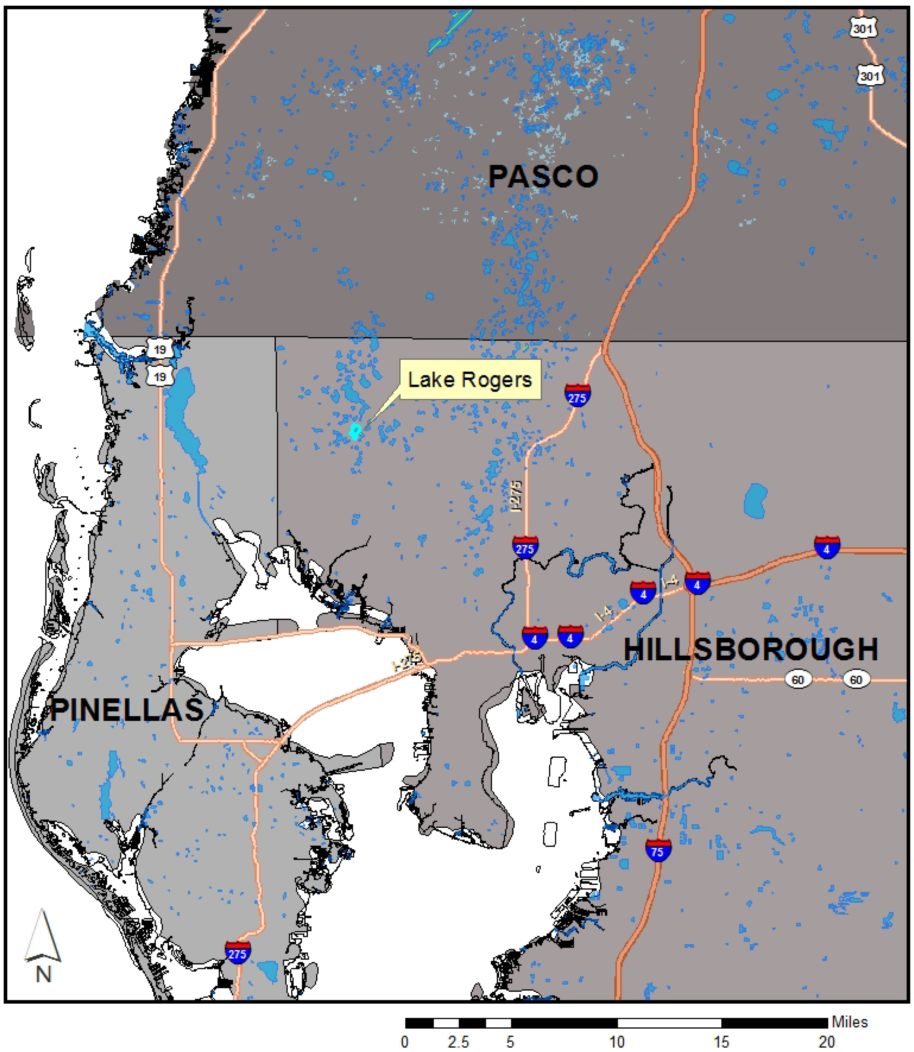


Figure 1. General location of Lake Rogers in Hillsborough County, Florida.

Figure 2. Location of District lake gages and vegetative indicators at Lake Rogers, Hillsborough County, Florida.

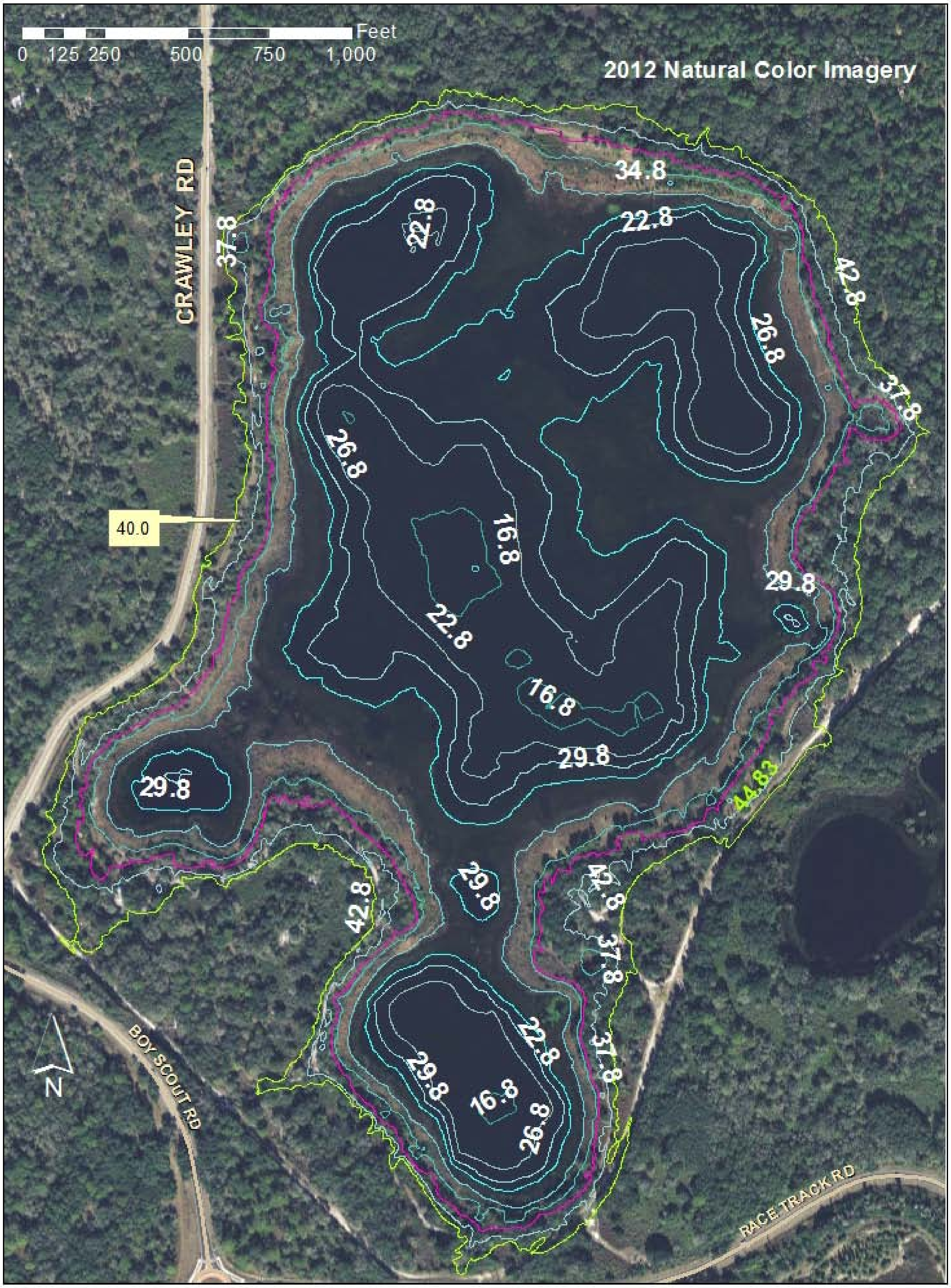


Figure 3. Approximate bottom elevation contours (as ft NGVD) within Lake Rogers, Hillsborough County. Contours were prepared using a combination of hydrographic survey (Peters 2012) and District LiDAR land surface elevation data.

Control Point Elevation and Structural Alteration Status

Information about the control elevation and structural alteration status is used during the development of minimum levels. 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). Structural alteration status is determined by determining whether any man-made alterations has occurred that alter the lake's ability to reach its historical highs. In most cases structural alterations involve drainage features that were constructed to reduce potential flooding impacts to surrounding homes and development. The minimum level process must also consider the elevations of existing structures (including residential and commercial building) within the immediate lake basin and along connected surface water features, so that flooding concerns are factored into the minimum level process.

The control point was determined by reviewing surveyed elevation data of outlet conveyance systems. A 24 inch culvert at an elevation of 43.49 ft NGVD located under Race Track Rd at the south end of the southern lobe of the lake is the control point for the lake; however, outflow from the lake has not occurred since the Hurricane Donna period in 1960-1961, some 52 years ago. The maximum stage achieved since1961 was approximately 40.0 ft NGVD.

The extent of structural alteration was determined by reviewing surveyed elevation data (see Table 1, Appendix A) and by reviewing a digital elevation model (DEM) of the lake watershed and lake basin produced from LiDAR. No significant drainage conveyance systems were observed within the DEM and the elevation of the outfall culvert under Race Track Road was significantly higher than the peak stage of the lake recorded over the past 52 years. Based on the review of the elevation of the surveyed structural features and DEM, Lake Rogers was determined to be a closed basin lake with no surface water structural alterations. Although the lake is not considered to have undergone surface water alterations, subsequent sections in this report and that of the hydrologic modeling report (Hancock and McBride 2013) indicate that structural alterations have occurred to the leakance properties of Lake Raleigh.

Groundwater Withdrawals and Impact Assessment

Lake Rogers is located within one of the first established wellfields in the District, which started production in 1930. In the 1950s, the wellfield was expanded by installing additional production wells along Gunn Highway to the north of the original wellfield. The wellfield produced roughly 3 million gallons per day (mgd) in the early 1930's and steadily increased production to roughly 21 mgd by the early 1960s (Figure 5). Production of the wellfield decreased significantly starting around 1963 and then varied widely from 1963 to the mid 1970s ranging between 4 mgd and 22 mgd since 1963. By the mid 1970s, the development of the Section 21 wellfield, also in Northwest Hillsborough County to the east of the Cosme-Odessa wellfield, allowed withdrawals at the Cosme-Odessa wellfield to be reduced to rates between 12 mgd to 14 mgd. Current withdrawal rates at the wellfield have averaged approximately 6 mgd.

An analysis of water use from 1992 to 2006 indicates there are significant withdrawals within the immediate vicinity of the lake (Figure 4) based on metered use of all users within the area. The cumulative average monthly water use between 1992 and 2006 within 1, 2, and 3 miles radius of the lake was 6.1 mgd, 8.3 mgd, and 10.4 mgd, respectively. The cumulative average monthly groundwater withdrawals extending out to 4, 5, and 6 mile radius is 16.8, 22.6, and 46.4 mgd, respectively. Modeled drawdowns predicted through the Integrated Northern Tampa Bay (INTB) model (Guerink and Basso, 2013) indicate that there is significant drawdown in both the water table and underlying Floridan surrounding Lake Rogers, Raleigh, and Horse.

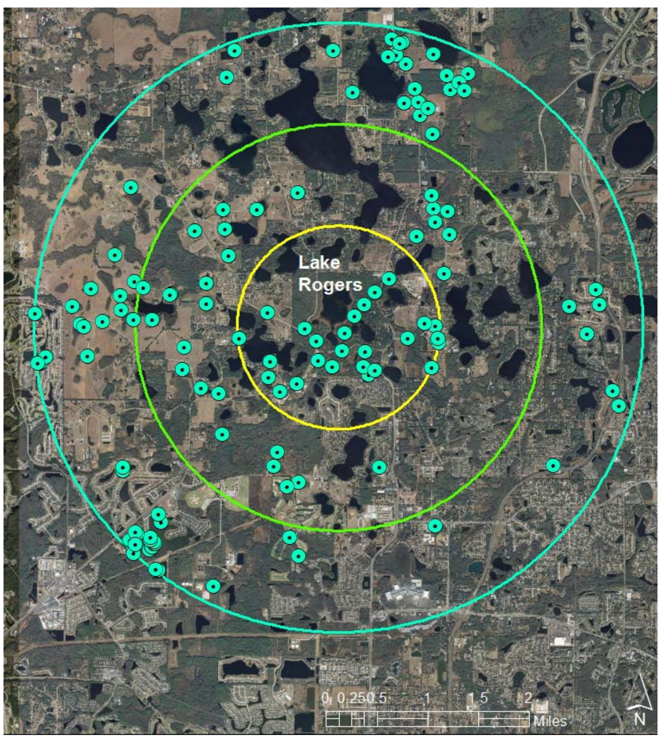


Figure 4. Permitted groundwater withdrawals within one, two, and three miles of Lake Rogers, Hillsborough County.

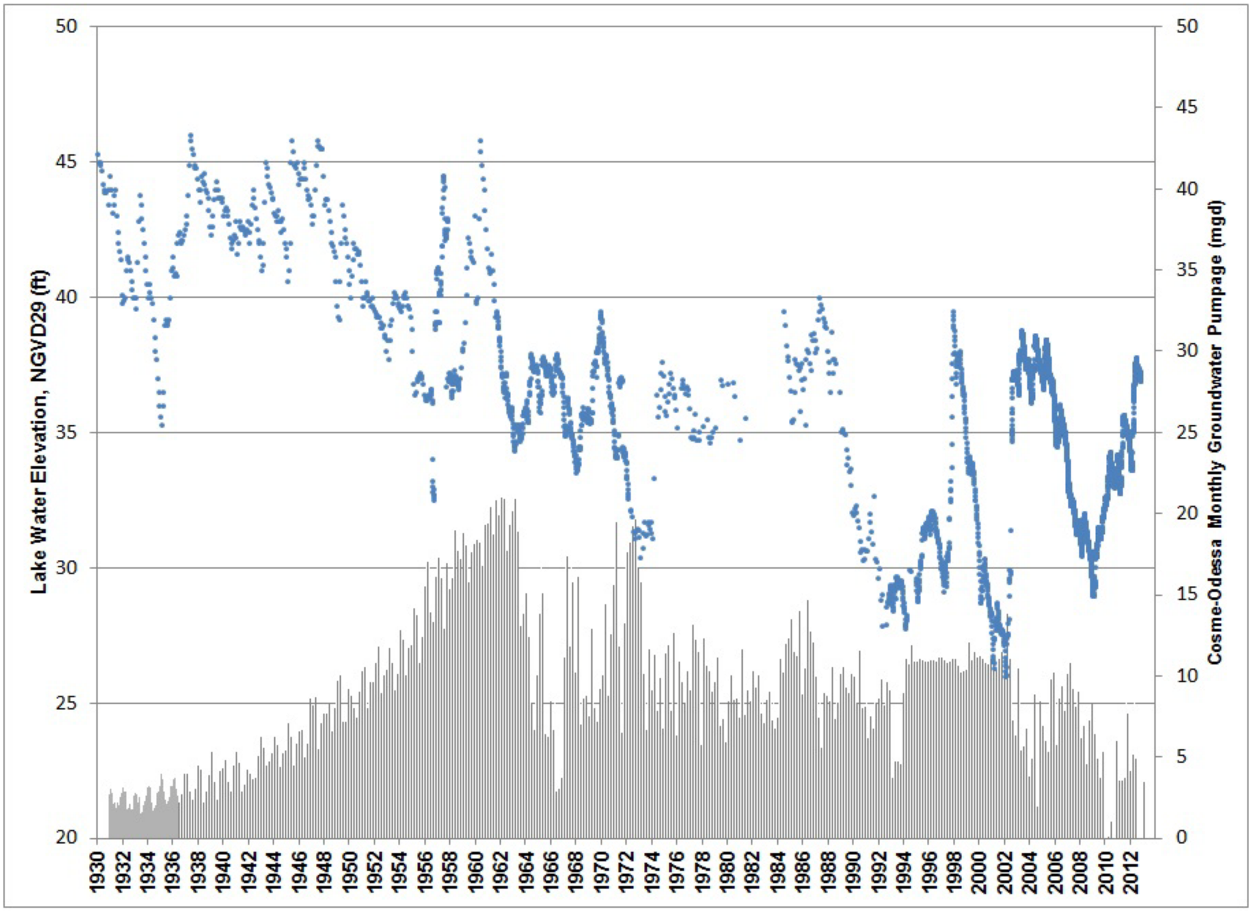


Figure 5. Daily surface water elevations (ft NGVD) through June 2012 for Lake Rogers and monthly groundwater pumpage (mgd) withdrawal from the Cosme-Odessa Wellfiell from 1932 until 2012.

Lake Stage Data and Exceedance Percentiles

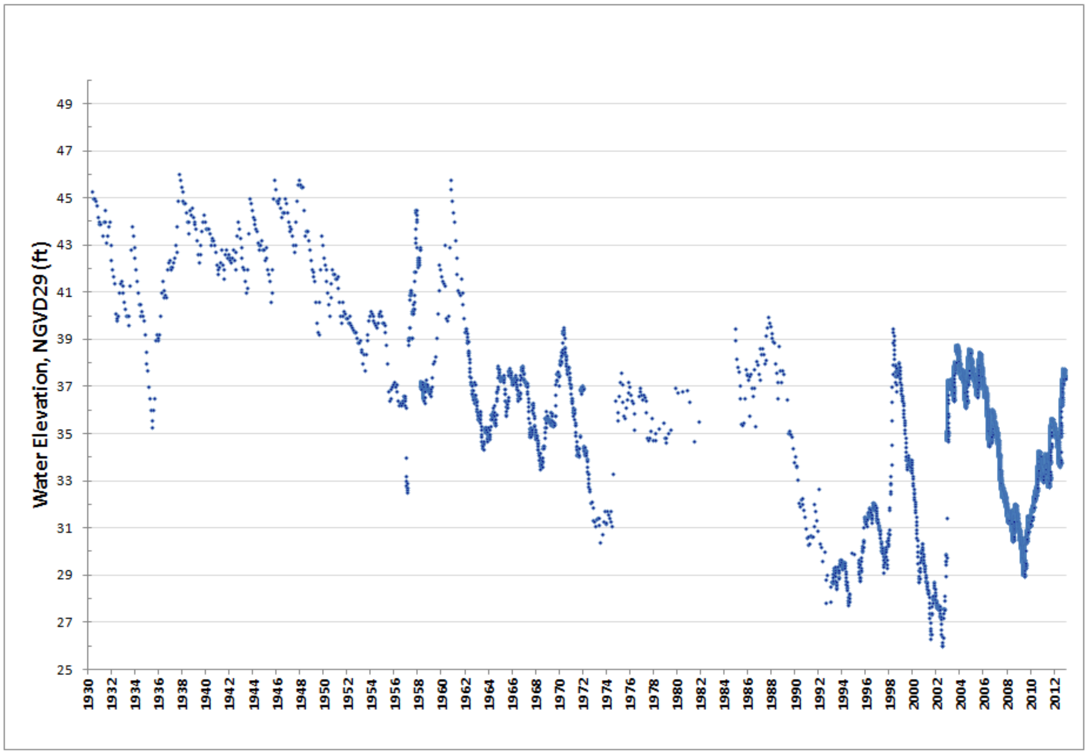
Lake stage data, *i.e.,* surface water elevations for Lake Rogers relative to ft NGVD were obtained from the District's Water Management Information System (WMIS) data base (Site Identification Number 19862, 19863, and 20007 respectively, see Figure 2 for the location of the SWFWMD lake water level gages). There is an 80-year period of record (POR) for lake stage data on Lake Rogers with the POR extending from May 1930 through present day. Although lake stage data is available starting in the 1930s, it’s important to note that all lake stage data were collected after groundwater withdrawals from the Cosme-Odessa wellfield began. The lake stage data is depicted in the hydrograph shown in Figure 6 below.

The frequency of lake stage recordings varied through time from 1930 to 2002. Monthly measurements were completed from 1930 to 1956. Starting after 1956 data collection frequency varied from one to six times per month. The frequency of data collection increased to hourly in January 2003 with the deployment of an automated stage recorder (Supervisory Control and Data Acquisition or SCADA system).

The highest surface water elevation recorded during the POR was 46.0 ft NGVD occurring in September 1937. Similarly, a high stage at 45.8 ft NGVD was recorded in September 1960 after Hurricane Donna. The lowest surface water elevation of 26.0 ft NGVD was observed in June 2002 during a very low rainfall period that affected many central Florida lakes. A long term decline is evident within the hydrograph over the 80 year period indicating both impacts from groundwater withdrawals and perhaps climate. The vertical fluctuation in lake stage is also greater within Lake Rogers than other lakes within the northwest Hillsborough County region. A 14-foot range between the highs and lows was observed and is indicative of groundwater pumping impacts.

The hydrograph illustrates two different water regimes over time with a shift downward occurring in the 1950s or 1960s. As a result of the regime shift, lake stage statistics calculated from the entire period of record are substantially higher than those calculated using only stage data after the shift. For example, the 50th percentile or median of the lake stage from 1930-2012 was 37.3 ft NGVD versus 34.7 ft NGVD for 1966-2012 (Table 2) for a difference of 2.6 feet. The shift in the water regime is believed to be due to an increase in leakance properties within the lake basin as described in the summary of water budget model developed for Lake Rogers (Hancock and McBride 2013). Based on a review of the lake hydrograph the change in leakance occurred sometime between the late 1950s to the mid 1960s. During this time period a significant increase and reduction in groundwater withdrawals from Cosme-Odessa wellfield also took place as indicated within the plot of the withdrawal quantities (Figure 5). It is possible that the physical stress associated with increasing pumpage rates and additional surface storage at flood elevations (Hurricane Donna event) altered leakance properties between Lake Rogers and the Upper Floridan Aquifer System, such as through sinkhole activity. There are no know drainage alterations (no positive outfall) during this period that could be associated with the precipitous shift in lake stage. Due to the physical alteration associated with the change in leakance properties, Lake Rogers can be considered as a structurally altered lake, since these man-made alterations prevent the lake from reaching its historical highs and the lower stage regime has persisted through time to the present period.

Although the change in leakance properties likely occurred over a period of time, a specific year was selected to estimate a post-shift period for calculating stage statistics representative of post structural alterations. The post shift data statistics were also used to assess changes in the vegetation communities around the lake that have taken place over the past 46 to 55 years. Review of historical imagery and photographs taken at the lake and tree coring data were also evaluated for this time period.



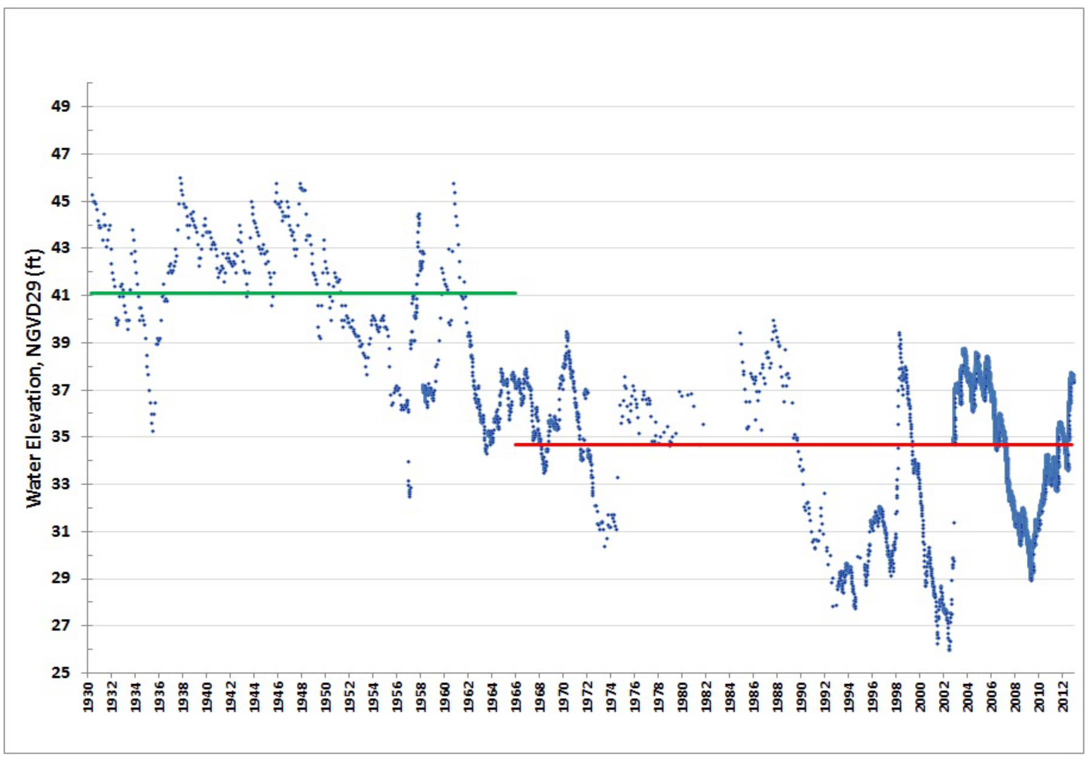


Figure 6. Top: Daily surface water elevations (ft NGVD) through June 2012 for Lake Rogers; and Bottom: Daily surface water elevations with median lake stage for 1930 to 1965 (green line), and for 1966-2012 (red line). Data source included SWFWMD WMIS site ID's 19862, 19863, and 20007.

The shift in the lake stage regime is apparent when comparing percentile statistics between the pre-shift (1930-1965) and post-shift periods (1966-2012). The median lake stage for the early period was 41.1 versus 34.7 for the later period considered (Table 2). Both medians are plotted in the bottom half of Figure 6 as horizontal lines. The P10 (90^{th} percentile) of the early data was 44.4. This elevation is fairly consistent with the normal pool elevation at 44.9 ft NGVD, measured by Leeper (2003). The P10 for the recent data was 37.8 ft NGVD. The P90 (10^{th} percentile) for each period was 36.1 and 29.4 respectively. The difference between the respective percentile elevations ranged between 6.4 and 6.7 feet (Table 2).

For the time period of 1966 to 2012 a peak stage of 38.97 was recorded in September 1987, and a similar peak stage of 39.48 ft above NGVD occurred in March 1998 as a result of the augmentation of the lake with water pumped from Pretty Lake through Lakes Horse and Raleigh (SWFWMD 2003 and Wylupek 2001). The lowest surface water elevation of 26.0 ft NGVD was observed in June 2002.

Table 2. Lake stage exceedance percentiles for the time period of 1930-1965 and 1966-2012.

Exceedance Percentiles	Observed Lake Stage in ft NGVD (1930-1965)	Observed Lake Stage in ft NGVD (1966-2012)	Difference as feet
P10	44.4	37.8	6.6
P50	41.1	34.7	6.4
P90	36.1	29.4	6.7

Lake Stage Decline, Vegetation Changes, and Recreational Uses

The vegetation communities surrounding Lake Rogers have been in transition over the past 46 to 55 years as a result of clear cutting activities in the 1950s and the onset of the lower lake stage regime in the 1950s to 1960s. The vegetation communities in place today no longer depict the historic lake stage that occurred prior to groundwater withdrawals in the region. Almost all of the cypress trees that are indicative of the normal pool (ordinary high stage) have either died off or were logged over the past 80 years. The base elevation of a single cypress tree on Lake Rogers and the base of several cypresses on nearby Lake Raleigh were used to establish normal pool at 44.9 NGVD (Leeper 2003) on Lake Rogers.

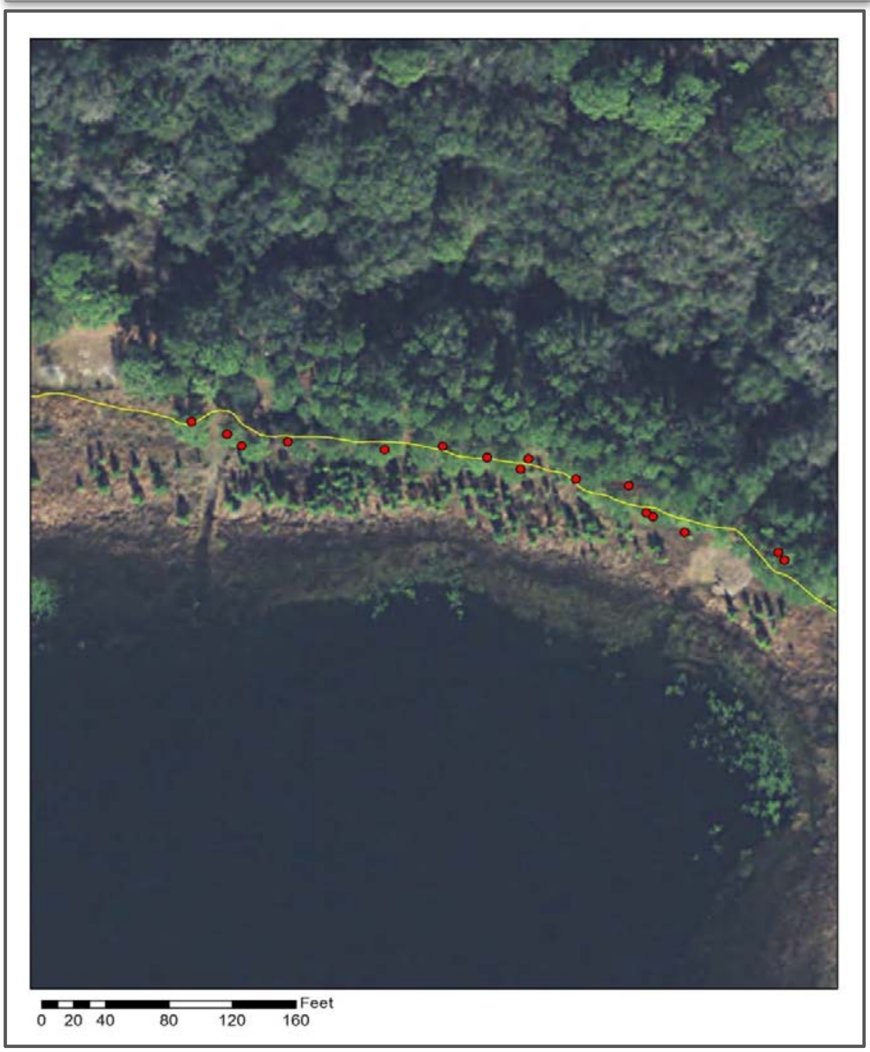


Figure 7. Top: Nov. 2012 photo of stand of slash pine trees 20 to 26 years old and smaller pines 4 to 6 years old; Bottom: 2012 Aerial view with yellow contour line and red dots depicting the lakeward line of pines shown in the photo**.**

Figure 8. Large trees located down gradient of the normal pool elevation. Top: large live oak (34") located along recreational trail; and Bottom: large laurel oak (36") located in camping area.

During the post shift time period, upland plant assemblages have encroached downward into the lake basin since the normal pool is no longer achieved. Normal pool elevations are often correlated to the long term P10 elevation (upper ten percent of the stage data). The P10 determined for the post-shift data period is 6.6 ft lower than the P10 of the pre-shift period indicating that the stage duration and frequency of normal pool elevation is no longer achieved (Table 2). Over time, the region below the normal pool elevation has developed into an assemblage of mature upland plants since the normal pool elevation has not been achieved.

Dense stands of slash pine (*Pinus elliotti*) have encroached into the former lake basin, especially along the north side of the lake where the lakeward line of slash pines occurs at an elevation of 37.8 to 38.0 NGVD (Figure 7). The transitions from herbaceous upland or wetland species to mature pine trees occurring in this elevation range were found to be coincident with historic scarp features measured at 38.64 NGVD (unpublished field data, Emery 2012). Numerous laurel oaks, live oaks, and water oaks with estimated ages of 50 to 60 years are also found in close proximity to the lake shore, ranging at base elevations from 39.5 NGVD to 43.6 NGVD, all below the normal pool (Figure 8).

Vegetation surveys conducted in 2012 found indicators of a transitional normal pool associated with the lower lake stage. In the case of Lake Rogers a transitional normal pool is defined as the approximate boundary between wetland plants and upland plants that indicates the post-shift average high water mark. The elevation of the transitional normal pool was determined by biological indicators representing approximate post-shift P10 conditions. Saw palmetto (*Serenoa repens)* shrubs were found scattered lakeward of the tree line around the perimeter of the lake (Figure 9). The average elevation of the shrubs (n=5) was 37.7 ft NGVD. The lakeward line of 20 to 26 year old slash pines was 38.0 ft NGVD (Figure 7). These elevations are consistent with the P10 (90^{th} Percentile) at 37.8 ft NGVD calculated for the post-shift data period (1966 -2012).

Based on the recent survey of vegetative indicators a transitional normal pool was set at 37.9 ft NGVD. The topographic contours equivalent to the elevation of the transitional normal and normal pools are shown in Figure 10. The area between these two contours shows the transitional vegetation zone where both the encroachment of upland vegetation has occurred, replacing former lake fringing wetlands. Based on the stage area completed for the Lake Rogers basin, the transitional zone comprises approximately 29 acres. This calculation is based on the difference between the stage areas of the normal pool and transitional normal pool.

Eighty percent of the recreational trail around the lake perimeter is located within the forest transition zone or in other words, below the elevation of the Normal pool (44.8 ft NGVD). Recreational facilities within this zone also include three picnic pavilions, a lakeshore campground, and several observation benches located along the trail. Several of these features occur at low elevations. There are approximately three 100 foot segments of the trail at an elevation of 39.5 ft NGVD. One of the picnic pavilions (named Osprey) located next to the lake is also at the same elevation. Four additional low spots in the trail occur at 40.5 ft NGVD. Consideration of the elevation of recreational facilities located down-gradient of the Normal pool was included in the development of the levels to assess potential flooding.

The minimum levels for Lake Rogers also mitigates for potential flooding of the transitional upland assemblage since the existing upland vegetation has both aesthetic and habitat value. For example, a large oak tree located along the recreational trail (Figure 8) at an elevation of 40.4 ft NGVD and several nearby smaller oaks ranging in elevations from 39.1 ft NGVD to 40.6 ft NGVD could be injured or killed as a result of sustained water levels above these the base elevations for durations greater than 3 to 4 months. A proposed minimum level lake stage regime with P10 at or above the base elevation of these trees would likely result in tree death and a change to upland plant assemblage. A substantial area of slash pines located along the north side of the lake would also likely experience mortality during periods of sustained inundation. The elevation of the lakeward line of slash pines ranges between 37.8 ft NGVD and 38.0 ft NGVD (Figure 7). A survey profile completed through the pines indicates pine trees ranging between 20 and 26 years old occur from the 37.8 ft NGVD up slope to approximately 41 ft NGVD. Older slash pines were found at elevations of 40 ft NGVD upgradient to the elevation of the Normal Pool. Large longleaf pine (*Pinus palustris*) were found upgradient of the Normal Pool (Leeper 2003). Slash pines are generally less sensitive to periods of inundation than oak trees; however, it is unlikely that they would survive extended periods of inundation greater than 6 months. For example, small 4 to 6 year old slash pines growing within the Lake Rogers basin at average elevation of 35.7 ft NGVD died after 3 to 4 months of inundation during the recent 2012 high lake levels (Figure 11).

A proposed minimum level lake stage regime with a P10 established at the base elevation of lakeward pines (38.0 ft NGVD) would not likely cause mortality of pine trees The post shift data (1966-2012) indicate a stage of 38.0 ft NGVD occurred 7.8 percent of the time, and during this time no pines trees have died upgradient of 38.0 ft NGVD. A P10 established at base of the lakeward pine trees (38.0 ft NGVD) would allow for flooding of the three trail segments and the low pavilion at 39.5 ft NGVD to occur only approximately one to two percent of the time and would have limited to no affect on the use of the trail over the long term. Based on the current lake stage the elevation of the low pavilion (39.5) was exceeded less than one percent of the time. The low return frequency at these elevations has resulted in the expansion of three invasive species below the elevation of the transitional normal pool, including cogongrass (*Imperata cylindrical)*, Melaleuca trees (*Melaleuca quinquenervia)*, and Brazilian pepper-tree (*Schinus terebinthifolius)*.

A proposed minimum level lake stage regime with a P10 slightly greater than the elevation of lakeward pine trees (37.8 to 38.0 ft NGVD) would likely result in some mortality of the 20 to 26 year old pine trees located along the upland plant edge; however, the low incidence of tree mortality would be outweighed by benefits of controlling invasive plants and exotic species through inundation. A minimum level regime with a P10 at or greater than 39.5 ft NGVD would allow for the flooding at three locations of the recreational trail and the low picnic pavilion at least ten percent of the

Figure 9. Examples of saw palmetto found within the lake basin indicative of a transitional normal pool. Elevations of the measured saw palmetto ranged between 37.56 and 37.96 ft NGVD (n=5), median 37.7 ft NGVD.

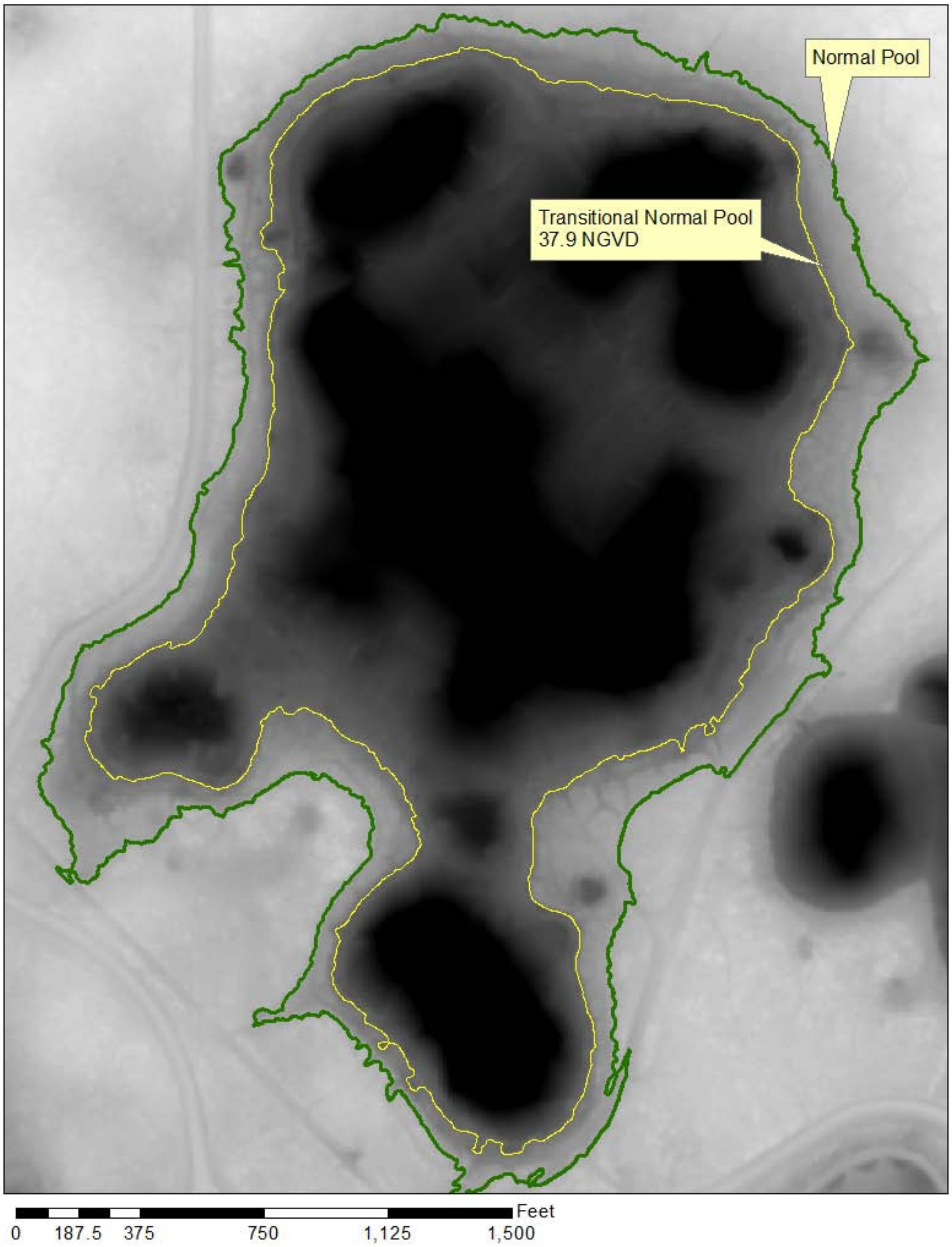


Figure 10. 44.8 ft NGVD (green) and 37.9 ft NGVD (yellow) topographic contours consistent with the elevation of the normal pool and transitional normal pool. Contours were derived from LiDAR.

Figure 11. Stressed and dead young slash pines within Lake Rogers basin after the recent period of sustained inundation in 2012-2013, date January 29, 2013.

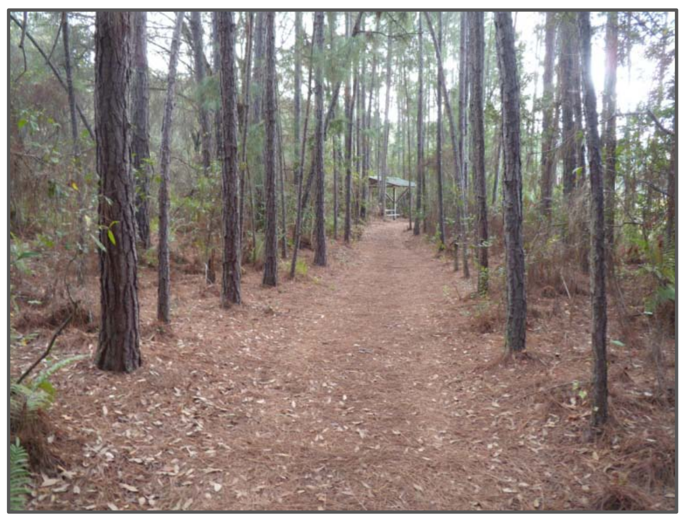


Figure 12.   Picnic pavilion (left) subject to flooding at lake stage of 39.5 ft NGVD and segment of trail (right) subject to flooding at a lake stage of 39.5 to 40.5 ft NGVD.

time (Figure 12), but would also provide natural maintenance of the woody understory. A P10 established at 40.5 ft NGVD would allow flooding of the trail at seven locations at least ten percent of the time (Figure 12) and would significantly reduce use of the park facilities.

Littoral Zone and Stage-Area Relationships

The herbaceous wetland vegetation found within the shallow fringes around the lake edge, called the littoral zone or emergent, are vital habitat for fisheries, waterfowl, wading birds, and other water dependent bird species (Hoyer and Canfield 1992, Emery 2009). The littoral zone also functions as nutrient sink providing a buffer for loading from the surrounding uplands. Prolonged low water levels can reduce littoral habitat through the exposure and drying of the lake sediments, loss of aquatic vegetation, and eventual encroachment of terrestrial vegetation into the lake basin. The significance of the loss depends upon the morphology of the lake basin including the shoreline slope and lake depth. An analysis of 295 lakes within the District found that regions of lakes with water depths of up to approximately four feet support herbaceous wetland vegetation (Leeper et al. 2001). Lakes with broad shallow gently sloping shoreline zones can undergo significant losses in littoral habitat due to prolonged low water levels. A much smaller reduction in littoral habitat occurs in lakes with steep shoreline zones and a general morphology described as bowl shaped.

An increase in aquatic macrophytes can occur during prolonged low water levels in regions of lakes that drop to less than 4 feet. Shallow gentle sloping basins (flat morphology) or basins with raised plateaus intermixed with deep zones can support extensive littoral vegetation during low periods. Within these types of lakes the littoral zone can expand as aquatic macrophytes expand across stable shallow zones. The increase in emergent macrophytes typically coincides with a loss of limnetic habitat. Lakes that remain shallow across the entire basin (flat morphology) during dry periods can become dominated by aquatic plants and may lose open water needed to maintain fisheries and recreational uses. Natural cycling between expanding and contracting emergent zones and limnetic zones is common in shallow basin wet prairie lakes and within some closed basin sandhill lakes, as observed on Lakes Bonable, Little Bonable, and Tiger in Marion County (Kolasa *et al* 2012).

The shape of Lake Rogers is irregular with three basins, one main basin and two smaller basins or lobes on the south side of the lake. Shallow zones are found between the main body and two smaller lobes. The shape of the lake bottom within the main basin is irregular with two raised ridges or shallow zones that extend into the middle of the lake (Figure 13: Left) ranging in elevation from roughly 29 ft NGVD to 32 ft NGVD.

The shallow zones have become exposed during low level periods (Figure 14). During extended periods of low levels these portions of the lake bottom have been subject to encroachment of terrestrial plants such as broom sedge (*Andropogon virginicus*) and dog fennel (*Eupatorium capillifolium)*, as well as woody plants like wax myrtle (*Myrica cerifera)* and Melaluca (*Melaleuca quinquenervia*). Encroachment of woody plants and the degradation of the littoral zone appears to occur after the lake stage drops below the littoral base elevation of 30.0 ft NGVD for extended periods (Figure 14). This elevation of the base of littoral zone was determined by reviewing aerial imagery, historical and current field photographs, stage hydrograph, the digital elevation model (DEM), DEM bottom slope, and bottom profiles developed from the lake basin DEM using the ArcMap 3D Analyst extension. A review of historical imagery and on-site photographs indicates a significant reduction in emergent plants occurred during the time periods of 1991-1995 and 2000-2003 when the lake stage dropped below 30.0 ft NGVD for extended periods.

The shallow zones within the main body of the lake and between the basins have supported growth of broad stands of emergent aquatic plants, during moderately low levels when the lake has remained above 30.0 ft NGVD. Based on the lake stage area

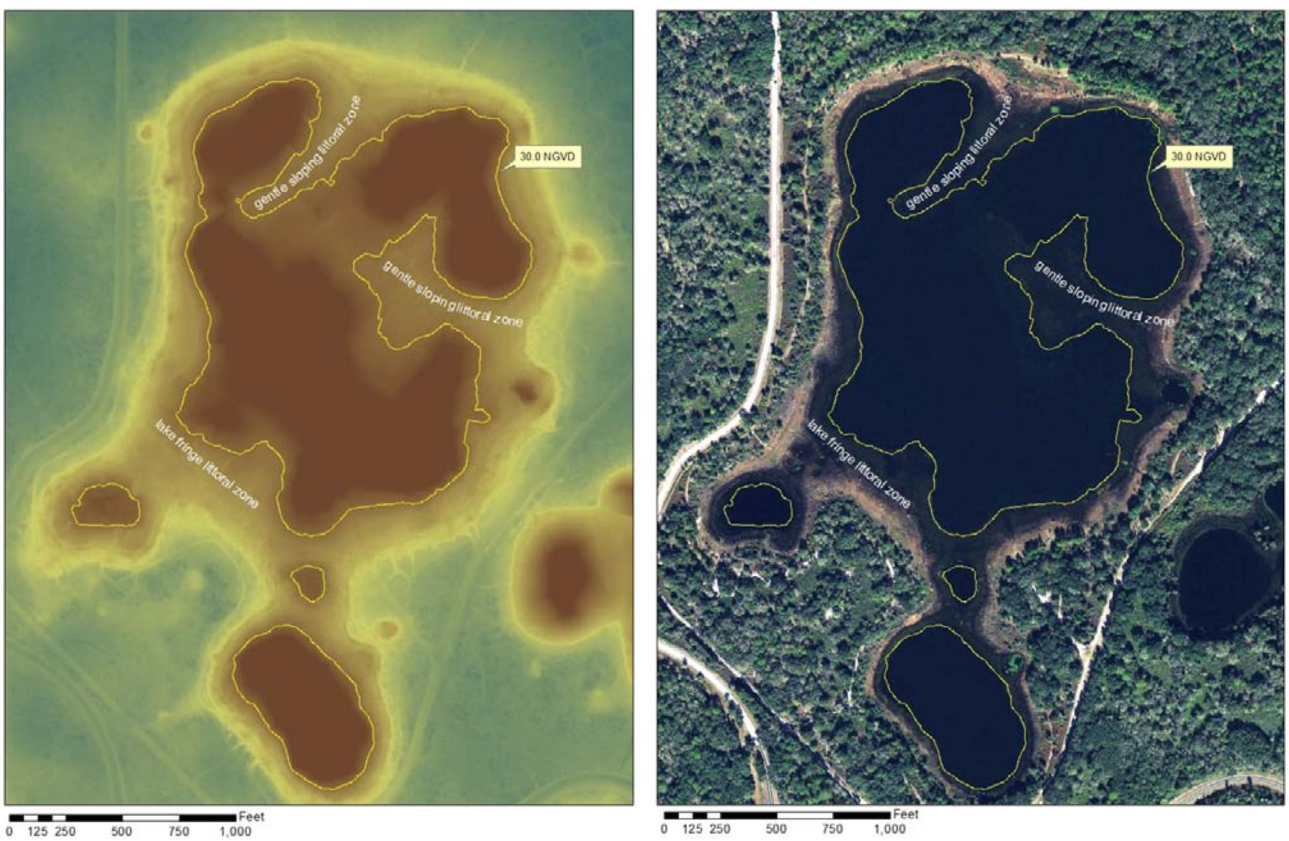


Figure 13. Left: Digital elevation model of Lake Rogers showing intermixed deep pools and gently sloped shallow ridges supporting emergent vegetation, and Right: Recent aerial view of Lake Rogers (Jan 2012) showing emergent vegetation within shallow zones (< 4 feet deep).

Figure 14. Top: 2000 aerial view of lake showing exposed lake bottom void of littoral vegetation, and Bottom: Photograph (Jan 2002) of encroaching terrestrial vegetation into littoral zone.

relationship developed from bathymetric model of the lake, Lake Rogers supports a larger area of littoral zone at moderately low levels. The relationship between lake stage and the expected area of emergent vegetation (herbaceous wetland) determined for Lake Rogers is shown in Figures 15 and 23. The area of emergent plants increases as the area of water with depth less than 4 feet also increases. The increase in littoral zone continues until the lake stage drops to approximately 32 NGVD. Although the shift in the lake stage regime (starting in the mid 1960s) allowed for a loss of forested wetlands and a transition to upland forest, the lower lake stage has allowed for an expansion of the littoral wetland at various time periods during the current data period (1966-2012). For example, the lake stage remained stable from 1976 to 1981, ranging between 34.9 and 37.4 NGVD as shown on the lake hydrograph (see Figure 6). Photographs of the lake taken in 1977 show a broad littoral zone that appears to be comprised of rush species currently found in the lake today (*Fuirena spp.*) (Figure 16, Top).

Based on field visits and review of aerial imagery the littoral zone has re-established as dense continuous stands over the past three years, as the lake stage has recovered during the recent above average rainfall and reduction in withdrawals from the Cosme-Odessa wellfield. The littoral zone is predominantly comprised of large stands of *Furiena scirpoidea* (Figure 16, Bottom) with smaller areas of intermixed maidencane (*Panicum hemitomon),* and numerous other wetland plant species. A recent vegetation assessment completed on the lake by the Florida Center for Community Design and

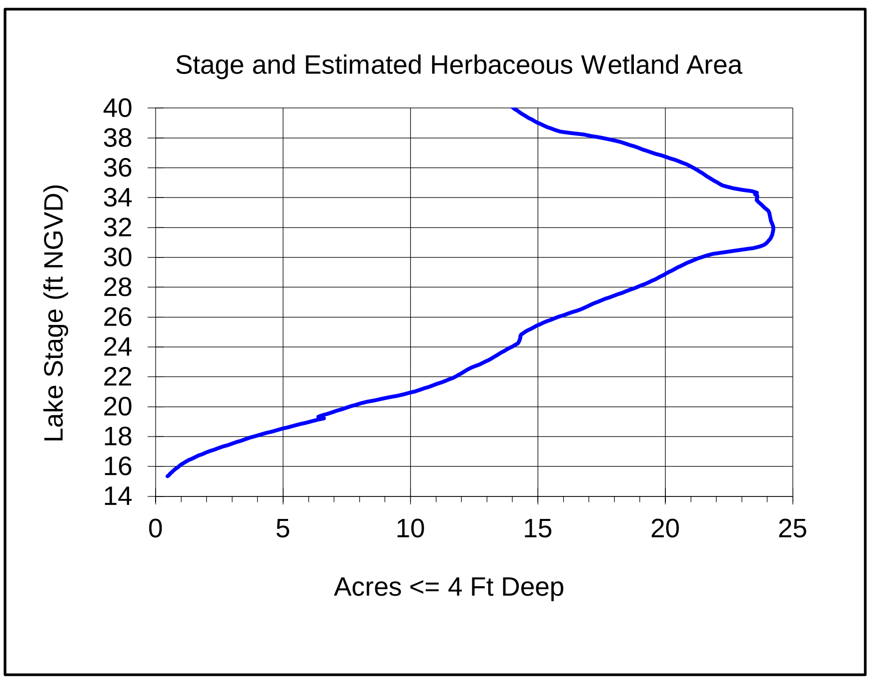


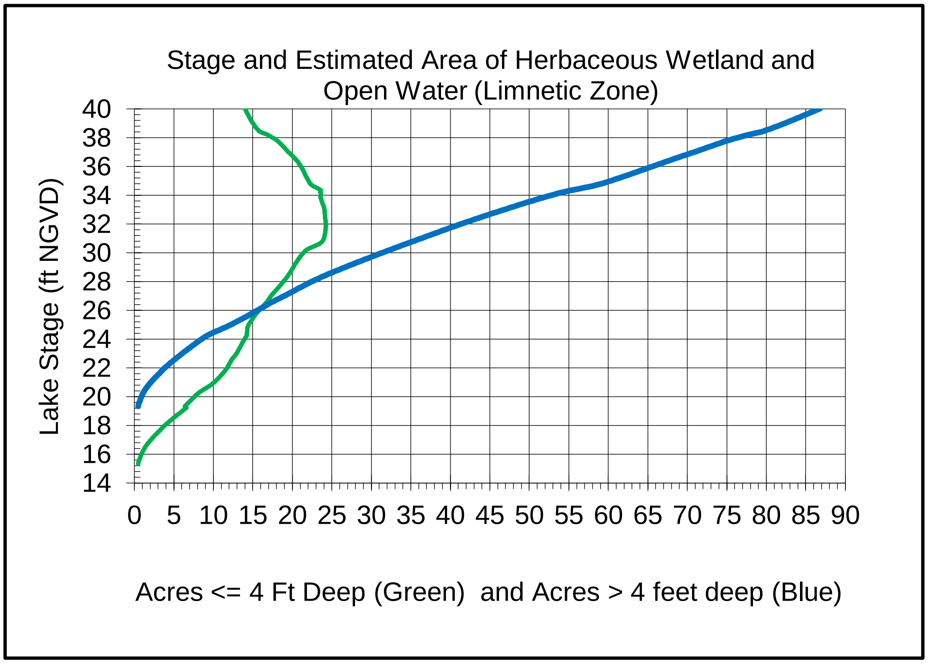
Figure 15. Top: Estimated area of herbaceous wetland (emergent vegetation) area in Lake Rogers as a function of lake stage (water surface elevation)

Figure 16. Top: 1977 photograph of expansive littoral zone comprised of *Fuirena spp* during stable lake stage, and Bottom: 2012 photograph showing recent restablishment of *Fuirena spp.*

Research (Eilers and Herzog 2011) found 42 emergent zone plant species with the lake receiving a Lake Vegetative Index (LVI) of 73, giving it one of the highest scores in Hillsborough County. The recent higher levels have also been observed to be beneficial to the lake system by reducing encroaching woody vegetation such as young slash pines and also invasive plants (specifically cogongrass, *Imperata cylindrical*).

The effect of more prevalent native emergent plants within Lake Rogers was considered. It would not restrict recreational uses, since no homes are located around Lake Rogers and watercraft use is limited to canoes and kayaks. The current passive recreational uses that take place on the surrounding park land such as wildlife viewing, bird watching, and canoeing benefit from moderate areas of the emergent zones providing valuable habitat. However, the area of the littoral zone or any expansion must be balanced with the available limnetic area needed for fisheries. Additionally, the critical elevation of other habitat components of the lake system should not be offset to achieve expansion of the emergent zone. The critical elevation for connectivity needed for fish and passage between basins is 34.2 ft NGVD for Lake Rogers. Inundation over the saddle elevation between the basins is needed to maintain the habitat function of the smaller basin, although the emergent zone area would potentially expand at a lake stage maintained one to two feet below 34.2 ft NGVD.

Figure 17 (bottom) depicts both the relationship between lake stage and estimated emergent zone and the relationship to the area of limnetic (pelagic or open water) zone. Although the area of the emergent zone gradually increases with the first eight feet of stage decline, a rapid decrease occurs for the area of open water. The corresponding changes shown in the plot from 40 ft NGVD as the peak elevation to 32 ft NGVD show an increase from 15 acres to 24 acres for emergent vegetation and a decrease from 86 to 40 acres, a 54 percent reduction in open water area. A steady decline occurs in the area of littoral zone below the elevation of the base of littoral zone (30.0 ft NGVD). The corresponding open water area decreases from 86 to 30 acres, a 65 percent reduction in open water. In the case of Lake Rogers, a small increase in the area of emergent zone at these lower lake stages does not outweigh the affects of the reduction in limnetic habitat. The lake stage has dropped below 30 NGVD for three periods during the past 20 years (1992 to 2012). Stage exceedance plots for this time period indicate the stage dropped below 30.0 ft NGVD 30 percent of the time allowing exposure of the littoral shelf for approximately six of the 20 years. The 10^{th} percentile or P90 for this time period was 28.6 ft NGVD indicating the lake stage dropped below this elevation ten percent of the time. The P50 for this time period was 31.9 ft NGVD.



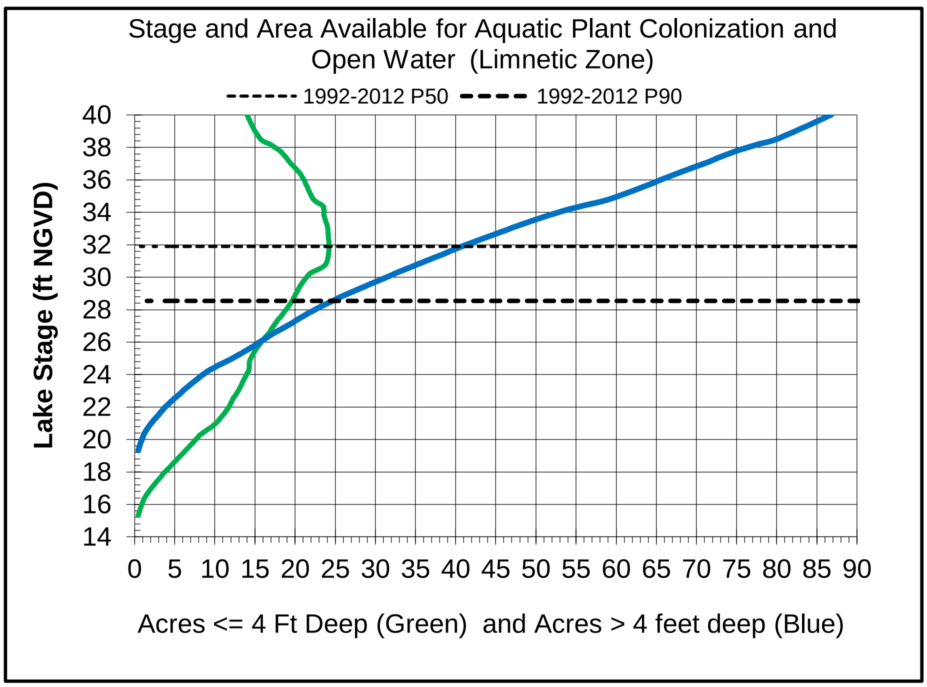


Figure 17. Top: Estimated area of herbaceous wetland and open water as a function of lake stage in Lake Rogers, and Bottom: estimated area of herbaceous wetland and open water as a function of lake stage with P50 and P90 of lake stage from 1992 to 2012 shown as horizontal dashed lines.

Previously Proposed Guidance Levels and Minimum Levels

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

Based on work conducted in 2001-2003 (Leeper 2003), the District developed recommended lake management levels for Lake Rogers (Table 3). The minimum levels were developed by applying standardized offsets developed from lake stage regime evaluated for a group of reference lakes within the Northern Tampa Bay region (SWFWMD 1999). The median range between the P10 and P50, and P50 and P90 determined for the reference lake water regime (RLWR) was 1.0 ft and 2.1 ft, respectively. These ranges were subtracted from the Lake Rogers Normal pool to determine the Historic P50 and P90. The minimum low level was determined by applying the District's category 3 lake change standards (Leeper 2006). Both the minimum low level (42.78 ft NGVD) and high low level (43.78 ft NGVD) determined with this method were well above elevations of the upland forest and park features. To mitigate for flooding concerns the levels were adjusted downward with the high minimum level proposed at 40.0 ft NGVD and a minimum level proposed at 39 ft NGVD (determined by subtracting RLWR P10 P50 difference of 1.0 from the high minimum level 40.0 ft NGVD).

The methodology used to recommend minimum levels for Lake Rogers in 2003 was a simplistic approach that did not include the development of a hydrologic model specific to the Lake Rogers and the existing hydrologic conditions. The methodology applied in 2003 made the assumption that Lake Rogers fluctuates similar to other regional lakes in the region and did not include assessing the change in leakance properties of the lake. Minimum and Guidance Levels developed using current methods will replace the proposed 2003 minimum levels upon adoption by the District Governing Board into Chapter 40D-8, Fla. Admin. Code.

Table 3. Minimum Levels proposed in 2003 for Lake Rogers, Hillsborough County, Florida

Level	**Elevation (feet above ft NGVD)**
High Guidance Level	44.88
High Minimum Level	40.00
Minimum Lake Level	39.00
Low Guidance Level	42.78

Summary Data Used for Development of Minimum and Guidance Levels

Minimum and Guidance Levels for Lake Rogers were developed using the methodology for Category 3 lakes described in Rule 40D-8.624, Fla. Admin. Code. 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 structural alterations and hydrologic stresses are stable. In the simplest of terms, the difference between Historic and Current data is that Historic data are from a period when influences of groundwater were absent or not measurable. Other factors including structural changes and long term climatic conditions are assumed to be the same as existing conditions.

Development of minimum levels for Lake Rogers was uniquely challenging since all long term data (1930 to 2012) coincided with significant groundwater withdrawals. The downward shift in the long term stage data limits the use of the long term data for modeling existing hydrologic conditions. A post-shift period (starting in 1966) associated with change in leakance properties is presented in this report to represent the structurally altered stage regime associated with the change in leakance properties. The summary statistics for the post-shift regime were related to changes in the vegetation communities around the lake and used to describe hydrologic differences that have affected the surrounding vegetation and downward shift of upland plants.

Current Data

The Current data period selected for the development of the hydrologic model was from 2002 to present. This period was selected because it represents a period of stabilized stress associated with the onset of the wellfied pumping cutbacks (see Figure 5). The pumpage reduction within the Cosme-Odessa wellfield was part of Tampa Bay Water's regional cutbacks from 150 mgd to 90 mgd. Prior to 2002 the lake was subject to wider variations in stress due to the severity of the 2001 drought and pre-cutback pumpage. Based on the lake stage hydrograph (see Figures 5 and 6) the lake stage began to recover from the record low levels experienced during the 2001 drought and conditions started to stabilize. Current data collected from Jan 2002 through December 2012 were used to calculate the Current P10, P50, and P90 (Table 4). The period used to develop the hydrologic model discussed below used a time period that included both pre-cutback and post-cutback conditions and used a less stable period with wider ranging pumpage quantities.

Modeled Historic Data

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. In the case of Lake Rogers, because the wellfield has affected water levels in the lake since before the beginning of data collection, no Historic data exist for this lake. Historic data is significant, because 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 a long-term Historic P50 (or median), P10, and P90 for the lake. If data representative of a Historic time period does not exist, or available Historic time period data is considered too short to represent long-term conditions, then a model is developed to approximate long-term Historic time period data. The development of lakes without Historic data will allow an estimate of long-term Historic percentiles, and allow for simulations of the effects of changing groundwater withdrawal rates.

Since no Historic data of any length are available, a water budget approach was chosen to model Lake Rogers (along with lakes Raleigh and Horse, which can drain to Lake Rogers under high water level conditions). A separate technical memorandum was completed (Hancock and McBride 2013) to provide an overview of the water budget model. The spreadsheet-based water budget tool includes natural hydrologic processes and engineered alterations acting on the control volume of each lake. The control volume consists of the free water surface within the lake extending down to the elevation of the greatest lake depth. A stage-volume curve was derived for each lake that produced a unique lake stage for any total water volume within the control volume.

The hydrologic processes in the HRR 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 model uses a daily time-step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels for each lake. The Lakes Horse/Raleigh/Rogers Water Budget Model (HRR) model was calibrated from 1988 to 2011, which provides a period of time that is considered long-term for purposes of determining Historic percentiles for Lake Rogers. This period also provides the best balance of using available data for all parts of the water budget and the desire to have a long-term period. It's important to note that the calibration focused on matching the long-term percentiles of the lakes, rather than short-term highs and lows.

The model calibration results are shown in Figure 18, providing a comparison of the observed data from each lake to the modeled water levels. Since the model calibration period includes a time period that the lake was augmented, the augmentation period was excluded from the model calibration period (Hancock and McBride 2013). The excluded augmentation period is shown in the bottom half of Figure 18.

Following the completion of the model calibration, Historic conditions were modeled by completing simulations of reduced groundwater withdrawal rates. The simulations used drawdowns determined through the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013) and monitor well data from both the Upper Floridan aquifer system and the surficial aquifer system. The monitor well data in the model were adjusted to reflect changes in groundwater withdrawals. To estimate lake levels during Historic conditions (without the influence of groundwater withdrawals but allowing for structural alterations), the well data in the model were adjusted to represent zero withdrawals. For the 1988 to 2011 model period, two periods of adjustment were used to reflect the cutbacks that took place at the Cosme-Odessa wellfield.

The modeled Historic stage regime representing Historic conditions was used to calculate the Historic Percentiles (Figure 19). The Historic P10 elevation, the elevation the lake water surface equaled or exceeded ten percent of the time during the Historic period, was 39.5 ft NGVD. The Historic P50 elevation, the elevation the lake water surface equaled or exceeded fifty percent of the time during the Historic period, was 36.4 ft NGVD. The Historic P90 elevation, the elevation the lake water surface equaled or exceeded ninety percent of the time during the Historic period, was 34.4 ft NGVD. The Historic percentiles along with the corresponding lake surface areas are listed in Table 4.

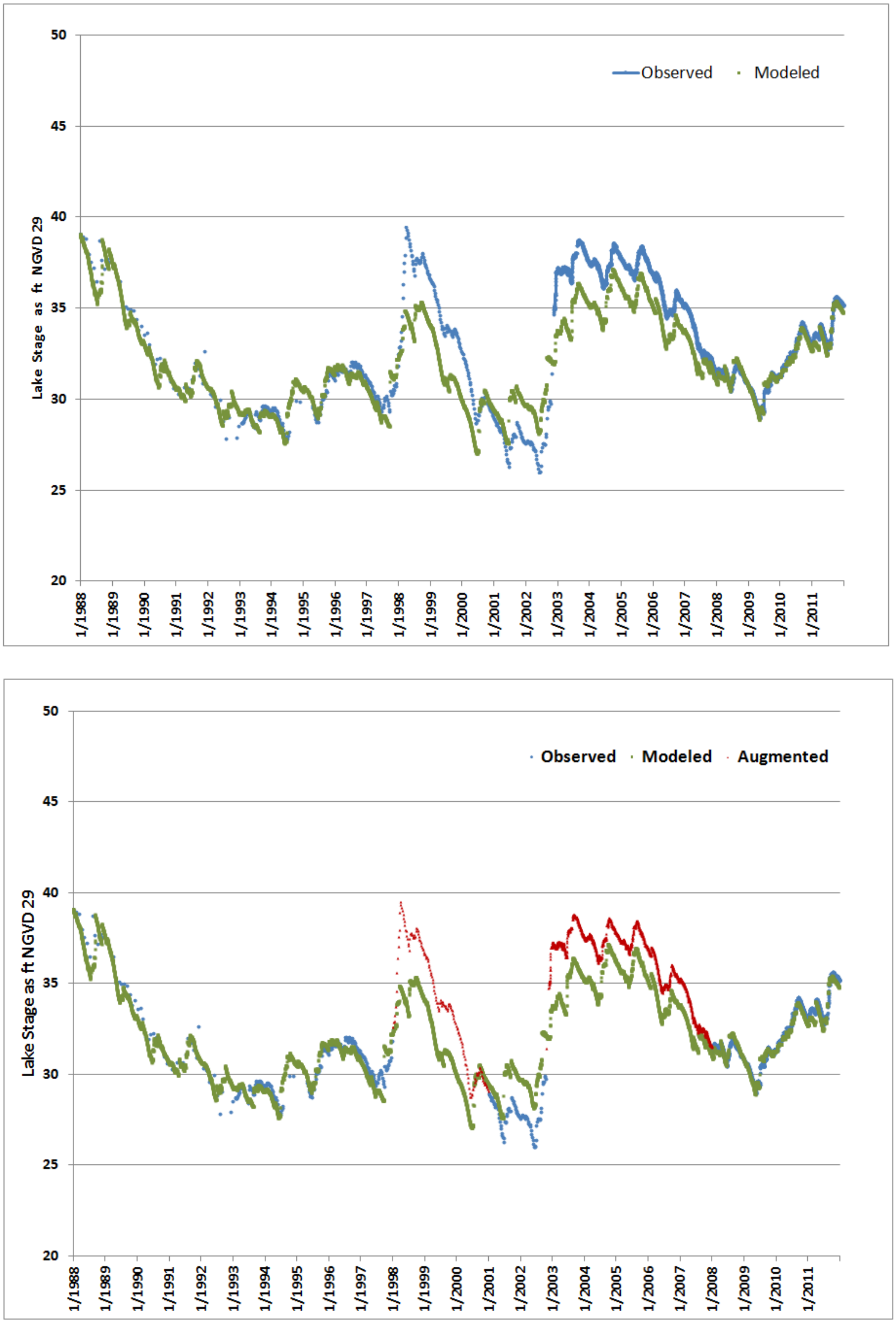
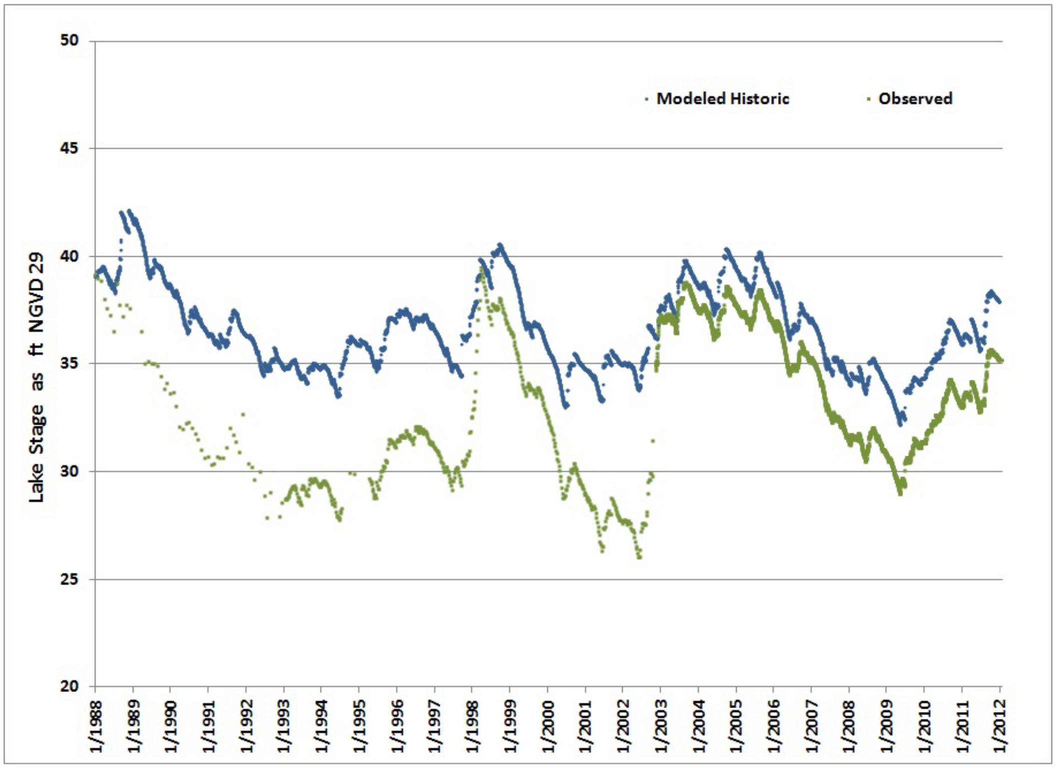


Figure 18: Top: Water budget model calibration results showing modeled (green) versus observed data (blue) and Bottom: data excluded (red) from model calibration due to augmentation period (Hancock and McBride 2013).



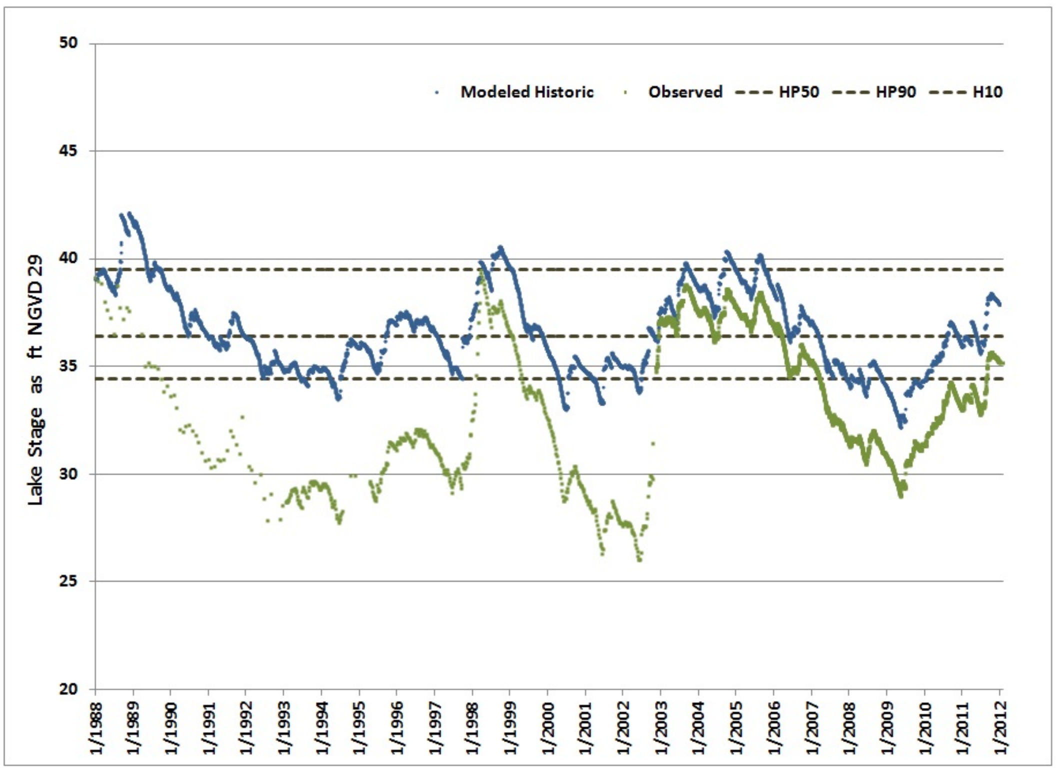


Figure 19. Top: Modeled Historic lake stage (as daily, see green points) from 1988 to 2011 and observed lake stage (as daily, see blue points) from 1988 to 2011 for Lake Rogers. Bottom: Modeled Historic lake stage and observed lake stage shown with Historic percentiles (HP10, HP50, and HP90).

Table 4. Minimum and Guidance Levels, lake stage exceedance percentiles, and control point elevations, significant change standards, and associated surface areas for Lake Rogers.

Levels	Elevation in Feet ft NGVD	Lake Area (acres)
Lake Stage Percentiles		
POR 1930 to 2012 - P10	43.5	114.9
POR 1930 to 2012 - P50	37.3	91.5
POR 1930 to 2012 - P90	30.7	58.6
1966 to 2012 - P10	37.8	93.3
1966 to 2012 - P50	34.8	81.5
1966 to 2012 - P90	29.4	49.3
Current P10 - (2002-2012)	37.6	92.6
Current P50 - (2002-2012)	34.4	79.5
Current P90 - (2002-2012)	30.0	52.9
Historic P10 (Modeled)	39.5	99.1
Historic P50 (Modeled)	36.4	88.3
Historic P90 (Modeled)	34.4	79.5
Normal Pool and Control Point		
Normal pool	44.8	122.8
Transitional Normal Pool (1968 to 2012)	37.9	93.7
Control Point	43.5	114.9
Significant Change Standards		
Basin Connectivity Standard	37.3	91.5
Wetland Offset Elevation	35.6	85.1
Aesthetics Standard	34.4	77.8
Species Richness Standard	33.9	75.9
Minimum and Guidance Levels		
High Guidance Level	39.5	99.1
High Minimum Lake Level	38.7	96.4
Minimum Lake Level	35.6	85.1
Low Guidance Level	34.4	79.5

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 Historic data record for Lake Rogers, the High Guidance Level for was established at **39**.4 ft NGVD (Figure 21, Table 4).

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 The modeled Historic data, the Low Guidance Level for Lake Rogers was established at 34.4 ft NGVD (Figure 21, Table 3).

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. Lake Rogers is not contiguous with any cypress-dominated wetlands of 0.5 of more acres in size and is therefore classified as a Category 3 Lake for the purpose of minimum levels development.

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, Fla. Admin. Code.). 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 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 1938 and 1948 indicates that a natural connection existed between the main body of the lake and the two southern lobes or basins to the south. The Basin Connectivity Standard was established at 37.2 ft NGVD, based on one foot for movement of biota and clearance of non-gasoline powered boats in the lake, a critical high-spot elevation of 34.2 ft NGVD (Figure 20), plus the difference between the Historic P50 and P90 (2.0 feet).

Based on the results of the modeled Historic stage regime, the connectivity standard is 0.8 foot greater than the Historic P50 and is not appropriate for the establishment of a minimum level for Lake Rogers. The area of the lake basin at an elevation of 37.3 comprises 94 percent of the basin area calculated at the transitional normal pool (37.9 NGVD) and 90.5 percent of the basin area at the peak stage of 40.0 NGVD recorded in March 1998. Based on the results of the Historic stage regime, significant flooding of the upland forest and recreational attributes would occur if the connectivity standard was established as the target minimum level.

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 Lake Rogers is 34.4 ft NGVD.   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 Modeled period.

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 (Hoyer and Canfield 1994, Emery 2009), 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 22) for a plot of lake surface area versus lake stage. For Lake Rogers, the Species Richness Standard was established at 33.9 ft NGVD. The Species Richness Standard was equaled or exceeded 95.3 percent of the time, based on the modeled Historic water level record. The standard elevation therefore corresponds to the Historic P95.3.

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 indicates the elevation at which the lake depth and bottom slope becomes susceptible to resuspension of bottom sediments. Review of the dynamic ratio for lake stages bounded by the High and Low Guidance Levels did not indicate that potential changes in basin susceptibility to wind-induced sediment resuspension would be of concern for minimum levels development (Figure 22).

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 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. No docks are located in the lake basin, so a Dock-Use Standard was not developed. Similarly, a Recreation/Ski Standard was not developed, based on area and depth restrictions imposed upon skiing activity within the basin.

Because the Lake Rogers basin contains significant herbaceous wetlands, it was determined that an additional measure of wetland change should be considered for minimum levels development. Based on a review (Hancock 2006) of the development of minimum level methods for cypress-dominated wetlands, it was determined that up to an 0.8 foot decrease (or Wetland Offset) in the Historic P50 elevation would not likely be associated with significant changes in the herbaceous wetlands occurring within lake basins. A Wetland Offset elevation of 35.6 NGVD was therefore established for Lake Rogers by subtracting 0.8 feet from the Historic P50 elevation. The standard was equaled or exceeded 63.5 percent of the time, based on the modeled Historic data, therefore corresponds to the Historic P63.5.

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 area available for submersed aquatic plant colonization in relation to change in lake stage indicated there would be a substantially larger increase in potential wetland area relative to the wetland area of the Historic P50 for both the Aesthetics Standard and the Species Richness Standard. Based on the area of the lake with depth less than 4 feet, a 15 percent increase in emergent aquatic plants is estimated to take place at the elevation of both of these standards relative to the wetland area of the Historic P50. Due to the increase in emergent plants a corresponding 19 percent and 24 percent decrease in open water area (area with depth greater than 4 feet) is estimated to take place at the elevation of the Aesthetics and Species Richness Standards, respectively. The elevation of the Aesthetic Standard and Species Richness standard are below the critical high spot elevation (34.2 ft NGVD) plus one foot needed for passage (35.2 or 34.2 ft NGVD plus 1 ft) between the basins (Figure 20). Connectivity between basins would occur less than 50% of the time if a minimum level was established at these lower elevation standards. Therefore, based on the increase in emergent plants, a reduction in open water, and the loss of connectivity, the use of these standards for the establishment of minimum levels would not be inappropriate.

Review of changes in potential herbaceous wetland area or area available for submersed aquatic plant colonization in relation to change in lake stage indicated only a small increase in potential wetland area within the lake basin at the Wetland Offset elevation relative to the potential wetland area at the Historic P50 elevation. Based on the area of the lake with depth less than 4 feet, only a 5 percent increase in emergent aquatic is estimated to take place at the wetland offset (35.6 ft NGVD) relative to the area of emergent vegetation at the a Historic P50 (36.4 ft NGVD). Additionally, the open water portion of the lake would decrease by approximately 7 percent. The Wetland Offset would provide for basin connectivity and the associated movement of aquatic fauna and canoe and small boat access among the lake sub-basins (1ft over saddle) for approximately 70 % of the time based on the Historic regime and 58 % of the time based on the Wetland Offset stage regime. The lake surface area at the Minimum Lake Level is about 90% of that associated with lake area at the transitional normal pool (38 ft NGVD) and 84% of the lake area at the peak stage elevation of 40 NGVD.

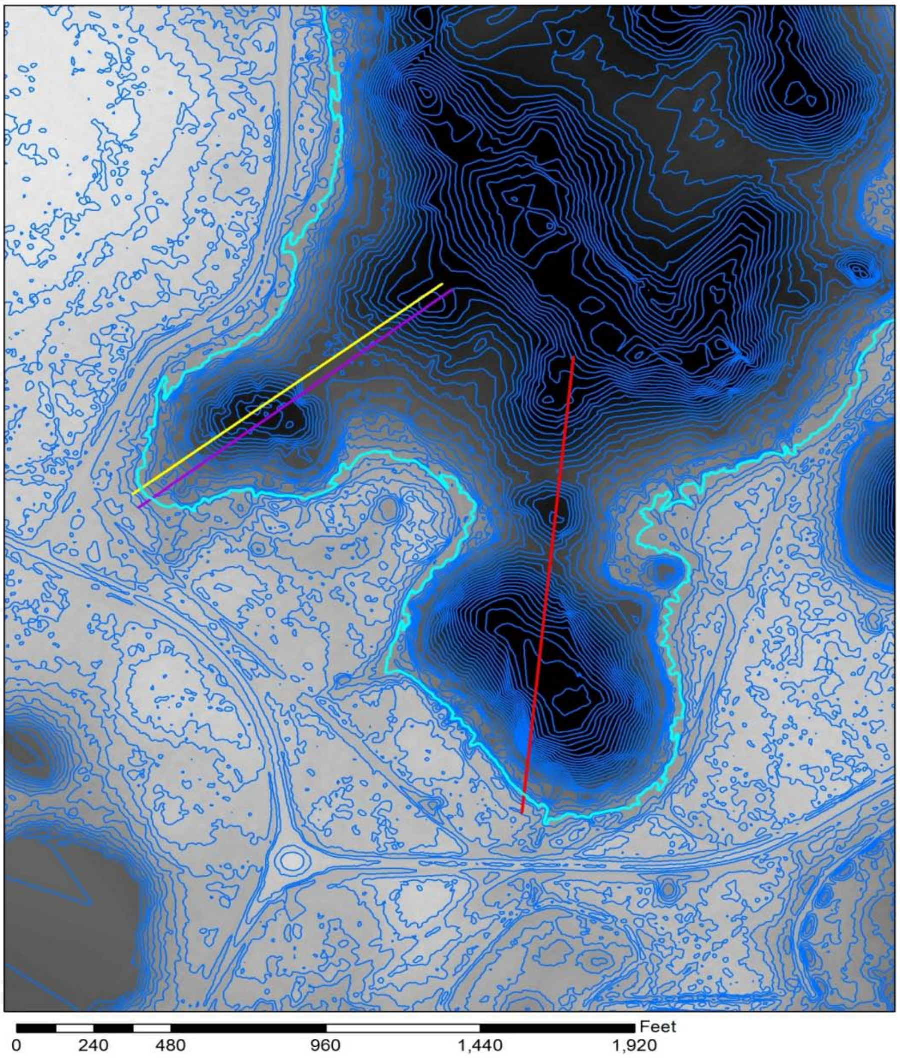


Figure 20. Location of DEM profile lines over critical high spot(s) used to evaluate the control elevation between basins and development of the connectivity standard for Lake Rogers, Hillsborough County.

Minimum Levels

Minimum Lake Levels are developed using specific lake-category significant change standards and other available information or unique factors, including: substantial changes in the coverage of herbaceous wetland vegetation and aquatic macrophytes; elevations associated with residential dwellings, roads or other structures; frequent submergence of dock platforms; faunal surveys; aerial photographs; typical uses of lakes (*e.g.,* recreation, aesthetics, navigation, and irrigation); surrounding land-uses; socio-economic effects; and public health, safety and welfare matters. Minimum Levels development is also contingent upon lake classification*, i.e.,* whether a lake is classified as a Category 1, 2 or 3 lake.

The **Minimum Lake Level (MLL)** is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. For Category 3 Lakes, the Minimum Lake Level is typically established at the elevation corresponding to the most conservative appropriate 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. The Minimum Lake Level was established at the Wetland Offset elevation, 35.6 ft NGVD, the most conservative standard below the Historic P50 (Figure 21) that considers both protection of the upland forest and park facilities and protection of the emergent zone. The Minimum Lake Level was equaled or exceeded 63.5 percent of the time, based on the Historic, composite water level record and corresponds to the Historic P63.5. This level is expected to afford protection to the natural system and human-use values associated with the identified significant change standards and also provide protection for wetlands occurring within the basin.

The **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 modeled Historic data for Lake Rogers, the High Minimum Lake Level was established at 38.7 ft NGVD (Figure 21), by adding the difference between the Historic P50 and Historic P10 (3.1 feet) to the Minimum Lake Level. The High Minimum Lake Level at 38.7 ft NGVD was equaled or exceeded 19.5 percent of the time, modeled Historic water level record, and corresponds to the Historic P19.5.

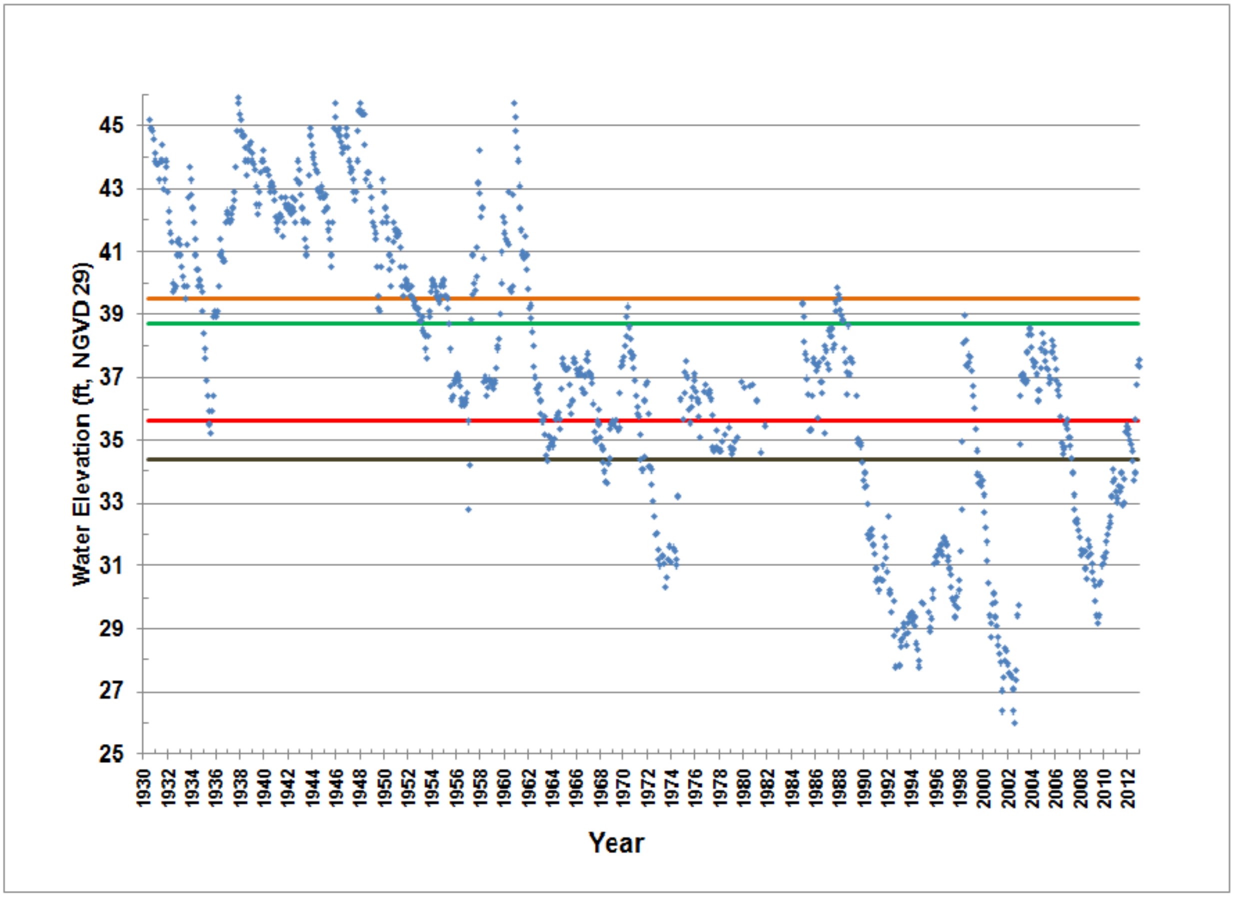


Figure 21. Mean monthly lake stage for Lake Rogers of the POR; and Minimum and Guidance Levels for Lake Rogers (as ft NGVD). levels shown as horizontal lines include the High Guidance Level (orange), High Minimum Lake Level (green), Minimum Lake Level (red), and the Low Guidance Level (black).

The final step in the development of minimum levels is to evaluate the levels for potential flooding of both man-made and natural lake attributes. Adjusting the minimum levels and high minimum levels downward is sometimes required to protect the function and use of the existing attributes from potential flooding. Although there are no residential dwellings on Lake Rogers there are several recreational attributes that were considered. In addition, elevations of the mature upland plant assemblages were also considered.

Staging of the lake at the minimum level as the Wetland Offset (see Figures 27 and 28) would not be expected to flood any man-made features or natural features within the immediate lake basin. A High Minimum Lake Level was established at 38.7 ft NGVD, an elevation corresponding to the Minimum Lake Level plus the difference between the HP10 and HP50. The High Minimum Lake Level is approximately 4.1 ft below the low spot in the park access road located between Lake Rogers and Lake Raleigh (42.8 ft

NGVD), so no flooding concerns are anticipated for this feature. The High Minimum Level is 0.8 ft below the lowest large live oak (see Figure 8) and approximately 4.4 to 5.7 feet below large laurel oaks found around the lake perimeter, with base elevations ranging between 43.1 to 44.4 ft NGVD (see Figure 8). Mortality of the large oak trees is not expected at the High Minimum Level.

Infrequent flooding at one of the picnic pavilions located at 39.5 ft NGVD and approximately three segments of the unimproved trail would be expected to occur 12.6 percent of the time based on the modeled Historic stage regime and 4.9 percent of the time using the Wetland Offset lake stage regime. The High Minimum Level is 0.8 feet above the lakeward line of slash pine forest located on the north side of the lake. Based on the Historic model regime the probability of inundation of the slash pines at 38.0 to 38.7 ft NGVD would be 26 to 27 percent. The probability of inundation decreases to 18 to 19 percent based on the modeled Wetland Offset stage regime.

Compliance with the minimum levels would result in limited flooding to the park's recreational feature but would provide a frequency of inundation above the transitional normal pool elevation (38.0 ft NGVD) needed for maintenance and control of encroaching shrubby upland plants including three invasive species found in the lake basin.

Target Minimum Level Stage Regime

The modeled Historic stage regime provides the predicted lake stage in the absence of groundwater withdrawals but allowing for structural alterations. This Historic baseline is used to calculate the Historic P10, P50, and P90 that provide the basis for determining the elevation of various change standards using the methods outlined in Chapter 40D-8.624, Fla. Admin. Code. 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, Fla. Admin. Code.). The thresholds based on the change standards typically allow for an offset from the Historic baseline, and therefore allow for an acceptable reduction in the lake area and associated vegetation and limnetic communities. No offset may be established when appropriate change standards are determined to be above the Historic baseline.

In the case of Lake Rogers the Wetland Offset was the most conservative offset below the elevation of the Historic P50, and was determined as the most appropriate change standard that also factors protection of the upland forest and park facilities. The wetland offset is 0.8 feet below the Historic P50. Because the Historic P50 was based on the modeled Historic stage regime, an offset stage regime (Wetland Offset in this case) was also modeled by reducing the affect of groundwater withdrawals to achieve an 0.8 foot offset below the Historic P50 (36.4 ft NGVD). The resulting wetland offset stage regime is the targeted minimum level regime.

The stage exceedance plots of both the modeled Historic regime and modeled Wetland Offset regime are provided in Figure 24. The stage exceedance of the long term current data (1966-2012) is shown for comparison in the plot to show the difference between the targeted Wetland Offset regimes to the observed stage regime over the past 46 years. Figure 24 also includes a comparison of the stage exceedance plots between the target Wetland Offset regime and the observed stage regime for the past 20 years (1992-2012). This plot was included since Lake Rogers reached its lowest stage during the recent 20 year period. The difference between the Wetland Offset regime and the stage regime of the past 20 years is significant with a difference of 1.3 feet between the P10's (38.8 and 37.4 ft NGVD), a difference of 3.7 feet between the P50's (medians)(35.6 and 31.9 ft NGVD), and a difference of 5.0 feet between the P90's (33.6 and 28.6 ft NGVD).

The greatest difference between the Wetland Offset regime and recent 20 year regime occurs at the P90, the elevation that is expected to be exceeded 90 percent of the time and not expected to drop below this elevation 10 percent of the time. Under the target Wetland Offset regime an elevation of 33.6 is expected to be exceeded 90 percent of the time indicating that staging of water over the critical base elevation of the littoral zone (30.0 ft NGVD) will be achieved 100 percent of the time.

Over the past 20 years the connectivity between basins has been restricted due to low water levels with staging of water over the saddle elevation (high spot between basins, 34.2 ft NGVD) only occurring 33 percent of the time. The P50 of the target Wetland Offset regime provides staging of water over the saddle approximately 70 percent of the time (Figure 24). A review of the stage area and estimated area of emergent versus limnetic zones indicates that the target P50 (35.6 ft NGVD) provides a balance between both habitats (Figure 26). A 25% reduction (30 acres) in open water area is expected to occur from a peak stage elevation of 40 ft NGVD to the target P50; whereas, a 42% increase (10 acres) is expected to occur in emergent vegetation (Figure 26).

It should be noted that during the past years the lake has shown a steady recovery of the emergent zone and open water habitat due to the higher lake stage. Examination of the stage fluctuation for this isolated time period (2010-2013) and stage regime shows a similar stage regime to that of the targeted stage regime (Figure 25). Based on these recently demonstrated improvements in the lake system, achieving the target MFL regime should afford protection of the existing flourishing emergent and open water habitat, but should also protect the upland forest and park facilities from long term flooding.

Compliance Evaluation

Minimum levels are intended to represent long-term conditions under a variety of expected hydrological conditions. The Minimum Lake Level represents the 50th percentile (median) of long-term water levels, while the High Minimum Lake Level represents the top percent of the lake stage data (90^{th} percentile) of long-term water levels. Therefore, to determine compliance, long-term data or model results should be used. Specific details of the process for determining compliance for Lake Rogers are summarized in a separate technical memorandum completed by Hancock and McBride 2013.

The HRR model used to develop the Historic percentiles was also used for the compliance assessment. Upper Floridan and surficial aquifer levels in the HRR model were adjusted to represent the current withdrawal rates in the area, and the model was run for the 1988 to 2011 period. Based on the information presented in the technical memorandum, it is concluded that Lake Rogers is not currently meeting the minimum levels (Hancock 2013) and recovery alternatives will need to be developed to achieve the target MFL regime. Additional details regarding the recovery alternatives are provided by in compliance technical memorandum (Hancock and McBride 2013).

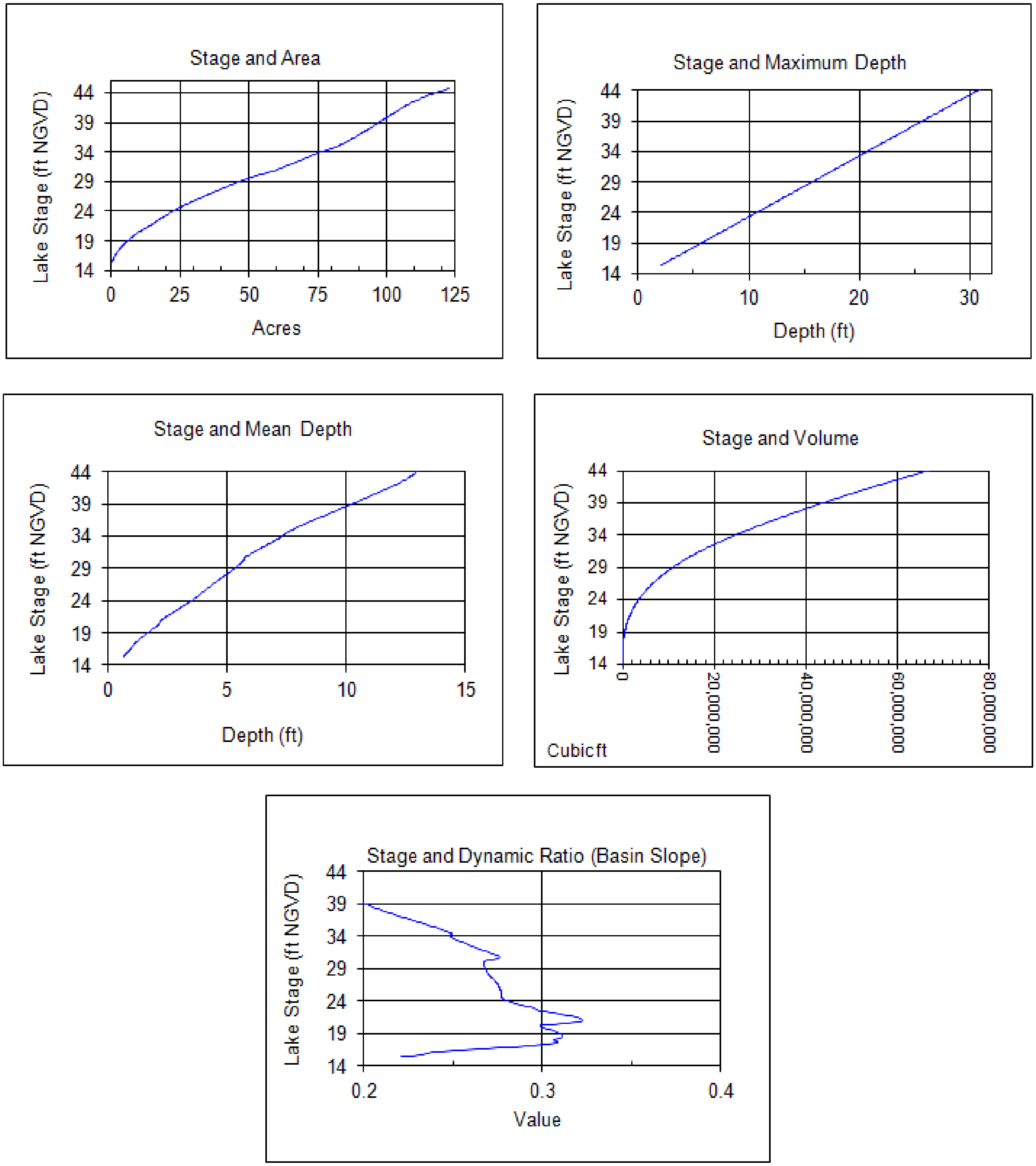
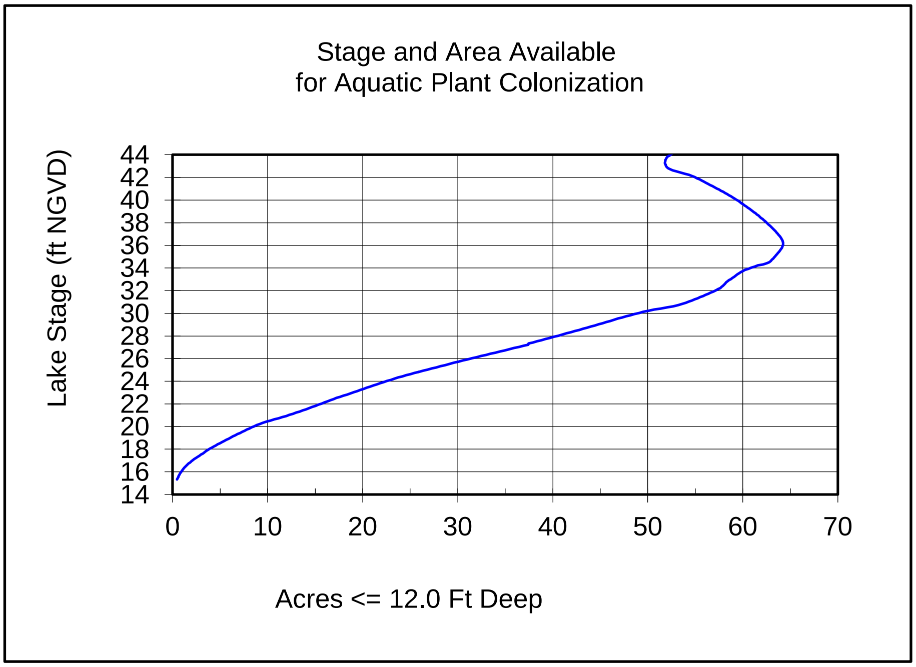


Figure 22. Surface area, maximum depth, mean depth, volume, dynamic ratio (basin slope) in feet above NGVD ft 29 for Lake Rogers.



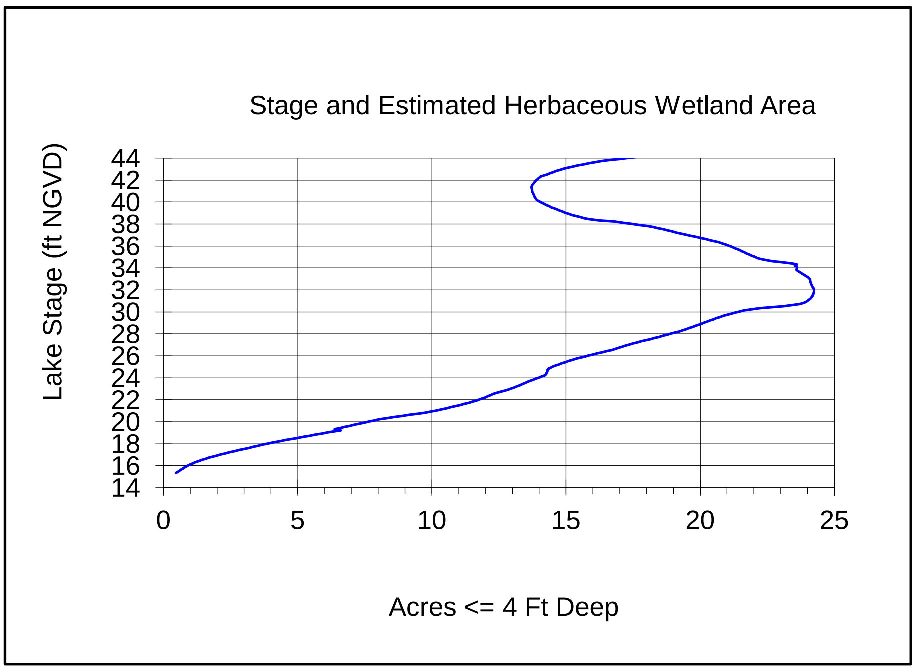
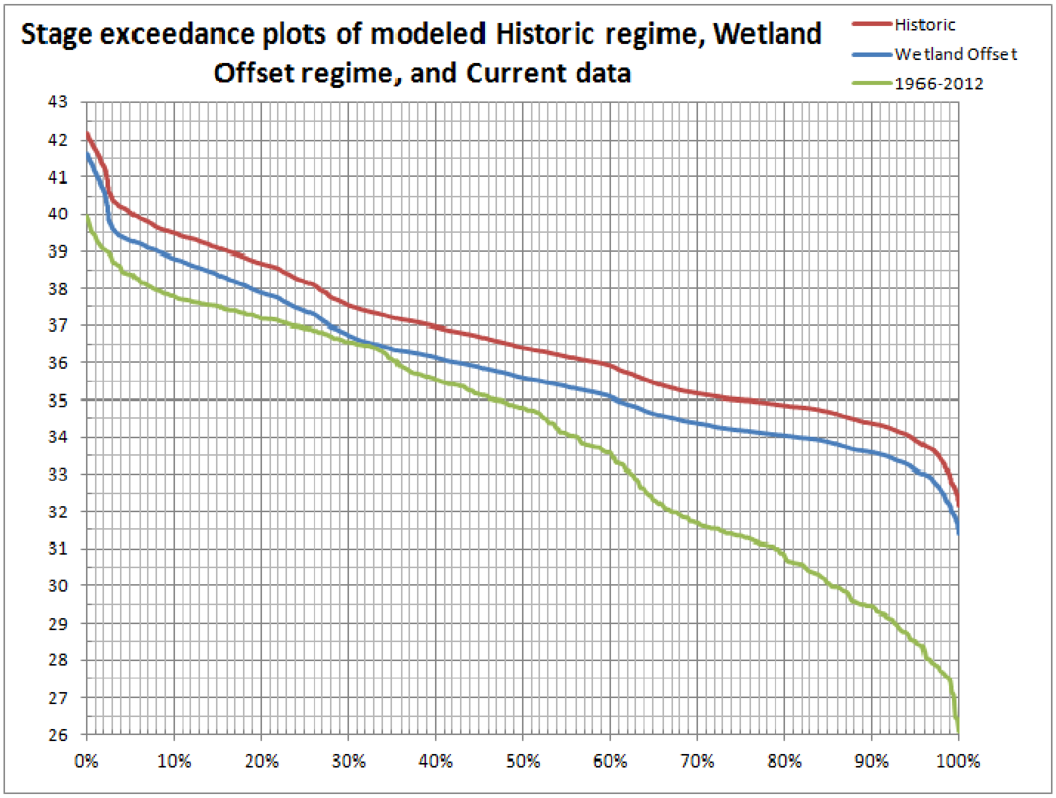


Figure 23. Potential area available for submersed macrophyte colonization (top) and estimated area of herbaceous wetland (emergent vegetation) area (bottom) in Lake Rogers as a function of lake stage (water surface elevation).



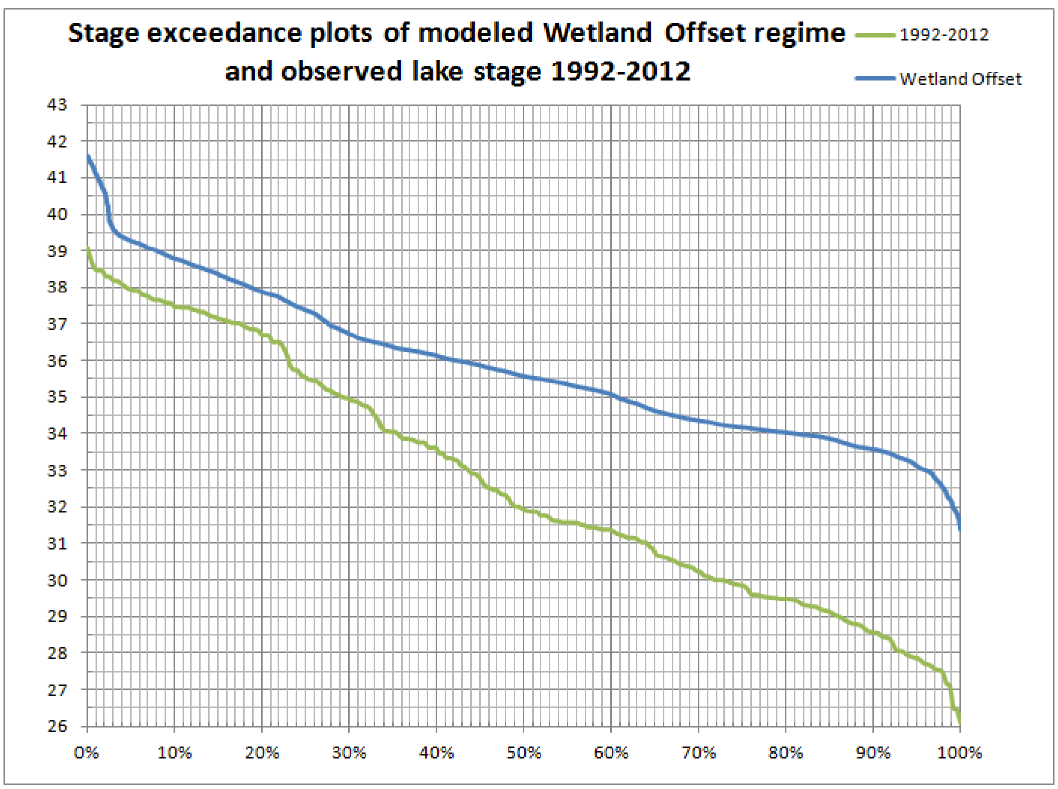


Figure 24. Top: stage exceedance plots of modeled Historic (red) and Wetland Offset (blue) regimes in comparison to the stage exceedance of the observed Current period; and Bottom: stage exceedance of the modeled Wetland Offset regime (blue) in comparison to the exceedance plot of observed data from 1992 to 2012.

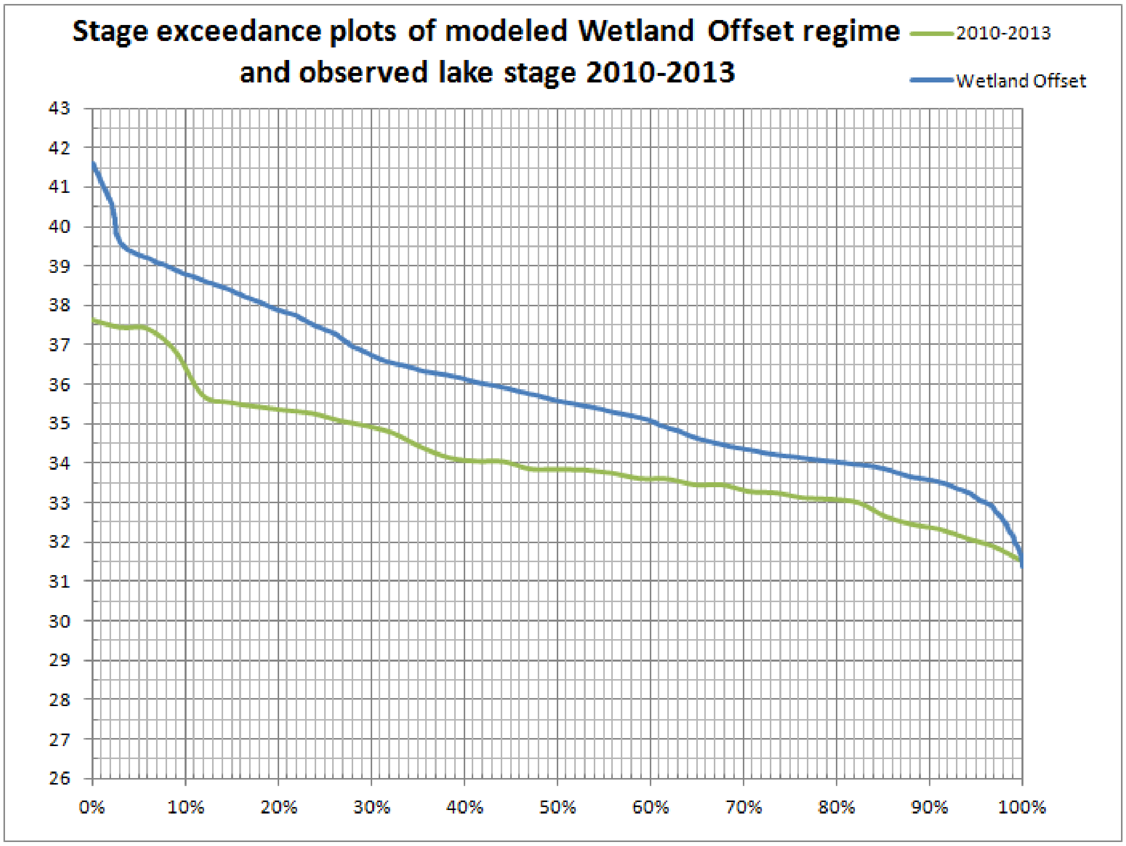


Figure 25. Stage exceedance of the modeled Wetland Offset regime (blue) in comparison to the exceedance plot of observed data from 2010 to 2013.

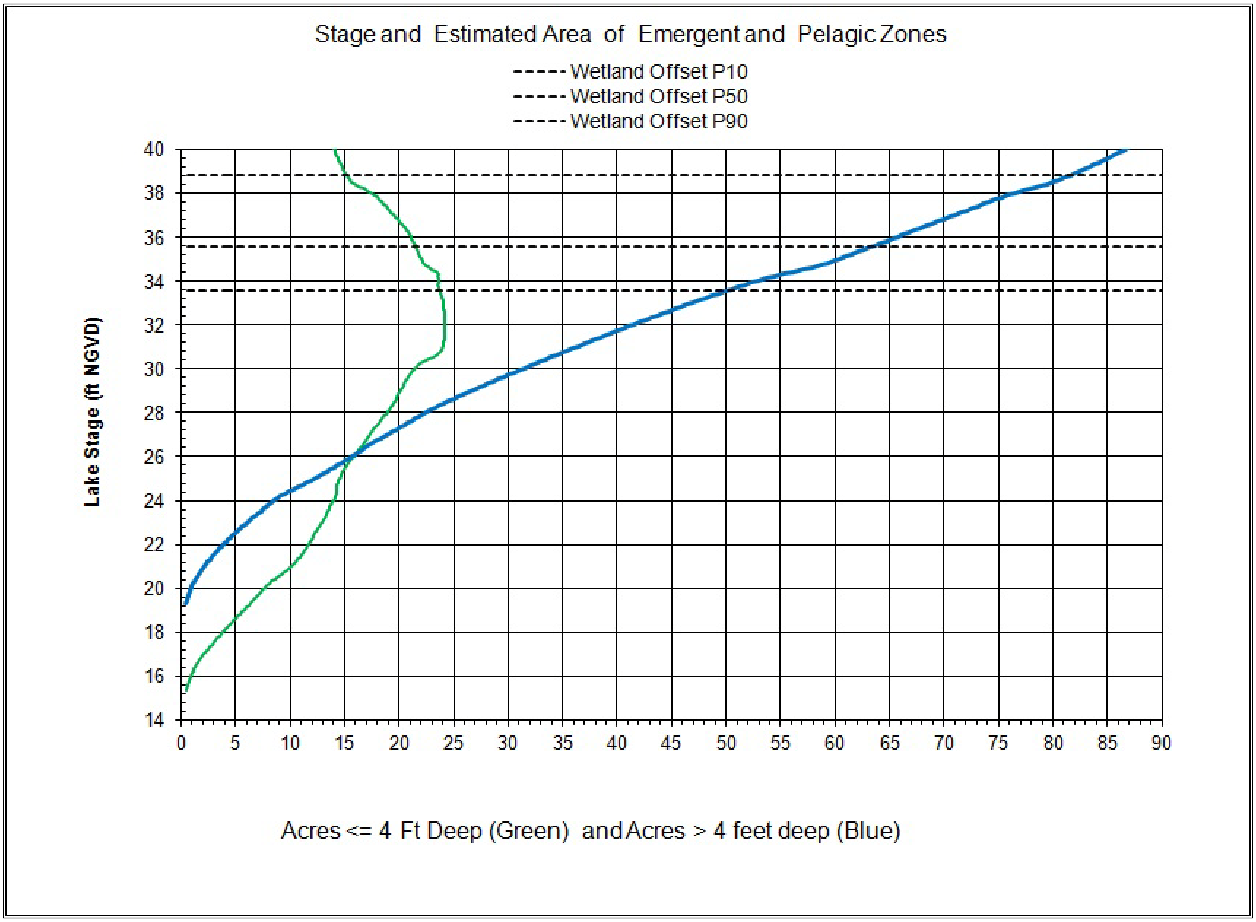


Figure 26. Top: Estimated area of herbaceous wetland (emergent zone) and open water as a function of lake stage as a function of lake stage in Lake Rogers with horizontal lines depicting the P10, P50, and P90 of the modeled Wetland Offset regime.

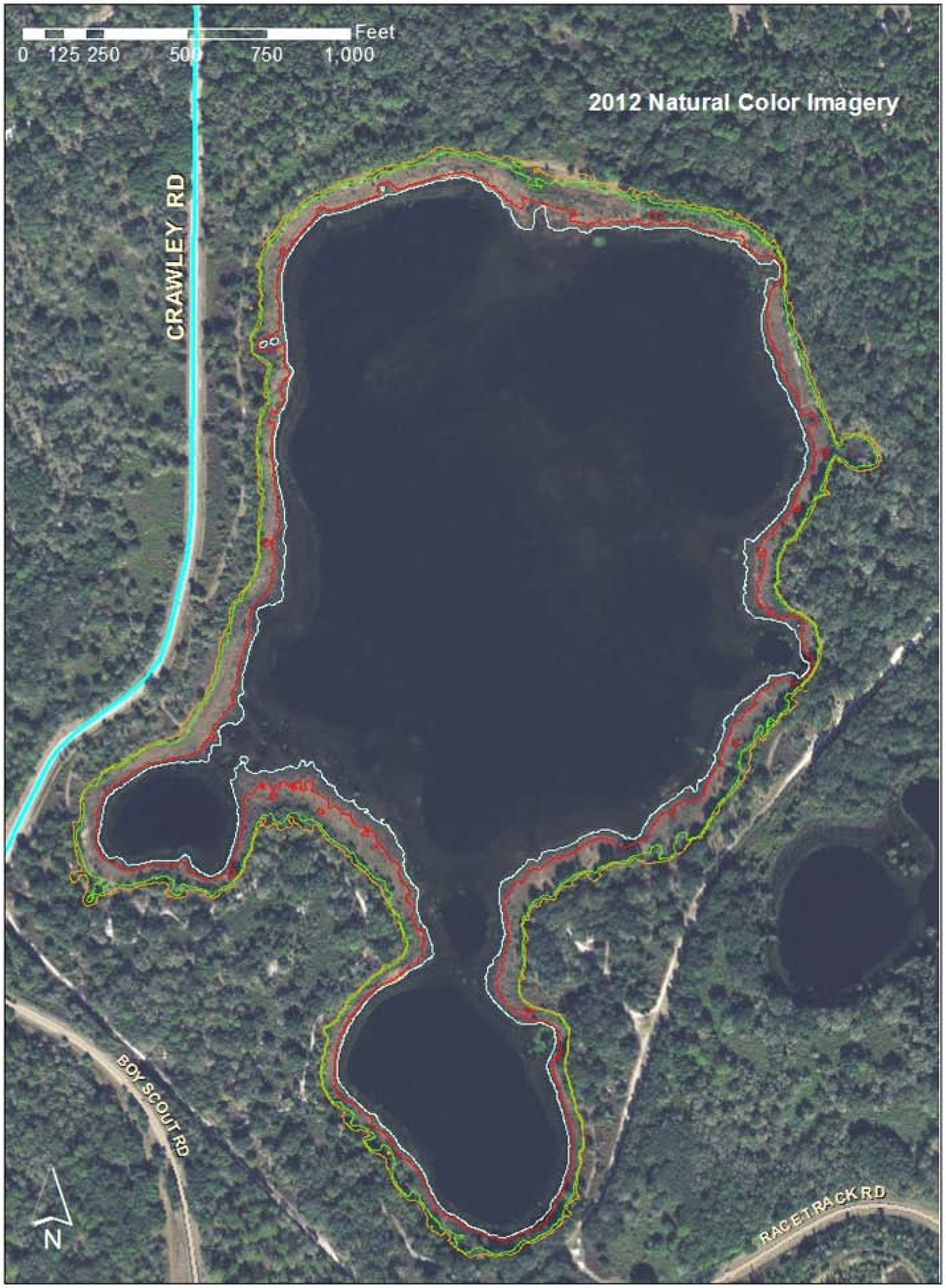


Figure 27. Recent (January 2012) aerial view of Lake Rogers with contour lines representing the High Guidance Level (39.5 ft NGVD), High Minimum Lake Level (38.7 ft NGVD), Minimum Lake Level (35.6 ft NGVD), and Low Guidance Level (34.4).

Figure 28. 2009 aerial view of Lake Rogers with contour lines representing the High Guidance Level (39.5 ft NGVD), High Minimum Lake Level (38.7 ft NGVD), Minimum Lake Level (35.6 ft NGVD), and Low Guidance Level (34.4).

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Appendix A

Summary of Surveyed Elevations and Relative Elevations of Vegetative Indicators

Table 1: Roads and Structures

Description	**Elevation (feet as ft NGVD)**
Low road (low spot in dirt road used for park access) *	42.8
Low road (Crawley Road, west of the lake) *	46.53
Low picnic pavilion and barbeque grill (Osprey Pavilion)	39.5
Low spot on trail (North Side of Lake)	39.9
Low spot on trail (South Side of Lake)	40.2
Invert at north end of 24 inch reinforced concrete pipe under Race Track Road (noted as partially buried)*	43.49
Low spot between lakes Rogers and Raleigh	44.0

*** -** Source of elevation is SWFWMD 2002.

Table 2: Vegetation Indicative of Transitional Normal Pool

Description and Statistics	**Elevation (feet as ft NGVD)**
Median base of saw palmetto *(Serenoa repens)* N = 5, standard deviation 0.16	37.77
Median of ground shots along lakeward line of slash pine *(Pinus elliotti)* * N = 25, standard deviation 0.56	38.03
Large 19” slash pine *(Pinus elliotti)* along north side trail *	40.23
Large 34” oak along trail at south lobe	40.42
Other oaks along trail at south lobe N = 5, standard deviation 0.97	40.41

***** Source McCormack 2013

Table 3: Large trees below Normal pool Elevation measured in 2012-2013.

Description	Elevation (ft NGVD)
Base of 24” live oak next to picnic pavilion north side of lake	43.56
Large laurel oak 36” next to picnic table north side of lake	44.44
Large live oak south side of lake near gage	42.07
Second large live oak south side of lake near gage	43.28
Third large live oak (48”) south side of lake near gage	43.58
Large Laurel Oak (36”) in campground	43.10

Table 4: Vegetative Indicators of Normal pool measured in 2012.

Description	Elevation (ft NGVD)
Median base of saw palmetto *(Serenoa repens)* N = 5, Standard Deviation 0.14	45.85